

# SiD Hadron Calorimeter

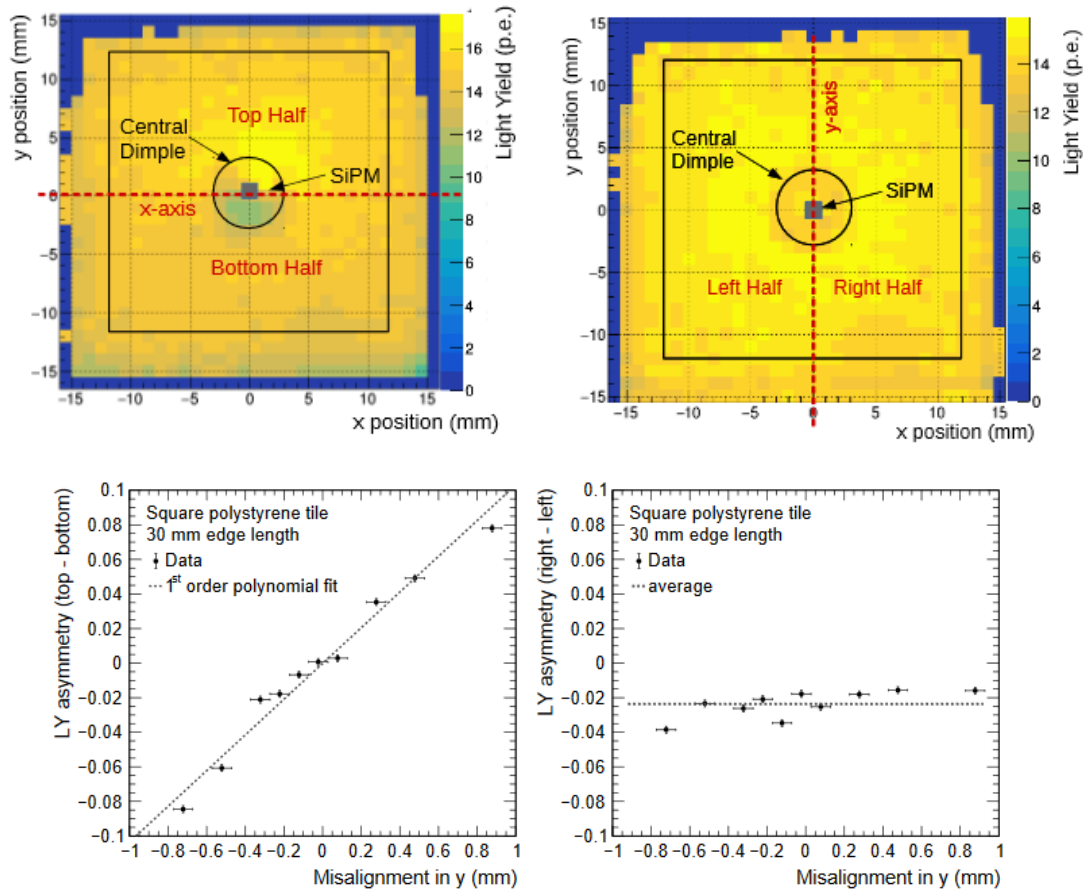
## Factors affecting resolution/performance

Explore factors for HCal:

- SiPM/Tile misalignment
- Tile response uniformity
- Tile wrapping response uniformity
- MIP calibration
- SiPM factors in simulation (Saturation, smearing, temperature,...)
- MIP threshold variation
- Dead channels
- Tile size(s)
- Sampling fraction
- ...?

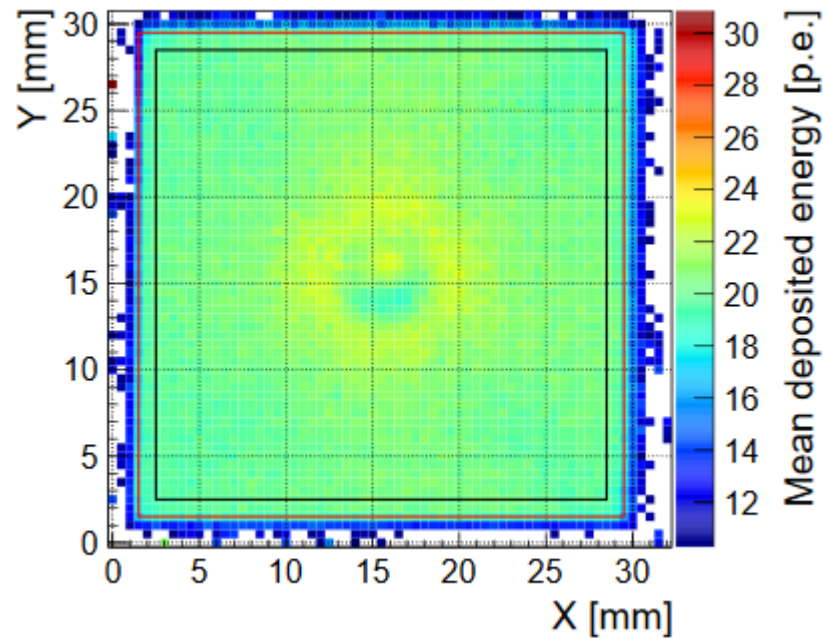
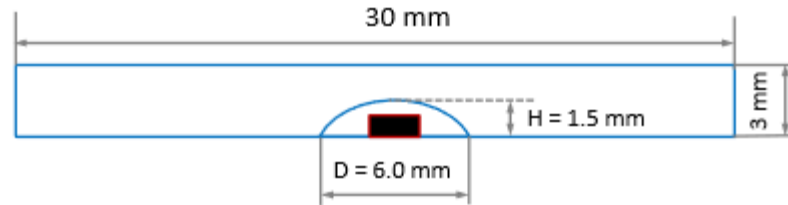
A. Prior, A. White – U. Texas at Arlington

# Effects of misalignment on response uniformity of SiPM-on-tile technology



Dipole asymmetry 0.1 per 1mm displacement  
~80% of Tile has response within 5% of mean  
-> **Limit asymmetry to 0.05 or 500  $\mu\text{m}$**

