First Results of the TOTEM Roman Pots

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on behalf of the **TOTEM Collaboration**

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Outline

The TOTEM experiment
physics programme
detector requirements
the Roman Pot system

Edgeless Silicon Detectors with Current Terminating Structure
concept and characteristics
performance studies

Roman Pot Production Tests

First LHC results

TOTEM Experiment – Detector Requirements

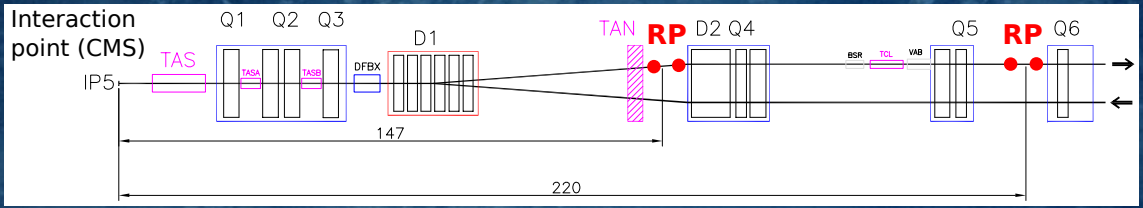
TOTEM physics programme

- total pp cross-section
- elastic scattering
- hard and soft diffraction

} detection of very forward protons
$\Downarrow$
special detectors needed: Roman Pots

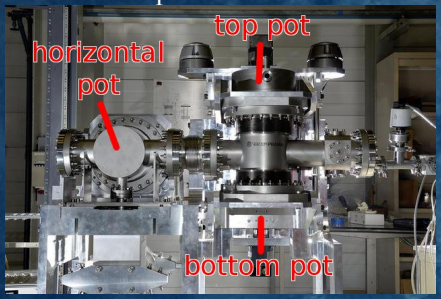
TOTEM Roman Pots

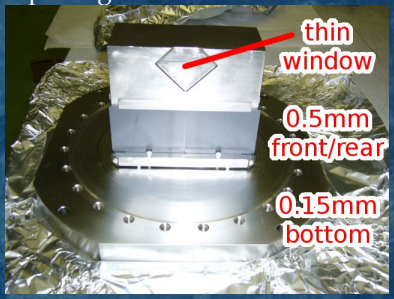
- stations at 147 m and 220 m on both sides of IP
- movable beam-pipe insertions
  – as close to the beam as safe ($\approx 10\sigma$)
  – retracted when beam instable

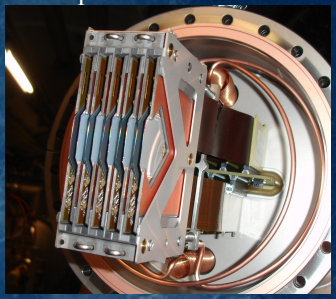


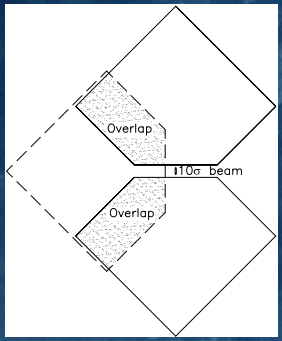
The Roman Pot System

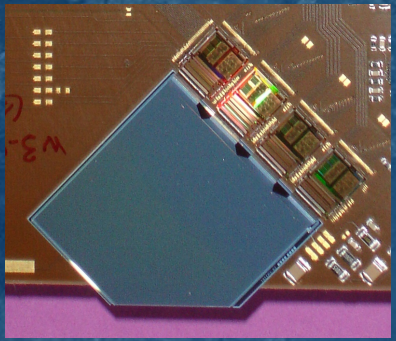
- each station has 2 units
- each unit has top, bottom and horizontal pot
- each pot contains a detector package
- each detector package comprises 10 Si detectors

