SDHCA status

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on behalf of the SDHCAL groups

Outline

- SDHCAL analyses & papers
- SDHCAL Beam Test 2022
- R&D activities
- Future (flash talk)

SDHCAL analyses & papers

Three topics were recently developed within the SDHCAL groups

- ❑ Energy reconstruction of PS&SPS data of 2015
- ❑ Angular impact on energy reconstruction
- ❑ Modelling the response of the SDHCAL RPCs

Energy reconstruction

$E_{rec} = \alpha(N_{tot})\, N_1 + \beta(N_{tot})\, N_2 + \gamma(N_{tot})\, N_3$

α , β , γ are **quadratic functions** of

They are computed by minimizing :

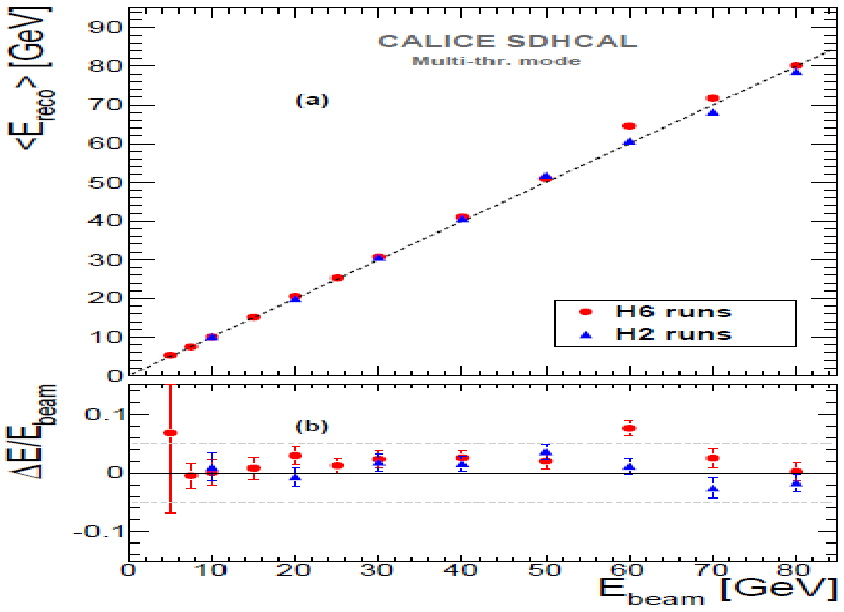
$\chi^2 = (E_{beam} - E_{rec})^2 / E_{beam}$

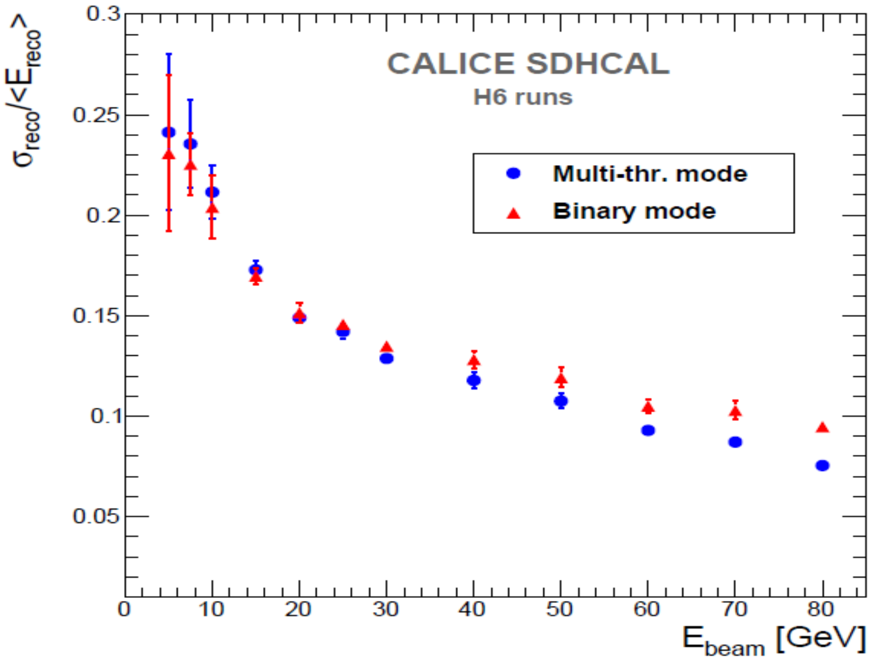
N_1 = Nb. of pads with **first threshold <signal < second threshold**

N_2 = Nb. of pads with **second threshold <signal < third threshold**

N_3 = Nb. of pads with **signal> third threshold**

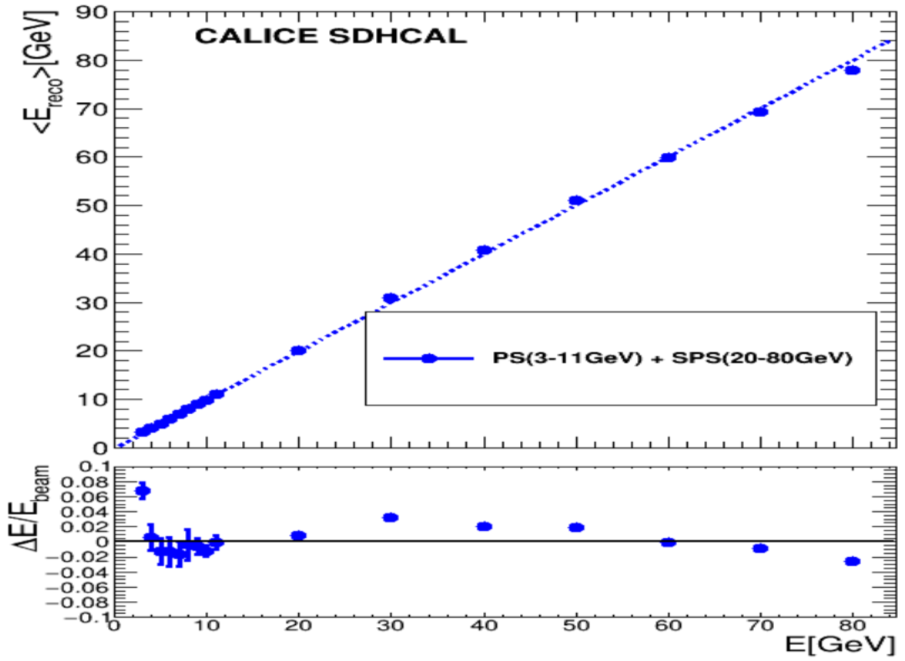
$N_{tot} = N_1 + N_2 + N_3$



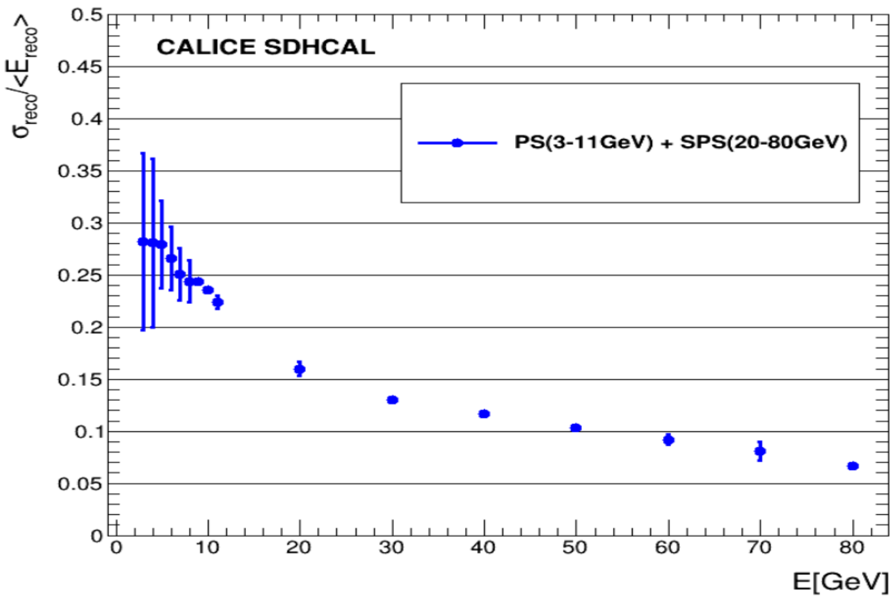


[JINST 11 (2016) P04001](#)

- The BDT-based PID technique was applied to have pure hadronic samples of beam test of 2015.
- Energy reconstruction was then applied to both PS and SPS data covering a a large energy region (3-80 GeV)

