Secondary Emission Ionization Calorimetry Detectors

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for
Fairfield/Iowa/Mississippi

Secondary Emission Ionization Calorimeter Sensors

- Secondary Emission: Rad-Hard, Fast
  - Metal-Oxide/Cs Dynodes survive > 500 GRad

- Signal from SE surface(s) in Hadron Showers:
  - SE yield δ: Scales with particle momentum ~dE/dx
  - e^-: 3 < δ <100, per 0.1 <e^-<100 KeV (material depnt)
  - δ~1.05 -1.1 or 0.05-0.1 SE e^- per MIP

    NB: *This is a **lower limit** on hadron shower SE signals*
  - 4-6 MIP equiv per GeV sampling calorimeters
  - ~50 SE e^- per 100 GeV pi shower w/ MIPs alone

- Achtung! SE e^- Must be Amplified!

Signal Generation from Hadron Shower

SEM Sensitivity (MIPs) :

$$1\,rad = \frac{100\,ergs}{gram}\cdot\frac{MeV}{1.6\cdot10^{-6}\,ergs}\cdot\frac{MIP\cdot gram}{2\,MeV\cdot cm^2} = 3.1\cdot10^{7}\ MIPs\ per\ cm^2$$

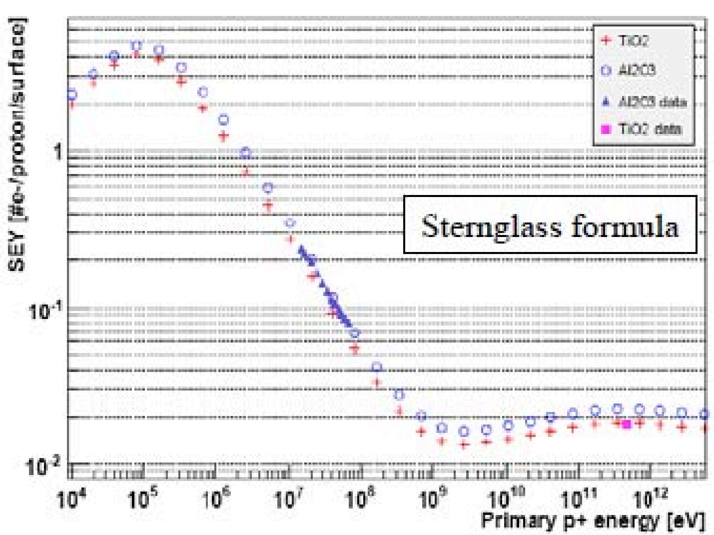
sensitive surface Ø = 3.2 cm = 8cm^2

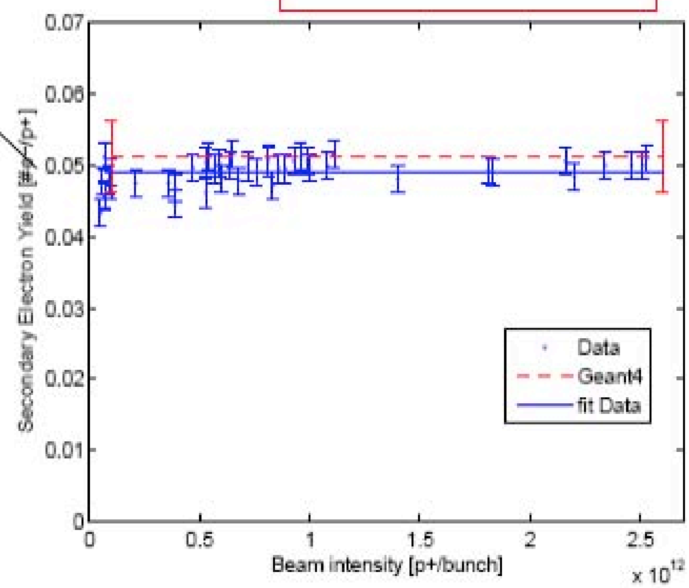
=> S_{SEM} = 2.5·10^8 MIPs/rad · 0.05 e$^-$/MIP · 1.6 ·10^{-19} C/ e$^-$ = 2 pC/rad (· **PMT$_{gain}$**)

