2007 Test Beam Analysis of 3D stc Detector

Joint 2007 beam test with Trento, Glasgow, Freiburg

Detailed analysis by Gregor Pahn (in NZ now) et al.

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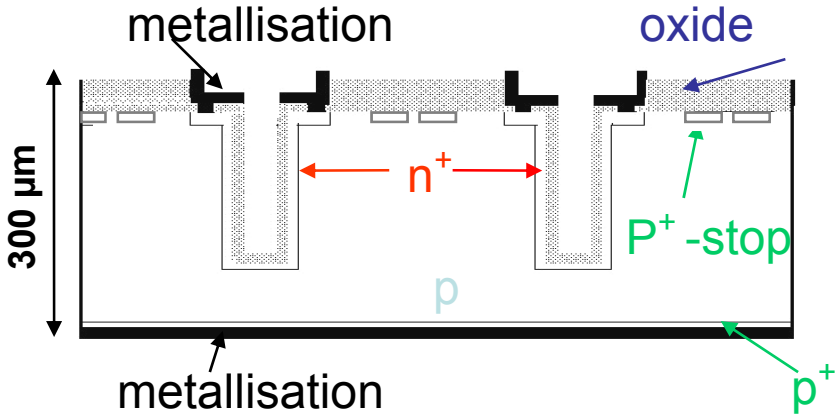
Overview

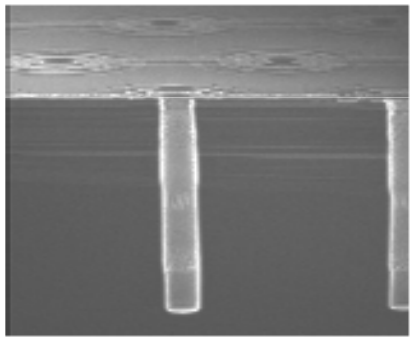
- 3D stc strip detectors
- Test beam set up & module
- Synchronisation issues
- Analyis
  - Signal shapes
  - Efficiencies
- Conclusions

3D-stc design

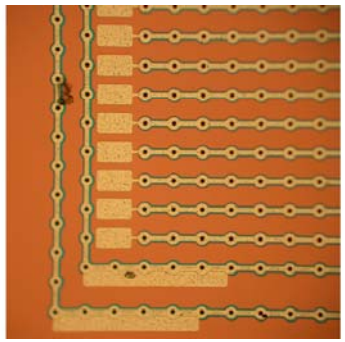
- 3D-stc: single type columns, not completely etched through
- Simplification of processing
  →higher yield, lower price
- Problem: low field region in the middle between 2 strips
- Important step to optimize technology and study charge collection mechanism in different field configurations



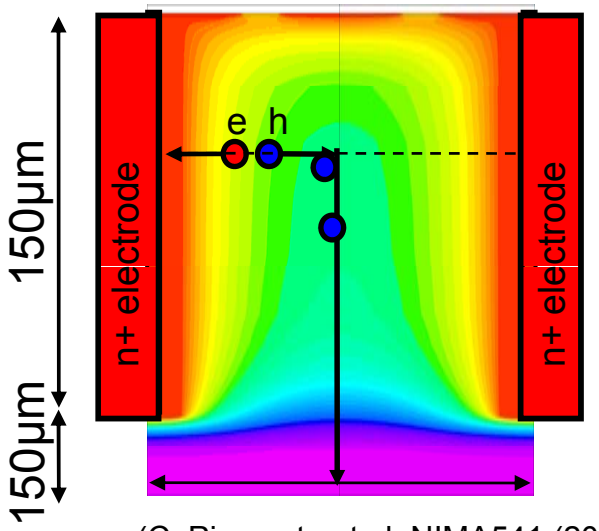
Sensors in the lab (microscope close-up)



