DAΦNE: the Italian Lepton Collider

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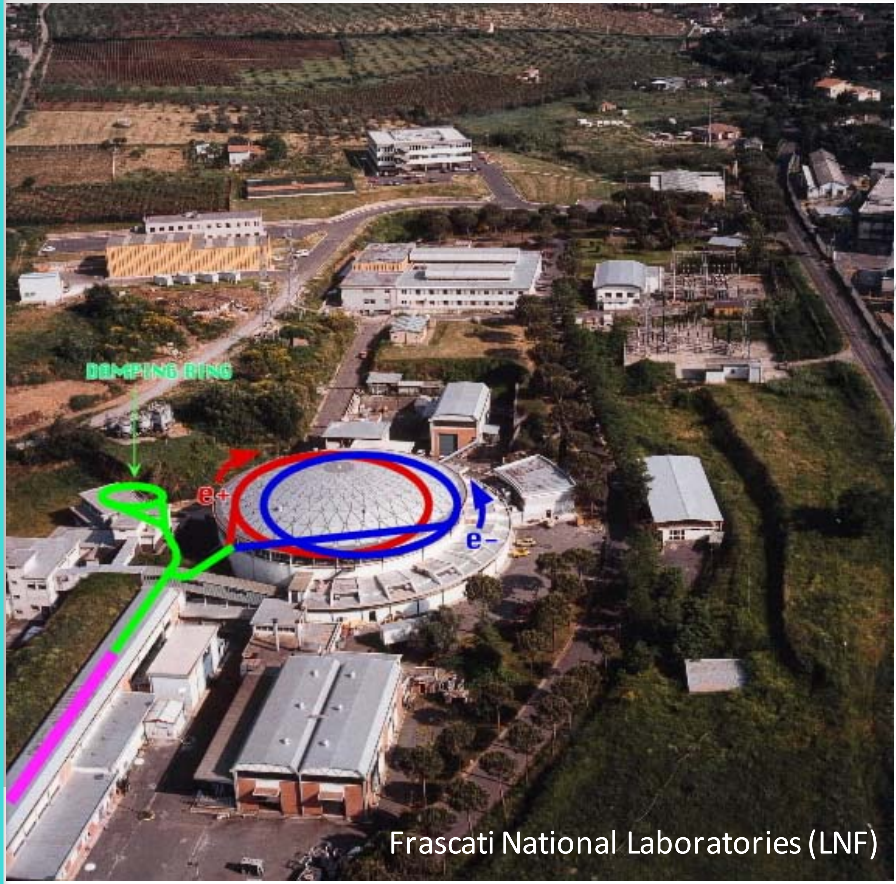
on behalf of the DAΦNE Team

Particle Accelerator Lectures, May 2016, La Sapienza, Roma

Outline

- *DAΦNE original configuration*
- *Looking for higher luminosity*
  - *Improving components and subsytems*
  - *new approach to collisions*
- *Crab-Waist Collision Scheme*
- *Testing the CW Collision Scheme with the SIDDHARTA experiment*
- *The new KLOE IR including CW*
- *CW collisions for the KLOE-2 detector*
- *Conclusions*

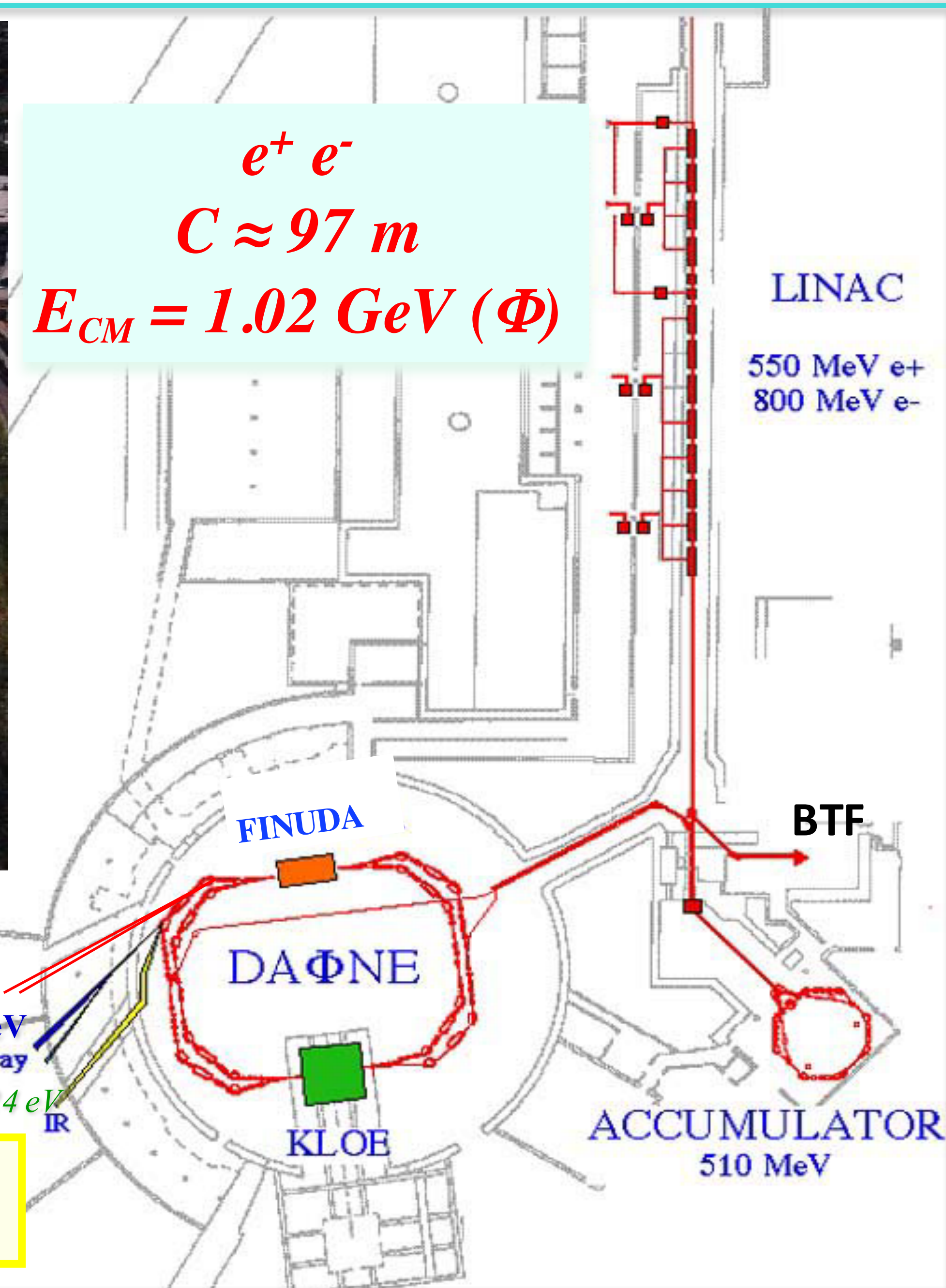
The DAΦNE Accelerator Complex



$e^+ e^-$

$C \approx 97\ m$

$E_{CM} = 1.02\ GeV\ (\Phi)$

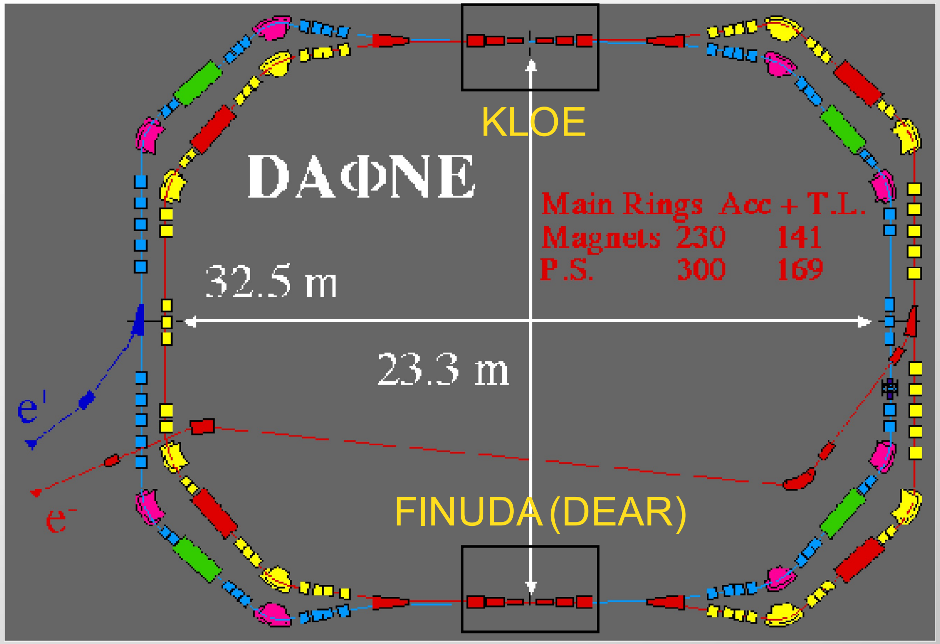


LNF are also part of the European synchrotron light Infrastructures

DAΦNE Parameters

(original configuration)

Energy, GeV	0.51
Circumference, m	97.69
RF Frequency, MHz	368.26
Harmonic Number	120
Damping Time, ms	17.8/36.0
Bunch Length, cm	1-3
Emittance, mmxmrad	0.34
Coupling, %	0.2-0.3
Beta Function at IP, m	1.7/0.017
Max. Tune Shifts	.03-.04
Number of Bunches	111
Max.Beam Currents, A	2.4/1.4



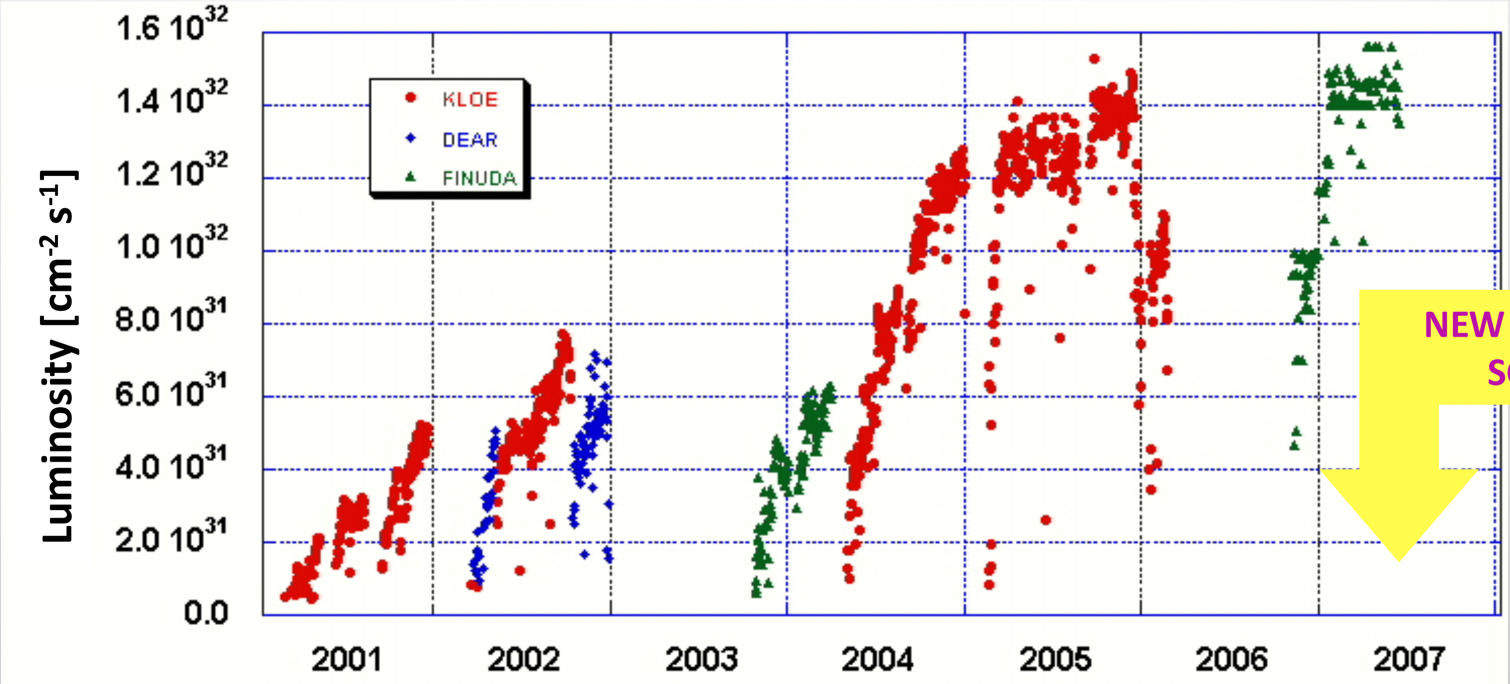
"Proposal for a Φ-factory", LNF-90/031 (IR), 1990.

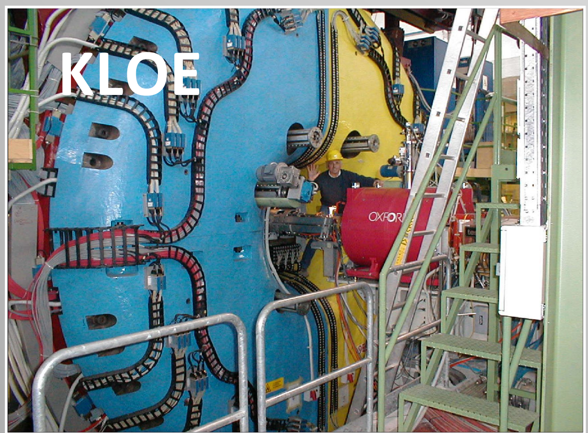
Colliding beams have:
- *low E*
- *high currents*
- *long damping time*

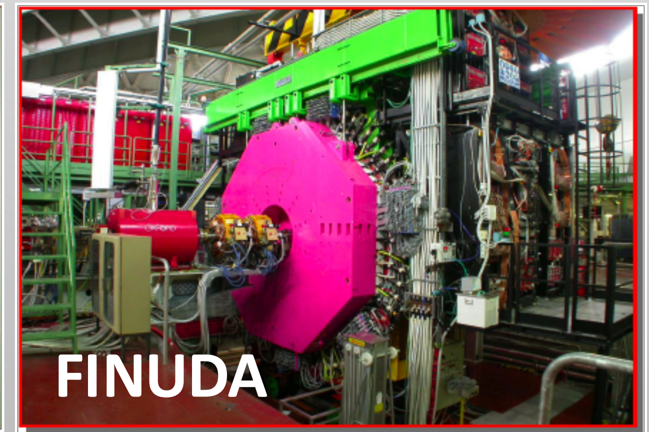
L_{peak} at DAΦNE 2001 ÷ 2007

L_{peak} had a remarkable evolution mainly due to several machine upgrades

Experiments took data one at the time, although DAΦNE had been originally conceived as collider with two IRs







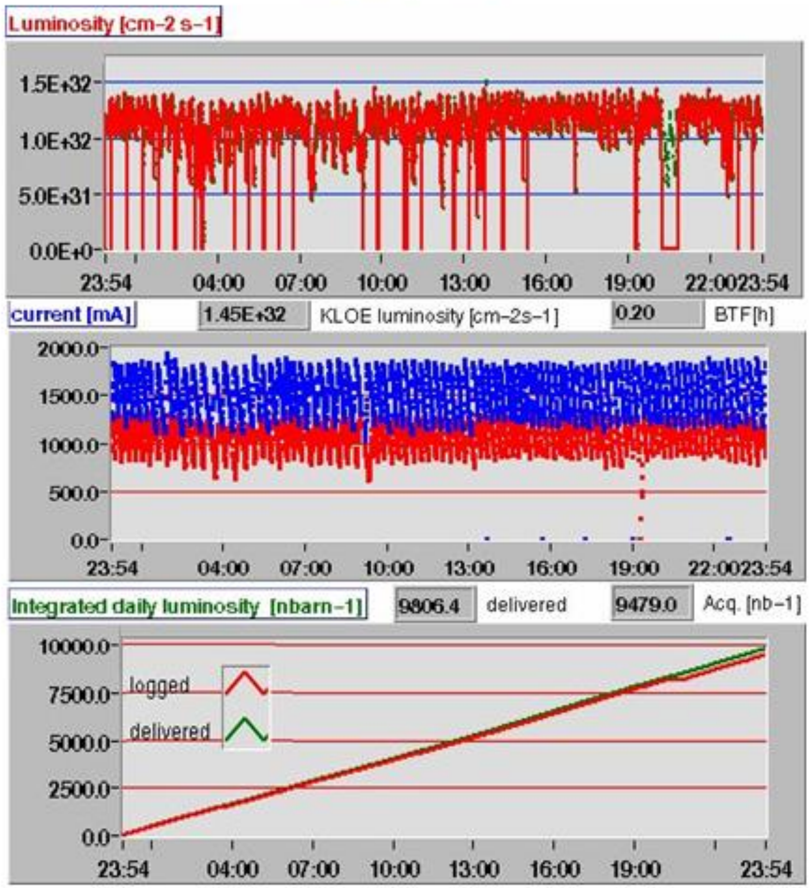
L_{logged} (fb^{-1}) 2001÷2007

KLOE	3.0
FINUDA	1.2
DEAR	0.2

The nature of a Φ-factory in itself indictates a minimum target luminosity of 10^{32} cm^{-2} s^{-1}….

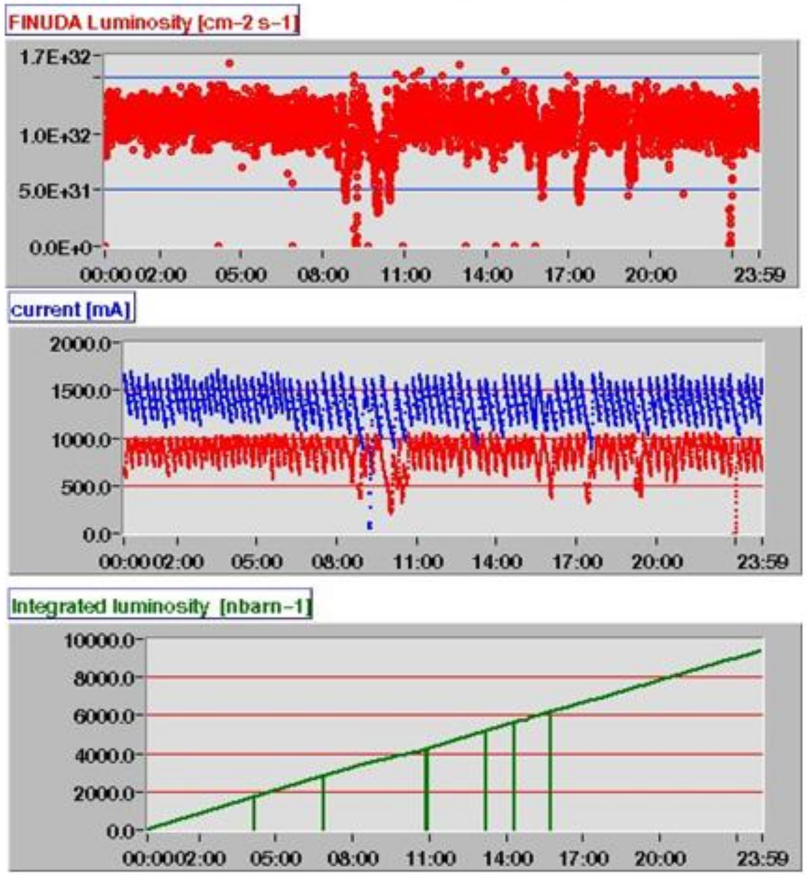
"Proposal for a Φ-factory", LNF-90/031 (IR),1990.

KLOE



111 bunches, β_y^*= 1.8 cm, β_x^*= 1.5 m

FINUDA



106 bunches, β_y^*= 1.9 cm, β_x^*= 2.0 m

Ideas, Tests and Proposals about DAΦNE

Ideas aimed at improving performances and increasing Luminosity:

- eliminate non linearities in the magnet fields mostly in the wiggler ones
- collisions with negative momentum compaction
- parasitic crossing compensation with wires
- collisions with a very high crossing angle
- strong RF focusing
- crab Waist collisions
- electrodes for e-cloud compensation

Proposals:

- DANAE (1.02 GeV $\div$ 2.4 GeV)
- Bunch lenght modulation experiment
- **Crab waist collision scheme**
- DAFNE-VE (0.6 GeV $\div$ 3 GeV with CW)

$\alpha_c < 0$ at DAΦNE

Properties of a lattice with negative momentum compaction:

- shorter bunch as a result of the focusing wake potential

    lower β^*_y

    smaller Piwinski angle Φ for a given crossing angle θ

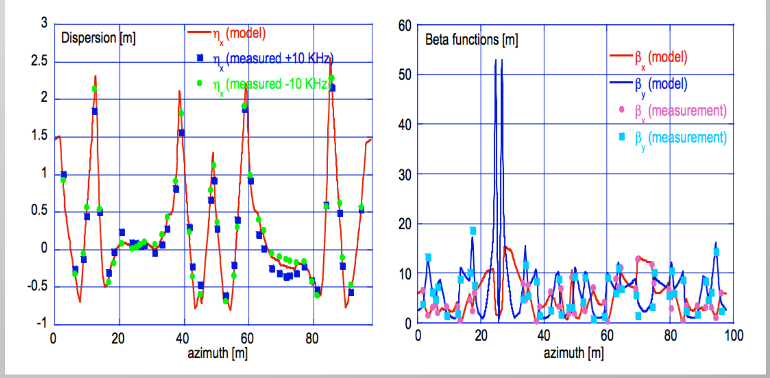
- beam-beam less harmful

    longer lifetime

    reduced transverse beam sizes blow-up

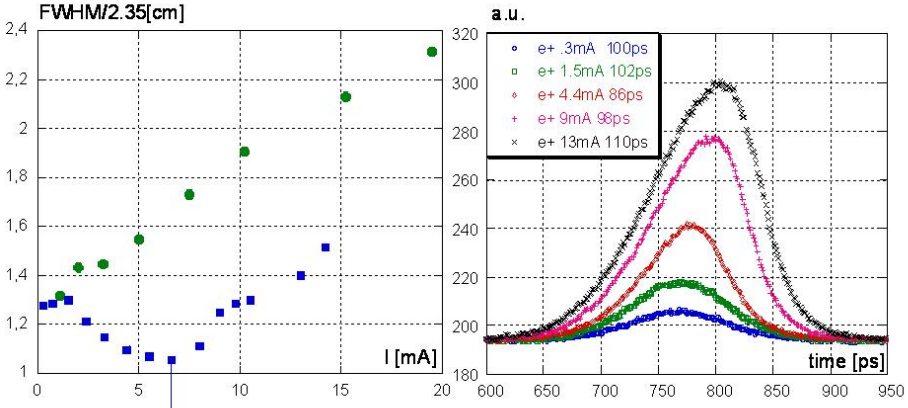
- can mitigate coherent and incoherent longitudinal instabilities
- can move the microwave instability threshold due to the vacuum chamber coupling impedance toward higher values
- single bunch head-tail instability occurs with positive chromaticity values

    It's possible operate the collider without sextupoles



$\alpha_c < 0$ at DAΦNE

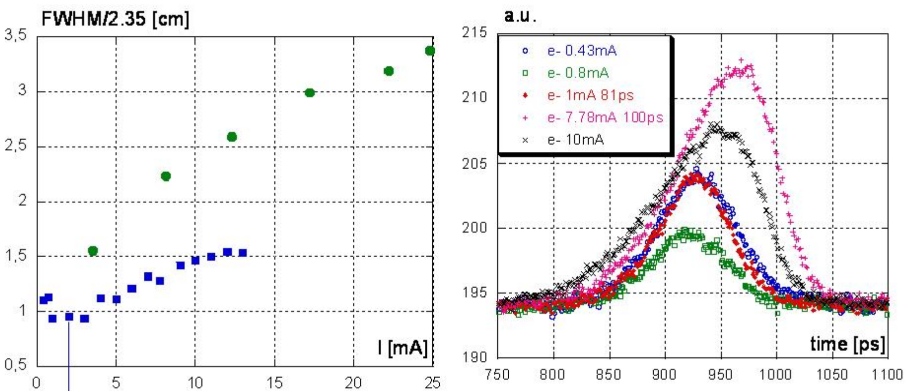
Bunch Shortening in the Positron Ring



I_{th} = 7 mA at $\alpha_c < 0$

I_{th} = 9 mA at $\alpha_c > 0$

Bunch Shortening in the Electron Ring



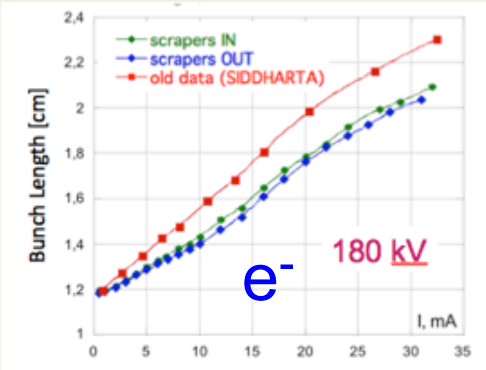
Low microwave instability threshold

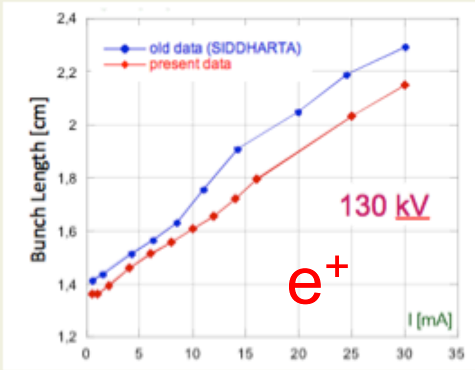
Summary of Results

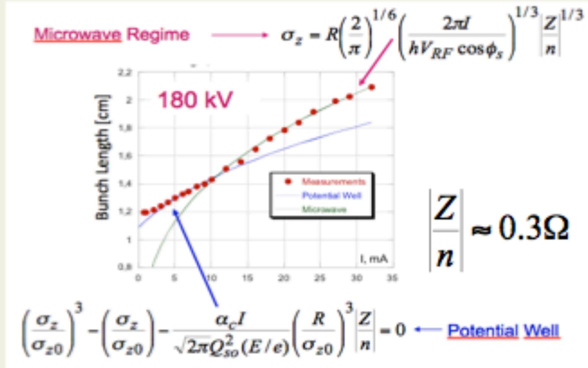
1. Flexible DAΦNE optics with α_c from +0.034 to -0.036.
2. Bunches shorten as predicted by numerical simulations.
3. It was possible to store high bunch current (~40 mA) with large negative chromaticity
4. Stable multibunch beams with currents -> 1 A
5. Specific luminosity gain of about 25% till 300 mA per beam
6. Higher current beam-beam collisions failed due to e- vertical size blow up above the microwave instability threshold

Ring Impedance

The ring impedance has been estimated relying on bunch length measurements as a function of bunch current.







