Studying the influence of the edge effects on the energy resolution of the novel GRAiNITA calorimeter

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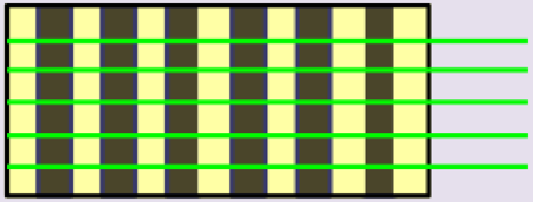
GRAiNITA calorimeter

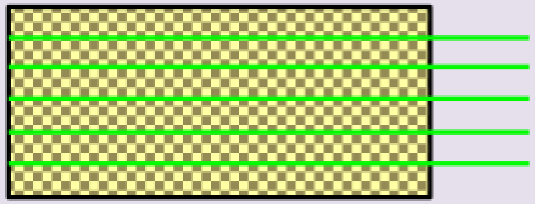
- The widely used "Shashlik" calorimeter technique provides a resolution of about $R \sim 10\%/\sqrt{E}$.

- A novel GRAiNTIA calorimeter technique applies stochastic capture of the scintillation light using scintillation grains and heavy liquid. The expected resolution for this type of calorimeter is $R \sim 2\%/\sqrt{E}$.

Shashlik calorimeter: alternating layers of scintillator and absorber



GRAiNITA: mix of scintillators grains and absorber in the same volume

