DAΦNE achievements with Large Piwinski Angle and Crab-Waist Collision Scheme

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(on behalf of the DAΦNE Team)

Japan-Italy Collaboration Meeting "Crab Factories"
Wednesday December 10th 2008 LNF Frascati

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Topics

DAΦNE luminosity achievements after the upgrade

Recent Luminosity breakthrough after a careful activity aimed at:

- *improving the collider performances by:*
  - Optics refinement
  - Beam dynamics studies
  - Subsystem developments to improve L and $L_{integrated}$
- *optimizing data taking and background for the SIDDHARTA experiment*

DAΦNE commissioning milestones (N0v 07 ÷ Jul 08)

- ***Commissioning*** started at the end of November 2007
- Both ***beams stored*** in the first days of December
- February 2008 ***Crab-Waist sextupoles in operation***
- February 11th ***Luminosity monitor installation***
- Beginning of March first $L \sim 10^{32}$ cm^{-2} s^{-1} measured
- March 10th ***SIDDHARTA installation***
- First half of March new ***transverse horizontal feedback installed in the MRe*** ring
- May $L_{peak} \sim 2.2*10^{32}$ cm^{-2} s^{-1} ***measured.***

DAΦNE Upgrade Parameters

	DAΦNE FINUDA	DAΦNE Upgrade
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm x mrad)	0.34	0.26
β_x^* (cm)	170	26
σ_x^* (mm)	0.76	0.26
$\Phi_{Piwinski}$	0.36	1.9
β_y^* (cm)	1.70	0.90
σ_y^* (μm)	5.4 (low current)	3.1
Coupling, %	0.5	0.5
I_{bunch} (mA)	13	13
N_{bunch}	110	110
σ_z (mm)	22	20
L ($cm^{-2}s^{-1}$) x10^{32}	1.6	5

Larger Piwinski angle

Lower vertical beta

Already achieved

Ring Optics Commissioning

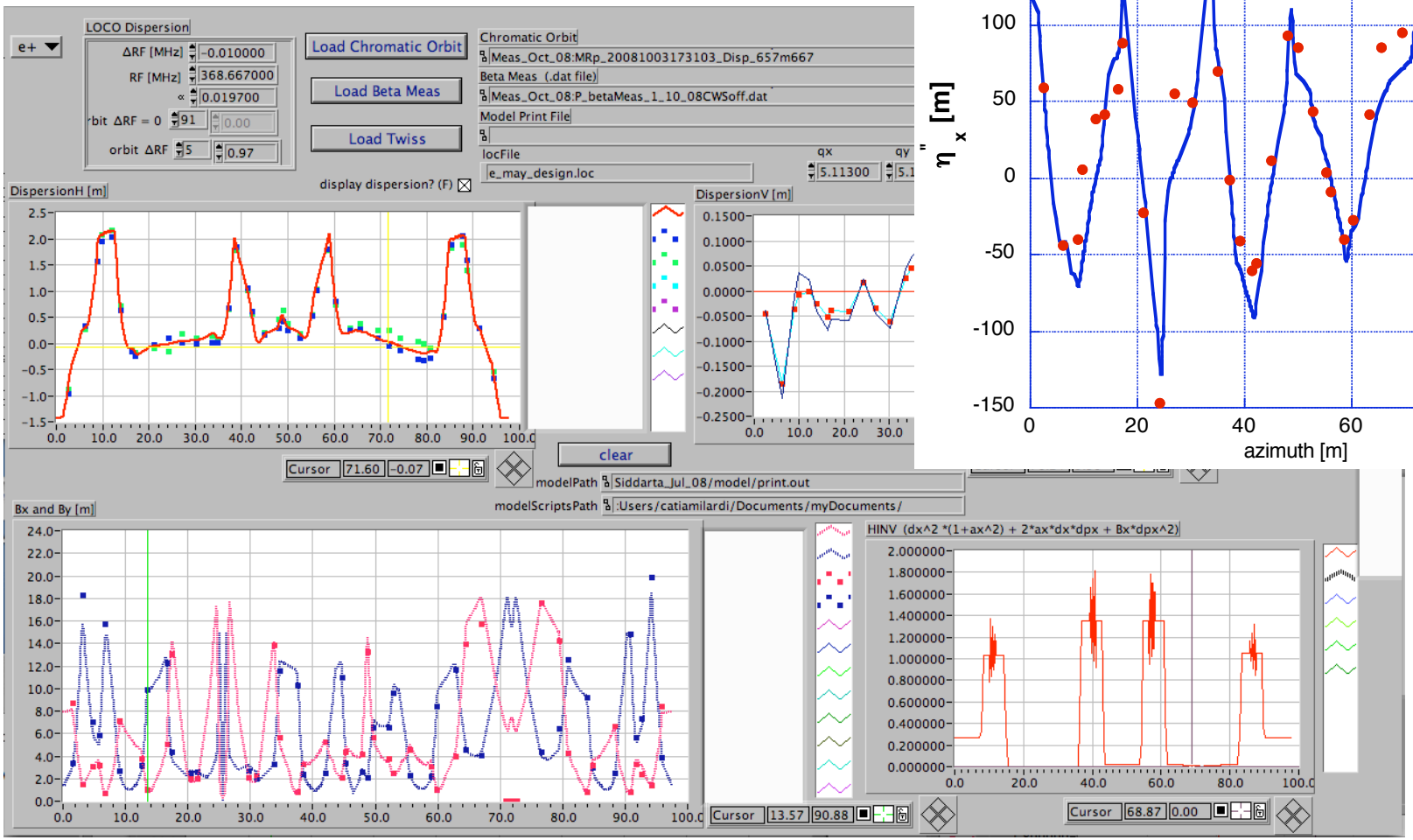
Ring Optics optimization required to:

- adjust the position of the low-β PM QUADs in order to compensate gradient slightly out of specifications
- fix misalignment errors in some elements
- correct transverse betatron coupling mainly by rotating the PM focusing QUADs in the IR
- minimize η_y by correcting the global orbit and centering the beam vertical position in the arc SXTs
- add 2 electromagnetic QUADs symmetrically with respect to the IP in order to meet the phase advance requirements imposed by the Crab-Waist collision scheme
- establish procedure for the CW SXTs alignment in single beam operation mode by:
  - ✓ switching on one SXT at the time
  - ✓ recovering the tune shift and the coupling variation by centering the horizontal and the vertical orbit respectively in the SXT
  - ✓ verifying that powering both CW SXTs $\nu_{x,y,}$ κ, τ and background remain constant

Ring Optics model

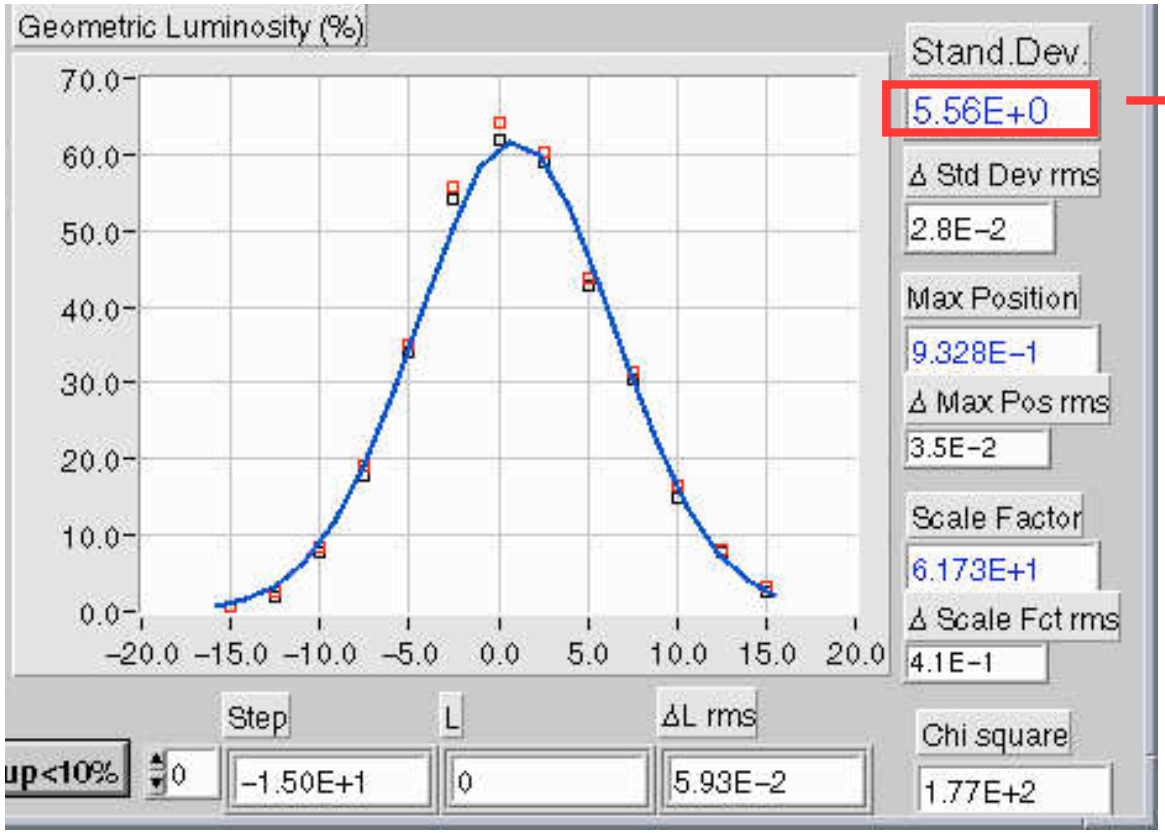
Ring model matches quite well beam measurements in terms of:

- linear optics $\nu_{x,y}$, $\beta_{x,y}$, η_x , ε_x
- non-linear optics energy acceptance and η''_x,