Numerical fits based on potential well as well as microwave regime converge to a ring coupling impedance of 0.3 Ω

Results show a bunch lengthening reduction of the order of 10% at a current of 20 mA with respect to the values attained during the test run with the SIDDHARTA detector. Measurements taken on the positron ring exhibit the same behaviour. Bunch length is neither affected by the insertion of the beam collimators nor, on the positron ring, by the presence of the new electrodes for electron clearing

Lower impedance thanks to:

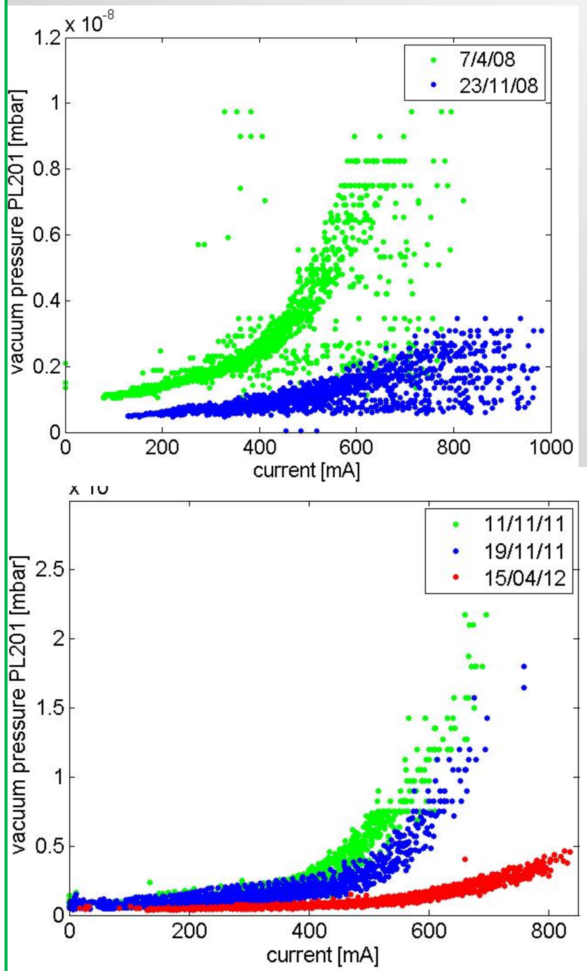
- Improved vacuum chamber and injection kickers design
- New bellows
- Removed Ion Clearing Electrodes in Mre
- Modified collimators

e-Cloud in DAΦNE

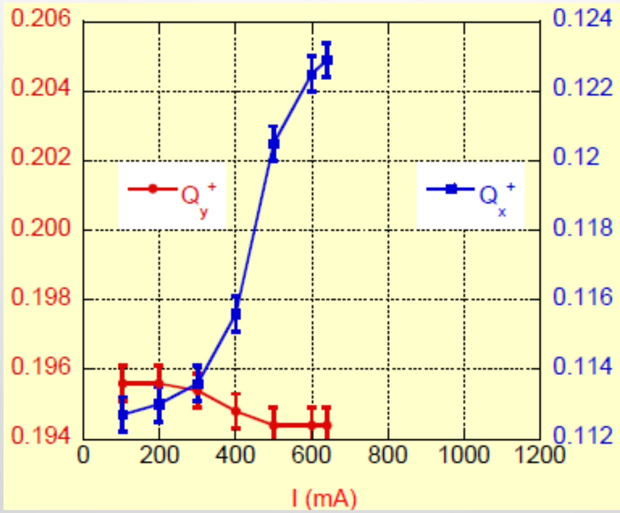
The worst case:

1. *Aluminium vacuum chamber*
2. *Shortest bunch separation of 2.7 ns*

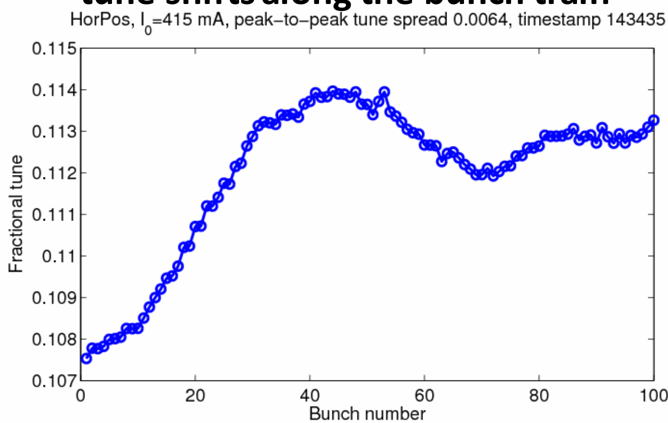
anomalous vacuum pressure rise



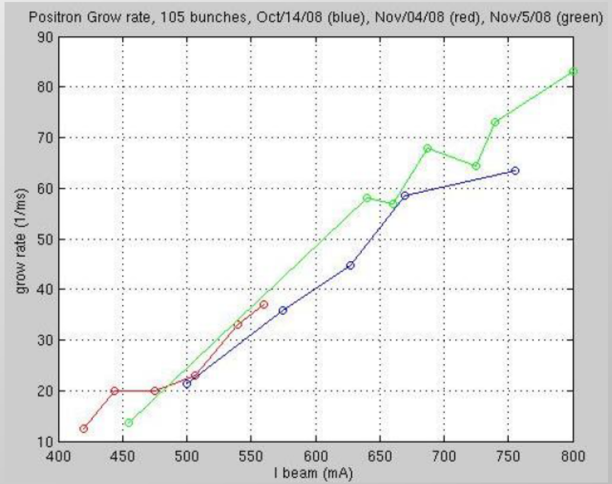
larger positive tune shift



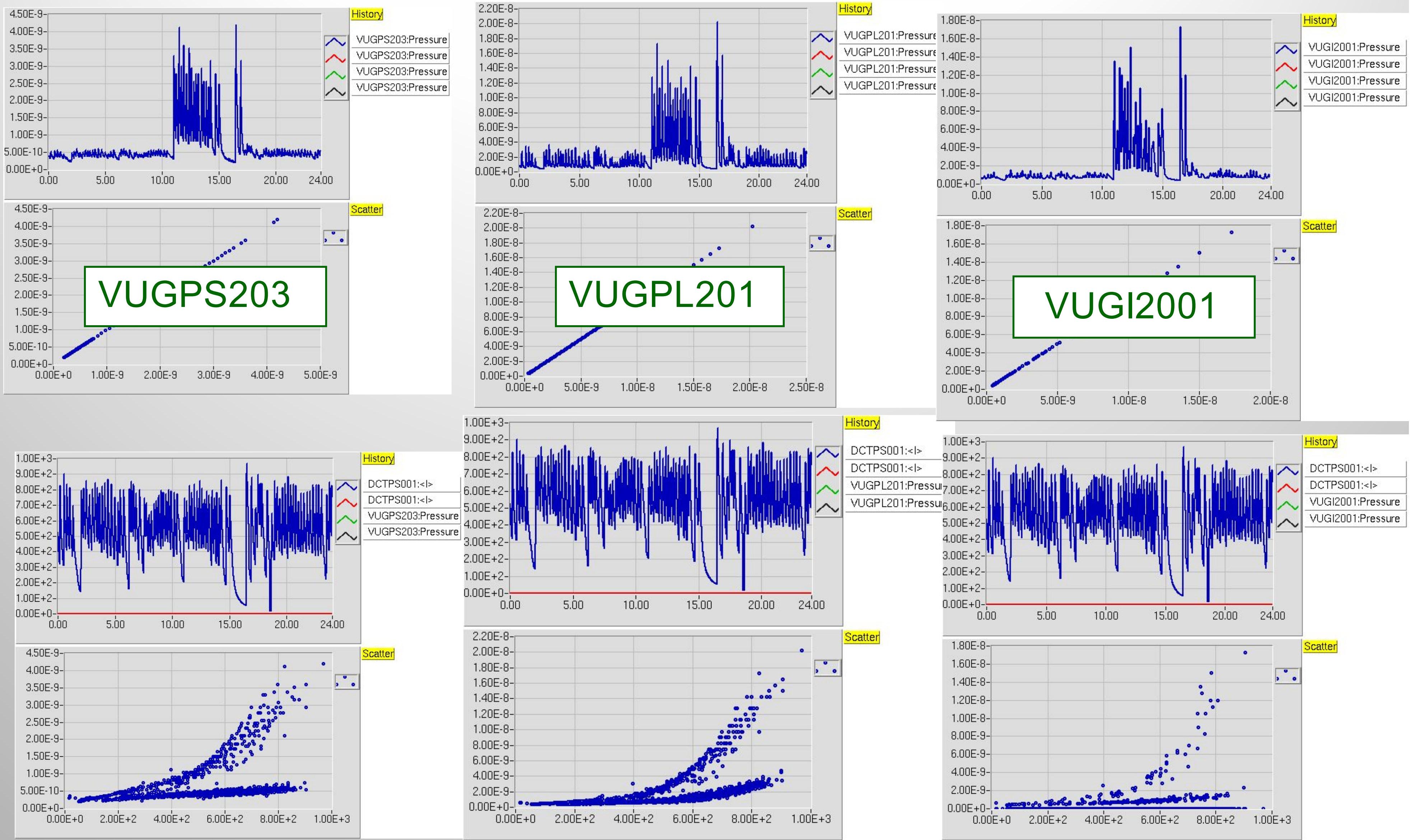
tune shifts along the bunch train



Very **fast horizontal instability** not explainable by parasitic HOMs



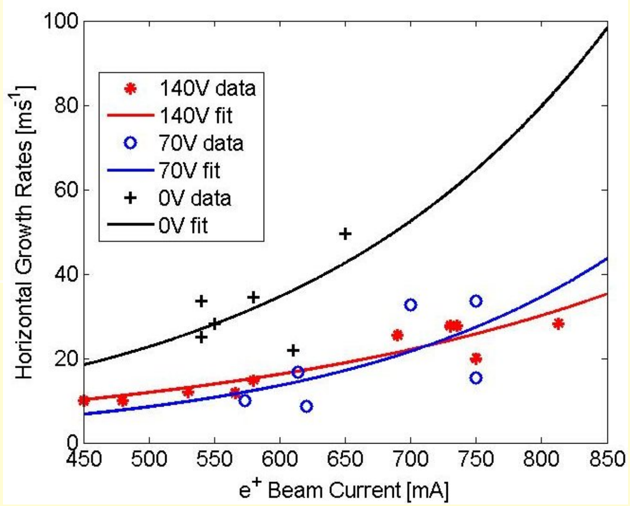
Solenoids Off 28/05/20122



Clearing electrodes for *e-cloud* suppression

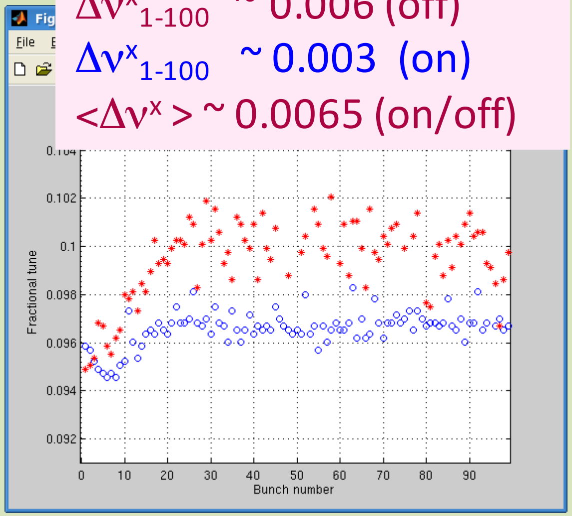
DAΦNE is the first collider operating routinely with long electrodes, for e-cloud mitigation. Electrodes let more stable operation with the positron beam, and allowed unique measurements such as: e-cloud instabilities' growth rate, transverse beam size variation, and tune shifts along the bunch train, demonstrating their effectiveness in restraining e-cloud induced effects.
(D. Alesini et al, Phys. Rev. Lett. 110, 124801 (2013))

Horizontal Instability Growth Rate measured busing bunch-by-bunch feedback as a function of the electrode voltage

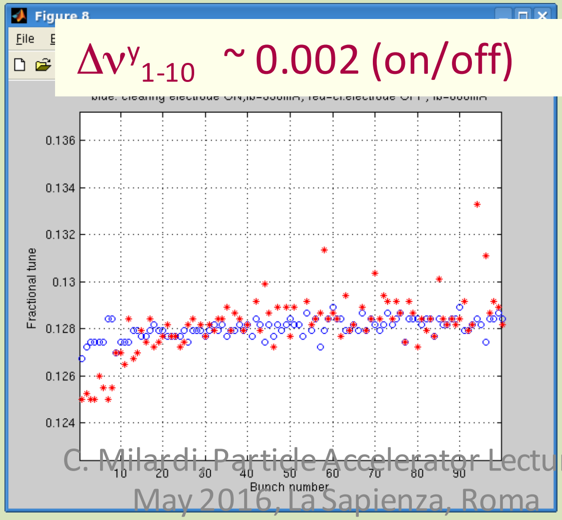


Tune Spread measurements

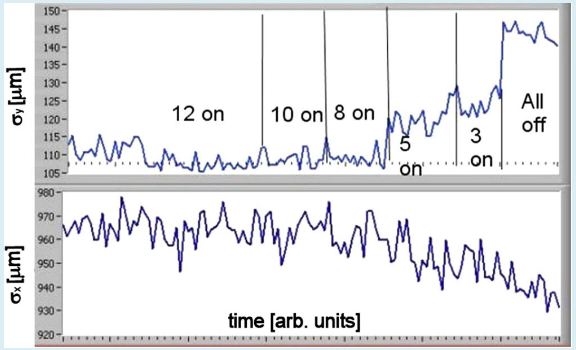
$\Delta\nu^x_{1\text{-}100}$ ~ 0.006 (off)
$\Delta\nu^x_{1\text{-}100}$ ~ 0.003 (on)
$<\Delta\nu^x>$ ~ 0.0065 (on/off)



$\Delta\nu^y_{1\text{-}10}$ ~ 0.002 (on/off)



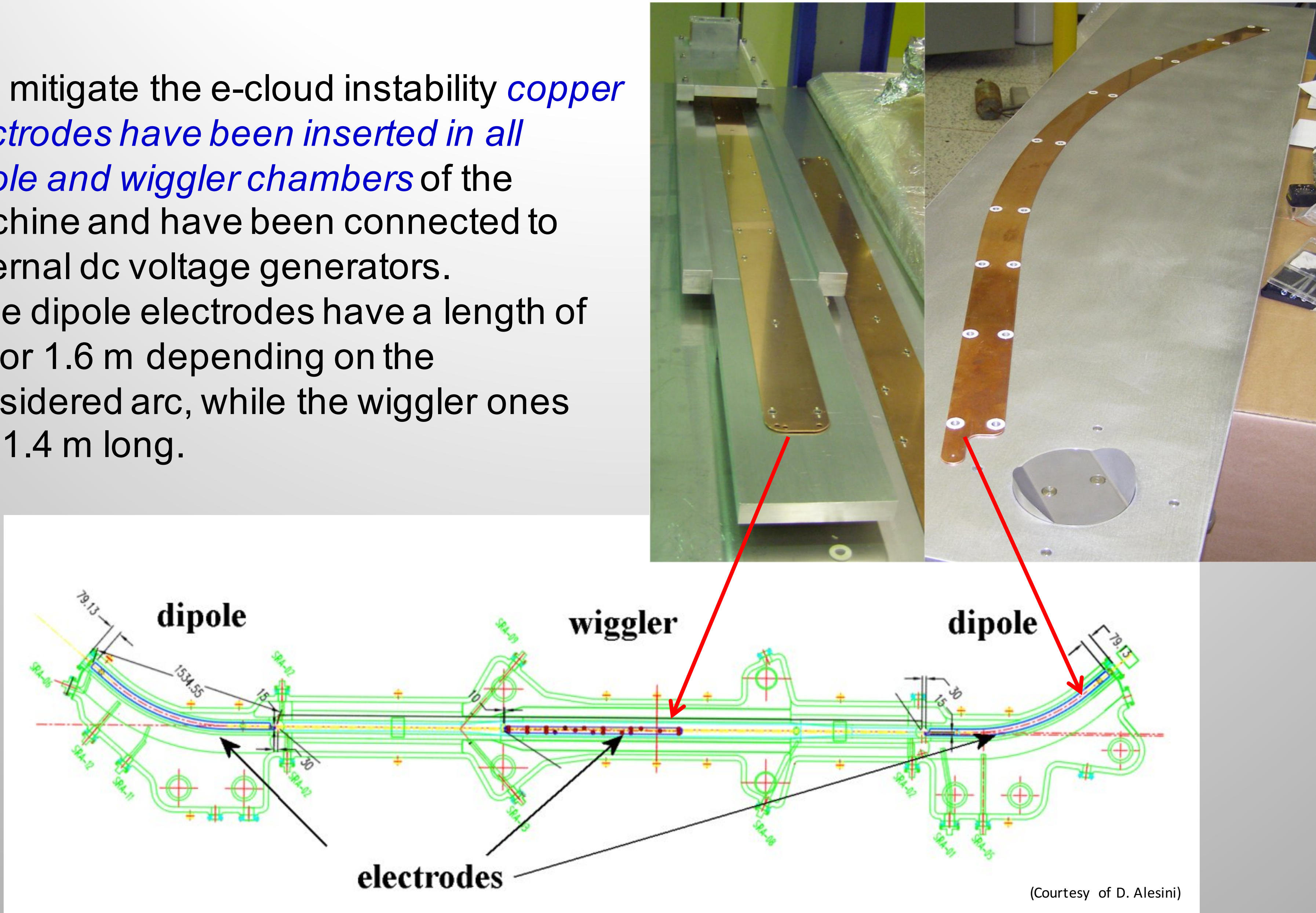
Beam Dimension



Electron Clearing Electrodes

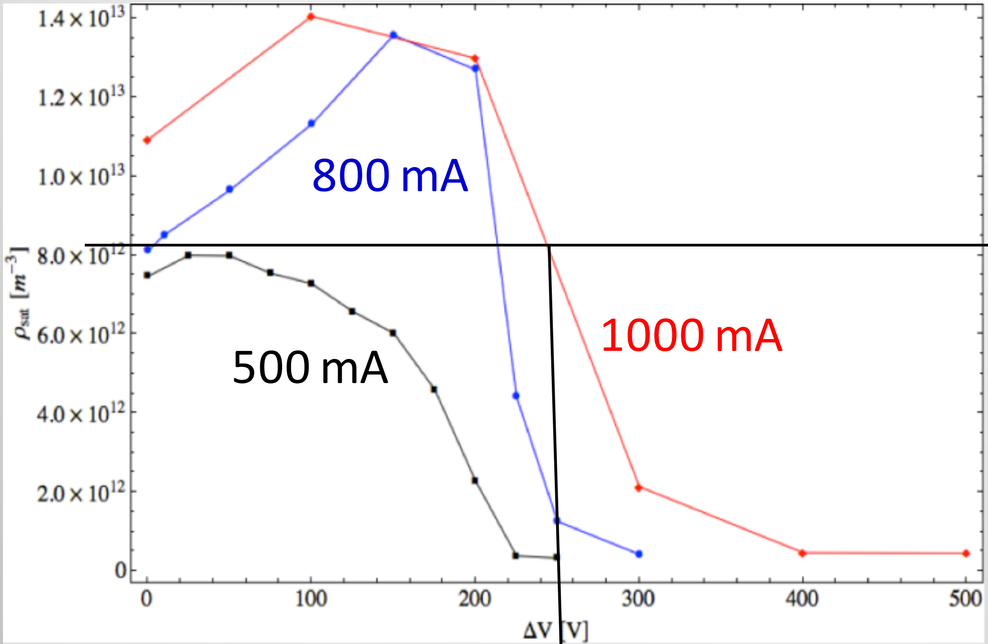
To mitigate the e-cloud instability *copper electrodes have been inserted in all dipole and wiggler chambers* of the machine and have been connected to external dc voltage generators.

The dipole electrodes have a length of 1.4 or 1.6 m depending on the considered arc, while the wiggler ones are 1.4 m long.



