NPOD ECAL Performace
preliminary study

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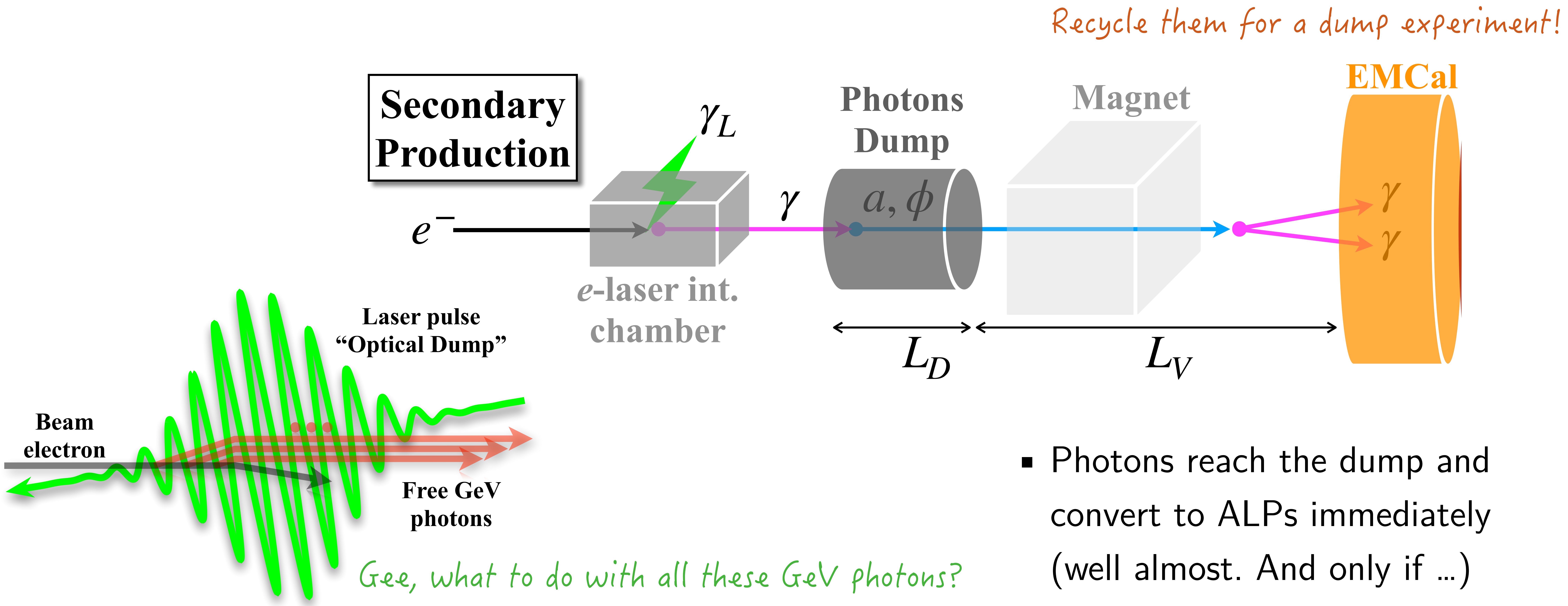
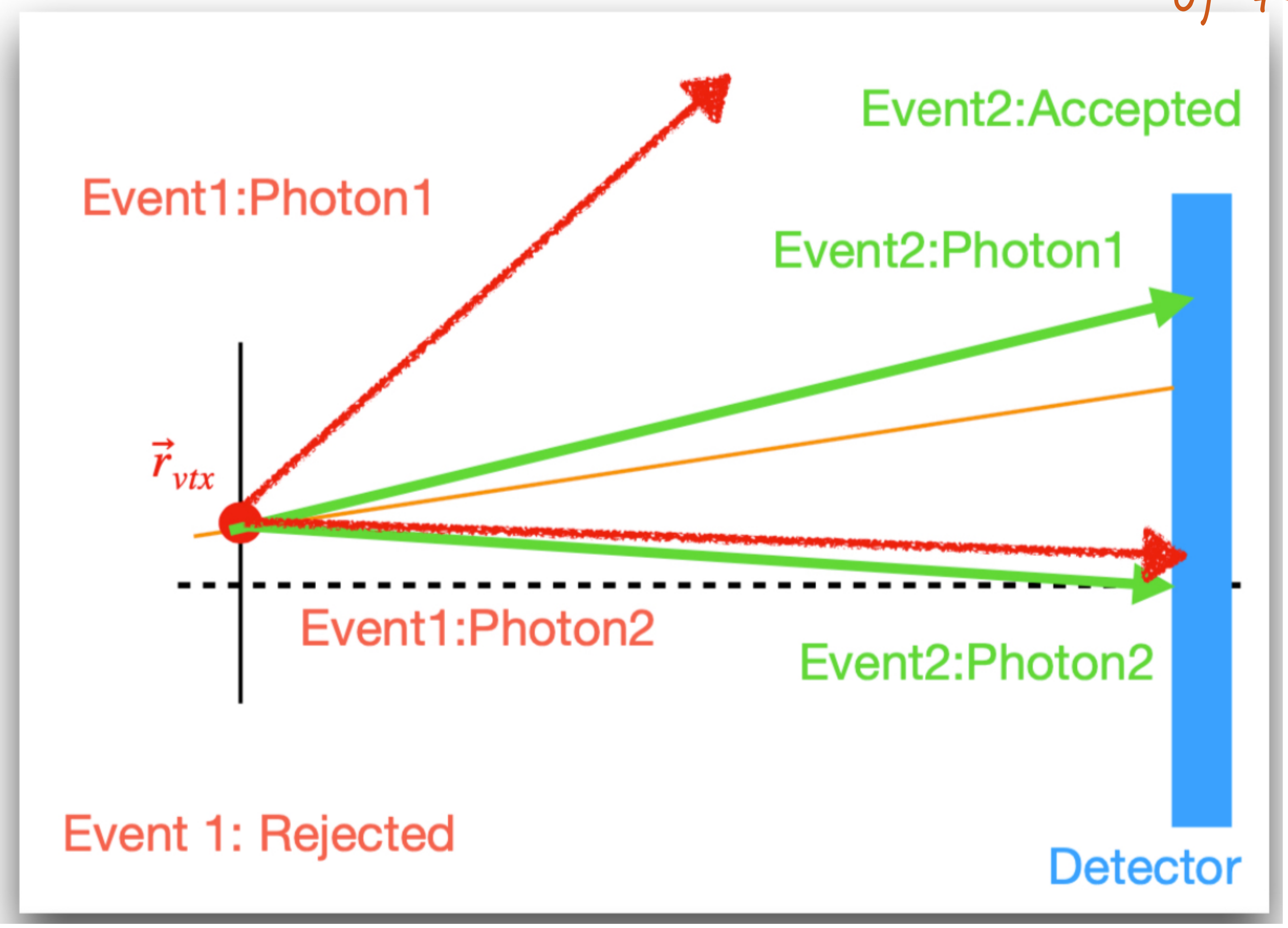
Recap …