cross-section



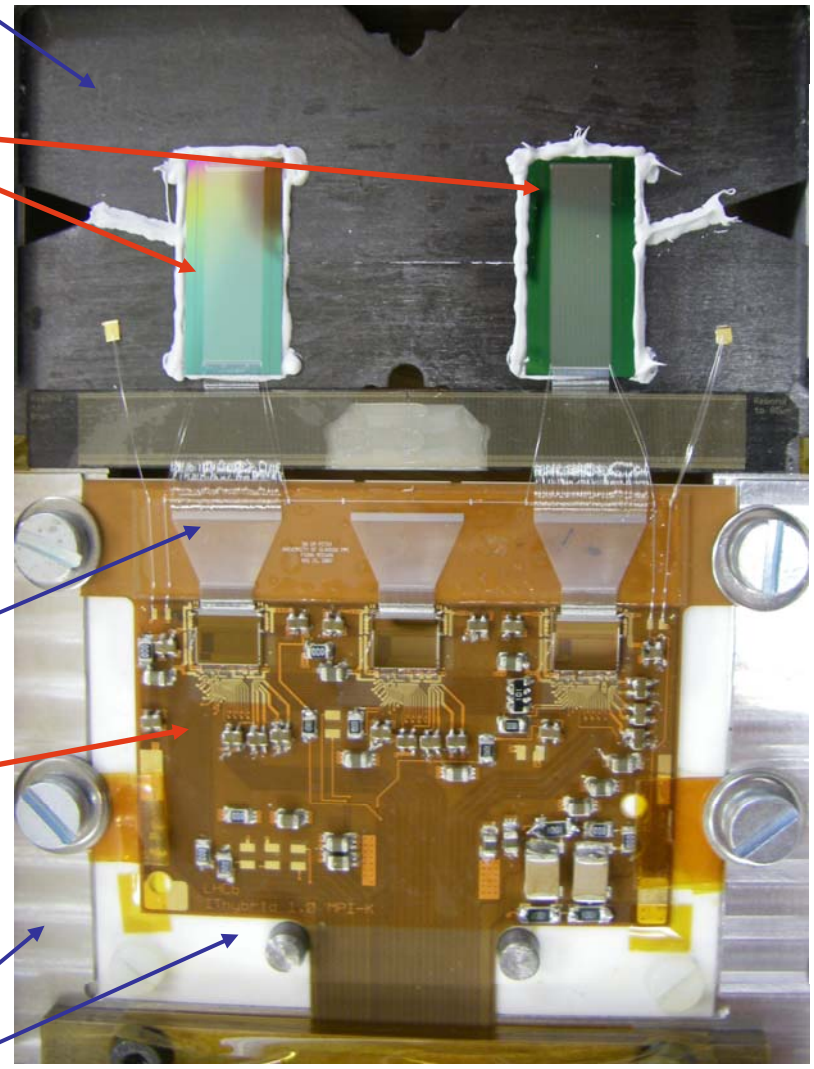
top view



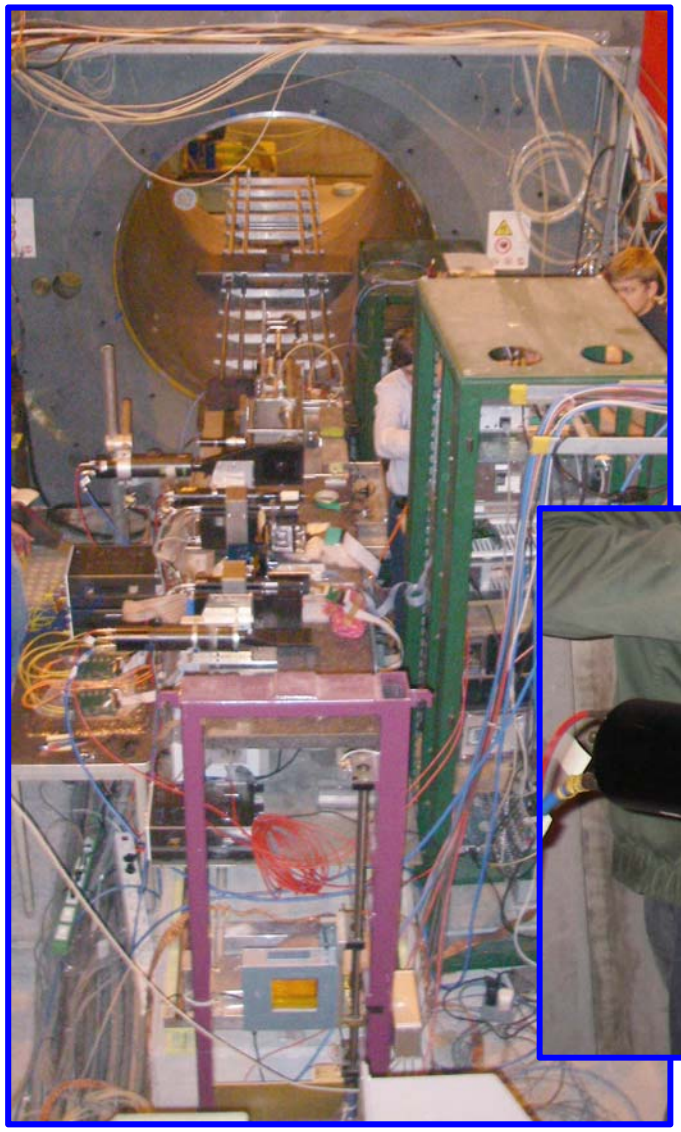
(C. Piemonte et al. NIMA541 (2005))

Devices under test

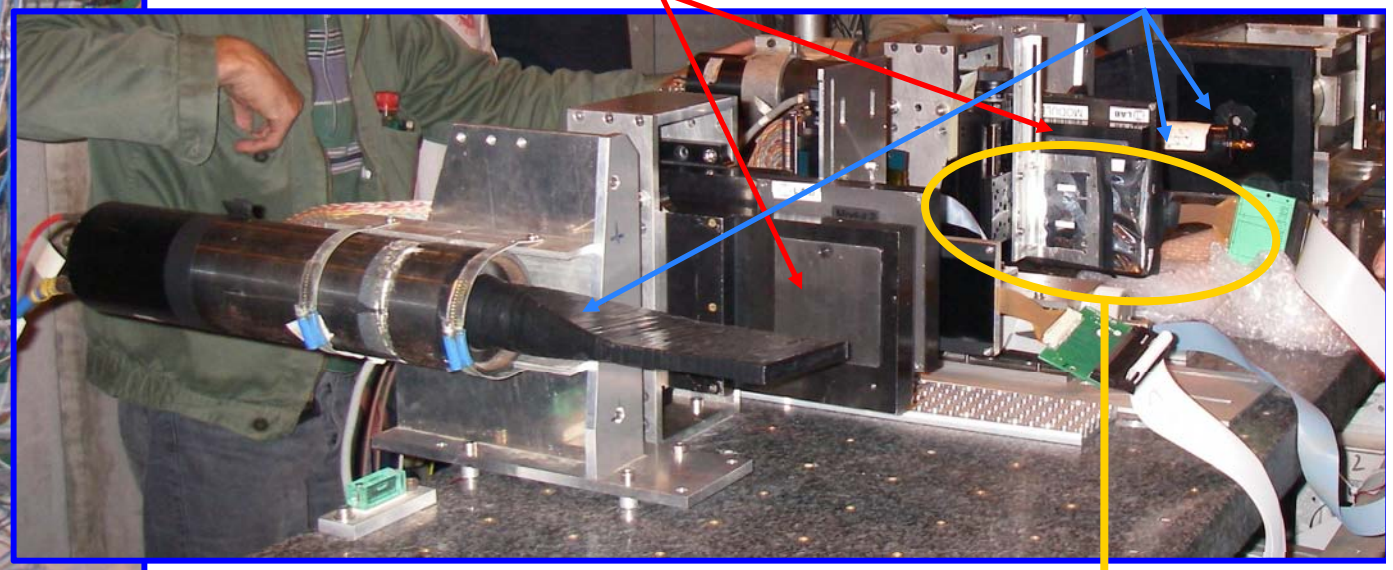
- Sensors
  - 3D-stc n^+-on-p mCz microstrip devices from FBK-irst, Trento
  - Thickness: 300μm / 380μm
  - Strips: 64 per sensor, length 18.4mm, pitch 80μm
  - Isolation: p-spray / moderated p-spray
  - Columns:
    - pitch 100μm (intra-strip)
    - Pitch 80μm (inter-strip)
    - depth 150μm
- Readout
  - Analogue 40MHz LHCb hybrid
  - Shaping time 25ns
  - 5 consecutive time bins read & stored