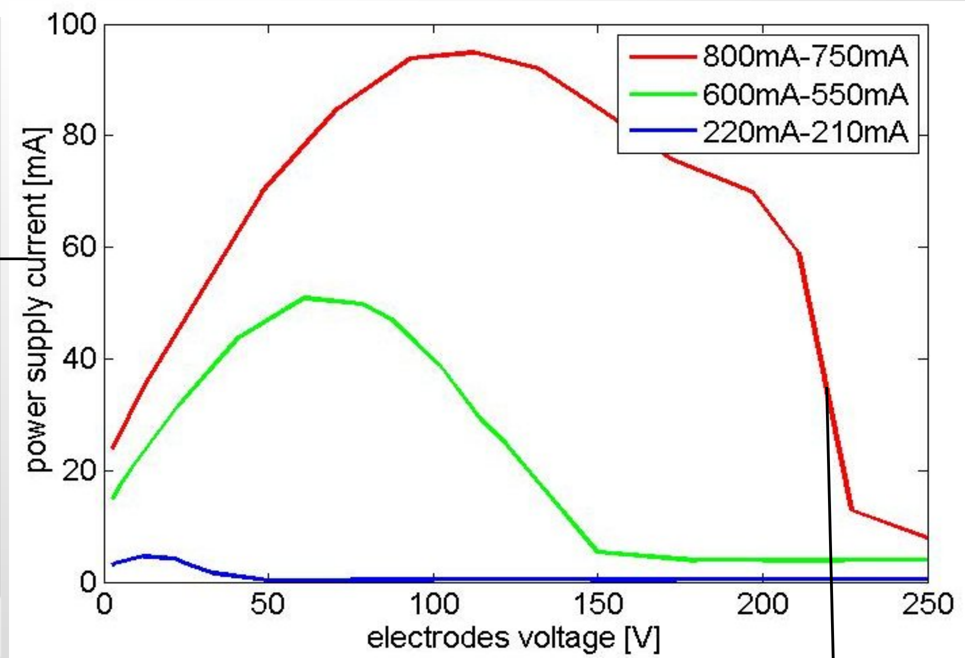
Effectiveness of Electron Cloud Clearing Electrodes

e-cloud density build-up



(Courtesy of T. Demma)

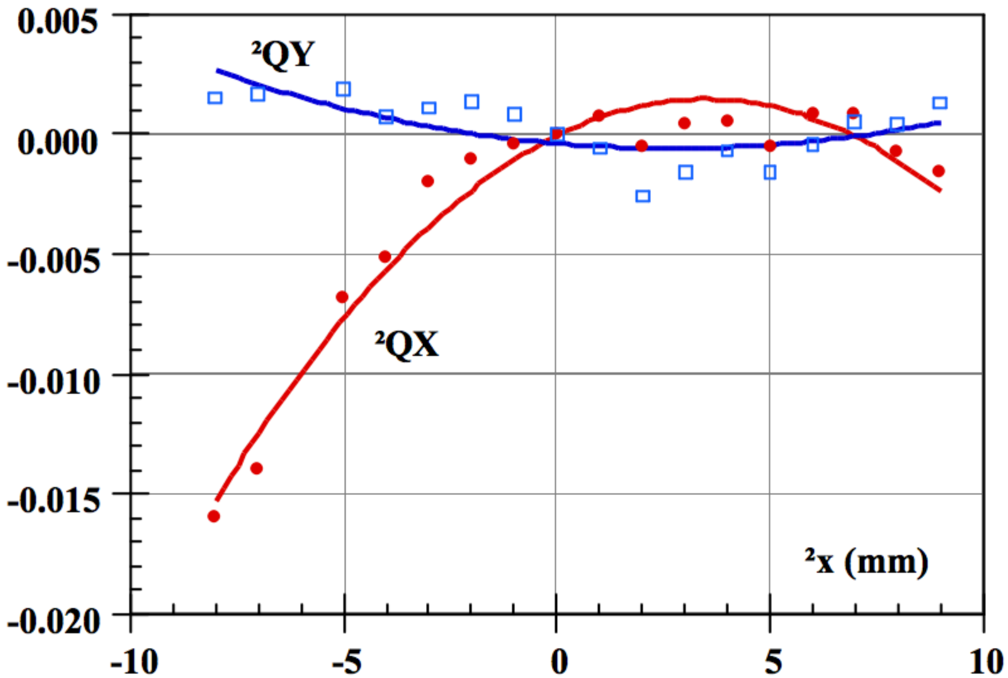
Measured absorbed e-cloud current



With a maximum voltage of 250 V the electrodes are effective till a positron current of the order of 800-900 mA .
For higher beam currents higher voltages are required

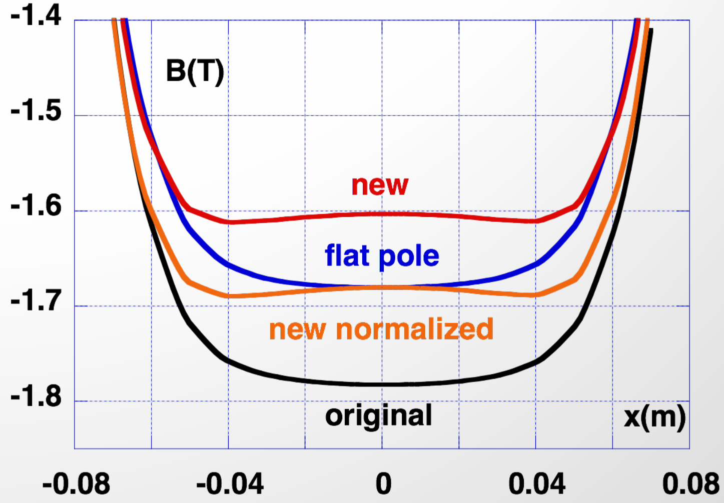
Non Linearity in the Wiggler Field

Measurement of tune shift as a function of beam displacement inside DAFNE wigglers exhibits a strong third order non linearity

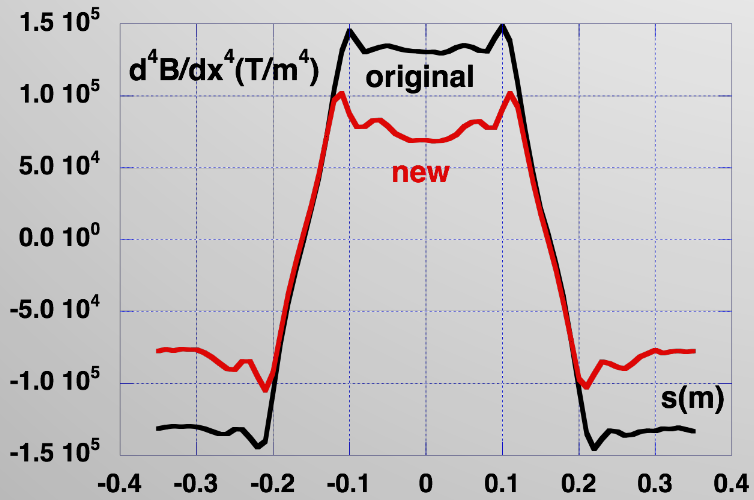


Wiggler poles modification (2002)

Additional plates glued on wiggler poles

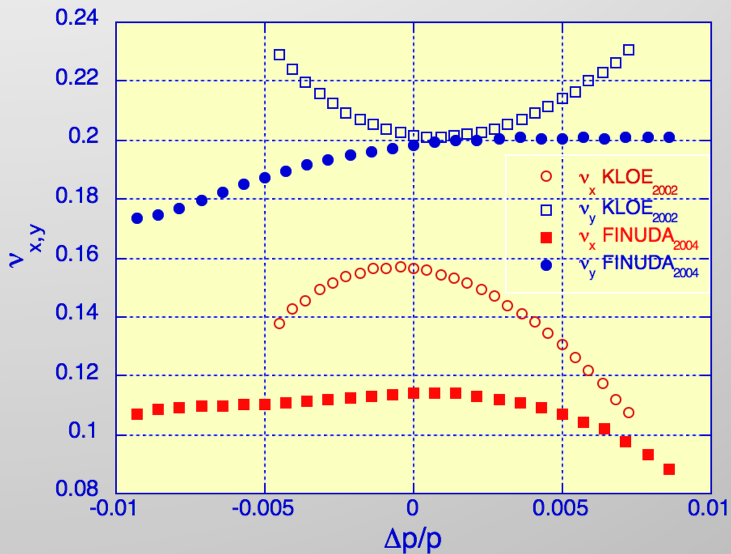


Field at pole center



Improvement of the 4th order term generating cubic nonlinearity

(M. Preger)

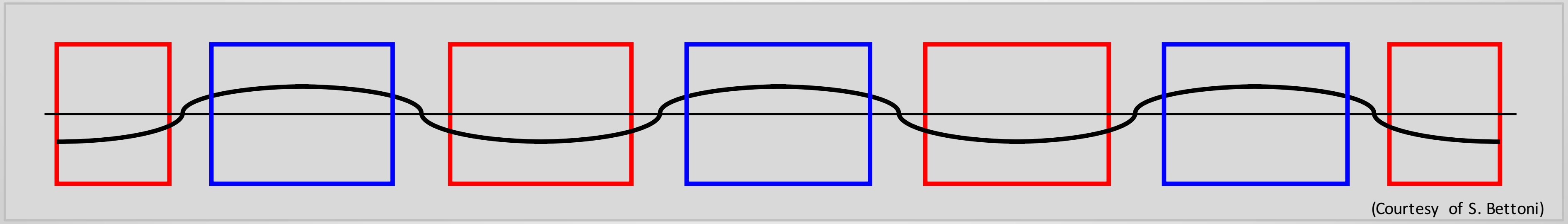


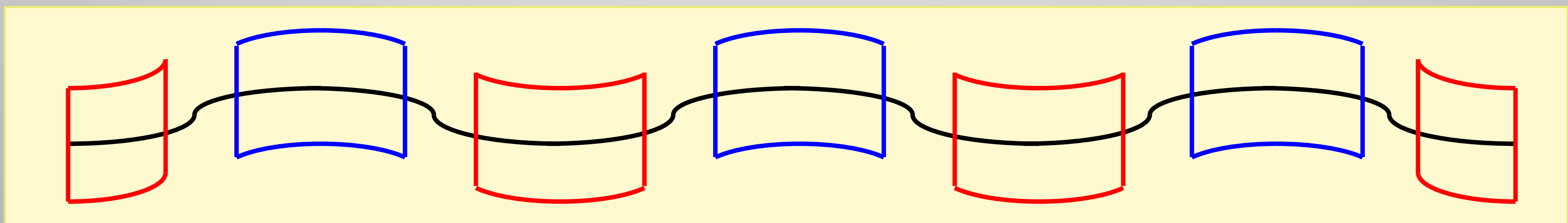
A factor 2 is gained in terms of energy acceptance

Wiggling wiggler

Motivation:

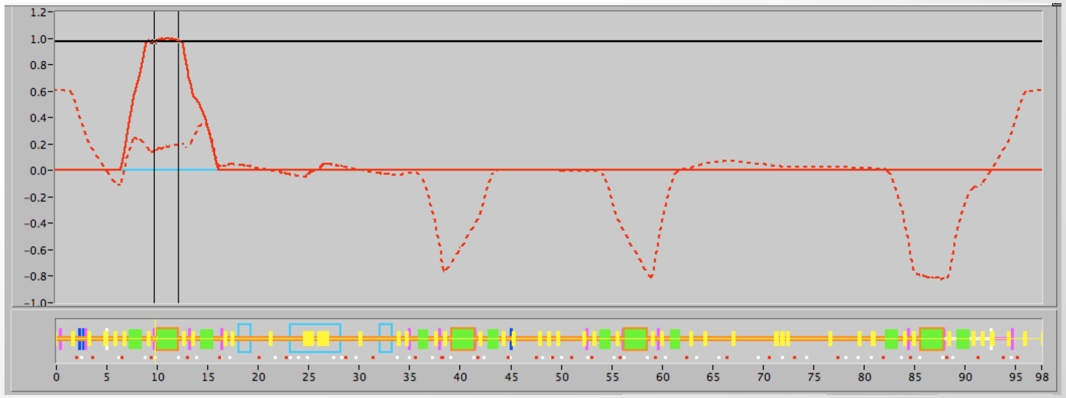
Build wiggler poles symmetric with respect to the beam orbit



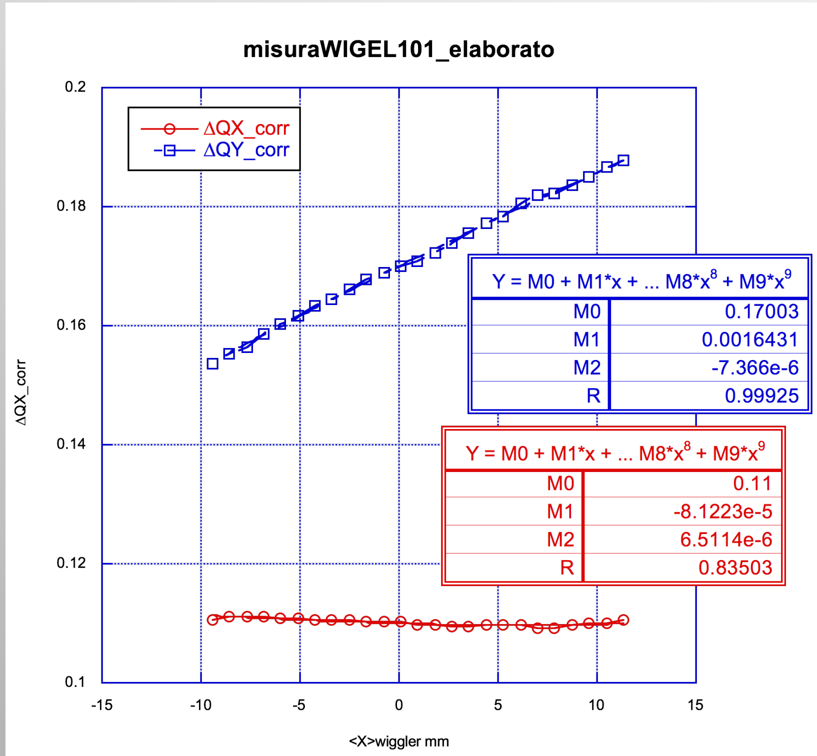


Wiggler measurement

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



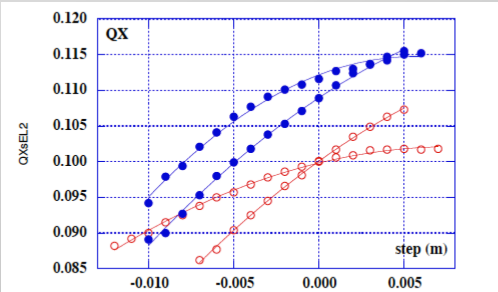


Figure 8: Measured horizontal betatron tune versus beam displacement in 4 wigglers

Published in 2004

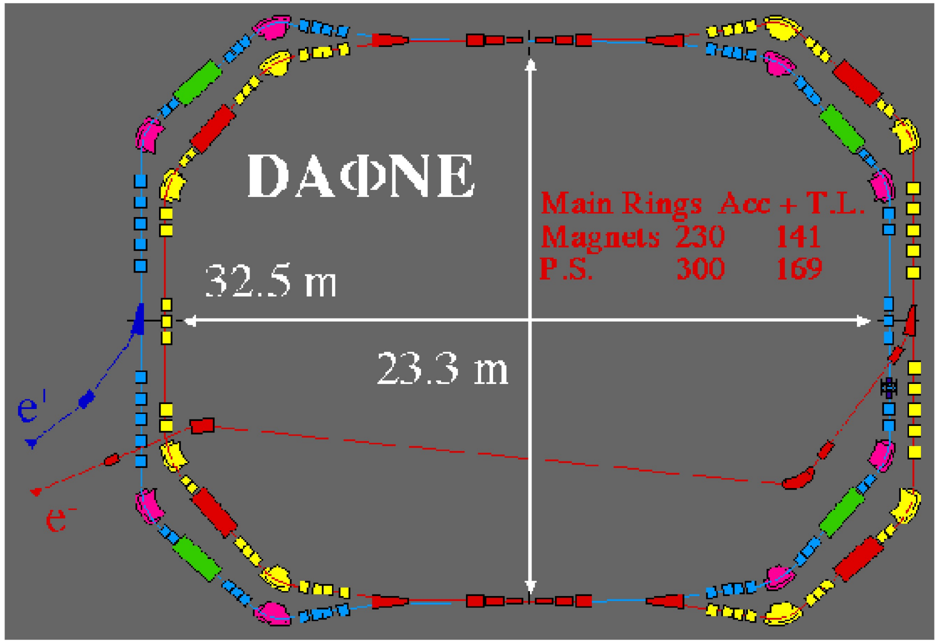
K^3 $[m^{-3}]$	Year
800	2001
360	2004
0	2011

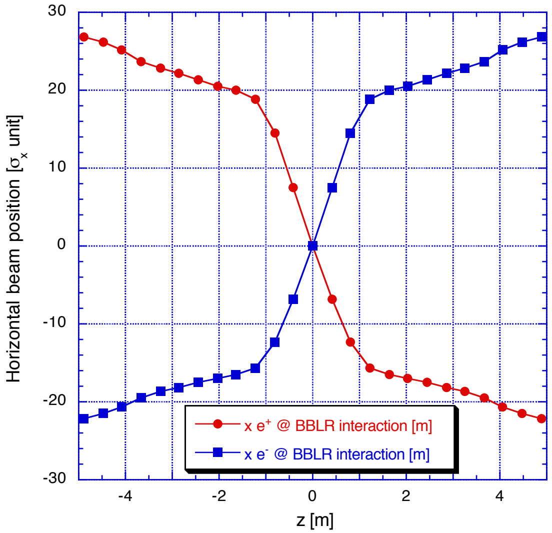
Long Range Beam-Beam Interaction at DAΦNE

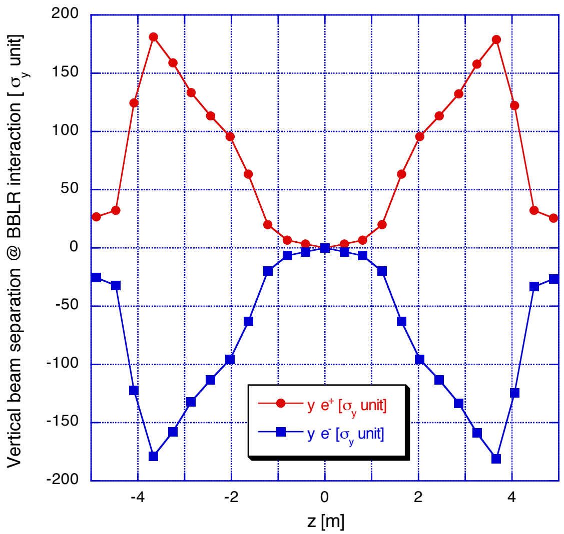
In the DAΦNE *original* configuration

- **e^+** and **e^-** stored in **105 - 111 bunches**
- 25 [mrad] crossing angle
- *2.7 [nsec] bunch spacing !!!!*
- 5 [m] long common IR
- ε 2.5 10^{-6} [m]

24 LRBB interactions







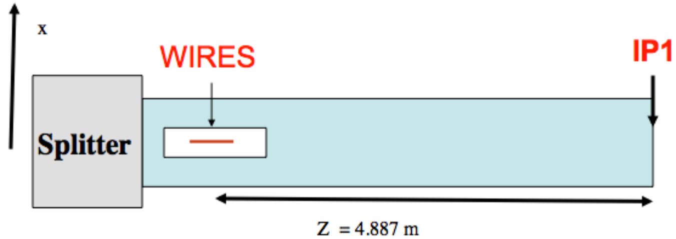
Wires for LRBB compensation at DAΦNE

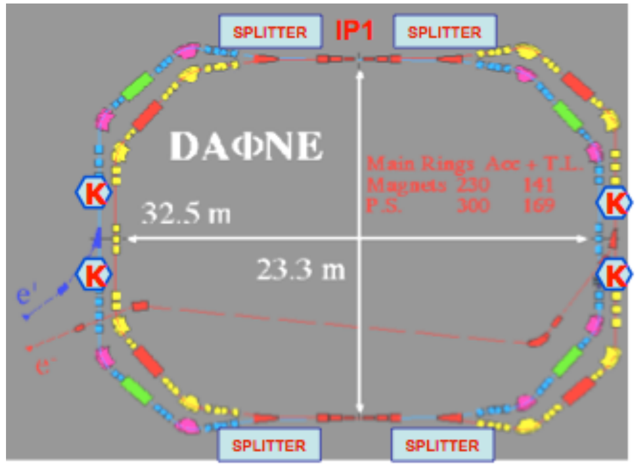
LRBB were causing

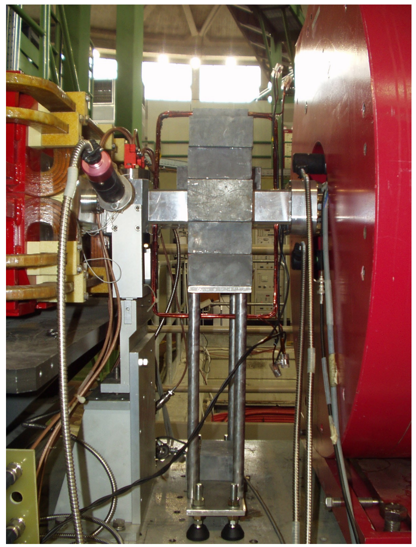
- Orbit distortion
- Beam lifetime reduction both during inject and coasting resulting in a limitation on
  - maximum storable current
  - peak and integrated ***L***

$$\Delta r' = \frac{2Nr_0}{\gamma r}$$

LRBB deflection

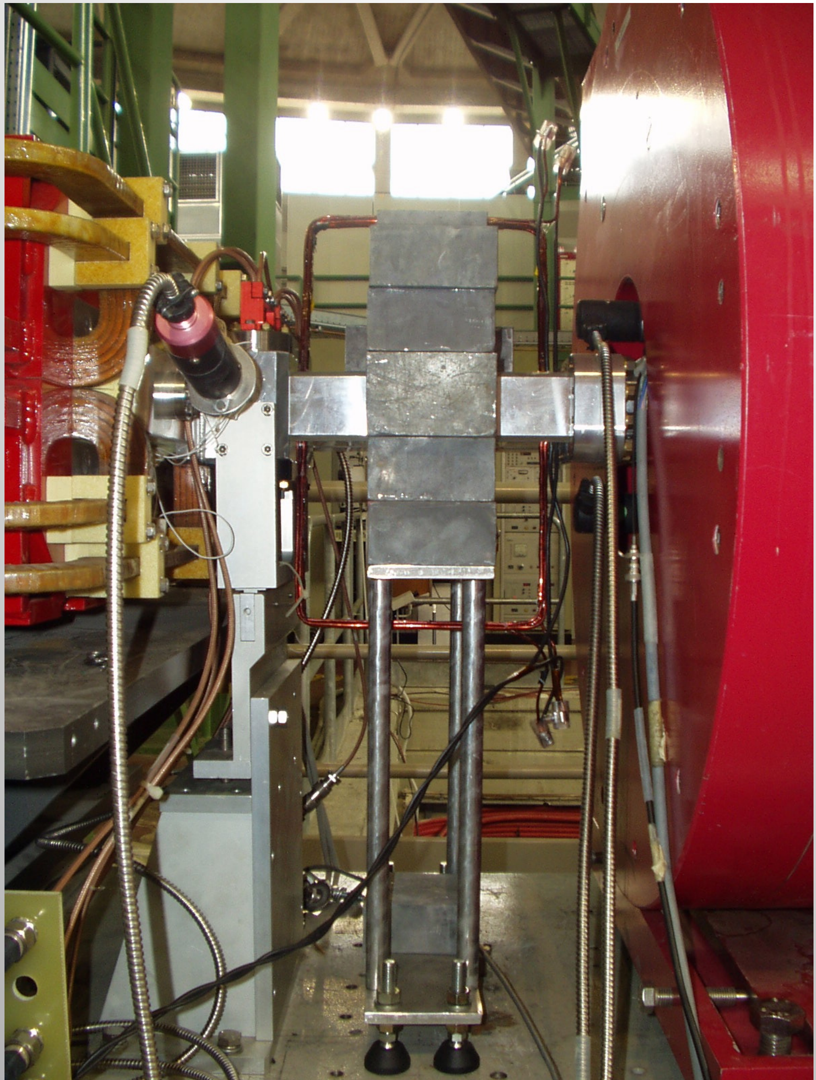


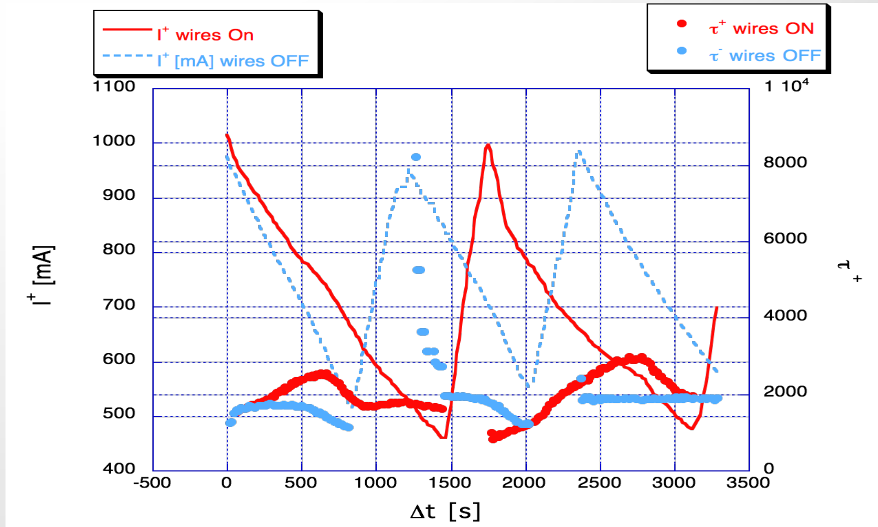




- Wires were installed outside the vacuum chamber using a short section in IR1, just before the splitters, where the vacuum pipes were separated.
- The wires carried a tuneable DC current, and produced a stationary magnetic field (1/r) with a shape similar to the one created by the opposite beam