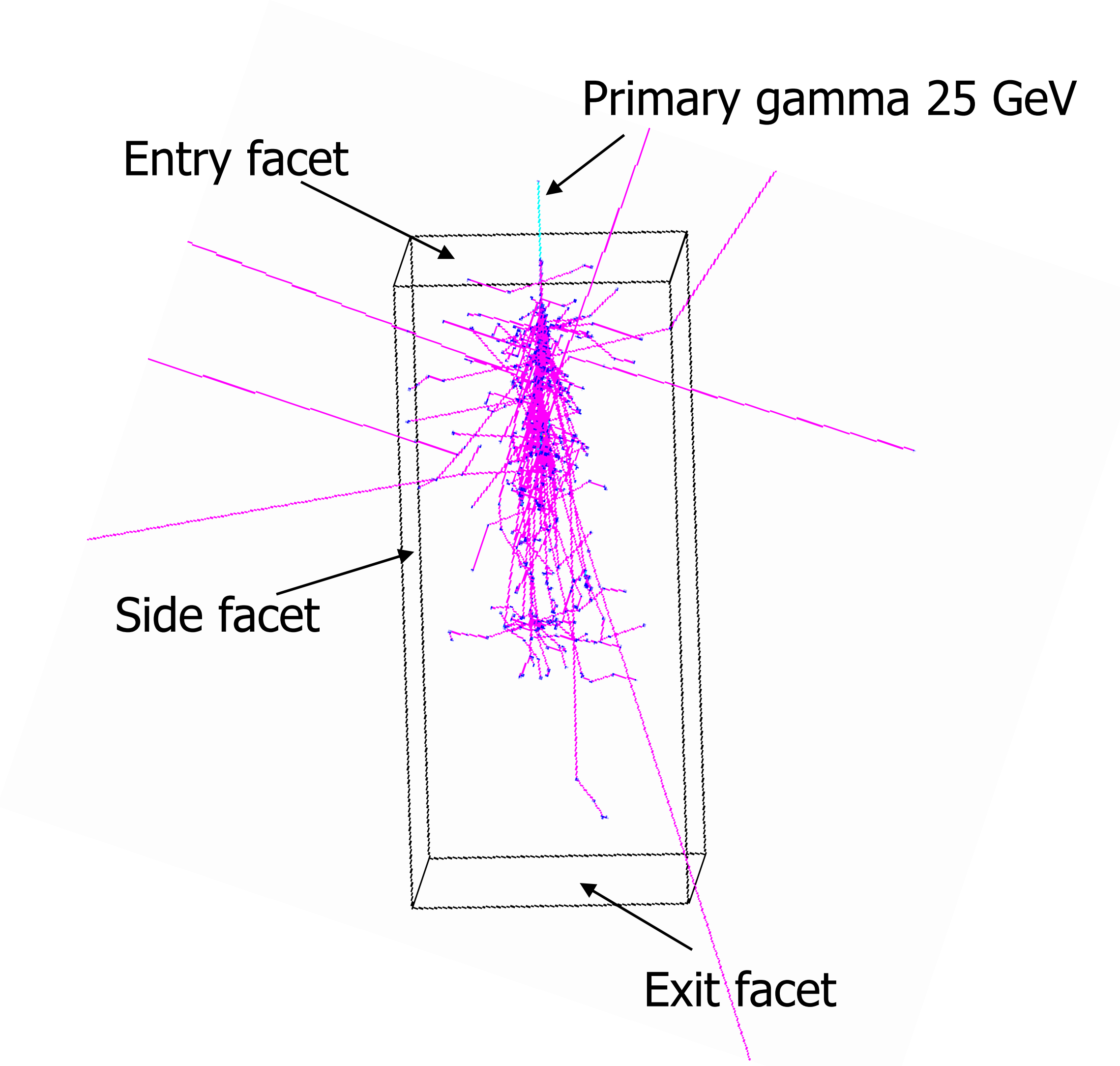


Resolution: constant term & Geant4 simulation

- The energy accuracy of ECAL is usually parametrized as

$$R \sim \sqrt{\left(\frac{x}{\sqrt{E}}\right)^2 + y^2}.$$

- Simulation is held in the box volume with dimensions 168 x 168 * 400 mm.
- Volume is simulated as with one material:
  - 4.53 $\frac{g}{cm^3}$ (partial density) of ZnWO4
  - 1.19 $\frac{g}{cm^3}$ (partial density) of heavy liquid
- The results in this presentation are for **25 GeV gammas** (if not specified otherwise).



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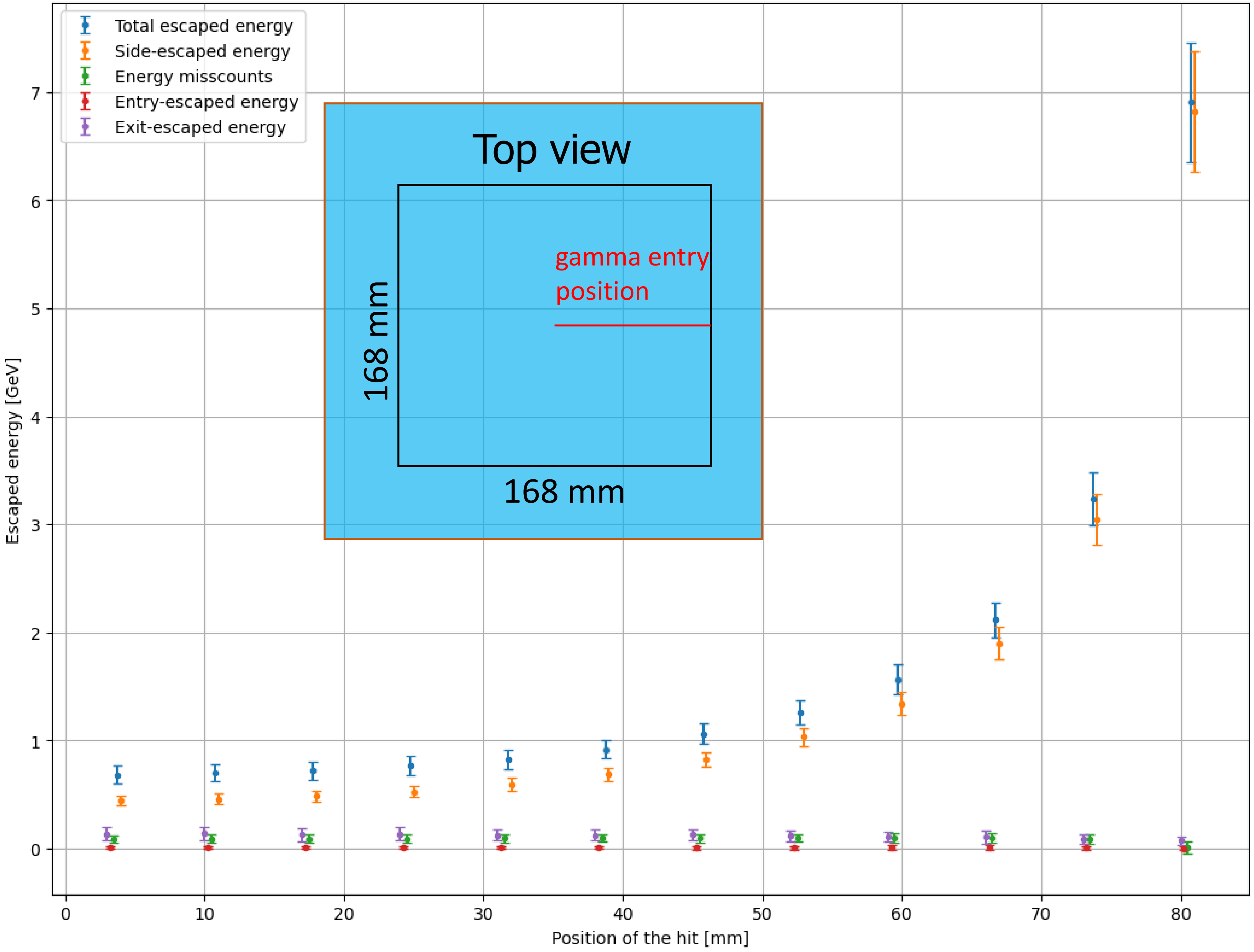
Escaping Energy vs hit position

