Luminosity measurements at DAFNE

The lumi Collaboration

M. Boscolo, F. Bossi, B. Buonomo, G. Mazzitelli,
F. Murtas, P. Raimondi, G. Sensolini
INFN LNF

M. Schioppa
INFN Cosenza

Paolo Valente
INFN Roma

P. Branchini
INFN Roma Tre

N. Arnaud, D. Breton, L. Burmistrov,
A. Stocchi, A. Variola, B. Viaud
LAL, CNRS-IN2P3, Université Paris-Sud

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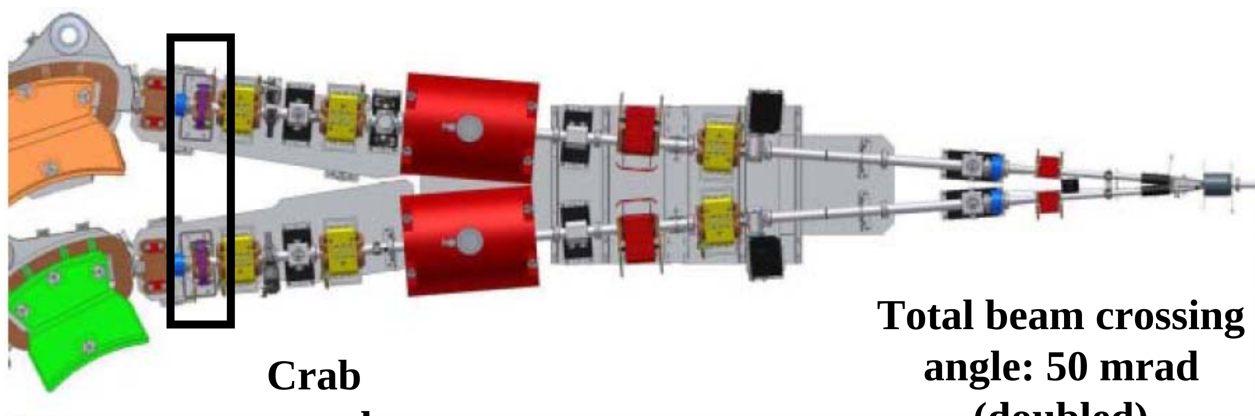
Overview

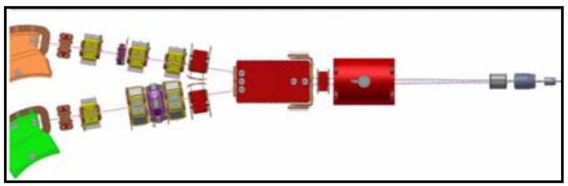
- Why and how measuring the luminosity?
- Detectors
- Simulation
- Performances
- Results
- Conclusions

Measurements

- New DAFNE interaction region (2007)
  → Goal: measuring the performances of the crab waist scheme
  → Significant luminosity gain expected w.r.t. previous Runs

Area substantially redesigned





Before upgrade

- Use Bhabha scattering and radiative Bhabha for luminosity measurements and IP diagnosis
  [SIDDHARTA collaboration looking for $\Phi \rightarrow K^+K^-$ production]
  → Different interactions ⇒ different detectors

Processes & detectors

- Bhabha scattering: $e^+e^- \rightarrow e^+e^-$
  $\rightarrow$ Few 100's Hz rate @ 10^{32} $cm^{-2}s^{-1}$ in the relevant θ-range
  $\rightarrow$ Clean process, back-to-back events
  $\rightarrow$ Luminosity measurements
  $\rightarrow$ Calorimeter [+ GEM tracker]

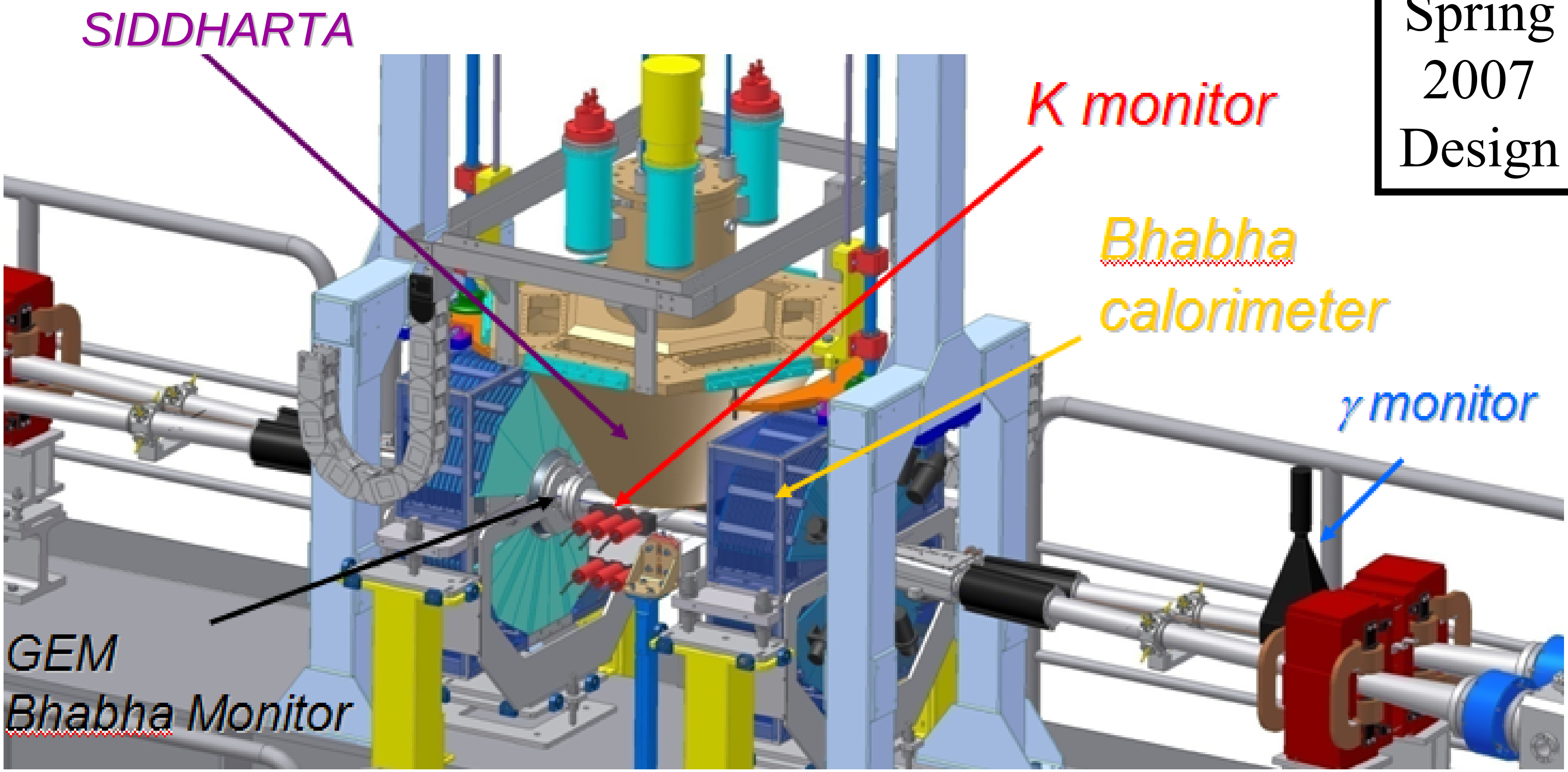
  Very steep dependence

- Radiative Bhabha: $e^+e^- \rightarrow e^+e^-\gamma$
  $\rightarrow$ 95% of the photons emitted in a cone of 1.7 mrad (very low angle!)
  $\rightarrow$ High rate, high background
  $\rightarrow$ IP diagnosis
  $\rightarrow$ Photon detector

- Absolute luminosity measurements
- Fast feedback to control room required
- Compare results to other measurements (beam monitors, etc.)

