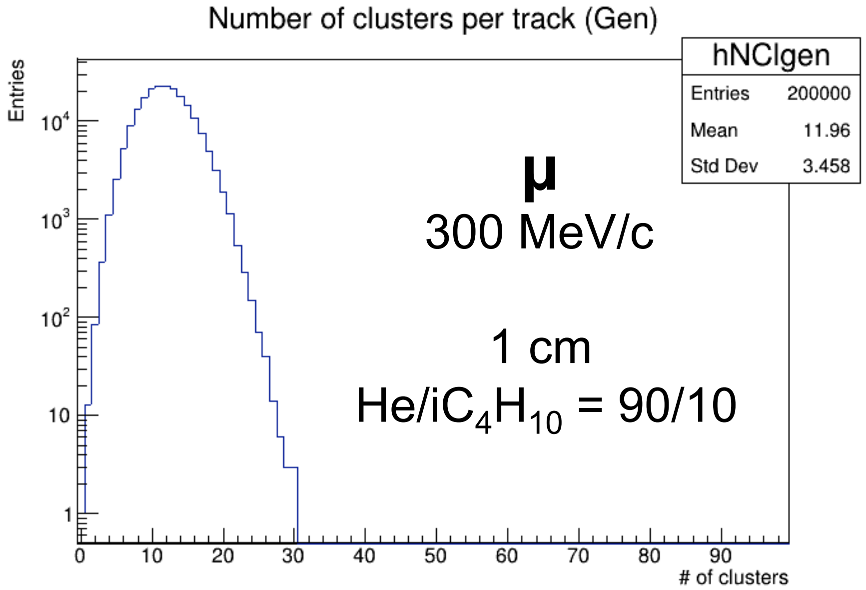
A proposal for a beam test on Cluster Counting

