RD_FA Collaboration Meeting
Università degli Studi di Milano
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Calorimetry and IDEA Vertical Slice Simulations

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simulations, simulations and simulations

- Dual-Readout Simulations
- IDEA Vertical Slice Simulations
- DREAM with Staggered Fibres

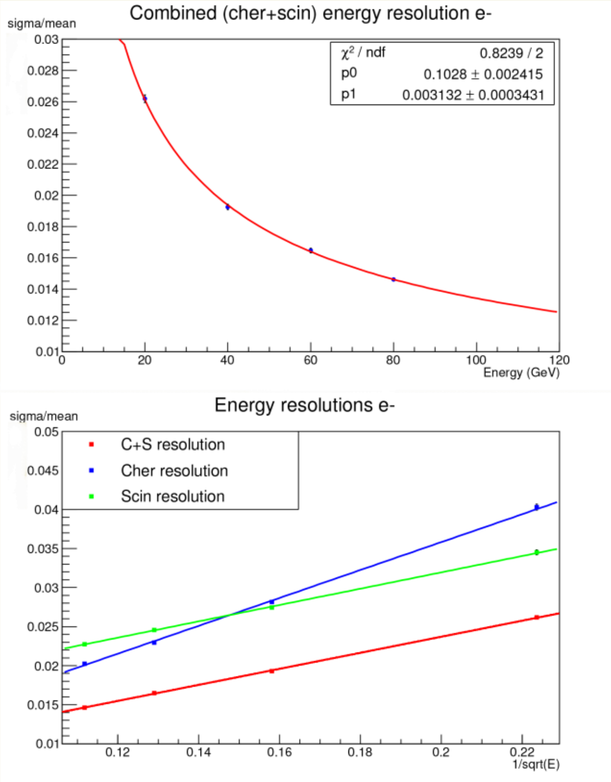
+ hints on future fast and full simulations of the IDEA Detector…

Dual-Readout Simulations

Past and Present

Dual-Readout Simulations

We simulated with Geant4.10.4.p01 a 90x90x250 cm^3 dual-readout calorimeter reaching excellent energy resolutions:

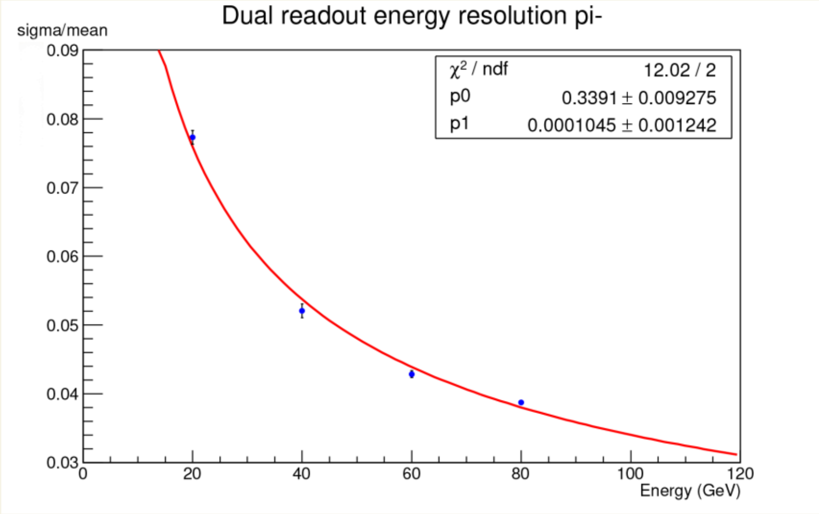


Electromagnetic

$$\frac{\sigma_{EM}}{E} = \frac{10.3\%}{\sqrt{E}} + 0.3\%$$

Hadronic

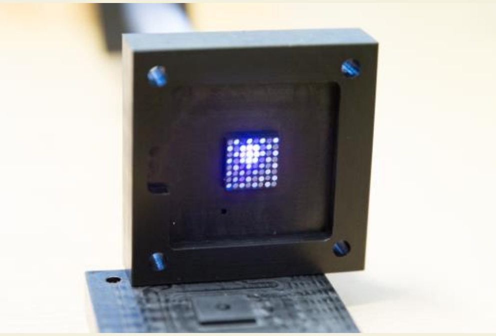
$$\frac{\sigma_{HAD}}{E} = \frac{34\%}{\sqrt{E}}$$

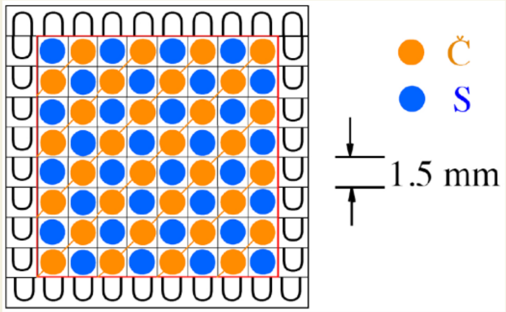


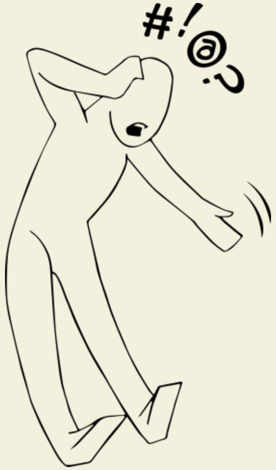
Dual-Readout Simulations

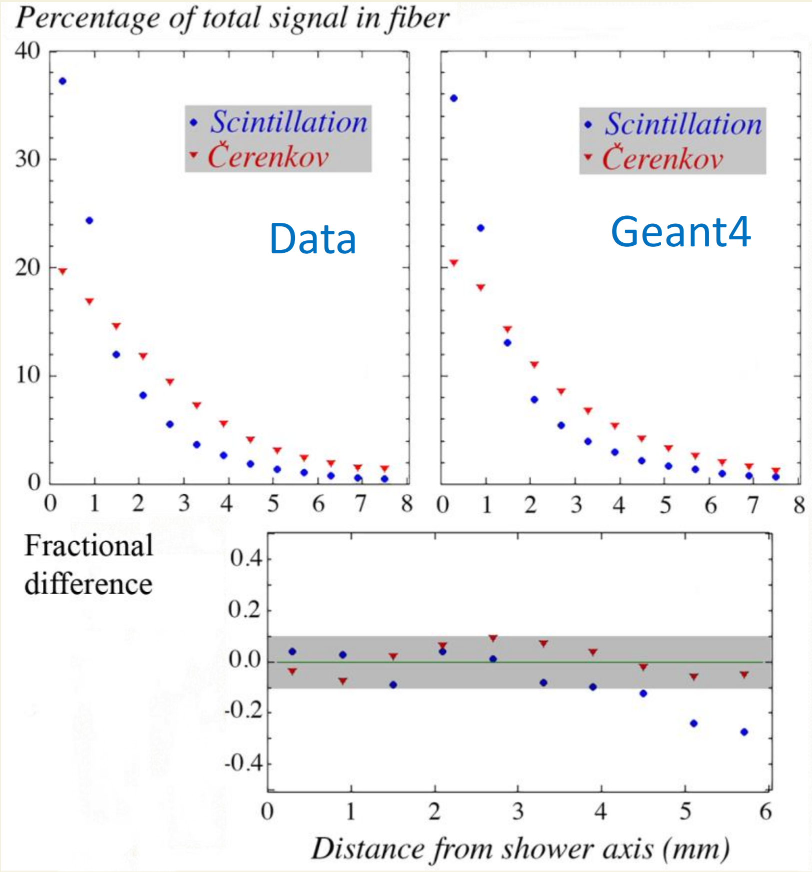
The same simulations were in very good agreement with data (taken with the SiPM module) while describing the electromagnetic shower profile very close to the shower axis.

