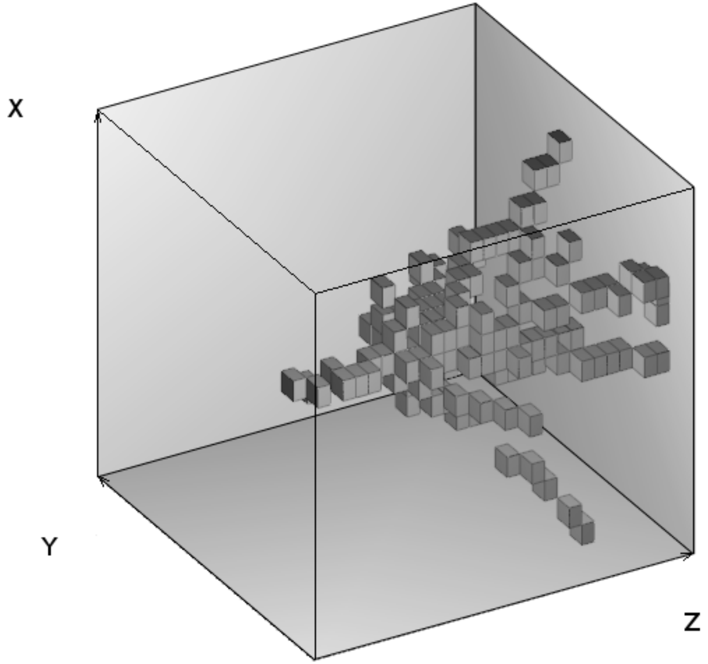


SiW-ECAL
Test Beam data analysis

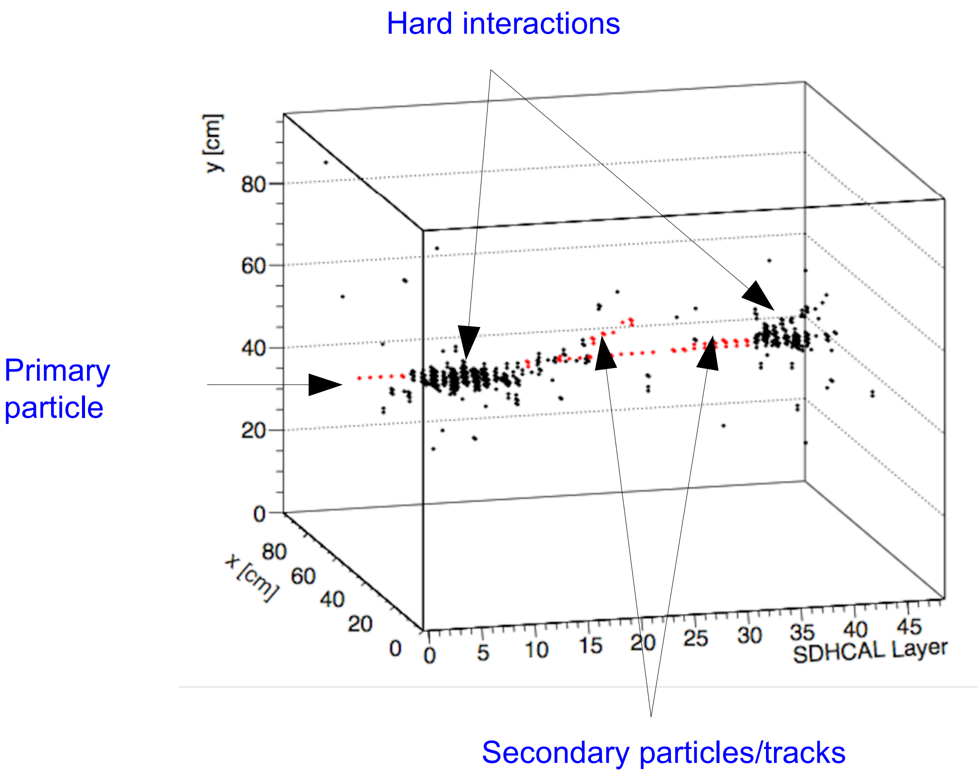
A. Irles, LAL-CNRS/IN2P3
on behalf the SiW-ECAL team

CALICE France Meeting 2019

Outline

- Physics prototype latest results
- Technological prototype

What do we see in CALICE Events



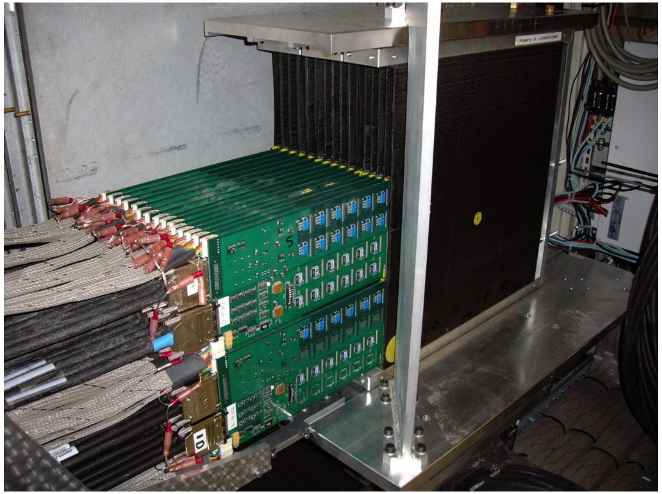
- **Detailed structure of hadronic showers**
  - "Modern bubble chamber"
- Prototypes comprise between **10000 and 500000 cells**
  - At the order or even **larger** number of cells **than** for **LHC Calorimeters**
- Bringing data into a shape to produce physics results is **challenging**
  - All cells need to be calibrated
  - Algorithms to cope with wealth of information

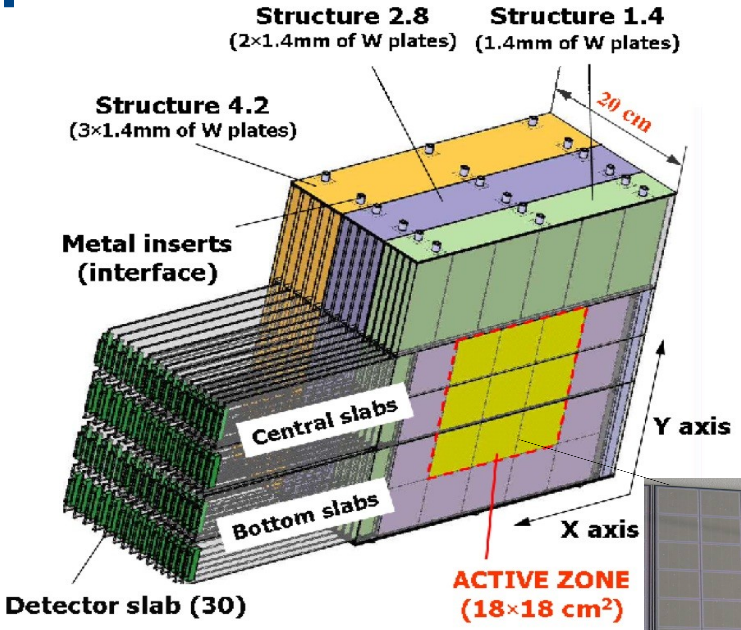
SiW ECAL – Physics prototype

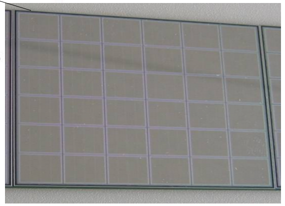
Absorber: Tungsten plates: 1.4-4.2mm:

Active material: silicon P-I-N Diodes
Thickness 525µm

Granularity: $10x10mm^2$







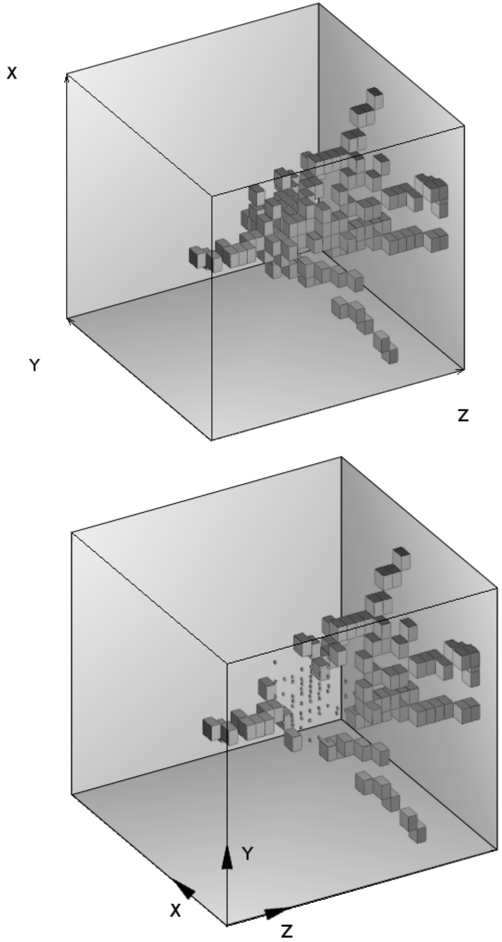
Three modules of with increasing W thickness
Total depth: **24 X_0,** 1 λ_I

Active Zone **$18x18\ cm^2$**
Total: **9720 Pixels/Channels**
Operated between **2005 and 2011**

(latest) **Published results: physics prototype**

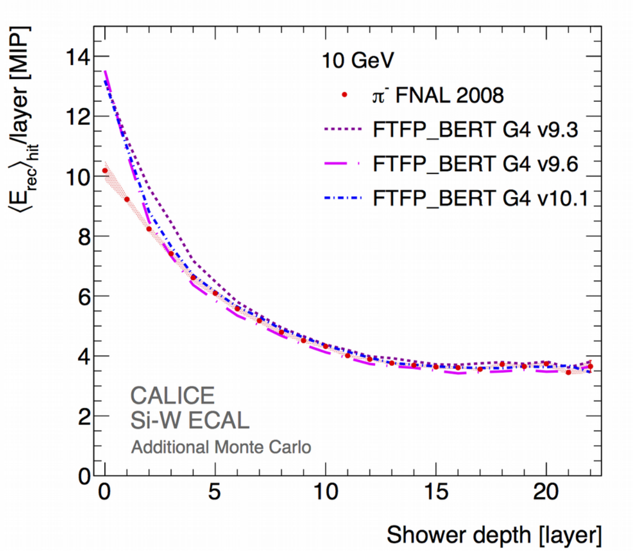
- Test beam data recorded at **FNAL in 2008** with Physics prototype
  - **π-** between 2 GeV and 10 GeV
  - ~60% of hadrons interact in SiW ECAL
  - Detection efficiency 60% - 93%
- **Highly granular ECAL permits detailed view into first hadronic interaction**
  - Study of interactions in terms of global observables: radial and longitudinal shower profiles: NIM A794 (2015) 240
  - PhD Thesis: H. Li (LAL), P. Doublet (LAL), PostDoc: N. Van der Kolk (P2IO, LAL/LLR)
- **Differential observables from track finding algorithm**
  - NIM A 937 (219) 41-52 PhD Thesis: S. Bilokin (LAL)
  - Response to electrons, see NIM A 608 (2009) 372

10 GeV π^- in SiW ECAL

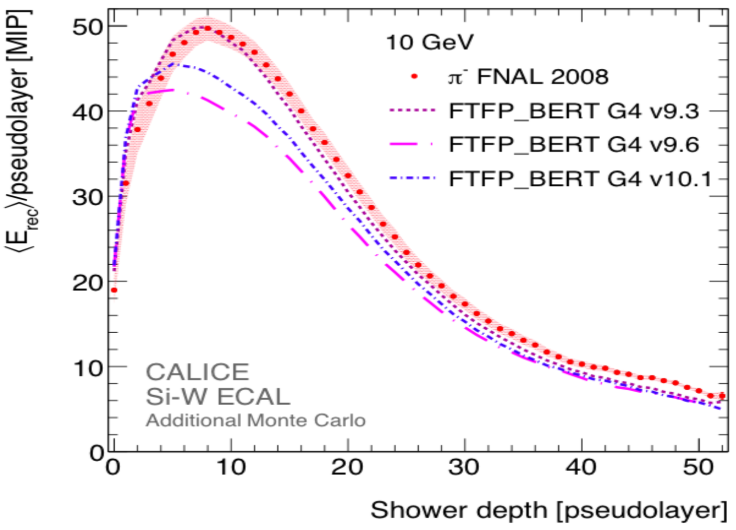


Fine sampling of shower start 2-10 GeV pions (NIM A794 (2015) 240)

Mean hit energy/pseudolayer

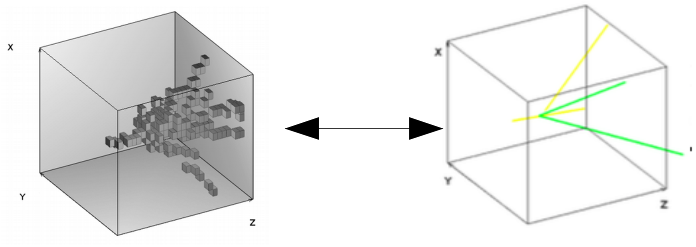


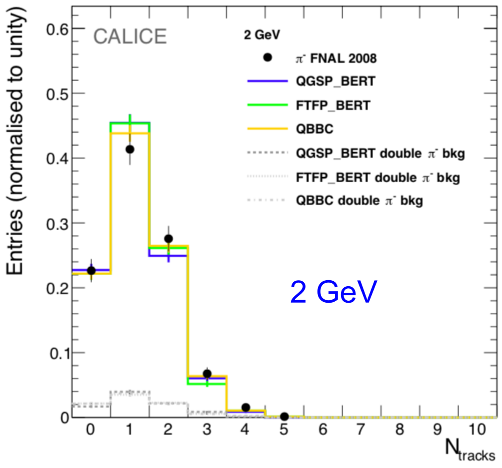
Visible energy / pseudolayer

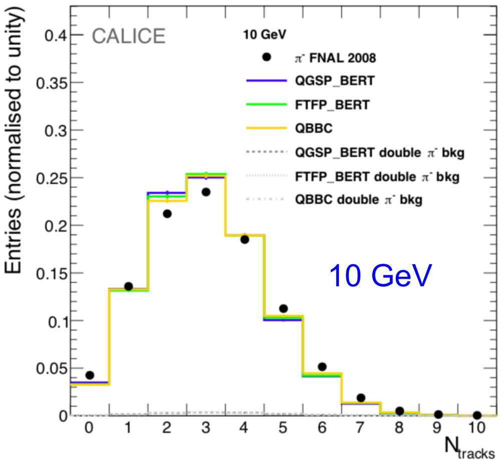


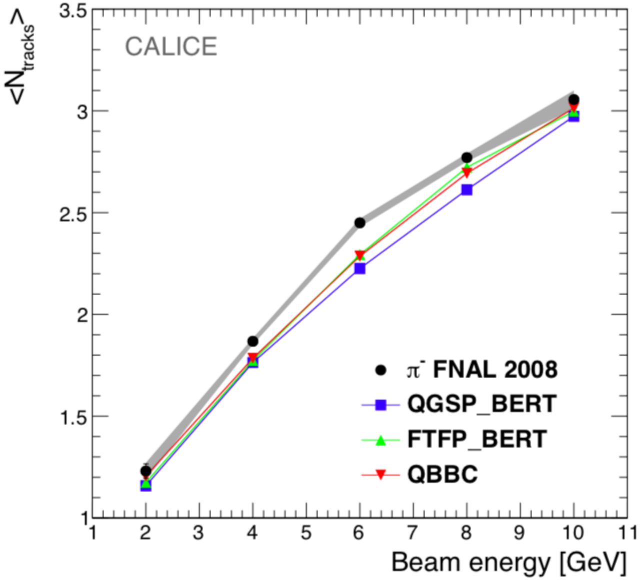
- Big change observed in FTFP_BERT observed between GEANT4 Versions 9.3 and 9.6
  - Only observed in silicon, not for scintillator prototypes;
- Bug in G4 v9.6, fixed in v10.0, however still insufficient energy in v10.1
- Disagreement in individual hit energies between data and G4 affects longitudinal profile