DAFNE interaction region layout

Spring
2007
Design



Calorimeter is 19cm thick and starts at 32.5cm from IP

γ monitor is at 1.7m from IP

Included in this talk: Bhabha calorimeter, γ monitor and GEMs

The Bhabha calorimeter

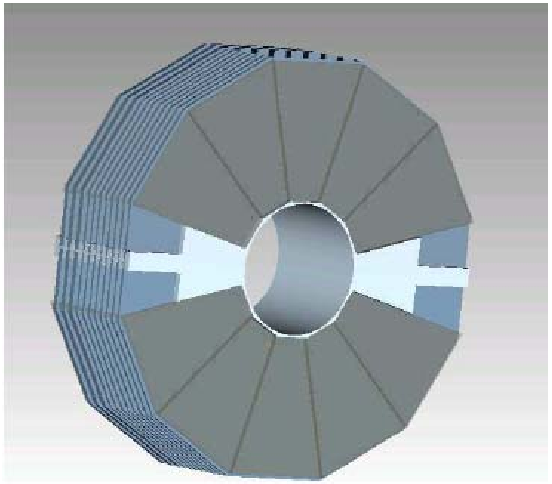
- Lead-scintillator sandwich calorimeter
  - → On each side of the IP
  - → 11 layers of lead: first 8 0.5 cm thick
    last 3 1.0 cm thick
  - → 12 layers of scintillator
  - → Longitudinal size matches QD0 quadrupoles

~ shower containment (12.5 X_0)

Ratio active/passive material is ~2:1, expect 15%/√E resolution

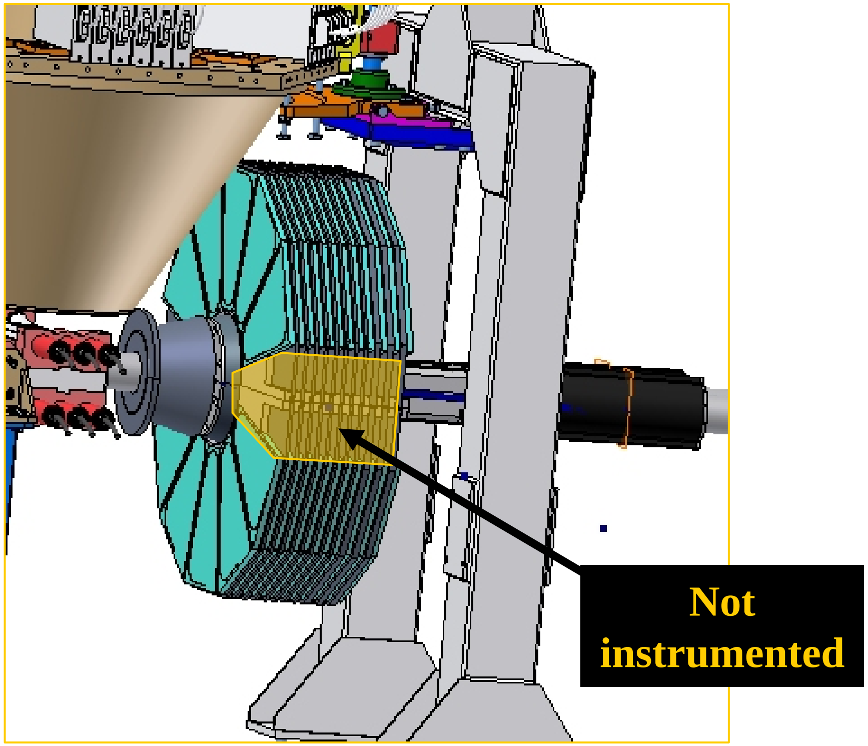
- Azimuthal segmentation: 12 sectors covering $\Delta\Phi = 30°$ each
  - → Compromise between # of channels,
    flexibility to define acceptance **[SIDDHARTA shielding]**
    and signal vs. bkg separation
  - → The 2 sectors crossing the beam plane ($\Phi \sim 0$ and 180°)
    are not instrumented: high background expected
    + mechanical support

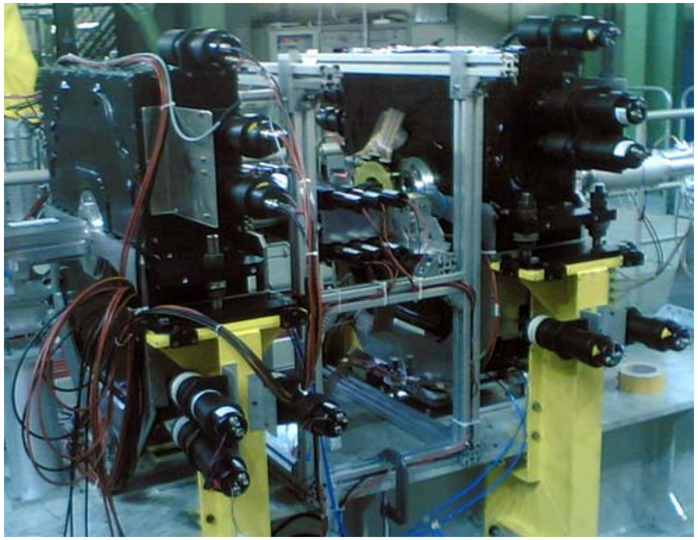
The Bhabha calorimeter (cont'd)



'Wheels' of lead and scintillator

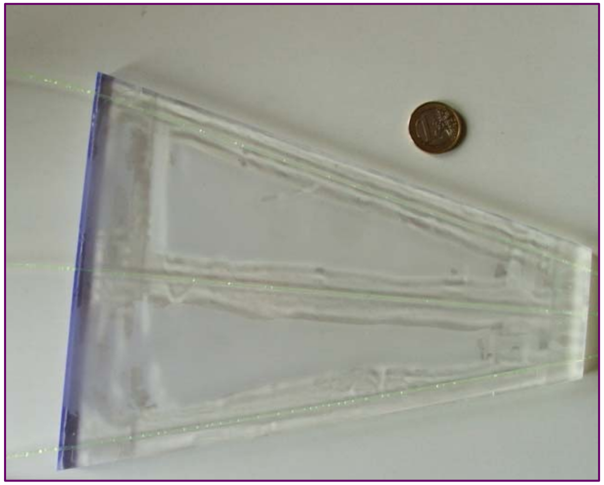
Building one module
(= set of 5 sectors)



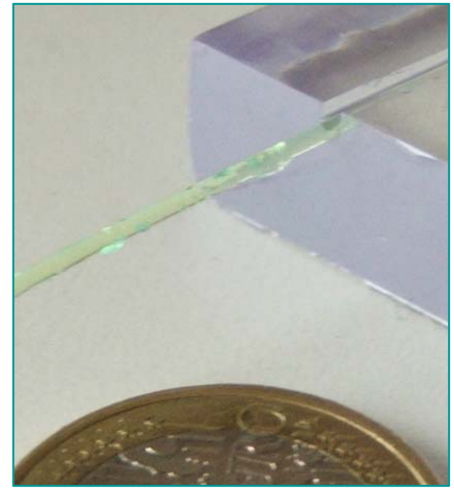


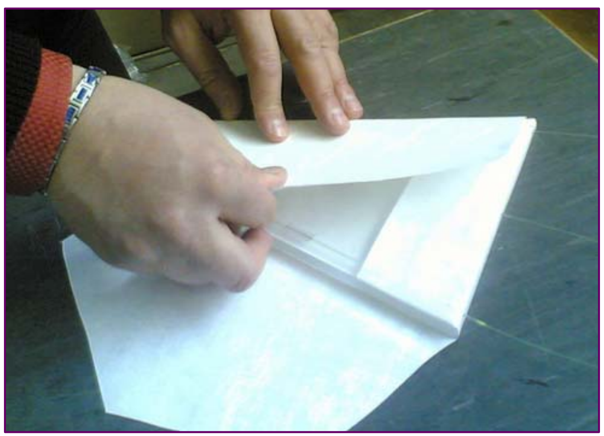
Calorimeter installed @ the IP

More on the scintillator tiles



Three 2mm-deep radial grooves in each tile containing wavelength shifting fibers of 1mm Ø



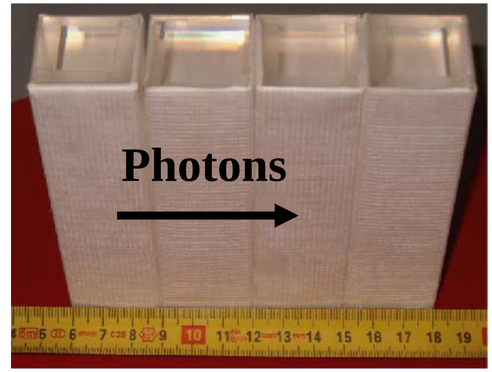


Each tile wrapped in Tyvek™ (Dupont) paper to improve light collection

In total for one sector: 12 tiles × 3 fibers / tile = 36 fibers feed to a single PMT

