# SiW ECAL Technological Prototype
# Test beam results

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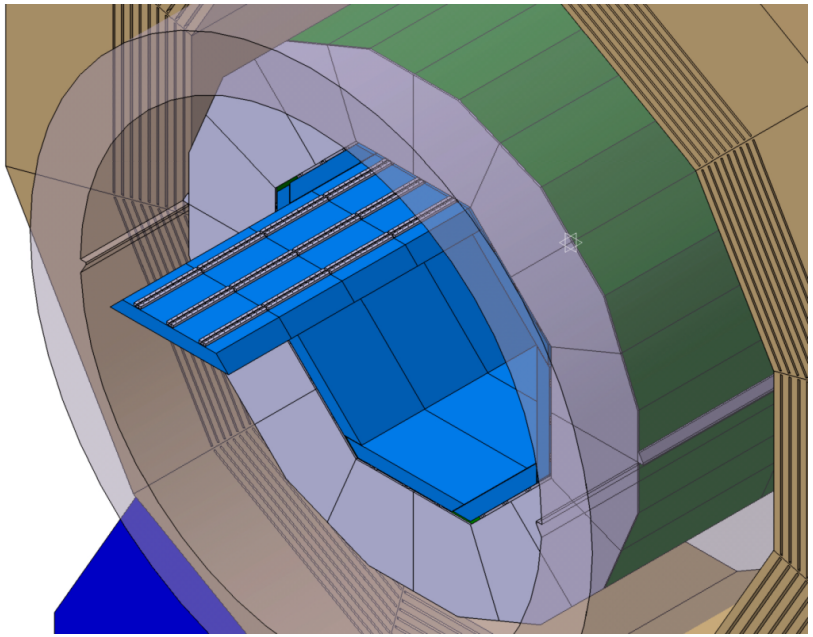
on behalf of the CALICE collaboration

AIDA
Advanced European Infrastructures for Detectors at Accelerators

# 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, $\lambda_I$=96mm
  - Narrow showers
  - Assures compact design

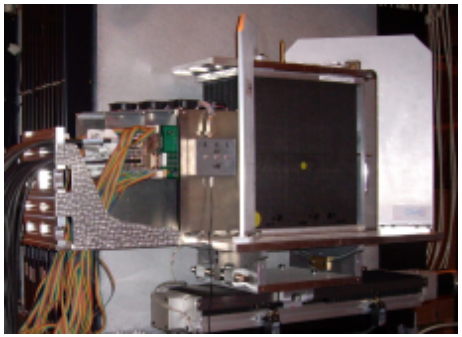
- Silicon as active material
  - Support compact design
  - Allows for pixelisation
  - Large signal/noise ratio

# SiW ECAL R&D

## Physics Prototype

Proof of principle

2003 - 2011



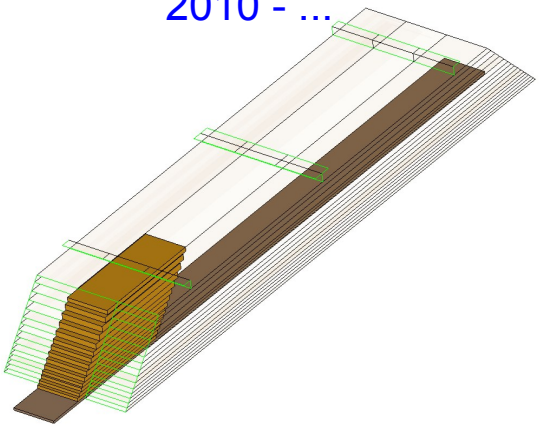
**Number of channels : 9720**

**Weight : ~ 200 Kg**

## Technological Prototype

Engineering challenges

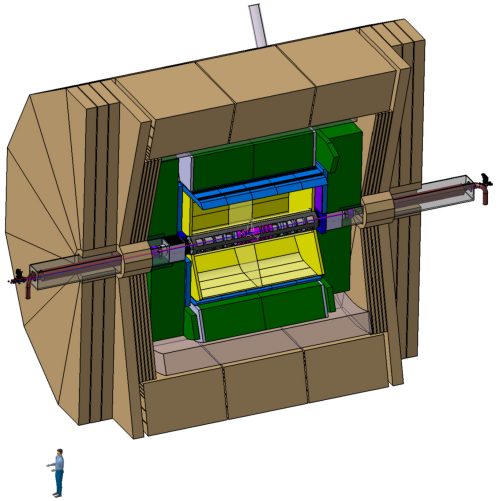
2010 - ...



