Muons & Particle ID

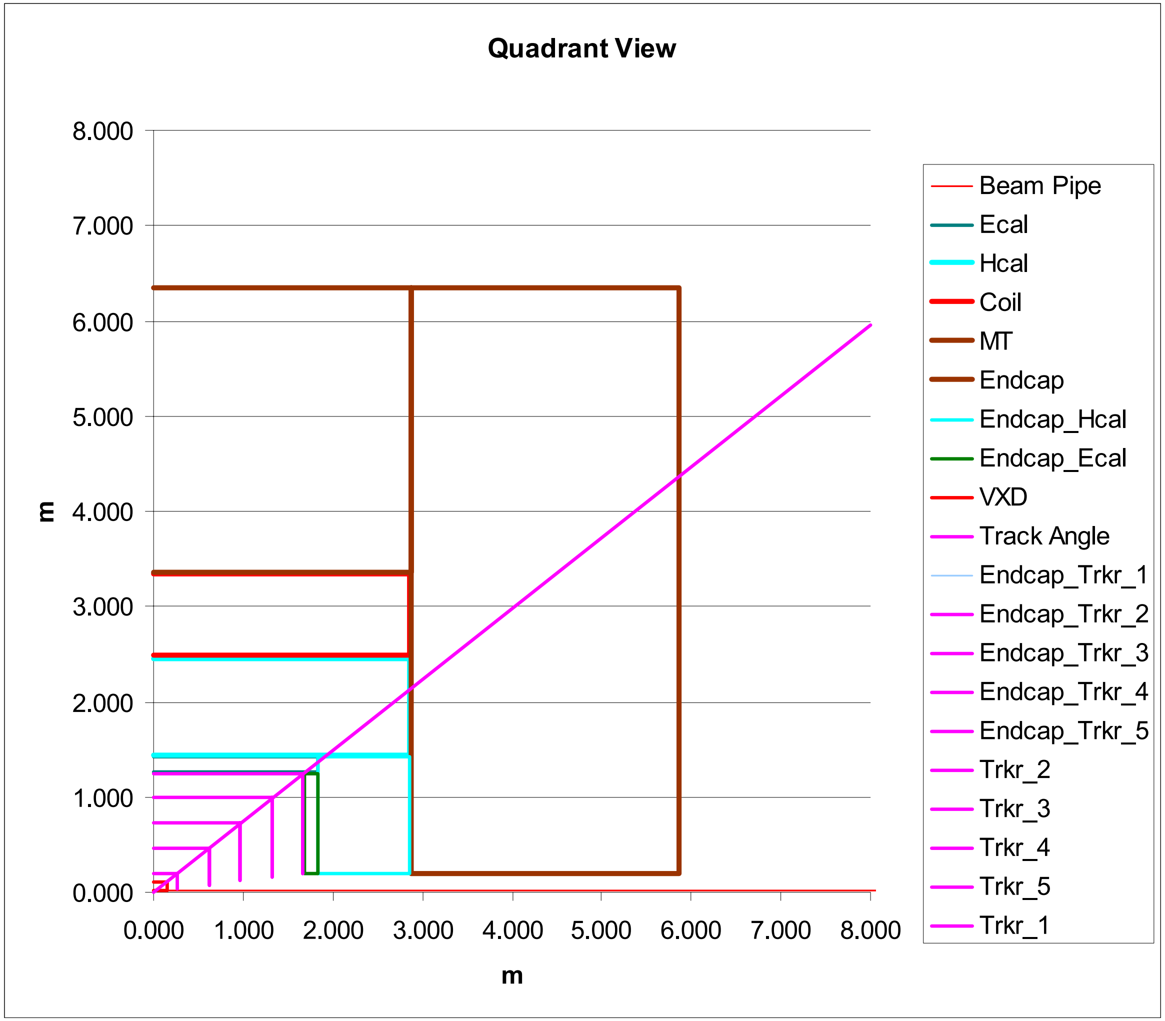
Muon/PID Studies

Global Simulation Software Dev. - A. Maciel - NIU
Tracking/ID w/μ, π, $b\bar{b}$ events – C. Milstene – NIU/FNAL
Scintillator Module R&D – G. Fisk – FNAL
MAPMT Tests/Calib/FE Elect. – P. Karchin – Wayne St.
Fiber Testing/Splicing/Routing – M. Wayne – Notre Dame
Digitization & Readout – M. Tripathi – UC Davis
Geiger Mode APD R&D - R. Wilson – Colorado St.

Muon System Design

- octagonal iron barrel with scintillator strips in slots
- 1 cm thick scintillator strips; 5 cm thick iron plates (SiD)
- wavelength shifting (WLS) fiber readout of strip
- clear fiber link between WLS fiber and photodetector
- multi-anode photomultiplier tube opto-electrical conversion

SiD Configuration



M. Breidenbach @ Cornell 2003

Major SoftwareIssues

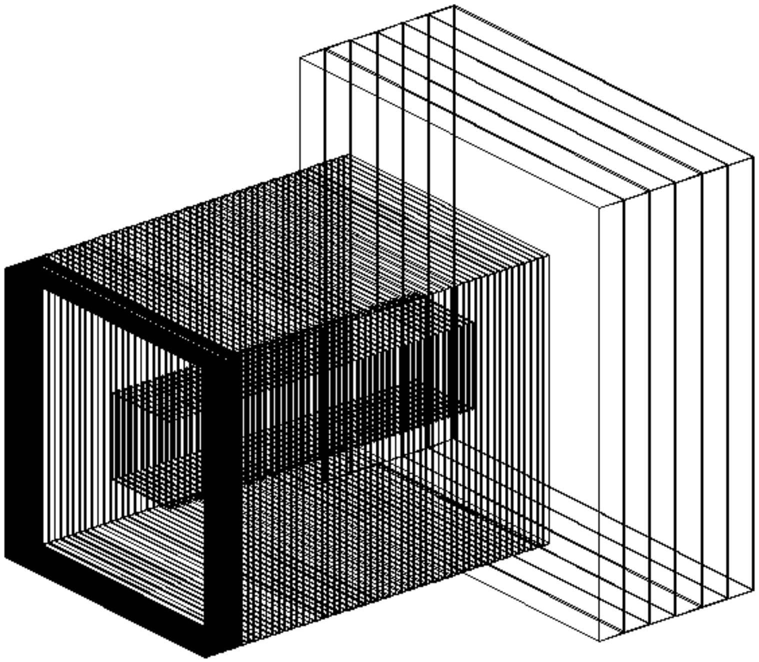
- Dev. of global cal/muon planar detector representations and first usage. A. Maciel
- Development of Muon Identification Algorithms
- Testing the algorithms on:
    - Muons
    - Pions
    - b Pair Event
- Pion punchthrough
- Low energy muons

C. Milstene

NIU – Tail-catcher / Muon system (for test beam w/CALICE collaboration)

For details see talk by V. Zutshi, Calorimetry session in Poincare Aud. Wed 4/21 15:00

- Planar detector plans
- GEANT4 simulation
- Resolution studies
- Scint. Strip extrusions
- Light yield properties



μ ID Algorithm Development 1/2004

SiD detector: R_{in} = 349 cm;
R_{out} = 660 cm.
5 cm thick Fe; 32/48 1.5 cm gaps instrumented.

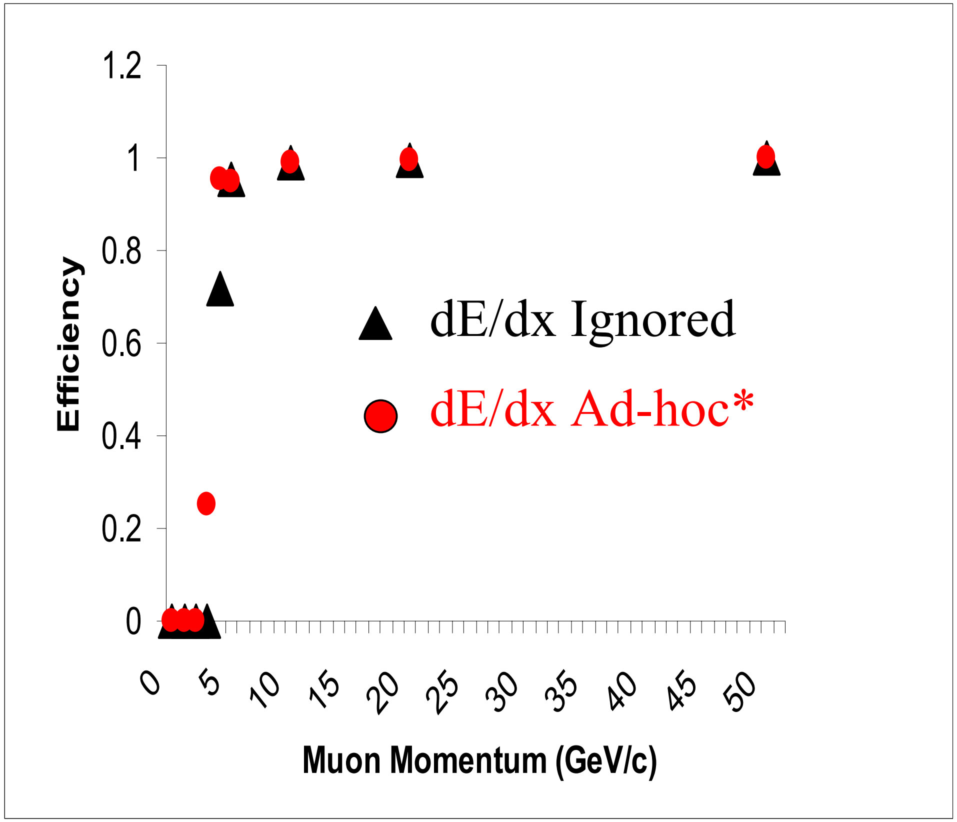
1. Extrapolate fitted tracks to EMCal, HCal and MuDet.

2. Collect hits in ($\Delta\theta$, $\Delta\varphi$) bins about extrapolated trks.

3. For muons with p $\geq$ 3 GeV/c requires 16hits in $\geq$ 12 out of 32 layers taking into account an Ad-Hoc dE/dx (* Hit collection within an angle varying ~1/p).

