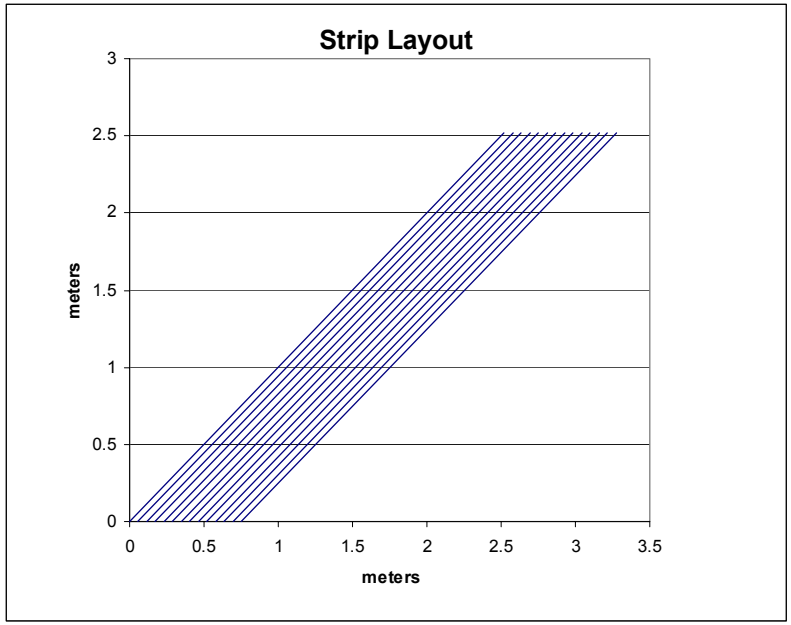
LC Muon Detector Studies

- Proposals (not yet funded).
- Institutional responsibilities and Personnel
- Hardware/software goals.
- Hardware progress.
- Software study results;
- Software development issues.
- Funding and Manpower needs.

Overview

- Scintillator strips + multi-anode PMT planes (MINOS).
- Identify muons. OK
- Use as backup calorimetry. OK
- Use in energy-flow algorithm? To be studied.
- Realiable/robust.



Largest modules: 9m (l) x 2.5m (w)
Strips: Barrel 51.2K - Ends 42.8K
Channels: <200K => 128 fibers/MAPMT
1500 – 2000 MAPMTs w/calib. chans.

LC Muon R&D Proposals

LCRD	UCLC
Wayne State – Paul Karchin Electronics –Multi-anode PMT+ front-end electronics R&D; calibration scheme,prototype module testing. FE electronic specifications.	No. Ill. Univ – Arthur Maciel Scintillator procurement & properties*; Scint. QA*, Extrusion mach. development * Software Development – Physics/Detector studies; Global software development.
UC Davis – Mani Tripathi Electronics – Read-out for prototypes modules; MAPMT fiber mux scheme; readout specifications for production system.	Notre Dame – Mitch Wayne Fibers - WLS and Clear meas., specs, joints, engineering, routes and handling; testing.

With *Fermilab, +UT Austin, UT Arlington, Rice

Personnel

LCRD	UCLC
Wayne State – Paul Karchin, Graduate student* Undergraduate student* Electronics engineer*	No. Ill. Univ – Arthur Maciel G. Blazey, A. Dychkant, D. Hedin, D. Chakraborty G. Lima, C. Milstene
UC Davis – Mani Tripathi Graduate student* Undergraduate student * Electronics engineer*	Notre Dame – Mitch Wayne Fiber engineer* Fiber technician* Undergraduate students

Fermilab – A. Bross, B. Choudhary, G. Fisk, K. Krempetz,
A. Para, O. Prokovief, R. Stefanski

Texas Austin – K. Lang Texas Arlington – A. White

Software Goals

- Establish muon ID and tracking algorithms for muon detectors using JAS.
- Extrapolate muons into the calorimeters and central tracking. Link-up to upstream tracks.
- Use tracking/id algorithms to measure punch-through probabilities and tracking efficiencies for diverse physics menu.
- Calculate contribution to E-flow of mu-cal.
- Test alternative muon detector designs with common software.
- Contribute to global software development effort (GENT4 based, ...)

Hardware Goals

- Test 16 pixel MAPMT - specifications and parameters.
- Test extruded MINOS-style scintillator and fiber.
- Develop prototype modules (2.5m W X 5.0m L) to:

  (1) Understand mechanical design/construction issues such as basic scint. layout, WLS fiber laying, WLS – clear fiber connections, fiber routing, bundling, optical multiplexing, mechanical engineering, etc.

  (2) Understand FE electronics, calibration and readout specifications.

  (3) Understand safety, testing and QA procedures.

  (4) Implement cosmic ray tests and eventually beam tests.

  (5) Make detailed cost estimates for a scintillator-based muon system.

No. Illinois Univ. Group Responsibilities

- **Tasks:** (awaiting funds from NSF for some tasks)

  Scintillator extrusion machine: die development, production; test stand for QC of extruded scintillator; light collection R&D, e.g. co-extrusion of scintillator + WLS fiber. Initial progress is good!

  Muon tracking for proposed detector geometry;

  Development of GEANT4 based simulation package that accepts external plug-in geometry description and outputs JAS, ROOT compatible event analysis files.

  Initial muon tracking progress achieved for JAS pkg.

- **Personnel: Hardware** – A. Dychkant, V. Rykalin, K. Francis MSc student.

  Software - R. Markelof/C. Milstene - Muon Tracking; A. Maciel, D. Chakraborty + students: M. Arov, J. McCormick and R. McIntosh + G. Lima (new NIU post-doc) continue development of the GEANT4-based simulation – with recent LCD guidelines.

Notre Dame Group Responsibilities

- **Tasks:** Design and fabrication of a technique to transport light from waveshifting fibers to multianode PMTs, including clear-waveshifter fiber connectorization, routing and mapping, light-tighting and calibration.

- **Experience:** Leadership of D0 fiber tracking effort
  Design/fabrication of clear fiber waveguides for the D0 fiber tracker (80K channels)
  Design/fabrication of "Optical Decoder" units for CMS HCAL

- **Personnel:** M. McKenna, M. Vigneault (mech.)
  B. Baumbaugh (elect.)
  M. Wayne (phys.)

