Scintillator Based LC Muon System

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Why scintillator?

- Mature and robust technology – used extensively to identify muons and measure jet energy.
- Excellent sensitivity, energy linearity and efficiency for both minimum ionizing particles and jets.
- Good timing; may be useful in sorting out background muons and as a CR trigger w/o beam.
- Potential hadronic shower tail-catcher; Backup calorimetry; Deep inelastic μ scattering.

Cal depth: 3.2 λ , 5.4 λ, 6.7 λ for NLC(P), TESLA, NLC(L)

Sampling calorimeter example from Dishaw et al.

Muon system requirements

- **Identification** **by penetration of charged tracks through Fe.**
- **Muon Tracking and Link-up with cent. tracking: ~15 hits in Fe**
- **High Tracking Efficiency: efficient detectors/minimal gaps.**
- **Charge & precise p from central tracking.** (Not a muon syst. task)
- **Tail-catcher Calorimeter for energy flow algorithm.**
- **Must identify: conventional, new physics and background muons.**

Candidate technologies:

(1) Resistive Plate Chambers

(2) Scintillator Based Detectors

(3) Wire chambers

Scintillator Based Muon System

- Proposed Parameters
  - 16 – 5cm gaps between 10cm thick Fe plates.
  - Module sizes: 940(L)X(174 to 252)(W)X1.5 cm^3.
  - 4.1 cm X 1 cm extruded scintillator: 8u & 8v planes.
  - Light output from both ends: 11(n) + 6(f) p.e.s.
  - Multianode PM; 94K fibers X 2 clear fibers.
  - Expect ~ $1/\sqrt{E}$ for calorimetry.

Sampling Calorimeter

E379 P. Dishaw SLAC-216 Fe & Plastic Scintillator 30" H X 30" W

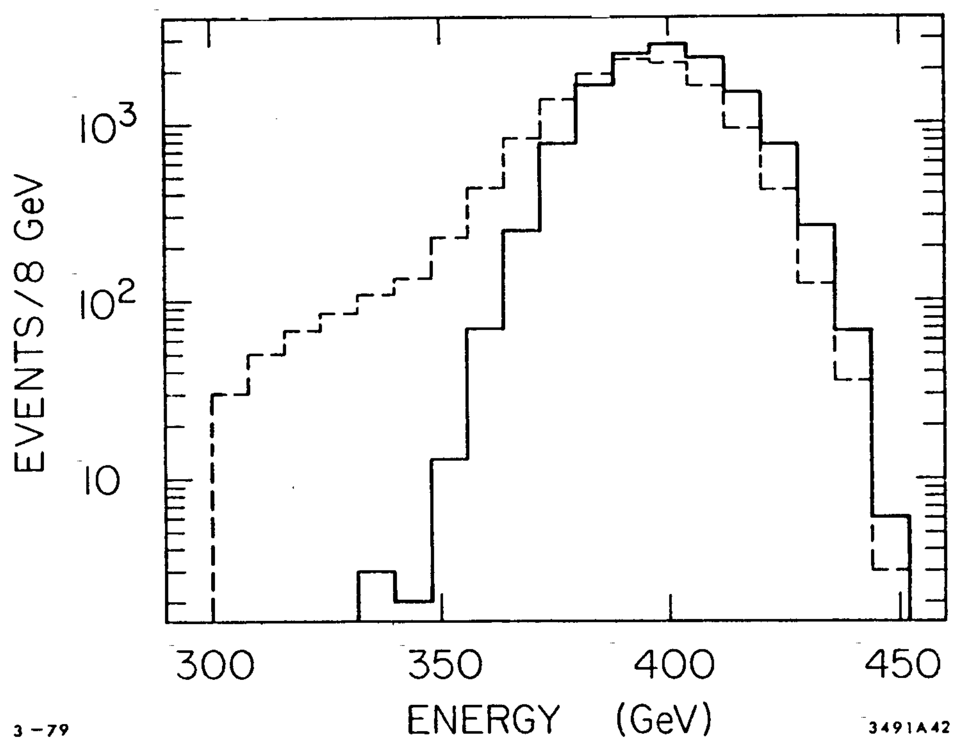


Fig. 39 Calorimeter measured energy for the full calorimeter (approximately 3 meters) (solid histogram) and the same distribution for a calorimeter consisting of only the first 30 plates (approximately 1.3 meters) (dashed histogram, arbitrarily cut off at 300 GeV). Noncontainment in the second case leads to nonGaussian behavior in the low side of the measured energy.

