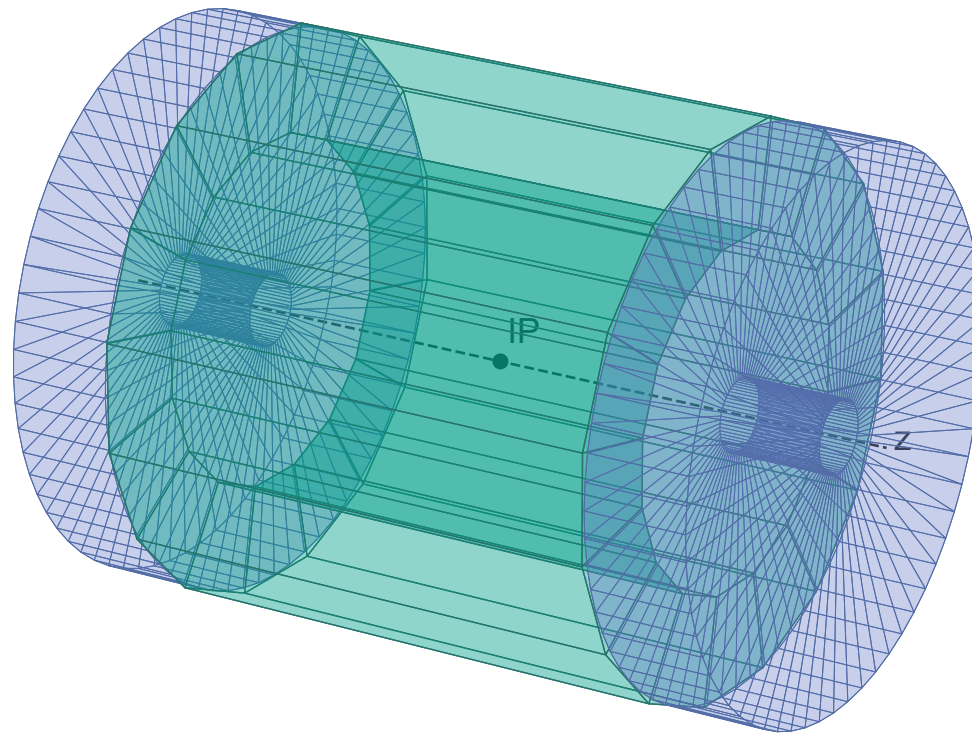




Plastic Scintillator HCAL

Geometry, Response and CyberPFA

Hongbin Diao



■ Barrel: 16 staves ■ Two endcaps

Barrel

$$|z| \leq 3.230 \text{ m}$$

Inner radius: 2.140 m

Outer radius: 3.455 m

Endcaps

$$3.260 \leq |z| \leq 4.575 \text{ m}$$

$$0.450 \leq r \leq 3.455 \text{ m}$$

Sampling stack

Plastic: $43 \times 30 = 1290 \text{ mm}$

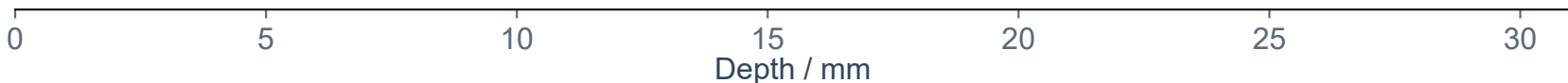
Glass: $48 \times 27.2 = 1305.6 \text{ mm}$

Barrel layer depth (common scale)

Glass

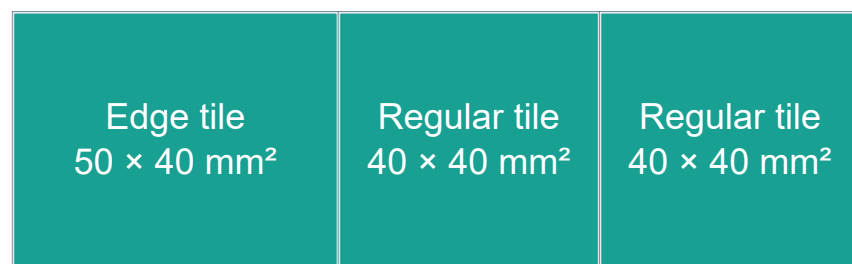


Plastic



■ Absorber ■ Steel plate ■ Air ■ PCB ■ Glass cavity ■ Plastic cavity

Barrel tiles (local plane)



Both local views: each physical tile is one channel.

Active thickness

Glass: 10 mm active / 10.2 mm cavity

Plastic: 3 mm active / 3.2 mm cavity

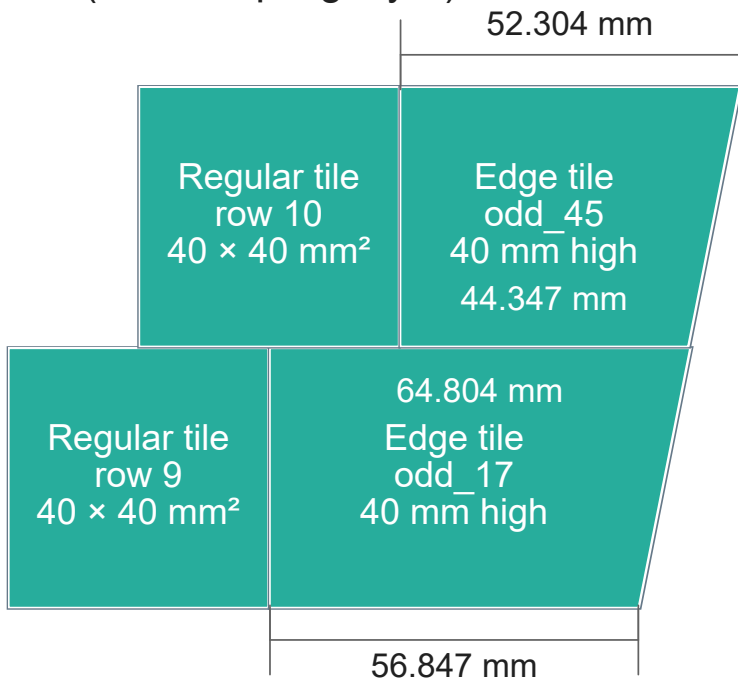
Plastic: 4.3 mm air gap before the PCB

Barrel interaction depth (DD4hep scan)

Glass: $6.265 \lambda_I$

Plastic: $5.515 \lambda_I$

Endcap tiles (one sampling layer)



Parameter	Glass reference (48 layers)	Current plastic (43 layers)
Simulation: active material	G4_GlassHCAL	G4_POLYSTYRENE
Simulation: Birks constant (mm/MeV)	0.01	0.126
Digitization: MIP response (MeV/MIP)	7.126	0.461
Digitization: detected light yield (p.e./MIP)	80	13.09
Digitization: SiPM pixels	57,600	7,284
Digitization: high gain (ADC/p.e.)	20	26.55
Digitization: threshold in MIP / MeV	0.1 / 0.7126	0.1 / 0.0461
Realistic / tile map / CalibrHCAL	1 / 0 / 1	1 / 0 / 1

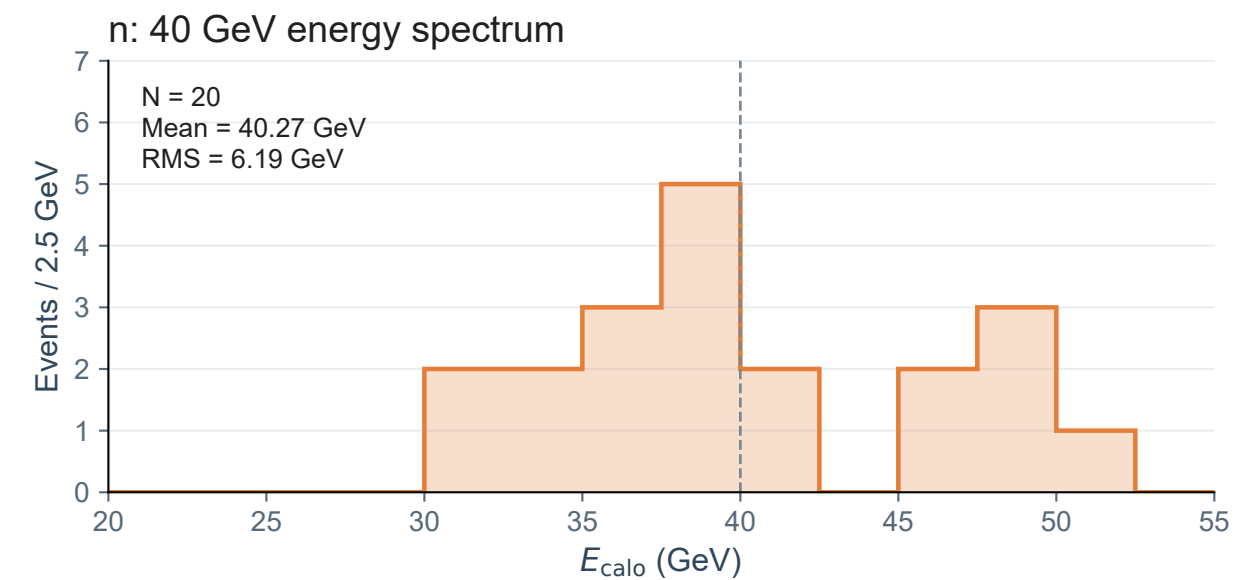
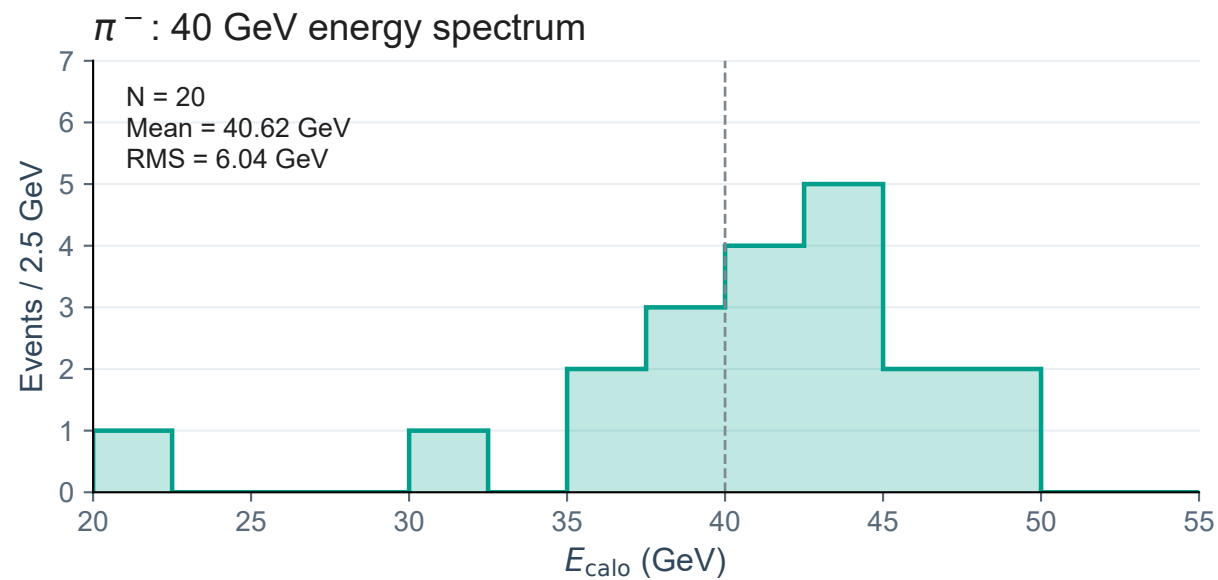
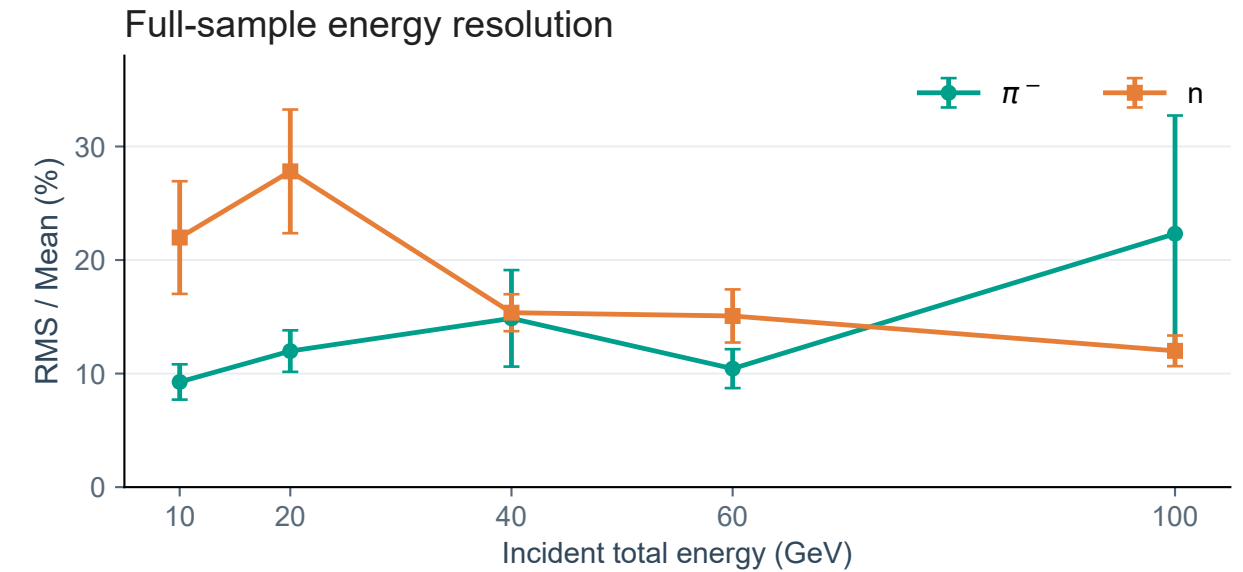
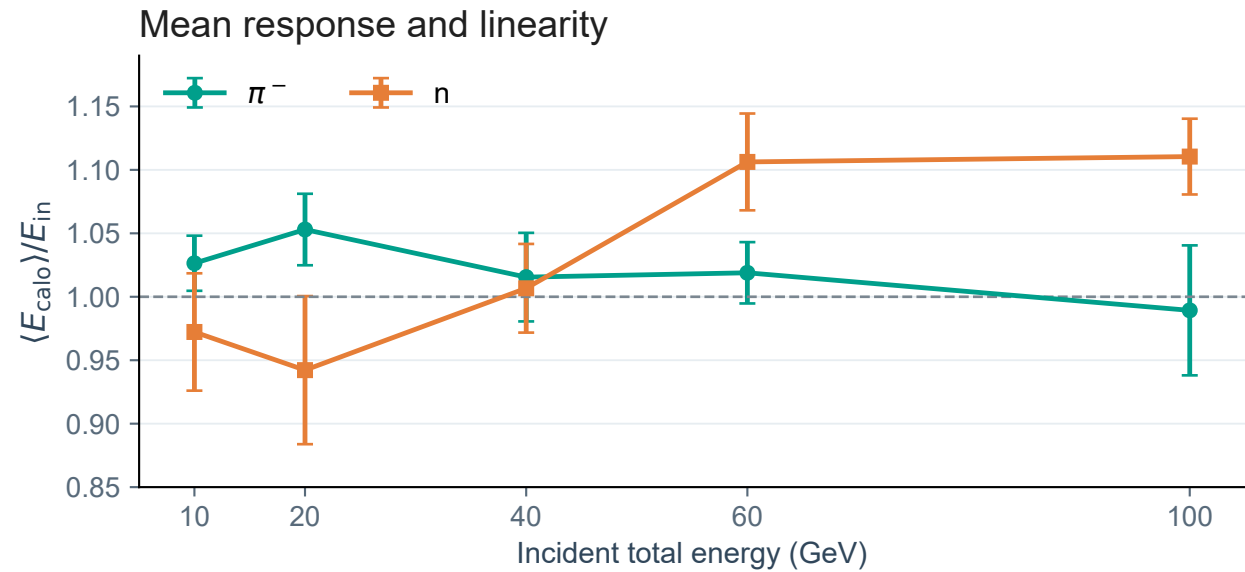
Shared electronics settings

