Optimization of ECAL for the LUXE experiment

M.Shchedrolosiev[1]

[1]Taras Shevchenko National University of Kyiv

May 5, 2020

1. ECAL geometry
2. Geant4 geometry
3. Energy and position resolition
4. Flow counting
5. Spectrum Reconstruction

At the IP, electron–positron pairs will be produced both in $\gamma_B + n\omega$ and $e^- + n\omega$ processes. A spectrometer system is again employed, using a dipole magnet to separate the electrons and positrons from each other and from photons which continue down the beam line. The calorimeter will allow matching of tracks from the silicon detectors to energy deposits and hence provide extra information in the measurement of the electron and positron energy spectra.

Supervised by: H.Abramowicz, O.Borisov, A.Levy, W.Lohmann
Representative from KNU: V.Aushev

Geometry ($\gamma + n\gamma_L \to e^+e^-$ case)

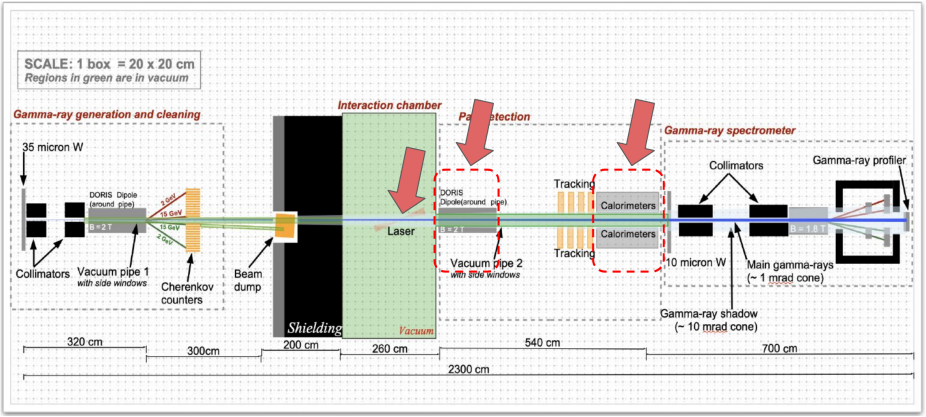


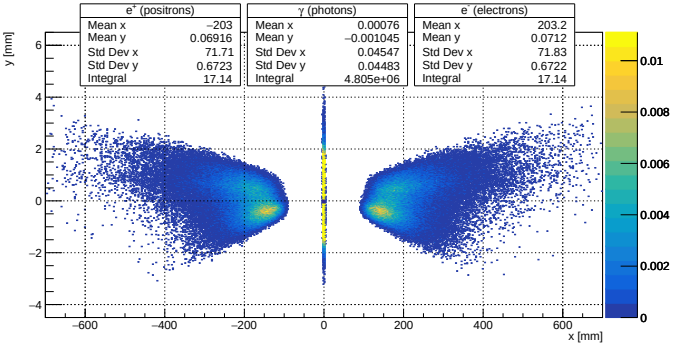
***Figure*3.**[1] Experimental setup of the LUXE experiment

- Magnet: 1.4 T
- Magnet profile: 60cm x 20cm x 150cm
- Nominal length: 1.029 m

- Magnet position: 100cm - 250cm
- ECAL position: 500cm

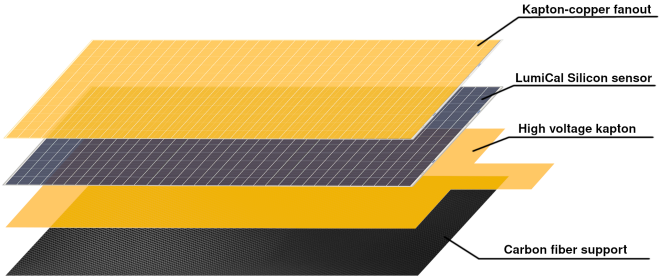
[1] arXiv:1909.00860

Geometry ($\gamma + n\gamma_L \to e^+e^-$ case)