Plates: 1 - 20 1.5" Fe
21 - 45 2" Fe
46 - 49 4" Fe

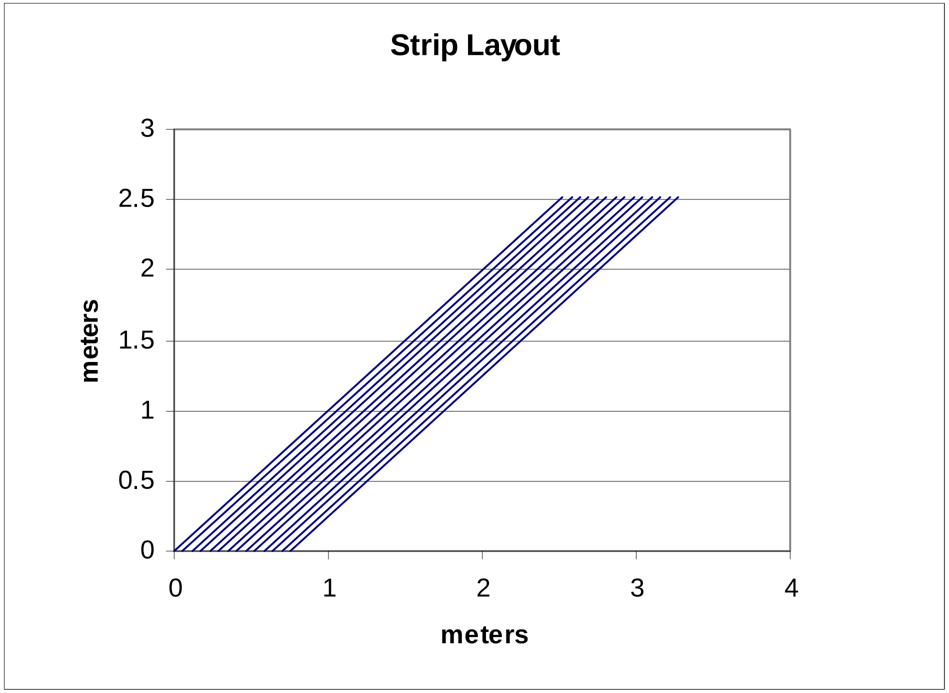
-- $\sum_{i=1}^{30} C_i \Rightarrow \frac{\sigma}{E} = 6.38\%$ 7.6 λ