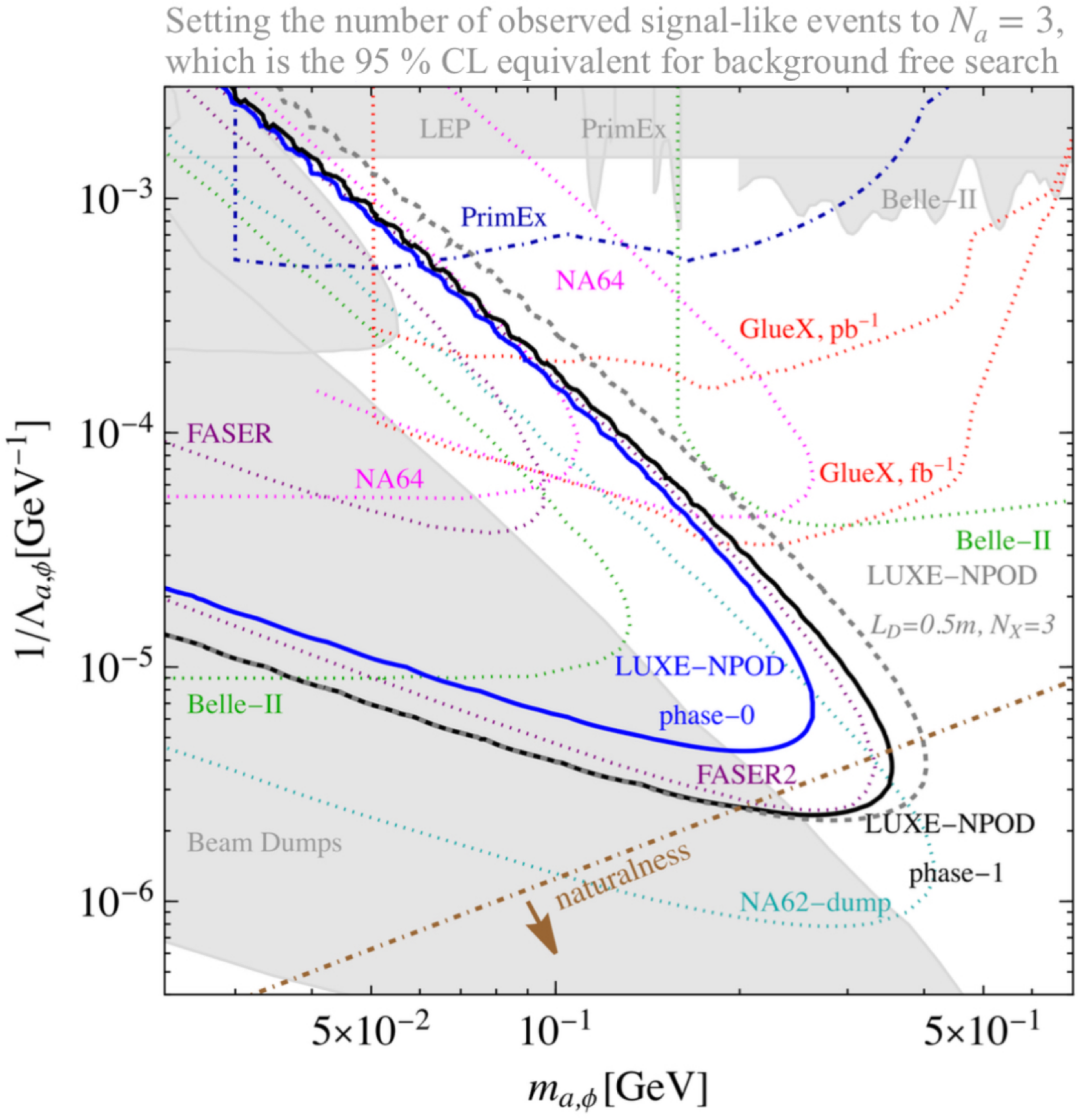


- Photons reach the dump and convert to ALPs immediately (well almost. And only if …)
- ALP goes through the dump and if it decays inside, no signal
- Neither if it fails to decay in time

… And if there is a signal

of ALP-diphoton decay





- Key parameters: ALP mass, coupling coefficient
- Mass comes from the invariant mass of the two photons
- Coupling coefficient comes from mass and vertex z

Detection requirements

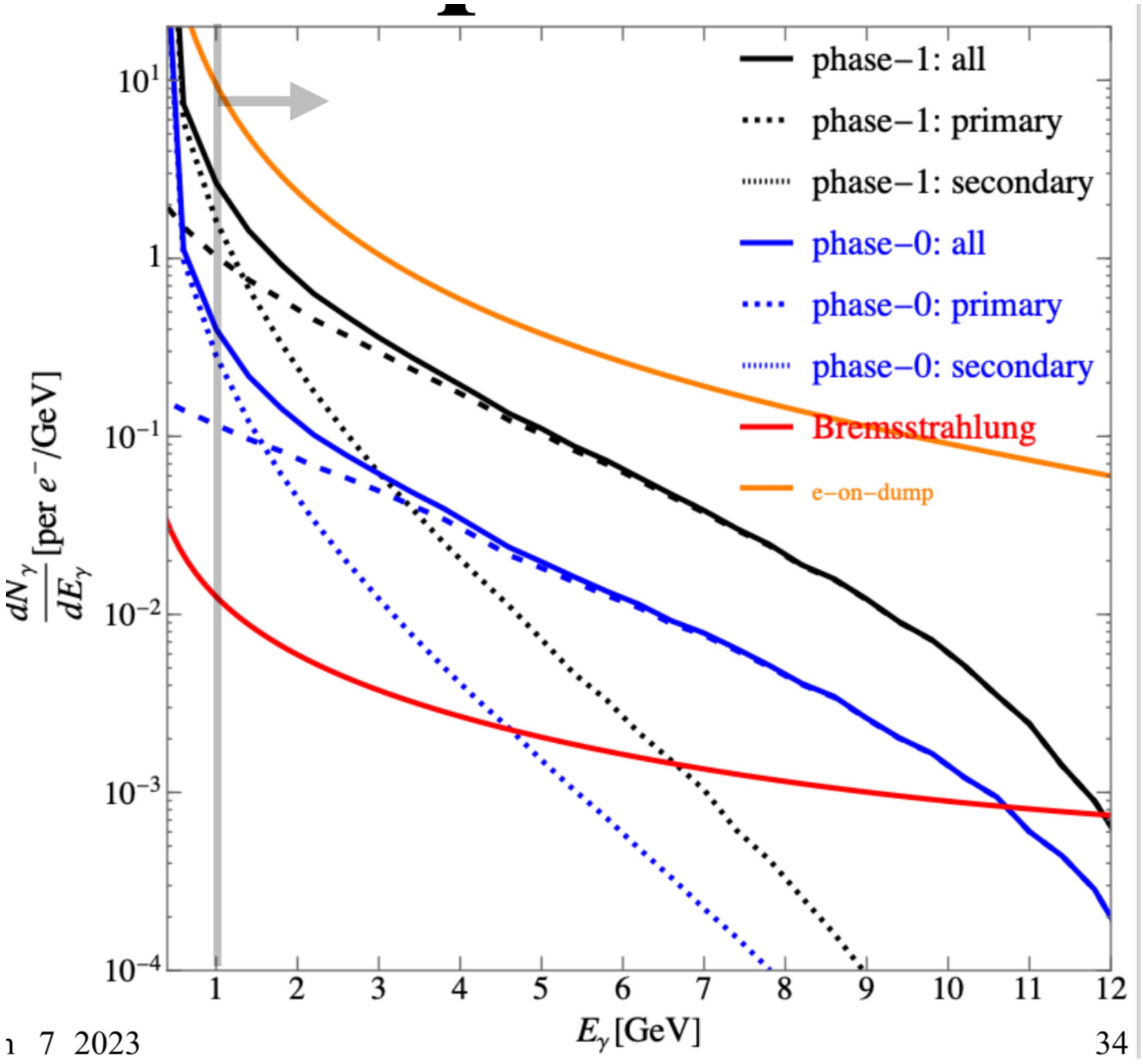
Uncertainty propagation

- Axion E = sum of **shower's E_i**
- Opening angle a_i is the angle between **shower direction** and propagating angle (supposedly, z axis)
- Axion m = $\mathrm{sqrt}\{E^2 - (E_i \cos a_i)^2\}$
- Vertex is reconstructed by extrapolations of **hit positions** and shower directions

NPOD requirement:

- Energy resolution
- Ability of shower separation (clustering)
  - KIT asks for d = 20 mm
- Position reconstruction
- Direction reconstruction
  - If d = 20 mm, decay length L = 2500 mm, the opening angle should be 0.008 rad
  - (similar estimate given by m = 0.1 GeV, E = 10 GeV)

