DAΦNE

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DAΦNE is an electron-positron Φ *meson factory* operating at Frascati since 1997. Factories are storage ring colliders designed to work at the energies of the meson resonances, where the production cross section peaks, to deliver a high rate of events to high resolution experiments.

The factory luminosity (the number of events per unit time produced by the reaction under investigation divided by its cross section weighted by the acceptance of the detector) is very high, about two orders of magnitudes larger than that obtained at the same energy in colliders of the previous generation. One of the key-points to get a substantial luminosity increase is the use of separated vacuum chambers for the two beams merging only in the interaction regions (IRs). When sharing the same ring the two N-bunch trains cross in $2N$ points and the maximum luminosity is limited by the electromagnetic beam-beam interaction. The unwanted effects of this interaction can be reduced with a very strong focussing (called "low-β") at the interaction point (IP), obtained by means of quadrupole doublets or triplets. However these magnetic structures take up much space and excite chromatic aberrations which must be corrected elsewhere in the ring.

This limitation does not hold for the double ring option, consisting in two separate rings crossing at two low-β points. The number of bunches that can be stored in such a collider is limited only by the geometry of the IR's.

DAΦNE is an accelerator complex consisting of a double-ring collider, a linear accelerator (LINAC), an intermediate damping ring to make injection easier and faster and 180 m of transfer lines connecting these machines. The beam accelerated by the Linac can also be switched into a laboratory called "Beam Test Facility (BTF)", for dedicated experiments and calibration of detectors. Three synchrotron radiation lines, two from bending dipoles and the other from the wiggler are routinely operated by the DAΦNE-LIGHT group in a parasitic mode, providing photons from the infrared to soft x-rays.

1 Injection System

In a low energy electron-positron collider, such as DAΦNE, the lifetime of the stored current is mainly limited by the Touschek effect, namely the particle loss due to the scattering of the particles inside the bunches. In the present typical operating conditions the Touschek lifetime is below 1000 s. It is therefore necessary to have a powerful injection system, capable of refilling the beam without dumping the already stored one. In addition, flexibility of operation requires that any bunch pattern can be stored among the 120 available buckets. The injection system of DAΦNE is therefore designed to deliver a large rate of particles in a single bunch at the working energy of the collider. It consists of a linear accelerator with a total accelerating voltage of 800 MV. In the positron mode, electrons are accelerated to ≈ 250 MeV before hitting a tungsten target (called positron converter) where positrons are generated by bremsstrahlung and pair production with an efficiency of $\approx 1\%$. The positrons exit from the target with an energy of few MeV and are then accelerated by the second section of the LINAC to their final energy of ≈ 0.51 GeV. The positrons are then driven along a transfer line and injected into a small storage ring, called Accumulator, at frequency of 50 Hz. Up to 15 positron pulses are stacked into a single bucket of the Accumulator, then injection stops and the bunch damps down to its equilibrium beam size and energy spread, which are much smaller than the LINAC ones. Damping takes ≈ 0.1 s and then the beam is extracted from the Accumulator and injected into the positron main ring at an overall repetition rate of 2 Hz. A powerful and flexible timing system allows the storage of any desired bunch pattern in the collider. In the electron mode, a magnetic chicane deviates the particle trajectory around the positron converter and electrons are directly accelerated to 0.51 GeV and injected into the Accumulator in the opposite direction with respect to positron operation. They are then extracted like in the positron case and injected into the electron main ring through the second transfer line.

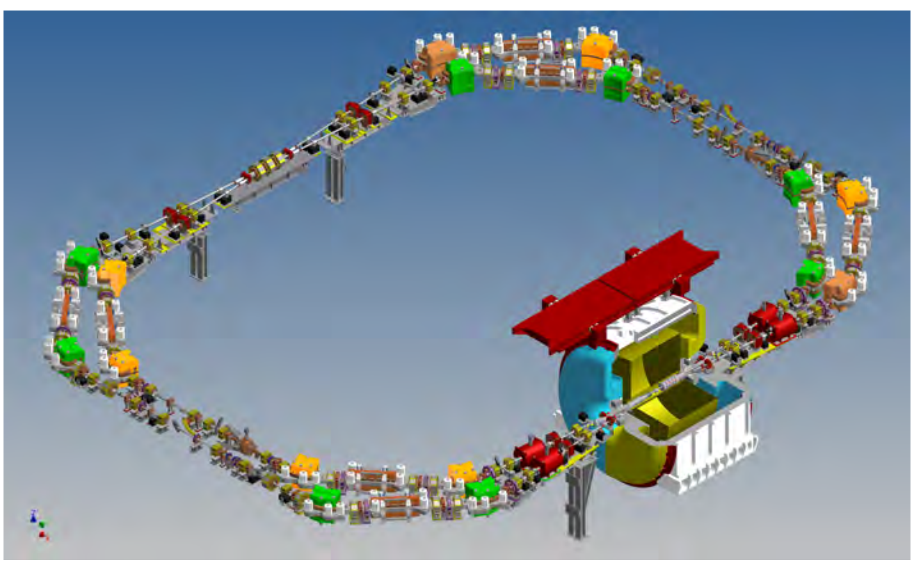

Figure 1: *The DAΦNE Main Rings in the present crab-waist scheme for the KLOE-2 run.*

The Accumulator ring has been introduced in the accelerator complex to increase the injection efficiency, especially for the positrons that are produced by the LINAC at 50 Hz rate in 10 ns pulses with a charge of $\approx$ 0.5 nC. Since the design charge of the main ring at the maximum luminosity is ≈ 1.5 μC and the longitudinal acceptance of the main rings is only 2 ns, the number of 50 Hz pulses necessary to fill the ring is of the order of 10^4. In order to avoid saturation it is therefore necessary that at each injection pulse a fraction smaller than 10^{-4} of the already stored beam is lost, and this is not easy to achieve. The Accumulator instead works with a lower frequency RF cavity and therefore with a larger longitudinal acceptance. In this way the full charge coming from the LINAC can be stored in a single RF bucket. In a complete injection cycle, that has a duration of 500 ms, up to 15 LINAC pulses can be stored in a single Accumulator RF bucket, and after being damped to the ring equilibrium emittances and energy spread, the whole stacked charge can be stored into a single RF bucket of the main ring. In this way the nominal single bunch charge can be stored with only one pulse from the Accumulator, reducing to 120 the number of injection pulses (at 2 Hz) into each main ring. As an additional benefit, the transverse beam size and energy spread of the beam coming from the Accumulator are at least one order of magnitude smaller than those of the LINAC beam, and this strongly reduces the aperture requirements of the main ring and, as a consequence, the overall cost of the collider.

2 Main Rings

In the DAΦNE collider the two beam trajectories cross at the interaction point (IP) with an horizontal angle that has been recently increased from ≈ 25 mrad to ≈ 50 mrad. A positron bunch leaving the IP after crossing an electron one will reach the following electron bunch at a distance of half the longitudinal separation between bunches from the IP.

Due to the horizontal angle between the trajectories of the two beams, the distance in the horizontal direction between the two bunches is equal to the horizontal angle times half the longitudinal distance between the bunches in each beam. The beam-beam interaction can be harmful to the beam stability even if the distance in the horizontal direction between bunches of opposite charge is of the order of few bunch widths at points where the β function is high and this sets a lower limit on the bunch longitudinal separation and therefore on the number of bunches which can be stored in the collider. However, the so called *crab waist collision scheme* (CW) recently implemented in the machine alleviates this problem, as it will be exhaustively explained in the following of this report.

By design the minimum bunch separation at DAΦNE has been set to ≈ 80 cm, and the maximum number of bunches that can be stored in each ring is 120. This number determines the frequency of the radiofrequency cavity which restore at each turn the energy lost in synchrotron radiation, which must be 120 times the ring revolution frequency. The luminosity of the collider can therefore be up to 120 times larger than that obtainable in a single ring with the same size and optical functions. Crossing at an angle could in principle be a limitation to the maximum single bunch luminosity. In order to make the beam-beam interaction less sensitive to this parameter and similar to the case of single ring colliders where the bunches cross head-on, the shape of the bunches at the IP is made very flat (typical ranges of r.m.s. sizes are $15 \div 30$ mm in the longitudinal direction, $0.2 \div 1.5$ mm in the horizontal and $2.5 \div 10$ μm in the vertical one). The double ring scheme with many bunches has also some relevant challenges: the total current in the ring reaches extremely high values (5 A in the DAΦNE design, $\approx$ 1.4 A in the DAΦNE operation so far) and the high power emitted as synchrotron radiation needs to be absorbed by a complicated structure of vacuum chambers and pumping systems in order to reach the very low residual gas pressure levels necessary to avoid beam loss. In addition, the number of possible oscillation modes of the beam increases with the number of bunches, calling for sophisticated bunch-to-bunch feedback systems.

