US ILC Muon Detector and Particle ID R&D

DOE/NSF ILC Detector R&D Review
Argonne National Laboratory
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Muon Detection

- Muon final states crucial to ILC physics program

  HZ, Z $\rightarrow \mu\mu$

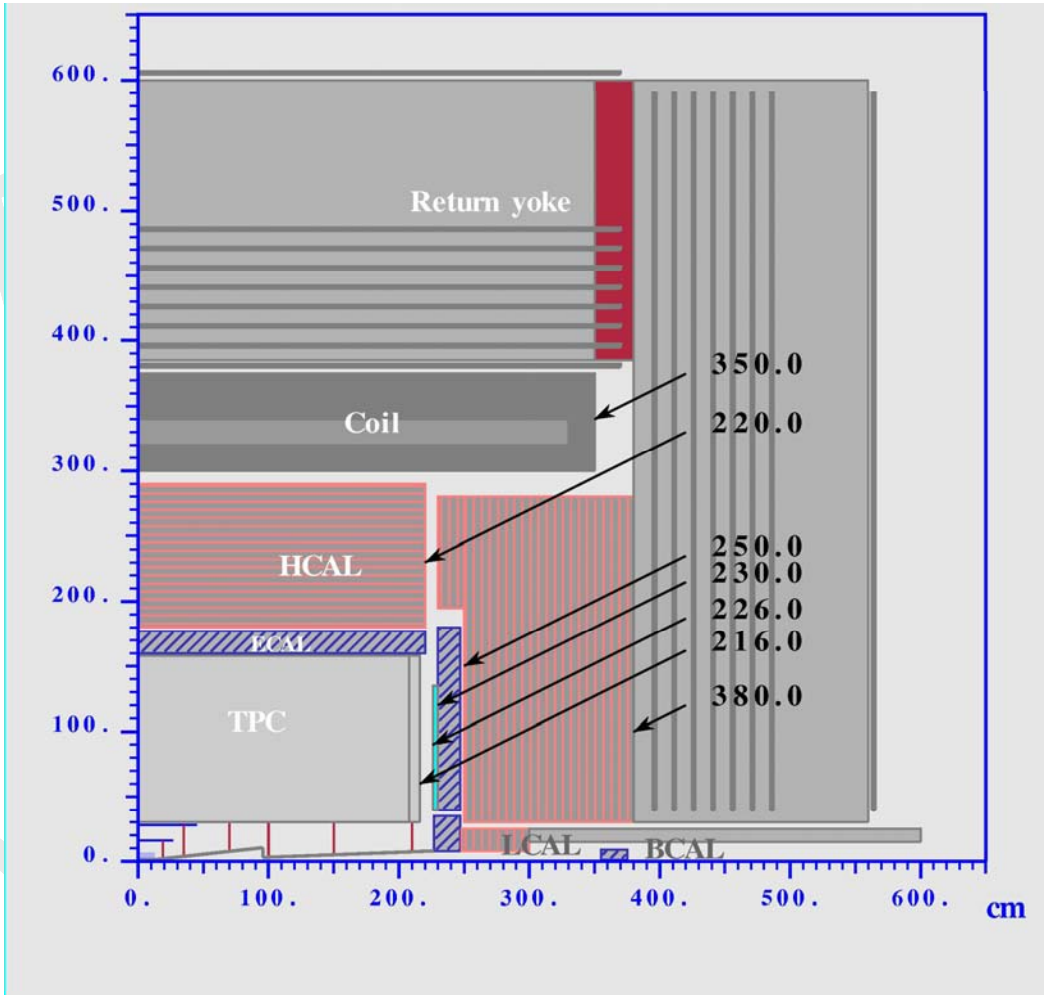
  t tbar, t $\rightarrow$ Wb, W $\rightarrow \mu\nu$ (μ + b-jet)

  s-$\mu \rightarrow \mu$ s-χ^0
- Large area detectors present unique challenges
- High efficiency and excellent hadron rejection needed
- Stability
- Cost effectiveness
- Performance depends on integration with full detector
- Simulation crucial in design stage
- Prototype construction and testing for realistic measure of performance and cost

Instrumented Iron Yoke Design – (GLC, LCD, SiD)

