Dafne Collaboration Team

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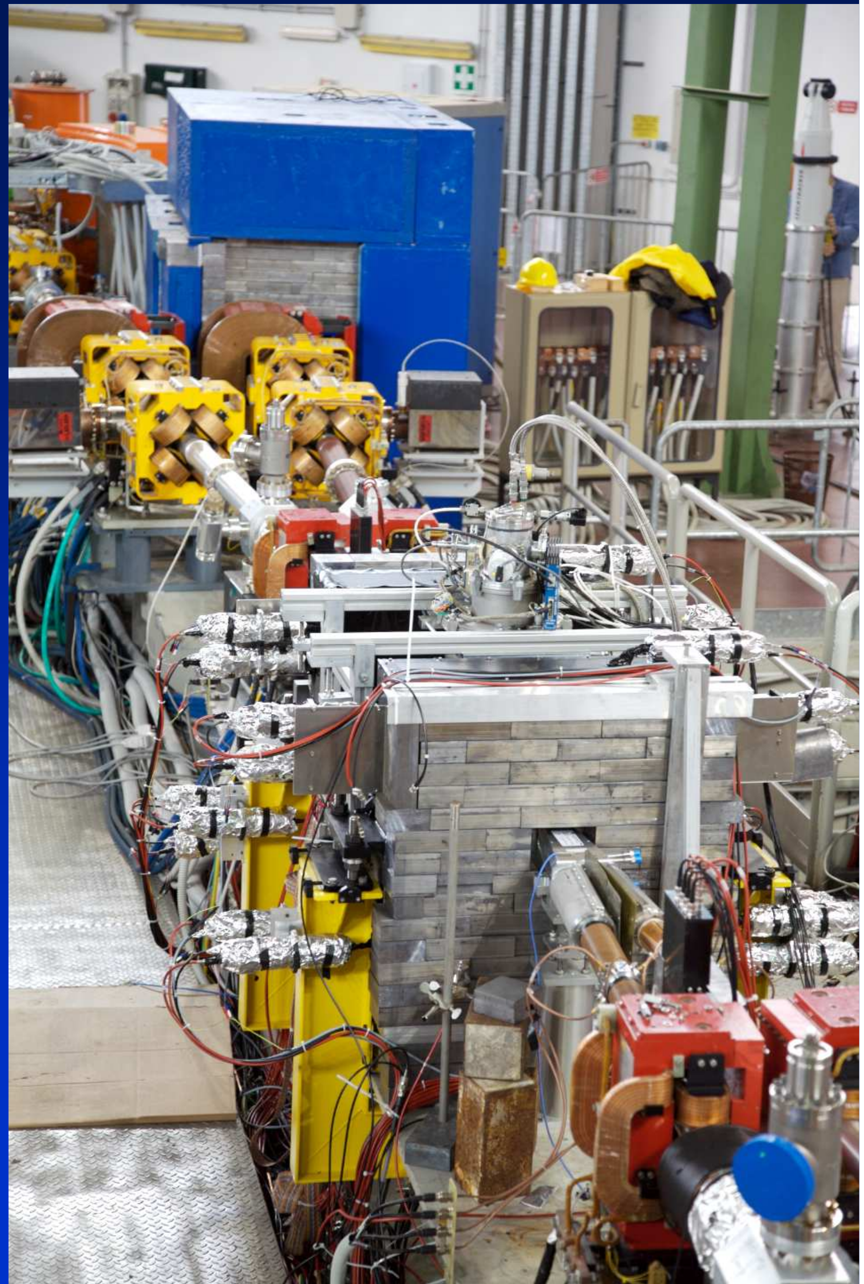
Results of the DAFNE Upgrade

P. Raimondi for DAΦNE Team



Perugia June-16,2009

OUTLINE

- Dafne Upgrade:
  - Hardware
  - Commissioning
  - Results and Perspectives
- Conclusions

A new idea for collisions

Thigher focus on beams at IP and a “large” crossing angle (large Piwinski angle) + use a couple of sextupoles/ring to “twist” the beam waist at the IP

- Ultra-low emittance
- Very small β^* at IP
- Large crossing angle
- “Crab Waist” transformation

- Small collision area
- Lower β^* is possible
- NO parasitic crossings
- NO x-y-betatron resonances

1. ***P.Raimondi, 2°SuperB Workshop, March 2006***
2. ***P.Raimondi, D.Shatilov, M.Zobov, physics/0702033***

Good Opportunity to prove and use the LPA & CW in Dafne

for Physics Programs

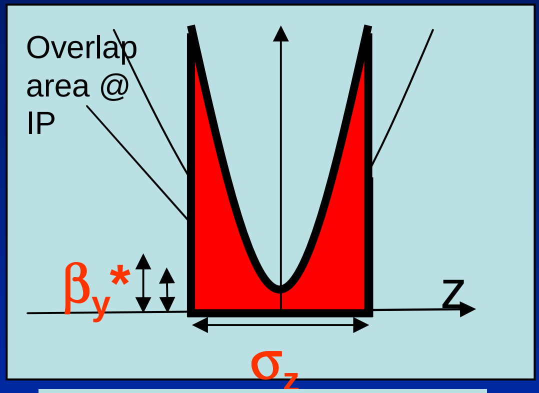
1. Fits DAΦNE schedule (shut down for SIDDHARTA installation in mid 2007)
2. Satisfies new physics programs (SIDDHARTA, KLOE2, FINUDA...)
3. Requires moderate modifications
4. Relatively low cost (1 mln Euro)

for Beam Dynamics

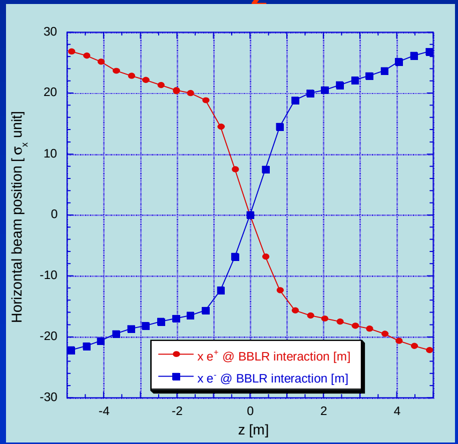
1. No detector solenoidal field
2. No splitter magnets
3. No compensating solenoids
4. No parasitic crossings
5. Lower beam impedance (simple IR, new bellows, new injection kickers)

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:

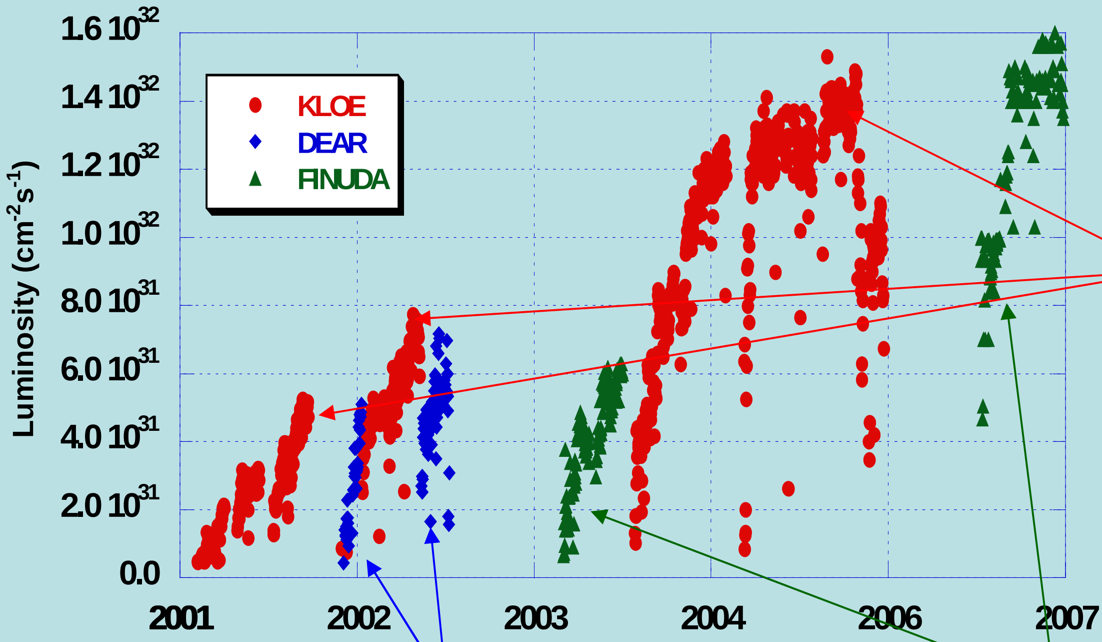


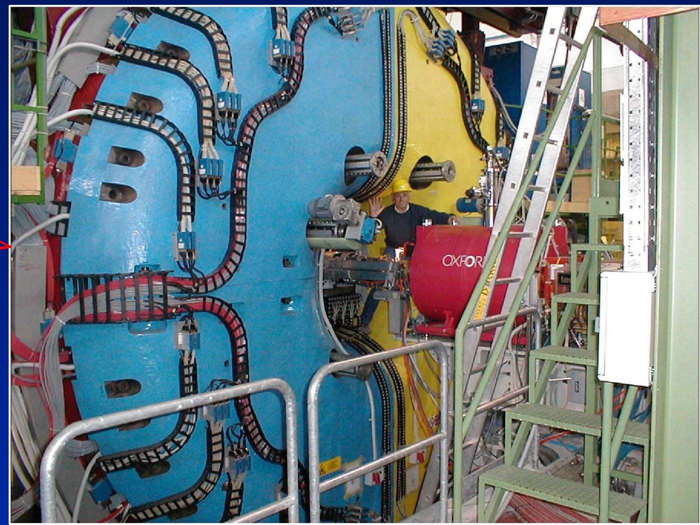
- $\beta^*_y \sim \sigma_z$ to avoid hourglass effect
- Long-range beam-beam interactions causing τ^+ τ^- reduction limiting I^+_{MAX} I^-_{MAX} and consequently L_{peak} and $L_\int$
- Transverse size enlargements due to the beam-beam interaction

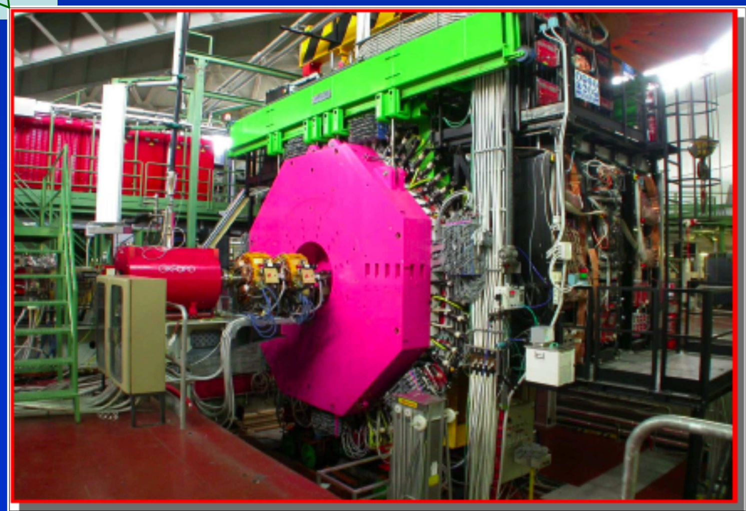


A new conceptual approach was necessary to reach L~10^{33}
Collision scheme based on **Large Piwinski** angle and **Crab-Waist**