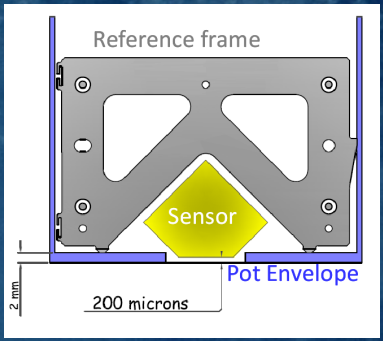






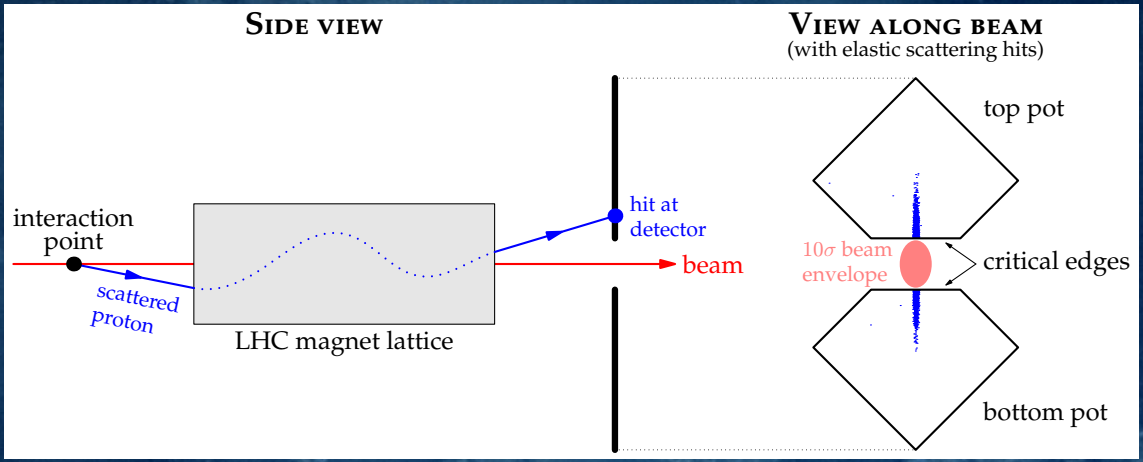






- overlap crucial for alignment

The Requirements for Sensors



maximization of acceptance for low scattering angles

⇓

detectors as close to the beam as safe

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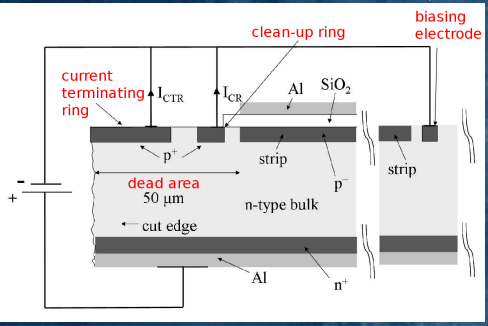
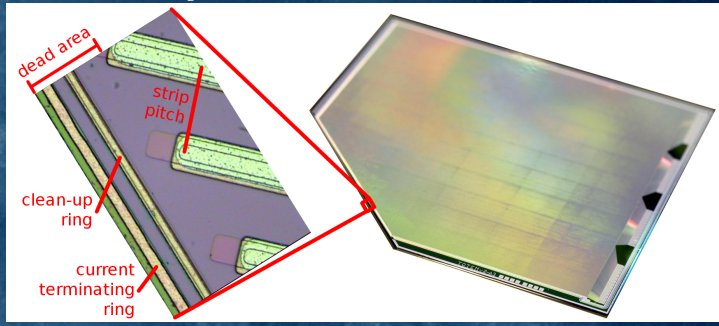
narrow insensitive edge needed

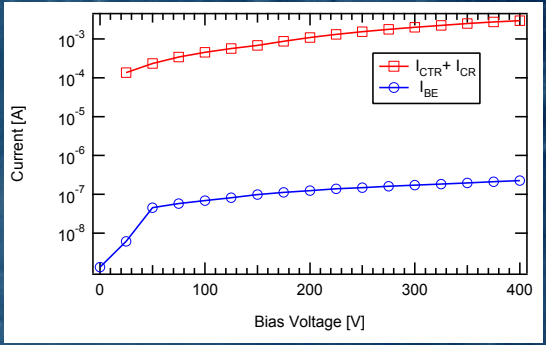
Edgeless Silicon Detectors with CTS

(CTS = Current Terminating Structure)





- TOTEM design
- very high resistivity Si n-type $\langle 111 \rangle$
- 300 μm thick, $V_{\mathrm{dep}} = 20$ V
- standard planar technology fabrication / dicing with diamond saw
- single sided detector, 512 microstrips (pitch 66 μm)
- pitch adapter on detector (VFAT / APV25 compatible)
- strips at 45° from the sensitive edge
- AC coupled (punch-through)
- only ≈ 50 μm of dead area (standard technology $0.5 \div 1$ mm)



