ECAL-NPOD
Vertex reconstruction

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This research is supported by:

Targets

Assuming no background

- Separation power:
  - If the (two signal) showers overlap, until how close are they can we separate them? Quantified by clustering efficiency
  - What if there are background showers?
  - … the photons have different energies?
- Reclustering
- Reconstruction

  Quality quantified by the residues of
  - vertex position
  - p_T
  - cos(Δphi)

Particle identification

- Given a shower created by one particle, how good can we determine which kind of particle generate this shower? Quantified by likelihood (see MAS)

Workflow

- Clustering (more than two clusters?)
- PID (two photons?)
- Reclustering (possible vertex?)
- Reconstruction

Codes at [this GitHub repository]

- Reminder: Reconstruction targets
- Reminder: dd4hep/Marlin
  - Optimization
- Results
  - Power of separation
  - Reconstruction

Simulation

- Geometry description of ECAL-E in dd4hep
- Standalone ECAL-E simulated by ddsim
  - Vacuum outside
- Facile digitization:
  - Hit deposit smearing 10%
  - Hit deposit cut at 1/2 MIP
- Gun relocated to avoid stave gaps
- Gun position smearing removed

Simulations for analysis:

- Mono-energetic particle sims
  - 0.5, 1.5, 3.5 GeV
- Two-particle sims for clustering
  - Parallel with various distances in between
    - z = -1.0 m; scanning Δx
  - From a fixed vertex with various angles
    - z = -2.5 m; scanning angles
- Flat-spectrum sims for PID (by MAS)
  - 0.5-3.0 GeV

dd4hep scripts at this GitHub path

Reconstruction

- Separation power (parallel sim.)
  - Nearest-neighbour clustering
  - Optimised for different energies
  - The deposits of the two clusters should be close enough ($0.5 < \text{ratio} < 2.0$)
  - How close the neighbours are?
    - dCut: $\sqrt{[15^2+(5.5*d)^2]}$ mm; $d = 1,2,3$
    - eCut: 1,2,…,10 MIPs

- Use the optimised parameters to continue with vertex simulations
  - Reclustering
    - Along parallel cylinders
  - Reconstruction
    - $vx_{\{x,\ y,\ z\}}$ vertex position residues
    - p_T transverse momentum
    - mass $= \sqrt{(E^2 - p_z^2 - p_T^2)}$
    - cos(Δphi)

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More neighbours

More neighbours

E = 0.5 GeV, Δx = 50 mm

	1	2	3	4	5	6	7	8	9	10
16.0	74.9%	64.2%	43.8%	19.9%	6.6%	1.9%	0.5%	0.2%	0.1%	0.0%
18.6	75.3%	65.2%	47.0%	22.4%	7.8%	2.3%	0.6%	0.2%	0.1%	0.0%
22.3	74.6%	65.4%	48.2%	23.7%	8.3%	2.4%	0.6%	0.2%	0.1%	0.0%

E = 1.5 GeV, Δx = 50 mm

	1	2	3	4	5	6	7	8	9	10
16.0	**94.8%**	89.4%	83.3%	77.3%	71.9%	63.0%	49.8%	35.5%	22.3%	12.5%
18.6	89.4%	89.6%	83.8%	77.9%	72.4%	64.0%	51.5%	37.0%	23.5%	13.3%
22.3	75.7%	85.8%	82.8%	77.8%	72.3%	64.3%	52.3%	37.7%	24.3%	13.8%

E = 3.5 GeV, Δx = 50 mm

	1	2	3	4	5	6	7	8	9	10
16.0	89.1%	**97.5%**	**97.6%**	**96.3%**	**94.3%**	**92.2%**	**90.0%**	87.4%	85.2%	81.9%
18.6	61.5%	89.2%	**95.3%**	**95.6%**	**94.2%**	**92.3%**	89.9%	87.4%	85.1%	82.0%
22.3	29.1%	70.8%	88.5%	**93.3%**	**93.5%**	**91.9%**	89.9%	87.4%	85.1%	82.0%

More neighbours

E = 1.5 GeV, Δx = 30 mm

	1	2	3	4	5	6	7	8	9	10
16.0	46.6%	72.9%	77.3%	74.8%	70.8%	62.2%	49.7%	35.5%	22.3%	11.7%
18.6	16.8%	48.6%	65.4%	69.2%	68.2%	61.7%	50.3%	36.7%	23.5%	12.6%
22.3	4.2%	25.2%	47.3%	58.0%	62.6%	58.5%	49.3%	36.5%	23.6%	12.8%

More neighbours

E = 1.5 GeV, Δx = 50 mm

	1	2	3	4	5	6	7	8	9	10
16.0	**94.8%**	89.4%	83.3%	77.3%	71.9%	63.0%	49.8%	35.5%	22.3%	12.5%
18.6	89.4%	89.6%	83.8%	77.9%	72.4%	64.0%	51.5%	37.0%	23.5%	13.3%
22.3	75.7%	85.8%	82.8%	77.8%	72.3%	64.3%	52.3%	37.7%	24.3%	13.8%

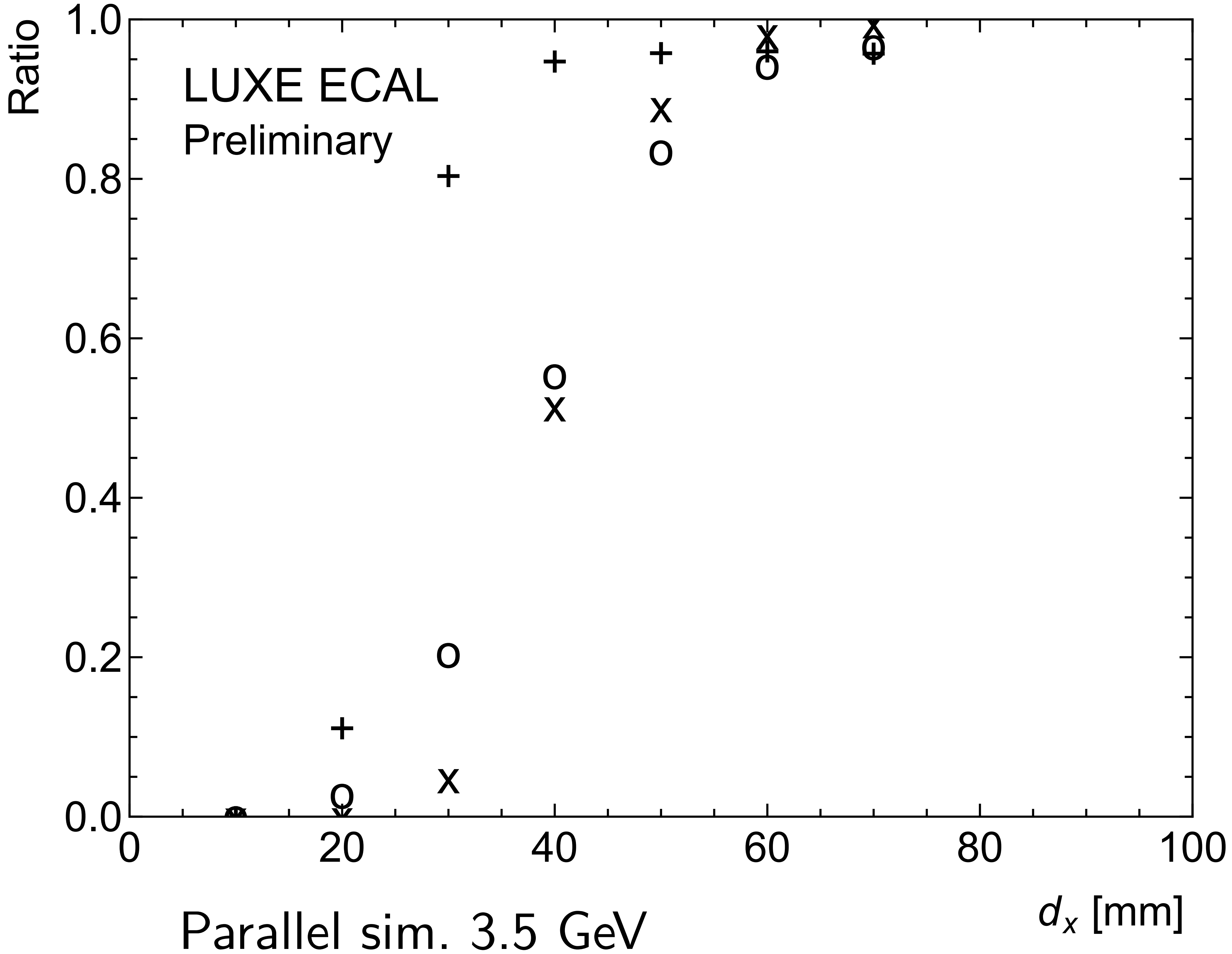
E = 1.5 GeV, Δx = 70 mm

	1	2	3	4	5	6	7	8	9	10
16.0	**95.8%**	89.1%	81.1%	74.4%	67.5%	58.6%	44.0%	29.2%	16.7%	8.4%
18.6	**96.5%**	**90.5%**	82.7%	75.4%	68.4%	59.9%	45.5%	30.6%	17.9%	9.3%
22.3	**95.7%**	**90.8%**	83.2%	75.9%	68.7%	60.1%	46.3%	31.5%	18.4%	9.7%

Power of separation

- Tune the parameter to fit
  - the (estimated) signal energy
    - Lower energy requires more neighbours
  - the requirement of separation
    - Closer showers require stricter cut

