DAΦNE at low Energy (958 MeV c.m.)

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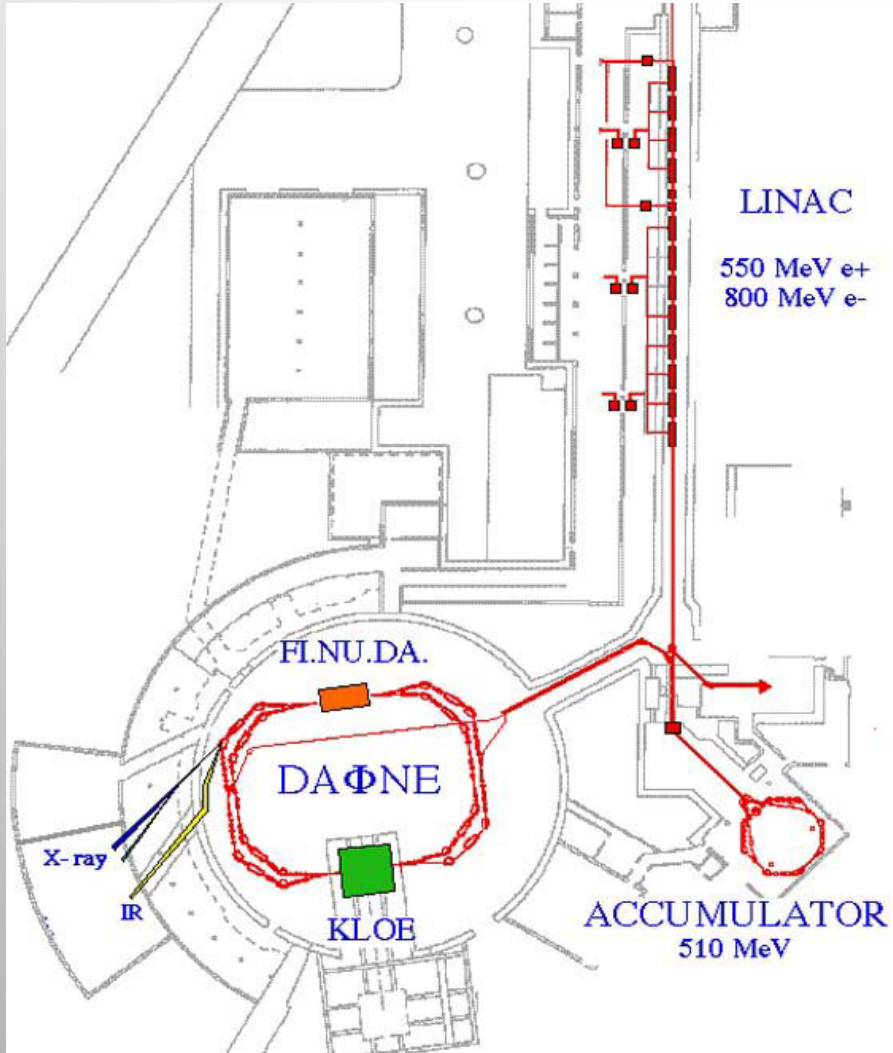
KLOE-2 Workshop, 26 – 28 October 2016

Requirements

- Operating DAFNE at 958 MeV requires to lower by **31 MeV** the nominal energy in each one of the two colliding rings
- Since beams stored in in the Main Rings are injected on energy all the components of the injection system must be properly reconfigured too

What changes in the DAΦNE accelerator complex



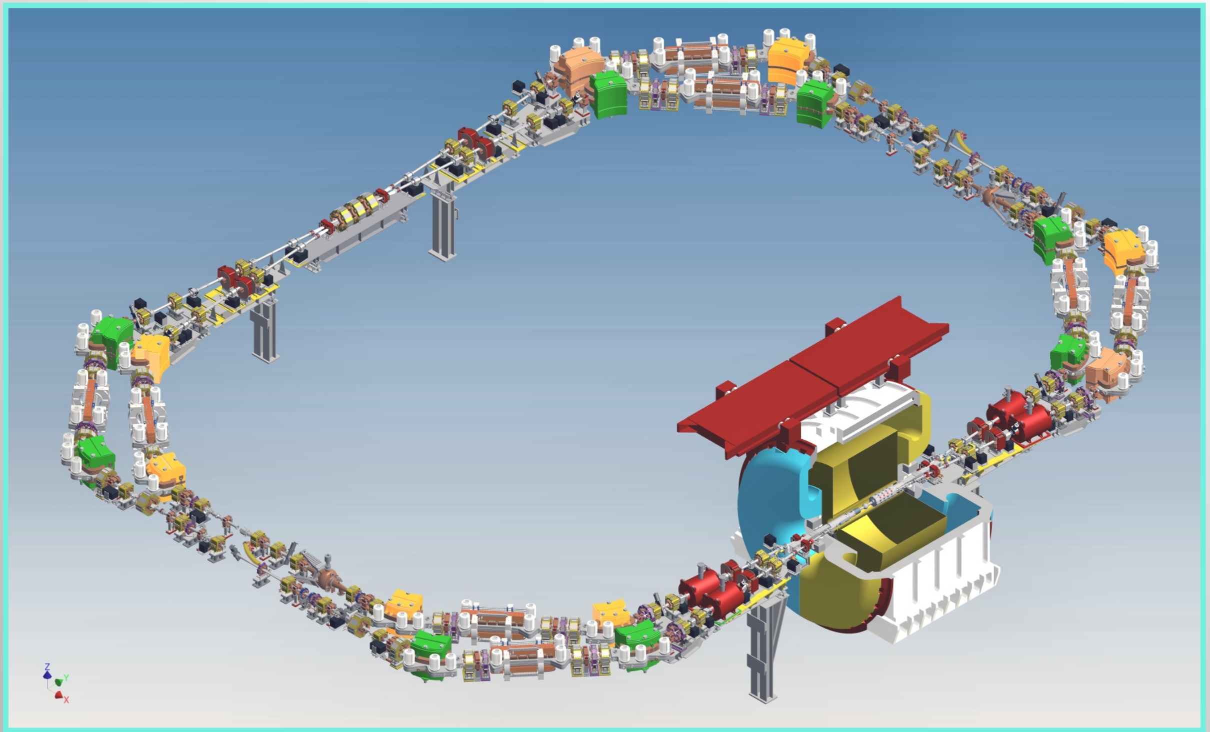
Linac must be reconfigurated in order to provide e$^-$ and e$^+$ beams at 479 MeV
Feasible

All the magnets:
- dipoles
- quadrupoles
- sextupoles
- correctors
- septa

installed along the the Transfer Lines (TLs) and in the Accumulator (A) must be scaled to deal efficiently with the new beam energy
Feasible

Lower the operation energy of the Main Rings is a different problem
It is not obvious and requires studies to get an answer

