Timing Counter

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PSI

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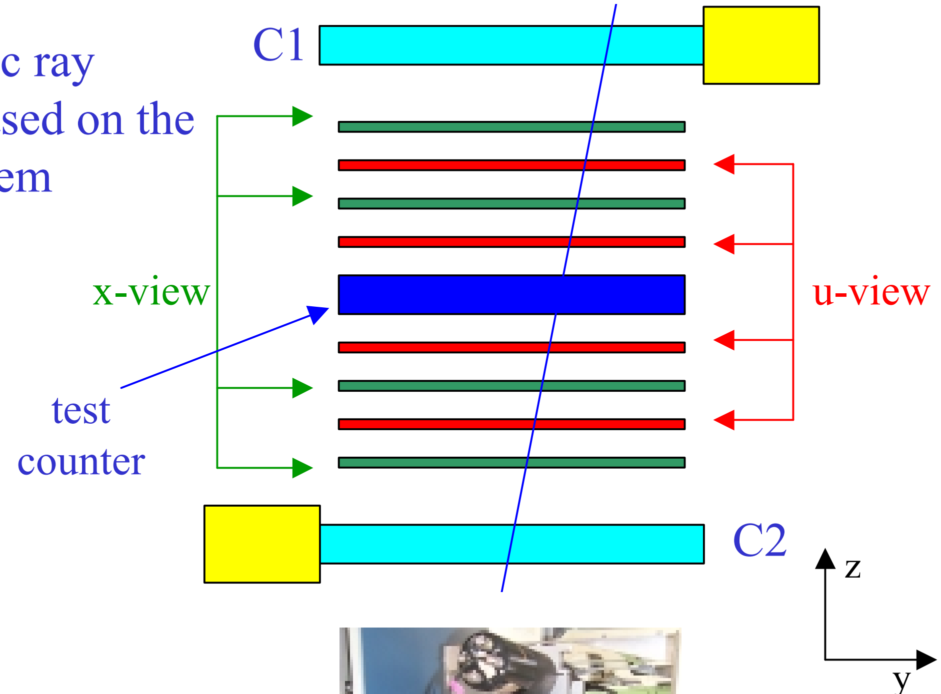
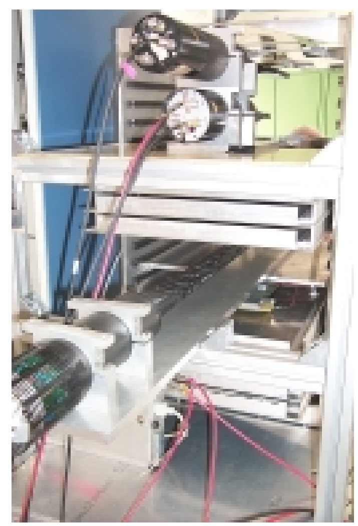
The CORTES facility

A high resolution (0.1÷1.0 mm) cosmic ray tracking system for detector studies based on the micro-strip gas chamber (MSGC) system

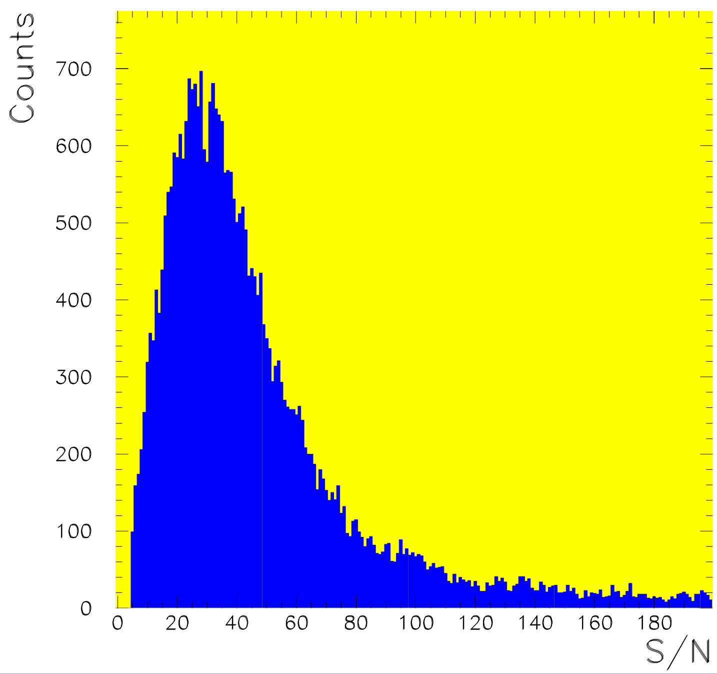
- 8 chambers
  4 x-view, 4 u-view (5.7° stereo)
- 512 strips, 3 mm gap, 200 µm pitch
  ⇒ 10.2 x 10.2 cm^2 sensitive area
- average cluster size ~ 3
  ⇒ σ ~ 35 µm in case of vertical muons
- 4cm spacing + 20 cm for test detector
- Trigger by scintillators C1,C2
  size = 12 x 12 x 2 cm^3, distance = 44 cm
  ⇒ cosθ > 0.95, Ω ≅ 0.05 sr
  ⇒ trigger rate ~ 0.1 Hz
- material thickness ~ 0.5 ÷ 1.0 X
  χ^2-cut to minimise Multiple Scattering effects
  ⇔ $E_\mu \geq 2$ GeV ⇔ $R_\mu \sim 0.03\ s^{-1}$





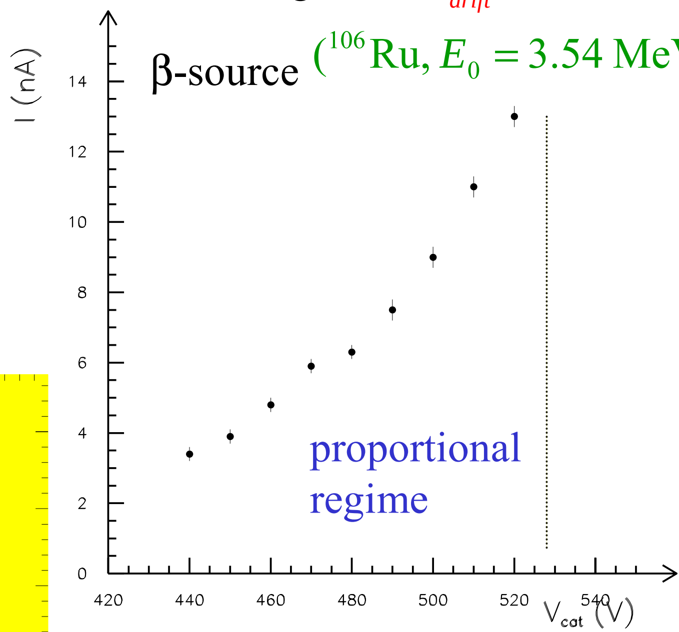
Operating MSGC's

- Gas mixture: Ne (50%)-Ethane(50%) (dI/dx ≈7*e*/mm for m.i.p. at s.t.p.)
- operating voltages: $V_{cat} = -530$ V, $V_{drift} = -3500$ V
- S/N ~ 30 at Landau peak
Gain ~ 1800
- ε > 99%



Current gain at $V_{drift} = -3000$ V

β-source $(^{106}\text{Ru}, E_0 = 3.54 \text{ MeV})$



Many thanks to MSGC people:

R.Bellazzini, A.Brez, G.Gariano, L.Latronico, N.Lumb, G.Spandre

The DAQ system

- **Front-end**

  Anode charge signals undergo:
  - pre-amplification
  - shaping
  - peak sampling
  - multiplexing

  accomplished by PREMUX chips

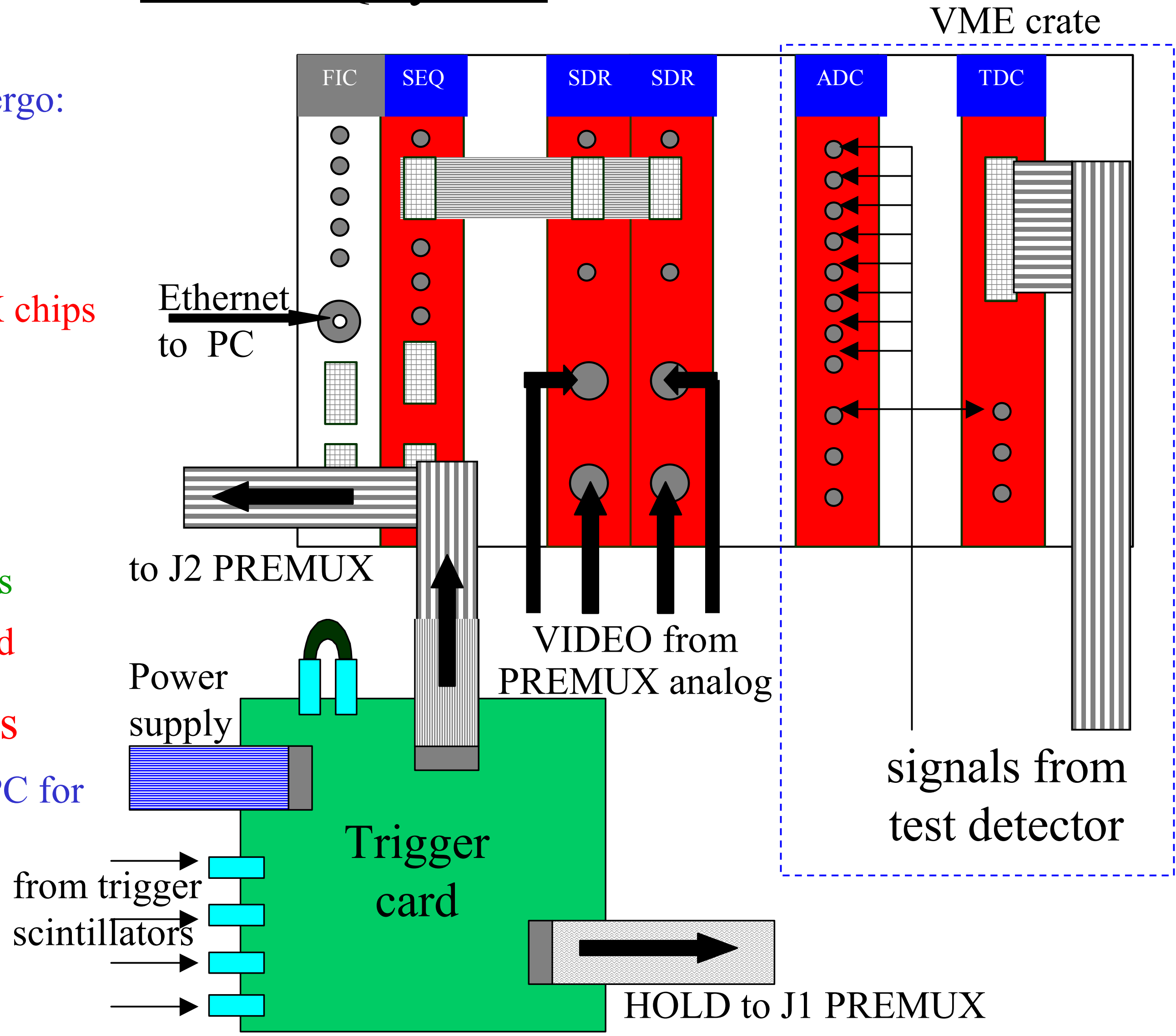
- **On-line**

  A VME system based on:
  - CPU FIC 8251
  - SDR-Sequencer
  - Sirocco Flash-ADC's

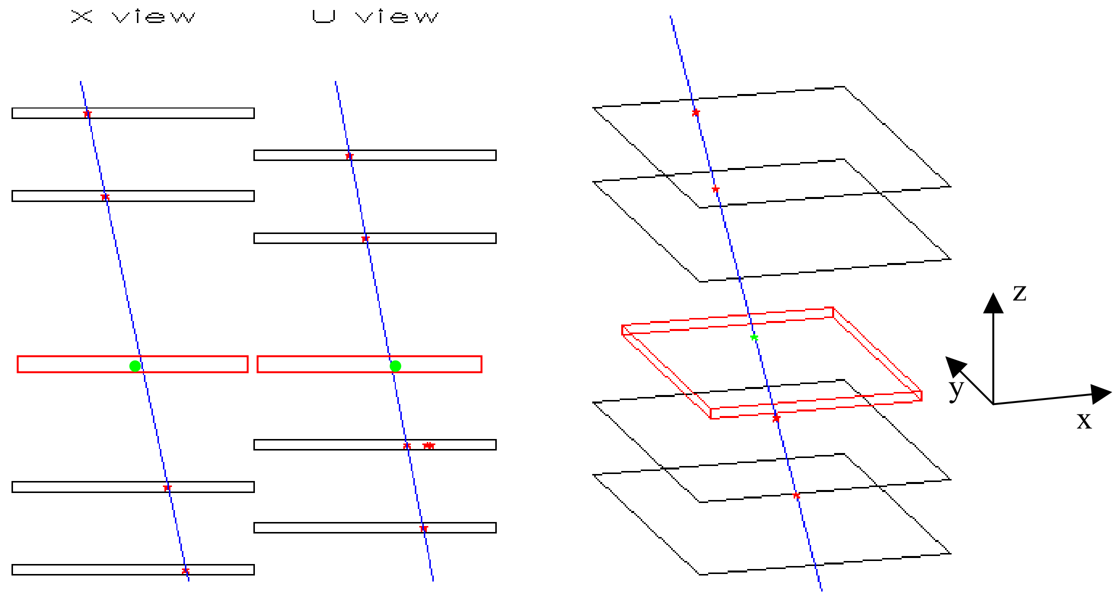
  driven by a fast Trigger card

- **Read-out and analysis**

  Data sent via TCP-IP to a PC for
  - event building
  - data write-out
  - histogram display



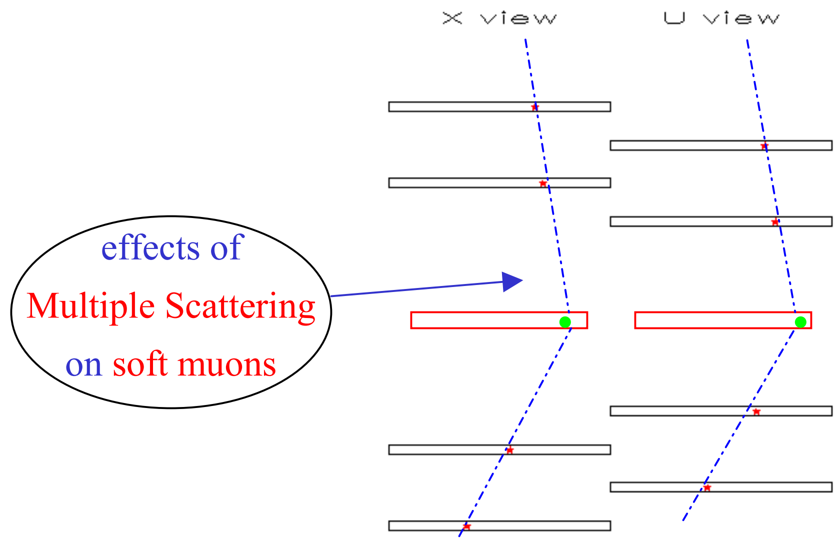
Tracking performances



- Independent fit of x and u-views → planes
- Plane intersection → cosmic ray track
- Track intercept with the detector plane → hit point
- Position resolution:

$$\sigma_x = \sigma_u = 65\,\mu\text{m}$$
$$\Rightarrow \sigma_y = 0.9\text{ mm}$$

(limited by stereo angle)



