A compact Si-W-Scintillator ECAL?

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ECAL requirements

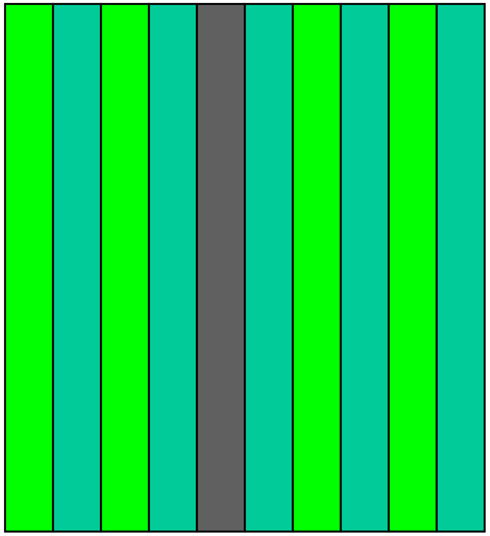
- Reasonable performance on single particle figures of merit :
  - Energy resolution : ≈ $10\%/\sqrt{E} \oplus 1\%$
  - Angular resolution : ≈ 1 mrad

  (a general purpose detector should not over-compromise on basic resolution)
- Hermetic – measurement of missing energy very important.
- Contribute to excellent jet energy resolution. Aim for $30\%/\sqrt{E}$.
  - Essential to separate photons from interacting charged hadrons
  - Higher B, higher R^2, smaller Moliere radius (transverse size)
  - So large volume, compact and dense
- Timing resolution.
  - Bunch crossings potentially every 1.4 ns.
  - Time resolution of 300 ps for photons helps
- Affordable.

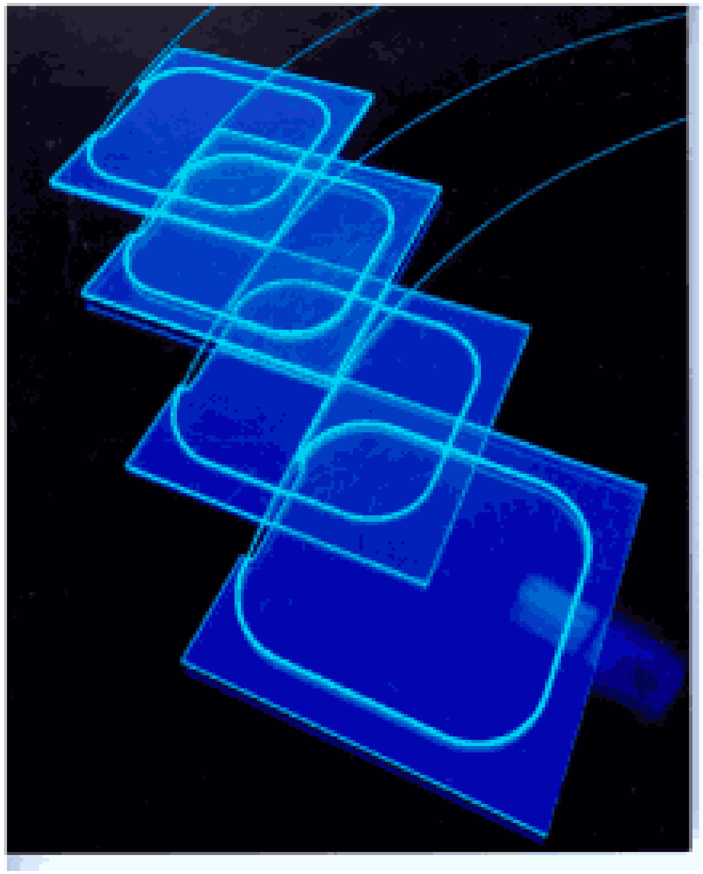
Tungsten-Silicon ECAL

- Proposals exist for W-Si ECAL.
- The TESLA design, R=1.7m, 40 layers of Silicon pads looks as if it can do the job (except maybe the timing), but is costed at 133 M$ (driven by 3$/cm^2 Si cost)
  - Eres = 10%/$\sqrt{E}$, Moliere radius = 16.5 mm
- Our proposal centers on developing a cost optimized ECAL, with similar performance. This hybrid calorimeter would use Silicon sensors to do the fine pattern recognition and position measurement, plastic scintillators for fine sampling and timing.