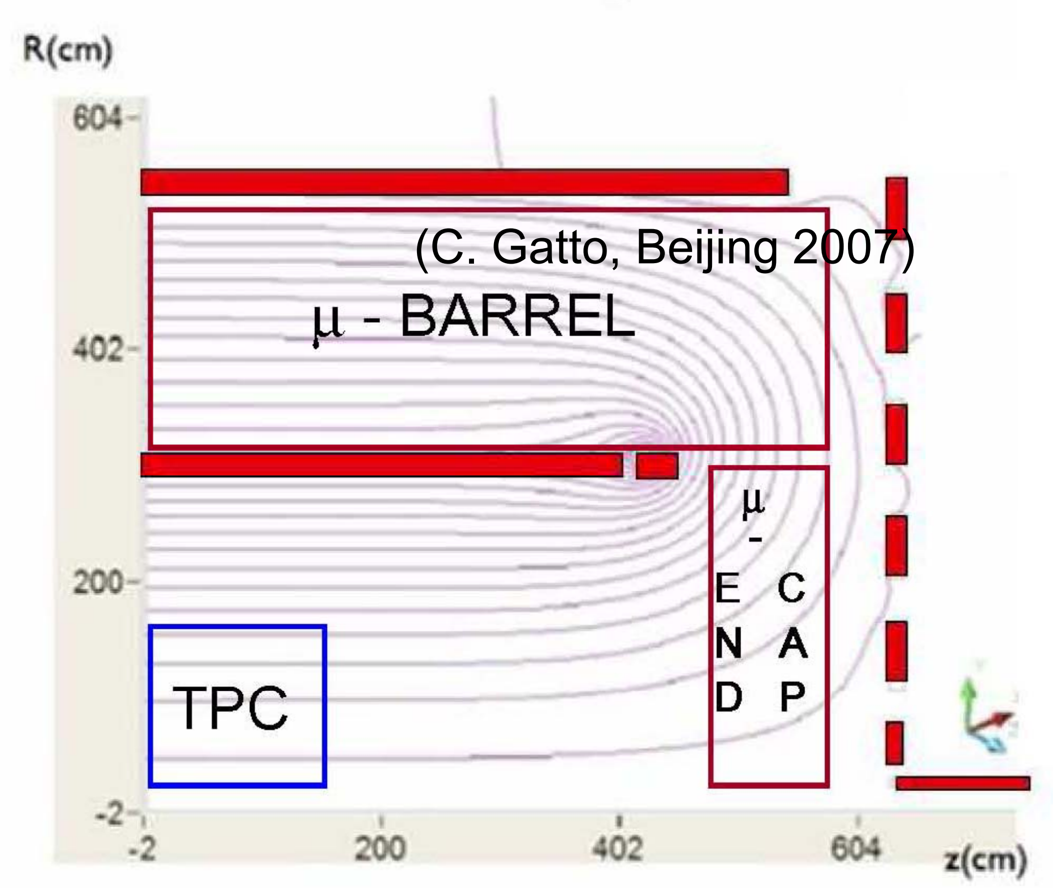
- muon detector is large!
- slots in return yoke
- accessibility & stability
- detector in B-field
- muon ID is penetration of iron
- integrated muon reconstruction using tracker and calorimeter
- central and forward muon coverage

LDC Version 2 June 2006



Double Solenoid with Air Core – (4th Concept)

- muon ID from calorimeter signature
- reduced multiple Coulomb scattering
- many requirements common with instrumented iron design



Particle ID

- π/K/p identification: an unexplored area of ILC physics – could be important!
- Possible applications:
  - Quark-flavor coupling of new particles by flavor-tagging jets
  - Spectroscopy of new particles decaying to (u,d,s,c,b) quarks
- Possible detection methods:
  - Time-of-flight
  - Tracker ionization loss
  - Cerenkov detectors
- Baseline work in phenomenology and detector simulation needed