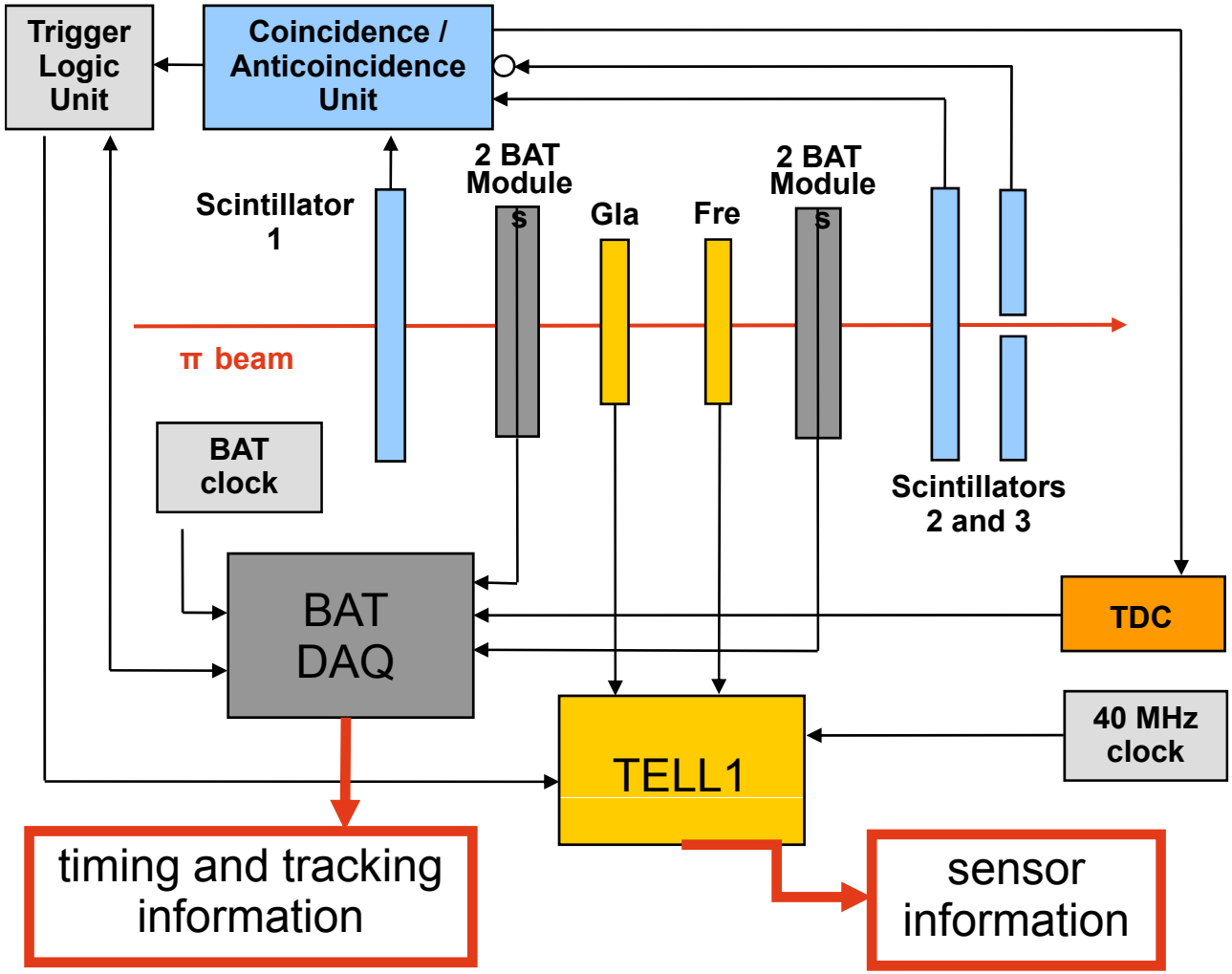
Test beam setup



- ATLAS 3DSi test beam 2007 at CERN H8 area
- This work: close collaboration with Glasgow
- 180 GeV π beam
- Bonn ATLAS Telescope (BAT), 5μm resolution



Setup schematic (simplified)