Vertical beam-beam *Luminosity scan*

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



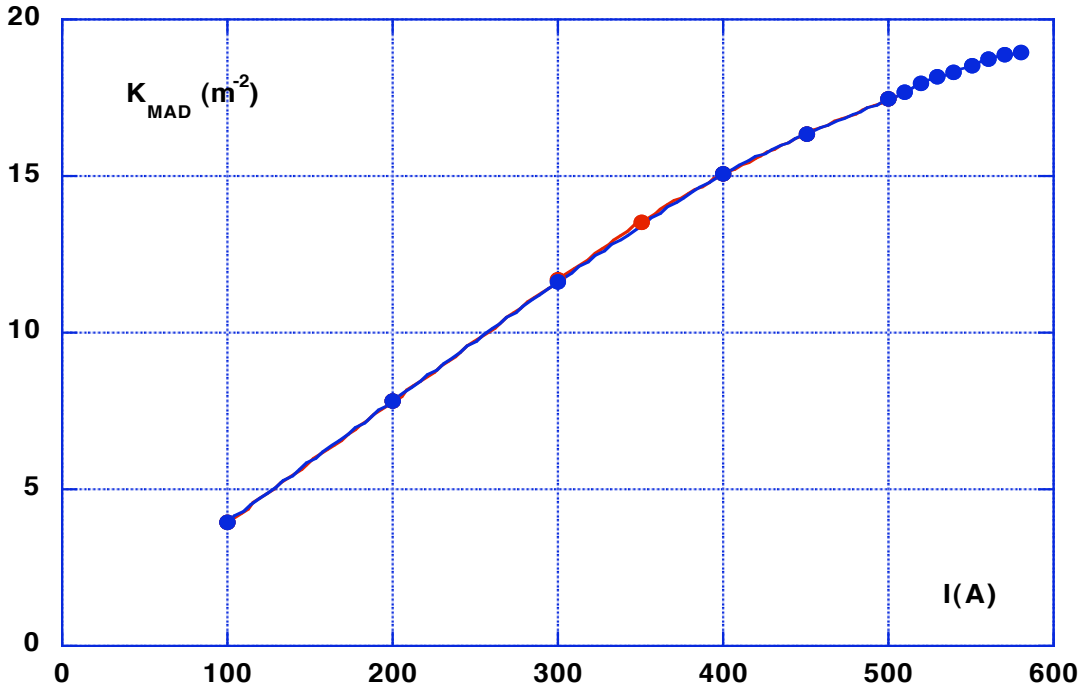
$$\sigma_y \approx 3.5\mu m$$

Design value 3.1μm

July 1st 2008

Crab sextupoles parameters

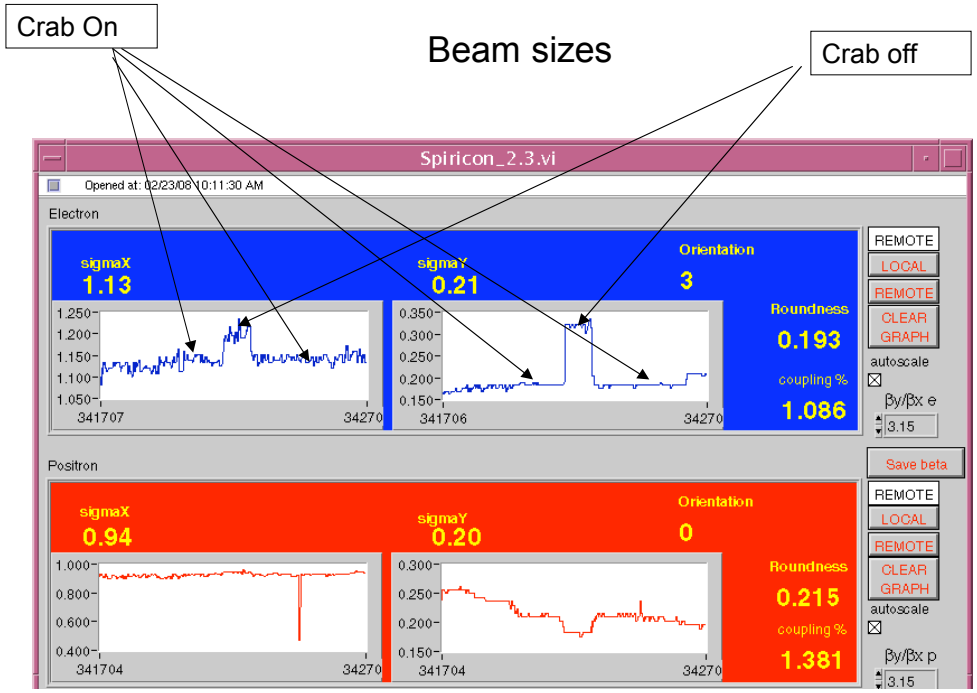
$$k_s = \frac{1}{2\theta}\frac{1}{\beta_y^* \beta_y^{sext}}\sqrt{\frac{\beta_x^*}{\beta_x^{sext}}}$$

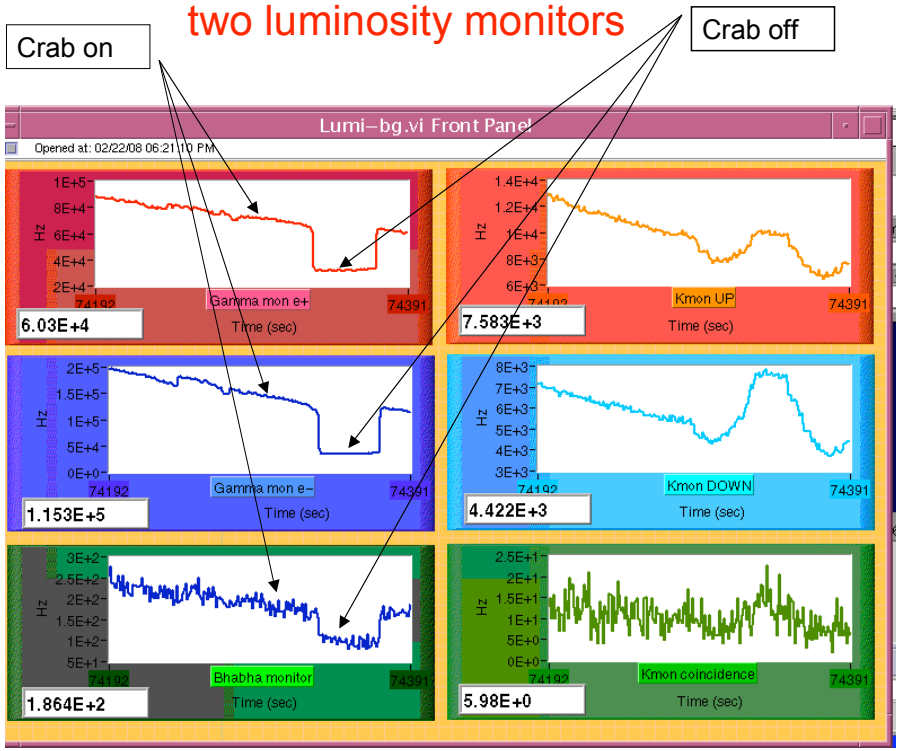


θ (mrad)	25
β_y*(mm)	10
β_x*(mm)	250
β_y^{sext}(m)	13.5
β_x^{sext}(m)	4.2
K_s (m^{-2})	36

On June 2008 Installed 4 "large" sextupoles of the arcs with $K_{max} \approx 25\ m^{-2}$, Now running at $K_s(m^{-2}) = 21$

