DAΦNE present and future

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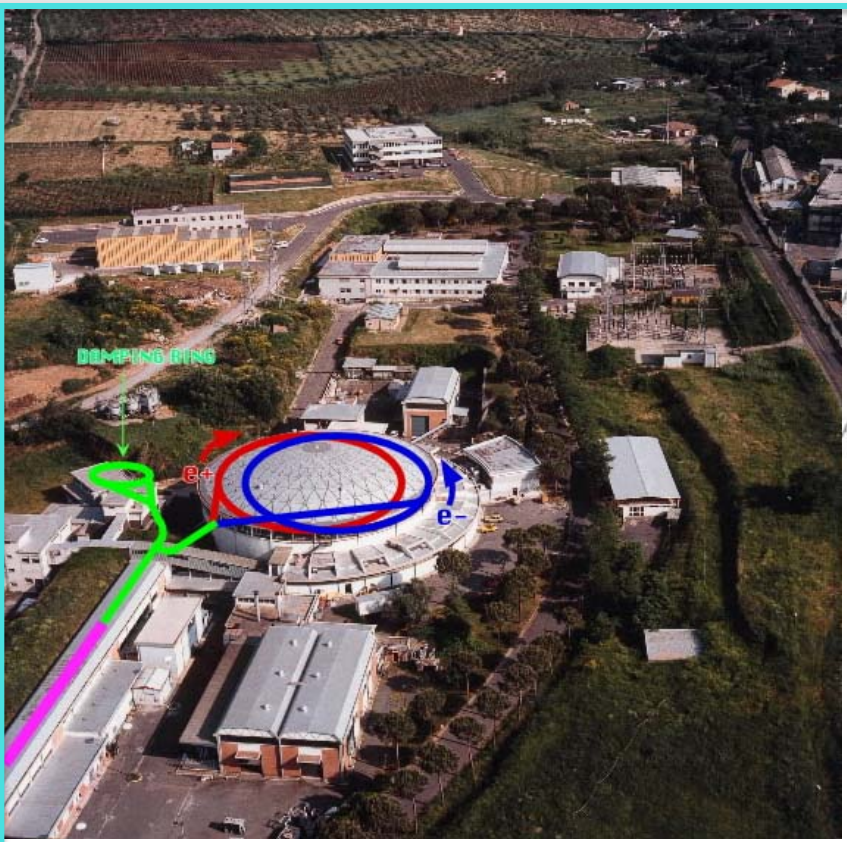
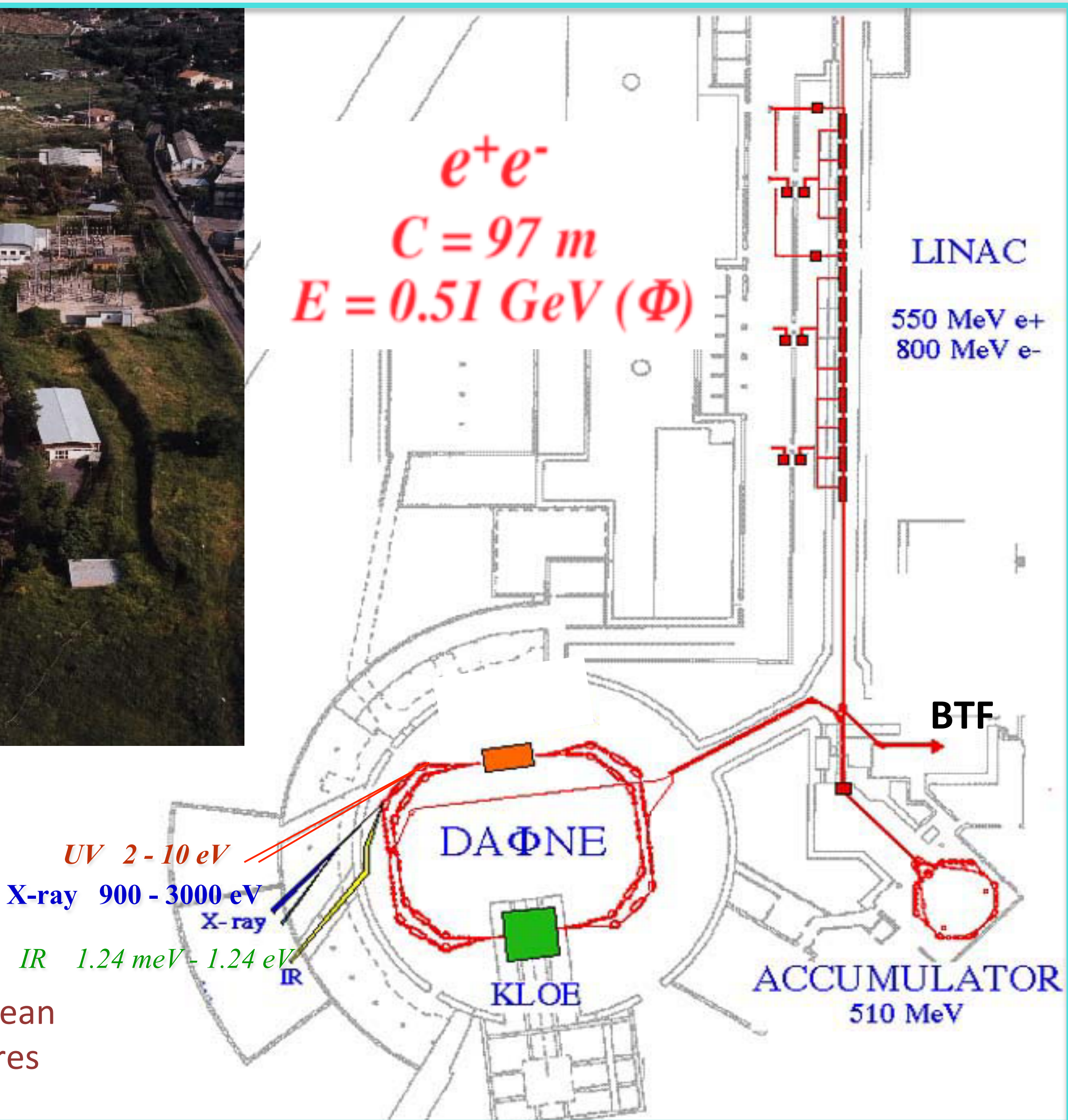
What next LNF: Perspectives of fundamental physics at the Frascati Laboratory
November 10th 2014, LNF, Frascati, Italy

Outlines

- *DAΦNE performances in the original configuration*
- *Crab-Waist concept and its implementation*
- *DAΦNE achievements during the SIDDHARTA run*
- *The new run with the KLOE detector*
  - *The new KLOE IR*
  - *First tests*
  - *Machine renovation*
- *DAΦNE contribution to the developments in the particle accelerator field*
- *Previous proposal relying on DAΦNE*
- *Conclusions*

The DAΦNE Accelerator Complex





LNF are also part of the European synchrotron light Infrastructures

Taking DAFNE to deliver a reasonable luminosity required long time and imposed to identify and cure several limiting factors concerning:

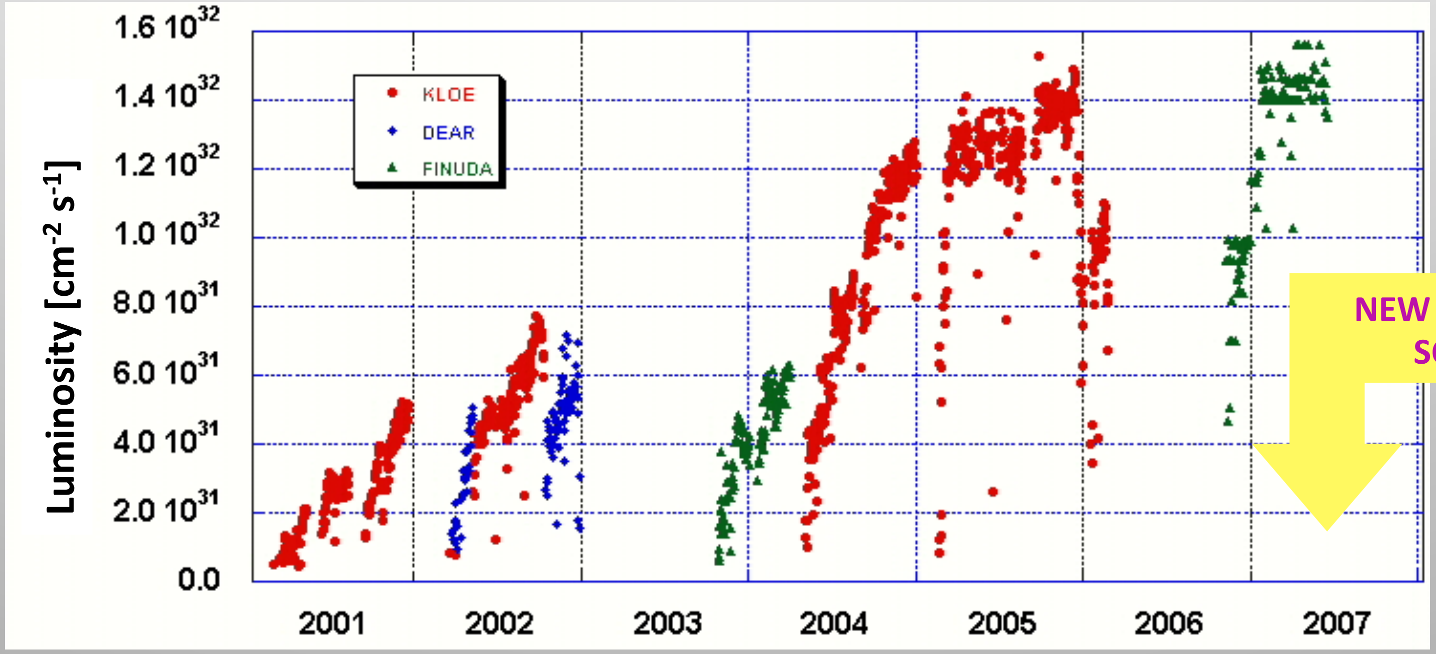
- Transverse betatron coupling
- Non-linear beam optics
- Transverse instability
- Beam dynamics & impedance budget
- Beam-beam interaction

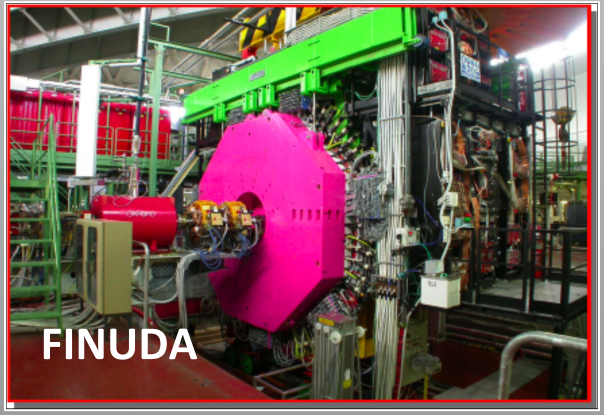
All aspects which are the front end of the research in the particle accelerator field

Luminosity 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 a double IPs collider

