SiW ECAL Technological Prototype
Test beam results

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ECAL Meeting 17/12/12 University of Tokyo

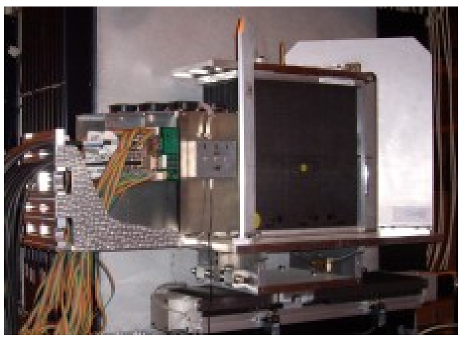
AGENCE NATIONALE DE LA RECHERCHE ANR
AIDA Advanced European Infrastructures for Detectors at Accelerators

SiW ECAL R&D

Physics Prototype

Proof of principle

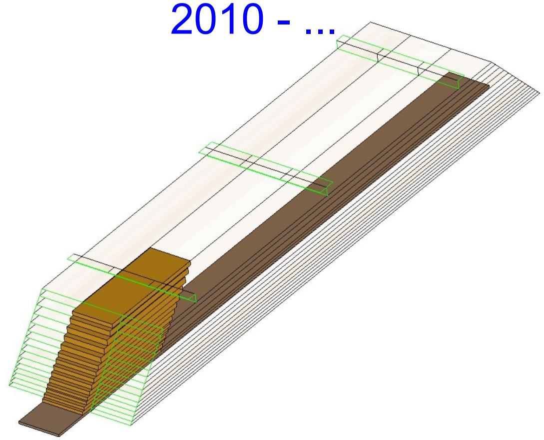
2003 - 2011



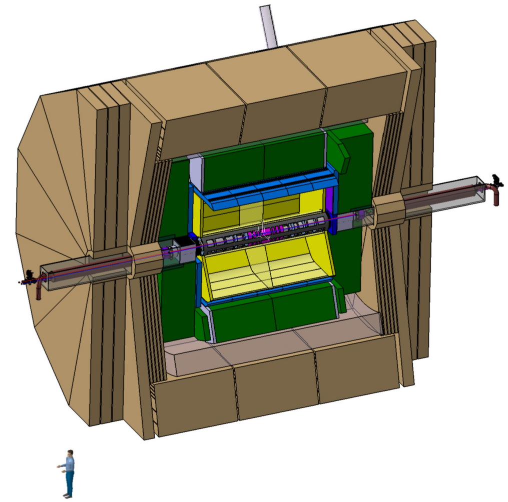
Technological Prototype

Engineering challenges

2010 - ...



LC detector



Number of channels : 9720

Weight : ~ 200 Kg

Number of channels : 45360

Weight : ~ 700 Kg

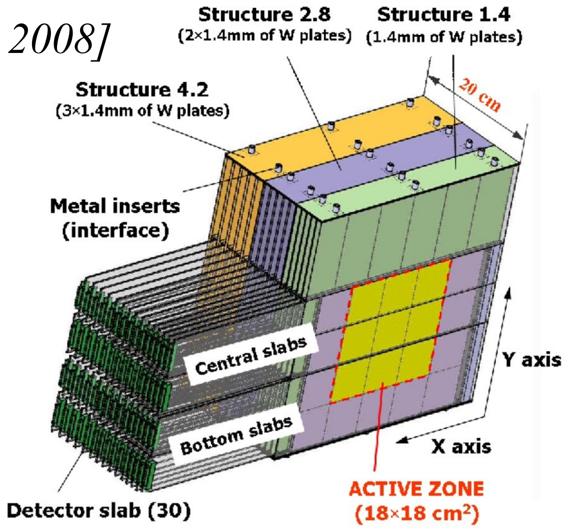
ECAL :

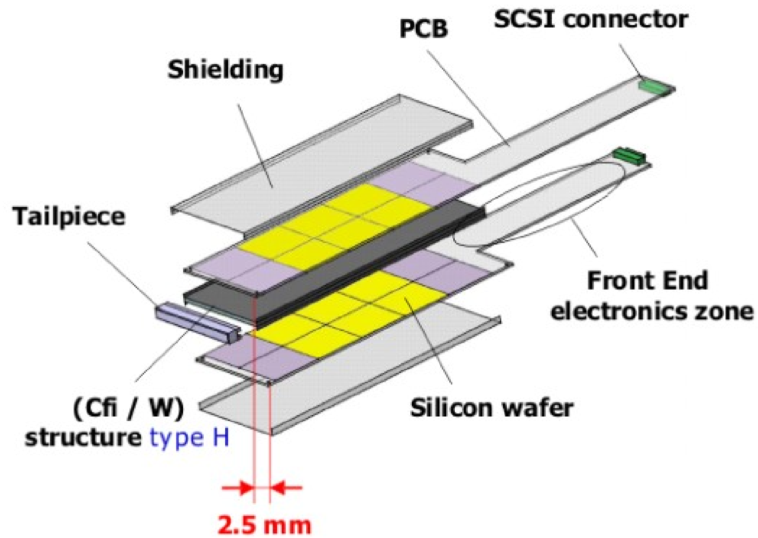
Channels : ~100 10^6

Total Weight : ~130 t

Physics prototype

[JINST 3, 2008]





Carbon-fibre mechanical structure

30 layers of tungsten: 24 X_0, 1 λ_I

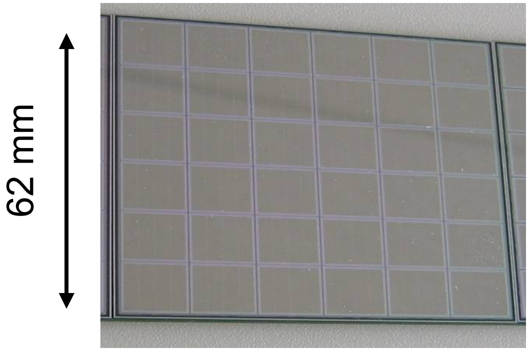
S/N ~ 8

$\sigma_E / E = 16.5/\sqrt{E(\mathrm{GeV})} + 1.1\ \%$

10k channels

6x6 PIN Diode Matrix – **1 x 1 cm²**

Résistivity: 5kΩcm - 80 (pairs e/hole)/μm



Thickness:

525μm

➡ Studied in various test beam facilities

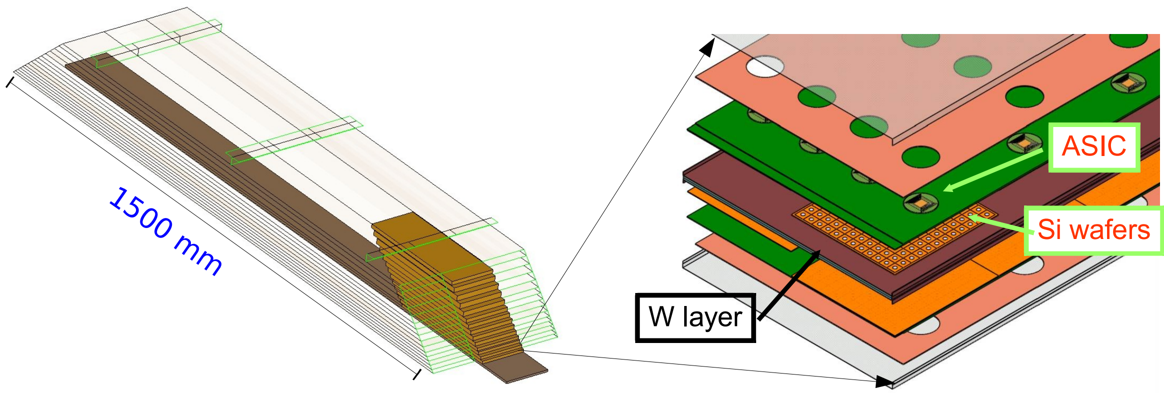
2006-2011: DESY, CERN, FNAL, e-, π, μ, p (1 → 180 GeV)