Crab Waist Works: First Experimental Evidence

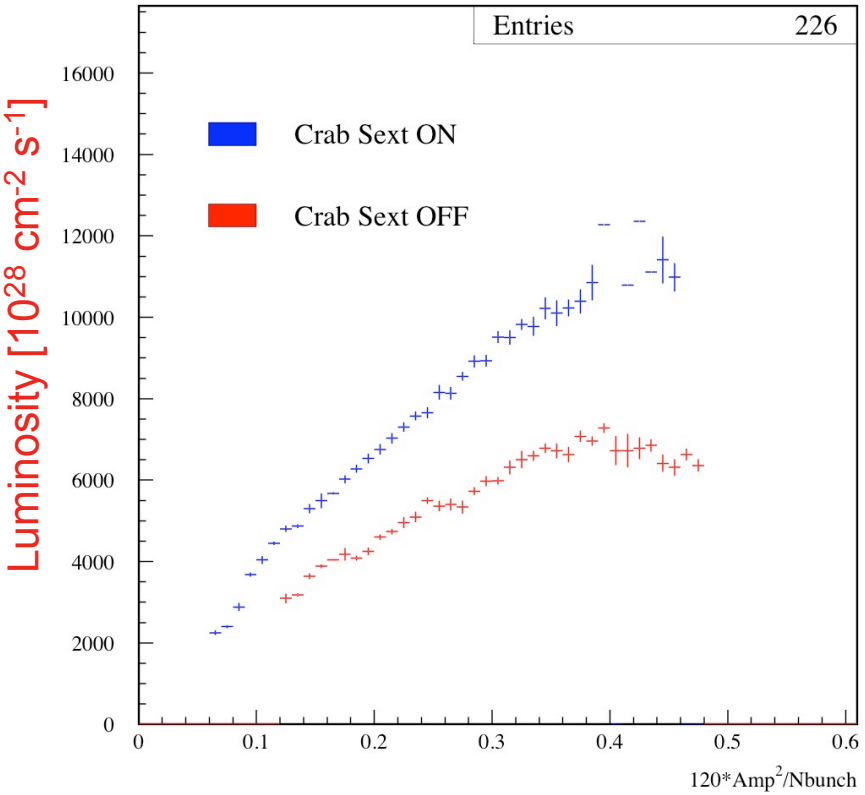


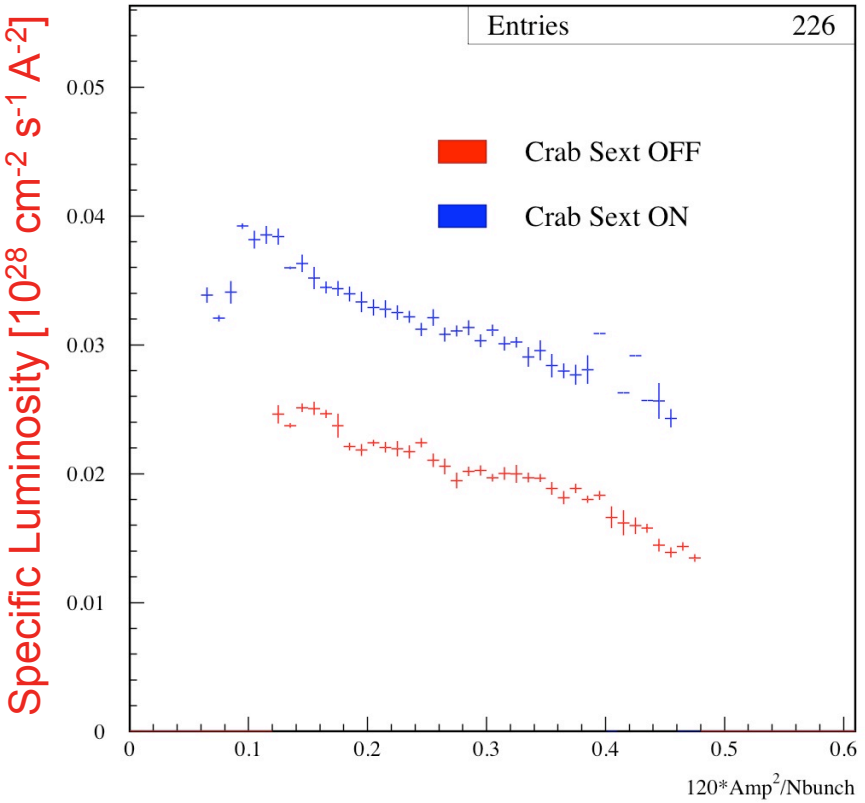


Crab Sextupoloes working since the first time they have been tested

Luminosity with CRAB Sextupoles ON/OFF

95 bunches

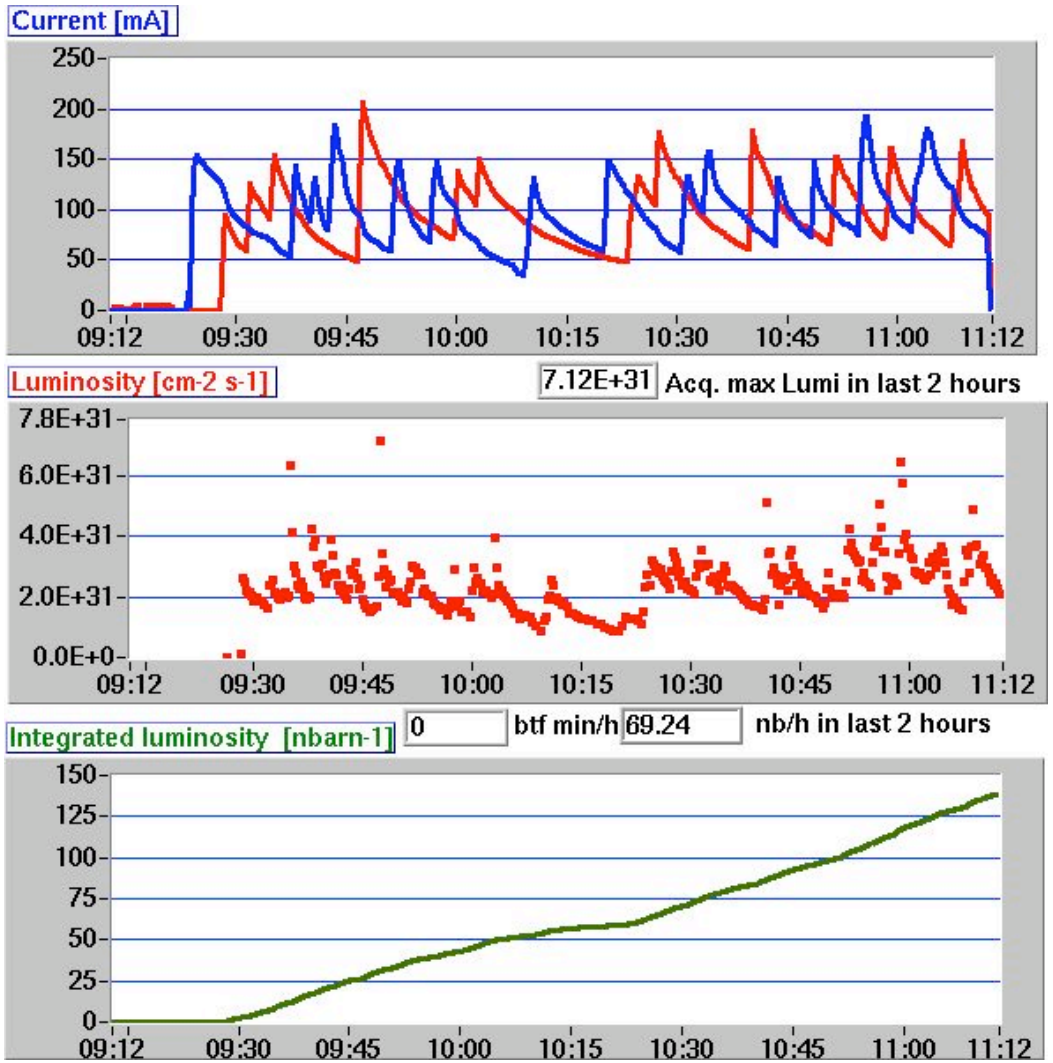




$$L_{specific} = \frac{L_{peak}}{N_{bunch} I^{+} I^{-}}$$

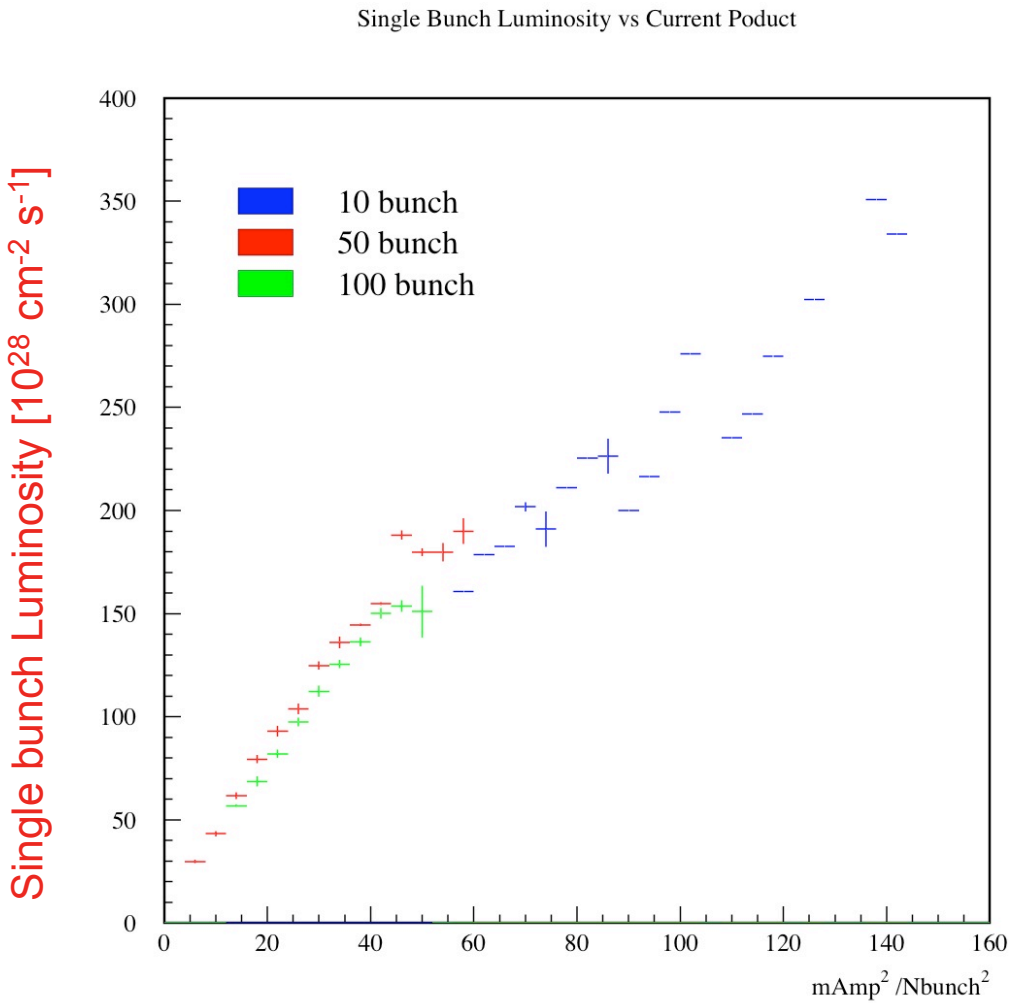
Luminosity at low current

10 colliding bunches
$I_b \approx 13$ mA/bunch
$L \approx 4 \times 10^{31} cm^{-2} s^{-1}$



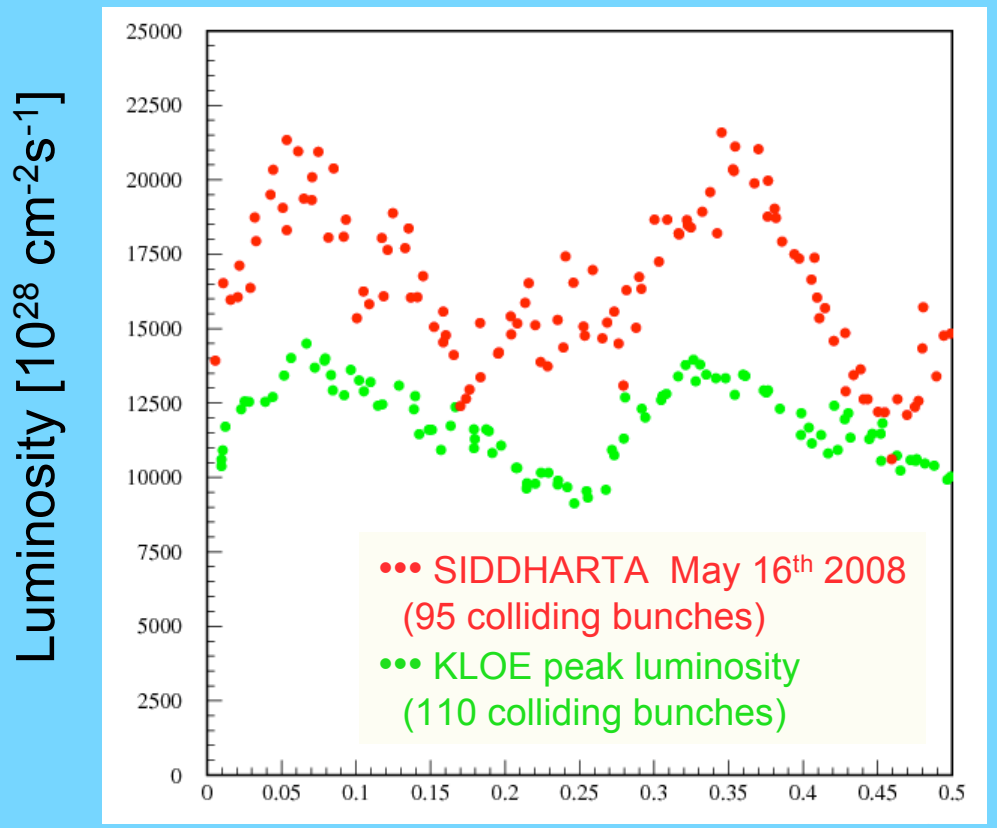
July 26th 2008

Single bunch Luminosity versus bunch pattern

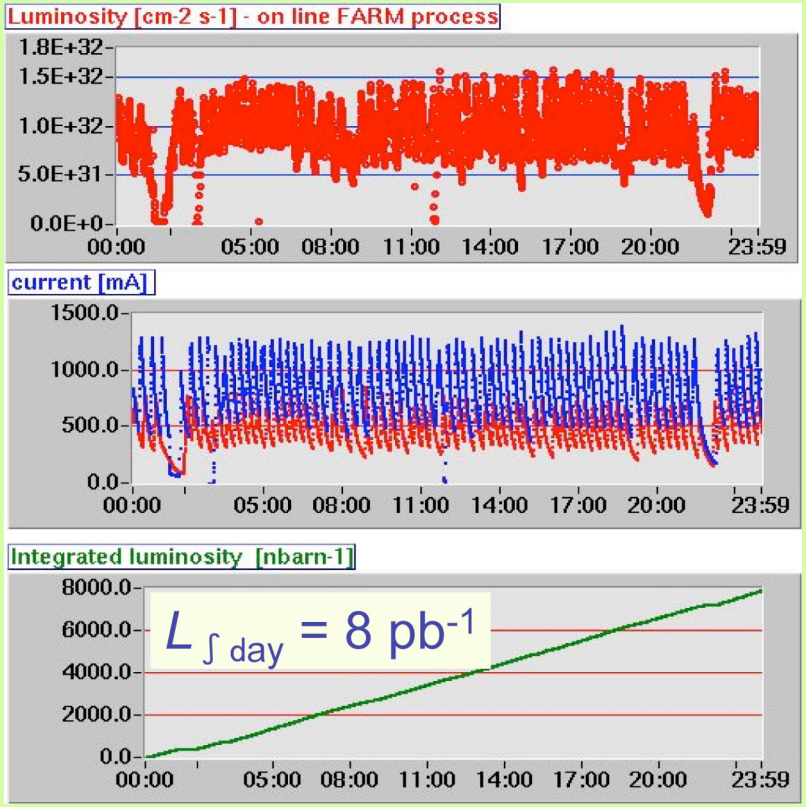


May 2008 achievements

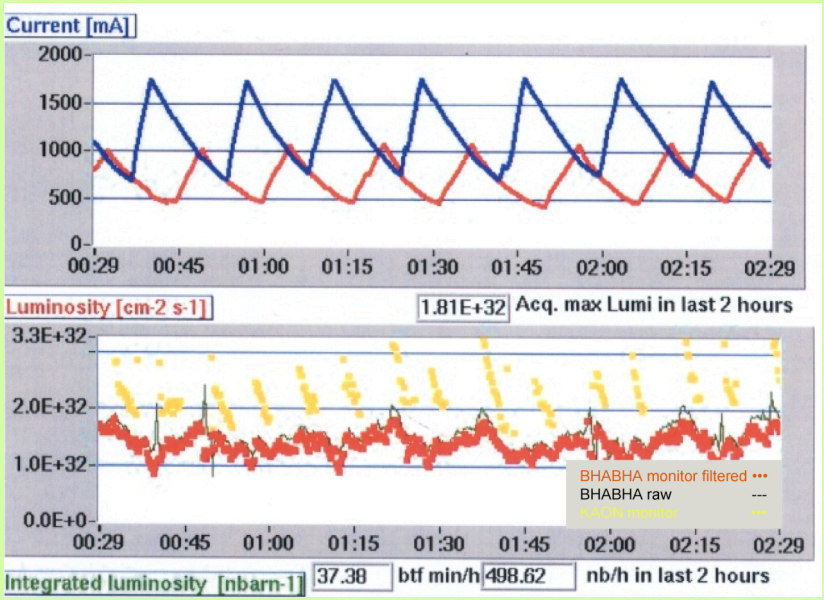
L_{peak} **= 2.2·10^{32} cm^{-2}s^{-1}** ⇒ ~ 30% better than past DAΦNE record (1.6 10^{32})
$L_{\int day}$ **= 8 pb^{-1}**
$L_{\int 1\ hours}$ **= .5 pb^{-1}** *(it was .44 pb^{-1} during KLOE run)*
Bunch length **~ 1.7 cm** @ 10mA
Current in collision ***1200 mA e$^-$*** *and* ***1100 mA e$^+$*** (95 bunches)