June 9, 2003

Wayne State University

Personnel:

Paul Karchin, Physicist
Alfredo Gutierrez, Research Engineer
Rajesh Medipalli, Physics Graduate Student (summer)

Work underway:

charge calibration system for pmt anode pulses
noise response of Hamamatsu M-16 pmt with MINOS base
fabrication of 16-hole fiber guide for pmt face
fabrication of led-driven clear test fiber
measurement of pmt I-V characteristic curve

Other work planned for this summer:

measurement of M-16 anode charge for single photo-electrons and dependence on pmt HV and anode channel

NLC R&D at UC Davis

Mani Tripathi, Britt Holbrook (Engineer)
Students: J. Lizarazo (Physics), Y. Bansal (EE)

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 the NLC muon detector readout.

Issues to be addressed:

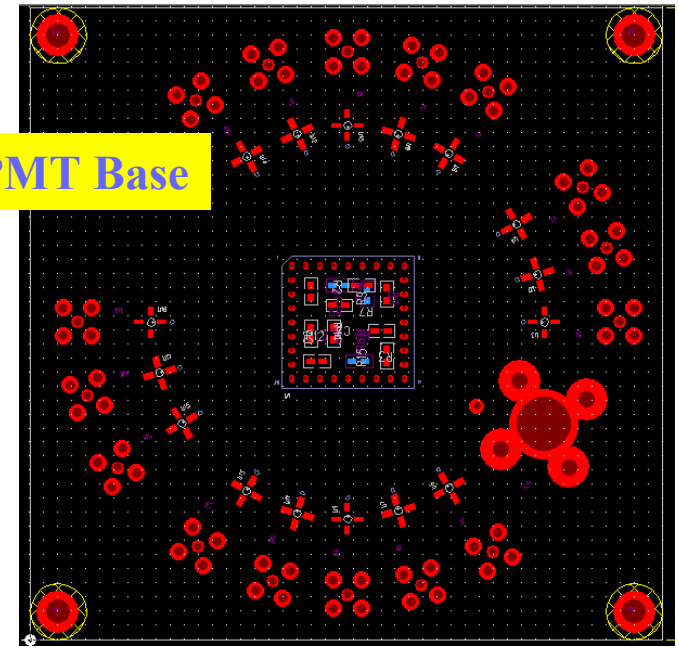
1. Multiplexing several fibers in one PMT channel
2. Noise rate in Multi-anode PMT at 1.5 p.e. threshold
3. Optimum resolution in time-of-arrival determination
4. Optimum resolution in pulse height/photon counting

Work Being Done:

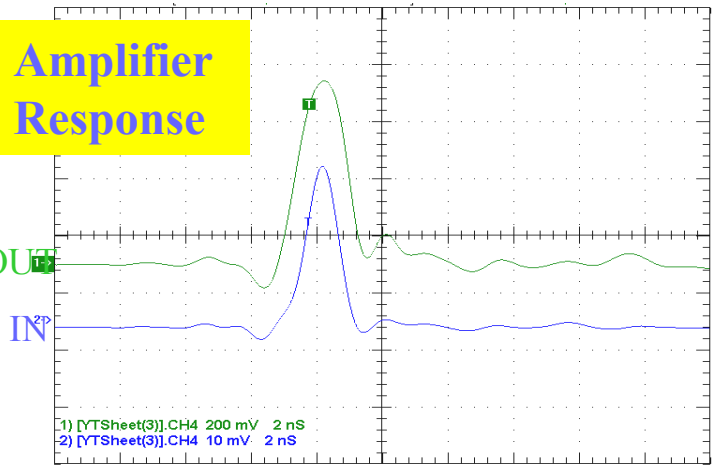
1. A PC board for a 16-channel PMT is being developed: 4.5" x 4.5". Dynode resistor chain is built-in. On-board preamps provide a gain of 10 and a bandwidth of 1.6 GHz.

2. Post-amplifiers with two outputs (gain of x3 each) have been developed. The signals will be recorded in TDCs and ADCs. Electronics modules have been borrowed from PREP for this purpose.