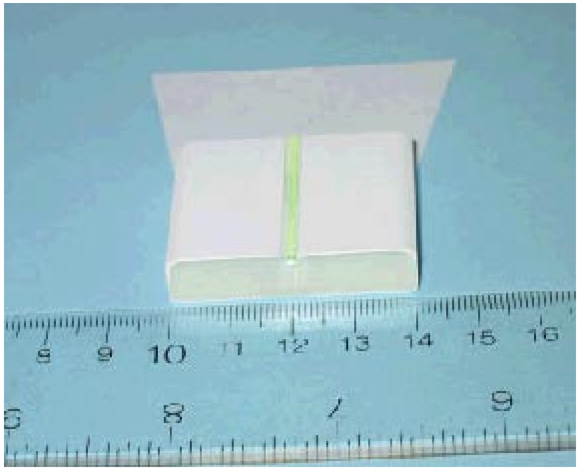
<E> = 389 GeV

— $\sum_{i=1}^{49} C_i \Rightarrow \frac{\sigma}{E} = 3.63\%$ 11.5 λ

<E> = 400 GeV

Scintillator Layout and Strips

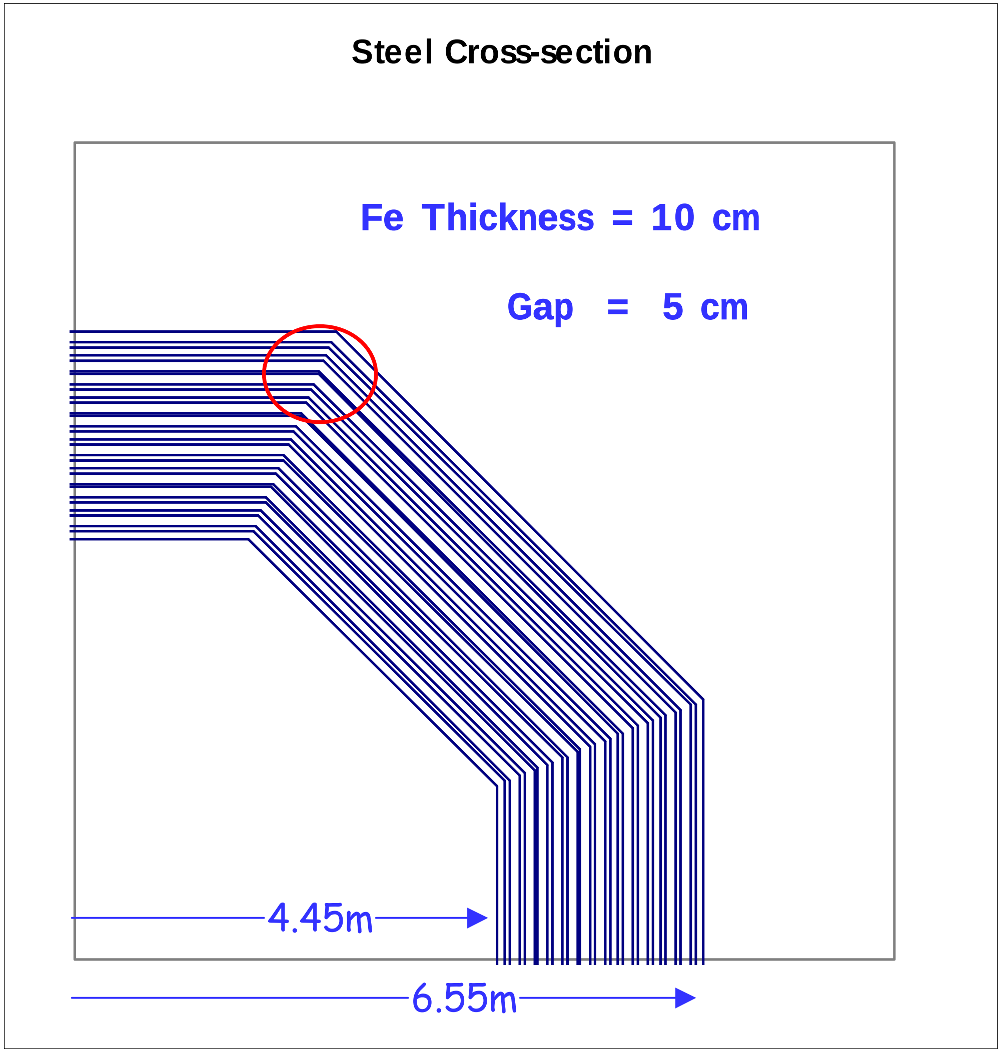


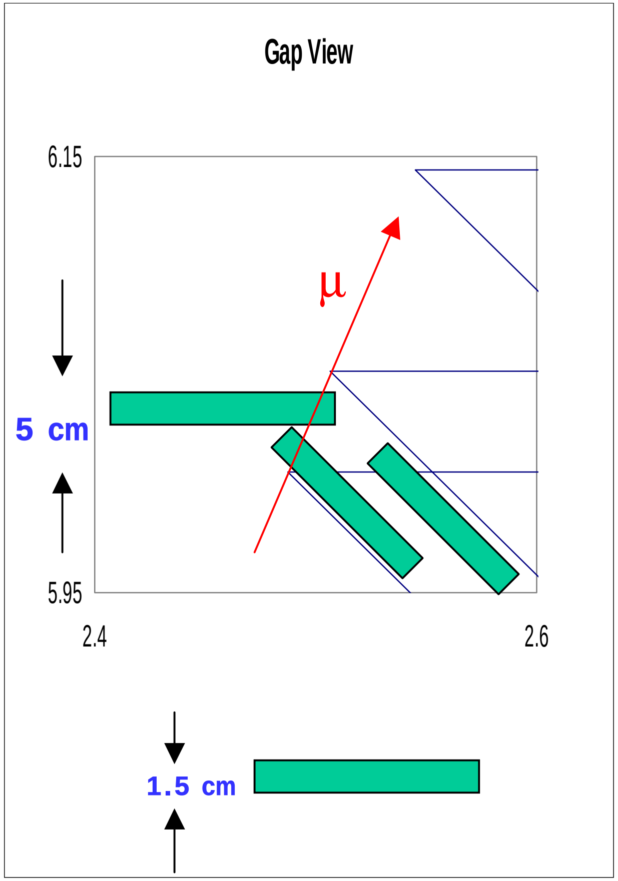