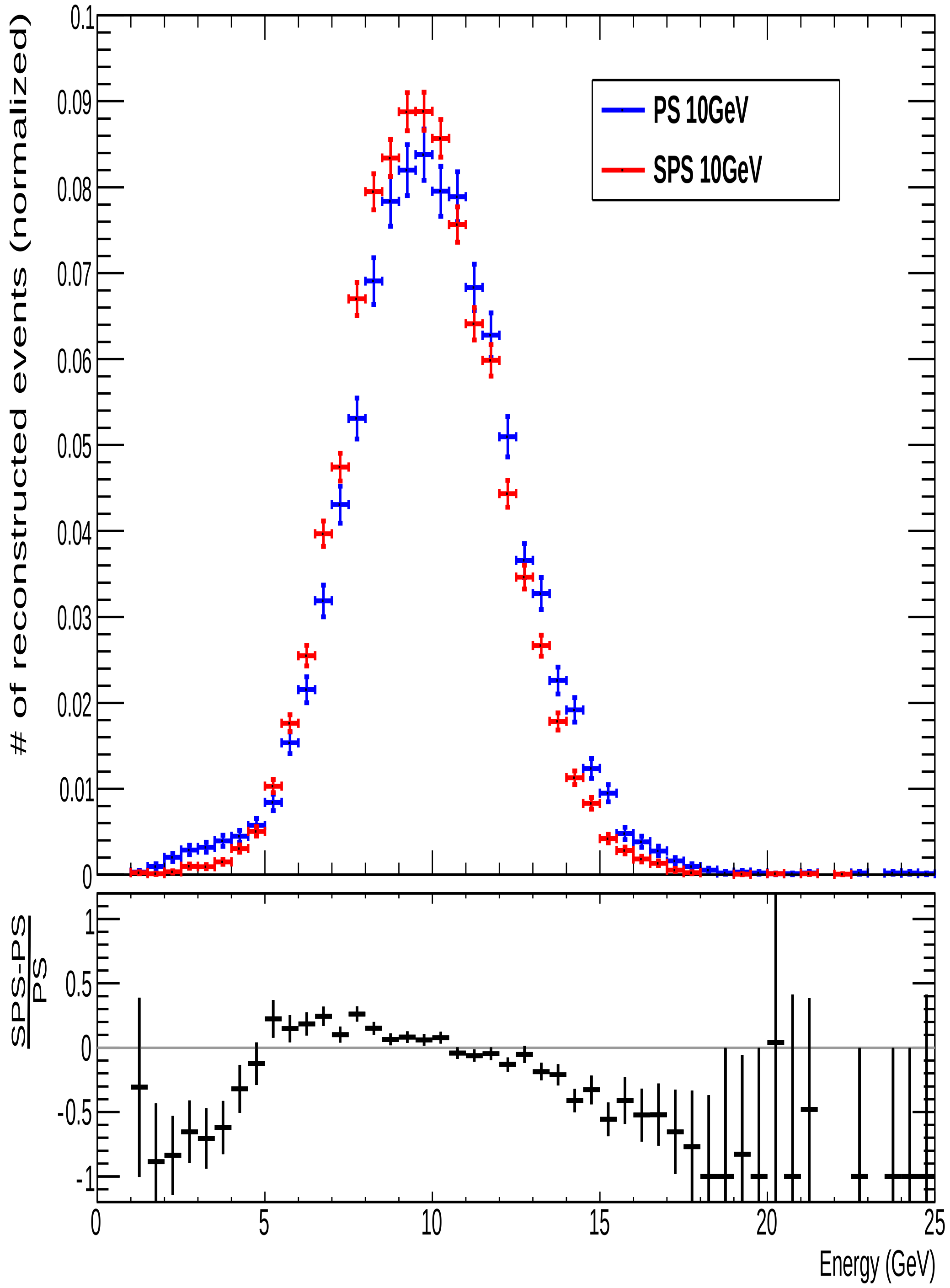


Linearity



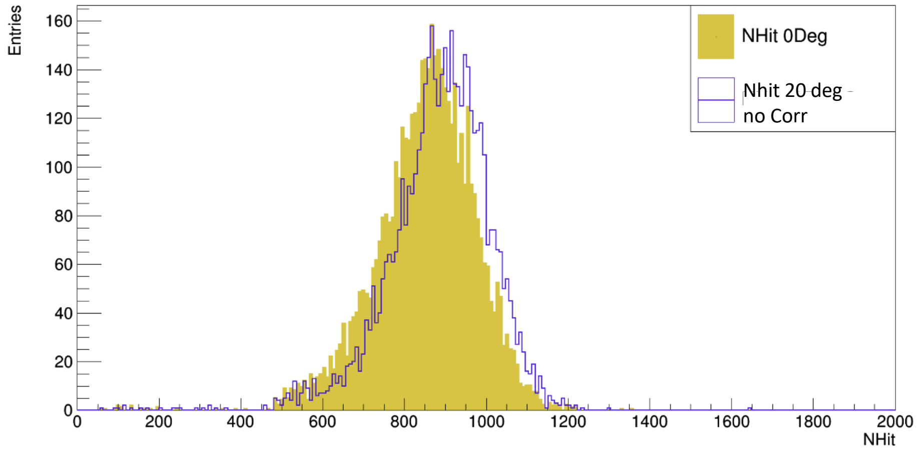
Resolution

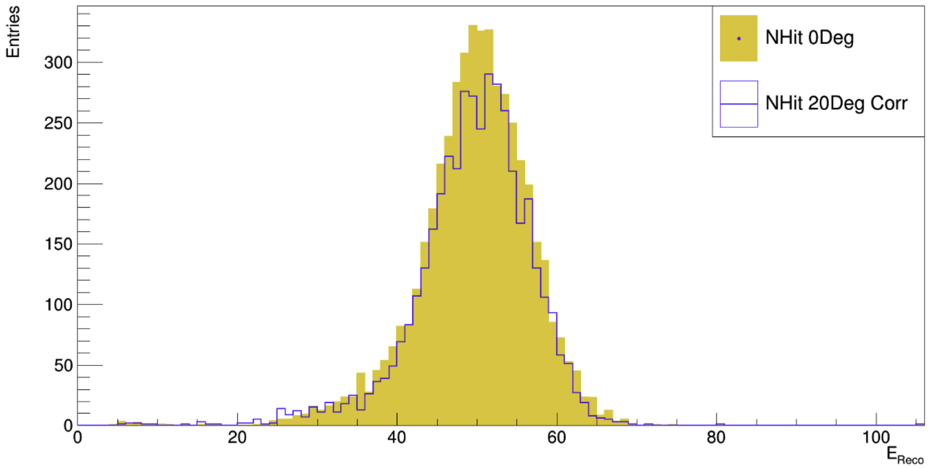
JINST 17 (2022) P07017

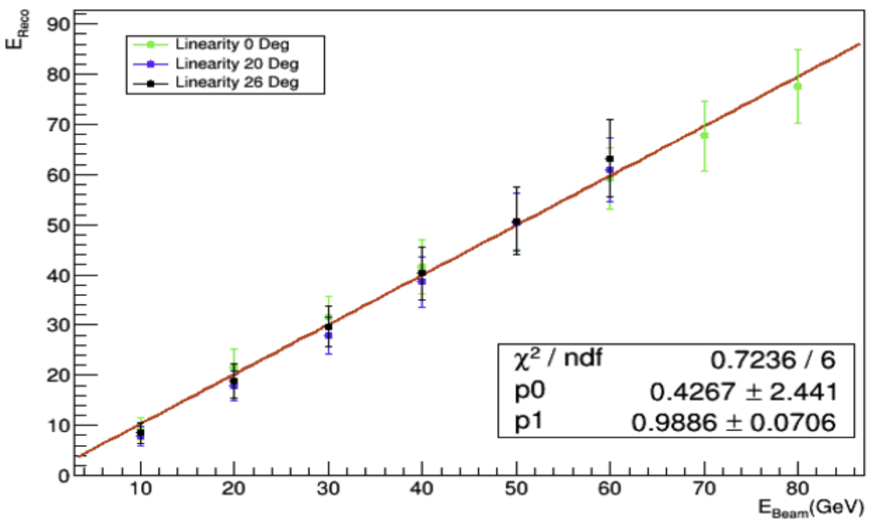

PS 10GeV
SPS 10GeV
# of reconstructed events (normalized)
SPS-PS / PS
Energy (GeV)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
-1
-0.5
0
0.5
1
0
5
10
15
20
25

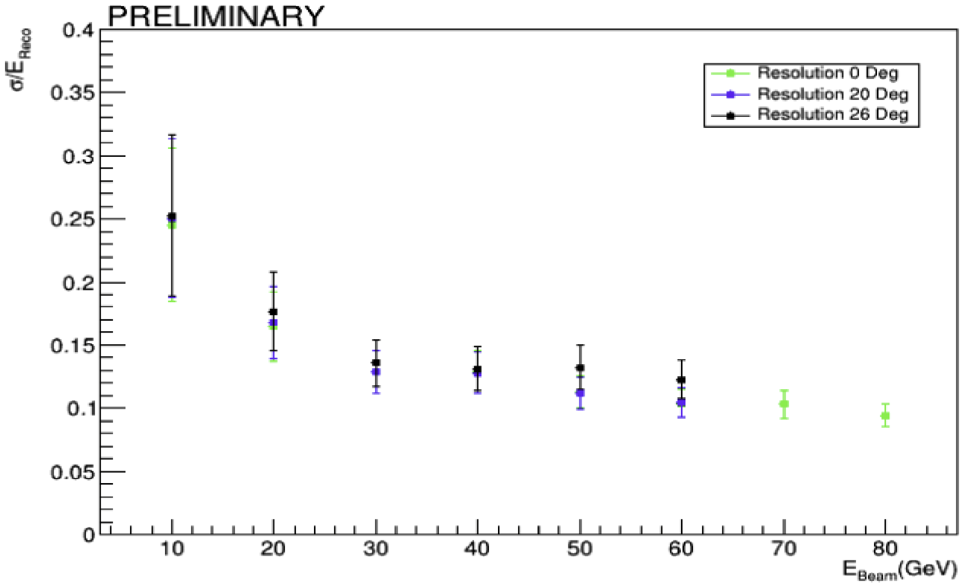
Paper in preparation

SDHCAL was exposed to hadron beams with three different angles.
A simple correction (Nhit_f = Nhit*cos(θ)) leads to similar results independently of the angle



