Lucite Hodoscope for SANE

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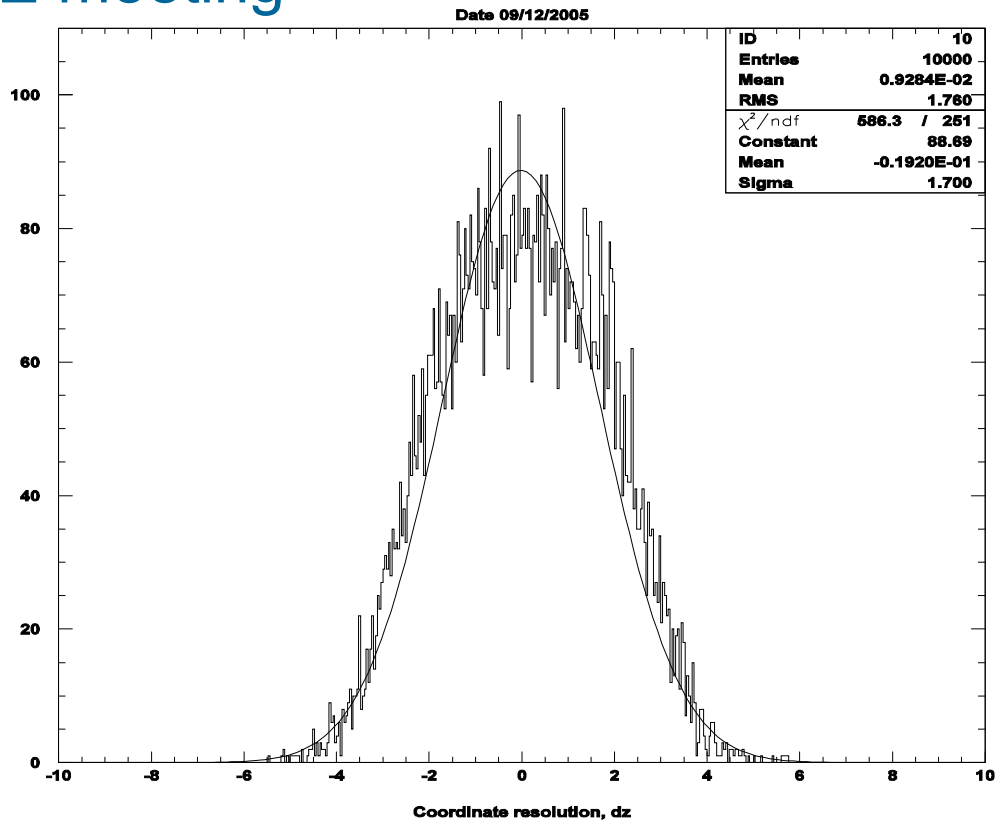
Outline

- Cosmic Ray test of a lucite prototype bar
  - The old result from Monte Carlo
  - Geometry consideration
  - Trigger
  - Electronics and DAQ
- Test Results
  - TDC distributions
  - Z-distributions
  - Position reconstructed vs measured, resolution
  - ADC Spectra

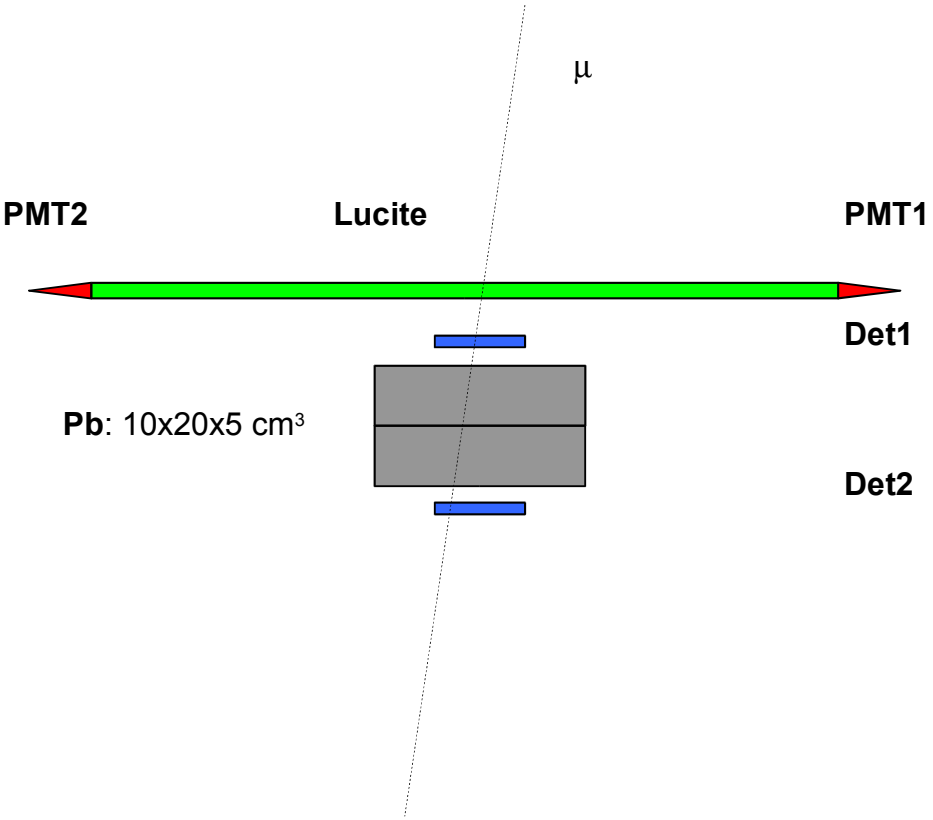
- Single Electron Peak measurements
- Conclusions from test
- Influence of the Hodoscope on Energy and Coordinate Resolution. Results of simple estimations
    - Multiple Scattering
    - Energy Lost
- Conclusions

LUCITE Hodoscope

Results of Monte Carlo simulation presented in December 2005 SANE meeting



Lucite Bar Test with Cosmic



Radiation of Cosmic Muons in Lucite

Sizes:

UVT Lucite – 80x6x3.1 cm^3

Det1, Det2 – 10x10x1 cm^3, scintillator

Two lead bricks: T_μ>168 MeV

Lucite is wrapped in black paper.