Compton Photons

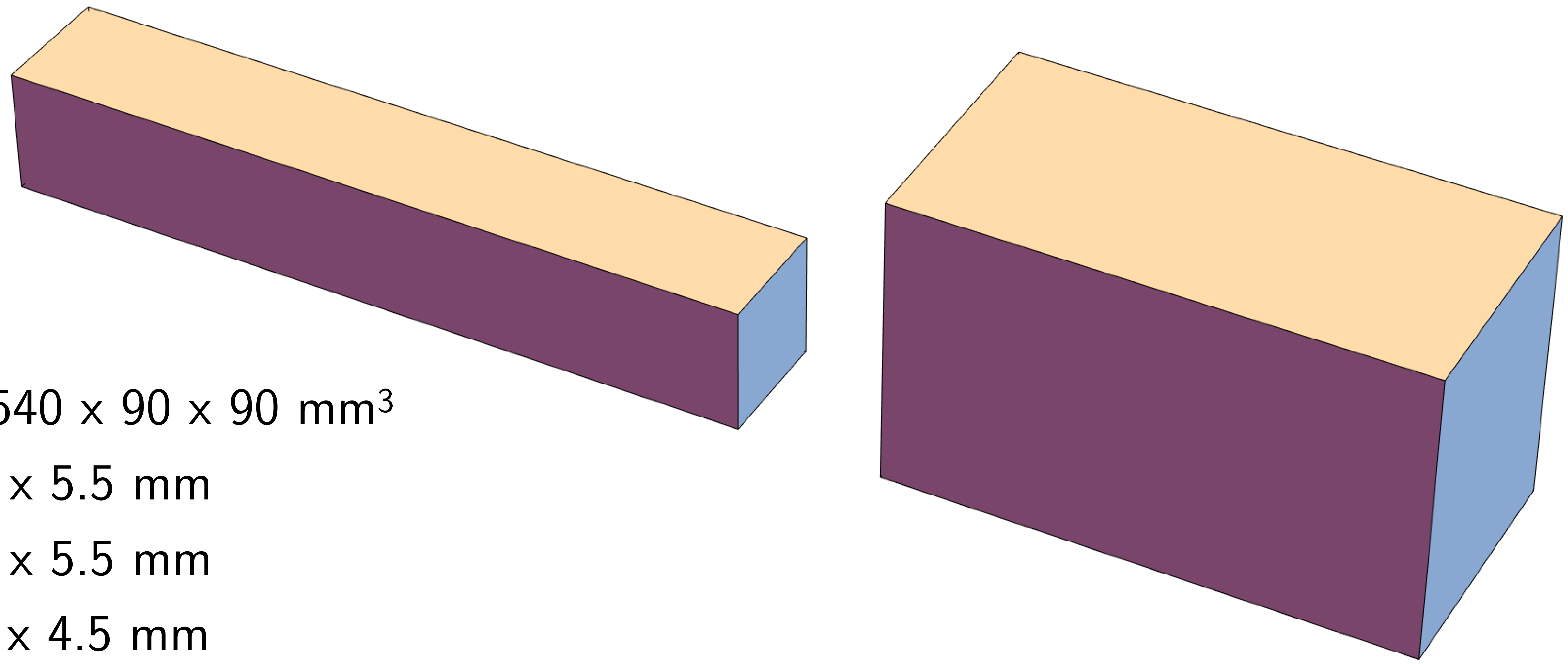


- ALP energy comes from photon (after a short interaction and energy loss within the dump)
- Two degrees of freedom in kinematics (photon energies and polar angle)

“HICS” photon spectrum:

- Most photons have energy lower than 10 GeV
- More intense laser leads more photons but lower the energy (Compton edge shift)
- Slight deviation angle from the z axis

ECAL-P/E



- ECAL-P: 540 x 90 x 90 mm^3
  - X = 96 x 5.5 mm
  - Y = 16 x 5.5 mm
  - Z = 20 x 4.5 mm
- ECAL-E: 360 x 180 x 210 mm^3
  - X = 64 x 5.5 mm
  - Y = 32 x 5.5 mm
  - Z = (15–1) x 15 mm

Simulation

- Geometry description of ECAL-E in dd4hep
- Monolithic layer without predefined gaps
- Standalone simulation done by ddsim (backend is GEANT4)
- Single particle simulation
- Gun positioned at $(z = -)1000$ mm away from ECAL-E front surface $(z = 0)$
- Transverse distribution (x/y) for smearing
- Angle set at $-2/0/+2$ degrees (no smear)

Pixelisation:

- Pixel sizes/pixel gaps/sensor dead areas implemented as the first analysis step
- No gap between two sensors

Merge:

- Overlay two independent simulations into one

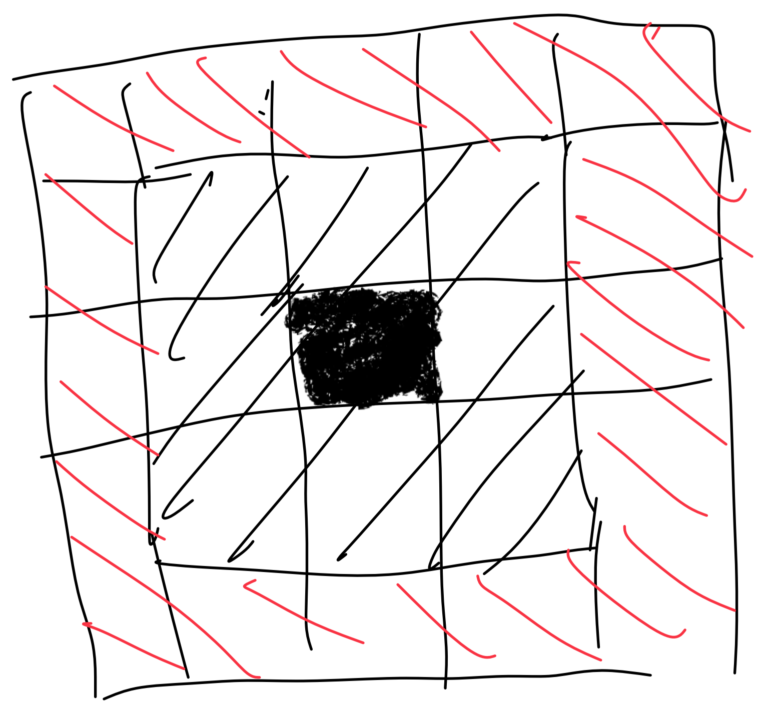
Digitisation:

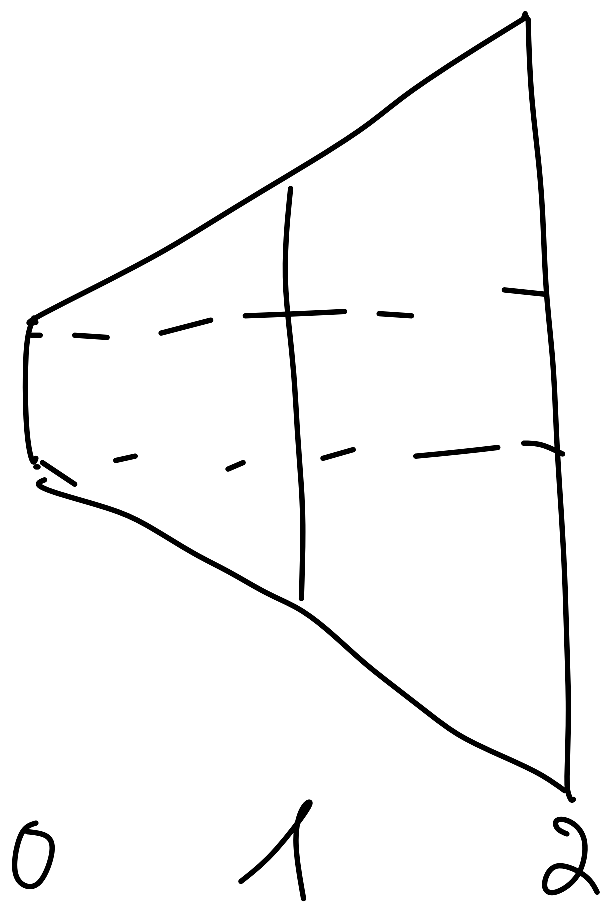
- MIP obtained via muon simulation
- Convert E_{dep} from GeV to MIP (a linear way to process non-homogeneous calorimeter)
- Deposit smearing 10%
- Deposit cut at 1/2 MIP

Analysis

"Pre"-Clustering:

- Arbor clustering from CEPC/IHEP, Chin. AS (work in progress)
- Nearest neighbour clustering tuned by AIQ: the immediate neighbours from the same layer, and the second immediate neighbours from the next layer, etc





Clustering:

- Directly taken from the nnclusters
- 4 proposed methods by AIQ
- No gap between two sensors
  - Simple plane division
  - Simple cylinder
  - Molière cylinder
  - Molière "core"

