AIDA-2020-SLIDE-2019-002

**AIDA-2020**

Advanced European Infrastructures for Detectors at Accelerators

**Presentation**

# Introduction to the CALICE/ILD SiW ECAL and recent testbeam results

Irles, Adrian on behalf of the SiW-ECAL collaboration

23 October 2018

The AIDA-2020 Advanced European Infrastructures for Detectors at Accelerators project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreement no. 654168.

This work is part of AIDA-2020 Work Package **14: Infrastructure for advanced calorimeters**.

# Introduction to the CALICE/ILD SiW ECAL and recent testbeam results

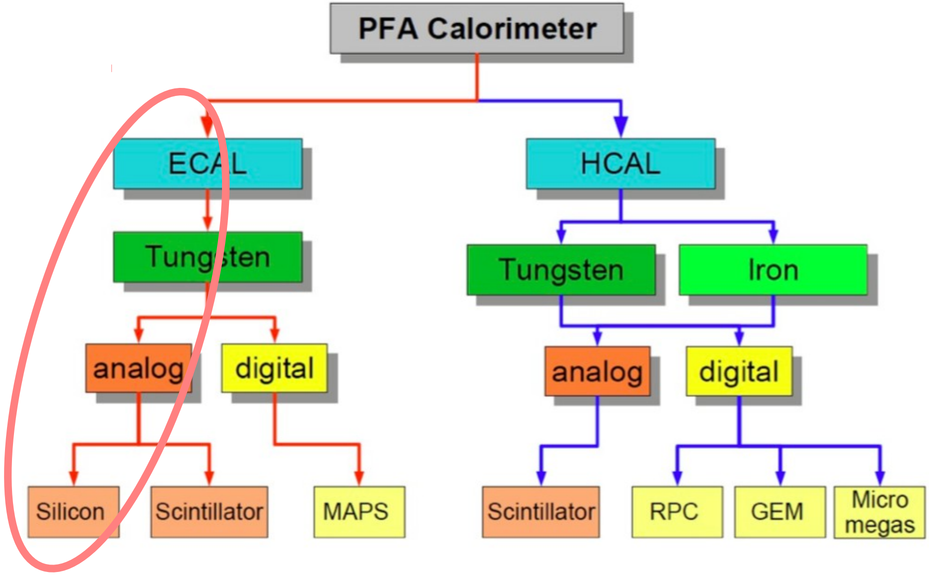
A. Irles (LAL-IN2P3/CNRS) on behalf the SiW-ECAL

23rd October 2018, LCWS2018

# Outline of the talk

- The SiW-ECAL technological prototype

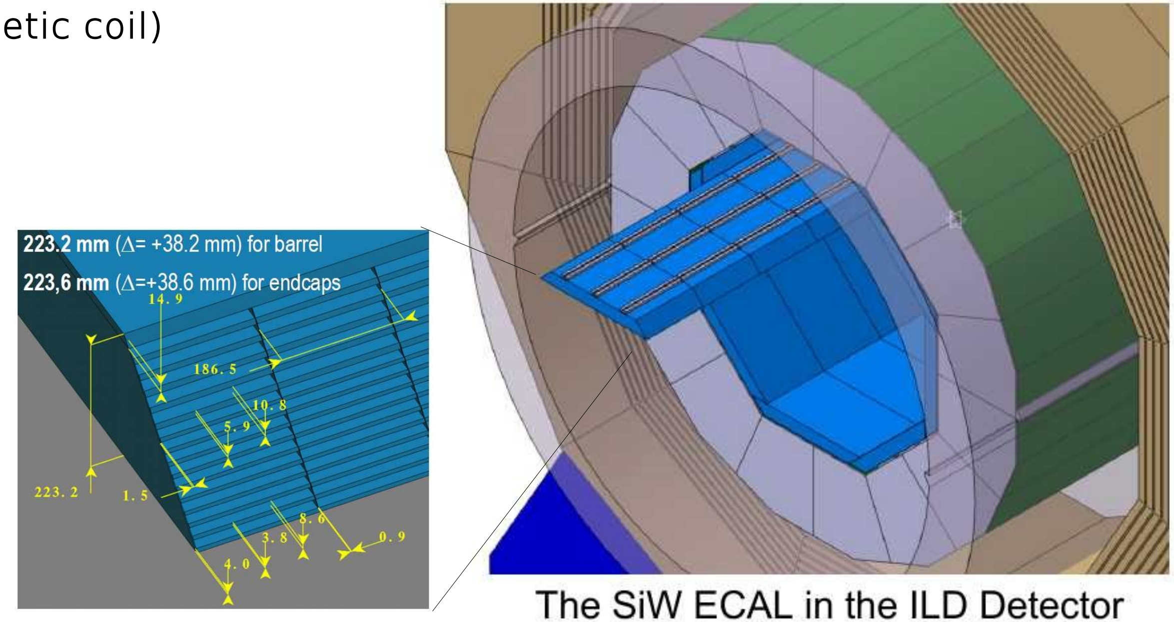
- Beam Test 2017 – DESY TB24
- Beam Test 2018 – DESY TB21 and TB24
- Beam Test 2018 – CERN H24



**Basic requirements** of a **PF calorimeter** for future linear colliders

- Extreme high granularity
- Compact and hermetic (inside magnetic coil)

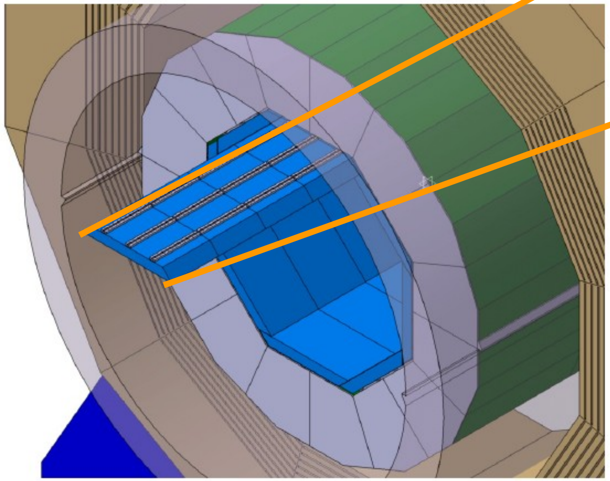
- **Tungsten** as absorber material
  - Narrow showers
  - Assures compact design
  - Low radiation levels foreseen at LC
  - $X_0$=3.5 mm, $R_M$=9mm, $I_L$=96mm
- **Silicon** as active material
  - Support compact designs
  - Allows pixelisation
  - Robust technology
  - Excellent signal/noise ratio



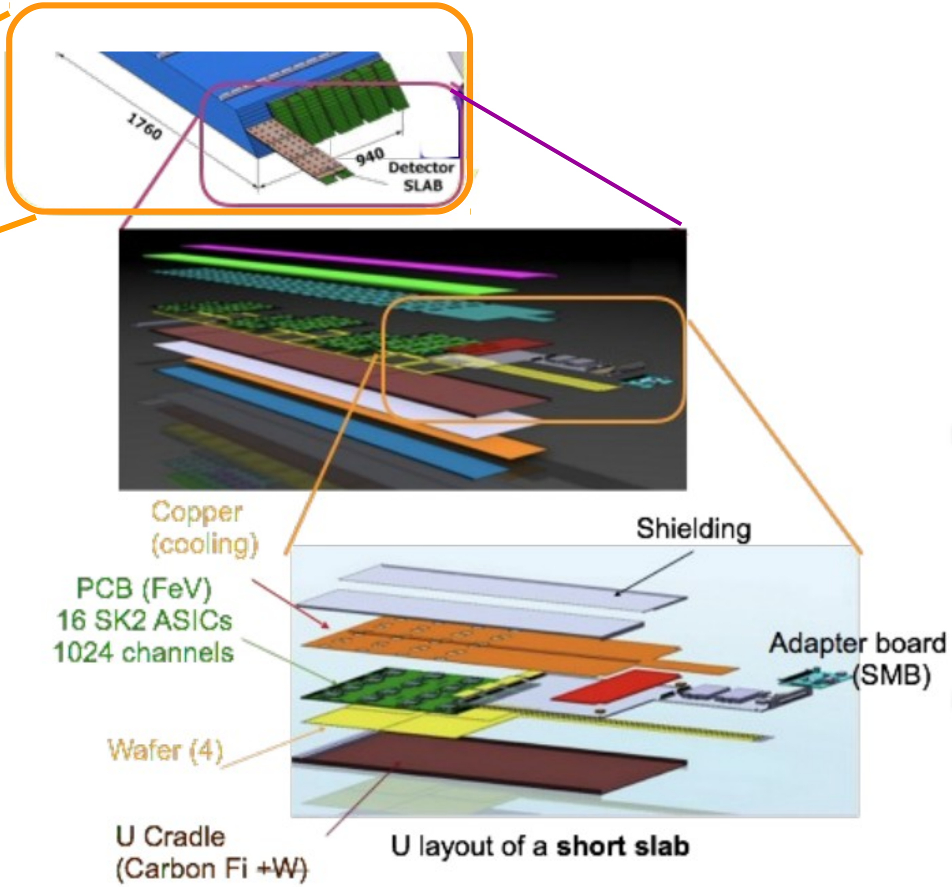
The SiW ECAL in the ILD Detector

The **SiW ECAL R&D** is tailored to meet the specifications for the **ILD** ECAL proposal