PMT Base



Amplifier Response



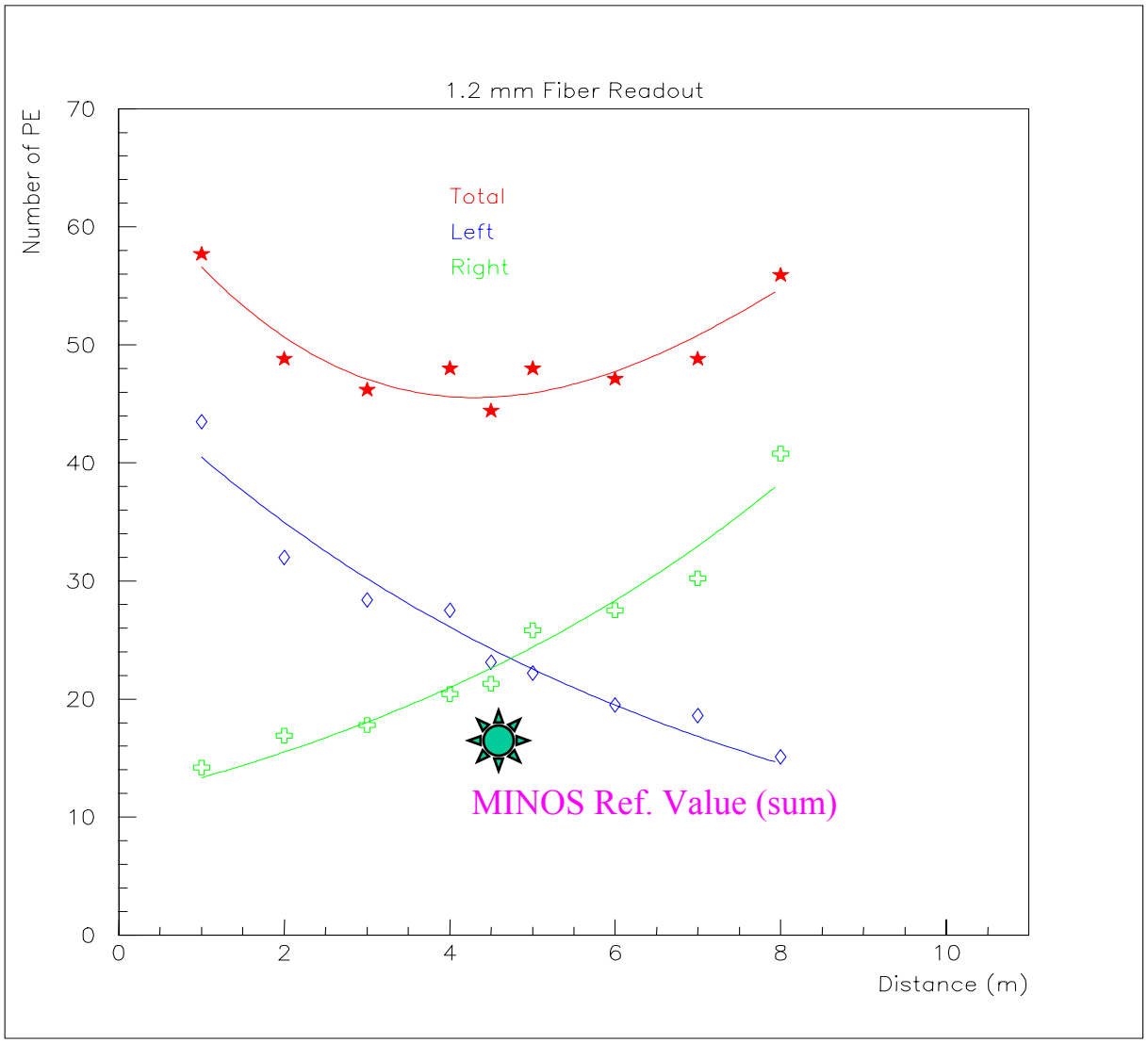
6/9/2003


Lab 5 at Fermilab
Berstorff Extrusion Machine
(purchased by NIU); Installed.
First articles of scintillator in June.

Extruded Scintillator Measurements at Fermilab

- Studied Wavelength shifting (WLS) fiber readout of scintillator extrusions for possible future large scale detectors
  - Scintillator: MINOS extrusions
    - 1 X 4 cm – grooved
    - TiO_2 reflector
  - Scintillator: KEK prototype
    - 1.2 X 2.5 cm – hole down the middle
    - TiO_2 reflector
  - WLS: Kuraray Y11
    - 1.2 mm 175 ppm (MINOS Standard)
    - 1.0 mm 200 ppm
    - 0.5 mm 200 ppm
  - Photodetector - Visible Light Photon Counter (VLPC)
    - Used D0 HISTE VI devices
      - QE=80-85%
      - Gain ≈ 60,000

VLPC Tests with MINOS Scintillator



- 1.2 mm WLS fiber (MINOS equivalent) results using VLPCs.

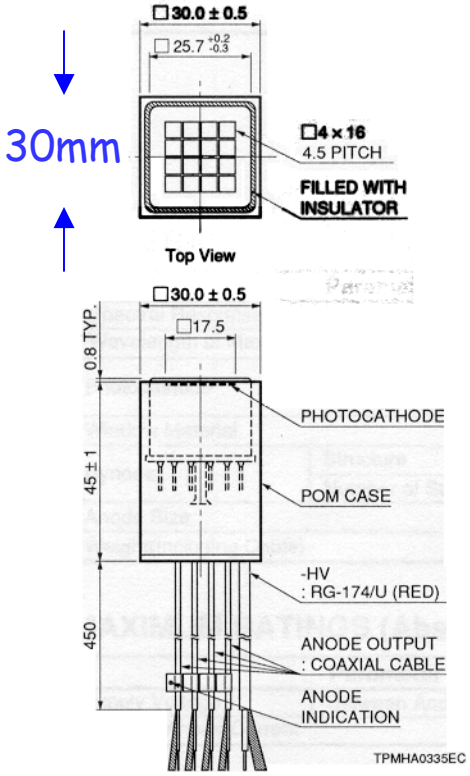
Tests of 1.0 & 0.5 mm fibers, etc.

Want to try co-extr of scint + fiber.