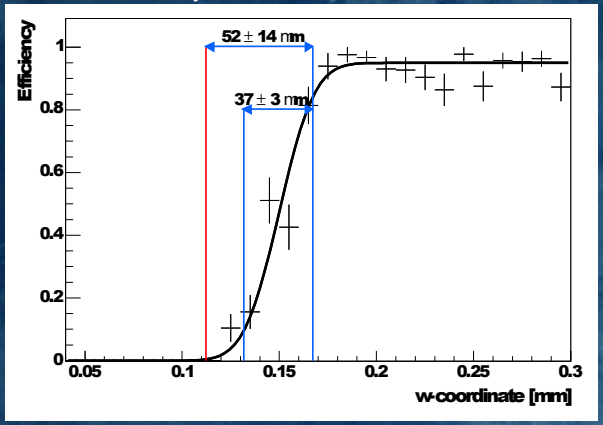
Silicon Detector Prototype Tests

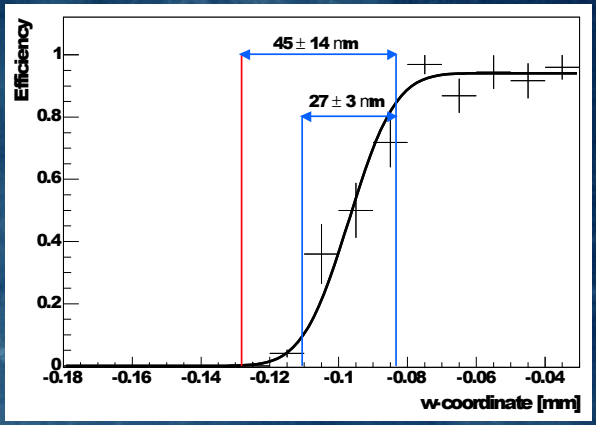
(details will be soon published in paper "Reconstruction Performance of Silicon Detectors with Reduced Edge Insensitive Volume Manufactured in CTS and 3D-Planar Technologies" by the TOTEM collaboration)

- muon beam, analogue readout with APV25
- alignment: metrology + software $\rightarrow$ 1 μm precision
- tracking uncertainty < 10 μm

Edge Efficiency

- efficiency curves for two of the test detectors

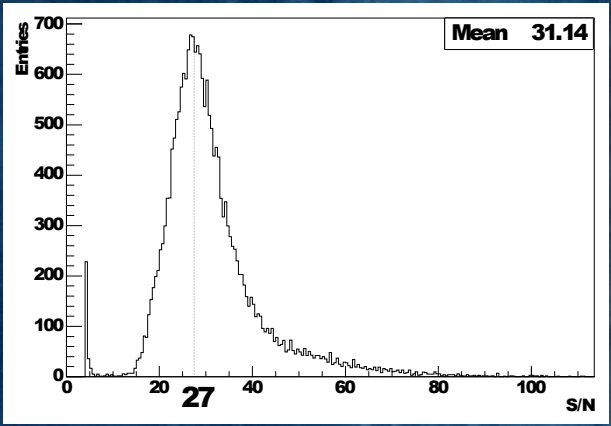




- w coordinate perpedicular to the edge
- red line represents the physical edge
- 10% $\div$ 90% rise (region with blue boundary) found in range 30 $\div$ 40 μm
- plateau at about 95% because of unbonded/noisy strips