# SiW-ECAL for the ILD

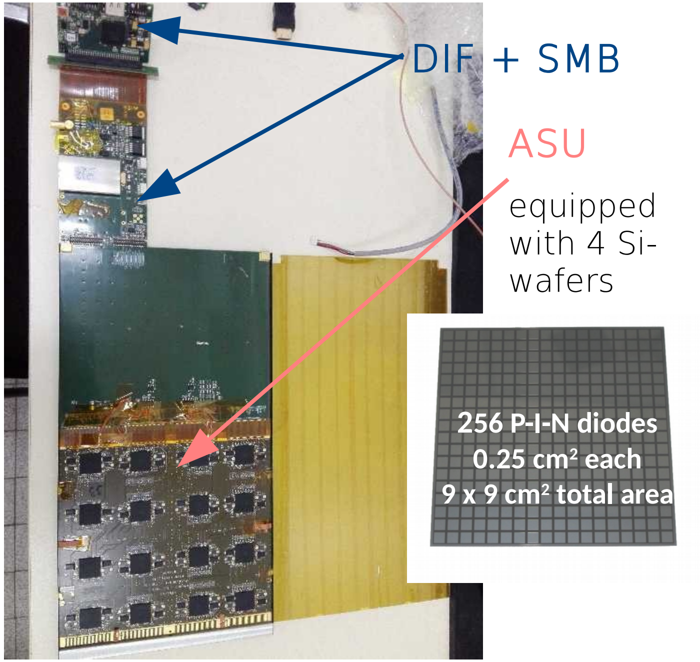


The SiW ECAL in the ILD Detector



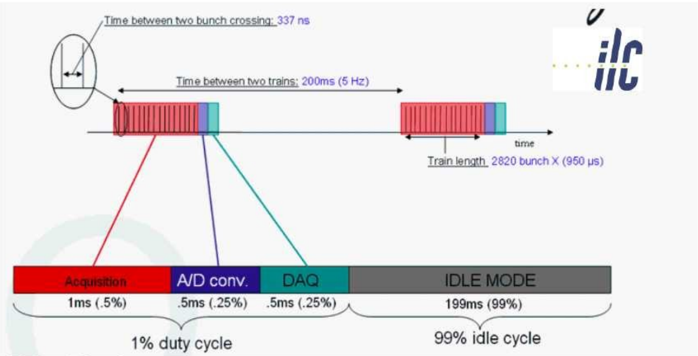

U layout of a short slab

# SiW-ECAL technological prototype




**Short slab:**

- Adapter board (**SMB**) and Detector Interface (**DIF**)
- **ASU (Active Sensor Unit),**
  - PCBs (FEV10/11) with silicon P-I-N diodes as active material (325um, 4 kΩcm, N-type)
  - 1024 channels per slab
- VFE electronics: 16 **Skiroc2 ASICS** (in the ASU)
  - Auto trigger, double gain ADC
  - Low power consumption & **power pulsing** (25µW/ch)



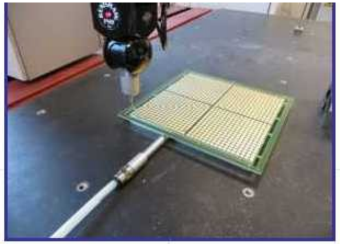

N.B. Final numbers may vary



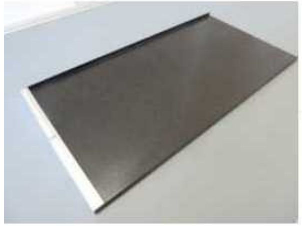
PRESTIGE POSTDOCTORAL RESEARCH FELLOWSHIPS IN FRANCE

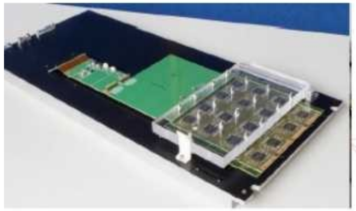
LABORATOIRE DE L'ACCÉLÉRATEUR LINÉAIRE

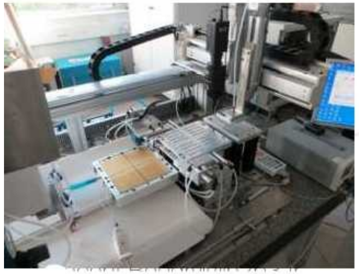
# Assembly chain

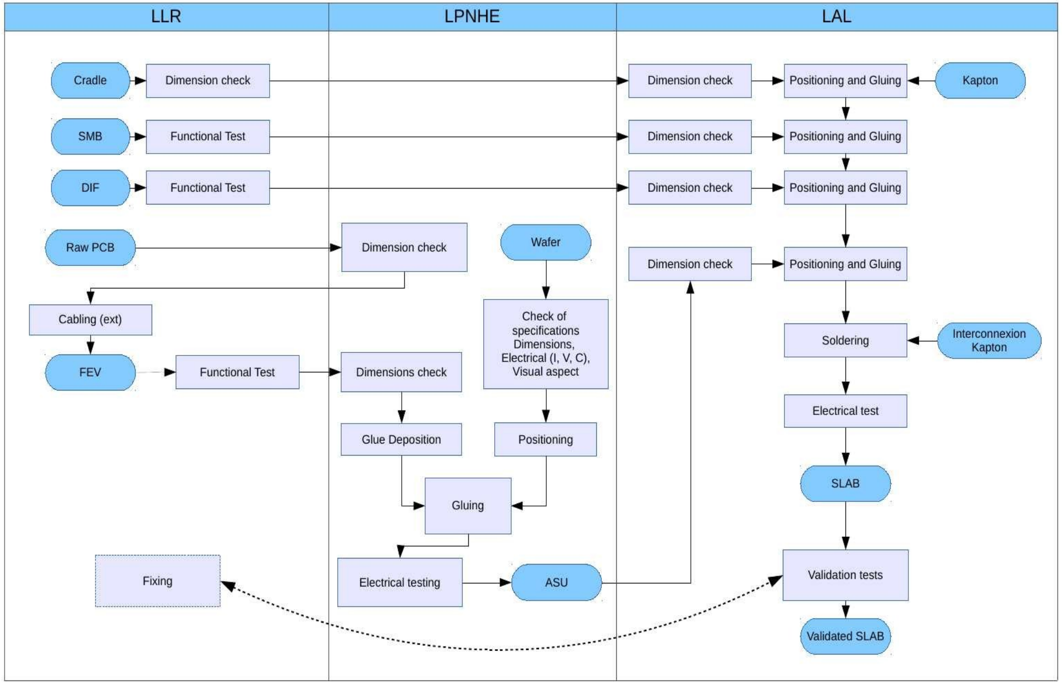


‘Simplified view’










'Assembly and QA chain demonstrator report` on https://cds.cern.ch/record/2166513

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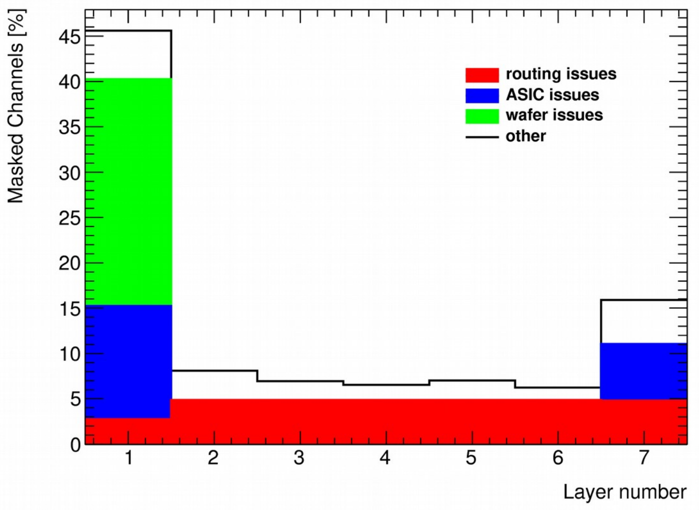
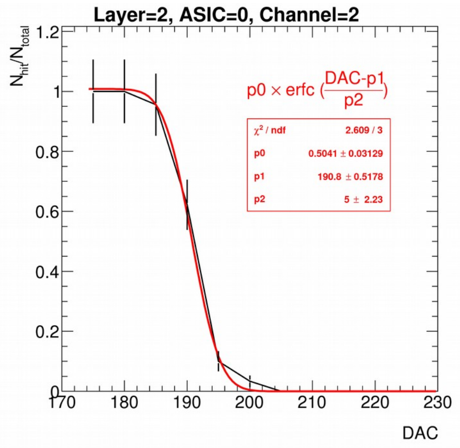
## **Commissioning** & Passport delivery

- **Noise control → noisy channels**: **7-8%**: very conservative approach.
  - Found a pattern on the spatial distribution of ~4% some noisy channels



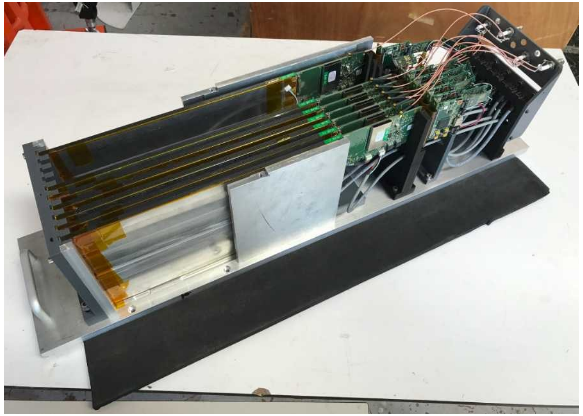

- **Autotrigger** optimization
  - Threshold scans made for all channels → one optimal threshold found for each ASIC

