STAR Collaboration Meeting
Nov. 13   2010

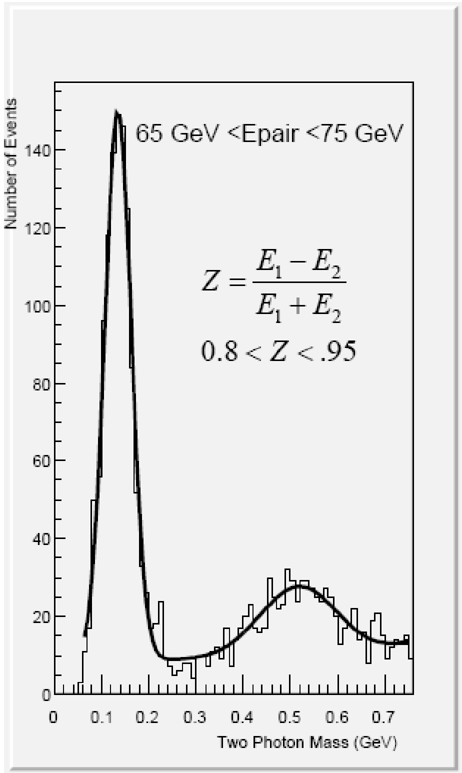
FMS Shower Shape
Single Photon Measurement
Geant4 Model
Cerenkov Photons

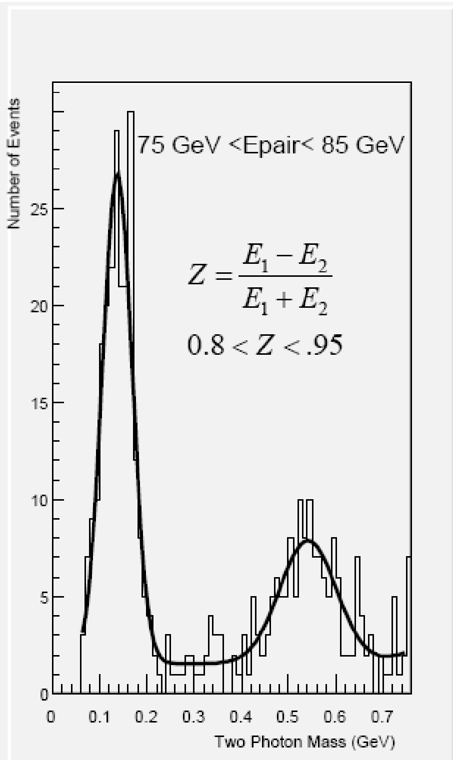
From Run 9 Eta Events, we can isolate a very pure sample of
High energy isolated single photons.

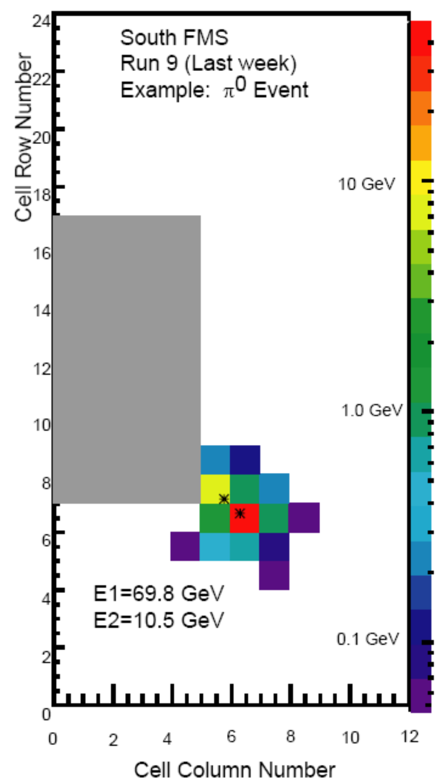
Isolated Photons of 70GeV illuminate ~15 small FMS cells to predict
3 variables (x position, y positin, energy)
~15-3 = 12 Degrees of freedom!

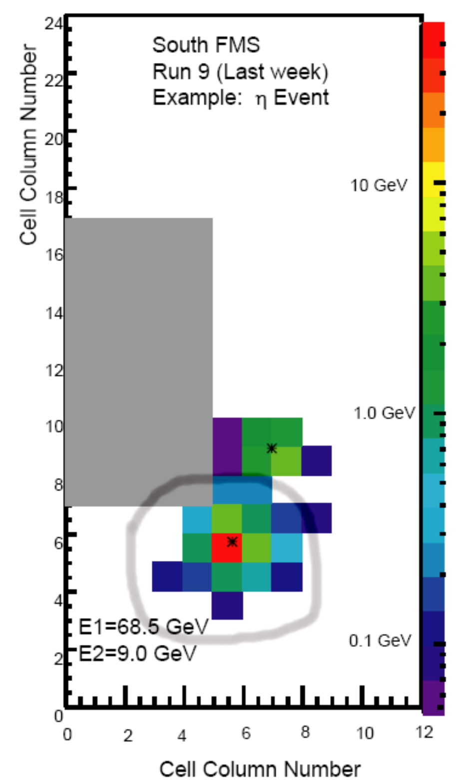
With a range of ADC response spanning nearly 3 orders of magnitude.

What can we predict about this distribution of ADC values.
How well can we distinguish between pi0’s and single photons?



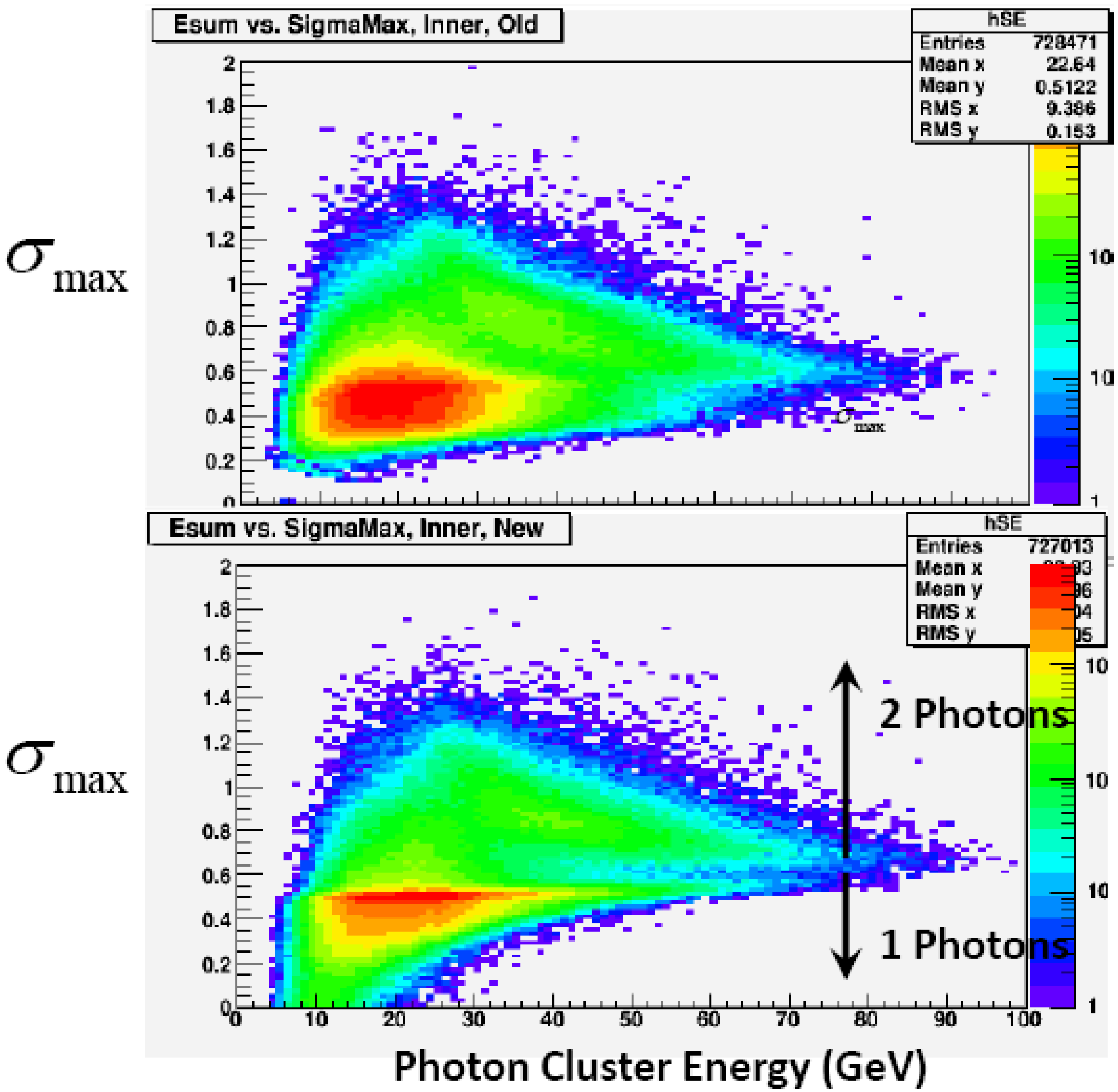






Separation of single photon cluster from two photon cluster based upon distribution of shower energy along a preferred axis.

$$\sigma_{\max} \equiv Max\ Eigenvalue\ of \begin{bmatrix} \Delta\sigma_x^{\ 2} & \Delta\sigma_x\Delta\sigma_y \\ \Delta\sigma_y\Delta\sigma_x & \Delta\sigma_y^{\ 2} \end{bmatrix}$$



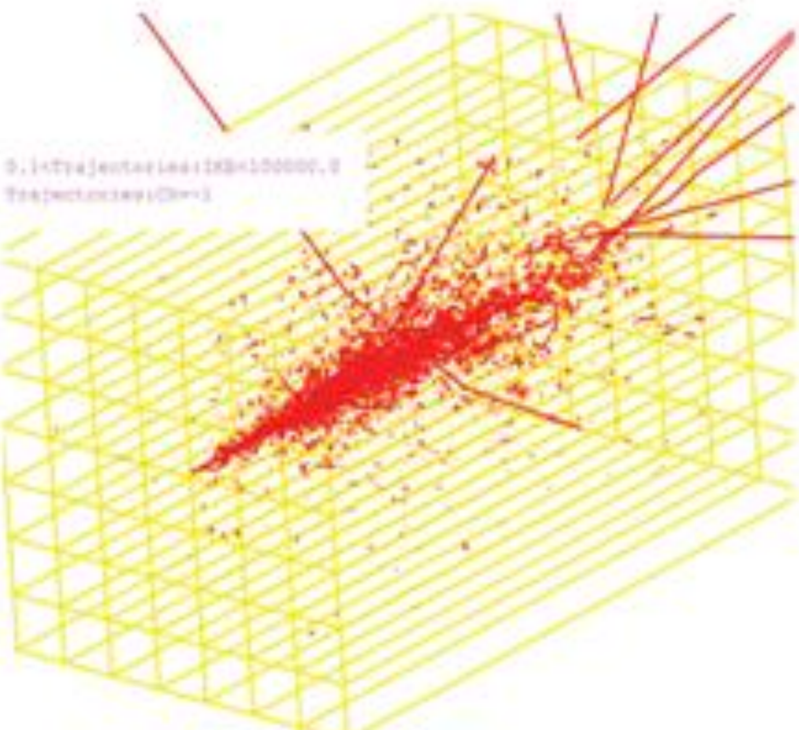
Old algorithm with
Energy weighted moments

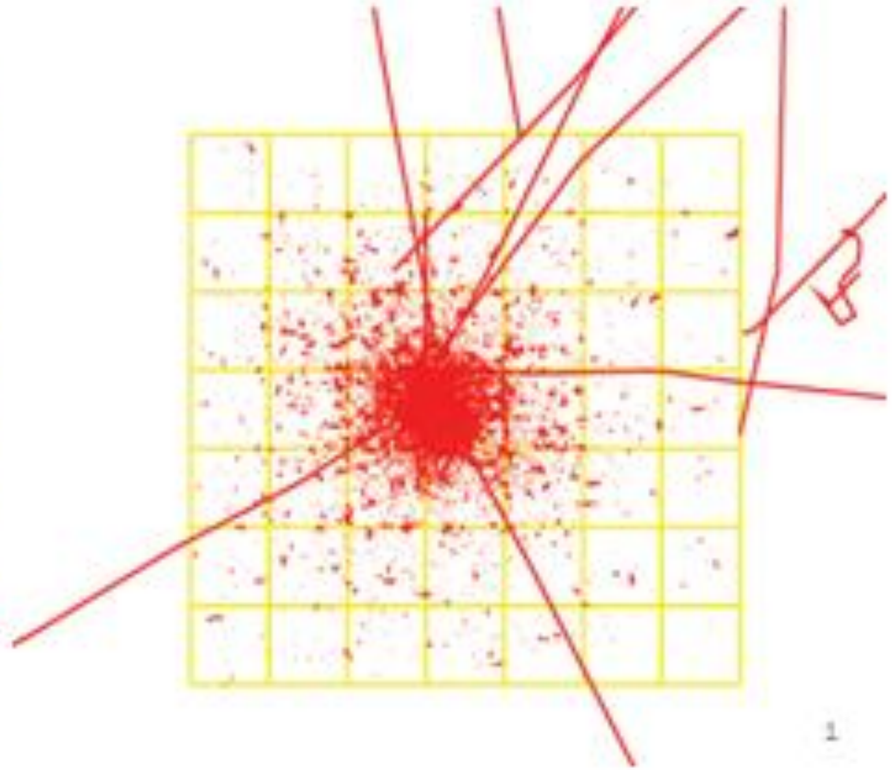
Improved algorithm with
log energy weighted moments.

Provides clearer separation
Between π^0 and single photon.
Clusters up to ~80 GeV.

Geant 4: "Pb Glass" Showers

7x7 Array Pb Glass (3.81x3.81) blocks
20 GeV Photon ;
Normal incidence
X=-1.41.4 cm Y=0. cm (from center)
Shown are all electrons with KE>100 KeV