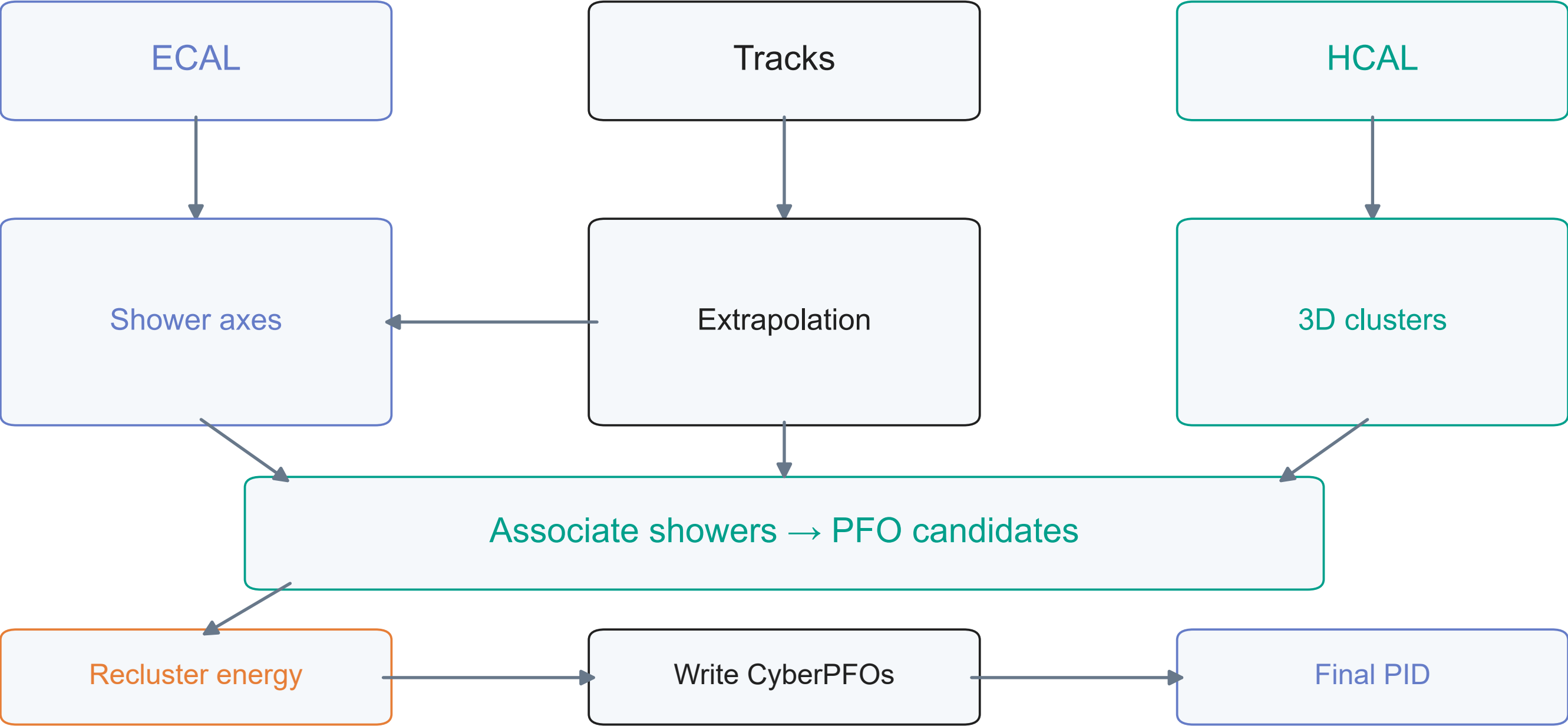
DCR = 1600 Hz; time window = 0 s; crosstalk = 0; gain spread = 0.08; electronic noise = 0 ADC.

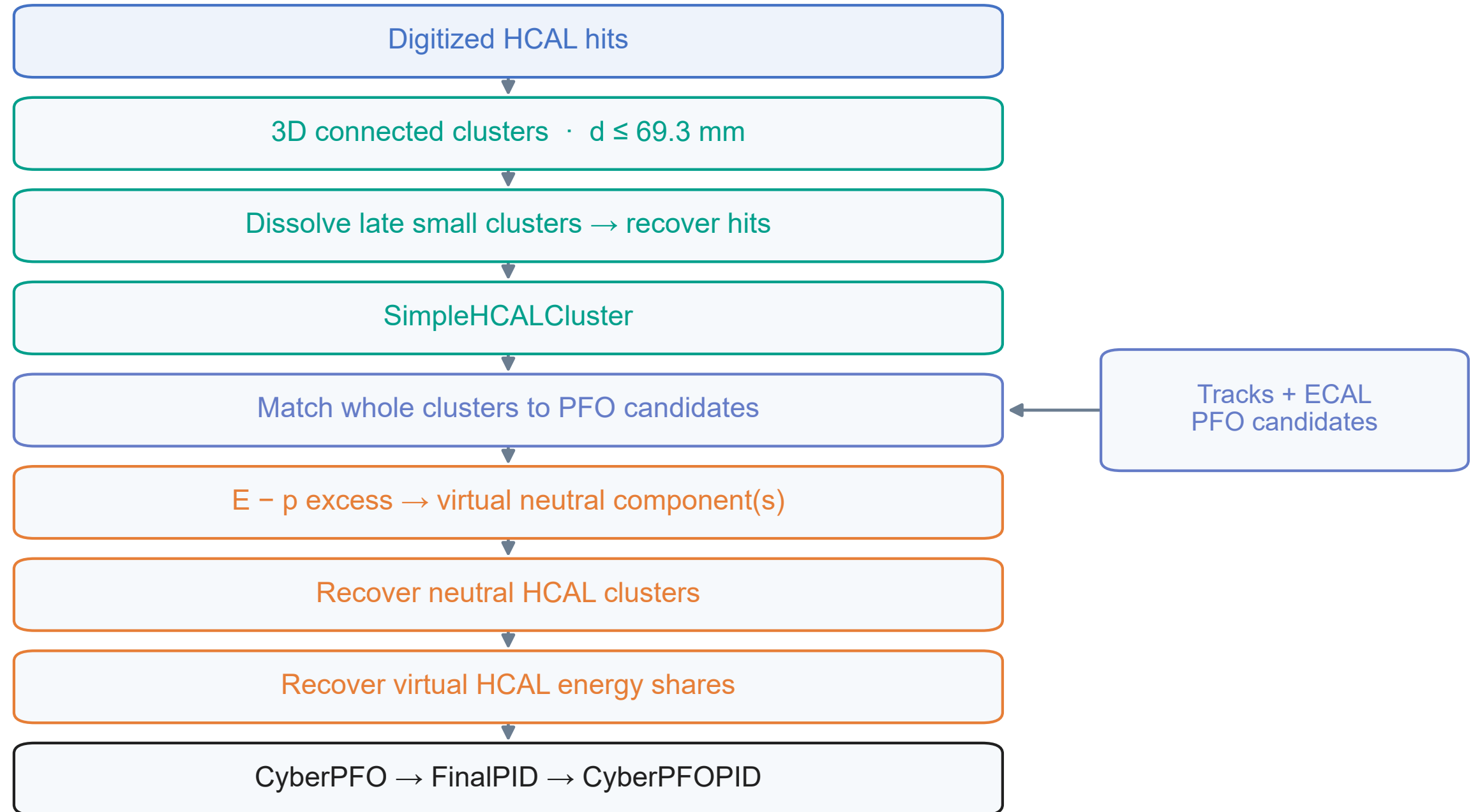
Pedestal = 50 ± 4 ADC; ADC = 8192; gain switch = 10^7 ; gain ratios = 50 / 60; temperature terms = 0.

Samples: π^- / n , 10–100 GeV; $\pi^- + n$, 20 + 20 GeV at 6° / 30°.

Plastic: 40 events/group; 560 independent full-detector events.





