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Photon Transport Monte Carlo

- Overview
- Physical processes
- PMT and electronics response
- Some results
- Plans

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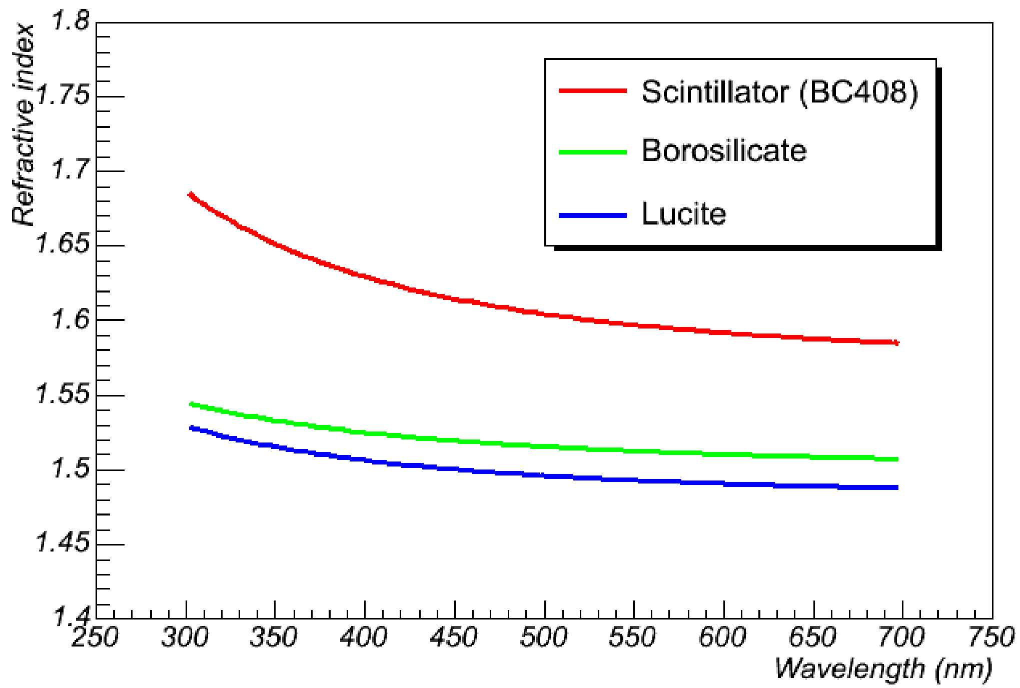
Overview

- A photon transport Monte Carlo was developed to interpret TOF results from Run-Ic.
- This developed into the current photon transport code.
- Current incarnation of “Photran” is in the repository