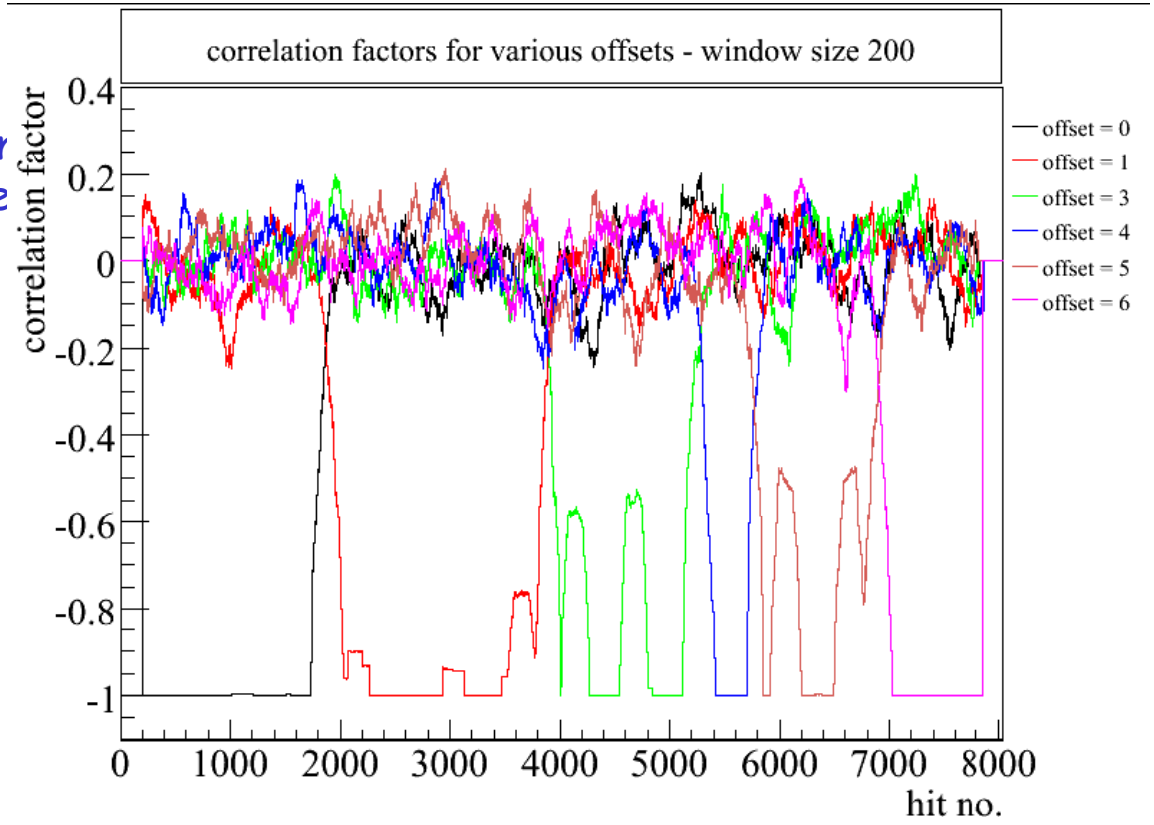


- Two 3D devices under test on Freiburg module, but data only from 300µm p-spray 3D
- Planar reference detector on Glasgow module
- Telescope/TDC and sensor separately read out
- Triggered by scintillators
- Active sensor area very small →use 3rd scintillator as veto

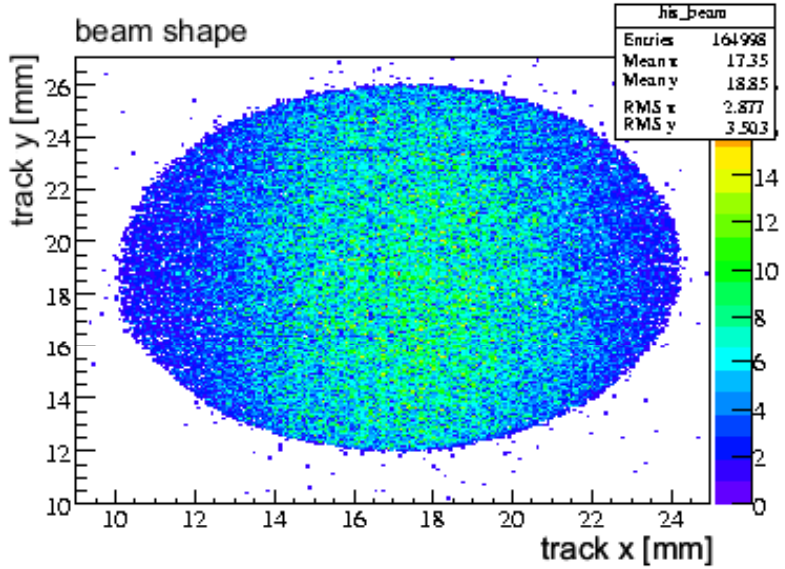
Loss of synchronisation

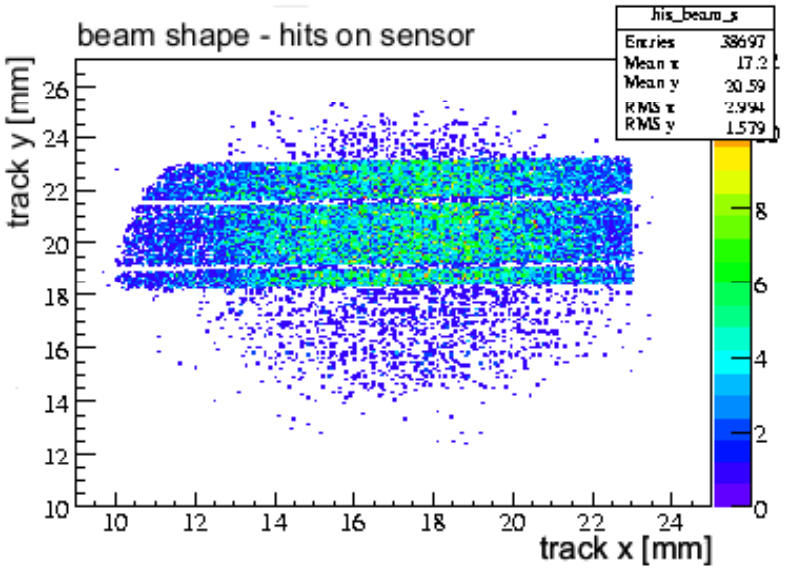
- **Data corruptions due to malfunctioning Trigger Logic Unit**
  - Telescope and sensor get out of synchronisation → wrong timing and tracks
  - Telescope modules also internally out of sync → track calculation difficult

