Present status of the DAΦNE upgrade and perspectives

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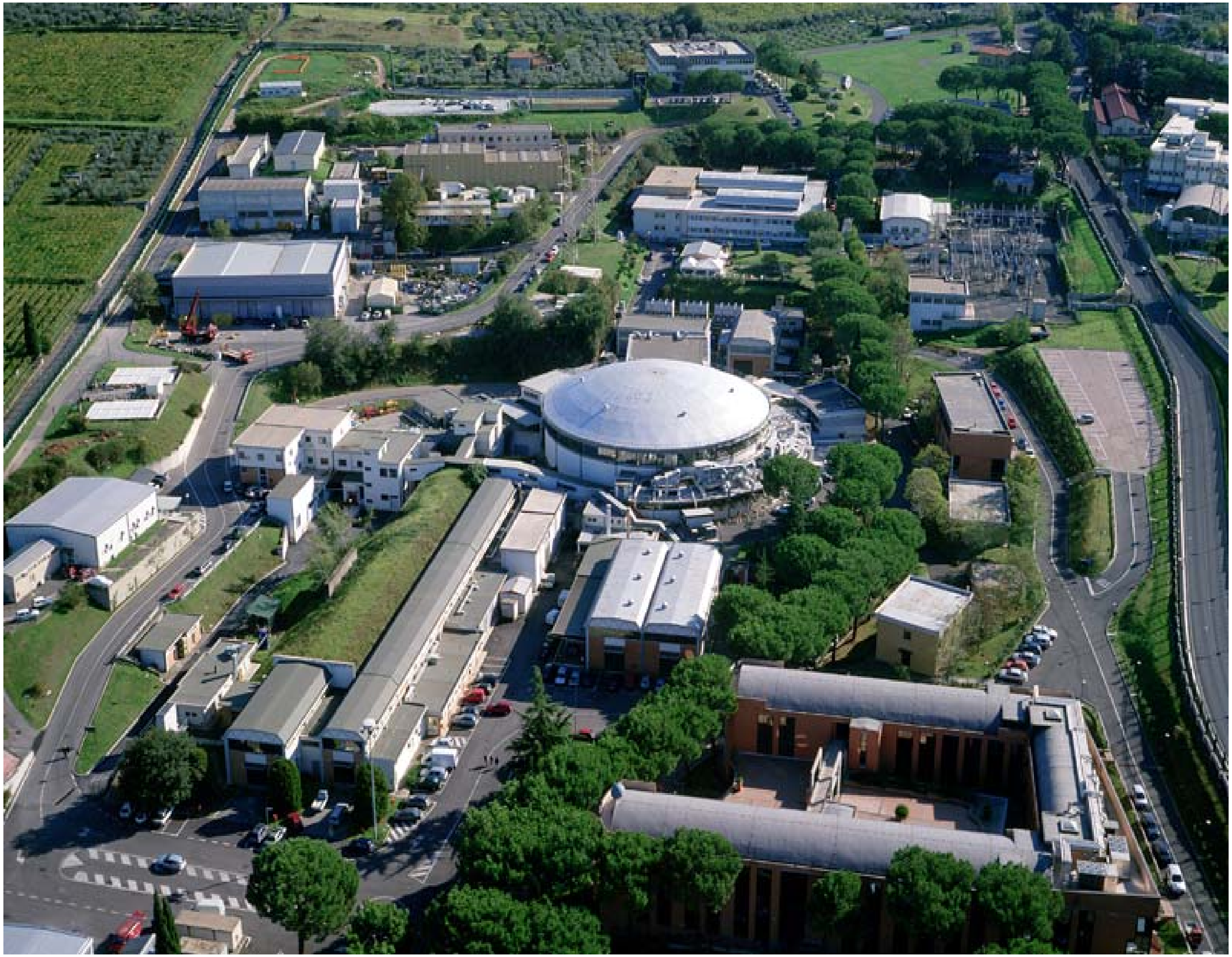
Frascati INFN Laboratory



Outline

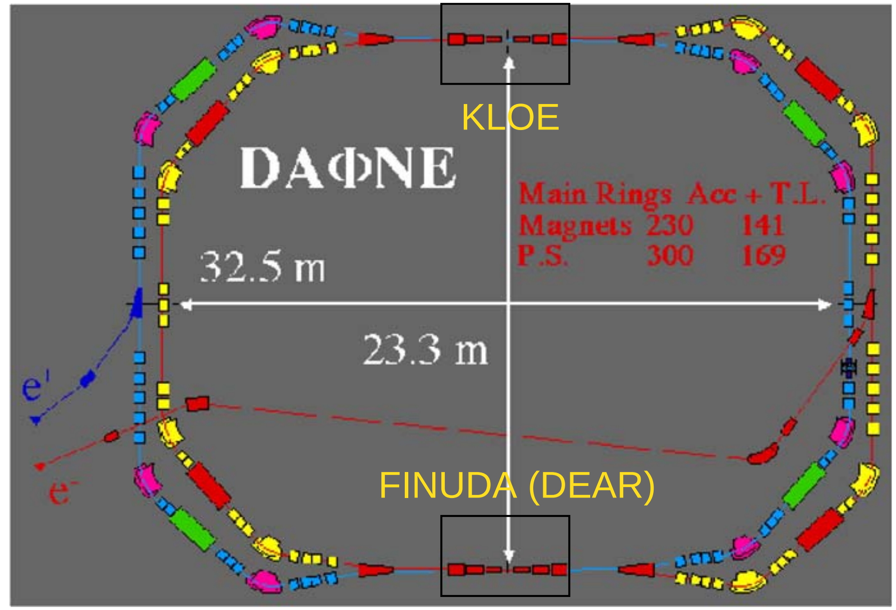
- *DAΦNE original configuration overview*
- *New collision scheme and collider upgrade:*
  - Large Piwinski angle and crab-waist
  - New IR1
  - New Ring Cross Region (RCR) replacing former IR2
  - New injection kickers
  - New bellows
- *Some issues related to the DAΦNE commissioning:*
  - Ring optics
  - Bunch length and ring impedance
  - Beam currents
- *New collision scheme test*
- *Luminosity measurements*
- *Background*
- *Perspectives*
- *Conclusions*

DAΦNE Parameters
(original configuration)

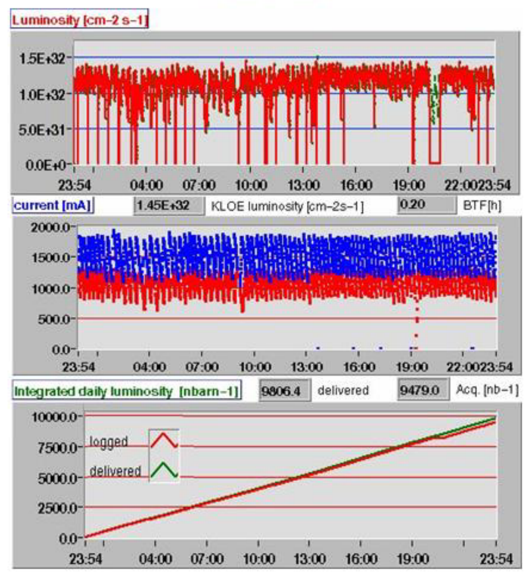
Energy (GeV)	0.51
Circumference, m	97.69
RF Frequency (MHz)	368.26
Harmonic Number	120
Damping Time (ms)	17.8/36.0
Bunch Length (cm)	1-3
Emittance (mm mrad)	0.34
Coupling %	0.2-0.3
$\beta_{x/y}$ Function at IP (m)	1.7/0.017 (KLOE) 2.0/0.019 (FINUDA)
Max. Tune Shifts	.03-.04
Number of Bunches	100÷111
Max.Beam Cur. I^-/I^+ (A)	2.4/1.4 (KLOE) 1.5/1.1 (FINUDA)

L_{logged} (fb^{-1})
2001÷2007

DEAR	0.2
KLOE	3.0
FINUDA	1.2

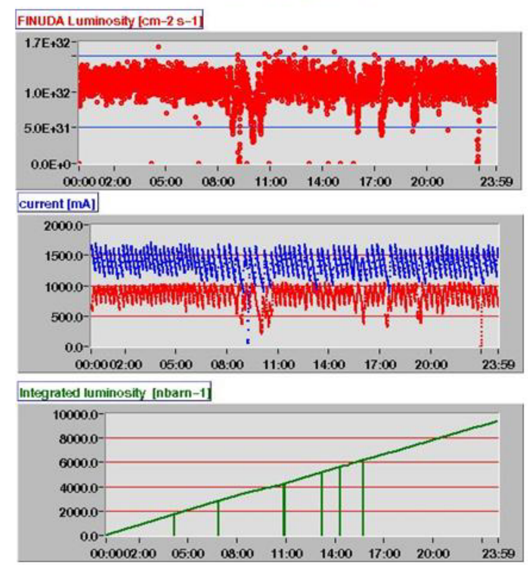


KLOE



111 bunches, $\beta_y^* = 1.8$ cm, $\beta_x^* = 1.5$ m

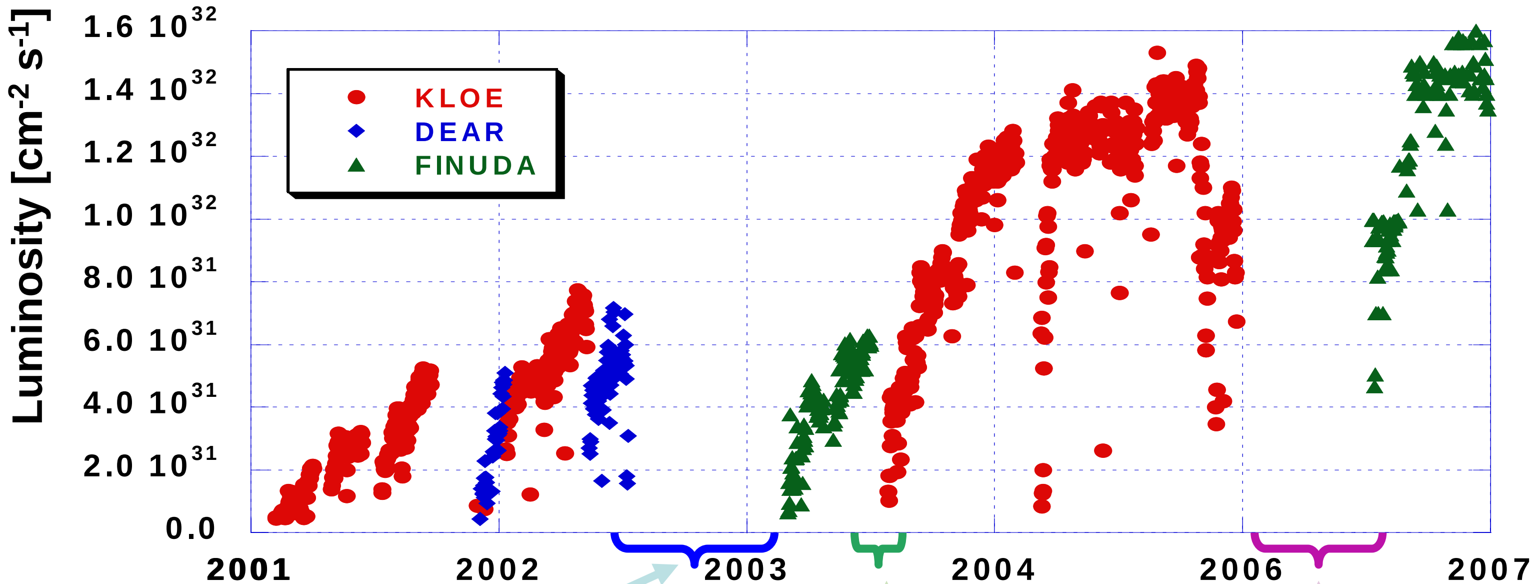
FINUDA



106 bunches, $\beta_y^* = 1.9$ cm, $\beta_x^* = 2.0$ m

L_{peak} at DAΦNE 2001 ÷ 2007

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



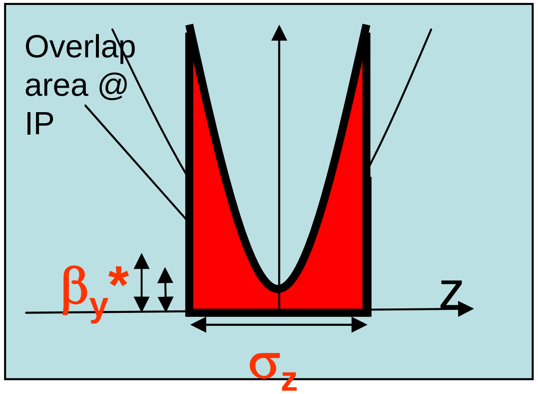
- FINUDA installation
- New KLOE IR optics & coupling correction
- New Transverse feedback installed
- WIGGLER field quality improved
- Injection kickers upgrade
- Ion clearing electrodes feed-through modification
- Scrapers and bellows maintenance & upgrade

- FINUDA removed & simplified IR2
- KLOE installed
- Wires for BBLR interaction compensation in IR1
- Extensive studies about the beam-beam limit at DAΦNE

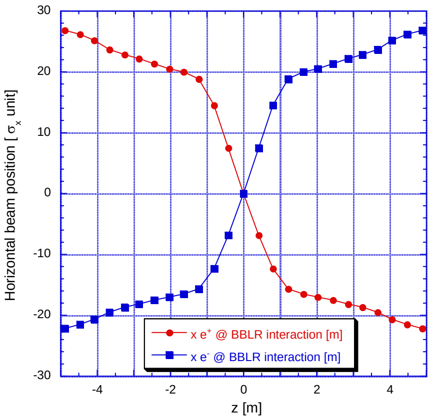
- KLOE removed & simplified IR1
- FINUDA installed
- WIGGLER Ion Clearing Electrodes removed
- WIRES for BBLR interaction compensation in IR2
- 3rd generation transverse and longitudinal FBK systems
- New BPMs with single turn measure capability

Rationale for the Upgrade

$L_{peak} \sim 1.6\ 10^{32}\ cm^{-2}\ s^{-1}$ 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 $L_\int$

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 $\boldsymbol{\Phi}$ obtained by:

$$\Phi \approx \frac{\sigma_z}{\sigma_x}\frac{\theta}{2}$$

smaller σ_x
larger θ

New IR layout
Lower beam ε
High colliding currents

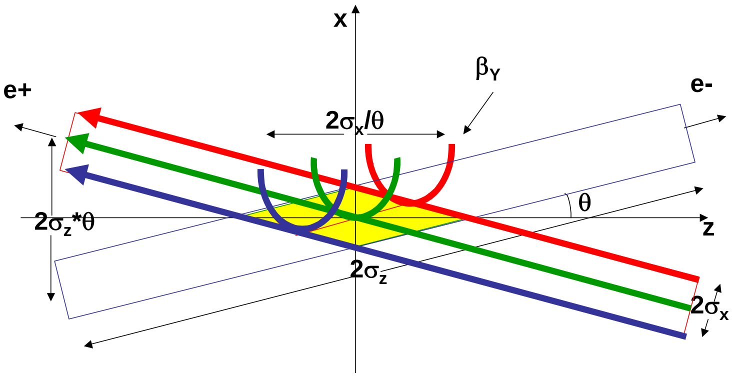
$$\zeta_y \propto \frac{N\sqrt{\beta_y^*}}{\sigma_z \theta} \qquad \zeta_x \propto \frac{N}{(\sigma_z \theta)^2} \qquad L \propto \frac{N\zeta_y}{\beta_y^*}$$

- lower ζ_x (tune sfit)
- $L_{geometric}$ gain (if N incr.)