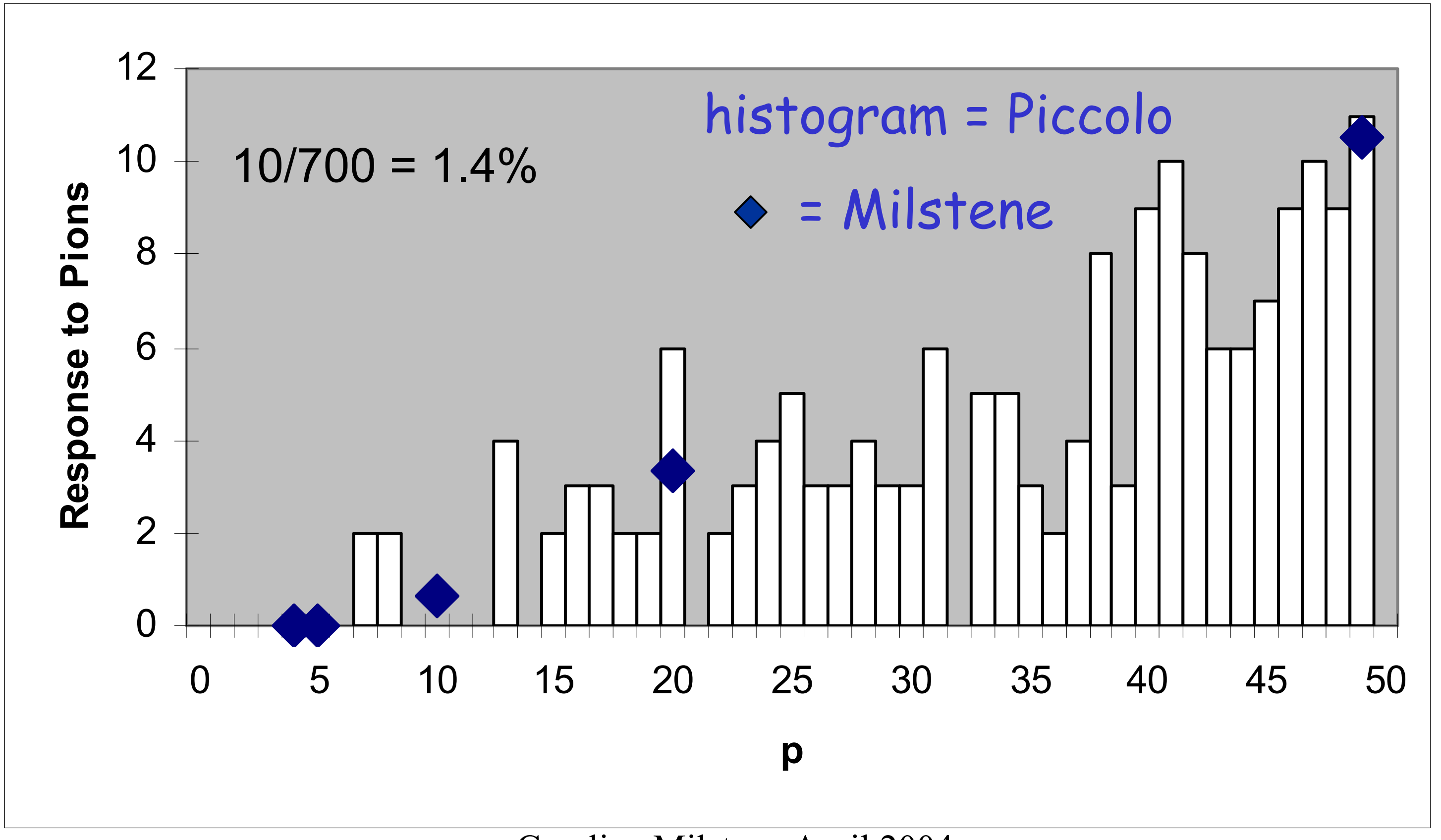
Similar TESLA studies by M. Piccolo

Single Muons with the Swimmer



μ ID Algorithm Development

Analyze single pions with the same algorithm to get punch-through. At 50 GeV/c it is 1.4%.

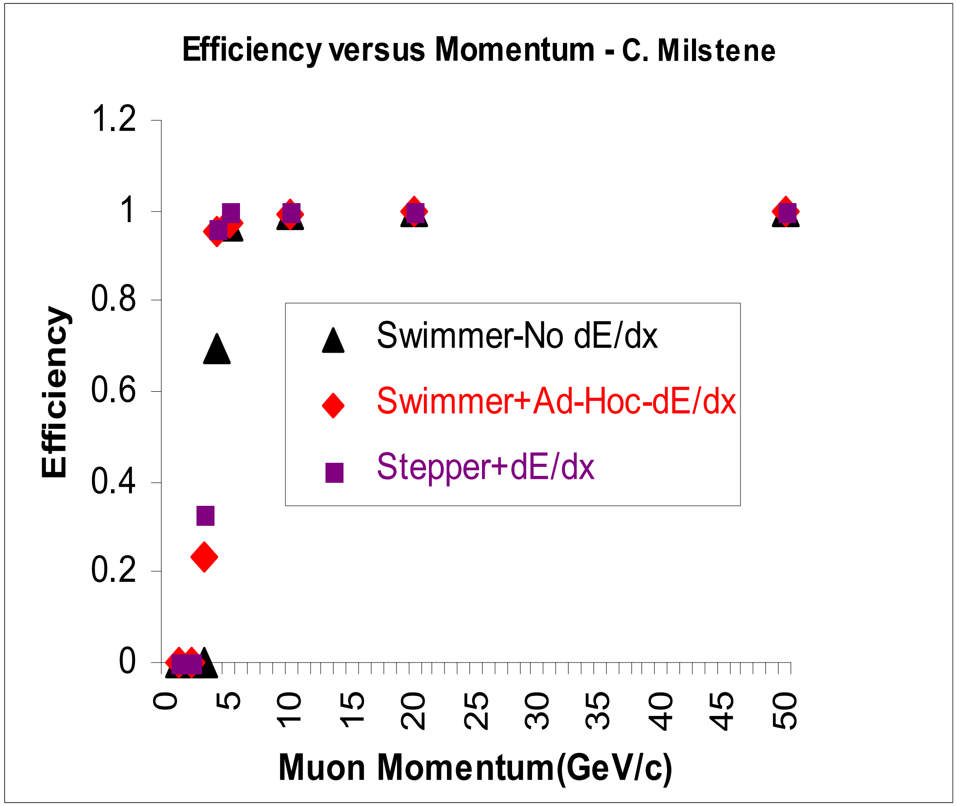


The Charged-Particle Stepper

- Combines magnetic field tracking and dE/dx energy losses in matching hits in the Hcal and Muon detector with tracks projected from the central tracking.
- Require 16 hits in $\geq$ 12 out of 32 planes in the muon detector and corresponding hits in Hcal; i.e. p $\geq$ 3 GeV. Not all 3 GeV muons reach the muon detector, but the efficiency is better than the previous matching of tracks using $\Delta\theta$ and $\Delta\varphi$ matching plus dE/dx through the calorimeters, SC coil and muon detector.

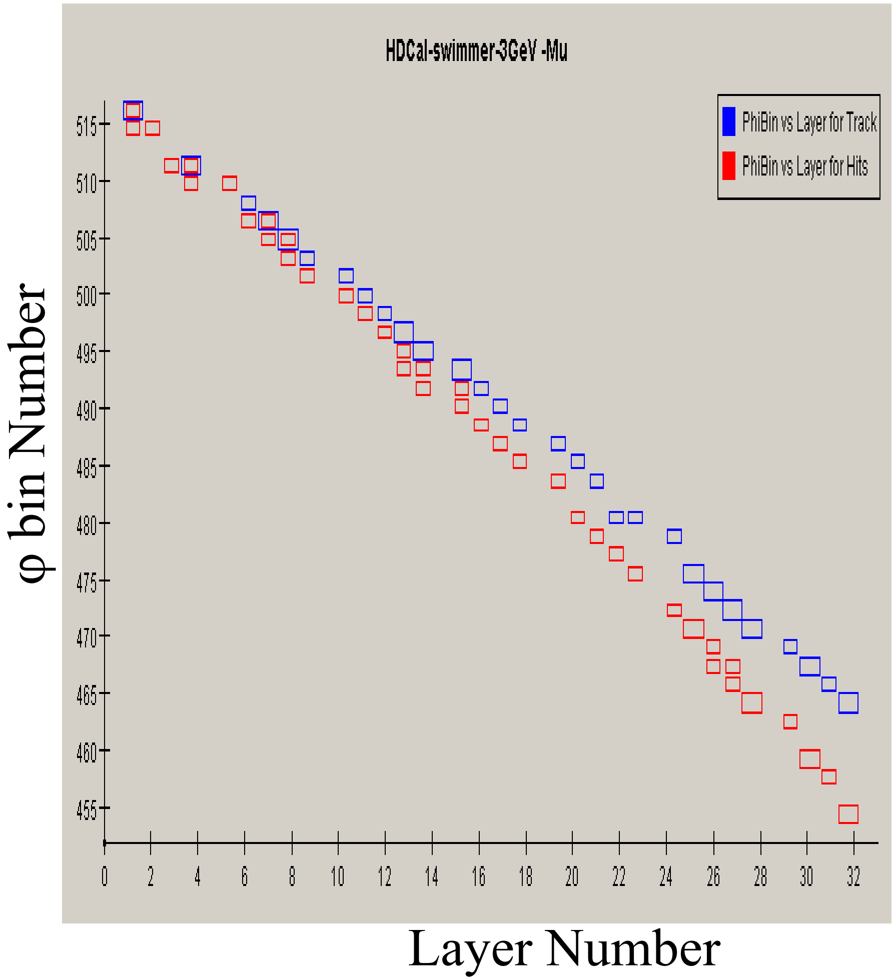
Stepper Results - Single Muons

E(GeV) \ Techn.	3	4	5	10
No dE/dx	0.06%	70%	97%	99.%
Ad-Hoc dE/dx	23%	95%	97%	99.%
V x B + dE/dx	33%	96%	99%	100%

