Simulation and reconstruction of CLAS12 Electromagnetic Calorimeter in GSIM12

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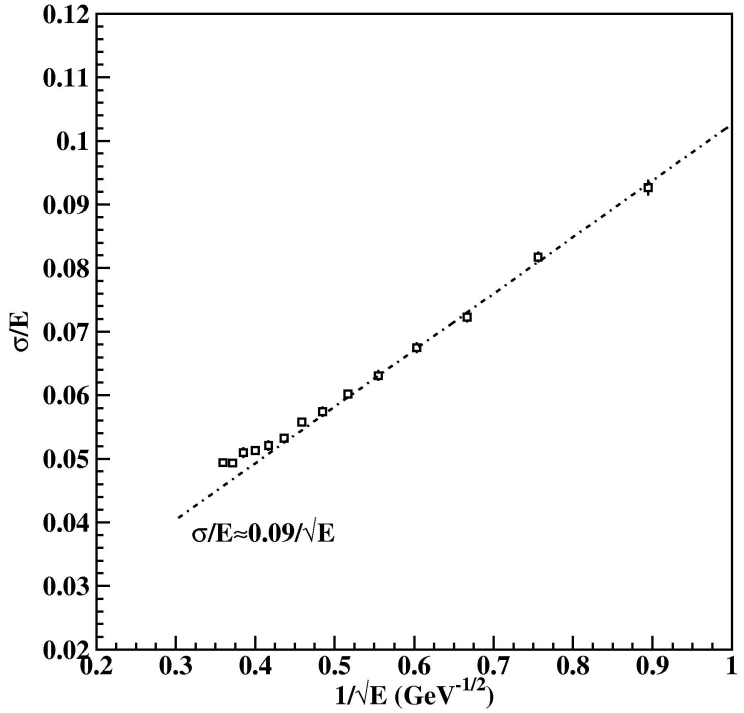
CLAS12 Detector workshop, February 21, 2008 , JLAB

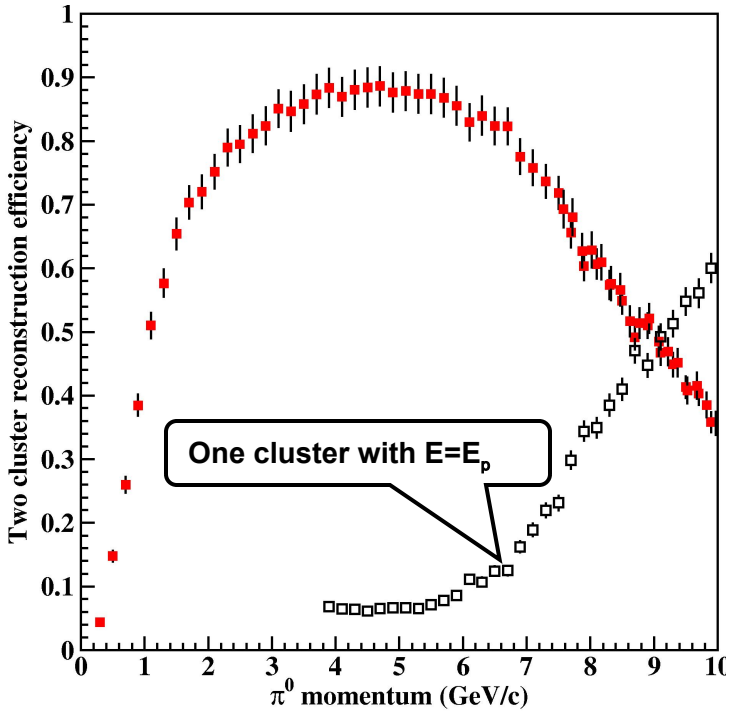
CLAS EC at high energies

Two problems will arise at high energies

Diminishing energy resolution due to leakage from the back



Separation of clusters from high energy p^0' gg decay



Both are important for successful execution of the CLAS12 physics program

GEANT simulation of the PCAL

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Goals:

- establish design parameters of PCAL
- determine characteristics of electromagnetic shower and ρ^0' gg reconstruction in the CLAS12 forward electromagnetic calorimeter

Tools:

- GEANT simulation package for the CLAS detector, GSIM, with PCAL positioned in front of EC
- CLAS event reconstruction package, RECSIS. Modified EC package for cluster reconstruction