Alan Bross
March2003

PM, Channel Count

16 channel
multi-anode PM

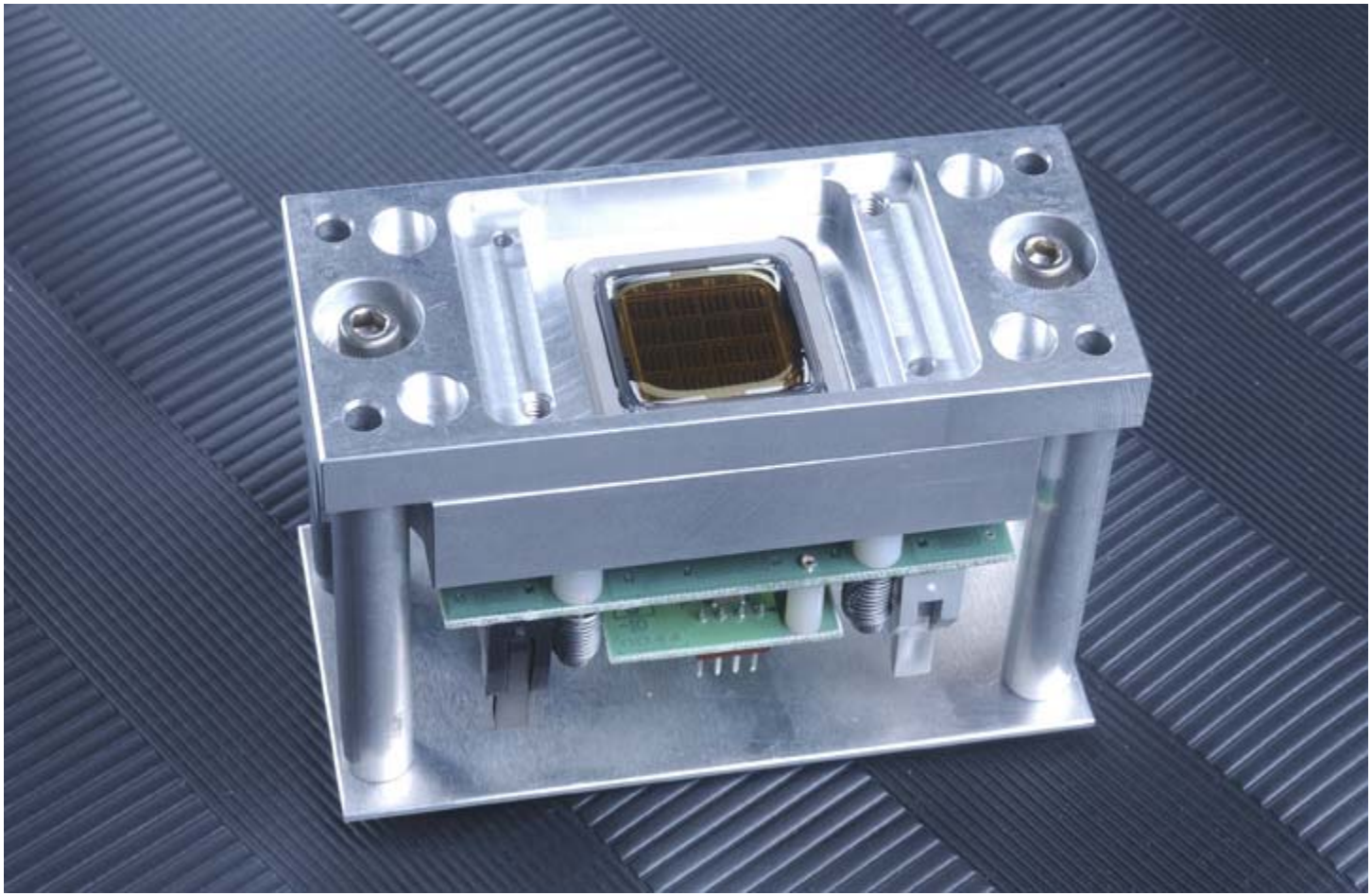


Hamamatsu H6568

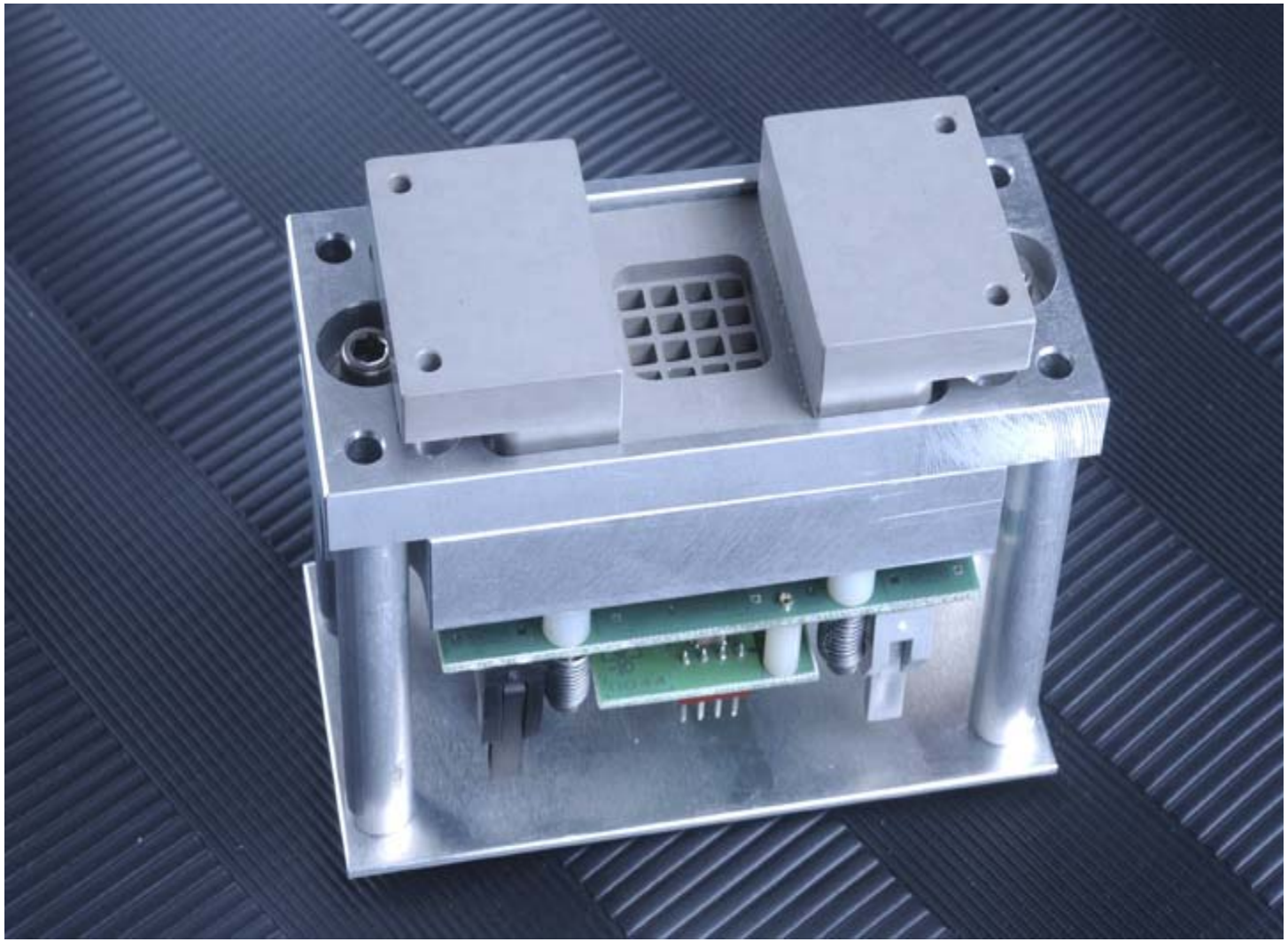
	Barrel	Ends	Total
WLS Fibers	51,200	42,766	93,966
Clear Fibers			187,932
Scintillator			
Area (m^2)	7,174	4,353	9,527
Vol. (m^3)			95.3
M (ρ=1.2g/cm^3)			114.3T