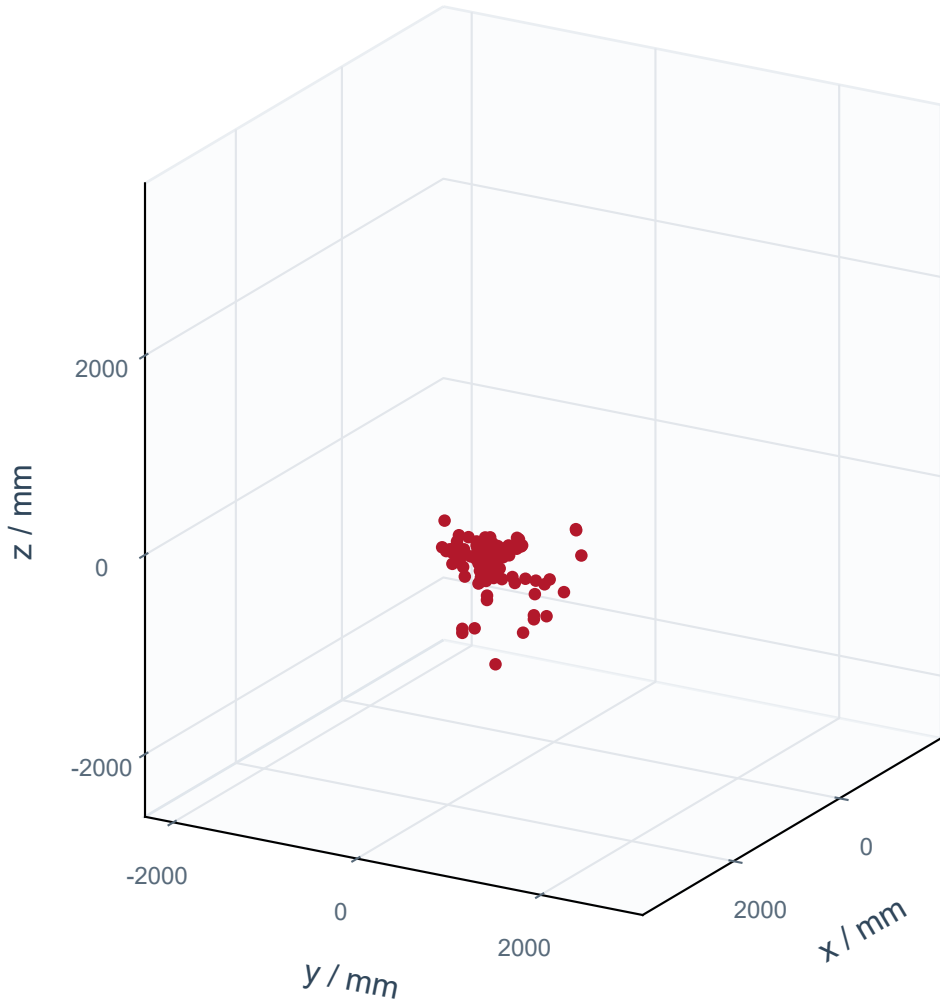


Glass → plastic: PFA changes

Aspect / change type	Original glass reference	Current plastic default
Track extrapolation Parameter adaptation	26.61 mm extrapolation period	30 mm period → 15 mm radial / z samples
Energy response Parameter adaptation	HCAL charged / neutral: 4 / 4 Residual coefficient $a = 0.4$	HCAL: 63.093288 / 85.090363; $a = 1.061289$
PFO association Logic repair	Unbounded attachment or signal loss	≥ 5 -hit clusters first; bounded matching Unmatched → neutral PFO
Neutral position Logic repair	Raw ECAL / HCAL signals mixed directly as position weights	Use calibrated ECAL / HCAL energy weights
Unchanged behavior Validation still needed	69.3 / 100 / 300 mm; 0.3 rad First-compatible matching; existing PID	

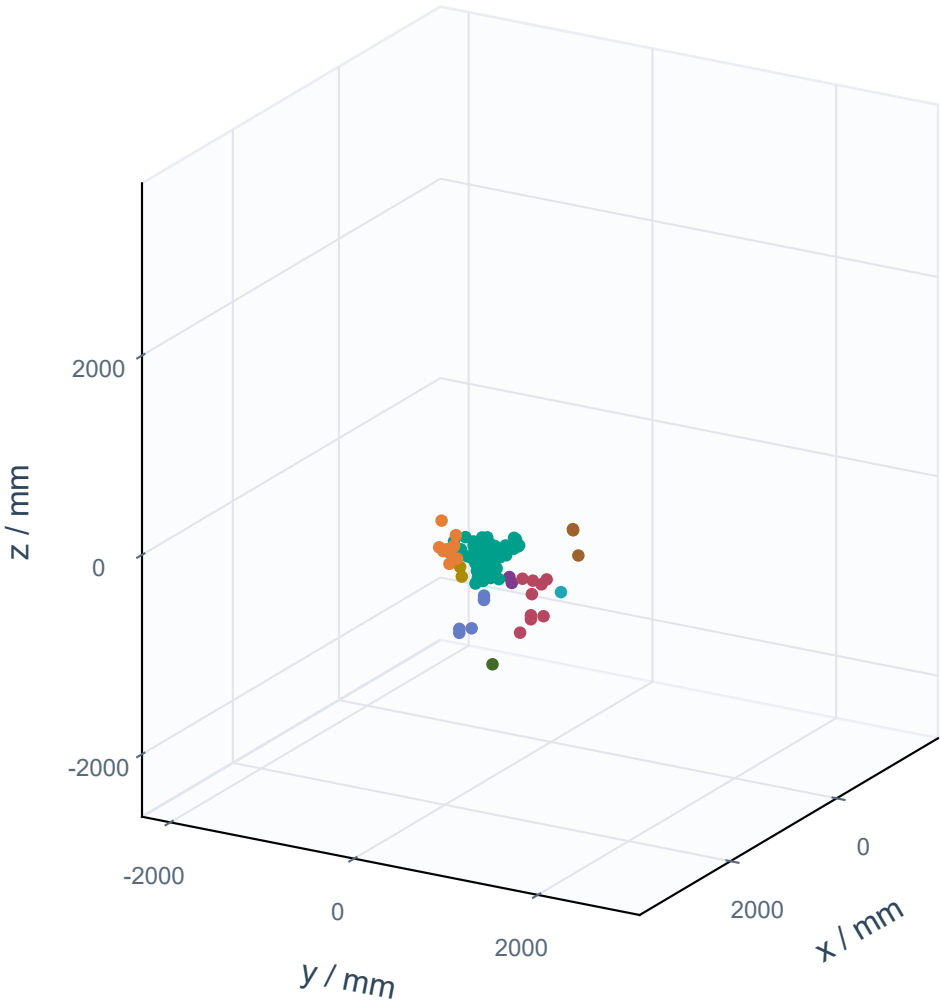
● $n \geq 90\%$

Primary truth source



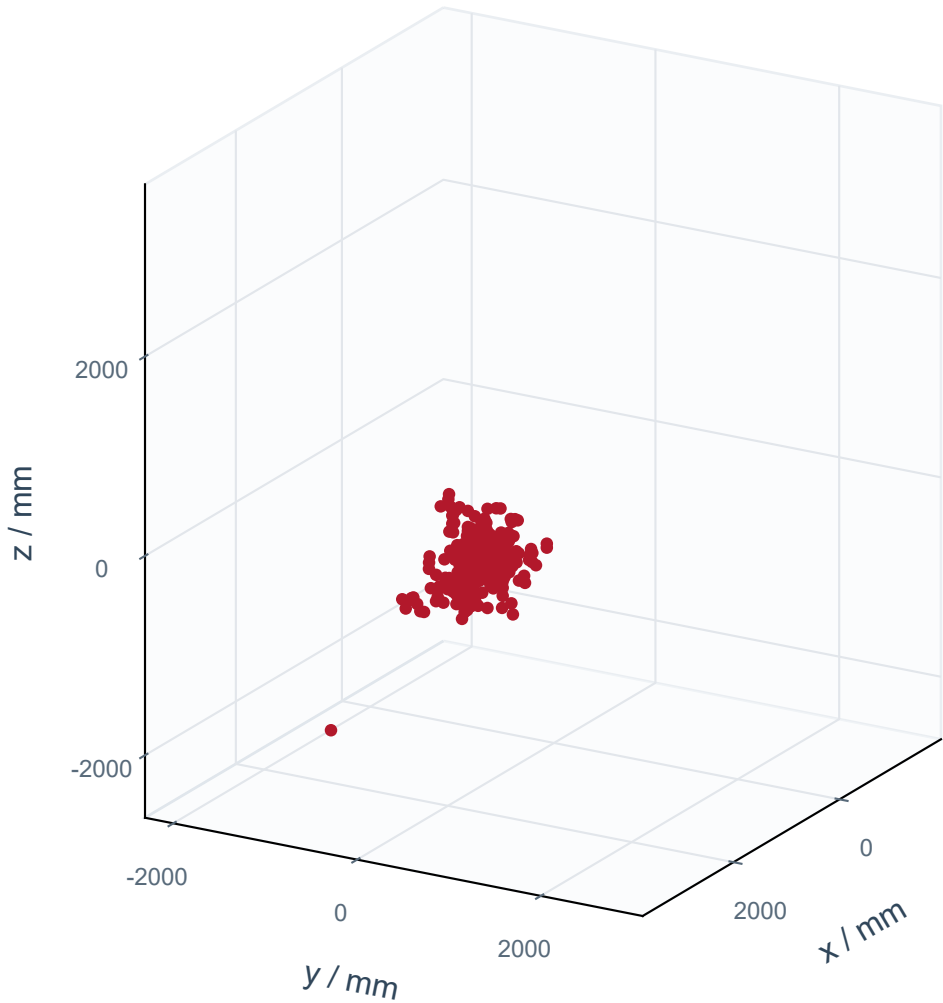
● P0 ● P2 ● P4 ● P6 ● P7 ● P8
● P1 ● P3 ● P5