- To test the best performance w/o taking the clustering error into account, wide separated samples are used for vertex recon.
- Δphi = 0.04 rad = 2.3°
- NNClustering parameters:
  - eCut = 1 MIP
  - dCut = 22, 18, 16 mm (for 0.5, 1.5, 3.5 GeV)



Parallel sim. 3.5 GeV

o dCut = 18, eCut = 2 (Previous results)

x dCut = 16, eCut = 1

+ dCut = 16, eCut = 4

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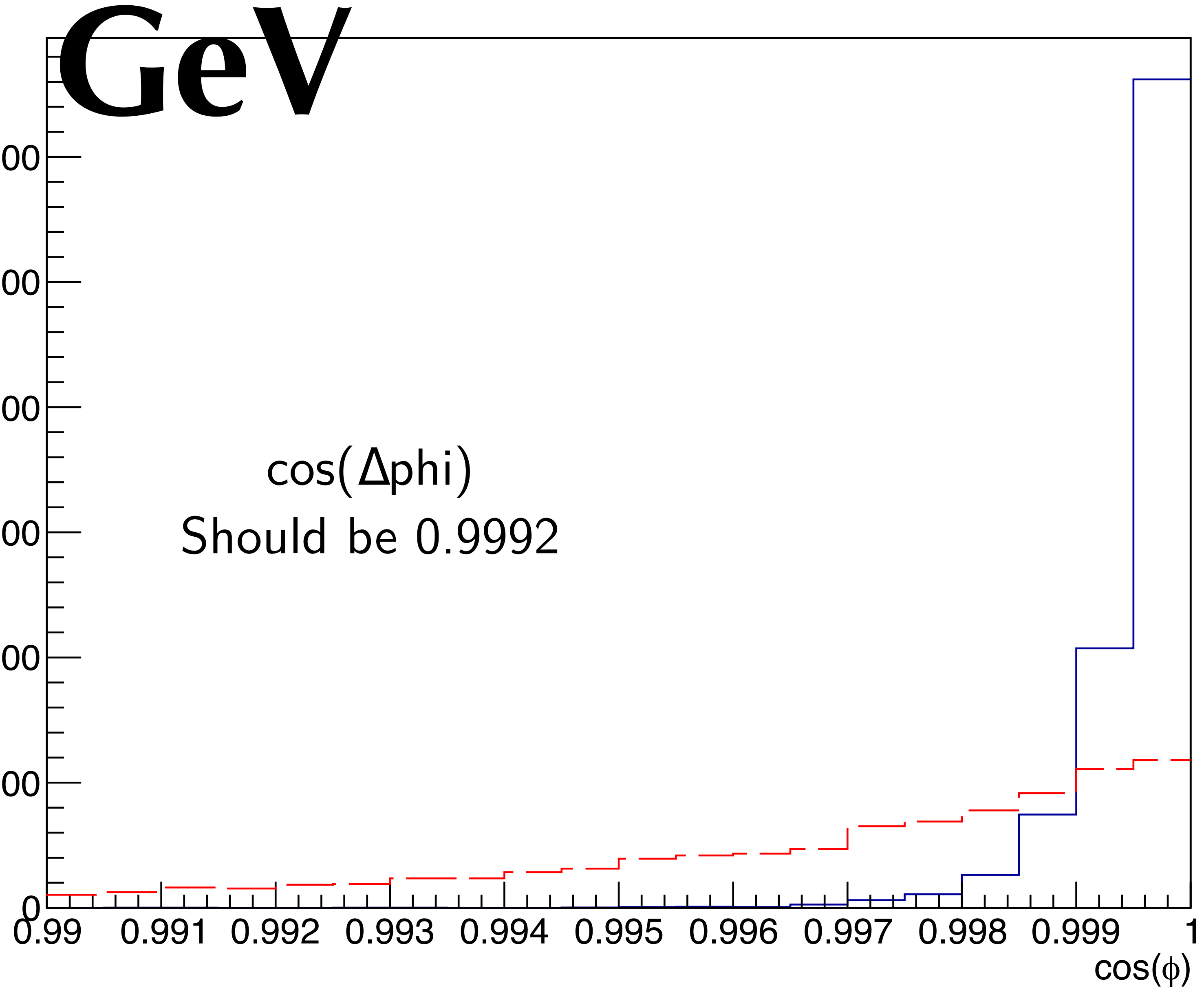
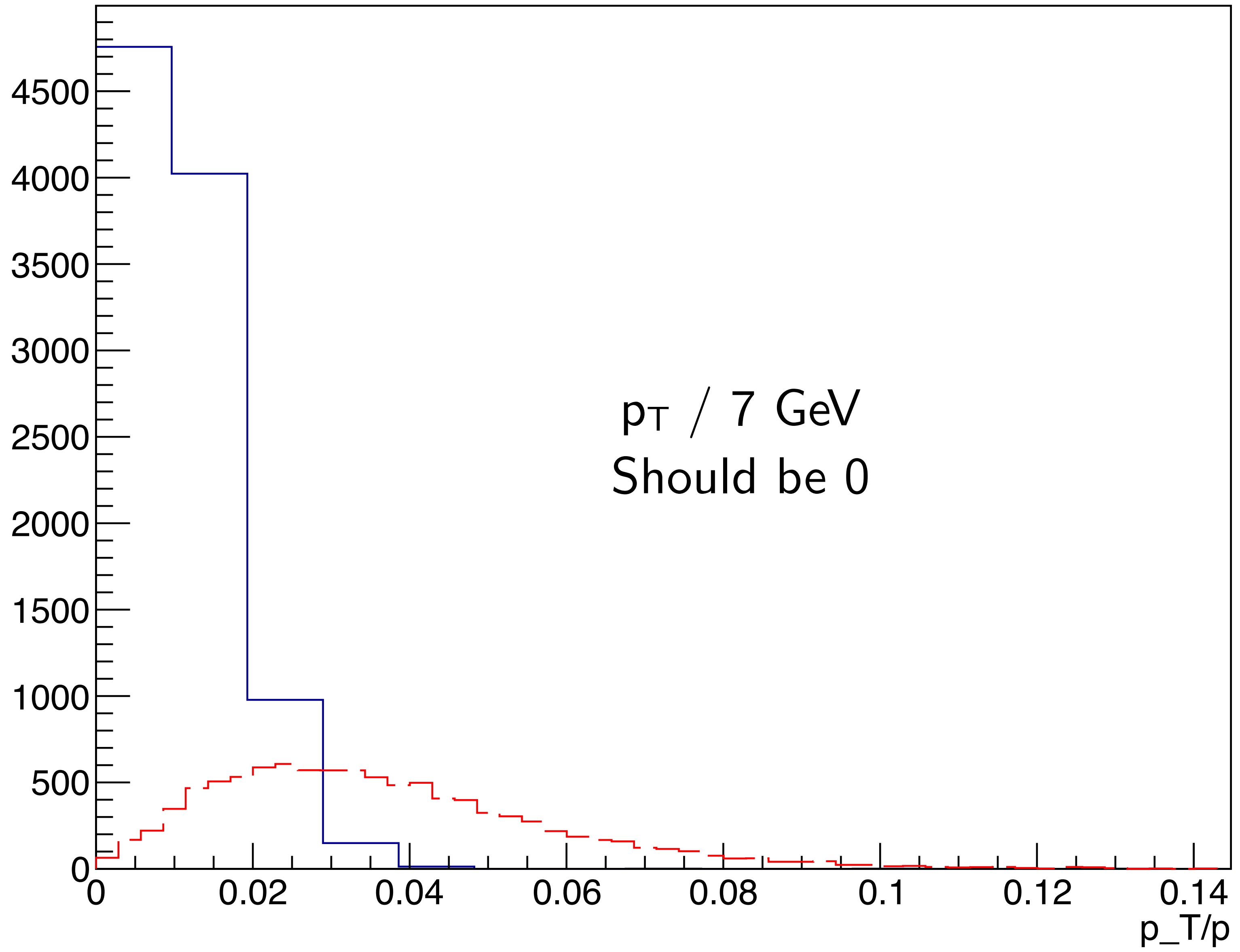
3.5 GeV