Technological prototype

Technological solutions for the final detector

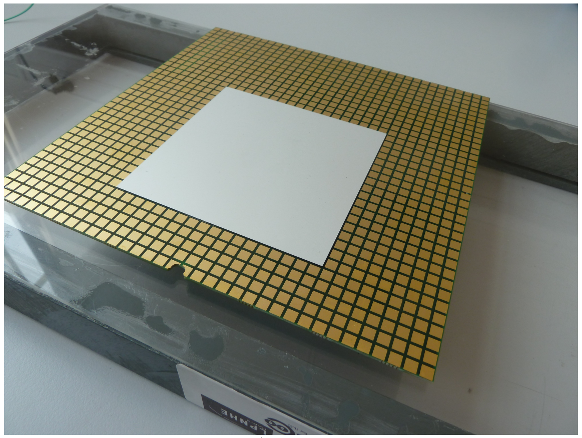
Construction start: 2010

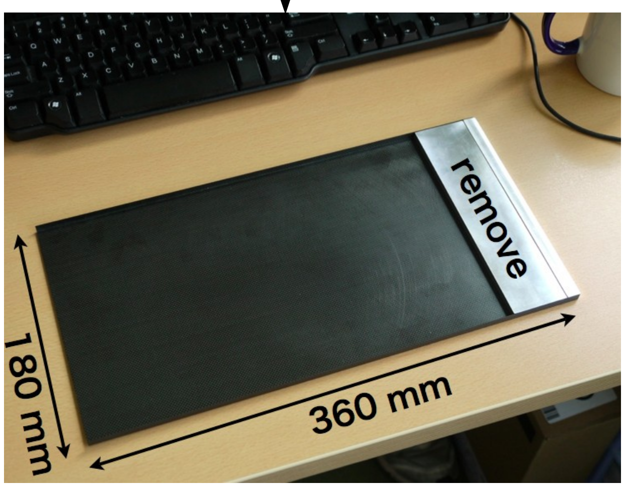
Test beam: 2012



- Realistic dimensions
- Integrated front end electronic
- Small power consumption (Power pulsed electronics)

Slab assembly I

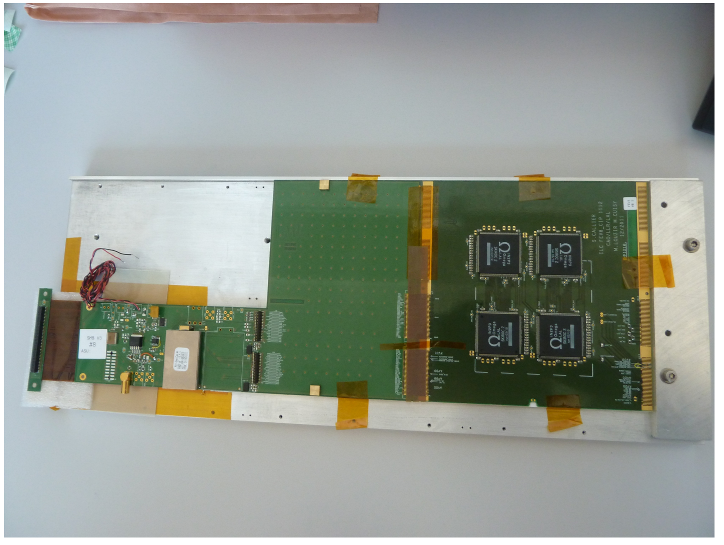


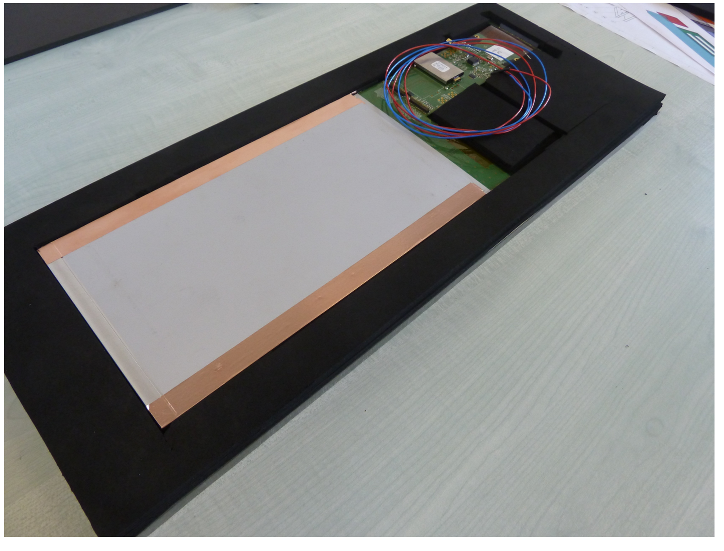


- Wafer glued onto PCB (FEV8_CIP)

- ASU is embedded into U structure

Slab assembly II





- Interconnection of ASU with adapter card

- ASU assembly in U structure

- Gluing of HV kapton

- All was realised with still relatively simple Tools sufficient for small production

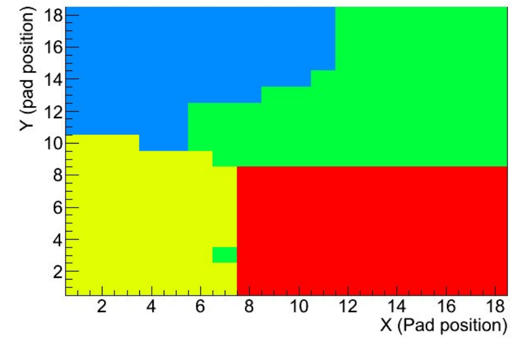
- NB: Procedure needs to be scrutinised for larger production

The road to the technological prototype

Intermediate step:

➡ First test in beam

➡ Benchmark to go further



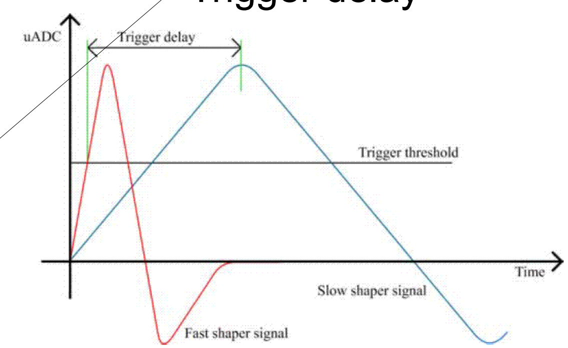
- U structure (single detection layer per slab)
- Si wafer:

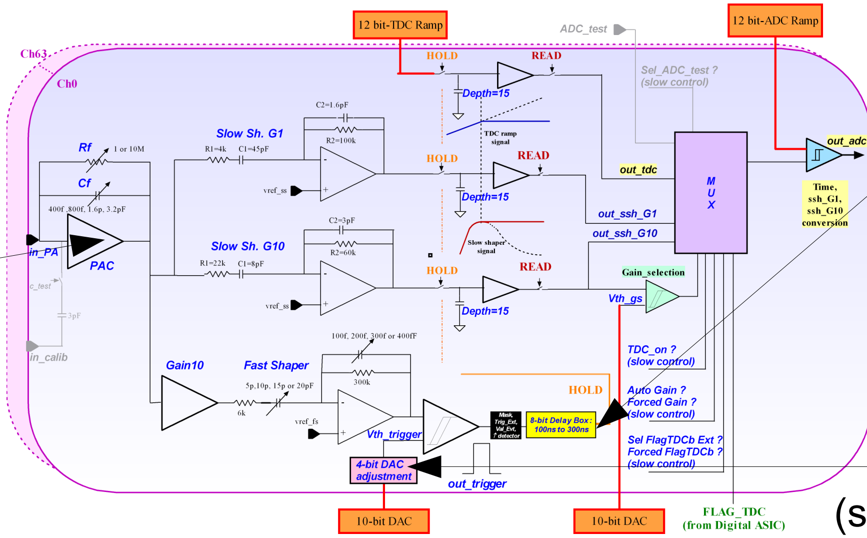
  9x9 cm^2 – Thickness = 320 μ m

  pixel size: 5x5 mm^2 :lateral granularity = 4 x better than physics prototype
- SKIROC2 ASICs
- 4 ASICs per slab (1⁄4 final design)

  4 SKIROCs x 64 channels = 256 channels/slab

Trigger delay





Preamplifier
(adjustable gain)

Internal trigger
(self-triggering capability)

First test beam with the technological prototype

DESY – April and July 2012

e- (1 - 5 GeV)

