

CALICE Si-W EM calorimeter

Preliminary Results of the testbeams 2006

1st part

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Imperial College London

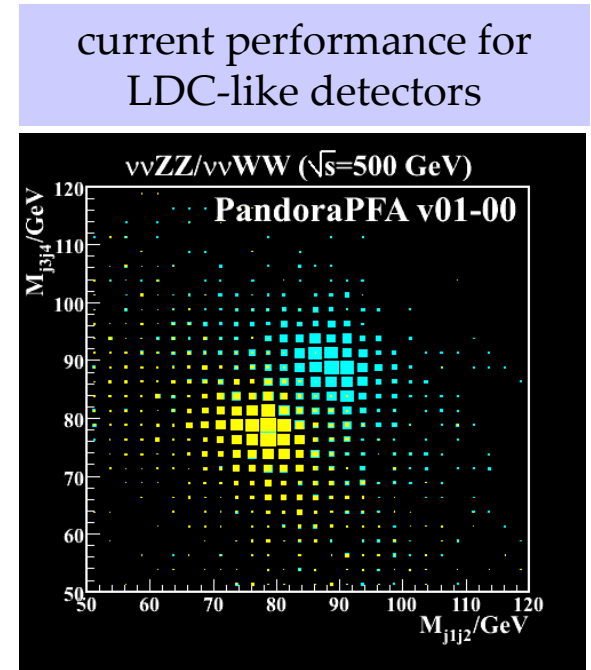
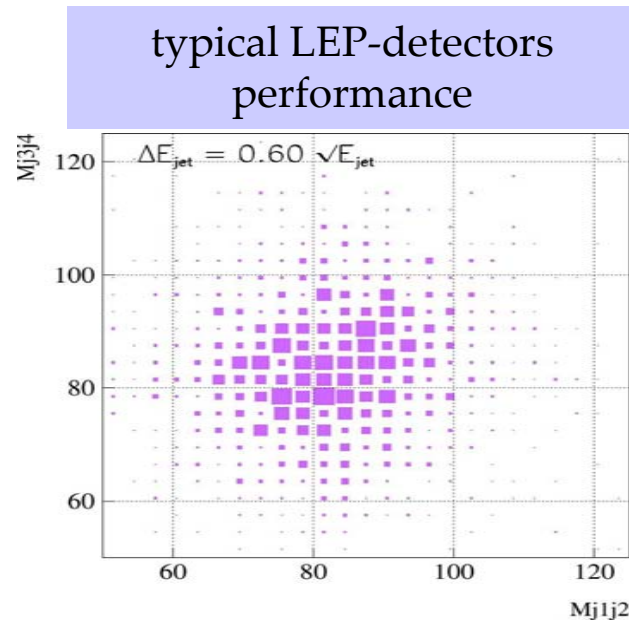
On behalf of the CALICE Collaboration

Why doing testbeam

- Calorimetry for ILC: mostly driven by **Particle Flow performance** to achieve

$$\frac{\sigma(E)}{E} \sim \frac{30\%}{\sqrt{E(\text{GeV})}}$$

see Mark Thomson's talk today



- **Optimum** design addressed by MC simulation
→ Need to validate the simulation against a **realistic** detector !
- And it allows to **discover design/hardware issues** in time to solve them.

Introduction: the ECAL prototype

I. the **testbeam setups**

II. **Calibration** procedure

III. **Pedestal** and **noise** and **crosstalk** issues

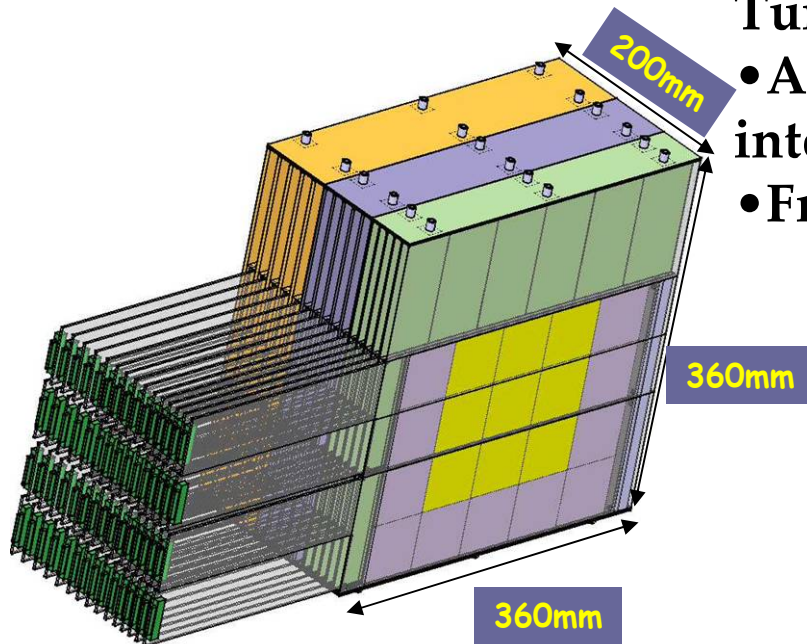
IV. Electron **selection** for the analyses

V. **Tracking resolution** at ECAL front face

Conclusion

The Electromagnetic Calorimeter prototype

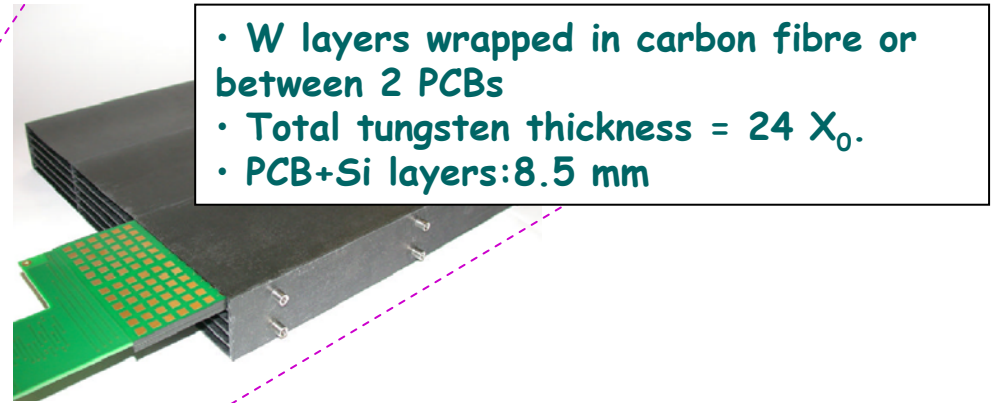
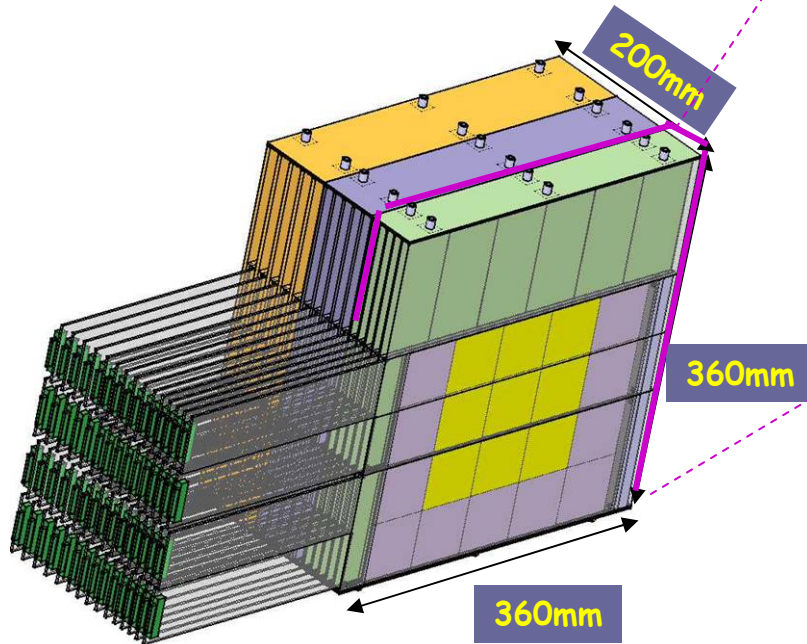
- ECAL prototype:



- 3 modules with variable thickness of Tungsten
- Active slabs with silicon layers+tungsten interleaved
- Front end chip and readout on PCB board

The Electromagnetic Calorimeter prototype

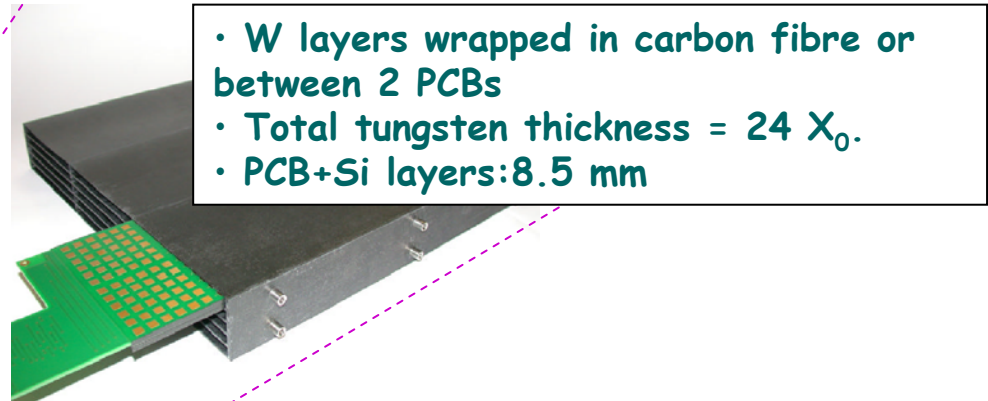
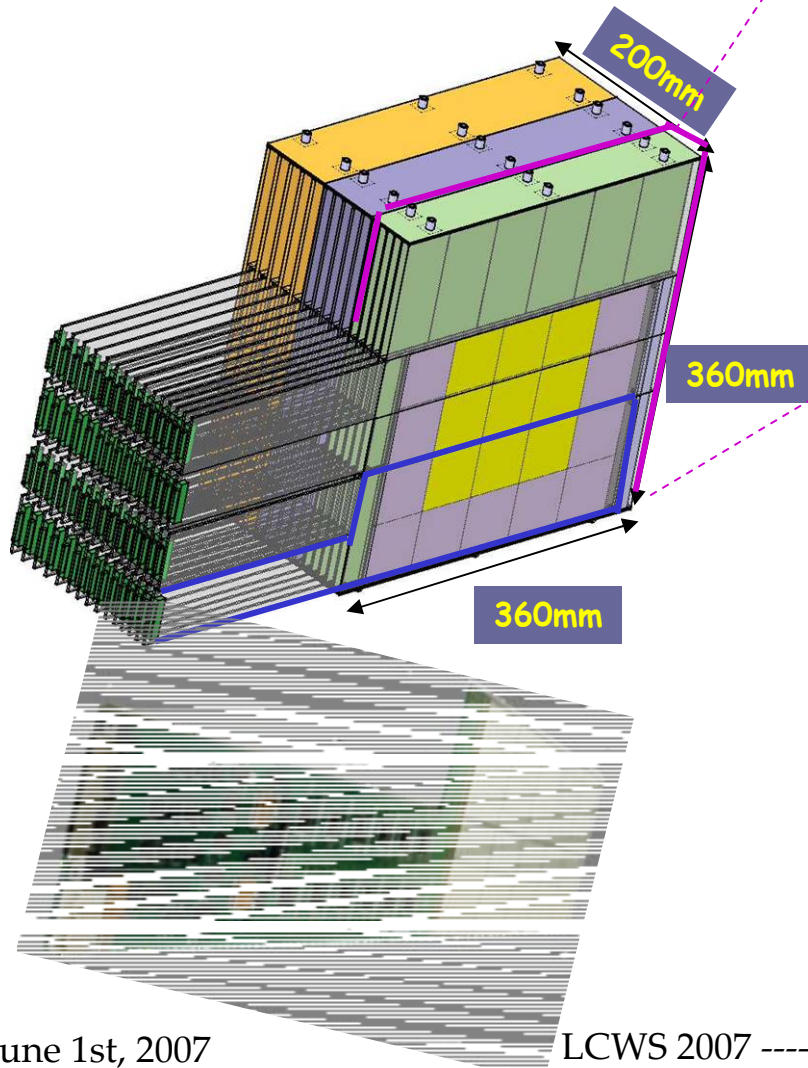
- ECAL prototype:



- W layers wrapped in carbon fibre or between 2 PCBs
- Total tungsten thickness = $24 X_0$.
- PCB+Si layers: 8.5 mm