Worldwide Muon R&D

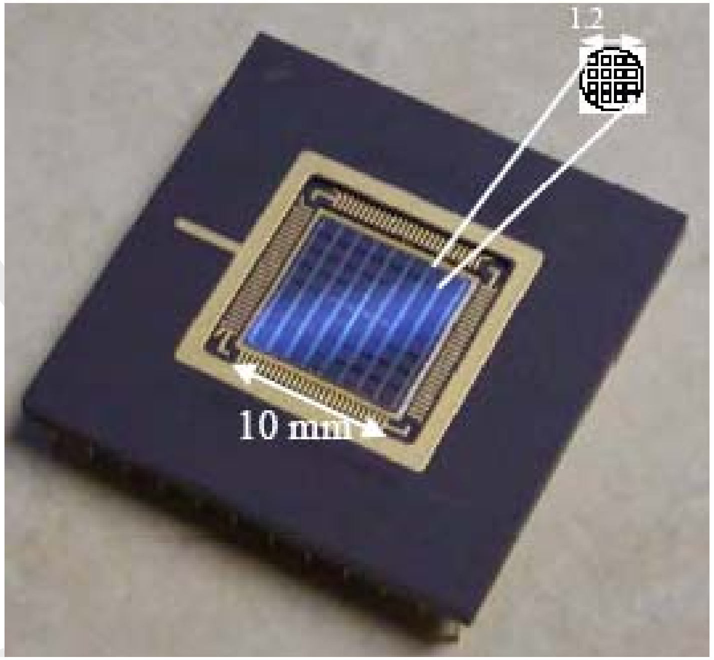
- Japan, Korea
  - Scintillator bars, Hamamatsu MPC (multipixel photon counters) in GLC; (T. Takeshita) Shinshu Univ., Kyungpook N. U.
- Italy
  - RPC (resistive plate chamber), simulation; (M. Piccolo) INFN-Frascatti
  - SiPM (silicon photomultiplier); (G. Pauletta) INFN-Trieste, Univ. Udine

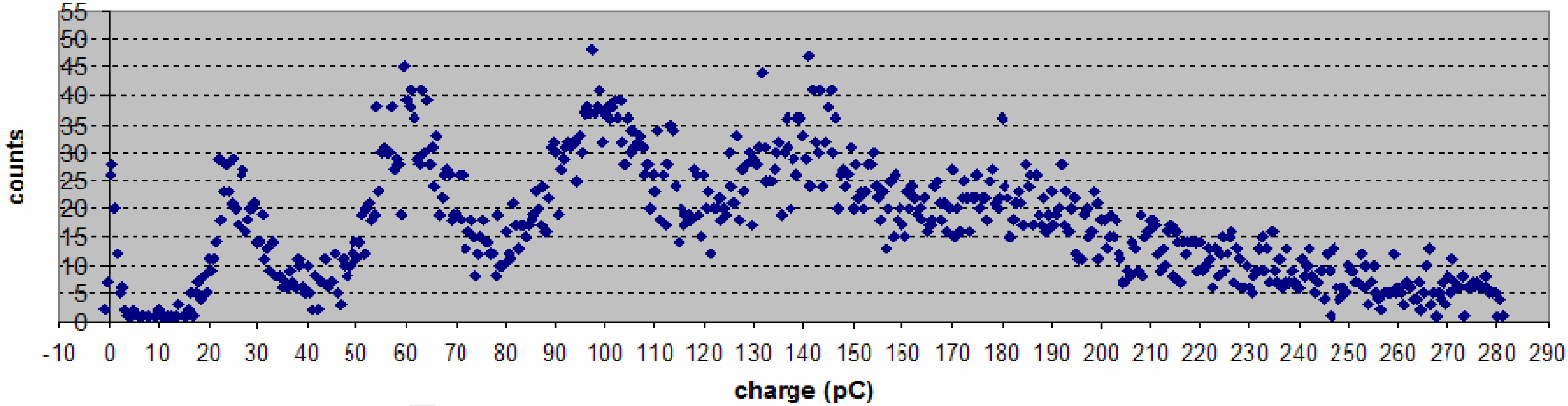
US Muon R&D

- Simulation; (C. Milstene) Fermilab
- GAPD (Geiger mode avalanche photodiode); (R. Wilson) Colo. State, aPeak Inc.
- RPC; (A.J.S. Smith) Princeton Univ.
- RPC, KPIX electronics chip, simulation; (H. Band) Univ. Wisconsin
- Tail Catcher Muon Tracker (TCMT); (G. Blazey) Northern Illinois Univ.
- Scintillator-MAPMT/SiPM, simulation; (H.E. Fisk, P. Karchin) Fermilab, Indiana Univ., Northern Illinois Univ., Univ. Notre Dame, Wayne State Univ.