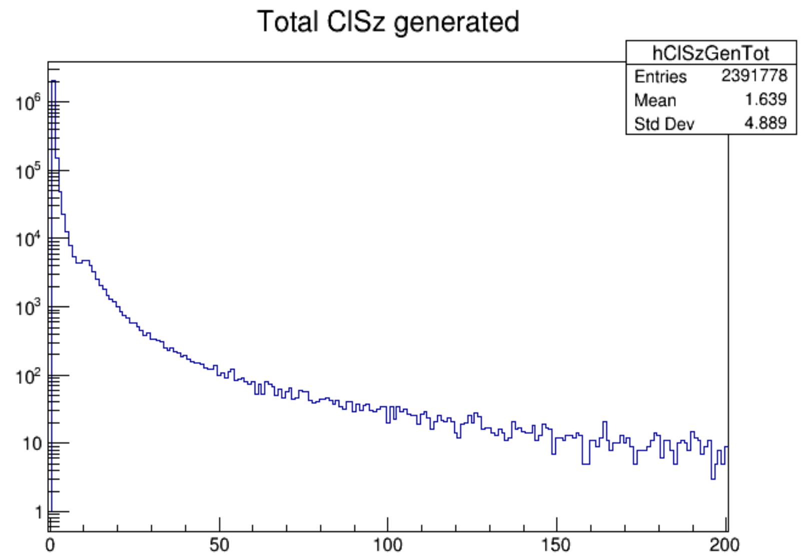
FCC-ee

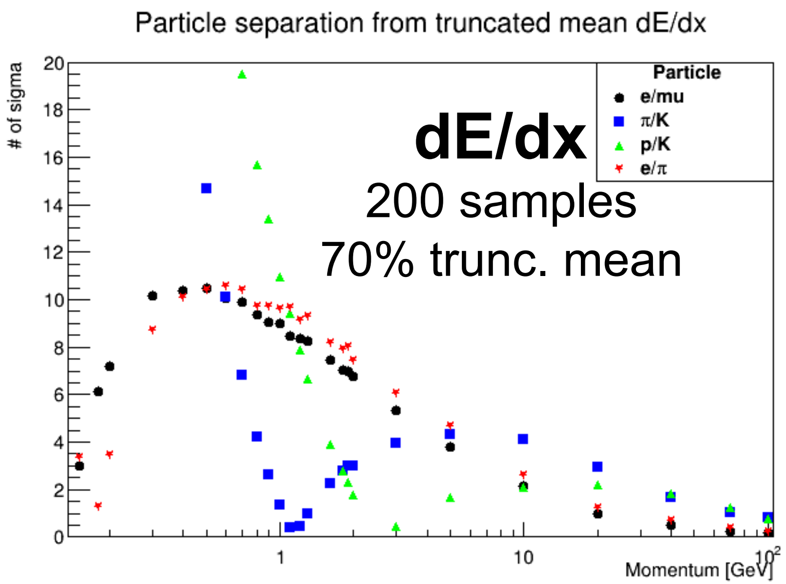
CEPC

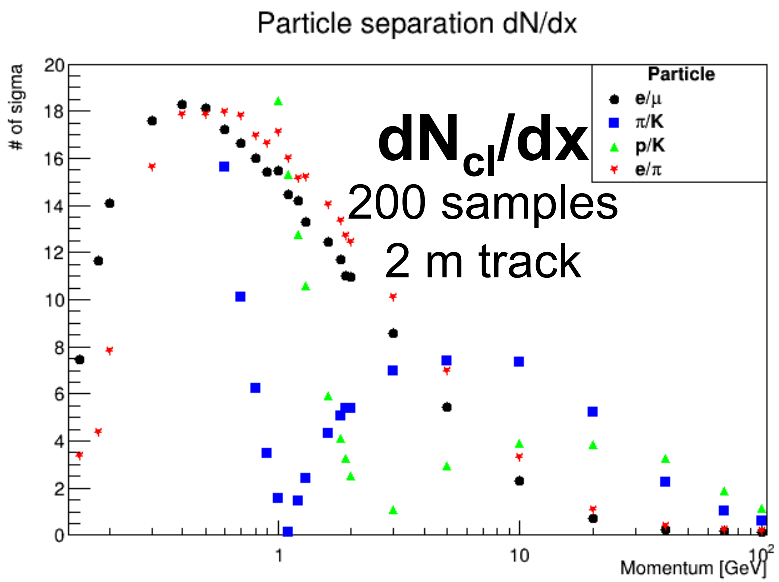
SCTF

Garfield++ results







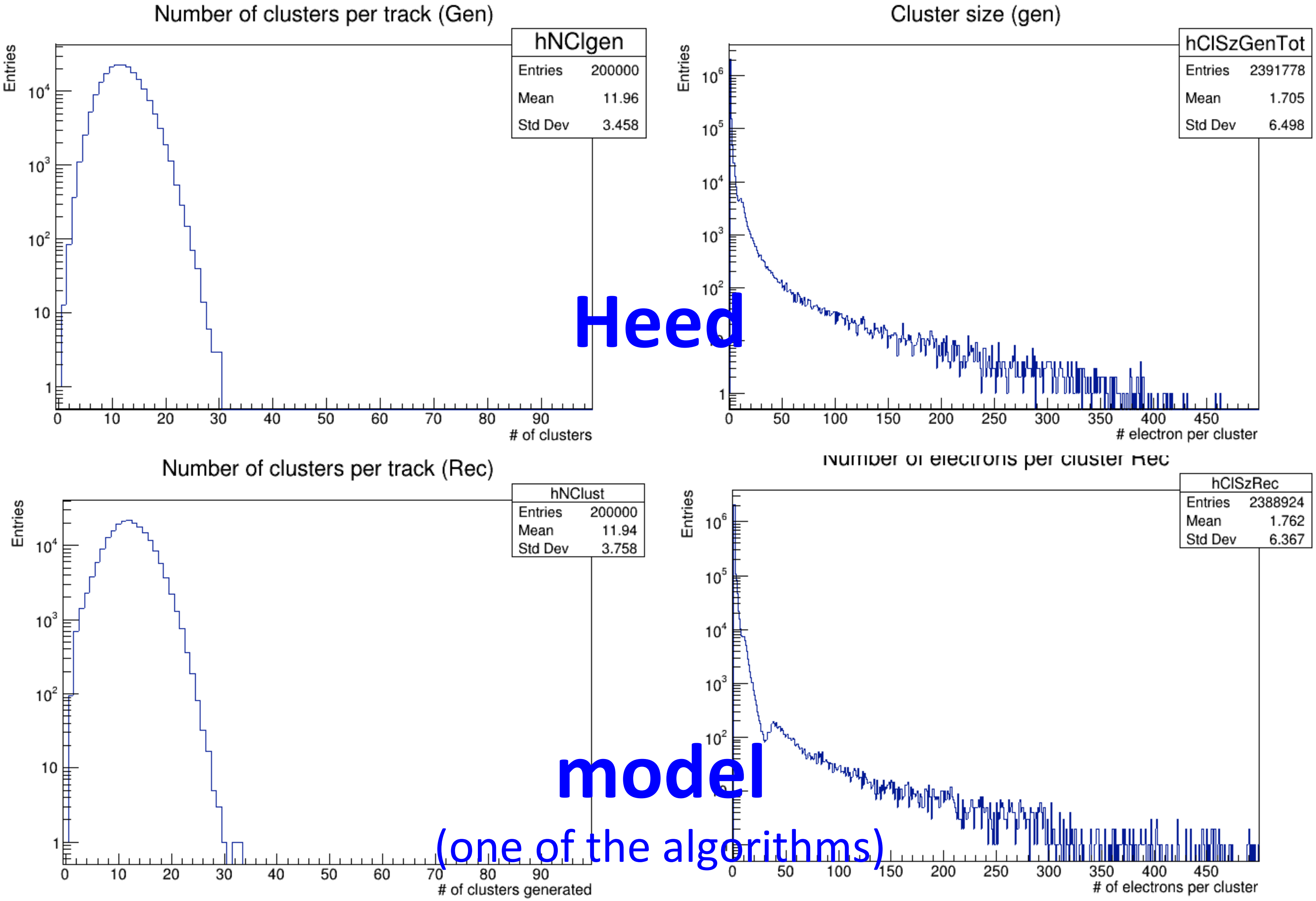


Preamble

- **Garfield++ (Heed)** simulates in deep detail the ionization processes in the gas, but it would be extremely cumbersome to follow an ionization particle inside the large volume of a tracking detector.
- **GEANT4** simulates the interaction of a particle with all the materials of a large detector but it doesn't simulate the ionization clustering process which is essential for cluster counting.
- **Define a model** for a fast simulation of the cluster density and the cluster size distribution according to the predictions of **Heed**, to be used taking into account the results of the particle interactions calculated by **GEANT4**.

Details at:
International Workshop on Future Linear Colliders, LCWS 2021, 15-18 March 2021
Title "*Simulation of particle identification with cluster counting technique*",
proceeding published on *SPIRES*. Arxiv number:***2105.07064***