Final PFO membership



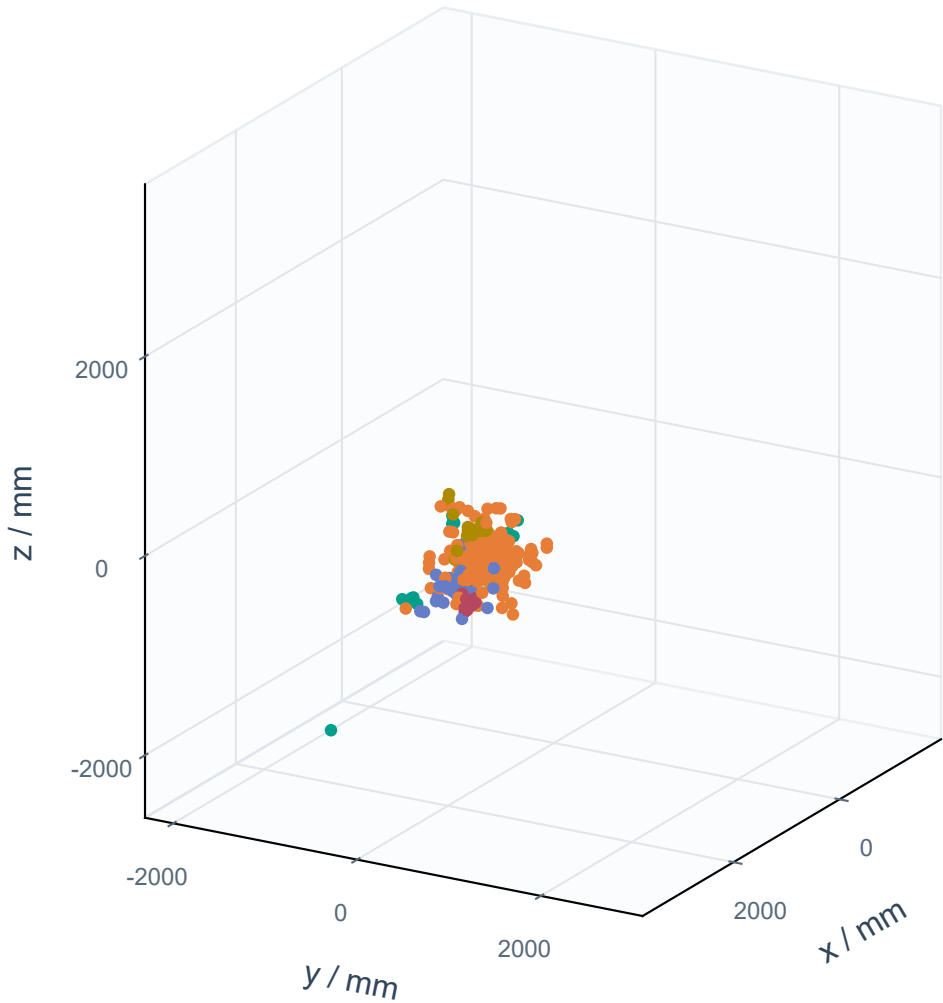
● $n \geq 90\%$

Primary truth source



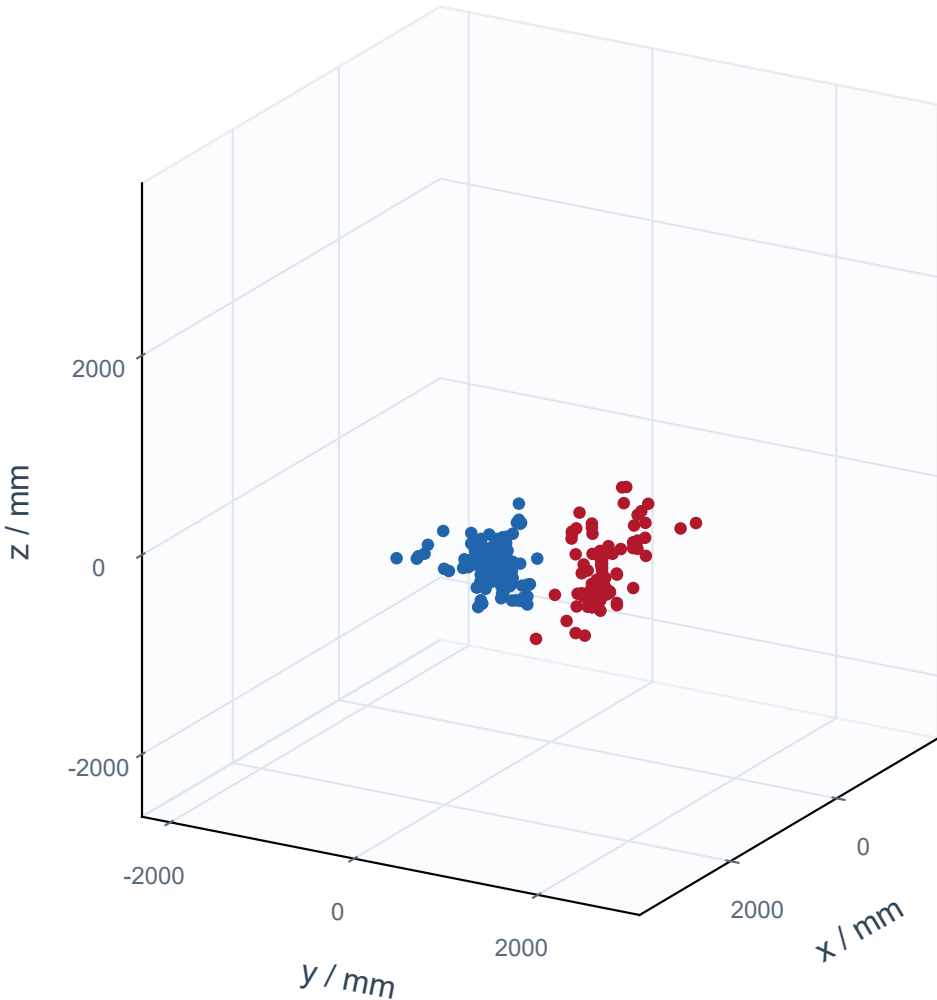
● P0 ● P1 ● P2 ● P3 ● P4

Final PFO membership



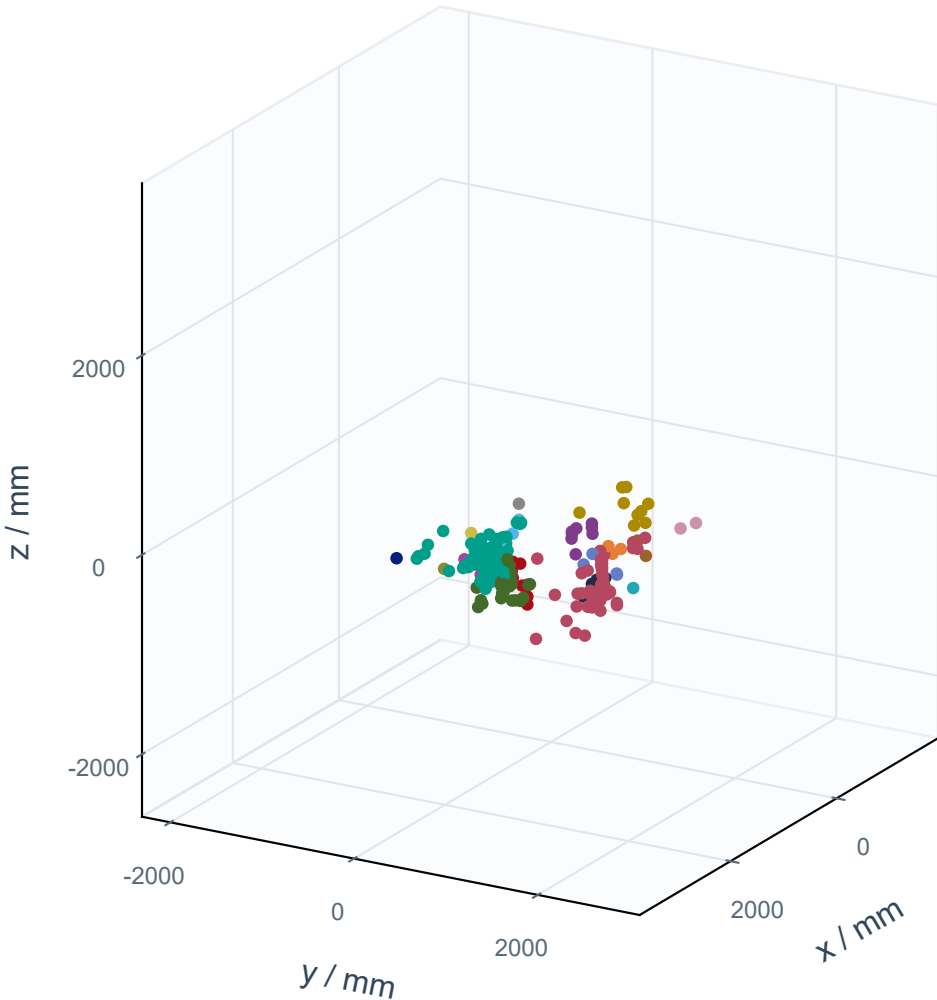
● $\pi^- \geq 90\%$ ● $n \geq 90\%$

Primary truth source



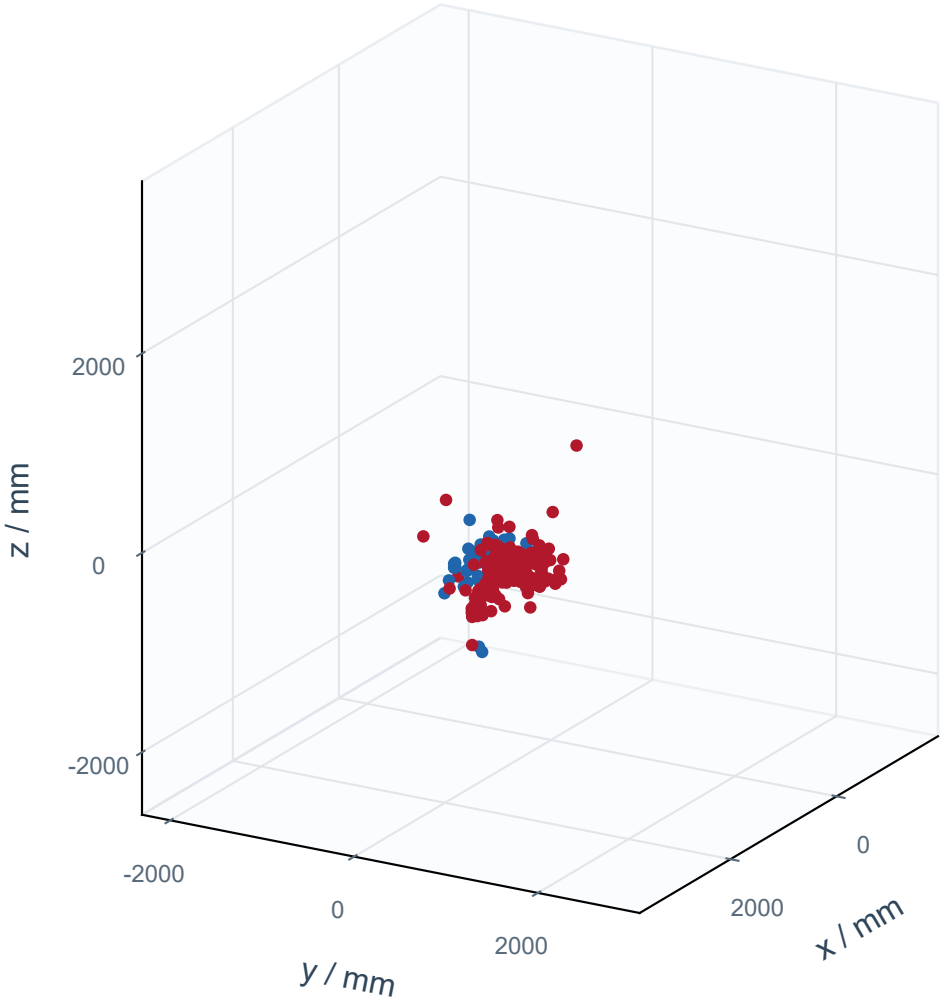
● P0: π track	● P3	● P6	● P9	● P12	● P15
● P1	● P4	● P7	● P10	● P13	● P16
● P2	● P5	● P8	● P11	● P14	● P17

Final PFO membership



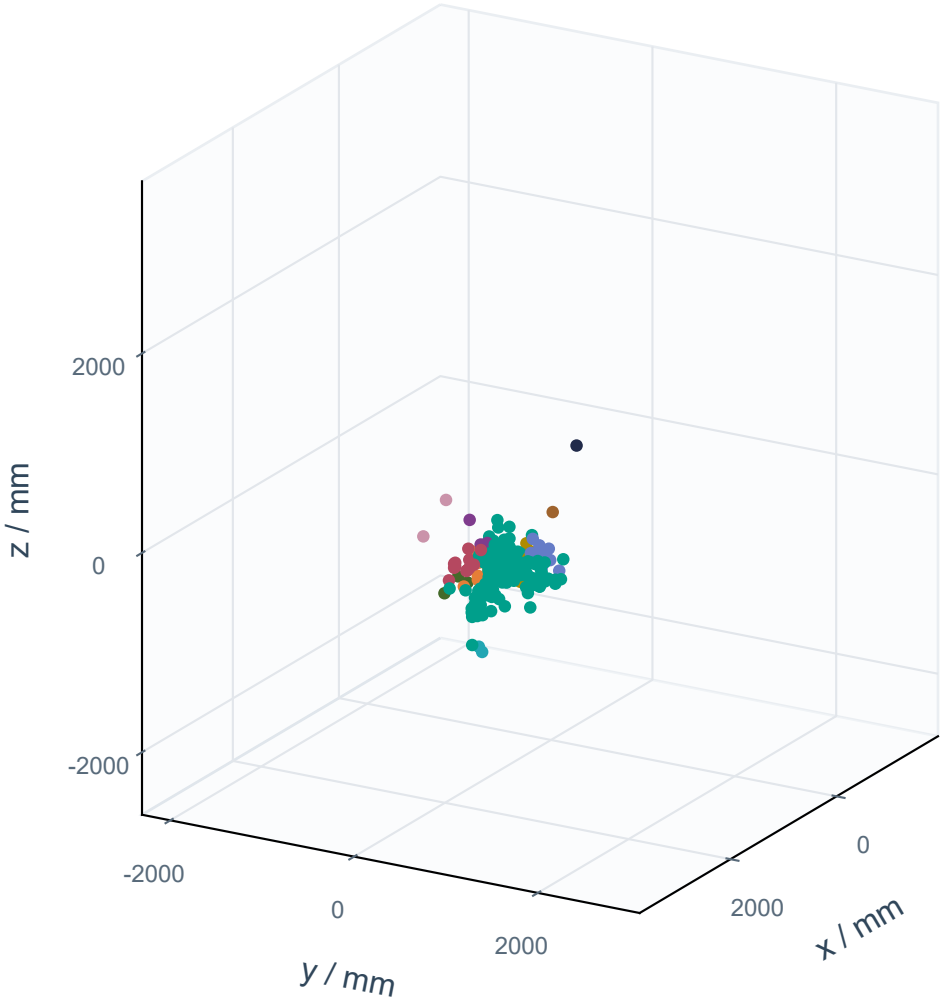
● $\pi^- \geq 90\%$ ● $n \geq 90\%$ ● Mixed