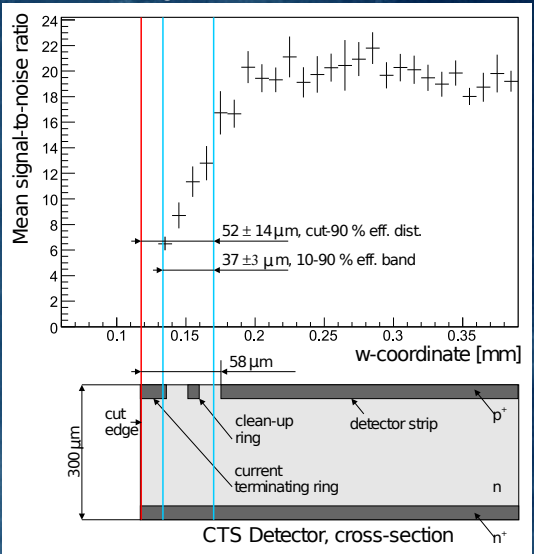
Signal to Noise

- signal-to-noise ratio histogram



– good noise/signal separation

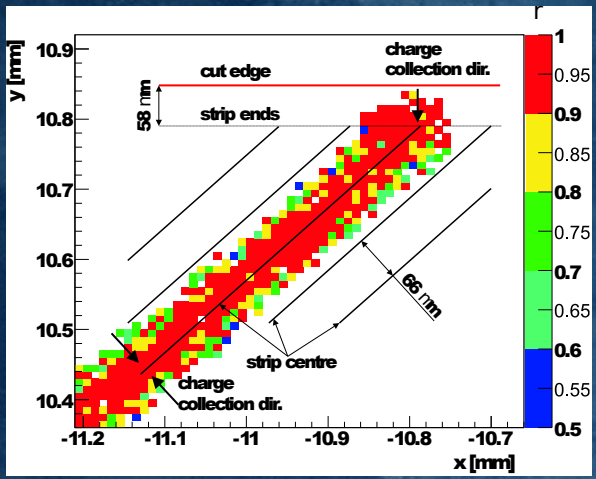
- signal-to-noise as a function of distance from the edge (w)



– the "dead" area is partially efficient

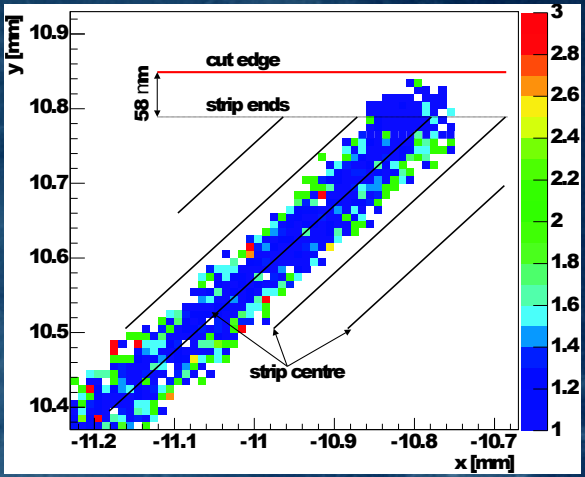
Charge Sharing and Cluster Size

- ratio $Q_{\text{main strip}}/Q_{\text{cluster total}}$



- hits close to a strip center: most charge collected by the strip
- hits between strips: reduced ratio, i.e. increased charge sharing

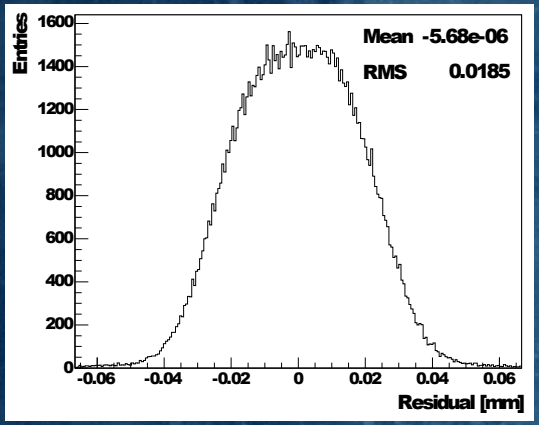
- mean cluster size



- hits close to a strip center: mostly one-strip clusters
- hits between strips: larger clusters

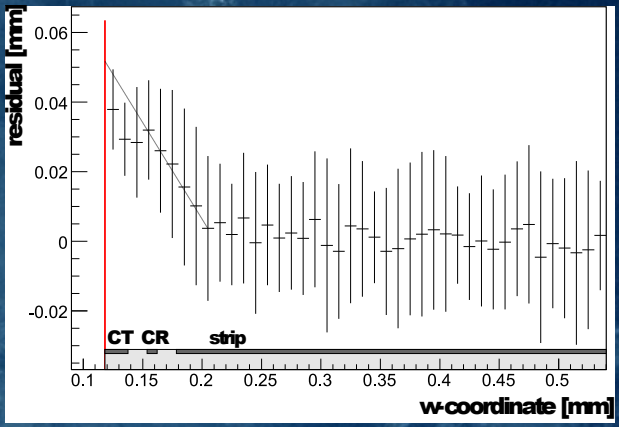
Track Reconstruction

- distribution of residuals in a test detector (residual = recon. hit - reference track)



