SDHCAL Optimisation strategy

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On behalf of the SDHCAL-GRPC groups

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- Hardware R&D and optimisation
- Software
  - Current energy resolution
  - Plans to improve energy resolution
  - Reconstruction algorithms
  - Some optimisation studies

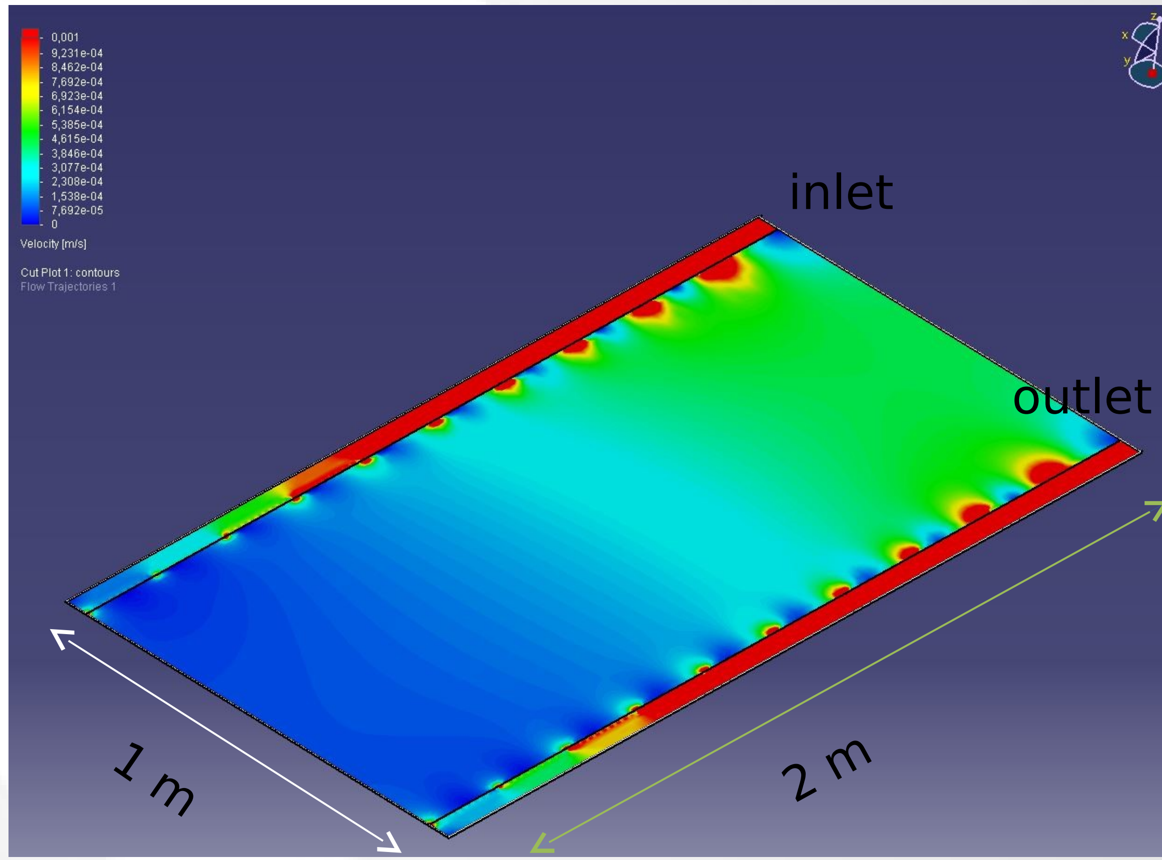
Finalize Baseline Detector : large GRPC

Large GRPC for ILD:

GRPC with a surface
≤ 3 m^2 are needed.

We intend to build
a $2m^2$ GRPC
(glass are already there).

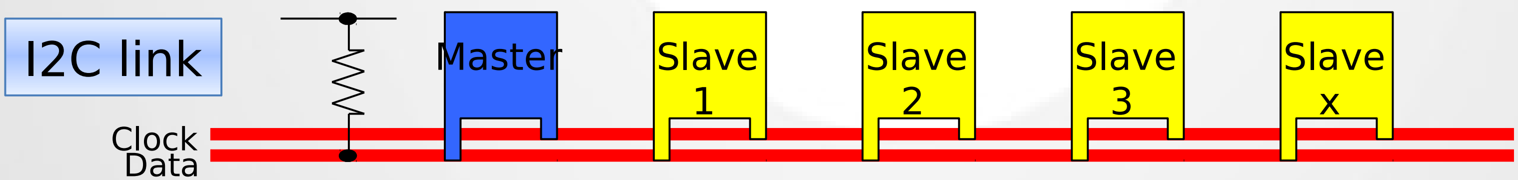
We are currently studying
the gas distribution system
to ensure a good gas
renewal.



Upgrade Baseline Detector : new ROC

HARDROC3 chip (HR3)

