Performance of a Highly Granular Scintillator-SiPM Based Hadron Calorimeter Prototype in Strong Magnetic Fields

IEEE Nuclear Science Symposium
Atlanta - 23.10.17

Christian Graf
for the CALICE Collaboration

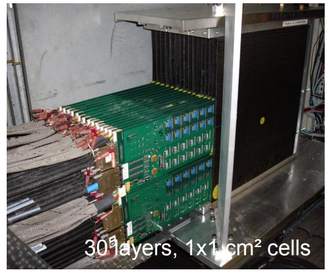
- Overview
- Technologies used
- Test-beam performance
- Outlook - full technical prototype

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

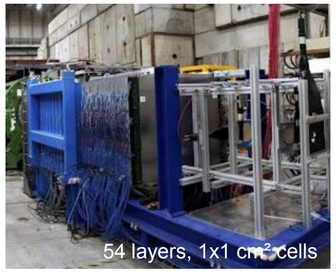
CALICE

- **Aim**: Development of new technologies for calorimetry with highly granular detectors
- Several technologies under study
- This talk: focus on **analog hadronic calorimeter** (AHCAL)

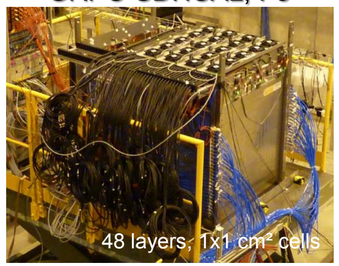
Si-W ECAL



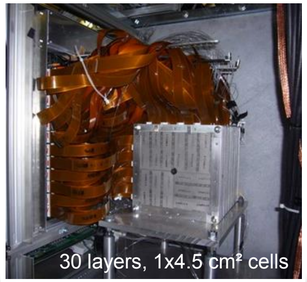
RPC-DHCAL, Fe&W



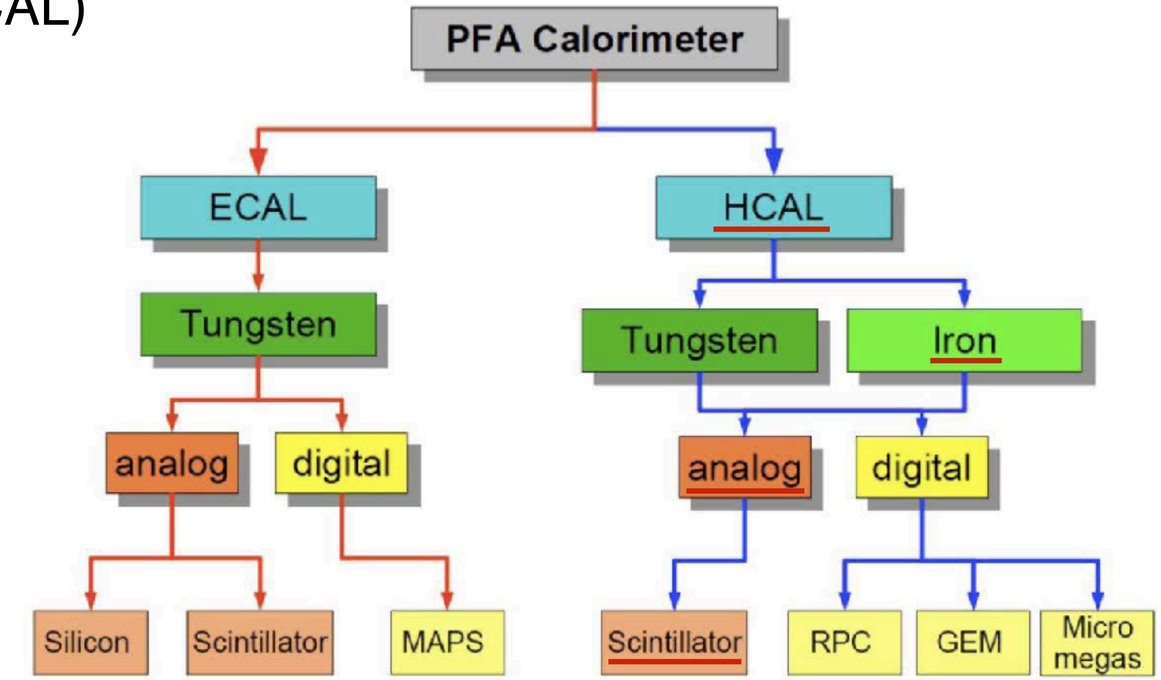
GRPC-SDHCAL, Fe



Sc-W ECAL

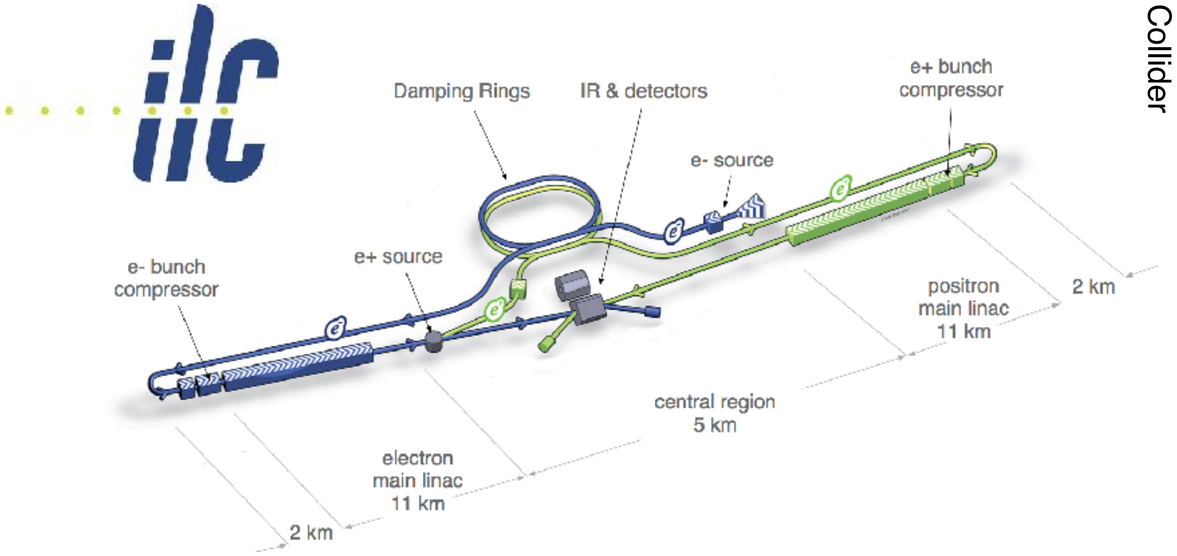


Sc-AHCAL, Fe

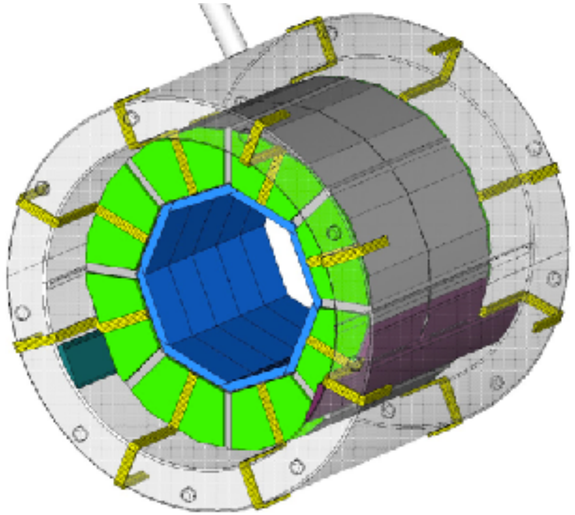


Highly Granular Calorimeters - Motivation

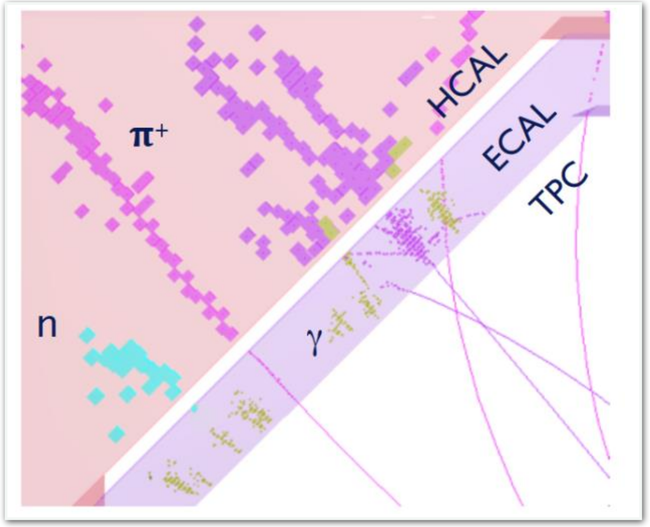
- Future linear accelerator e.g., ILC or CLIC
- Detectors rely on Particle Flow algorithm to achieve ~ 3% jet energy resolution
- Highly granular calorimeters needed to resolve single particles in a jet
- —> 8 Mio channels
- Other applications:
  LHC (CMS), neutrino experiments, …