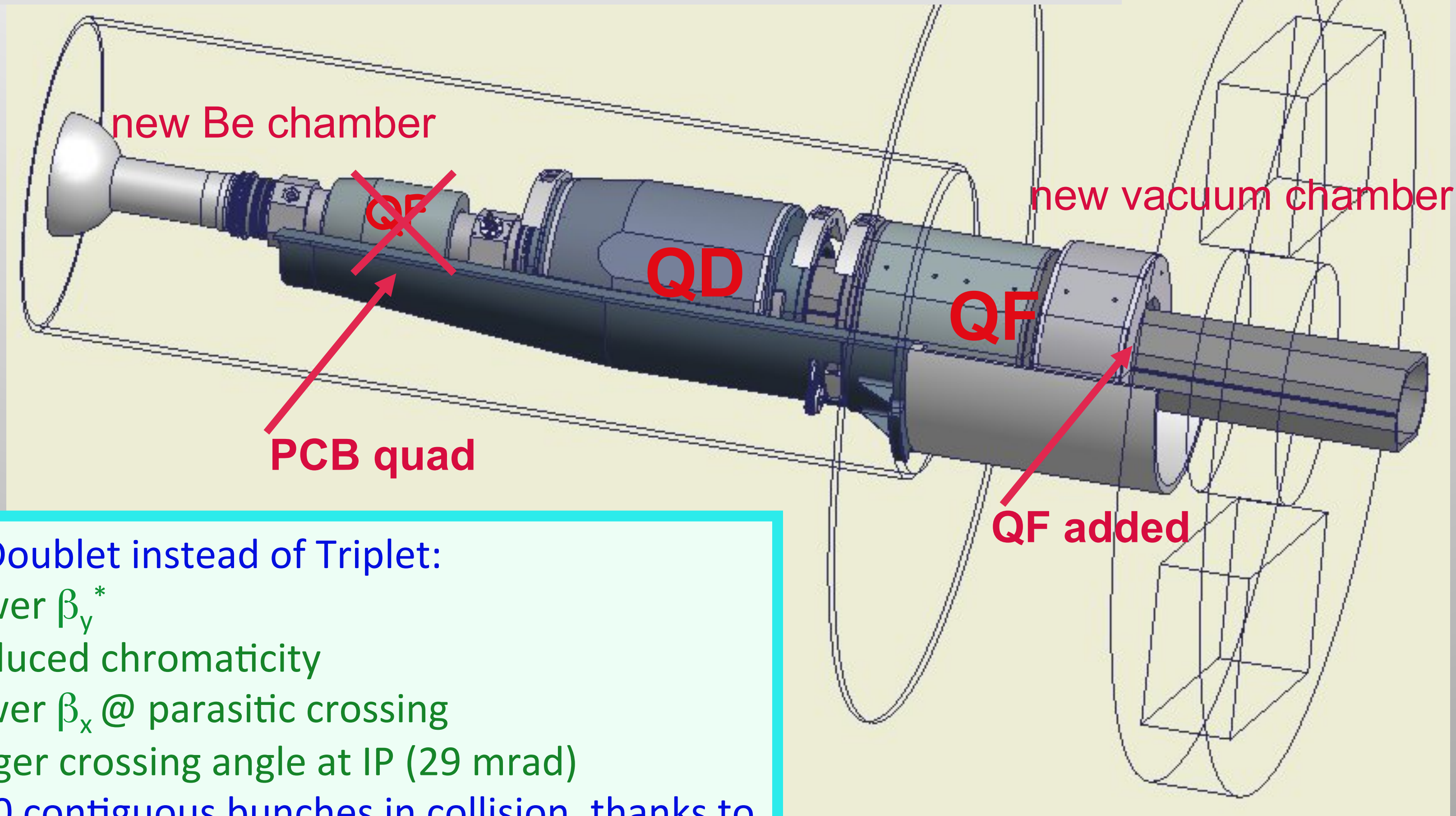




L_{logged} (fb^{-1}) 2001÷2007

KLOE	3.0
FINUDA	1.2
DEAR	0.2

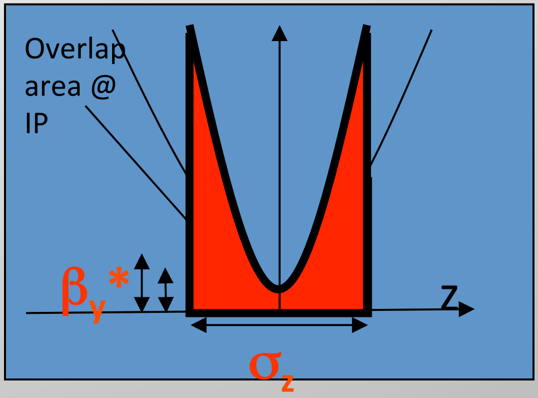
New KLOE Interaction Region (2003)



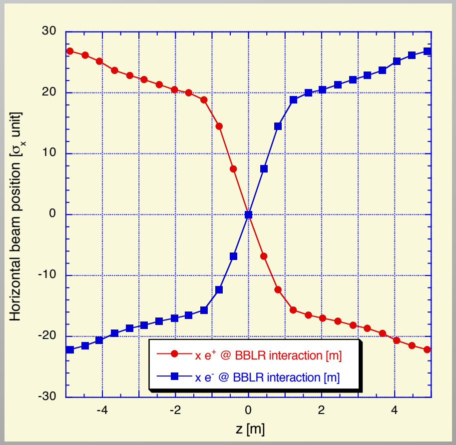
- QUADs Doublet instead of Triplet:
    - lower β_y^*
    - reduced chromaticity
    - lower β_x @ parasitic crossing
    - larger crossing angle at IP (29 mrad)
- up to 120 contiguous bunches in collision, thanks to powerful feedbacks too (A. Drago)
- FINUDA and it’s low-β removed
- independently rotating QUADs:
    - better coupling correction
    - different solenoid current allowed

Upgrade Motivations

$L_{peak} \sim 1.6\ 10^{32}$ 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 $\tau^+\ \tau^-$ 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 $L \sim 10^{33}$

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

Large Piwinski angle

Large Piwinski angle Φ obtained by:

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

small σ_x

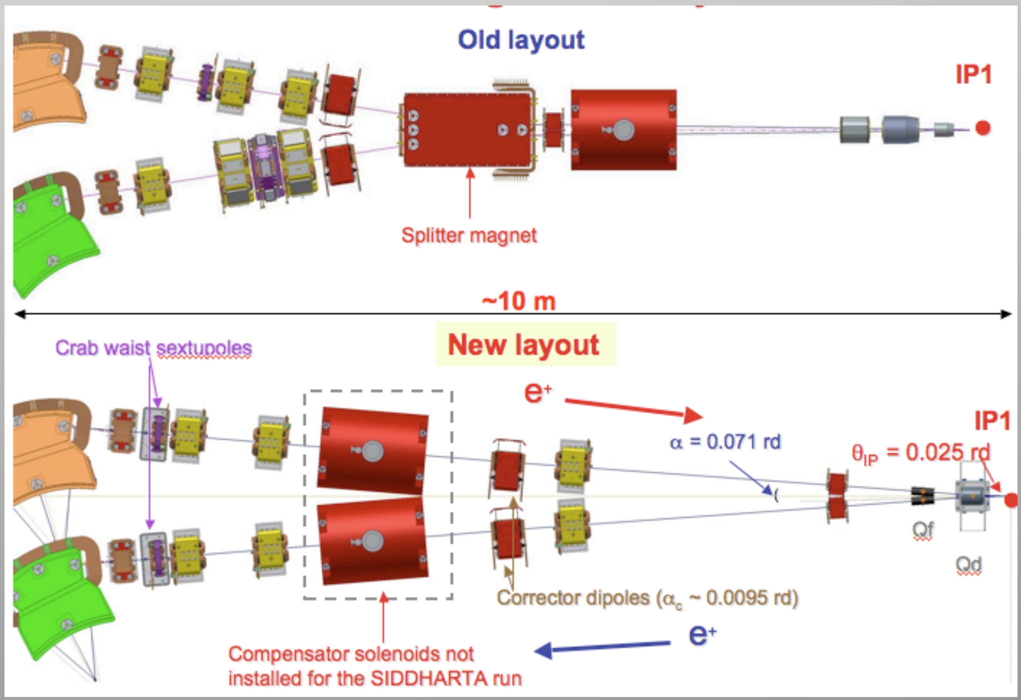
large θ

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

- low ζ_x
- $L_{\text{geometric}}$ 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

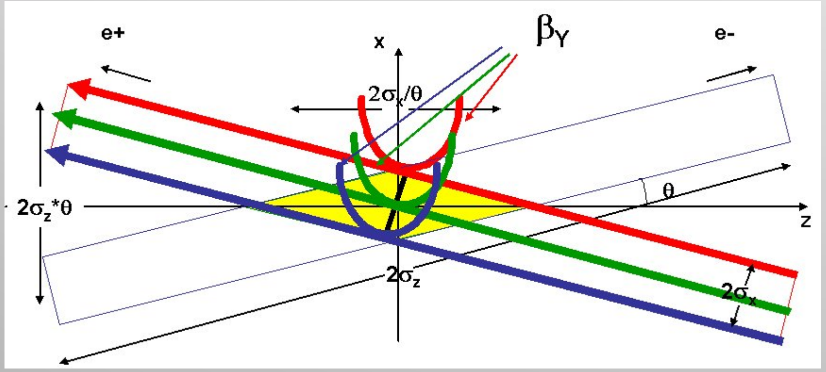


Lower β^*_y possible

Small β_y^* in fact the bunch overlap area Σ is:

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

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



New low-β section

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

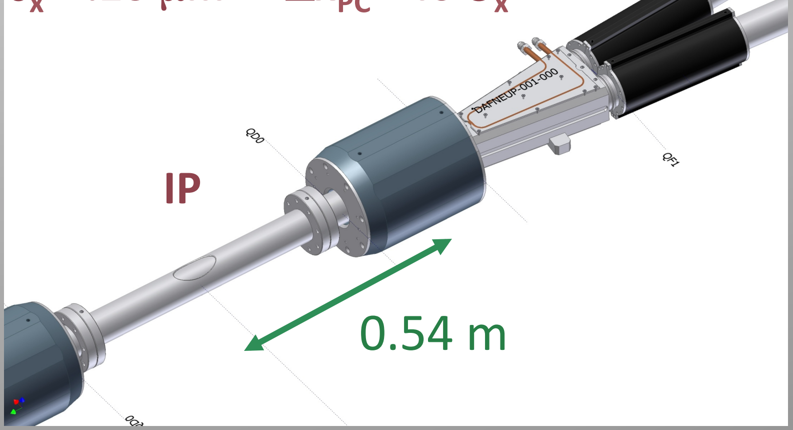
K_{QD} = -29.2 [T/m]

K_{QF} = 12.6 [T/m]

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

Only 1 parasitic crossing

ε_x ~ .26 μm -> Δx_{PC} ~ 40 σ_x



Crab-Waist compensation

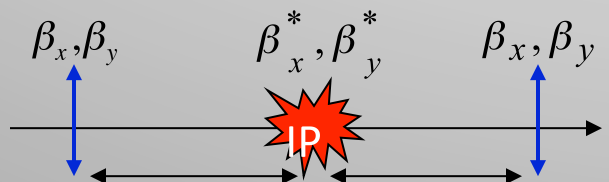
Collision with large θ had already been considered in the past .....

Large θ + Crab-Waist transformation is a new idea
(P.Raimondi et al., 2006)

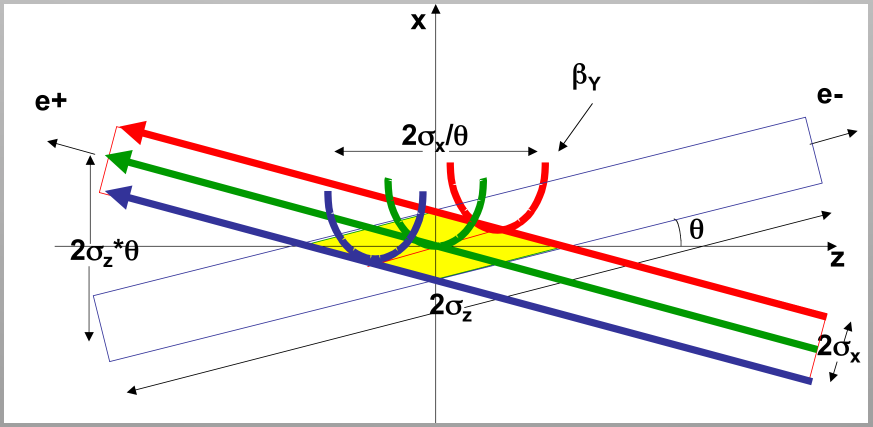
$$y = \frac{xy'}{2\theta}$$

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

sextupole anti-sextupole



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

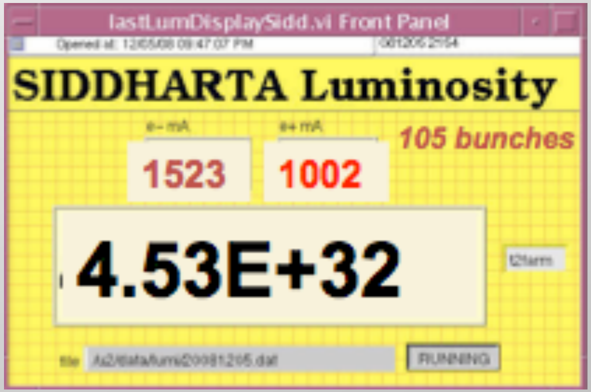


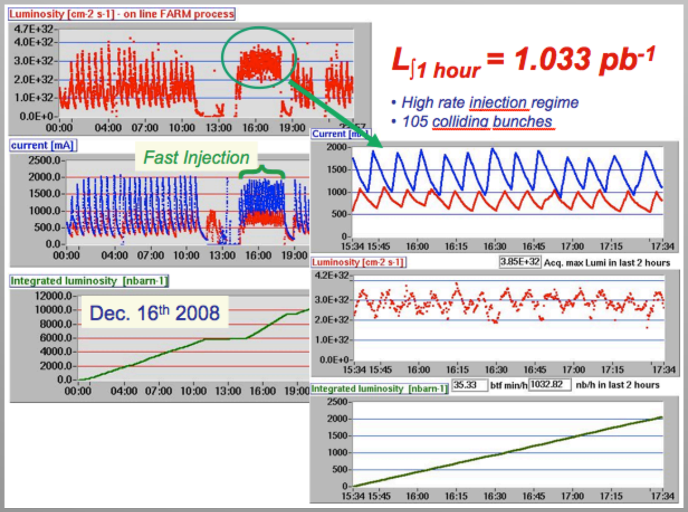
Crab-Waist collision scheme and SIDDHARTA

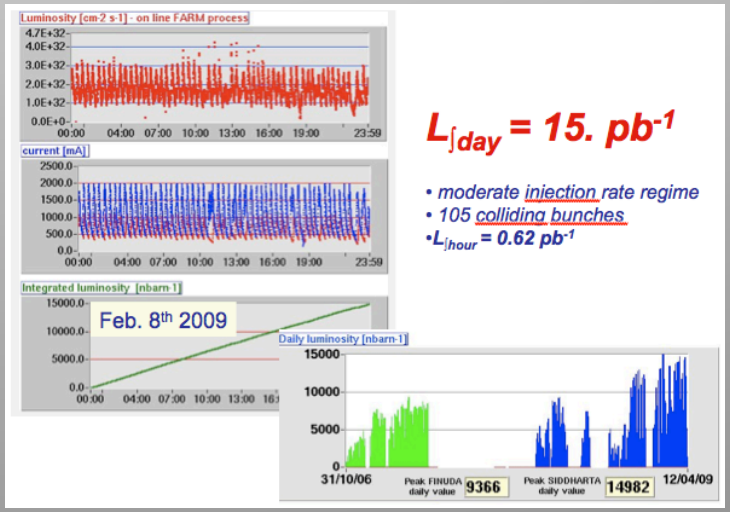
- Large crossing angle and Crab-Waist scheme proved to be effective in increasing luminosity, a factor 3 higher than in the past