# Tile Response Uniformity

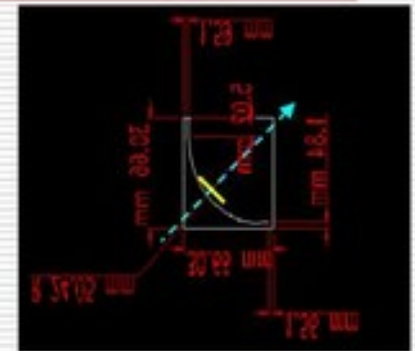
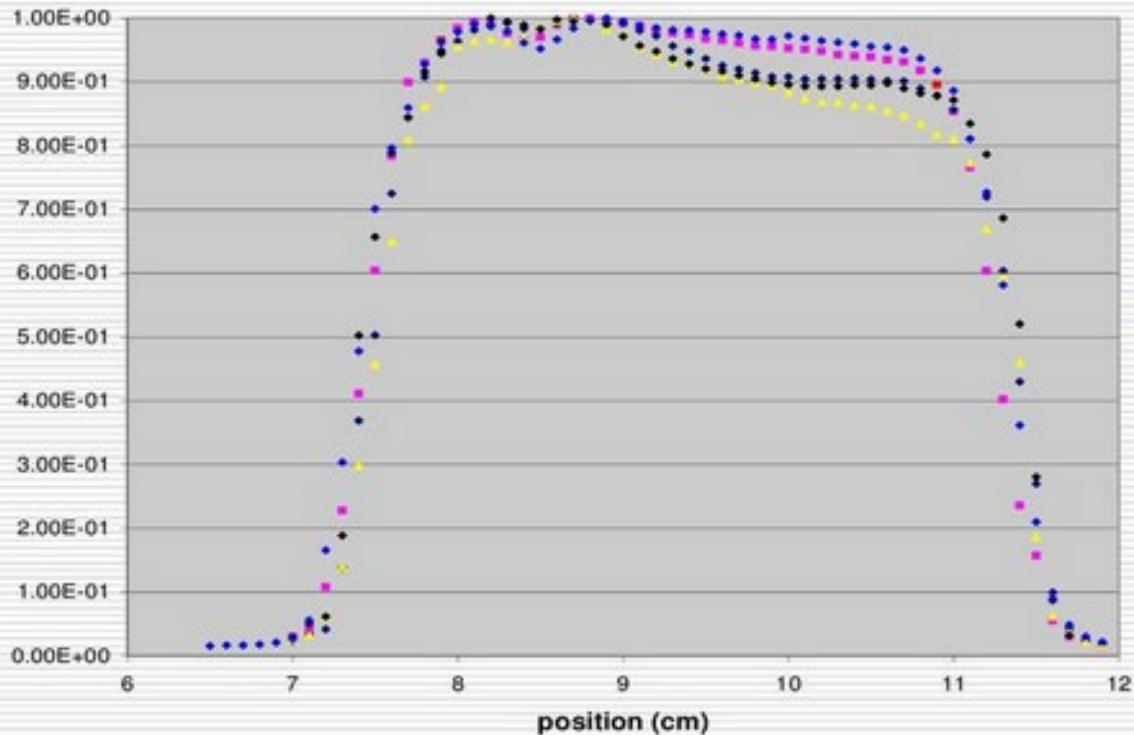


97.1% (80.8%) of the tile area is within 10% (5%) deviation from the average response of 20.6 p.e. to electrons ( $^{90}\text{Sr}$ )

2015

# Uniformity and Reflectors

Normalized to Maximum for each set of data



- 1 layer VM2002 June 11
- 2 layers Tyvek June 14
- 1 layer CM500 June 15
- 2 layers Tyvek June 8
- 1 layer VM2000

11/23/2018

V. Zutshi,ALCPG04,Victoria

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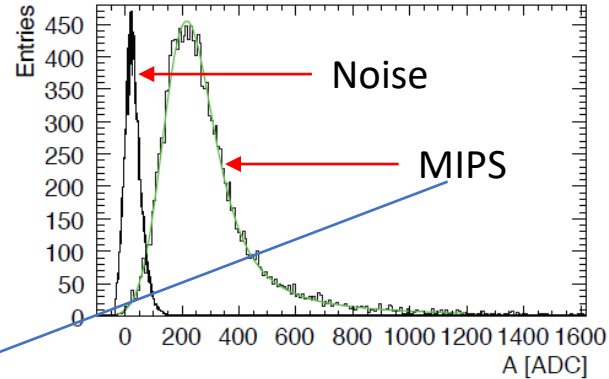
# HCal Calibration



## CALICE AHCAL Prototype

### MIP calibration using muons

SiD - per channel MIP calibration using muons  
 – time for whole calorimeter exposure?