The double annular structure of the DAΦNE collider as it is now after the recent modifications to implement the crab waist scheme (described in the following sections) with KLOE is shown schematically in Fig. 1. Both rings lay in the same horizontal plane and each one consists of a

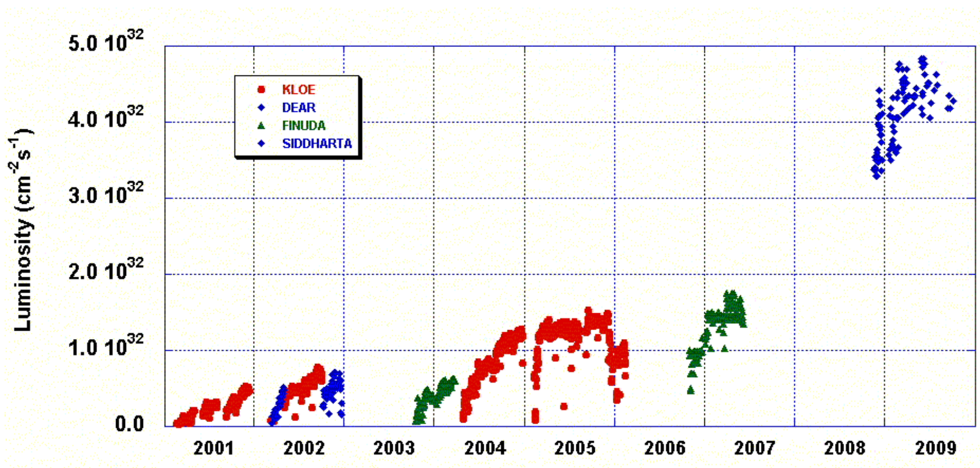

Figure 2: *Peak luminosity at DAΦNE.*

long external arc and a short internal one. Starting from the IP the two beams share the same vacuum chamber while traveling in a common permanent magnet defocusing quadrupole (QD) which, due to the beam off-axis trajectory increases the deflection of the two beam trajectories to $\approx$ 75 mrad. Shortly after the QD, the common vacuum chamber splits in two separated ones connected to the vacuum chambers of the long and short arcs. Two individual permanent magnet quadrupoles (QFs) are placed just after the chamber separation. Together with the previous QD they constitute the low-β doublets focusing the beams in the IP. The long and short arcs consist of two "almost achromatic" sections (deflecting the beam by $\approx$ 85.4 degrees in the short arc and $\approx$ 94.6 degrees in the long one) similar to those frequently used in synchrotron radiation sources, with a long straight section in between. Each section includes two dipoles, three quadrupoles, two sextupoles and a wiggler. This structure is used for the first time in an electron-positron collider and it has been designed to let DAΦNE deal with high current beams.

The amount of synchrotron radiation power emitted in the wigglers is the same as in the bending magnets and the wigglers can be used to change the transverse size of the beams. The increase of emitted power doubles the damping rates for betatron and synchrotron oscillations, thus making the beam dynamics more stable, while the possibility of changing the beam sizes makes the beam-beam interaction parameters more flexible.

The straight section in the long arc houses the kickers used to store into the rings the bunches coming from the injection system, while in the short straight arc there are the radiofrequency cavity and the equipment for the feedback systems which are used to damp longitudinal and transverse instabilities. The vacuum chambers of the arcs have been designed to stand the nominal level of radiation power emitted by the beams (up to 50 KW per ring). They consist of 10 m long aluminum structures built in a single piece: its cross section exhibits a central region around the beam and two external ones, called the antechambers, connected to the central one by means of a narrow slot. In this way the synchrotron radiation hits the vacuum chamber walls far from the beam and the desorbed gas particles can be easily pumped away. The chambers contain water cooled copper absorbers placed where the radiation flux is maximum: each absorber has a sputter ion pump below and a titanium sublimation pump above. The Main Rings have undergone many readjustments during the years to optimize the collider performances while operating for different detectors.

In principle the rings could host two experiments in parallel, but only one at a time has been operated so far. Three detectors, KLOE, DEAR and FINUDA, have taken data until 2007 and logged a total integrated luminosity of ≈ 4.4 fb^{-1} with a peak luminosity of $\approx 1.6 \cdot 10^{32}$ cm^{-2} s^{-1} and a maximum daily integrated luminosity of ≈ 10 pb^{-1}.

KLOE has been in place on the first IP from 1999 to 2006, while DEAR and FINUDA have alternatively run on the second one. The detectors of KLOE and FINUDA are surrounded by large superconducting solenoid magnets for the momentum analysis of the decay particles and their magnetic fields represent a strong perturbation on the beam dynamics. This perturbation tends to induce an effect called "beam coupling", consisting in the transfer of the betatron oscillations from the horizontal plane to the vertical one. If the coupling is not properly corrected, it would give a significant increase of the vertical beam size and a corresponding reduction of luminosity. For this reason two superconducting anti-solenoid magnets are placed on both sides of the detector with half its field integral and opposite sign, in this way the overall field integral in the IR vanishes.

The rotation of the beam transverse plane is compensated by rotating the quadrupoles in the low-β section. In the case of KLOE the low-β at the IP was originally designed with two quadrupole triplets built with permanent magnets, to provide high field quality and to left room to the detector. The structure of the FINUDA IR is quite similar to the KLOE one. Since its superconducting solenoid magnet has half the length (but twice the field) of the KLOE one, the low-β focusing at the IP was obtained by means of two permanent magnet quadrupole doublets inside the detector and completed with two other conventional doublets outside.

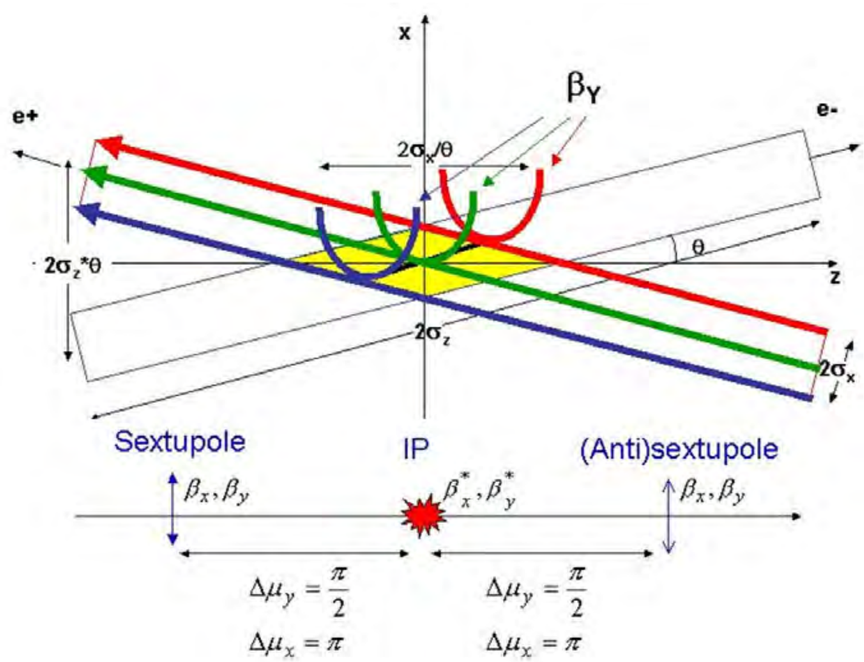

Figure 3: *Crab waist scheme*

The DEAR experiment, which was installed on the IR opposite to KLOE, took data during the years 2002-2003. It does not need magnetic field and therefore only conventional quadrupoles were used for the low-β. FINUDA rolled-in at DEAR's place in the second half of 2003 and took data until spring 2004. It was then removed from IP2 in order to run the KLOE experiment with only one low-β section at IP1, and rolled-in back in 2006 for a second data taking run ended in June 2007. After that the detector has been rolled-out again, and presently there are no detectors installed in IR2. The two chambers are vertically separated so that the two beams do not suffer from parasitic interactions in the whole IR2. A summary of the peak luminosity during these runs is shown in Fig. 2.

3 The large Piwinski angle and crab waist collision scheme at DAΦNE

In standard high luminosity colliders the key requirements to increase the luminosity are: very small vertical beta function β_y at the IP, high beam intensity I, the small vertical emittance ϵ_y and large horizontal beam size σ_x and horizontal emittance ϵ_x required to minimize beam-beam effects. The minimum value of β_y is set by the bunch length to avoid the detrimental effect on the luminosity caused by the hour-glass effect. It is very difficult to shorten the bunch in a high current ring without exciting instabilities. Moreover, high current implies high beam power losses, beam instabilities and a remarkable enhancement of the wall-plug power. In the CW scheme of beam-beam collisions a substantial luminosity increase can be achieved without bunch length reduction and with moderate beam currents. For collisions under a crossing angle θ the luminosity L and the horizontal ξ_x and vertical ξ_y tune shifts scale as:

$$L \propto \frac{N\xi_y}{\beta_y} \propto \frac{1}{\sqrt{\beta_y}} \tag{1}$$

$$\xi_y \propto \frac{N\sqrt{\beta_y}}{\sigma_z\theta}; \tag{2}$$

$$\xi_x \propto \frac{N}{(\sigma_z\theta)^2} \tag{3}$$

The Piwinski angle ϕ is a collision parameter defined as:

$$\phi = \frac{\sigma_z}{\sigma_x}\tan\left(\frac{\theta}{2}\right) \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2} \tag{4}$$

with N being the number of particles per bunch. Here we consider the case of flat beams, small horizontal crossing angle $\theta << 1$ and large Piwinski angle $\phi >> 1$. In the large Piwinski angle and Crab Waist scheme described here, the Piwinski angle is increased by decreasing the horizontal beam size and increasing the crossing angle. In such a case, if it were possible to increase N proportionally to $\sigma_z\theta$, the vertical tune shift ξ_y would remain constant, while the luminosity would grow proportionally to $\sigma_z\theta$. Moreover, the horizontal tune shift ξ_x would drop like $1/\sigma_z\theta$. However, the most important effect is that the overlap area of the colliding bunches is reduced, as it is proportional to σ_x/θ (see Fig. 3). Then, the vertical beta function β_y can be made comparable to the overlap area size (i.e. much smaller than the bunch length):

$$\beta_y \approx \sigma_x/\theta << \sigma_z \tag{5}$$

We get several advantages in this case:

- Small spot size at the IP, i.e. higher luminosity L.
- Reduction of the vertical tune shift ξ_y with synchrotron oscillation amplitude.
- Suppression of synchrobetatron resonances.

Table 1: DAΦNE Beam parameters for KLOE (2006) and SIDDHARTA (2008-2009)

PARAMETERS	KLOE Run	SIDDHARTA Run
L [$\mathrm{cm}^{-2}\mathrm{s}^{-1}$]	$1.5 \cdot 10^{32}$	$4.5 \cdot 10^{32}$
N_{part}/bunch	$2.65 \cdot 10^{10}$	$2.65 \cdot 10^{10}$
I_{bunch} [mA]	13	13
ϵ_x [10^{-9} m · rad]	340	260
ϵ_y [10^{-9} m · rad]	1.5	1
σ_x [μm]	760	200
σ_y [μm]	5.4	3.5
σ_z [mm]	25	17
β_x^* [m]	1.7	0.25
β_y^* [mm]	17	9
θ [mrad]	2×12.5	2×25

There are also additional advantages in such a collision scheme: there is no need to decrease the bunch length to increase the luminosity as proposed in standard upgrade plans for B- and Φ-factories. This will certainly help solving the problems of HOM heating, coherent synchrotron radiation of short bunches, excessive power consumption etc. Moreover, parasitic collisions (PC) become negligible since with higher crossing angle and smaller horizontal beam size the beam separation at the PC is large in terms of σ_x.