- Detecting trigger losses
  - Telescope track coordinate ar hit position on sensor must be correlated
  - Calculate correlation factor for a window of 100 hits
  - Scan run for correlation loss (running window) →upper limit
  - Scan backward with trigger offset →lower limit
  - Discard unreliable events between limits and continue scan with trigger offset

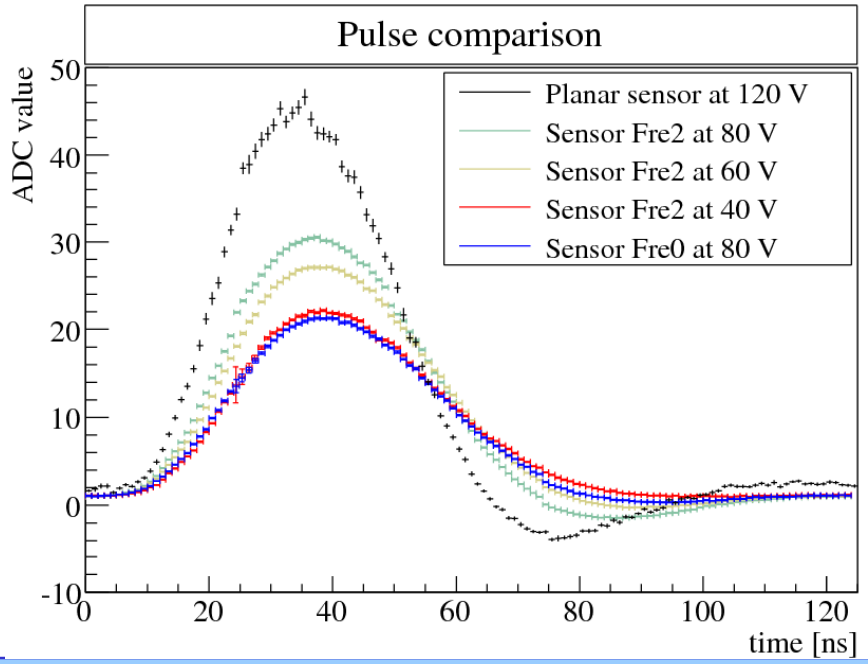


Beam Shape



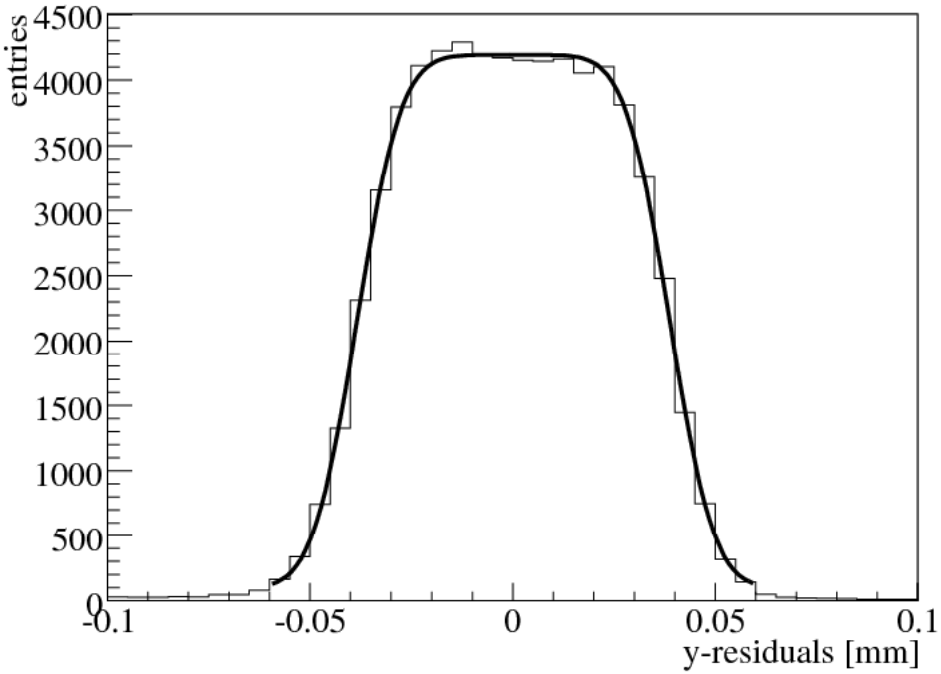


- Round beam spot defined by 3rd (veto) scintillator
- 3D detector almost fully illuminated
  - one edge is not -> problem
- Reconstruct pulse shape even without tracking