Sc-W-Sc-W-Si-W-Sc-W-Sc-W



Tile/fiber technique



(CMS photo)

Use blue scintillator.

Embed wavelength shifting fiber which absorbs blue light, re-emits in the green.

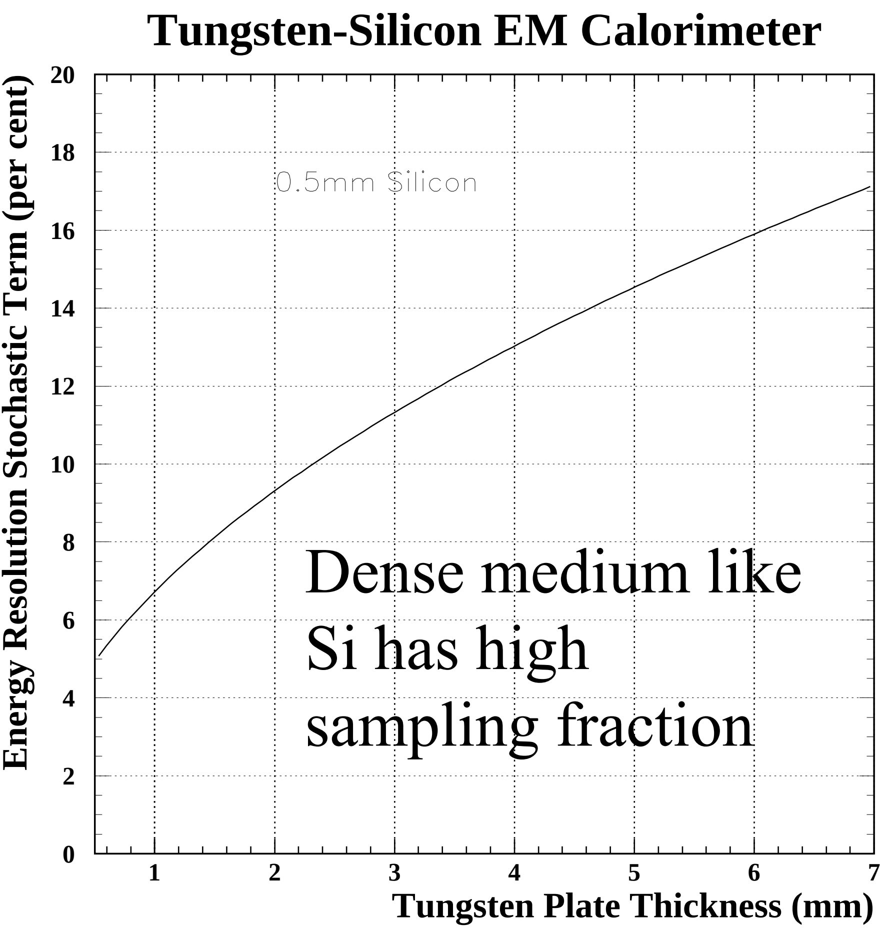
See sample – from OPAL scintillating tile detector (rescued from CERN garbage)

