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INFN TORINO

Beam background simulation with the CLIC framework

Muon Collider Workshop

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Simulation workflow overview

Using the CLIC framework to perform GEANT4 simulation of detector hits

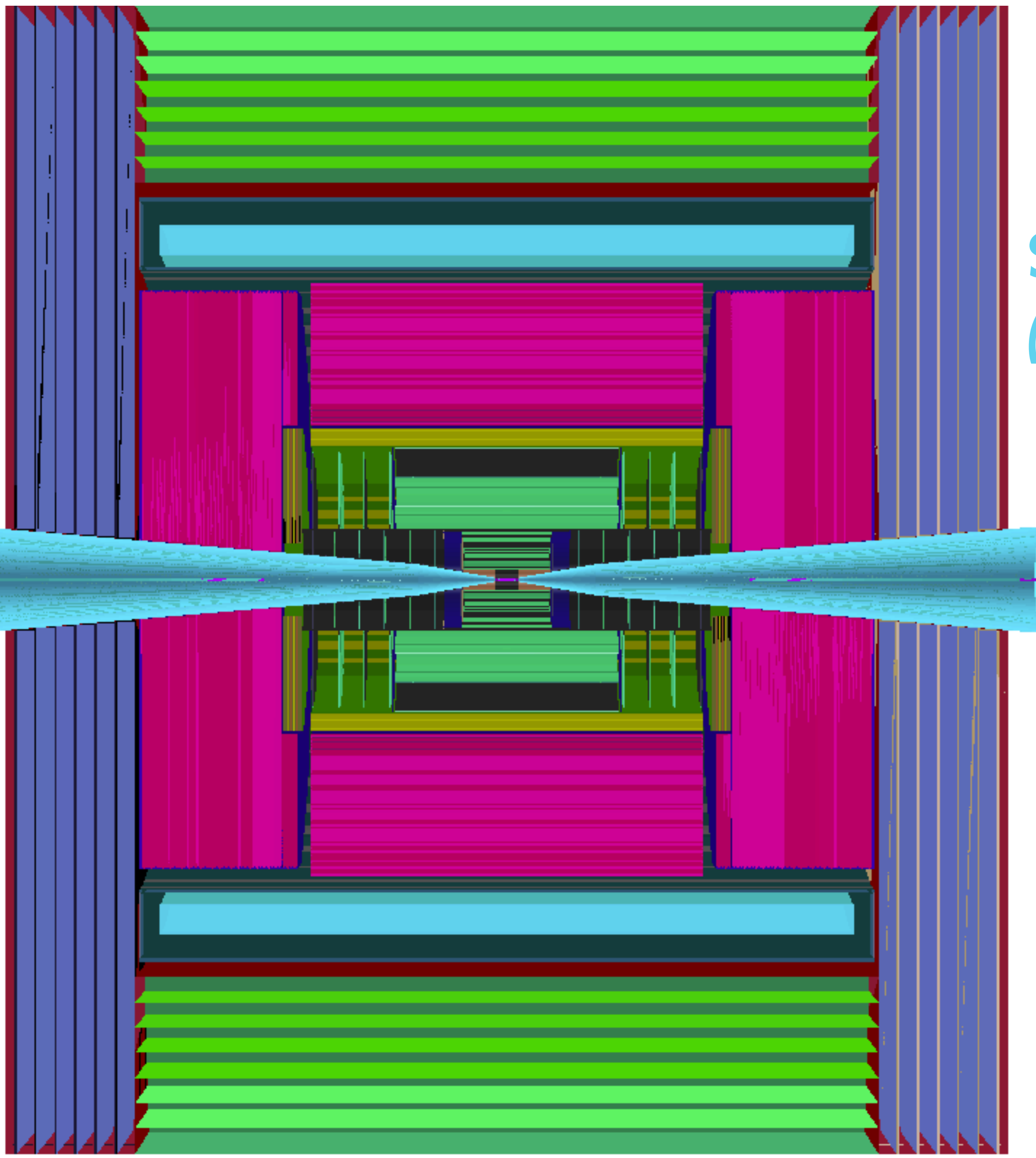
Beam-induced background from MAP provided in *.dat text files

1. **Converting MARS *.dat → CLIC *.slcio file**
   - **1000 particles × 23** *(smeared in φ)* **→ 1 event** [7K events/beam]
   - **Each MCParticle is assigned with:**
     mass, charge, PDG id, 3-position, 3-momentum, time
2. **Running GEANT4 detector simulation with *ddsim***
   - **using the CLIC detector geometry modified to fit the MAP nozzles**
   - **configurable physics list:** *QGSP_BERT_HP, QGSP_BERT, …*
   - *QGSP_BERT_HP* **was used in MAP studies**
     - **more precise simulation of thermal neutrons**
     - **×10 slower than the default *QGSP_BERT***
3. **Processed all background particles from the μ^+ and μ^- beams**
   - ***~8 days at 8 parallel threads*** *(only 1 event! Ideally need more. ~1K?)*

Detector geometry: CLIC based

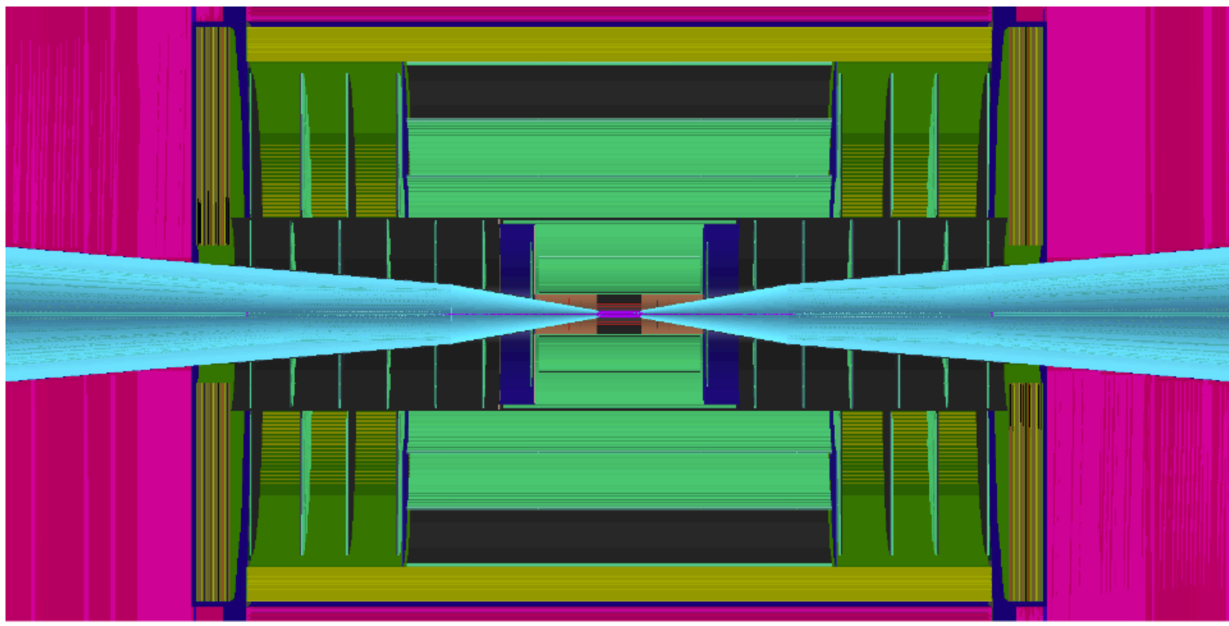
Using the CLIC framework to perform GEANT4 simulation of detector hits:

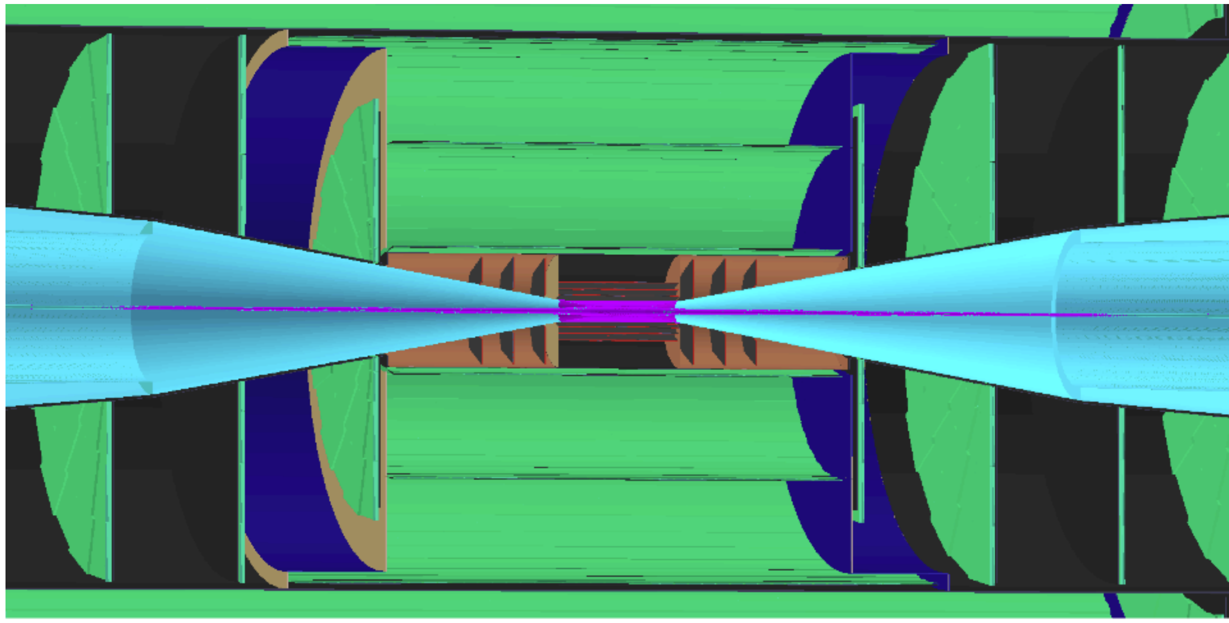
Vertex Tracker, (3 + 3×2) × 2 | **Inner Tracker,** 3 + 6×2 | **Outer Tracker,** 3 + 4×2 | **ECAL,** | **HCAL,** | **Muon Detector** 7 + 6×2