Timing Counter test

• Prototype counter assembled with :

- •BC-404 100x5x1 cm³
- •fish-tail light-guides
- •PMT Philips XP2020/UR, 2" and HAMAMATSU 5946 (1.5")

T1,T2 (transit time spread = 470 ps FWHM)

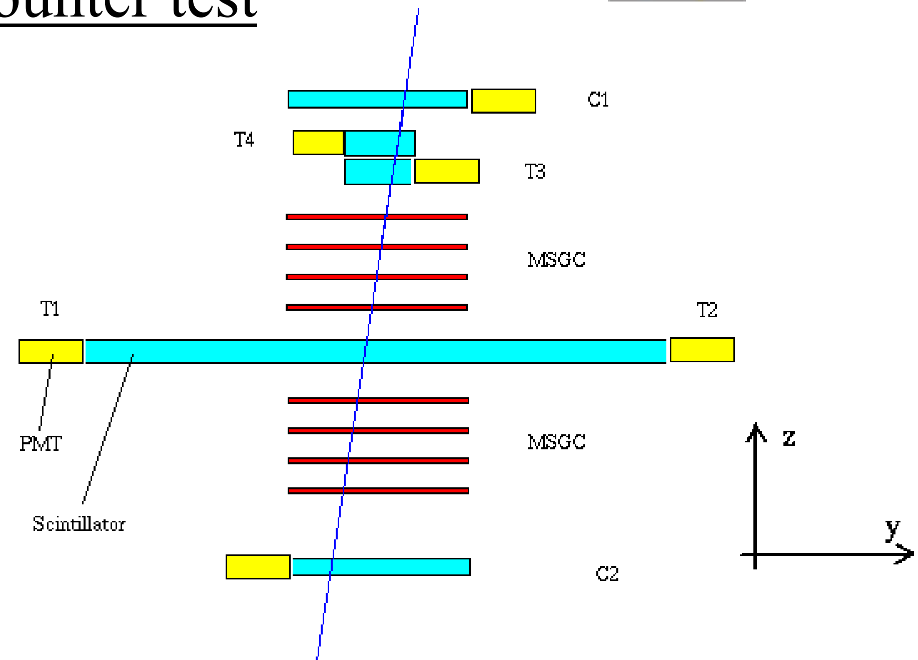
• $N_{phe} \approx 200$ for m.i.p. at centre

• Scintillation counter aligned along y-axis

$\Rightarrow$ (σ = 1 mm)

• Time reference provided by T3,T4

(BC-404, 5x5x1 cm³)



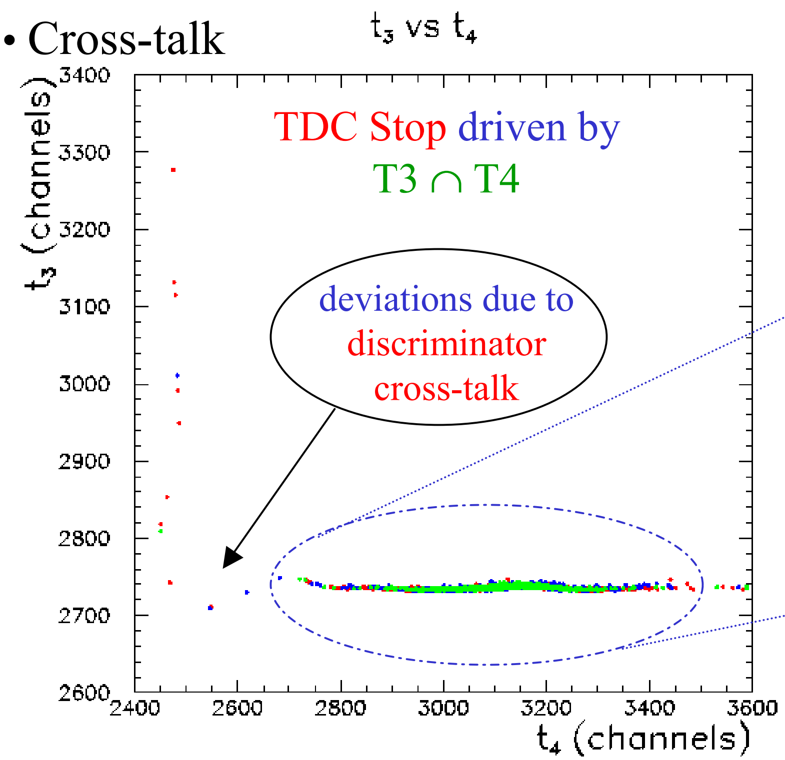
Front-end & digitizers

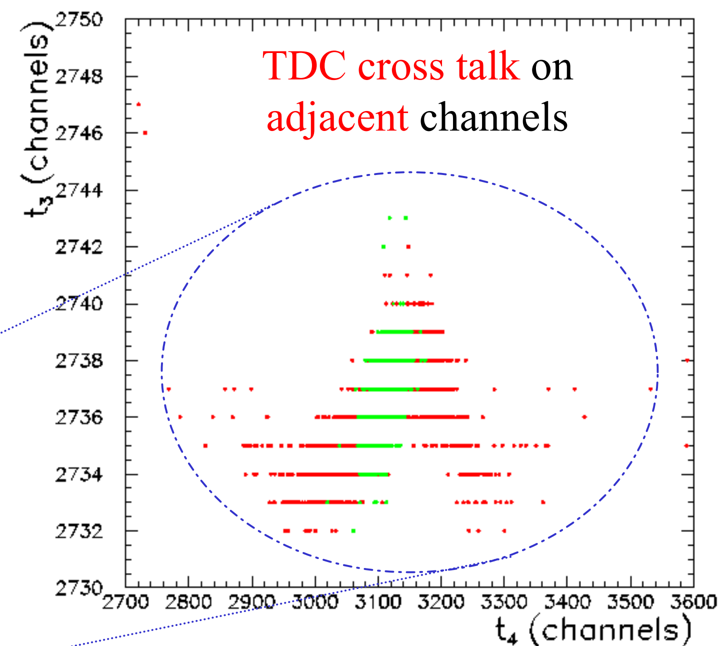
Cross talk in the final electronics?

•DAQ electronics consisting in:

- NIM LeCroy 623B discriminators driven by PMT anode pulses
- CAEN V488AS TDC's (16 ps least count) operated in Common-Stop mode (C1-C2)
- CAEN V465 ADC's integrating PMT last dynode pulse
- VME DAQ system (see above)

• Cross-talk





- Either discriminator input delayed by 10 ns
- Use of "far" TDC channels on the same board