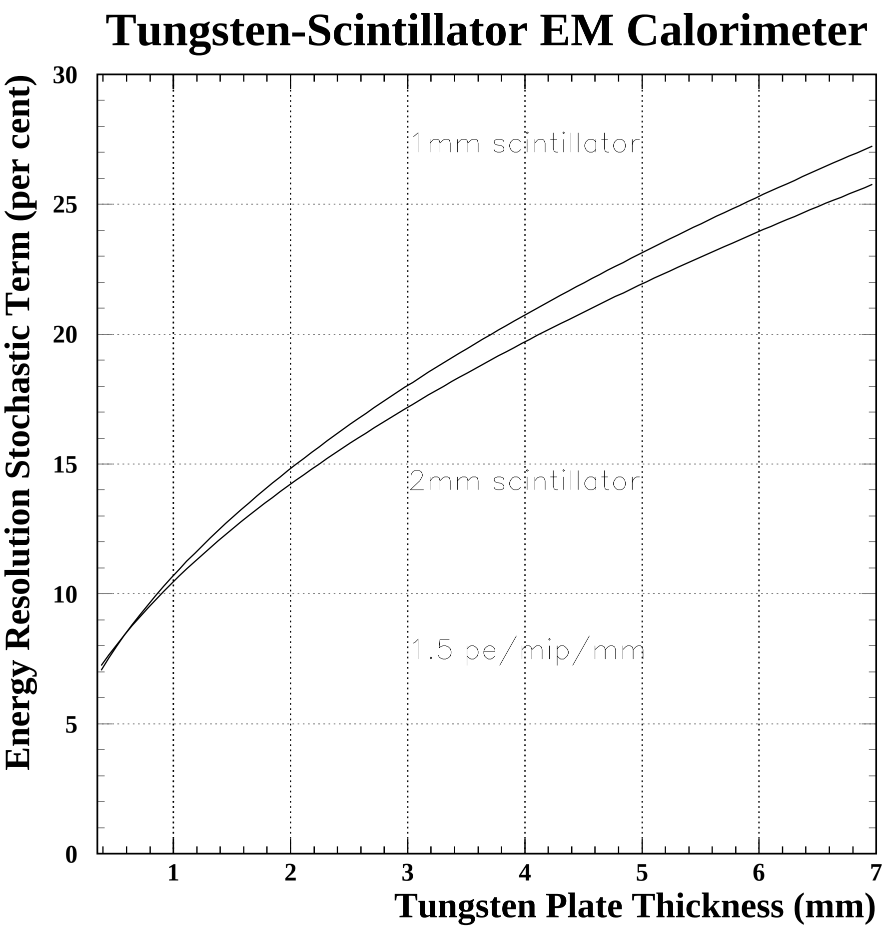
Several fibers can be seen by one photo-detector

CDF existence proof (plastic transparency)

Hopefully this will be scanned.

