日本物理学会2007年年次大会 @首都大学 2007年3月26日

MEG陽電子タイミングカウンタのビーム中での性能評価と解析方法の研究

*

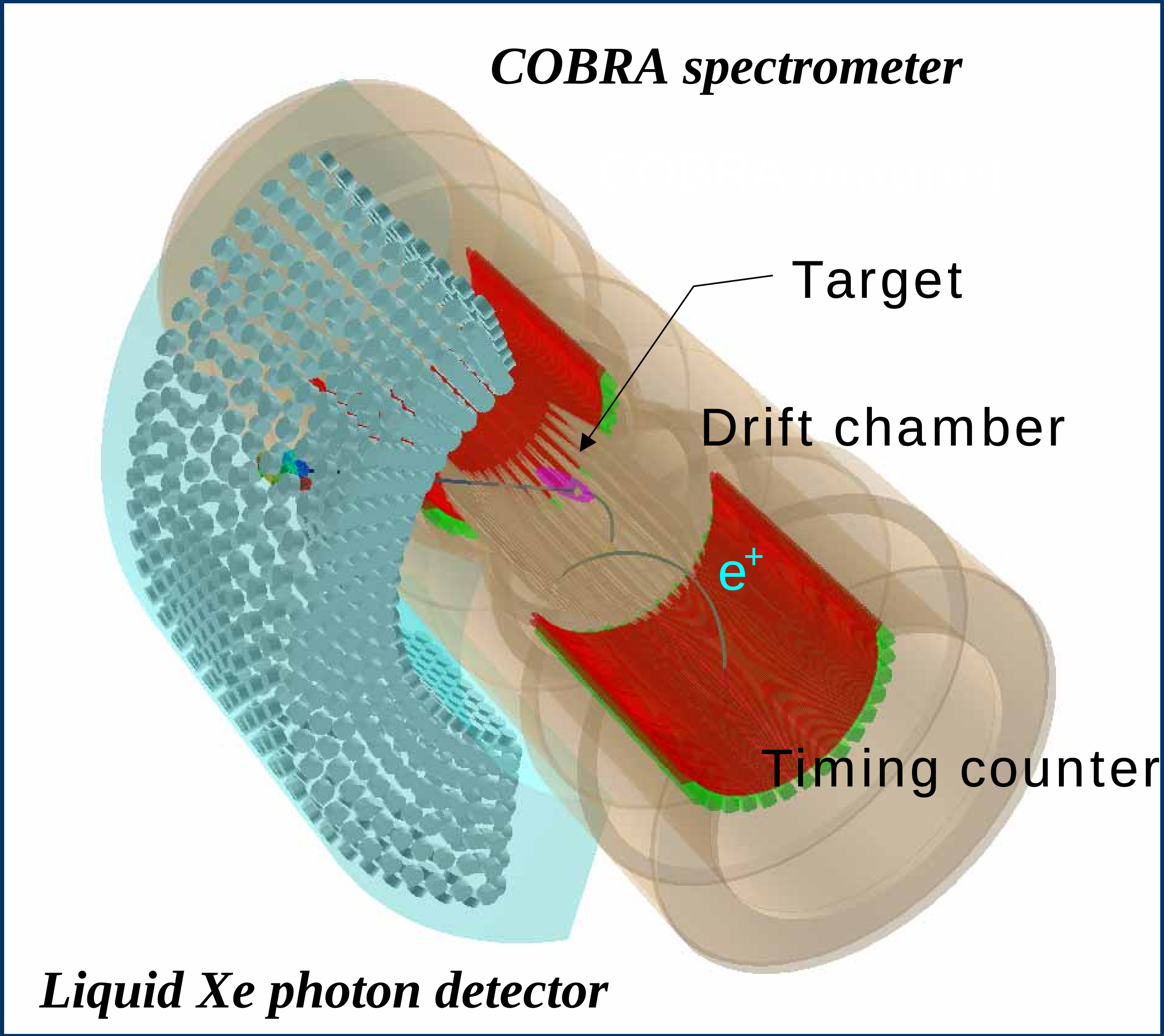
東京大学
THE UNIVERSITY OF TOKYO

内山雄祐

東大素粒子セ, INFN-Genova[A], INFN-Pavia[B]

森俊則
F. Gatti.[A] ,S.Dussoni[A] ,G.Boca[B] ,P.W.Cattaneo[B] ,
他MEG Collaboration

Detector

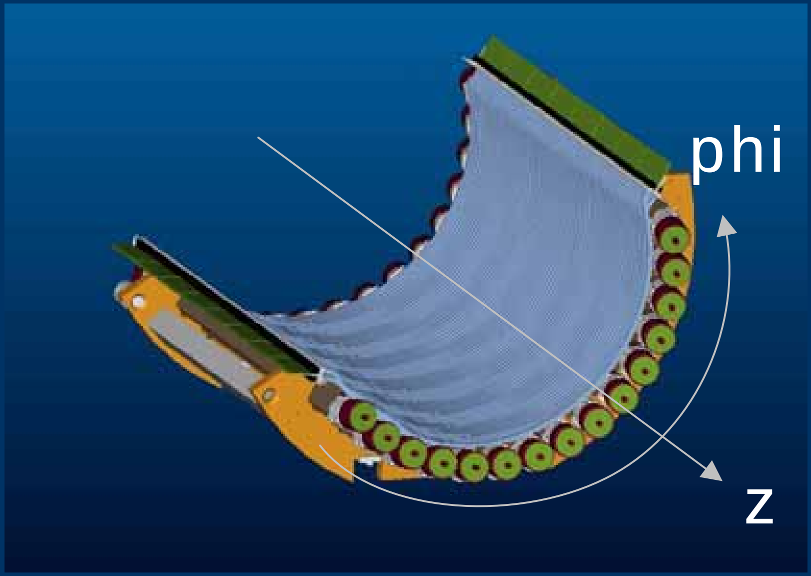


COBRA spectrometer
Target
Drift chamber
e+
Timing counter
Liquid Xe photon detector

Timing Counter

Two layers of scintillator hodoscope

- Orthogonally placed along phi and z direction



Requirements

- Provide fast signal for low level trigger
  - High timing resolution (~ns)
  - Direction of e^+ emission
  - High efficiency (>90%)

- Precise determination of e+ kinematics
  - Impact point for track reconstruction
  - High timing resolution for e^+-γ coincidence (100ps FWHM)

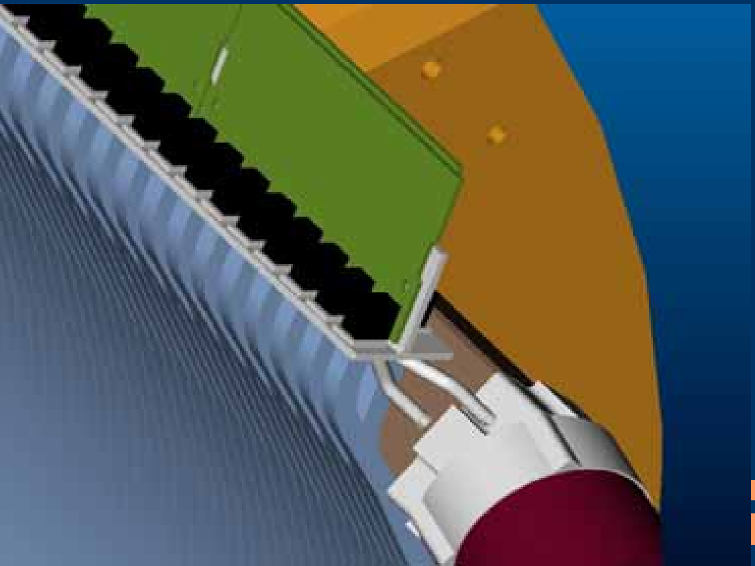
Transverse Counter (Z measuring scintillating fibre)

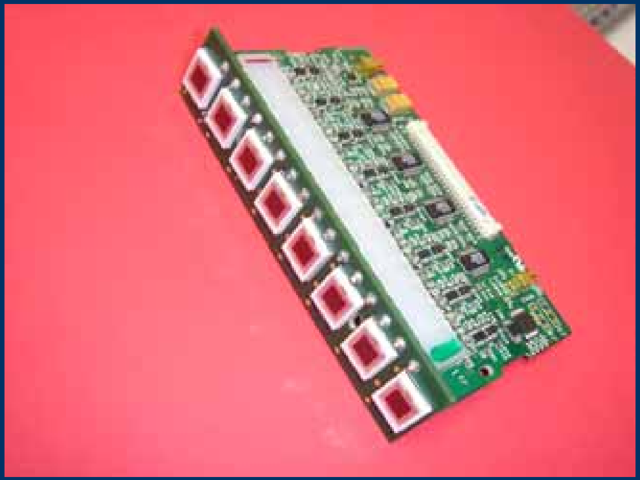
- Hit pattern for trigger
- Precise measurement of impact point
- Not measure timing

- High granularity for precise impact position
- Perpendicular to the magnetic field

