DAΦNE: STATUS REPORT

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(on behalf of the DAΦNE team)

LNF SCIENTIFIC COMMITTEE
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OUTLINE

- *Short summary about the many technical faults which affected DAΦNE operations:*
  - *Injection septum of the positron ring*
  - *Injection system: Linac gun cathode and D modulator*
  - *Cooling system of the KLOE magnet power supply*
  - Vertical orbit oscillation

- *Some details from DAΦNE commissioning:*
  - *Ring optics*
  - *Closed orbit correction*
  - *Betatron coupling optimization*
  - *Magnetic layout adjustments*
  - *Collision tuning*

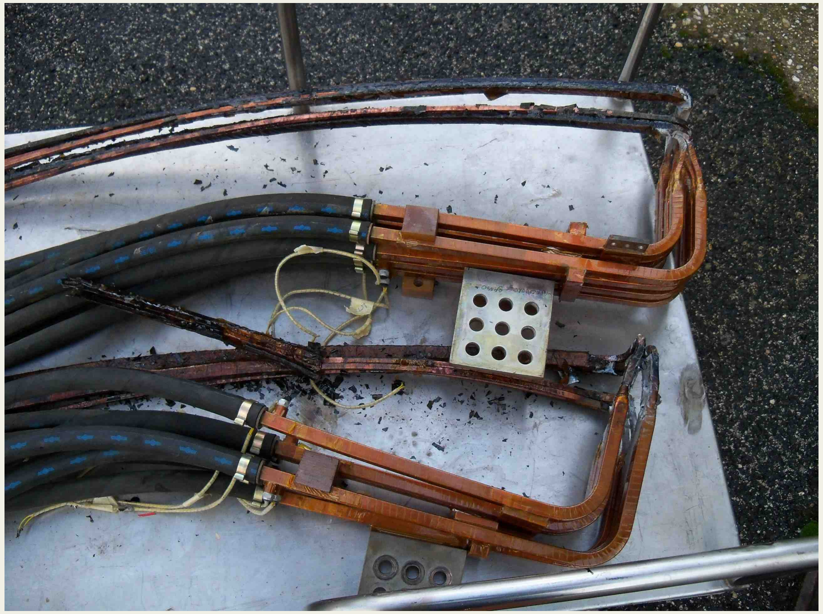
- *Preliminary Luminosity results*

- *Conclusions and few considerations about the future ….*

Fault in the injection septum of the e^+ ring

- The four 34^0 injection septa installed on the DAFNE Main Rings and on the accumulator require quite strong water cooling
- The coils have to cope with a very high current flux $F_i = 90A/mm^2$
- In fifteen years of operation they all required several repairs and maintenances

On January 2011 the e^+ injection septum got seriously damaged due a flow-meter fault
No spare coil was available although a procedure to get new coils had started on November 2010



January 3rd ÷ March 30th positron beam could not be injected in the Main Ring!

Septum coil replacement

- A copper conductor with acceptable geometric dimension has been found at CERN (rectangular section 6.2 mm x 7.0 mm with 3.6 mm diameter inner hole)

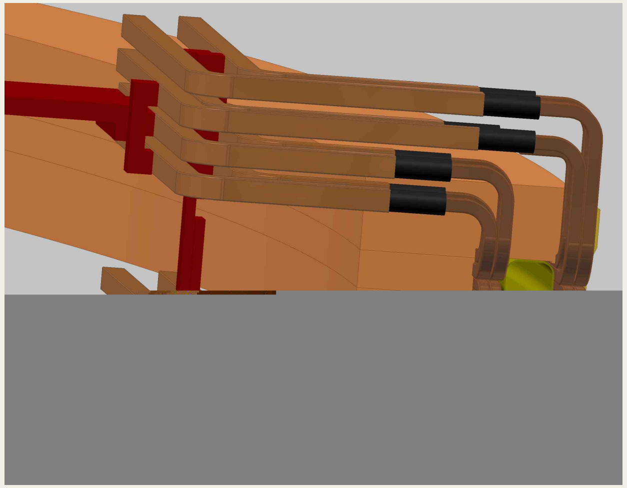
- A new coil has been built and thanks to a small difference in the conductor section with respect to the original one (6.0 mm x 6.0 mm) it was able to reduce by ~ 1/3 the power needed for operation

Future developments

- The four 34^0 injection septa will be all replaced adopting the new coil design and reducing the gap (26 mm -> 22 mm) in order to get further wall plug power reduction (~ 50% with respect to the original devices)

- Two spare coils have been also committed

- The first new coil is already in the Lab and is going to be installed on the electron Main Ring

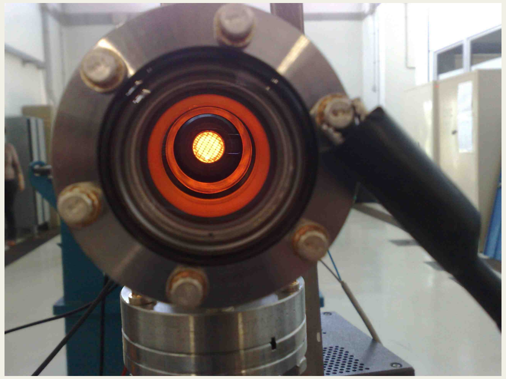


Linac GUN faults

- On February 2010 the original cathode of the Linac gun, definitely exhausted after 15 years operation, was replaced with one of the two available spares of the same age.
- In about one year operation (mainly devoted to the BTF operation) it degraded significantly its performance
- On December 2010 the last spare was installed, it lasted 1 week

- A less performing cathode (1/3 smaller surface) but with the same mechanical parameters was received from SLAC and installed on the Linac gun. It worked in a very discontinuous way till May 25th

- On April 2011 five new cathodes have been ordered, they will be available in 20 weeks (beginning September)



DAFNE operations have been stopped due to the impossibility to run the injection system

D modulator fault

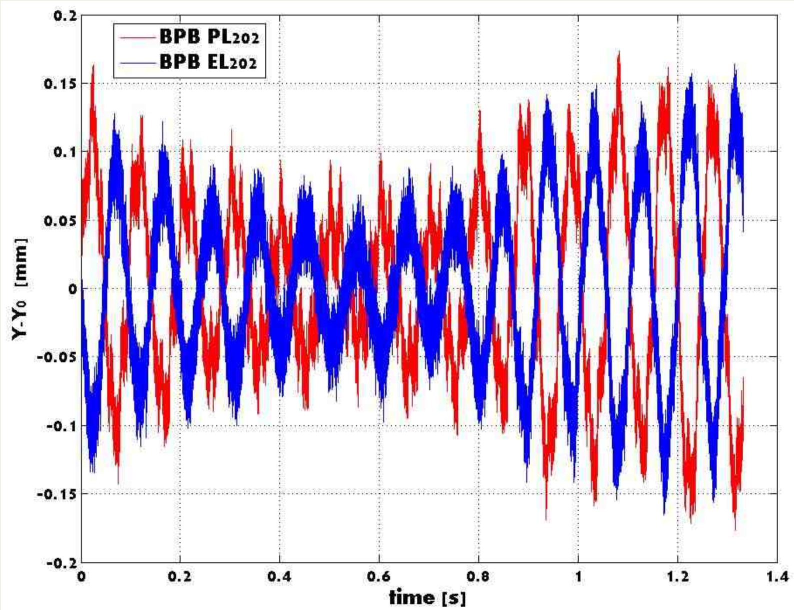
- The ceramic window between the klystron of the D modulator, essential for the positron production, and the SLED has been replaced due to discharges related to vacuum leakage

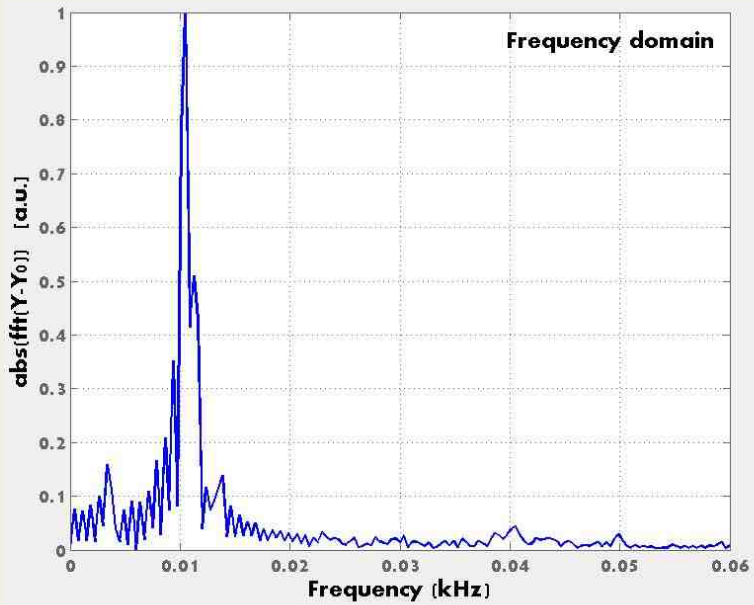
KLOE magnet power supply fault

- On January ÷ February 2011 several power faults affected the power supply of the KLOE magnet
- The problem has been fixed by cleaning the water cooling system and modifying the hydraulic circuit in order to improve the thermal exchange efficiency