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

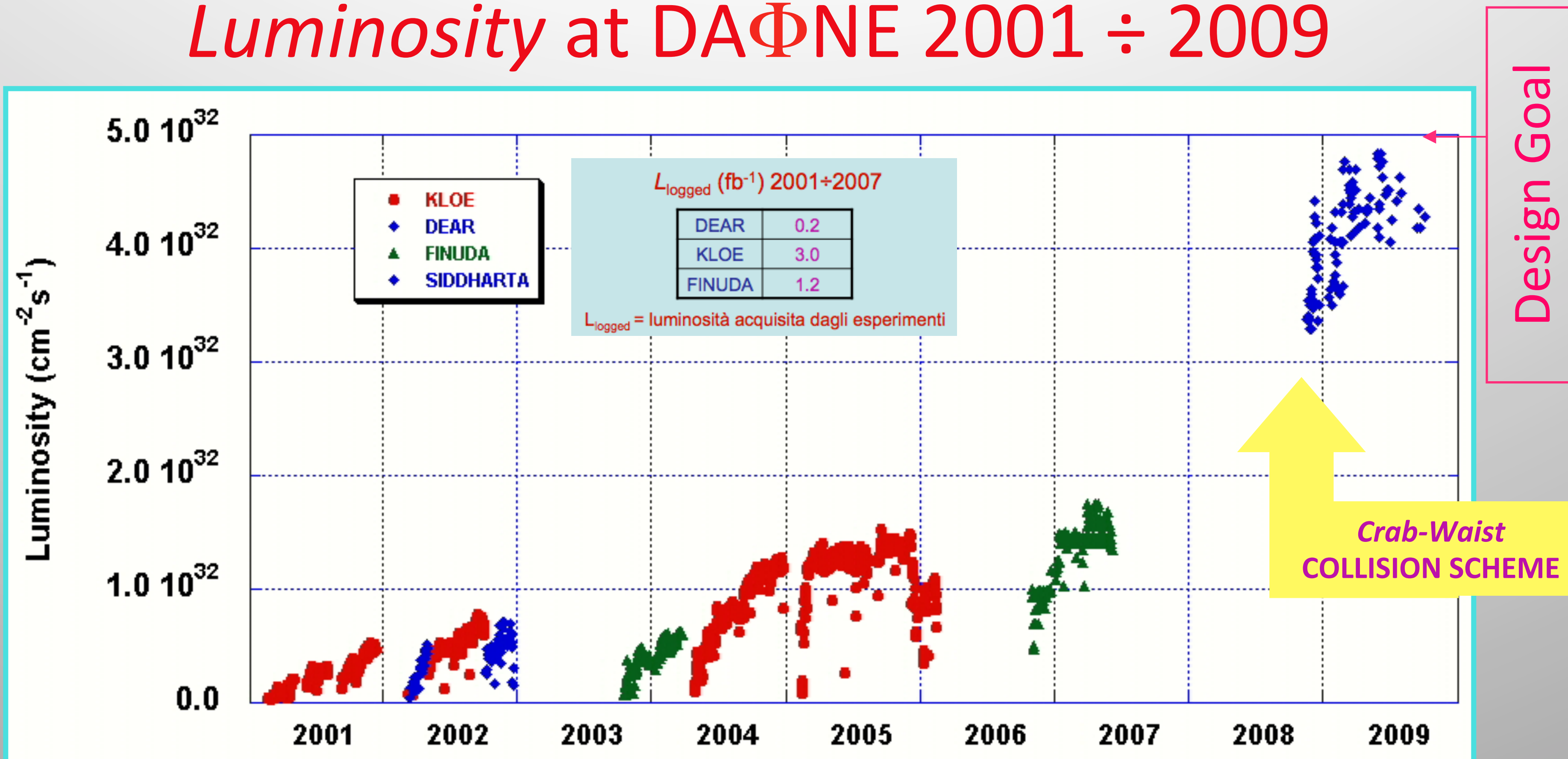
$L_{peak}= 4.5*10^{32}\ cm^{-2}\ s^{-1}$
$L_{\int 1\ day}= 15.0\ pb^{-1}$
$L_{\int 1\ hour} = 1.033\ pb^{-1}$
$L_{\int run}\sim 2.8\ fb^{-1}$ (SIDDHARTA detector)







Luminosity at DAΦNE 2001 ÷ 2009



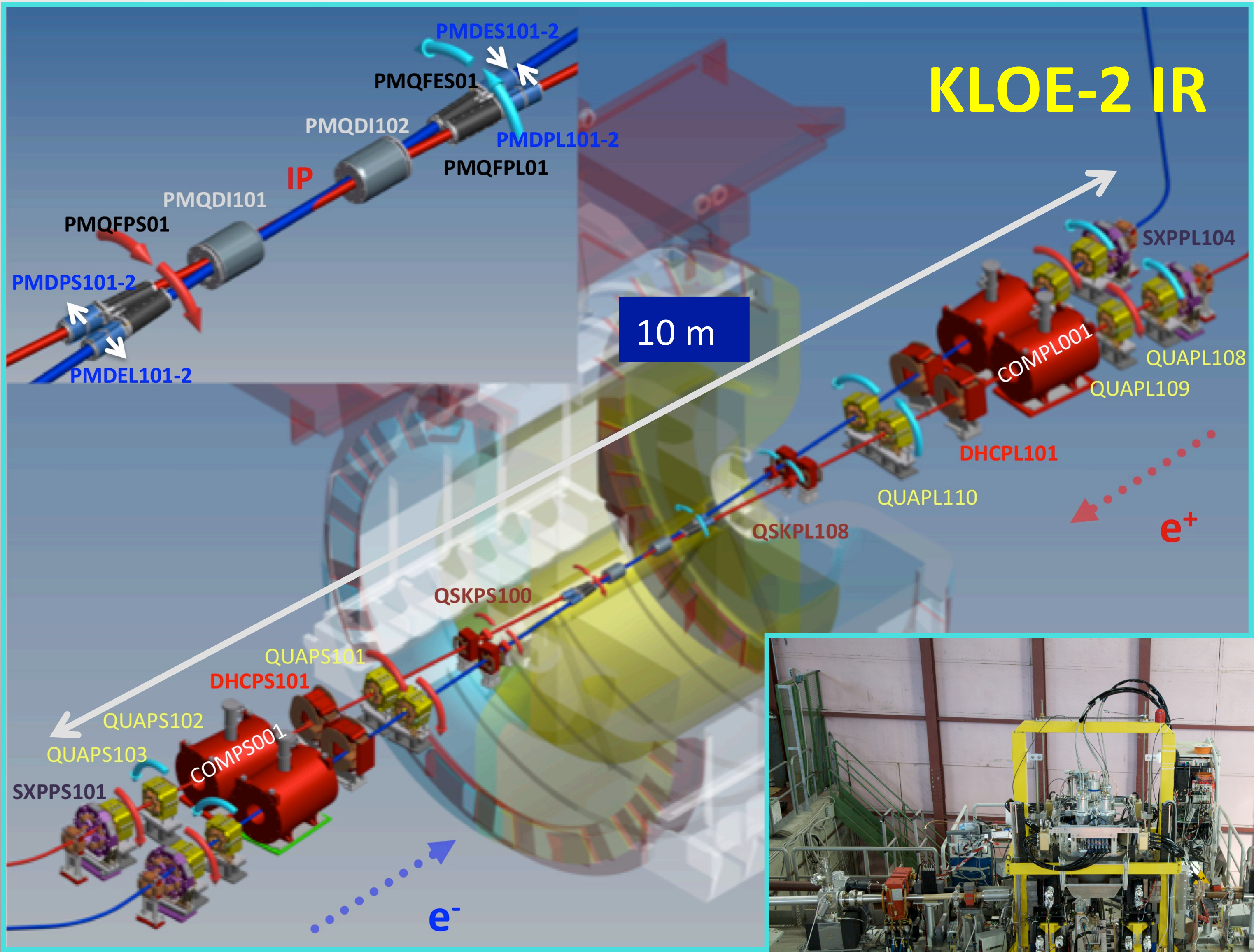
CW-Collision scheme for the KLOE detector

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:

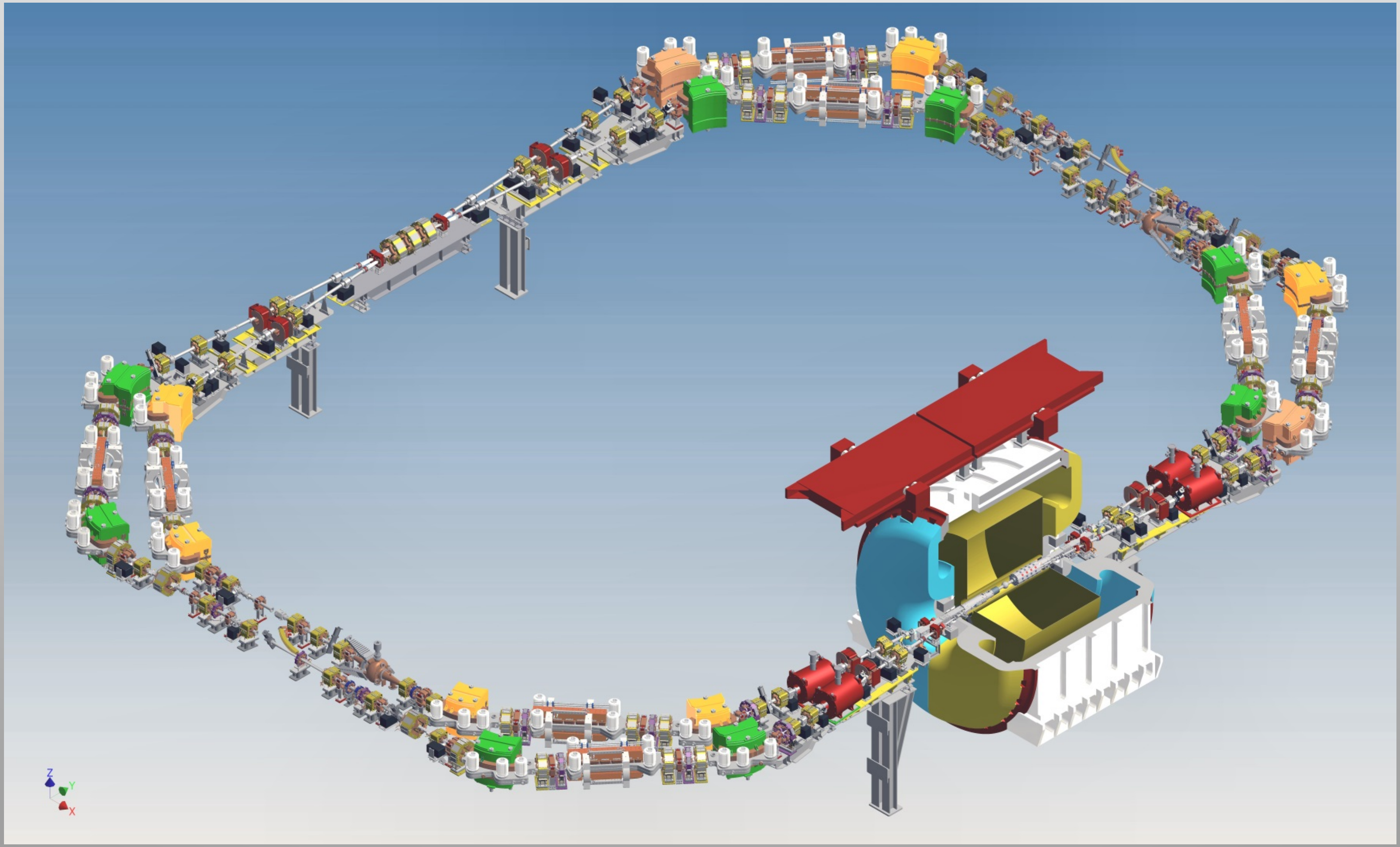
IR optics complying with:
- Low-β
- ***Crab-Waist*** collision scheme
- Coupling compensation
- Beam trajectory control

IR mechanical design allowing:
- Large crossing angle
- Early vacuum pipe separation after IP
- Mechanical stability of the low-β doublet



(C. Milardi et al., JINST 7 (2012) T03002)

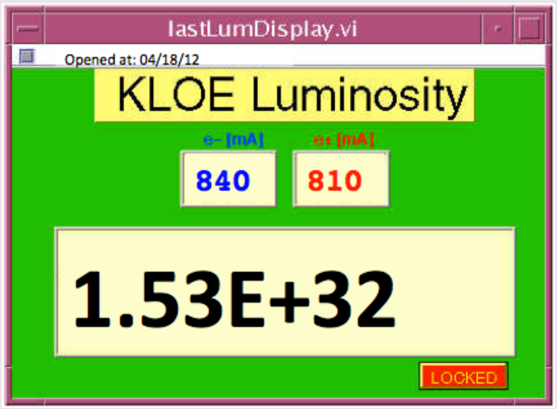
DAΦNE and KLOE



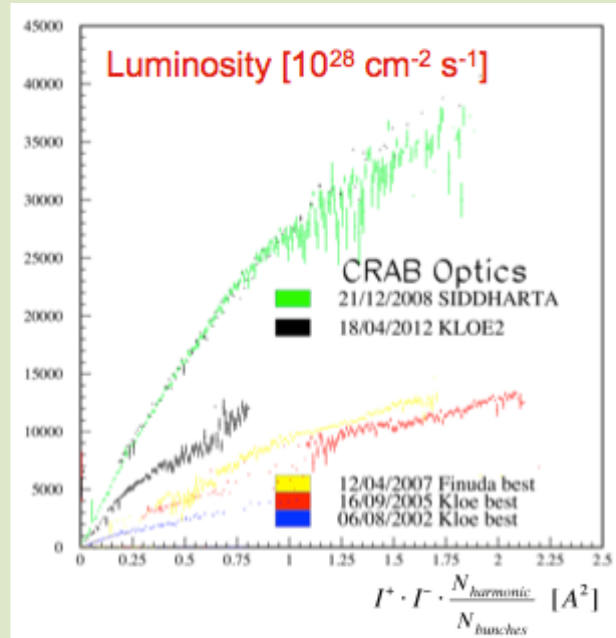
KLOE CW-IR preliminary test

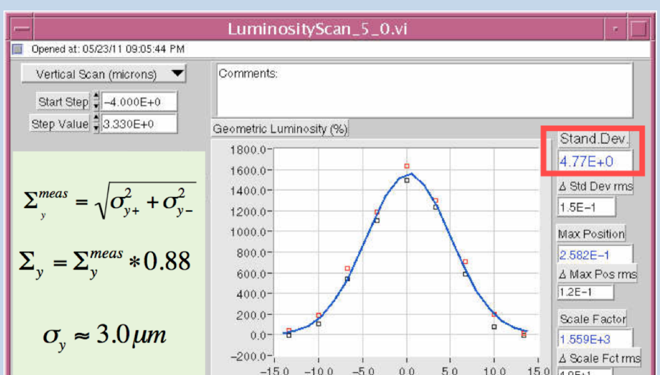
2012 achievements

Peak Luminosity (100 bunches)



Comparison Among DAΦNE Best Runs with and without *Crab-Waist*





Vertical beam-beam scan

KLOE – AMADEUS Synergy

Half-cylinder (for K^+ tagging) pure carbon target inserted inside the KLOE drift chamber by the end of August 2012, to study kaon-nuclei interaction processes at low energies.