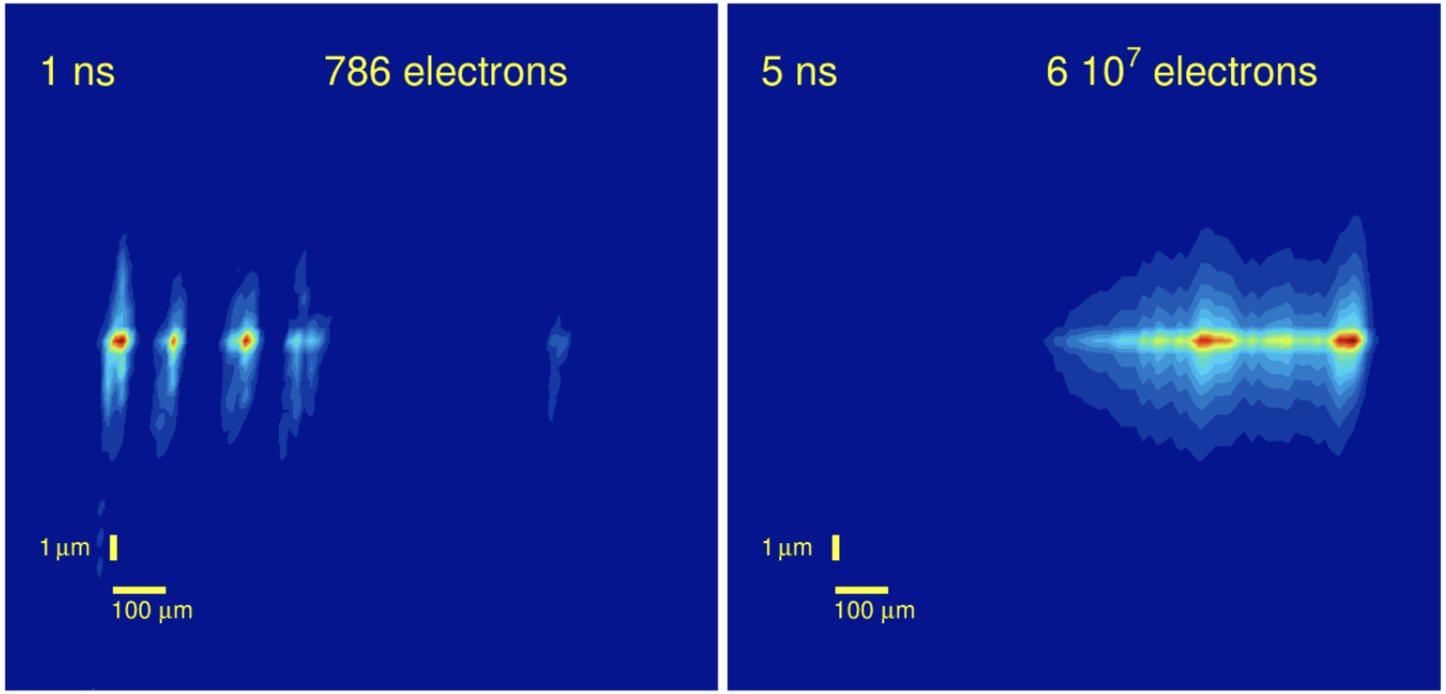


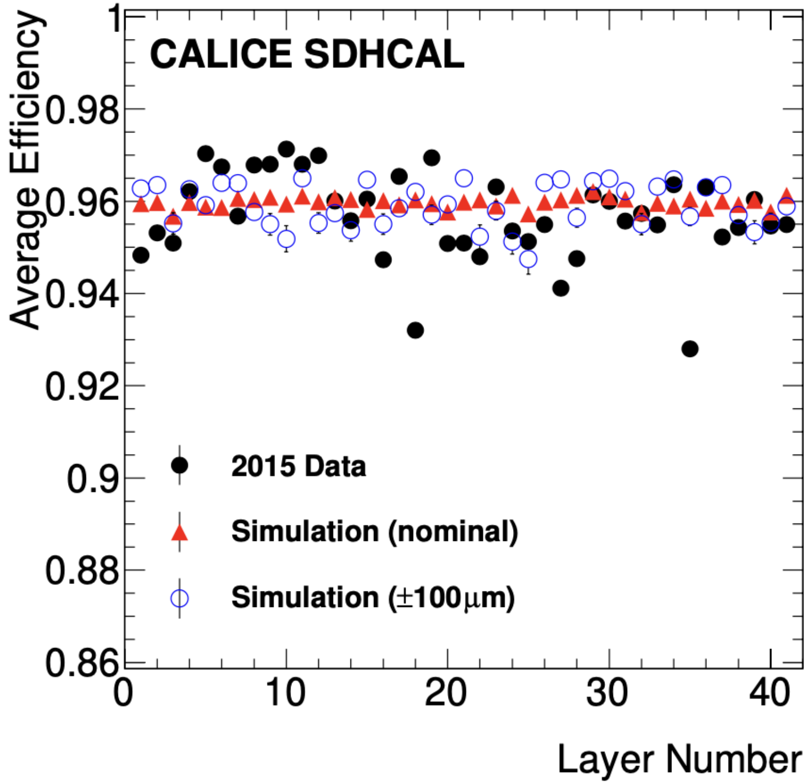




- Modelling the RPC response based on full MC simulation of avalanches
- Analysis of test beam data and comparison with the simulation
- Description and stability of a RPC-based calorimeter in electromagnetic and hadronic shower environments (temperature, pressure..etc).

Paper submitted to JINST: arXiv. https://doi.org/10.48550/arXiv.2207.06291






SDHCAL beam test 2022

Main goals

- ❑ Apply a new calibration scheme (based on equalizing the response by applying different threshold value/ASIC) in order to improve on the SDHCAL response homogeneity.

- ❑ Study the difference of hadronic showers produced by protons, pions and kaons in order to exploit their differences in developing new PID techniques.

Beam requirements:

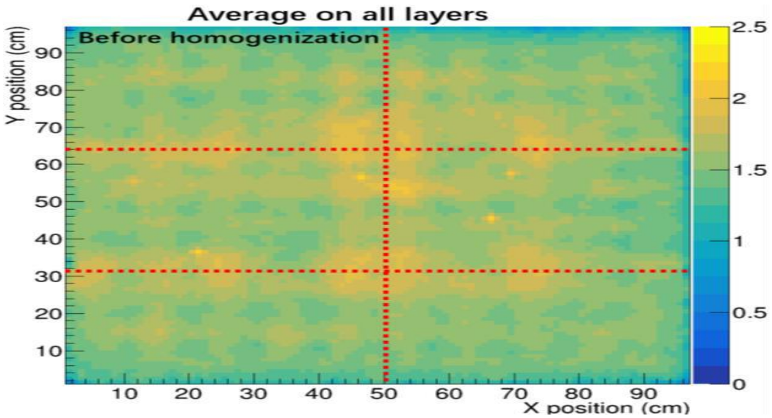
- Muons
- Pions, kaons, protons, from 20 to 80 GeV (pure hadrons)
- Low intensity beam (< 1000 particle/cm2/spill)
- Polarity: positive

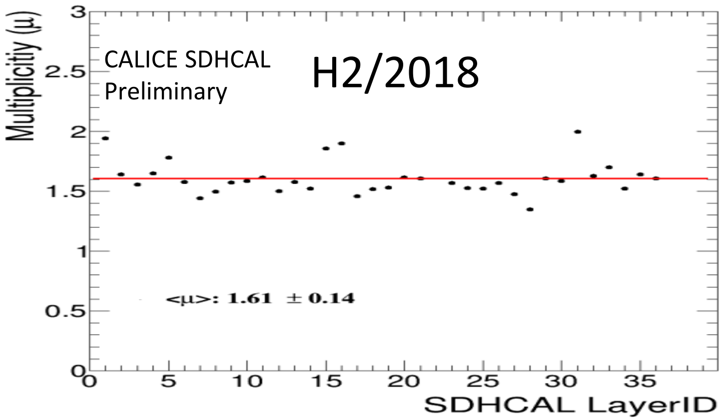
Test beam took place from 14 to 28 September.
Beam conditions were not very good.

37 layers were exposed. One slot was without a detector and one of the RPC suffered a trip. It was repaired but we failed to run it

Detector homogeneity

The homogeneity of the detector response is important to achieve better energy reconstruction





A new calibration method based on varying the thresholds rather than the electronic gain was found to be powerful. Muon runs were taken with different thresholds Thr1: 0.1-0.42 pC, Thr2: 0.4-5, Thr3:4.7-24) and efficiency and multiplicity were measured for each value. The values of the three thresholds of each ASIC were fixed to obtain the same multiplicity (first threshold) and the same efficiency for thr2 and thr3.