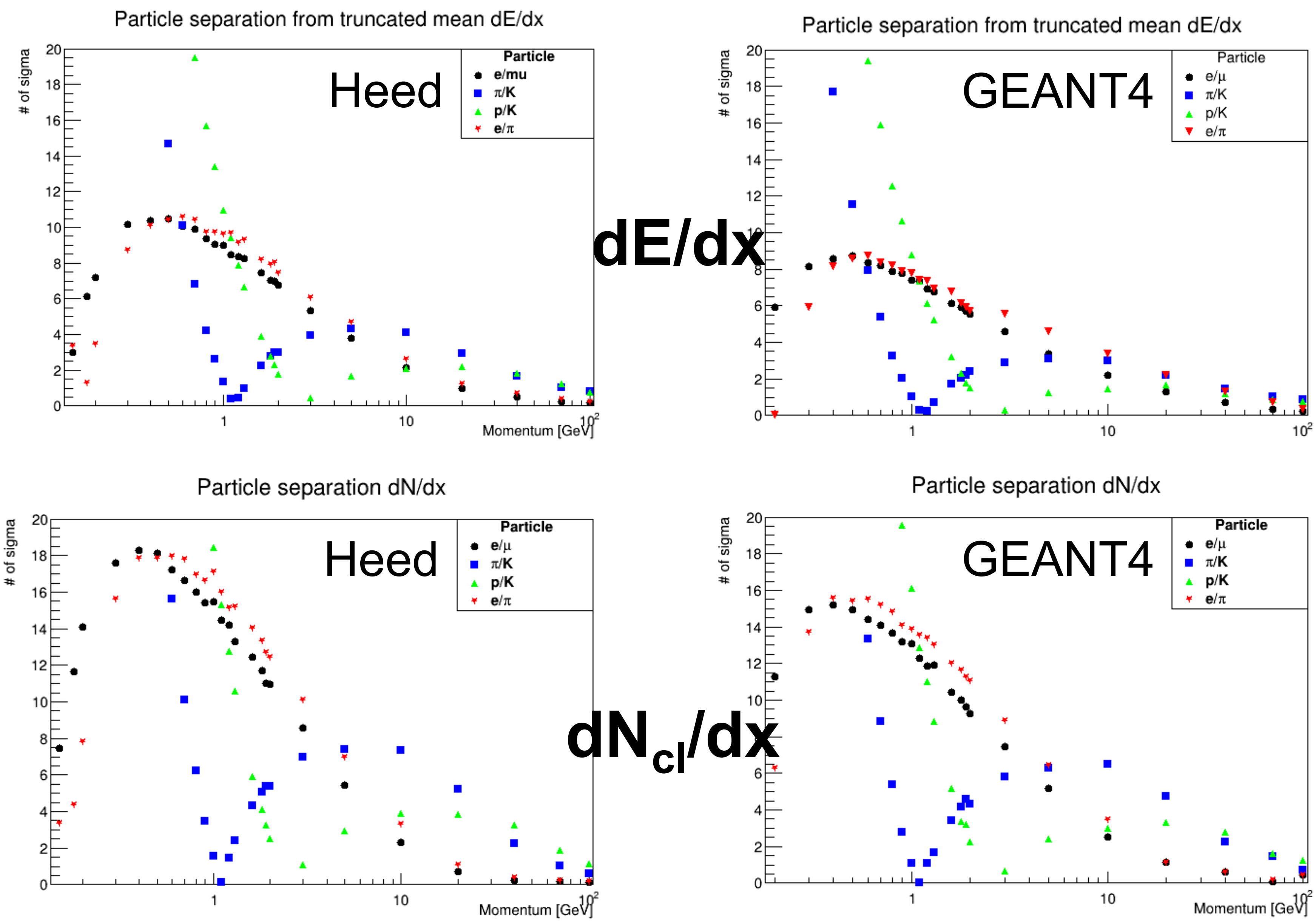
Heed model



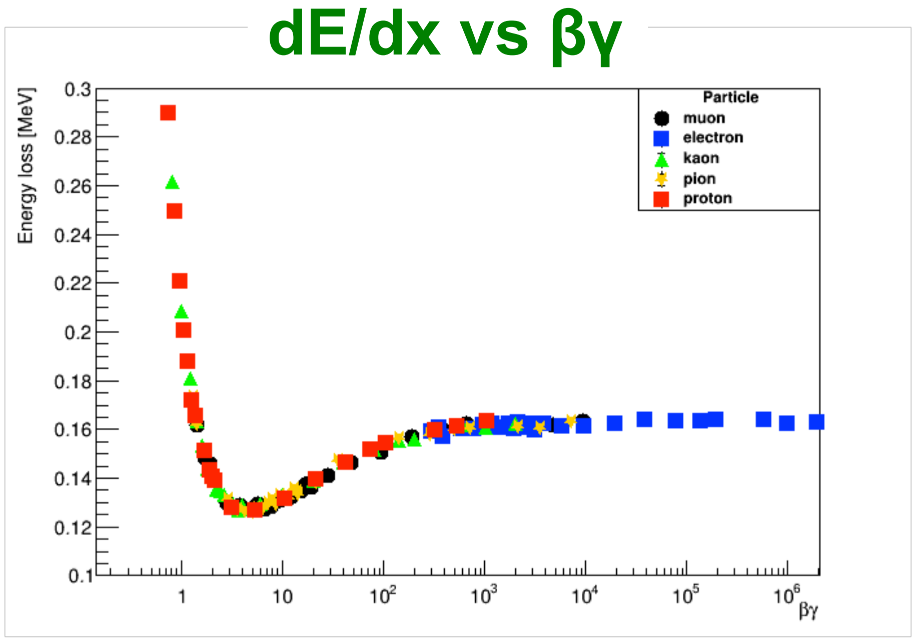
Heed model

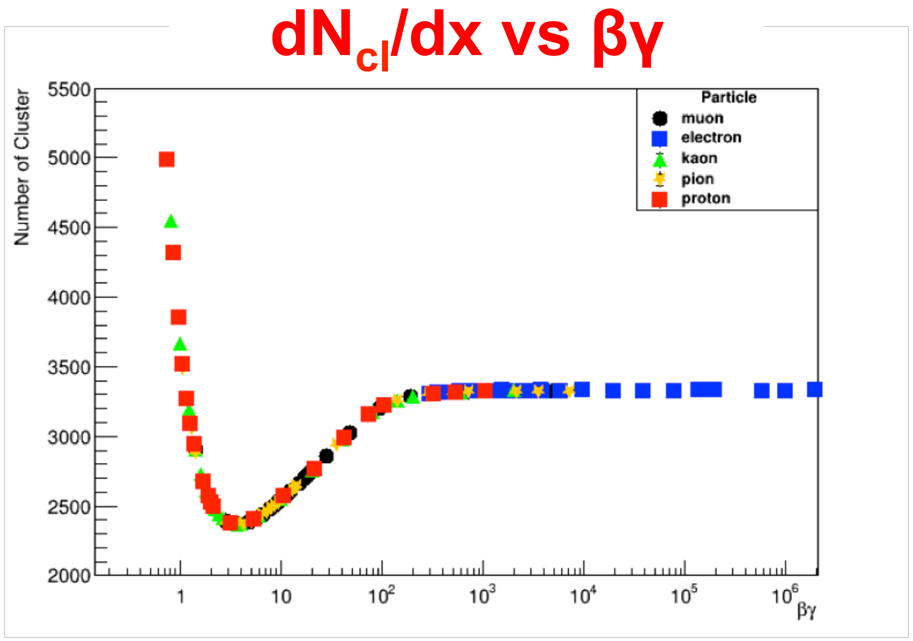
(one of the algorithms)

