DAΦNE Status and Prospects

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KEK Nov-2004

OUTLINE

- Introduction and history
- Status of the Kloe run
- Performances expectations for the Kloe run
- Upgrades plans
- Conclusions

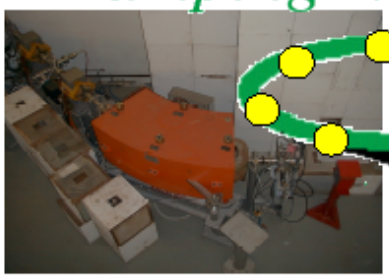
DAΦNE

e^+e^-

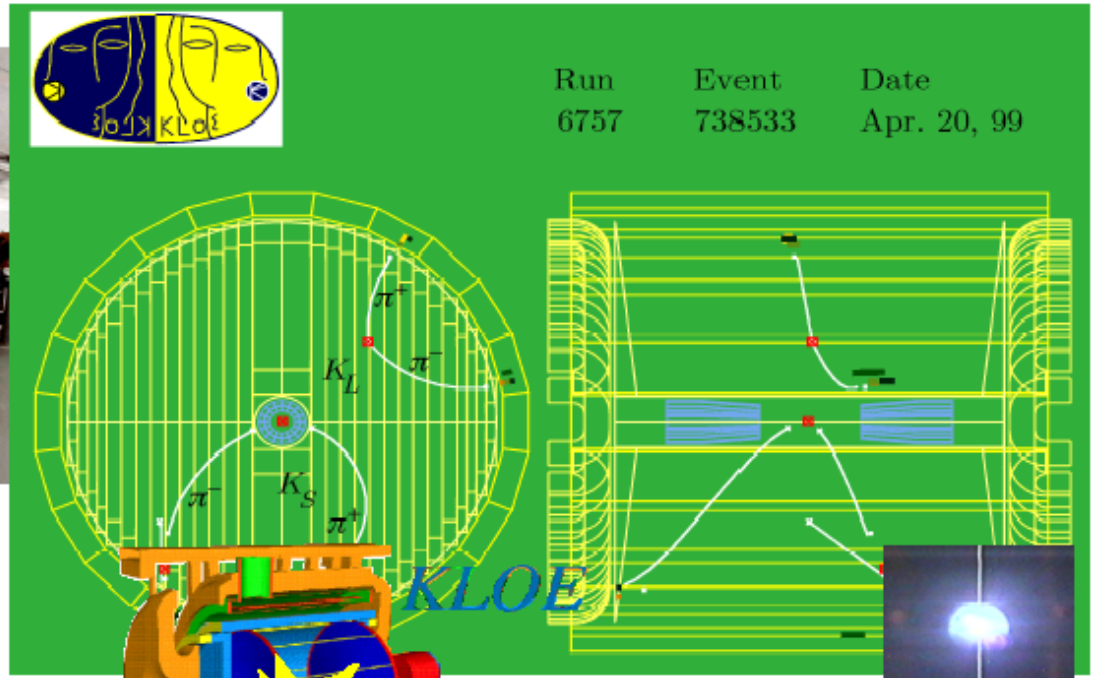
$C = 97$ m

$E = 0.51$ GeV (Φ)

Damping ring



Test beam



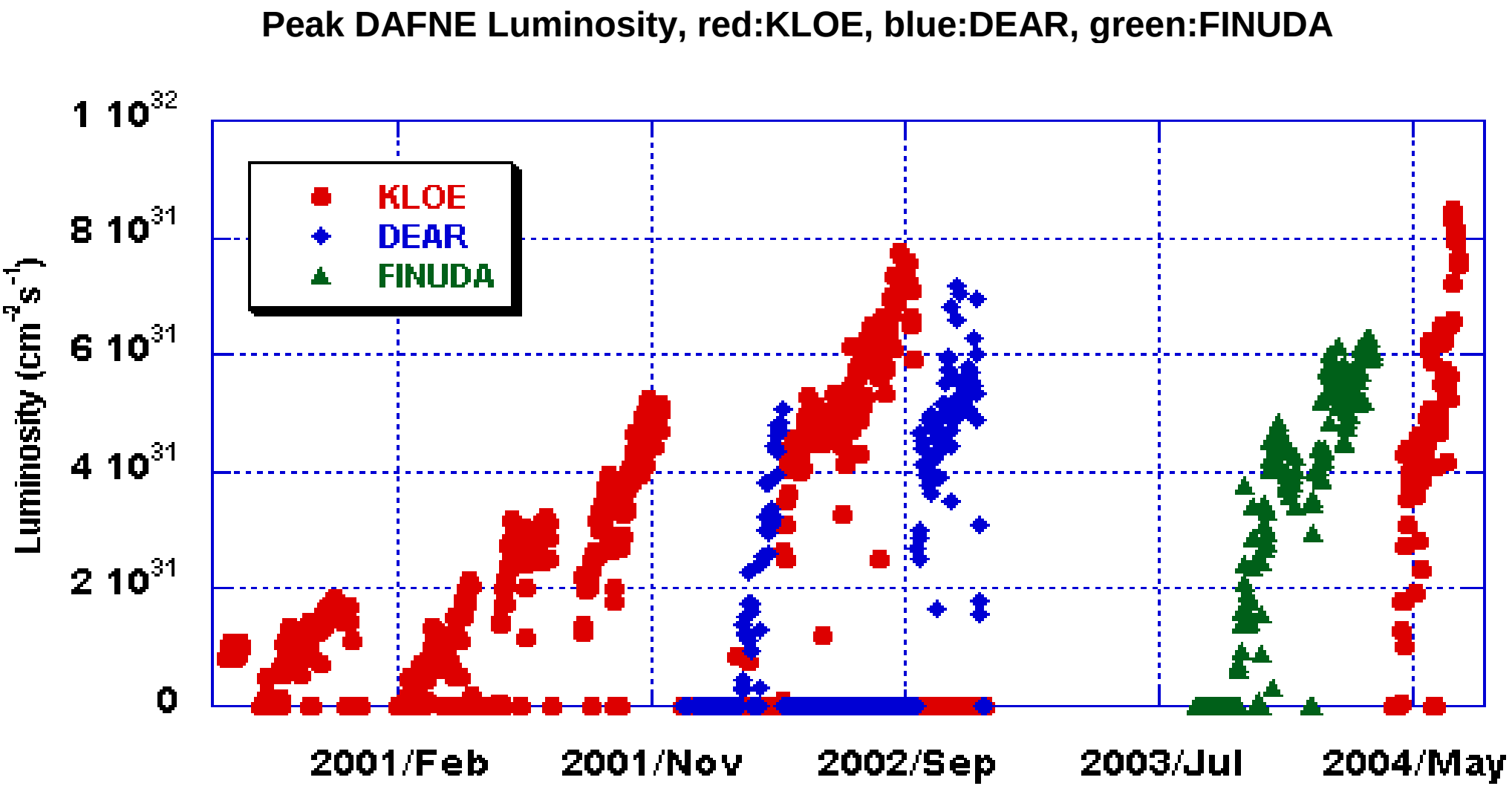
Main rings

DAFNE-Light

Linac

DEAR & FINUDA

- Physics runs in Dafne begun in the second half of 2000
- KLoe and Dear have shared beam time in the two avalaible interaction regions until the end of 2002
- Delivered target 300pb-1 to KLOE and 60pb-1 to DEAR in 2002
- Several upgrades implemented in a 6 months shutdown in the first half of 2003
- Physics run for FINUDA (second IR) from Oct 2003 to March 2004, delivered target 250pb^{-1}
- FINUDA detector and IR2 removed in April
- Physics run for KLOE started in May 2004, run will end in Dec-2005, target is 3fb^{-1}
- Second run for FINUDA scheduled for 2006, target is 1fb^{-1}
- Third run for DEAR scheduled for the first six months of 2007
- DAFNE upgrades toward higher luminosity or energy start in the second half of 2007



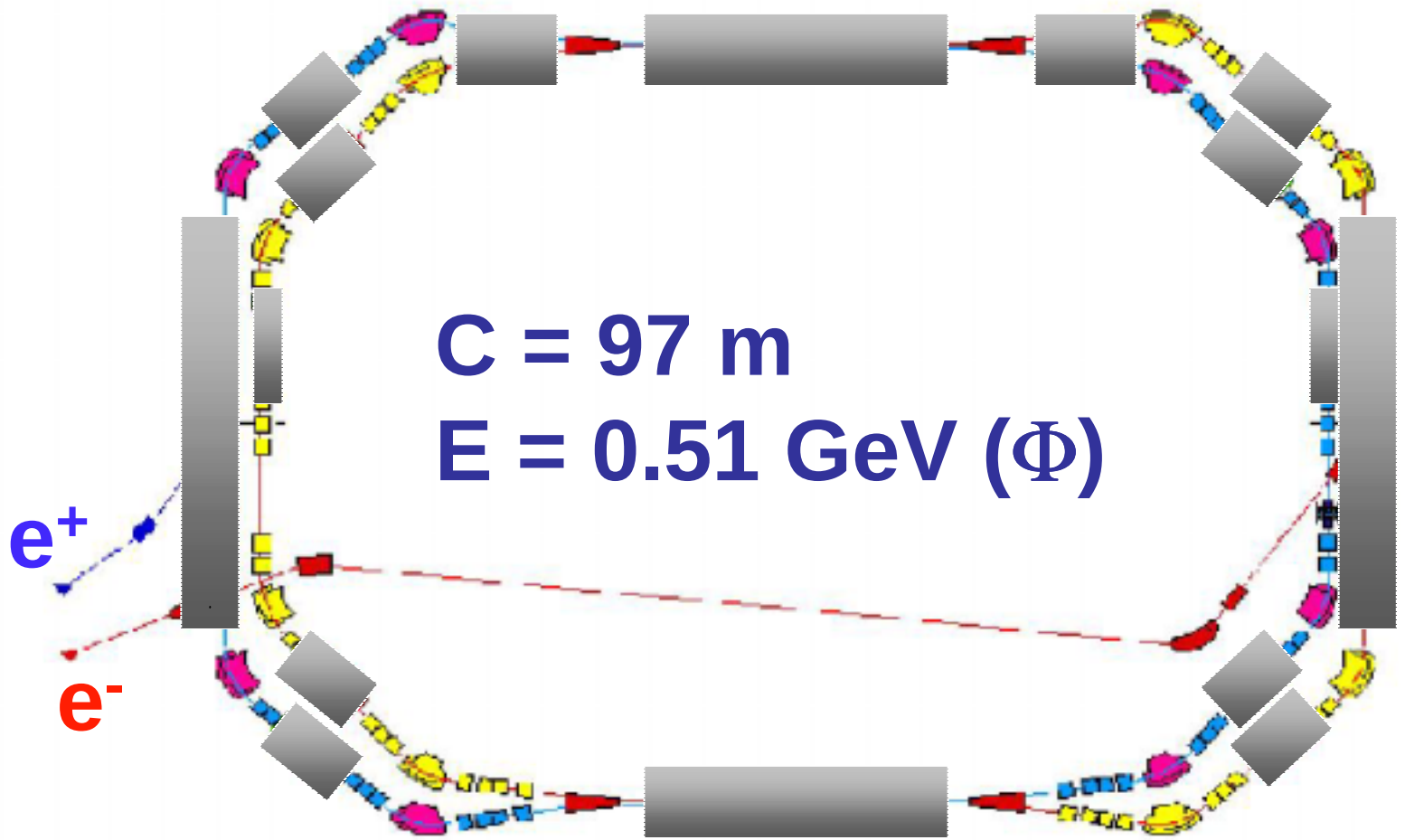
DEAR and FINUDA run with KLOE IR installed (two low betas insertions in the ring)

2003 MAIN HARDWARE ACTIVITIES

- Finuda Installation
- Kloe new I.R. installation
- Straight long sections and kickers mods
- Scrapers mods
- Bellows mods
- New Ion clearing electrodes
- Wigglers poles shimming

. . . 70% of the accelerator has been modified!

(parts grayed out)



New Kloe Interaction Region

- **The interaction regions for KLOE has been modified (triplet to doublet configuration) in order to:**

  -decrease the IP beta-functions and lattice chromaticity

  -optimize background rejection

  - provide variable quadrupoles rotation to operate at different magnetic fields (from 0 to maximum) in the solenoids and optimize coupling correction.