There is no white reflector.

n=1.49

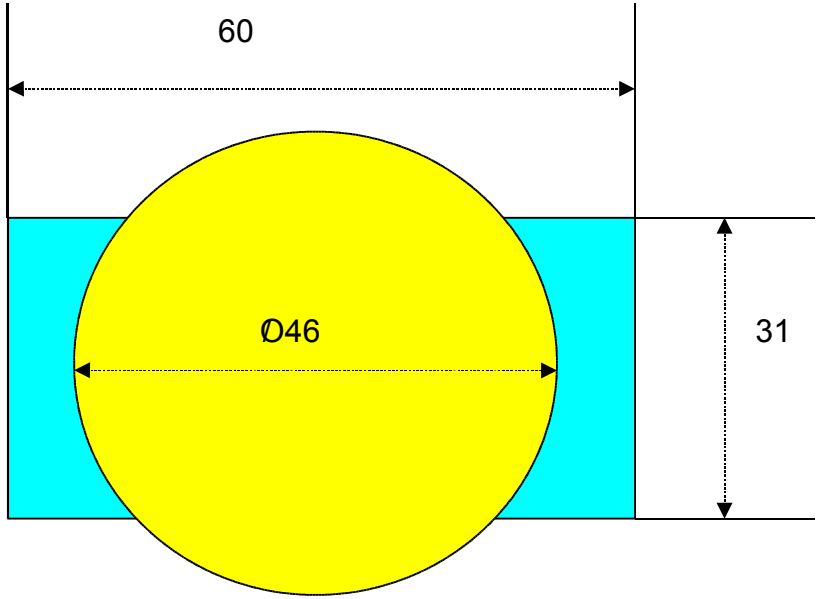
TIR angle =42°

β=0.923

Cherenkov angle: cos θ = 1/(nβ), θ = 43°

PMT-Lucite interface

- Interface is made of optical grease.
- The geometrical efficiency of the interface is about 75%



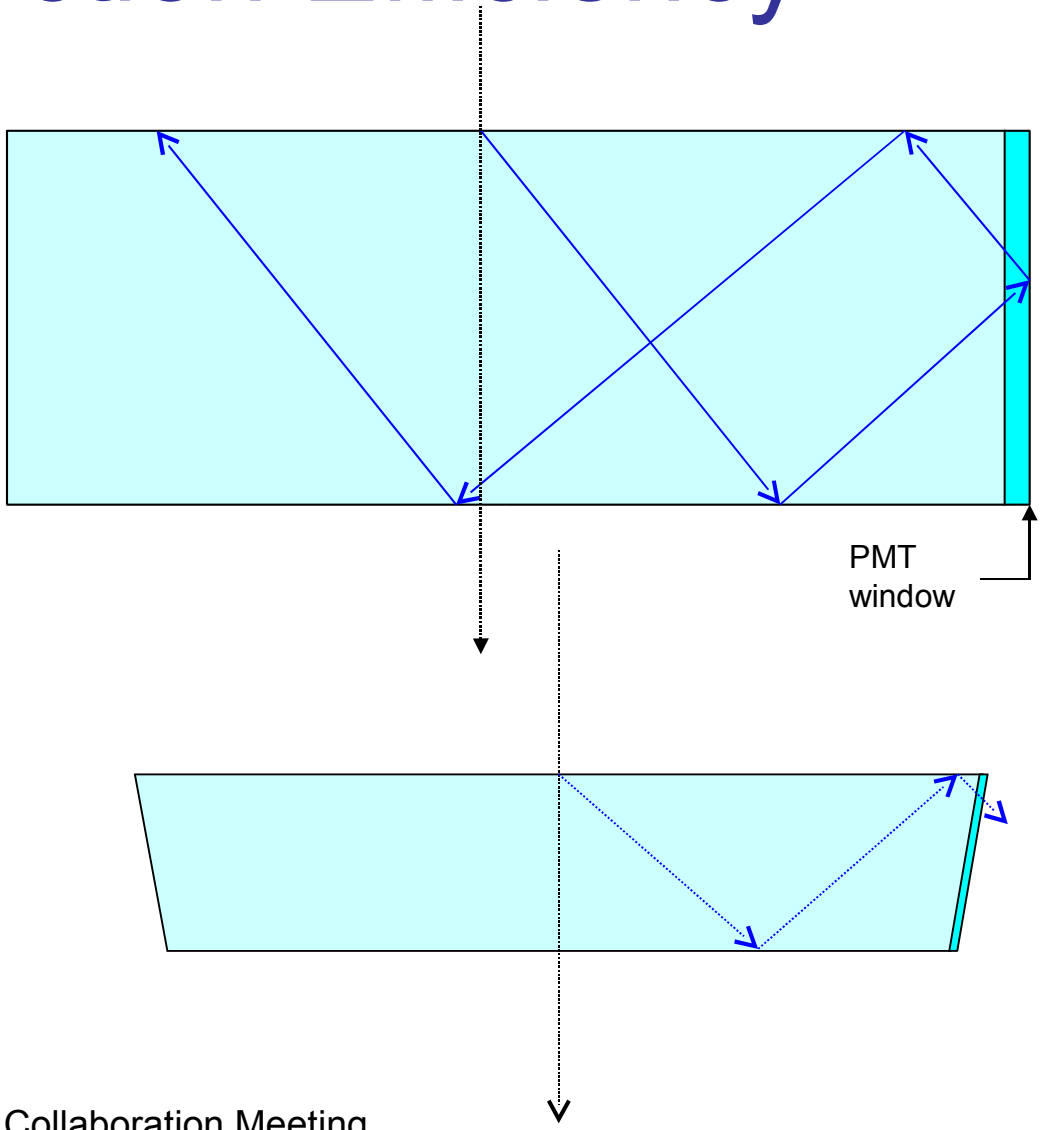
Light Collection Efficiency

Do we lose more light?
YES!

This is were observed reflections come from.

Adiabatic light guide is needed?

Or/and the face cut must be at different than 90^{o} angle?