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

New low-β section
Ad hoc low-β optics

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



- $L_{geometric}$ gain
- lower ζ_y
- Y synchro-betatron resonances suppression

Crab-Waist compensation

Collision with large θ is not a new idea …..

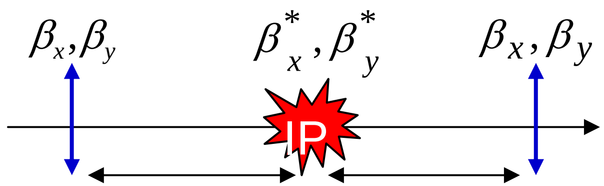
Crab-Waist transformation is !

(P.Raimondi, 2006)

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

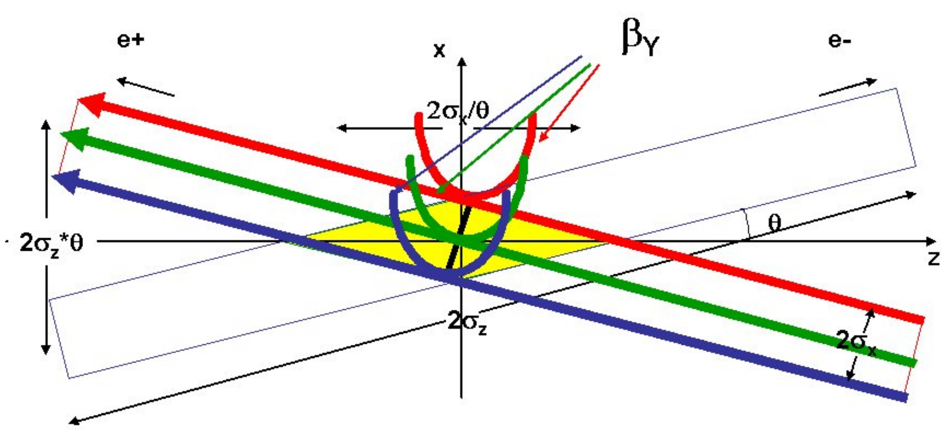
Powerful Sextupoles
Proper IR optics

sextupole (anti)sextupole



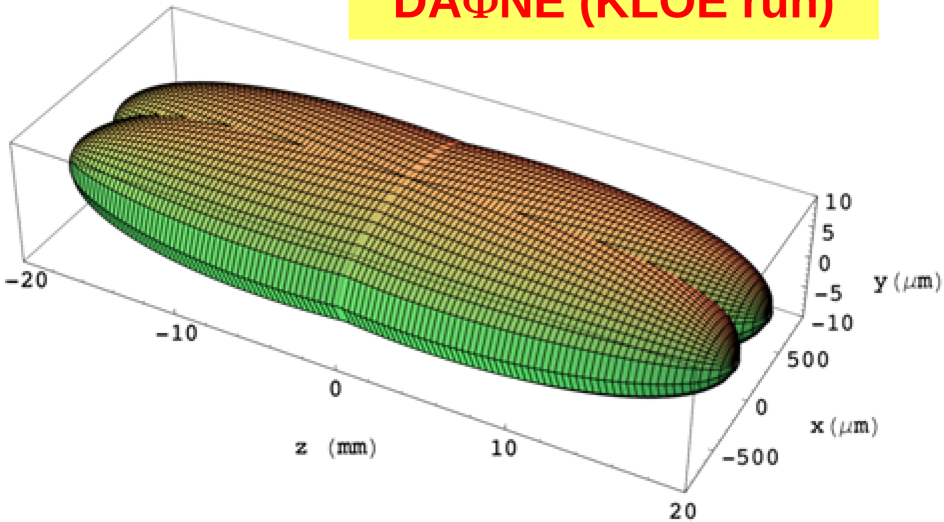
$$\Delta\nu_x = \pi$$
$$\Delta\nu_y = \frac{\pi}{2}$$

- $L_{geometric}$ gain
- X-Y synchro-betatron and betatron resonance suppression

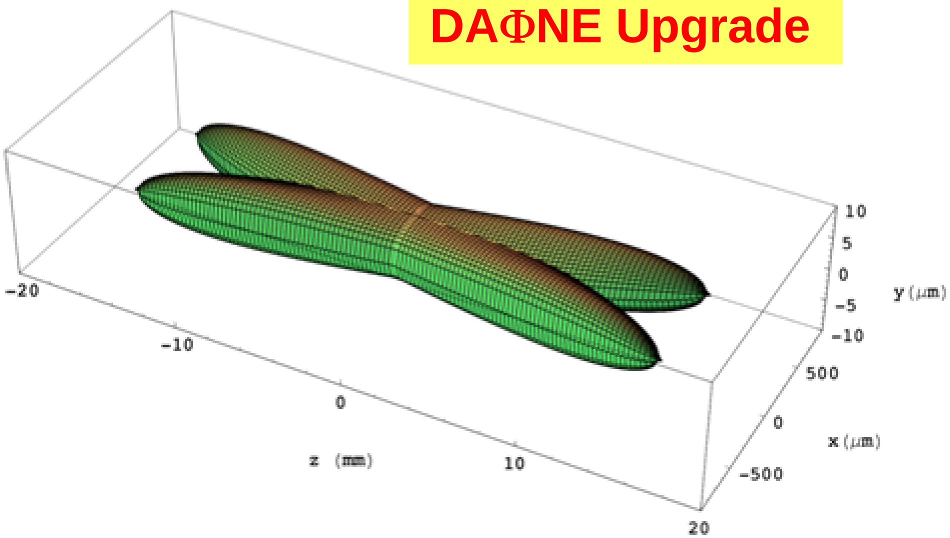


BEAM PROFILES @IP AND NEW PARAMETERS

DAΦNE (KLOE run)



DAΦNE Upgrade



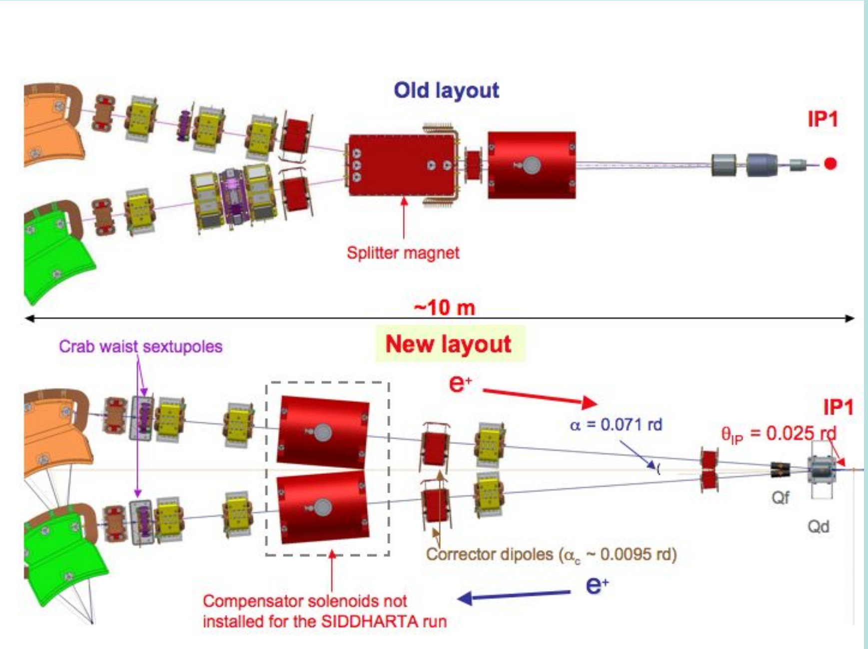
	DAΦNE (KLOE run)	DAΦNE Upgrade
I_{bunch} (mA)	13	13
N_{bunch}	110	110
β_y* (cm)	1.7	0.65
β_x* (cm)	170	20
σ_y* (μm)	7	2.6
σ_x* (μm)	700	200
σ_z (mm)	25	20
Horizontal tune shift	0.04	0.008
Vertical tune shift	0.04	0.055
θ_{cross} (mrad) (half)	12.5	25
$\Phi_{Piwinski}$	0.45	2.5
L ($cm^{-2}s^{-1}$)	1.5×10^{32}	$>5\times10^{32}$

IR1 Evolution

- splitter magnets and compensator solenoids removed
- large collision angle ~ 50 mrd
- *low-beta* section based on Permanent Magnet QUADs:

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

  k_{QF} = 12.6 [T/m]
- e^+ e^- vacuum chambers separate after the Q_D
- four C type corrector dipole are used to mach the vacuum chamber in the arc



Beam Beam Long Range interaction almost cancelled

1PC -> Δx_{PC}~20 σ_x

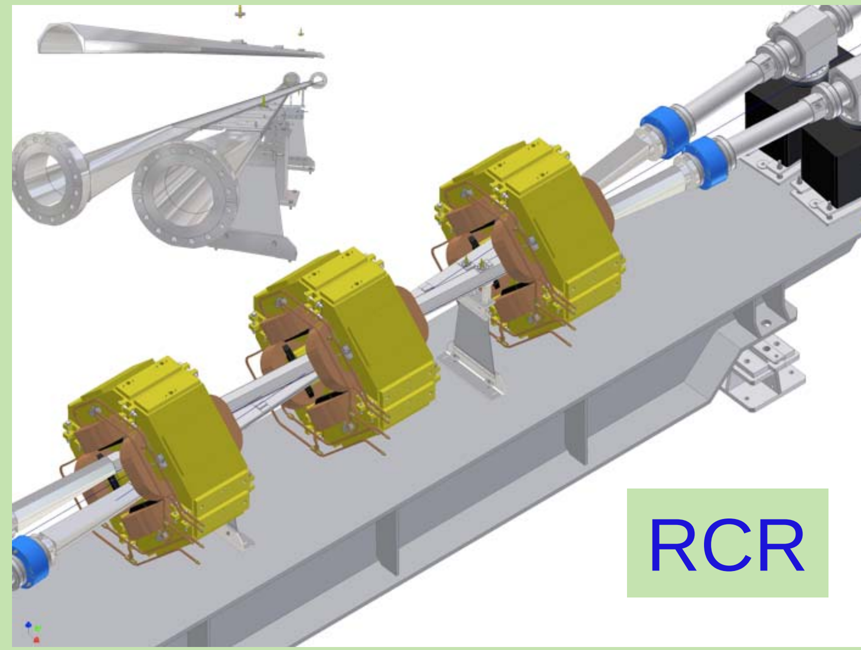
Ring Crossing Region

Splitter magnets and compensator solenoids removed

Geometrical layout symmetric to the IR1

“Half Moon” vacuum chamber:

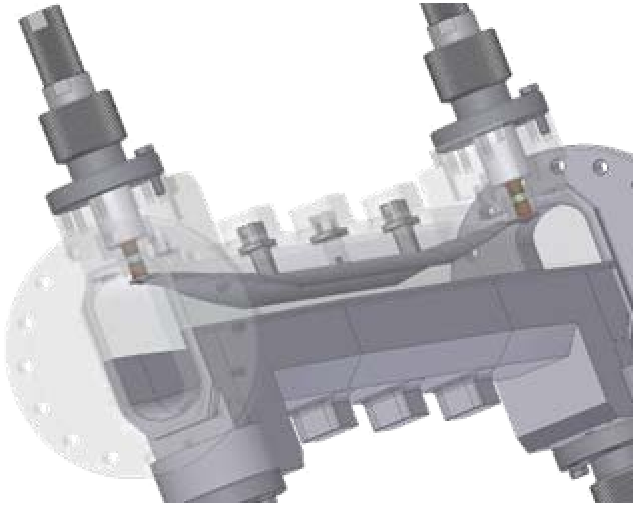
- provides full beam separation
- designed to fit inside the existing EM quadrupoles
- can be easily replaced by an IR