**Number of channels : 45360**

**Weight : ~ 700 Kg**

## LC detector



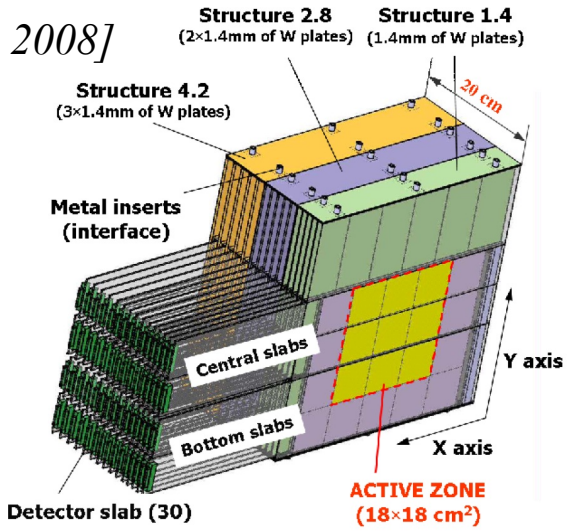
**ECAL :**

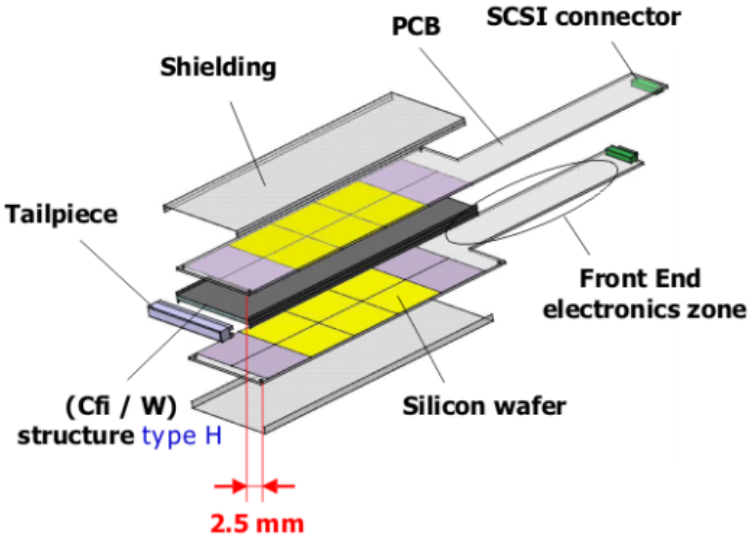
**Channels : ~100 $10^6$**

**Total Weight : ~130 t**

# Physics prototype

*[JINST 3, 2008]*




Carbon-fibre mechanical structure

30 layers of tungsten: 24 $X_0$, 1 $\lambda_I$

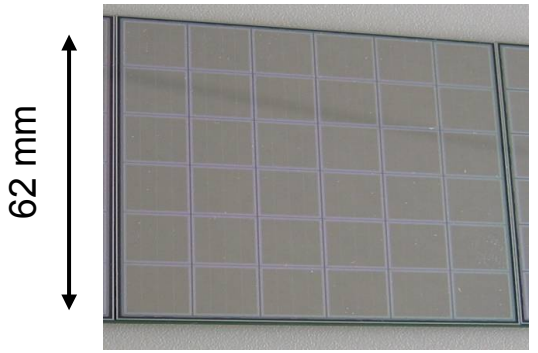
S/N ~ 8

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

10k channels

6x6 PIN Diode Matrice – **1 x 1 cm²**

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




Thickness:

525μm

➡ Studied in various test beam facilities

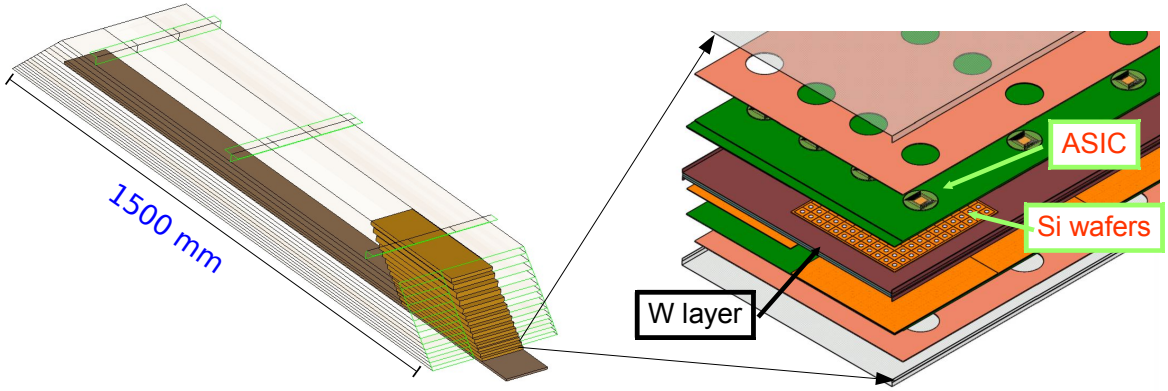
2006-2011: DESY, CERN, FNAL, e-, π, μ, p (1 → 180 GeV)

# Technological prototype

## Technological solutions for the final detector

Construction start: 2010

Test beam: 2012



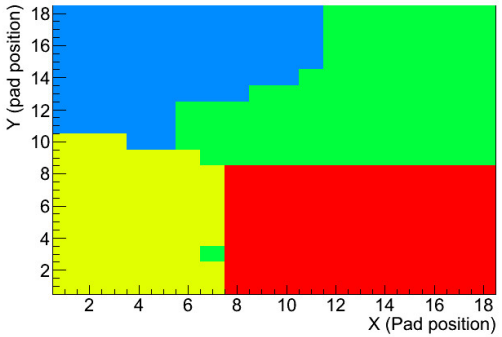

- Realistic dimensions
- Integrated front end electronic
- Small power consumption (Power pulsed electronics)

# The road to the technological prototype

Intermediate step: (See Rémi Cornat's Talk)