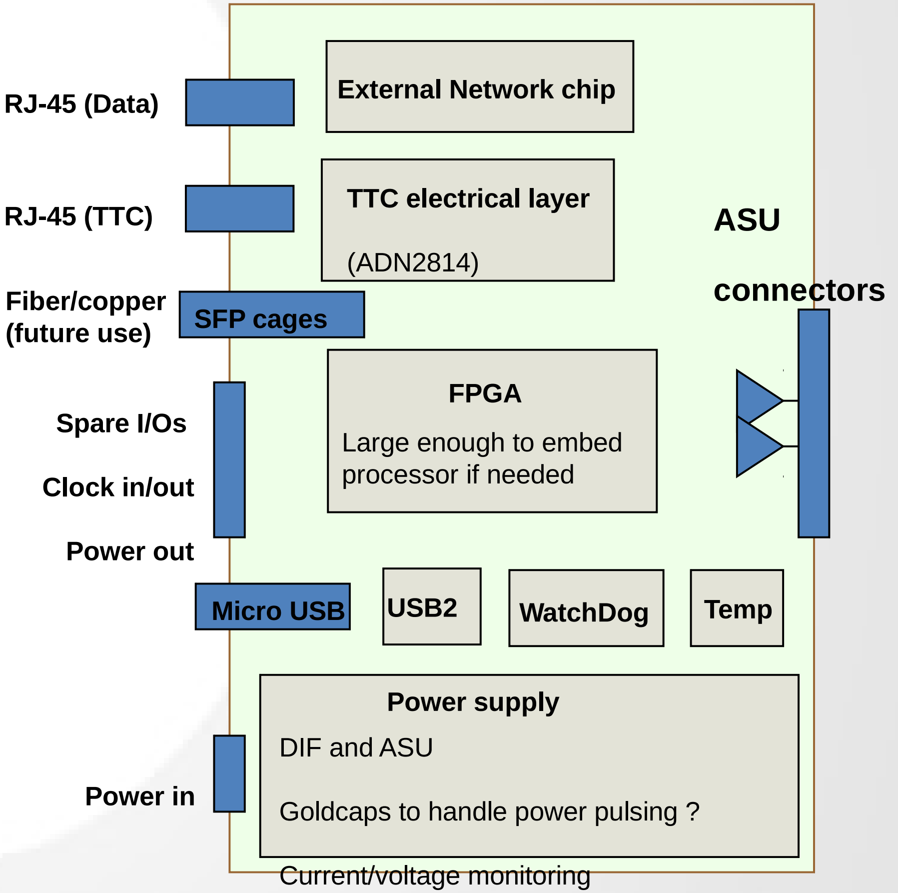
- **Wider dynamic range for thresholds.**
- Include a temperature sensor (slope = 6mV/°C)
- Better clocking : PLL, input frequency 2.5 MHz =>output frequency: 10, 20, 40, and 80 MHz available
- Add a « Roll mode » using circular memory for test beam.
- Major improvement : **I2C link**
  - **64 independant channels**
  - **No need to daisy-chain the communcation between ROCs**
  - **Triple voting communication (Slow Control)**



Upgrade Baseline Detector : DIF & DAQ

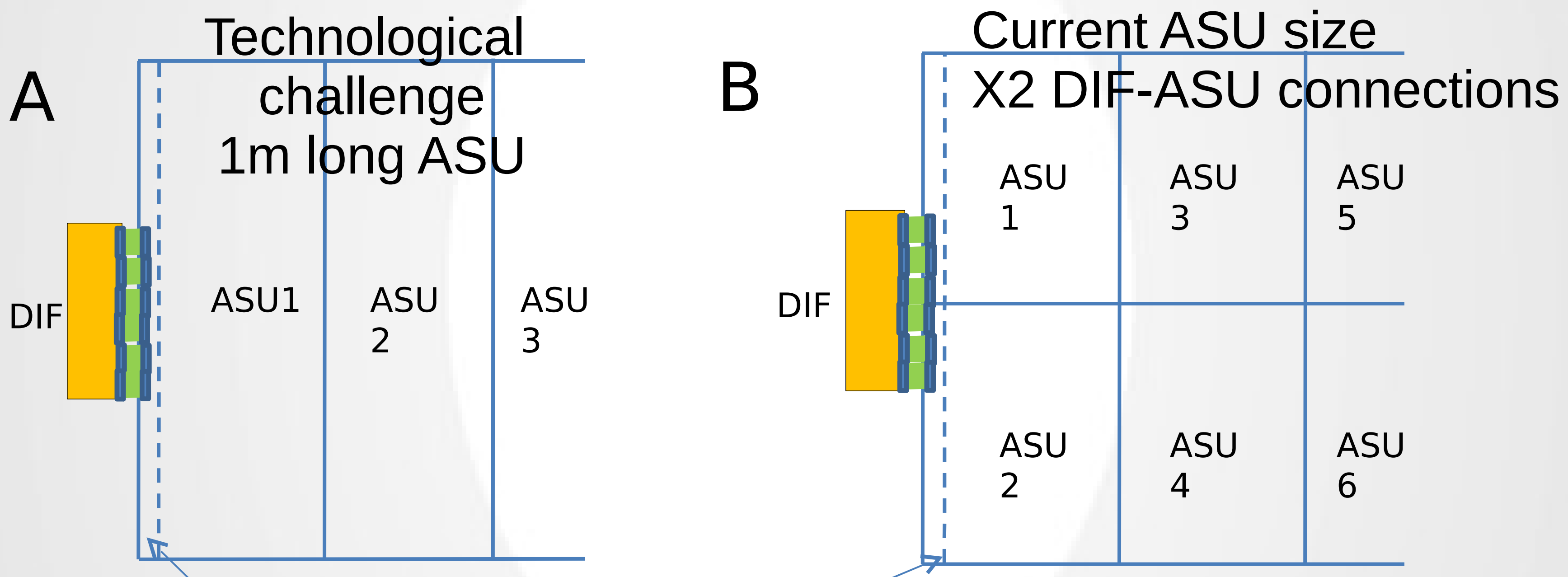
DIF: Designed for ILD SDHCAL

- Only one DIF per plane. For the maximun lenght plane (1x3m) the DIF will handle 432 HR3 chips
- Slow control through the new HR3 I2C bus
- Data transmision to DAQ by Ethernet using comercial switches for concentration
- Clock and syncronization by TTC (developped for LHC)
- USB 2.0 for debugging



Upgrade Baseline Detector : new ASU

One DIF per plane : rearrange ASU and ROC to minimize number of DIF-ASU connections