U/V strips with wls shifted light exiting both ends. Add left/right signals from clear fibers with optical SUM to provide one signal per strip.

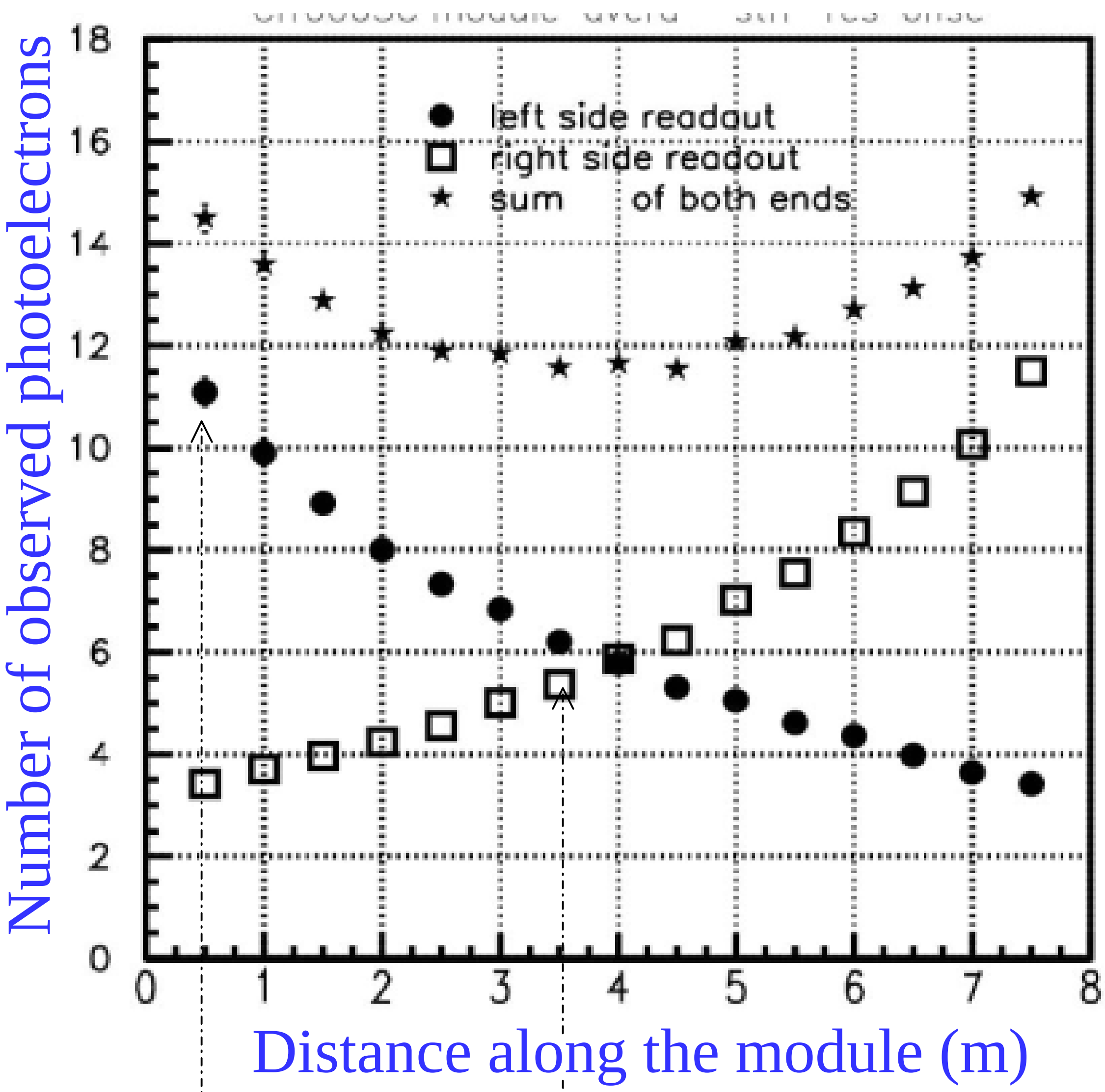
Scintillator: 4.1 X 1 cm^2 co-extruded strips with 1 mm dia. WLS fiber and outer reflector of TiO_2.