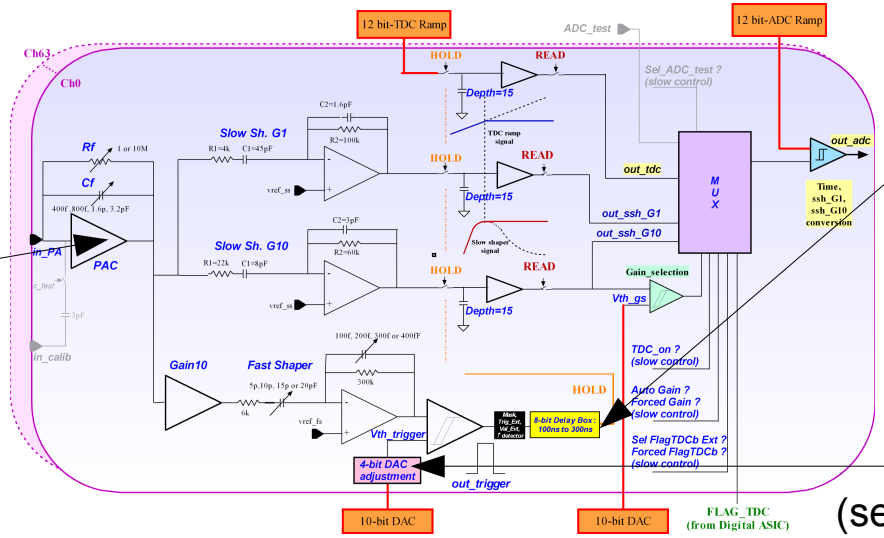
➡ First test in beam

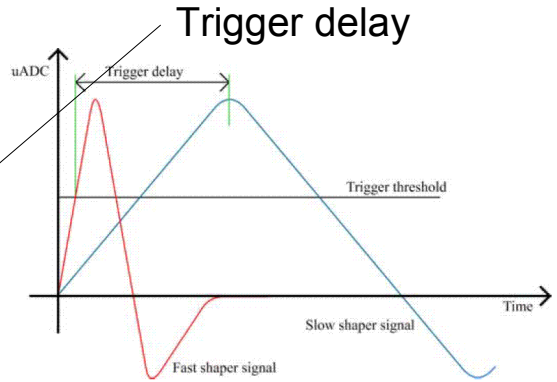
➡ Benchmark to go further




- U structure (single detection layer per slab)
- Si wafer:
  - 9x9 $cm^2$ – Thickness = 320 µm
  - **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

Preamplifier
(adjustable gain)




Internal trigger
(self-triggering capability)

# First test beam with the technological prototype

**DESY – April and July 2012**

e- (1 - 5 GeV)

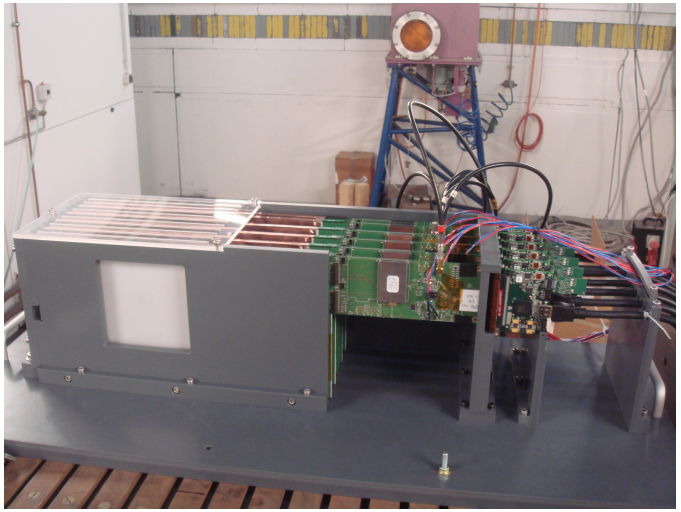
- 6 layers (FEV8)
  - Internal trigger

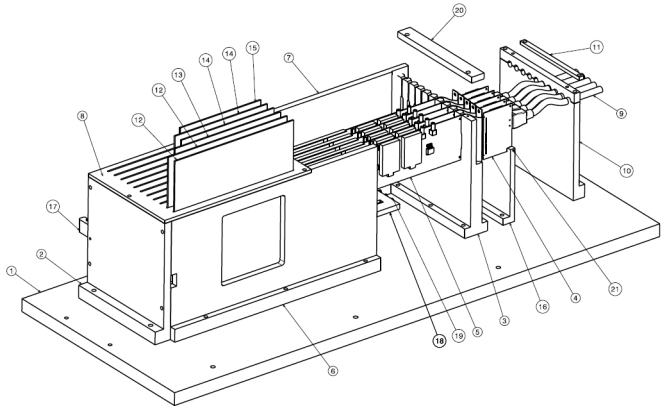
**Total = 1536 channels**

PreAmplifiers of noisy channels are switched off

**total active channels = 1278**

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





**Goals:**

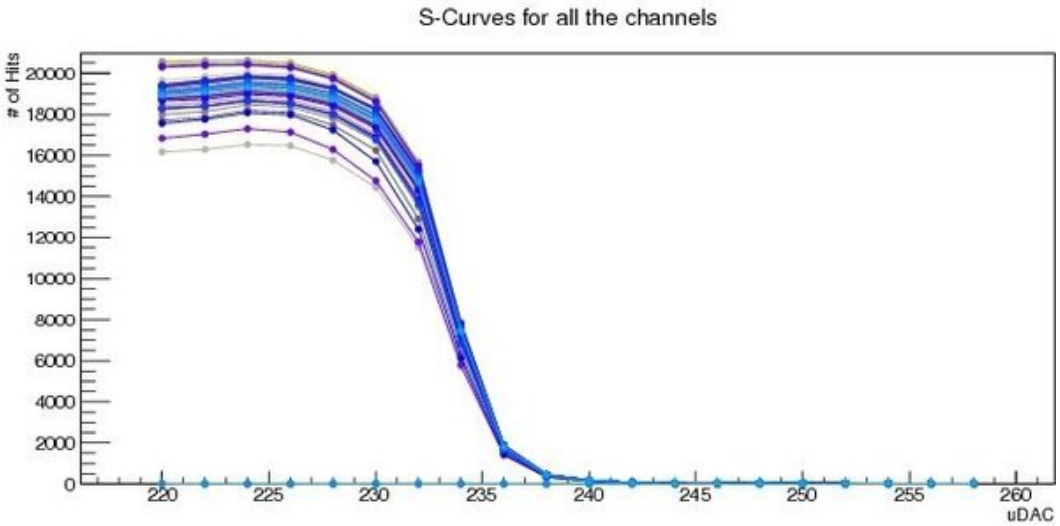
- **Determine signal over noise ratio of the detector**
- Operate first layers of the technological prototype
- Establishment of calibration procedure for a large number of cells
- Homogeneity of response (x,y scan of detector)