- Dots indicate a mean value.
- Error bars indicate the Gaussian sigma.
- For inner volume (> 14 mm from edge) sigma is below 1%.
- The escape energy could be calibrated in case the hit is in the inner part of the detector.



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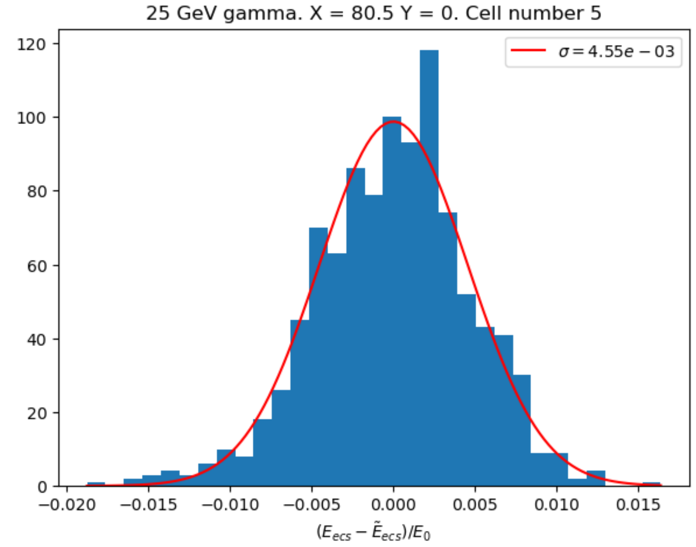
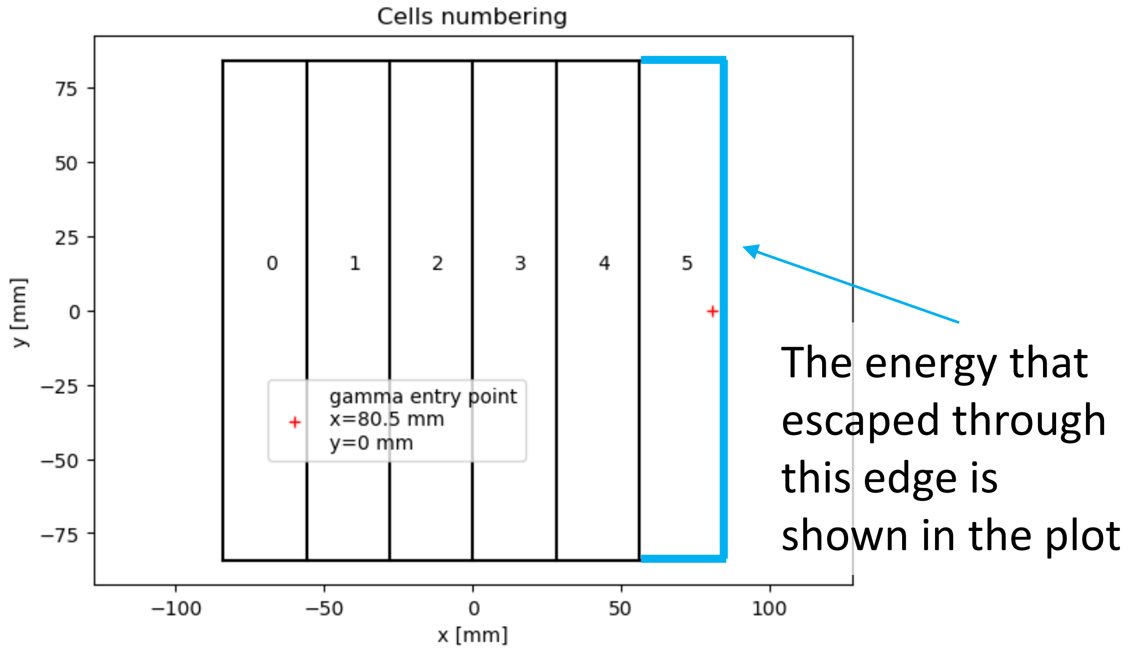
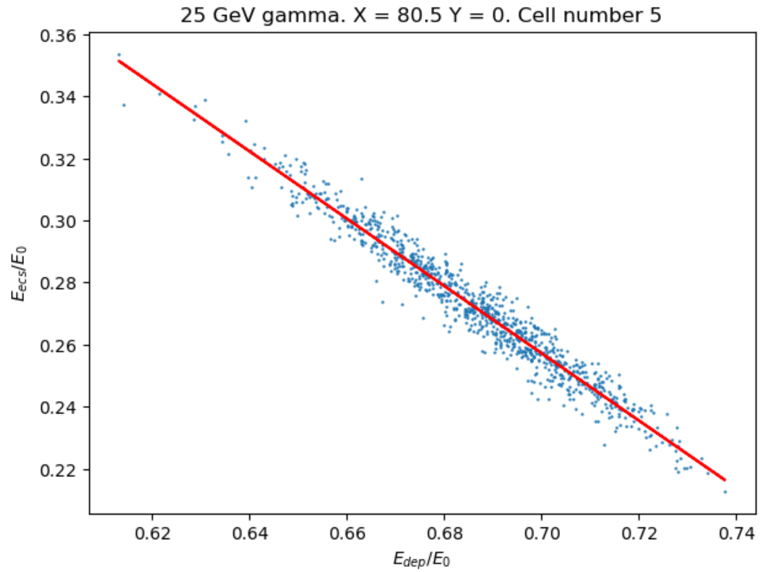
Edge-close hit E_{dep} VS E_{esc} calibration