Physical Processes

- Photon propagation:
  - Dispersion effects
  - Bulk attenuation
  - Scattering



Physical Processes

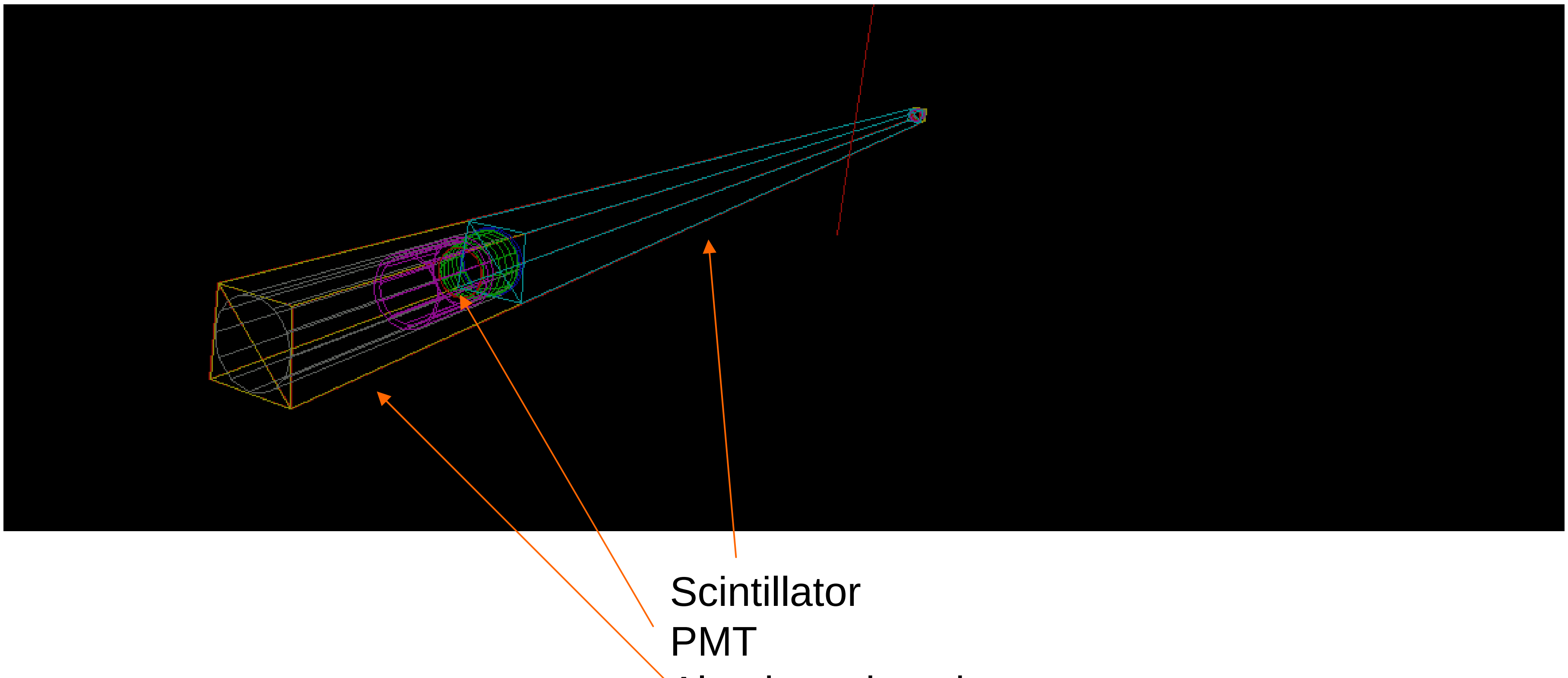
- Material boundaries:
  - Transmission with refraction
  - Reflection
  - Internal reflection
- Material interfaces:
  - White paper: iterative scattering/reflection
  - Black paper: reflection/absorption
  - Black tape: absorption
  - Air: reflection/refraction

Geometry Primitives

- Bounded surfaces:
  - Rectangle, triangle, circle, annulus, …
  - Numerical description of more complex surfaces (eg, curved surface of Winston cone)
- Volumes (regions bounded by surfaces):
  - Box, prism, lens, disc, …
  - Winston cone
- Materials (volumes + physical properties)
  - Scintillator, Lucite, BC634A, Borosilicate
  - Aluminum, air, …

TOF Geometry

- Description of a bar with PMT's at both ends in their aluminum housings:



Response to radiation

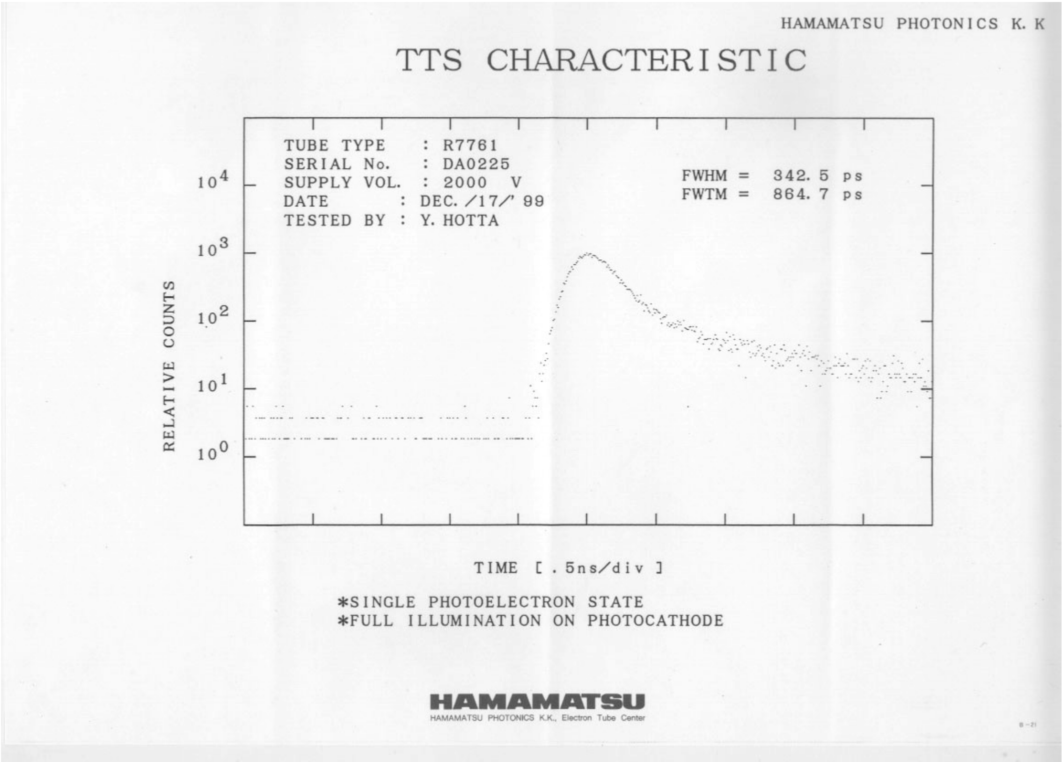
- Scintillation:
  - Energy loss in material
  - Scintillation efficiency
  - Spectrum of emitted light
- Cherenkov emission:
  - Useful for some studies
  - Usually overwhelmed by scintillation process

Photon Transport Problem

- Given an incident charged particle:
  - Calculate the energy loss
  - Photons are created along its path
  - Photons propagate throughout the system
  - Record the times at which they hit the photocathodes of any PMT's in the system

Simulation of PMT

- Parameterizations for:
  - Wavelength dependent quantum efficiency
  - Anode response (Polya distribution)
  - Transit time
  - Pulse shape
  - TTS