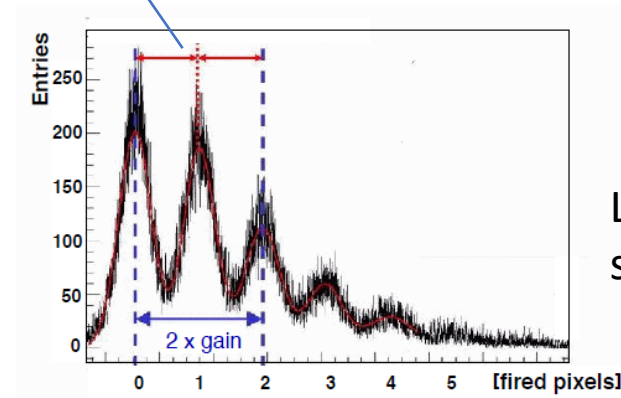


Noise cut efficiency ~95%  
 - expected to be much lower with newer SiPMs

$$E[\text{MIP}] = A/A_{\text{MIP}} \cdot f(A/A_{\text{pixel}})$$

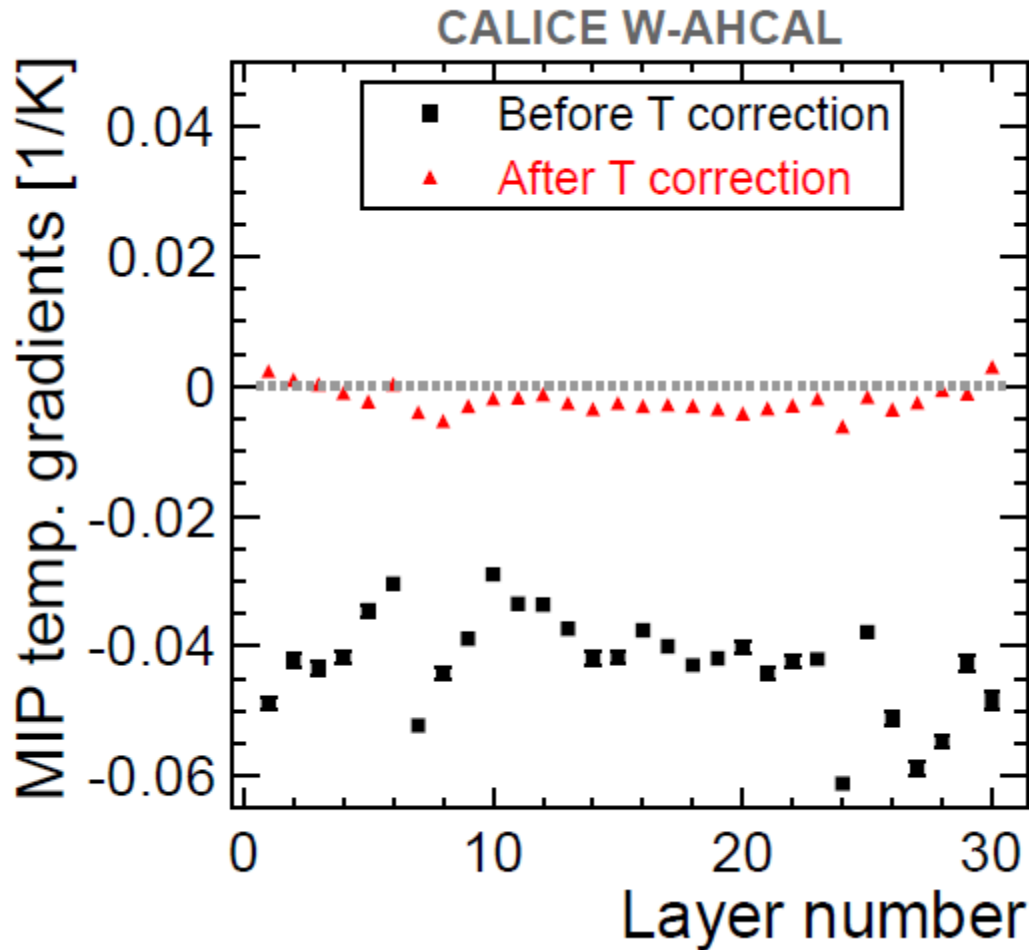
Determined on test bench for each SiPM

Gain calibration  
 (Separation of photoelectron peaks)



LED induced signals

# Temperature variations and corrections



Residual variation  
after correction  
~ few per mil.

$$V(T) = V_{\text{bias}} - V_{\text{breakdown}}(T)$$

$$50 \text{ mV/K}$$

$$E[\text{MIP}] = A/A_{\text{MIP}} f(A/A_{\text{pixel}})$$

$$A(T) = A(T_0) \cdot (1 + C_T \cdot (T - T_0))$$

F. Sefkow, A. White et al.  
REVIEWS OF MODERN PHYSICS, VOLUME 88

# SiPM simulation – as implemented

- 1) Basic energy to number of p.e. conversion:

$$npe = \text{Energy (GeV)} \times pe\_per\_MIP/mip\_calib$$

- 2) Saturation from limited number of pixels:

$$npe = N_{pixel} \times (1 - e^{-(npe/N_{pixel})})$$

- 3) Binomial smearing:

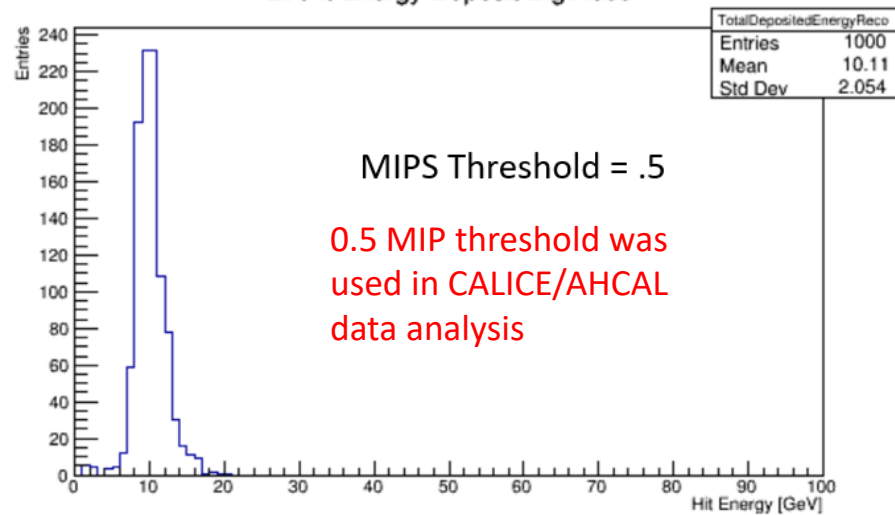
$$npe = \text{RandomBinomial}(N_{pixel}, p) \quad p = \text{fraction of hit pixels on SiPM}$$

- 4) Variation of pixel capacitance:

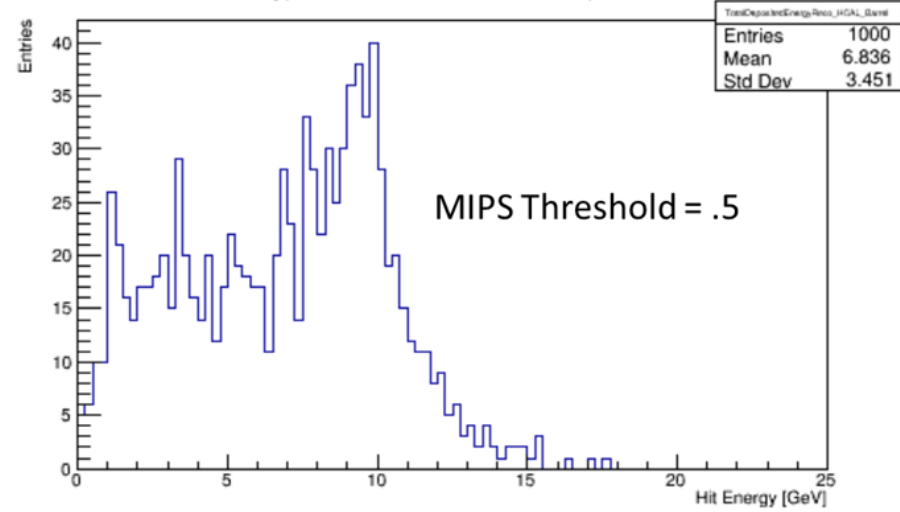
Gaussian distribution.

