First results from the SiW-ECAL 2018 DESY Beam Test

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on behalf the **SiW-ECAL team**
19th September 2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 654168

- Beam Test 2018 – DESY
  - One week at TB21 and on week at TB24

Goals:

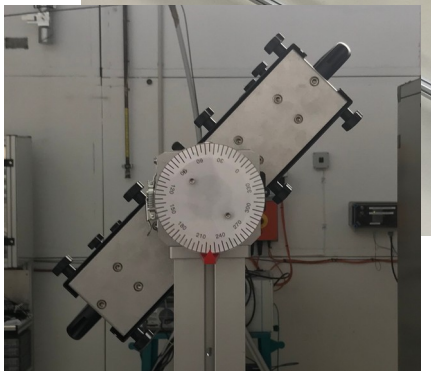
- Test of the new electric long slab prototype
  - Evaluate the performance of the long slab: electrical behavior, transmission of data and clocks, response on beam conditions.
  - Electrical & consumption studies (at lab)
- Crosscheck and finalize calibration and noise studies for FEV11
  - S/N in the trigger branch
- Test of new FEV13-Jp prototype
- Test the new FEV11-COB
  - Not ready on time.. (last minute baby sensor gluing didn't work well)

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

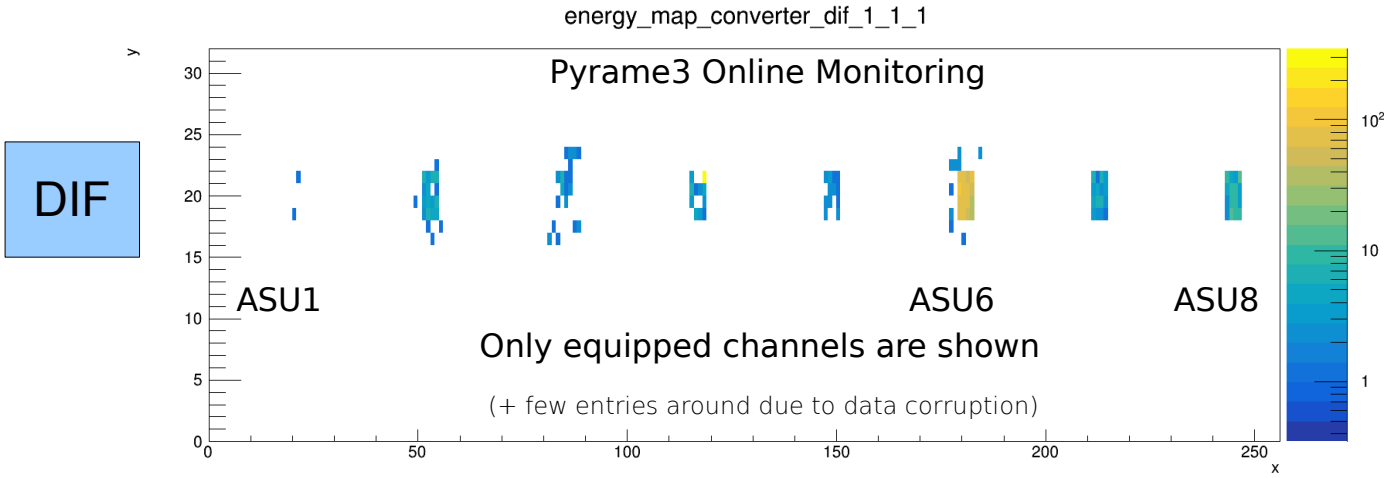
DESY@2018 – Long Slab Setup

- 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)



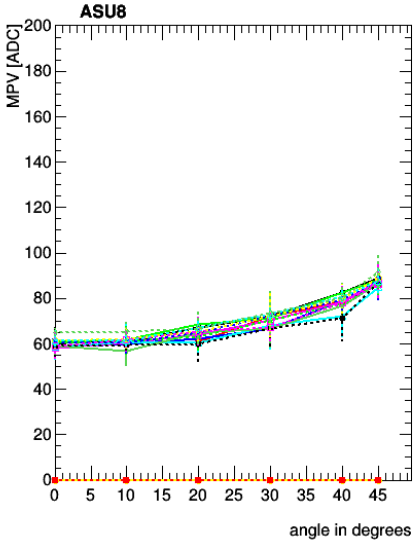
Long Slab performance

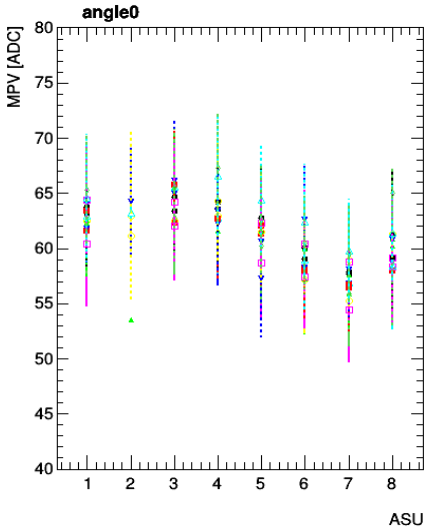
- Final commissioning done on site.
- The slab was too noisy for data taking until thursday when more HV RC filters were added: → a total of one every two ASU
- Noise levels became compatibles with short slabs made with FEV11

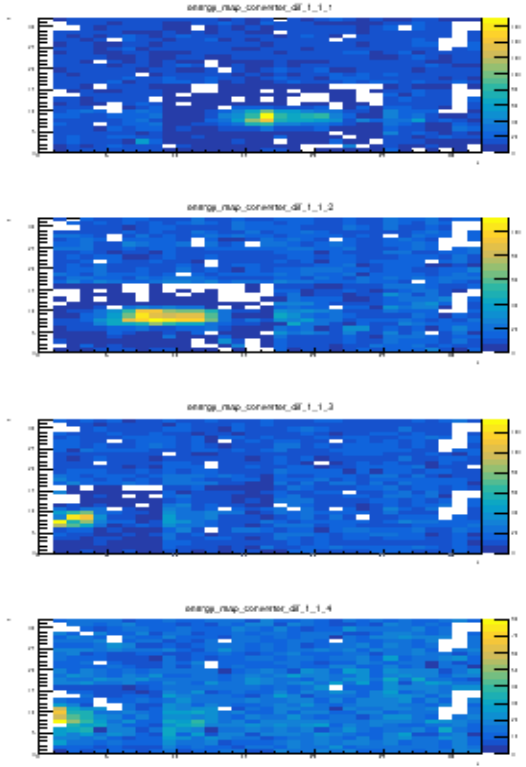


DESY@2018 – long slabs program

- Single cell calibration using 3GeV electrons with the slab oriented at different angles
  - Calibrate the 8 ASUs
  - With short slabs as reference (running with independent DAQs)
- Long slabs response to showers
  - 5X0 of lead in front of one ASU





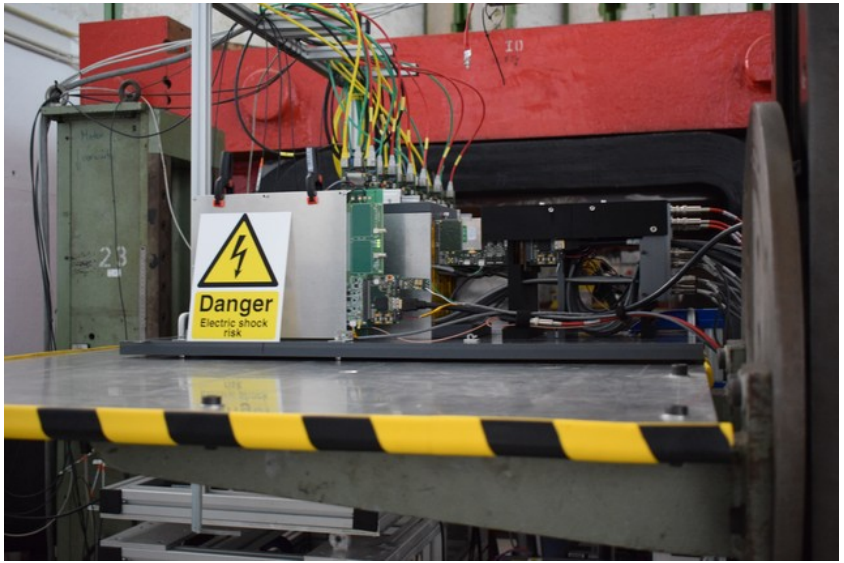


Preliminary results analyzed on site: E. Mestre & V. Lohezic

More in Oleksander's talk.