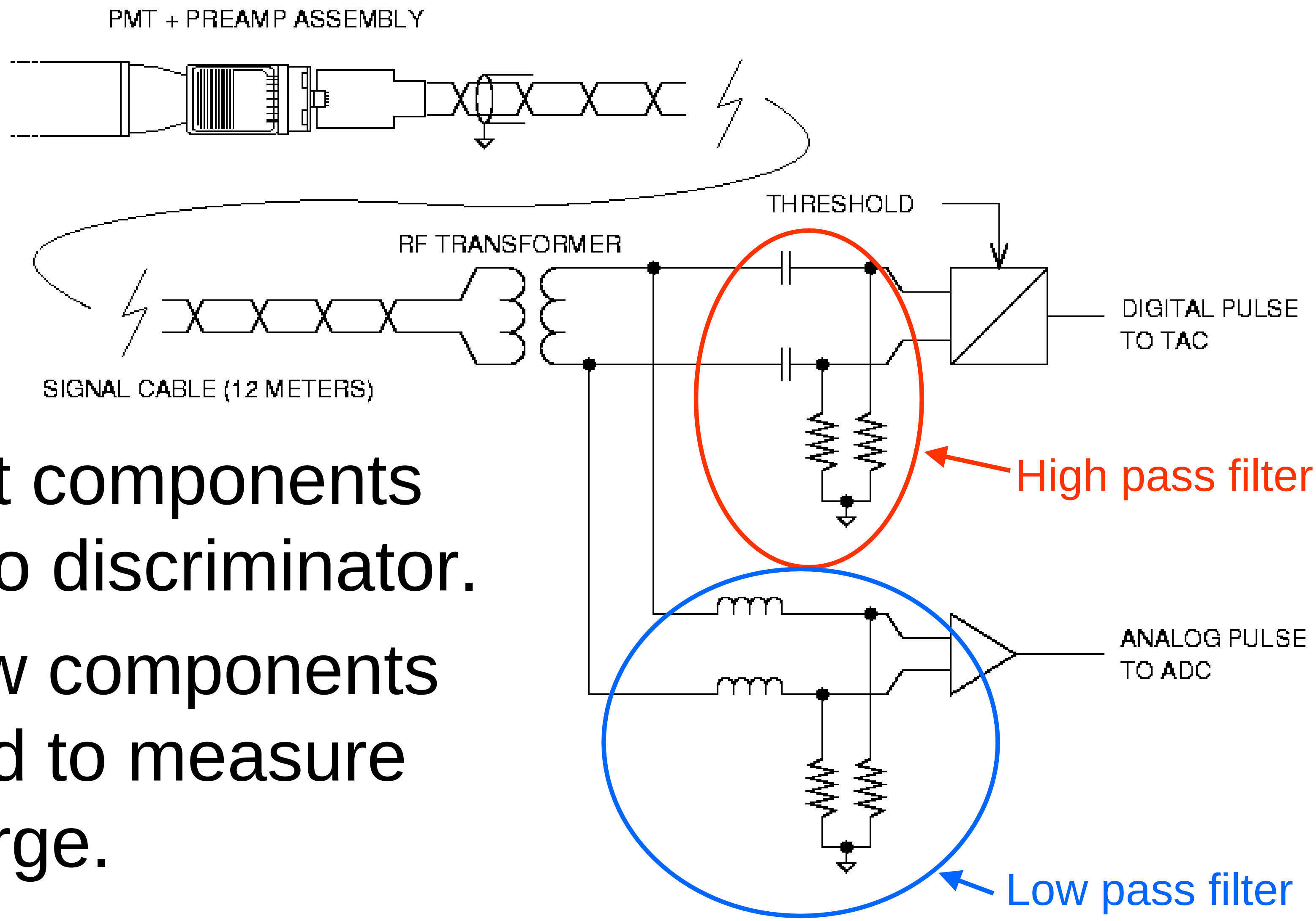
Simulation of Base

- Two pole impulse response (Note 5358):