# MIP Threshold dependence

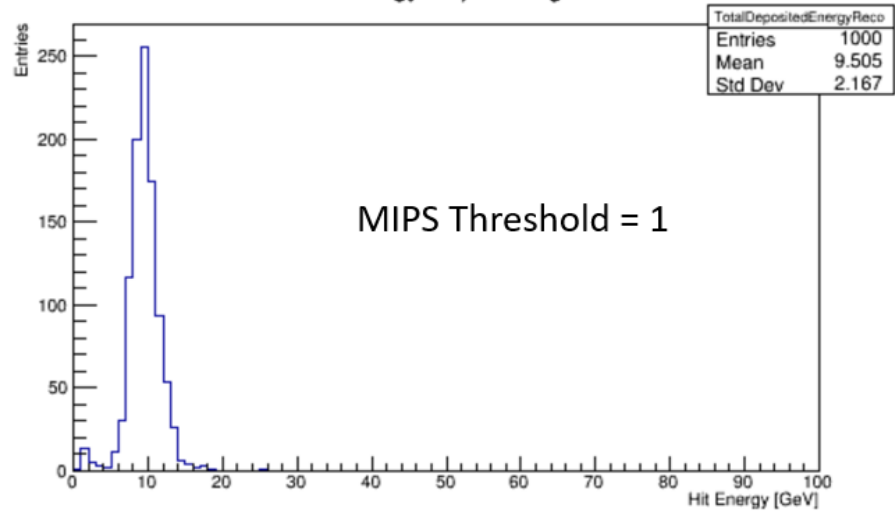
Event Energy Deposit DigiReco



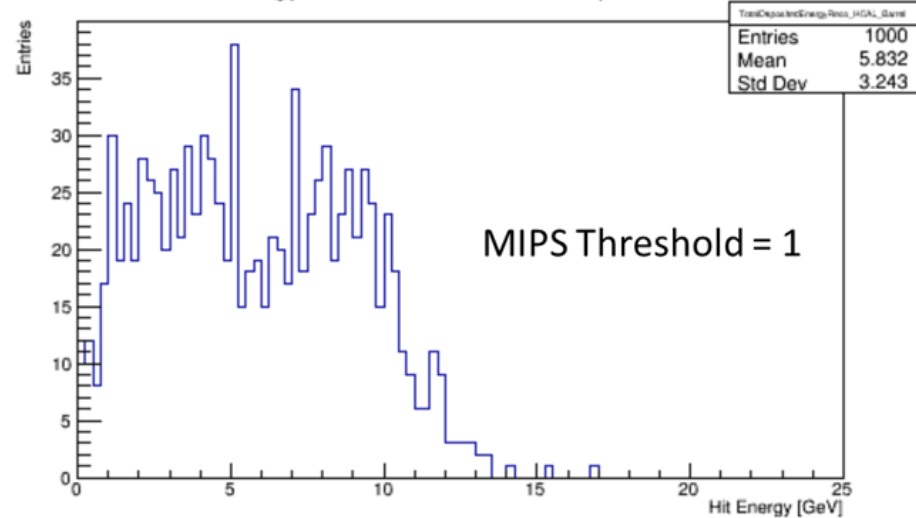
Total Energy of all hits AHCAL Barrel per reco event