→
  - Layer of scintillating fibres (5x5mm2)
  - Read out by APDs (512ch)

scintillating fibre
SAINT-GOBAIN BCF-20





APDs & frontend card
HAMAMATSU 8664-55

*Longitudinal Counter (**Phi** measuring scintillator bar)*

- For the timing measurement

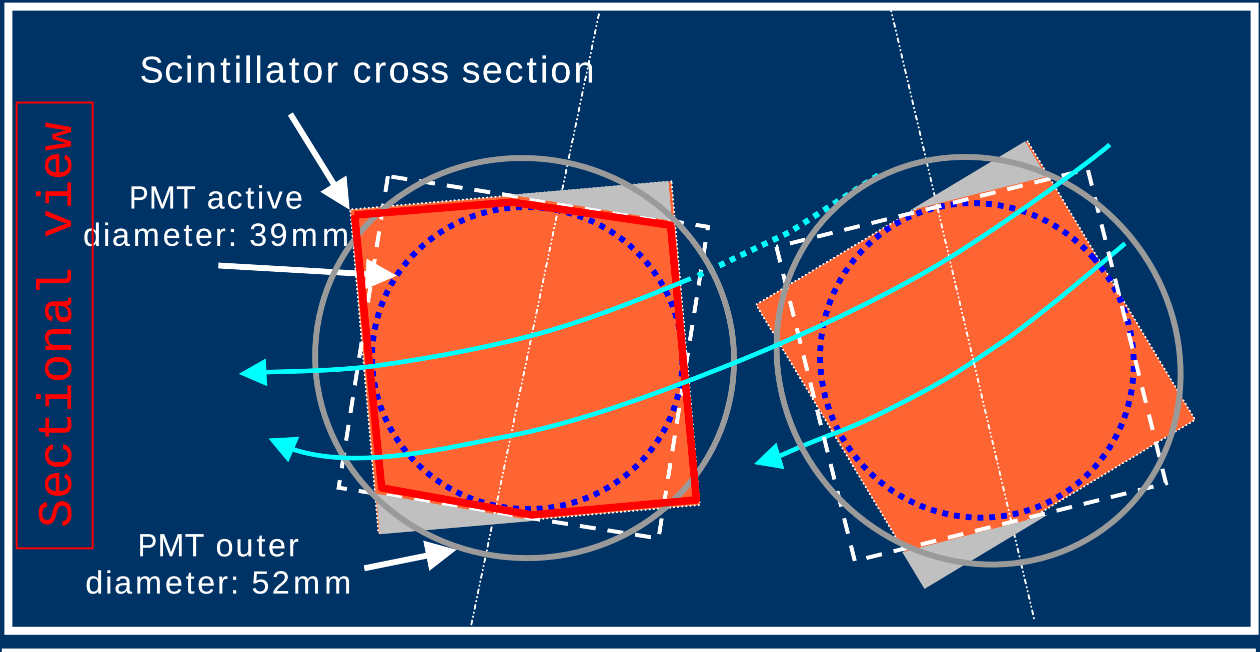
- 15 bars, almost square: 40x40mm2 x 80cm length
- Read out by 2” fine-mesh PMTs (HAMAMATSU R5924)
- Record waveforms at 2GHz sampling

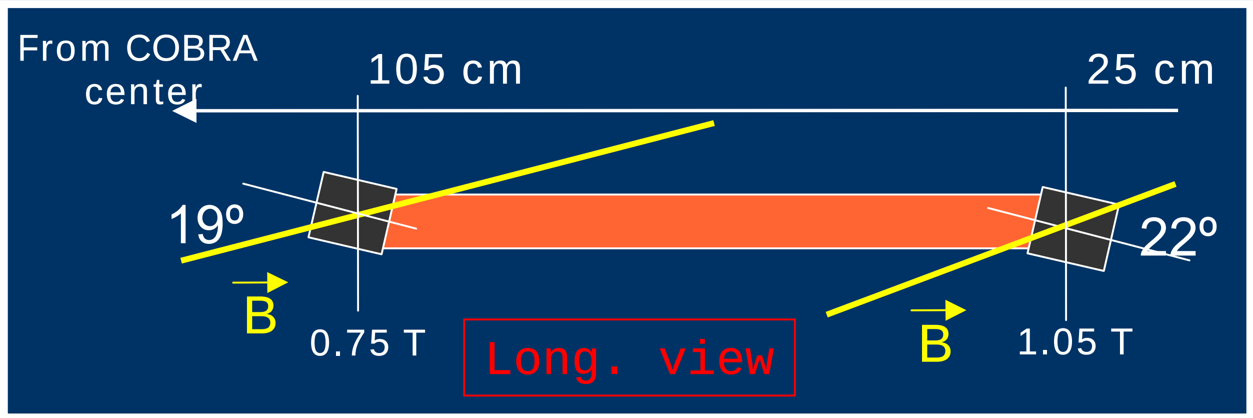
- Main concept ;
  - timing on the 'first photon'
  - homogeneous e^+ track

Optimization of the design

guided by MC study & several beam tests

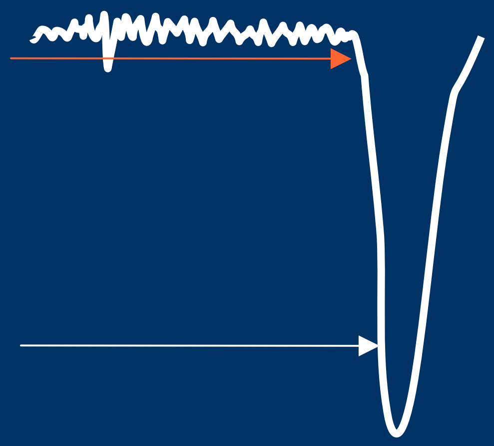
- 20°rotation increase response uniformity
- Positron path-length(5cm) enough for the required timing Res.
- Maximal matching scintillator-PMT
- Optimal compromise between PMT field gain suppression factor and available space. PMT tilted ~20° respect to the mag.





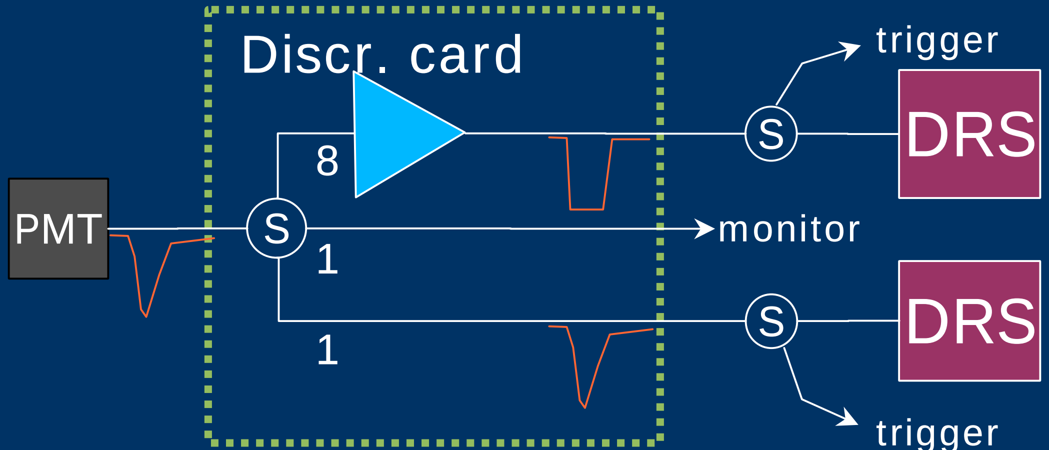
Frontend electronics

- Double Threshold Discriminator
  - Allow to pickoff timing at 1p.e. level
  - Minimize time-walk effect



- Only use waveform digitizer, no ADC, TDC.
  - DRS : digitizer developed for MEG @PSI
  - Sample at 2 GHz

- Record 2 signals
  - Direct signal of PMT output
  - NIM signal from the discriminator



Commissioning run 2006

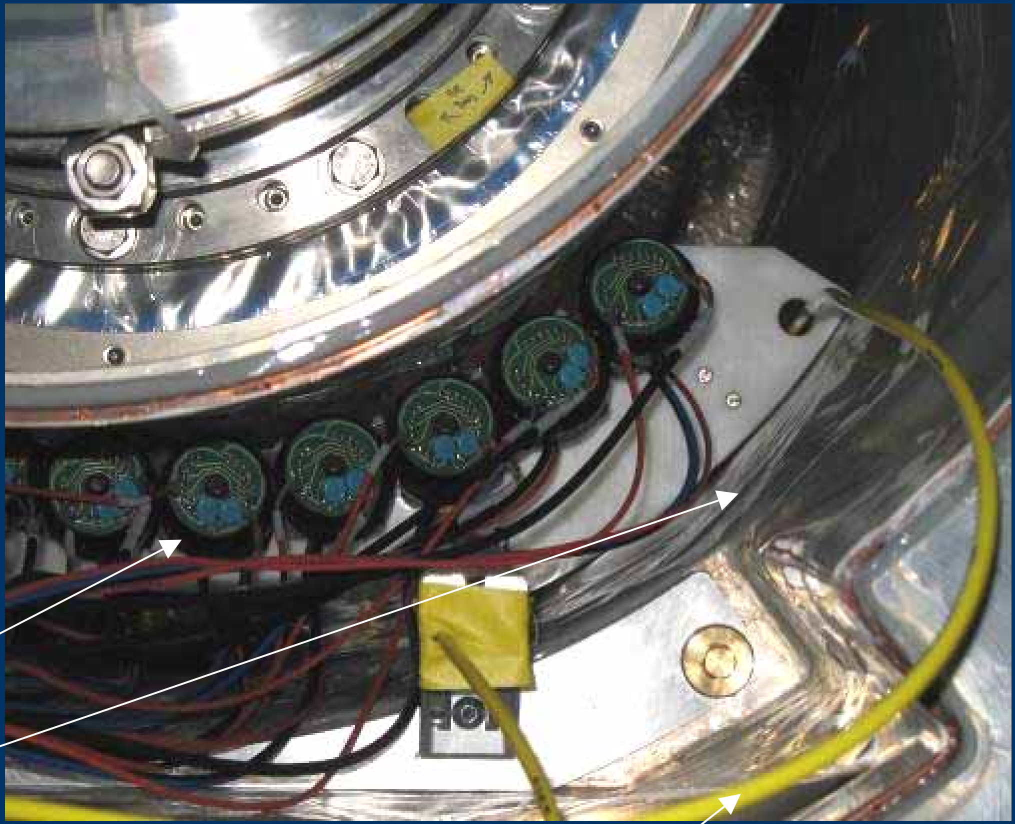
Setup

- Only the bar counters (w/o z measuring fibres)
- Not the final electronics (w/o discri. card)
  - Acquired PMT direct signal (0.5GHz & 2GHz)
  - Some channel of final electronics were tested
- Cosmic rays w/ and w/o magnetic field
- e^+ from muon decay
  - low ~ full beam intensity
- TC self triggering
  - uniform in z direction