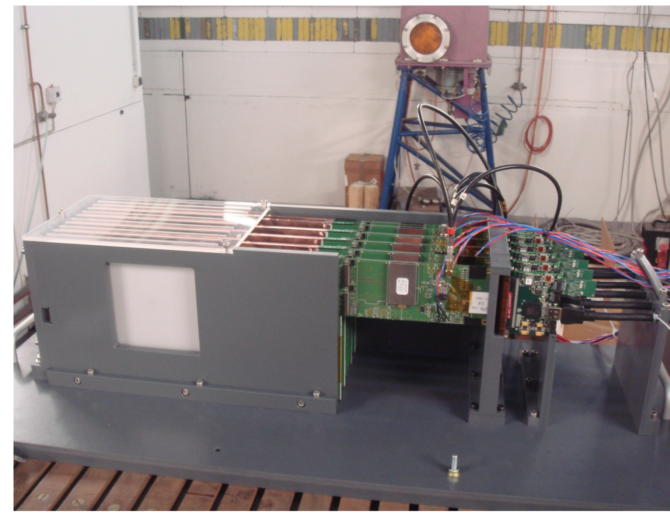
- 6 layers (FEV8)
  - Internal trigger

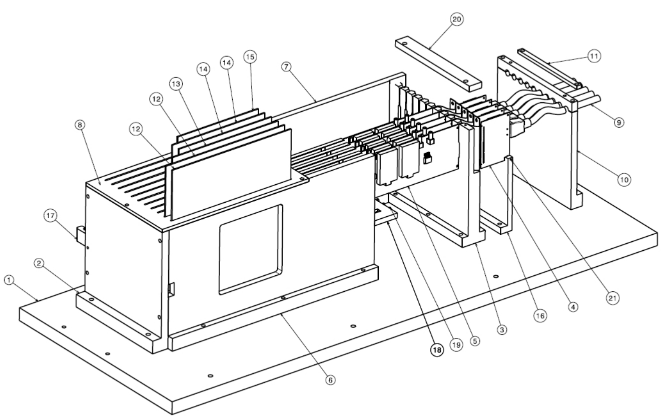
Total = 1536 channels

PreAmplifiers of noisy channels are switched off

total active channels = 1278

- PVC structure
  - position for tungsten plates (2.1 mm)





Goals:

- **Determine signal over noise ratio of the detector**
- Operate first layers of the technological prototype
- Establishment of calibration procedure for a large number of cells
- Homogeneity of response (x,y scan of detector)

Event filtering

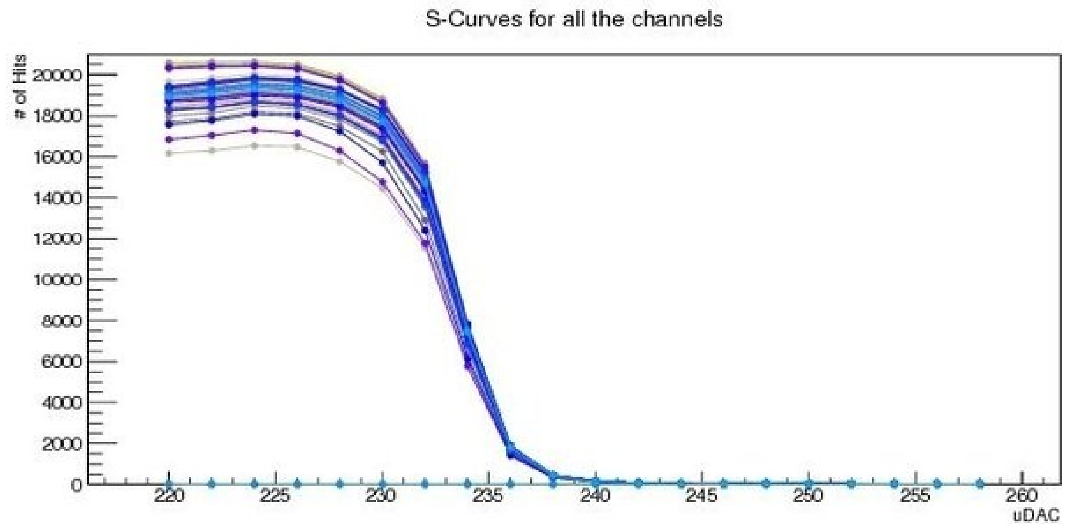
- **Ricochet / BCID+1 effect (without hit)**
  - Seen with SKIROC2 test bench and in TB
  - Understood, studied by Romain with test bench (cf Stéphane's talk, Monday)
  - Cut in TB analysis (cut event if delta BCID == 1)
- **BCID +1 +2, +3.... (with hits)**
  - With SKIROC2 test bench: seen for high injected charges (> 50 MIPs)
  - In TB: seen with low injected charges (<10 MIPs), seems to be related to plane events
  - Cut in TB analysis (see planes events)
- **Plane events**
  - Not seen with SKIROC2 test bench → PCB effect?
  - Seems to be correlated with an unstable acquisition (bad pedestal in whole acquisition, BCID +1 +2 +3.....)
  - Cut in TB analysis:
    - MIP data: Number of hits > 10 in one chip AND delta BCID <= 5
    - Showers: Number of hits > 40 in one chip AND delta BCID <= 5 (this cut has not been optimized)
- **Isolated hits**
  - Reconstruction needed to see this effect (not yet well studied: noise, cosmic, related to plane events?)
  - Cut in TB analysis:
    - No cut in layer independent analysis (energy calibration, S/N measurement, pedestal studies....)
    - Cut if we need event reconstruction (MIP detection efficiencies, showers...):
      - we ask at least 3 planes with hits in the same event (after reconstruction)