Geiger Mode Avalanche Photodiode

- Colorado State Univ. in collaboration with aPeak, Inc. (SBIR funded)
- “silicon PMT” using array of Geiger-mode avalanche photodiodes
- 64 fiber readout prototype device
- Response to LED equivalent of m.i.p. showing peaks for 1,2,3,4 photoelectrons (operation at -19^{0}C)

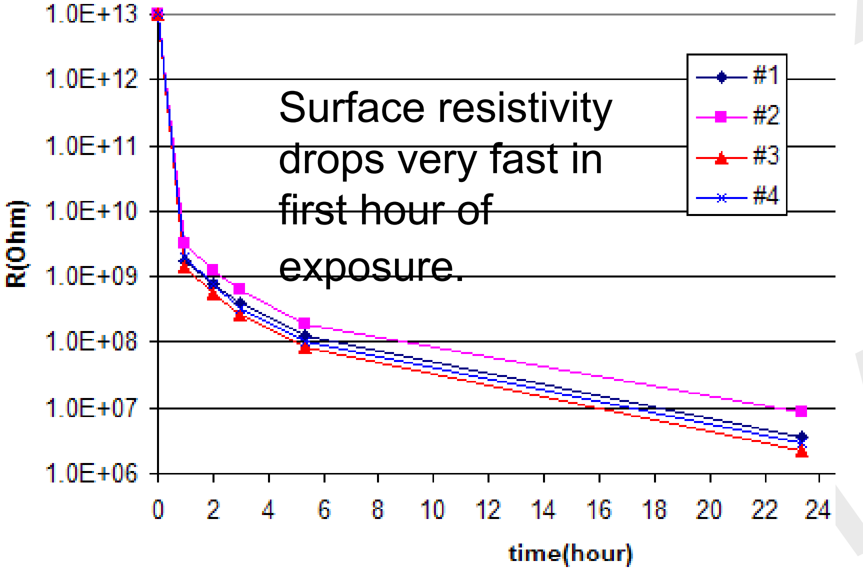




Resistive Plate Chambers for Muon Detection

Changguo Lu, Princeton University

The major component in RPC gas mix is R134A - C2H2F4. In the electrical discharge it can produce significant fluoride radicals, and further form HF. HF is notoriously chemical reactive, it can attack many different materials.



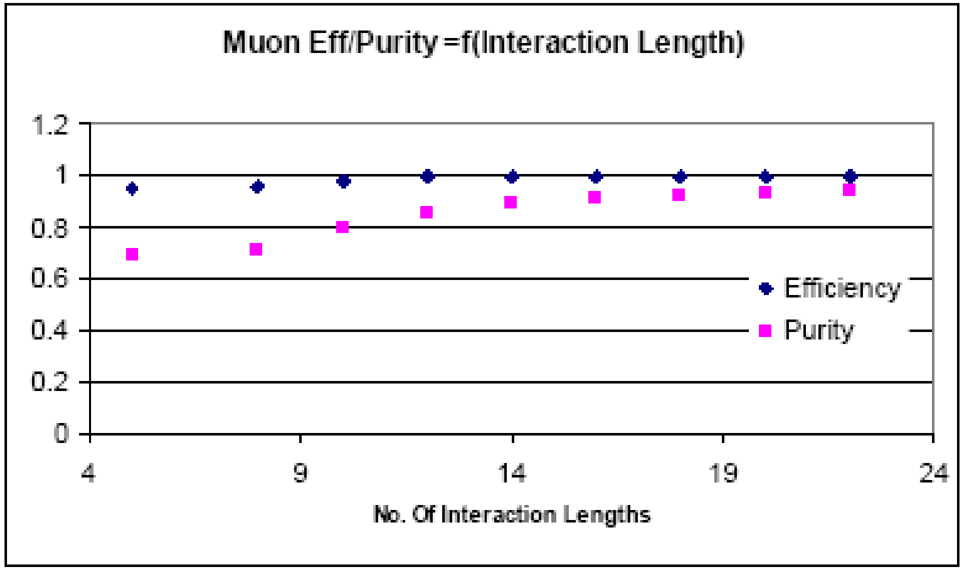
IHEP Bakelite RPC does not require Linseed oil coating. We are working with IHEP and Gaonenkedi to develop this new material.