Ring Arcs



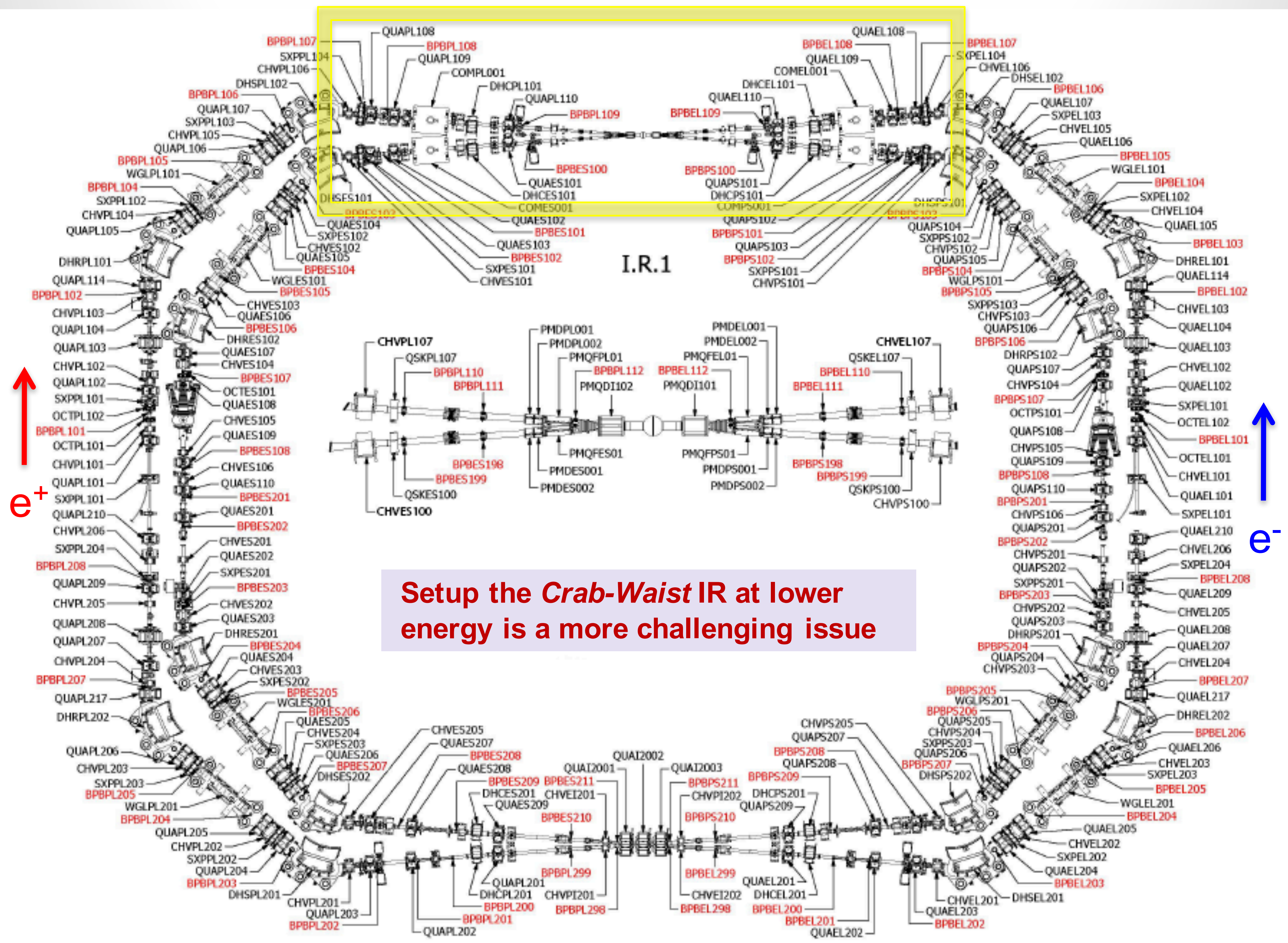
All the magnets:
- dipoles
- quadrupoles
- sextupoles
- correctors
- septa

Placed in the long and short arcs must be scaled to deal with the beam having lower energy

Operating frequency of the RF cavities must be set properly

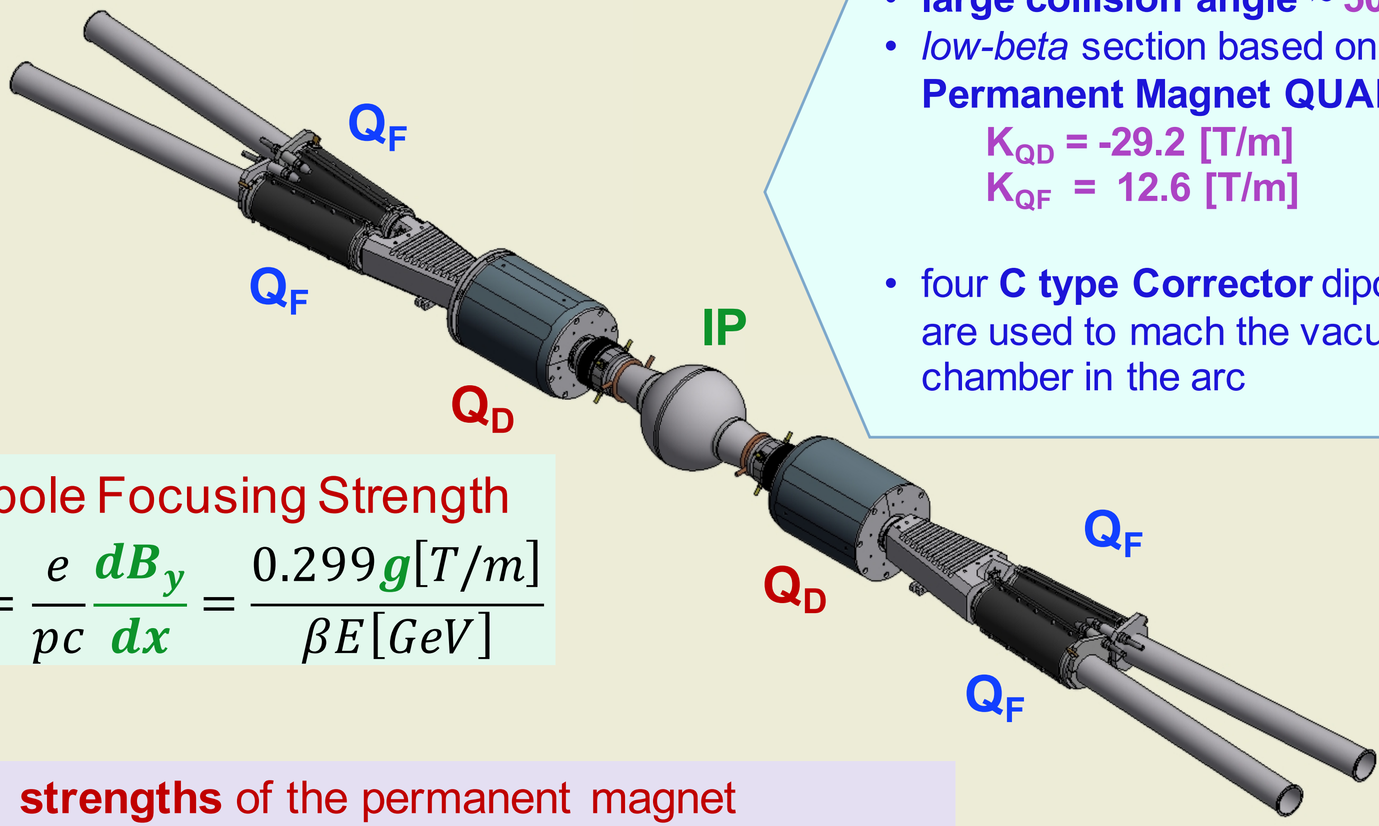
$$-\alpha_c \frac{\Delta p}{p} = \frac{\Delta f_{RF}}{f_{RF}}$$