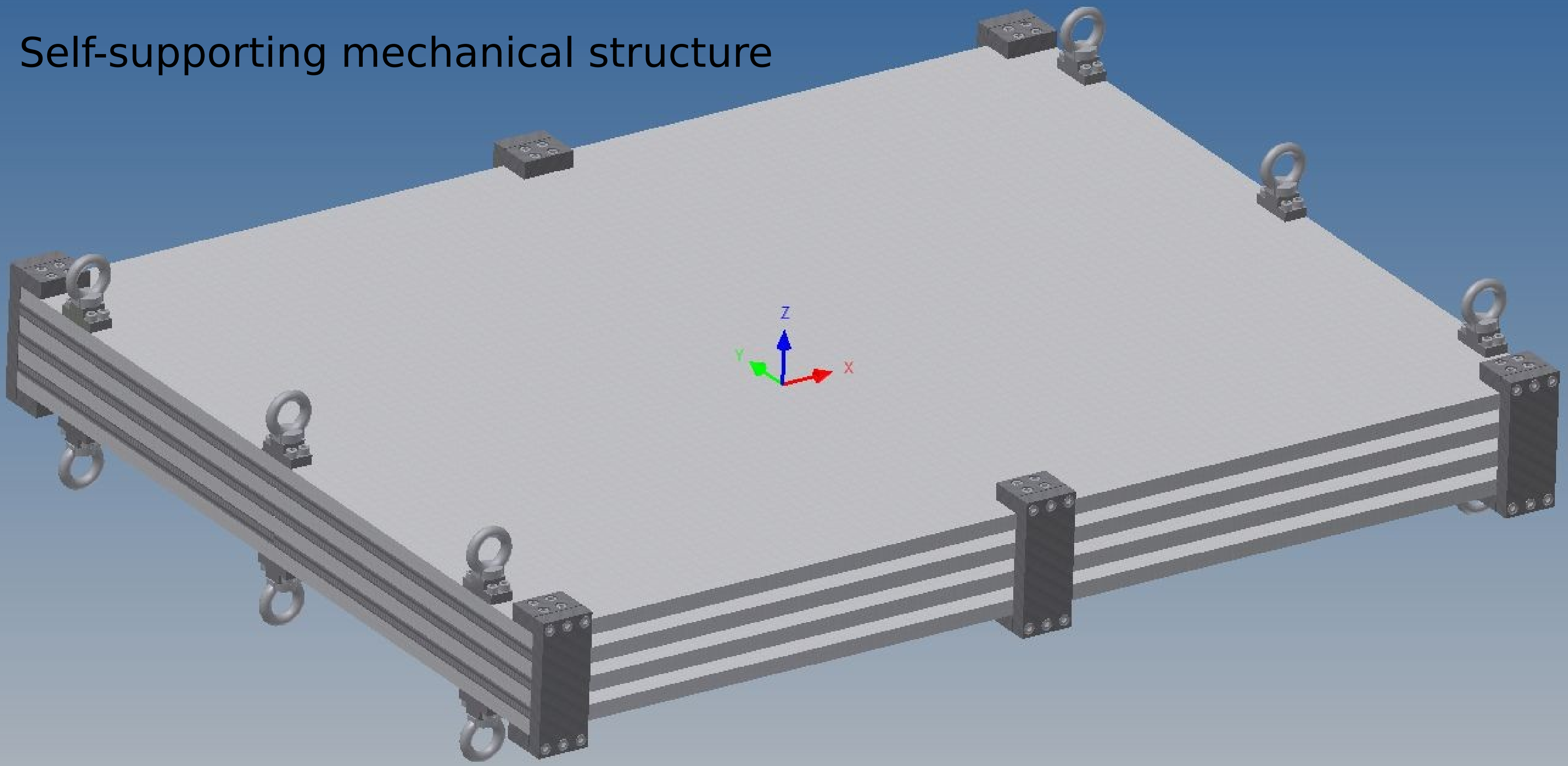


First ASU extension for drivers & connectors

- More design option for connectors
- Heating component (drivers) out of the detector.

Upgrade Baseline Detector : structure

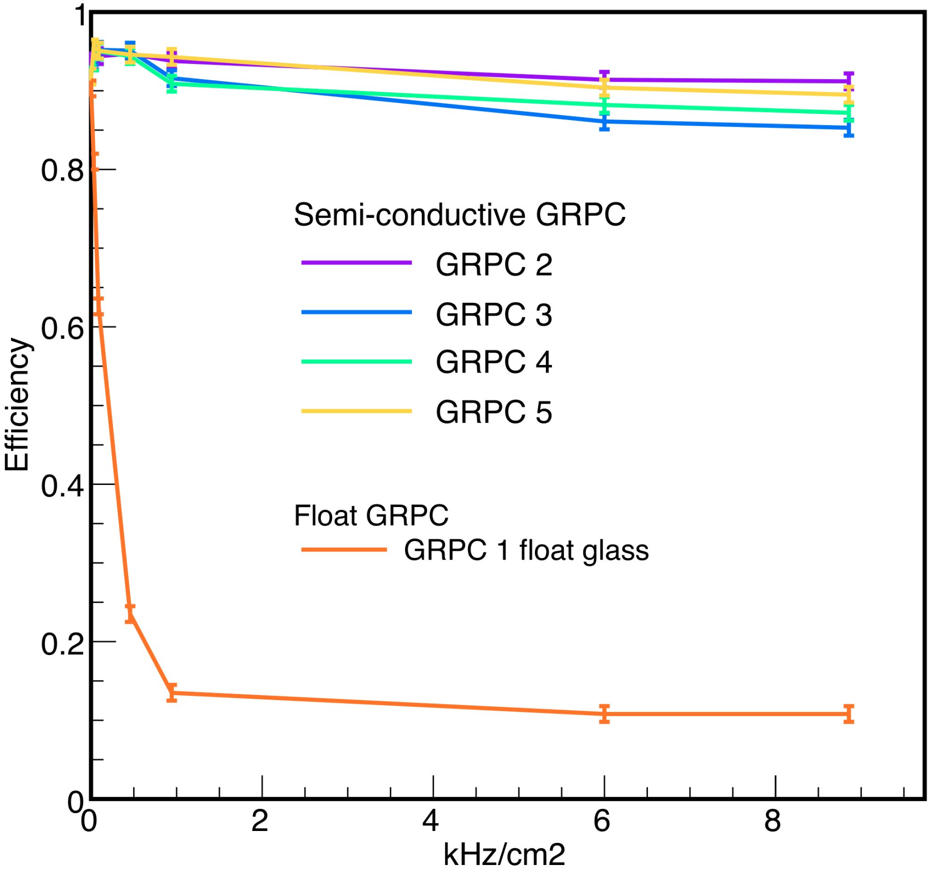
Self-supporting mechanical structure

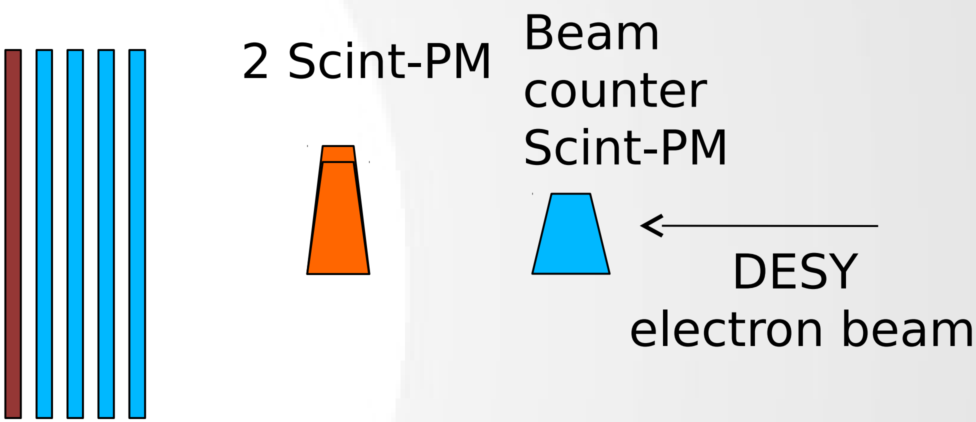


Tests techniques on how to maintain the structure (bolt, welding, ...)
Cost/stability optimisation