$$\varepsilon(t;\bar{q},\delta,\epsilon_0) = \varepsilon_0 \cdot \left(1 - \int_0^t P(q;\bar{q},\delta)dq\right)$$

$$P(q;\bar{q},\delta) = \frac{1}{\Gamma\left(\frac{\bar{q}}{\delta}\right)\delta^{\frac{\bar{q}}{\delta}}} q^{\frac{\bar{q}}{\delta}-1} e^{-\frac{q}{\delta}}$$

$$\mu(t;f,p,c) = f \cdot t^p + c$$

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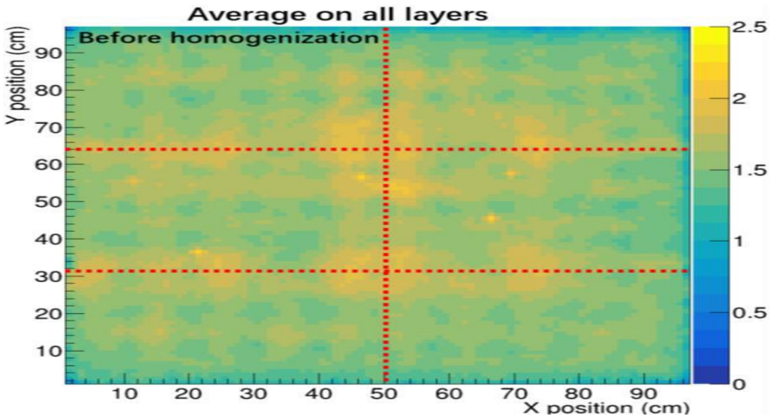
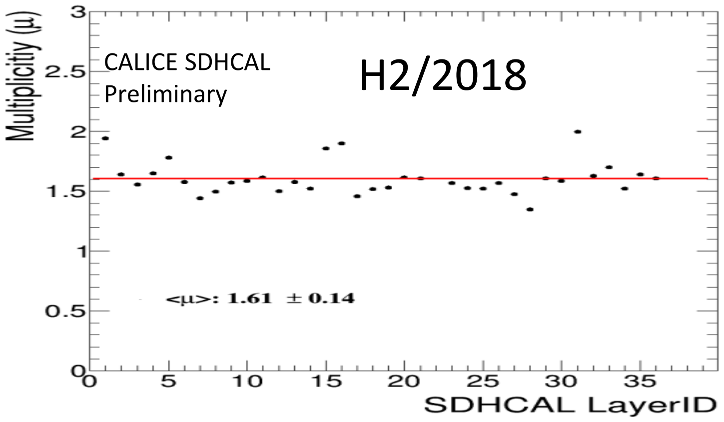
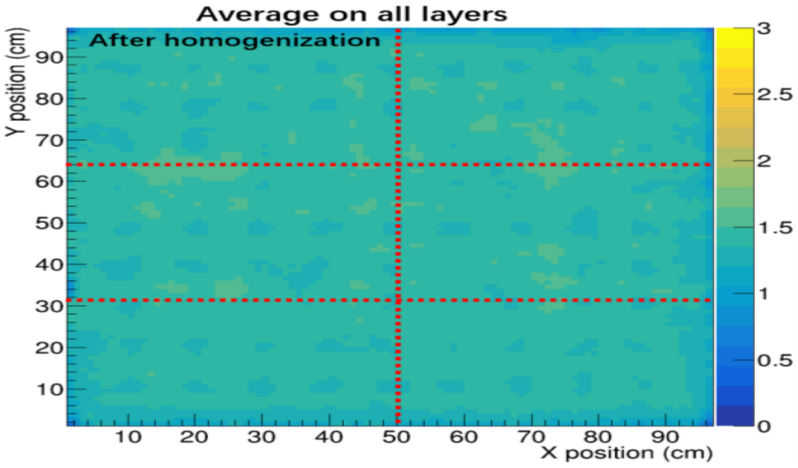
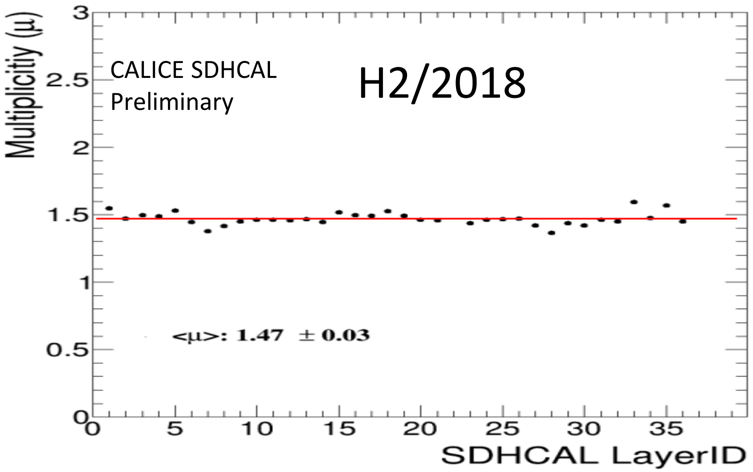


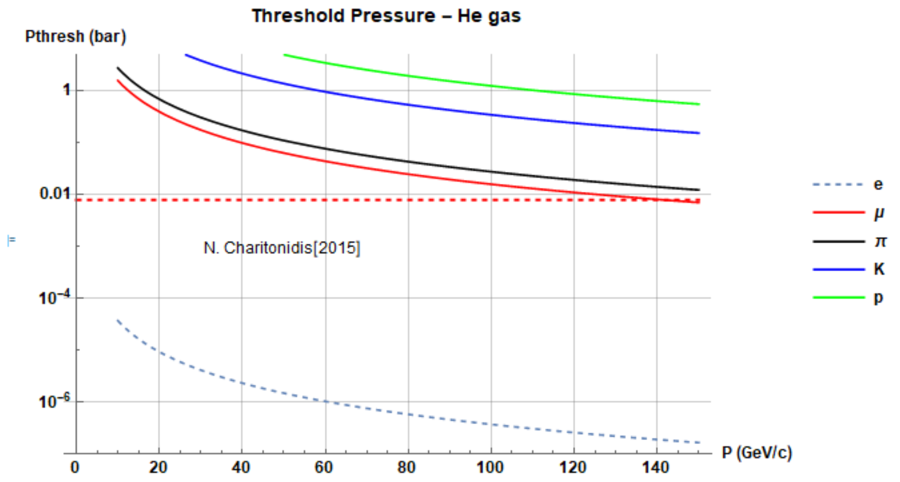


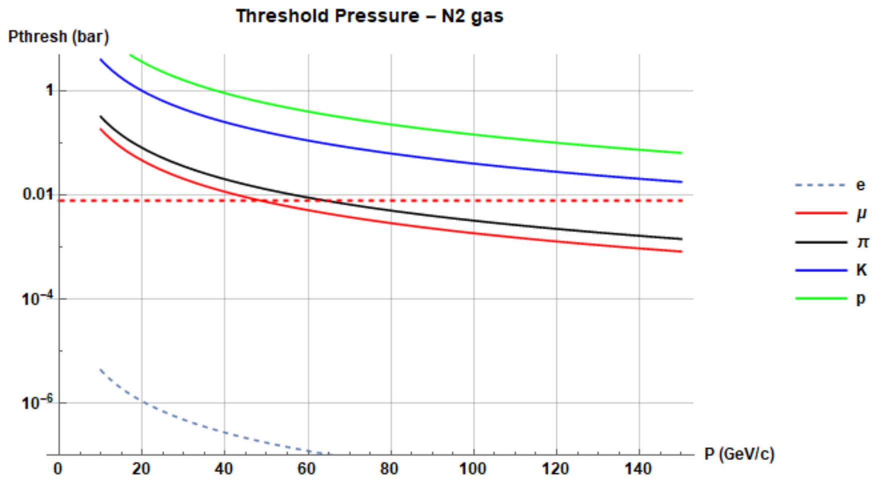




PID

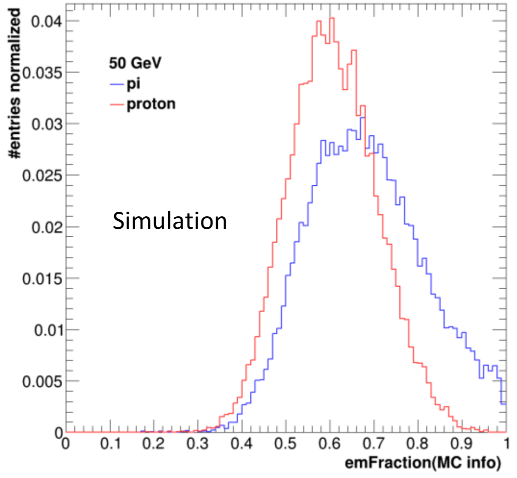
1) Discriminate pions against other hadrons
2) Try to discriminate between kaons and protons (difficult)





Our readout system was equipped with two boards (modified DIF) to receive the signal of each of the two Cerenkov and to record the information using the same format as for the SDHCAL hits.

PID

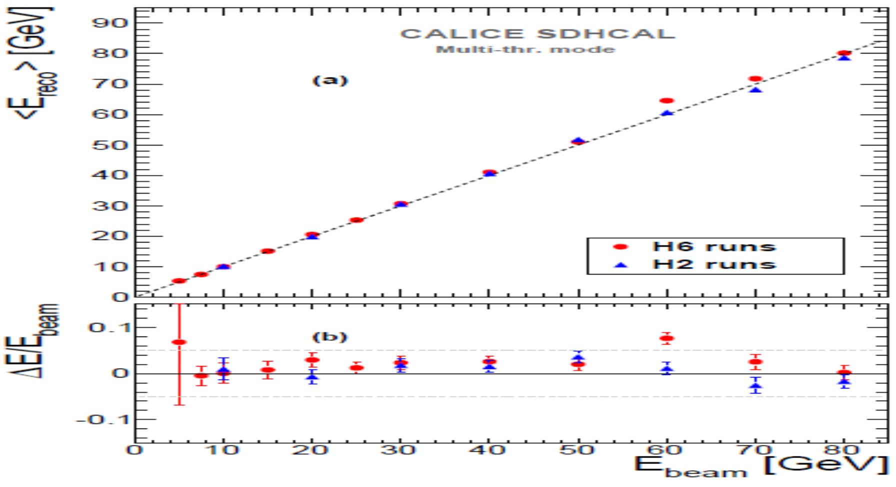


The energy reconstruction method has been applied to hadron events with no distinction made between pions and other hadrons.