Calibration of ASICs

Establishment of calibration procedure for a larger number of cells

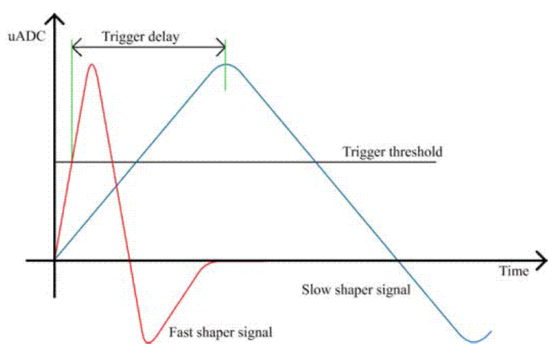
Trigger threshold

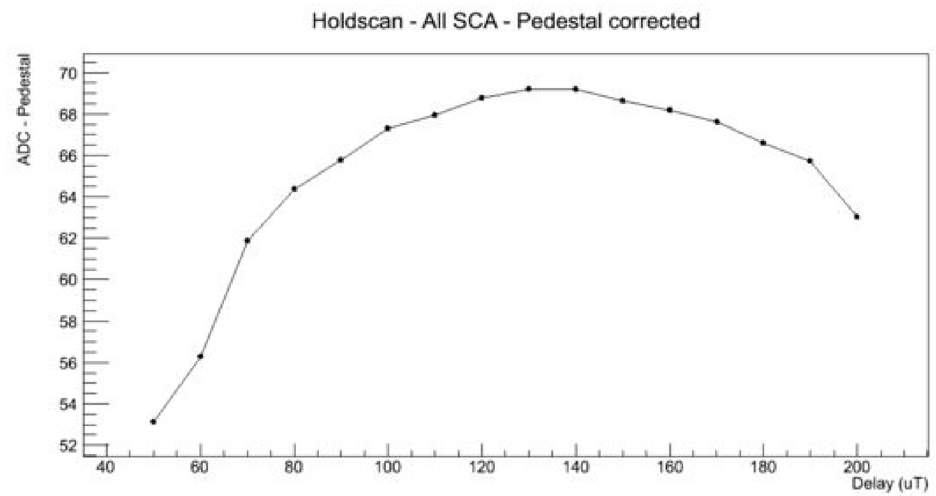
- depends on the gain



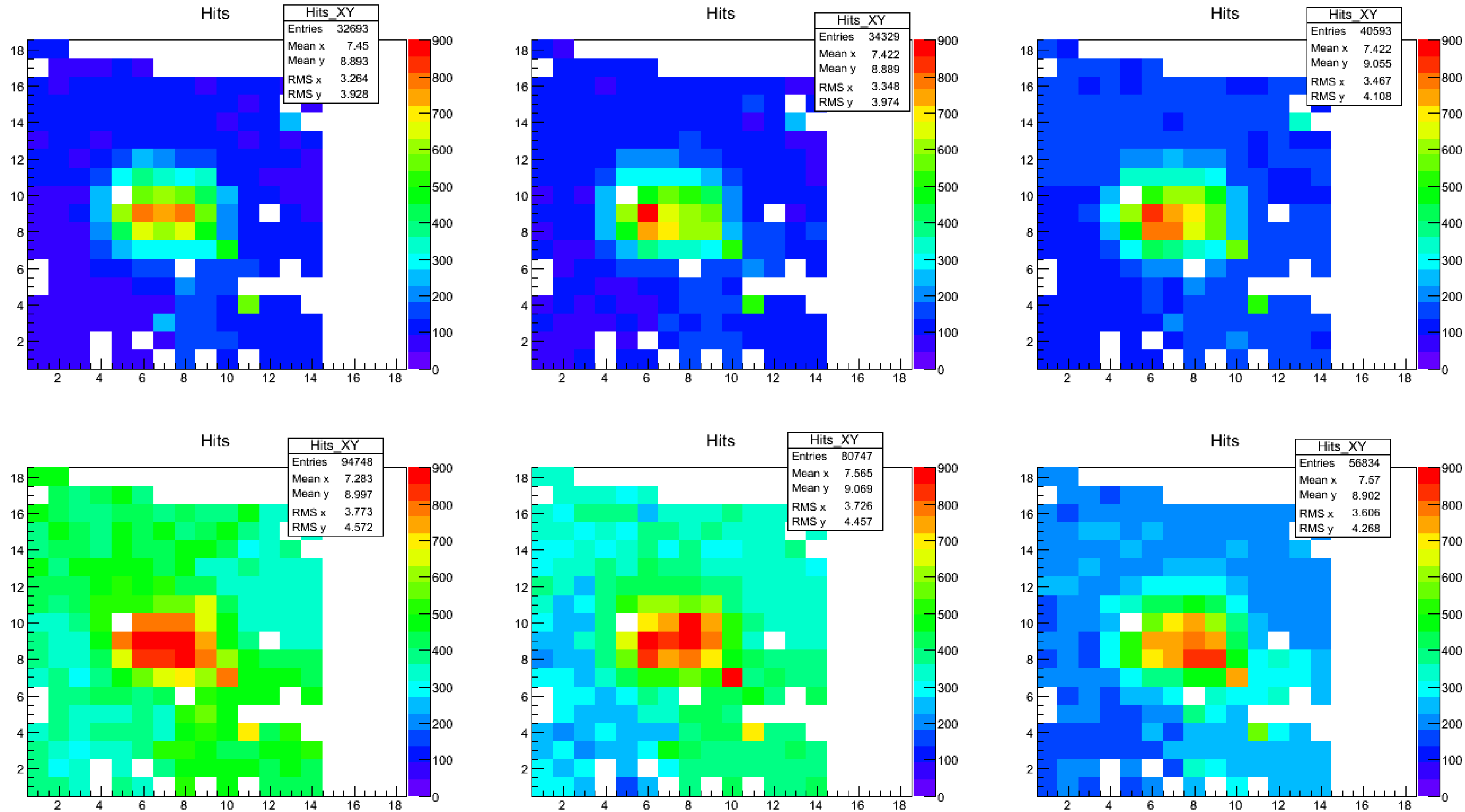
Trigger delay

- depends on the trigger threshold





Beam spot


Hits
Hits_XY
Entries 32693
Mean x 7.45
Mean y 8.893
RMS x 3.264
RMS y 3.928
Hits
Hits_XY
Entries 34329
Mean x 7.422
Mean y 8.889
RMS x 3.348
RMS y 3.974
Hits
Hits_XY
Entries 40593
Mean x 7.422
Mean y 9.055
RMS x 3.467
RMS y 4.108
Hits
Hits_XY
Entries 94748
Mean x 7.283
Mean y 8.997
RMS x 3.773
RMS y 4.572
Hits
Hits_XY
Entries 80747
Mean x 7.565
Mean y 9.069
RMS x 3.726
RMS y 4.457
Hits
Hits_XY
Entries 56834
Mean x 7.57
Mean y 8.902
RMS x 3.606
RMS y 4.268

Detection efficiency

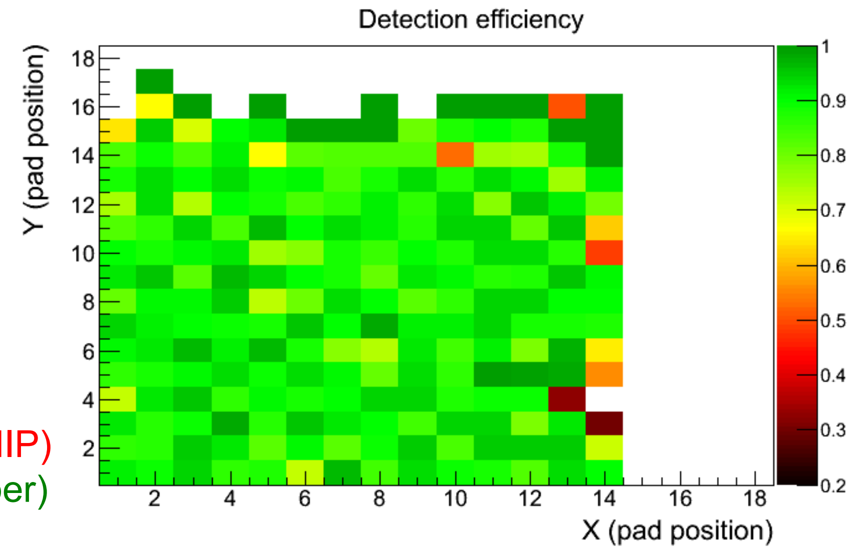
Data: 3GeV – No W – XY scan
Total number of events: $2,3.10^6$
Track selection:

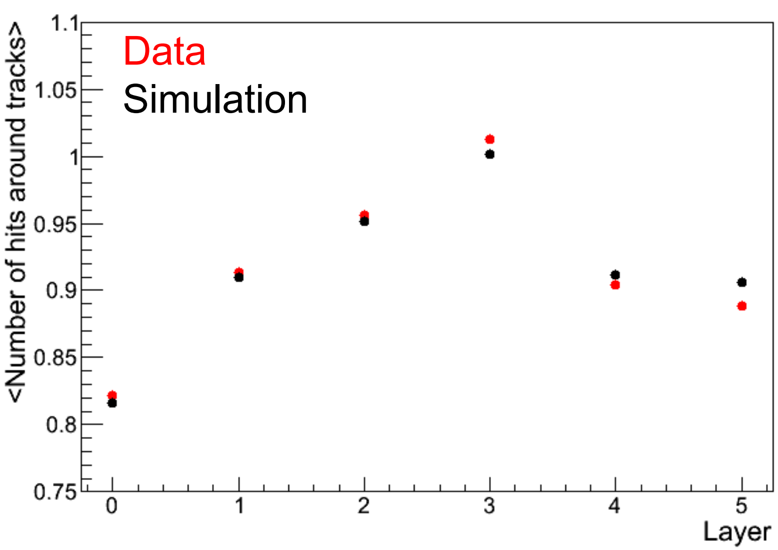
- At least 3 layers with hits
- Linear fit of the e- track
- Nhits<10

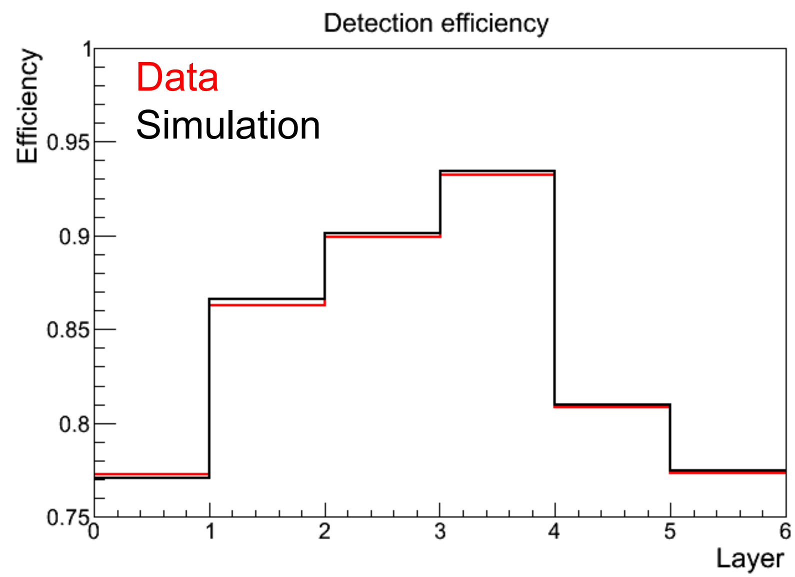
Inefficiencies due to:

- Switched off channels
- Too high trigger thresholds (80%-95% of the MIP)

