Circular colliders
The DAΦNE Φ-Factor
Part III

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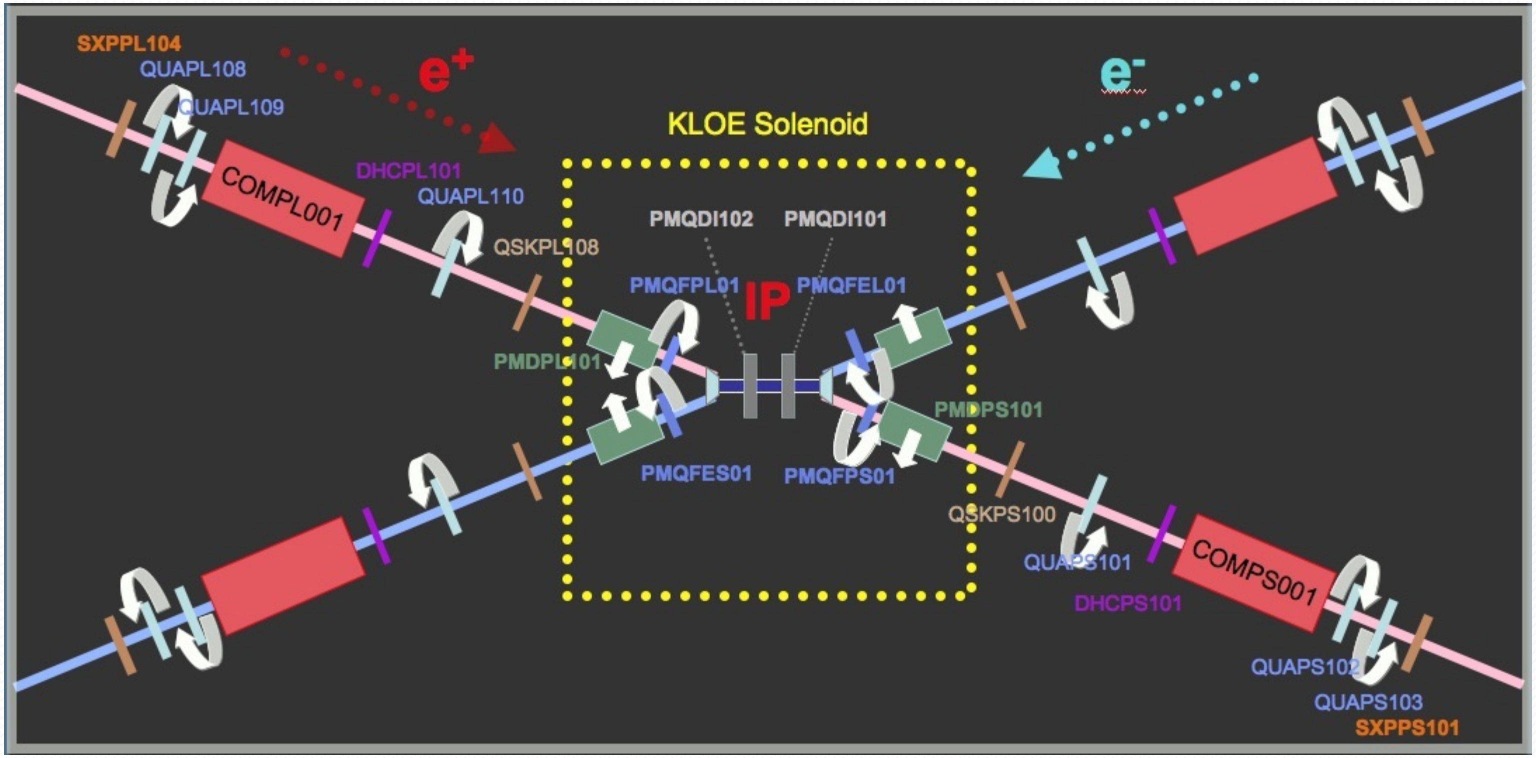
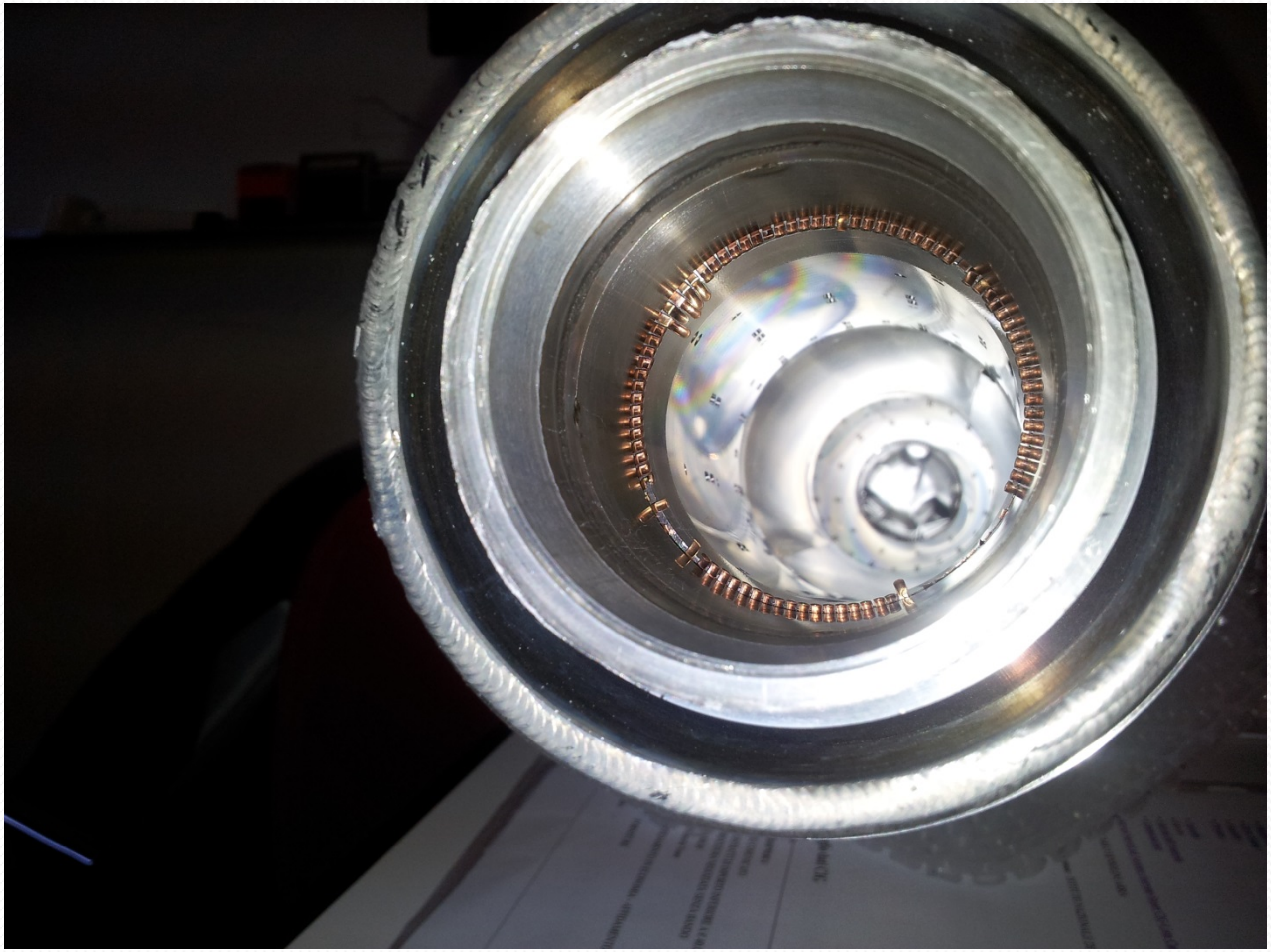
Interaction Region detail (very complicated!)

- The solenoidal field of KLOE2 must be corrected because it induces a strong beam coupling (beam rotated by 22.5° at IP if not corrected)
- Two compensating solenoids are installed in each ring outside the IR
- Quadrupoles need also to be tilted to follow the beam rotation inside the IR
- Residual coupling can be corrected by other skew quadrupoles in the ring
- Correctors provide the orbit adjustment in the IR