Data taken with a 1.5x1.5x112 cm^3 brass module with an average em energy containment of 45%







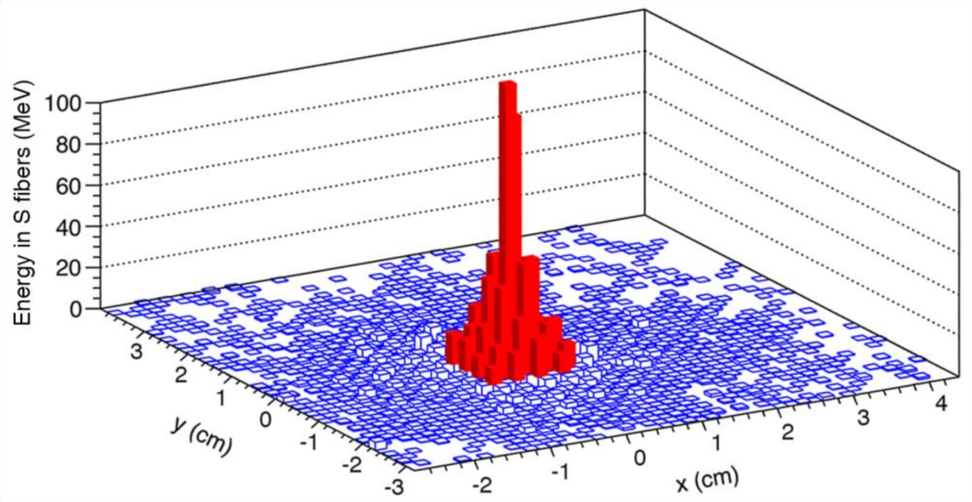


arXiv:1805.03251v1

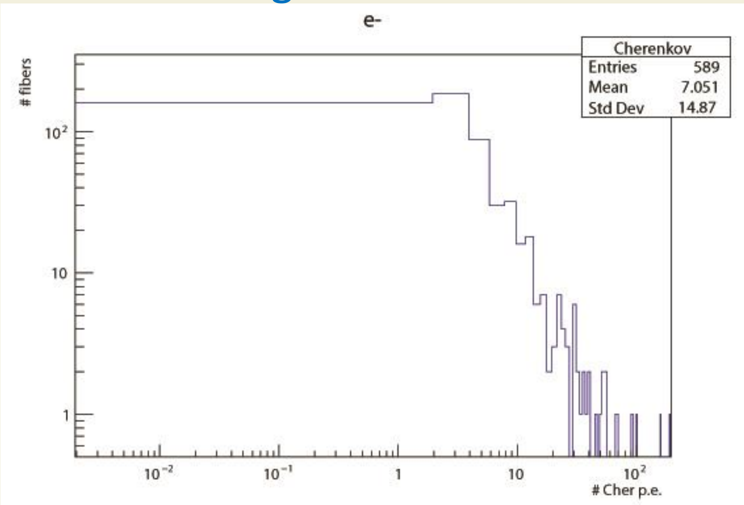
What we discovered with simulations

100 GeV electron

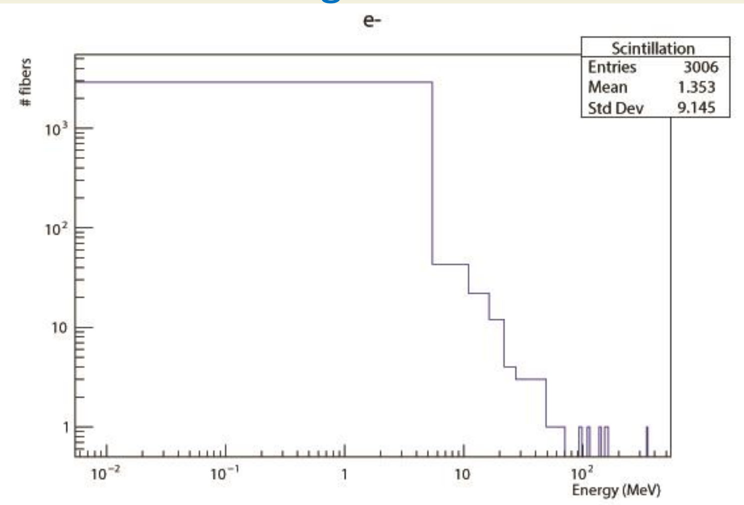
50 GeV electron



Cherenkov Signal vs. # clear fibres



Scintillation Signal vs. # scin fibres



The energy deposition is driven by many very small contributions and few extremely large: 10% of an em shower is deposited within 1 mm from the shower axis, i.e. in a single fibre!

Possible problem for the SiPM readout -> to be better studied in September test beam.

DREAM + Machine Learning

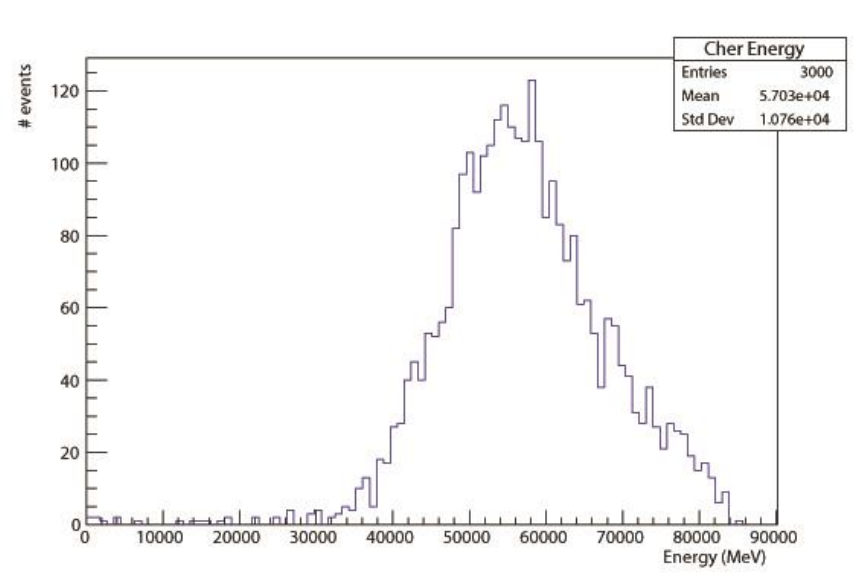
Now

Traditionally a dual-readout calorimeter must be calibrated at the em scale, i.e. with electrons.