# Calibration of ASICs

Establishment of calibration procedure for a larger number of cells

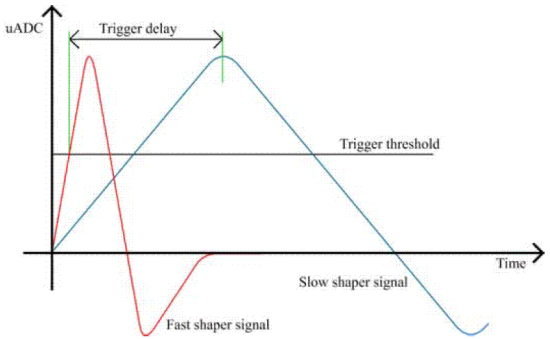
## Trigger threshold

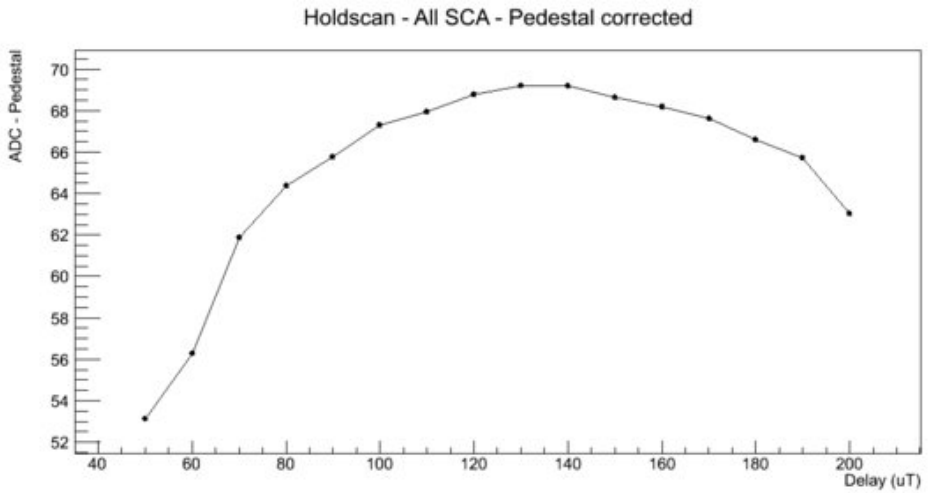
- depends on the gain



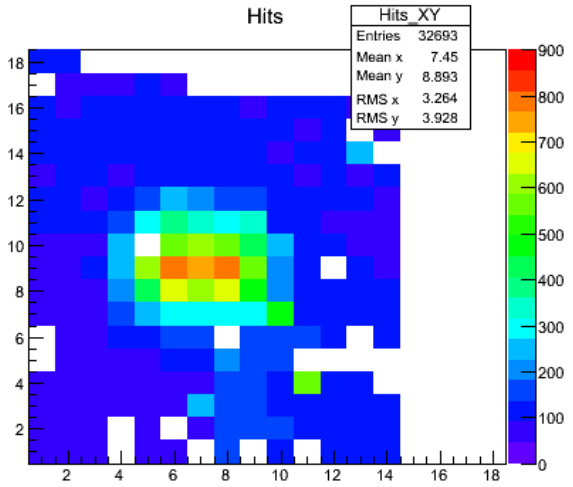

## Trigger delay

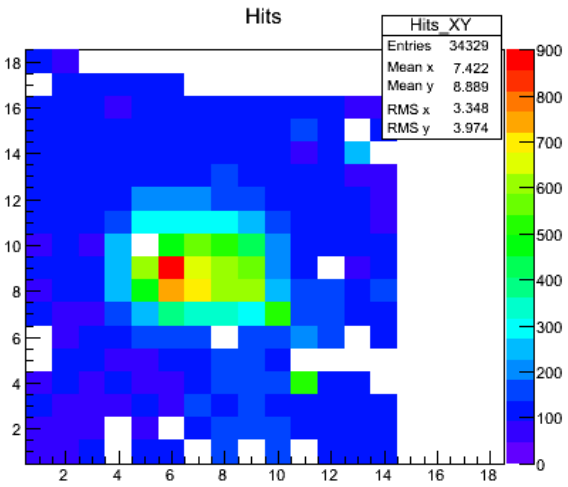
- depends on the trigger threshold

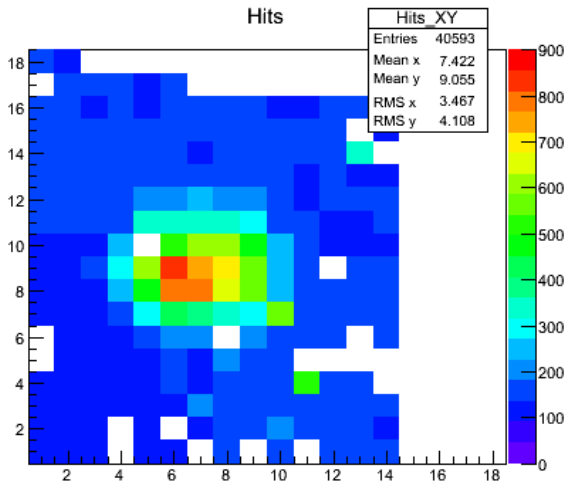


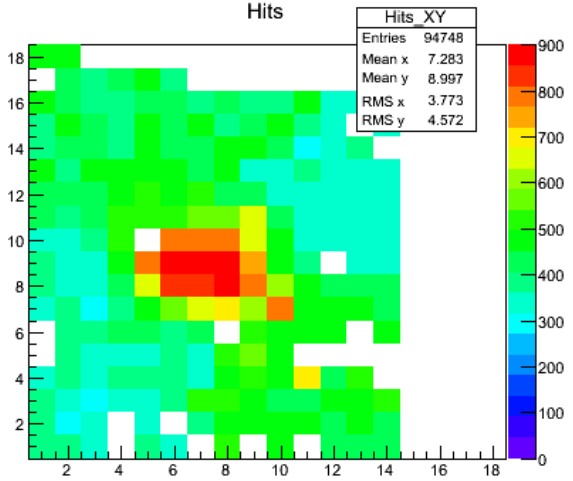



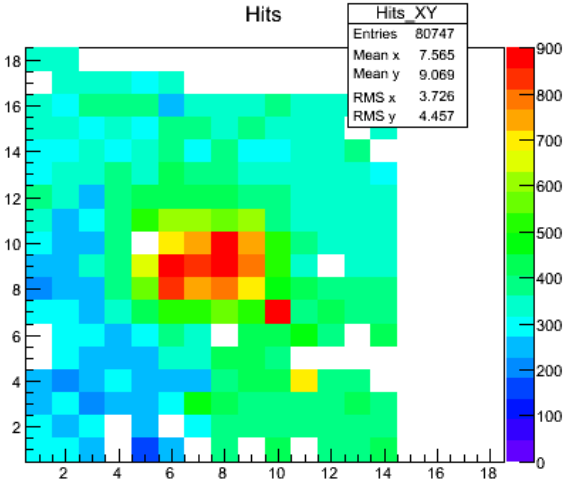
# Beam spot

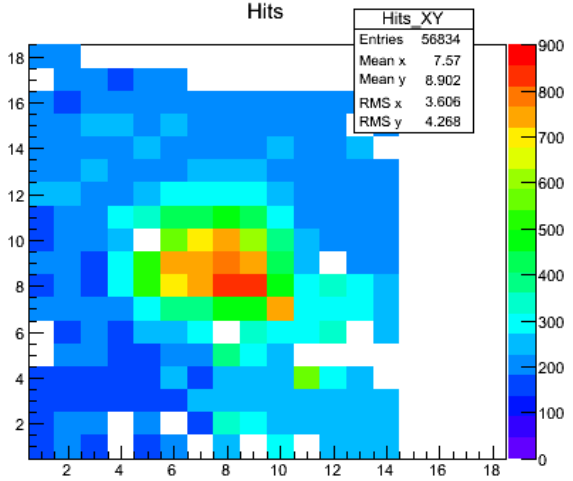

