DAΦNE: results and consolidation activities

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on behalf of the DAΦNE Team

47th LNF Scientific Committee, Frascati, 14-15 Nov. 2013

Outline

- *shutdown activities overview*
- *DAΦNE start-up in July*
- *Fixing unexpected problems*
- *commissioning results*
- *Conclusions*

DAΦNE activities

DAΦNE shut-down started on December 16th 2012 and was expected to end up by mid June 2013.
It was intended to consolidate the collider and to upgrade the KLOE detector

Consolidation activities involved almost all the components and the subsystems of the DAΦNE accelerator complex:

- auxiliaries' automation and control system
- Cooling system
- Cryogenic plant
- Magnets and power supplies
- Modification of the LLRF controllers
- Linac
- Control system
- Vacuum installation (windows, scrapers actuators, electrode power supplies
- new horizontal kicker for the MRe feedback
- Additional BPMs and improved tools for beam profile measurements

IR consolidation

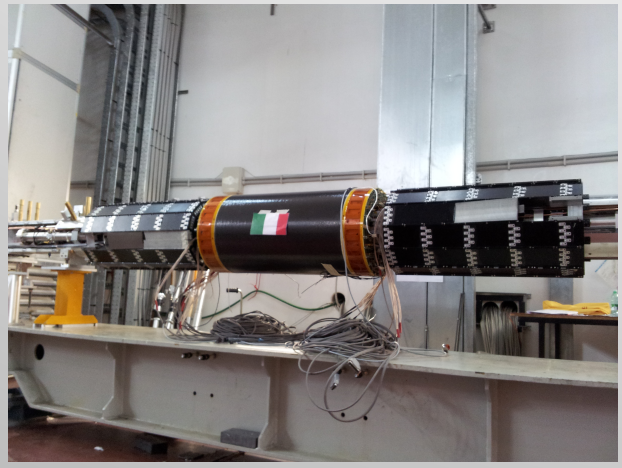
IR vacuum chamber evolution

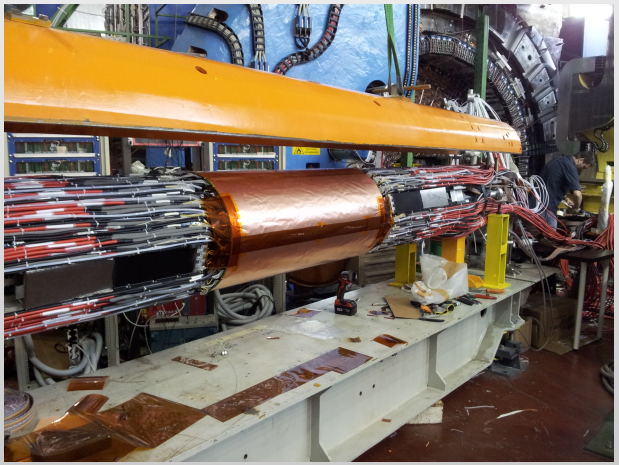
- Single vacuum chamber tapered
- New bellows with improved design
- 2 BPMs around the IP
- water cooling added
- New beryllium screens

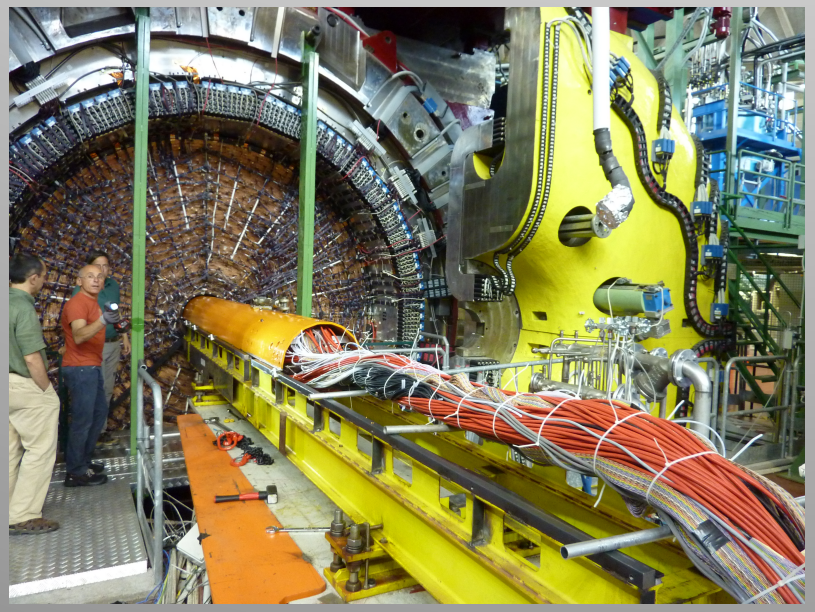
Mechanical modification

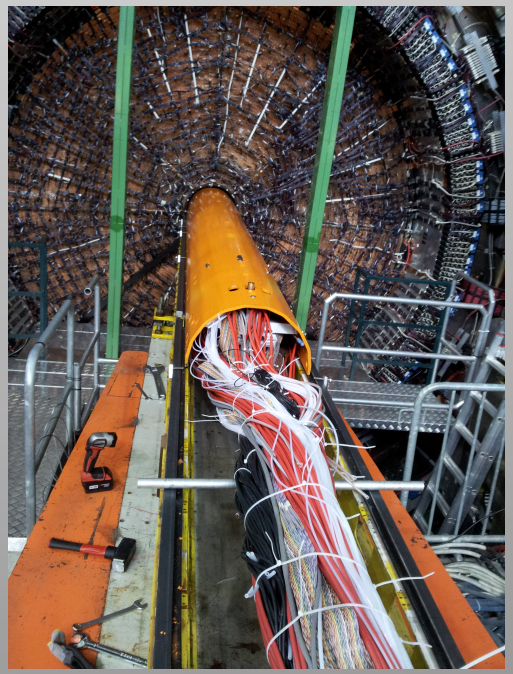
- New Cylindrical vacuum chamber support
- H supports reinforced with plates
- Modification of tail support of the girder
- Temperature probes added
- Carbon fiber composite additional supports
- Lead toroidal shields added
- Alignment tools improvements
-

The new KLOE detector layers have been wired
Whole structure has been inserted inside the experimental apparatus

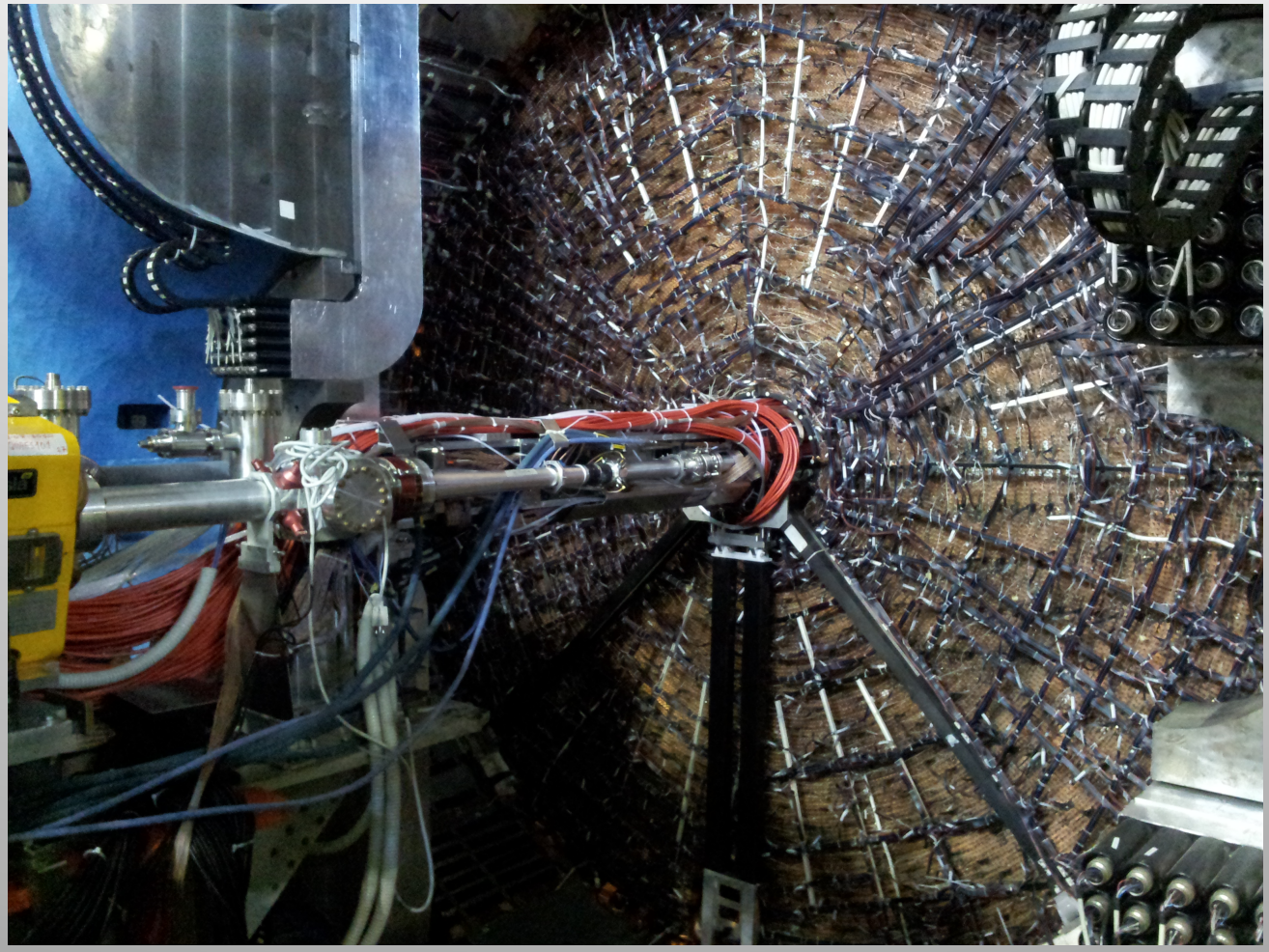








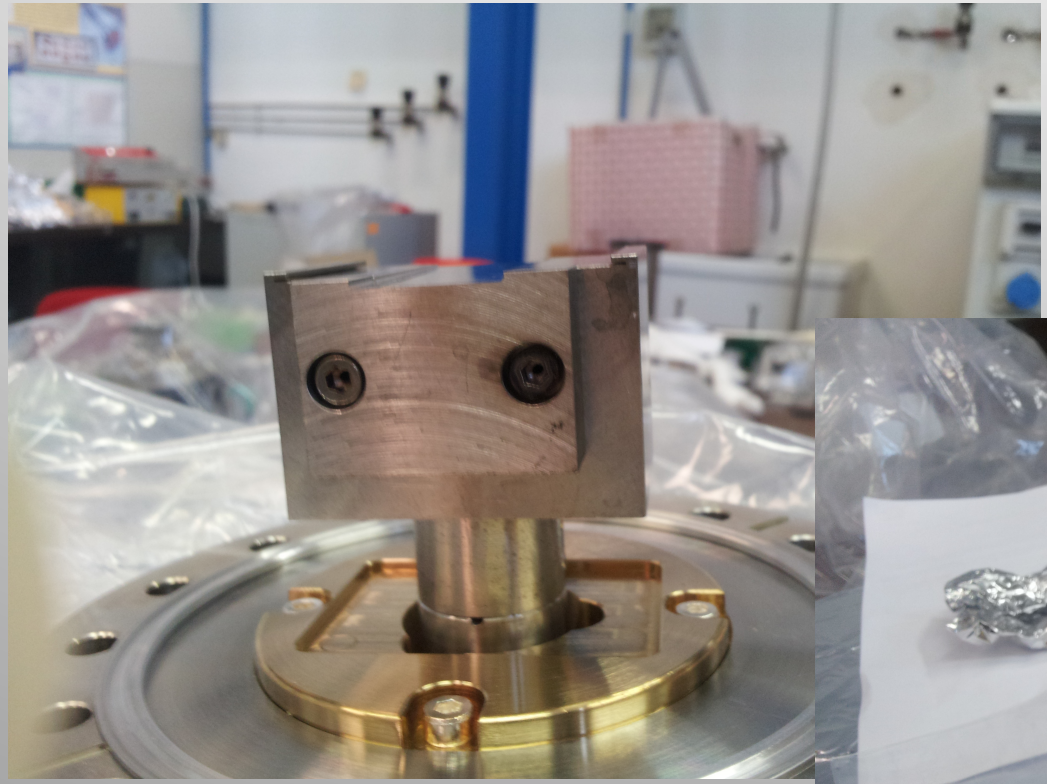
Third carbon fiber support installed

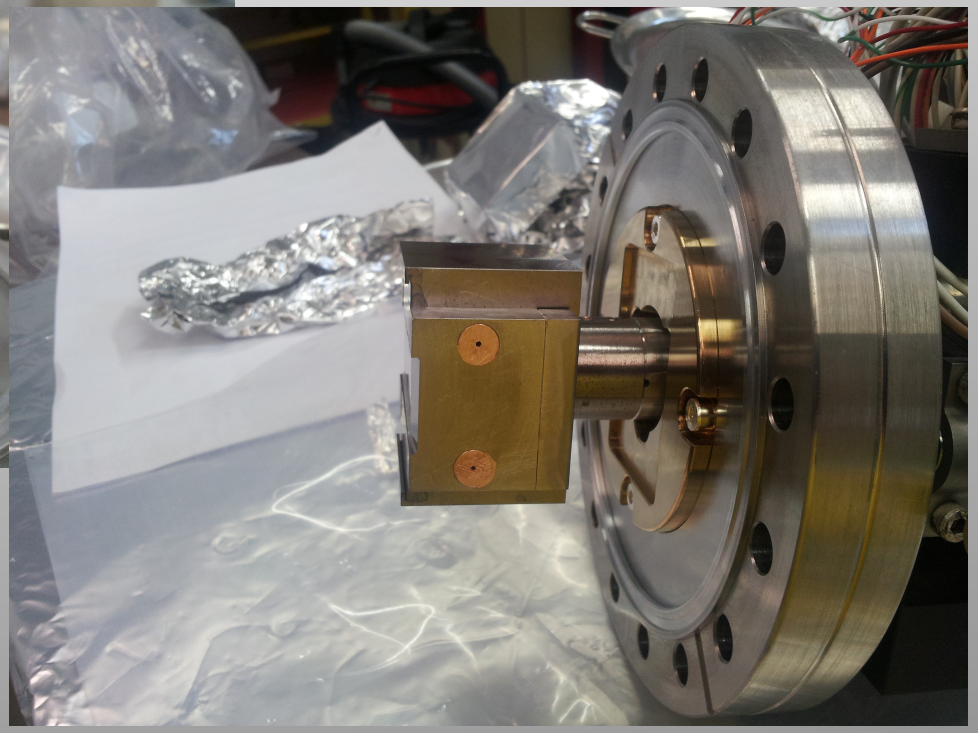


IR branches outside the detector reassembled and aligned
Shut-down activities completed by mid July

Collimators

Collimators installed at the two sides of the IP and of the RCR have been modified





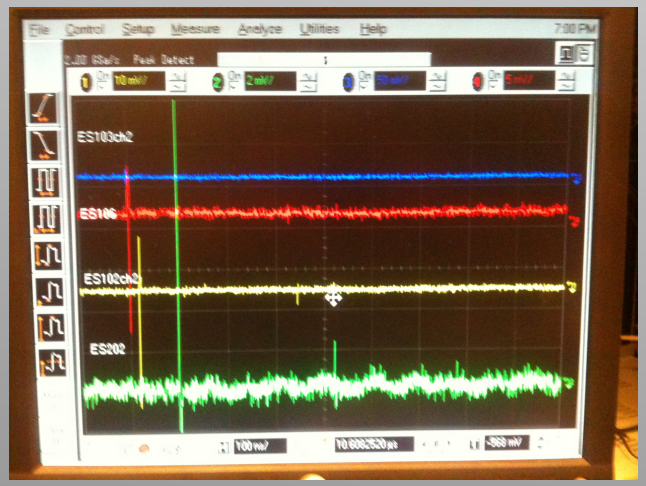
DAΦNE warm-up (before summer)

Commissioning restarted by end of July:

- Jul 16th - 17th radioprotection measurements
- Jul 18th - 19th shielding structure installed (after RCR e-)
- Jul 22nd KLOE-2 end-caps closed

Machine shutdown was planned on August the 2nd in the morning

Activities have been prolonged by few more days to understand why transporting the e- beam through the ring was almost completely impossible ....