- In case the primary photon hits the detector close to its edge, there is a correlation between escape and deposited energy.
- Escaped energy can be predicted based on deposited energy in such cases.







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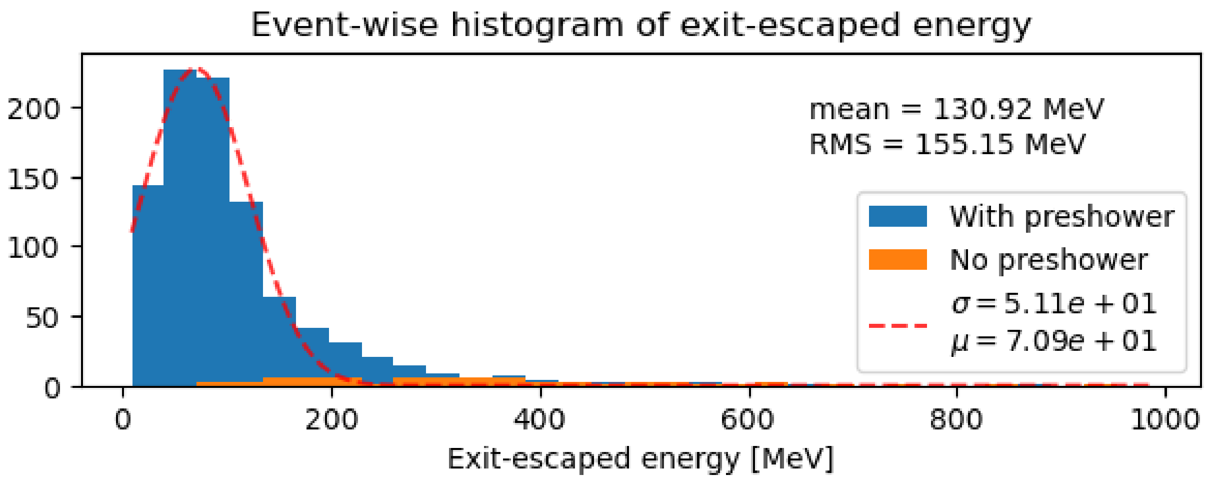
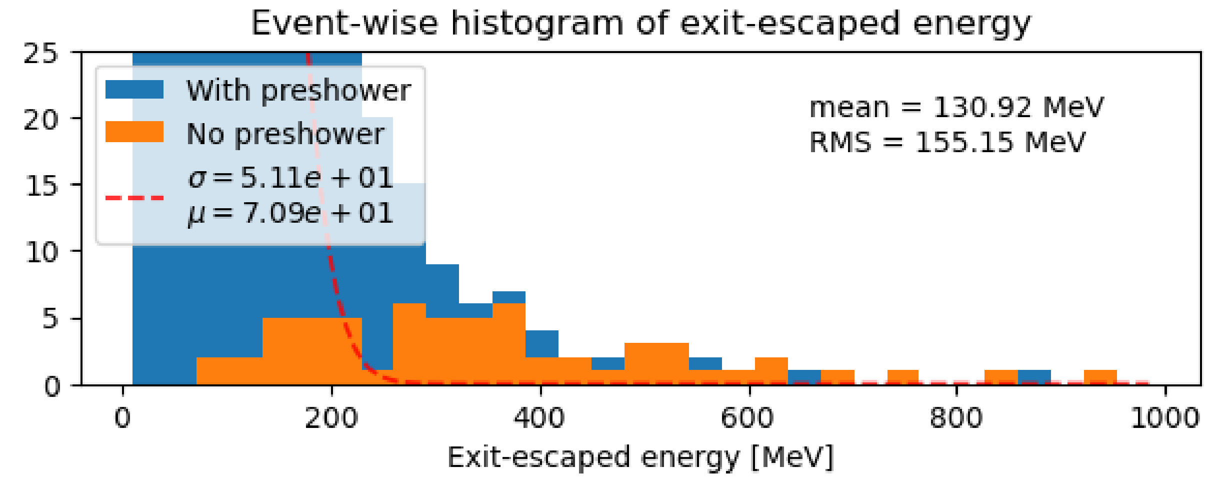
High exit-escape energy events