Hits
Hits_XY
Entries 32693
Mean x 7.45
Mean y 8.893
RMS x 3.264
RMS y 3.928


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

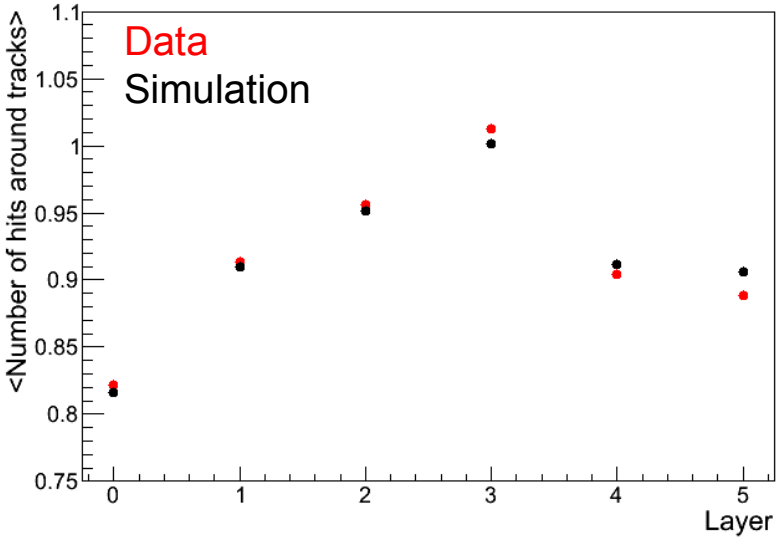
Data: 3GeV – No W – XY scan
Total number of events: 2,3.$10^6$
Track selection:

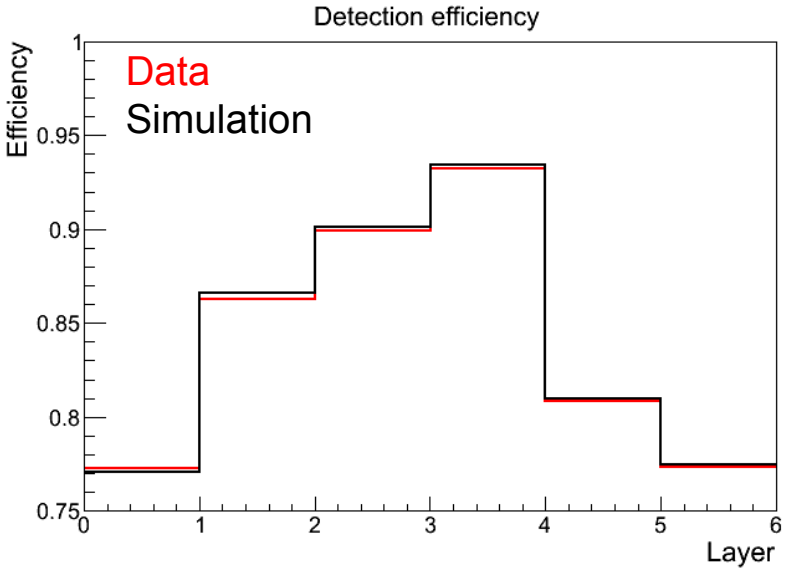
- At least 3 layers with hits
- Linear fit of the e- track
- Nhits<10

Inefficiencies due to:

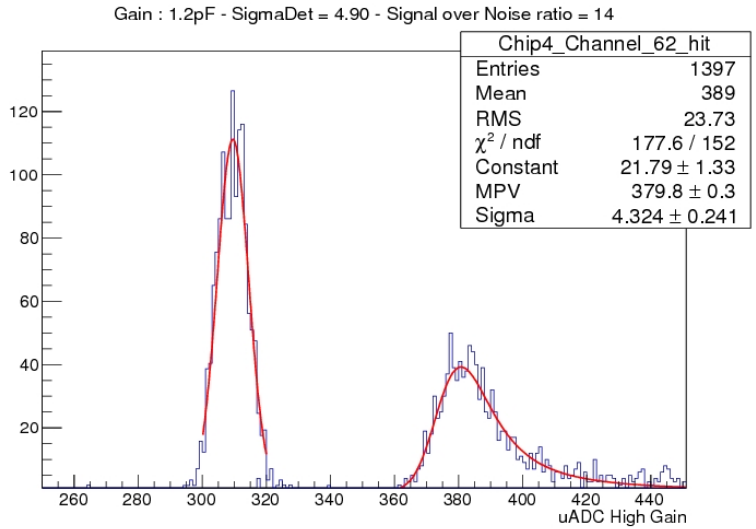
- Switched off channels
- Too high trigger thresholds (80%-95% of the MIP)