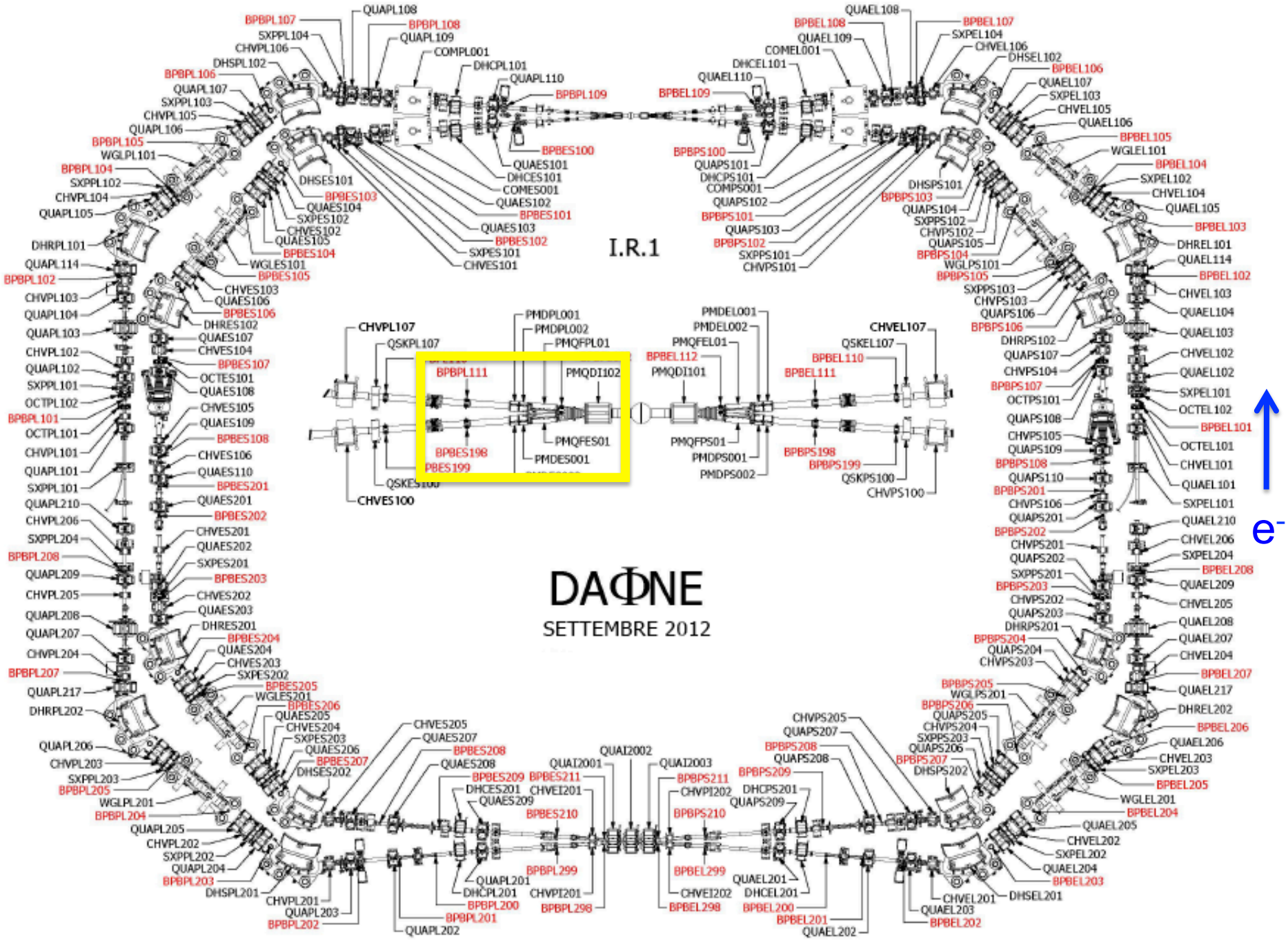


Uptime quite low since:

- new subsystems had bugs to be fixed
- electrical cables mixed for some magnets
- wrong polarities due to the power supplies maintenance

Severe faults affected:

- Linac modulators and gun
- Power supplies
- Cooling system
- Mechanical part of one cooling tower


I.R.1
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WGLPL101
QUAES101
BPBPL104
DHCES101
SXPPL102
COMES001
CHVPL104
DHSES101
QUAES102
QUAPL105
BPBES103
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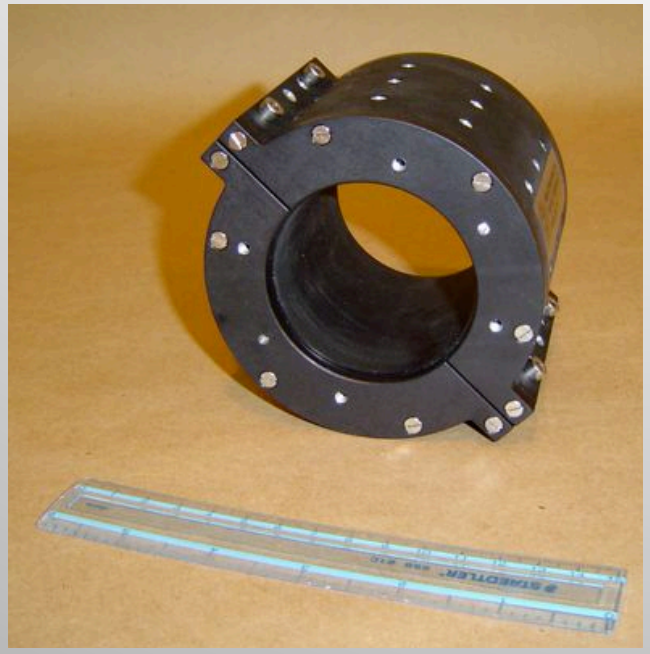
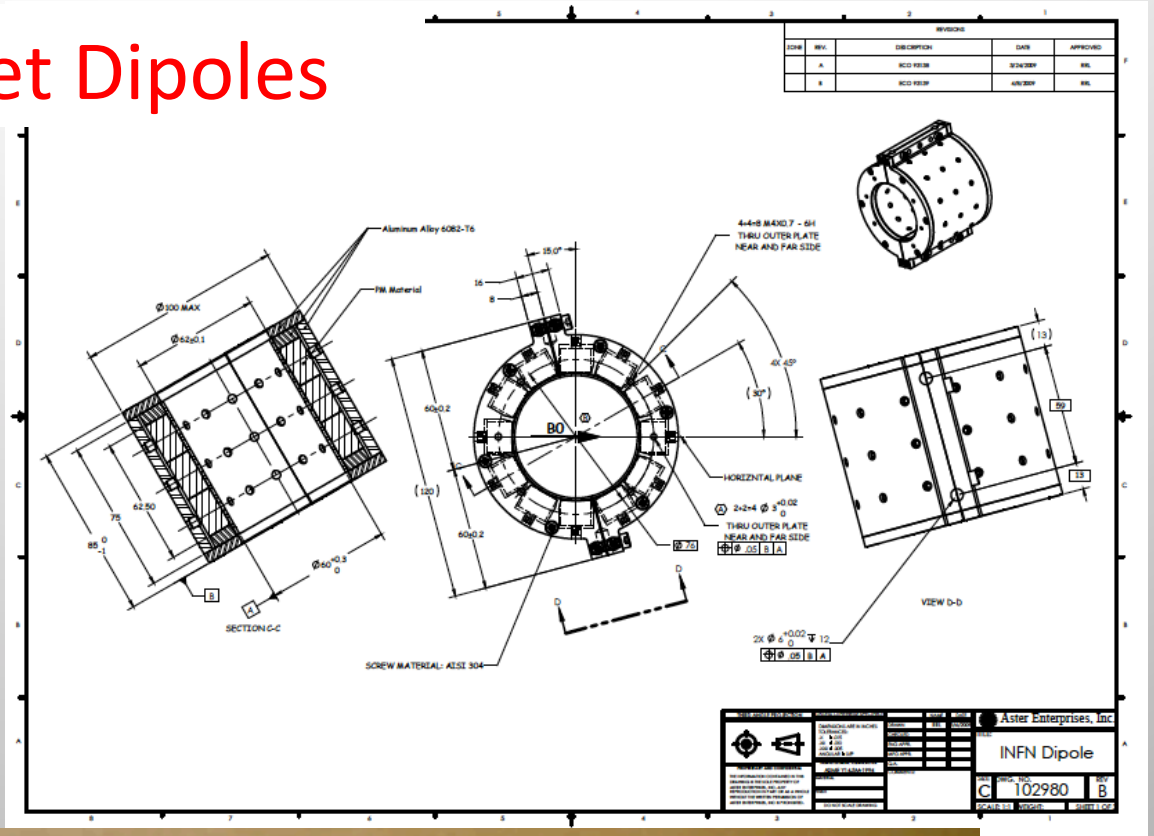
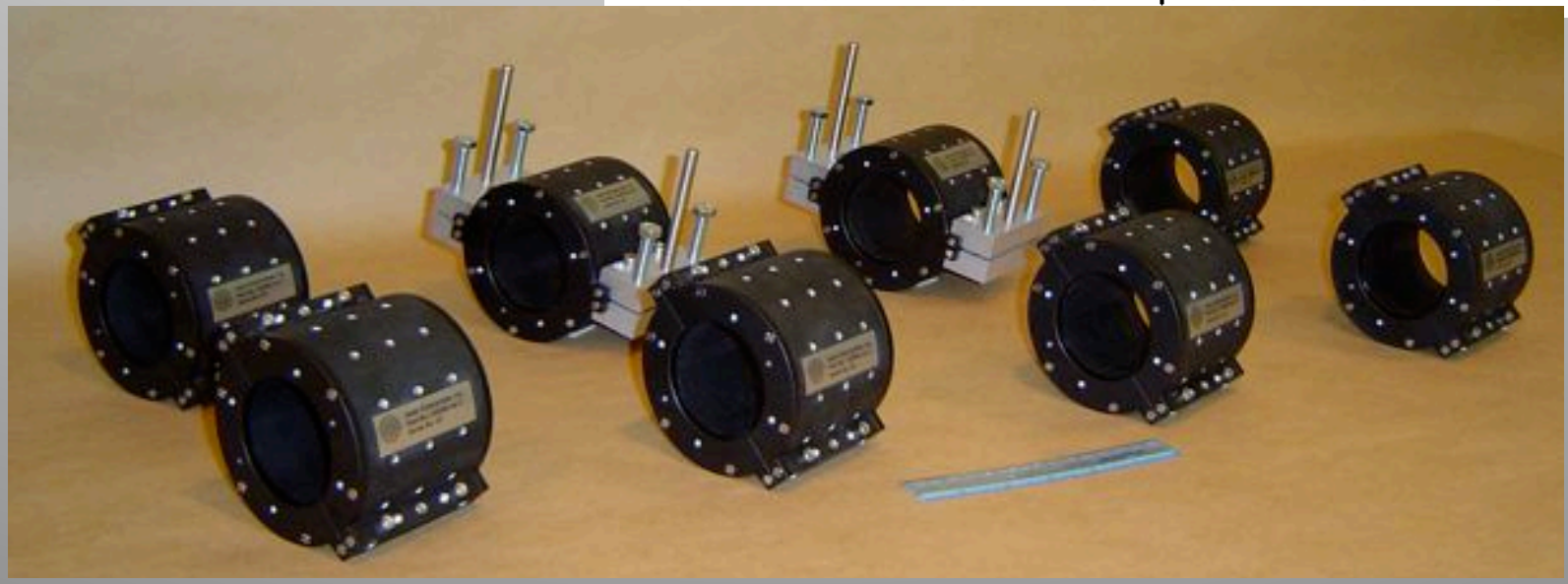
Permanent Magnet Dipoles



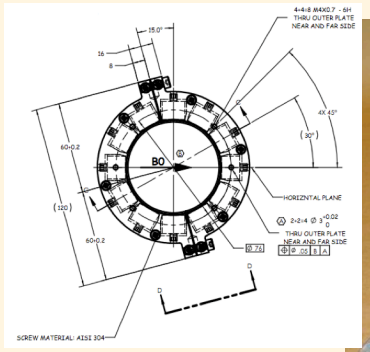




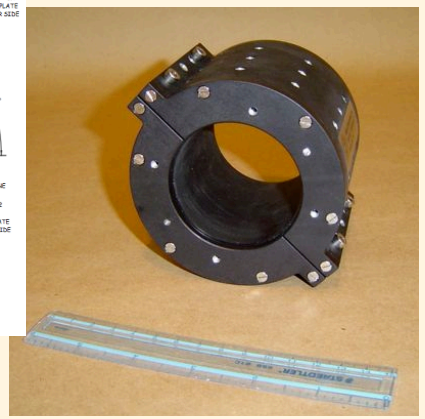
Beam Trajectory in the new IR

- *The beam trajectory in the IR is an order of magnitude larger than in the past KLOE run due to:*
  - *larger crossing angle*
  - *stronger first low-β quadrupole (PMQD)*
  - *experimental solenoidal field*

- *A **Permanent Magnet Dipole** is used to keep under control the vertical beam trajectory.*