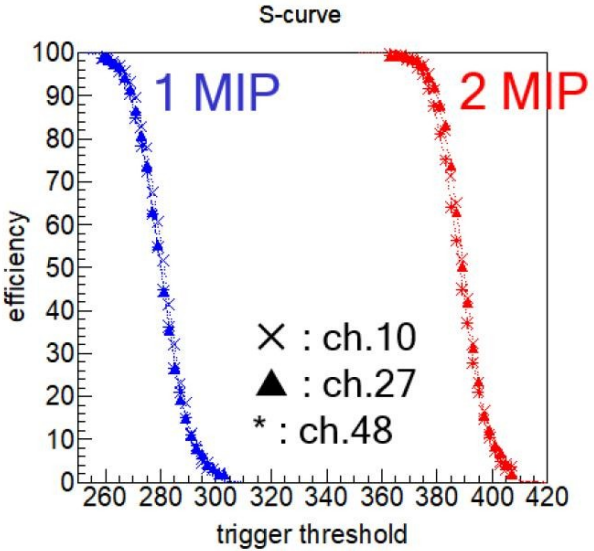
Short slabs stack

- Same configuration than in 2017 for all FEV11.
  - One slab, the 21, became too noisy for data taking. Being inspected at lab. Note: It has travel around the world…
- New all **plastic structure** to avoid grounding loops: In the first look, we didn't see any noise burst!
  - 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, the S/N is defined by the study of the trigger line (fast shaper) → threshold scans (aka scurves)

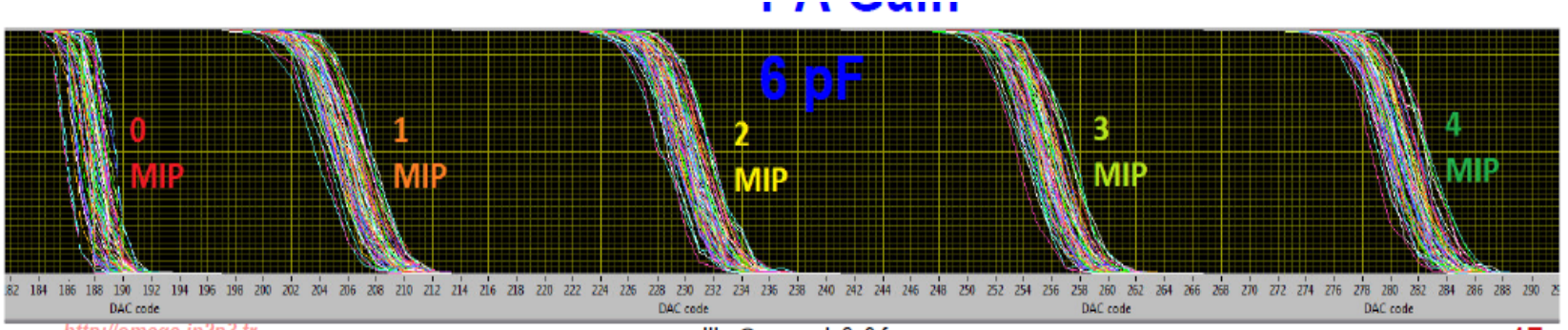


Injection tests in SK2 testboard by Taikan et al (CHEF2017)

- S/N(trig) = 2MIP(50%) - 1MIP(50%) / width = **12.9**
  - *allows to set the trigger using low energy signals (0.5MIP)*
  - The threshold curve is interpreted as theintegral 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.

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.



http://omega.in2p3.fr
callier@omega.in2p3.fr

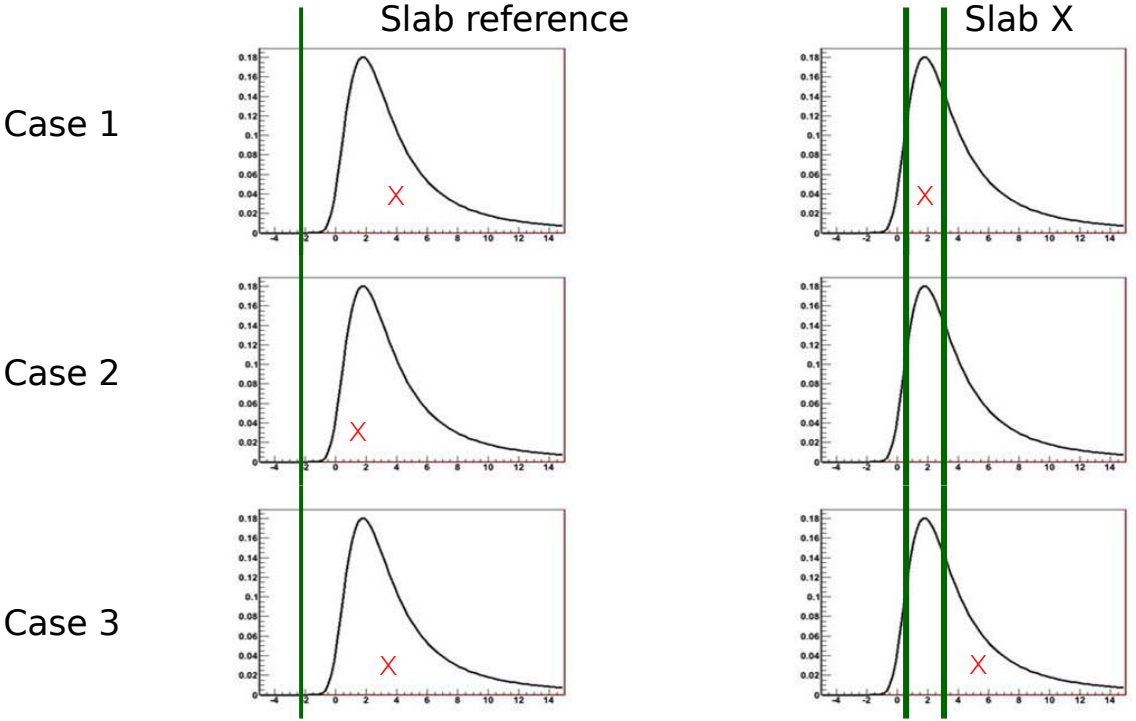
Callier, CALICE2016,
Arlington, SK2a

S/N in the trigger line: 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 (since different cells are used in every run) but per SLAB.

