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Beam Dynamics Newsletter

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1   Foreword

1.1   From the Chairman

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1.1.1   Workshops

At its meeting in Amsterdam on 30 July, ICFA approved the 29th ICFA Advanced Beam Dynamics Workshop: Beam Halo Dynamics, Diagnostics, and Collimation (HALO'03) to be held on Long Island, New York, USA, 19-23 May 2003. This workshop will include a parallel workshop on Beam-beam Interactions. Further information on this and all other Panel activities can be found later in this newsletter and on our home page

http://wwwslap.cern.ch/icfa/

1.1.2   Working Groups within the Beam Dynamics Panel

The ICFA Beam Dynamics Panel has three sub-panels, or working groups, that work to stimulate activity on the beam dynamics problems of certain important types of particle accelerator. A Panel member chairs each of these groups. Two of them, the working group on Future Light Sources and the working group on High Intensity High Brightness Hadron were founded several years ago. They have run several ICFA Beam Dynamics Workshops and the more informal Mini-Workshops and have established important roles for themselves in their respective fields.

The Panel's working group on Future High Luminosity e+e- Colliders was founded more recently under the chairmanship of Yoshihiro Funakoshi of KEK. In view of the remarkable success of the present generation of factory colliders, this group is looking at the potential for even higher luminosity circular colliders and has held one workshop (the 23rd ICFA Advanced Beam Dynamics Workshop in Cornell last year). Dr Funakoshi has recently resigned as chairman because he is himself very busy with KEK-B. On behalf of the Panel, I would like to thank him for bringing this working group into being. The new chairman is Caterina Biscari of LNF-INFN who joined the Panel earlier this year and is also editor of the present issue of the newsletter.

We are sometimes asked why the Panel does not have working groups on subjects like hadron colliders, linear e+e- colliders or neutrino factories which are, of course, the most important accelerator types for the future of high energy physics. The answer is simply that there are other well-established frameworks for international collaboration on these topics and there is no need to duplicate them.

Of course, the beam dynamics problems in these high-energy frontier machines are prime subjects for ICFA Advanced Beam Dynamics Workshops and discussion in the newsletter. Indeed our most recent workshop (see the report later in this issue on the "Nanobeam" workshop) was devoted to a crucial linear collider topic and the next issue

of the newsletter, to be edited by Alessandra Lombardi of CERN (another recent addition to the Panel), will have the special theme of Neutrino Factories.

1.2   From the Editor

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The European synchrotron radiation community is facing a huge increment of its possibilities in the next future with the construction of three new third generation facilities: DIAMOND (3GeV) in the U.K, SOLEIL (2.75 GeV) in France, and LLS (2.5GeV) in Spain. The construction of DIAMOND (http://www.diamond.ac.uk/) has already begun in the CCLRC Rutherford Appleton Laboratory and the first beamlines producing ultra-violet and X-ray beams will be ready for use in 2006.

This issue of the ICFA Beam Dynamics Newsletter dedicates a section to the description of the french and spanish projects.

SOLEIL (http://www.soleil.u-psud.fr/default.htm) with its beamlines producing VUV and soft X-rays will be complemetary to ESRF.

LLS (http://www.lls.ifae.es/) is the first accelerator facility to be built in Spain: it is a first priority project for the Spanish science. It will be housed at Barcelona, and will produce high brightness soft X-rays in the region 0.05 - 2 keV and high intensities X-rays in the region 4 - 30 keV.

An interesting article has been written by prof. Khan on the necessity of creating an International Asian Facility. He appeals the Asian scientists and institutions to collaborate in the construction of an Asian Accelerator Laboratory (AAL), which could promote exchange of progress and technologies among all the Asian countries.

Several activity reports have been included in this issues:

- An important step at the CLIC test facilities, demonstrating the feasibility of the recombination principle for the frequency multiplication system.
- The description of the NewSUBARU storage ring, operated in the positive momentum compaction mode.
- The studies on the radiation wigglers to be installed at CESR for the luminosity runs at lower energies.
- The analytical description of many beam dynamics aspects by Gao at LAL.

Two exhaustive descriptions on the 26th and 27th ICFA Advanced Accelerator and Beam Dynamics Workshops have been written: the first one by M. Ferrario, assisting the workshop on "The Physics and Applications of High Brightness Electron Beams", held in Sardinia at June and the second by R. Assmann and F. Zimmermann, organizers of the workshop 'Nanometre-Size Colliding Beams', held at Lausanne at beginning of September.

This Newsletter has been completely written in Word. Its editing would not have been possible without the help of Pina Possanza, the LNF Accelerator Division Secretary. I want to thank her in the name of the ICFA Beam Dynamics Panel.

2   Letters to the Editors

2.1   Comment on a previous article on Shintake's work

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We would like to comment on article 3.1 of ICFA newsletter 27, June 2002, describing the work of Dr Tsumoru Shintake. The shown pictures of the electric field-lines of a moving charged particle are not correct. The lines do not follow the direction of the electric field given by the retarded Lienard-Wiechert potentials.

About a year ago, we developed a program based on the same simple and intuitive approach as Dr. T. Shintake to plot electric field-lines of a moving charged particle. The method expands field-lines with the speed of light, starting from a Lorentz-contracted 'pincushion' distribution. Our results for this approach are identical to the results shown in the ICFA newsletter and to the downloadable software of Dr. T. Shintake. However, direct numerical calculation of the retarded LW-potentials proves that this 'expansion' method does not produce lines in the direction of the electric field. For curved trajectories, a significant part of the radiation term is not included in the algorithm. A modification of the equations to produce the proper field-lines might be possible, but this requires further study.

An algorithm to obtain the correct field-lines is given by R. Tsien, Pictures of Dynamic fields, AJP Volume 40, (1972) p 46. In various cases the similarity between the two approaches is both striking and deceptive, as can be observed by comparing the synchrotron radiation case at v=0.9 c. At first sight the plots may look identical, but there is a field-error of about 45 degrees in the center of the plot of Dr. T. Shintake. In other cases, for example relativistic harmonic motion, the error is even larger.

3   New European Synchrotron Radiation Facilities

3.1   A synchrotron called SOLEIL: Main characteristics of the French synchrotron source

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On September the 11th, 2000, the French Minister of Research, announced, in agreement with the Prime Minister, the decision to build the 3rd generation synchrotron light source SOLEIL on the plateau of Saclay,near by Paris. This decision was following the recommendation from a committee composed of members of the French parliament which stressed the mandatory need for the construction of a new synchrotron in France. SOLEIL aims at a worldwide leadership in the field of VUV and soft X-rays while being still competitive for medium energy X-rays, thus achieving a good complementarity with the ESRF, optimised for hard X-rays. SOLEIL will largely supersede the present LURE sources, SuperACO and DCI, which will be presumably shut down at the end of 2003.

3.1.1   Background

In February 1996, on request of the secretary of state for research, a project group was installed for three years by CNRS and CEA with the mission to design a third

generation synchrotron light source, SOLEIL. After three years, the conclusions of this work were gathered in the so-called APD (Avant Projet Détaillé) report and presented to the minister of national education, research and technology in July 1999. Following the decision in September 2000 to build "SOLEIL", the project studies developed in the APD report (foundation phase report June 1999) were resumed with the objective of launching the construction phase at the beginning of year 2002.

Since the beginning of 2001, a new SOLEIL team is being constituted with the goal of finalising the project detailed design [1] in order to start the construction in 2002 with a commissioning of the source and of 10 beamlines expected at the end of 2005 (phase 1), and a gradual installation of 14 other beamlines in parallel to operation up to 2009 (phase 2). Due to the new scientific context and taking into account the progress in technologies and the experience given at others SR Sources recently built, improvements have been brought to several parts of the SOLEIL equipment.

The SOLEIL facility will be built and operated by a non-trading company, with Denis Raoux as a chief executive Officer, Jean-Marc Filhol as a project leader for the machine and building programs, Michèle Sauvage and Roger Fourme as scientific directors, Michel Bessière as a technical services director, Brigitte Gagey as a computer director and Dider Bordet (Christian Bozec from September) as an administration Director. The company was founded on Tuesday October 16, 2001, by Geneviève Berger, General Director of the CNRS, and Pascal Colombani, Chief executive of the CEA (French Atomic Energy Commission). The CNRS currently holds 72% in the company, and the CEA 28%. The shareholding could be rebalanced to include other French or foreign partners.

The public local institutions: the "Conseil Régional d'Ile de France" and the "Conseil Général de l'Essonne" have decided to support the SOLEIL project during the decision making phase and committed themselves to participate in the funding, in partnership with the government, up to a contribution of 148 M€ and 34 M€ respectively.

As the local authorities, "Région Ile de France and Département de l'Essonne", will not be members of the company, a specific convention has been signed between them, the State and SOLEIL company to define the funding and control procedures and to ensure a fair return on matters of specific interest for the academic and industrial local communities.

A short while ago, the "Région Centre", another French local authority, has decided to contribute to the SOLEIL company and its experimental program. Region Centre will participate to the building of three beamlines: two projects already existing and a new project of beamline.

Specific conventions have been set-up with the CEA, the CNRS and the Universities to fix the rules of integration of their staff within the SOLEIL structure.

3.1.2   The main uses of Synchrotron Radiation

The main features of this 3rd generation synchrotron radiation source make it one of the most performing in the international context.

A very broad spectrum of scientific research activities is concerned with the use of synchrotron radiation, both for fundamental and applied purposes. In basic research, SOLEIL will fulfil the needs in condensed matter physics, chemistry, materials science, life science and particularly crystallography of biological macromolecules, earth,

atmospheric and environmental sciences. A large panel of spectroscopic tools, from the infra-red to the hard X-rays will be available together with the access to powerful diffraction and scattering structural probes. Compared to the present LURE[1] potentialities, the brilliance of the new source will provide orders of magnitude improvements not only in terms of sample minimum size, brought down to the sub-micron scale (of major importance for nanotechnologies) or of extreme dilution of the studied species (of particular interest for environmental sciences, chemistry and catalysis...) but also in terms of time resolution with dynamic studies accessible in the picosecond range. Combination of unprecedented spectral and spatial resolution with a high flux will offer totally new opportunities to study dilute samples (ions, clusters, molecular complexes, adsorbates) of interest in photochemistry or astrophysics for instance. The possible design of micro-focused beams from the IR up to the medium hard X-rays opens the way to a variety of imaging techniques exploiting all the processes involved in synchrotron radiation interaction with matter (absorption, diffusion, fluorescence..) thus allowing studies of heterogeneous complex materials of all sorts, including those involved in life science purposes. In addition, the various polarisation states of the light will be extensively used to characterize the magnetic properties of surfaces, interfaces of new materials relevant for microelectronics.

SOLEIL will also be broadly open to applied research and fine characterization in fields as varied as drugs and medical sciences, chemistry and petrochemistry, environmental and nuclear sciences, nanotechnologies, micromechanics and microelectronics, etc. It will also be a place to develop and upgrade methods for metrology and detector calibrations in the UV and X-ray ranges, in particular for astrophysics.

Each year, the installation will receive more than 2000 French and foreign researchers using the experimental stations developed on the beamlines. SOLEIL will thus be broadly open to the international scientific community.

3.1.3   2.75 GeV nominal energy and a new lattice

In order to satisfy the demand of high brilliance for high energy photons (3-18 keV) the initial nominal energy has been pushed from 2.5 GeV to 2.75 GeV. As a consequence, the photon flux from undulators is increased by a factor 5 at energies above 10 keV while it is reduced by less than 30% around 5-10 eV.

The machine equipment has been revised to guarantee a reliable operation at 2.75 GeV with a beam current of up to 500 mA. This concerns more specially the dipole photons absorbers for which a new solution based on the SLS and ANKA modified design was developed, the RF system and the dipole magnets for which the H shape has been preferred to the previous C shape to minimize saturation effects.

Taking into account the need of more and more insertion devices, the SOLEIL team looked for the possibility of increasing the number of straight sections without increasing the number of cells which would be prohibitive for the budget. The idea was to create a new straight section (3.6 m) by drifting apart the two quadrupole doublets located in-between the two bending magnets of the Double Bend Achromat cell. In order not to increase too much the total circumference of the machine, only two cells over the four cells of a super period were modified (the modified cells are the central

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[1]   French existing Synchrotron radiation Facilities with two rings called SUPERACO and DCI.

ones). With the same motivation, the four long straight sections have been shortened from 14 m to 12 m.

The circumference of the storage ring increased from 337 m to 354 m with a lengthening of 17 m i.e. 5%. With this minor modification the machine provides now 24 straight sections (4x12 m, 12x7 m, 8x3.6 m) among which 21 are dedicated to install insertion devices (one long straight is necessary to locate the injection equipments and two medium straights will be occupied by the super-conducting RF cavities). The total effective length available to install insertion devices is 104 m which represents a record value of 29 % of the machine circumference.

Figure 3.1.1 shows the optical functions of one of the four super periods of the new lattice integrating 8 bending magnets, 6 straight sections (1x12 m, 3x7 m, 2x3.6 m), 40 quadrupoles (8 triplets on each side of the large and medium sections, 8 doublets) and 30 sextupoles.

Linear and non linear optics were optimised and very good results have been obtained leading to the same performances than those of the previous lattice [2].

With tunes $Q_x = 18.28$ and $Q_y = 10.26$, we have the following results:
- Horizontal emittance $\varepsilon_x = 3.7$ nmrad @ 2.75 GeV
- Beta functions in the small straight section matched for "high energy" undulators: $\beta_y = 2$ m allowing small gap and $\beta_x = 17$ m which gives a low horizontal divergence more favourable to operation on high harmonics.
- Good dynamic acceptance even for large energy deviation $\delta = \Delta p/p$ (up to 6%) thanks, among others, to a small variation of the tune with energy.

A peak RF voltage of 4.8 MV was determined to insure also longitudinal energy acceptance of ± 6 %.
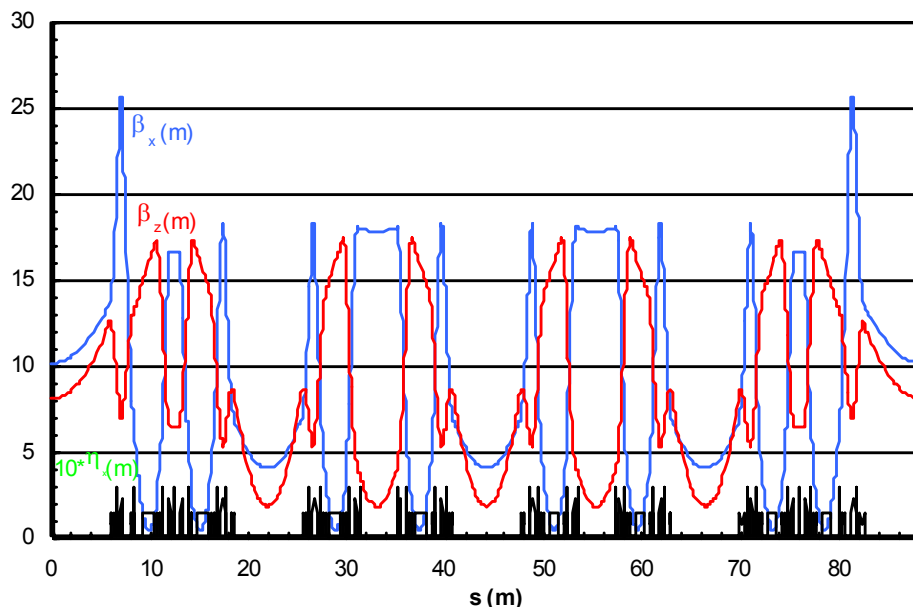
Figure 3.1.1: Lattice and optical functions for one super period of the storage ring.

Nevertheless, this value was computed using the first order of the momentum compaction: $\alpha = \alpha_1 + 2\alpha_2$. If α_1 is small α_2 must be considered, the synchrotron motion becomes non linear and the RF bucket centered around $\delta = 0$ is asymmetric in energy leading to a decrease in Touschek beam lifetime.

For SOLEIL, $\alpha_1 = 4.38 \ 10^{-4}$ and $\alpha_2 = 4.454 \ 10^{-3}$. The RF bucket is then asymmetric with an upper limit at $+ 5\%$ ($|\alpha_1/2\alpha_2|$) and a lower limit at $- 10\%$ ($-|\alpha_1/\alpha_2|$). A particle with a positive energy deviation of $+ 5\%$ for example can be lost because its separatrix will bring it to a negative energy deviation as high as $- 10\%$. Due to this non linear effect, the Touschek lifetime is reduced by a factor 1.5 [3].

3.1.4   Insertion devices

SOLEIL was initially optimized for soft X-ray, for which the brilliance reaches a value larger than 10^{20} ph/s/0.1%bw/mm^2/mr^2, but the challenge is to serve a very large scientific community with high performances in an energy range as large as 5 eV to 30 keV [4].

For low energy photon production, long period insertions are needed, so they will be installed in the long straight sections. Vertical polarized beams are requested by nearly all low and medium energy beamlines. The limitation will come from the maximum power density acceptable by the beam line optics but also from the heating of the slot in the dipole vacuum chamber. For example to reach 5 eV we chose an electromagnetic 500 mm period length with 20 periods. At 2.75 GeV, with 100% vertical polarization rate the power deposited in the vacuum chamber is 378 W with a power density of 920 W/mrad^2. The vacuum chamber has been redesigned with a water cooled copper slot in order to avoid too much heating.

For high energy photon production, short periods are needed and the undulators will have to be operated on high harmonics. To reach 18 keV, we propose 1.8 m long in vacuum undulators of 20 mm period, which could be installed in the short straights of the new lattice. With a 5 mm gap bringing a 15% lifetime reduction, the brilliance would then be about 10^{19}. For the $30 - 50$ keV domain, a hybrid type wiggler, 100 mm period, 2.2 T, 1.8 m long, is proposed. It gives a 7.10^{16} brilliance at 30 keV. However, due to the non zero dispersion, such a wiggler increases the ring emittance by 7% which is still considered acceptable. The 2nd order effect of all the insertion devices on the dynamic aperture is being investigated.

3.1.5   Beam stability

3.1.5.1   *Beam position stability*

During the APD phase, solutions have been found to minimize the effect of mechanical vibrations as well as closed orbit drifts in the long or medium term [1]. Moreover several vibration measurement campaigns were performed on the site. It appeared that the present site cultural noise has a quasi-sinusoidal variation between night and day with a maximum excursion for the day of 0.35 mm peak to peak, on which some singular events going up to 0.7mm were recorded.

The analysis showed that almost all these events are at a frequency of 2.5 Hz and then can be simulated as a planar wave. The specifications on the acceptable emittance

variation $\left(\delta\sigma/\sigma < 10\%,\quad \delta\sigma'/\sigma' < 10\%\right)$ are well met for a standard coupling of 1% but are not completely satisfied if the coupling factor is decreased to 0.1%. After new investigations it was found that the source of large events are generated by some particular trucks travelling on the 2 adjacent roads, in correlation with some kind of irregularities of the roads. The repair of these roads and the maintenance of the quality of their surface in the time will get us rid of these vibrations which should guarantee a very good beam position stability.

Furthermore, the foundations of the synchrotron building were reviewed and it was shown that the initial solution could not guarantee the stability requirement for the experimental hall slab (differential settlement in comparison with the ring tunnel). The new solution consisting in a unique slab (0.80 m thick) for storage ring and experimental hall, built on simple piles anchored down to the sand layer at - 15 m satisfies the stability specifications. Furthermore, when a new beamline is installed, the total static deformation of the nearest point of the ring will be less than 40 μm.

3.1.5.2 *Longitudinal stability*

A superconducting HOM free RF system was developed for SOLEIL in collaboration with CERN and CEA/DAPNIA. The first power tests of the cavity prototype were made with success in December 1999. An accelerating field of above 7 MV/m was obtained in the 2 cells of the superconducting cavity exceeding widely the specifications (5 MV/m). Some anomalies were observed on the liquid helium distribution, on the mechanical tuning system and on the tuning of the HOM's couplers. After some minor modifications this cryomodule was mounted in January 2002 on the ESRF storage ring in order to be tested with beam during the year 2002 [5]. In parallel, the re-design of a second cryomodule integrating all the experience gained on the prototype has just been launched.

3.1.6 Main parameters

Main parameters of the storage ring are given in the following table:

Energy	2.75 GeV
Circumference	354.097 m
Horizontal emittance (rms)	3.73 nmrad
N. of cells / N. of super periods	16 / 4
Straight sections	12 m x 4 ;
	7 m x 12 ;
	3.6 m x 8
N. of dipoles / Nominal field	32 / 1.71 T
N. of quad. / Max. gradient	160 / 23 T/m
N. of sextu. / Max. strength	120 / 320 T/m^2
Betatron tunes, Q_x / Q_y	18.28 / 10.26
Chromaticities ξ_x / ξ_y	- 2.84/- 2.23
Momentum compaction	4.38×10^{-4}
Energy dispersion	$1.16\ 10^{-3}$
Radio Frequency	352.202 MHz
Peak RF Voltage	4.8 MV
Energy Loss per Turn (with Ids)	1 300 keV

The expected performances in the 2 main operation modes will be:

Operation	Multibunch	Temporal structure
Beam current	500 mA	8 x 10 mA
Beam lifetime	20 h	18 h
Coupling factor	$K^2 = 1\%$	$K^2 = 10\%$

Note: Beam gas and Touschek lifetimes are calculated with the following hypothesis:
  - The pressure is 10^{-9} torr for 500 mA.
  - The vertical aperture is 13 mm (respectively 8 mm) for an undulator of 6 meter long (respectively 3.6 m), and 7 mm for 1.8 m long in vacuum undulator.

Touschek lifetime is calculated for natural bunch length ($\sigma_s = 14$ ps).

3.1.7   Injector

The injector system, composed of a 100 MeV electron LINAC followed by a full energy (2.75 GeV) booster synchrotron has being updated in view of top-up injection:
  - The LINAC specifications have been upgraded in order to be able to compensate a lifetime as bad as 4 hours by injecting one pulse every 2 min.
  - The new booster design [6] has the same basic structure but 22 FODO cells with only 2 straight sections and 36 dipoles. It provides a 130 nmrad emittance. The switched mode power supplies will work at 3 Hz frequency and are being signed to operate on a single pulse basis.
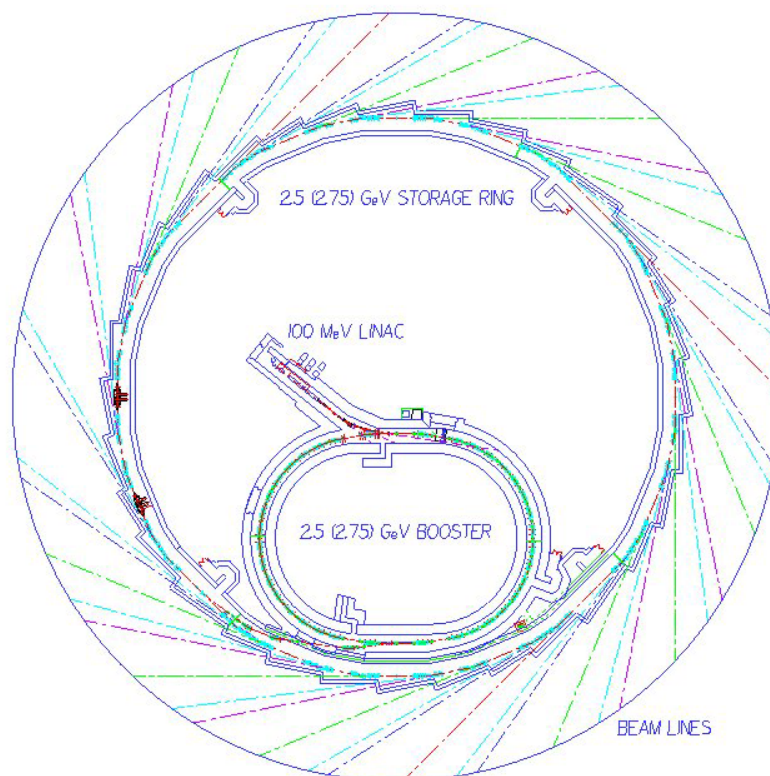
The 1999 SOLEIL design has been modified in order to better answer to the new user requests and to integrate new developments. The total cost was reevaluated leading

to an investment cost of 207 M€ (for 24 beamlines) out of which 59 M€ for the accelerators and sources.