Wires have beed used for beam-beam parasitic crossing compensation



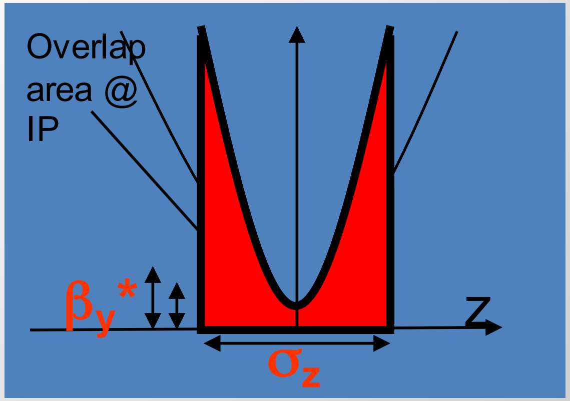


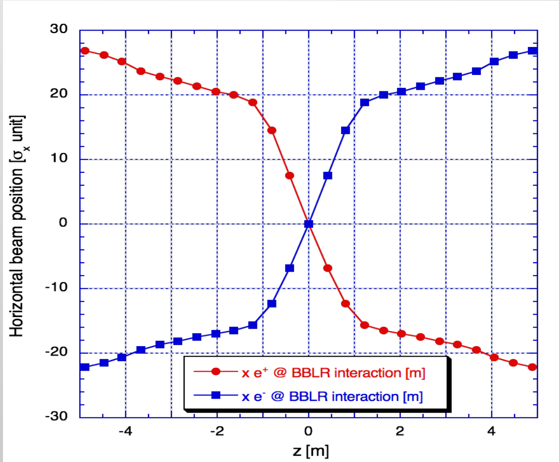
- ✓ Switching on and off the wires we obtain the same luminosity while colliding the same beam currents.
- ✓ The positron lifetime is on average higher when wires are on, while the electron one is almost unaffected.
- ✓ The beam blow-up occurring from time to time at the end of beam injection, corresponding to a sharp increase in the beam lifetime, almost disappear.
- ✓ It is possible to deliver the same integrated luminosity injecting the beam two times only instead of three in the same time integral, or to increase the integrated luminosity by the same factor keeping the same injection rate.
- ✓ A higher t means less background on the experimental detector.
- ✓ It is possible to optimize the collision at maximum current

Rationale for the Upgrade

L_{peak} ~ 1.6 10^{32} cm^{-2} s^{-1} was the maximum luminosity achievable in the original DAΦNE configuration due to:

- $\beta^*_y \sim \sigma_z$ to avoid hourglass effect
- Long-range beam-beam interactions causing τ^+ τ^- reduction limiting I^+_{MAX} I^-_{MAX} and consequently L_{peak} and $L_\int$
- Transverse size enlargements due to the beam-beam interaction





A new conceptual approach was necessary to reach L~10^{33}

Collision scheme based on **Large Piwinski** angle and **Crab-Waist**

Crab-Waist Collision Scheme

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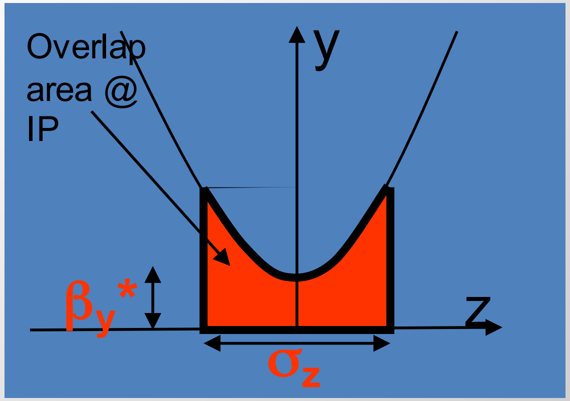
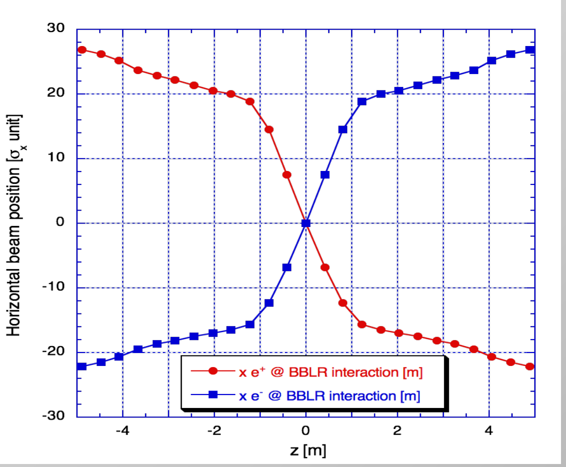




A new conceptual approach was necessary to reach L~10^{33}
Collision scheme based on **Large Piwinski** angle and **Crab-Waist**

Large Piwinski angle

Large Piwinski angle Φ obtained by:

$$\Phi \approx \frac{\sigma_z}{\sigma^*_x}\frac{\theta}{2}$$

larger θ

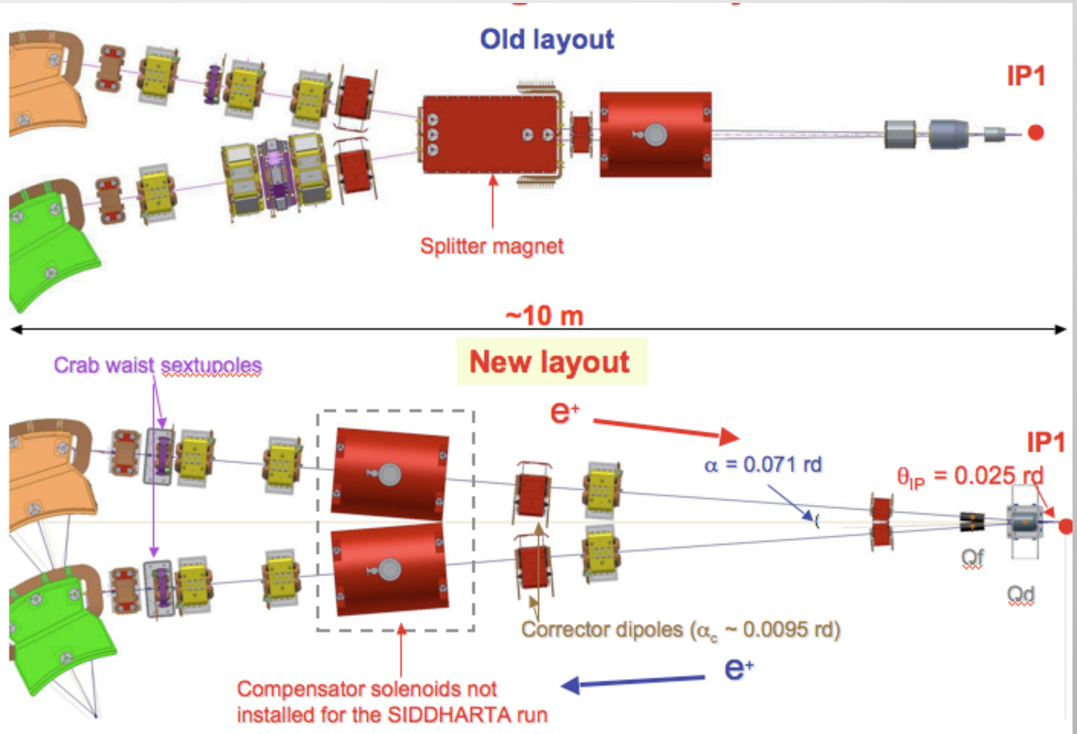
smaller σ_x

$$\xi_y \propto \frac{N\sqrt{\beta_y^*}}{\sigma_z\theta} \qquad \xi_x \propto \frac{N}{(\sigma_z\theta)^2} \qquad L \propto \frac{N\xi_y}{\beta_y^*}$$

- low ξ_x
- $L_{geometric}$ gain
- no parasitic crossing

New IR magnetic layout

- Splitter magnets and compensator solenoids removed
- New low-β
- Sector dipols around IP rotated
- large collision angle ~ 50 mrd
- Four C type corrector dipoles used to mach the vacuum chamber in the arc

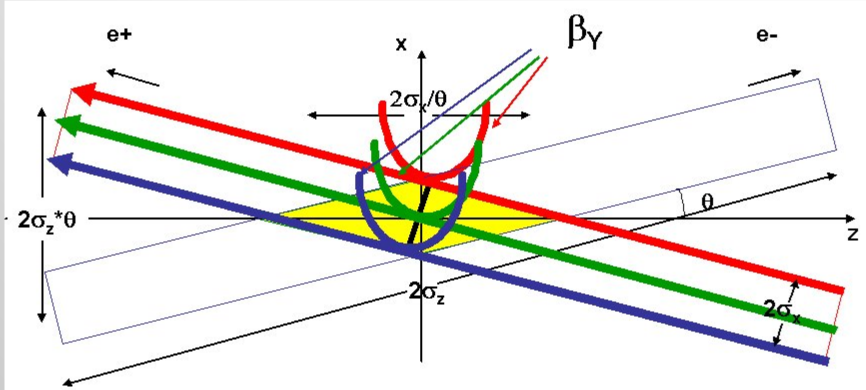


Lower β^*_y possible

Small $\boldsymbol{\beta_y^*}$ in fact the bunch overlap lenght Σ is:

$$\Sigma \propto \frac{\sigma_x}{\theta} \qquad \beta_y \propto \frac{\sigma_x}{\theta} << \sigma_z$$

- $L_{geometric}$ gain
- low ξ_y
- Vertical synchro-betatron resonances suppression



New low-β section

•*low-beta* section based on PM QUADs:

K_{QD} = -29.2 [T/m]

K_{QF} = 12.6 [T/m]

•$e^+ e^-$ vacuum chambers separate after Q_D

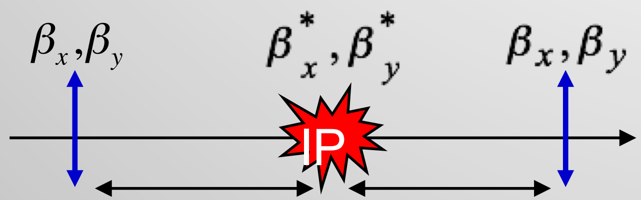
Crab-Waist compensation

Collision with large Φ is not a new idea .....

Crab-Waist transformation is !

$$y = \frac{xy'}{2\theta}$$

sextupole (anti)sextupole

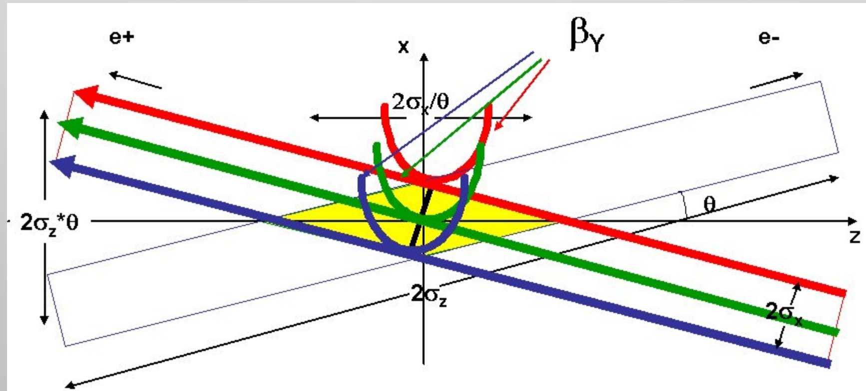


$$\Delta\nu_x = \pi$$

$$\Delta\nu_y = \frac{\pi}{2}$$

- $L_{geometric}$ gain
- x-y synchro-betatron and betatron resonance suppression

P. Raimondi et al., arXiV:physics/0702033
C. Milardi et al., Int.J.Mod.Phys.A24, 2009
M. Zobov et al., Phys. Rev. Lett. 104, 2010



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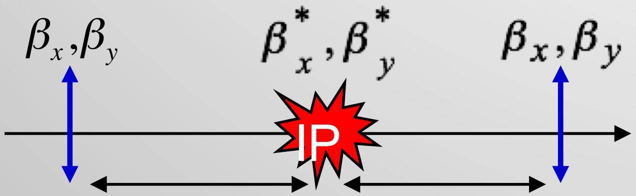

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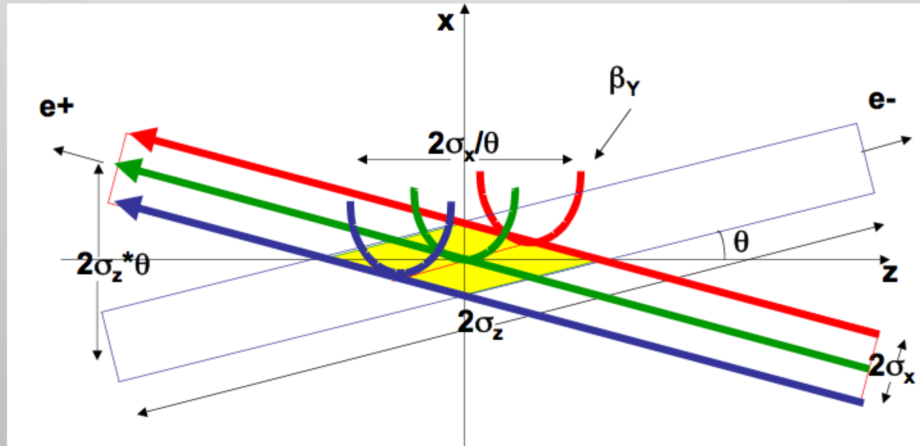
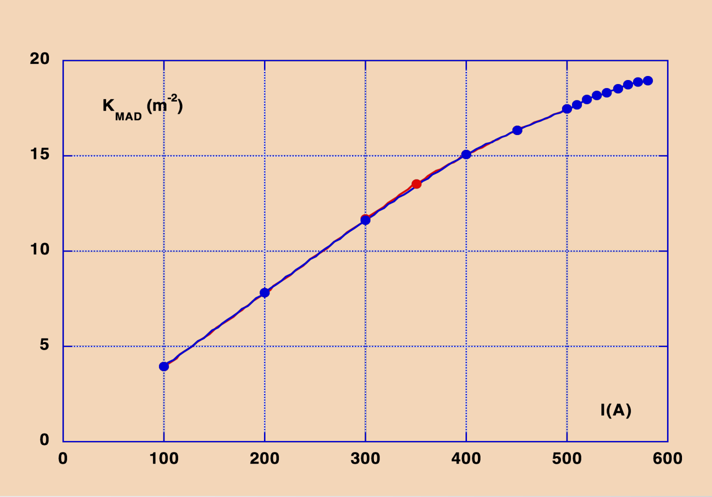
P. Raimondi , 2° *SuperB Workshop, March 2006*
P.Raimondi, D.Shatilov, M.Zobov, physics/0702033
C. Milardi et al., Int.J.Mod.Phys.A24, 2009
M. Zobov et al., Phys. Rev. Lett. 104, 2010



Crab-Waist Sextupole Parameters

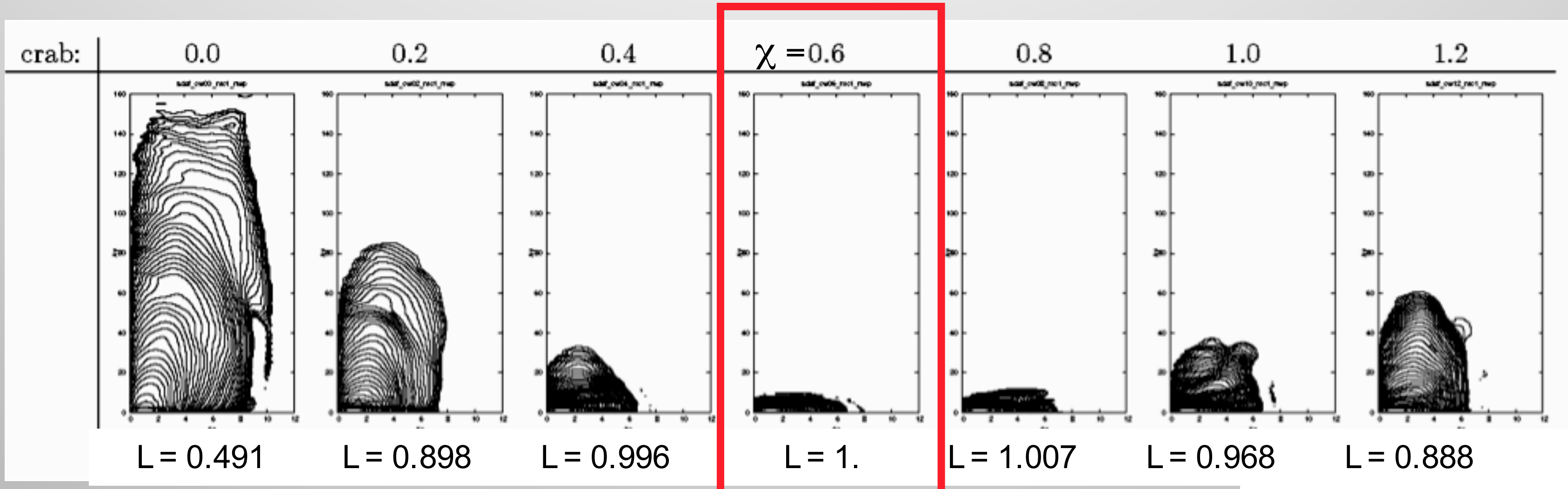
CW-Sextupoles are high strength magnets

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



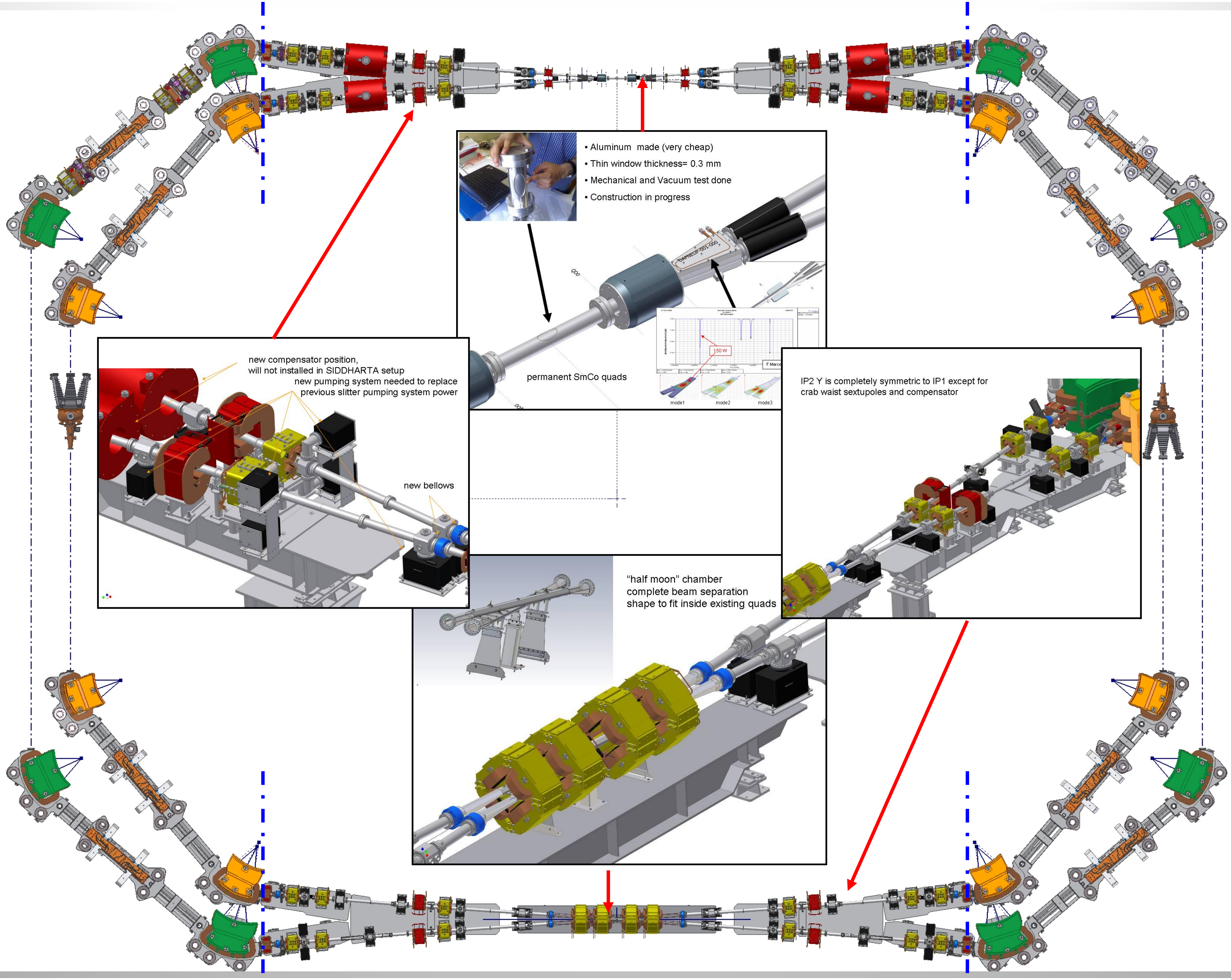
χ nominal 0.6

χ **used value 0.5**



Lifetrack D. Shatilov

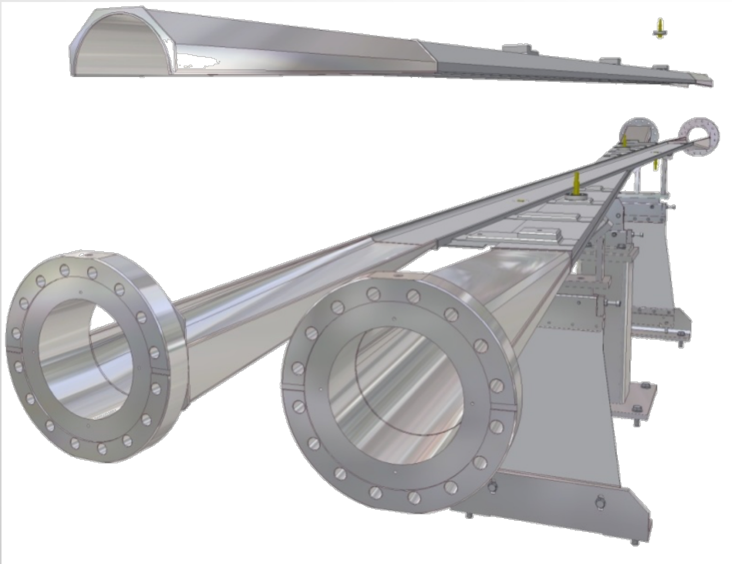
Luminosity (arbitrary unit) *and **Beam tails versus waist rotation*** χ