ECAL Design Issues : Sampling Frequency

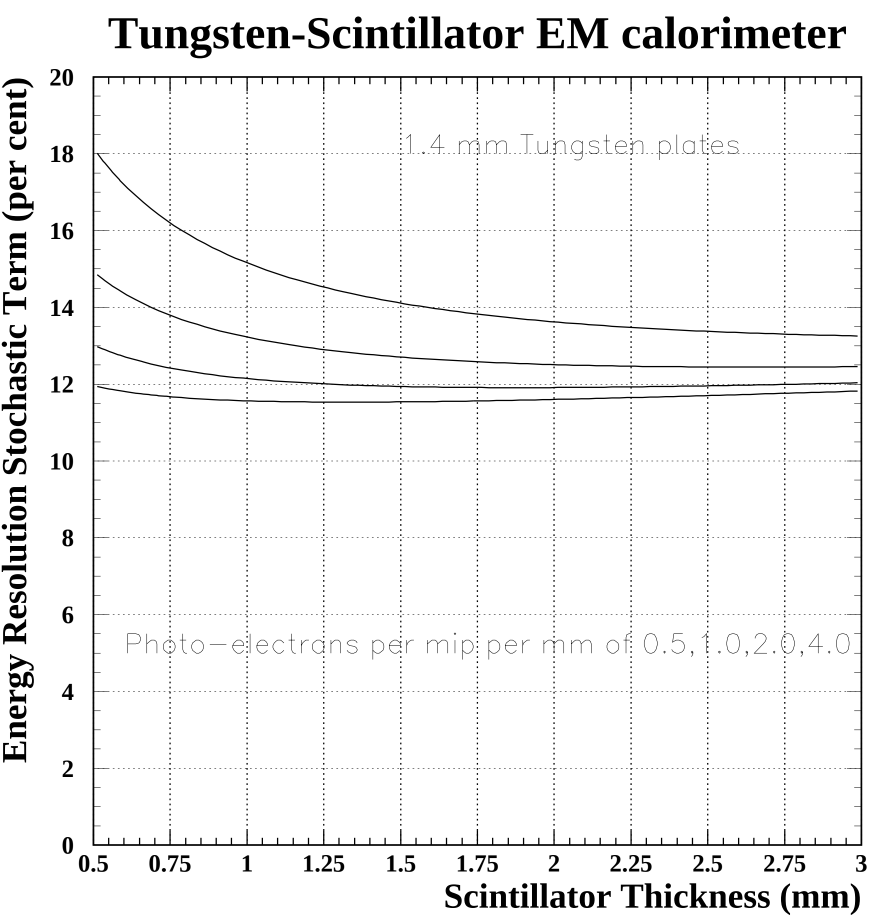


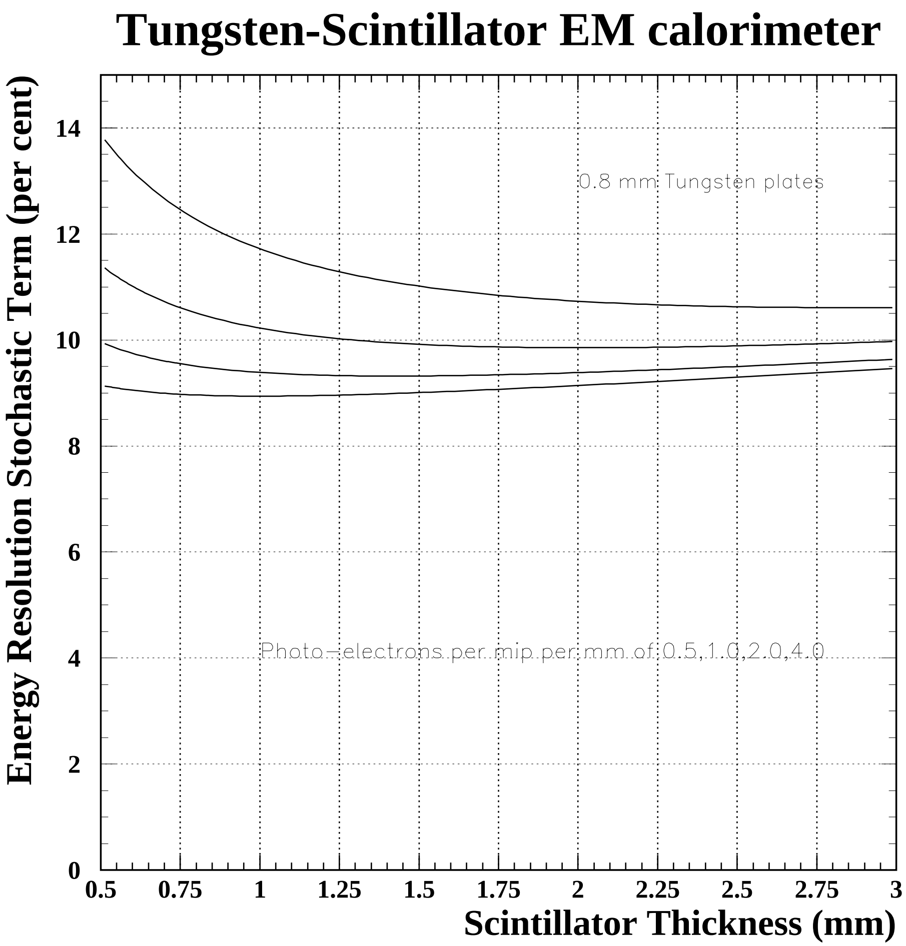


Issues : cost of many layers of active medium

Cost of thin sheets of absorber.