Analysis

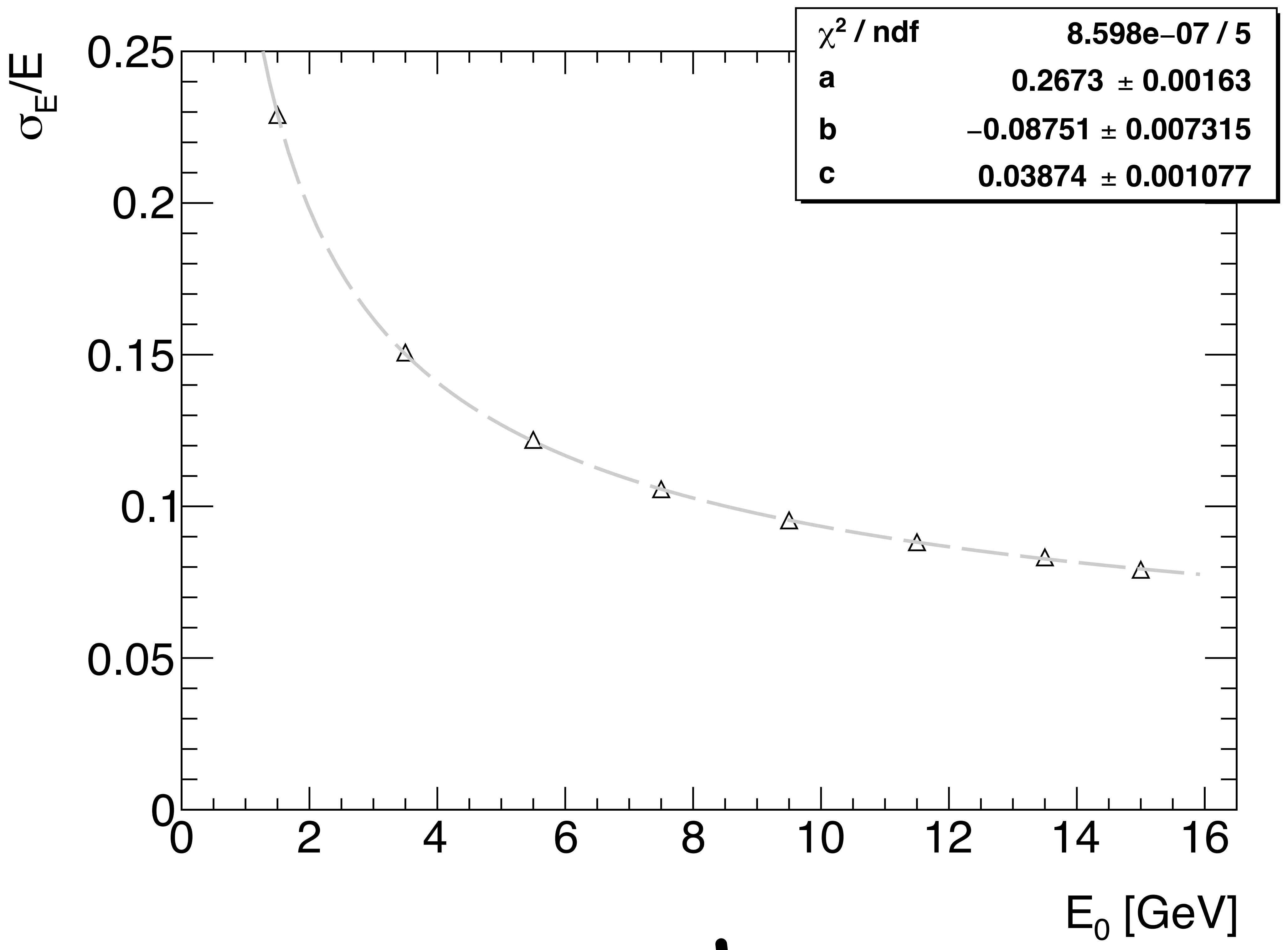
Finally, from a cluster to a shower

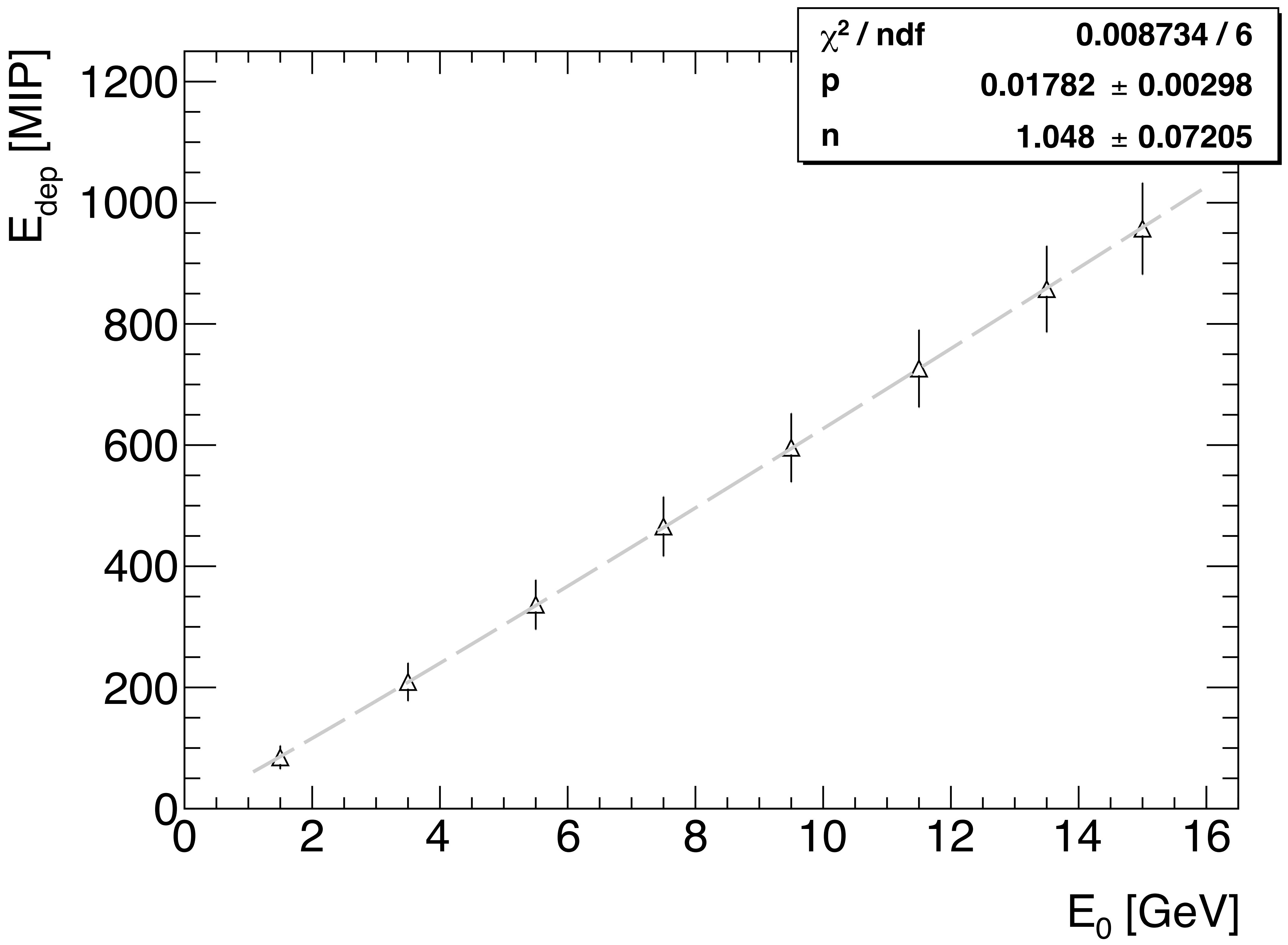
- Cluster = a bunch of hits
- Use a cluster to estimate a shower
  - A successful clustering should have two major clusters with similar energy (the ratio is set at 2, but tunable in future)
  - The properties of a cluster become the properties of a shower
- Cluster energy: sum of hit energies
- Cluster position: weighted average (centre of gravity)
  - from the whole cluster
  - from the first few layers
- Cluster direction: fitted “symmetric” axis
  - from hit’s covariant matrix
  - other fitting methods
  - analogue ECAL: fit relies on the deposit
  - digital ECAL: fit relies only on if there is any (over-threshold) hit or not

Evaluation (work in progress):