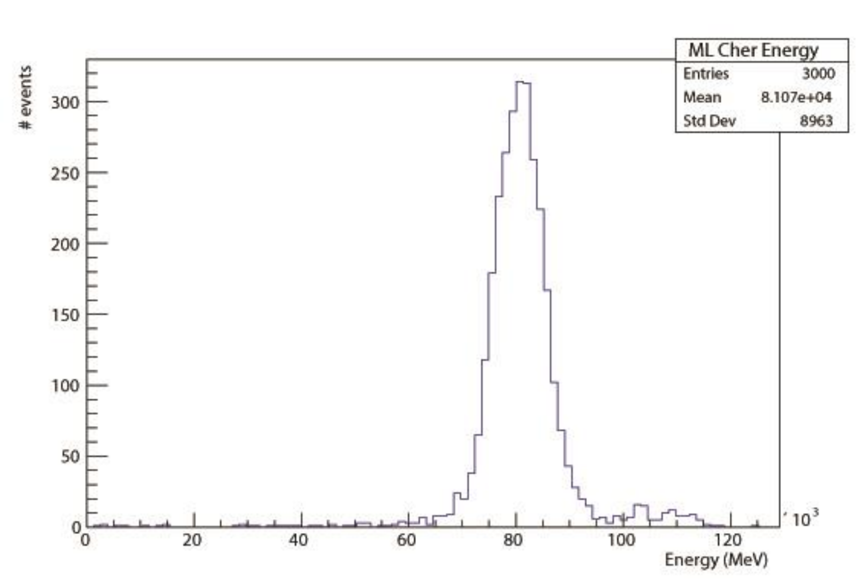
However, we discovered that with a very simple machine learning alogorithm a dual-readout calorimeter can be calibrated also with hadrons.

80 GeV pion

Traditional (dual-readout) method
Energy reconstructed w/ Cherenkov signal



Machine learning method
Energy reconstructed w/ Cherenkov signal

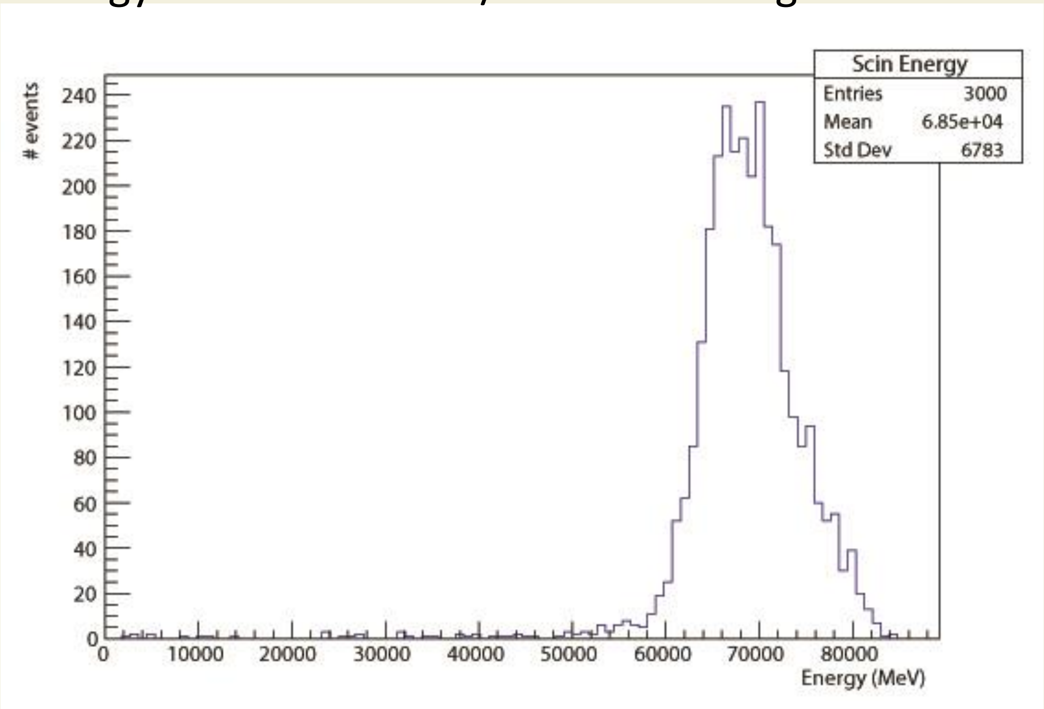


DREAM + Machine Learning

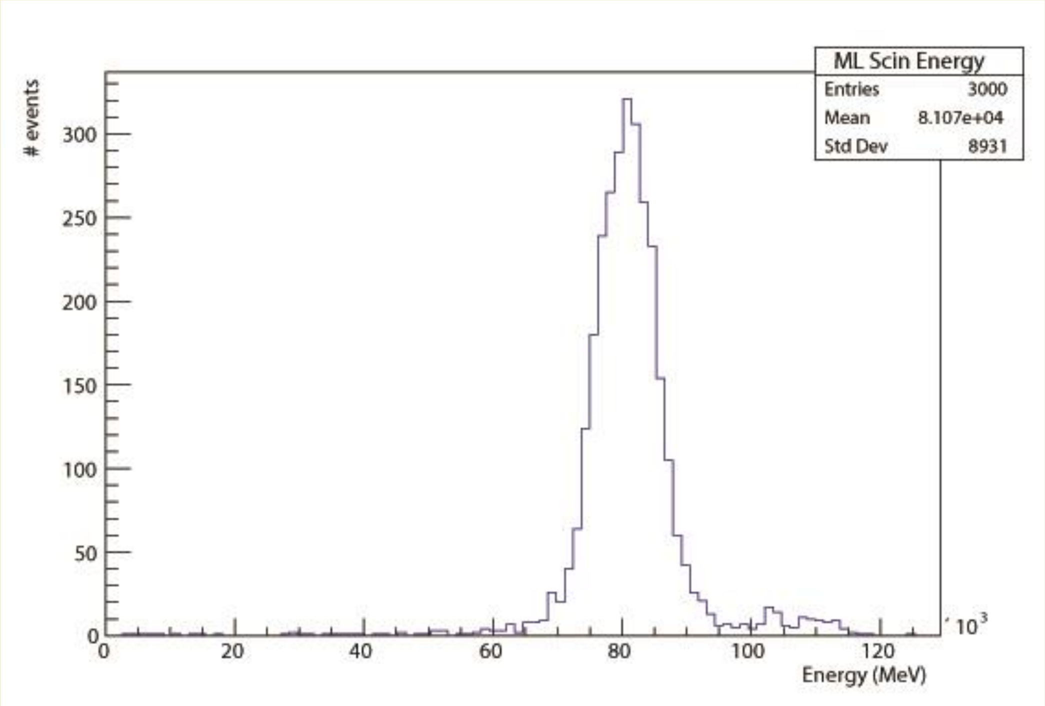
As a result, the correct hadron energy is reproduced withboth channels (Cherenkov and scintillation)

80 GeV pion

Traditional (dual-readout) method
Energy reconstructed w/ scintillation signal



Machine learning method
Energy reconstructed w/ scintillation signal



Full simulations toward fast simulations

The implementation of the IDEA detector into the Papas fast simulation framework is the fastest way to get physics out of it. What do we need in that respect:

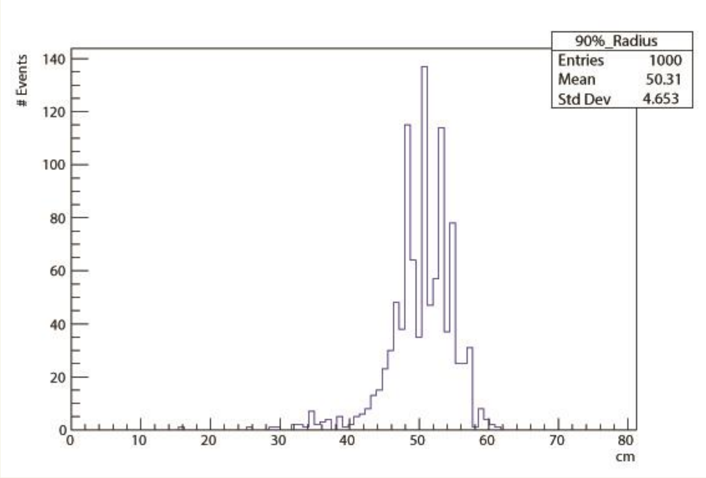
- ✓ Simple geometry
- ✓ Material
- ✓ Resolutions
- ? Cluster size to model the calorimeter granularity