VERTICAL ORBIT OSCILLATION

- A random amplitude 10 Hz vibration has been observed on both beams which is compatible with a vibration in the defocusing low-beta quadrupoles. In fact when comparing the orbit variation for the two beams:
  - ✓ it has the same amplitude
  - ✓ The beam oscillations (red e+ blue e-) recorded in symmetric locations wrt the IP are opposite in phase indicating that the vibration source is $\pi/2$ in phase advance from the IP





- The vibration induces a vertical orbit displacement of the order of $1\sigma_y$

- Fortunately the vibration has the same phase for the two beams and does not affect the luminosity, but it is harmful to the synchrotron beam lines users

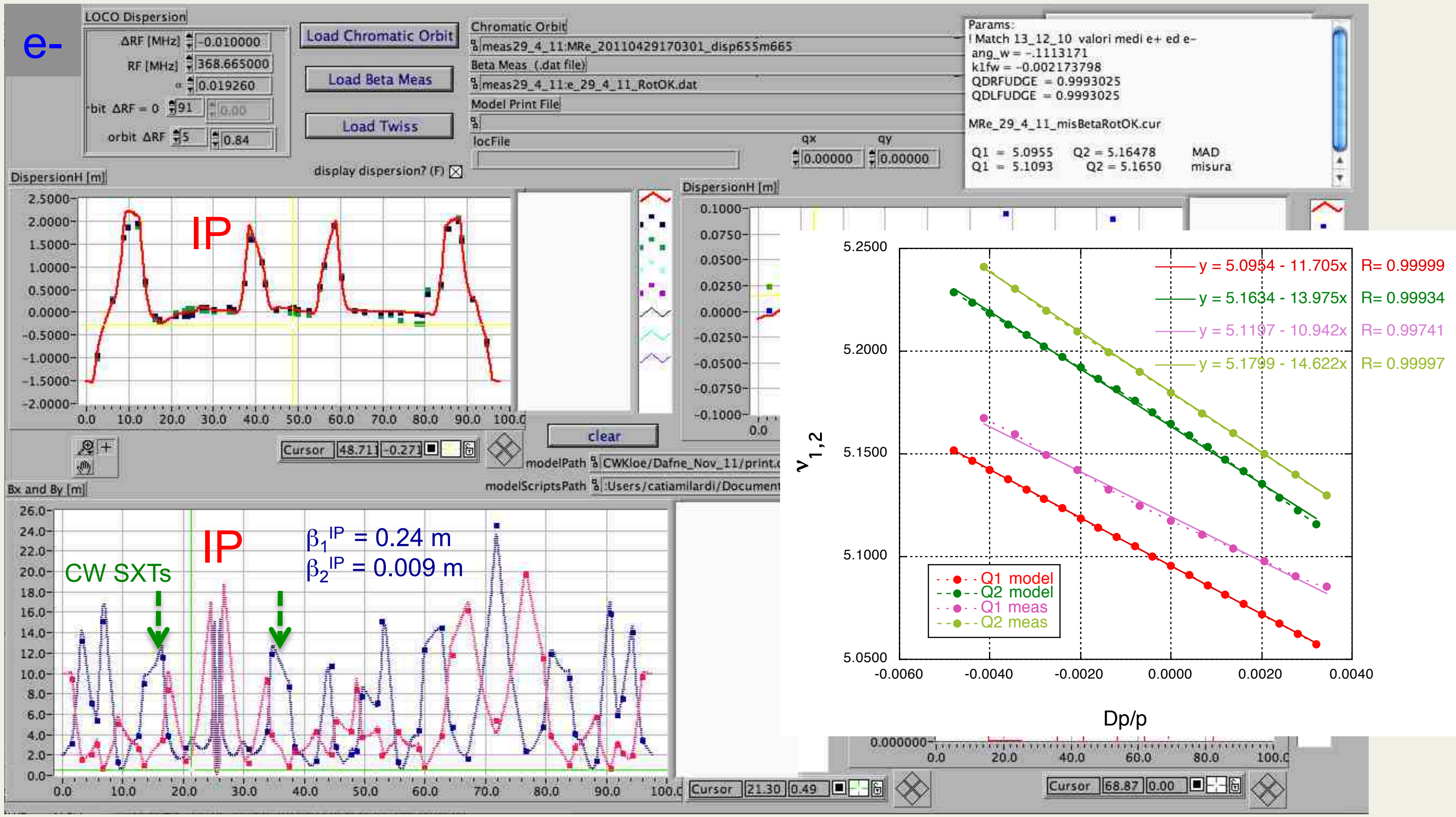
Beam Measurements

Main ring optics

Linear optics measurements (β_1, β_2, ν_1, ν_2, $\eta_{x,}$ $\eta_{x,}$ $\xi_{x,}$ ξ_y) have been used for

- model optimization
- optics matching

The optics is the one suitable for the *Crab-Waist* collision scheme

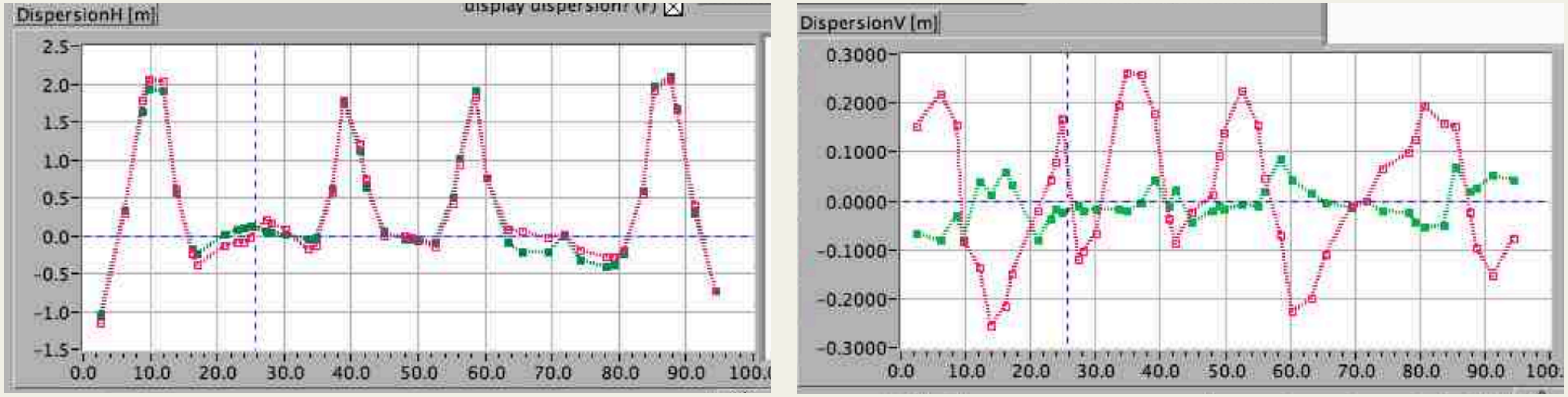


Main rings tuning

Closed Orbit Correction and steering magnet strength minimization to:

- Point out errors in the magnetic layout
- Reduce non-linear contributions to the beam optics
- Optimize beam dispersion
- Minimize transverse coupling
- Reduce background hitting the experimental detector and ameliorate scrapers efficiency

Sextupoles alignment to avoid contribution to linear optics



Dispersion evolution before (red MRp_29_11_2010) and after (green MRp_23_5_2011) closed orbit optimization and sextupole alignment

Relying on closed orbit studies

Several problems have been fixed:

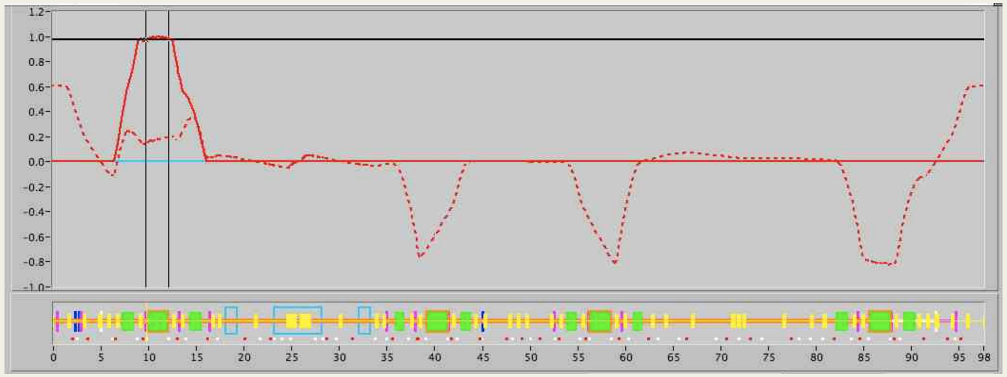
C correctors installed in the IR have been rotated to reduce their impact on the betatron coupling. These correctors are extensively used to optimize the beam overlap at the IP