Hardware optimisation : doped glass

Semi-conductive glass has lower resisitivity than float glass.



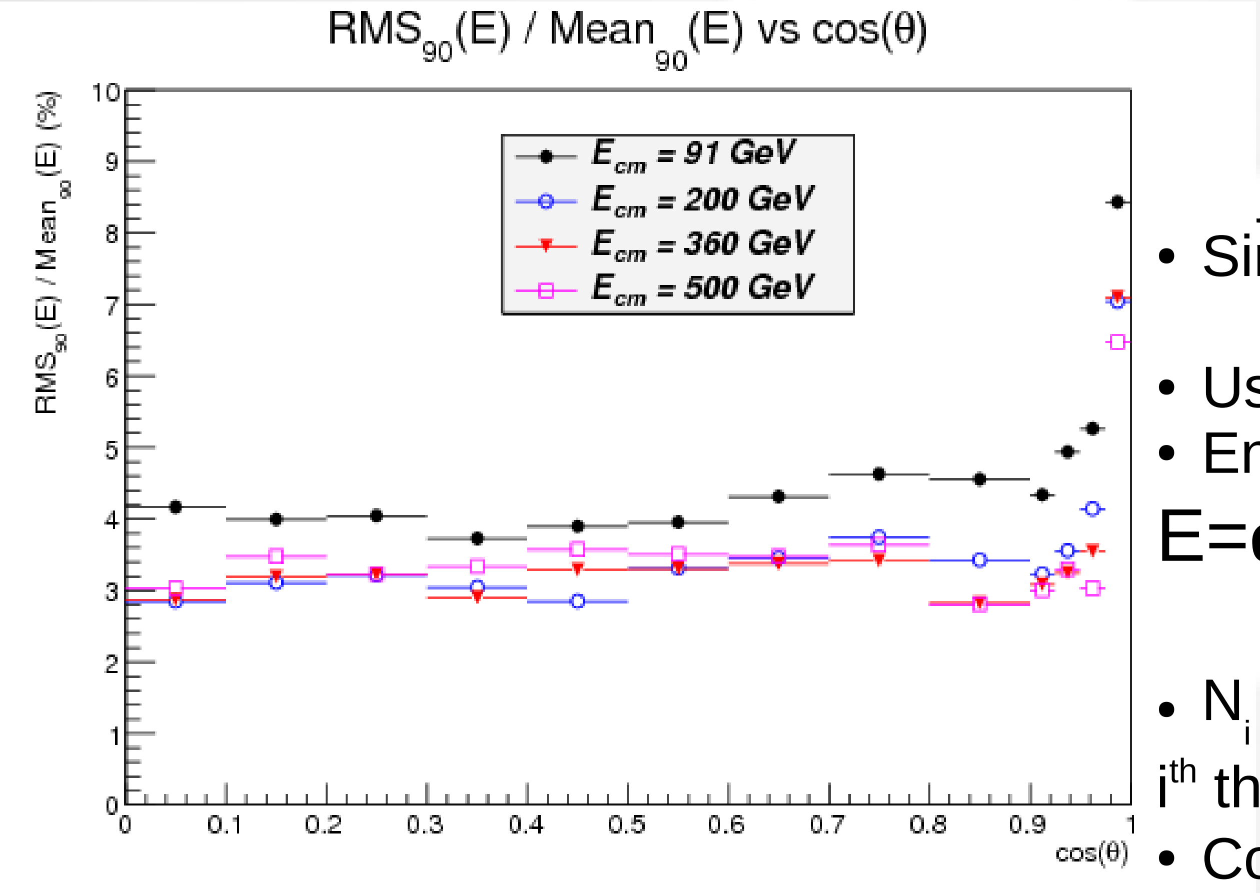


1 standard GRPC
+ 4 semi-conductive GRPC (1/6 m^2)

Still efficient at 9kHz/cm^2 (max available rate)

We have a technological solution for higher particle fluxes if needed.