- Preshower ⇒ more than 20 MeV in first 64 mm (4X0) of volume.
- 1000 events were simulated.
- Most of the events with high exit escape energy have no pre-shower.
- The high exit escape energy is mostly due to the late start of the shower development.





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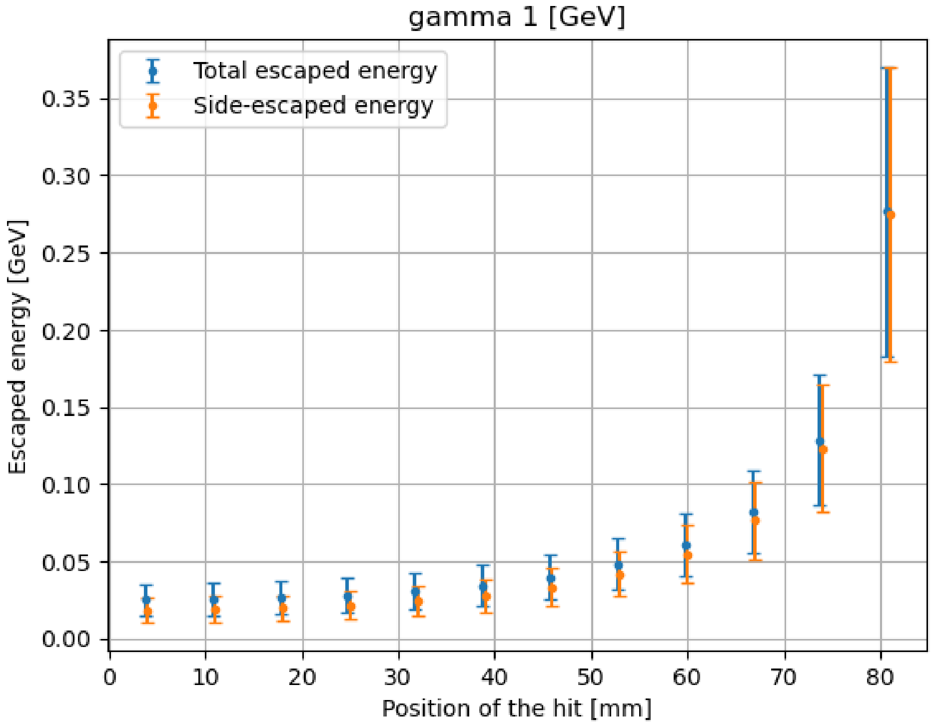
Results for 1 GeV gammas