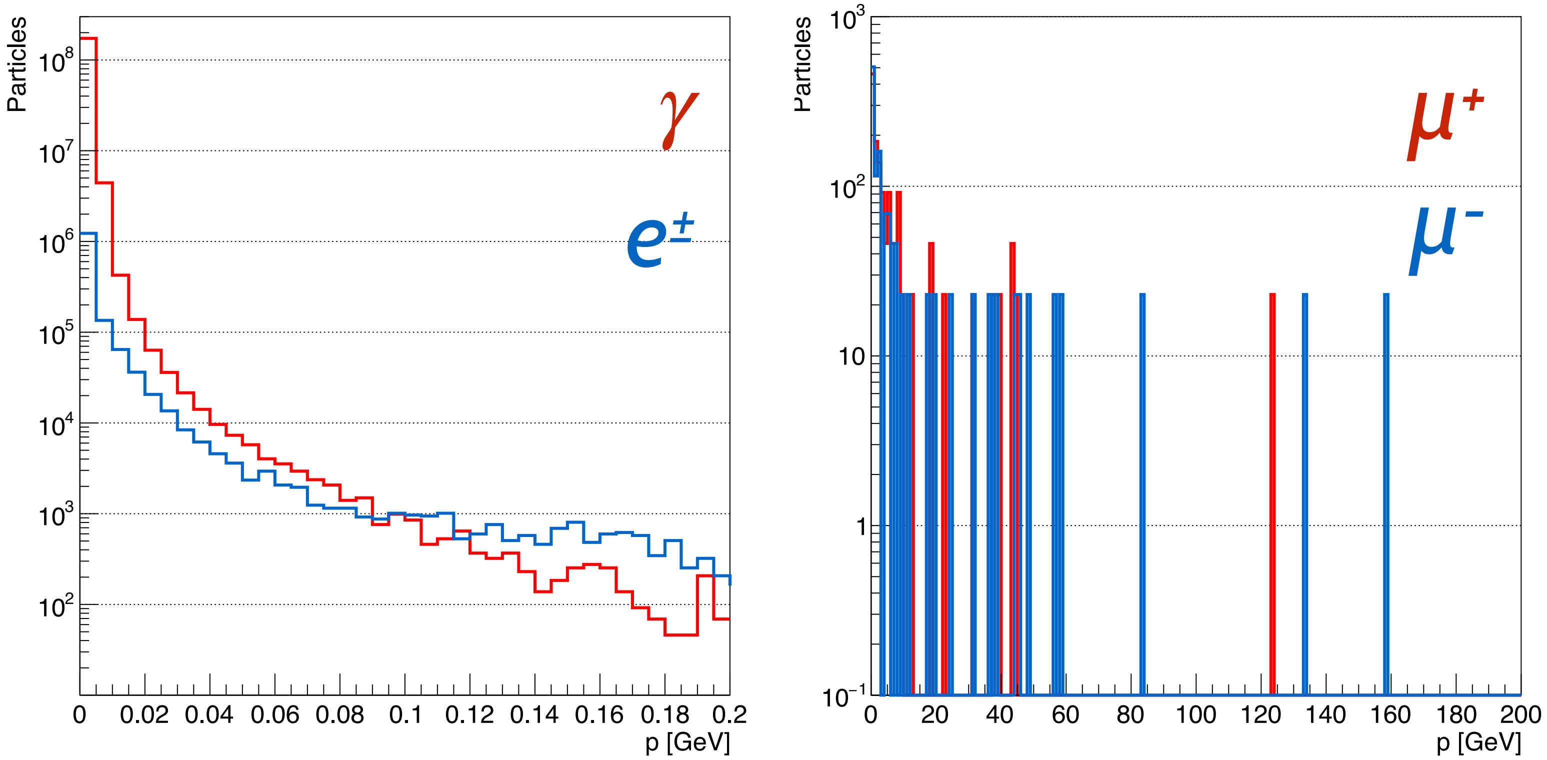
Solenoid
(4T)