Feasible



Setup the *Crab-Waist* IR at lower energy is a more challenging issue

Low-β section



- **large collision angle ~ 50 mrd**
- *low-beta* section based on **Permanent Magnet QUADs**:
  K_{QD} = -29.2 [T/m]
  K_{QF} = 12.6 [T/m]

- four **C type Corrector** dipole are used to mach the vacuum chamber in the arc

Quadrupole Focusing Strength

$$\boldsymbol{k}[m^{-2}] = \frac{e}{pc}\frac{\boldsymbol{dB_y}}{\boldsymbol{dx}} = \frac{0.299\,\boldsymbol{g}[T/m]}{\beta E[GeV]}$$

Focusing strengths of the permanent magnet quadrupoles grow with the inverse of the **energy**

stay clear aperture
Crab-Waist conditions
dynamic aperture
background hitting the detector

KLOE field ~ 0.5 [T]

Crab-Waist Optics Requiremets

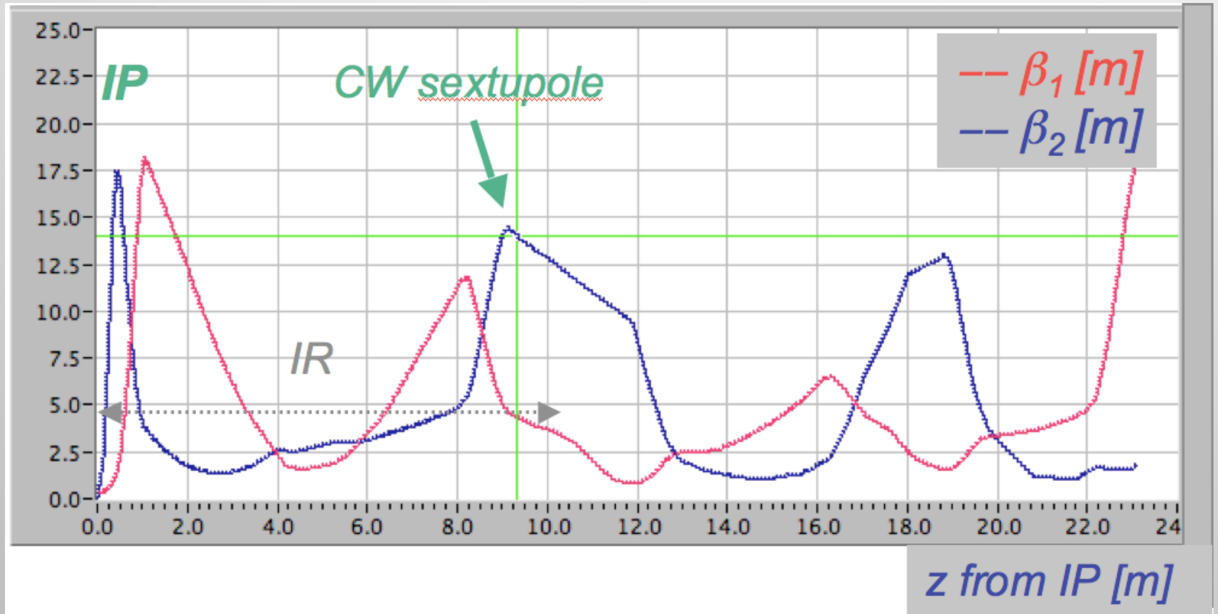
IR design criteria:

- *Coupling matrix = 0   before CW SXT*
- $\Delta\nu_x = \pi$
- $\Delta\nu_y = \pi/2$
- *highest* β_y *at the CW sextupole*

$$\boxed{k_s = \frac{\chi}{2\theta}\frac{1}{\beta_y^* \beta_y^{sext}}\sqrt{\frac{\beta_x^*}{\beta_x^{sext}}}}$$

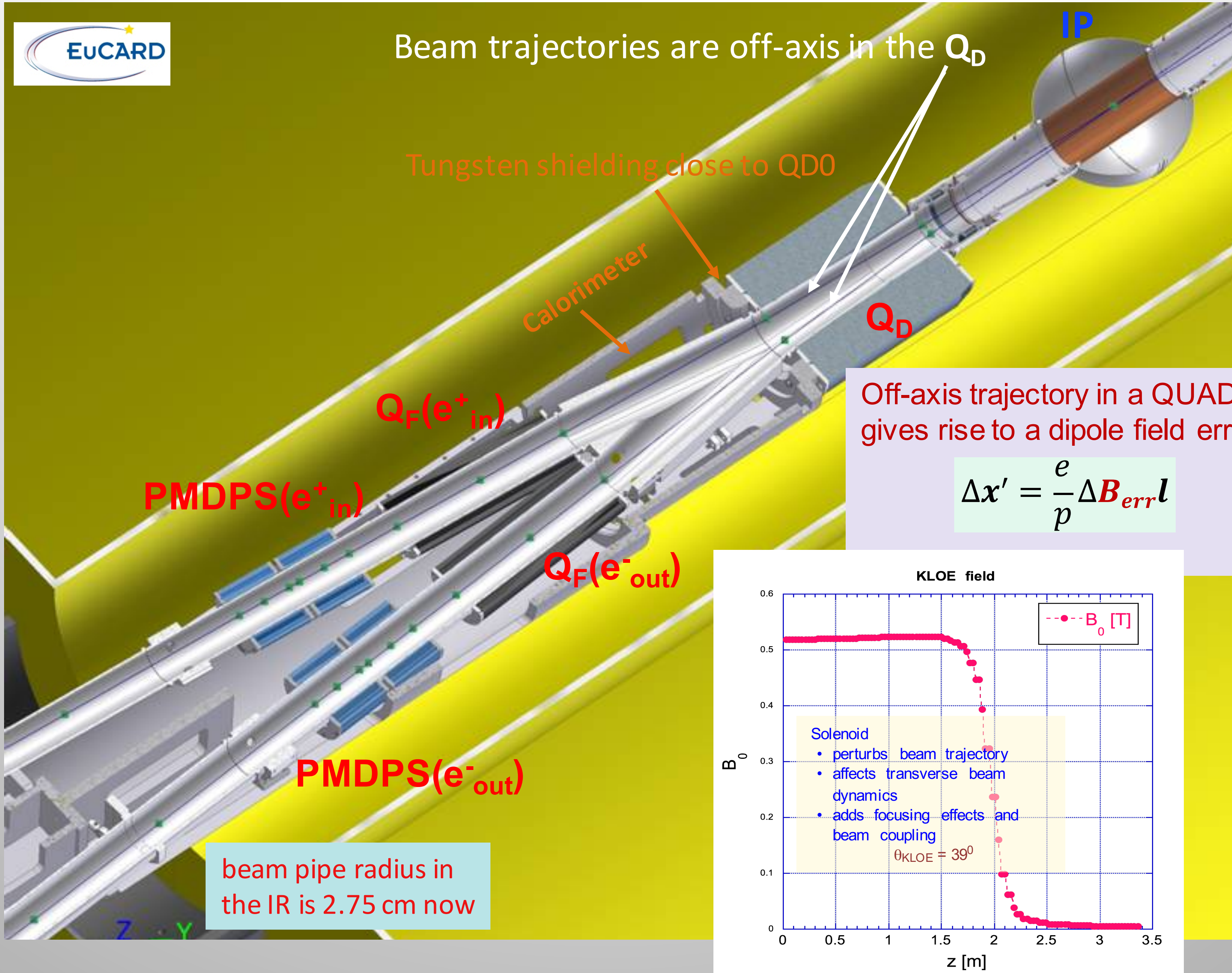
Low-β parameters:

- β^*_x = 26.5 cm
- β^*_y = 8.5 mm
- θ_{cross} = 50 mrad



It must be verified that lowering the ring energy is still possible to satisfy the Crab-Waist conditions

Radial section of *Crab-Waist* low-β

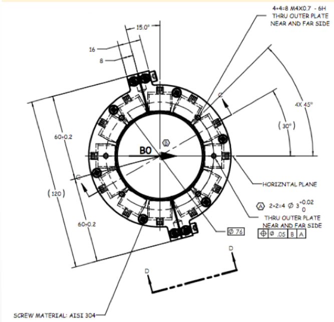


Off-axis trajectory in a QUAD gives rise to a dipole field error

$$\Delta x' = \frac{e}{p}\Delta B_{err} l$$

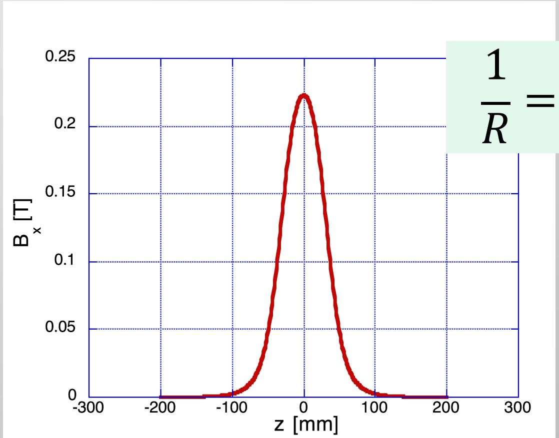
Beam Trajectory in the *Crab-Waist* Interaction Region

- *The beam trajectory in the IR is an order of magnitude larger than in the 2005 KLOE run due to:*
  - *larger crossing angle (50 mrad)*
  - *stronger first low-β quadrupole (PMQD)*
  - *experimental solenoidal field*
- *A **Permanent Magnet Dipole** is used to keep under control the vertical beam trajectory.*



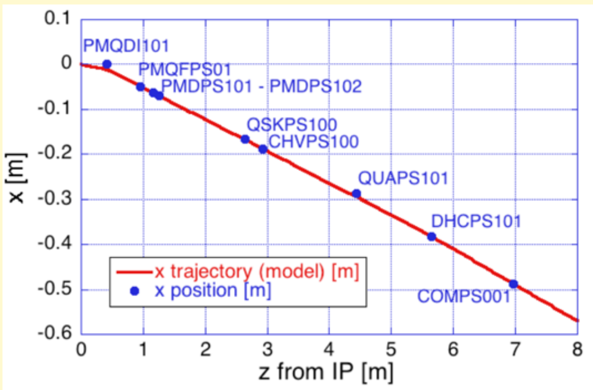
Magnetic length (mm) 75
field (T) 0,22933
Good field region radius (mm) 15
Magnet material type SmCo

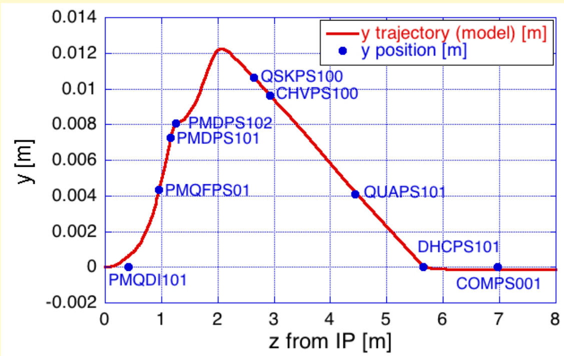
PMD consists of two halves each of them:
- Magnetic length 75.0 mm
- BL = 0.0168 Tm
- Bx is directed inward and outward in the e+ and e- rings respectively
- α_y ~ 10.0 mrad



$$\frac{1}{R} = \frac{e}{p} \boldsymbol{B}_{\boldsymbol{x0}}$$

PMQ$_F$ and other electromagnetic 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





PM DIPOLES should work even at lower energy, but it is better to check

Beam Stay Clear Aperture

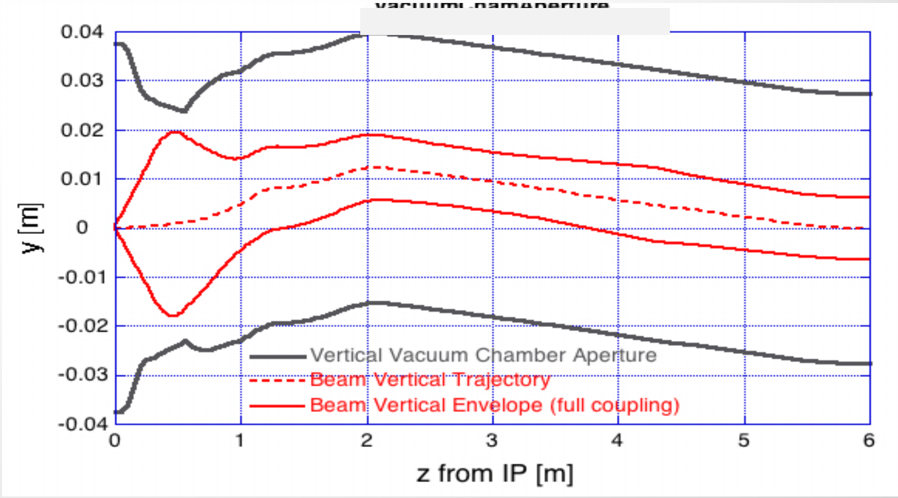
The horizontal and vertical beam stay-clear requirements have been defined as:

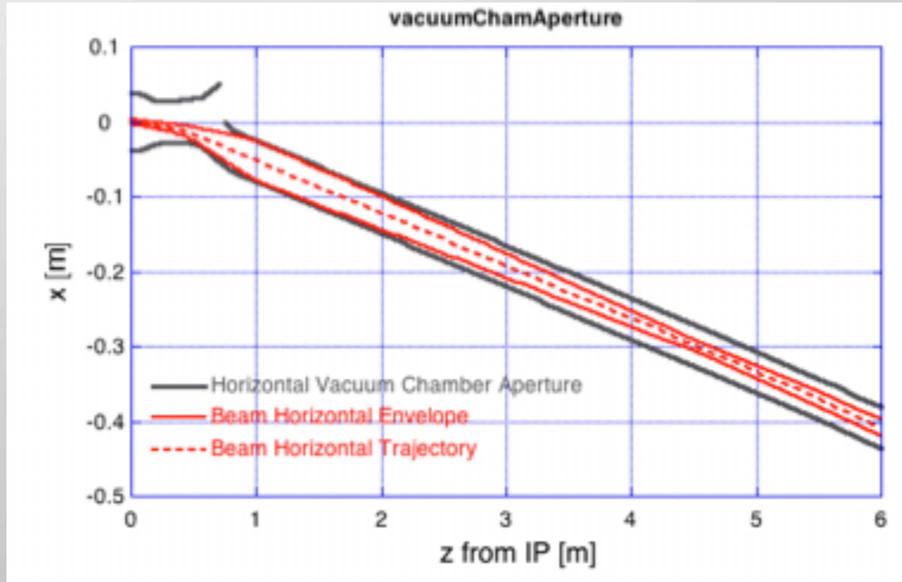
$$X_{SC} = x_{trj} \pm 10\sigma_x$$

$$Y_{SC} = y_{trj} \pm 10\sigma_y$$

where σ_x and σ_y are the horizontal and vertical rms beam sizes respectively. Their values, computed with the collider emittance $\varepsilon = 0.4\ 10^{-6}$ m for the horizontal plane and full coupling for the vertical one.

Vacuum beam pipe is tailored on the beam trajectory





Coupling correction

$\int_{KLOE} B\bullet dl$ canceled by 2 anti-solenoid for each beam

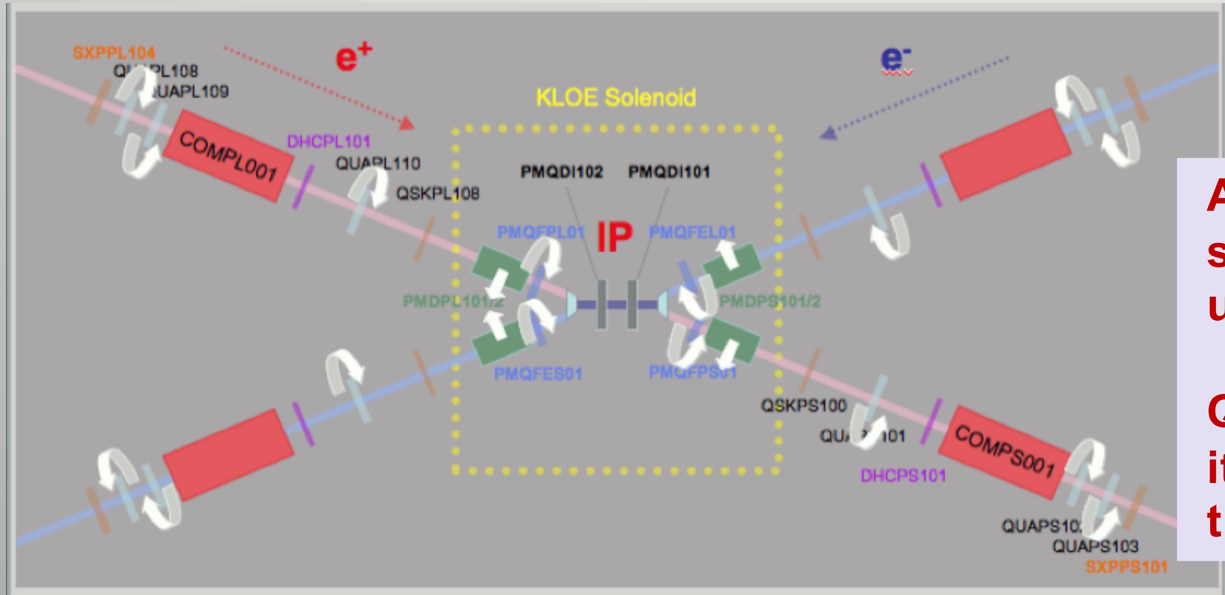
$$\int_{KLOE} B\cdot dl = 2.048 \quad [Tm] \quad \rightarrow \quad I_{KLOE} = 2300.[A]$$

$$\int_{comp} B\cdot dl = \pm 1.024 \quad [Tm] \quad \rightarrow \quad I_{comp} = 86.7[A]$$

In order to have coupling compensation also for off-energy particles

Fixed QUAD rotations

	Z from the IP [m]	Quadrupole rotation angles [deg] *Anti-solenoid current [A]*
PMQDI101	0.415	0.0
PMQFPS01	0.963	-4.48
QSKPS100	2.634	used for fine tuning
QUAPS101	4.438	-13.73
QUAPS102	8.219	0.906
QUAPS103	8.981	-0.906
COMPS001	*6.963*	*72.48 (optimal value 86.7)*

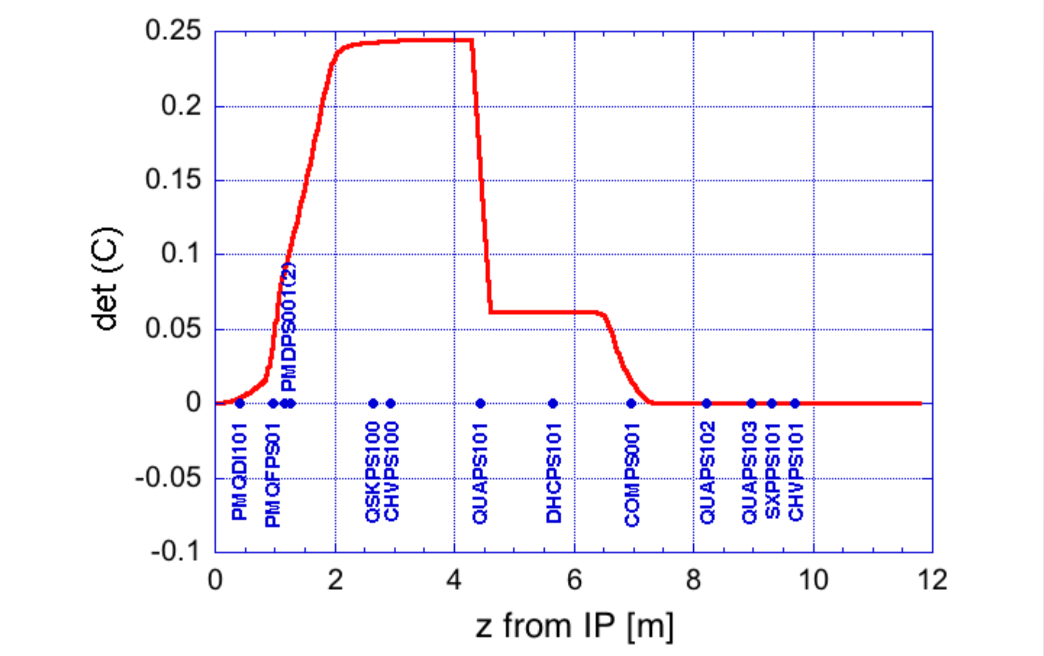


Anti-solenoid set-points will be the same as far as the KLOE field is unchanged

QUADs rotation must be revised it would be desirable not to move the PMQFs

Coupling correction

Betatron coupling is carefully compensated before the CW sextupoles making the terms of the **coupling matrix C** vanish at QUAPS103