  - reduce parasitic beam-beam crossing to double the number of bunches from 50 to 100

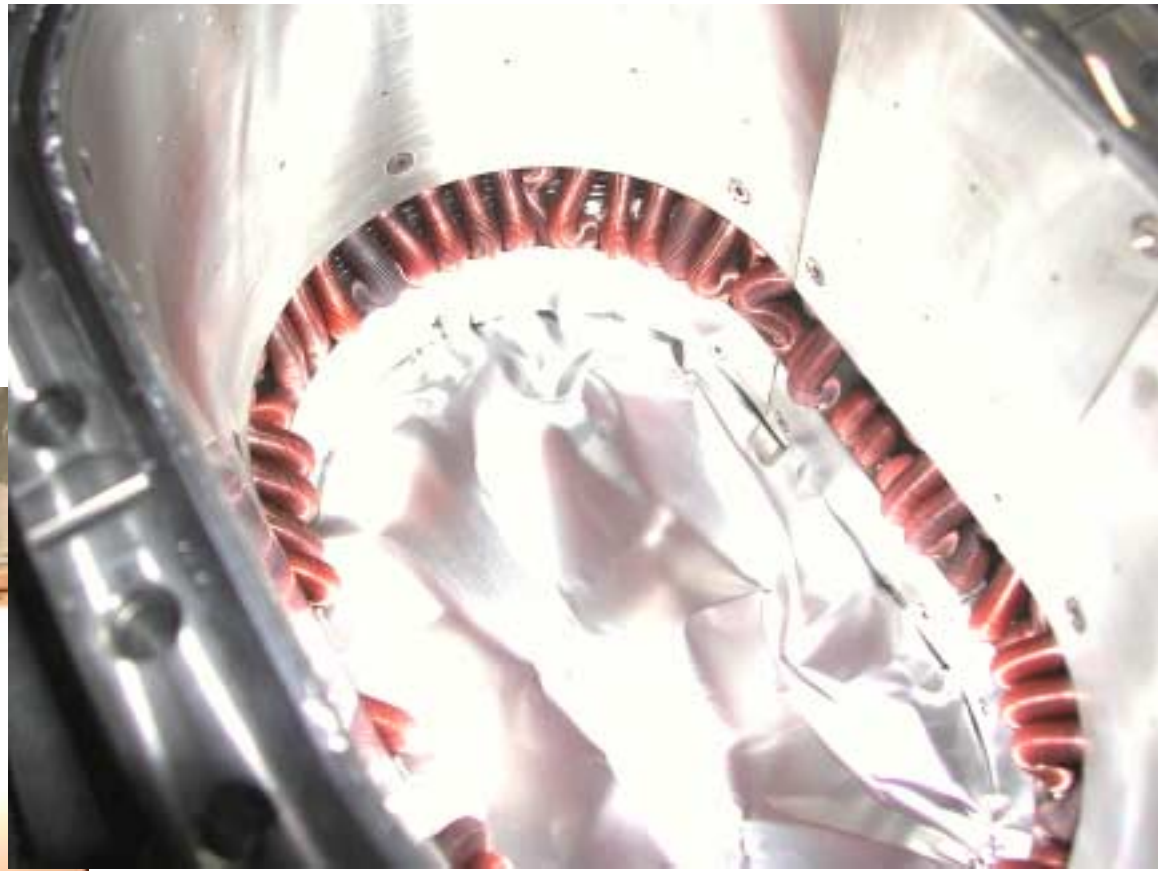
Kloe new IR installation

Straight Sections Modifications

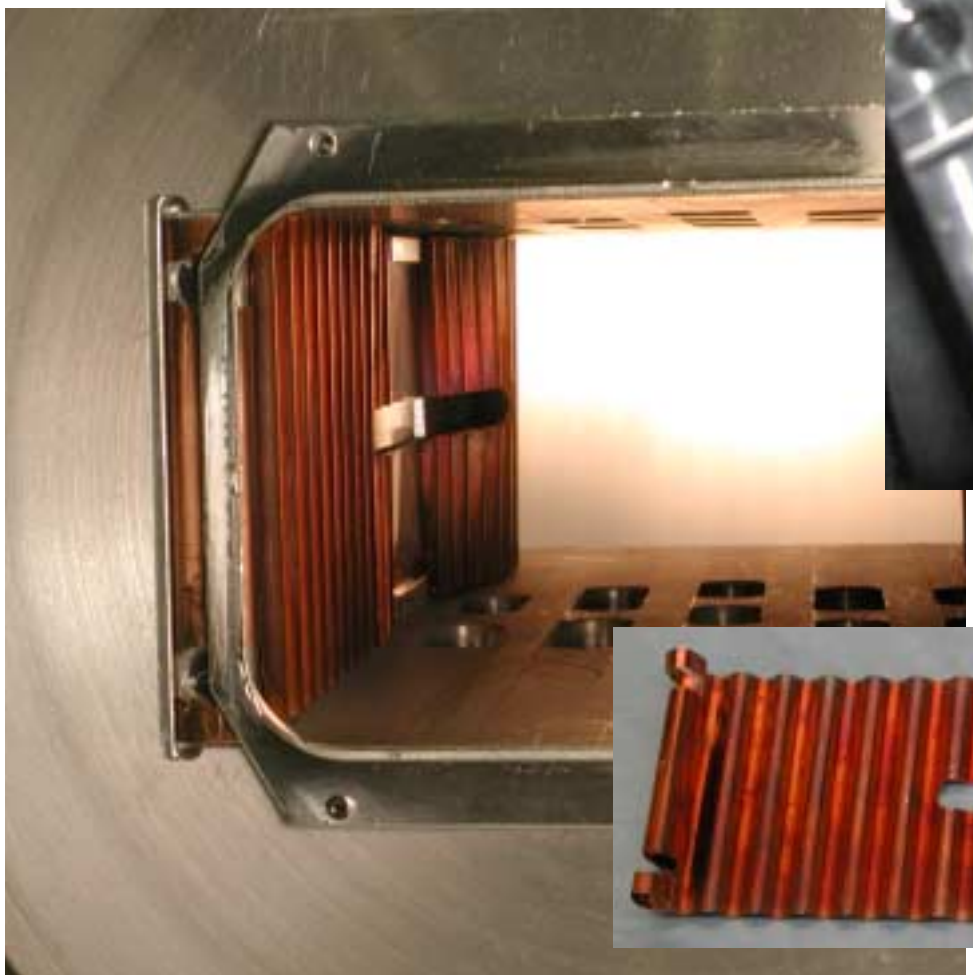
The straight sections, where the beams are injected, have been modified in order to:

- **Improve injection efficiency**
- **Decrease injection sensitivity of the stored beam (kick angle and kick duration both reduced by 50%)**
- **Reduce dispersion at the septum**
- **Optimize Optic functions and phase advance in the section w.r.t. dynamic aperture**

Bellows shields as found



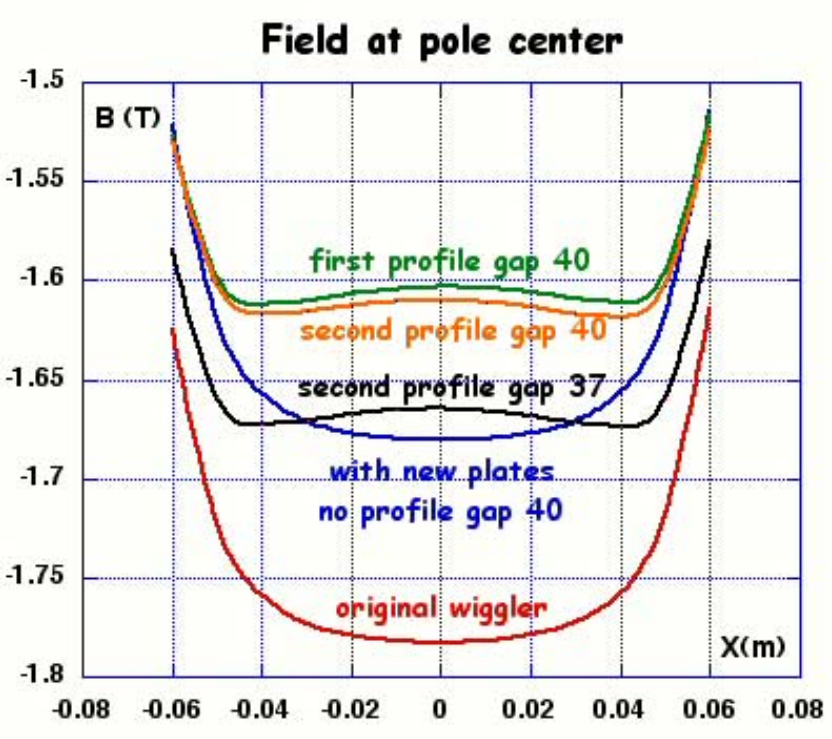
Collimators tapers As found

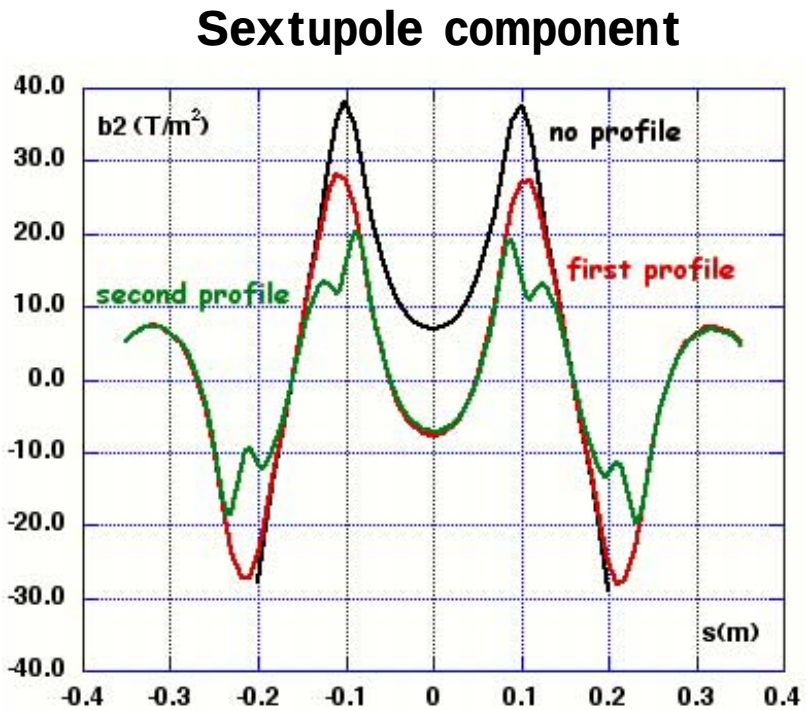


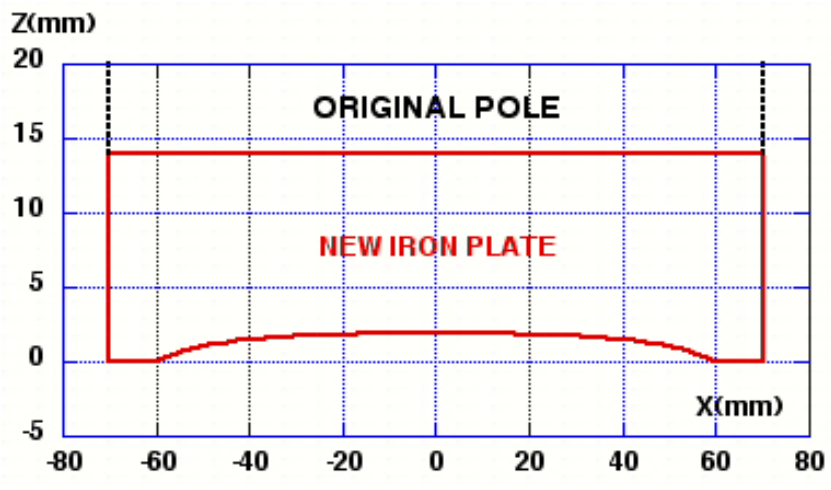
Wigglers modifications

- A new wiggler (arrived at the lab. beginning 2003) has been used to map the magnetic field and to study the pole modifications in order to improve the field quality.
- Final profile defined, Dafne wigglers modified accordingly, from June-1 to June-20.
- According to tracking, the dynamic aperture and lifetimes more than doubles.