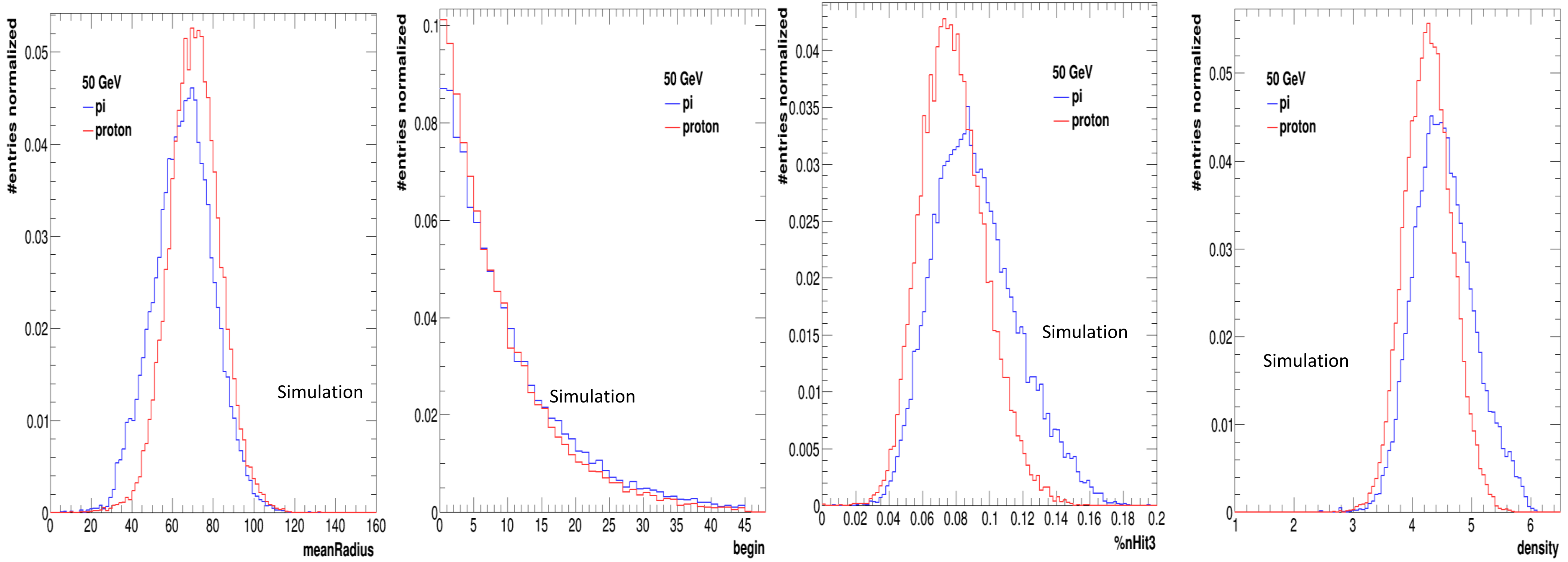
Hadronic showers of pions and protons are not identical.

We expect more hits with pions than with protons (saturation of the EM in the SDHCAL). Compensation with the third threshold may not be enough.

This may explain the different in reconstructed energy between data collected in 2012 between H2 and H6 In particular at high energy where the contamination of pion beam by protons is higher (not the same in the Beam lines)



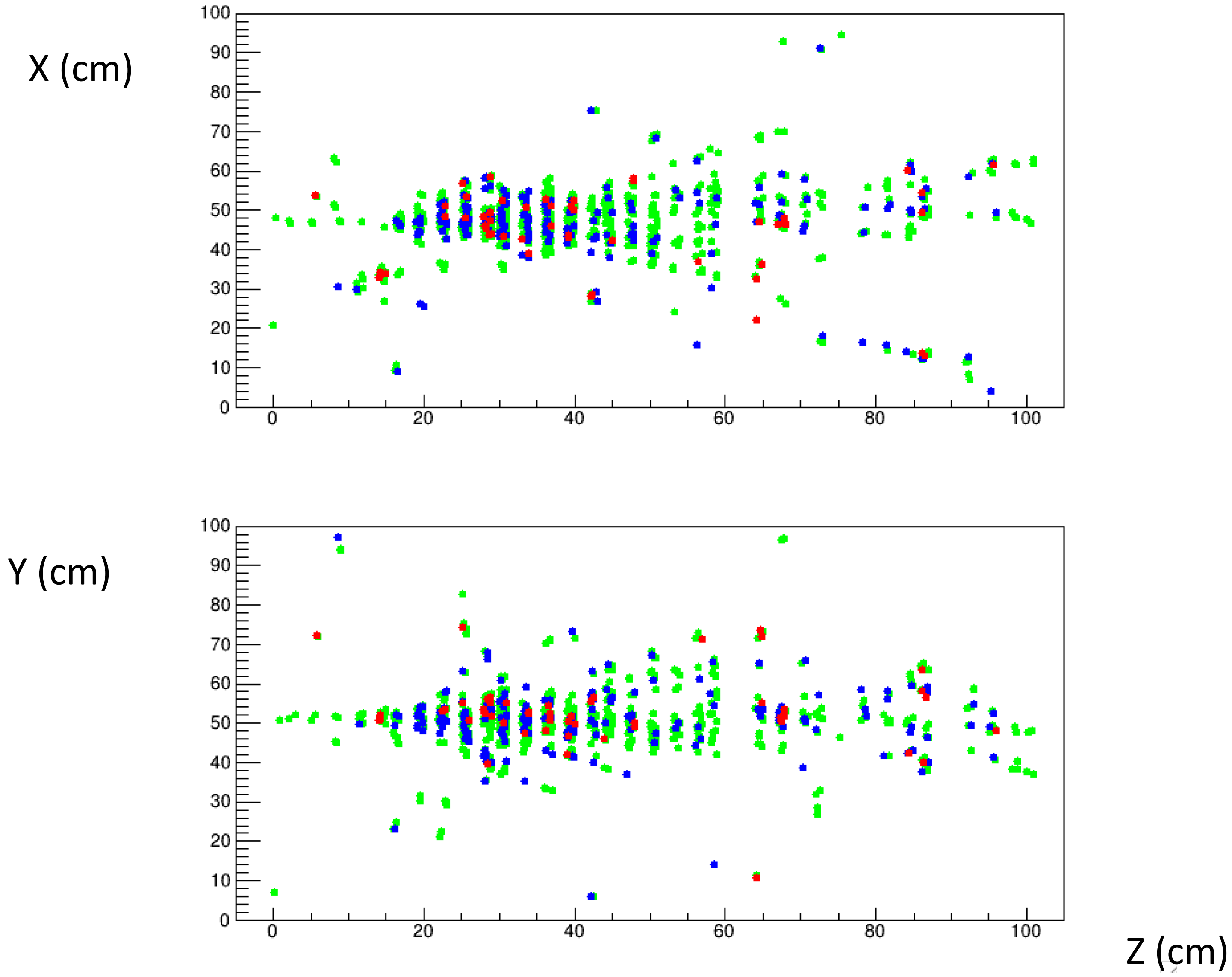
Our goal is to compare the variables associated to each category between data and simulation



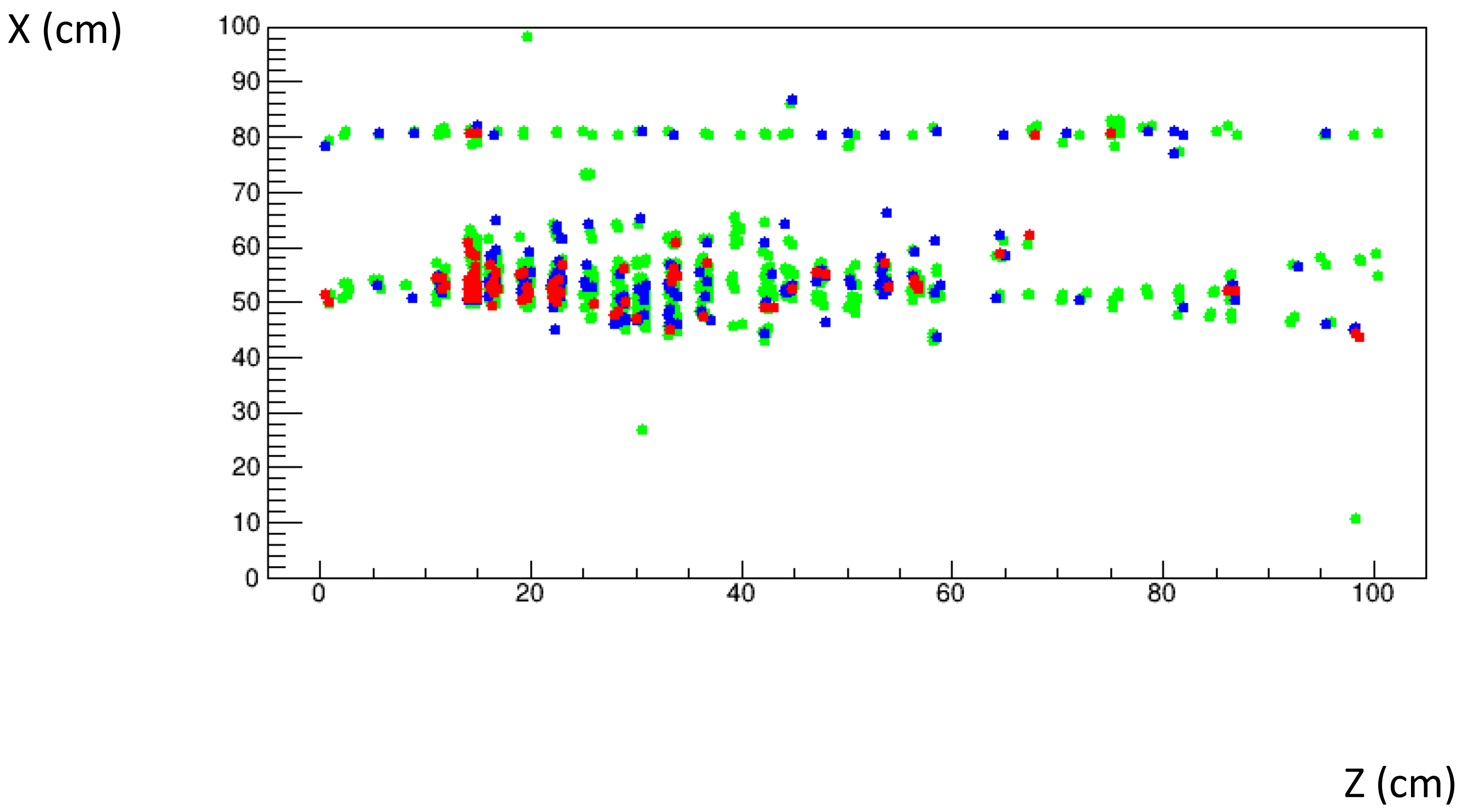
Try to identify as much as possible pions from protons and then reconstruct their energy with different (α,β,γ) parameters

$$E_{rec} = \alpha\,(N_{tot})\,N_1 + \beta\,(N_{tot})\,N_2 + \gamma\,(N_{tot})\,N_3$$