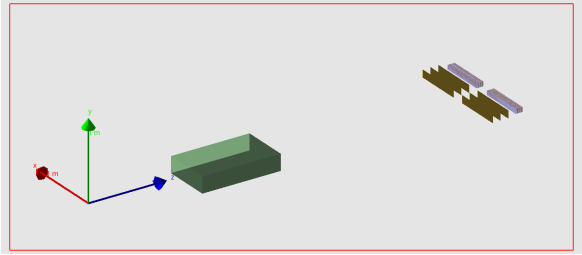


LumiCal sensors parameters:

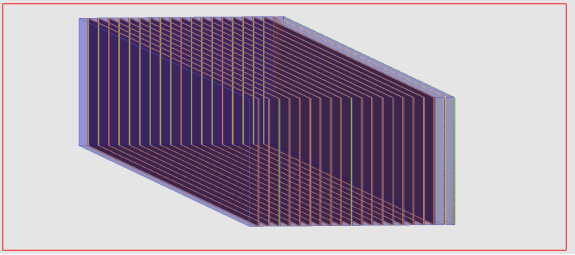
- Layer gap: 0.2mm
- Silicon: 0.32mm
- Carbon: 0.1mm
- Aluminium: 0.02mm
- Tungsten: 3.5mm
- Density: $19.3 g/cm^3$
- Fanout (both): 0.15mm (with epoxy)



Geometry ($\gamma + n\gamma_L \to e^+e^-$ case)



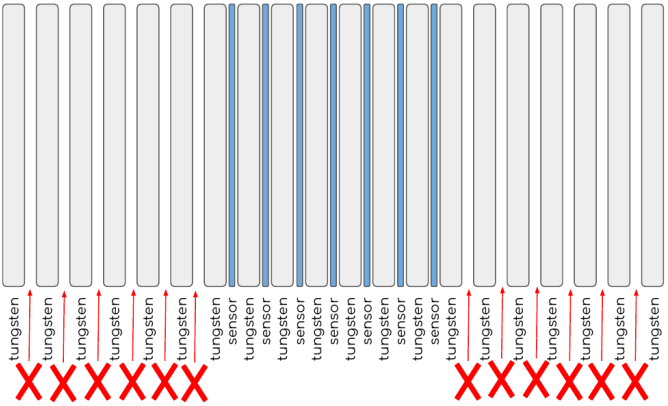
IP is in the beginning of coordinates.



20 Layers of W-Si calorimeter.

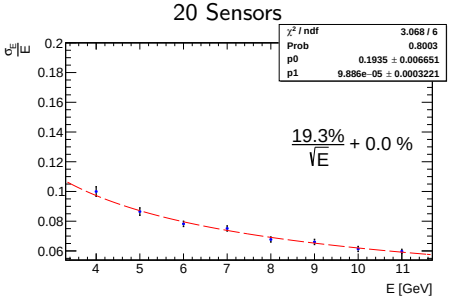
Region covered in $\perp$ coordinate x: 100mm .. 650mm
Region covered in $\perp$ coordinate y: -27.5mm .. 27.5mm