The call for tender for the LINAC has already been launched, the ones for the booster and storage ring magnets will follow in the next months and the groundbreaking is planned for the beginnings of 2003.

References

[1]   SOLEIL foundation report (1999).

[2]   A. Nadji et al., "a modified lattice for SOLEIL with a larger number of straight sections", SSILS Shanghai September 24-26,2001.

[3]   A. Nadji et al., "The effect of nonlinear synchrotron motion on the SOLEIL energy acceptance" PAC 99.

[4]   O. Marcouillé et al, "Insertion Devices for SOLEIL" EAPC 2002.EPAC 2002.

[5]   J. Jacob et al, "Test of SOLEIL SC cavity prototype on ESRF ring" EPAC 2002.

[6]   A. Loulergue et al, "New booster design for SOLEIL" EPAC 2002.

3.2 Main guidelines of the new Spanish synchrotron accelerator (LLS)

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3.2.1 Introduction

Here we present the main guidelines for a source to provide Synchrotron Light (SL) mainly to Spanish users, which hereafter we name the *Laboratori de Llum Sincrotró* (LLS). The conceptual design here presented has been the basis for the Spanish government to approve the project.

The origins of this study go back to July 1992 when, under the auspices of the *Generalitat de Catalunya*, a Committee was created to study the feasibility of a SL source in Catalonia. As a consequence of this study[2], reviewed elsewhere[3], the construction of a SL source was formally proposed by the catalan *Comissió Interdepartamental de Recerca i Innovació Tecnològica* (CIRIT). Following on from this early work, an agreement was signed in 1995 between the *Spanish Comisión Interministerial de Ciencia y Tecnología* (CICYT) and CIRIT to carry out, among other things, the work we report here. This conceptual design for the LLS was finished at the end of 1997. After several independent evaluations commissioned by the scientific authorities, finally in 2001 the LLS conceptual design was submitted to the Spanish Big facilities advisory committee, who qualified the LLS project as the first priority for Spanish science. In March 8th of the current year the Spanish Minister cabinet finally approved the funding of the project, with an estimate cost of 120 M€.

3.2.1.1 *LLS specification*

A generally accepted classification of SL sources is to describe them as belonging to the first, second or third generation. First generation SL sources (e.g. NINA in the UK and DESY in the FRG) made parasitic use of the SL emitted by the bending magnets of particle accelerators whose primary purpose was elsewhere (usually high energy physics). Second generation SL sources (e.g. the SRS in the UK) were designed with the primary purpose of delivering optimised SL to users but (at least initially) relying only on the emission from the bending magnets. With the advent of insertion devices (IDs) a new generation of SL sources, called third generation (e.g. ELETTRA in Italy, MAX-II in Sweden and practically all the accelerators designed in the last 10 years), has appeared. The design aim of these installations has been to make provision from the very start for the production of optimised SL from both the bending magnets and IDs.

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[2] J. Bordas, E. Fernández, S. Ferrer, A. Mariné, C. Miravitlles, P. Miró, A. Oliva, X. Ortega, J. Pascual, P. Pascual, R. Pascual and R. Tarrach, The synchrotron laboratory of Catalonia. Feasibility study. External report LSB/01/93(ER), Barcelona 1993.

[3] R. Pascual, The synchrotron laboratory of Catalonia, Journal de Physique IV, vol. 4 (1994) c9-337.

The survey mentioned above demonstrated that the numerically largest community needs to work in the X-ray region with photon energies ranging from 4 to 30 keV, with the next largest in the soft X-ray region from 0.1 to 2 keV (Figure 3.2.1). The results of this survey, consideration of the scientific techniques which are in use and likely to continue to remain important in the future, the potential for future upgrades and the requirement to keep the construction budget within a reasonable envelope have formed the basis for the specification of the LLS.

Two principal technical requirements emerged:
−   The need to produce high brightness soft X-rays in the region 0.05 - 2 keV.
−   The need to produce high intensities of X-rays, with moderate brightness, in the region 4 - 30 keV.

The LLS has been conceived with these characteristics in mind. Therefore, it will be a third generation SL source. The IDs of the type Undulator will generate the required brightness in the soft X-ray region whilst those of type Multipole Wigglers (MPWs) will deliver the high intensity for the harder X-rays. It has been determined that in order to produce the required light characteristics the LLS must have a minimum energy of 2.5 GeV.

It should be noted that as the energy and the circumference of the accelerator increase so do the intensity and brightness output of IDs, but the costs also increase. The size of the LLS has been kept as small as possible to achieve a compromise between minimum cost and the production of high performance SL. Thus, the LLS will have only 12 cells but, with the choice of a triple bend achromat (TBA) lattice, it can achieve performances comparable to that of other proposed or operating third generation national sources.
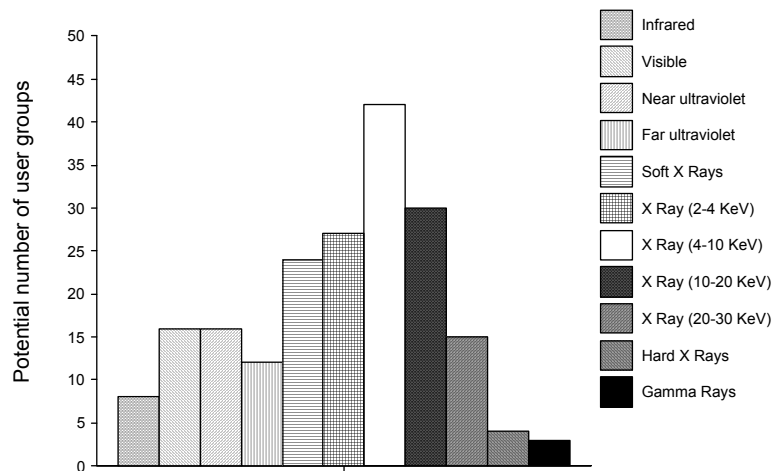
Figure 3.2.1: Potential number of user groups classified according to the energy range they require.

3.2.1.2   *Potential future upgrades*

The LLS would be the first and, in all likelihood for many years, the only Spanish SL source. As for most SL facilities, it is anticipated that the competitive lifetime of the LLS will be ca. 30 years. Given the relative lack of experience in accelerator construction in Spain, the design of the LLS must be ¨safe¨, in other words the initial specifications must be conservative enough to ensure that the LLS will function from day one according to specifications. In this context, the emittance (and thus the

brightness) proposed for the LLS can be easily enhanced by changing the quadrupole strength and allowing for non-null dispersion in straight lines. However, we propose to achieve the LLS operative state according to a design that initially will not push the performance of any of the crucial components. On the other hand, it is important that the LLS has built-in the potential to remain a competitive facility well into the 21st century. Therefore, several possible areas for improvement, when and if needed, are included in the initial specifications.

These are:

- *Increase the energy.* Because the bending magnets are designed to operate initially with a ¨safe¨ performance, it should be eventually possible to increase their magnetic field strength. Thus, the energy of the machine could be upgraded at the relatively inexpensive cost of additional RF power and, possibly, new magnet power supplies.
- *Introduce superconducting elements.* Pairs of central magnets in the TBA cells could be replaced with superconducting bending magnets, thus broadening the photon range of utilisation, without unduly deteriorating the brightness of the photon beams. An option that might be even more attractive is to include superconducting multipole wigglers in some of the straight sections. This would have the advantage of not only increasing the critical energy, but also to increase the available intensity. In addition, in the event of failure, the rest of the accelerator complex would be totally unaffected.
- *Reduce beam sizes in the straight sections to improve ID performance.* Given the flexibility of individually choosing quadrupolar strengths, one might consider adjusting additional pairs of quadrupoles so that the electron beam sizes are reduced at the straight sections and matched to the optimal performance of IDs. For example, one might choose to reduce the beam size at the expense of beam divergence and accommodate mini-gap undulators. When developed, these could provide beams of exceptionally high brightness in the X-ray region.
- *Increase the intensity of circulating current in the LLS.* Because the LLS is designed to operate initially with a ¨safe¨ performance, i.e. with minimized instabilities, it should be eventually possible to increase the circulating current in the machine. Thus, the beamlines flux could be upgraded at the relatively inexpensive cost of additional control loops and, possibly, extra cooling systems.
- *Perform topping-up injection.* This is a mode of operation in which lost particles are replaced by continuous injection of new ones. Such mode of operation may have good reasons for its implementation in future (e.g. an upgrade based on the use of narrow gap undulators, which significantly reduce the beam lifetime). Safety issues have to be addressed before such an upgrade.
- *Increase the number of beamlines.* At least 2x12 beamlines using light from the central bending magnets could be available at the LLS. In fact, this is a rather conservative number as it is considerable that many of the bending magnets could accommodate up to three beamlines and associated experimental stations. If ever required, and although more difficult but still technically possible, at least other 12 beamlines from the downstream bending magnets could be accommodated.

3.2.1.3 *Choice of insertion devices*

Given that currently the major fraction of the potential users is concentrated in the X-ray region, probably the most numerous IDs will be MPWs. Newly developed magnetic materials (permanent magnets and soft magnetic materials) will be used. It should be possible to generate magnetic field strengths up to ca. 2 T and include MPWs with up to 80 poles, therefore delivering very high intensity X-ray beams. Nevertheless, at this stage we propose that initially the MPWs should be less ambitious. Undulator IDs provide quasimonochromatic radiation with exceptionally high brightness and can be tuned over a limited range. The intention is that undulators should cover the electromagnetic spectrum within the limits imposed by the energy and physical characteristics of the accelerator (i.e. photon energies from ca. 50 eV to ca. 2 keV) by choosing a range of undulators with different periods. Generic examples of typical undulators with periods of 44 and 73 mm have been considered. In practice the undulators and MPWs will be designed to closely match the research needs at the time.

3.2.1.4 *Beamlines and experiments*
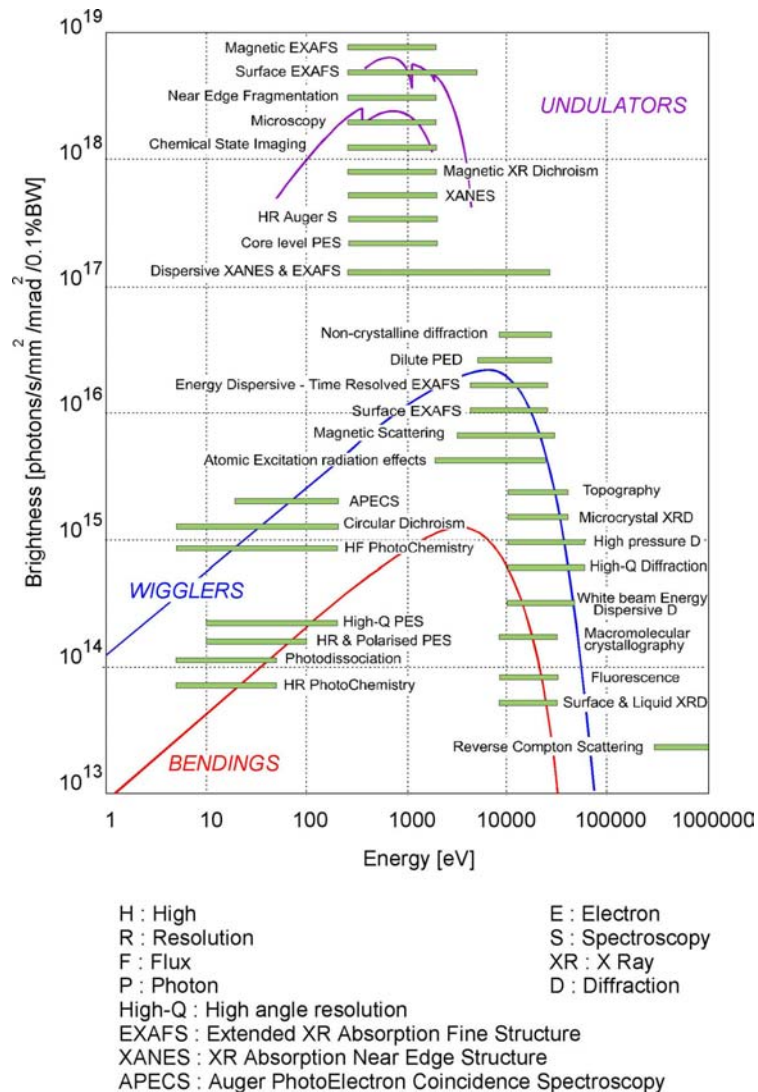
Figure 3.2.2: Energy range of photon beam required for each SL technique.

3.2.2   Energy and magnetic lattice

3.2.2.1   *Introduction*

The energy and the magnetic lattice of an accelerator predetermine the properties of the accelerator as a light source. Because of this, we have devoted a great deal of attention to the choice of the LLS´s energy and magnetic lattice with the aim to find the best compromise between cost, performance, user requirements and potential for future expansion.

The magnetic lattice has been chosen so that the best fit to the requirements, identified in a survey of future users carried out in 1995[4], is achieved without resorting to an exceedingly large ring. This study established the following priorities:

- The usable range of photon energies should extend to at least 20 keV.
- The photon beam should have high stability and a lifetime of at least 8 hours.
- The accelerator should incorporate straight sections for a variety of insertion devices (IDs).
- The total vertical dimension of the source at the extraction point should be, at most, 1 mm.
- The light source should have a vertical collimation comparable to that of the natural SL emission.
- The total horizontal dimension of the source should not exceed 3 mm.
- The accelerator design should have the potential for future upgrades.
- The temporal structure of the light source should allow some use of the single bunch mode for dynamic studies.

In addition, we have imposed the criteria that the accelerator design should be simple enough to guarantee its feasibility and, also, that its cost should be comparable to that of other currently planned SL sources in Europe.

The above considerations have led us to an accelerator energy of 2.5 GeV and a magnetic lattice of the Triple Bend Achromat (TBA) type.

3.2.2.2   *Accelerator energy*

In order to satisfy the requirement of having an useful range of photon energies extending to at least 20 keV, the critical energy (ε_c), i.e. the median of the photon power emitted by the bending magnets, must be 4-5 keV. This is because defining the useful range of utilisation as that extending up to photon energies where the intensity is within 1/10 of maximum emission, we find that the useful emission from the bending magnets extends up to photon energies of ca. $3.5\varepsilon_c$ (Figure 3.2.3). In addition, emission from conventional insertion devices of the multipole wiggler type can be extended to photon energies of up to $7\varepsilon_c$.

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[4]   J. Campmany, *User requirements for a synchrotron facility in Spain*. LSB external report LSB/01/95-ER (1995).
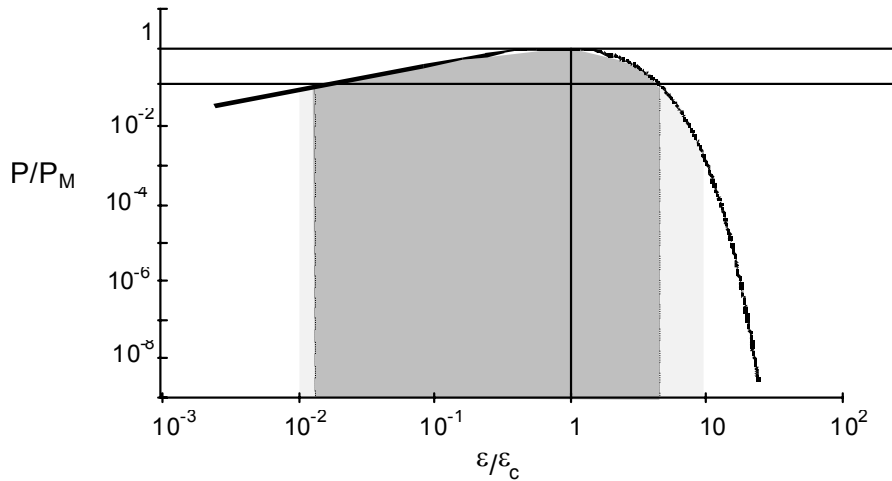
Figure 3.2.3: Generic spectrum of the power (P) emission of a bending magnet relative to maximum power (P_M) of the emission as a function of photon energy (ε) relative to the critical energy (ε_c). The dark shaded zone corresponds to the usable range of the spectrum, defined as where the emitted power is above 10% of the maximum. The clear shaded zone corresponds to the extension in the useful range given by conventional insertion devices.

The photon critical energy (in keV) is related to the accelerator energy E (in GeV) and the bending magnet field strength B (in T) by the relationship:

$$\varepsilon_c = 0.665 \ B \ E^2$$

We have limited the field strength in the bending magnets to a value around 1 T because:

- It delivers a good accelerator emittance (thus enabling the source to become sufficiently small to fulfil the requirements on the source size; see below for further details).
- In the proposed design the magnets are far from saturation, and therefore they offer the potential for increasing the strength of the magnetic field, thus the operating energy.
- With a ca. 1 T magnetic field, one finds that the minimum accelerator energy necessary to achieve the required range of usage must be 2.5 GeV.

The alternative to increase the magnetic field strength and reduce the accelerator energy has been dismissed because it limits the useful range of undulator radiation, because the magnets will be uncomfortably close to the saturation limit of conventional electromagnets, and because the lifetime of the stored beam could be unacceptably low.

3.2.2.3 *Lattice*

For a given lattice type, the smaller the number of magnetic cells the lower the cost. On the other hand, the smaller the number of cells the worse is the emittance. Essentially for these reasons, we have found that 12 cells is the smallest acceptable minimum. There are many different lattice types that can be considered; however, for an accelerator with 12 cells, one is immediately drawn to the choice of an *achromatic lattice* (i.e., a lattice with sections without dispersion). This is because this type of

lattice yields a small horizontal source dimension and, because of the nil dispersion in the straight sections, good energy resolution for the insertion devices.

Having considered lattices of the Double Bend Achromat (DBA) and of the TBA types,[5] it became clear that within the cell number and site size limitations we have imposed, in an attempt to reduce the cost, the best choice was a TBA lattice. This is because, considering the relative merits of a DBA and TBA for our site dimensions, we find that altogether the TBA:

- Offers the lower emittance.
- Provides larger straight sections for ID.
- Different working points can be chosen without affecting the accelerator emittance.
- Has the smallest source size at the main points of light extraction.
- Offers the possibility of an important potential upgrade by replacing pairs of symmetrically placed central bending magnets with superconducting ones to provide light extracting points with much higher critical energies than those delivered by the conventional bending magnets, without serious detrimental effects on accelerator performance.

3.2.2.4   *Summary description of the proposed TBA lattice.*

The basic parameters defining our TBA lattice are summarised in the following table:

Basic parameters		
Lattice type		TBA
Energy	E [GeV]	2.5
Number of cells	N_s	12
Circumference	C [m]	251.8
Length of ID useful straight sections	L [m]	7.3
Dipolar magnetic field	B [T]	1.01
Natural emittance	ε_{x0} [nm rad]	8.48
Energy spread	σ_E/E	$8.61 \cdot 10^{-4}$
Critical energy	ε_c [keV]	4.2
Betatron tunes	Q_x	14.3
	Q_y	8.2
Natural chromaticities	Q'_x	-24.6
	Q'_y	-24.6
Circulating current	I [mA]	250
Emittance ratio	χ [%]	5
RF frequency	f_{RF} [MHz]	500

As shown schematically in Figure 3.2.4 the proposed TBA is composed of a doublet of quadrupoles in the dispersion free regions, an achromatic section with three combined bending magnets (i.e. with a dipolar field and a quadrupolar component), DBM -downstream bending magnet-, CBM -central bending magnet-, UBM -upstream bending magnet-, a quadrupole between each pair of bending magnets, and six sextupoles. The quadrupoles and sextupoles are labelled accordingly to the family to which they belong (i.e. QF -focusing quadrupole-, QD -defocusing quadrupole-, QC -

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[5] A. Ropert, *High Brilliance Lattices and the Effect of Insertion Devices*, «CERN Accelerator School», CERN-90-03, p. 164.

central quadrupole- SV -vertical plane sextupole-, SH -horizontal plane sextupole-, and SA -auxiliary sextupole-). An exhaustive description of the magnetic characteristics of each family is given in section 3.3.8.
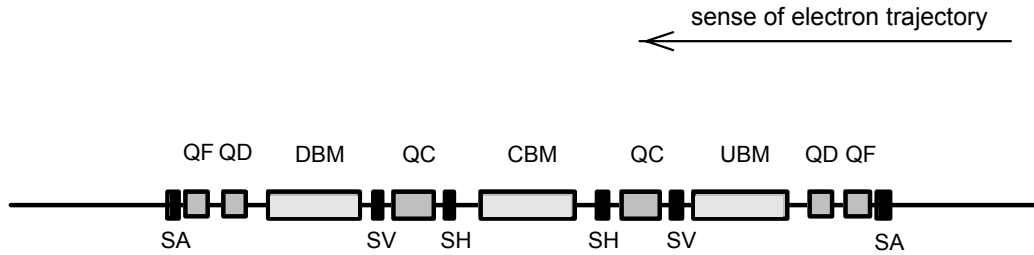
Figure 3.2.4: Scheme of the basic cell for the LLS lattice. Names of each element are related with their magnetic characteristics.

Other parameters characterising our proposed magnetic lattice are given in the table below.

Parameters		
Damping times:		
horizontal	τ_x [ms]	6.67
vertical	τ_y [ms]	10.03
longitudinal	τ_s [ms]	6.71
Synchrotron radiation integrals	I_1	$4.90 \cdot 10^{-1}$
	I_2	$7.62 \cdot 10^{-1}$
	I_3	$9.23 \cdot 10^{-2}$
	I_4	$-3.84 \cdot 10^{-1}$
	I_5	$1.04 \cdot 10^{-3}$
Partition numbers	J_x	1.505
	J_y	1.00
	J_E	1.495
Revolution frequency	f_0 [MHz]	1.190
Harmonic number	h	420 (2^2x3x5x7)
Momentum compaction factor	α_c	$1.9 \cdot 10^{-3}$

A more realistic view of the LLS cell is shown in Figure 3.2.5.
The total number of magnetic elements necessary to achieve the initial design objectives can be summarised as follows:

Magnet inventory at storage ring		
Combined bending magnets		36
Quadrupoles	QF	24
	QD	24
	QC	24
Sextupoles	SH	24
	SV	24
	SA	24
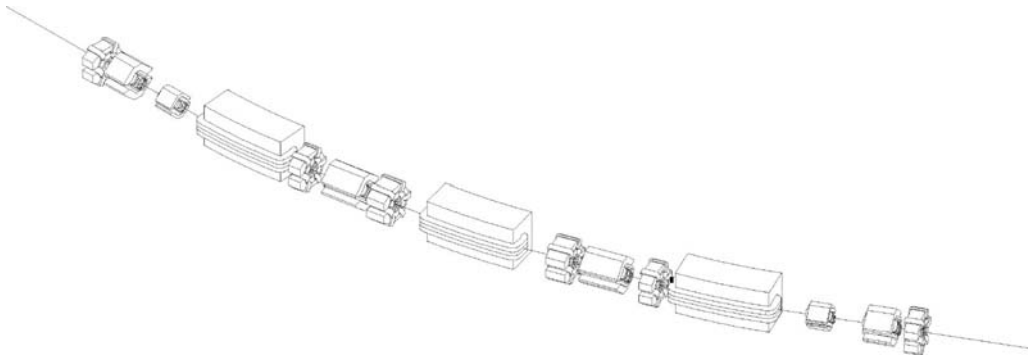
Figure 3.2.5: View of LLS storage ring magnetic cell.