DAΦNE Peak Luminosity

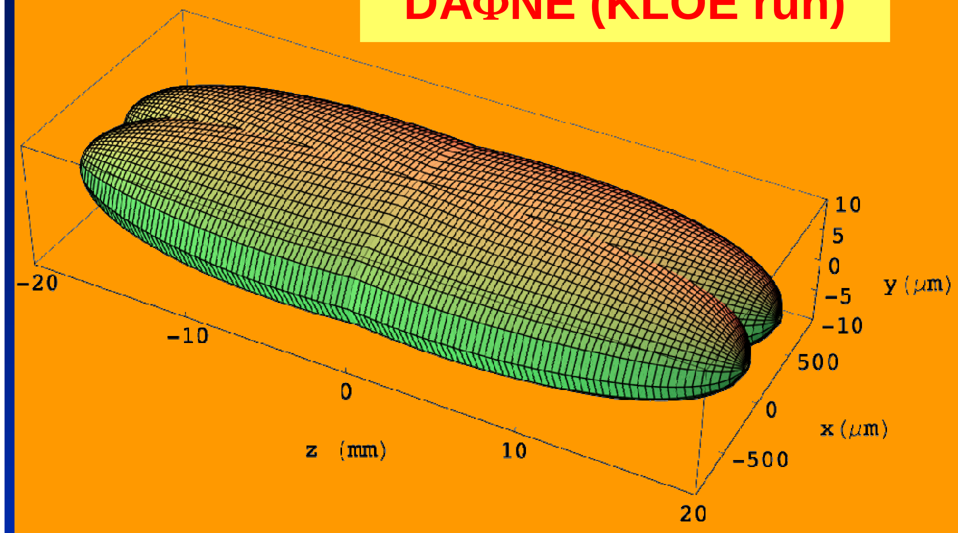




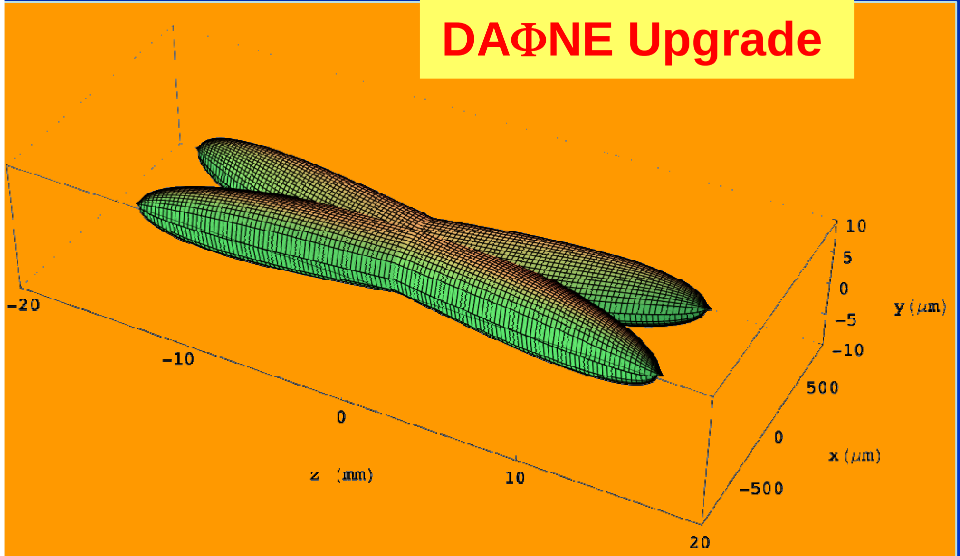


BEAM PROFILES @IP AND NEW PARAMETERS

DAΦNE (KLOE run)



DAΦNE Upgrade



	DAΦNE (KLOE run)	DAΦNE Upgrade
I_{bunch} (mA)	13	13
N_{bunch}	110	110
β_y^* (cm)	1.8	0.85
β_x^* (cm)	160	26
σ_y^* (μm)	5.4 low curr	3.1
σ_x^* (μm)	700	260
σ_z (mm)	25	20
Horizontal tune shift	0.04	0.008
Vertical tune shift	0.04	0.055
θ_{cross} (mrad) (half)	12.5	25
$\Phi_{Piwinski}$	0.45	2.0
L ($cm^{-2}s^{-1}$)	1.5×10^{32}	$>5\times10^{32}$

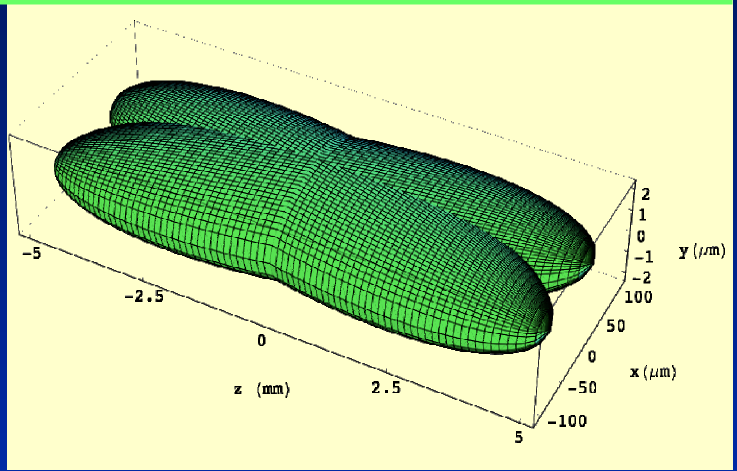
3 times more luminosity obtained just with 3 times smaller vertical beam

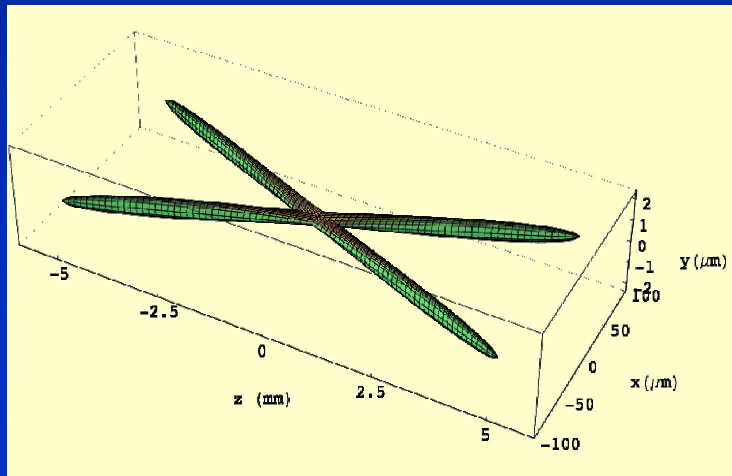
Comparison of SuperB to Super-KEKB

Parameter	Units	*SuperB*	Super-KEKB
Energy	GeV	4x7	3.5x8
Luminosity	10^{36}/ cm^2/s	1.0 to 2.0	0.5 to 0.8
Beam currents	A	1.9x1.9	9.4x4.1
β_y*	mm	0.22	3.
β_x*	cm	3.5x2.0	20.
Crossing angle (full)	mrad	48.	30. to 0.
RF power (AC line)	MW	20 to 25	80 to 90
Tune shifts	(x/y)	0.0004/0.2	0.27/0.3