No BBLR interaction contribution from RCR

New injection KICKERS test

New stripline kicker providing better deflecting field uniformity

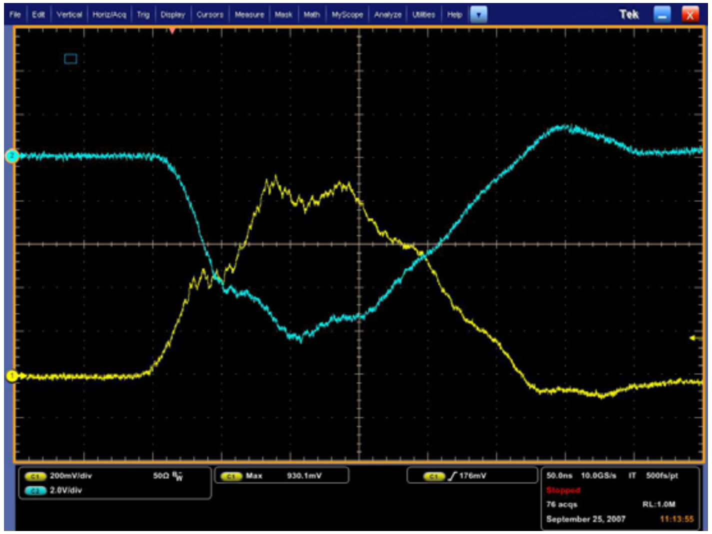


⇒ The new kickers are powered by ***new pulsed power supply (6 ns pulse length***), and they are also compatible with the old pulsers (200 nspulse length)

⇒ ***First test on e+ ring with fast pulsers have been successfully done.***

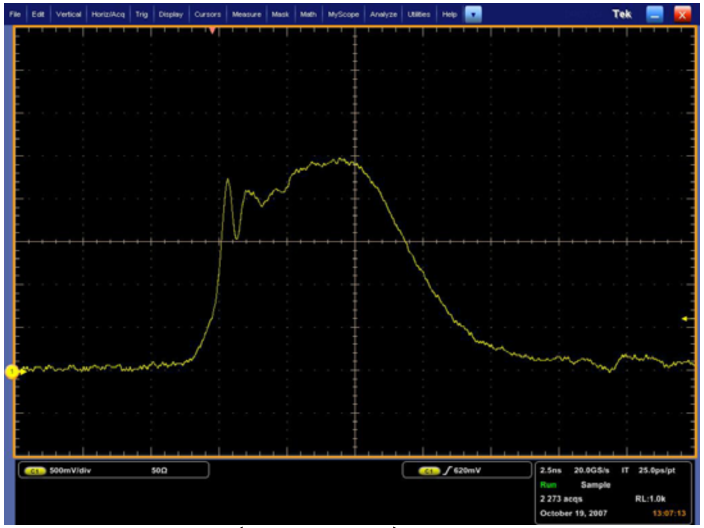
⇒ Unfortunately we had ***problems with the new fast FID pulsers*** after few hours of operation. They have been now recovered and ready to be re-installed.

25 kV



200 ns

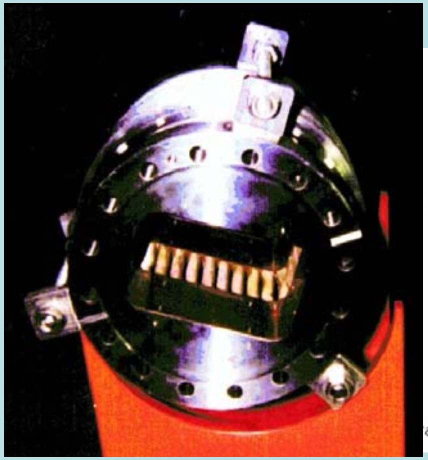
45 kV

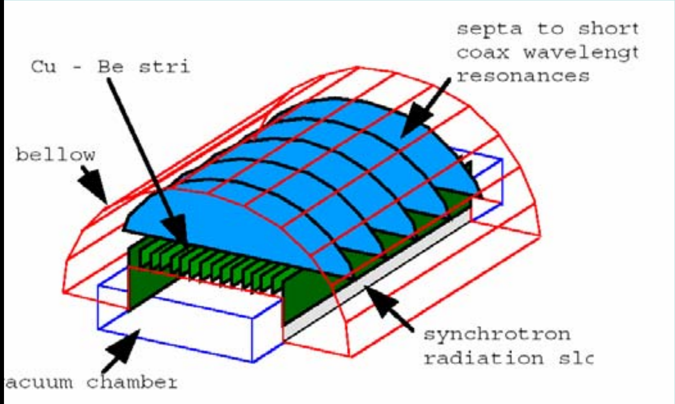


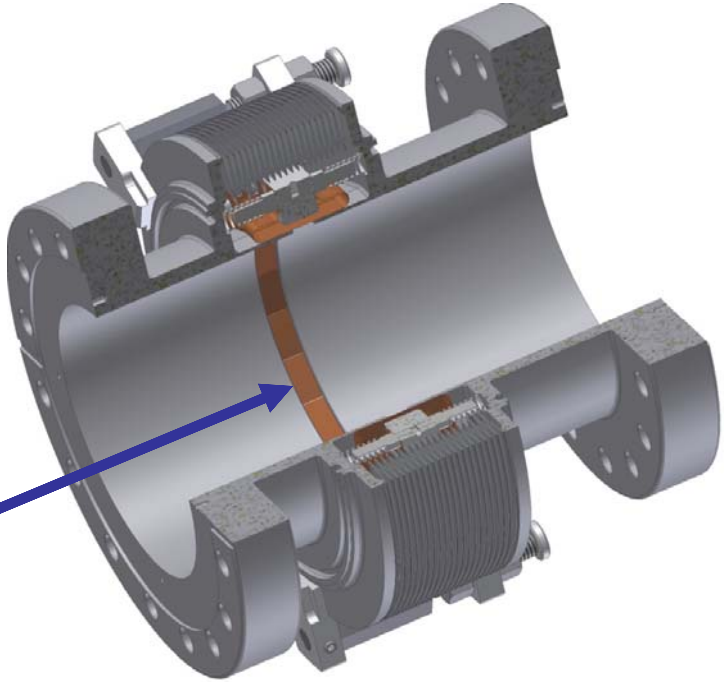
6 ns

NEW BELLOWS

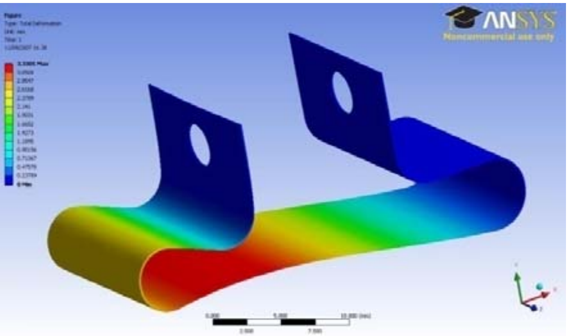
OLD BELLOW

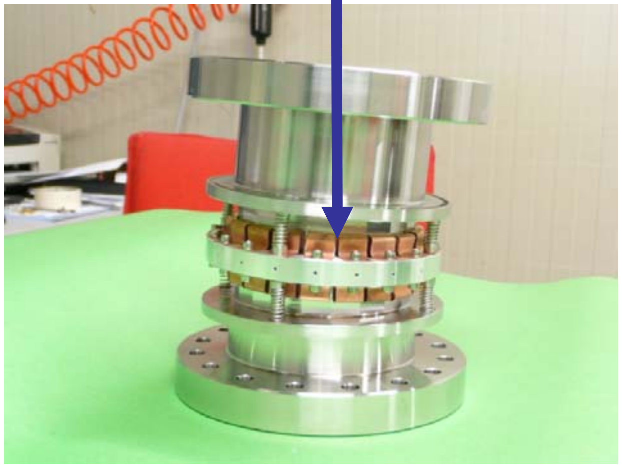






- 6 new bellows for each ring;
- Shielding based on Be-Cu Ω strips 0.2 mm thickness;
- lower impedance and improved mechanical specifications;





DAΦNE commissioning milestones

- ***Commissioning*** started at the end of November
- Both ***beams stored*** in the first days of December
- February ***Crab-Waist sextupoles in operation***
- February the 11th ***Luminosity monitor installation***
- Beginning of March first $L \sim 10^{32}$ cm^{-2} s^{-1} measured
- March the 10th ***SIDDHARTA installation***
- End of April $\boldsymbol{L_{peak} \sim 2 \cdot 10^{32}}$ ***cm^{-2} s^{-1} measured.***

Present SIDDHARTA Optics

$$\frac{\vartheta^+}{2} = 25mrd \qquad \frac{\vartheta^-}{2} = 25mrd$$

$$\beta_x^* = 0.266m$$

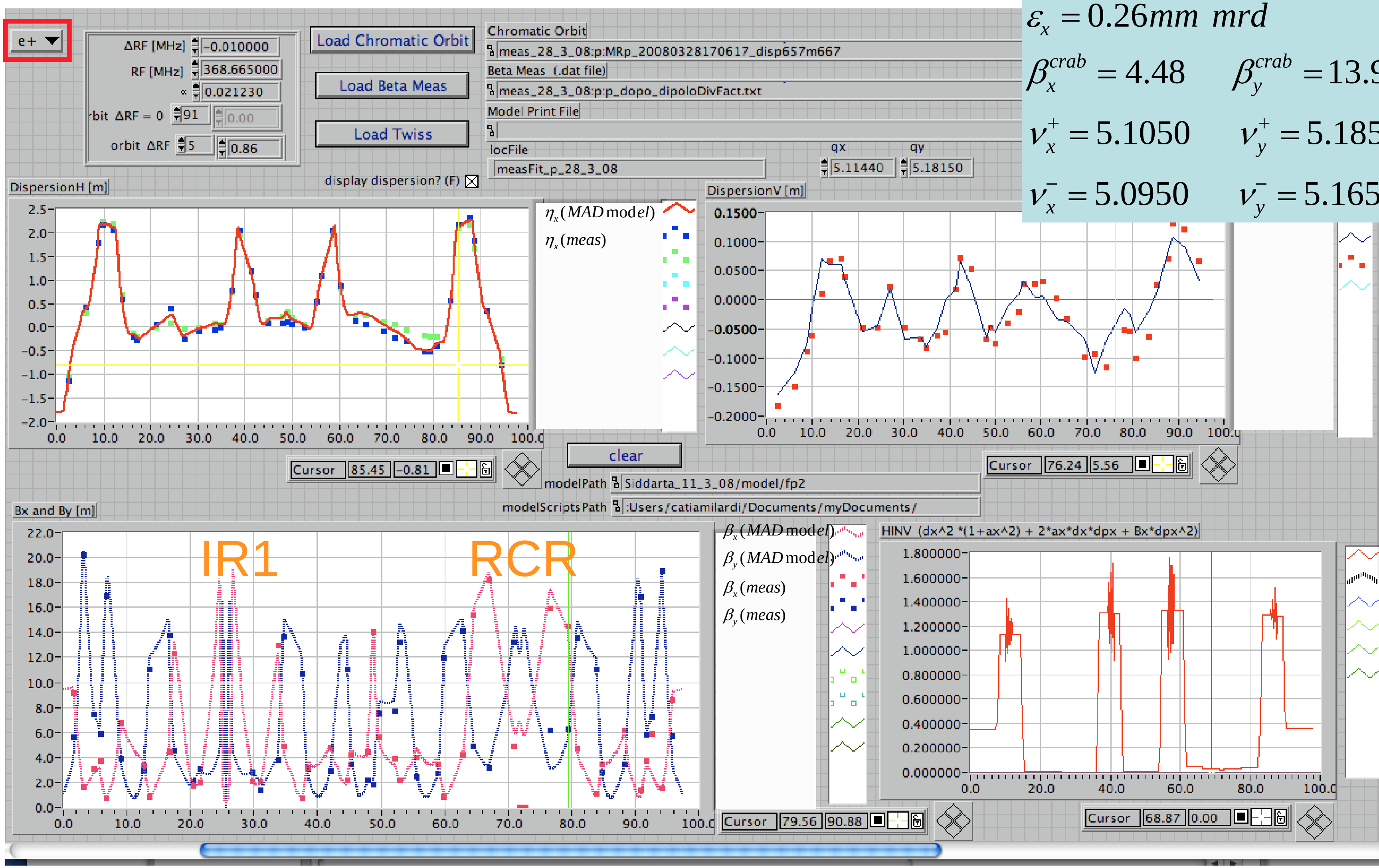
$$\beta_y^* = 0.01m$$

$$\varepsilon_x = 0.26mm\ mrd$$

$$\beta_x^{crab} = 4.48 \qquad \beta_y^{crab} = 13.9$$

$$\nu_x^+ = 5.1050 \qquad \nu_y^+ = 5.1850$$

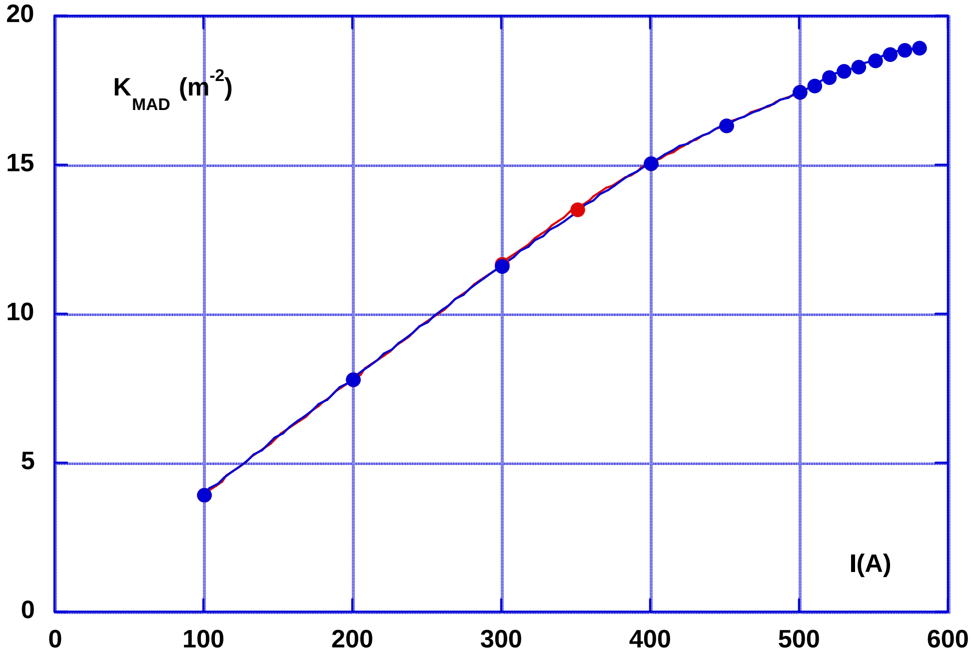
$$\nu_x^- = 5.0950 \qquad \nu_y^- = 5.1650$$