S/N in the trigger line: analysis

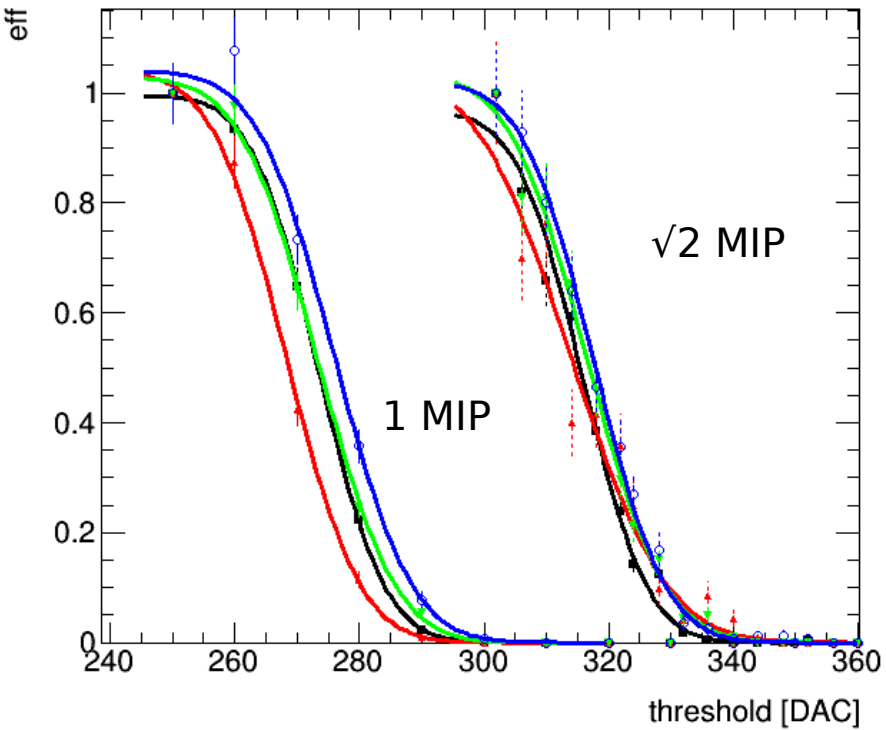
- The analysis is repeated for every slab after the first. An event is accepted if:
  - the first slab has only a hit with E>0.5
  - The studied slab hasn't an event outside (MPV-wLandau,MPV+wLandau)
- Then all events within (MPV-wLandau,MPV+wLandau) are counted for each threshold value



- Accepted and counted as triggered in slab X.
- Accepted and counted as not triggered in slab X
- Vetoed.

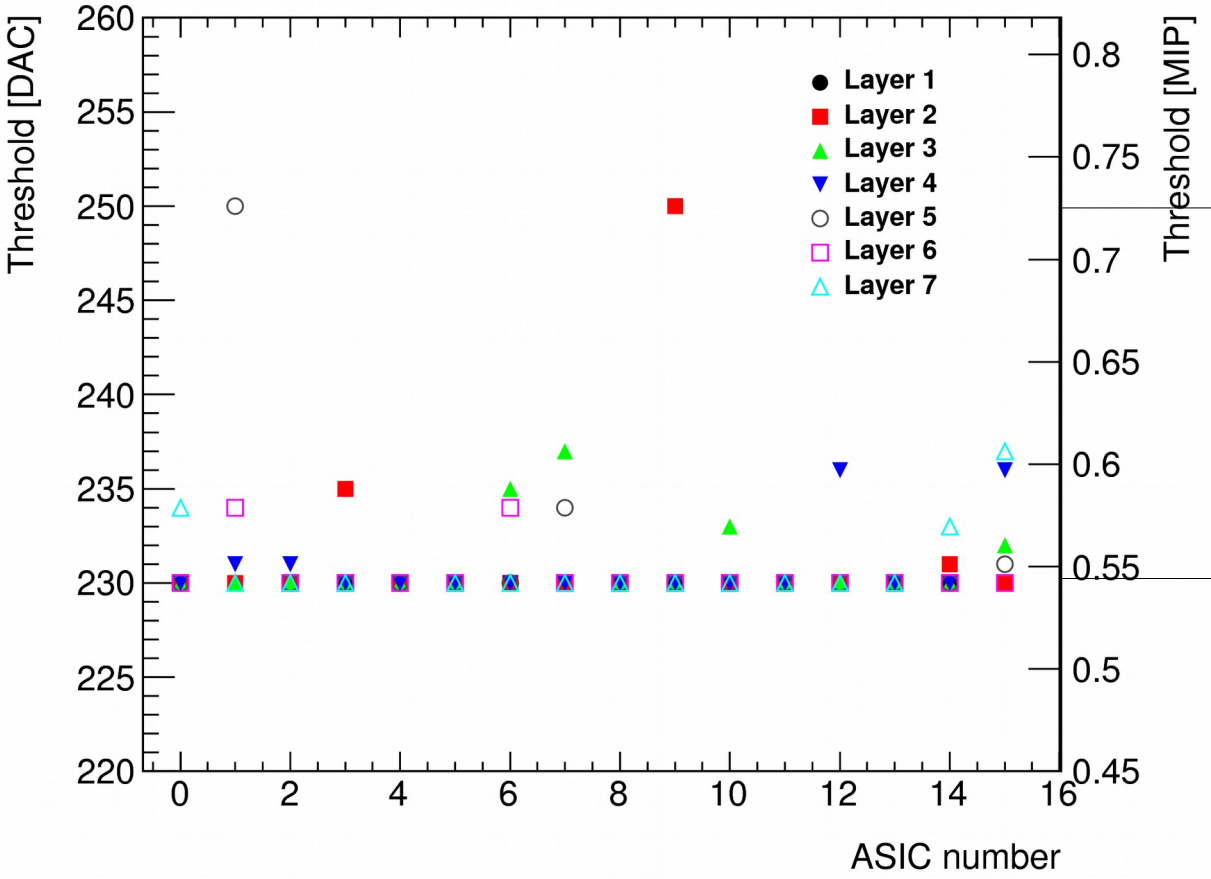
S/N in the trigger line

- Results for 1 & 1.4 MIP signals.



- Slab **17**, **18**, **19, 20**
- **S/N = 11.6 ± 0.7**
  - 6% unc estimated includes the differences from different slabs and the different widths of 1MIP and 1.4MIP
- This plot, and plot in side 8, allow to know the position of our trigger threshold →