The proposed LLS lattice, together with the other associated accelerators, pre-injector and booster, is shown to scale in Figure 3.2.6.
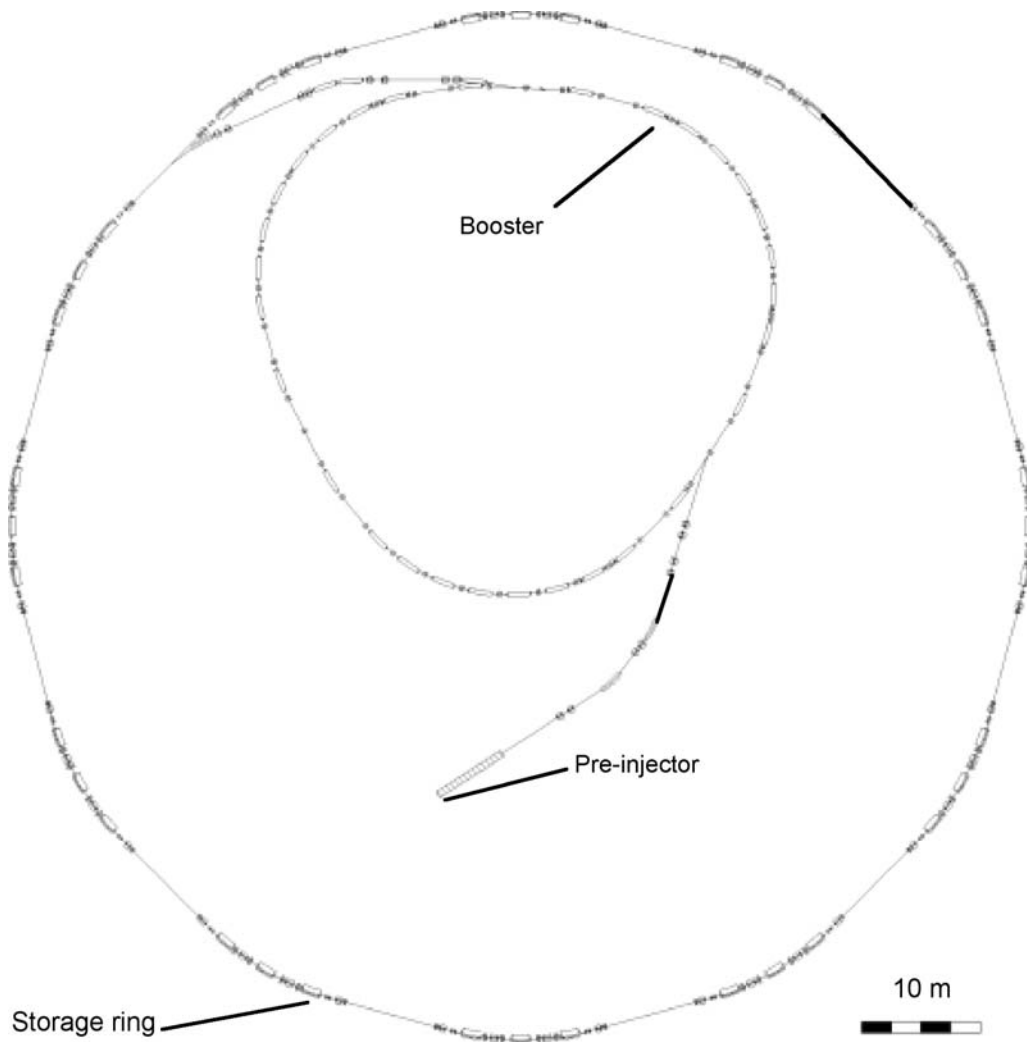
Figure 3.2.6: Sketch of LLS main ring, booster and pre-injector. In the storage ring, we can observe the 12 cells separated by long straight sections.

3.2.2.5 *Other design considerations.*

In addition to the considerations described above, on which we have based our decision of energy and lattice type, our choice has been based also on the following aspects.

With regards to the structure of the magnetic lattice we have taken into account:
– The number of cells.
– The working point.

With regards to magnets, we have considered:
– The use of gradients in the bending magnets.
– Whether to use doublets or triplets of quadrupoles in the straight sections.
– The total number of sextupoles.

With regards to other options, we have explored:
– Whether to have straight sections with high beta values, or whether to have a scheme in which alternate straight sections have high and low beta values.
– The option to provide straight sections for unusually long insertion devices by having an accelerator with a racetrack layout.

The outcome of these considerations is given below.

3.2.2.5.1 Number of cells.

For any given lattice there is a theoretical minimum emittance. This minimum value is given by the expression[6]:

$$\varepsilon_0 = \frac{E^2}{J_x} f_{CELL} \frac{1}{N_{BM}^3}$$

where E is the energy of the electron beam in GeV, J_x is the partition number which for the proposed lattice is ca. 1.5, N_{BM} is the number of bending magnets in the lattice and f_{CELL} is a function which depends on the type of lattice considered. For a TBA such as proposed here, $f_{CELL} = 1.56 \cdot 10^{-5}$.

The expression above shows that the emittance depends critically on the number of bending magnets, i.e. the number of cells determines the emittance. The table below shows how the minimal theoretical emittance (MTE) of a TBA lattice depends on the number of cells.

Number of cells, N	MTE at 2.5 GeV [nm rad]
16	0.59
12	1.39
10	2.41
8	4.70

The MTE cannot be achieved in practice without incurring severe penalties in flexibility, high sensitivity to errors and high chromaticity. Therefore, one must always

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[6] A. Ropert, High Brilliance Lattices and the Effect of Insertion Devices, «CERN Accelerator School», CERN-90-03, p. 172.

consider that the accelerator will have an emittance that is around 6 times greater than the MTE. In our case, the requirements on source size demand that the horizontal emittance should be 20 nm rad or better. Moreover, the low symmetry in a lattice with either 8 or 10 cells would make the accelerator very sensitive to resonances. This leads to the choice of a minimum of 12 cells. This choice offers a reasonable emittance whilst keeping the cost and size within reasonable levels.

3.2.2.5.2 Working point.

The solution to the equations of motion of particles circulating under the influence of magnetic fields shows that the particles undergo horizontal and vertical oscillations up to maximal amplitude. These are the so-called *betatron oscillations*.

The numbers of betatron oscillations, both in the horizontal and vertical planes of the orbit, during a revolution are known as the Betatron Tunes Q_x and Q_y. The selected pair (Q_x, Q_y) is called the working point of the accelerator. The two-dimensional representation of all the possible working points is called the working diagram.

The ideal oscillatory movement of the particles can be disturbed by magnetic imperfections. As in the case of a harmonic oscillator, these imperfections can lead to instabilities when the tunes fulfil the resonance relationship:

$$mQ_x \pm nQ_y = p$$

where m, n and p are integer values. The plot of the lines defined by the previous equation in the working diagram shows us the places to avoid when selecting the working point.

When an accelerator is composed of N_s identical cells, the previous equation changes to:

$$mQ_x \pm nQ_y = N_s \cdot p$$

and a large number of possible resonances are now forbidden by symmetry.

Not all the resonances are unacceptable. The effect of a resonance becomes weaker when the order of the resonance (the sum of $|m| + |n|$) increases. In general, for an electron storage ring, the resonances of order greater than 5 are negligible. Also, only the resonances with a "+" sign in the left hand side of the equation ("sum" resonances) lead to an unstable motion of the particles. Those with a "−" sign in the left hand side of the equation ("difference" resonances), lead to a transfer of oscillations between the horizontal and vertical plane, and viceversa, but the motion remains stable. This last process is called coupling and it increases the vertical emittance.

Even though, especially on the light of operational experience, the working point can always be redefined at a later date, we have chosen for the purpose of this feasibility study the working point shown in Figure 3.2.7. This Figure shows that this working point is sufficiently away from destructive resonances to allow for small tune changes that occur in practice. These are elaborated in sections 3.2.3.3.1 and 3.2.3.3.2.
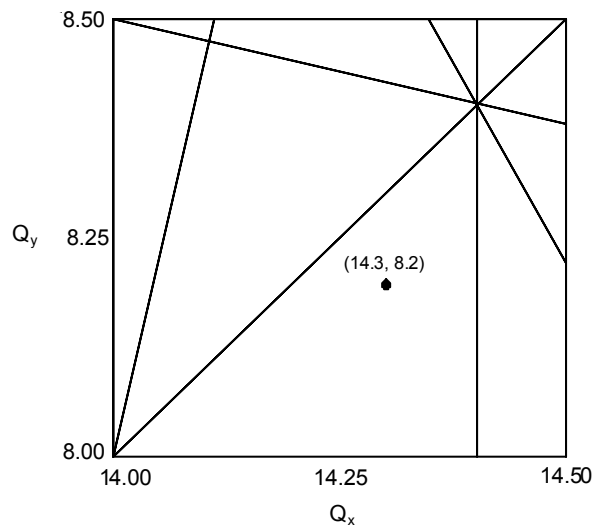
Figure 3.2.7: Representation of the working point in the working diagram of the LLS.

3.2.2.5.3 Bending magnets with gradient.

Bending magnets with gradient, i.e. bending magnets which have dipolar and quadrupolar field components, limit the maximum attainable dipolar magnet field strength, but on the other hand they significantly reduce the space necessary for the achromatic cell and, in some instances, the emittance of the accelerator is reduced by up to 50%. As we wish to keep the size of the accelerator relatively small, and as we have found that the magnets we propose should allow for a future increase (if needed) of the accelerator energy up to 3 GeV, we find that bending magnets with gradient should be used. The positions of bending magnets in the cell are shown in Fig. 3.2.8.
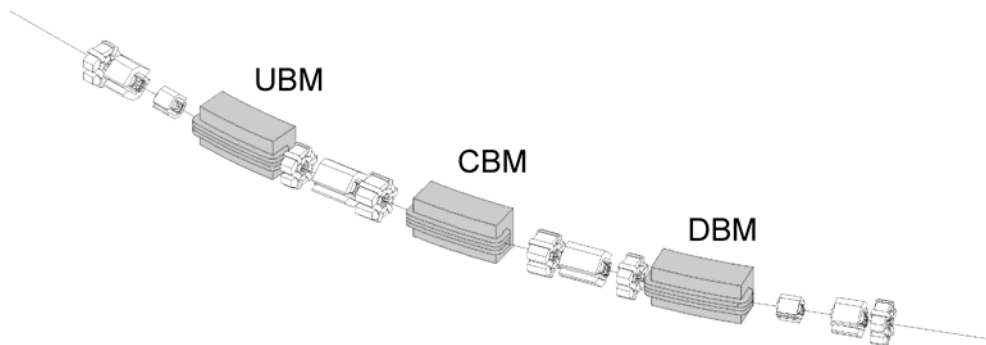
Figure 3.2.8: Position of bending magnets in the LLS storage ring cell. The sense of the electrons in the Figure is from left to right.

3.2.2.5.4 Why use doublets of quadrupoles in the straight sections.

The choice of doublets or triplets of quadrupoles determines the flexibility available for the control of betatron functions in the straight sections. The triplet is more flexible and allows for better compensation of the optical distortions induced by the IDs. On the other hand, triplets of quadrupoles may introduce more chromaticity and sensitivity to magnetic errors. However, the main technical disadvantage for our

purposes is that triplets occupy much more space and, in fact, the space available for IDs in the straight section would be reduced by ca. 2m. Therefore, to achieve the length for IDs we require, it would mean to increase the size of the accelerator, and thus the cost. Because of this, we propose to start with doublets of quadrupoles, i.e. we have accepted relatively high betatron functions in the straight sections. However, a future upgrade to triplets of quadrupoles could be easily carried out, thus providing the option to modify the betatron functions if/when needed in the straight sections.

The proposed distribution of quadrupoles is shown in Figure 3.2.9.
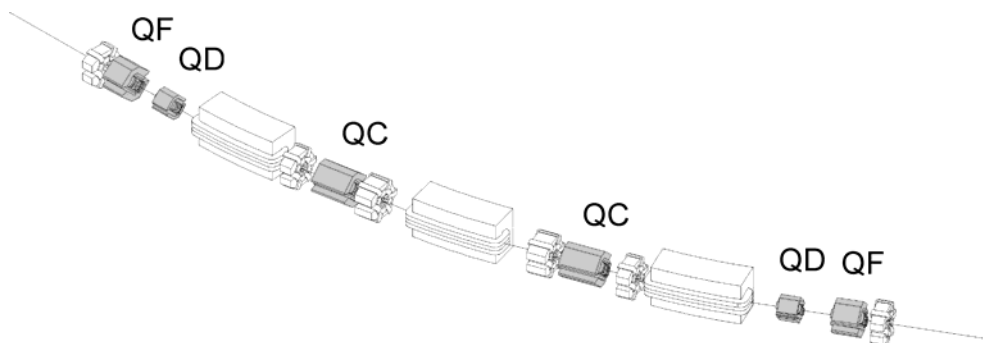
Figure 3.2.9: Distribution of quadrupoles in the LLS basic cell.

3.2.2.5.5 The total number of families of sextupoles.

Sextupoles are used to compensate for chromaticity. In general, the chromatic correction in a TBA lattice is carried out with two families of sextupoles. One (SV) is placed between the QC and the external bending magnet, and the second one (SH) between the QC and the central bending magnet. We have judged convenient to include another family (SA) placed near the QF so that compensation for the non-linear effects induced by the SV and SH sextupoles could be achieved if needed.
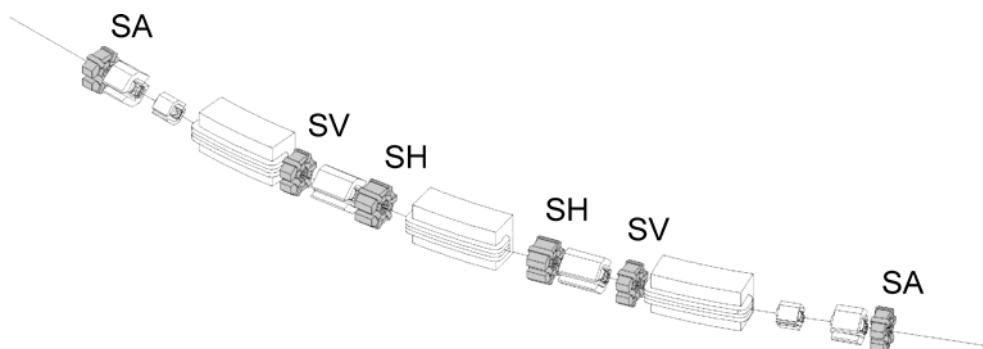
Figure 3.2.10: Distribution of sextupoles in the LLS basic cell.

3.2.2.5.6 Straight sections: the betatron functions and the option of non-zero dispersion.

We have considered the option, used in MAX-II and proposed for SOLEIL, to have straight sections with non-zero dispersion in order to achieve smaller beam sizes. This option remains as a possibility for a future upgrade, but considering that its advantages

are not as significant in a TBA as they would be in a DBA lattice, we have discarded it in the initial design.

Whether one wishes to have high or low beta functions in the straight sections is largely dependent on the type of IDs that will be used. At this stage, we have chosen a design with high beta functions in all straight sections (*non-hybrid*). Nevertheless, if needed (for example, in the event of wishing to use narrow gap IDs), the option remains open for the future inclusion of symmetrically placed pairs of a third family of quadrupoles. This should allow for a further reduction of the beta function in some straight sections.

3.2.3   Properties of the LLS lattice.

The brightness of a photon source at the points of light extraction is primarily determined by the betatron functions at these points, which are in turn determined by the magnetic properties of the lattice. Here we review the expected behaviour of the electron beam in the transverse plane, i.e. that determining the size of the source seen by the user, for the LLS lattice.

3.2.3.1   *Horizontal and vertical betatron functions.*

The strength of quadrupoles QC has been chosen so that the horizontal dispersion $D_x(s)$ and its derivative $D_x'(s)$ are zero at the straight section. The strength of the quadrupoles QF and QD has been adjusted to select the working point $Q_x = 14.3$ and $Q_y = 8.2$. This working point offers low emittance, low ratio between vertical and horizontal emittances and low chromaticity and thus, a rather large dynamic aperture. Figure 3.2.11 shows the optical functions (i.e., betatron and dispersion functions) in the horizontal and vertical planes for a cell.
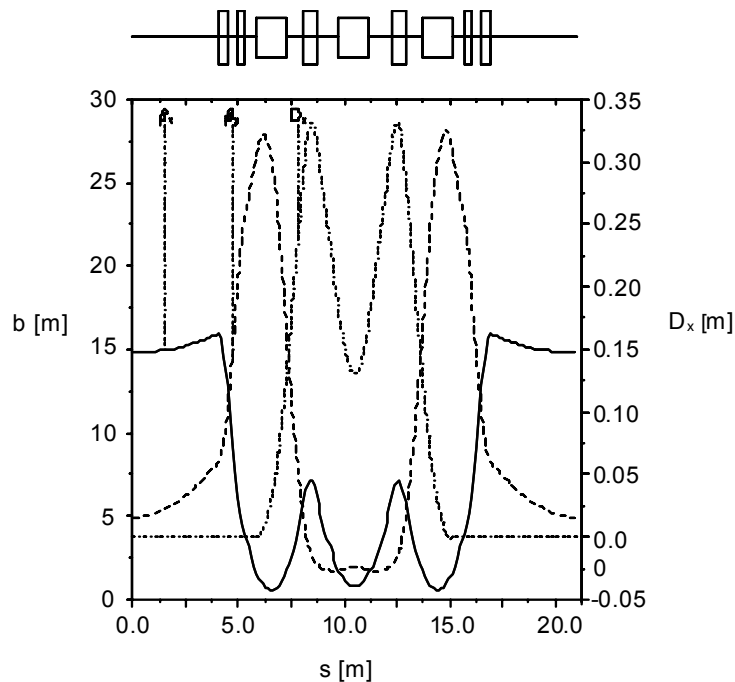
Figure 3.2.11: Betatron functions in horizontal and vertical planes, with the dispersion function along one cell.

An important advantage of the TBA lattice is its flexibility for choosing working points without affecting the performance of the storage ring. For example, the horizontal tune can vary in the range $14 < Q_x < 14.5$ whilst the emittance and chromaticity change by less than 5%.

3.2.3.2 *Beam sizes and emittance.*

The size of the electron beam largely determines that of the photon source. Because of this, it is one of the most important parameters of an accelerator from the point of view of its use as a light source. In an ideal accelerator the horizontal and vertical emittances are essentially the natural emittance ε_{x0} and zero, respectively. However, due to inevitable errors in the magnetic fields (to be expanded in section 3.2.4), in practice there is an increase of the vertical emittance, usually at the expense of the horizontal one, relative to that expected from the ideal machine. The so-called *emittance ratio* is given by the relationship:

$$\chi = \frac{\varepsilon_y}{\varepsilon_x}$$

and relates the horizontal (ε_x) and vertical (ε_y) emittances to the natural emittance ε_{x0} by:

$$\varepsilon_x = \frac{1}{1+\chi}\varepsilon_{x0}$$

and

$$\varepsilon_y = \frac{\chi}{1+\chi}\varepsilon_{x0}$$

Theoretical models and simulations indicate that the emittance ratio expected from the LLS should not be greater than 2% (see section 3.2.4.6). Nevertheless, in our beam size calculations we have assumed a conservative value of 5%. With the proposed lattice, the natural emittance is 8.48 nm·rad. With our assumption of 5% emittance ratio, we estimate that the horizontal and vertical emittances will be 8.08 and 0.4 nm·rad, respectively. These values have been used to work out the beam size along the ring. The following tables show the expected performance of the LLS at the three lattice points susceptible to light extraction.

	Σ_x [mm]	Σ'_x [mrad]	Σ_y [mm]	Σ'_y [mrad]
Light source half-sizes at critical energy				
Centre of UBM and DBM	0.192	0.404	0.265	0.176
Centre of CBM	0.361	0.311	0.074	0.174

3.2.3.3 *Effects due to sextupoles.*

Chromaticity, i.e. the tune shift experienced by an electron due to its departure from the nominal energy, may induce loss of particles. Because of this, the chromaticity must be adjusted to zero from its natural negative value. This is accomplished by means of

sextupoles placed in sections of the lattice with finite dispersion. An additional consideration is the instability known as *head-tail*, which results from the interaction between the electrons in the head of the electron bunch with those travelling back in the same bunch. When chromaticity is negative, the head-tail effect may lead to a size increase and an eventual loss of the beam, whilst for positive chromaticity, this effect only results in harmless longitudinal particle oscillations. Therefore, the sextupolar fields must be adjusted so that the chromaticity is somewhat greater than zero. We propose to carry out chromaticity corrections by means of two families of sextupoles, SH and SV. This is the minimum number needed to compensate the chromaticity on both the vertical and horizontal planes.

The introduction of non-linear elements such as sextupoles may cause tune variations and unstable motions. In order to have greater flexibility to compensate for these we propose to install a third family of sextupoles SA in the straight sections. Nevertheless in the description below, we have assumed that the SA sextupoles are not activated. In practice they may or may not be used depending on the effects of the non-linear elements.

The presence of SH and SV sextupoles has several effects:

– a reduction in the dependence of the tune on particle energy,

– a dependence of the tune on the amplitude of oscillations,

– a limitation of the dynamic aperture (DA).

We describe below these effects.

3.2.3.3.1 Tune dependence on particle energy.

The horizontal and vertical tune dependence on the particle departure from nominal momentum (the so-called *momentum dispersion* $\Delta p/p$) with and without sextupoles is shown in Figures 3.2.12 and 3.2.13, respectively. Note that the inclusion of sextupoles leads to a large reduction in tune-shift.
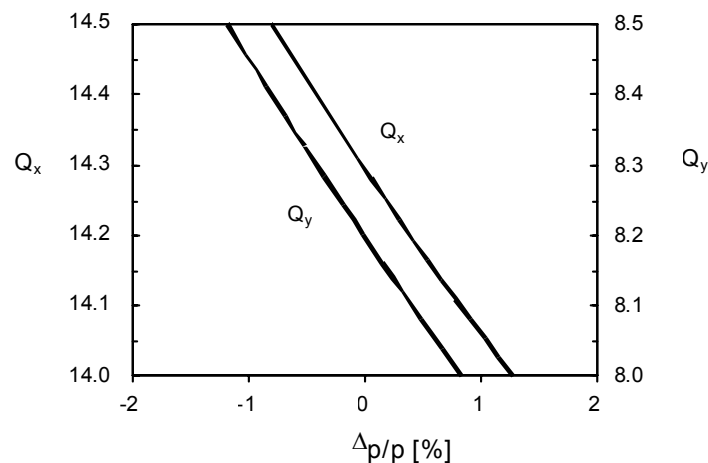
Figure 3.2.12: Variation of working point for momentum variations up to ±2% without sextupoles
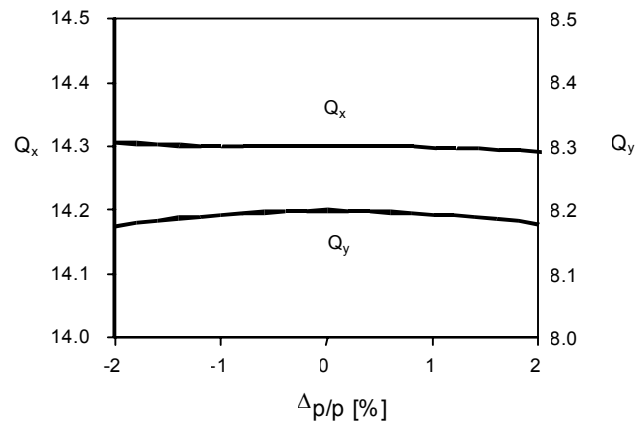
Figure 3.2.13: Variation of working point for momentum variations up to ±2% with sextupoles.