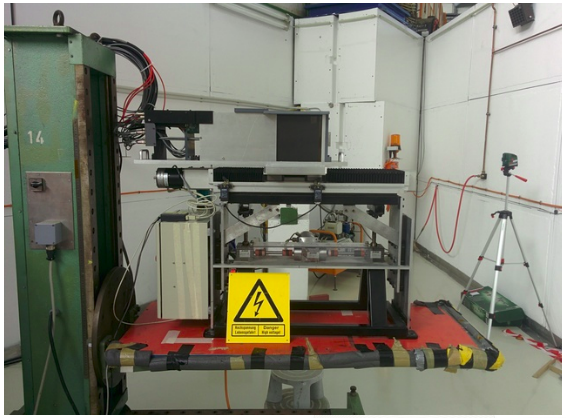



Threshold scan curves with noise

# DESY@2017 – Setup & program

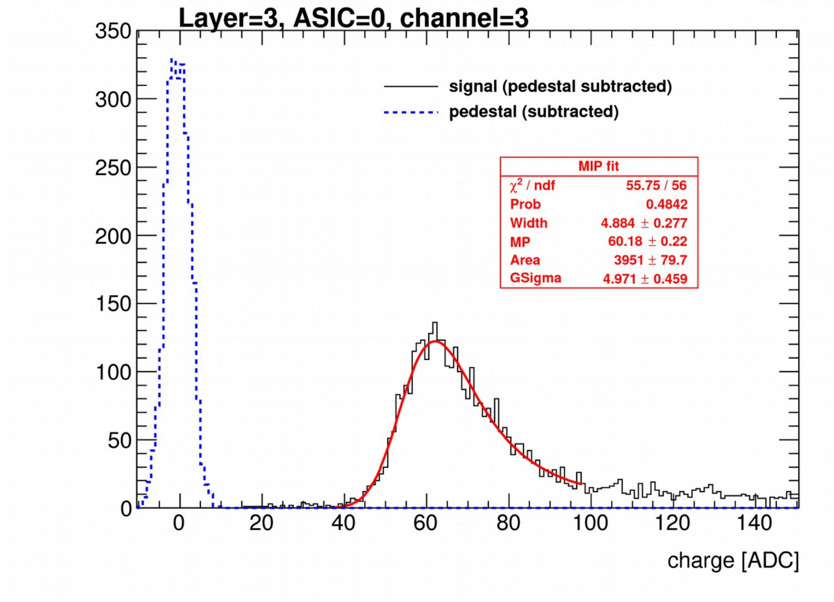
- **Setup** :
  - 7 FEV11 each equipped with 4 325um Si wafers and 16 Skiroc2
  - Power pulsing and ILC mode (emulated ILC spill conditions)
- **Physics program:**
  - Calibration run with 3 GeV positrons perpendicular beam without tungsten absorber plates
  - Electromagnetic showers program.
  - Calibration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

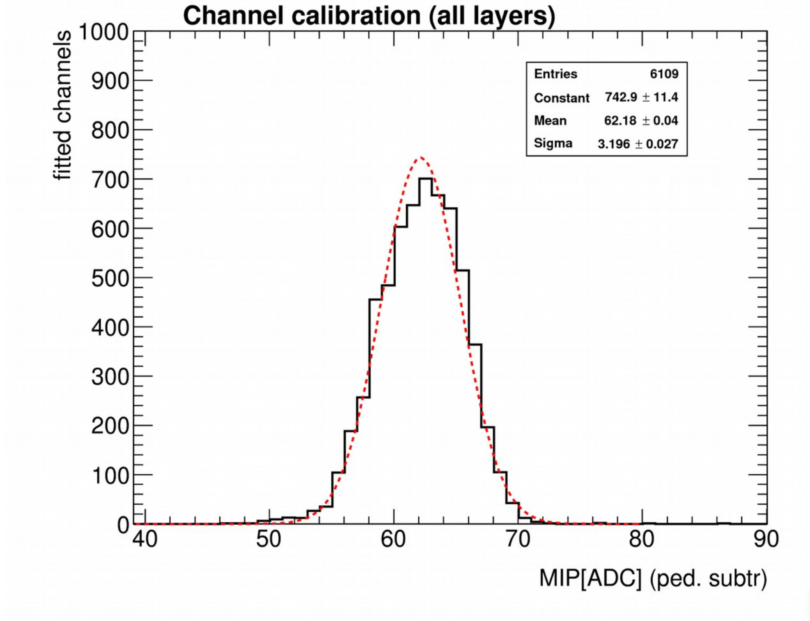




# DESY@2017 – MIP calibration

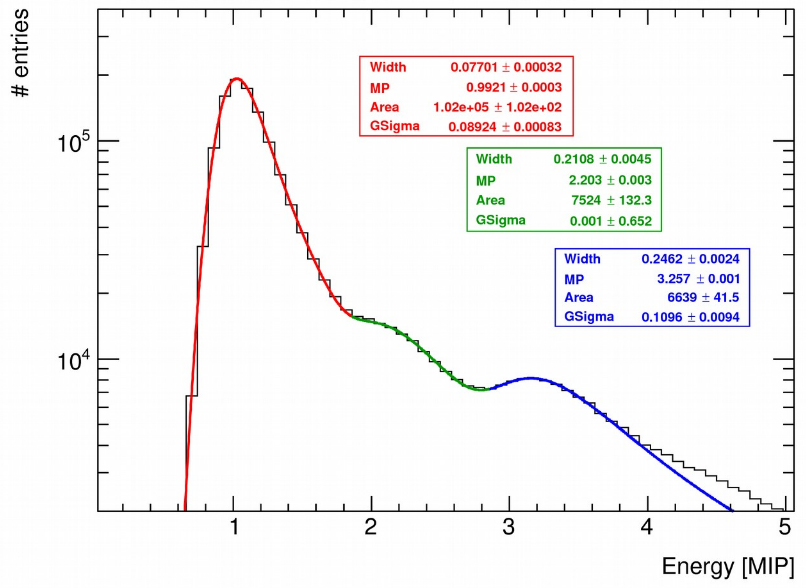
- MIP scan: Si - ECAL **(w/o the W)**
  - Positrons of 3 GeV (~2 kHz rate, beam spot with slightly irregular shape and size <2cm diameter)
  - Simple analysis done module by module
  - Pedestal correction done chip/channel/sca wise, Energy calibration done chip/channel wise
  - MIP: We fit the **98%** of available channels → MPV = 62.2 ADC, sigma= 3.2 ADC (dispersion of 5.1 %)



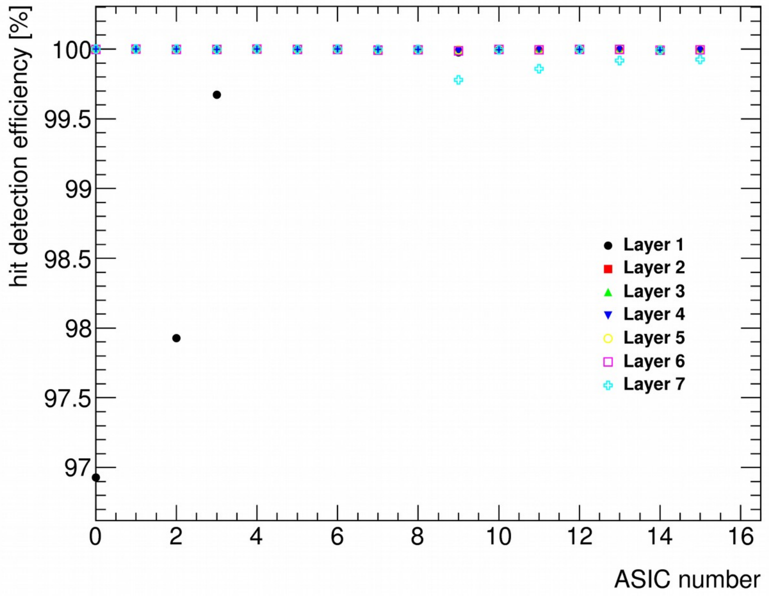



# DESY@2017 – Hit detection efficiency in tracks

- After calibration we performed the track reconstruction.