$$i(t) = \frac{1}{2C_a Z}\frac{be^{bt} - ae^{at}}{b-a}\Theta(t)$$

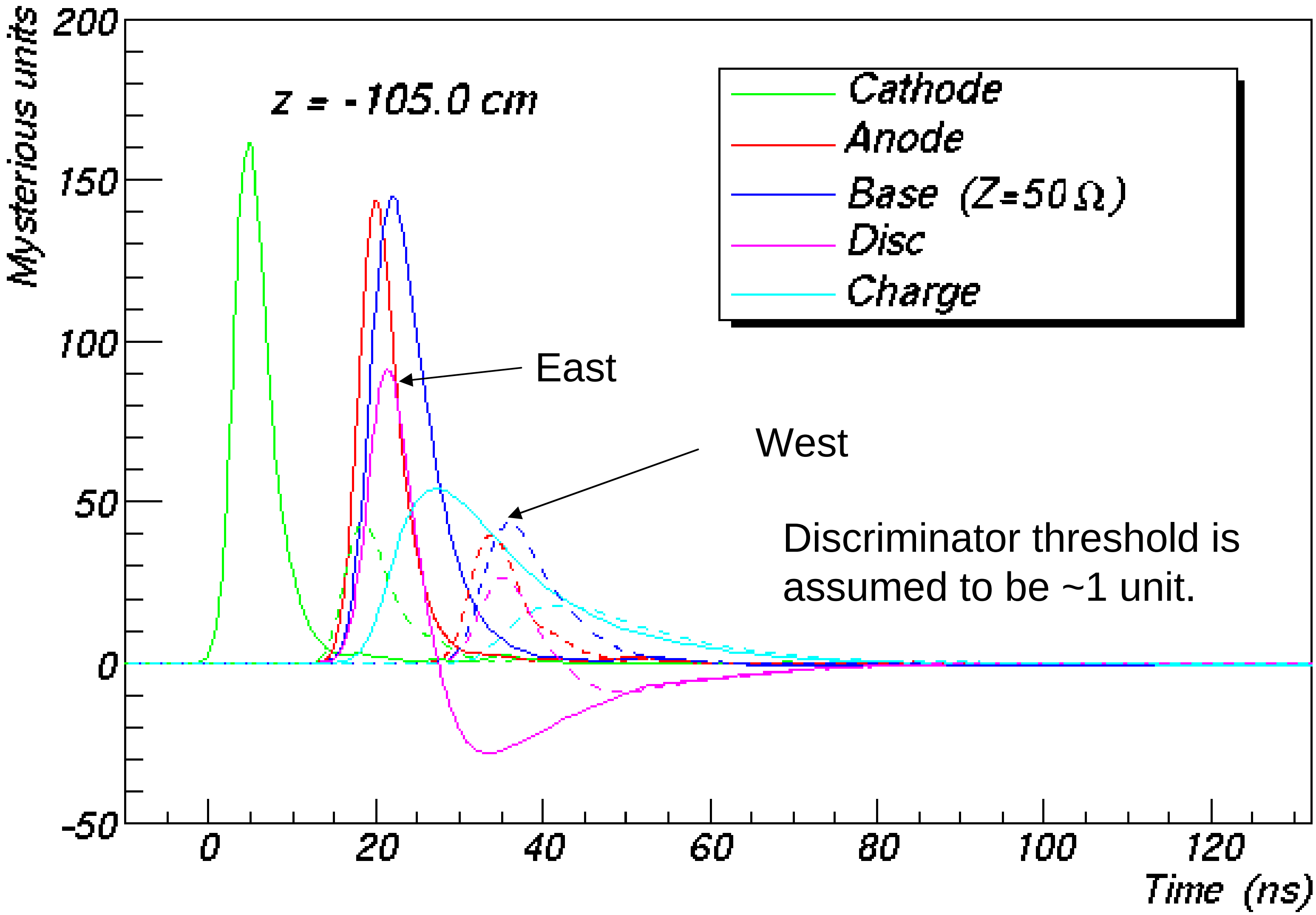
- Convolution with Gaussian PMT response
- Preamp adds additional small contribution to pulse width
- Not simulating gain switching in preamp
- Not explicitly simulating dispersion in cable