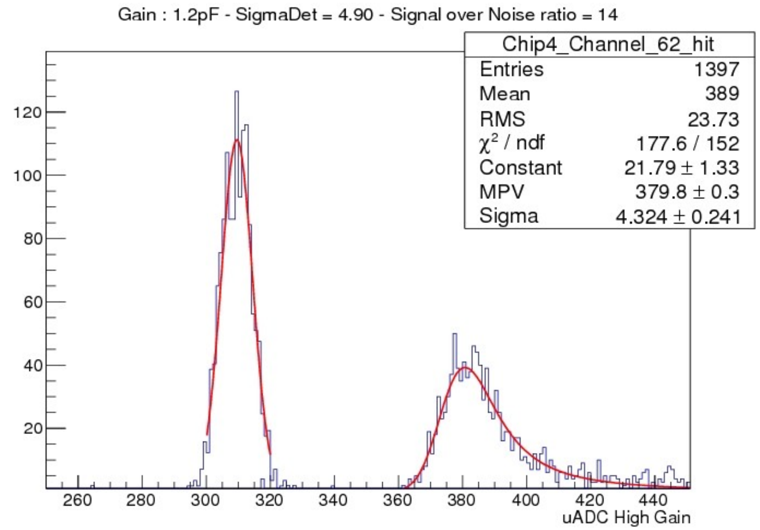
➡ Should be improved with the next test beam (December)

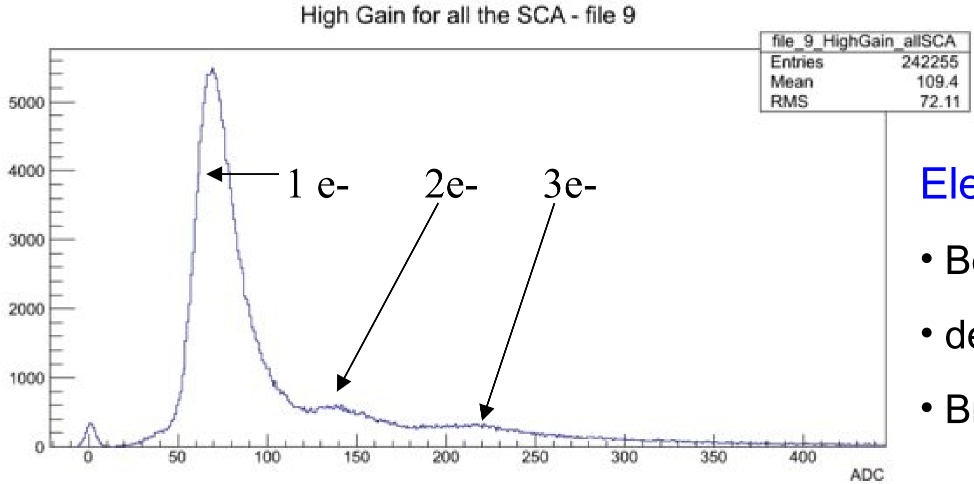






Energy measurement





Electron sources:

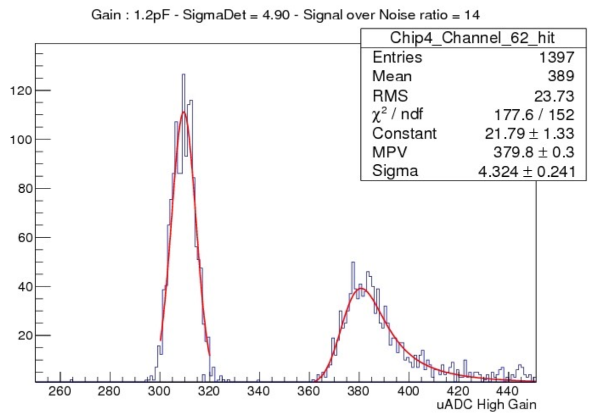
- Beam
- delta rays
- Bremsstrahlung + gamma conversion (2e-)

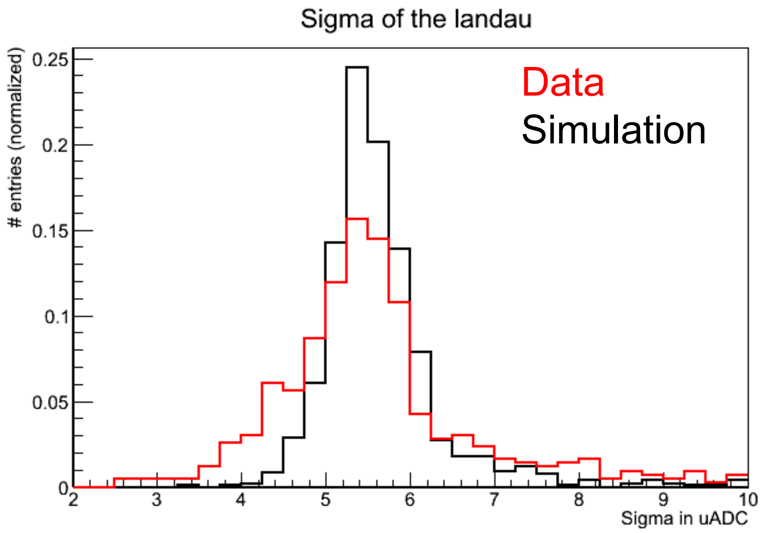
  + Compton

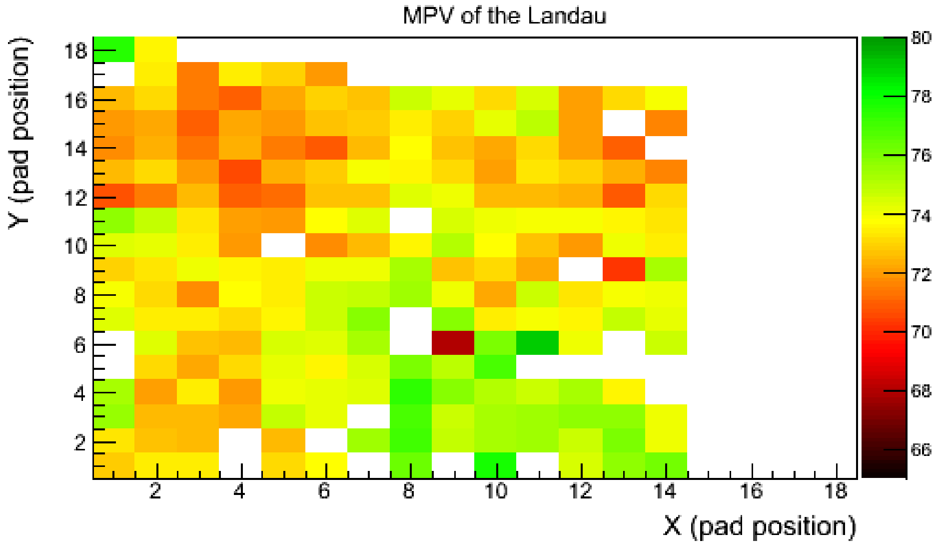
Energy calibration

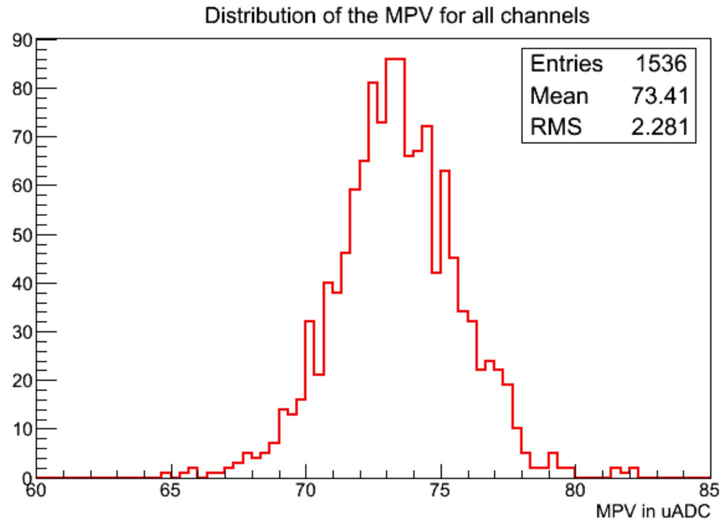
Establishment of calibration procedure for a larger number of cells

Homogeneity of response (x,y scan of detector)