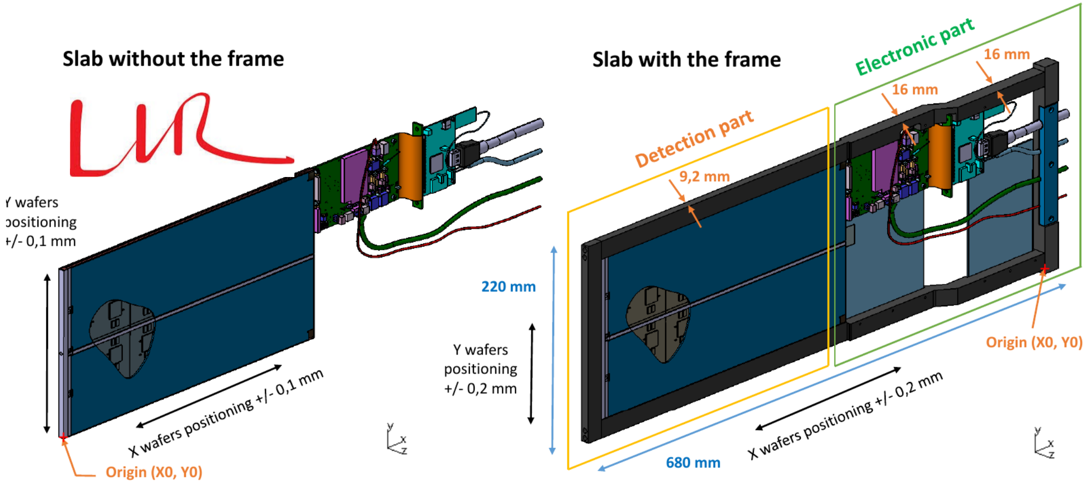

Hit energy distribution in tracks for all calibrated cells




Hit detection efficiency for tracks

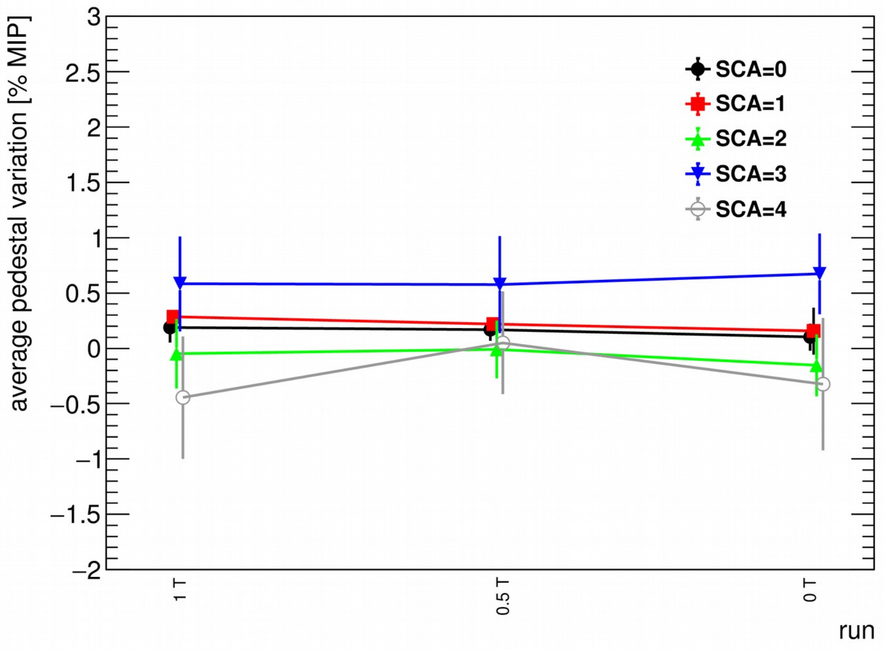
# DESY@2017 – Tests under Magnetic Fields

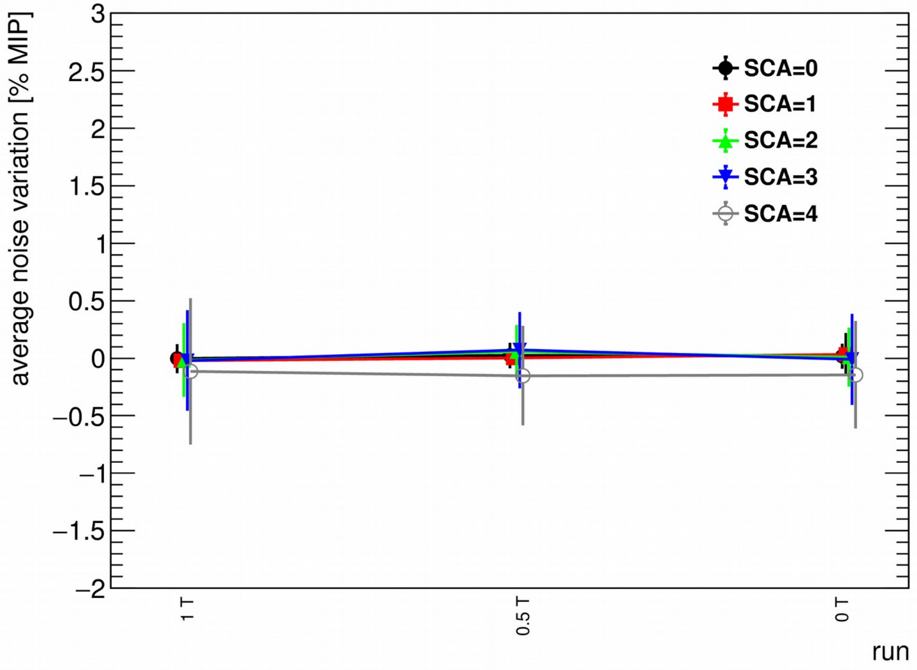
- Magnetic field tests
  - One slab in a special plastic support
  - Magnetic field from 0 to 1 T.
  - With and without beam.
- **No failure/loss of performance observed during the operation and after the first analysis.**
  - ~20 hours of data in total.



# DESY@2017 – Tests under Magnetic Fields

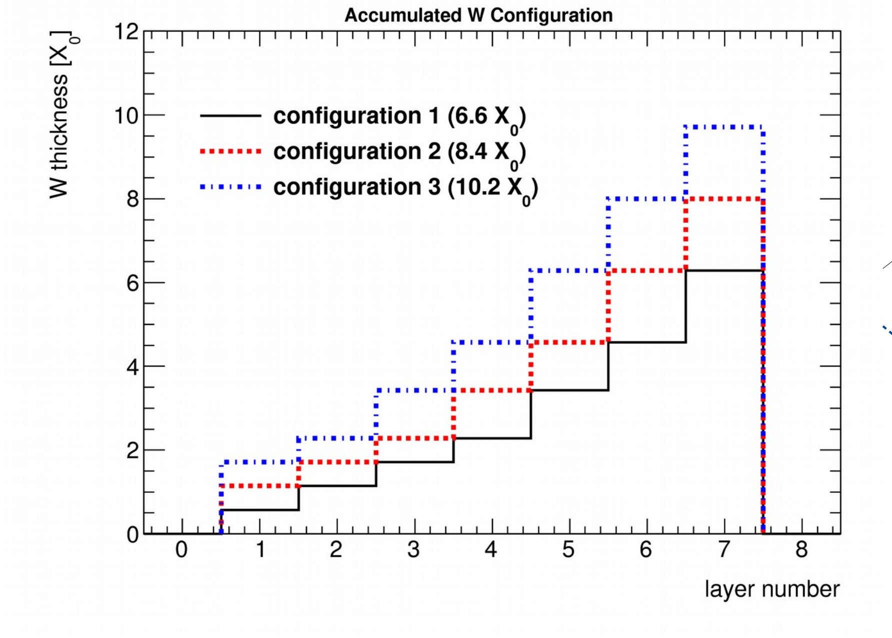
- Very stable noise conditions (note the %MIP scale)



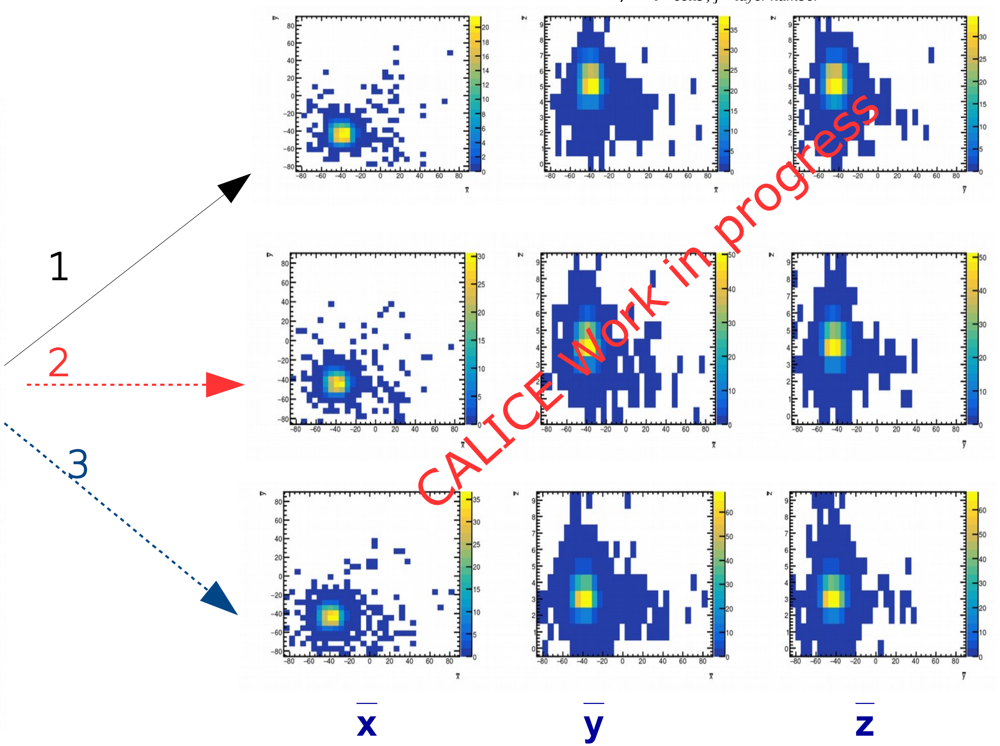
## Tungsten program

- Scans of various energies (from 1-5.8 GeV).
- Scan using different tungsten configurations



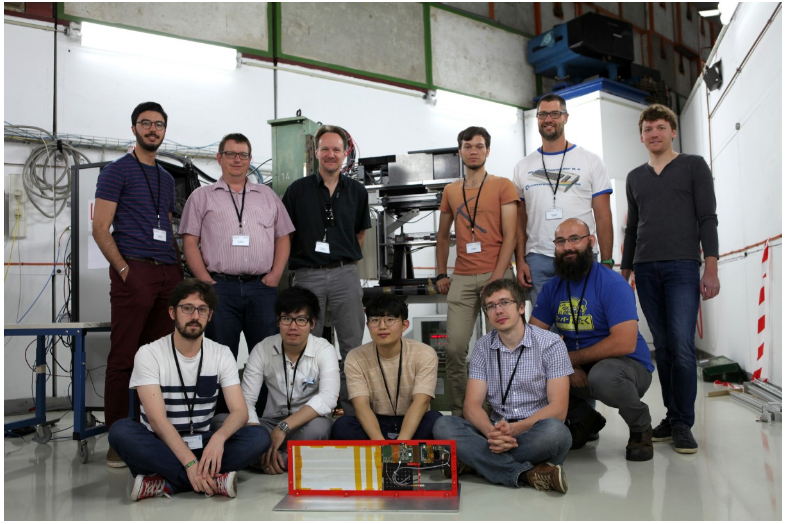

Raw shower barycenter maps

$$\overline{x} = \sum_{i=cells,\ j=layer\ number} x^i w_0^j E_i \Big/ \sum_{i=cells,\ j=layer\ number} w_0^j E_i$$



# DESY@2017 – Summary

- Successful beam test of the SiW-ECAL technological prototype.
  - first time with fully assembled detectors elements (first 7 of 10000 needed for ILD)
- MIP calibration achieved at the **5% level.**
- First looks at **shower response are very promising**
- **Operating in 1T magnetic field**
  - Also nice and consistent calibration results



- Presentations + proceedings for **CHEF2017, IEEE2017, LCWS2017**
- Beam test performance **paper ongoing**.