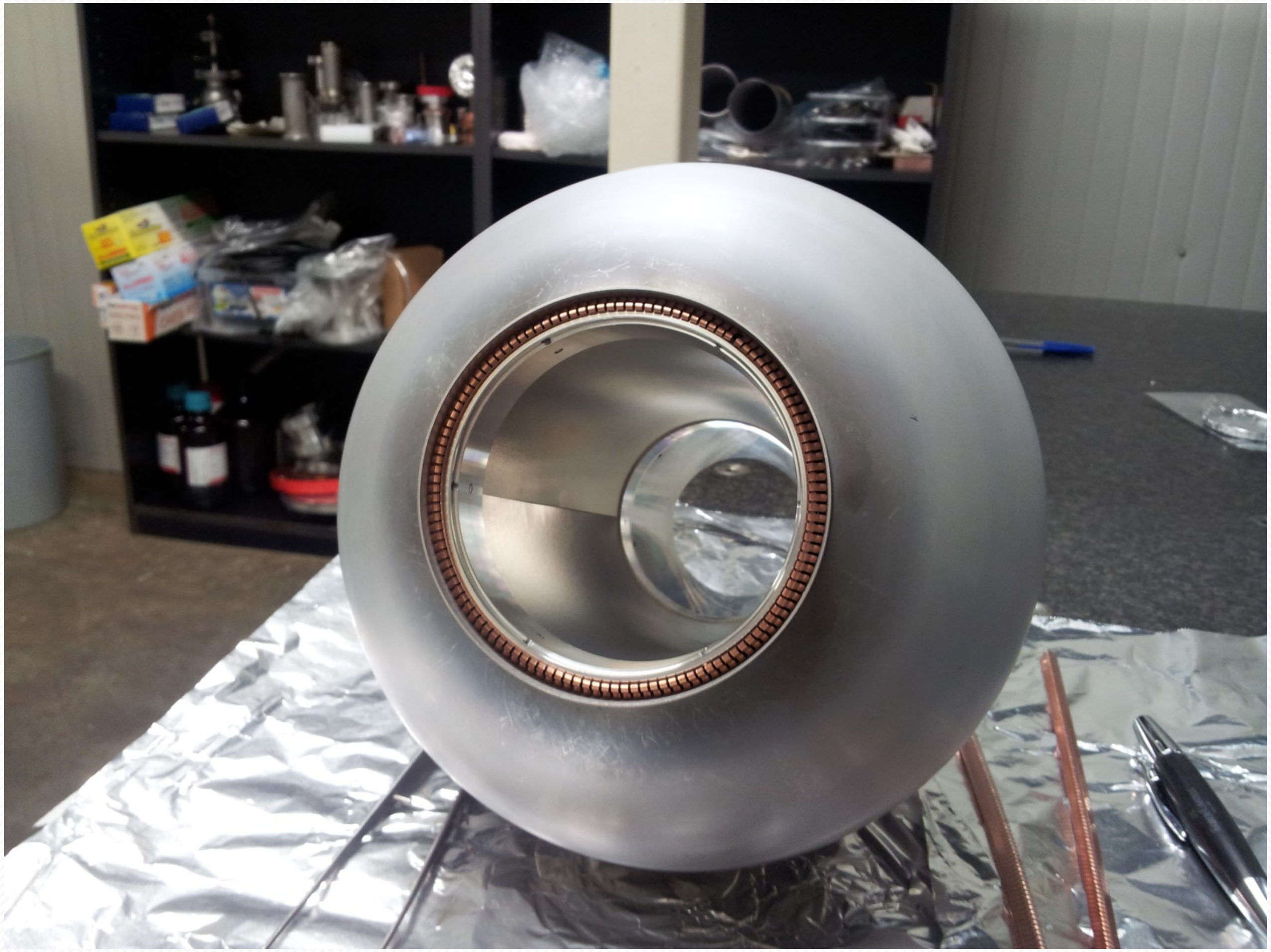


Old Spherical vacuum chamber with damaged RF contacts

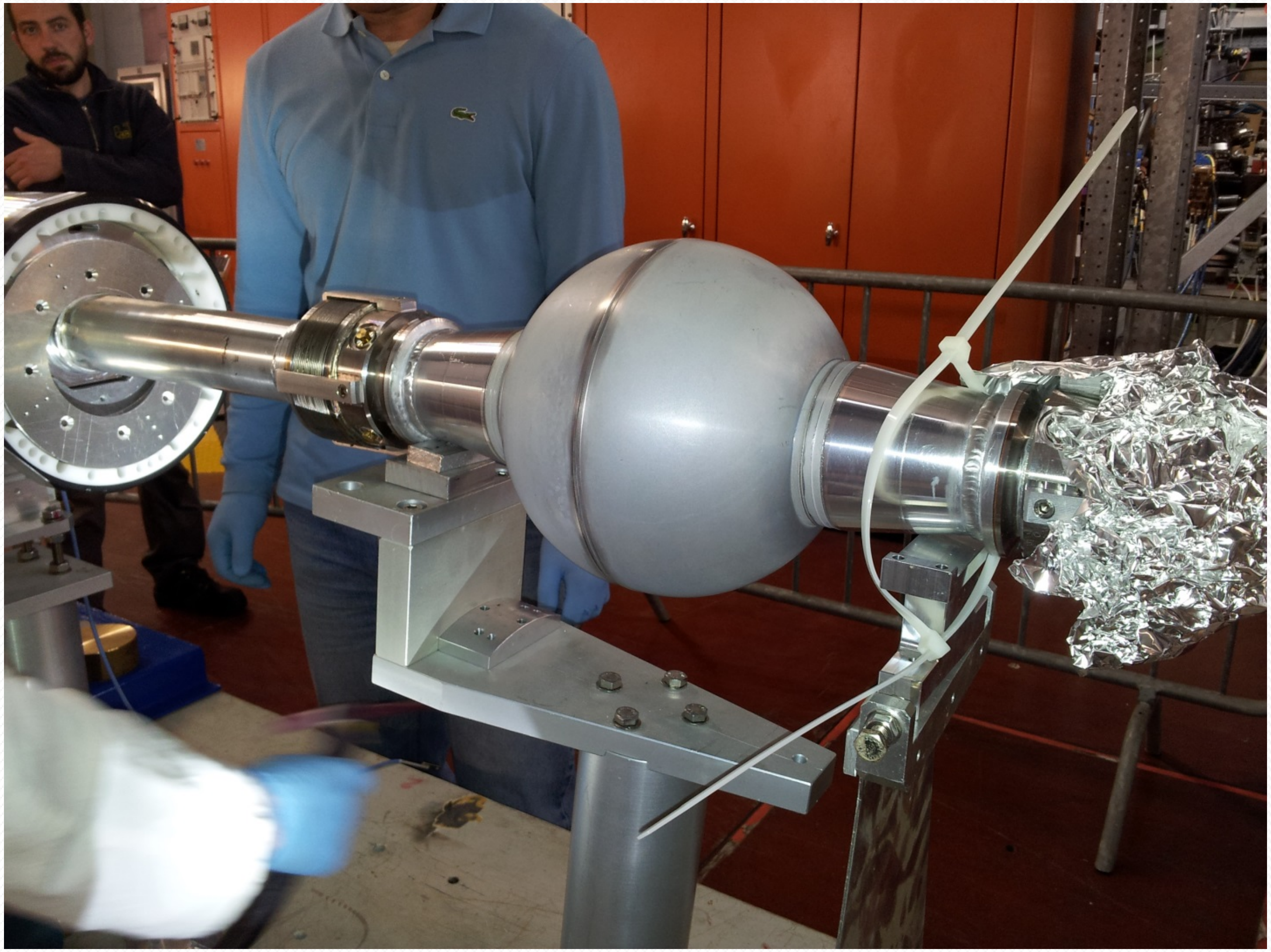


High beam currents can damage devices in the beam pipe !

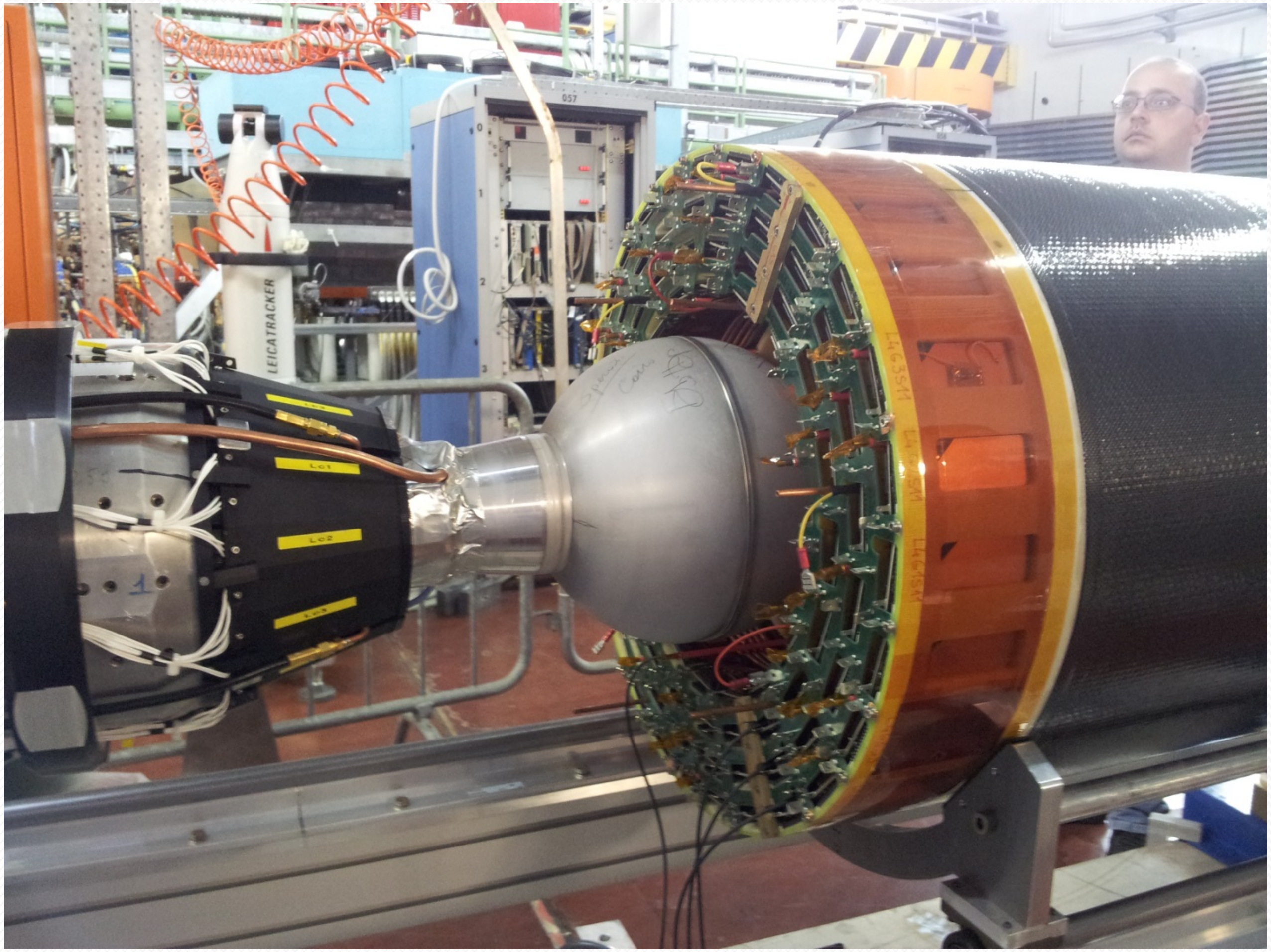
New spherical Vacuum chamber before EB welding (RF contacts between sphere and Be shield)