Al_2O_3, TiO_2

~0.05 e$^-$

per MIP



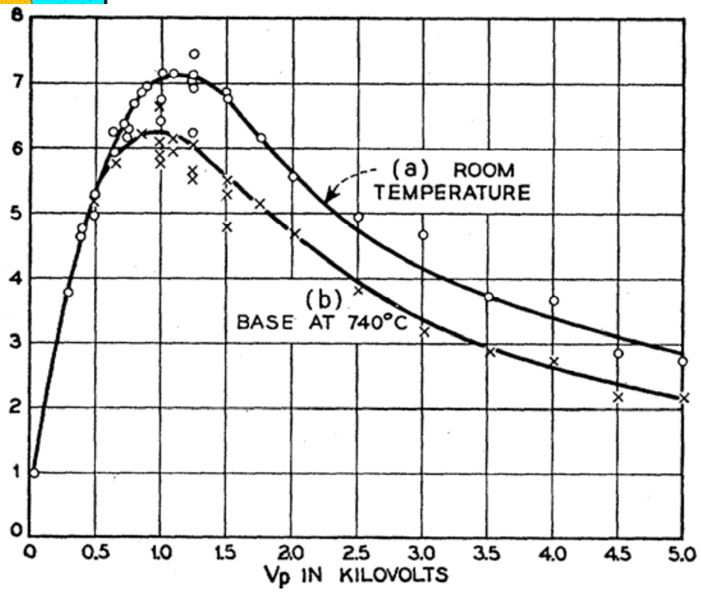


Hadron Showers: Sub-mip Charged particles

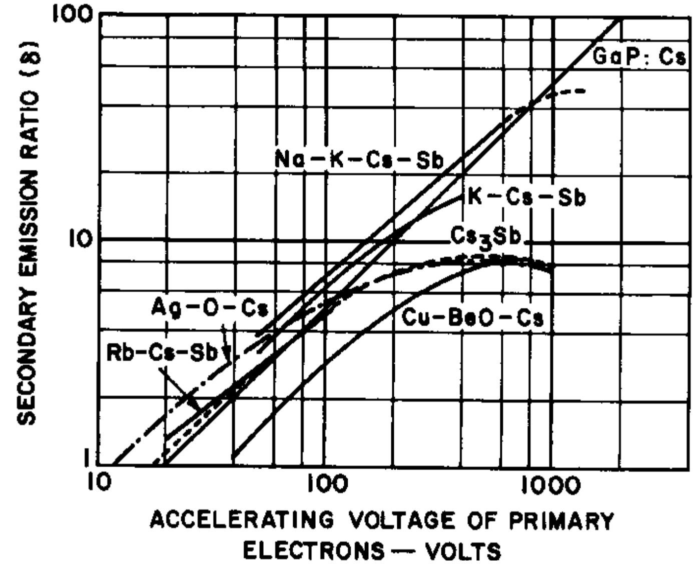
High SE Yield Materials

Yields x2-10 >Alumina Easy

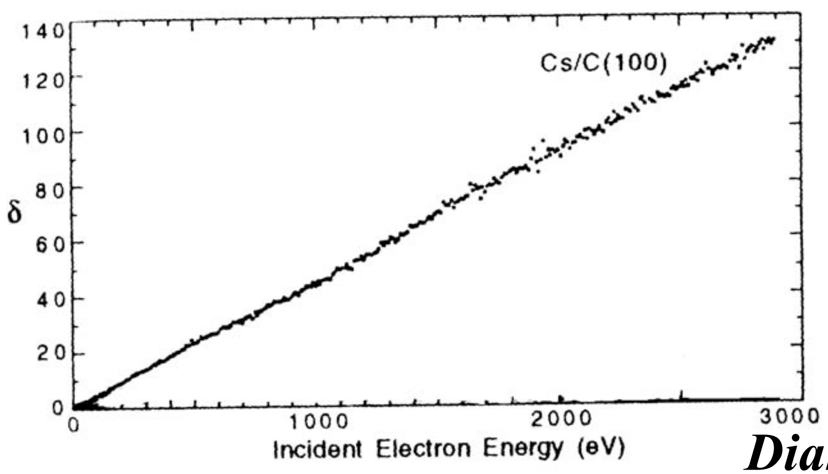
MgO

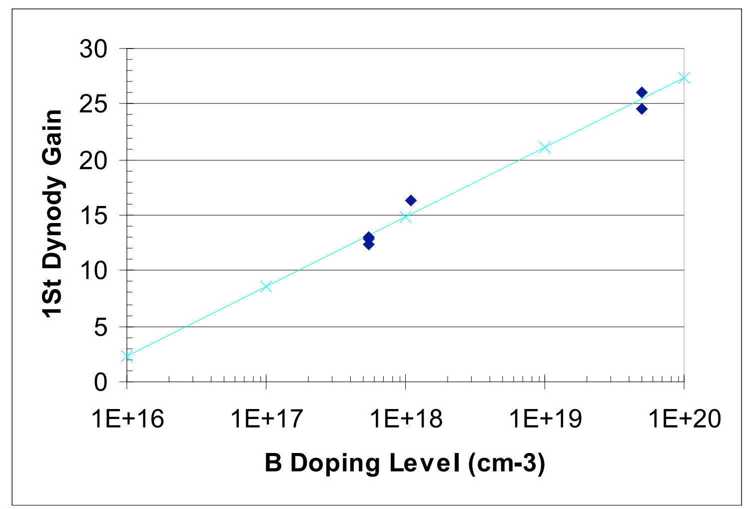


Electrons on MgO



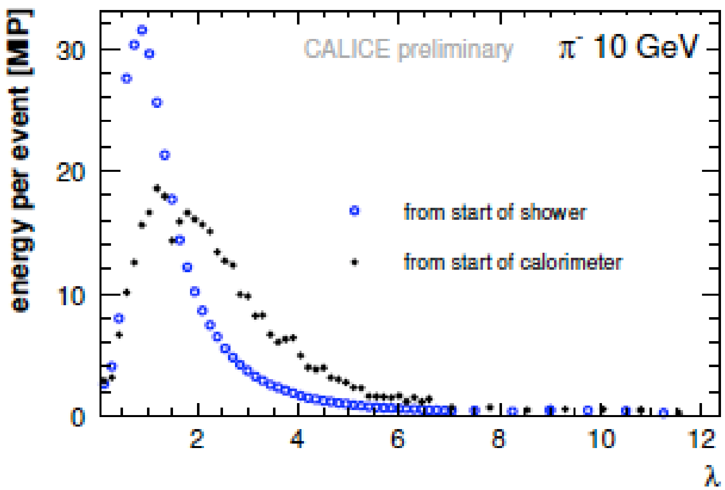
Diamond Yield

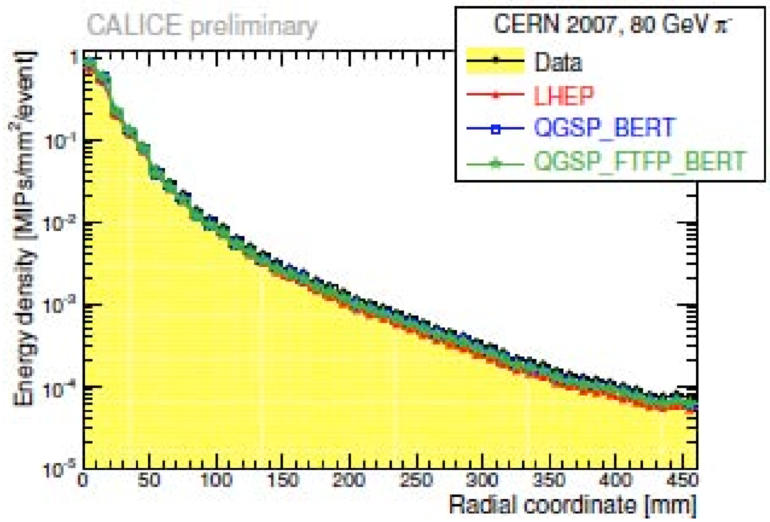


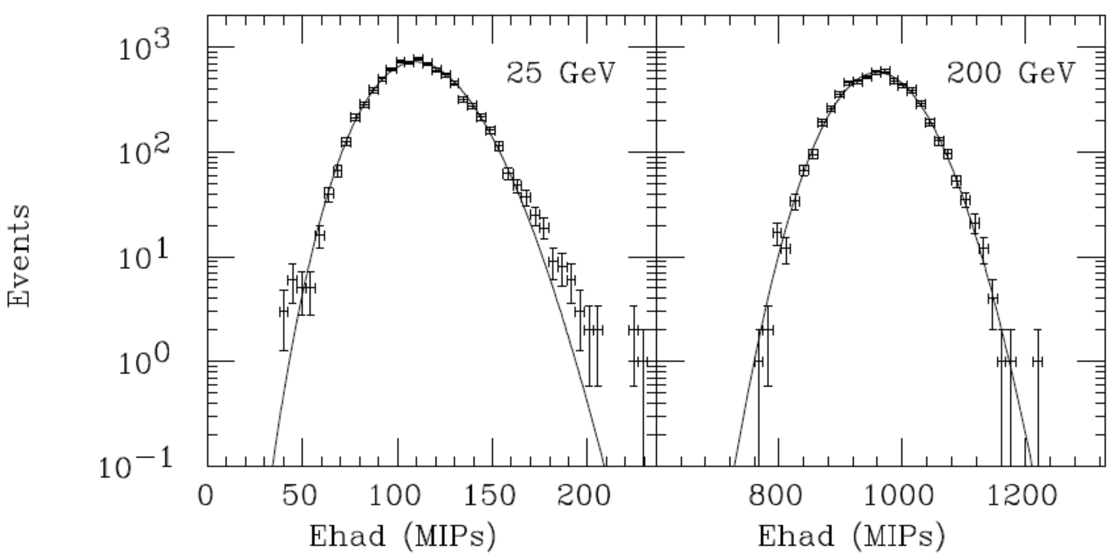


Diamond Gain 300 V vs B Doping Level

SE Signal: MIP Equivs in Hadron Calorimeter







~5cm Fe Sampling HCal:
~4-6 mip equiv/GeV
The Lower Limit on Signal:

100 GeV HF/HECal:
***Minimum* of 50 SE e-**
…But need amplifier!

SE MIP Detector w/ 5 x 10^7 Gain

G.O.A.

SE e- Already In Vacuum

Use Dynodes To Amplify

NUCLEAR RADIATION DETECTOR TYPE: 9841