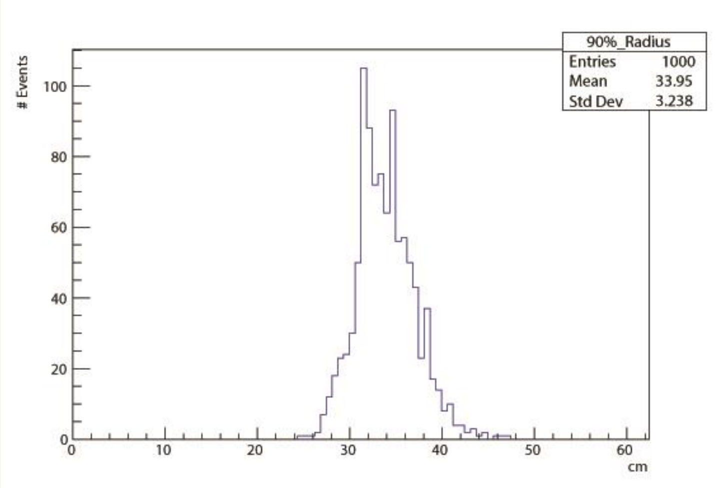
Brass

80 GeV pion: 99.9% energy contained with a radius of 50.1 cm

100 GeV electron: 99.9% energy contained with a radius of 33.95 cm

A first help by Colin Bernet during Patrizia Azzi's meeting:
https://indico.cern.ch/event/738515/





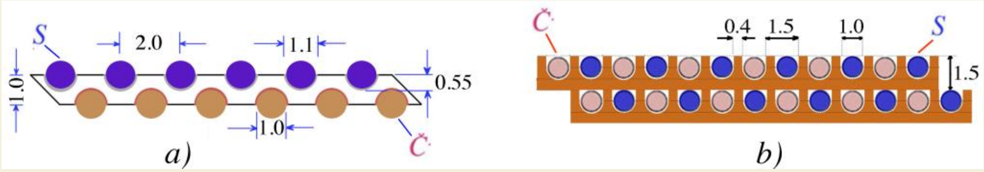
IDEA Vertical Slice Simulation

PRELIMINARY

RD_52 Calorimeter + Preshower

- ✓ The RD_52 calorimeter is now fully simulated: 9 modules, 30x30x250 cm^3, lead based, 19044*2 fibres.

Lead geometry

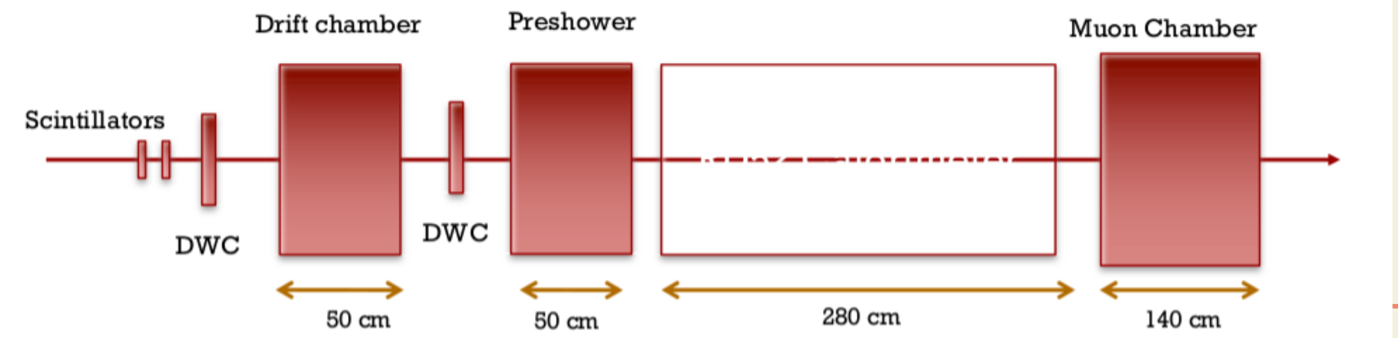


Brass geometry

- ✓ The preshower is now fully simulated: 10x10 cm^2 GEM chamber with a very detailed geometry (even Kapton foils included!).

...many thanks to Lia Lavezzi & Gianluigi Cibinetto

- ? Strategy: we take the interaction point on the anode (X,Y from MC truth) and apply a gaussian smearing of 130 µm. Do we want any information on energy deposition in the preshower?
- Downstream of the calorimeter there will be GEM+µRWell: µRWell description will be ready in two weeks.
- Drift chamber not included yet.



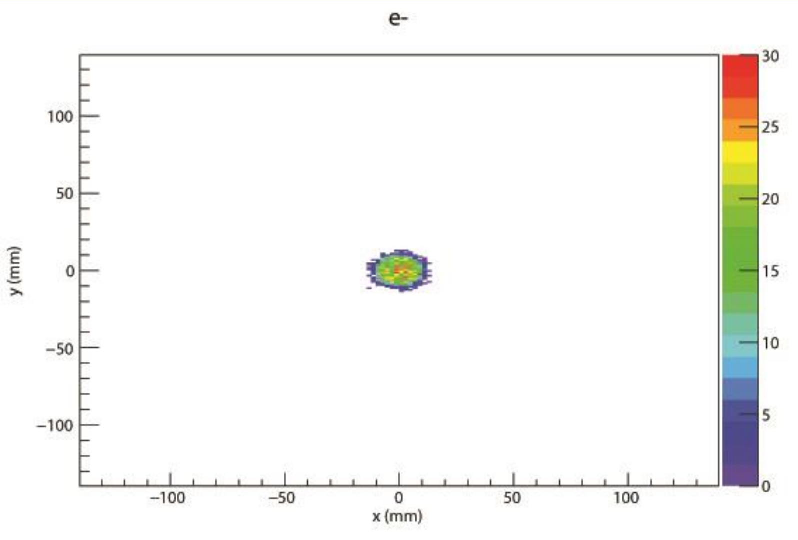
GEM tracking vs. calorimetry tracking

Taking the signal from each fibre turns the calorimeter itself into a good tracker: the beam profile is very well reproduced with the calorimeter alone by calculating the signal bariocenters.