Installation

- December 2006

Z measuring fibre counters were not installed



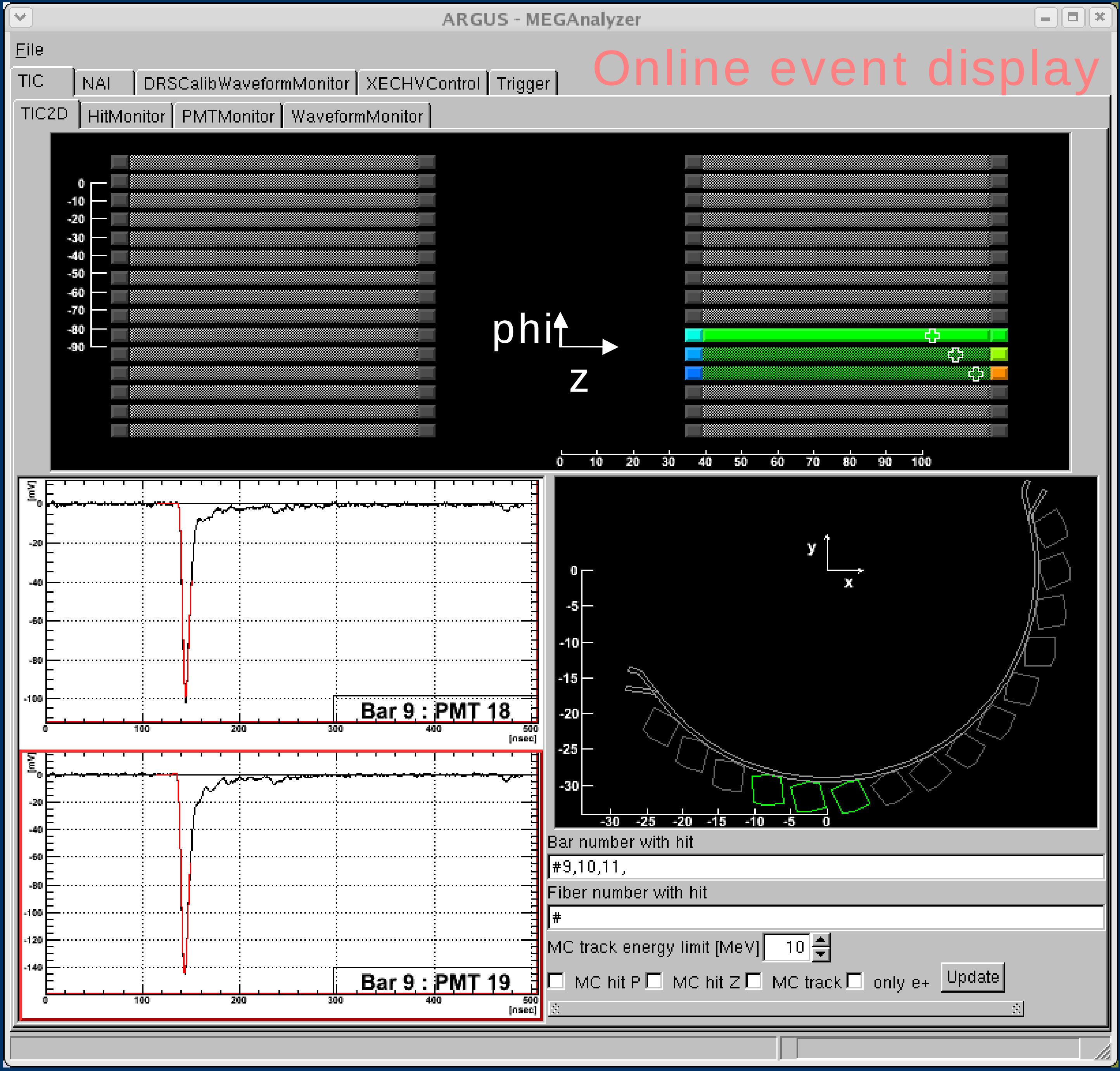
PMTs

N_2 bag

N_2 flushing tubes

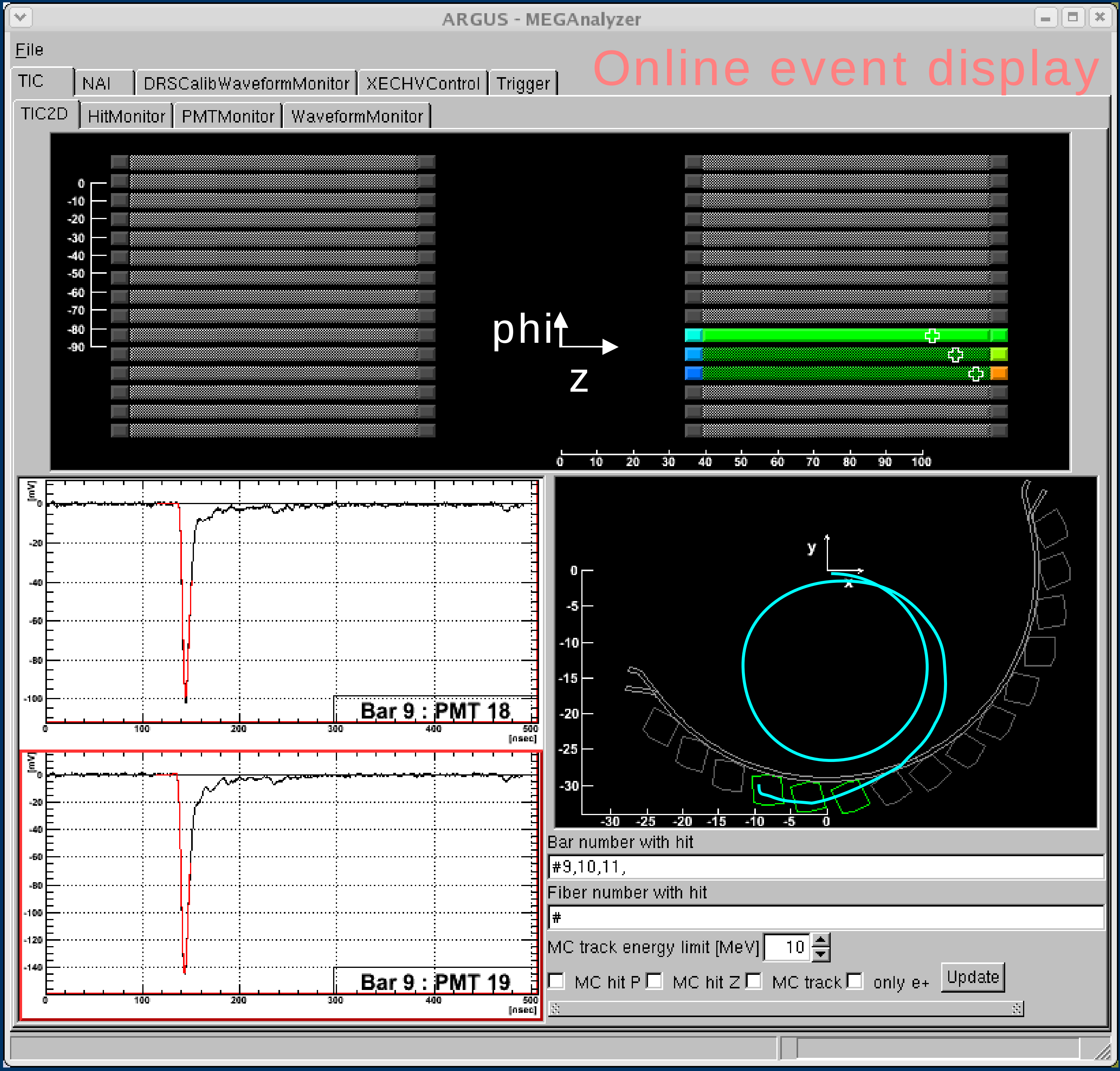
Event

- Typical event of e^+ from target
- e^+ goes through a few bars



Event

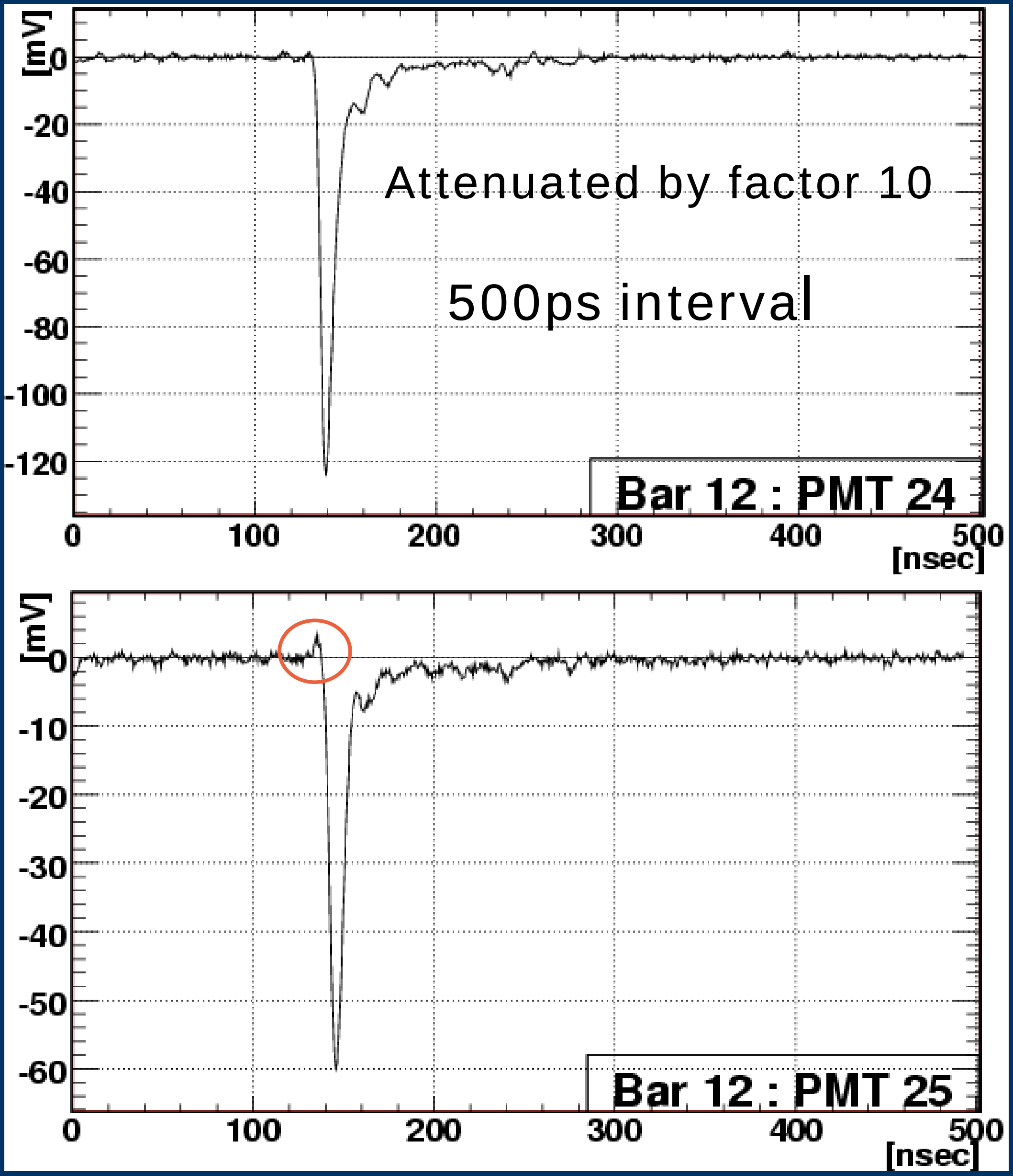
- Typical event of e^+ from target
- e^+ goes through a few bars



Online event display

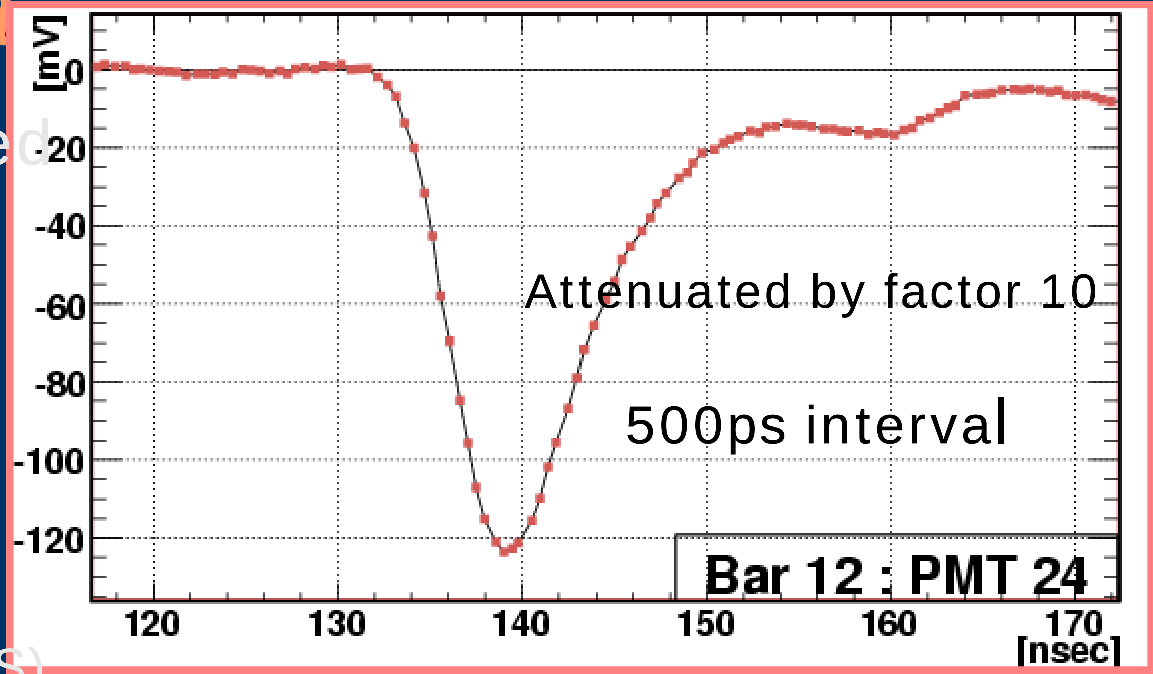
Waveform data

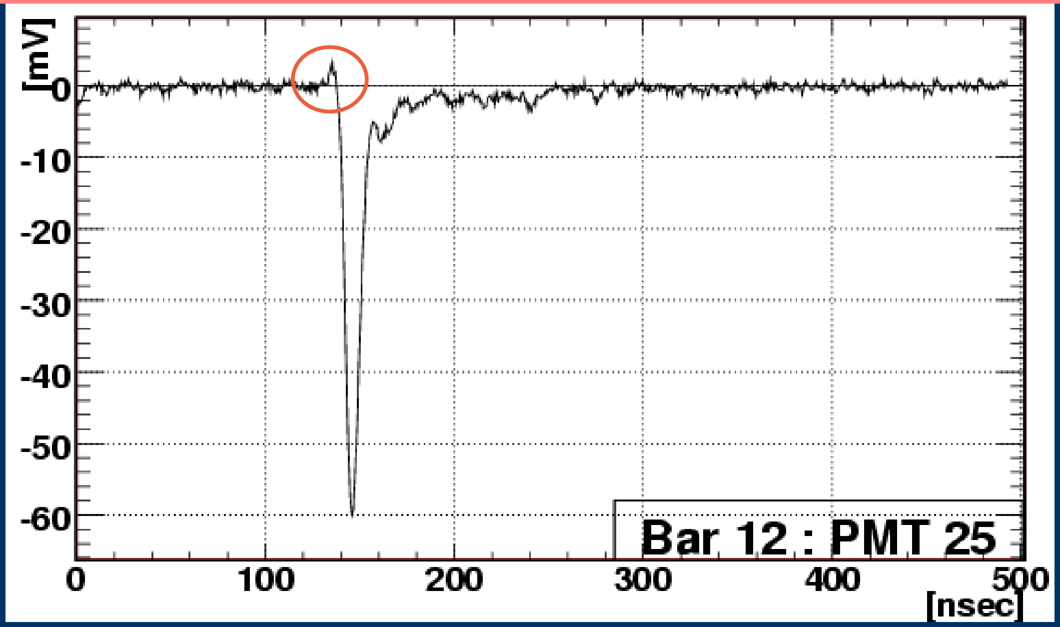
- PMT signals were obtained by waveform digitizer
  - 2GHz sampling
  - sampled after attenuation factor 10
  - low noise level
    S/N ~ 200 (0.3 mV RMS)
  - stable baseline
  - cross-talk
    - 5% at maximum
    - mainly in DRS chip



Waveform data

- PMT signals were obtained by waveform digitizer
  - 2GHz sampling
  - sampled after attenuation factor 10
  - low noise level
    S/N ~ 200 (0.3 mV RMS)
  - stable baseline
  - cross-talk
    - 5% at maximum
    - mainly in DRS chip