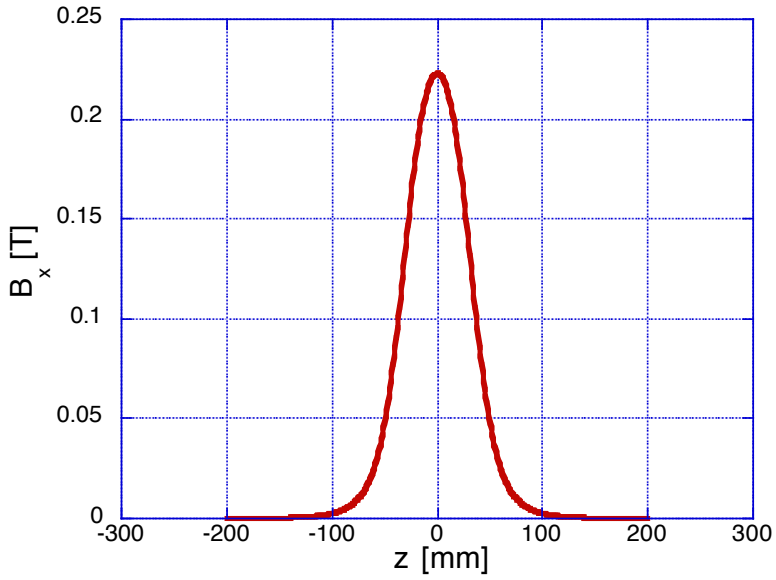


Magnetic length (mm) 75
field (T) 0,22933
Good field region radius (mm) 15
Magnet material type SmCo



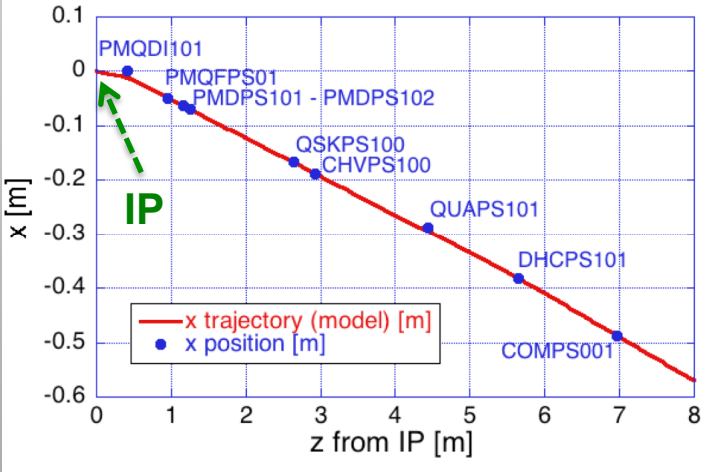
PMD consists of two halves each of them:

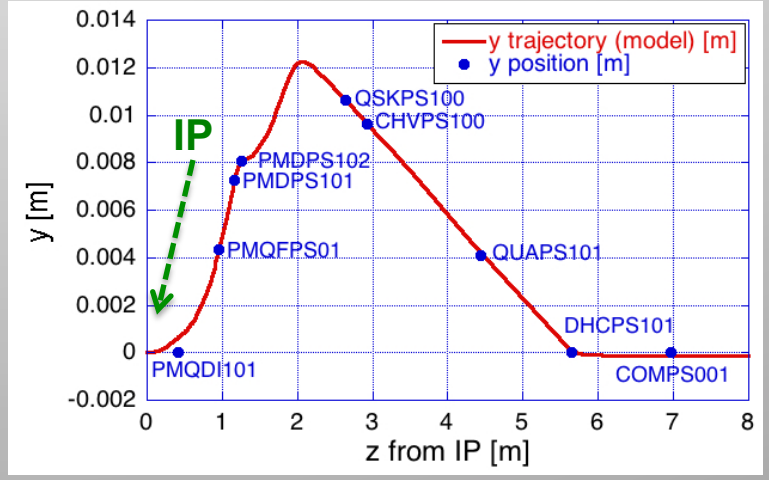
- Magnetic length 75.0 mm
- BL = 0.0168 Tm
- Bx is directed inward and outward in the e + and e- rings respectively
- α_y ~ 10.0 mrad



Beam Trajectory in the IR

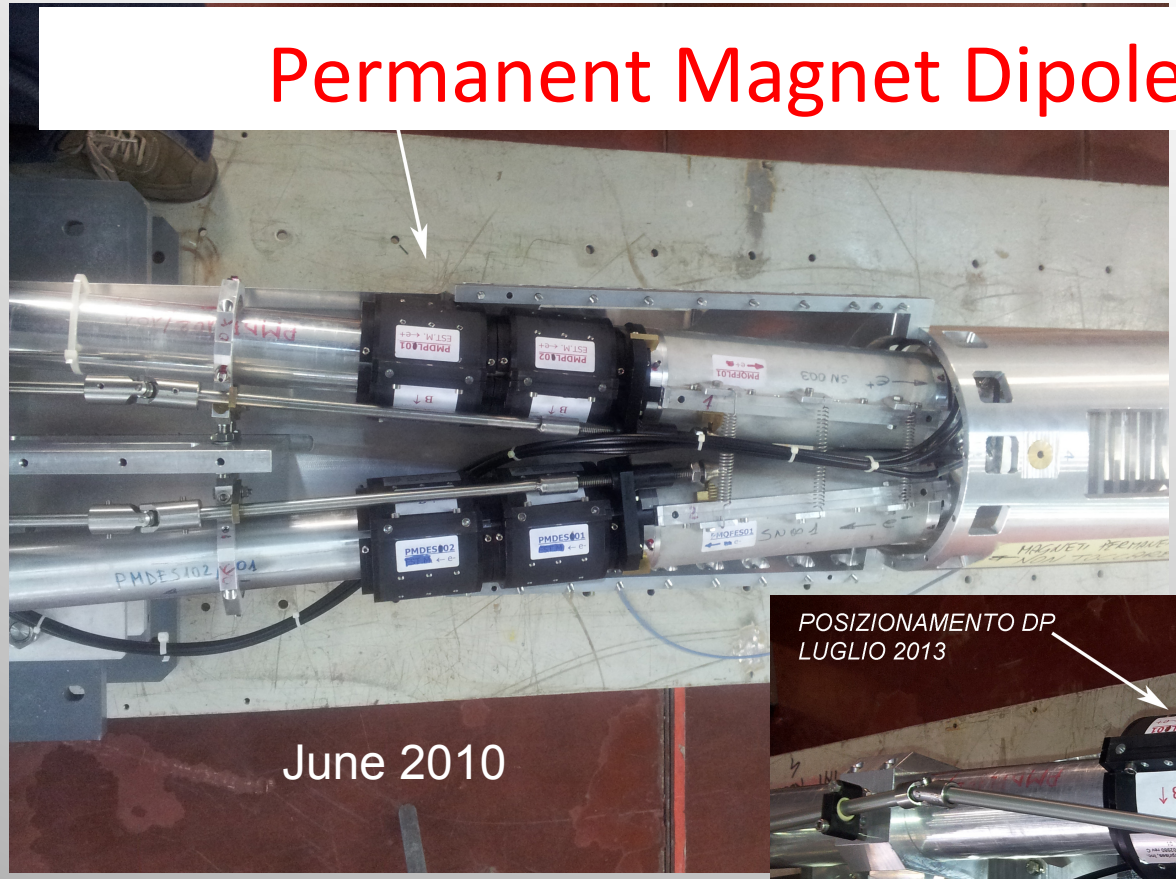
QUADs are centered as much as possible on the beam trajectory to improve beam acceptance.
Vacuum chamber design is very much simplified: straight sections and few bellows

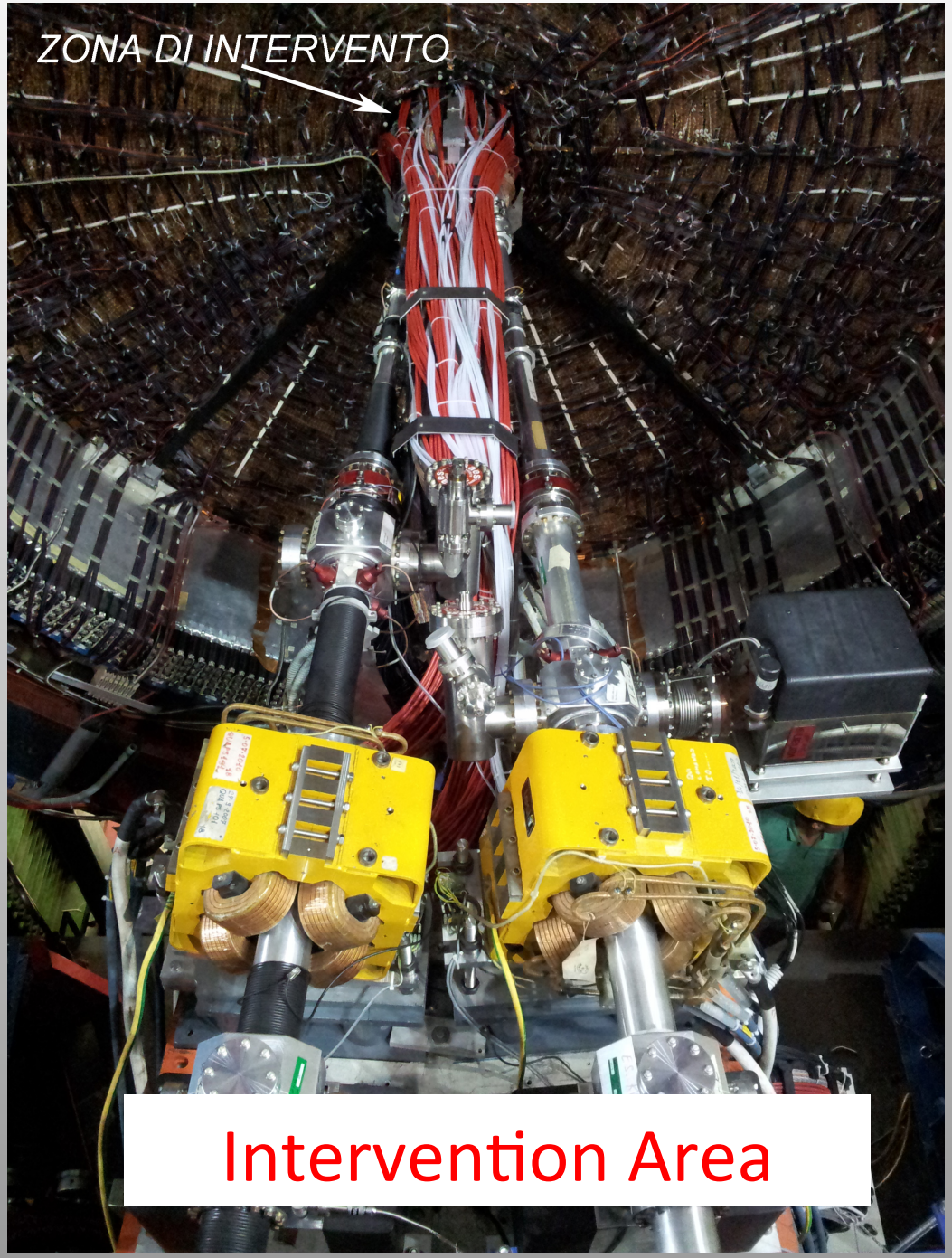




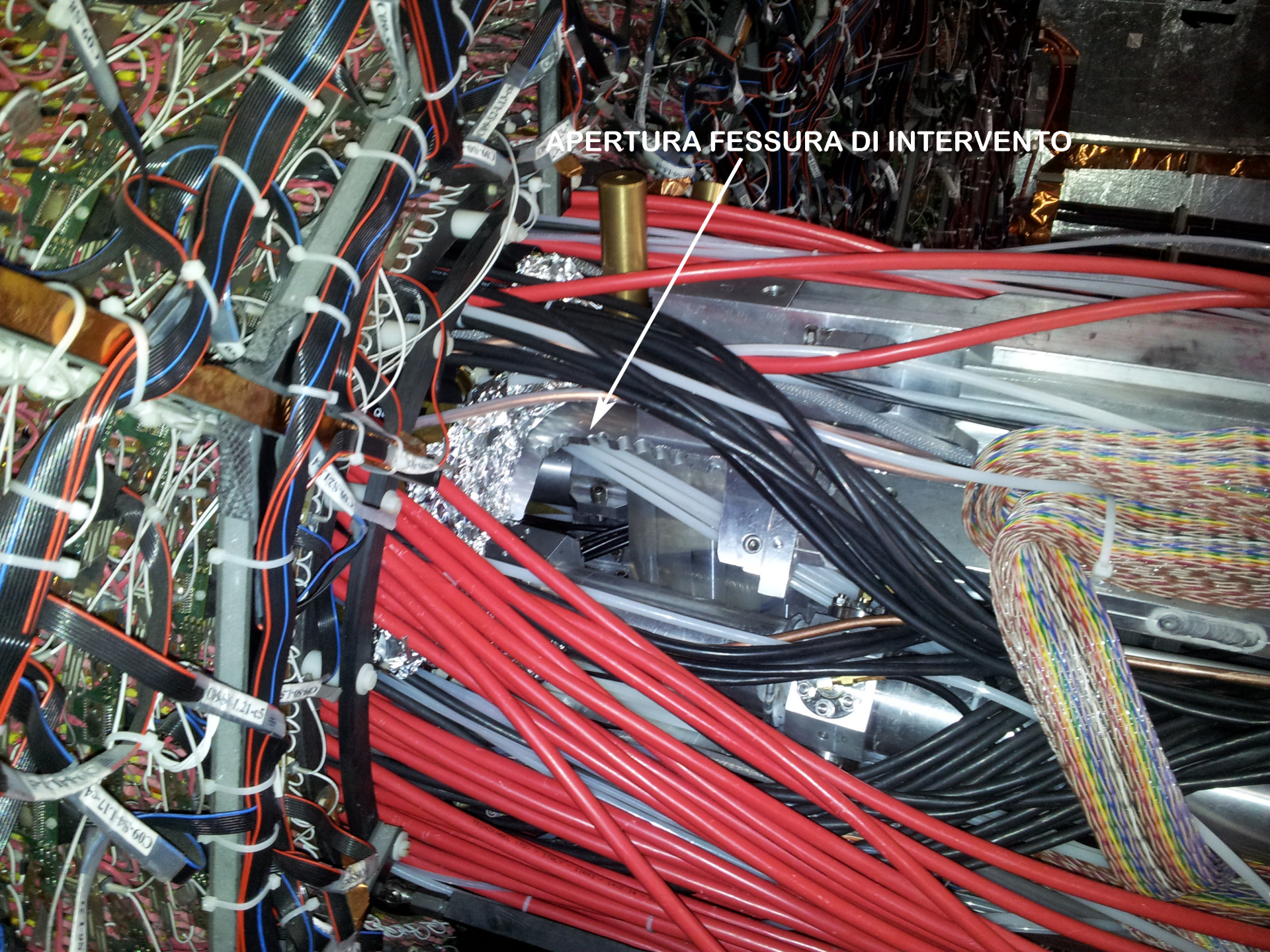
Trajectories and element position for the IR branch of the positron ring pointing to the short arc the corresponding branch for the electron ring being symmetric