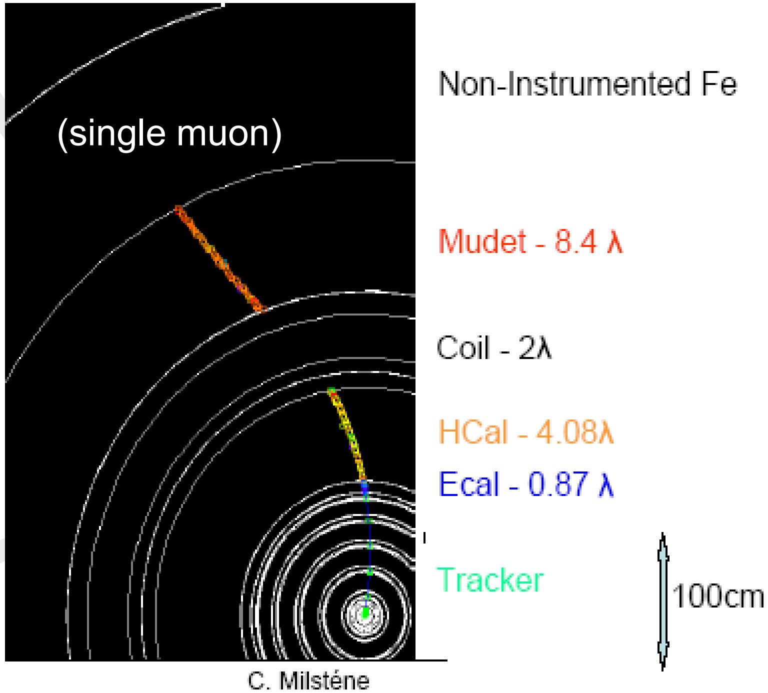
Simulation

C. Milstene & H.E. Fisk, Fermilab

GEANT4 Simulation of 10,000 b-bbar events

integrated pattern recognition





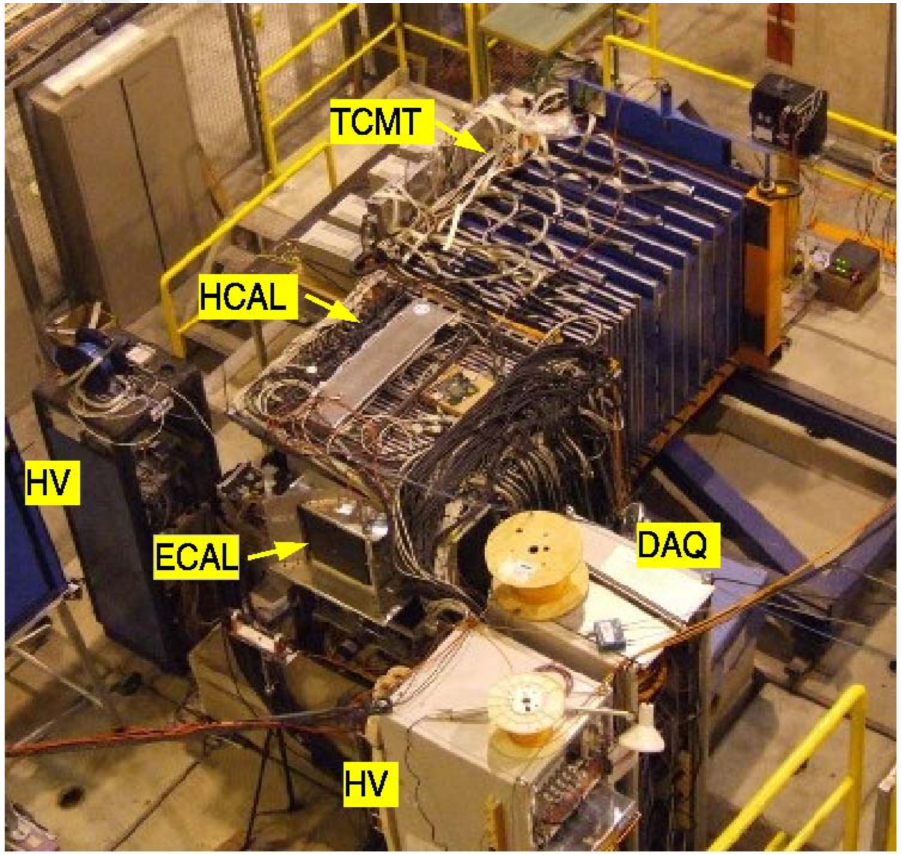
• purity improves from 69% at end of HCAL (5 λ) to 94% at end of MUDET (15 λ)

• efficiency improves from 95% to 99.6%

Tail Catcher Muon Tracker (1)