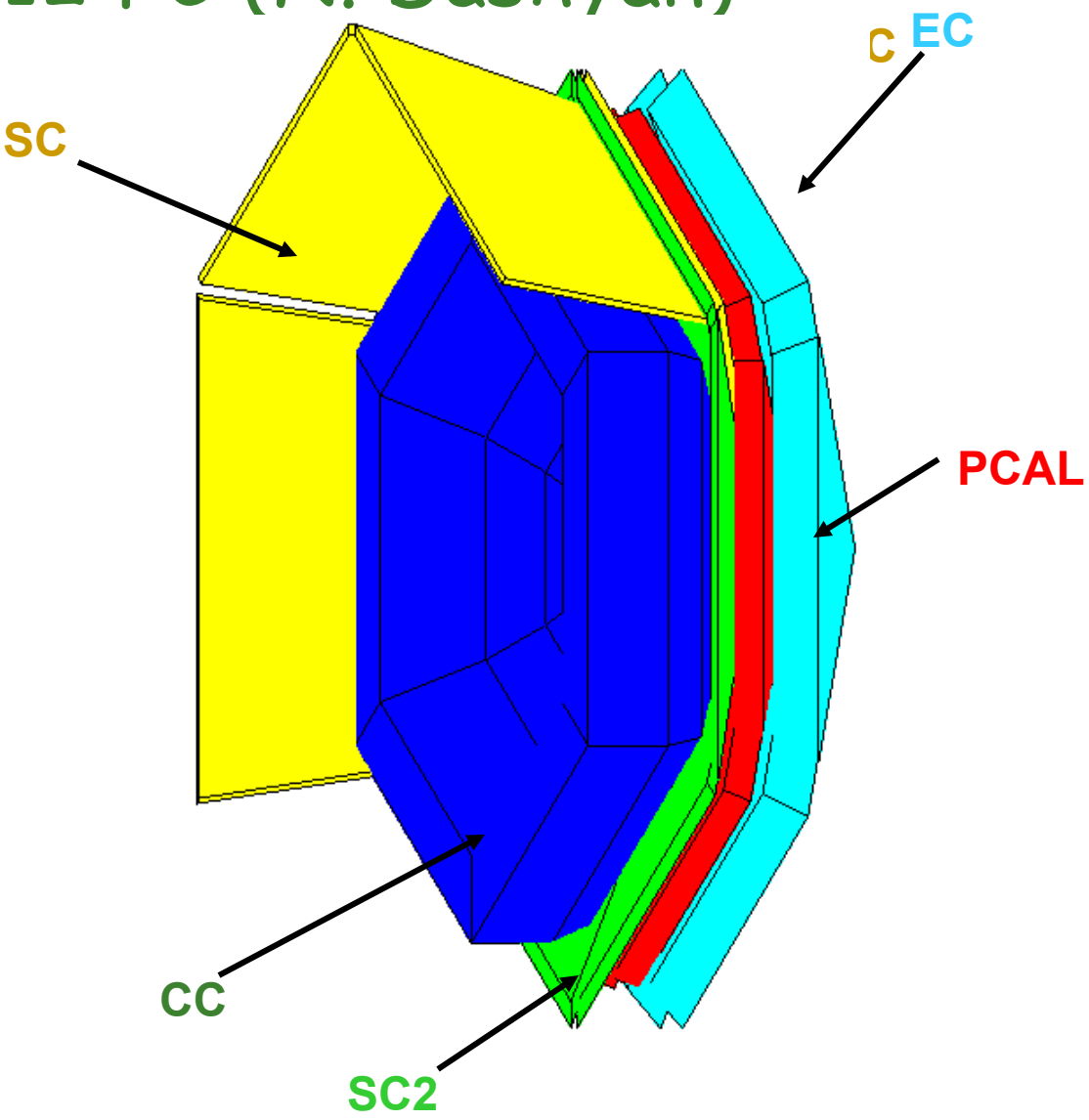
GSIM12 – CLAS12 FC (N. Dashyan)

CC – Low threshold Cerenkov counter

SC, SC2 – Time –of-flight scintillator arrays (FTOF)

PCAL – Pre-shower electromagnetic calorimeter

EC – CLAS forward electromagnetic calorimeter



PCAL- status of simulation

The model of PCAL in GSIM12 based on results of earlier simulations and the engineering design.

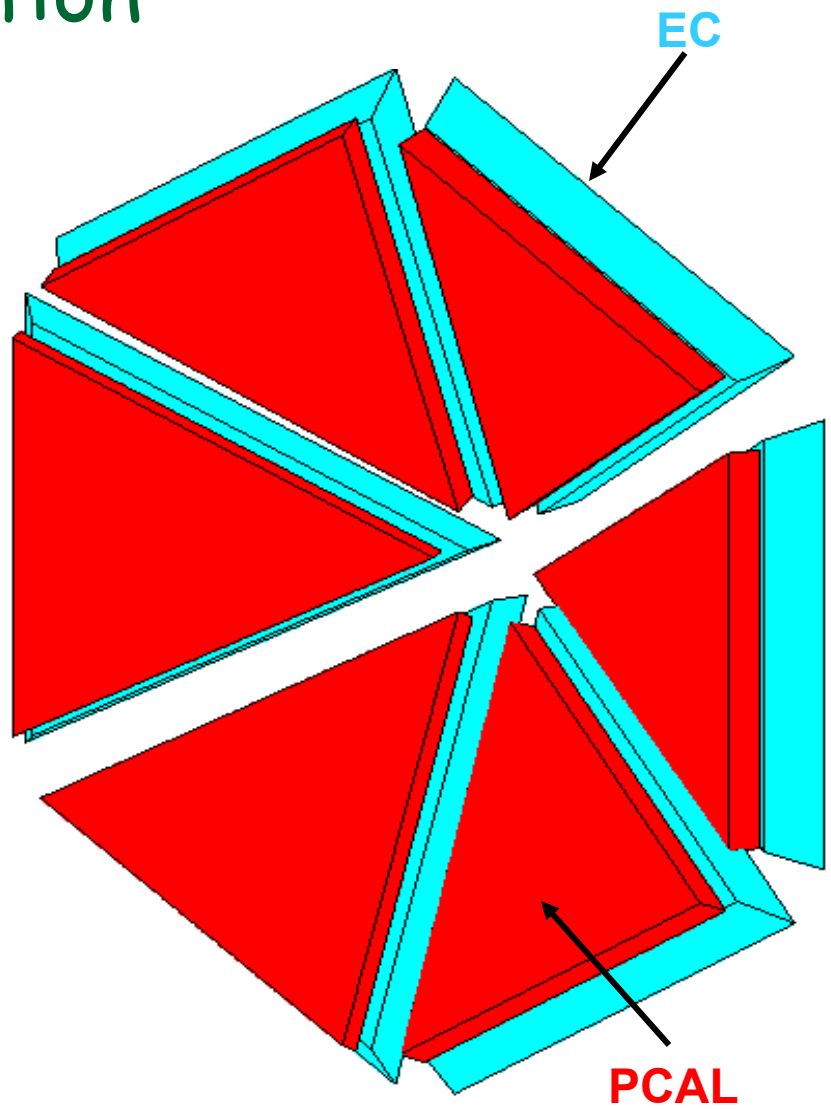
Currently it has:

- final dimensions of the PCAL,

- final dimensions and materials of the PCAL layers,

- cover plates (end plates of the container that will be contain scintillators, lead and support elements),

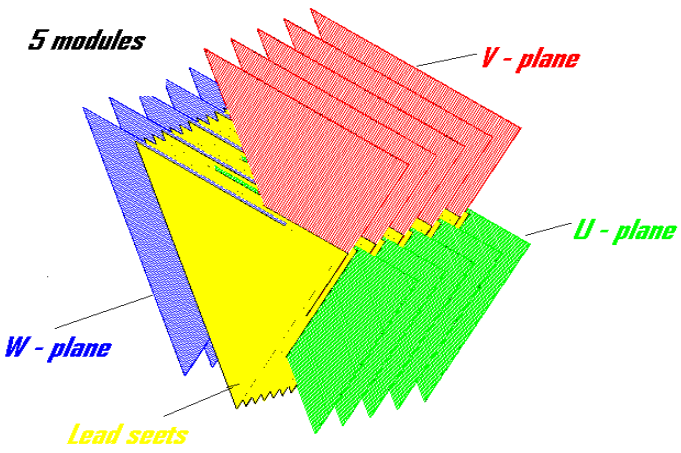
- correct position relative to EC

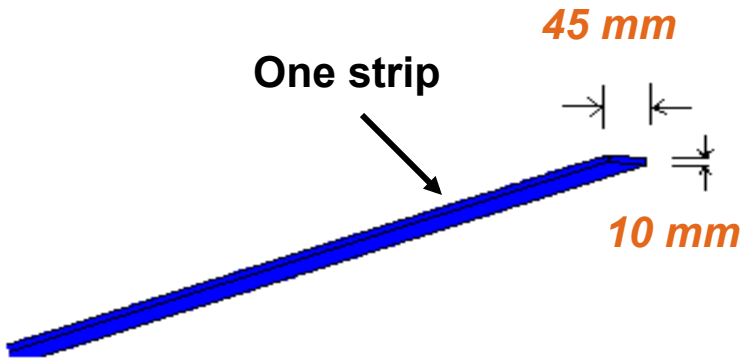


Pre-shower in GSIM12

Internal geometry of the PCAL:

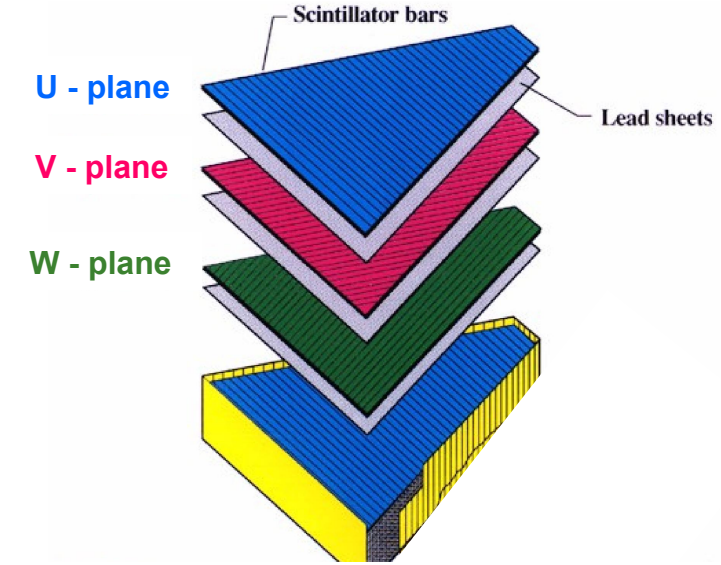
- alternating layers of scintillators and lead
- 10 mm thick scintillator, 2.2 mm thick lead
- triangular shape layers to match the geometry of the EC
- three stereo readout views (U, V, and W)
- 15 layers of scintillators (5 per view) and 14 layers of lead
- the whole stack was sandwiched between two end plates, constructed from composite foam and 2mm thick SS sheets
- scintillator layers were sliced into 108 strips of equal width





CLAS forward electromagnetic calorimeter (EC)

- Lead-scintillator sandwich, 16 radiation lengths
- 39, 10mm thick scintillator and 38, 2.3 mm thick lead layers, each - almost an equilateral triangle, with 8 m^2 coverage
- Three stereo readout planes (13 layers per view), each following scintillator layer have strips rotated to 120 degrees relative to the orientation of the previous layer
- Projected geometry, 36 strips per layer, scintillator strip width 10 to 12 cm, readout from one end via bundle of clear optical fibers
- In the direction of the shower, readout is segmented into 2 parts: 5 layers per view for “Inner” and 8 layers “Outer” parts



FEC Cluster reconstruction algorithm

ADC ⇨ energy
TDC ⇨ time
Layer "Whole"

For each layer

Search for peaks on stereo views

grouping of strips with $E>E_{thr}$, separated by strips with no energy deposition. # strips for separation is a parameter for ec code

Energy and position of peaks (also moments)