SDHCAL optimisation : software



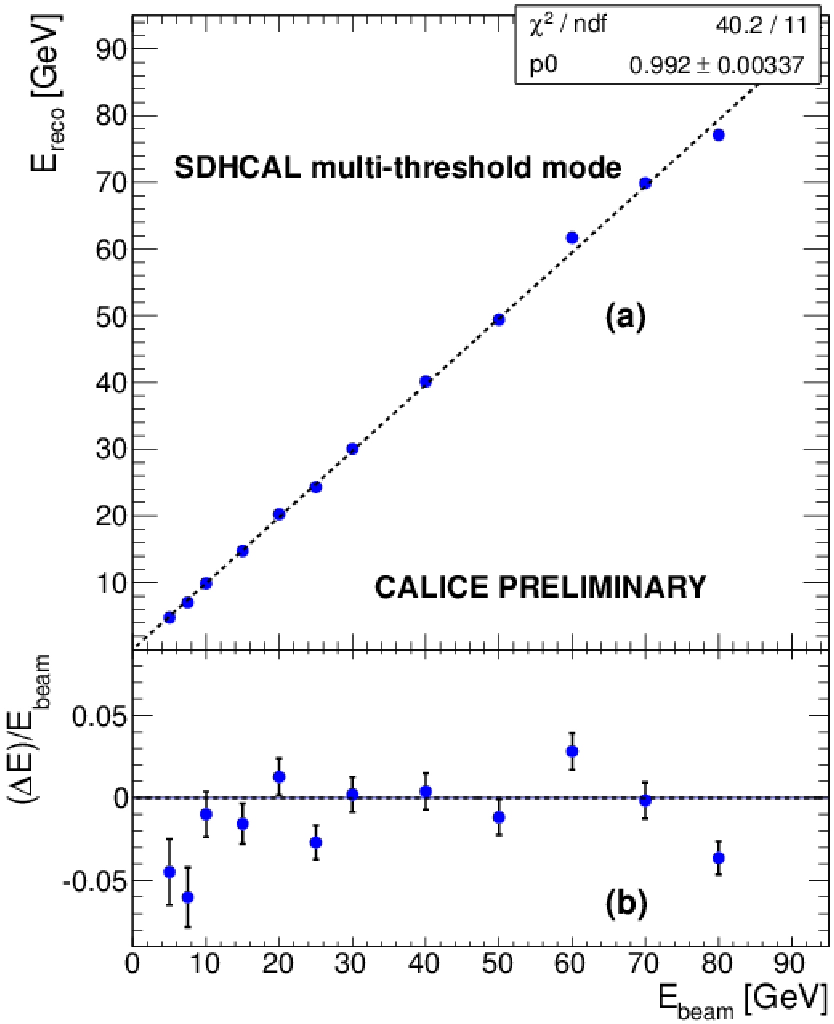
SDHCAL DBD
jet energy resolution

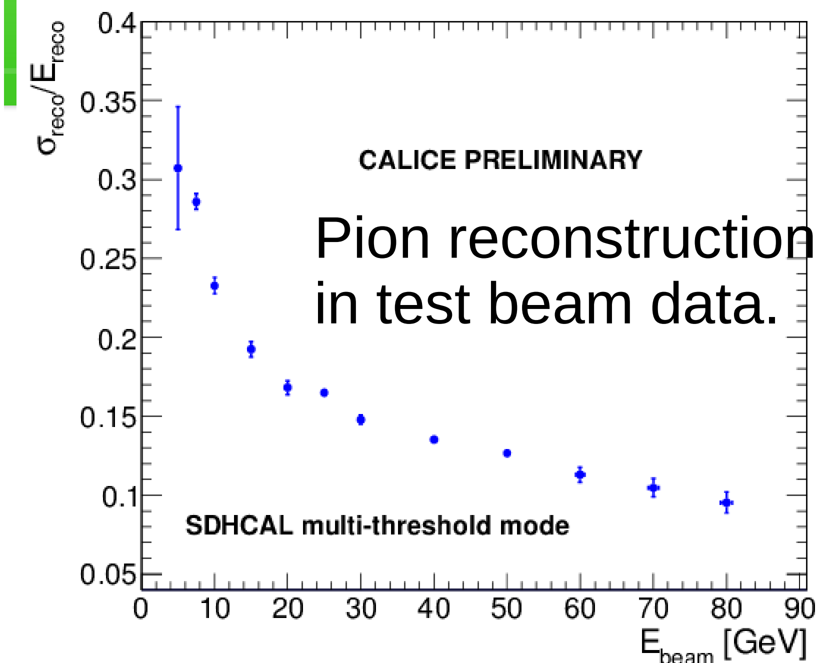
- Simulate GRPC response (digitizer)
- Use PandoraPFA
- Energy is reconstruted as

$$E=\alpha N_1 + \beta N_2 + \gamma N_3$$

- N_i = number of hits above i^{th} threshold.
- Coeff α,β,γ tuned on pion and muon data

SDHCAL reconstruction : energy





Pion reconstruction in test beam data.

$E = \alpha(N_{hit})N_1 + \beta(N_{hit})N_2 + \gamma(N_{hit})N_3$

$N_{hit} = N_1 + N_2 + N_3$

α, β, γ quadratic functions

Better linearity

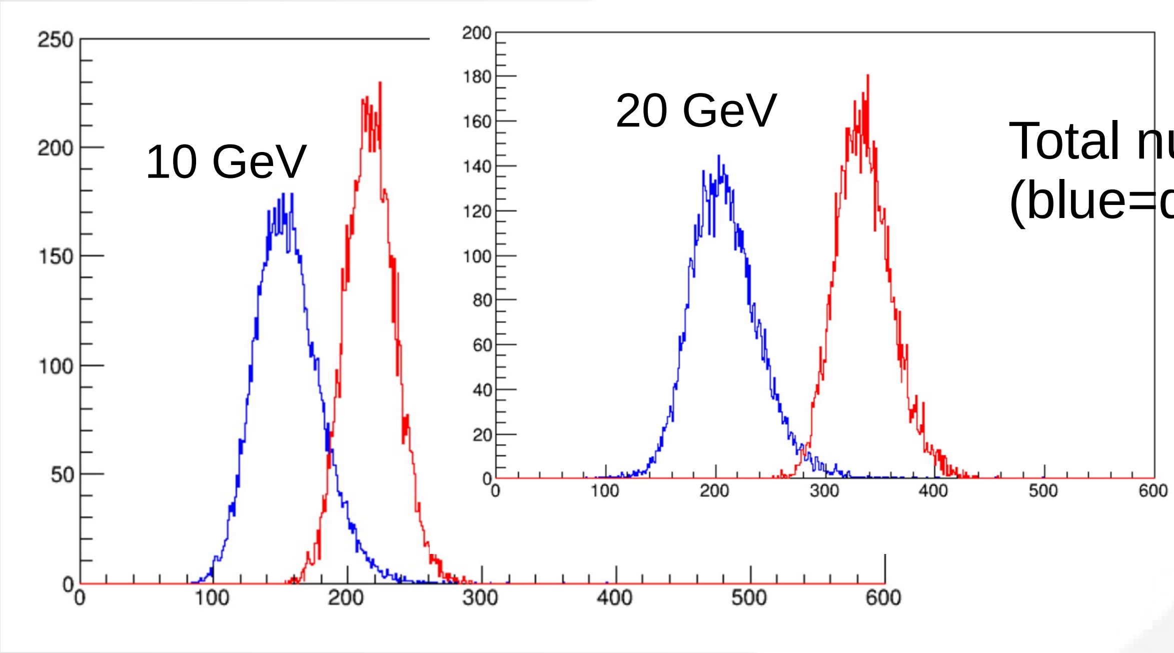
Plan to modify PandoraPFA to cope with more complex energy reconstruction

Improve resolution : Neural Network with more variables (see algorithms)

SDHCAL optimisation : digitizer

Current digitizer has been tuned on pion data with normal incidence

- Indications that number of hits may depend on incidence angle
- Use of electrons to improve the digitizer (GRPC response simulation)



Total number of hits for electrons (blue=data, red=simulation)

Digitizer improvements is a preliminary step for further optimisation studies (cell size, thresholds change, ...)