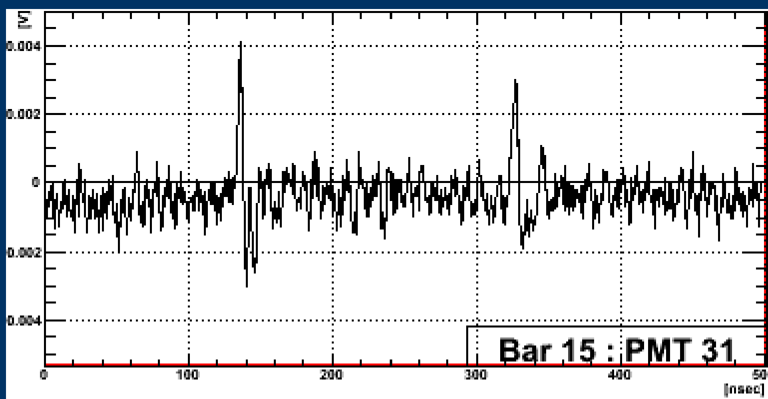


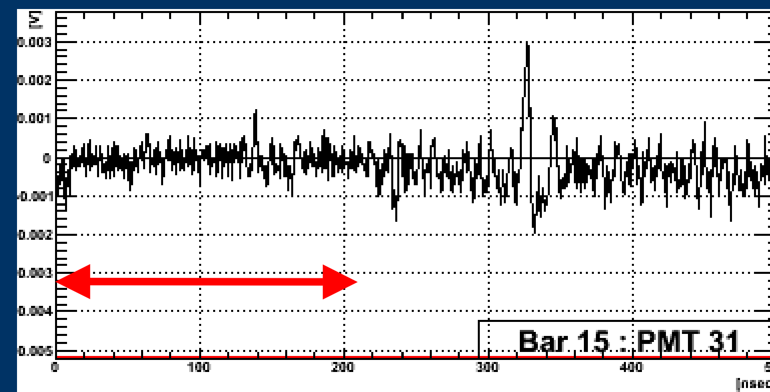


Noise reduction

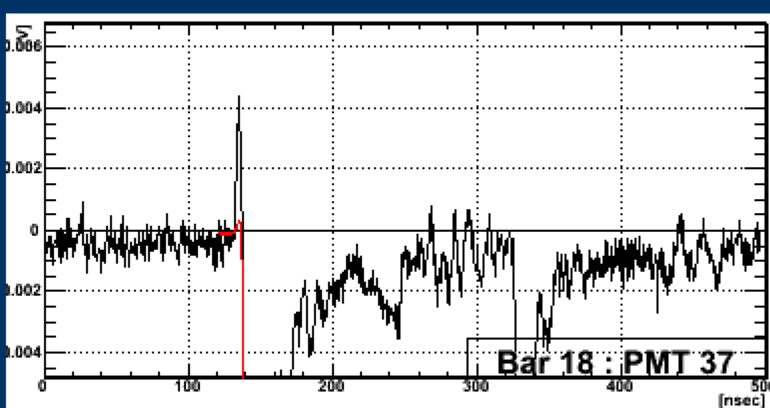
Waveform data enable us to improve data quality offline

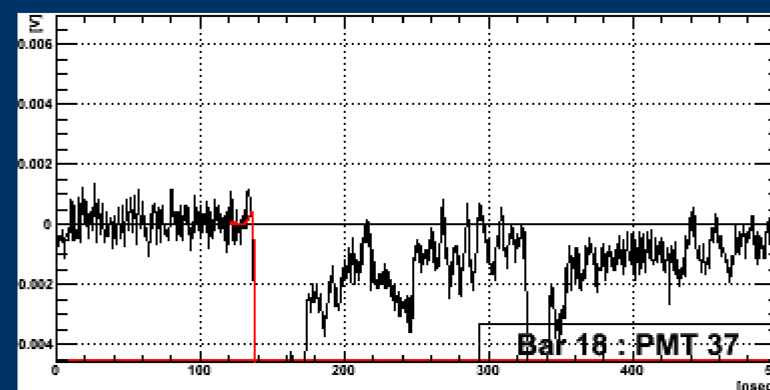
stable baseline, low noise level and cross-talk reduction





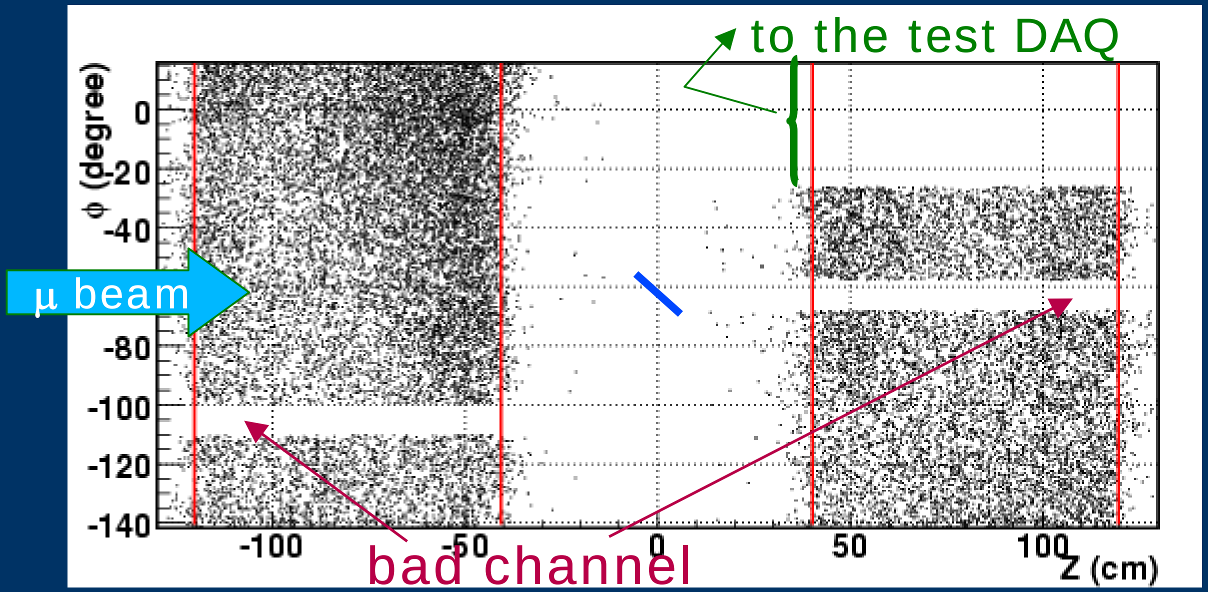
subtract noise (0 ~ 200ns)

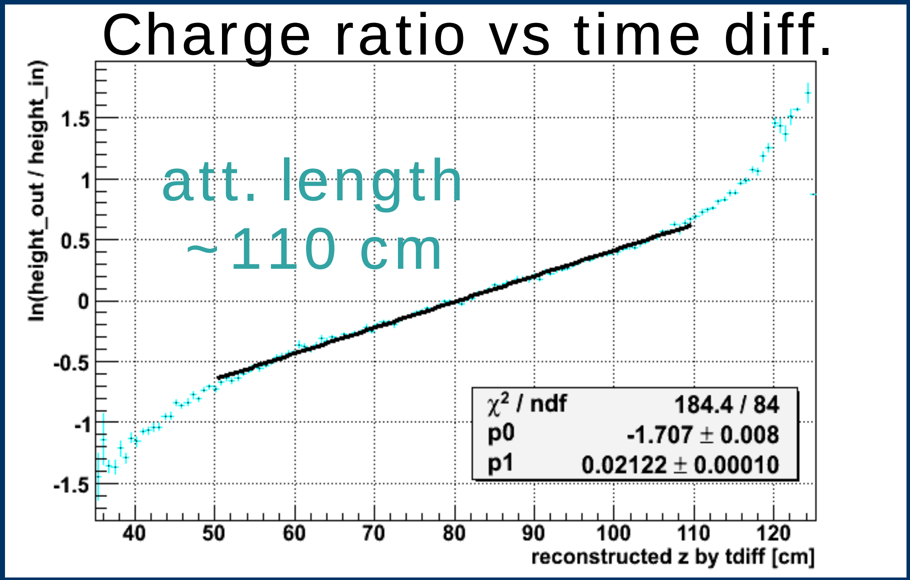


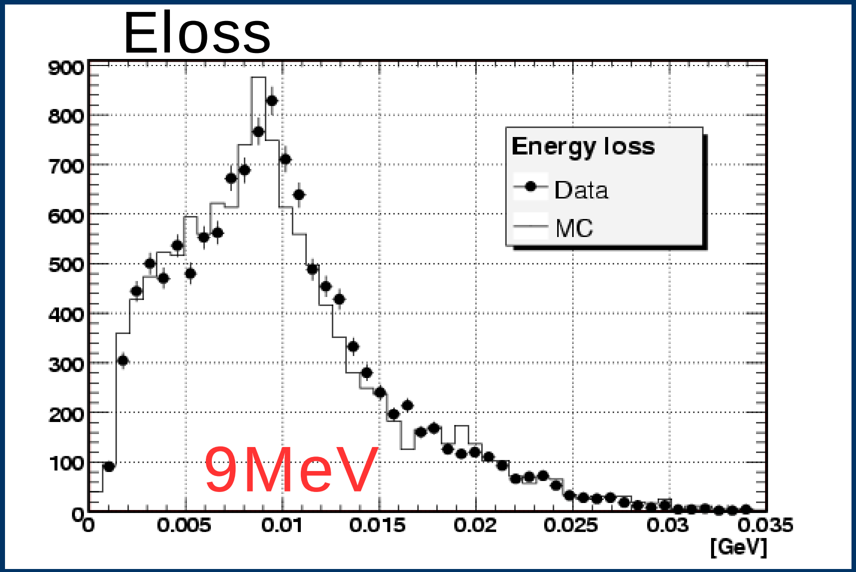


Event distributions

- Z reconstruction by time difference
- rough calibrations
  - time pedestal
  - attenuation length
  - effective light velocity
  - relative gain correction