MINOS Hamamatsu H6568 Multi-anode PM

16 anodes ea. 4 x 4 mm^2



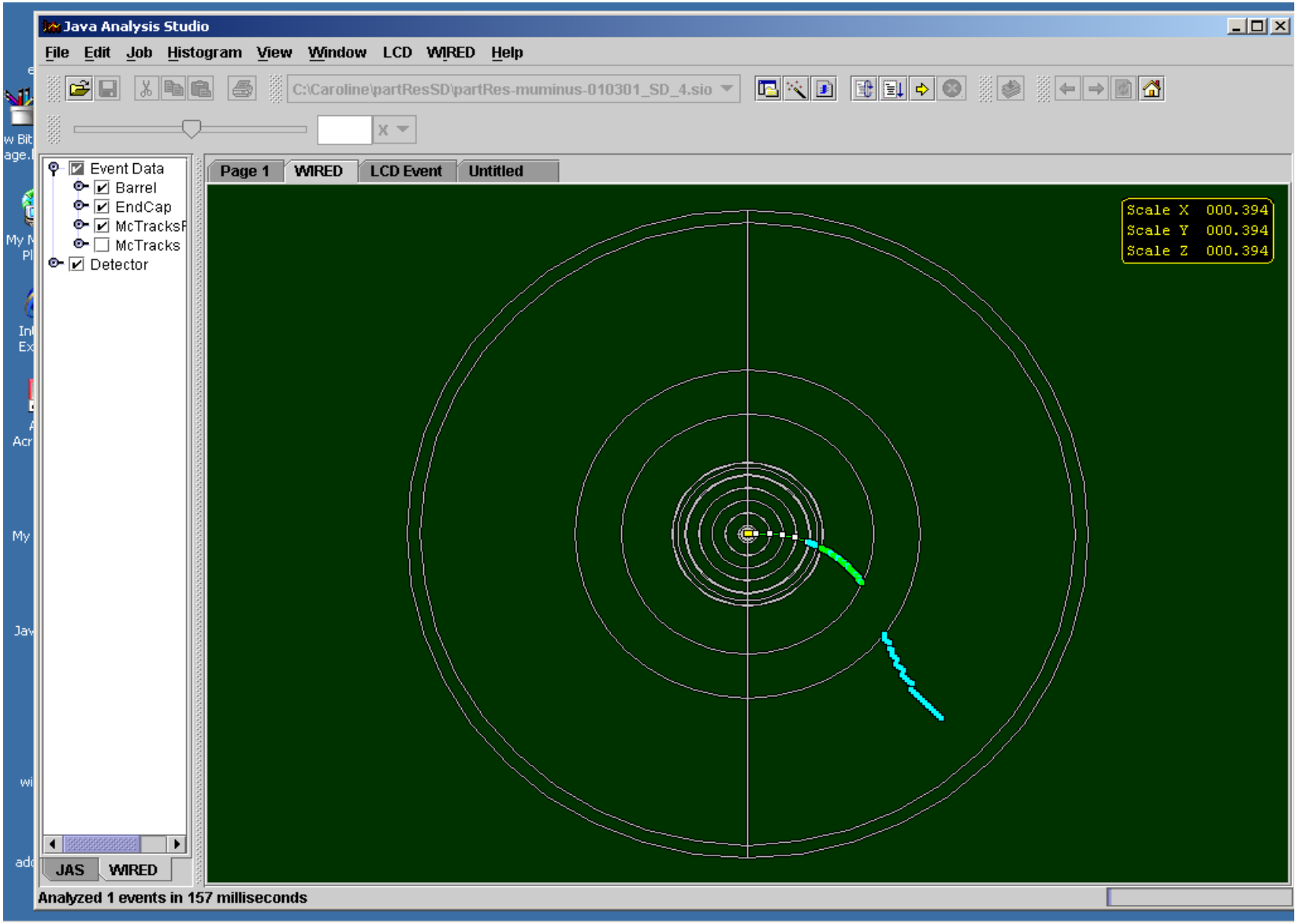
MINOS – MAPMT with fiber guide



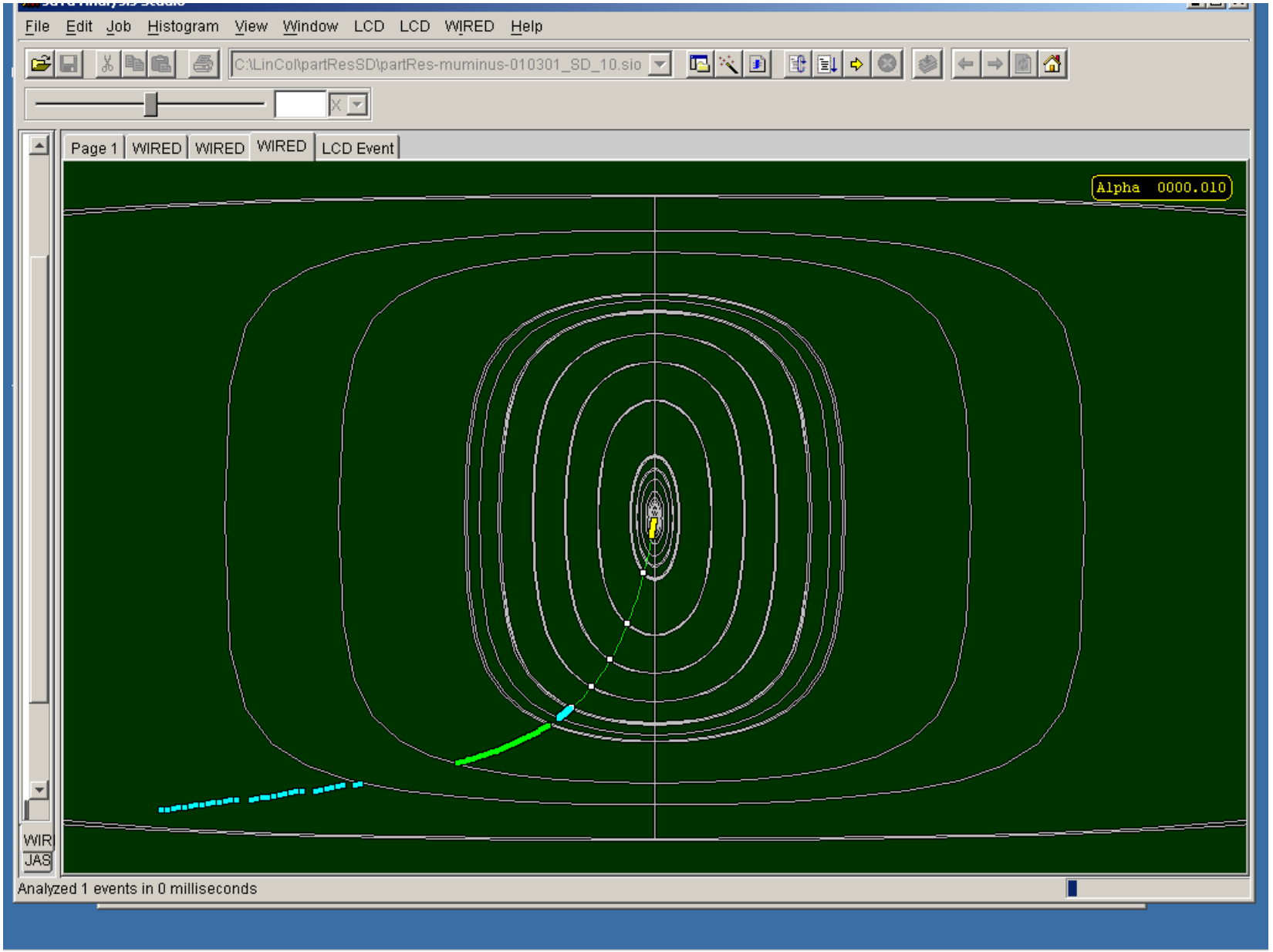
Simulation Software Development/Studies

- Development of LCD framework with GEANT4 simulation: Chakraborty, Maciel, Zutshi, *Lima,* students
  - Toward universal use;
  - Specific representations for Cal/Mu;
  - I/O compatibility with JAS & ROOT.
- Development of muon (calorimeter) analysis code: Maciel, Markelof, Milstene
  - Muon ID & tracking algorithms:
  - Studies of single muons and pions
  - Comparison with TESLA studies
  - Studies of various final states.
- We have looked only at SD muon geometry: detectors every 5 cm of Fe.