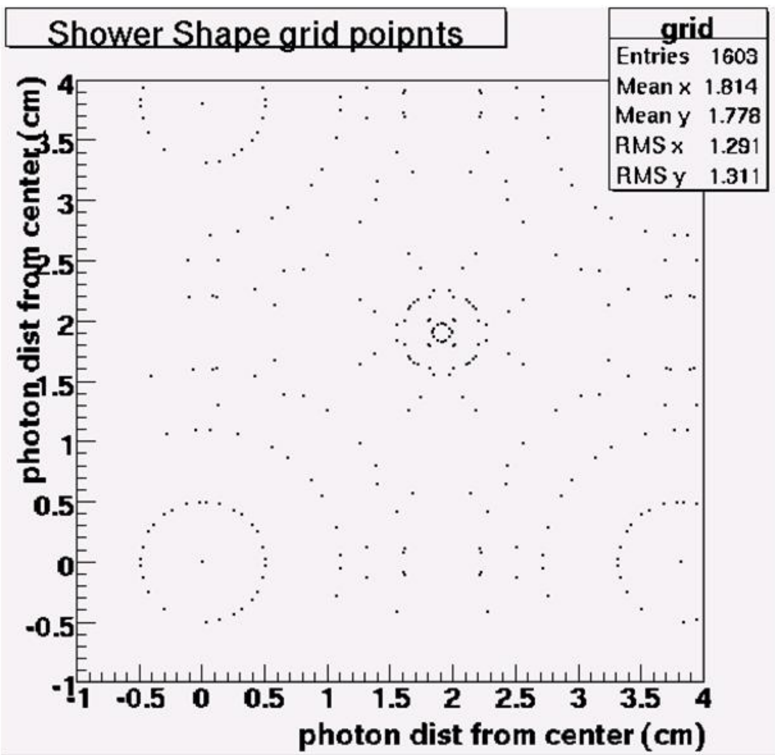


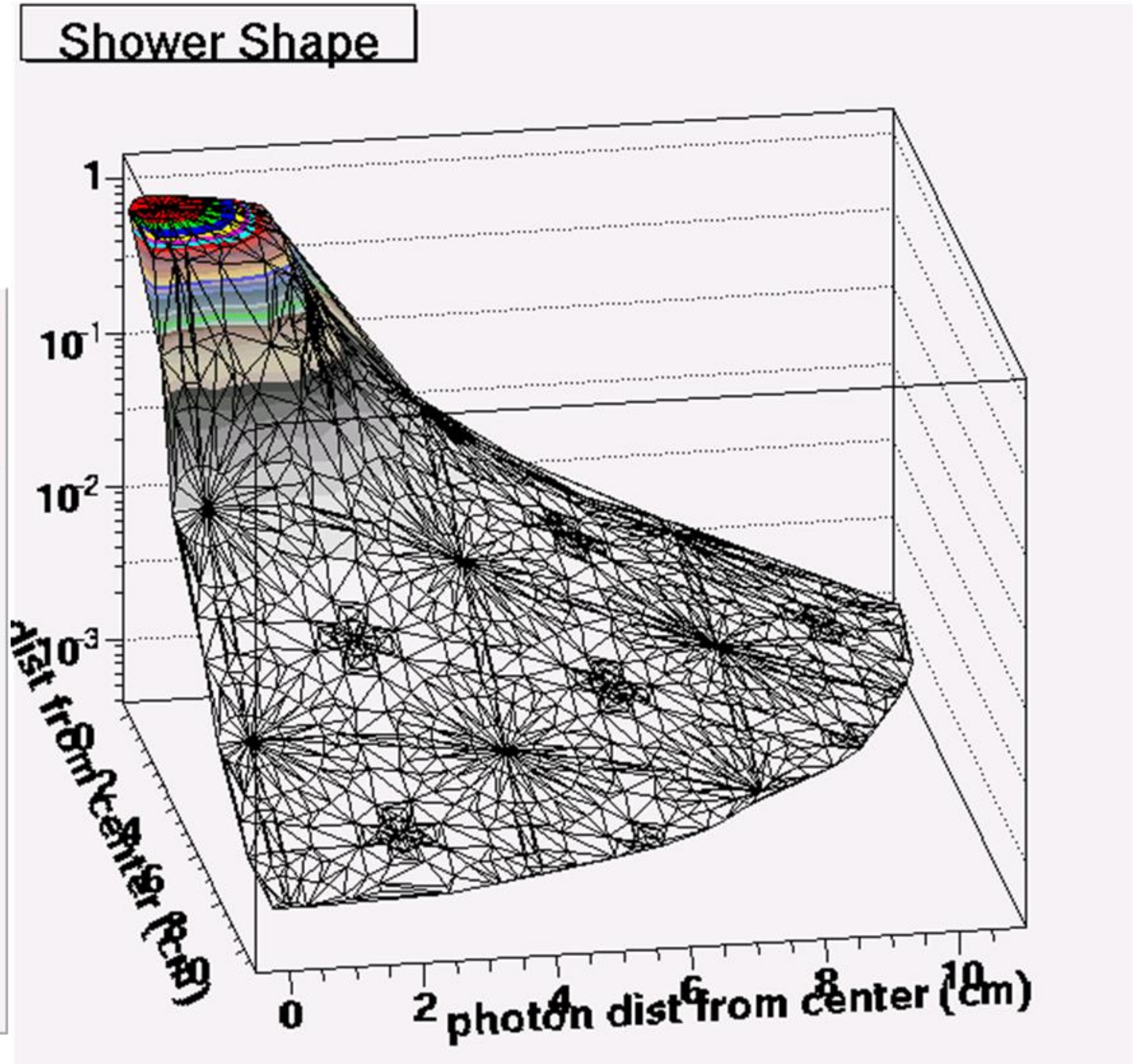


Generate 1000 photons at each location (x,y) shown below-left. Photons incident directions are along "z" axis. Resulting shape shown below-right.

Triangular interpolation between Generated points .

To generate continuous function Shape(x,y).





Compare simulation to 1 photon hypothesis

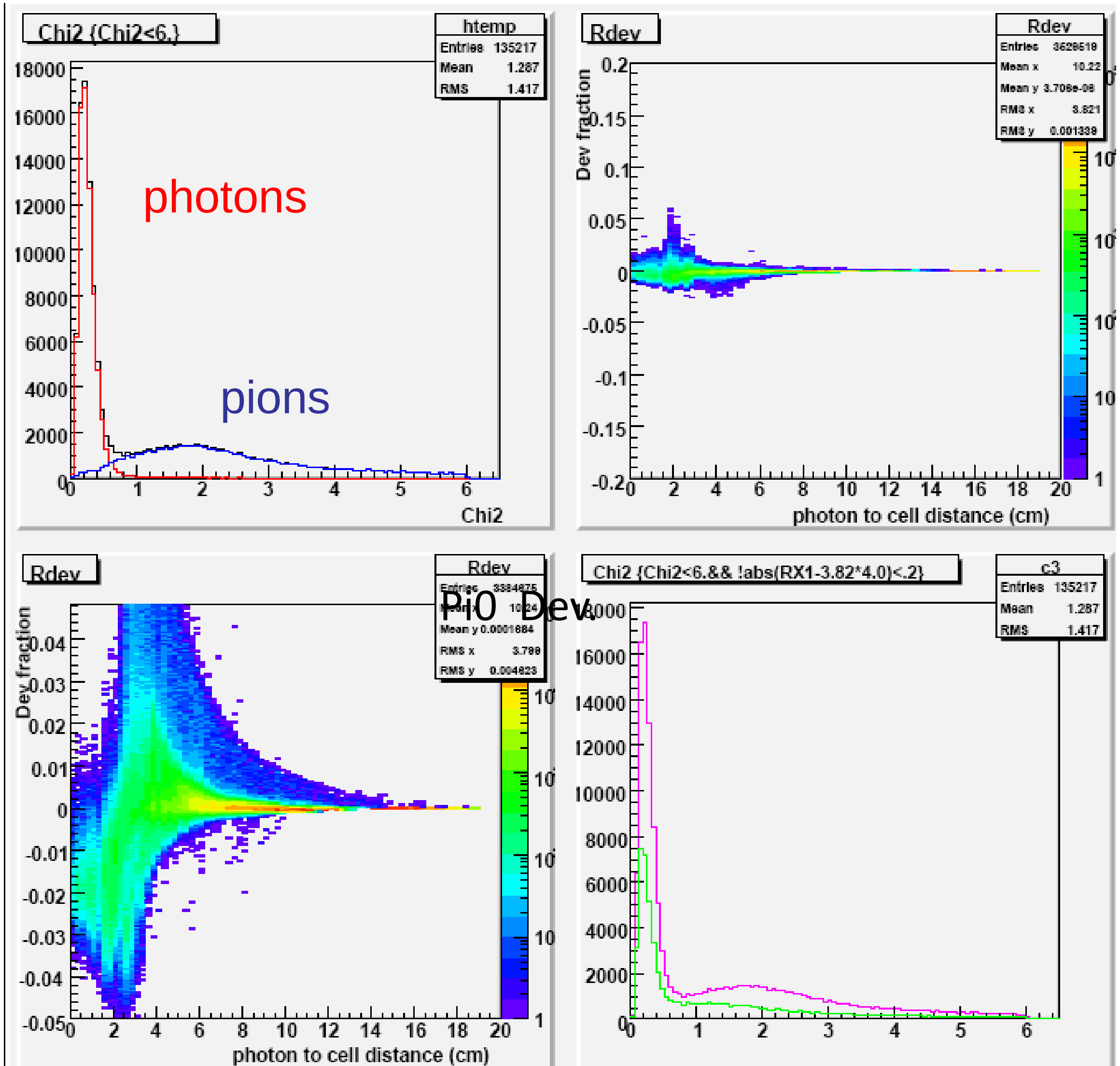
chis2/dof for photon hypothesis

Energy photon or pi0 = 100 GeV

Equal numbers of photon and pi0

Energy digitization step = .05 GeV

Const Err=.1 GeV



Excellent separation
But what does this
Simulation have to
do with real showers.

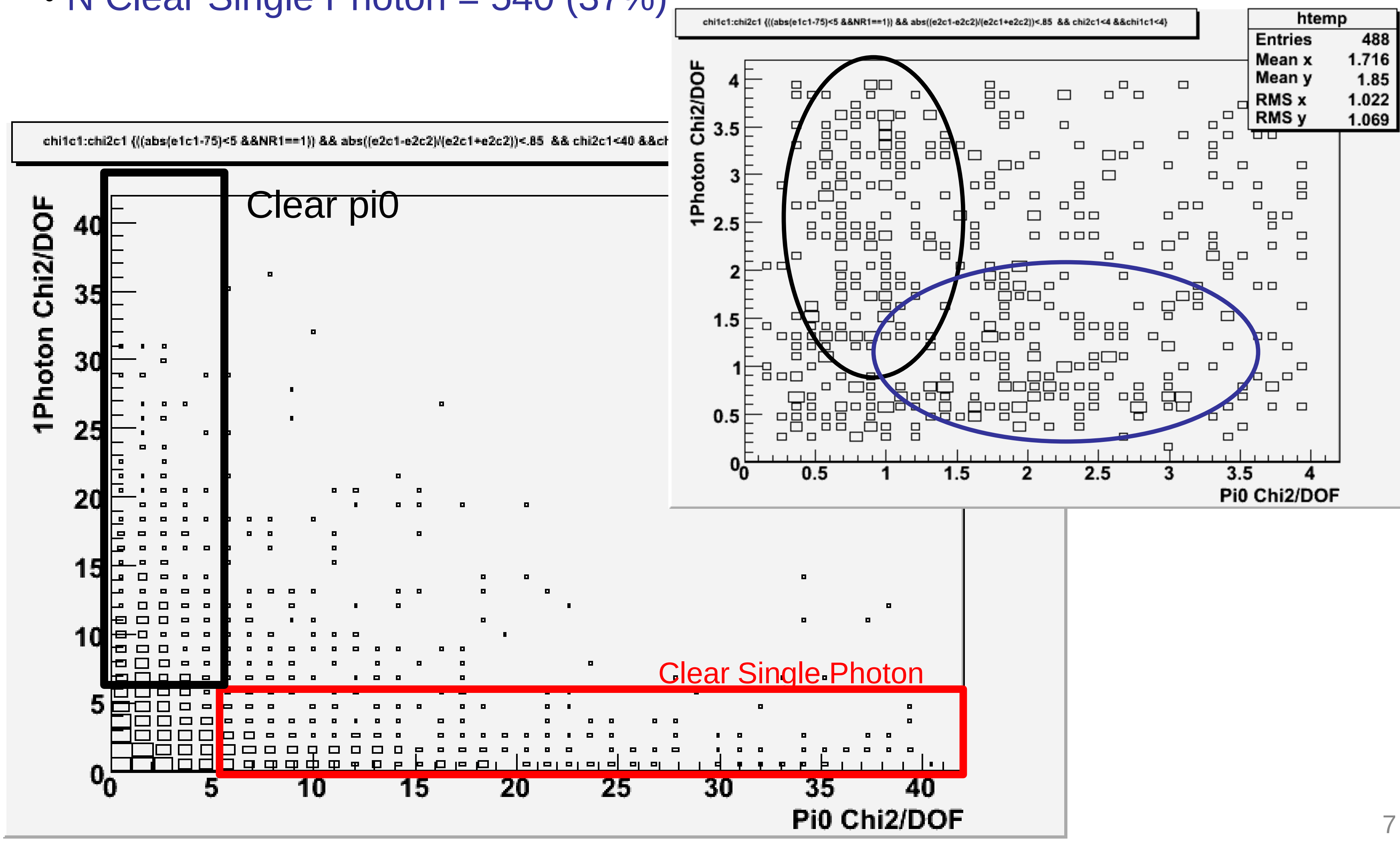
How good is our shower Model?

1) Does the model reproduce simulated showers well?

2) Does the simulated shape agree with the data shape?

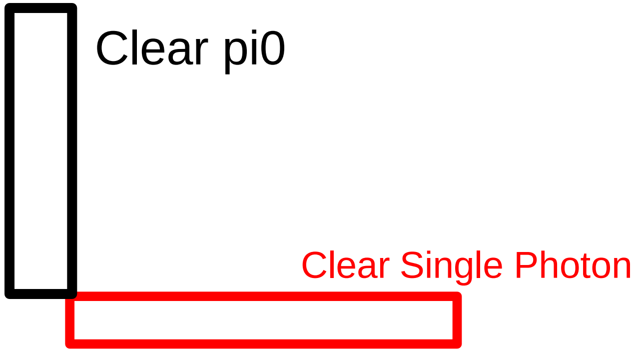
Geant4 Simulation
70-80 GeV Single Cluster Events.

- N =1870
- N chi2(photon)<5 && chi2(pi0)<5=488 (33%)
- N Clear pi0 = 460 (30%)
- N Clear Single Photon = 540 (37%)

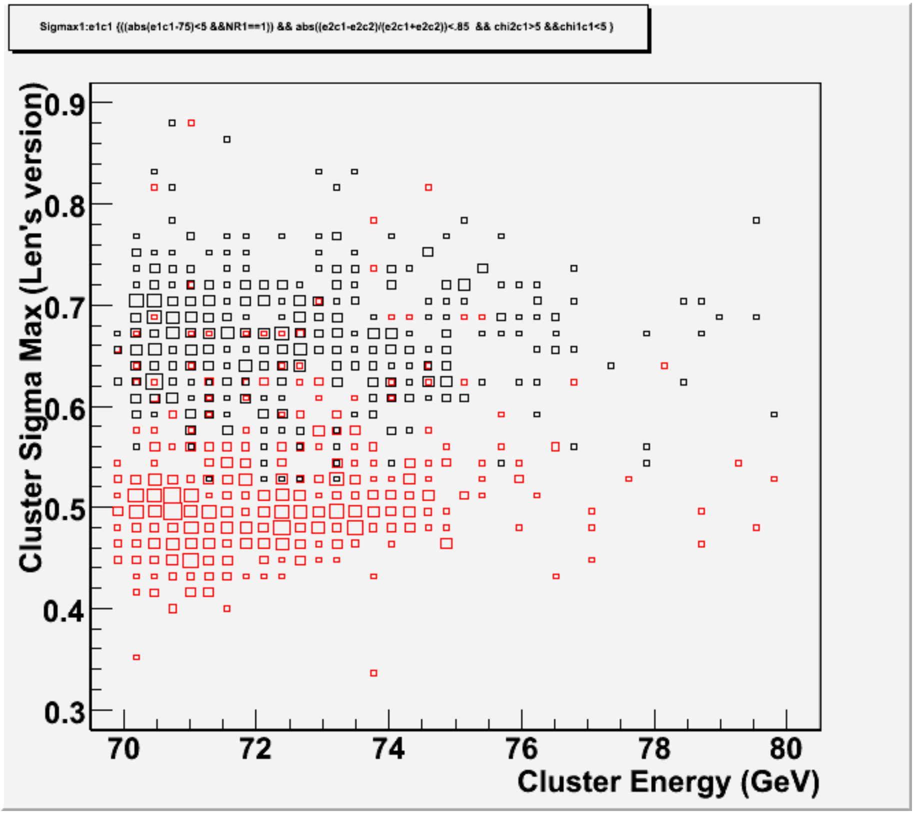


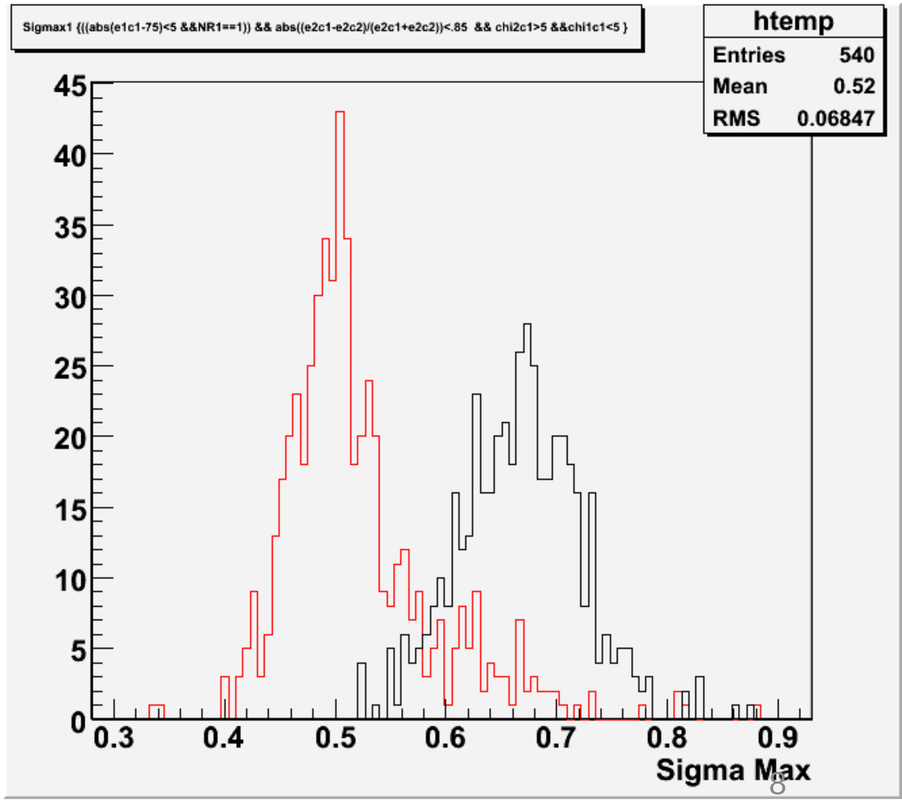
Sigma Max for the 67% of events that have well separated pi0 and single photon.