Integrated Luminosity



Best $L_{\int day}$



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

(0.44 pb^{-1} during the KLOE run)

DAΦNE operations (Sep ÷ Dec 2008)

- *August **SIDDHARTA** final setup installation*
- *some components of the **e+ longitudinal feedback** have been substituted (delay lines, phase shifter, etc.)*
- ***$I^+_{treshold}$ ≤ 0.8 A***
  due to a fast transverse horizontal instability (mainly mode m-1)

  ✓ studies aimed at sorting out possible sources of instability:
  anomalous wake field in the e^+ vacuum chamber

  ✓ grow-rate studies by:

  Solenoids on/off

  halving β_x in the RF cavity

  varying the relative horizontal phase advance between Wigglers

  $\Delta\nu_x \sim 0.5$ in PS1-PS2

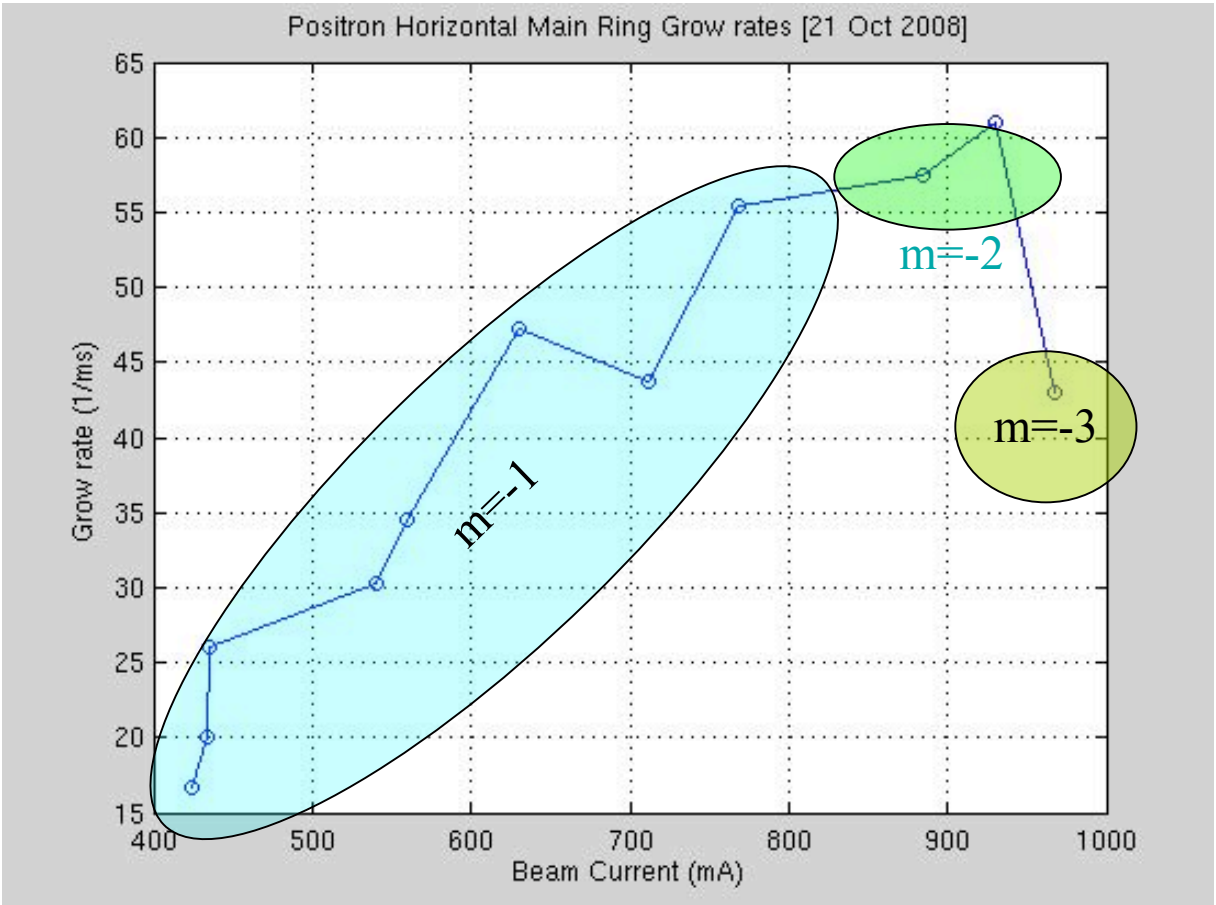
  $\Delta\nu_x \sim 1.$ In PS1-PS2 & RCR

  ✓ second transverse horizontal feedback implementation

- discorying and mitigating unexpected beam dynamics limiting factor

Very meaningful but did not improve $I^+_{treshold}$

Instability grow rates measurements for the e+ beam



The beam current does not seem limited by the horizontal instability

New e^+ Transverse Horizontal Feedback

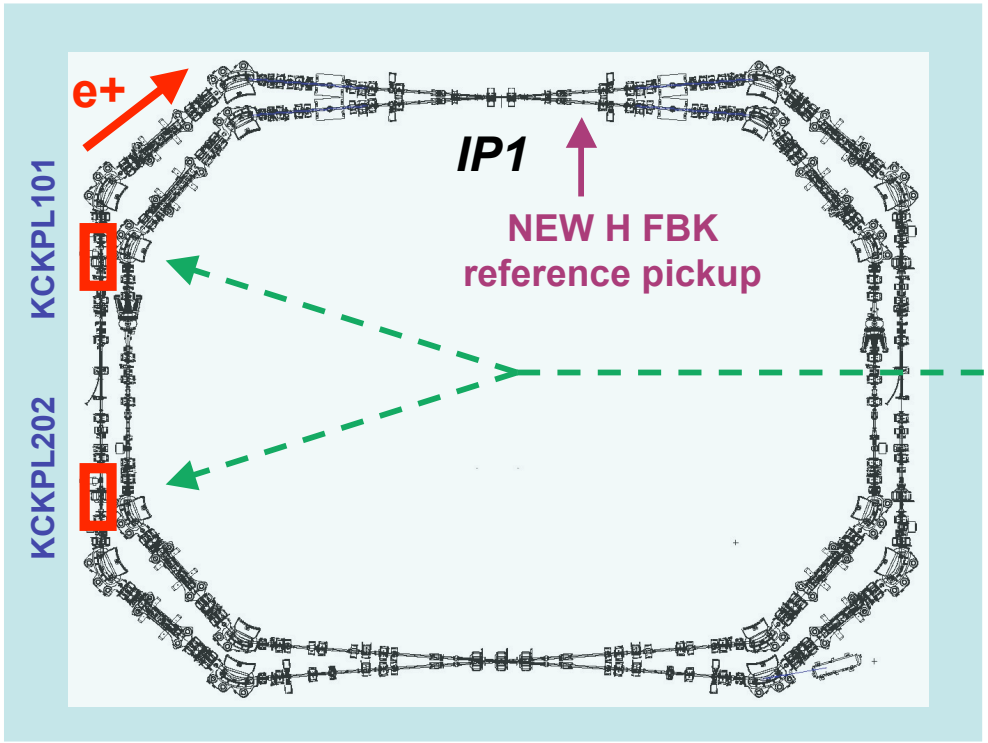
The damping times of the two feedbacks add up linearly

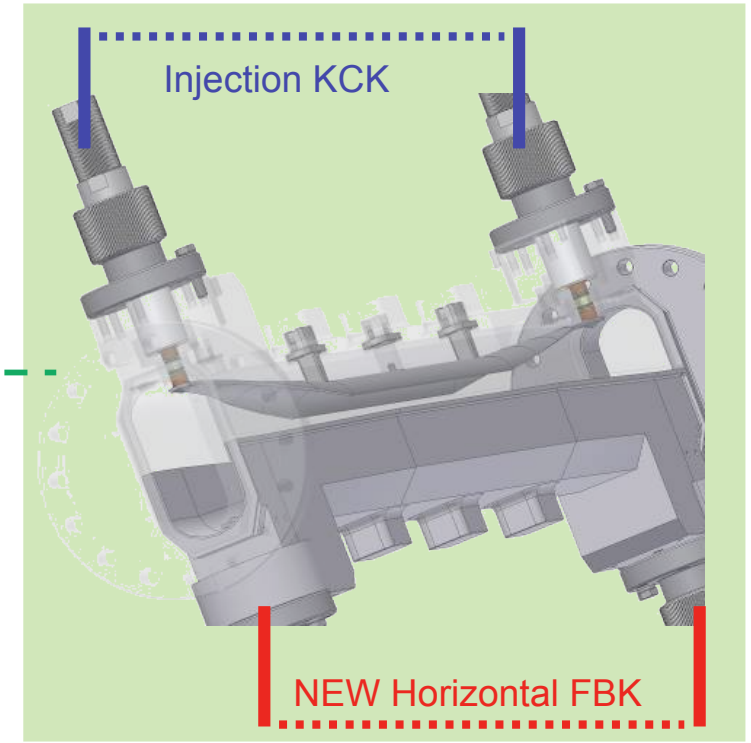
Damping time measured:

80 ms^{-1} (1 FBKs $t_{damping}$~ 10 μs)

200 ms^{-1} (2 FBKs $t_{damping}$~ 5 μs)