However, large Piwinski angle itself introduces new beam-beam resonances which may strongly limit the maximum achievable tune shifts. At this point the crab waist transformation enters the game boosting the luminosity, mainly because of the suppression of betatron (and synchro-betatron) resonances arising (in collisions without CW) through the vertical motion modulation by the horizontal oscillations. The CW vertical beta function rotation is provided by sextupole magnets placed on both sides of the IP in phase with the IP in the horizontal plane and at $\pi/2$ in the vertical one (see Fig. 3).

For comparison, the parameters used during the last DAΦNE run with the KLOE detector (2005-2006) are shown in Table 1. As discussed above, in order to realize the CW scheme in DAΦNE, the Piwinski angle ϕ should be increased and the beam collision area reduced: this is achieved by increasing the crossing angle θ by a factor 2 and reducing the horizontal beam size σ_x. In this scheme the horizontal emittance ϵ_x is reduced by a factor 1.5, and the horizontal beta function β_x lowered from 1.5 to 0.2 m. Since the beam collision length decreases proportionally to σ_x/θ, the vertical beta function β_y can be also reduced by a factor 3, from 1.8 cm to 0.6 cm. All other parameters are similar to those already achieved at DAΦNE.

4 Hardware upgrades for the Crab Waist test at DAΦNE with the SIDDHARTA run

DAΦNE has been upgraded to allow the CW collision scheme test with the SIDDHARTA run during the summer shutdown of 2007.

The major upgrades on the machine are summarized as:

- new IR1 geometry for the CW test;
- new IR2 geometry with two completely separated vacuum chambers with half moon profile;
- new shielded bellows;

- the four e^+ e^- transverse feedbacks have been upgraded;
- solenoid windings in the two long IRs sections of the e^+ ring;
- new calorimeter for luminosity measurement and tuning;
- new longitudinal position of the two IRs horizontal collimators;
- new injection kickers.

The need of a new IR geometry is essentially due to have a very small β_y (9 mm) and a large crossing angle (25 mrad per beam). Splitter magnets installed in the original design have been removed thanks to the large crossing angle in the CW scheme. Defocusing and focusing quadrupoles (QD, QF) on both sides of the IP have been placed to obtain the required low-β structure. Further trajectory separation is provided by two small dipole correctors upstream and downstream the quadrupole doublets, while other three quadrupoles are used to match the betatron functions in the arcs.

The low-β section quadrupoles near the IP are of permanent magnet (PM) type. The QDs are located near the IP where the beams share a common vacuum chamber, while the QFs are positioned where the chambers are splitted and each one acts on a single beam. Therefore a total of two QDs and four QFs is required to get the two doublets around IP1. Four corrector dipoles provide a deflection of 9.5 mrad to match the inlet and outlet arc chamber flanges.

CW sextupoles are placed at ~ 9.3 m far from the IP1. Bending dipoles facing the IRs have been rotated and their field adjusted according to requirements. They have been powered with independent supplies to match these requirements.

For the SIDDHARTA experiment a new aluminium alloy (AL6082T6) chamber with two thin windows (0.3 mm 0.02 thickness) in the top and bottom sides has been designed and built.

Electromagnetic simulations have shown the presence of trapped modes which add resonant contributions to the beam coupling impedance in the Y-chamber junctions, the regions where the two separate ring pipes merge in the common vacuum chamber near the IP. In the worst possible scenario, that occurs when a beam spectrum line at a frequency equal to a multiple to the bunch repetition rate is in full coupling, the joule loss does not exceed 200 W. To keep this effect under control the Y-chambers have been equipped with cooling pipes.

This additional cooling circuit allows to remove the beam induced HOM heating and, if necessary, to reduce it by detuning the mode frequencies with respect to the dangerous beam spectrum lines.

A new design of the central IR2 beam pipe has been implemented, the two vacuum chambers are completely separated and their cross section has an half moon profile.

The main Bhabha monitor consists of a 4-modules sandwich calorimeter, made of lead and scintillator. Four modules of calorimeters surround the final permanent quadrupole magnets, located at a distance of 32.5 cm on both sides of the IR, as shown in Fig. **??**. They cover an acceptance of $18 \div 27$ degrees in polar angle, and are segmented in azimuthal angle in five sectors, 30 degrees wide.

Two gamma monitor detectors are located 170 cm away from the IR, collecting the photons radiated by electron or positron beam. The detectors are now made of four PbW04 crystals (squared section of 30×30 mm^2 and 110 mm high) assembled together along z, in order to have a 30 mm face towards the photon beam, and a total depth of 120 mm corresponding to about 13 X_0. Thanks to the high rate, those detectors are mainly used as a fast feedback for the optimization of machine luminosity versus background, since the relative contribution of background is changing with the machine conditions. A total systematic uncertainty on the luminosity measurement of 11% can be estimated.

Table 2: DAΦNE luminosity performances with the CW scheme and low-β parameters compared to the KLOE and FUNUDA runs. SIDDHARTA data taking does not profit of the fast injection rate system, that would increase $L_{\int logged}$.

	SIDDHARTA March 08 ÷ Nov 09	KLOE May 04 ÷ Nov 05	FINUDA Nov 06 ÷ Jun 07
L_{peak} [cm^{-2}s^{-1}]	4.5	1.5	1.6
$L^{MAX}_{\int day}$ [pb^{-1}]	15.24	9.8	9.4
$L^{MAX}_{\int hour}$ [pb^{-1}]	1.033	0.44	0.5
$I^{-\ MAX}_{coll}$ [A]	1.4	1.4	1.5
$I^{+\ MAX}_{coll}$ [A]	1	1.2	1.1
$n_{bunches}$	105	111	106
$L_{\int logged}$ [fb^{-1}]	2.9	2.0	0.966
β^*_x [m]	0.25	1.5	2.0
β^*_y [m]	0.009	0.018	0.019
ϵ_x [10^{-6} m·rad]	0.25	0.34	0.34
ξ_y	0.0443	0.025	0.029

5 Luminosity achievements during the SIDDHARTA run

The commissioning of the upgraded machine started in November 2007. At the end of the year the ring vacuum was almost recovered, the beams were stored in the upgraded rings, all the sub-systems went quickly to regime operation.

The first collisions in the CW scheme have been obtained in February 2008, with the first experimental confirmation of the potentiality of the new configuration in terms of specific luminosity growth and reduction of the beam-beam detrimental effects.

DAΦNE luminosity as a function of the colliding bunches compared to past runs is reported in Fig. 4. Blue and red dots refer to the two KLOE runs, with the initial triplet low-β IR quadrupoles and with the new IR doublet, respectively. Yellow dots refer to the FINUDA run; in green is the luminosity with the CW scheme. The gain provided by the new IR gets higher with the products of the currents and the difference with respect to collisions with the crab sextupoles off can reach 50%. During 2009 the peak luminosity has been progressively improved by tuning the collider and increasing the beam currents; the maximum value achieved is $\approx 4.5 \cdot 10^{32}$ cm^{-2}s^{-1} measured in several runs with good luminosity to background ratio. The present peak luminosity is close to the nominal one predicted by numerical simulations. The highest single bunch luminosity achieved is $\approx 5 \cdot 10^{30}$ cm^{-2}s^{-1} measured with 20 bunches in collisions instead of the usual 105. The single bunch specific luminosity, defined as the single bunch luminosity divided by the product of the single bunch currents, at low currents exceed by 4 times the best value measured during the past DAΦNE runs (present values are red and blue dots in Fig. 5). It gradually decreases with colliding beam currents, as can be seen in Fig. 5. This reduction can be only partially explained by the growing beam size blow up due to the beam-beam interaction. Another factor comes from the fact that in the large Piwinski angle regime the luminosity decreases with the bunch length, which in turn is affected by the ring coupling impedance. The impact of the Crab-Waist sextupoles can be recognized comparing runs taken with CW sextupoles on and off (Fig. 5). At low current the

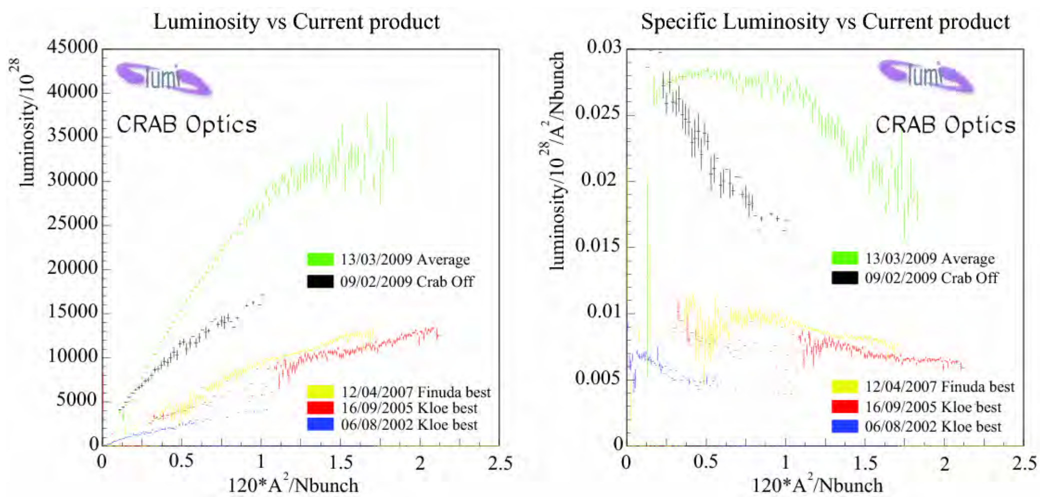

Figure 4: *Comparison of the upgraded DAΦNE perfomance (green) with respect to the results during previuos KLOE (blue, red) and FINUDA runs (yellow).*

luminosity is the same in the two cases and higher than the one measured with the original collision scheme. As the product of the stored currents exceed 0.3 A, the luminosity with CW sextupoles off becomes lower and a corresponding transverse beam size blow up and beam lifetime reduction are observed as a consequence of the uncompensated beam-beam resonances. The convolved vertical beam size at the IP in collision has been measured by means of a beam-beam scan technique. The measured Σy of 5.6 μm is compatible with the value obtained by using the coupling value ($k = 0.7\%$) as measured at the Synchrotron Light Monitor (SLM), being the single vertical beam size at the IP1 of the order of 4 μm.