Event Energy Deposit DigiReco

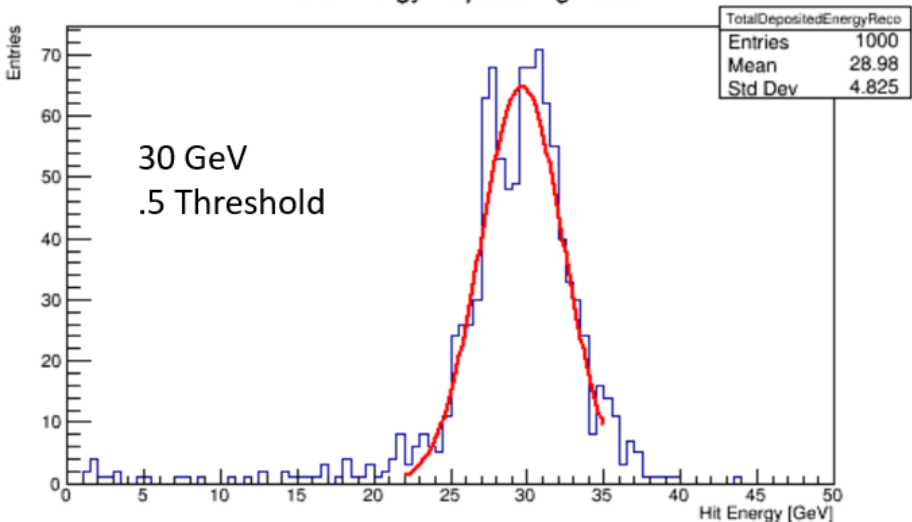


Total Energy of all hits AHCAL Barrel per reco event

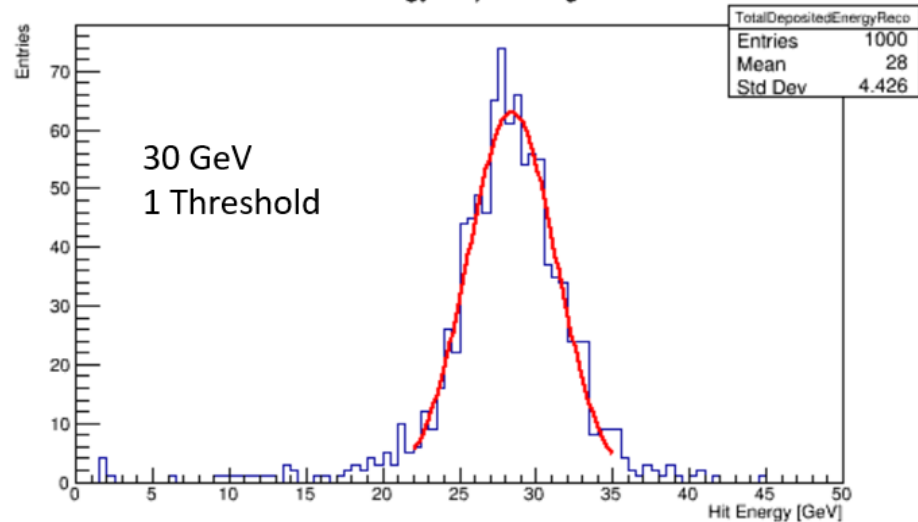




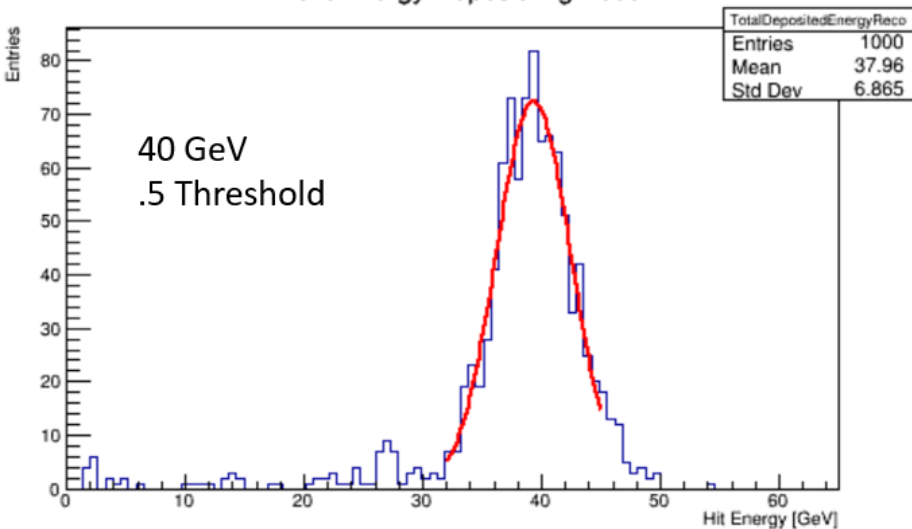
Event Energy Deposit DigiReco



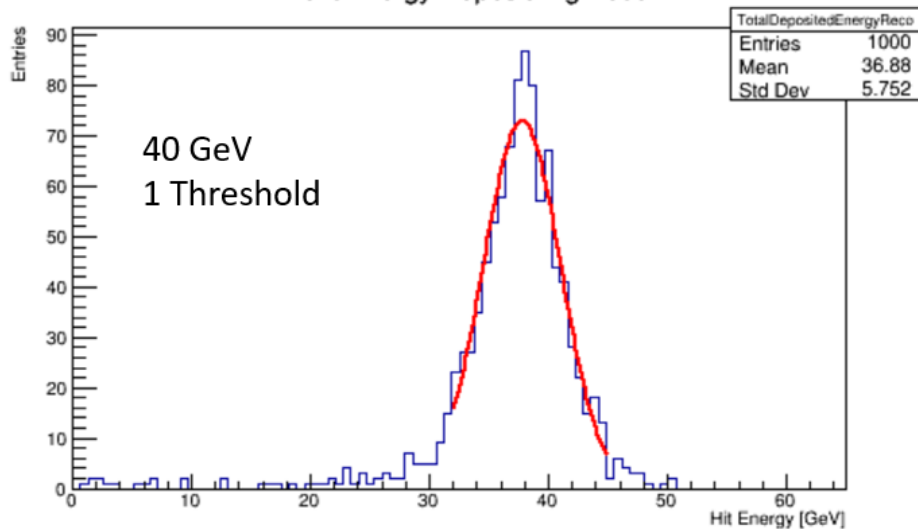
Event Energy Deposit DigiReco



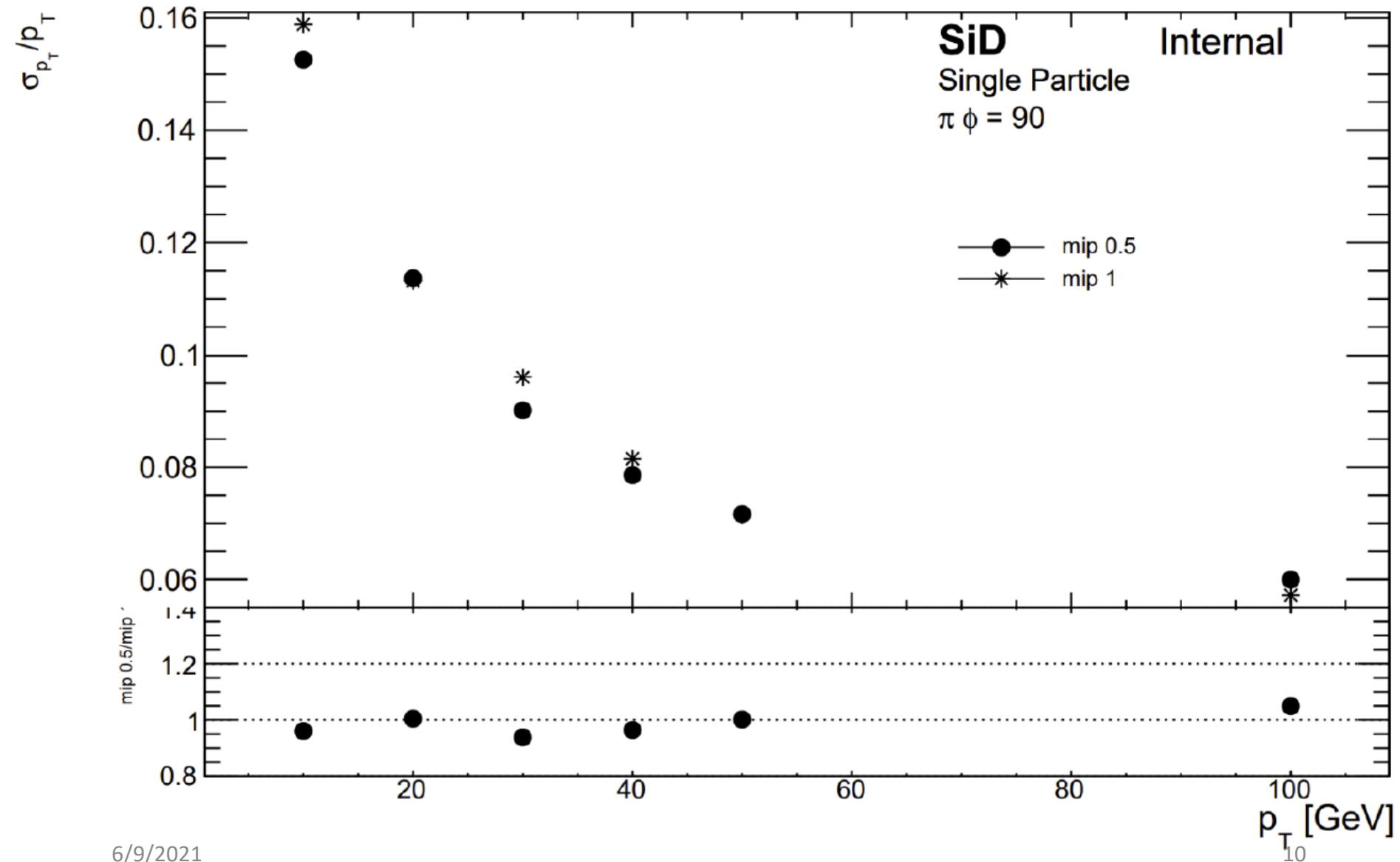
Event Energy Deposit DigiReco



Event Energy Deposit DigiReco

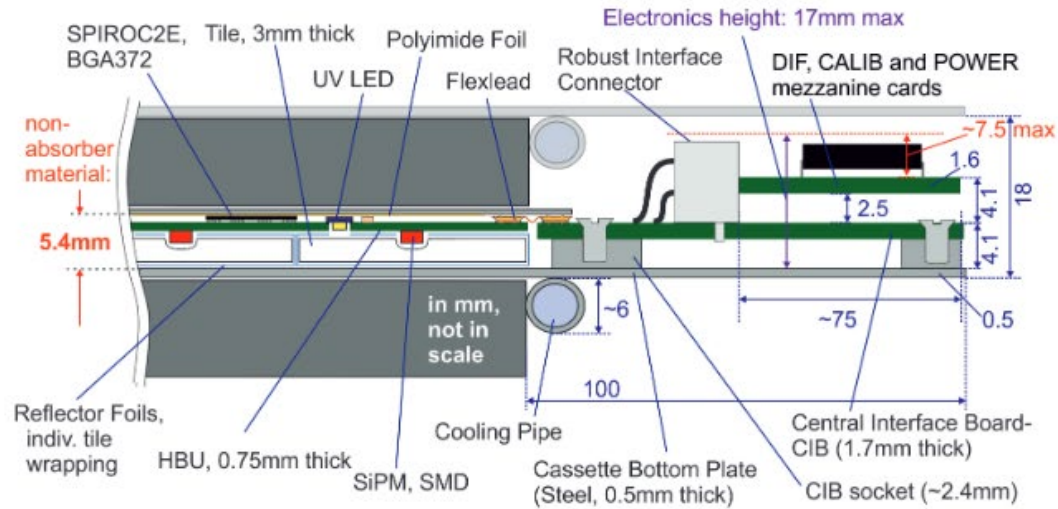