International Linear Collider



HCAL Barrel



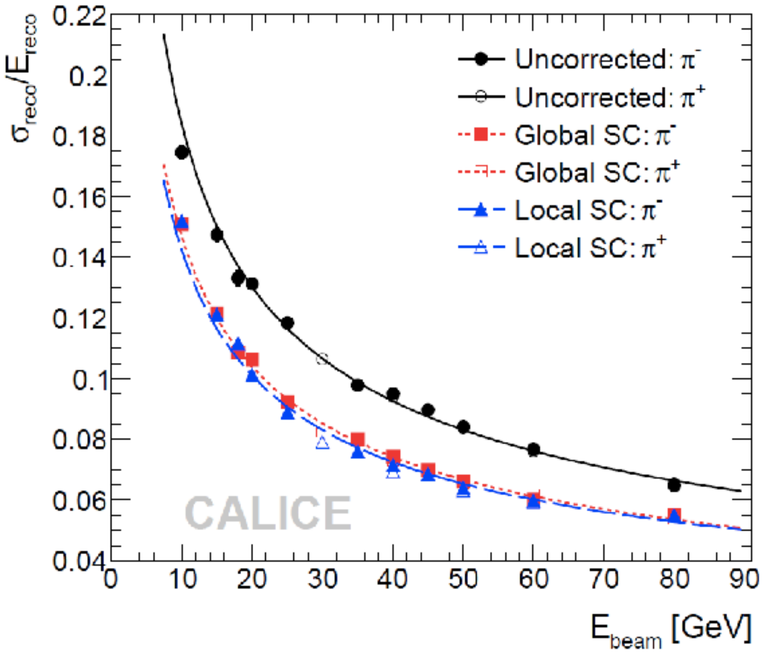
Particle Flow Concept

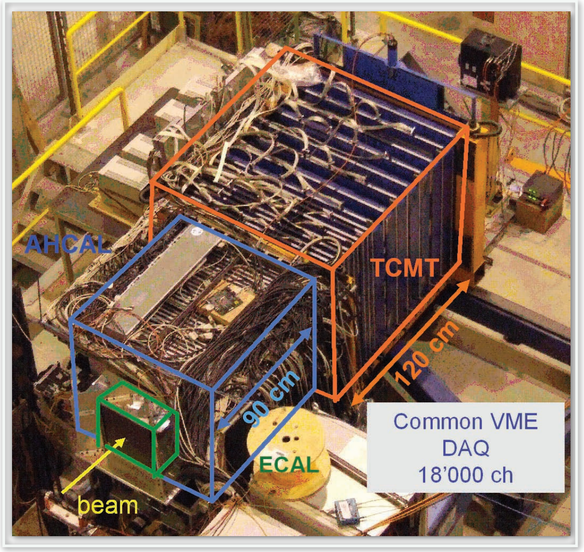
AHCAL - Physics Prototype

2001	2006	2015	Present	2018	???
CALICE founded	**Physics prototype**	Technical prototype	Prove concept of techn. prototype	Large technical prototype	Full Detector

- Show principle of highly granular calorimeters (~8000 channels)
- Successfully tested in DESY, CERN, FNAL test-beam campaigns
- Proved competitive single hadron energy resolution and two particle separation

[Jinst 7 P09017 (2012)]





Physics prototype

AHCAL - Technical Prototype

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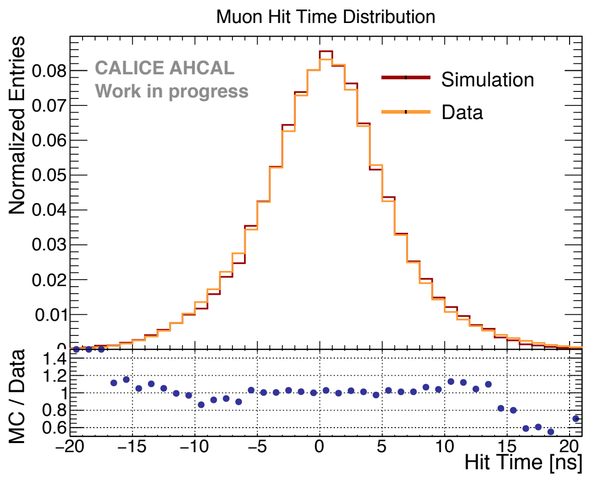
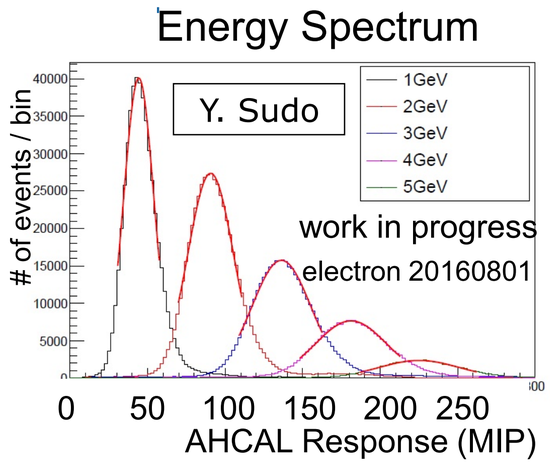
CALICE founded	Physics prototype	**Technical prototype**	Prove concept of techn. prototype	Large technical prototype	Full Detector

- Prove scalability to full detector
- Steel and tungsten absorbers
  - partially instrumented
- Time measurements possible
- Small steel stack:
  - Precision measurements of em showers
  - Test of temperature compensation / power-pulsing
- Data analysis still ongoing

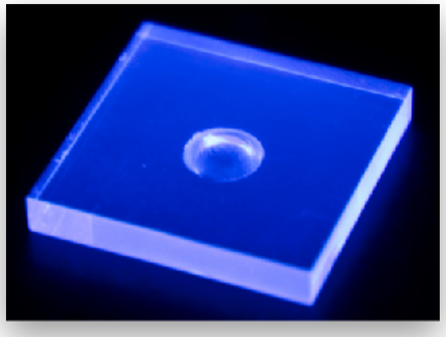
Technological Prototype

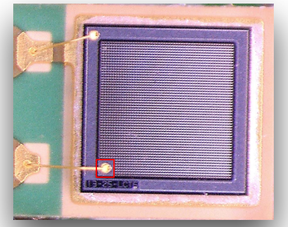
Technical Prototype in small steel stack