Primary truth source



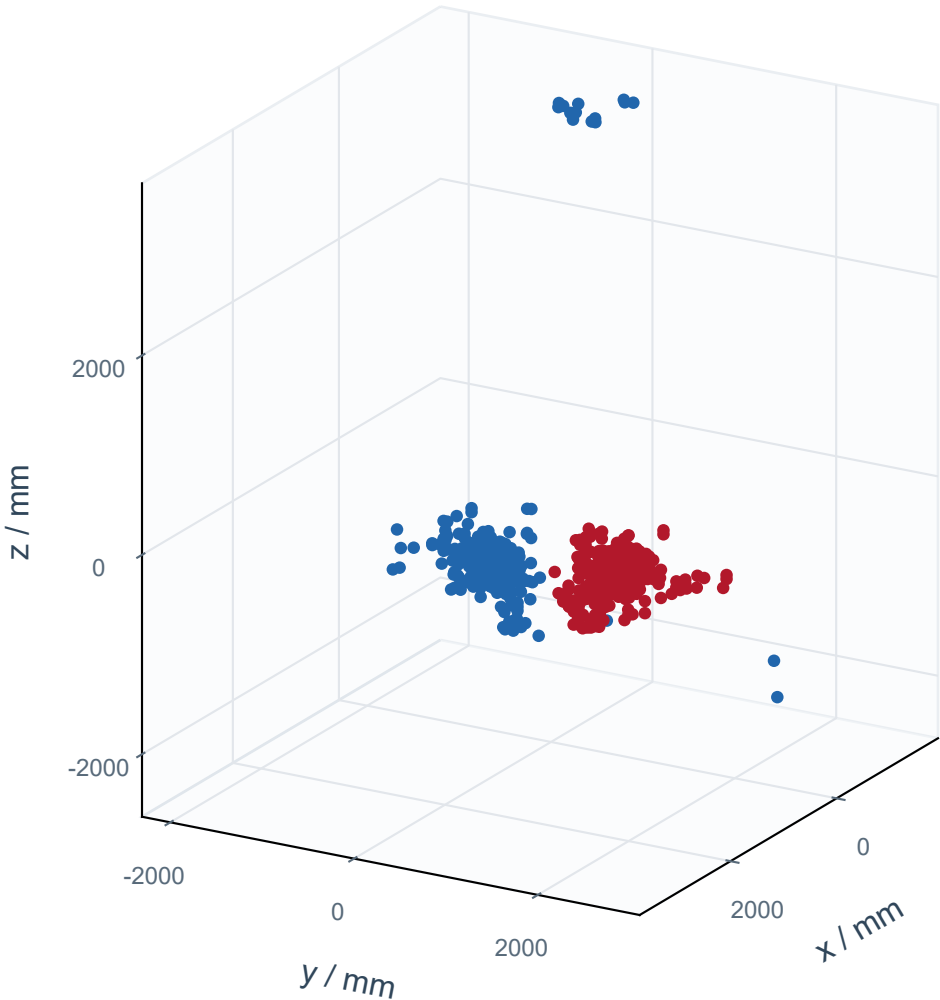
● P0: π track ● P2 ● P4 ● P6 ● P8 ● P10
● P1 ● P3 ● P5 ● P7 ● P9

Final PFO membership



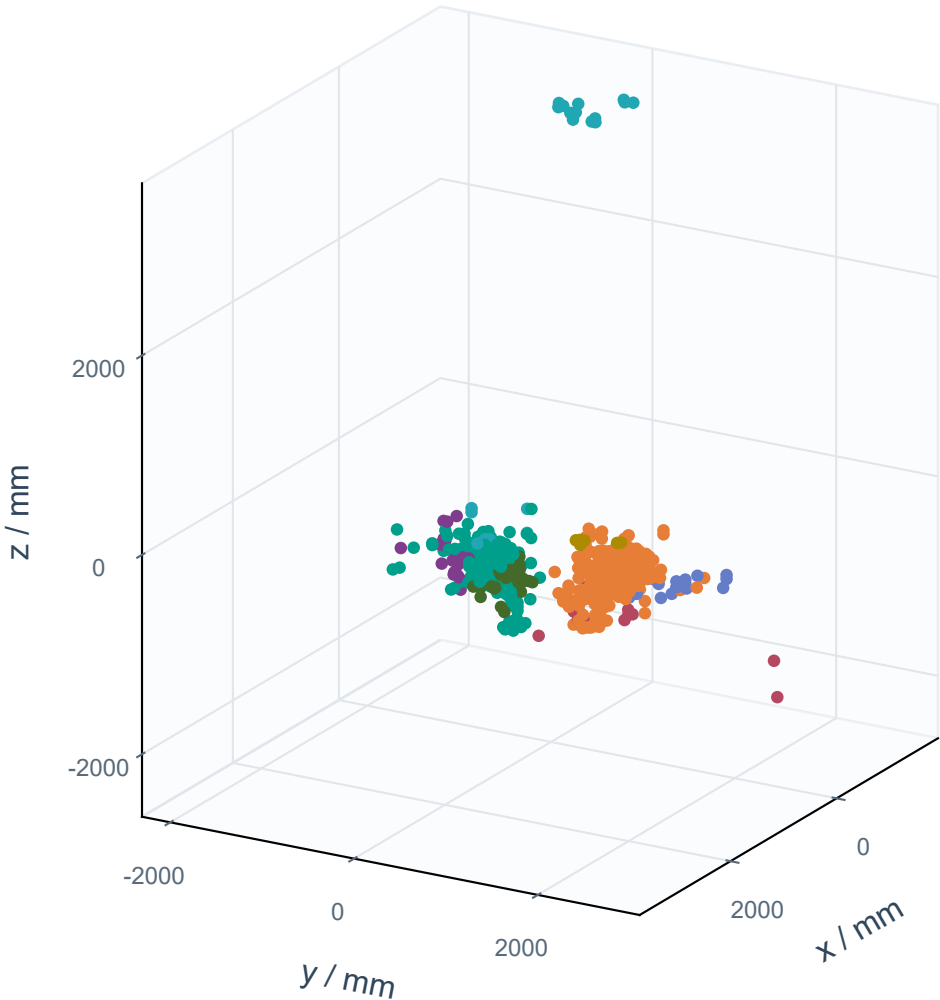
● $\pi^- \geq 90\%$ ● $n \geq 90\%$

Primary truth source



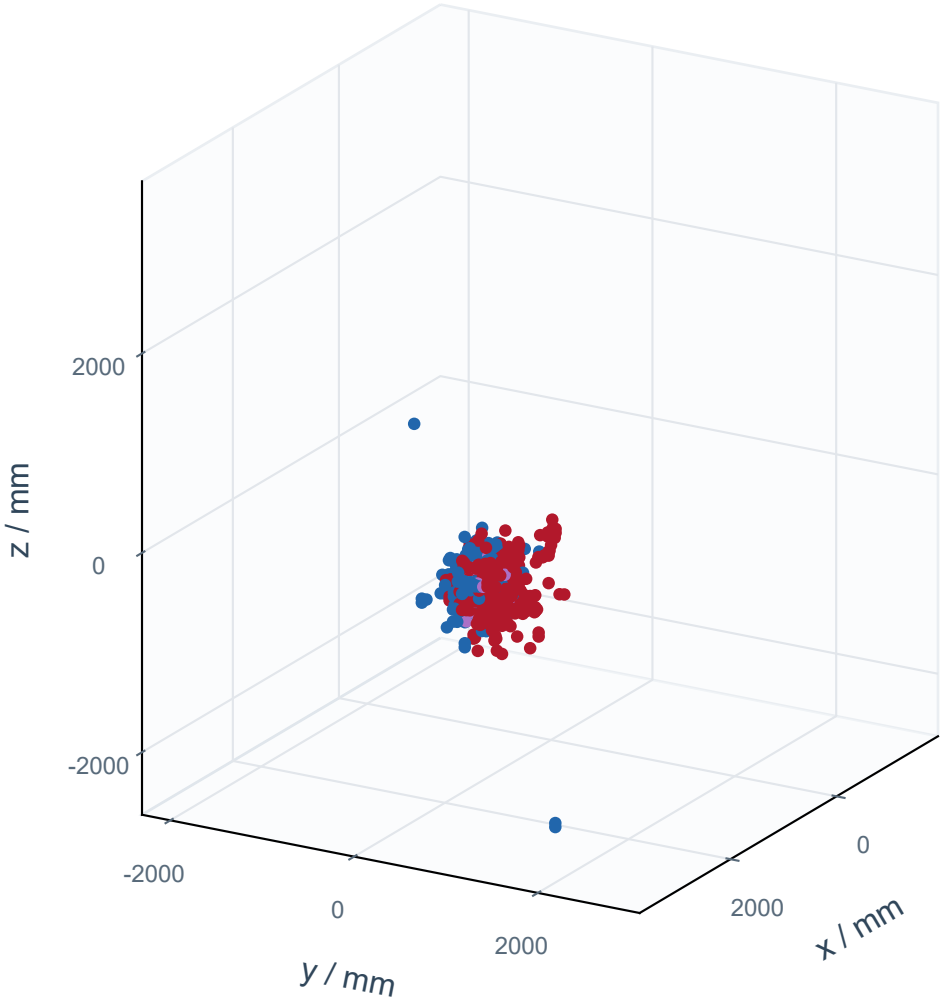
● P0: π track ● P3 ● P5 ● P6 ● P7 ● P8
● P2 ● P4

Final PFO membership



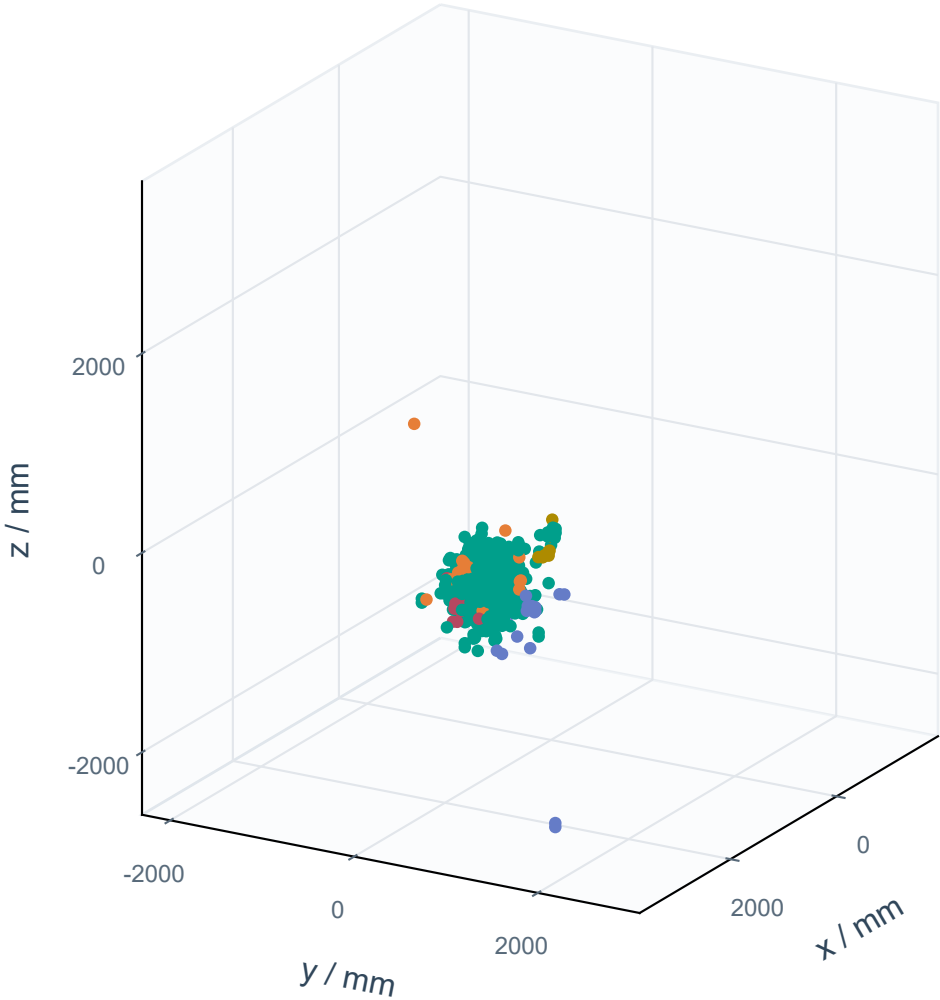
● $\pi^- \geq 90\%$ ● $n \geq 90\%$ ● Mixed