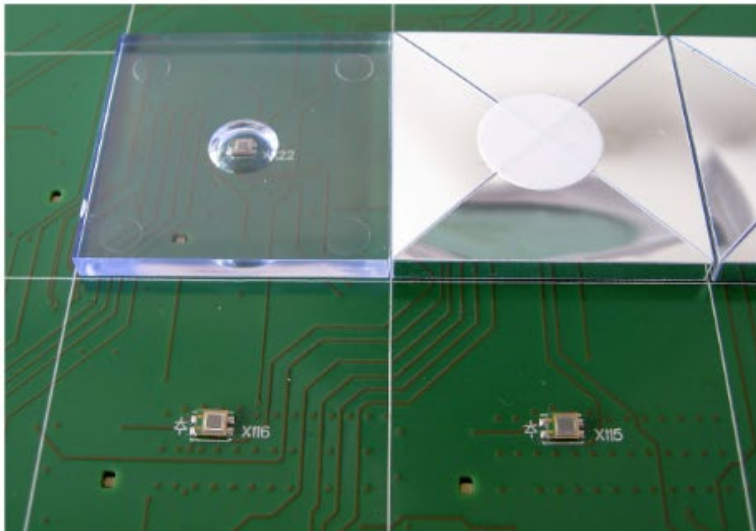


# MIP Threshold dependence



# Dead and Uncalibrated channels

## CALICE HCal Technological Prototype



Number of channels = 21,888

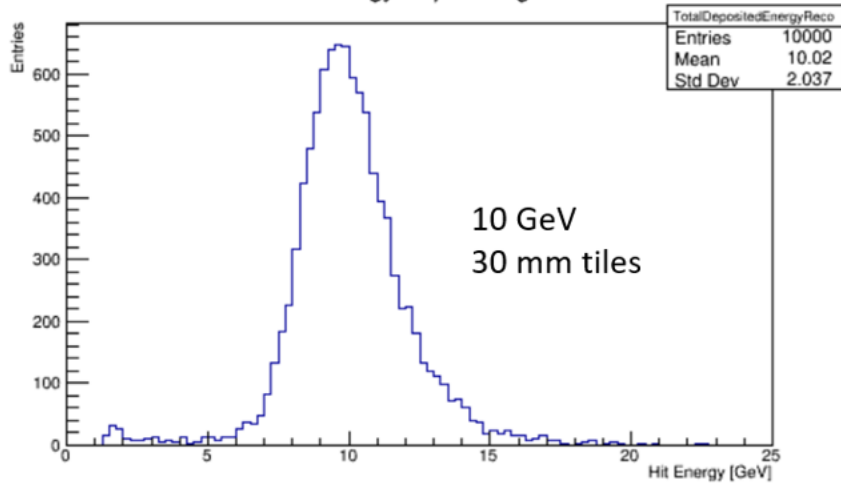
Number without possible MIP calibration = 19 (~0.1%)

Number of dead channels = 6 (out of 19) ~0.03%

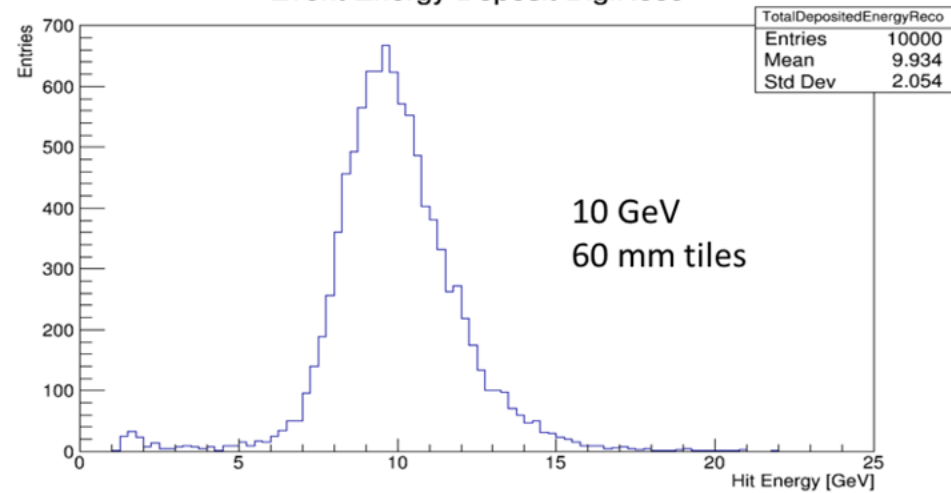
(Was 2% in first prototype + 0.5% after transport CERN to Fermilab)