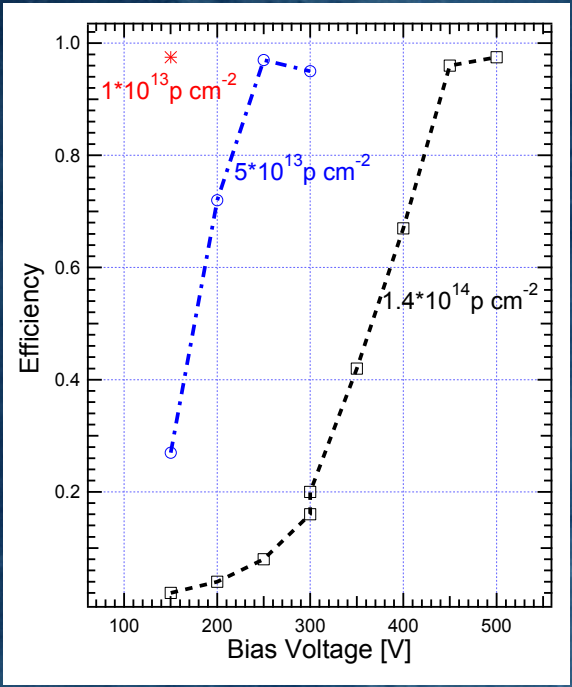
– std. deviation close to the expected value $66\ \mu\text{m}/\sqrt{12} \approx 19\ \mu\text{m}$

- mean residuals as a function of distance from the edge (w)



– small bias ($< 40\ \mu\text{m}$) close to the edge, fully correctable

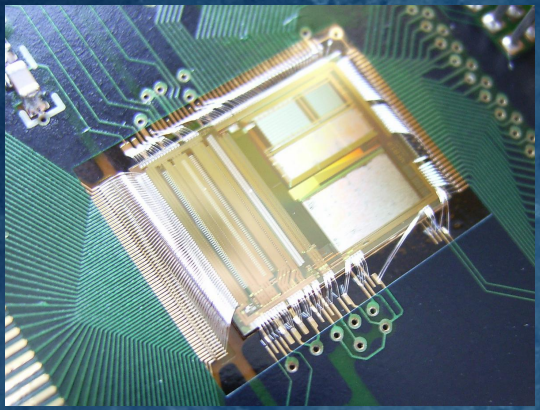
Irradiation Tests

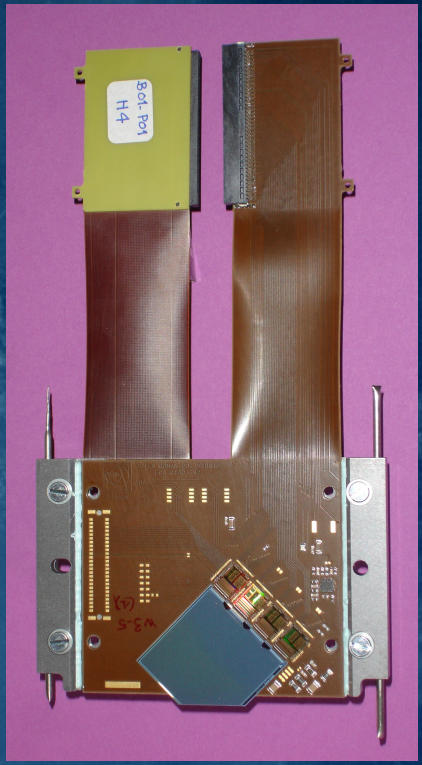


- detectors irradiated with 24 GeV protons
- no efficiency decrease for irradiation below 10^{13} $\mathrm{p \cdot cm^{-2}}$
- higher bias needed to reach full efficiency for irradiations above 10^{13} $\mathrm{p \cdot cm^{-2}}$

Final Electronics System

- custom-developed front-end chip: VFAT2
  - digital
  - trigger capability
  - 128 channels (4 chips per sensor)
  - 256 clock cycles memory
  - used for all TOTEM sub-detectors (also T1 and T2)
- and much more (backup slide)

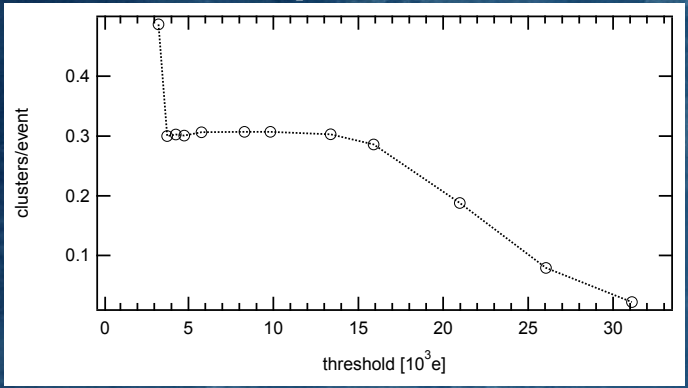




Production Tests 2007-2009

- every detector package tested
- with final electronics
- with muon beam/with cosmic rays