Wiggler field modifications

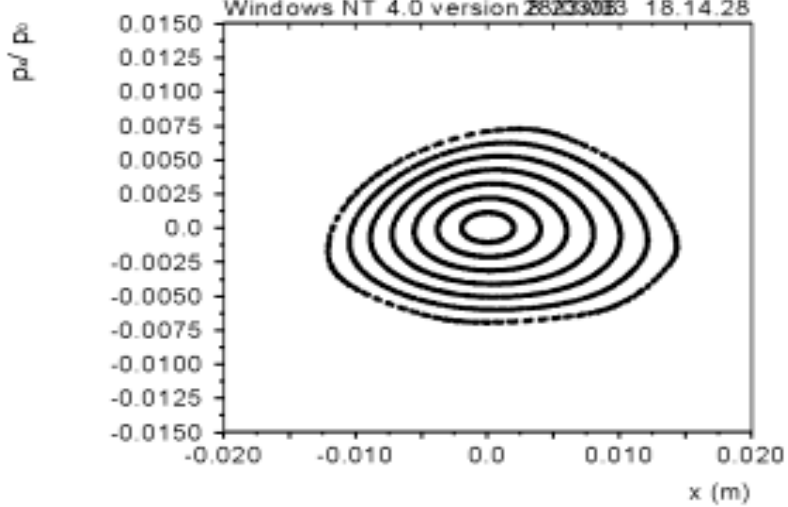


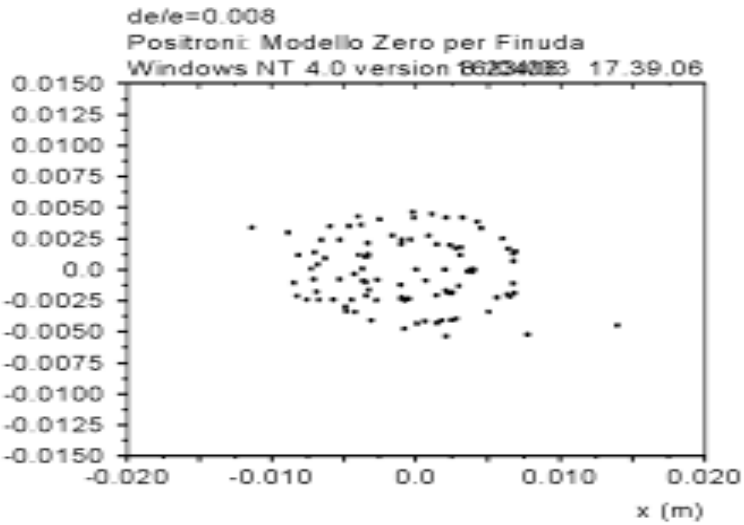




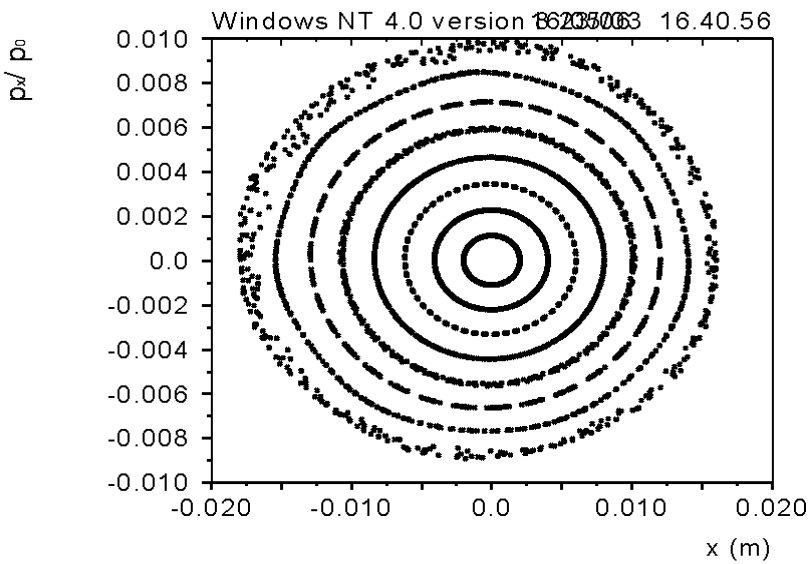
Reduction of the dynamic aperture due to:

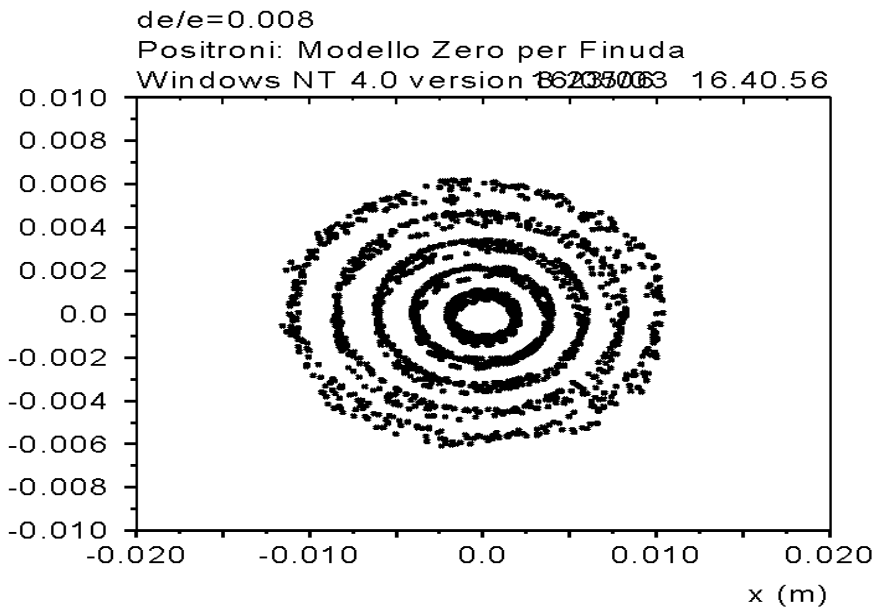
- **Strong sextupole components ($\sim x^2$ like)**
- **Field roll off at large offsets ($\sim x^6$ like)**





Horizontal dynamic aperture with original wigglers for on energy and off energy particles before mods

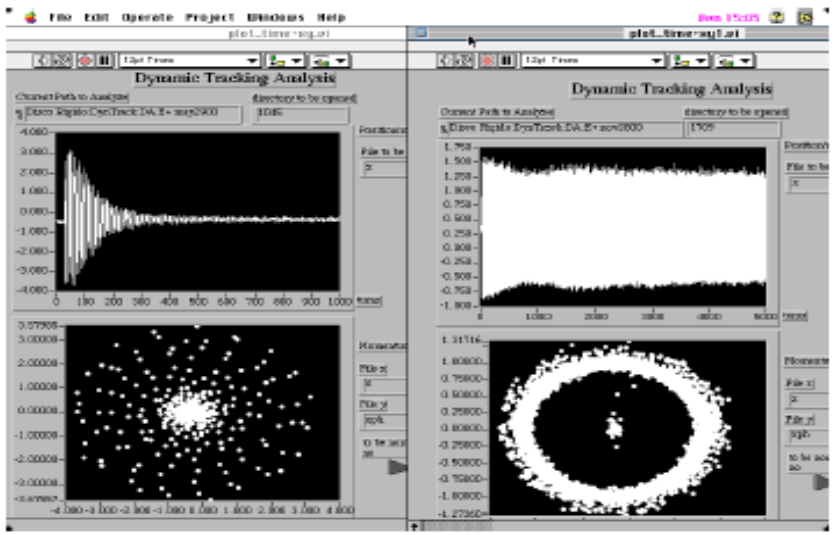




Horizontal dynamic aperture with original wigglers for on energy and off energy particles after mods

Measurements with beam show:

- 3rd order term reduced by more then a factor 3
- a factor 2 in the energy and transverse acceptance

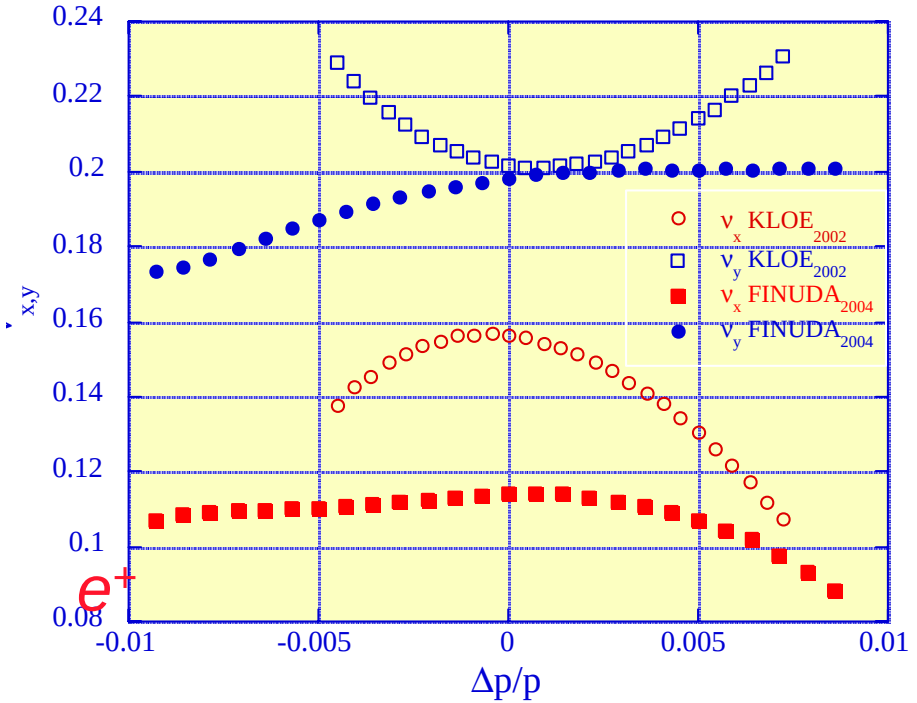


DECOHERENCE BEFORE SHIMMING

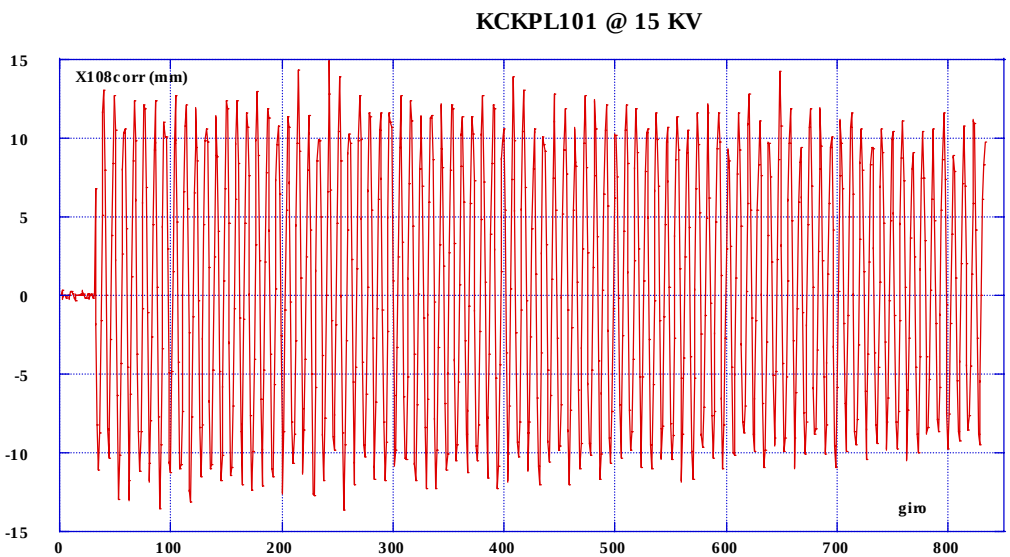
Wigglers ON Wigglers OFF

DECOHERENCE AFTER SHIMMING

Wigglers ON only



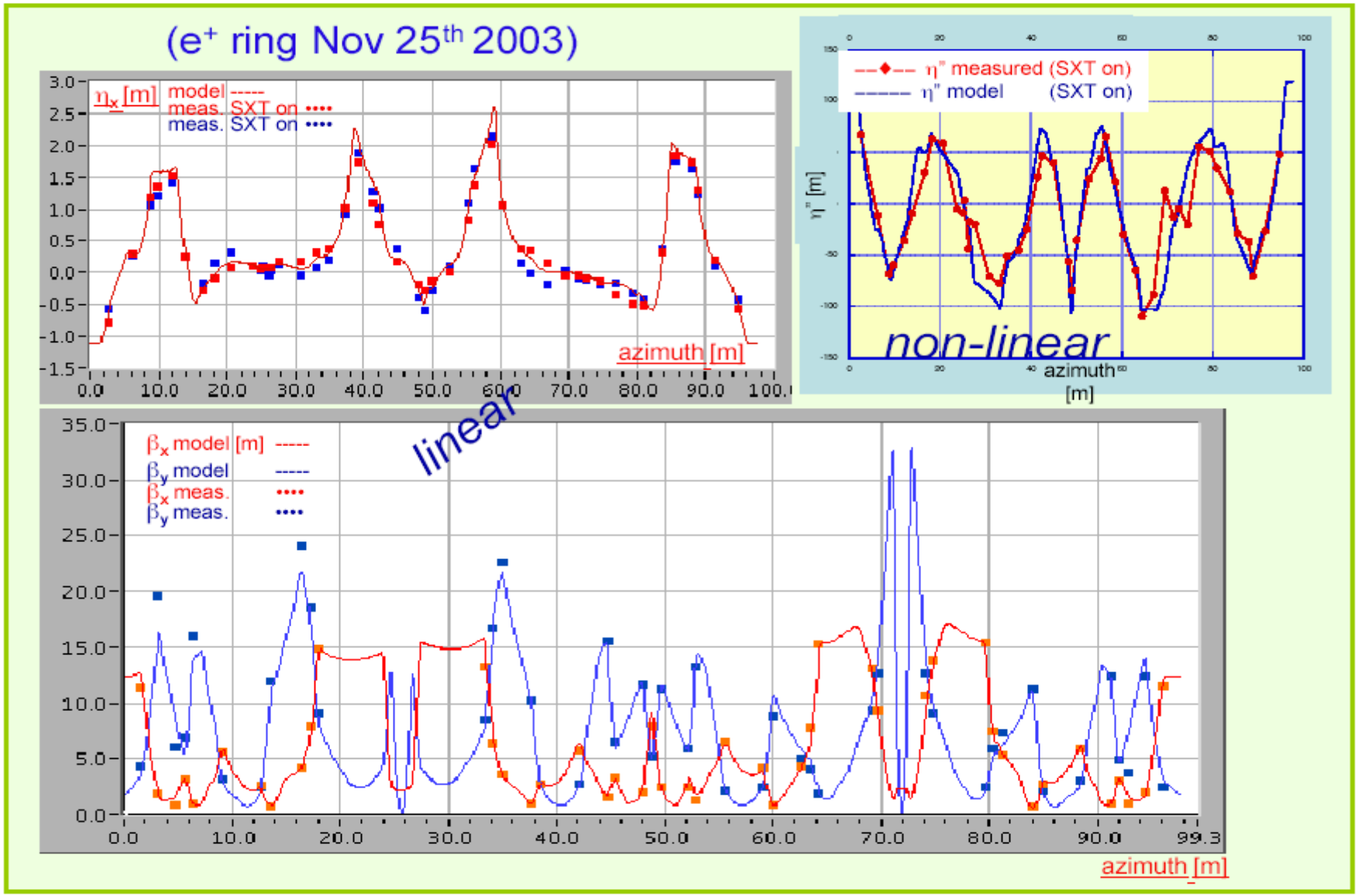
Chromaticity before and after shimming



Status of the present Kloe run

- Commissioning completed in May
- coupling corrected at 0.3%
- measured Σ_y down to 6um!!
- standard check outs ok (β_s η_s etc)
- Physics run started on June
- steadily increased currents while

trying to maintain good quality beams



First and second order model

High current progression

Transverse and longitudinal feedbacks constantly reoptimized at higher and higher current:

- Reduced unwanted noise in all planes

- Increased positron horizontal gain in order to fight the instability

Reduced time-duration of the injection kickers:

-Increased injection efficiency

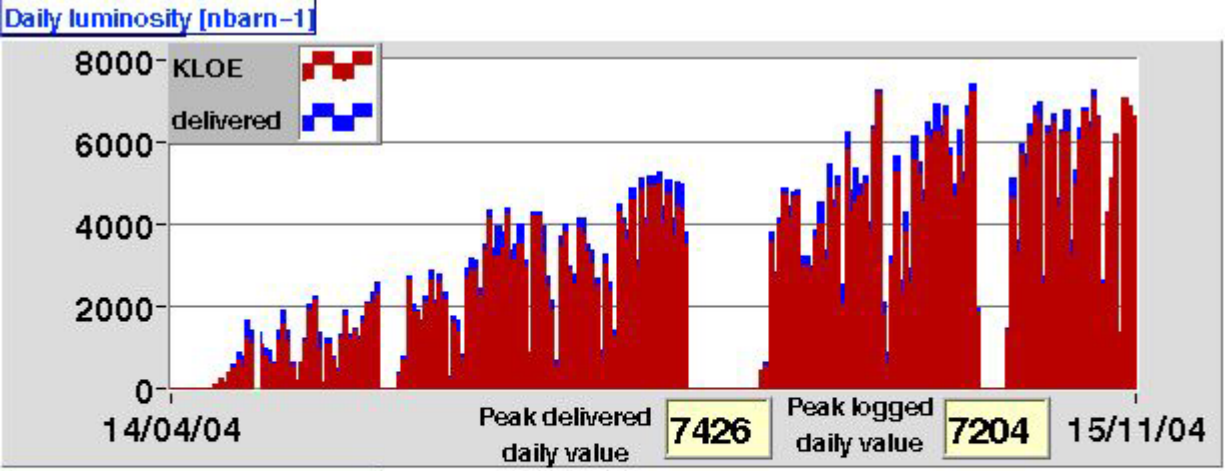
-Reduced the excitation of the horizontal instability during the injection

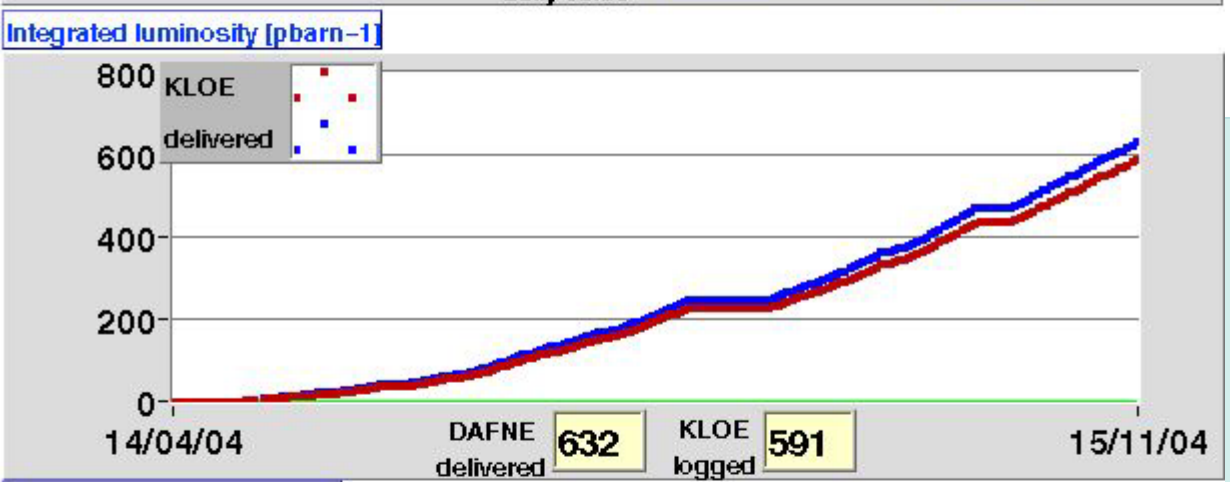
Optimzed sextupoles and octupoles settings:

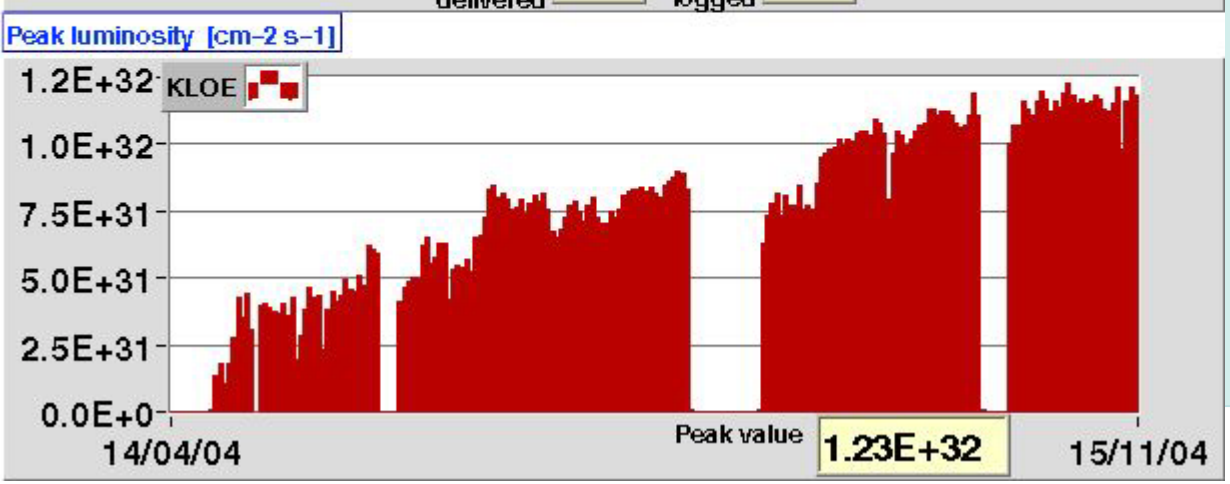
-Increased dynamic aperature and lifetimes:

-Increased injection efficiency

-Reduced lifetime-drop due to beam-beam from parasitic crossing







DAΦNE DELIVERED *L* IN YEAR 2004 for KLOE

105 bunches

I^-_{peak} =1.92 A

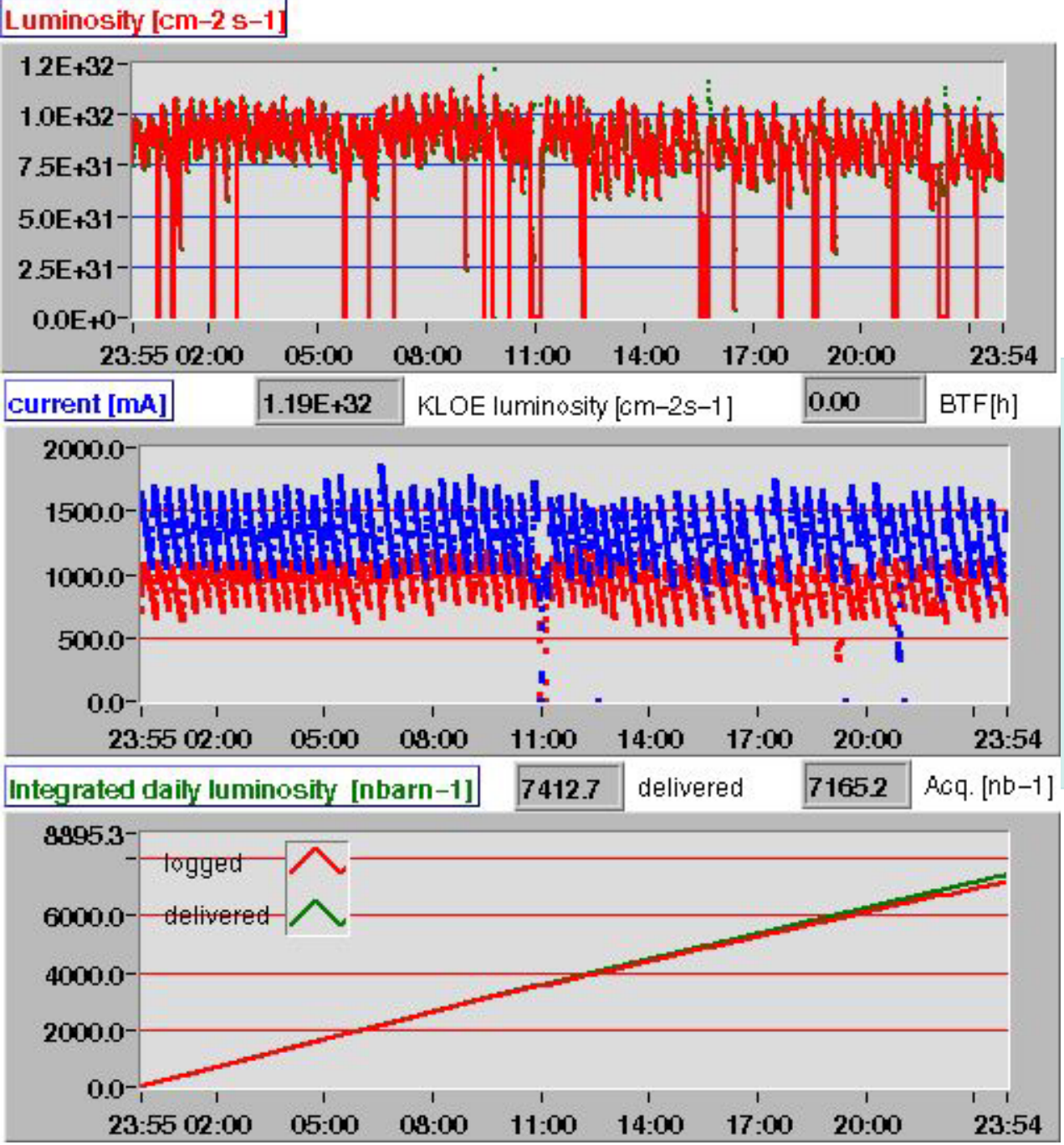
I^+_{peak} = 1.26 A

L_{peak} = 1.23e32 $cm^{-2}s^{-1}$

$L_{day\ peak}$ = 7.42 pb^{-1}

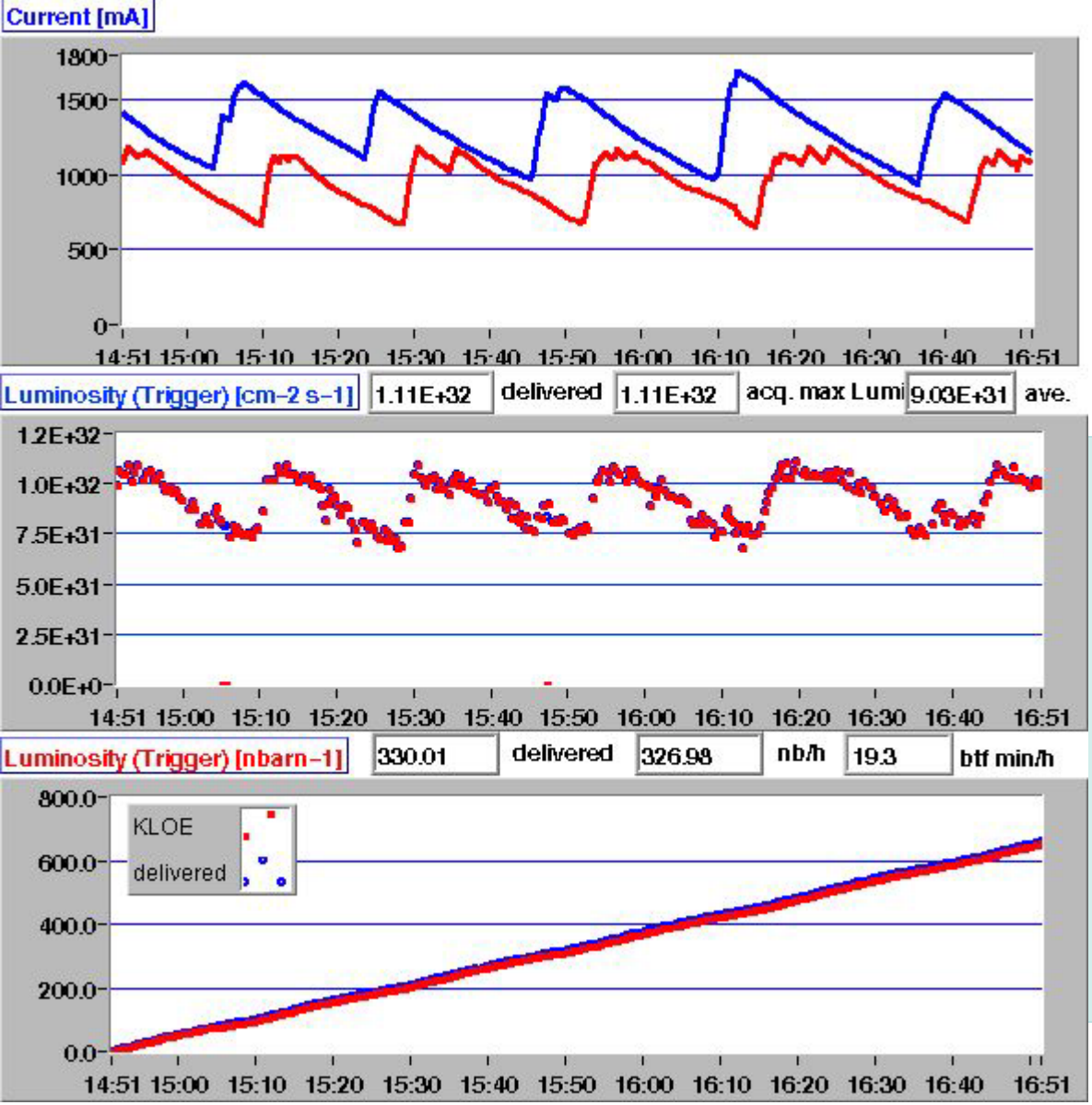
L_{month} > 165 pb^{-1}

L_{2004} > 630 pb^{-1}



DAΦNE best day

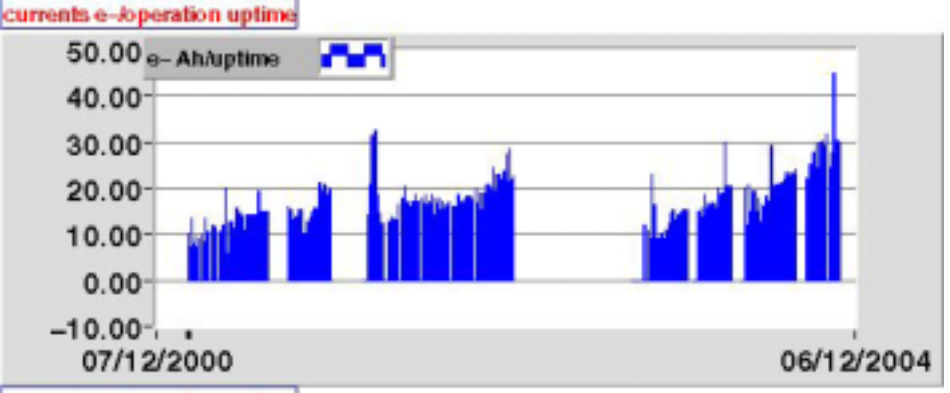
$L_{best\_day} = 7.41 pb^{-1}$

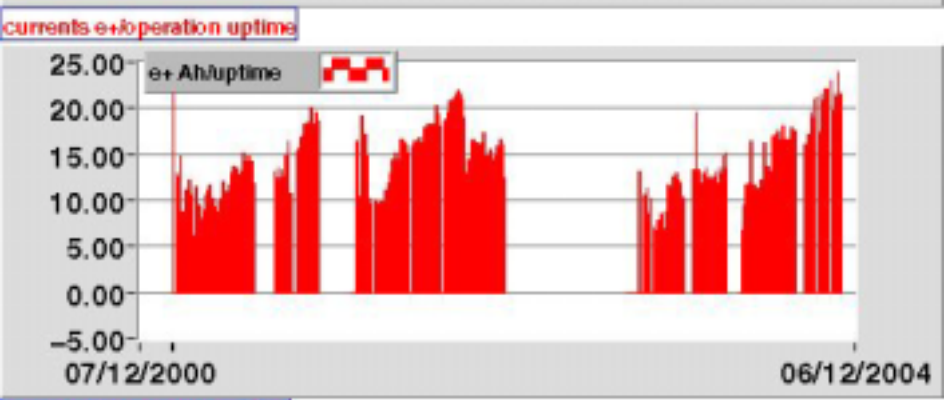


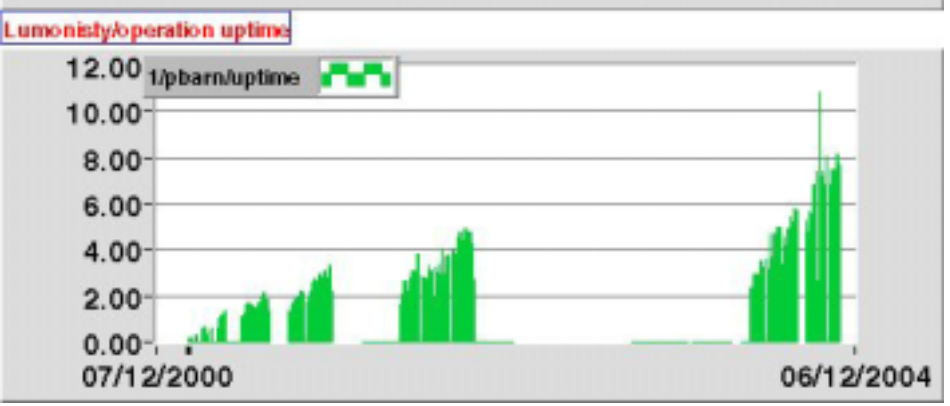
DAΦNE Peak rate on a 2hrs interval

$L_{hour\ peak} = 334 nb^{-1}/hr$

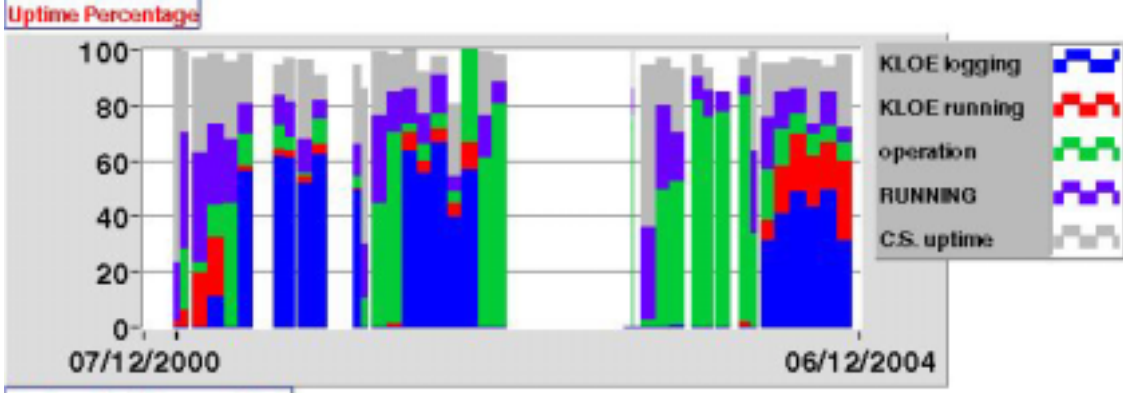
Corresponding to a potential of $8.0 pb^{-1}$ in 24hrs of continuos operations

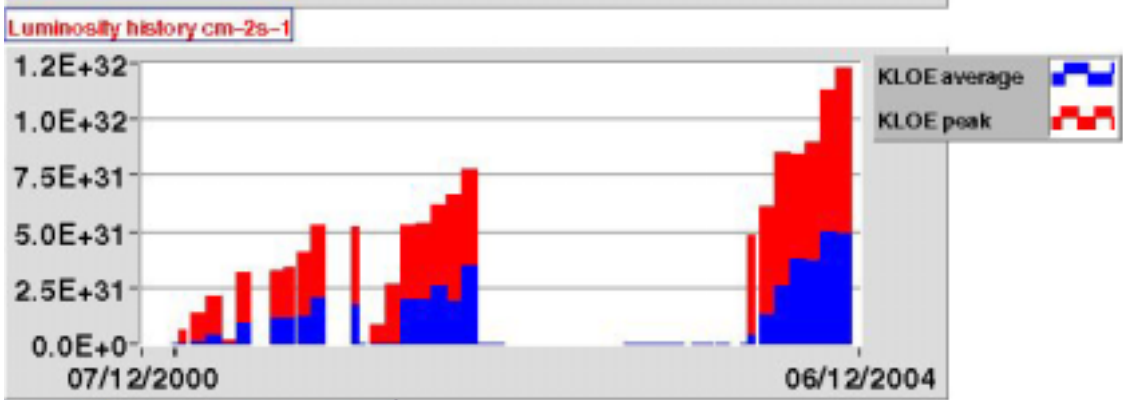


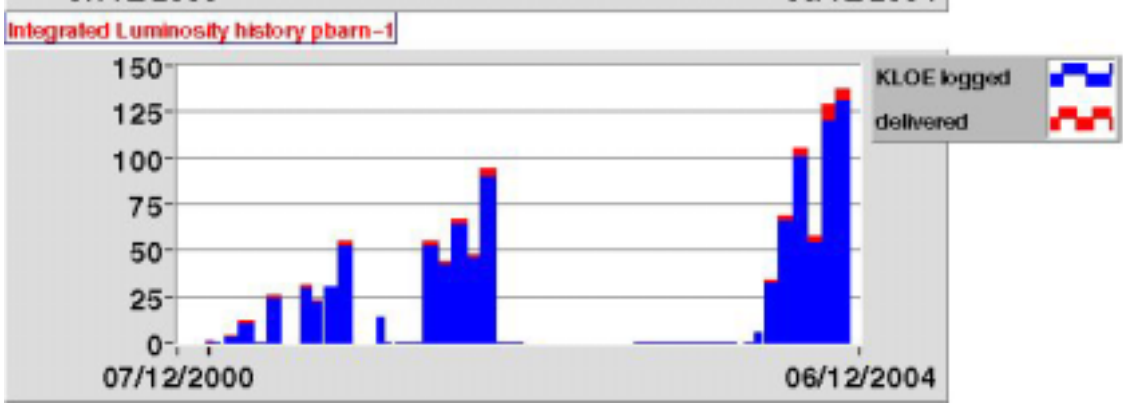




Integrated daily currents and luminosity, normalized with the uptime, from 2001 to 2004







Monthly uptimes and integrated luminosity from 2001 to 2004

Machine set-up: where we stand now

β_X=1.7m very close to the optimal, tried 20% smaller value resulting in 5% loss in luminosity, higher value incompatible with 105 bunches operation

β_Y=18mm very close to the optimal value (σ_z=25mm), max 3% more gain possible from further squeeze, but at the cost of increased chromaticity and instability in the vertical plane

- Tunes very close to the optimal working points near to the integer, around Qx=0.10, Qy=0.17 and seem the best compromise between minimum beam-beam blow-up and several other parameters: life-times, electrons ion trapping, maximum storable positron current, injection efficiency etc.

tested smaller values but not tried yet in collision

Machine set-up: where we stand now

- **Specific luminosity goes down while the currents increase, making the luminosity going up just about linearly with current. This is mainly due to the following well quantified effects:**

  -Bunches become longer, due the the finite ring impedance, causing about a 30% loss due the hour glass effect