Heed - GEANT4 comparison



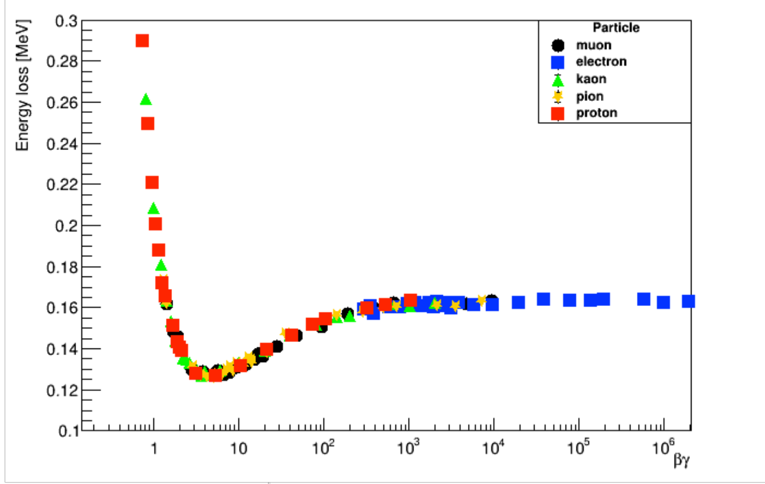
GEANT4 predictions



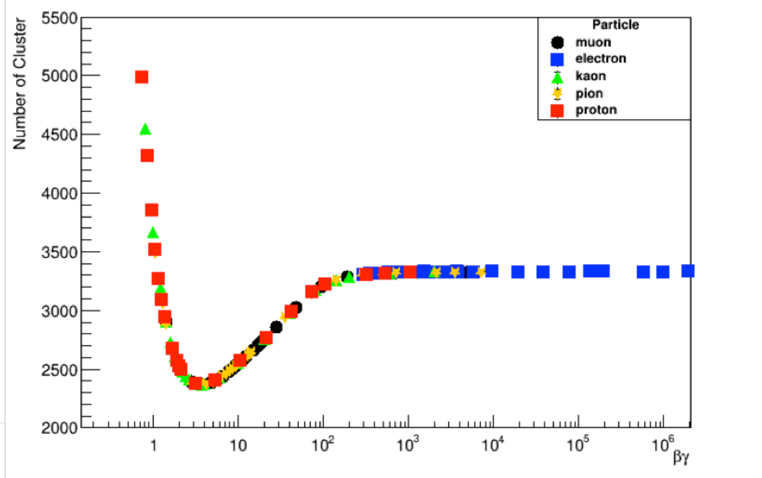


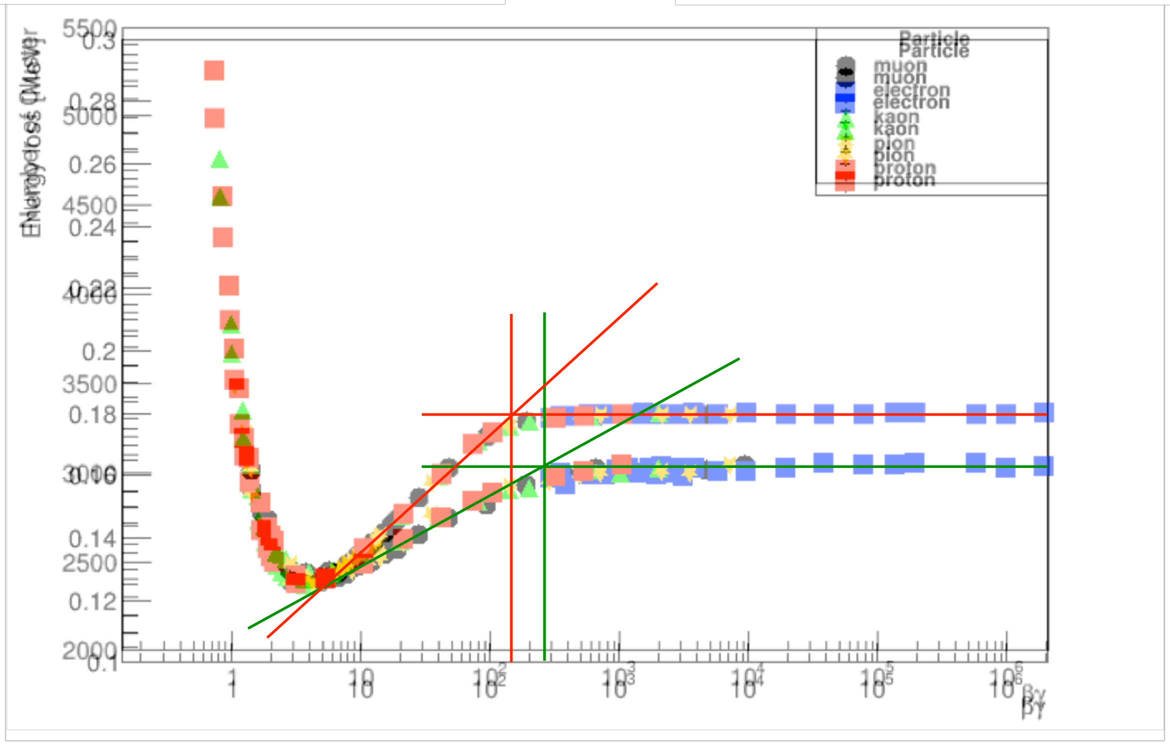
GEANT4 predictions

dE/dx vs βγ



dN_{cl}/dx vs βγ





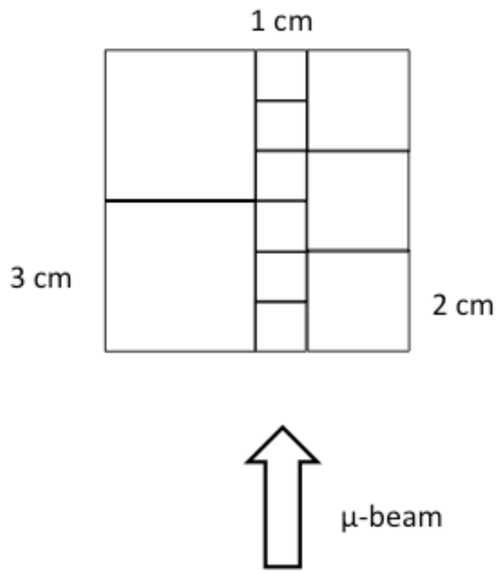
Open questions

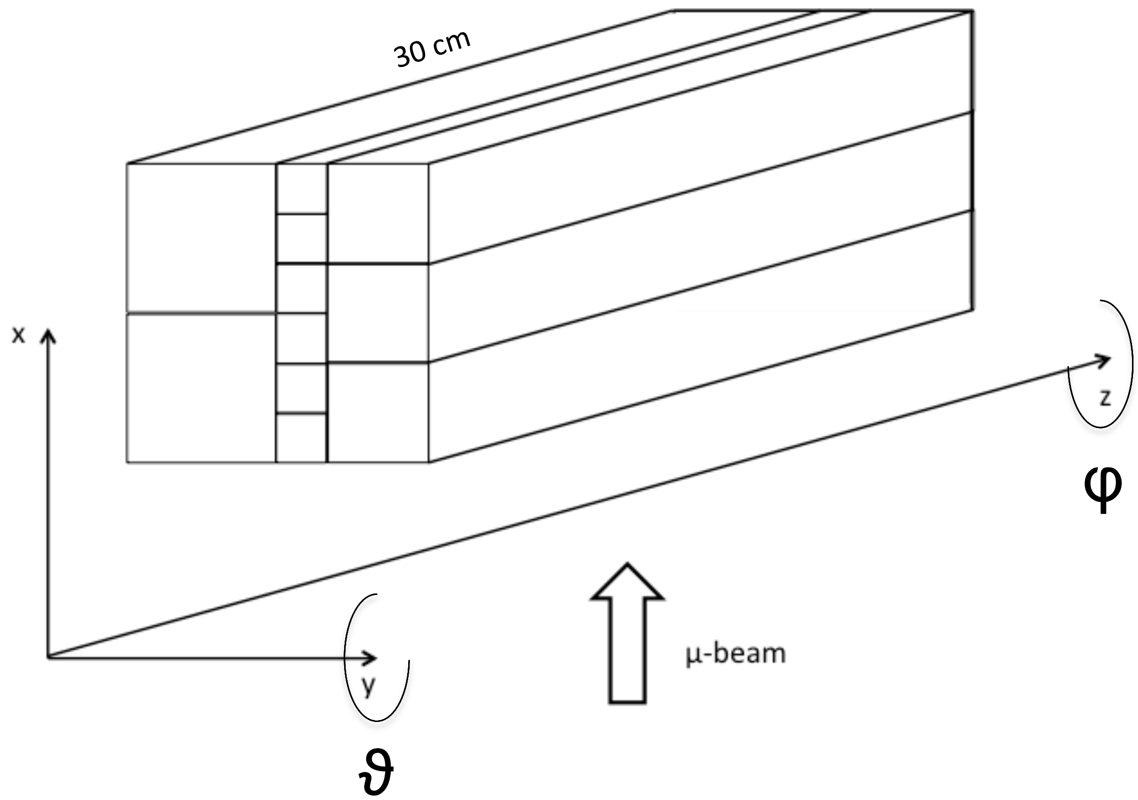
1. Lack of experimental data on cluster density and cluster population for He based gas. Particularly in the relativistic rise region to compare calculations.
2. Despite the fact that the Heed model in GEANT4 reproduces reasonably well the Heed