ECAL Design Study : Sampling Thickness

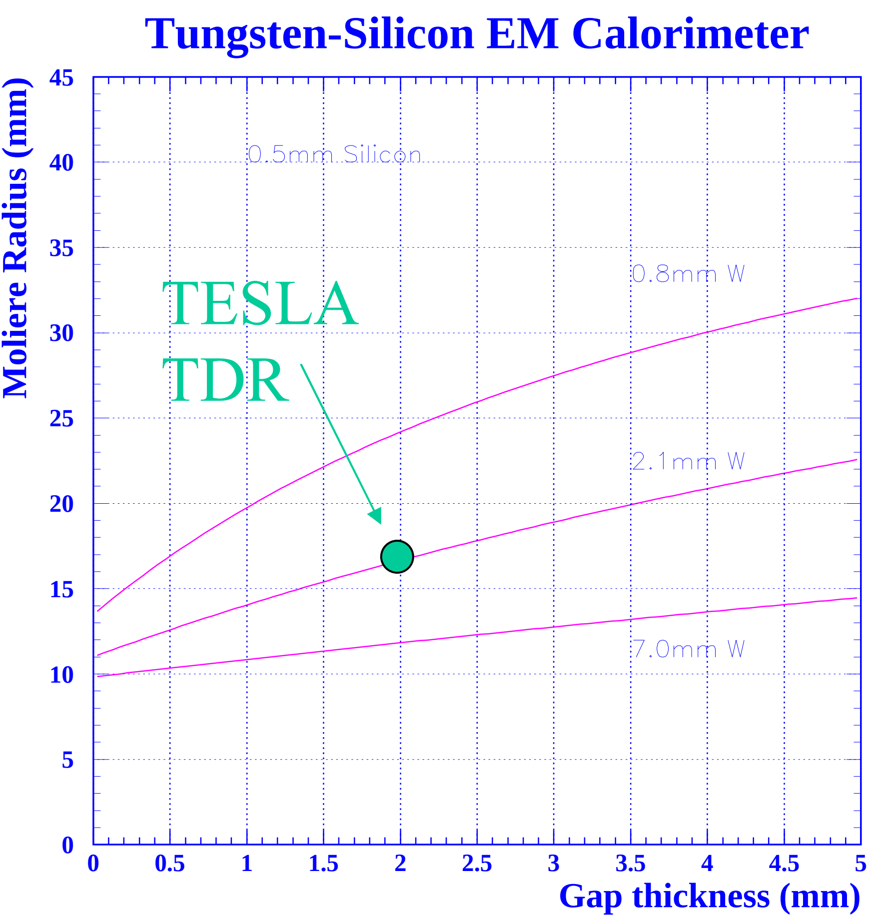


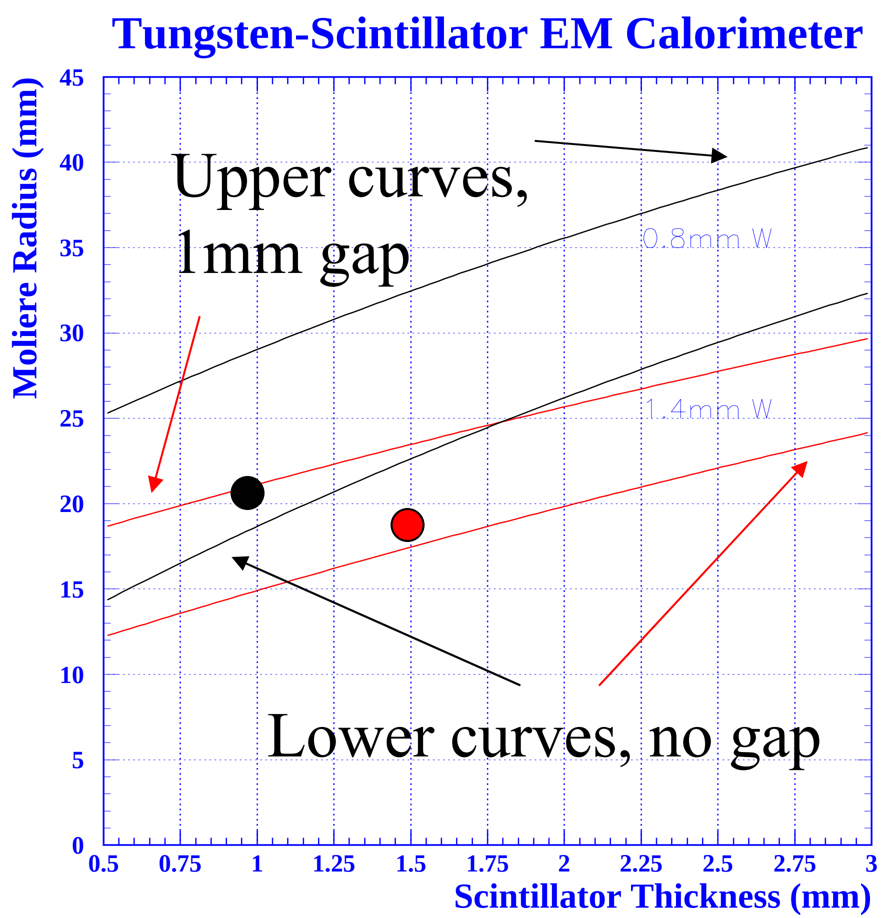


For thin scintillators, need enough photo-electron statistics. (Kawagoe et al, 3.2pe for 1mm scintillator)

