Time of Flight System for the GlueX experiment

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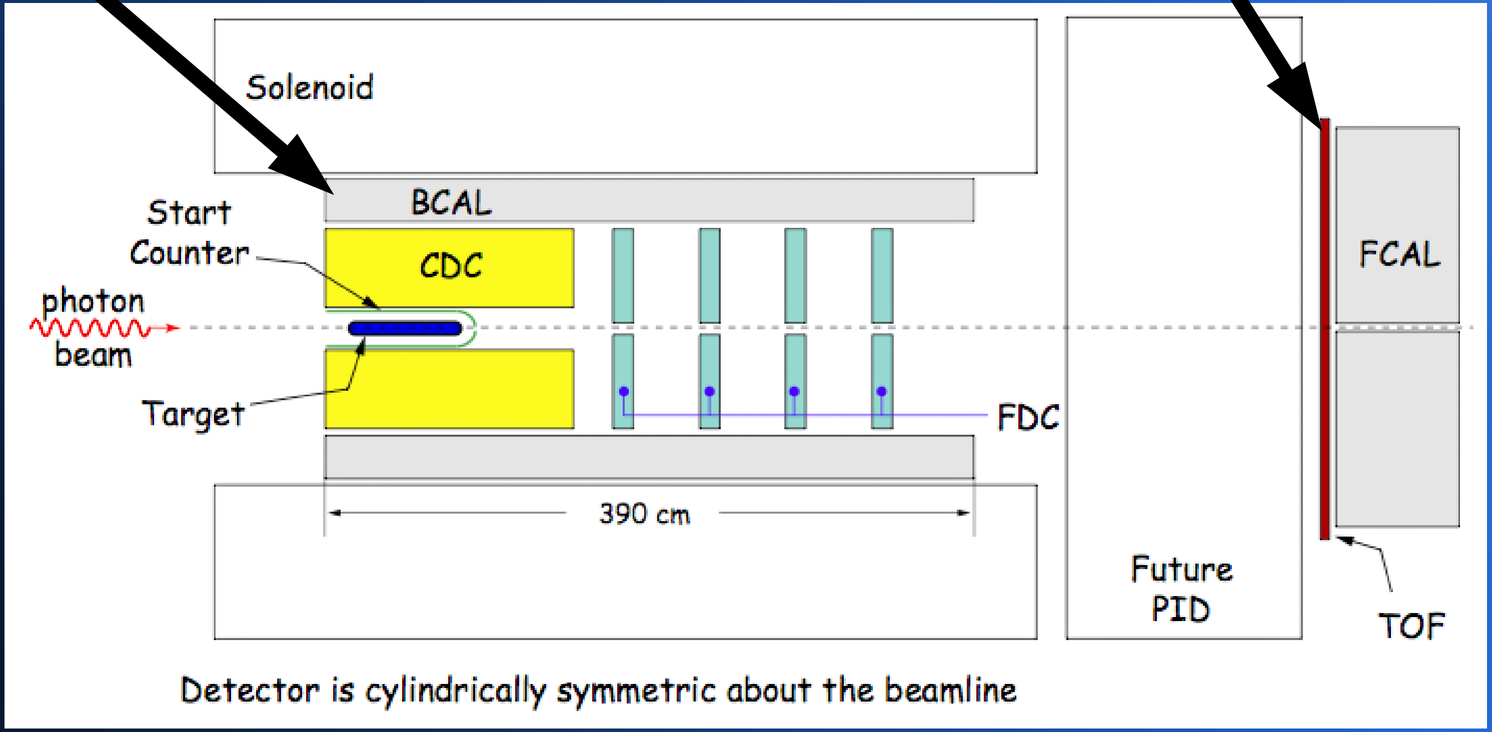
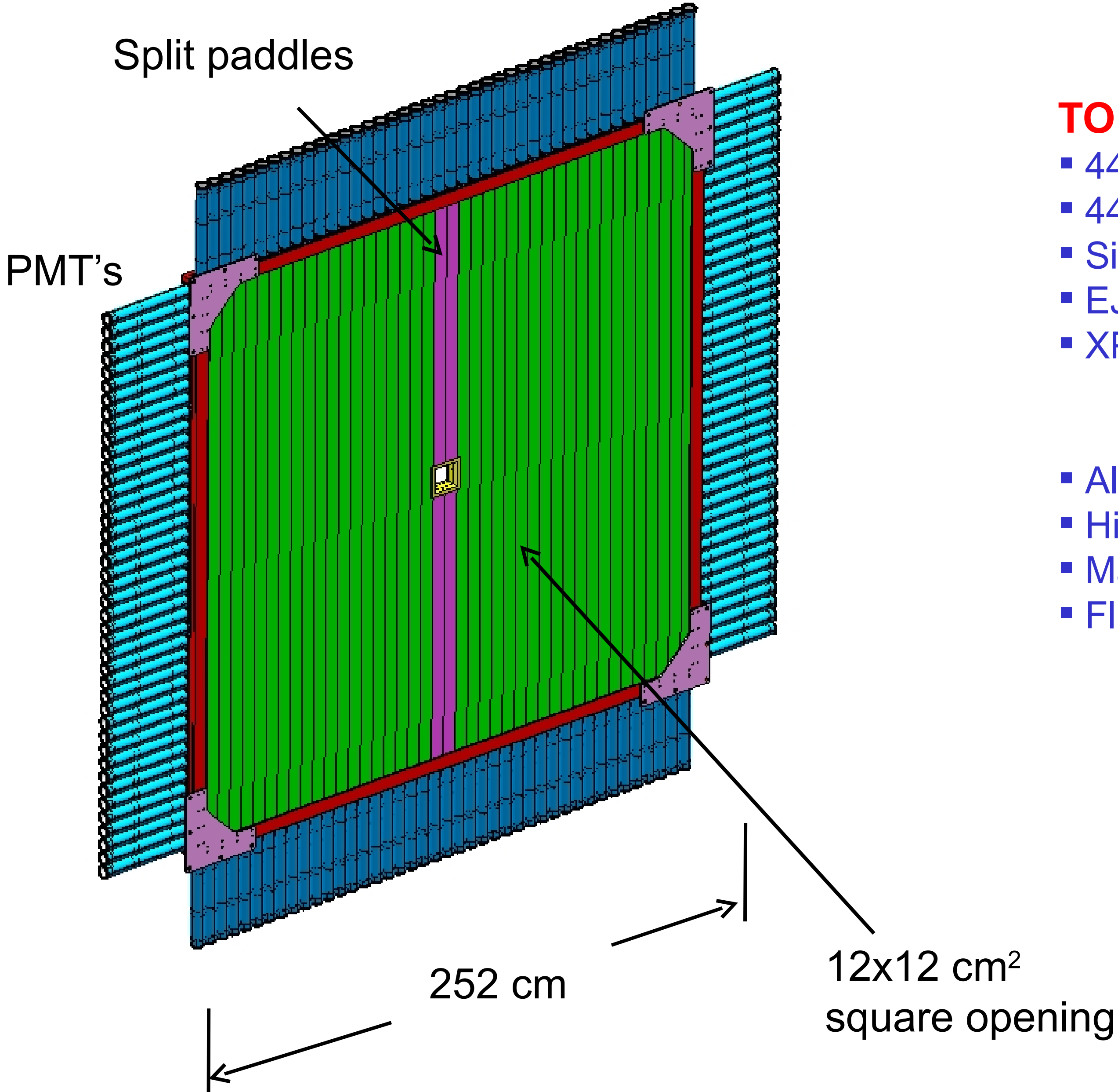
GlueX Particle Identification by Time-of-Flight