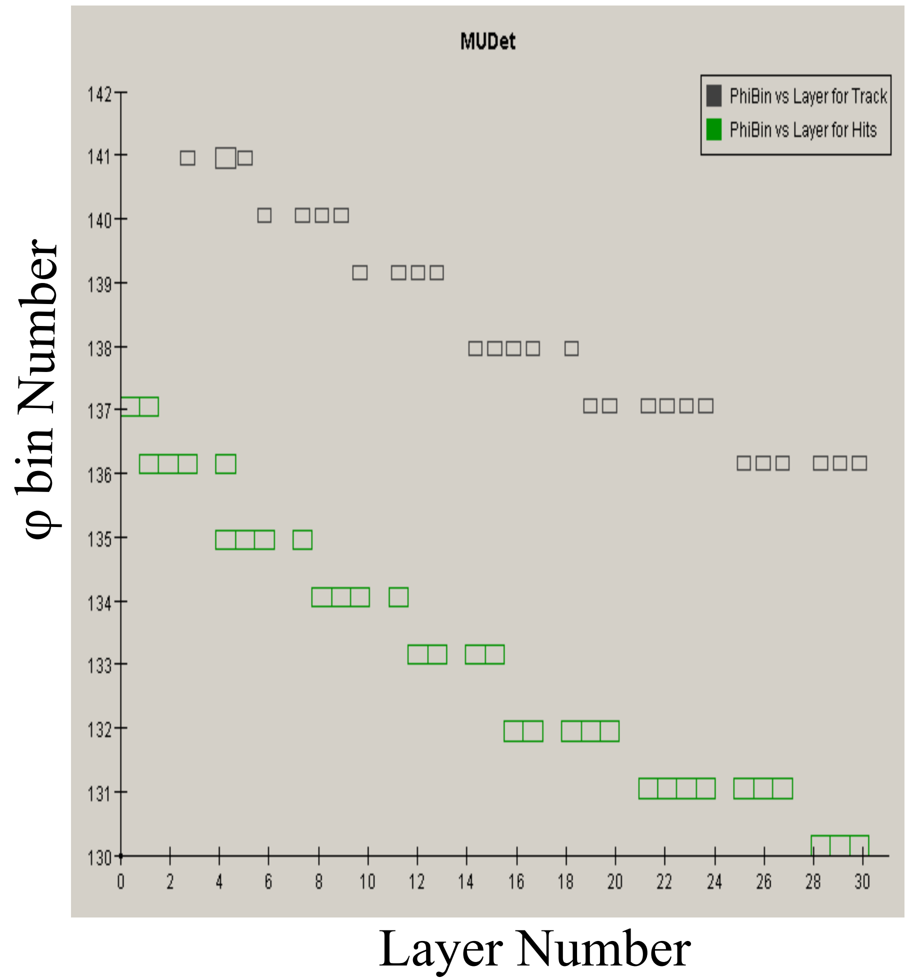


Swimmer in H Cal and μ Det
Angle Bin versus Layer 3 GeV Muon

H Cal: 1200 φ bins / 34 Layers



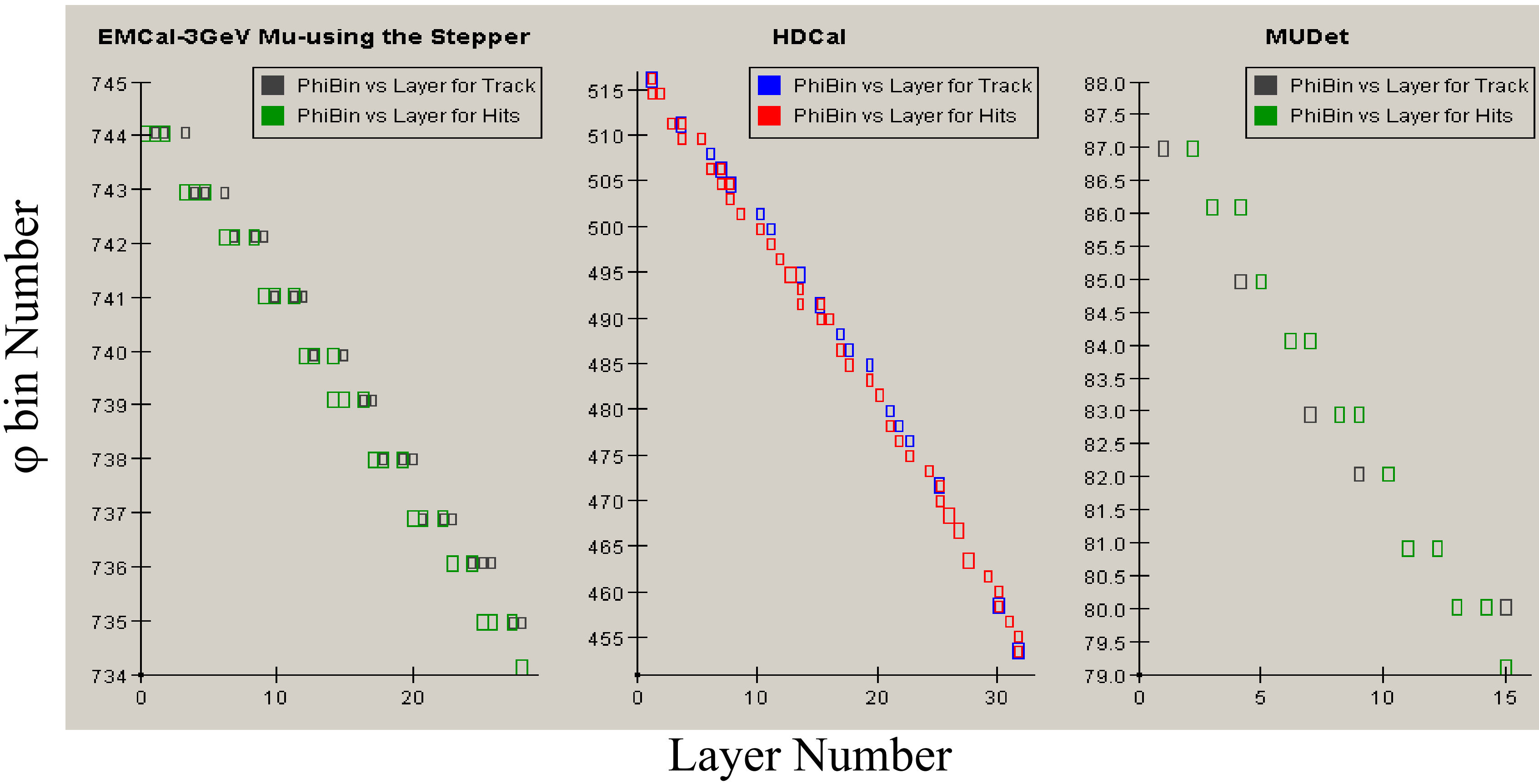
μ Det: 300 φ bins / 32 Layers



Caroline Milstene April 2004

Stepper in EM, H Cal and μ Det
Angle Bin versus Layer 3 GeV Muon

E Cal: 1680 φ bins/30Layers H Cal: 1200 φ bins/34Layers μ Det- 300 φ bins/32Layers

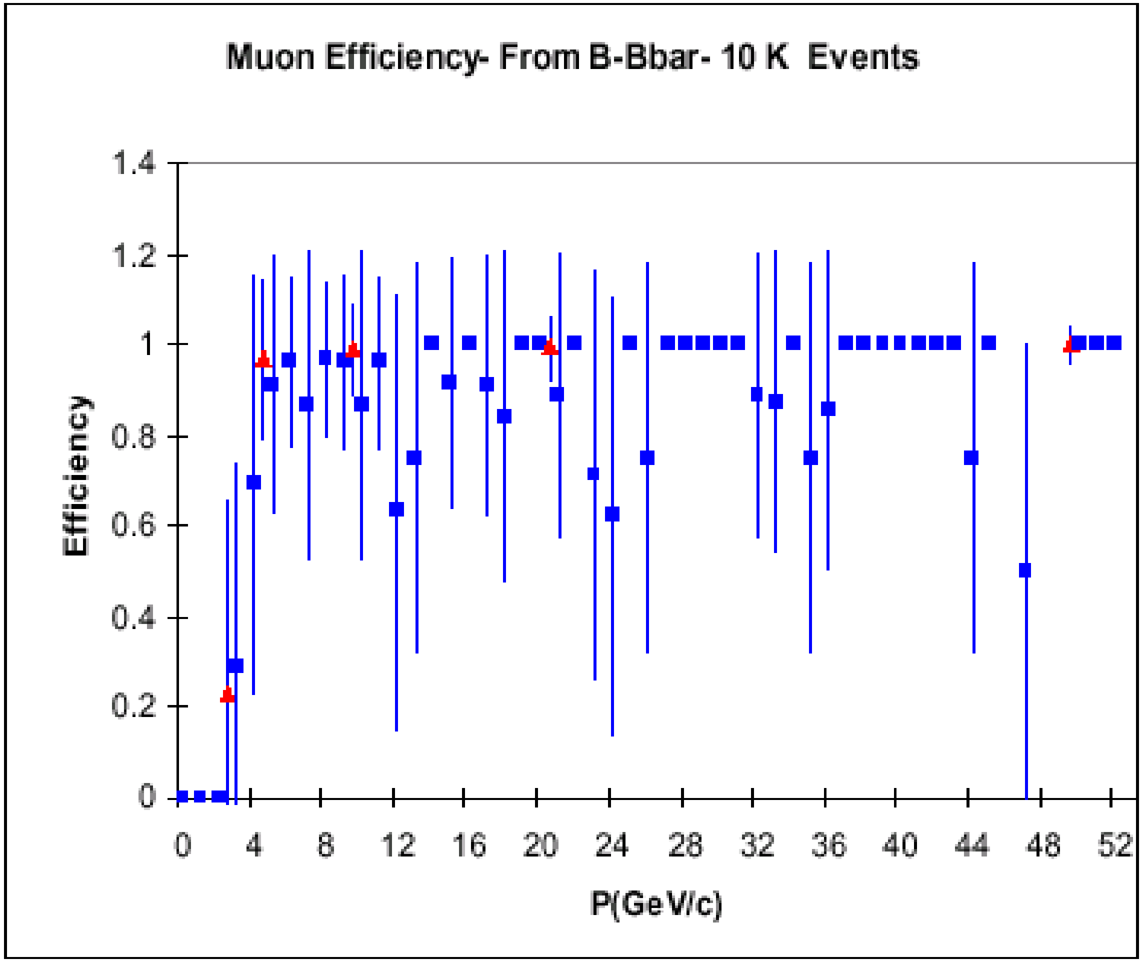


Caroline Milstene April 2004

Muon ID for $b\bar{b}$ Events

10K bb events
@ 500 GeV
Pandora Pythia
generated at NIU.

- ▲ Single muon eff.
- ■ μ from bb



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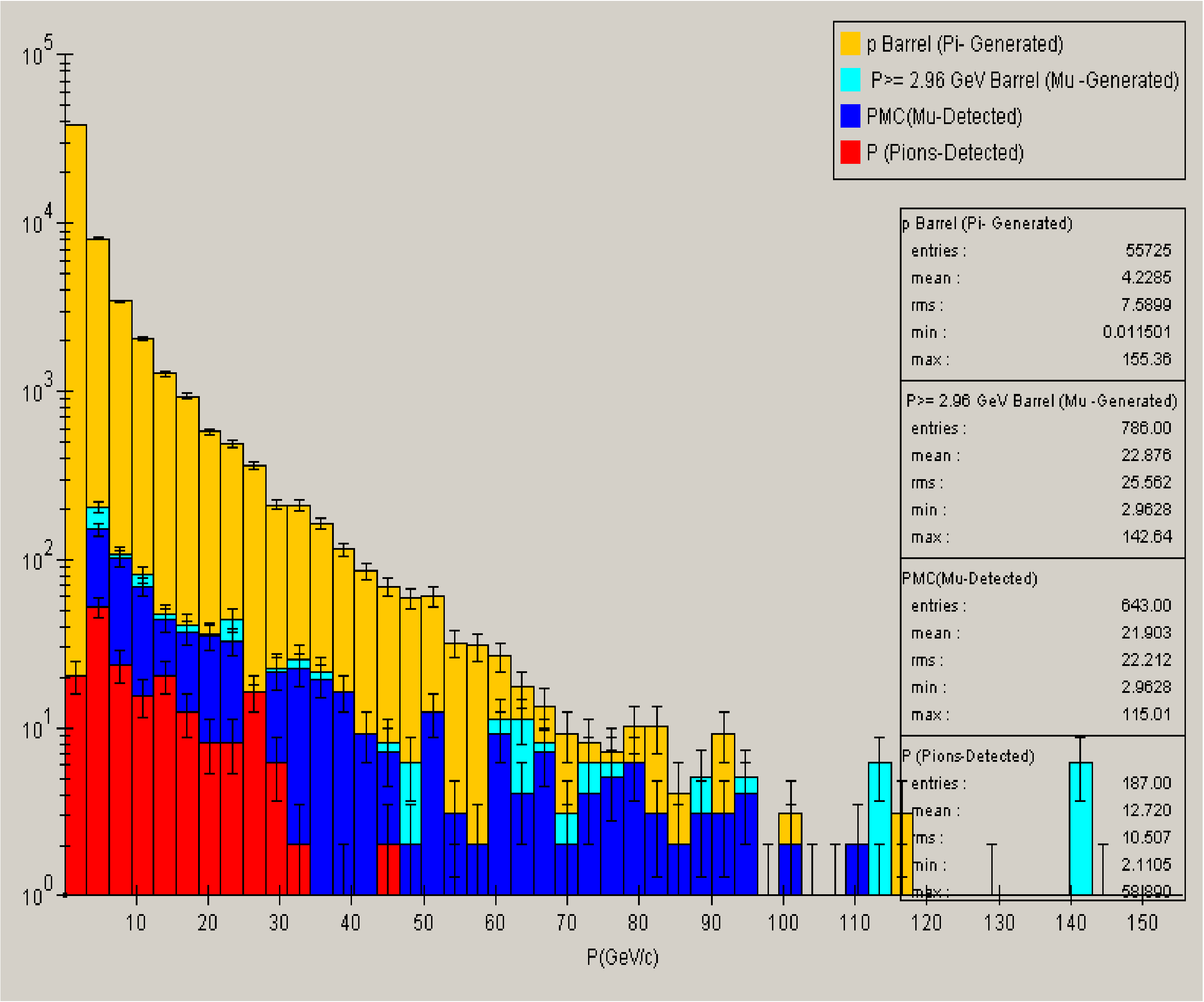
P-Distribution of μ & π Generated vs Detected from 10000 B-Bbar



- Generated Pions in Yellow
- Generated Muons in light blue
- Detected Muons in navy blue
- Pions Detected as Muons in Red.

The Pion Rejection is shown to be ~80 to 1

!Preliminary!