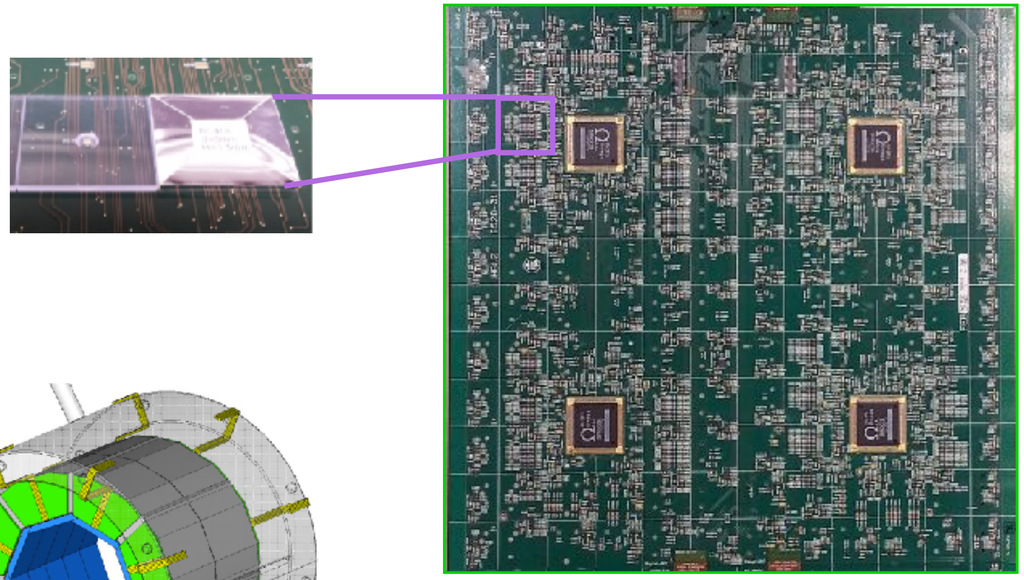


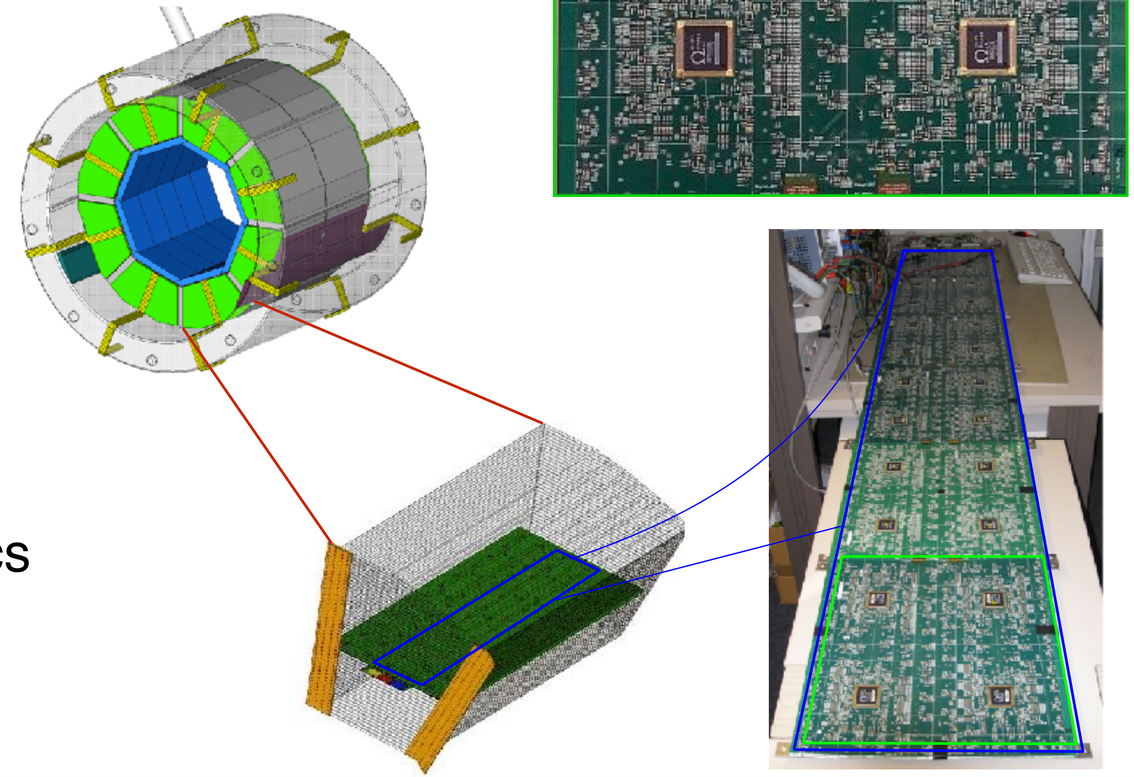


Technologies





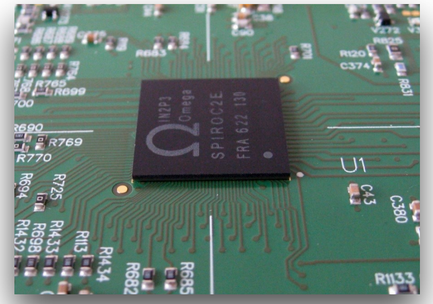




- Sampling calorimeter based on scintillators and silicon photomultipliers (SiPMs)
- Scintillator tiles of size 3 x 3 x 0.3 cm^3, dimple for light focussing, wrapped in reflecting foil
- HCAL base unit (HBU) with fully integrated electronics

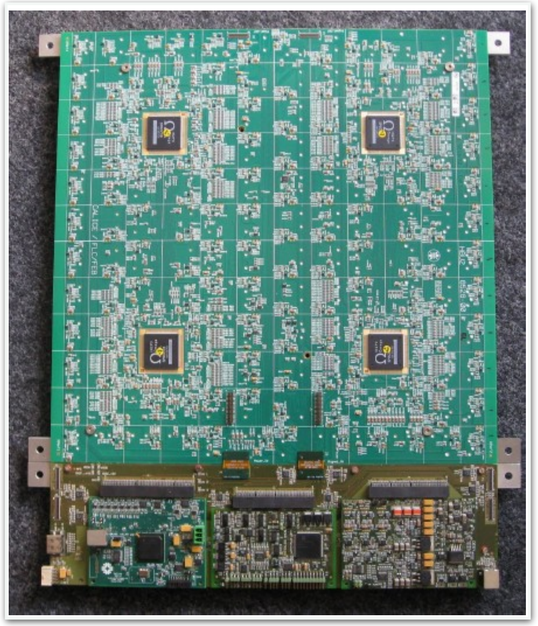
Readout

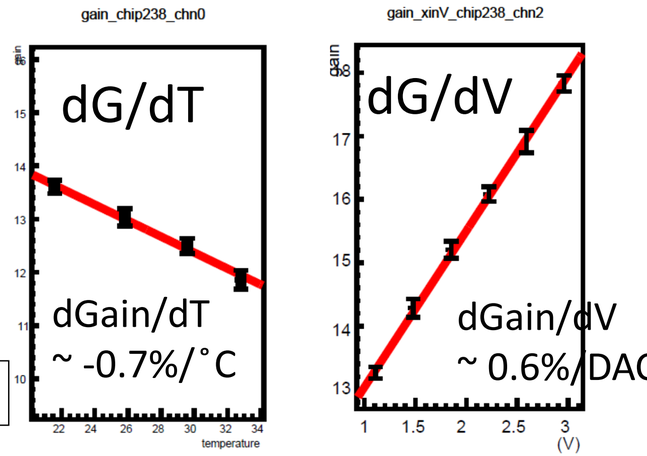
- Readout ASIC: **Spiroc2b**
- 36 channels (ext. trigger or auto-trigger)
- 12 bit ADC for energy and time measurement
- 16 memory cells per channel
- Central Interface Board (CIB)
  - fitted for space constraints in real detector
  - Contains: Detector Interface (DIF), Calibration, Power
  - Power board capable of **power pulsing** and **software adjustment of SiPM power voltage**



