Status of 3D R&D in Freiburg

Ulrich Parzefall
for Waltraud Buchenberg, Karl Jakobs, Susanne Kühn, Gregor Pahn, Andreas Waltz, Sebastian Walz, Andrea Zoboli*

Freiburg University (*also at fbk-IRST)

Lars Eklund, Celeste Fleta, David Pennicard
Glasgow

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Introduction

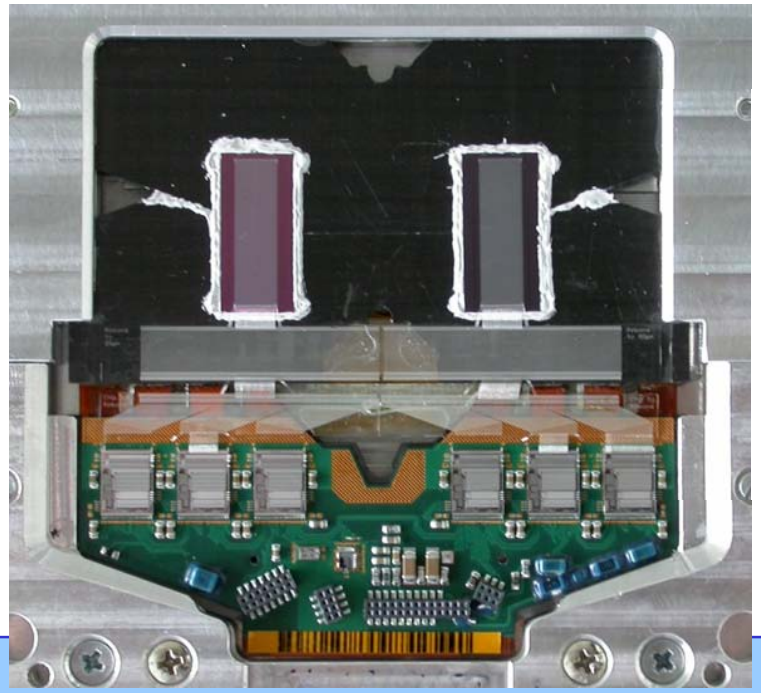
- Module overview
- Lab test results
- Test beam set-up & analysis
- Conclusions

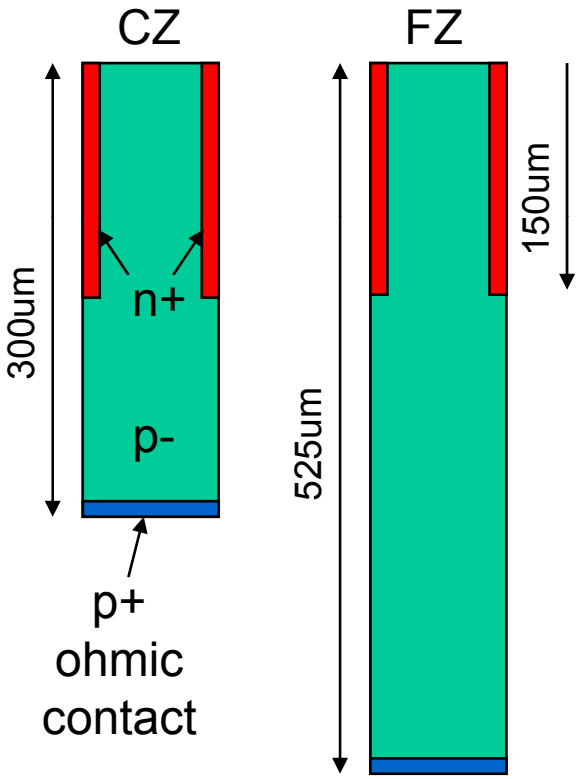
The Modules

- Available modules
  - Sensors are 3D-microstrip devices made by fbk-IRST
  - Fanins custom-made in house
  - Electronics: most modules use ATLAS SCT readout from EC module production
  - One module uses LHCb-Velo readout with Beetle-ASICs. This was in the test beam.

3D-STC Module

- Module with two 3D-STC sensors
- Irradiated to $0.98 \cdot 10^{15} N_{eq}/cm^2$
  - 80um strip and inter-column pitch, 230 columns per strip, 64 strips, ~2cm strip length matched to short strip layer in SLHC trackers
  - 2 sensors: FZ (CZ) p-type substrate, p-spray isolation, 525 µm (300µm) thick