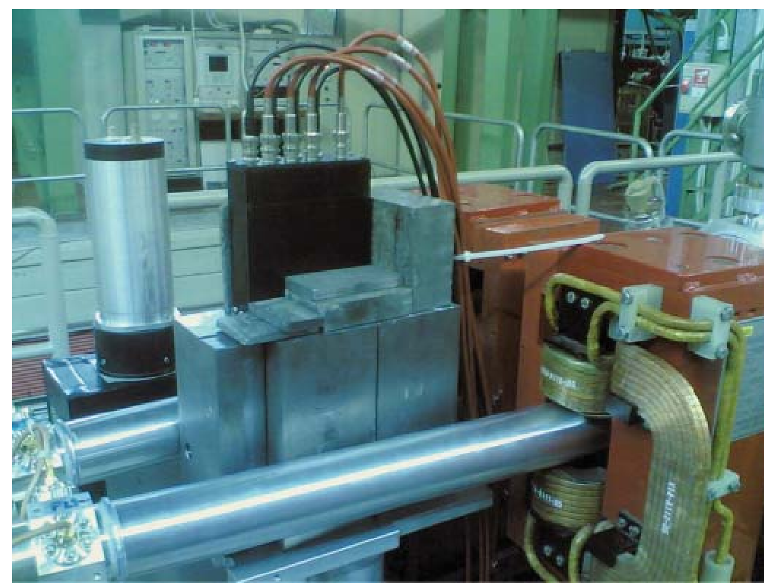
The γ monitor

- 4 $PbWO_4$ crystals on each side, 170 cm away from IP
- PMT readout
- Compact and fast detector → Ideal for online monitoring
- Very close from beam pipe



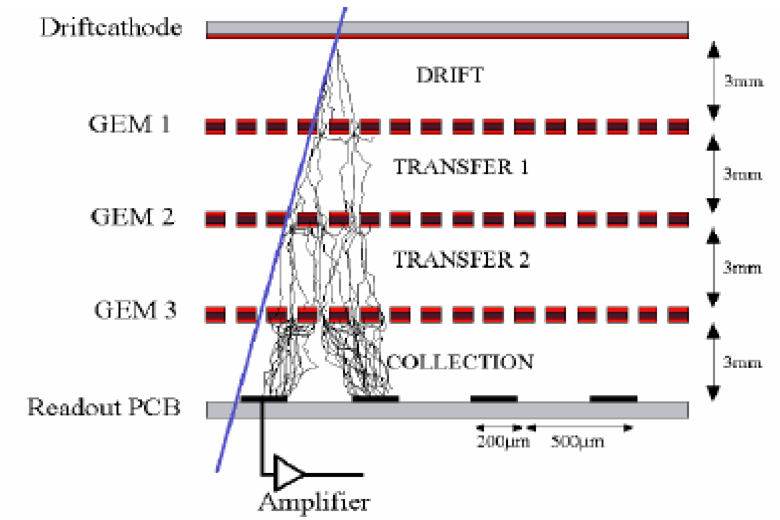
12 cm ⇔ 13 X_0

One such monitor on each side of the IP



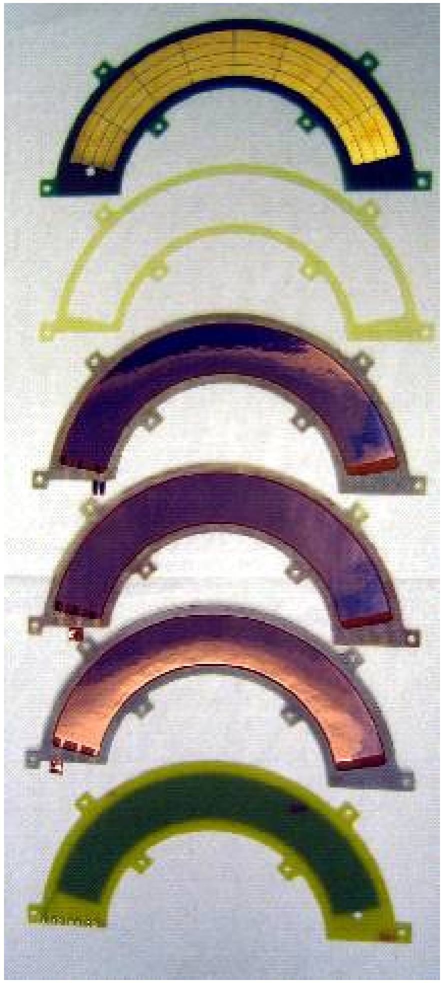
GEM tracker

- Triple layers, half-moon shaped
  $\Rightarrow$ amplification ~ $20^3 = 8000$



- Aim was to help identifying
  e^+/e^- tracks before reaching calo

Kapton/copper sandwich

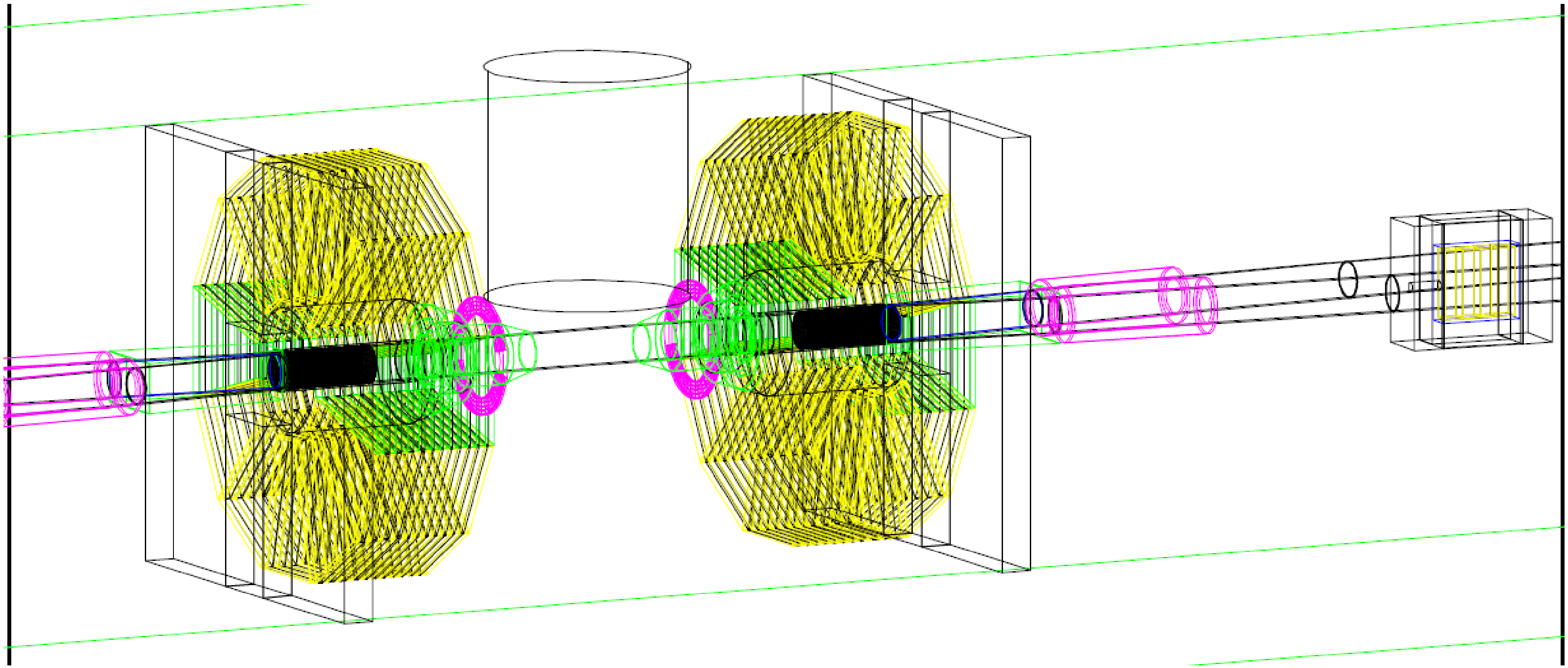


- Couldn't be used for actual lumi measurements so far due to space conflict with SIDDHARTA shielding