HBU

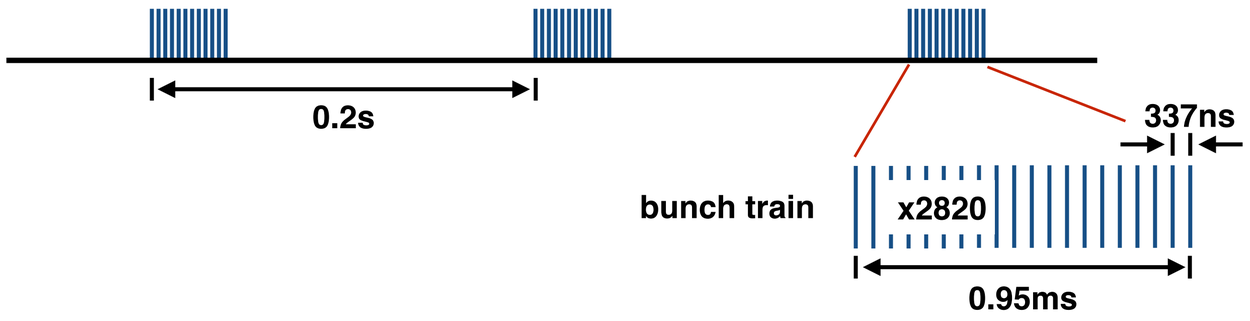
CIB

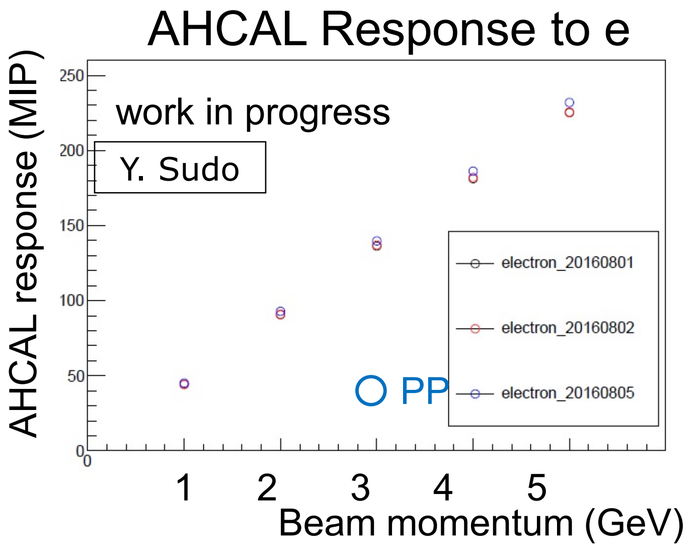




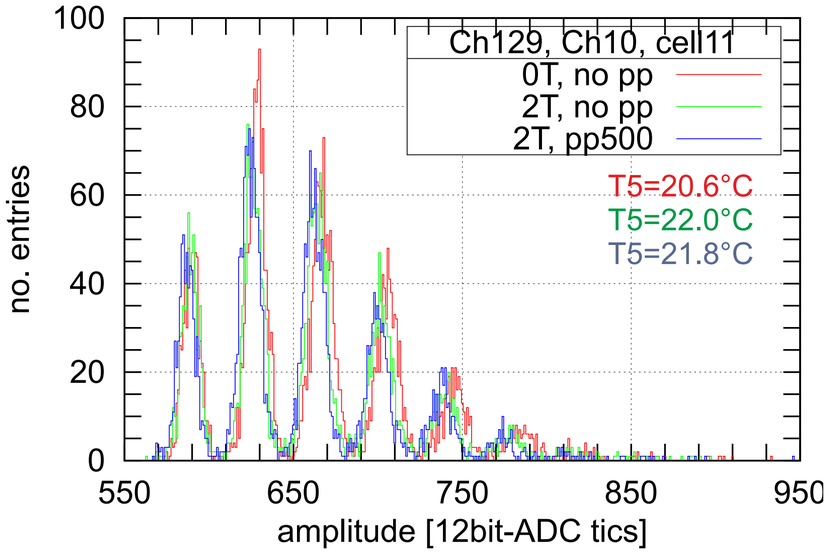
Y. Sudo

Power Pulsing





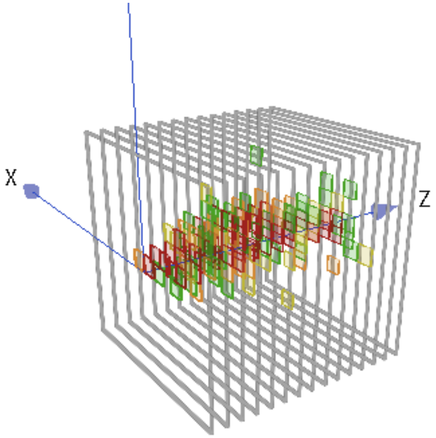
- **Power pulsing**: 8 Mio channels, no active cooling —> reduce power consumption
- Rapidly cycling the power according to the beam structure of a linear accelerator
- 1ms train of bunches spaced ~300ns apart, 199ms idle time
- SiPM gain stays stable with power pulsing



AHCAL Test-beam with Magnetic Field

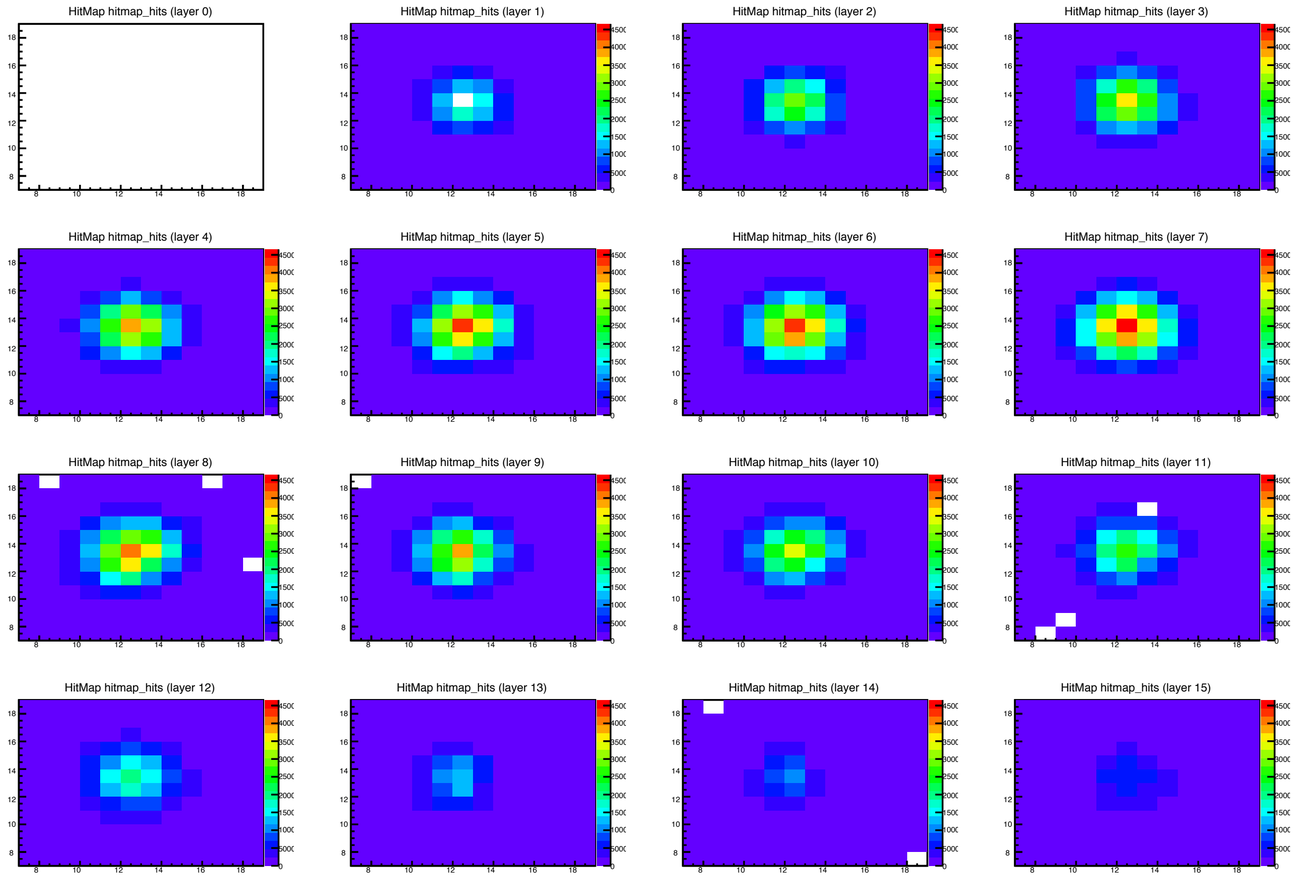
2001	2006	2015	Present	2018	???
CALICE founded	Physics prototype	Technical prototype	**Prove concept of techn. prototype**	Large technical prototype	Full Detector