Nozzles

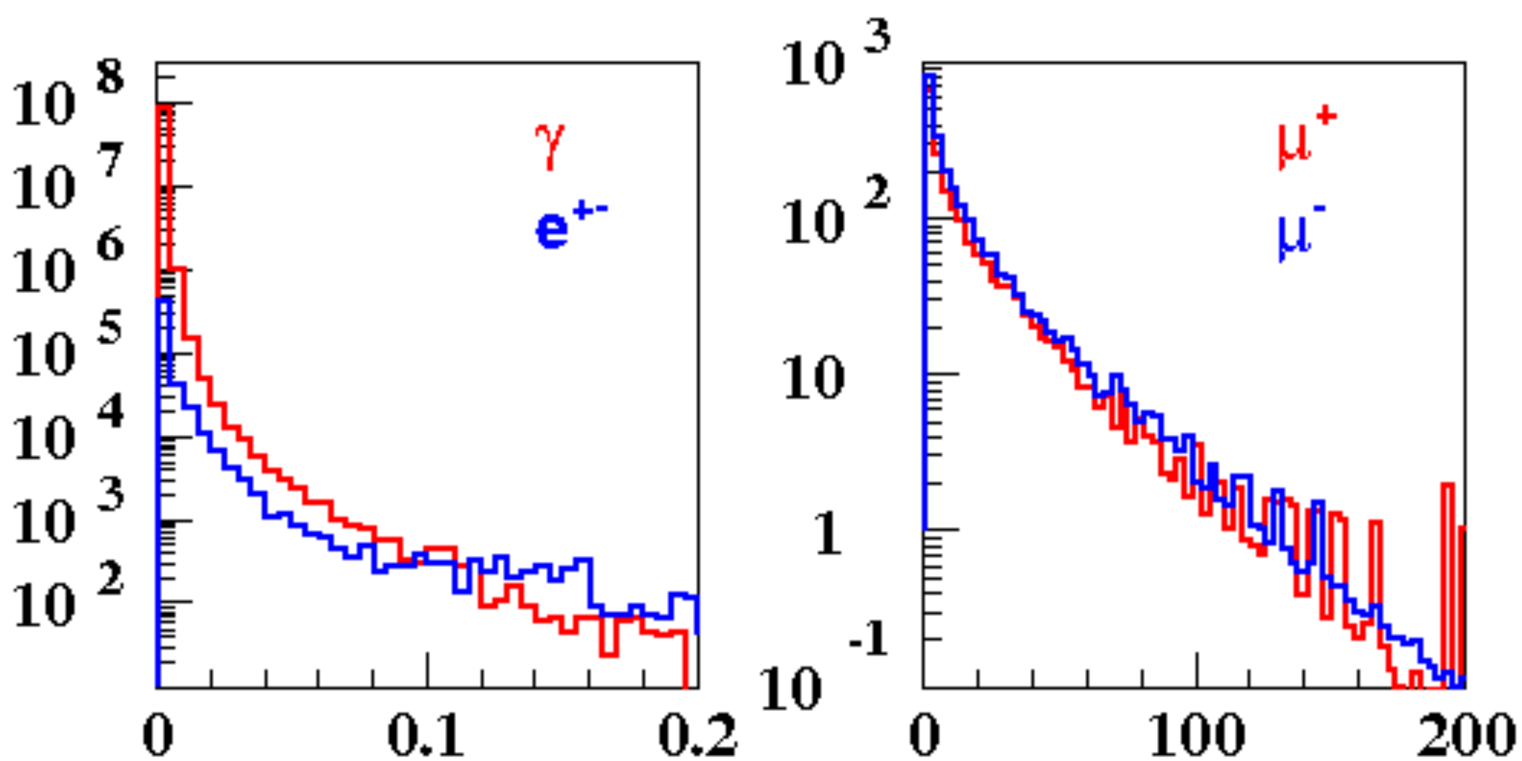




Verifying the proper conversion of MARS particles: ✓ consistent with MAP



μ± beams

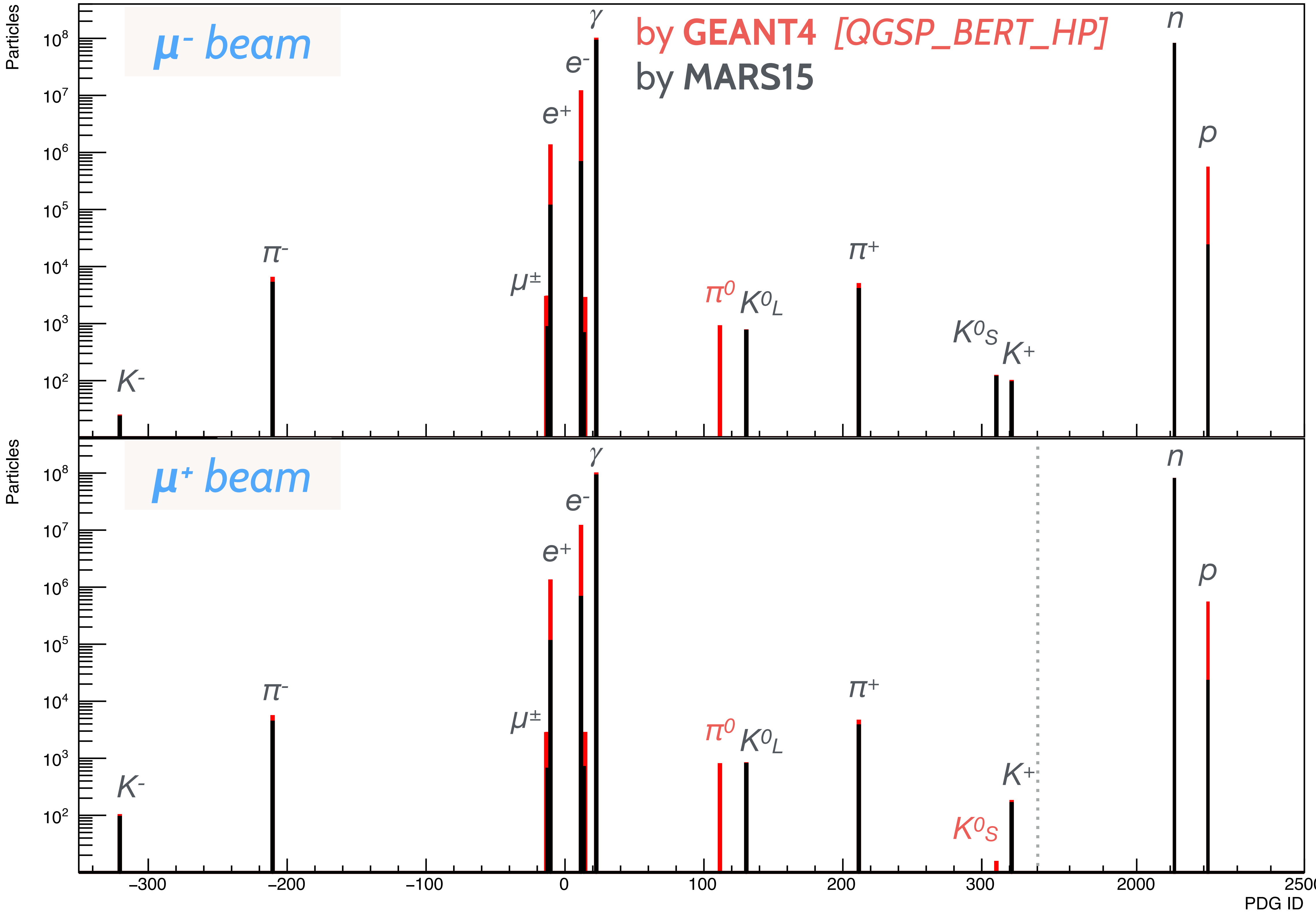


MAP publication

μ+ beam

MCParticle properties: PDG ID

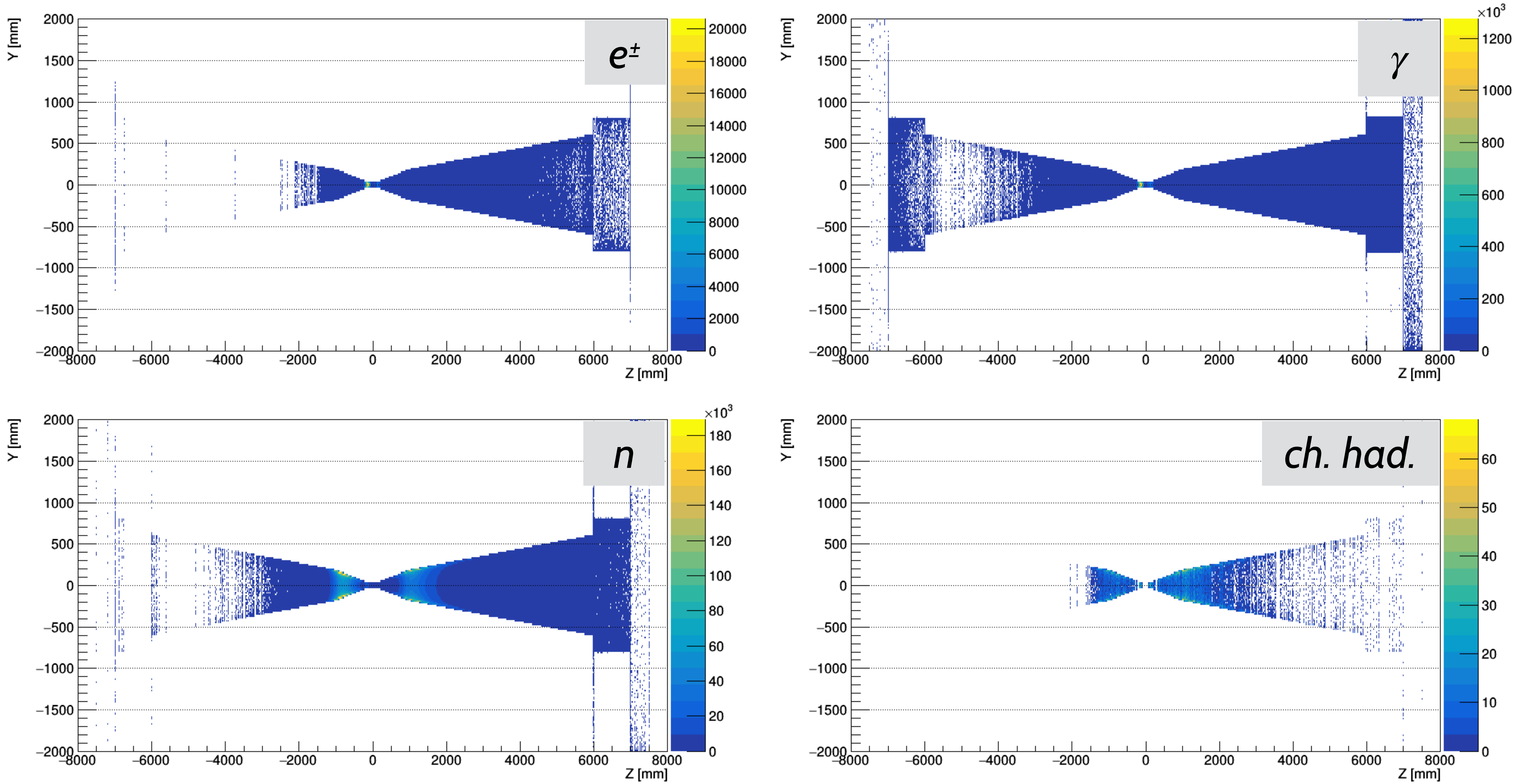
Processed all MARS particles from the μ^- *and* μ^+ beams



MCParticles from MARS: production vertex

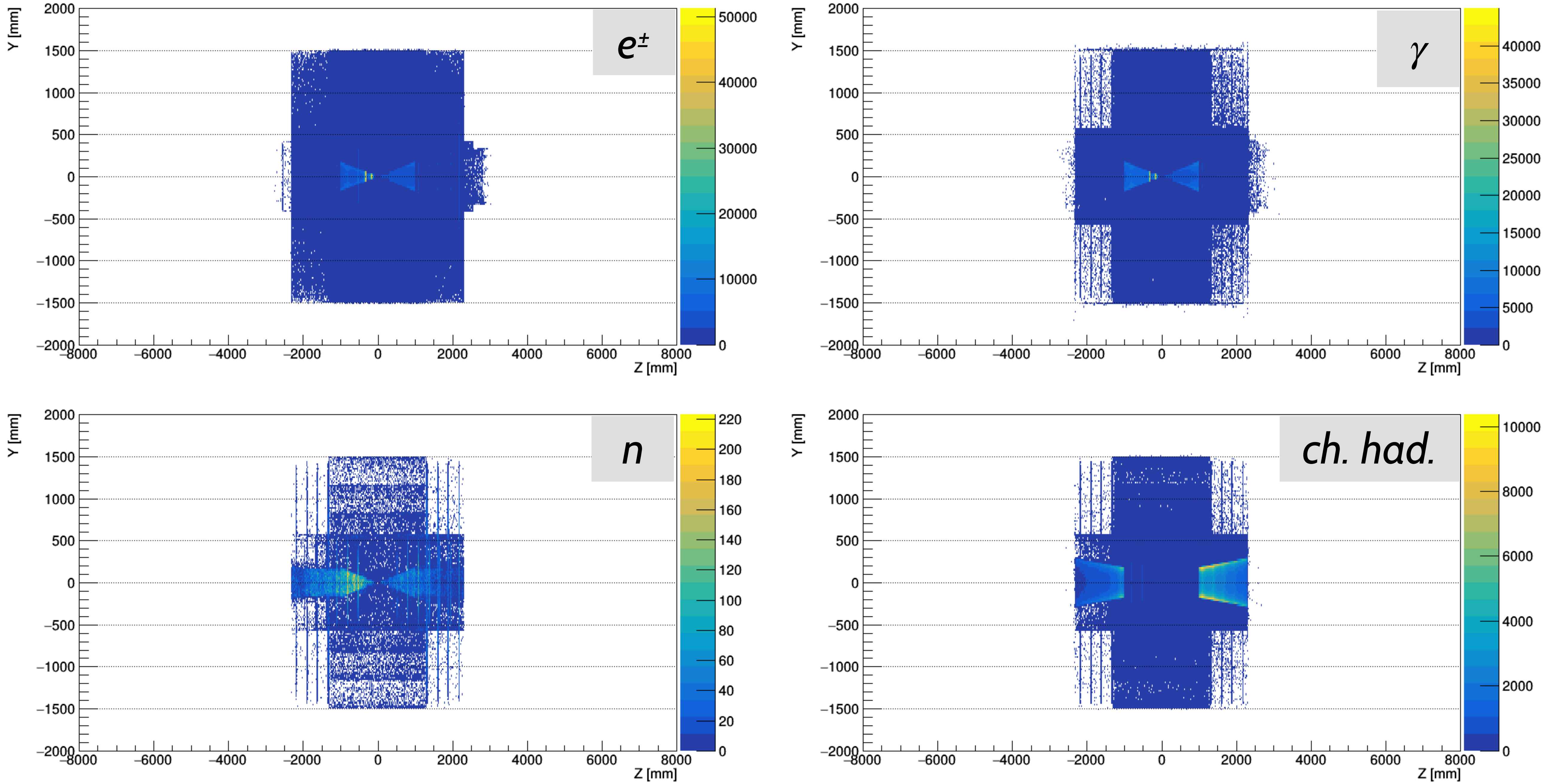
Plotting the MCParticle's production vertex position in Y:Z plane