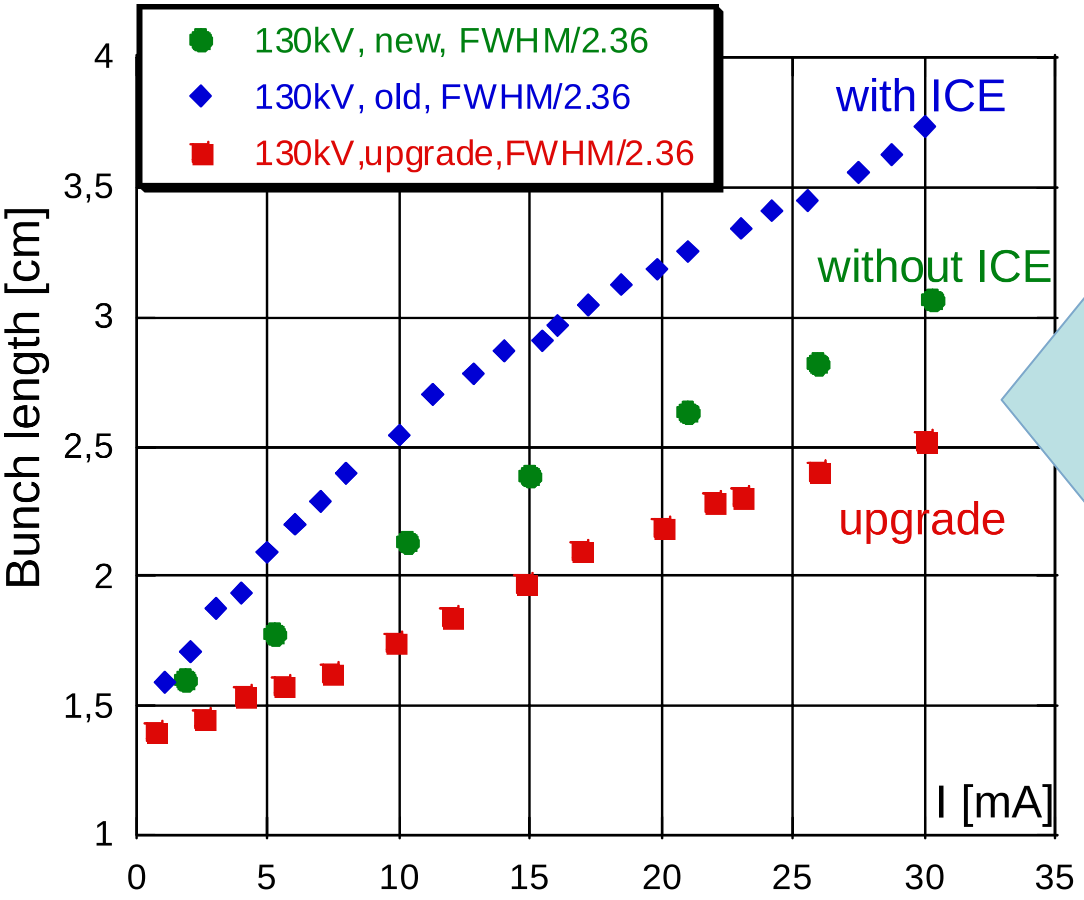
CRAB Sextupoles

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

$K_{s=}$ 38.9 m^{-2} more than a factor 5 larger than the average required for the normal sextupoles used for chromaticity correction



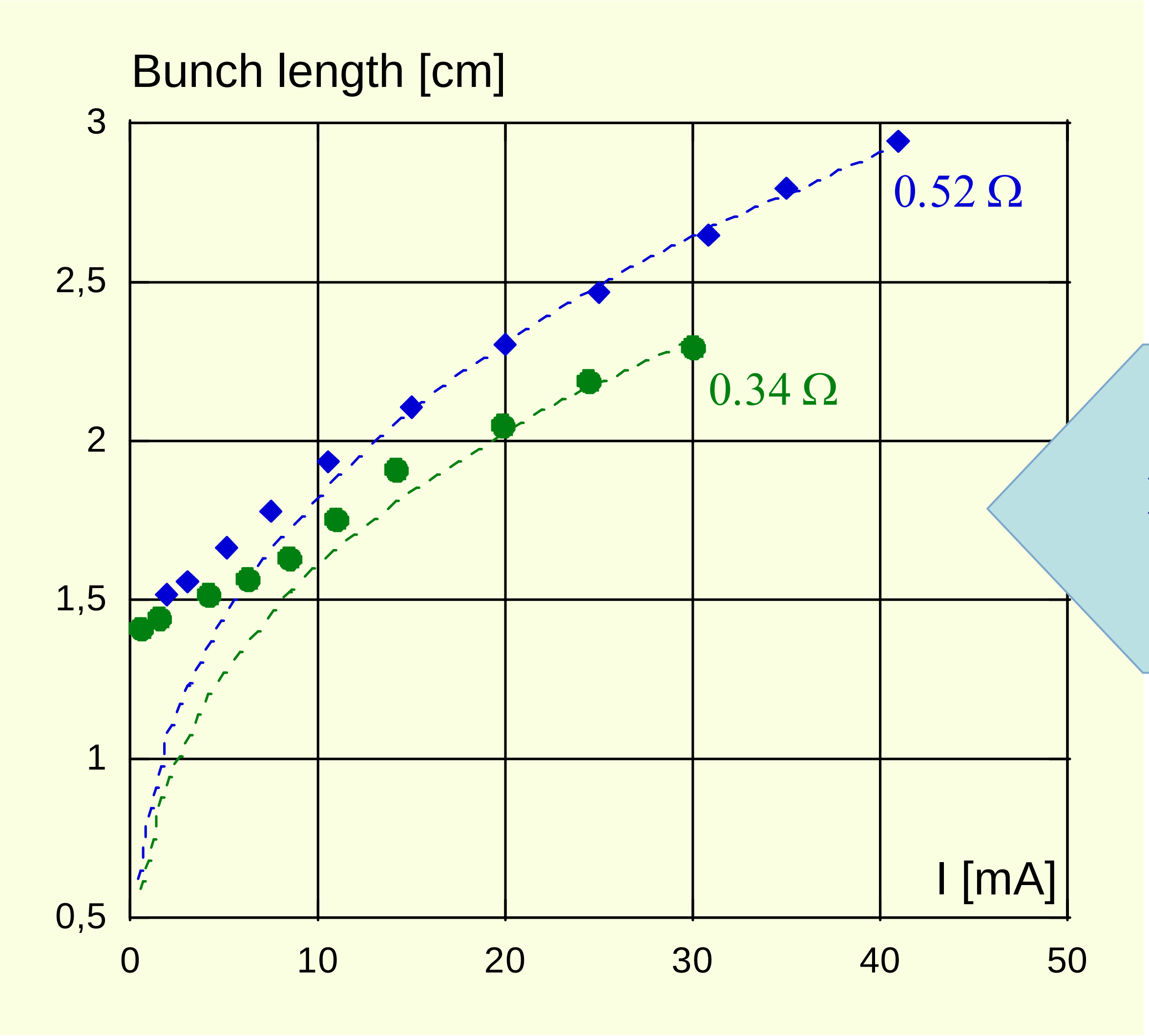
e^- bunch length measurement



20% bunch length reduction @ I_{bunch} ~ 10 mA due to:

- ICE removal
- New injection kickers
- New bellows

e^+ bunch length measurement

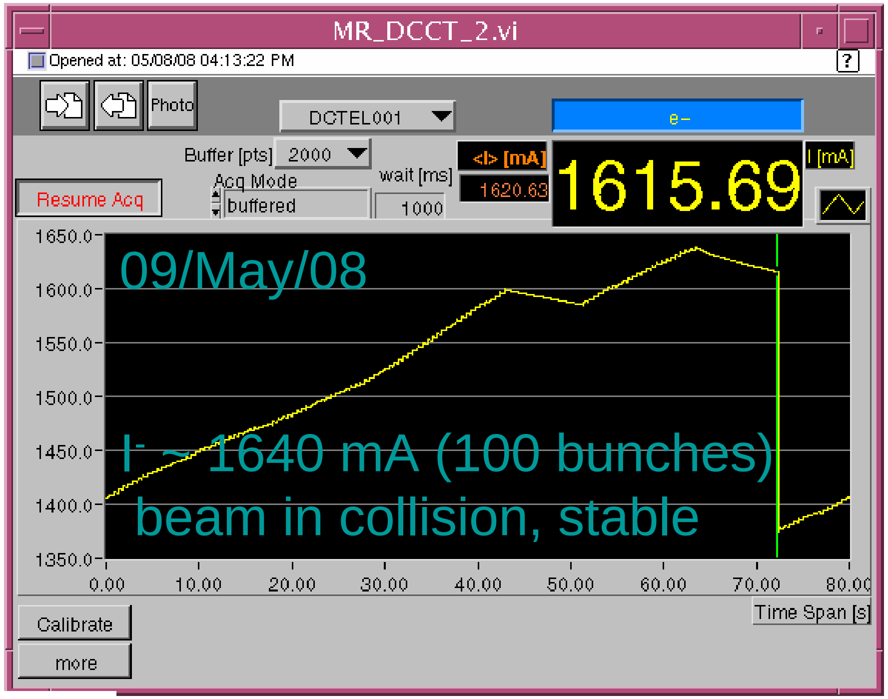


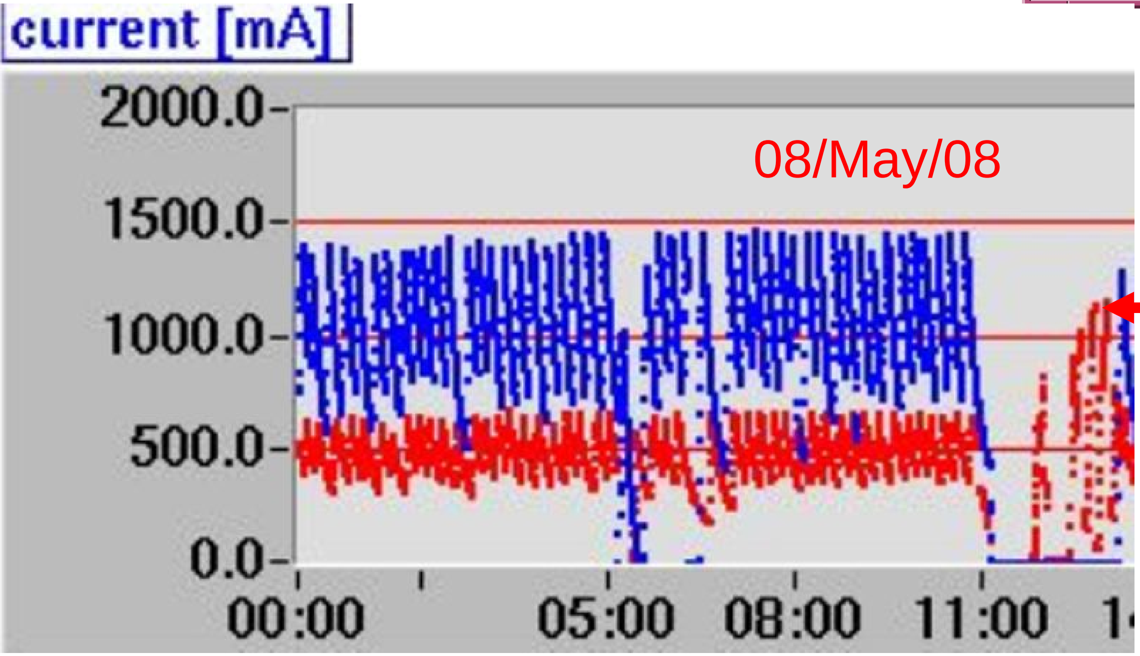
Few % reduction in bunch length due to:

- New injection kickers
- New bellows

Getting high currents

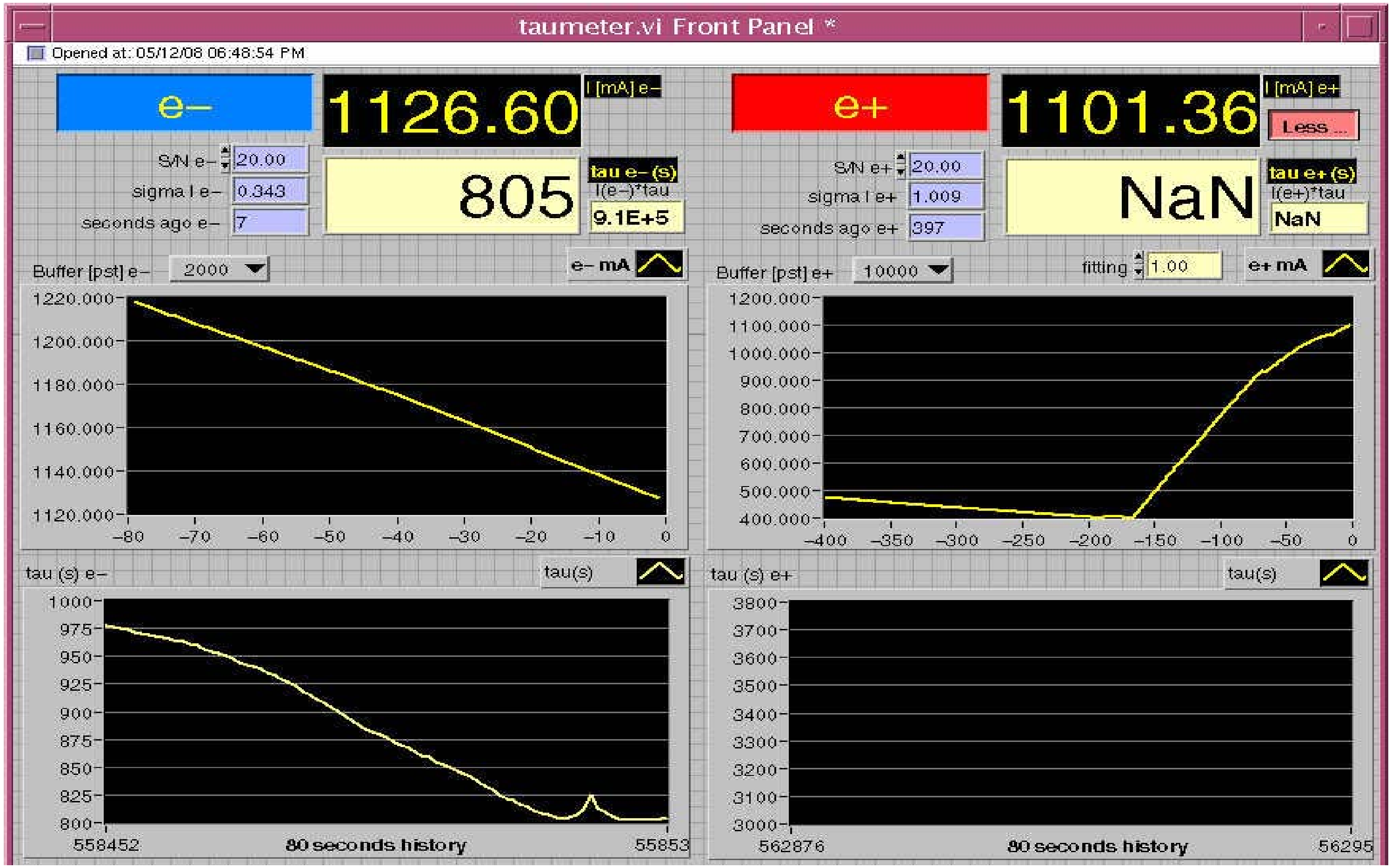
- Vacuum recovering
- Lower ring impedance
- New injection kickers
- Transverse and Longitudinal Feedback upgrade & optimization
- Winding solenoids (B_{sol} ~ 45 Gauss) in large section of the <u>e^+ ring only</u>





I^+ > 1150mA (120 bunches)
I^+ single beam best result

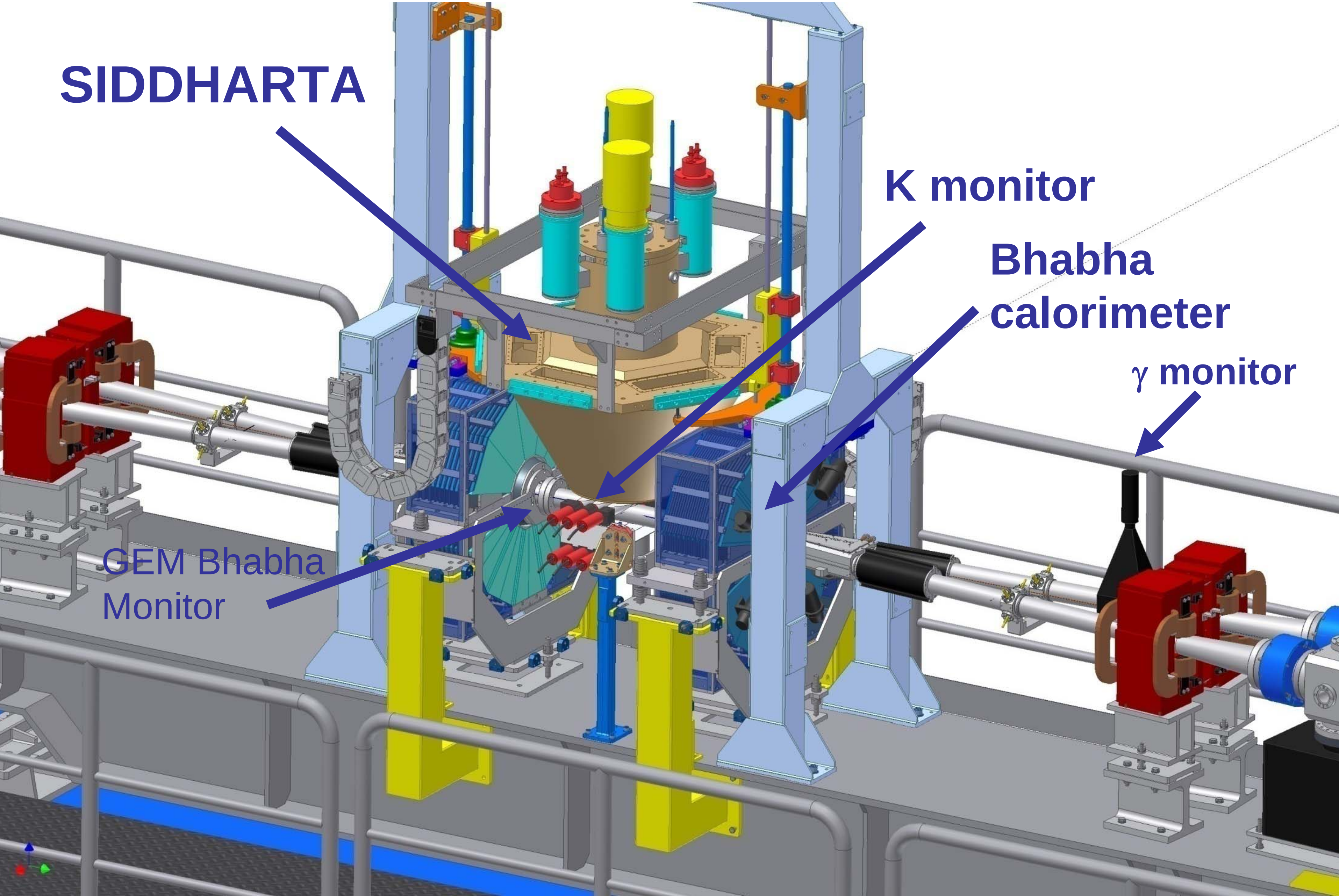
Maximum currents stored in collision



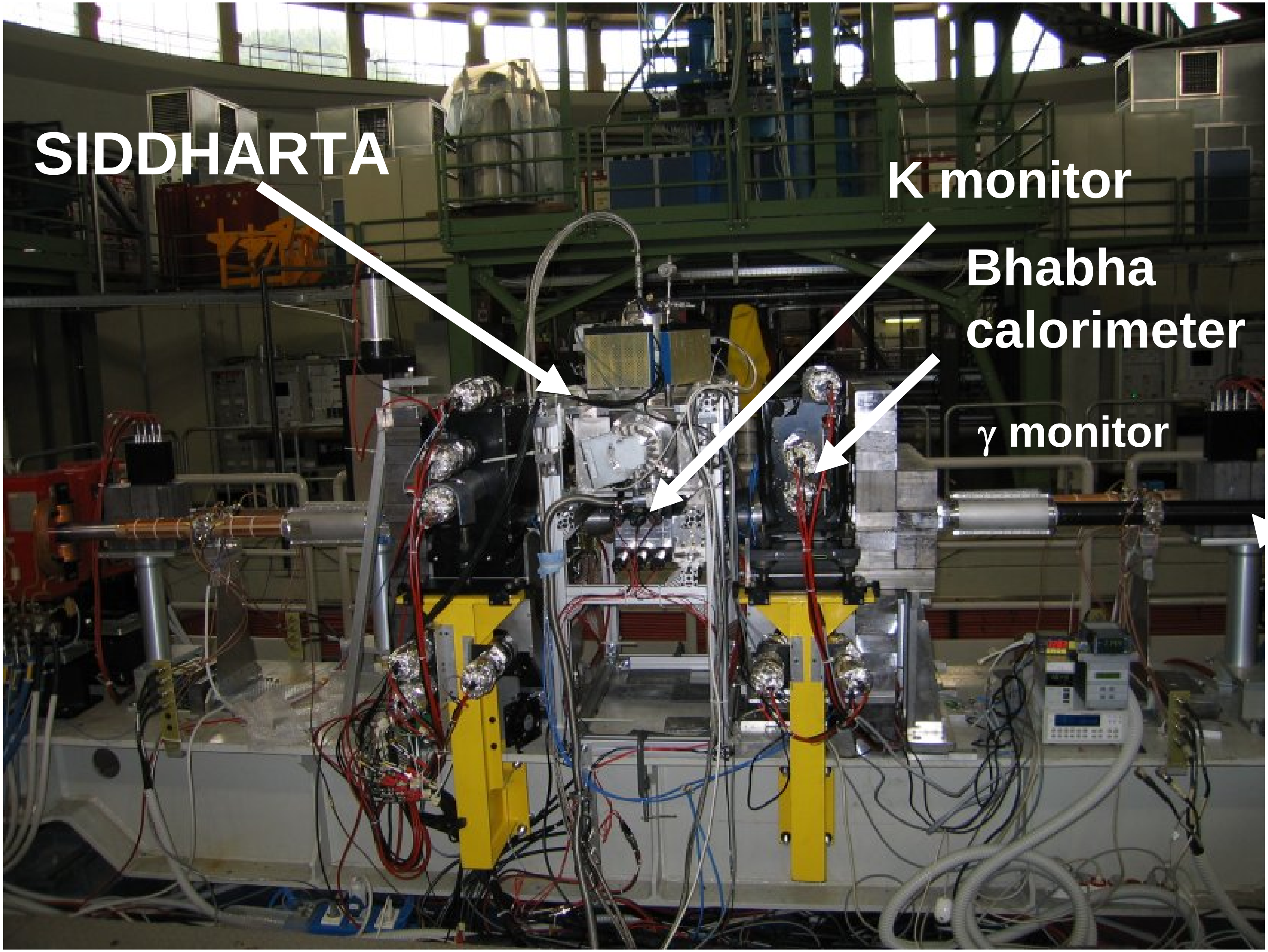
$I^{-/+}_{MAX}$ ~ 2.4/1.4 (KLOE run 111 colliding bunches))

$I^{-/+}_{MAX}$ ~ 1.5/1.1 (FINUDA run 106 colliding bunches)

IP LAYOUT AND LUMINOSITY MONITORS



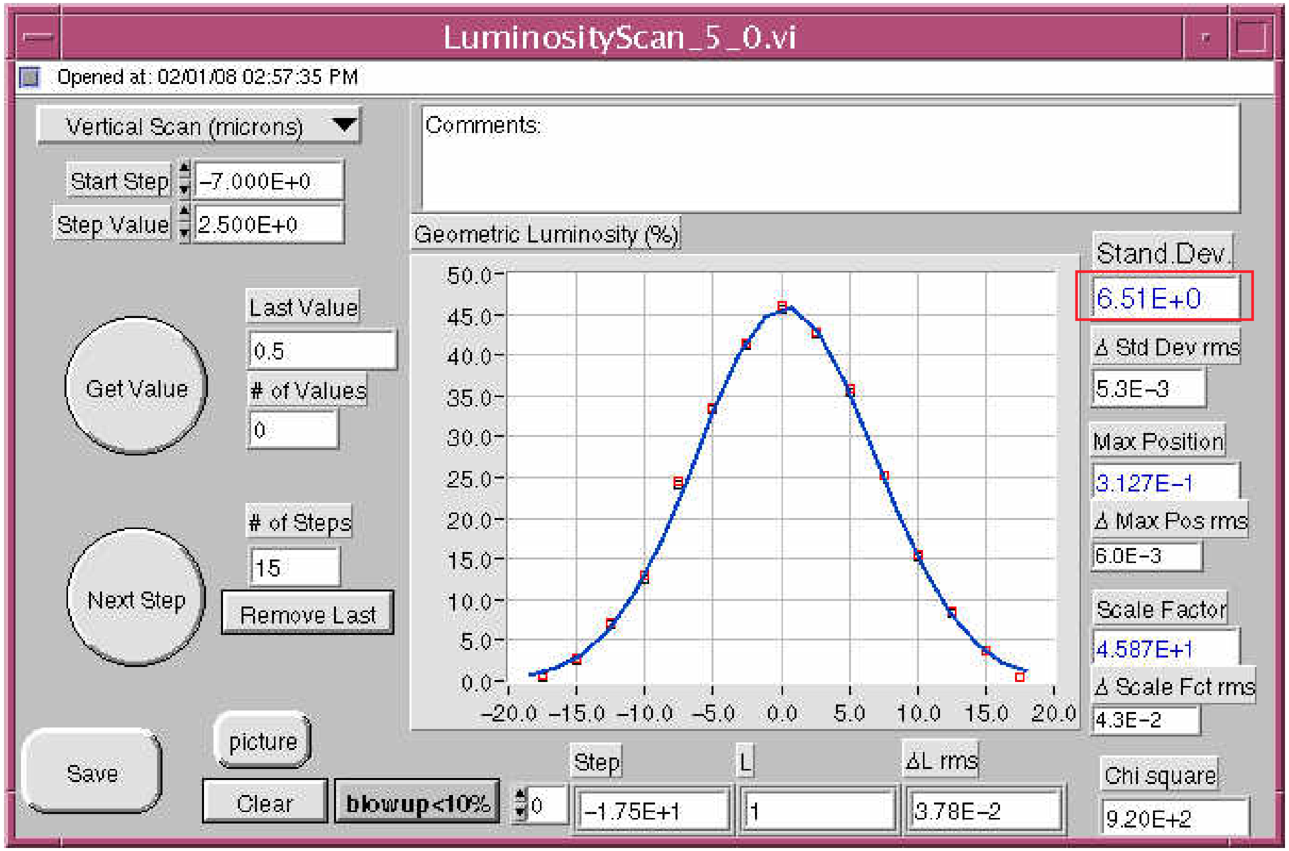
IP LAYOUT AND LUMINOSITY MONITORS



Vertical beam-beam Luminosity scan

$$\Sigma_y = \sqrt{\sigma_{yp}^2 + \sigma_{ye}^2} \qquad \Sigma_y = \Sigma_y^{meas} * \underline{0.88}$$