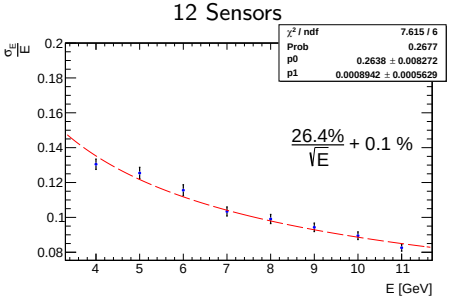
Energy resolution

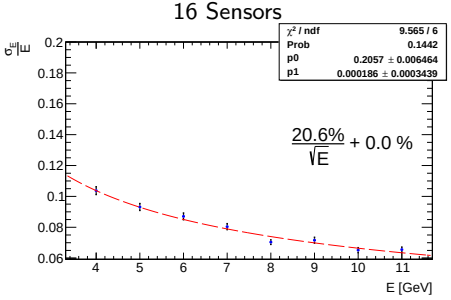


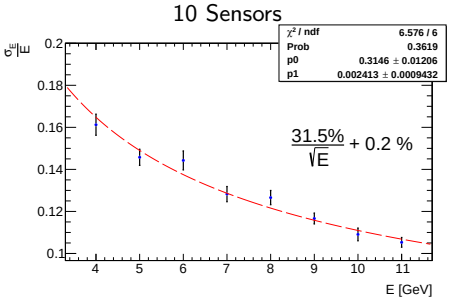
1. Monoenergetic particles are used
2. MC is generated for energies: 4GeV - 11GeV
3. MC runs per energy: 10k
4. Reduce number of sensors starting from external layers
   1. 20 Sensors
   2. 18 Sensors
   3. ..
   4. 12 Sensors
   5. 10 Sensors
5. All the hits are reconstructed as one shower $E_{cluster} = \sum E_{hits}$
6. $\sigma(E)/E = \sqrt{(c_1/\sqrt{E})^2 + c_2/E + c_3}$

Energy resolution





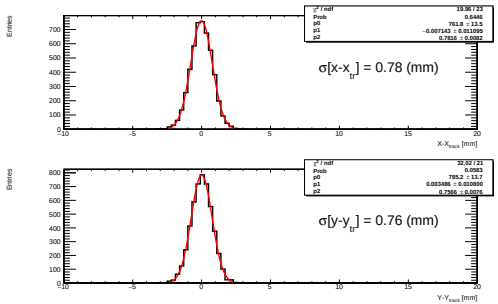




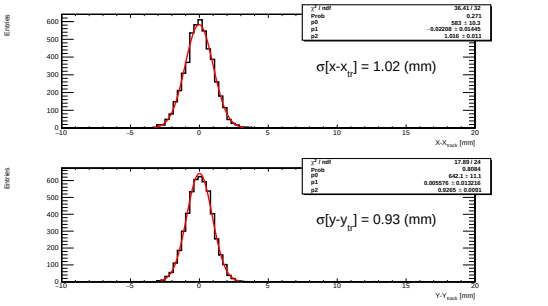
Position resolution (logarithmic weights)

1. Energy: 6GeV; MC runs: 10000
2. Pixel size:
   1. 0.5cm x 0.5cm (110 $\times$ 11 cells, W = 4.5)
   2. 0.78cm x 0.78cm (70 $\times$ 7 cells, W = 5.5)
   3. ...
   4. 1.8cm x 1.8cm (30 $\times$ 3 cells, W = 11.5)
3. $X = \sum X_i W_i / \sum W_i$,
   $W_i = max(0, W + log \frac{E_i}{E_{cluster}})$
4. Fit for $X_{track} - X_{cluster}$ and $Y_{track} - Y_{cluster}$

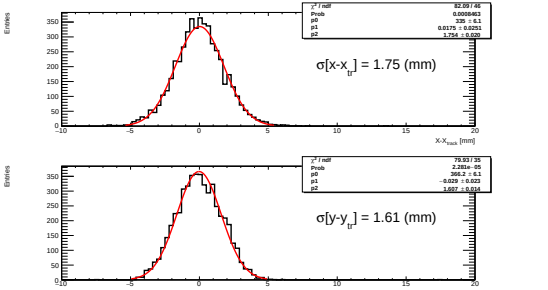
0.5cm x 0.5cm (110 $\times$ 11 cells, W = 4.5)



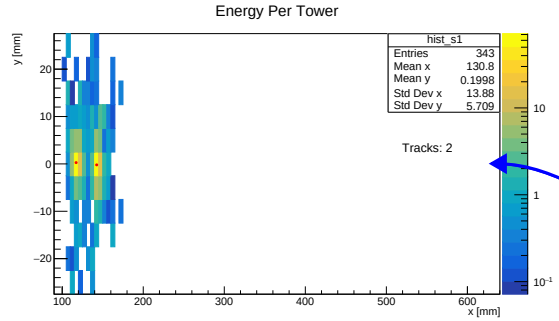
0.78cm x 0.78cm (70 $\times$ 7 cells, W = 5.5)