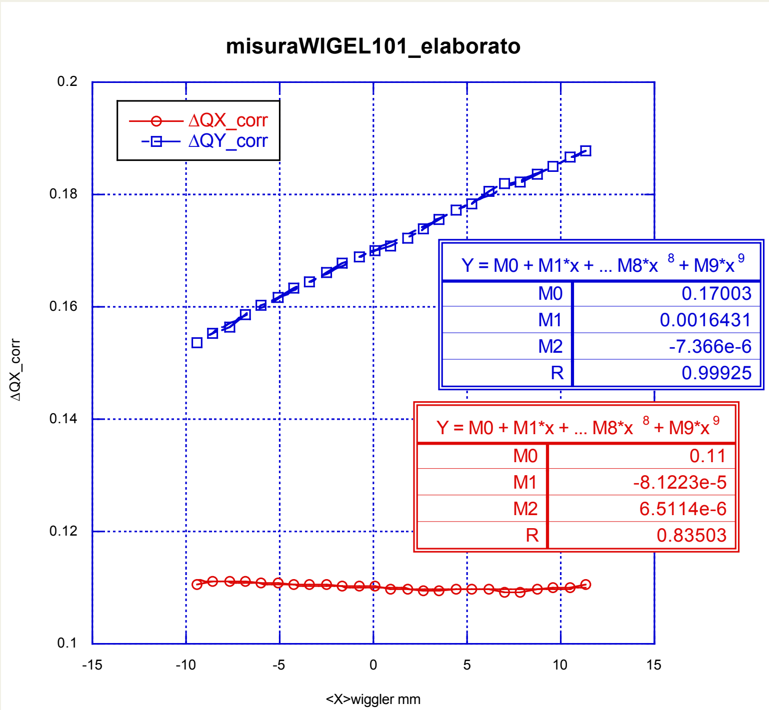
Lambertson correctors are going to be replaced with spare devices having a higher magnetic field quality

The end pole clamps aperture of the eight wigglers have been adjusted to achieve a substantial reduction of the nearby steering magnets strength

Wiggler measurement

The non-linear components of the WIGEL101 field are evaluated by measuring the beam tune shift dependence on the horizontal displacement bump at its place after switching off the sextupoles in that sector





- $\Delta\nu_x$ and $\Delta\nu_y$ exhibit an evident linear behaviour excluding the presence of any octupole-like or higher component in the magnetic field
- A small sextupole-like dependence is observed in $\Delta\nu_y$ only, probably originated in the nearby dipoles included in the bump

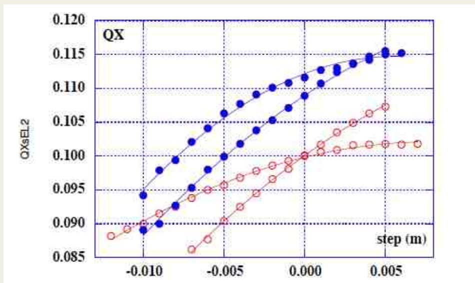


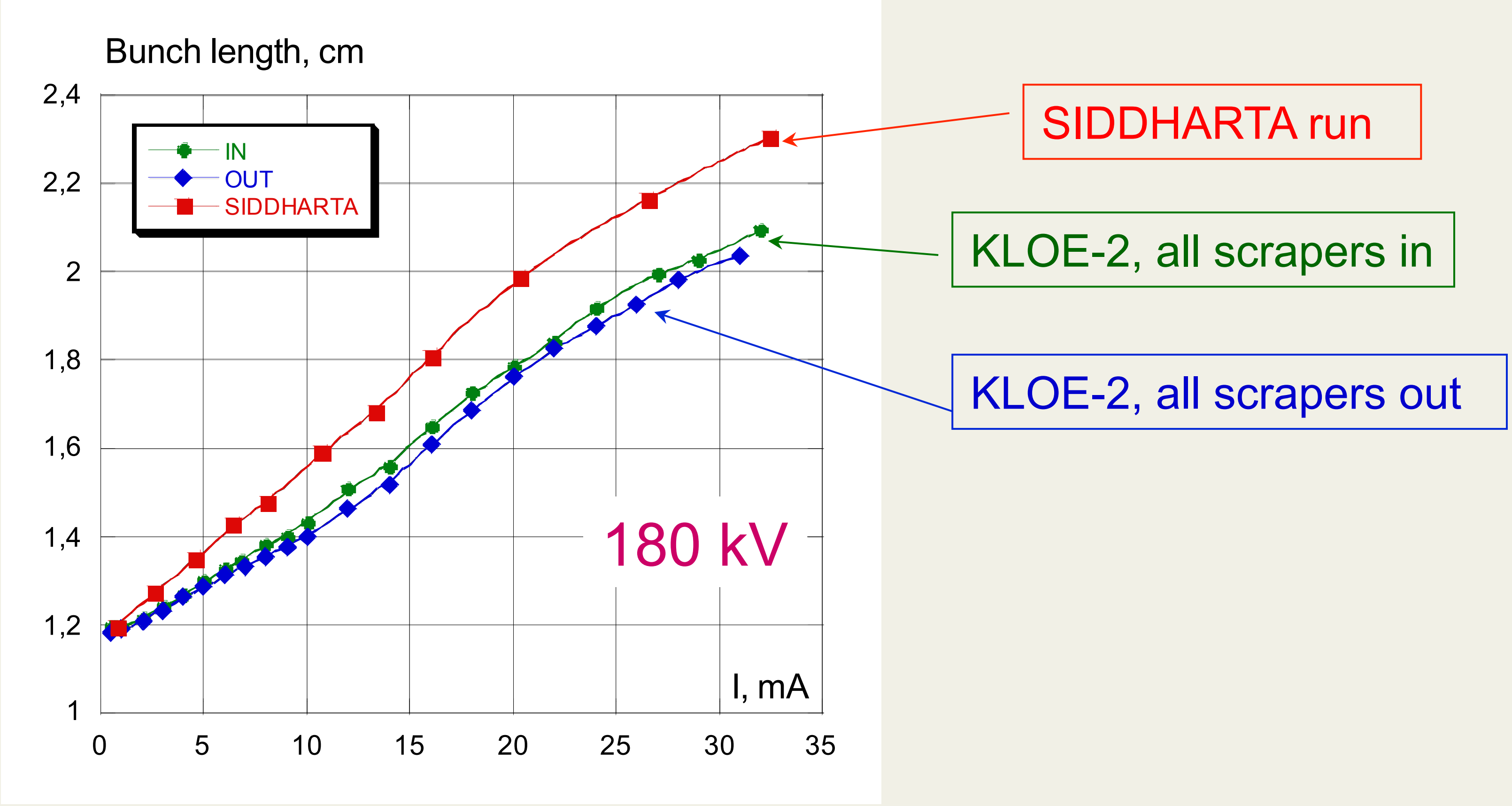
Figure 8: Measured horizontal betatron tune versus beam displacement in 4 wigglers

Published in 2004

K^3 $[m^{-3}]$	Year
800	2001
360	2004
0	2011

Bunch Lengthening in the Electron Ring

Electron bunches now are shorter due to lower coupling impedance.
The impedance contribution of the scrapers is relatively small.

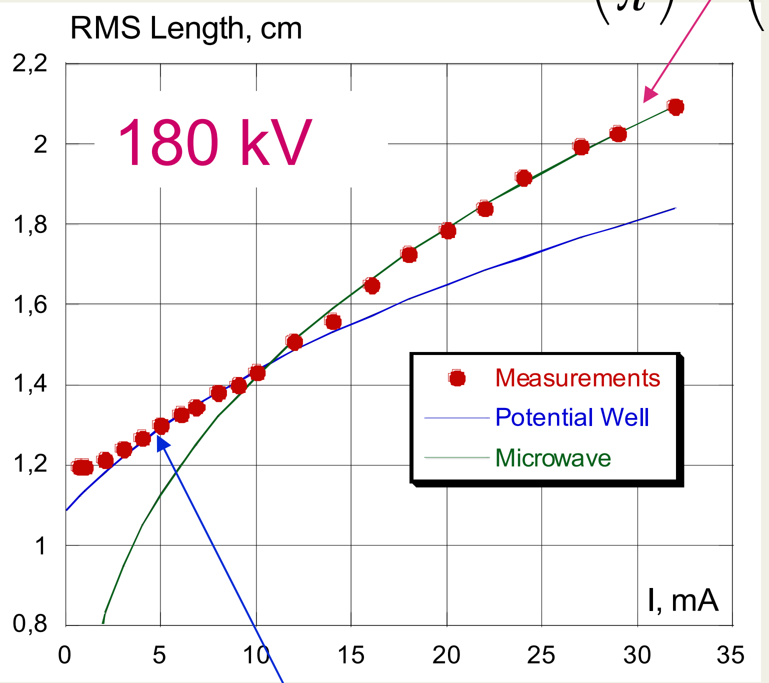


Bunch Length analysis in the Electron Ring

Numerical fits for both the microwave regime and the potential well regime give the same value of the coupling impedance of 0.3 Ω to be compared with 0.4 Ω in the previous SIDDHARTA run

Microwave Regime →

$$\sigma_z = R\left(\frac{2}{\pi}\right)^{1/6}\left(\frac{2\pi I}{hV_{RF}\cos\phi_s}\right)^{1/3}\left|\frac{Z}{n}\right|^{1/3}$$