Using the “one cluster” events (70 to 80 GeV) from the previous page:
We now look at “Len’s Sigma Max” variable that is used to categorize Clusters.



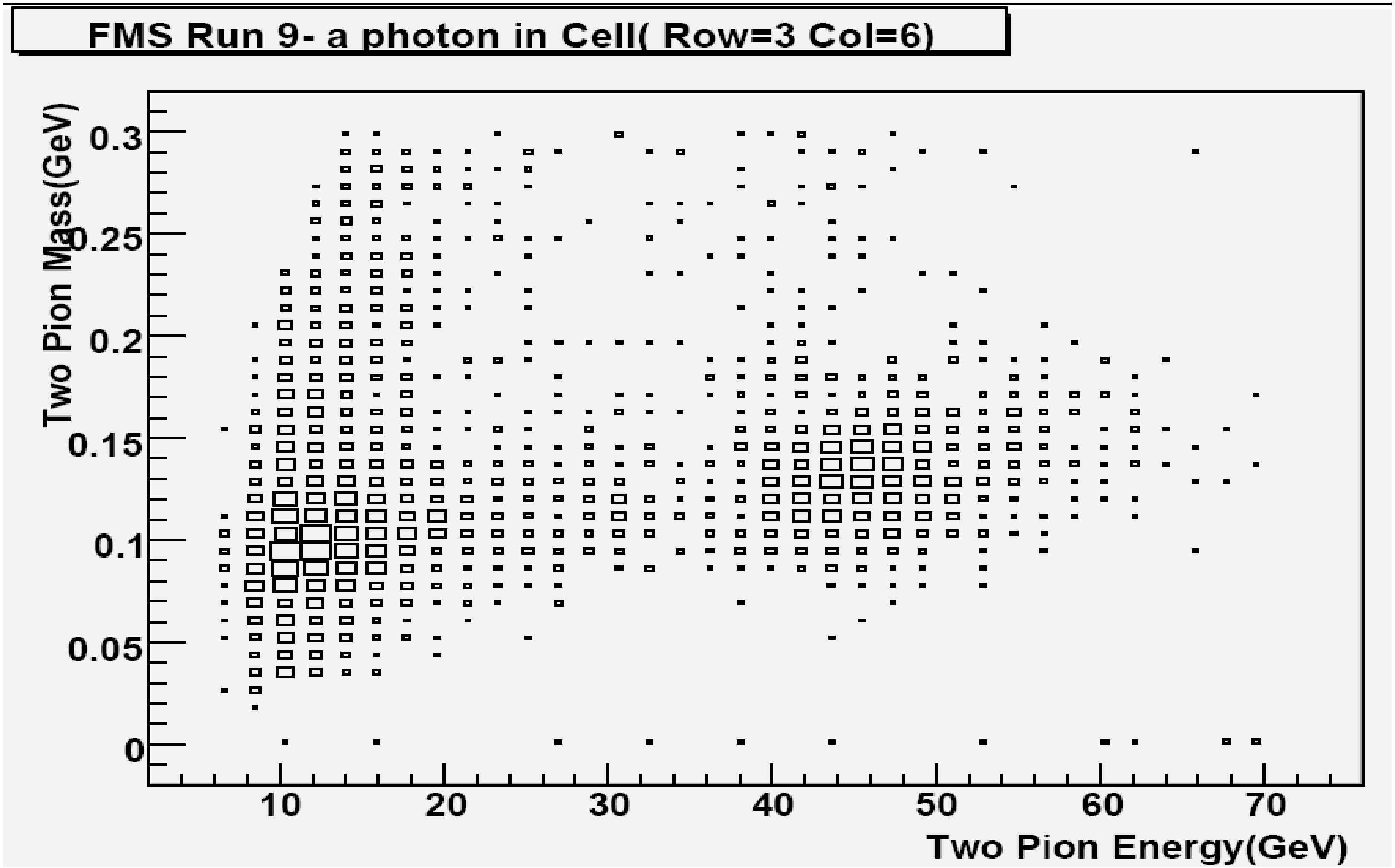
In the figures below, the “Sigma Max” distributions are shown.
The red represents events with chi2(pi)>5 && chi2(gamma)<5.
The black represents events with chi2(pi)<5 && chi2(gamma)>5.



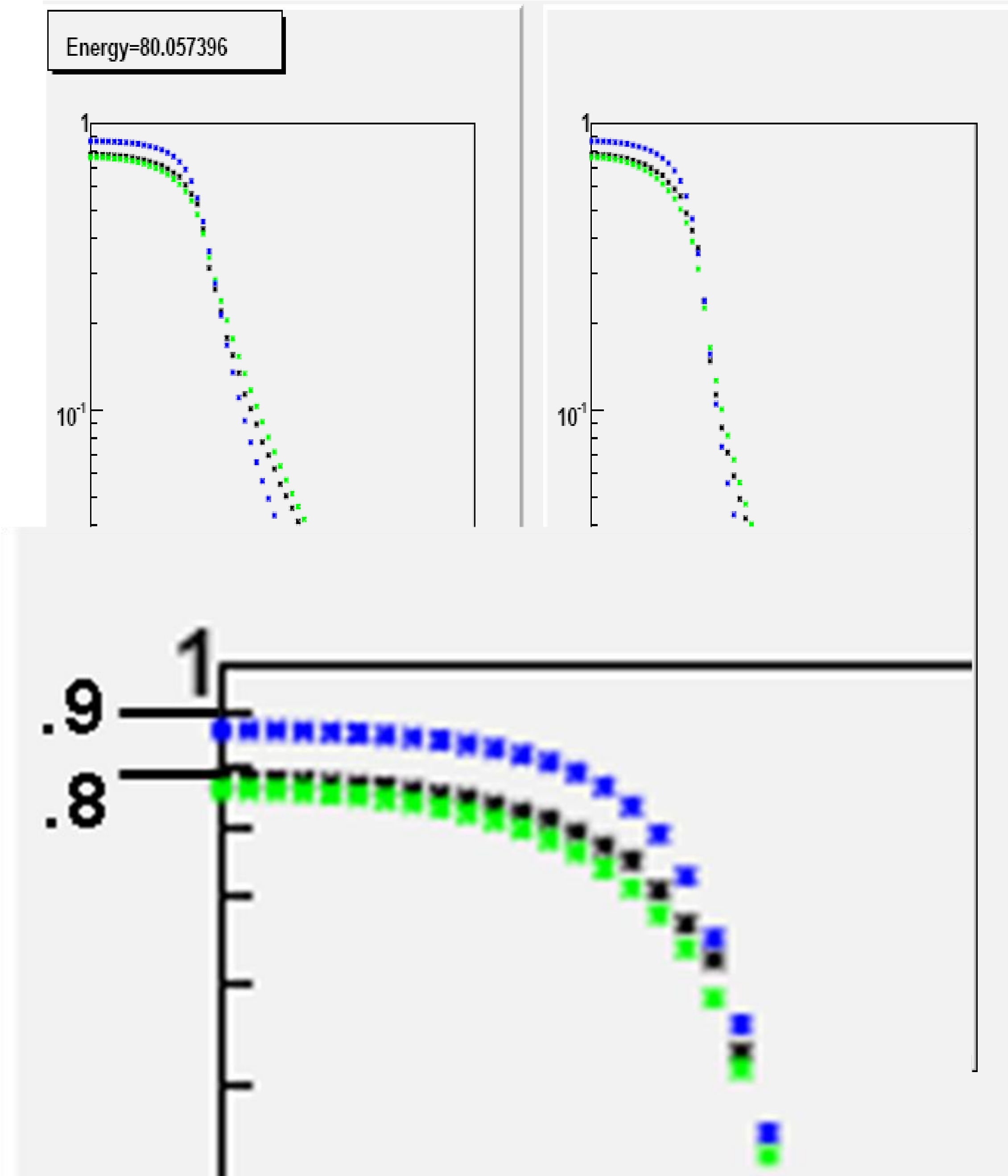


Long Standing Energy dependent gain problem????
Raising questions about simulation?

A typical Cell in the FMS South
Mass vs Energy
slope: >30% for Two Photon Energy between 10 and 60 GeV.



Shower Shape from FMS Real Data (Eta photons)



Black upper: Shower shape from Geant4 analysis.

Green: default Shower Shape from reconstruction

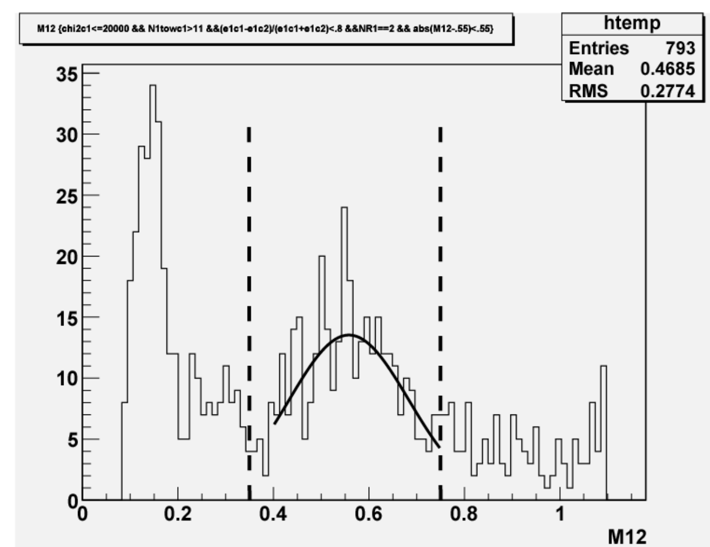
a0[3]={.8,.3,-.1};

b0[3]={.8,.2,7.6};

Blue Fit to FMS data (Eta photon)

a1[3]={0.814, 0.882, -0.64};

b1[3]={0.33 , 0.318, 0.32};



Model 1

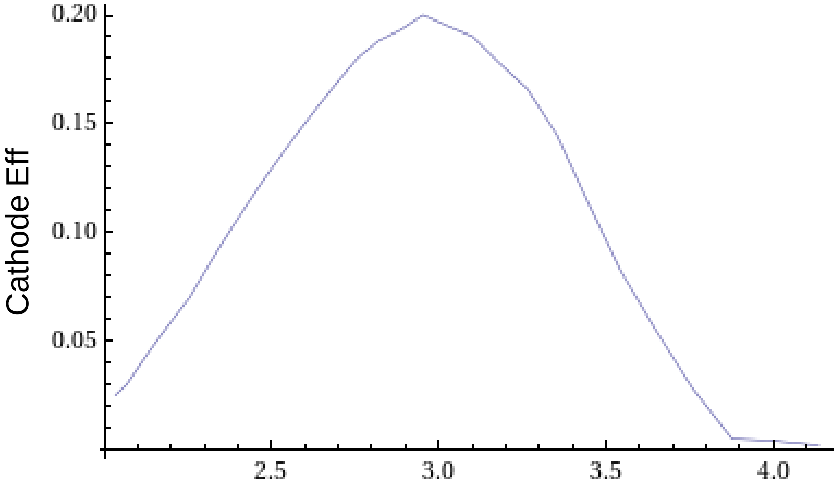
Pb Glass (same as GSTAR)

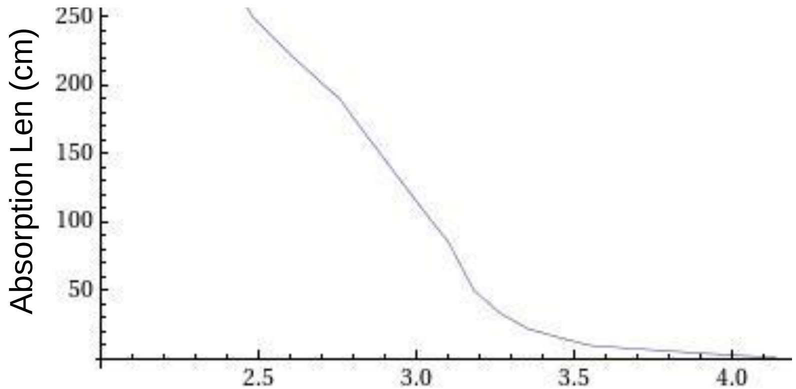
Cerenkov Photon Signal.

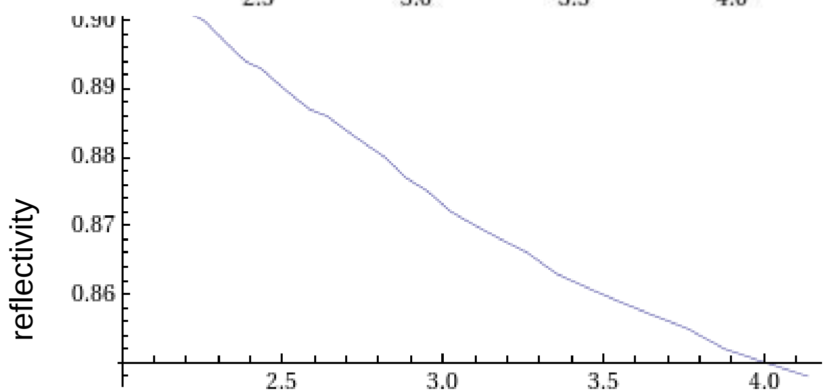
Photo cathode efficiency set by hand.

Reflectivity of surface set by hand.

Photon absorption length of Pb Glass set by hand.







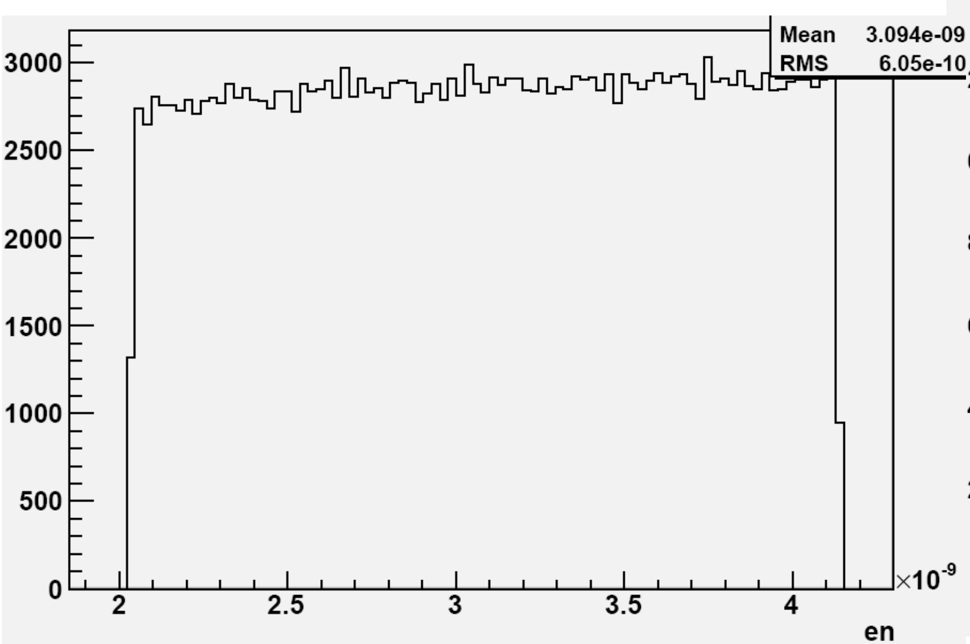
This is a study of a Geant4 based model of a 7x7 Small Cell FPD type detector.