Sphere assembly in final position before TIG welding

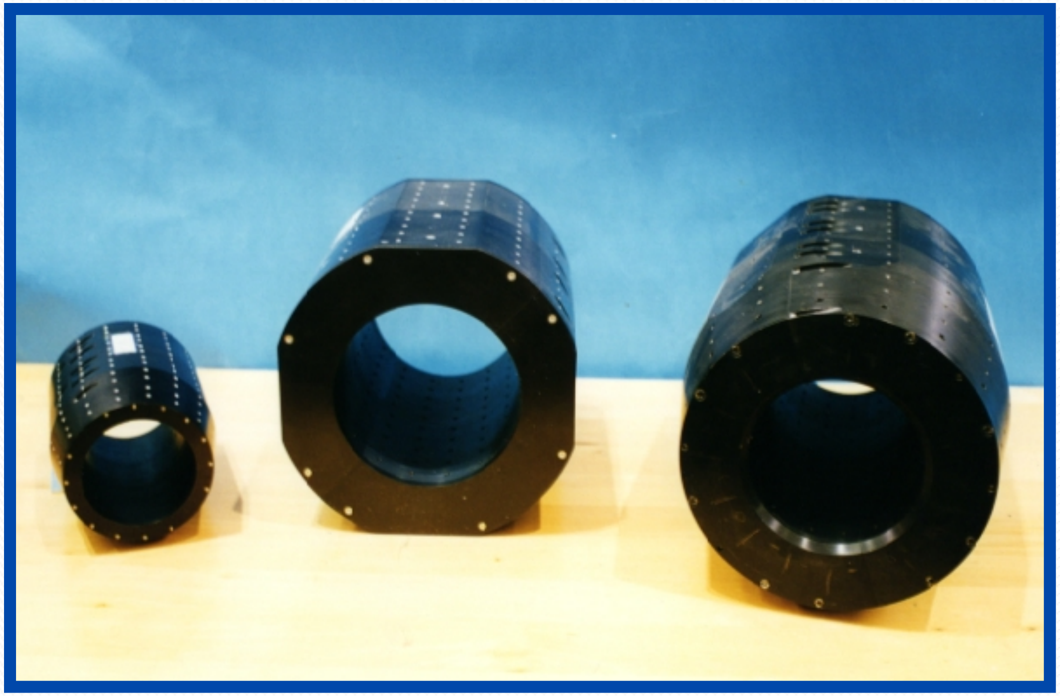


Insertion of the IT, before the 2°welding



Permanent Magnets

- For some applications materials which are permanently magnetized are used
- B field is fixed and cannot vary with the beam energy, but they are extremely compact and don't use any power



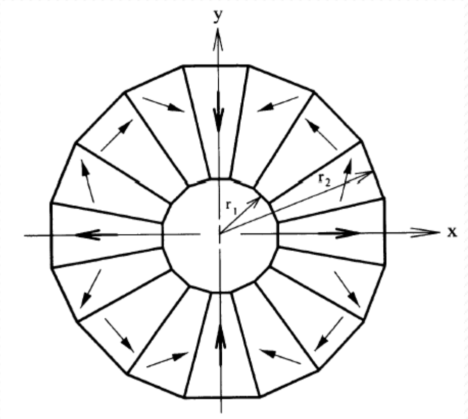
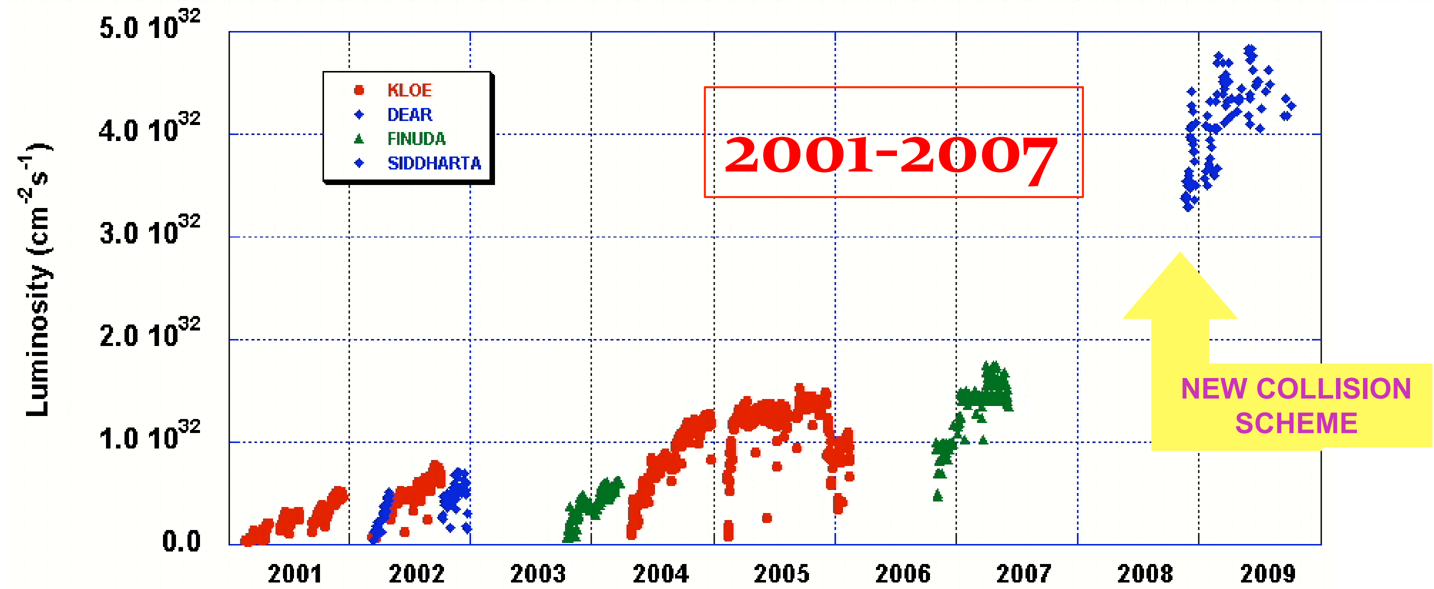
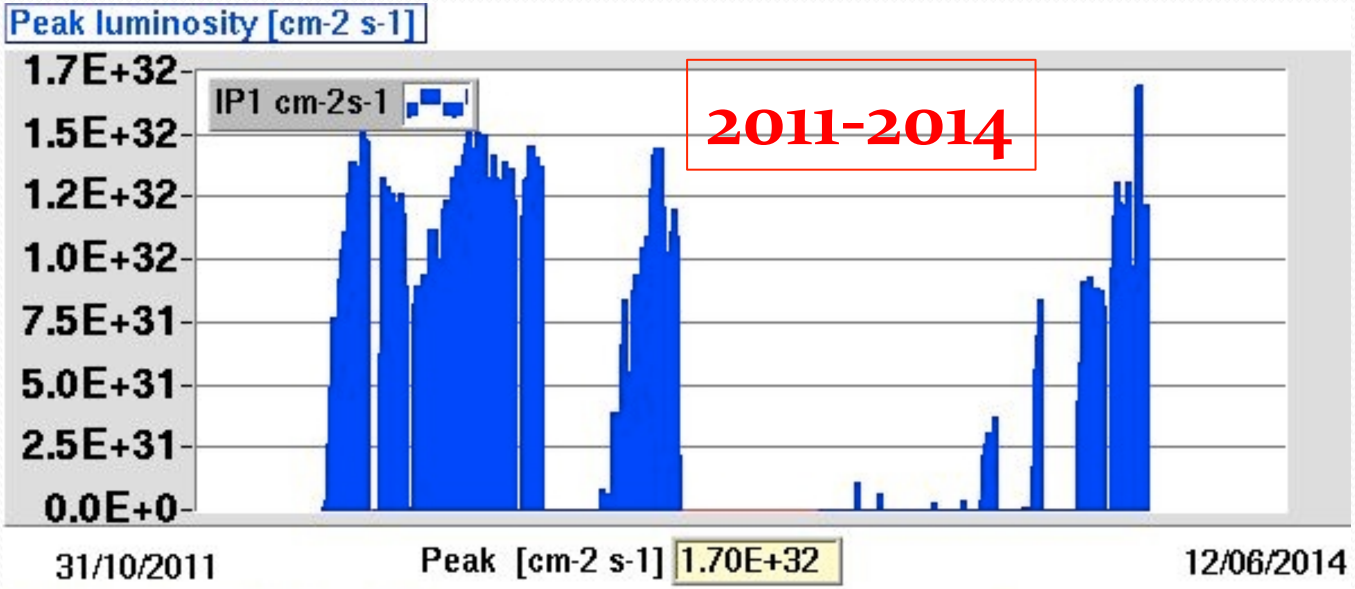