Hourglass factor



$$\Sigma_y = 5.63\mu m$$

$$\sigma_{ye}^2 \cong \sigma_{yp}^2 \cong \sigma_y^2$$

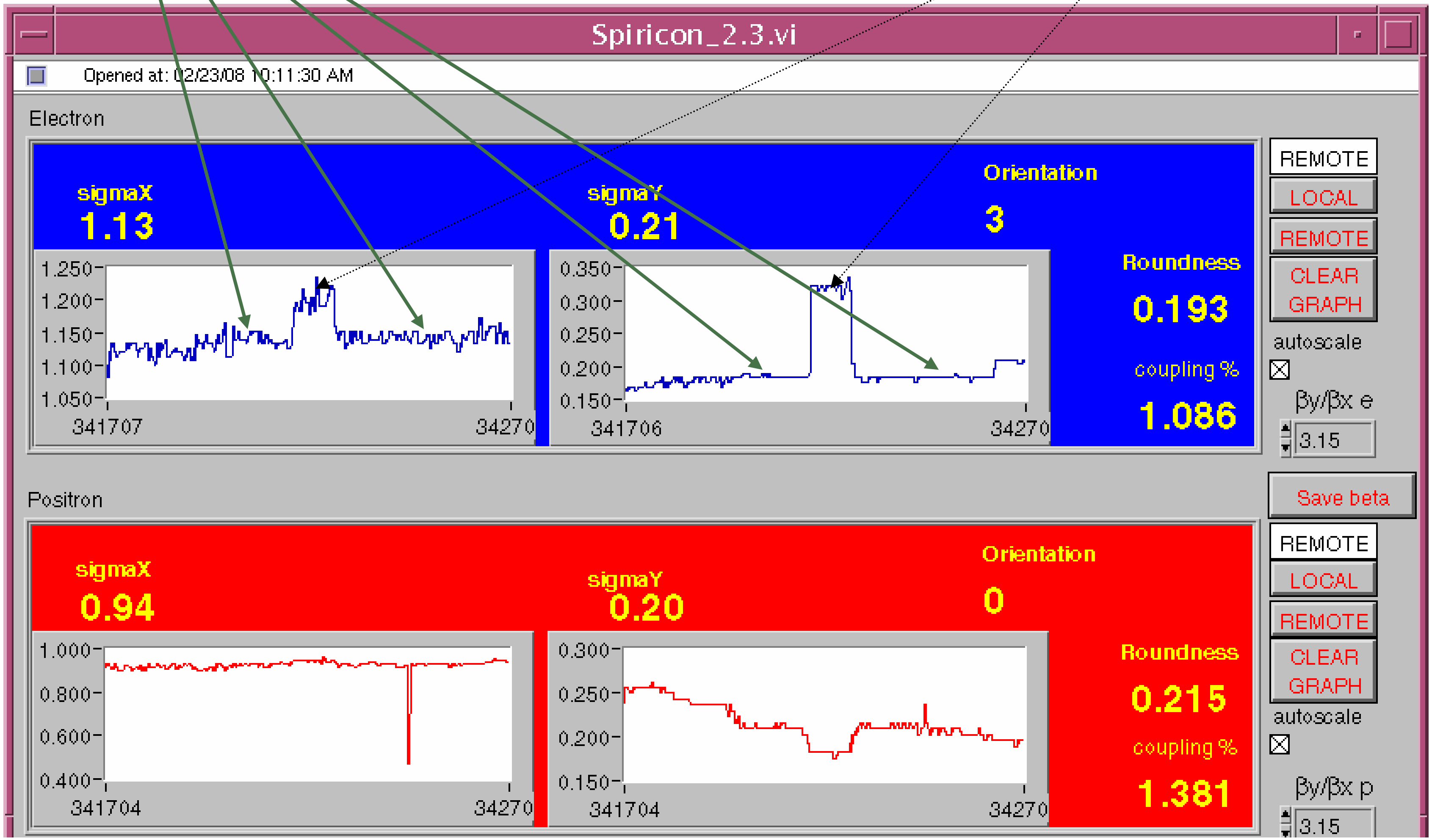
$$\sigma_y \approx 4\mu m$$

Measured Σ_y is compatible with the value obtained by using the coupling value (κ ~.7%) measured at the SLM

CRAB Sextupoles & Beam sizes (on electron beam)

Crab On

Crab off

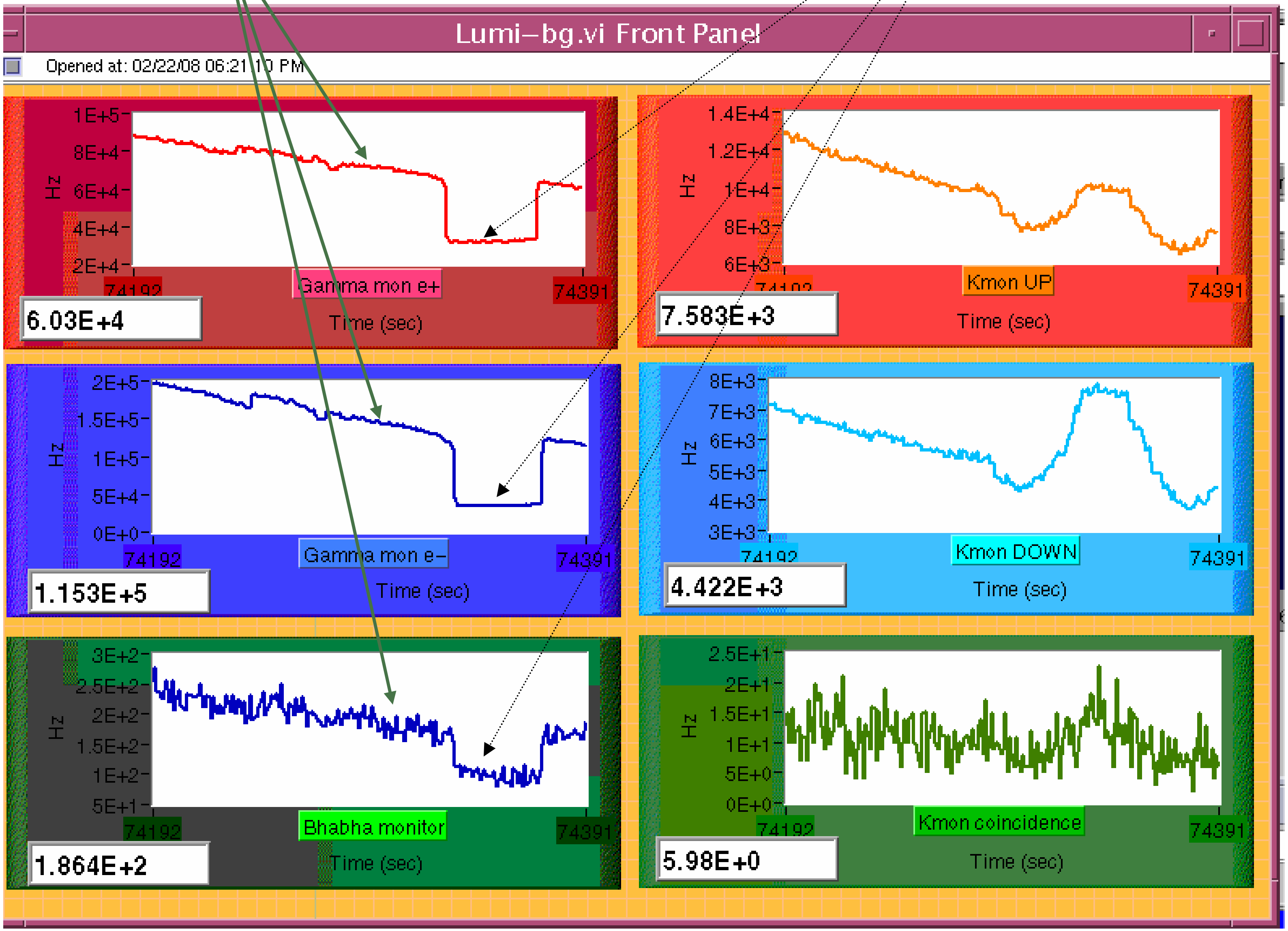


Beam lifetime is not affected by the CRAB Sextupoles

Luminosity monitors (colliding beams)

Crab On

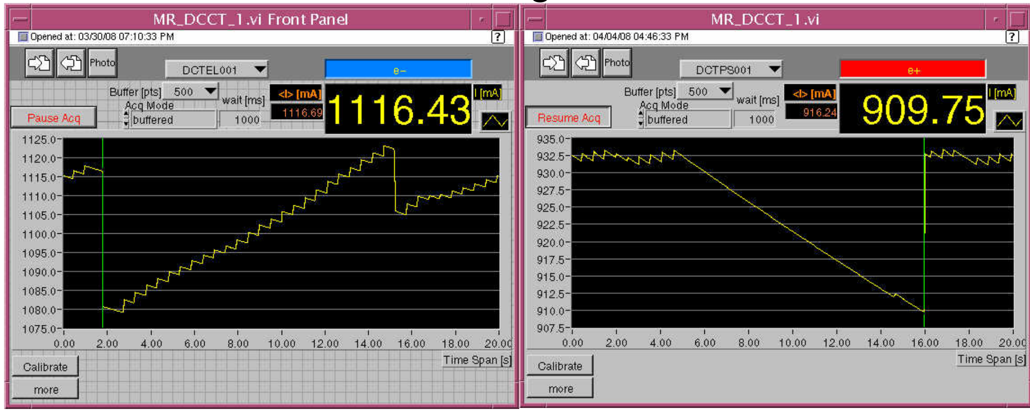
Crab off



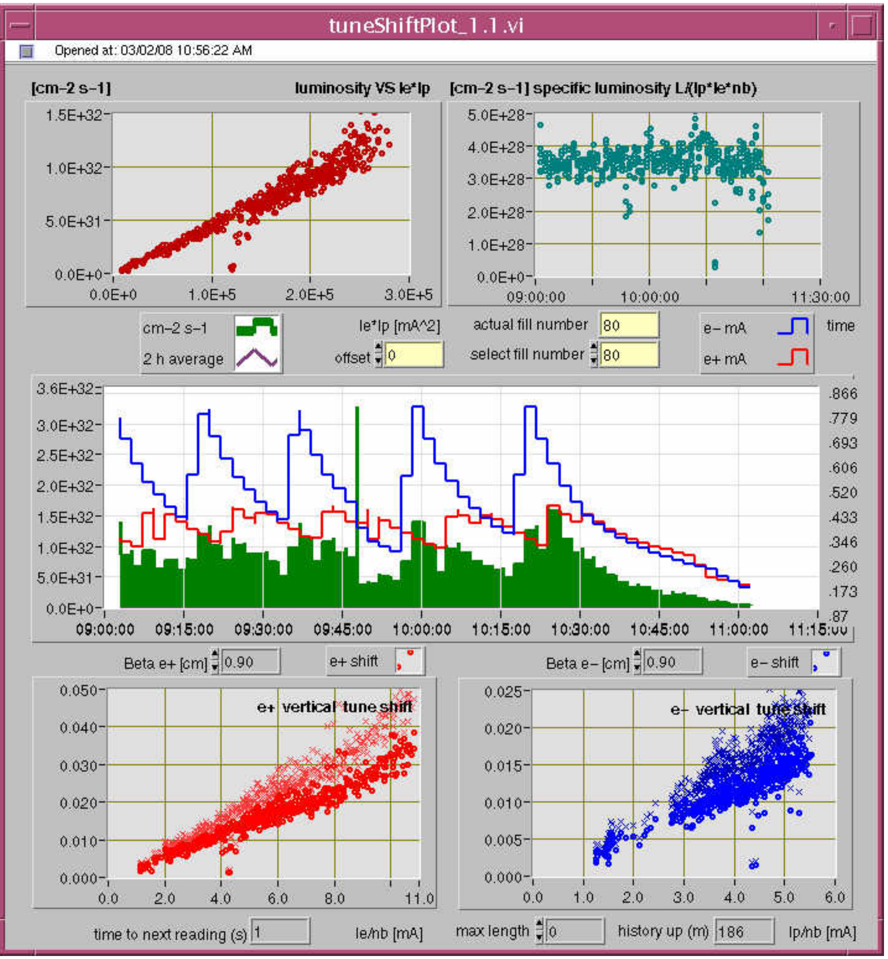
LUMINOSITY PERFORMANCES

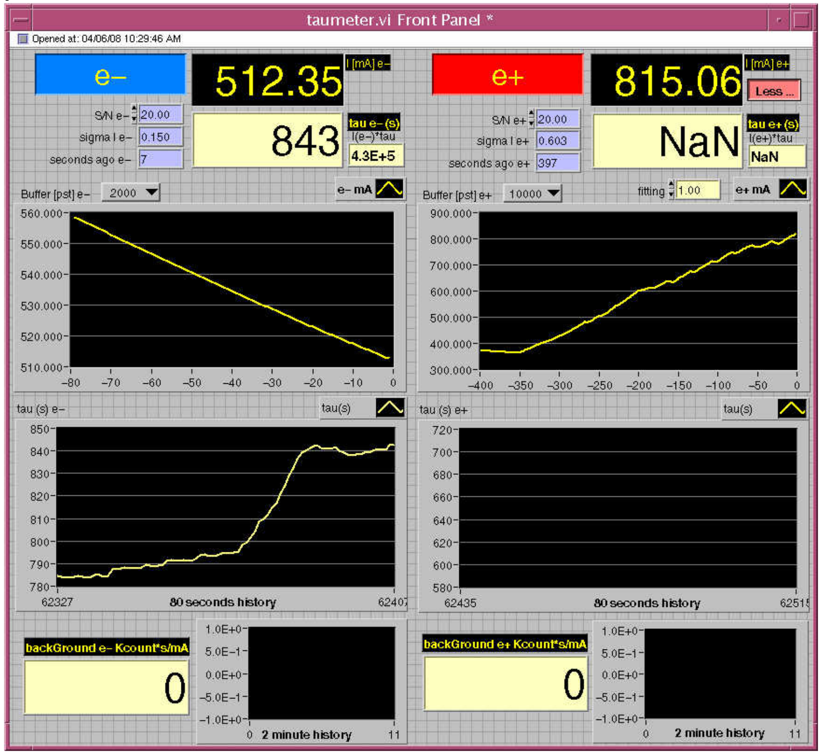
- **Specific *Luminosity* is 3÷4 times higher** than during the past best runs, **as expected**.
- ξ^{-} ξ^{+} exhibit a linear behaviour