Front-end Electronics

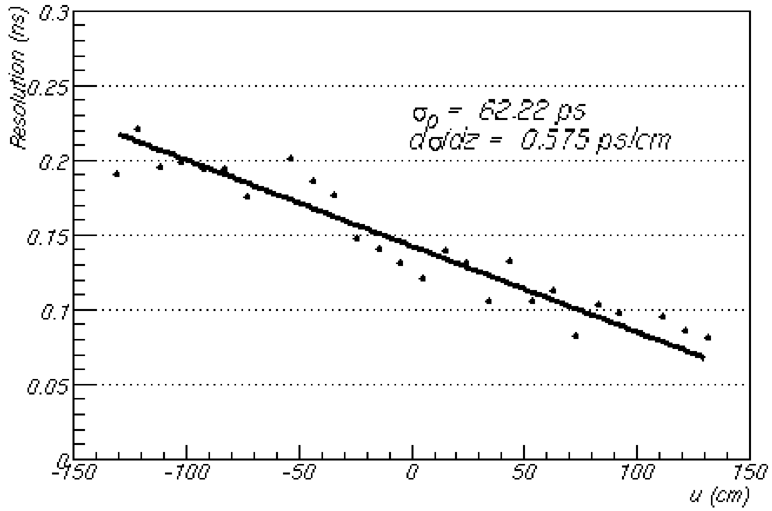


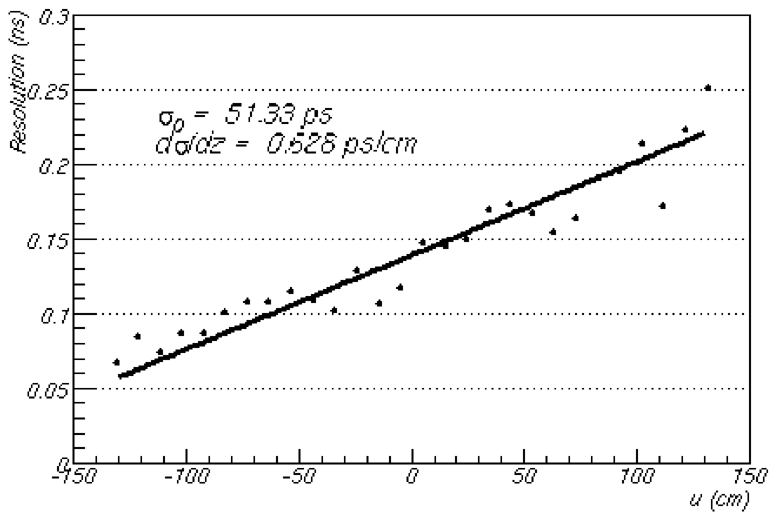
- Fast components go to discriminator.
- Slow components used to measure charge.