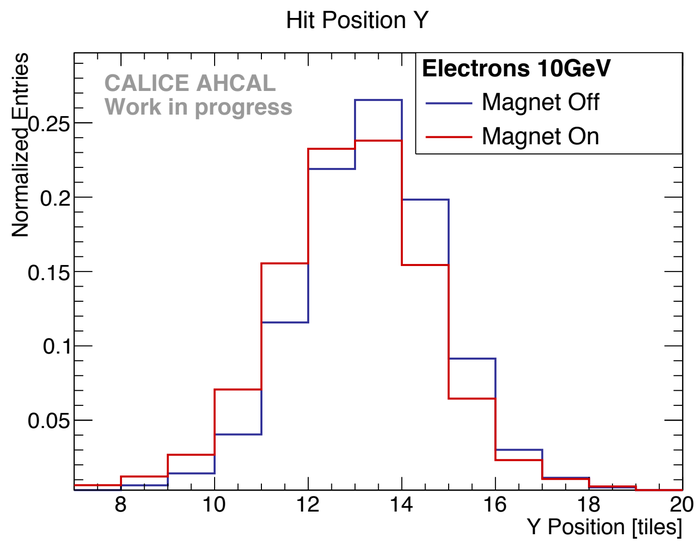
- 15 Layers in small steel stack, > 2000 channels
- Taking data with and without 1.5T magnetic field
- Muons, 10-60GeV Electrons
- Detector survived 2.4T

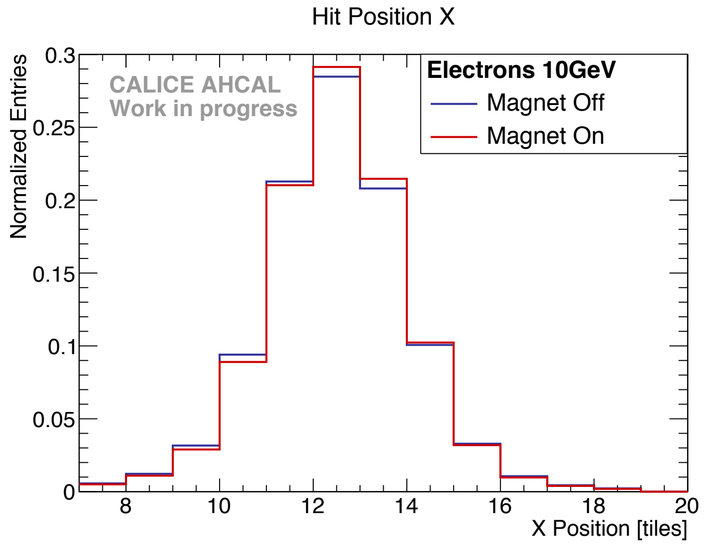


Event Display of em. shower

First Results (Work in Progress)



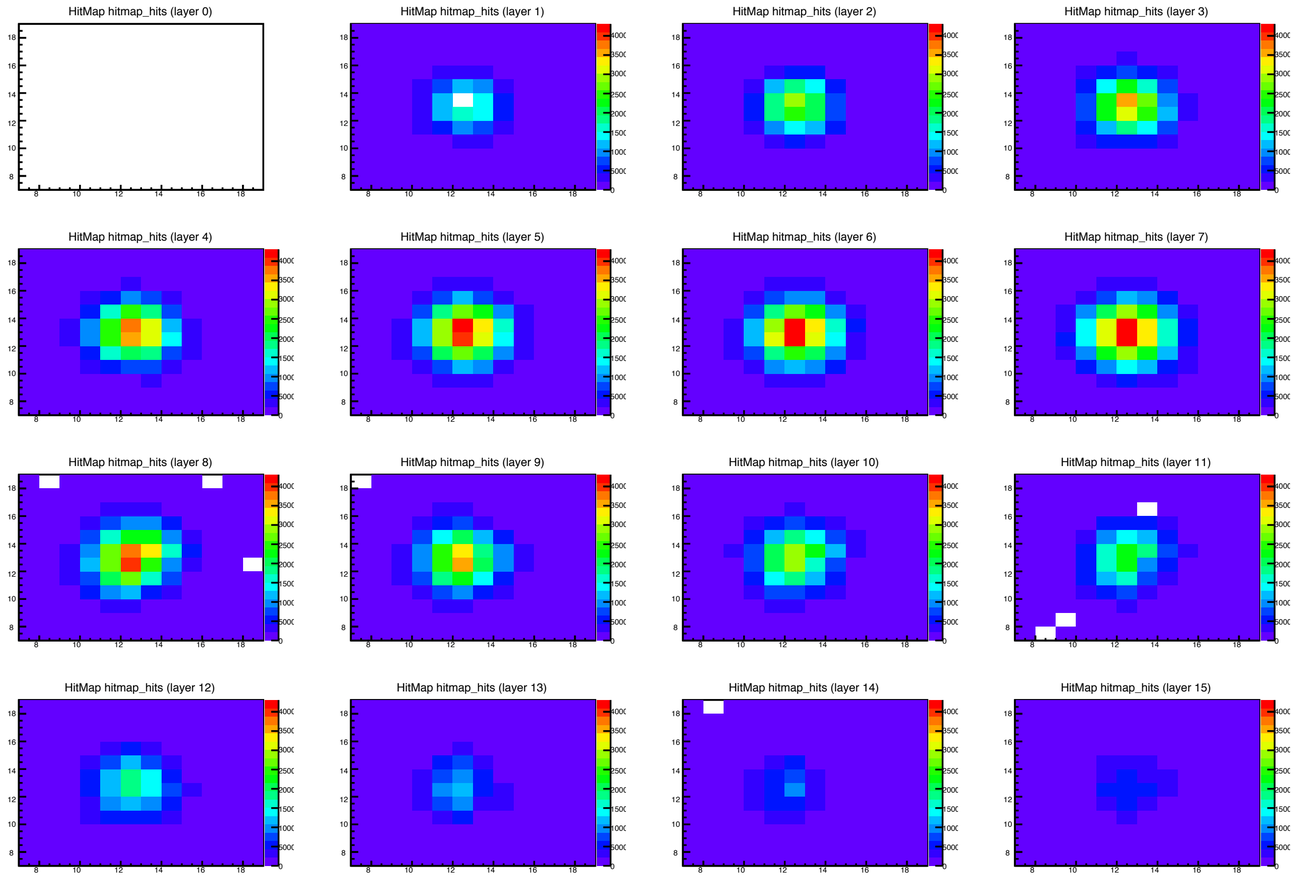


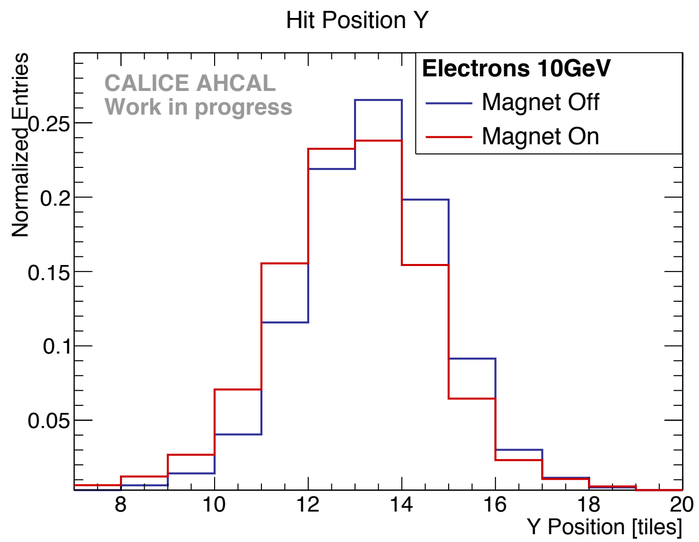


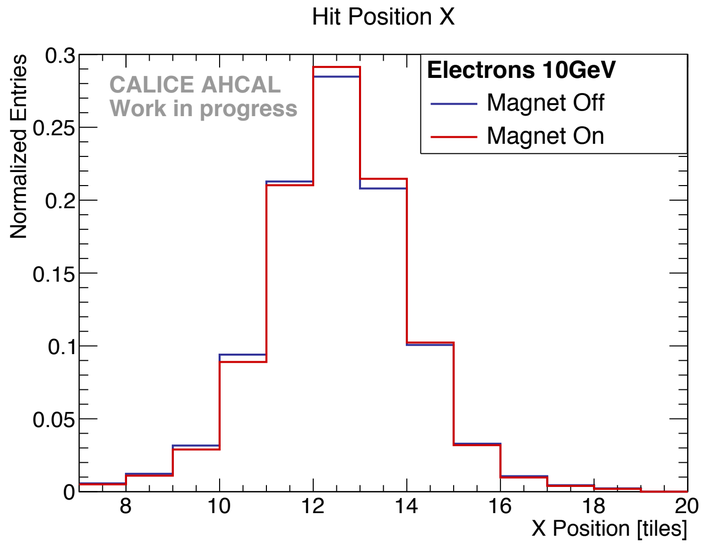
Magnet off

10 GeV Electrons

First Results (Work in Progress)