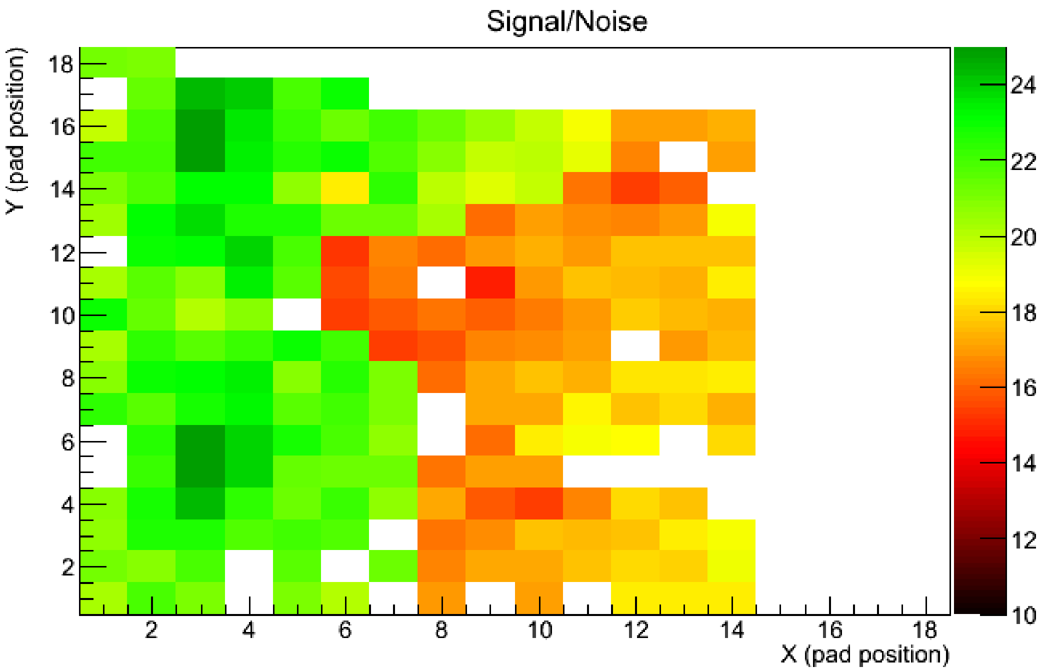






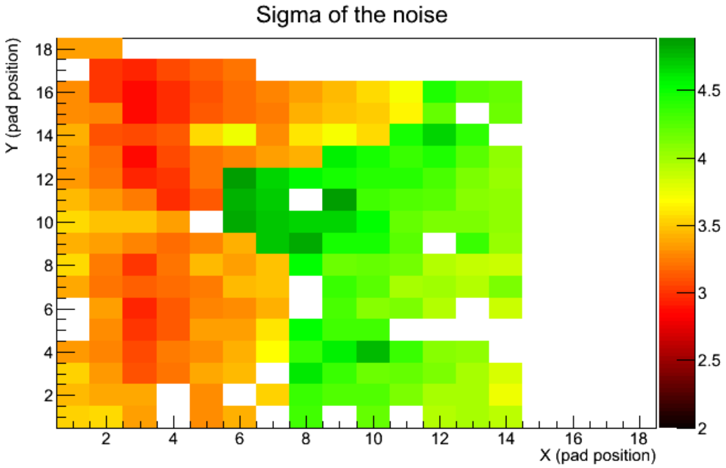


Signal over noise ratio

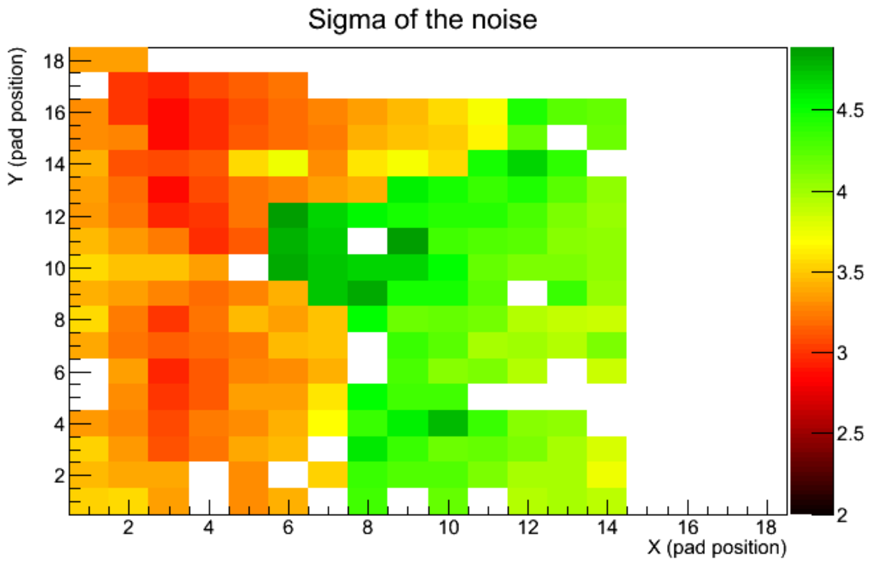


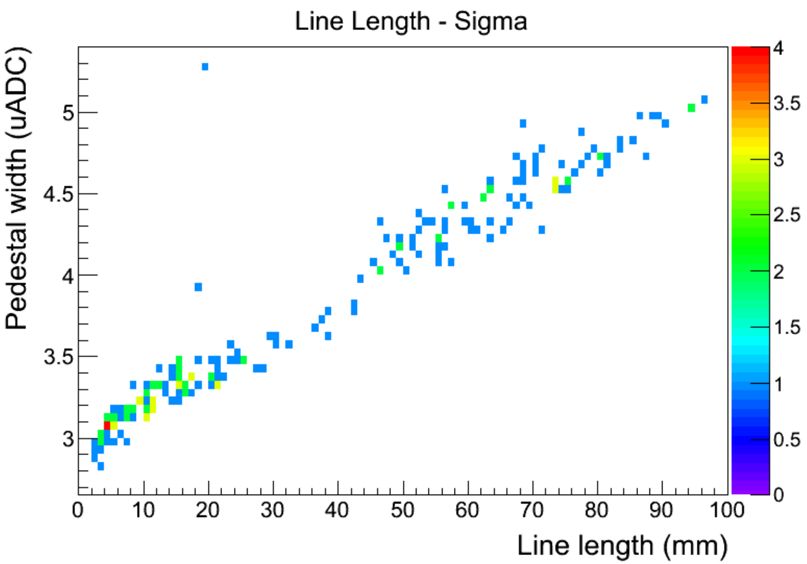
R&D target is 10:1

S/N > 10
(for all gains available with SKIROC2)



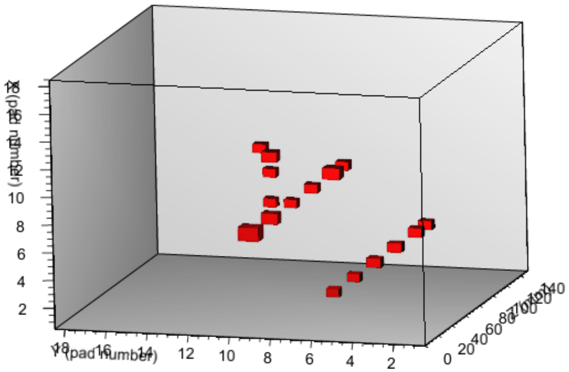
Noise width


Sigma of the noise
Y (pad position)
X (pad position)

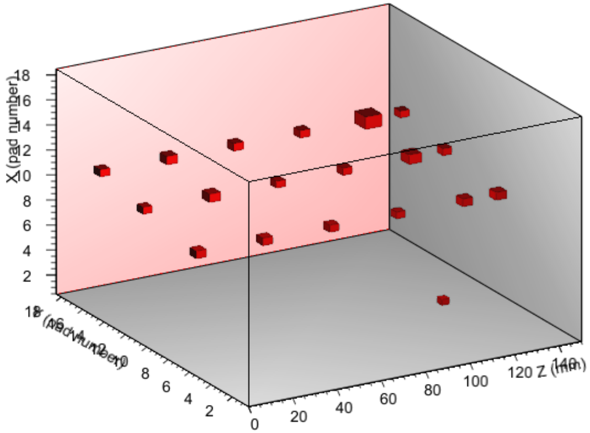

Line Length - Sigma
Pedestal width (uADC)
Line length (mm)