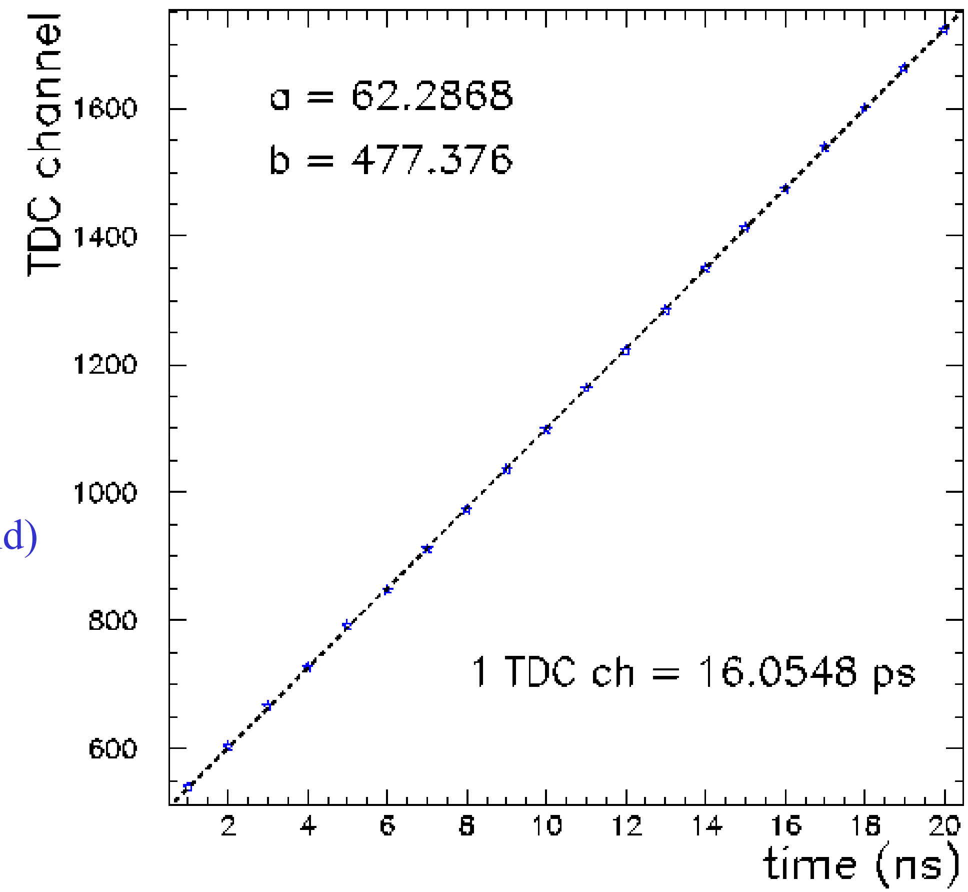
TDC calibration

• TDC least count

Use of a calibrated pulser with delayable outputs

1 TDC ch. = 16 ps on average

Calibration needed for individual TDC channels (QAC gain variation ~ 2% found)



Off-line corrections

- event position

$$T_i = t_i' - t_{ref}' + \frac{1}{v_i}\left[\frac{L}{2} - (-1)^i y\right]$$

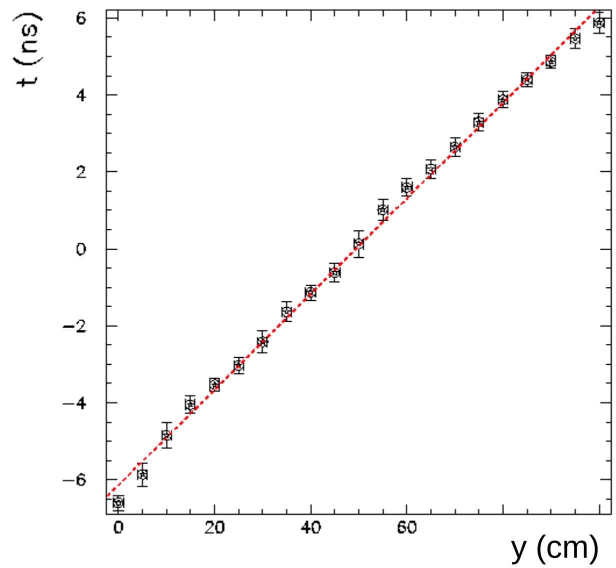
Use of a β-source (^{106}Ru) along the counter to determine the effective light speed

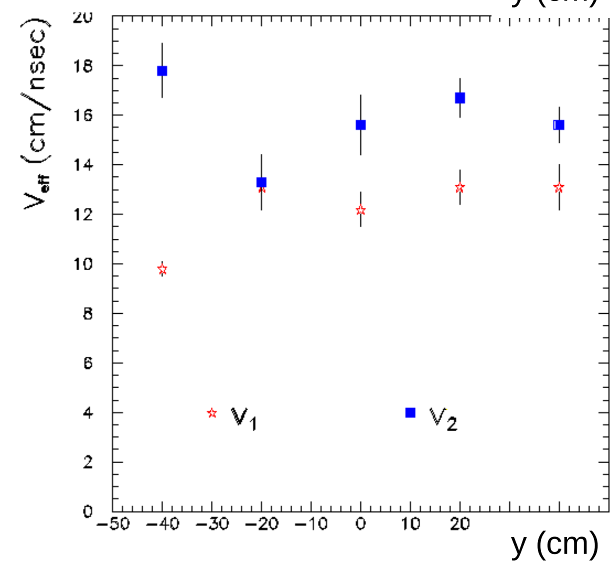
v = (15.7 ± 0.3) cm/ns average value

Sizeable deviations from linearity at counter-ends (direct photon collection, no reflection on walls)

Also minor local effects (due to wrapping) are present ⇒ need to account for variations of light speed along the counter: v=v(y)

Can be measured for each counter





Off-line corrections (cont.)