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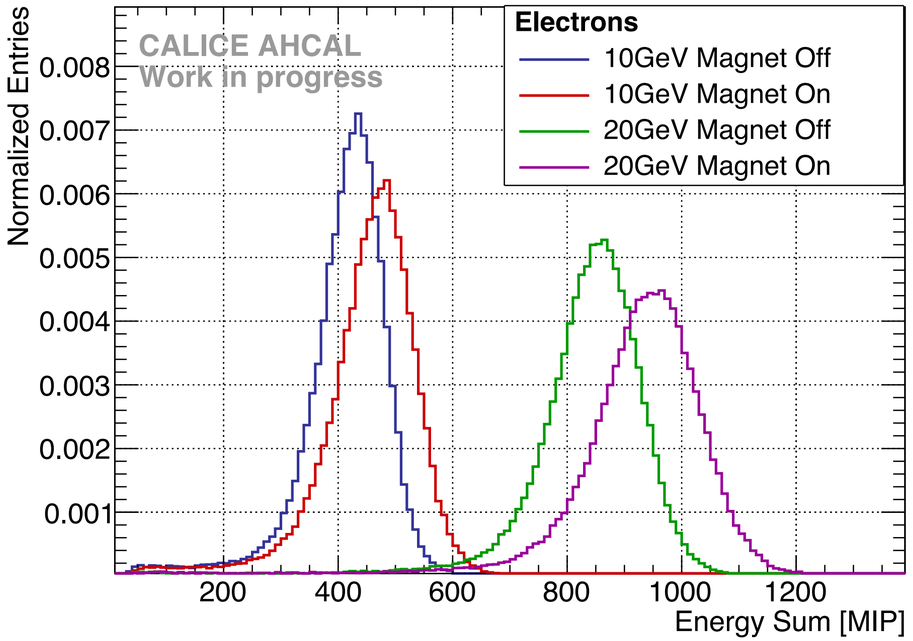
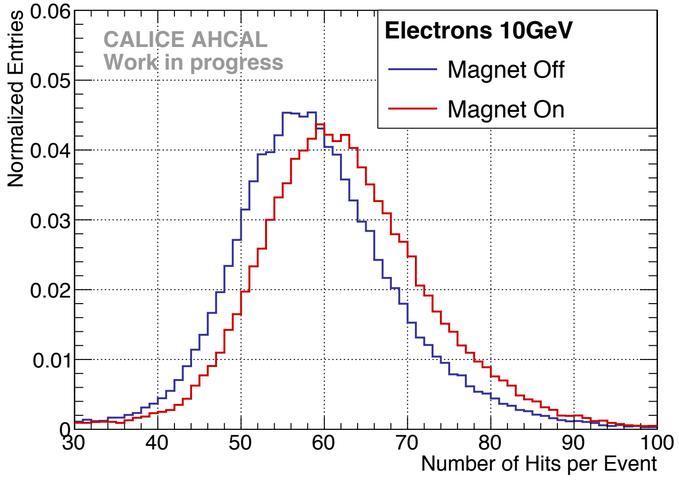
First Results (Work in Progress)

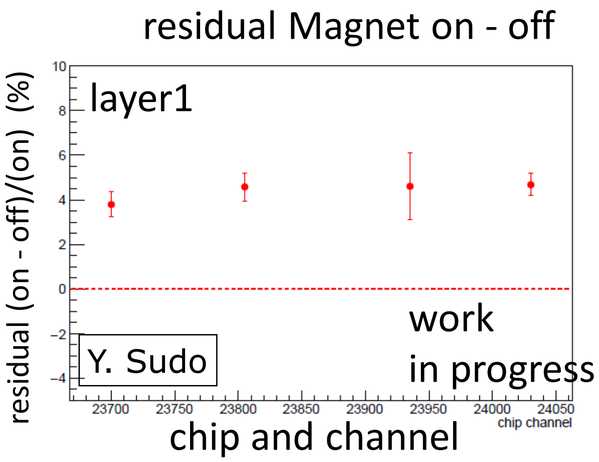
- Energy sum increases with magnetic field for electrons

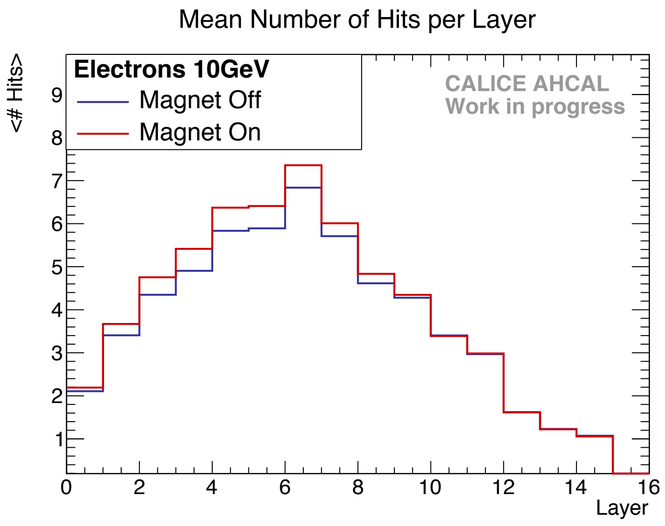


First Results (Work in Progress)

- Energy sum increases with magnetic field for electrons
- Effect is two-fold:
  1. increase in MIP scale
  2. increase in number of hits

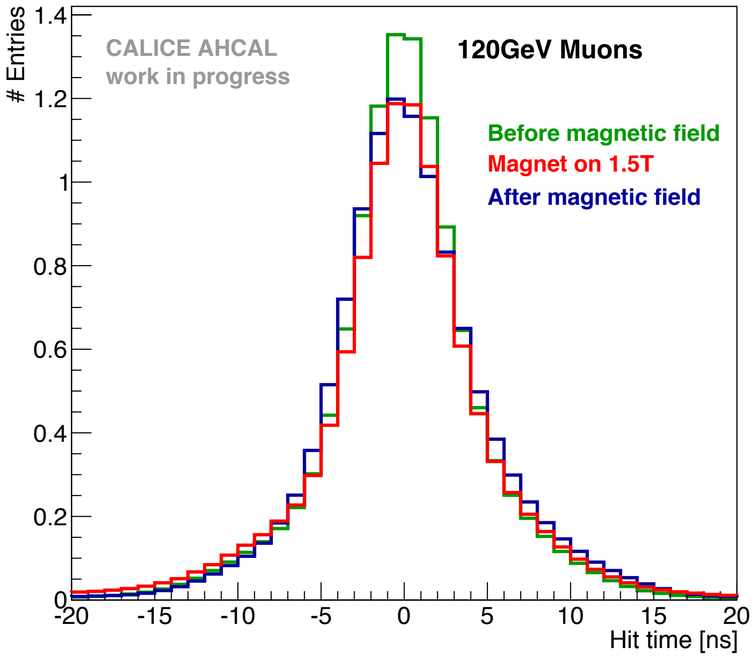






First Results (Work in Progress)