Event display

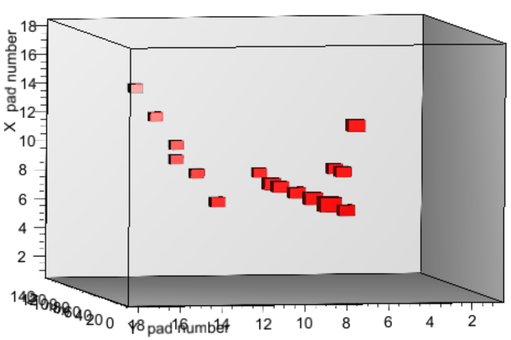
2 e- (3 GeV, no tungsten)



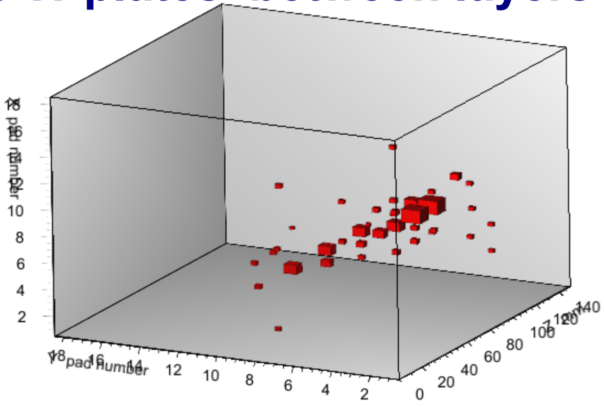
3 e- (3 GeV, no tungsten)



1 cosmic + 1 e- (3 GeV, no tungsten)



1 e- (5 GeV)
5 W plates between layers



What's next

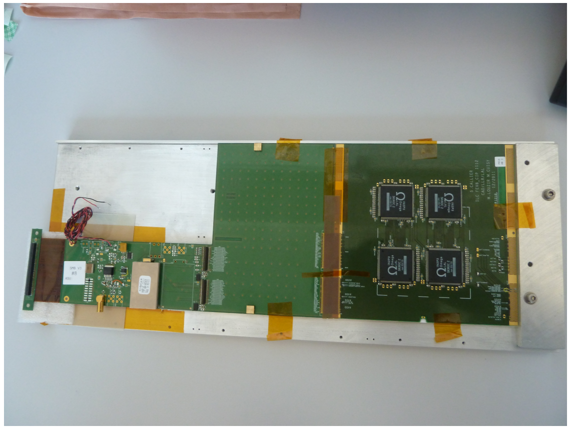
- Beam tests in 2012 were extremely useful for 'team formation' and to obtain experience with new hardware
- Need to understand shortcomings of e.g. SKIROC2 to go to SKIROC3
  - SKIROC3 not before beginning of 2014
- Scrutinising of slab production
  - some wafers got broken during production
  - Revision of tools
  - Make use of small production to establish procedure/specs for mass production (where possible)
- Address power pulsing
  - Hardware understood well enough to address this important step (need for proof was highlighted many times during PAC meeting)
  - Have already beam test slots at DESY → DESY Planning 2013

DESY Testbeam Schedule 2013 - version of December 14 2012

	Week		TB21		TB22		TB24/1		TB24
			DATURA (telescope)	none	Telescope	CAL	Telescope PCMAG	PCMAG	none
	2		---	---	---	---	---	---	---
14-Jan	3		---	ITER	Tele setup				
	4		X0		---	CALICE AHCAL			
	5		CMS Pix-irrad	---	---	CALICE AHCAL	---	TPC MMG	ECAL
2-Feb	6		CMS Pix-fwd	---	ATLASPix	---	---	TPC MMG	---
	7		CLICpix	---	---	SiPM	LorAngle	---	---
	8		---	SiW ECAL	---	SiPM	LorAngle	---	---
	9		---	Sc ECAL	EUTelescope	---	---	DESY TPC	---
4-Mar	10								
	11		ALICE ITS	---	MuPix 2	---	---	DESY TPC	---
	12		CMS Pix-irrad	---	APIX PPS	---	---	DESY TPC	---
	13		CMS Pix-KA	---	APIX PPS	---	---	LCTPC Time	---
1-Apr	14		---	GRPC-SDHCAL	APIX IBL	---	---	LCTPC Time	---
	15		---	GRPC-SDHCAL	APIX DBM	---			
	16		X0		ILCPOL				
	17		---	SiW ECAL	ILCPOL		SBS GEM		
	18		---	SC ECAL	---	RD50	SBS GEM		
6-May	19		DEPFET	---	---	RD50	LorAngle		
	20		FE-I4		---	CAL MMG	---	GridPix	---
	21		CMS Pix-ro		---	CAL MMG	---	---	Belle 2 PID
	22		X0			CALICE AHCAL			
3-Jun	23		CLICpix	---	---	CALICE AHCAL			
	24		CLICpix	---	MuPix 3	CALICE AHCAL			
	25		ALICE ITS	---	APIX 3D		---	---	PICSEL
	26		CMS Trk II	---	DIA-SiGe	---	---	---	PICSEL

First period looks ok, 2nd period too short after first one (to my taste)
Arrangements with other CALICE groups possible

Elements to be tested in 2013



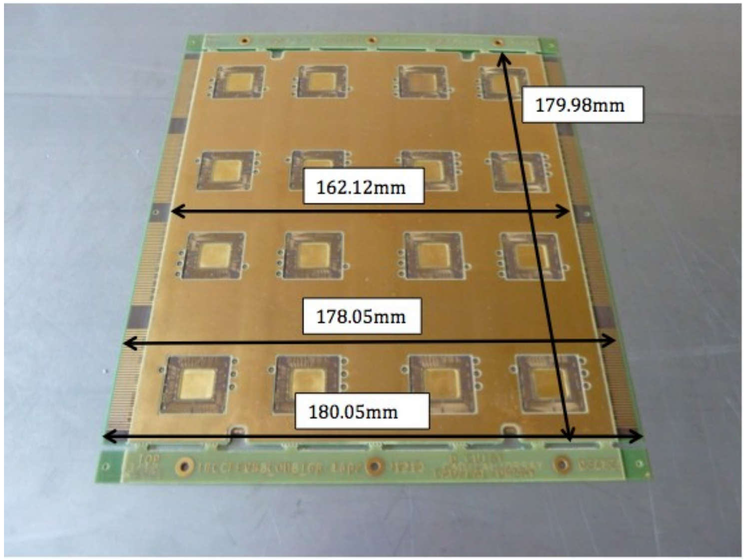
Short slab prepared for power pulsing
i.e. no decoupling capacitances
Preparations ongoing

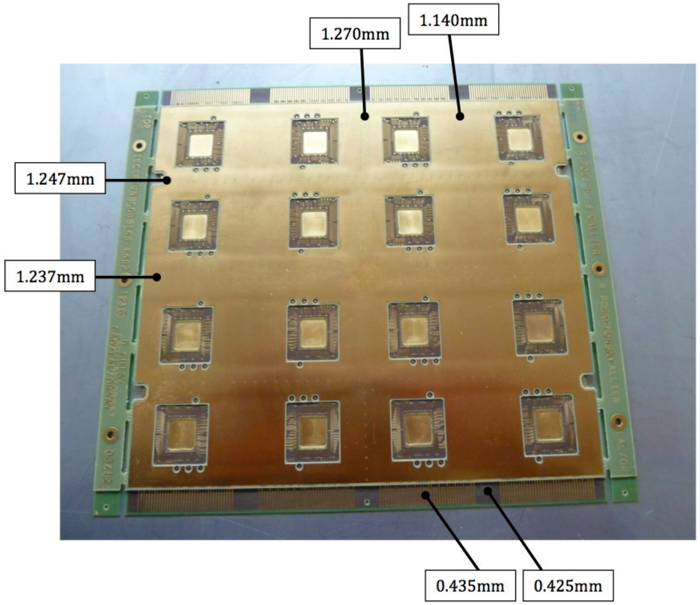
w/o picture

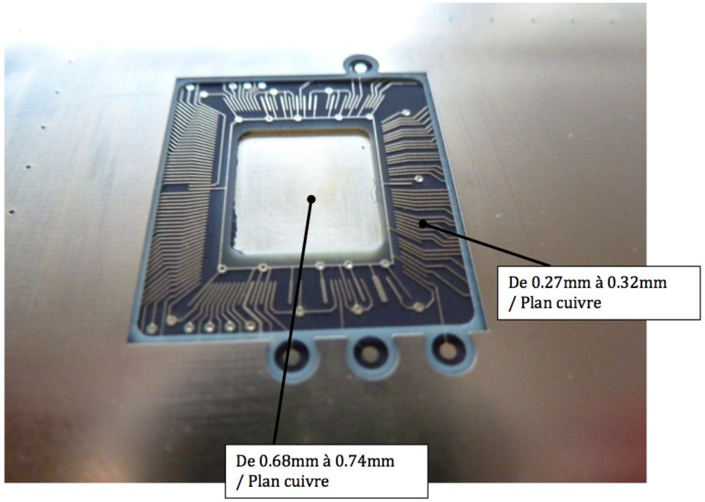
Behaviour of long slabs in magnetic fields
Setup ready to measure currents across
Interconnections
Magnet of 2 T available at DESY
(outside beam area)