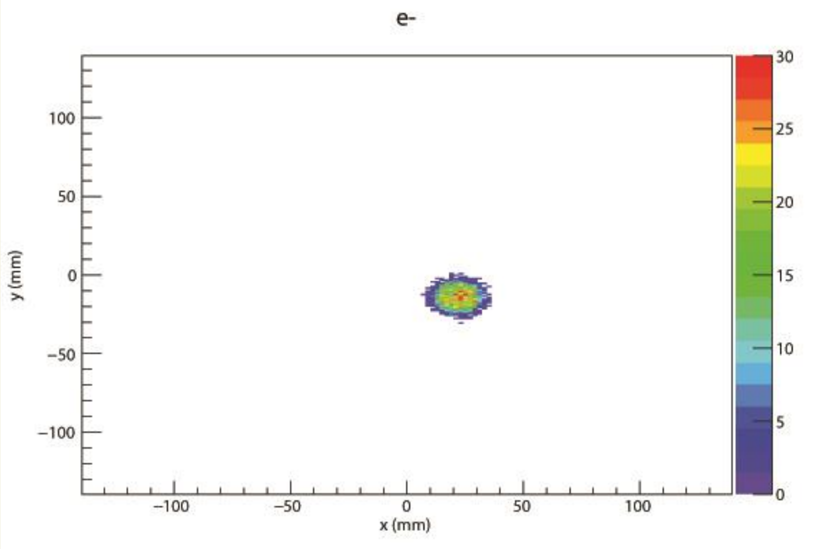
10 GeV electrons

Calorimeter slightly rotated to avoid channeling

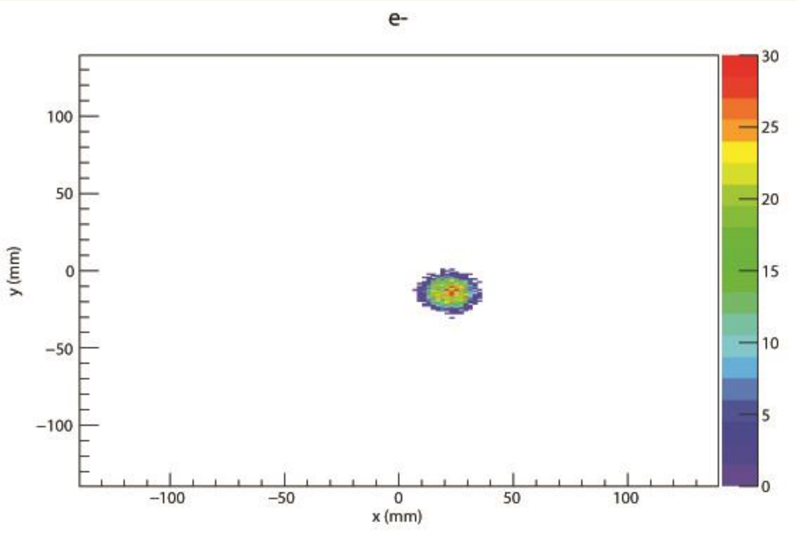
GEM



Scintillation

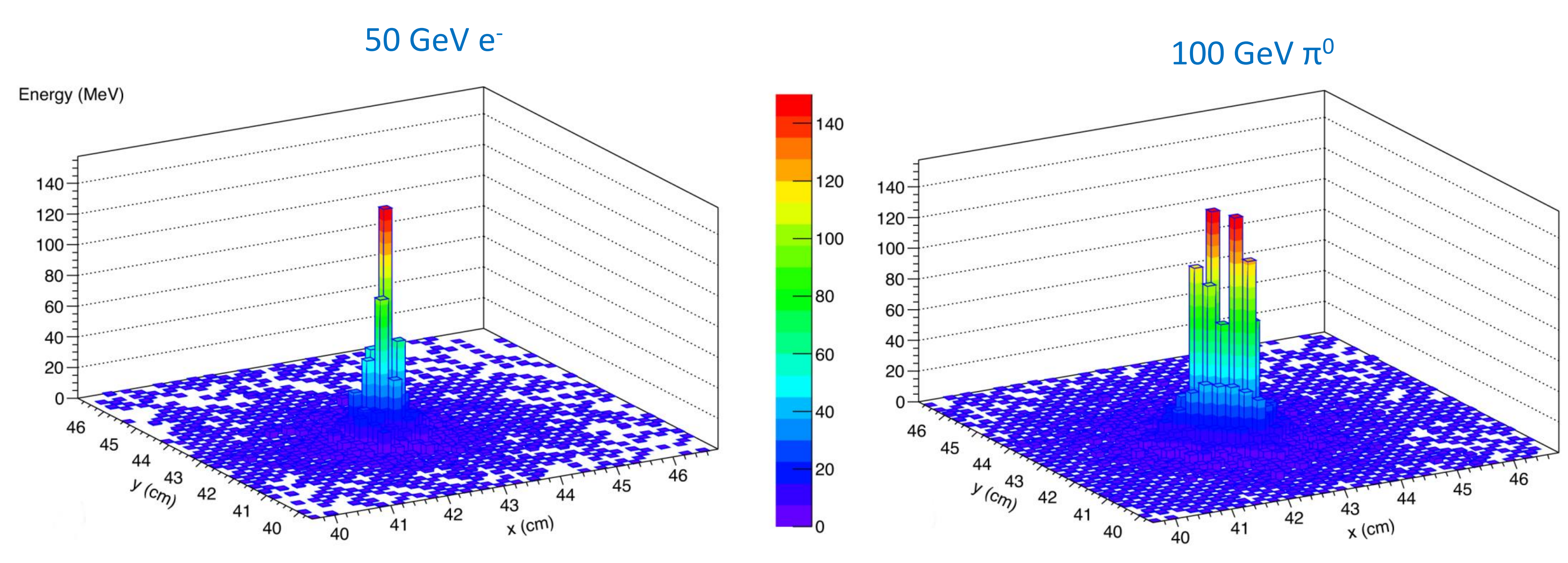


Cherenkov



e^-/π^0 separation

The extremely high granularity may in fact help in identifying a single neutral pion as two separated em showers.



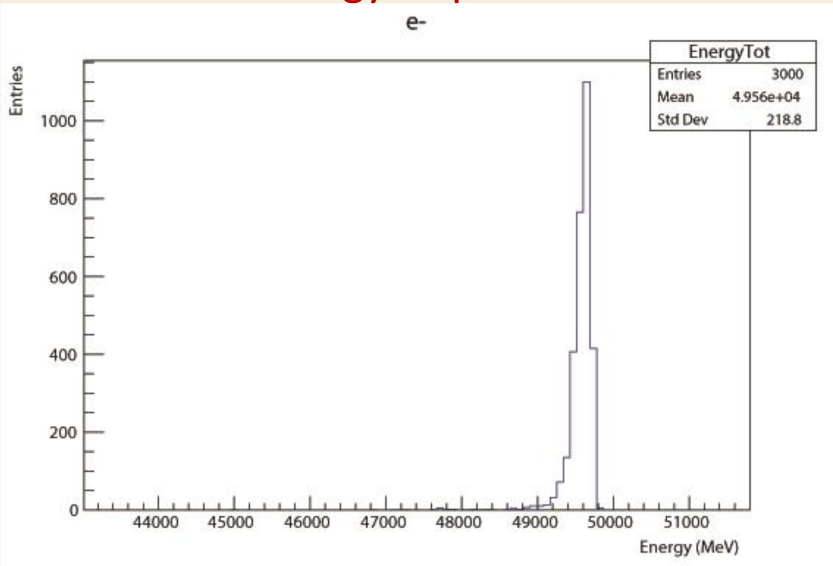
Energy containment and preshower effect

We estimated an average em energy containment of 99% for the RD_52 lead calorimeter.