100 times more luminosity obtained just with 100 times smaller vertical beam

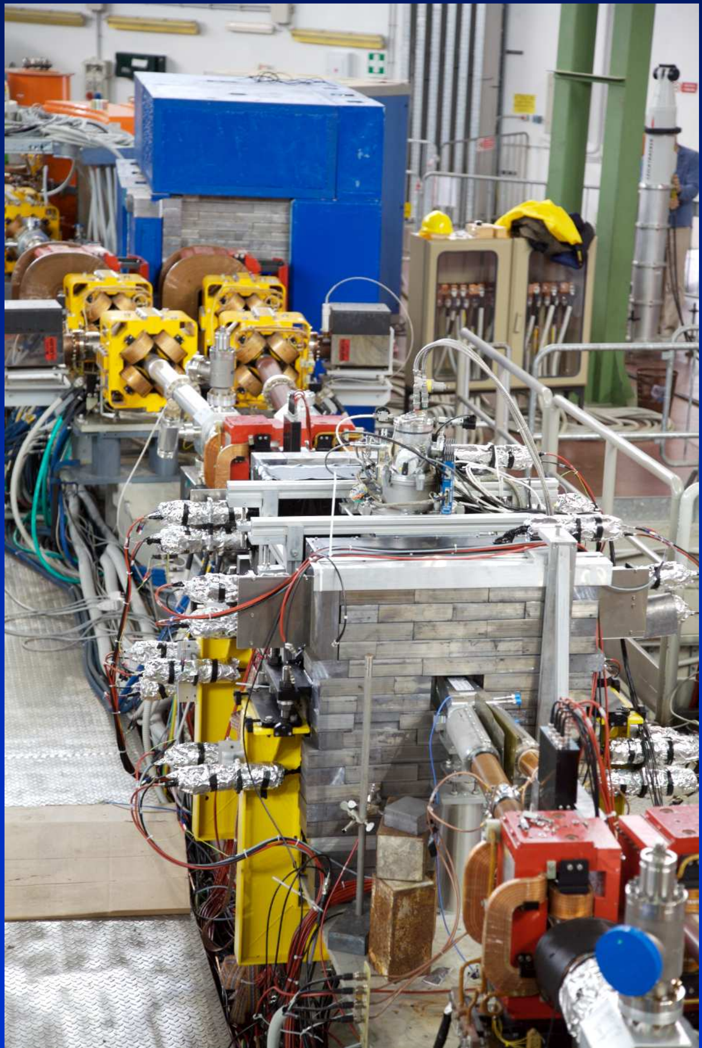
IP beam distributions for KEKB

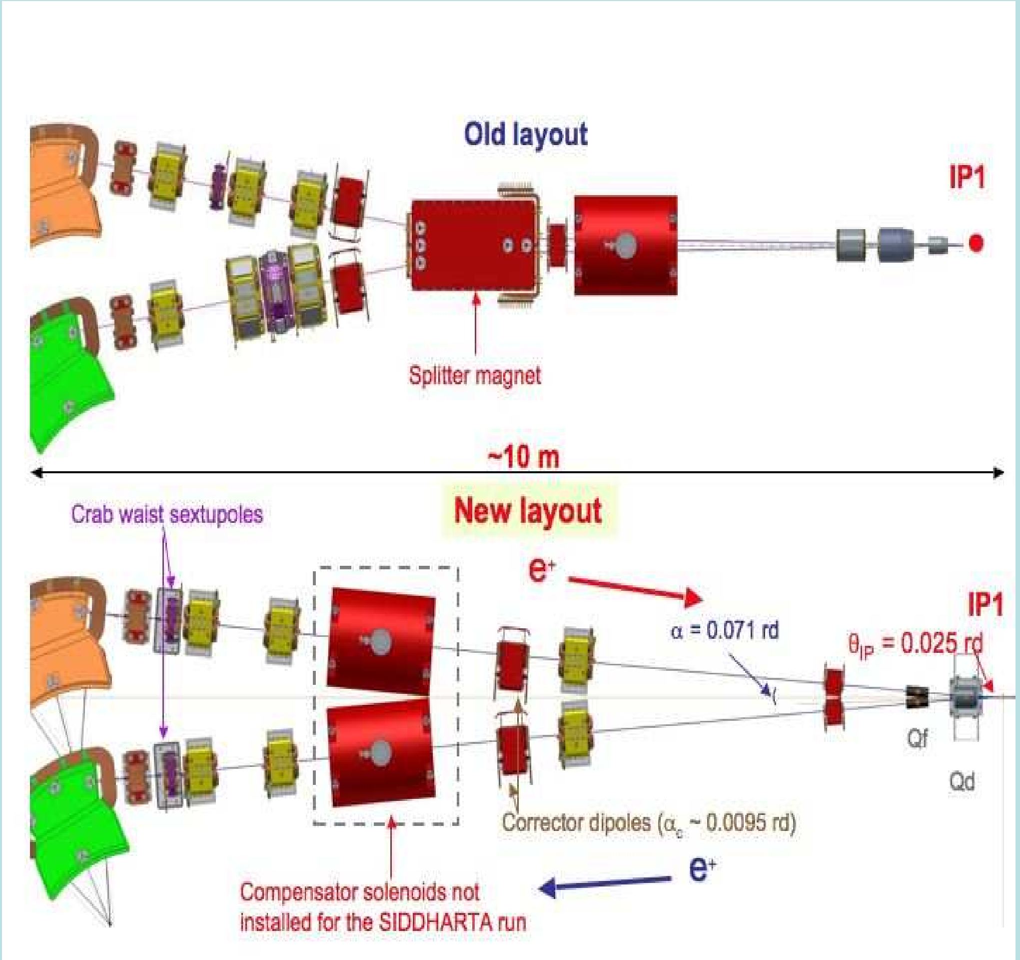


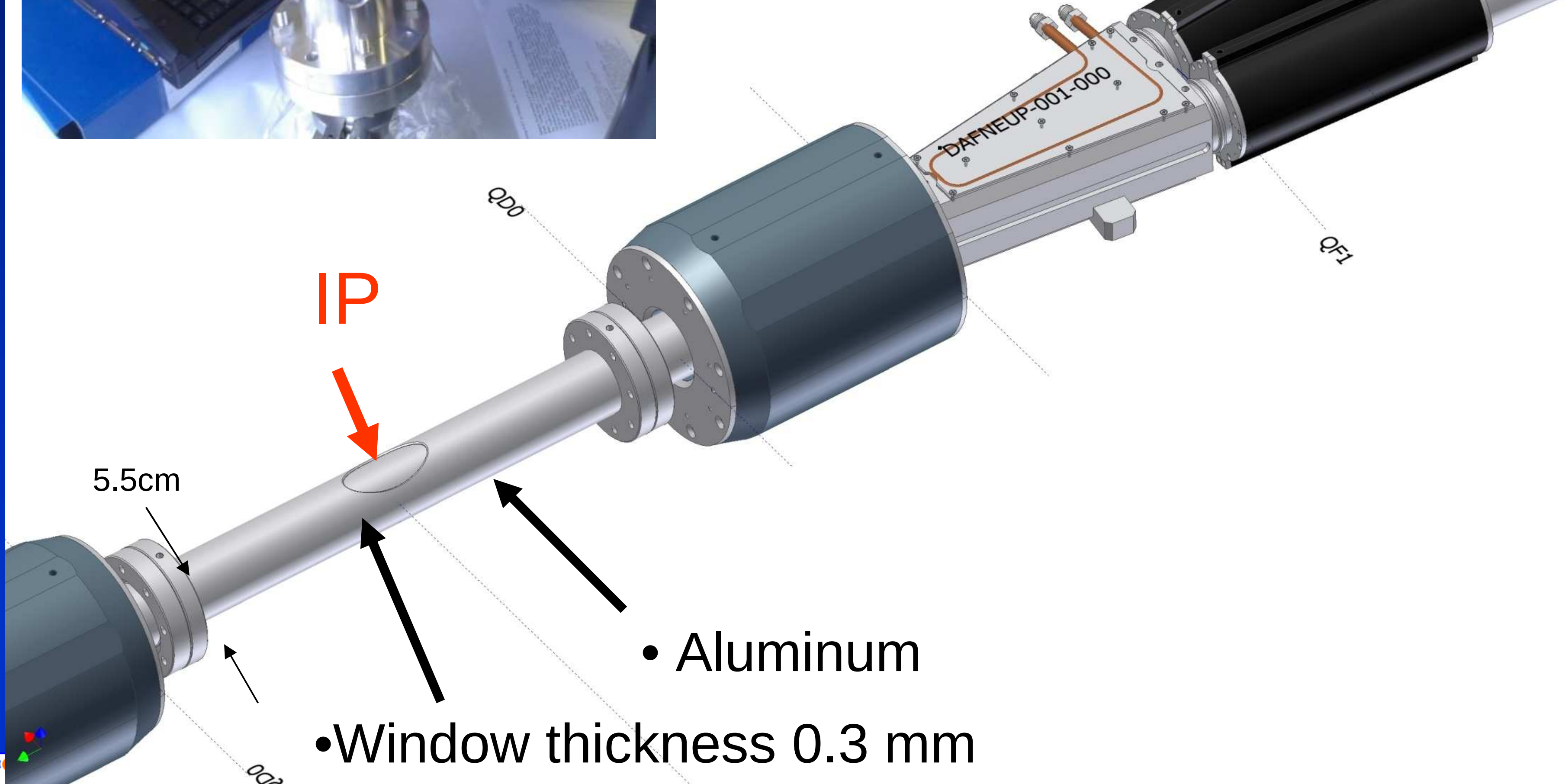


IP beam distributions for *SuperB*

New Experimental Interaction Region






DAFNEUP-001-000
QD0
QF1
IP
5.5cm
• Aluminum
•Window thickness 0.3 mm
QD0

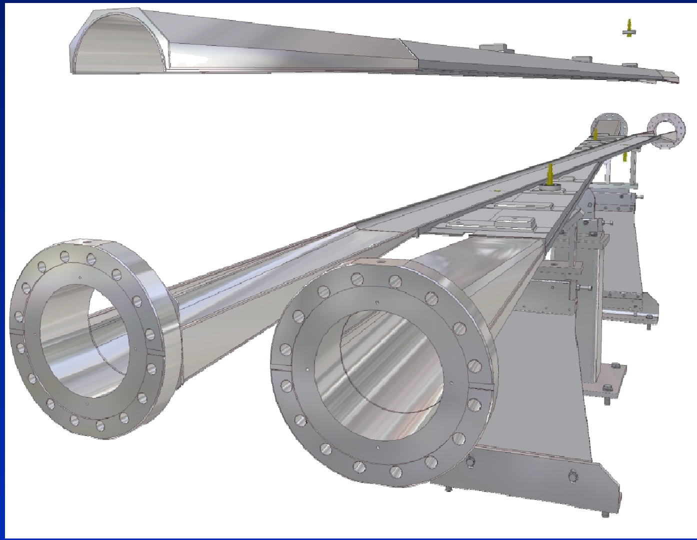
High current operation

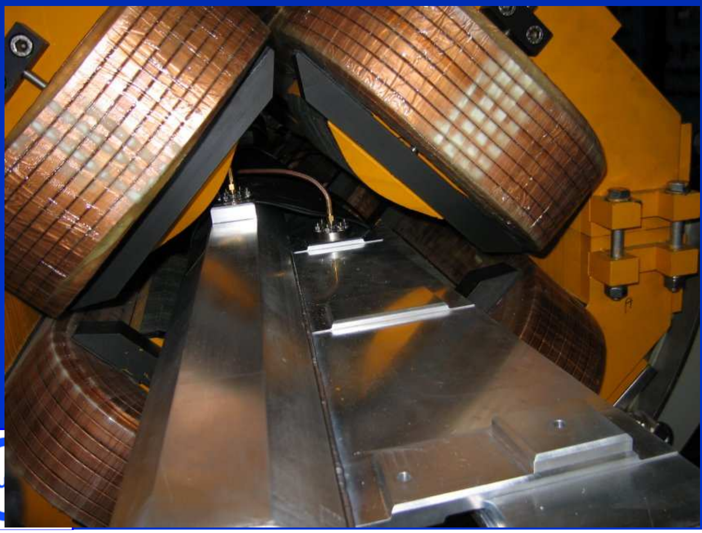
- Three main hardware upgrades have been implemented to improve the stored current:

- Fast kickers
- Feedback upgrade
- Lower impedance vacuum chamber
- Solenoid Windings

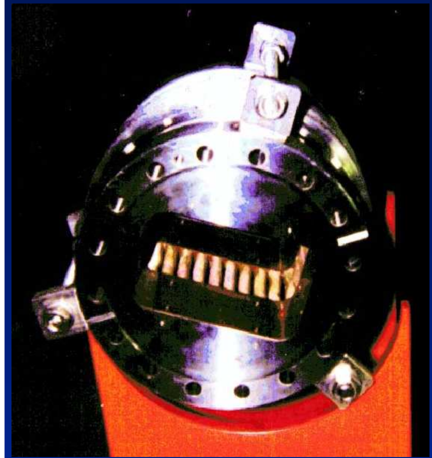
SECOND CROSSING REGION LAYOUT

- Second crossing region ***symmetric*** with respect to first one (Possibility to use it as an alternative interaction point)
- “Half Moon” chamber allows complete beam separation (no 2nd IP)

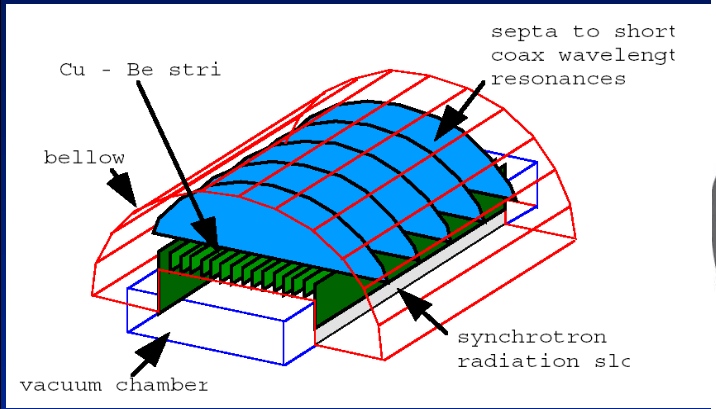


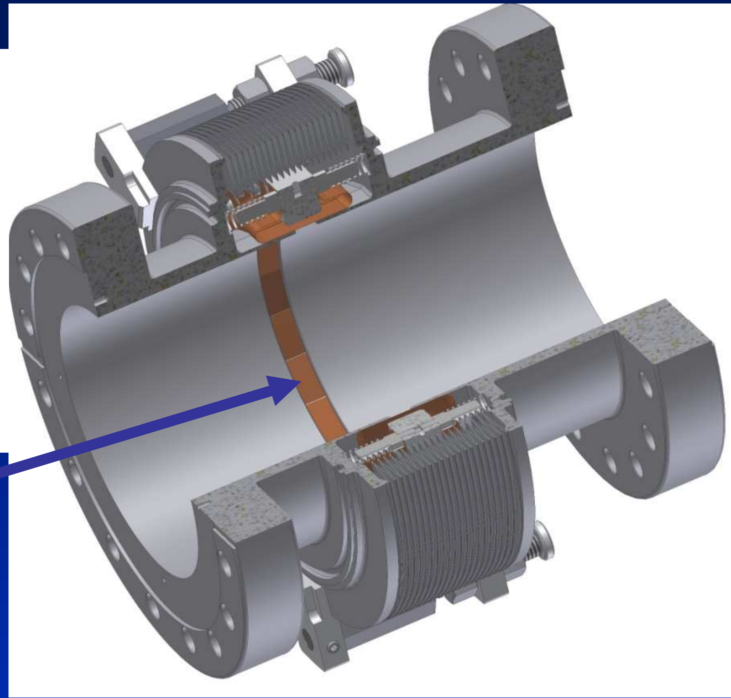


NEW BELLOWS

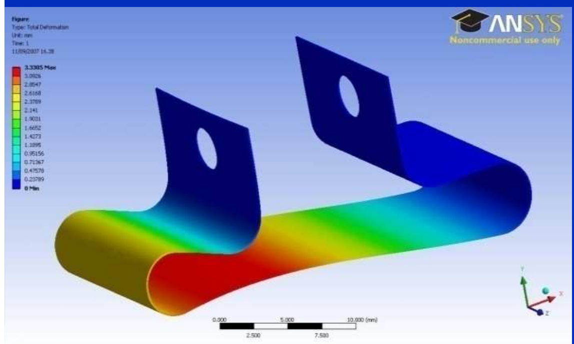


OLD BELLOW



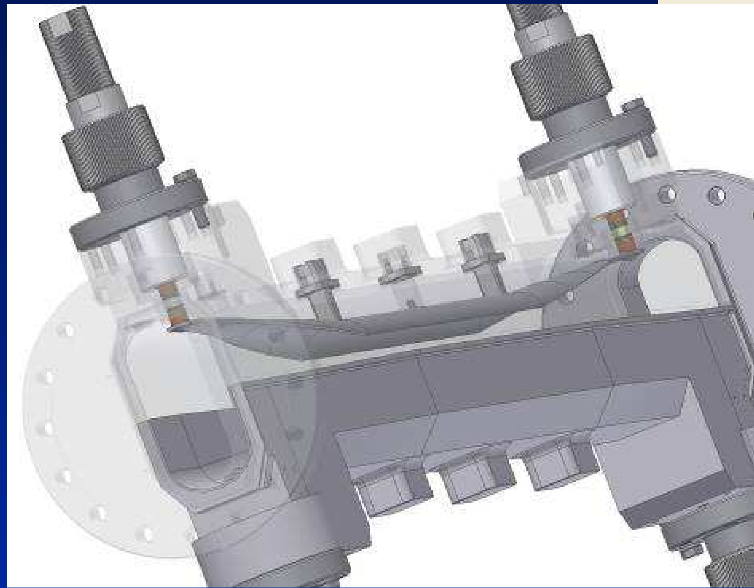


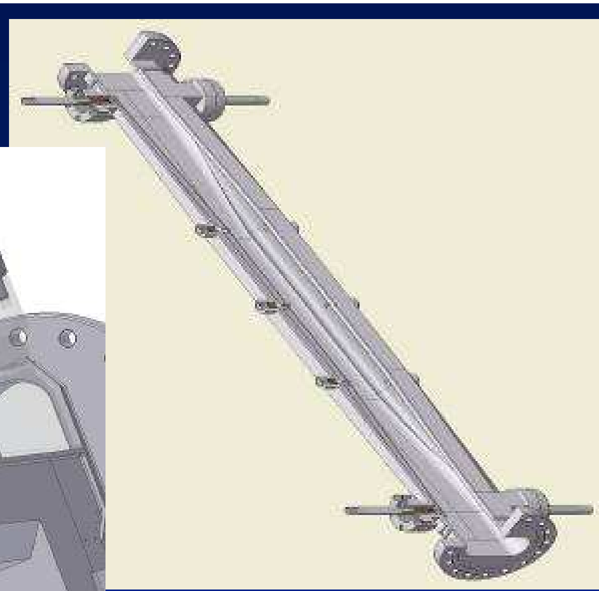
- 6 new bellows for each ring
- Shielding based on Be-Cu W strips 0.2 mm thick
- lower impedance and better mechanical performance