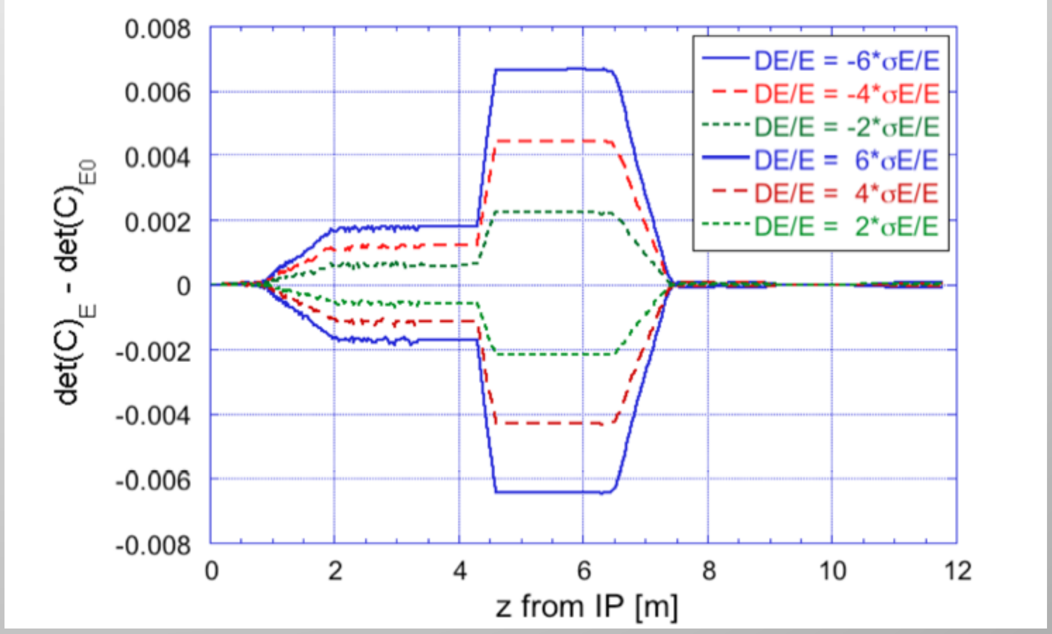


Relative deviation of the **C determinant** with respect to the nominal energy is

$$-0.7 < \left(|C|_E - |C|_{E0}\right) < 0.7$$

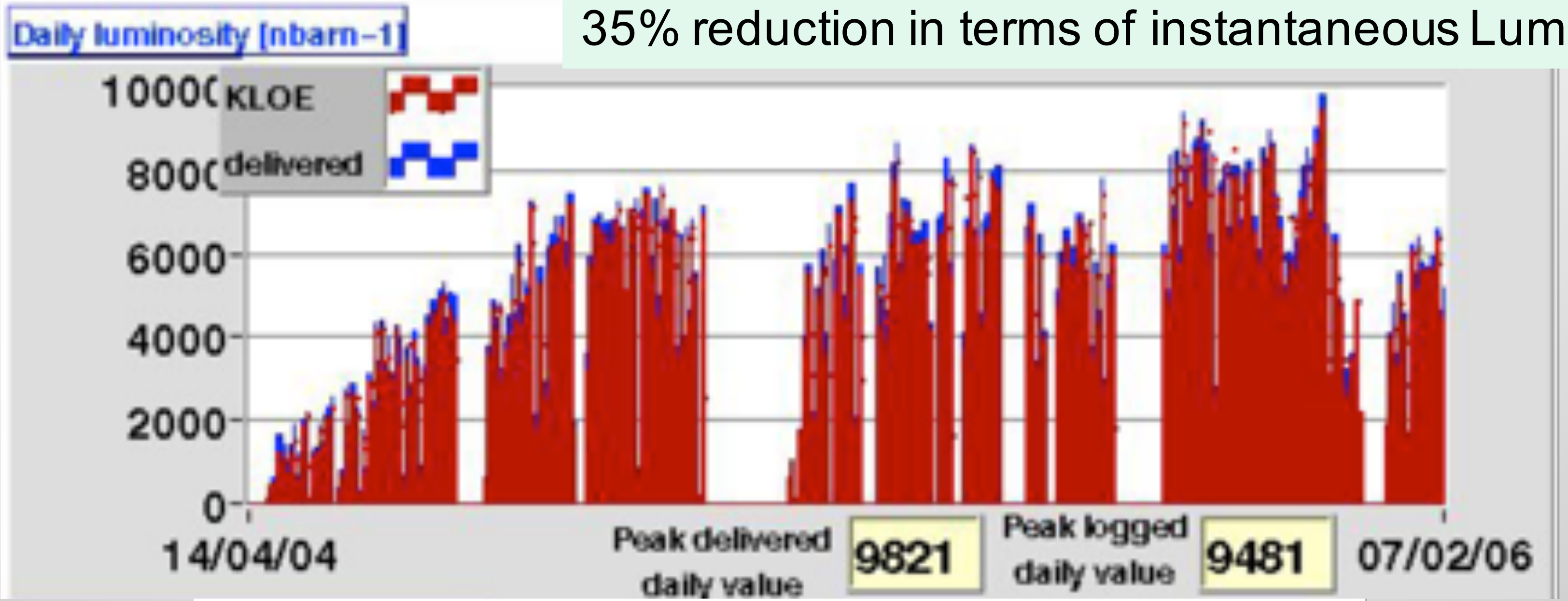
for $$-6\frac{\sigma_E}{E} < \frac{\Delta E}{E} < 6\frac{\sigma_E}{E}$$