# HCal Tile Size

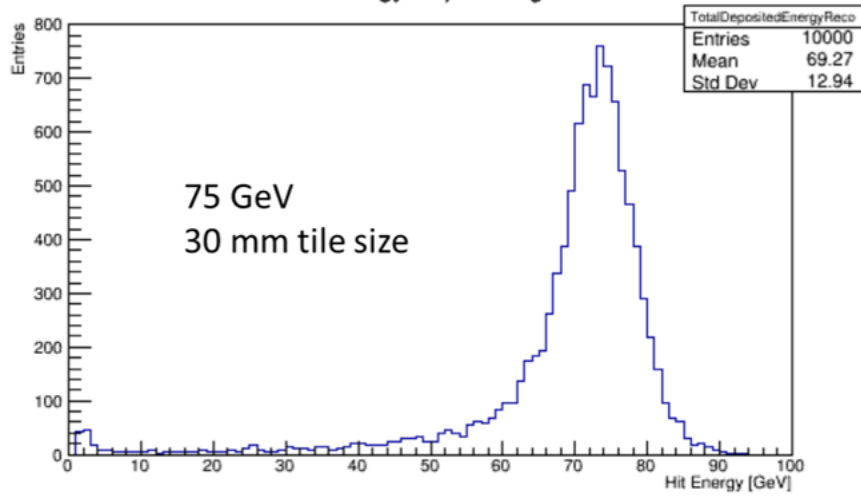
Event Energy Deposit DigiReco



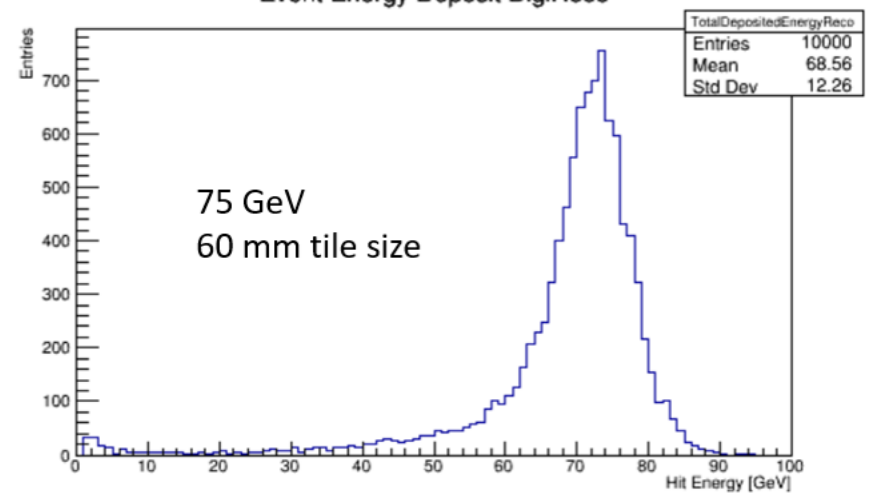
Event Energy Deposit DigiReco



Event Energy Deposit DigiReco

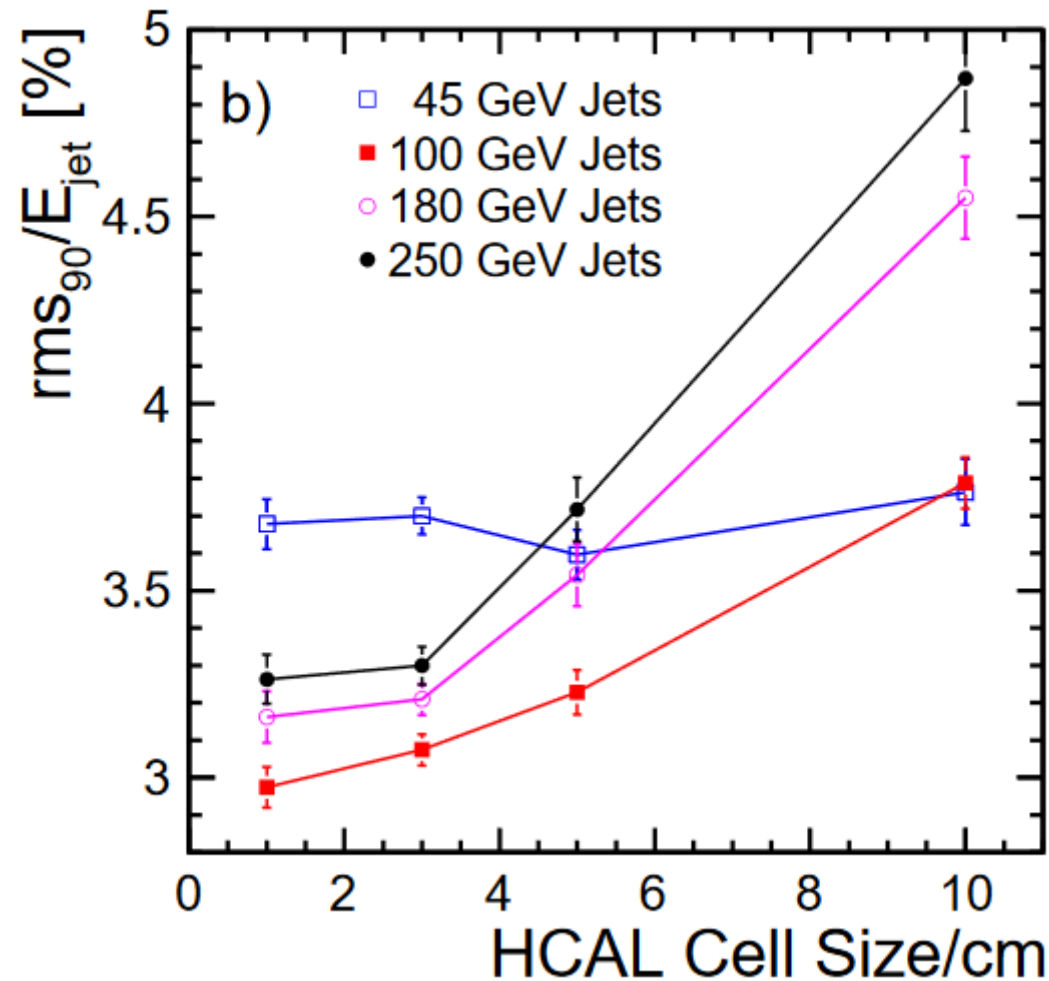


Event Energy Deposit DigiReco



-> Not much variation

However, improvement for 3 x 3 cm<sup>2</sup> vs 6 x 6 cm<sup>2</sup> tiles  
- particularly for higher energy jets