3.2.3.3.2 Tune dependence on the amplitude of the betatron oscillations.

The calculated tune variations, both in the horizontal and vertical directions as a function of the amplitude of betatron oscillations A_x and A_y are shown in Figures 3.2.15 and 3.2.16, respectively.
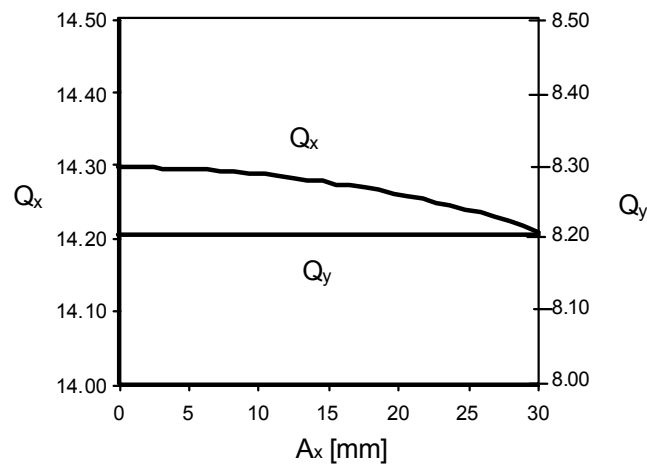
Figure 3.2.15: Horizontal tune Qx dependence with horizontal betatron amplitude Ax for LLS. The vertical tune Qy remains unchanged at 8.2.
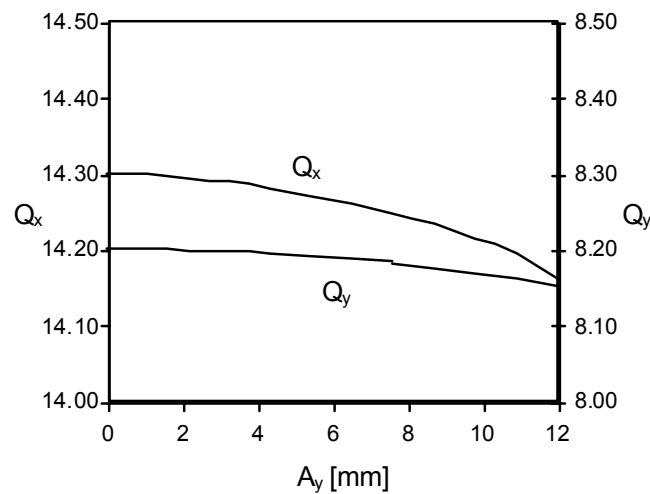
Figure 3.2.16: Horizontal tune Qx and vertical tune Qy dependence with vertical betatron amplitude Ay for LLS

Note that the amplitudes of the horizontal and vertical betatron oscillation extend to their maximal possible value given by the physical aperture (basically defined by the vacuum chamber aperture). We also note that within these limits, the expected parabolic change in tune does not cross any unwelcome resonance (see section 3.2.2.5.2) and, consequently, the trajectories will remain stable.

3.2.3.3.3 Dynamic aperture.

The inclusion of sextupolar fields reduces the maximum stable oscillations which particles can undergo. The area comprising the region within which the particles remain stable is called the dynamic aperture (DA). In order to achieve a practical accelerator, the DA must be comparable to the physical aperture, and of the order of 50 times the particle beam dimensions. We have determined the DA of the LLS with the code Tracy2,[7] for more than 500 revolutions. Similar results have been obtained with codes such as Racetrack,[8] and MAD.[9]

Figure 3.2.17 provides an estimate of the limits of the DA for on-momentum particles with nominal energy and for particles with an energy deviation of 2%.

We note that in both cases, the beam remains stable even for particle oscillations at the limit defined by the physical aperture (ca. 25 and 10 mm) in horizontal and vertical direction respectively. Additional effects on the DA, due to imperfections and errors in magnetic fields are evaluated in section 3.1.7.
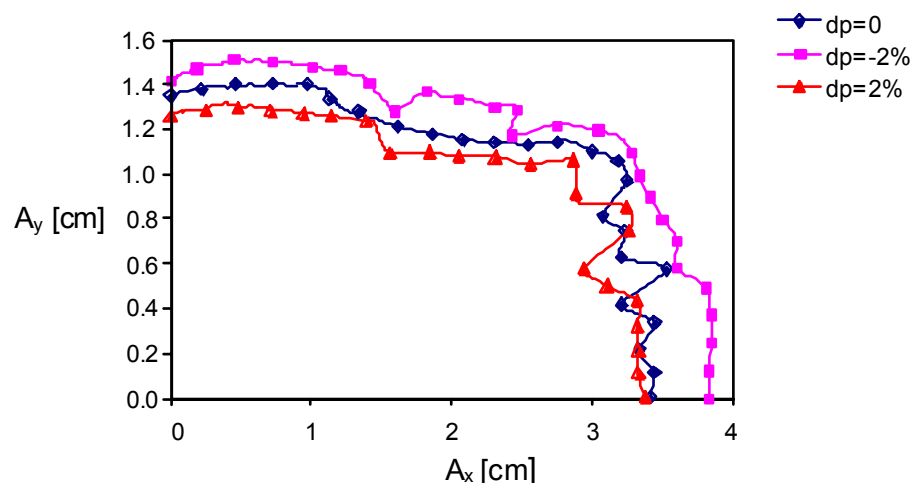
Figure 3.2.17: DA without magnetic errors, at the centre of straight sections, for three cases, one in which the particles have the nominal energy, whilst the other two have energies of 2% above and below the nominal energy, respectively.

The DA in previous figure has been calculated by simulating the trajectories of several particles with different initial betatronic amplitudes. Figure 3.2.18 shows a plot of the phase-space trajectory for several of these particles which are assumed to circulate in the steady state around the ring starting at a position with zero transverse momentum and initial amplitudes x_0 and y_0.

[7] J.Bengtsoon, E.Forest, and H.Nishimura, *Tracy2*, LBL

[8] F.Iazzourene, C.J.Bochetta, R.Nagaoka, L.Tosi, A.Wrulich; *Racetrack User's Guide*, ST/M-91/11, Elettra.

[9] H.Grote, F.C.Iselin, *The MAD Program, User's Reference Manual*, CERN/SL/90-13 (AP).
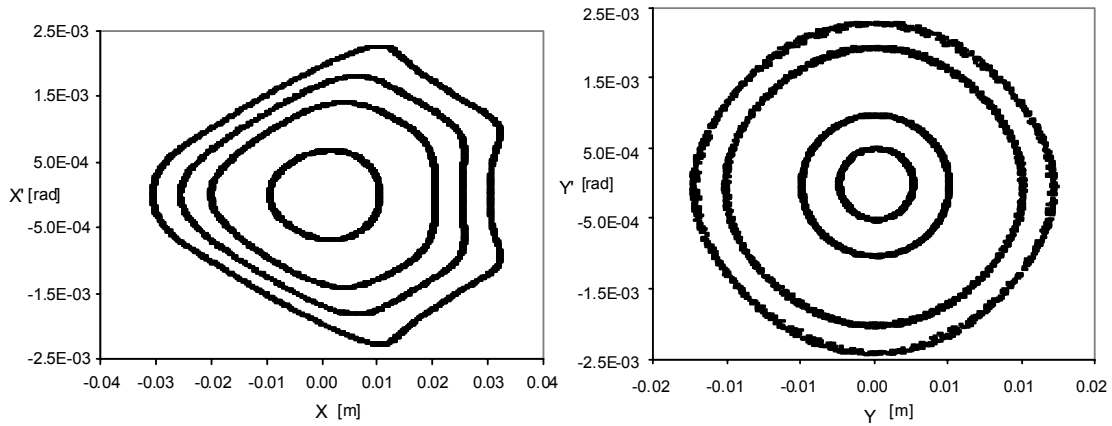
Figure 3.2.18: Phase space trajectory, at the center of the straight section, of several particles with nominal energy, but with different initial positions.

3.2.4 Effects of magnetic errors.

3.2.4.1 *Introduction.*

Given that the optimal use of SL requires a highly stable source, it follows that the stability of the electron beam is one of the most important aspects of the design. The sensitivity of the accelerator to systematic and random magnetic errors must be as small as possible. Here we expand upon the study we have carried out on the effect of errors in the behaviour of the LLS.

Essentially there are two types of errors that must be considered, namely:

– Dipolar errors, which basically affect the closed orbit, arise from imperfections in dipole fields and in the position of the quadrupoles.

– Quadrupolar errors, which fundamentally influence the betatron functions and the tune, arise from imperfections in the quadrupole fields.

3.2.4.2 *Dipolar errors.*

The ideal trajectory, from which the electrons oscillate around, passes through the centre of the magnets. The existence of spurious dipolar fields along the machine will change it to a new closed orbit. In order to achieve good stability of the light source, this distortion, after correction, should be of the order of 1/10 of the beam size in the horizontal plane. The effect of a vertical dipolar error ΔB of length l is a kick $\Delta x'$ in the horizontal plane given by:

$$\Delta x' = \frac{\Delta B l}{B\rho}$$

An equivalent expression for horizontal dipolar errors defines the kick in the vertical direction.

The effect of one of such kicks is a distortion of the closed orbit around the machine given by:[10]

$$\Delta x(s) = \frac{\sqrt{\beta(s)\beta(s_k)}}{2\sin \pi Q}\frac{\Delta Bl}{B\rho}\cos(Q\Delta\mu)$$

where s_k is the azimuthal co-ordinate of the error, Q the betatron tune, β(s) the betatron function and Δμ the betatron phase advance between the position of the error and s.

In practice, we have a random distribution of such kicks around the accelerator. The orbit distortion in a point of the machine is related to the rms value of kicks in all the error sources by the expression:

$$\Delta x(s) = \frac{\sqrt{\beta(s)}}{2\sqrt{2}\,\sin \pi Q}\sqrt{\left[\sum_i\left(\left(\frac{\Delta Bl}{B\rho}\right)_{rms}\right)^2 \beta(s_i)\right]_i}$$

where the summation extends to all these error sources.

3.2.4.2.1 Sources of dipolar errors.

The main sources of dipolar imperfections are:

− Average quadrupole displacement, represented by $\Delta x,y_{rms}$. The rms value of the kick $\frac{\Delta Bl}{B\rho}$ induced by such a displacement is given by:

$$\left(\frac{\Delta Bl}{B\rho}\right)_{rms} = k\cdot l\cdot\Delta x, y_{rms}$$

and the closed orbit distortion is:

$$\Delta x, y(s)_{rms} = \frac{\sqrt{\beta(s)}}{2\sqrt{2}\,\sin \pi Q}\sqrt{\sum_i (k_i l_i)^2 \beta_{x,y}(s_i)}\,\Delta x, y_{rms}$$

where $\Delta x,y(s)_{rms}$ is the value of closed orbit distortion in the point s of the orbit, β the betatron function, Q the tune in the plane where the distortion is computed, k the quadrupole strength and l its effective length.

− Imperfections in the dipolar field of the bending magnet, $\Delta B/B_0$. Affects only the orbit in the horizontal plane. The horizontal closed orbit distortion $\Delta x(s)_{rms}$ is:

$$\Delta x(s)_{rms} = \frac{\sqrt{\beta(s)}}{2\sqrt{2}\,\sin \pi Q}\sqrt{\sum_i \beta_x(s_i)}\,\theta\frac{\Delta B}{B_0}$$

where θ is the bending angle, Q the horizontal tune and $\Delta B/B_0$ is the relative field error.

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[10] J. Rossbach and P. Schmuser, Basic course on accelerator optics, in «Proceedings of the Fifth General Accelerator Physics Course», CERN 94-01, CERN-CAS, 1994.

- Roll angle $\Delta\phi$ in the bending magnets. A roll angle error $\Delta\phi$ produces a horizontal field proportional to the error.

$$\left(\frac{\Delta Bl}{B\rho}\right)_{rms} = \theta \cdot \Delta\phi$$

and the closed orbit distortion $\Delta y(s)_{rms}$ is given by:

$$\Delta y(s)_{rms} = \frac{\sqrt{\beta(s)}}{2\sqrt{2}\,sin\,\pi Q}\sqrt{\sum_i \beta_y(s_i)}\,\theta \cdot \Delta\phi$$

3.2.4.2.2 Amplification factor.

It is useful to define the so-called Amplification Factor, A(s). It is a function of the co-ordinate s, and is defined as the ratio between the rms value of the closed orbit distortion produced by a set of dipolar error, divided by the rms value of the dipolar error:

$$\Delta A_\zeta(s) = \frac{\Delta\zeta_{rms}(s)}{rms\ value\ of\ error}$$

where   stands for x or y coordinate. Figures 3.2.19 and.3.2.20 show the amplification factor for the horizontal and vertical displacement of quadrupoles, and imperfections in the dipolar field and in the roll angle for the bending magnets respectively.
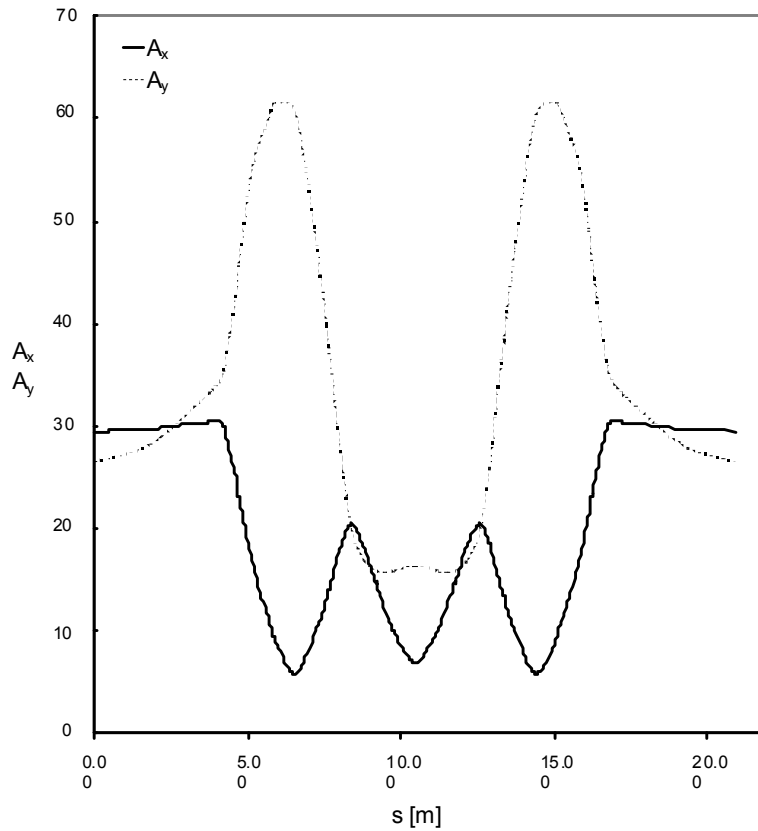
Figure 3.2.19: Amplification factor due to errors in the quadrupole position.
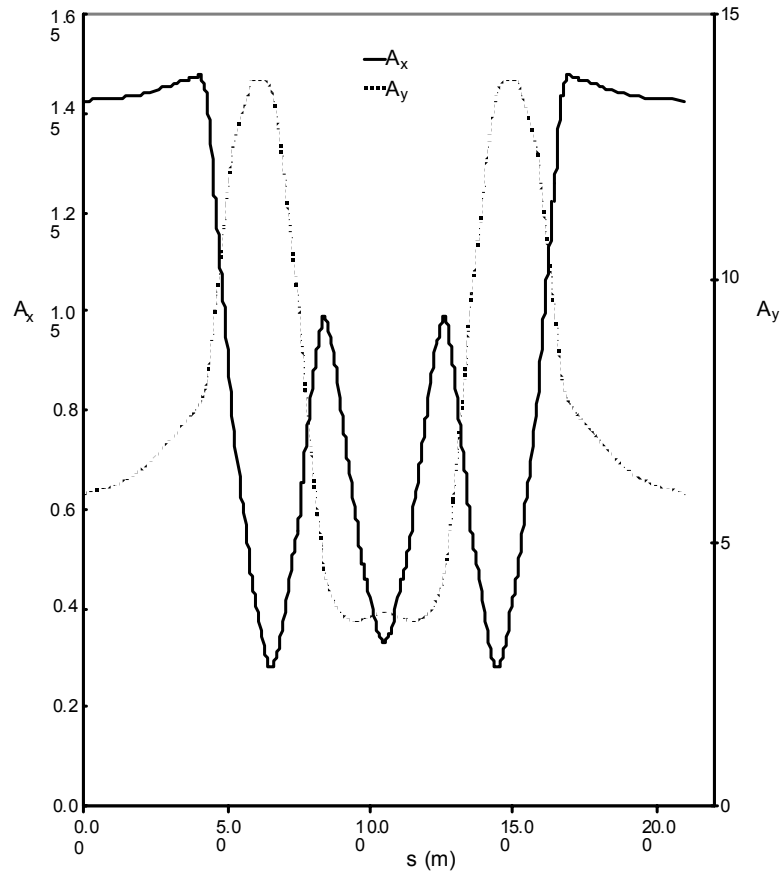
Figure 3.2.20: Amplification factor due to error in the dipole field (left axis) and roll angle (right axis) in the bending magnet.

The amplification factor at an arbitrary point in the lattice has a contribution of the different families of magnets that affect the error (bending magnets for $\Delta B/B_0$ and $\Delta\theta$, quadrupoles and bending for errors in position). In order to know what are the main sources of possible closed orbit distortion is useful to know the contribution of each family to the different amplification factors. Next table shows the relative contribution to the four sources of errors listed above of each family of magnetic elements. One can see that the closed orbit error in the horizontal direction results mainly from the two families of focusing quadrupoles, with an additional contribution due to the field error in the bending magnets.

Contribution to:	A_x [m]	A_y [m]	A_x [m]	A_y [m]
Source of error:	Δx	Δy	$\Delta B/B_0$	$\Delta\theta$
Family	contribution [%]	contribution [%]	contribution [%]	contribution [%]
QF	17.9	8.4		
QD	1.5	5.3		
UBM	0.8	26.3	29.6	48.2
QC	29.4	9.0		
CBM	1.0	1.9	40.8	3.5
QC	29.4	9.0		
DBM	0.8	26.3	29.6	48.2
QD	1.5	5.3		
QF	17.9	8.4		

In the vertical plane, the primary contribution is due to the external bending magnets.

Note that to evaluate the closed orbit distortion produced by the various errors a linear model of the machine is assumed, i.e. the effect of the sextupoles is not included.

3.2.4.2.3 Modelling the effect of dipolar errors.

The effect of dipolar errors has been evaluated using the formulae given in the preceding paragraphs and with a variety of simulation codes (MAD and Tracy2) [11,12] and using pessimistic assumptions. These assumptions were:

− Transverse alignment errors: $\Delta x,y = 0.1$ mm.

− Errors in the angular alignment: $\Delta\theta = 5 \cdot 10^{-4}$ rad.

− Imperfections in dipolar field strength: $\Delta B/B_0 = 5 \cdot 10^{-4}$

The Figure 3.2.21 shows the expected rms value of the closed orbit distortion predicted by the theory.
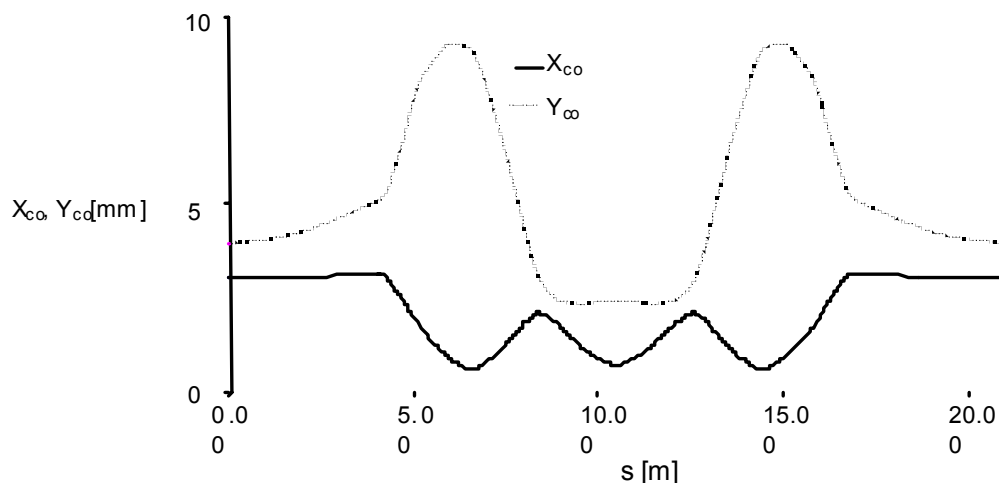
Figure 3.2.21: Expected rms closed orbit distortion.

The average values of the rms closed orbit distortion are:

$$<X_{CO}> = 2.10 \text{ mm}$$

$$<Y_{CO}> = 5.16 \text{ mm}$$

and the values of the rms closed orbit distortion at the centre of the ID section are:

$$X_{CO}(ID) = 3.03 \text{ mm}$$

$$Y_{CO}(ID) = 3.97 \text{ mm}$$

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[11]   H. Grote, F. C. Iselin, The MAD Program, User's Reference Manual, CERN/SL/90-13 (AP).
[12]   J. Bengtsoon, E. Forest, and H. Nishimura, Tracy2, LBL.

We have used the simulation codes MAD and Tracy2 to check these results. We have simulated 100 machines, each one with a different distribution of errors. Each program uses a different algorithm for simulating the dynamics of the electrons and for the effect of the errors. In these simulations (and for the rest of the study, unless explicitly stated) the sextupoles have been set to zero strength. This is reasonable, and corresponds to a method often used in commissioning, where the sextupoles are set to zero or low values until initial closed orbit correction takes place.

The average values of: the rms closed orbit distortion around the machine; the maximum closed orbit distortion; the closed orbit distortion at the centre of the straight section; and the rms value at the position of the beam position monitors (BPM), are given in the following table. The values are in mm.

	Theory		*MAD*		*Tracy2*	
	Horizontal	*Vertical*	*Horizontal*	*Vertical*	*Horizontal*	*Vertical*
rms	2.1	5.16	2.09	5.46		
max	3.2	9.3	5.89	15.88	5.7	14.6
ID	3.03	3.97	3.16	3.65	2.90	3.57
BPM			1.93	5.58	1.86	4.95

We can see that there is a good agreement between the results of the rms values yielded by the simulations and the theory. Figure 3.2.22 shows the orbit around the machine for 4 different sets of errors.
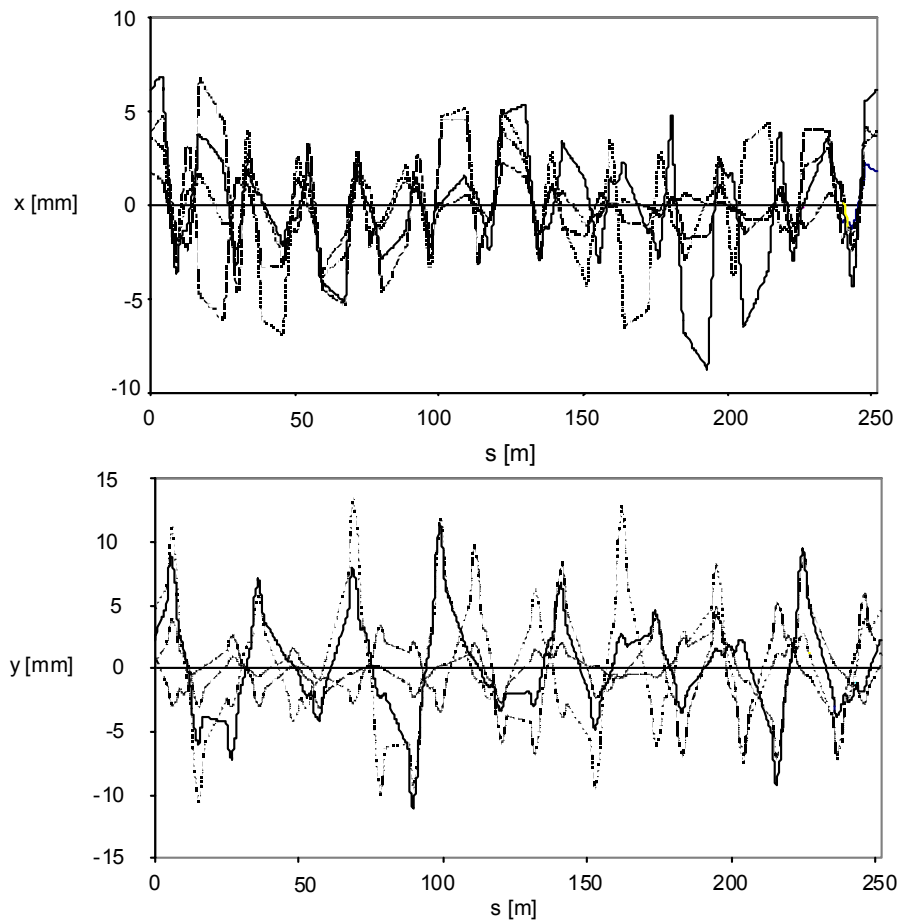
Figure 3.2.22: Horizontal (top) and vertical (bottom) closed orbit with errors.