Track angle cosine

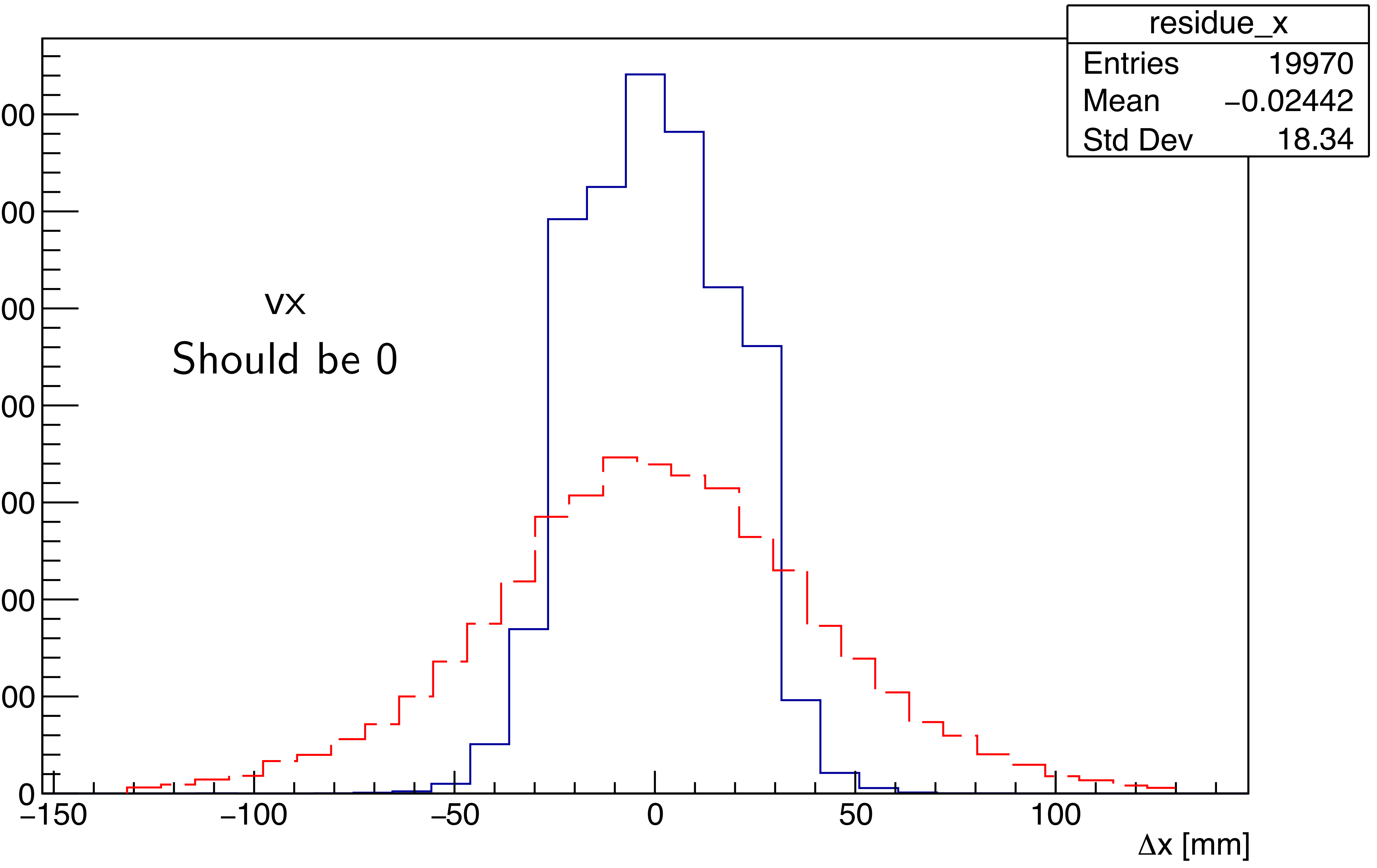


cos(Δphi)
Should be 0.9992

Transverse momentum

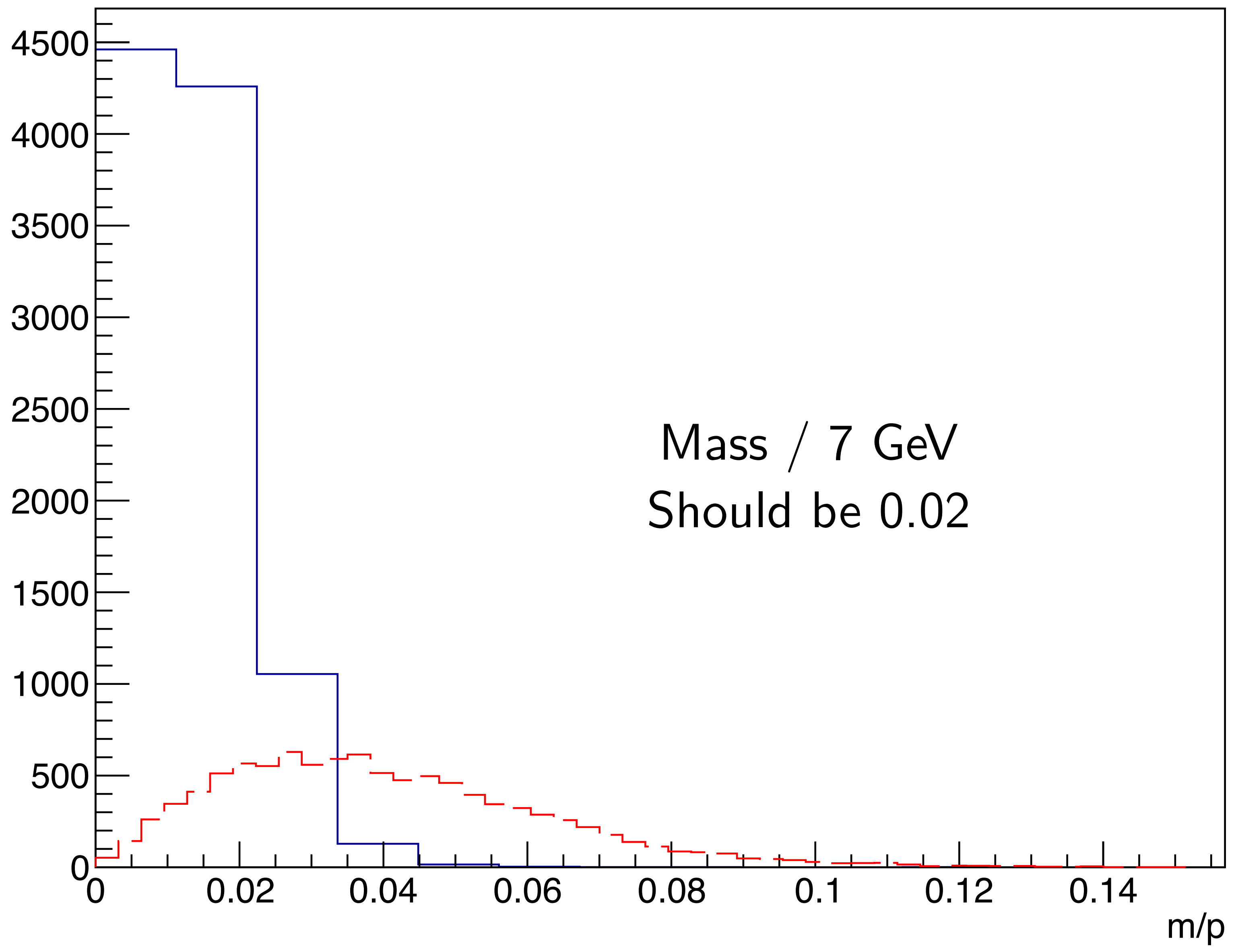


p_T / 7 GeV
Should be 0



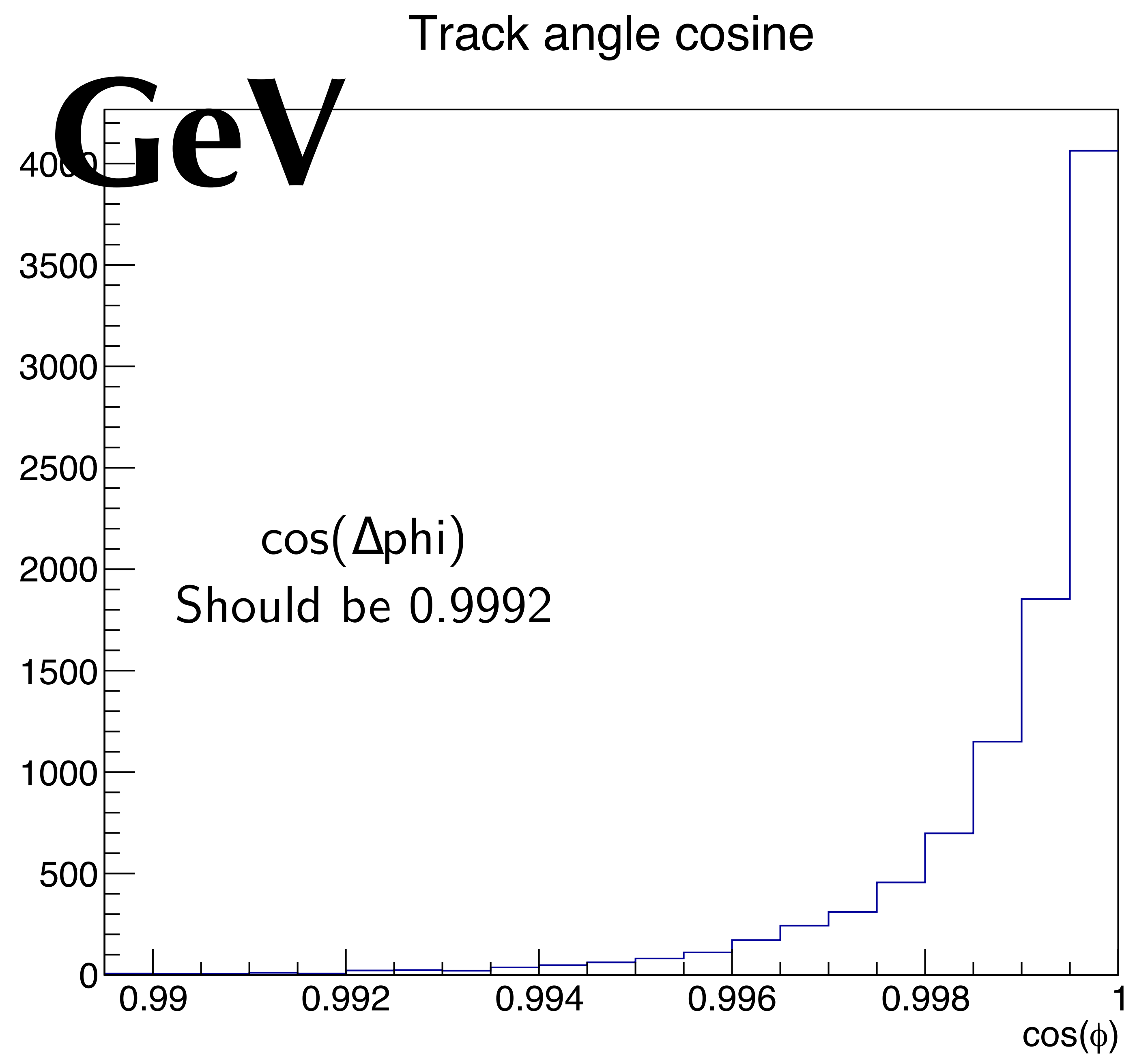