109 colliding bunches



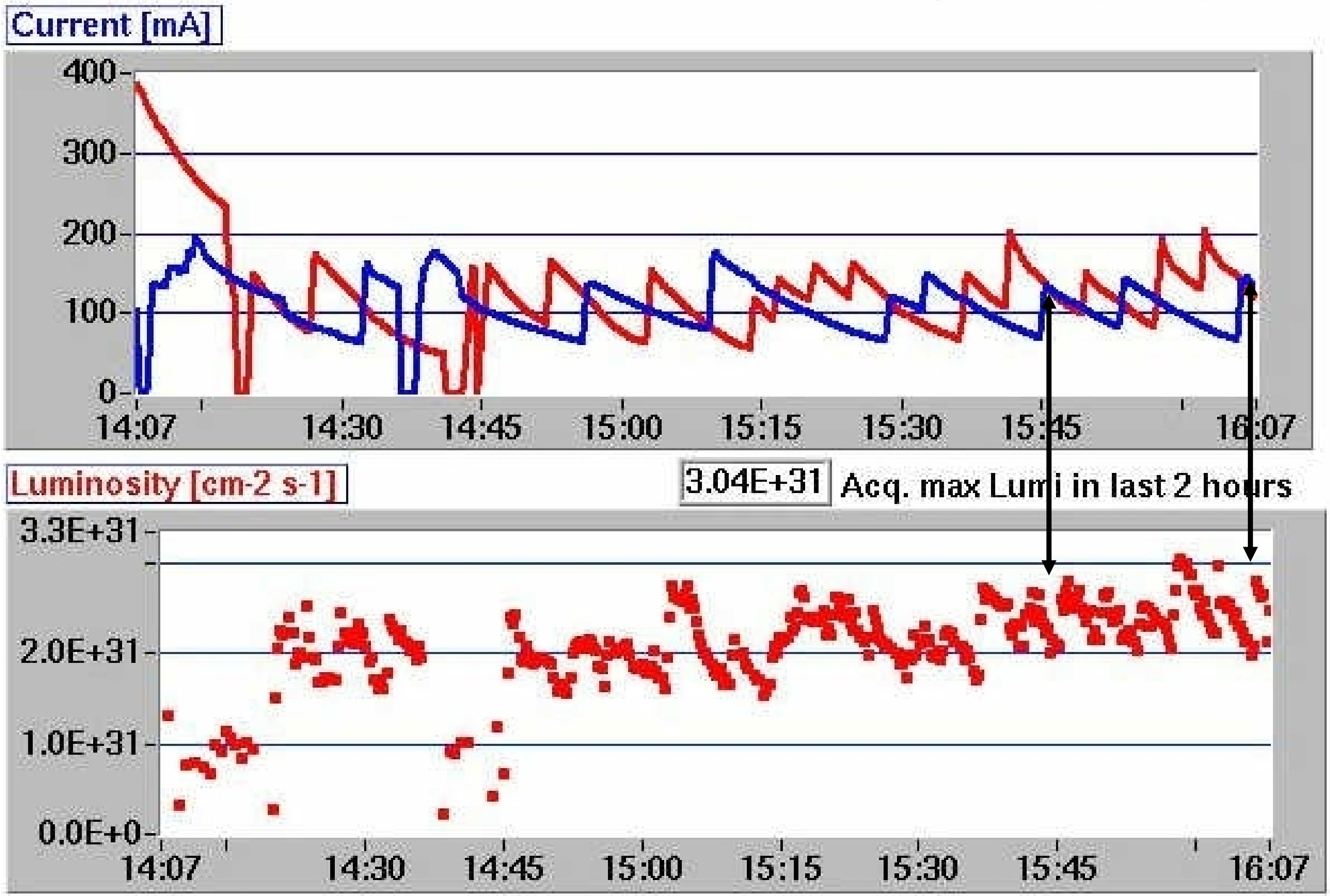
Achieved 1200mA e^- and 850mA e^+ in collision, L_{max} simultaneous about 700mA against 700 mA





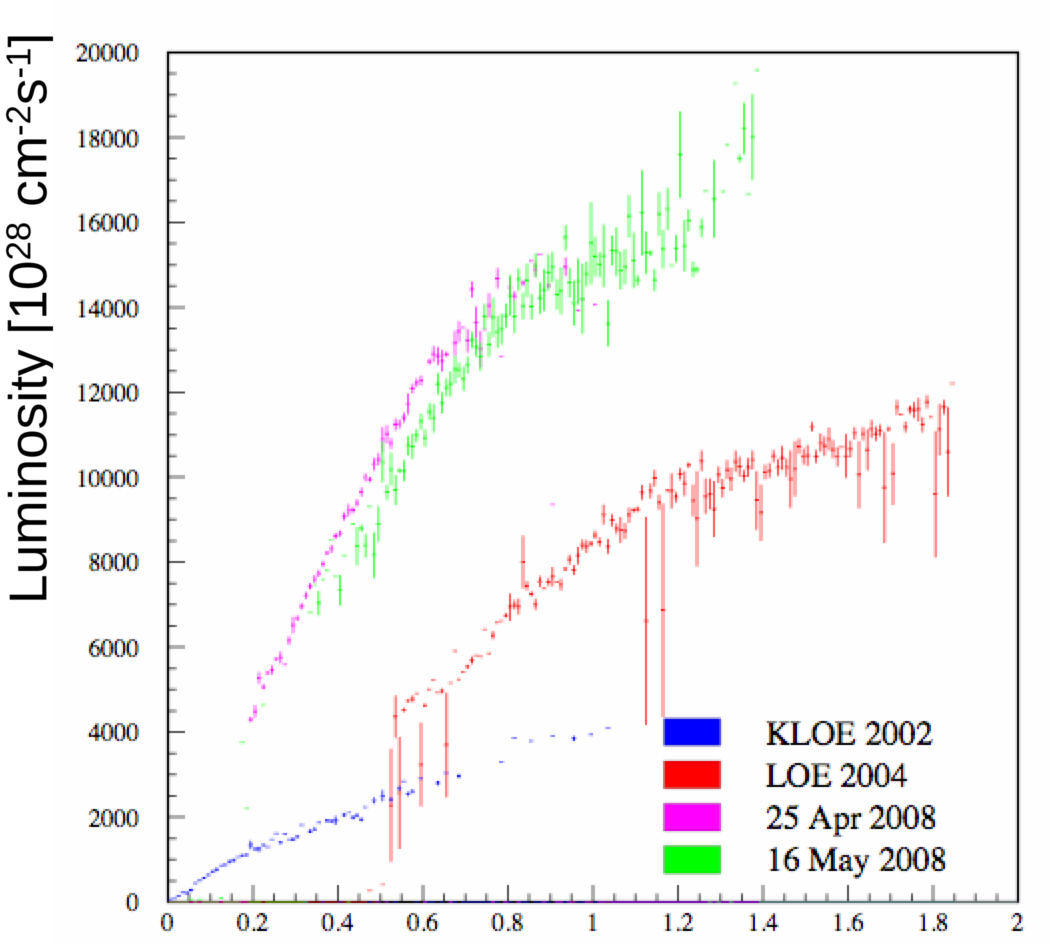
Luminosity at low current

10 colliding bunches
$I_b \approx 13$ mA/bunch
$L \approx 3\times10^{31} cm^{-2}s^{-1}$



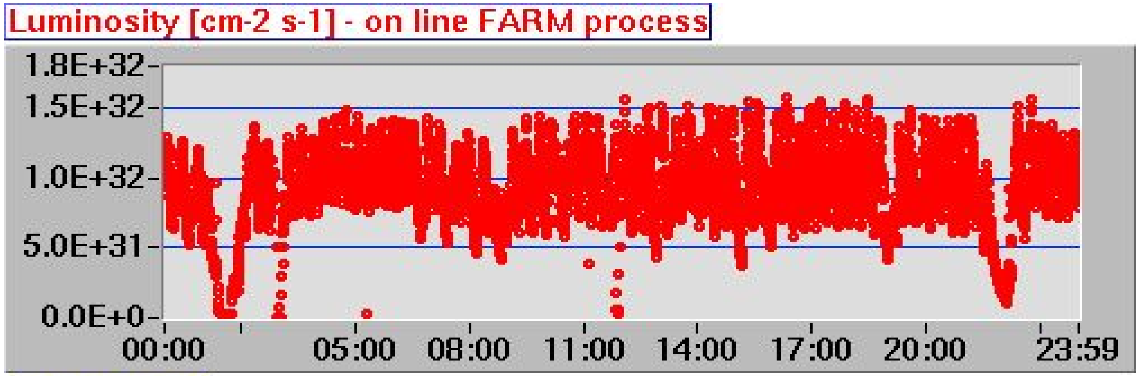
Luminosity versus colliding currents

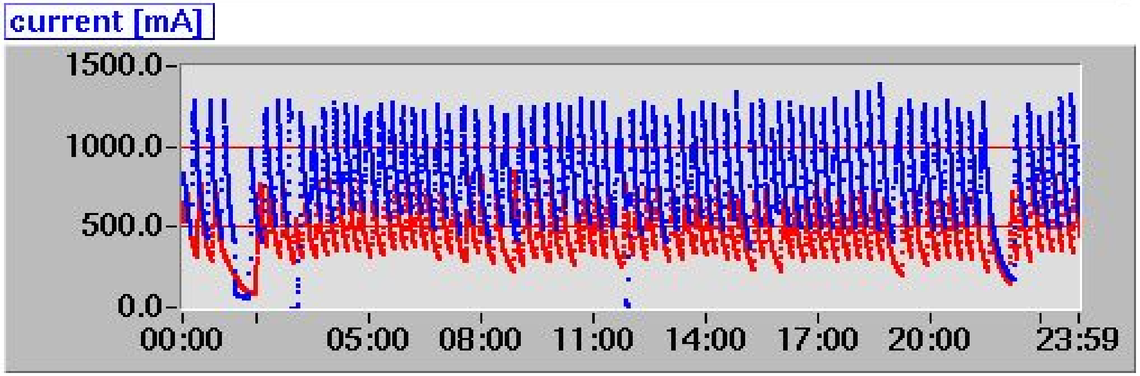
(*L* from BHABHA monitor)