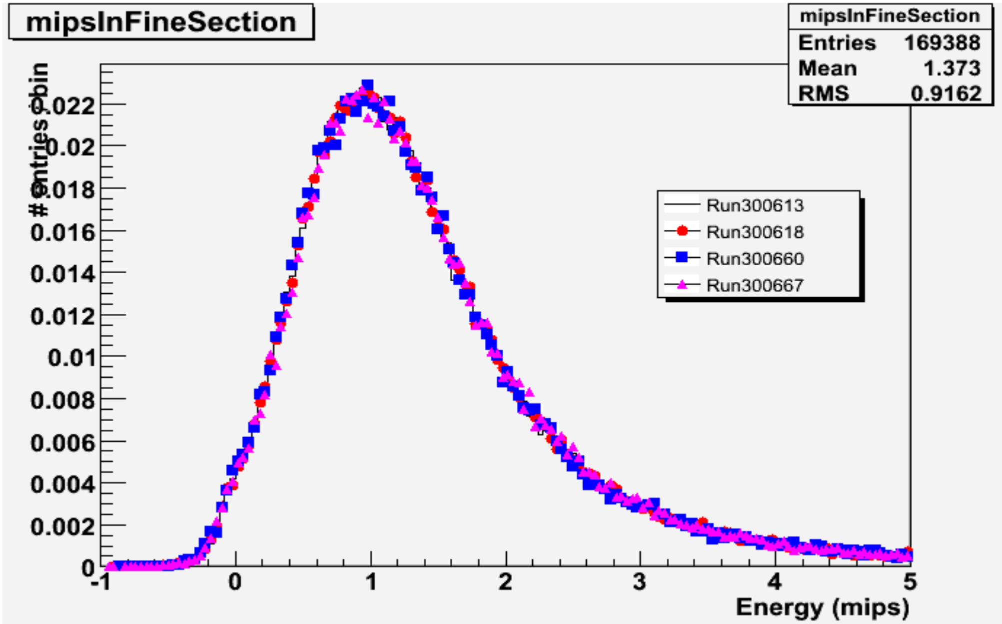
Northern Illinois Center for Accelerator and Detector Development (NICADD), Northern Illinois University, DESY, Fermilab

- 16 scintillator-steel layers
- layer area 1m X 1m
- alternate x,y layer orientation
- SiPM-readout of scint. strips
- each strip 100 x 5 x 0.5 cm^3
- 16 layers x 20 strips = 320 channels
- Oct/2006 10-20 GeV test beam at CERN



Tail Catcher Muon Tracker (2)

response for muons extracted from 10 GeV pion runs



more data taking:

Jul/Aug 2007 at CERN,

late 2007 at MTBF, FNAL

SiPM readout is successful

TCMT improves energy resolution for hadron showers

Scintillator-Based Muon Detector (1)

Collaboration: Fermilab, IRST/INFN-Udine, Indiana Univ., Northern Illinois Univ., Univ. of Notre Dame, Wayne State Univ.

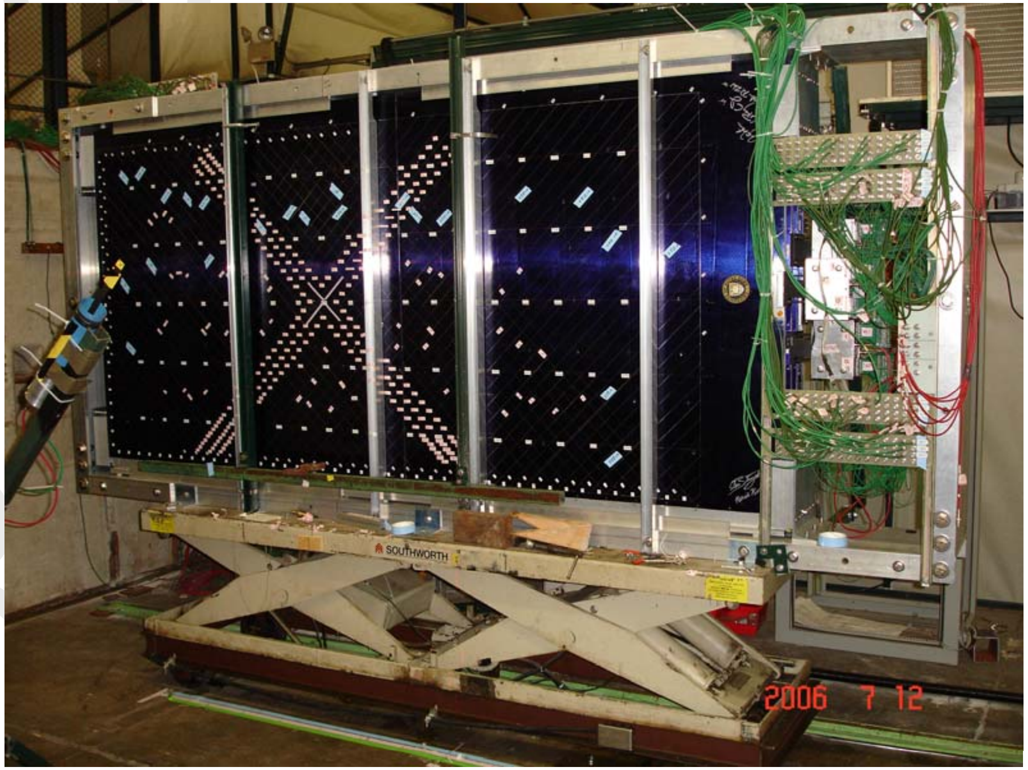
Four 1.25m X 2.5m scintillator-strip planes installed in Fermilab Meson Test Beam Facility with 120 GeV secondary beam, most recent data Fall 2006