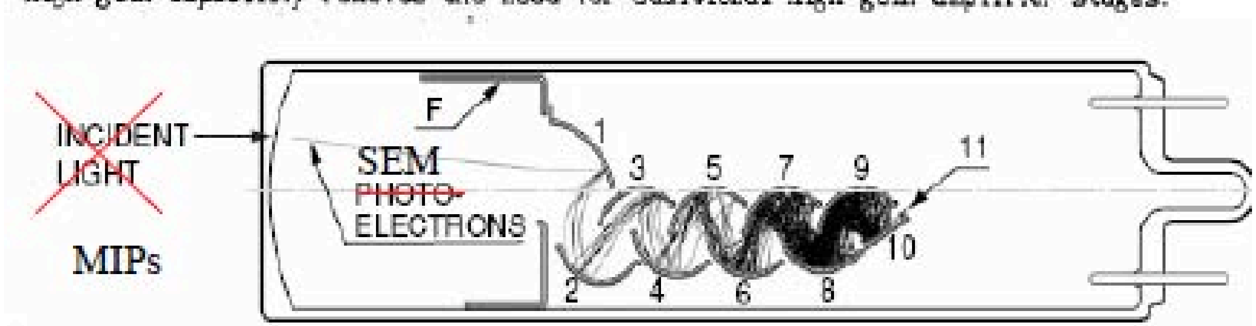
(Aluminium Cathode Electron Multiplier)

Description

Ø 32 mm

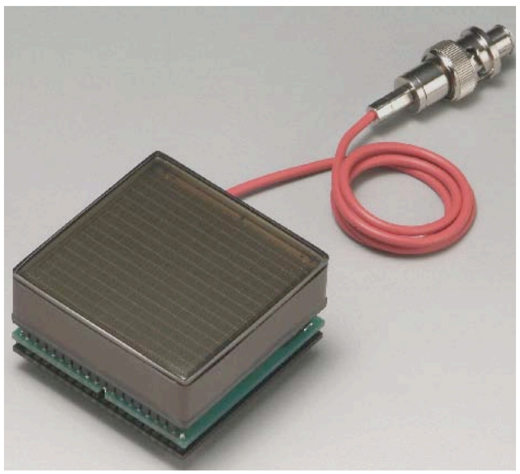
Cathode; Aluminium.
Window; Borosilicate.
Dynodes; 10 linear focused type with CsSb secondary emitting surfaces.
Base; B14B.

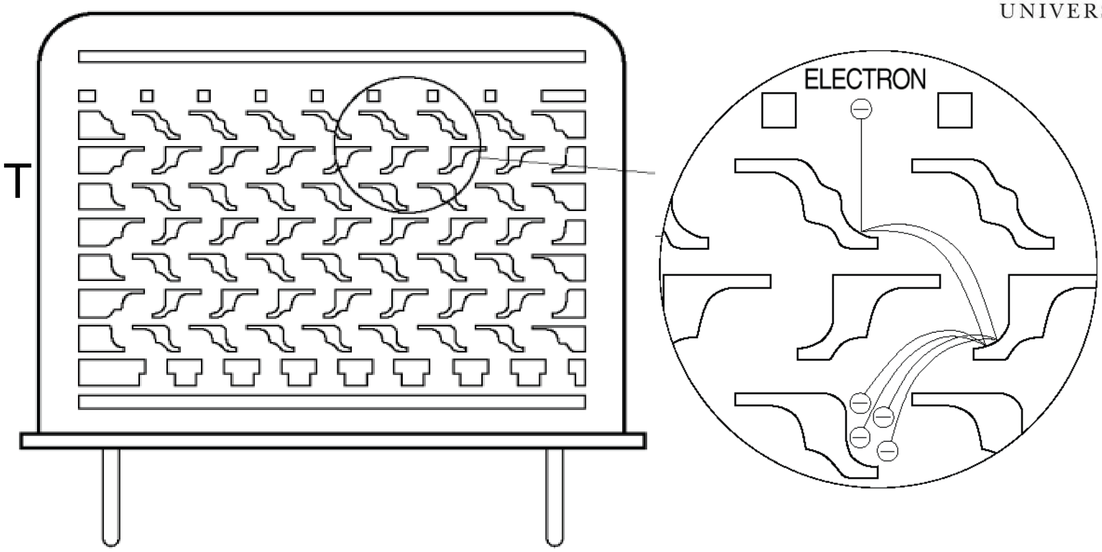
This tube is a development from the THORN EMI 9902 photomultiplier for direct measurement of ionising radiation, in the MeV to GeV region, associated with particle accelerators and nuclear reactors. It is intended as an alternative to the use of an ionisation chamber with improved linearity and response time over a wide dynamic range. The tube also has a high resistance to radiation and its high gain capability removes the need for additional high gain amplifier stages.