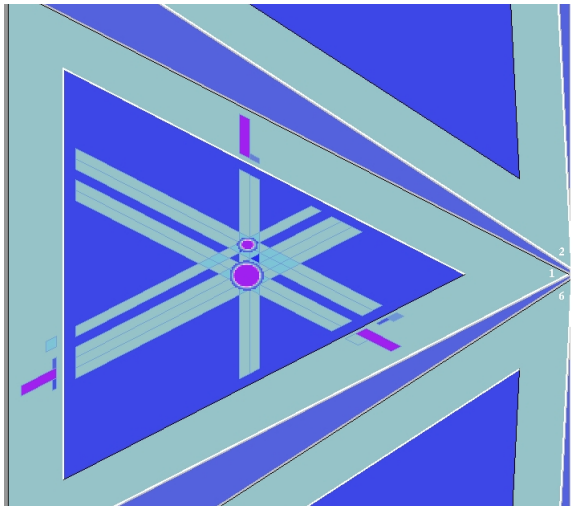
$$E_p = \sum \varepsilon_s$$

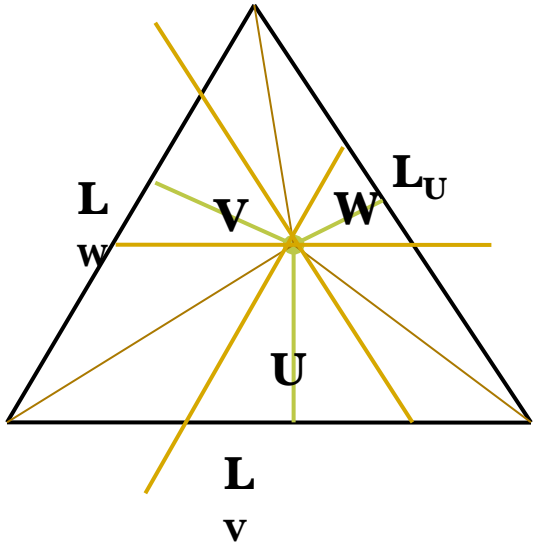
$$X_p = \frac{\sum x_s \varepsilon_s}{\sum \varepsilon_s}$$

Attenuation corr.

Clustering of peaks (Dalitz rule), cluster energy, time and position

Output – clusters in 3 layers





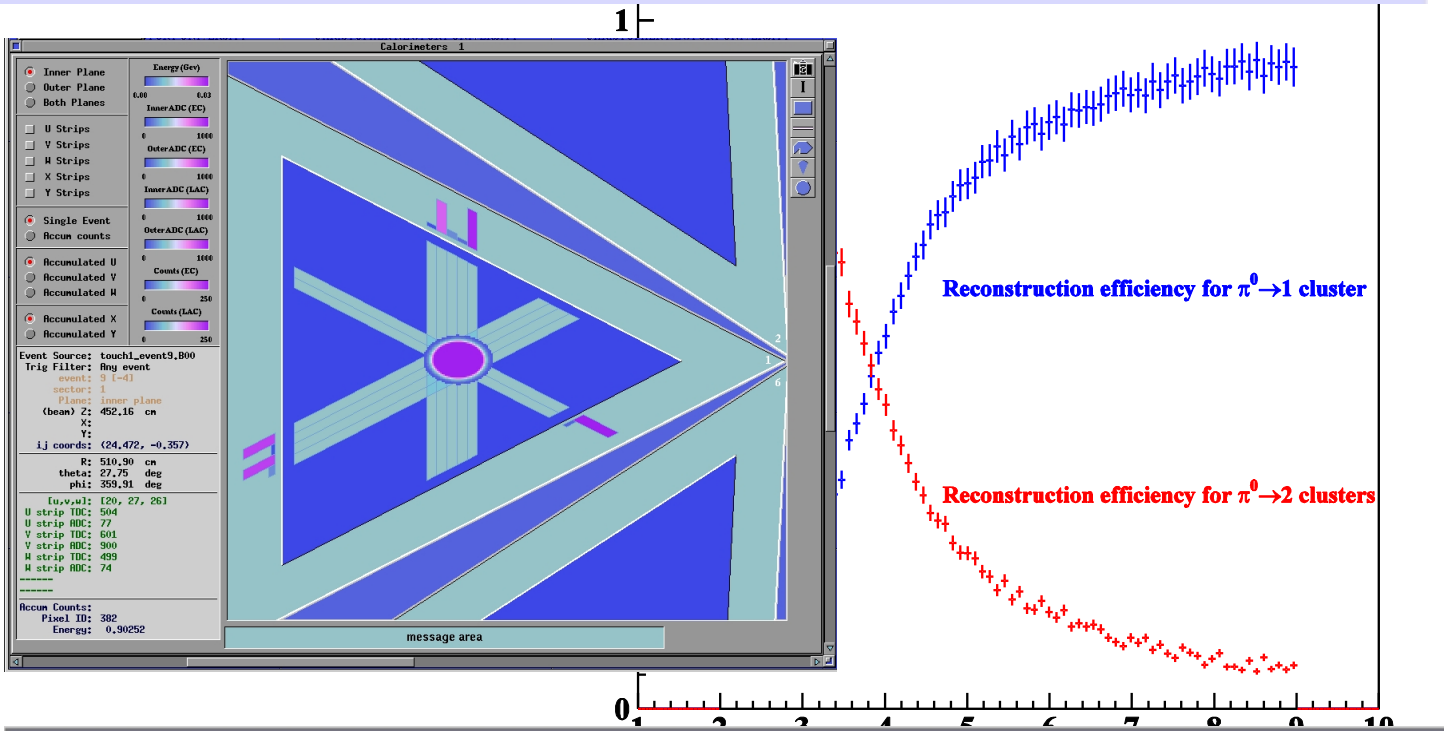
PCAL reconstruction

- The same algorithm as for EC, just one more layer (“Cover”)
- New BOS bank, EC2
- Layer “Cover” switches on if EC2 exists in the input data stream
- Uses different layer segmentation for position and moments calculations
- Allows use of variable width for layer segments