In the following presentation

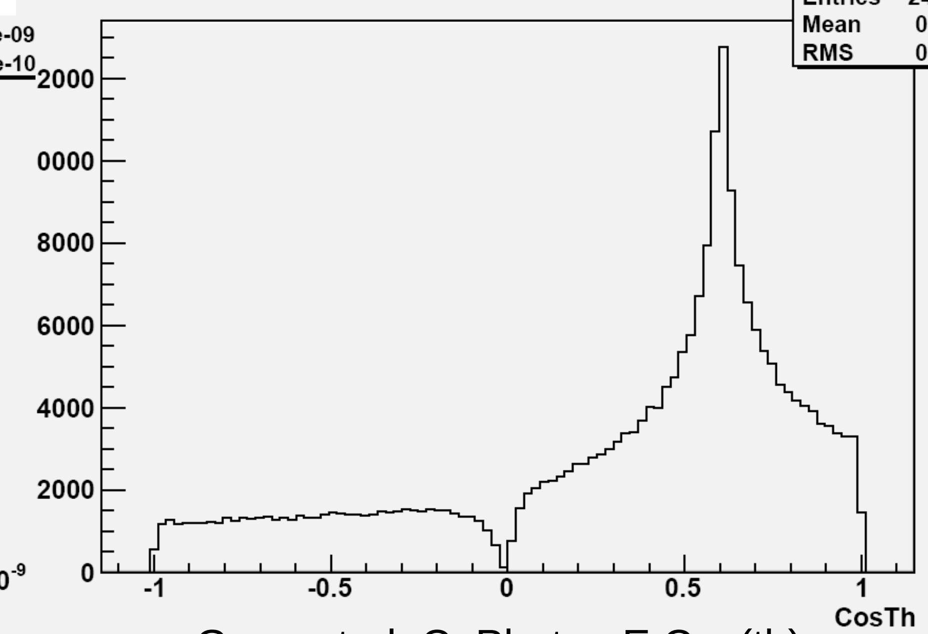
- The signal is modeled both as **energy deposited** in cells and simultaneously as **Number of Cerenkov** produced in the cell and detected at the photo cathode

- Simulation involves a single photon directed in the center of the center cell of a 7x7 array of cells. The cells are arranged with their long axis along the z axis and the photon momentum is in the z direction.

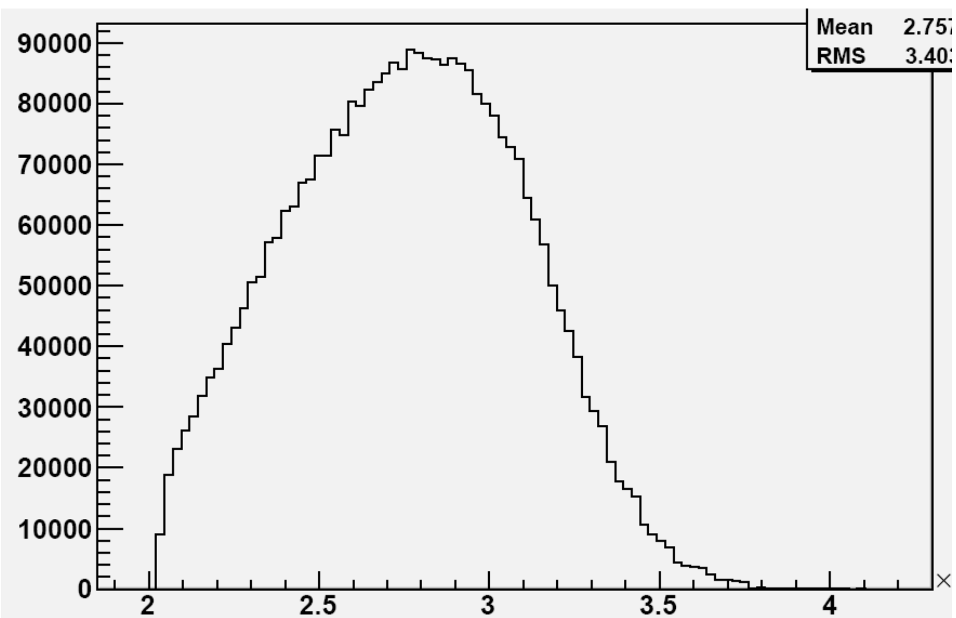
- The detected Cerenkov signal is reduced from the number of produced Cerenkov by three factors
  - Photocathode efficiency as a function of photon energy
  - Absorption length of glass as a function photon energy
  - Reflectivity of Cell surfaces as a function of energy.



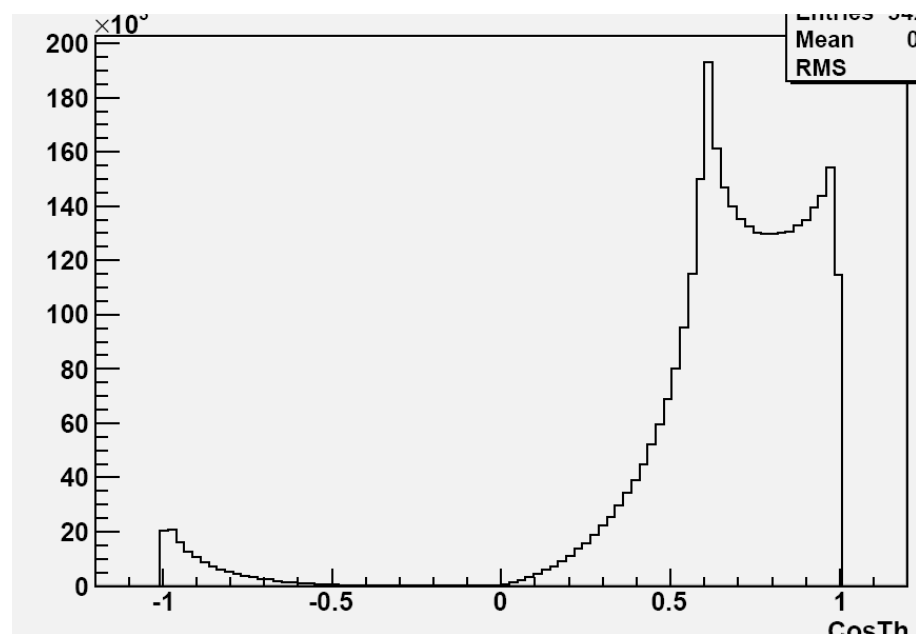
Generated C. Photon E Distribution (eV)



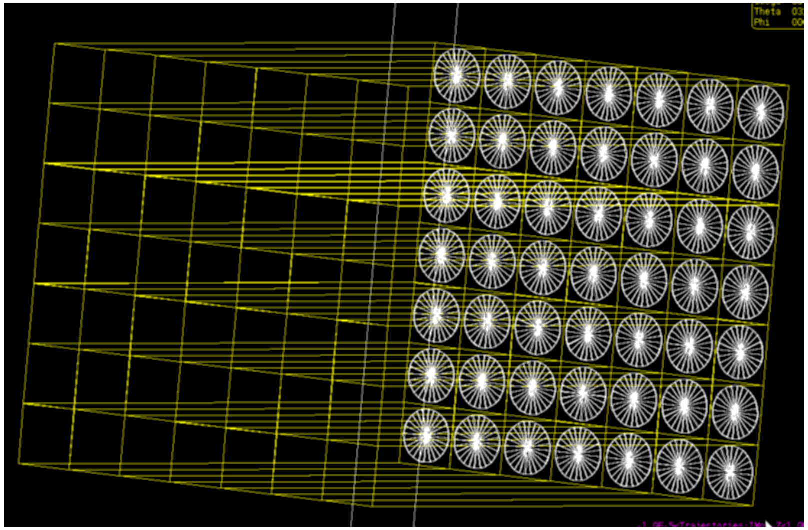
Generated C. Photon E Cos(th)



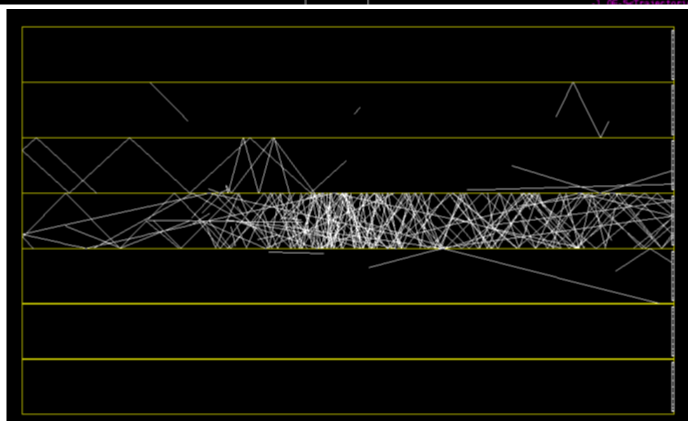
Detected C. Photon E Distribution (eV)



Detected C. Photon E Cos(th)



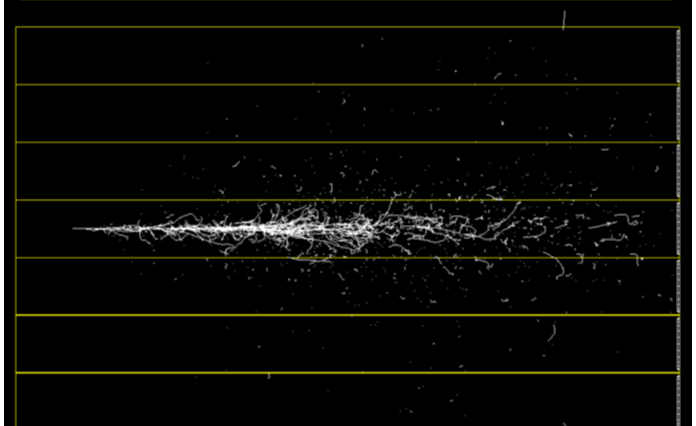
7x7 FPD like detector with disc shaped photocathode regions near the end of each cell.



For 10 GeV incident photon.

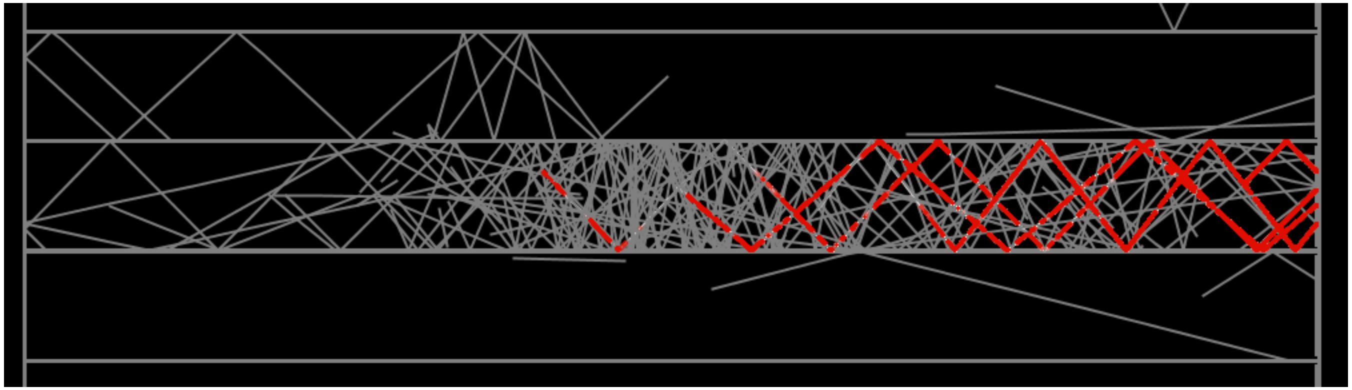
Full simulation of Cerenkov photons with full absorption, reflection and photo-cathode efficiency.

Only 1/1000 of the detected Cerenkov photons are shown.



For 10 GeV incident photon.

Full simulation of electrons.



For a 4 GeV incident photon.

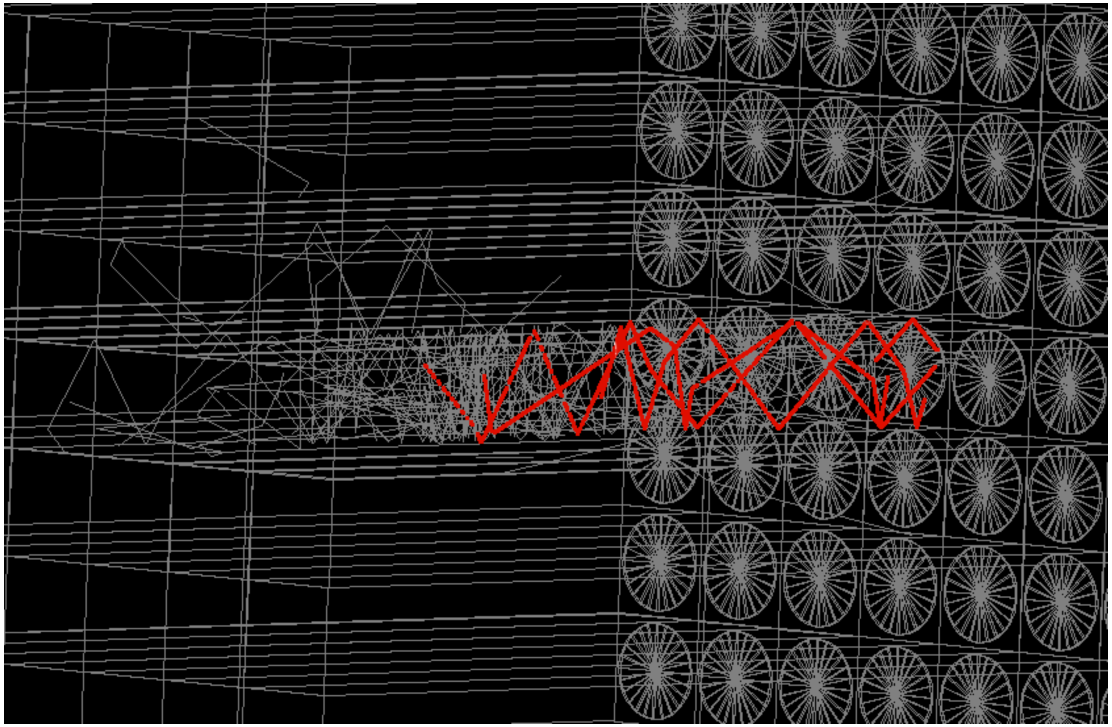
1/1000 of Cerenkov Photons shown.

42461 Cerenkov photons produces
33743 Cerenkov photons come from the central cell (row==3 col==3) (80%).

4246 Generated Photons/GeV
660 Detected Photons per GeV
(~ 1.5%)

1/1000 of all Cerenkov Photons shown.
8 Detected Photons shown in figure.

5 of detected central bin Photons shown in red.

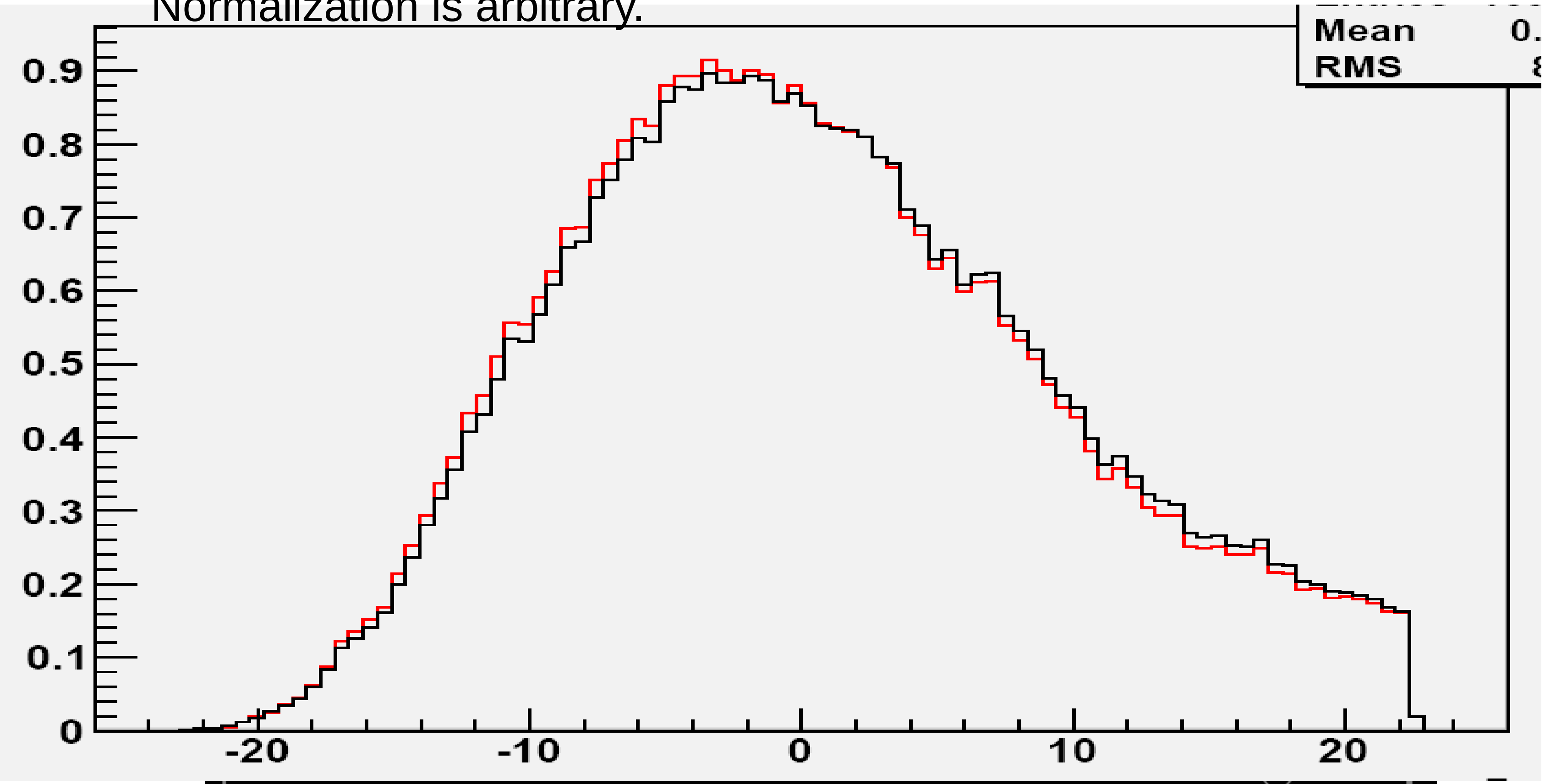


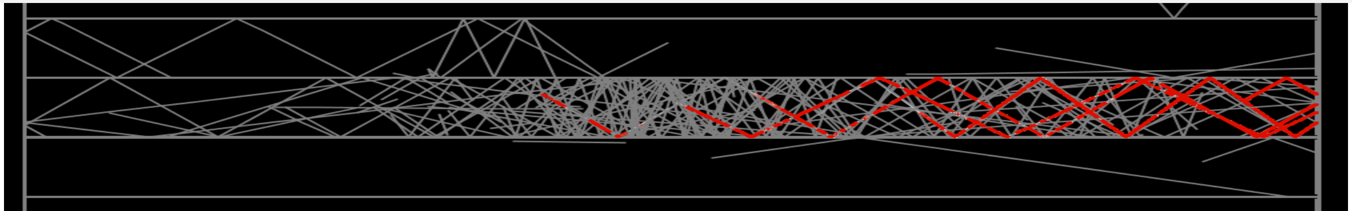
For a 40 GeV incident photon.