Fig. 6 reports another proof of the crab sextupoles effectiveness, where the positrons transverse beam profile measured at the synchrotron light monitor with crab sextupoles OFF (left plot) and with crab sextupoles ON (right plot) is shown. The measurement refers to collision in a strong-weak regime (1 A electrons beam current against 0.1 A of positrons beam current): it is evident that the transverse beam size is smaller and its shape remains Gaussian during collision with the sextupoles ON.

The crab waist sextupoles proved to be of great importance for the collider luminosity increase, since much lower luminosity is achieved with crab sextupoles off, with a larger blow up and a sharp lifetime reduction is observed for single bunch currents greater than 8-10 mA. This is in agreement with beam-beam simulations taking into account the DAΦNE nonlinear lattice. The results achieved at DAΦNE have pushed several accelerator teams to study and consider the implementation of this scheme on their machines. Besides, the physics and the accelerator communities are discussing a new project of a Super B-factory with luminosity as high as 10^{36} cm^{-2}s^{-1}, i.e. by about two orders of magnitude higher with respect to that achieved at the existing B-factories at SLAC and KEK.

6 Hardware modifications for the KLOE-2 run

During 2009 the new interaction region design for KLOE has been completed and several components of the new hardware have been acquired. In beginning 2010 the KLOE detector has been

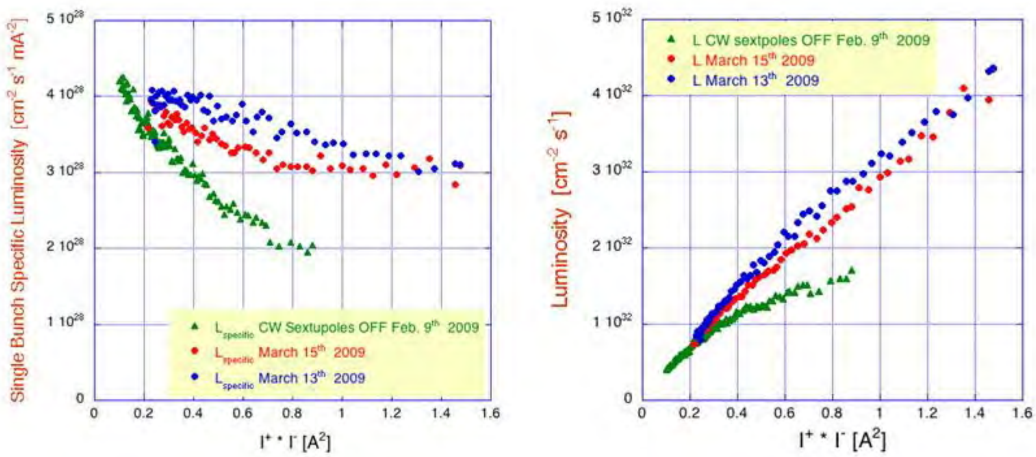

Figure 5: *Single bunch specific luminosity (left) and luminosity (right) versus the product of the colliding currents for two of the best run and for the crab waist sextupoles off.*

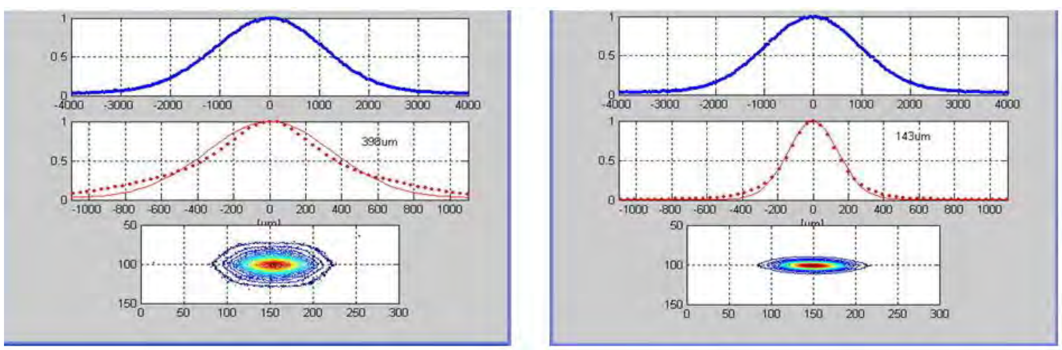

Figure 6: *Transverse positron beam profile as measured at SLM with crab sextupoles off (left) and crab sextupoles on (right) for beams in collisions (103 bunches).*

rolled in on IR1.

The new IR magnetic layout, sketched in Fig. 7, has been designed in order to maximize the beam stay clear letting the beam trajectory pass as much as possible through the center of the magnetic elements. The field integral introduced by the solenoidal detector is almost cancelled by means of two anti-solenoids, installed symmetrically with respect to the IP in each ring, which provide compensation also for off-energy particles. Due to the larger crossing angle, the vertical displacement of the beam in the IR is about an order of magnitude larger than in the last KLOE run. To keep the beam vertical trajectory within reasonable values, two permanent magnet dipoles (PMD) have been added just after the first permanent magnet horizontally focusing quadrupole, inside the detector magnetic field, in each one of the four IR branches (see Fig. 7). The PMDs are based on a modular design in view of a possible KLOE-2 run at a lower solenoidal field. Since the two beams are vertically deflected in opposite directions by the KLOE solenoid, they provide a horizontal magnetic field directed towards the center of the ring in the positron ring and towards the outside in the electron one. Four new skew quadrupoles have been added on the IR, just outside the KLOE magnet, to provide fine tuning for the coupling compensation.

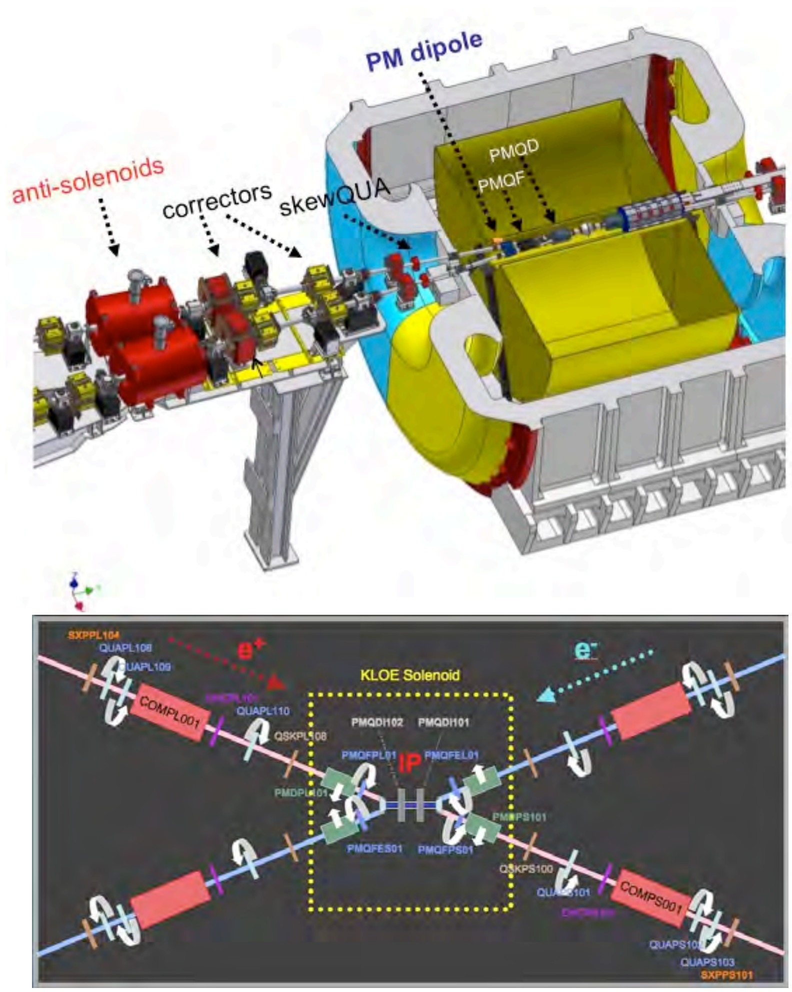

Figure 7: *(Top) The KLOE-2 detector and the new DAΦNE Interaction Region 1. (Bottom) Schematic drawing of the DAΦNE Interaction Region 1 magnetic layout.*

The shimmed plates added on the wiggler poles in 2004 have been removed and the poles displaced alternately in the horizontal direction by ±8 mm with respect to the wiggler axis in order to keep the beam trajectory as much as possible centered with respect to the pole axes. Due to the reduction of the gap and of the overall length of the magnetic circuit, this new configuration allows to reach, at a current of 450 A, a magnetic field still higher than that achieved at 550 A in the previous configuration with shimmed plates inserted. A further improvement has been obtained by powering in series all the 7 poles of the wigglers, while before each couple of terminal poles was powered independently. This has been obtained by short-circuiting one out of the five windings in the terminal poles coils and correcting the field integral in each wiggler below 1 Gm by tuning the end pole clamps aperture. In this way eight power supplies are no more necessary and the cycling procedure at startup is much more reliable. All the DAΦNE wigglers have been removed, modified and measured.