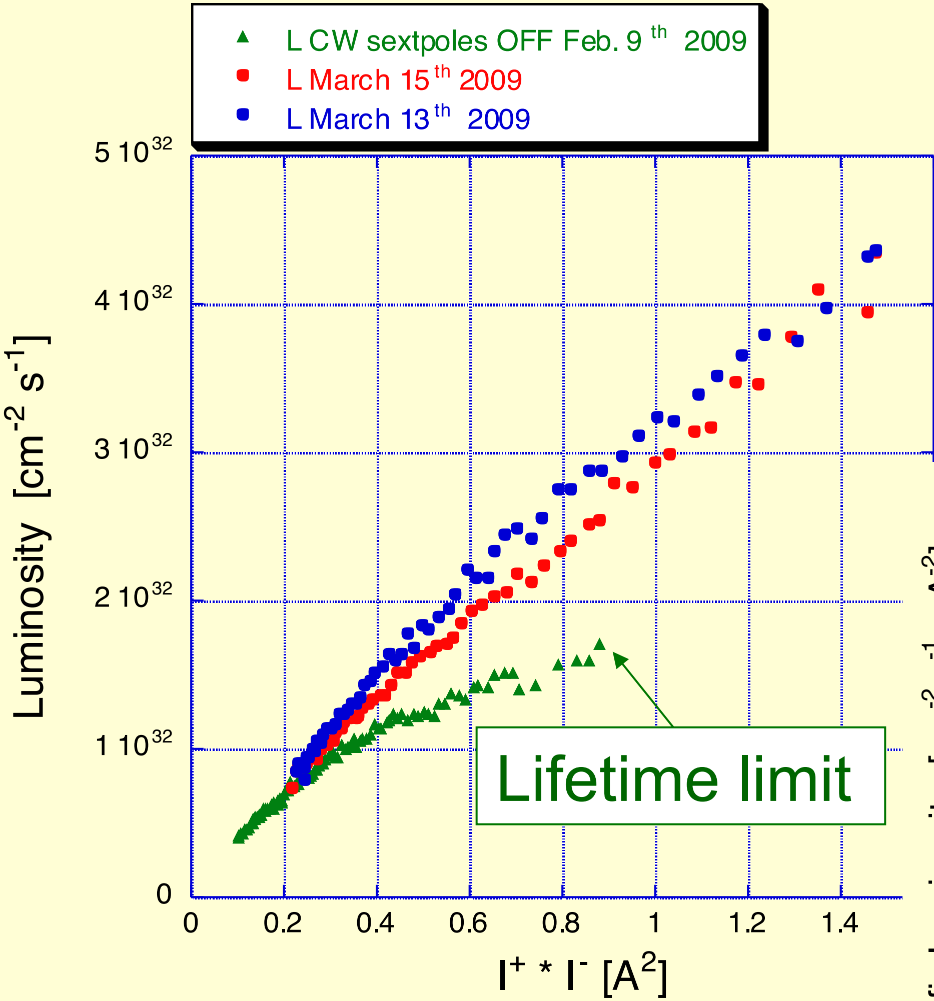
Fig. 4 Segmented quadrupole magnet

Quadrupoles used in DAΦNE Interaction Region

DAΦNE peak luminosity

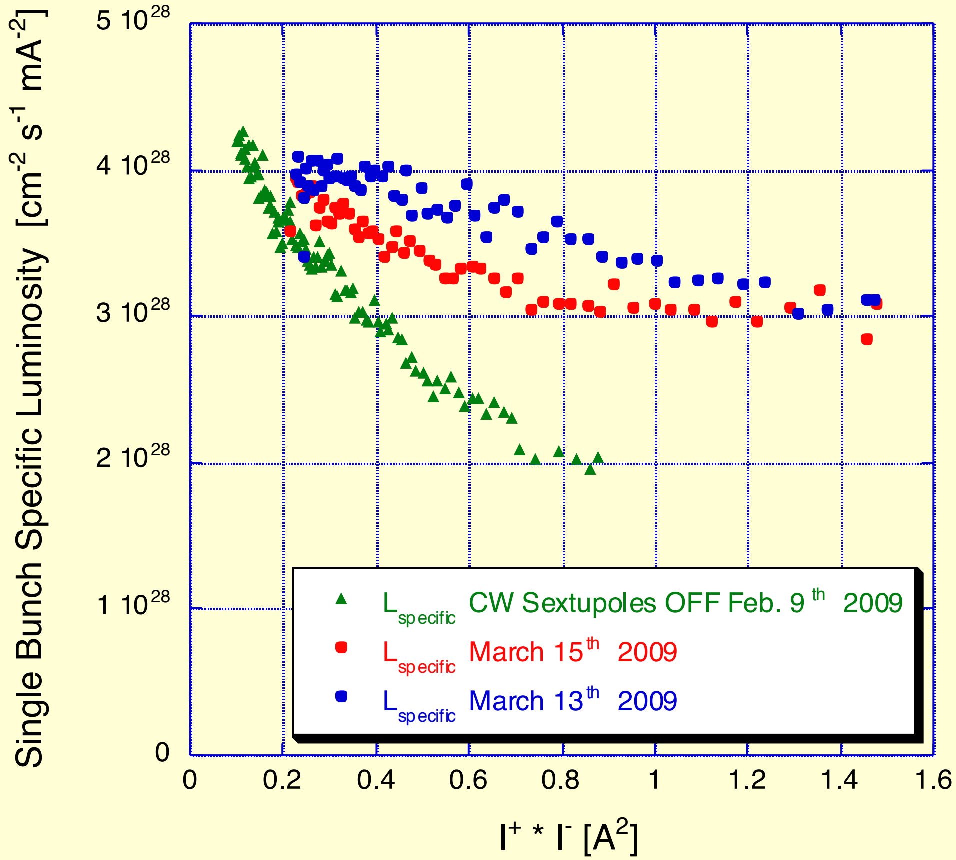




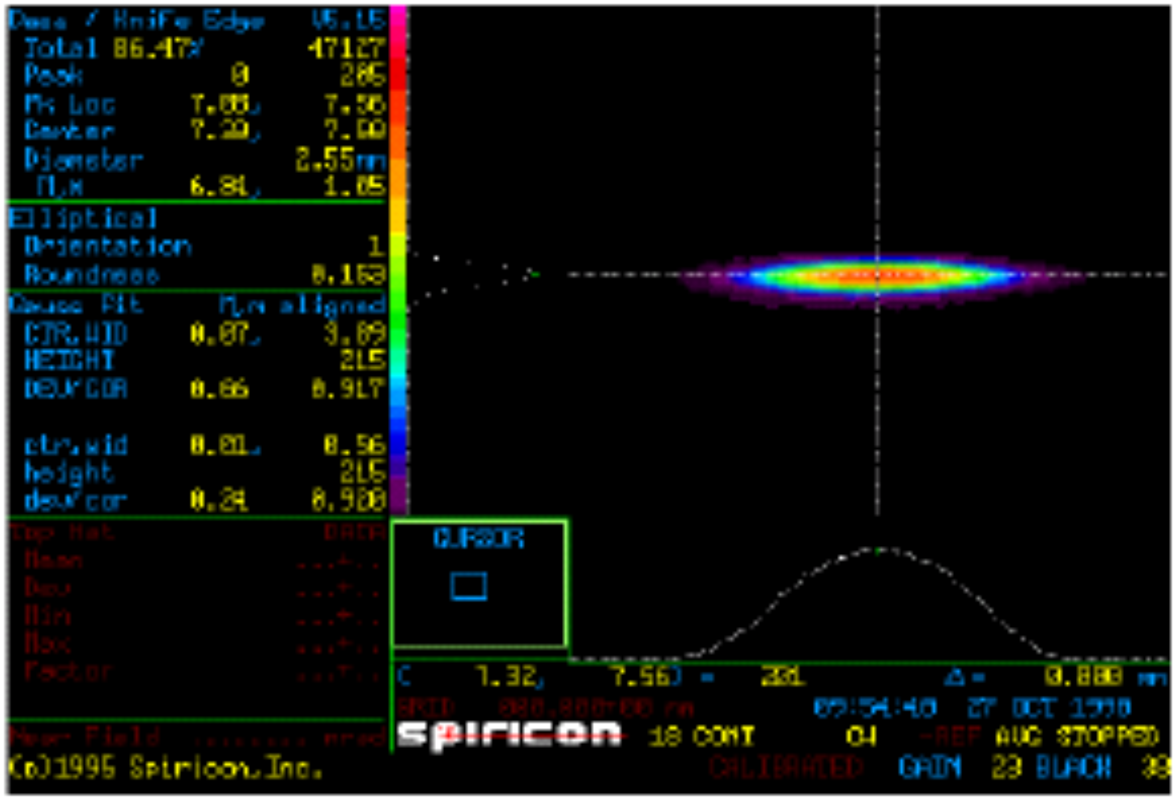


Luminosity vs. I^+I^- Crab ON/OFF

Specific Luminosity vs. I^+I^- Crab ON/OFF



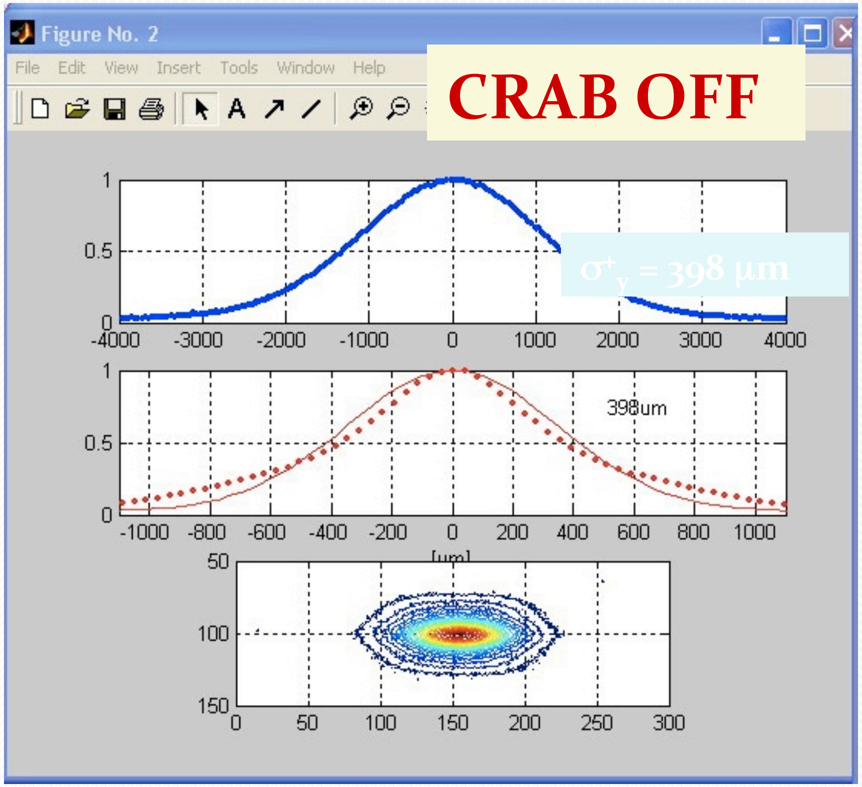
DAΦNE Synchrotron light monitor