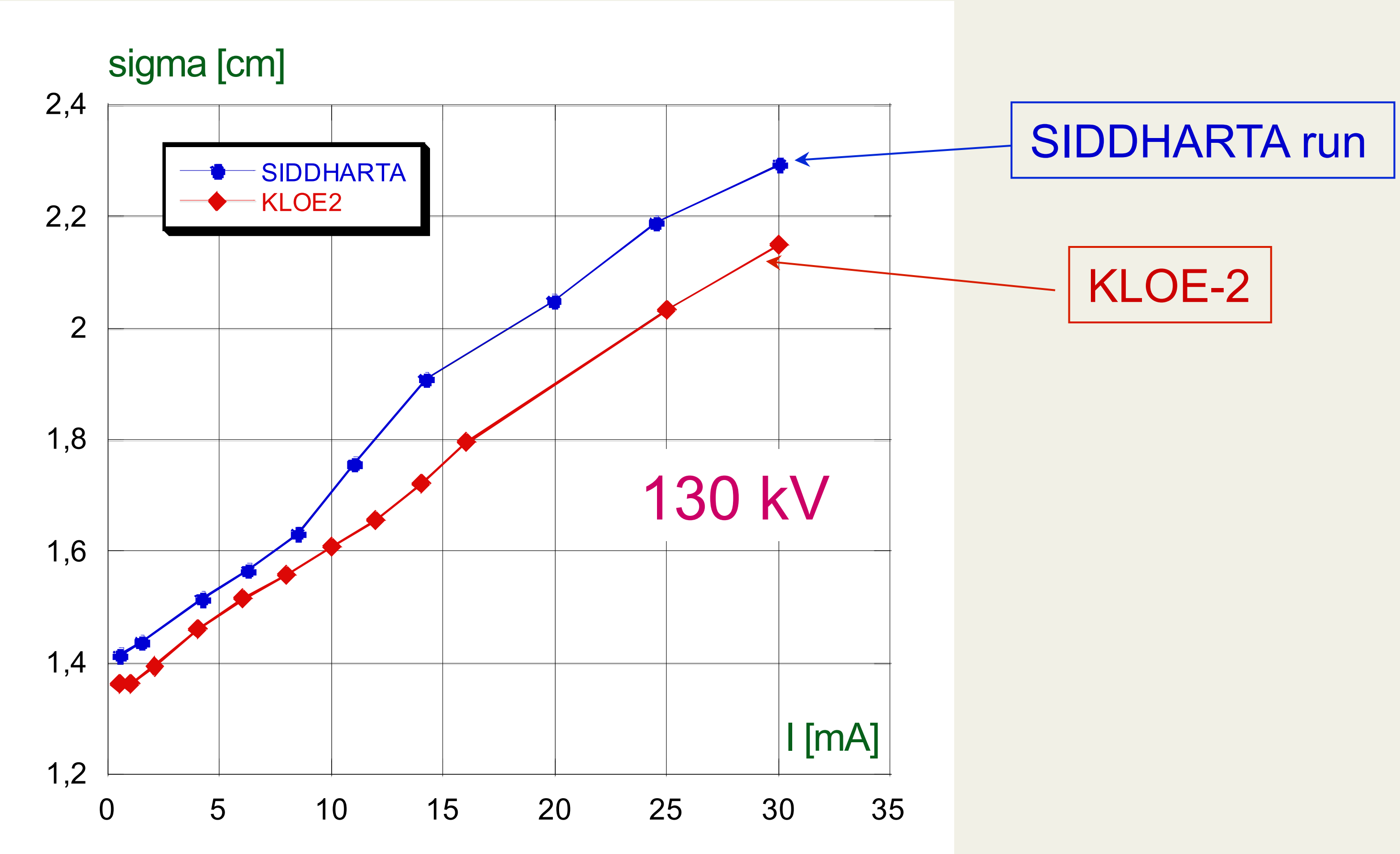
$$\left|\frac{Z}{n}\right| \approx 0.3\Omega$$

$$\left(\frac{\sigma_z}{\sigma_{z0}}\right)^3 - \left(\frac{\sigma_z}{\sigma_{z0}}\right) - \frac{\alpha_c I}{\sqrt{2\pi}Q_{so}^2(E/e)}\left(\frac{R}{\sigma_{z0}}\right)^3\left|\frac{Z}{n}\right| = 0$$

← Potential Well

Bunch Lengthening in the Positron Ring

The coupling impedance of the positron ring is also lower now despite the electron cloud electrodes have been installed



Feedback system upgrade

On November 2010, new units have been installed on the vertical plane feedbacks: the iGp12 (12bit Digital Processing Unit in place of the old 8bit unit) is the core of the new betatron bunch-by-bunch feedback system.

These systems have been upgraded from the previous iGp feedback developed in collaboration with KEK and SLAC (2002-2005) and based on the old longitudinal bunch-by-bunch feedback designed in collaboration ('93-96 by SLAC/LNF/LBL for PEP-II, Dafne, ALS).

This year, we have tested the new feedback behavior together with all the old beam diagnostics tools:

all the tests show that the iGp12 works very well, and does not show any compatibility trouble with the previous software version.

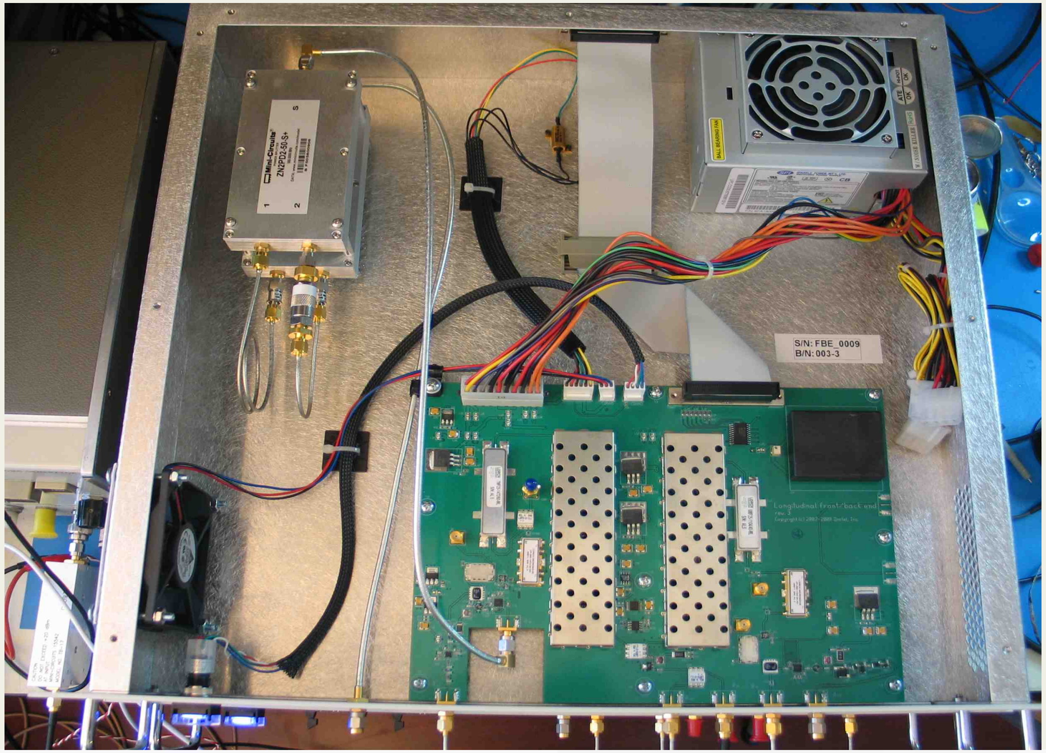
Longitudinal frontend / backend analog module

The old synchrotron feedback hardware has been replaced with new iGP (8bit) systems.

These units allow to use new front/ back-end modules.

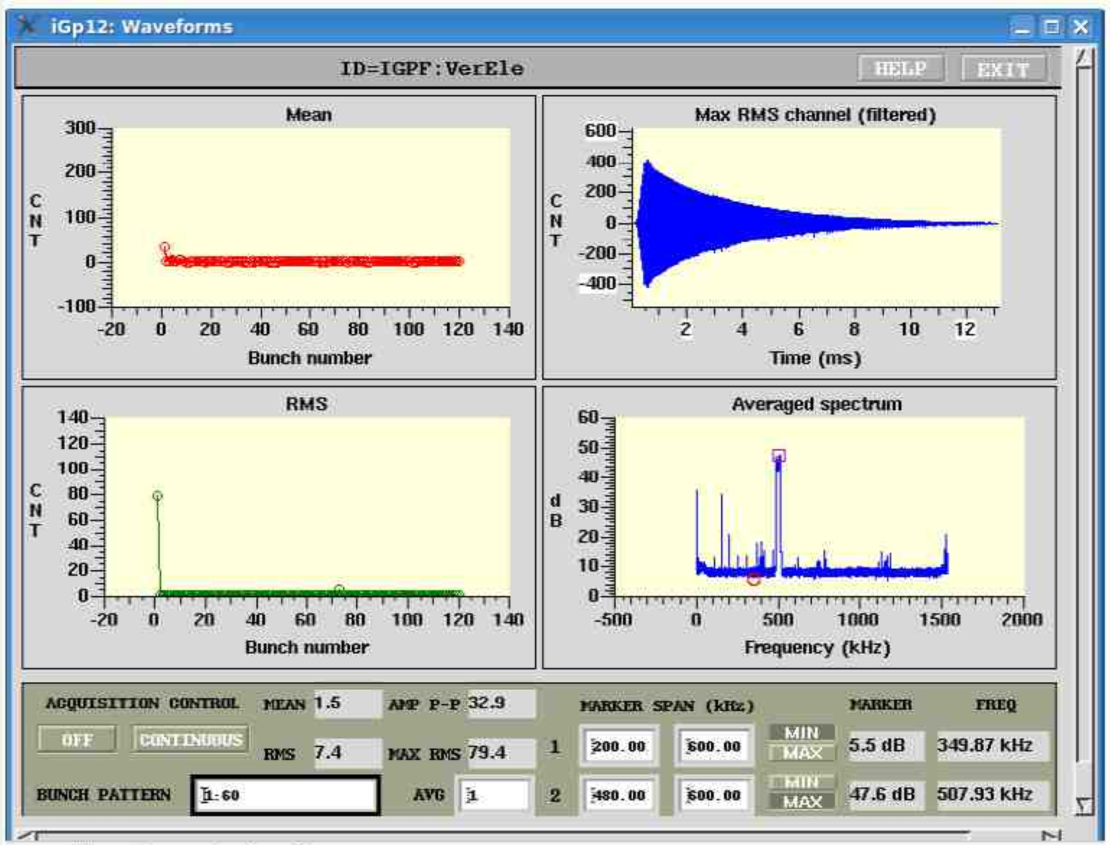
They rely on a simplified electronic design