The z distribution of the point of generation for Cerenkov photons (red).

The z distribution of energy deposited (black).

Normalization is arbitrary.

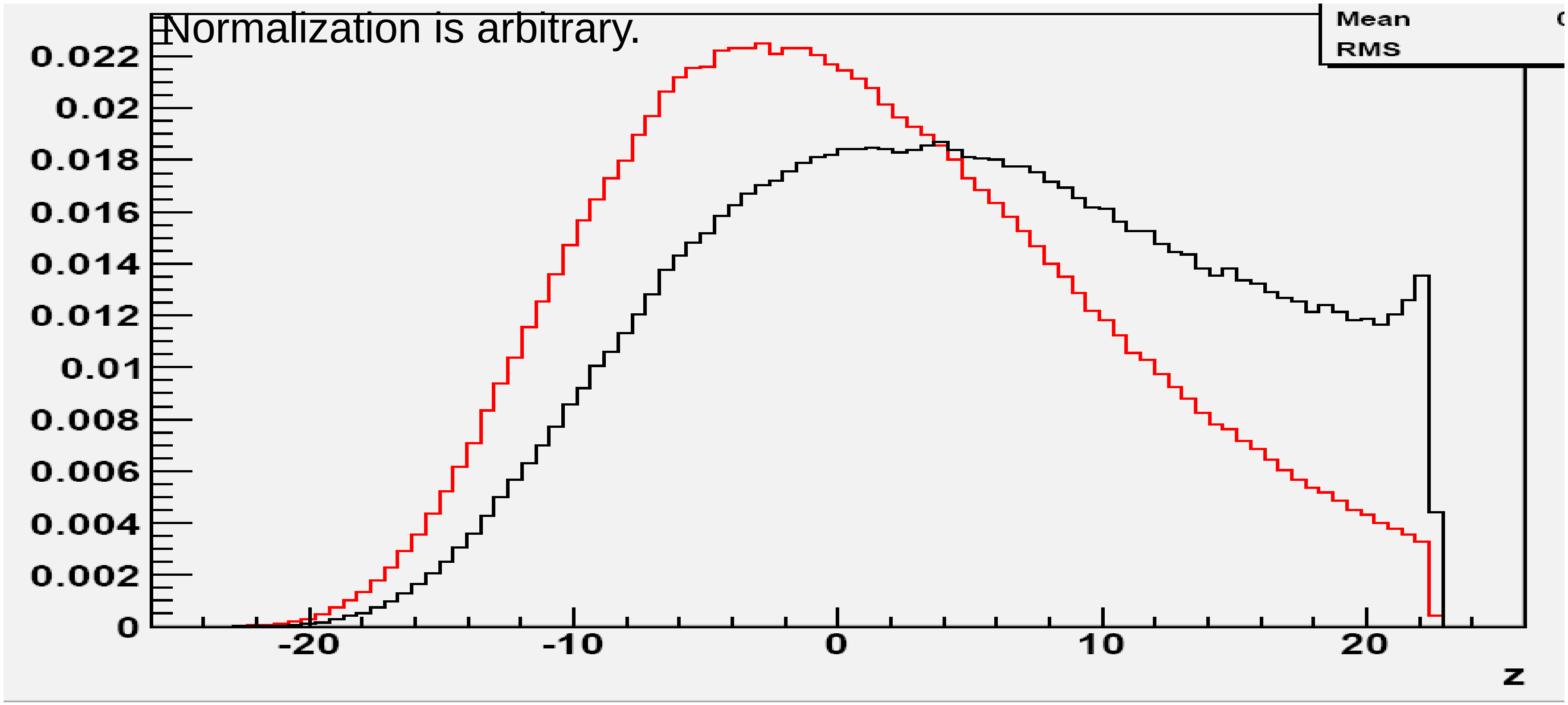


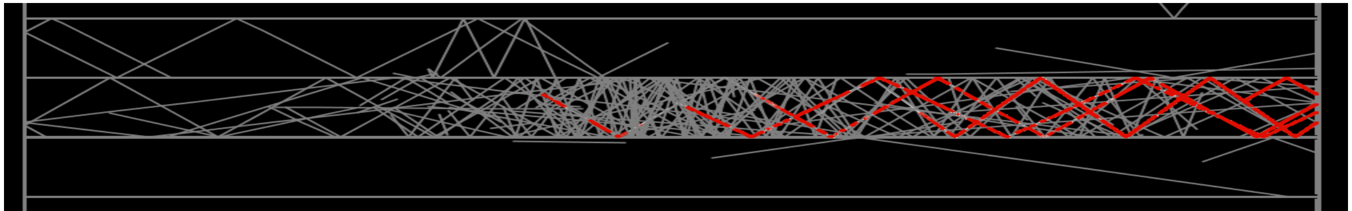


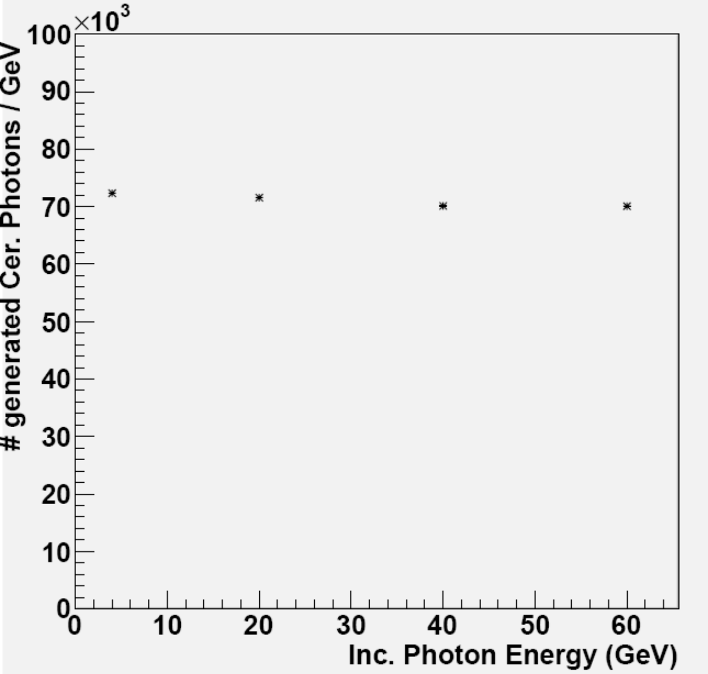
For a 40 GeV incident photon.

The z distribution of the point of generation for Cerenkov photons (red).

The z distribution of the point of generation for detected Cerenkov photons (black).



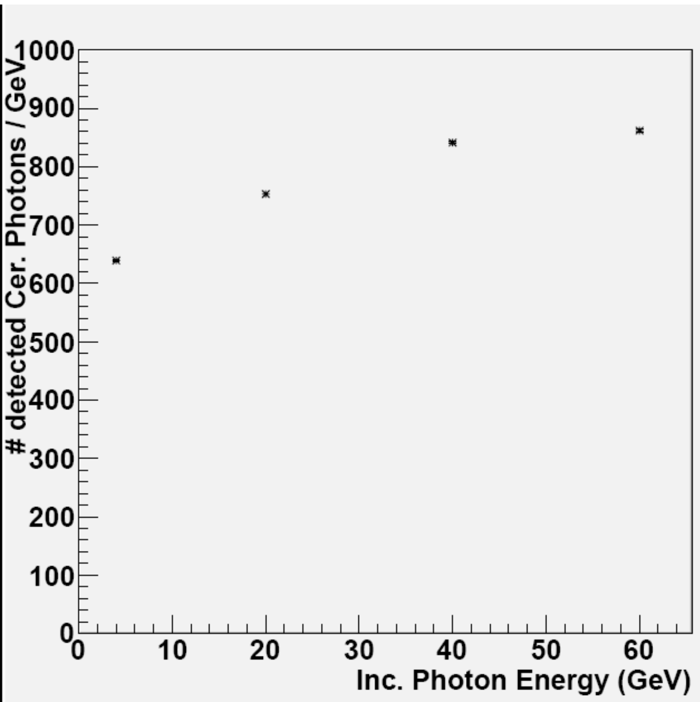




Number of Generated Cerenkov Photons

~ 70000 Photons/GeV

Independent of Photon Energy



Number of Detected Cerenkov Photons

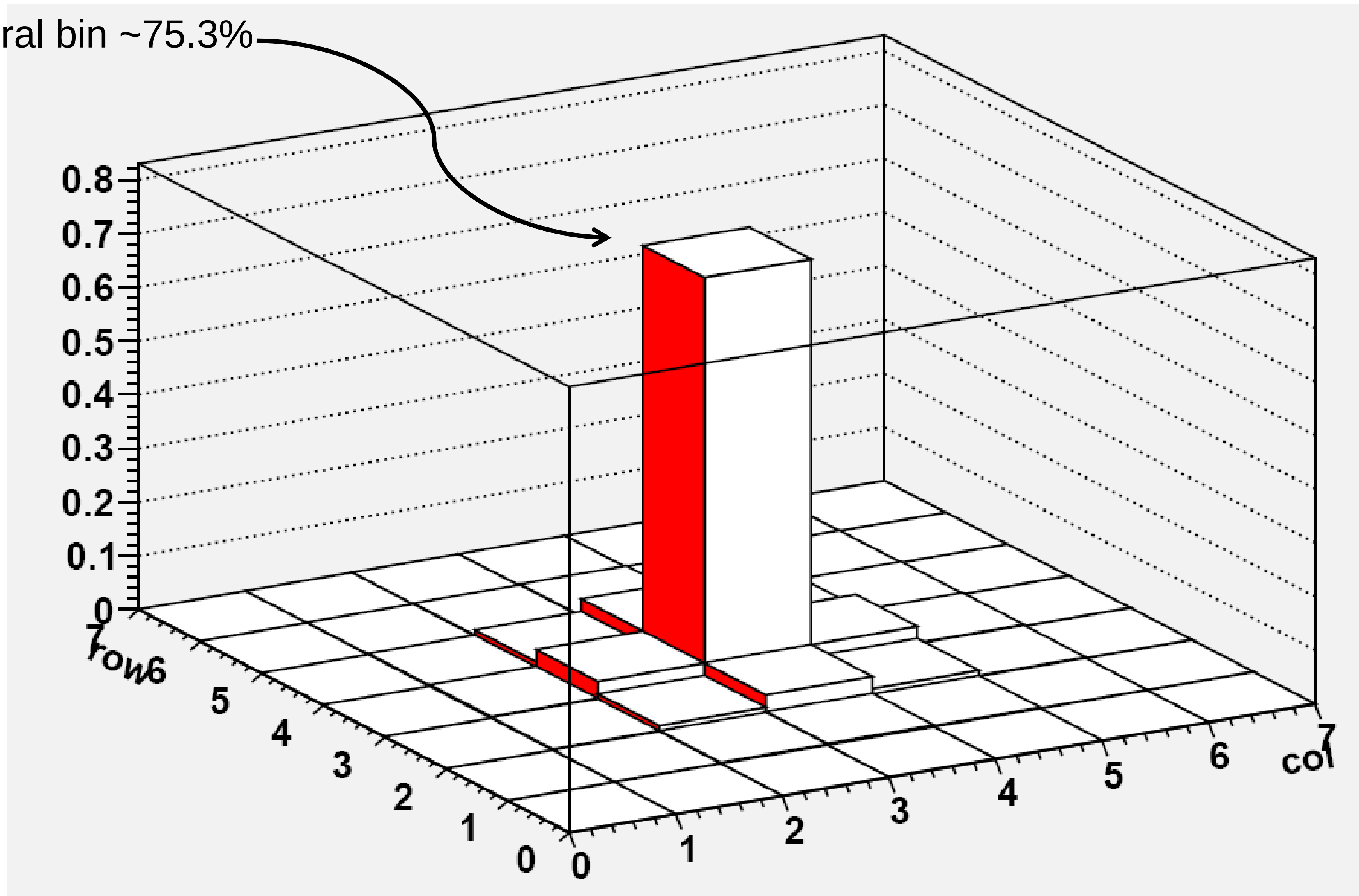
600 to 800 Photons/GeV

30% CHANGE IN NUMBER
for Energy from 4 to 60 GeV

For 40 GeV incident photon:

Shower shape for central (normal) photon with measurement **based on energy deposition.**