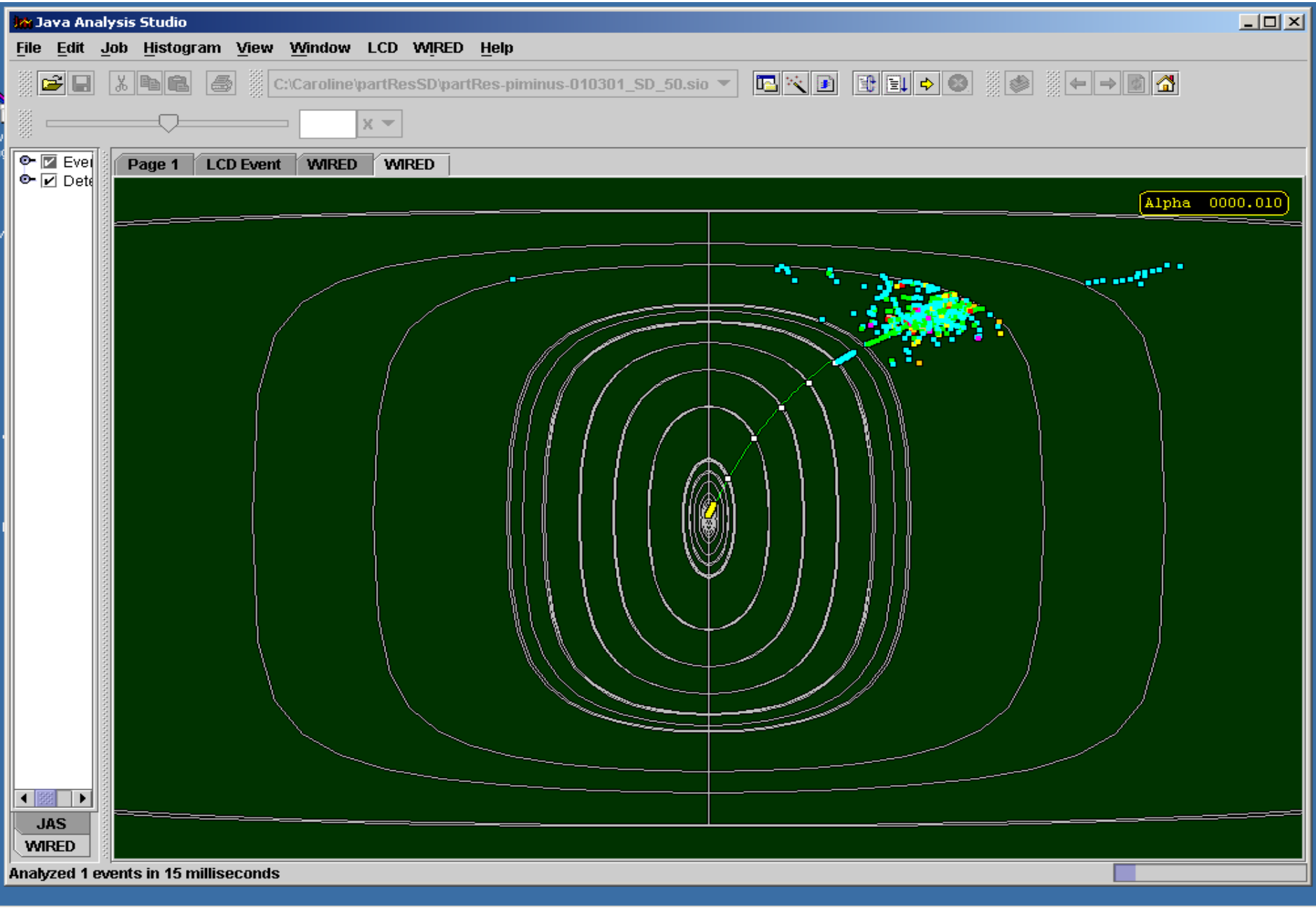
4 GeV μ^- Run 1 event 2 - 32 hits in the Muon Barrel