3.2.4.3 *Closed orbit corrections.*

3.2.4.3.1 Global correction for closed orbit errors.

The various errors evaluated above induce a closed orbit distortion that must be corrected. In order to achieve the required orbit stability (1/10 of the electron horizontal beam size at the ID location), we plan to use a correction system composed of 8 beam position monitors (BPMs) and 8 correctors per cell. The position of these BPMs as well as those of the corrector magnets in one cell is shown in Figure 3.2.23. Six of eight correctors are integrated in the sextupoles, and the other two are dedicated magnets. In the straight section used for injection, the two dedicated correctors are not installed in order to provide space for the injector bumper magnets. Therefore, in order to achieve closed orbit corrections we propose to use a total of 96 BPMs and 94 correctors.
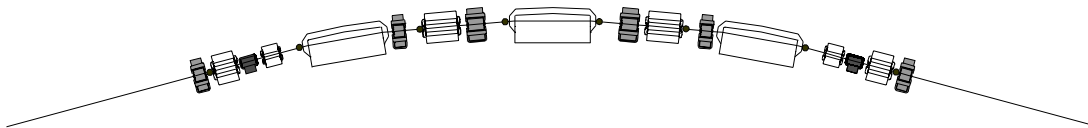
Figure 3.2.23: Scheme for the positioning of BPMs and correctors in LLS cell. Black points indicate the position of the BPMs, whilst dark and clear greys indicate the positions of the two dedicated and the six sextupole mounted correctors, respectively.

Evaluation of the closed orbit correction scheme has been carried out with the codes MAD and Tracy2, using two different correction schemes (MIKADO algorithm for MAD and local bump for Tracy2).[13] Simulations with both codes yield essentially identical results. The values of the corrected closed orbit and the required magnetic corrector strength (given in deflection units) are given in the tables below. The statistical numbers given in the tables correspond to those obtained for the simulations of the 100 machines studied in section 3.2.4.2.3.

	Corrected Closed orbit statistics [mm]			
	MAD		Tracy2	
	Horizontal	Vertical	Horizontal	Vertical
rms	0.038	0.035	0.026	0.039
max	0.205	0.192	0.120	0.250
ID	0.034	0.029	0.024	0.035

	Statistics of corrector strengths [mrad]			
	MAD		Tracy2	
	Horizontal	Vertical	Horizontal	Vertical
rms	0.160	0.138	0.136	0.136
max	0.498	0.457	0.429	0.320

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[13] A. Ropert, Linear Imperfections in Circular Accelerators, in «Joint Universities Accelerator School», 1996.

Figures 3.2.24 and 3.2.25 show the distribution of the rms strength and the maximum values of the correctors, evaluated with MAD.
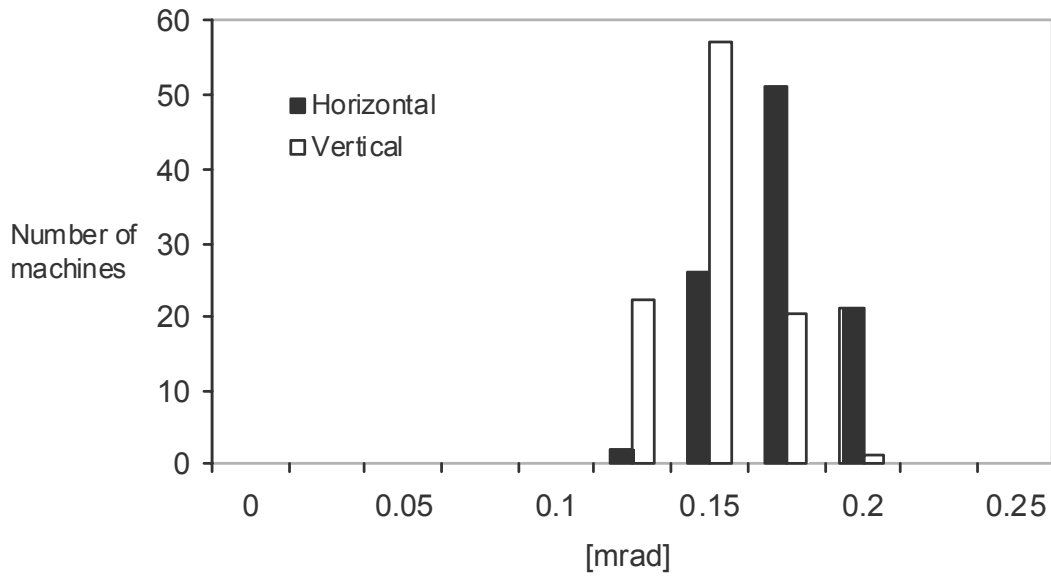
Figure 3.2.24: rms value of correctors deflection for 100 simulations.
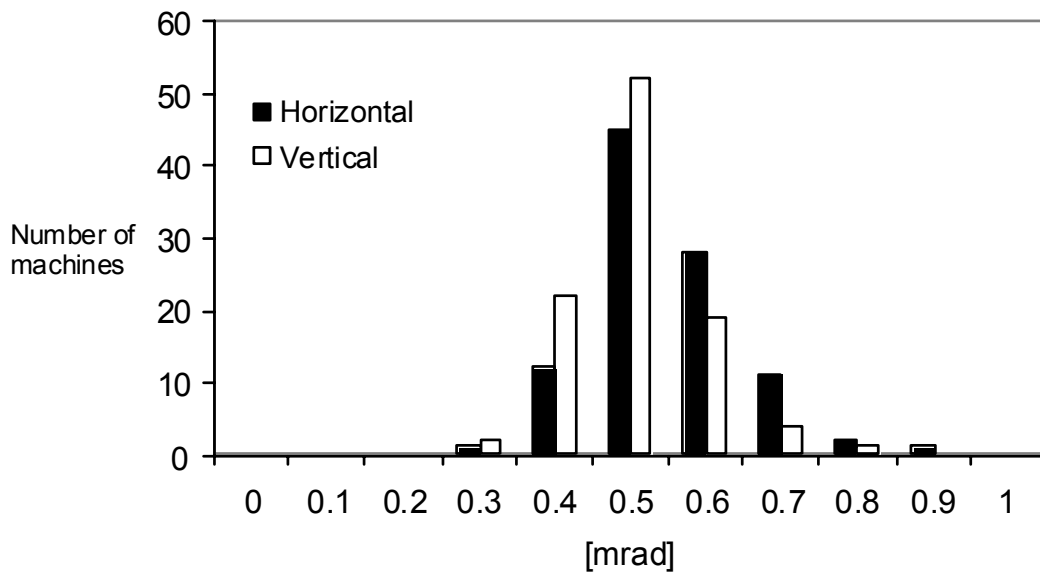
Figure 3.2.25: Maximum value of correctors deflection for 100 simulations.

Figure 3.2.26 shows the corrected closed orbits along the whole of the machine for both the horizontal and vertical planes. These have been evaluated with Tracy2 for the four sets of errors given in Figure 3.2.27.
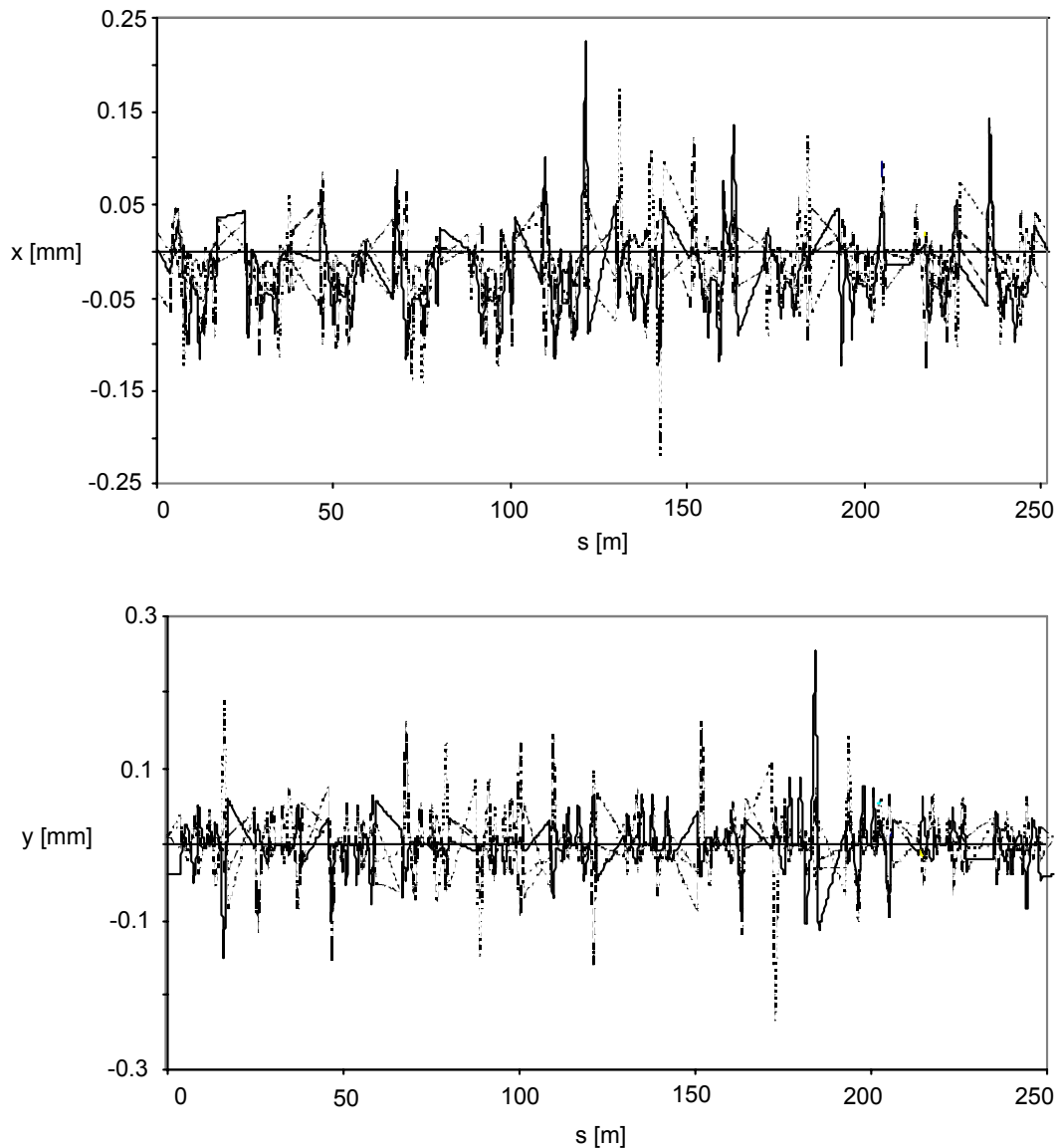
Figure 3.2.27: Horizontal (top) and vertical (bottom) closed orbit with correction.

After correction the maximum residual deviations are less than 0.25 and 0.3 mm in the horizontal and vertical planes, respectively, i.e. improvement factors in excess of 40 and 50 times relative to the uncorrected orbits. We note that in general the adjustment of the beamline optics will not be necessary after each injection and global orbit correction.

3.2.4.3.2 Local corrections for closed orbit errors.

With regards to user defined corrections at the points of light extraction such as bending magnets and IDs, i.e. local bumps, we propose to adjust the families of correctors near the source points to provide the extra deflection required. For example, a maximal deflexion of 1.5 mrad by the correctors will allow an orbital motion of up to 3 mm in the region of the IDs.

3.2.4.4 *Effect of quadrupole errors.*

The other important type of error we have considered is that due to the quadrupolar fields. The main effect of this kind of error is a perturbation of the optical functions and thus a change in the tunes.

This change in the tunes is given by:

$$\Delta Q_{x,y} = \frac{1}{4\pi} \oint \beta(s)\Delta k(s)ds$$

where $\Delta k(s)$ is the quadrupolar error around the machine.

Correction of this type of error is done in two steps: a first step where the global tune is restored and a second step using the "system matrix response" technique. This technique has been successfully used elsewhere (e.g. at ALS).[14] The central idea of this approach is to measure the orbital positions (using the 96 available BPMs) and construct a matrix ("response matrix") relating these measurements to the orbital deflections induced by the 94 available correctors. Each element of the response matrix depends on the strength of the quadrupoles. One constructs a model matrix relating quadrupolar strengths to orbit position. This is then used to work out the changes required in the quadrupolar fields to compensate for the quadrupolar errors without altering the corrector fields.

3.2.4.5 *Effects on the dynamic aperture.*

Even though a stable and reproducible orbit can be achieved, the applied corrections may not totally compensate for the errors. Therefore, a residual distortion relative to the nominal orbit may remain. This residual error could generate a random quadrupolar field when the electrons traverse the sextupoles, which, together with the fact that the ideal accelerator symmetry may be reduced because of the corrections, might lead to a reduction of the DA. To evaluate whether this could become a problem we have calculated the DA with errors such as those described above (i.e. using pessimistic assumptions) and with the correctors operating. Figure 3.2.28 shows the DA evaluated with MAD.

It is reassuring that the DA is more than 50 times the beam size in both the horizontal and vertical directions (i.e. more than 80 times greater horizontally and 400 times vertically) for particles with the nominal energy.

All codes tried out have produced essentially the same result, which testifies for the robustness of the proposed design.

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[14] D. Robin, G. Portmann, H. Nishimura, J. Safranek, Model calibration and symmetry restoration of the Advanced Light Source, Proceedings of EPAC-96, p. 971.
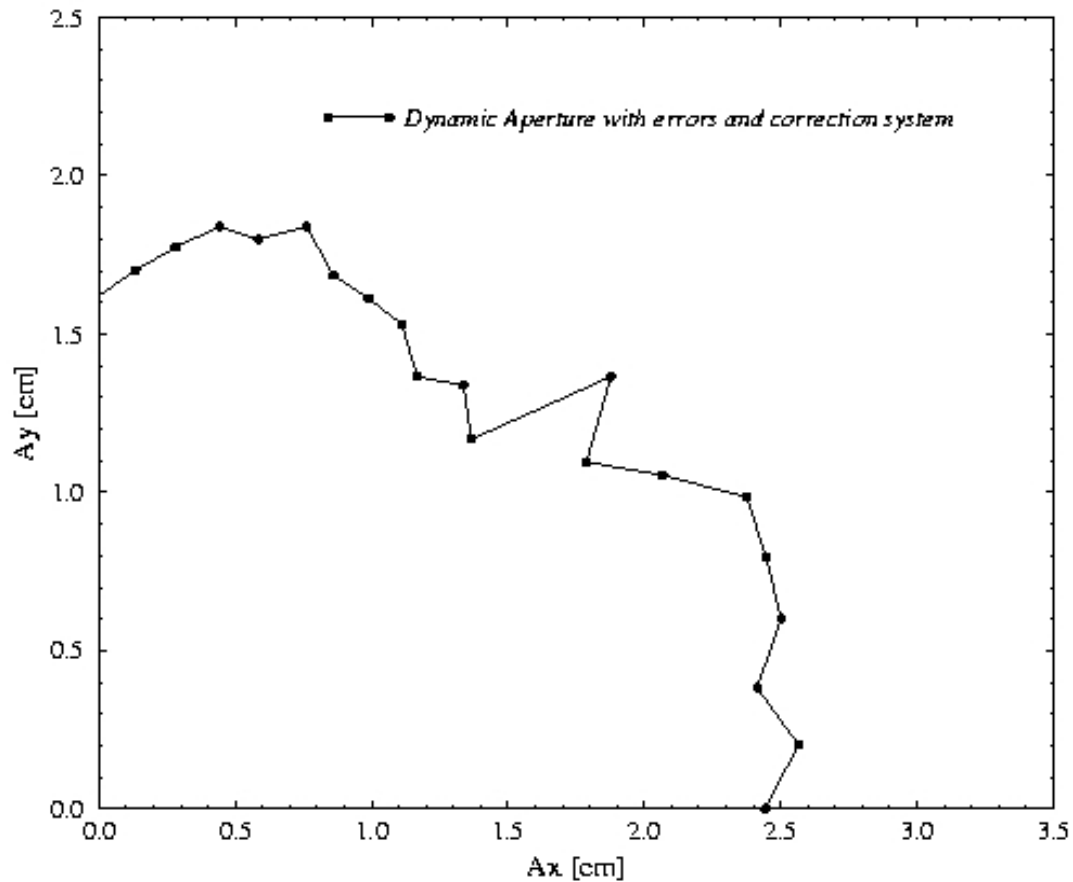
Figure 3.2.28: LLS dynamic aperture taking into account dipolar errors and its correction.

3.2.4.6 *Vertical emittance and coupling.*

As the bulk of beamline optics are vertically dispersive, the performance of any light source is mostly determined by its vertical emittance, specifically by the vertical beam size. In a perfect machine (no errors and only linear components), the vertical emittance ε_y is several orders of magnitude smaller than the horizontal.

The two processes that increase the vertical emittance are:[15]:

– Presence of horizontal dipolar magnetic fields $\vec{B} = (B_x, 0, 0)$, which create vertical dispersion, hence vertical emittance.
– Linear coupling of the motion in the horizontal and vertical planes, generated by skew quadrupolar fields and vertical closed orbit distortion in sextupoles.

These two processes are independent and the final emittance is given by the sum of the two contributions. The parameter used to evaluate the effect is the emittance ratio χ:

$$\chi = \frac{\varepsilon_y}{\varepsilon_x}$$

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[15] M. Muñoz, Assessment of the achievable emittance ratio in DIAMOND, Proceedings of EPAC-96, p. 938.

The brightness B of the machine is inversely proportional to this ratio:

$$B \propto \frac{1}{\chi}$$

Using the sets of errors and the correction system described above, we have employed MAD and Tracy2 to evaluate χ. Both programs give similar results, and yield an emittance ratio:

$$\chi = 1.1\%$$

With the help of a skew quadrupolar field component on the SA magnets and shifting the working point closer or further away from resonances, we find that this value may be adapted (by increasing or decreasing it) to user needs.

3.2.4.7   *Additional considerations and conclusion.*

Some issues still remain unresolved concerning beam stability. The main one refers to the magnet support system. However, before resolving this question, a complete analysis of the constructed site is required. With the information available at present, we foresee the use of a slow feedback system to ensure the stability at the source points. In this case, the use of photon beam position monitors along the beamlines will provide a good complement to the electron BPMs.

In summary, the proposed correction system for the LLS is composed of 8 BPMs and 8 correctors per cell acting in both planes, thus giving a total number of 96 BPMs and 94 correctors (2 correctors are missing to allow space for the injection kickers). This system can compensate the closed orbit distortions generated by the assumed magnetic imperfections. The strength of the correctors required is well within tolerable values, and allows for a stable beam at source points. The emittance ratio generated by the errors is also well corrected by the correction system.

3.2.5   Conclusions

We have presented here the main conceptual guidelines for the future synchrotron accelerator in Spain (LLS).

More information about the magnets, RF power, control system, beam diagnostics and beamlines can be found in our webpage http://www.lls.ifae.es/

However, some of the initially considered options can be changed, especially those regarding the booster. The possibility to design a booster able to fit the same shielding used for the main ring is currently under consideration, in order to reduce costs and make easy the topping up injection running mode.

Currently, the Spanish and Catalan governments are setting up the legal institution which will built and manage the LLS. It is expected to begin the detailed engineering design of the machine at the end of 2002 and to begin the building design and construction earlier in 2003. The source is expected to be operative at the end of 2008.

4   Activity Reports

4.1   When will there be an Asian Accelerator Laboratory?

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mail to: rohelakhan@hotmail.com   http://www.imsc.ernet.in/~jagan/khan-cv.html

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Abstract

We address the theme of international collaborations based on accelerator sciences and present the proposal for international facilities to enhance cooperative science in Asia.

4.1.1   Introduction

The problem with articles that have a question mark in their title is that the question posed in the title is usually not answered in the article! This article is not an exception. However, the posed question is addressed in detail. Science is the shared heritage of humankind; here the reference to the Asian region is exclusively in the context of regional cooperation, with a global perspective. Asian region is one of the major economic blocks and is home to more than half of the world's population. SIAM and SESAME synchrotrons are examples of regional international facilities in Asia. It is to be recalled that Japan gifted a synchrotron to Thailand in 1996; the 1.0 GeV Siam Light Source is intended to serve scientists throughout Southeast Asia [1,2]. This generosity of Japan made Asia the birth-place of the *Era of Relocated Synchrotrons* [3]. This tradition of gifting synchrotrons in Asia was followed by Germany who gifted a 800 MeV synchrotron to the region of Middle East, which is being upgraded to a 2.0 GeV third-generation light source. SESAME Project is envisaged to be a mini-CERN in the Middle East [4]. We need more of such international facilities.

Accelerator-based sciences in Asia are as old as the subject itself. In 1934 Cockroft-Walton accelerators were built in Taiwan and Japan respectively. In 1940 a 37inch cyclotron was developed in India. By 1950's the accelerator programmes were flourishing in several countries across Asia. There are about fifty synchrotron radiation facilities in twenty-three countries around the world. Of these thirty are located in nine Asian countries: Armenia, China, India, Japan, Jordan, Korea, Singapore, Taiwan and Thailand. Notable among these is the 8.0 GeV Super Photon Ring (SPring-8) synchrotron radiation facility in the Harima Science City in the Hyogo Prefecture of Japan. It is the largest one in the world! At present there are seven electron-positron rings operational in the world and two of them are in Asia; one in China and one in Japan respectively. There are excellent programmes in several other countries. A detailed description of the various accelerator activities is to be found in the *Special Chapter* on *Accelerators in Asia*, with twelve contributions in the August 2000 issue of

this newsletter [5]. Other sources are the APAC Proceedings [6,7], the ACFA Website [8] and the articles in [9,10].

The design construction and operation of all these accelerators has lead to an increased activity in Asia in the fields of particle physics, nuclear physics, materials and biological sciences. Accelerators have become an indispensable tool in medical and industrial research. With strong economic growth over the last few decades, Asian countries have increasingly promoted accelerator-based sciences, leading to an increased collaboration among these countries, to share resources and expertise. This resulted in the establishment of new Forums including: the Asian Committee for Future Accelerators (ACFA) in 1996; Asian Particle Accelerator Conferences (APAC) in 1998; Asian Accelerator Schools (AAS) in 1999. The other Forums include: the Particle Accelerator Society of China (PASC) [11,12]; Japanese Beam Physics Club (JBPC) [13,14]; and the Accelerator & Beam Physics Schools in India [15].

With all the remarkable developments cited above the *absence* of an *International Asian Facility* is very noticeable and somewhat paradoxical. We need to enhance close collaboration in this region for efficient use of its resources not only to understand nature but also to advance technology to improve the quality of life. Asia is home to the largest number of developing countries. Accelerator-based sciences can provide the much needed vehicle for more intensive international collaborations in Asia. CERN has been providing one such means of international collaborations in Europe, since its inception in 1954. Another related joint initiative in Europe is the 6.0 GeV European Synchrotron Radiation Facility (ESRF) which was conceived in 1975; construction began in 1988 and opened for users in 1994. Such facilities can also be created in Asia. We need to evolve a programme towards an Asian Accelerator Laboratory (AAL).