New stripline electrodes have been designed and inserted in the wiggler and dipole vacuum chambers of the positron ring. These electrodes, powered by DC voltages, counteract the parasitic electron cloud formation, which helps in increasing the positron beam current threshold.

The exhausted LINAC gun cathode has been replaced with a new one.

The modifications on the machine for the KLOE-2 run have been completed at the beginning of May. At the end of June the KLOE magnet has been partially warmed-up to allow the installation of the anti-solenoids cryogenic transfer lines. Since then, and up to mid November, several problems at the cryogenic plant and its ancillary systems occurred, preventing the KLOE solenoid energization. In September a magnetic setup without the KLOE magnet, but using the anti-solenoids, has been found to allow the DAΦNE beam conditioning. Up to about 1 A of positrons has been stored in the main ring with this optics, while the electron current was limited to ≈ 0.1 A due to ion trapping. On November 16th, the KLOE magnet was cooled and energized and beam conditioning in the nominal configuration was started with currents around 0.8 A stored at the same time in both rings, with half circumference filled in each one to avoid beam-beam interactions.

The first phase of the main ring commissioning has been done with the KLOE detector off. The lack of focusing from the solenoid has a strong impact on the ring optics, which had to be deeply modified. In November all the six DAΦNE bunch-by-bunch feedback systems have been upgraded to new software and hardware versions. The two (electron and positron) longitudinal feedbacks have been completely replaced with new ones, with the goal to have more compact systems with updated hardware components and new software programs compatible with the currently used operating system. These efforts are motivated also by reaching lower noise in detecting and better performance in damping the beam longitudinal oscillations. The vertical feedback systems have been equipped with 12-bit AD and DA converters in place of the 8-bit old units to reduce the quantization noise impact in the system gain. The positron ring horizontal feedback power has been doubled (1 kW now) providing about 40% increase in the kick strength. Furthermore, the horizontal feedback kicker has been replaced with a device with a double length stripline and reduced plate separation, providing larger shunt impedance at the low frequency typical of the positron horizontal unstable modes. The kicker has been also moved in a position with a higher horizontal β value.

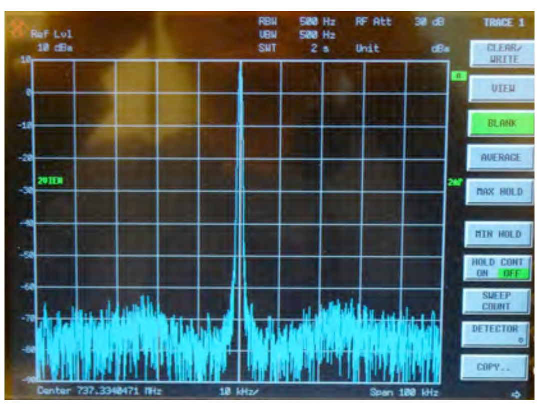

Figure 8: *Beam spectrum snapshot.*

7 DAΦNE commissioning for the KLOE-2 run

DAΦNE upgrade for the KLOE-2 run has been completed in July 2010. KLOE cool-down started on the second half of April 2010, however several problems involving the cryo-plant prevented to

energize the detector till October 25^{th}.
From November 2010 until June 2011 there have been several faults involving:

- injection septum of the positron ring;
- linac gun cathode and D modulator of the injection system;
- cooling system of the KLOE magnet power supply;
- vertical orbit oscillation in both rings.

These faults slowed down the commissioning and caused two major unscheduled shut-down periods. On January 11^{th} the 34 degrees injection septum of the positron ring got permanently damaged due to a water leakage together with a fault in the alarm system. Since no spare part was available it has been impossible to store the positron beam for three months. However, the accident had a positive drawback: the new septum coil has been optimized by reducing the coil gap and changing the geometrical dimension of the conductor, thus achieving a 50% reduction in the wall plug power with respect to the original device.
The cooling system of the KLOE magnet power supply experienced a faulty behaviour (from February 20^{th} to March 30^{th}), which has been linked, eventually, to the internal oxidation of the cooling circuit, that has been fixed in two weeks.

The Linac had several problems concerning the D modulator system, essential for positron production and the gun cathode, which required several replacements till to run out of spare parts by mid-May. This circumstance forced the last, and more relevant, unscheduled shut-down four months long.

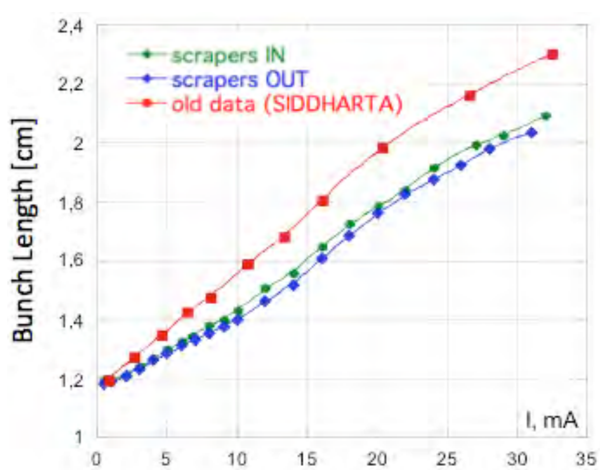

Figure 9: *Bunch length measurements in the electron ring.*

Suspending the DAΦNE activity gave a useful opportunity to start an extensive program of maintenance and consolidation involving almost all the collider subsystems.
It is the case of the test and replacement activities involving several Linac components such as: radio frequency loads in the gun area, modulators with their high power units, buncher phase shifter, diagnostic tools and cathode test station.
Concerning magnetic elements: all the four 34 degrees septa have been replaced and four correctors in the IR replaced with devices having better field quality.

About mechanics and layout many vibration measurements have been done in the Interaction Region area to sort out the source of the vertical oscillation observed, on both beams. Measurement analysis indicated how to consolidate the Interaction Region supports halving the vertical oscillation.

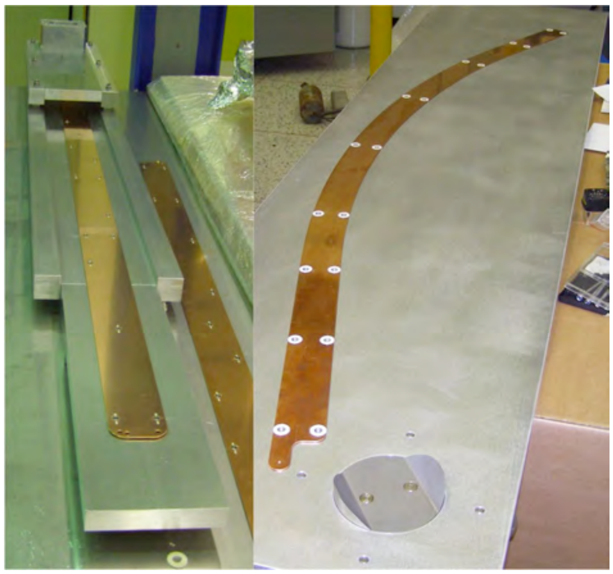

Figure 10: *Pictures of the electrodes inserted in the chambers of the dipole (on the right) and in the wiggler (left picture).*

Alignment has been revised in several sections of the main rings relying on beam measurement analysis.
The cryogenic plant has been maintained with a standard cleaning procedure.
Concerning controls: the fluid plant low-level interface has been upgraded and front-end controls for several class of elements have been ported to new more performing processors.
A lot has been done to reduce and optimize the demand for electric power. In fact the electric power necessary to run DAΦNE is $\approx 3.34\ MW$ now, which is $\approx 2.56\ MW$ lower than during the last KLOE run with a consequent reduction of $\approx 2.0\ Meuros$ on the electric bill due for a 200 days long run.

Although the collider uptime has been very limited, especially for the positron ring, some relevant work has been done to test the upgraded systems and to tune the Main Rings optics.

As for all circular colliders, the DAΦNE beam longitudinal dynamics is very much affected by the Low Level Radio-Frequency (LLRF) control. In particular, the dynamics of the beam barycentre motion (the coupled bunch zero-mode) is very sensitive to the large RF cavity detuning required to compensate the reactive beam loading, which is particularly huge at DAΦNE where the operating conditions are characterized by relatively low accelerating gradients ($\approx$ 200 kV) e large stored currents (up to 2 A). For this reason a fully analog RF feedback loop has been added to the LLRF system and commissioned on both e^+ and e^- rings, resulting in a drastic limitation of the synchrotron zero-mode coherent frequency shift that have affected the operation of the collider in the past. The measured beam spectrum around the RF 2^{nd} harmonics is shown in Fig. 8, where the sidebands of the longitudinal barycentre motion appear much lower and broader compared to what we observed in the past before the feedback implementation. The efficiency of the RF system

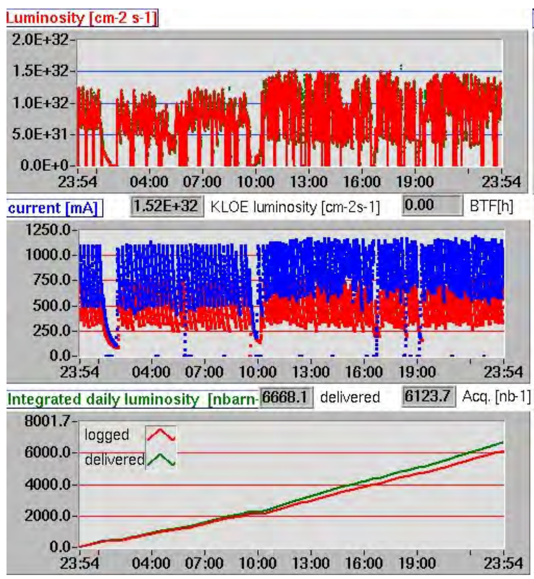

Figure 11: *(Top) Luminosity, (Middle) beam currents, (Low) Integrated luminosity for the best day, Dec.* 17^{th} *2011.*

has been also increased since no extra cavity detuning is necessary with direct RF feedback in operation. The RF systems of both rings are now operating reliably in the new configuration.