- Central Time-of-Flight System
- Forward Time of Flight Detector



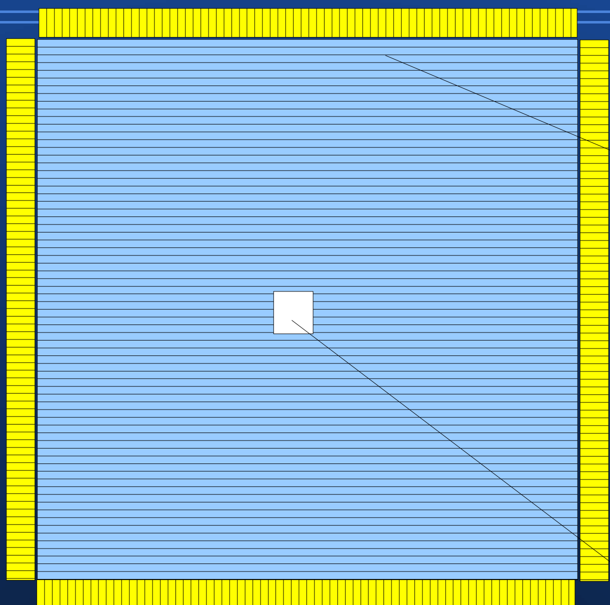
Forward TOF System
(What we are building at FSU)