vx
Should be 0

ALP mass

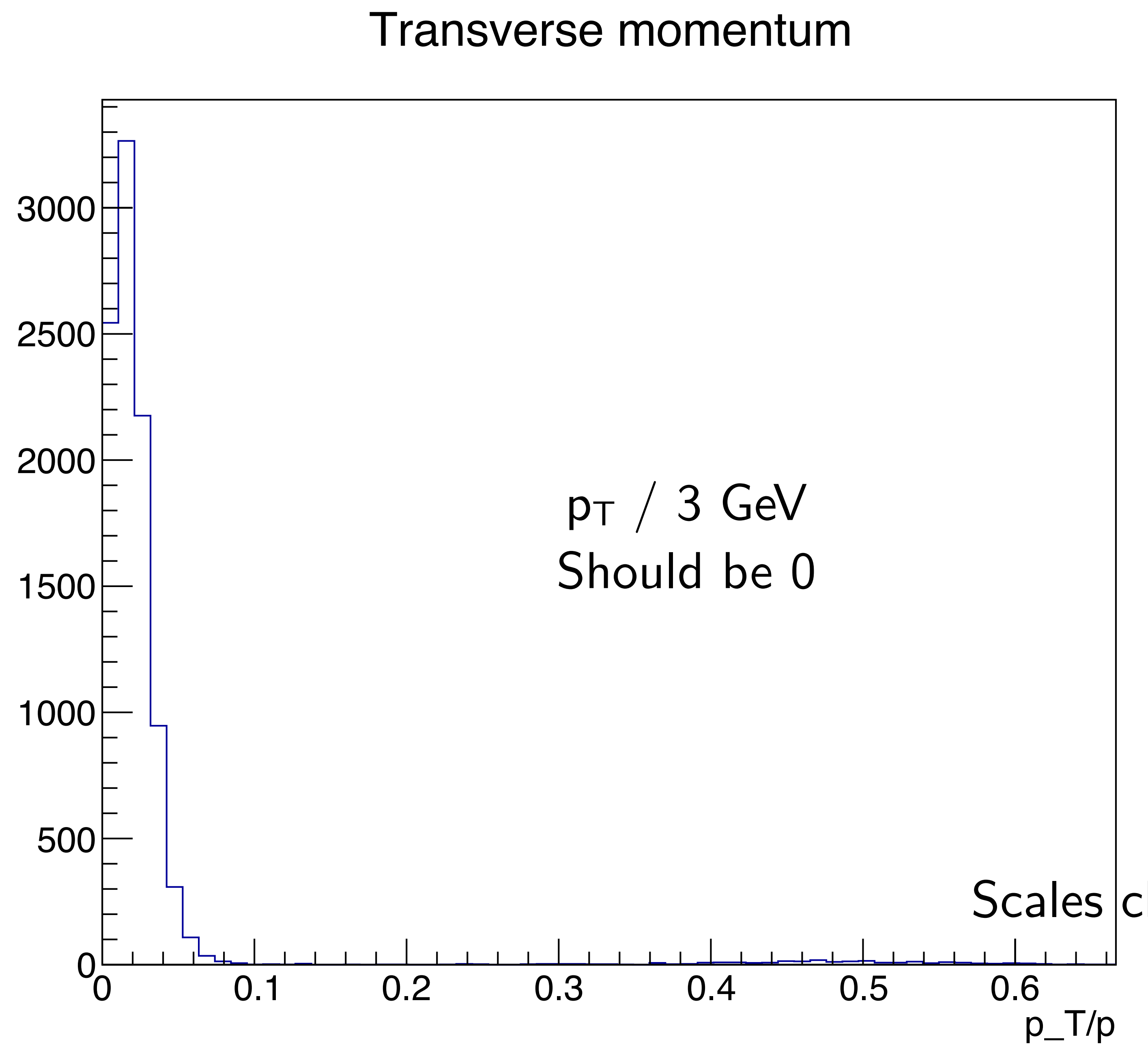


Mass / 7 GeV
Should be 0.02

1.5 GeV

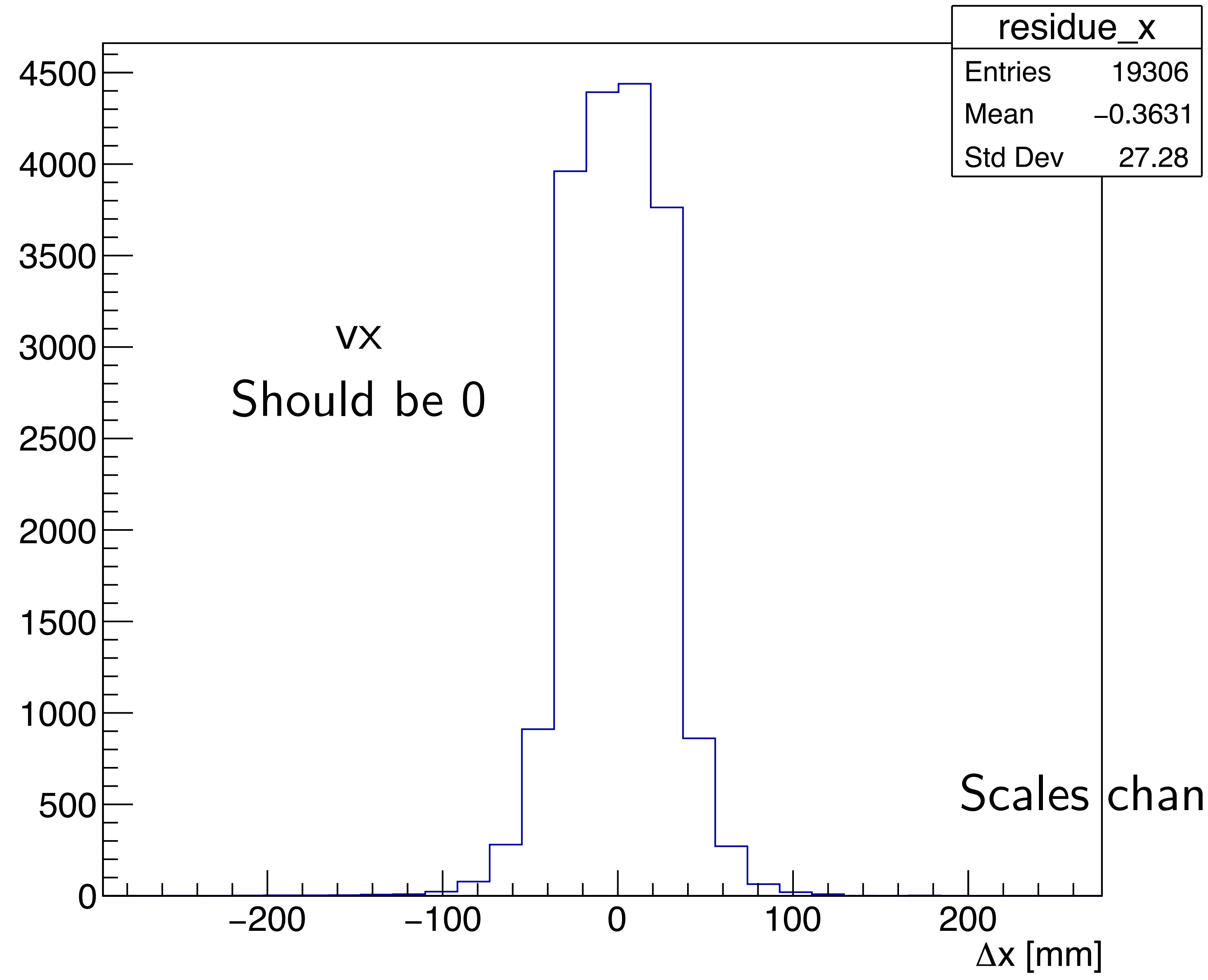


cos(Δphi)
Should be 0.9992



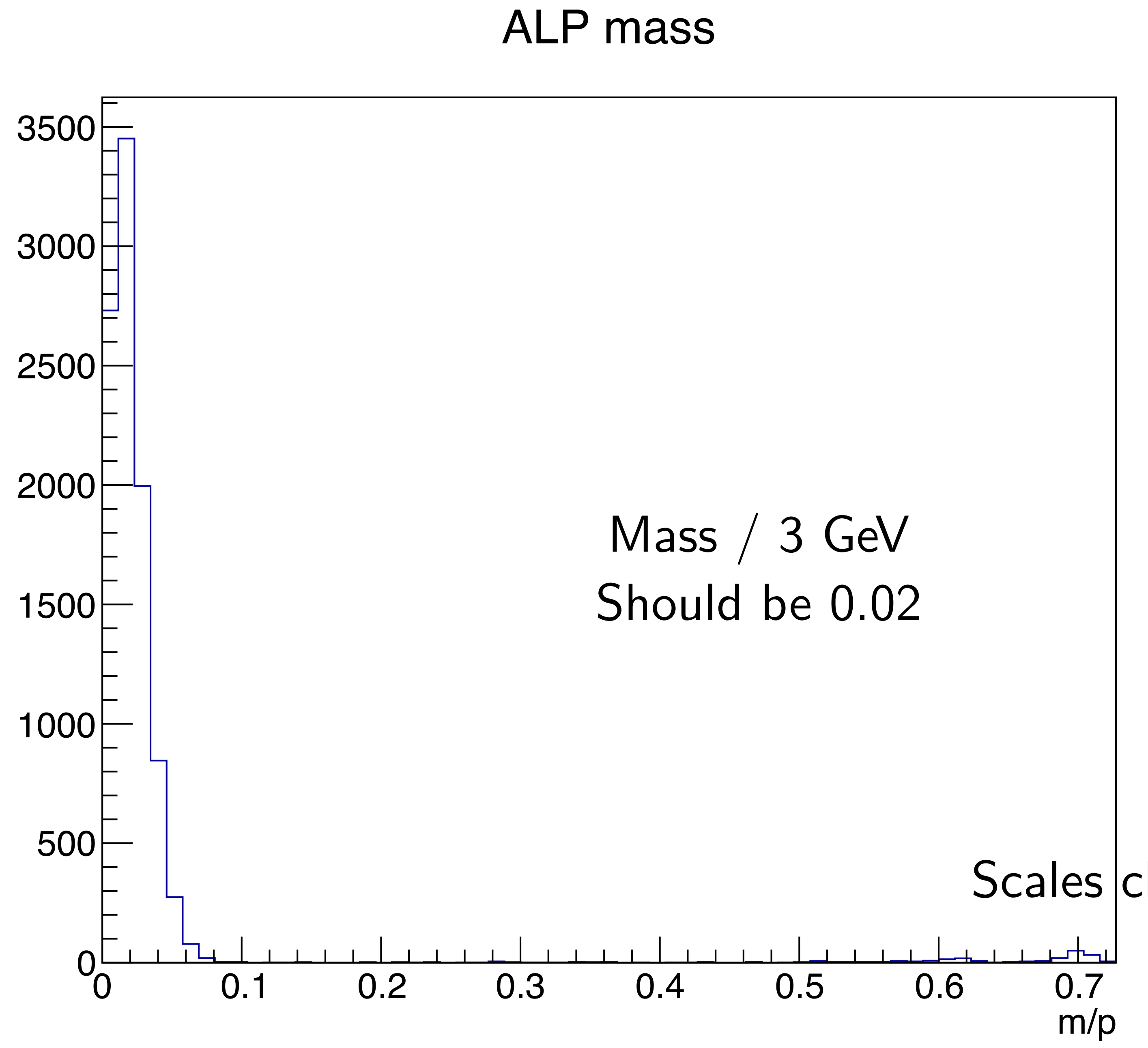