1.5 pe/mip/mm looks like a sensible target for thin tiles

Compactness





Need to minimise gaps, reduce space needed for fiber routing, by sharing fiber routing gaps among layers

Two strawman designs

- 1.4mm W plates
- 12 layers Si
- 48 layers of 1.5mm Scintillator
- 4 layers ganged together (1.5pe/mip/mm) -> 9 pe per super-layer.
- 12 super-layers in total with mip-detection in each super-layer

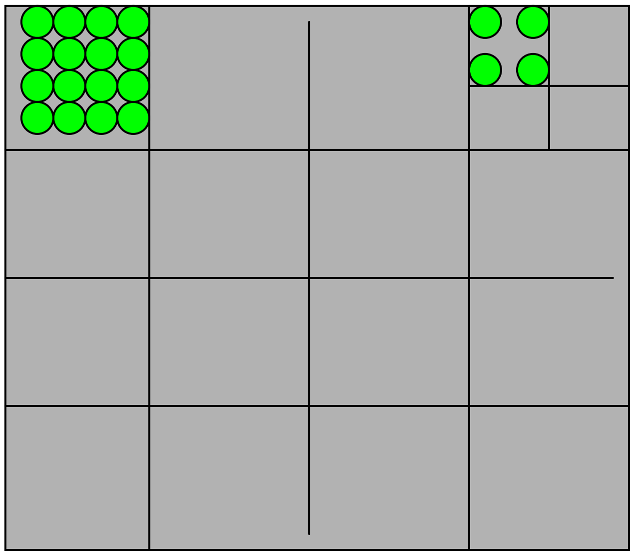
- 0.8mm W sheets
- 12 layers Si
- 96 layers of 1mm Sc
- 8 layers ganged together -> 12 pe/mip/super-layer
- 12 super-layers in total with mip-detection in each super-layer

E res :	12%/√E	9%/√E
Moliere radius :	18 mm	21 mm

30% of the Silicon cost

(TESLA TDR 10%/√E, 16.5 mm)

Possible photo-detectors



Makes optical summing of several layers easy

Hamamatsu, multi-anode PMT, with 18mm×18mm sensitive area.

16-channels has 16×4.5× 4.5mm (16 1mm ϕ fibers)

64-channels has 64 × 2.25 × 2.25 mm (4 1mm ϕ fibers)

Wacky ideas ??

- Temporal calorimetry. Time-stamp every energy deposit.
- Lead-loaded scintillator
  - denser, better response to soft photons.
- Germanium ? (Ge > Si > Sc.)
- Using different response of scintillator and Silicon to differentiate neutron induced energy deposits.
- Multiplexing in time if time resolution good enough
- Hybrid design – Si can aid scintillator response calibration

Scintillator/WLS matching (plastic transparency)

Hopefully this will be scanned

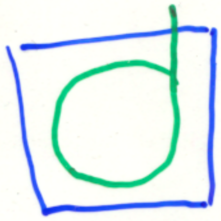
R&D issues

- Calorimeter design optimization.
  - No. of layers, R, absorber thickness, detector thickness, sampling frequency vs depth, transverse granularity of Si/Sc, tile shapes, groove patterns, gap sizes. Should Si-layer be independent of scintillator layers ? How many Sc. Super-layers. (12,6,4,3,2,1 ?). Fiber routing. Timing resolution.
  - Need to study with full shower simulation.
  - Plan to use OPAL optics simulation in tile-fiber design and testing studies.
- Demonstrating basic performance characteristics
  - Light yield for thin scintillating tiles
  - Response uniformity
  - Scintillator/WLS/Photo-detector for timing
  - Fiber routing for compact calorimeter
  - Sound mechanical design
  - Good quality thin absorber plates (sintering is cheap ..)
  - Photo-detector characteristics