The power of the H FBK has been doubled

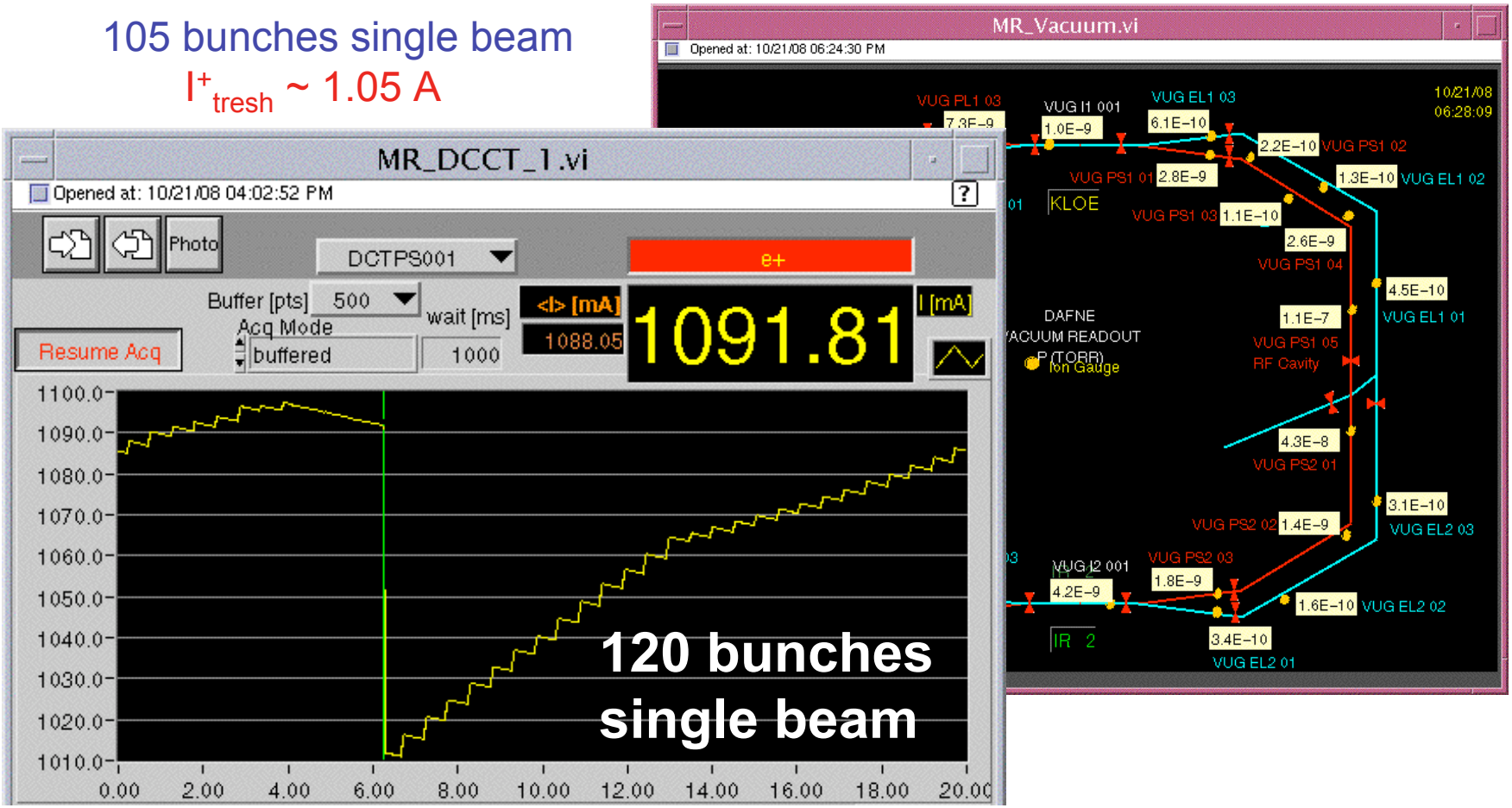




e^+ maximum beam current

105 bunches single beam

I^+_{tresh} ~ 1.05 A



In collision

I^+_{tresh} ~ 0.9 A

- injection saturates above I^+_{tresh}
- Few beam loss events at injection end cause the loss of the whole beam

Beam Dynamics Limiting factor

A real improvement in the DAΦNE operation has been obtained by pointing out and mitigating a 50 Hz noise propagating throughout the ground system and affecting:

- Some beam instrumentation (DCCT)
- e+ longitudinal and transverse feedbacks
- RF system

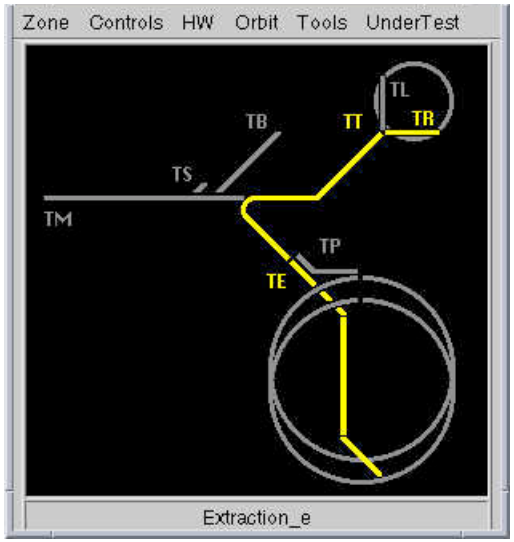
and producing:

- e+ beam longitudinal instability at high current and transverse beam size blow-up
- spurious phase modulation of the RF voltage at line frequencies (50 HZ and multiples), disturbances entered through the feedback system stabilizing the beam barycentric coherent oscillation mode

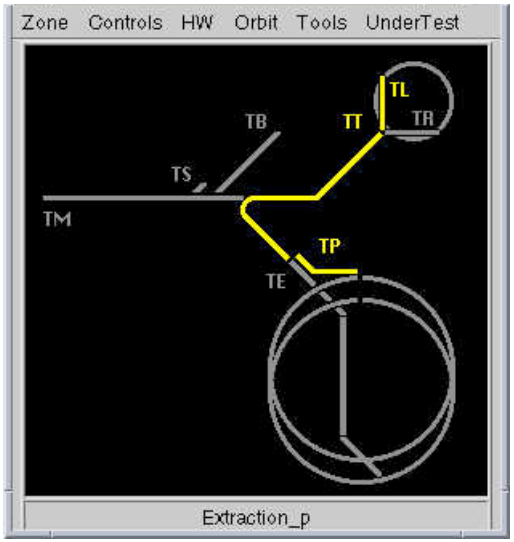
Under those condition :

- the beams were unstable and did no longer overlap correctly
- Beam -beam resonances were excited

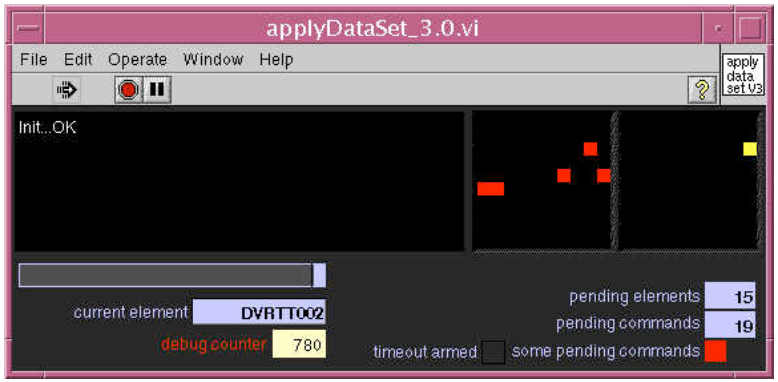
Injection System fast switch



Switch time
150 [s] --> 40 [s]



Obtained executing in parallel the procedure commands



(A. Stecchi)

General timing upgrade

The maximum number of pulses injected in the Accumulator has been increased:

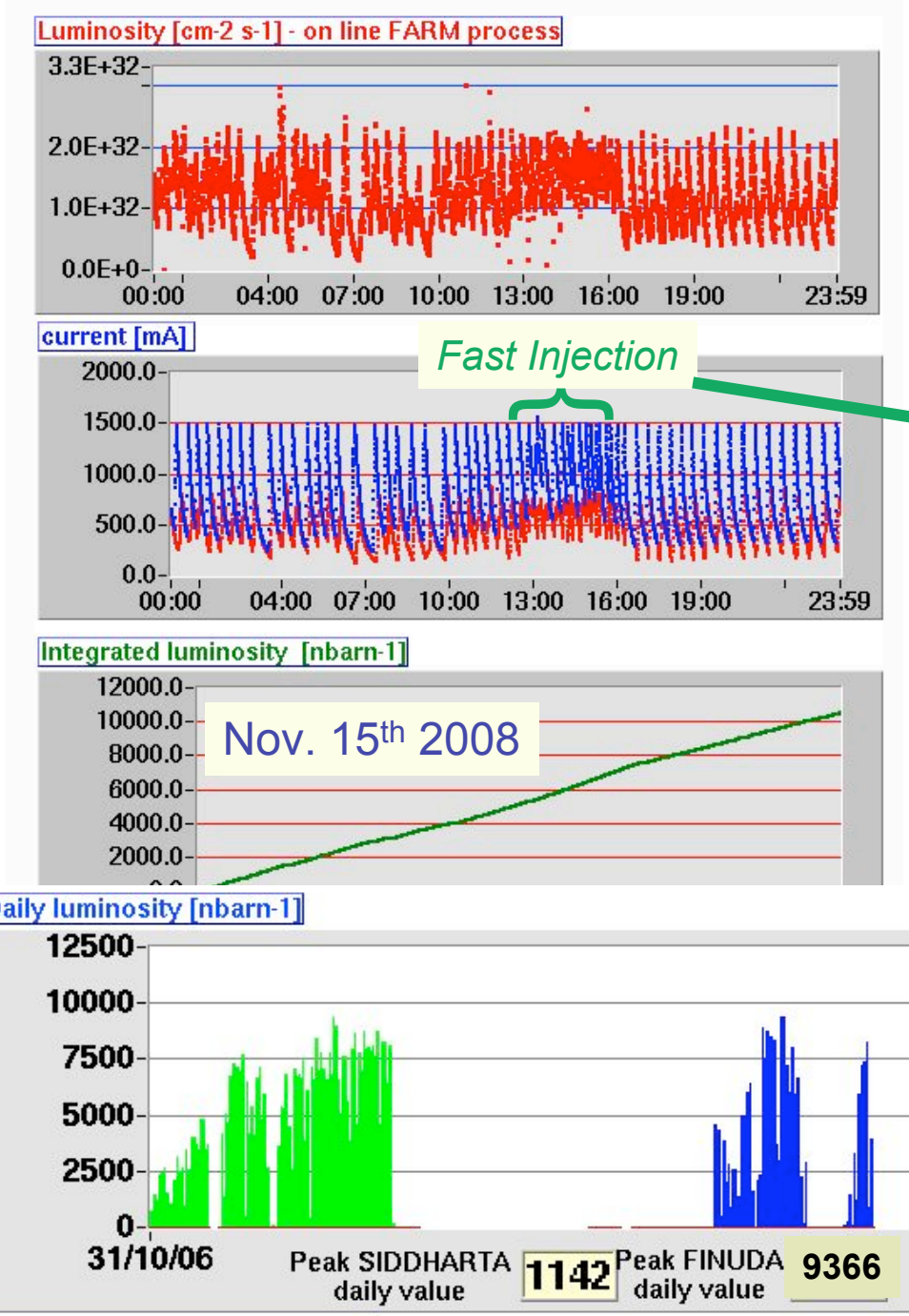
15 --> 17 $\Delta I \sim +13\%$ in the A (measured)

Useful to speed up the injection in the Main Rings.

Linac gun trigger can be inhibited for a given shot number when starting injection

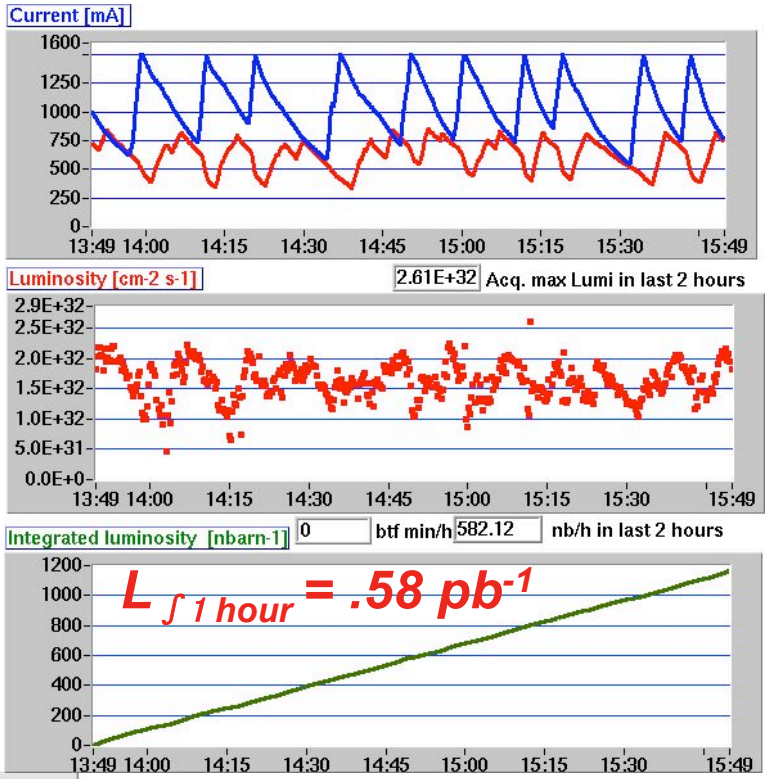
Useful to avoid dangerous background burst on the detector.