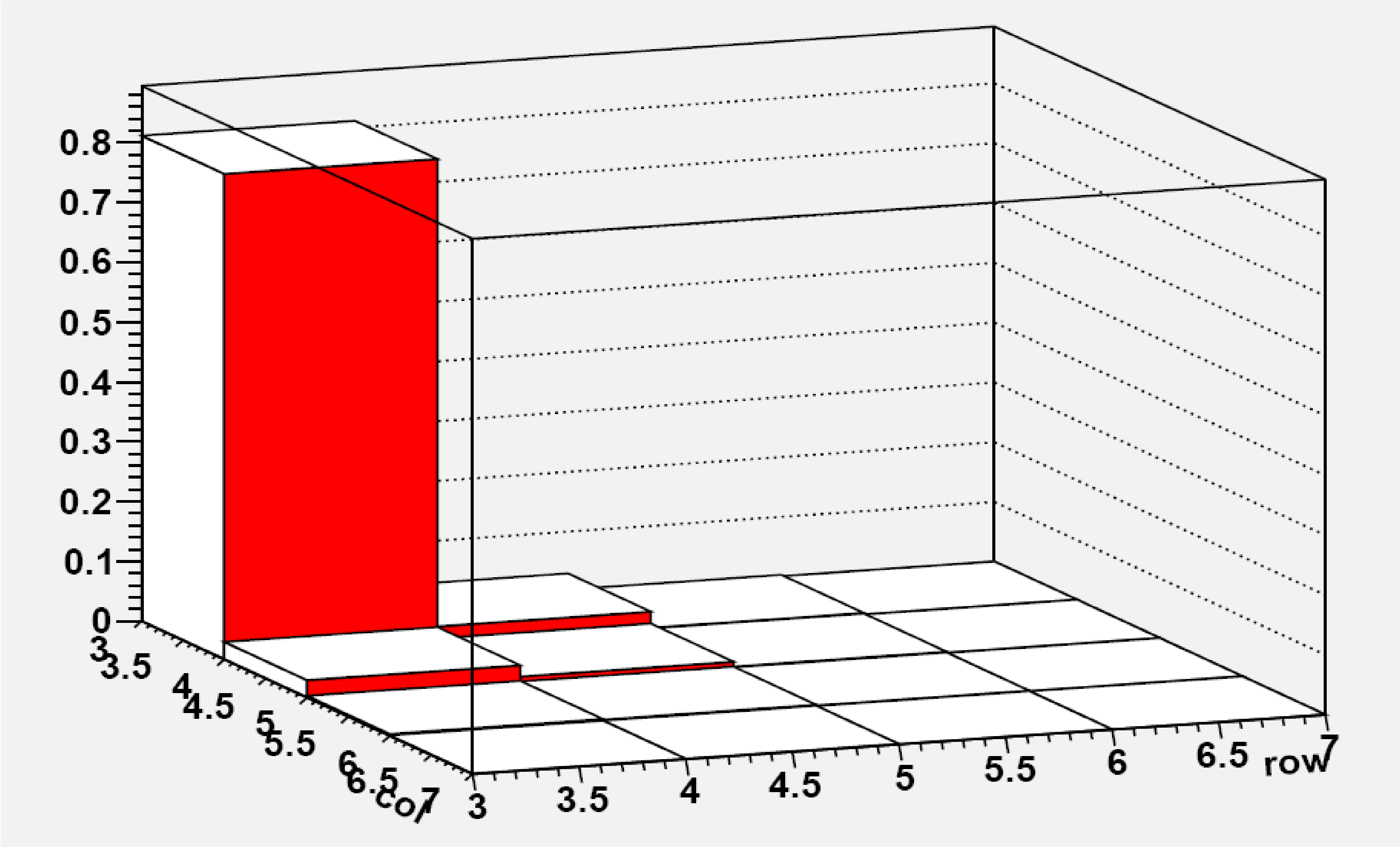
Central bin ~75.3%



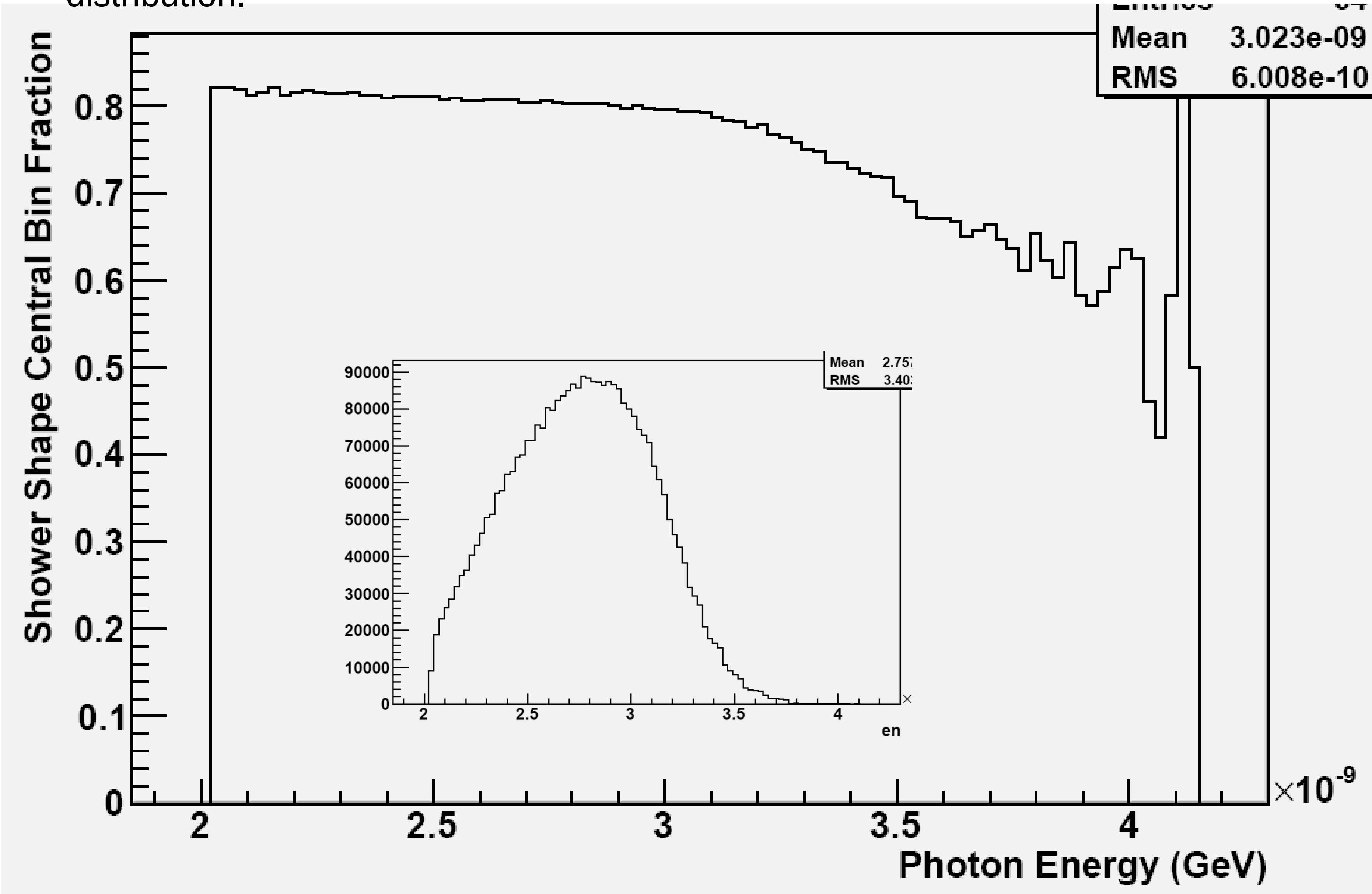
Ephoton = 40 GeV

Shower Shape based on detected Cerenkov Photon count.

Peak fraction = 80.4%



For 40 GeV photons, the fraction of detected Cerenkov photons in the central bin is shown with an inset showing the actual detected energy distribution.



Model 2

Pb Glass (same as GSTAR)

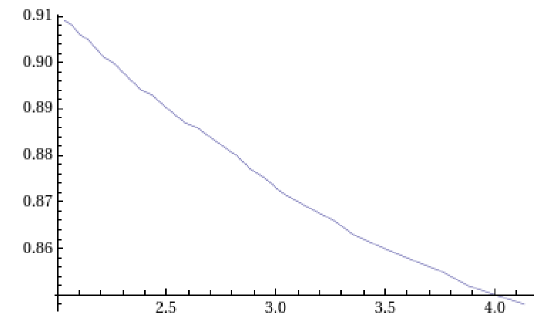
Cerenkov Photon Signal.

Photo cathode efficiency set by hand.

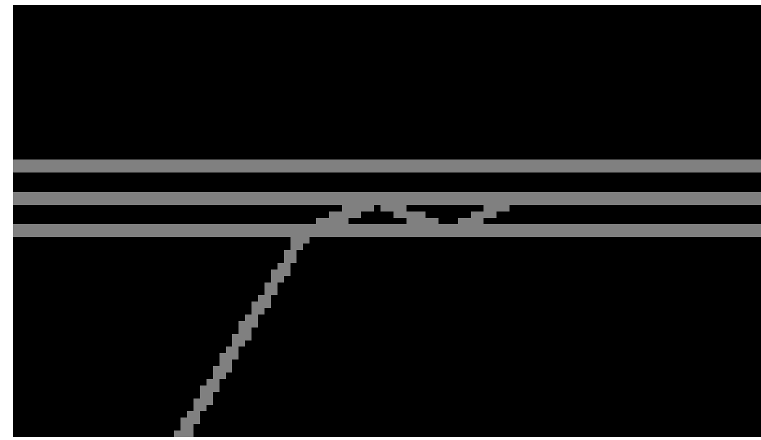
Surface with a air gap backed up by aluminum.

Internal Reflection at glass to air interface.

Reflection from graph at air to aluminum interface (as before)

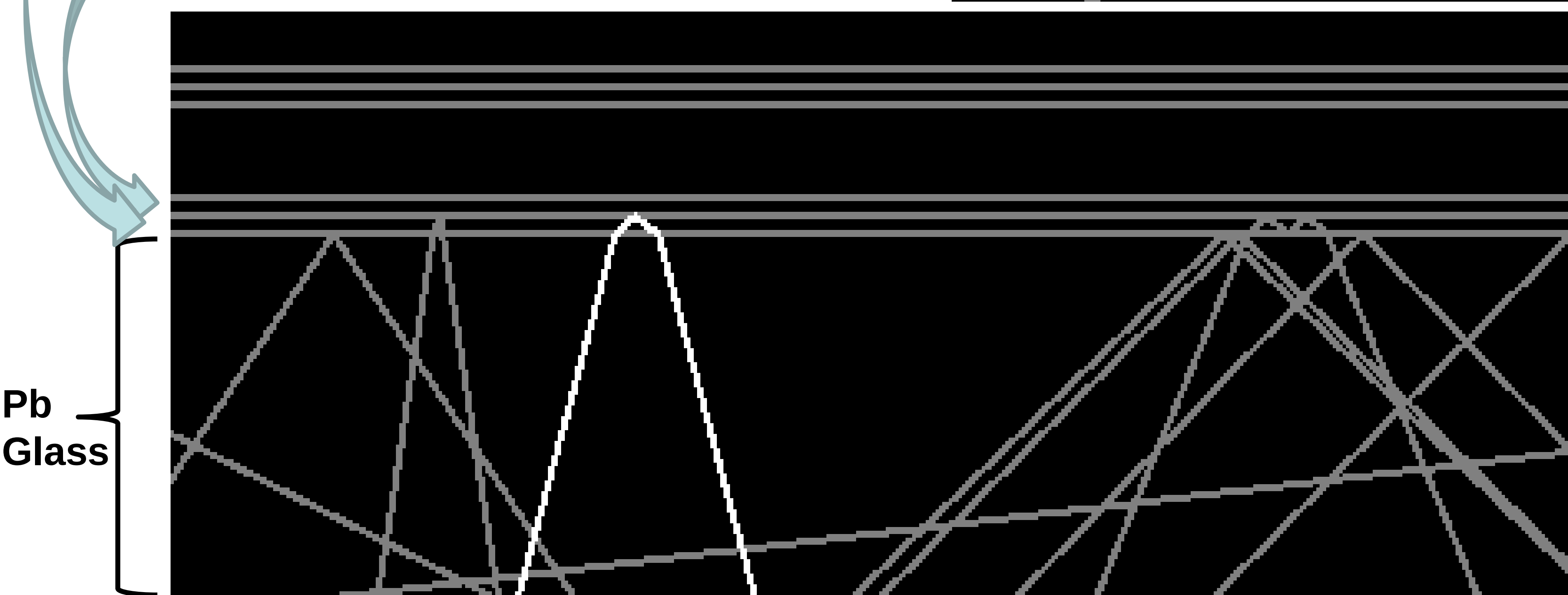


Air-Aluminum Surface Absorption



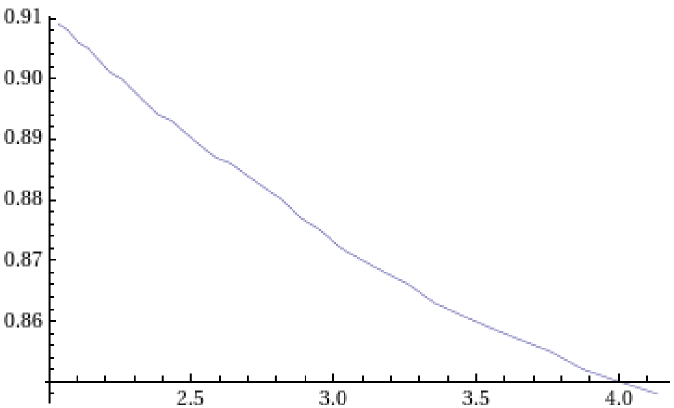
Air Layer

Aluminum Layer

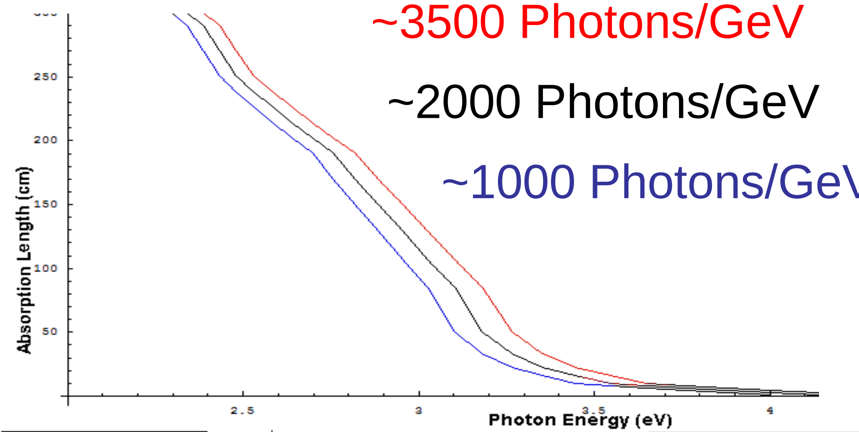


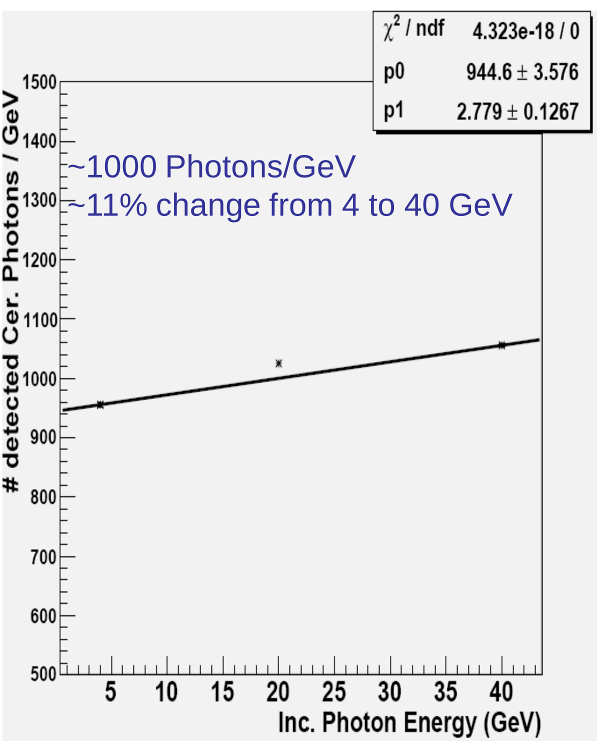
Using PbGl-Air-Aluminum with Air aluminum reflectivity

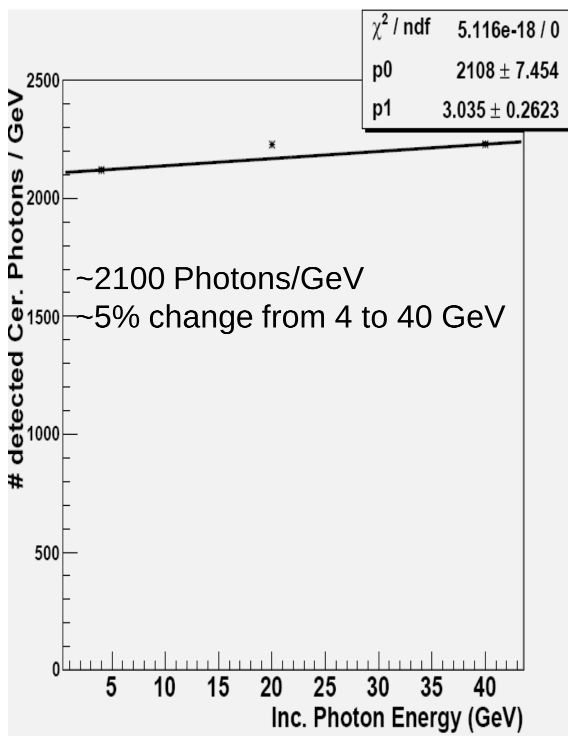
~1200 Photons/GeV
~10% change from 4 to 40 GeV