Side-escape [MeV]	1 GeV			25 GeV		
Hit position	Mean [MeV]	RMS [MeV]	Sigma [MeV]	Mean [MeV]	RMS [MeV]	Sigma [MeV]
3,5 [mm]	18,38 (1,83%)	9,21 (0,9%)	7,88 (0,78%)	447,92 (1,79%)	43,98 (0,18%)	44,7 (0,18%)
59,5 [mm]	54,58 (5,45%)	22,26 (2,2%)	18,7 (1,87%)	1343,47 (5,37%)	110,08 (0,44%)	109 (0,44%)

- The escape energy (relative to primary gamma energy) is similar to 25 GeV, but the fluctuations are much larger.

- Larger fluctuations are due to fewer particles in the shower.



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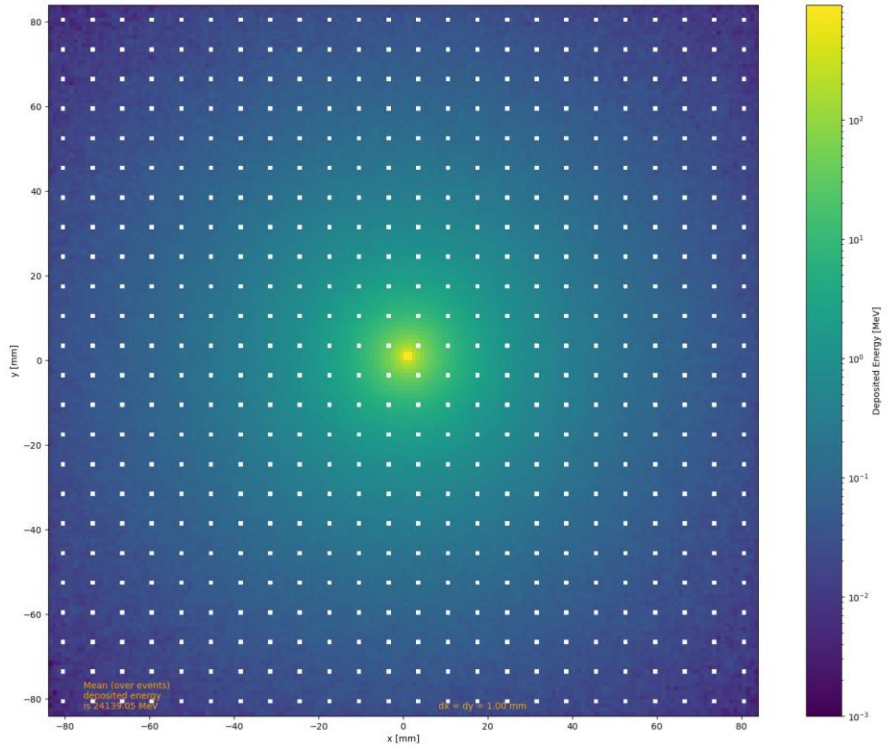
Simulations for nonuniformity