(G. Di Pirro)



Fast Injection

5 injections in 1 hour

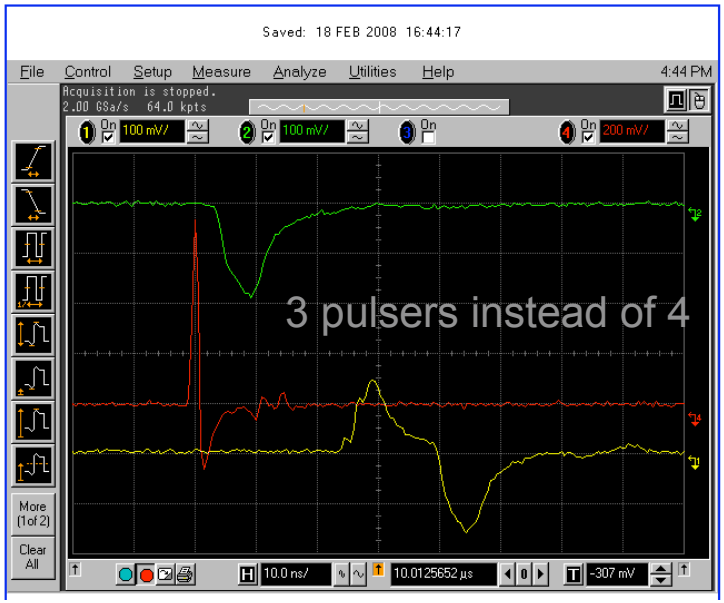


$L_{\int 1\ hour} = .58\ pb^{-1}$

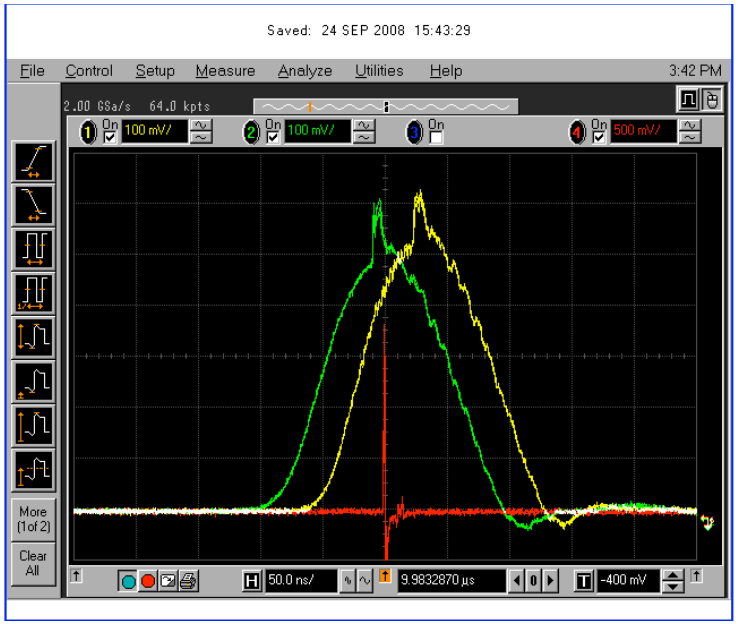
Fast injection is not compatible with the SIDDHARTA operations

Fast Hybrid Injection Kickers

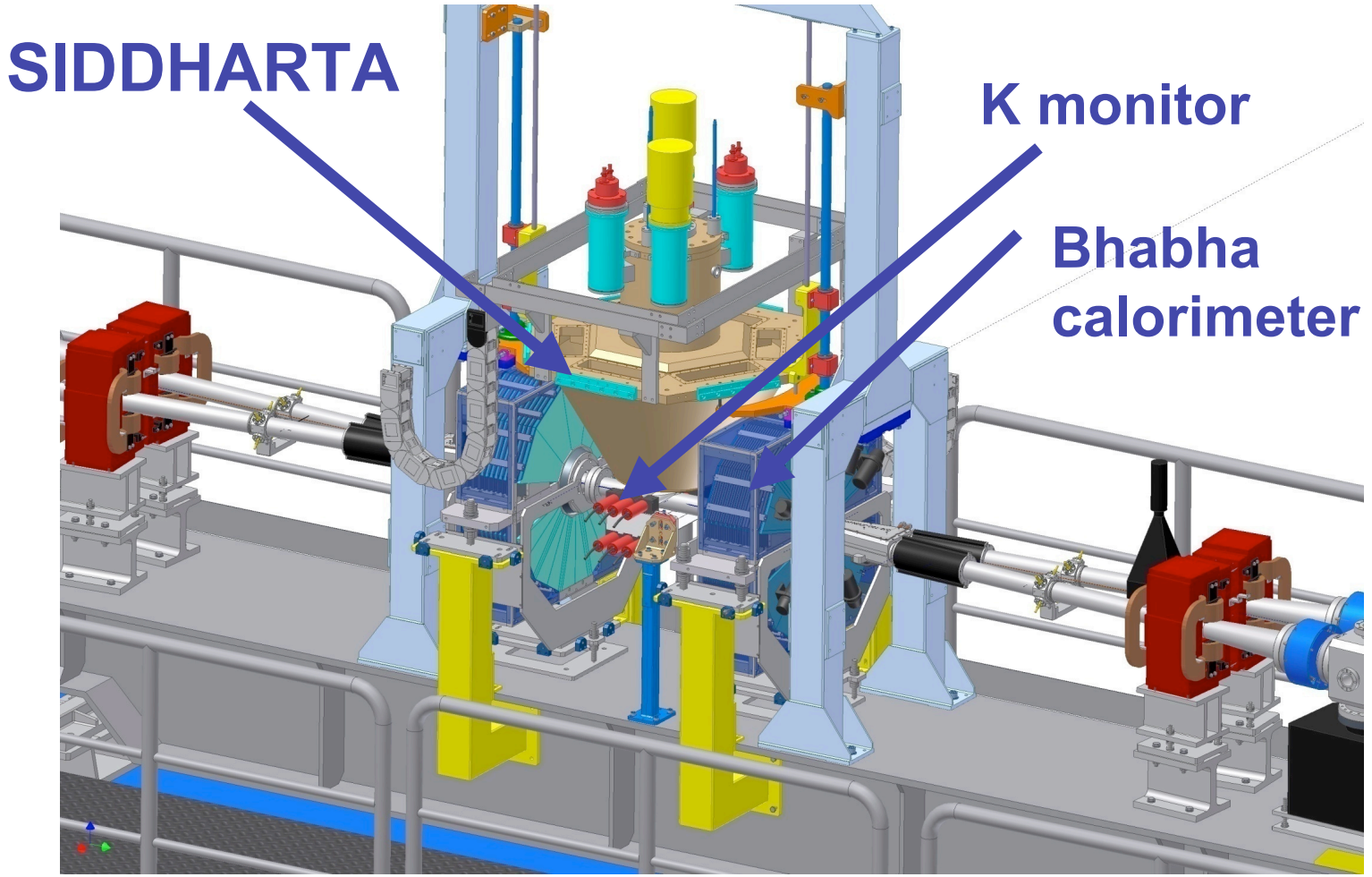
Fast high voltage pulsers (5 ns, 40 kV) had a faulty behaviour when working with the beam.



Fast low voltage pulser (5 ns, 20 kV) have been used to feed one out of the two striplines for each injection kickers.
The required voltage level is obtained powering the second stripline by means of the ordinary pulser (12 kV).



BHABHA monitor



- BHABHA monitor geometric acceptance has been revaluated by Montecarlo after SIDDHARTA installation
- Phototube calibration
- Time window for the background subtraction optimized

Background during beam injection

After the SIDDHARTA detector installation the beam injection was producing high background rates causing SDD detectors latch-up.

For the e^+ beam the problem has been fixed by closing the injection bumps and optimizing the injection process.
As a result the counting rate returned by the kaon monitor, in single beam during the injection, was reduced to few KHz.

The same approach did not work for the e^- beam.
It was impossible to have a reasonable injection efficiency with the injection septum and injection kickers set to their nominal values.
The **injection septum has been mechanically aligned** obtaining:

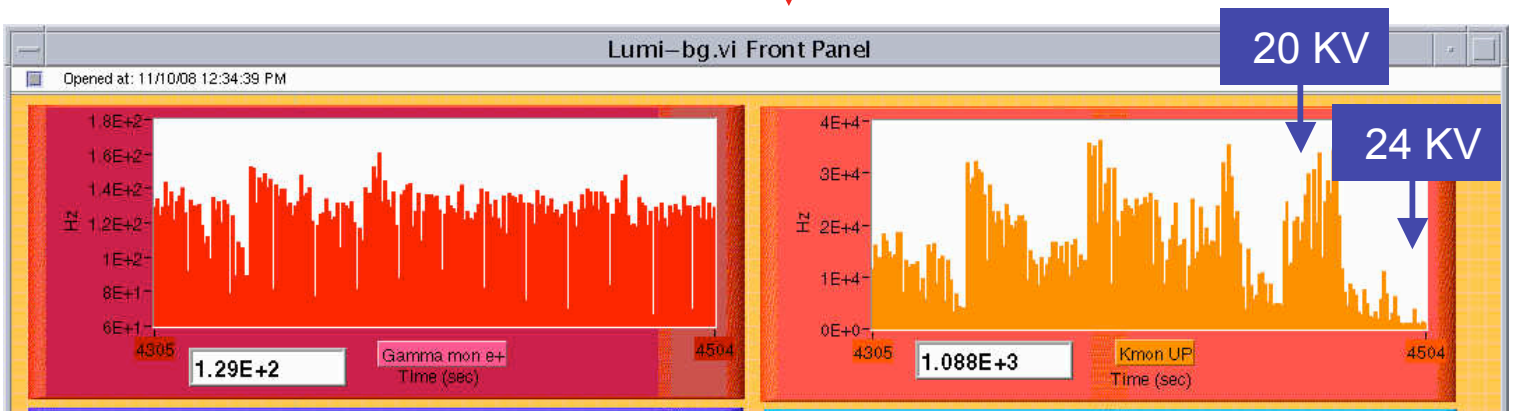
- Smaller asymmetry in the Injection Kickers
- Injection septum closer to the nominal value

However the background level was not yet compatible with the SDD operation.