The Detector: Metal Sheet Dynodes

Hamamatsu Metal Envelope PMT
Slat dynodes - products up to 6”

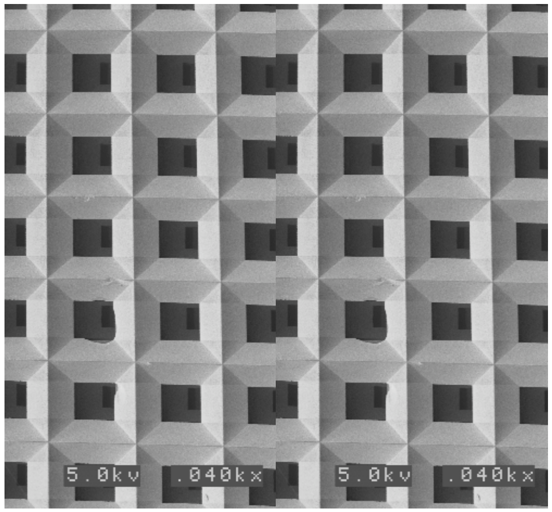


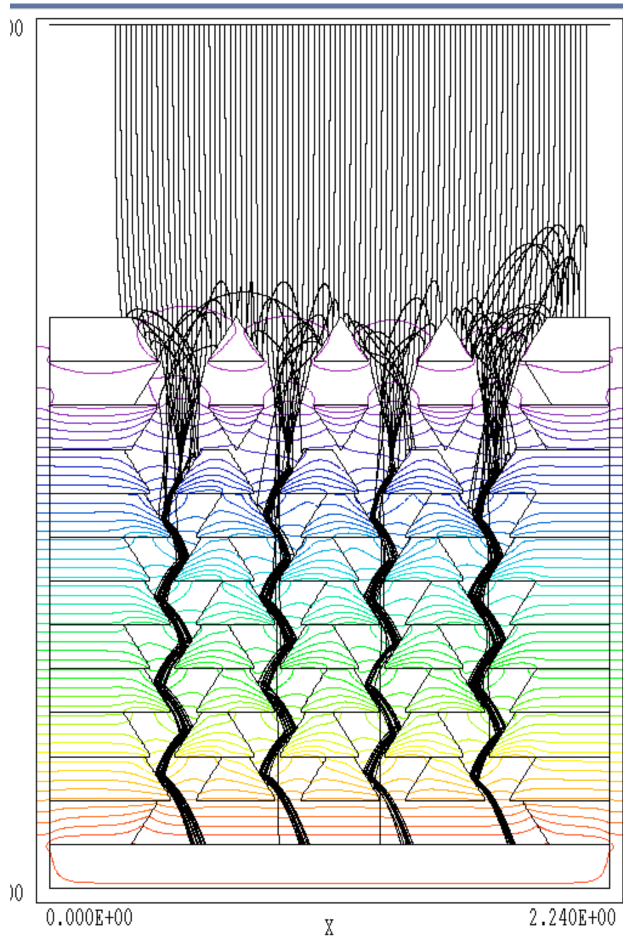


- Chemo-electromachined Metal “Mesh” Dynode Sheets
-~1mm thick dynode layer - scale to 500-200 μm
- HV Vacuum: <10KV/mm -> 500V/0.2 mm ok.
- Sheets can be up to square meters
- Pressure + HV insulators: monotonous insulators
  -walls, posts, fibers (glass ceramics oxides)

- Quasi *Channelized:* e- confined ->MCP operation
- Metal cathode directly D1
- ***B -> 2+T, as in previous mesh dynode PMT***

MEMS Mesh Dynodes





µMachined Mesh Dynodes
Low Cost ~ 30 minute process
Channel Width ~200 µm
Offset layer layer helical channels
Insulator: Si_3N_4 or SiO_2
Confined e- = High B
Can be taken to air repeatedly
~ microTorr operation ok

Anticipated Performance: SE Hadron Calorimeter

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Minimum Signal: muon MIP

~0.2 SE e^- per module

(delta rays ~ peak of SE emission), <g> > 100,000

~ 20 Samples

-> MIP Signal ~ 4 SE electrons/MIP

~ 1 “SE electron”/GeV @ 10^5/SEe

Hadron Shower Signal:

Larger SEe per GeV- particles of lower momentum:

->SE δ~1.5-6 compared with 1.1-1.05 for MIP.