Primary truth source



● P0: π track ● P1 ● P2 ● P3 ● P4

Final PFO membership

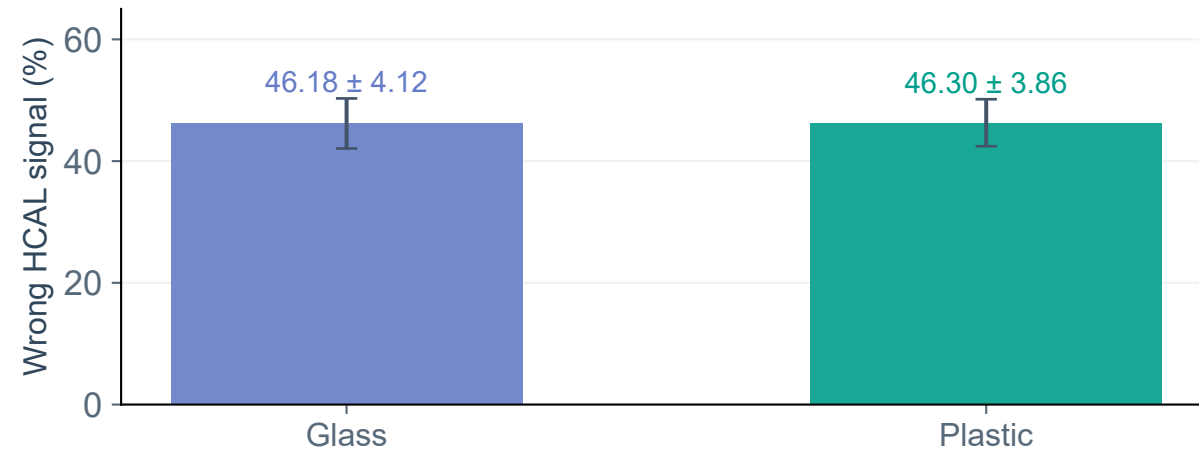


Default PFA: glass and plastic



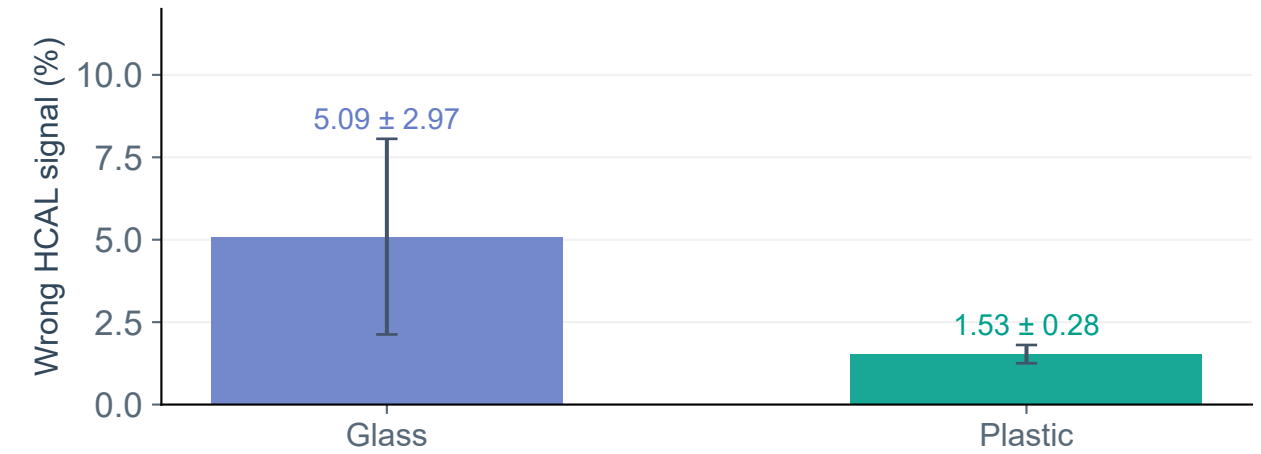
■ Glass reference, 48 layers ■ Plastic default, 43 layers

Near pair: 6° separation



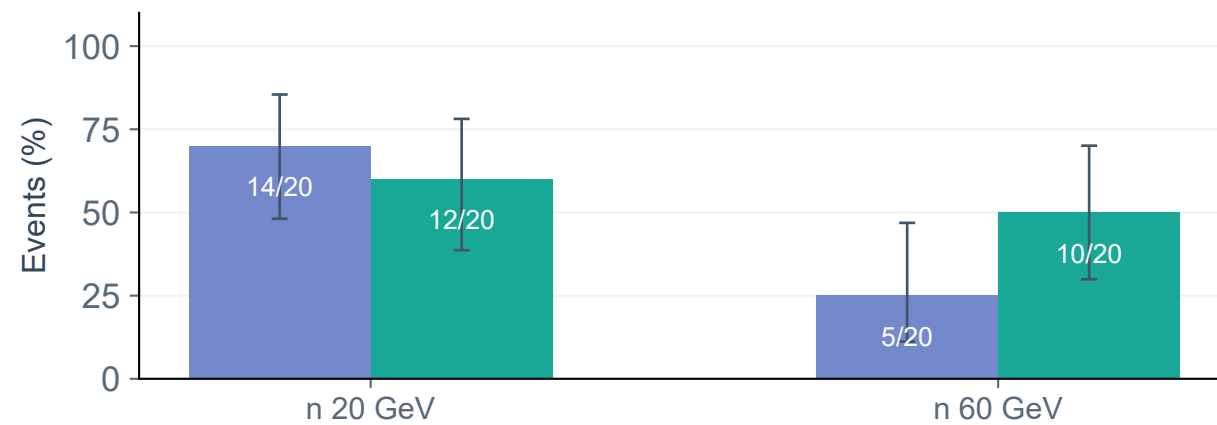
Mismatched events: 20/20 / 20/20

Far pair: 30° separation



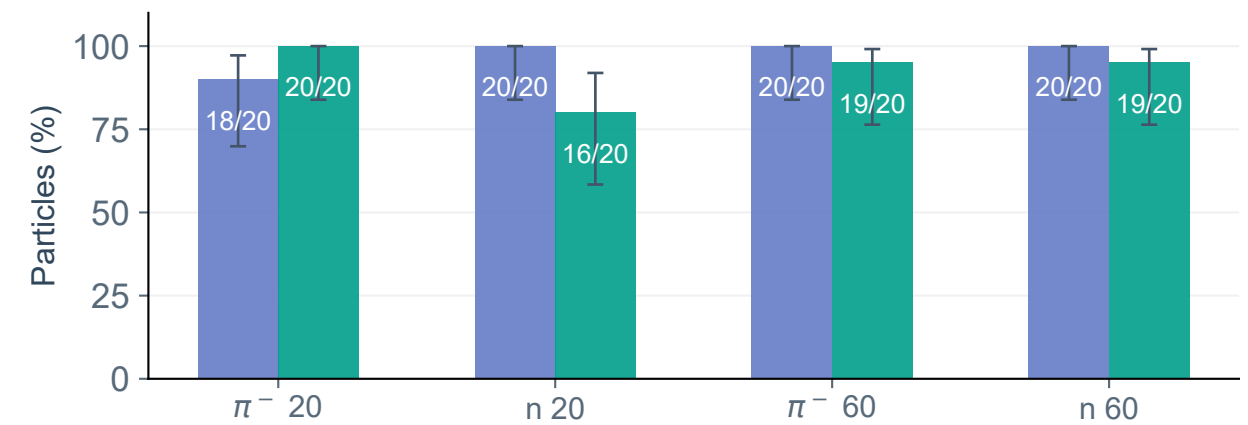
Mismatched events: 1/20 / 0/20

Isolated neutron fragmentation



Fragmentation: ≥ 2 PFOs, each with $\geq 5\%$ of primary HCAL signal. Strict ownership: real-calo purity $\geq 90\%$ + class/PID + track truth.

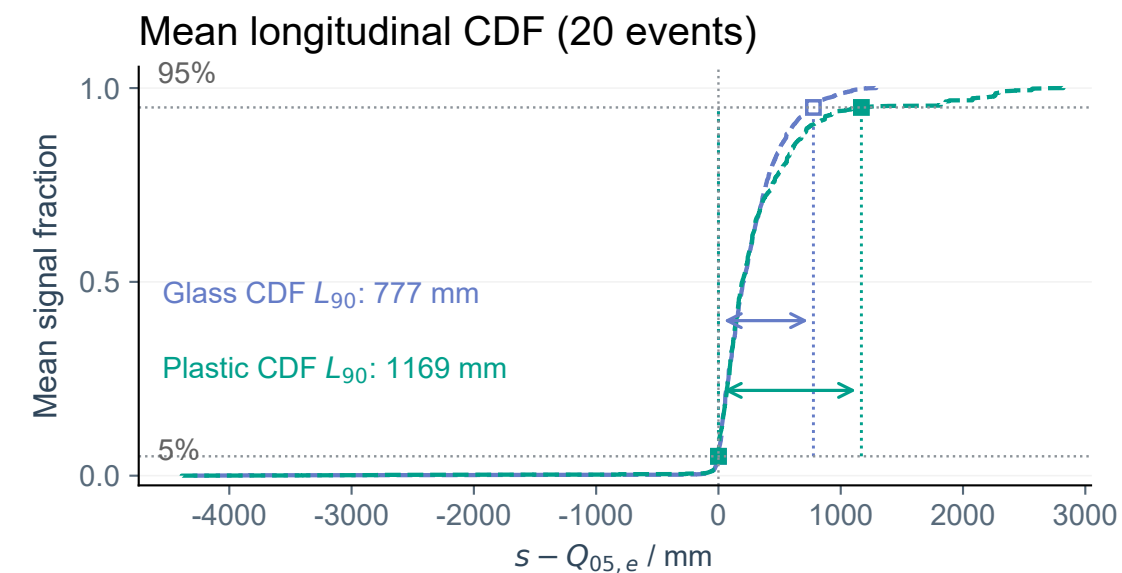
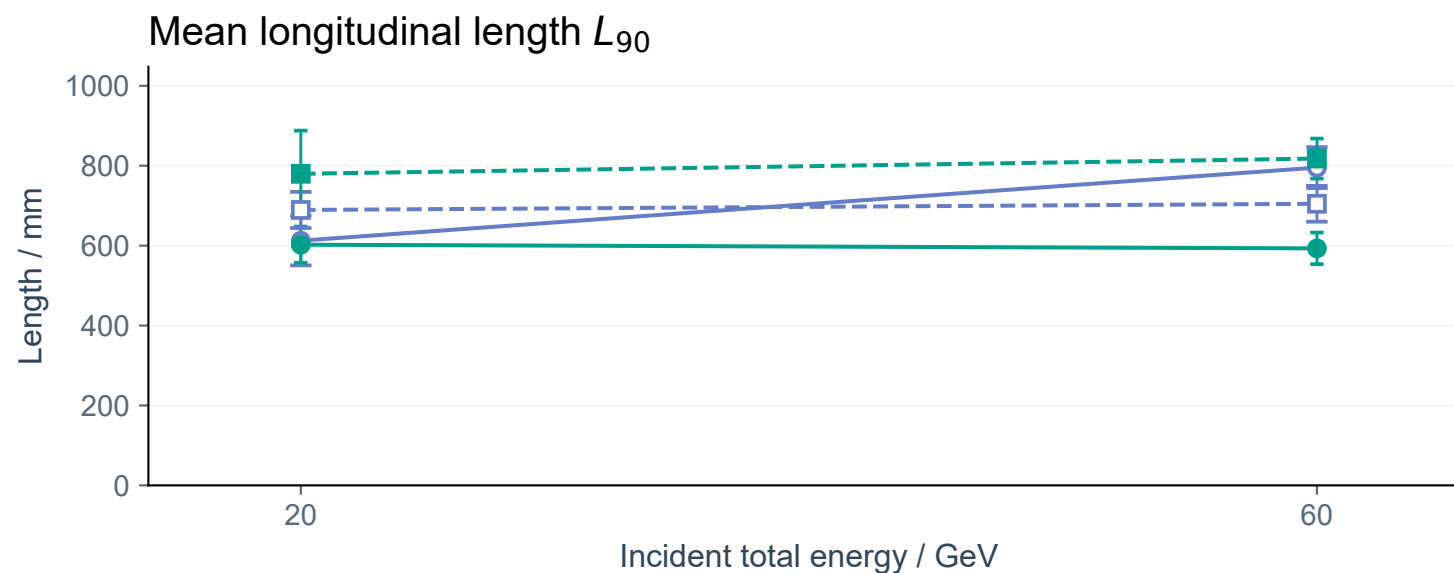
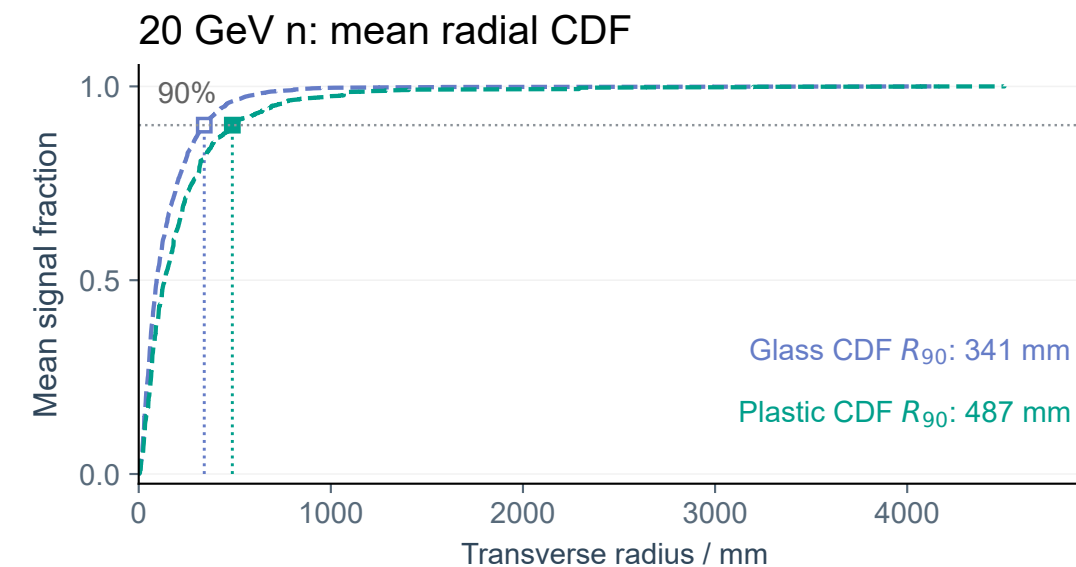
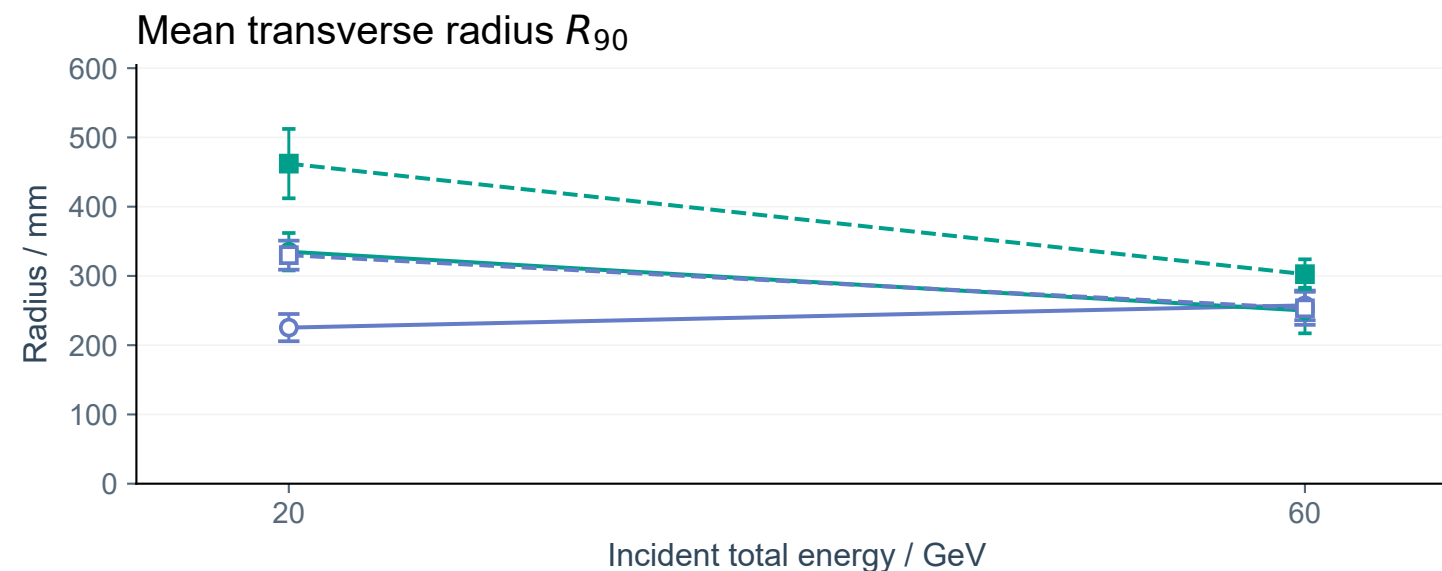
Strict ownership + PID