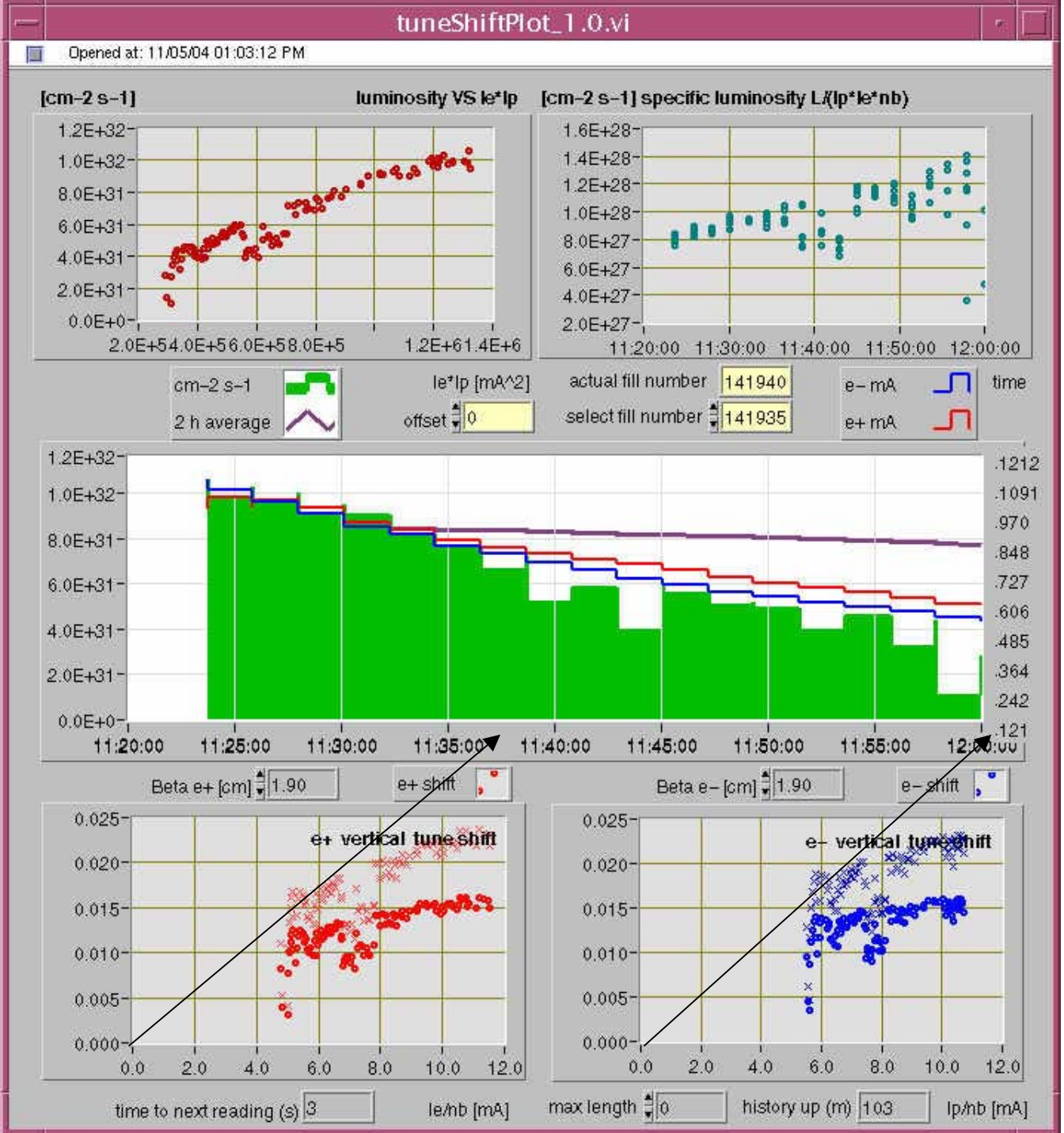
  -An additional indirect loss from longer bunches is in an increased tune-shift (or beam-beam effects) of about 30%

  -Beam-beam interaction enlarges the vertical emittance, thus increasing the vertical sizes by about 20%

  -Ion-trapping and microwave instability increase the electron vertical size by about 30%

  -Noise generated by the vertical feedbacks causes a reduction in luminosity by about 5%, and forces to run with a reduced gain (noise greatly reduced now but some further improvement still possible)

  All these effects are evaluated at about 1.4Amps/beam and scale roughly linearly with current



Tune shift in Oct 2004

Light Xs show the effective tune shift once the correction for the finite bunch lenght is applied

Blow-up from beam-beam and other unwanted high-current effects of the order of 65%

Machine set up: where we are going

We understand very well all the machine parameters

We have reached record small sizes at low current

We have a very clear idea of what are the causes of the specific luminosity drop at higher current.

Reached record currents for both beams: I^- 2A I^+ 1.26A in collision

We do not have a clear idea of why the positrons experience a strong horizontal instability above 600mAmps, not seen for electrons and not seen until 2002,

Electron Cloud instability has been excluded in a large part of the ring. Solenoids installed in almost all the free spaces have proved completely ineffective to ameliorate the instability.

Possible that some hardware bug did pop in during the 2003 shut-down (still looking for…).

Possible that the electron clouds in the wigglers worsened because the shimming

Possible that the instability was already present in 2002 but at higher current.

All the efforts in the next few months will be aimed at:

- reducing the beam degradation at higher currents
- increasing the positron current with any means
- find the source of the positron instability HELP WELCOME!!!!!

Machine set up: where we are going

Maintain nice stable and small beams is very challenging, expecially for the feedbacks system.

Just for comparison with the B-Factories, Dafne stores very similar currents but:

-beams about 10 times less stiff (hence more unstable) because the lower energy

-perturbations last longer because much longer damping time (100000 turns)

-much harder to control the individual bunches in the 110-bunches mode because the reduced bunch spacing (2.8ns)

Shopping list for Luminosity Improvements in the next few months

- 5% increasing the bunches up to 110 as the vacuum still improves (asintotic limit) in the next 2-3 months
- 5% from the reduction of the vertical electron size from better vacuum as well (less ion trapping)
- 5% from the reduction of the vertical size with vertical feedback upgrade (reducing the noise induced on the beam by the amplifiers) in the next 3-4 months
- 10% from positron current increase with the horizontal (doubling the power) feedback upgrade
- 10% from positron current increase by optimizing the current set-up and parameters
- 5-10% from adiabatic tuning of the present set-up and small changes of the "standard machine parameters", already very close to the optimal, in the next 3-6 months
- Present performances expect to improve between 10-20% by the end of the year and up to 30% by the end of the run,

L=1.5e32 is the asintotic limit of the present machine

Negative α_c to go further up in luminosity

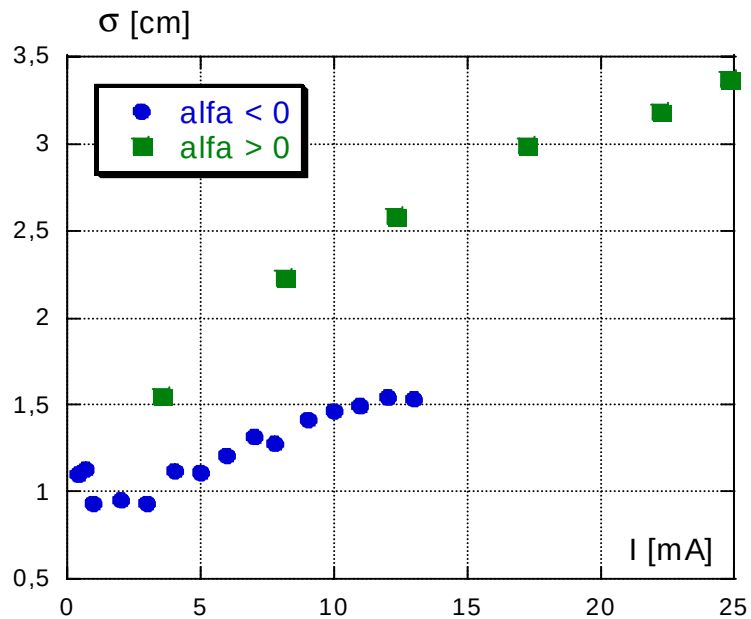
A possible gain of about 60% in luminosity can be attained by shortening the bunch length by changing sign to the ring momentum compactionì

Successful tests have been already made in 2 dedicated shifts:

- **bunch shortened according theory**
- **beam emittances ok**
- **life times ok**
- **stored more then 300mAmps both beam**

One week of MD will be dedicated in February to fully evaluate the feasibility of providing reasonable luminosity to KLOE

Bunch Length Comparison for
e- DAFNE Ring,
measured on 15/6/2004



Prospects for the Kloe RUN

- No standing and no foreseen problems that can seriously limit the desired goals for the run:

  L_{peak} > 1.3e32 up to 1.5e32

  L_{day} > 8pb^{-1} up to 10pb^{-1}

  L_{month} > 170pb^{-1} up to 200pb^{-1}

- Planned goal of 3fb-1 by the end of the run in 2005 already achievable with the present rates and our “standard” 20% down-time due to hardware failures

DAFNE UPGRADE

In Sept-2003 held a joint workshop (in Alghero, Sardinia) between Particles and Accelerators Phisicists in order to assest the case for an energy and/or luminosity upgrade of DAFNE

Conclusions from Accelerator side:

- Solution to increase the energy to 2.4 GeV possible with minor mods
- Solution to increase the luminosity to 1.0e33 possible with medium mods
- Solution to increase the luminosity to 1.0e34 possible with major mods
- No solution found for 1.0e35 luminosity

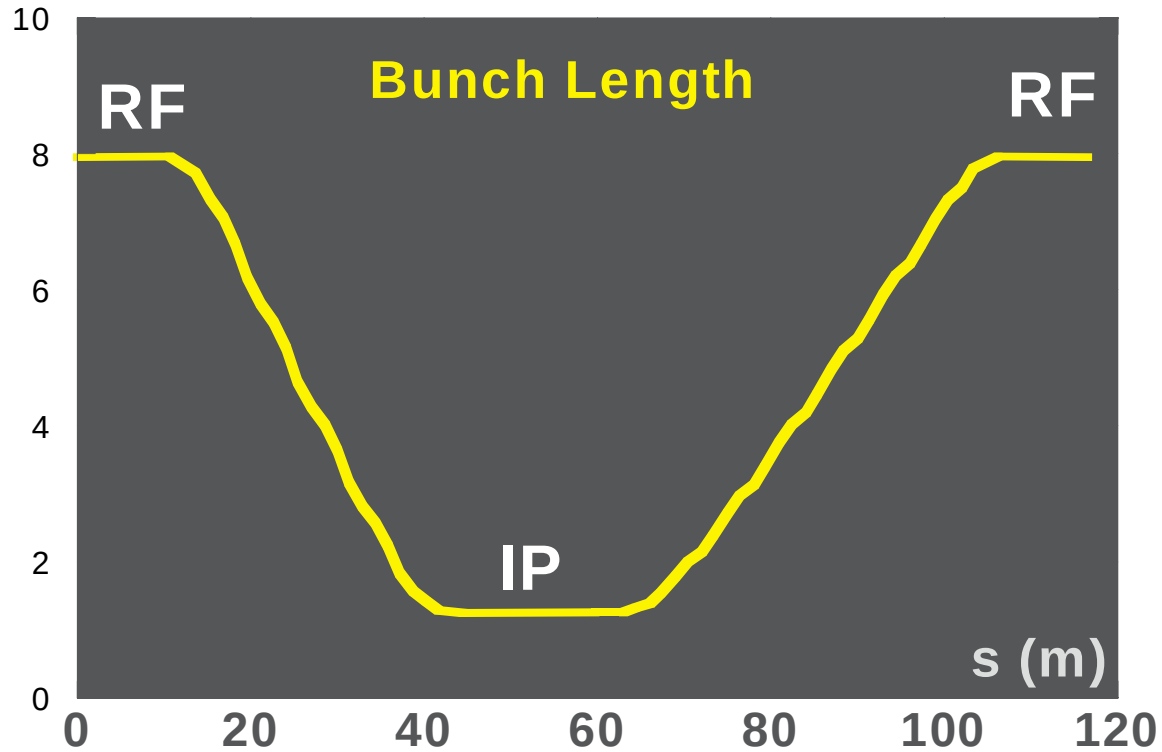
Conclusion from Particle Physicists side:

- minor physics and general consensus/interest on energy upgrade
- some physics and interest on 1.0e33
- above 1.0e33 new interesting physics starts at 1.0e35

- Unanimous consensus on Energy above 1TeV and Luminosity above 1.0e36

DAFNE[34]

