Noble Liquid Calorimetry for an FCC-ee Experiment

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Introduction

Noble liquid calorimeters have been successfully used in the past (D0, H1, NA48) and are currently operating in NA62 and ATLAS. Their very good energy and timing resolution, stability, linear response, uniformity and radiation hardness make them also very good candidates to equip detectors at future facilities such as FCC-hh, LHeC and FCC-ee.

The very demanding FCC-ee physics program and its exquisite statistical precision set strict constraints on the detector designs [1]. A broad R&D program has started to develop a noble liquid calorimeter meeting these detector requirements with, among others, an increased granularity and a decreased dead material budget before the sensitive volume.

Detector concept

FCC-ee noble liquid ECAL barrel

- Sampling calorimeter, 40 cm deep sensitive area (22 X0)
- 1536 Lead or Tungsten absorbers, inclinded by 50°
- Noble liquid sensitive 1.2 - 2.4 mm gap:
  - LAr or LXe (or LKr)

- Optimized for Particle Flow (PFlow)

- Sampling calorimeter, 40 cm deep

- Increased granularity ↔ increased number of channels from extract to the cryostat (warm electronics scenario)
  - 2 M channels for the barrel (10 times more than in ATLAS)
  - Increased area dedicated to signal extraction (x2)
  - Increased number of channel per flange (x5)

- Connector-less
  - 20 000 wires per feedthrough
  - G10 structure with slits, indium seal, Epo-Tek glued Kapton strip cables

- Observed to be leak tight over several thermal cycles (77 K, 3.5 bar)

Highly granular readout electrodes

- Signal extraction
  - Purely analog until the inner/outer radius of the electrode (cold electronics) or until the cryostat feedthroughs (warm electronics)
  - Multi-layer PCB readout electrodes (Fig. 2)
    - Homogeneity, hermeticity, high sampling fraction

- Cross-talk
  - Capacitive coupling between signal pick-up pads and extraction traces
  - Fully derived from FEM studies (Scattering parameters)
    - 12% peak to peak current at the PCB output without ground (GND) shield (Fig. 3)
    - < 2% with two GND shields surrounding signal extraction trace
  - Further reduced by long signal shaping (no pile-up noise)
  - < 1% with one GND shield and shaping time > 150 ns

Conclusions & Outlook

Intensive R&D started to adapt noble liquid calorimetry to FCC-ee

- Simulations show that a cross-talk < 1% together with a MIP S/N > 5 is achievable for a typical cell
- A solution for high density connector-less feedthroughs has been identified
- Small scale prototype of a carbon fibre cryostat produced and validated
- First performance results from a full simulation Key4Hep implementation
- Mid-term objective: design and produce a prototype for test beams

References