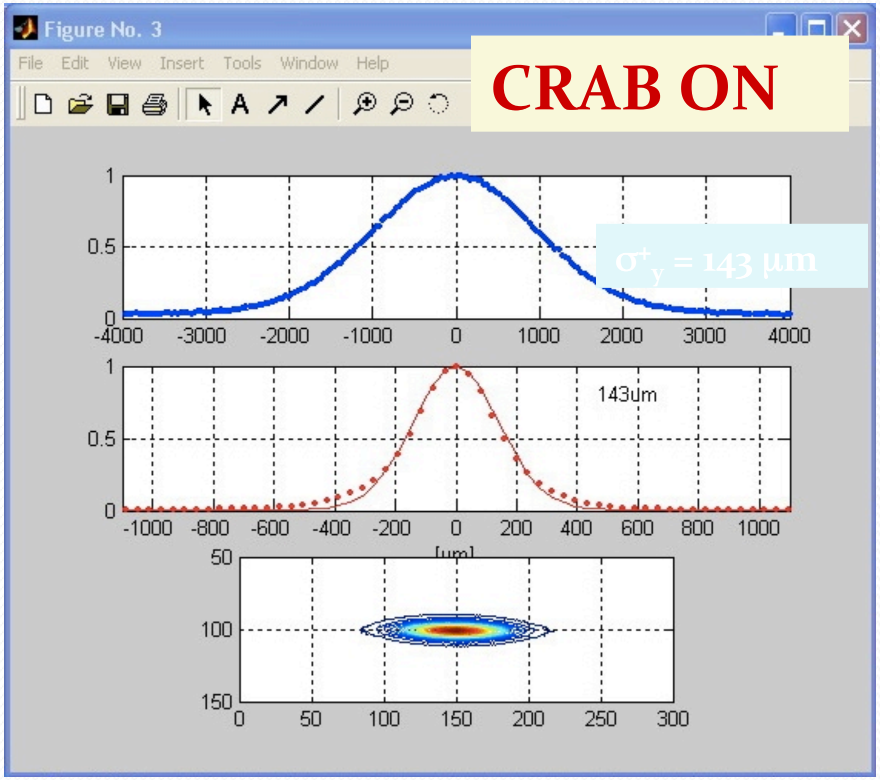


Measures the transverse beam sizes by means of the emitted synchrotron light

Transverse Beam Profile Measurements

103 colliding bunches





Non Gaussian tails are reduced

Positron vertical beam size versus Crab-Sextupole strength

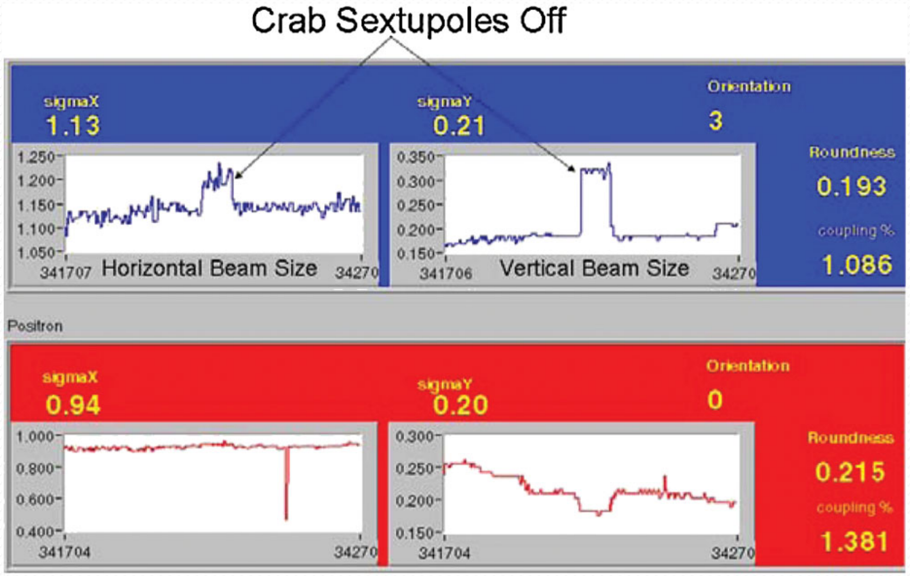
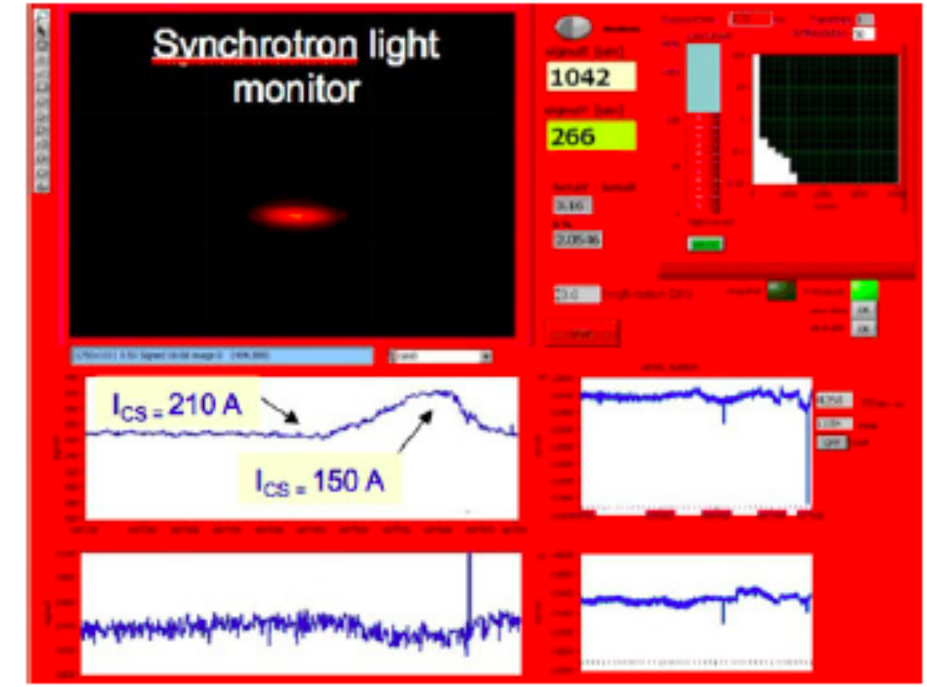
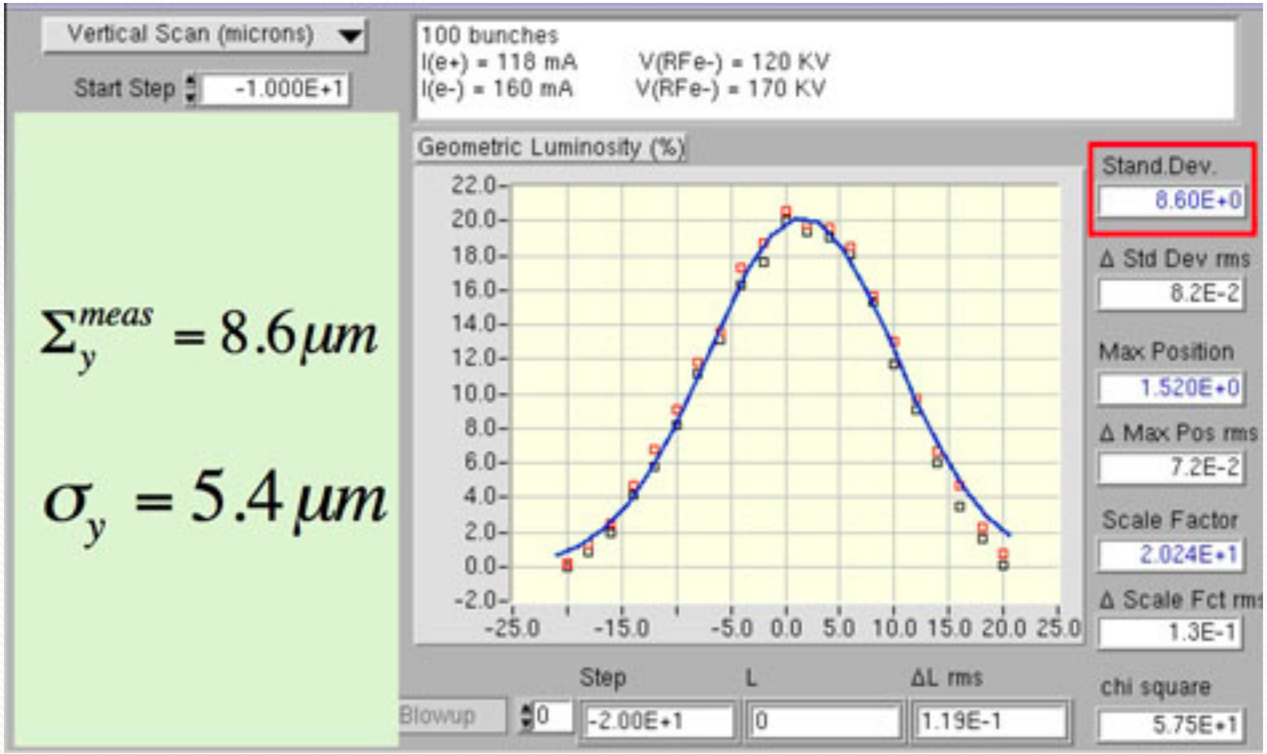