New vs. old algorithm for peak finding

Old - reconstruction of high energy p^{0}' gg

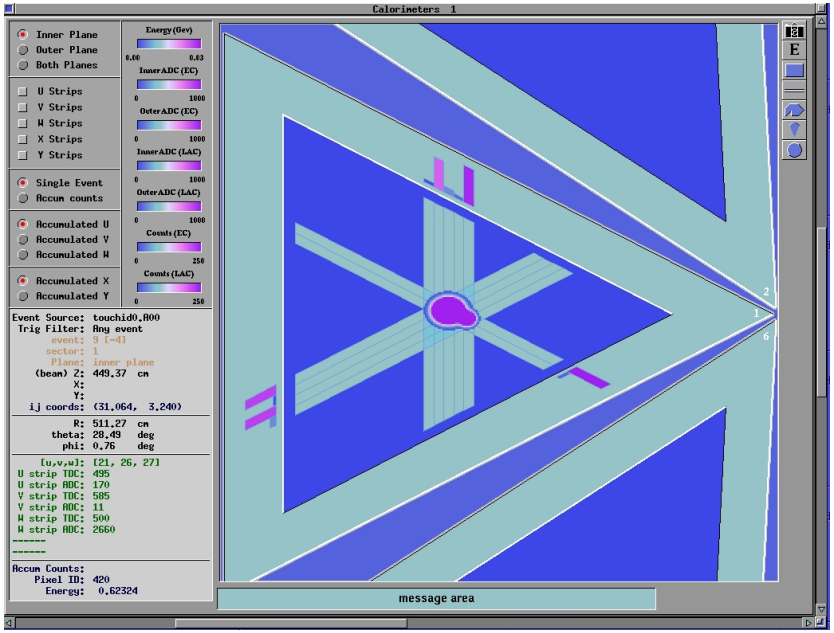
```
---- MCTK bank ----  count: 3
 Cx       Cy       Cz       P[Gev]   M[Mev]    Q     tflag   b_vtx   e_vtx   parent  Particle
 0.458    0.000    0.889    5.441    135.000   0     11      1       1       0       pi0
 0.444   -0.008    0.896    3.638     0.000    0     1       1       0       1       gamma
 0.485    0.016    0.874    1.805     0.000    0     1       1       0       1       gamma
```




```
---- ECPI bank ----  count: 3
 sect    lay      nhit    hit     iloc     jloc     di       dj       R        E
  1      both     101      0     22.594    2.150    9.973    7.519   12.944   1.443
  1      inner    101      0     23.945    1.256    9.596    6.828   11.777   0.929
  1      outer    101      0     23.074    1.210    9.259    6.588   11.777   0.501
```

New – the same event

- Search for peaks on each view by analyzing the line shape of the energy distribution for strips with $E>E_{thr}$, # strips for separation =0
- Energy shearing for strips that belong to two groups

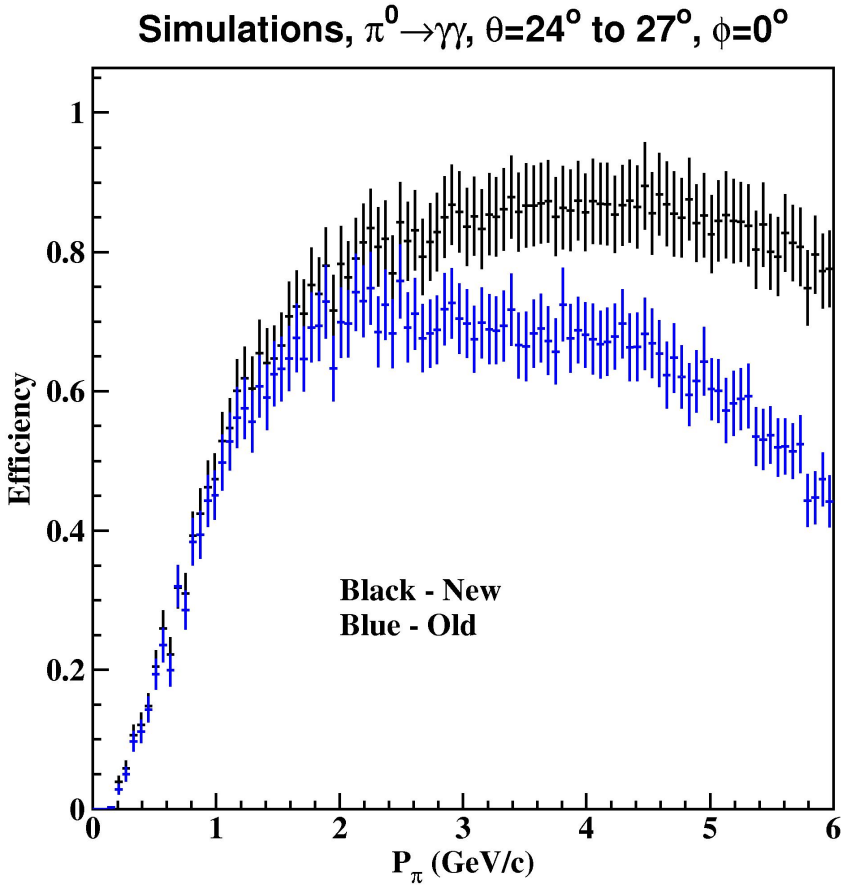



```
---- ECPI bank ----  count: 4
 sect     lay     nhit     hit      iloc     jloc      di      dj      R       E
   1     both     101        0    21.496    1.712    9.416   7.215   12.294   1.438
   1     inner    201        0    30.786    3.904    7.140   5.701    9.137   0.628
   1     inner    202        0    11.321   -4.216    4.137   3.561    5.458   0.299
   1     outer    101        0    19.424    0.916    9.456   7.212   12.325   0.501
```

Comparison with simulated data

- p^0' s were generated in the momentum range from 0.1 to 6 GeV/c, in the polar angular range of 24° to 27° in the middle of the sector 1
- Standard GSIM version was used to simulate CLAS
- Reconstruction:
  1. user_ana linked with old EC library and number of strips for separation of peaks on the edges =1, **blue**
  2. User_ana linked with new EC reconstruction algorithm and the separation parameter =0, **black**