With about 100 pb^{-1} a gain of a factor ~ 3 w.r.t. 2002-2005 data

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UNPRECEDENTED STUDIES OF THE LOW-ENERGY NEGATIVELY CHARGED KAONS INTERACTIONS IN NUCLEAR MATTER BY AMADEUS*

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The AMADEUS experiment deals with the investigation of the low-energy kaon-nuclei hadronic interaction at the DAΦNE collider at LNF-INFN, which is fundamental to solve longstanding open questions in the non-perturbative strangeness QCD sector. AMADEUS step 0 consisted in the analysis of 2004–2005 KLOE data, exploring the K^- absorptions

* Presented at the II International Symposium on Mesic Nuclei, Kraków, Poland, September 22–25, 2013.

(753)

100 pb^{-1} have been delivered to KLOE-SIDDHARTA collaboration in ~20 days operation

DAΦNE Consolidation Activities

DAΦNE shut-down was intended mainly to upgrade the experimental detector (KLOE became KLOE-2), and it has been very useful to consolidate the entire collider.

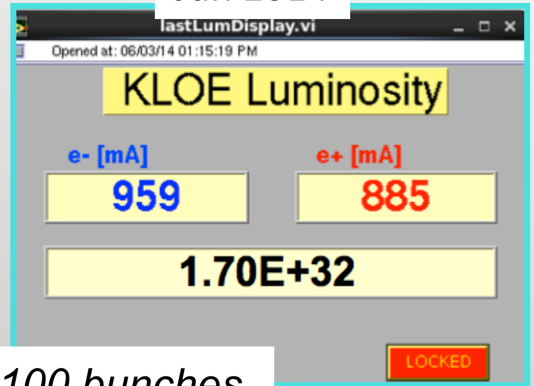
December 16th 2012 ÷ mid July 2013

Activities involved almost all the components of the DAΦNE accelerator complex:

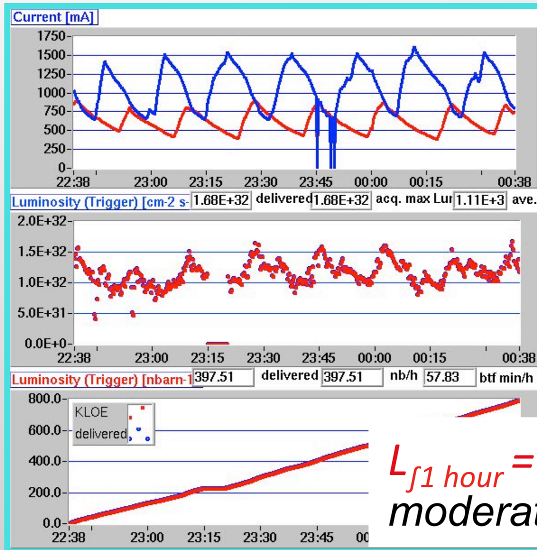
- IR mechanical structure and IP vacuum chamber
- auxiliaries' automation and control system
- Control system
- Vacuum installation (windows, scrapers)
- Cooling system
- Cryogenic plant
- Magnets and power supplies
- Modification of the LLRF controllers
- Linac
- E-cloud electrode power supplies
- new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

Peak Luminosity

Jun 2014



100 bunches



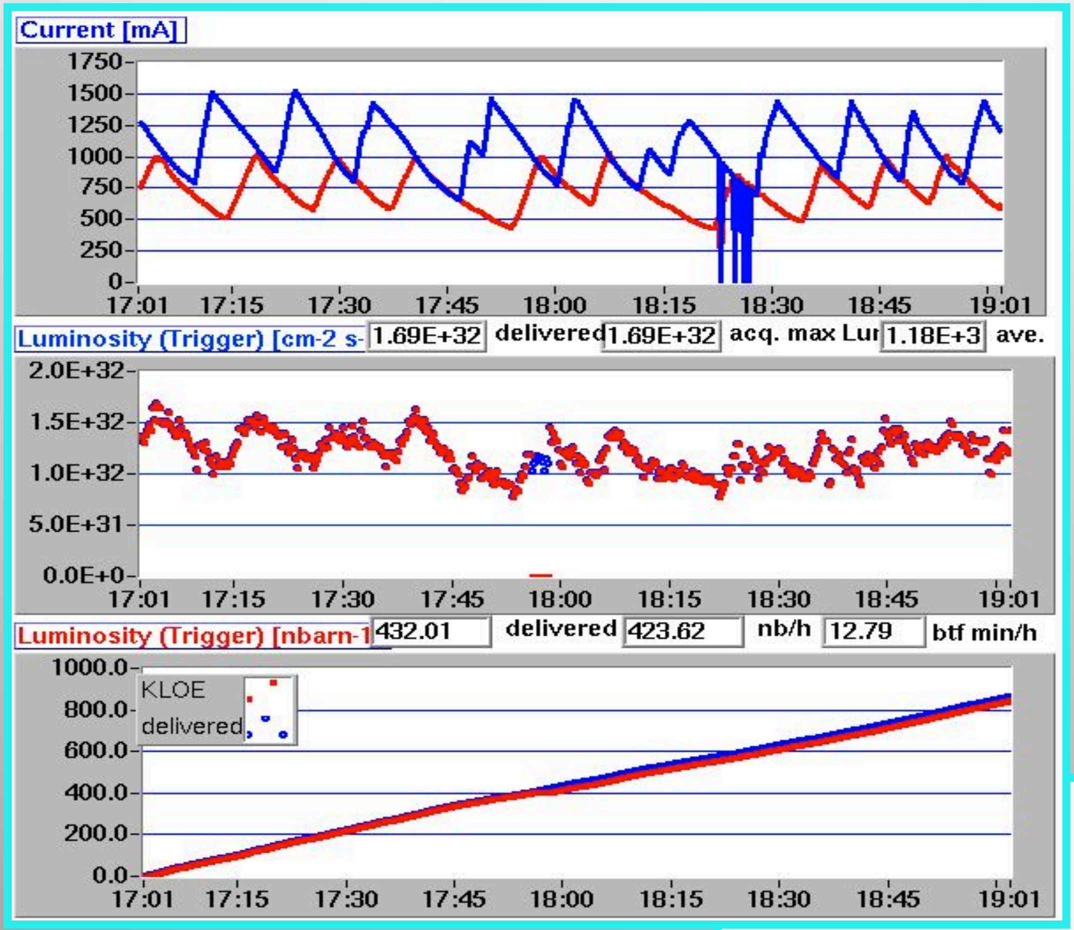
$L_{\int 1\ hour} = 0.4\ pb^{-1}$
moderate injection regime

	DAΦNE CW upgrade SIDDHARTA (2009)	**DAΦNE** KLOE (2005)	**DAΦNE (CW)** KLOE (2012)	**DAΦNE (CW)** KLOE-2 (2014)
L_{peak} [$cm^{-2}s^{-1}$]	**$4.53 \cdot 10^{32}$**	$1.50 \cdot 10^{32}$	$1.52 \cdot 10^{32}$	**$1.70 \cdot 10^{32}$**
I^- [A]	**1.52**	1.4	0.93	**0.96**
I^+ [A]	**1.0**	1.2	0.72	**0.89**
$N_{bunches}$	**105**	111	100	**100**

L_{peak} exceeds by a 13% the best luminosity ever achieved, at DAΦNE, during operations for an experimental apparatus including high field detector solenoid

Background presently has been reduced to levels almost compatible with the detector data-taking

Best hourly integrated luminosity



July 29th

$L_{peak} = 1.69 \bullet 10^{32}\ cm^{-2}s^{-1}$

$L_{\int 1h} = 432\ nb^{-1} \rightarrow L_{\int day} > 10\ pb^{-1}$

KLOE-2 data taking test

Thursday 31st 2014

several injections moderate currents

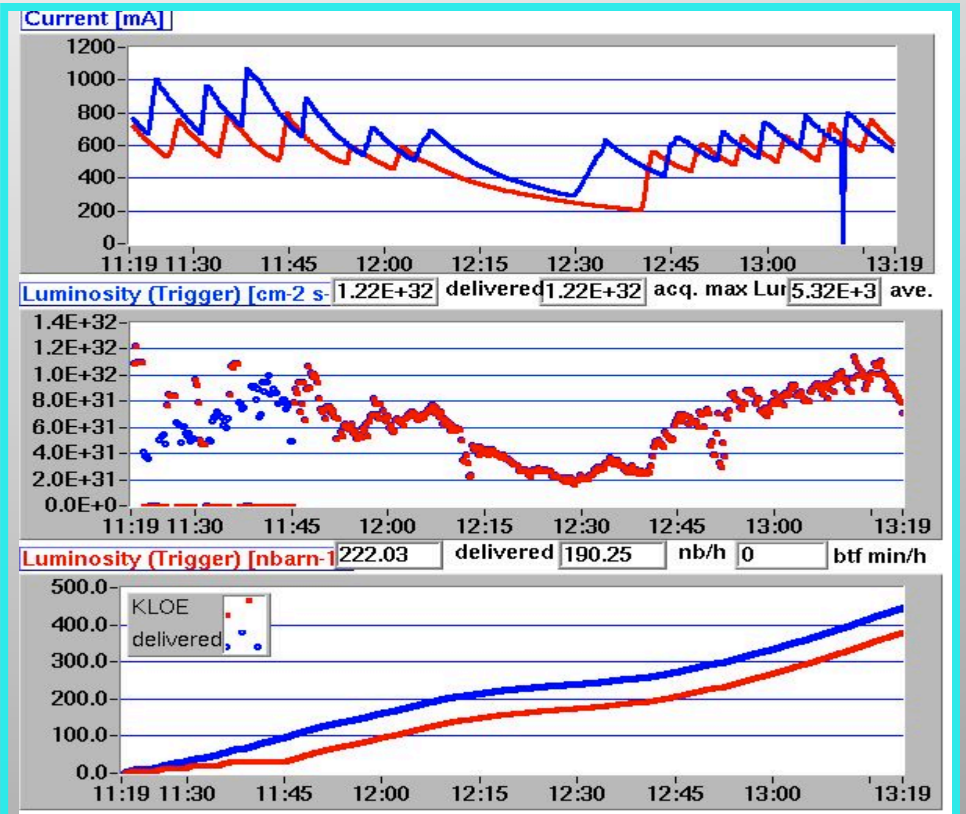
$L_{peak} \sim 1.14 * 10^{32}$

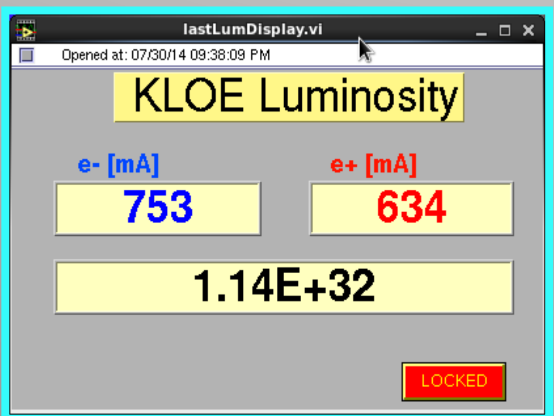
$L_{\int 1h} \sim 210\ nb^{-1}$ (stored on disk)

All detector components on

T_2 rate ~ 6 kHz

Hot rates ≤ 400 kHz





Conclusion about the KLOE-2 run

There is a continuous substantial progress in the collider performances

The first KLOE-2 data-taking tests have been successfully done

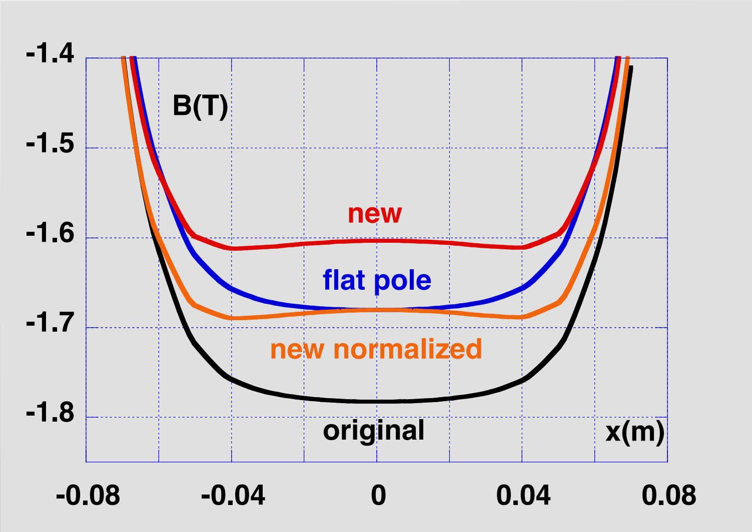
A well defined plan has been defined to deliver data to the KLOE-2 detector

Concerning uptime and reliability of the DAΦNE subsystems we are on the verge of inverting the negative trend, which requires: a lot of efforts, quite long time and a proper framework.