Fe Cross Section





MINOS Scintillator

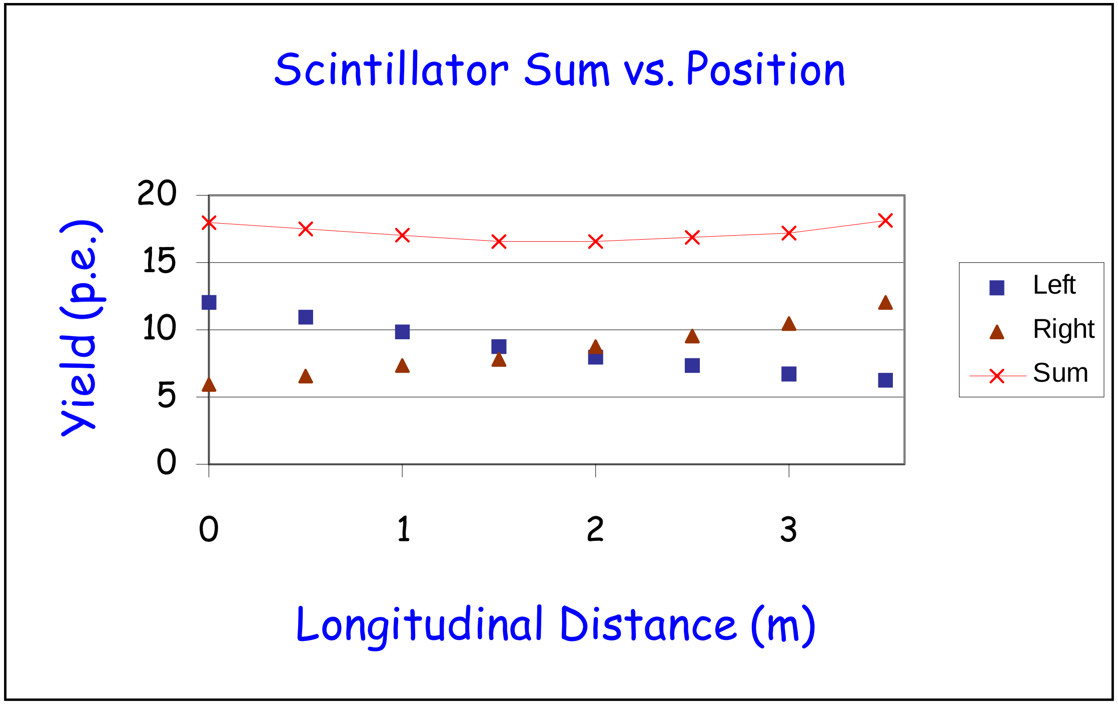


Measured light output using the complete MINOS optical system: Connectors, clear fibers, multi-anode PMT's

Near
11±3 p.e.