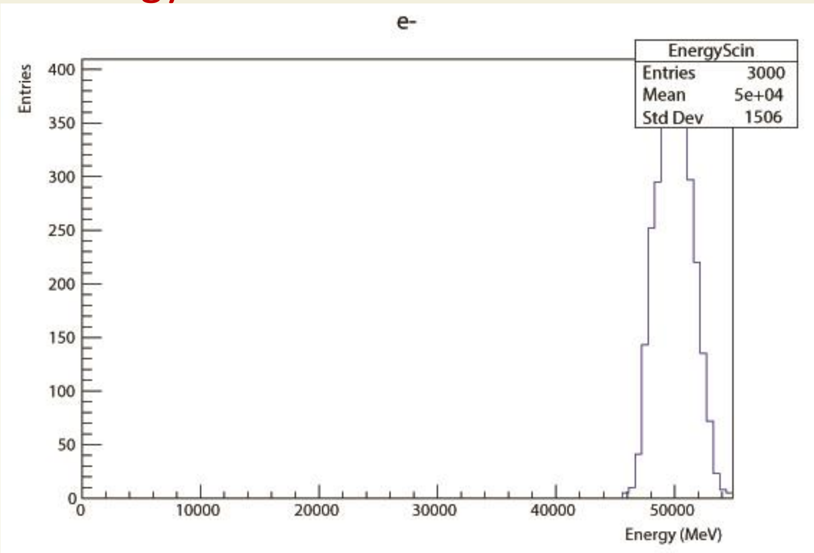
❓ With 0.56 cm of iron in front of the preshower the em energy resolution is not spoiled at all. What kind of absorber are we going to use in next test beam?

50 GeV electrons

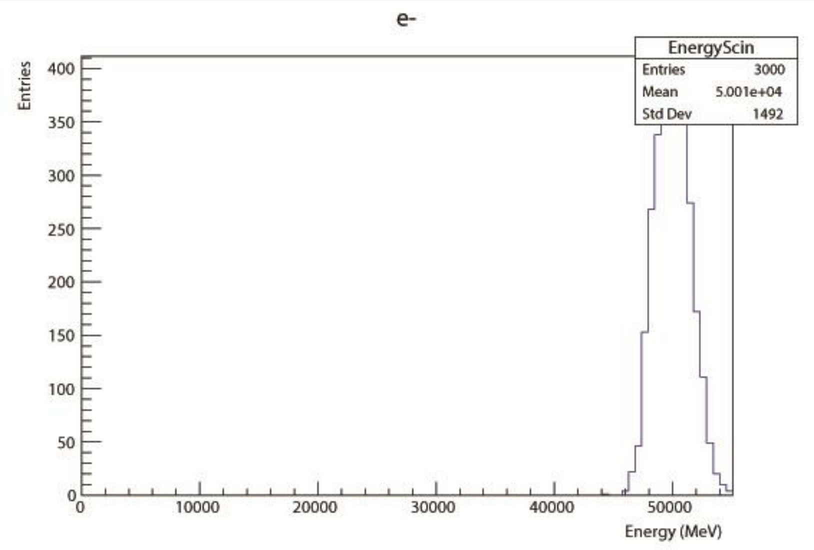
Energy Deposit



Energy Reconstructed with absorber



Energy Reconstructed without absorber



Dream with Staggered Fibers

PRELIMINARY

The idea

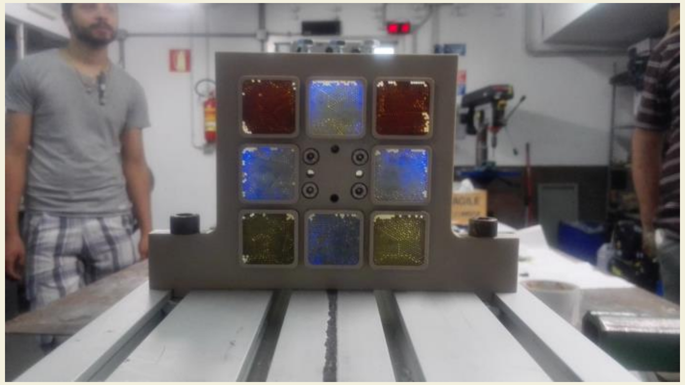
The possibility to have a calorimeter with half of the fibers starting ≈ 1 λ_{INT} after the front face could help in the particle ID process in a multiparticle environment.

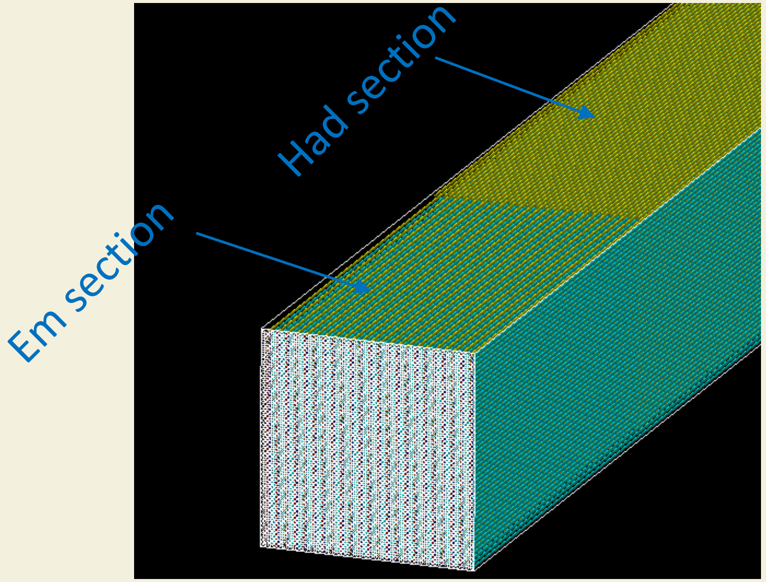
A 9.3x9.3x250 cm^3 lead module will be disassembled and rebuilt in Pavia with short and long fibers -> Geant4 precits a 90% em energy containment.

The RD52 lead calorimeter

1 λ_{INT} = 25 cm

1 X_0 = 3.1 cm





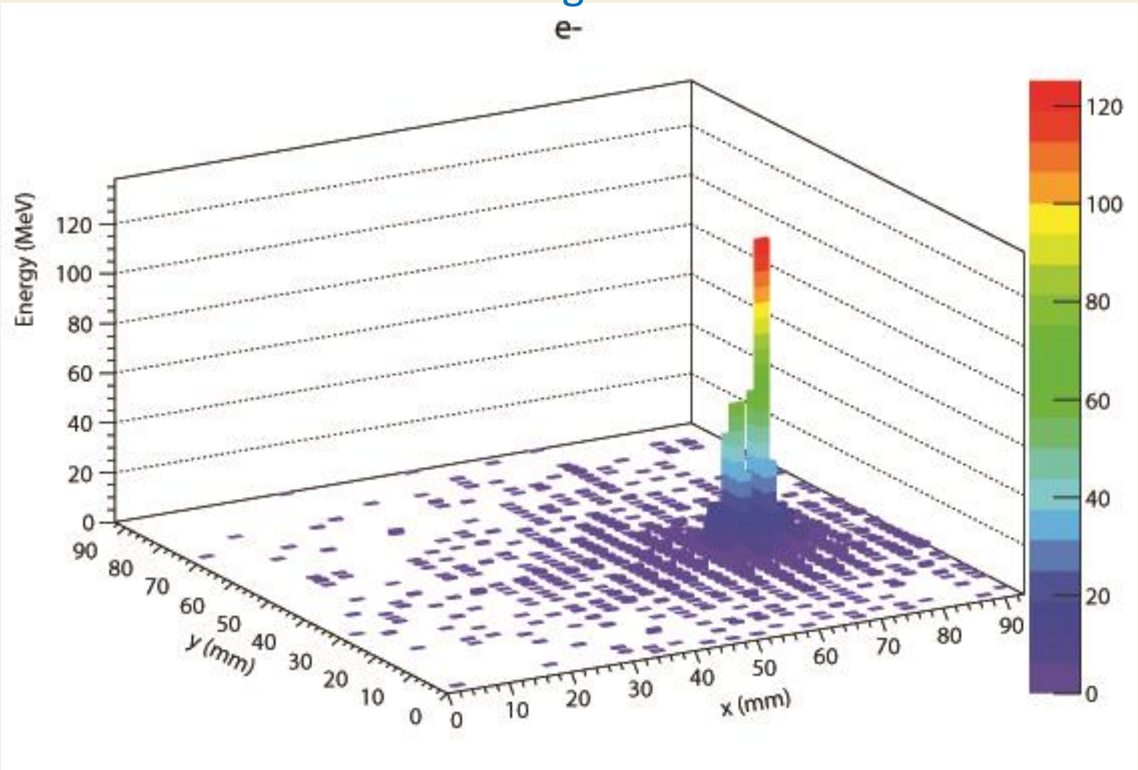
Simulations already implemented with air at the beginning of displaced fibers -> probably need to fill it with blind plastic.