p_T / 3 GeV
Should be 0

Scales changed!



vx
Should be 0

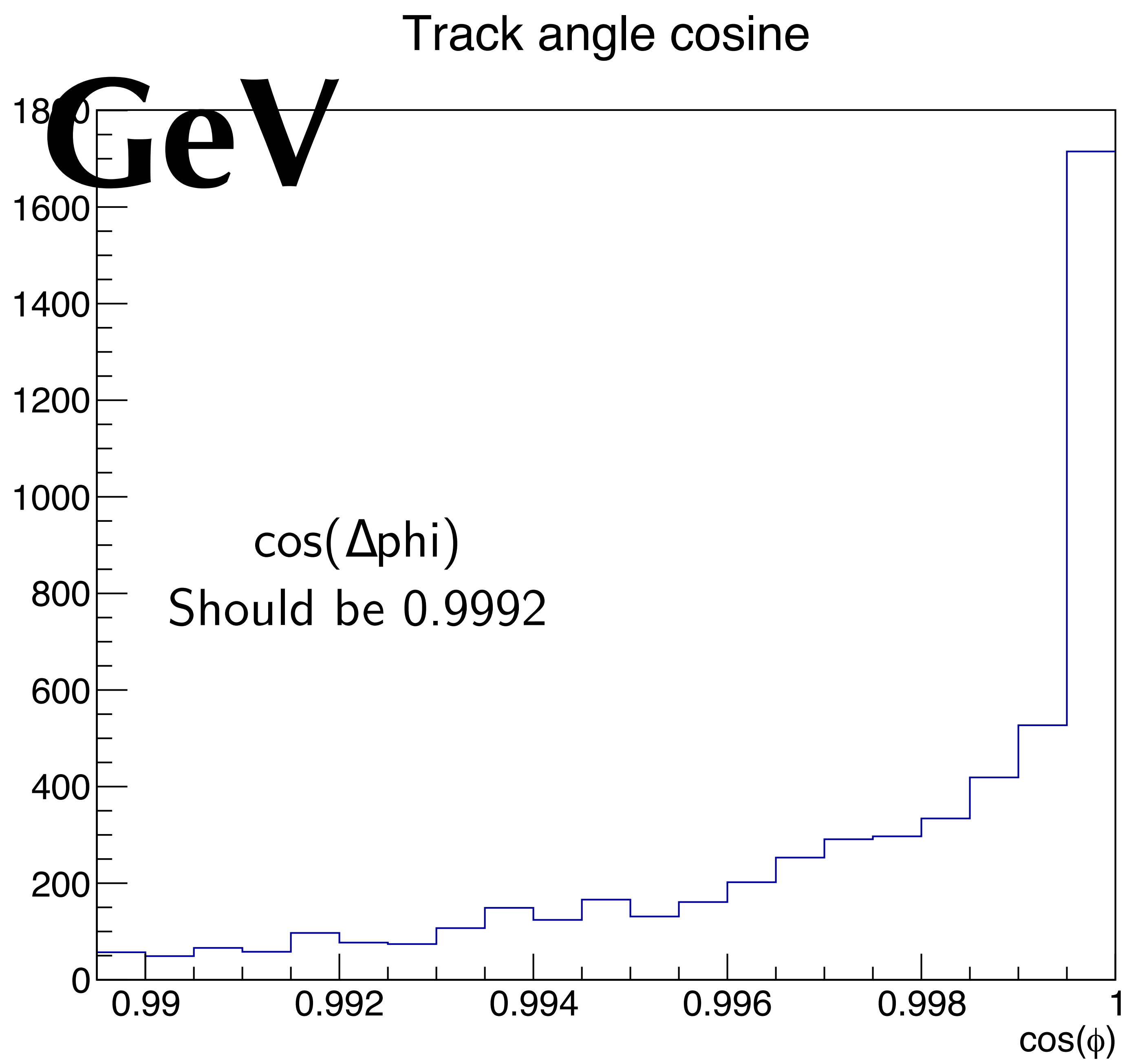
Scales changed!



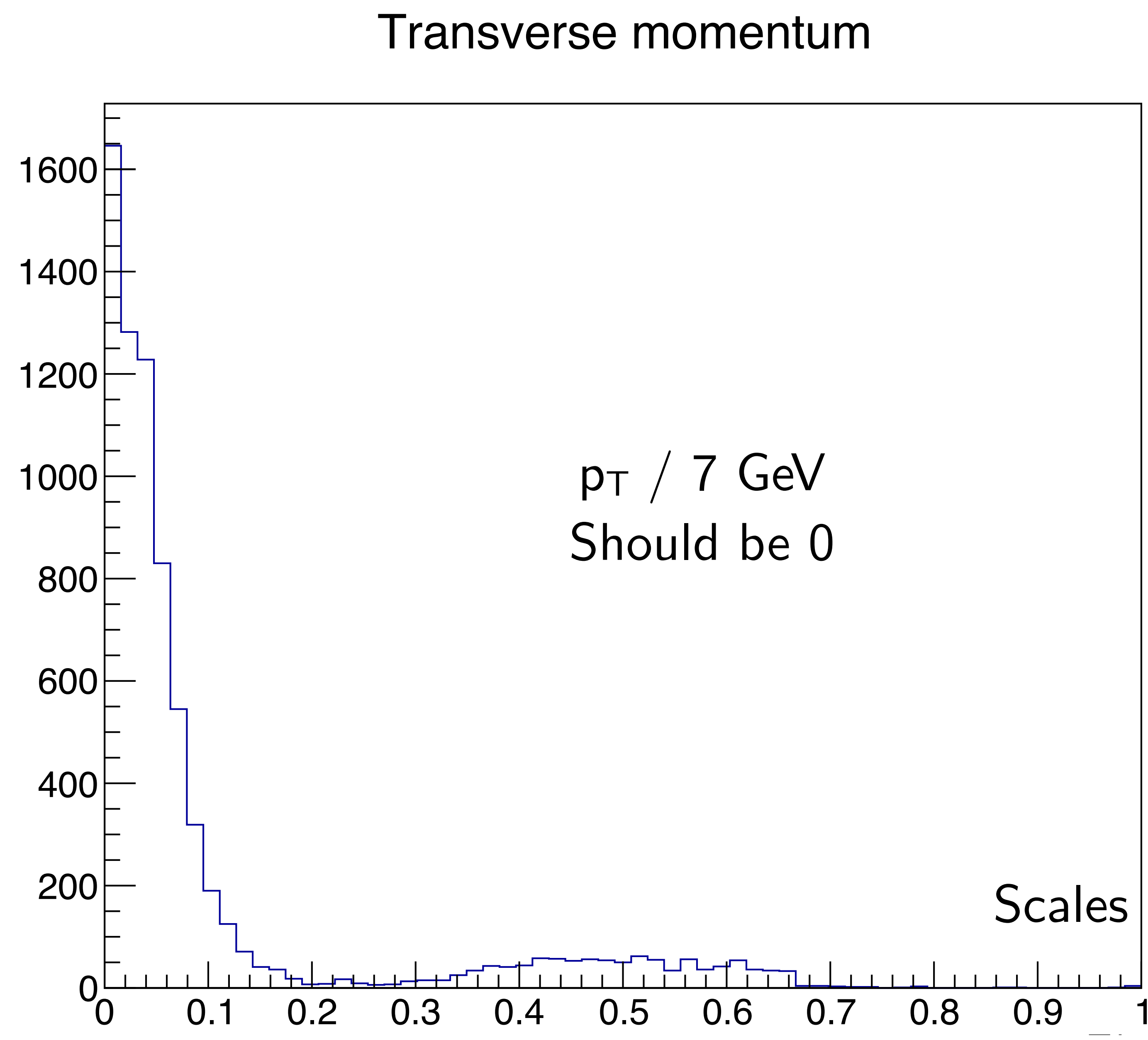
Mass / 3 GeV
Should be 0.02

Scales changed!