- Helps monitoring bkg and Bhabha tracks angular correlation

Simulation

- GEANT3-based



- Geometry, material (shielding), detector responses taken into account

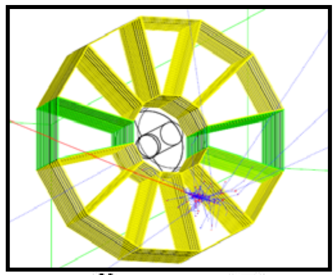
- BHWIDE used as (radiative) Bhabha generator
- Touscheck events used for dedicated studies

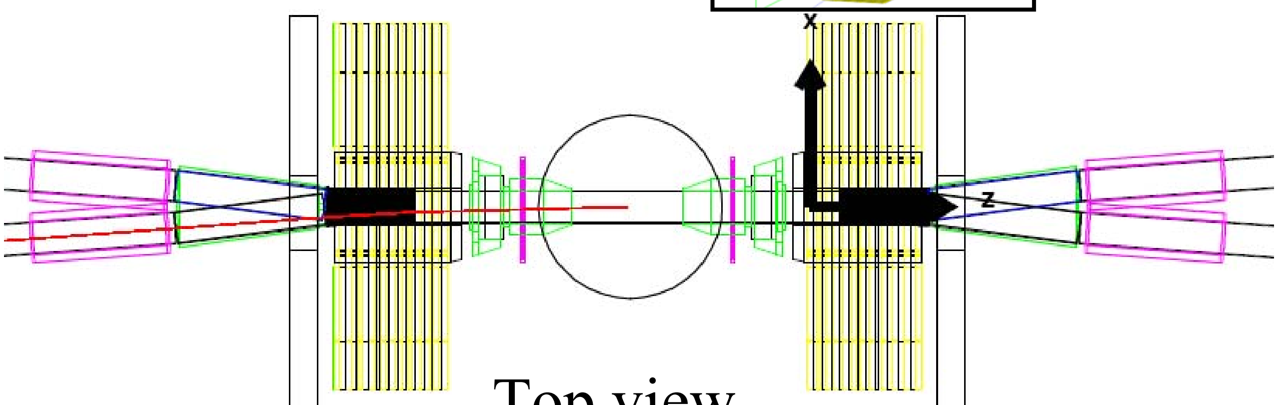
Simulation (cont'd)

- Predicts Bhabha rate @ given luminosity
  → Bhabha selection algorithm implemented (see later)
  → Comparison with actual rates provides machine luminosity

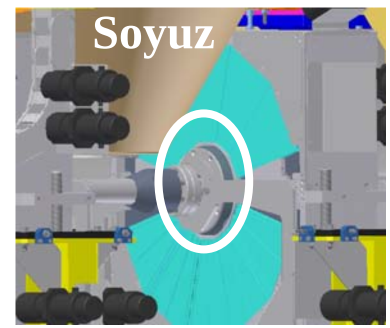
- Estimation of systematics (~15% in total)
  → components alignment, reconstruction, background, etc.

Dominant
(cross-section ~ $1/\theta^3$)

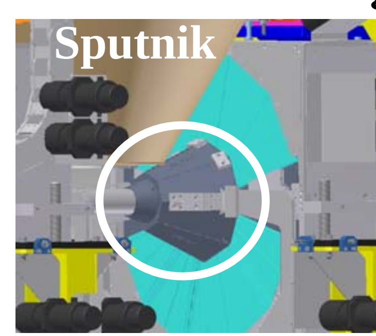




Top view



Different shieldings



DAQ

- Hardware and software mainly KLOE-based
  → Simple and efficient system
  → No deadtime up to tens of kHz
  → Whole system installed in the DAFNE hall

- Calorimeter
  → TDC (ADC) resolution of 1.04 ns (25 pC)
  → Sectors readout when trigger asserts (see next slide)

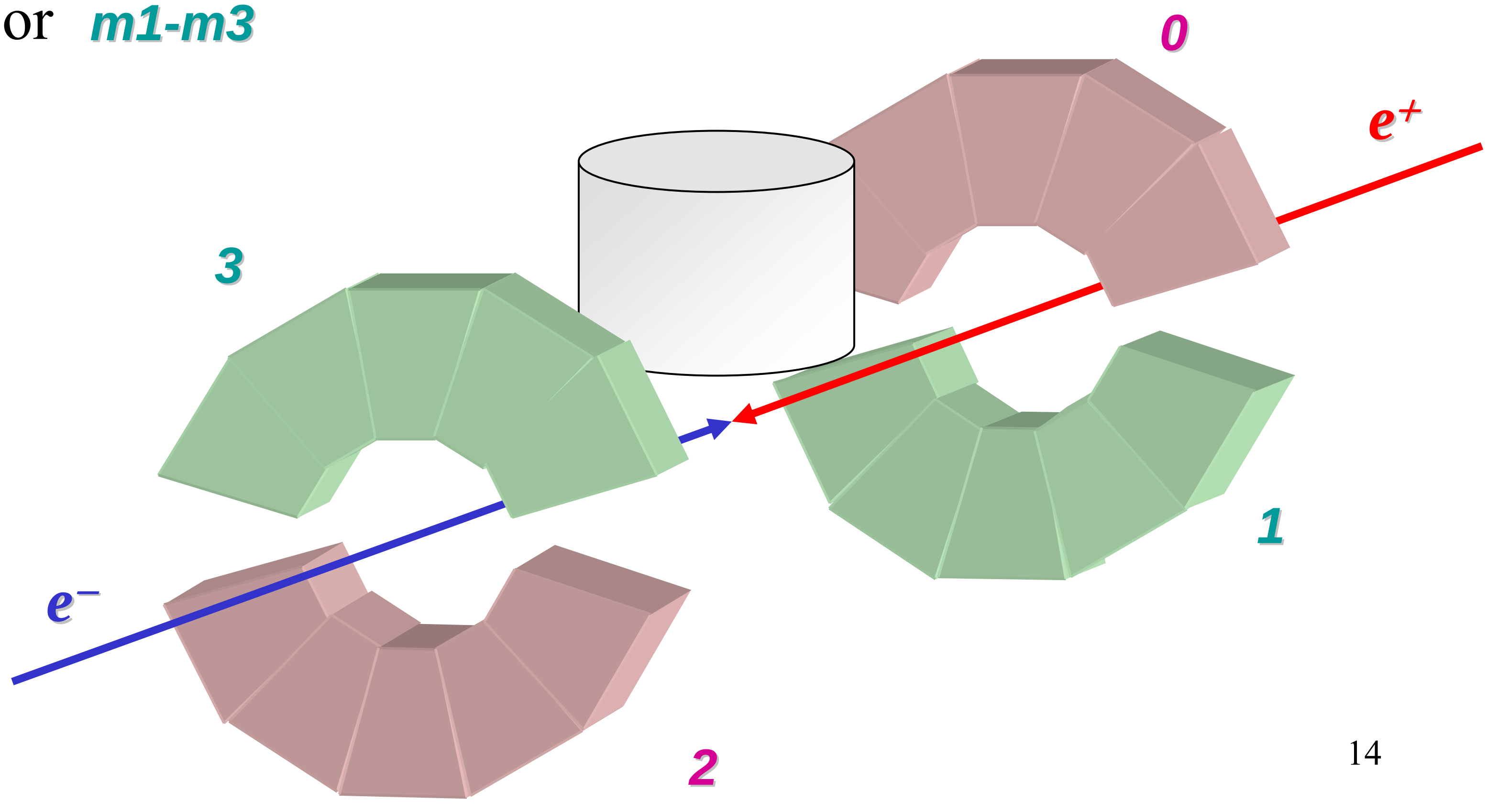
- γ Monitor
  → Signal sent to the DAFNE control room via a scaler readout module

- GEM tracker
  → Readout triggered by the calorimeter

Trigger

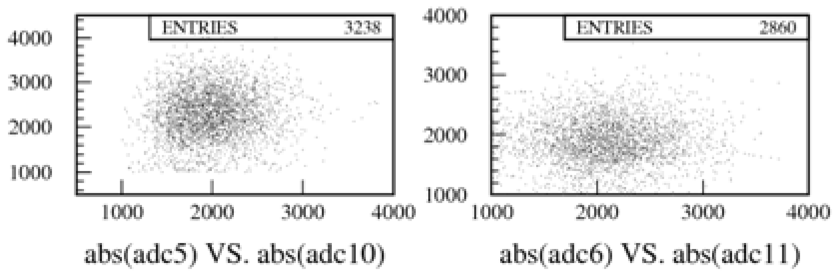
- ADC Counts from the same ***module*** (group of 5 adjacent sectors) are summed up and discriminated