<E> per calo counting particles ~ 60 MeV per ~2cm cube

Calice: ~23 “particles”/Hadron GeV

-> x4-10 SEe/GeV hadron calorimeter showers

NB: possible compensation when combined with other response media

SLHC R&D technology –Secondary Emission Sensor Modules for Calorimeters

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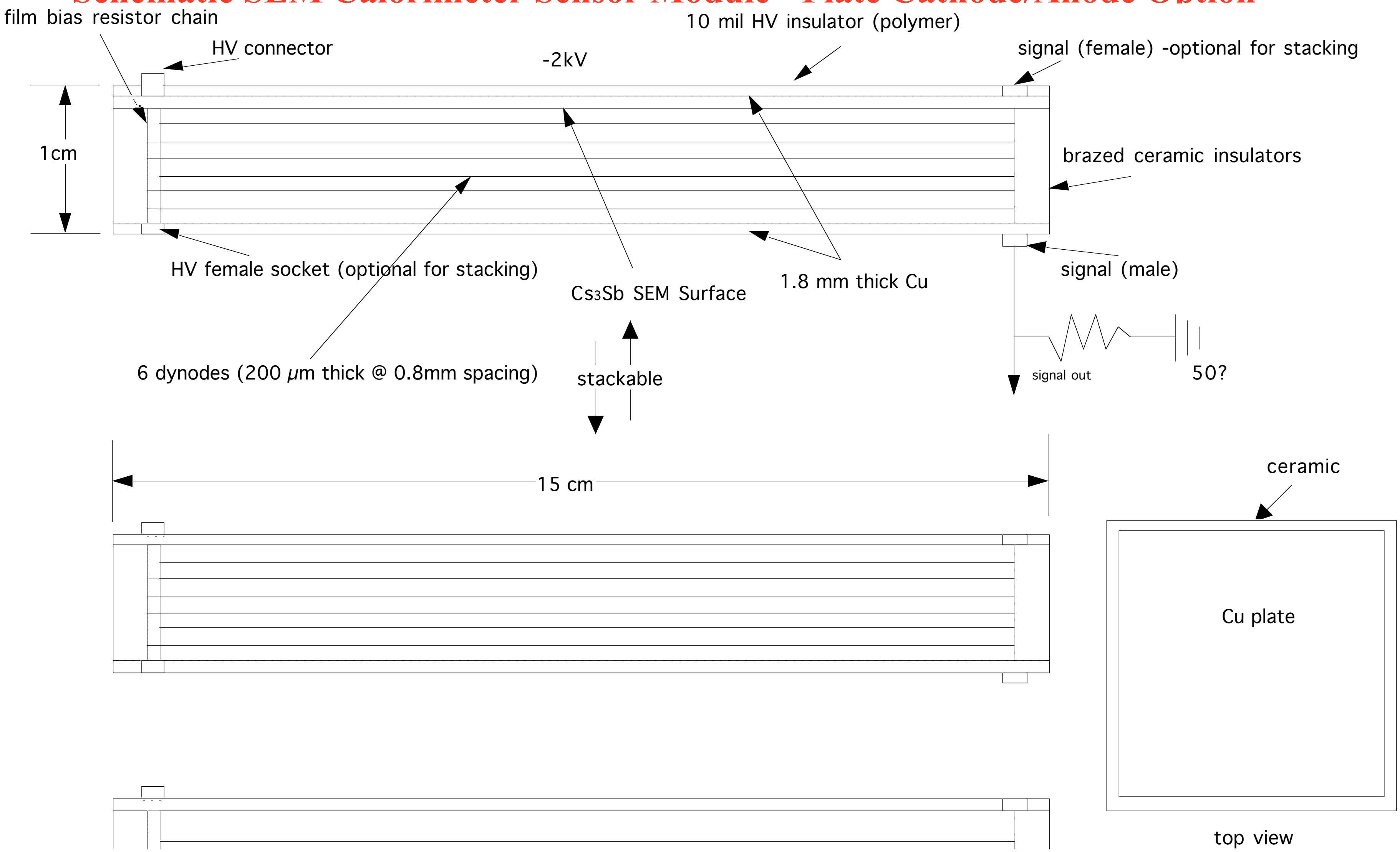
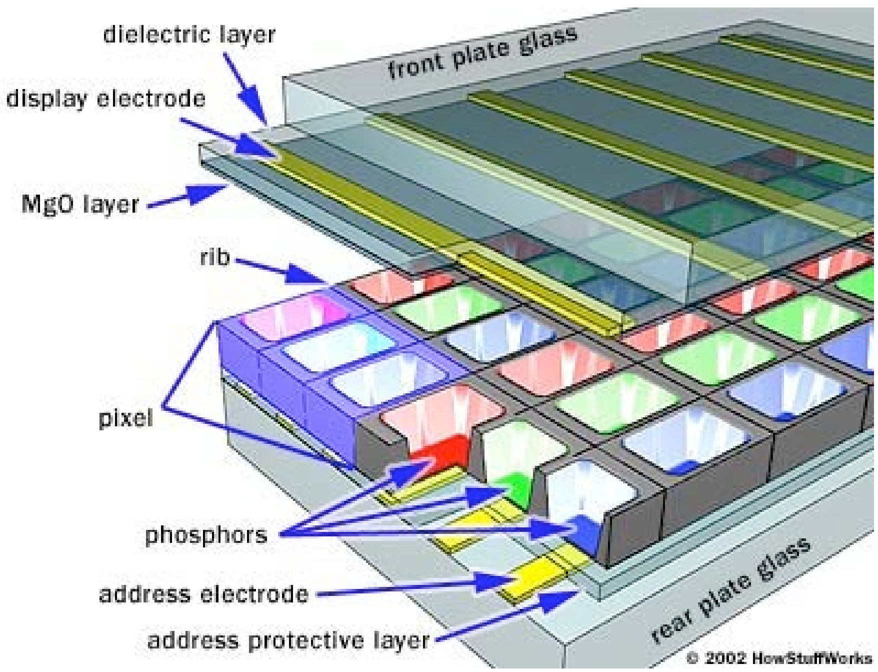
Schematic SEM Calorimeter Sensor Module - Plate Cathode/Anode Option

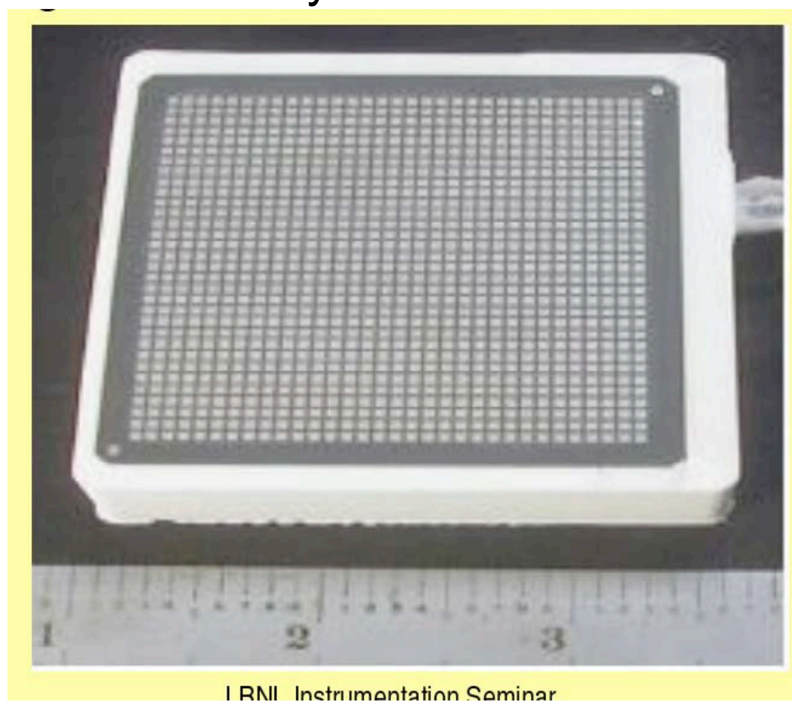


SE Calorimeter Manufacture Issues

- Similar to m^2 Low Pressure Gas Plasma Display Technology
- Proof of Principle/Manufacture - SE Calo sensor far simpler
- Hermetic + Voltages similar to dynodes
- Vacuum Supported by Ceramic walls or posts
  -> thin metal windows