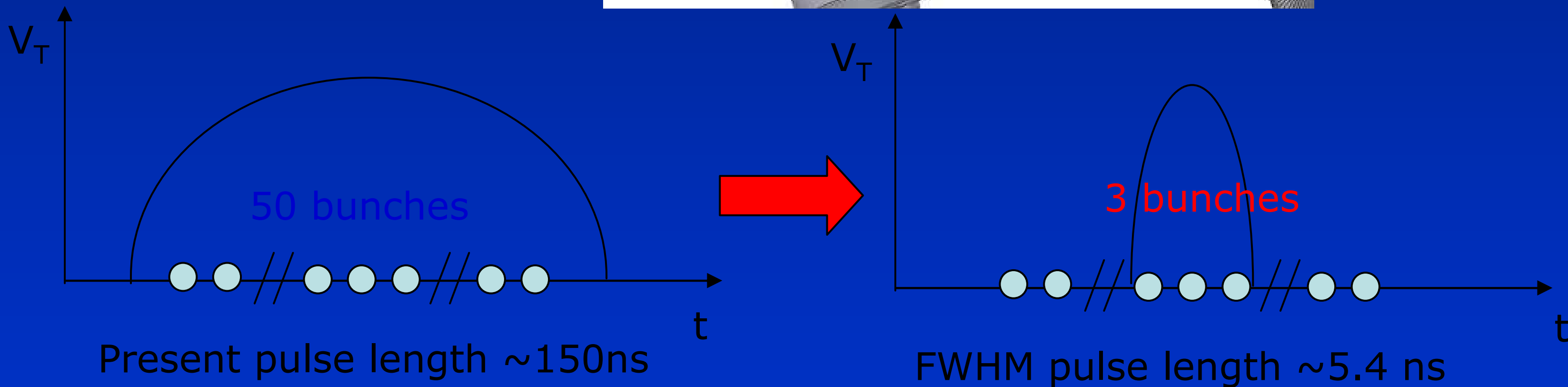


New Fast Injection Kickers

New injection kickers with 5.4 ns pulse length to reduce perturbation on stored beam





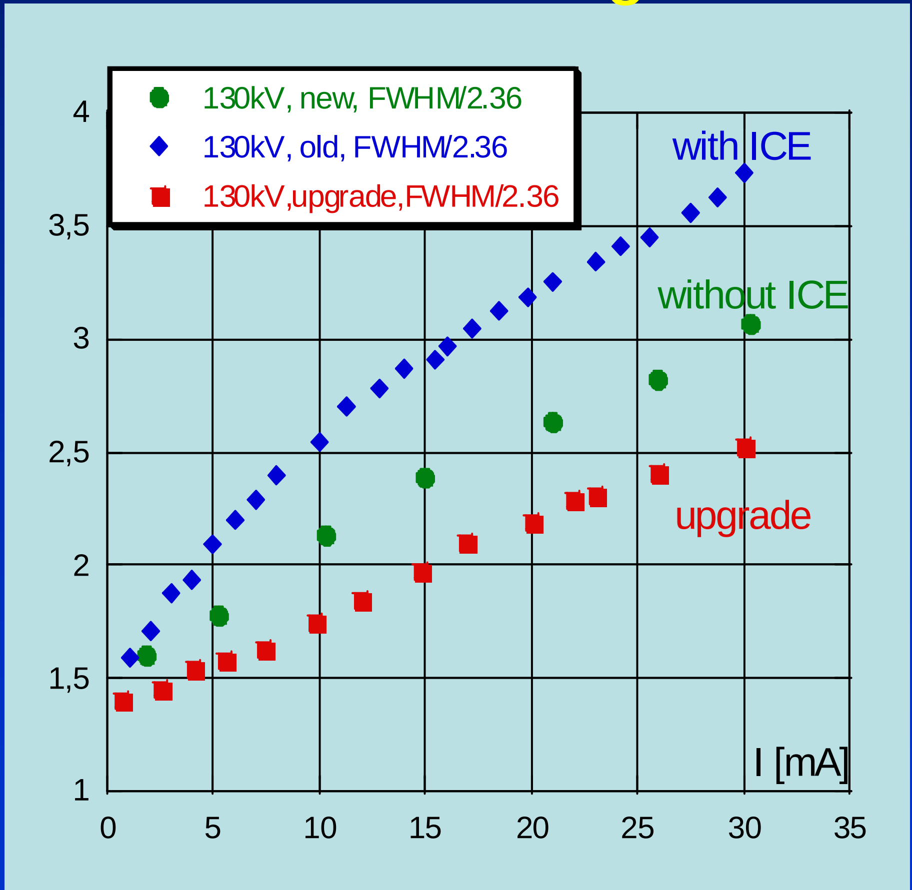


Expected benefits:

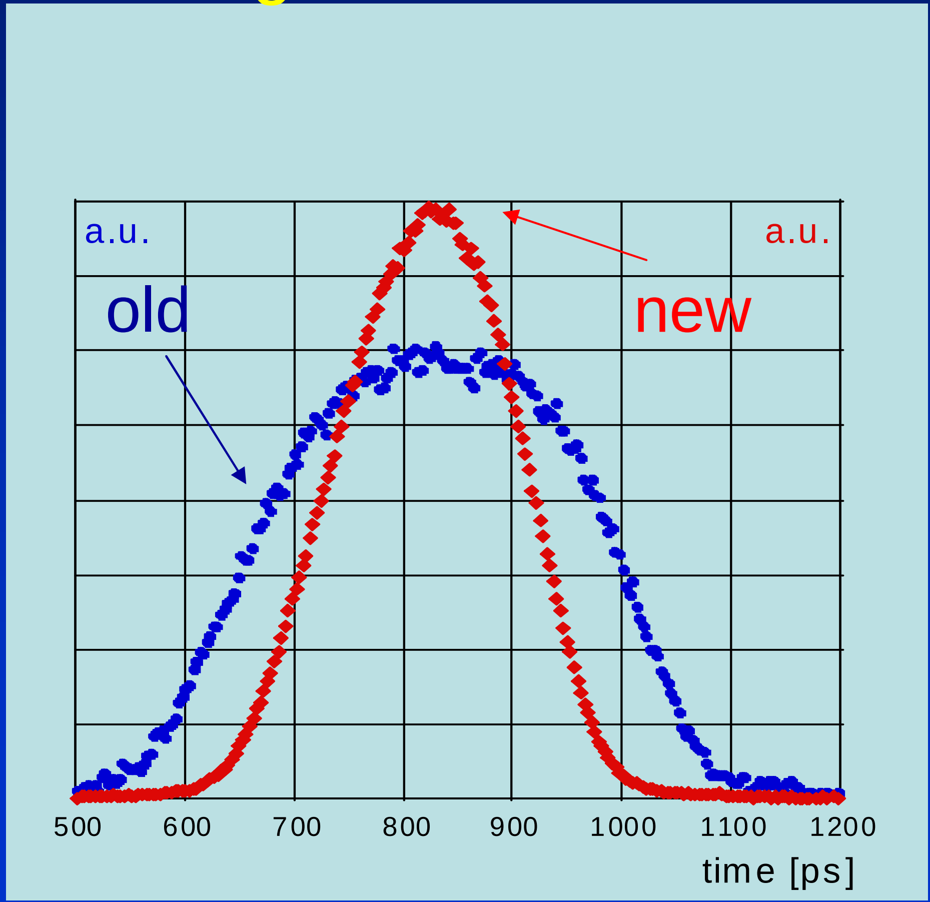
- **higher maximum stored currents**
- **Improved stability of colliding beams during injection**
- **less background allowing data acquisition during injection**