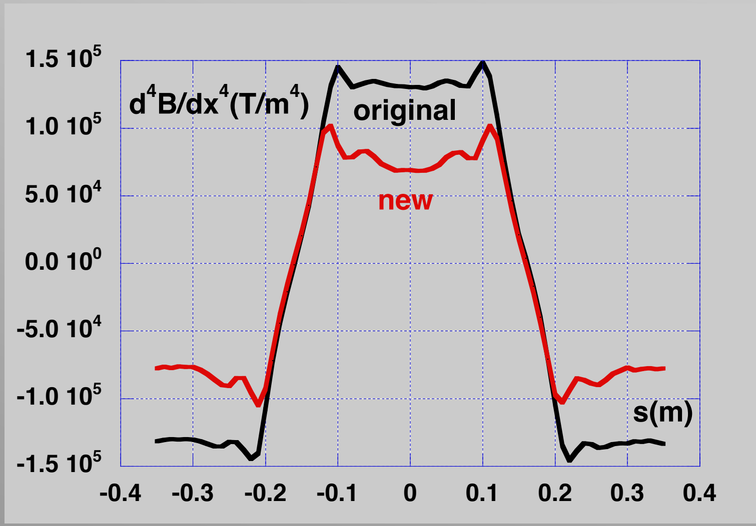
Wiggler poles modification (2002)

Additional plates glued on wiggler poles

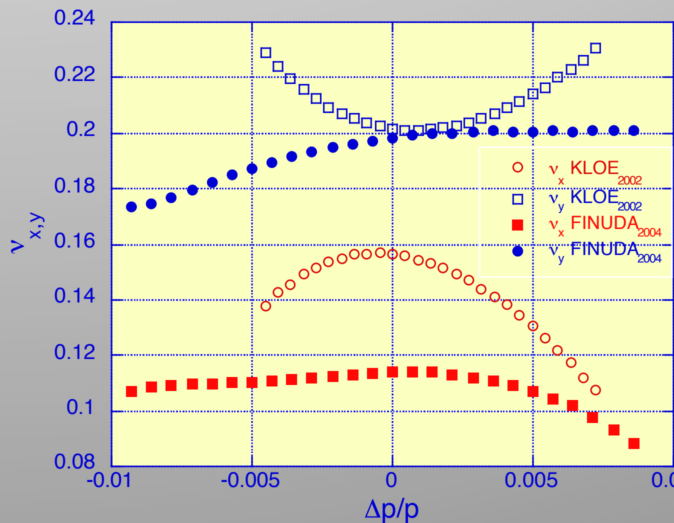
(M. Preger)



Field at pole center

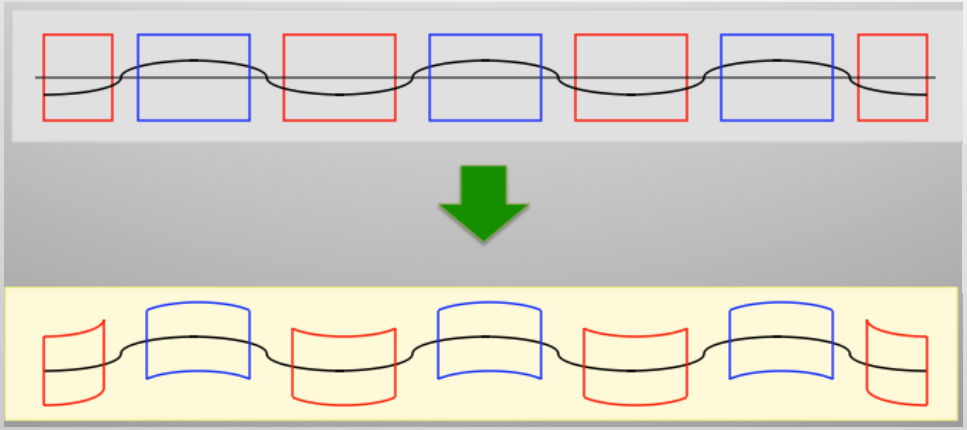


Improvement of the 4th order term generating cubic nonlinearity

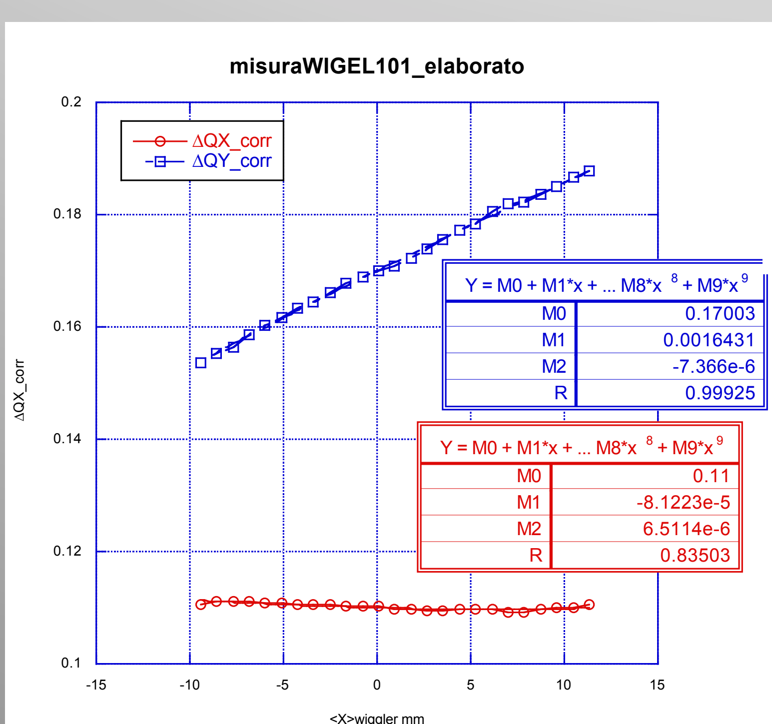


A factor 2 is gained in terms of energy acceptance

Wiggling wiggler



To have wiggler poles symmetric with respect to the beam orbit



- $\Delta\nu_x$ and $\Delta\nu_y$ exhibit an evident linear behaviour
- A small sextupole-like dependence is observed in $\Delta\nu_y$ only, probably originated in the nearby dipoles included in the bump

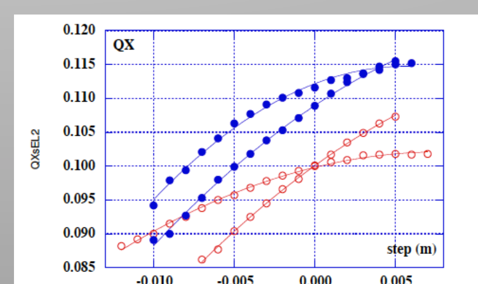


Figure 8: Measured horizontal betatron tune versus beam displacement in 4 wigglers

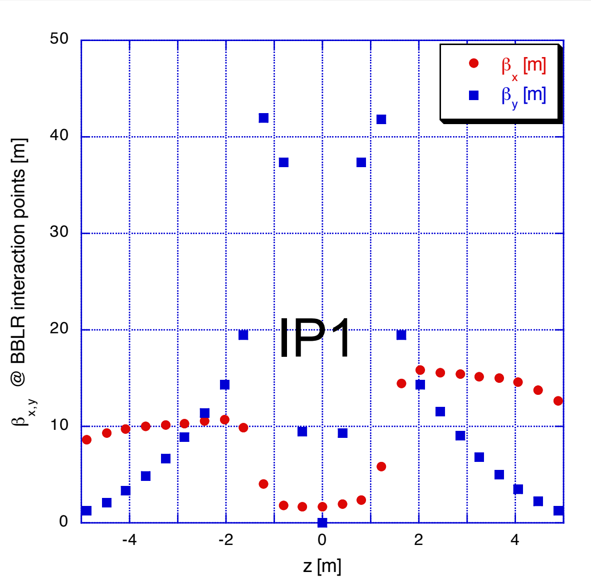
Published in 2004

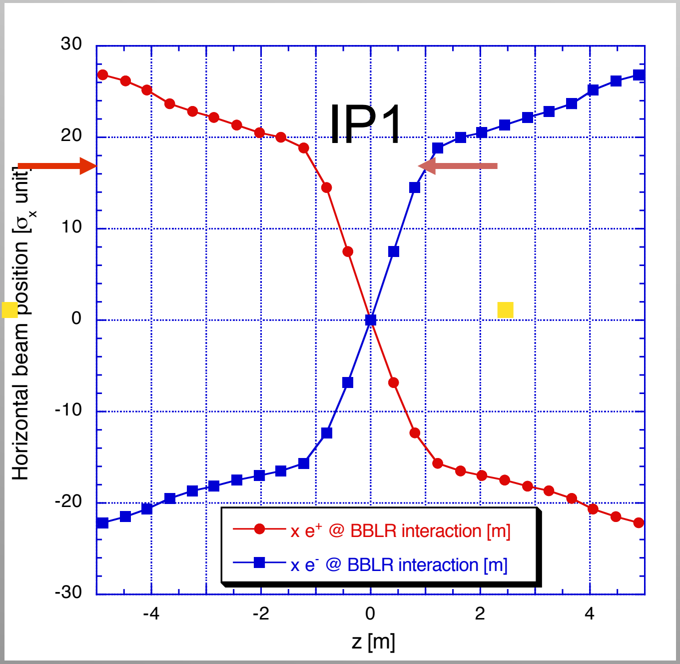
K^3 [m^{-3}]	Year
800	2001
360	2004
0	2011

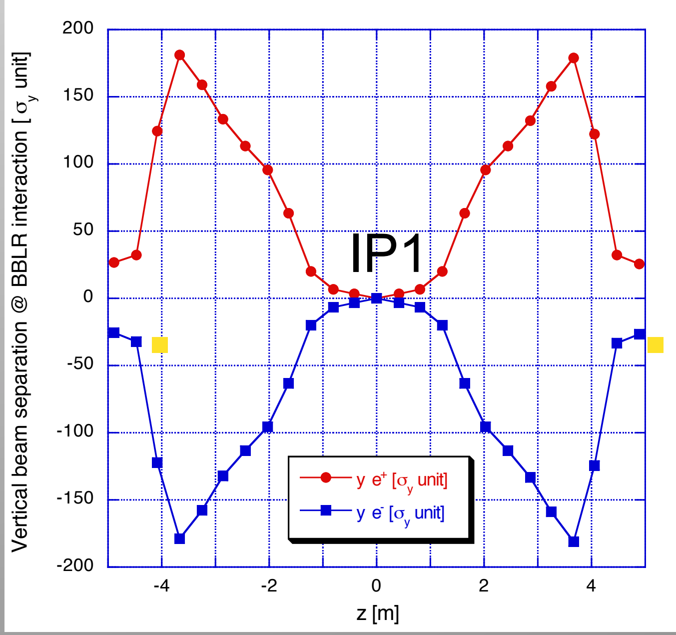
Parasitic Crossings in the DAFNE old IR1

In the IRs original configuration the beams experience 24 Long Range Beam Beam interactions

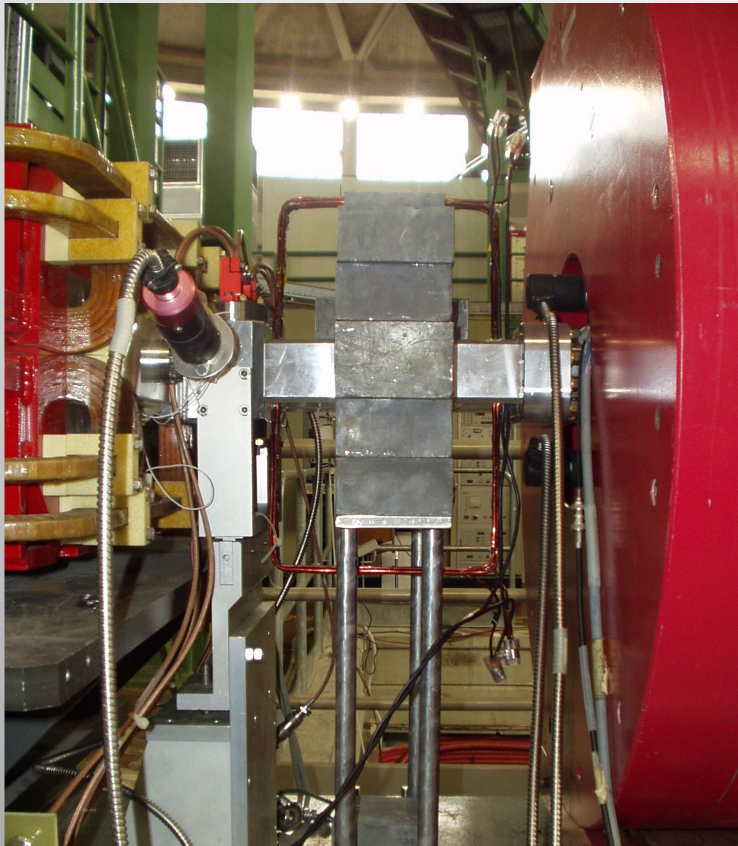
Bunch spacing 2.7 ns
Harmonic number 120
Colliding bunches 105 ÷ 111