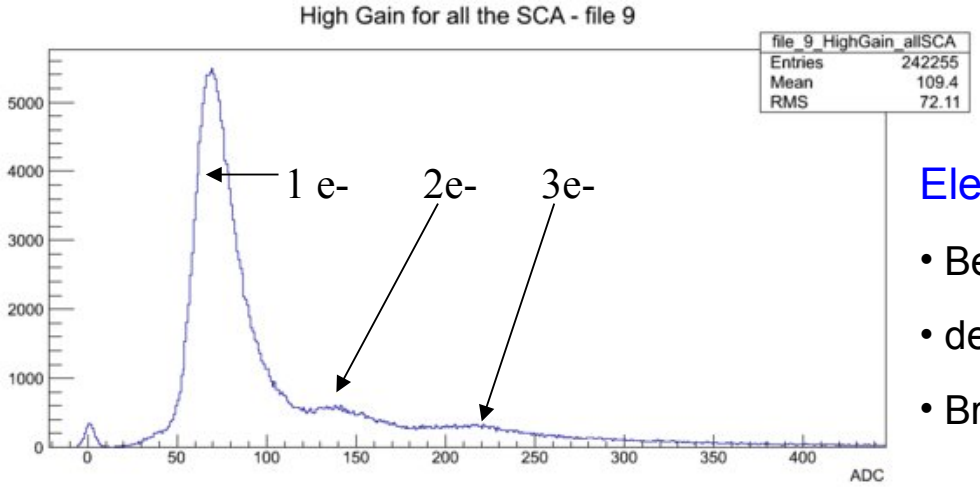
➡ Should be improved with the next test beam (December)

# Energy measurement



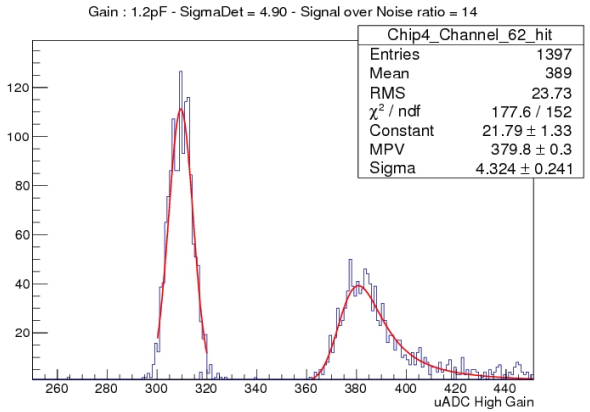



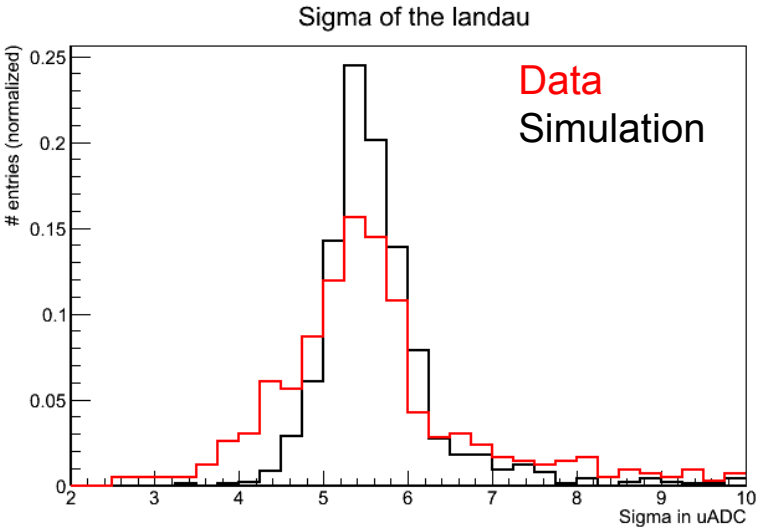

Electron sources:

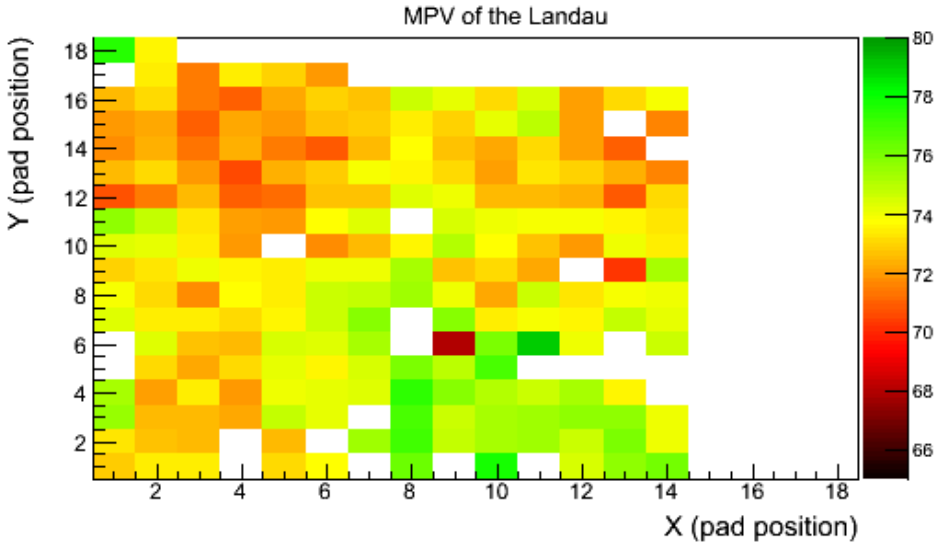
- Beam
- delta rays
- Bremsstrahlung + gamma conversion (2e-)
  + Compton