μ^- beam



Plotting the MCParticle's production vertex position in Y:Z plane

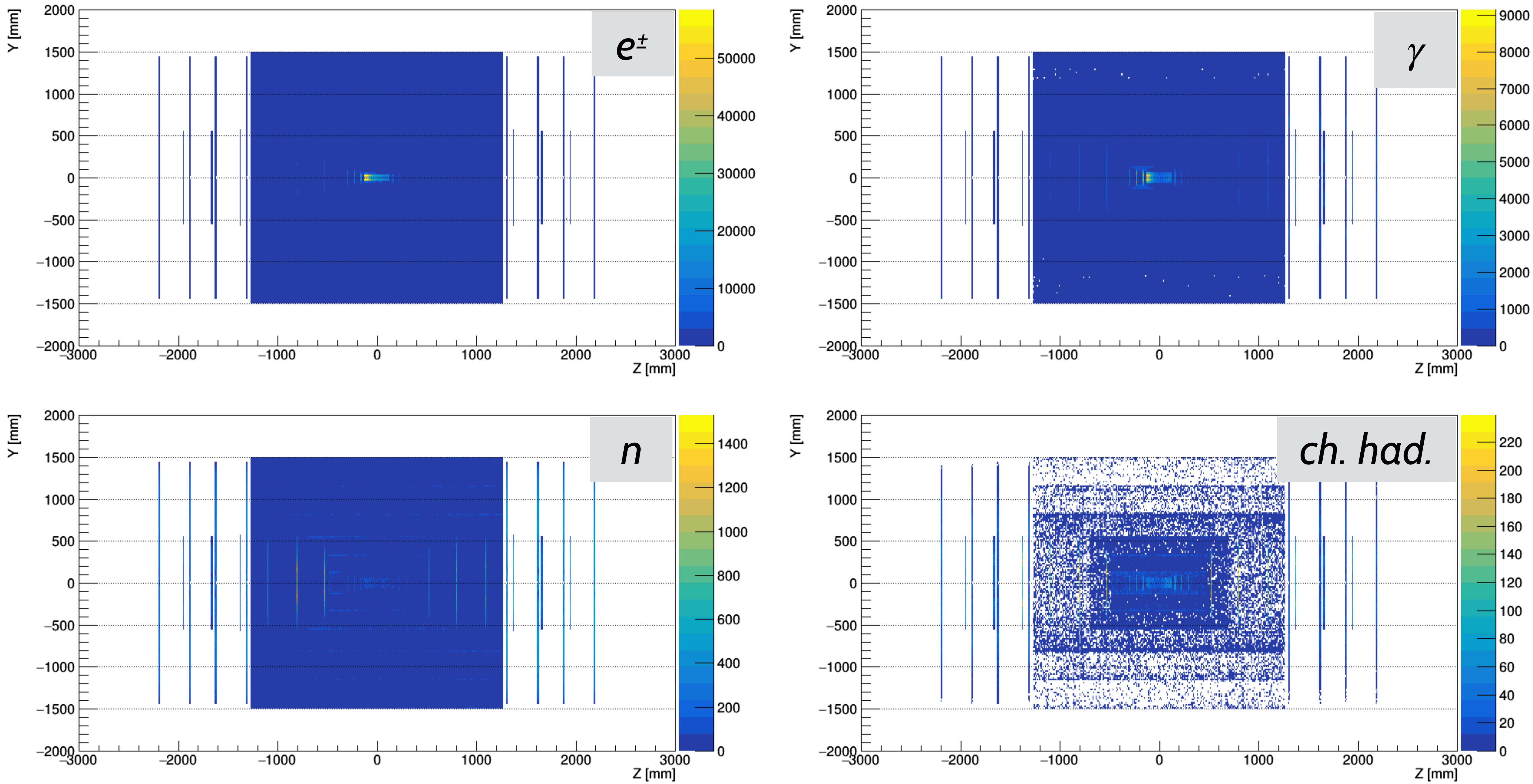
μ^- beam



Plotting the Vertex + Inner + Outer Tracker hit positions in Y:Z plane

μ^- beam

- biggest impact on the Vertex Tracker

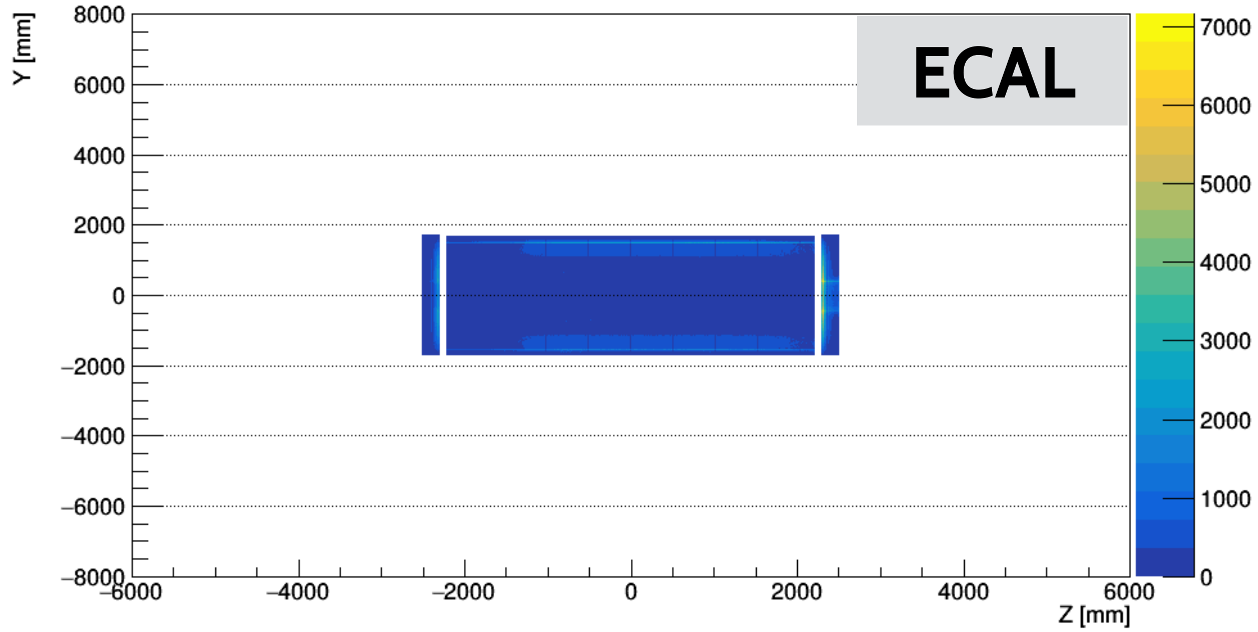


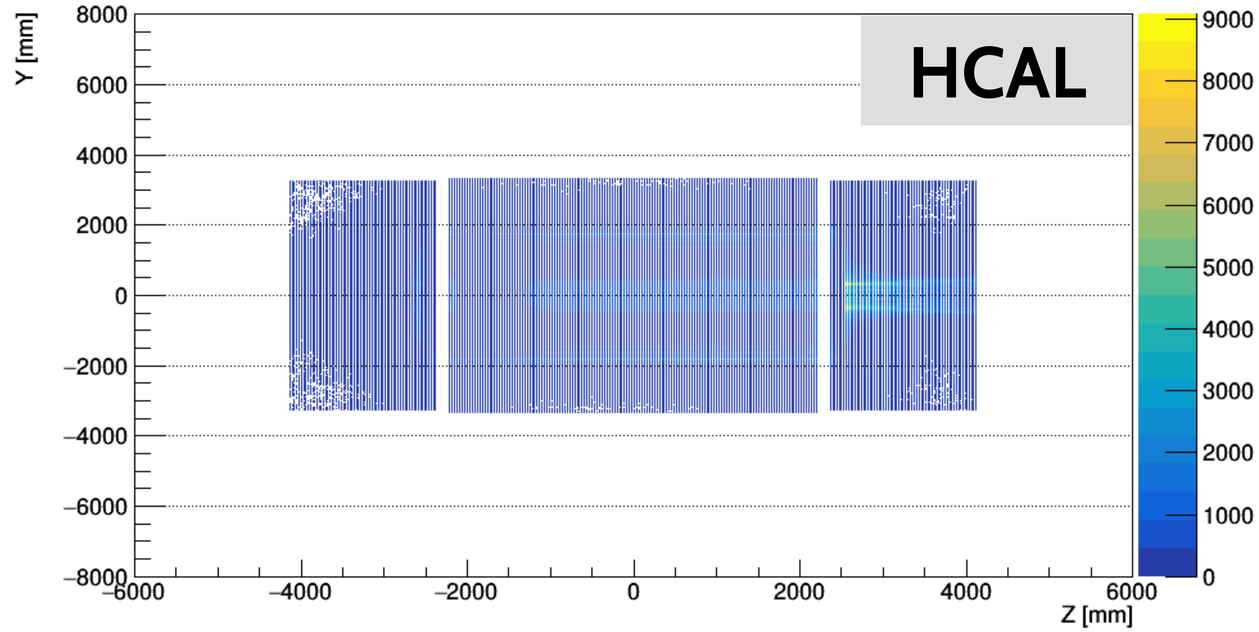
Calorimeter + Muon hits: spatial distribution

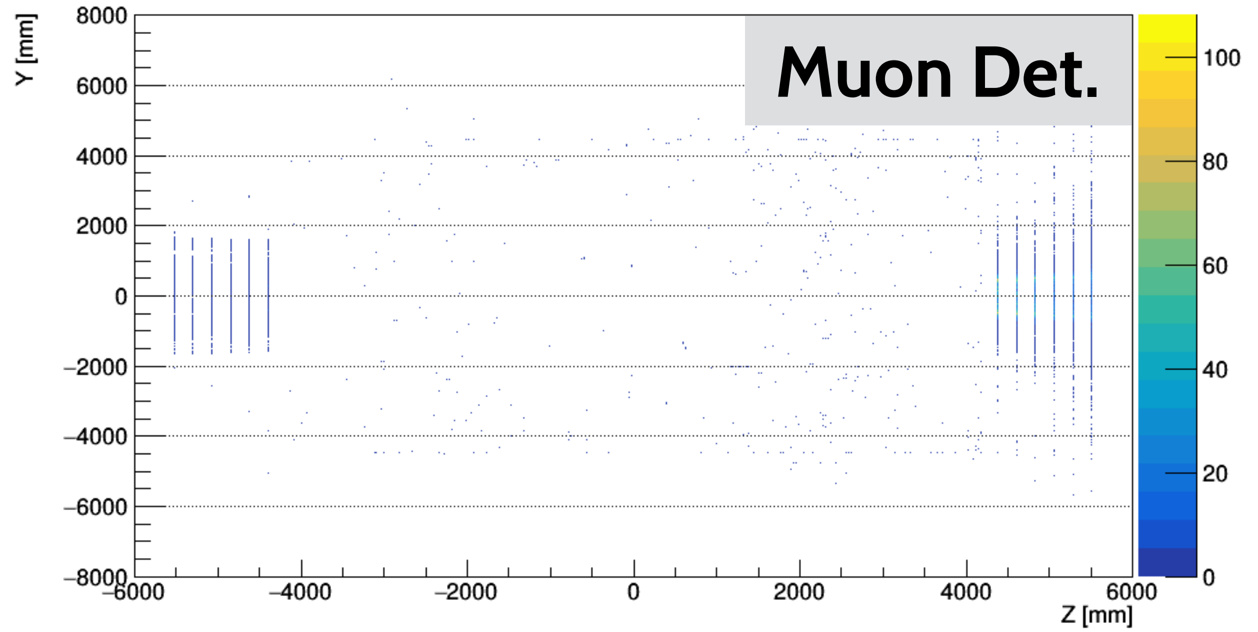
Plotting the <u>ECAL</u> / <u>HCAL</u> / <u>Muon Detector</u> hit positions in Y:Z plane