The ring impedance has been estimated relying on bunch length measurements as a function of bunch current. Numerical fits based on potential well as well as microwave regime converge to a ring coupling impedance of 0.3Ω; it was 0.4Ω during the previous run (see Fig. 9).

One of the main limitations in the maximum stored current of the positron ring has been identified in previous runs, in a horizontal instability due to the electron cloud effect. To mitigate such instability, metallic -copper- electrodes have been inserted in all dipoles and wigglers chambers of the machine and have been connected to external dc voltage generators in order to absorb the photo-electrons. With a dc voltage of about 200 V applied to each electrode we expect a reduction of such density by two orders of magnitude that will contribute to reduce substantially the source of the instability. The pictures of the electrodes inserted in the dipole and wiggler chambers are shown in Fig. 10.

The dipole electrodes have a length of 1.4 or 1.6 m depending on the considered arc (short or long), while the wiggler ones are 1.4 m long. They have 50 mm width, 1.5 mm thickness and their distance from the chamber is about 0.5 mm. This distance is guaranteed by special ceramic supports made in SHAPAL and distributed along the electrodes. This ceramic material is also thermo-conducting in order to partially dissipate the power released by the beam to the electrode through the vacuum chamber. Moreover, the supports have been designed to minimize their beam coupling impedance as well as to sustain the strip. First experimental measurements on the electrodes effectiveness in mitigating the electron cloud effects in the positron beam are very encouraging.

The new configuration of the wiggler magnets, based on shifted poles has proved to be effective in reducing the non-linear terms in the magnetic field (B) . The field quality has been tested by measuring the beam tune shift induced by a horizontal closed orbit bump at the wiggler place. This bump, including the two dipoles adjacent to the wiggler, slightly changes the ring energy: this effect has been carefully compensated tuning the frequency of the RF cavity. The orbit position at the wiggler centre has been obtained by averaging the readout from two beam position monitors

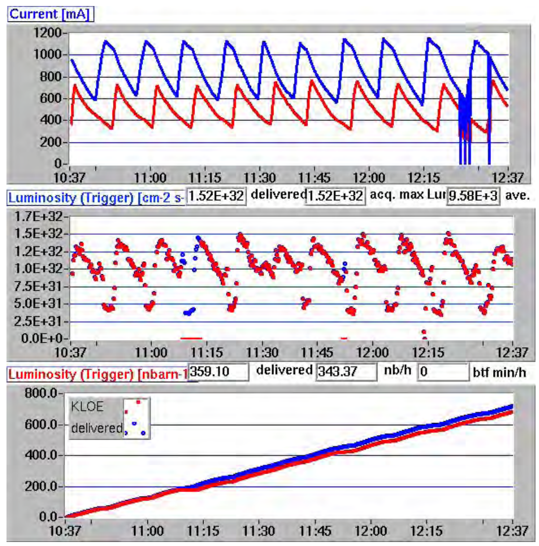

Figure 12: *Best two hours for KLOE-2 run.*

(BPM) placed at the magnet end side. For large values of the bump the BPMs non-linearity have been taken into account and properly corrected. The measured horizontal and vertical tune shifts exhibit a clear linear behaviour.

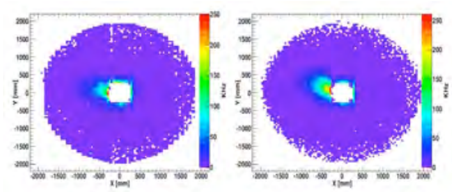

Figure 13: *Transverse profile of the backward EmC rates. Left and right plots are data and MC, respectively.*

The lattice for the KLOE-2 run with the crab-waist scheme has been optimized and matched to the real beams, relying on optics measurements (beta functions, dispersion, chromaticity, coupling, betatron tunes). The lowest value of the betatron coupling that has been measured is as small as 0.14% with a $\sigma_y = 75\mu m$ at the syncrotron light monitor. The vertical beam-beam luminosity scan showed that vertical orbit oscillation does not affect beam size at the IP, $\sigma_y = 3\mu m$ has been measured at IP. The new configuration of the wiggler magnets, based on shifted poles has proved to be effective in reducing the non-linear terms in the magnetic field. Luminosity is still not at nominal value due to different reasons, however beam-beam is not a limiting factor, and crab-waist sextupoles work well, as expected.

The luminosity has been optimized by storing 100 bunches in collision at low current. The single bunch specific luminosity at low currents is of the order of about $\approx 4.5 \cdot 28$ cm^{-2} s^{-1}, the same as the one measured during the crab-waist test without the detector solenoid. The DAΦNE performances at the end of December 2011 reproduced the best ones obtained during the previous KLOE run. In fact, up to now the maximum peak luminosity is $1.52 \cdot 10^{32}$ cm^{-2} s^{-1}, obtained on December 17^{th} 2011, with $I^- = 0.93\ A$ and $I^+ = 0.719\ A$ stored in 100 bunches. This value can be compared to the same luminosity $1.53 \cdot 10^{32}$ cm^{-2} s^{-1} with $I^- = 1.4$ A and $I^+ = 1.2$ A with 111 bunches, achieved during the KLOE run in 2005. The same day (December 17th) has been also the best day in terms of daily integrated luminosity (see Fig. 11).

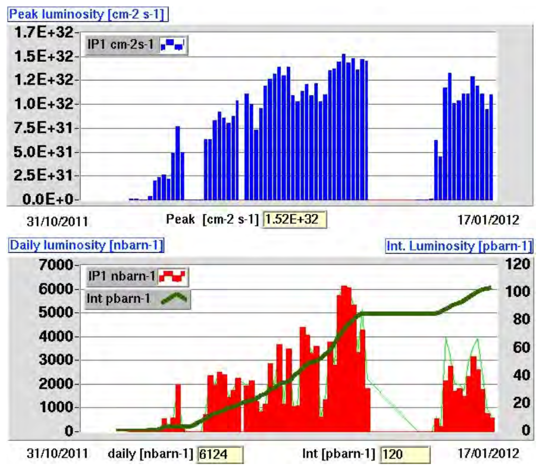

Figure 14: *Summary of current and luminosity during year 2011.*

The plot with the highest luminosity per hour is shown in Fig. 12. The best hourly integrated luminosity is 0.359 pb^{-1}, which might provide 8.62 pb^{-1} per day.

However, an efficient data taking requires not only high luminosity but also background rates induced in the detector as low as possible.

The two collimators mostly effective are the one upstream the IR and the one just after the old IP2, as predicted also by numerical simulations. The beam stay clear at these two collimators has been reduced to intercept Touschek scattered particles that would be lost at the IR. They proved to be very much effective in reducing background showers. However, after careful orbit optimization and collimator tuning, an additional lead shielding 1 cm thick has been added around the inner layer (QCAL) of the KLOE-2 detector to prevent background contamination in the physics events without reducing the detector acceptance. A full Monte Carlo (MC) simulation that allows a direct comparison between the expected and measured background rates at the KLOE electromagnetic calorimeter (EmC) has been developed in the new KLOE-2 configuration. The data/MC background rates are in agreement within a factor of two in the different regions of the KLOE EmC and the main features of the shapes are well reproduced (see Fig. 13). A good agreement for the Touschek lifetime is found between measured and calculated lifetime with scrapers inserted at the experimental set. On the contrary, the comparison without scrapers shows a disagreement of about a factor 1.9, which might be explained by a misalignment of the on-energy beam orbit that induced beam scraping in the IP2 section. This allows us to expect some margins of optimization, especially by correcting orbit and dynamic aperture.

The summary of current and luminosity during year 2011 is shown in Fig. 14. In order to push the collider performances in terms of luminosity, multibunches and high current operation must be consolidated and improved by tuning the working points in the two rings, the coupling at the IP for the two beams, the non-linear beam dynamics and, last but not least, beam-beam interaction. Background has been improved especially at high current and mainly for the positron ring. Dedicated studies may help to optimize the collimator configuration and to understand the possibility to introduce additional shieldings between the beam pipe and the detector.

8 DAΦNE setup and data taking tests with the KLOE-2 detector

DAΦNE activity in year 2012 has been aimed at completing the machine commissioning and at starting the detector data taking. However the machine operation has been seriously slowed down by several technical problems and faults that outlined a clear need for planning a radical consolidation program involving the whole accelerator complex.

On mid January a sudden rise, more than 90 ℃, occurred in the temperature of the beam pipe inside the detector, which was compatible with the lack of electrical continuity in the bellows of the section common for the two beams. It occurred close by the low-β defocusing quadrupole installed at the incoming side of the electron beam. In order to avoid a rather long machine shutdown, an attempt has be done to fix the problem by pushing the two halves of the IR from outside the detector, thus achieving a considerable reduction of the temperature variation in the range $25 \div 55$ ℃. This excursion, albeit reduced, has been causing sudden and unpredictable variation in the vertical tune and non-reproducibility in the betatron function measurements. In fact the low-β QDs are permanent magnet made by a SmCo alloy and experience a rather relevant variation in the gradient with the temperature of the order of ~ 0.0004 m^{-2} ℃$^{-1}$.

Many faults affected the cooling system causing also water leakages in the wiggler magnets of the electron ring, which, in turn, required several not simple soldering interventions to fix holes and to replace two end poles coils.

In the first months of the year in spite of the considerable downtime several encouraging results have been obtained in terms of luminosity. The maximum values achieved for peak, hourly and daily integrated luminosity have been: $L_{peak} = 1.53 \times 10^{32}$ (with colliding currents $I^- = 840$ mA and $I^+ = 810$ mA stored in 100 bunches), $L_{\int 1hour} = 0.350$ pb^{-1} and $L_{\int day} = 7$ pb^{-1}. The specific luminosity, at low current, exceeded by more than a factor of 2 the best value measured during the KLOE run in 2005 (see Fig. 15).