Background during e^- beam injection

The counting rate during injection has been studied and minimized as a function of:

- Collimator insertion
- Closed orbit bump at the injection septum
- Closed orbit bump in the RCR (Δy, Δx, Δxp)
- Incoming beam trajectory (x,y)
- Injection kicker voltage

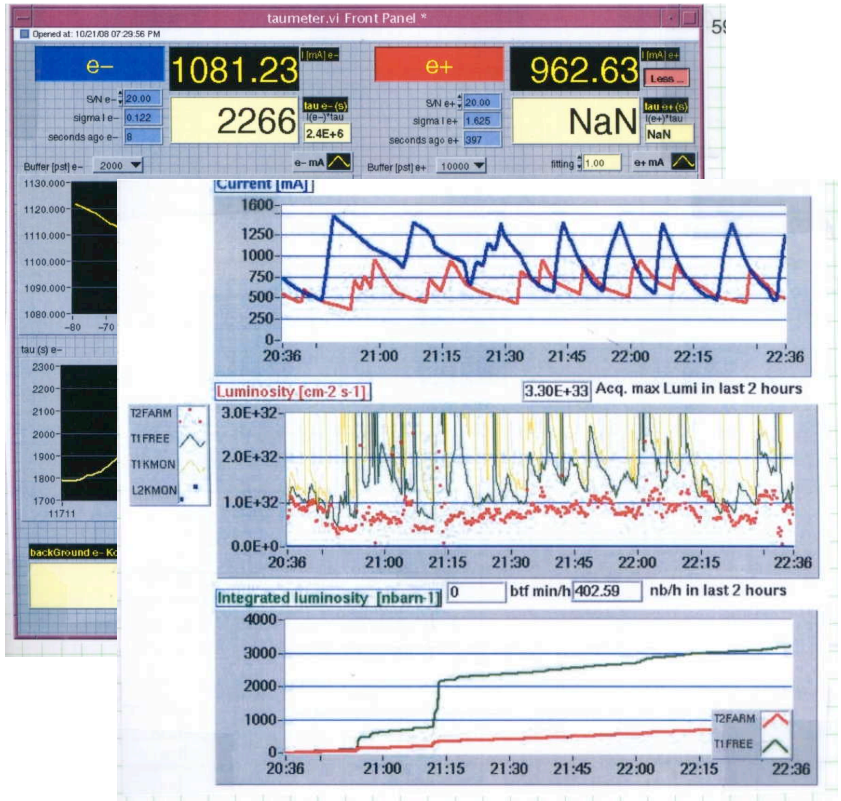


95% injection efficiency

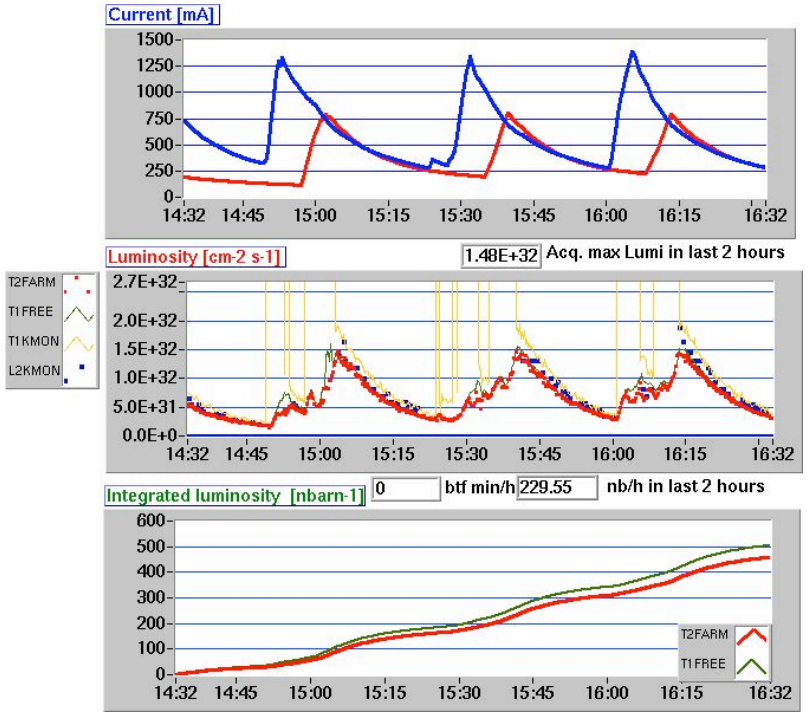
80% of running SDD survived the injection of $I^- = 1.2$ A

Background during beam coasting

The kaon monitor trigger treshold is presently lower than during the operation with the SIDDHARTA preliminary apparatus.



May optics reloaded on October 21st



November 9th 2008

The present agreement between the T1FREE and T2FARM gives a clear indication about a relevant background reduction

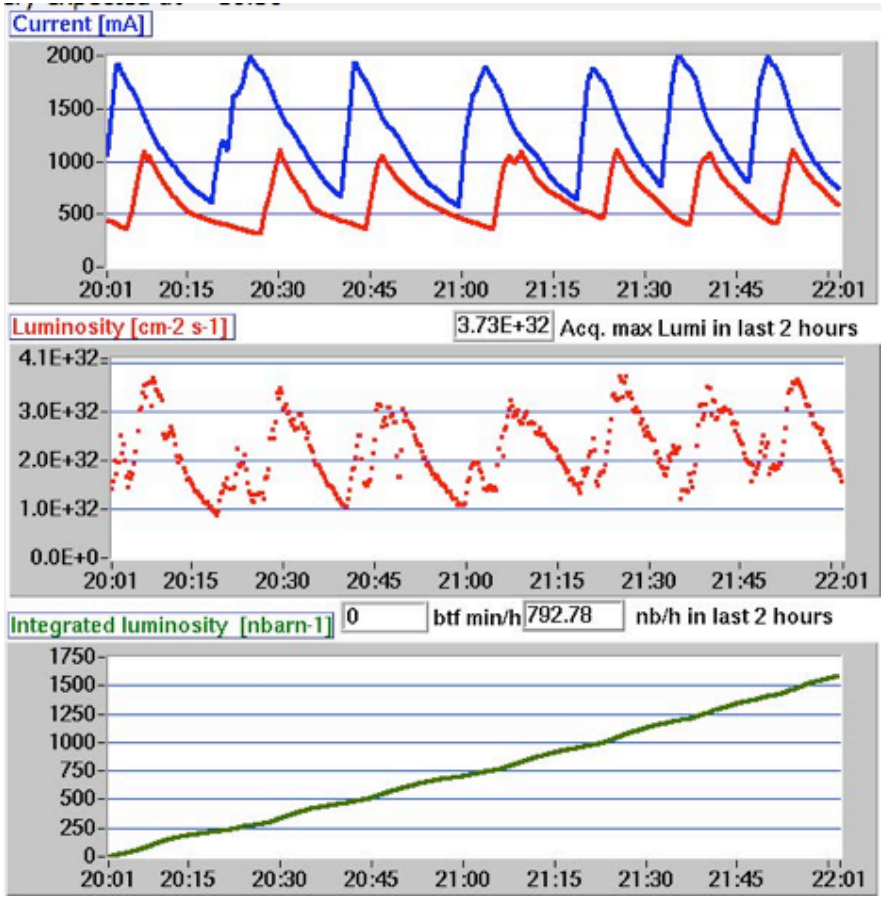
Recent Achievements

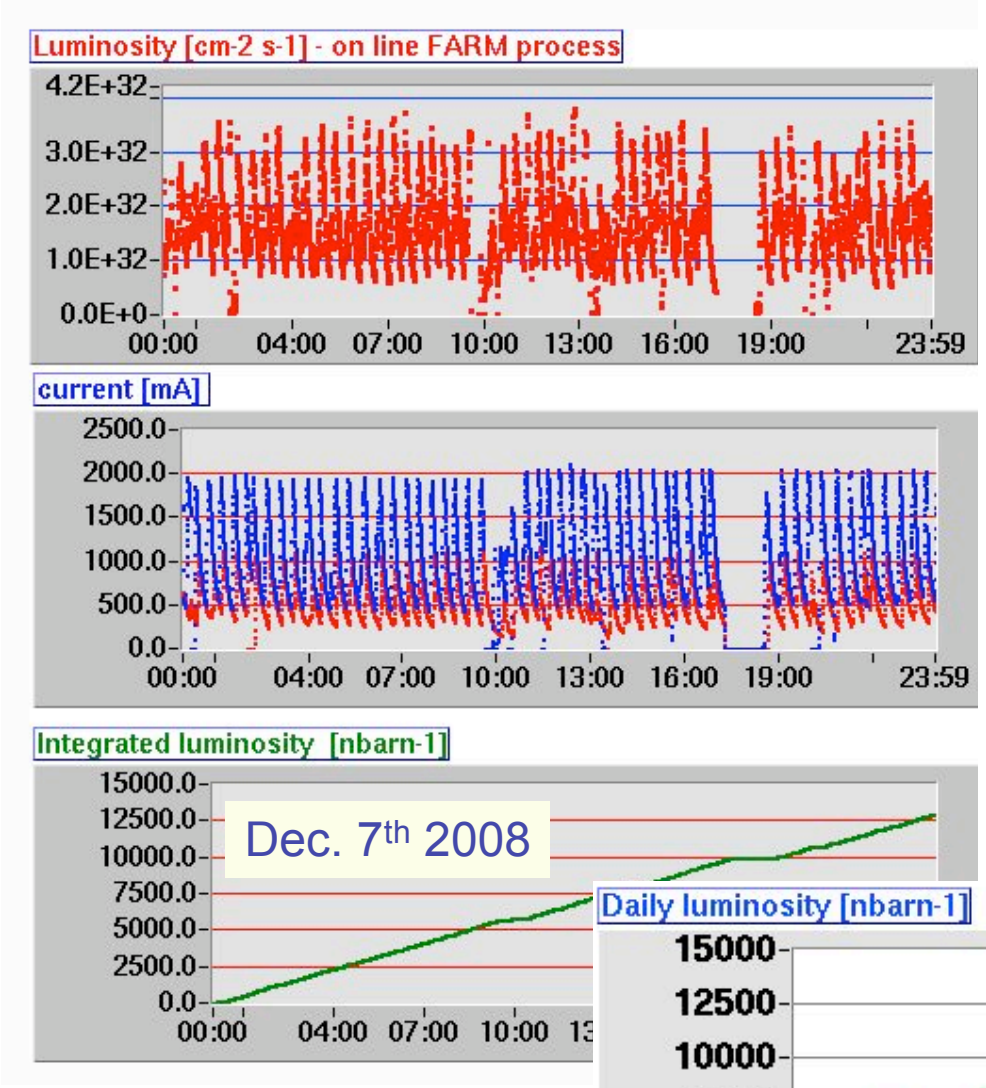
$L_{peak} = 4.05\ cm^{-2}s^{-1}$

Dec. 5th 2008

+ 150 % (FINUDA 2007)