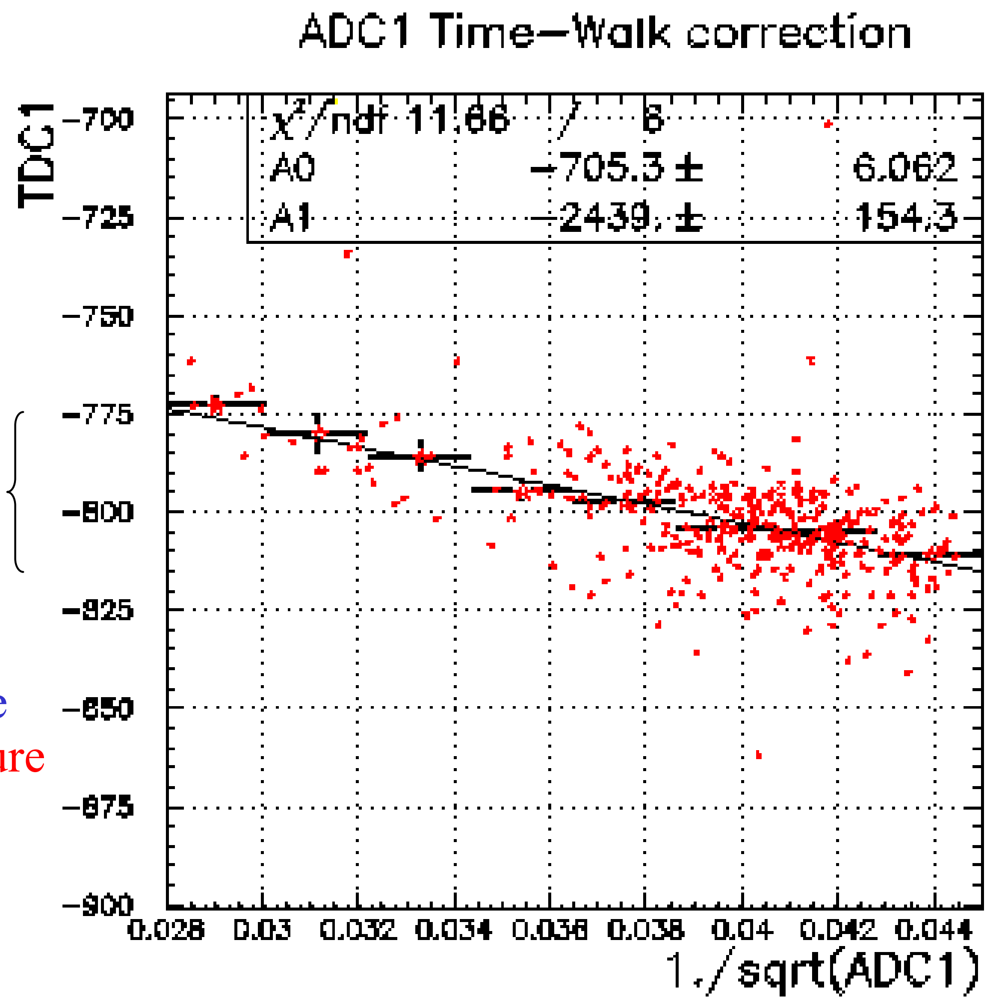
- time-walk

$$t_i' = t_i + \frac{w_i}{\sqrt{q_i}}$$

measured TDC time

measured ADC charge

~ 600 ps walk along the Landau spectrum



Both light speed and time walk are determined by an iterative procedure

Timing resolution

Two independent estimates of timing resolution

- Weighted average

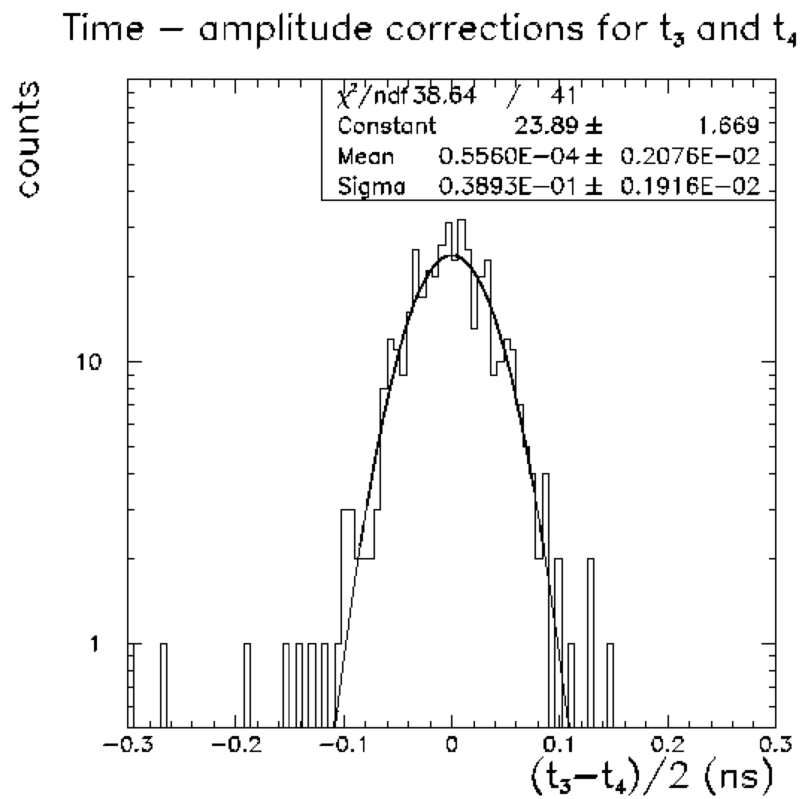
  Absolute time computed from independent PMT estimates

$$T_{wa} = \frac{T_1/\sigma_1^2 + T_2/\sigma_2^2}{1/\sigma_1^2 + 1/\sigma_2^2}$$

Reference resolution needs to be unfolded from PMT time distribution

$$\sigma_i^2 = \sigma_{T_i}^2 - \sigma_{ref}^2$$

$\sigma_{ref} = 56$ ps from rms of (T3-T4)/2 distribution



- (T1 - T2)/2

  independent of reference counter

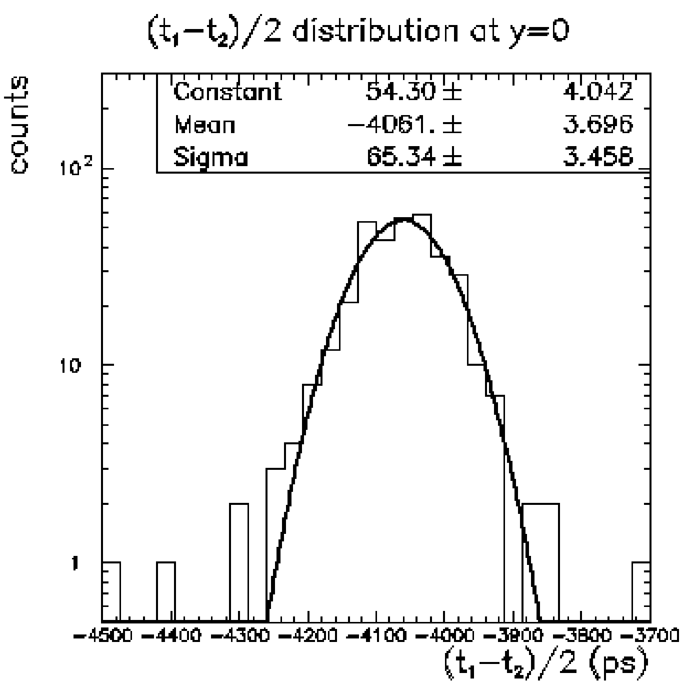
Results

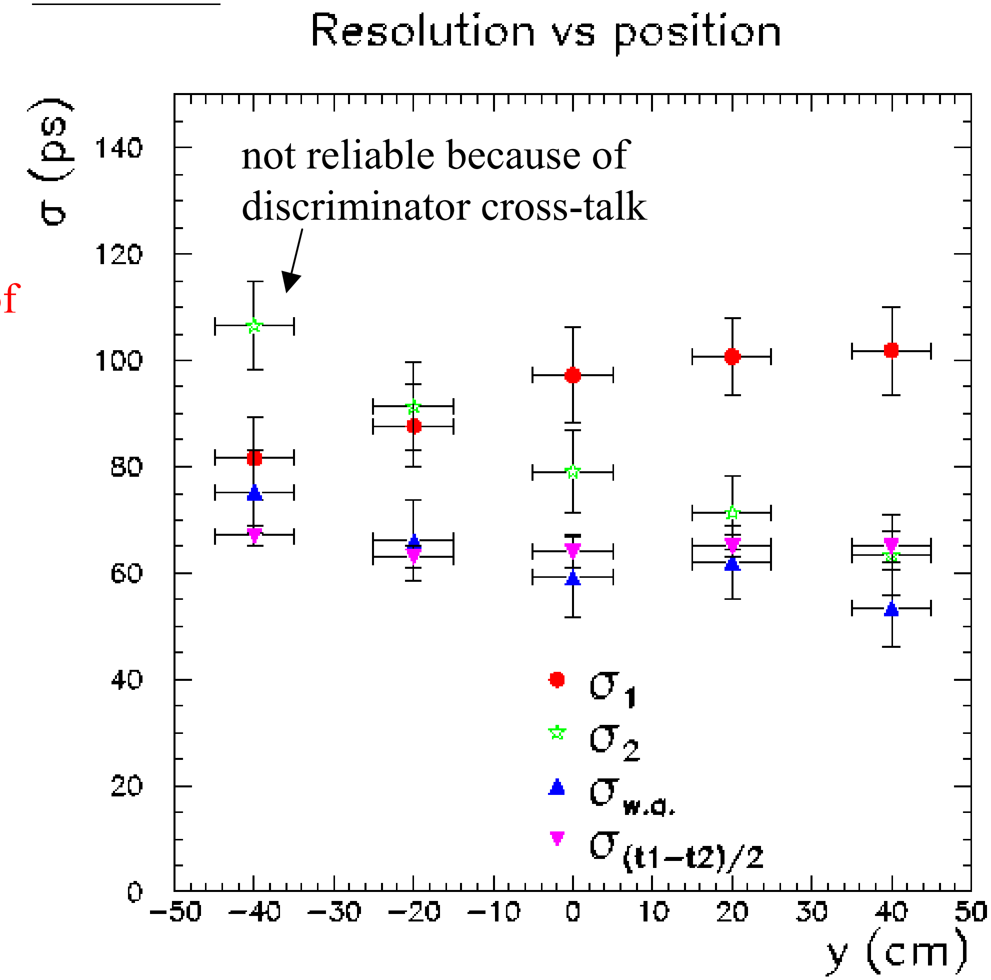
We obtain

$\sigma_{w.a.} \sim 60$ ps

almost independent of muon passage along the counter

(although $\sigma_{1,2}$ depend on the number of photoelectrons)





$\sigma_{(t_1-t_2)/2}$ provides similar results

Do we need precise position determination?