The Electromagnetic Calorimeter prototype

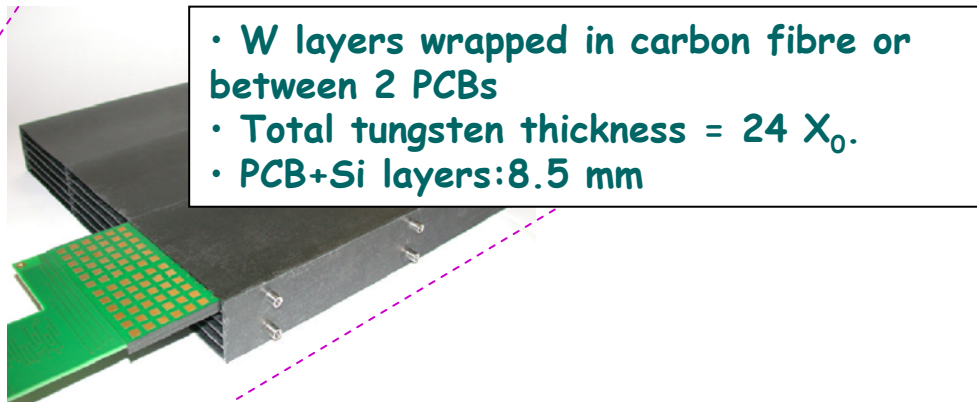
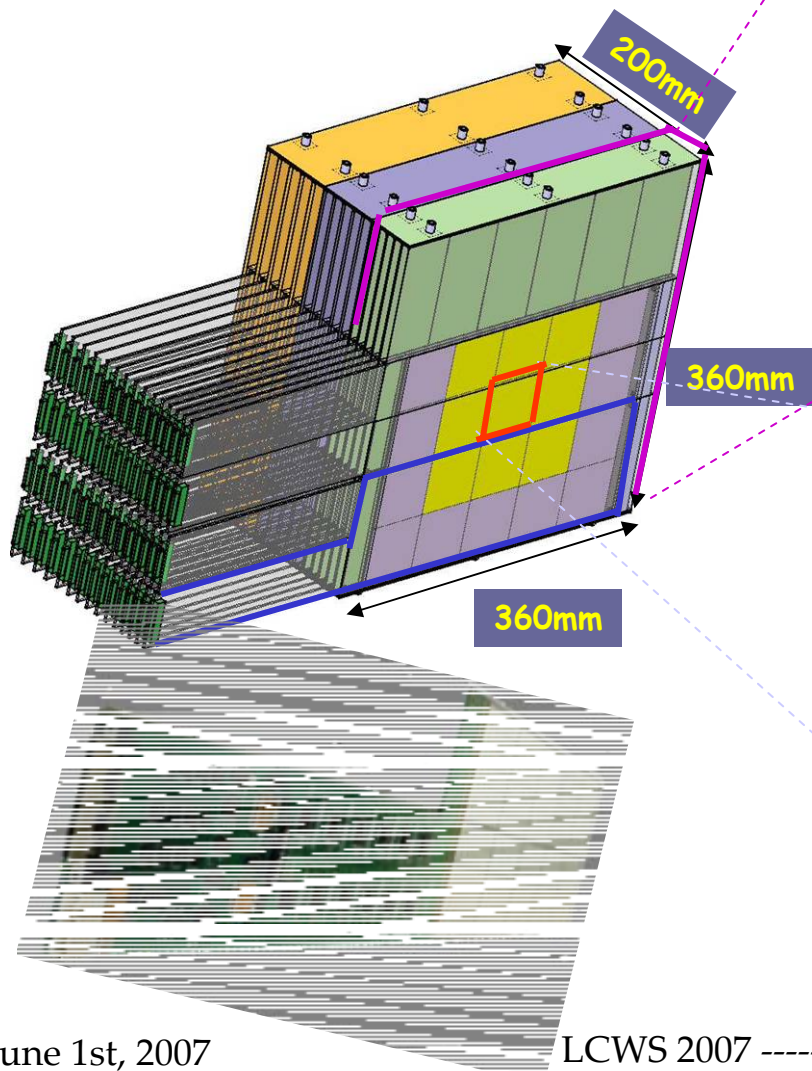
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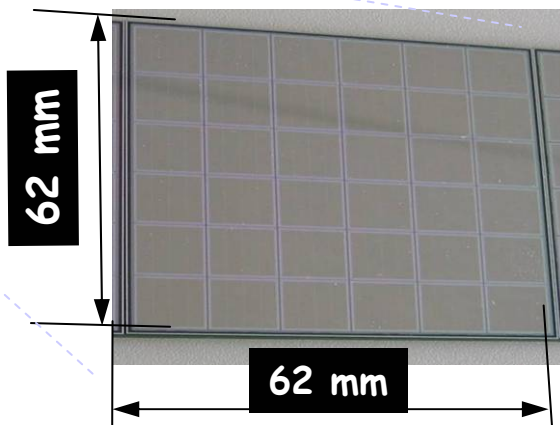
The Electromagnetic Calorimeter prototype

- ECAL prototype:



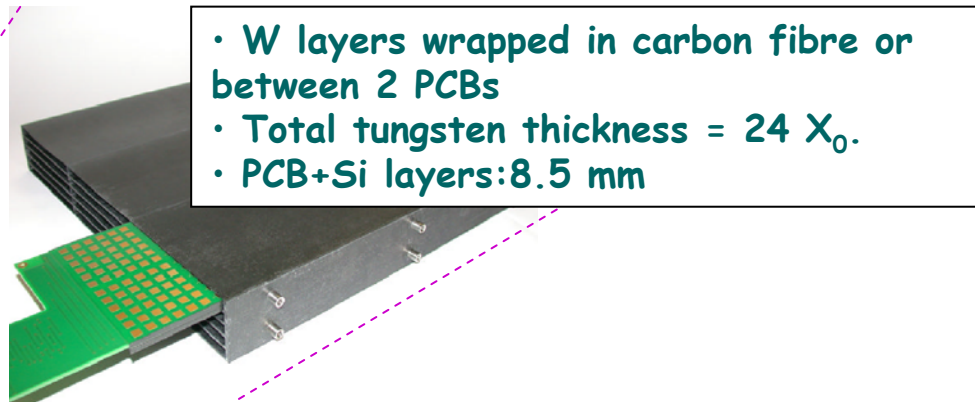
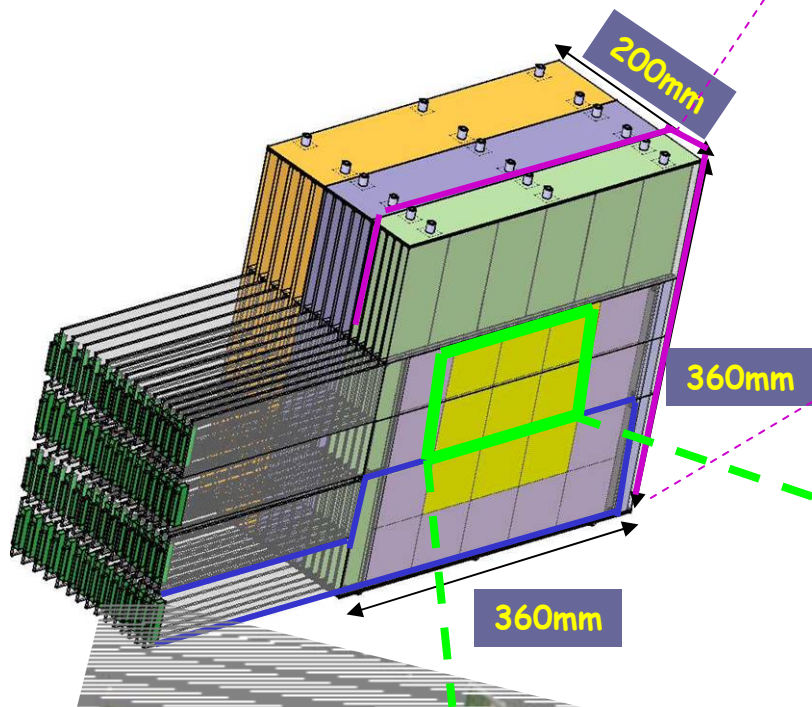
- W layers wrapped in carbon fibre or between 2 PCBs
- Total tungsten thickness = $24 X_0$.
- PCB+Si layers: 8.5 mm

- 6x6 $1 \times 1 \text{ cm}^2$ Si pads
- Conductively glued to PCB



The Electromagnetic Calorimeter prototype

- ECAL prototype:

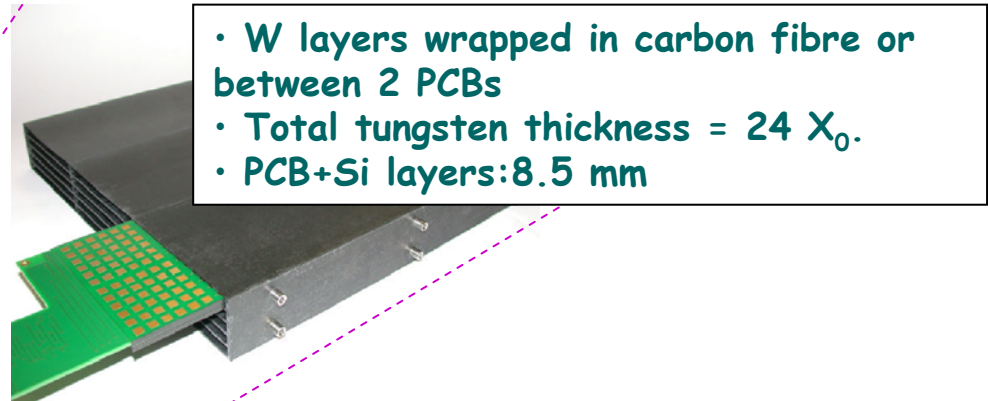
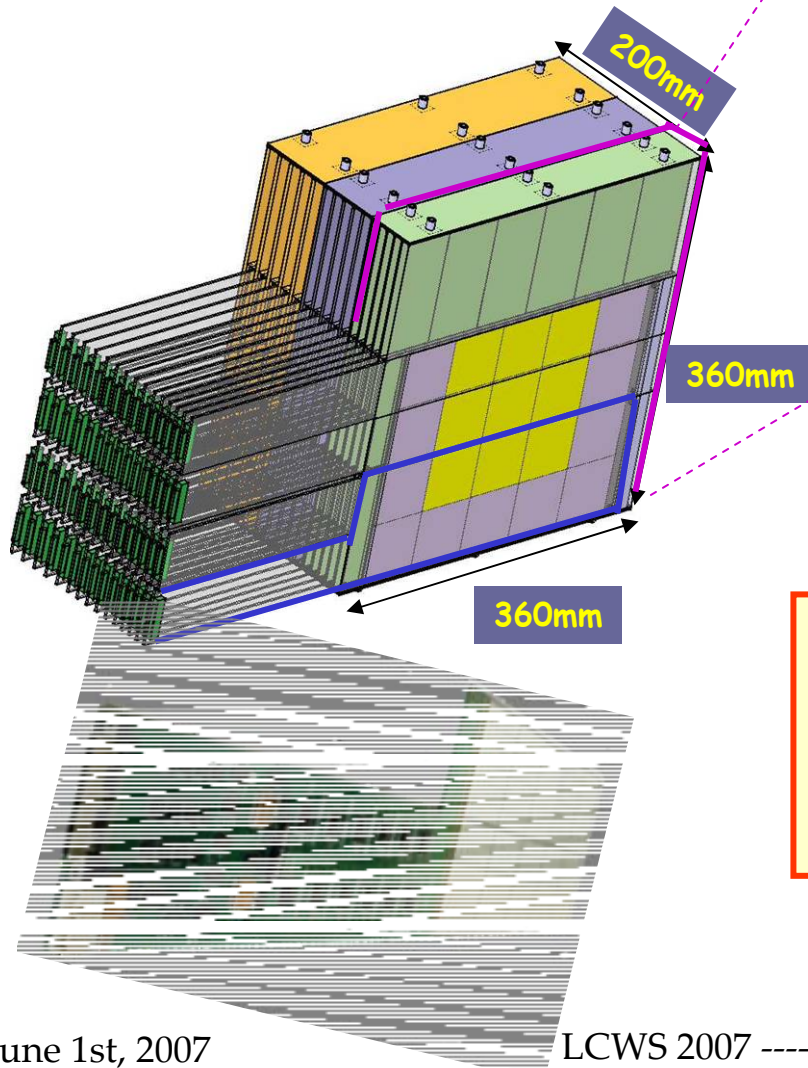


- W layers wrapped in carbon fibre or between 2 PCBs
- Total tungsten thickness = $24 X_0$.
- PCB+Si layers: 8.5 mm

Active area of $12 \times 18 \text{ cm}^2$ completed for 30 layers
Last 1/3rd : expected by July 2007,
 ~50% already completed

The Electromagnetic Calorimeter prototype

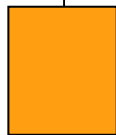
- ECAL prototype:



Detailed implementation in the Geant4-based simulation for ILC: MOKKA (v06-03)
Output data format: LCIO.

I- Overview of last year TB

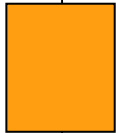
May



DESY TB area, with only 24 layers . 14 days in total
~8 Million triggers, 7 energies (1-6 GeV), 5 angles, 3 positions

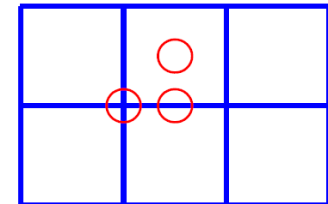
I- Overview of last year TB

May

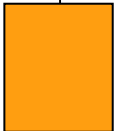



DESY TB area, with only 24 layers . 14 days in total
 ~8 Million triggers, 7 energies (1-6 GeV), 5 angles, 3 positions

Angle	0 ° (k events)	10 ° (k events)	20 ° (k events)	30 ° (k events)	45 ° (k events)
6 GeV	594	688	200	185	200
5 GeV	304	300	200	325	200
4 GeV	400	224	200	300	200
3 GeV	304	200	200	324	200
2 GeV	400	200	200	300	200
1.5 GeV	486	200	200	300	200
1 GeV	400	300	345	200	200
Total	2888	2112	1545	1934	1400