FIG. 3 (color). Transverse beam sizes at the synchrotron light monitors (electrons: blue windows, positrons: red windows).



Crab sextupoles reduce the beam blow-up due to bb forces

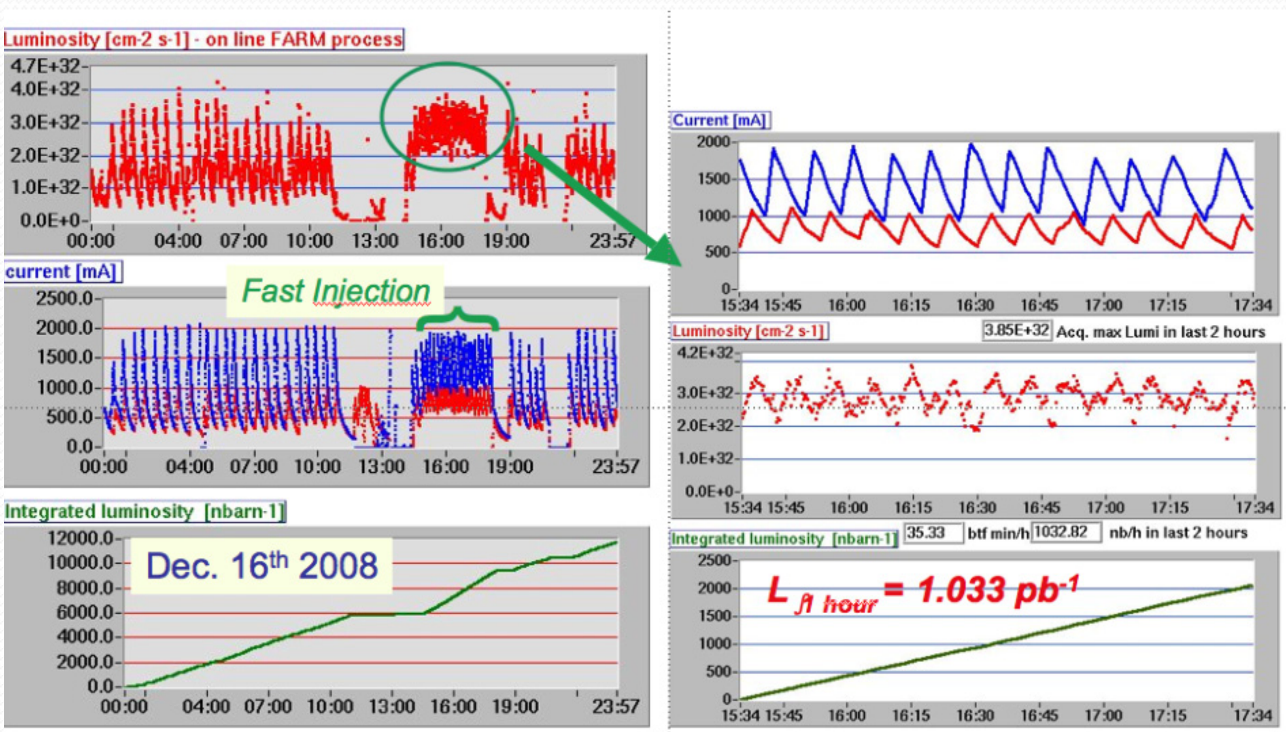
Beam size in collision (beam-beam luminosity scan)



Luminosity measured at different longitudinal positions of the collision point (changing RF phase) → Fit gives convoluted beams dimension at crossing

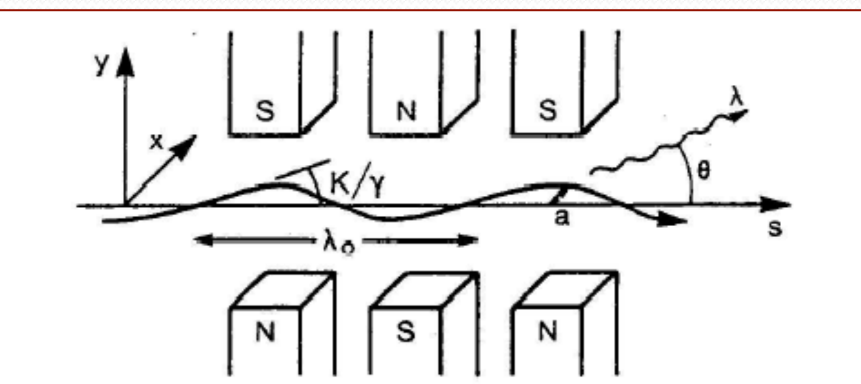
Integrated luminosity (example)

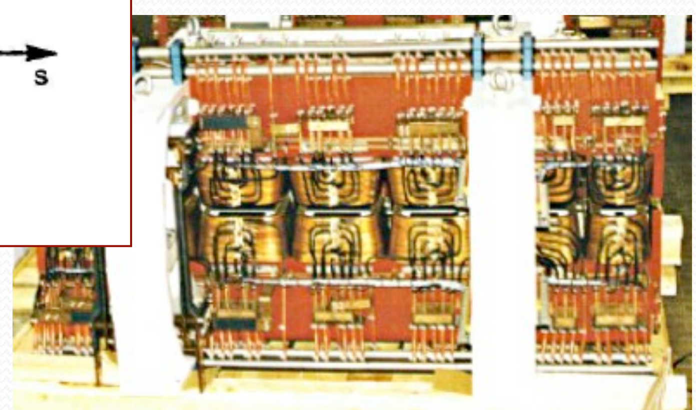
- The measure of collider performances is not only the peak Luminosity, but the integrated Luminosity, that gives the number of events collected by the experiment, and must be the largest possible

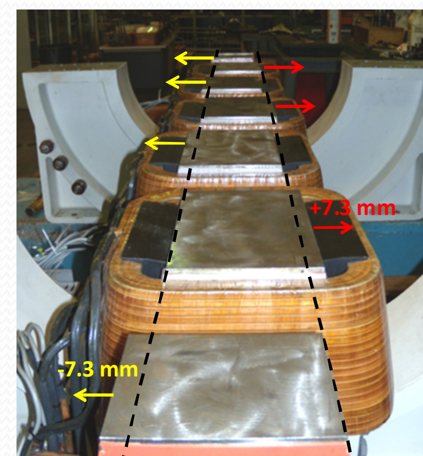


DAΦNE wigglers

- Wigglers, multipolar magnets with alternating positive and negative B field, are use to increase the natural damping and manipulate the emittance
- The beam orbit “wiggles” with a small amplitude around the ideal orbit, emitting photons that are used from synchrotron light users
- At DAΦNE 4 wigglers are installed in each ring
- Recently a modification of the arrangement of the poles has allowed to correct intrinsic non-linearities improving the dynamic aperture