Resulting pulses



Timing Resolution



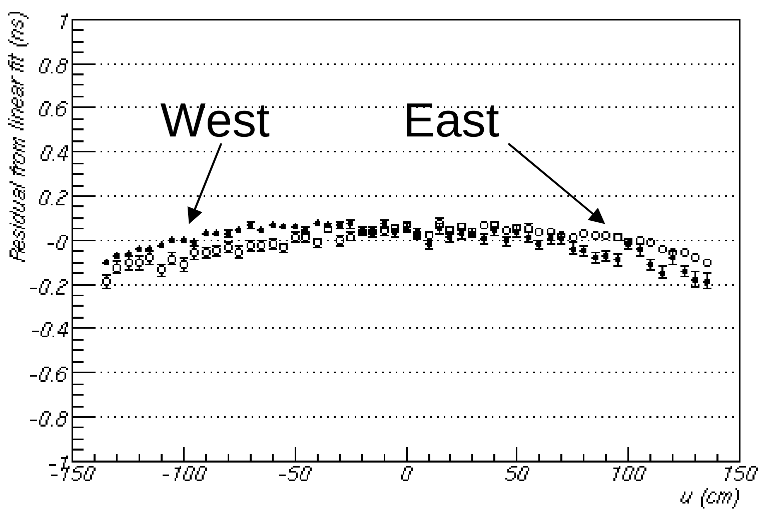


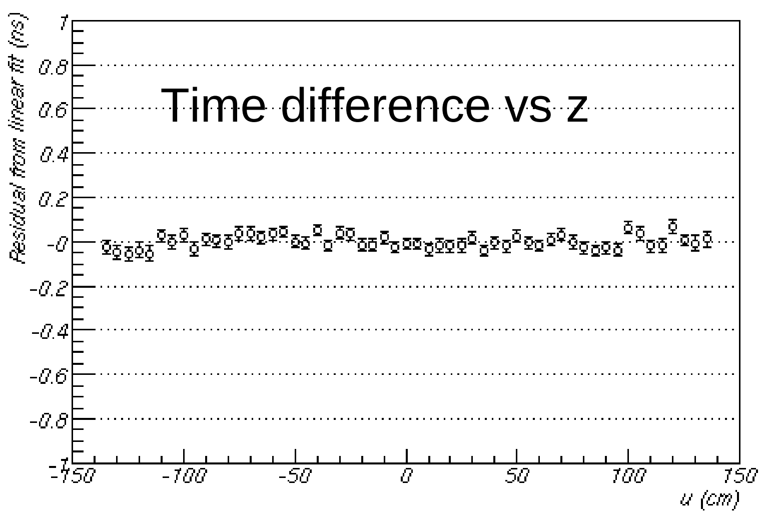
- Without any tuning,

$$\sigma_0 = 50 - 60 \text{ ps}$$
$$d\sigma/dz = 0.6 \text{ ps/cm}$$

- Current limitations:
  - Poisson photon statistics, not Landau
  - Constant gain conversion: not simulating primary photoelectron statistics (Polya distribution)

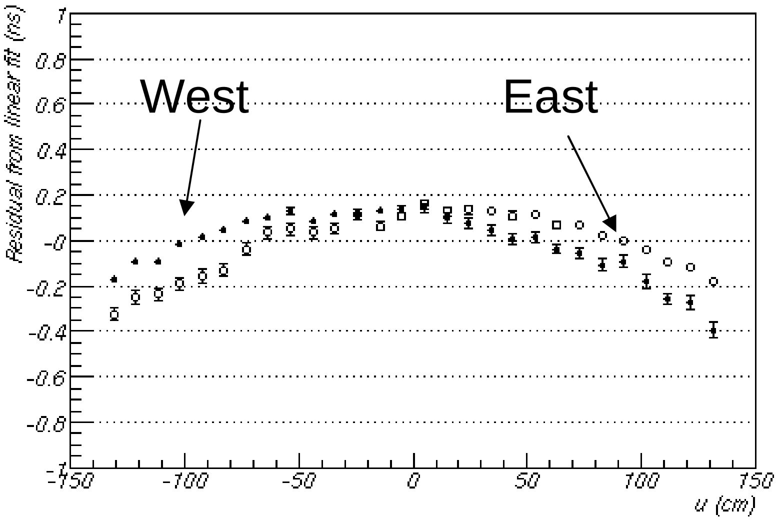
Time difference analysis

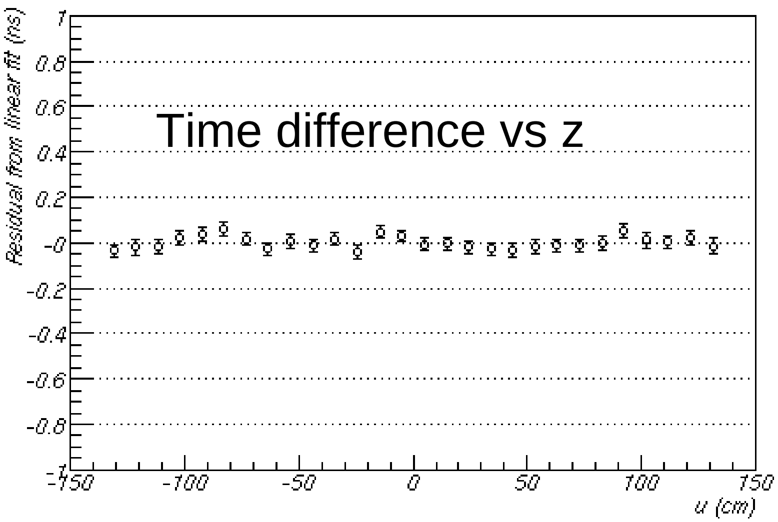




- 2 GeV muons (MIP's)
- Normal incidence
- Plot residuals to linear fit:
- "Speed of light" is s ~ 15 cm/ns
- Agrees with results from calibration: s=14-15 cm/ns