Number of tracks in SiW ECAL (NIM A 937 (219) 41-52)





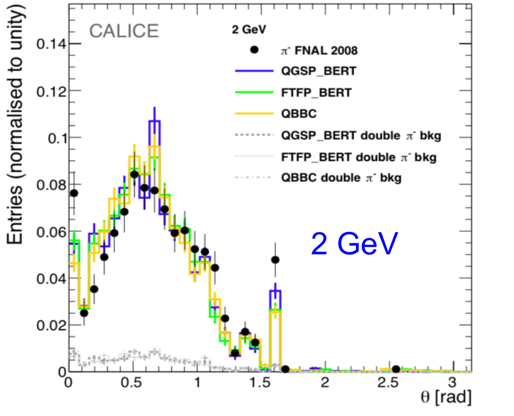


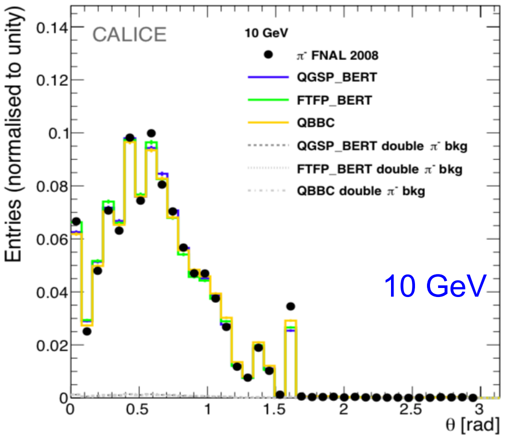


- Mean number of secondary tracks increases with beam energy as expected from fixed target kinematics for π--tungsten scattering
- Good reproduction of data by simulation with GEANT4

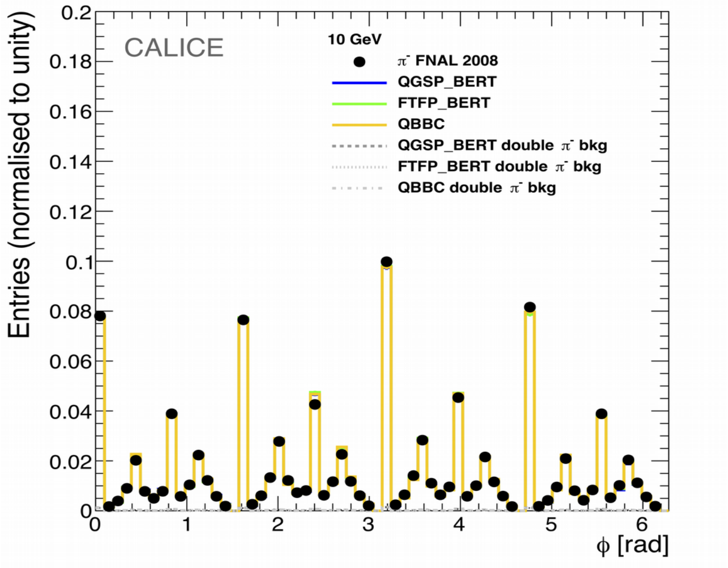
Angular distributions (NIM A 937 (219) 41-52)

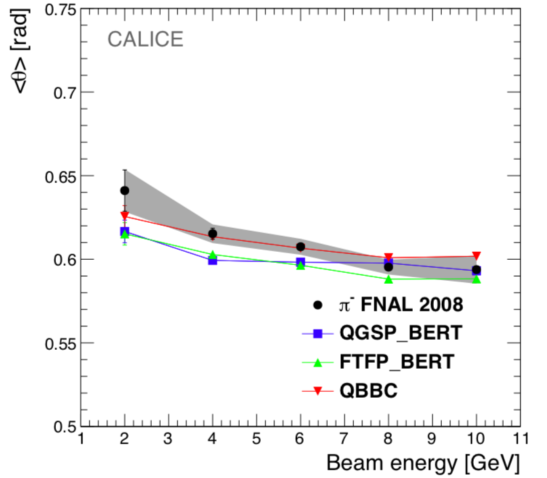
Polar Angle





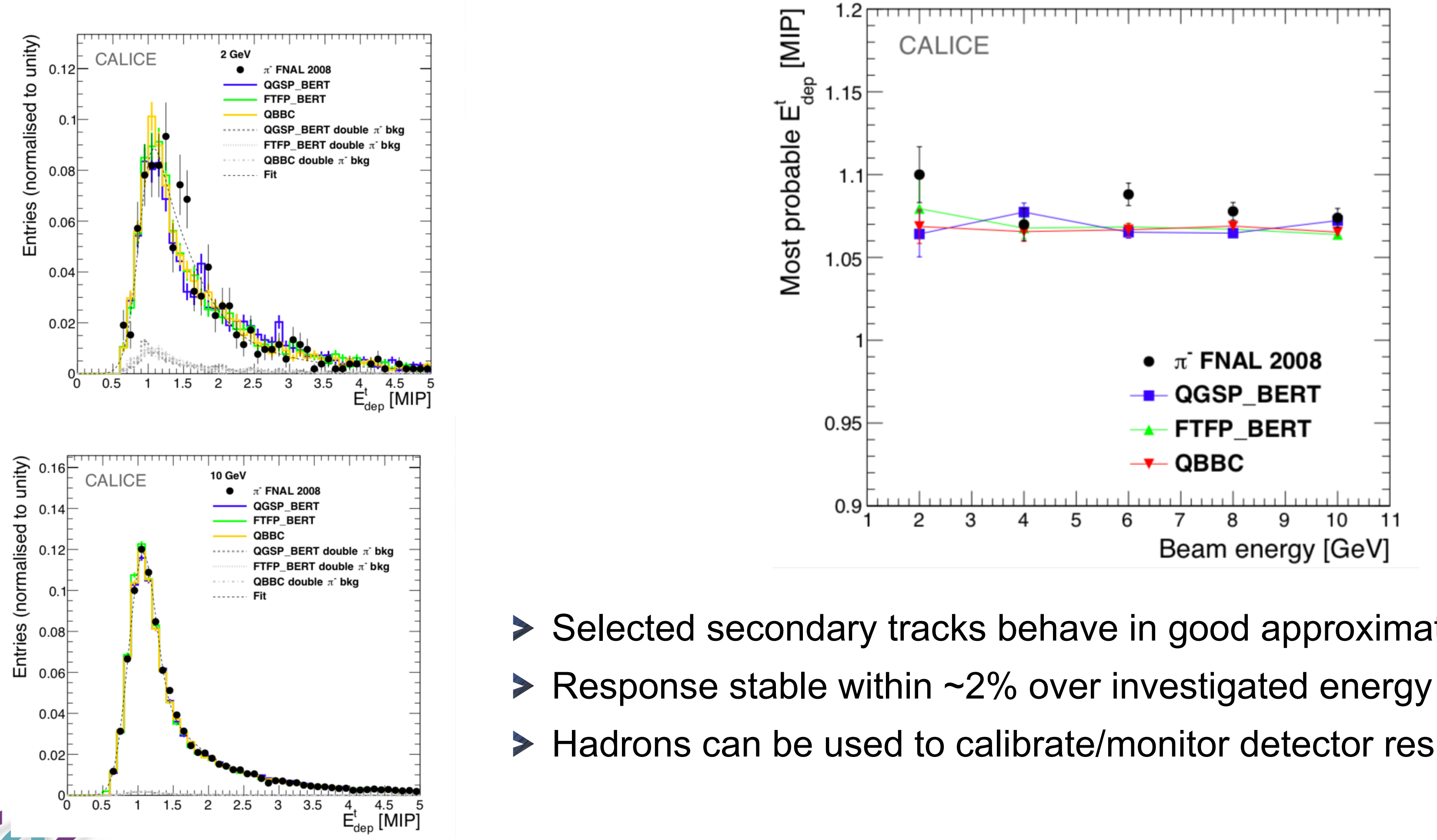
Azimuthal Angle





- Observables available due to high granularity of detector
- Good reproduction of data by MC even at this high level of detail