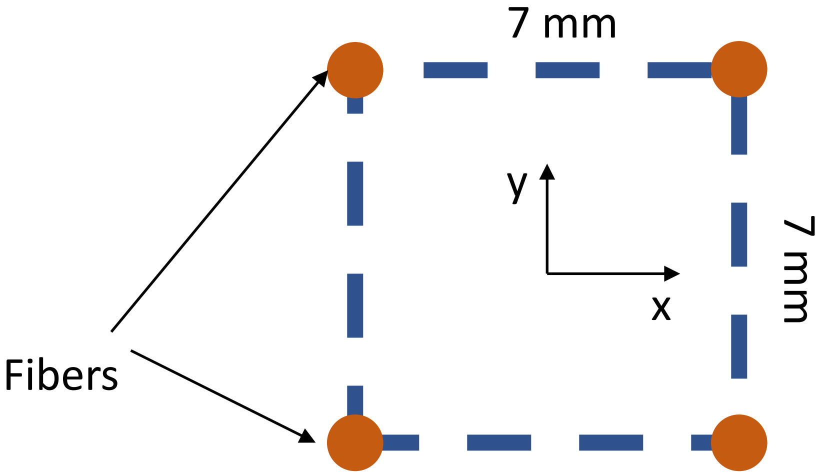
- Fibres are simulated as cylinder shapes of a diameter equal to 1 mm. The distance between fibres is 7 mm.

- The detector was virtually split into strips with dimensions of 1 mm by 1 mm by 400 mm.

- The energy deposited in each strip was multiplied by the following weight

$$F = 1 - a\cos\left(\frac{2\pi x[mm]}{7}\right) - \mathrm{b}\cos\left(\frac{2\pi y[mm]}{7}\right)$$

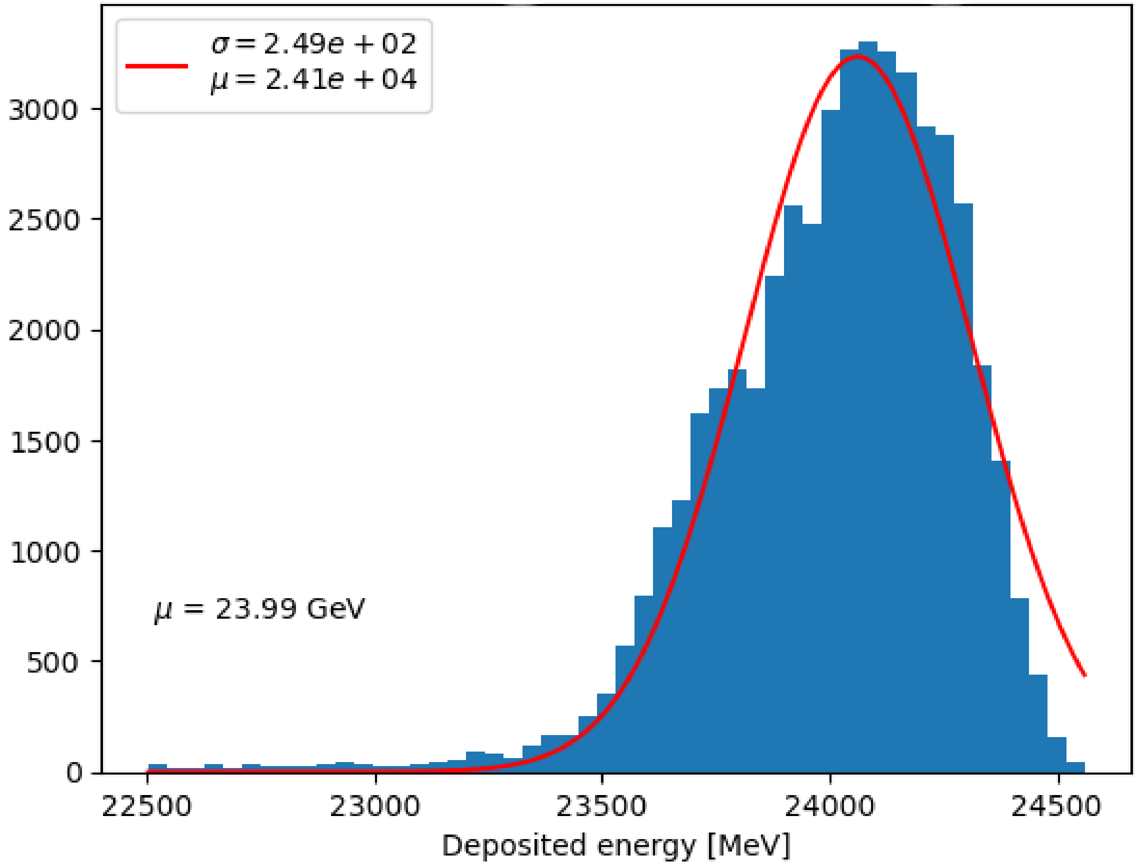




Energy deposition histogram.