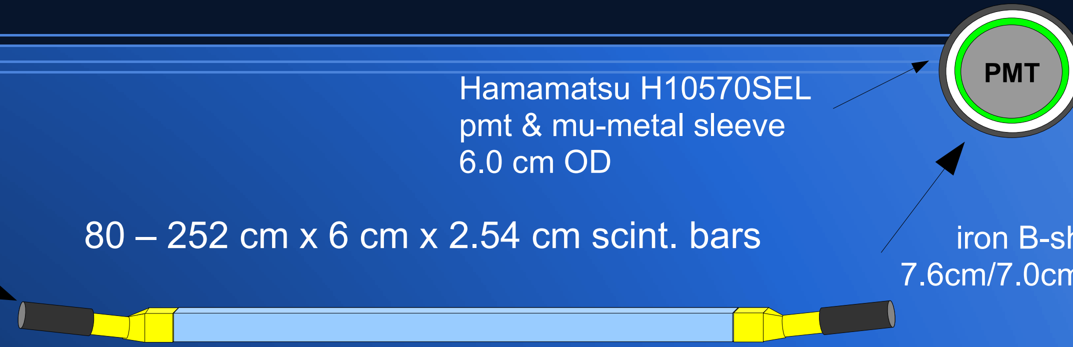


TOF scintillators

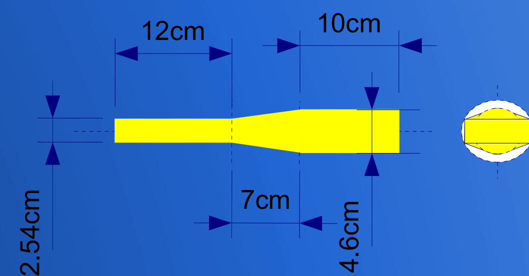
- 44 vertical scintillators
- 44 horizontal scintillators
- Size: 2.5 x 6.0 x 252 cm^3
- EJ-200 (BC-408)
- XP2020 PMTs
  - Two-sided readout (except on beamline)
- All joints are glued
- High-rate HV divider
- Magnetic shielding required
- Flight path is ~ 560 cm

Time of Flight Modules



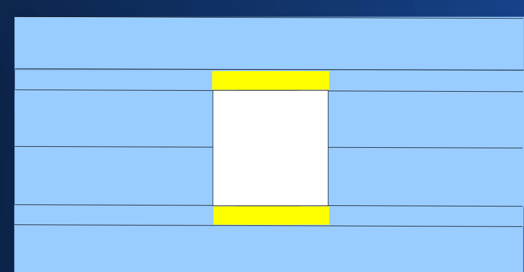


2 modular TOF planes
92 total modules
176 readout channels



Light guide design

beam hole region*



A. Somov [GlueX-doc-1471]

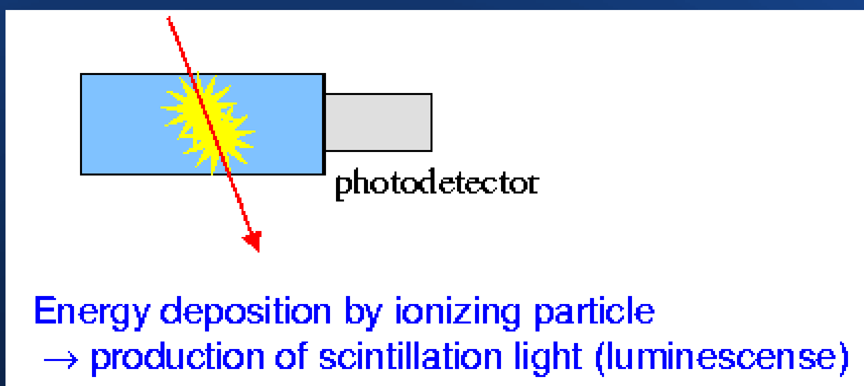
** concept under consideration*

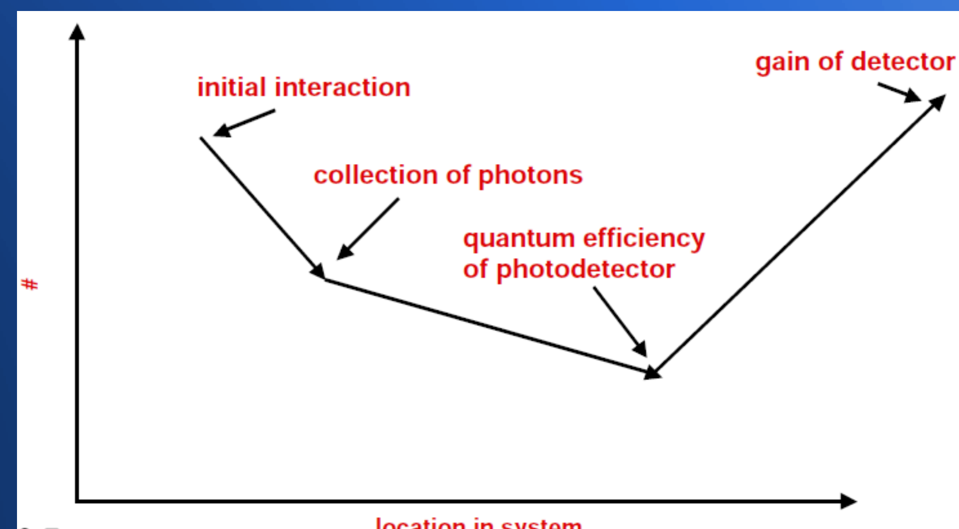
Main Use of TOF System

- Particle identification
  - allow separation of pions from kaons up to 2-3 GeV/c and pions from protons up to 6 GeV/c
- Triggering
  - Provide multiplicity of charged particle tracks per event for fast decision making

How it works

- How it works:





Basic Concept:

- Radiation interacts in material
- Energy converted to photons
- Photons collected by photodetector
- Photodetector produces electrical signal
- Relative time of electrical signal is measured

Key Properties of Scintillators

- Sensitive to energy
- Fast time response
- Pulse shape discrimination

Two material types:

- Inorganic → high light output but slow
- Organic → lower light output but fast

We use plastic scintillators:

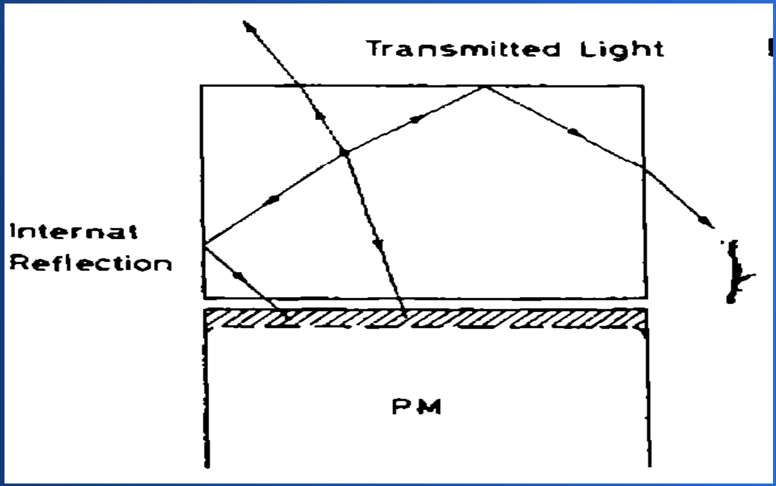
- 1 photon per 100 eV
- Decay time ns
- Easily to shape

Resolution Depends on Light Yield

The loss of light from a scintillator can occur in two basic ways:

- Through absorption by the scintillator material
- Through the scintillators boundaries (most important reason)

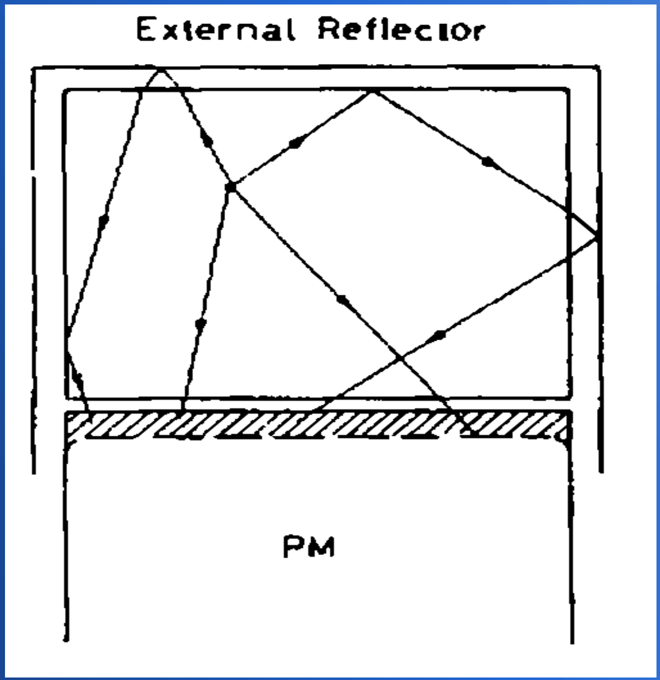
$$\theta_B = \sin^{-1}\left(\frac{n_{out}}{n_{scint}}\right)$$



Scintillation Light Collection

In plastic scintillators the internal reflection is facilitated by:

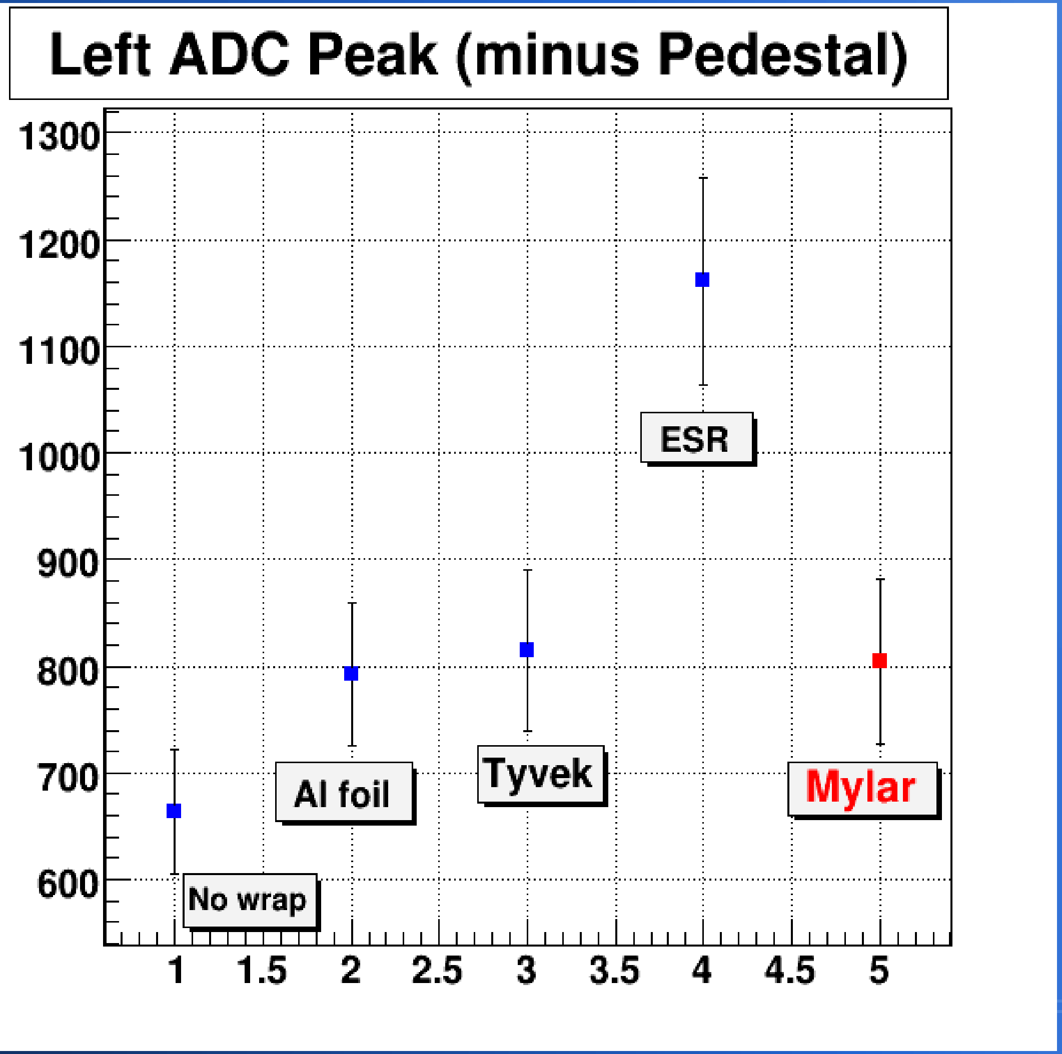
- Polishing the surfaces of the plastic
- Wrap by a reflector, living a layer of air between the reflector and the scintillator
- Wrap to make light-tight enclosure