Each unit can be remotely programmed through an EPICS interface



Decoherence measurements

Transverse feedbacks have been used to implement horizontal and vertical dechoerence measurements



- The Feedback unit is used to kick the beam, by applying a 0.4 ms anti-damping signal, as well as to record the beam response to the perturbation
- The measurement accuracy profits from the high resolution of the system and data storage capability
- Vertical decoherence measurements have never been done before at DAFNE since there was no way to kick the beam in the vertical plane

Collisions tuning

Coupling correction by
•fixing two errors in the IR electromagnetic QUAD rotation
•compensator solenoids are set at the nominal values
•fine tuning by rotating the focusing QUADs in the low-beta section
•tuning the skew quads installed in the IR

Crab waist alignment

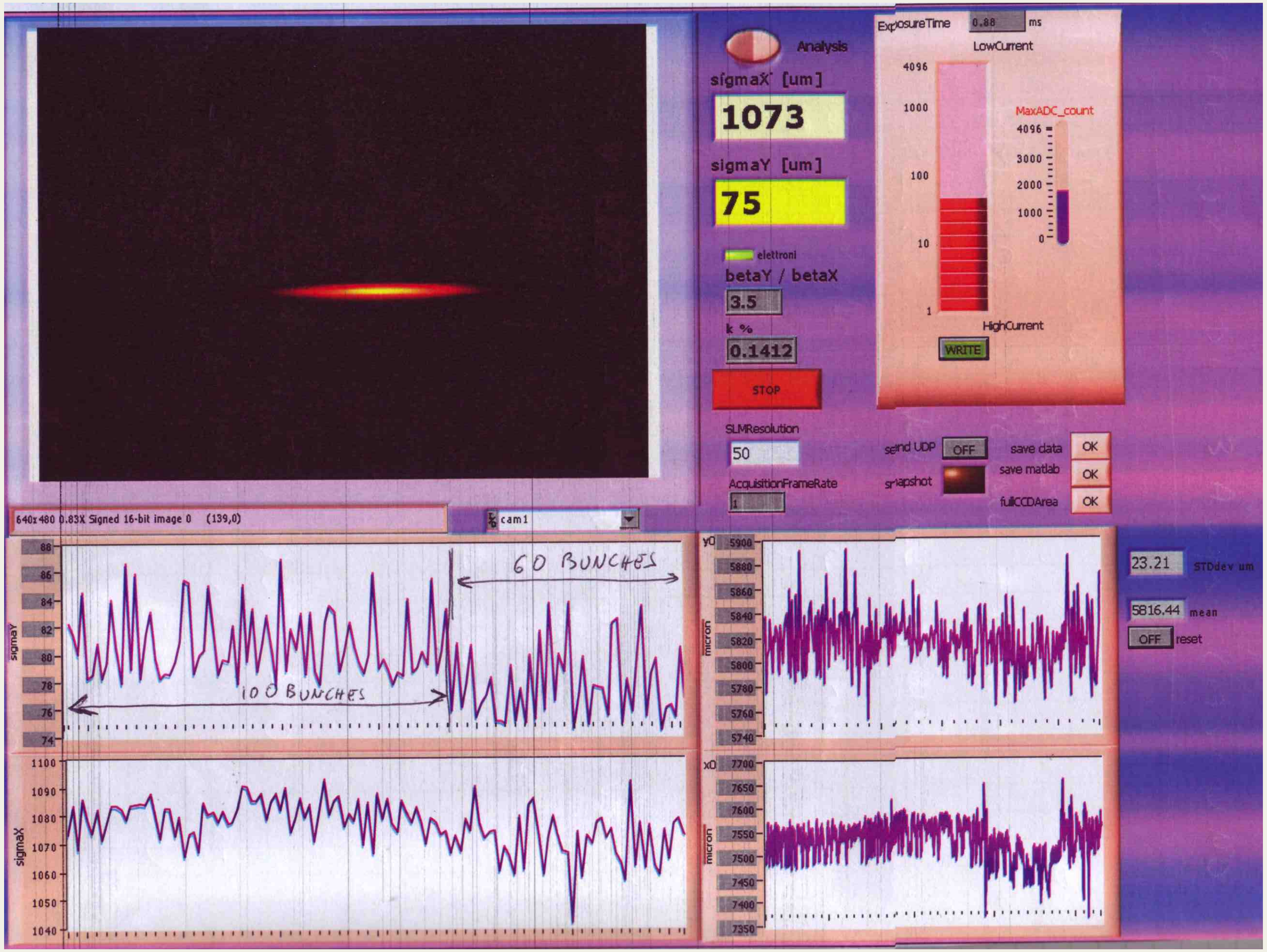
Beam-beam scan

Betatron Coupling correction

σ_y = 75 μ at the SLM

κ ~ 0.14%

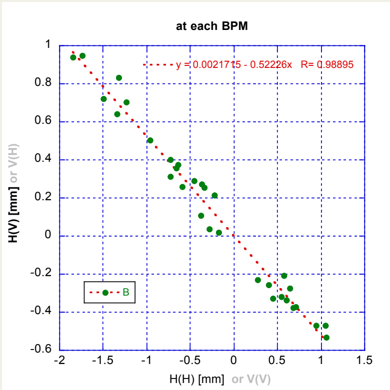
κ ~ 0.2 ÷ 0.3 % during the last KLOE run