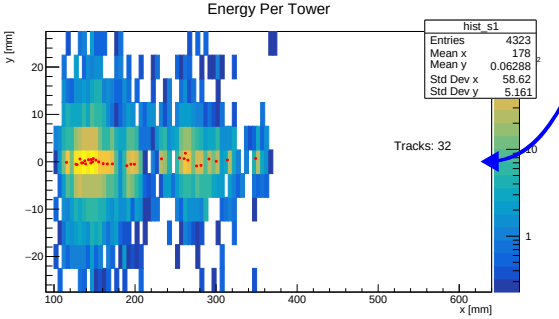


1.8cm x 1.8cm (30 $\times$ 3 cells, W = 11.5)



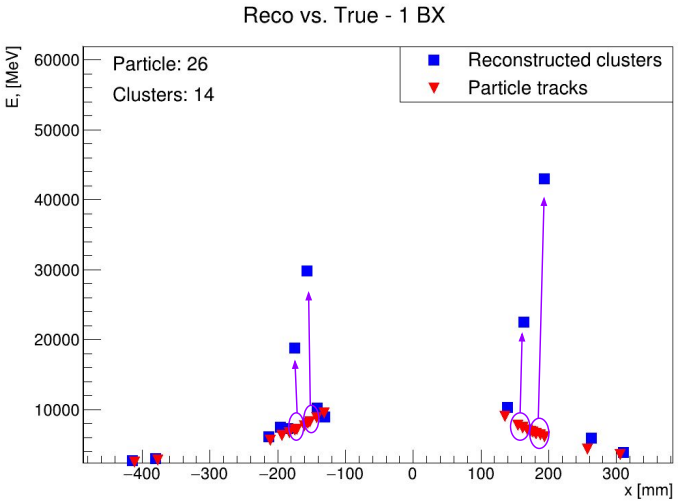
Reconstruction (status) $\gamma_B + n\omega \Rightarrow e^+e^-$





- Cases of $E_{electron} = 17.5 GeV$
  Laser: 0.2J, 0.35J, 0.5J
  give up to $\sim 4e^+e^-$ per BX
- Cases of $E_{electron} = 17.5 GeV$
  Laser: 0.7J, 0.85J, 1.0J
- Highly overlapping showers can not be separated

Reconstruction $\gamma_B + n\omega \Rightarrow e^+e^-$



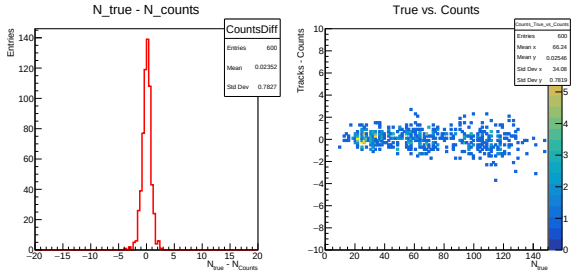
Reconstructed clusters

Shower energy predicted from tracks

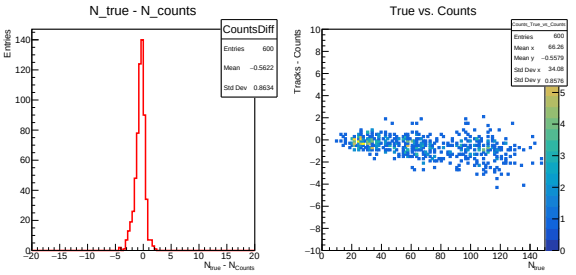
- Reconstructed with the simple closest pad neighbour approach
- $X_{cluster} = \sum x_{hit} E_{hit} / E_{cluster}$ + bias correction
- X - position of the cluster corresponds to fixed energy of the track
  $\Rightarrow$ can calculate number of tracks inside cluster $N = \frac{E_{cluster}}{E_{track}(x)}$
- "Counted particles" $= \sum N$