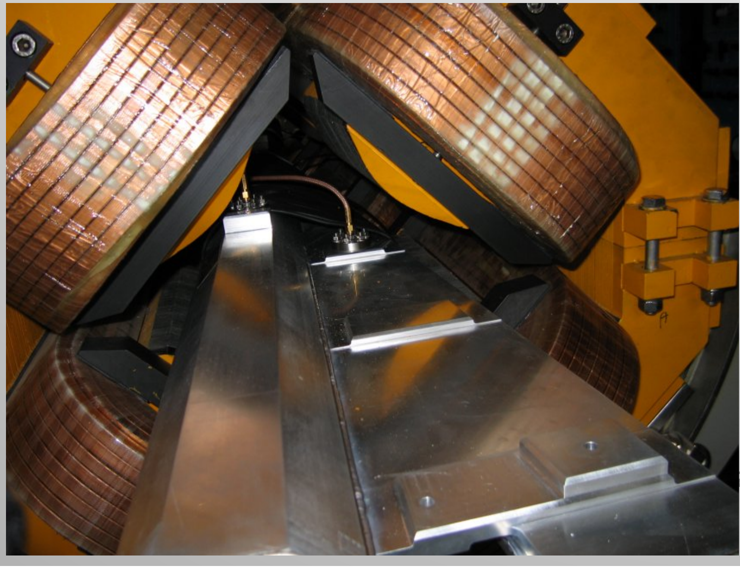


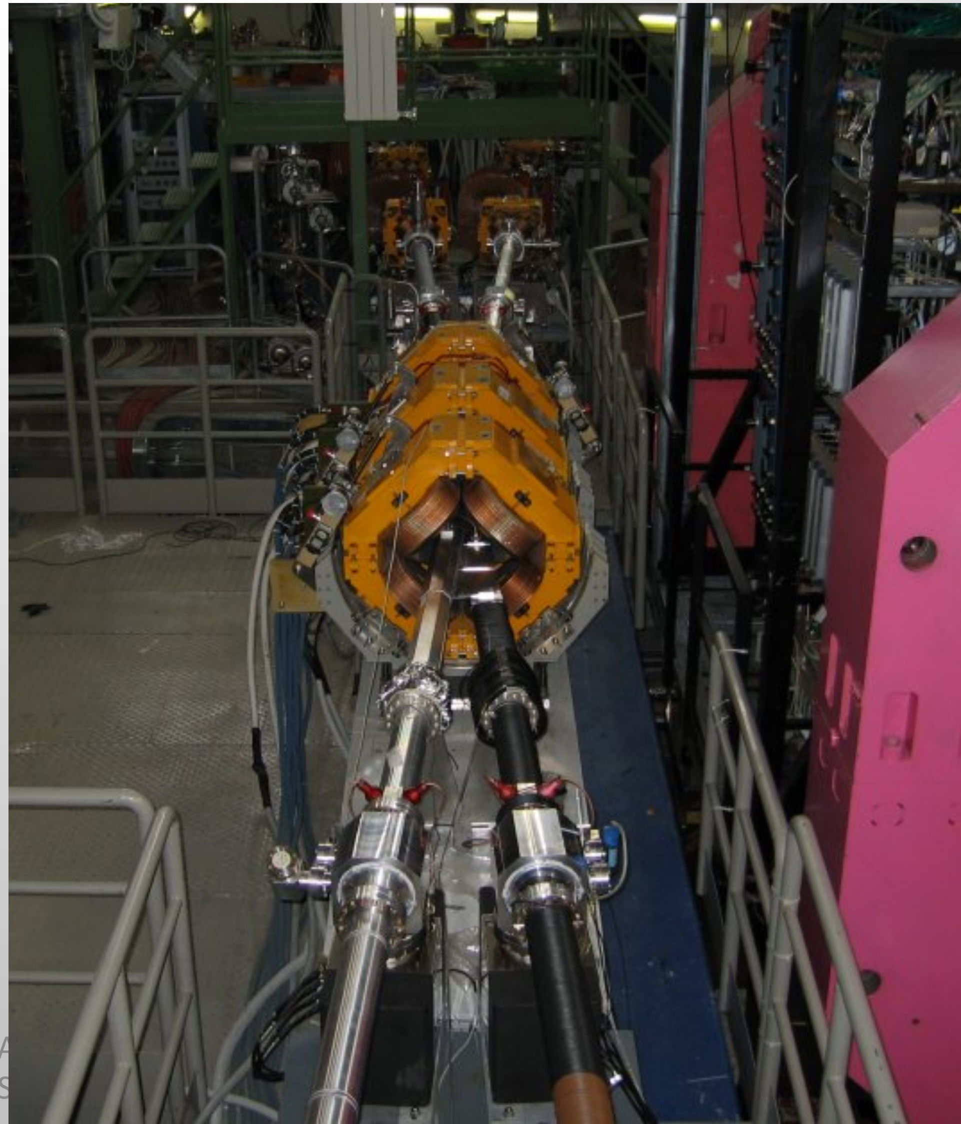
• Aluminum made (very cheap)
• Thin window thickness= 0.3 mm
• Mechanical and Vacuum test done
• Construction in progress
permanent SmCo quads
new compensator position,
will not installed in SIDDHARTA setup
new pumping system needed to replace
previous slitter pumping system power
new bellows
IP2 Y is completely symmetric to IP1 except for
crab waist sextupoles and compensator
"half moon" chamber
complete beam separation
shape to fit inside existing quads

RING CROSSING REGION LAYOUT

- Second crossing region ***symmetric*** with respect to first one
- "Half Moon" chamber allows complete beam separation (no 2nd IP)



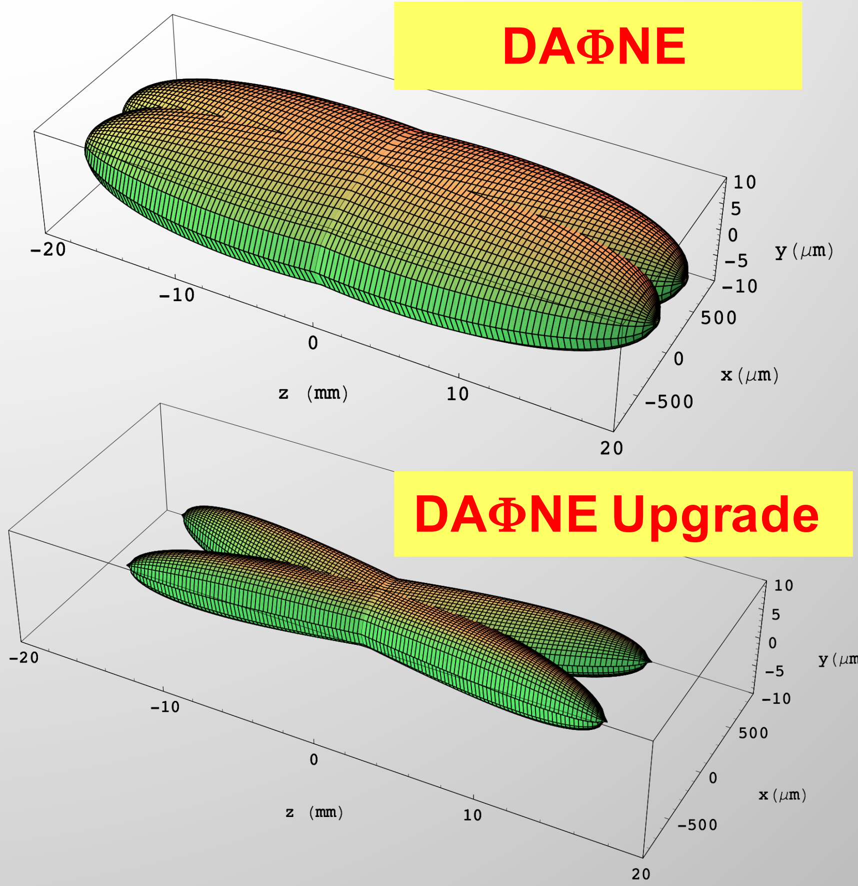




DAΦNE Upgrade Parameters

	DAΦNE KOE	DAΦNE Upgrade
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mmxmrad)	0.34	0.26
β_x^* (cm)	160	26
σ_x^* (mm)	0.70	0.26
$\Phi_{Piwinski}$	0.6	1.9
β_y^* (cm)	1.80	0.85
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
I_{bunch} (mA)	13	13
σ_z (mm)	25	20
N_{bunch}	110	110
L ($cm^{-2}s^{-1}$) x10^{32}	1.6	5

Beam distribution @ IP



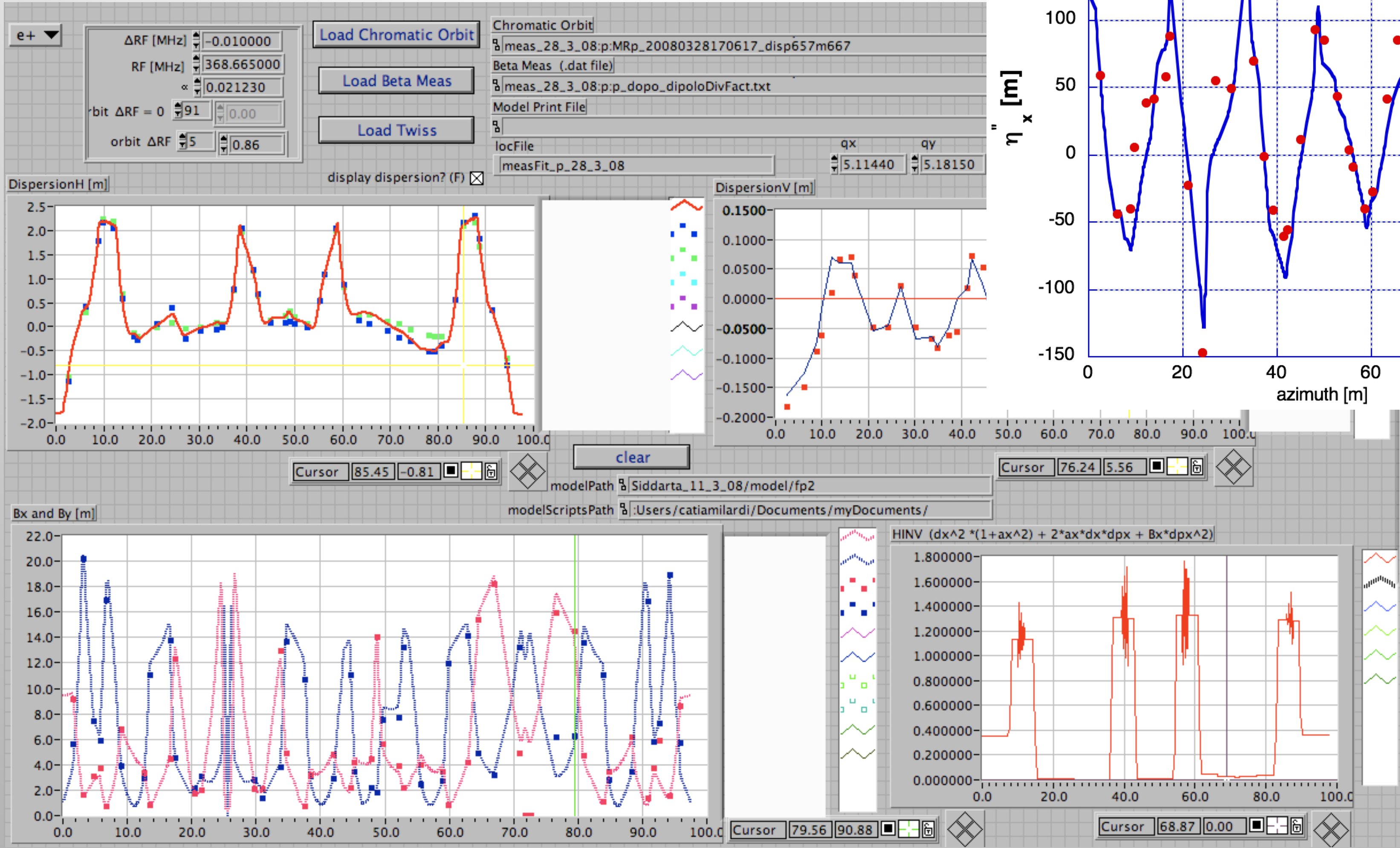
- *In 2007 the DAΦNE accelerator complex has been upgraded in order to implement a new collision scheme based on **large Piwinski angle**, **low–β** and **Crab-Waist compensation** of the synchro-betatron resonances*
- *The upgrade took ~ **five months***
- ***Since May 2008** DAΦNE is delivering luminosity to the SIDDHARTA experiment.*

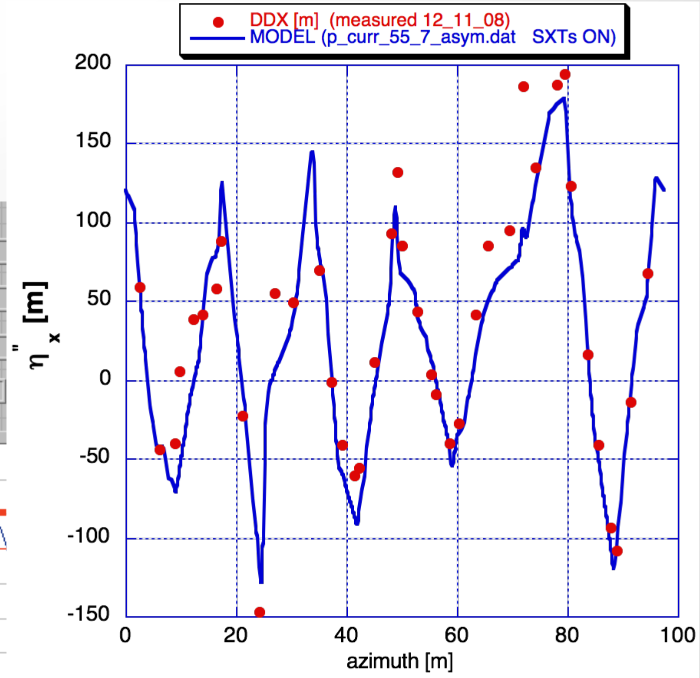
Ring Optics model

Ring model matches quite well beam measurements in terms of:

linear optics $\nu_{x,y}$, $\beta_{x,y}$, η_x , ε_x

non-linear optics energy acceptance and η''_x,





•*In 2007 the DAΦNE accelerator complex has been upgraded in order to implement a new collision scheme based on* ***large Piwinski angle***, ***low–β*** *and* ***Crab-Waist compensation*** *of the synchrobetatron resonances*

•*The upgrade took ~* ***five months***

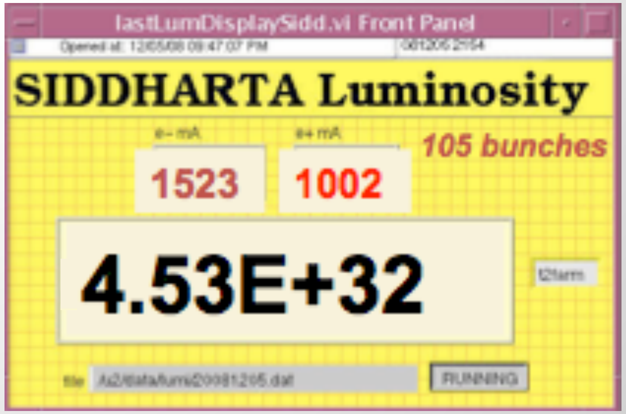
•***Since May 2008*** *DAΦNE is delivering luminosity to the SIDDHARTA experiment*

SIDDHARTA run ended by mid November 2009

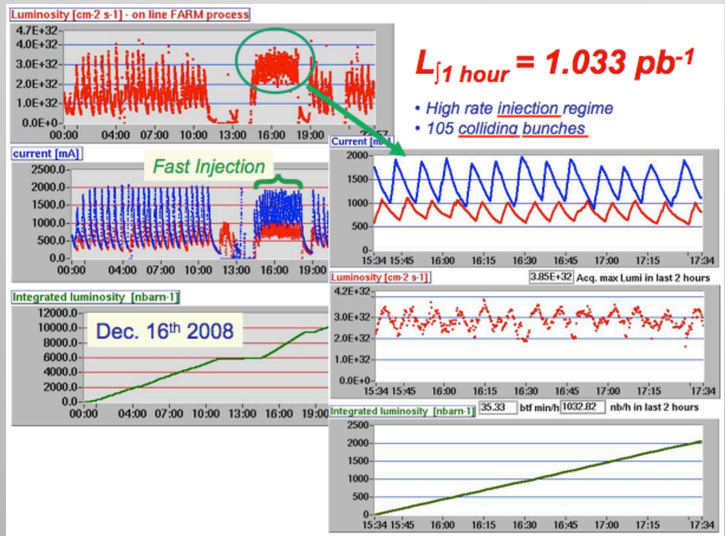
Crab-Waist collision scheme and SIDDHARTA

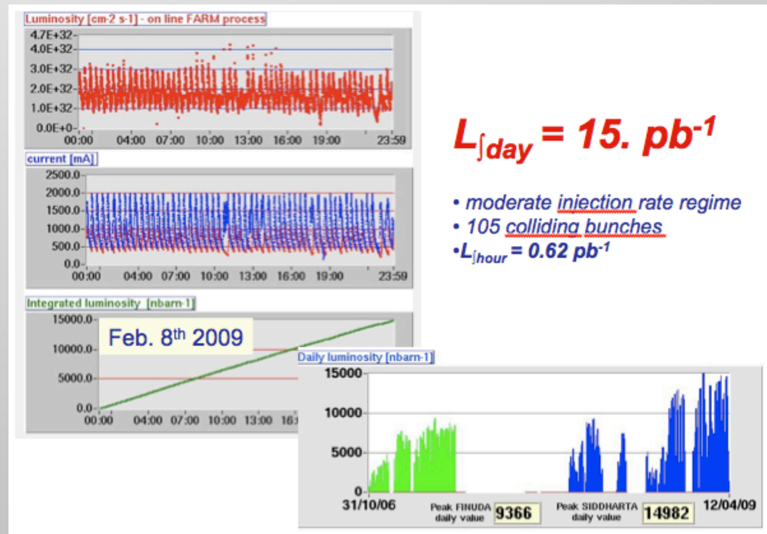
- Large crossing angle and Crab-Waist scheme proved to be effective in increasing luminosity, a factor 3 higher than in the past

- The DAΦNE collider, based on a new collision scheme including Large Piwinski angle and Crab-Waist, has been successfully commissioned and has delivered:



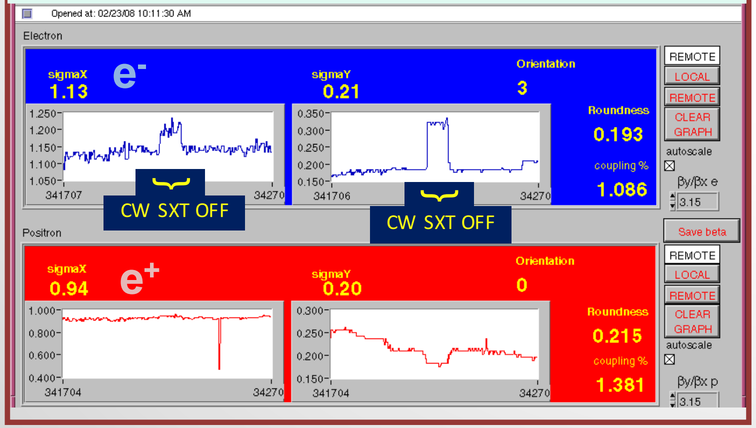
L_{peak}= 4.5*10^{32} cm^{-2} s^{-1}
$L_{\int 1\ day}$= 15.0 pb^{-1}
$L_{\int 1\ hour}$ = 1.033 pb^{-1}
$L_{\int run}$~ 2.8 fb^{-1} (SIDDHARTA detector)