predictions, why particle separation, both with dE/dx and with dN_{cl}/dx, in GEANT4 is considerably worse (-20%) than in Heed?
3. Despite a higher dN_{cl}/dx Fermi plateau than dE/dx, why this is reached at lower values of $\beta\gamma$ with a steeper slope?
4. These questions are crucial for establishing the particle identification performance at **FCCee**, **CEPC** and **SCTF**
5. The only way to clarify these issues is an experimental measurement!

Beam test motivations

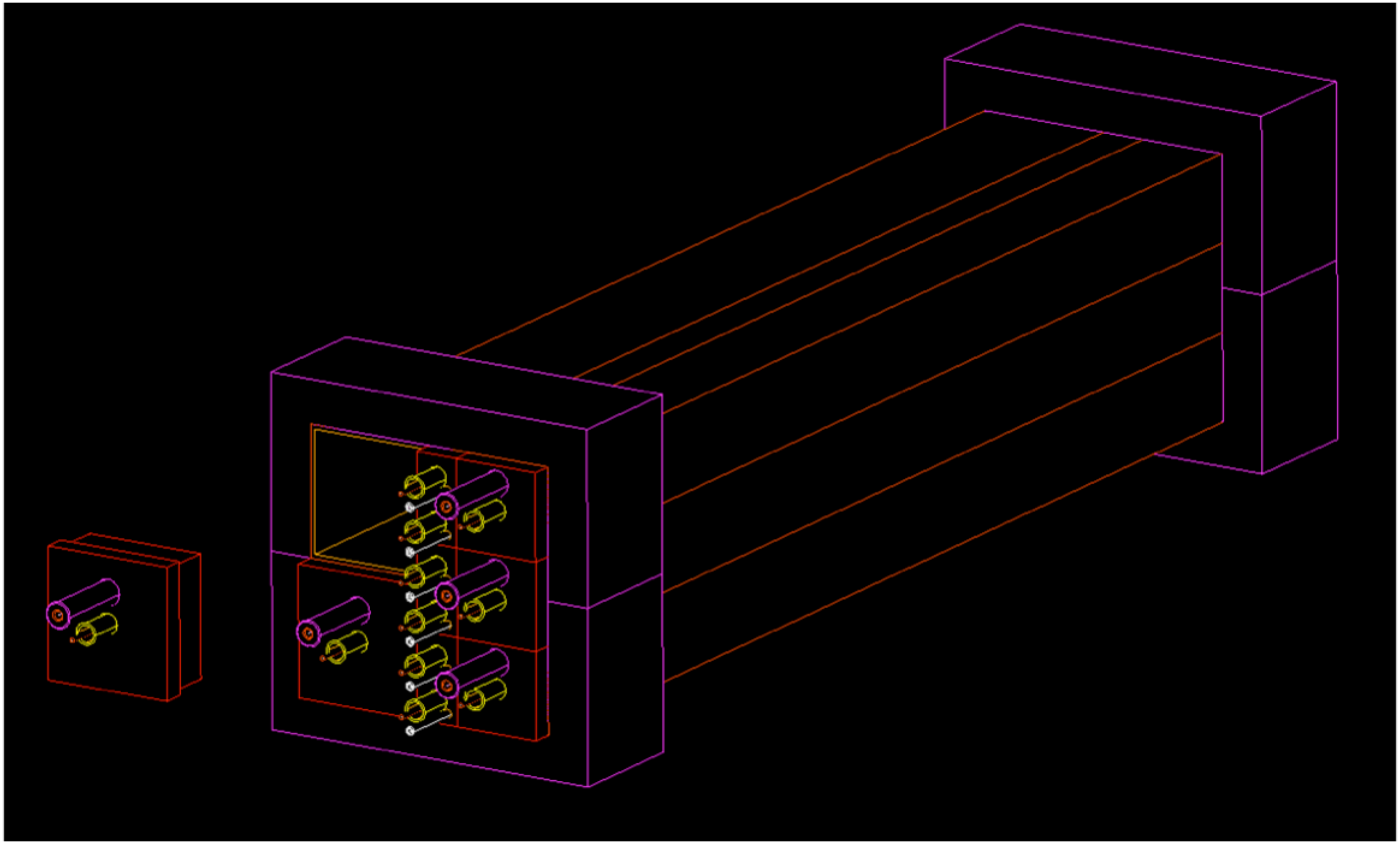
1. First of all, need to assess the **ability to count clusters**:
   at a fixed βγ (e.g. muons at a fixed momentum) count the clusters by
   - doubling and tripling the track length;
   - changing the gas mixture.
2. Establish the **limiting parameters** for an efficient cluster counting:
   - cluster density (by changing the gas mixture)
   - space charge (by changing gas gain, sense wire diameter, track angle)
   - gas gain saturation
3. Measure the relativistic rise as a function of βγ, both in dE/dx and in dN_{cl}/dx, by scanning the muon momentum from the lowest to the highest value (from a few GeV/c to about 250 GeV/c at CERN/H8).