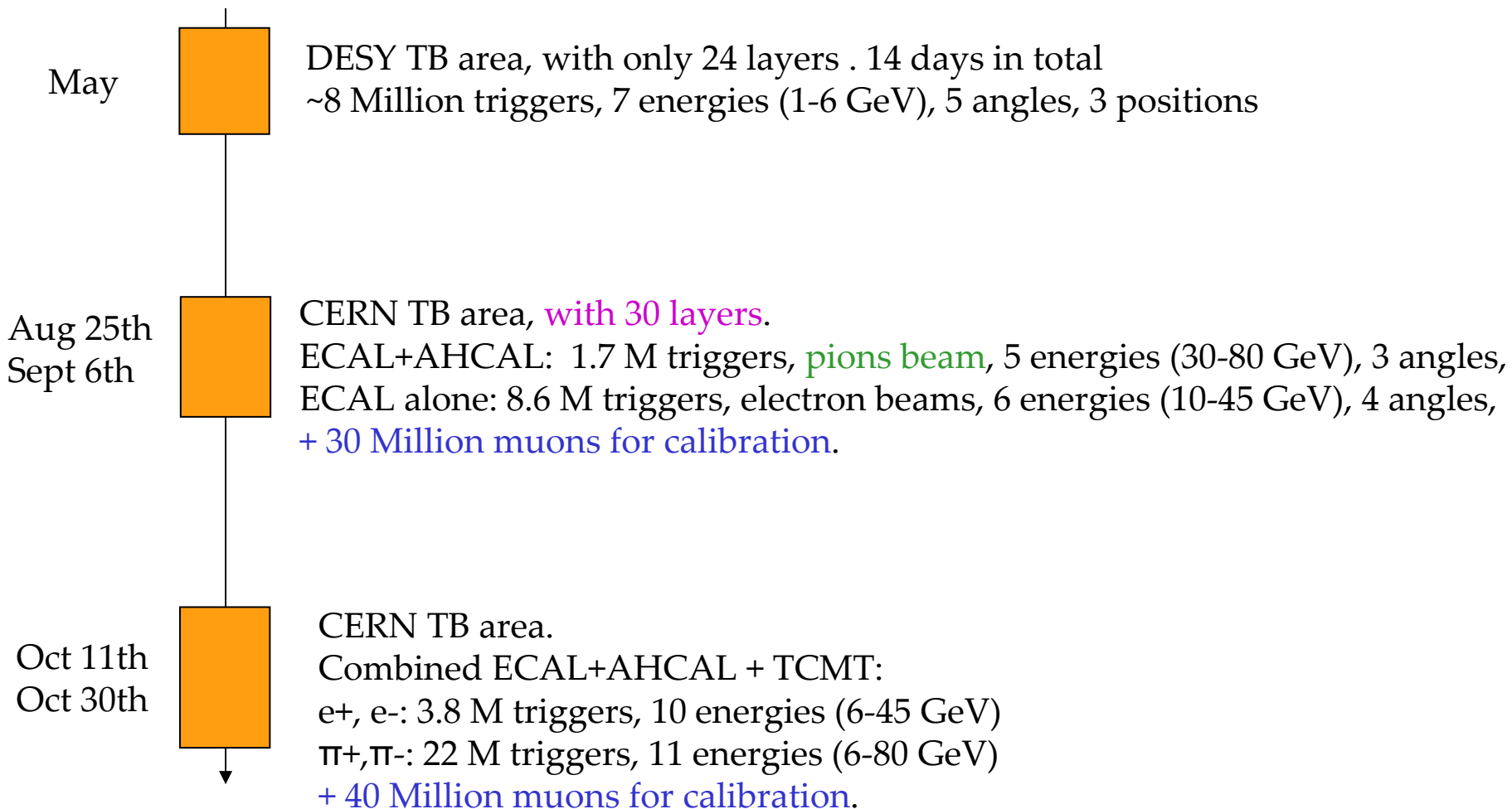
I- Overview of last year TB

May  DESY TB area, with only 24 layers . 14 days in total
~8 Million triggers, 7 energies (1-6 GeV), 5 angles, 3 positions

Aug 25th
Sept 6th  CERN TB area, with 30 layers.
ECAL+AHCAL: 1.7 M triggers, pions beam, 5 energies (30-80 GeV), 3 angles,
ECAL alone: 8.6 M triggers, electron beams, 6 energies (10-45 GeV), 4 angles,
+ 30 Million muons for calibration.

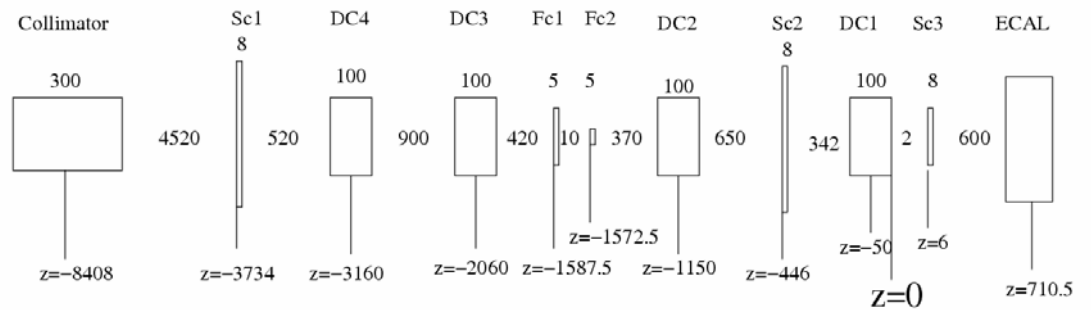


I- Overview of last year TB



Testbeam setup in DESY

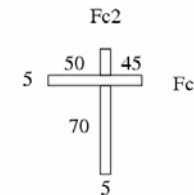
TOP – Desy May 2006



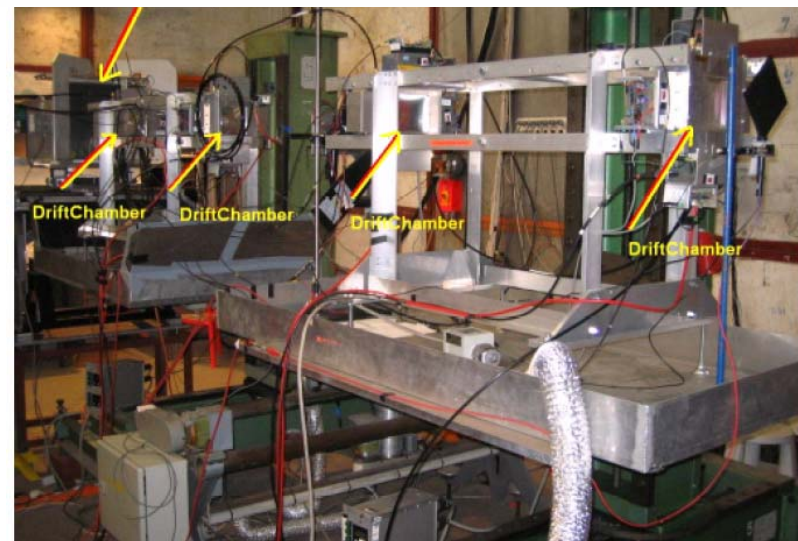
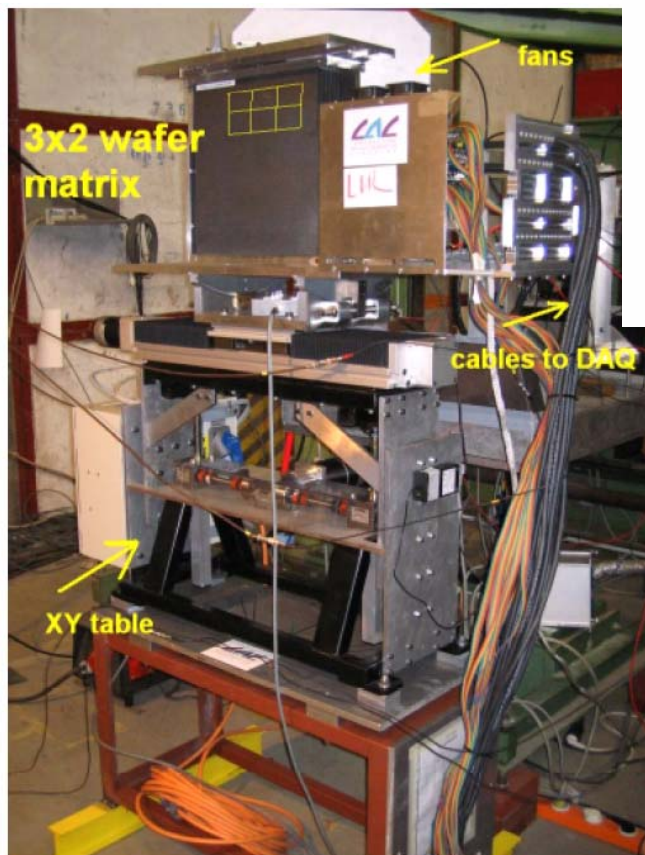
FRONT



Sc1 and Sc2 are 200x200
Sc3 is 120x120



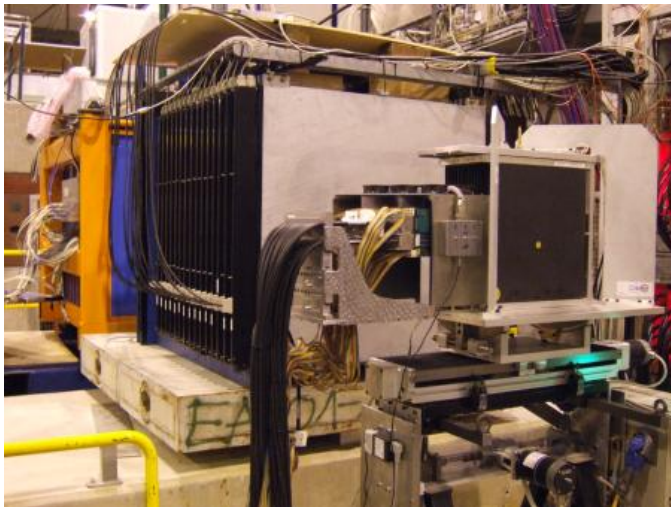
All distances are in mm



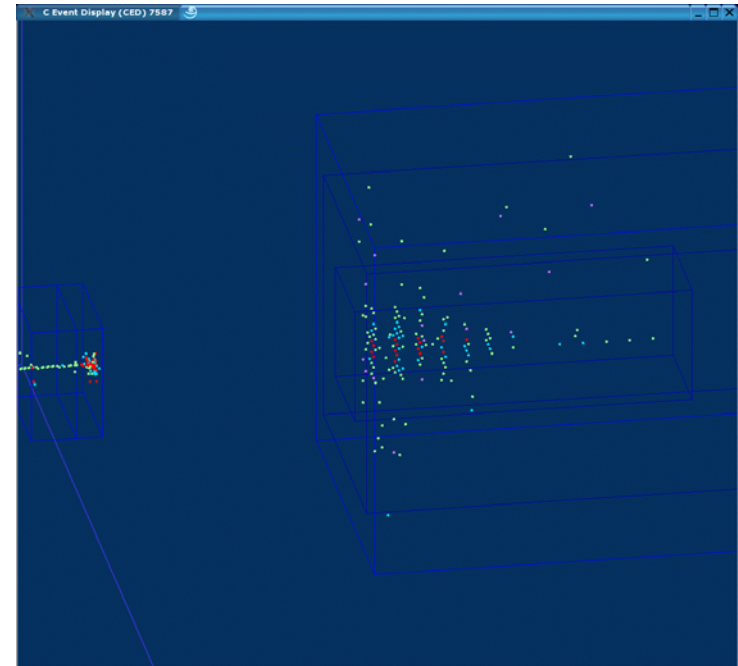
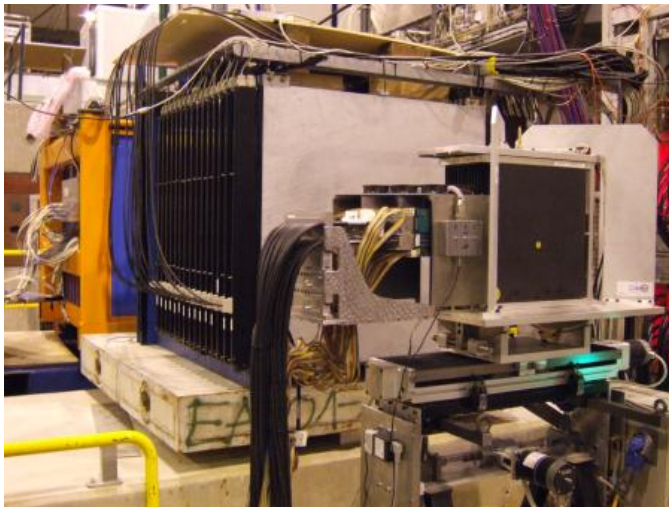
Testbeam setup in CERN - August