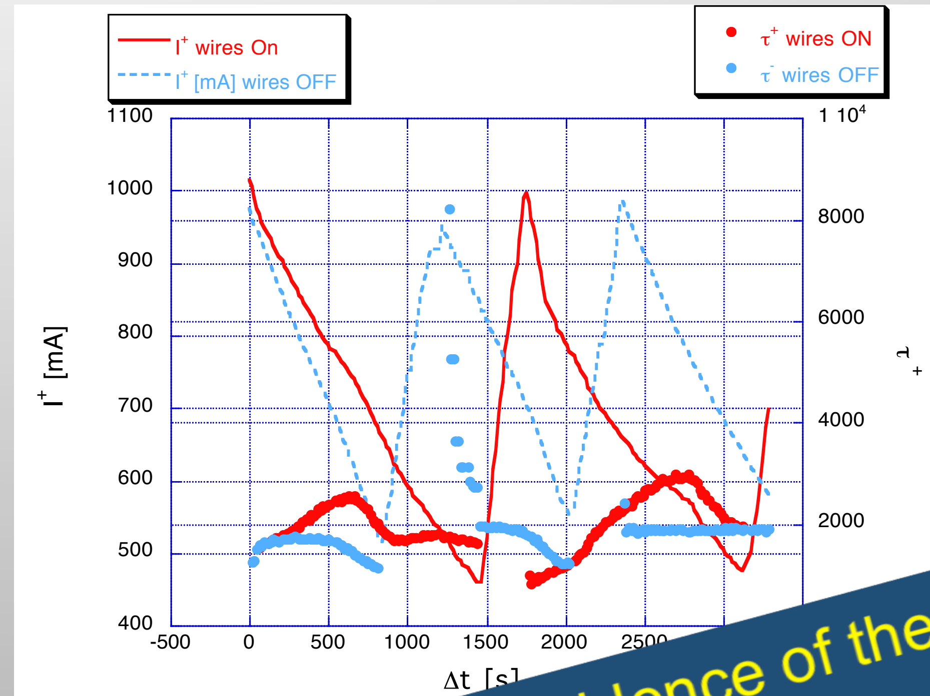






Wires have beed used for beam-beam parasitic crossing compensation





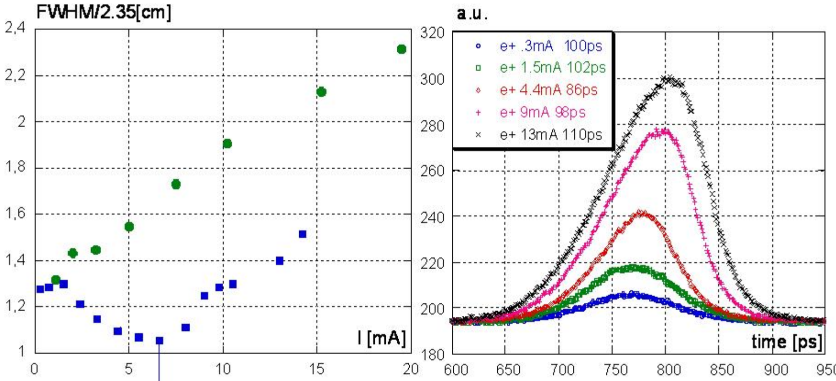
This is hitherto the only experimental evidence of the wires effectiveness in LRBB compensation

- ✓ Switching on and off the wires the same lum ... the beam currents.
- ✓ The positron τ^+ is on average high ... one is almost unaffected.
- ✓ The beam blow-up oc ... ection almost disappear.
- ✓ the same inte ... ting the beam two times only instead of three in the same time integral, ... sity by the same factor keeping the same injection rate.
- ✓ A higher τ mea ... ound on the experimental detector.
- ✓ It is possible to ... ptimize the collision at maximum current

(C. Milardi et al., physics/0607129)

α_c < 0 at DAΦNE

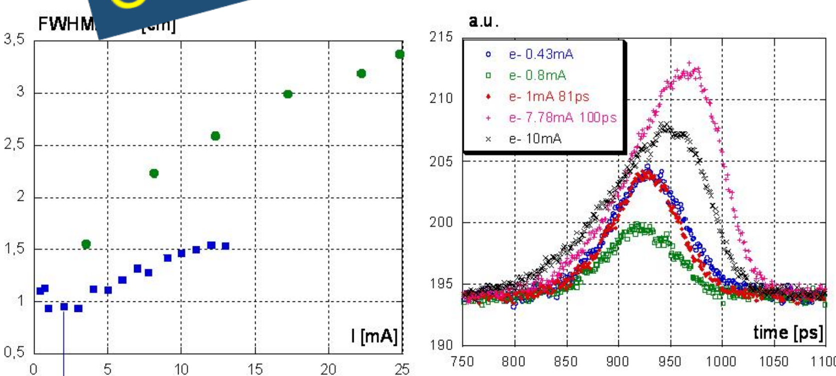
Bunch Shortening in the Positron Ring



I_{th} = 7 mA at α_c < 0

I_{th} = 9 mA at

Bunch ... Electron Ring



Low microwave instability threshold

Collisions with ac < 0 have never been tested elsewhere

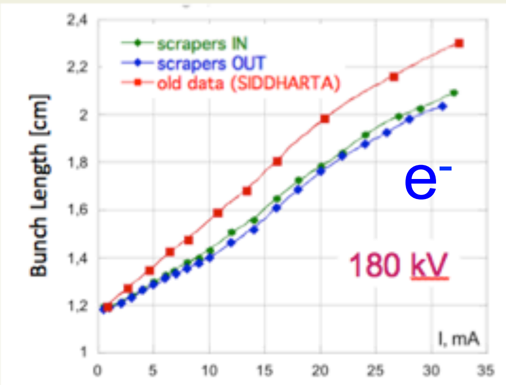
Summary of Results

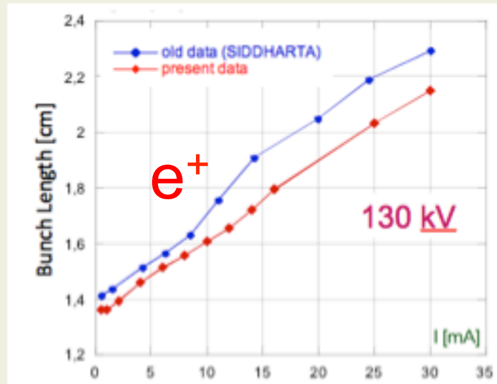
1. Flexible DAΦNE optics with α_c from +0.034 to -0.036.
2. Bunches shorten as pred... by numerical sim...
3. ...ssible to store high bunch current (~40 mA) with large negative chromaticity
4. Stable multibunch beams with currents > 1 A
5. Specific luminosity gain of about 25% till 300 mA per beam
6.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

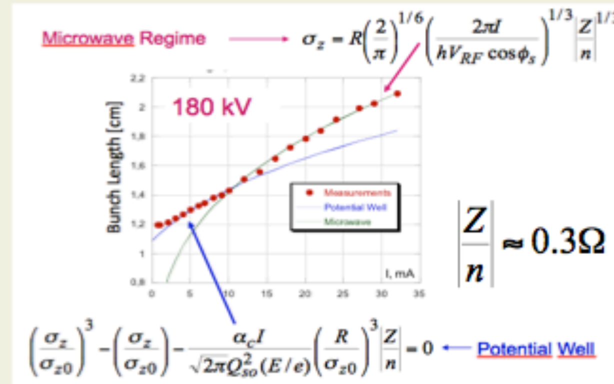
(M. Zobov et al.. physics/0607036)

Ring Impedance

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





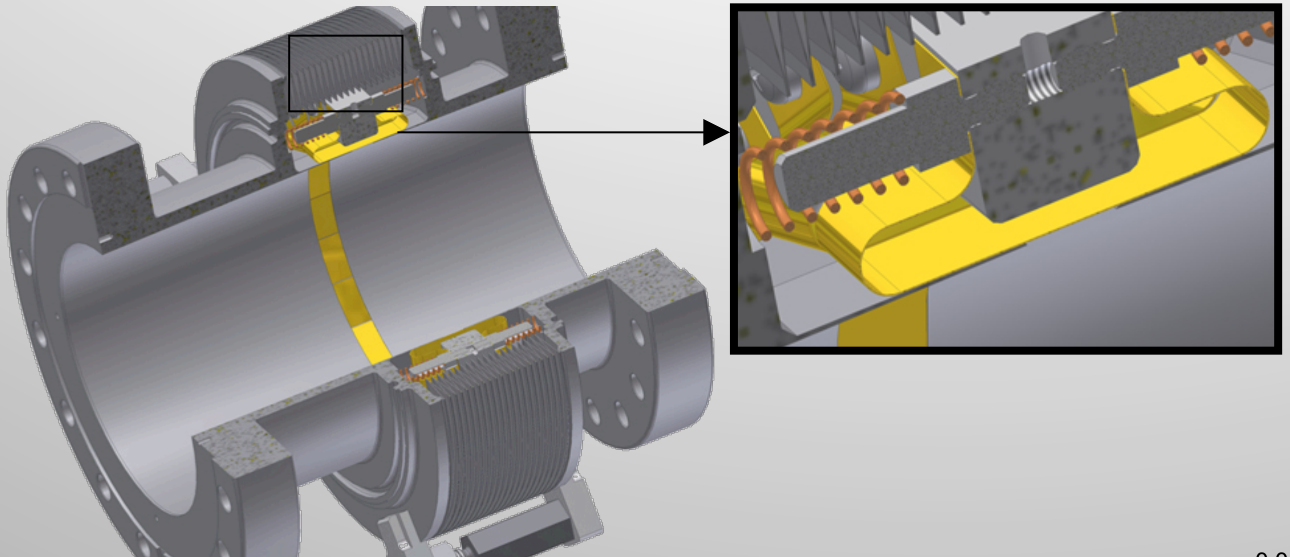


Numerical fits based on potential well as well as microwave regime converge to a ring coupling impedance of 0.3 Ω

Lower impedance thanks to:

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

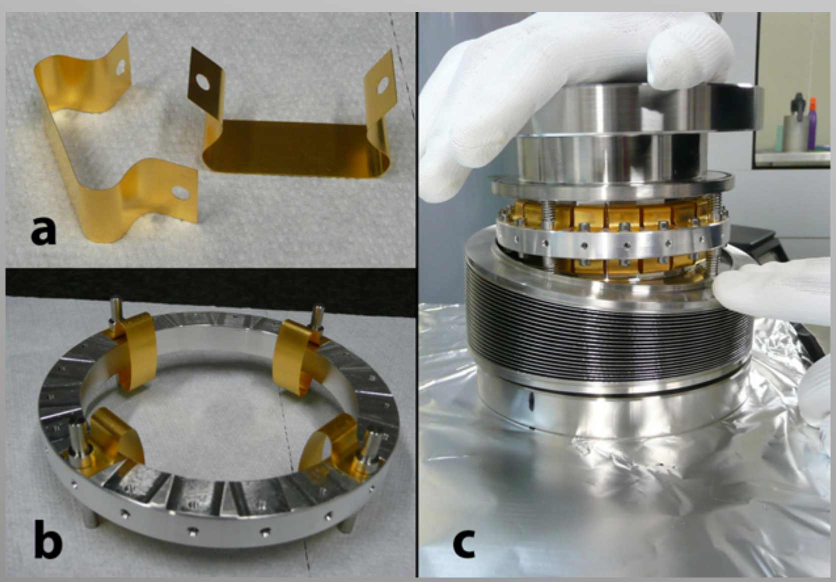
THE NEW DAΦNE BELLOWS



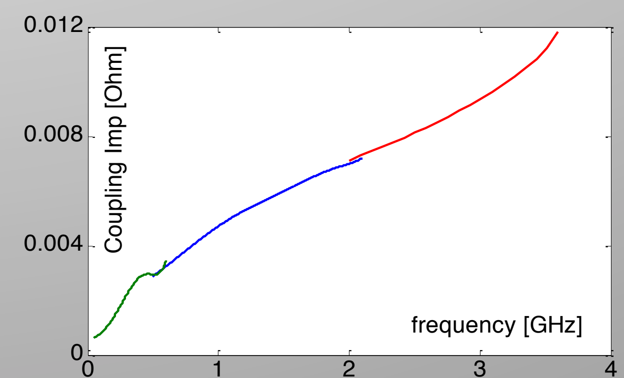
Designed for a circular cross section (ø 88 mm) chamber.

The shield consists of:

- 2 cylindrical pipes, welded at the bellows ends, giving continuity to the beam pipes except for the gap between them.
- 20 Ω shaped, gold-coated, Be-Cu strips, shields the gap. Each is 0.2 mm tick.
- the 20 strips are bolted on a floating thick aluminium ring



gold coated strip (a), supporting Al ring (b), bellows assembly (c).



