Towards Realistic Implementations of Large Imaging Calorimeters

LP2019

The CALICE Program

Development of highly granular electromagnetic and hadronic calorimeters for particle flow reconstruction in future collider experiments. Key steps:

- ***Validation*** of the concept of high granularity with physics prototypes ✓
- ***Technical realization*** of detector systems satisfying collider constraints - Technological prototypes with fully embedded electronics tested in particle beams
- ***Application*** of CALICE expertise and technology in running experiments e.g. CMS HGCal

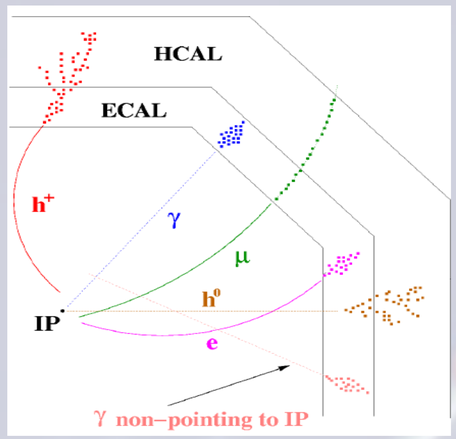
A key element: Use of ***common technologies and infrastructure***, such as a common ASIC family (SKIROC, SPIROC, HARDROC) to facilitate combined running.

Particle Flow Calorimetry

- High sampling frequency and granularity in calorimeters to separate particle showers
- Avoid dead material between tracker and calorimeters

➤ Calorimeters have to be inside the magnet coil

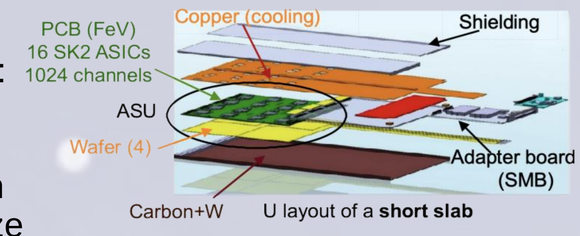
- Requires the design of very compact service electronics and active layers sensitive to the MIP level
- Requires precise mechanical assembly of the calorimeter structure allowing only small tolerances over large areas



Silicon Readout

ECAL with tungsten absorber **(SiW ECAL)**:

- Silicon pixels as active material
- 9x9 cm^2 wafers with 5.5x5.5 mm^2 cell size

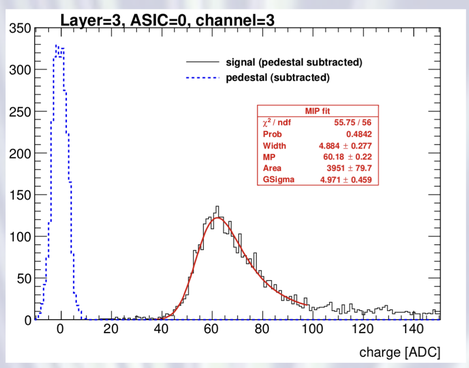


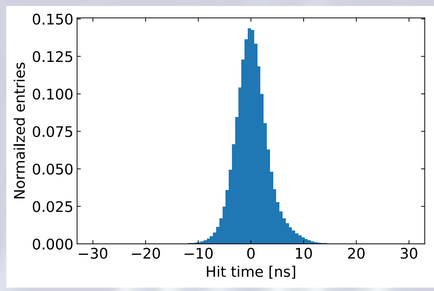
- Single base units (ASU's) validated at low energies
- 16 ASICs and 1024 channels per ASU
- Full QA and assembly chain
- Validation of up-scalability to long slabs of 8 chained modules (barrel ECAL)

Achievements

Signal to Noise ratio = $MPV_{MIPS}/\sigma_{Noise}$ ~20 in the SiW ECAL:

➤ Ability to trigger on and read out small signals (MIPS) demonstrated

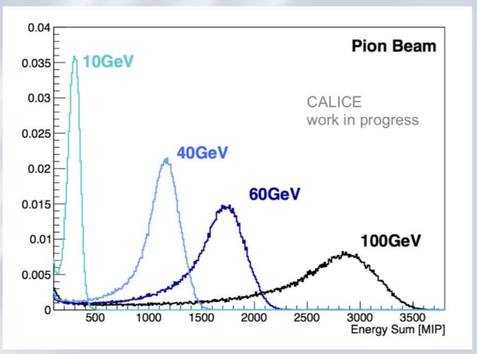




Timing on a single cell level: ~3.3ns for the AHCAL in test beam mode, higher time resolution possible with faster clock setting

Successful single cell MIP calibration of the full AHCAL prototype:

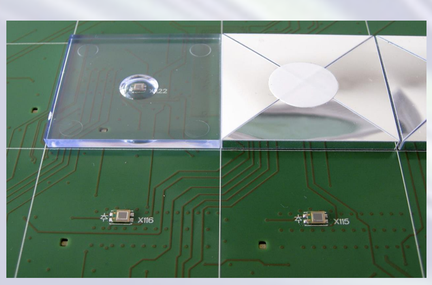
- Good overall detector response
- Signal to Noise ratio = $MPV_{MIPS}/\sigma_{Noise}$ ~50

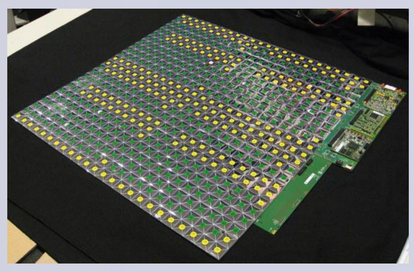


SiPM-on-Tile

Analogue HCAL **(AHCAL)**:

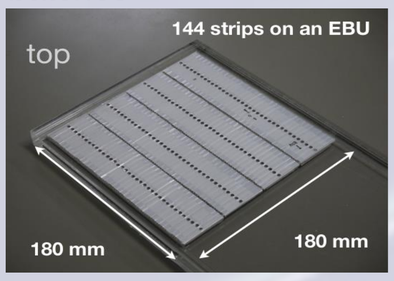
- Scintillator tiles with individual MPPC readout
- 3x3 cm^2 segmentation





Automated assembly of large layers by pick and place machines

QA assurance of all modules
Sample testing of MPPC batches

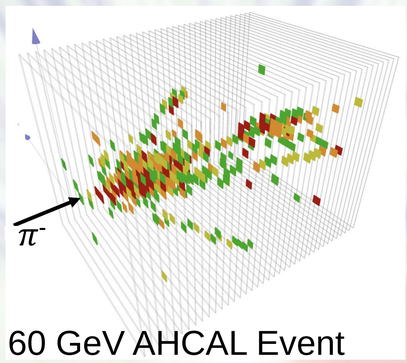


Similar technology used for a scintillator strip ECAL:

➤ High effective granularity achieved by crossed strips in adjacent layers

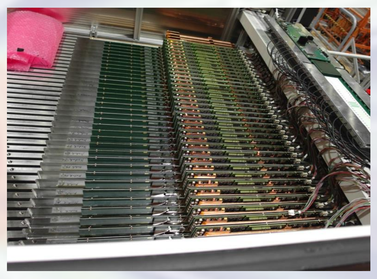
Beam Tests of Technological Prototypes

Assembly of ~1 m^2 prototypes with fully embedded electronics



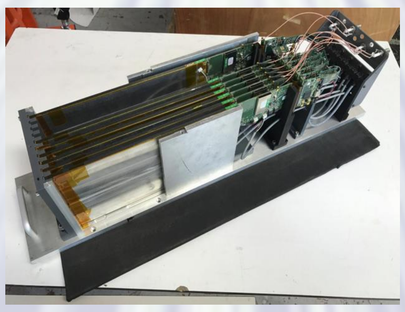
60 GeV AHCAL Event

Rigorous testing of all technologies at TB facilities at CERN/DESY

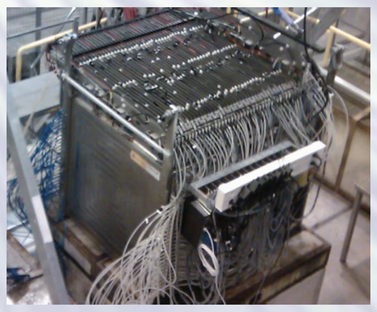


AHCAL prototype with 39 layers

SiW ECAL prototype with 15 layers

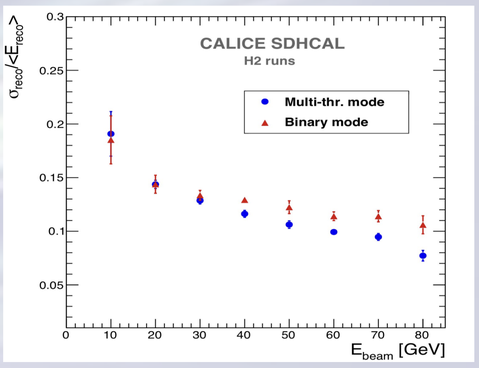


SDHCAL prototype with 48 layers



Testing of binary versus multi threshold mode of the GRPCs:

➤ Two bit multi threshold mode improves energy resolution in SDHCAL



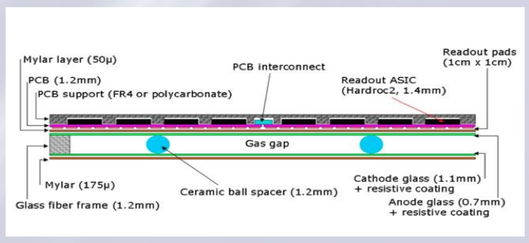
Integration

Small scale detector interfaces (DIF) as link between ASICS and DAQ system

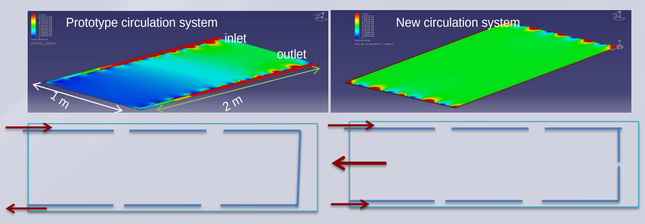
Gaseous Readout

GRPC based hadronic calorimeter **(SDHCAL)**:

- binary and two bit readout
- 1 cm^2 pad size

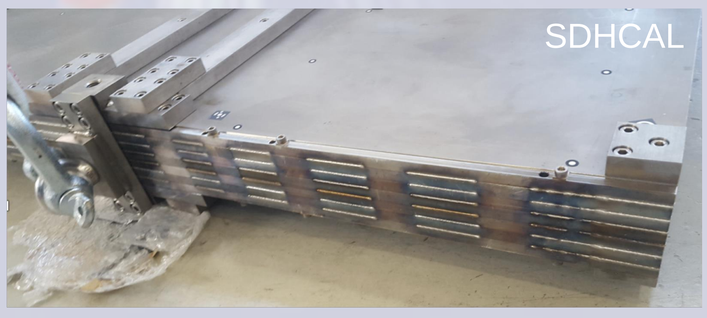


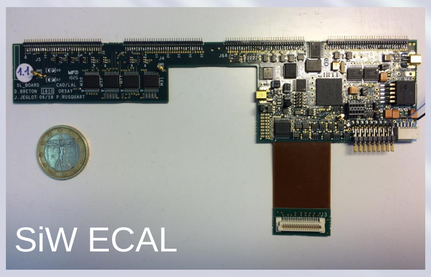
Key developments towards scalability to full size experiments



Improved gas flow for new 1x2 m^2 GRPC plates

Precision mechanics to assemble structural components, e.g. Electron beam welding of absorber structure for excellent surface flatness and minimal deformation over large areas





Compact SL-board and low profile connectors as interface for slow control and readout of up to 15 chained slabs

Development of flat interconnections between detector modules to facilitate compact layers

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