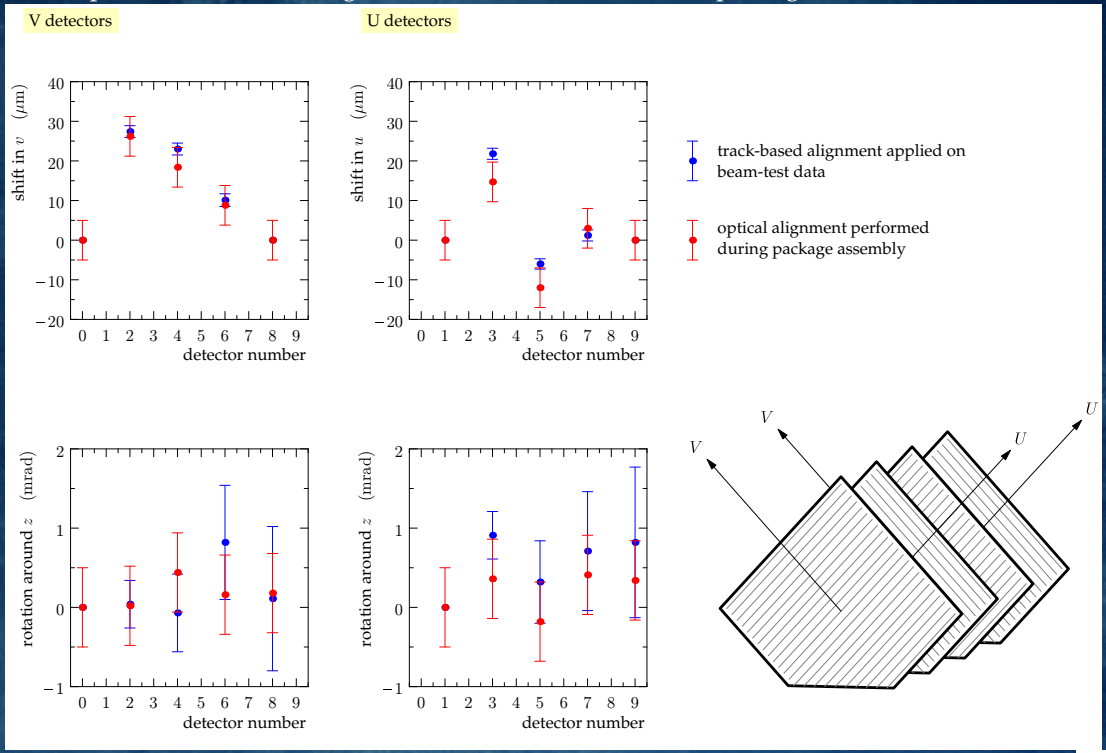
- threshold scan with pion beam



– noise stops at $\approx 3\,000$ e
– plateau up to $\approx 15\,000$ e
– efficiency reduced to about half at $22\,000$ e
– with noise maximum around $1\,000$ e $\Rightarrow$ signal-to-noise between 20 and 25