SDHCAL optimisation : algorithms

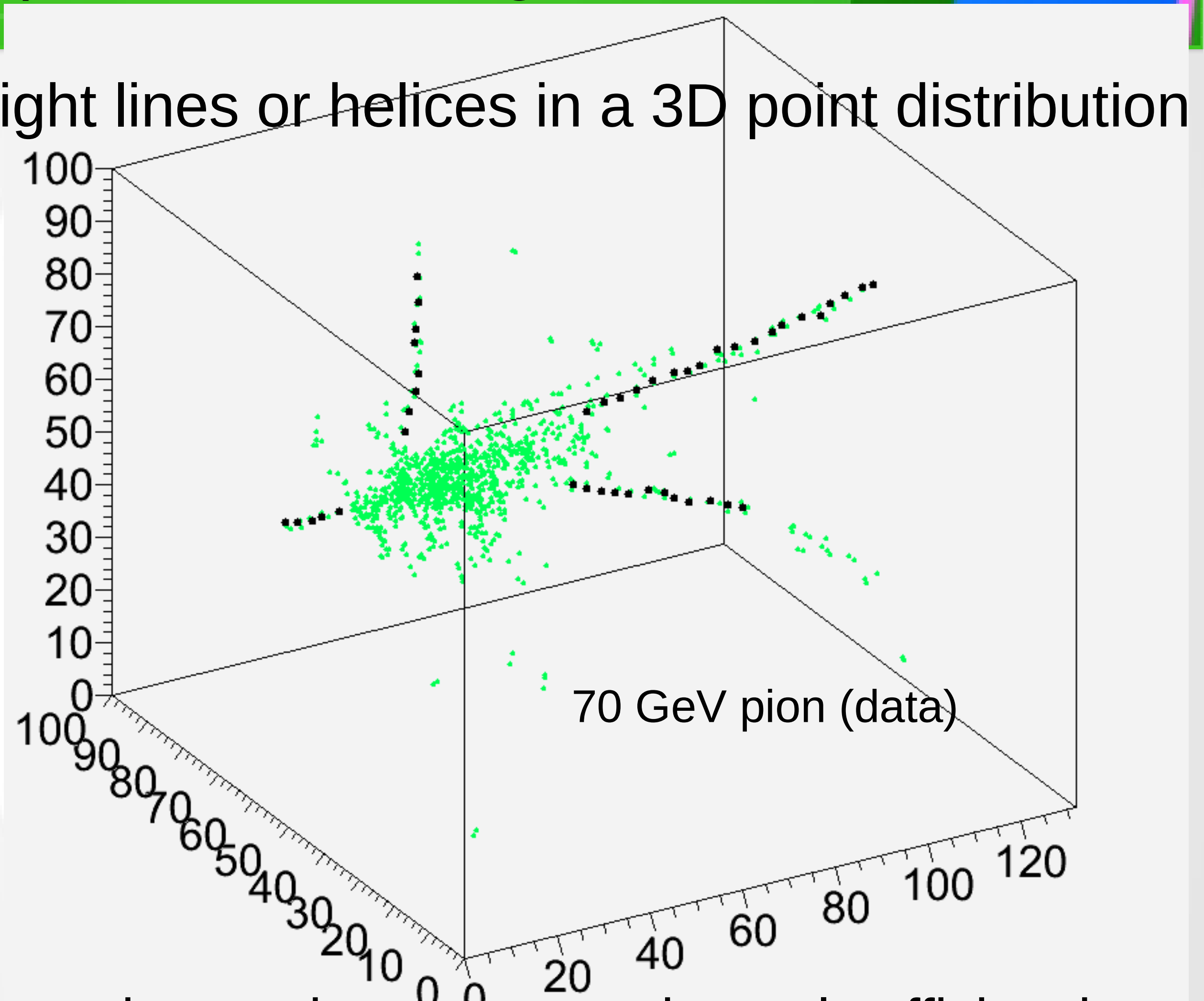
Algorithms' outputs might serve as input for energy reconstruction.

Algorithm looked so far :

- Box Fractal Dimension (Particle ID and energy reco)
- Shower core hit tagging (Energy reco)
- Hough transform (Tracking and energy reco)
- Minimum Spanning Tree (Particle ID and energy reco)
- Arbor (PFA, particle Id and energy reco)