S/N in the trigger line



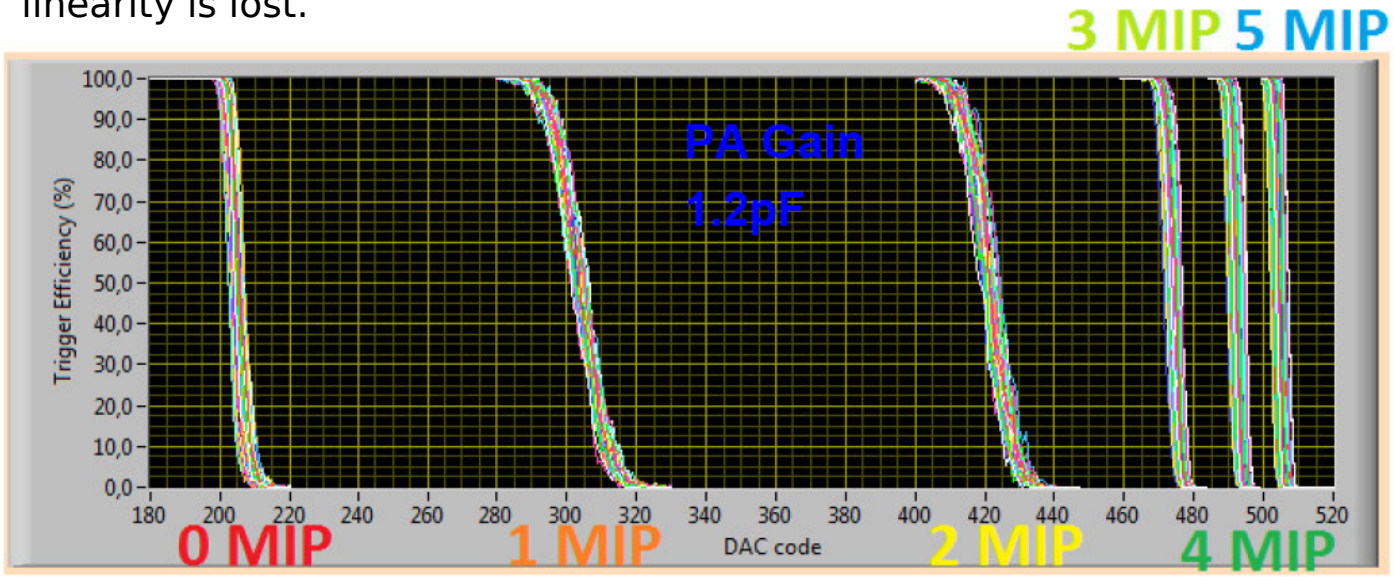
Distance to MIP in σ_{noise}

250DAC ≈ 2.8σ of the MIP

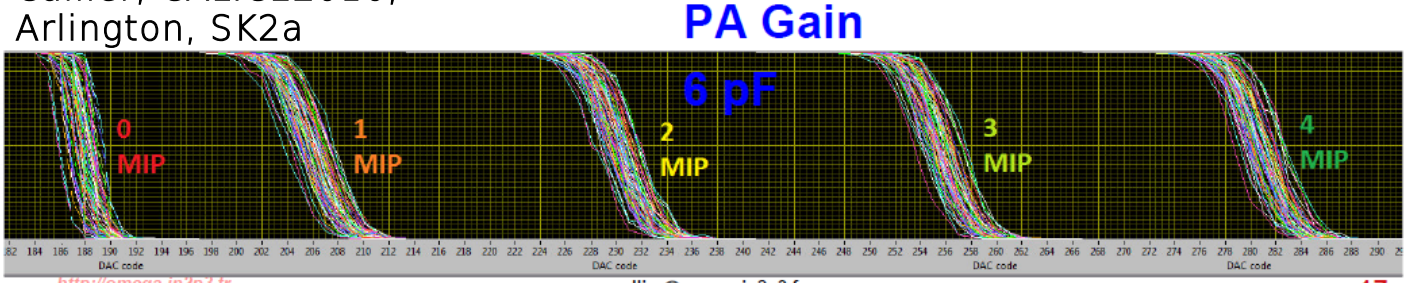
230DAC ≈ 5.1σ of the MIP

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.



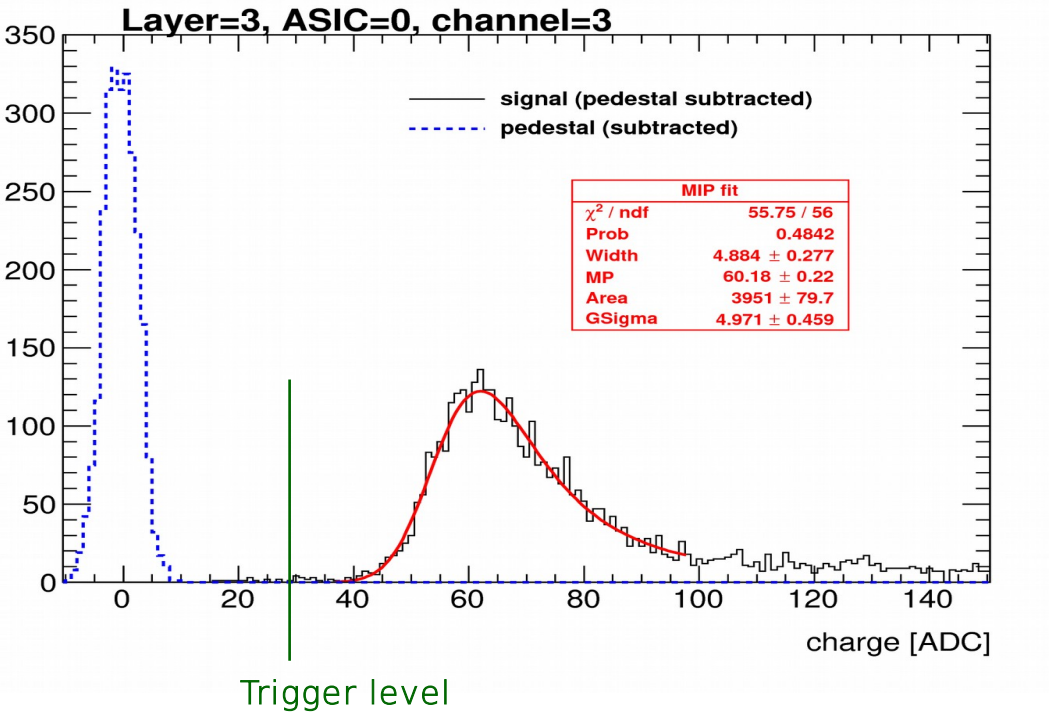
Callier, CALICE2016, Arlington, SK2a



- **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!

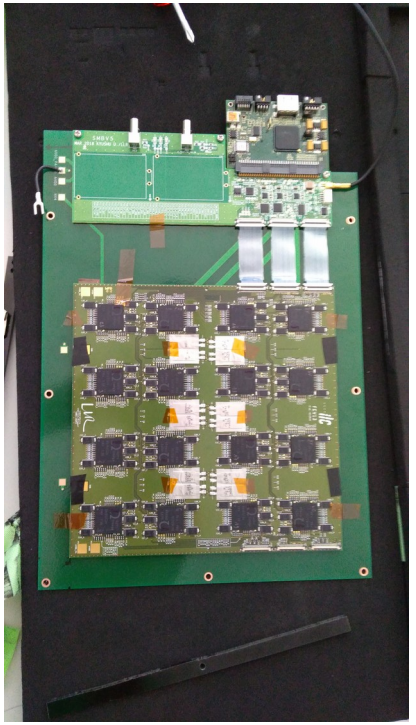
S/N in the ADC

- 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)**



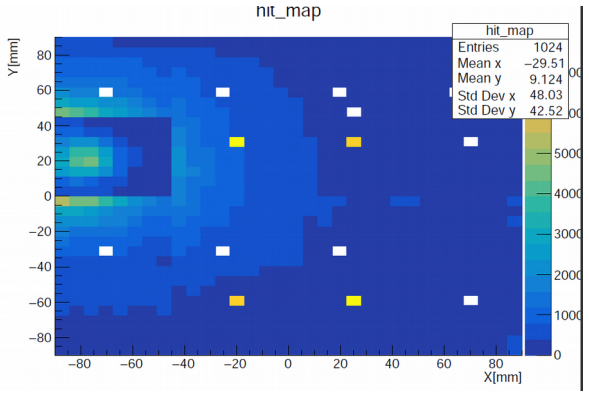
FEV13-Jp test

- 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
  - 4x750 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.**
  - Enough data for pedestal studies and calibration (see Taikan talk)