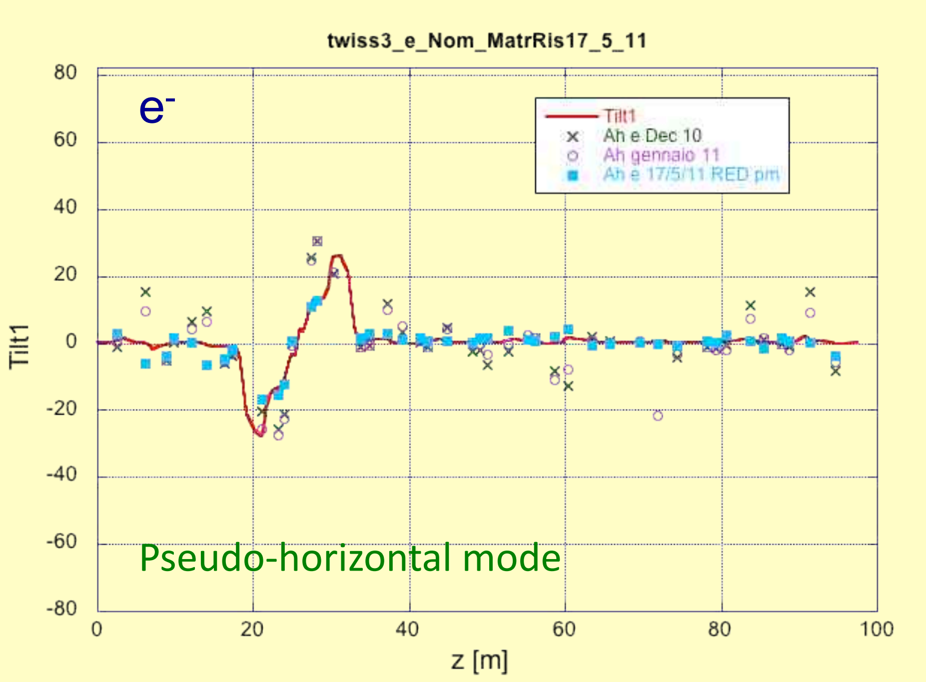


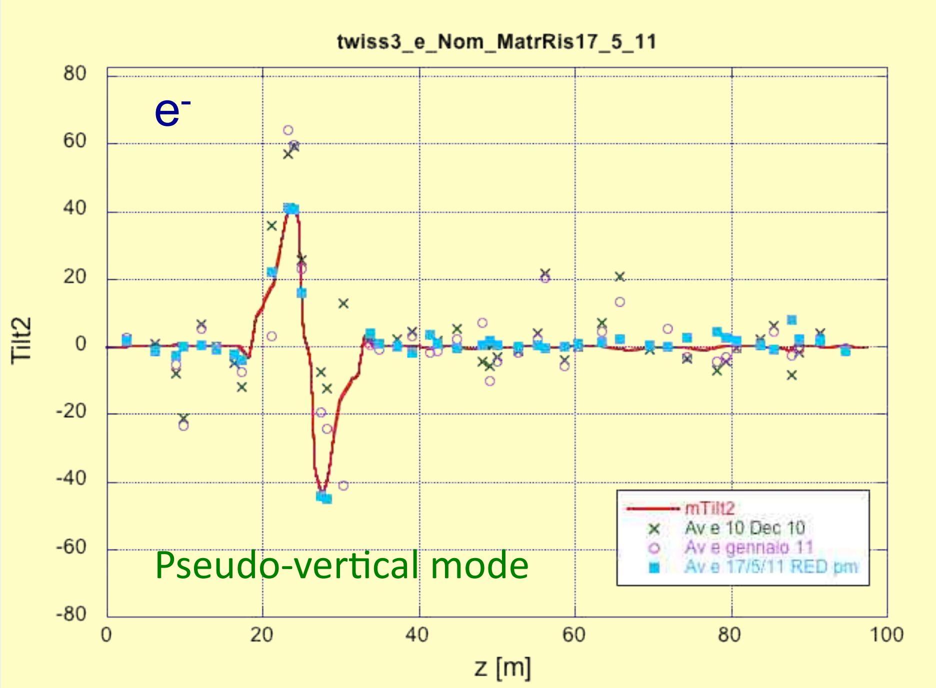
e$^-$

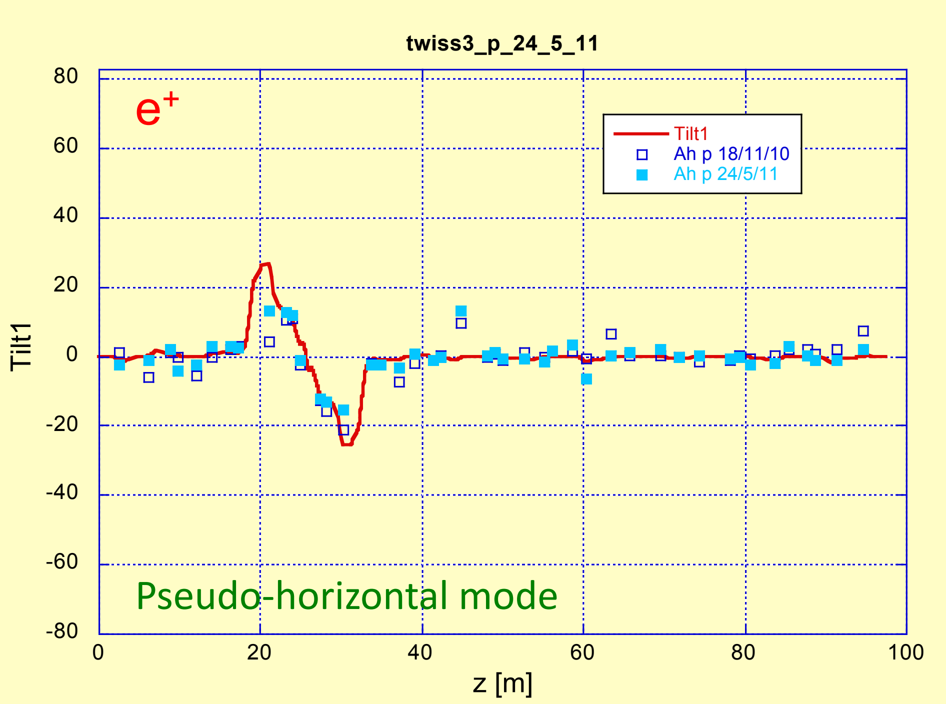
Betatron coupling analysis

- Transverse beam dynamics in presence of coupling is represented by two normal modes
- normal modes when projected on the x-y plane are represented by an ellipse with a given eccentricity and tilt
- In this graphs the normal mode tilts computed from the ring model are compared with the corresponding values obtained from the measured steering magnet response matrices








twiss3_p_24_5_11
e+
Tilt1
Ah p 18/11/10
Ah p 24/5/11
Pseudo-horizontal mode
Tilt1
z [m]
80
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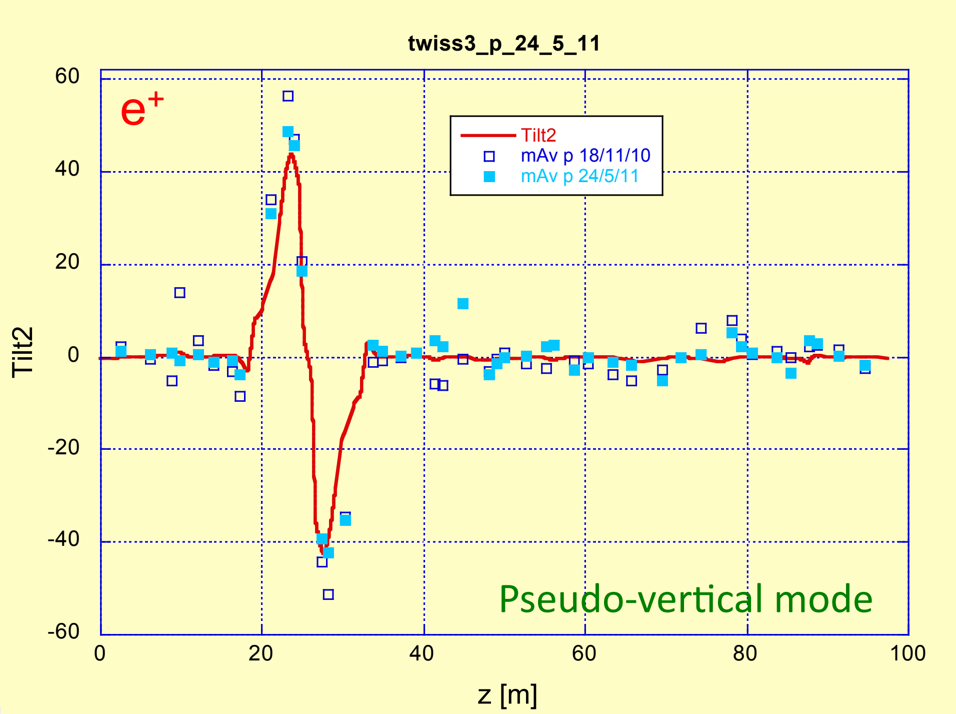
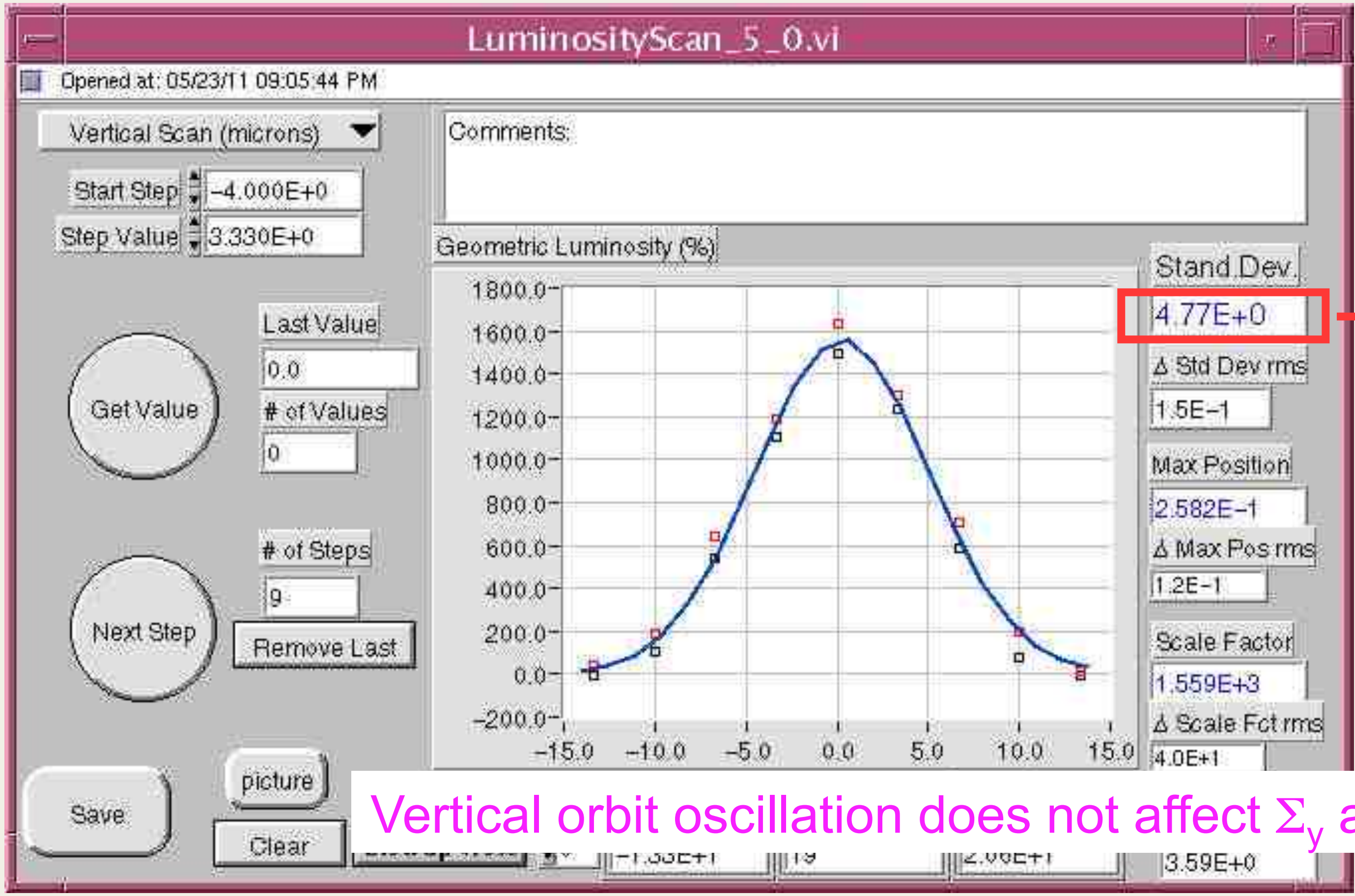

twiss3_p_24_5_11
e+
Tilt2
mAv p 18/11/10
mAv p 24/5/11
Pseudo-vertical mode
Tilt2
z [m]
60
40
20
0
-20
-40
-60
0
20
40
60
80
100