SDHCAL optimisation : hough transform

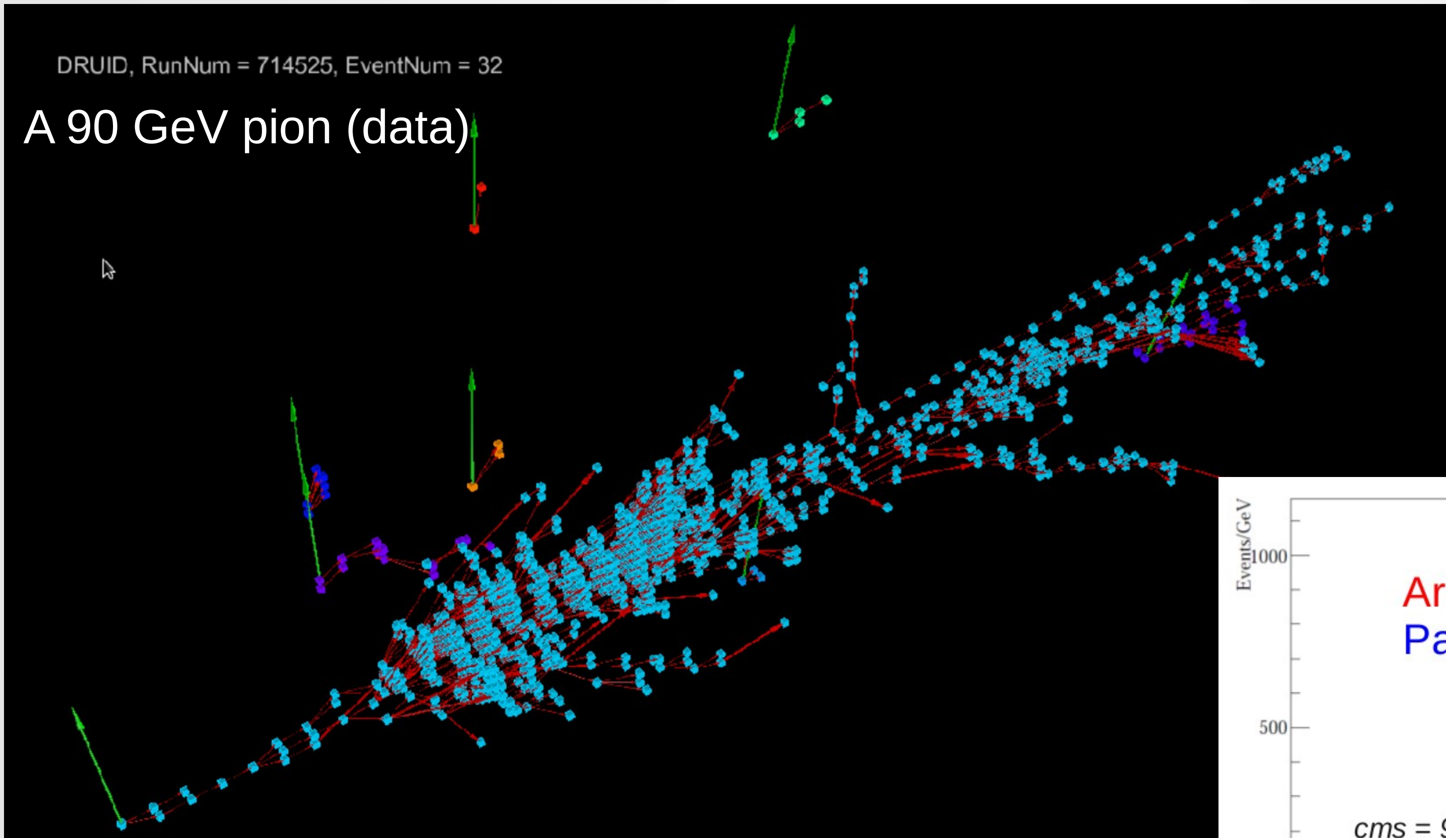
Technique to find straight lines or helices in a 3D point distribution



- Reconstructed tracks can be used to measure channels efficiencies
- Hits on tracks can be treated differently for energy reconstruction.

SDHCAL optimisation : arbor

A shower looks like a tree : try to reconstruct it as a tree.



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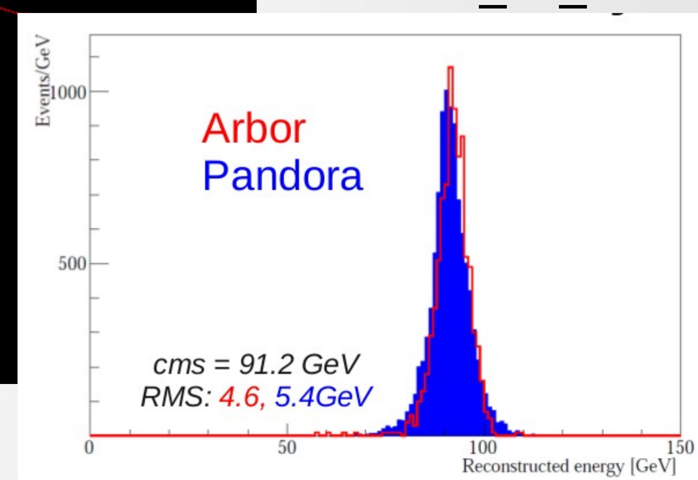
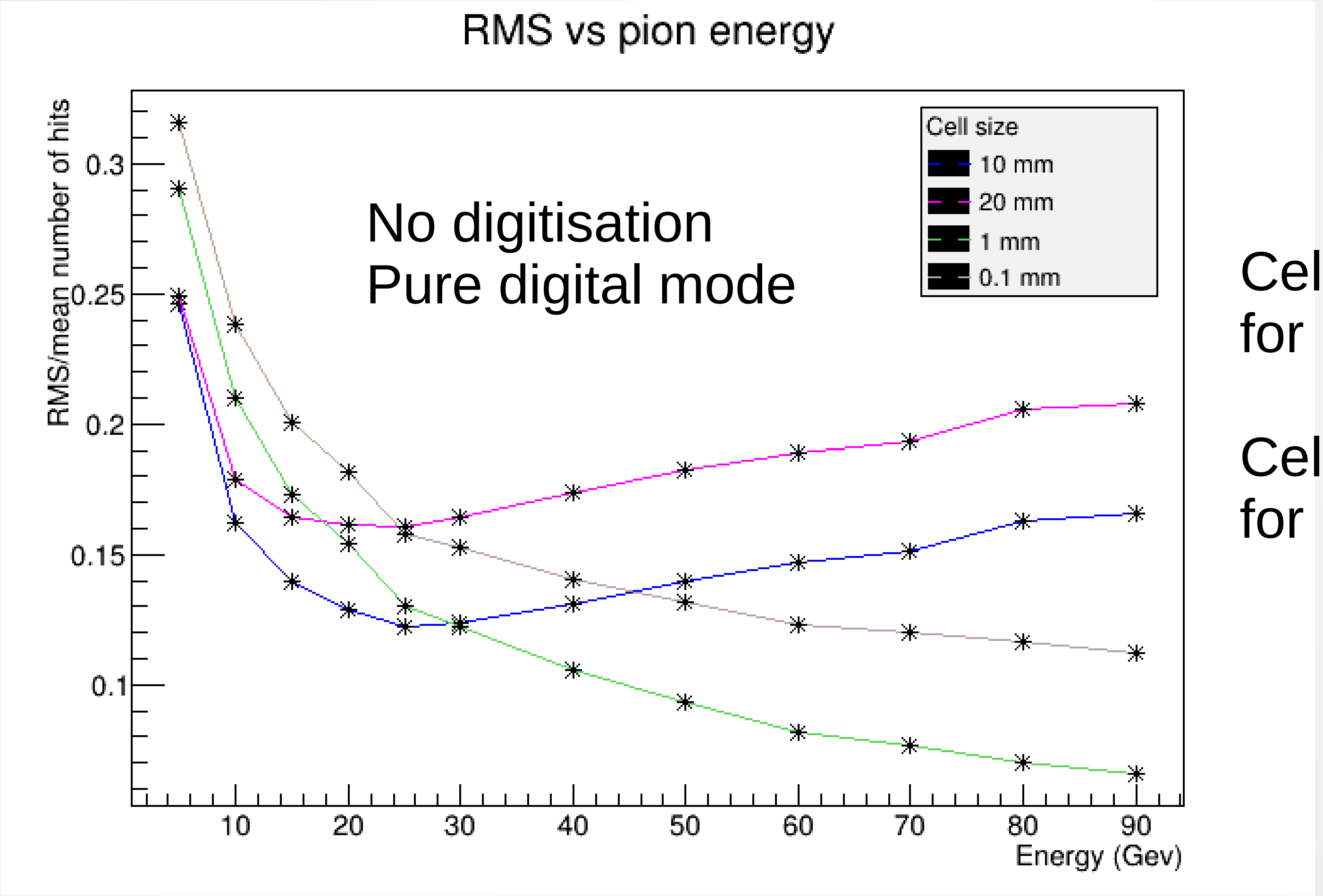