Counting particle flow by clusters

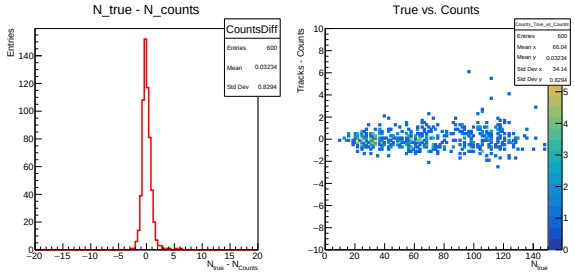
pixel: 110 x 11 $\sigma = 0.78$



pixel: 30 x 3 $\sigma = 0.86$

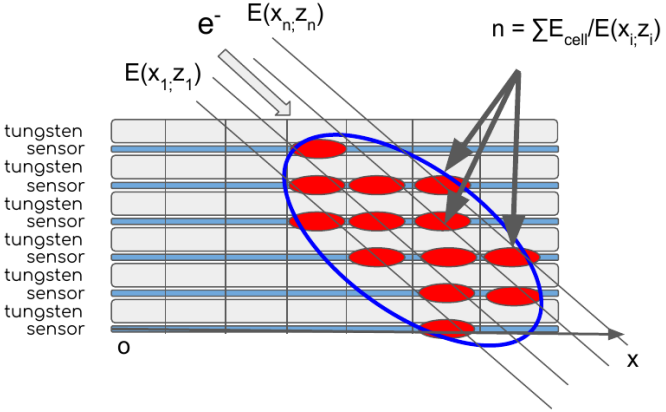


pixel: 70 x 7 $\sigma = 0.82$



- First plot is difference between number of the tracks and the number of counted particles
- Second plot is Number of tracks from number of counted particles
- Each plot is for 600 BX for laser power of 0.7J + 0.85J + 1.0J

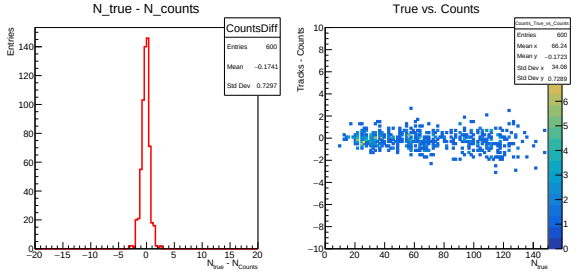
Counting particle flow by Cells



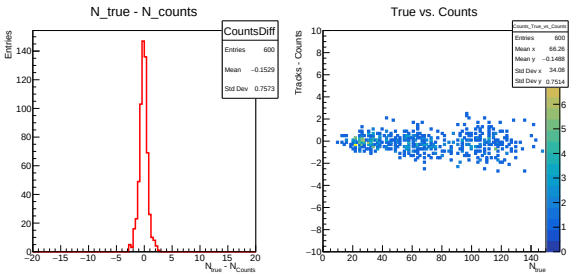
- We have energy absorbed in very cell of the calorimeter (E_{cell})
- Basing on analytical formula ($E_{expected}(x_{cell}, y_{cell}, z_{cell})$ can be found
- "Particle density" in the cell $N_{cell} = \frac{E_{cell}}{E_{expected}}$
- Number of particles $N = \sum N_{cell}$

Counting particle flow by Cells

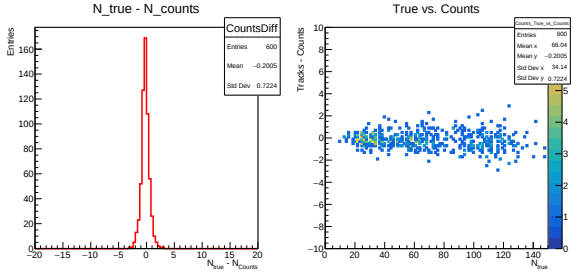
pixel: 110 x 11 $\sigma = 0.72$



pixel: 30 x 3 $\sigma = 0.75$



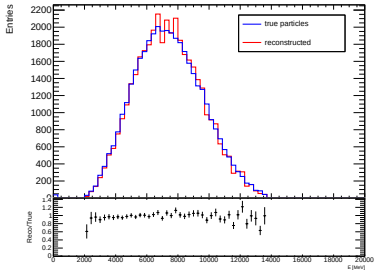
pixel: 70 x 7 $\sigma = 0.78$



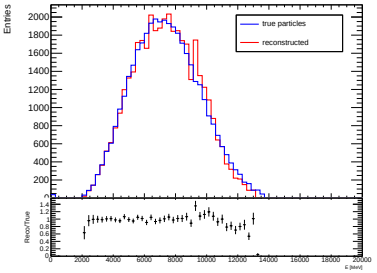
- First plot is difference between number of the tracks and the number of counted particles.
- Second plot is difference between number of the tracks and the number of counted particles vs. number of real particles.
- Each plot is for 600 BX for laser power of 0.7J + 0.85J + 1.0J.