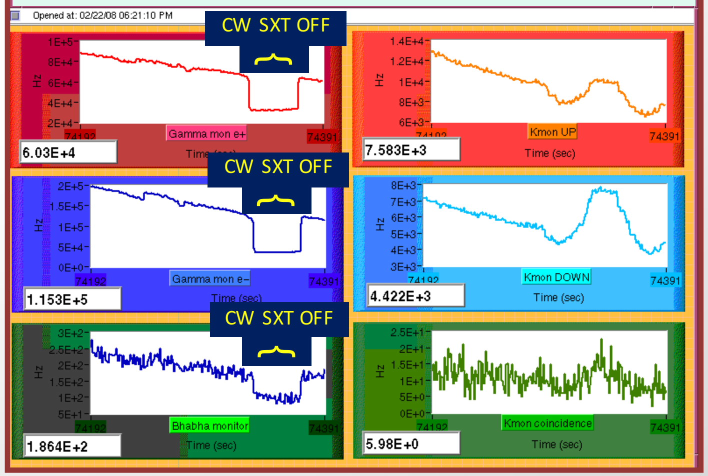


Crab-Waist Compensation First Experimental Evidence

Beam transverse size measured at the SLM

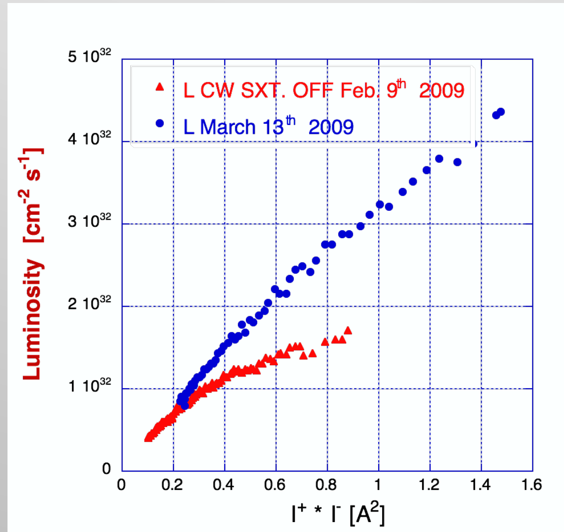


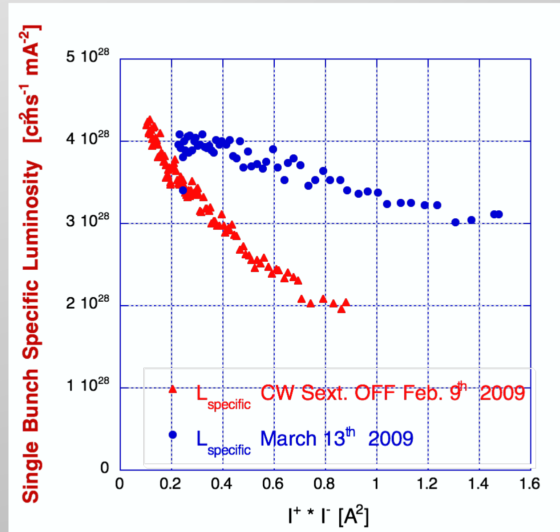
Luminosity from 2 different monitors



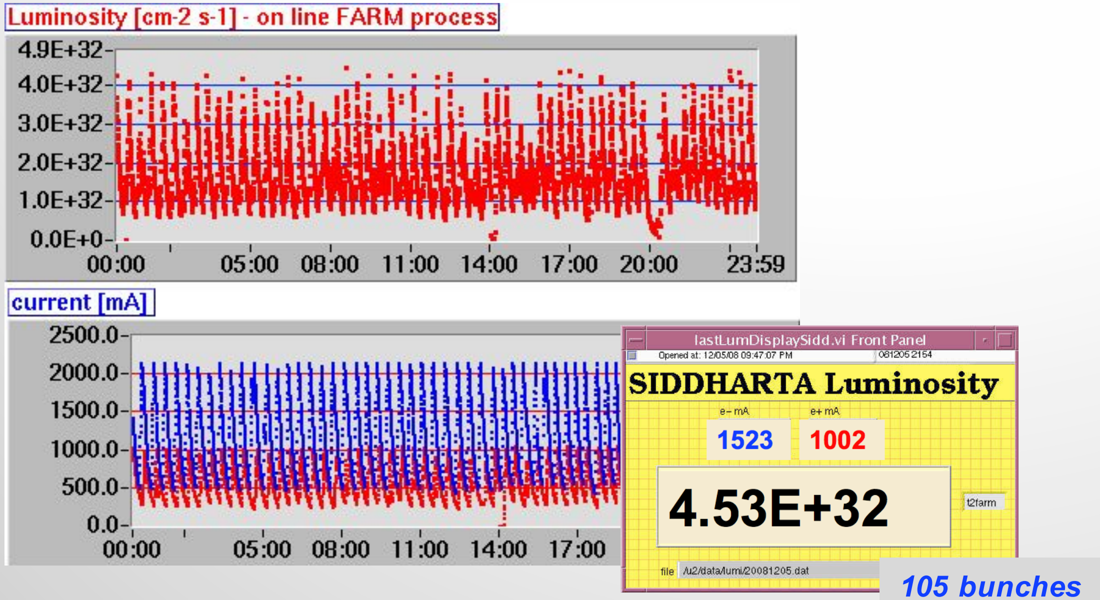
Transverse sizes (left) and **luminosity** (right) dependence on the ***CW-Sextupole* excitation** in the e$^-$ ring

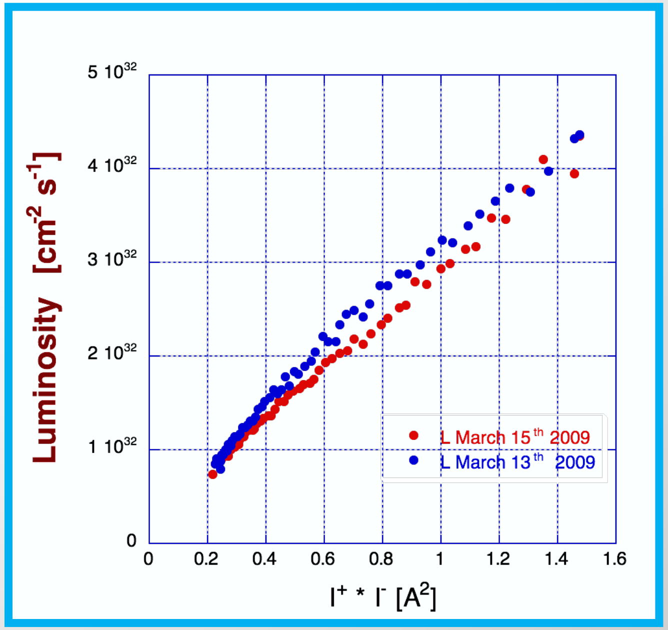
Luminosity as a function of colliding currents *CW-Sextupole* excitation



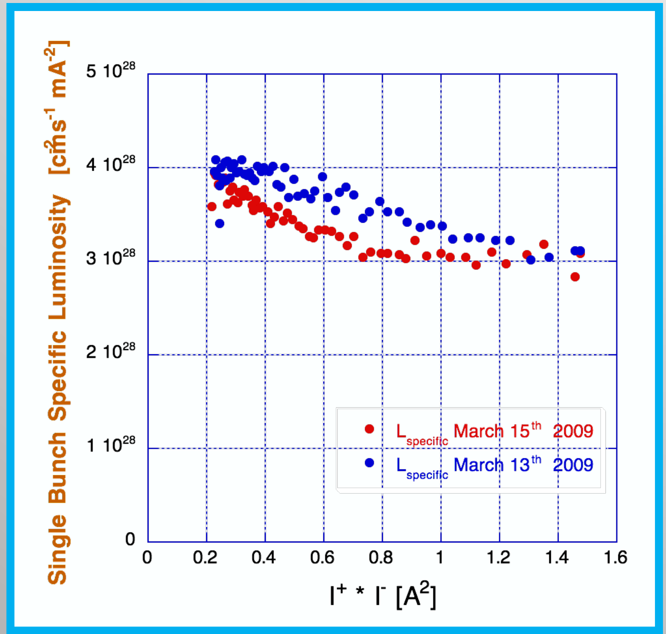


Peak Luminosity





ξ_y (MAX) ~ 0.0443



Specific Luminosity:

- Drops with the product of the colliding currents due to:
  - residual beam-beam blow up
  - bunch lengthening
- At low currents is four times higher than in the original configuration without *Crab-Waist*
- improvement is underestimated since collisions are optimized mainly at high ***I***

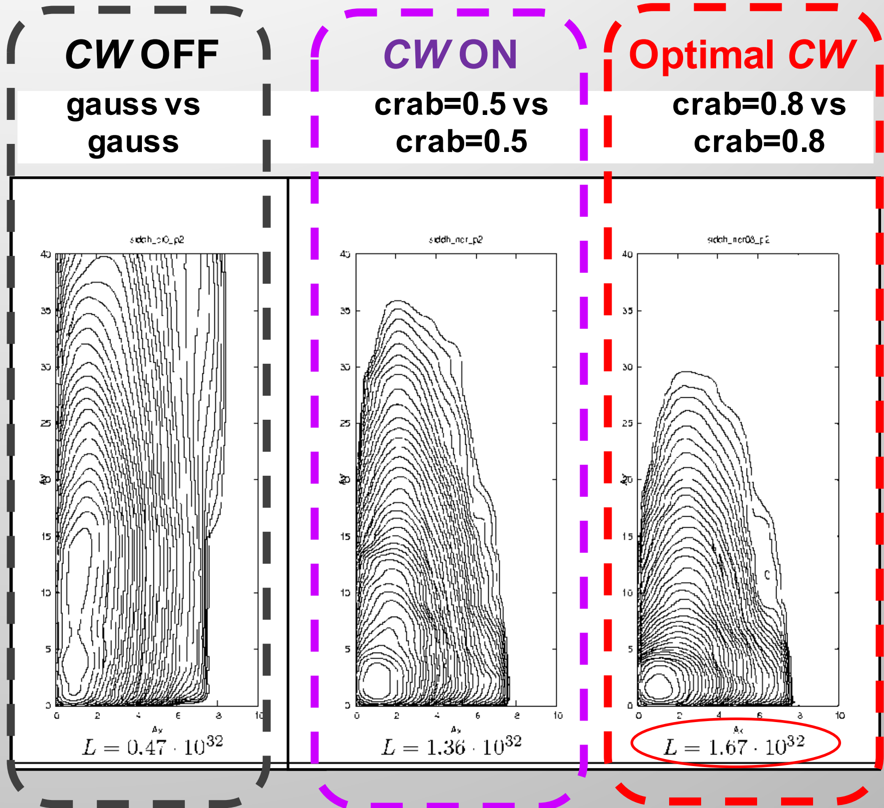
DAΦNE Luminosity and Tune Shift

	KLOE (Spt 2005)	FINUDA (Apr 2007)	SIDDHARTA *CW* (Jun 2009)
Luminosity $[10^{32}\ cm^{-2}s^{-1}]$	1.53	1.6	**4.53** (5.0)
I(ele) [A]	1.38	1.50	1.52
I(pos) [A]	1.18	1.1	1
n_b	111	106	105
ε_x [mm mrad]	0.34	0.34	0.28
β_x [m]	1.5	2.	0.25
β_y [cm]	1.8	1.9	0.9
ξ	0.0245	0.0291	**0.0443 (0.074)**

Weak-Strong Tune Shift

Crab-Waist compensation works in weak-strong regime also, and measured luminosity is in good agreement with *Lifetrack* code (D. Shatilov) predictions

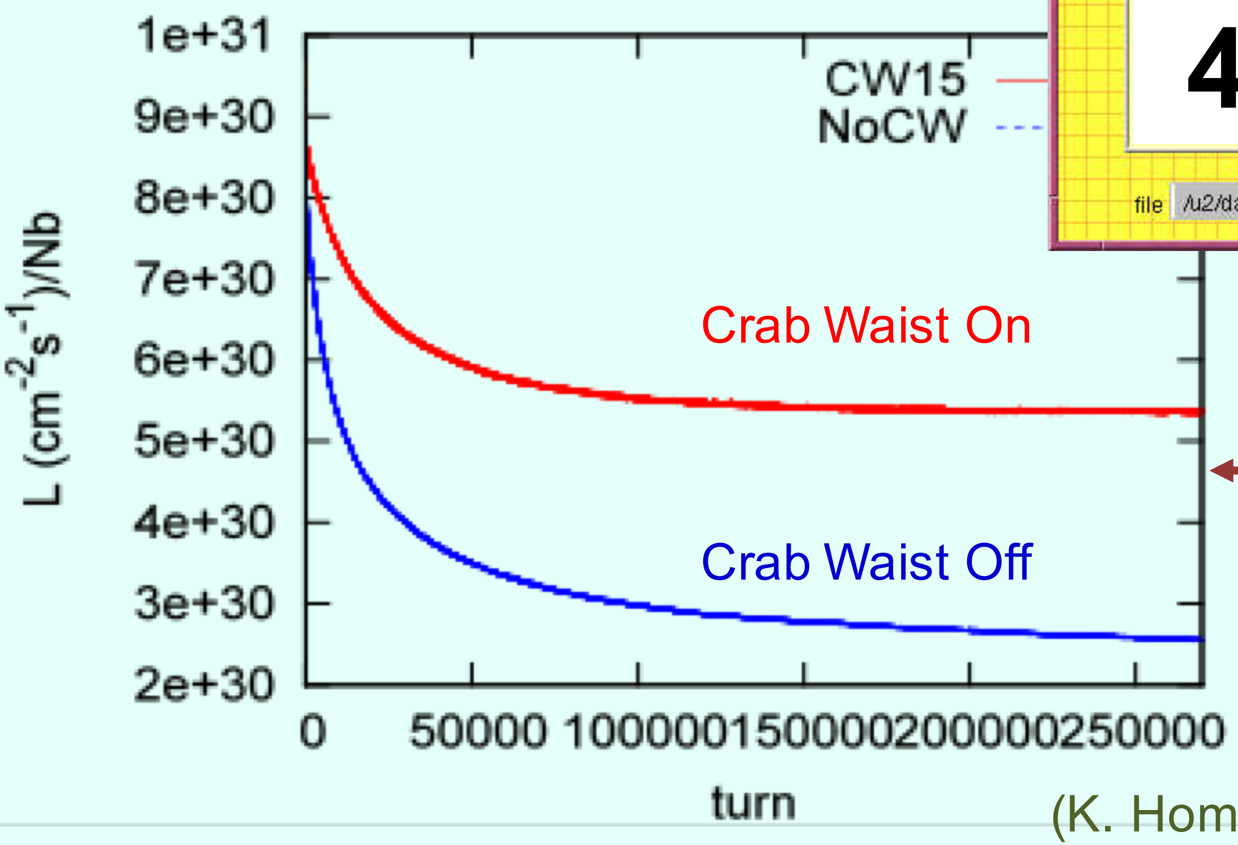
$\xi_y = 0.074$



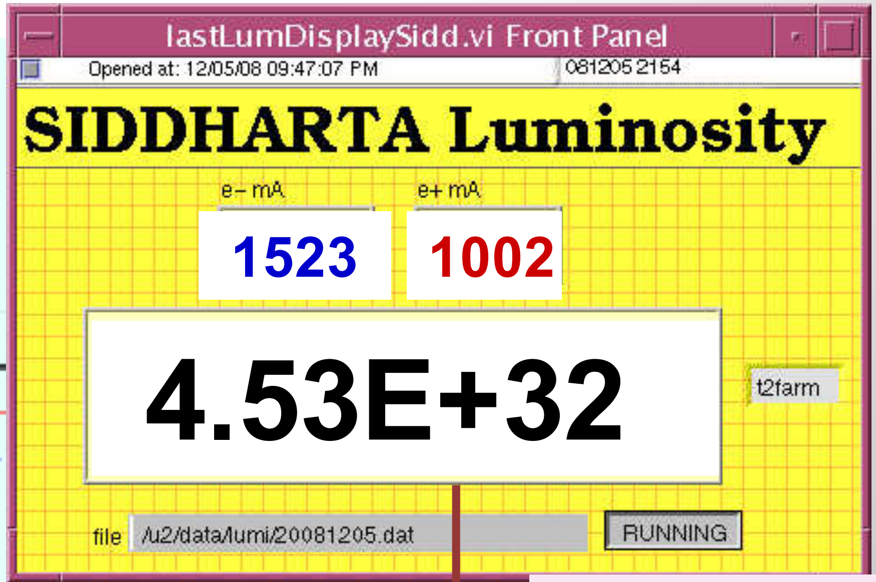
Strong-Strong Beam-Beam Simulations

Single Bunch Luminosity

(Damping time = 110.000 turns)



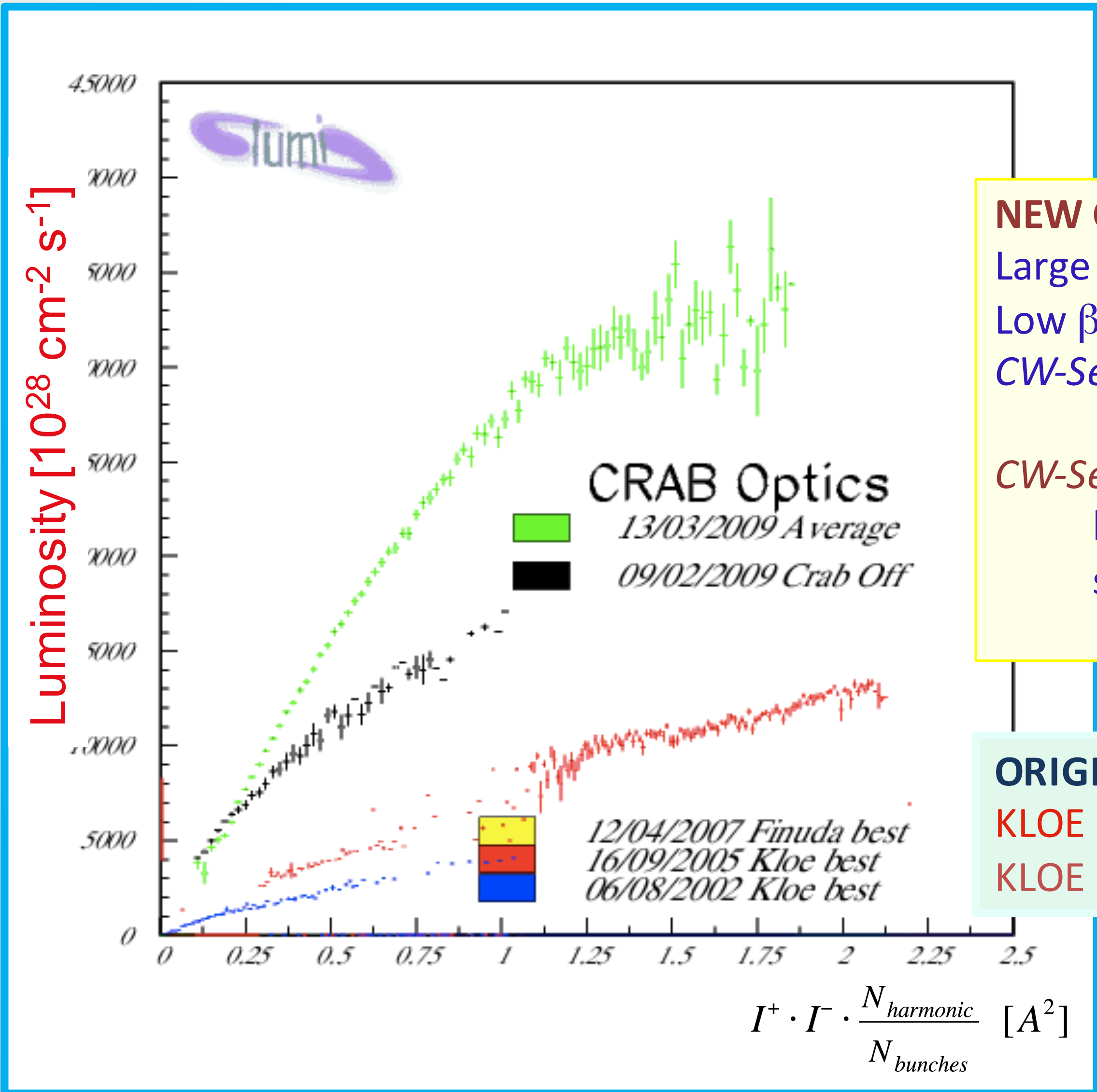
(K. Homi)



105 bunches

about 20% lower

Crab-Waist Collision Scheme & Luminosity



NEW COLLISION SCHEME:

Large Piwinski angle $\Phi = 1.9$

Low β^*_y $\beta^*_y = 9.0$ [mm]

CW-Sextupoles $\chi = 0.6$

CW-Sextupoles off

larger transverse beam size blowup

sharp lifetime reduction

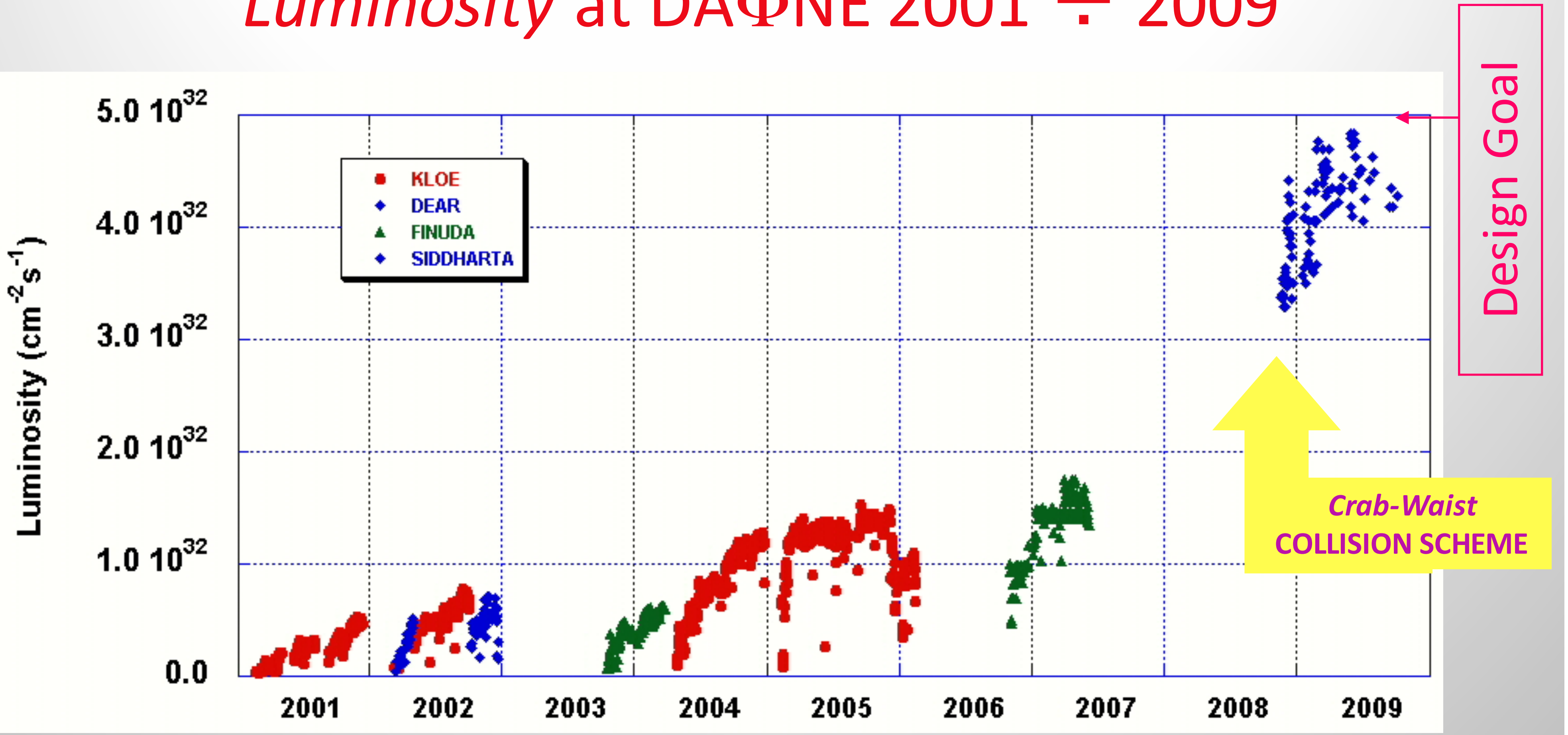
ORIGINAL COLLISION SCHEME:

KLOE 2005 $\Phi = 0.6$ $\beta^*_y = 18.$ [mm]

KLOE 2002 $\Phi = 0.3$ $\beta^*_y = 25.$ [mm]

20% L reduction at high currents because of bunch lengthening due to the ring impedance. L $\propto 1/\sigma_z$ in Large Piwinski Angle & Crab-Waist regime.