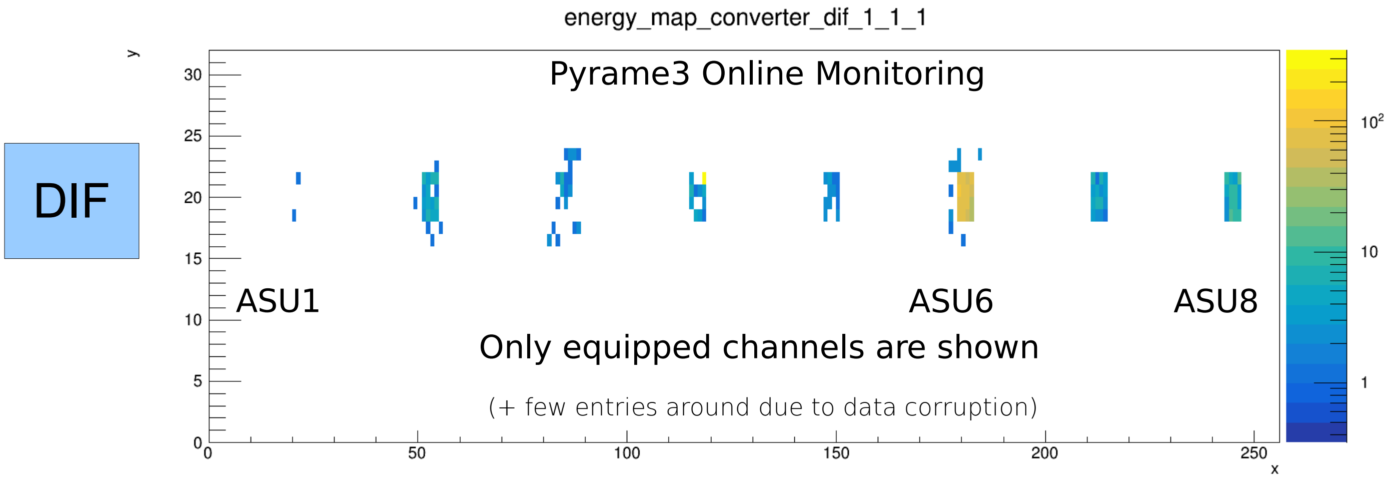
# DESY@2018 – Electrical prototype of Long Slab

- Daisy chain of 8 ASU (extendable to 12)
- Corresponding to typical barrel length
- Based on FEV12 ASU & SMBv4 (in stock)
  - FEV12 is an adiabatic modification of FEV11
- No ILC geometrical constraint (thickness)
- Baby-wafer 4x4 pixels on each ASU
- HV filtered by RC circuits to reduce noise
- Adaptation of impedance of any lines (simulations)
- DAQ resizing to cope with chips multiplicity

- **See V. Boudry's talk.**

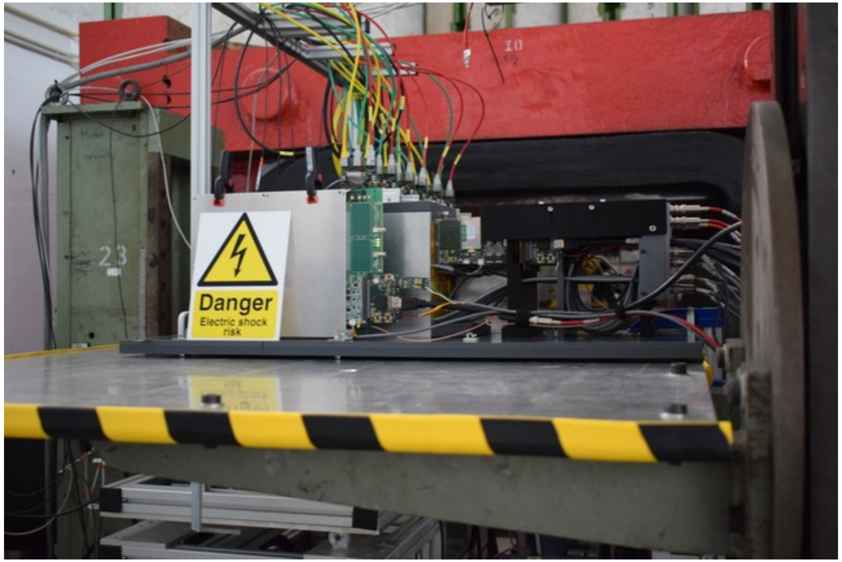
# Long Slab performance

- Final commissioning done on site.
- The slab was too noisy for data taking until thursday when more HV RC filters were added: → a total of one every two ASU
- Noise levels became compatibles with short slabs made with FEV11



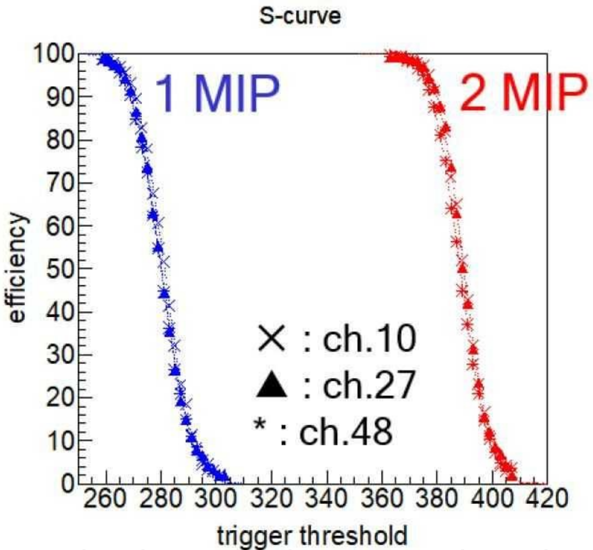
# Short slabs stack

- Same configuration than in 2017 for all FEV11.
  - One slab became mute. Being inspected at lab. *Note: It has travelled around the world…*
- New all **plastic structure** to avoid grounding loops
  - Old issue from 2016-17.
  - It is also true that we didn't inserted tungsten plates between all slabs…
- We got enough data for:
  - Crosscheck the calibration of FEV11.
  - Scurves with beam → S/N in the trigger branch.
  - Test the performance of FEV13-Jp.
  - Some simple shower studies (5 X0 of Tungsten in front)
  - Very first tests of new features of the SK2a. (i.e. individual channel trigger threshold, TDC)



# S/N in the trigger line

- For the physics prototype, we worked with externally triggered events → the S/N was measured only in the ADC.
- Working in autotrigger, an additional S/N can also defined by the study of the trigger line (fast shaper) → threshold scans
  - The threshold curve is interpreted as the integral of the gaussian distribution of the noise. The width is 1sigma of that gaussian, i.e.: half the difference between the thresholds for 50±34% of the efficiency.




Injection tests in SK2 testboard by Taikan et al (CHEF2017)

- S/N(trig) = 2MIP(50%) - 1MIP(50%) / width =

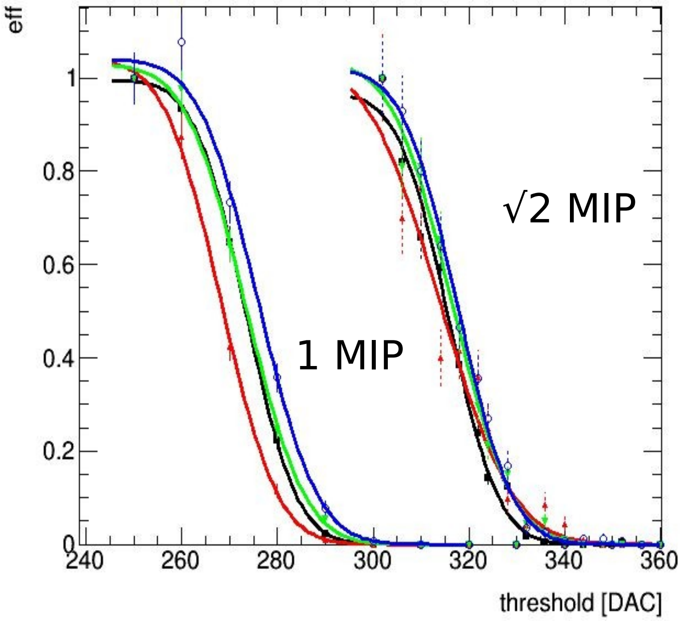
  **12.9 ± 3.4**
  - *Central value determined by injected signals runs*
  - *Uncertainty estimated using cosmic rays simple studies. Without external references.*

# S/N in the trigger line for MIPs: analysis

- Dedicated runs have been taken during last beam test to repeat these s-curves with different size signals (1MIP, 1.4MIP and 2 MIP)
  - For the following results, we use data taken at 1 and 1.4 MIP (45 degrees)
- Run settings
  - The first slab is always at a low threshold → used as reference
  - Single cell calibration is done in all slabs for the lowest threshold run.
  - Event building + filtering is done.
- The S/N is not calculated per cell but per SLAB (since different cells are used in every run).