Permanent Magnet Dipoles Installation



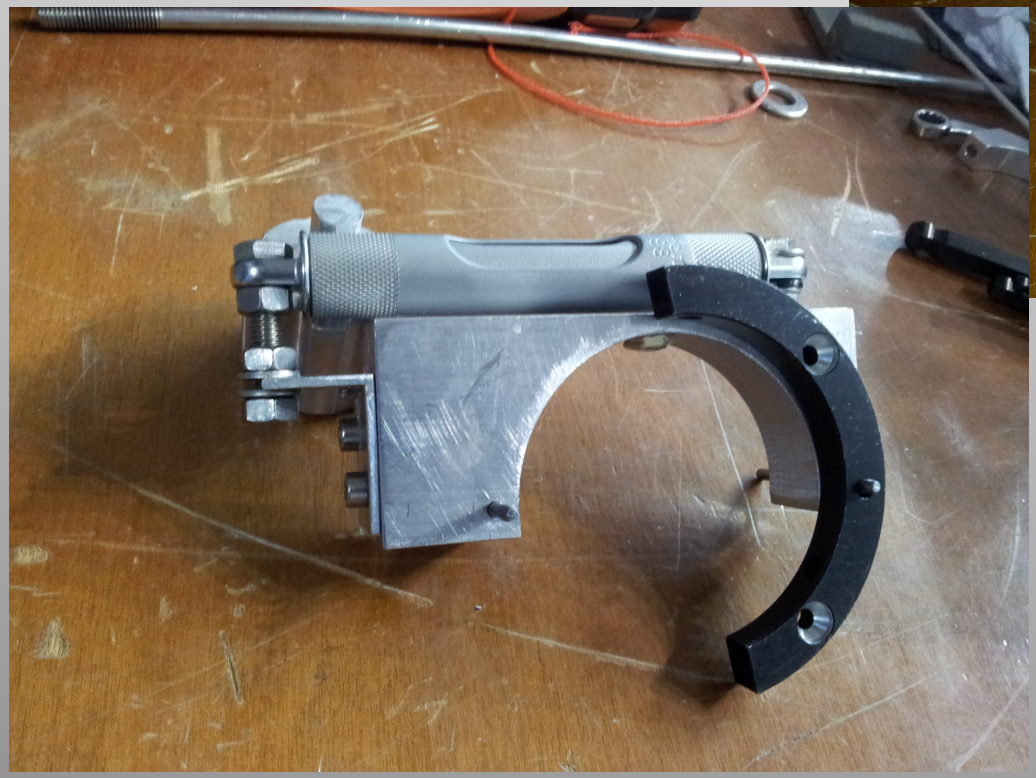

ZONA DI INTERVENTO
Intervention Area

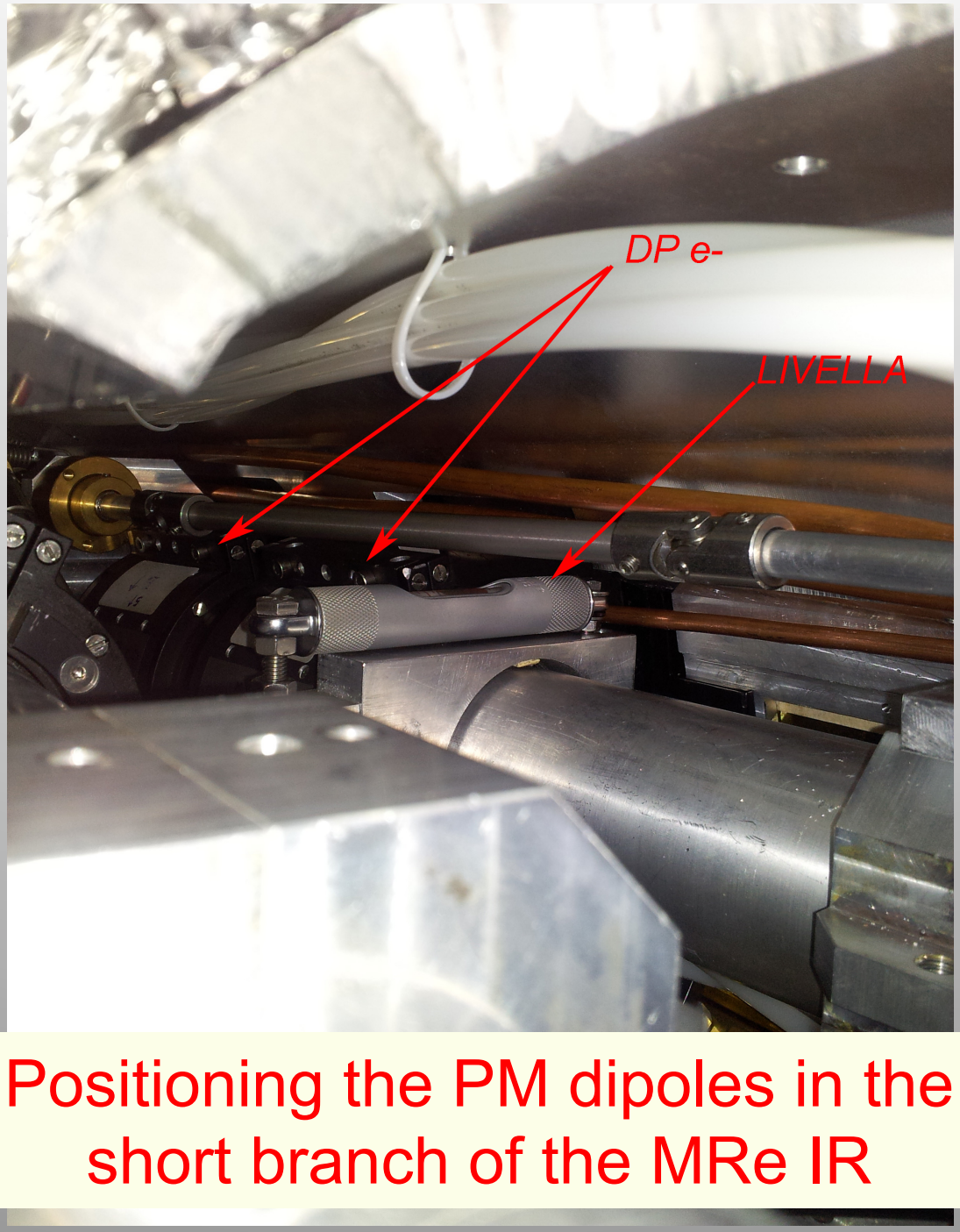

VISTA PRIMA DEL TAGLIO


APERTURA FESSURA DI INTERVENTO

Positioning Tool

Based on a centesimal grading bubble level

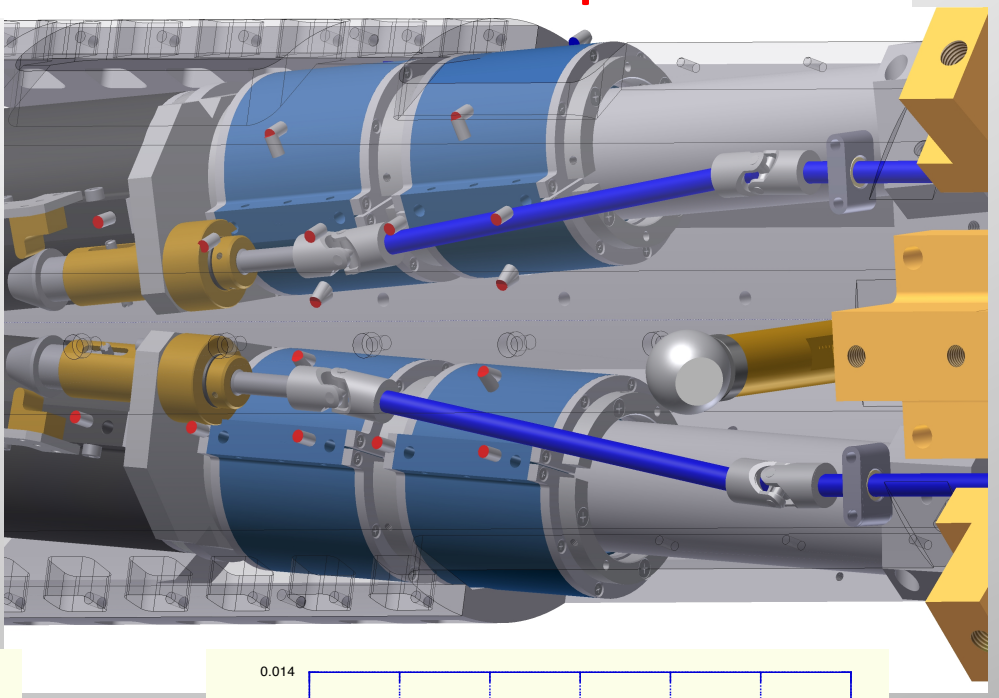


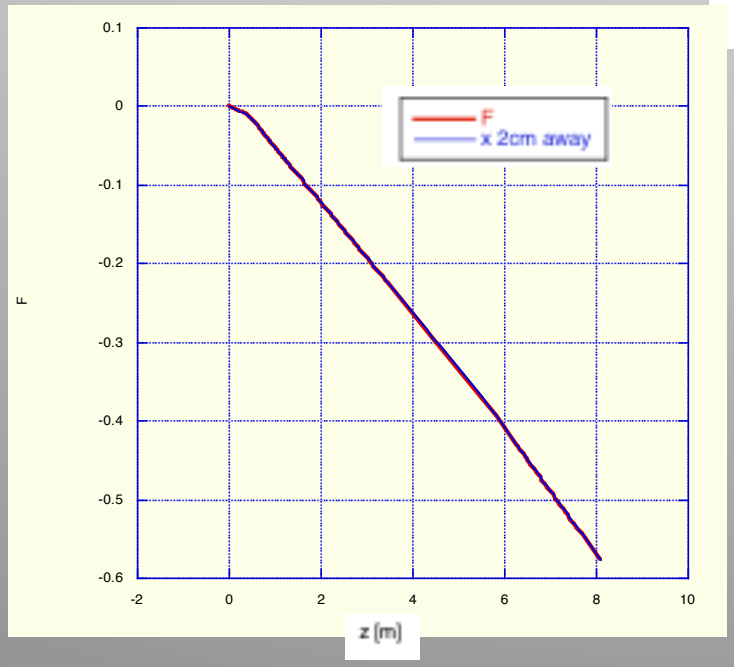


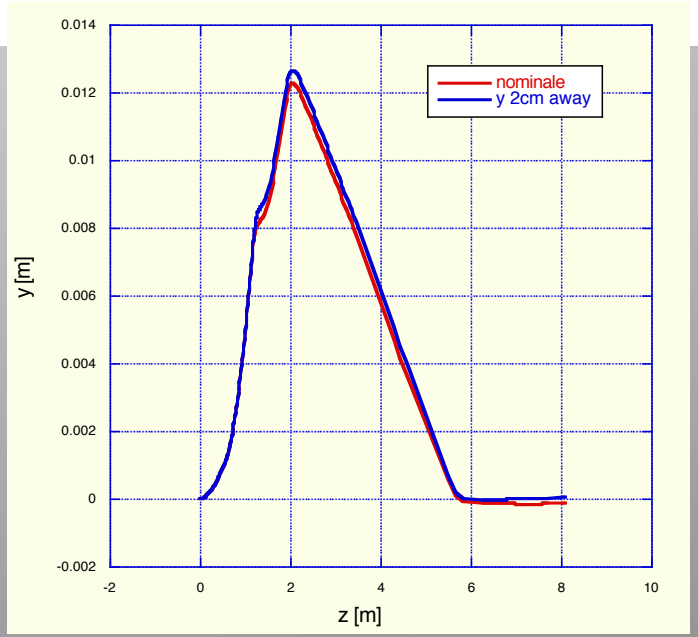
Positioning the PM dipoles in the short branch of the MRe IR

Longitudinal position of the PM dipoles

Mechanical interferences imposed to shift the dipoles, in the short IR branch of the MRe ring, 2cm away from the IP in the longitudinal direction







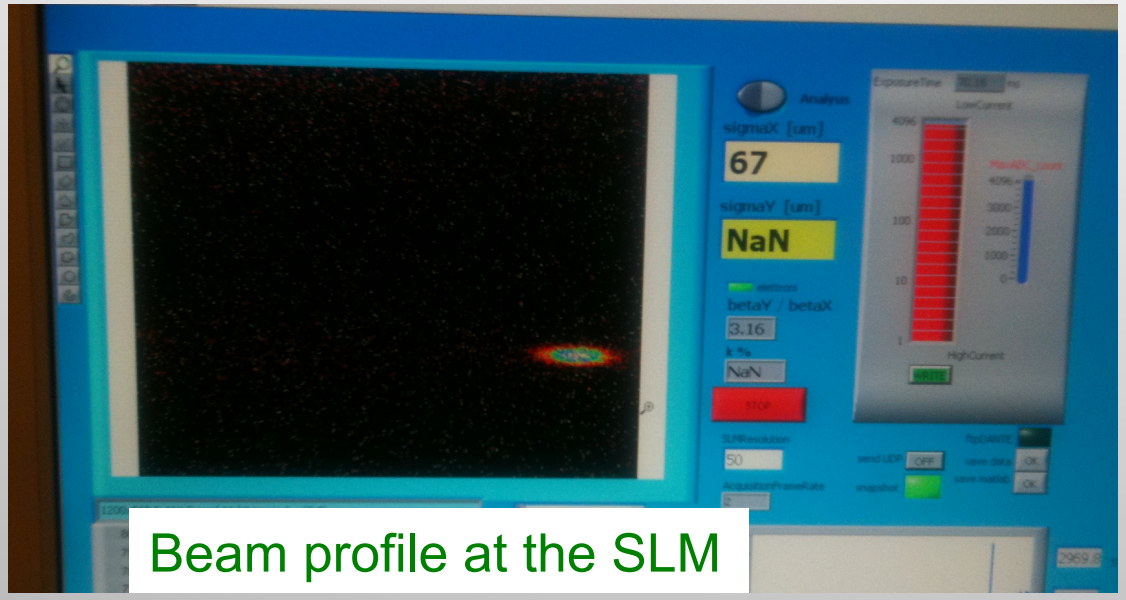
September the 5th

permanent magnet dipoles in the right position thanks to the fantastic collaboration between DAFNE & KLOE people (Sensolini, Paris, Putino, Mascio & Martini)