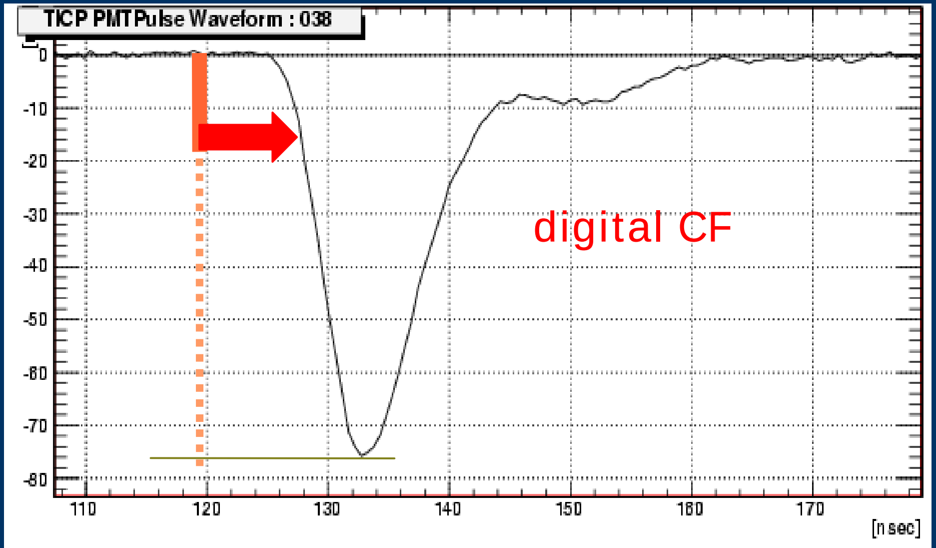
COBRA magnet & Timing Counter are working properly

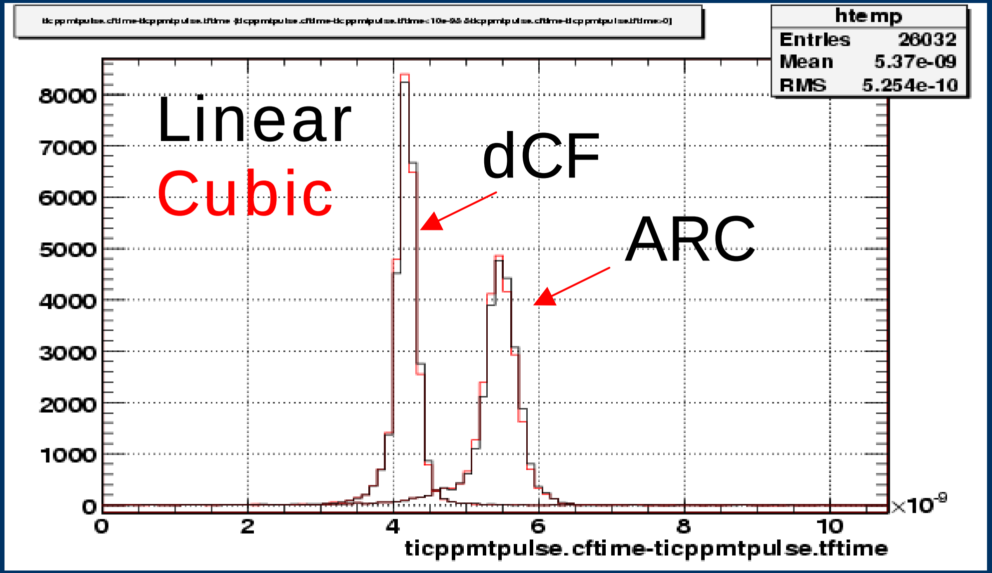
Time pickoff method 1

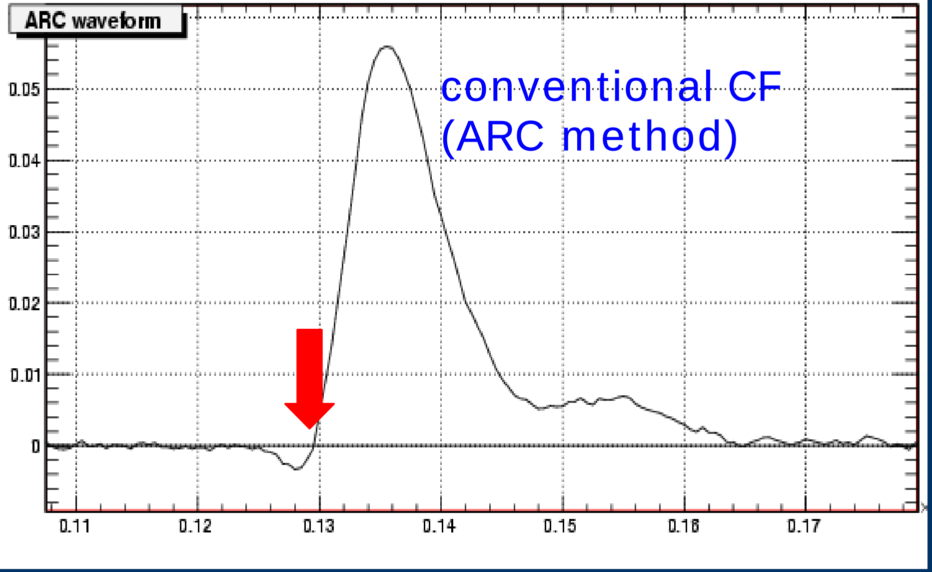
- Constant fraction method
  - timing at constant fraction of peak height
  - no dependence on pulse height
  - fast and assured way