# S/N in the trigger line for MIPs: analysis

- Results for 1 & 1.4 MIP signals.

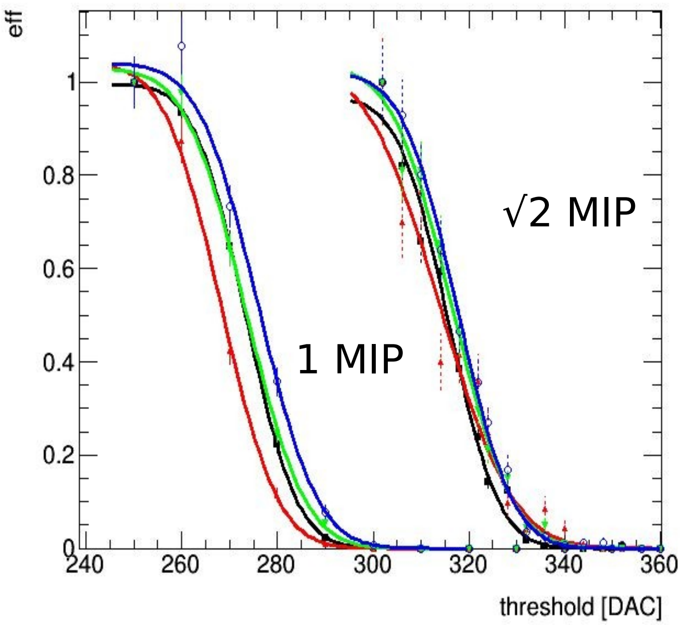


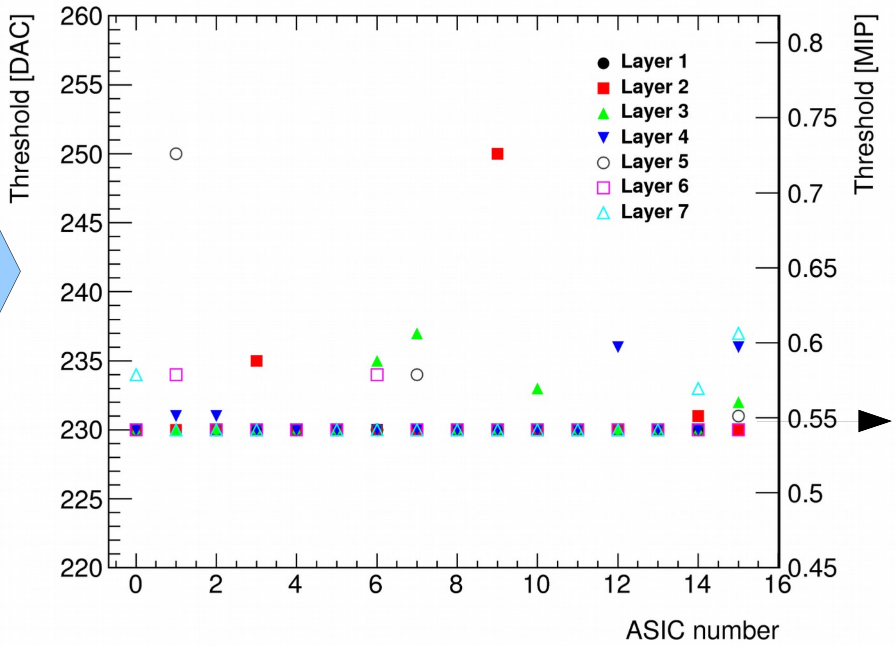

- Slab **17**, **18**, **19**, **20**
- **S/N = 11.6 ± 0.7**

ILD baseline requirements: S/N=10

# S/N in the trigger line for MIPs: analysis

- Results for 1 & 1.4 MIP signals.



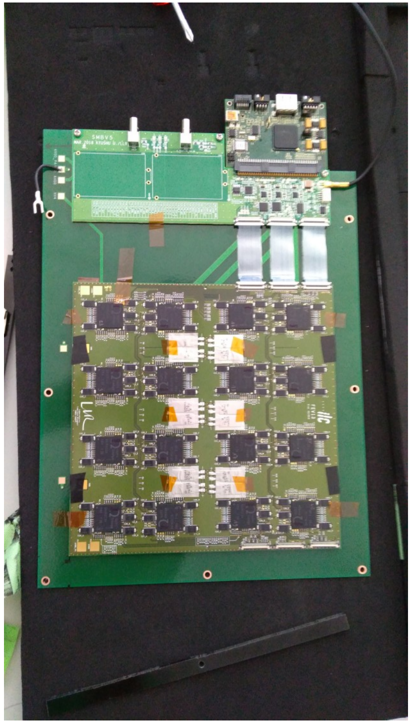

230DAC ≈ 5σ distance of the MIP

- Slab **17**, **18**, **19**, **20**
- **S/N = 11.6 ± 0.7**

ILD baseline requirements: S/N=10

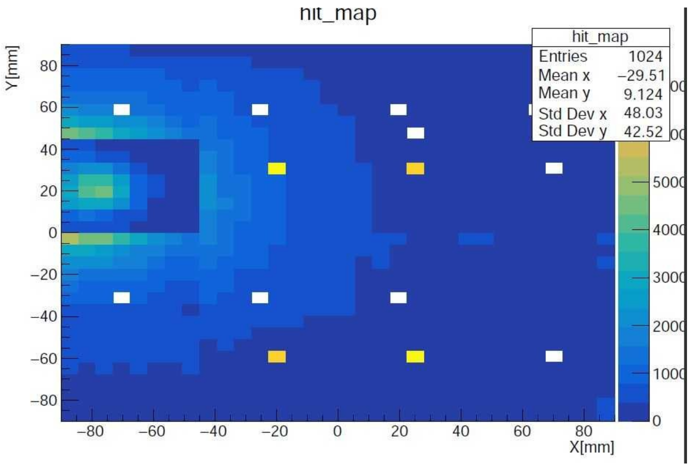
# FEV13-Jp test

- Performance of the FEV13-JP + SMBv5 (LLR+Kyushu collab.)
  - See **Taikan's** talk for more details
  - FeV13-Jp developed with the **aim of noise level improvement** by separating PCB layers for the analogue and digital power of the ASIC and specific re-design of pad-channel routing
  - 4x650 µm wafers (instead of 320µm)
  - Equipped with Sk2a: allows for fine tunning of thresholds + brings the possibility to use the TDC
- Integration in the DAQ worked out-of-the-box.



Example of FEV13-JP hit map

(still some systematically noisy channels)

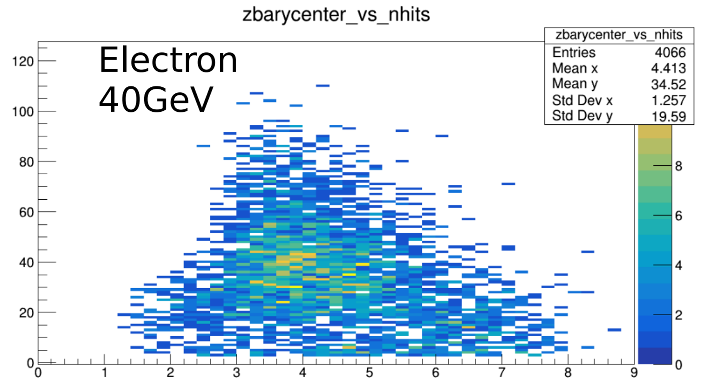


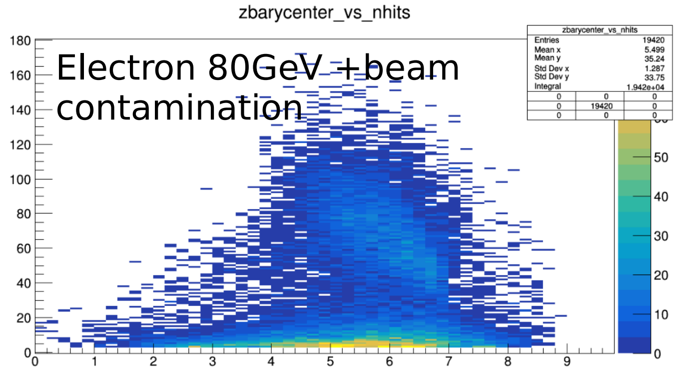
# CERN@2018 SiW-ECAL and SDHCAL

- Two weeks from the 26/09 to 3/10 at CERN with part of the beam time shared on standalone runs and part in common spills with SDHCAL.
  - 10 ECAL slabs in the stack.
  - 6 FeV11 + 4 FeV13-Jp
- Standalone runs with different number of layers (between 7 and 10)
  - muon calibration
  - Electron showers (10,20,40,80,150 GeV)

List of slabs (beam from the bottom)

| plane | HDMI# | GDCC:04 | GDCC:03 | DIF/SLAB | DIF# | Comments |
|---|---|---|---|---|---|---|
| Slab16 | 9 | 1 | | 9 | dif_1_1_1 | |
| Slab19 | 2 | 6 | | 6 | dif_1_1_4 | |
| Slab18 | 4 | 3 | | 7 | dif_1_1_3 | |
| FEV13_K2 | 1 | | 2 | 2 | dif_1_2_3 | 650µm |
| FEV13_P3 | 5 | | 5 | 5 | dif_1_2_4 | 320µm |
| FEV13_P2 | 3 | | 6 | 10 | dif_1_2_5 | 650µm |
| FEV13_K1 | 8 | 5 | | 4 | dif_1_1_5 | 650µm |
| Slab20 | 10 | | 1 | 3 | dif_1_2_1 | |
| Slab22 | 6 | | 3 | 1 | dif_1_2_2 | was dif_1_2_3 @DESY2017 |
| Slab17 | 12 | 2 | | 8 | dif_1_1_2 | |