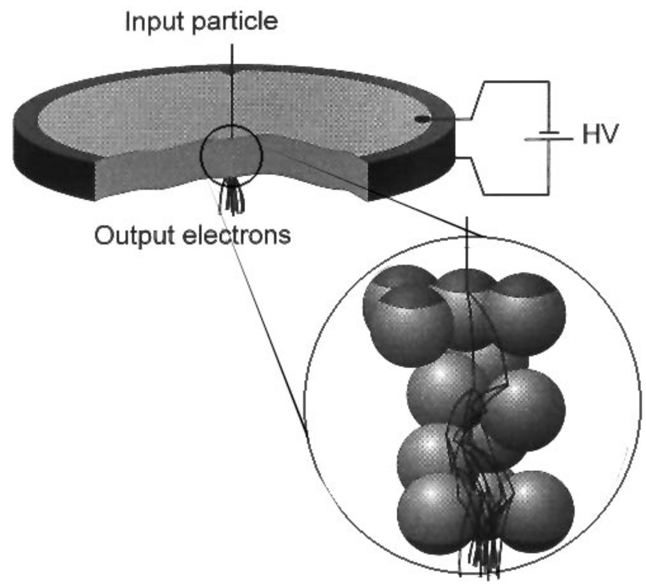


Ceramic Body 2.5” MCP-PMT

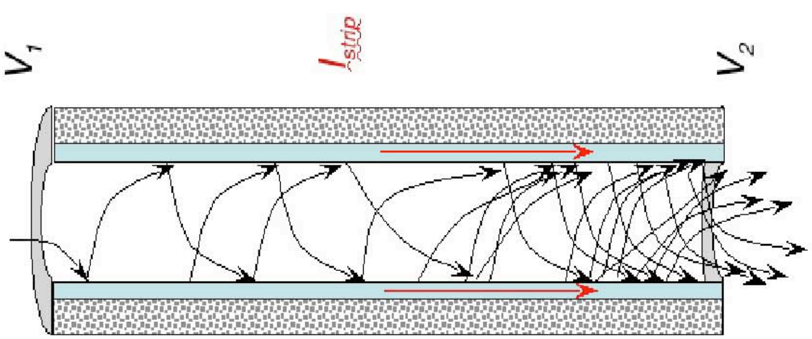


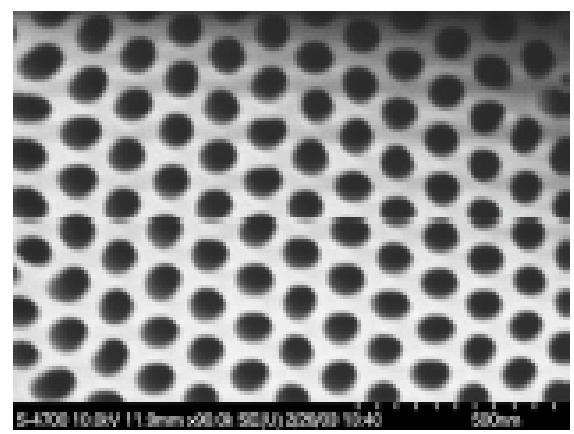
Alternative High-B SE e- Gain Mechanisms: MCP-Like Devices

A - El-Mul/A.Breskin
Sintered SE MicroSpheres ~20- 100 µm
Porous Plate: ~0.5-1 mm thick
Gain ~ 10^6 at 3000 V @ 1GΩ



B - Anodic Alumina ~ MCP-like?
~100 nm pores
Aspect ratio ~ 50-100:1





SLHC R&D technology
Secondary Emission Sensor Modules for Calorimeters

- **Basic Idea:** *Dynode/SE Stack is a High Gain Radiation Sensor*
- High Gain & OK Efficient (MgO yield ~0.1 e/mip)
- Compact (micromachined metal ~0.3-1mm thick/stage)
- Rad-Hard (PMT dynodes>100 GRads)
- Uber-Fast
- Potentially low cost/Non-Critical Assy
- Simple Al oxide SEM monitors proven at accelerators
- Rugged/Could be structural element
- Easily integrated into large calorimeters/Arbitrary Shapes
- ~Minimal Dead Areas
- Minimal services needed.