Bunch Lengthening in Upgraded Vacuum Chamber

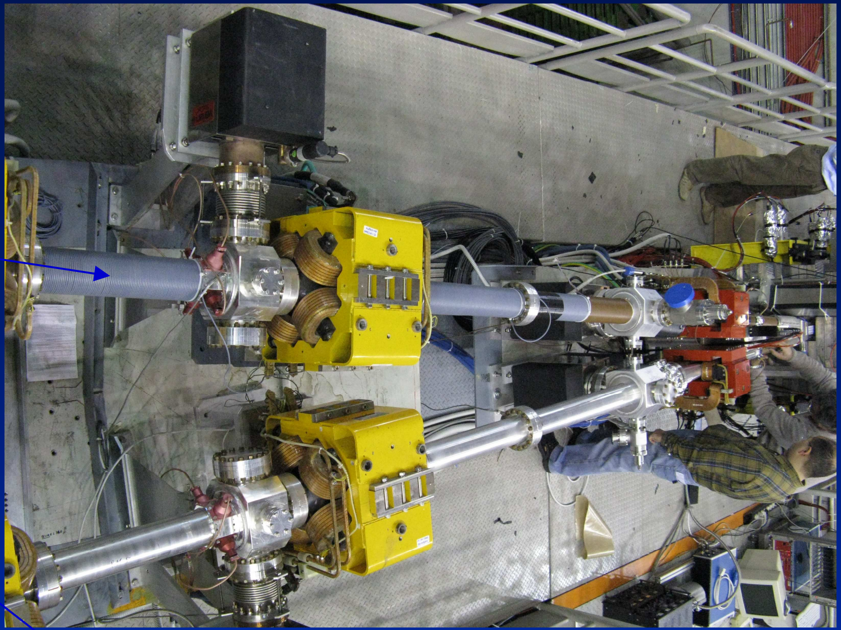
Bunch Length

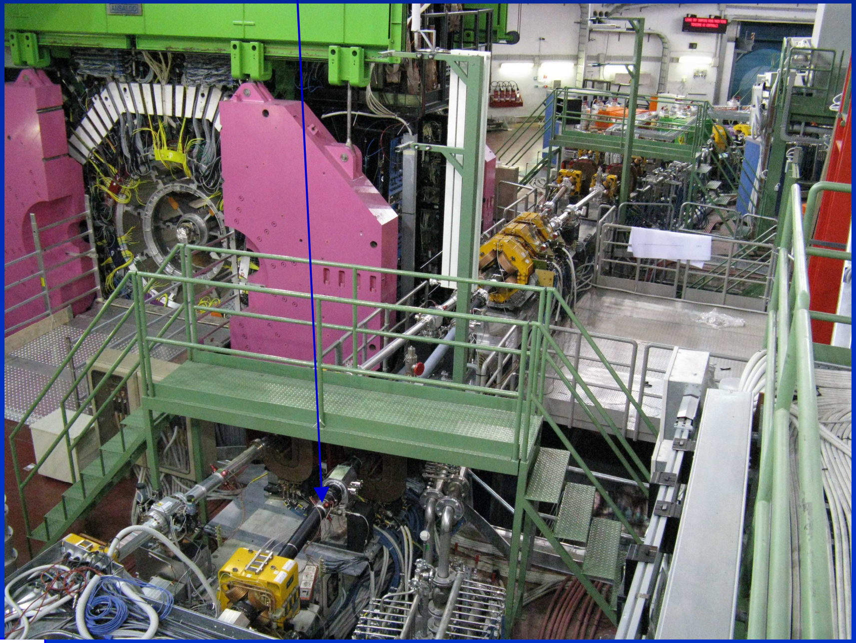


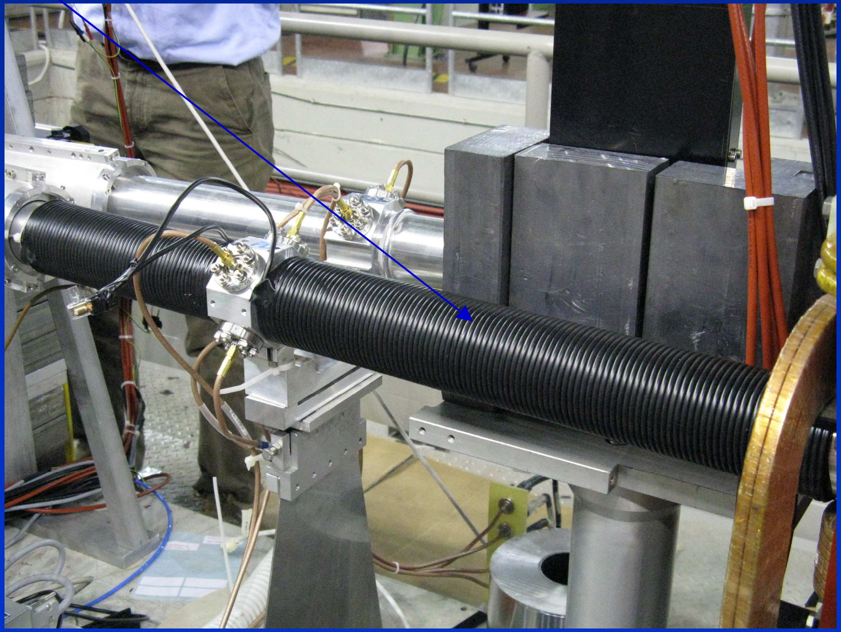
Charge Distribution



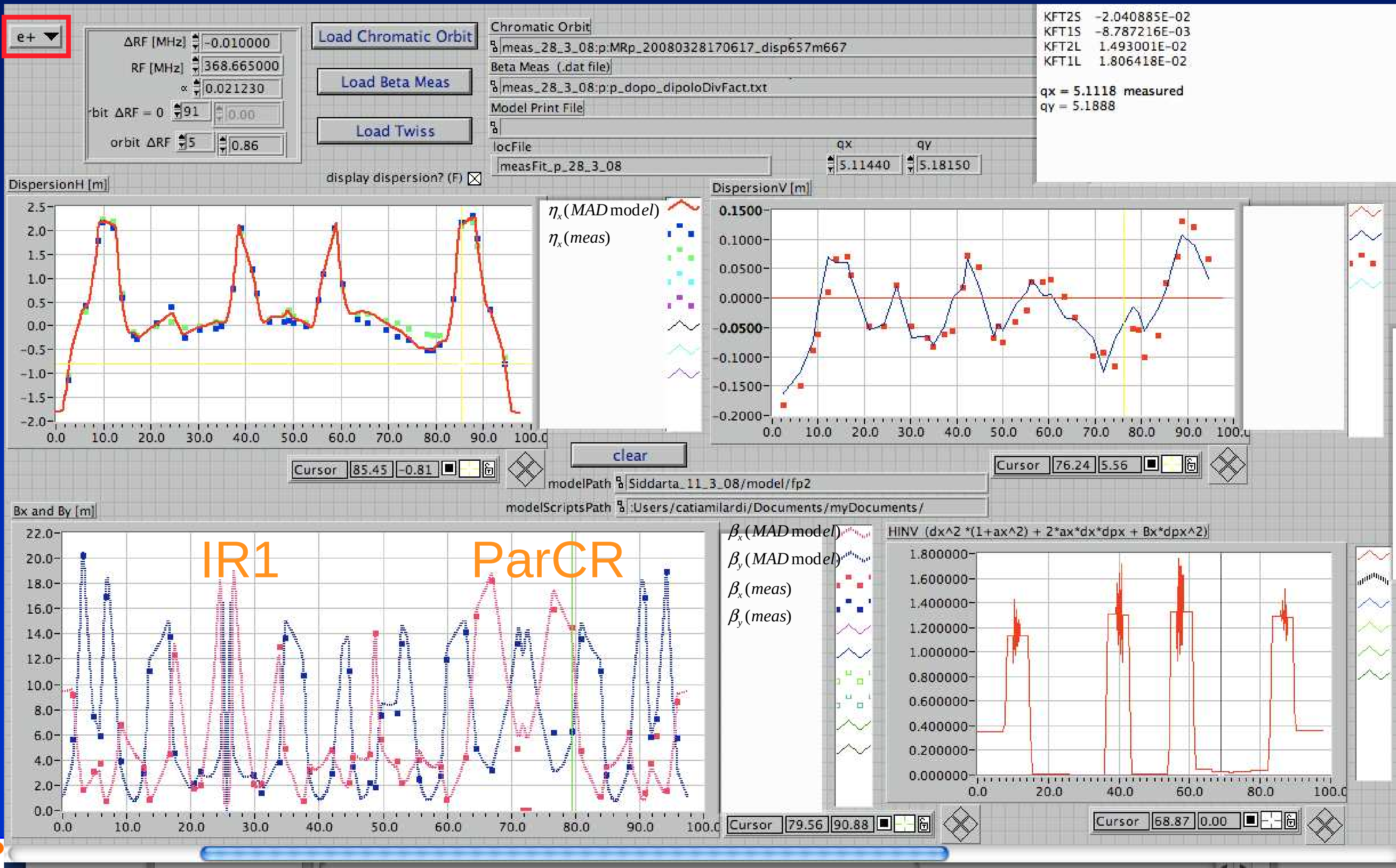
Solenoids







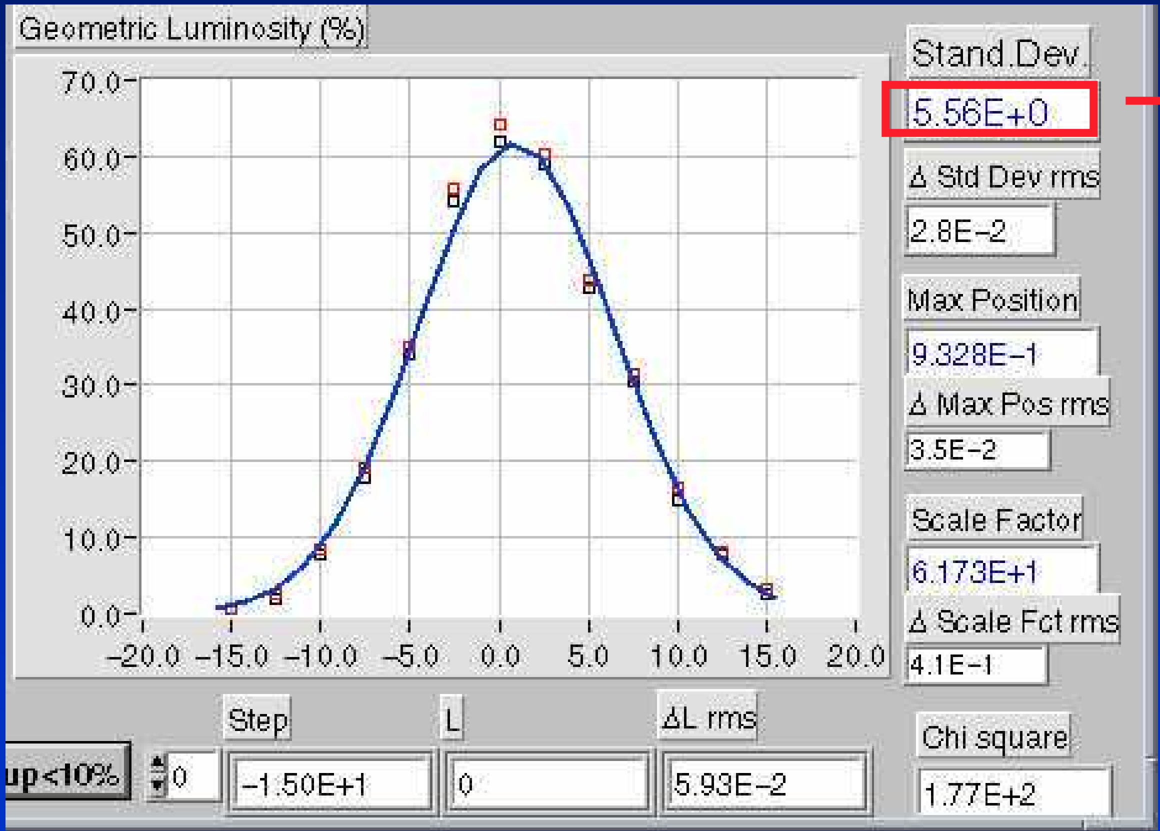
Present SIDDHARTA Optics



Vertical beam-beam Luminosity scan

$$\Sigma_y = \sqrt{\sigma_{yp}^2 + \sigma_{ye}^2}$$

$$\Sigma_y = \Sigma_y^{meas} * 0.88$$



$$\sigma_y \approx 3.5\mu m$$

Design is 3.1μm

July 2008

LPA & CW Optics Commissioning

- Lot of work done to match the optic (main problems from IP-Permanent Magnets out of specs w.r.t. gradient)
- Well established the proper CW optics requirements Sext=>IP=>AntiSext
- Well define sextupoles aligned procedure in single beam mode:

  - turn on one sext at the time, measure the tune shift and move the orbit:

    1) horizontally until no tune shift is observed

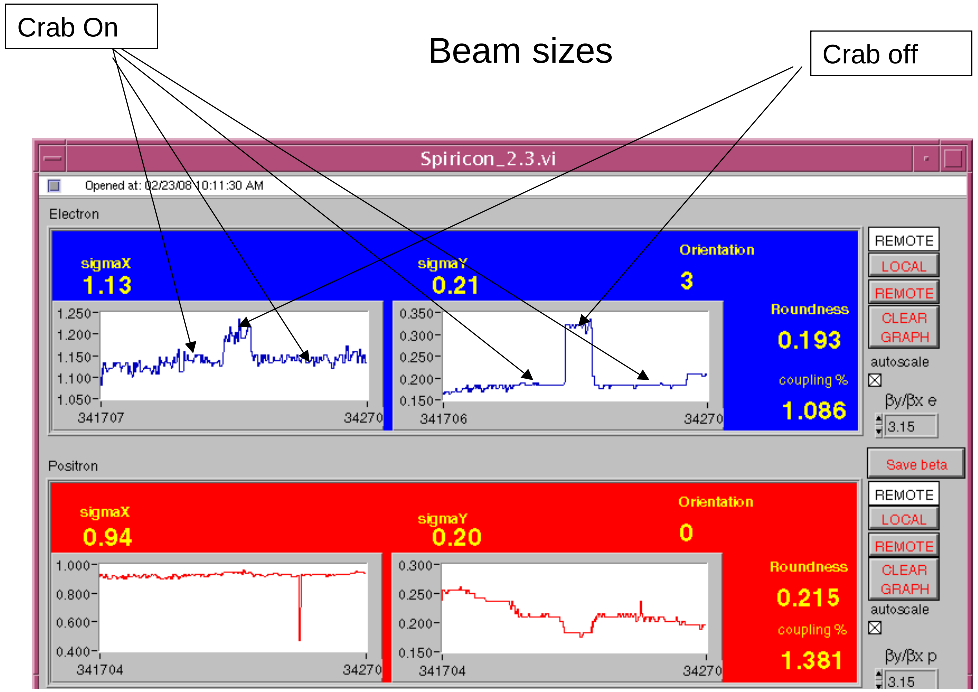
    2) vertical until no coupling change is observed on our Synchrotron Light Monitor