- The histogram shows the energy deposited in the calorimeter, after encountering strip weights and excluding energy deposited in fiber strips.

- The primary gammas were shot quasi-randomly in a square area with dimensions 7 by 7 mm.



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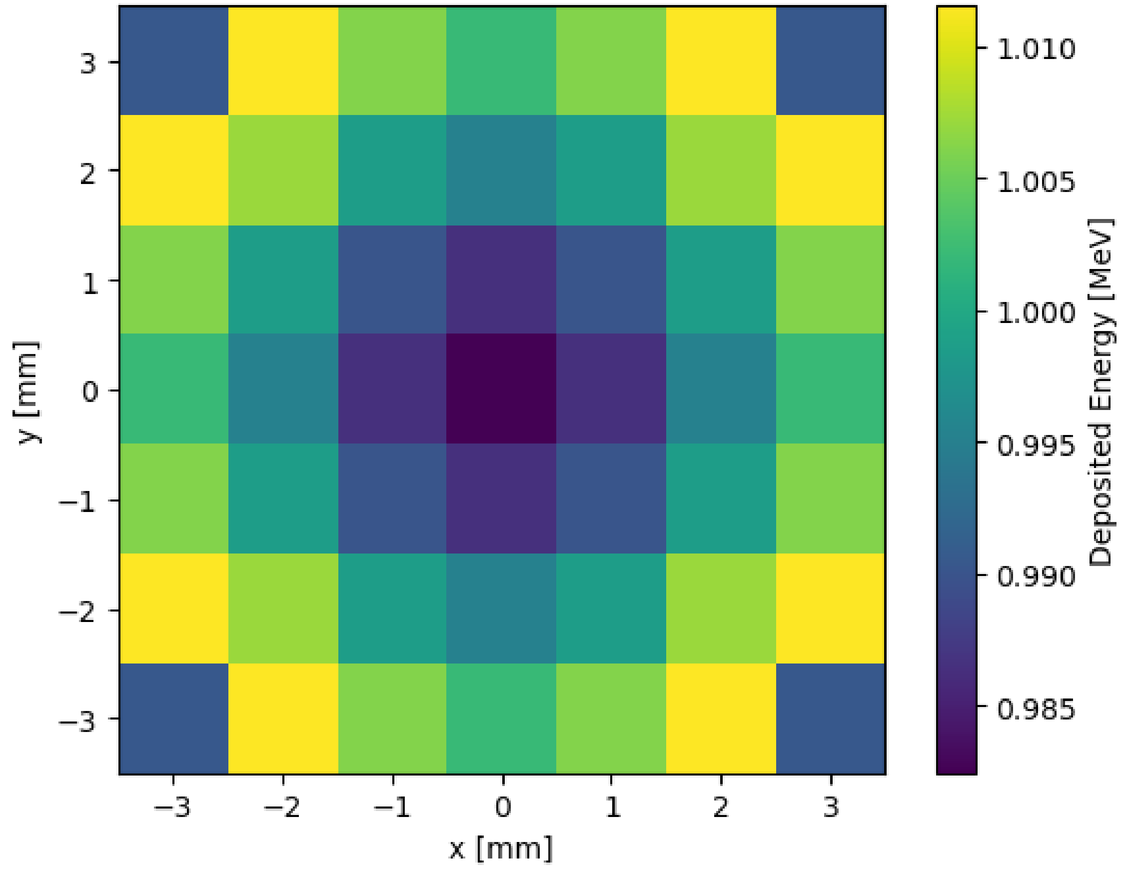
Efficiency map

- Each bin of the histogram represents the mean (over 1000 events) energy that was deposited if the primary hit was in this specific bin.

- The histogram is rescaled in such a way that its mean value is equal to 1.



Conclusions

- The simulation of the prototype of the GRAiNITA was made with the Geant4 framework. The simulation results show the following:
  - Most of the energy escaping from the side of the detector
  - The large escape from the exit faces is due to the late start of shower development
  - The uncertainty on the escaped energy is less than 1% from incoming particle energy for hits in the inner part of the detector.
  - If a primary hit is lost to the detector edge, the energy escaping correlates with deposited energy.
  - Results of the simulations with nonuniformity included show that energy resolution is about 2% from incoming particle energy.

Thank you for your attention