0.5 GeV

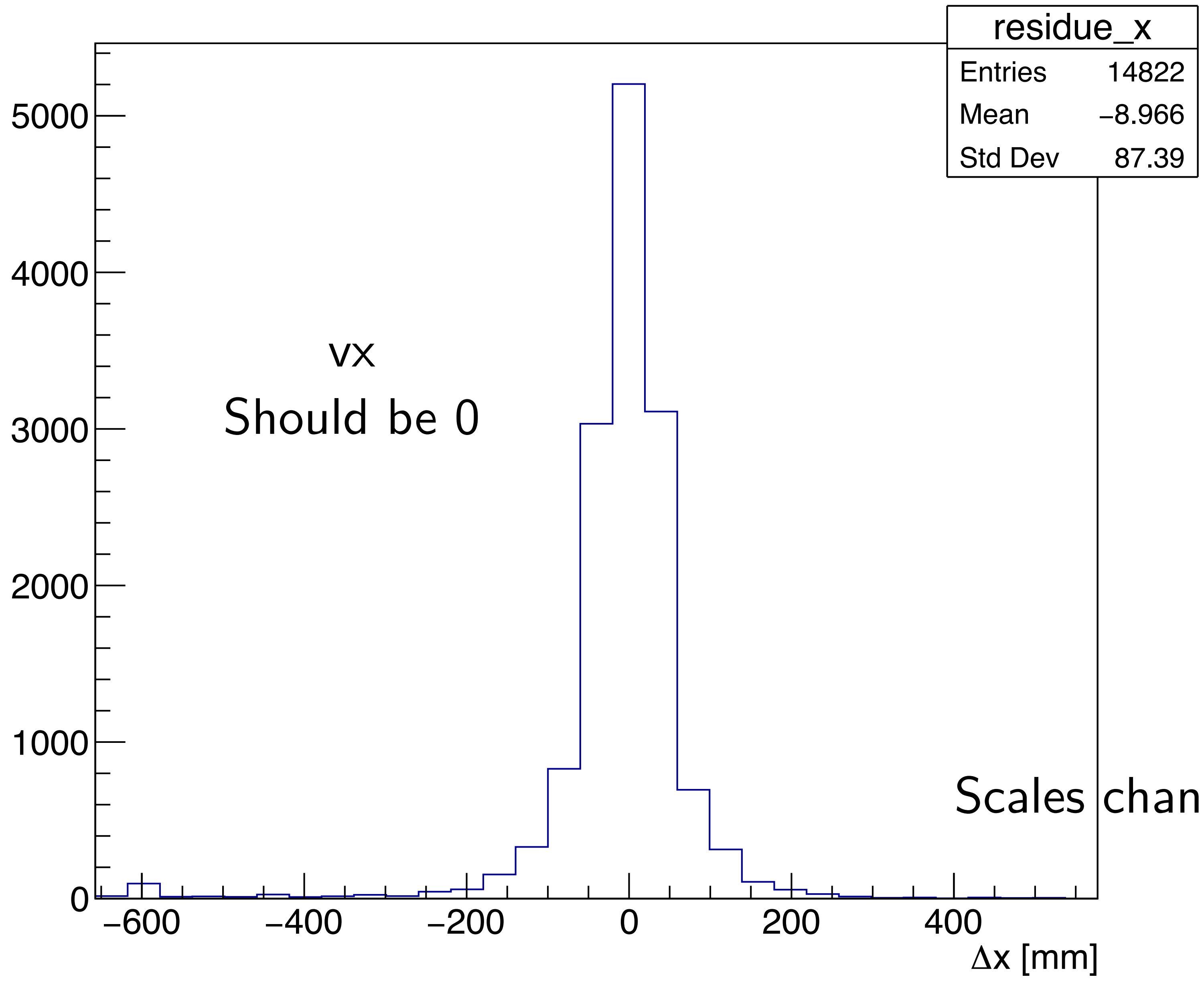


cos(Δphi)
Should be 0.9992



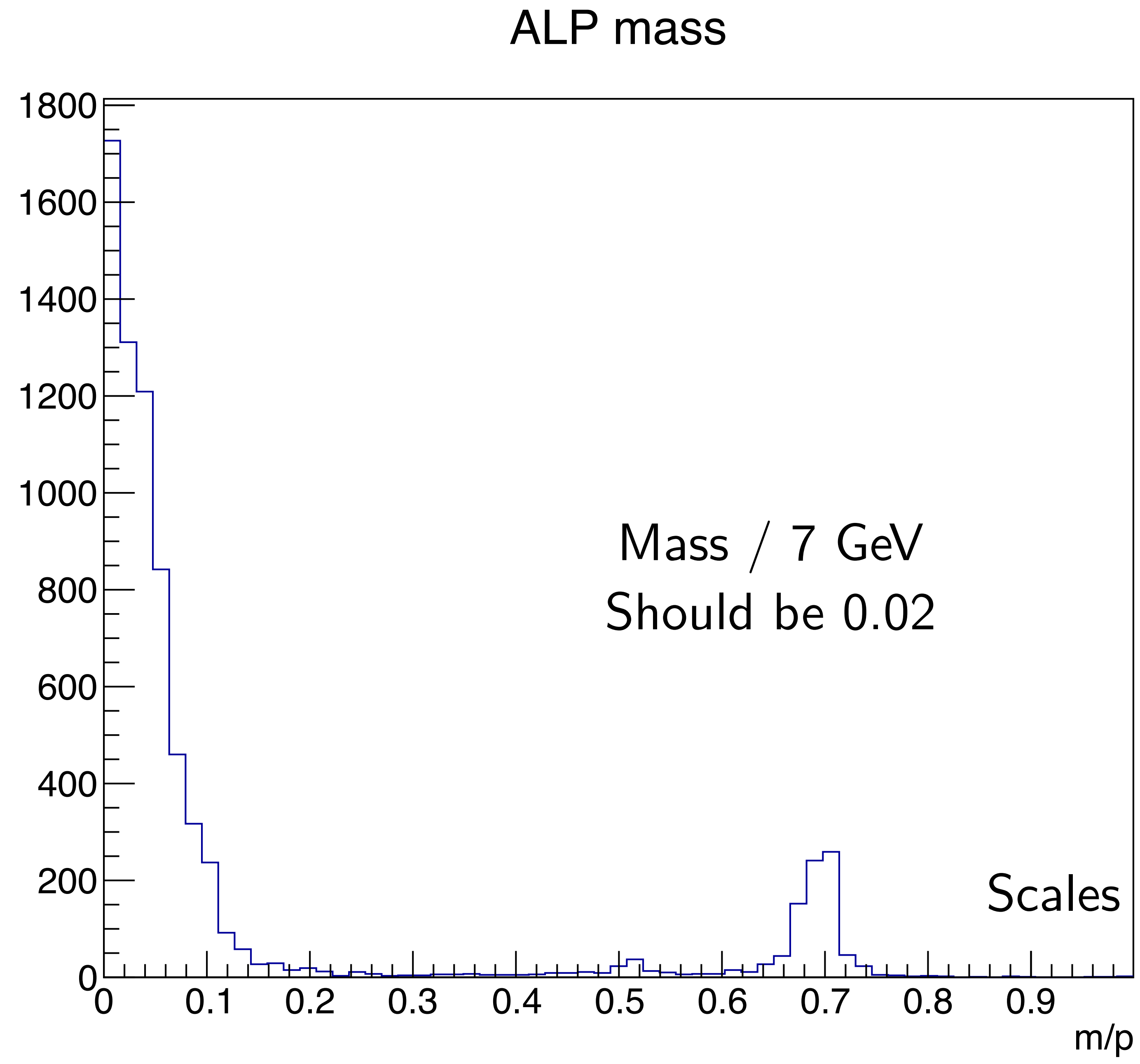
p_T / 7 GeV
Should be 0

Scales changed!



vx
Should be 0

Scales changed!