C. Milstene 4/2004

B-Bbar Swimmer Analysis

10,000 events generated.
Charged tracks with 0.9 < θ < 2.2 = Barrel

Particle	Generated	Pass μ ID
π	55,725	187
K	8,291	85
p	2,814	25
μ	768	643

Avg. π Punchthrough Probability ~ 1/80

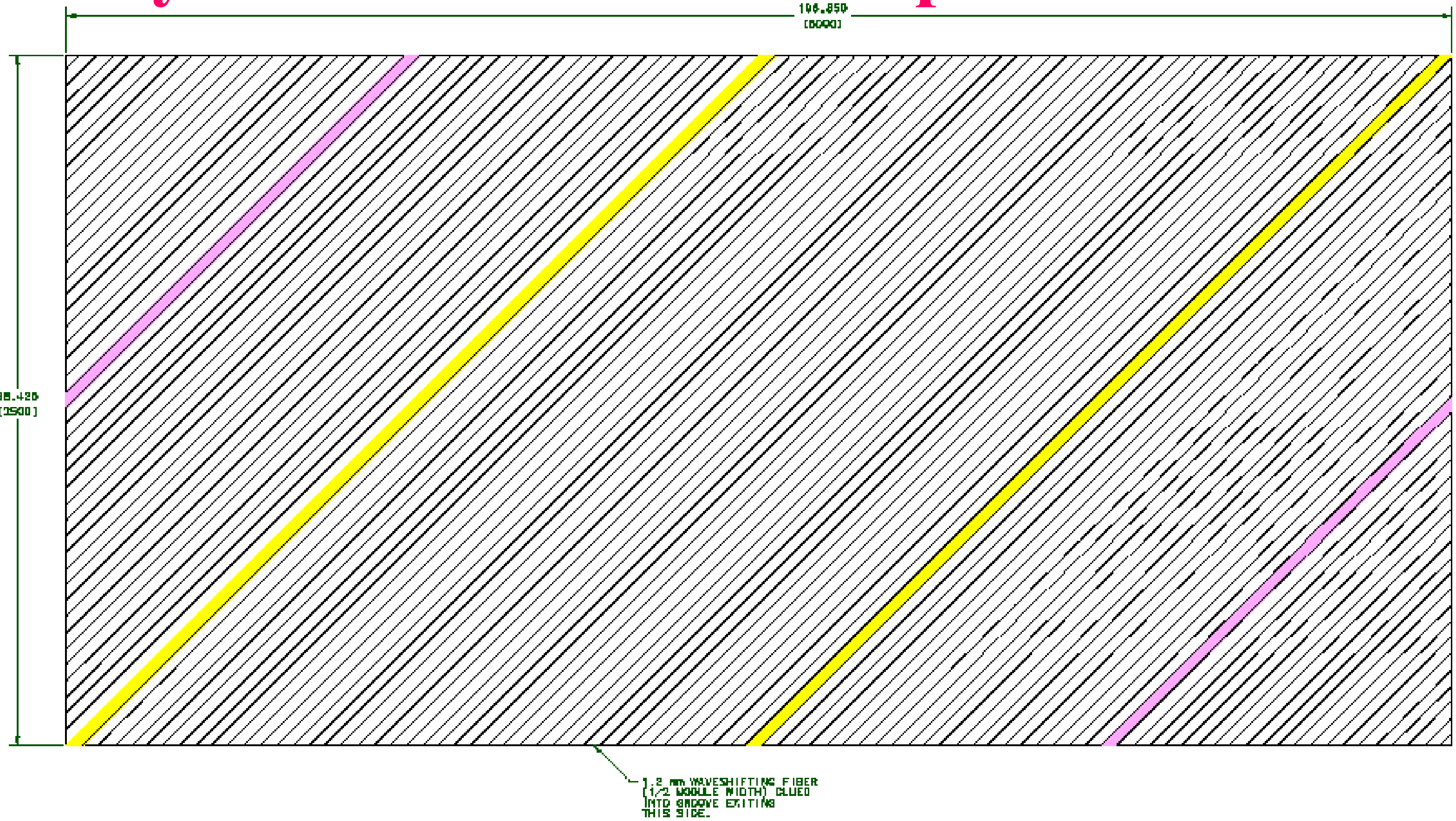
! Very Preliminary !

Hadrons near muons…. for $b\bar{b}$

- For 5000 bb events there were 136 tracks that satisfied the μ algorithm but were labeled as hadrons entering the μ detector, because there was a hadron in the allowed (Δθ, Δφ) window of the extrapolated track. Many of these are low p tracks.
- About 70% of these tracks have two, or sometimes three, nearby tracks where one is a true μ.
- By using the μ ID algorithm in Hcal, (# of hits/layer, etc.) perhaps 2/3 of these tracks can be identified as muons or hadrons. Stepper analysis anticipated.
- These studies are not complete; chi-squared track matching? ; use energy loss from the measured calorimeter/μ detector E measurement?.

Hardware Development

Layout of Scintillator Strips in one Plane



Procurement of Scintillator at FNAL

- 4.5 km of Kuraray WLS and 3.0 km of Kuraray clear fiber delivered; 1.2mm dia.

- ~ 700 pieces of 3.5m X 4.1cm X 1cm MINOS type extruded scintillator were produced at Itasca Plastics in St. Charles, IL on Dec. 10th and delivered. For ~ 8 planes 2.5m X 5.0m.

- We have 25 ~3 ft. long pieces for testing. Gluing tests are starting.

Multi-Anode Photomultiplier Tube Tests, Calibration and Front-End

Scintillator Based Muon System R&D for a Linear Collider

Paul Karchin
Wayne State University
Department of Physics and Astronomy

Personnel:

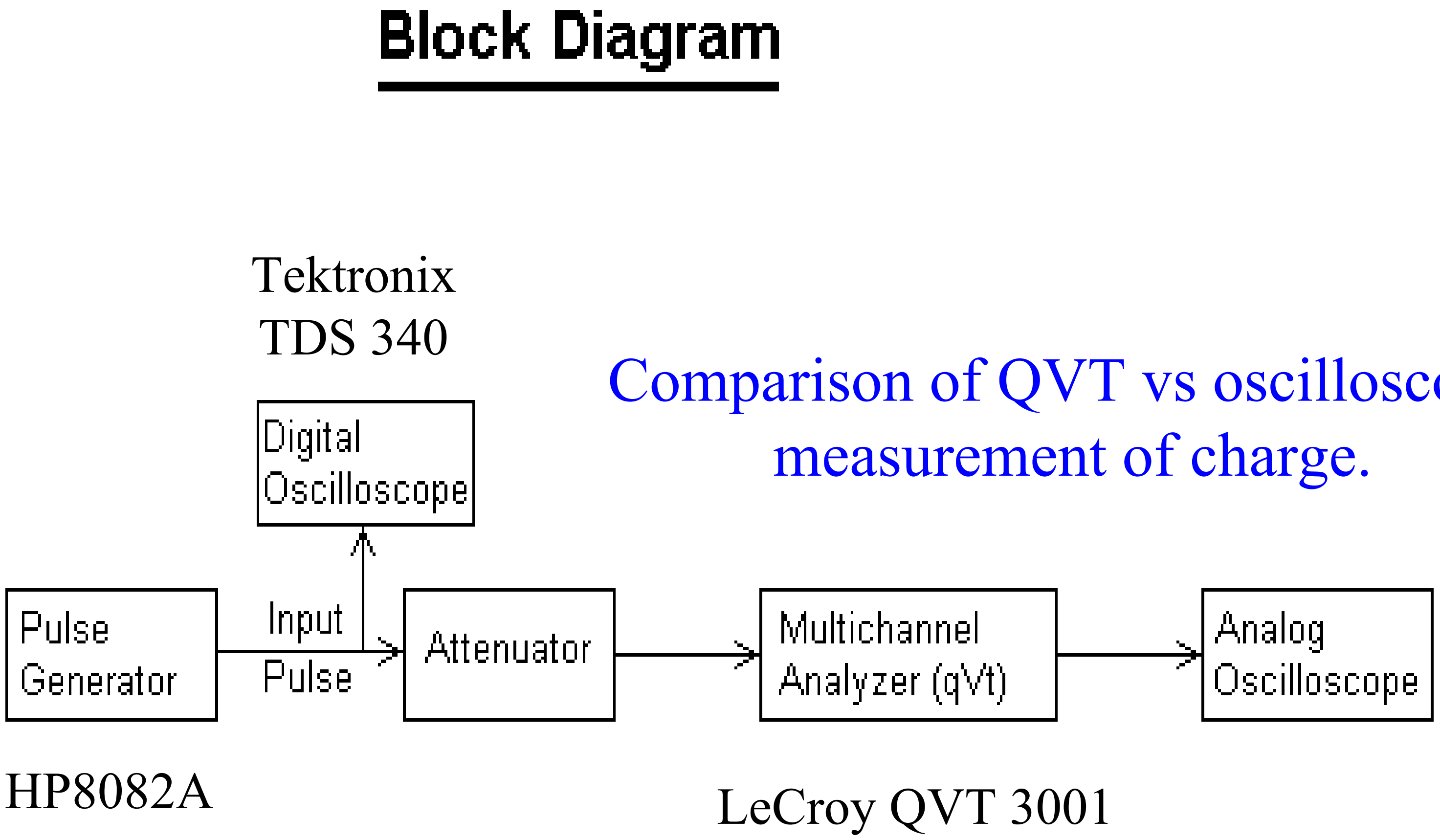
- Paul Karchin, Physicist
- Alfredo Gutierrez, Research Engineer
- Marcel Leonard, Undergraduate Physics Student (Fall 2003)
- Rajesh Medipalli, Physics Graduate Student (Summer 2003)

Stability and In-Situ Calibration of a Large Scale System

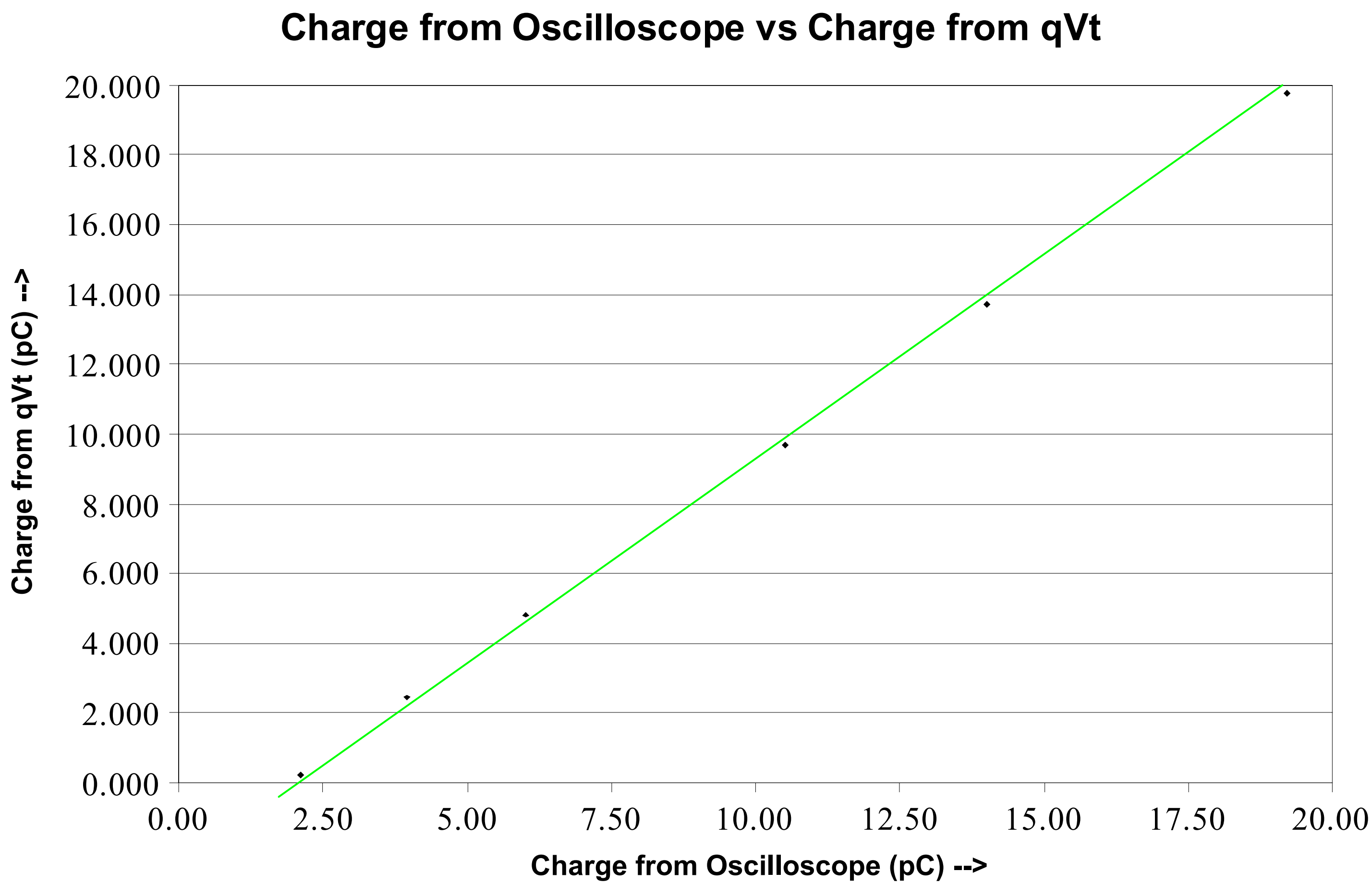
Test set-up generated with an LED pulser, etc to:

- Establish linearity of pulse height analysis system;
- Measure the properties of MAPMTs.
- Investigate potential use of LEDs for detector calibration.
- Eventually compare with other methods of calibration:
  - Cosmic rays
  - Radioactive sources

Charge calibration system for pmt anode pulses



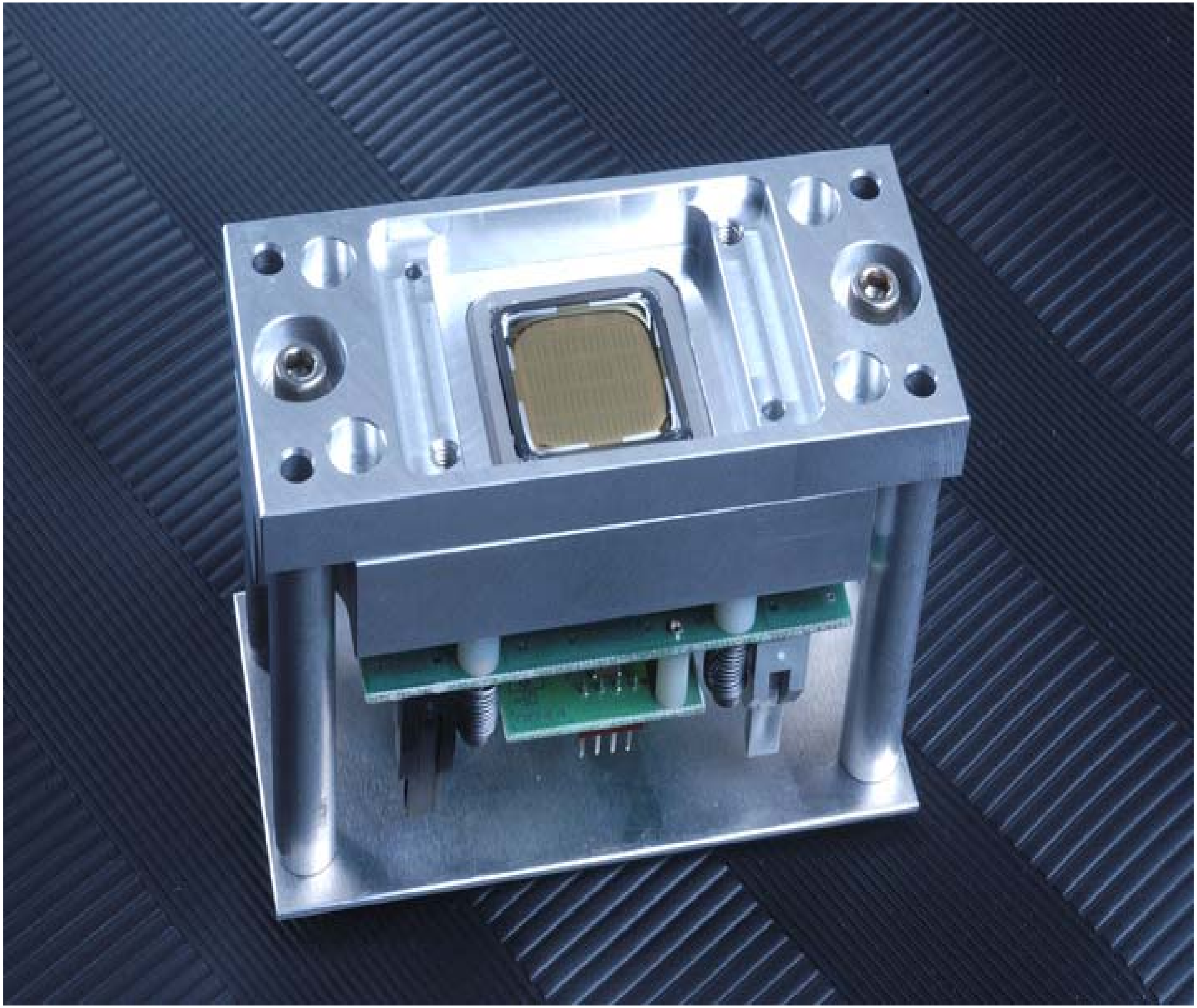
Comparison of QVT vs oscilloscope measurement of charge.



To prepare for precise measurement of the charge in MAPMT pulses, a Lecroy QVT 3001 was calibrated with a pulse generator and a Tektronix TDS 340 digital oscilloscope. A charge of 1 pC is the expected response from the MAPMT for a single photoelectron and MAPMT gain of 6×10^6. The calibration curve is linear with a significant pedestal offset of about 2 pC.

Paul Karchin April 2004

MINOS base NIM HV supply - Bertan 375 X



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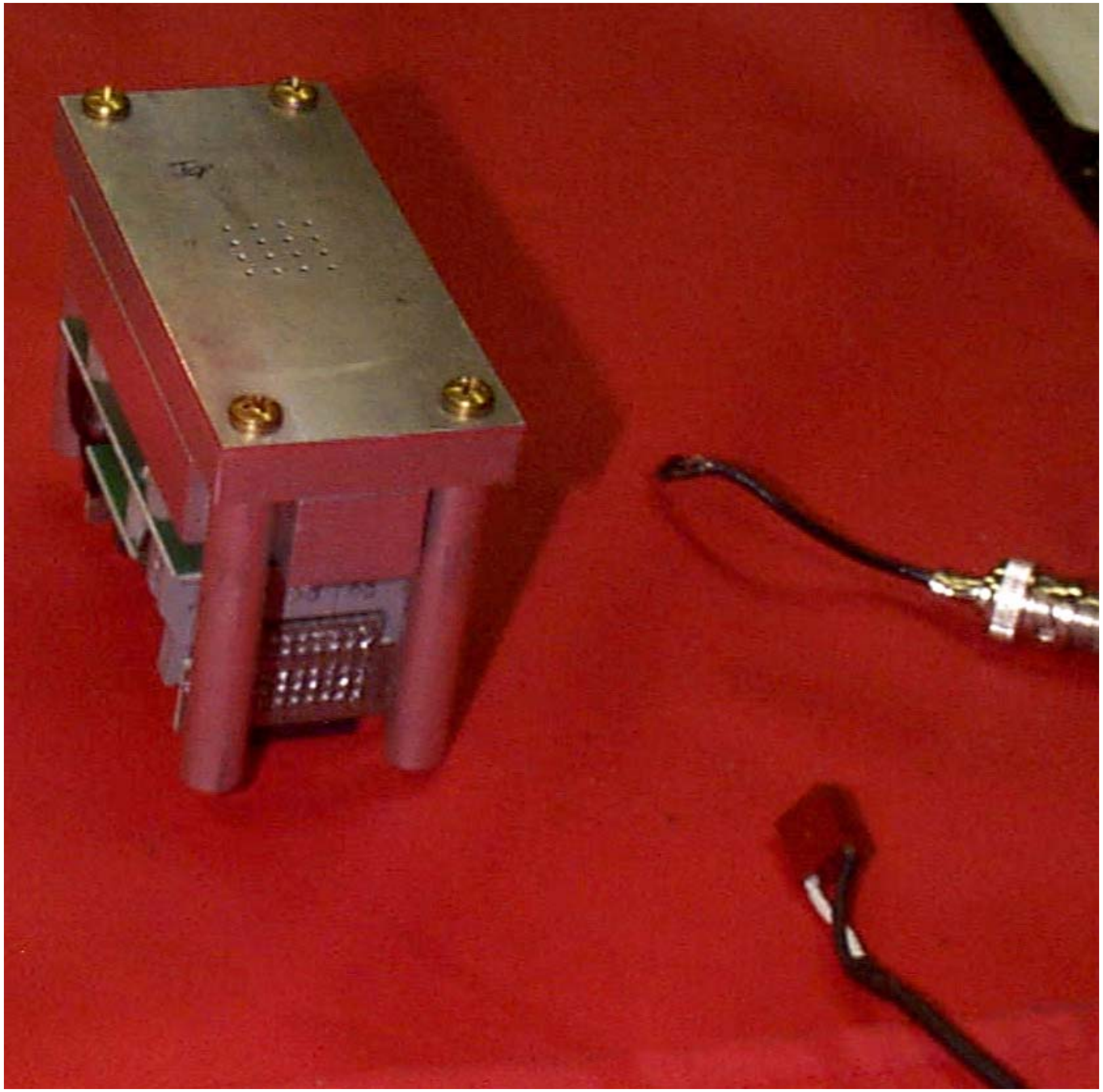
Light Injection and PMT Readout

A Hamamatsu R5900-M16 MAPMT mounted in a MINOS (far detector) base. The assembly has been modified to accommodate an aluminum guide for optical fibers. The 16 holes in the aluminum block are aligned With the MAPMT photocathode grid. Ambient light or pulses from an LED are injected into individual pixels. Cables are visible for HV bias and anode signal readout.



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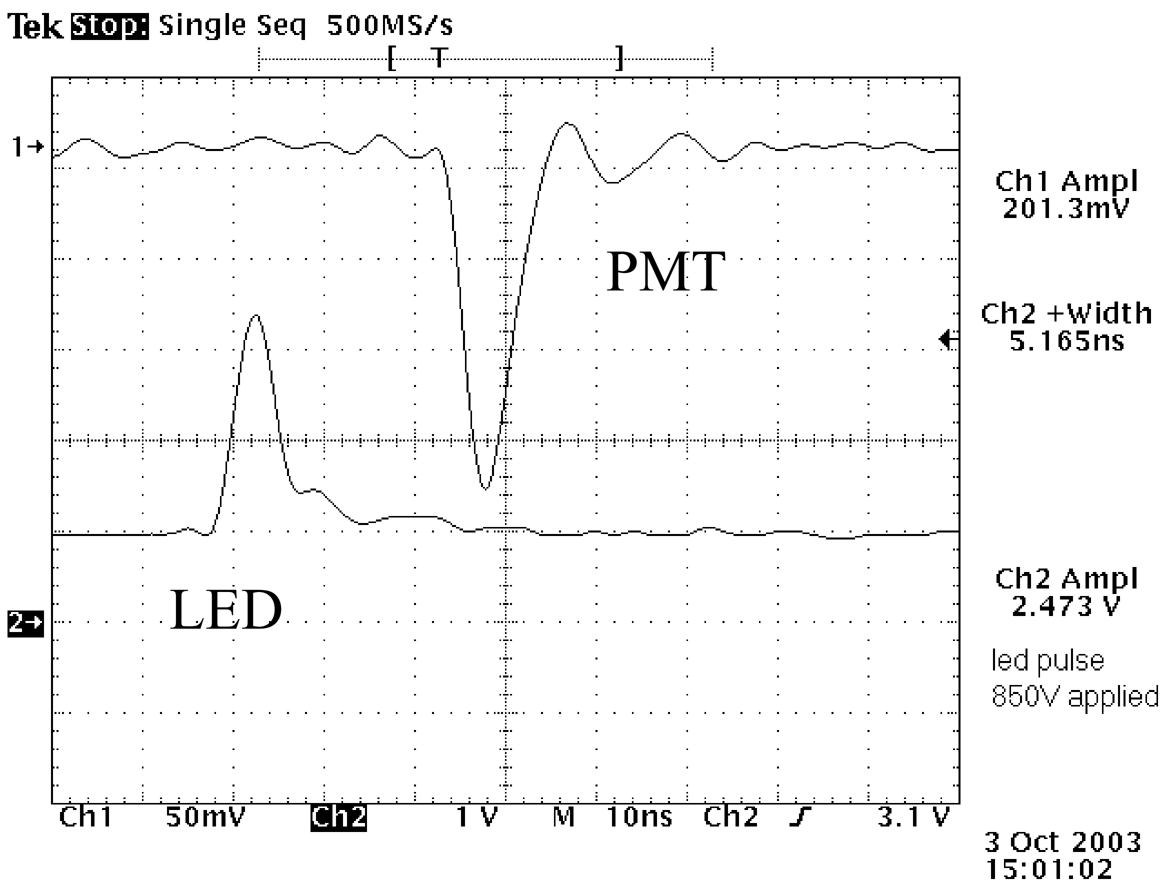
M16 PMT with MINOS base – response to LED pulse