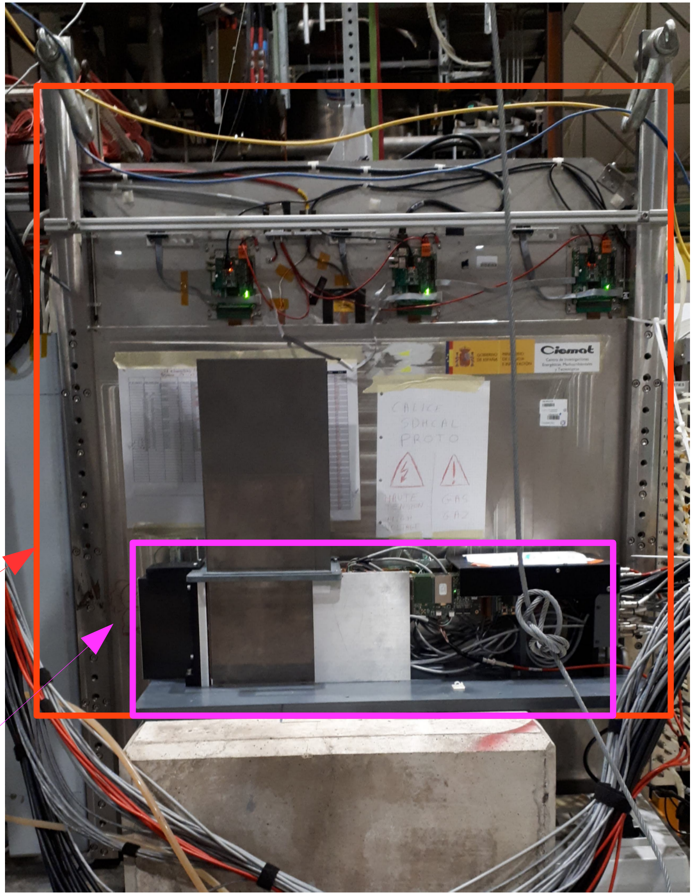




6 FEV11 +
1FEV13-Jp

# CERN@2018 SiW-ECAL and SDHCAL

- Two weeks from the 26/09 to 3/10 at CERN with part of the beam time shared on standalone runs and part in common spills with SDHCAL.

- Common running for the last ~ week.
- Independent clocks, common spills with common start acquisition with busy signal from the SDHCAL.
- Common runs:
  - Electrons 150 GeV
  - Muons 200 GeV
  - Pions 40, 50, 60, 70, 80 GeV
  - Data processing and analysis is ongoing.



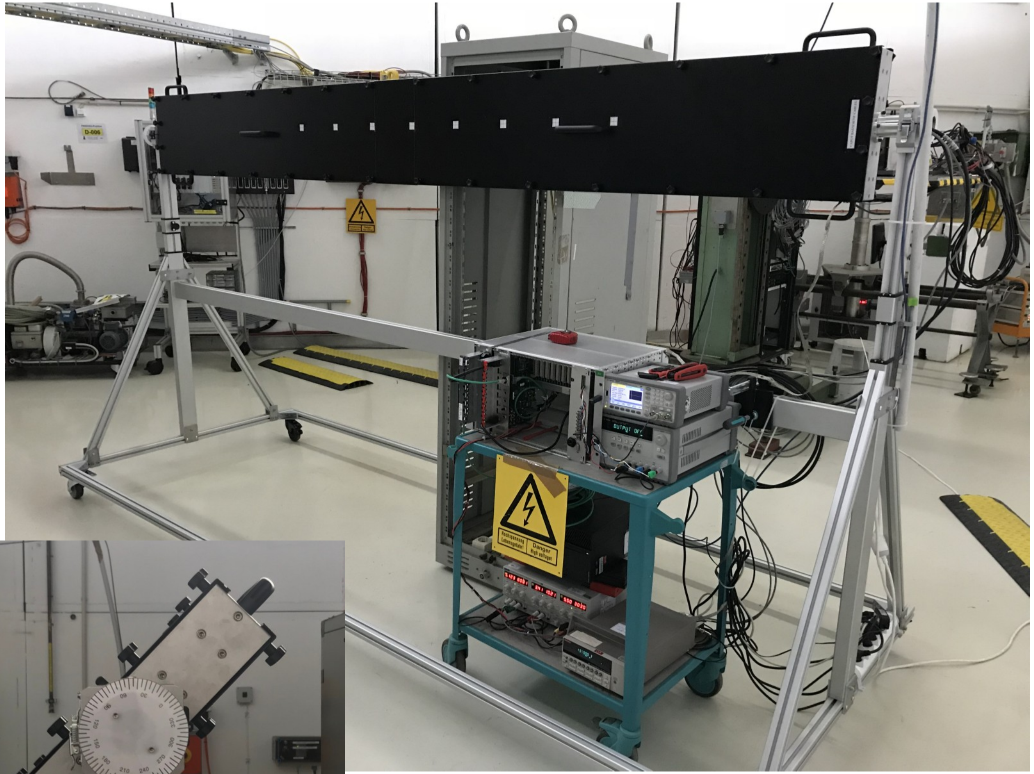
# Conclusion

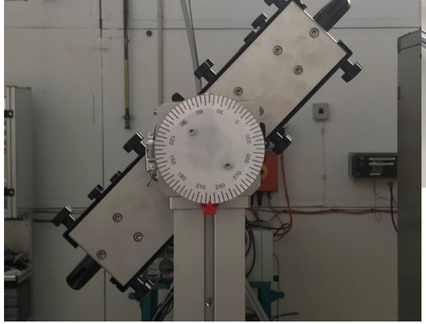
- We are in an exciting R&D phase on SiW-ECAL technollogical prototype with intensive debugging and performance studies in beam test and lot of developments ongoing
  - See talks from V. Boudry, T. Suehara and R. Poeschl

# Back-up

# DESY@2018 – Long Slab Setup

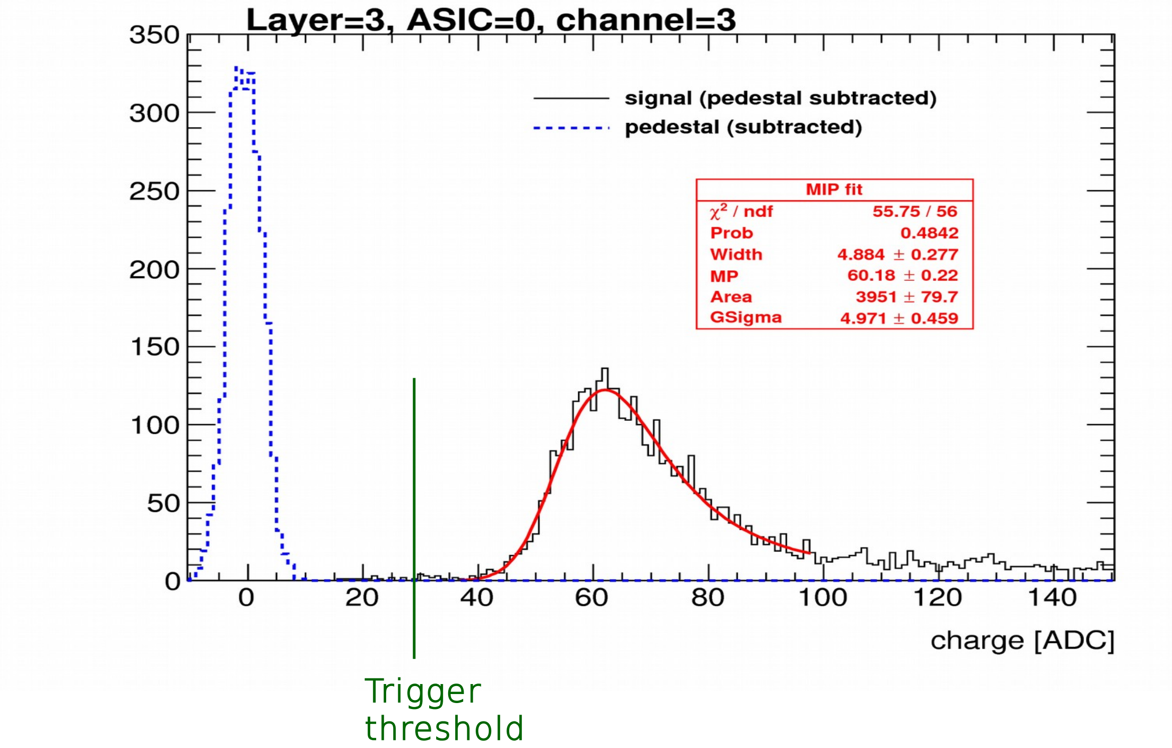
- Mechanical structure with mono-directionnal wheels for precise positionning
- Full rotation system with index
- Black cover for light isolation
- Laser alignment with silicon pads
- Compact DAQ on a wheel table
- 3224mm long
- 8 target accessible in zone 21 (beam centered), only 7 in zone 24 (beam on the side)