Testbeam setup in CERN - August



Testbeam setup in CERN - August



Testbeam setup in CERN - October

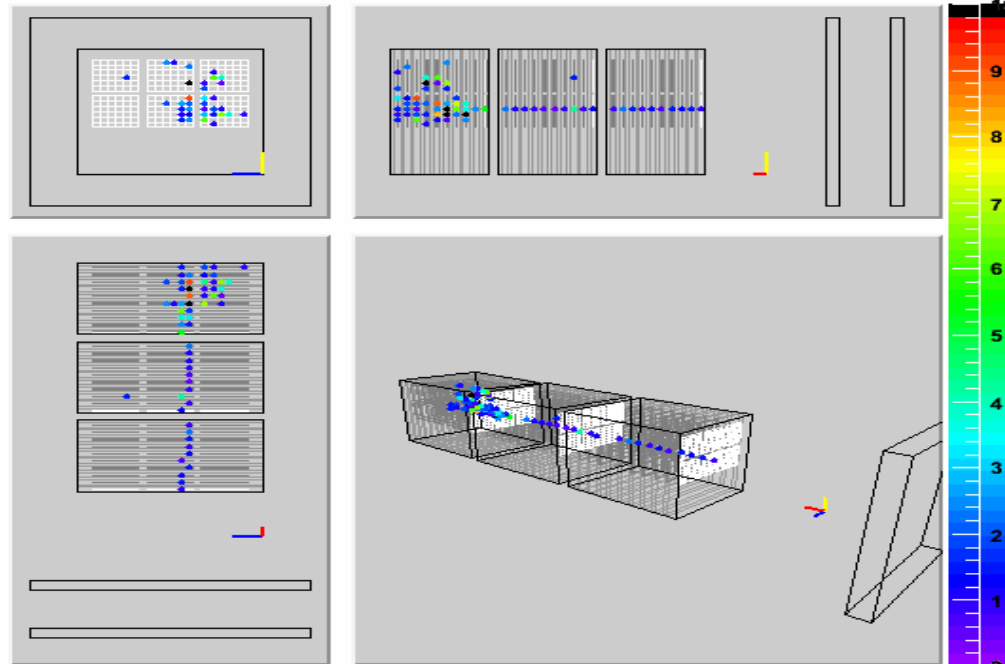


10 GeV pion event, taken Oct 16th 2006

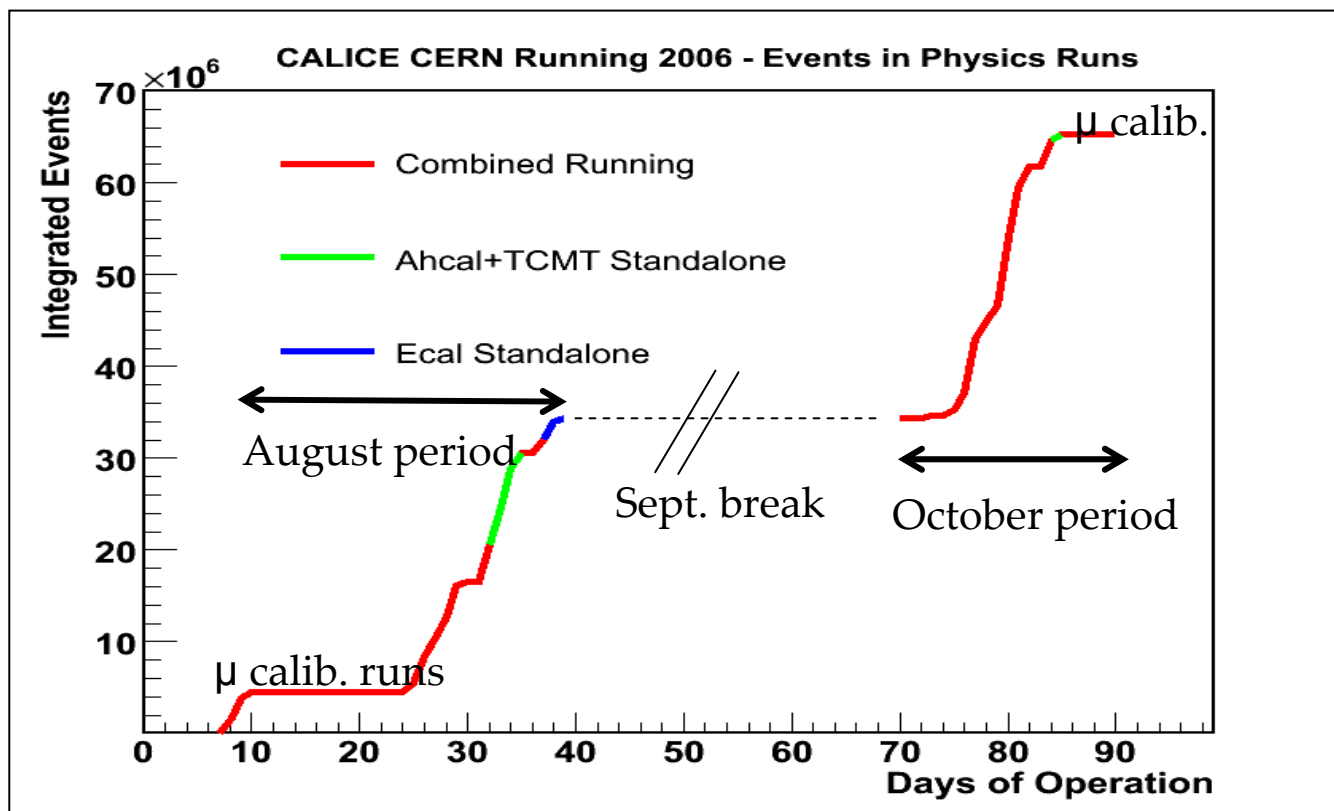
Run 300579:0 Event 78280

Time: 12:12:26:953:042 Mon Oct 16 2006

Hits: 89 Energy: 343.98 mips



Summary of the data taken



Size on disk: ~ 40 kB/evt

➔ 65M events = 2.5 TB for CERN Physics runs

➔ + 70 M = 3 TB for muon calibration runs

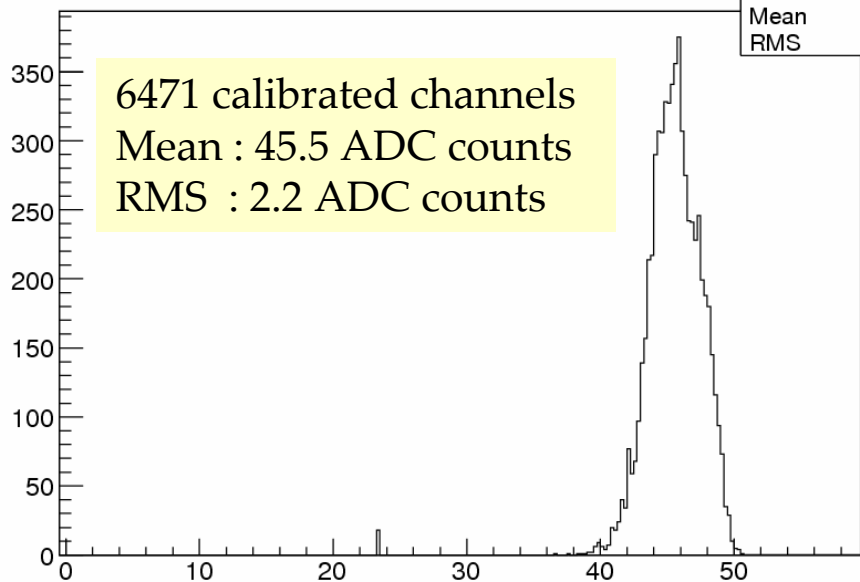


All the reconstruction has been done using the GRID !

II- ECAL calibration

- Using muon runs taken in October: ~18M events
- Taken with another experiment upstream → wide spread muon beam
- Procedure:
 - reject noise with a fixed cut at 25 ADC counts (~0.5MIP)
 - selection of MIP-like tracks : $15 \leq N_{\text{hits}} \leq 40$, in a 2 cm tower
 - fit with a Landau convoluted with a Gaussian

Calibration Constants

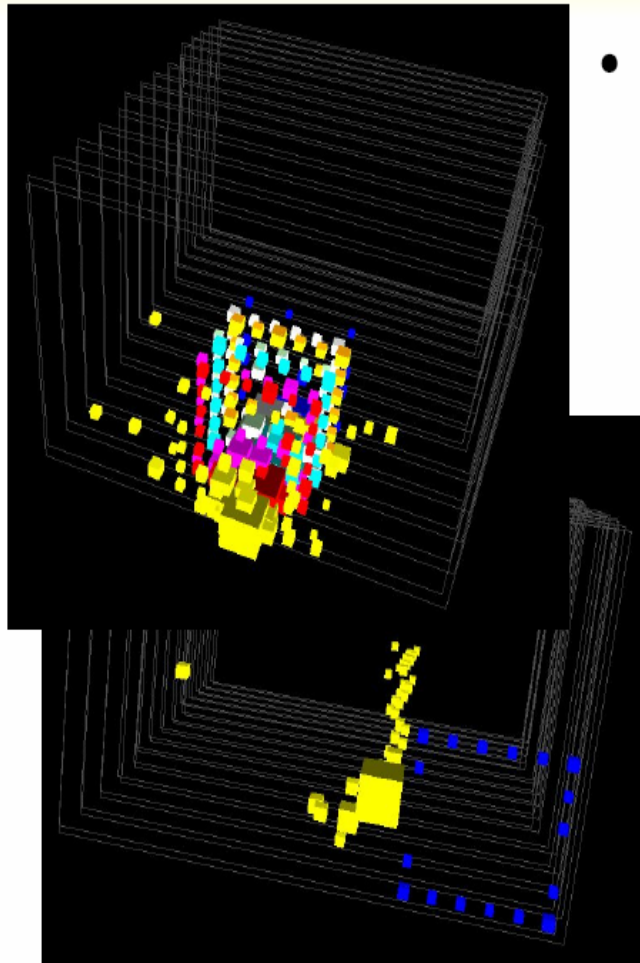


CalibConsts	
Entries	6471
Mean	45.54
RMS	2.181

- only 9 dead channels: 1.4‰ !!
- 6403/6471 : 98.9% convergent fit.
- 18/6471 needed a special treatment because of high noise.
- 14/6471 have been calibrated thanks to their neighbours.
- One wafer (=36 cells) with a relative calibration : appears to be not fully depleted, 0.517×normal signal !!

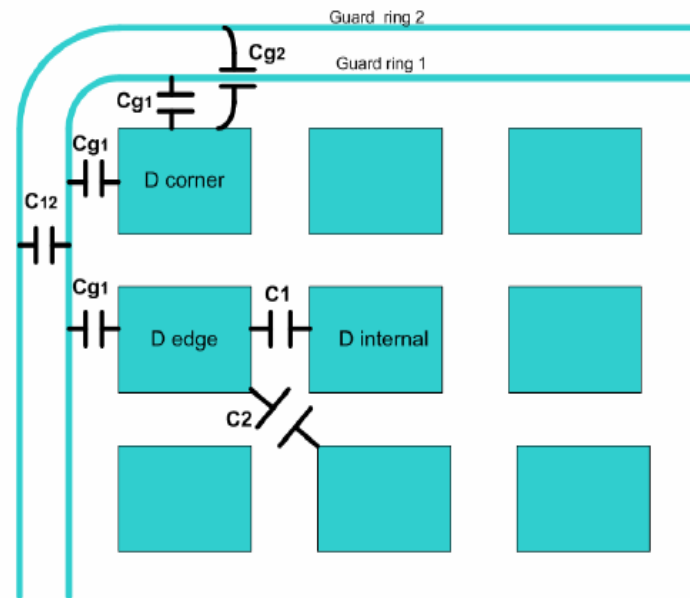
III- Pedestal, noise and crosstalk issues

1- Square events : crosstalk with guard ring



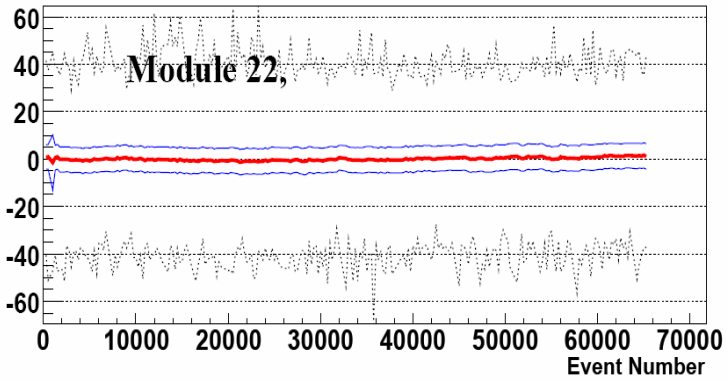
- “Square events”

- cross talk between guard rings and pixels



2- Pedestal instabilities

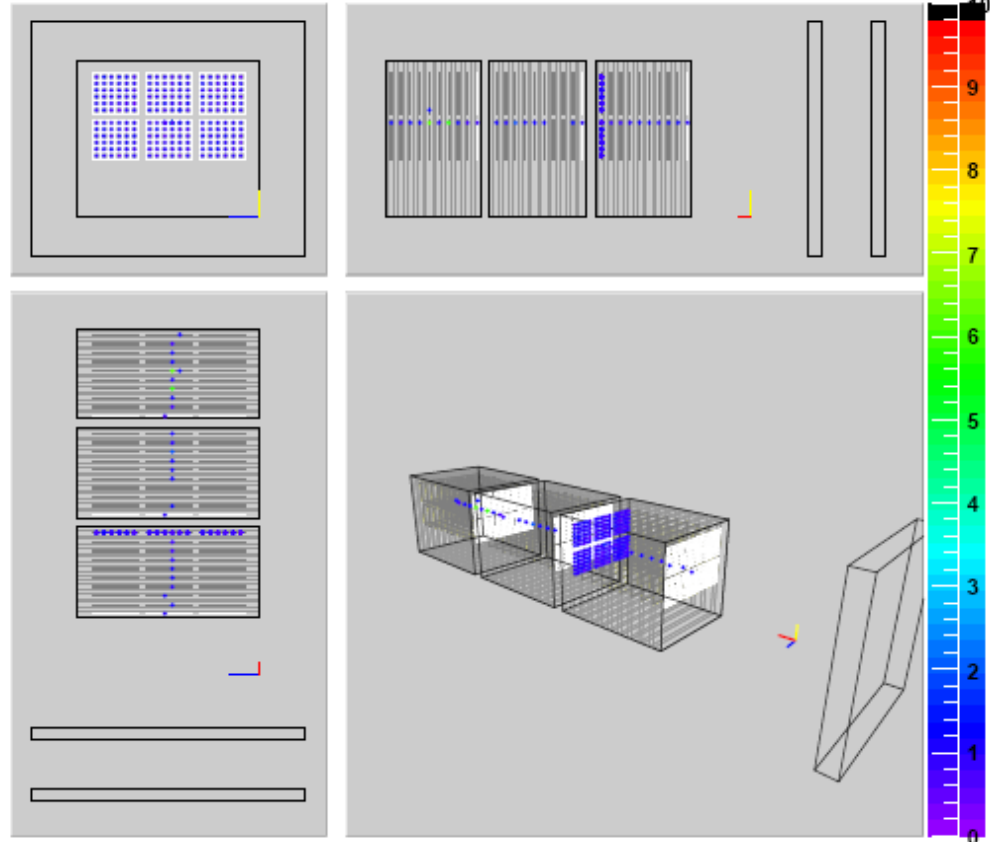
A Good PCB



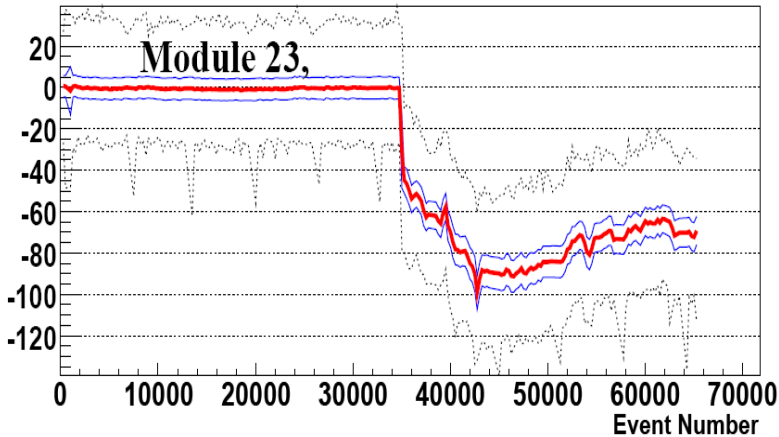
Ex: Muon run (ECAL threshold : 0.5 MIP)