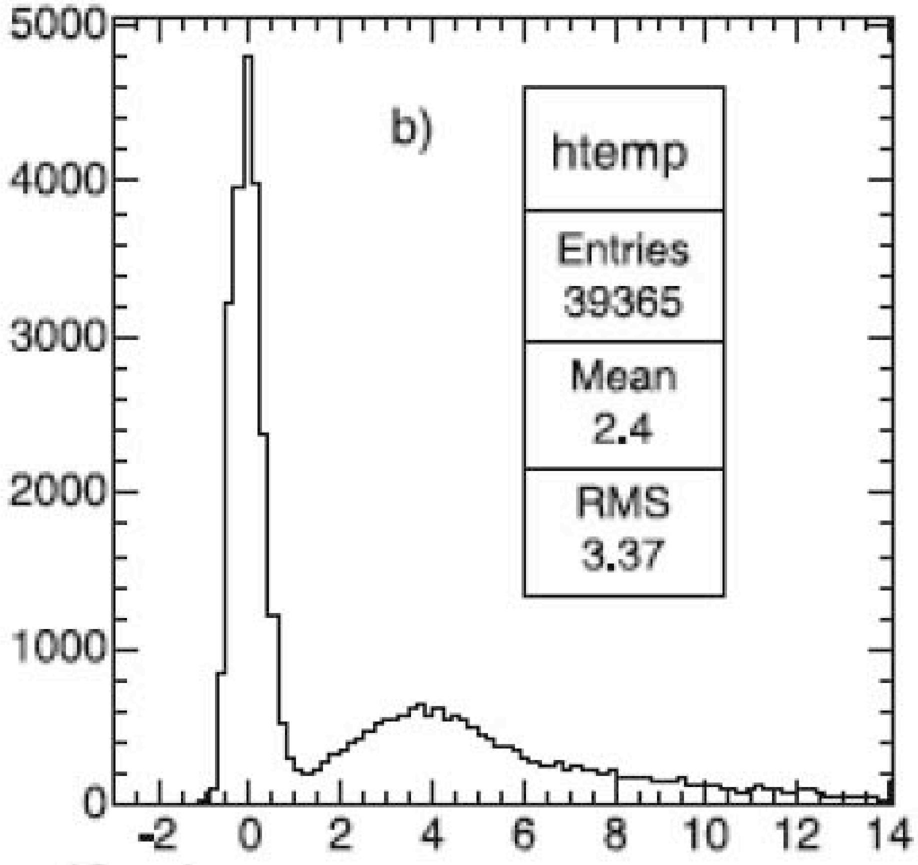
SE Detector Modules Are Applicable to:

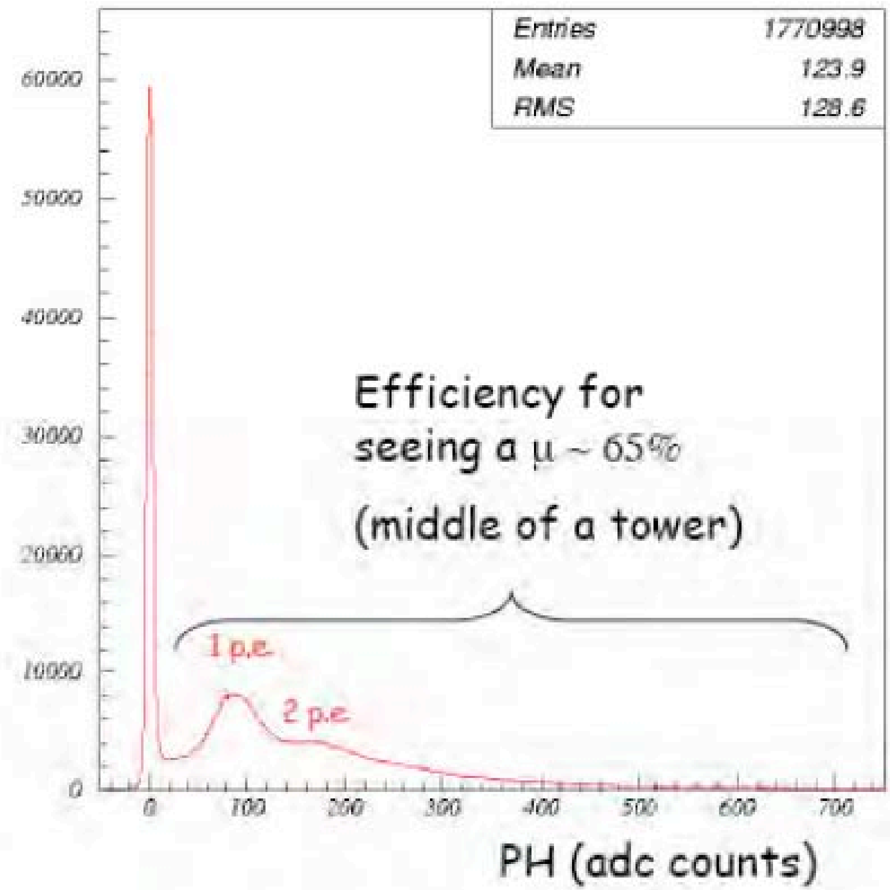
- Energy-Flow Calorimeters

- Forward Calorimeters

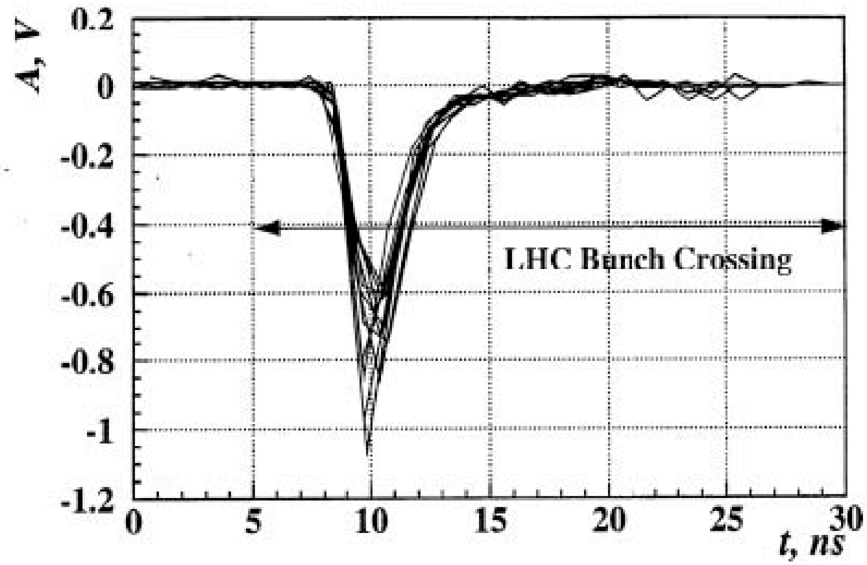
- Compensation

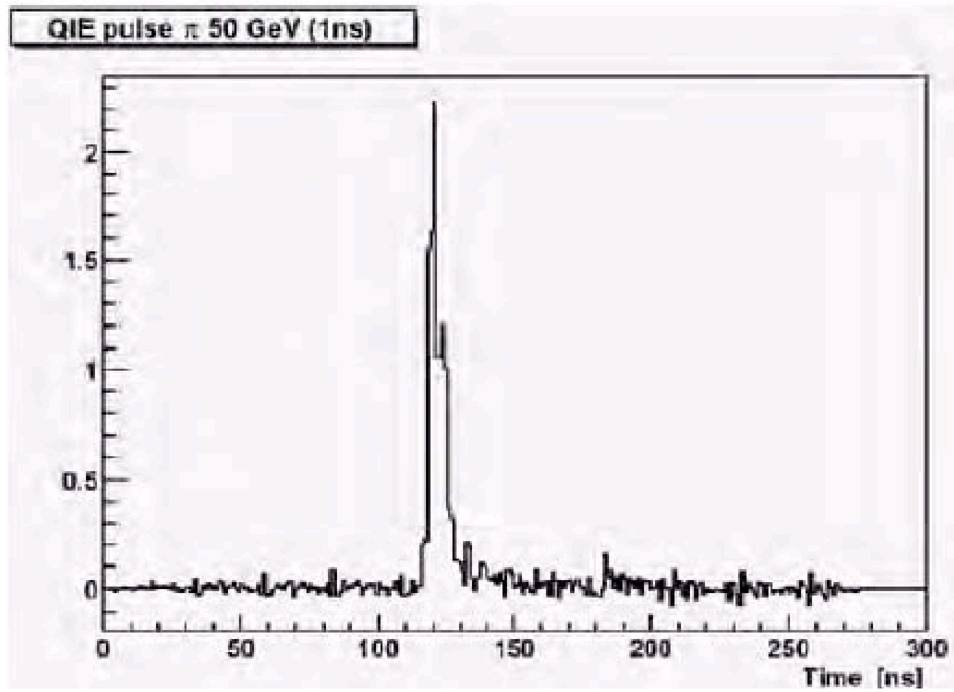
UBA Photocathode: Factor 2 Signal Size Enhances capability muon (inter)calib & ID





HF Muon Response: about 4 GeV/p.e., and >30% in pedestal/unduseable region. 1 MIP ~ 4 GeV in HF. This response would nearly double with modern photocathode PMT.

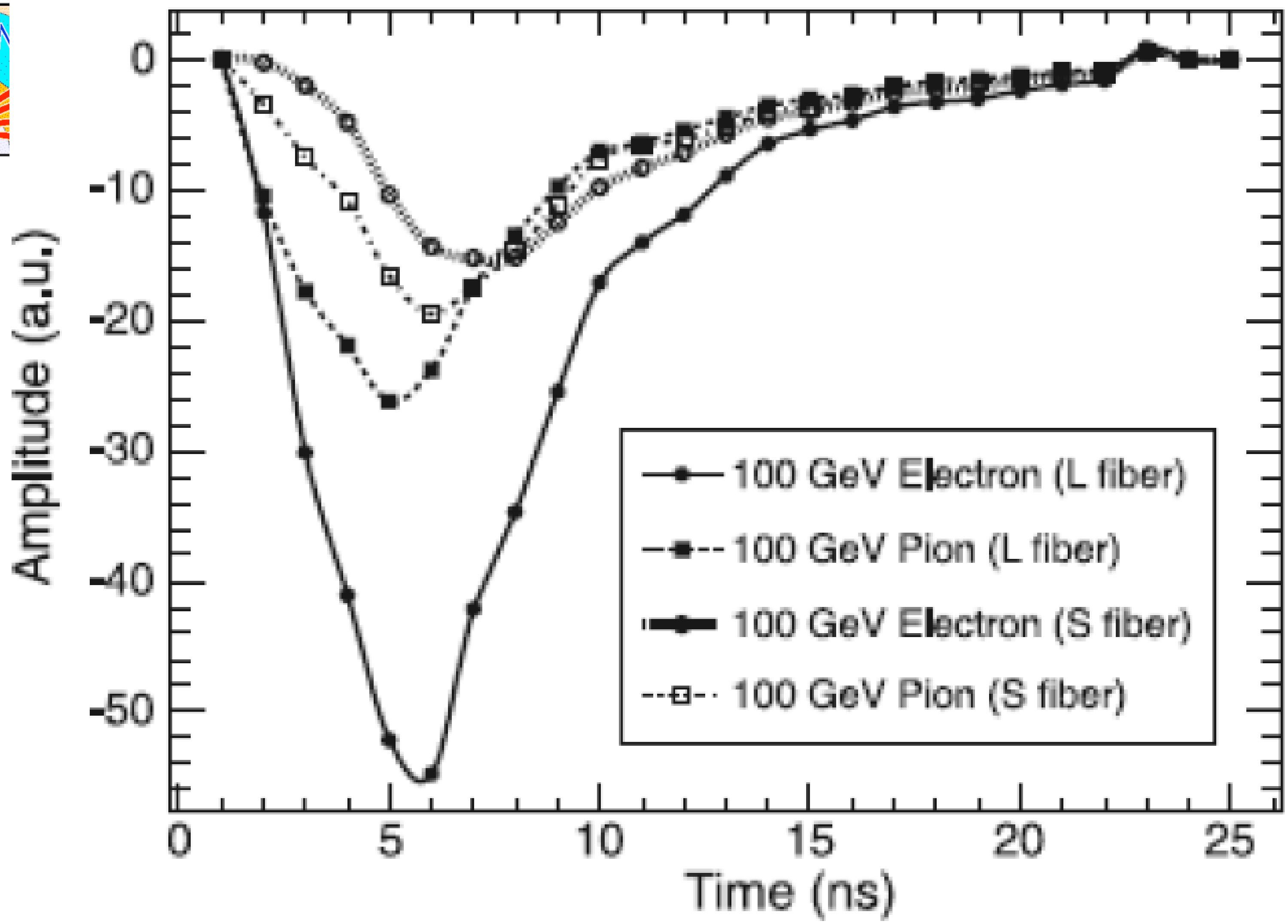




350 GeV pi's ('scope) ***Fast. Damn Fast.*** 50 GeV pi: FW10thMx 13 ns

Make QIE integration time variable for HF

12.5 ns integration removes 50% cosmics/beam halo, etc



Pulse Peak shifts by ~1 ns on good events from long/short fibers!

(ave skew rays ~ 1.5x slower than axial rays)

Use "constant fraction" peak timing to ID good events.

~1 ns Timing precision on pulse edges and peak enables:

- Tag/reject cosmics, beam-gas, halo, pit shine etc by x10-20

- Identifies events from IR

- Consistency checks/intercalibration between towers, L/S

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