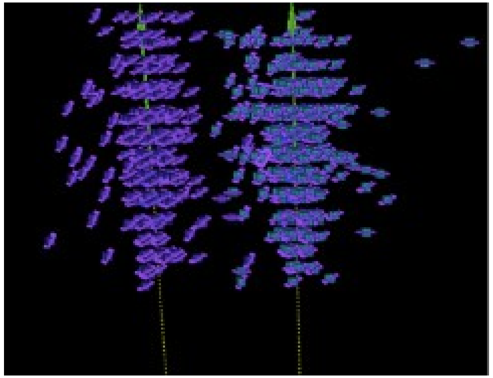
In situ calibration ? (NIM A 937 (219) 41-52)

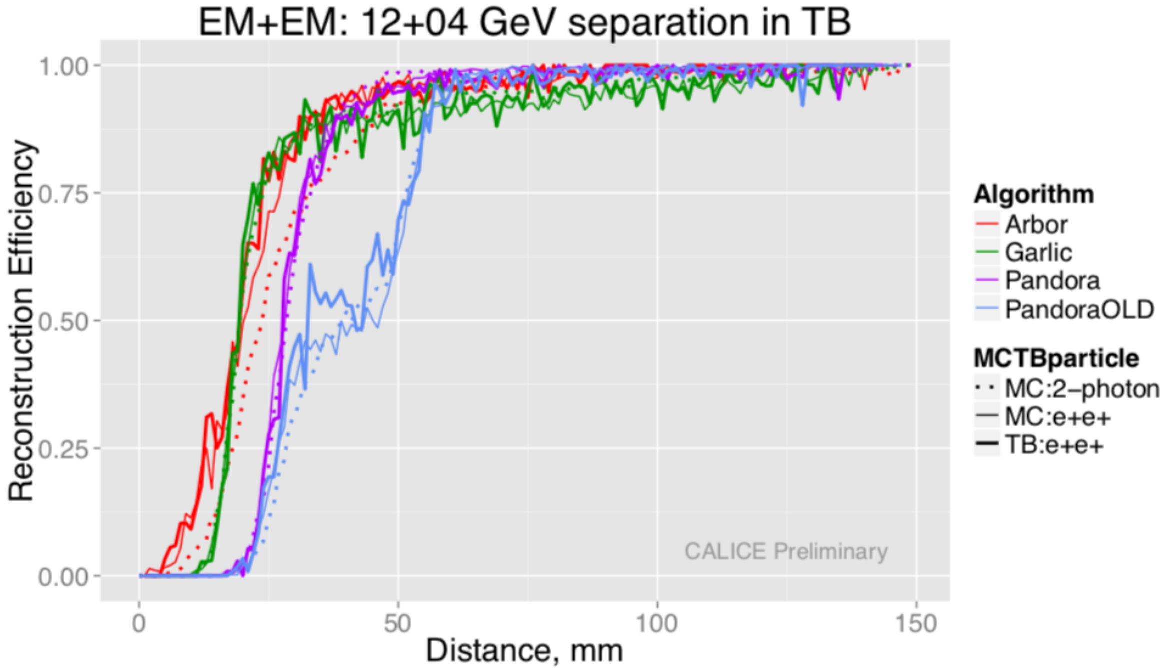


- Selected secondary tracks behave in good approximation as MIPs
- Response stable within ~2% over investigated energy range
- Hadrons can be used to calibrate/monitor detector response in-situ

Particle separation with the SiW-ECAL

Photon-pion: Separation using beam test data





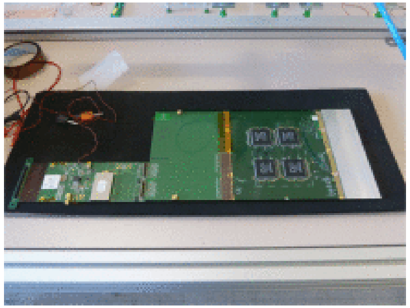
PhD Thesis **K. Shpak (LLR)**
CALICE-CAN-2017-001

- Test of particle separation using different particle flow algorithms
  - ARBOR, GARLIC developed by in2p3 (LLR, IPNL)
- Full separation power at around 30mm

Technological prototype

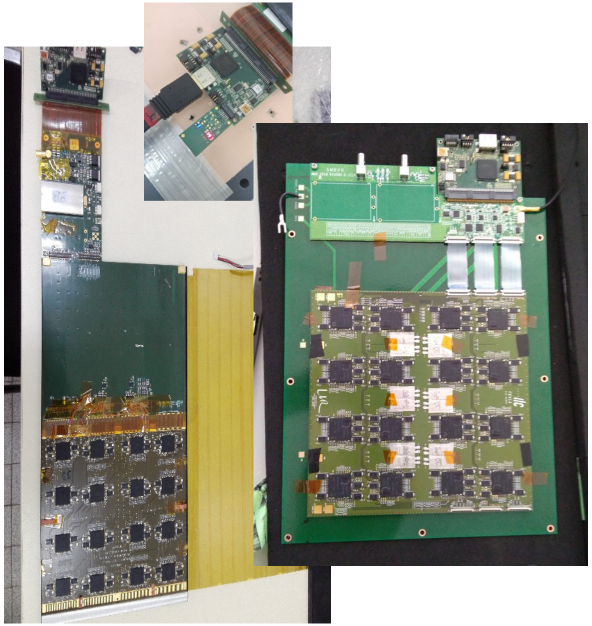
- Front end and VFE compactification with self-trigger ASIC (SKIROC2/2a) operated in power pulsing, higher granularity (5x5mm), compact modules