Short bunches at low energy



σ_{RF}

σ_{IP}

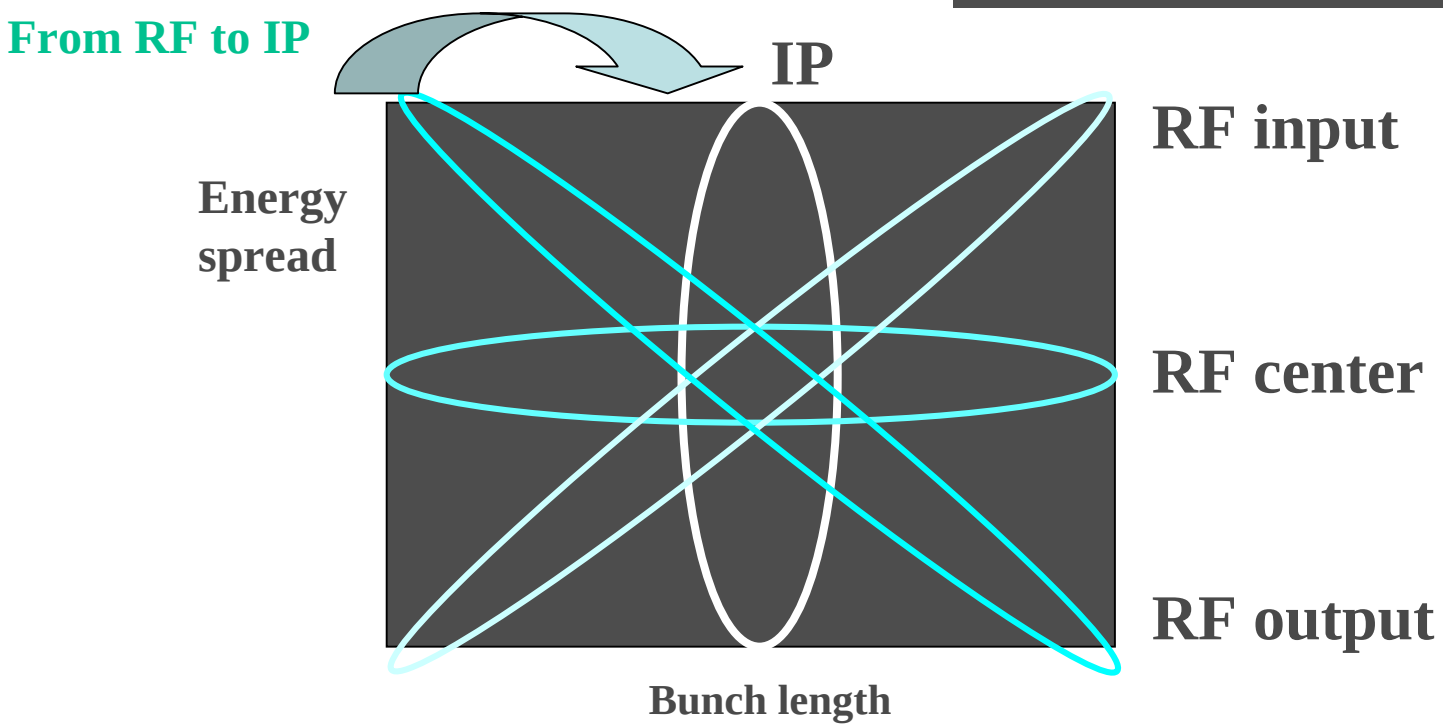
Strong RF Focusing (SRFF)

Modulation of bunch length along the ring with a minimum at the IP

Allows very small vertical β* (few mm)

High RF voltage + **Magnetic lattice which correlates longitudinal position with energy deviation (high α_c)**

Longitudinal phase space



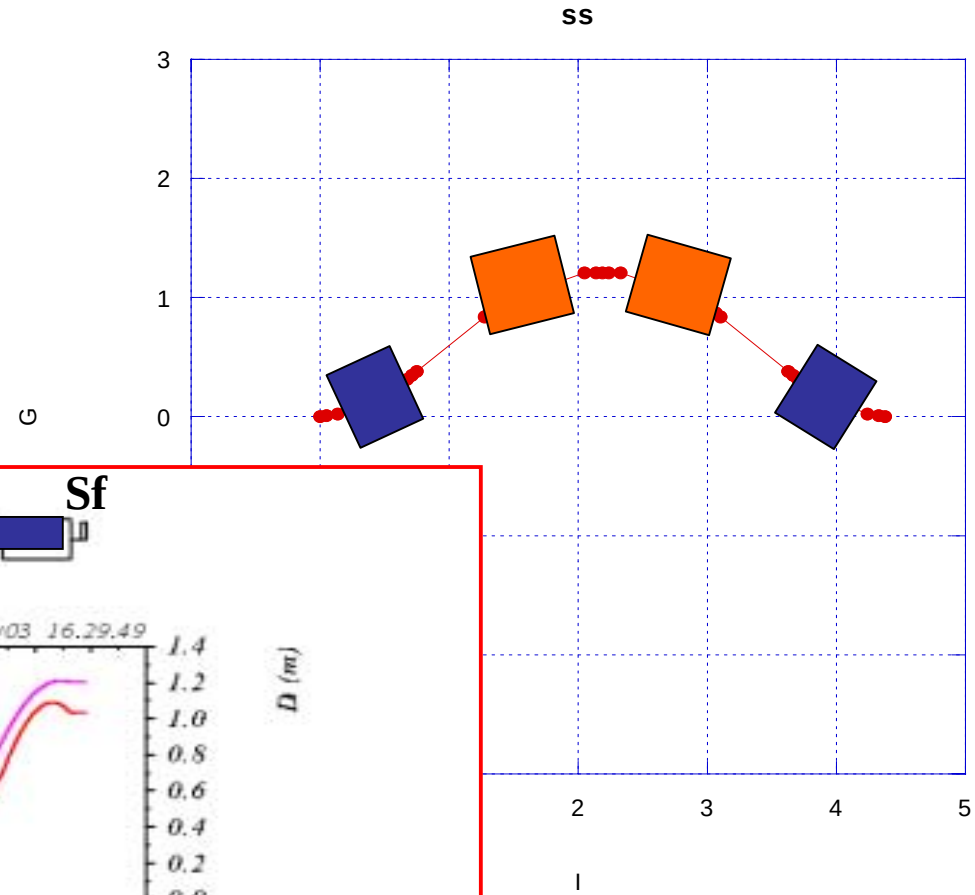
$$\frac{\sigma_{z_{\min}}}{\sigma_{z_{\max}}} = \sqrt{\frac{1+\cos\mu}{2}} \qquad \cos\mu = 1 - \pi \frac{\alpha_c L}{\lambda_{rf}} \frac{V_{rf}}{E/e}$$

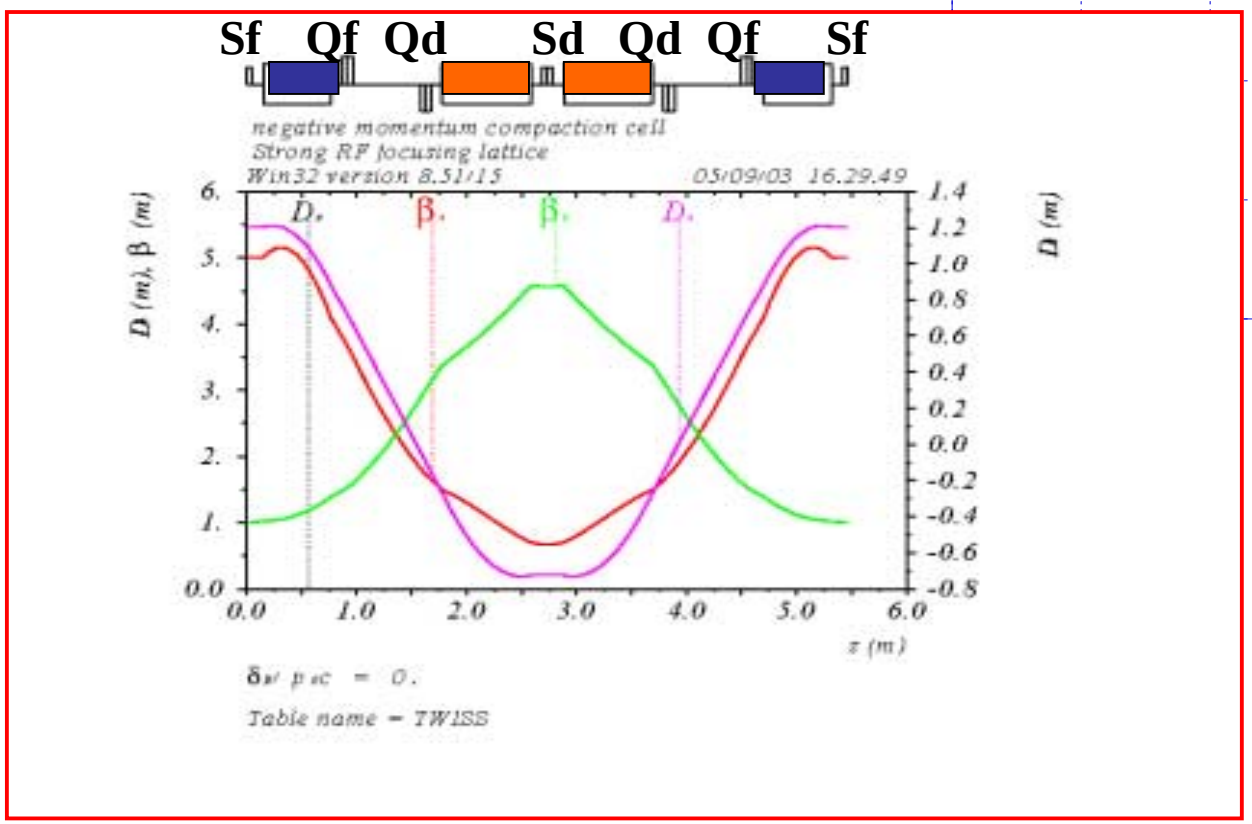
μ = one-turn longitudinal phase advance

DAFNE[34] LATTICE:

HIGH and NEGATIVE MOMENTUM COMPACTION

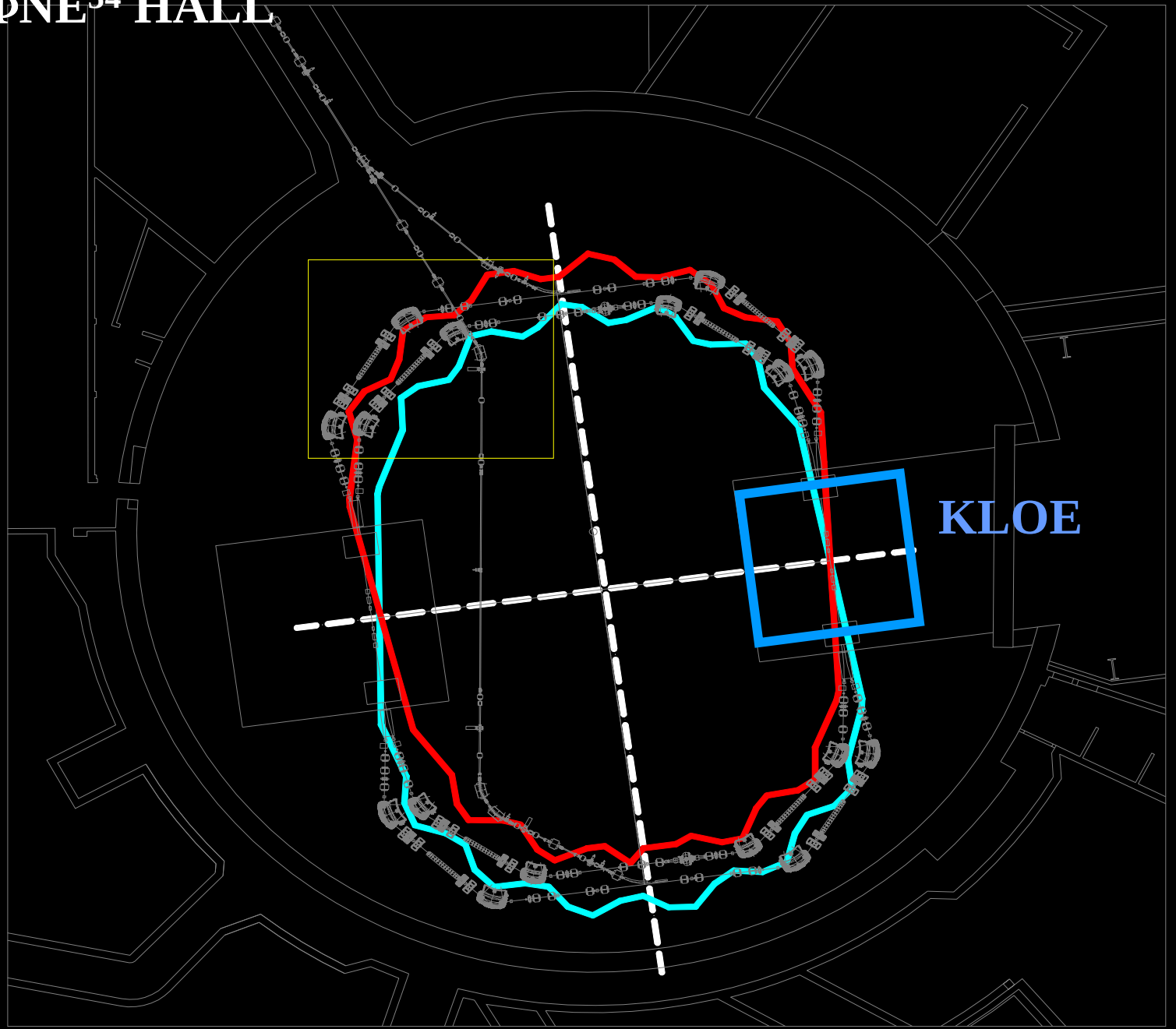
strong RADIATION emission





Alternating positive and negative bending dipoles

DAΦNE[34] HALL



F. Sgamma

Strategy and Logistic for DAFNE^{33}

Minimize the down time after the end of the scheduled physics runs and the restart of the operations

Minimize the recommissioning time

Minimize the risks of failure

Minimize the cost

Optimize just ONE-IR-AND-ONE-ENERGY solution.

