THE SEMI-DIGITAL HADRONIC CALORIMETER (SDHCAL) FOR FUTURE LEPTON COLLIDERS

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FOR THE CALICE COLLABORATION

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Introduction

The CALICE-SDHCAL technological prototype [1] is a 1x1x1.3 m^3 high-granularity hadronic calorimeter using 48 Glass Resistive Plate Chambers (GRPC) as sensitive medium. Its first published results [2] constitute a major step in the demonstration that this technology is compatible with the requirements of the future International Linear Detector (ILD) in terms of efficiency, compactness and power consumption.

To validate completely the SDHCAL option, a new phase of R&D has started with the conception and the realization of a new prototype. The new one is intended to host fewer but larger active layers with its dedicated mechanical structure. They will be equipped with a new version of the electronic readout and an improved gas distribution scheme.

The SDHCAL technological prototype

- **Semi Digital** = 3 Thresholds detection (2-bits)
- 48 Layers of **1x1m²** GRPCs
- Self-supporting Stainless Steel structure
- 442000 electronic channels
- Embedded power pulsed electronics
- Trigger-less acquisition

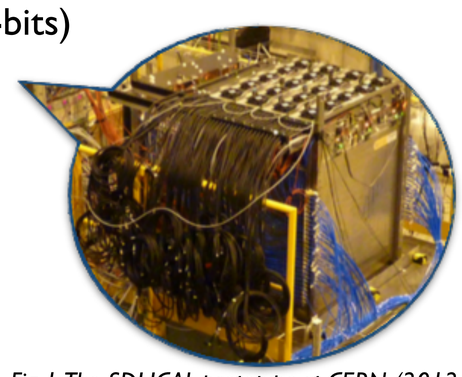

Fig 1:The SDHCAL prototype at CERN (2012.

- Electronics for one layer:
  - 1m^2 electronic board
  - 3 Detector InterFace (DIF) boards:
    - Transmit information between DAQ & detector electronics
  - 144 HARDROC2B ASICs [3] with 64ch
  - 9216 1x1cm^2 copper pick-up pads

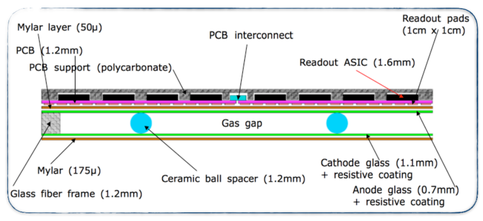

Fig 2: Schematic cross-section of an active layer.(not to scale)

SDHCAL for the ILD

- To validate the SDHCAL option for ILD:
  - Build larger detectors
  - Up to layers of 94cm x 293.5cm
- Next intermediate milestone:
  - Prototype with several (2x1m^2) layers
- A new gas distribution system is also proposed to improve gas circulation inside the chamber.

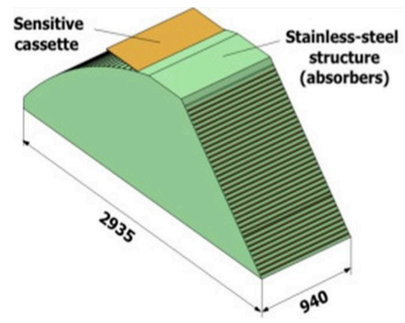

Fig 9: one of the SDHCAL ILD barrel module.

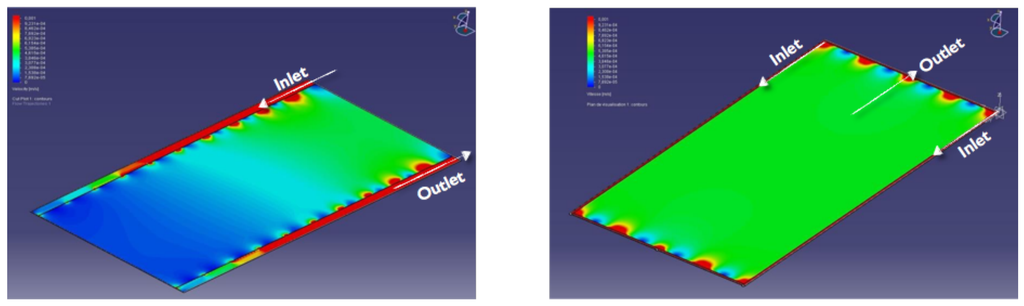

Fig 10: Gas circulation simulation in a 2m x 1m GRPC using the SDHCAL prototype scheme (left) and the new one (right).

Trigger-less event building

- Measure number of hits instead of energy
- Physical events built with time clustering
- Particle identification based on topological criteria

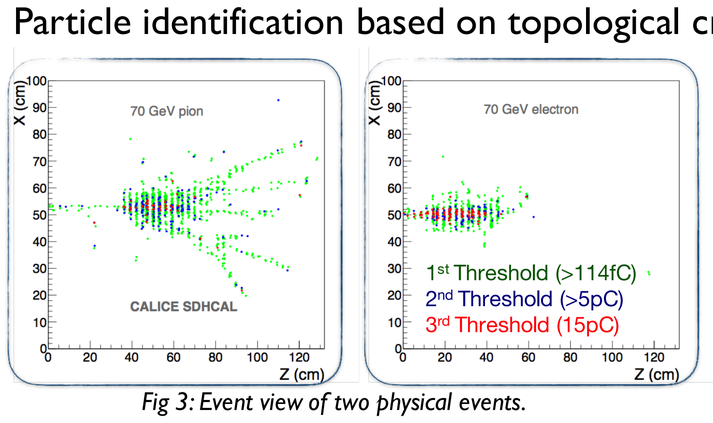

Fig 3: Event view of two physical events.