  - tried different algorithms
  - linear or cubic interpolation

  - Fast and sure way – for online



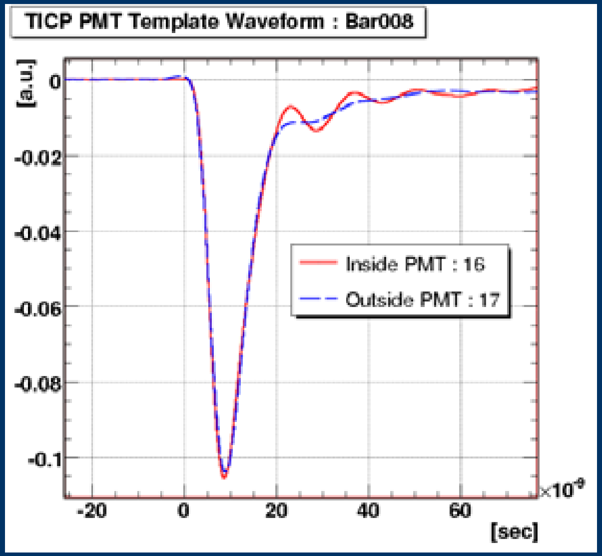




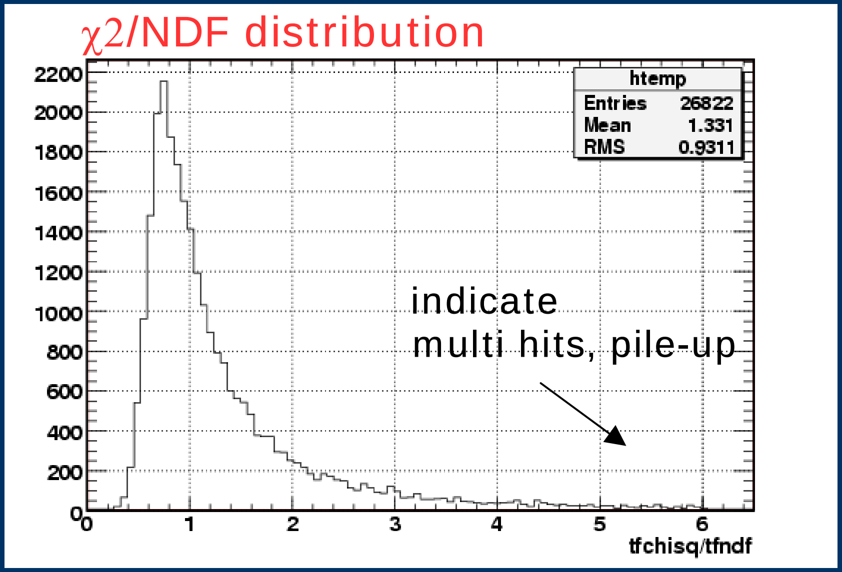
Time pickoff method 2

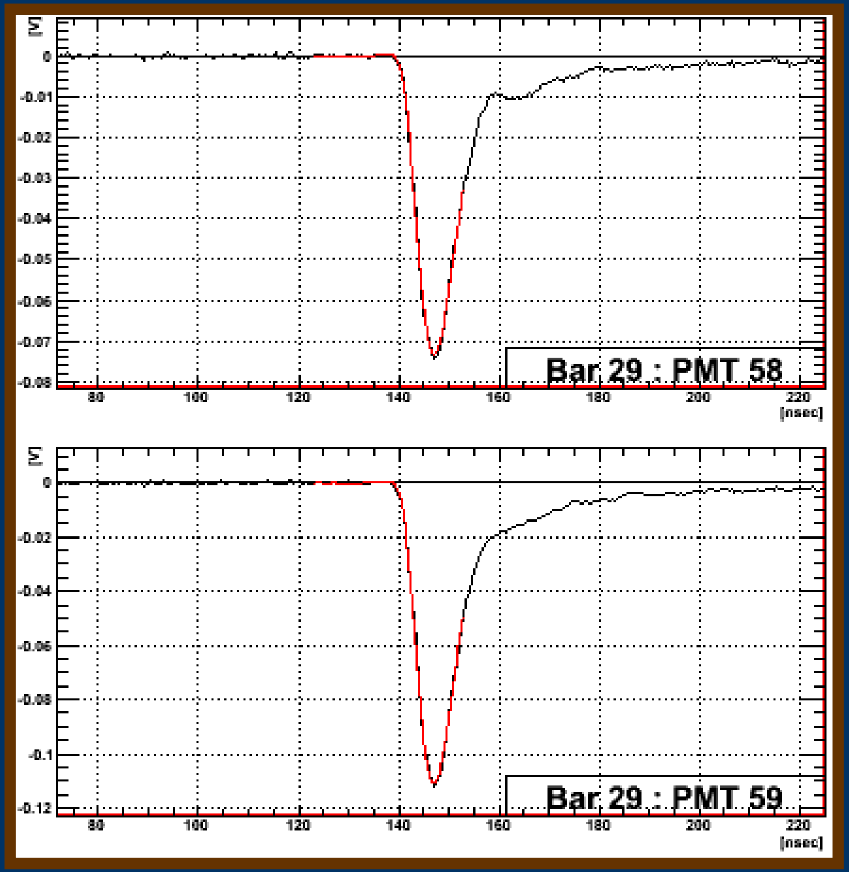
- Fitting with template waveform
  - template by average waveform
  - template for each channel

  - good performance
  - additional information



average waveform for template

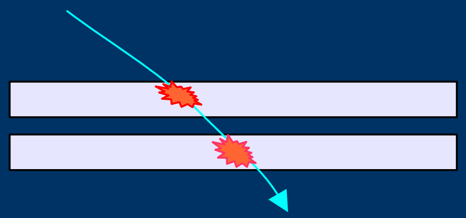




Timing resolution

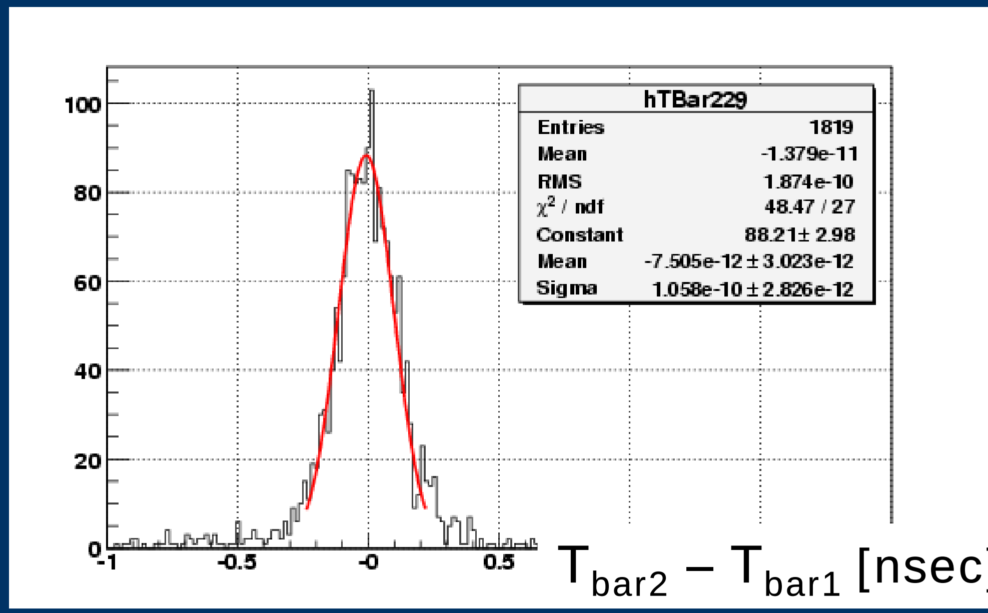
- Estimate timing resolution by time difference between hits on adjacent bars
  - Hit time by average of 2 PMTs

    $t_{hit} = (t_{in} + t_{out})/2$
  - Template fitting is a bit better than CF
  - Event selection
    - hits on adjacent bars
    - energy loss > 6 MeV for both bars
    - z difference 1~6.5 cm
    - $\chi 2$/NDF of template fitting < 3



Time fluctuation from variation of e^+ trajectory ~30 psec

1 bar resolution
176 ps FWHM



Possible improvements

- Final electronics
  - Discriminator output
    - Improvement of S/N (factor 10)
    - First photon timing
- precise and independent determination of impact position
  - Z counter
  - Z counter + track
- Reduce cross-talk
  - cabling and channel assignment
- Improvement of the digitizer : DRS 3   from next year run
  - high linearity
  - large dynamic range
  - low cross-talk
  - low sampling time jitter

Several beam tests confirmed the intrinsic time resolution <100ps

Summary

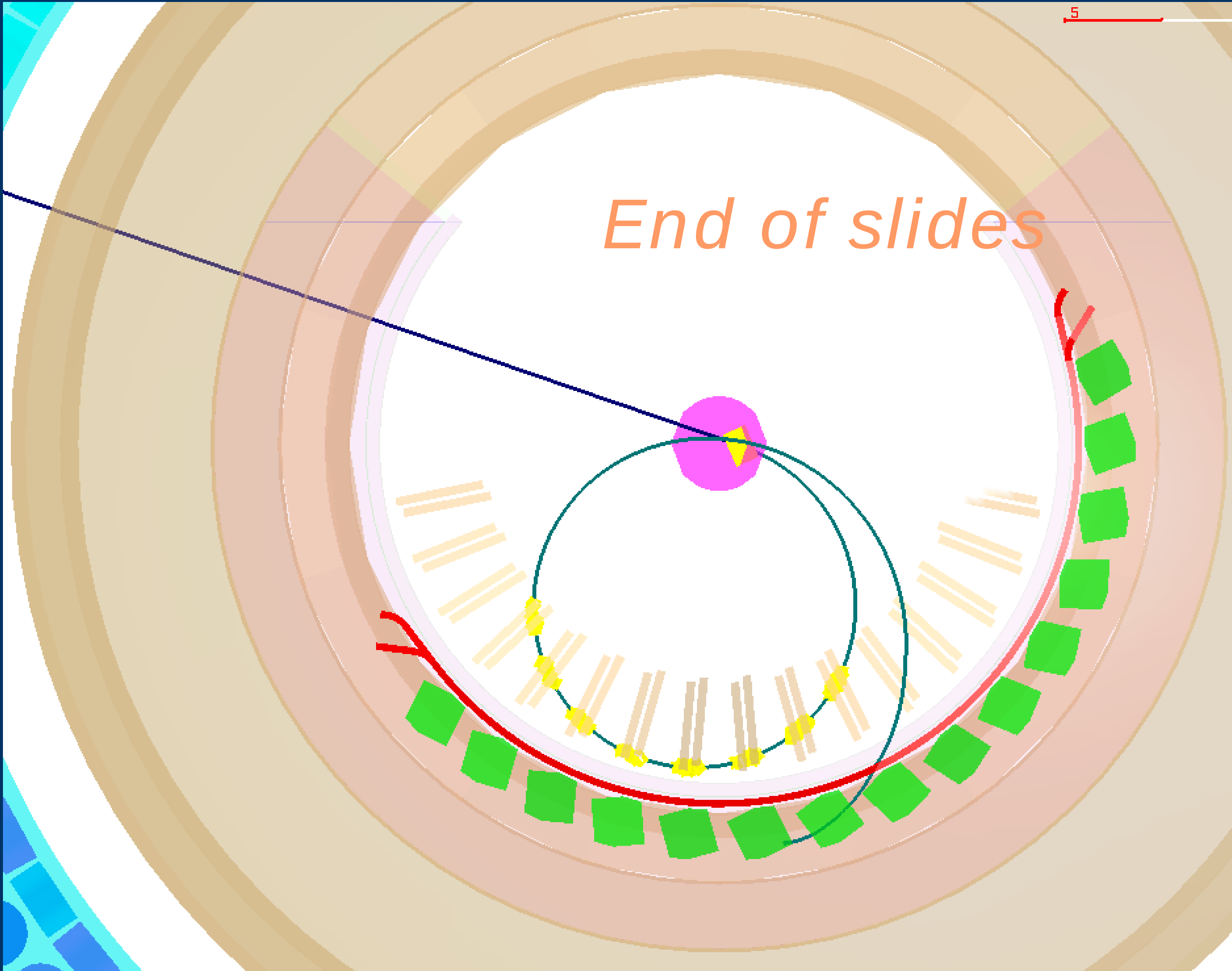
- Timing counter optimized for MEG were completed.
  - Now fibre counters are also ready

- Commissioning run was done with Phi counter
- COBRA e^+ spectrometer worked fine.