Time measurement of both PMT are affected by position error

But T_1, T_2 are anti-correlated

if T=$T_1 + T_2$ T would be independent of y

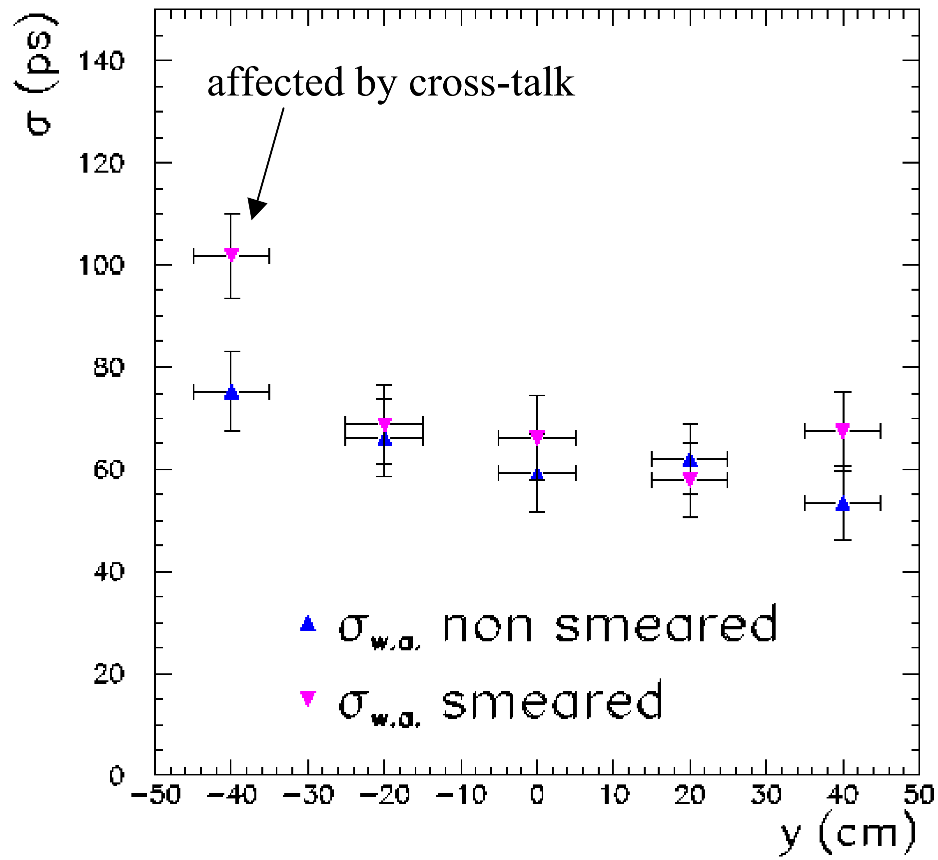
- Use of data sample with y-position extracted from $N(\bar{y}, \sigma_{MC})$ with $\sigma_{MC} = 0.5$ cm

(from positron track fit extrapolation to the TC)

- Given y, obtain $T_{w.a.}, \sigma_{w.a.}$ from previous formulae

$\sigma_{w.a.} \sim 65$ ps

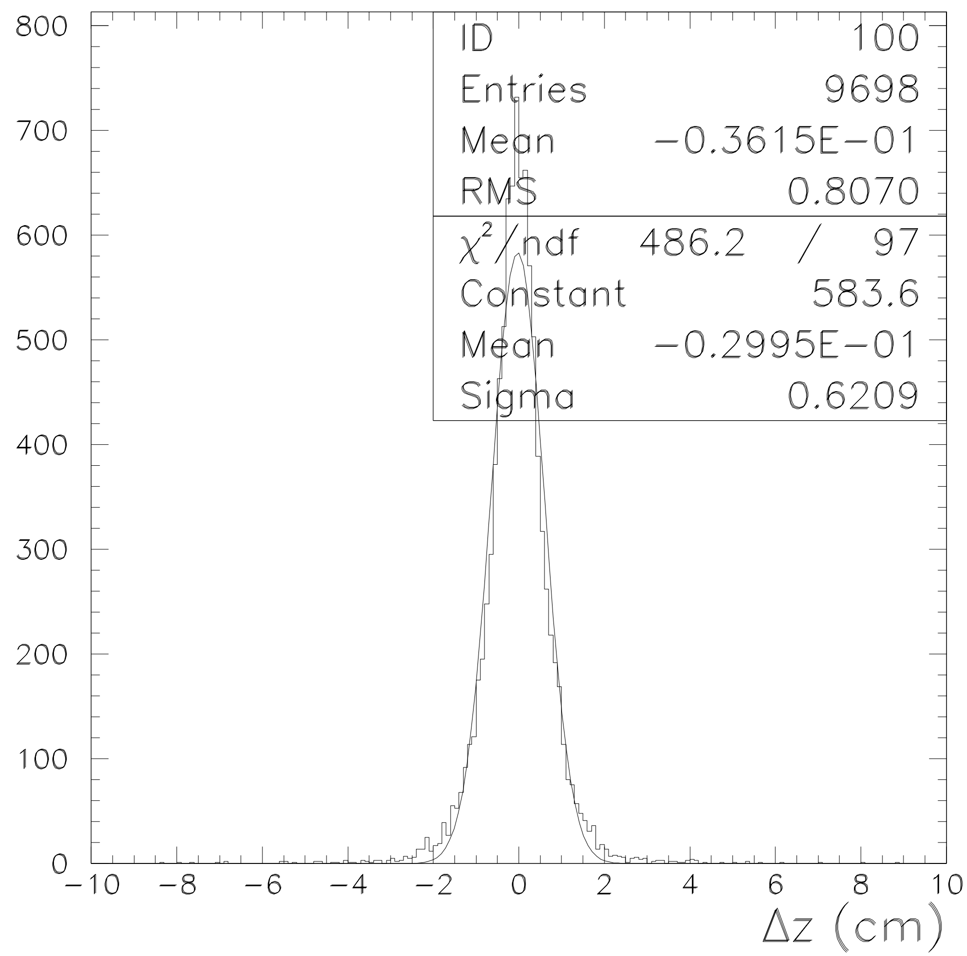
(~1σ larger than non-smeared value)