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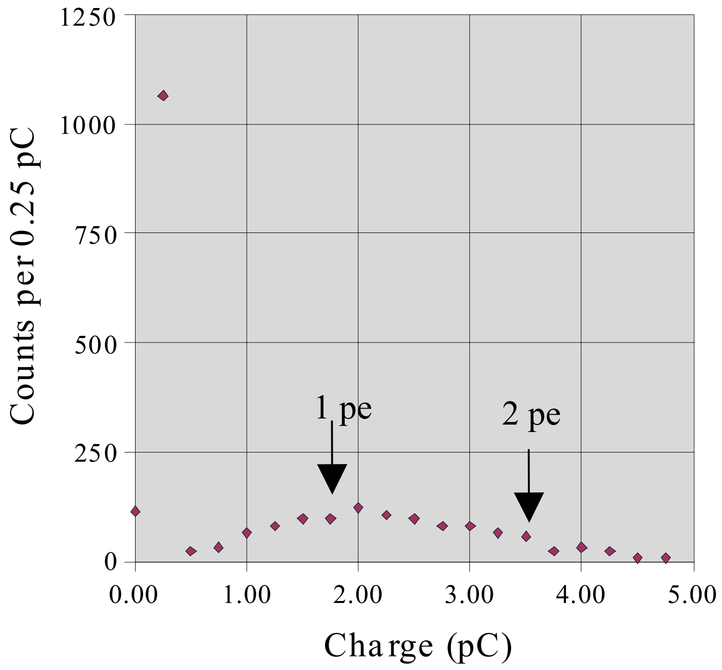
Measurement of single channel charge distribution in response to low light level LED pulses

MINOS MAPMT Channel 15 at 950 V



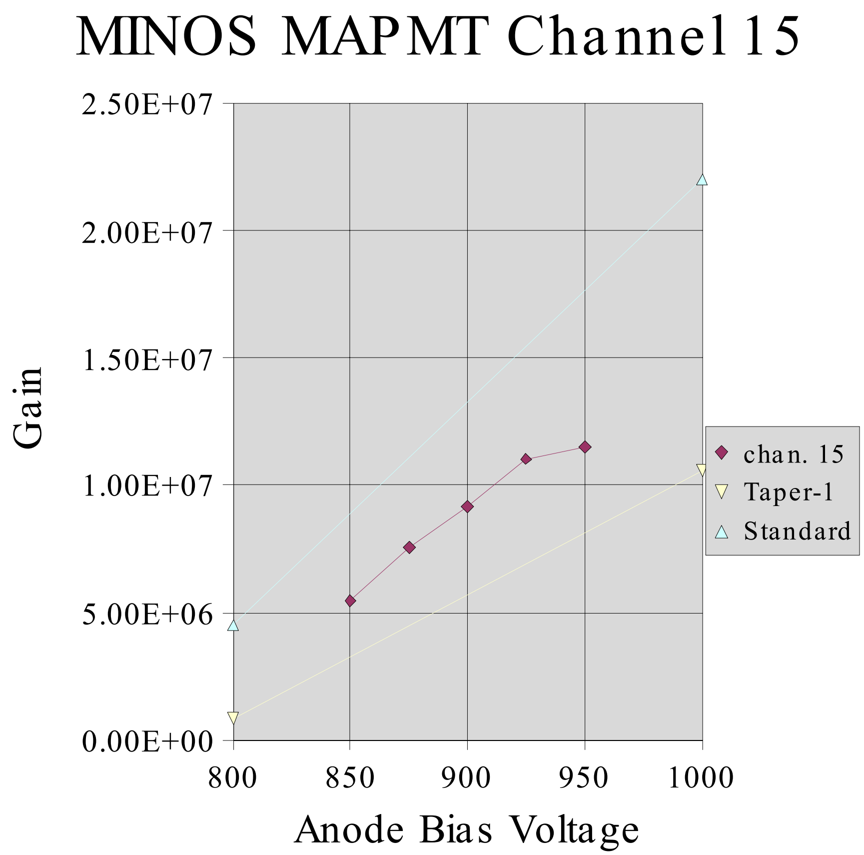
Prob(0) = sum(pedestal)/sum(ped+signal)

$\langle N_{pe} \rangle = -\ln \text{Prob}(0) = 0.66$

$\langle Q \rangle = 1.23 \text{ pC}$

$$\text{PMT Gain} = \frac{\langle Q \rangle}{\langle N_{pe} \rangle e} = 1.15 \text{ X } 10^7$$

Measured gain versus anode bias voltage for a single MAPMT channel and comparison to R5900-00-M16 reference data



Paul Karchin April 2004

Optical Fiber Work at Notre Dame

Personnel: Mitch Wayne (physicist), Mike McKenna (technician)
Mark Vigneault (technician), Tom Burger (undergraduate student)

Fiber Splicing

Motivation

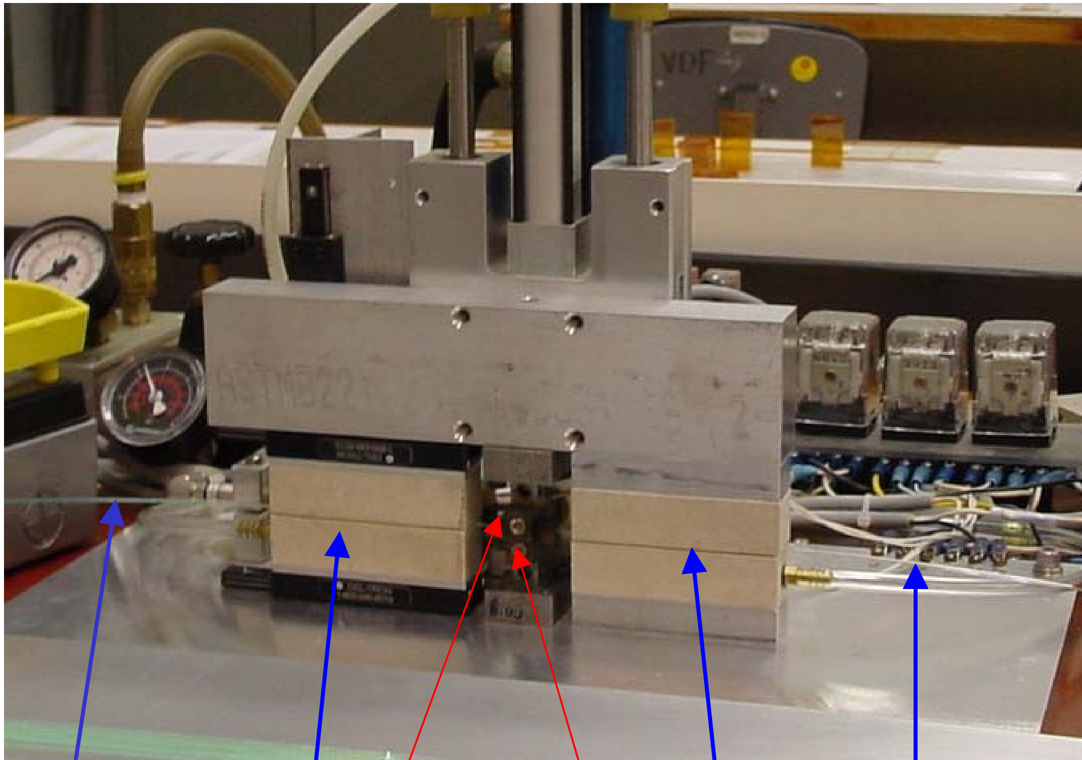
–Splicing the waveshifting fiber to the clear readout fiber provides a secure, space efficient connection. The need for connectors is eliminated and the overall design of the muon detector is simplified.

Drawbacks

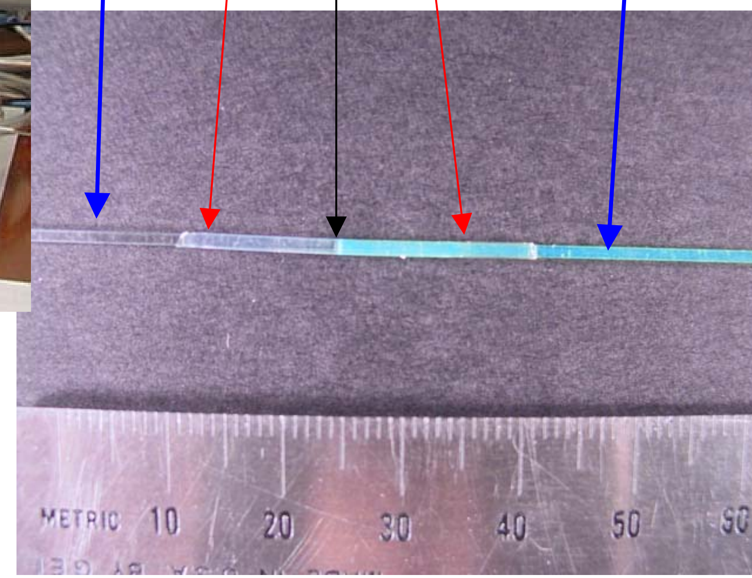
–Splicing is “manpower intensive”.

–Splice is permanent, can’t be repaired once it is installed.