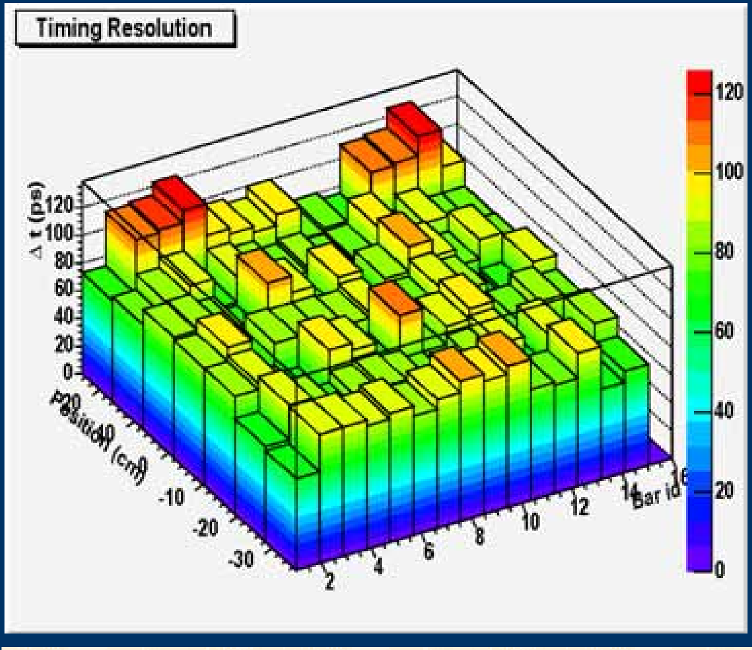
- Waveform data of PMT output were obtained
  - studied waveform analysis

- Worse timing resolution than required
  - Previous beam test confirm the required resolution
  - The cause to be understood
  - We can expect several improvement for the final setup.

End of slides



Beam test results



ΔT ~ 90psec

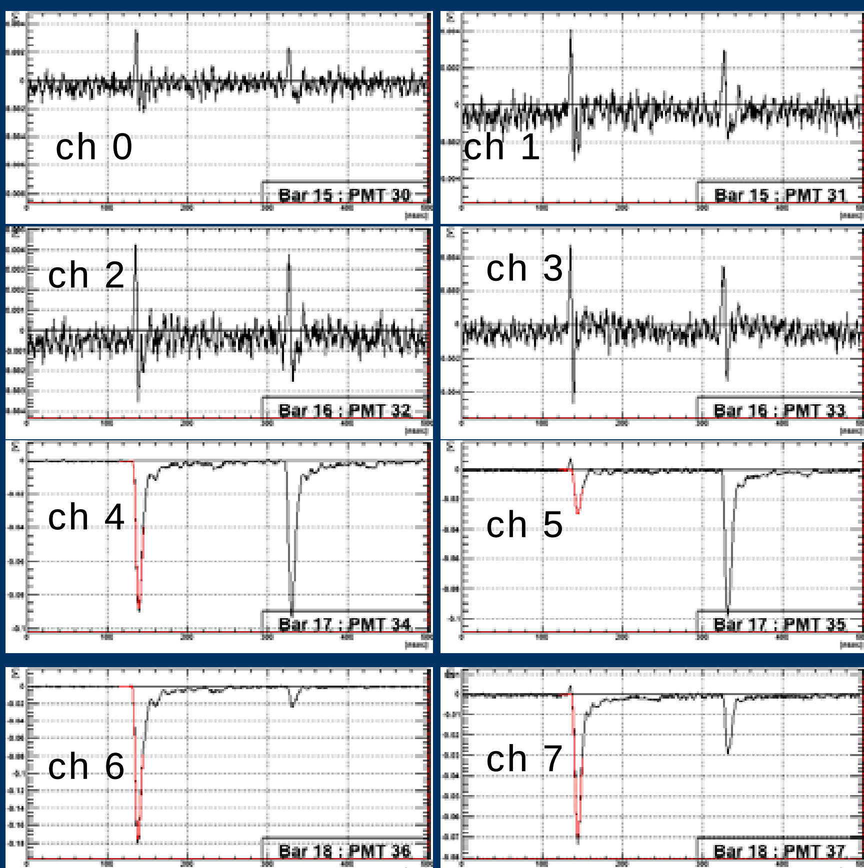
Table form E.Nappi / Bari

Exp. application (*)	Counter size (cm) (T x W x L)	Scintillator	PMT	λ_{att} (cm)	σ_t(meas)	σ_t(exp)
G.D.Agostini	3x 15 x 100	NE114	XP2020	200	120	60
T. Tanimori	3 x 20 x 150	SCSN38	R1332	180	140	110
T. Sugitate	4 x 3.5 x 100	SCSN23	R1828	200	50	53
R.T. Gile	5 x 10 x 280	BC408	XP2020	270	110	137
TOPAZ	4.2 x 13 x 400	BC412	R1828	300	210	240
R. Stroynowski	2 x 3 x 300	SCSN38	XP2020	180	180	420
Belle	4 x 6 x 255	BC408	R6680	250	90	143

- **MEG TC 4x4x80 BC404 R5924 140 38**

Baseline & noise analysis : Coherent Noise

- If noise consists of coherent component, subtracting no signal channel from signal channel can reduce the noise.
- It requires the efficient and safe algorithm to distinguish noise and siganl.



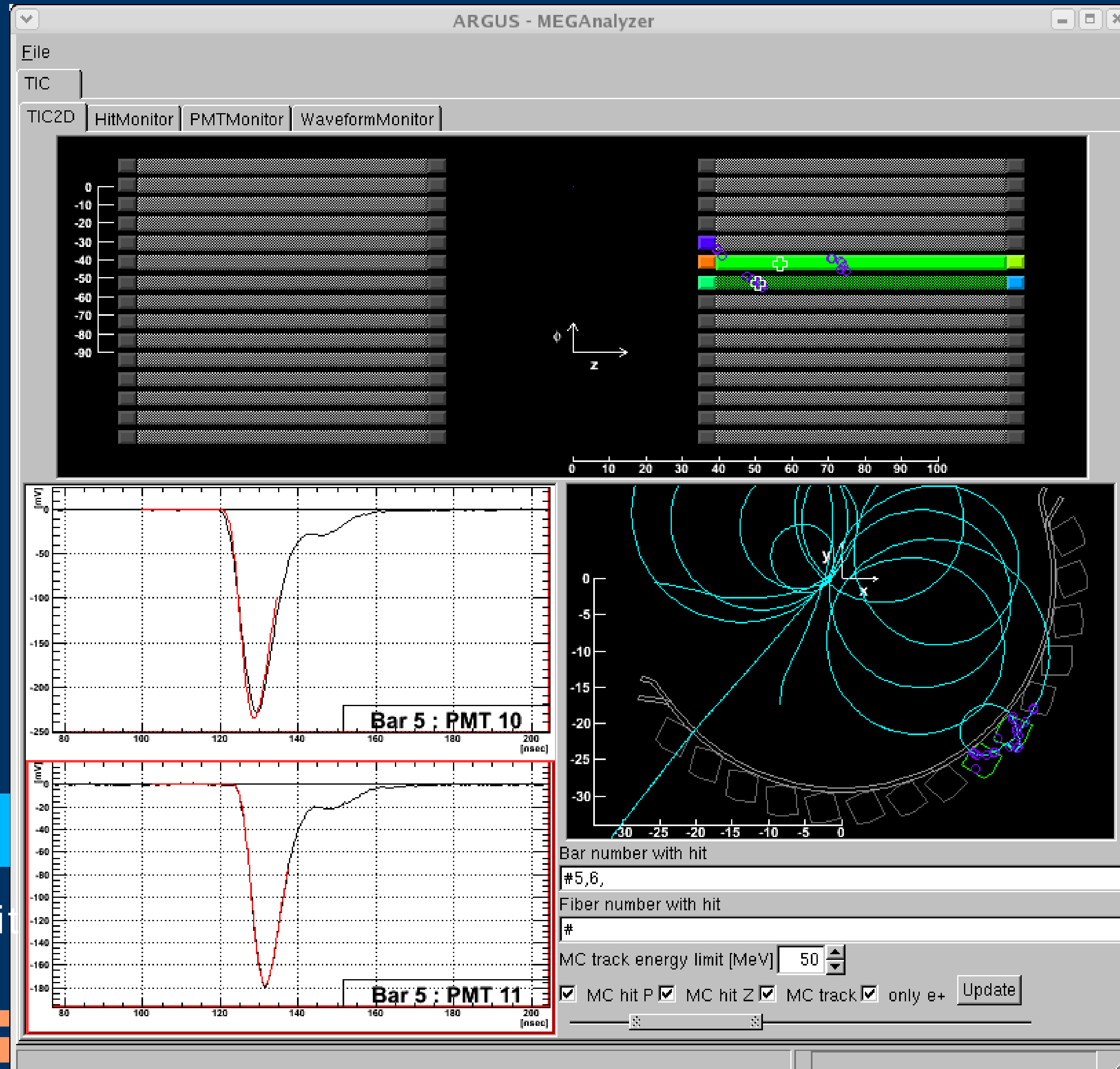
ex.)
Using channels in one DRS chip
Make coherent noise by averaging
no signal channel (ch 0, 1, 2, 3)
Subtract the noise from all channels

Noise Level 0.5 -> 0.32mV
Baseline Fluctuation 0.27-> 0.07mV

Double hits

- some e+ hit same bar twice
- faile z reconstruction
- worse time resolution

- large Chi2/NDF



reach after a few ns delay

reach earlier than 1st hit