μ^- beam

- no pointer to the MCParticle in the default SLCIO -> ROOT conversion macro



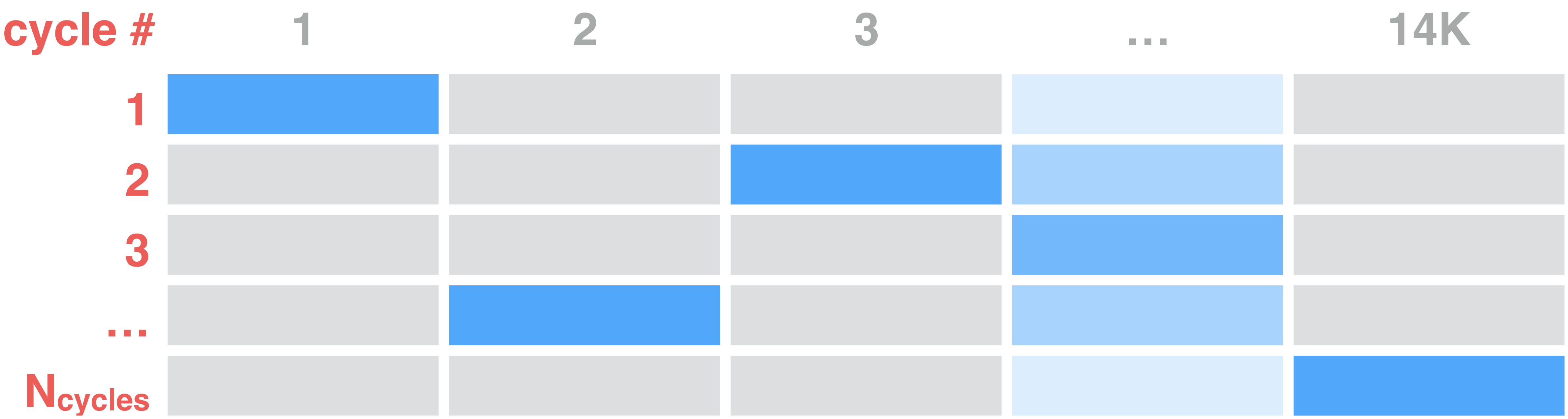




Simulation optimisation

Simulation of the beam-induced background is very slow. Need to optimise.

1. **Use random mixing of chunks of the particles from different simulated cycles**
   - 1 full bkg. sample is currently split into 2×7K events (23K particles/event)



2. **Use a faster-performing physics list if possible**
   - have to make sure that simulation results remain valid for our use case
   - comparing simulation results between 2 GEANT4 physics lists:
     - **QGSP_BERT_HP:** used by MAP; most precise;
     - **QGSP_BERT:** less precise treatment of thermal neutrons; x10 faster;

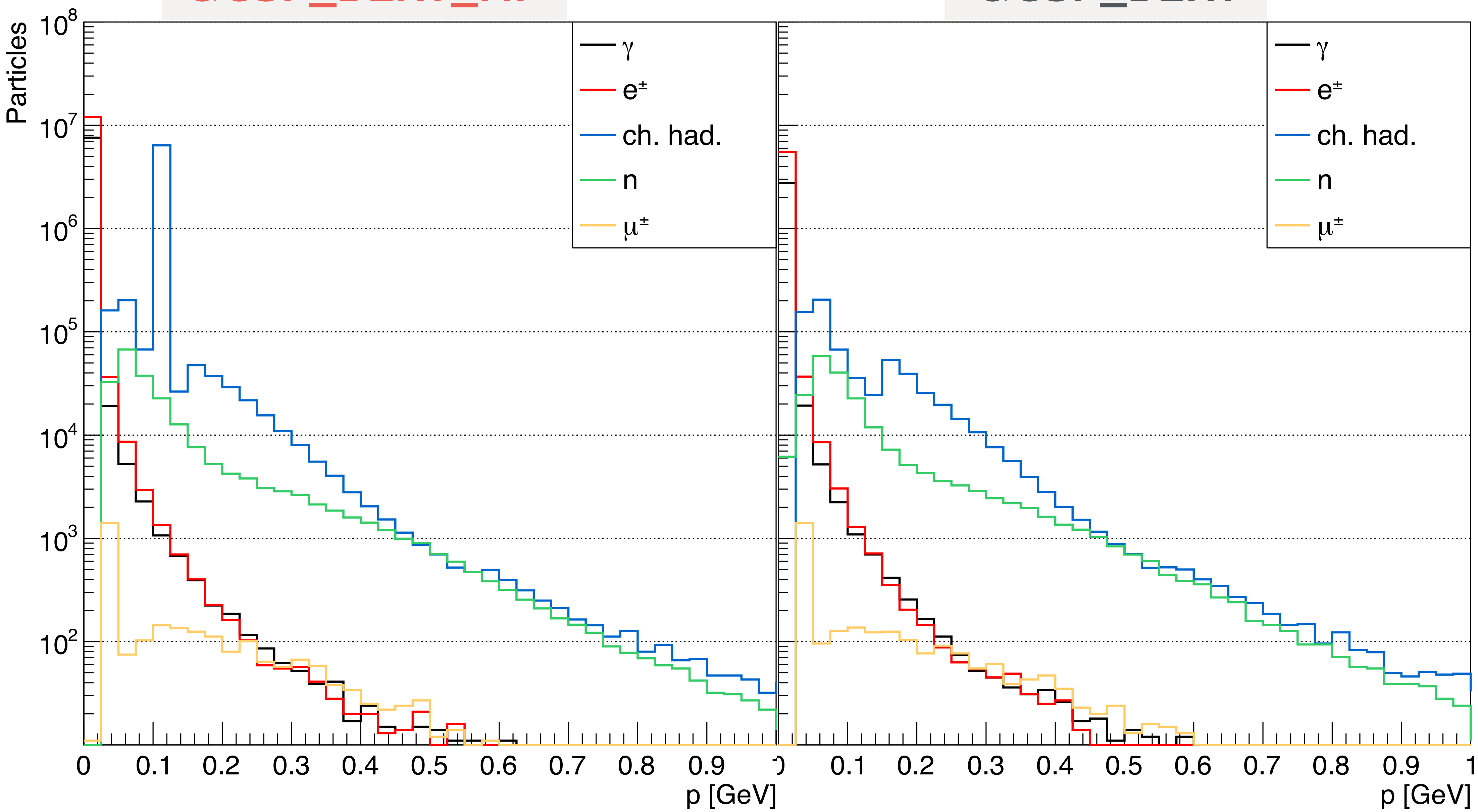
A number of clear differences at the level of MCParticles:

μ^- beam

- fewer soft electrons;
- more soft neutrons; missing a huge chunk of charged hadrons;