2010-2015

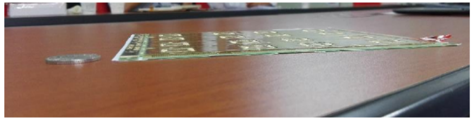


- Version 0 of techn. Prototype
- 256 channels
- 1st power pulsing tests

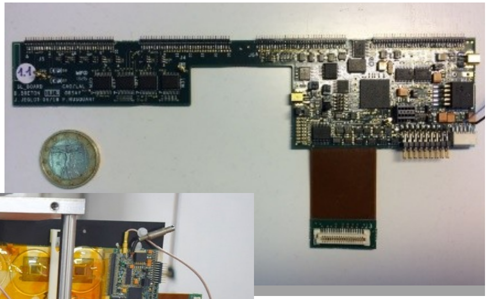
2015-2018



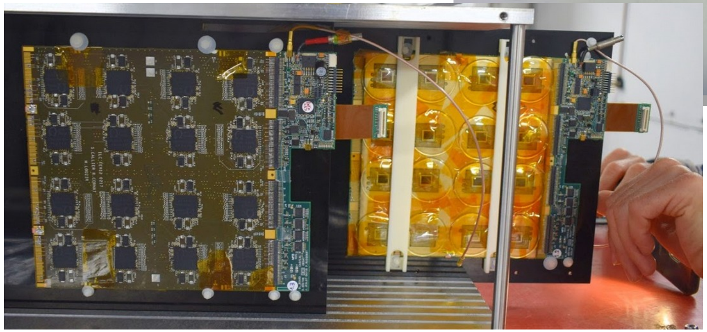
2015-2019



- Ultra thin PCB (COB) with wirebonded ASICs



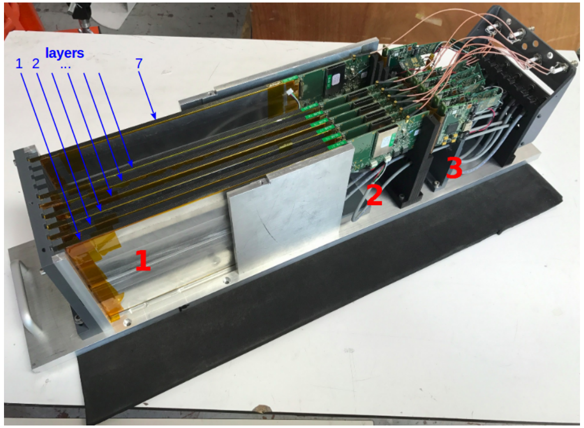
2018-2019

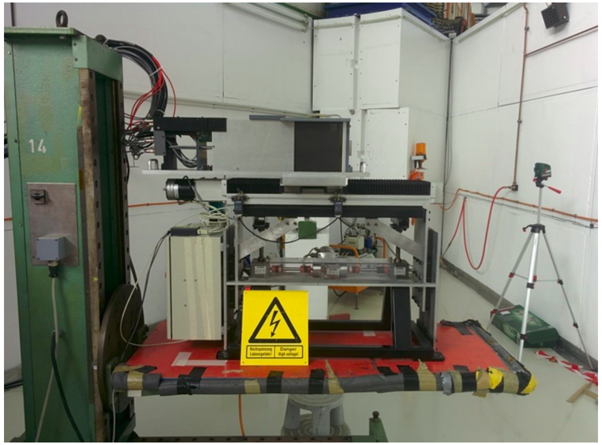


- **1024 chns per module in a 18x18xm surface**
- **Ultra compact DAQ and PCBs**

Test Beam at DESY 2017

- **Setup** :
  - 7 FEV11 each equipped with 4 325um Si wafers and 16 Skiroc2
  - **Skirocs working in Power pulsing and ILC mode** (emulated ILC spill conditions)
  - **More than 7000 calorimeter cells!!**
- **Physics program:**
  - **Calibration** run with 3 GeV positrons perpendicular beam without tungsten absorber plates
  - **Electromagnetic showers program.**
  - **Calibration** run with 3 GeV positrons in **~45 degrees** (6 slabs)
  - **Magnetic field tests** with 1 slab (up to **1 T**)





Beam test performance of the highly granular SiW-ECAL technological prototype for the ILC.

K. Kawagoe[a], Y. Miura[a], I. Sekiya[a], T. Suehara[a], T. Yoshioka[a], S. Bilokin[b,*], J. Bonis[b], P. Cornebise[b], A. Gallas[b], A. Irles[b,**], R. Pöschl[b], F. Richard[b], A. Thiebault[b], D. Zerwas[b], M. Anduze[c], V. Balagura[c], V. Boudry[c], J-C. Brient[c], E. Edy[c], G. Fayolle[c], M. Frotin[c], F. Gastaldi[c], R. Guillaumat[c], A. Lobanov[c], M. Louzir[c], F. Magniette[c], J. Nanni[c], M. Rubio-Roy[c,*], K. Shpak[c], H. Videau[c], D. Yu[c,d], S. Callier[e], F. Dulucq[e], Ch. de la Taille[e], N. Seguin-Moreau[e], J.E. Augustin[f], R. Cornat[f], J. David[f], P. Ghislain[f], D. Lacour[f], L. Lavergne[f,*], J.M. Parraud[f], J. S. Chai[g], D. Jeans[h]

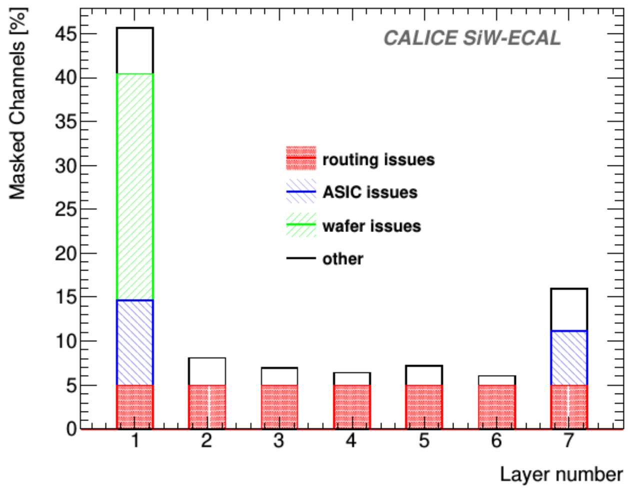
Arxiv:1902.00110 just accepted by NIMA
https://authors.elsevier.com/a/1ZwMZcPqbansi

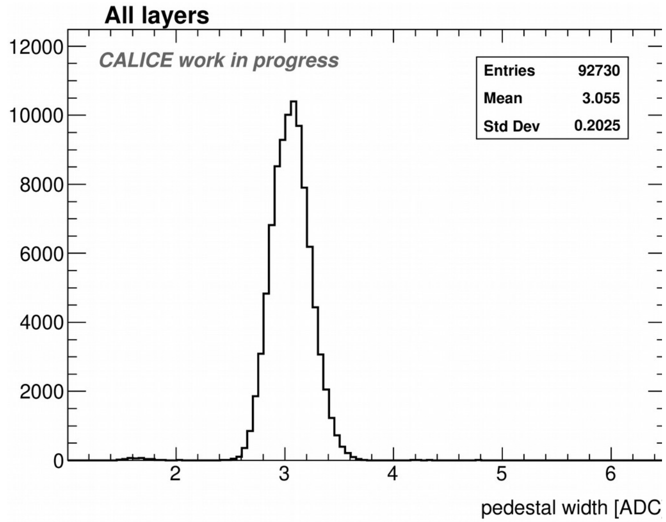
Results presented in **IEEE2017 (poster), CHEF2017 (parallel)**

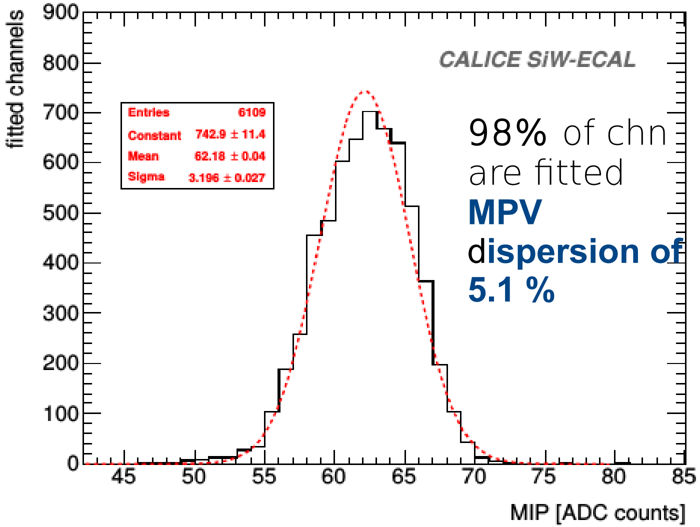
VCI2019 (Plenary)

Commissioning & single cell calibration

- Masking of noisy channels (~6-8% in each slab except if other issues are present)
- Self trigger optimization. Calibration (DAC to Energy) done only for one ASIC and assumed common for all.
- Homogeneous distribution of the witdth of pedestal distributions
- Single cell calibration homogeneity at 5% level