DAFNE^{33} Upgrades plan

The luminosity projections are based on the estrapolation of the estimated peak DAFNE performances:

$2*10^{32}$ at 2Amps against 2Amps.

(now about $1.25*10^{32}$ at 1.7Amps against 1.2Amps)

The upgrades are targeted at a factor 5 luminosity increase at <u>any given current</u>, this means that with the present running conditions DAFNE^{33} will deliver a luminosity of about $0.6*10^{33}$

Basic concepts for the Upgrade

In a tune-shift limited regime the luminosity goes with $1/(\text{damping\_time}^{\alpha} * \text{bunch\_lenght}^{\beta})$

α in the range between 1/3-1 in Dafne

$\beta > 1$ in Dafne

The specific luminosity will be increased by a factor five by:

1) reducing the the damping time by a factor > 2

2) reducing the bunch lenght by a factor > 2.5

At the same time β_y at the IP will be reduced by a factor 2.5 and there will be headroom to decrease β_x as well.

3) ancillary mods to gain few more percents and safety margins

Upgrades plan

Damping time can be reduced by a factor>2:

- decreasing the gap of the DAFNE wigglers (from 41mm to <20mm), thus increasing the gap field from 1.7T up to 2.3-2.4 T.

- adding wigglers (2 pairs, two meters each) in the second IR region (a superconduting solution could be explored as well)

Upgrades plan

Bunch length can be reduced by a factor>2.5 replacing:

- all the vacuum chambers (also necessary to decrease the wigglers-gap),
- the tapers (now 25% of the total ring impedance)
- all the Ion Clearing Electrodes (now responsible for about a 40% bunch lenghtening for e-)
- all the bellows (10% of the ring impedance)
- the injection and feedback kickers (now 30% of the ring impedance)
- the scrapers (10% of the ring impedance)
- the feedbacks cavities (15% of the ring impedance)

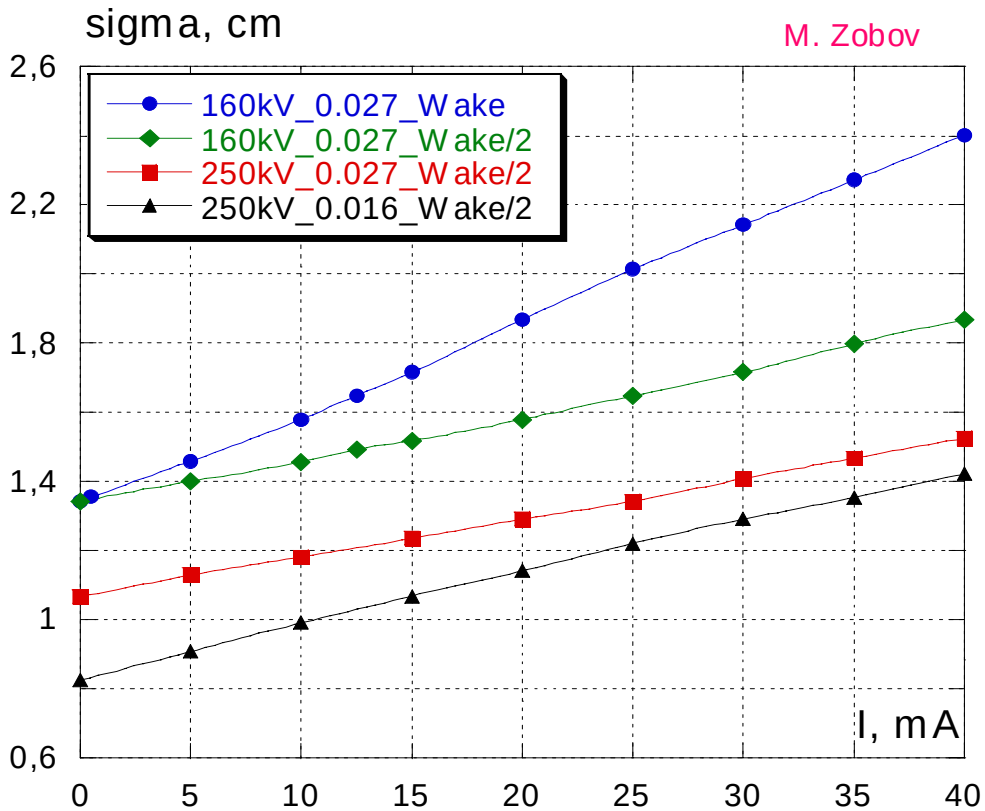
The new elements will be redisegned to be “very-low-impedance”, the target impedance should be between 2 and 3 times smaller than the present one.

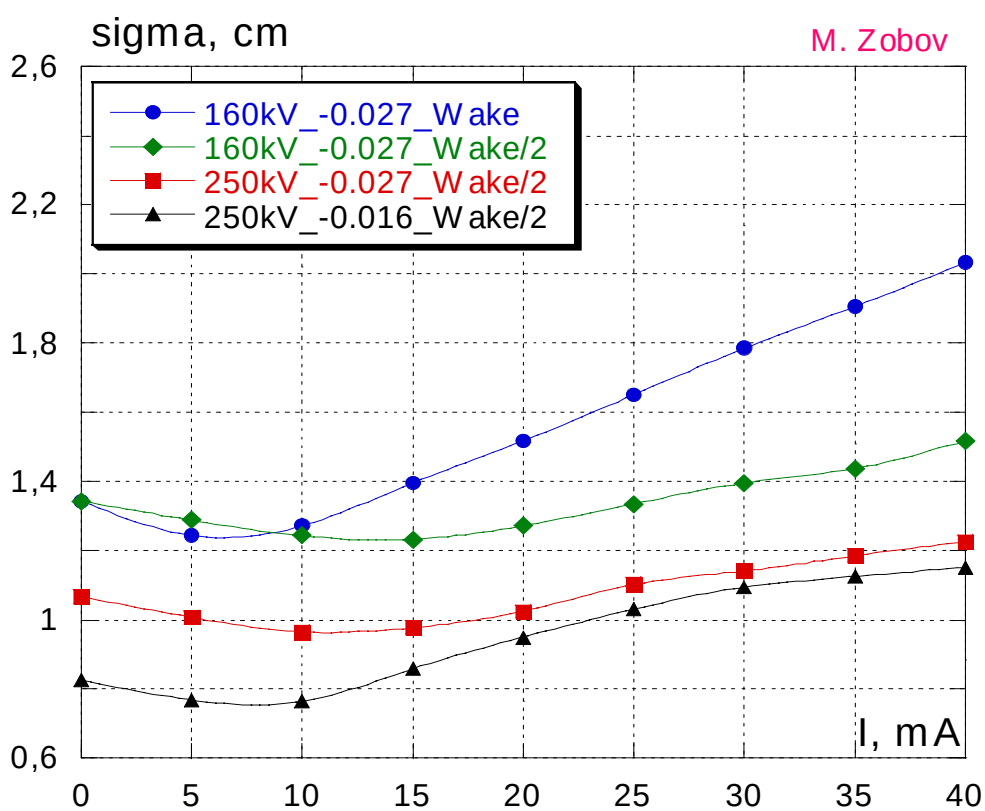
The positron chamber will also have an antichamber to minimize the Electron Cloud that seems a good candidate to explain the present strong horizontal instability and peak current limit for positrons.

All the vacuum chamber modifications relay on standard acquired technology (here or in other labs, e.g. KEK).

Bunch Lengthening in DAΦNE

(only for scaling purposes)





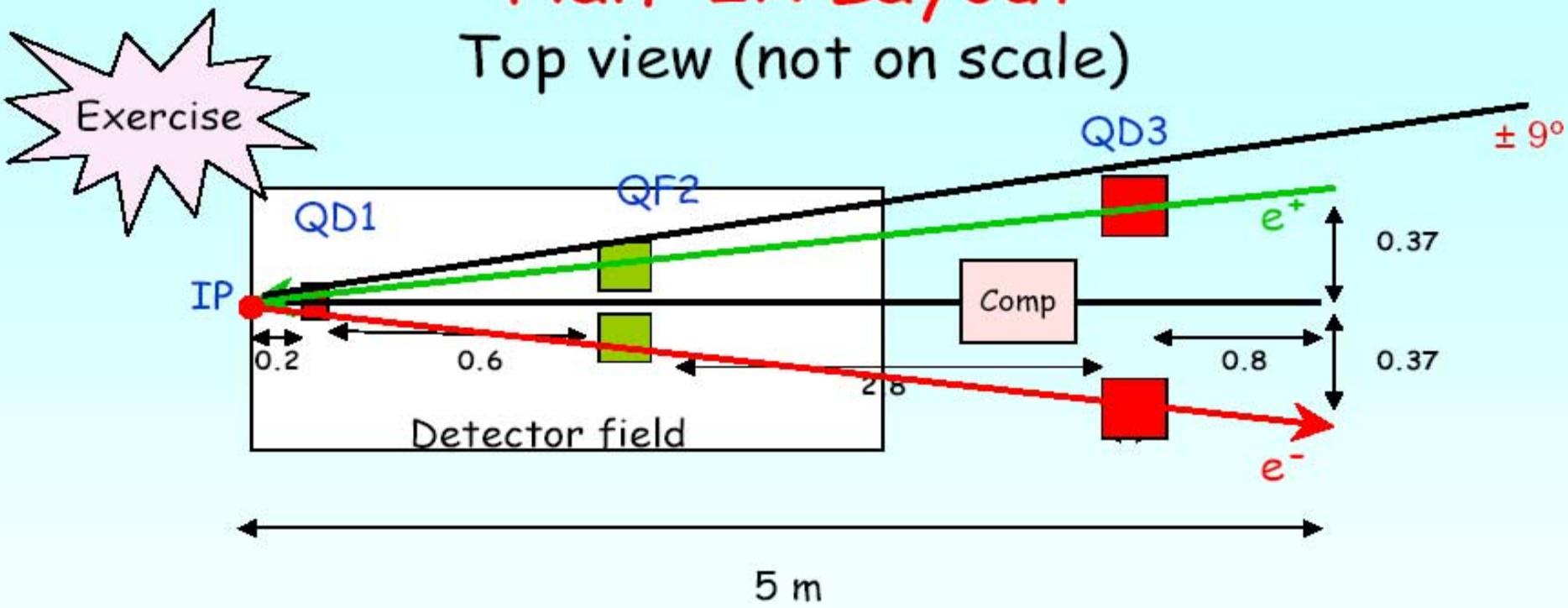
Upgrades plan

The IR optics, aimed at smaller β_y will be rebuild with:

- smaller L*
- stronger quadrupoles (PM quads should suffice, although we could explore a SC solution as well)
- optimized geometry to increase the beam separation
- optimized mechanics for the rotation needed for the coupling compensation

Half-IR Layout

Top view (not on scale)



With ± 10σ_x clearance, ± 9° cone, ±30 mrad angle:

small

QD1: L= 20 cm, pole radius = 1.5 cm, R_{ext} = 3 cm, pm thickness= 1.5 cm

QF2: L= 20 cm, pole radius = 11 cm, R_{ext} = 16 cm, pm thickness= 1.5 cm, 4 cm space between 2 quads

QD3: L= 20 cm, pole radius = 15 cm , R_{ext} = 63 cm, 25 cm space between 2 quads

Upgrades plan

Lower impedance will also benefit the beam stability in general.

More “smaller” upgrades to increase our safety margin will also be made, for example:

- feedbacks (more power, faster responces, optimized positions etc.)

A Crab Cavity will be installed (KEK tests very helpful) in order to minimize beam-beam effects and geometric luminosity reduction due to the crossing-angle.

The machine will support also the “negative momentum compaction” optic that provides an additional 30% reduction in the bunch-length

More will be added

...

Time and budget

The bulk part of the optics, hence all the magnets (bends, quadrupoles, sextupoles, correctors etc) and power supply will stay and will be reutilized, small changes (mostly little reshuffling of the elements) will be done, in order to improve the rings dynamic aperture and flexibility of the optic.

The basic idea is to split open the magnets, replace the chamber and reassemble the rings.

This will simultaneusly minimize:

-cost (<20ME)

-reinstallation time (about one year), providing that all the new harware will be present at the beginning of the shut-down

-recommissioning time (three months including vacuum conditioning).

Decision should be taken and the project founded at most by mid-2005, in order to have about 12 months for the design and 12 months for the acquisition of the new hardware. Construction should begin by mid-2007

Conclusions

- **Dafne is successfully delivering the targeted integrated luminosity with more than acceptable background conditions to all the different experiments since 2002**
- **Peak luminosity still improving (scored 4th worldwide), but will never reach the DAFNE design: 5e32**
- **Integrated daily luminosity very close now to the DAFNE design: 10pb^{-1}/day**
- **Several solution to extend the life and the physics reach of DAFNE and have "home-made physics" are possible, DAFNE33 best candidate at the moment:**
  - **The acquired know-how and almost all the hardware will be reutilized**
  - **The time frame and the effort might fit with the LNF and Accelerator Division programs and resources**
  - **Physics reach of Dafne might extend until 2015**
  - **Synchrotron light will benefit from the upgrade as well**