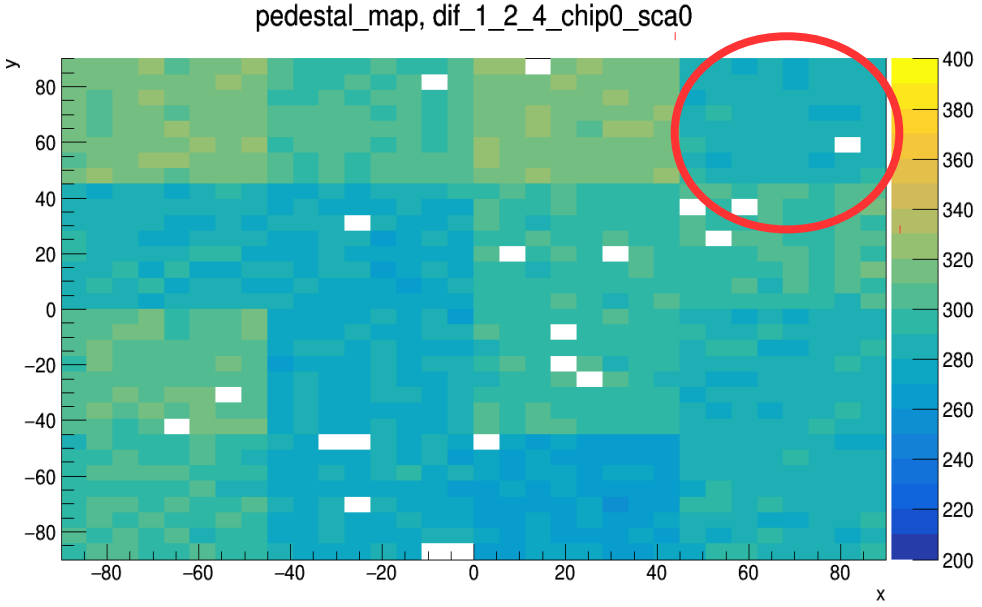
Example of FEV13-JP hit map, **seen as soon as we had been :)**

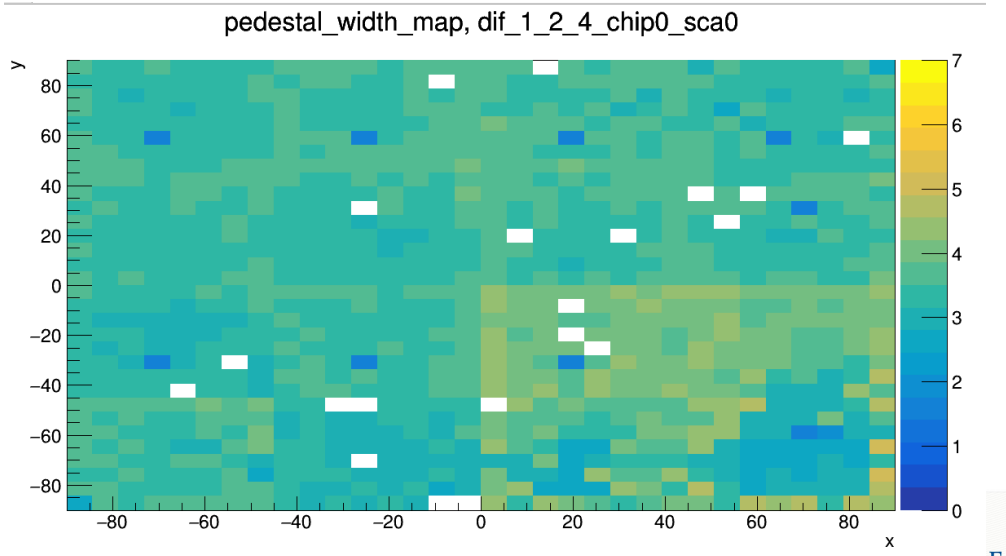
(still some systematically noisy channels)



FEV13: pedestal studies

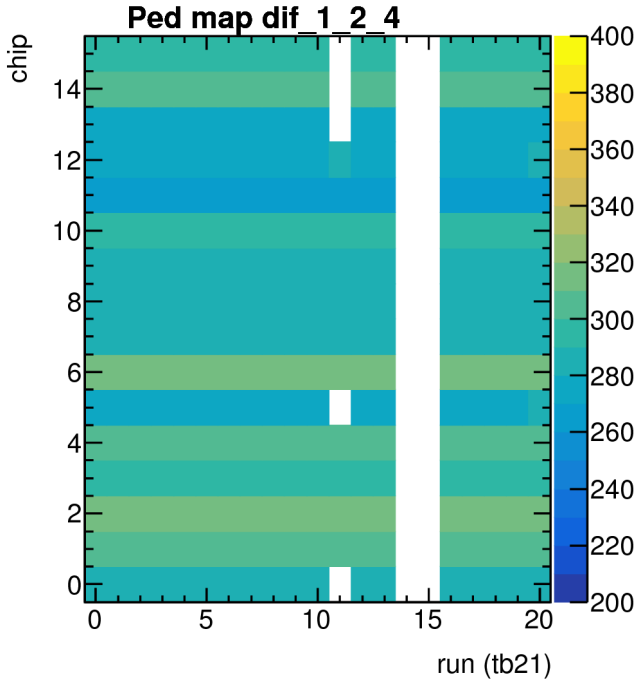
- The pedestal mean and width distributions looks very similar to FEV11 and SK2. Pedestal mean is a bit larger.
  - beam spot inside the red circle
- For the first runs, the “typical” double pedestal distributions for events tagged as retriggers were not present or at very lower levels. Retriggers were observed, though.
- But the pedestal width didn’t remain constant on time and the double pedestals appeared back with retriggers…

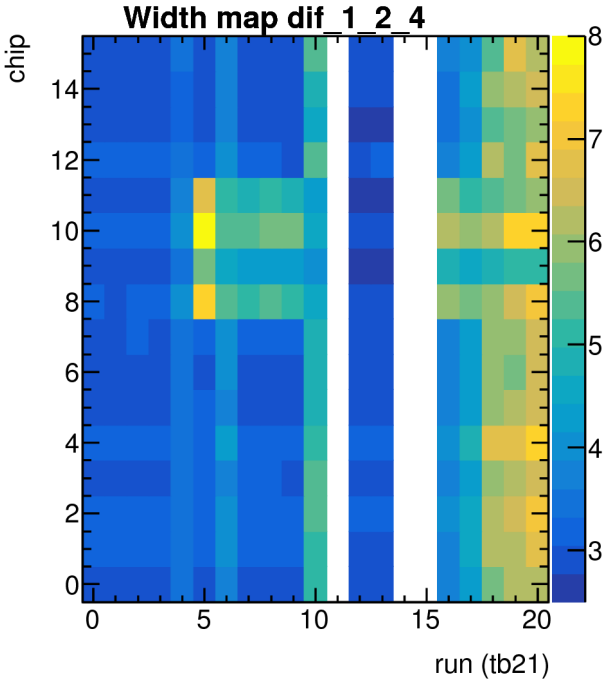




FEV13: Pedestal width drift

- We plot the average for every chip of the mean (and width) of the pedestal distributions for runs in TB21. In TB24, the value of the width remained at ~7-8 ADC all the time
  - Width of ~3 ADC are in FEV11.