4.1.2   Asian Accelerator Laboratory: A Proposal

The realizability of large-scale projects such as the proposed AAL can be analyzed by examining the following factors:

4.1.2.1   *Technological Feasibility*

AAL shall initially have one or more synchrotrons. This is technically possible as several countries in Asia have the long experience and the expertise of making and running such facilities. The AAL may also have projects such as the *Energy Recovery Linac* (ERL) and the *Spallation Neutron Source* (SNS), which are based exclusively on proven pieces of technology. There **can not** be an iota of doubt in successfully executing the technological aspects of the proposed AAL. More ambitious programmes involving large machines (such as the *Next Large Hadron Colliders*) or designs based on new ideas & technologies can be tried at a later date.

4.1.2.2   *Financial Viability*

Having realized the technological feasibility in Step-I, the next step is to explore the financial viability. The cost of constructing a facility similar to say, the 6.0 GeV European Synchrotron Radiation Facility (ESRF) is 550 million US$ with annual running costs of about sixty million US$. The total construction cost of the 7.0 GeV third-generation Advanced Photon Source (APS), in Argonne, USA is 467 million US$. Let us note, that the combined total GNP of the twenty CERN Member States is about 9,000 billion US$, with net R&D allotment of about 190 billion US$. The

corresponding figures for the thirteen ACFA Member Countries are 7,000 billion US$ and 145 billion US$ respectively. In terms of percentages the CERN member states are spending on an average over 2.10% of their GNP towards R&D. When we compute the average percentage for ACFA member countries (*minus* Japan), it turns out to be 0.98%. This aspect of the expenditure on R&D has been recorded in the statistical Tables 4.1.1 and 4.1.2. The required funds of one billion US$ for the AAL can come from, by increasing the R&D allotment from 145 to 146. This is about increasing the percentage from 0.98 to 1.01, an *infinitesimal step* towards the proven international norms of the GNP formula (1.0% to 2.0% of their GNP towards R&D, this is discussed in detail in [16]). This is precisely the source which can and has to generate, the funds for the AAL. If we include the statistics of Japan, the percentage figures for increasing the allotment towards R&D will be appreciably less. In these figures we have excluded Japan as it contributes more than half to the total GNP of the ACFA Member Countries and has the very high allotment of 2.8% towards R&D. The primary funding for the AAL should preferably come from those countries, which are not yet meeting the norms of the GNP formula, and they should find some means to afford this. In the beginning it will be difficult for some countries, but the rewards are assured. We have focused on the ACFA countries in the analysis, only for convenience and significantly to demonstrate the feasibility of AAL. In the process we have also recorded the low allotment towards R&D in most of the ACFA countries. Other countries should not miss the opportunity to participate in ACFA and the AAL.

Table 4.1.1: Statistical Data for ACFA Member Countries

Country	Population (thousands) 2001	GNP per captia (US $) 1998	Scientists/ Engineers in R & D (per million inhabitants)	Expenditure on R & D (million US$)	Expenditure On R & D (% of GNP)
Australia	19,339	20,640	---	6,192	1.60
Bangladesh	140,369	350	52 (1995)	13	0.03
China	1,284,974	750	454 (1996)	5,634	0.61
India	1,025,096	440	149 (1994)	3,120	0.73
Indonesia	204,840	640	182 (1988)	248	0.19
Japan	127,334	32,550	4,909 (1996)	114,495	2.80
Korea	47,069	8,600	2,193 (1996)	11,246	2.82
Malaysia	22,633	3,670	93 (1996)	195	0.24
Pakistan	144,971	470	72 (1997)	566	0.92
Singapore	4,108	30,170	2,318 (1995)	1,079	1.13
Taiwan	22,500	12,330	1,028 (1997)	---	1.74
Thailand	63,584	2,160	103 (1996)	172	0.13
Vietnam	79,175	350	334 (1985)	---	---

Sources:
UNESCO Statistical Year Book (1999) [18].
World Bank Atlas (2001) [19].
¨---¨ indicates non-availability of data.

Table 4.1.2: Statistical Data for CERN Member Countries

Country	*Population* (thousands) 2001	*GNP* per captia (US $) 1998	*Scientists/ Engineers* in R & D (per million inhabitants)	*Expenditure* on R & D (million US$)	*Expenditure* On R & D (% of GNP)
Austria	8,075	26,830	1,627 (1993)	3,250	1.50
Belgium	10,263	25,380	2,272 (1995)	162	1.60
Bulgaria	7,866	1,220	1,747 (1996)	58	0.57
Czech Republic	10,260	5,150	1,222 (1997)	636	1.20
Denmark	5,332	33,040	3,190 (1997)	3,416	1.95
Finland	5,178	24,280	2,799 (1995)	3,077	2.46
France	59,453	24,210	2,659 (1996)	34,144	2.33
Germany	82,008	26,570	2,831 (1995)	50,353	2.31
Greece	10,624	11,740	773 (1993)	580	0.47
Hungary	9,017	4,510	1,022 (1996)	311	0.68
Italy	57,503	20,090	1,318 (1997)	25,570	2.21
Netherlands	15,929	24,780	2,219 (1996)	8,093	2.08
Norway	4,488	34,310	3,664 (1995)	2,645	1.74
Poland	38,577	3,910	1,358 (1996)	1,165	0.77
Portugal	10,034	10,670	1,182 (1995)	660	0.62
Slovak Republic	5,404	3,700	1,814 (1995)	209	1.05
Spain	39,920	14,100	1,305 (1996)	4,941	0.89
Sweden	8,833	25,580	3,826 (1995)	20,876	3.76
Switzerland	7,170	39,980	3,006 (1996)	7,387	2.60
United Kingdom	59,541	21,410	2,448 (1996)	24,654	1.95

Sources:
UNESCO Statistical Year Book (1999) [18].
World Bank Atlas (2001) [19].
¨---¨ indicates non-availability of data.

A more ambitious facility like the SPring-8 (one billion US$) or a programme like the Large Hadron Collider (LHC) at CERN (two billion US$) should also be explored. The proposed AAL can be evolved into a high energy physics facility (such as an electron-positron collider in the *TeV regime*) to look for *New Physics beyond the Standard Model of Particle Physics*. ICFA provides excellent *guidelines* for realizing such ideas. The costs of construction are distributed over several years of planning & construction, and are to be shared by the participating countries *via* the GNP rule (pay in proportion to their GNP respectively) or any mutually convenient arrangement. AAL funding can follow the proven examples of CERN or/and ESRF. As is well-known, the required time for the *conceptual study & planning* is several years, before the actual ground-breaking. This provides adequate time to the funding governments to reorient their expenditures, to enable the incremental funding of the proposed AAL.

So, in principle Asia can conveniently afford the proposed AAL.

4.1.2.3 *Political Will*

Having ascertained the technological feasibility and the financial viability for the AAL, its execution is more a question of a political will on part of the participating countries (their governments and the *science policy makers* in particular). It is the responsibility of the scientific community to push such a proposal through the existing Forums, and creating new Forums at the national level where required. Europe has done several such projects (CERN to be counted in plural due to the long chain of projects; ESRF; European Space Agency; …). Why can not Asia begin even one? What is the scientific community waiting for?

Such projects take a long time to mature. Sooner they are started the better it is. A pilot study for the AAL should begin right away.

4.1.3 Concluding Remarks and Future Outlook

The larger accelerator projects can not be realized by single countries, and are thus a source of international collaborations. This is more true for countries with smaller scientific or/and economic resources. CERN and ESRF are excellent examples of such collaborations. Asian countries should very closely examine these examples in their own perspective and work towards the AAL. Large laboratories not only lead to a better understanding of nature, but also pave the path for many technological and commercial spin-offs. Here, we shall cite just one example: the creation of the *World Wide Web* at CERN. This is one of the many examples of technology transfer from big-science laboratories to industry and finally to the public.

The proposed AAL provides a wonderful opportunity for collaboration and cooperation between scientists and their institutions in countries spread across Asia [17]. Working together on the many common problems that the Asian countries face, scientists could become the frontline in promoting greater harmony, facilitating a purposeful attack on the formidable development issues faced by some of the Asian countries. Cooperative science is a laudable human endeavor and may indeed help the Asian countries and its people move towards a better future. The world is moving closer, economically, intellectually and scientifically. In few years there will be not one AAL, but several facilities in Asia, such as an Asian Synchrotron Radiation Facility (ASRF). The proposed AAL will set a trend for several other disciplines such as *Space Exploration*, *Fusion Research*, *Biotechnology*, to name a few. AAL shall also serve as an example for other regions such as the continent of Africa, which is yet to have its first synchrotron radiation facility. *When will there be an African Synchrotron Radiation Facility (ASRF)?* This question shall be addressed later!

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4.2   A major step at the CLIC Test Facility (CTF3) at CERN

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The design of CLIC (Compact Linear Collider) is based on the so-called Two-Beam Acceleration scheme. The e+e- main beams are accelerated using high frequency (30 GHz) normal-conducting structures. A low-energy, high-intensity electron beam (Drive beam) runs parallel to the main linacs and is decelerated in resonant structures to provide the RF power needed for the main beam acceleration.

The third generation CLIC Test Facility (CTF3) should demonstrate the technical feasibility of the key concepts of the CLIC RF power source:

1) generation of high-current, high-frequency drive-beam trains by combination of electron bunch trains in an isochronous ring using transverse RF deflectors.

2) operation with a fully-loaded drive-beam accelerator.

The project makes maximum use of existing equipment and infrastructure of the LEP Pre-Injector (LPI) complex, which became available after the closure of LEP.

The project is based in the PS Division of CERN, with collaboration with other Divisions and external institutes (INFN-Frascati, SLAC, LAL-Orsay, Uppsala University, RAL-Didcot, Strathclyde University).

In the first stage of the CTF3 project, the existing LEP Injector Linac (LIL) and Electron Positron Accumulator (EPA) ring, both modified to suit the new requirements, are used to investigate the technique of frequency multiplication by means of interleaving bunches from subsequent trains in a combiner ring. First low-current demonstration of the bunch train recombination process has been achieved in 2002.

A first success has been recorded on 31st May 2002, when 2 trains were recombined in the modified ring. Each train is composed of 20 electron bunches, 8 ps (rms) bunch length, spaced by 333 ps (or 10 cm) corresponding to the 3 GHz linac frequency. The trains are spaced by 420 ns, corresponding to the ring revolution time. RF deflectors, whose 10 cm wavelength is equal to the bunch spacing, replace the classical injection kickers. The bunches coming from 2 consecutive trains are interleaved, thus reducing the bunch spacing by a factor 2 and increasing the beam

current by the same factor. This test has demonstrated for the first time the principle of particle injection using RF deflectors into an isochronous ring.

A second success has been achieved, on 18th June, with a recombination of 4 trains, as foreseen for the CLIC project. The bunch spacing, after recombination, is 83 ps (a quarter of 333 ps).

A third success has been recorded, on 21st June 2002, when 5 consecutive trains were recombined as foreseen for the final stage of CTF3. The bunch spacing becomes 66 ps, corresponding to a repetition frequency of 15 GHz.

The figure below shows the experimental results recorded with a streak camera after the 1st turn and after the 4th turn in the isochronous ring.

CTF3 Preliminary Phase : Combination factor 4

Charge: 1×10^{10} e- / train or 0.1 nC / bunch   Beam energy: 350 MeV   Bunch length (rms) ~ 8 ps

1st turn – 1 train from the gun

$\Delta t = 333$ ps

4th turn – 4 trains from the gun

$\Delta t = 83 \times 4$ ps
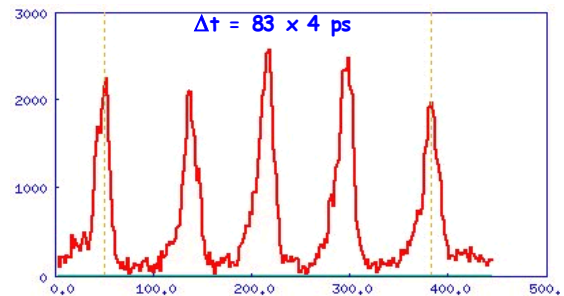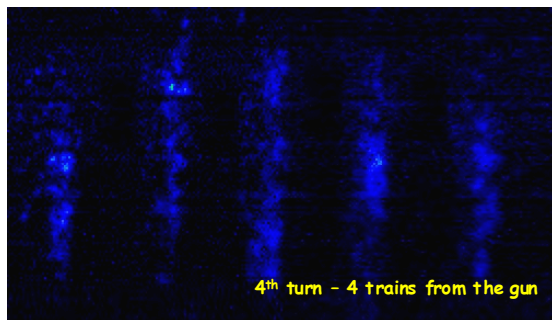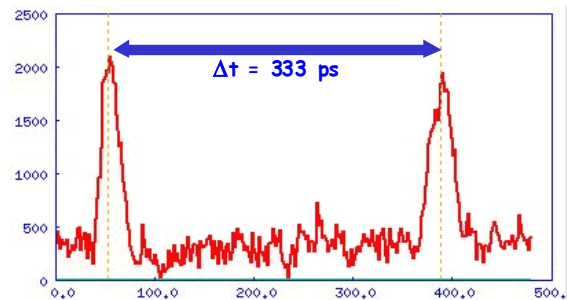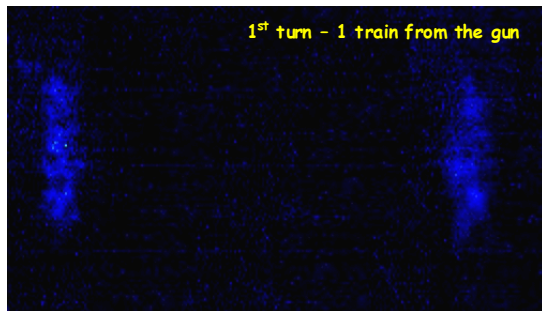
18th June 2002   R. Corsini, L. Rinolfi, P. Royer, F. Tecker

4.3   Machine characteristics of NewSUBARU

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NewSUBARU / SPring-8

4.3.1   Introduction

The NewSUBARU storage ring [1] is now operated in the positive α_p mode given in Table 4.3.1 and the plane view is shown in Fig. 4.3.1 β_x and β_y are estimated from the tune shifts due to the perturbation of quadrupole magnets (QM) and agree with the designed values in the accuracy less than about 10%.

Table 4.3.1

Energy	1.0 ~ 1.5 GeV
Tune ν_x / ν_y	6.30 / 2.23
Circumference	118.731 m
Chromaticity ξ_x / ξ_y	~5.0 / ~5.0
Natural emittance	38 nm @ 1 GeV
Linear coupling constant	1 %
Filling pattern	Successive 80 + 80 bunches
Maximum current	50 mA/single-bunch 460 mA /ring @ 1 GeV
Lifetime @ 100mA	6.2 hrs @ 1 GeV 8.0 hrs @ 1.5 GeV
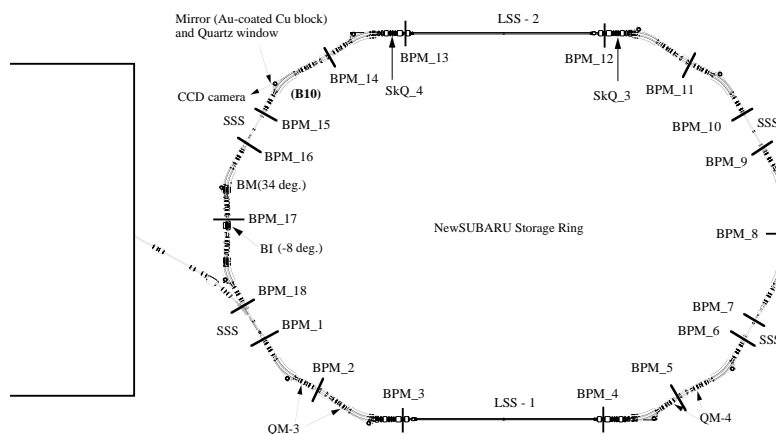
Figure 4.3.1: Plane view of the NewSUBARU storage ring.

There are three insertion devices and eight beam lines in operation. The storage ring is mainly operated at 1 GeV and the beam from the SPring-8 LINAC is injected about every 10 seconds to keep the stored current of more than 200 mA level for user time. There are remarkable achievements in micro-fabrication, in particular, EUVL (extreme ultra-violet lithography) and LIGA.

4.3.2 Vertical dispersion and α_p

4.3.2.1 *COD shift*

The dispersion is estimated from the COD shifts due to RF frequency change (Δf) if α_p is known. The open circles and real lines in Figs 4.3.2 and 4.3.3 shows the measured values but in these figures the averaged values given by $\Delta z = (COD(-\Delta f) - COD(+\Delta f))/2$ are used to avoid the higher order effects of nonlinear field.
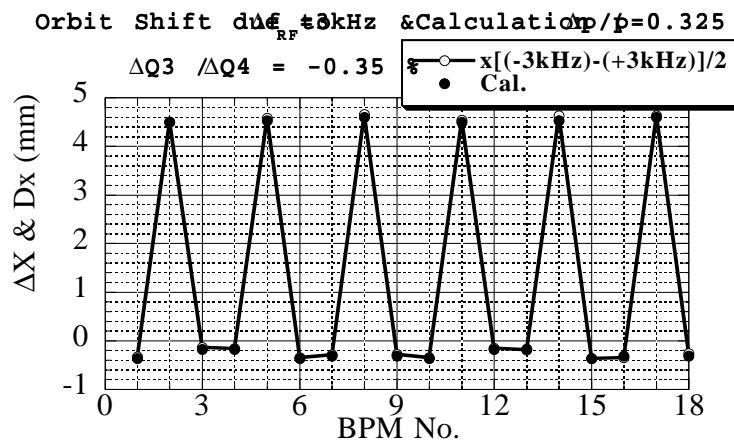
Figure 4.3.2: Horizontal COD shift. Open circles and real line are measured data, closed circles are fitting calculation.
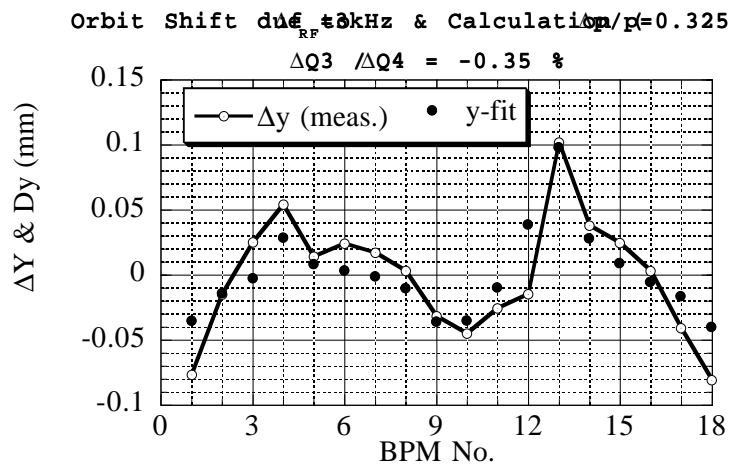
Figure 4.3.3: Vertical COD shift. Open circles and real line are measured data, closed circles are fitting calculation.

Δx except at BPM-n (n=2+3k, k=0,1,…,6) should be vanishing if the lattice is completely adjusted as designed. The non-zero values are easily caused by the incorrect excitation of QM-3 & -4 located at the both sides of BI, which is mainly due to the ambiguity of the effective length of magnetic field.

The main source of Δy is skew quadrupole field (SkQ) in the ring.

4.3.3   Measurement of SkQ distribution

To explain Δy, the SkQ distribution was estimated by the following method.
1)   Make the trapezoid shape orbit in the y-plane at the adjacent 4 BPM's. The maximum excursion was 2 mm.
2)   Measure the x-COD shift due to this y-bump.
3)   Find the most effective single kick in x-direction. The location and the strength were searched in this y-bump.
4)   The most effective SkQ was then obtained as the strength divided by the y-excursion.
5)   The typical fitting result is shown in Fig. 4.3.4. As seen from this figure the single kick solution is not complete but the obtained distribution should show the essential aspect of SkQ.
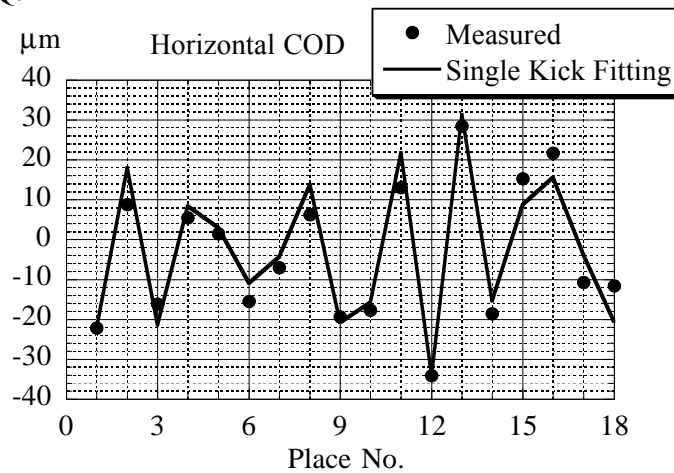
Figure 4.3.4: Typical horizontal COD shift and the fitting of the single kick.

4.3.4   Numerical tracking and α_p

Using the above SkQ and taking into account the sextupole field from correcting sextupole magnets and bending magnets (BM & BI), the numerical tracking was done to explain the measured Δx & Δy by changing $\Delta p/p$ and excitation errors ΔQ3 & ΔQ4. The results are also shown in Figs. 4.3.2 and 4.3.3 by the closed circles and α_p is calculated as,

$$\alpha_p = (\Delta f/f)_{RF} / (\Delta p/p) = 1.8 \times 10^{-3} \text{ for } |\Delta f| = 3 \text{ (kHz)}.$$

Using this value the horizontal dispersion at BPM-n (n=2+3k, k=0,1,…,6) becomes 1.4 m and 0.47 m at the source point of SR monitor. These well agree with the designed.

The integral over the fitted orbit of numerical tracking gives α_p =1.7 x 10^{-3}. Therefore α_p is concluded as (1.7~1.8) x 10^{-3}.

4.3.5   Linear coupling constant

The driving term of ν_x - ν_y -4=2δ (=0.07) resonance is calculated as,

$$\kappa = \lambda \exp(i\chi), \quad \lambda = 5.35 \times 10^{-3}, \quad \chi = 1.84 \text{ (rad)},$$

from the obtained SkQ.

By the other hand this resonance was corrected to minimize the vertical spot size of visible SR radiation (SR monitor) by two skew quadrupole magnets, SkQ-3 & SkQ-4. This correction gives $\lambda = 5.30 \times 10^{-3}$ and $\chi = 1.80 - \pi$ (rad).

Then the coupling constant is calculated as k = $(\lambda /2)^2 / (\lambda^2 + \delta^2)$ = 1.1 (%).

4.3.6   Microwave instability and natural emittance

In the single bunch operation, the horizontal rms-beam-size (σ_x) of the SR monitor increases as the stored beam current (I_b) increases as shown in Fig. 4.3.5. σ_x^3 was almost linear to I_b for I_b > ~2 (mA) which strongly suggested the existence of microwave instability (turbulence). Setting σ_x^2 = B + $(D*\sigma_p)^2$, σ_p =A*$I_b^{1/3}$ and D=0.47 (m), we have B = 9.5 x 10^{-2} (mm^2) and A = 4.0 x 10^{-4} ($mA^{1/3}$). The threshold current is calculated as 1.0 mA by setting σ_p = 4.7 x 10^{-4} (designed natural spread). The natural horizontal emittance is estimated as 38 nm (almost equals to the designed value) from B / β_x and β_x = 2.49 (m).

The total broadband impedance is estimated as |Z/n| = 0.23 (Ω) from ZAP calculation.