September the 10th

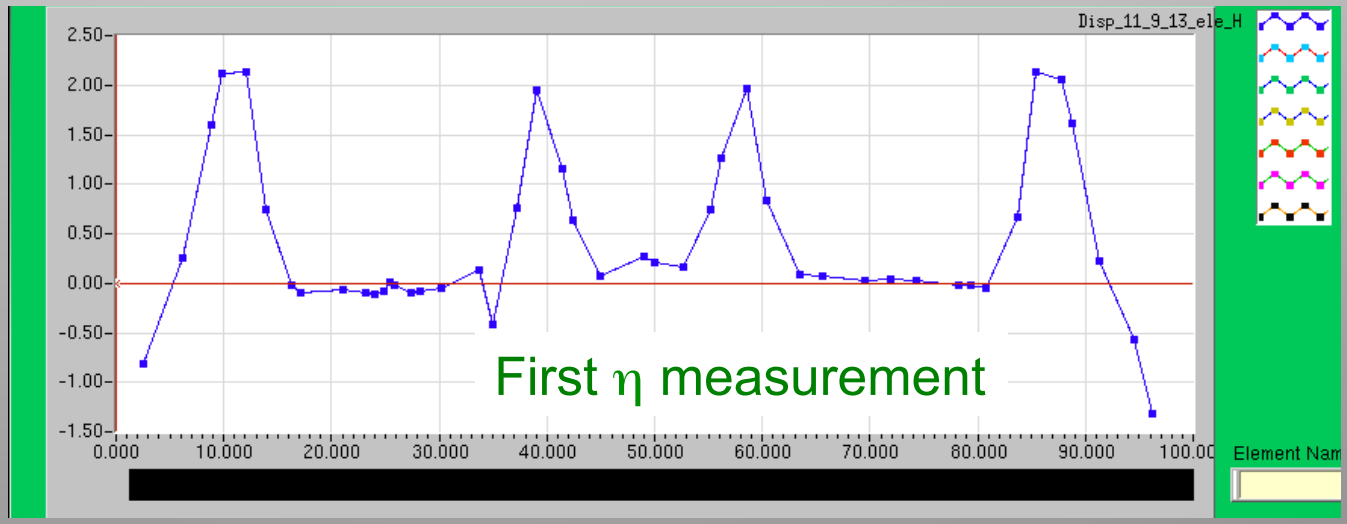
KLOE end-cap closed

First beam on September 11th 2013



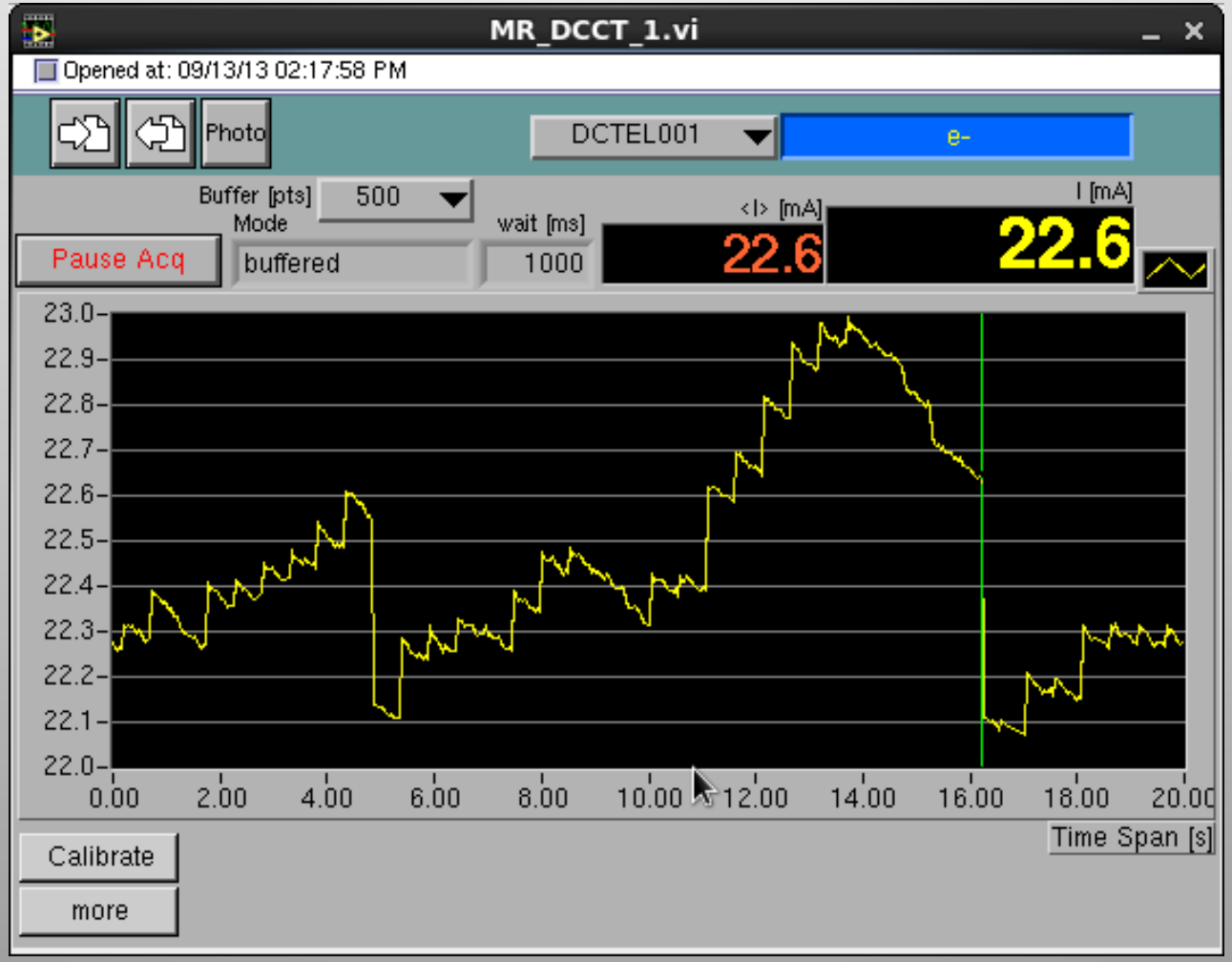
Beam profile at the SLM

electron beam stored in few hours!!!



First η measurement

Single bunch current
(September 13th 2013)



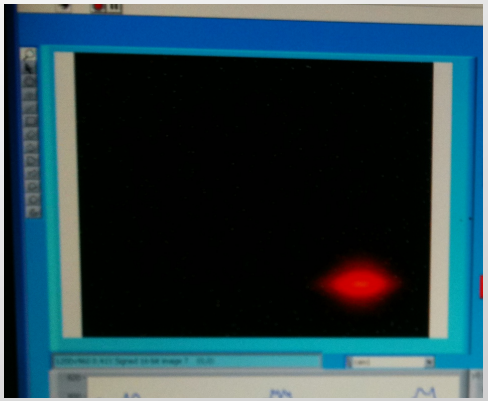
50 bunches
14/9/2013

After:

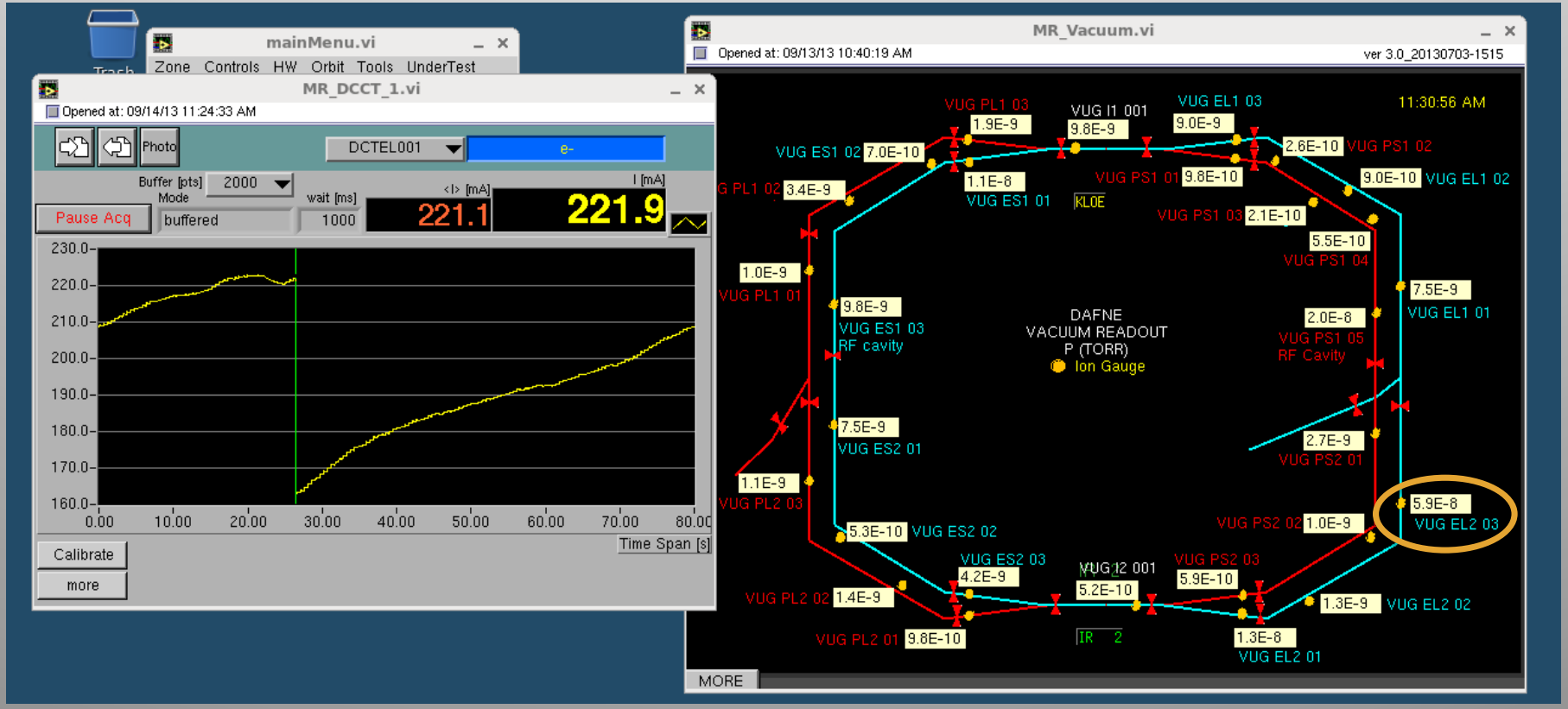
Sublimation

Optimization concerning:

- Injection
- orbit
- tunes
- transverse beam size
- bunch length

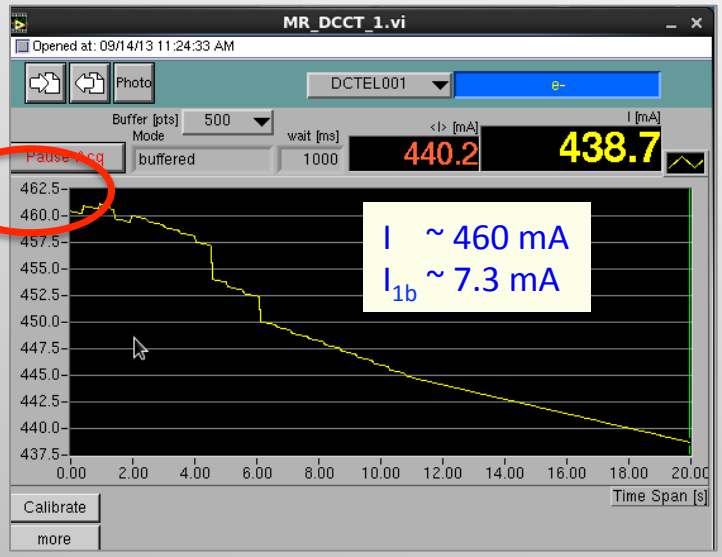


$I_{1b} \sim 4.4$ mA



63 bunches

September 15th 2013

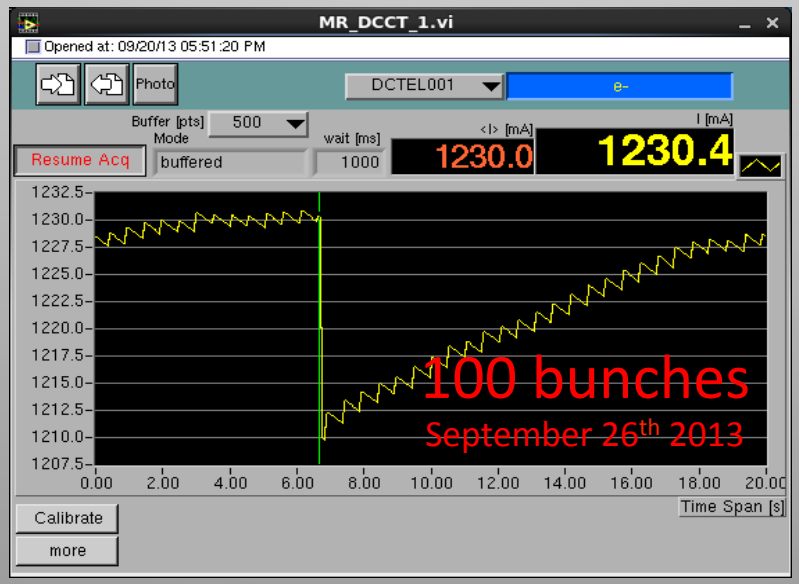


Beam current limited by collective effects:

- Transverse beam size grows with the current due to ion trapping
- transverse instabilities appear above ~ 460 mA.

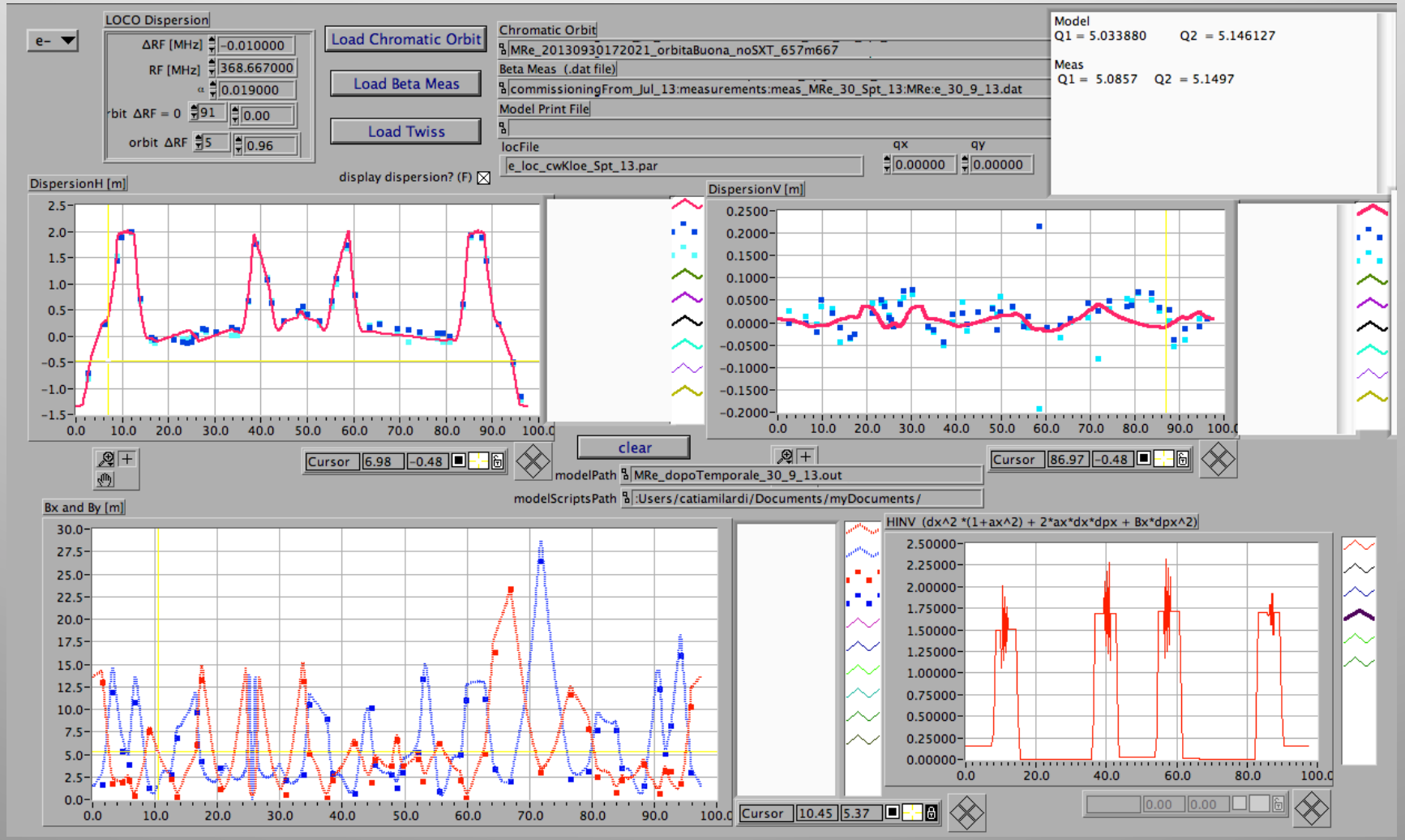
Further improvements required:

- recovering optimal vacuum condition
- tuning transverse feedbacks

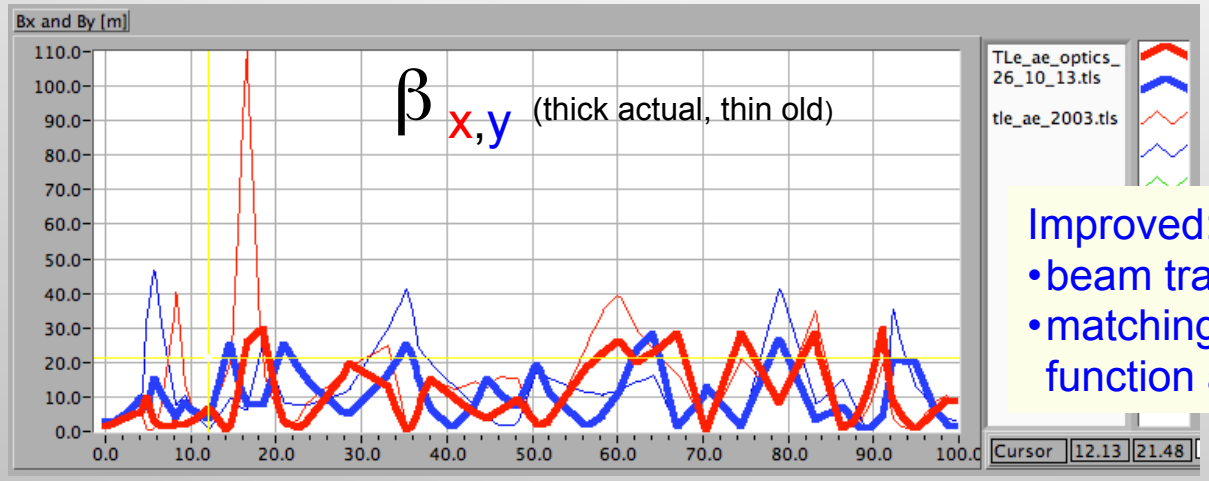


Optics measurements

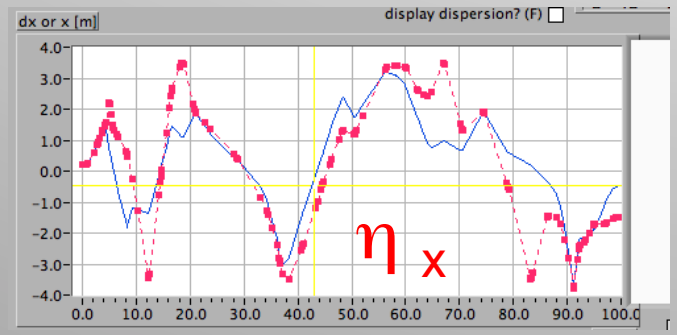
electron

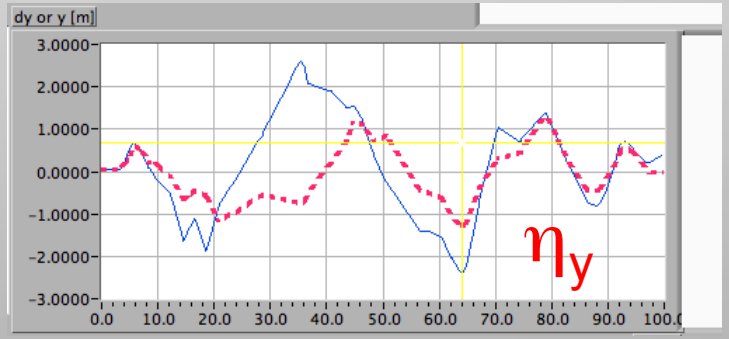


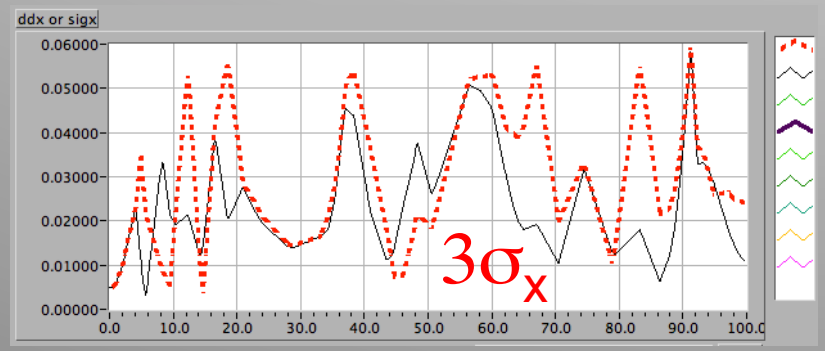
Electron Transfer Line (TLe) optics

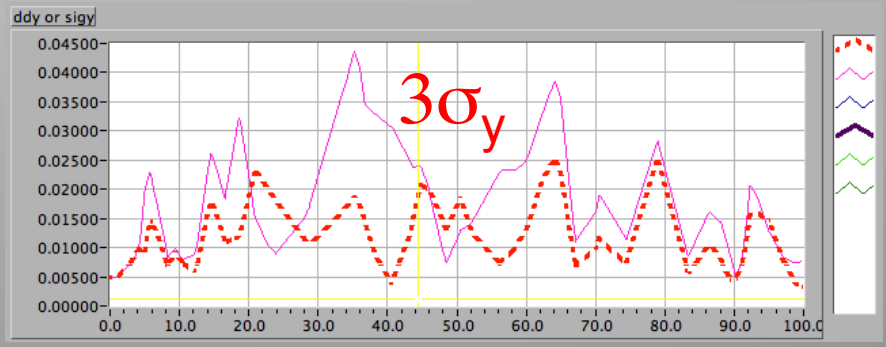


Improved:
- beam transport
- matching between TLe and MRe Twiss function at the injection septum



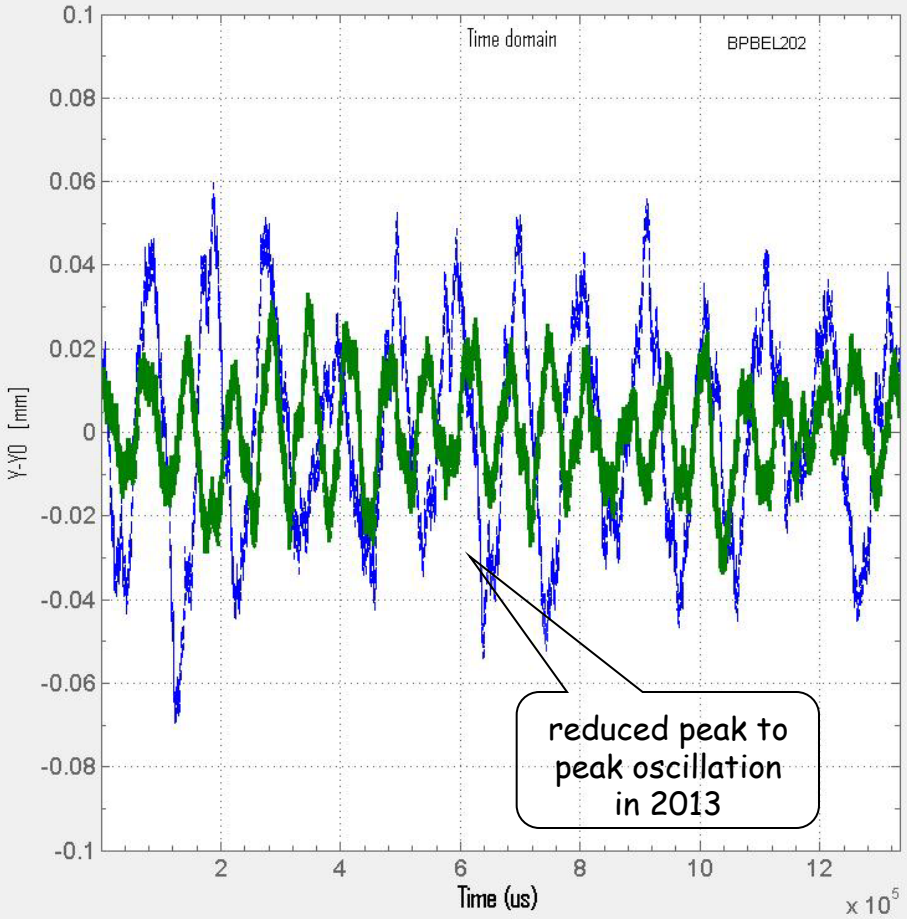




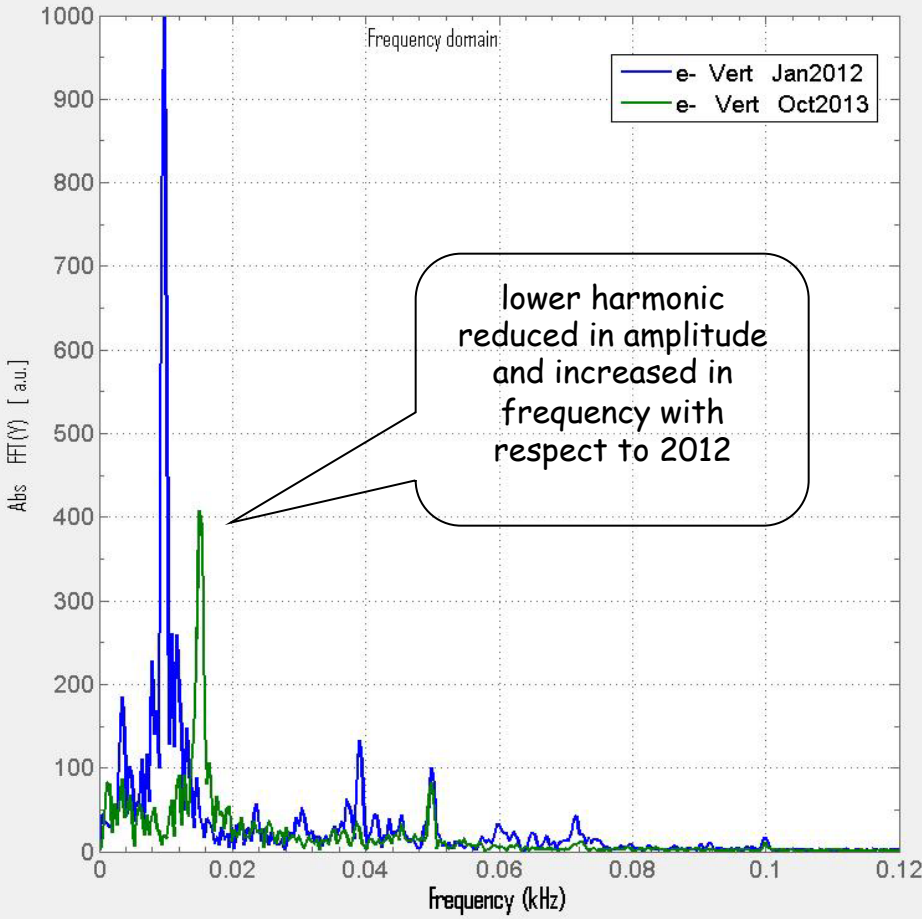


vertical orbit oscillation

recent measurements on e- beam compared with 2012



time domain



FFT analysis

natural beam oscillation around the reference orbit as recorded at BPBEL202

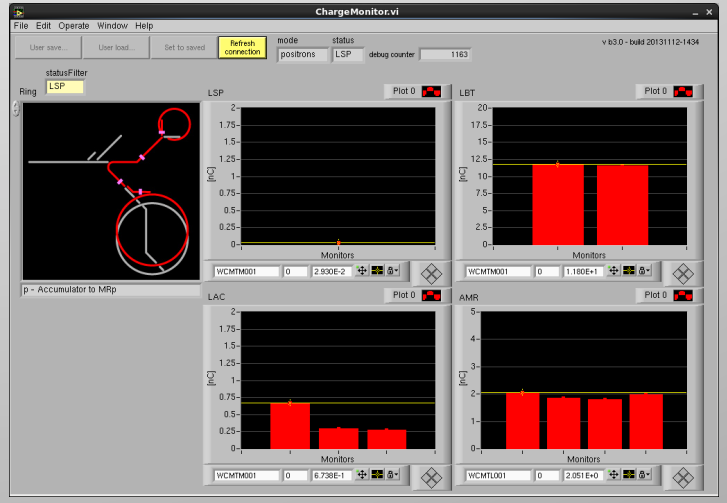
Further Transfer Line optimization

New diagnostics:

- Odoscope
- Wall Current Monitor
- Frame grabber still under development

Commutation time between e^+ e^- injection has been almost halved (~120 sec -> ~ 70 sec)

Transfer Lines parameters are much more stable and reproducible thanks to the new PLC and Supervisor system



Radiation level in the Control Room

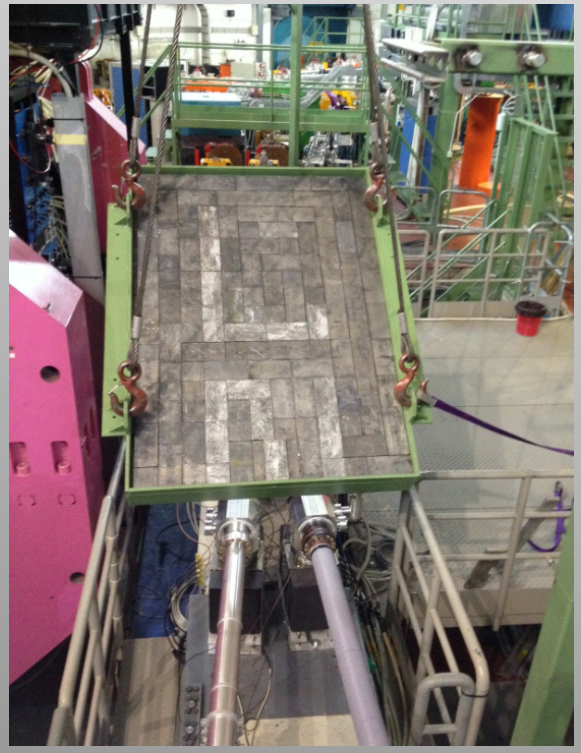
Electron beam losses in the DAΦNE hall caused anomalous γ photon level in the control room mainly during injection and some times during coasting