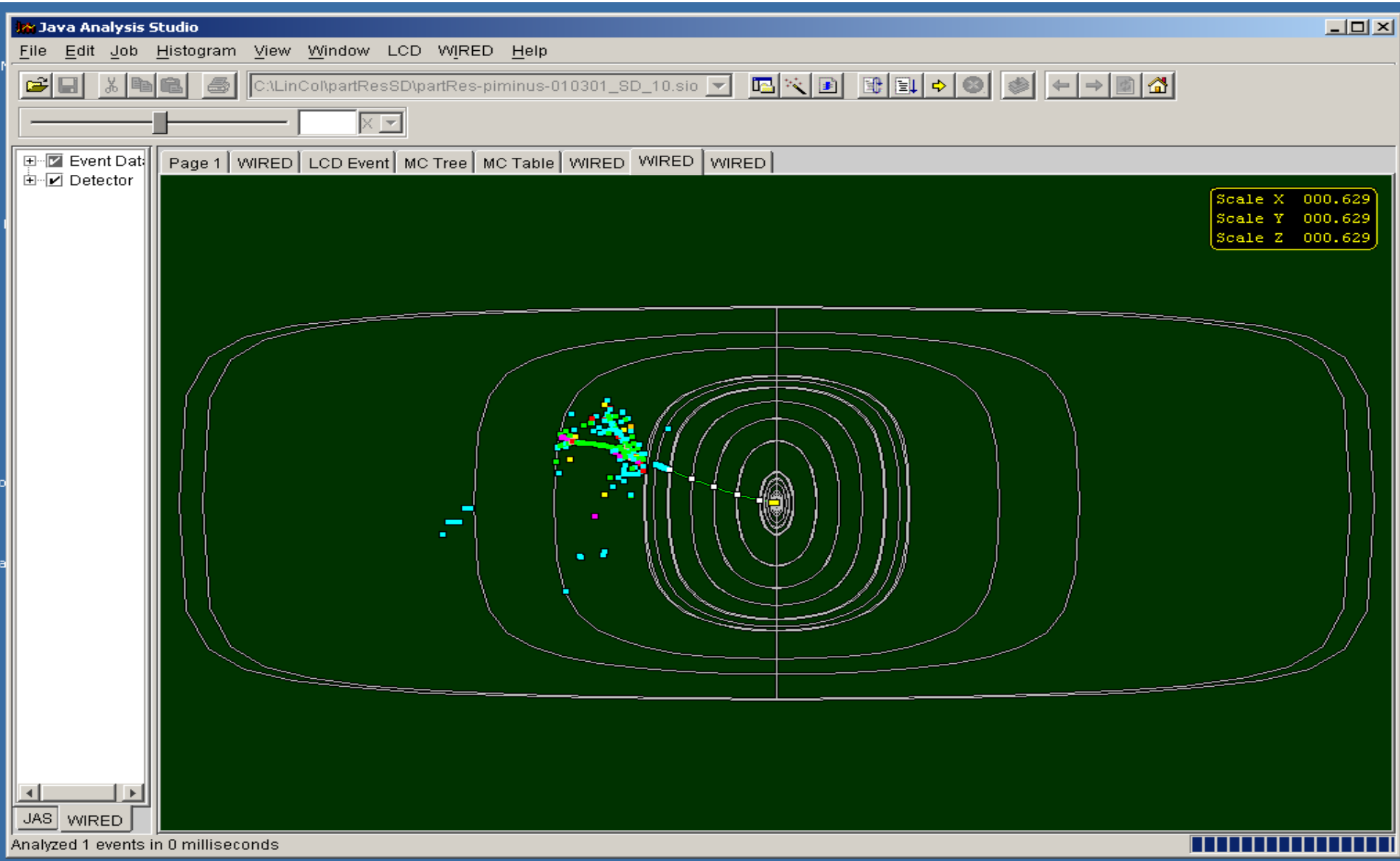
10 GeV μ^- Event 3 Run 1 with 33 Hits in MuDet



50 GeV π- event 11 run 0 EyeFish View-18 hits in Muon Detector



10 GeV punchthrough π-event 118-Run1- 6 hits MuDet SD



Tracking Algorithm Development

Use the basic algorithm developed by M. Piccolo : compare the muon candidate hits with the track extrapolated from central tracking. Use $\Delta\theta$ and $\Delta\varphi$ cuts in doing the matching.

Study: Pion punchthrough vs momentum (>80cm μ Fe) using a simple algorithm – 16 or more hits in 16 or more gaps in μ system (similar cut in Hcal) with

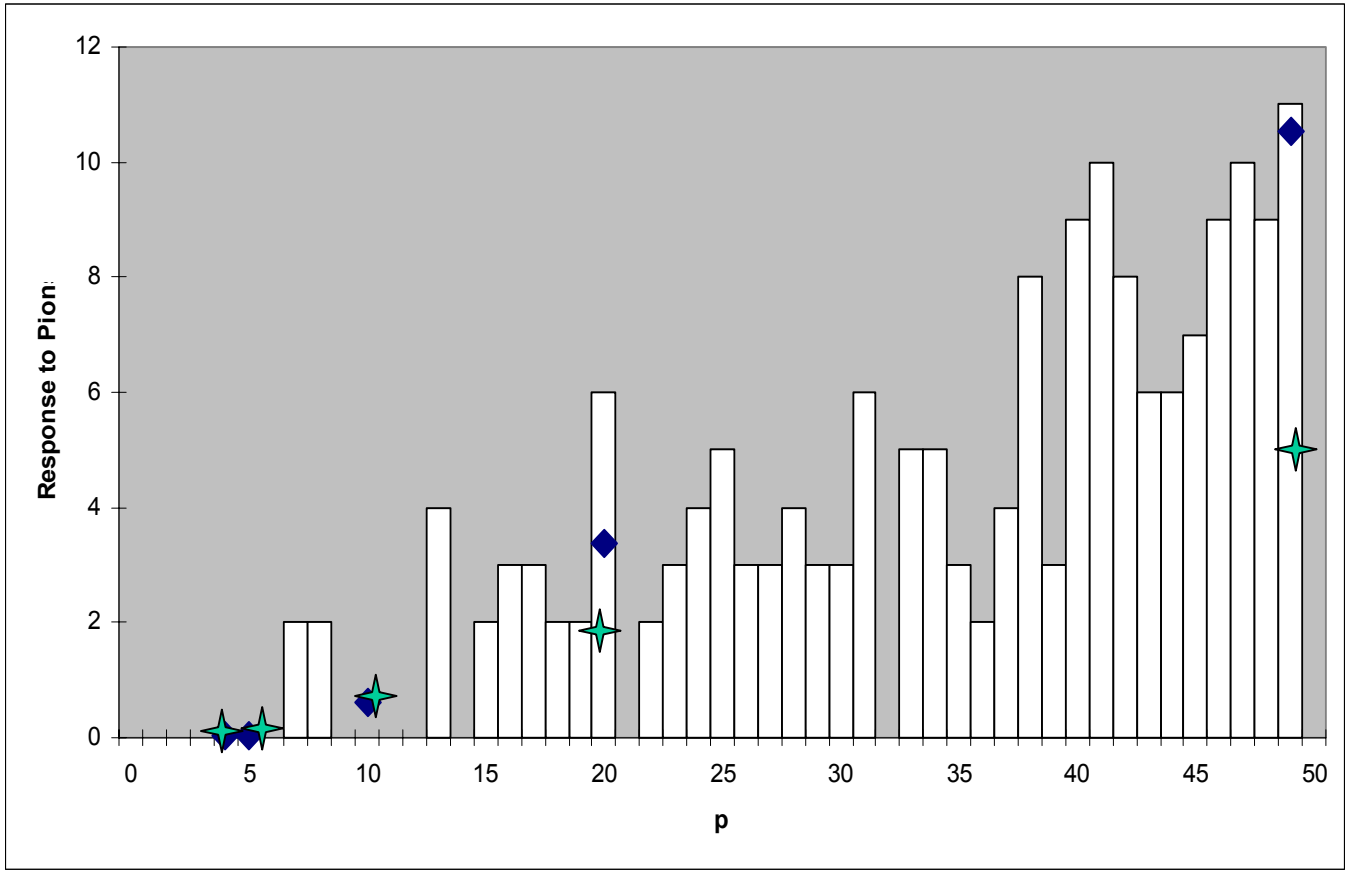
$(\Delta\theta , \Delta\varphi) < (3,2)$ bins where ea. bin is 21 mr.