SDHCAL optimisation : cell size

LCIO can store GEANT4 steps : possibility to recompute hits for any cell size.
Study done with SDHCAL prototype simulation, no attempt to linearize the response.



Cell size ~1cm better for low energy pions.

Cell size ~1mm better for high energy pions

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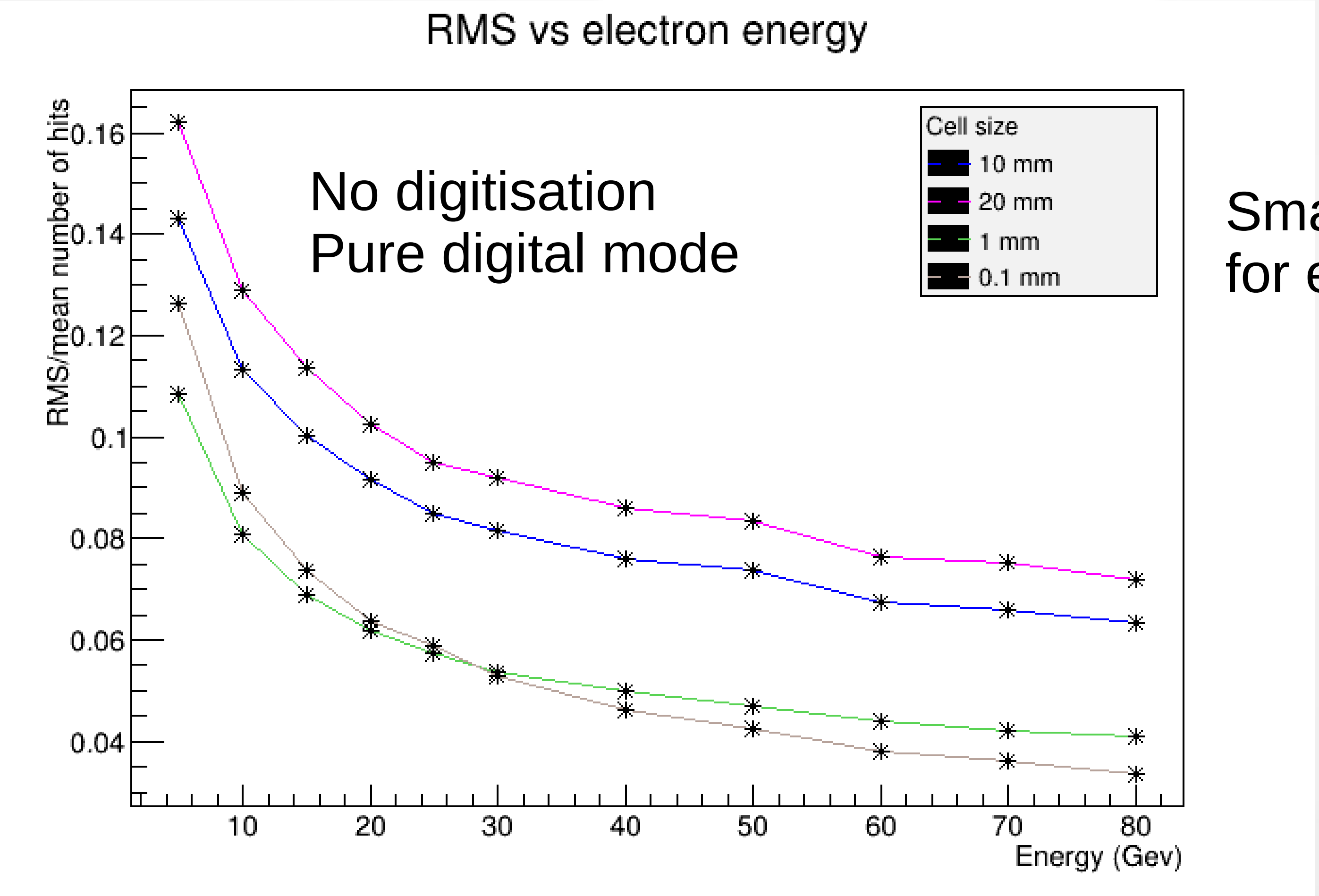

Small cell size better for electrons.

SDHCAL optimisation : geometry

Smaller ECAL → smaller HCAL
Collaboration started with ECAL group.

Planned study :

- Can we estimate shower leakage with hit distribution in last SDHCAL layer ?
- If yes, can we reduce SDHCAL number of layers ? (smaller yoke)

Conclusion

Continuing R&D : hardware optimisation.
- More efficient ROC.
- Possibility to sustain higher particle fluxes.
- ...

Main path for SDHCAL optimisation : software
- Improve GRPC response modelisation
- Develop algorithms to probe the shower structure :
  - Software compensation
  - PFA
  - Tracking
  - Leakage estimation (?)
  - Electromagnetic fraction estimation
  - ...