Following the indication of the radio-protection group a lead shield has been installed around the collimator just after the RCR in the MRe without any relevant improvements

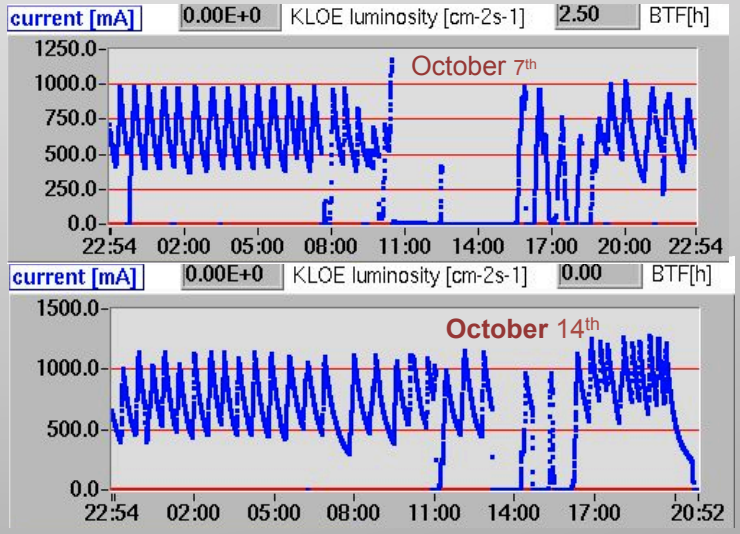
Identifying the radiation source

Optimizing the TLe optics produced a 15% reduction in the average level of the γ photons detected in the Control Room (*less particles lost during injection means less background on the KLOE detector during data taking*)

On October 14th a lead screen has been suspended at the exit of the RCR bended by 37^{0} toward the incoming beam and with the lower side 50 cm far from the center of the vacuum chamber

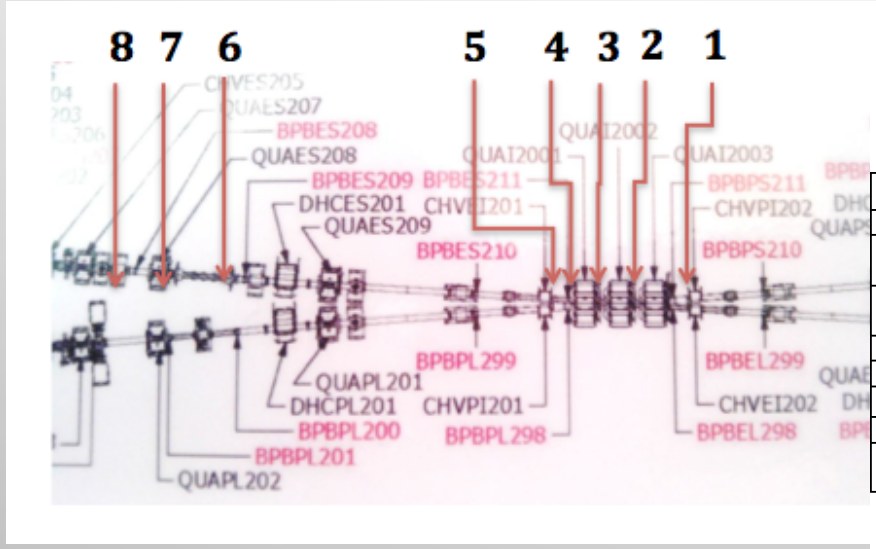


(data from radio-protection group)



Date	Time interval	Average Dose (μSv/h)
October 7th 2013	16:30 – 17:15	1.1
	17:15 – 18:15	1.4
	18:15 – 19:00	1.1
October 14th 2013	**16:45 – 20:00**	**0.25**

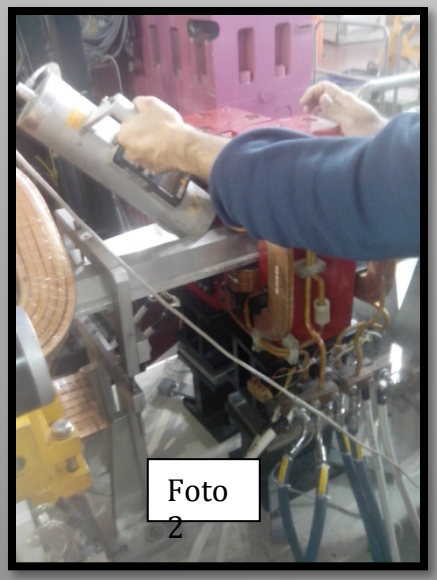
Activation Measurements along the RCR beam pipe

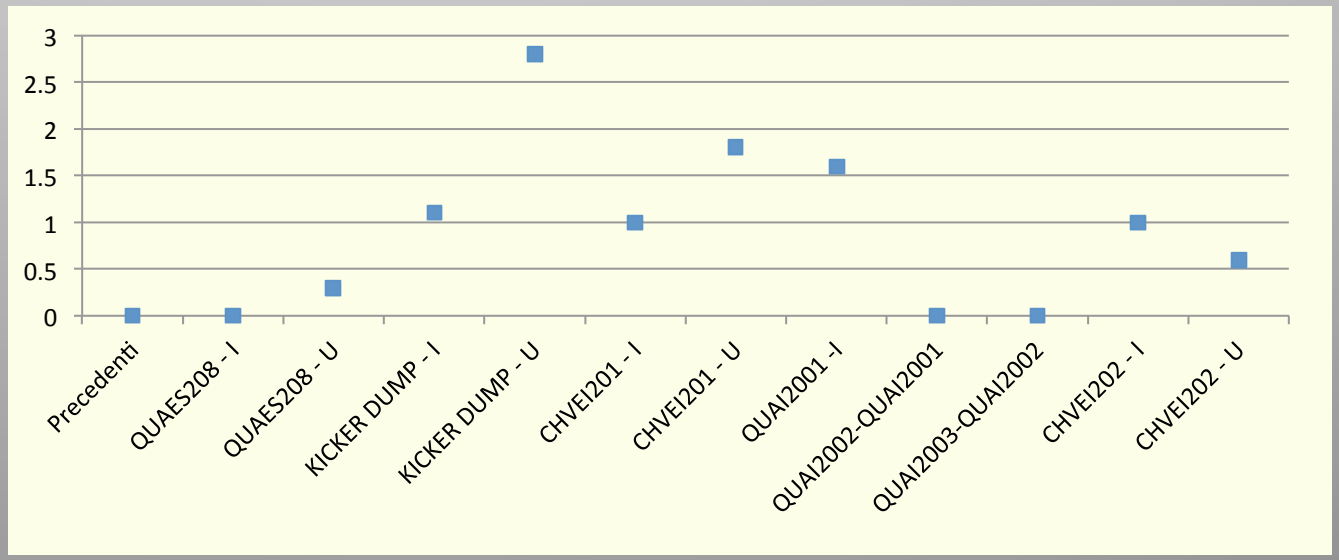


Misure:

Elemento	Ingresso	Uscita	Ref - Note
1 - CHVEI202	1	0,6	Foto1 - uscita
2 - Spazio intermedio fra QUAI2003-QUAI2002	fondo		Il punto di misura era esterno alle bobine
3 - Spazio intermedio fra QUAI2002-QUAI2001	fondo		Il punto di misura era esterno alle bobine
4 - QUAI2001	1,6	Misura QUAI2002-QUAI2001	Foto2 - Ingresso
5 - CHVEI201	1	1,8	Foto2 - Uscita
6 - KICKER DUMP	1,1	2,8	Foto4 (I) – Foto3 (U)
7 - QUAES208	fondo	0,3	Foto5
8 - Punti precedenti (nel senso del fascio)	fondo	fondo	

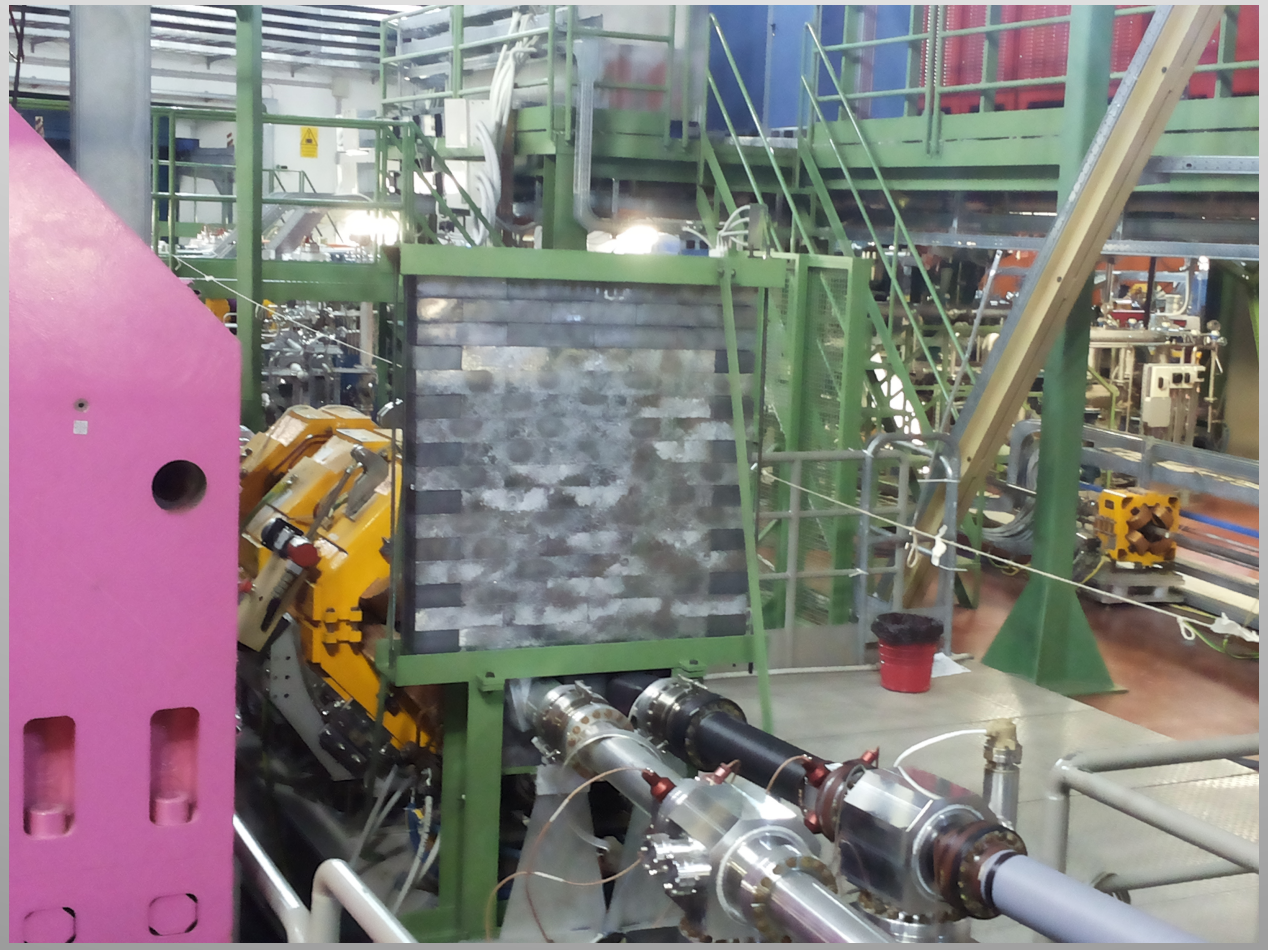
e^- are lost mainly in the dump kicker and in the half-moon vacuum chamber





Final shield configuration

Vertical lead screen (90 cm x 90 cm x 10 cm)



LINAC

- All the activities planned for the shutdown have been completed in time
- Linac warm-up on June 3rd
- Stability condition have been reached in 1 week
- June 17th beam delivered to BTF (h 24 operation)
- Extraordinary maintenance required to cope with several faults in modulator and oil-filled tanks.
- Electron beam has been delivered to DAFNE without any problem
- Positrons had not the proper energy to be injected in the collider due to the klystron D

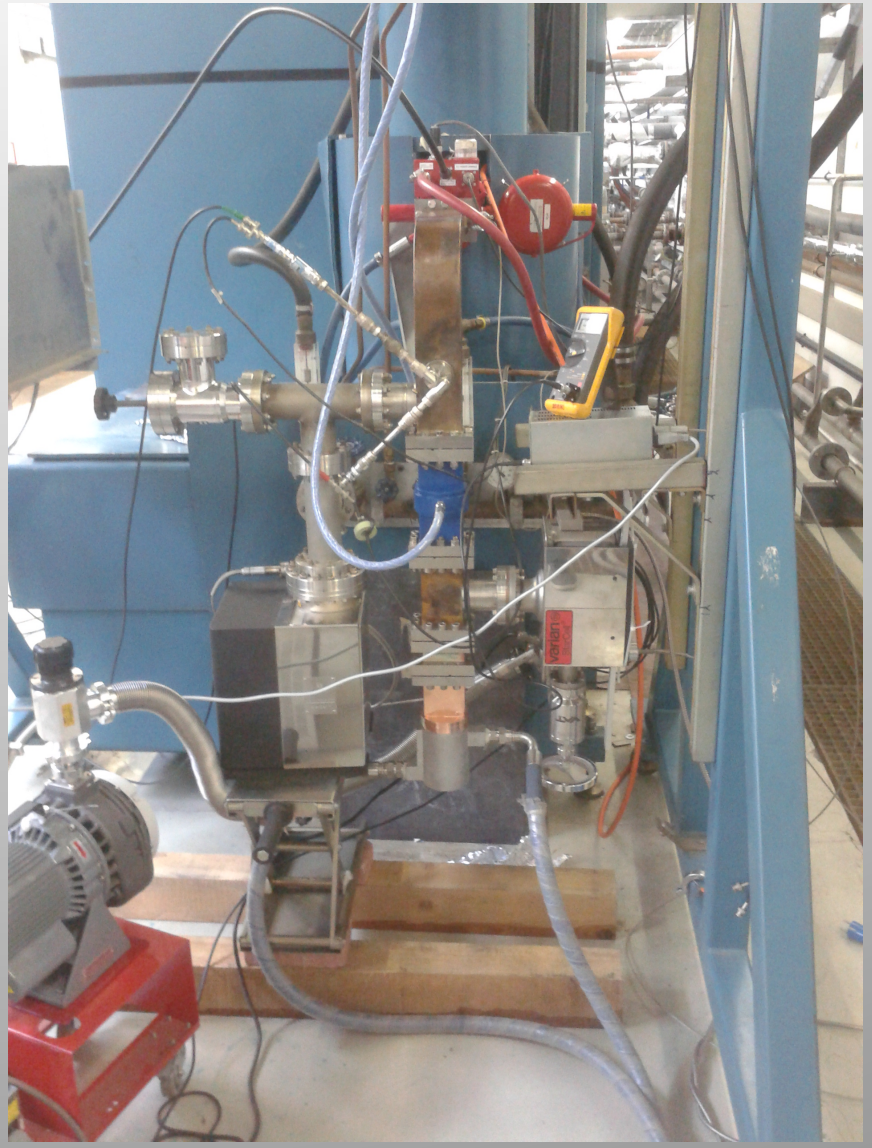
Conditioning klystron D

Klystron D had several faults during conditioning (vacuum interlock downstream the output window)