The set up





Layout



List of materials

- 6 drift tubes 1 cm × 1 cm × 40 cm
  - 2 with 15 μm sense wire, 2 with 20 μm, 2 with 25 μm
- 3 drift tubes 2 cm × 2 cm × 40 cm
  - 1 with 20 μm sense wire, 1 with 25 μm, 1 with 30 μm
- 2 drift tubes 3 cm × 3 cm × 40 cm
  - 1 with 20 μm sense wire, 1 with 30 μm
- 11 preamplifier cards (1 GHz, 20 db) + termin.
  - more than just one configuration?
- 11 independent HV power supply channels
- 11 digitizer (2 GSa/s, 12 bit) (WDB + O-scope)
  - max drift time ≈ 2μs for 3 cm drift at 45°
- gas mixing, control and distribution (only He and iC_4H_{10})
- 2-3 trigger scintillators (HV, discr., coinc., TU)

Drift Tubes

- commercial copper (brass) square tubes 30 cm long, 1 mm (or smaller) wall
- end piece: glued peek with center pin and gas in/out-let
- sense wire (soldered to pin)
- amplifier connected to the pin
- (terminated back-end)

Aim of a **first test** (October 2021) in parasitic mode (fixed muon momentum 180 GeV/c)

- number of clusters versus **cell size** and **gas mixture**:
  - **12** (90/10), **15** (85/15), **18.5** (80/20), **21.5** (75/25) for **m.i.p. in 1x1 cm^2**
  - **24** (90/10), **30** (85/15), **37** (80/20), **43** (75/25) for **m.i.p. in 2x2 cm^2**
  - **36** (90/10), **45** (85/15), **55** (80/20), **64** (75/25) for **m.i.p. in 3x3 cm^2**
  - **measure counting efficiency versus cluster density**
- number of clusters versus **space charge effects**:
  - different **gas gain** (from 1×10^5 to 5×10^5) for He/iC_4H_{10} = 90/10
  - sense wire diameters **15, 20, 25, 30 µm** for the same **gas gain** (5×10^5)
  - angle between track and wire: 0°, 30°, 45°, 60° for the same **gas gain** (5×10^5)

Aim of a **second test** (spring 2022) as main users (muon momentum 6 ÷ 250 GeV/c)

- choose optimal operating conditions (counting efficiency):
  - gas mixture
  - gas gain
  - sense wire diameter
  - track angle
- scan muon momentum ($\beta\gamma$ = 40 ÷ 1800) and measure relativistic rise: essential to predict particle separation independently of the assumptions in Heed and Geant4 simulations.