QGSP_BERT_HP

QGSP_BERT

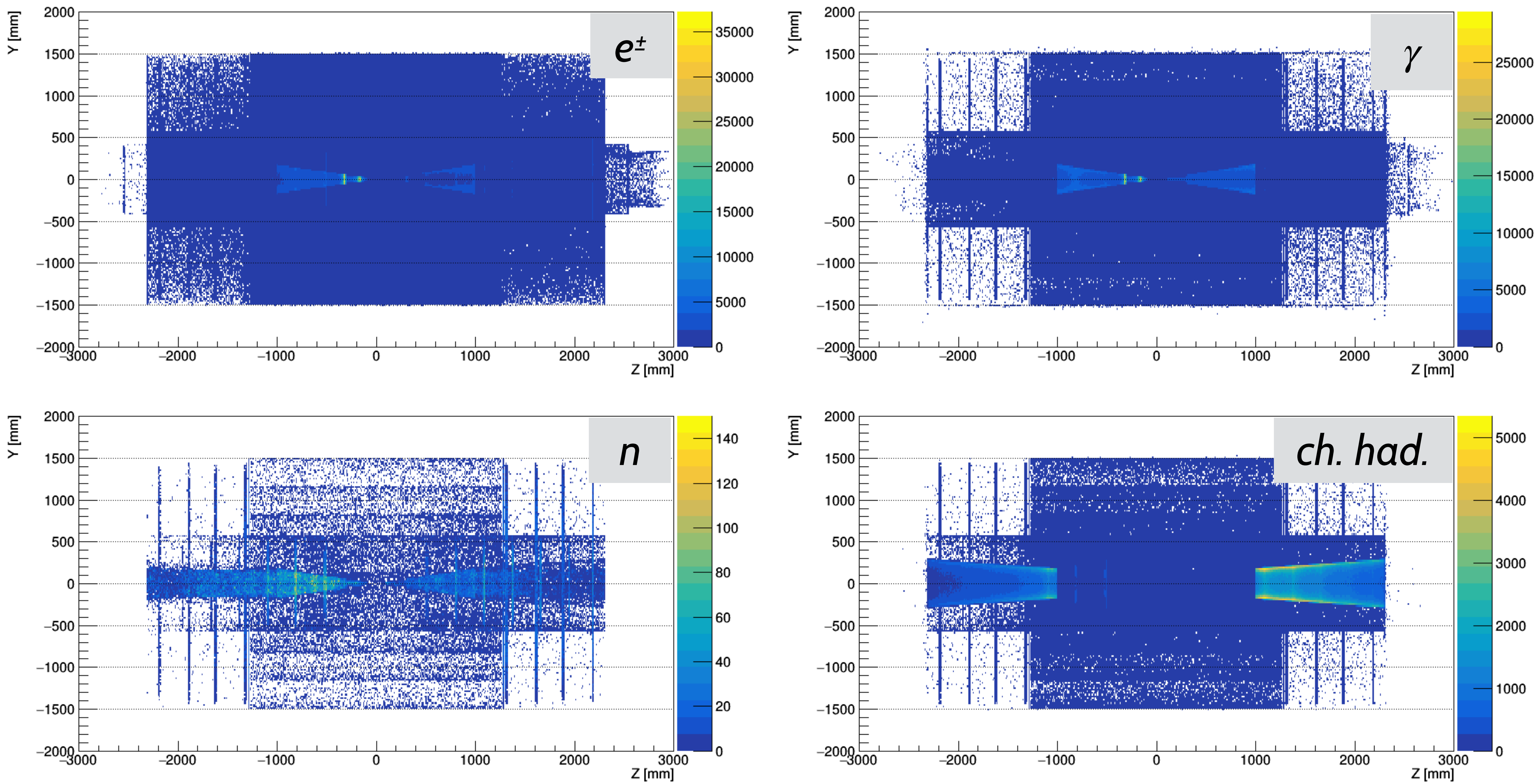


MCParticles from GEANT4: production vertex

Plotting the MCParticle's production vertex position in Y:Z plane

μ^- beam

QGSP_BERT_HP

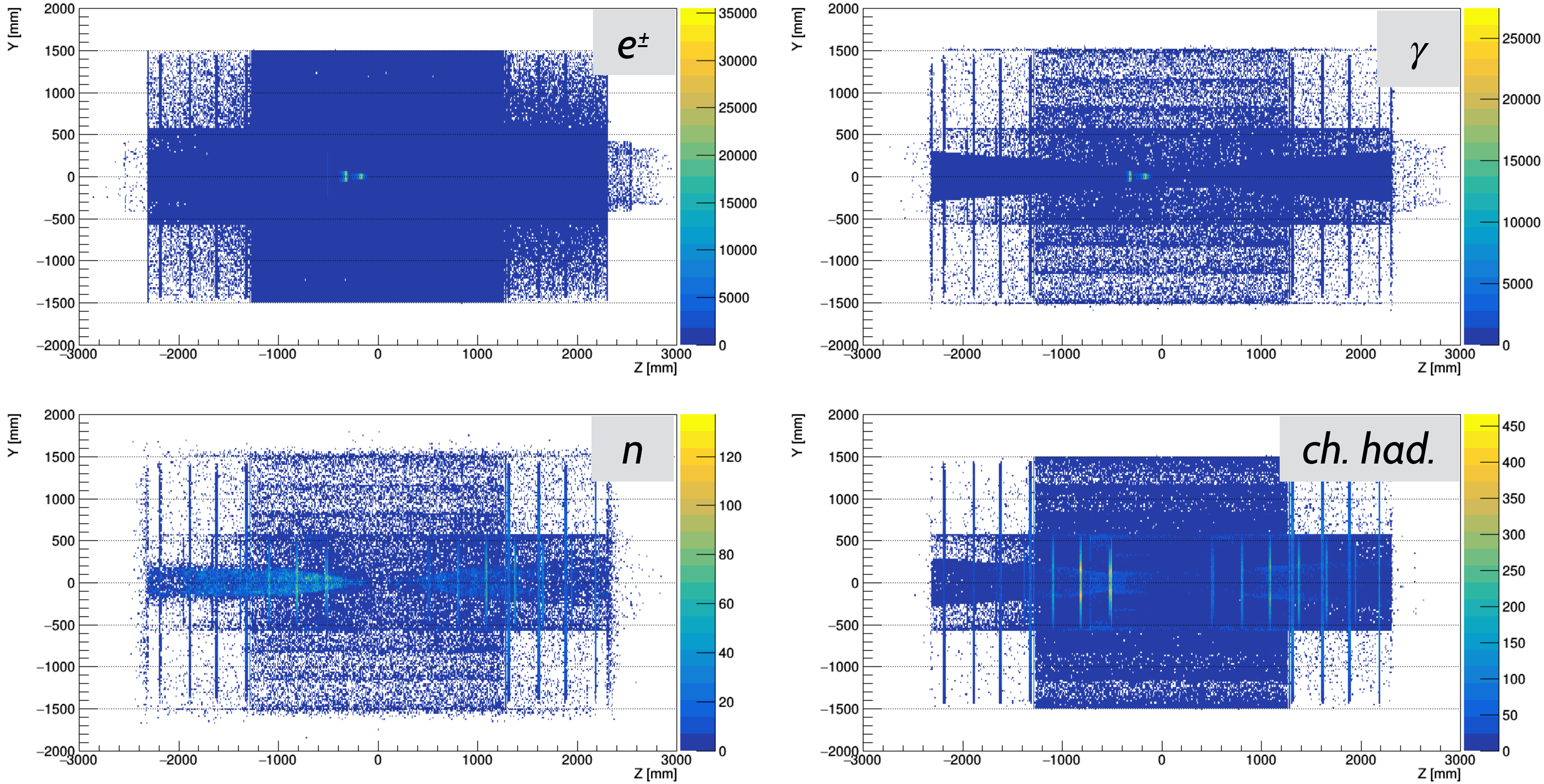


MCParticles from GEANT4: production vertex

Missing most of the charged hadrons produced at the nozzle surface

μ^- beam

QGSP_BERT

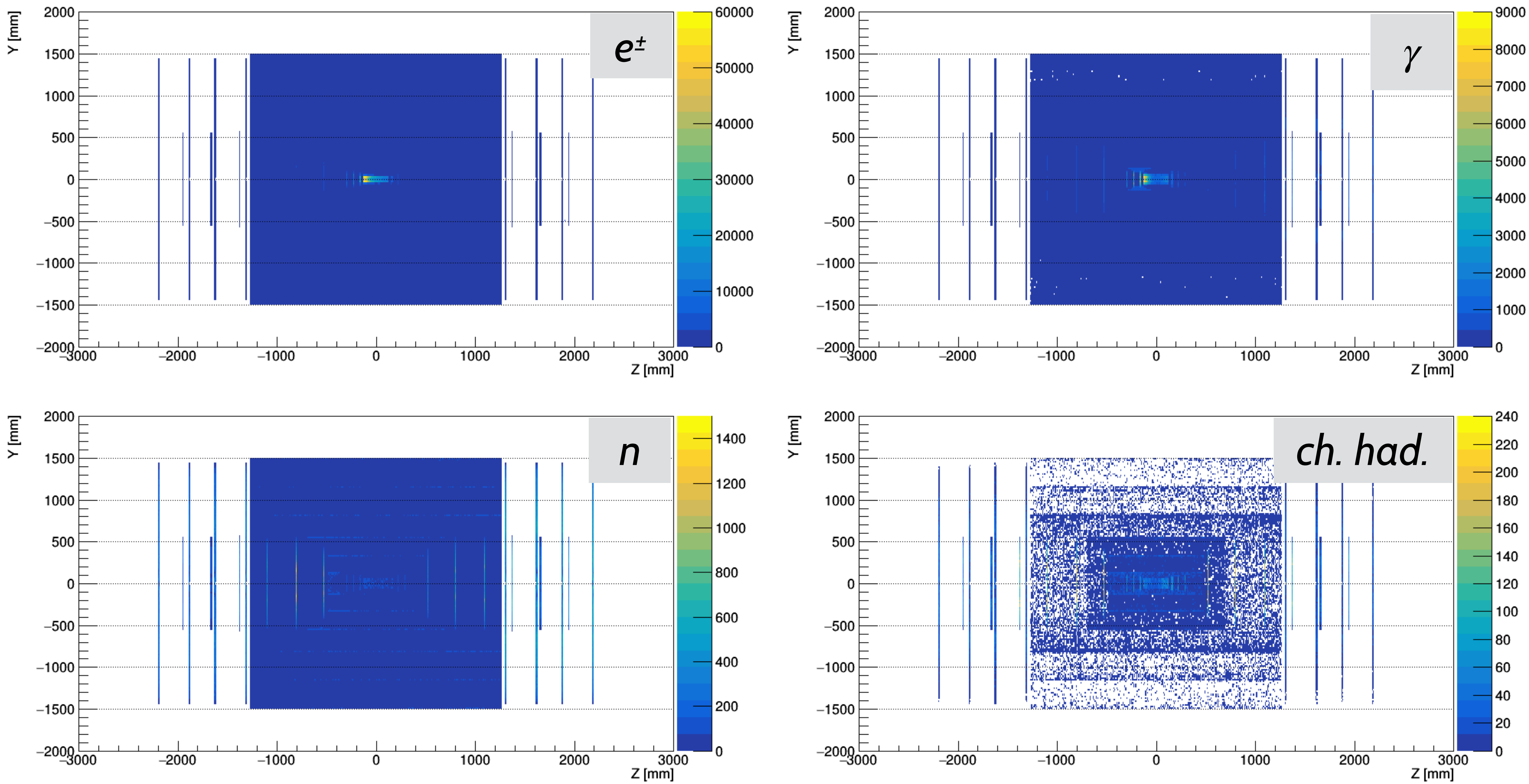


Tracker hits: spatial distribution

Plotting the <u>Vertex</u> + <u>Inner</u> + <u>Outer</u> Tracker hit positions in Y:Z plane