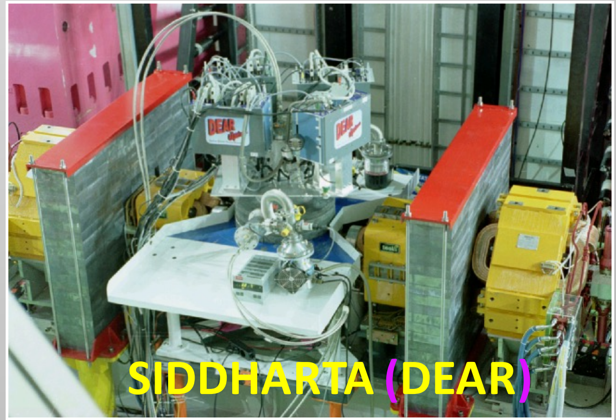
Luminosity at DAΦNE 2001 ÷ 2009



A factor 3 higher luminosity achieved without increasing beam currents

No evidence of vertical BB saturation with *CW-Sextupoles* on (ξ_y = 0.044)

LRBB interaction cancelled



KLOE-2 run

Integrating the high luminosity collision scheme with a large experimental detector introduces new challenges in terms of:

- IR layout
- optics
- beam acceptance
- coupling correction

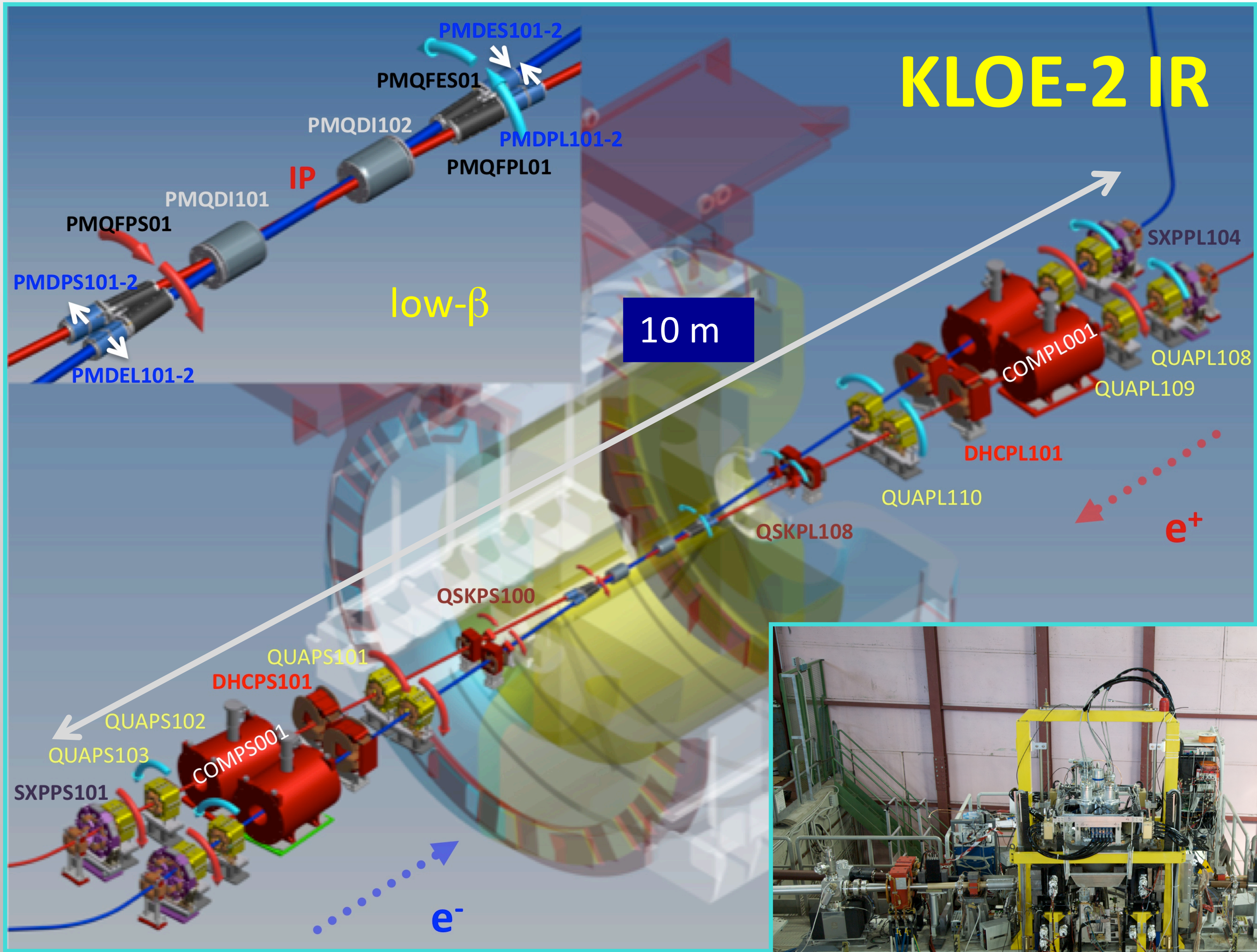
Crucial Points:

IR optics complying with:

- Low-β
- ***Crab-Waist*** collision scheme
- Coupling compensation
- Beam trajectory control

IR mechanical design allowing:

- Large crossing angle
- Early vacuum pipe separation after IP inside the detector

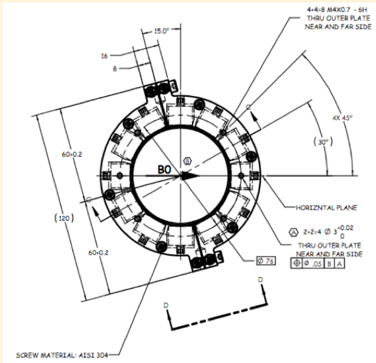


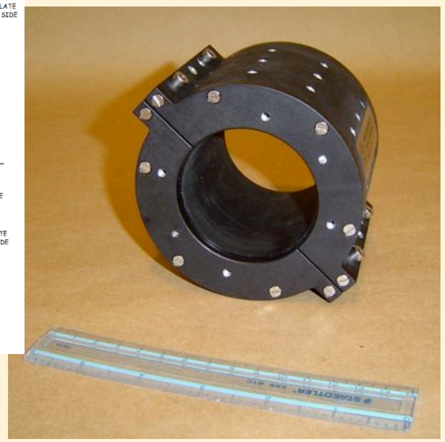
C. Milardi *et al 2012 JINST 7 T03002.*

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 quadrupoles (PMQD)*
  - *experimental solenoidal field*

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



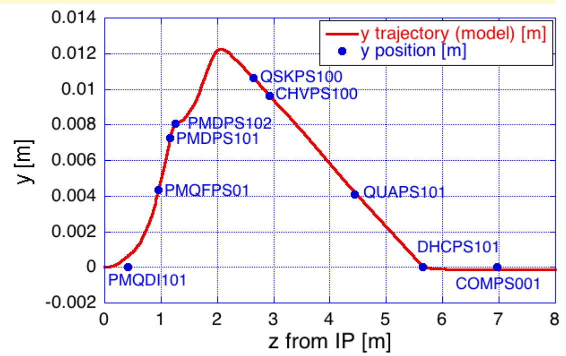


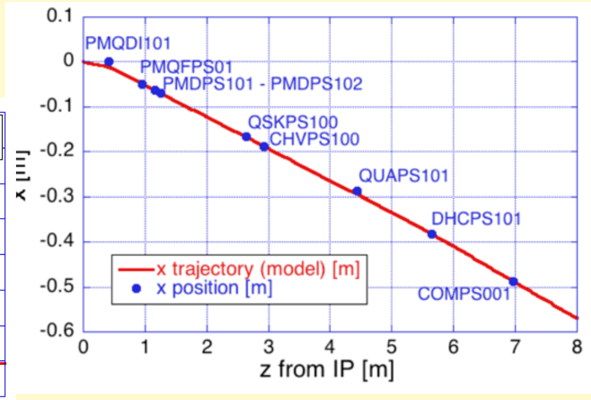
Magnetic length (mm) 75
field (T) 0,22933
Good field region radius (mm) 15
Magnet material type SmCo

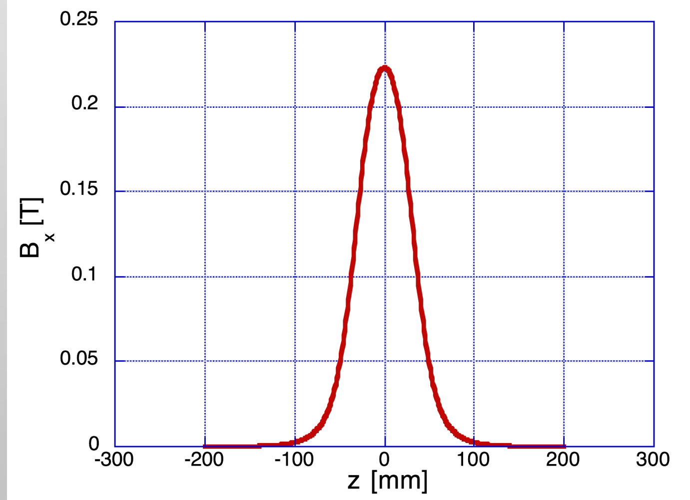
PMD consists of two halves each of them:

- 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

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







Betatron Coupling correction

$\int_{KLOE} B \bullet dl$ *canceled by 2 anti-solenoids 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

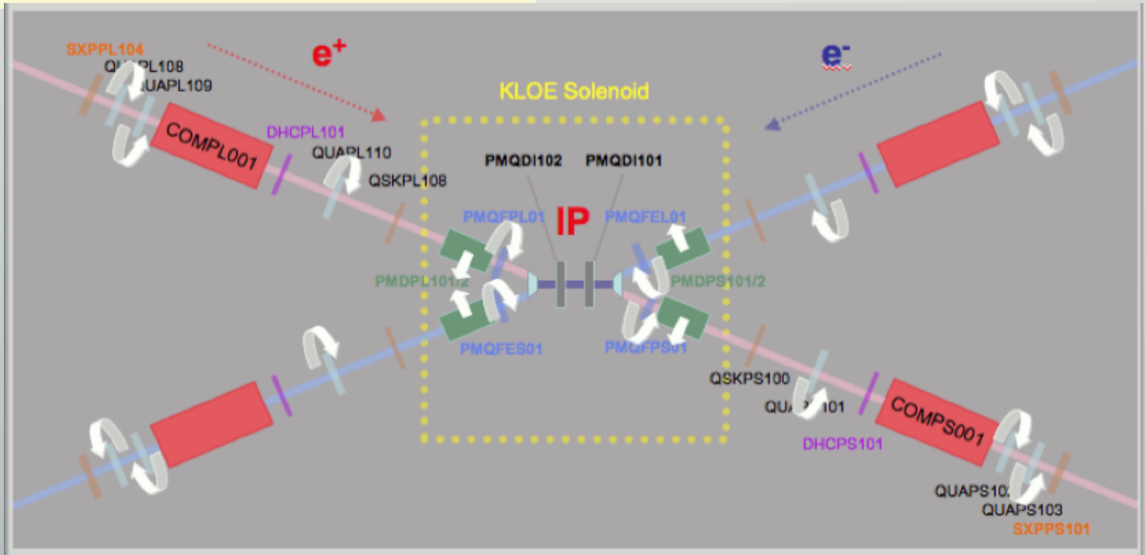
Fixed QUAD rotations

κ is expected to be lower than for KLOE past

$$\kappa_{KLOE1} = 0.2 \div 0.3 \ \%$$

	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)*

C. Milardi *et al 2012 JINST 7 T03002.*



Crab-Waist Collisions for KLOE-2

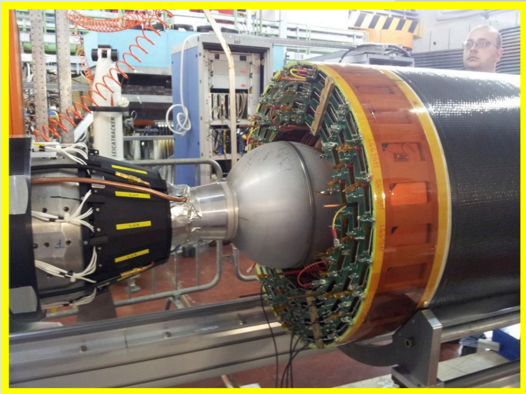
Operations with the Crab-Waist collision scheme and the KLOE detector have been organized in four stages:

July 2010 - Dec 2012

- KLOE rolled in and the new IR based on *CW Collision Scheme* installed
- Collision tested despite high fault incidence
- Physics run with a pure C target (100 pb^{-1})
- Peak instantaneous luminosity $1.52 \cdot 10^{32}\ cm^{-2}s^{-1}$

Dec 2012 - Jul 2013

- IR extracted mended and modified
- Detector upgrade KLOE -> KLOE-2
- Several component and subsystems replaced, maintained and upgraded



Jul 2013 - Nov 2014

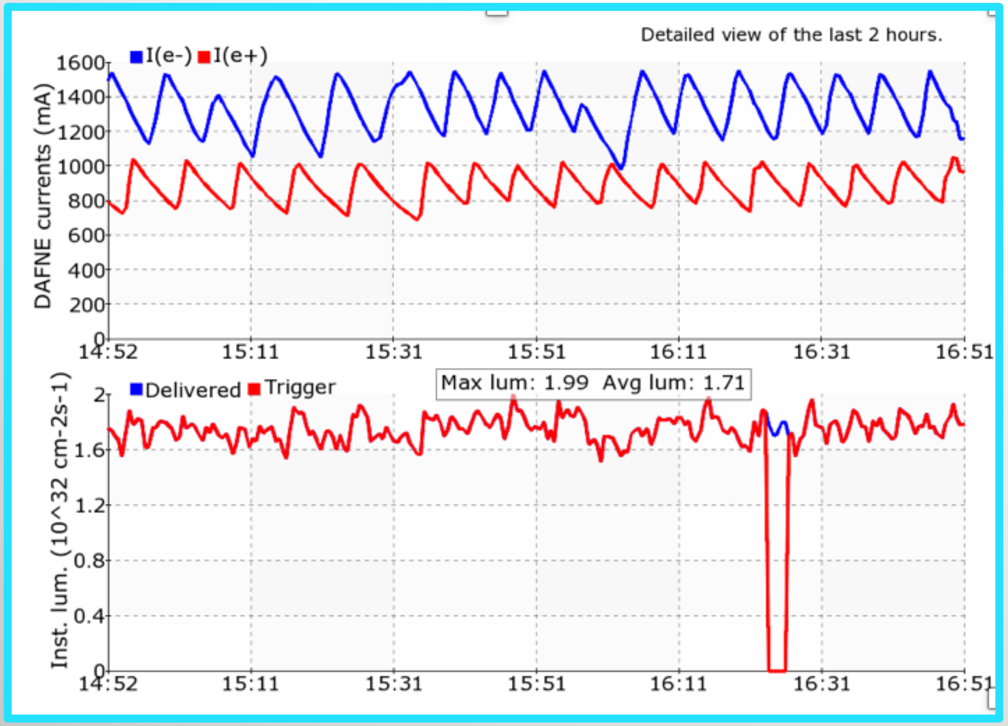
- Infrastructural problems affecting the whole Lab
- Commissioning

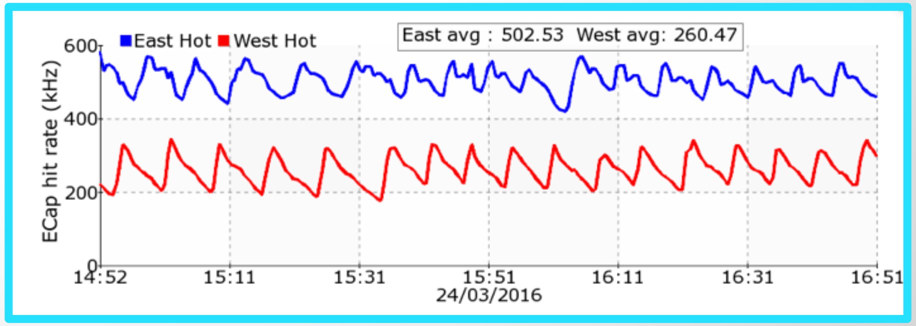
Mid Nov 2014

- KLOE-2 systematic data taking

C. Milardi *et al ICFA Beam Dynamics No.67*

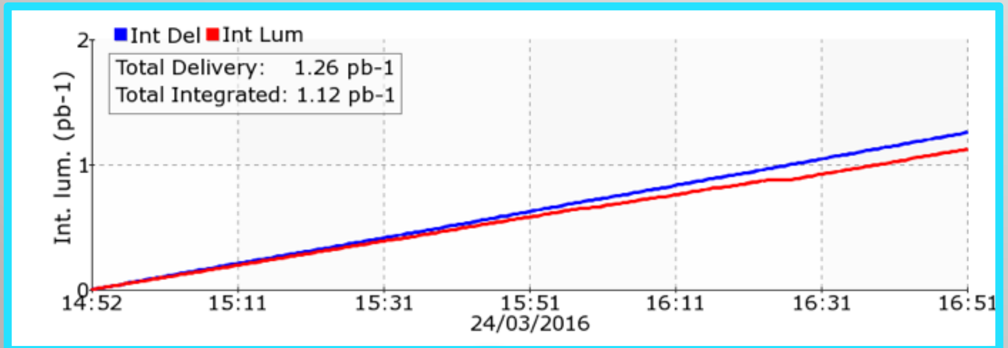
Best Hourly Integrated Luminosity





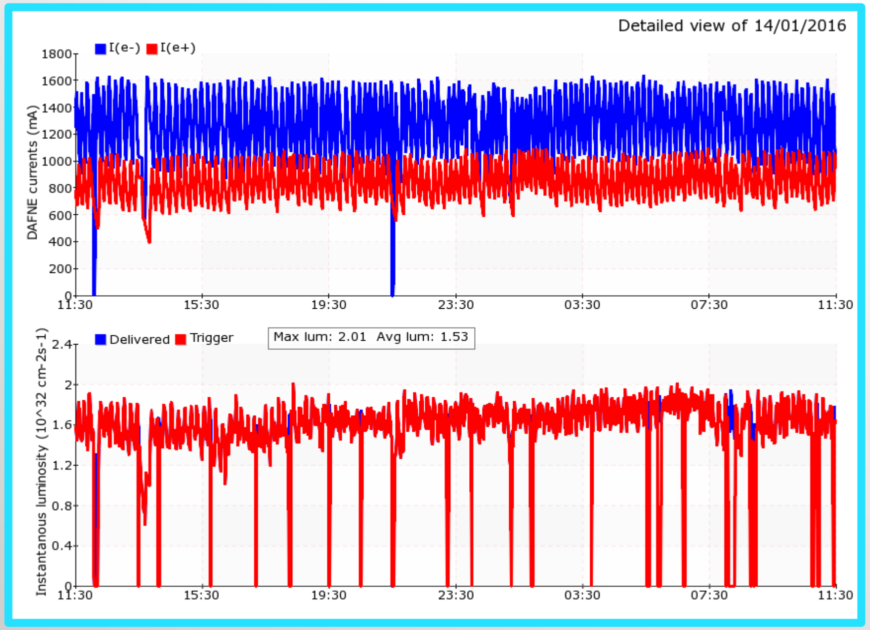
$L_{\int 1h}$ ~ $0.63\ pb^{-1}$

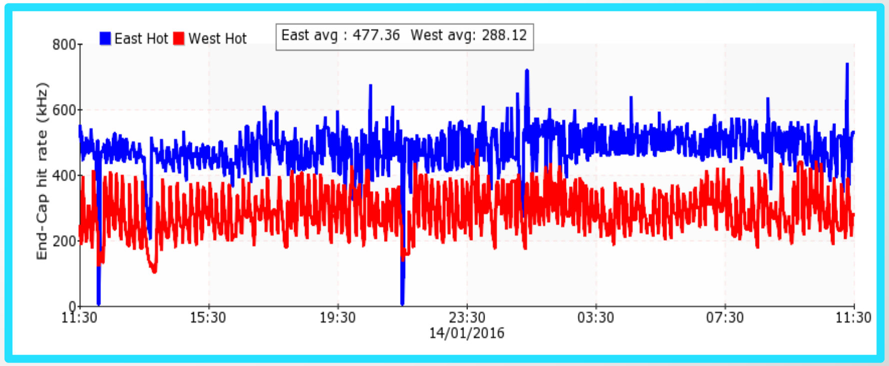
$L_{\int 1day}$ ~ $15.1\ pb^{-1}$



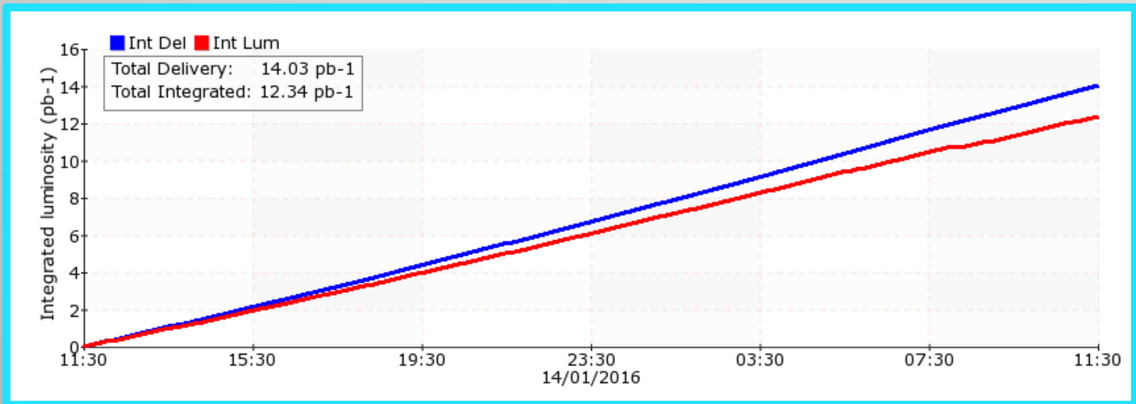
- *Collisions suitable for KLOE-2 data taking*
- *Background compatible with an efficient acquisition*
- *$L_{\int 1\,hour}$ is the highest ever measured with the KLOE detector*

Best 24 Hours Integrated Luminosity





- 2 beam losses due to PS faults
- 105 bunches
- $I^-_{MAX} = 1.5 \div 1.6$ A
- $I^+_{MAX} = 1.0 \div 1.16$ A
- Sustainable background