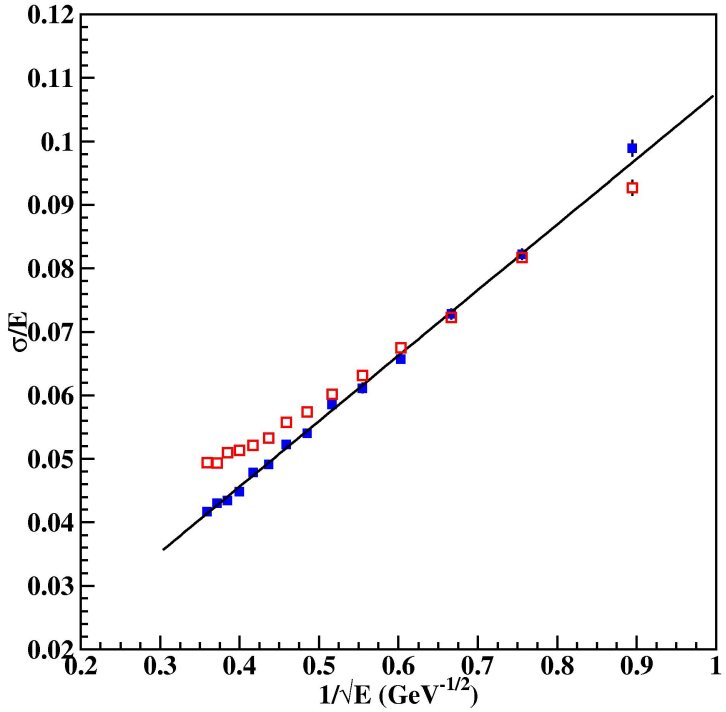
Reconstruction of 2 clusters



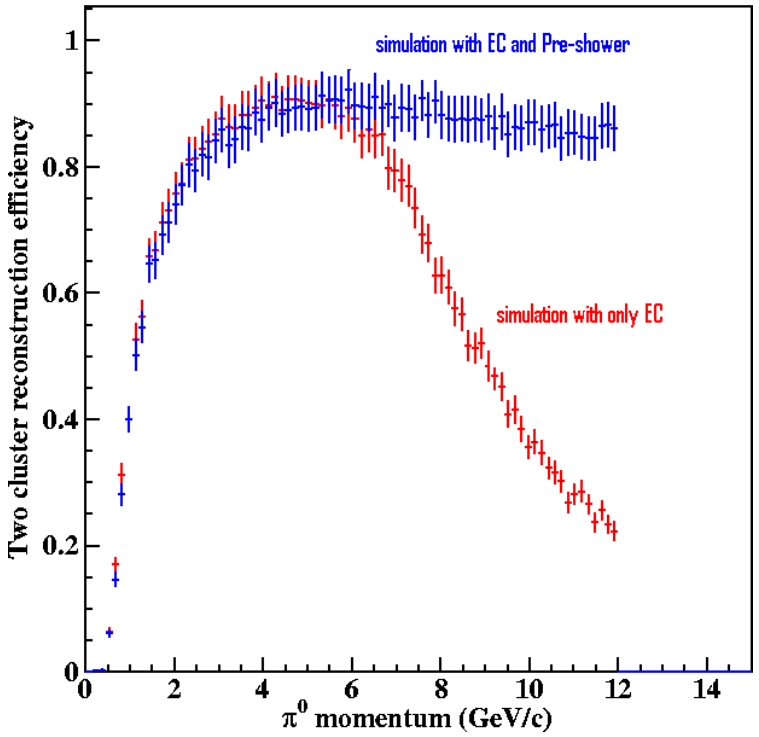
PCAL+EC simulations (15 layers and 108 strips)