Hit point on TC

$\Delta Z = Z_{MC} - Z_{fit}$

difference of MonteCarlo generated point versus track fitting extrapolation

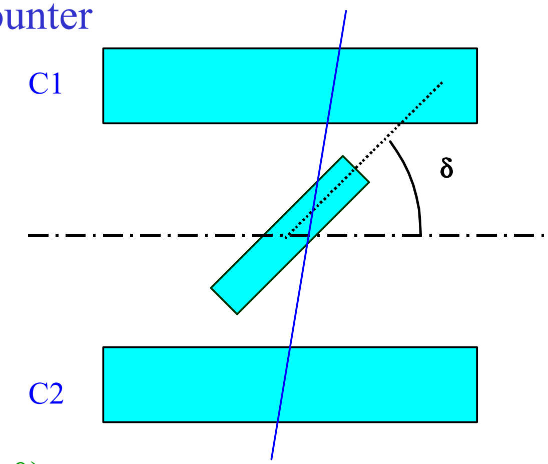


⇒ track fitting provides a good determination of the TC hit point

Further checks

•Resolution vs. number of photoelectrons

Different slant angles to vary the muon path inside the counter



$$\frac{\sigma(\delta=0)}{\sigma(\delta)} = 1.18 \pm 0.05$$

in agreement with photoelectron statistics

$$\sqrt{\frac{n(\delta)}{n(\delta=0)}} = \sqrt{\frac{1}{\cos\delta}} = 1.22$$

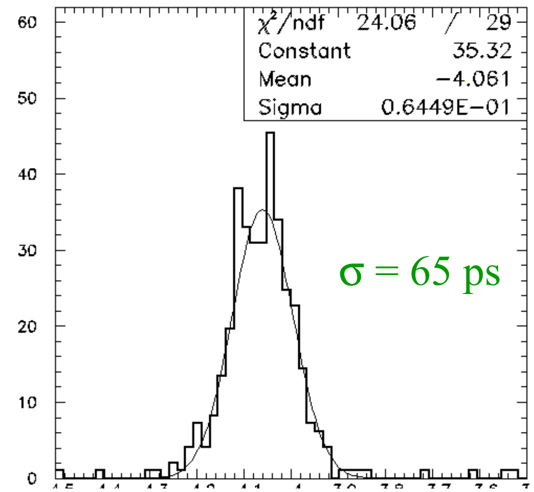
•Test counter with different PMTs

Use of new fine-mesh Hamamatsu PMTs

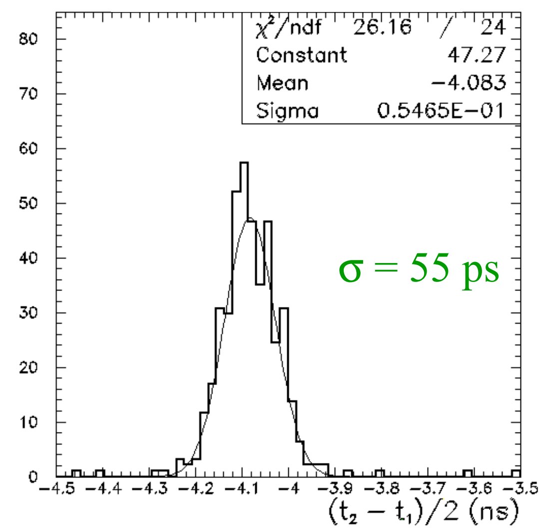
(20 stages, Ø = 1.5 ", time jitter = 470 ps FWHM)

data analysis in progress

$\delta = 0$



$\delta = 48.5^o$



MC studies

•Timing efficiency

σ ≈ 60 ps for ΔE ≈ 2 MeV

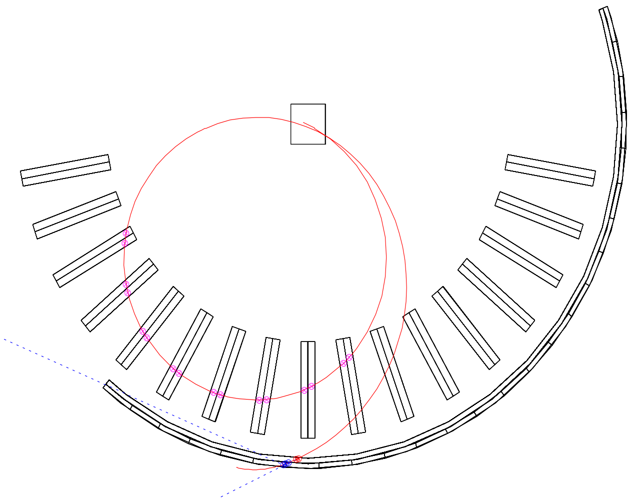
mainly dominated by photoelectron statistics

⇒ ΔE > 5 MeV energy deposit on adjacent ϕ-cells to achieve 100 ps FWHM resolution

$$T_{w.a.} = \frac{\sum T_i / \sigma_i^2}{\sum 1/\sigma_i^2}$$

use of more than 2 PMT's

need to know T(E,x,z)

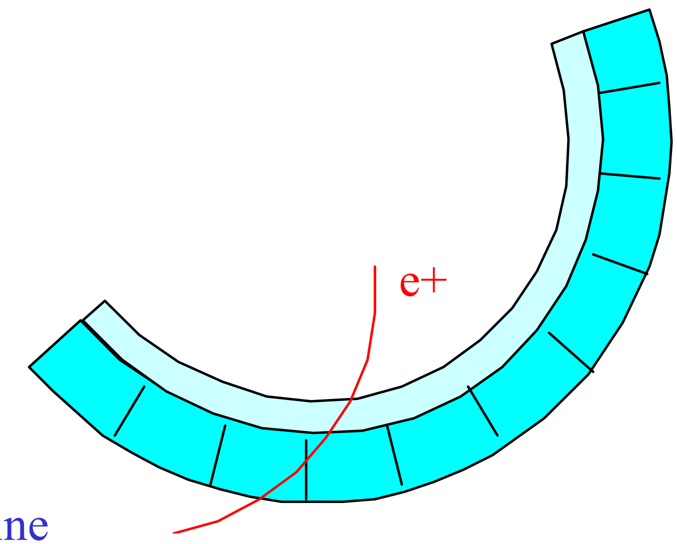


•Trigger efficiency

Use of hit z-cells and ϕ-cells to determine initial positron direction

⇒ correlation with max. charge PMT in LiXe calorimeter (providing γ direction)

Yet to be studied: use of Q1/Q2 (instead of z-cells layer or in addition: pattern recognition) to determine the z-position

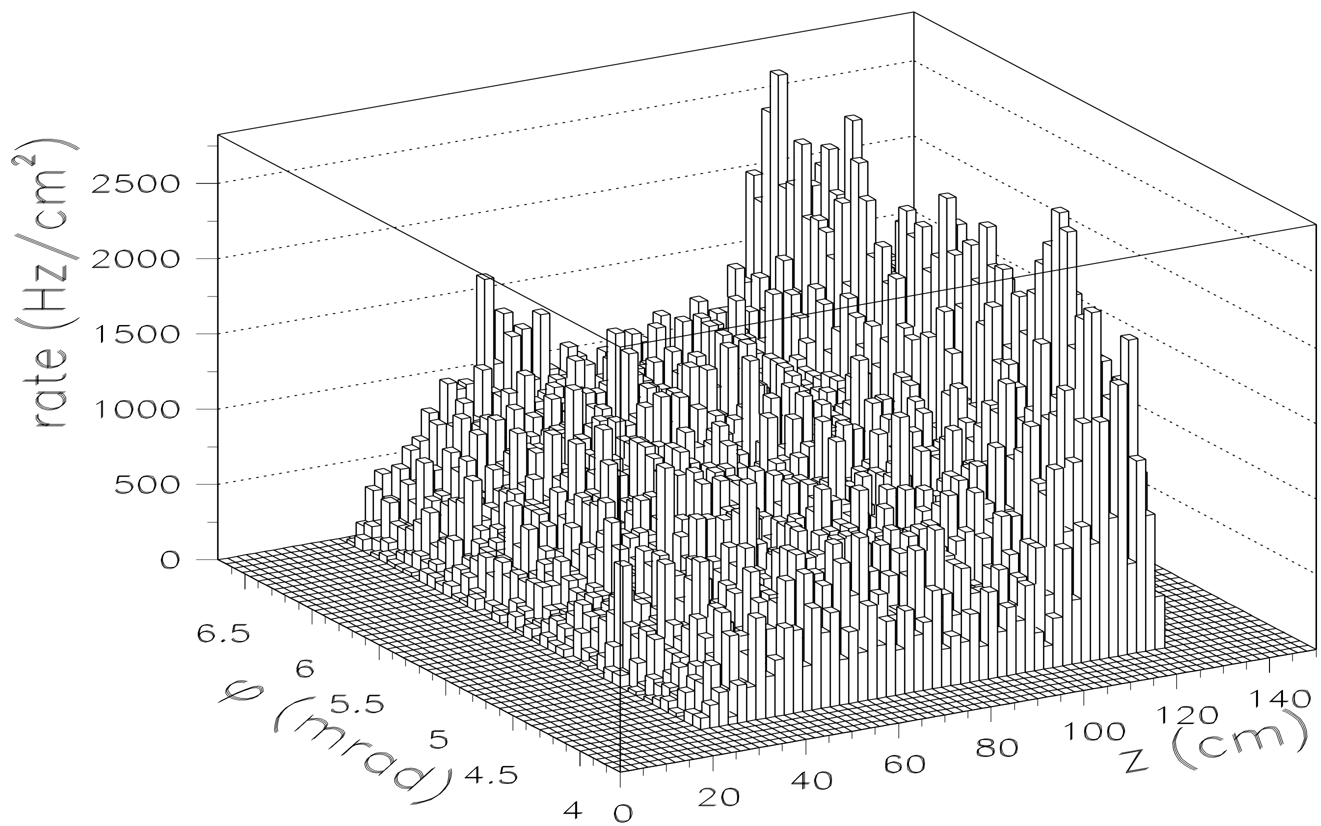


TC occupancy

Average hit rate ≈ 1 KHz/cm² with

Global positron rate ≈ 5 MHz

$R_{\mu} = 10^{8} s^{-1}$



Distribution - uniform in φ (from axial symmetry)