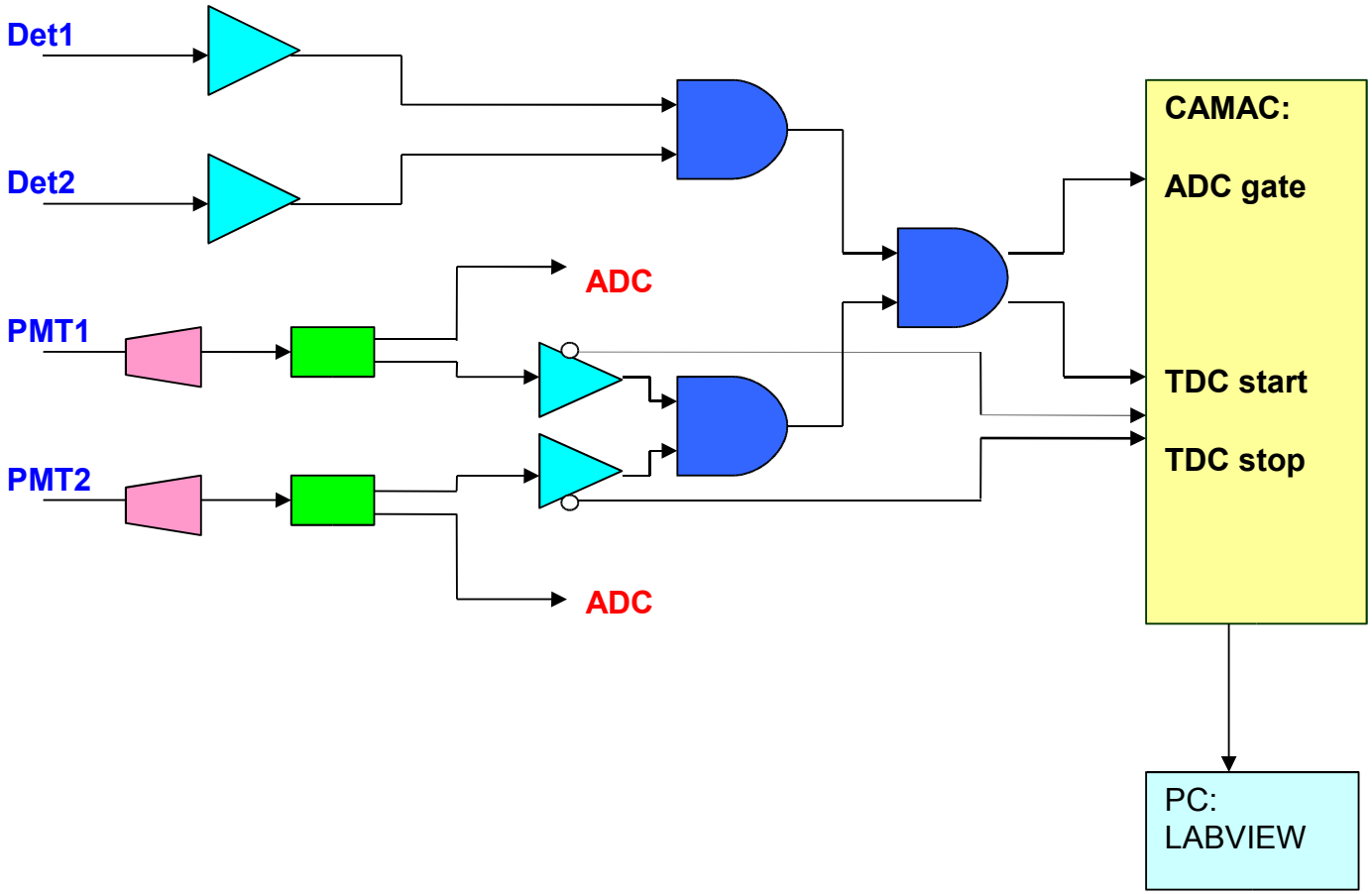
Test with Cosmic

If we tilt the bar by 2^{o}, then TIR will not take place and one of PMTs will not get primary cherenkov light

Trigger: M=(Det1 x Det2) x (PMT1 x PMT2)

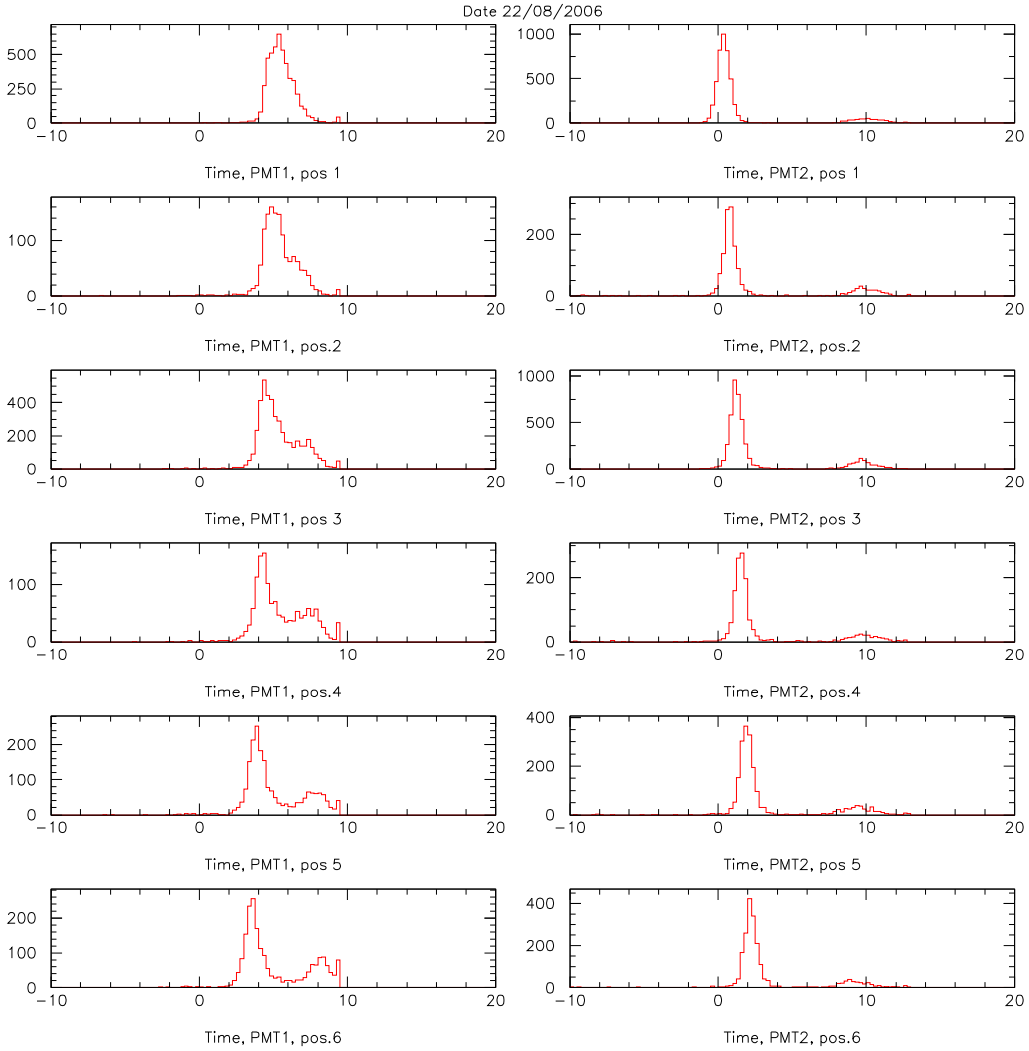
Signals for ADC and TDC analysis: PMT1 and PMT2