μ^- beam

QGSP_BERT_HP

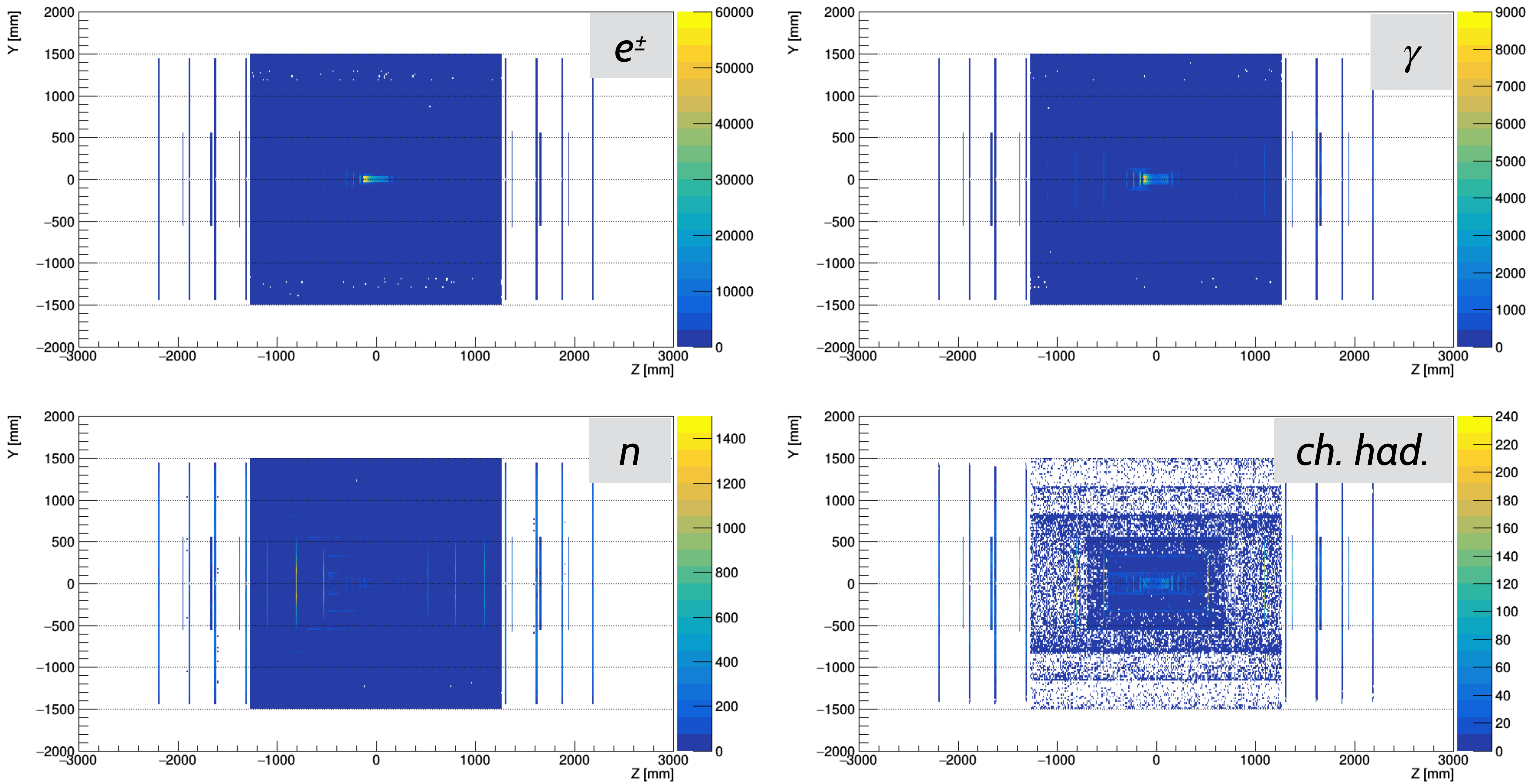


Tracker hits: spatial distribution

No visible differences at the level of Tracker hits

μ^- beam

QGSP_BERT



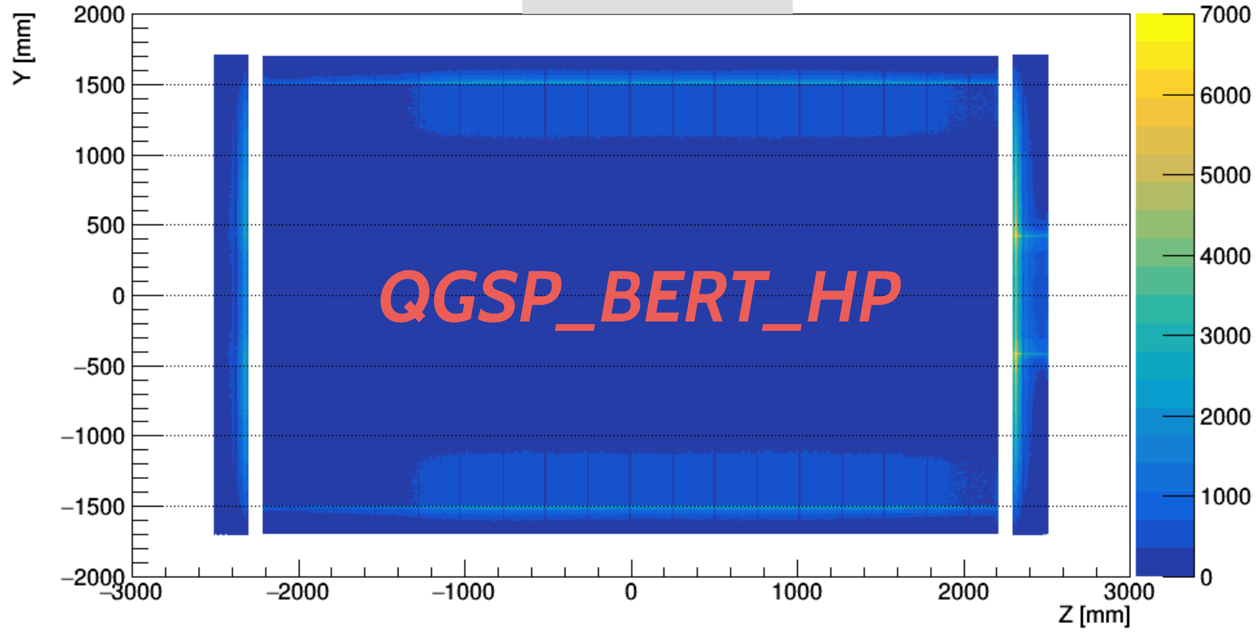
Noticeable difference in the # of calorimeter hits

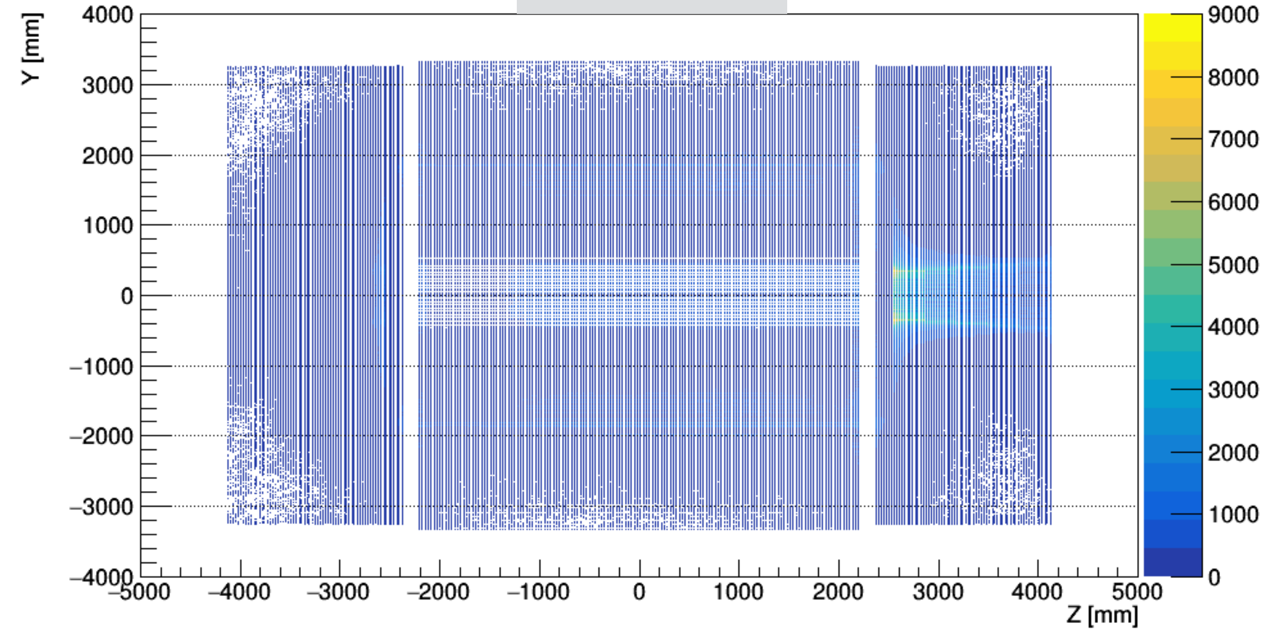
μ^- beam

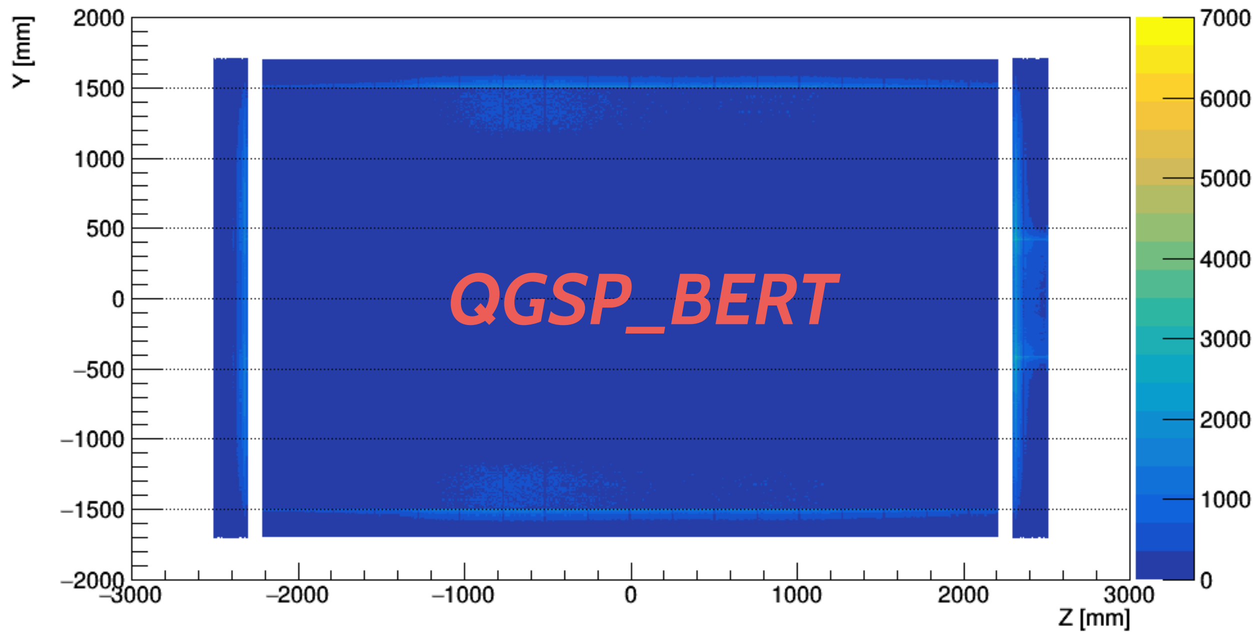
- spatial distribution remains the same between the 2 particle lists