98% of chn are fitted
MPV dispersion of 5.1 %

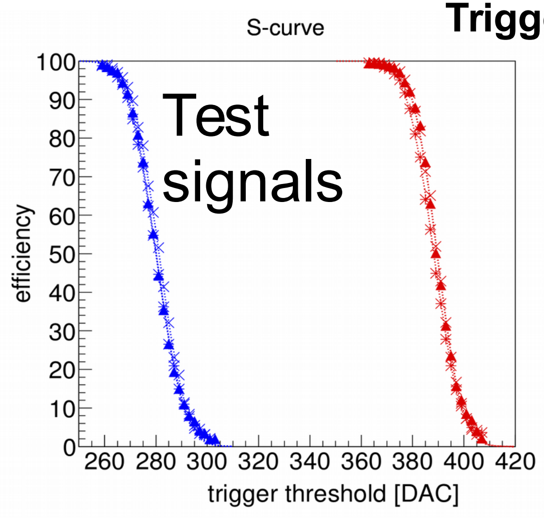
Arxiv:1902.00110 accepted by NIMA

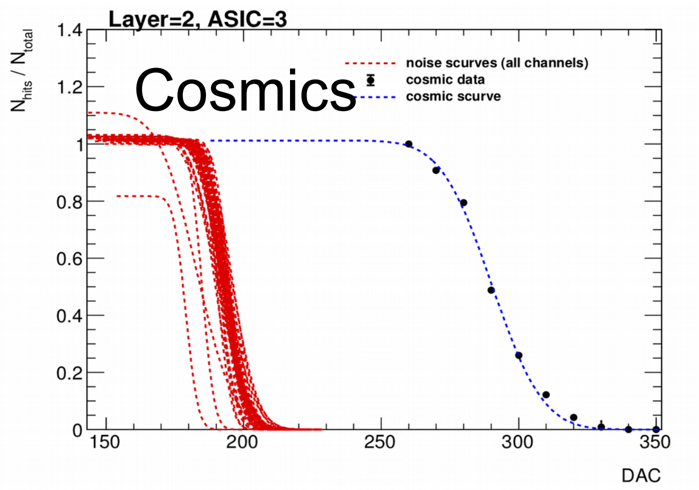
Performance at MIP Level - II

Arxiv:1810.05133

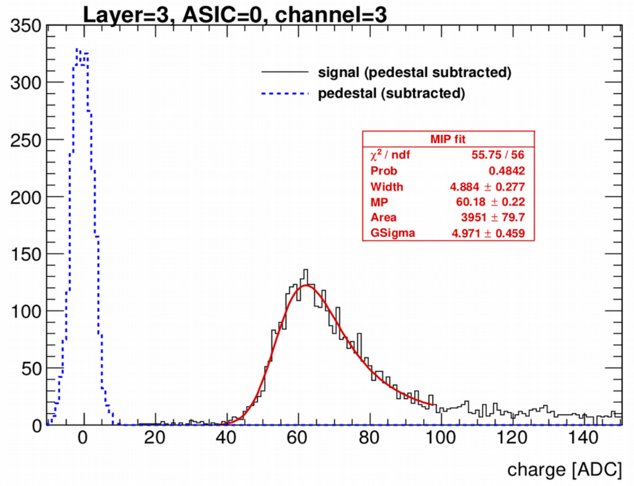
- Objectif: Trigger and readout of small signals, **Design criterion: S/N ~ 10:1**

Trigger curves





Charge measurement

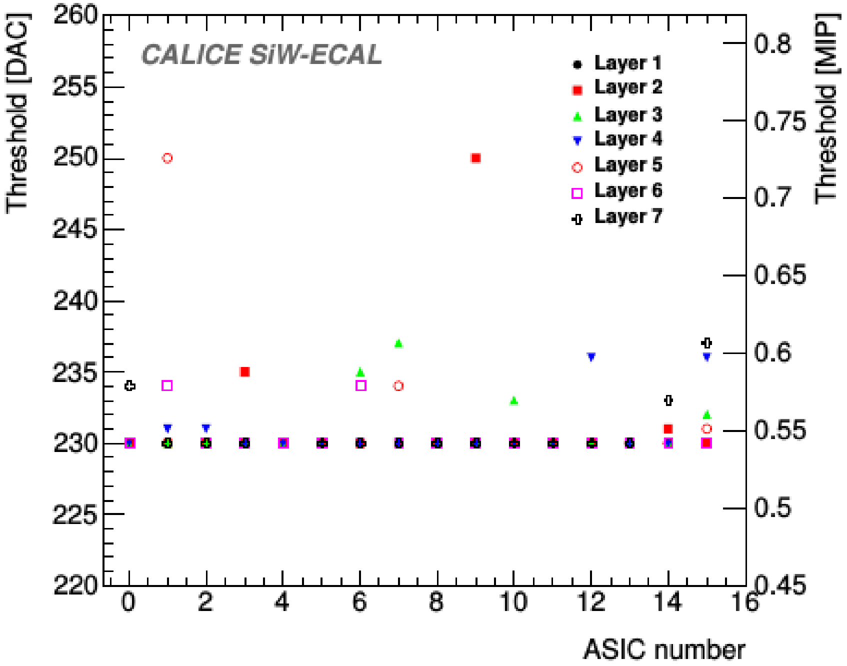


- S/N ratio from relative position and width of threshold curves
- Result here **S/N ~12.9±3.4**
- **Dedicated runs in 2018 TB**