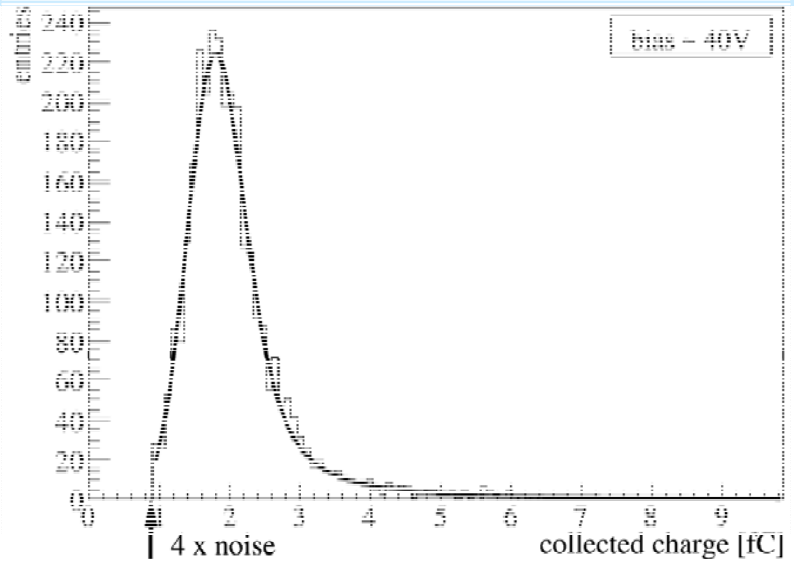
Alignment

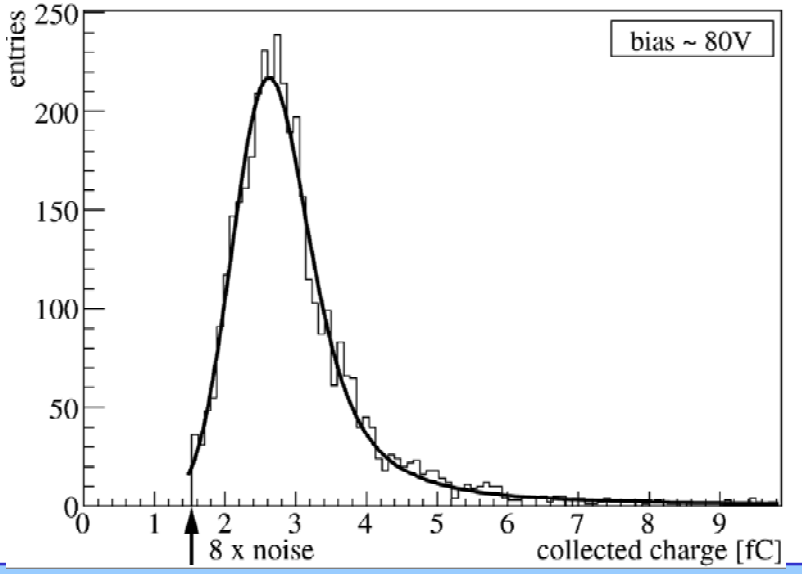
- Use tracks to align 3D
- Alignment not perfect but sufficient
  - (track extrapolation error 8.6 ± 0.2 µm)
  - likely cause: minor bugs in tracking
- Residual distribution well described by Gaussian folded with rectangle
- Residual rms: 26 µm
  - 23 µm expected for binary readout (no charge sharing)



Signal

- Signal increases with bias voltage
- SNR is reasonable
- 3D is depleted at 80V, with signal level at ~70% of planar detector
- Comparable to signal seen in β-source measurements presented at IEEE Dresden
- Suspect ballistic deficit/ charge loss from low field regions

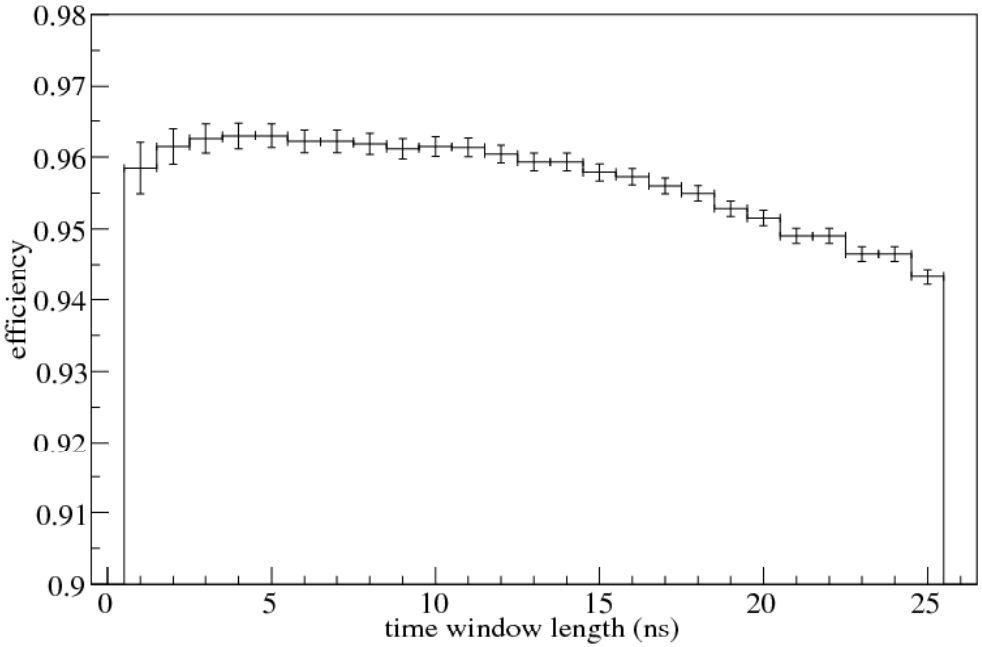




Bias voltage	Noise	Collected charge	SNR
40 V	1.4 ke$^-$	(1.67 ± 0.01) fC	7.5
60 V	1.2 ke$^-$	(2.13 ± 0.01) fC	11
80 V	1.1 ke$^-$	(2.46 ± 0.01) fC	13.2