Run 300960:0 Event 1060

Time: 13:36:24:033:166 Mon Oct 30 2006
Hits: 244 Energy: 226.062 mips



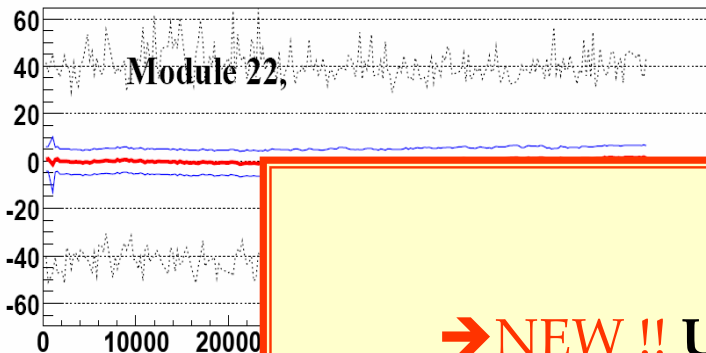
A PCB with unstable pedestals



pedestal
noise

2- Pedestal instabilities

A Good PCB



Ex: Muon run (ECAL threshold : 0.5 MIP)

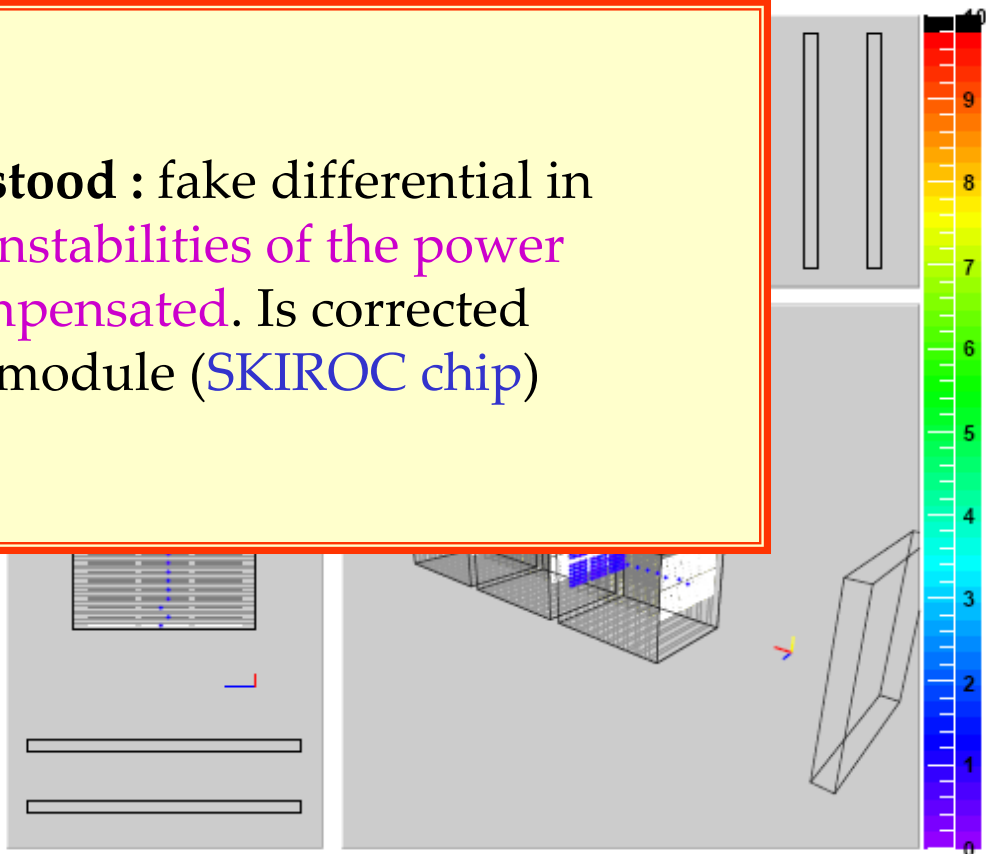
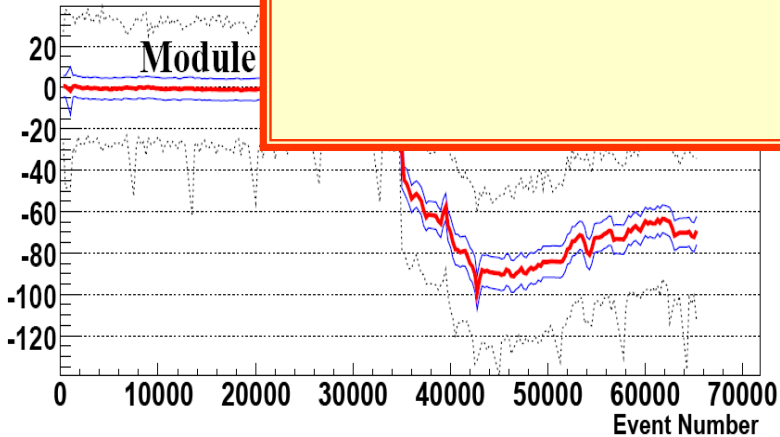
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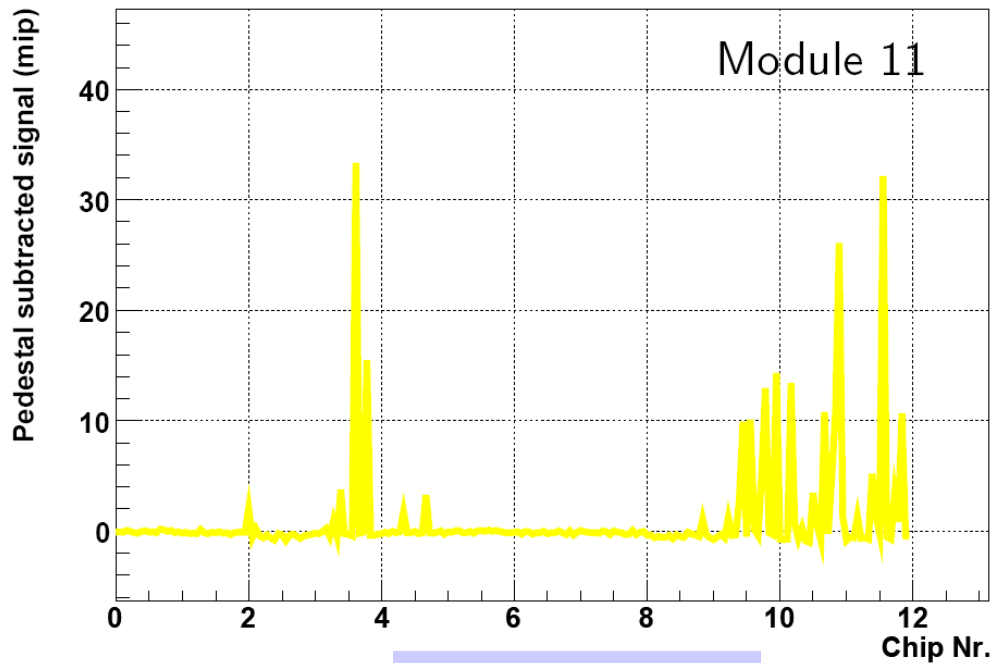
→ **NEW !! Understood** : fake differential in the chip due to **instabilities of the power supply not compensated**. Is corrected in the EUDET module (**SKIROC chip**)

A PCB with un



3- Signal induced pedestal shift: crosstalk @ wafer scale

The effect

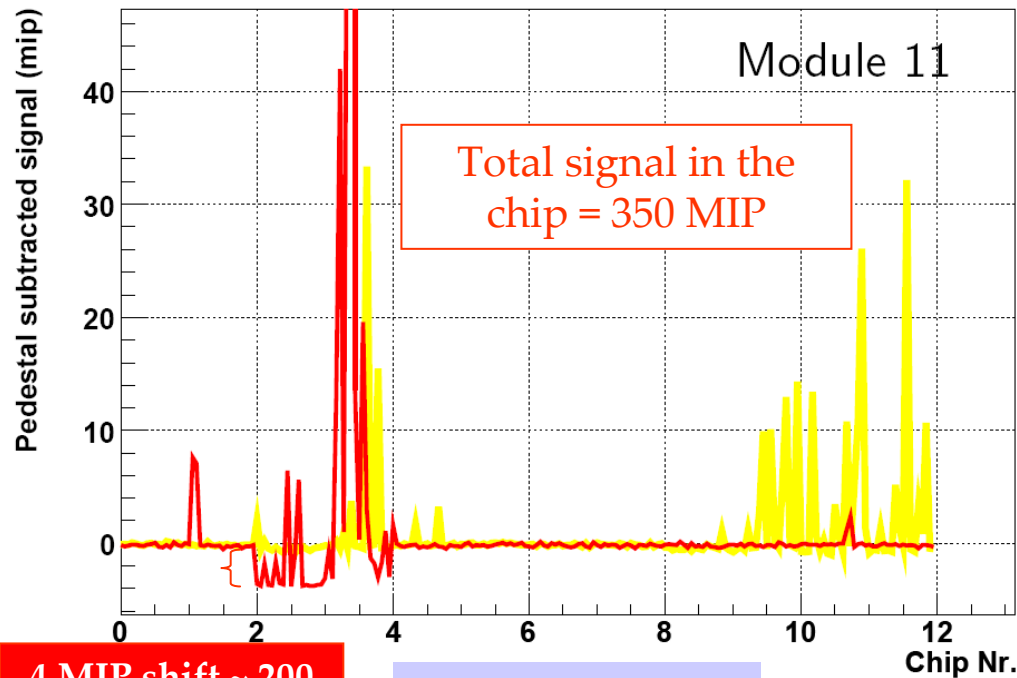


1 chip = 18 channels
2 chips = 1 wafer

1- Pedestal subtracted signal of all pads of one PCB

3- Signal induced pedestal shift: crosstalk @ wafer scale

The effect



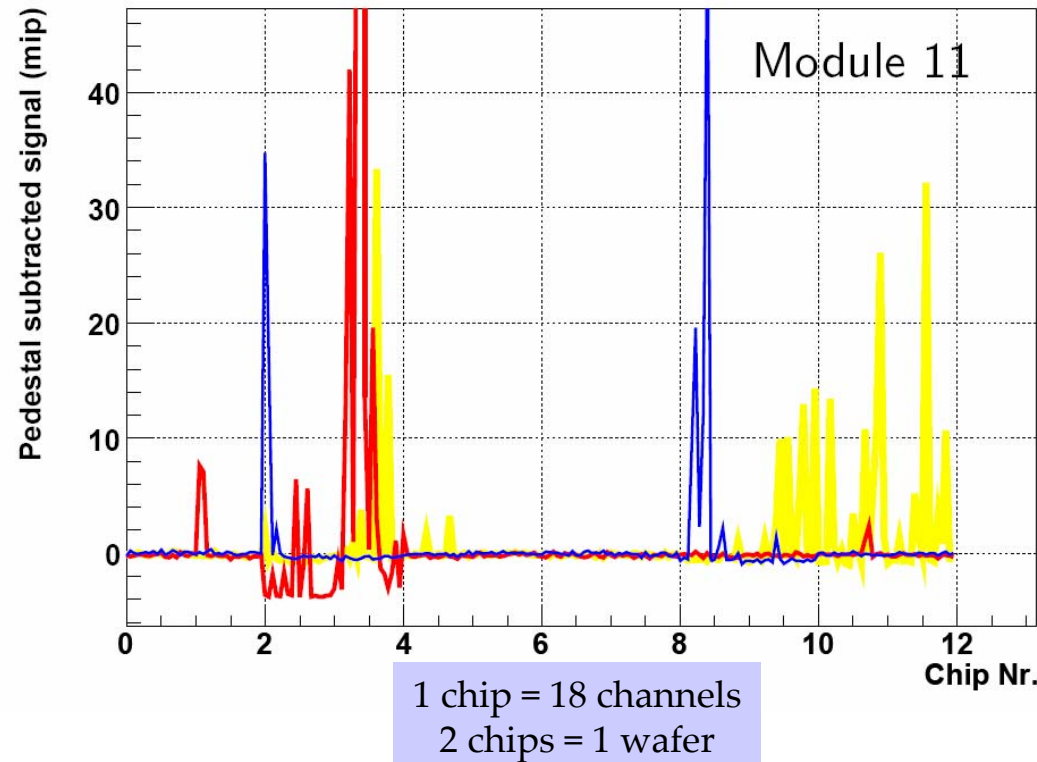
**4 MIP shift ~ 200
ADC counts**

1 chip = 18 channels
2 chips = 1 wafer

2- Beam hit the second wafer (chips #2 and #3)