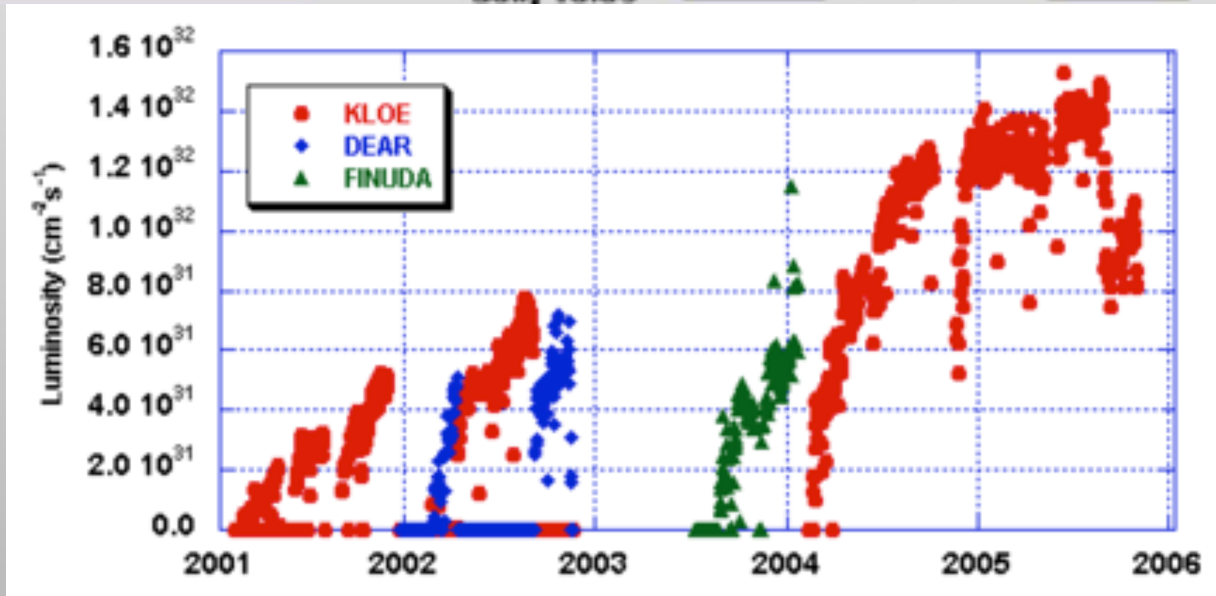
with $$\frac{\sigma_E}{E} \sim 3.4\times10^{-4}$$



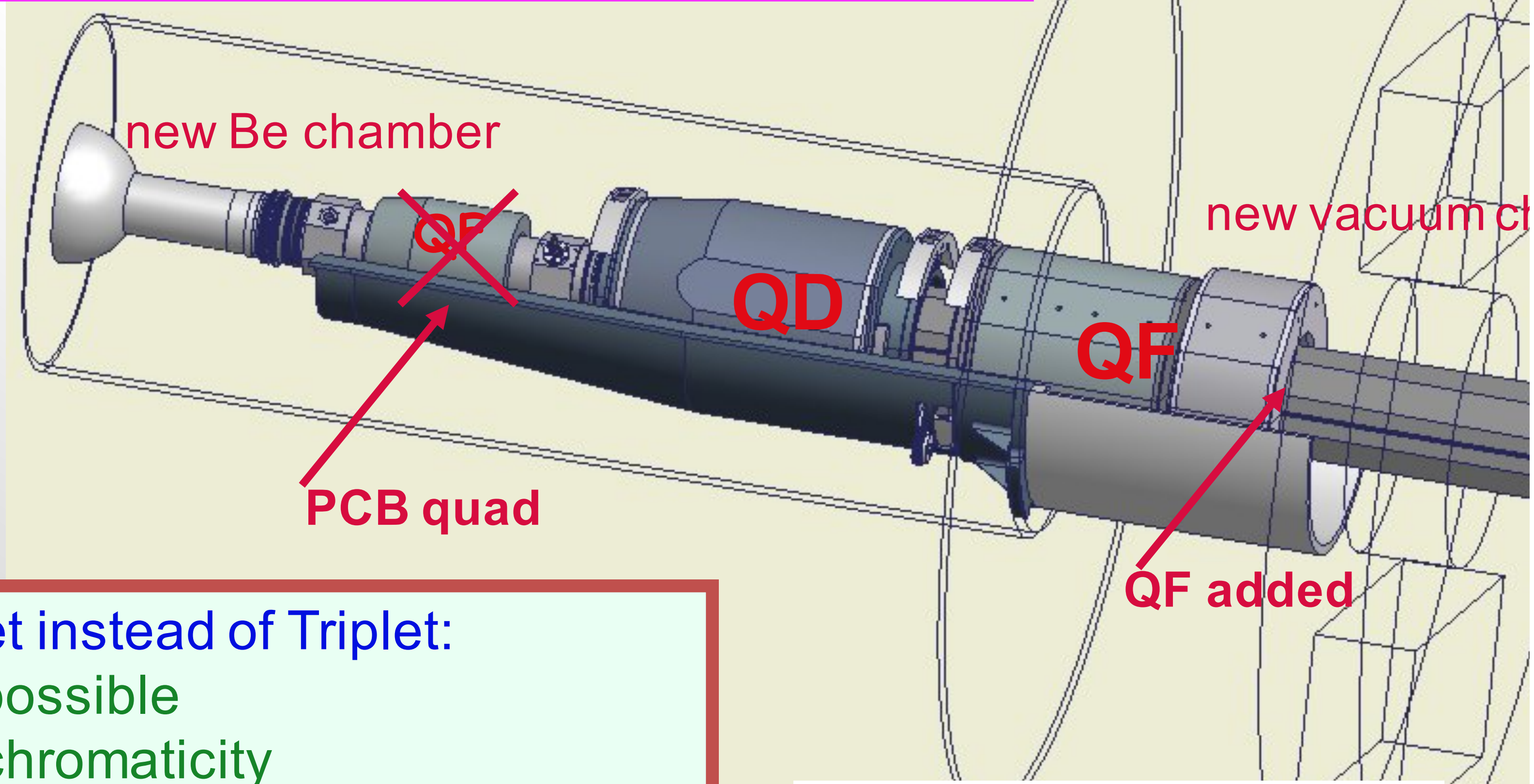
In 2005

200 pb^{-1} delivered at **20 MeV** below threshold
35% reduction in terms of instantaneous Luminosity





New KLOE Interaction Region



In 2004

QUADs Doublet instead of Triplet:

- lower β_y possible
- reduced chromaticity
- lower β_x @ 1st parasitic crossing

up to 120 contiguous bunches in collision

Independently rotating QUADs:

- different solenoid current allowed
- better coupling correction

Energy [GeV]	0.51
Trajectory lenght [m]	97.69
RF frequency [MHz]	368.26
Harmonic number	120
Damping time, τ_E τ_x [ms]	17.8 36
Bunch lenght [cm]	1 – 3
Emittance, ε_x [mm·mrad] (KLOE)	0.34
Coupling, %	0.2 – 0.3
IP beta function, β_x β_y [m]	1.7 0.017

Low-β Quadrupole Strengths
(KLOE 2005 no *Crab-Waist*)

Table I - DAΦNE Main Rings Quadrupole types

Type	N in 2 rings	L_q (cm)	R (cm)	L_c (cm)	R_c (cm)	R_c/L_c	G_{max} (T/m)	K_{max} (m^{-2})	Note
1- S	56	30.	5.0	30.	10.	0.333	10.	6.	Straight - Oxford
2- M	28	30.	5.4	29.2	10.6	0.363	6.	3.5	Arcs+shortKloeAnsaldo
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4- QF1	2	20.	5.2	20.	8.	0.40	5.93	.49	Pm-KLOE - ASTER
5- QD	2	35.	7.3	35.	12.	0.34	9.66	.68	Pm-KLOE - ASTER
6- QF2	2	27.	9.2	27.	16.	0.59	4.74	.79	Pm-KLOE - ASTER
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
8- Q2	2	29.5	6.5	29.5	11.	0.373	10.80	6.35	Pm-FINUDA - ASTER