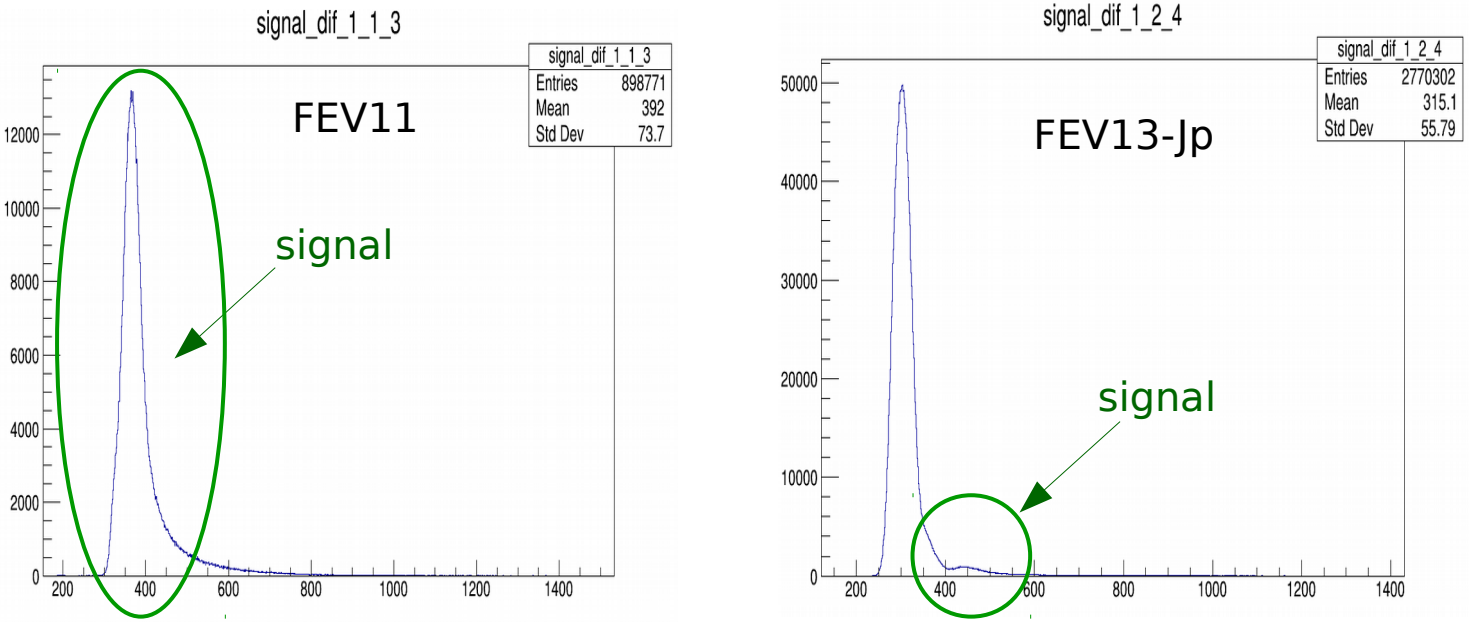




Z-axis, ADC

Tracking efficiency

- Signal events vs noise events ratio ? FEV13-Jp noise levels are much higher. Compromise the DAQ efficiency. When reconstruction tracks: only ~10-50% of the events have a hit in the FEV13-Jp (depending on the run)

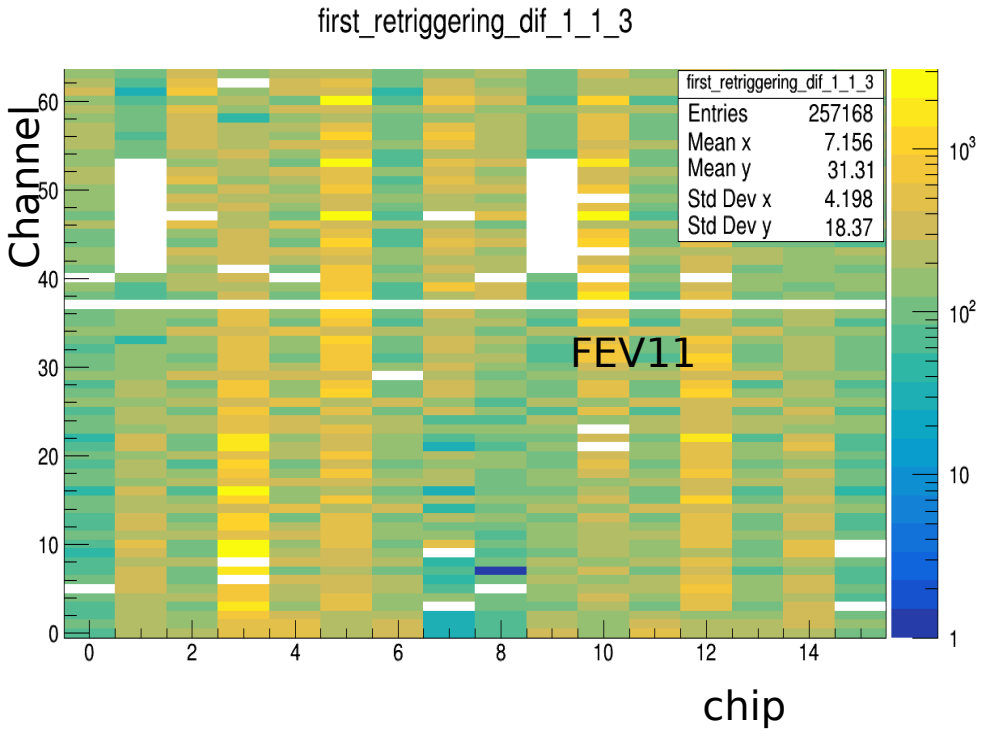


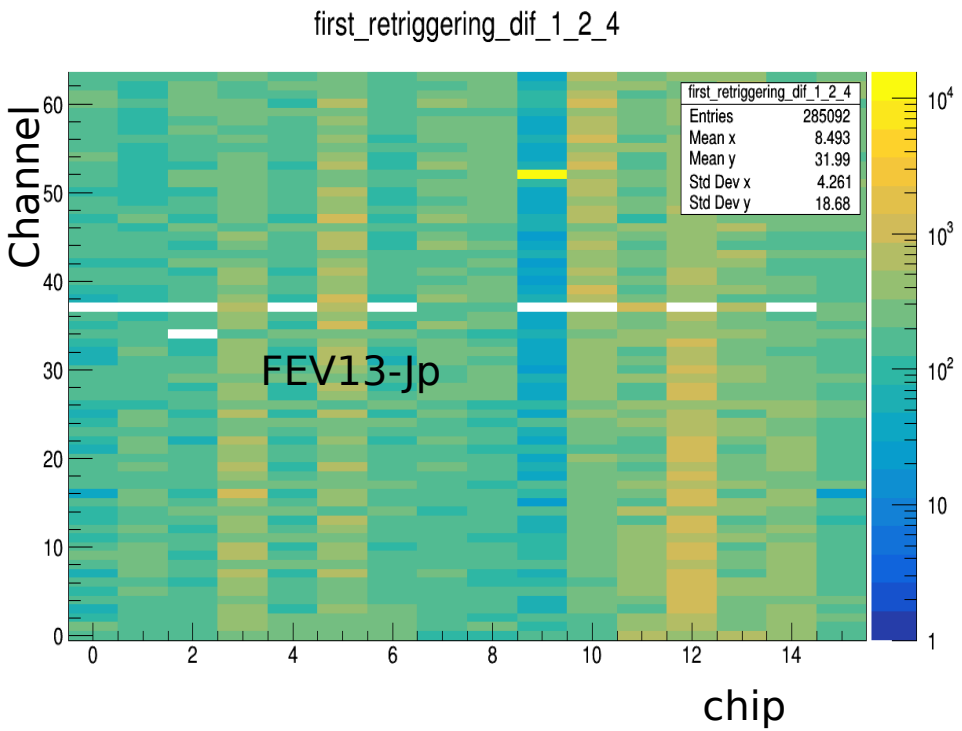
ADC (for all channels with trigger, no SCA pedestal correction)

(TB24, common run with long slab, beam in ASU7 for the long and chip 6-7, angle0)

Retriggers

- 2-D map of the cells starting of the retriggers in a **shower** run. Similar (or larger) levels of retriggers.