3- Signal induced pedestal shift: crosstalk @ wafer scale

The effect

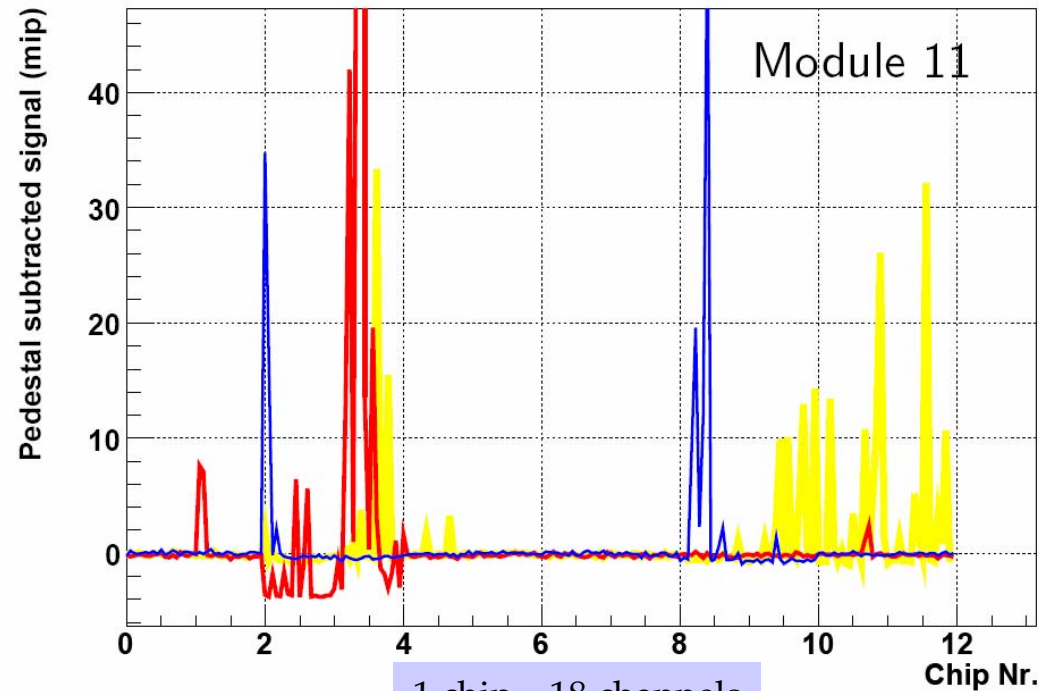


3- Small signal in same wafer

3- Signal induced pedestal shift: crosstalk @ wafer scale

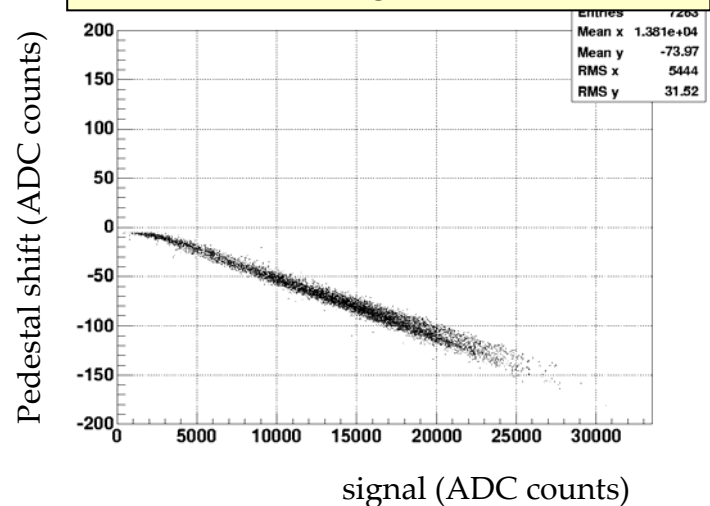
The effect

- ➔ Not understood yet
- ➔ under investigation
- ➔ Correlated with signal intensity
- ➔ Affects a few wafers randomly in space and time...



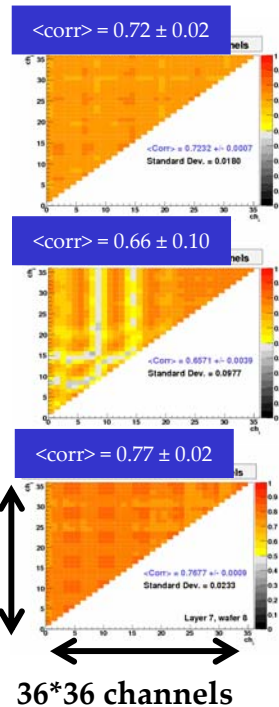
3- Small signal in same wafer

Correlation between pedestal shift and signal recorded

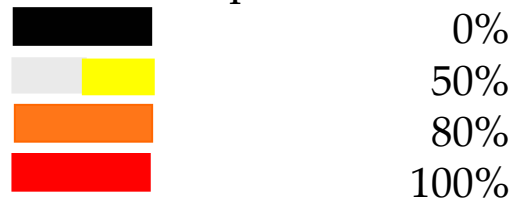


Impact on the noise and software correction procedure

PCB layer 9 in 6 GeV e- run (DESY)
 Wafers of the middle row
 before any corrections



Correlation between 2 channels, per wafer.



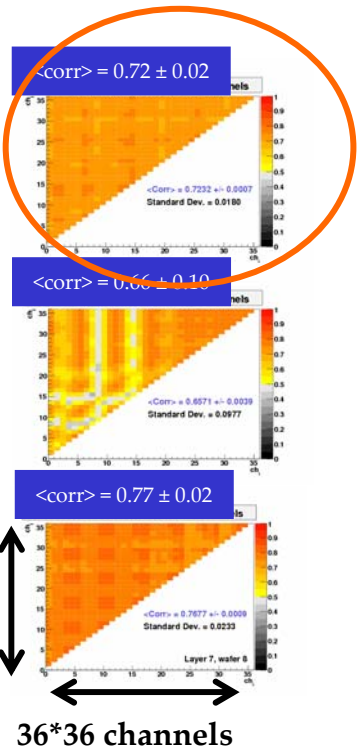
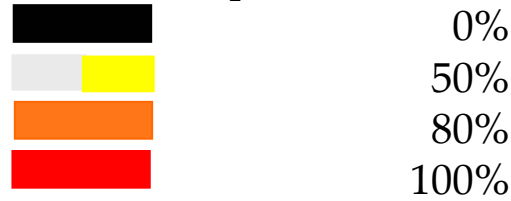
Impact on the noise and software correction procedure

PCB layer 9 in 6 GeV e- run (DESY)
Wafers of the middle row
before any corrections

Wafers of the middle row
after corrections

Pedestal instabilities:
corrected event by event by
iterating on the mean and RMS
in wafers without signal

Correlation between 2
channels, per wafer.

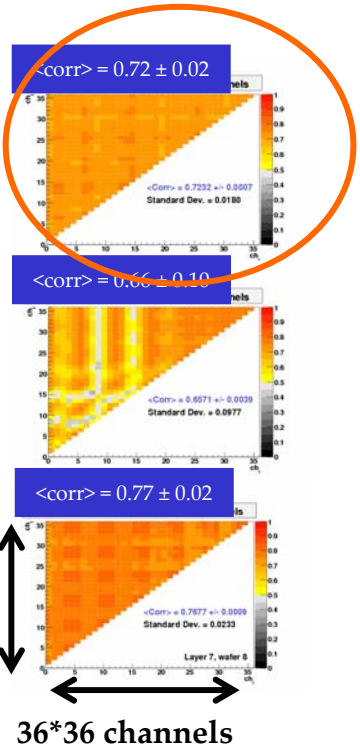


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Wafers of the middle row
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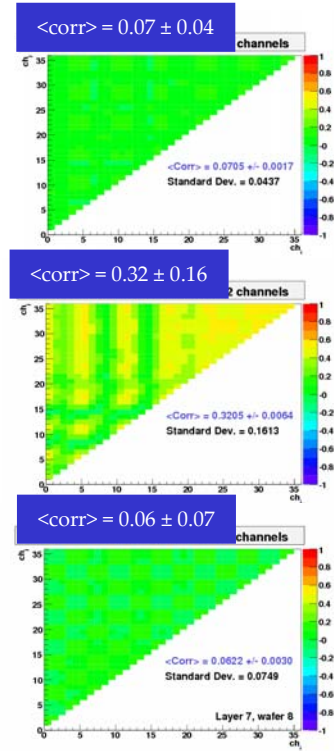
Correlation between 2
channels, per wafer.



0%
50%
80%
100%

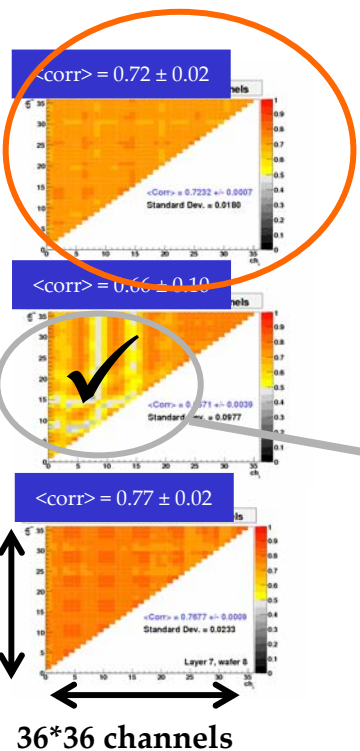


-100%
0%
50%
100%



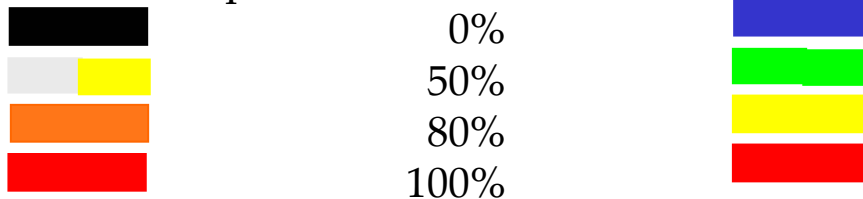
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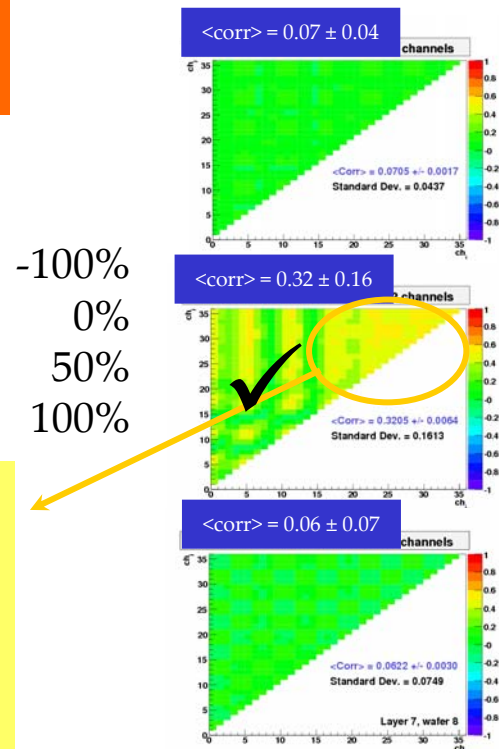


Signal Induced Pedestal Shift:

corrected event by event by iterating on the
channels having no signal but in a wafer
recording a signal.

✓ **position of the signal:** less cells to
perform the calculation=less correlations...

Wafers of the middle row
after corrections

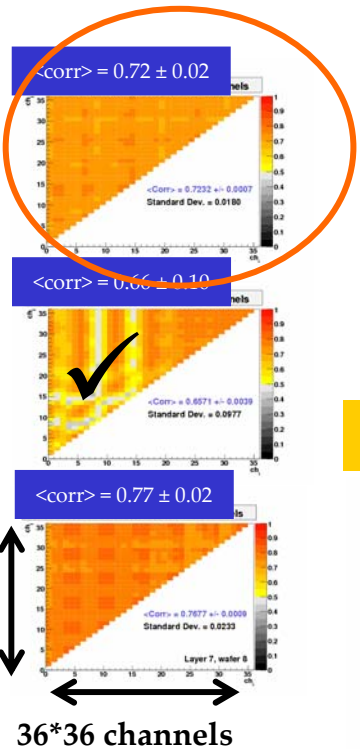


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Wafers of the middle row
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Correlation between 2
channels, per wafer.

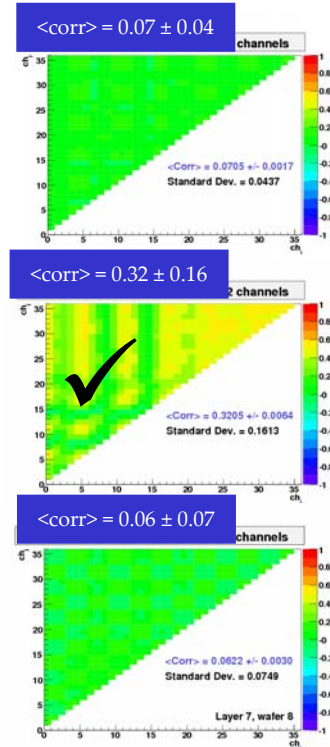
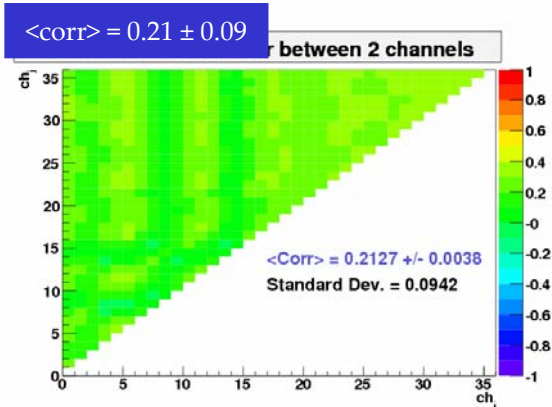


0%
50%
80%
100%



-100%
0%
50%
100%

After all corrections in wafer recording a signal:

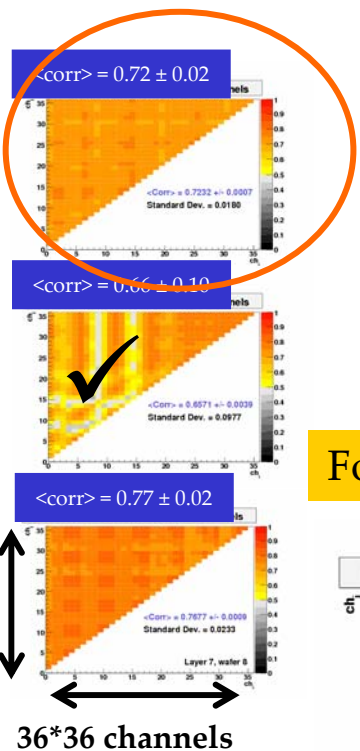


Impact on the noise and software correction procedure

PCB layer 9 in 6 GeV e- run (DESY)
Wafers of the middle row
before any corrections

Pedestal instabilities:
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Wafers of the middle row
after corrections



Correlation between 2 channels, per wafer.