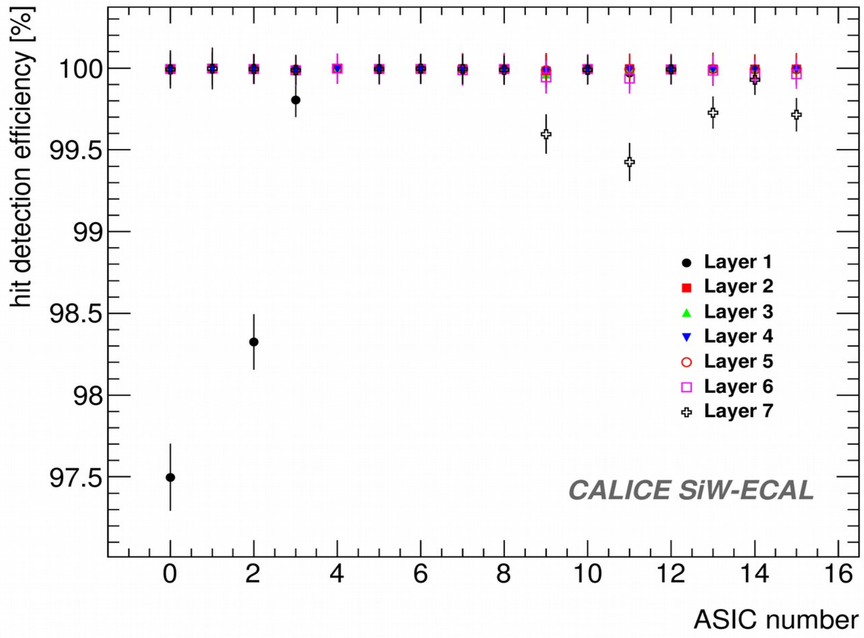
S/N ~ 20

Ability to trigger on small signals and to read them out for analysis

Performance at MIP level - II



Trigger thresholds uniform at around 1/2 MIP

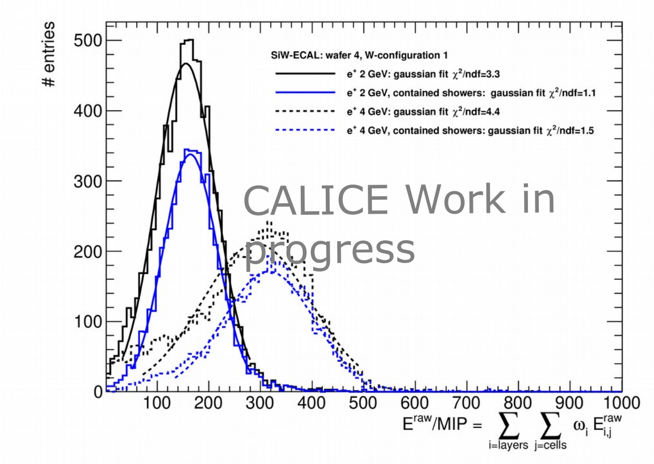


MIP detection efficiency ~ 100%

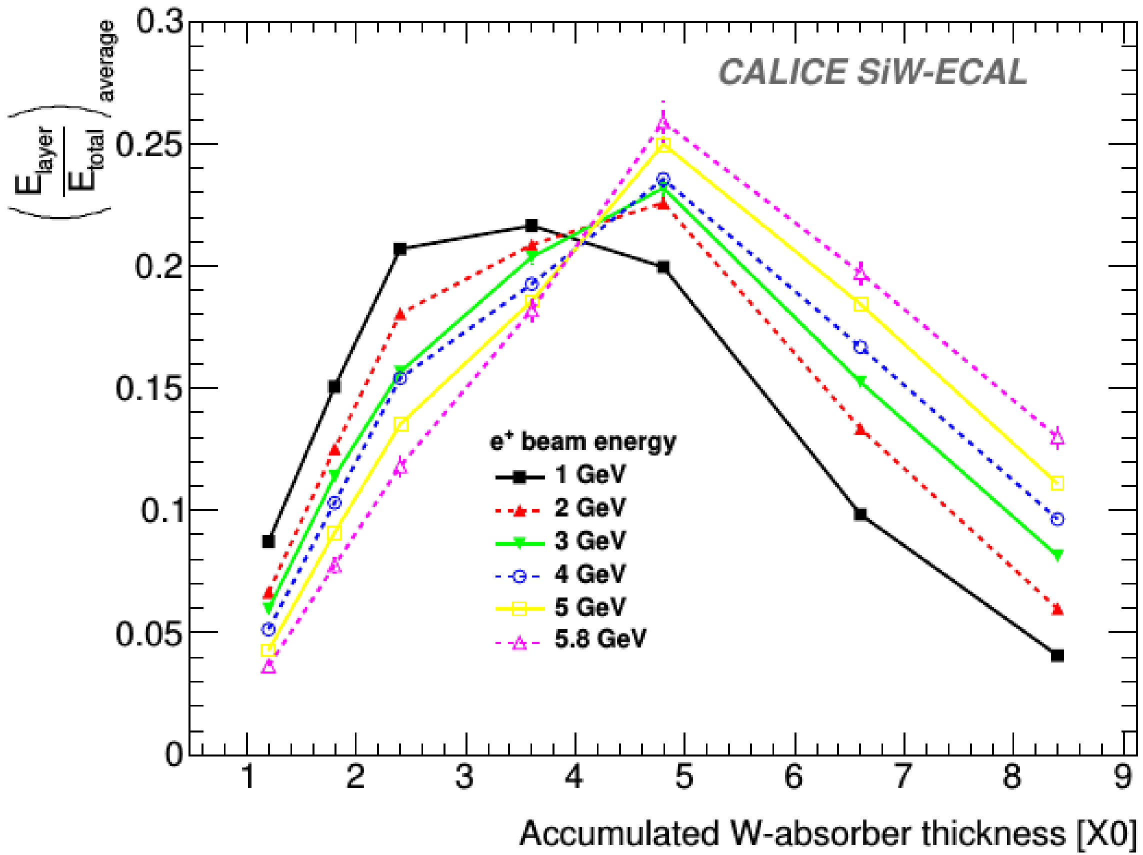
- **PFA requires:**
  - **Access to small signals -> Low trigger thresholds ✔**
  - **Tracking in calorimeters -> High MIP detection efficiency ✔**

Raw shower profiles

- Qualitatively analysis: performance of the SiW-ECAL for low energy electromagnetic shower profiles.
- Comparison of raw shower profiles for several energies.

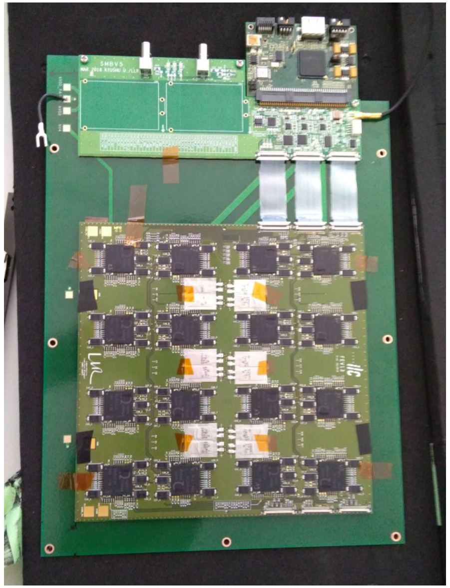


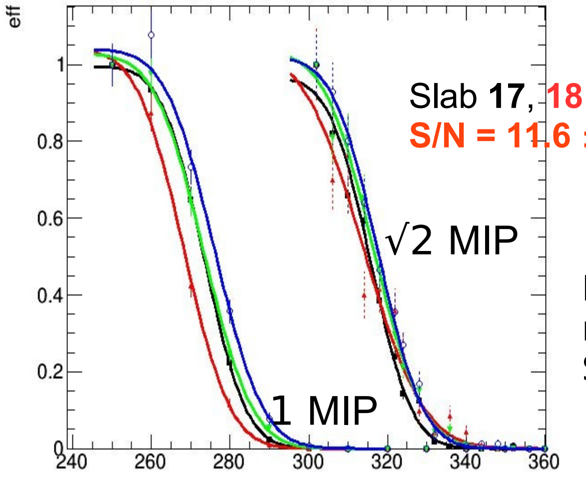
- Dedicated studies (MC comparisons, etc) to come.



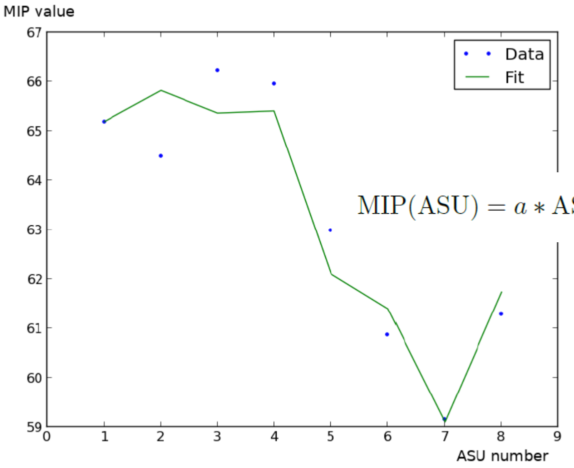
TB 2018: DESY

- **Setup 1:**
  - 6 FEV11 each equipped with 4 325um Si wafers and 16 Skiroc2
  - + 1 FEV13-Jp with 650um Si Wafers and 16 Skiroc2a.
- **Setup 2:**
  - Electrical Prototype of long slabs (8 ASUS with a 4x4 cells wafer each)





ILD baseline requirements: S/N=10



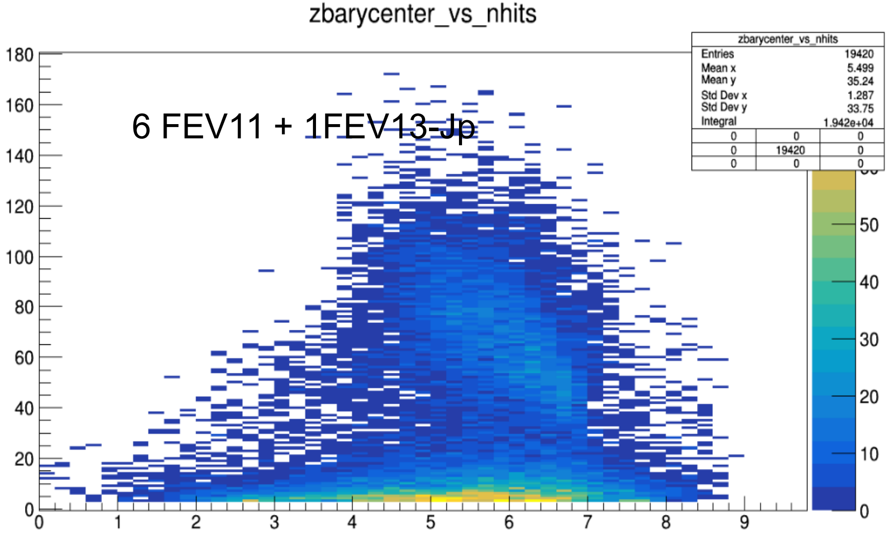
$$\mathrm{MIP(ASU)} = a * \mathrm{ASU} + b - c * \mathrm{bandgap(ASU)}.$$

Results presented in **VCI2018 (poster)**

TB 2018: CERN (combined with SDHCAL)