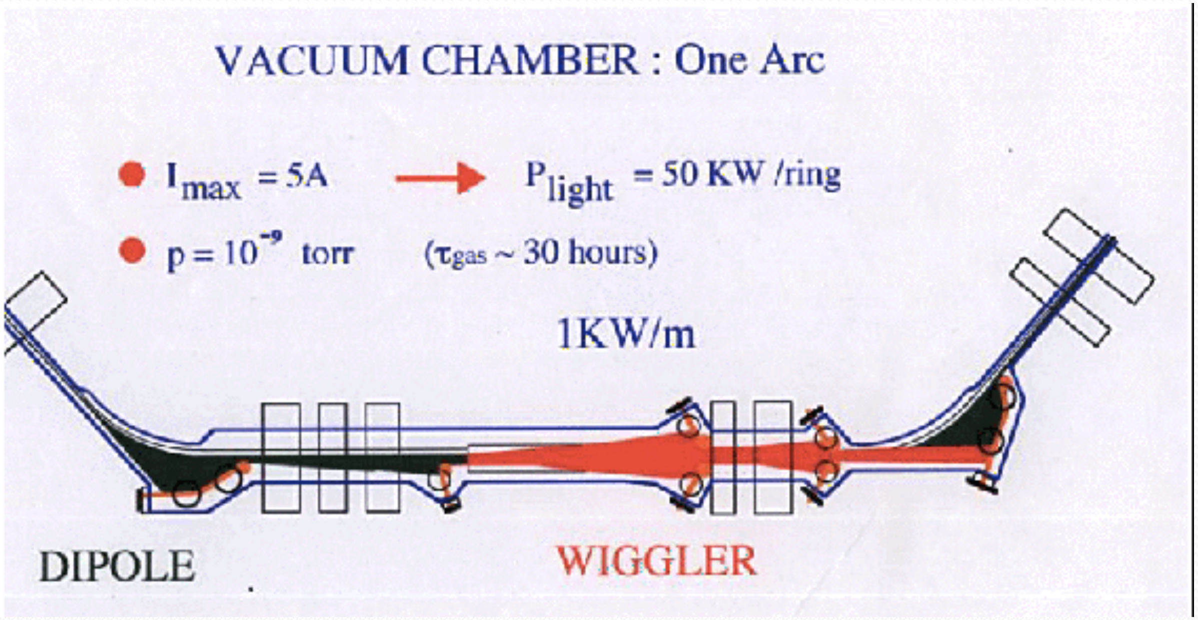




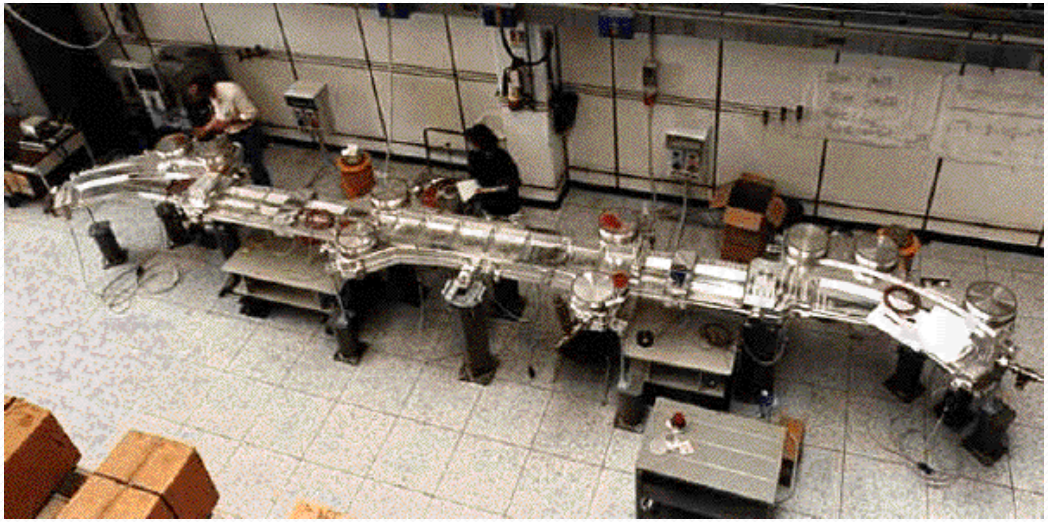


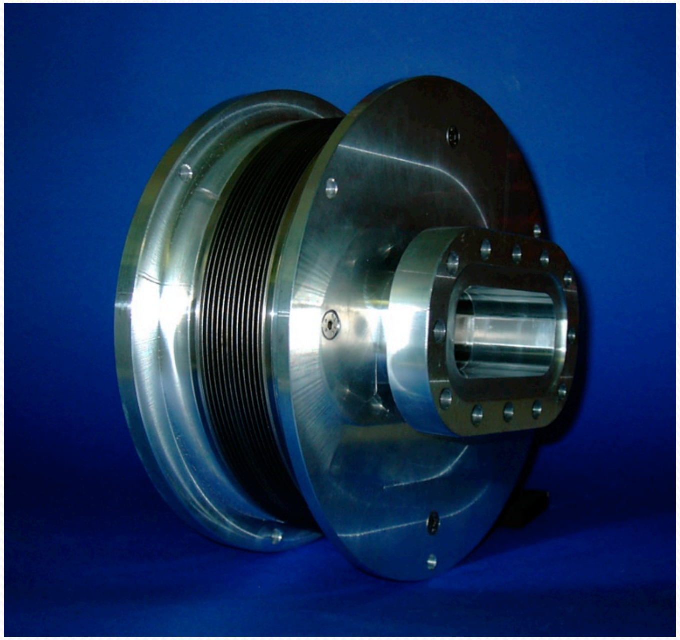
DAΦNE Arc Vacuum chamber

- Specially designed stainless steel chamber
- Radiation from dipoles and wiggler travels through the slots to the antechamber, where it hits special water-cooled copper absorbers.
- Near each synchrotron radiation absorber there is a titanium sublimation pump (~2000 liters per second)



DAΦNE Arc vacuum chamber (one piece)





Bellow, used to join different beam pipe pieces

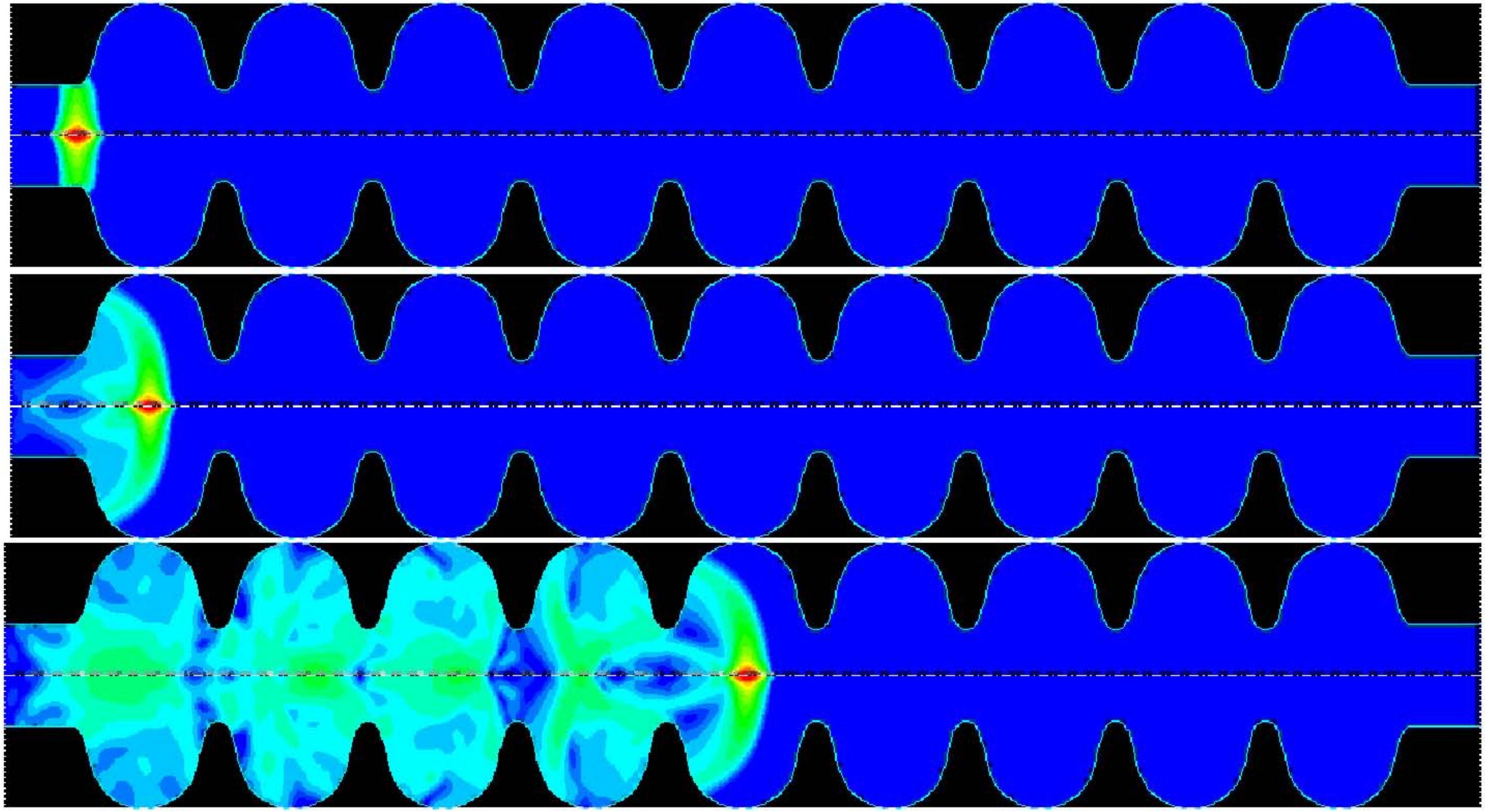
Collective effects

- The particle motion in reality is non independent (i.e. "incoherent"), besides the charge in high intensity beam can be very high (order of Amperes)
- What happens if all particles move in phase ("coherent" motion) when excited ?
- Particles interact in 2 ways :
  - Direct Coulomb Interaction (space charge effects, Intra Beam Scattering,…)
  - Through the beam pipe (transverse and longitudinal instabilities)

Collective effects 2

- A particle is a "source" of e.m. fields: self fields
- These fields interact with the environment (beam pipe, RF cavity, diagnostics), are modified and interact back with the beam
- Small perturbations to the bunch motion change these induced fields: if this change amplifies the perturbation (for ex. with variations of the beam betatron and synchrotron frequencies) instabilities can occur, with consequent modification in the beam distribution, bunch lengthening, possible beam loss
- These phenomena, dependent on the number of particles in the bunch, are called "collective effects"