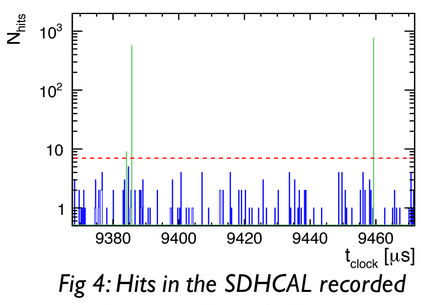

Fig 4: Hits in the SDHCAL recorded with auto-trigger DAQ mode.

SDHCAL performance

- Prototype exposed to beams of muons, electrons and hadrons at CERN facilities.
- Efficiency and cluster size measured using muons.

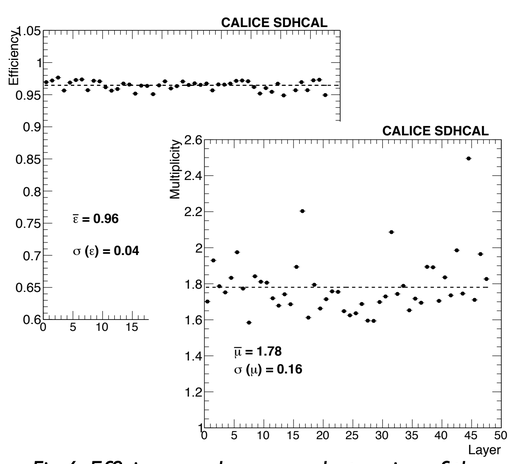

Fig 6: Efficiency and average cluster size of the 48 SDHCAL units measured with beam muons.

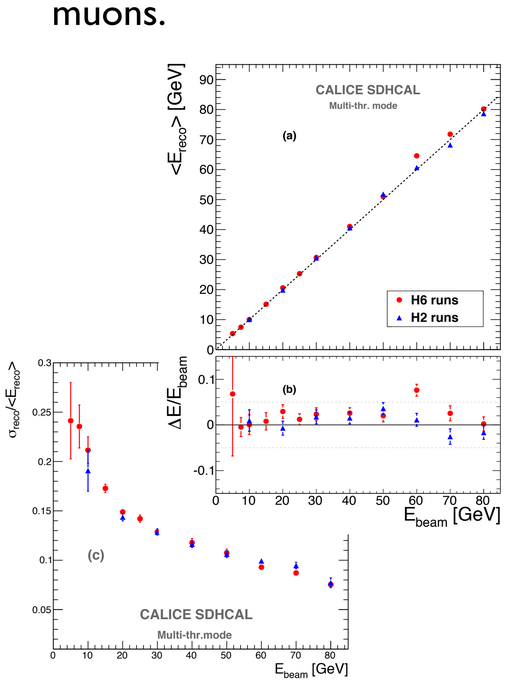

Fig 5: Linearity (a,b) and energy resolution (c) of the SDHCAL.

Energy of hadronic shower estimated with:

$$E_{rec} = \alpha N_1 + \beta N_2 + \gamma N_3$$

where:

$$\alpha = \alpha_0 + \alpha_1 N_{tot} + \alpha_2 N^2_{tot}$$
$$\beta = \beta_0 + \beta_1 N_{tot} + \beta_2 N^2_{tot}$$
$$\gamma = \gamma_0 + \gamma_1 N_{tot} + \gamma_2 N^2_{tot}$$

Parameters obtained by fitting part of the data.

New electronic readout

- Improved version of the HARDROC ASIC :
  - Independent channels
  - Extended dynamic range (up to 50pC)
  - I2C protocol
  - Etc.

  700+ ASICs were produced and tested.
- New PCB of 100x33cm^2 will host 48 ASICs
- New DIF:
  - Only 1 per layer
  - I2C protocol
  - TTC [4] vs HDMI for clock signals
  - Ethernet vs USB for data readout

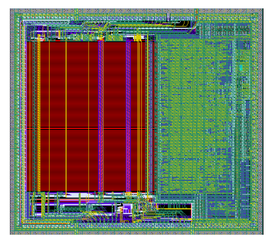

Fig 12 :The HARDROC3 ASIC.

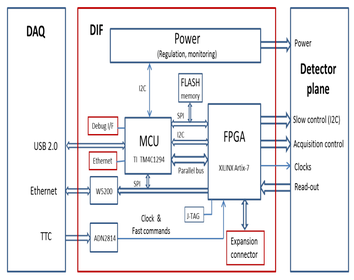

Fig 14 : Block diagram of the new DIF.

New mechanical structure

- Self-supporting structure:
  - Stainless steel plates
  - Electron Beam Welding assembly (EBW)
    - Reduce deformation and dead zones
  - Roller levelling technique
    - Sub-mm flatness over 3m steal plates

Fig 15 : Roller levelling technique.

Fig 17 : Electron beam welding technique.

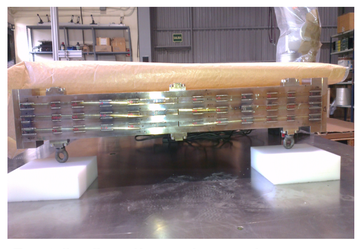

Fig 18 : Small mechanical structure assembled by EBW.

References:

- [1] G. Baulieu, et al., *Construction and commissioning of a technological prototype of a high-granularity semi-digital hadronic calorimeter*, JINST **10** (2015) no.10, P10039.
- [2] V. Buridon, et al., *First results of the CALICE SDHCAL technological prototype*, JINST **11** (2016) no.04, P04001.
- [3] S. Callier, et al., *ROC chips for imaging calorimetry at the International Linear Collider*, JINST **9** (2014) no.02, C02022.
- [4] B. Taylor, [RD12 Project Collaboration], *TTC distribution for LHC detectors*, IEEE Trans. Nuclear Science **45** (1998) no.03, pp. 821-828.