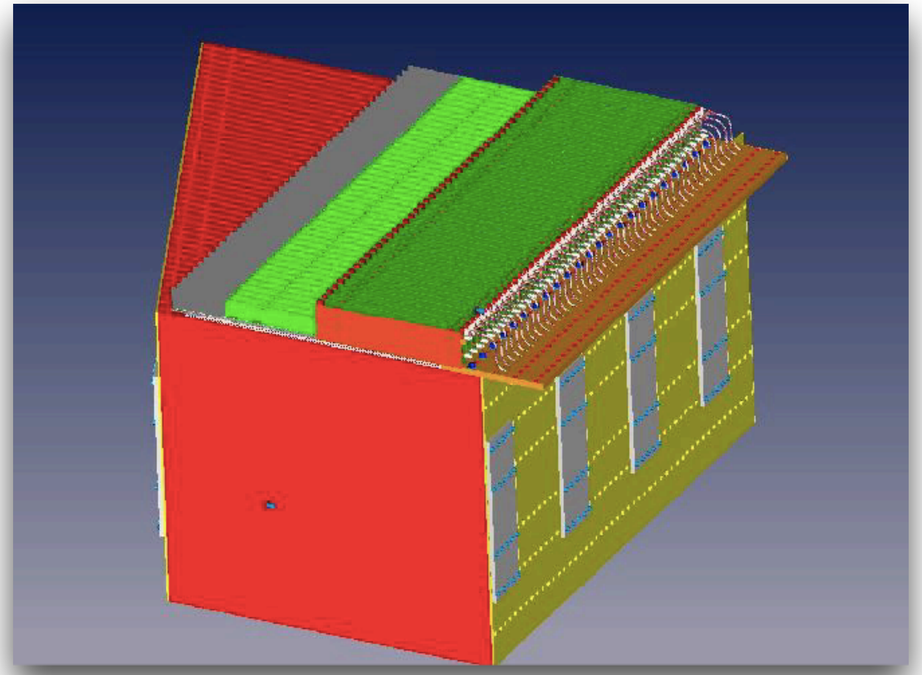
- Energy sum increases with magnetic field for electrons
- Effect is two-fold:
  1. increase in MIP scale
  2. increase in number of hits
- Time distributions stay stable with slight broadening of distribution during / after magnetic field



Outlook

2001	2006	2015	Present	2018	???
CALICE founded	Physics prototype	Technical prototype	Prove concept of techn. prototype	**Large technical prototype**	Full Detector

- Construction of large technological prototype
- 40 Layers, 160 HBUs, 23000 channels
- Mass production:
  - SiPM testing and characterization
  - AISIC tests
  - PCB construction and testing
  - Automatic scintillator tile wrapping and assembly
  - Cosmic ray tests
- Towards hadronic test-beam at SPS in 2018



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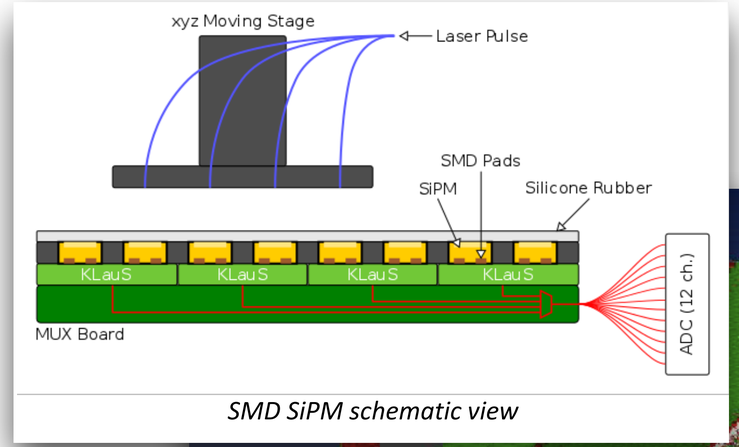
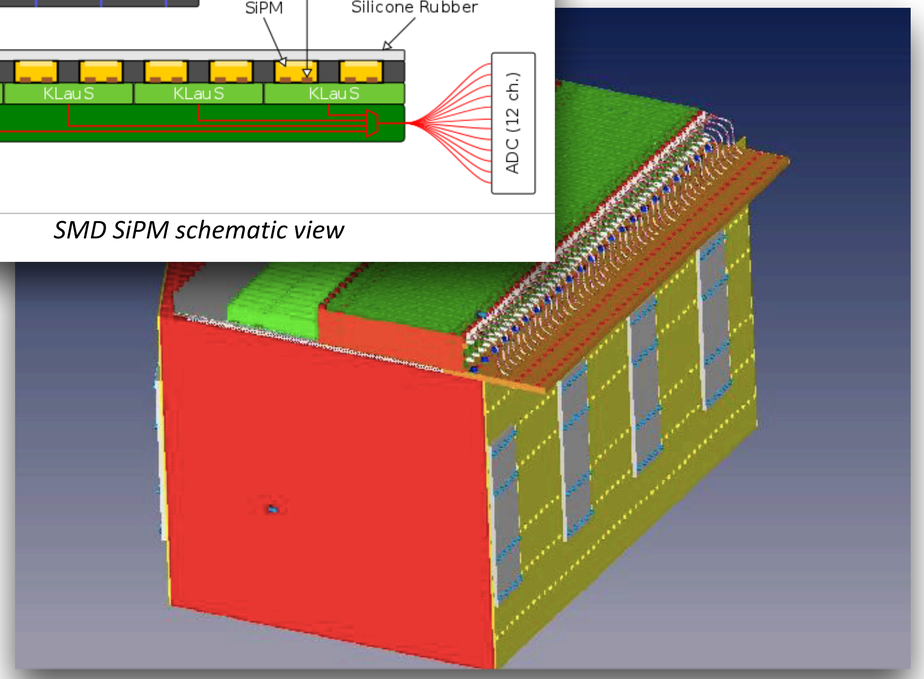


SMD SiPM schematic view



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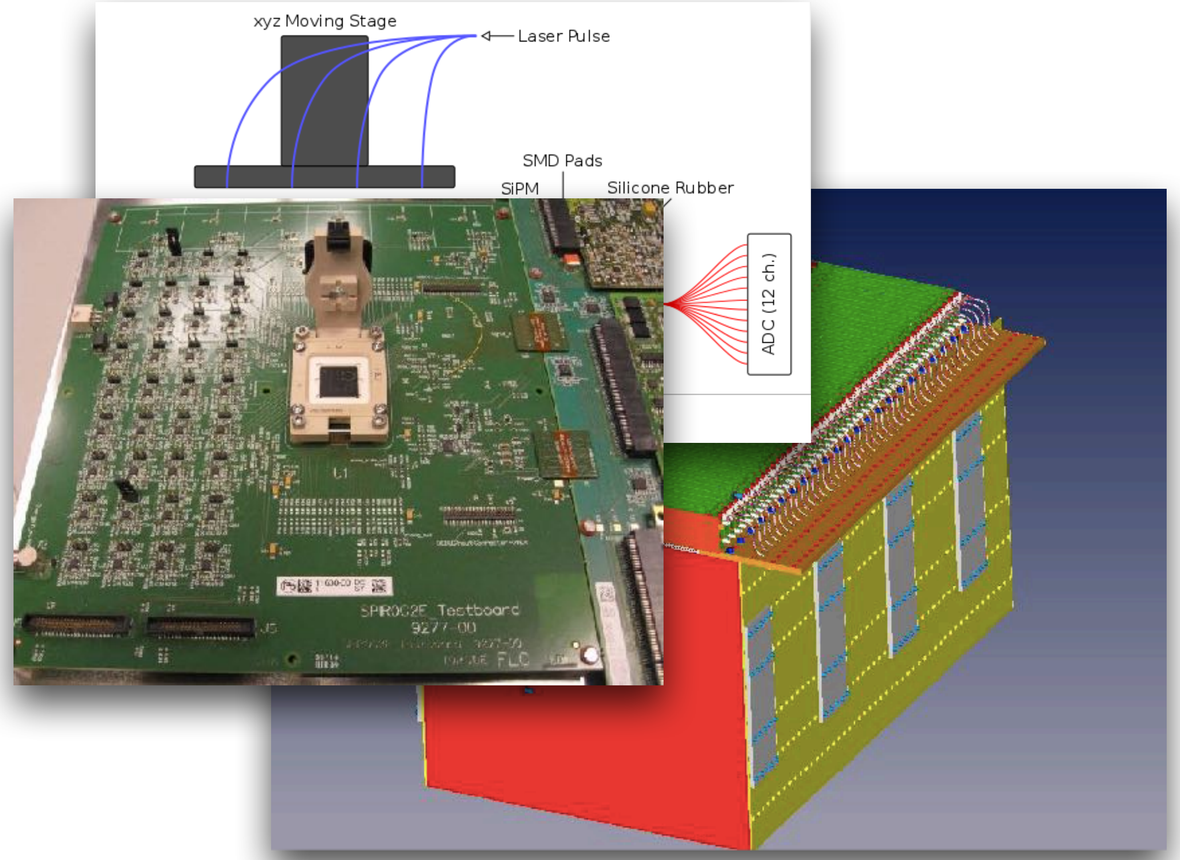