- Trigger: two high enough energy deposits in back-to back modules
  m0-m2 or ***m1-m3***

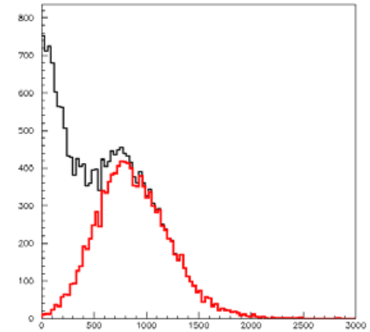


Performances

- Clear Bhabha peak



Correlated Adc counts for opposite sectors



Energy deposit in a sector

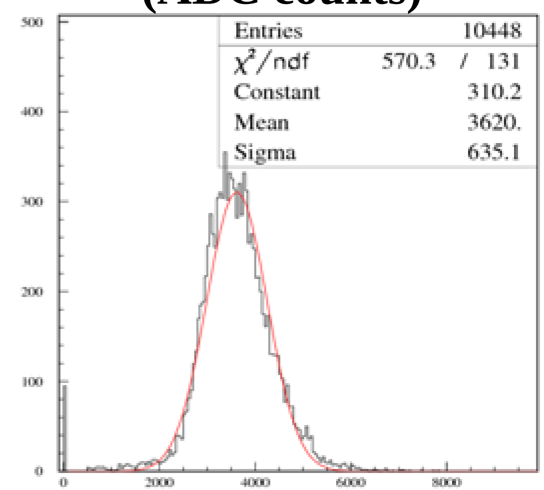
Same when module is triggering

- Good energy resolution

  → like during test beams

$\sigma_E/E=17.5\%$ @510 MeV $\Leftrightarrow 12.4\%/\sqrt{E}$ (GeV)

Measured E (ADC counts)



- Timing resolution allows bkg rejection online

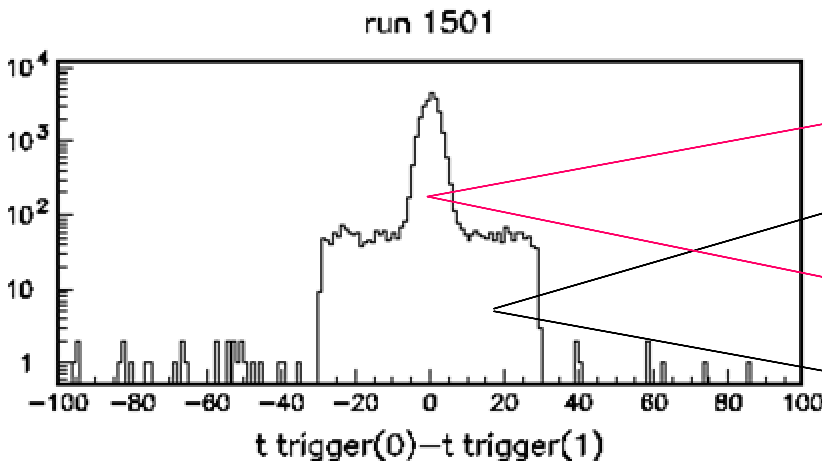
  → real events: energy deposits in opposite modules occur simultaneously

  → background: fake coincidences ⇒ no time correlation

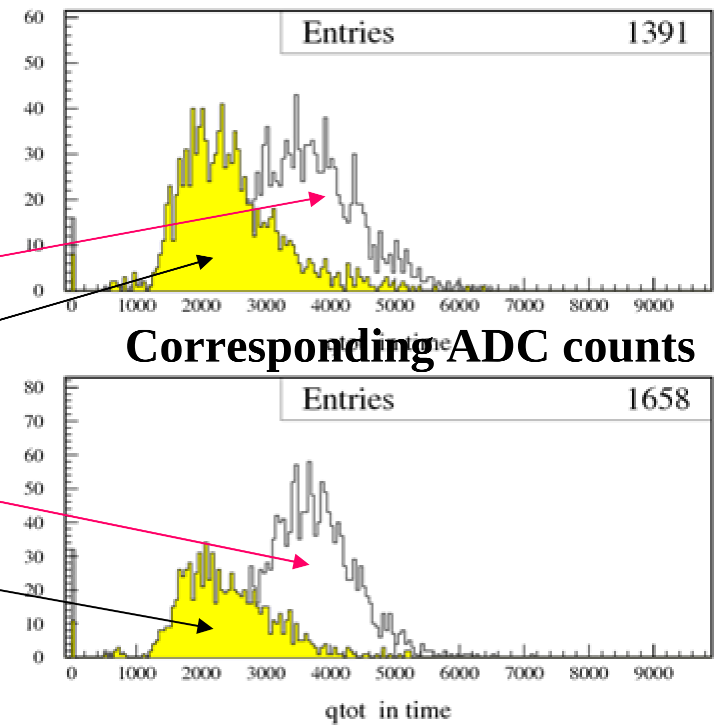
More on the online background rejection

Spring 2008 data

- Main source of background:
  two spurious energy deposit in the allowed timing coincidence window

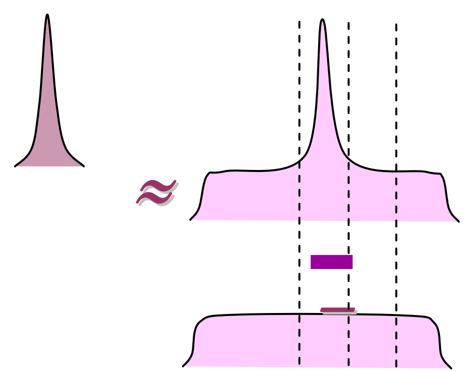


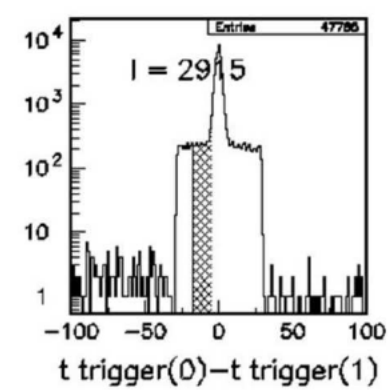
Time difference between 2 triggering modules



Corresponding ADC counts

- Genuine Bhabha peak on top of a flat background
  → Use sidebands to estimate background under the peak





More on the online background rejection (cont’d)