Mass / 7 GeV
Should be 0.02

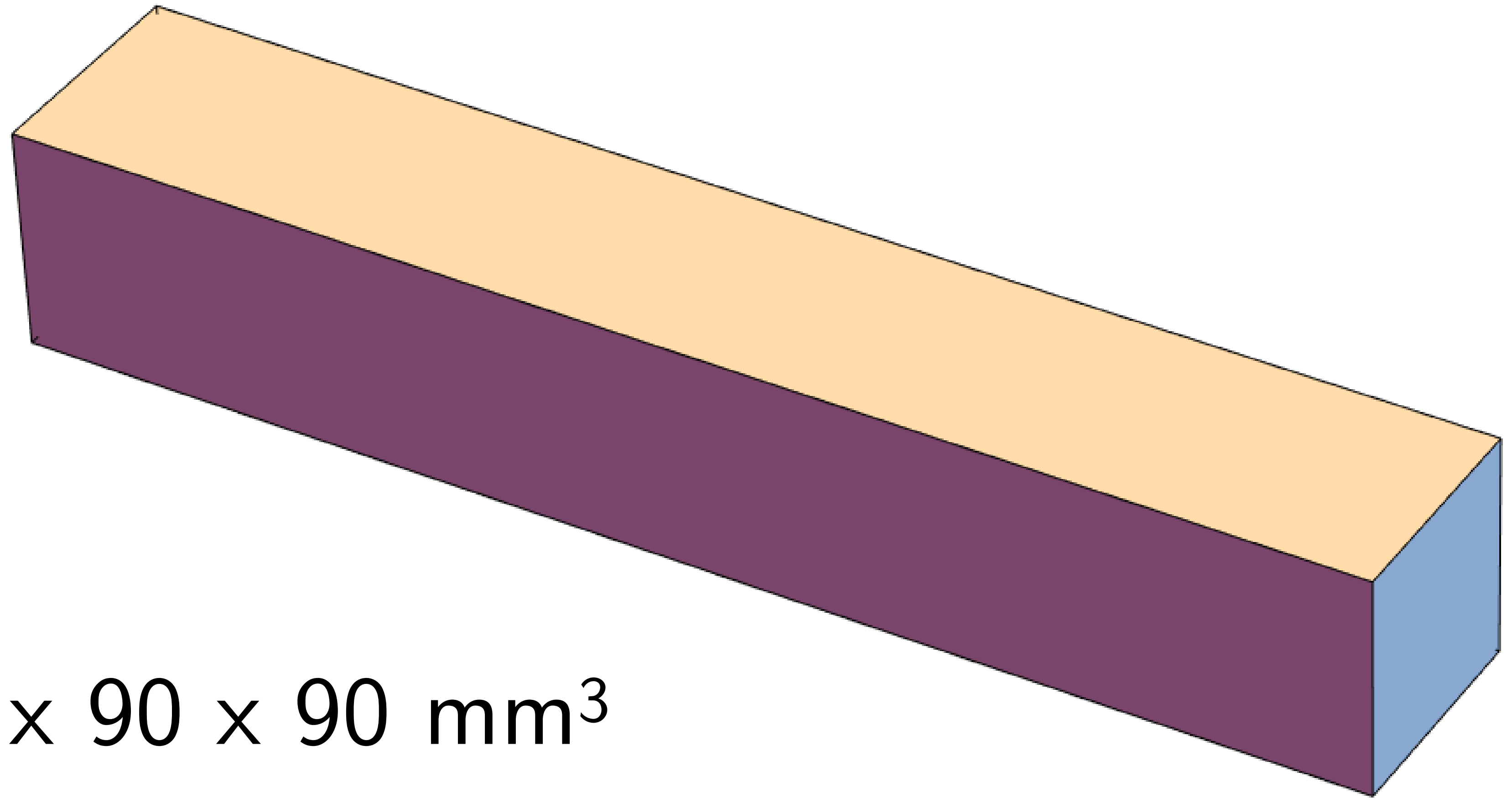
Scales changed!

Reconstruction

- Still work in progress
  - Bin sizes...
  - Understanding the irregularities
  - Enlarge the search range to optimise the lower energetic ones?
- Backgrounds?

Backup

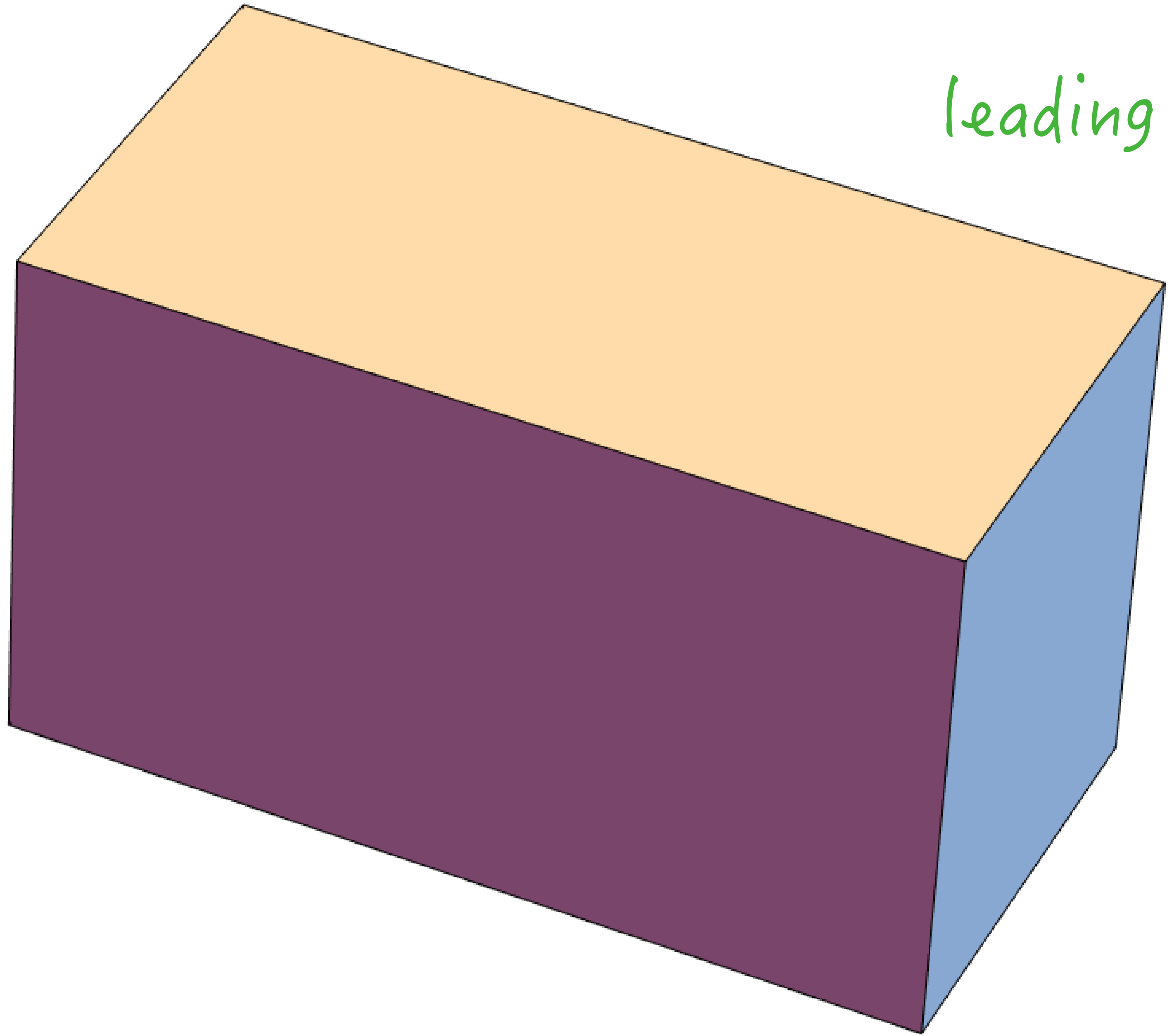
ECAL-P/E



- 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
    - W = 3.5 mm = 1.0 X_0
    - Si = 0.320 mm

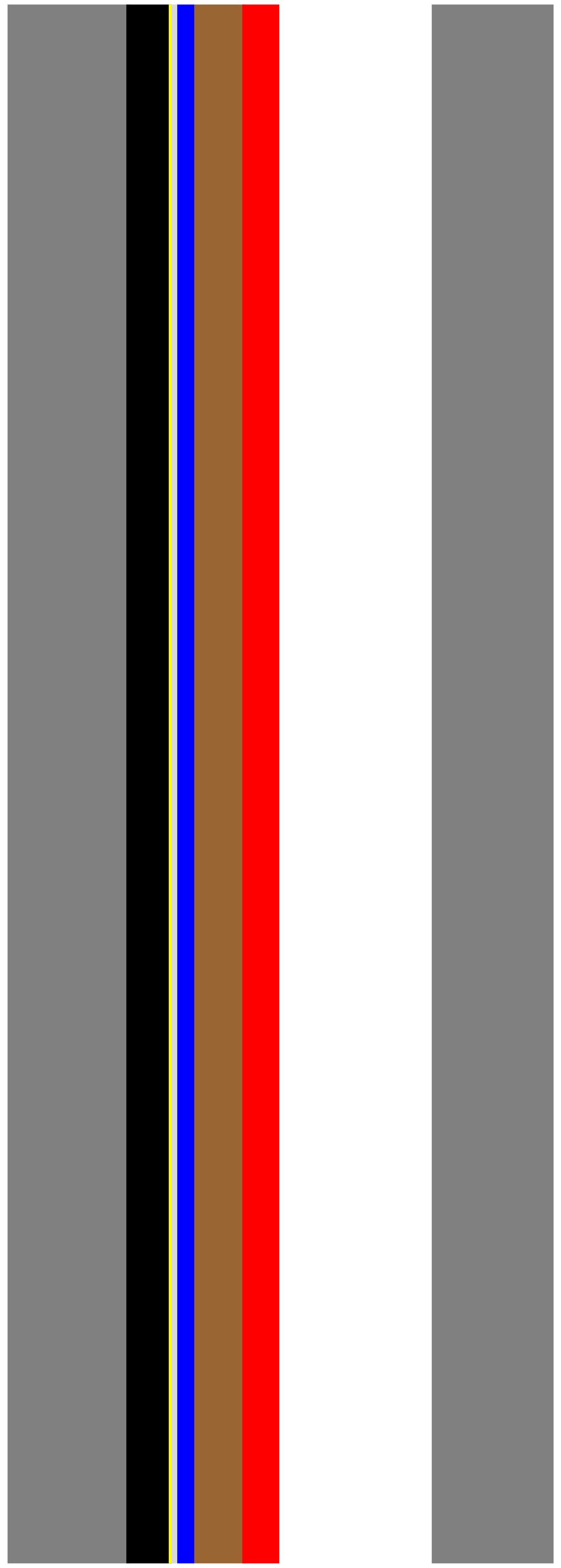
ECAL-E = ECAL-NPOD

leading candidate!