By the end of August the following components have been replaced:

- klystron (second time)
- vacuum section between klystron and Linac (RF elbow)
- vacuum gauge

Regardless the new components the **D** RF power plant did not achieve the nominal working point

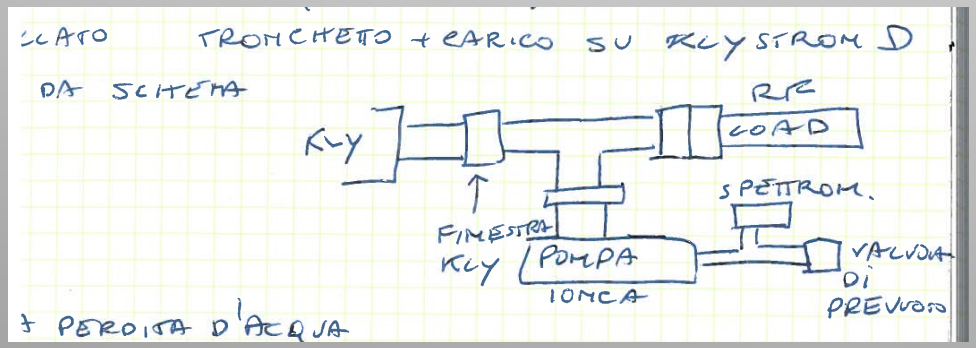


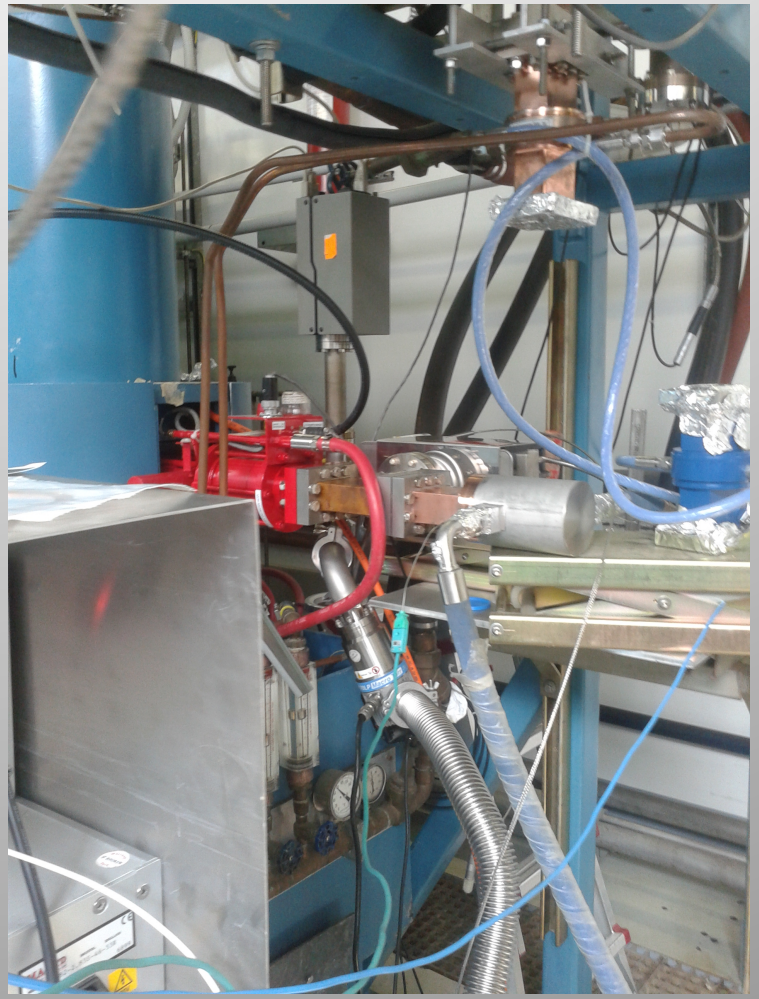
Simplified test configuration

RF elbow removed

Simplified configuration included:

- directional coupler
- vacuum gauge
- RF load
- spectrometer

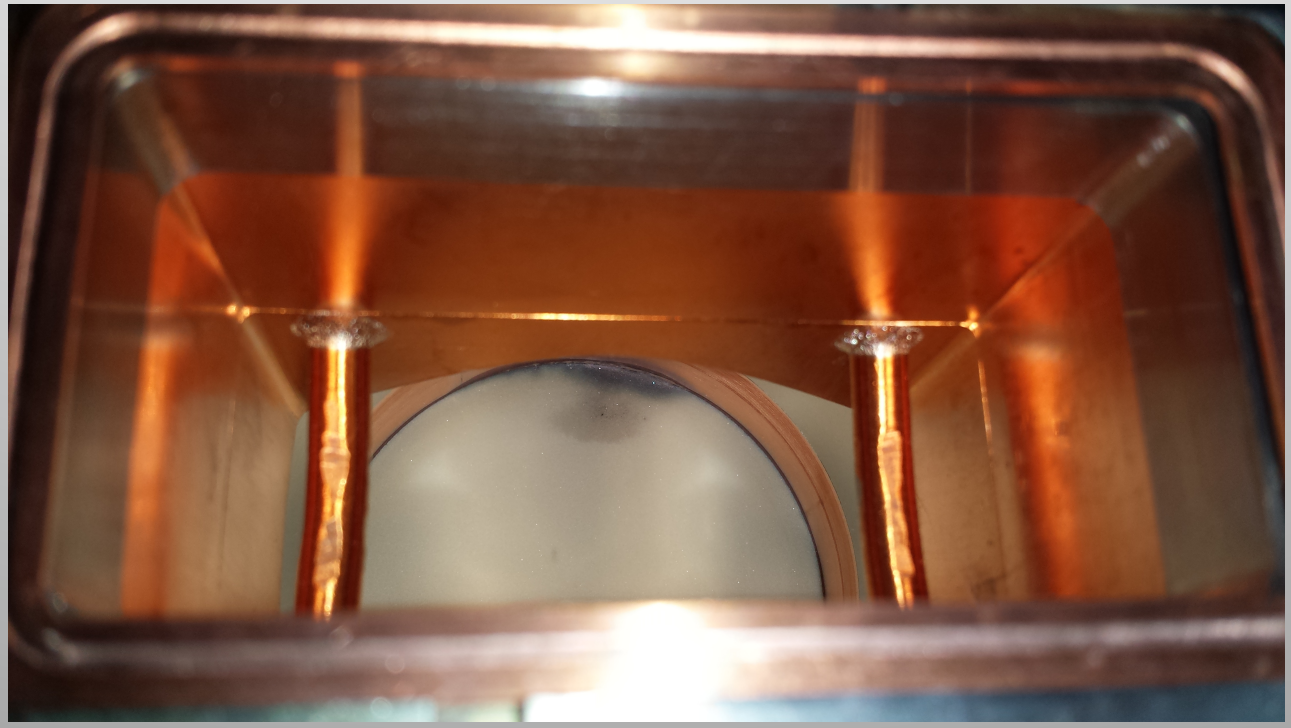




B klystron replaced for the third time

(Oct 4th 2013)

Removing the RF elbow a black spot has been observed close by the brazing of the ceramic window



This Klystron was new and under warranty

B klystron conditioning

Proper Klystron performances have been achieved in about a week time on the test configuration

Conditioning procedure consisted in modulating the width of the RF pulse in the range 0.500 μsec – 4.5 μsec while monitoring:

- vacuum level
- forward and reverse power signal at the klystron output

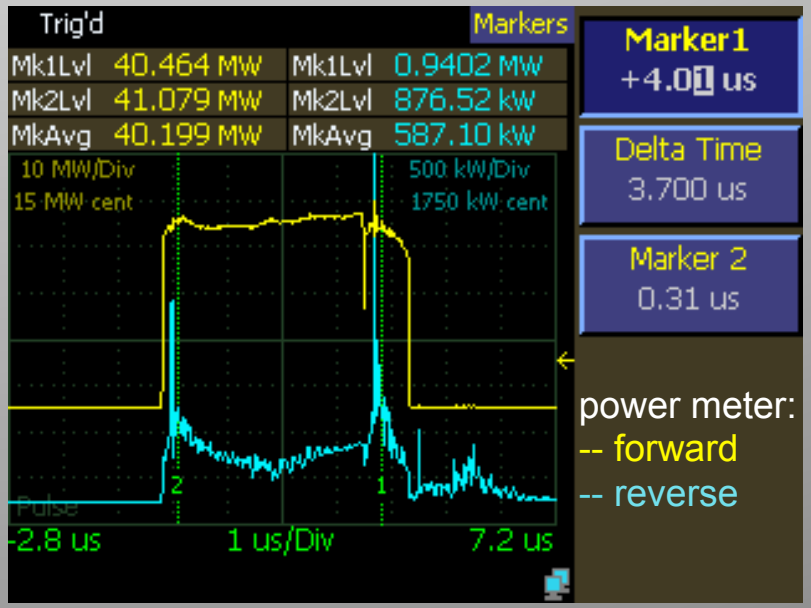
On Oct 17th we had a consult with an expert from the Thales company to review the conditioning procedures and to discuss the term of the klystron warranty

Reinstalled the original RF elbow after a careful cleaning and backing cycle

Regime situation achieved in few days

General tuning procedure:

- control and tuning the four SLED cavities
- timing setup



B RF power plant fault

(Oct 28th – Nov. 2nd)

Fault concerning the modulator blower

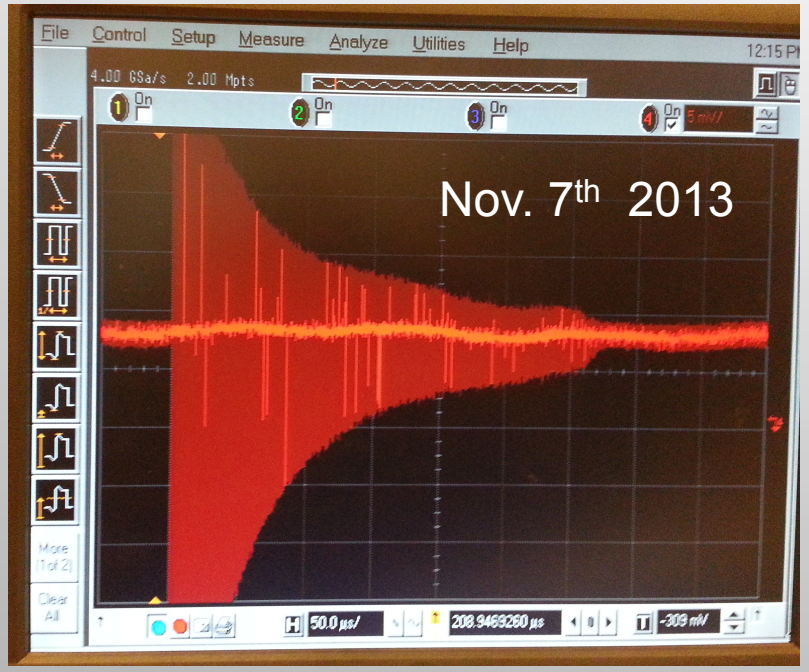
Water leakage in the ceramic window before the SLED system (20 years old)

Ceramic window has been replaced

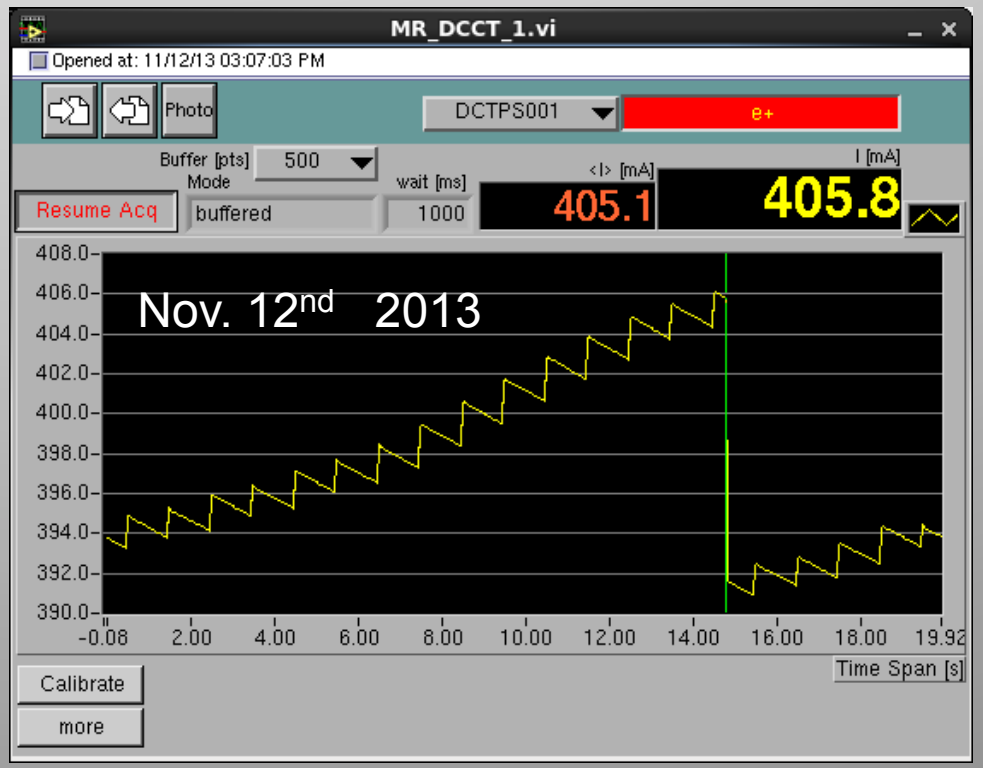
Thyratron of the D modulator replaced

In the shadow radio-protection prescription have been implemented:
Polyethylene screen installed in the Damping Ring
A a lead screen in the DAFNE hall

First positron beam



stored in few hours!!!



Conclusions

DAΦNE consolidation plan has been completed almost in time

Main limitations have been affecting DAΦNE commissioning:

- Electron beam
  - Permanent magnet dipoles installed deep inside the detector had a wrong rotation (this aspect has been understood in few days of operation and fixed in 15 days)
- Positron
  - D RF power plant had severe problems in achieving the nominal working point and 3 klystron had to be replaced

Both beams have been stored

Mre has been already partially optimized (40% of the work necessary for collisions has been done)

MRp all must be done

Maximum single bunch current so far:

- I^-_{bunch} (MAX) ~ 21 mA
- I^+_{bunch} (MAX) ~ 7 mA

…. and

TLe optics has been considerably improved

Limitation due to the radiation dose in the control room has been understood and fixed

IR mechanical vibration have been halved with respect to 2012

PLC and supervisor system are performing in an excellent way, it had a big role in improving stability and reproducibility of the DAΦNE injection system

LLRF control Control System became operative almost immediately

Control System faced a major upgrade, presently two different architectures coexist and nevertheless the system fault rate is considerably reduced

Special thanks to all the colleagues from AD and DT,
We made a great job!!

…… but it’s just the beginning ….

Thank you for your attention