Energy resolution for electrons thrown in the center of the of the calorimeter

$$\frac{\sigma_E}{E} \approx \frac{0.1}{\sqrt{E}}$$

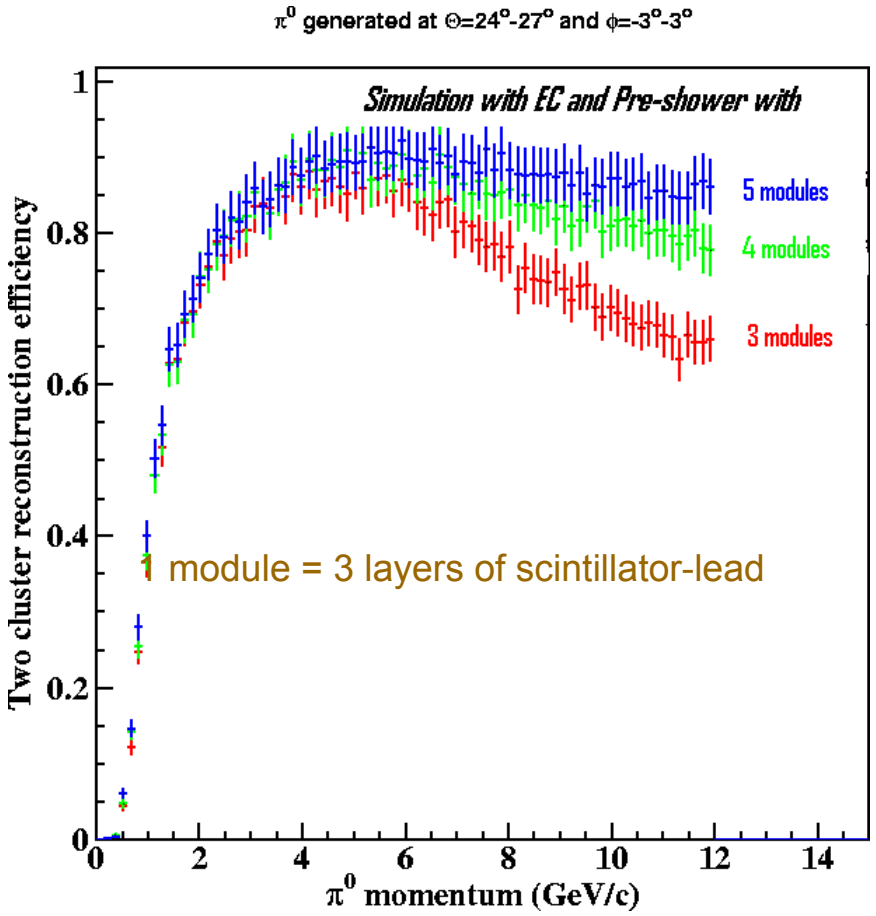


Efficiency of two photon cluster reconstruction from high energy p^0' gg decays



Configurations with 9, 12, and 15 layers

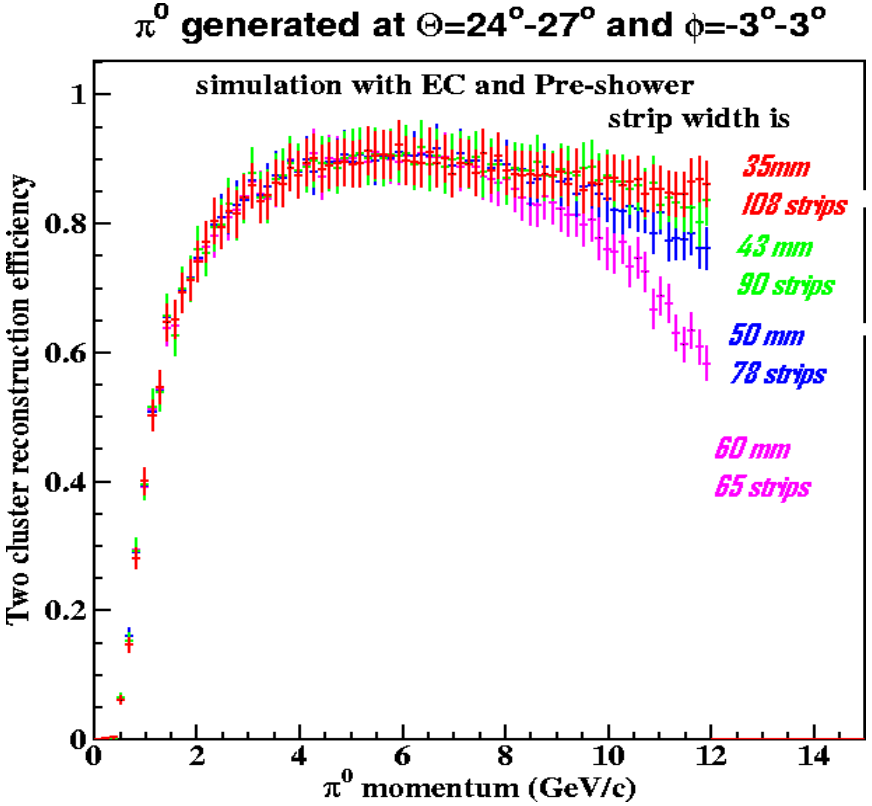
- p^0 reconstruction efficiency decreases at high energies for 12 and 9 layer modules
  - not enough radiator thickness and some of high energy photons do not convert
- 12 layers configuration with first 3 layers of lead with double thickness had comparable efficiency but ~10% worse energy resolution