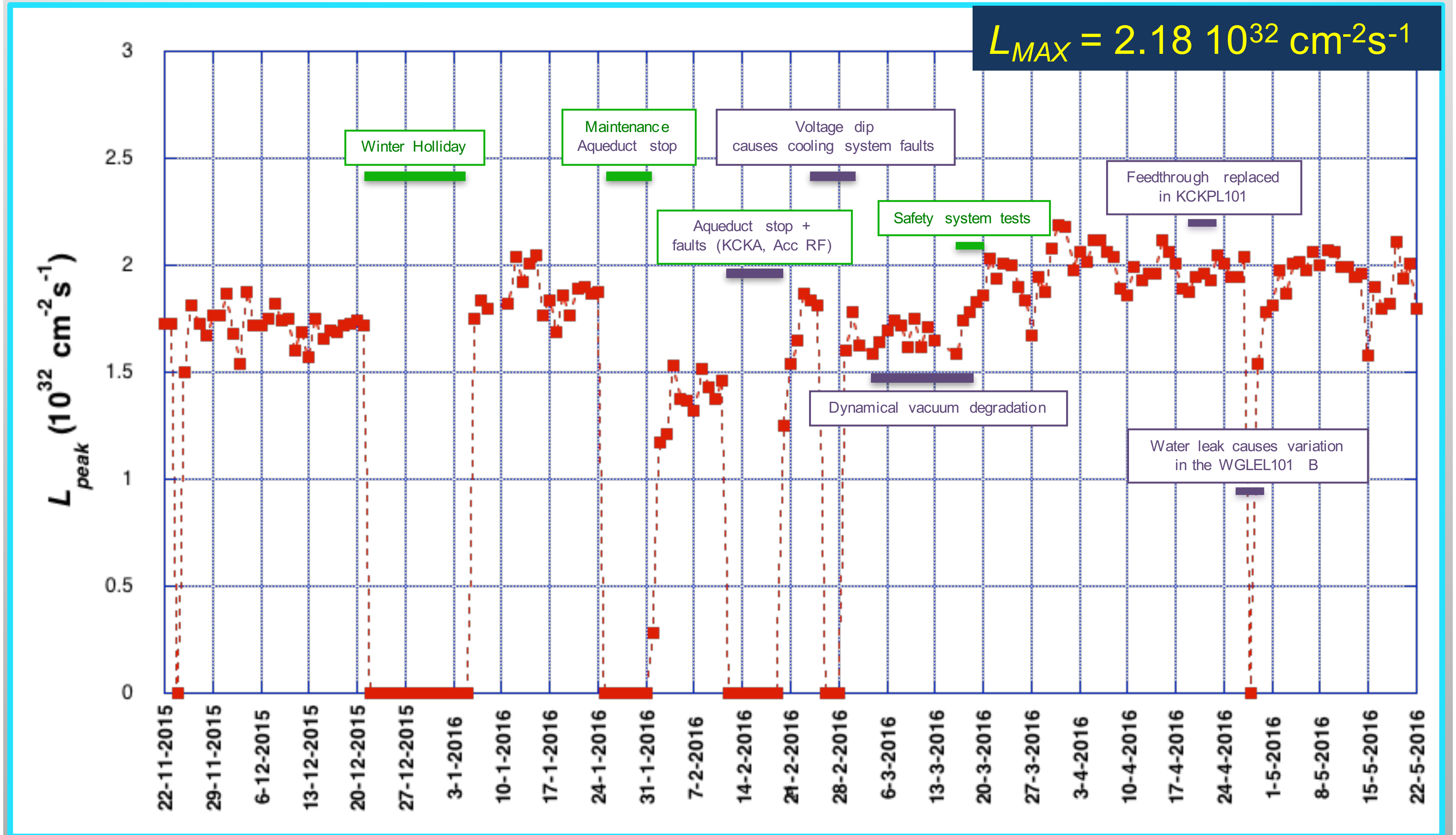


$\int_{del} L \sim 14.03\ pb^{-1}$

$\int_{acq} L \sim 12.34\ pb^{-1}$

Uptime ~98%

Peak Luminosity Trend



Energy Scan

C.M. energy has been studied by varying the frequency of the main ring RF cavities

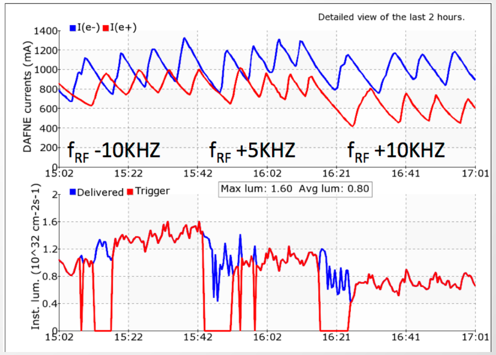
$$-\alpha_c \frac{\Delta p}{p} = \frac{\Delta f_{RF}}{f_{RF}}$$

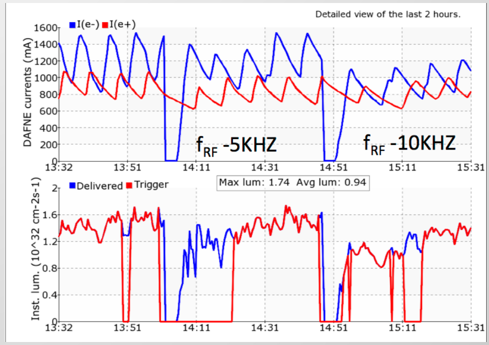
In the range

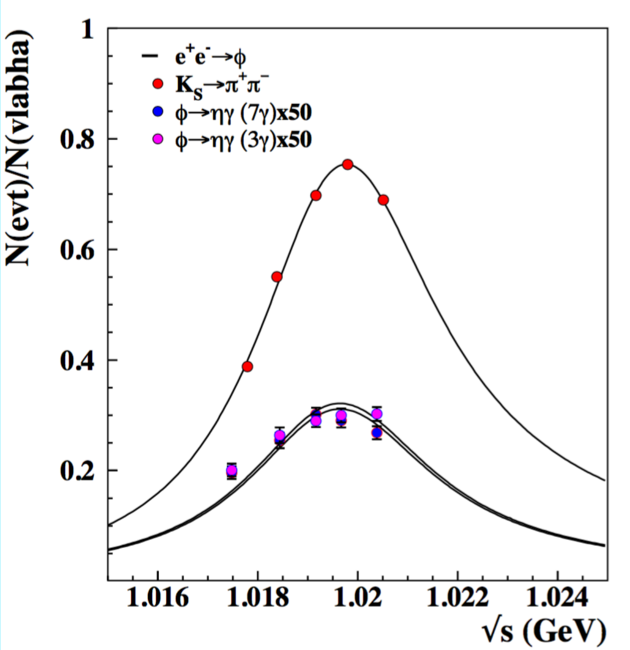
$-10\ \mathrm{KHz} \le f_{RF} < 10\ \mathrm{KHz}$

Corresponding to an energy variation per beam

$-1.5\ \mathrm{MeV} \le E < 1.5\ \mathrm{MeV}$





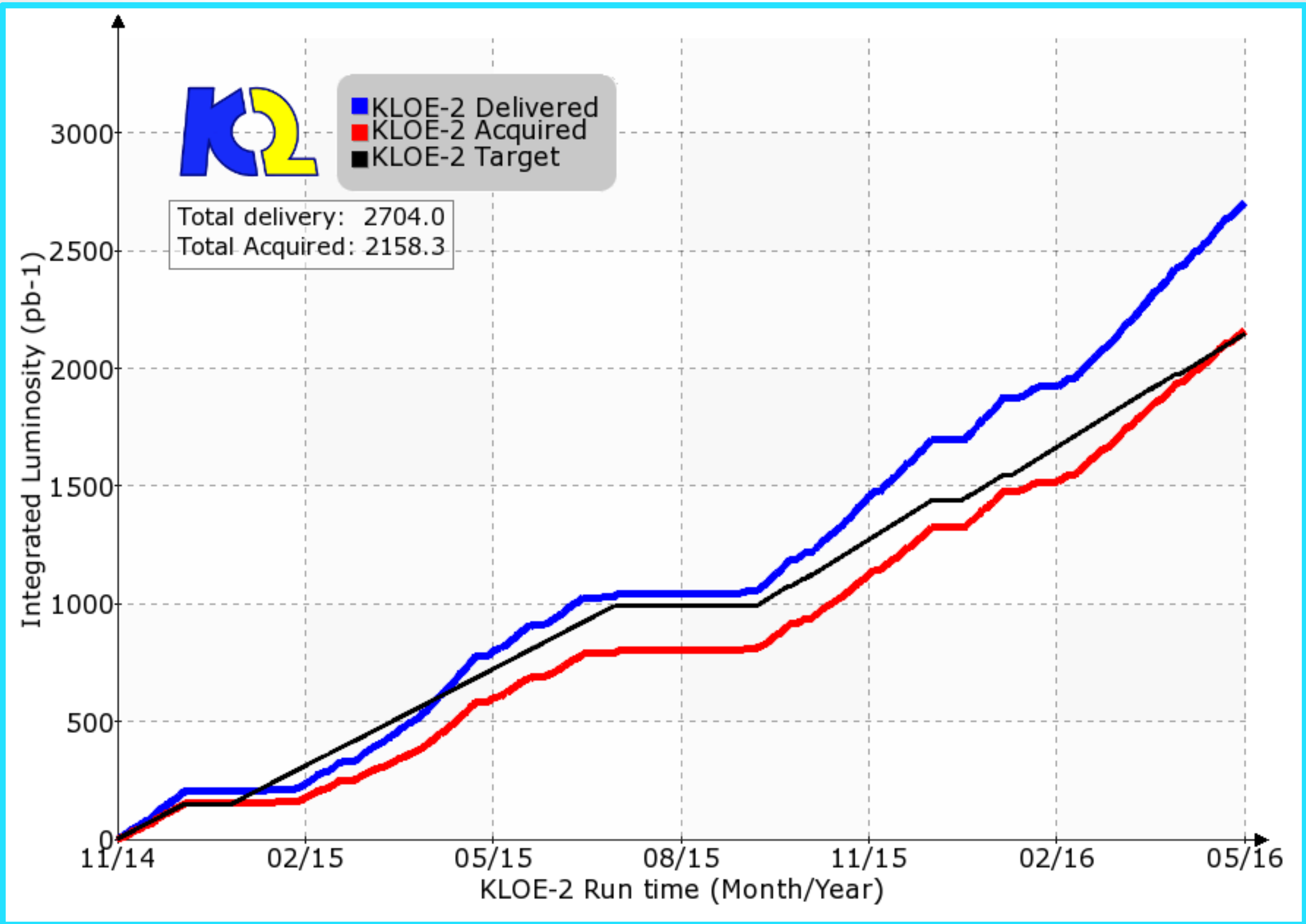


On May 16th the c.m. energy of the colliding beams has been changed

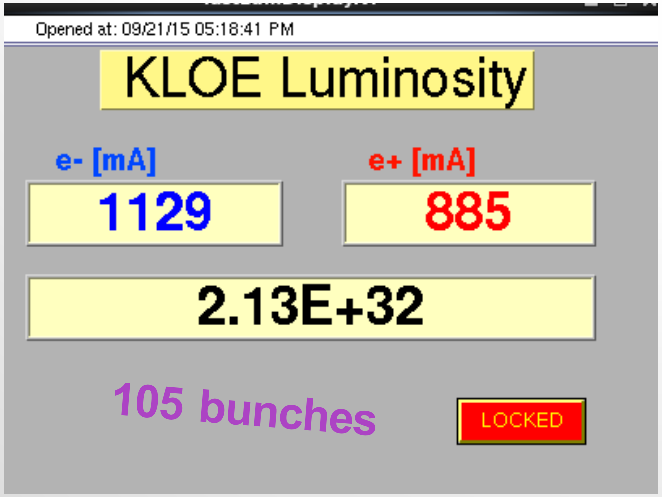
$\Delta E_{CM} = +\ .5\ \mathrm{MeV}$

by varying the main ring bending magnets maintaining the same performances in terms of luminosity and background

Total Integrated Luminosity



Maximum Peak Luminosity so far



Still the full potential of the new *CW* collision scheme has not been completely exploited

	DAΦNE CW upgrade SIDDHARTA (2009)	DAΦNE CW KLOE-2 (2016)
L_{peak} $[10^{32}\ cm^{-2}s^{-1}]$	4.53 (5.0)	**2.13**
$L_{\int day}$ $[pb^{-1}]$	14.98	**14.03**
$L_{\int 1\ hour}$ $[pb^{-1}]$	1.033	**0.62**
I^{-}_{MAX} in collision [A]	1.52	**1.129**
I^{+}_{MAX} in collision [A]	1.0	**0.885**
$N_{bunches}$	105	**105**

36th MEETING OF THE LNF SCIENTIFIC COMMITTEE
FINDINGS AND RECOMMENDATIONS

Not least among these is the fact that the principle of crab-waist compensation has been shown to work; this must be recognised as a major advance in the long history of fighting the beam-beam effect in e^+e^- colliders.

The 36th meeting mainly focused on the status and the outlook of the upgraded DAΦNE collider and the planning of its experimental program. Specific recommendations were made on the running and/or installation of three DAΦNE experiments: they are recorded in this document.

The Committee also reviewed two external activities belonging to the LNF external program: the LARES and the BaBar experiments. A talk by P. Raimondi described the status of the design of a Super B-factory. The status of the SPARC and SPARX projects was discussed in closed session.

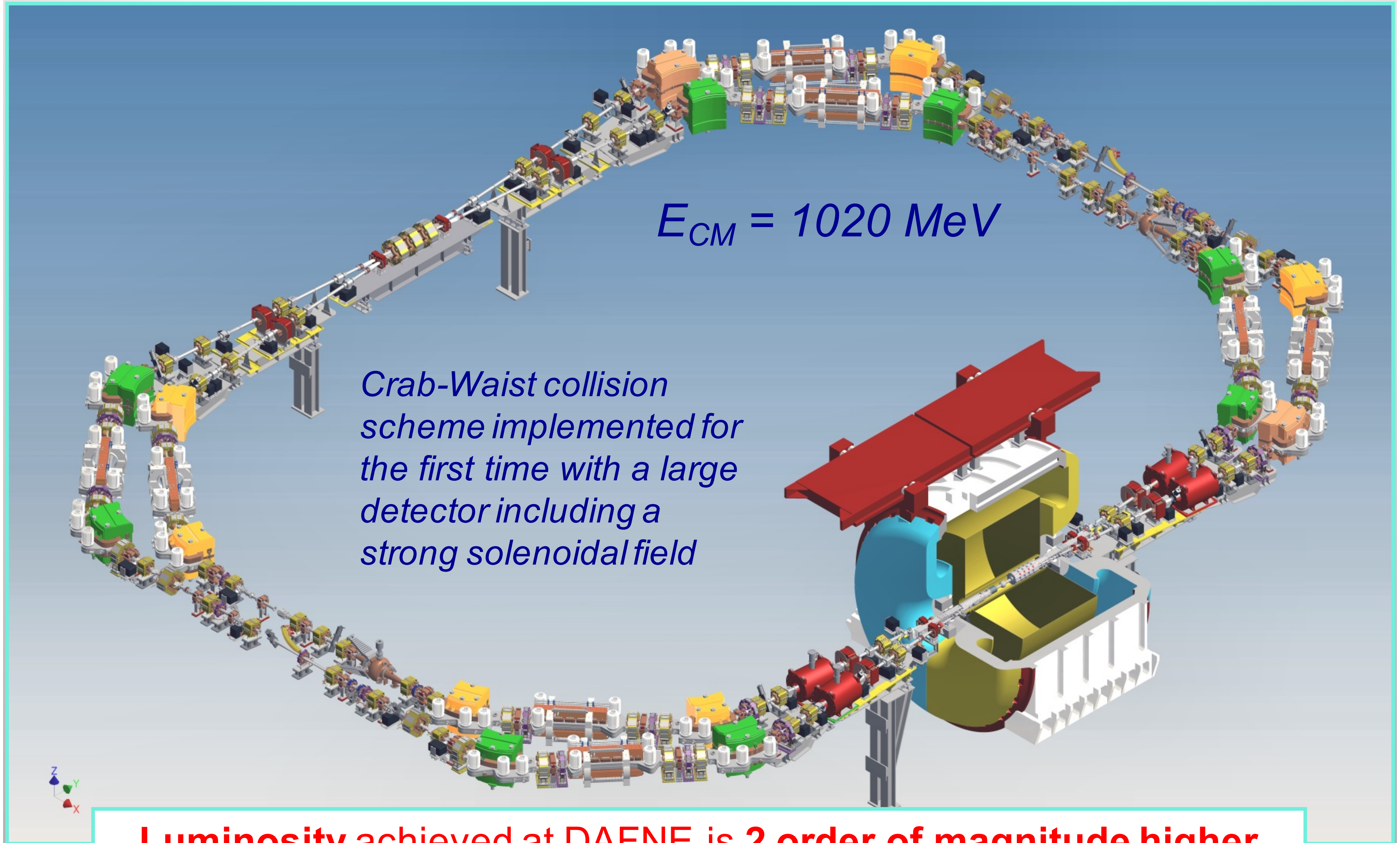
The Committee welcomed a new member, C. Matteuzzi, who joins it as chair of the Beam Test Facility Committee.

1 THE DAΦNE PROGRAM: STATUS AND RECOMMENDATIONS

1.1 DAΦNE UPGRADE: PERFORMANCE AND OUTLOOK

DAΦNE has now operated for a few months with the new scheme of colliding beams with large Piwinski angle and crab-waist compensation. The commissioning of the new configuration, with the prototype SIDDHARTHA experiment is about two months behind the expected schedule. While peak luminosities have exceeded previous records by up to 40%, daily integrated luminosities are not yet up to previous operational levels and backgrounds are high. These are grounds for serious concern. On the other hand, analysis of the present situation (see below) shows that there are also rational grounds for optimism. Not least among these is the fact that the principle of crab-waist compensation has been shown to work; this must be recognised as a major advance in the long history of fighting the beam-beam effect in e^+e^- colliders. It is also an important step towards validation of the SuperB design concepts.

DAΦNE and KLOE-2



Luminosity achieved at DAFNE is **2 order of magnitude higher** than the best measured in colliders working at the **same E**

Conclusions about the *CW* Collision Scheme

The new collision scheme including Large Piwinski angle and Crab-Waist compensation of the beam-beam interactions has proved to be a viable approach to increase the luminosity of the DAΦNE collider

- *It has been succesfully tested and routinelly used during the SIDDHARTA run when a factor 2.7 higher instantaneous luminosity has been measured*
- *Crab-Waist collision scheme has also been the leading concept in designing the new IR for the KLOE-2 experiment.. KLOE-2 is currently taking data profiting from a daily integrated luminosity comparable with the best ever measured at DAΦNE, despite the instantaneous luminosity gain is still a factor 2 lower wrt the one measured with the SIDDHARTA optics.*
- *The KLOE-2 run has also clearly assessed the Crab-Waist* collision scheme effectiveness even in presence of a large detector including high intensity solenoidal field
- *The Crab-Waist collision scheme has been considered to upgrade one of the LHC interaction regions*
- *The design study of several new circular colliders includes the CW collision scheme as a main design concept.*

Crab-Waist Colliders

Colliders	Location	Status
DAΦNE	Φ-Factory Frascati, Italy	In operation
SuperKEKB	B-Factory Tsukuba, Japan	Commissioning starts in first months of 2016
SuperC-Tau	C-Tau-Factory Novosibirsk, Russia	Russian mega-science project
FCC-ee	Higgs-Factory CERN,Switzerland	100 km, CW baseline design option
CEPC	Higgs-Factory China	54 km, local double ring option with CW
LHC Upgrade	LHC CW Option CERN,Switzerland	LHC with very flat beams (low priority)

Conclusioni

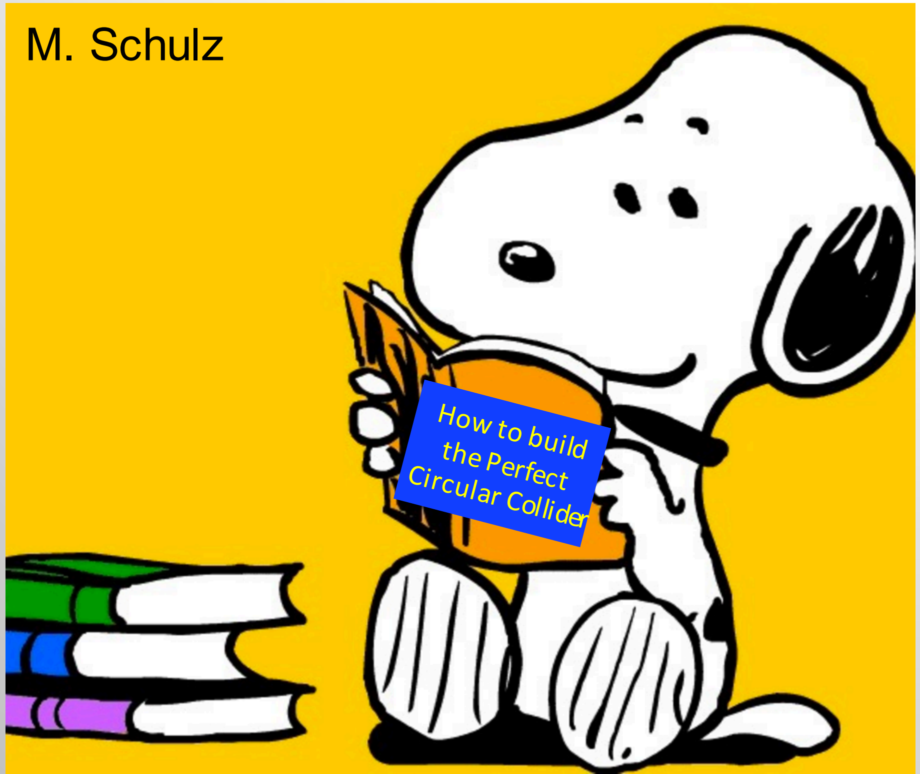
DAΦNE e' il complesso di acceleratori realizzato per produrre eventi di fisica all'energia di risonanza dei mesoni Φ.
Costituisce una delle più grandi infrastrutture dell'INFN, come tale rappresenta un'opportunità unica in Italia per esperimenti di fisica delle particelle e nucleare.

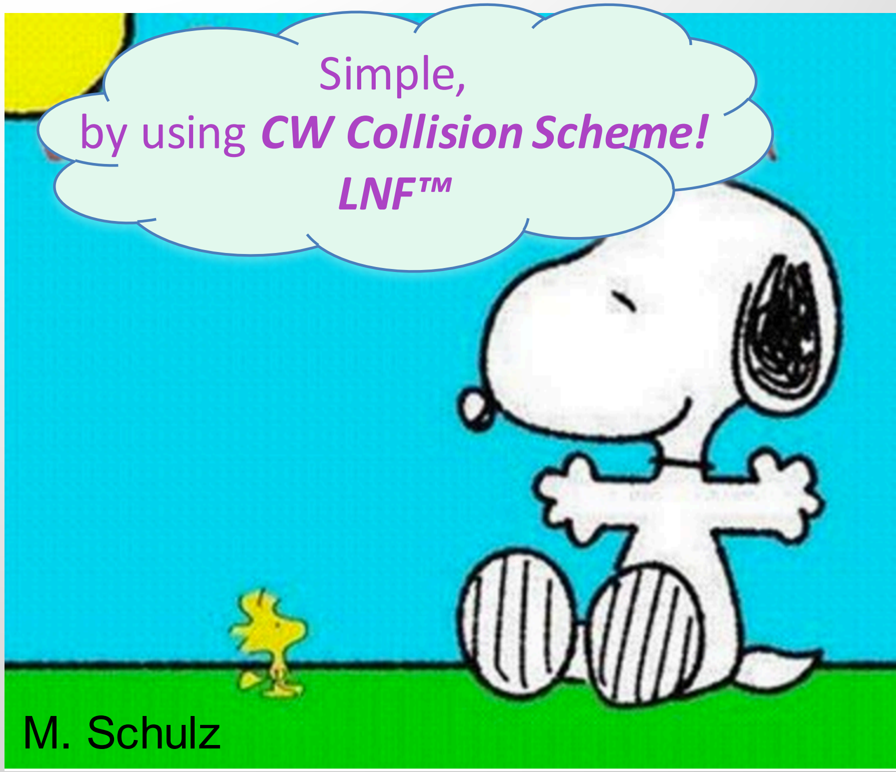
DAΦNE ha fornito dati a tre diversi esperimenti KLOE, FINUDA e DEAR-SIDDHARTA migliorando, al tempo stesso, le proprie prestazioni in termini di luminosità mediante un'intensa attività di studi e prove sperimentali.

Questo approccio ha portato a proporre e a realizzare, nel 2007, un nuovo schema di collisione chiamato 'Crab-Waist' che provato con l'esperimento SIDDHARTA ha consentito di triplicare la luminosita' di picco, aprendo la strada ad un'ulteriore fase sperimentale per il rivelatore KLOE, che prenderà dati nei prossimi 3-4 anni.

Gli studi di fisica di acceleratori intrapresi su DAΦNE hanno contribuito in maniera sostanziale alla comprensione e agli sviluppi relativamente a problematiche quali: le nonlinearità delle strutture magnetica, l'interazione dei fasci collidenti, l'ottimizzazione dell'ottica e gli effetti collettivi caratteristici di fasci di particelle ad alta intensita'.

.... let me joke





Thank you for your attention