Vertical beam-beam *Luminosity scan*

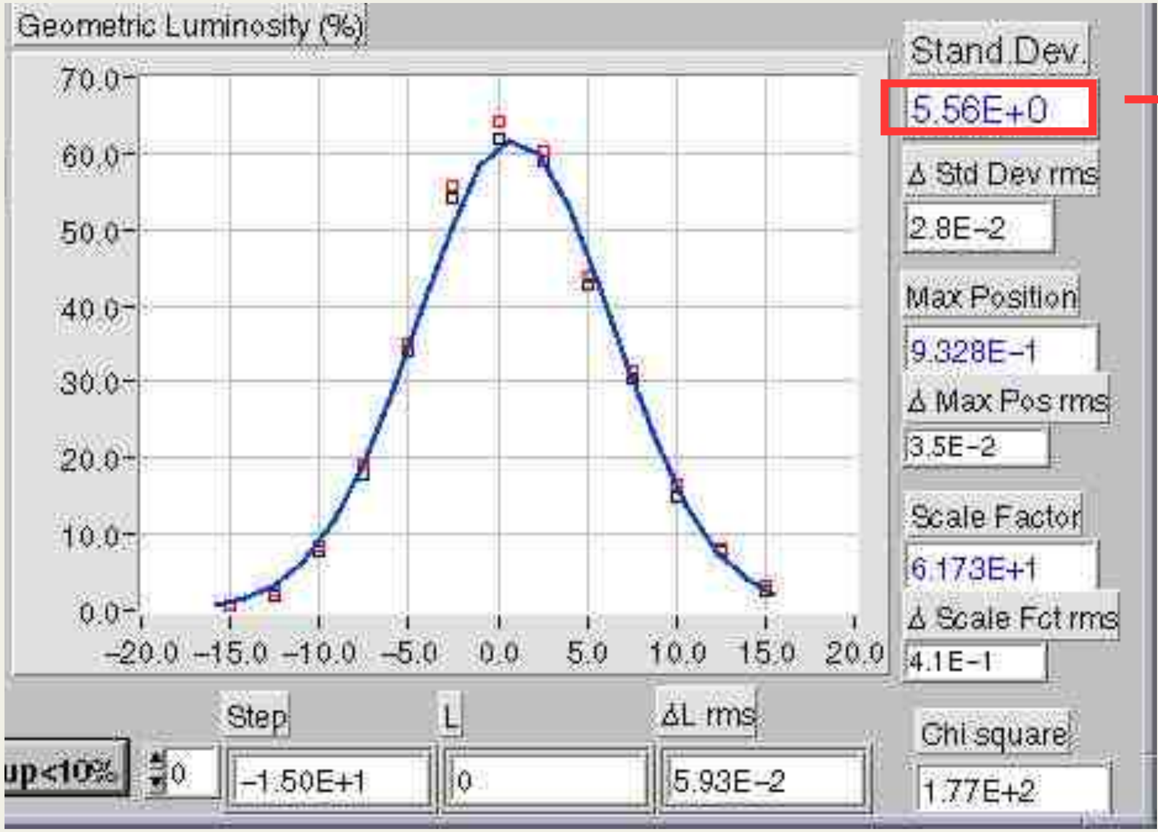
$$\Sigma_y = \sqrt{\sigma_{yp}^2 + \sigma_{ye}^2} \qquad \Sigma_y = \Sigma_y^{meas} * 0.88$$



$\sigma_y \approx 3.0\,\mu m$

Vertical orbit oscillation does not affect Σ_y at IP!!

Vertical beam-beam *Luminosity scan* *(SIDDHARTA run)*



$\sigma_y \approx 3.5\mu m$

Design value 3.1μm

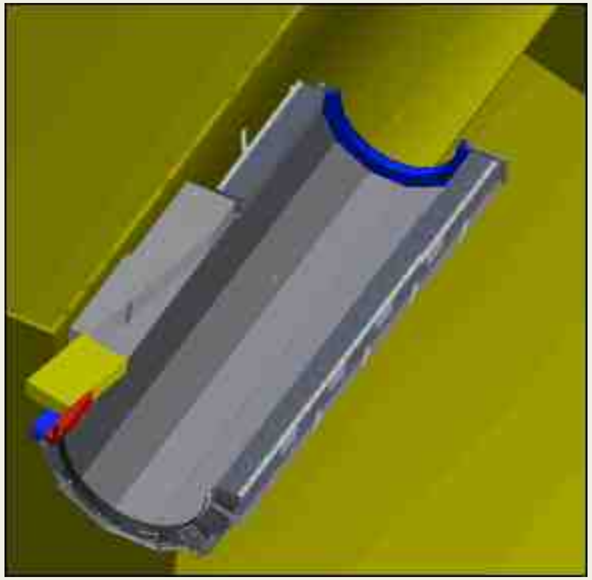
July 1st 2008

SIDDHARTA was a compact detector without solenoidal field !!

Background optimization

The new collimators installed in each one of the four IR branches have been conditioned by using the beam. They proved to be very effective in reducing the background shower hitting the experimental apparatus as predicted by numerical simulations.

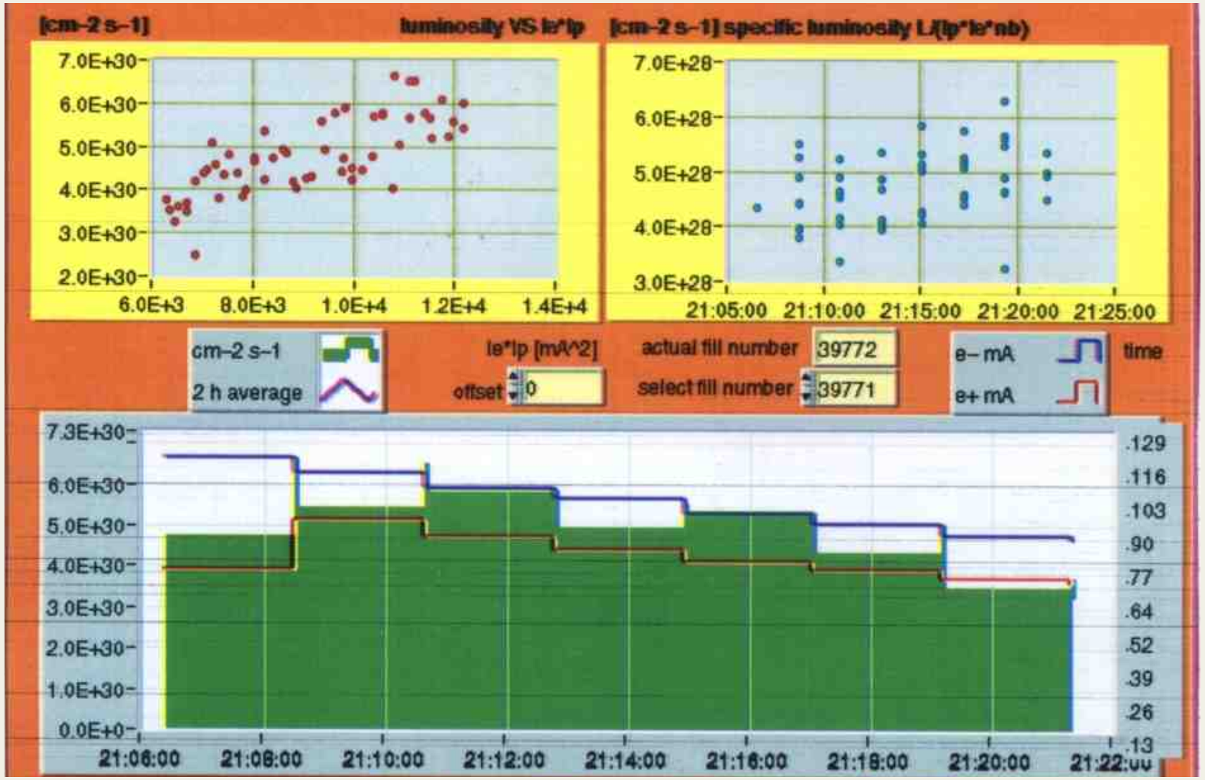
In February 2011 an additional lead screen, 1 cm thick, has been added around the inner layer (QCAL) of the KLOE-2 detector. Preliminary measurements have shown a considerably reduction in the background hitting KLOE-2.