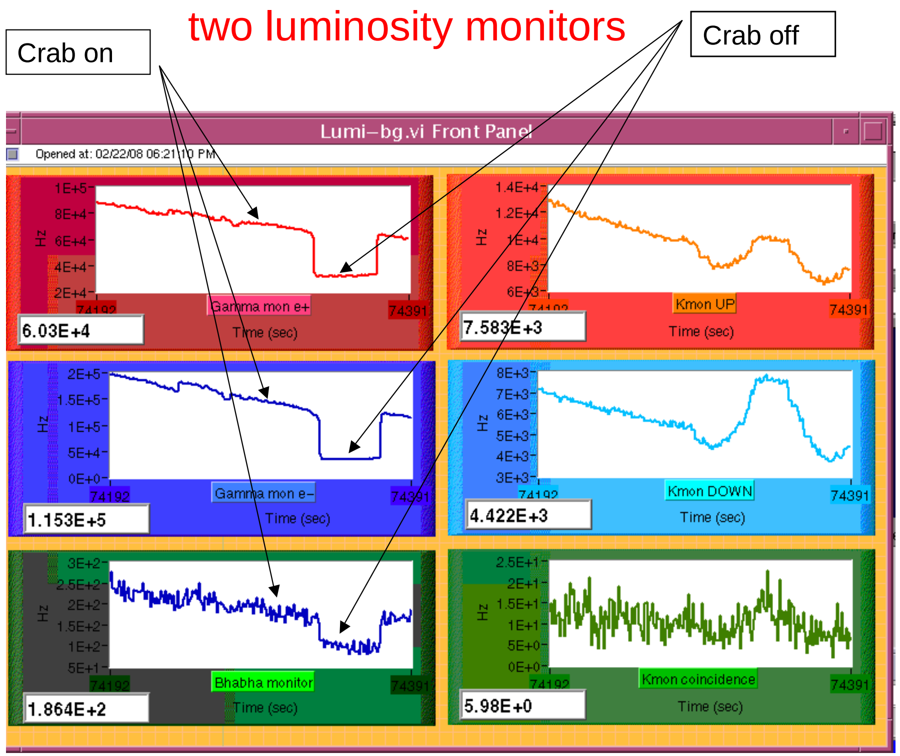
  - Verified that turning on both sextupoles there are no effects on:

    - Tunes
    - Coupling
    - Lifetime
    - Background

Finally we did turn on the sextupoles in collision for the first time…

Crab Waist Works: First Experimental Evidence





Crab Sextupoles on all the time since the first time we tested them

Present Performances

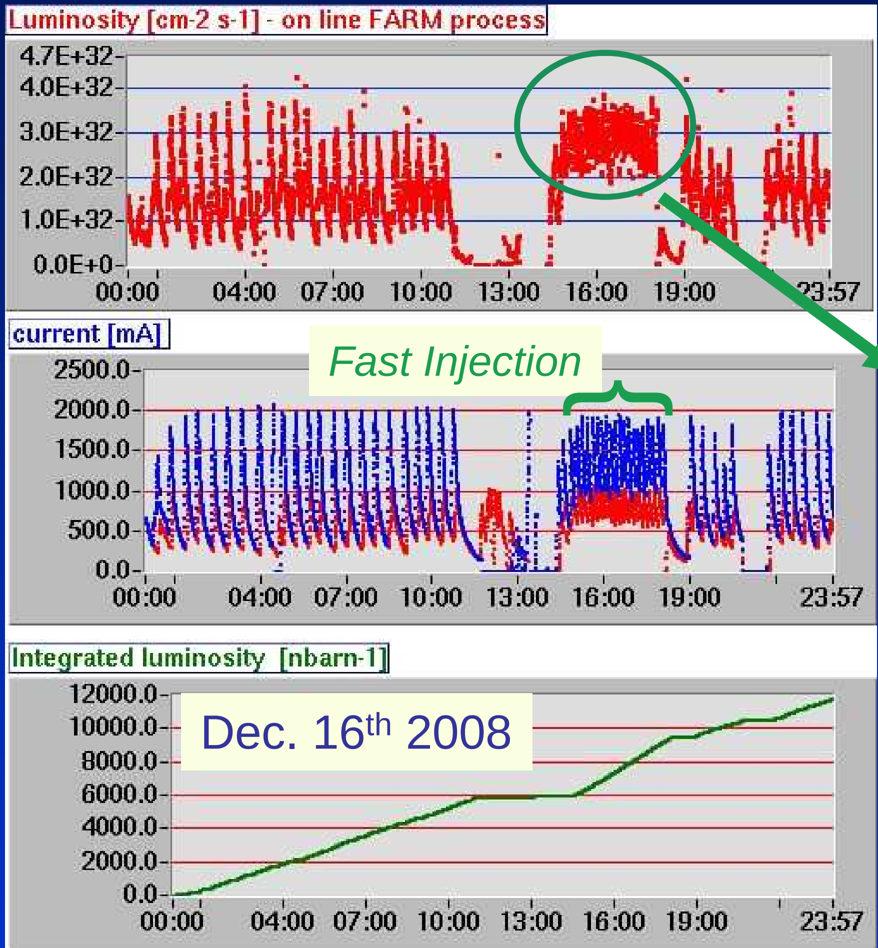
- Peak Luminosity: 4.53e32 (1.52e32) obtained with 1.40 (1.55) Amps e- vs 1.1 (1.25) Amps e+ 105 (110) Bunches
- Peak Hourly rate 1.023 (0.44) pb-1/hour
- Peak Daily rate 15.0 (9.83) pb-1 with long coasting (Long coasting needed for Siddharta, not for Kloe or Finuda)

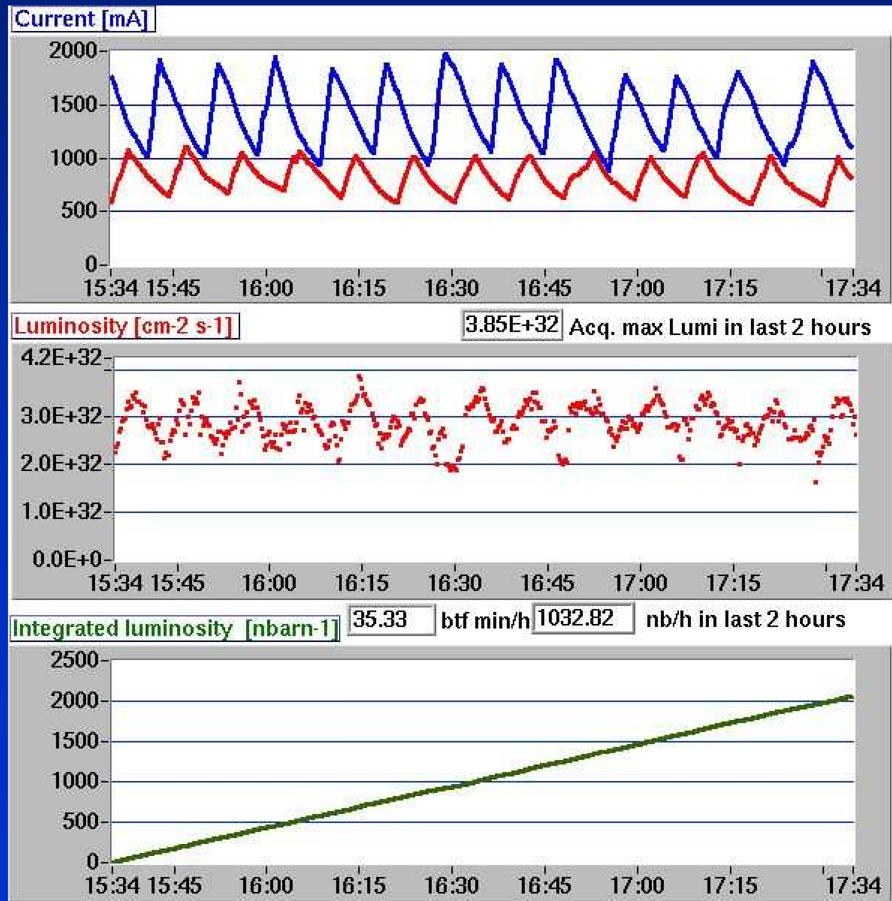
Red are the Kloe records before the upgrade

Best hourly integrated luminosity

$L_{\int 1\ hour} = 1.033\ pb^{-1}$

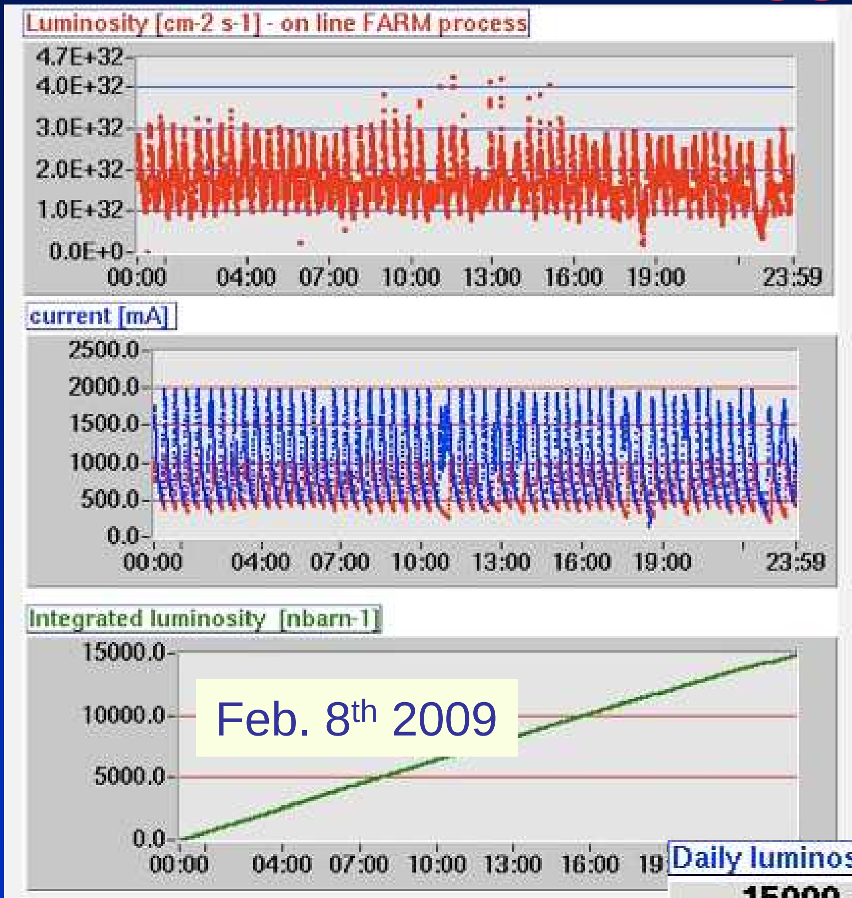
- *High rate injection regime*
- *105 colliding bunches*
- *Very **useful for a future KLOE run***





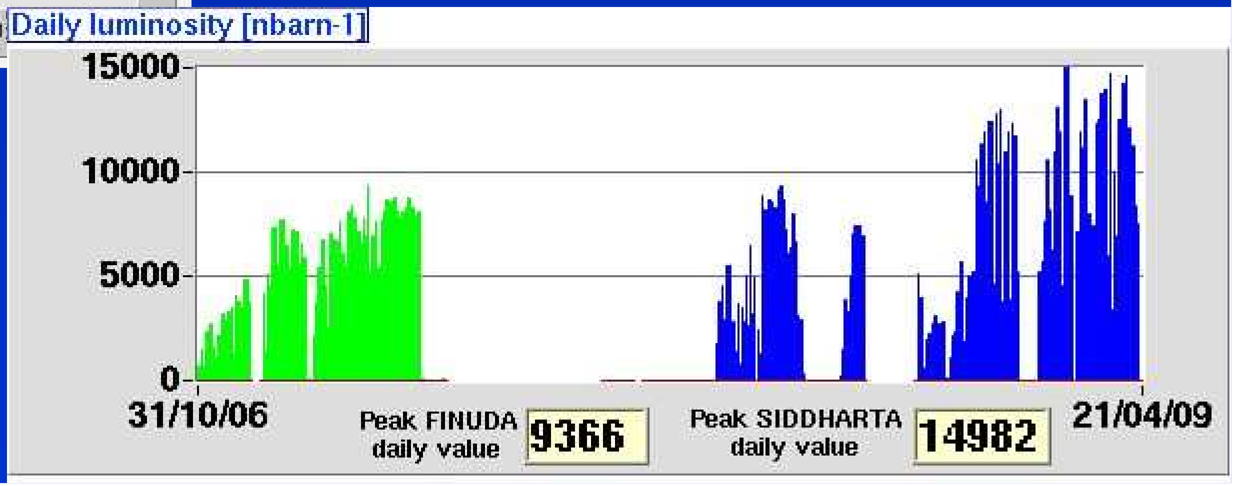
Fast injection is not compatible with the SIDDHARTA operations!