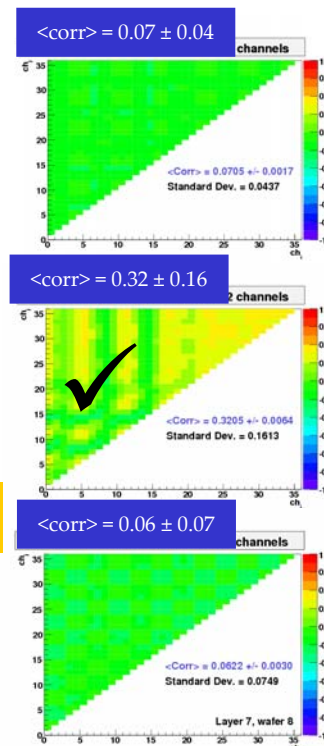
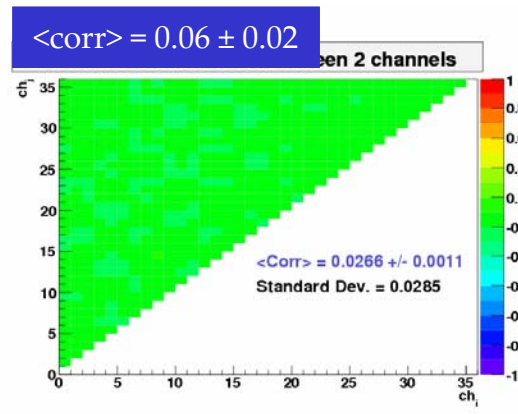
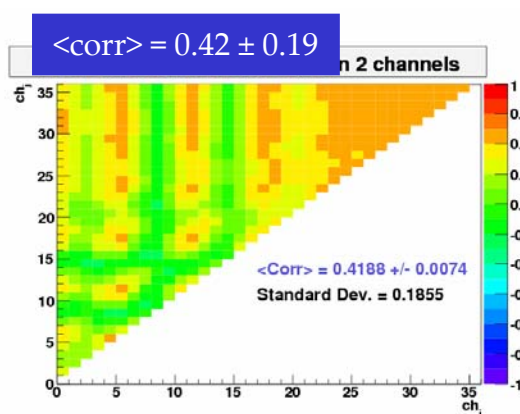


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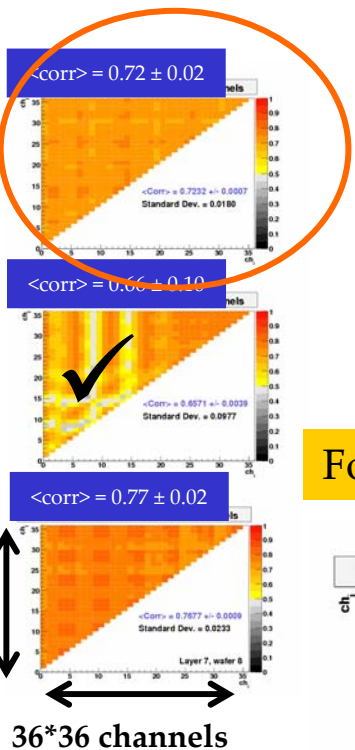
-100%
0%
50%
100%

For completeness : a wafer only affected by signal induced shift:



Impact on the noise and software correction procedure

PCB layer 9 in 6 GeV e- run (DESY)
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Wafers of the middle row
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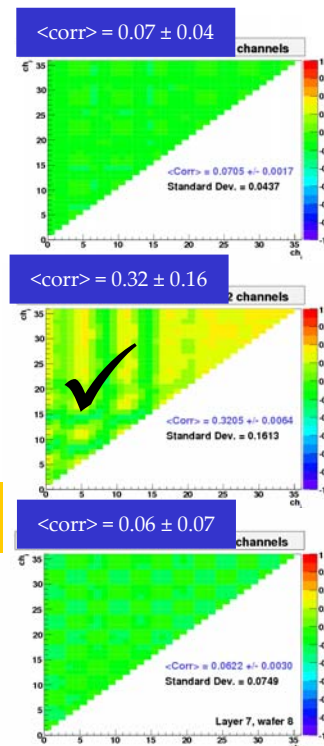
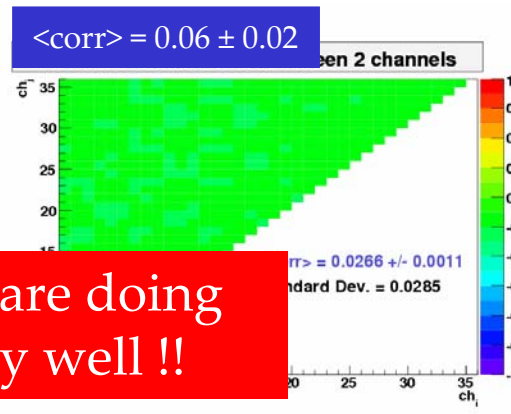
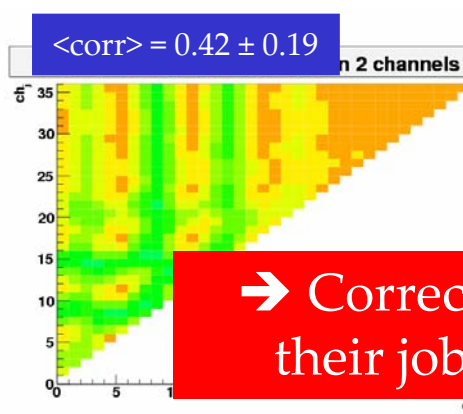


0%
50%
80%
100%



-100%
0%
50%
100%

For completeness : a wafer only affected by signal induced shift:



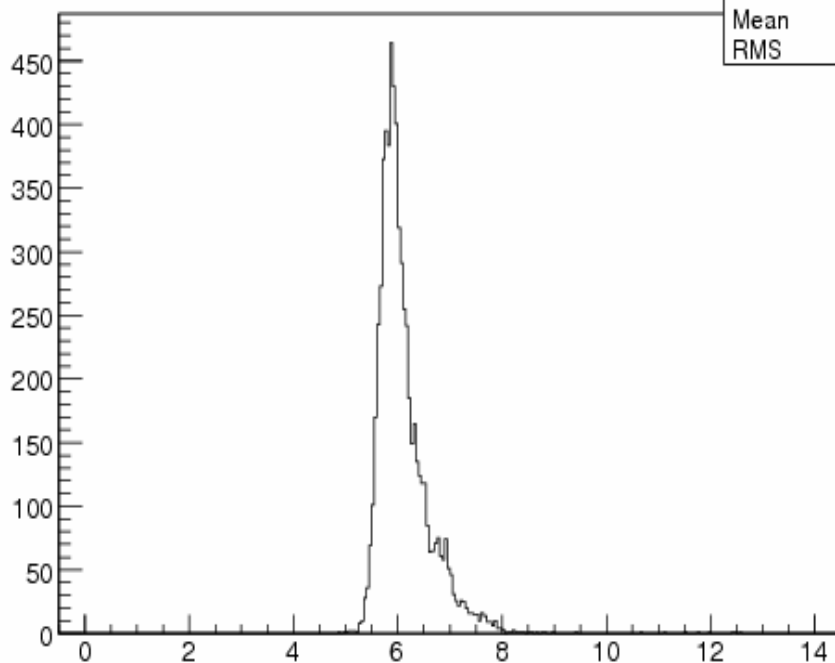
→ Corrections are doing
their job pretty well !!

Noise after all corrections

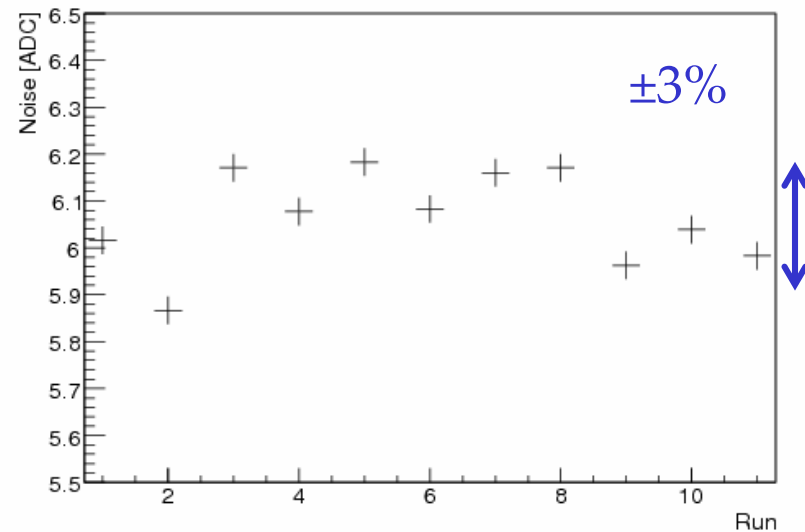
Extracted from 11 runs
at different energies

Mean noise @ CERN

Noise



Noise stability

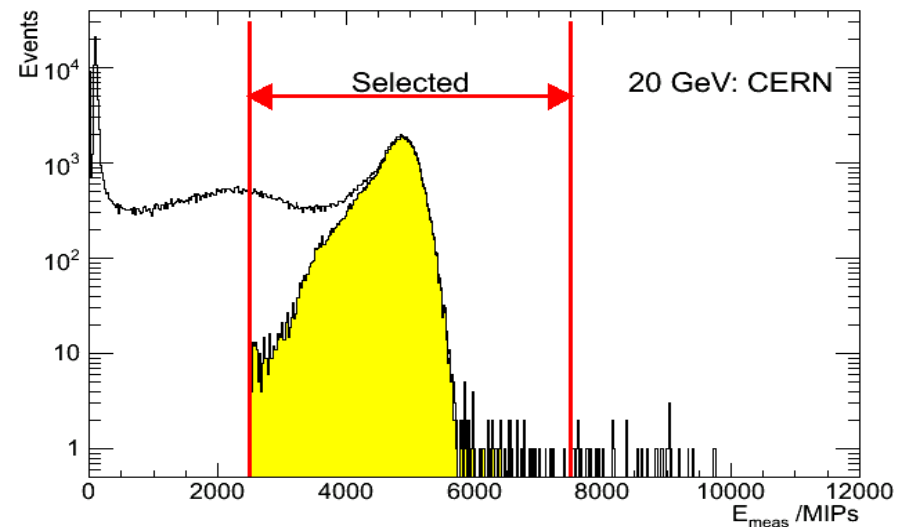
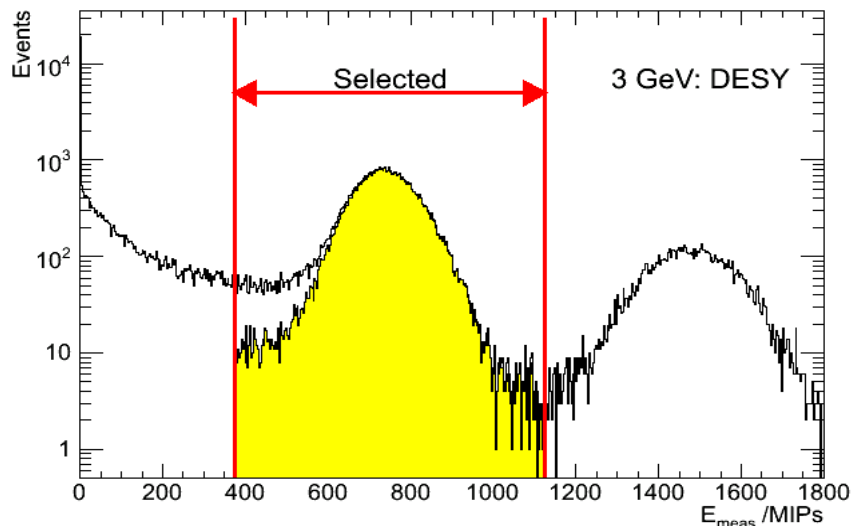


IV- Electron selection

- Triggering : coincidence of 3 scintillators along the beam line.
- Signal threshold: 0.6 MIP
- Selection of single electron events:

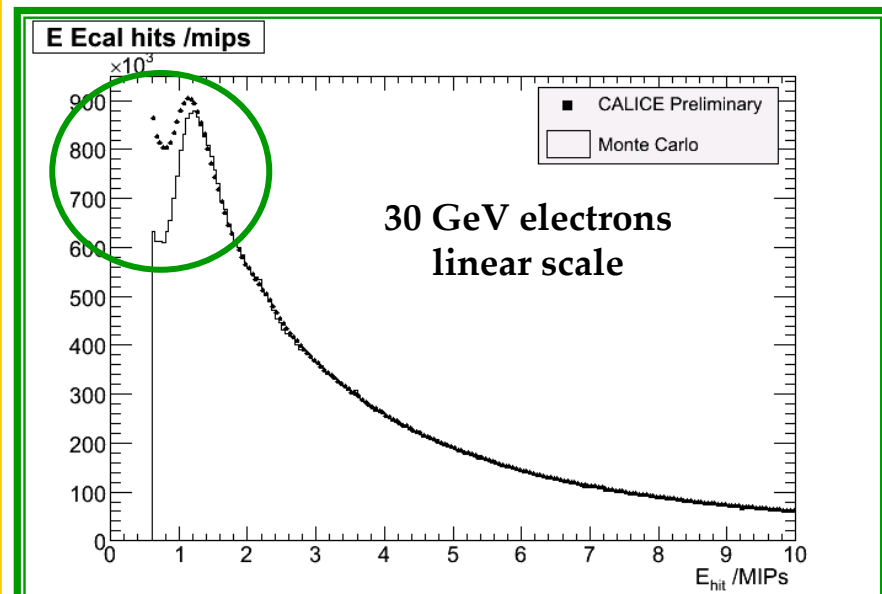
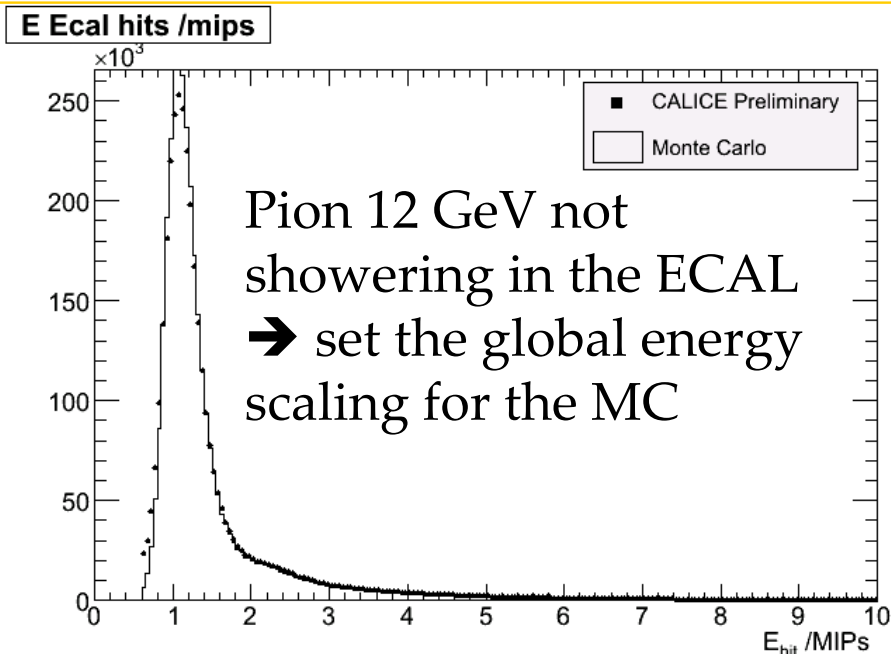
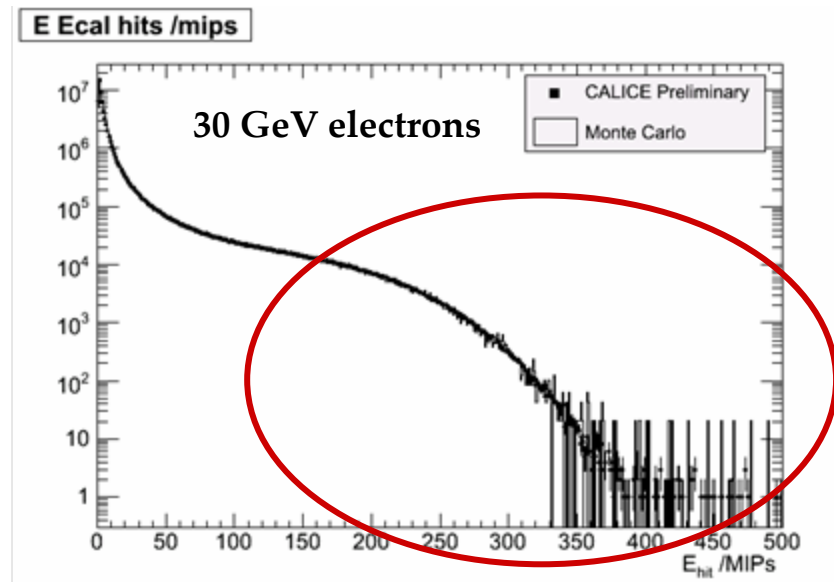
$$125 \times E_{beam} < E_{tot} \left(= \sum_{l=1}^{10} E_l + 2 \times \sum_{l=11}^{20} E_l + 3 \times \sum_{l=21}^{30} E_l \right) / MIP < 375 \times E_{beam}$$

- CERN: Čerenkov counter to remove pion contamination
- DESY : shower barycentre in the region expected from the beam profile.

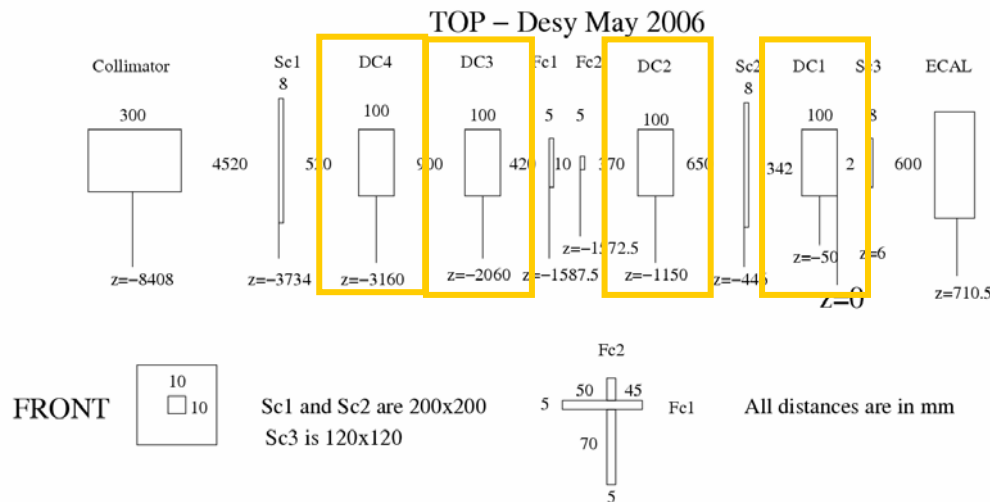


Data/MC comparison

- High energy tails very well reproduced, also up to 1.5 MIP
- Low energy disagreement not yet understood, under investigation
- But little influence on the total energy
 → present analyses based on the energy.

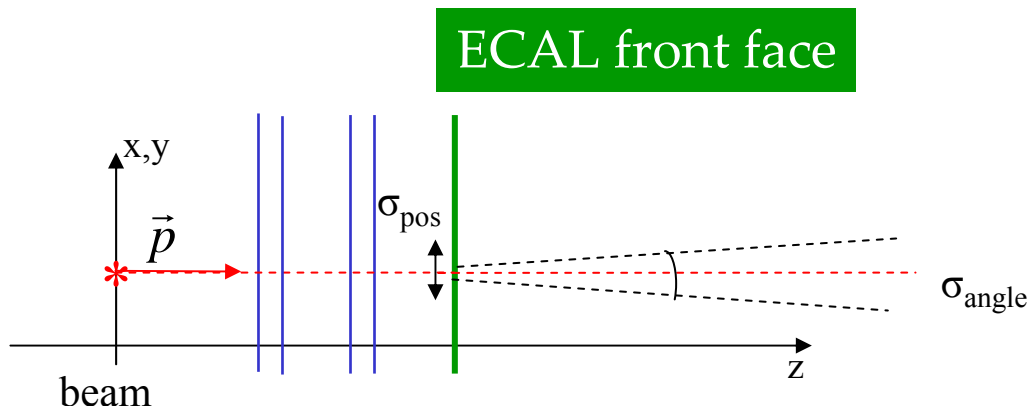


- In view of extracting the ECAL resolution, need to subtract the tracking resolution
- Tracking: best linear fit with 4 chambers is considered to give the expected position and direction at ECAL front face.
- Error matrix contains intrinsic chambers resolution and scattering in front of the ECAL.
- Systematic errors in extrapolation to ECAL front face directly affects ECAL performance:



For 1 GeV Beam Energy - DESY		
Source of error	Position (mm)	On Angle (mrad)
Simulation statistic	0.02	0.02
residual misalignment	0.16	0.02
material modelling	0.13	0.23
Intrinsic resolution	0.05	0.03
Background rate	0.05	0.14
total	0.22	0.27

Results for the tracking resolution

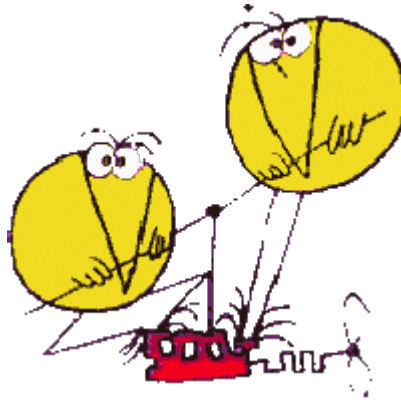


Track resolutions in x @ ECAL front face		
Ebeam	Position (mm)	Angle (mrad)
1 GeV	1.68 ± 0.22	2.48 ± 0.27
2 GeV	1.00 ± 0.12	1.34 ± 0.13
3 GeV	0.81 ± 0.09	0.92 ± 0.09
4 GeV	0.72 ± 0.07	0.73 ± 0.07
5 GeV	0.66 ± 0.06	0.62 ± 0.06
6 GeV	0.60 ± 0.06	0.53 ± 0.05

Introduction's conclusions

- Testbeams 2006 have been a **complete success**:
 - **discovery of hardware problems**:
 - capacitance issues giving raise to so-called “square events”,
 - Importance of compensating power supplies for the stability of pedestal lines,
 - ... and more to come ! Crosstalk issue affecting pedestals at wafer scale ??
 - **exercise real life detectors and data handling**: e.g. GRID setup, reconstruction software, simulation and digitisation issues.
 - allowed to **improve already the detector simulation models**.
 - Lots of data taken, with a full spectrum in energy, angle, position
- Really good training for coming testbeam with a completed prototype : summer 2007, starting in 3 weeks.
 - learning from our mistakes : even more efficient shift organisation + faster analyses and feedback expected.
- **Preliminary results on performance presented by C. Carloganu right now !**

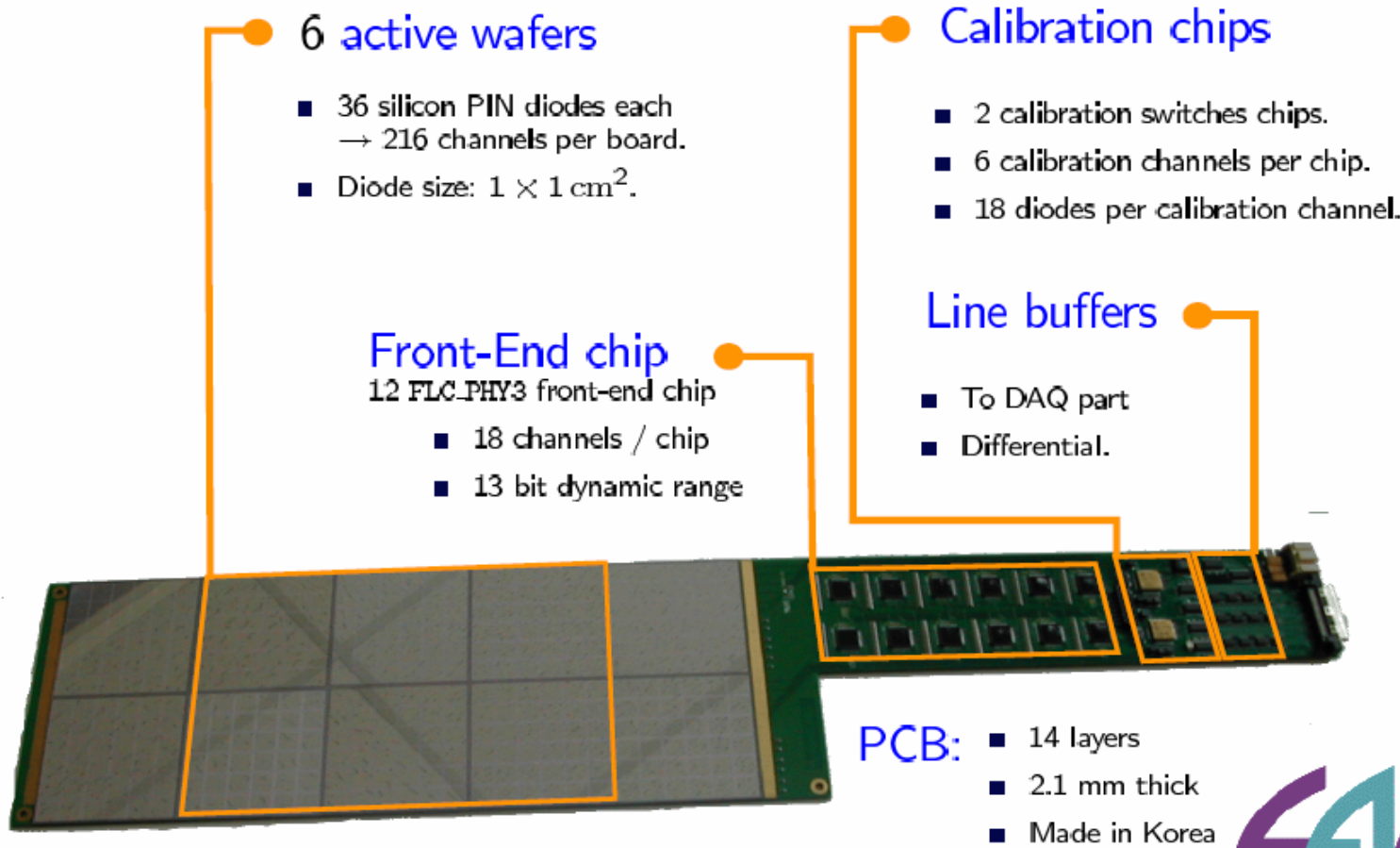
Thank you for your attention



Backup

Detailed view of ECAL PCB

ECAL board



noise after corrections