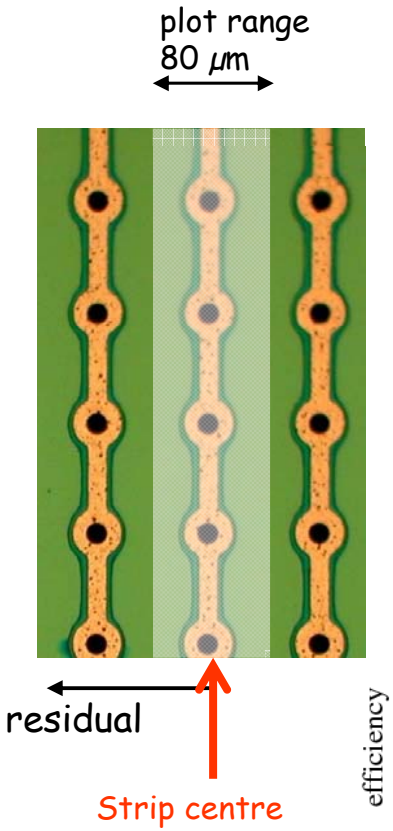
Global efficiency

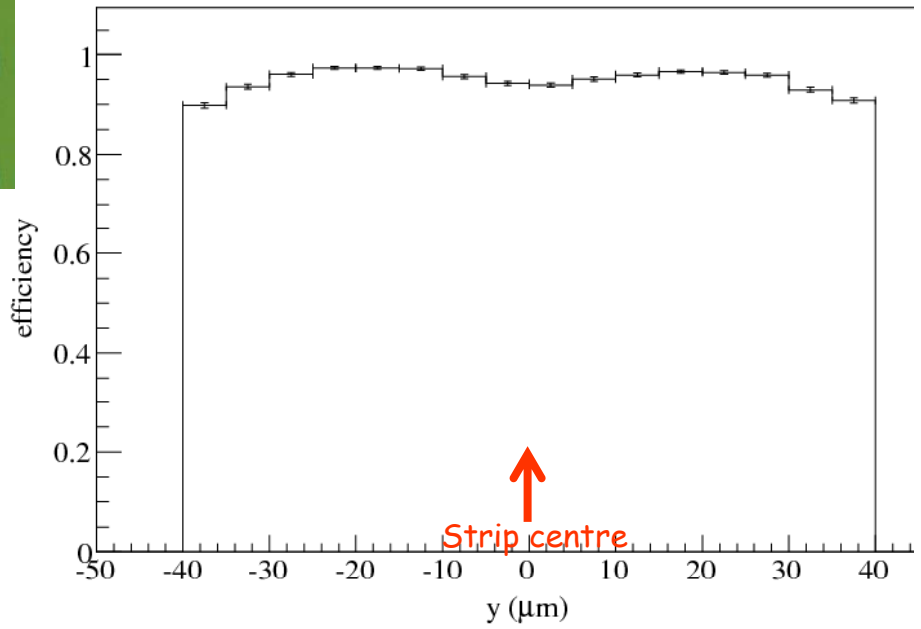
- From simulations and laser measurements expect local signal variations – let's start global
- Average eff. over entire sensor area to get figure of merit.
  - Global efficiency 96%
- Timing issue:
  - eff. depends on timing
  - Max eff. at pulse peak
- Efficiency reaches 98% in some regions even at 40V bias with 1fC signal cut (S/N cut ~ 4)
- All eff. plots for 40V



Efficiency in Beam Test

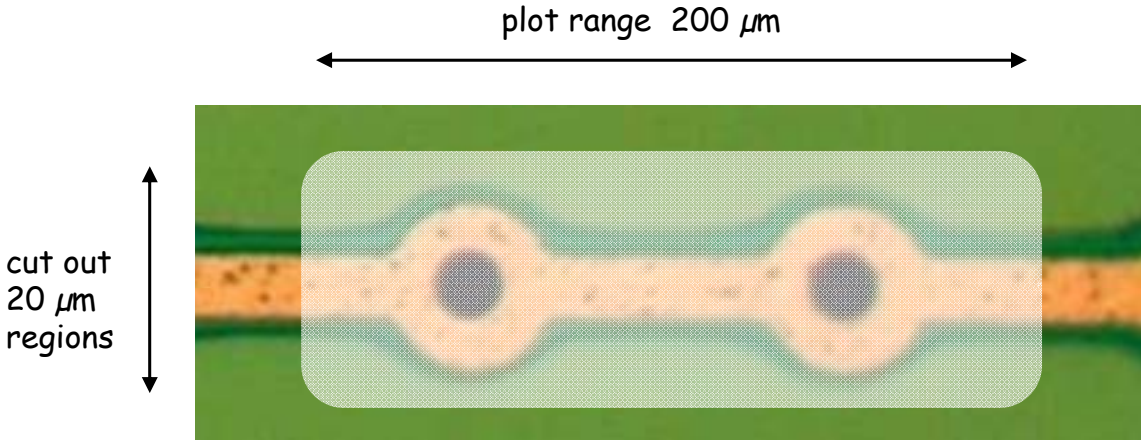
- Alignment much better orthogonal to strips due to small beam shape
- Study 1-D efficiency orthogonal to strip
  - number of hits on 3D matched to tracks as a function of distance to strip centre
  - map entire detector onto one strip
- Low efficiency at
  - large distance to strip: **low field region**
  - strip center: **no charge deposition in hollow columns**