Reflective Wrapping

Signal amplitude for 4 different materials:

- Mylar, Tyvek and AL foil wrappings are similar
- ESR* wrapping prevents 40-45% more light



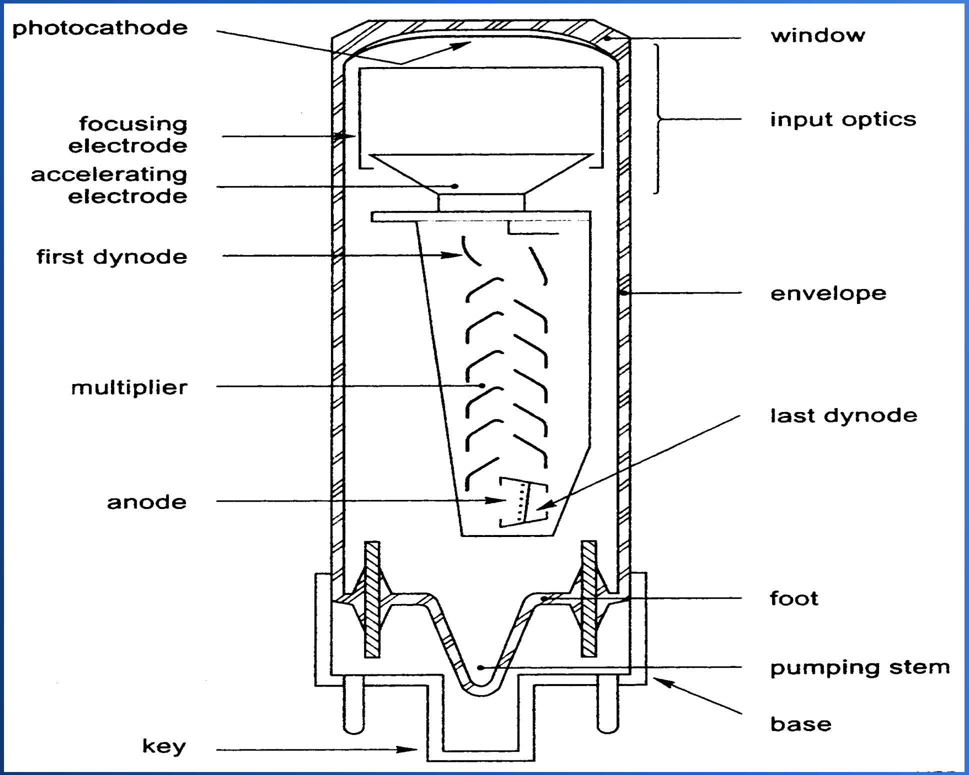
ESR*: New material made by 3M with 99.95% reflectivity over the visible spectrum

Photomultiplier Tube

main phenomena:

- The photo-cathode converts incident light into a current of electrons: $Q.E. = \frac{N\ p.e.}{N\ photons}$

- Secondary emission from dynodes, for example 10 dynodes with gain=4: $4^{10} \approx 10^6$



Hamamatsu H10534
Ultra-fast PMT
10 stages, 250ps spread

Magnetic Field Effects

PMT's are very sensitive to magnetic-fields (even to earth field: 30-60 μT)

- shielding is require: Iron shield thickness = 2.75mm with 0.4mm μ metal (75% nickel, 15% iron, plus copper and molybdenum)

Coupling PMT and scintillator:

- We can make the optical contact directly with silicone grease
- In our case we use light guides to make this optical coupling, the light guide is glued on to the end of each media