256 strips/ plane

384 MAPMT readout chans.

2 planes single & 2-planes double-ended readout

strips: 4.1cm X 1cm X 1.8m (max)



Scintillator-Based Muon Detector (2)

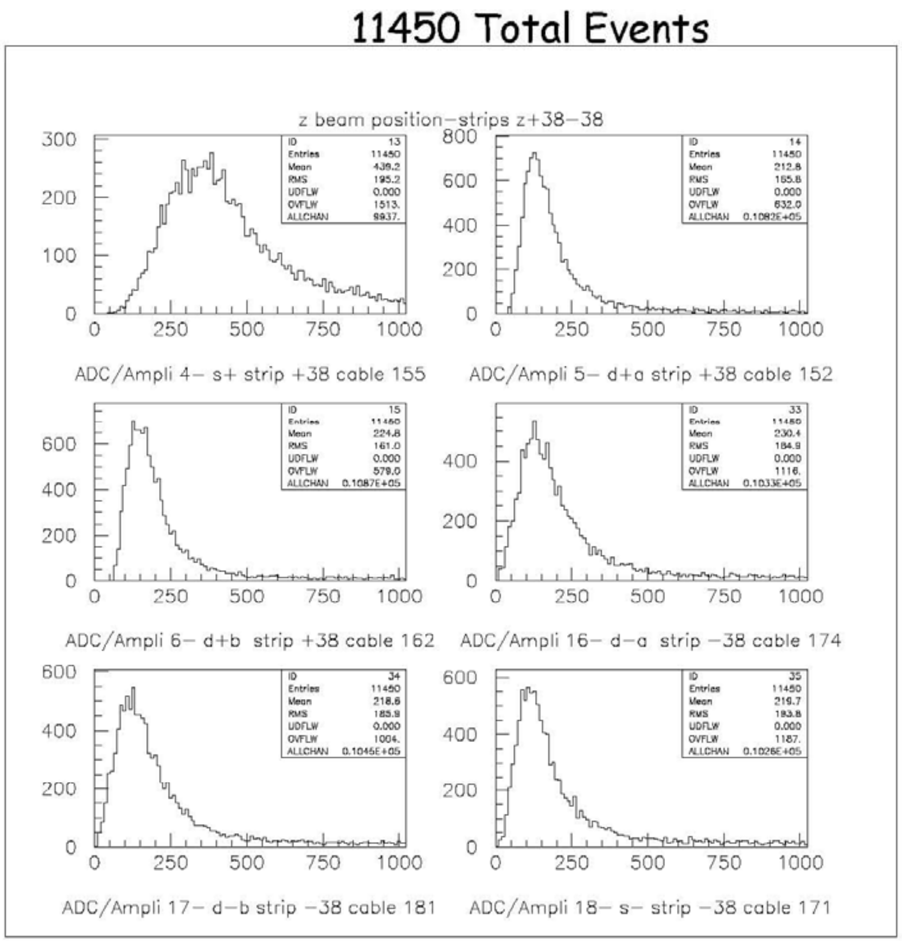
Some initial results:

single-ended readout signals
~ 3 – 4 pC

summed signals from both ends
~ 5 pC.