- peaked at higher z (due to positron hitting TC after their 2nd turn)

Efficiencies

Timing efficiency evaluated for different configurations:

- 1cm thick inner layer, 2 cm thick outer layer

ε(ΔE>5 MeV) = 85 %

(mainly due to e+ interaction in the inner layer)

ε(trigger) = 96.8 %

- 0.5 cm thick inner layer, same thickness for outer

ε(ΔE>5 MeV) = 93.6 %

ε(trigger) = 97.4 %

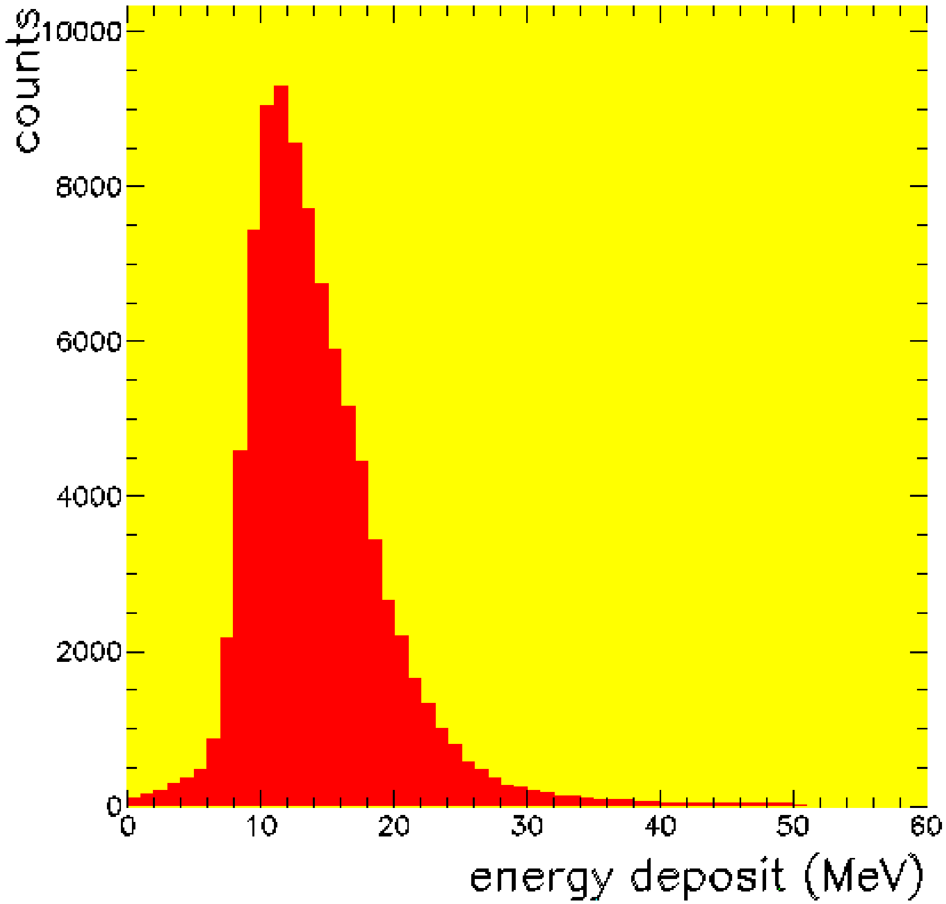
- reversed layers

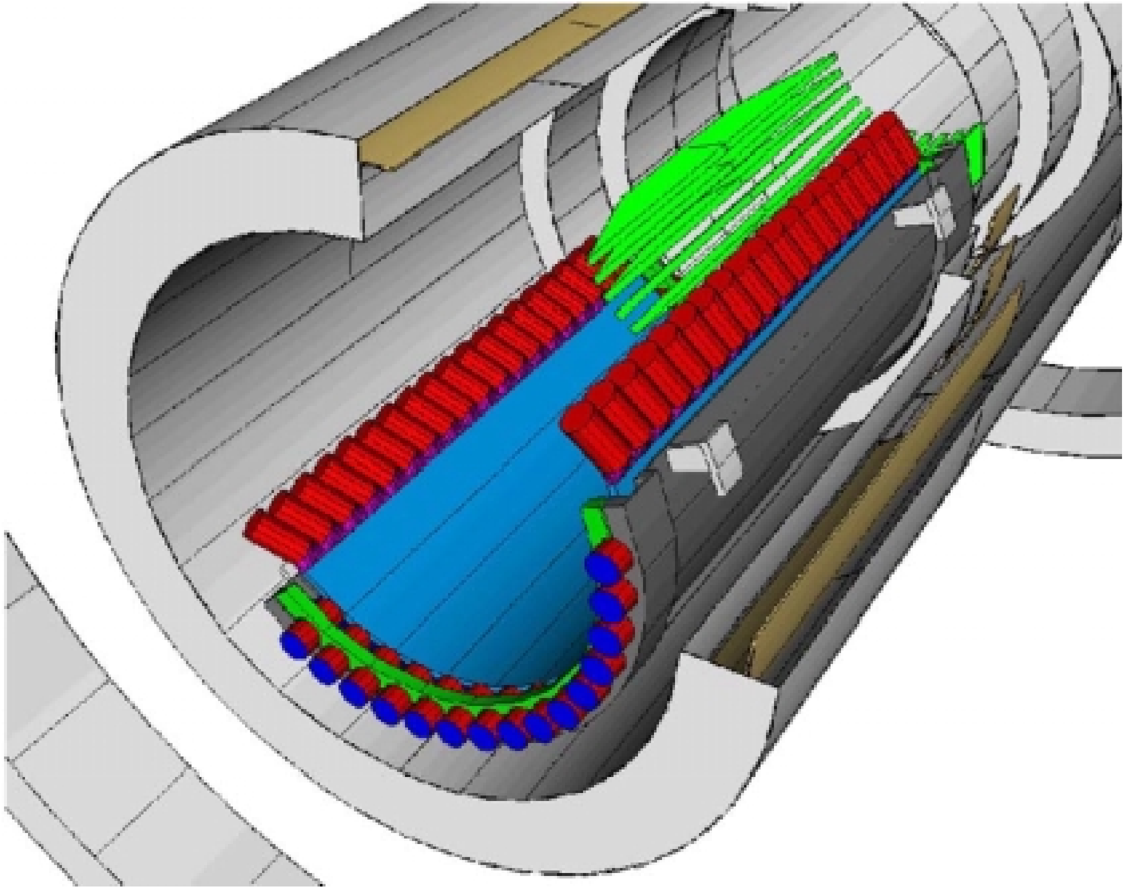
ε(ΔE>5 MeV) = 97.5 %

ε(trigger) = 75.4 %

(many events with no hit on z-sliced layer)

unavailable provided one uses Q1/Q2 to determine z





Calibrations(ideas)

- On-line: ~2 ns (trigger) ==> LASER system needed also for gain calibration and for monitoring the PMTs
- Off-line: relative scintillator calibration by using the 5 MHz positrons: the uncertainty in the distance from one counter to another should be of the order of ~mm =>Δt ~ 10 ps. There are however LASERs with a stability in the time-jitter between the laser pretrigger and the light pulse better than 10 ps. HAMAMATSU PLP-02, 410 nm, low intensity (we have it in Pisa).
- Relative timing positron-photon by changing the trigger conditions and using radiative decays