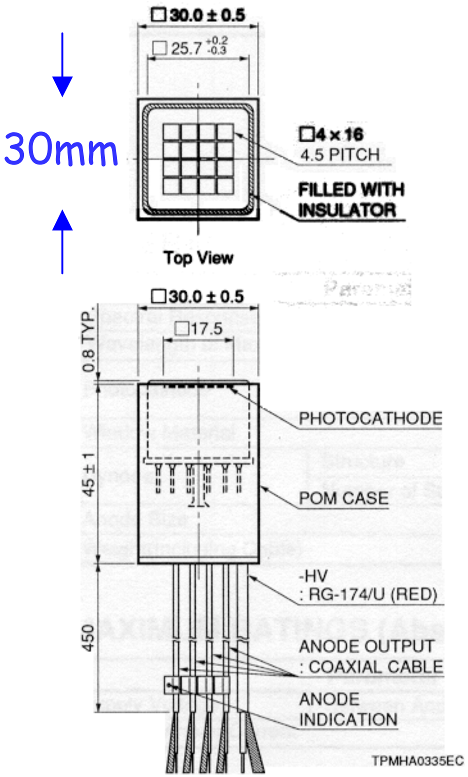
Far (3.6 m for the proposed layout)
6±2 p.e.

Left/Right Summed Output



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

MUX output from 4 strips/anode. => 1468 PM's.

Some Selected Costs

Extruded scintillator: ~ $13/kg => $1.5M

WLS fiber: $1 - $3/m => $2.5M

Clear fibers: $1 - $3/m => ?

Multi-anode PM $600 ea. (16 anodes)

1600 PM's * $600/PM => $1.0M

1500 channels of signal processing ...

Calibration system ....

Looks possible, but too early to quote real costs!

R&D Issues

❖ <u>Muon Software</u> (w. D. Hedin, A. Maciel)

• Event sample analysis: What muons? What jets? All the knowledge you already have in your head. Test bed of MC for the muon system.

• Muon detector tracking and link-up with central tracking.

• Shower leakage into muon detectors. (A.M., C. Milstene, Marcello Piccolo INFN)

• Sampling calorimeter and Energy Flow algorithms: e.g. $\langle E_{jet1} + E_{jet2} \rangle$ comparison.

• Is 4.1 X 1 cm^2 the optimal scintillator cross section? (NIU, A. Para,)

R&D Issues (cont.)

❖ Muon Detector Planes

- Scintillator design, specs, prototype extrusions using NIU/NICADD extrusion machine at Fermilab. (NIU)
- Fiber specs, fiber routing, bending, fiber guides/molds. Two fiber SUM. (NICAAD, A. Bross)
- Prototype detector plane engineering, R&D proposal, construction (J. Blazey, G. Fisk)
- Quality checks – mechanical, meas. w. radioactive sources, test electronics.

❖ Electronics/Cosmic Ray Test Stand

- PM Specs, PM tests & selection, FE electronics (10 p.e.s), CR => LC detector?

R&D Issues (cont.)

❖ Electronics/Cosmic Ray Test Stand (cont.)

• Small DAQ sys., Test scenario (NIU, ?)