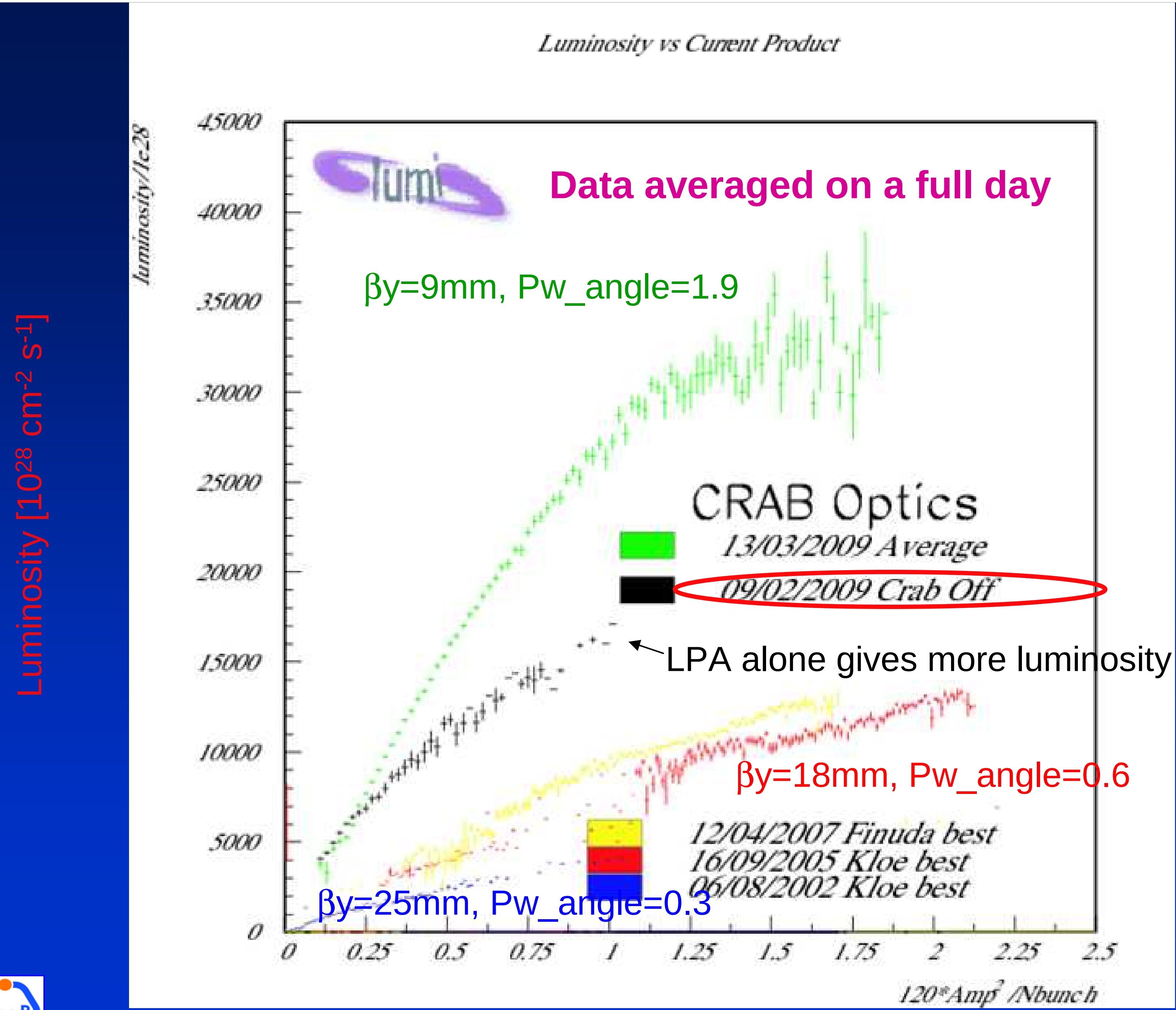
Best daily integrated luminosity



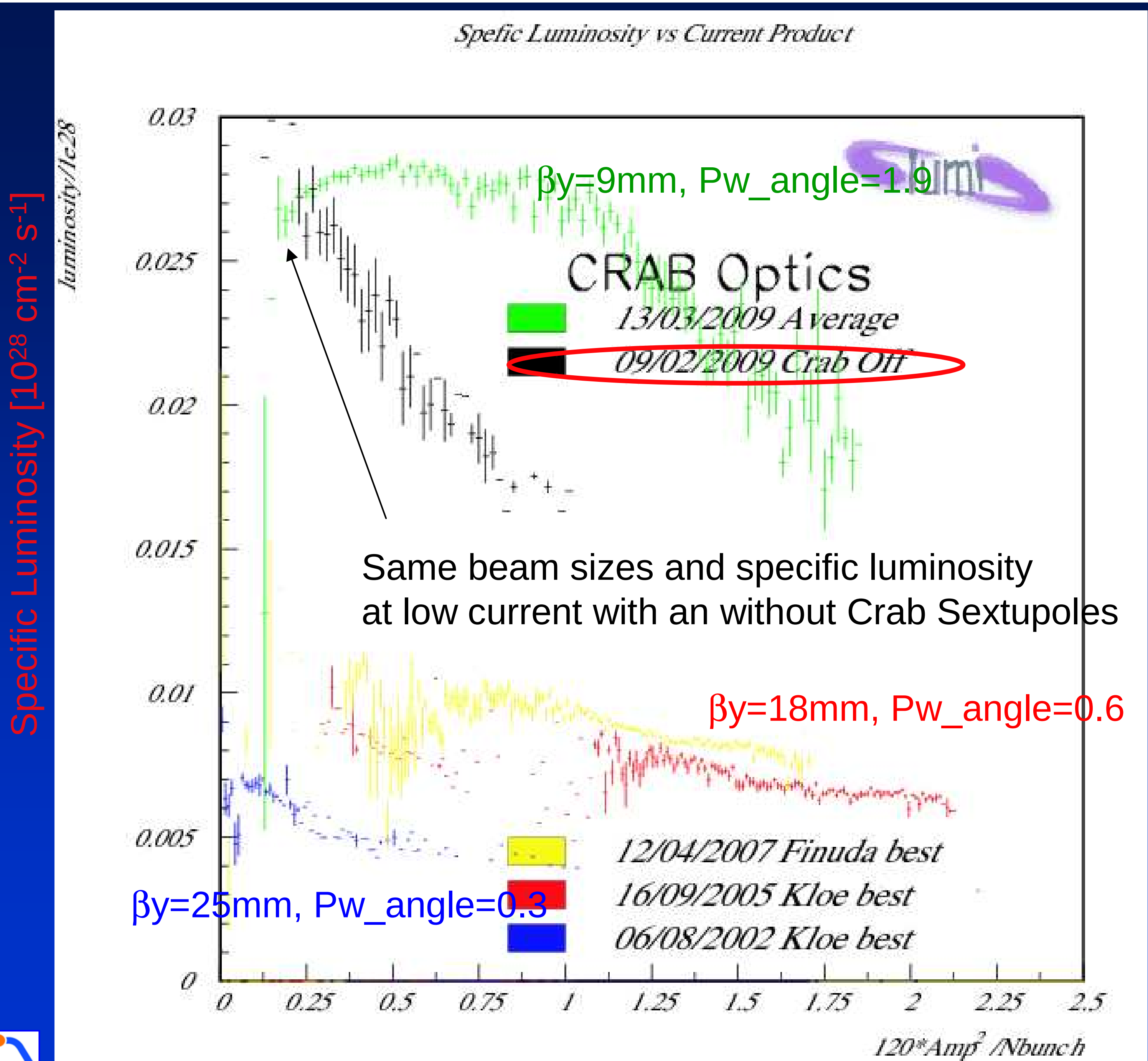
$L_{\int day} = 15.\ pb^{-1}$

- *Long Coasting Regime*
- *105 colliding bunches*
- $L_{\int hour} = 0.62\ pb^{-1}$