First results with staggered fibers

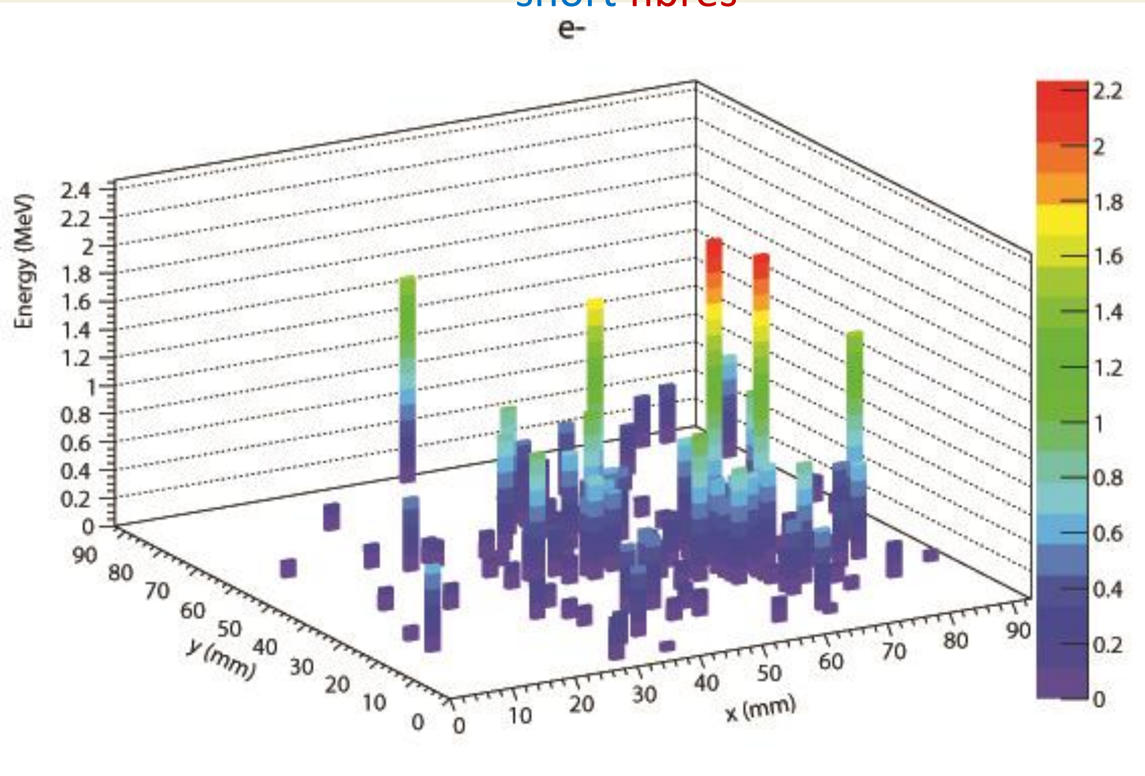
When dealing with electrons almost all the signal is deposited in the first section!