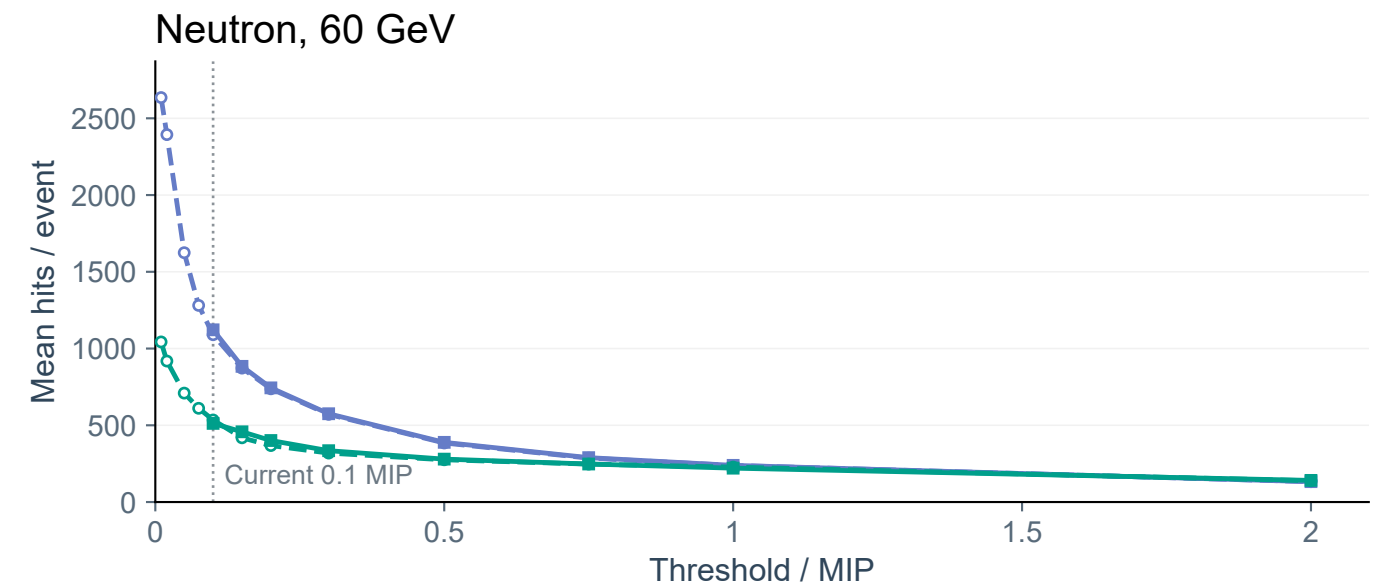
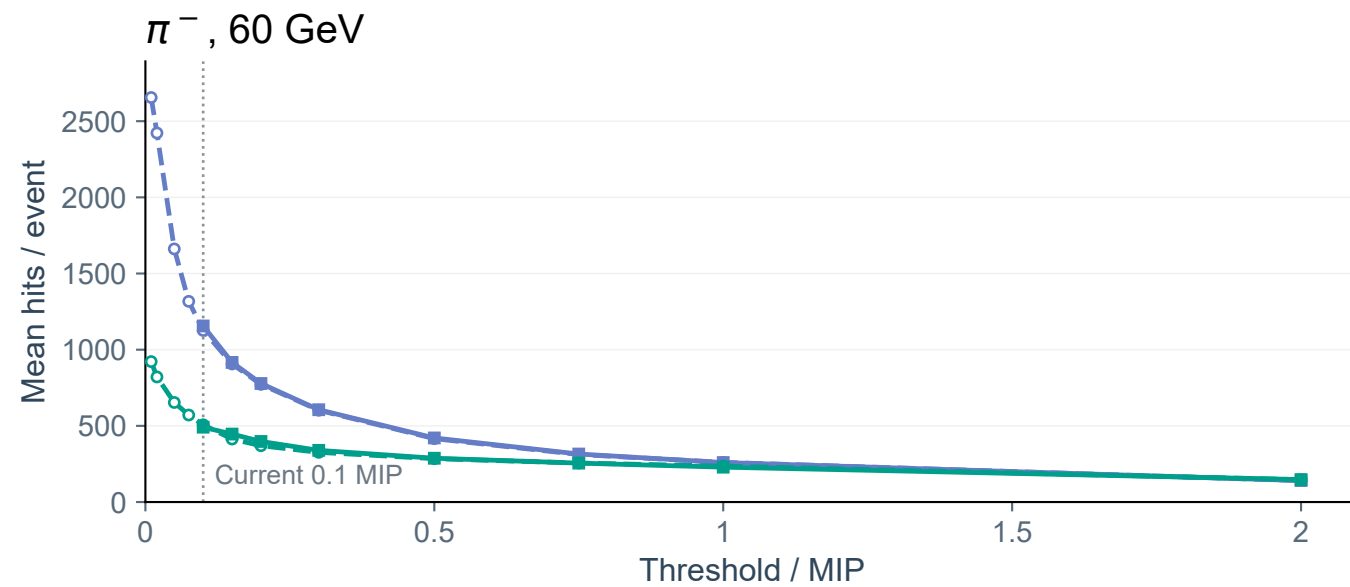
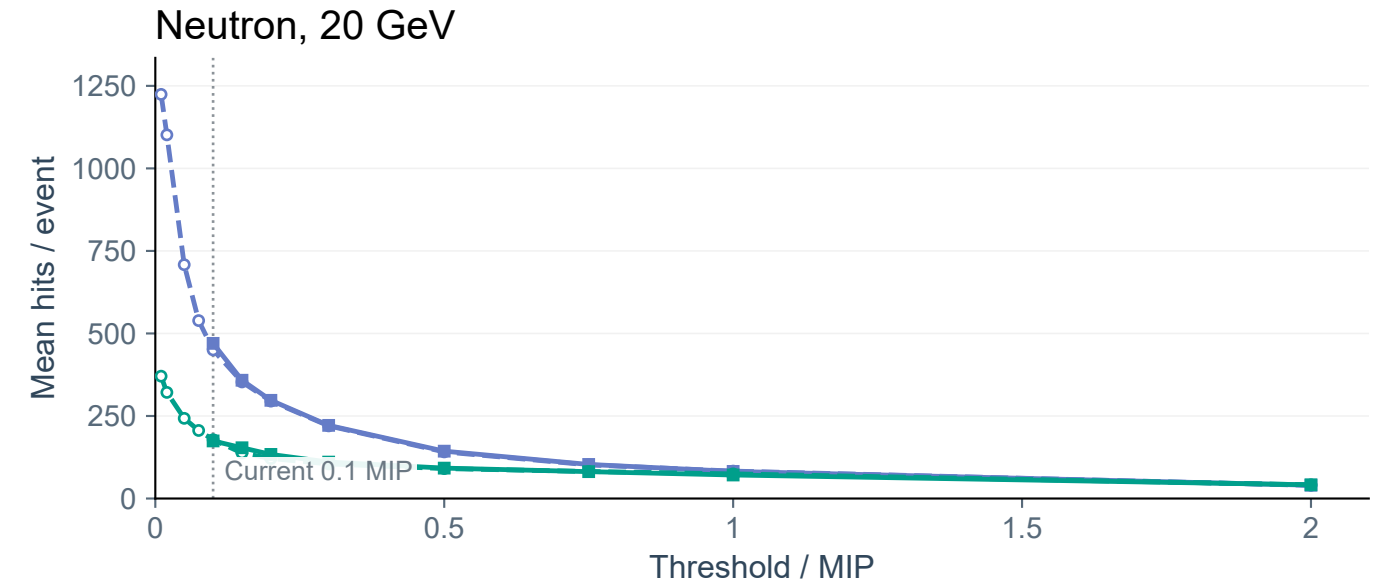
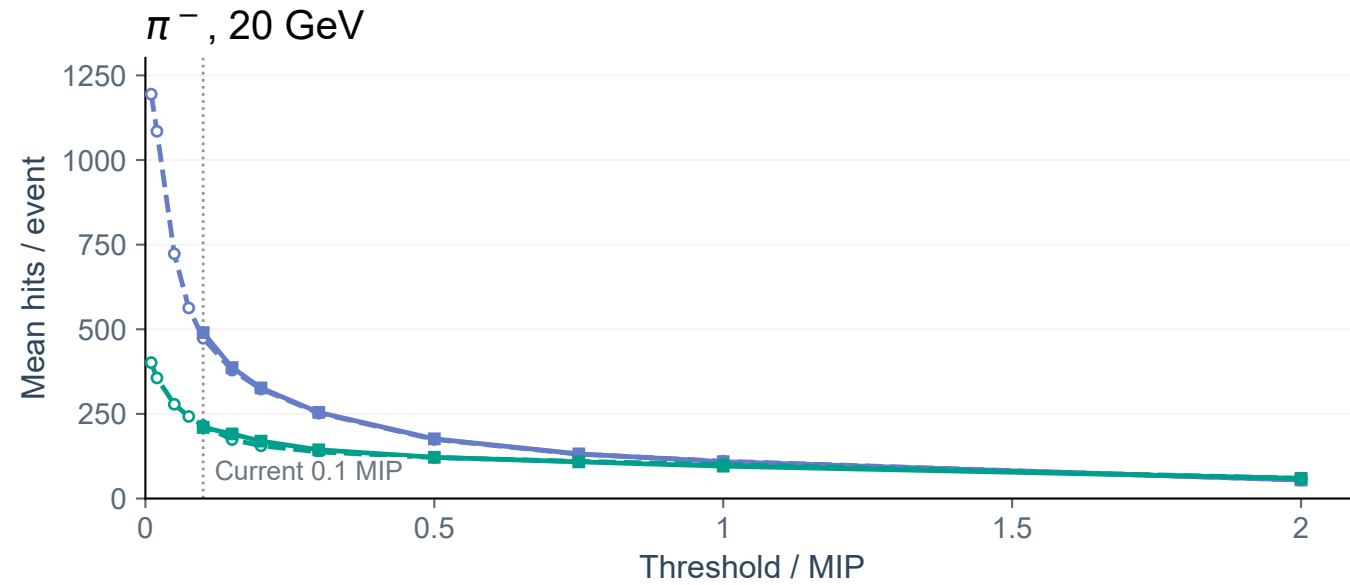
HCAL shower size: means and average CDFs