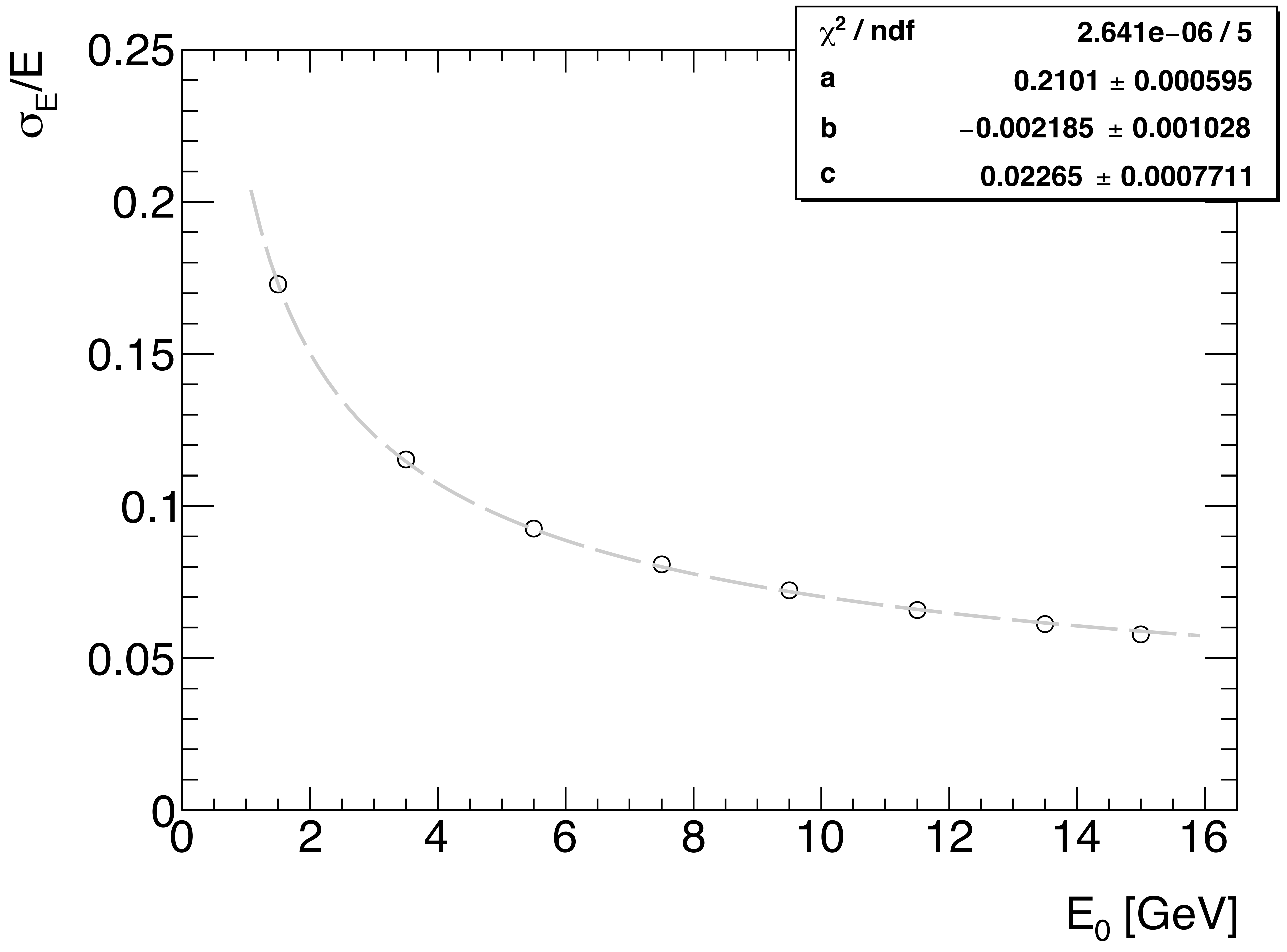
- ECAL-E: 360 x 180 x 210 mm^3
    - X = 64 x 5.5 mm
    - Y = 32 x 5.5 mm
    - Z = 15 x 15 mm (10 mm possible)
    - W = 4.2 mm = 1.2 X_0
    - Si = 0.500 mm

ECAL-E layer (in sim.)



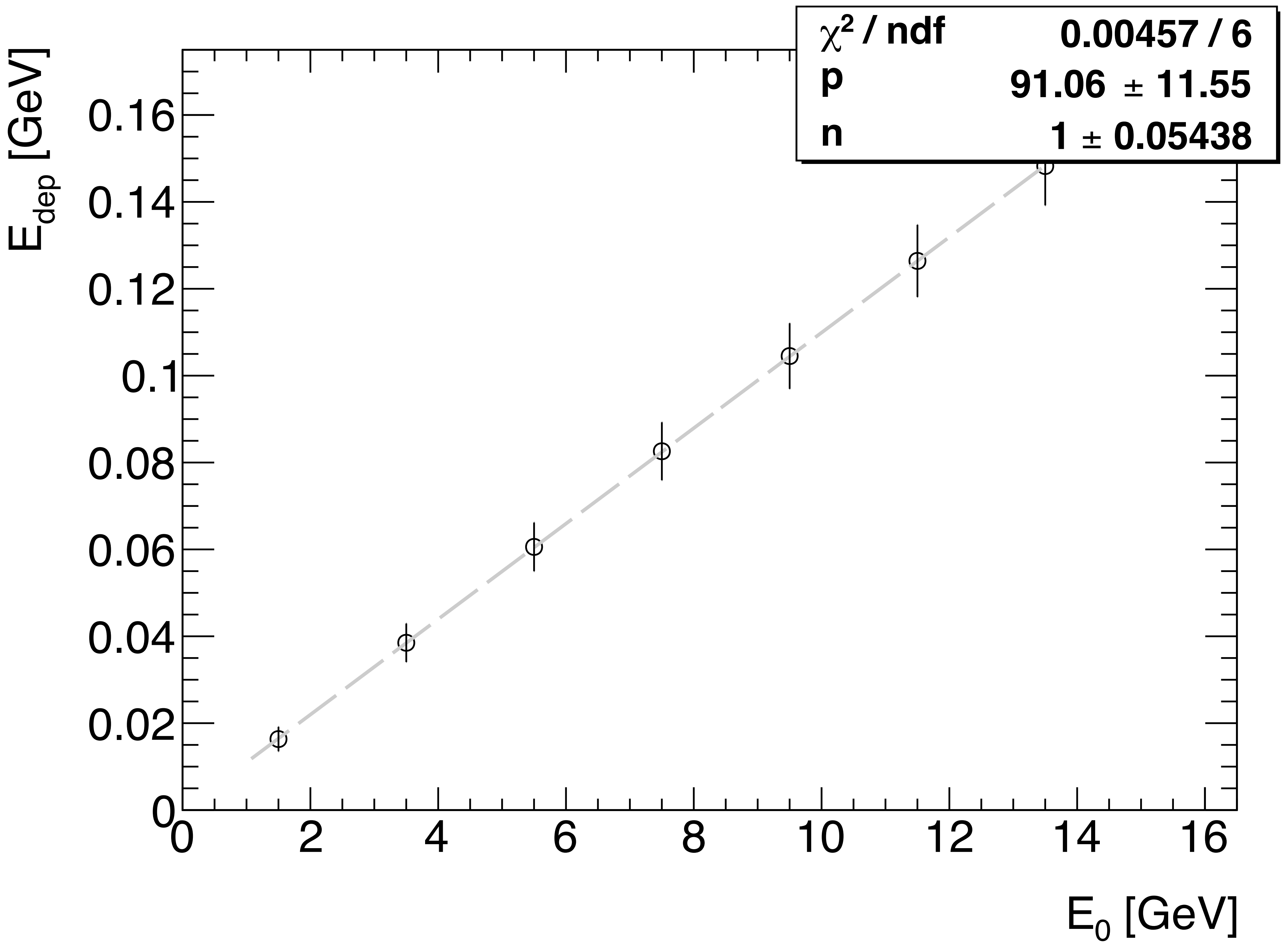
Material	d [mm]
W	4.2
C fibre	1.5
Kapton	0.1
Glue	0.1
Air	0.1
Si	0.5
Air	0.1
PCB	1.7
ASICs	1.2
Air	5.5 (or 0.5)
Total	15

ECAL-E perform. baseline



Intrinsic energy resolution

$$\frac{\sigma_E}{E_0} = \frac{a}{\sqrt{E_0/\mathrm{GeV}}} \bigoplus \frac{b}{E_0/\mathrm{GeV}} \bigoplus c$$



Intrinsic linearity

$$E_0 = pE_{\mathrm{dep}}^n$$