The above works are published in N.I.M.-A, **481** (2002) 43-47 and **485** (2002) 805-810, but in those α_p is supposed to be 1.3 x 10^{-3}.
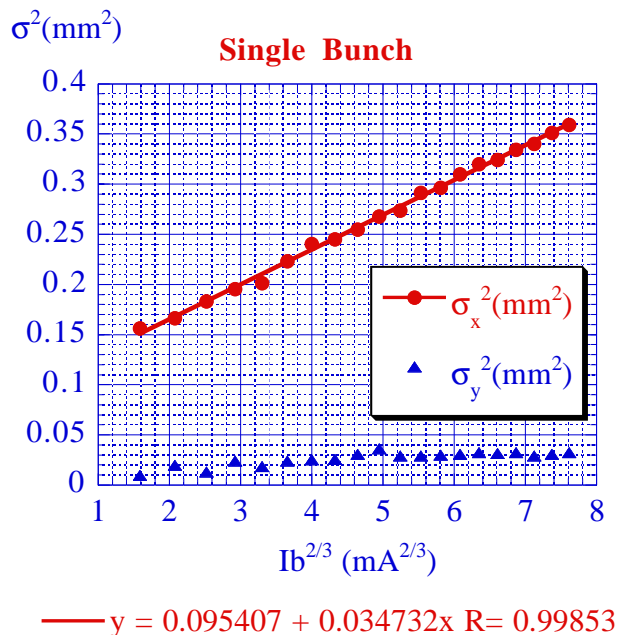
Figure 4.3.5: Beam size versus stored current.

4.3.7 Transverse mode coupling instability

TMCI or fast head-tail instability limited the maximum value of the stored current at the initial operation. Setting both chromaticities to ~5.0, it seems there is no limit. The study was done in detail by setting the vertical chromaticity to ~1.0 in the single bunch mode operation. The 0-mode and 1-mode couple very clearly as summarized in Fig. 4.3.6. In this report, m=+1(-1) corresponds to the higher (lower) frequency peak of the 1-mode sidebands. The tune difference of m=0 & -1 became ~0.001 at ~3 mA and then beam was lost. Figure 4.3.6 also shows the analytical calculation using Sacherer's theory for Gaussian distribution, where the resistive impedance comes from the 40-m SUS chamber with the full height of 24 mm.
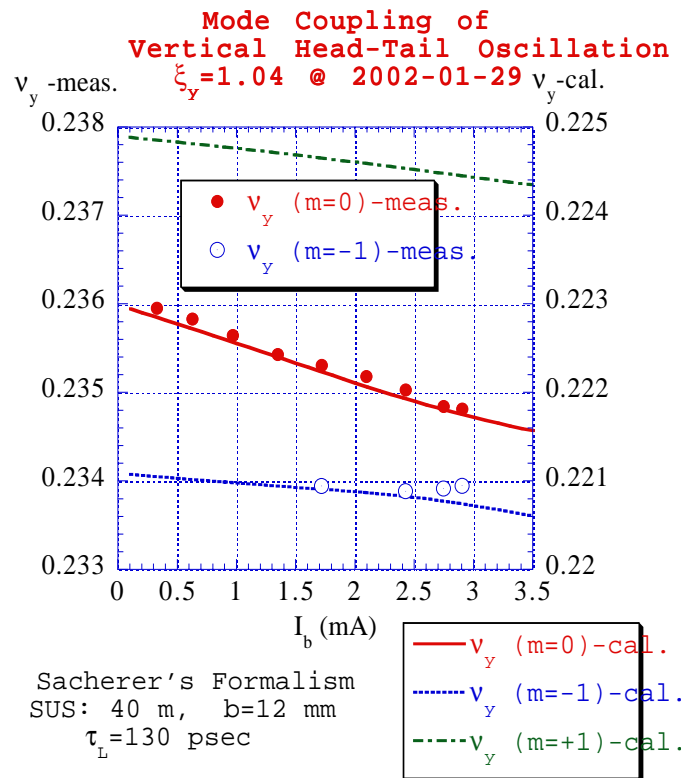
Figure 4.3.6: Measured and calculated tune shift versus stored current.

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4.4 Beam dynamics activities at LEPP, Cornell University (Laboratory for Elementary-Particle Physics, formerly LNS – Laboratory of Nuclear Studies)

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CORNELL

Assessment of the effects of strong wigglers on the beam dynamics of a storage ring has been a major beam dynamics activity at LEPP during the past year. Optimization of luminosity performance of the 768 m circumference e^+e^- collider CESR at 1.9 GeV is a critical objective of the CESR-c conversion project. In order to achieve a reasonable damping rate at the low energy, approximately 18 m of 2.1 Tesla peak field wigglers will be installed. 90% of the synchrotron radiation power in the ring will be produced in the wigglers. The non-linear properties of the wigglers are a concern for high luminosity operation.

In order to understand the effects of the wigglers, both to guide the design of the magnets and to optimize storage ring parameters, extensive modeling and tracking have been done recently.

The wiggler fields have been calculated using two 3-D codes Mermaid and TOSCA. Results from both programs are in very good agreement. Measurements of a full size prototype wiggler also agree well with the models, with the exception of a small net integral skew quad component which is likely caused by mechanical misalignments or stray field from high current leads.

Starting with the 3-D field maps described above, we use in-house developed software for modeling wiggler fields and incorporated the model in our lattice design and dynamic aperture tracking. Our strategy is similar to that described by A.Wolski and Y.Wu (PAC 2001). A linear combination of functions that satisfy Maxwell's equations is fit to the fields computed with the finite element codes. The analytic form can be used to generate Taylor maps, for Runge Kutta integration and for symplectic integration. We can then map phase space through the wiggler using two distinct techniques: Runge Kutta integration through the field table, and symplectic integration based on hamiltonian derived from the fitted vector potential. We find that if the wiggler has an even number of poles (8) we readily find excellent agreement between the two mapping techniques. For a wiggler with an odd number of poles (7), the agreement between the two techniques is not nearly so good, and inadequate to the task of reliably determining long term stability.

We have also confirmed the result recently reported by Wurtele, Penn, and Cary in PRST-AP that long term tracking using Runge Kutta integration (thousands of wiggler passes) indicates an artificial damping effect. The "damping" does not appear with tracking based on symplectic integration.

In CESR, the sextupole distribution is unique to the linear lattice. The distribution is designed to minimize amplitude and pretzel dependent distortion of optical functions. The wiggler mapping, based on the symplectic integration, is included in the design process.

Lattice modeling and tracking are done using BMAD, a software library suite designed to do accelerator modeling. Specifically BMAD can read in lattice specification files (Based upon the MAD input format, but with provision for superimposed elements and other extensions to improve flexibility), calculate Twiss parameters, closed orbits, etc.

To extend the range of BMAD, BMAD has been interfaced to the Lie-algebraic FPP/PTC package of Etienne Forest. FPP/PTC (Fully Polymorphic Package/Particle Tracking Code) permits the analysis (normalization) and manipulation of Taylor series maps. With this FPP/PTC one can compute lattice functions, tune shifts, Courant-Snyder invariants, damping decrements, equilibrium beam-sizes, etc.

A wiggler model in BMAD/FPP/PTC has been developed which models the wiggler field as a small sum of analytic functions obeying Maxwell's equations. The model does not assume periodicity of the field so the model can easily include fringe fields. This model permits fast symplectic integration to obtain transfer maps for tracking and Twiss analysis.

Some measurements have been made during CESR machine development periods to compare measured and calculated non-linear effects from existing (but weaker) wigglers in the CESR storage ring. During the next few months measurements on a full size CESR-c wiggler will be made.

4.5   Beam Dynamics Activities at LAL/Orsay

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4.5.1   Introduction

Since our last report on the beam dynamics activities at LAL/Orsay in 1999 [1], many research works have been done towards the application of nonlinear physics to some long standing beam dynamics problems in particle accelerators, such as dynamic apertures, beam-beam effects in electron storage ring colliders, and longitudinal single bunch collective effects in electron storage rings, etc. It is noticed that standard mapping finds its wide field of applications in particle accelerators, and that the statistical description of the stochastic behavior exhibited in the standard mapping [2] is a very important subject of research in understanding the anomalous diffusion (Lévy diffusion) [3] phenomena observed in different accelerators. In this report we will briefly recall some of our main research results and the interested readers are encouraged to consult the formal publications given in the references.

4.5.2   Analytical formulae for dynamic apertures in storage rings

We start with one dimensional motion and assume that there is only one nonlinear multipole located at any place on the ring. Starting from the perturbed one dimensional Hamiltonian, one uses action-angle variables and replaces the Hamilton's equations by difference equations. By applying Chirikov criterion for the onset of stochastic motion in the standard mapping, one obtains the general analytical formulae for the one dimensional dynamic apertures for a single 2m (m $\geq$ 3) pole. The detailed derivation, discussion for many multipole case, two dimensional problem, and comparison with numerical results can be found in ref. [4]. These formulae find many applications in other beam dynamics problems, such as beam-beam effect in circular colliders to be discussed below.

4.5.3   Beam-beam effect limited beam lifetimes and maximum beam-beam tune shifts

Beam-beam effect in circular colliders is a challenging problem for both experimentalists and theorists in its limiting the available luminosity and in its complexity to be understood. Equipped with the analytical tool developed above, we try to test its efficiency by attacking the long standing beam-beam effect problem. For two head-on Gaussian colliding bunches, the incoherent kicks felt by each particle can be calculated by using Bassetti-Erskine formula. Limited to the lepton circular colliders, for either the round or flat beam cases, to treat all the particle inside a bunch on the same footing, one has to make average over the kicks felt by the test particles according to the probability function of their transverse displacement. After establishing the

perturbed Hamiltonian by the delta function (interaction point) beam-beam nonlinear forces, by analogy, one can apply the general formulae for the dynamic aperture established in the above section to calculate the beam-beam effect limited beam lifetimes. It is discovered that the normalized beam-beam lifetimes (beam-beam lifetime divided by the damping time of the corresponding transverse plan) depend solely on the beam-beam tune shifts. From this research work one can understand why the maximum vertical beam-beam tune shift is about 0.045 for flat colliding beams and almost doubled for round ones. More detailed studies and discussions on this subject and on the colliding beams with a crossing angle can be found in refs. [5][6].

4.5.4 Bunch transverse emittance increase in electron storage rings

The ATF damping ring at KEK is the only storage ring dedicated to the machine studies for future linear colliders, where one has obtained many interesting experimental results such as bunch transverse emittance growth vs the bunch current with extremely low zero current transverse emittances. In a series publications of K. Bane et al [7][8][9], the experimentally measured transverse emittance grow up vs the bunch current is explained by the intrabeam scattering theory, and at the same time, they claim constantly that the comparison results especially in vertical plane are not satisfactory. Stimulated by these claims, we revisited the intrabeam scattering theory and found that the intrabeam scattering effect should not be the dominating one. On the contrary, we assume that the short range transverse wakefield of the ring be responsible mainly for these emittance growths. In short, we have established two emittance equations in both vertical and horizontal planes [10], where the information concerning the transverse loss factor scaling law with respect to the bunch length and bunch lengthening vs bunch current can be obtained from refs. [11] and [12]. By neglecting intrabeam scattering effects and applying our theory established in ref. [10], we have tried to explain the ATF damping ring experimental results corresponding to the values denoted in ref. [13] as "Wire scanner 2001/2/8". The fitting with the experimental results gives reasonable estimation results on the vacuum chamber misalignment errors and close orbit distortions. It is concluded that to avoid excessive emittance growth, both the closed orbit distortions and the vacuum chamber misalignment errors should be under careful controls with the same rigor.

4.5.5 Miscellaneous

In this section we mention briefly some other fields which interest us and on which we have spent times to tackle the corresponding problems. Firstly, halo formation in high current proton linacs and the halo particle loss rate estimation have been our research subjects since many years. We tried to treat this difficult problem in an analytical way[14] and to compare the analytical results with those obtained from the experiments[15]. Secondly, in high current proton linacs, it is necessary to calculate the wakefields in disk-loaded structures produced by nonrelativistic charged particles. In ref. [16] we derived the corresponding analytical formulae where the particle's velocity (Vp) is assumed to be much larger that the group velocity (Vg) of the electromagnetic waves inside the structure. If one has Vp is comparable to Vg, the wakefield expression in ref. [16] should be multiplied by a factor of (1-Vg/Vp) (apparently, if Vg is greater than Vp the multiplying factor should be zero). Finally, concerning the waveguide

cavity coupling system, we illustrate in a quite general way how to determine the coupling coefficient for a given coupling aperture [17]. These formulae will be very useful in linac constructions.

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5 Workshop and Conference Reports

5.1 27th ICFA Advanced Accelerator and Beam Dynamics Workshop on "The Physics and Applications of High Brightness Electron Beams"

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The Physics and Applications of High Brightness Electron Beams Workshop was held in July 1-6 in the excellent location of Chia Laguna in Sardinia, Italy.

This workshop is a successor to similar workshops held at UCLA in 1994 and 1999 (sponsored by the ICFA Panel on Advanced Accelerators), and Indiana in 1995. It is also meant as partial successor to the Arcidosso series (sponsored by the ICFA Panel on ICFA Beam Dynamics). This workshop was jointly sponsored by both ICFA Panel on Advanced Accelerators and Beam Dynamics

As pointed out by J. Rosenzweig (co-chairman, UCLA) in his workshop themes overview, the frontiers of high brightness electron beam physics and technology have recently advanced to new limits. This progress has in turn enabled two significant new applications:

1) Advanced, ultra-high frequency accelerators, mainly based on lasers and/or plasmas;

2) Self-amplified, spontaneous emission free-electron lasers.

Physical characteristics in common to both the high brightness beam system and applications have been the organizing theme for the workshop.

Morning sessions were in fact devoted to review talks dedicated to the physics of high brightness electron beams, the methods used to describe and analyze physical effects in these systems, and the issues surrounding the creation, preservation, and diagnosis. As the leading-edge applications of high brightness beams are intimately connected to their production, the use of these beams in plasma accelerators, X-ray FELs, and other systems have been also reviewed.

In the opening plenary talk, L. Serafini (co-chairman, INFN) reported about the new perspectives and programs in Italy for advanced applications of high brightness beams. Last year in fact the Italian Government launched a call for proposals to the Italian research institutions for the design and construction of an Ultra-Brilliant X-ray Laser: 94 million ¤ is the total funding for this initiative. The Italian community responded by submitting two proposals for a similar machine, basically consisting of a

few GeV Linac driving a SASE-FEL operated at a minimum wavelength around 15 Å. Serafini described the essential features of the two proposals: SPARX prepared by a collaboration among CNR-ENEA-INFN and Universita' di Roma "Tor Vergata", and FERMI@ELETTRA by INFM and Sincrotrone Trieste. The choice between the two proposals is expected by the end of this year. He also illustrated the status of the R&D project SPARC, aiming at the design and construction of an advanced 150 MeV photo-injector for generating a high brightness electron beam to drive a SASE-FEL in the optical range. This project has been already approved by the Italian Government to conduct an R&D activity aimed to be strategic on the way to the coherent X-ray source; it is pursued by a CNR-ENEA-INFN-Universita' Tor Vergata-INFM-ST collaboration and will be located in the INFN National Laboratory at Frascati.

Next P. Piot (DESY) reviewed the experimental results on high brightness electron beams sources, from the new high frequency injector design, 17 GHz at MIT, down to the 144 MHz ELSA-2 project and DC guns. As important achievements he recalled that ATF at BNL has set a new record in brightness: ε=0.8 mm-mrad for Q=0.5nC and I=200 A has been measured, while both BNL/UCLA/SLAC-type and DESY-type guns have driven short wavelength single-pass FELs to saturation (LEUTL, TTF-1). ELSA-2 at Bruyeres-le-Chatel has demonstrated the targeted emittance of 1 mm-mrad at 1 nC (to the expense of bunch length). Presently achieved performances with a DC gun at Jlab are comparable in terms of brightness to rf-guns running with high duty cycle. In the superconducting RF gun experiment (DROSSEL collaboration) the first photo-electrons have been recently observed. A new integrated PWT photo-injector design (PEGASUS experiment) has been installed at UCLA. For its better vacuum conductance, as required by GaAs cathodes, it has been considered also as a good candidate for polarized electron beam production.

A comparison of peak brightness achieved is reported in the following figure:
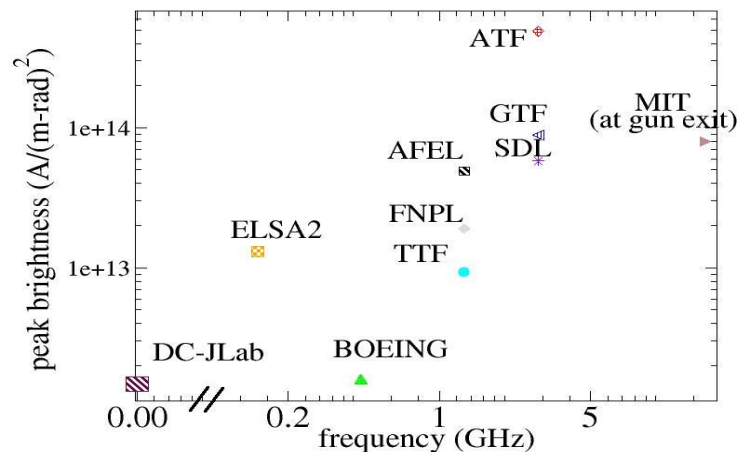
P. Muggli (USC) reported about the high brightness beam application to plasma wakefield accelerators and the experimental results recently obtained by the SLAC/USC/UCLA, NIU/FNAL/UCLA and LANL collaborations. Muggli reported also recent progress to increase the active length of the plasma up to 1.4 m (SLAC E-162 experiment), with an energy gain of 150 MeV. As a first application a short plasma

accelerator will be used to extend the future conventional linear colliders to higher energy, as recently proposed for the SLC collider.

A. Varfolomeev (Kurchatov-Institute) reported about applications to laser accelerators. In particular he described the Inverse Free Electron Laser project at Neptune, a UCLA/Kurchatov-Institute collaboration, in which an energy gain of 41 MeV is expected in a 50 cm long undulator with the high brightness beam delivered by the Neptune facility.

A review of high brightness beam application to SASE-FELs has been reported by S. Reiche (UCLA). He pointed out that the performance of Free-electron Lasers depends strongly on the beam quality (brightness) of the driving electron beam as the very exciting results of VISA, LEUTL and TTF-FEL experiments that reached saturation at 850 nm, 130 nm and 95 nm respectively have shown. For future shorter wavelength FEL low emittance and high current are required. The emittance is the most crucial parameter, determining the saturation power and length of the FEL. Difficulties are partially mitigated by the fact that with high beam energy the longitudinal information exchange occurs only over a cooperation length (Lc = l/4pr) that is much shorter than the bunch length. Different parts of the bunch radiate independently. For this reason the beam is best parametrized by the beam properties per slice where the slice length is defined by the cooperation length. The non-uniformity of the beam parameters along the bunch defines the envelope of the spiky profile of the SASE FEL pulse. Reiche concluded his talk with a remark of the importance of start to end simulations to estimate with a realistic beam model how the beam line can guarantee that the degradation of the initial beam parameters stays within acceptable limits.

At the end of day 1, M. Ferrario (INFN) reported about novel ideas for high brightness electron beam production based on photo-injectors. A revival of longitudinal focusing techniques with a deeper understanding of emittance compensation theory has opened a new possibility to compress the beam inside an RF structure or in the downstream drift, with a proper solenoid focusing. Thus avoiding the emittance degradation observed in magnetic chicane caused by coherent synchrotron radiation (CSR) emitted in bends. kA beams with low emittance have been predicted by simulations for the so called RF rectilinear compressor configurations. At Neptune (UCLA) and DUVFEL (BNL) preliminary experimental results in not optimized beam lines, have verified the usefulness of this idea, despite the space charge induced emittance degradation observed. More dedicated experiments with external focusing optimized according to the theory prescriptions are foreseen in the near future at UCLA, LLNL, BNL, and LNF. Ferrario also reported about a new technique recently proposed and tested by a DESY/FNAL collaboration for the so called flat beam production, an important target for linear colliders. It consists in a simple transformation of a magnetized round beam, with equal emittances in both transverse planes, produced by a photo-cathode embedded in a solenoid field, followed by a quadrupoles triplet. With a proper matching a flat beam, with high transverse emittance ratio (300) as required by linear colliders, could be obtained. Experimental results have at present achieved an emittance ratio of 50.

Every machine is as good as its diagnostics, is the message of V. Verzilov (ST) from his review of optical diagnostics for high-brightness electron beams in the morning of day 2. Beam diagnostics has significantly advanced to meet specific requirements of high-brightness beams: taking into account space charge forces, improving resolution from several millimeters to few tens of micrometers in both longitudinal and transverse planes with a large dynamic range both in terms of beam intensity and measuring interval. Among the wide choice of available techniques for measuring beam parameters in the transverse plane, Verzilov said, optical diagnostic like Transition Radiation has significant properties as instantaneous emission, linearity (no saturation effects), high resolution, small perturbation to the beam , small radiation background and can be used in a wide range of g >2-5, despite its relatively low photon yield that is a limitation in pepper-pot measurements. Verzilov reported also about 90 deg Thomson scattering, space charge effects in pepper-pot and quads scan techniques for emittance measurements, the ambiguity of bunch shape reconstruction from form-factors, bunch length measurements by Coherent Diffraction Radiation, Electro-optic Sampling. He also pointed out that difficulties persist with measurements at mm and sub-mm level in the transverse plane.

A survey of experimental results in magnetic compressor has been presented by S. Anderson (UCLA). All the experimental data reported taken at many different facilities (CTF, TTF, SDL, APS, UCLA, …) show a 6D phase space deterioration caused by collective effects arising from acceleration fields (CSR) and/or velocity fields (Space-Charge). Simulations reproduce quite well rms quantities, but are not as good in reproducing the intricate phase space structures seen in the experiments, like the phase space filamentation observed both in longitudinal and transverse planes. Anderson reported also about a recent experiment performed at UCLA at low energy (< 12 MeV) where space-charge may play significant role in compression. The bifurcation observed in the transverse phase space by increasing the compression ratio, has been described with an heuristic beam model based on a series of longitudinal slices. This model shows that in the last bending magnet space-charge forces push a slice via the fields at its centroid due to the other slices and cause an emittance growth inversely proportional to beam size, as observed.

The Physics and compressor design issues have been presented by P. Emma (SLAC). In particular he discussed the capability of a two stages compression to improve the stability against timing & charge jitters, the current spikes formation caused by RF curvature and 2nd-order compression and the way to correct it by an harmonic RF cavity at decelerating phase. Longitudinal geometric wakefields bring advantages and disadvantages like energy chirp cancellation after compression allowing weaker chicane and less CSR but also they induce current spikes formation during compression due to the longitudinal phase space non linearity's accumulated by the beam before compression. In addition transverse wakes may dilute emittance of long bunch. Is the best linac made by superconducting L-band cavities (low wakes) before compression and S-band or C-band cavities (high wakes) after? Emma also discussed the possible reduction of projected emittance degradation due to CSR, with a proper b-matching or double chicane configurations. Nevertheless CSR can amplify small current modulations resulting in unwanted microbunching formation. He showed that

microbunching can be damped by inducing uncorrelated energy spread with a super-conducting wiggler prior to the compressor.

New photo-injector schemes based on high voltage DC gap connected with a S-band cavity or with multi-stage DC gaps have been presented by J. Luiten (Eindhoven University). High accelerating fields (1 GV/m) can be obtained in the early stages of acceleration thus damping almost immediately space charge forces and allowing for short bunch production with low emittance without bunch compressors. Simulation predict emittance lower that 1 mm for 0.5- 1 kA beams. In a recent proposal 100 fs, 0.1 nC bunches would be generated by accelerating photoelectrons to 2 MeV over a 2 mm gap diode whose anode is the back wall of standard RF booster cavity. Because no space charge induced longitudinal emittance blowup is expected the device could become a good source of (low charge) ultrashort bunches.