An event display of the 2022 SDHCAL TB



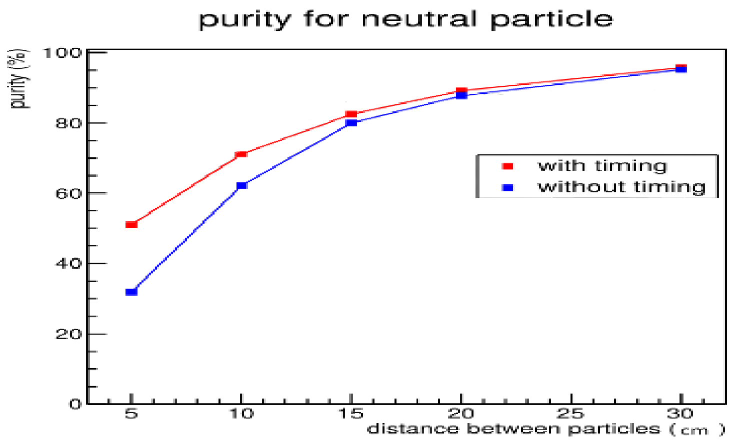
Another event display of the 2022 SDHCAL TB

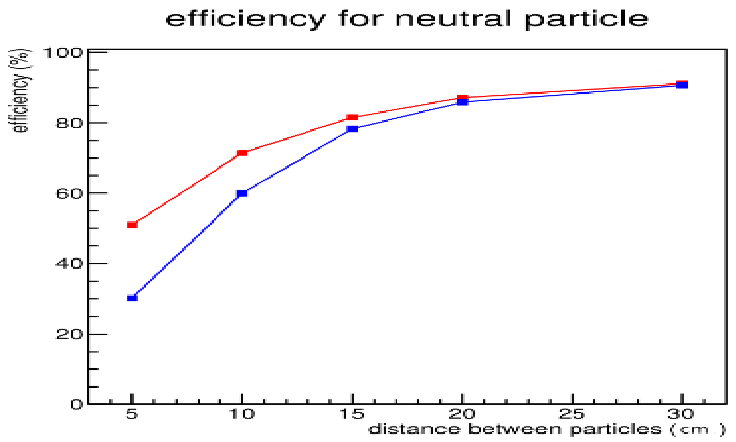


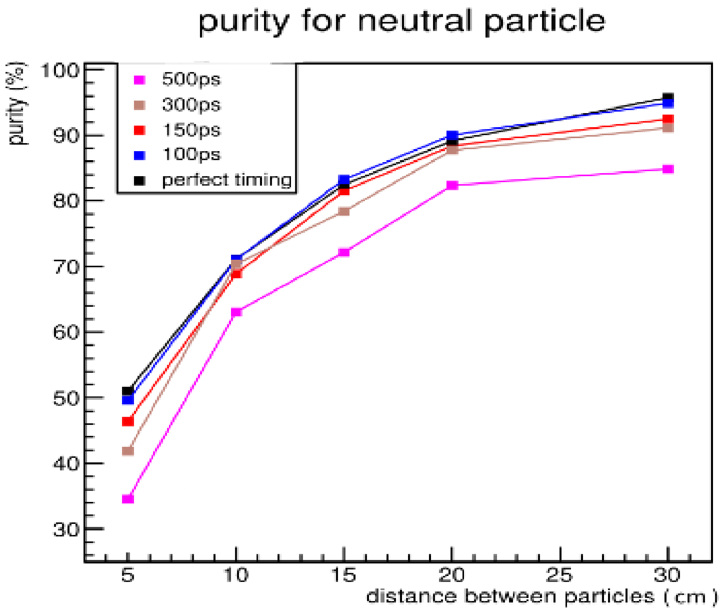
R&D activities

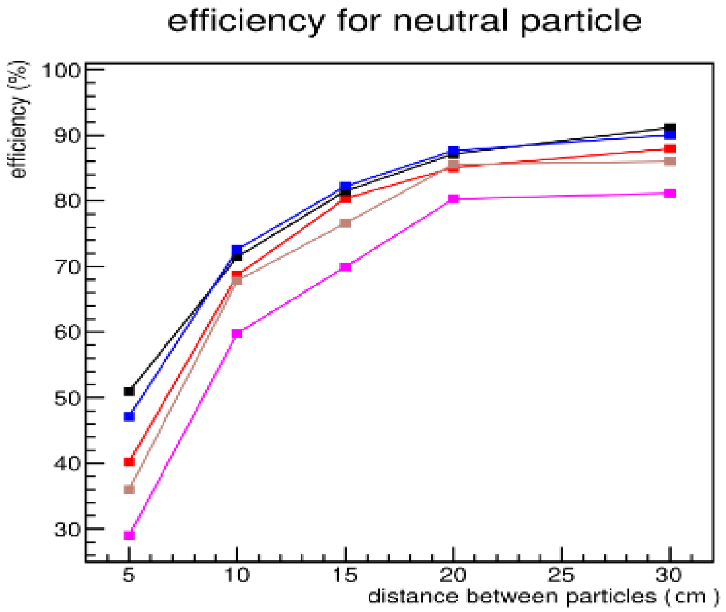
T-SDHCAL

Impact of time information on hadronic shower separation.
For this, April based algorithm was used with time information exploited







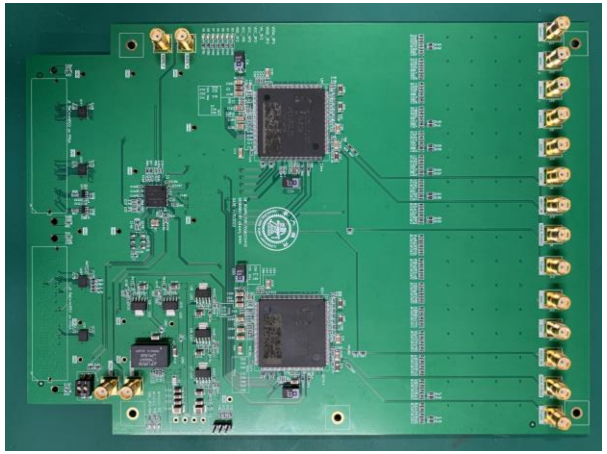


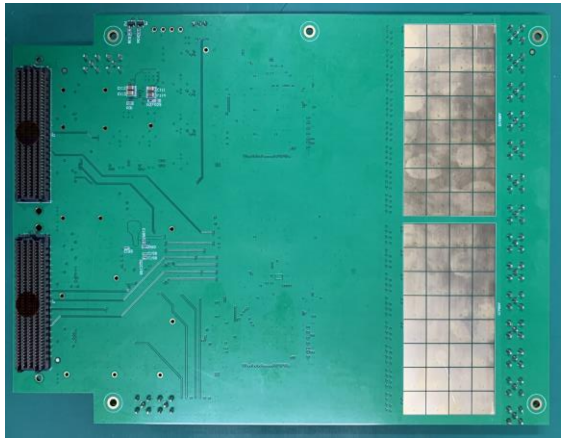
T-SDHCAL

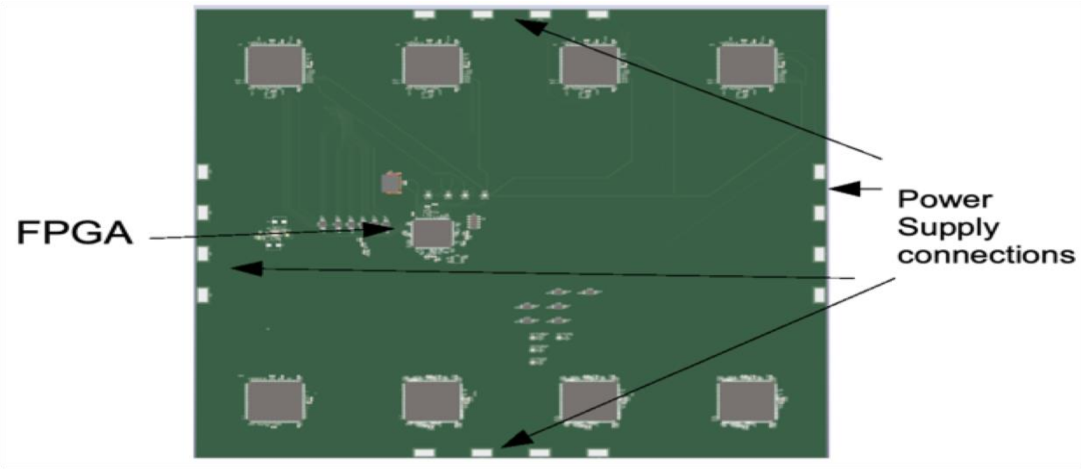
- A small board hosting 4 PETIROCs conceived and produced. A new board was recently produced with 2 PETIROCs to mitigate a noise problem caused by some power lines.