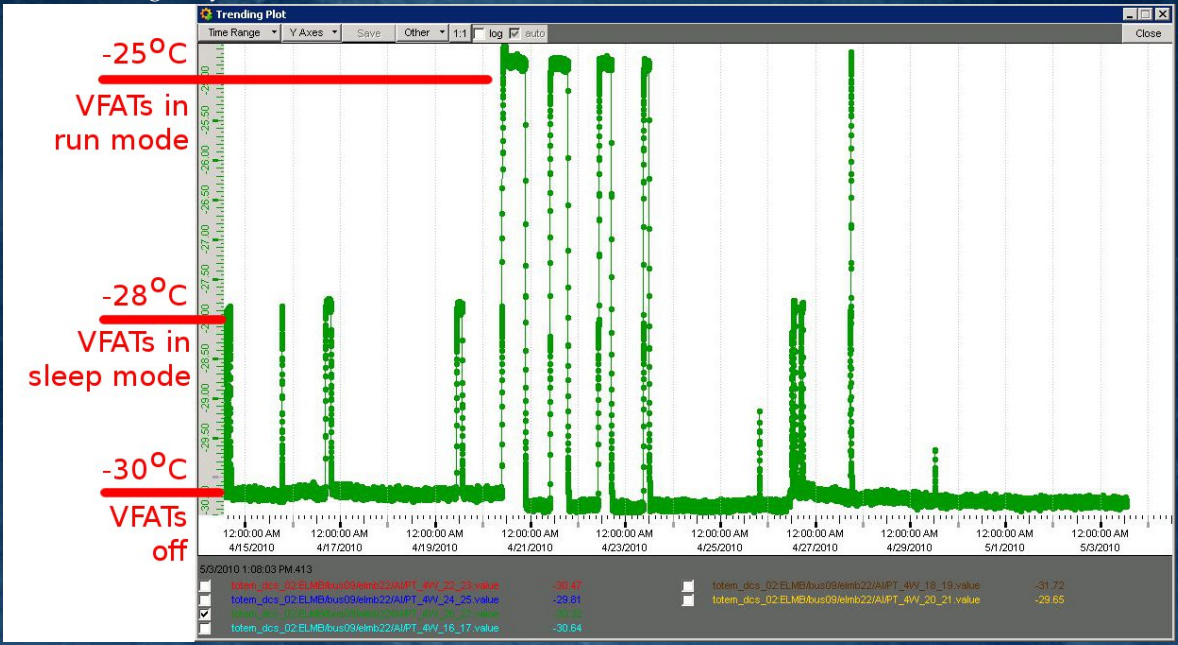
Internal Alignment

- comparison of internal alignment results for one detector package



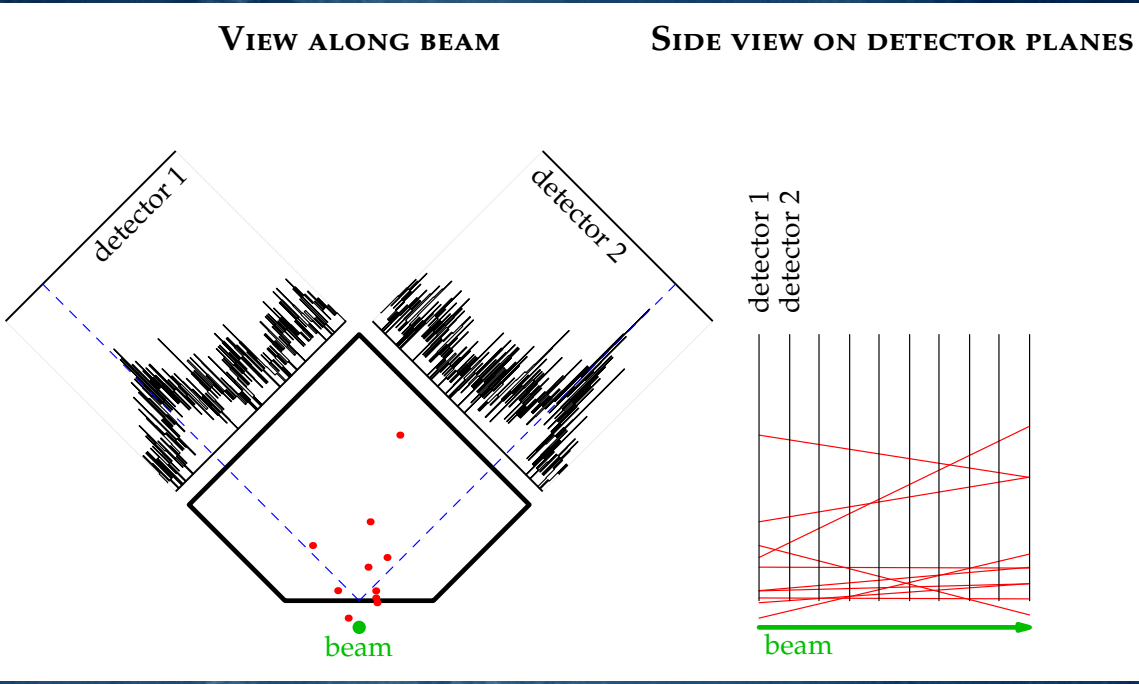
Cooling

- cooling fully functional



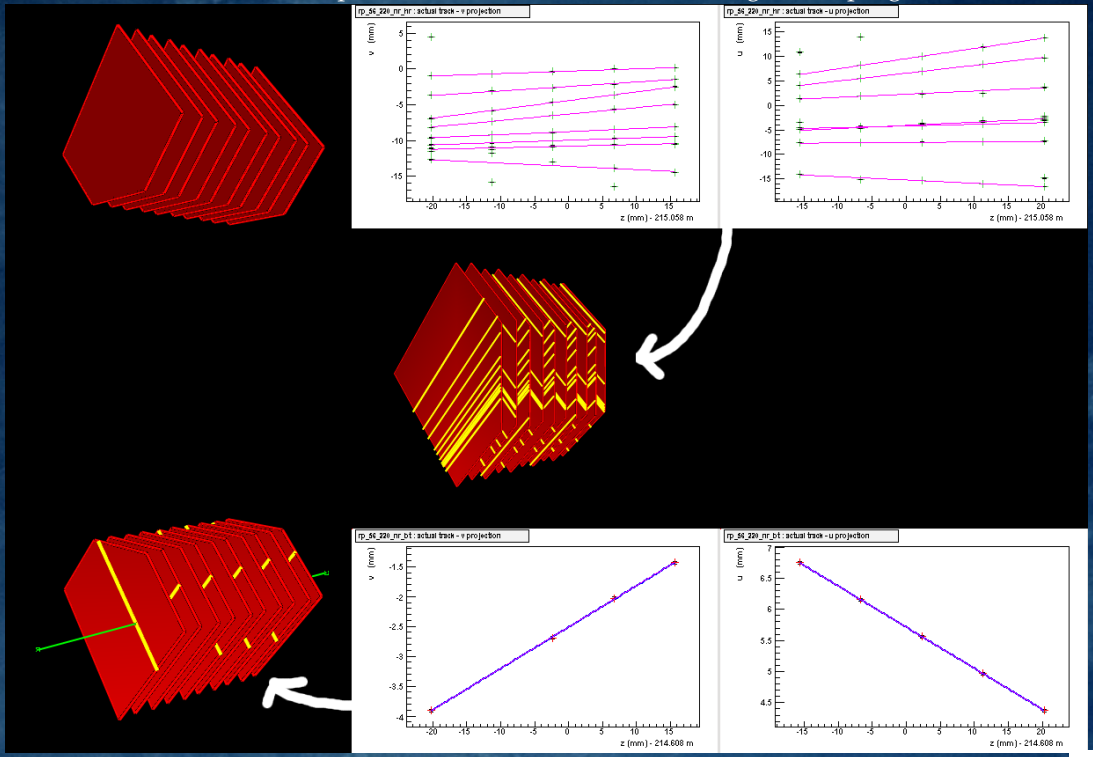
First LHC Data, December 2009

- pot edge at about 4.5σ from the beam



Recent LHC Data, April 2010

- showers seen in retracted position (movement commissioning still in progress)



Summary & Outlook

- both stations at 220 m fully equipped and installed
  - 99% of channels working
  - first data taken and analyzed (commissioning)
  - ready to take physics data
  - Roman Pot position calibration – precondition for routine RP insertions

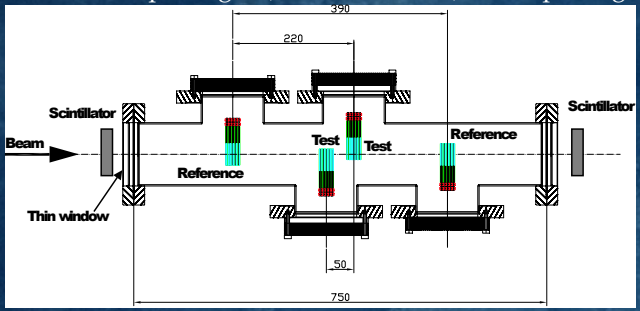
- detectors for stations at 147 m in production/under test

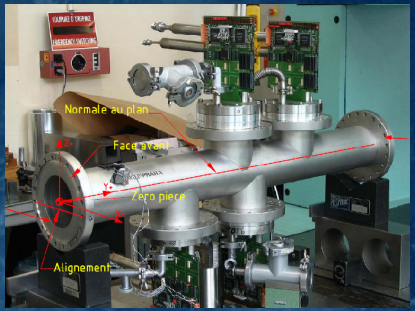
Backup slides

Silicon Detector Prototype Tests

(details will be soon published in paper "Reconstruction Performance of Silicon Detectors with Reduced Edge Insensitive Volume Manufactured in CTS and 3D-Planar Technologies" by the TOTEM collaboration)

- muon beam, $\approx 4 \cdot 10^5$ events, analogue readout with APV25
- 2 reference packages (track definition), 2 test packages





- careful alignment
  - metrology
  - software alignment (shift in read-out direction, rotation around beam, edge position)
  - eventually 1 μm precision
- track interpolation in test packages: uncertainty $< 10\ \mu$m

Final Electronics System