Remove π decays (less than 1% for $p_\mu > 3$ GeV).

Find punch-through reaches about 1.5% at 50 GeV. Smaller if one asks for 5 planes with g.e. 2 hits; hadron-like.

C. Milstene/M. Piccolo

Pion Response of the Muon System



•The response to π reported for 35000 events (Tesla) By M . Piccolo has been Reproduced

<u>The blue diamonds</u> represent The SD Points for π *after Normalization to account for the Difference in interaction length and statistics*

<u>The Green stars</u> Correspond to an Extra cut: Requiring 5 planes with >=2 hits

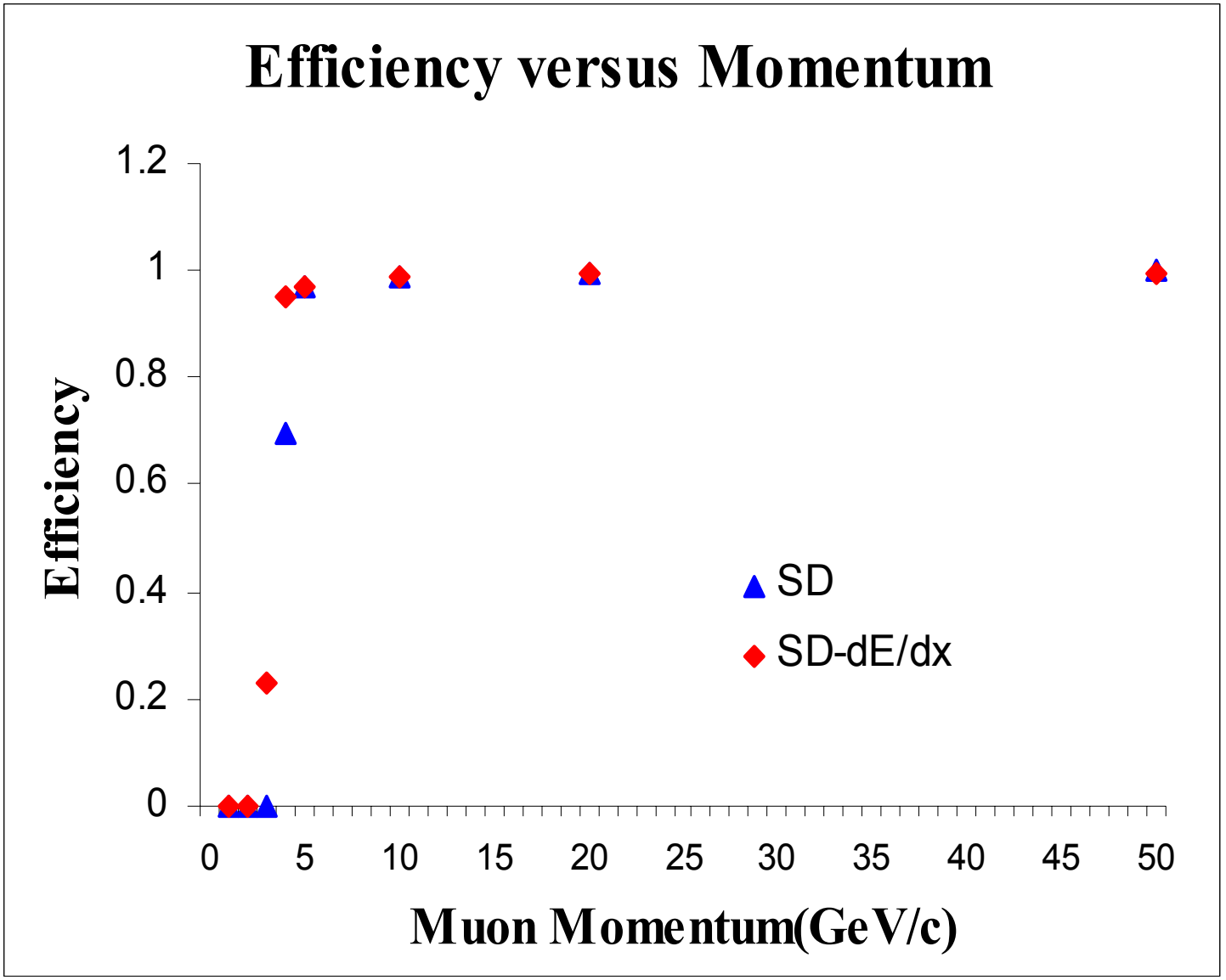
Improved low momentum muon ID

Inspection of the ($\Delta\theta$, $\Delta\varphi$) distributions as a function of p_μ showed asymmetric and skewed distributions. This was traced to a an omission of dE/dx in the projection of central tracks into the calorimeter and muon systems.

Fixing this problem has significantly improved the matching efficiency for low momentum muons, 3 to 6 GeV/c. e.g. the efficiency in the 3-4 GeV bin is 70%.

C. Milstene

Muon ID with dE/dx Correction



Other allied R&D with FNAL Help

- UT Arlington (A. White et al) is working on GEMs for readout of Hcal. Fermilab support is requested for:
- (1) the "identification/provision of suitable multi-channel readout electronics." This electronics support request is for readout of a multi-cell double GEM device. "Fermilab" => Yarema/Albrow. The GEMs could be of interest for muon tracking detectors.
- (2) For a full calorimeter layer prototype, there is a request for Fermilab to design the readout layer, incl. The spec for the charge preamp, second stage amplifier if needed, discriminator and register.

More to Do!

- Study muon ID in jets.
- Need progress on the muon system's use as a calorimeter – potentially important.
- Need advances in improved simulation software for planar detectors.
- Need to investigate utility of a set of (wire?) chambers between the solenoid and the muon Fe. Or hybrid wire chambers/RPC/scintillator syst.
- How to handle and calibrate 188K channels?
- We lack personnel and funding through UCLC & LCRD. All collaborators are spending some of their own resources on LC R&D, but progress is very slow without sufficient money/manpower.