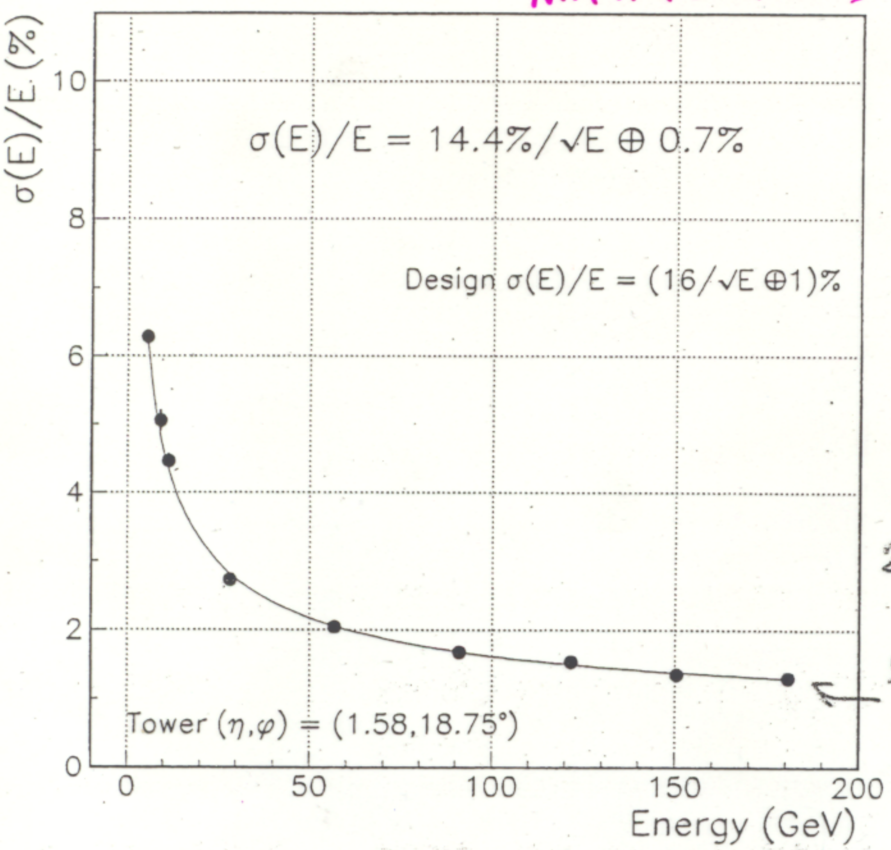
Getting started with lab test-stand with cosmic rays and sources. Good for involving students.

CDF PLUG CALORIMETER

TILE / FIBER



NIM A 480 (2002) 524.



22 LAYERS

$n_{pe/layer/MIP} = 6$
(REQUIRED 3)

4 mm Scintillator.

$20X_0$

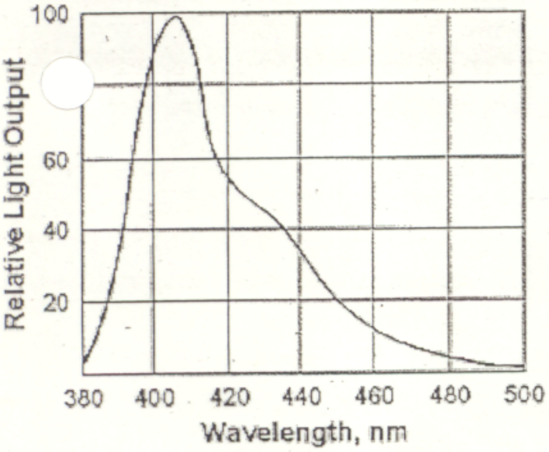
leakage?