Types 1, 2, 4 have been already measured at LNF[1,2,3,4]. It is possible to fit the gradient

Conclusions

Running DAΦNE at the center of mass energy of 958 MeV requires a comprehensive preliminary study and a not negligible investment in terms of work, time and manpower

- Numerical simulations about:
  - *Stay clear aperture*
  - *Transverse betatron coupling compensation*
  - *Crab-Waist optics*
  - *Dynamic aperture*
  - *Background on the detector*
- Commissioning and luminosity tuning

Moreover the following points must be taken carefully in to account

- *Crab-Waist* conditions could not be recovered
- Data taking might require longer time since a considerably lower luminosity is expected

It would be important to know the size of the data sample that the KLOE-2 collaboration would like to collect

Thank you for your attention

JINST

High luminosity interaction region design for collisions inside high field detector solenoid[1]

Catia Milardi[2], ~~Miro Andrea Preger, Pantaleo Raimondi and Francesco Sgamma~~

… and a relevant contribution of G. Sensolini

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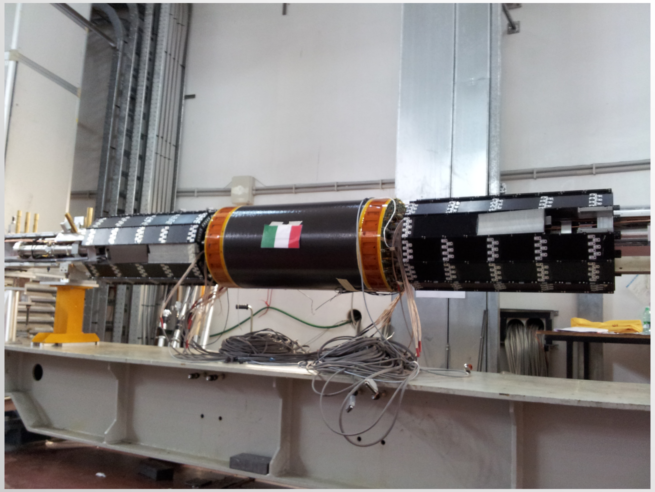
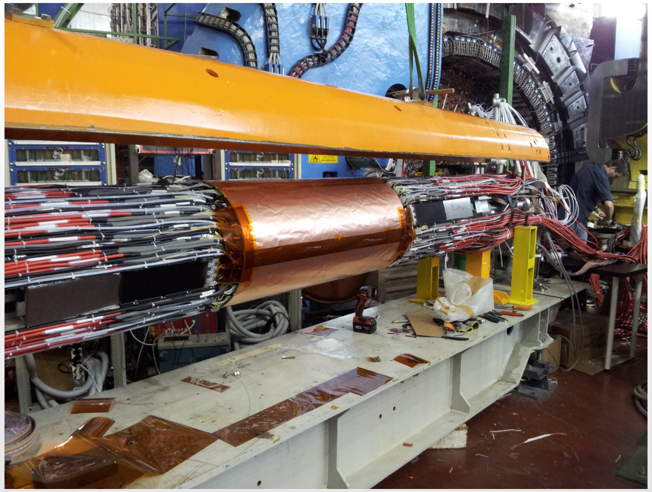
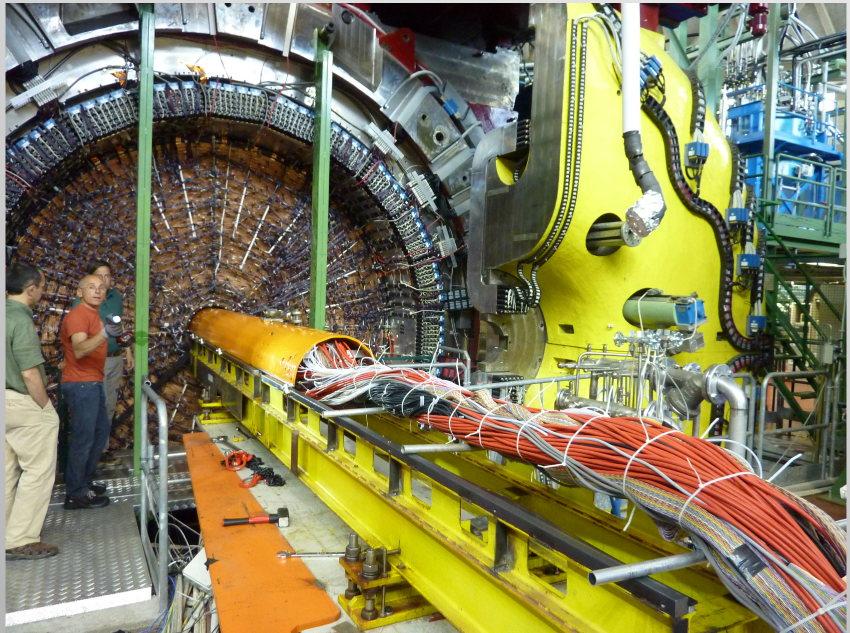
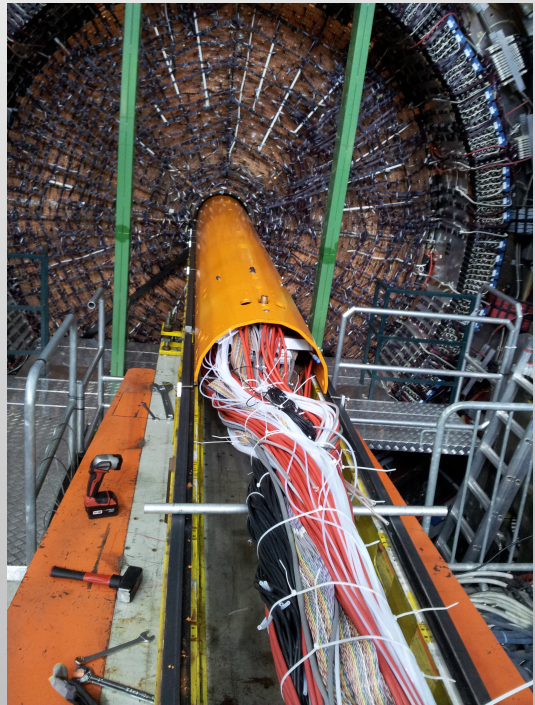
ABSTRACT: An innovative interaction region has been recently conceived and realized on the Frascati DAΦNE lepton collider. The concept of tight focusing and small crossing angle adopted to achieve high luminosity in multibunch collisions has evolved towards enhanced beam focusing at the interaction point with large horizontal crossing angle, thanks to a new compensation mechanism for the beam-beam resonances. The novel configuration has been tested with a small detector without solenoidal field yielding a remarkable improvement in terms of peak as well as integrated luminosity. The high luminosity interaction region has now been modified to host a large detector with a strong solenoidal field which significantly perturbs the beam optics introducing new design challenges in terms of interaction region optics design, beam transverse coupling control and beam stay clear requirements. Interaction region design criteria as well as the first luminosity results obtained with the beams in collision are presented and discussed.

KEYWORDS: Beam Optics; Accelerator Subsystems and Technologies.

Section Break (Next Page)

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

Final cams and last joints of the Q_F moving device