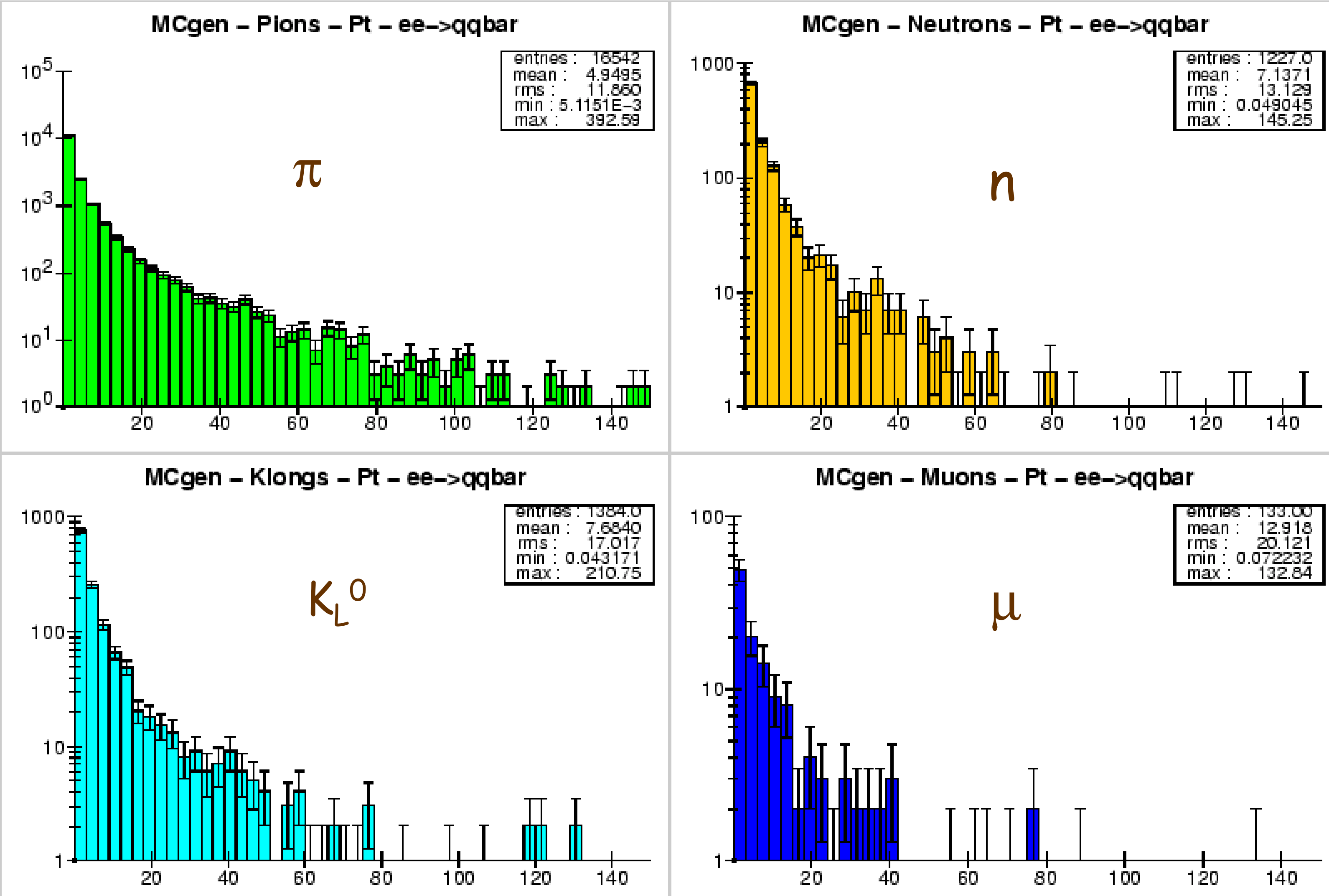
❖ Test Beam

• A proposal is needed for a 120 GeV/c test beam from the Main Injector.

• Muon prototype detector tests with Fe + scintillator planes (full width, shortened length) to understand system issues such as backgrounds from jets, software, calibration, participation with other detectors. Such a facility would provide **data** for decisions on detector design issues.