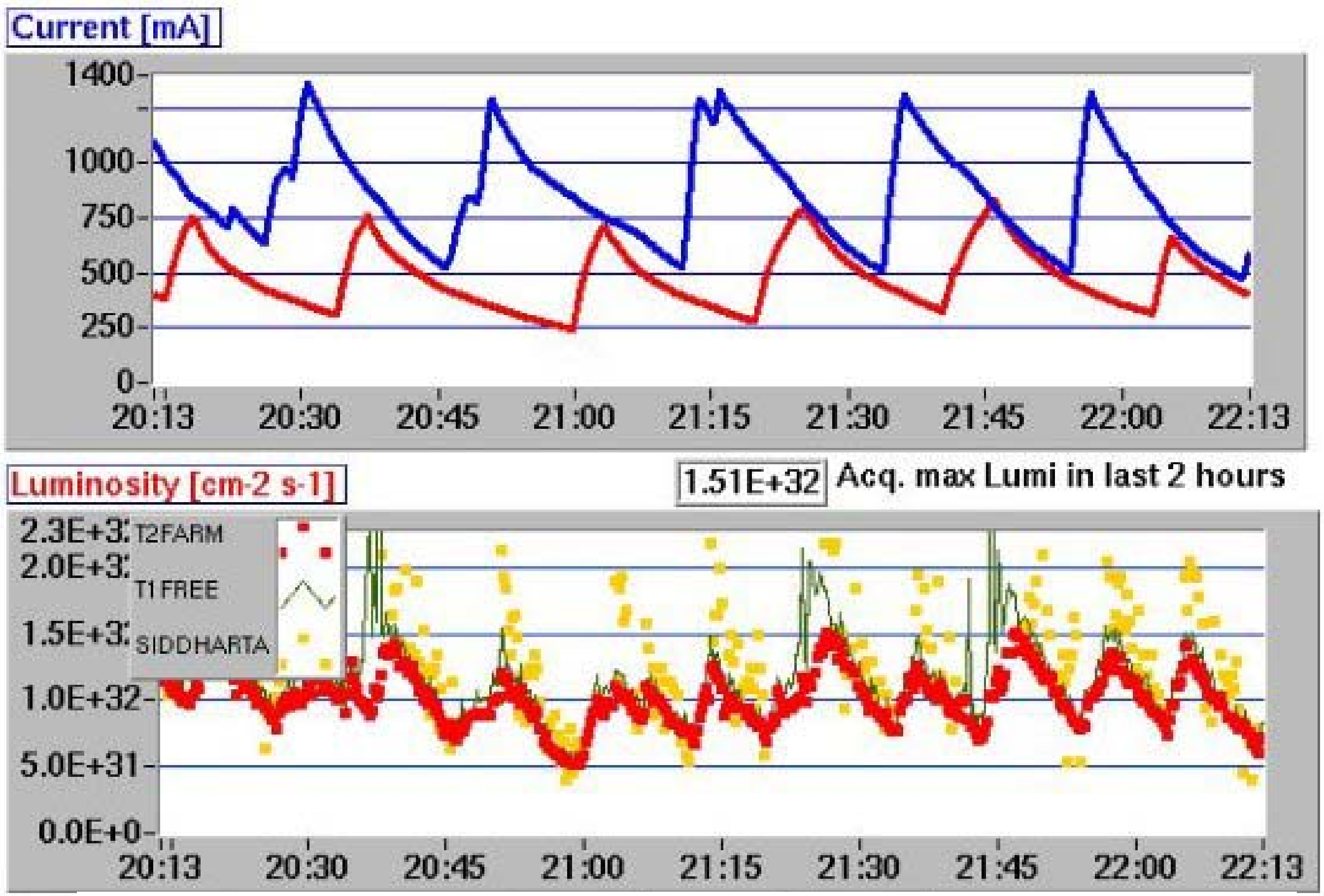
- Online subtraction performed every1000 events (DAQ) or averaged over 15 seconds (control room signal)

e^+ current

e^- current

Raw luminosity

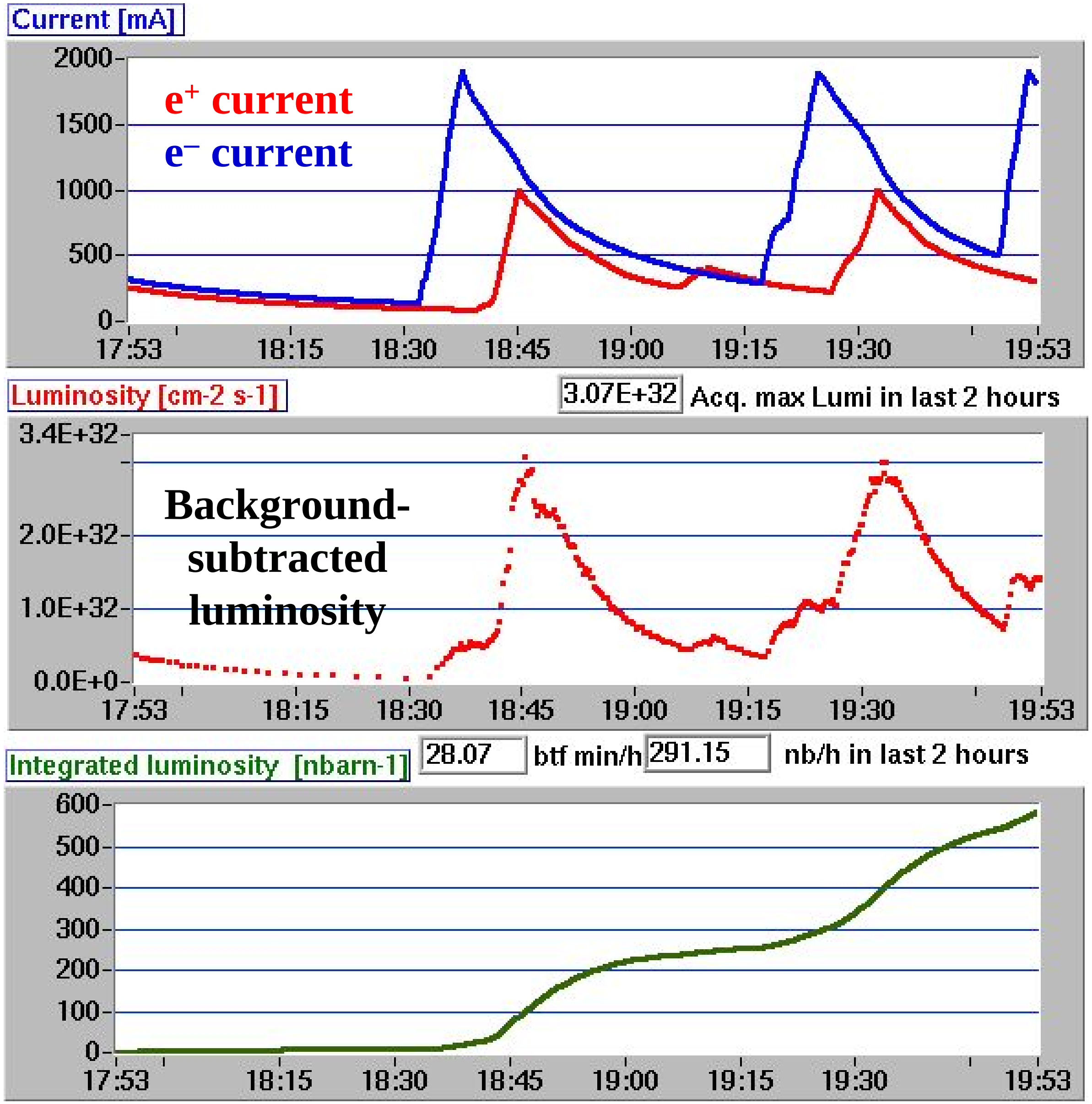
Bkg-subtracted luminosity



Corrected signal insensitive to periods of bad background!

Online luminosity measurements

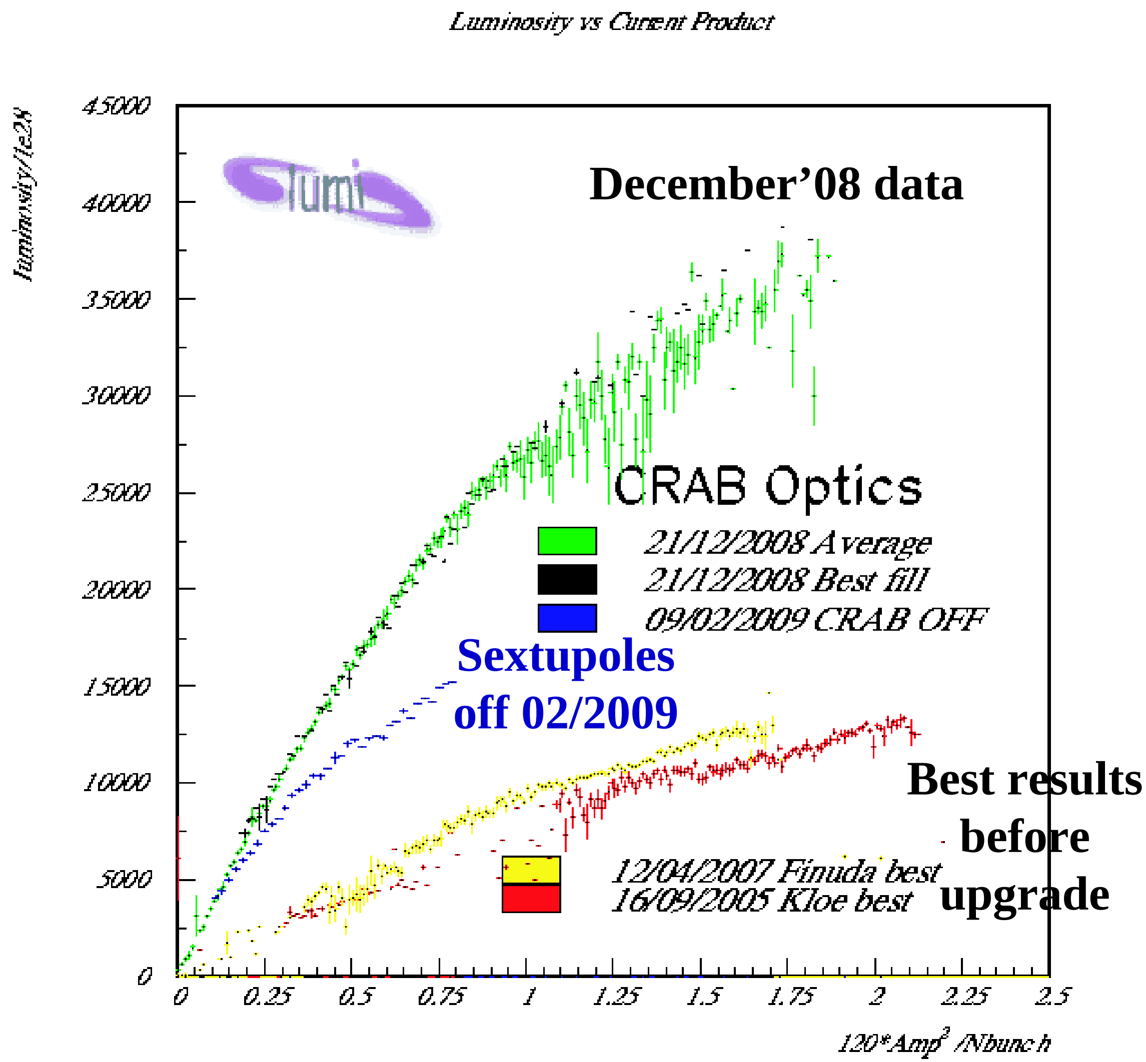
- Example from last Friday
- Correction very stable and working without problem since May last year