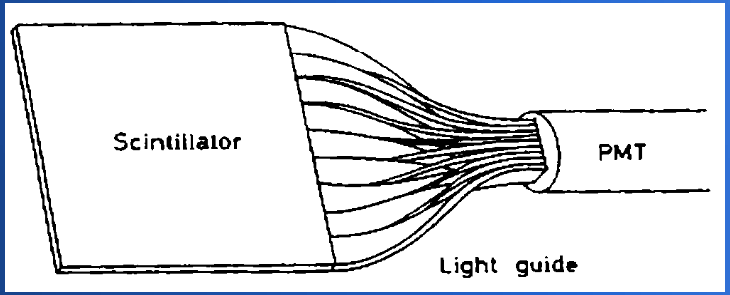
Light Guide

connecting rectangular bar end to circular PMT face

Why we are using light guide:

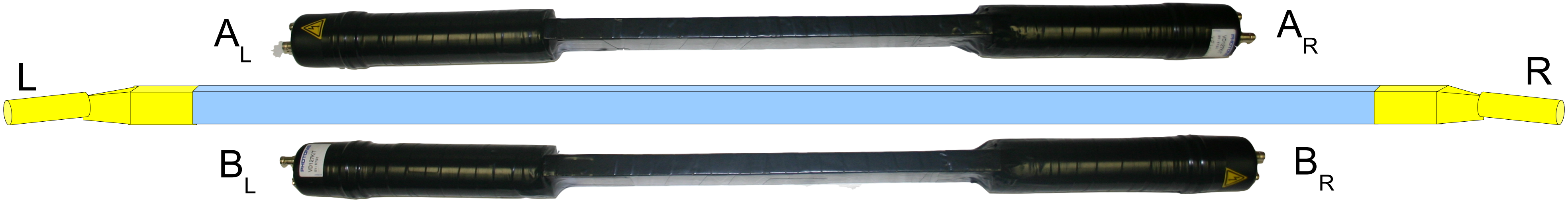
- Fast PMT's require well design input optics to limit chromatic and geometric aberrations
- Inconvenient scintillator shape with the PMT
- Locate PMT w/ shield for optimal module stacking