- A middle board hosting up to 12 PETIROC has been conceived

In the two cases the internal TDC of PETIROC will be used (50-100 ps time resolution)

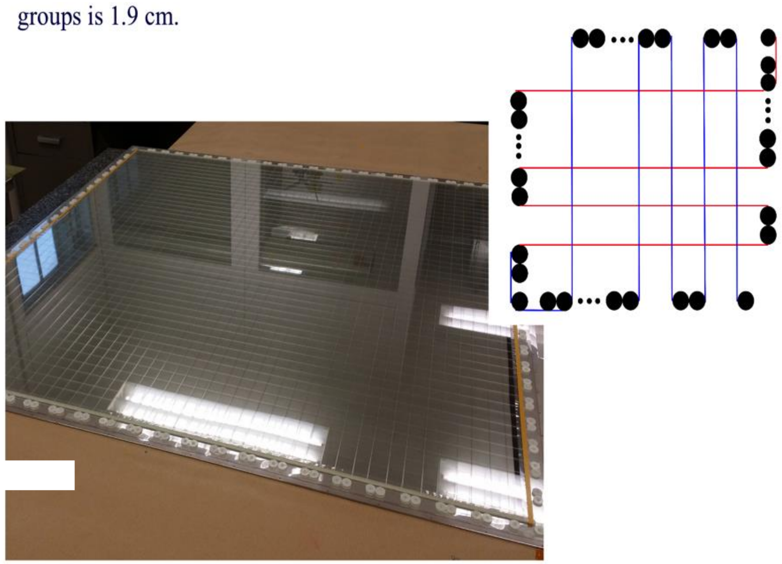






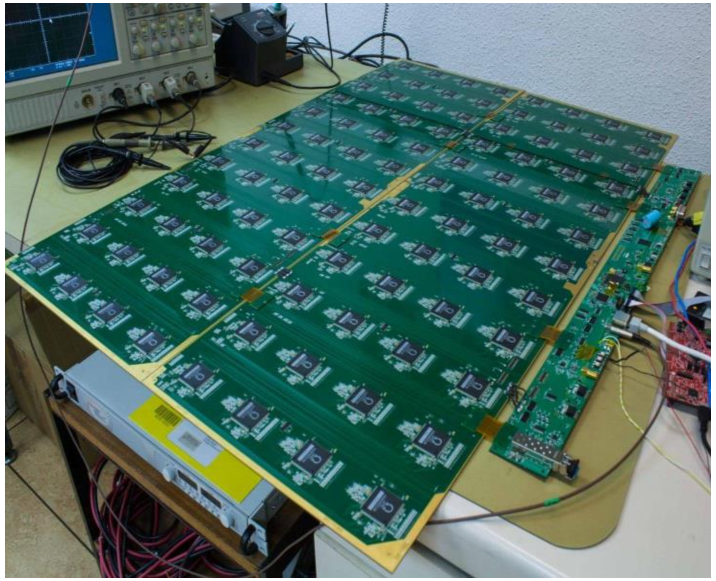
T-SDHCAL

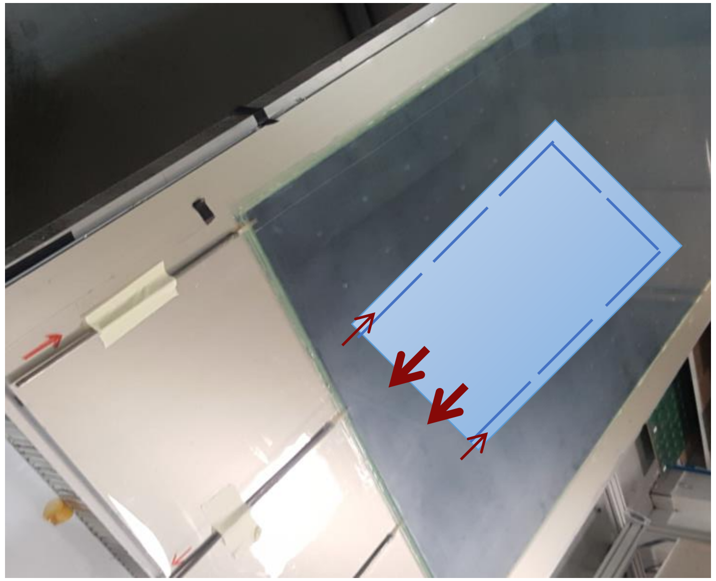
- Large MRPC have been built using fishing line techniques
- New technique is being developed to build large MRPC in much a simpler way



Large SDHCAL module

- 12 long PCB hosting each 48 ASICs were produced as well as the inter-connecters (to cover up to 4 M^2)
- 5 DAQ boards (DIF) conceived and buil
- A mechanical structure to host 4 detectors (as large as 3 m) with a self-supporting structure (Electron Beam welding was used to minimize the dead zones) produced
- A few large GRPC (2 m x 1 m) detectors were produced with a new gas distribution system
- Improved Master card to communicate with DIFs was conceived and produced

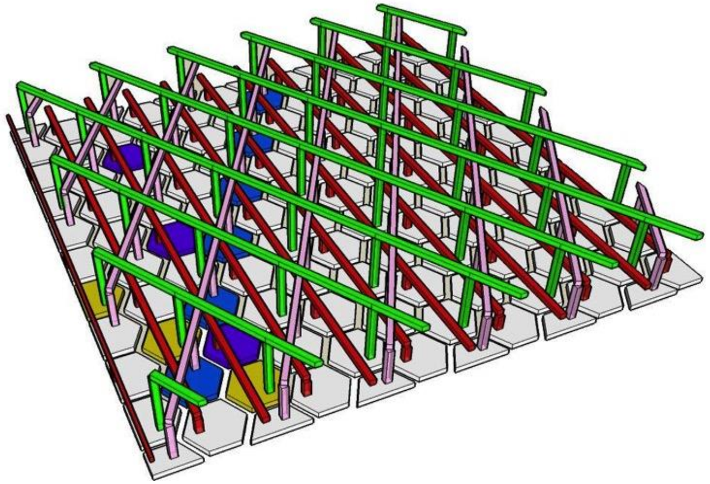


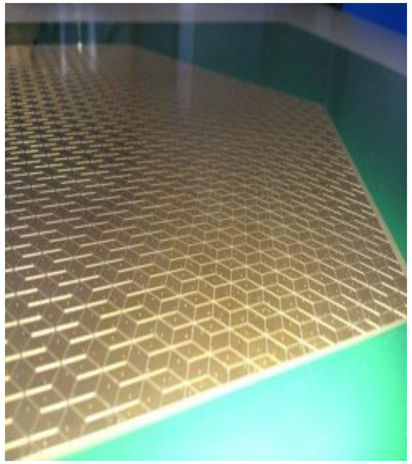


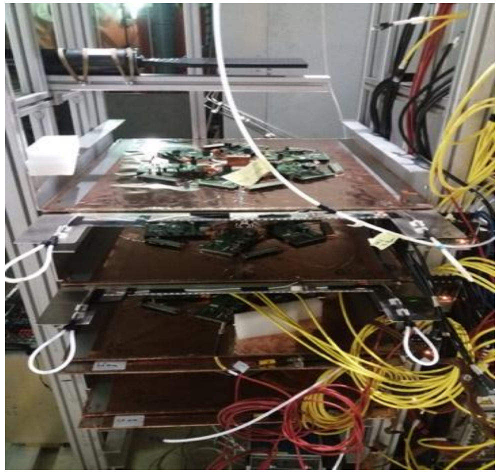
To finish this work , an electronics engineer is needed to take over the work of CIEMAT engineers. This will allow us to validate the concept and test it (few papers are expected)

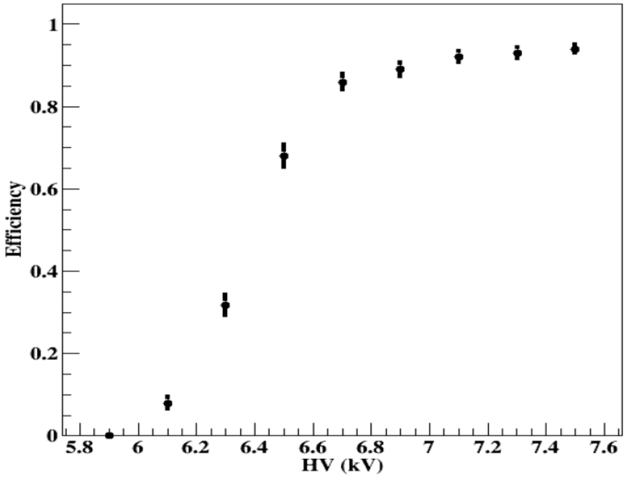
New readout scheme for large muon chambers for tail catchers:

PCT/EP2018/053561

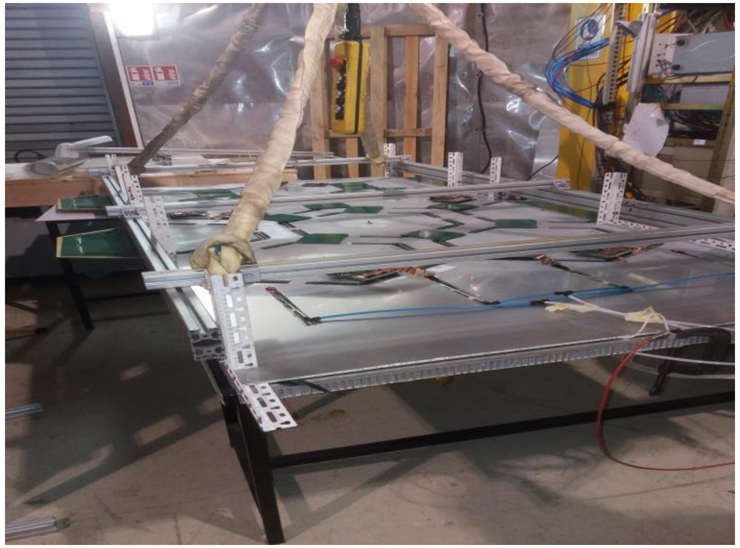


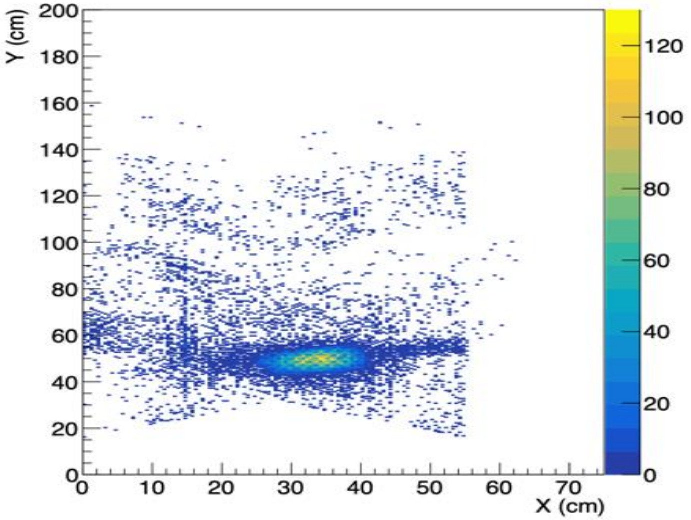






Woven strips: interconnected pads using strips along three directions. Electronic channels number : NXN → 3 N





Flash Talk

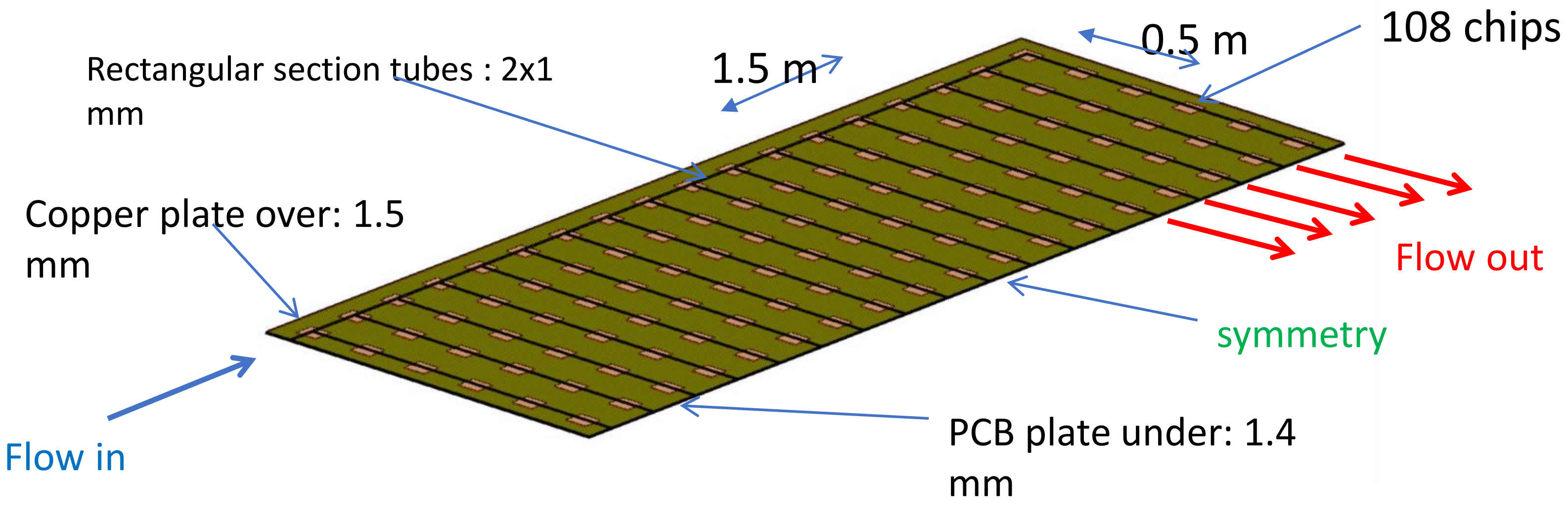
Three axes will be our major activities in the near future

Timing:

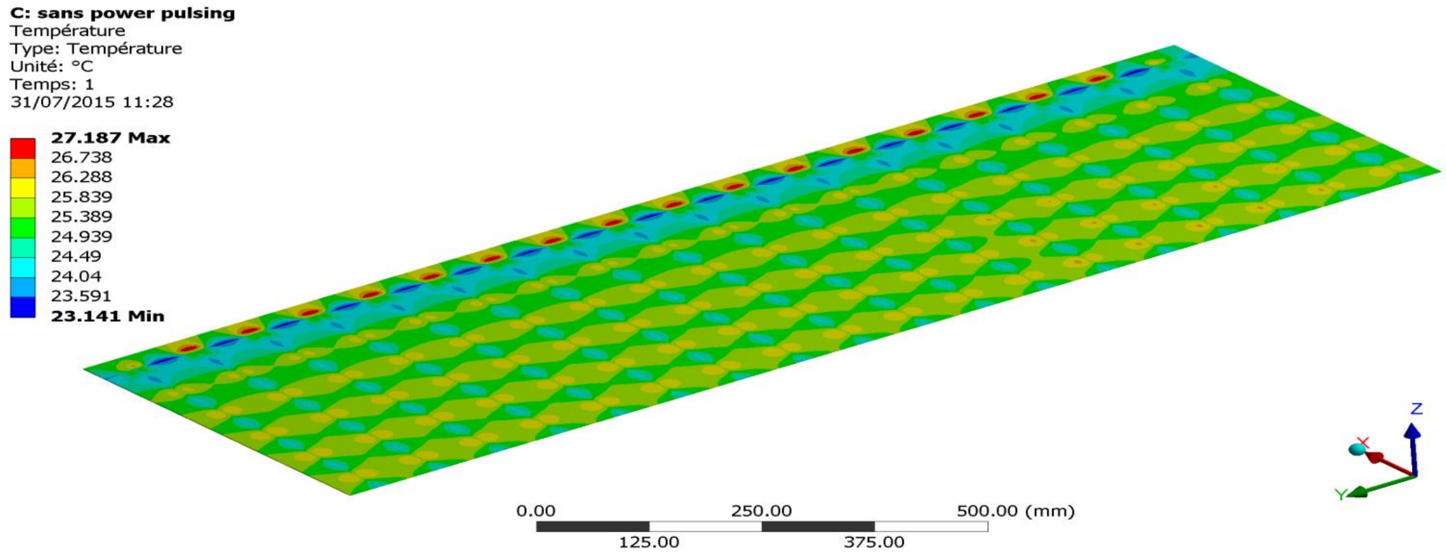
- Build a few MRPC detectors of 1m X 1m and equipped them with timing readout system .
- insert them in the SDHCAL
- Develop a common DAQ system to read both (almost done)
- Study the time development of hadronic showers

Active cooling:

- Complete the cooling study we started within CEPC
- Build a cooling system and modify the SDHCAL mechanical structure to cope with



0.8 mW/chips with power pulsing → 80 mW/chips without power pulsing



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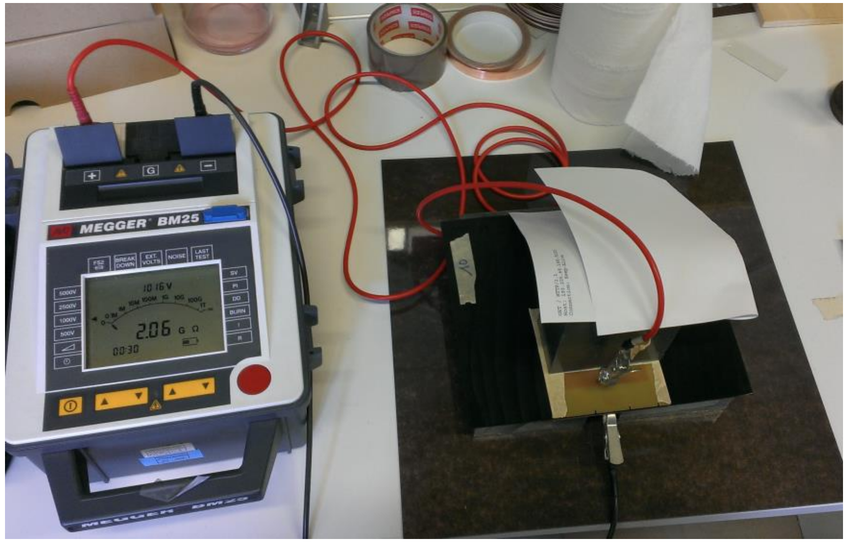
High Rate RPC/MRPC:

High-Rate capability

RPC is low-rate capability detector due to the resistive nature of the electrodes. The capability could be increased by developing low resistivity materials. Our R&D started within the CMS-mu upgrade project

Resistive material development



PVdF and **PEEK** are very stable and chemically inert thermoplastic

-New kind of PVdF developed with the help of PolyOne (Germany).
 Doped with CNT we achieved a bulk resistivity of $10^{11\text{-}12}$ Ω.cm
-New charged PEEK developed with the help of Krefine (Japan).
Doped with BC a bulk resistivity of $10^{8\text{-}9}$ Ω.cm was achieved.

A few small detectors were made using doped PVdF plates of 2-3 mm thickness.
An excellent efficiency is obtained with cosmic but resisitivity is not low enough for high rate.

Plates made with charged PEEK were produced
but homogeneity issues are still there.
More efforts need to be made to finalize this material.
(M)RPC has excellent timing with respect to MPWD