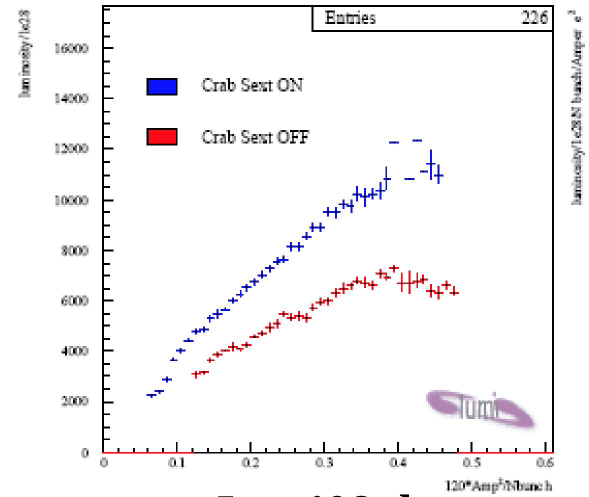


Performances

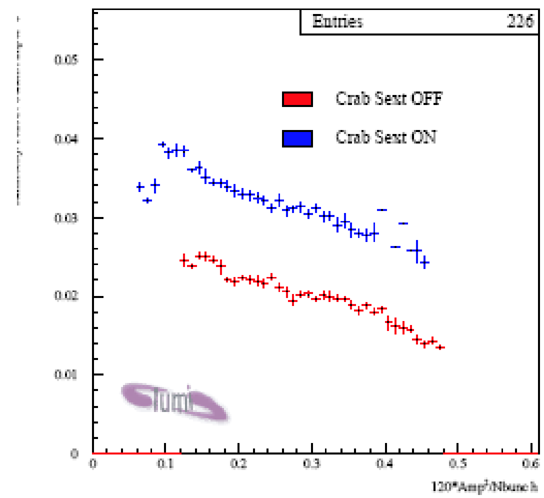
- Much higher lumi: crab sextupoles work!

Sextupoles ON
Sextupoles OFF





June'08 data



Performances (cont’d)

- Machine is improving over time

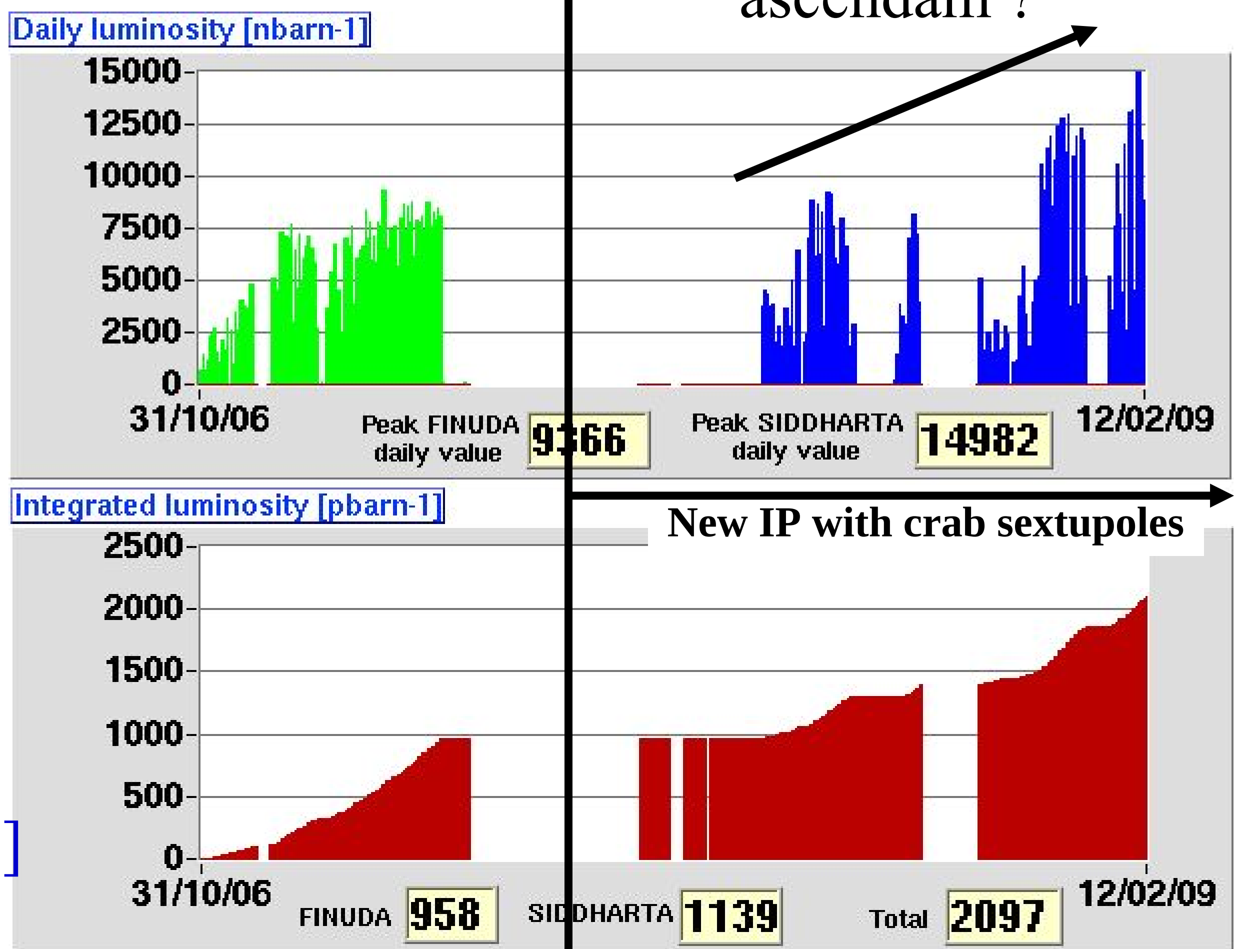
Quo non ascendam ?