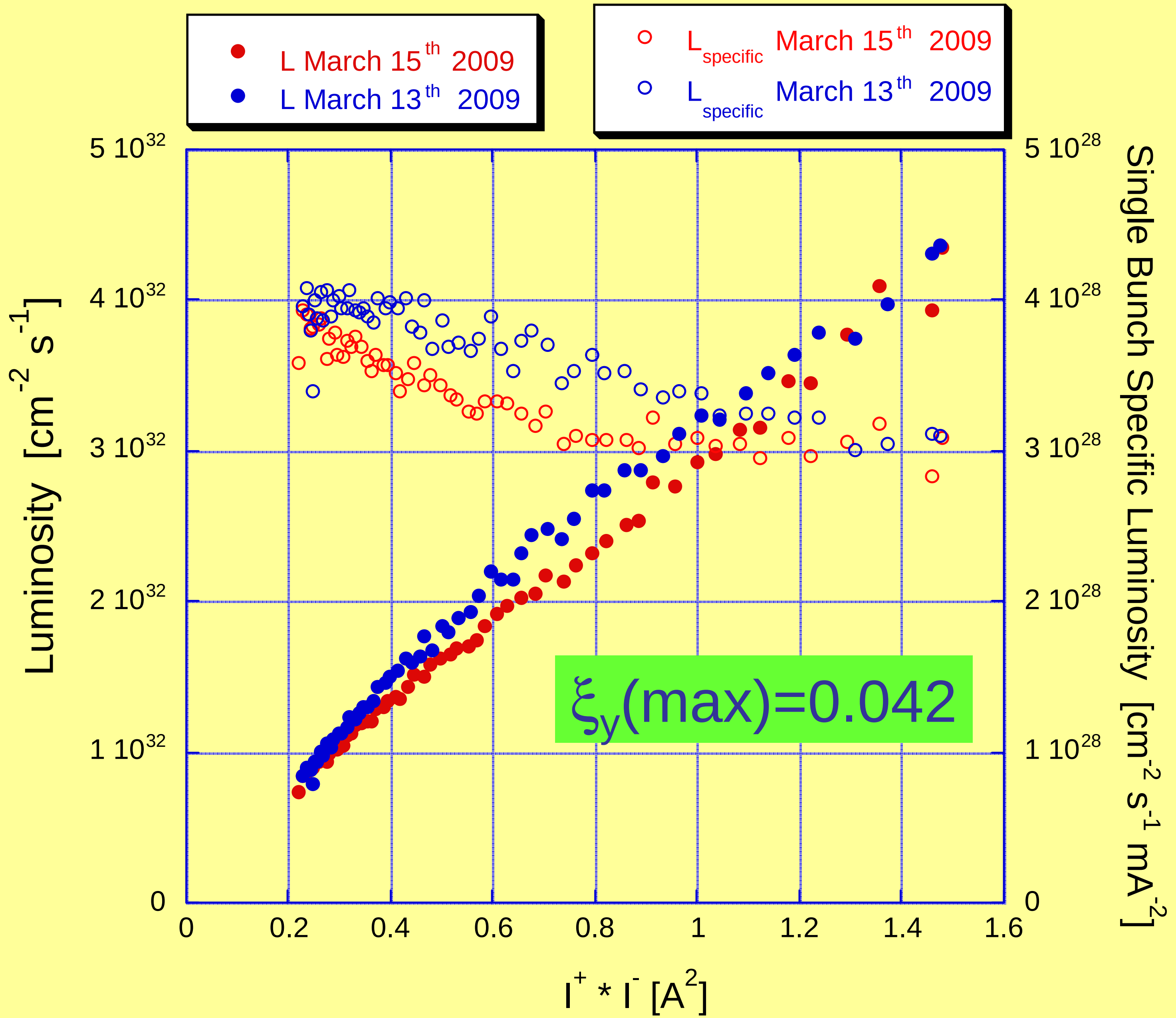




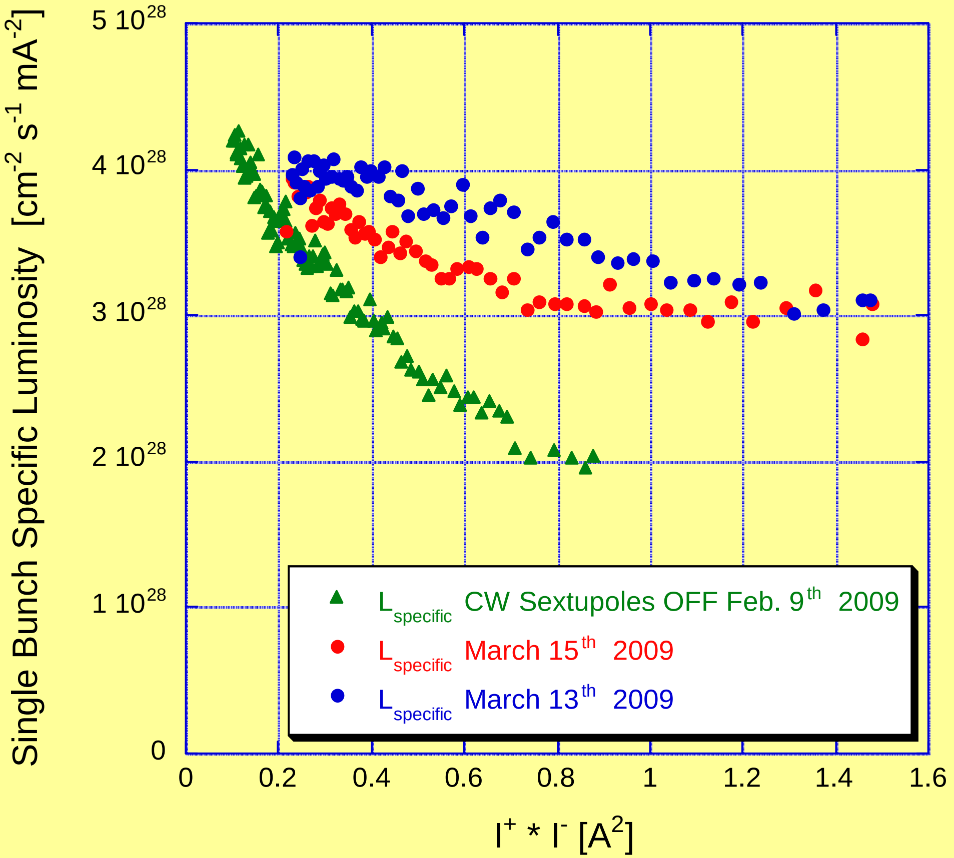
Luminosity vs Current Product
luminosity/1e28
Luminosity [10^{28} cm^{-2} s^{-1}]
Data averaged on a full day
βy=9mm, Pw_angle=1.9
CRAB Optics
13/03/2009 Average
09/02/2009 Crab Off
LPA alone gives more luminosity
βy=18mm, Pw_angle=0.6
12/04/2007 Finuda best
16/09/2005 Kloe best
06/08/2002 Kloe best
βy=25mm, Pw_angle=0.3
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
120*Amp^2 /Nbunch


Spefic Luminosity vs Current Product
luminosity/1e28
Specific Luminosity [10^{28} cm^{-2} s^{-1}]
0.03
0.025
0.02
0.015
0.01
0.005
0
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
120*Amp^2 /Nbunch
βy=9mm, Pw_angle=1.9
CRAB Optics
13/03/2009 Average
09/02/2009 Crab Off
Same beam sizes and specific luminosity
at low current with an without Crab Sextupoles
βy=18mm, Pw_angle=0.6
12/04/2007 Finuda best
16/09/2005 Kloe best
06/08/2002 Kloe best
βy=25mm, Pw_angle=0.3

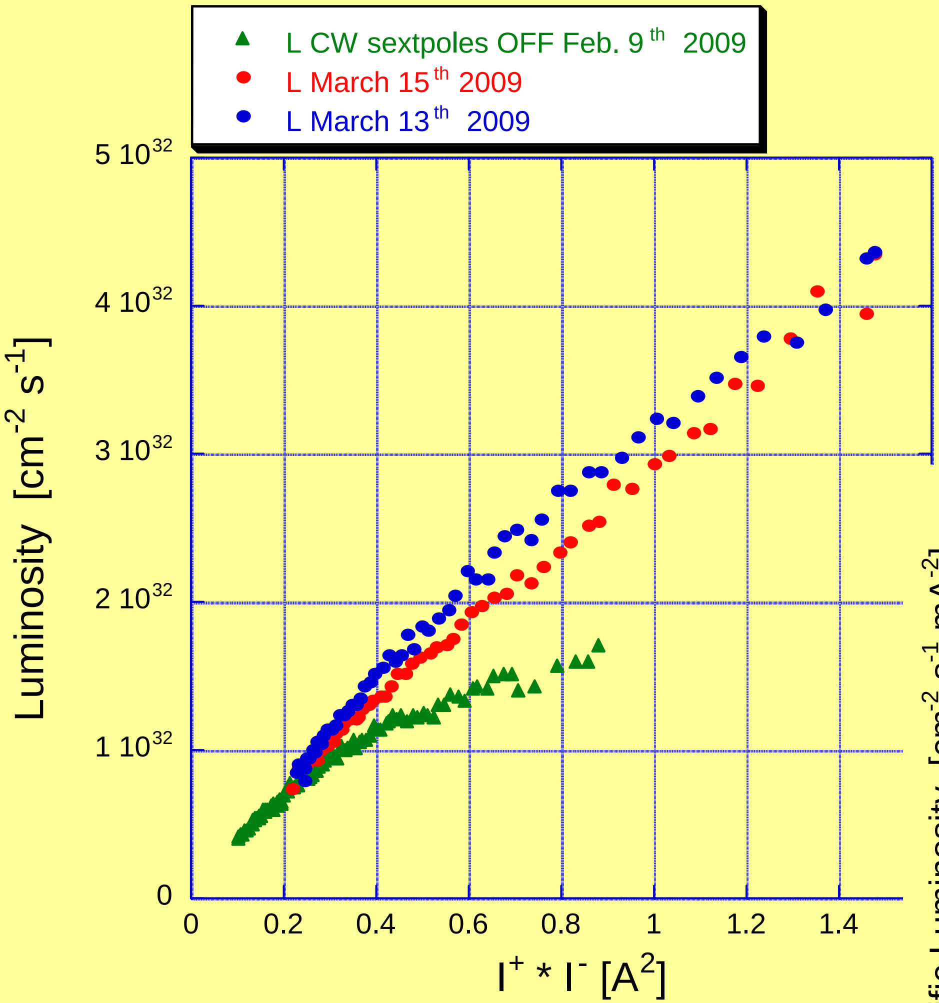
Best two fills Luminosity vs Current Product



Crab on/off Specific Luminosity vs Current Product



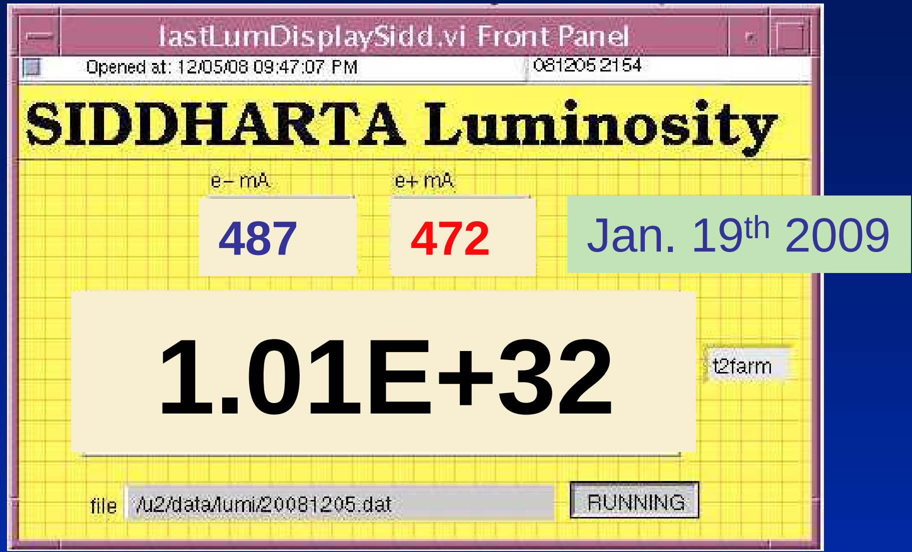
Crab on/off Luminosity vs Current Product



Luminosity in weak-weak and strong-weak regime

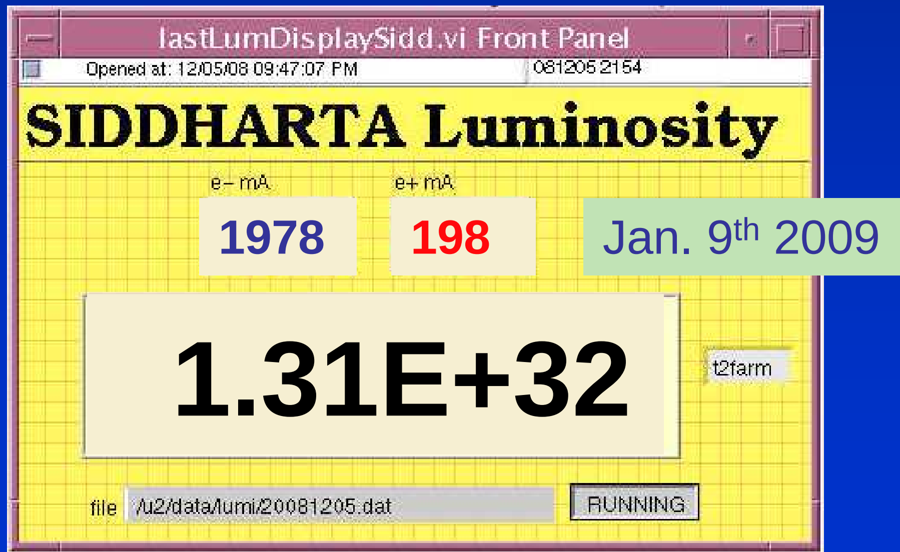
Low currents

$\xi_y \sim 0.020$



Asymmetric currents

$\xi_y \sim 0.0626$



- Results even more striking since we have also reduced the Dafne Wigglers Field (less damping needed since beam-beam is small) in order to save on running cost:

  - 6 MW Wall Plug power during the Kloe data taking

  - 4 MW now

- Performances are still limited because of “standard problems”:

  - e-cloud
  - Ion trapping
  - RF stability

- We hope to further reduce their impact on the performances and gain more in Luminosity at a given current and in peak currents

36th MEETING OF THE LNF SCIENTIFIC COMMITTEE

FINDINGS AND RECOMMENDATIONS

1 THE DAΦNE PROGRAM: STATUS AND RECOMMENDATIONS

1.1 DAΦNE UPGRADE: PERFORMANCE AND OUTLOOK

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.

Finally, the effect of the crab-waist compensation is striking. As we were able to observe directly in the control room, excitation of the sextupoles on either or both beams reduces the corresponding beam sizes in collision, as predicted.

Conclusions

LPA & CW is promising to push forward the high luminosity frontier for storage rings colliders

Tests on adapting an existing machine, Dafne, have been very succesfull, the Siddharta experiment is taking data very smoothly. The HEP program at Frascati has been extended and a new physics run for Kloe has been approved, aimed at >5fb^{-1}/year for at least 3 years