Trigger Electronics and DAQ



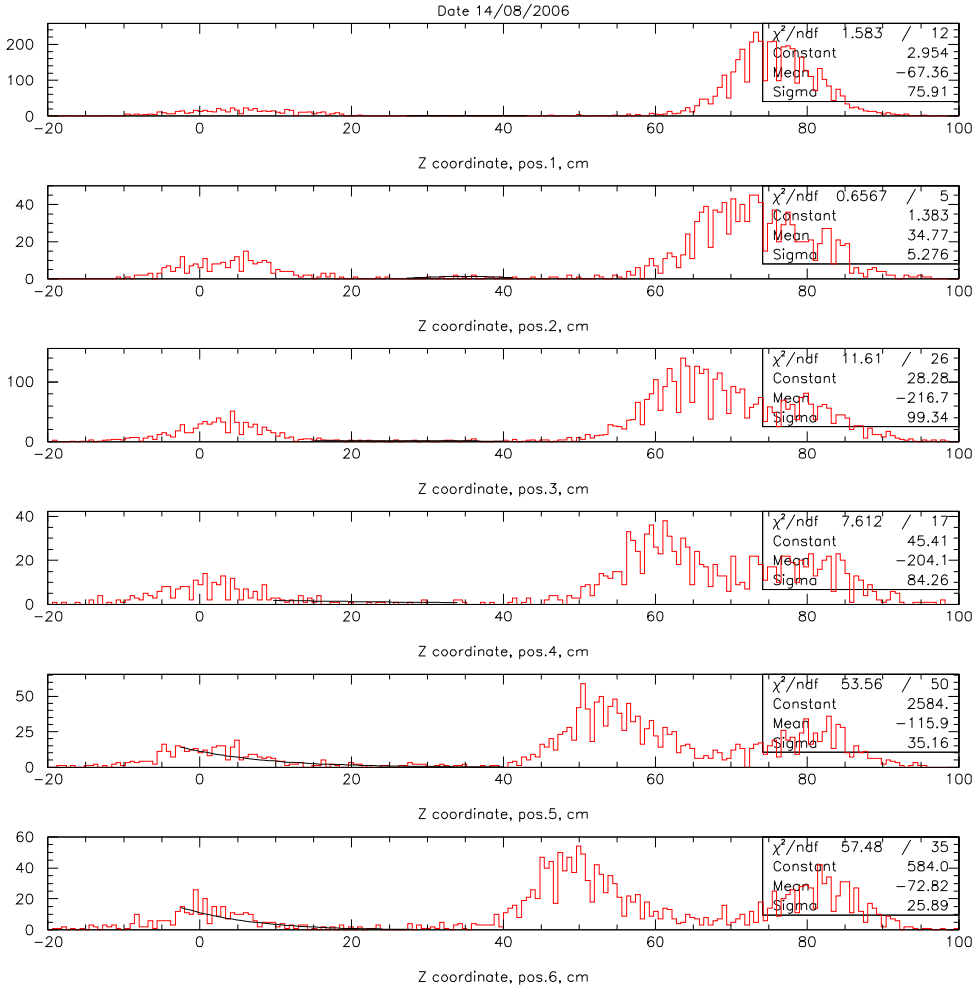
Results of Analysis

- TDC distributions:



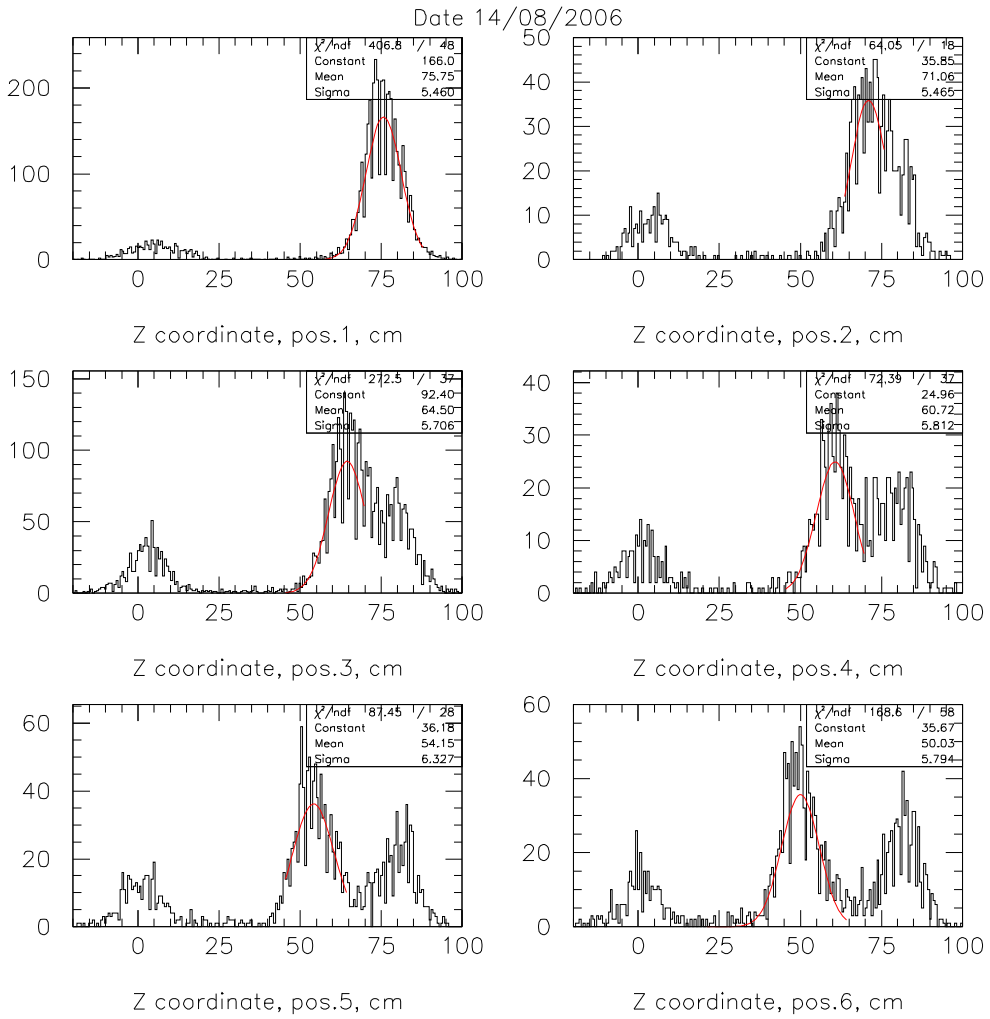
Results of Analysis (cont.)