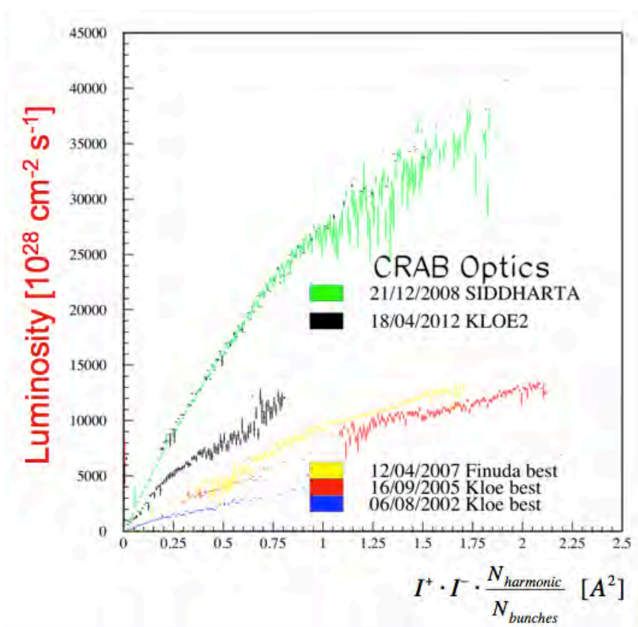

Figure 15: *Luminosity versus the product of the colliding currents normalized to the number of colliding bunches. Data refer to runs acquired before (bottom) and after (top) implementing the Crab-Waist scheme.*

DAΦNE is the first collider operating routinely with long electrodes, for e-cloud mitigation, installed in all dipole and wigglers vacuum chambers. These electrodes not only permitted a more stable operation with the positron beam, but have also allowed unique measurements such as e-cloud instabilities growth rate, transverse beam size variation, and tune shifts along the bunch train, demonstrating their effectiveness in mitigating the e-cloud induced effects. All measurements have been done with positive voltage polarity. The power supplies connected to the electrodes absorb electrons from the cloud. Betatron tune measurements taken by a spectrum analyzer have shown an average tune shift, especially in the horizontal plane, when switching off the electrodes. For this reasons a more sophisticated analysis has been done using the front-end data of the bunch-by-bunch feedbacks, which can measure the tune-shift for each bunch in the train [1]. The results are presented in Fig. 16.

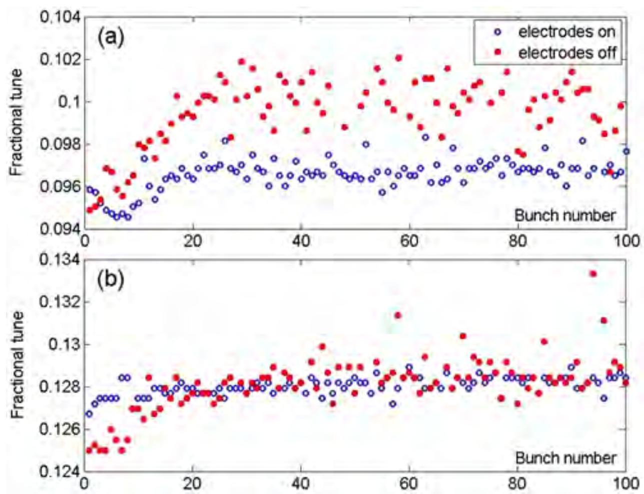

Figure 16: *Bunch by bunch measurements of horizontal (a) and vertical (b) fractional tunes for a positron current of the order of* $\sim$ *500 mA.*

When the electrodes are off horizontal tunes show a typical modulation along the train induced by the e-cloud density variation. The measured values increase progressively and reach a steady state regime after $\sim$ 20 bunches. The head-tail tune spread is about $0.006 - 0.008$. Switching the electrodes on the tune shift reduces by a factor of 2-3, but still the tune spread is not completely cancelled. This is likely due to the fact that the electrodes in the wigglers cover only 67% of the total magnet length. On the contrary the vertical tune spread is notably smaller and the electrodes almost completely cancel it.

A clear effect due to the single bunch e-cloud instability has been detected measuring the vertical beam size at the synchrotron light monitor by gradually turning off the electrodes. The observed beam size increases from about 110 μm with electrodes on, to more than 145 μm with the electrodes off. The e-cloud plasma can interact with RF waves transmitted in the vacuum chamber changing the phase velocity of the waves. The e-cloud changes the electromagnetic properties of vacuum, which can induce a shift of the resonant frequencies modes trapped in the chamber. In principle, from these shifts it is possible to evaluate the e-cloud density. Resonant TE-like modes are trapped in the DAΦNE arcs and can be excited through button pickups. A first measurement of these resonant modes has been done at DAΦNE for several beam currents with the electrodes on and off [2]. A preliminary analysis of the data has given the following results: (a) all modes have a positive frequency shift with the positron beam current and it is between 100 and 400 kHz depending on the modes taken into account; (b) switching on the electrodes the frequency shift can be partially cancelled for almost all modes; (c) the quality factor of the modes decreases with positron current.

The power supplies connected to the electrodes absorb cloud electrons. The current delivered by the generator has been measured as a function of the generator voltage for different beam currents. The result is given in Fig. 17.

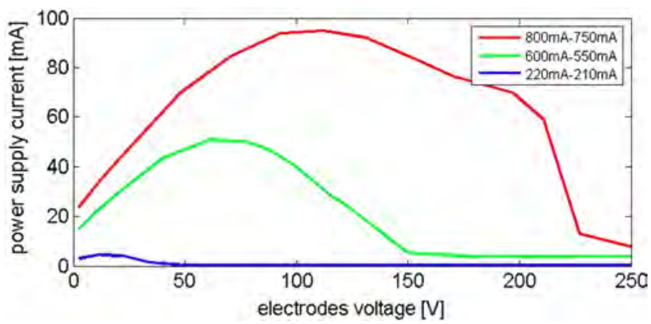

Figure 17: *Current supplied by the DC generator as a function of the applied voltage and beam current; the e-cloud is completely adsorbed when* $I = 0$.

Relying on numerical predictions, confirmed by measurement, it was evident that, in order to store positron beam currents higher than 1 A, voltages of the order of 250 V (presently available) are no longer adequate to completely absorb and suppress the e-cloud in DAΦNE.

Since the effectiveness of the e-cloud suppression does not depend on the voltage polarity it is preferable using negative voltages in order to avoid damages, caused by electron bombardment of the electrodes, and power supply overcurrent.

On July a medium intensity earthquake caused a relevant misalignment in the IR vanishing large part of the achievements obtained during the previous part of the commissioning: luminosity reduced dramatically and, in the positron ring, even beam injection was problematic. These circumstances forced an anticipated summer shutdown which has been exploited to undertake several activities. The detector end-caps have been opened to measure and restore the nominal position of the low-β elements. The electromagnetic quadrupoles in the IR have been checked too.

An endoscopic inspection of the low-β vacuum chamber confirmed the presence of broken bellows at the place where the temperature rise had been observed. However that component has not been replaced because the operation required the disassembly of the whole IR. An additional air-flow based cooling system has been installed in the IR to stabilize the temperature level. The functionality of the low-level system supervisor, based on old components no longer in production, has been restored by using part from another broken equipment.

Concerning the experimental detector, a half cylinder pure carbon target has been inserted inside the detector drift chamber to study the kaon-nuclei interaction process by using the KLOE-2 apparatus. This study, in fact, can lead to interesting scientific results by acquiring a rather modest data sample of the order of $\sim$ 100 pb^{-1}, for this reason it was quite compatible with the preliminary tests needed before the main KLOE-2 data taking.

DAΦNE operation restarted on mid September. The optics of the two rings has been refined as well as the alignment of electromagnetic quadrupoles in the IR and the Crab-Waist sestupoles by using beam based alignment techniques.

In less than three months performances in terms of peak luminosity have been recovered, $L_{peak} = 1.44{\times}10^{32}$ m^{-2} s^{-1}, while hourly and daily integrated luminosity had even some improvements achieving the values: $L_{\int 1hour} = 0.415$ pb^{-1} (Fig. 18) and $L_{\int day}$ 8 pb^{-1} respectively

(Fig. 19).

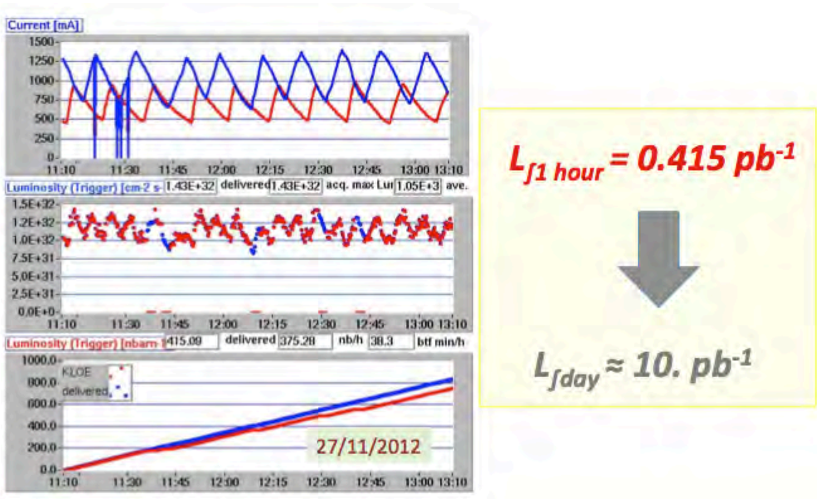

Figure 18: *Best hourly integrated luminosity.*

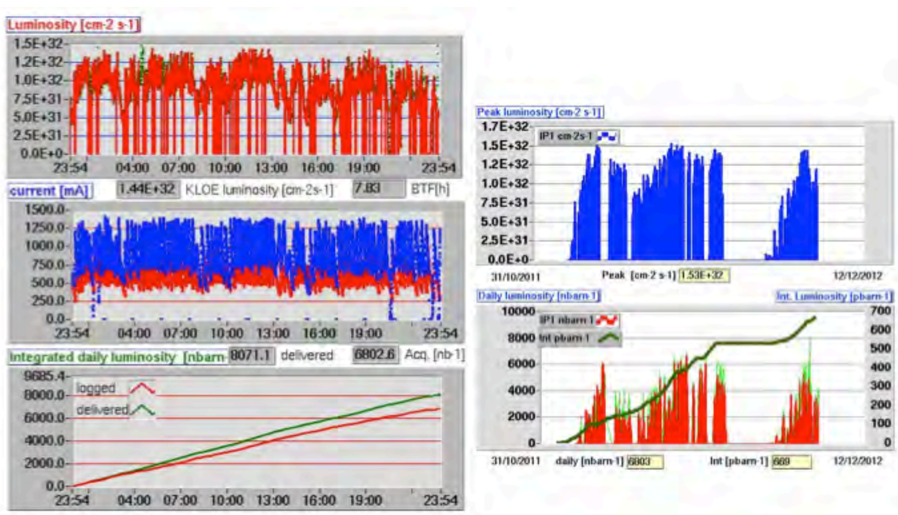

Figure 19: *Best daily run (left), peak luminosity (right top), daily integrated luminosity (right bottom).*

By the end of the year two important tests have been done concerning the effectiveness of the Crab-Waist sextupoles in presence of a strong solenoidal field introduced by the detector, and the maximum achievable luminosity putting 10 bunches in collision.