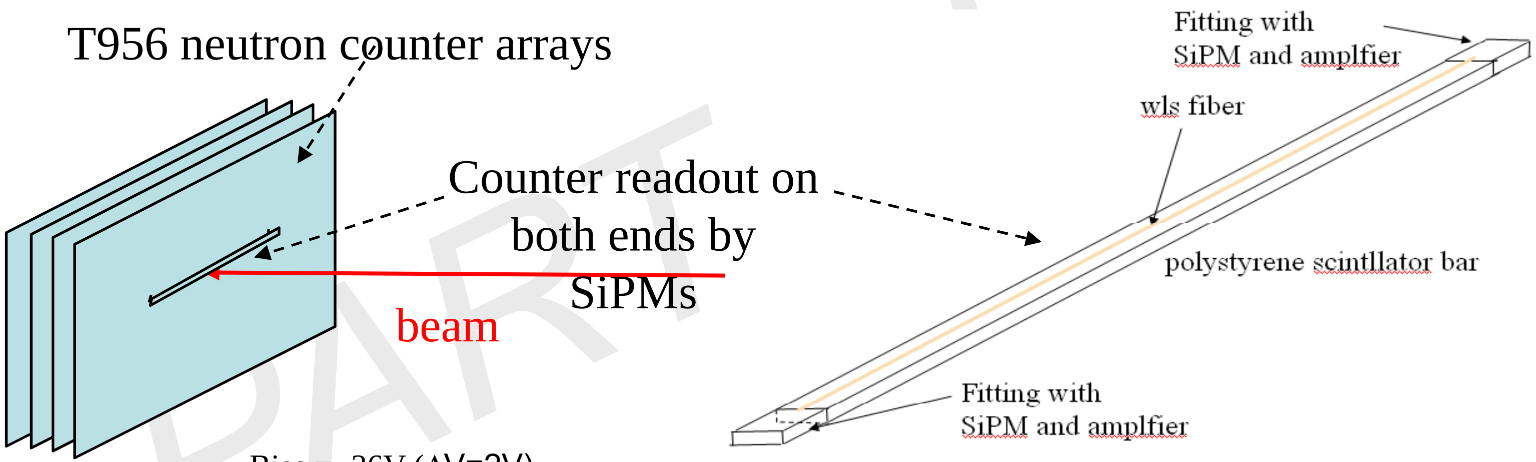
little attenuation over 1.8m of
WLS fiber as anticipated.

to do: # p.e. from absolute
MAPMT gain calibration

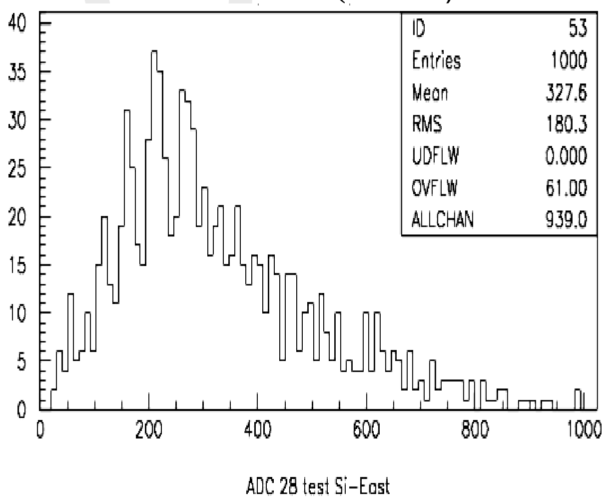


Scintillator-Based Muon Detector (3)

Preliminary study Scint. Strip viewed by IRST SiPM



Bias = -36V (ΔV=2V)



Data with 120 Gev p - beam

$$N_{p.e.} \approx 6.5\, p.e.$$

$$\varepsilon = 99\%$$

$$N_{d.c.} \approx 1.5 MHz$$

$$G \approx 1.6 \times 10^{6}$$

US R&D Accomplishments & Plans

- Significant progress on
  - simulation with integrated muon, calorimeter & tracking algorithm
  - development and testing of SiPM devices
  - scintillator strip detectors with MAPMT and SiPM readout

- Continuation of scintillator-based muon detector tests with CERN and Fermilab beams of hadrons and muons
  - Common readout for TCMT and large area planes
- Procurement and tests of SiPM-type devices
- Development of improved RPC detectors and electronics
- Simulation of more physics processes and inclusion of end-cap detector

Caveat: pace and depth of studies has been limited by lack of personnel FTEs