The flux density of photons in a light guide is incompressible



The twisted light guide

TOF Studies at FSU



$t_A = (A_L + A_R)/2$

$t_B = (B_L + B_R)/2$

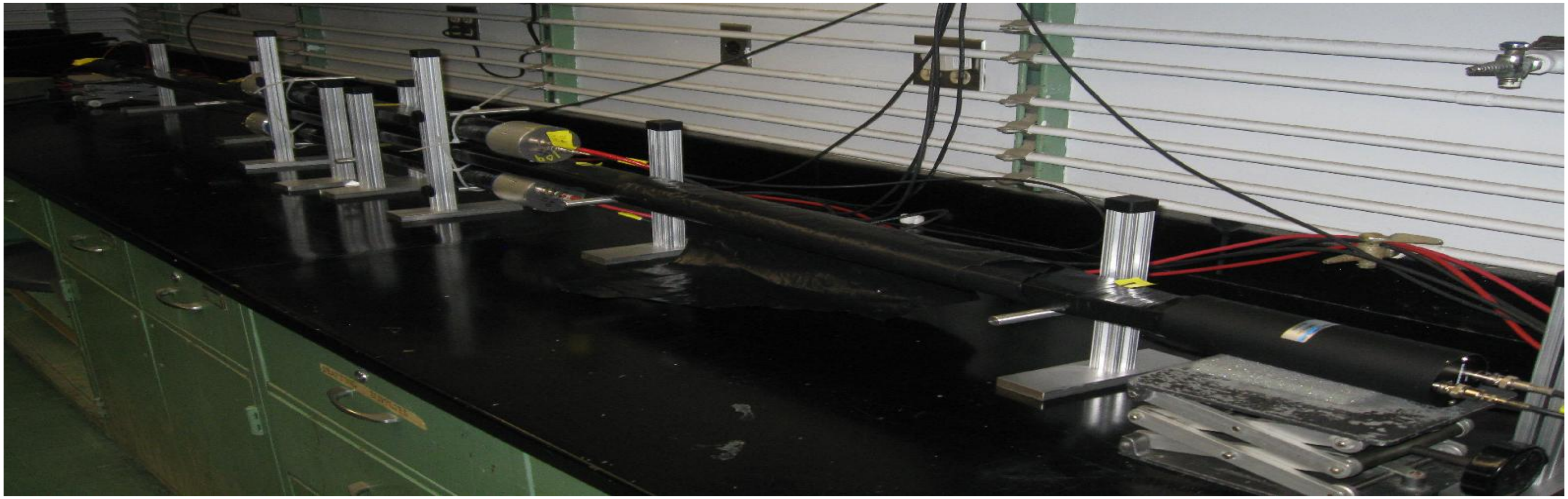
$t_{ref} = (B_L + B_R - A_L - A_R)/2$

$t_{TOF} = t_A + t_{ref}/2 = (A_L + A_R + B_L + B_R)/4$

But also $\mathbf{t_{TOF} = (L+R)/2}$

$\Delta t_{AB} = (L+R)/2 - (A_L + A_R + B_L + B_R)/4$

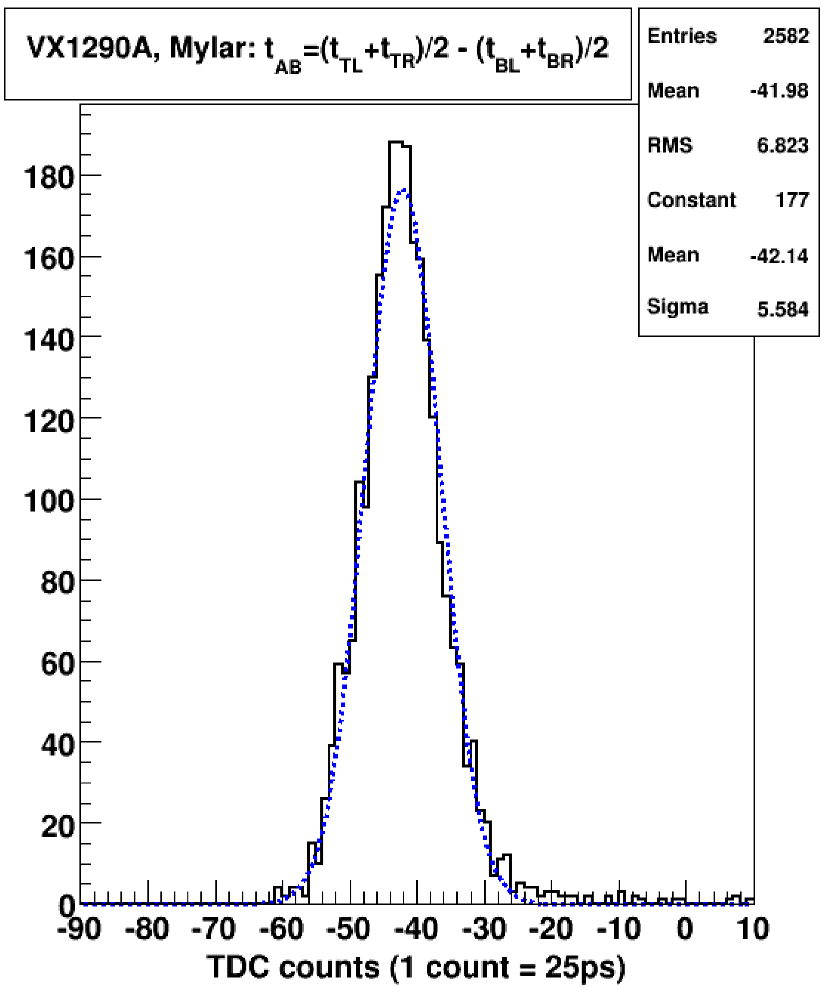
$$\boldsymbol{\sigma^2(t_{TOF}) = \sigma^2(\Delta t_{AB}) - \sigma^2(t_{ref})/2}$$