M. Thomson  
arxiv.org: 0907.3577

# Tile-tile gaps?

Tyvek tile wrapping

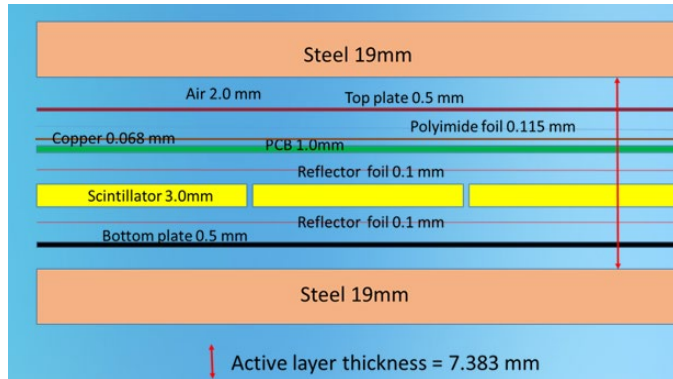
7.3 mil thick = 185  $\mu\text{m}$  -> tile-tile gap = 370  $\mu\text{m}$

Offset tile layers?



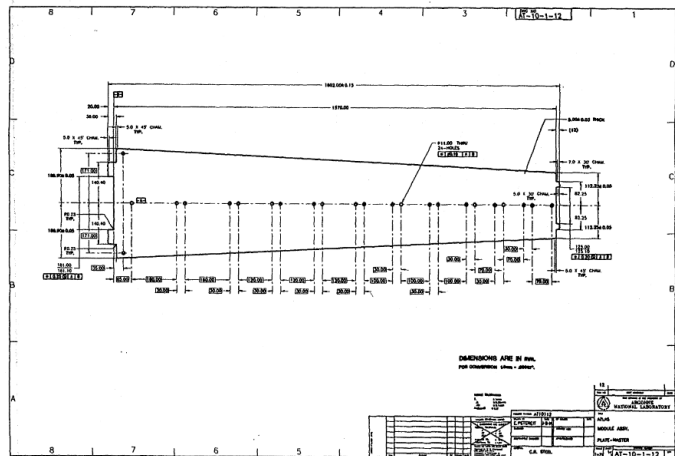
Robotic assembly – pick, wrap, place (+offset?), edges of modules?

# Steel plate thickness variations and sampling fraction



19mm steel plates.

Thickness tolerance?



ATLAS Tile Calorimeter

5mm steel plates  
(low Carbon rolled steel)  
 $\pm 0.03$  mm single plate tolerance

# SiD Hadron Calorimeter

## Factors affecting resolution/performance

Next:

- Evaluate parameters worth varying in simulation.
- Single particle tests.
- Test effects on jet energy resolution.
- Calibration/validation procedures



Extra

HCAL Threshold = 1, ECAL Threshold = 1 (30 GeV)

```
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with name c1
FCN=23.4779 FROM MIGRAD STATUS=CONVERGED 67 CALLS 68 TOTAL
EDM=2.23554e-10 STRATEGY= 1 ERROR MATRIX ACCURATE
EXT PARAMETER STEP FIRST
NO. NAME VALUE ERROR SIZE DERIVATIVE
1 Constant 6.42798e+01 2.78655e+00 5.21238e-03 -2.62198e-07
2 Mean 2.82600e+01 1.02038e-01 2.44801e-04 -2.67198e-05
3 Sigma 2.81373e+00 8.86744e-02 2.01175e-05 1.92925e-03
Energy Resolution = 0.0937908605773 +/- 0.0886744052577 tile size = 30
```

HCAL Threshold = .5, ECAL Threshold = .5 (30 GeV)

```
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with name c1
FCN=44.2089 FROM MIGRAD STATUS=CONVERGED 60 CALLS 61 TOTAL
EDM=2.01729e-07 STRATEGY= 1 ERROR MATRIX ACCURATE
EXT PARAMETER STEP FIRST
NO. NAME VALUE ERROR SIZE DERIVATIVE
1 Constant 6.48830e+01 2.84391e+00 7.27940e-03 5.94204e-05
2 Mean 2.96535e+01 1.00075e-01 3.26432e-04 -4.83726e-03
3 Sigma 2.70488e+00 8.63146e-02 2.77868e-05 -2.25348e-02
Energy Resolution = 0.0901627736731 +/- 0.0863145570931 tile size = 30
```

Fits to ECal + HCal  
energy distributions  
for MIP threshold 0.5  
and 1.0

HCAL Threshold = 1, ECAL Threshold = 1 (40 GeV)

```
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with name c1
FCN=17.2297 FROM MIGRAD STATUS=CONVERGED 68 CALLS 69 TOTAL
EDM=1.2534e-07 STRATEGY= 1 ERROR MATRIX ACCURATE
EXT PARAMETER STEP FIRST
NO. NAME VALUE ERROR SIZE DERIVATIVE
1 Constant 7.89563e+01 3.74743e+00 5.61805e-03 -1.55268e-04
2 Mean 3.76122e+01 1.33449e-01 2.65824e-04 1.59074e-03
3 Sigma 3.22920e+00 1.45672e-01 2.36239e-05 -1.24523e-02
Energy Resolution = 0.0807300355743 +/- 0.145672157677 tile size = 30
```

HCAL Threshold = .5, ECAL Threshold = .5 (40 GeV)

```
Info in <TCanvas::MakeDefCanvas>: created default TCanvas with name c1
FCN=19.2238 FROM MIGRAD STATUS=CONVERGED 71 CALLS 72 TOTAL
EDM=1.63402e-08 STRATEGY= 1 ERROR MATRIX ACCURATE
EXT PARAMETER STEP FIRST
NO. NAME VALUE ERROR SIZE DERIVATIVE
1 Constant 7.83307e+01 3.62842e+00 5.97138e-03 6.50961e-05
2 Mean 3.92806e+01 1.26804e-01 2.69400e-04 4.45111e-06
3 Sigma 3.11056e+00 1.25034e-01 2.30693e-05 8.42860e-03
Energy Resolution = 0.0777640392813 +/- 0.125034039787 tile size = 30
```