PRETTY IMPRESSIVE (BUT AT CENTER OF TOWER)

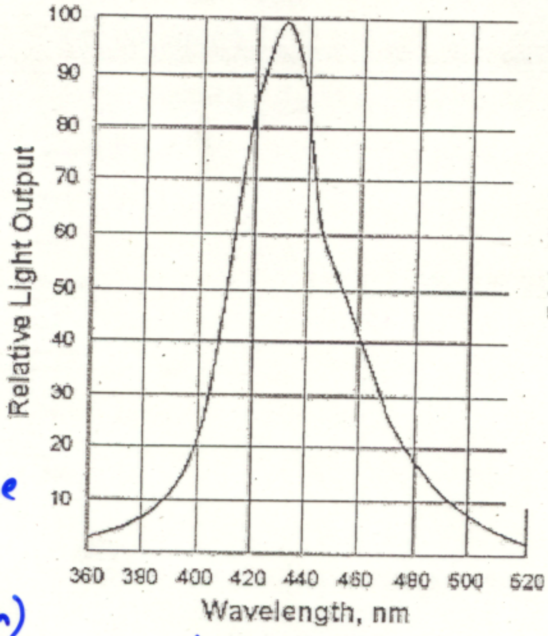
RESPONSE NON-UNIFORMITY ≃ 2%
(& AT SOME LEVEL – CORRECTABLE)

$C_{STOCHASTIC} < 15\%$, $C_{CONSTANT} < 1\%$
INDEPENDENT OF POSITION.

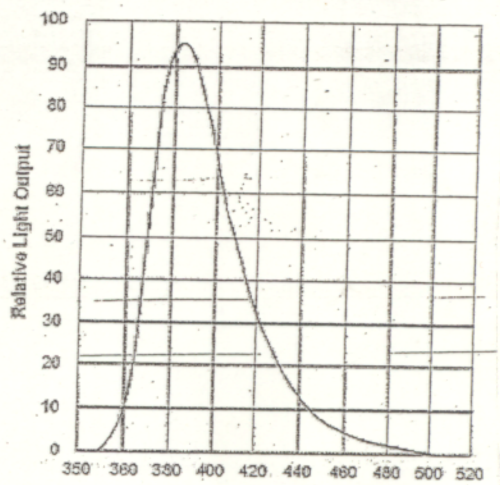
Emission Spectra - BC-404



Emission Spectra - BC-408



Emission Spectra - BC-418 & BC-420



Light : 68% Anthracene
Δt : 2.2ns
λ : 140cm (t=1cm)

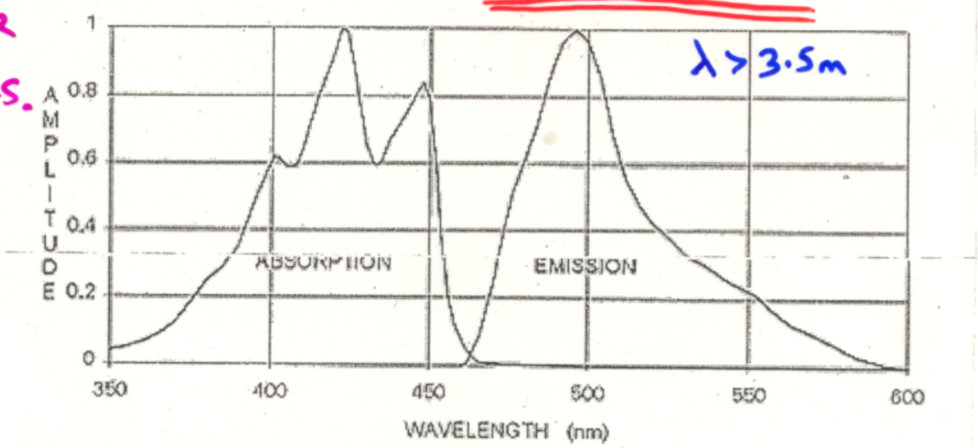
Light : 64%
Δt : 2.5ns
λ 210cm

64%
Δt 1.3ns
λ 140cm
RISE-TIME = 0.5ns

STANDARD
BC408 (SCINTILLATOR)
+ BCF91A (WLS FIBER)
HAS RELATIVELY POOR
TIMING CHARACTERISTICS.

Optical Spectra - BCF-91A

DK time : 12ns
λ > 3.5m



ESPECIALLY FOR
SMALL TILES
(BC-404 OR BC-420)
+ BCF92
WITH λ ≃ 400nm
MAY HAVE BETTER
WLS ABSORPTION MATCH
+ FAST TIMING.

Optical Spectra - BCF-92

DK time : 2.7ns
λ > 3.5m