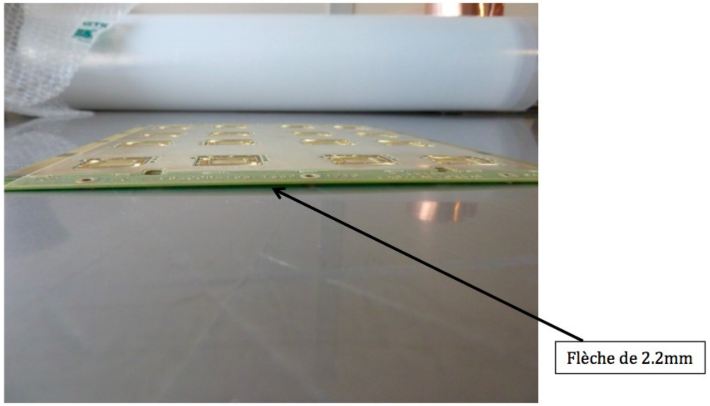
Later 2013
Tests with 4 wafers for ASU and
Test of long slab

FEV_COB – Engineering highlight









Conclusion

Successful beam test

Excellent stability of the DAQ
Stable operation of the wafers and the electronic

Establishment of calibration procedure for a larger number of cells
Homogeneity of response studies

- Energy calibration
- Detection efficiency

Determination of the signal over noise ratio: S/N > 10

Hardware effects revealed.
Data and detector about to be understood.

Test beam in early 2013 ➡ Power pulsing

Thanks

Special thanks to our experts:

Frédéric, Mickael, Patrick, Rémi and Stéphane

And to everyone who took part in the preparation of the test beam:

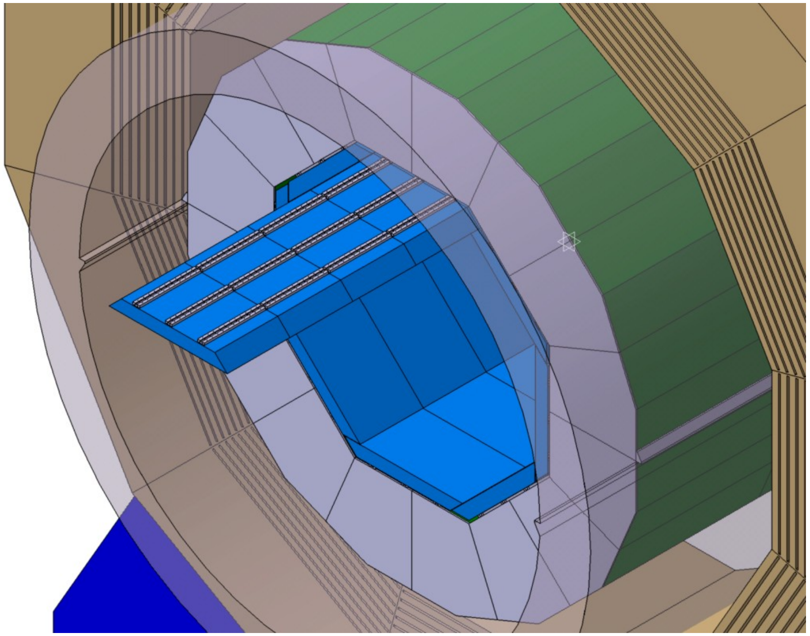
- LLR, LAL+OMEGA, LPNHE
- Kyushu University, Tokyo University, Nippon Dental University
- SKKU

Back up

SiW ECAL for a future LC

SiW ECAL is one of the prototypes for future LC detectors

→ Optimized for Particle Flow Algorithm:



The SiW ECAL in the ILD Detector

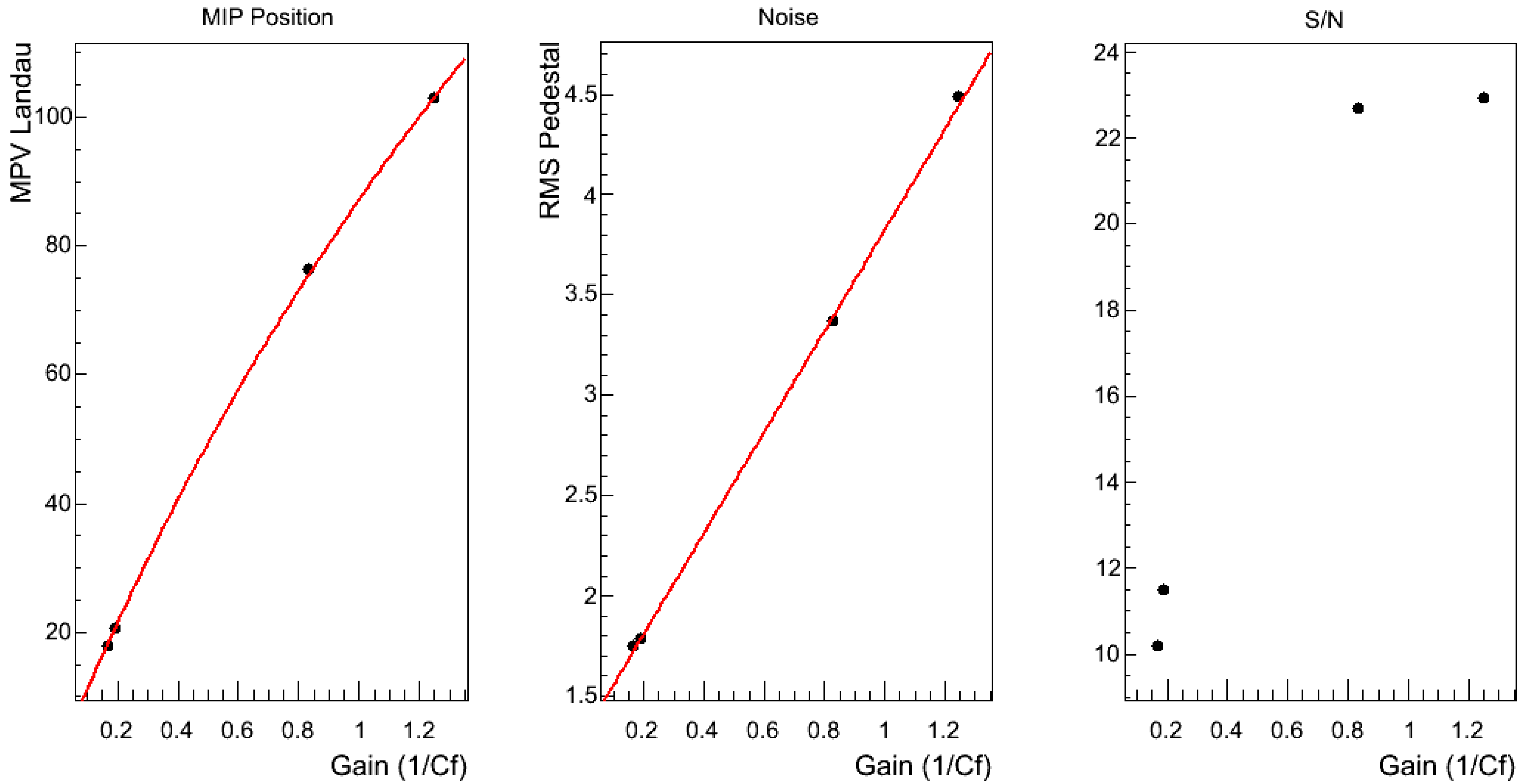
Basic Requirements:

- Extreme high granularity
- Compact and hermetic

Basic Choices:

- Tungsten as absorber material
  - X_0=3.5mm, R_M=9mm, λ_I=96mm
  - Narrow showers
  - Assures compact design
- Silicon as active material
  - Support compact design
  - Allows for pixelisation
  - Large signal/noise ratio

Signal sur noise – 'bonne' voie



Signal sur noise – 'moins bonne' voie