D. Umstadter (Michigan University) went beyond photo-injectors in his talk on laser-plasma guns and wigglers. In particular he described an "all-optical" system devised to trap and accelerate ultrashort electron bunches and capable of GeV/cm gradients, micrometer spot sizes, femtosecond long bunches and GA/cm2 current densities. In this scheme electrons are injected into the wakefield of a plasma wave generated by the first of two orthogonal laser beams illuminating a confined gas. The first laser (drive) pulse creates a plasma wave by ionizing the gas with amplitude lower than its self-trapping threshold, i.e. free electrons oscillate around ions. The transverse ponderomotive force of the second (injection) orthogonal pulse imparts to the plasma electrons an extra kick in the wave direction, injecting them into the the drive pulse wake with the correct phase to be trapped and accelerated. This principle has been recently demonstrated by very exciting experiments as reported by Umstadter, more studies are under way to better understand its performances in terms of emittance reduction.

Day 3 began with L. Giannessi (ENEA) who gave an overview of simulation codes for high brightness electron beam experiments, with a detailed analysis of Injector - Compression - FEL families of codes. He described advantages and disadvantages of "first principles" based codes: in which completeness is usually paid in terms of CPU time. Giannessi pointed out that since only a reduced number of particles can be included in a simulation, the effects of noise must be suppressed in the bandwidth of self consistency and he described the specific solution for each families of codes. He also considered semi-analytic codes based on some "smart" theory, which despite hiding some physics, allow fast relaxation of the usually large number of parameters involved and are not necessarily less physically insightful.

Few years ago surface roughness was indicated as a possible source of beam quality degradation inside the undulators, a review of these effects was the subject of the L. Palumbo (La Sapienza University & INFN) presentation. As he recalled in the last five years several theoretical models have been developed showing an inductive effect, causing energy spread, and the possible existence of a synchronous mode, causing energy spread and energy loss. For the random roughness, theory predicts a negligible inductive impedance while a periodic roughness can sustain "synchronous" modes which produces a wake fields. Some discrepancies exist among the theories about the

amplitude of such a mode, probably due to the different assumptions on the roughness properties. Synchronous mode can be sustained also by a random roughness, when the wavelength is much larger than the corrugation size. When the wavelength is comparable with the corrugation size, scattering phenomena makes the effect much weaker. Recent measurements at DESY and BNL-ATF on random and periodic corrugations have partially confirmed the theoretical results. Today, it is commonly believed that for FEL undulators the roughness impedance is smaller than the resistive wall impedance.

A the end of the morning session of day 3 G. LeSage (LLNL) described the application of high brightness beams to Thompson X-ray sources and the proposed RF rectilinear compressor experiment at LLNL.

In the afternoon sessions four working groups have deeply explored with additional presentations and discussions the issues presented in the review talks:

– WG A) High brightness beam production (convener: J. Schmerge (SLAC))

– WG B) Collective effects and instabilities during electron beam pulse compression (convener: T. Limberg (DESY))

– WG C) Application to FELs (convener: H.-D. Nuhn (SLAC))

– WG D) Application to Advanced Accelerators (convener: M. Uesaka (Tokyo University))

Almost all the transparencies of the plenary talks and WG presentations, with the proper references (omitted in this summary), can be found at the following address:

http://www.lnf.infn.it/conference/icfa2002/

or at the main workshop web page:

http://www.physics.ucla.edu/AABD

In conclusion, this workshop was considered to be a great success both from the scientific and from the organizational points of view by almost all participants, who also enjoyed the marvellous location in southern Sardinia, rich of natural as well as archeological wonders, like emeral green sea waters and pre-roman pre-fenician nuraghi or roman villa-mosaics right on the coastal reef.

5.2 NANOBEAM 2002: 26th Advanced ICFA Beam Dynamics Workshop on 'Nanometre-Size Colliding Beams'

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CERN

The NANOBEAM 2002 workshop was held on the Lausanne campus from 2 to 6 September 2002. It was organized jointly by the University of Lausanne, the Ecole Polytechnique Federale Lausanne, and CERN. More than 85 participants from 35 institutes used this opportunity to discuss the recent state of the art in producing and stabilizing nanometre size beams and maintaining their collisions. Nanometer beam sizes are required by all future linear collider projects (TESLA, NLC, JLC, and CLIC). These spot sizes represent a reduction by 2 to 3 orders of magnitude compared to previous collision beam sizes and place new demands on beam quality, beam-optical systems, diagnostics, and especially stabilization of beamline components. Next generation synchrotron light sources face similar challenges in beam quality and stability, requiring the use of similar advanced technology. The exchange of ideas between different accelerator physics communities, universities, industrial companies, and research institutes was an explicit focus of this workshop. The presentations from the workshop and additional information (scientific program, list of participants, photographs,…) are available in electronic form on the Nanobeam02 web site:

http://www.cern.ch/nanobeam

The first Nanobeam02 session, chaired by Aurelio Bay (Lausanne), brought the workshop off to a good start. The opening talk by Luciano Maiani, the Director General of CERN, highlighted the importance of the workshop for pushing the frontier of particle physics. It also reassured the community of CERN's continued commitment to accelerator R&D, in particular on CLIC. This was followed by a presentation by the CERN theoretician John Ellis, who discussed the search for the Higgs and various extensions to the standard model. He emphasized that multi-TeV collision energies are important to make new discoveries beyond the reach of the LHC, and that a luminosity scaling with the square of the energy is essential. A subsequent presentation on the gravitational wave detector VIRGO by Flaminio Raffaele (LAPP) demonstrated the sophisticated stabilization of mirrors to the picometer level, far surpassing present demands of accelerator builders. Excellent overview talks on linear collider projects by Swapan Chattopadhyay (TFNAF), on X-ray SASE FELs by Kwang-Je Kim (U. Chicago and ANL), on stability and ground motion by Andrei Seryi (SLAC), and innovative ("weird") technological solutions by Joe Frisch (SLAC) prepared the stage for the subsequent discussions.

The following sessions were devoted to
- Beam Delivery, Final Focus & Collimation (chaired by Nicholas Waker, DESY, and Angeles Faus-Golfe, University of Valencia),
- Stabilization (chaired by Andrei Seryi, FNAL, and Vladimir Shiltsev, FNAL),
- Interaction Region (chaired by Tom Markiewicz, SLAC),
- Energy Measurement in Future Linear Colliders (mini-workshop organized by Mike Hildreth, University of Notre Dame, USA),
- Laser Wires (mini-workshop organized by Grahame Blair, Royal Holloway, London; chaired by Junji Urakawa, KEK and Marc Ross, SLAC),
- Tuning, Feedback & Diagnostics (chaired by Phil Burrows, Oxford, UK, and Susan Smith, CLRC Daresbury),
- Generation of Low-Emittance Beams (chaired by Leonid Rivkin, PSI, and Gilbert Guignard, CERN),
- Engineering Demonstration and R&D Plans (chaired by Witold Kozanecki, CEA/Saclay, and Hans Braun, CERN),
- and Chairman Summary Talks (chaired by Carlo Wyss, CERN).

Among the highlights of the workshop were the discussions on magnet stabilization, compact final focus optics, novel diagnostics, new test facilities and future collaborations.

Stabilization of accelerator components is one of the central pieces that any future linear collider will have to master. Subnanometer stability of quadrupoles has been demonstrated by the CLIC stability study (presentations by Ralph Assmann, and Stefano Redaelli), where also the effect of cooling water was investigated. In parallel, extensive design and development work is ongoing at SLAC (Joe Frisch, Andrei Seryi, F. LePimpec) and at the University of British Columbia (Tom Mattison). These developments include inertial systems decoupling the magnets from the ground, which are pursued at SLAC, and optical anchors, which on the contrary attach the magnet to the ground so as to follow the natural ground motion, built at UBC. Encouraging results from operating machines were reported from many laboratories around the world, including several light sources, e.g., the ESRF achievements were described by L. Zhang, and those from the PSI by T. Schilcher. Ground motion and its effect on the magnets and on the beam have been measured and suppressed at these and other storage rings. Reports about magnet motion at the Tevatron by Vladimir Shiltsev and at RHIC by Christoph Montag further exposed the participants to real-life problems, e.g., Christoph Montag presented evidence that the RHIC low-beta quadrupoles appear to vibrate by up to 500 nm at frequencies around 10 Hz.

The disturbing effects from vibrating accelerator components can be alleviated with ultra-fast beam-based feedbacks. In a linear collider, such feedbacks act on a typical time scale of milliseconds, between bunch trains, and over only a few 10s of nanoseconds within a bunch train, in order to correct the beam position at the collision point, as discussed in several illuminating presentations by Linda Hendrickson, Nan Phinney, and Steve Smith (SLAC). The intra-pulse feedback keeping the beams in collision would be the fastest and most challenging of these systems. A simplified

prototype configuration is being tested by the FONT project at the SLAC NLCTA. It was presented by Glen White from Oxford. In addition, at a linear collider the orbit must be controlled throughout the linac and the beam delivery system, so as to preserve the small transverse emittance. Impressive experience with similar systems is available from synchrotron light sources, as was splendidly illustrated in two presentations by Susan Smith and Hywel Owen from ASTEC Daresbury UK. Light-source global-orbit feedbacks reach bandwidths of 200 Hz and stabilize the beam orbit at the micron level. Additional feedbacks are employed to stabilize the position and angle of the synchrotron radiation delivered to the users.

A detailed recipe for the design of a compact final focus were provided by Andrei Seryi. This recipe will benefit the entire community. An impressive progress was made on the development and experimental tests of laser wires. Reports from the KEK ATF by Yosuke Honda, the PETRA storage ring at DESY by Thorsten Kamps, and the CTF-2 by Thibault Lefevre described the present state of the art. First realistic simulations of laser wire measurements in a linear collider beam-delivery system have revealed the presence of a large background from beam halo scraped in the collimation system and suggest that the precise location of the laser wire will be critical (Grahame Blair). The use of rf cavity BPMs for measuring both the slope of the beam trajectory and the tilt of the bunches is an interesting new concept, presented by Marc Ross and Tor Raubenheimer of SLAC. Marc Ross also challenged the community to develop procedures whereby optics tuning can directly identify the source of an error. Tor Raubenheimer discussed a novel instability driven by coherent synchrotron radiation, which may arise in the dipoles and wigglers of linear-collider damping rings. This instability needs to be better understood as present design parameters are close to the predicted threshold. Several possible test facilities for nanobeam issues were under discussion, e.g., at the former SLC (LINX), at KEK (ATF-II) and at CERN (at CTF-3). All these proposals include the construction and experimental test of the compact final-focus system (the experimental verification was not deemed to be necessary, but considered a nice benefit), and of beam-tail folding using pairs of octupoles (a demonstration was thought to be essential as the computer predictions show significant differences for particle trajectories at large amplitudes).

The beam energy measurement at future linear colliders relies on bending magnets and on the quality of the beam position measurement. Accuracies on the order of 10^{-4} are aimed at, as discussed by Mike Hildreth of Notre Dame University. An interesting alternative method using spin rotation and polarimeters was proposed by Valery Telnov of BINP. Issues related to photon-photon collisions were presented by Mayda Velasco from Northwestern University, in application to the SLAC LINX project. The emittances achieved at the KEK ATF damping ring, damping ring tuning procedures, and the further plans at the ATF were presented by Junji Urakawa and Marc Ross. The CLIC design emittances approach the limit of what can be produced in conventional damping rings, carefully balancing the effects of synchrotron radiation and intrabeam scattering, as described in a talk by Maxim Korostelev from CERN and Lausanne.

The workshop ended in lively discussions and with the prospect of improved collaborations between the various laboratories, universities, and industry. Several study groups were established, which will pursue the questions of, and come up with logical proposals for, stabilization (coordinated by Andrei Seryi, SLAC), optics design (coordinated by Frank Zimmermann, CERN), superconducting magnets (coordinated by Brett Parker, BNL), permanent magnets (coordinated by M. Kumada, NIRS), diagnostics (coordinated by Marc Ross, SLAC), and damping rings (coordinated by Lenny Rivkin, PSI).

6 Forthcoming Beam Dynamics Events

6.1 ICFA Advanced Beam Dynamics Workshops

6.1.1 28th: Quantum Aspects of Beam Dynamics 2003

The Joint 28th ICFA Advanced Beam Dynamics & Advanced Novel Accelerators Workshop ON QUANTUM ASPECTS OF BEAM PHYSICS - and Other Critical Issues of Beams in Physics and Astrophysics – will be held on January 7-11, 2003 Hiroshima University, Higashi-Hiroshima, Japan. Information is available at

http://home.hiroshima-u.ac.jp/ogata/qabp/home.html

6.1.2 29th: Beam Halo Dynamics, Diagnostics, and Collimation (HALO'03) (in conjunction with 3rd workshop on Beam-beam Interactions) (First Announcement)

Motivation

Beam halo is one of the fundamental factors that limit the performance of existing and proposed high-intensity, high-brightness, and high-energy hadron accelerators. Although progress has been made in recent years, physical understanding of halo dynamics is still far from comprehensive, and experimental bench-marking is just beginning. State-of-the-art techniques are required for the detection and diagnosis of the formation and development of beam halo, and technically demanding design and material selection are needed for the scraping and collimation systems. Among accelerators directly facing such challenges are high-intensity rings like the ISIS, the US Spallation Neutron Source (SNS), the Japan Joint project (JKJ), and proposed proton drivers, as well as high-energy colliders like the Relativistic Heavy Ion Collider (RHIC), the Fermilab Tevatron, the Large Hadron Collider (LHC), and the proposed lepton linear colliders. It is becoming urgently important to bring together theoretical and experimental physicists and engineers, with expertise on beam dynamics, diagnostics, and collimation design working on both linear and circular accelerators, for focused discussions and investigation of the subject. The HALO'03 workshop is intended to provide such a platform for experts from the fields of accelerator physics, diagnostics, engineering and material science, and to stimulate the process during its preparation.

Workshop organization

We are planning a four-day workshop for the week of May 19–23, 2003 (immediately following the week of 2003 US Particle Accelerator Conference), at the Gurney's Inn, located at the eastern end of Long Island, New York, approximately 100 km from the Brookhaven National Laboratory. There will be three working groups: *halo dynamics* (e.g., space charge, magnetic nonlinearities, resonance excitation, beam-

beam, intra-beam scattering, instabilities and electron cloud, noise and diffusion processes, analytical and simulation techniques), *halo diagnostics* (e.g., diagnostics requirements, instrumentation design and performance, machine protection, experimental machine studies), and *halo collimation* (e.g., lattice design, betatron and momentum collimation design, scraper and collimator design, material tests, machine tests). We expect a non-local attendance of 60-80 people. We intend to publish both the plenary and contributed papers as American Institute of Physics (AIP) Proceedings.

The 3rd Workshop on Beam-beam Interactions will be organized in parallel with the HALO'03 Workshop. This offers the unique opportunity of scientific communication on the role of beam-beam effects in halo formation in the framework of the HALO Workshop. Specific beam-beam topics will be addressed at the Beam-beam Workshop, organized by W. Fischer and F. Pilat (BNL). A single registration fee allows a participant to attend both workshops.

Details of the HALO'03 workshop will appear on the web at

http://www.sns.bnl.gov/HALO/HALO2003.htm

Details of the Beam-beam'03 workshop will appear on the web at

http://www.rhichome.bnl.gov/AP/BeamBeam/Workshop03

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Sponsorship

Spallation Neutron Source Project
Brookhaven National Laboratory
Brookhaven Science Association
US Department of Energy
ICFA Panel on Beam Dynamics.

6.1.3   ICFA Mini Workshop on High Intensity, High Brightness Hadron Beams - SPACE CHARGE SIMULATION

The 12th ICFA Beam Dynamics Mini-Workshop, devoted to Space Charge Simulation and sponsored by the Rutherford Appleton Laboratory, will be held at Trinity College, Oxford, England from April 2nd-4th 2003. The focus of attention will be the study of aspects of particle accelerators in which space charge effects play a prominent role. Topics will include space charge issues in linacs and rings, recent code development, benchmarking and comparisons between simulation results and experimental observations.

The aim is to create a coherent programme with talks on the main space charge issues leading into constructive discussion. There will be no parallel sessions. At the conclusion, we would expect to have a clearer idea of the major problems to tackled, an order of importance and a well-defined path towards their solution.

Participants will be accommodated in Trinity, which is one of the smallest of the colleges that make up Oxford University, and is set in spacious grounds in the heart of the city. In recent years, the weather in early April has generally been fine and sunny, and, with trees in blossom and spring bulbs in flower, Oxford is particularly attractive. Participants will have access to the college's main facilities; the Bodleian Library, the Ashmolean Museum, other colleges and the main shopping areas are within a very short walk of the main gates. By providing a residential package, we aim to create an informal, friendly atmosphere in which ideas will flow, not only during the workshop sessions, but also over meals in the Dining Hall, in the Beer Cellar, and while strolling in the Gardens.

Suggestions for talks and topics for discussion would be welcomed. Presentation of a paper should, however, not be regarded as a pre-requisite for attending, and equal importance is attached to the presence and participation of as many of those as possible who are active or merely interested in the field.

Full details (including an on-line registration form) are available at

http://www.isis.rl.ac.uk/AcceleratorTheory/workshop/workshop.htm

or by emailing a member of the Organising Committee:

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6.2   Other Conferences

6.2.1   2002 Charged Particle Optics Conference (CPO-6) - October 22-25, 2002 Marriott Hotel Greenbelt 6400 Ivy Lane Greenbelt, Maryland Second Announcement and Call for Applications

The International Conference on Charged Particle Optics (CPO) brings together a diverse group of scientists and engineers working on different aspects of charged particle optics: accelerators, synchrotron sources, focused electron and ion beam instrumentation, spectrometers and cathode ray tubes, among other areas. The purpose of the meeting is to encourage people form different research backgrounds to learn what is going on in related fields, in the hope that a cross-fertilization of ideas will take place. For this reason there are no parallel sessions.

For further information please visit the conference web site which can be found at

http://www.ireap.umd.edu/CPO_6/

Because this conference only takes place every four years, in order to encourage the maximum amount of time for meetings and discussions all conference activities will be in the conference hotel. The exceptions are the tour of the accelerator facilities at the Institute for Research in Electronics and Applied Physics at the University of Maryland, and the optional outing.

Registration includes hotel rooms and meals for the duration of the conference. Rooms are covered for the nights of October 22 through October 24, and meals are covered from dinner on October 22 through lunch on October 25. The registration fee is $1100. The deadline for registration is September 20, 2002. Registration is limited to 150 persons.

The conference is being held at the Marriott Hotel Greenbelt, a modern hotel with first rate accommodations and facilities. The hotel is located about a ten-minute drive from the University of Maryland and is convenient to the Baltimore-Washington International Airport (BWI), the Ronald Reagan Washington National Airport (DCA) and to the Dulles International Airport (IAD), all of which serve the Washington DC area.

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TOPICS

- Accelerators, Storage Rings, and Synchrotrons
- Focused Ion Beam and Electron Beam Systems: Design and Novel Applications
- Aberrations and Aberration Correction
- Spectroscopy

- Calculational Methods for Charged Particle Optics
- Beam Cooling and Coulomb Effects on Beams
- Progress in Theory of Optical Systems
- Computer Methods Including New Tools, Applications to Optical and Source Design, Field Calculations,
- Trajectory Calculations
- Simulation of Optical Systems, and Methods for Optimization.

ABSTRACTS

The deadline for abstracts is August 31 (if sent by mail, abstracts must be postmarked by this date).

Please send abstracts to Professor Jon Orloff. Abstracts should be no more than two (2) pages including figures. Please up 12 point type with 1.5 line spacing. The abstract should fit into a space of 8.5 x 11 inches or 21.6 x 28 cm. Please include author affiliation(s) and main author contact information.

An abstract book will be provided at the meeting. If abstracts are submitted electronically, please submit them in WORD or WORDPERFECT format. If submitting a hard copy, please send a clear copy suitable for the abstract book

MANUSCRIPTS

Original manuscripts must be submitted at the conference. Format for Papers: Please follow the instructions for authors given in the journal "Nuclear Instruments and Methods in Physics Research A" at

http://authors.elsevier.com/JournalDetail.html?PubID=505701&Precis

7 Announcements of the Beam Dynamics Panel

7.1 ICFA Beam Dynamics Newsletter

7.1.1 Aim of the Newsletter

The ICFA Beam Dynamics Newsletter is intended as a channel for describing unsolved problems and highlighting important ongoing works, and not as a substitute for journal articles and conference proceedings which usually describe completed work. It is published by the ICFA Beam Dynamics Panel, one of whose missions is to encourage international collaboration in beam dynamics.

Normally it is published every April, August and December. The deadlines are 15 March, 15 July and 15 November, respectively.

7.1.2 Categories of Articles

The categories of articles in the newsletter are the following:

1. Announcements from the panel.

2. Reports of Beam Dynamics Activity of a group.

3. Reports on workshops, meetings and other events related to Beam Dynamics.

4. Announcements of future Beam Dynamics-related international workshops and meetings.

5. Those who want to use newsletter to announce their workshops are welcome to do so. Articles should typically fit within half a page and include descriptions of the subject, date, place, Web site and other contact information.

6. Review of Beam Dynamics Problems: this is a place to bring attention to unsolved problems and should not be used to report completed work. Clear and short highlights on the problem are encouraged.

7. Letters to the editor: a forum open to everyone. Anybody can express his/her opinion on the beam dynamics and related activities, by sending it to one of the editors. The editors reserve the right to reject contributions they judge to be inappropriate, although they have rarely had cause to do so.

8. Editorial.

The editors may request an article following a recommendation by panel members. However anyone who wishes to submit an article is strongly encouraged to contact any Beam Dynamics Panel member before starting to write.

7.1.3   How to Prepare a Manuscript

Before starting to write, authors should download *the latest* model article file, in Microsoft Word format, from the Beam Dynamics Panel home page

http://wwwslap.cern.ch/icfa/

It will be much easier to guarantee acceptance of the article if the latest model is used and the instructions included in it are respected. These model files and instructions are expected to evolve with time so please make sure always to use the latest versions.

The final Microsoft Word file should be sent to one of the editors, preferably the issue editor, by email.

The editors regret that LaTeX files can no longer be accepted: a majority of contributors now prefer Word and we simply do not have the resources to make the conversions that would be needed. Contributions received in LaTeX will now be returned to the authors for re-formatting.

In cases where an article is composed entirely of straightforward prose (no equations, figures, tables, special symbols, etc.) contributions received in the form of plain text files may be accepted at the discretion of the issue editor.

Each article should include the title, authors' names, affiliations and e-mail addresses.

7.1.4   Distribution

A complete archive of issues of this newsletter from 1995 to the latest issue is available at

http://wwwslap.cern.ch/icfa/

This is now intended as the primary method of distribution of the newsletter.

Readers are encouraged to sign-up for to electronic mailing list to ensure that they will hear immediately when a new issue is published.

The Panel's Web site provides access to the Newsletters, information about Future and Past Workshops, and other information useful to accelerator physicists. There are links to pages of information of local interest for each of the three ICFA areas.

Printed copies of the ICFA Beam Dynamics Newsletters are also distributed (generally some time after the Web edition appears) through the following distributors:

Weiren Chou	chou@fnal.gov	North and South Americas
Helmut Mais	mais@mail.desy.de	Europe* and Africa
Susumu Kamada	Susumu.Kamada@kek.jp	Asia** and Pacific

  * Including former Soviet Union.
** For Mainland China, Chuang Zhang (zhangc@bepc3.ihep.ac.cn) takes care of the distribution with Ms. Su Ping, Secretariat of PASC, P.O.Box 918, Beijing 100039, China.

To keep costs down (remember that the Panel has no budget of its own) readers are encouraged to use the Web as much as possible. In particular, if you receive a paper copy that you no longer require, please inform the appropriate distributor.

7.1.5   Regular Correspondents

The Beam Dynamics Newsletter particularly encourages contributions from smaller institutions and countries where the accelerator physics community is small. Since it is impossible for the editors and panel members to survey all beam dynamics activity world-wide, we have some *Regular Correspondents*. They are expected to find interesting activities and appropriate persons to report them and/or report them by themselves. We hope that we will have a "compact and complete" list covering all over the world eventually. The present *Regular Correspondents* are as follows

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We are calling for more volunteers as *Regular Correspondents*.

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The views expressed in this newsletter do not necessarily coincide with those of the editors. The individual authors are responsible for their text.