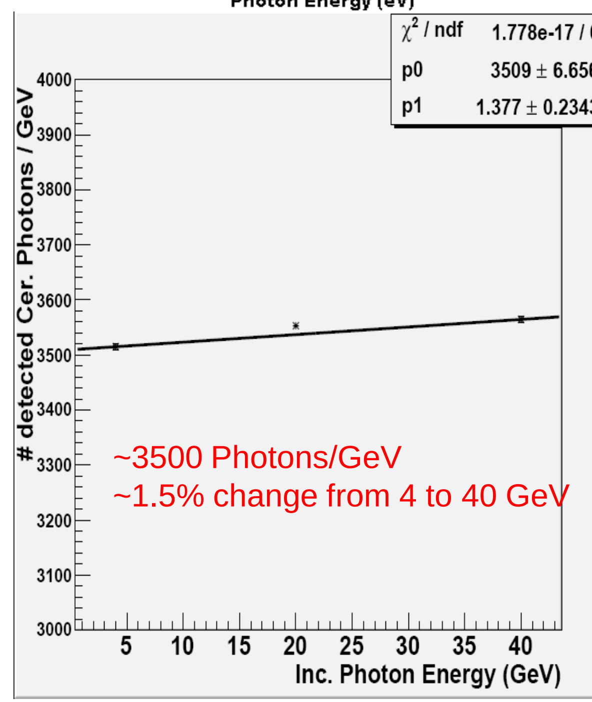


Vary the air-aluminum absorption by shifting in absorption vs energy





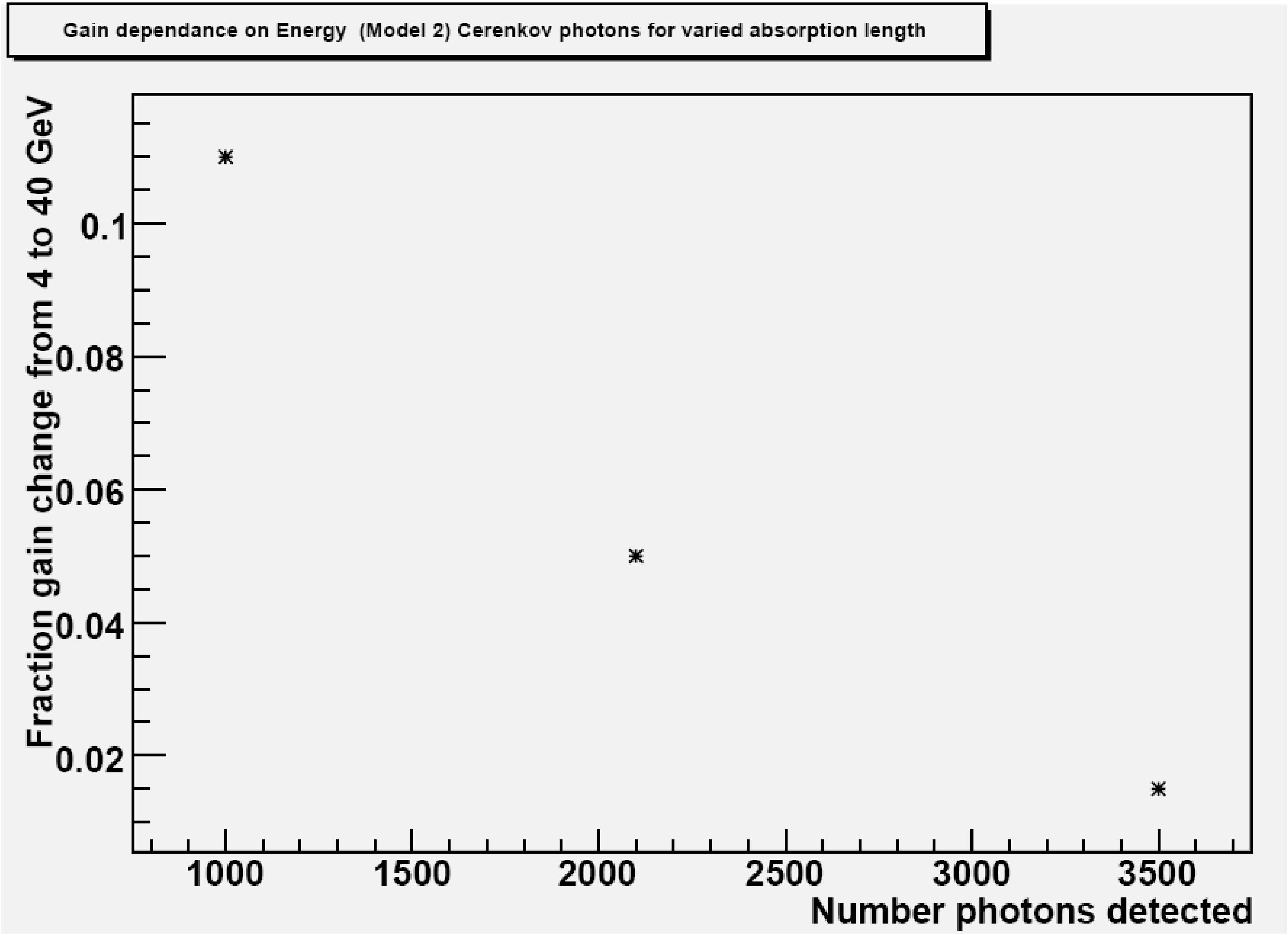




Fractional Gain Change for change in incident photon energy from 4 to 40 GeV.

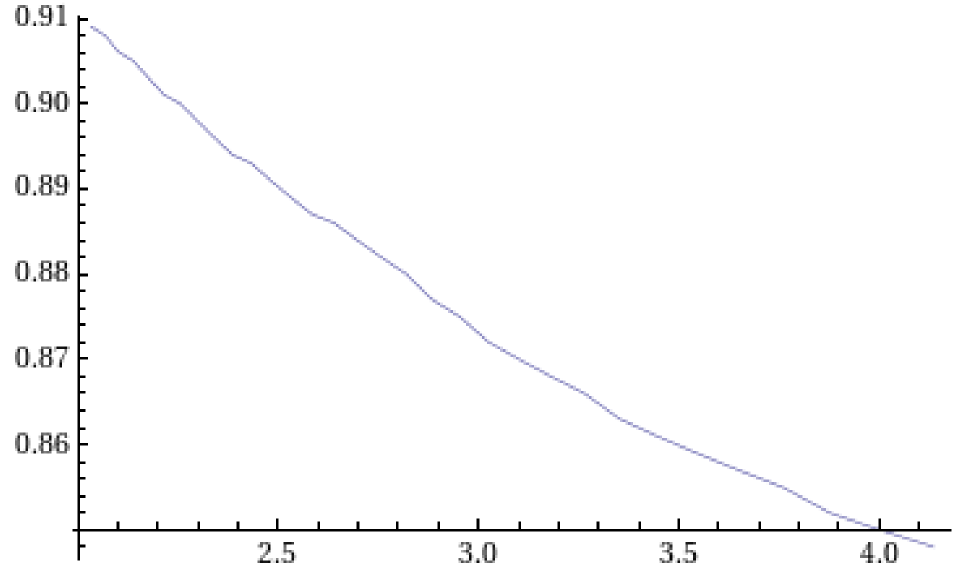
(Model 2) for Observed Cerenkov Signal.

The absorption (and number of detected photons) is varied.



Without P. Cathod Eff.
70,000 PE/Gev

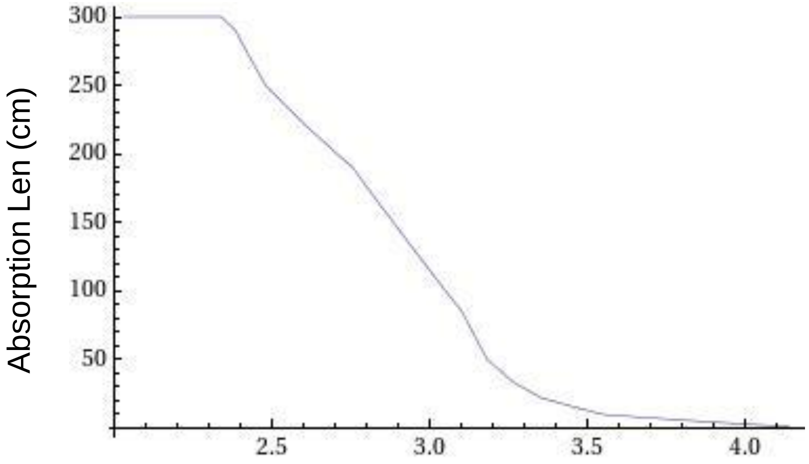
With P.Cathode Eff applied.
For Abs Glass = 4000 cm
For Reflectivity = .999
For Abs Al-Air from graph
@10 GeV
7000 PE/GeV



With P.Cathode Eff applied.
For Abs Glass = 4000 cm
For Abs Al-Air from graph
@10 GeV
4900 PE/GeV
% central bin = 83.8 %

For Abs Glass = graph on right
For Abs Al-Air from graph
@10 GeV

1200 Cer photons / GeV
% central bin = 83. %



Response to Cerenkov Photons

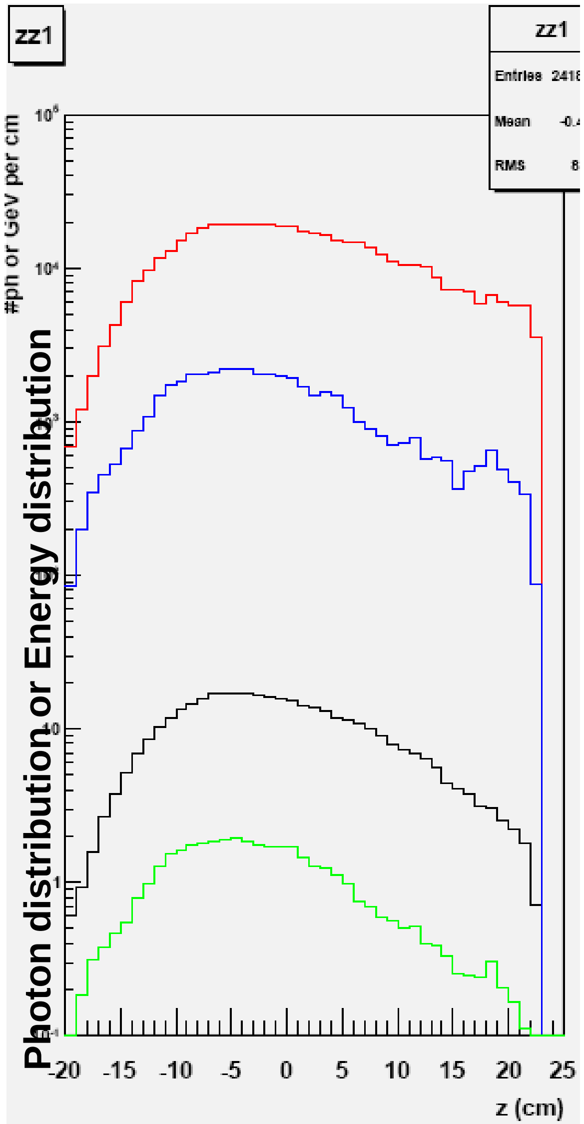
The shower shape is most narrow in the upstream region (center bin>90%)
The shape is most wide in the downstream region (center bin ~ 50%)
The shape is narrower about (central bin 5% to 10% larger) for Cerenkov photons than deposited energy.

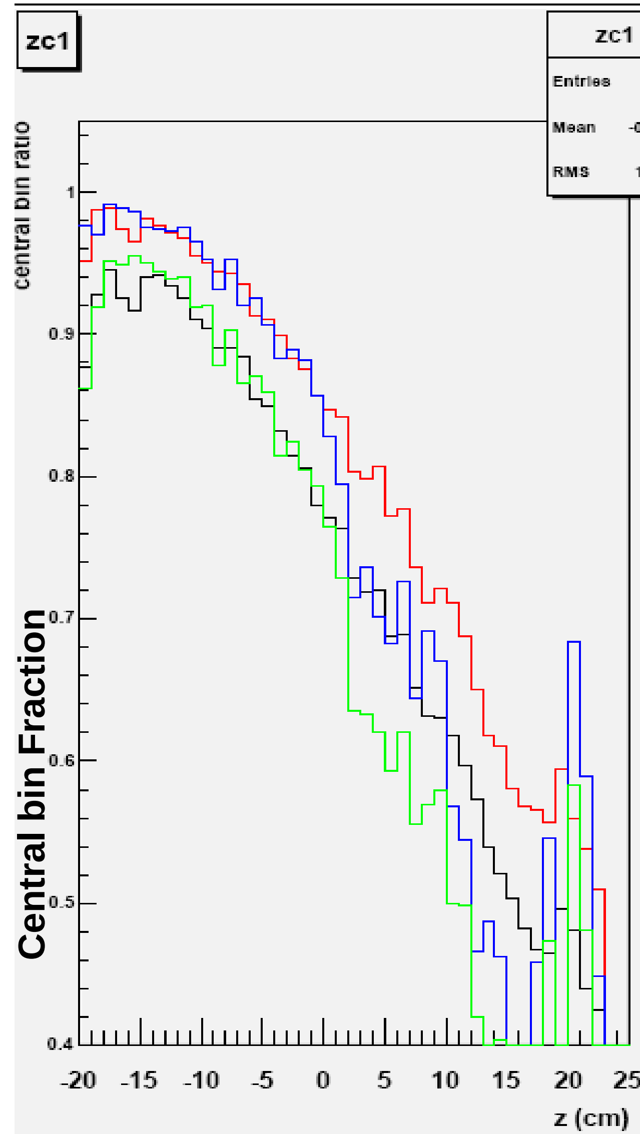
40 GeV (# photons detected)

4 GeV (# photons detected)

40 GeV (energy deposited)

4 GeV (energy deposited)



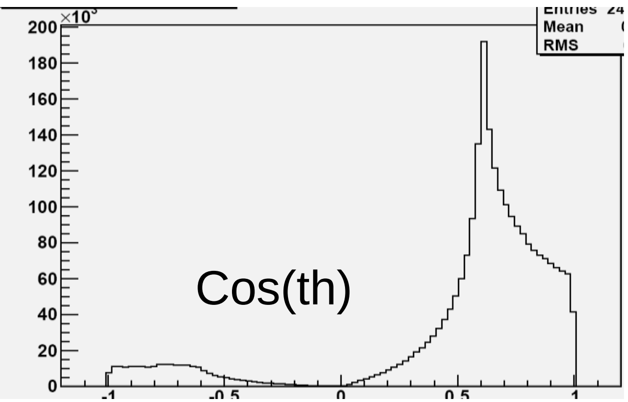


Response to Scintillation Photons

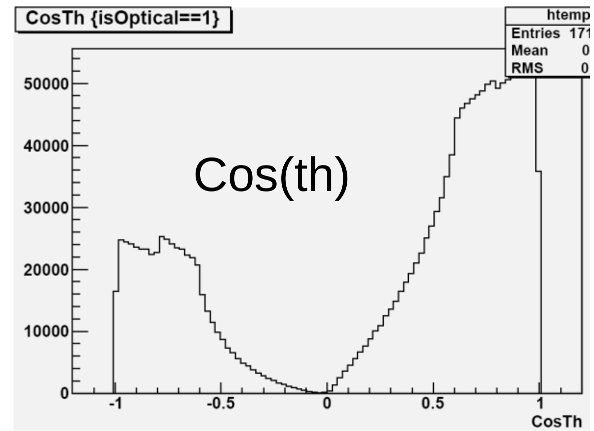
Now we study the difference (in model 2 with nominal absorption and reflection) between a Cerenkov photon signal and a scintillation photon signal.

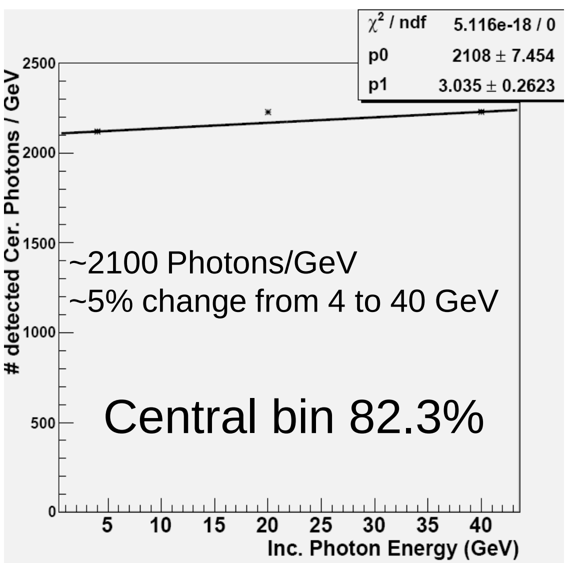
Overall number of generated scintillation photon rate is not known.