Thermal Fiber Splicer



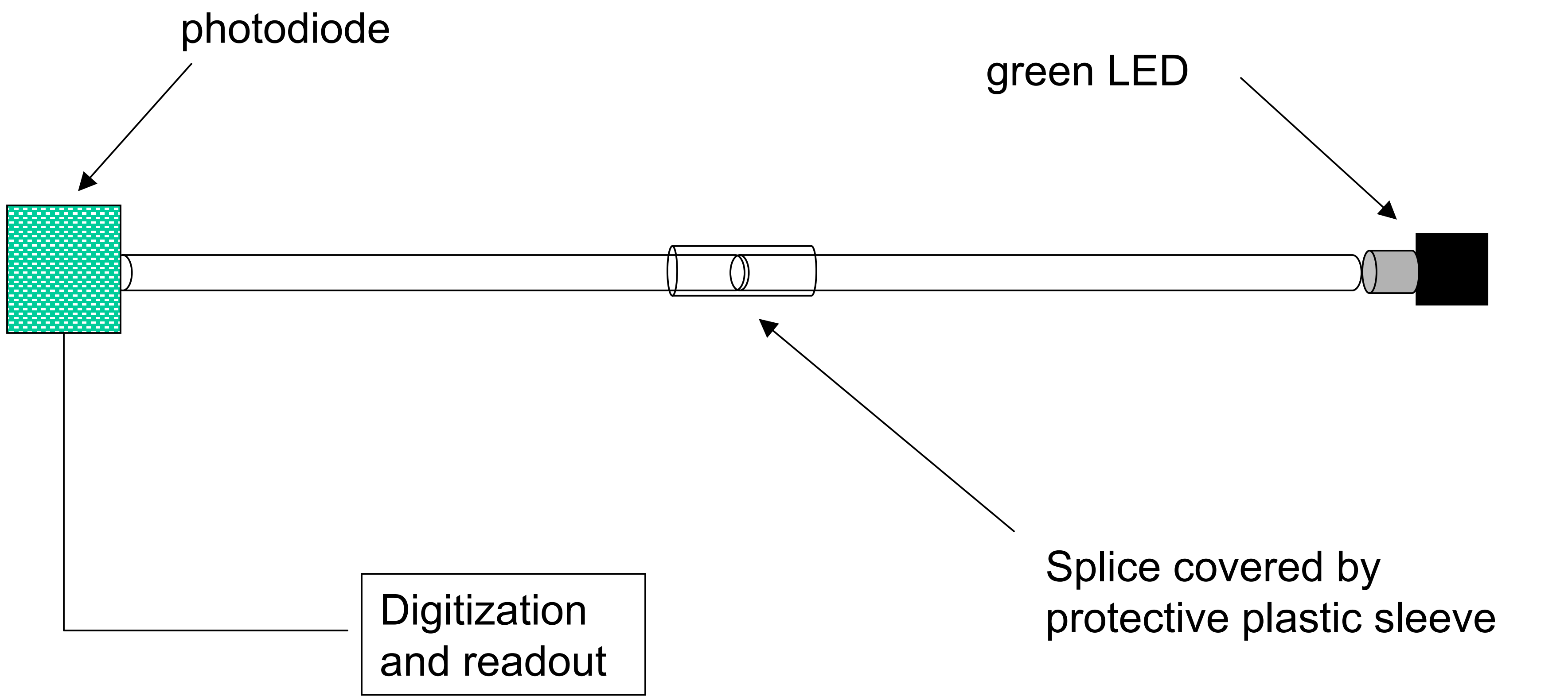
Sample Splice



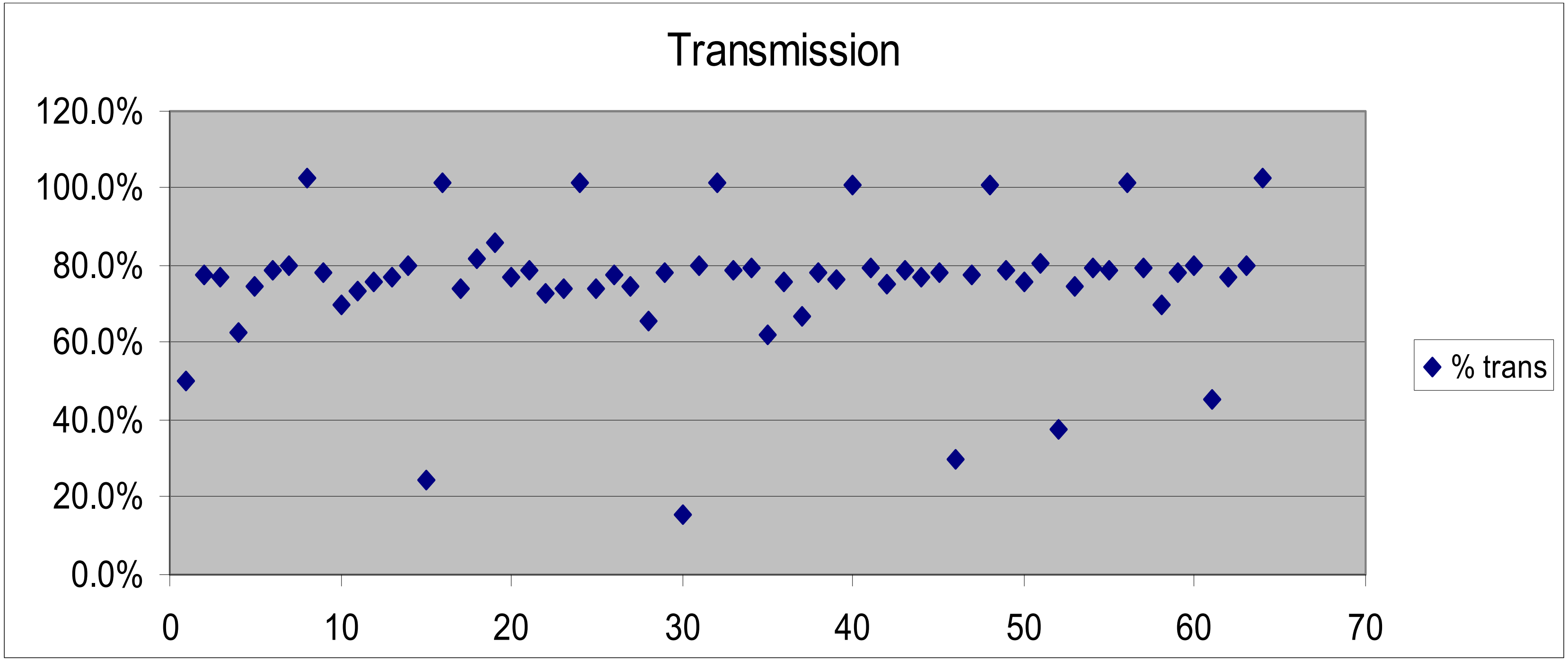
Procedure

- 64 clear Kuraray multiclad fibers, 830 micron diameter, were cut to 8 meter lengths and both ends were polished.
- All 64 fibers were measured with an LED-photodiode system at Notre Dame.
- 56 fibers were cut in half and spliced back together at Lab 7 in Fermilab (8 fibers left whole as control fibers).
- All 64 fibers were re-measured and light transmission was calculated.

Apparatus

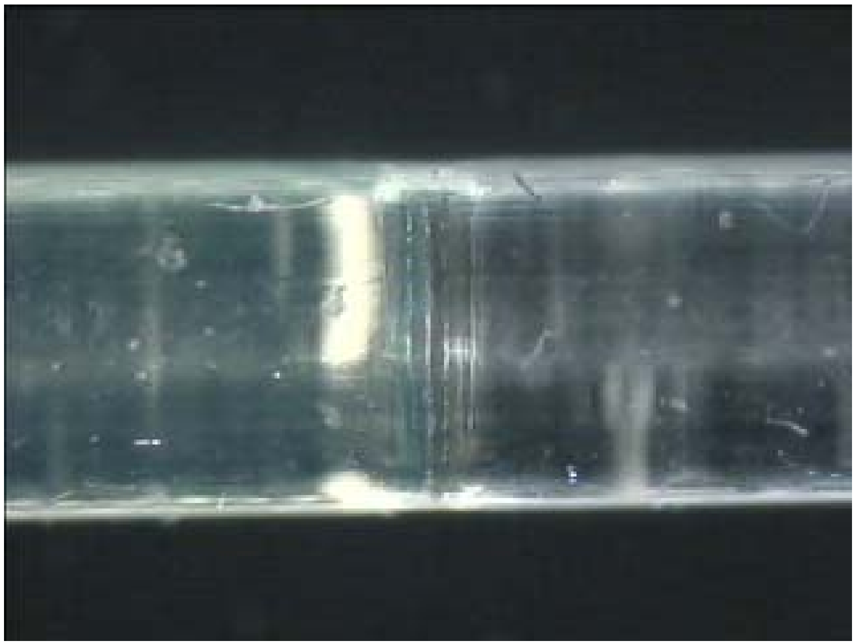

photodiode
green LED
Splice covered by
protective plastic sleeve
Digitization
and readout

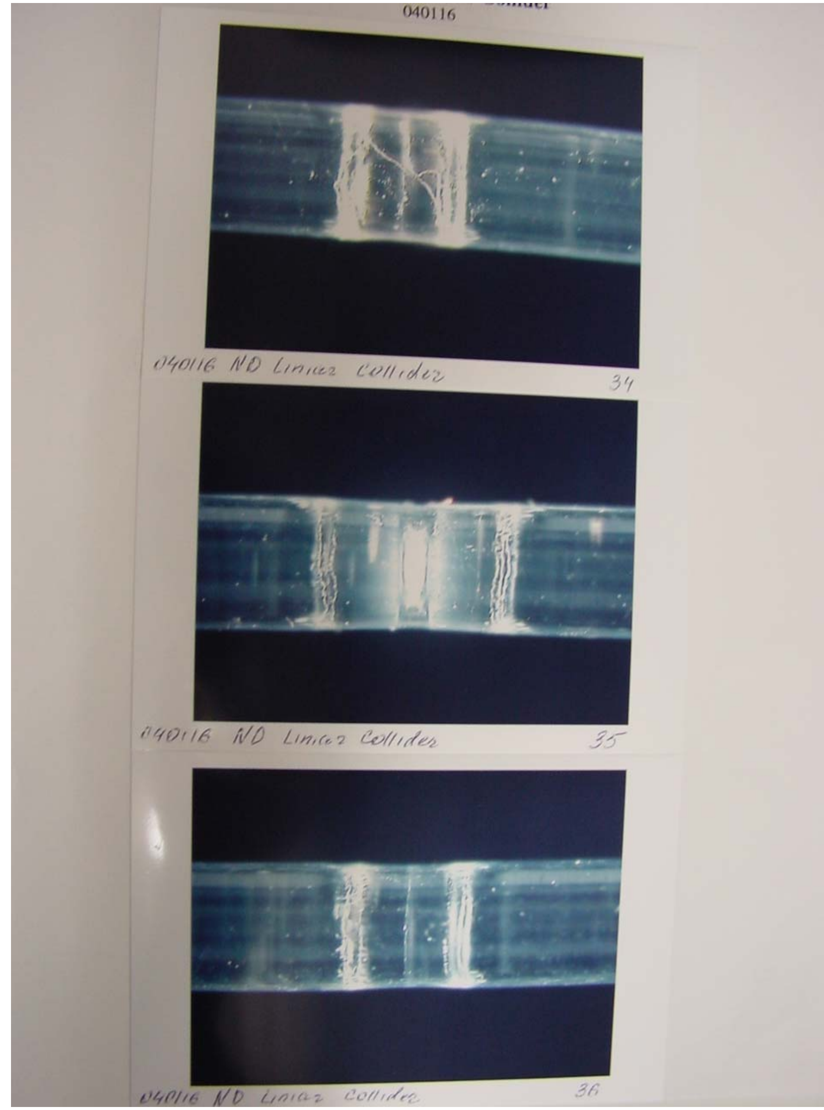
Results



- Several splices with very poor transmission (losses > 50%)
- Typical transmission of ~75 - 80%
- Control fibers w/100% transmission show system stability.

Fiber Splice Pictures





Eileen Hahn April 2004

Fiber Summary

- Results are not satisfactory, but:
  - Photographs taken of each splice show that all the very poor splices can be identified and eliminated.
  - Typical results of ~20% loss may be improved with optimization of splicing procedure (losses of ~10% have been achieved for splices with slightly different diameter fiber).
  - Test will be repeated with 1.2 mm diameter fiber specified in detector design.
  - May need different dimension heating block tooling.

Readout Electronics Development for the NLC Muon Detector

Mani Tripathi
Britt Holbrook (Engineer)
Juan Lizarazo (Physics student)
Yash Bansal (EE student)

The group is developing readout electronics for initial use with the prototype test-stand at Fermilab. This work will contribute towards the design and cost-estimate for a full-scale NLC muon detector readout.

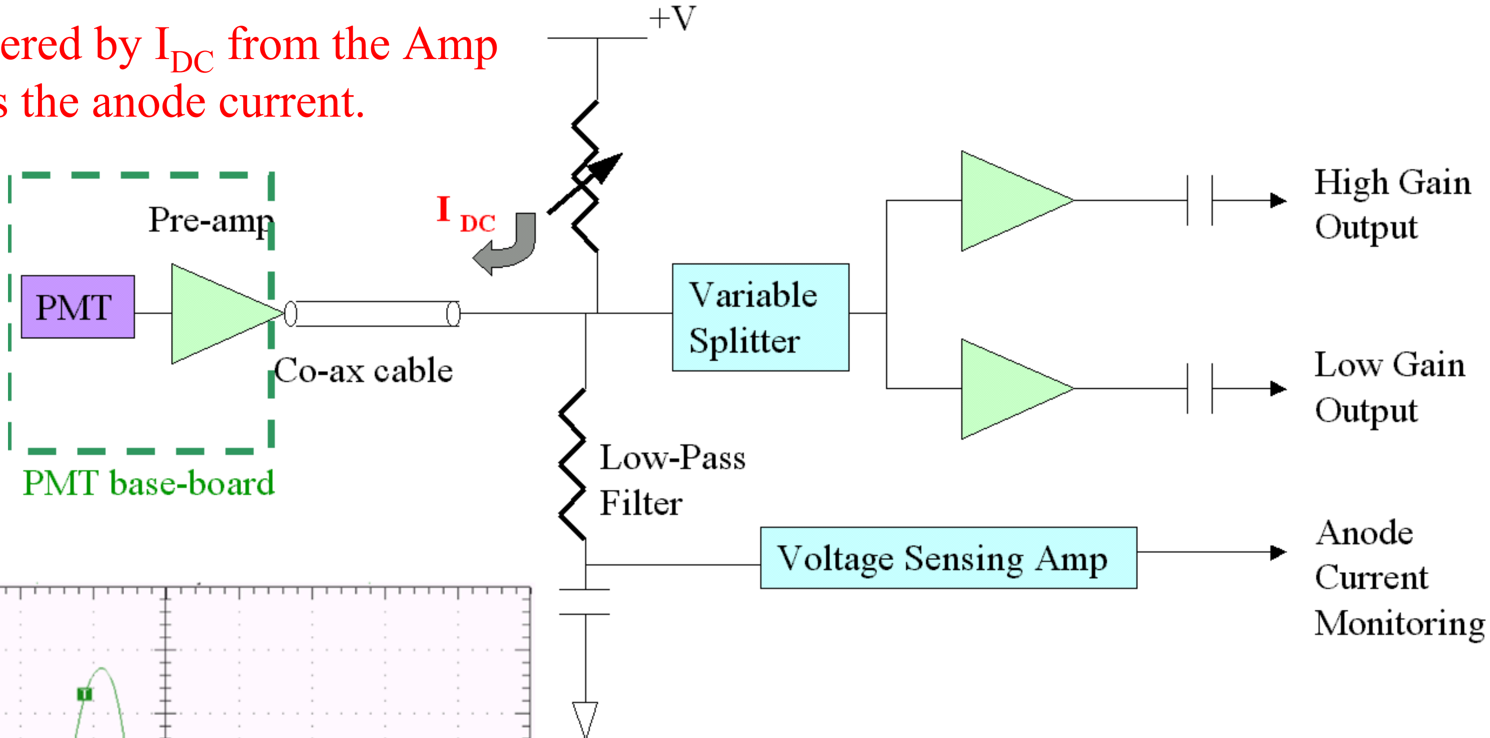
Work in Progress

- A PC board for housing 16-channel PMT is being developed.
  - Dimensions 4.5” x 4.5”.
  - Dynode resistor chain is built-in.
  - On-board preamplifiers.
  - Preamp gain ~ x10
  - Preamp bandwidth ~ 1.6 GHz.
- Post-amplifiers with two outputs have already been developed.
  - The two channels can have different gains for extending resolution in digitization.
- DAQ for the test-stand will consist of CAMAC TDCs and ADCs.
  - Modules have been borrowed from PREP for this purpose.