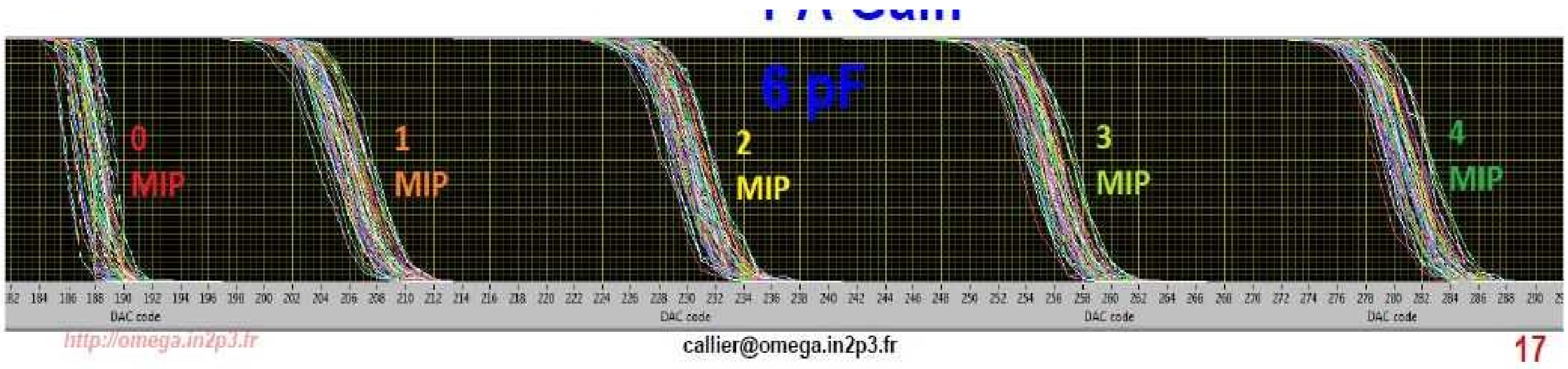
# S/N in the ADC

- The high S/N=20 from the ADC is only valid for already triggered cells and **it allows for the filtering of spurious signals (i.e. retriggers)**



# S/N in the trigger line

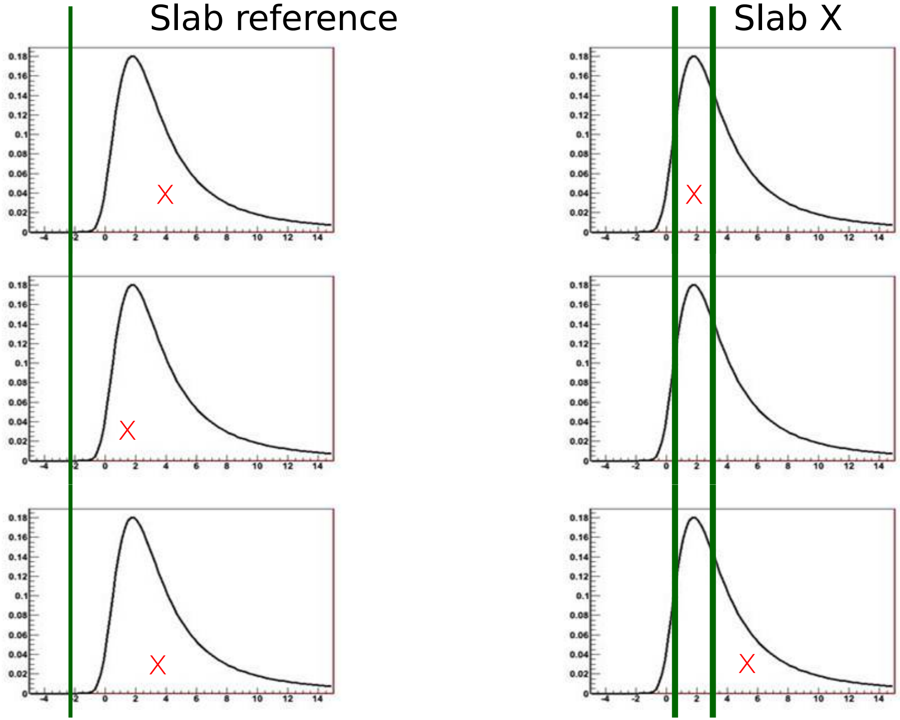
- How this curve looks for real signals measured in fully equipped detector modules ?
  - Similar test was done with ~1MIP cosmics → larger width and slightly different mean value. Using this we can estimate the uncertainty from the previous measurement:
  - S/N = 12.9±3.4 (very large uncertainty!)
- What about using the information of the threshold scan in absence of signal (noise-scurves)
  - The width and 50% position for 0-MIP scurves is not describing only the noise → competing effects between white noise and the sampling on the fast shaper.




Callier, CALICE2016, Arlington, SK2a

# S/N in the trigger line: analysis

- The analysis is repeated for every slab after the first. An event is accepted if:
  - the first slab has only a hit with E>0.5
  - The studied slab hasn't an event outside (MPV-wLandau,MPV+wLandau)
- Then all events within (MPV-wLandau,MPV+wLandau) are counted for each threshold value



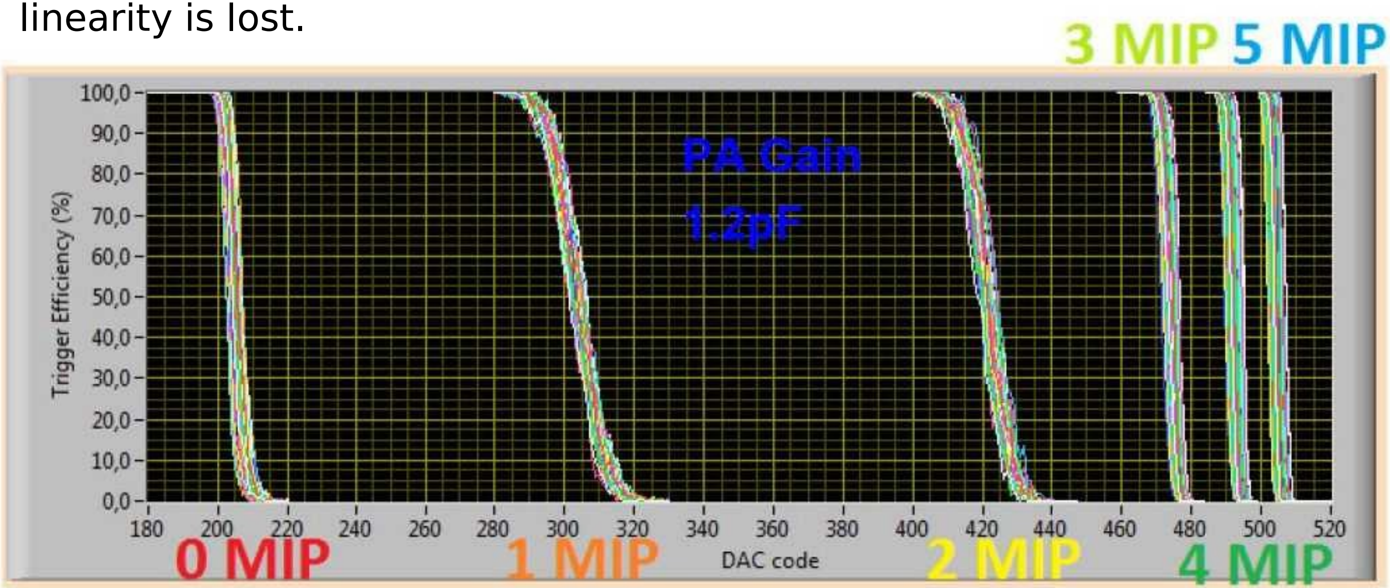

Case 1
- Accepted and counted as triggered in slab X.

Case 2
- Accepted and counted as not triggered in slab X

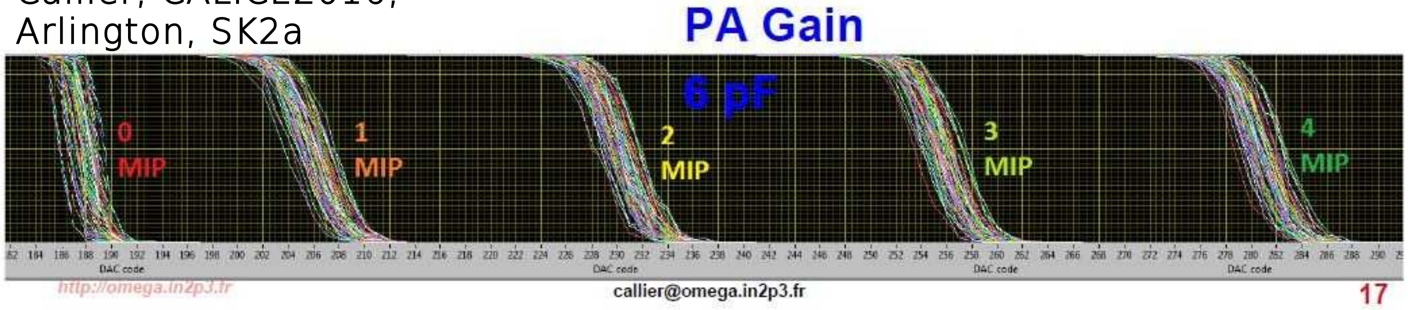
Case 3
- Vetoed.

# S/N in the trigger line

- **SK2a,** position of 0MIP (and width) disagrees with the expected from 1 and 2 MIP. For large signals, the linearity is lost.




Callier, CALICE2016, Arlington, SK2a




- **PA=1.2pF** (high gain for beam test)
  - S/N ~12, (rough estimation from the plot!)
- Similar for **6pF** (ILC gain) since the factor 5 reduction in distance is compensated by a smaller width of the curve → to be evaluated in beam!