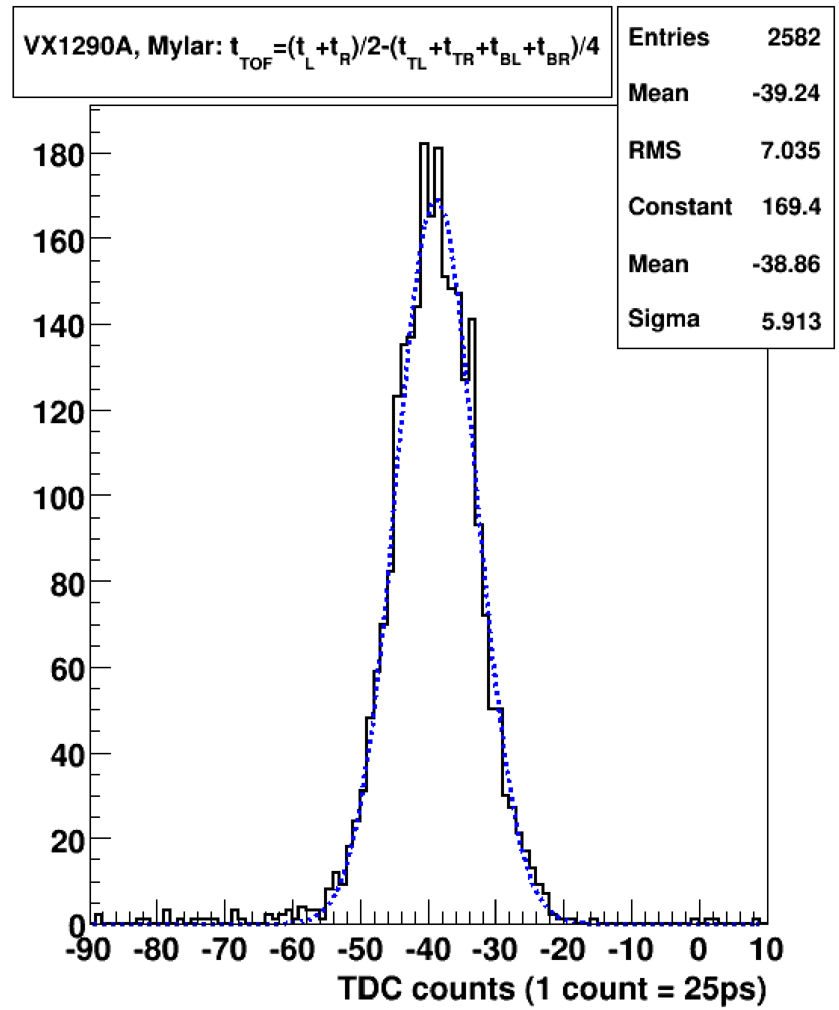


TOF Timing Resolution

Cosmic Ray Studies

- 6 PMT method
- v812 CFD
- Mylar wrapping
- 2000V HV





$VX1290A_{TDC}$: $\sigma(t_{TOF})$ = ~ 100ps per plane including TDC resolution

Time of Flight Particle Identification

$$p=\beta E \rightarrow \frac{p}{\sqrt{p^2+m^2}} = \frac{\Delta\, path}{\Delta\, TOF}$$

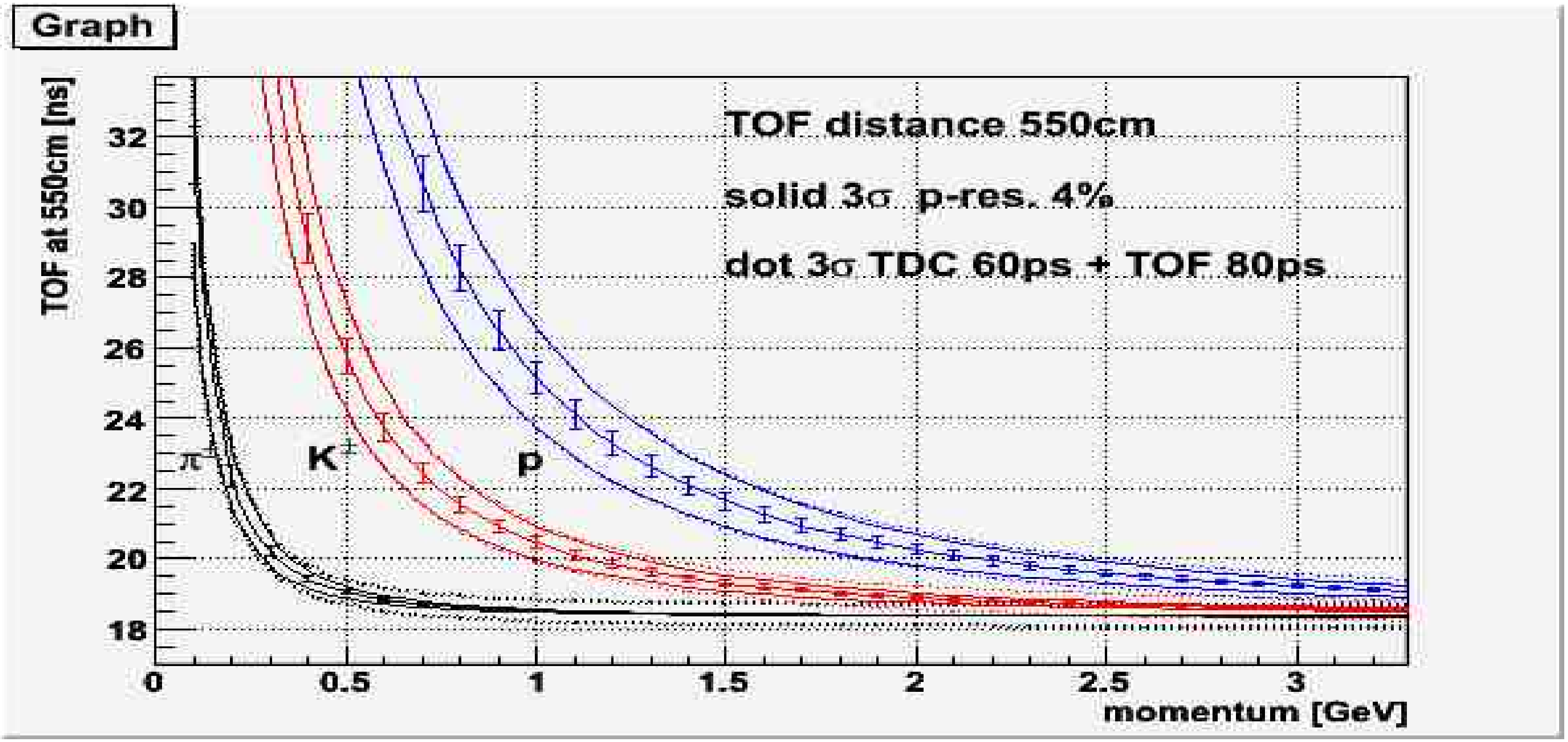
In order to do particle identification we need to find it's mass:

- Momentum p → drift chambers
- Velocity β = Δx/Δt : path length and time-of-flight

Drift chambers

accelerator t0 and TOF

TOF Particle Identification



The above plot shows that the TOF system will be able to identify kaons with high efficiency and low contamination up to momenta of 2GeV/c. Proton identification with very good efficiency and low contamination will be possible up to 3 GeV/c. This performance of PID at low momentum is nicely complementary to the momentum range of a RICH detector systems which can provide PID down to momenta of about 2 GeV/c.