- Residues of angle/position/energy
- Bias and resolution

Preliminary results



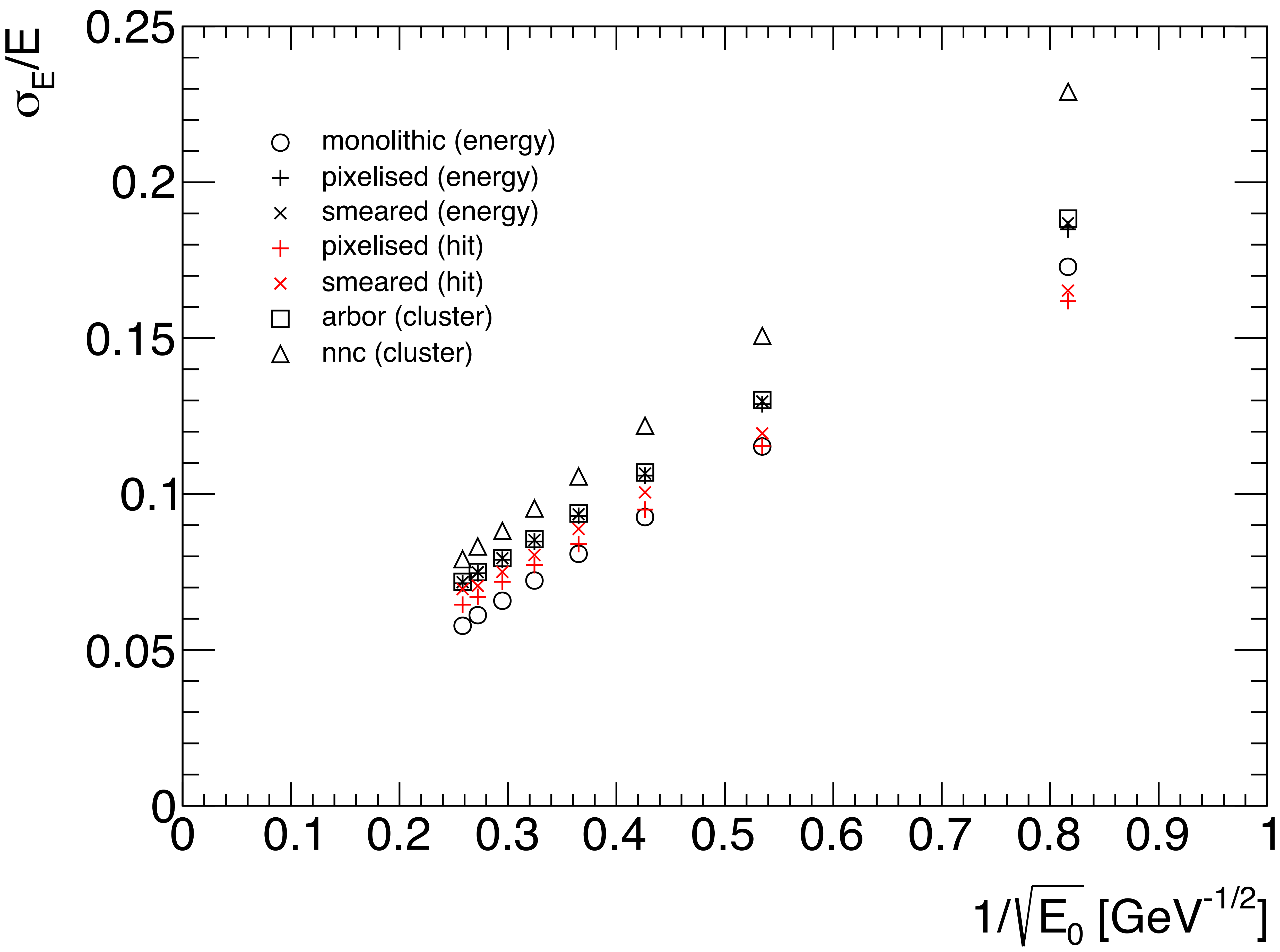


$$\frac{\sigma}{E} = \frac{a}{\sqrt{E}} \oplus \frac{b}{E} \oplus c \quad [\text{GeV}]$$