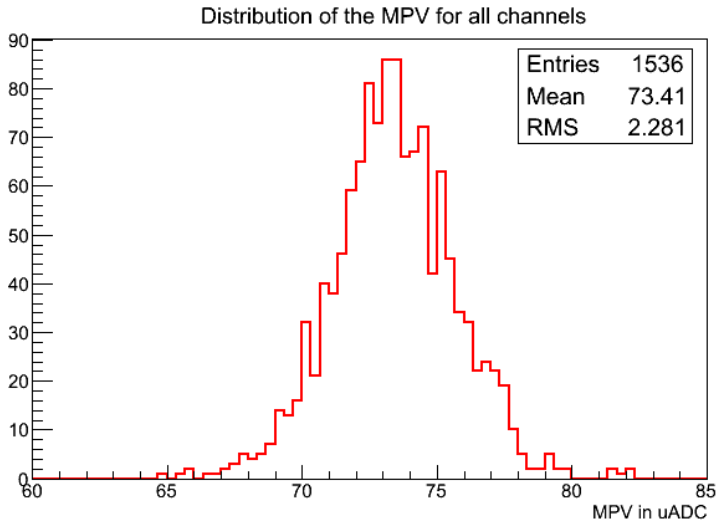
# Energy calibration

Establishment of calibration procedure for a larger number of cells
Homogeneity of response (x,y scan of detector)

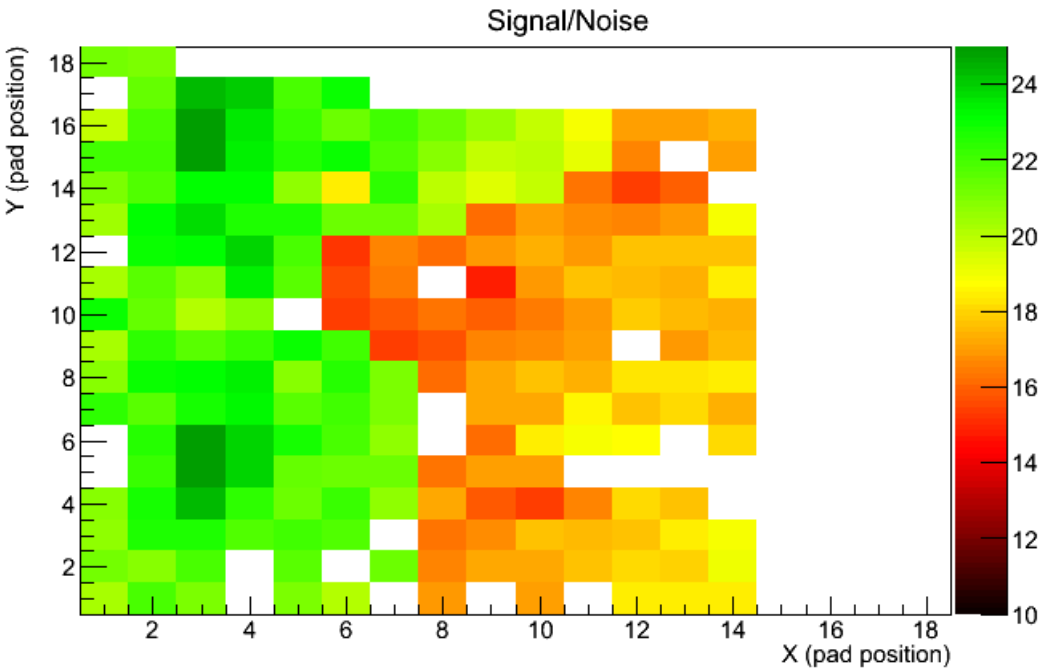


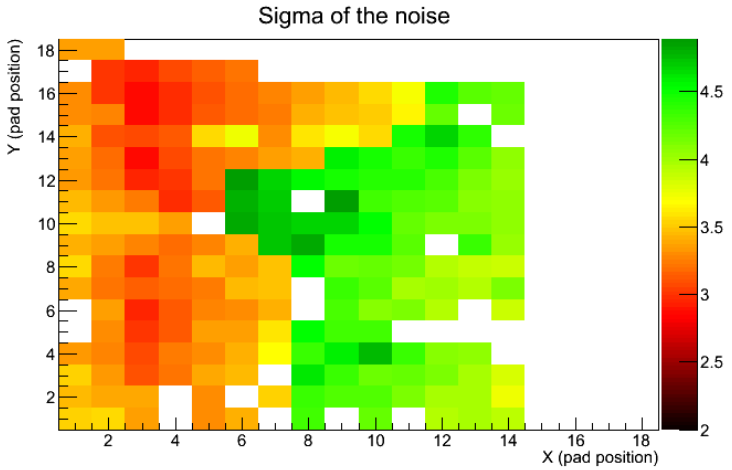
# Signal over noise ratio




R&D target is 10:1

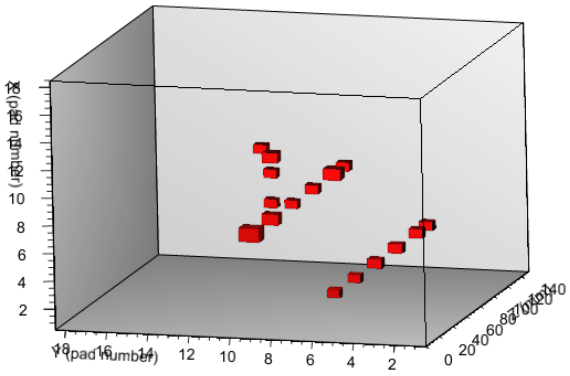
S/N > 10

(for all gains available with SKIROC2)