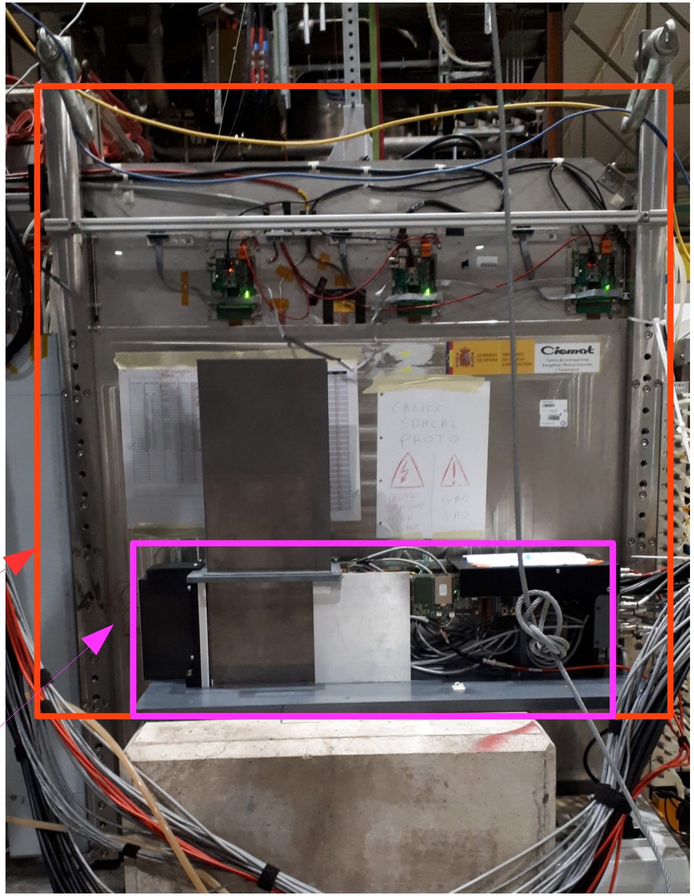
- **SDHCAL**
- **ECAL:** started with 6 FEV11 + 1 FEV13-Jp and finished with 6FEV11 + 4 FEV13-Jp (3 of them not fully operative).

Electron 80GeV +beam contamination



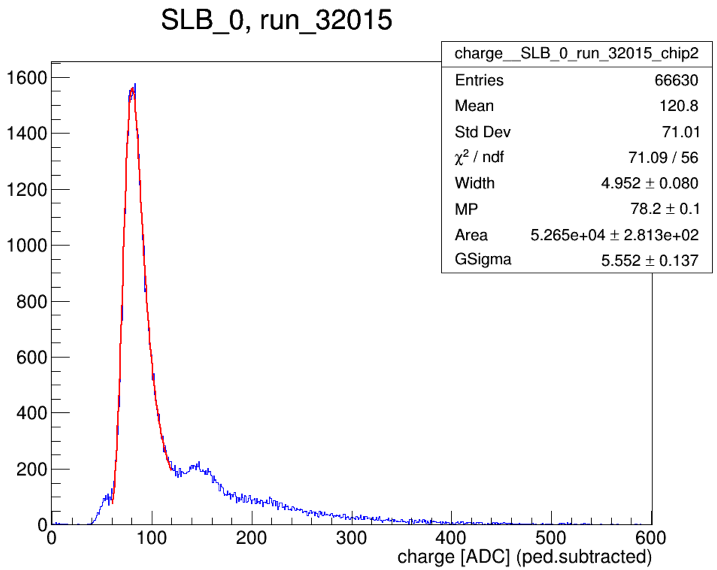
SDHCAL

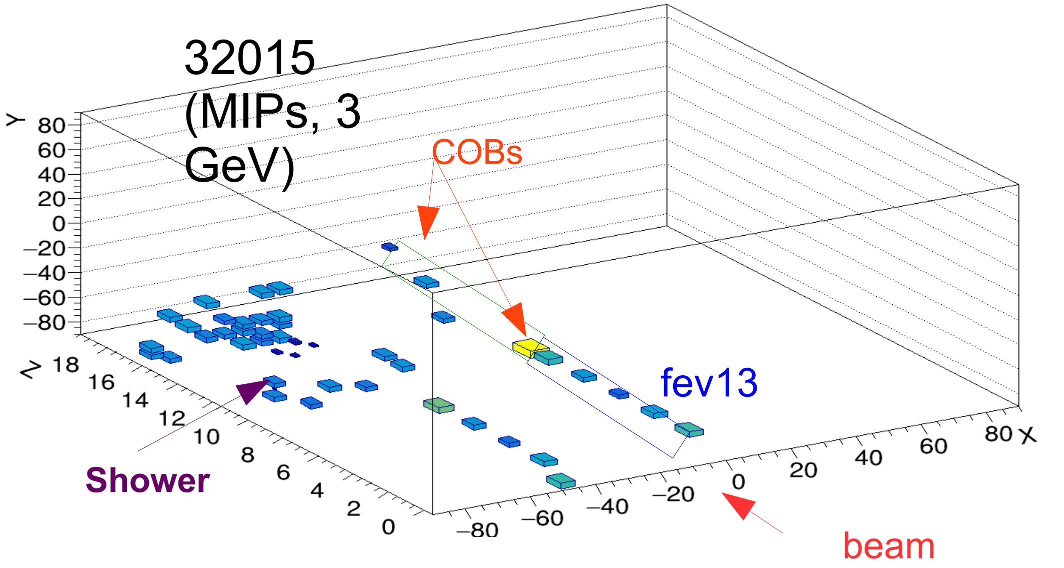
SiW-ECAL



TB 2019

- 5 **FEV 13Jp** controlled by the DIF-generation of front-ends
- 2 **FEV12** and 2 **FEV12-COB** (ultra thin chip on board pcbs) controlled by the new ultra compact front-ends **(SL-Board + Core MotherDaughter)**





Results presented in **TWEPP2019 (poster)** and **IEEE2019 (poster**, end of the month)

SiW-ECAL CALICE publications

- ***JINST 3 (2008) P08001*** Corresponding author: A. M. Magnan (Imperial College, London)
- ***NIM A608 (2009) 372*** *Response of the CALICE Si-W Electromagnetic Calorimeter Physics Prototype to Electrons,*
  - Corresponding author: **C. Carloganu (LPC-CNRS/IN2P3)**
- ***JINST 5 (2010) P05007*** Corresponding author: D.R. Ward (University of Cambridge)
- ***NIM A 654 (2011), 97*** *Effects of high-energy particle showers on the embedded front-end electronics of an electromagnetic calorimeter for a future lepton collider*
  - *Corresponding author:* **R. Poeschl (LAL-CNRS/IN2P3)**
- **NIM A778 (2015) 78-84** *Beam test performance of the SKIROC2 ASIC*
  - *Corresponding author:* **T. Frisson (LAL-CNRS/IN2P3), (PhD Thesis Jeremy Rouene (LAL))**
- **NIM A794 (2015) 240-254** *Testing Hadronic Interaction Models using a Highly Granular Silicon-Tungsten Calorimeter*
  - *Corresponding author:* **N. Van der Kolk (Postdoc P2IO LAL/LLR) (PhD Theses Philippe Doublet (LAL) and Hengne Li (LAL))**
- **NIM A937 (2019) 41-52** *Characterisation of different stages of hadronic showers using the CALICE Si-W ECAL physics prototype*
  - *Corresponding author:* **S. Bilokin (LAL-CNRS/IN2P3) (PhD Thesis Sviatoslav Bilokin (LAL))**
- **NIM A (recently accepted)** *Beam test performance of the highly granular SiW-ECAL technological prototype for the ILC*
  - *Corresponding author:* **A. Irles (LAL-CNRS/IN2P3)**

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- **NIM A778 (2015) 78-84** *Beam test performance of t…*
  - *Corresponding author:* **T. Frisson (LA… …D Thesis Jeremy Rouene (LAL))**
- **NIM A794 (2015) 240-254** *T… …raction Models using a Highly Granular Silicon-Tungsten Calorimeter*
  - *Corresponding…* **…olik (Postdoc P2IO LAL/LLR) (PhD Theses Philippe Doublet (LAL) and Hengne Li (LAL))**
- **N… …-52** *Characterisation of different stages of hadronic showers using the CALICE Si-W ECAL physics …*
  - *Corresponding author:* **S. Bilokin (LAL-CNRS/IN2P3) (PhD Thesis Sviatoslav Bilokin (LAL))**
- **NIM A (recently accepted)** *Beam test performance of the highly granular SiW-ECAL technological prototype for the ILC*
  - *Corresponding author:* **A. Irles (LAL-CNRS/IN2P3)**

https://twiki.cern.ch/twiki/bin/view/CALICE/CALICEResults

BACK-UP

BACK-UP