THE RF SHIELD CAN FIT DIFFERENT BEAM PIPE CROSS SECTIONS

Beam Current compared with other factories

Parameters	PEP-II		KEKB		DAΦNE	
	LER	HER	LER	HER	e+	e-
Circumference (m)	2200	2200	3016	3016	97.69	97.69
Energy (GeV)	3.1	9.0	3.5	8.0	0.51	0.51
Damping time (turns)	8.000	5.000	4.000	4.000	110.000	110.000
Beam Currents (A)	3.21	2.07	1.70*	1.25*	1.40	**2.45**

Maximum positron beam current

Maximum currents with SC cavities

Maximum electron beam current

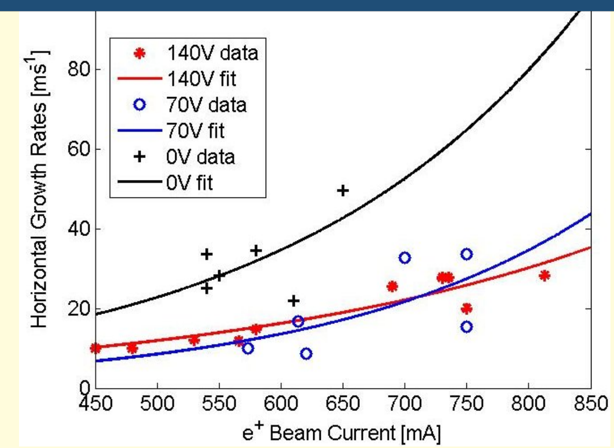
* 2.00 A and 1.40 A without crab cavities

Clearing electrodes for *e-cloud* suppression

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)

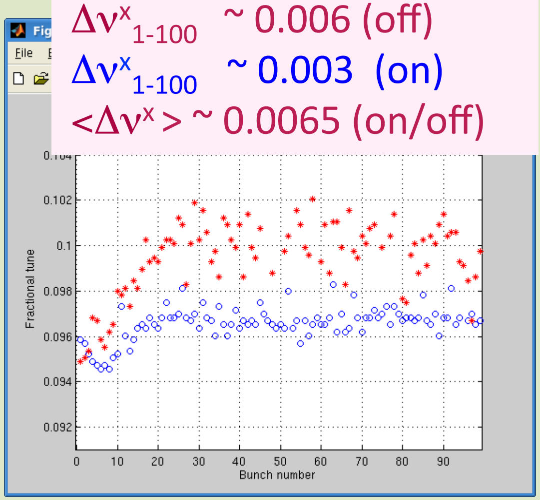
DAΦNE is the first collider operating routinely with long electrodes, for e-cloud mitigation.

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

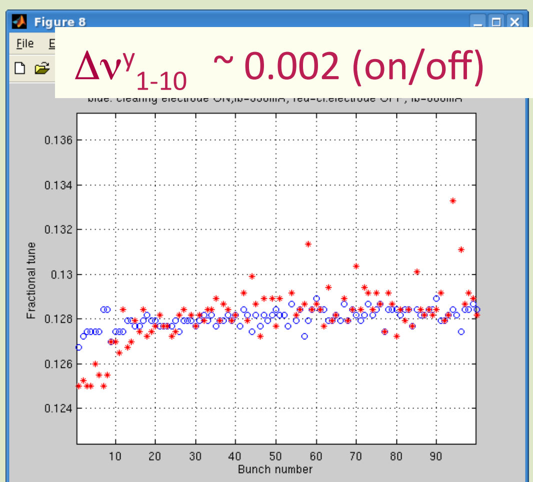


Tune Spread measurements

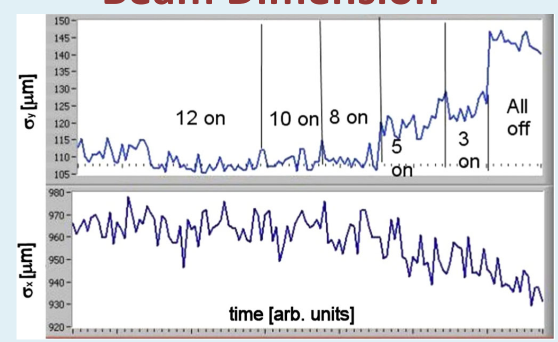
$\Delta\nu^{x}_{1\text{-}100}$ ~ 0.006 (off)
$\Delta\nu^{x}_{1\text{-}100}$ ~ 0.003 (on)
$<\Delta\nu^{x}>$ ~ 0.0065 (on/off)



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



Beam Dimension



DAΦNE energy saving and run cost

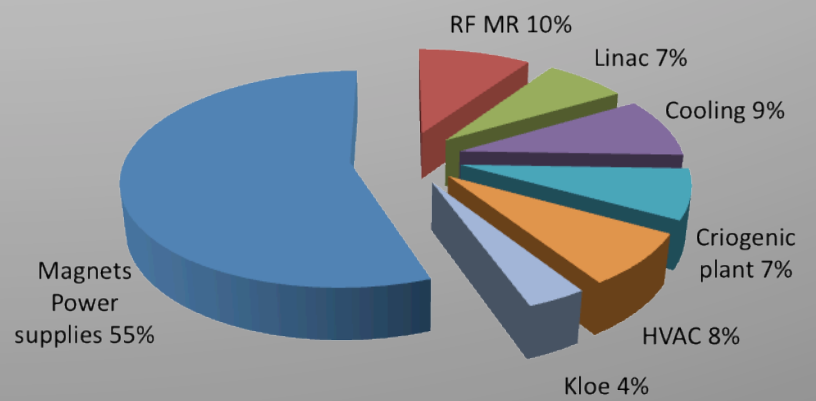
	kW	€cent/kWh	K€/day	1 year bill (200 run days) [M €]	Up-to date 1 year bill [M€]
Run KLOE 2005-2006	5.900	9,8	13,88	2,78	5,12
Run KLOE (Dec 2013)	3.340	18,08	14,49	2,90	2,90
Power demand reduction =	**2.560**		**200 days run saving =**		**2,22**

(R. Ricci)

	Dec-2005	NOW
Magnets Power supplies	3.984	1.850
RF MR	524	320
Linac	201	233
Cooling	600	300
Criogenic plant	250	250
HVAC	250	260
Kloe	150	120
TOT	5.959	3.333

Wiggler pole shaping and current reduction (730-> 400 A)	1700 kW
n. 4 Septa 34° magnets new coils	250 kW
n. 4 Splitter magnets removal (new interaction zone for the crab-waist)	160 kW
Dafne RF system optimization	170 kW
Dafne cooling system optimization	280 kW
Total power demand reduction	2.560 kW

DAΦNE bill might be reduced even more ……



CONCLUSIONS

DAΦNE contribution to research and developments in the particle accelerator field is undisputed

DANAE project

DANAE Letter of Intent

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INTRODUCTION

Lepton factories based on double storage rings and high frequency collisions of flat beams were designed in the 1990s, and came to operation just before the end of last century. The Φ-factory in Italy, DAΦNE[1], and the two B-factories on opposite sides of the Pacific Ocean, KEKB[2] in Japan and PEPII[3] in USA, are planning the end of their operations after almost one decade of operation. The community is waiting for the first beams of the new factories, BEPCII[4], the Chinese tau-charm at Beijing, and VEPP-2000[5], the first collider based on round beam collisions, in Novosibirsk. The future upgrades after 2010 of the two B-factories and of the Phi-factory are the subjects of discussions in the flavour physics communities.

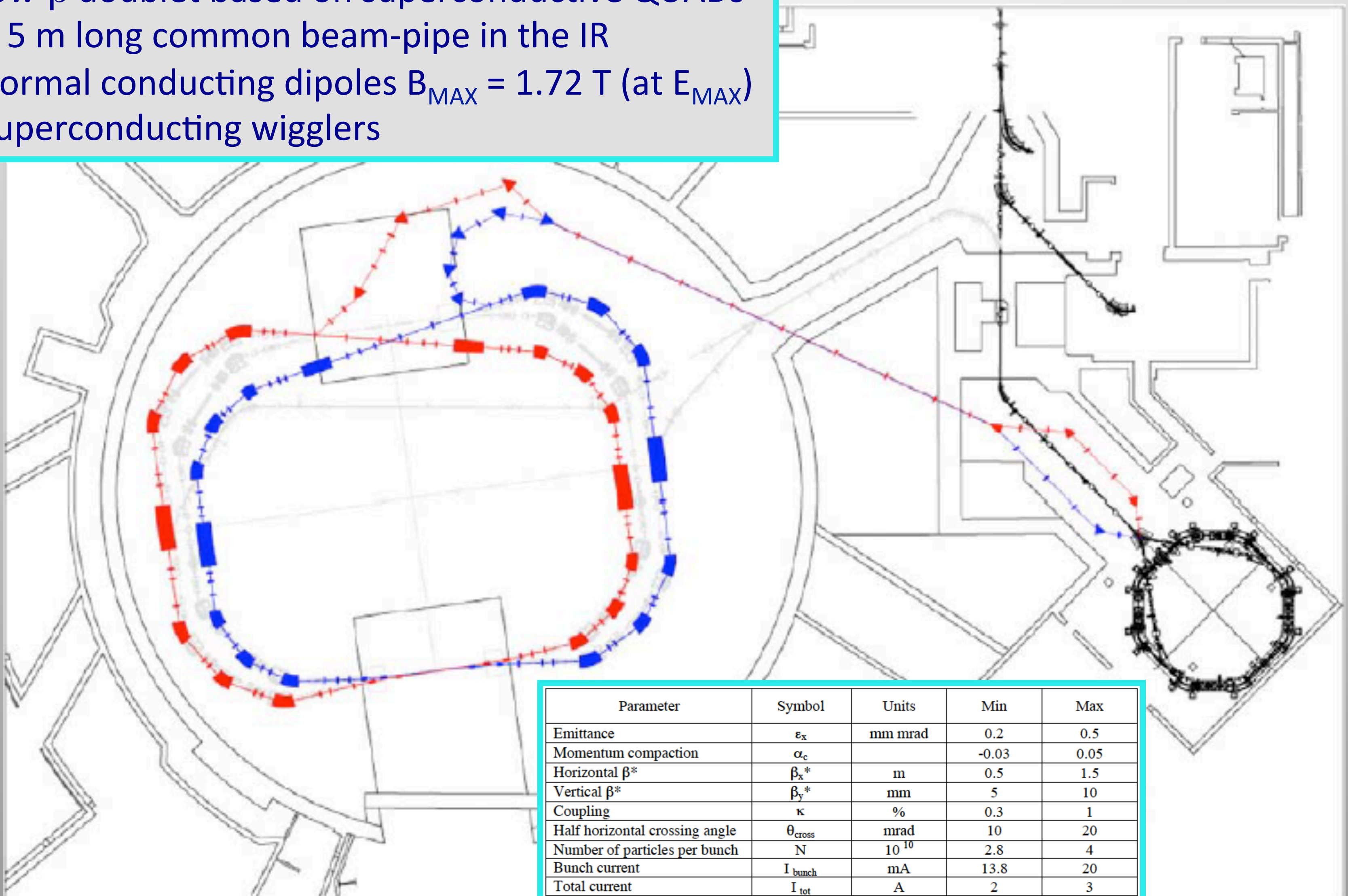
In Frascati the DAΦNE original physics program, ranging from K-physics, to nuclear and atomic physics, will be completed well before 2010, when the three experiments, KLOE[6], FINUDA[7] and DEAR[8], will collect the required statistics. Interest in pursuing further these research fields, together with a wider particle physics program, including γ–γ experiments, has shown up and is described in separated documents [9-12]. The proposed experiments at the Φ are more demanding in terms of luminosity with respect to the present DAΦNE parameters, and even the foreseen collider upgrades for the next future will not fulfill completely the experimental requirements. A flexible range of energy is furthermore requested, to cover the energy span in between the Φ and the tau-charm resonances.

This document describes the feasibility study of an e^+e^- collider whose range of energy and luminosity is shown in Table I. The design is site dependent since it is optimized to use DAΦNE buildings, infrastructures, injection system, and part of the ring hardware, with an overall minimization of cost and construction time.

Following the Frascati tradition of applying mythological names to its accelerators, we have called it DANAE (DAφne New with Adjustable Energy). Danaë, the daughter of the King of Argos, shut by her father in a tower with bronze doors, was visited by Zeus in the form of a shower of gold falling from a cloud, and from their union Perseus was born.

DANAE layout

low-β doublet based on superconductive QUADs
~ 5 m long common beam-pipe in the IR
normal conducting dipoles B_{MAX} = 1.72 T (at E_{MAX})
superconducting wigglers



Parameter	Symbol	Units	Min	Max
Emittance	ε_x	mm mrad	0.2	0.5
Momentum compaction	α_c		-0.03	0.05
Horizontal β*	β_x*	m	0.5	1.5
Vertical β*	β_y*	mm	5	10
Coupling	κ	%	0.3	1
Half horizontal crossing angle	θ_{cross}	mrad	10	20
Number of particles per bunch	N	10^{10}	2.8	4
Bunch current	I_{bunch}	mA	13.8	20
Total current	I_{tot}	A	2	3
rf voltage	V	MV	0.4	1.5
Bunch length	σ_L	mm	8	15
beam-beam tune shift	$\xi_{x,y}$*		0.025	0.06
Synchrotron tune	Q_s		0.02	0.10

STRONG RF FOCUSING FOR LUMINOSITY INCREASE: SHORT BUNCHES AT THE IP

A. Gallo, P. Raimondi, M. Zobov, INFN - LNF

Abstract

One of the key-issues to increase the luminosity in the next generation particle factories is to reduce the bunch length at the interaction point (IP) as much as possible. This will allow reducing proportionally the transverse beta functions at the IP and increasing the luminosity by the same factor. The strong RF focusing consists in obtaining short bunches by substantially increasing the lattice momentum compaction and the RF gradient. In this regime the bunch length is modulated along the ring and could be minimized at the IP. If the principal impedance generating elements of the ring are located where the bunch is long (in the RF cavities region) it is possible to avoid microwave instability and excessive bunch lengthening due to the potential well distortion.