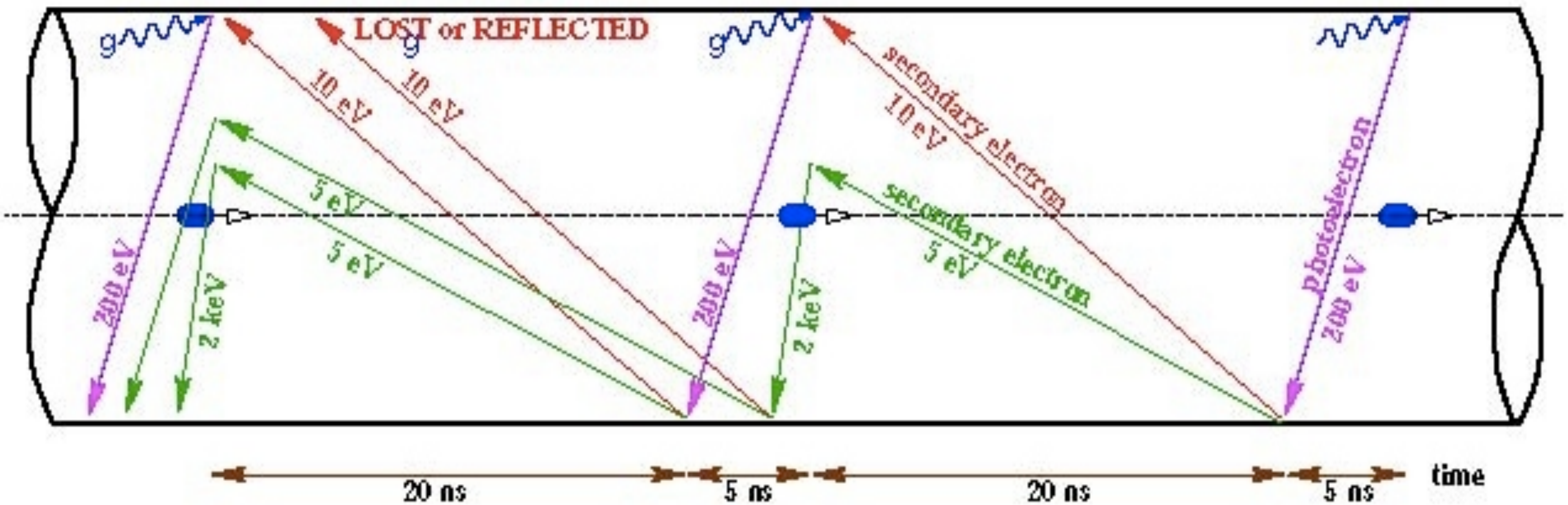
Example of "wake fields"



The e.m. fields induced by the beam can act on the particles arriving later (tail of the bunch) or even in the following turns ⇒ Instability

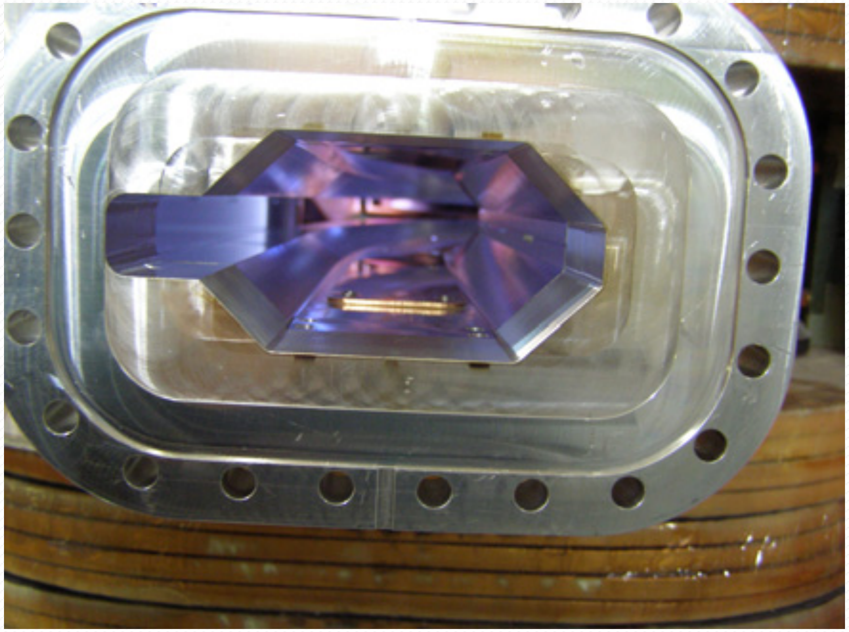
Example of collective effect in DAΦNE positron ring: electron cloud instability

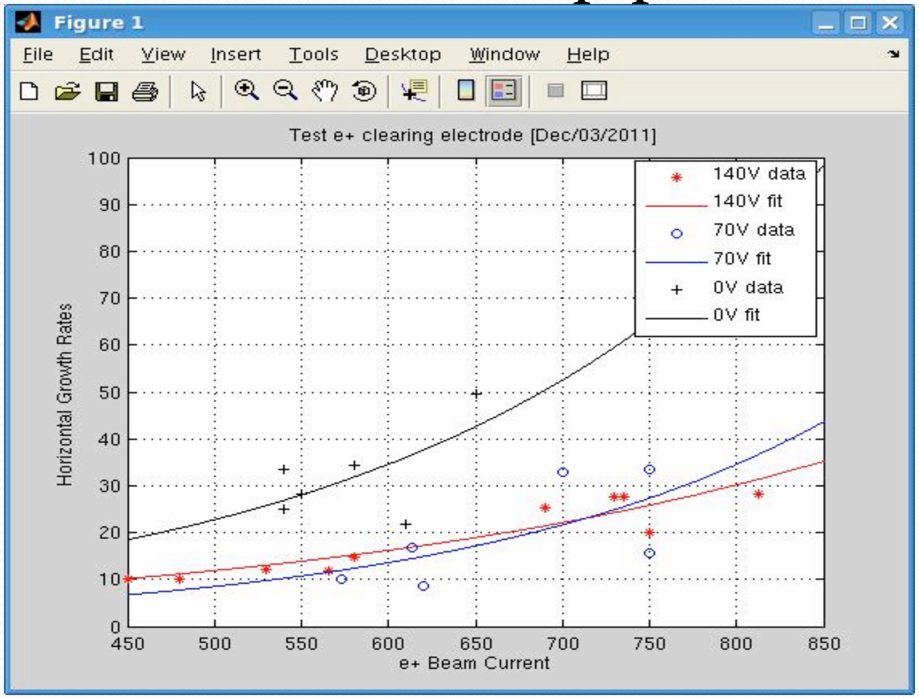
- "*Electron cloud*" instability comes from the interaction between the beam and the vacuum chamber for positively charged beams (positrons, protons, heavy ions)
- The beam emits synchrotron radiation → photons hitting the pipe walls emit photo-electrons that bounce on the walls, with a "cascade" effect
- This effect is amplified by the successive passages of many bunches
- Photo-electrons produce secondary electrons: the number depends from the secondary emission coefficient SEY of the pipe material (which has to be reduced as much as possible)



e-cloud clearing electrodes

- In DAΦNE this instability has been reduced by installing in the dipoles and wigglers special electrodes whose voltage can attract photo-electrons back to the pipe walls

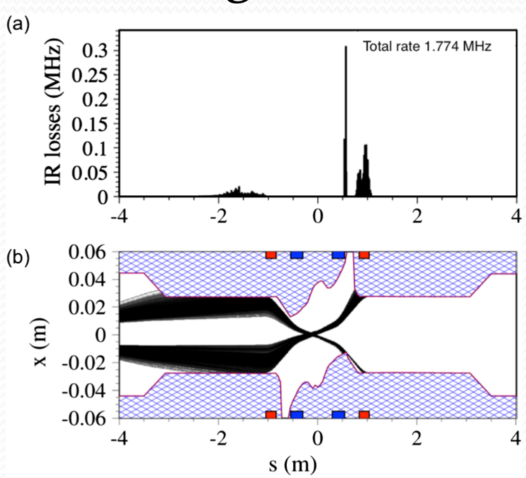




Instability growth rates (ms^{-1}) vs. beam current (mA) at different voltages applied to the clearing electrodes

Touschek effect

- Touschek effect is a Coulomb scattering between 2 particles in the same bunch at large angle, associated with a transfer of momentum from the transverse plane to the longitudinal plane.
- As a consequence particles with a large energy deviation can be lost outside of the accelerator acceptance
- Total effect is the decrease of the beam "lifetime" (up to few minutes!)
- Usually important for energy below 2 GeV. In DAΦNE is a dominant effect
- It depends from energy acceptance of the RF cavity and the dynamic aperture
- An intense work is routinely done to mitigate this effect with collimators and improving the dynamic aperture
- Monte Carlo tracking codes allow to predict lost particles rates and position



(a) IR loss particles distribution for the KLOE crab-waist optics, with scrapers at their experimental set.
(b) Trajectories with hit positions on the physical aperture that the particles actually see.

Conclusions

- Among all e^+e^- colliders DAΦNE is unique also as a test bench of new ideas in the Accelerators field
- The present performances are close to the top for an accelerator of this low energy
- Continuous work is spent in optimizing the beam properties and luminosity, and in maintaining all hardware components performances at their best
- Optimizing the collider performances is generally a difficult task, but in DAΦNE one has also to cope with the reliability of hardware systems designed and built almost 20 years ago
- The Physics of colliders is a difficult but very fun field!

Thank you for your attention !