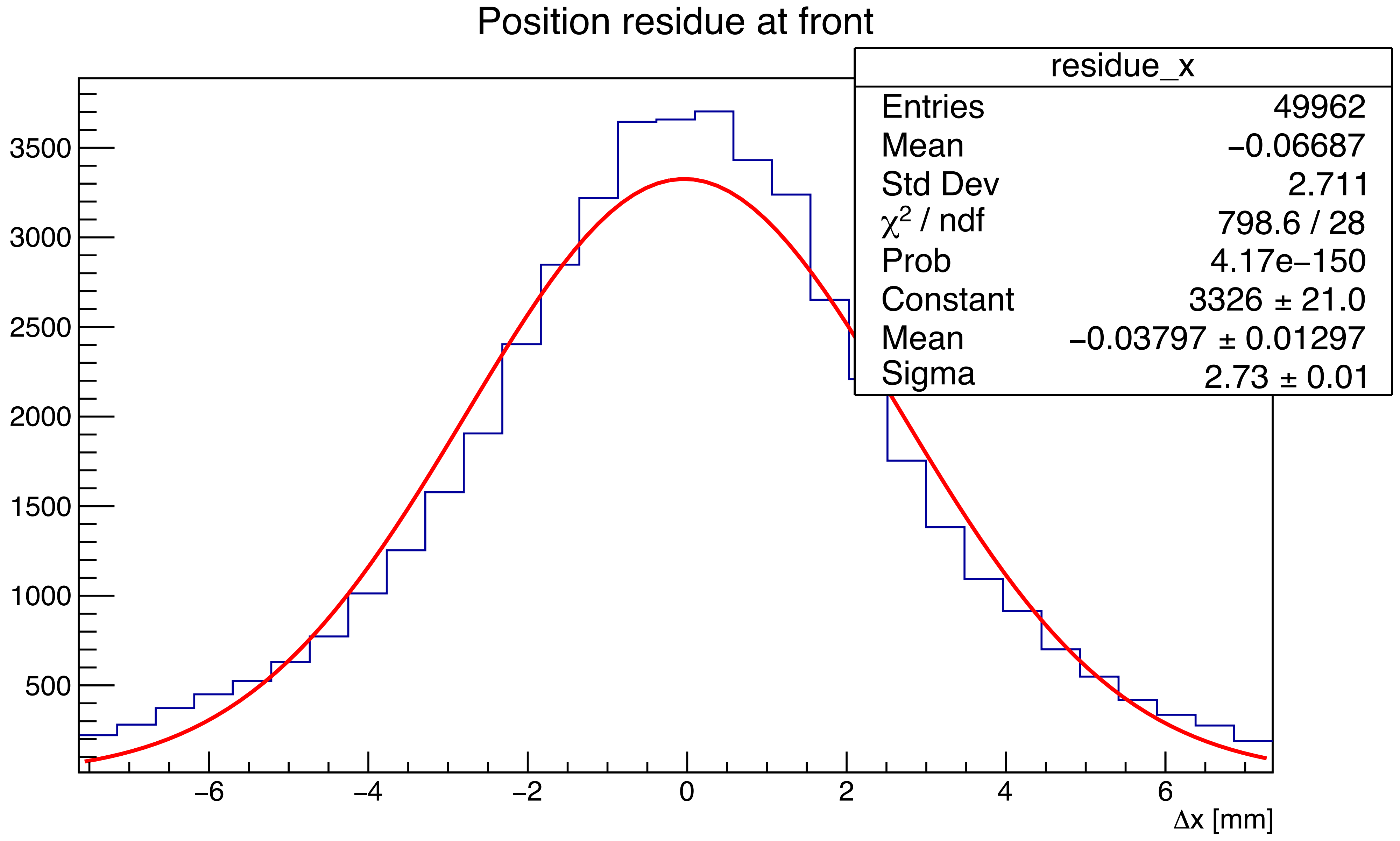
$$E_{dep} = \frac{1}{p} E_0^n$$

Simple NNC

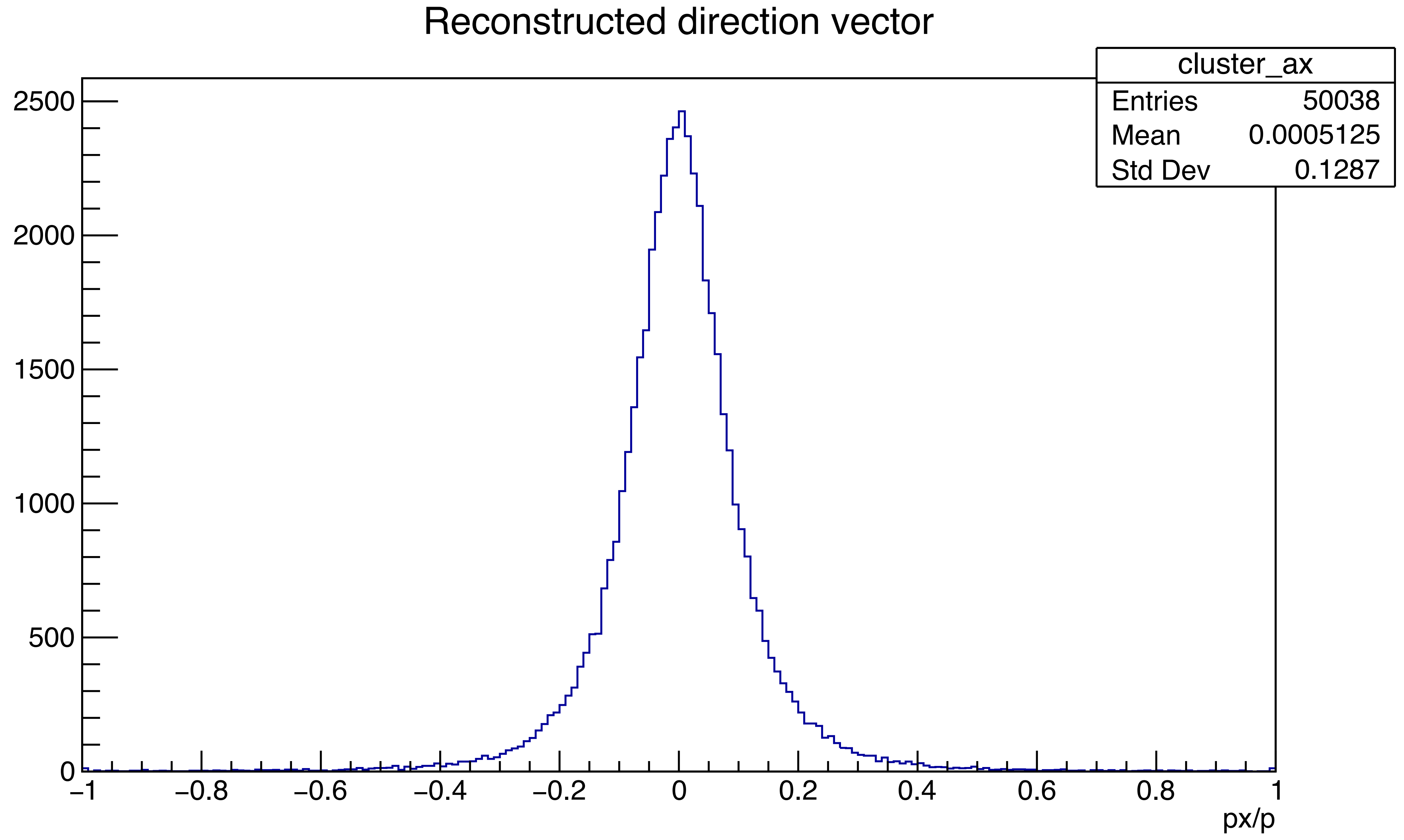
Preliminary results



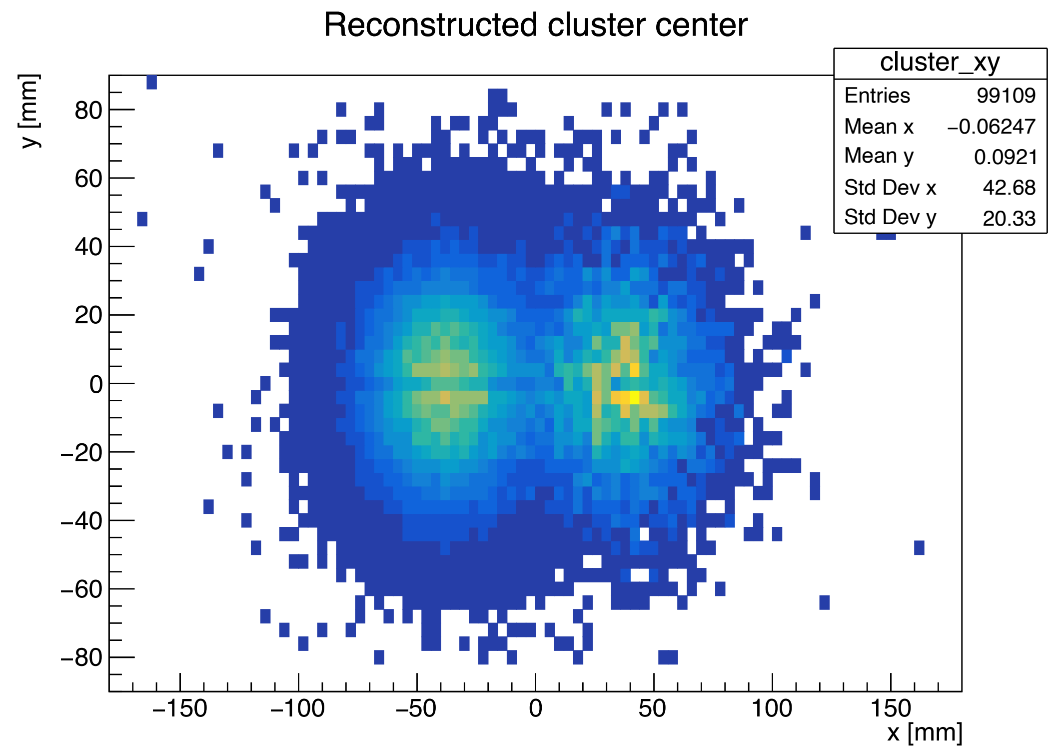
Preliminary results



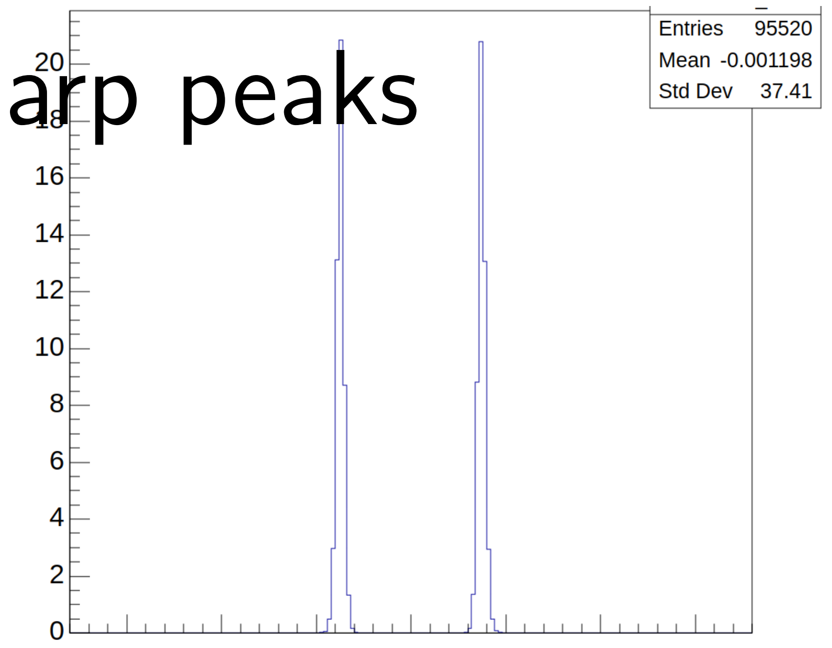
Position resolution



Shower direction (x component)