50 GeV electron

Energy deposited in Scintillating long fibres



Energy deposited in Scintillating short fibres

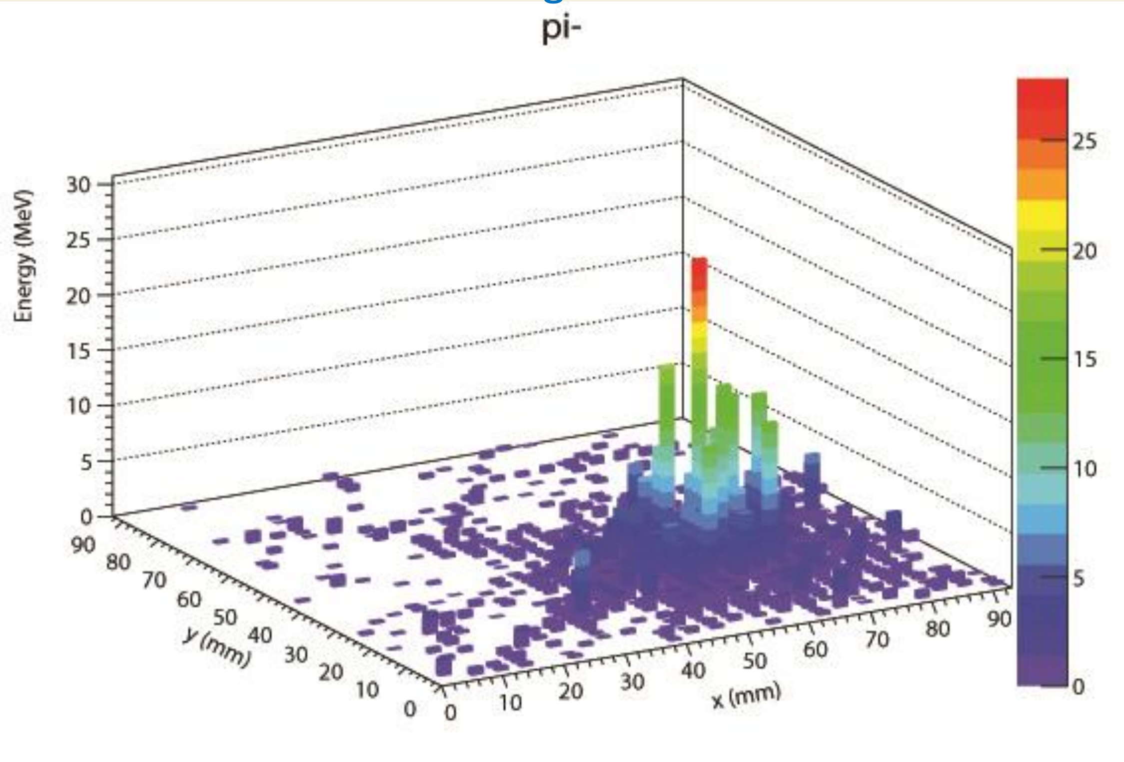


First results with staggered fibers

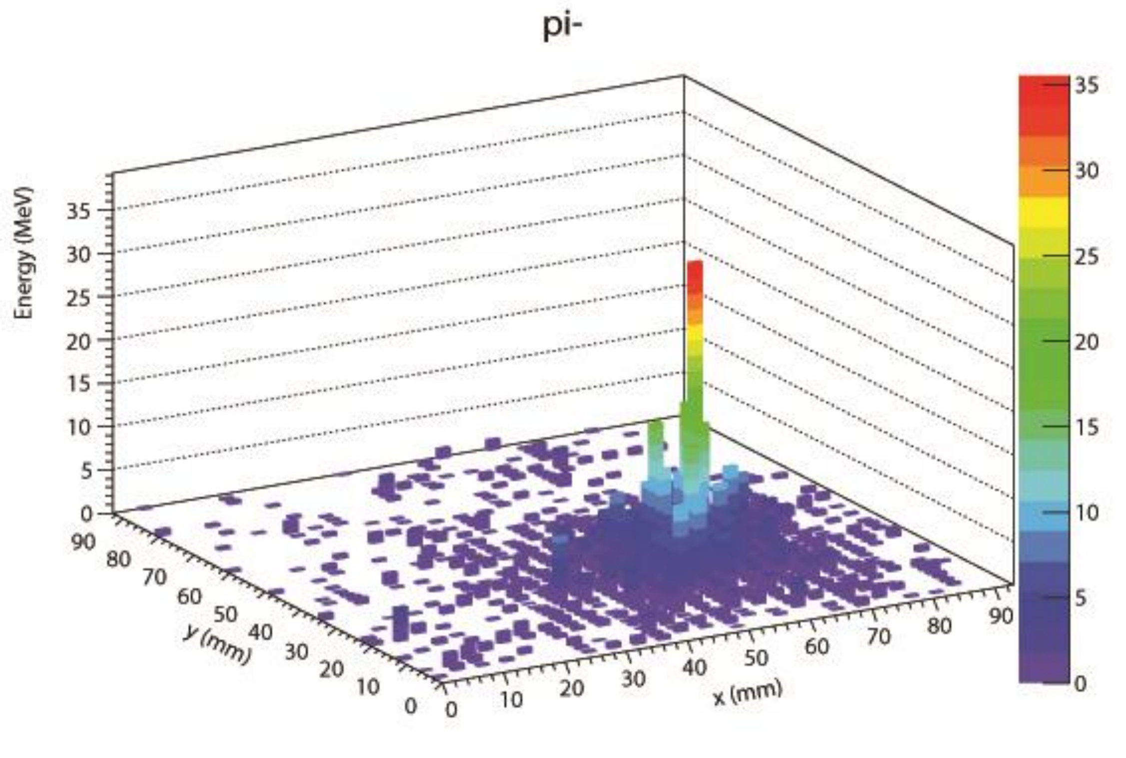
When dealing with hadrons the two signals are much more similar.

50 GeV pion

Energy deposited in scintillating long fibres



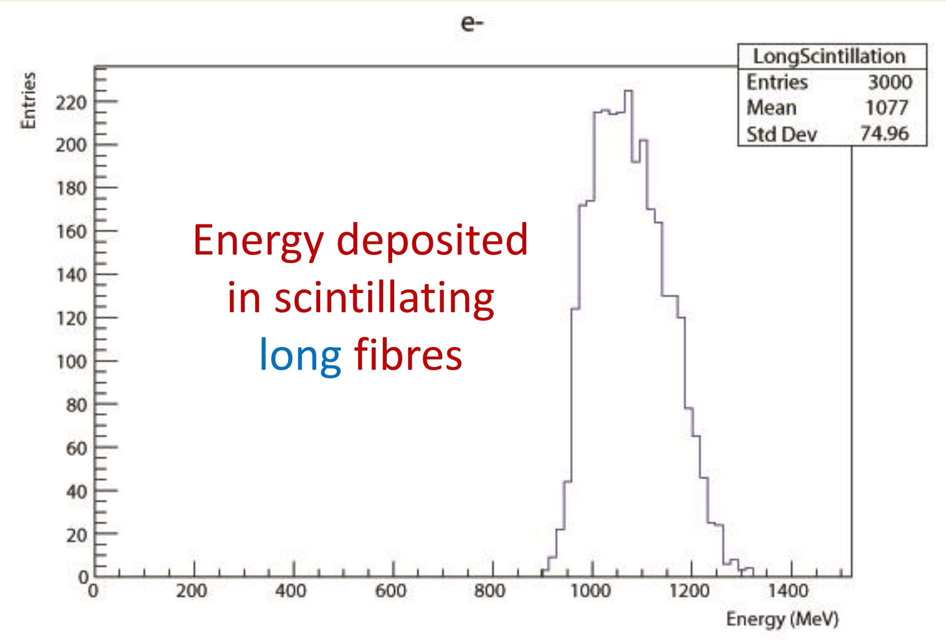
Energy deposited in scintillating short fibers

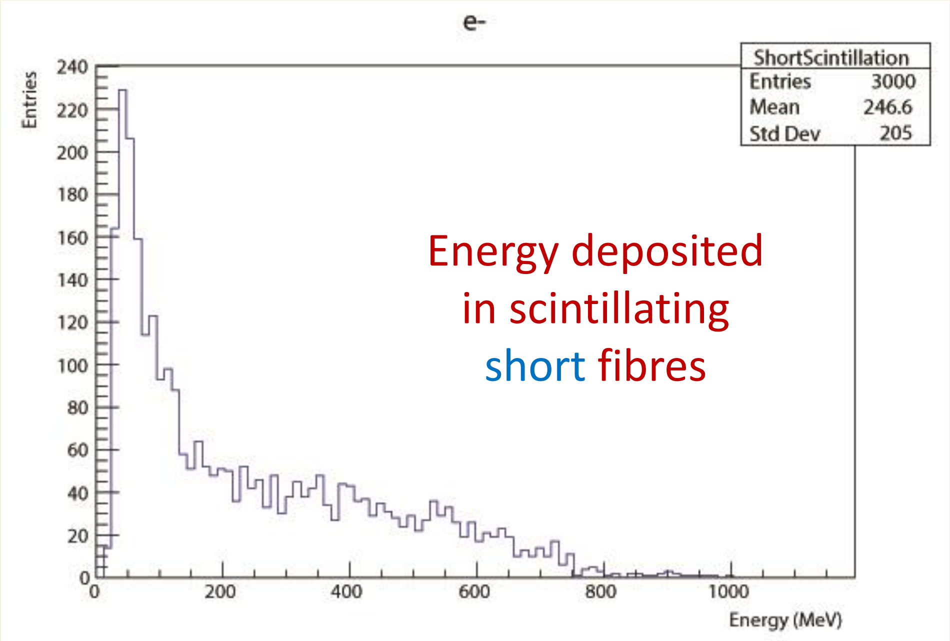


However, some open issues…

- ? How to calibrate this detector? A possible solution might come from tilting the module in such a way that electrons hit the calorimeter already at second compartment (the hadronic one).
- ? Simulations show very long tails in the short compartment for electron events. Still to be understood…

50 GeV electron





Conclusion

Full simulations of a dual-readout calorimeter standalone showed that this detector can achieve an extremely good energy resolution for electrons and hadrons togheter with good particle identification capability.

Many possible paths:

- Implementation of the IDEA Detector into the Papas framework: fast and relatively easy + possible help to start from Colin Bernet.
- Finish the IDEA Vertical Slice full simulation: need to know what kind of meaurements (especially if combined) we would like to have.
- Bring the dual-readout calorimeter into the FCC(ee)SW.