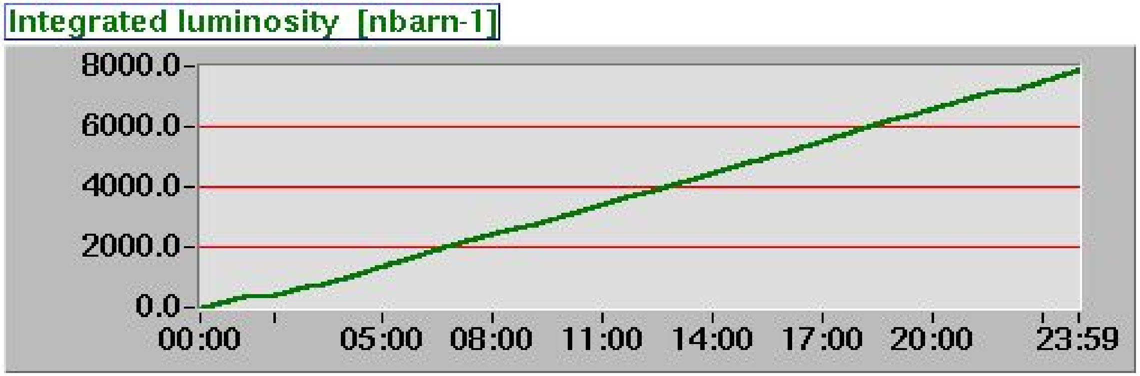


... Higher as expected

"BEST" INTEGRATED LUMINOSITY on APRIL 25th







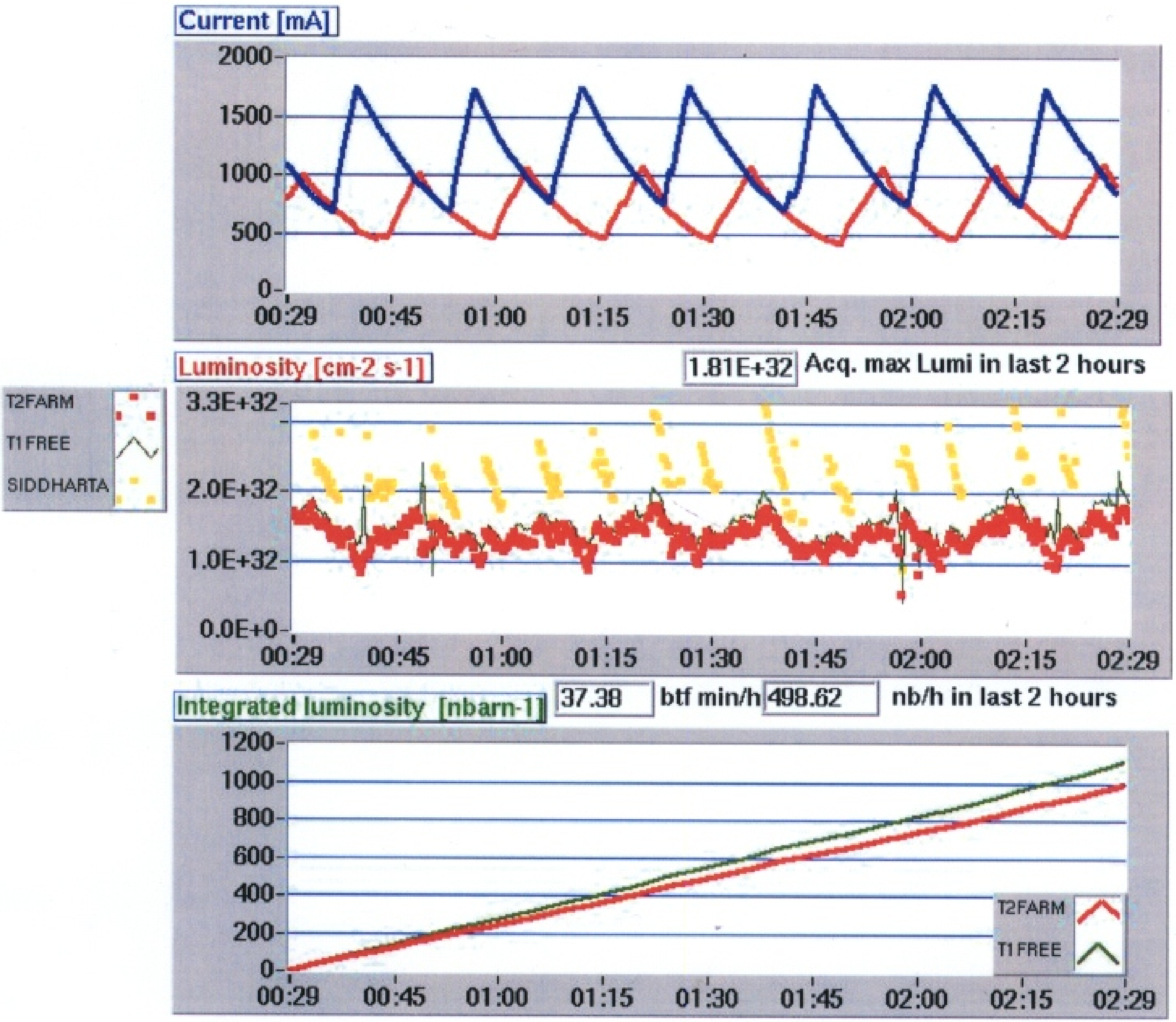
L measured by Bhabha monitor with background subtraction

Maximum interacting currents
≈800+800 mA

in 90 colliding bunches

$L_{\int \mathrm{day}} = 8\ \mathrm{pb}^{-1}$

2 hours luminosity



Luminosity by:

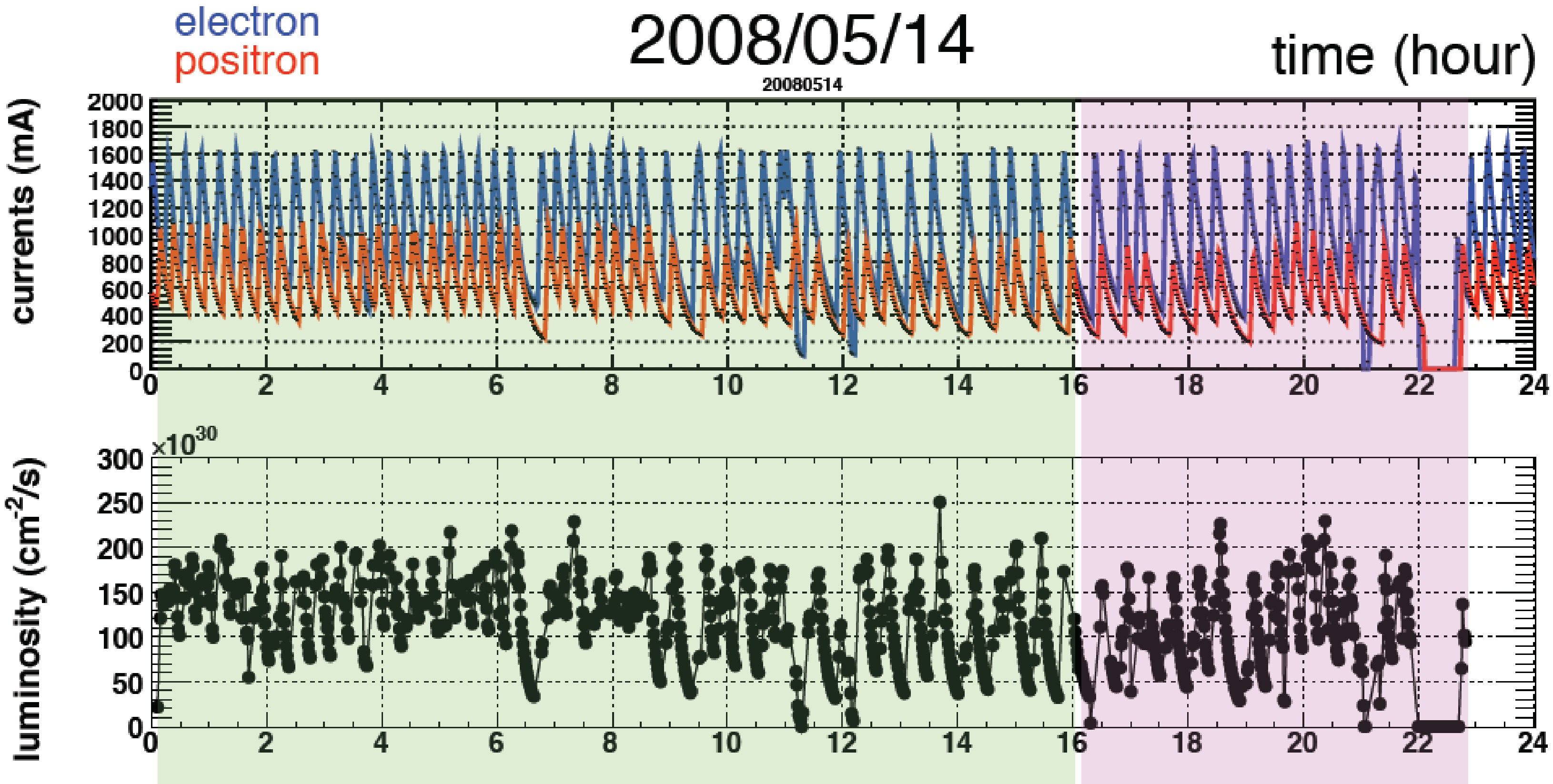
- kaon monitor without background subtraction

-- Bhabha monitor without background subtraction

- Bhabha monitor with background subtraction

$$L_{\int 1h} = .5\ pb^{-1}$$

Kaon monitor luminosity (average on a single run scaled by the product of stored currents)



L measured by Kaon monitor and by Bhabha calorimeter do not agree:

$$L_{KAON} \sim 1.4\ L_{BHABHA}$$

due to:

- geometric acceptance which has to be reevaluated by Montecarlo after shielding modification
- assumption in the Montecarlo itself

Background optimization

Background has been optimized by:

- Beam orbit & corrector strengths minimization
- Scrapers position tuning
- Improving beam acceptance
- Tuning the colliding beam positions in the RCR and IR1
- Installing additional shielding around IR1 to improve signal/noise ratio on the Siddharta SDDs.

Still the background rate must be reduced by a factor 5 to fit the requirements imposed by the SIDDHARTA experiment.

Present Achievements

Bunch length **~ 1.7 cm** @ 10mA

Stored current ***e^- 1790 mA*** (95 bunches 450 mA e^+)

Stored current ***e^- 1150 mA*** (120 bunches)

Current in collision ***1200 mA e^-** and **1100 mA e^+*** (95 bunches)

Transverse betatron ***coupling k ~ 0.4%***

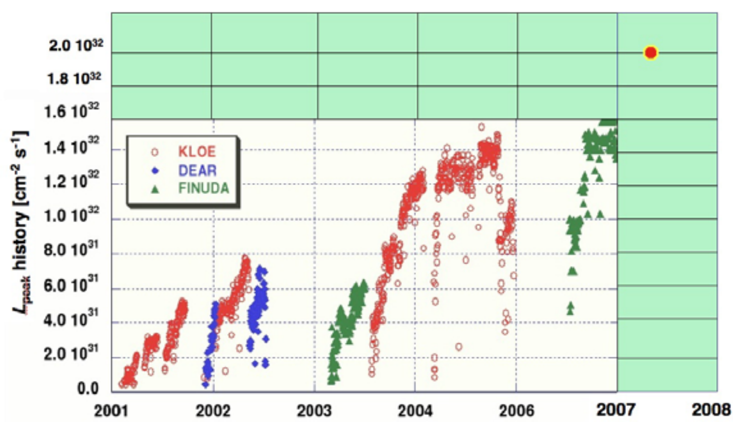
measured σ_y @ ***IP1 ~ 4 μm***

luminosity measured by Bhabha monitor (best values since now):

L_{peak}= $2 \cdot 10^{32}$ $cm^{-2}s^{-1}$ $\Rightarrow$ ~ 25% better than the past DAΦNE record (1.6 10^{32})

$L_{\int day}$= 8 pb^{-1}

$L_{\int 1\ hours}$= .5 pb^{-1} *(it was .44 pb^{-1} during KLOE run)*



Further developments

- Equalization and availability on line of all kinds of luminosity measurements direct and estimated:
  - Bhabha
  - Kaon monitor with background subtraction
  - γ monitor
  - "geometric" luminosity from currents and beam sizes
- Increase number of colliding bunches from 95 to 110
- β_y^* from 10 to 9 mm
- Faster switch between electron and positron injection and faster positron injection rate
- Increase Crab sextupoles intensity
- Install final Siddharta detector
- **Overall luminosity increase by ≈50% expected**

Perspectives

Scaling the present data from the BHABA monitor:

Projecting $L_{\int 1\ hours} = .5\ pb^{-1}$ over a day $\Rightarrow$ $L_{\int day} \sim 12\ pb^{-1}$

Assuming 80% uptime for the collider $\Rightarrow$ $L_{\int month} \sim .3\ fb^{-1}$

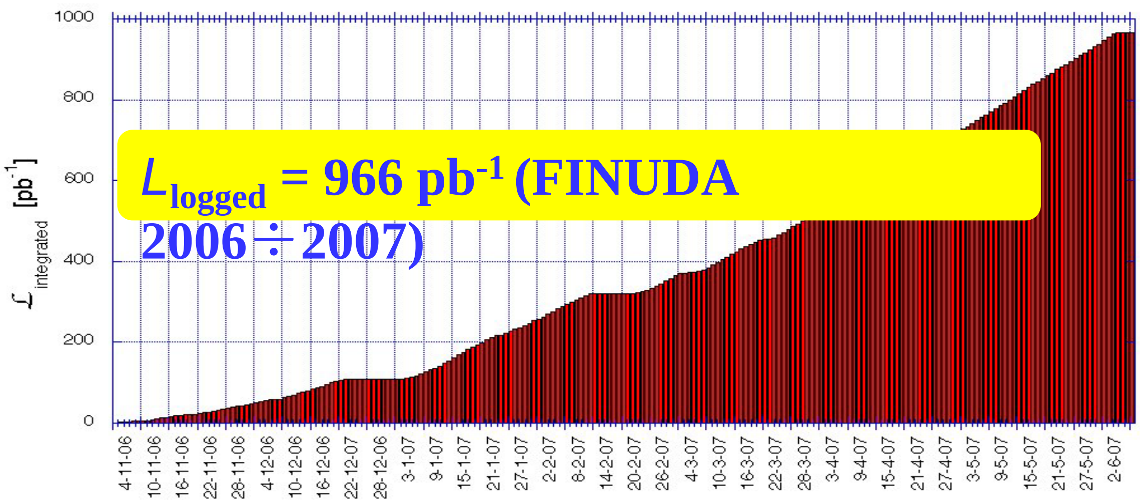
lower limit

Assuming to get $L_{peak} = 4{\cdot}10^{32}\ cm^{-2}s^{-1}$ from the developments under way

$L_{\int month} \sim .5\ fb^{-1}\ s$

conservative

SIDDHARTA can acquire in ~ 2 months what FINUDA collected in a six months run



Conclusions

- The **DAΦNE collider has been successfully commissioned** in the new collision scheme mode and is presently **delivering luminosity to the Siddharta prototype** detector to establish the best background rejection configuration.

- Peak and average luminosity are already sufficient to **perform the Siddharta experiment in few months**, provided background conditions are improved by a significant amount. Tight collaboration with the Siddharta team is under way to reach this goal.

- Further improvements of machine operation are likely to fulfill the requirements for a **future roll-in of KLOE and FINUDA**.