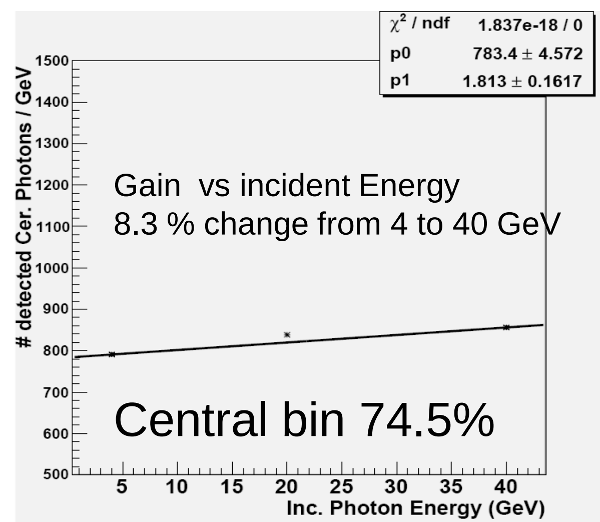
Detected Cerenkov Photons



Detected Scintillation Photons



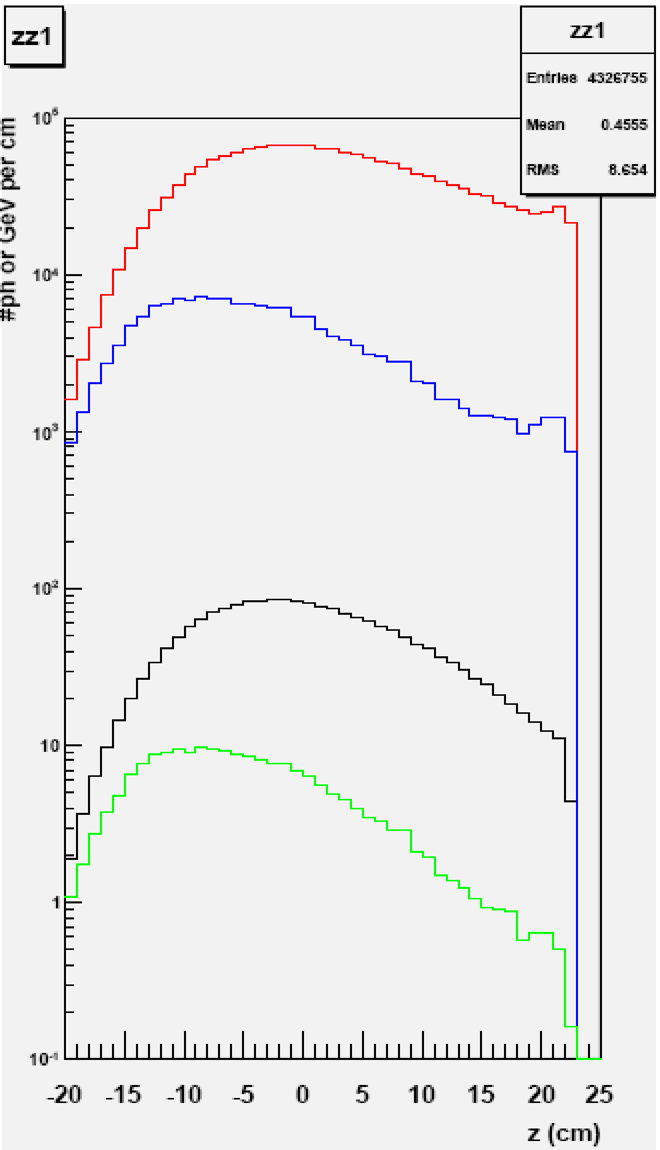




Response to Scintillation Photons

Z distribution of # photons and energy deposited for 4 & 40 GeV incident photons

The fraction the observed signal in the central bin vs z position of energy deposition and photon source.

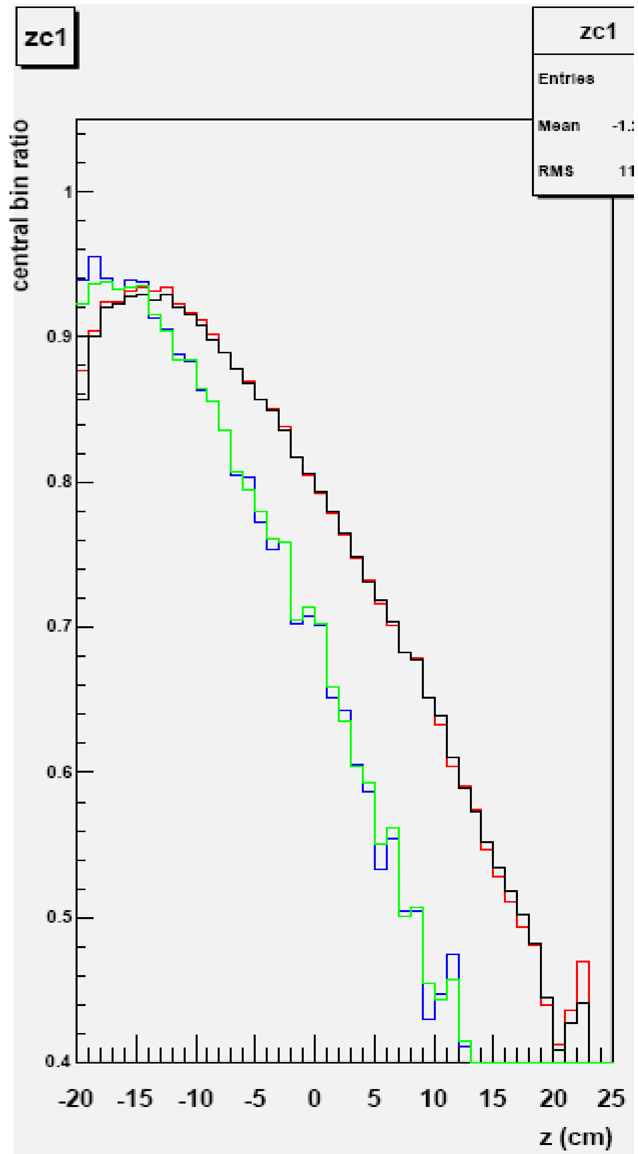


40 GeV (# photons detected)

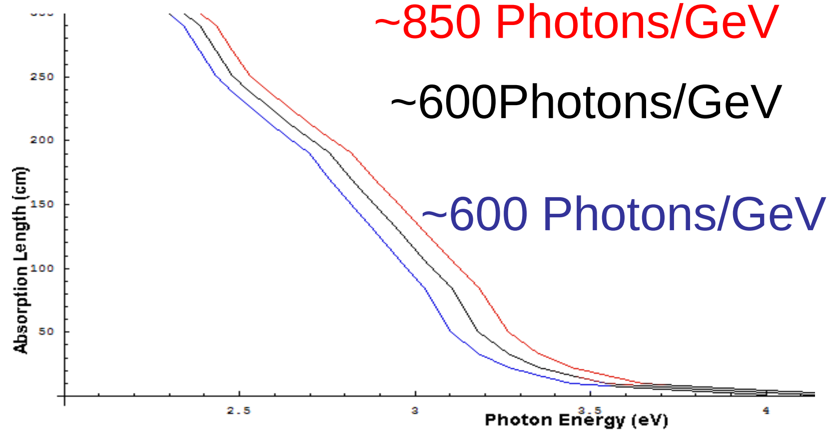
4 GeV (# photons detected)

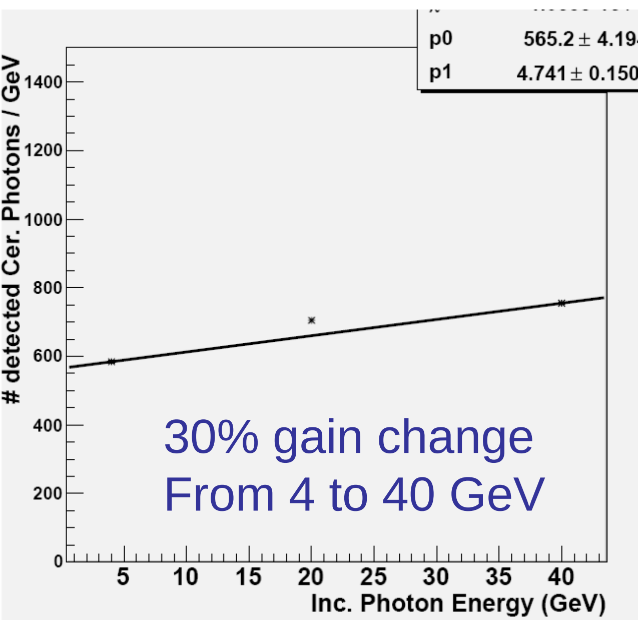
40 GeV (energy deposited)

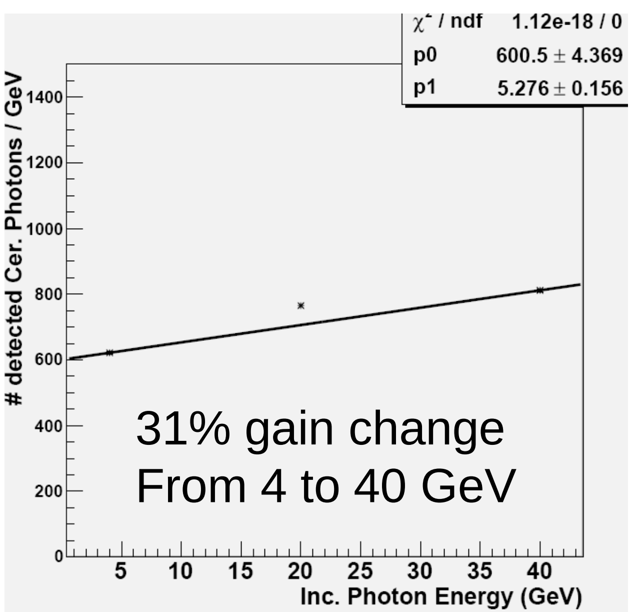
4 GeV (energy deposited)

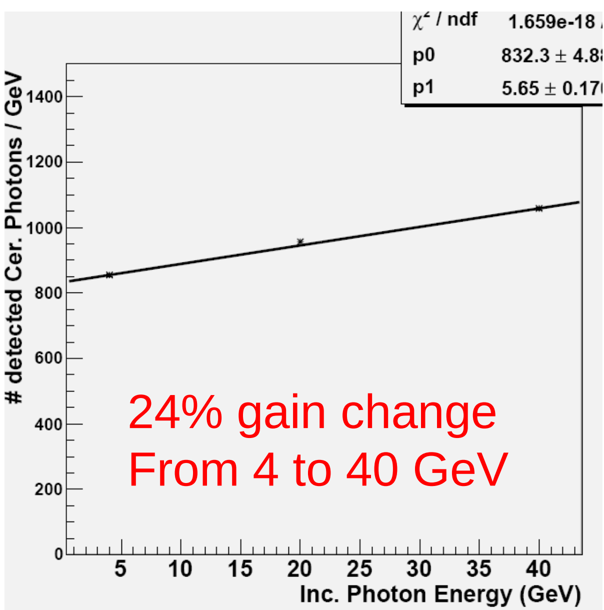


Gain-Energy slope vs Absorption
Response to Scintillation Photons



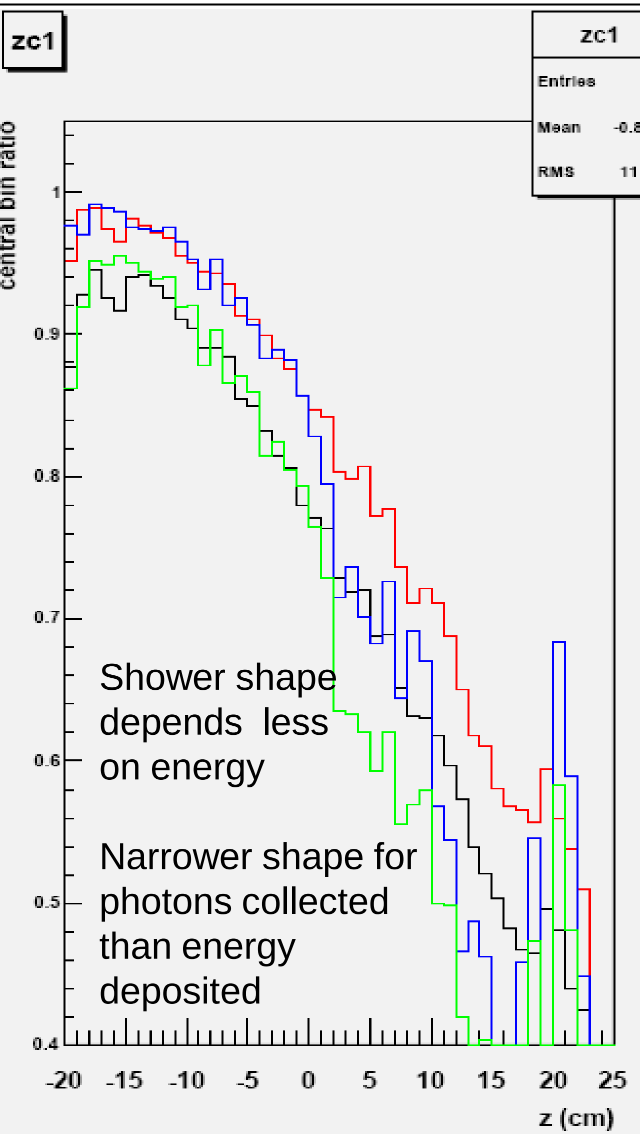






Shower Central bin Fraction for Cerenkov Photons (nominal absorption effects)

Shower Central bin Fraction for Scintillation Photons (nominal absorption effects)

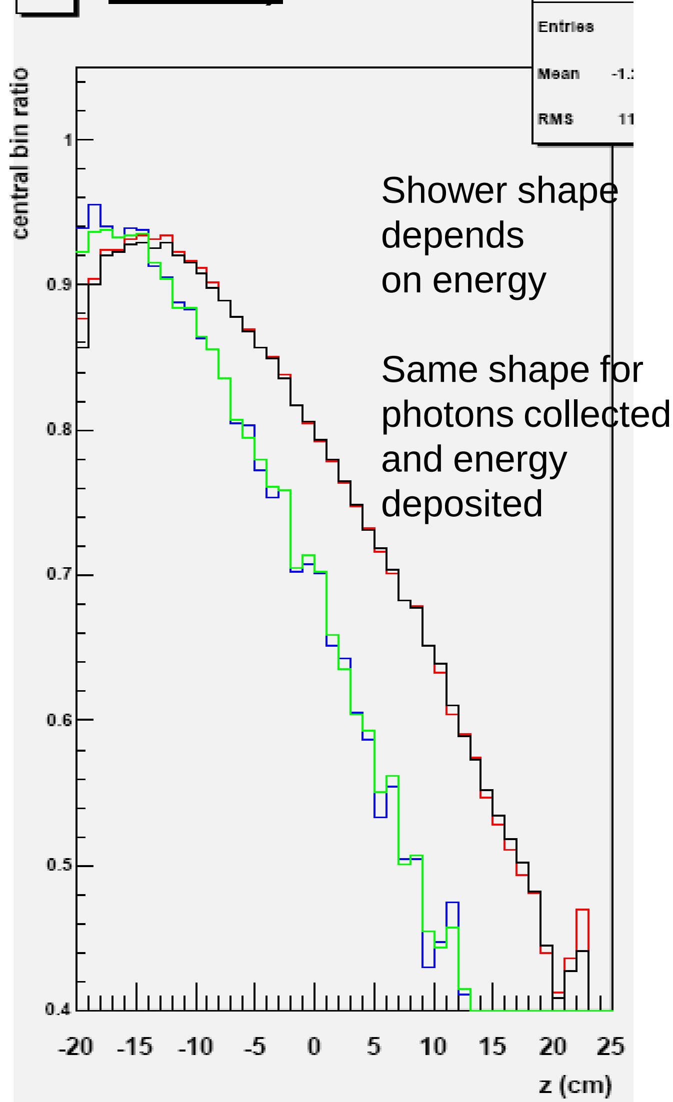


40 GeV (# photons detected)

4 GeV (# photons detected)

40 GeV (energy deposited)

4 GeV (energy deposited)



Summary of Geant4 small cell studies.

- **Two observables**
  - **Width of Shower (% in central bin)**
  - **Gain vs Energy**

- The shower width appears narrower in Run 9 FMS than Run 6 FPD
- The FMS appears to have more energy dependence of the gain than the FPD

- The effect of observing Cerenkov photons would be a narrower shower (~5 to10%) for central bin in comparison to the energy deposition shape.

- Radiation damage will shift the absorption spectrum to lower energy.
  - This would lead to an increase in energy dependence of gain. (as seen in FMS)
  - This would lead to a widening of the shower (in contrast to what is seen in the FMS)

- The extra lead glass in front of small cells may also widen the Run 6 FPD result in comparison the FPD Run 9 result.