- Z - distribution:



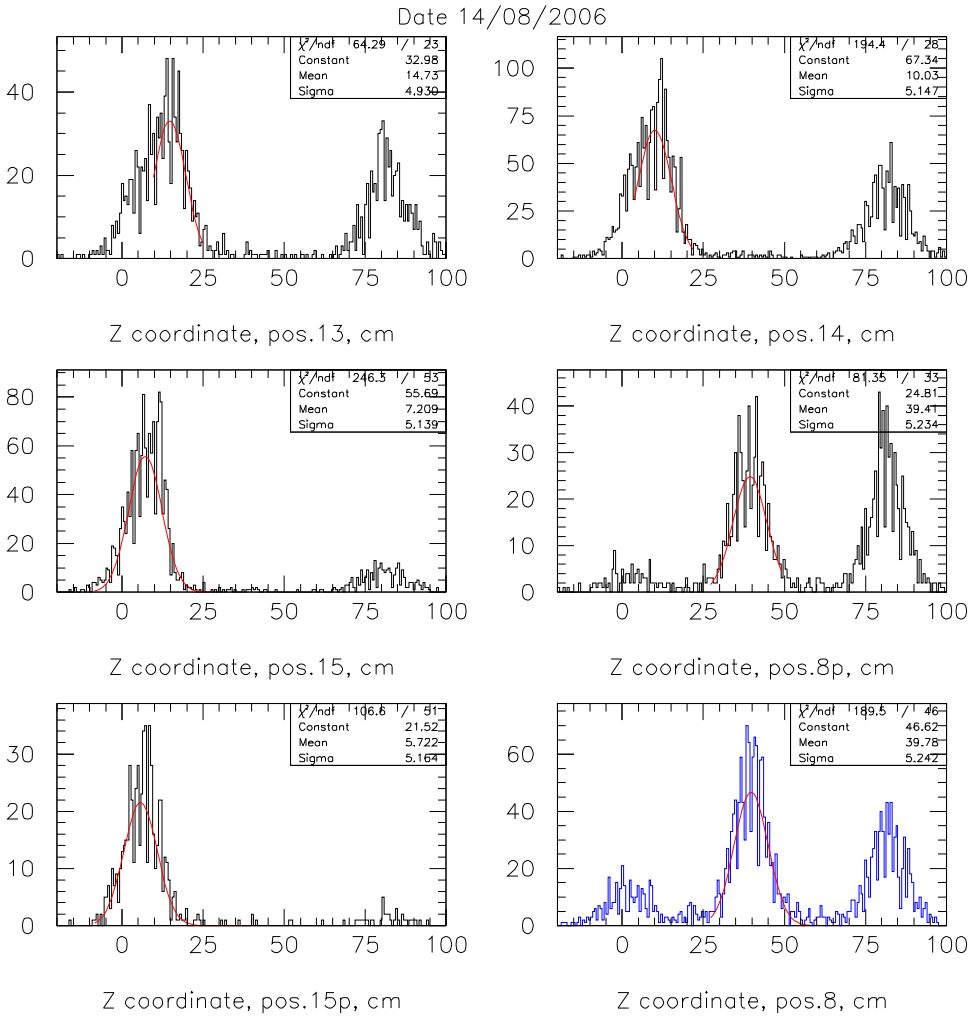
Results of Analysis (cont.)

Extracted Z-position



Results of Analysis (cont.)

Tilted Lucite (6^o)

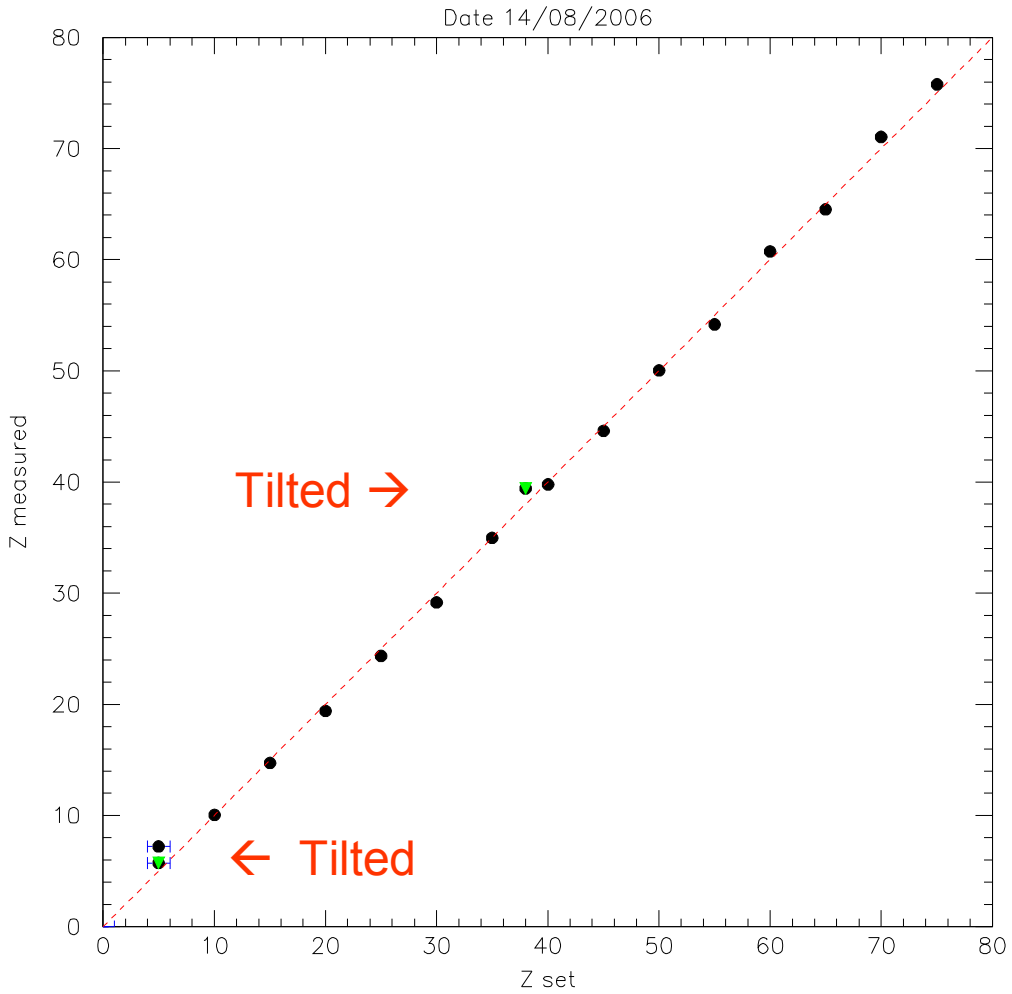


Results of Analysis (cont.)