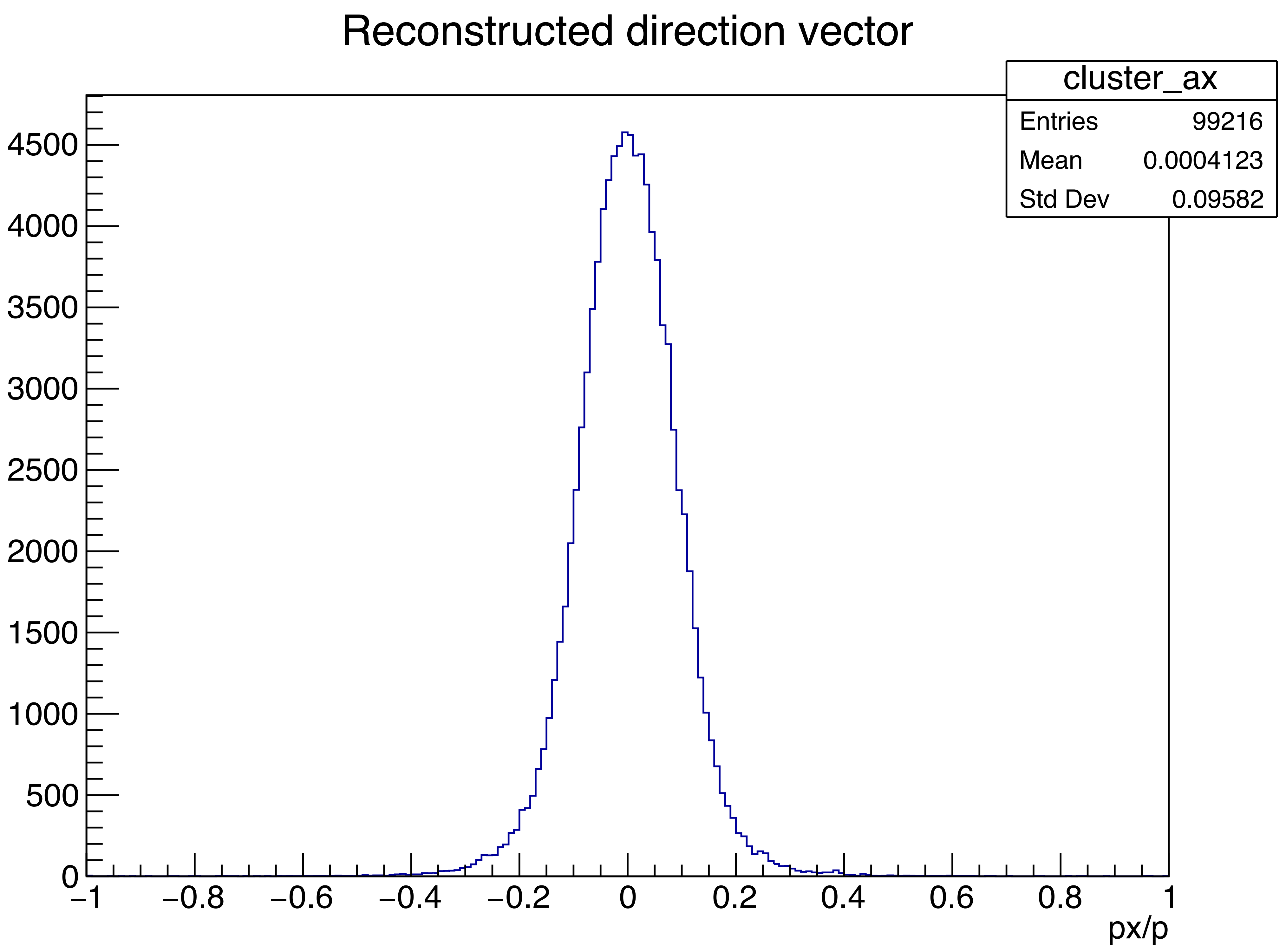


Expecting double sharp peaks

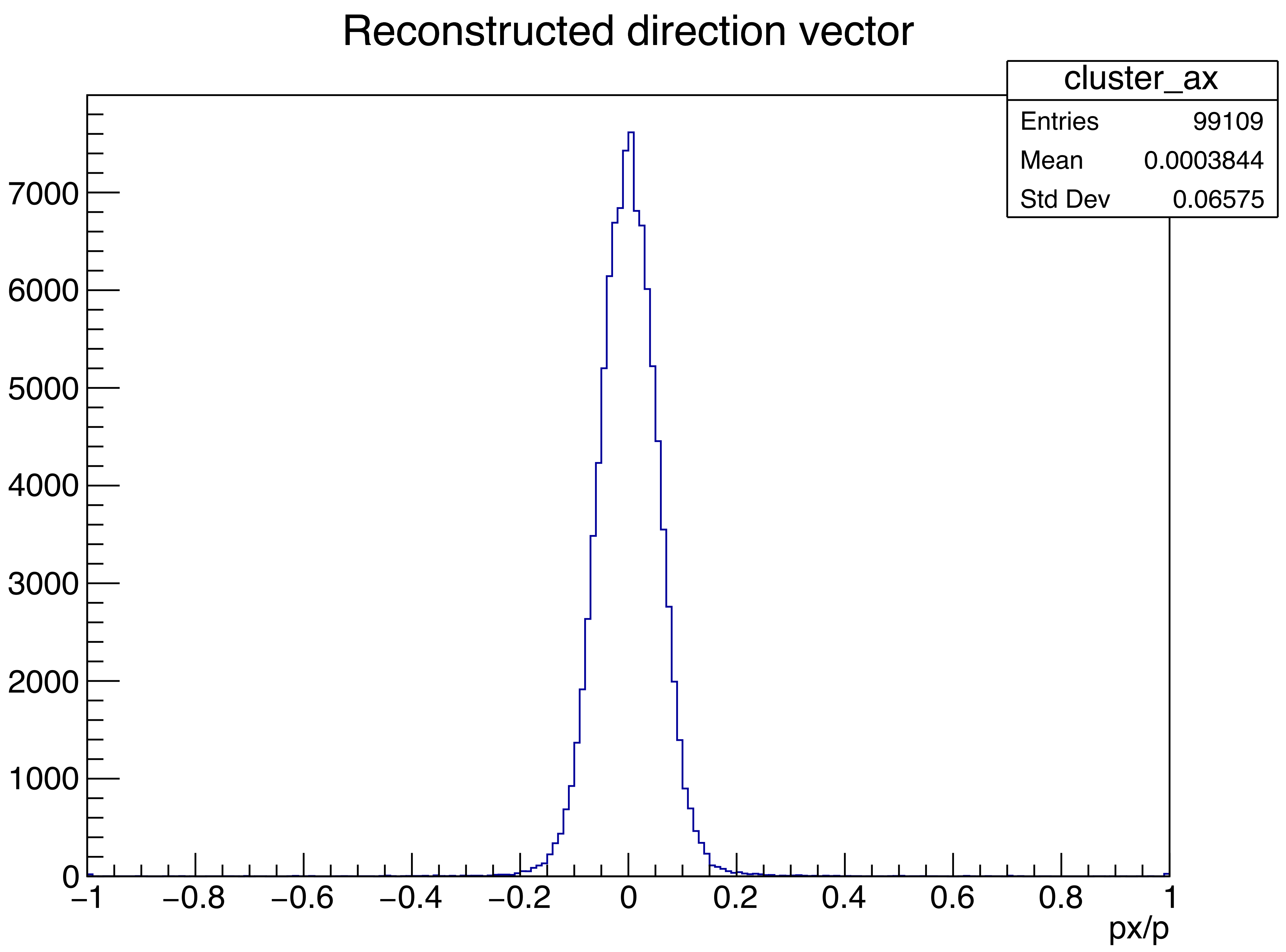


Two elections at 3.5 GeV

Benefit from AIQ strategies



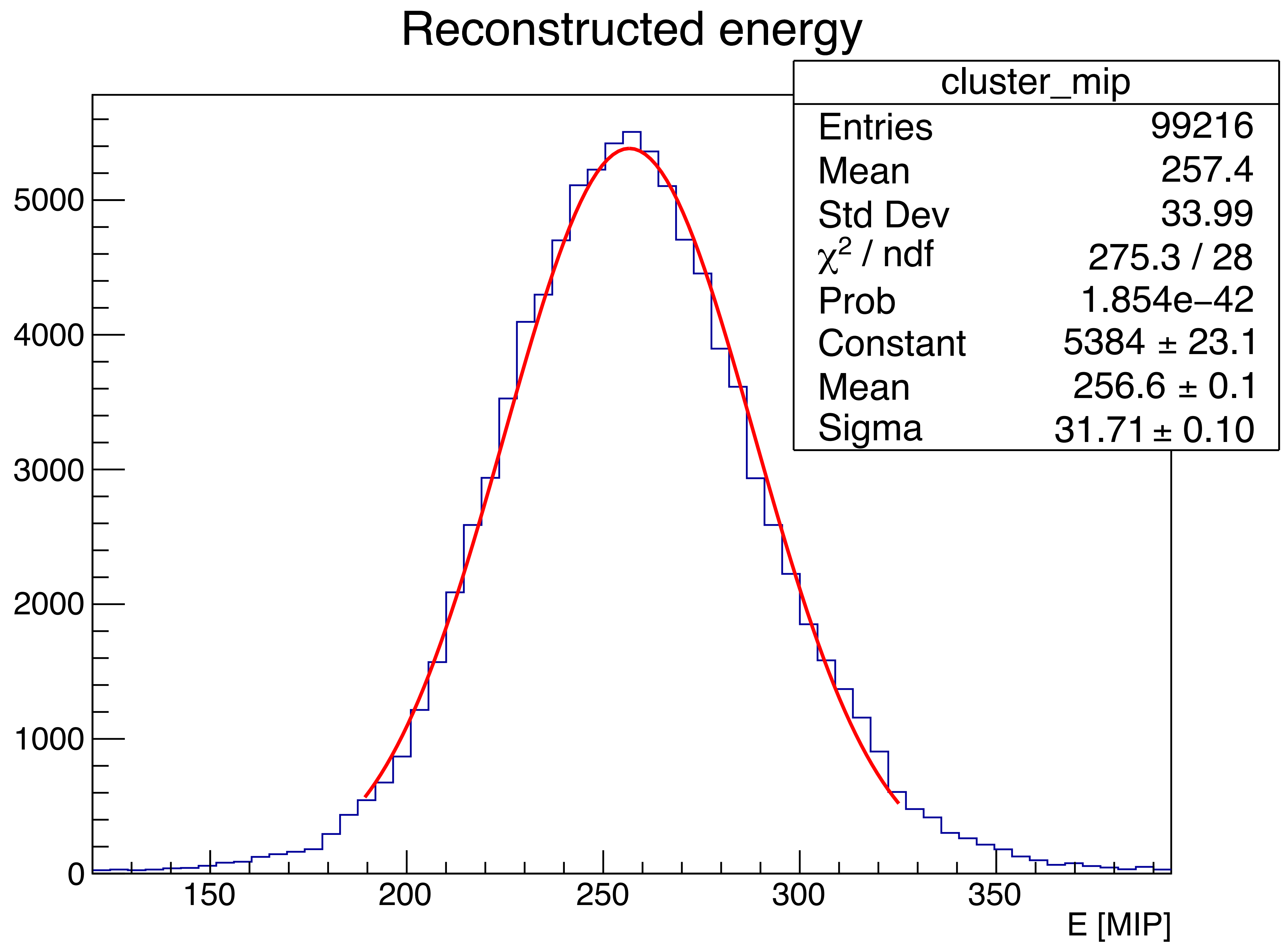
Strategy 1



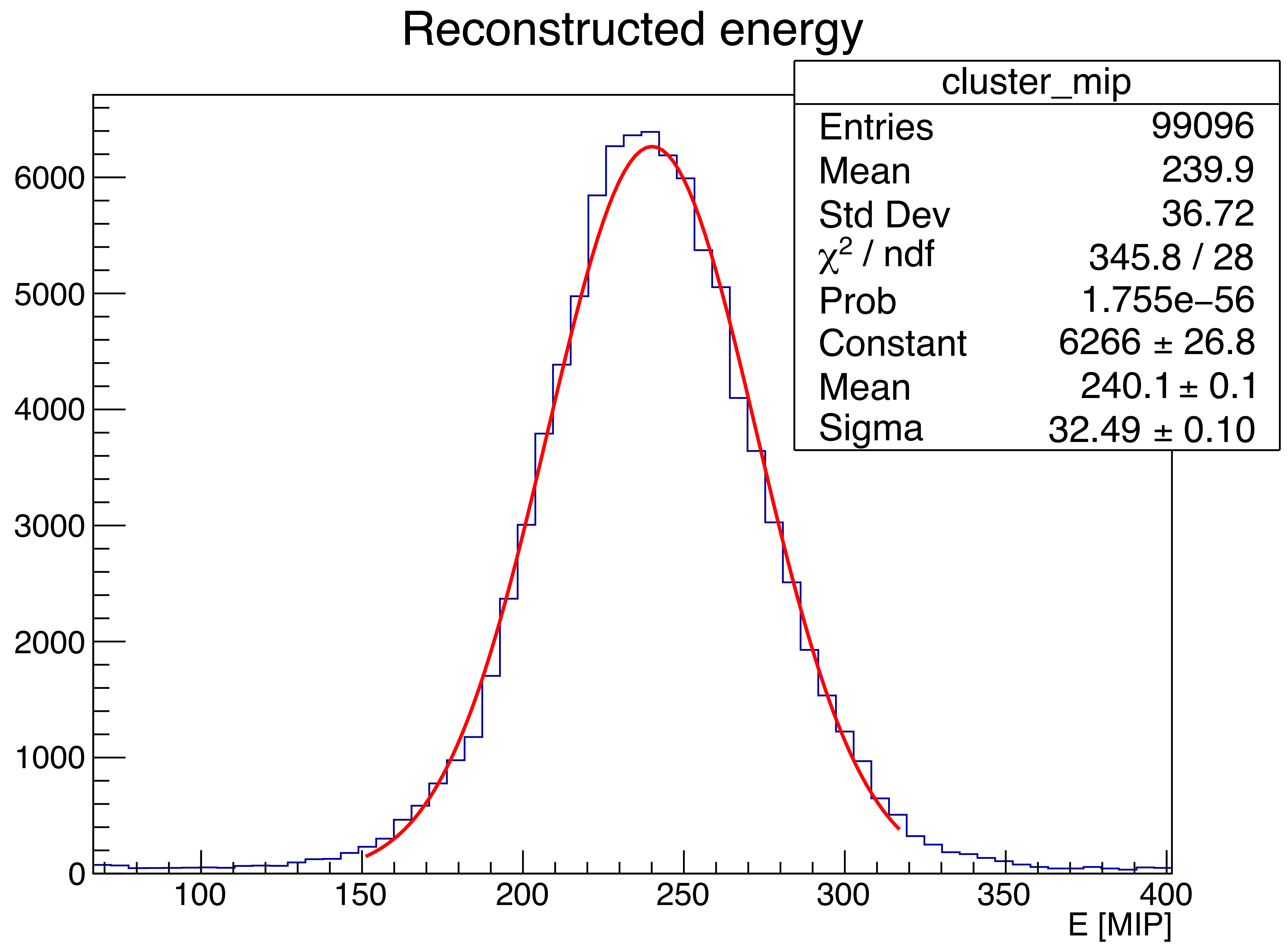
Strategy 2

Two electrons at 3.5 GeV

Benefit from AIQ strategies



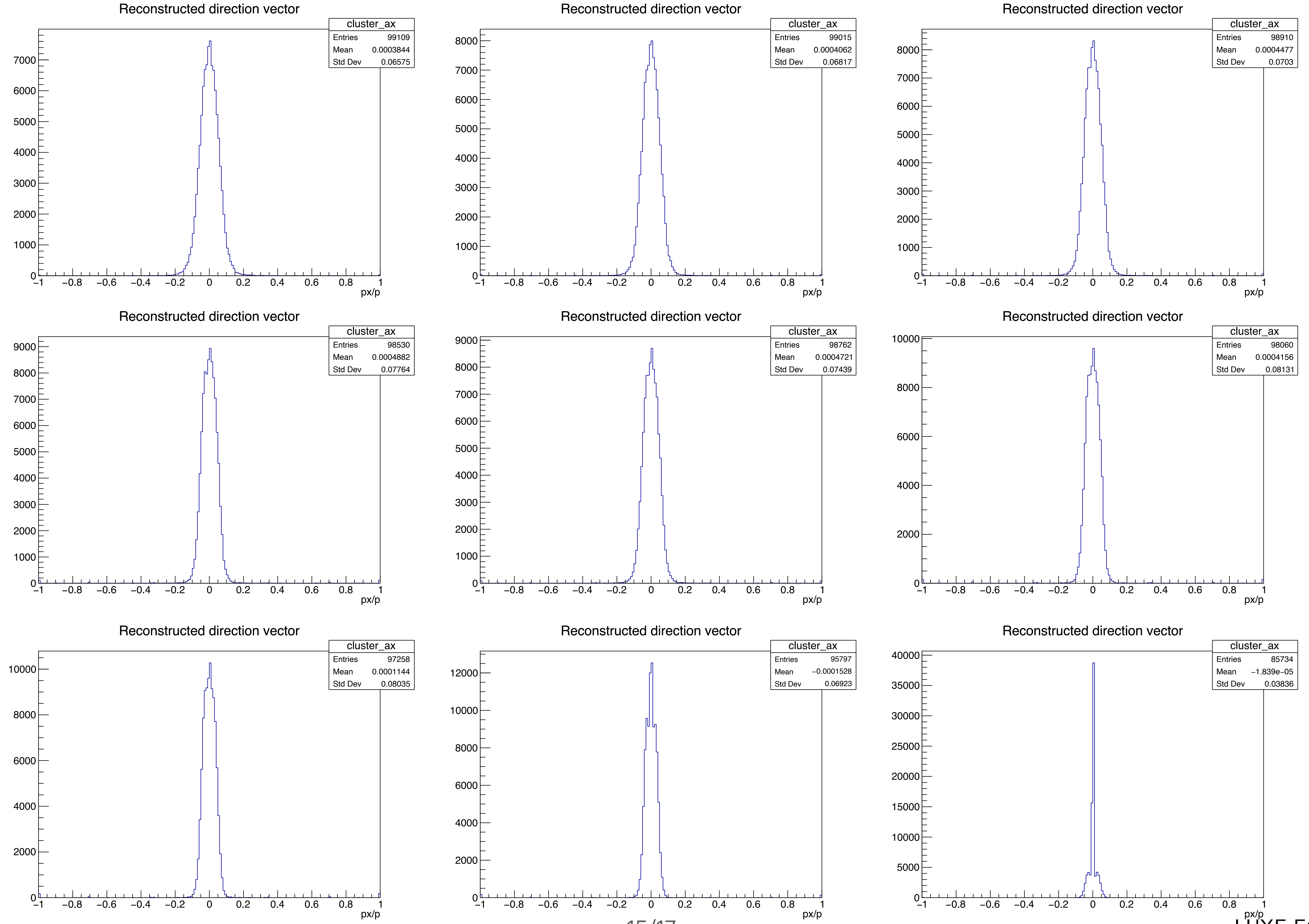
Strategy 1



Strategy 2

Two electrons at 3.5 GeV

Radius tuning



Distance of two showers

Table 1

distance mm	number of event	cluster pairs	
70	50000	48486	0.96972
60	50000	47386	0.94772
50	50000	42581	0.85162
40	50000	30036	0.60072
30	50000	14842	0.29684
20	50000	7747	0.15494
10	50000	7103	0.14206

Preliminary summary

- Obtained a valid work flow for ECAL analysis
- Easy to migrate to ECAL-P test beam geometry
- NPOD ECAL Performance in the close surroundings of NPOD requirements
  - More analysis is ongoing: many parameters to play with

- Optimising all parameters through the assistance of machine learning?

Reconstruction based on neural network

Works presented by Nir, et al

- See previous slides in 2023
- Tuning of reconstruction parameters with machine learning
  - Energy spectrum
  - Single shower energy/position
  - ...
- Needs generalisation with a much larger dataset (~100k?)
- How?

- Fast SFQED simulation (10k BX in 1 h)
- Slow lxsim simulation (1 BX in 1/2 h)
  - 1 BX = 1k particles/events
  - can run in parallel
- Change of geometry
  - laser parameters
  - magnetic fields, etc
- Could we reuse lxsim event?
  - by picking up events from "energy bins" and form dummy bunch-crossings