$L_{\int 1\ hour} = .79\ pb^{-1}$



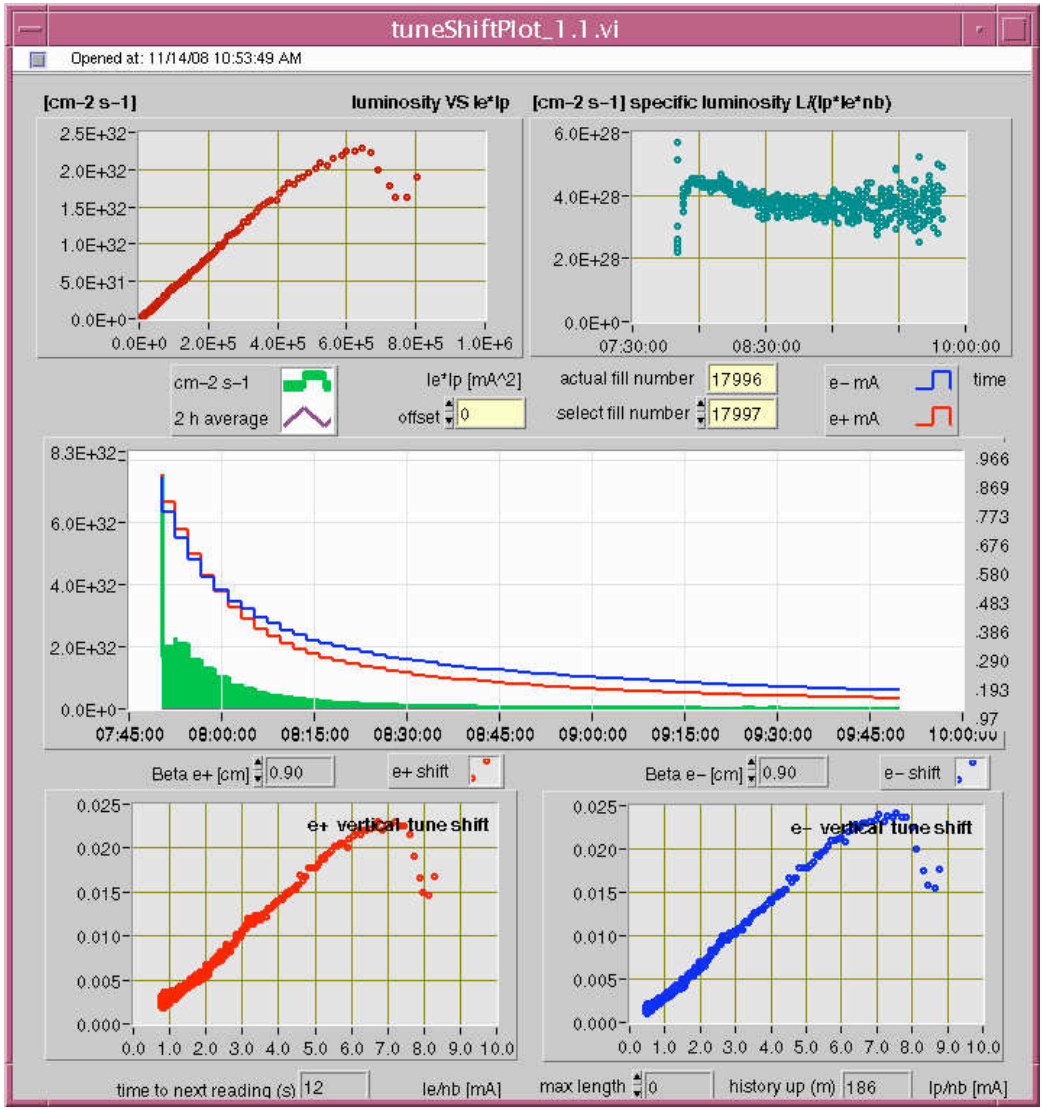


$L_{\int day} = 13.\ pb^{-1}$

(mainly in moderate injection rate regime
107 coliding bunches)

+ 39 % FINUDA 2007

Tune shift



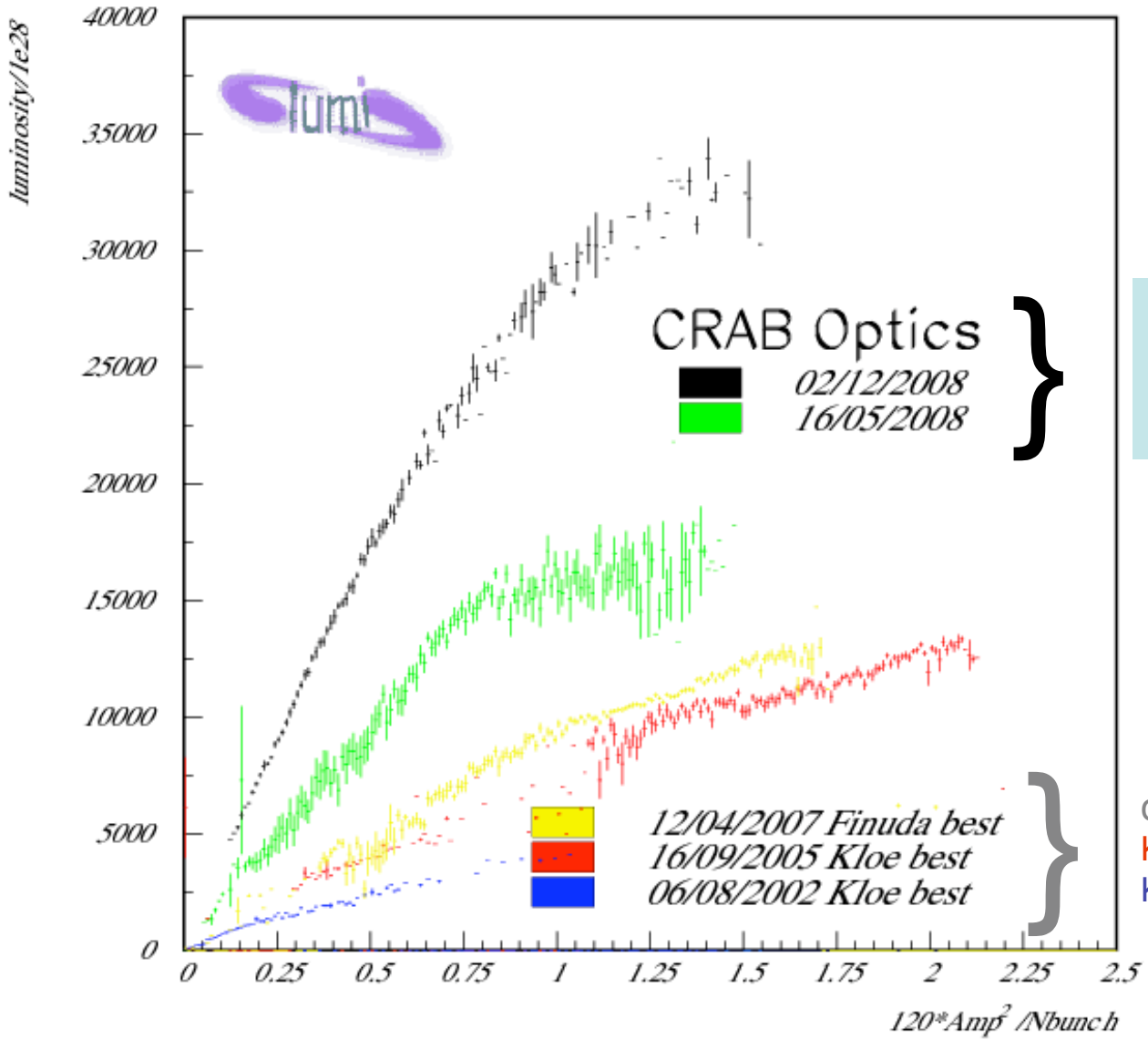
$$L_{specific} = \frac{L_{peak}}{N_{bunch} I^{+} I^{-}}$$

$L_{specific}$ is:

- constant
- ~ 4 times the best achieved in the past

ξ_y is linear

DAΦNE Luminosity versus colliding currents



NEW COLLISION SCHEME:
Large Piwinski angle
Crab-Waist compensation SXTs
θ_{PW} = 1.9 β_y = 9.0 [mm]

original collision scheme
KLOE 2005 θ_{PW} = 0.6 β_y = 18. [mm]
KLOE 2002 θ_{PW} = 0.3 β_y = 25. [mm]

Perspectives

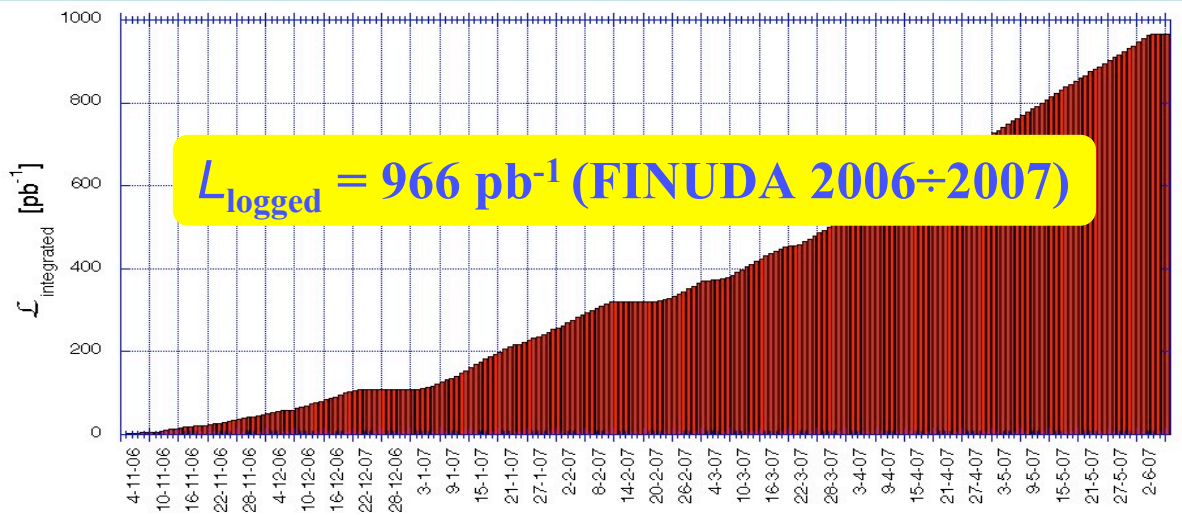
Scaling the present data from the BHABA monitor:

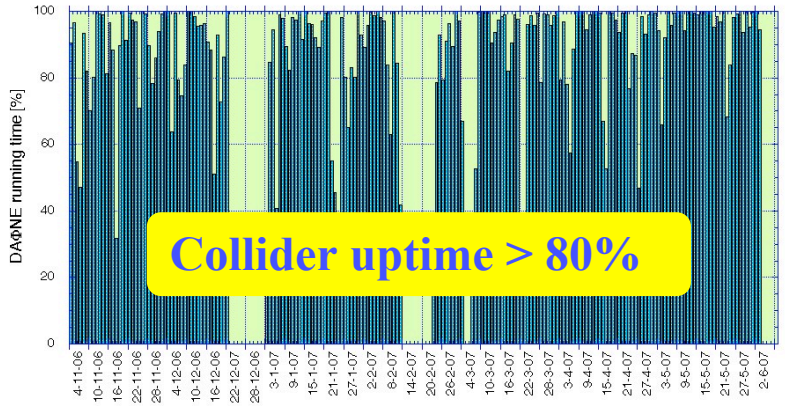
$L_{\int 1\ hours} = .79\ pb^{-1}$ over a day $\Rightarrow$ $L_{\int day} \sim 19\ pb^{-1}$

Assuming 80% uptime for the collider $\Rightarrow$ $L_{\int month} \sim .45\ fb^{-1}$

lowest limit

$L_{\int day} \sim 20.\ pb^{-1}$ very much possible!





Short term developments

- *Further investigation about the e^+ instability source (closed orbit bumps in the displaced dipoles)*
- *Improve vacuum condition (1- 2 months) in order to get 110 bunches in collision*
- *Further systems stability optimization (RF FBKs)*
- *Increase Crab sextupoles strenght to reduce the transverse beam size increase due to beam-beam*
- *Standard tuning*

Long term developments

- *Installation of a new dedicated kicker for the second transverse horizontal feedback in a position with higher β_x (β_x = 3 [m] -> 17 [m]) in order to increase the feedback dynamic range by a factor > 2*
- *Equip the second transverse horizontal feedback with two power amplifiers providing 500W output (now 250W)*
- *Install the hybrid kickers for the e- and e+ injection*
- *Install collimators in the transfer-lines*
- *Further optics refinements in order to optimize:*
  - L_{peak}
  - $L_{integrated}$
  - *Lifetime*
  - *Background*

Conclusions

The new collision scheme works and the CW SXTs are effective in controlling transverse beam blowup and increasing luminosity.

$L_{peak} = 1.6\ 10^{32}\ cm^{-2}s^{-1}$ $L_{\int day} = 10.\ pb^{-1}$

$L_{peak} = 4.0\ 10^{32}\ cm^{-2}s^{-1}$ $L_{\int day} = 13.\ pb^{-1}$ (NOW)

$L_{peak} = 5.0\ 10^{32}\ cm^{-2}s^{-1}$ ***(expected after the upgrade)***

Performances are still limited by well defined problems:

- e-cloud
- Ion trapping
- RF stability

In this context is quite reasonable to plan a further DAΦNE upgrade in view of the KLOE2 experiments run.