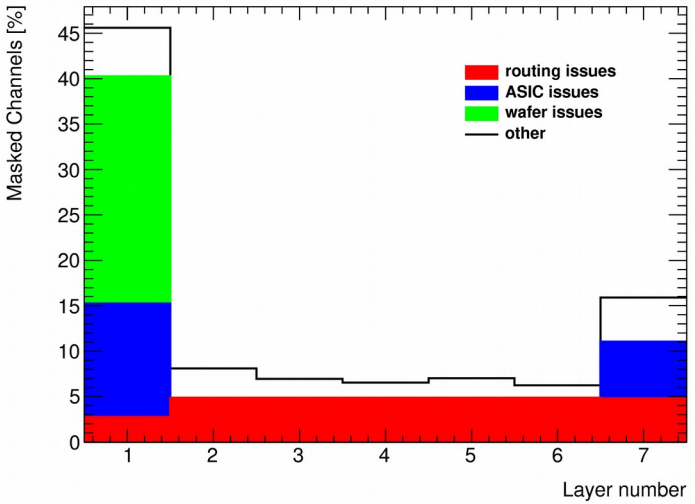
Summary

- Although the complexity of the beam test itself (rather techical), the tight schedule for both commissioning and beam time, **we had achieved all data taking goals** except that we didn't manage to test the COB (see R. Poeschl's talk)
- **The long slab was a big success and a major step forward! See Oleksander's talk** for more results.
- For **FEV11** we have enough data to crosscheck last year results but we lost a full slab and to measure the **S/N in the trigger**.
- The **FEV13-Jp was well integrated and responding but presented some issues:**
  - Still there are channels systematically noisy… only the 37? To be checked with.
  - The pedestal width (the noise!) is unstable and very large.
  - The retrigger rates are larger or equal than in FEV11.
  - The tracking efficiency is very low since we record much more noise than signals.
  - See Taikan's talk for more.

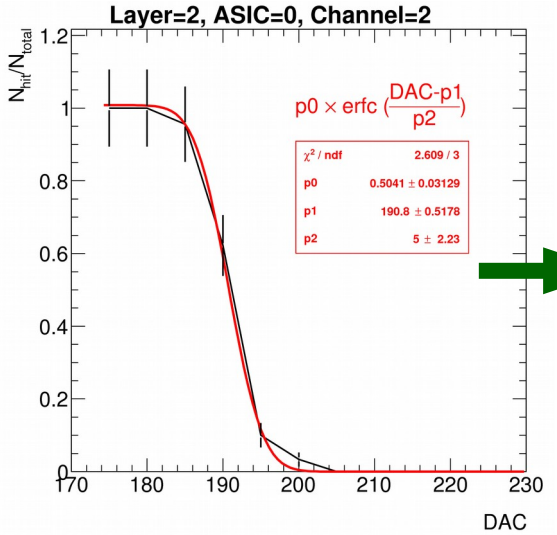
Back-up & extra material

Commissioning & Passport delivery

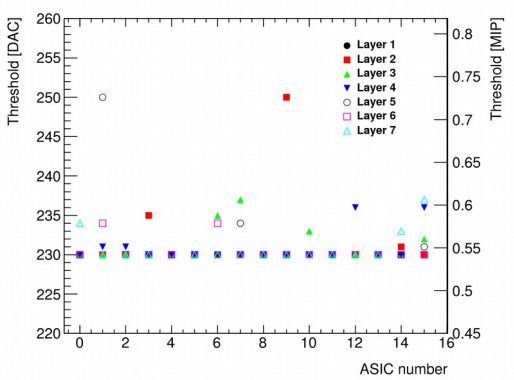
- **Noise control → noisy channels**: **7-8%**: very conservative approach.
  - Found a pattern on the spatial distribution of ~4% some noisy channels



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



Threshold scan curves with noise



Auto trigger threshold set at ~0.5 MIP

Data Taking Summary: TB21

	run type	data	time	comments
TB21, short slabs	commissioning	2.3GB	1-2 days	
	MIP scan (1)	147GB	~4days	From 2018/07/03 15:48:27 to 2018/07/06 11:01:43, long stop on wednesday
	MIP scan (2)	15G	12h	Why ? : some points missing in the FEV13 (beam spot ouside of the slab) + chips 8-11 with low stats and (les important) the FEV11 wrongly configured in several runs
	Scurves with signals (1MIP)	9.2GB	20h	For each point, we run a MIP scan + a scurve. Start 20180706_154816 end 20180708_062533 plus a run in the sunday evening.
	Only used as reference for long slab	5.3GB	1day	Fixed position
total	**6 days**			
total (with long)	**3.5days**			

	run type	data	time	comments
TB21, long slabs	Commissioning + debugging	28Gb	3.5days	
	Runs before debugging	?		
	Scan of positions (angle 0)	46GB	2.5day	The Long slab became fully operative on thursday afternoon → after the RC filters https://llrelog.in2p3.fr/calice/1774 data taking in parallel by the short slabs
	Angle Scan (ASU8)	2.3GB	1day	together with short slabs
Total (with shorts)	**3.5 days (from thursday noon)**			

- Long slab and short slabs always taking data in paralell.
  - Until thursday afternoon, the FEV13 MIP scan was run while the long slab debugging was ongoing (barely some data quality checks for the FEV11s was done)
- Long slab became fully operative on thursday afternoon.
- Short slabs unoptimally configured for several days → fixed ~ when long slab became operative.
- FEV13 MIP scan time went from 1-2 days to 5-6 (5Hz vs 1 Hz)

Data Taking Summary: TB24

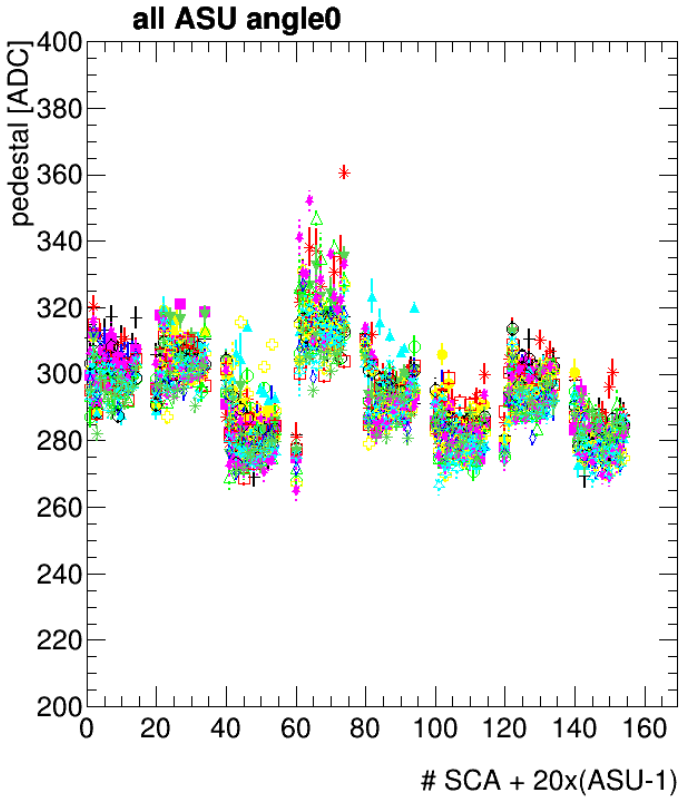
	run type	data	time	comments
TB24, short slabs	common runs with long slab	99GB	2days	Angle 0 and several up to 60. Finished on the night of the tuesday to wednesday
	Scurve with 60 degrees	2.2GB	2.5h	Before the W program (the DESY machine development took shorter than expected)
	Showers, 5X0 in front of the detector	74GB	~0.75day	Wednesday noon until wednesday evening
	TDC studies	48GB	20h	Wednesday evening and thursday daylight
	Last scurve with optimal spill	1.3GB	6h	Thursday evening + night
total	**4 days**			
total (with long)	**2 days**			