Front-end Electronics: System Schematic

Single p.e. Signal: **1 p.e.** [for gain ~ 4 x 10^6 & rise ~ 0.6 ns] = **53 mV into** 50 Ω

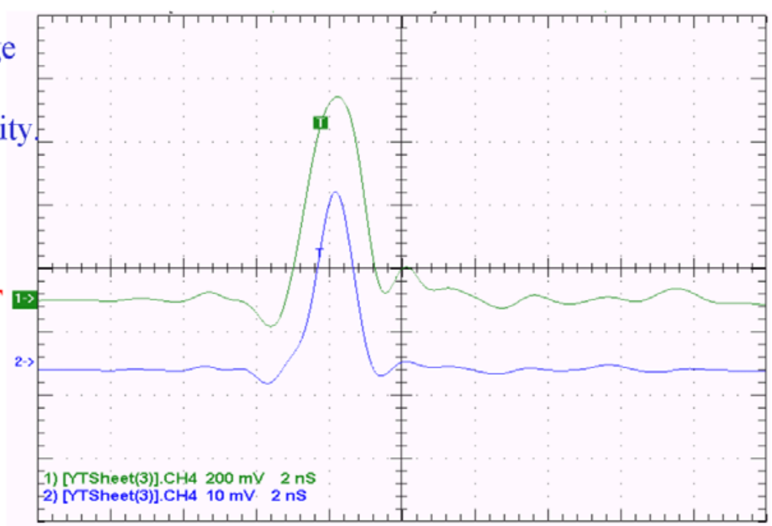
The Pre-amp is powered by I_{DC} from the Amp which also measures the anode current.



Second stage restores the signal polarity

OUTPUT

INPUT



The design uses inexpensive RF amplifier chips.

MONOLITHIC AMPLIFIERS *50Ω*

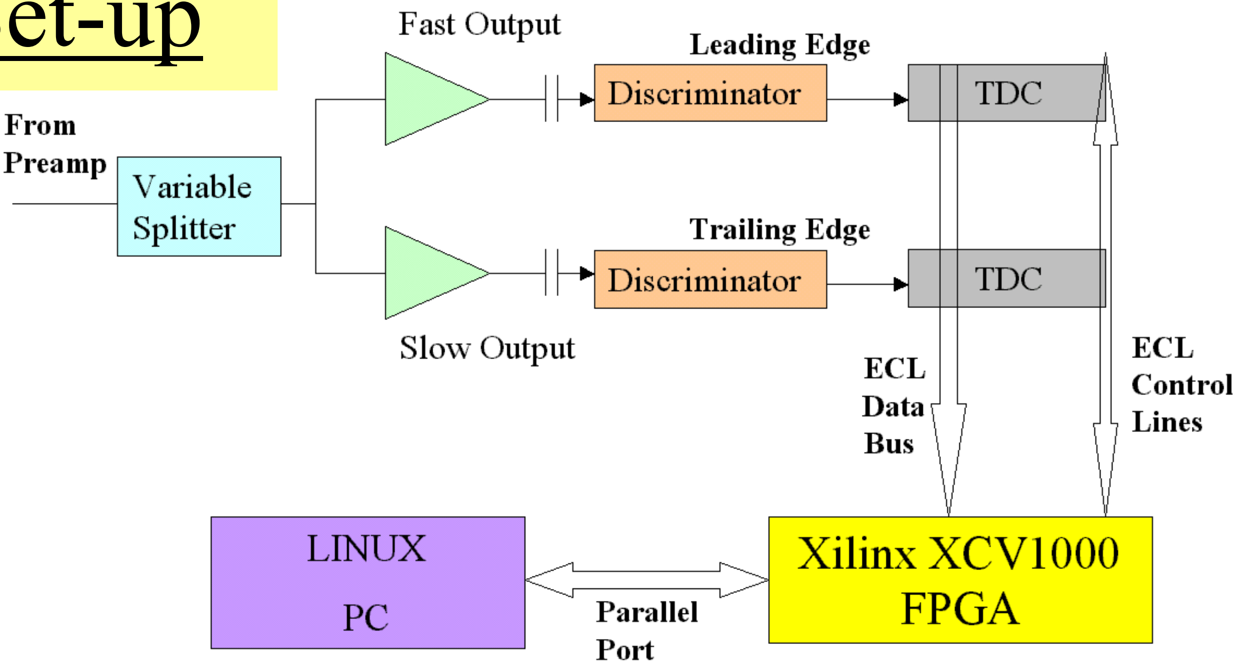
BROADBAND *DC to 8 GHz*

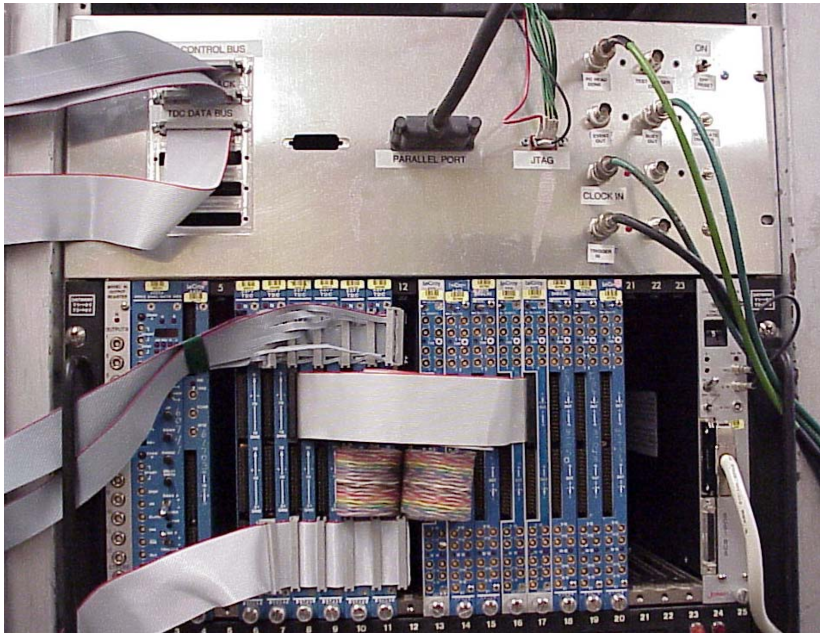
TDC Readout Set-up

Time of arrival measurement with 0.5 ns resolution.

Easily achieved by utilizing CAMAC TDCs (LRS 3377) available at Fermilab. These modules provide *O*(8 ns) two pulse separation.

The FPGA reads out the TDCs at 20 Mbytes/sec and can buffer 4x8KB events.





Pulse height measurement with *O*(10 bit) resolution is desirable.

Commercial chips are available and will be utilized. However, they work at 120 Msps and hence, one output of the amps will need to be shaped to ~100 ns for good sampling.

For the prototype system we will use time over threshold measurements using the TDC readout.

Summary

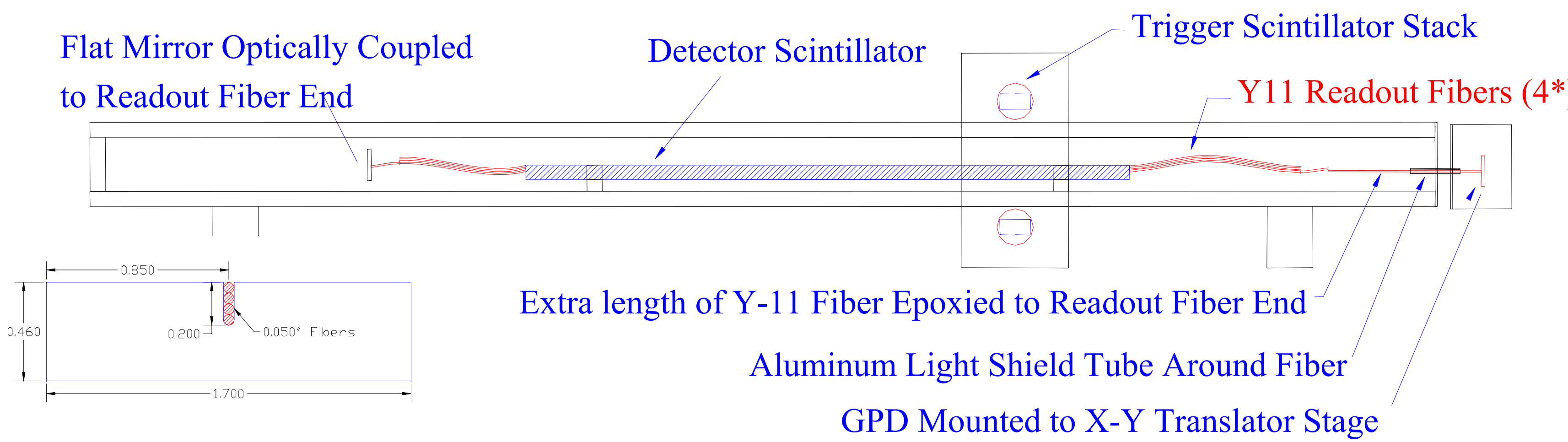
•Amplification system has been developed. Prototypes will be produced this summer, finances permitting.

•DAQ modules have been acquired for the temporary system for the test-stand.

•A digitization and acquisition system is being designed.

Geiger Mode Avalanche Photo-Diode R.Wilson

GPD Scintillator/Fiber Test Bed



* For these measurements only a single fiber was instrumented with GPD readout.

- *Estimate* average 4 photons/event at the end of spliced 1 mm diameter Y11 cores fiber and 0.15 mm GPDs.
- Use *QE*A=0.069* estimated for single 150 micron GPD at 20^{o}C using LED - predict DE~0.24 neglecting additional losses, such as Fresnel reflection at the Y11-GPD interface.

- Preliminary measured detection efficiency in test bed: 21±5(stat.)±??(sys.)%

Future Activities

Simulation

- Global development of simulation software; Simulation of test beam tail-catcher.
- Muon ID algorithms: low p_μ ID using Ecal/Hcal; isolation cuts; full detector tracking χ^2 for μ/had discrimination; w/SiD.
- Event samples: μ, π, bb, $\mu\mu$ with (m_μ - m_{lsp}) small.

Hardware

- QA existing scintillator, WLS & clear fiber.
- 1m strip R&D: fiber splice tests, fiber routing, light tighting, MAPMT mech., HV, etc.
- MAPMT calibration, cross talk, noise, shielding, etc.
- FE electronics, prototype digitization and DAQ – for 128 channels (single plane).