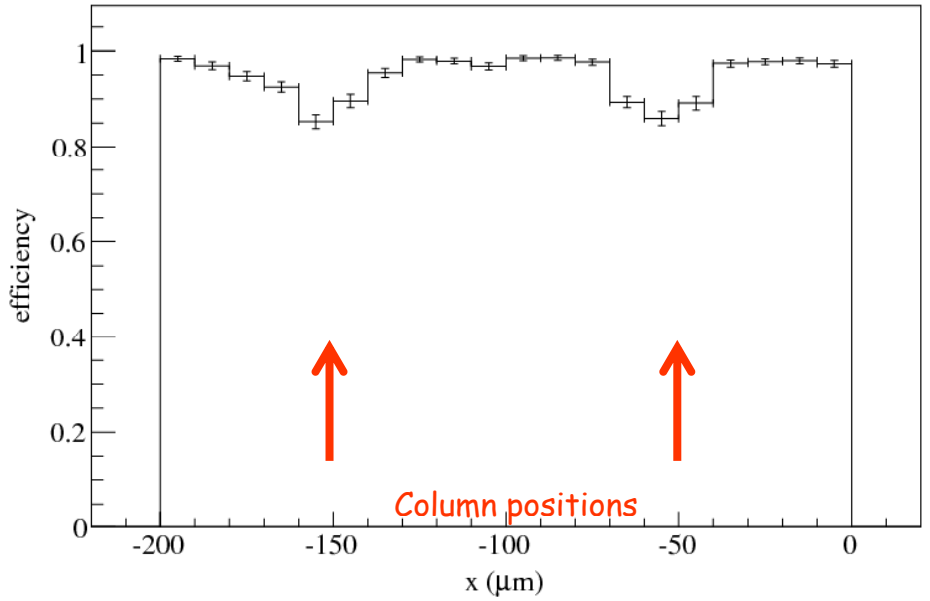




Efficiency in Beam Test

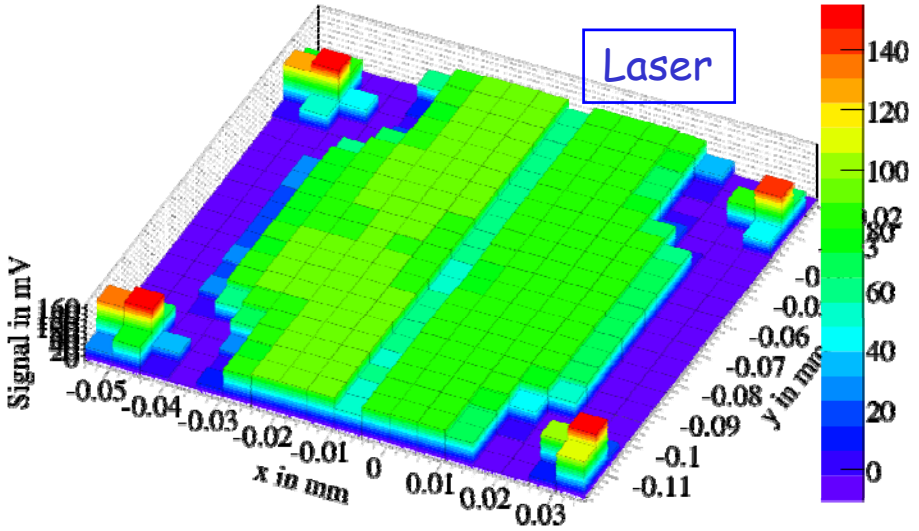
- Can also study 1-D efficiency parallel to strip
  - "Looking for columns"
  - Restrict to hits 10µm each side of strip centre
  - Map 20µm wide bands from entire detector onto 200µm long cell
  - Structure with 100µm spacing is visible, but washed out due to
    - Track Resolution
    - 2.5°Tilt angle and angle uncertainty
  - **Columns have lower efficiency**

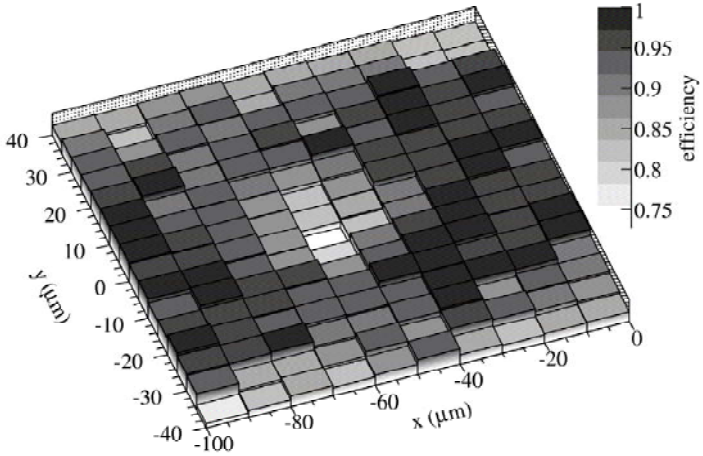


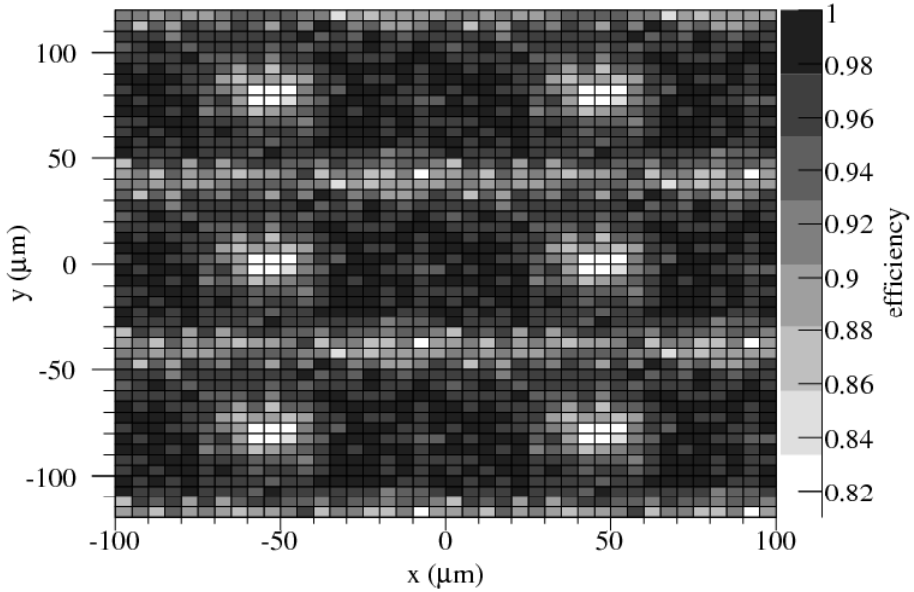


2D Efficiency Map

- Efficiency map in 2D
- Map all data onto one unit cell
- Re-plot unit cell six times
- Reduced efficiency at columns and inter-strip region







Conclusions

- 2007 test beam analyis complete and ready for publication
- 3D stc strip detectors now well understood
- Probably near the end of 3D stc work
- 2008 test beam with 3D ddtc
  - different set-up (Helsinki CMS) under analysis now
  - no de-sync problems but no TDC
  - Sarah Houston & Michael Köhler
  - subject of next talk

- SLHC / ATLAS Tracker Upgrade:
  - Recently very promising radiation hardness results for planar detectors mean very tough competition for 3Ds