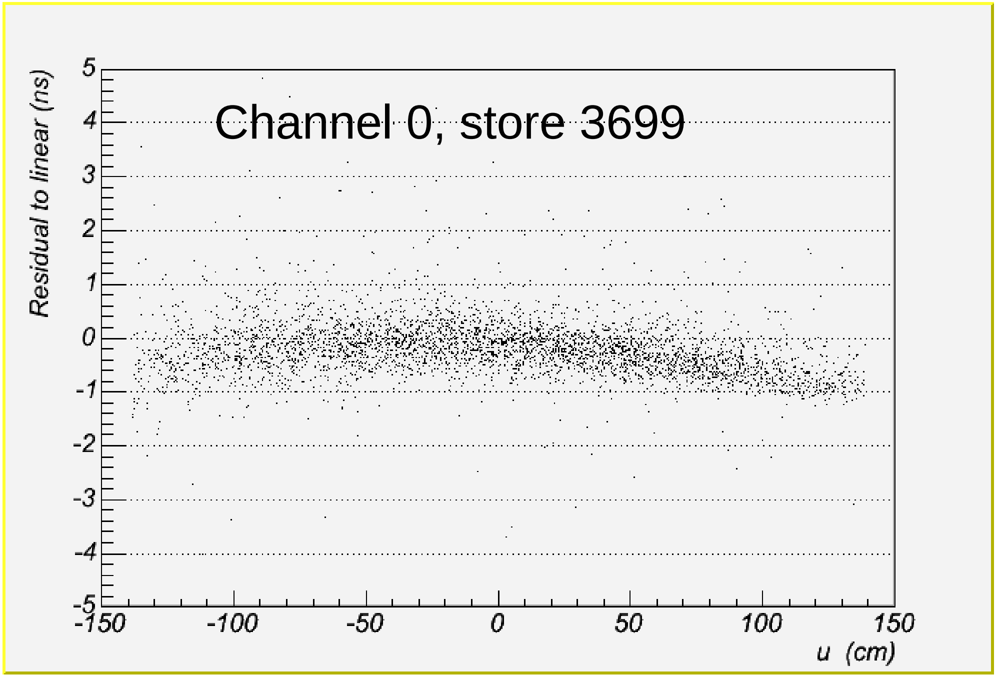
Time difference analysis





- 2 GeV muons (MIP's)
- Typical angular distribution: R=140 cm, σ_z~30 cm
- Larger nonlinear systematic variation with z

Comparison with data



- Qualitative comparison limited by resolution
- The scale of the effect is about right
- Need to study dependence on discriminator threshold

Some current issues

- Need to validate response of front-end electronics to quantify discriminator thresholds:
  - PMT and base should be fine (Note 5358)
  - Preamp has Z ~ 100 ohms
  - Preamp gain is about 15 (small signals)
  - Haven't checked preamp shaping recently
  - Need to check front-end electronics response: needs pulser, test stand and oscilloscope
- Still won't have exact prediction for n_{pe} for a MIP
- Need to parameterize gated charge integration

Ongoing studies

- For identical particle configurations (particle type, entrance point, entrance angle, momentum), all information is contained in the shape of the leading edge of the discriminator pulse and the integrated charge.
- Most studies involve measuring time slewing function for different particle configurations.

Ongoing studies

1. Slewing correction function for central muons: compare qualitative behavior with calibration results, artificially enhanced/degrade light output.
2. Slewing corrections for slow particles: normal incidence, artificially restricted light output.
3. Slewing corrections for corner clippers.
4. Slewing corrections as a function of angle: look for “critical angle” effects.

Conclusions

- Photran package works well enough for most studies of immediate interest
- Current studies expected to be good modulo absolute measure of pulse height
- Plan is to relate ratios of calculated quantities to ratios of measured quantites in data