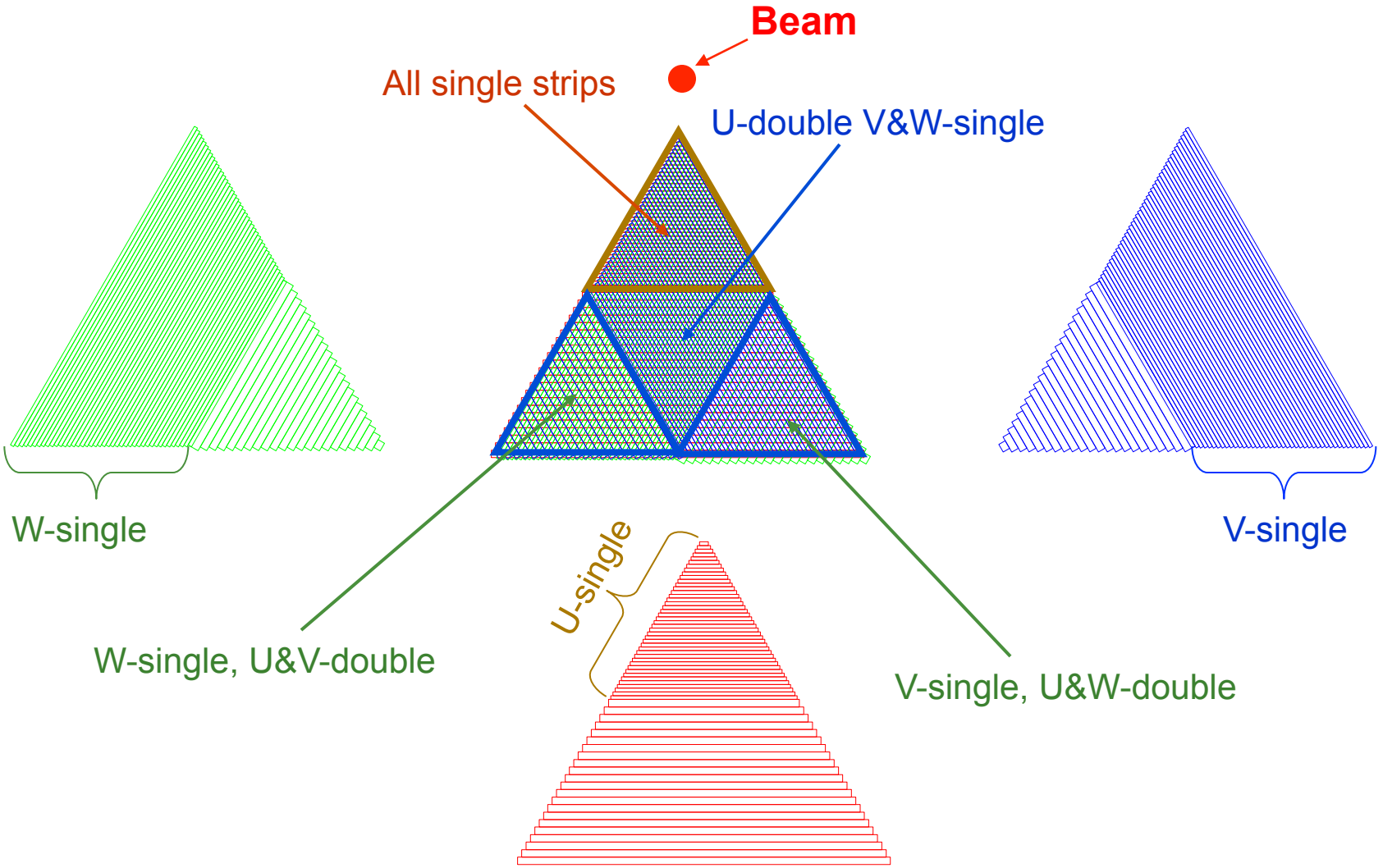
Different readout segmentations

Simulations with 15 layers of scintillators and 14 layers of lead

- Efficiency of reconstruction of two clusters from p^0' gg decay decreases for small number of readout segments
- For p^0 energies up to 10 GeV efficiency of two cluster separation is reasonably high for 4.5 cm wide segmentation



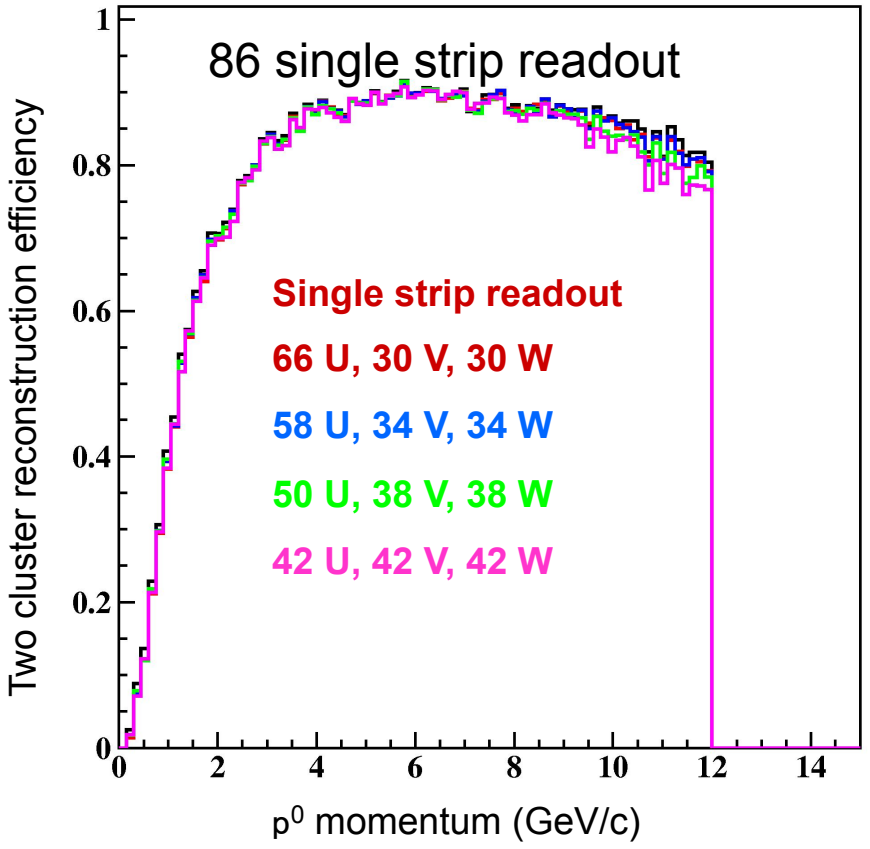
Readout with variable segmentation



Variable segmentation with 196PMTs/sector

- Total of 86x4.5 cm wide strips in each readout view (U, V, and W)
- Finer segmentation (4.5 cm) of short U strips and long V and W strips will allow to achieve desired results with smaller number of readout channels
- Final number of strips per layer and arrangement of the readout will be performed after design is completed

Simulations with 15 layers, 4.5 cm strip width



Summary of simulations

- Design parameters of the pre-shower have been established using a full GEANT simulation of the CLAS12 electromagnetic calorimeter system
- Proposed configuration for the pre-shower:
  - 15 layers of the lead and scintillator, 2.2mm lead, 10mm scintillator
  - three stereo readout views, UVW (5 layers per readout view)
  - 4.5 cm segmentation of the scintillator layers in the forward region for all three UVW views. In the backward region, double-strip (9 cm) readout for U view (perpendicular to the beam direction) and single- or double-strip readout for V or W
- Simulations and reconstruction will continue -
  - final arrangement of the readout segmentation
  - photoelectron statistics
  - realistic attenuation of light in the fibers and photoelectron statistics
  - digitization - fADC
  - integration of the PCAL+EC configuration into the CLAS12 simulation and reconstruction packages