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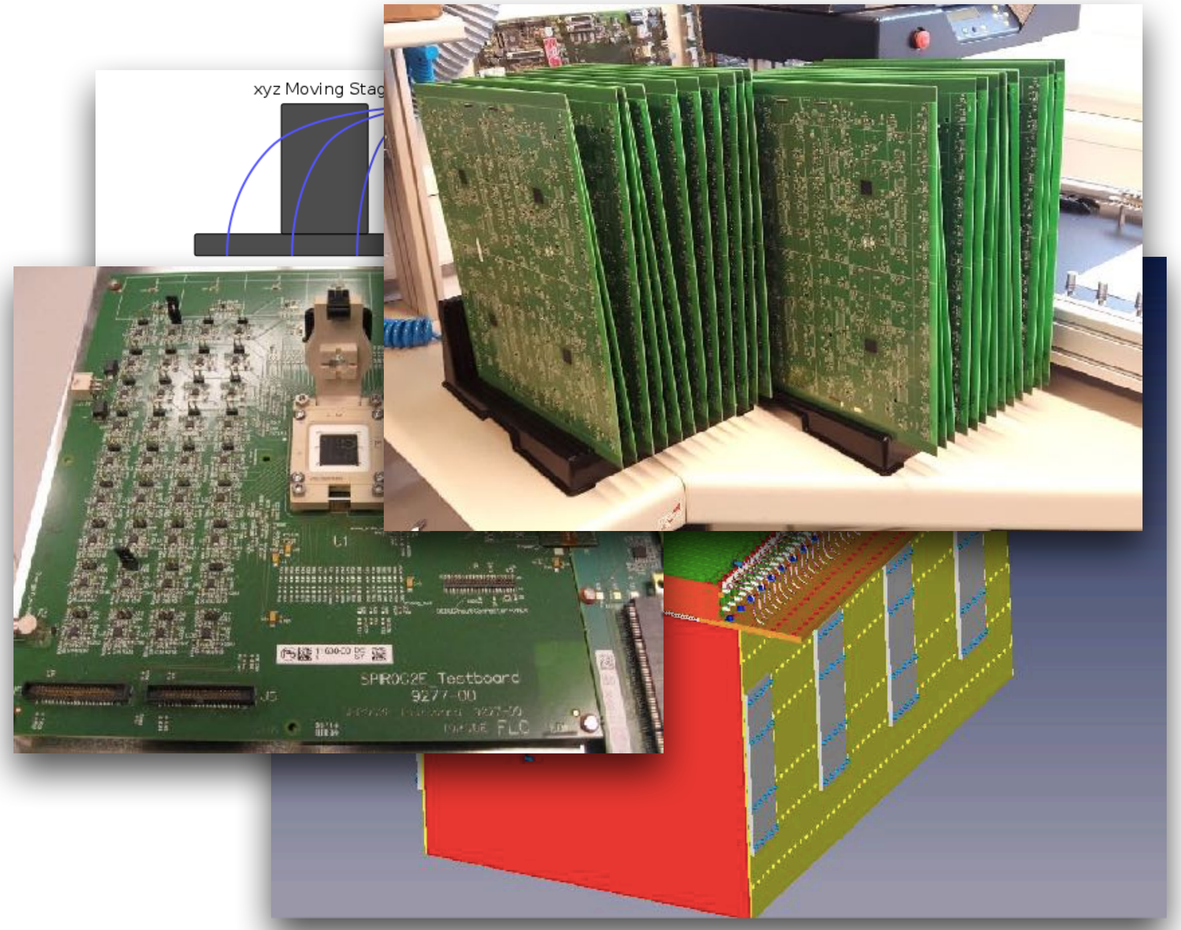

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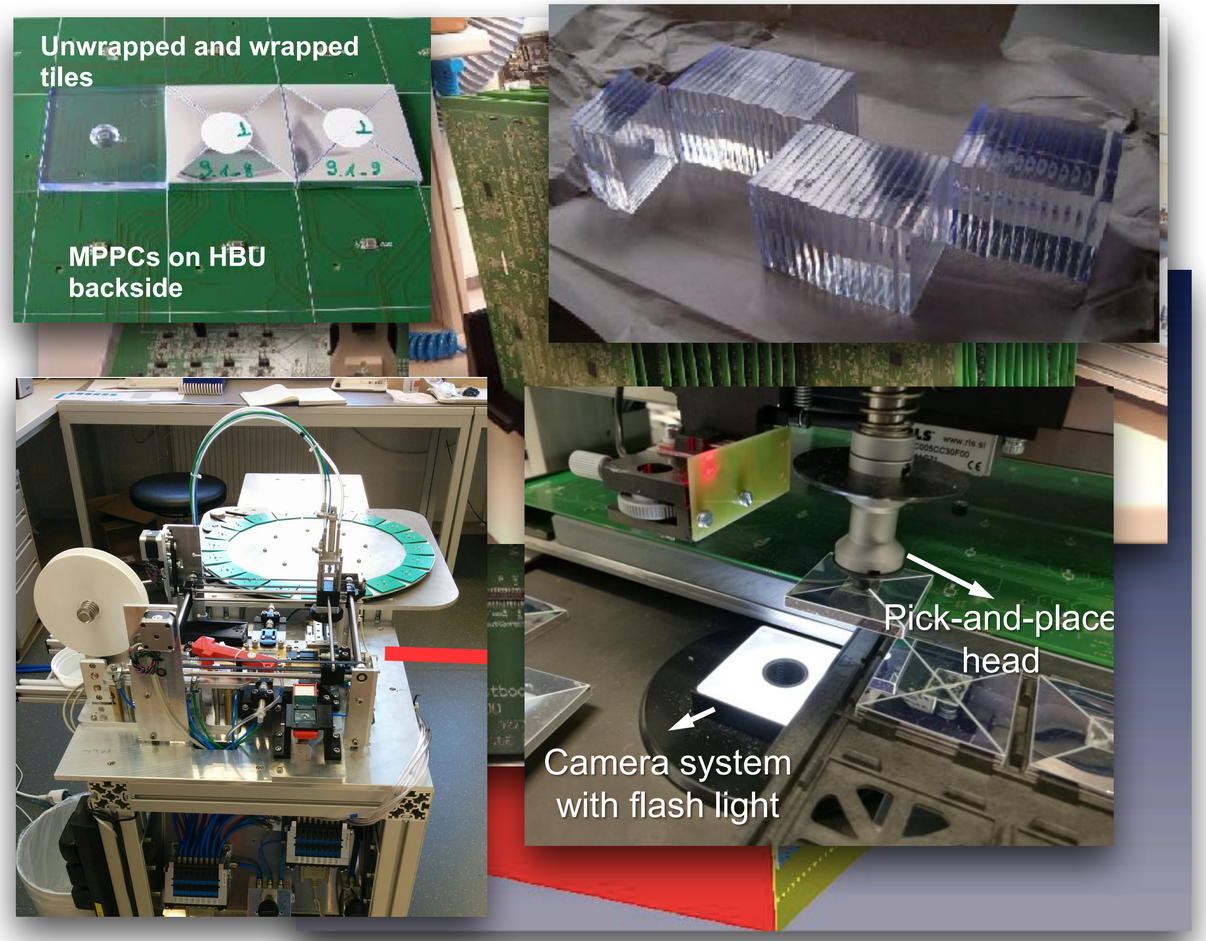

Summary

- Successful test-beam campaign with 1.5T magnetic field
- Power pulsing and temperature compensation established
- Data analysis of various test-beam campaigns ongoing
- Construction of new fully instrumented AHCAL technological prototype ongoing

Backup