Spectrum reconstruction

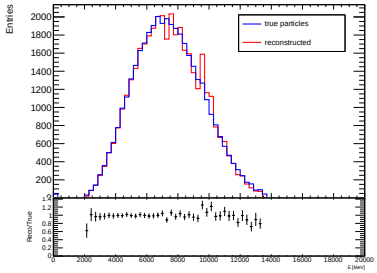
110 × 11 pixels



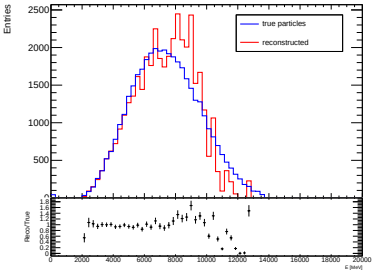
50 × 5 pixels



70 × 7 pixels



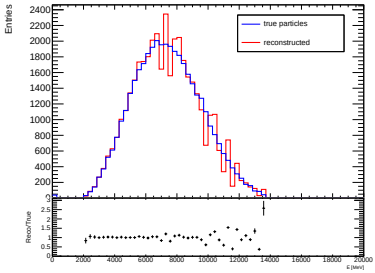
30 × 3 pixels



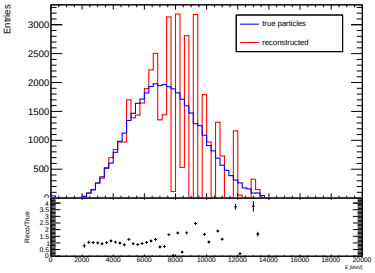
- $E_{expected}(x_{cl}, y_{cl}, z_{cl})$ taken as energy of the "particle".
- $N = \frac{E_{cluster}}{E_{expected}}$
- Fill Spectrum histogram .Fill($E_{expected}, N$)

Spectrum reconstruction

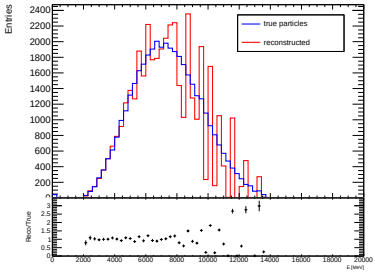
110 × 11 pixels



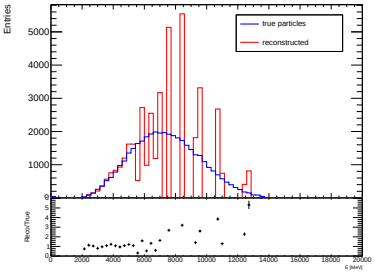
50 × 5 pixels



70 × 7 pixels



30 × 3 pixels



- $E_{expected}(x_{cell}, y_{cell}, z_{cell})$ taken as energy of the "particle".
- $N = \frac{E_{cell}}{E_{expected}}$
- Fill Spectrum histogram .Fill($E_{expected}, N$)

Summing up

Conclusions:

- Basic geometry was implemented
- Energy resolution:

number of sensors	resolution
21	18.9%+0.0%
17	19.7%+0.1%
13	25.9%+0.2%
9	35.1%+0.8%

- Positional resolution (for 6GeV electrons):

pixel size	σ_x	σ_y
0.5cm x 0.5cm	0.76mm	0.73mm
0.75cm x 0.75cm	0.96mm	0.88mm
0.91cm x 0.91cm	1.05mm	1.0mm

σ_x, σ_y asymmetry - to be understood

- Spectrum reconstruction looks reasonable.
- Quantified "counting method" for different positional resolutions
- Estimated impact of dead zones
- Estimated influence of background: around $\sim$300 GeV are left in calorimeter

Thank you for your attention!