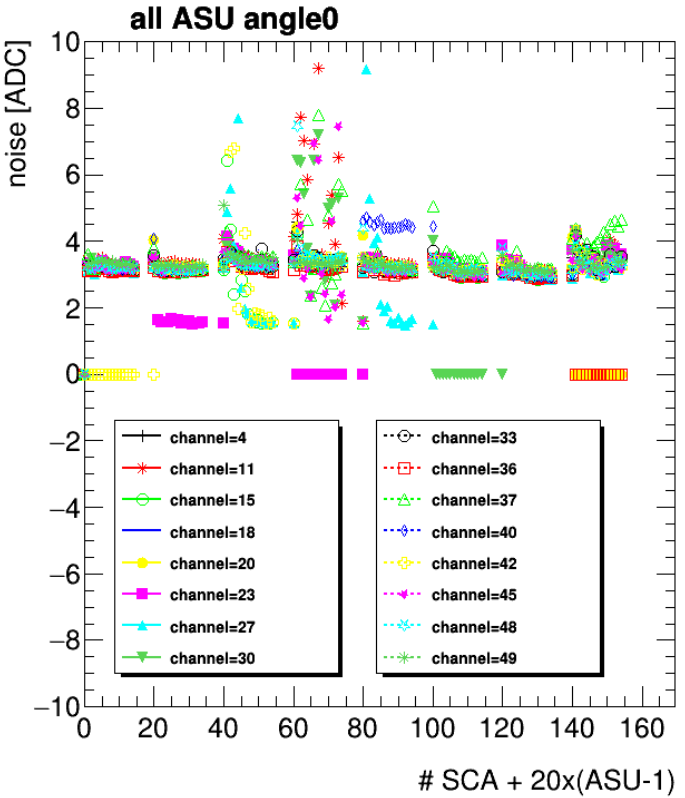
	run type	data	time	comments
TB24, long slabs	common runs with short slabs		2days	Angle 0 and several up to 60. Finished on the night of the tuesday to wednesday
	Showers, 5X0 in front of the detector		~0.25day	Wednesday morning after machine development
total	**2.25 days**			
total (with short)	**2 days**			

- Some playing with the spill to make it a bit more optimal.
- Long slab + short slab angle run until wednesday.
- Showers ~ 0.7 days.
- First tests of the TDC → although the non-linear scale makes the data suboptimal for studies.
- Last run (scurves) on thursday night.

Long Slab performance

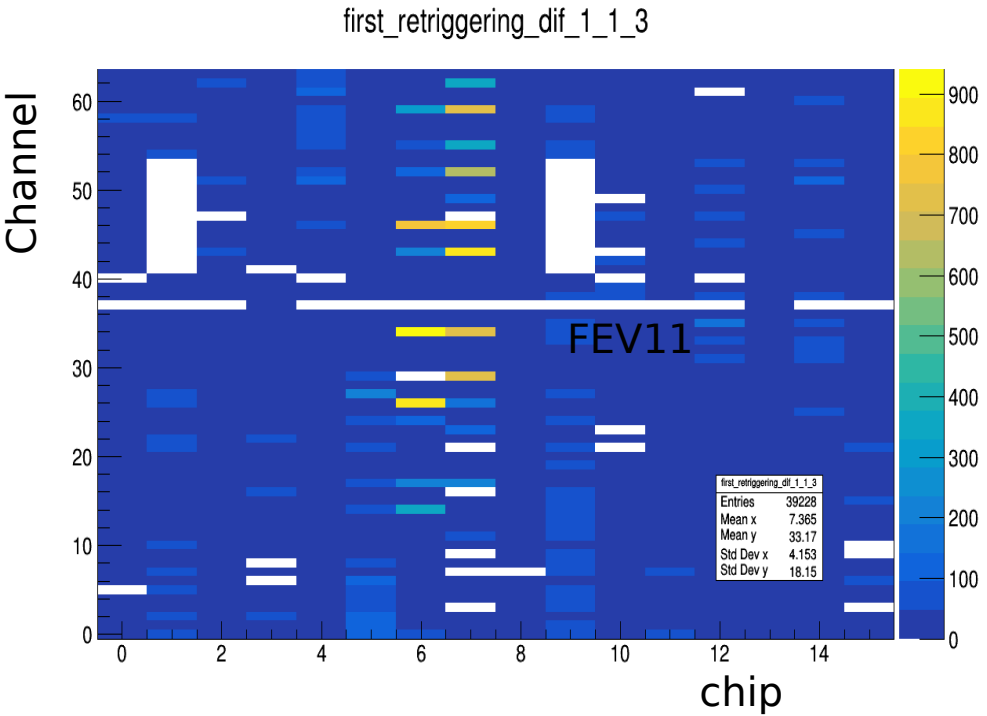
- Pedestals (TB24)

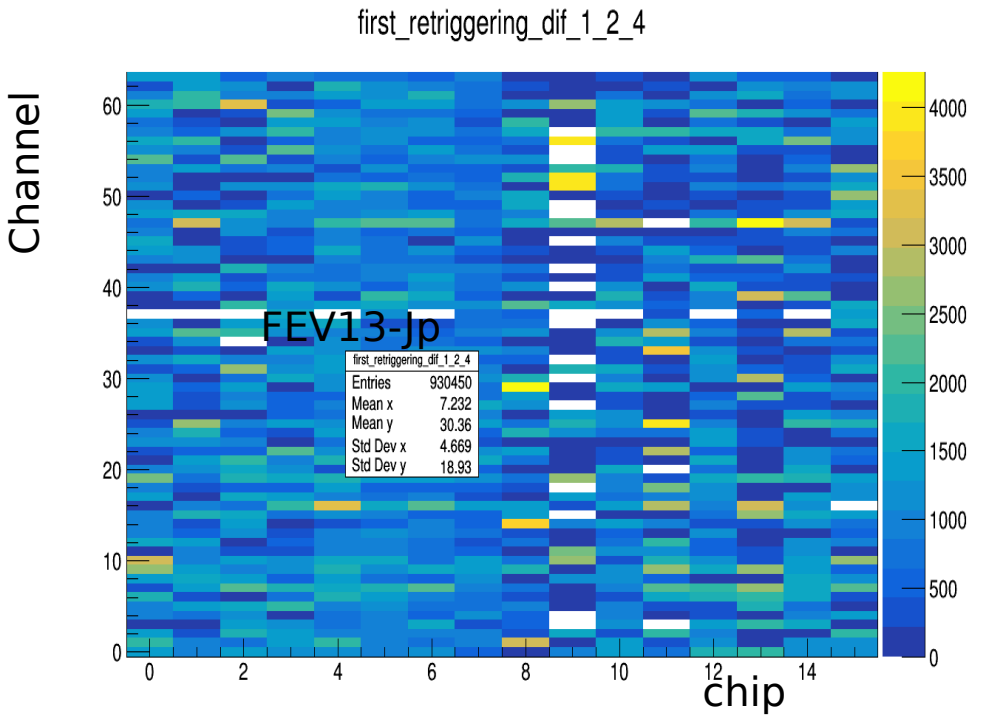




Retriggers

- 2-D map of the cells starting of the retriggers in a **MIP calibration** run. Very low thresholds?





Test beam info

- Wiki page: https://twiki.cern.ch/twiki/bin/view/CALICE/SiWDESY201807
  - Commissioning procedure https://twiki.cern.ch/twiki/bin/view/CALICE/CommissioningProcedure
- E-log
  - https://llrelog.in2p3.fr/calice/
- Analysis tools:
  - https://github.com/SiWECAL-TestBeam/SiWECAL-TB-analysis

    Branch: TB201807_long for the long slab
    Branch TB201807 for the short