April 2008: 0.6
May: 1.6

[Summer shutdown]

November: 2.2
December: 3.3
3.5
Recently: 4.05
[Goal: 5]

Peak luminosity
($\times 10^{32}$ cm^{-2}s^{-1})

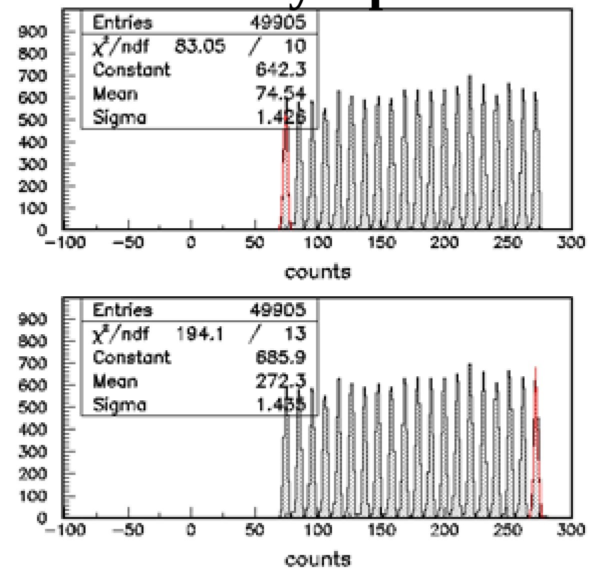


SIDDHARTA run luminosity estimeted by DAFNE luminosity
Bhabha monitor, data logging starts 14/03/2008

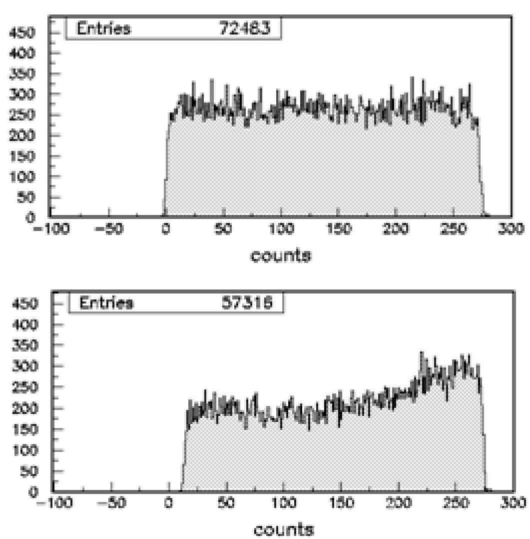
Bunch Luminosity

- Calorimeter timing accurate enough to separate contributions from individual bunches (when rings not completely filled)
- Rate ⇒ bunch by bunch lumi. information
- Bunch spacing consistent for the different patterns: ~ 2.6 ns in average

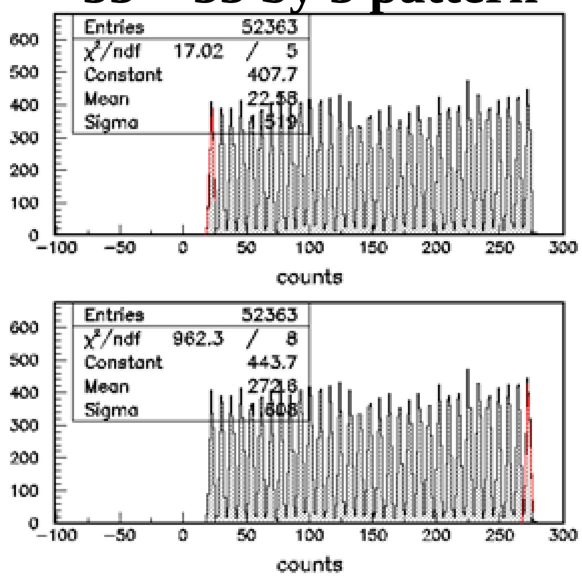
20+20 by 4 pattern



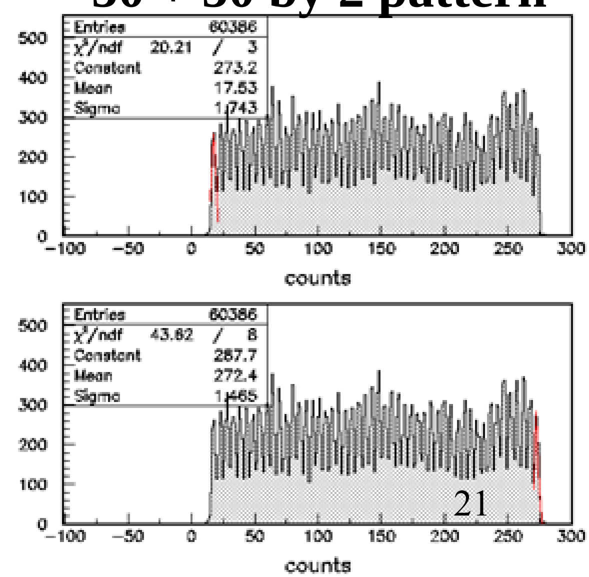
2 runs with 'all' bunches



33 + 33 by 3 pattern



50 + 50 by 2 pattern



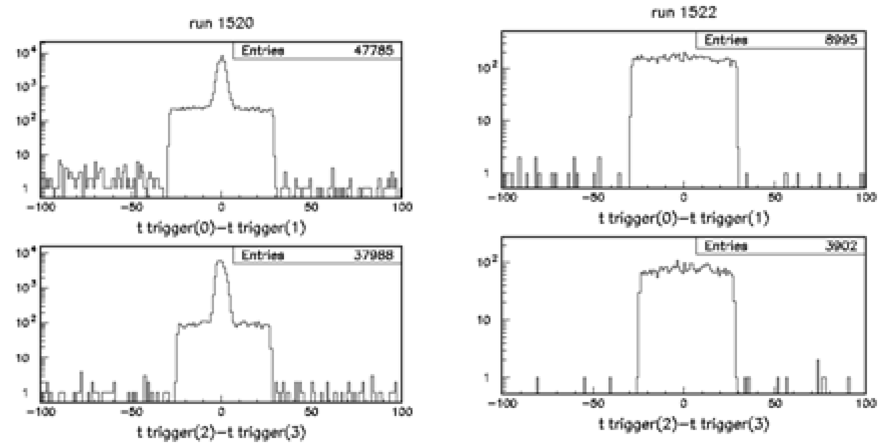
Outlook

- Bhabha luminometer fulfilled specifications
- Very smooth running since beginning of data taking
- Luminosity measurements + various IP diagnosis
- DAFNE improvements are significant and consistent with expectations
- NIM paper in preparation
  → To be submitted ‘soon’ once background studies completed

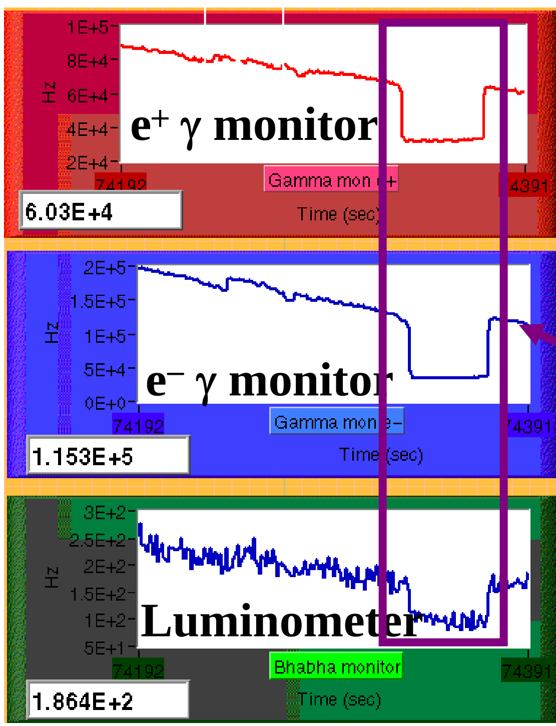
Backup slides

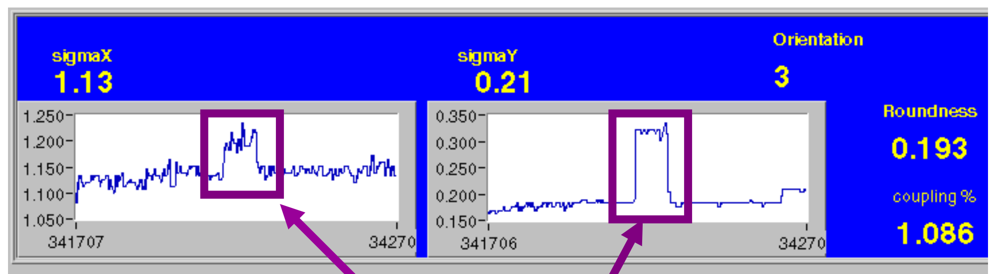
Crosschecks

- Bhabha timing peak disappears when beams out of collision



- What happens when crab sextupoles are turned off





e⁻ beam size from synchrotron light monitors

Crab sextupoles turned off