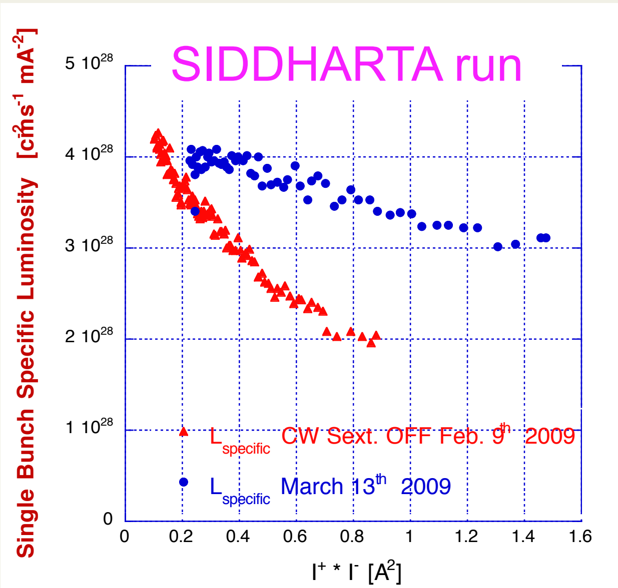


Background counting rate from the e^- beam is compatible with KLOE-2 operation and is a factor 3 lower than the one from the e^+ beam

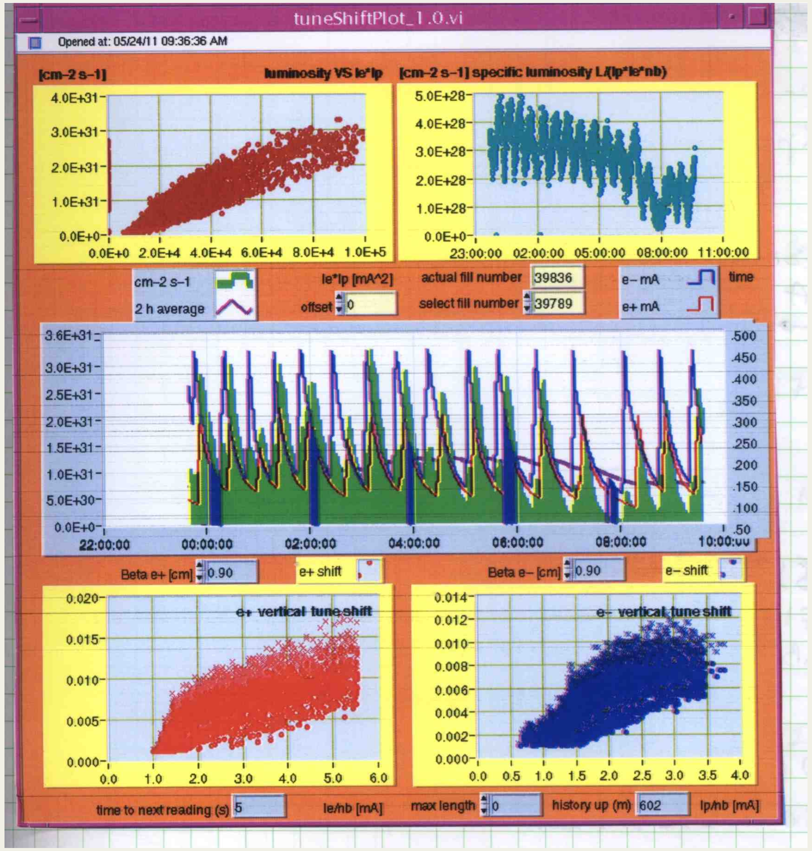
Specific Luminosity L_{sp}

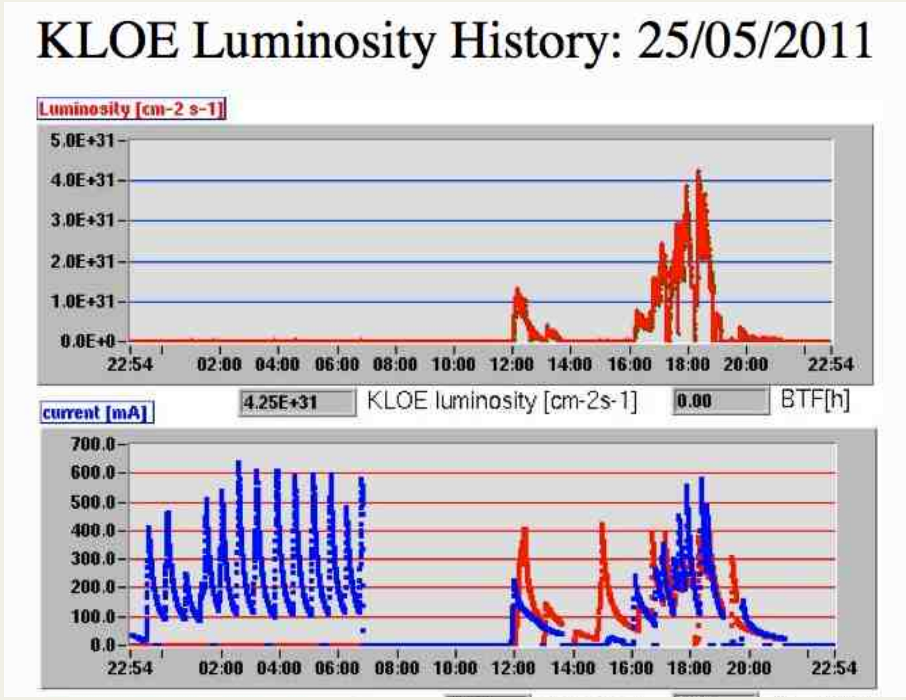
$$L_{sp} = \frac{L_{sb}}{I_{sb}^{+} \cdot I_{sb}^{-}}$$





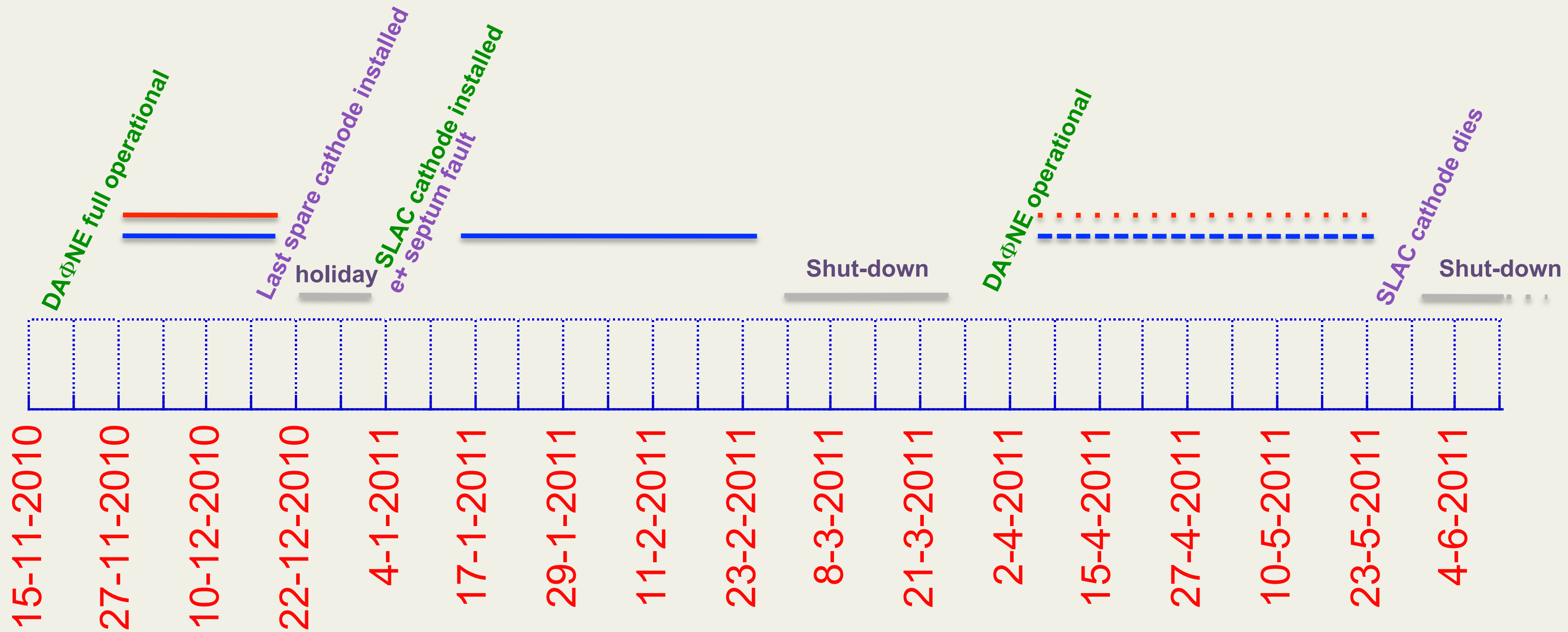
At low currents L_s exceeds by 4 times the best value measured during the past KLOE runs





Last beams circulating and colliding in DAΦNE !!

DAΦNE operation summary



Conclusions

Many relevant faults affected DAFNE operations

The machine uptime has been absolutely poor

Compatibly with this situation all the possible has been done to:

provide beam to BFT and SR beam lines

tune-up main rings for collisions

Preliminary results about luminosity, at low current, are quite good, but high current regime must still be explored

Where from here ……

To secure a fruitful data-taking to the KLOE-2 experiment a clear commitment is necessary to consolidate several parts of the DAFNE accelerator complex investing in financial resources and manpower to grant reliable machine operation

A detailed example about the injection system:

3 new klystron
Ceramic windows
Electronic components
test station for cathode measurements and maintenance

Spare parts must be provided and general maintenance planned for:
Magnet power supplies
Cooling system
Cryogenic plant
RF system
Vacuum equipments