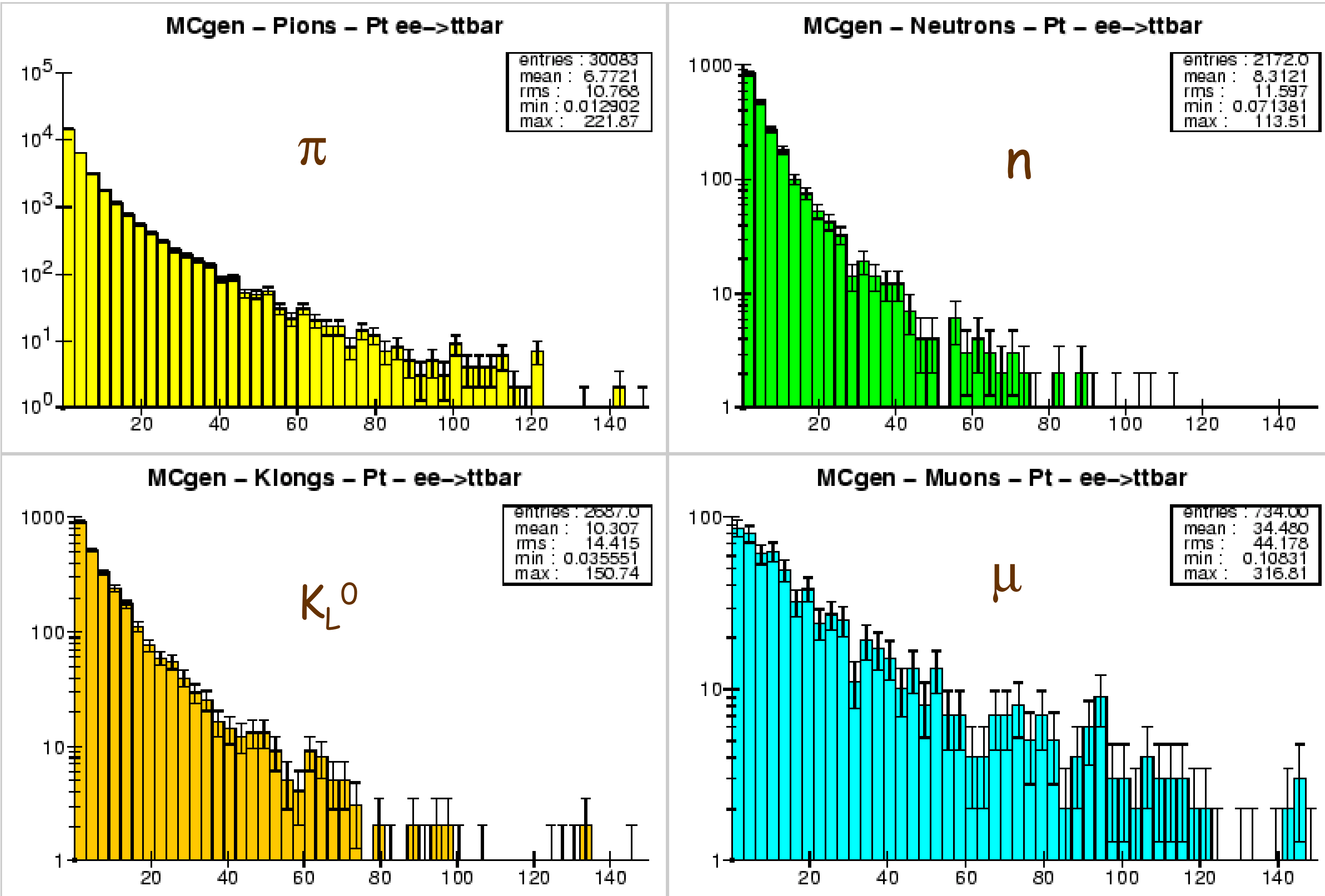
• Examples: Energy flow software/algorithm development with prototype detectors; tracking, calorimetry, and muon electronics tests; calibration schemes.

$$e^+ + e^- \to q + \bar{q} \text{ at } 1\text{TeV}$$



A. Maciel - NIU

$$e^+ + e^- \rightarrow t + \bar{t} \text{ at } 1\,\text{TeV}$$



Summary, etc.

1. Studies on the use of scintillator in the detection of LC muons should continue to further understand its feasibility, cost, etc. So far the idea looks interesting.

2. We should understand more fully the complementary roles of tracking devices and scintillator; e.g. tracking chambers at the front face of the Fe may be desired.

3. A next step in the scintillator studies is to write down in some detail a pre-proposal.

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