Position measured vs reconstructed

Errors are included

Detector is tilted by 6°



Results of Analysis (cont.)

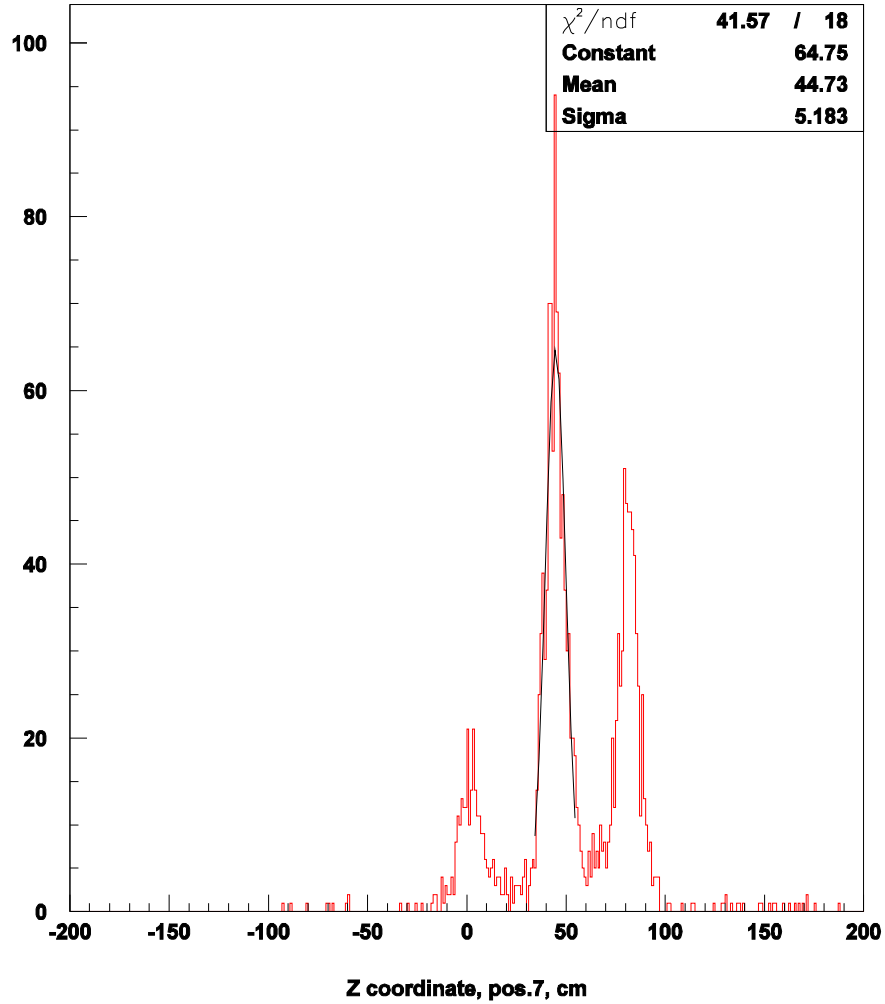
Reconstruction uncertainty:

σ_{total} = 5.2 at the position #7 (center) and 6.0 to the edges

detector size is +-5 cm

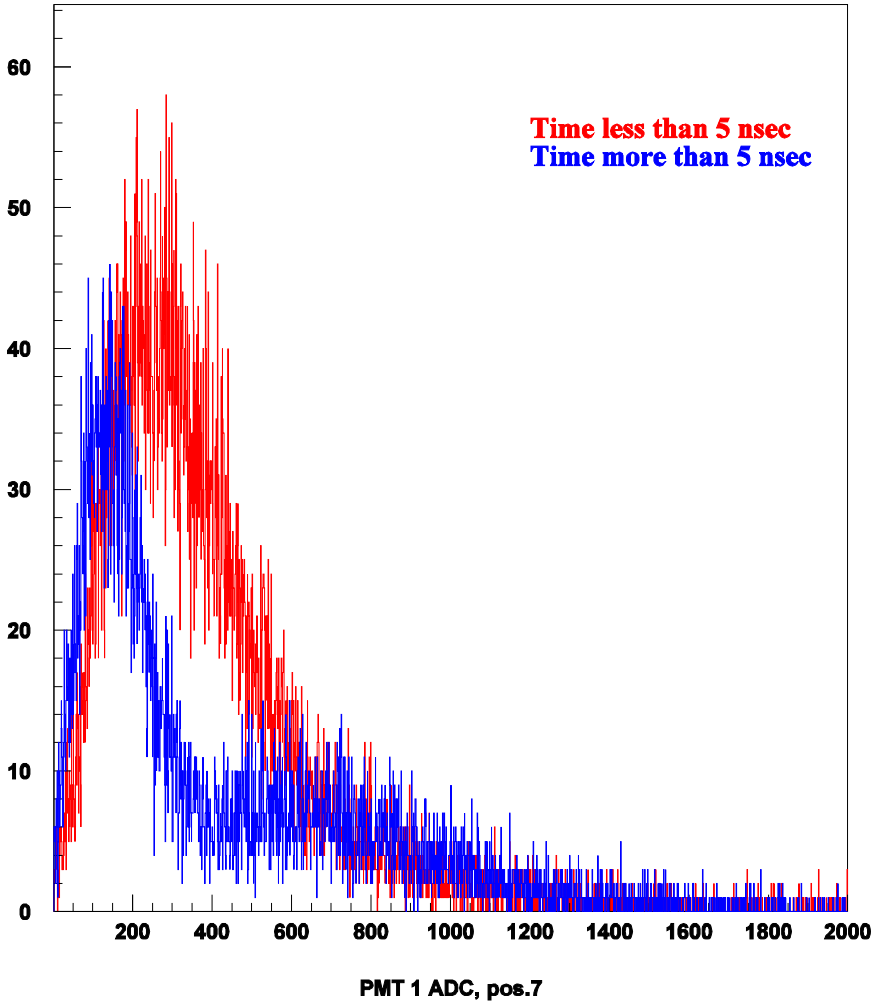
$\sigma_{reconst} = SQRT(\sigma_{total}\text{^}2\text{-}d_1\text{^}2)$