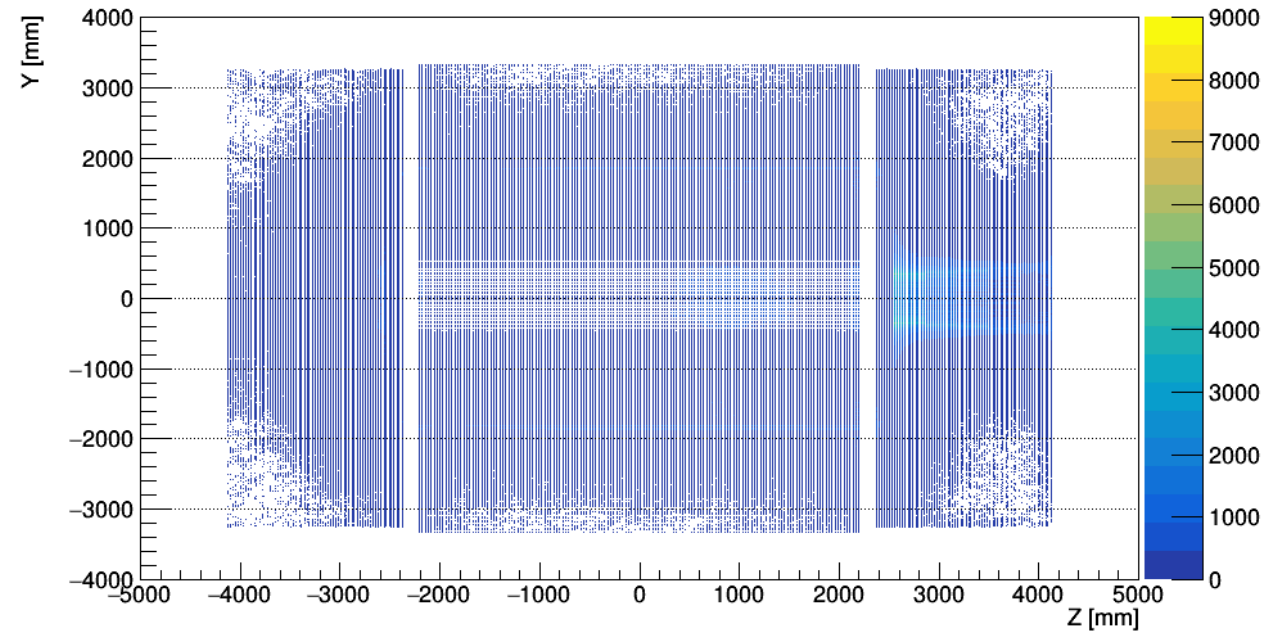
ECAL

HCAL









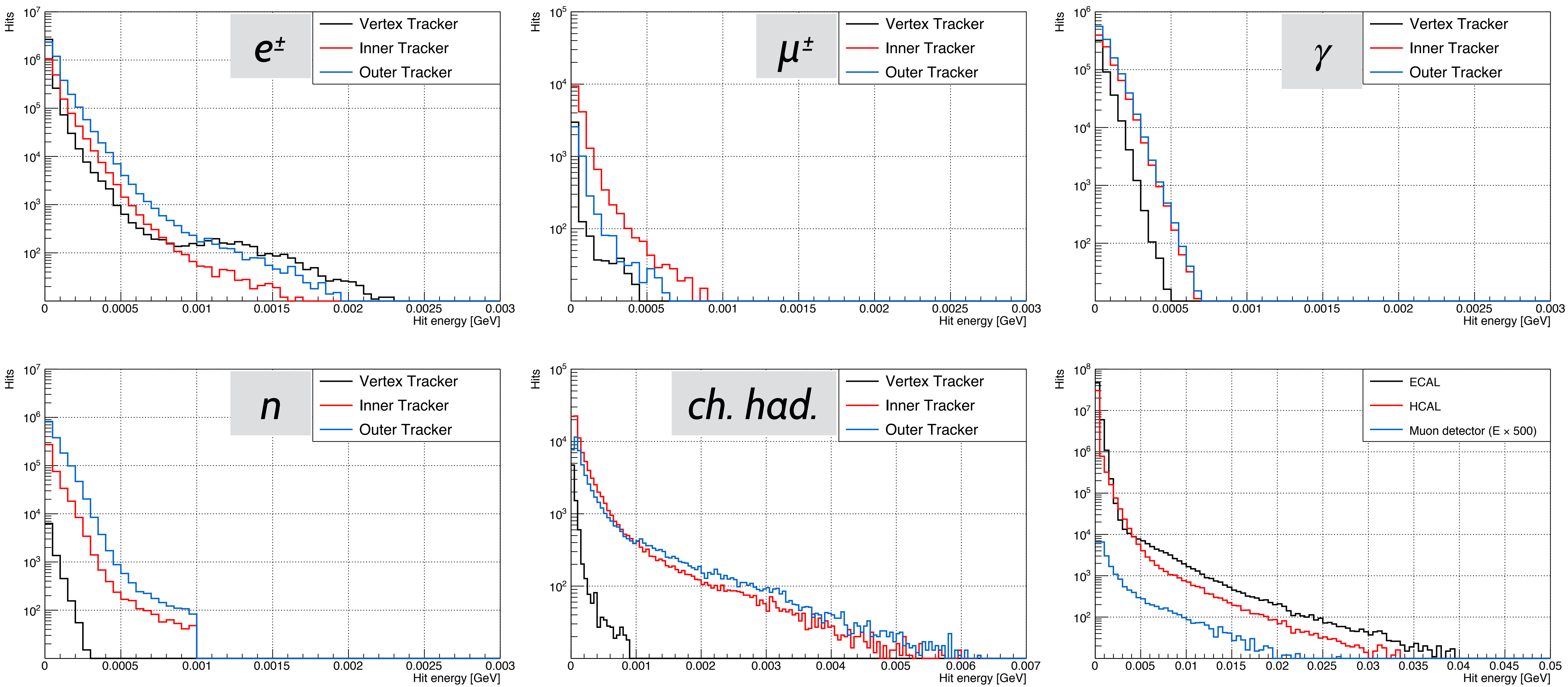
Tracker + Calorimeter hits: energy distribution

Comparing the deposited energy in Tracker and Calorimeter hits

μ^- beam

QGSP_BERT_HP

- Tracker hits separated by particle type
- Calorimeter/Muon hits shown all together



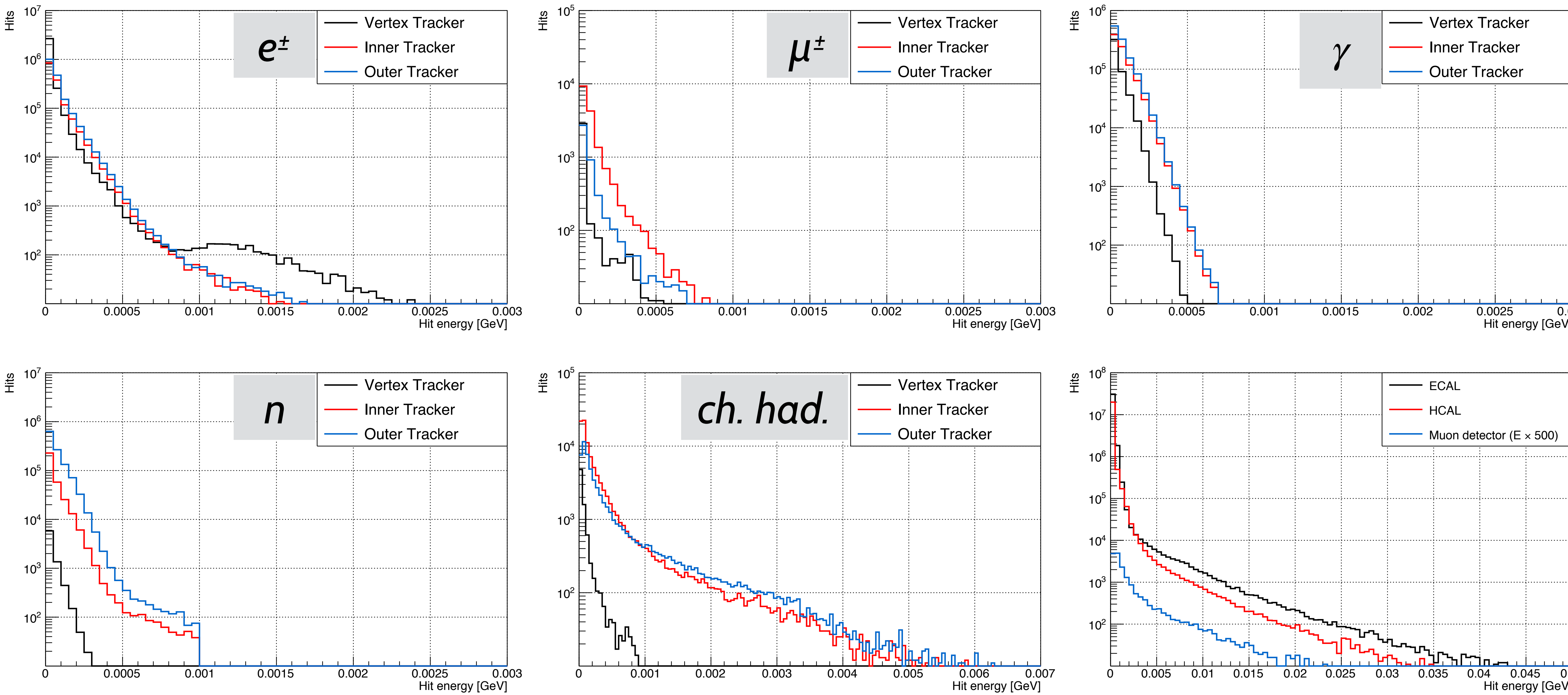
Tracker + Calorimeter hits: energy distribution

μ^- beam

QGSP_BERT

A couple of significant differences are clearly visible

- less Inner/Outer Tracker hits from e± and n
- less low-energy ECAL/HCAL hits



Summary

Detector simulation workflow is already in place

- CLIC framework + adapted detector geometry + MARS15 background
- simulation results consistent with MAP

Performance is the main issue

- ~8 days to simulate one event
- $\times$2-4 improvement possible with more virtual machines
- further $\times$10 improvement possible with faster physics list (but underestimated occupancy in Outer Tracker + ECAL + HCAL)