All the tests concerning the Crab-Waist sestupoles have been done in collision. A clear increase in the transverse vertical dimension of the electron beam, σ_y^-, has been observed as the Crab-Waist sextupoles strength is reduced in the corresponding ring, see Fig. 20; at the same time σ_y^+ decreases as a consequence of the reduced beam-beam kick.

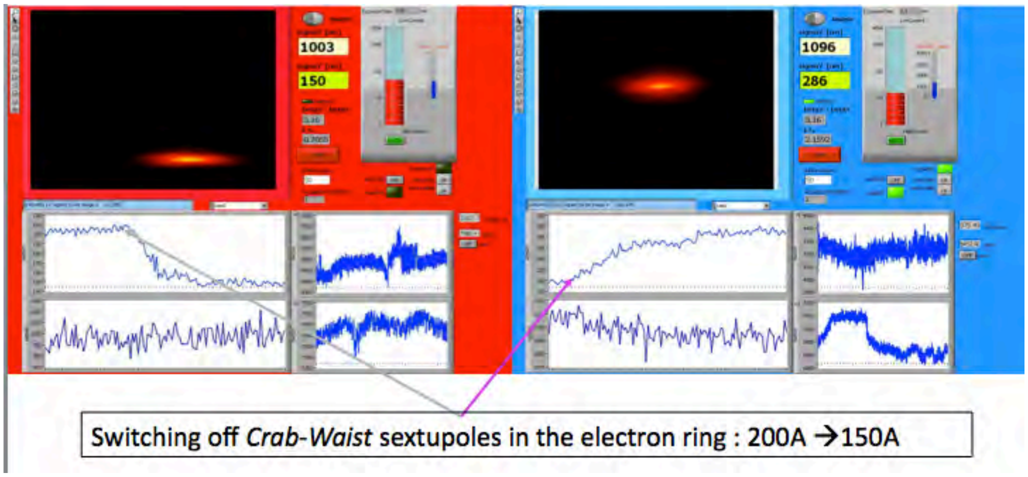

Figure 20: *Vertical beam dimension of the colliding beams as Crab-Waist sextupoles are switched off in the electron ring.*

A consistent behavior is observed when the Crab-Waist sextupoles are progressively turned off in both rings, see Fig. 21. In this case the transverse vertical beam dimensions become larger for both beams.

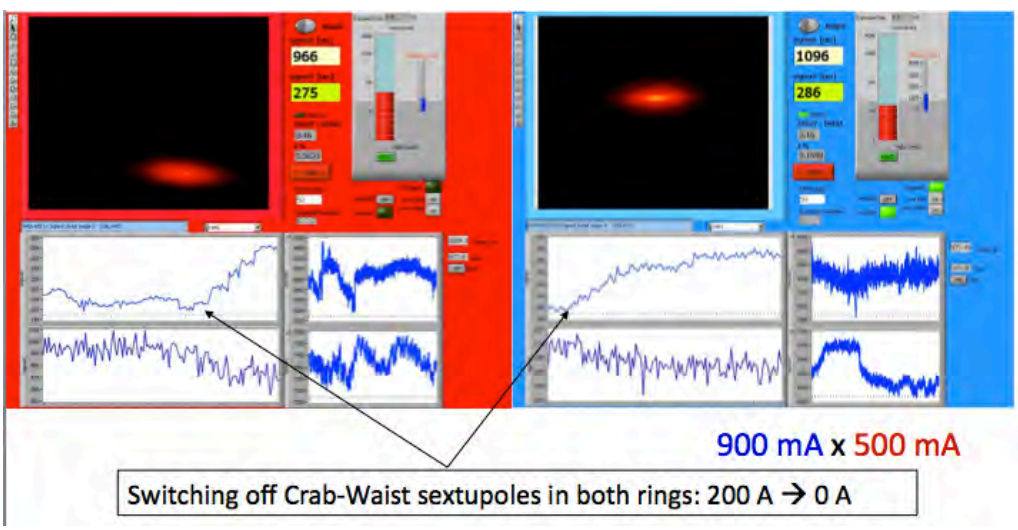

Figure 21: *Vertical beam dimension of the colliding beams as Crab-Waist sextupoles are switched off in both rings.*

Data from the machine γ-monitor and from the detector, see Fig. 22, point out an evident reduction in the luminosity when the Crab-Waist sextupoles are off. These observations all together give a clear evidence about the Crab-Waist sextupoles capability in keeping under control the coupling resonances due to collision with large horizontal crossing angle even in presence of a large detector having a strong solenoidal field.

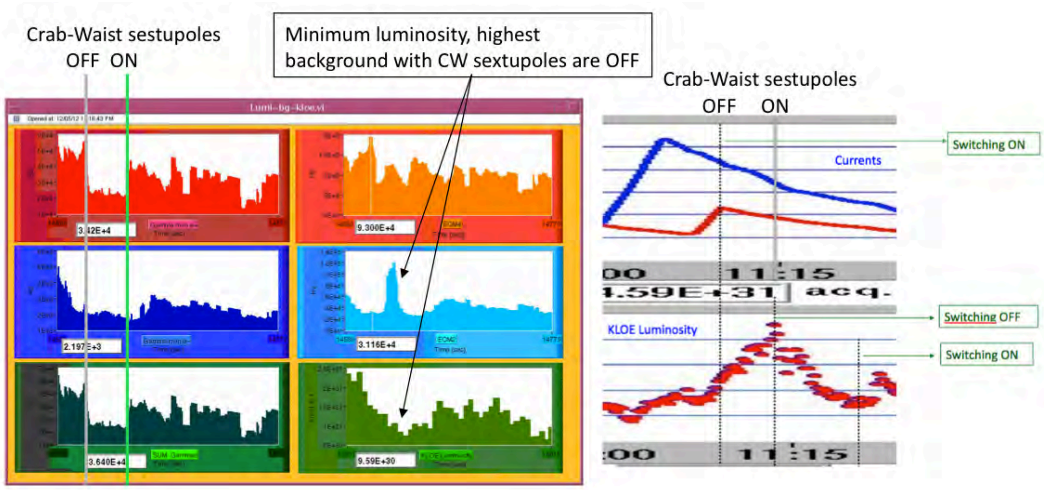

Figure 22: *luminosity evolution as measured from the DAΦNE γ-monitor (left) and from the KLOE detector (right), while switching on the Crab-Waist sestupoles in both rings.*

Collisions with 10 consecutive bunches permit to measure the maximum achievable luminosity independently from the effects introduced by multi-bunch operations. The maximum value obtained by now in this configuration with the KLOE-2 optics has been 2.19×10^{31} cm^{-2} s^{-1}, which devises the possibility to achieve a peak luminosity of the order of $\sim 2.5 \times 10^{32}$ cm^{-2} s^{-1} by optimizing 110 bunches operations. This test has been also relevant in showing that the present limit in the measured peak luminosity does not depend on the beam-beam or on the Crab-Waist collision scheme.

By beginning of November, contextually with the machine studies, the data taking activity has started. This phase has been quite relevant to optimize the collider background, to improve adiabatically the collisions as well as to deliver to the KLOE-2 detector the 100 pb^{-1} integrated luminosity required for the experiment with the carbon target.

Consolidation Plan

The DAΦNE accelerator complex has been working for more than 15 years. Recent operation experience has clearly shown that an extraordinary consolidation effort is required in order to provide a 80% uptime in the next years and secure a reliable data taking for the KLOE-2 experiment. A brainstorming on DAΦNE refurbishment started on past spring, stemming from a detailed analysis of the fault occurrences and a critical revision of all the subsystems containing old or out of production parts.

A list of mandatory items has been defined and the relative costs have been evaluated. The more relevant items are:

- Revamping of the low level control system.
- Control system upgrade.
- New power supplies for the skew correctors.

- Improved diagnostic in the accelerator complex.
- Power supplies for e-cloud suppression replaced with devices providing higher voltage.
- New kicker for the transverse feedback in the electron ring.
- Improved design for the vacuum chamber of the low-β section and the relative support.

The consolidation plan has been endorsed and funded by the INFN management. This revamping program will be implemented during the six months long shut starting on January 2013, which has been planned to complete the KLOE-2 detector upgrade.

9 Publications

1. A. Drago, D. Alesini, T. Demma, A. Gallo, S. Guiducci, C. Milardi, P. Raimondi, M. Zobov (INFN-LNF), "Mitigation and control of instabilities in DAΦNE positron ring", Beam Instrumentation Workshop 2012, Apr 2012.
2. T. Demma, A. Drago, A. Gallo, S. Guiducci, C. Milardi, P. Raimondi, M. Zobov, D. Alesini (INFN-LNF), S. De Santis (LBL, Berkeley), "Experimental measurements of e-cloud mitigation using clearing electrodes in the DAΦNE collider", IPAC-2012 Conf. Proc. C1205201 (2012) 1107-1109