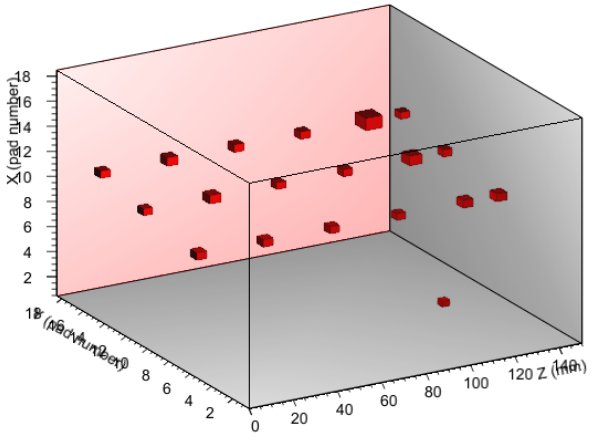


# Event display

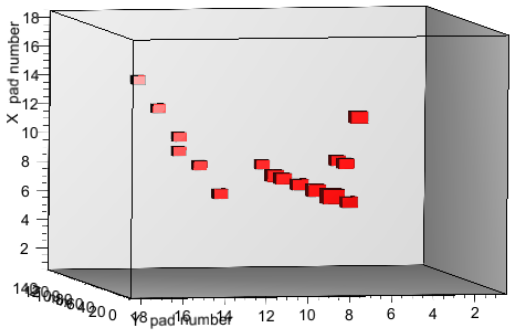
## 2 e- (3 GeV, no tungsten)



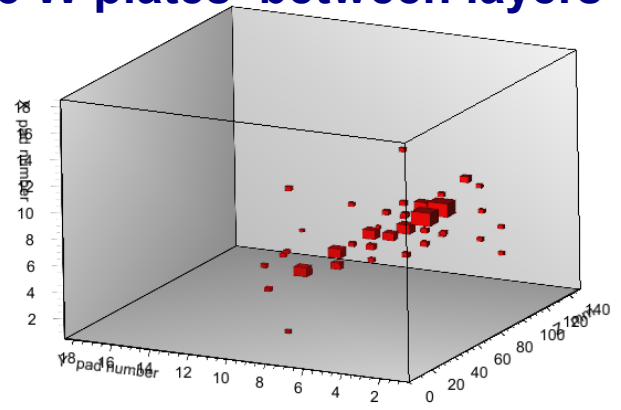

## 3 e- (3 GeV, no tungsten)




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




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



# 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 December ➡ Power pulsing

# Thanks

Special thanks to our experts:

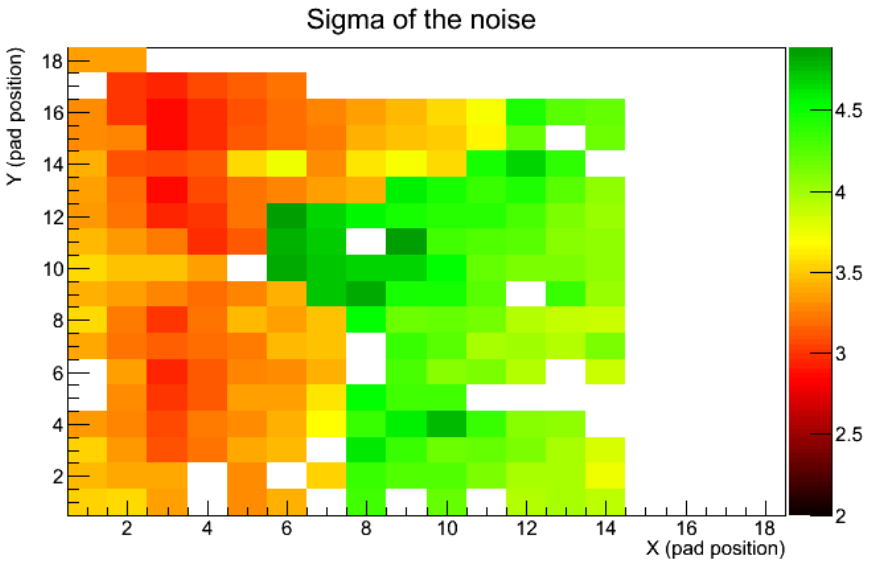
Frédéric, Mickael, Patrick, Rémi and Stéphane

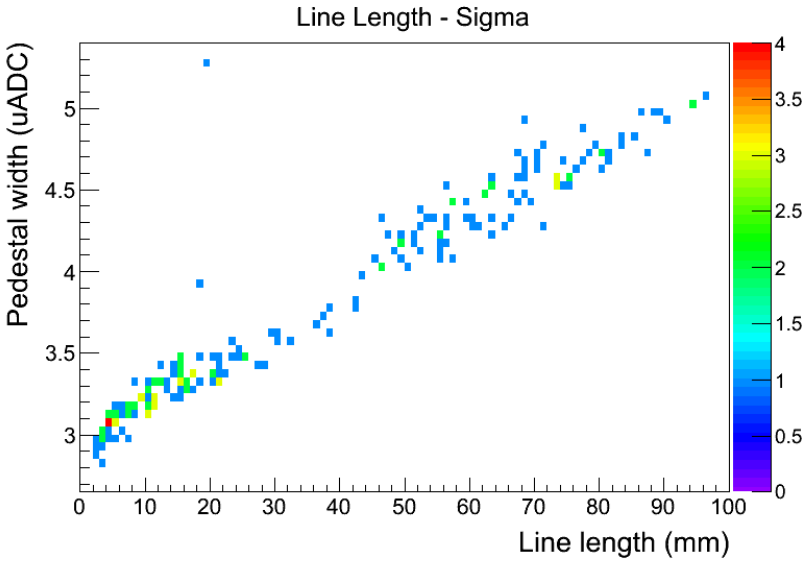
And to everyone who took part in the preparation of the test beam:

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

# Back up

# Noise width


Sigma of the noise
Y (pad position)
X (pad position)
2
4
6
8
10
12
14
16
18
2
2.5
3
3.5
4
4.5


Line Length - Sigma
Pedestal width (uADC)
Line length (mm)
3
3.5
4
4.5
5
0
10
20
30
40
50
60
70
80
90
100
0
0.5
1
1.5
2
2.5
3
3.5
4