1. INTRODUCTION

The minimum value of the vertical beta-function β_y at the IP in a collider is set by the hourglass effect [1] and it is almost equal to the bunch length σ_z. Reduction of the bunch length is an obvious approach to increase the luminosity. By scaling the horizontal and vertical beta functions β_x and β_y at the IP as the bunch length σ_z, the linear tune shift parameters $\xi_{x,y}$ remain unchanged while the luminosity scales as $1/\sigma_z$ [2]:

$$L \propto \frac{1}{\sigma_x \sigma_y} \propto \frac{1}{\sqrt{\beta_x \beta_y}} \propto \frac{1}{\sigma_z} \qquad (1)$$

A natural way to decrease the bunch length is to decrease the storage ring momentum compaction and/or to increase the RF voltage. However, in such a way we cannot obtain very short bunches since the short-range wakefields prevent this because of the potential well distortion and microwave instability.

In this paper we consider an alternative strategy to get short bunches at the IP. In particular, we propose to use strong RF focusing [3] (i.e. high RF voltage and high momentum compaction) to obtain very short bunches at the IP with progressive bunch elongation toward the RF cavity.

With respect to the case of short bunches with constant length all along the ring, the situation seems more comfortable since the average charge density driving the Touschek scattering is smaller. Besides, this allows placing the most important impedance generating devices near the RF cavity where the bunch is longest thus minimizing the effect of the wakefields.

2. STRONG RF FOCUSING

In order to compress the bunch at the IP in a collider a strong RF focusing can be applied. For this purpose high values of the momentum compaction factor α_c and extremely high values of the RF gradient are required. It is estimated that, for a Φ-factory collider, an RF voltage V_{RF} of the order of 10 MV is necessary provided that the α_c value is of the order of 0.2.

Under these conditions the synchrotron tune ν_s grows to values larger than 0.1 and the commonly used "smooth approximation" in the analysis of the longitudinal dynamics is no longer valid. Instead, the longitudinal dynamics is much more similar to the transverse one, and can be analyzed on the base of transfer matrices of the simple linear model reported in Fig. 1. In this model the cavity behaves like a thin focusing lens in the longitudinal phase space, while the rest of the machine is a drift space, where the "drifting" variable is the $R_{56}(s)$. In Fig. 1 $\lambda_{RF} = c/f_{RF}$ is the RF wavelength, E/e is the particle energy in voltage units, while L is the total ring length.

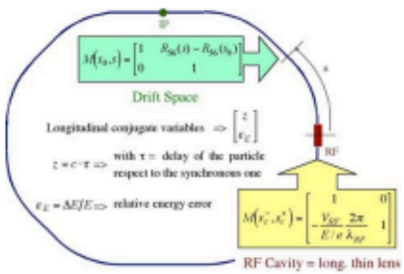


Figure 1: Longitudinal dynamics linear model.

The $R_{56}(s)$ parameter relates the path length to the normalized energy deviation of a particle, and is given by:

$$R_{56}(s) = \int_0^s \frac{\eta(\bar{s})}{\rho(\bar{s})}\, d\bar{s} \qquad (2)$$

where $\rho(s)$ is the local bending radius and $\eta(s)$ is the ring dispersion function.

Taking the cavity position as the reference point $s = 0$, the one-turn transfer matrix $M(s, s + L)$ of this system

Proposal for the DAΦNE Variable Energy Design Study

C. Milardi, D. Alesini, A. Gallo, M. Preger, A. Drago, P. Raimondi, B. Spataro, S. Tommasini, C. Vaccarezza, M. Zobov Accelerator Division.
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41st LNF Scientific Committee 22 – 23 November 2010

Preamble

Proposal for the DAΦNE energy upgrade, named DAΦNE_VE, in the framework of the FP7 call for infrastructures 2011 (deadline 25 November 2010)

The idea is not new a letter of intent has been already presented in 2006 for a collider called DANAE

DAΦNE has been upgraded including a new conceptual approach to the beam-beam interaction, the **Crab-Waist collision scheme** which was promising to give in principle **a luminosity of the order of 10^{33} cm^{-2}s^{-1}** .

The Crab-Waist concept has been successfully tested (L = 4.5 10^{32} cm^{-2}s^{-1})

Since then it is reasonable to consider the Crab-Waist as a basic concept for a variable energy collider.

The submission of this project to the European Community is still *sub iudice:* the INFN management should take a decision in few days (23 November 2010).

Design study strategy

The proposed design study is aimed at verifying the feasibility of an electron/positron collider working at variable center of mass energy:

$$0.6\ \text{GeV} \leq \mathbf{E_{CM}} \leq 3.0\ \text{GeV}$$

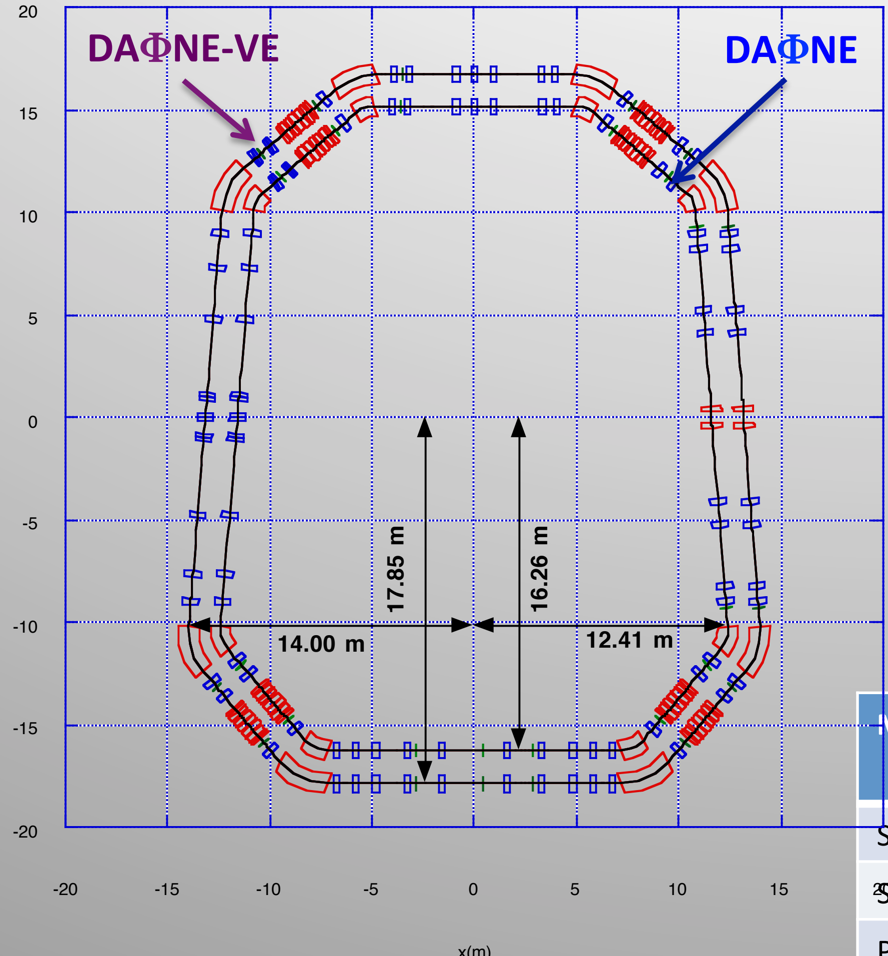
providing a luminosity

$$10^{32} \leq \mathbf{L} \leq 10^{33}\ \text{cm}^{-2}\text{s}^{-1}$$

reusing as much as possible the infrastructure of the DAΦNE accelerator complex in Frascati.

Search in the field of high energy physics requires large and expensive infrastructures requiring long time for design and construction. For this reason there is a generalized tendency around the world in reusing as much as possible existing facilities; it is the case for several colliders: BEPC2 in China, VEPP2000 in Russia and Super KEKB in Japan.

Rings can fit in the DAΦNE hall



Main Rings Toy-Layout

B (.5 GeV) ~ 1.2 T (DAΦNE)

B (1.5 GeV) ~ 1.7 T
B (0.3 GeV) ~ 0.33 T (DAΦNE-VE)

Magnet type	Θ (rad)	ρ (m) @ 0.51 GeV	ρ(m) @ 1.5 GeV	$L_{magnetic}$ @ 1.5 GeV
Sector long	0.7874	1.53	3.	2.3622
Sector short	0.7834	1.27	3.	2.3502
Parallel long	0.86394	1.4	3.	2.5918
Parallel short	0.70686	1.4	3.	2.1206

Laboratori Nazionali di Frascati

LNF–10/ 25 (IR)
December 21, 2010

A HIGH-LUMINOSITY $e^+ e^-$ COLLIDER FOR PRECISION EXPERIMENTS AT THE GeV SCALE

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(the total list of authors is reported in the last page of the document)

Abstract

This document, prepared for the European Call FP7-INFRASTRUCTURES-2011-1, describes the proposal for a design study for a high-luminosity ($10^{33}cm^{-2}s^{-1}$) electron-positron (e^+e^-, *in the following*) collider with a variable center of mass energy in the range from about 0.6 GeV to about 3 GeV.

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1. Scientific and/or technical quality, relevant to the topics addressed by the call

1.1 *Concept and objectives*

1.1.1 Leading ideas

We propose a design study for a high-luminosity ($10^{33}cm^{-2}s^{-1}$) electron-positron (e^+e^-, *in the following*) collider with variable center of mass energy in the range from about 0.6 GeV to about 3 GeV. This machine, named DAΦNE-VE will be an ideal tool, unique in Europe, for precision tests of the Standard Model (*SM, in the following*) in lepton-quark interactions at low energies, a region which is still poorly known both from experimental and theoretical point of view.

The high statistics provided by this machine, more than 100 times larger than that collected by any previous collider in this energy range, will allow a precise measurement of the hadronic cross sections, with accuracy up to one order of magnitude better than the existing measurements in the energy region between 1 and 3 GeV. This energy region currently represents the bottleneck for improving the accuracy of the SM prediction of the anomalous magnetic moment (g−2) of the muon, which is one of the very few observables where a significant deviation from the SM is observed. There are plans for new experiments at FNAL and J-PARC to improve the accuracy of the measurement of (g−2) of the muon by a factor of four or even more. While currently the SM prediction and the measured value of (g-2) have comparable accuracies, the planned experiments will require comparable improvements of the theoretical prediction as well. The knowledge of the hadronic cross sections with 1% accuracy will dramatically improve the SM prediction of (g-2), and with it the sensitivity to contributions from physics beyond the SM (BSM, *in the following*). This will help significantly to discriminate between different BSM models in the case that new physics will be found at the Large Hadron Collider (LHC) at CERN.

DAΦNE-VE will have also a strong impact on the determination of the effective fine-structure constant at the scale of the Z boson mass, $\alpha_{em}(M_Z^0)$, which is a key ingredient in the so-called electroweak precision fits of the SM, which provide indirect tests of the SM through higher-order effects, complementary to direct searches at the LHC. For further progress, a reduction of the error of $\alpha_{em}(M_Z^0)$ is mandatory and will be crucial for the physics program at future high-energy lepton colliders like the International Linear Collider.

Therefore, DAΦNE-VE will complement high-energy experiments at the LHC and future linear colliders through its ability to improve the determination of precision observables of the SM, like, e.g., (g-2) of the muon, which are, through quantum effects, sensitive to possible BSM physics at high scales of the order of hundred GeV or TeV.

In addition, an important motivation for DAΦNE-VE is the possibility for extensive studies of two-photon physics processes which would allow precise measurements of the transition form factors of scalar-, pseudoscalar- and axial-mesons (with the potential to improve the hadronic light-by-light scattering contributions to (g-2) of the muon); the spectroscopy of light meson and baryon states; precise tests of the conserved vector current (CVC) hypothesis which relates e^+e^- annihilation into isovector hadronic states with corresponding hadronic decays of the τ lepton; and searches for exotics or hypothetical light vector bosons weakly coupled to SM particles.

On the technological side the scope of the proposal is to make sure that Europe remains at the frontier of electron-positron collider and detector development for this energy range. The Frascati laboratory (Rome, Italy) had a leading role in the development of electron - positron Colliders, which started with ADA, a storage ring built in Frascati in 1960 where e^+e^- collisions have been proved to be feasible for the first time. ADA paved the way to a more ambitious project for a collider, named ADONE, working at a center of mass energy of ~3 GeV and providing a luminosity ~$3 \cdot 10^{29}$ $cm^{-2}s^{-1}$. ADONE has been in operation until 1993, and five years later the new accelerator complex DAΦNE was ready for commissioning.

Some facts

Any realistic plan cannot ignore some contextual boundary conditions

It's seems unlikely that the LNF will be able to significantly increase its manpower and budget in the near future

Concerning DAΦNE a not negligible effort has been done to implement a preliminary renovation program.

A huge investment has been done to upgrade the KLOE detector and the KLOE-2 collaboration has a robust scientific plan

The success of the KLOE-2 run should be of general interest for the collider community

Some facts

DAΦNE has proved to be quite productive for nuclear physics experiments, the SIDDHARTA a collaboration is asking since long time to install its new apparatus

Nuclear physics experiments can be very much synergic with the KLOE apparatus as it has been proved by the KLOE-AMADEUS short data taking

Last but not least the DAΦNE feature and complexity make it attractive as machine test facility also.

Thank you for your attention