$\sigma_{reconst}$ = 1.5 cm – 3.3 cm

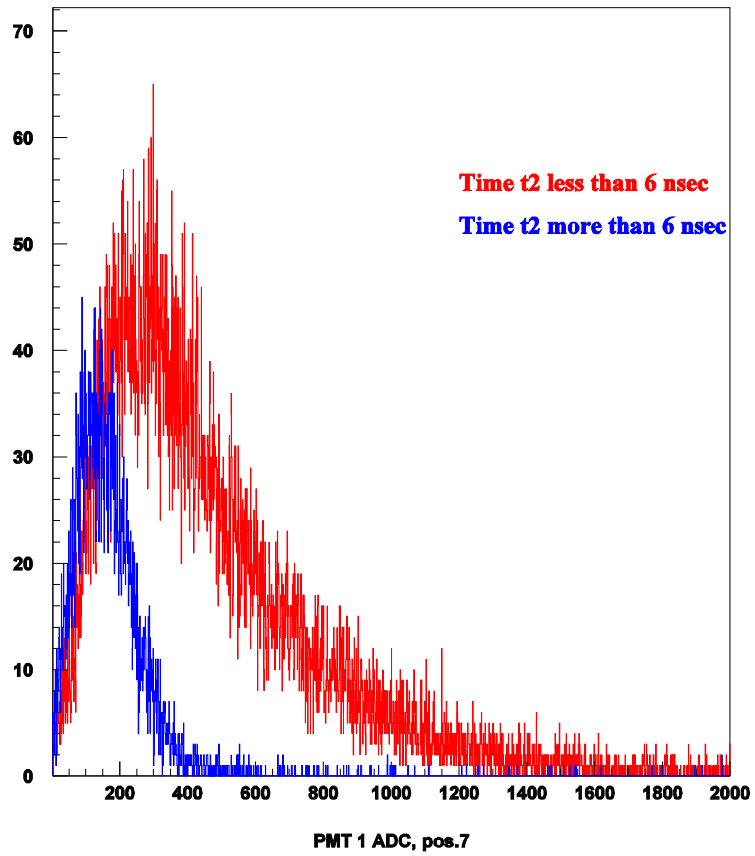


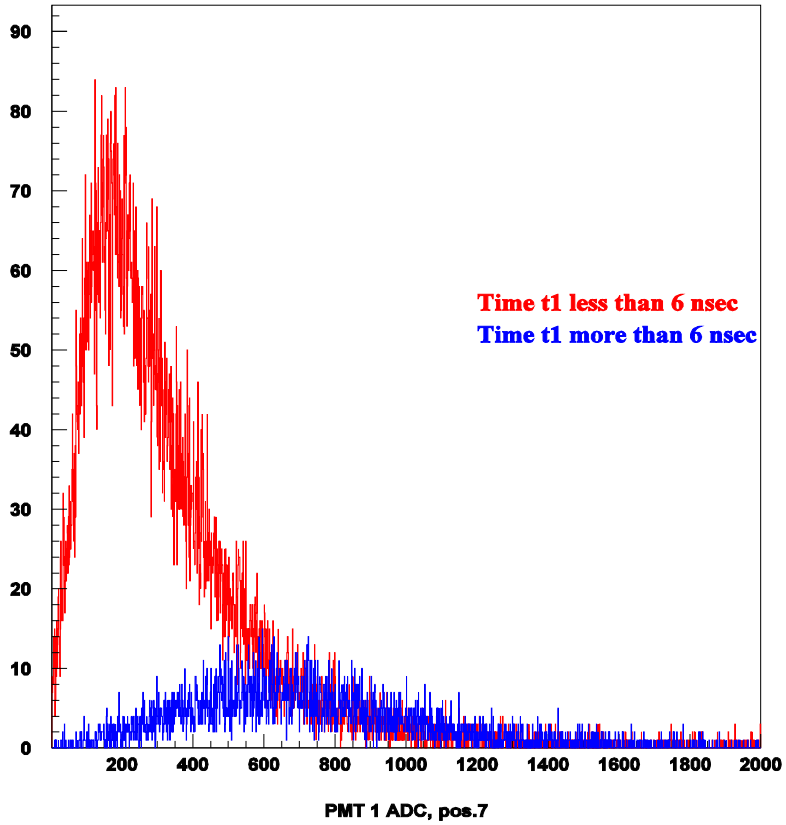
Results of Analysis (cont.)

- ADC distributions:



Results of Analysis (cont.)





Single Electron Peak

Using blue LED:

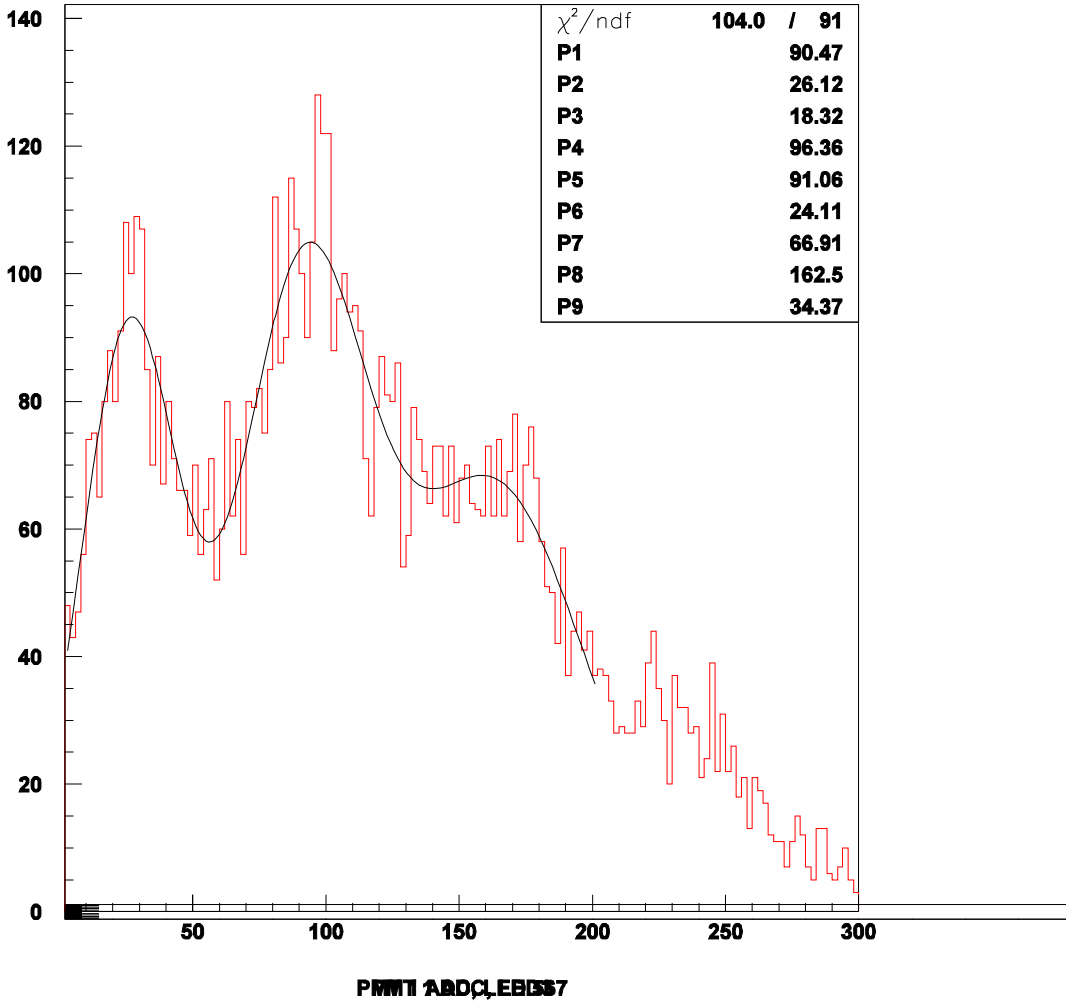
<λ>=470 nm

Pulse duration: 15 nsec

Repetition rate ~100 Hz

Trigger: pulse generator

Timing cut: +/-5 nsec



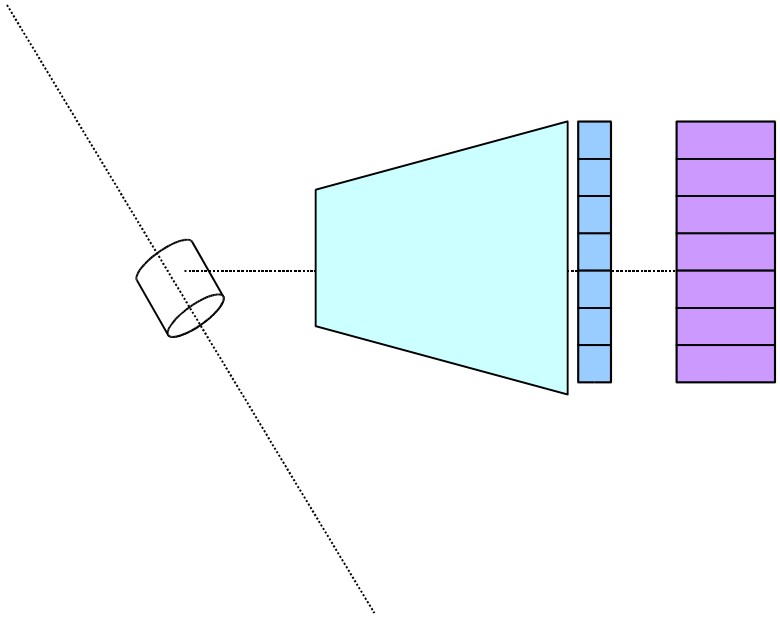
Conclusions: results of the cosmic test

- Number of Photoelectrons for vertical events:
  260/26=10 to 1200/26=46 for 3.1 cm.
  We expect with light guides 650/26=25 p.e.
- The PMT XP2268 we were using, had low quantum efficiency. We ordered a new PMT XP2020 for test, it did not arrive yet.
- Use of adiabatic light guides is mandatory.
- Tapered shape of the bar maybe optimal for light extraction.
- Coordinate resolution of the hodoscope is 1.5cm - 3.3 cm
- The resolution is worse at the edges due to reflections and due to angles of particles other than 90^{o}. We have discussed with St. Gobain about possible curving the bars by $+-6^{o}$.

Influence of the Hodoscope on Energy and Coordinate Resolution

Multiple Scattering and Energy Lost of e^- in the material:

- Target exit windows
- Gas Cherenkov
  - windows
  - mirror
- Lucite



Influence of the Hodoscope on Energy and Coordinate Resolution (cont.)

Simple Estimation: Multiple Scattering (M.S.)

E_e=1000MeV

$\langle\theta\rangle_{Al} = 6\times10^{-4}$ rad

$\langle\theta\rangle_{glass} = 2\times10^{-3}$ rad

$\langle\theta\rangle_{lucite} = 4\times10^{-3}$ rad

M.S. in lucite will add an additional coordinate uncertainty at the calorimeter face, of the order of 3.5 mm to the lead glass which is

$$\Delta X = \frac{6mm}{\sqrt{E(GeV)}}$$

Adding quadratically, we obtain 7 mm total for E_e=1GeV

Influence of the Hodoscope on Energy and Coordinate Resolution (cont.)

Total reconstructed uncertainty at the target level will be worsen by +-0.5 cm due to the multiple scattering in Lucite.

Energy Lost takes place mainly due to cascade development in the material (lucite)

$$\Delta E = \int_0^{0.11} \frac{dE}{dt} dt$$

$$\frac{dE}{dt} = Eb \frac{(bt)^{a-1} e^{-bt}}{\Gamma(a)}$$

$$b = 0.5 \cdots 0.7$$

$$a = 4b + 1$$

$$Z = 3.6$$

$$C_5 O_2 H_8$$

Total energy deposit for E_e=1000 MeV is 5.5 MeV in lucite

The angular divergence of the cascade is in the order of mc^2/E_e which gives an additional 0.5×10^{-3} rad,

Conclusions

- Do we need to do beam test? Maybe yes.
- Number of Photoelectrons for vertical events: 650/26=25 for 3.1 cm with proper light guides
- Coordinate resolution of the hodoscope is 1.5 - 3.4 cm, Beam test would confirm this number.
- The resolution is worse at the edges due to reflections and due to angles of particles other than 90^{o}
- Total energy deposit for E_e=1000 MeV is 5.5 MeV in lucite.
- Estimated total reconstructed uncertainty at the target level will be worsen by +-0.5 cm due to the multiple scattering in Lucite.