—○— Glass π^- —●— Plastic π^- - -□- - Glass n - -■- - Plastic n



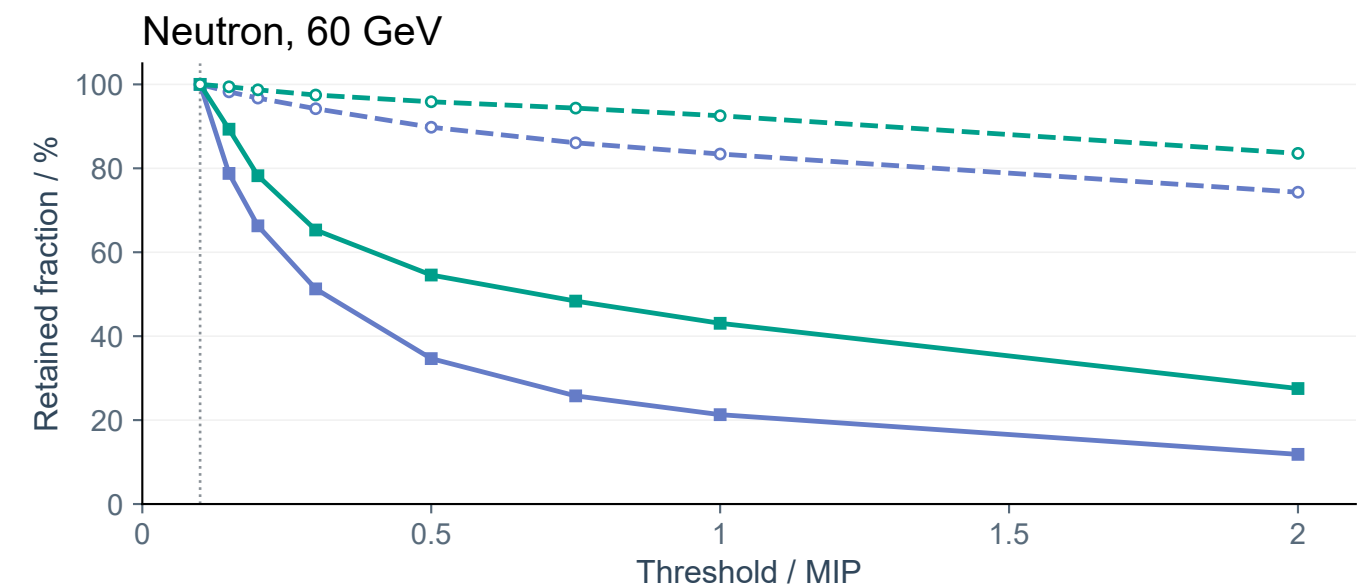
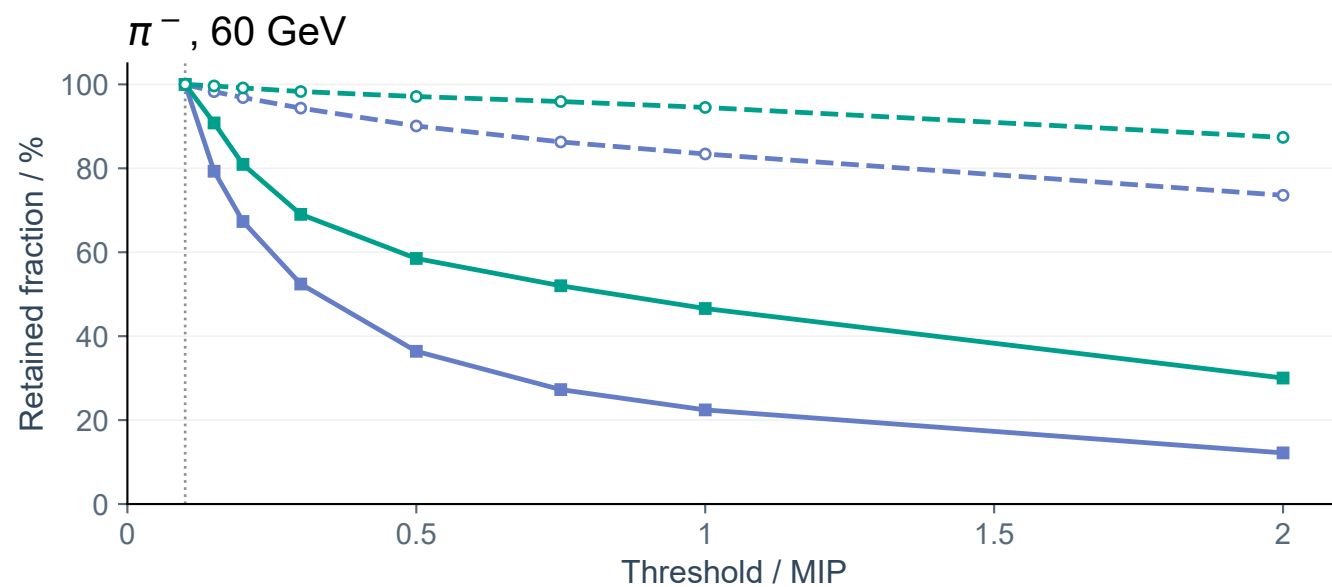
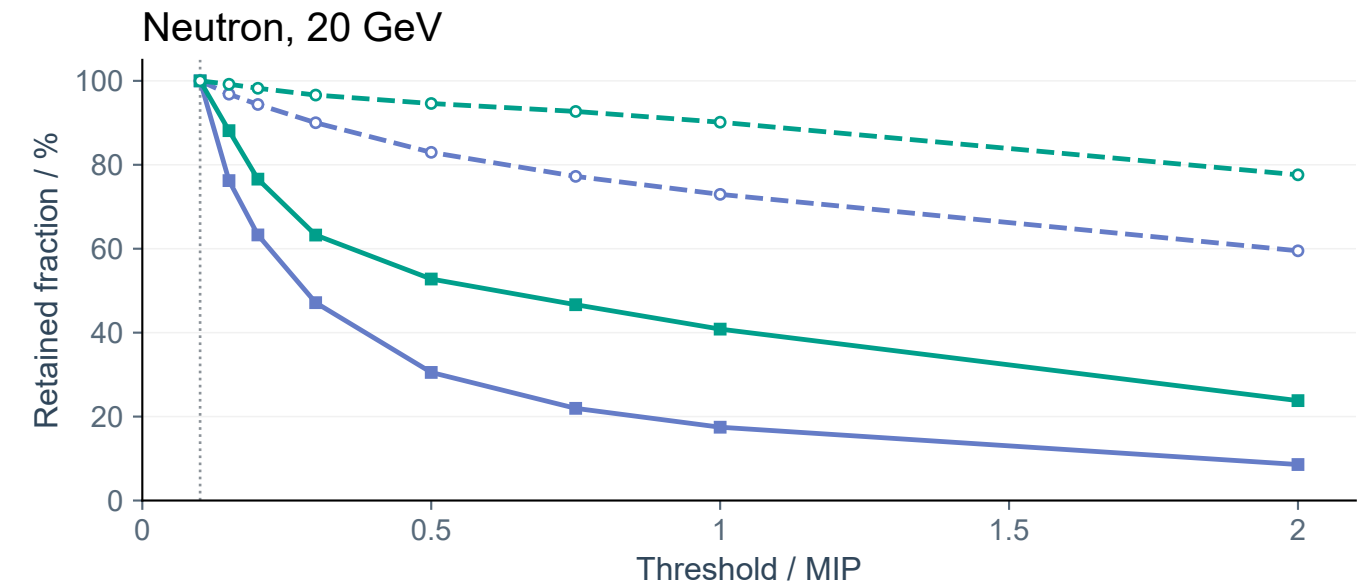
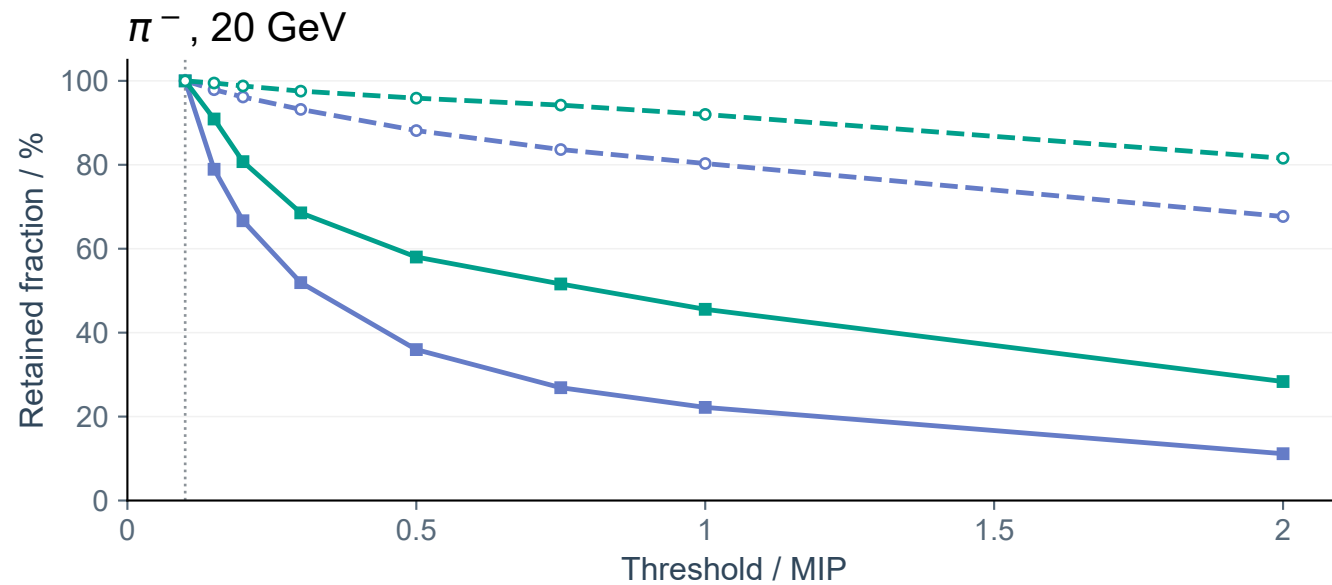
HCAL hit count versus threshold



-○- Glass: ideal cut on SimHit cell sums
 -■- Glass: stored digi + software cut

-○- Plastic: ideal cut on SimHit cell sums
 -■- Plastic: stored digi + software cut

HCAL hit and signal retention



—■— Glass: hits (mean / mean)
-○- Glass: visible signal (sum / sum)

—■— Plastic: hits (mean / mean)
-○- Plastic: visible signal (sum / sum)

Established

43 layers, 30 mm sampling period

Realistic digitization and full PFA

560 independent physics events

Outstanding

Near-pair mismatch: 20/20 events

Isolated neutron fragmentation

High-energy neutron response: +11%

Next priorities

Improve track–shower association

Recover neutral shower fragments

Understand energy-dependent response

Validate angles, endcaps and PID

Provisional HCAL factors: charged 63.093288; neutral 85.090363; residual $a = 1.061289$.