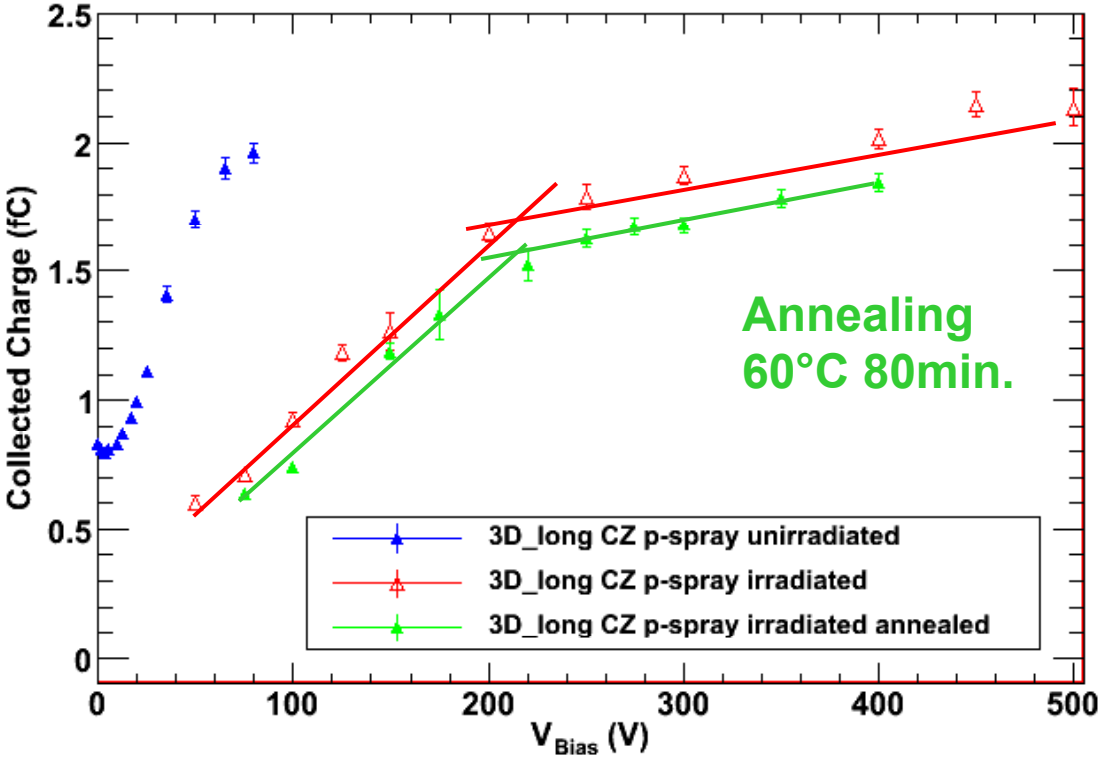




CZ p-type

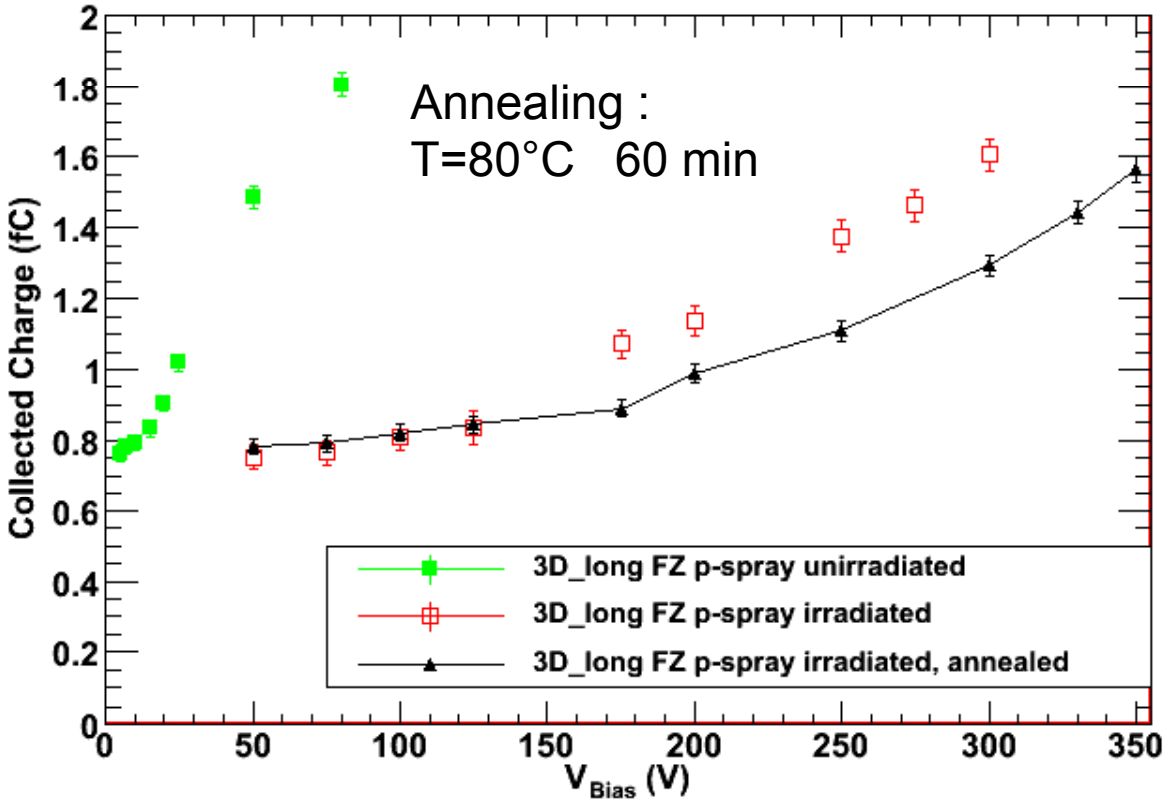
- Sr90 beta source measurements on irradiated 3D-STC after annealing
- V_{FD} ~ 230V as predicted for CZ p-type
- Charge collection is reduced by irradiation, and also slightly by annealing
- Post-annealing effect could be explained by
  - Increased hole trapping
  - Hole trapping is important between columns
  - Simulations by Andrea Zoboli

Expected V_{LAT} = 33V
Expected V_{FD} = 230V



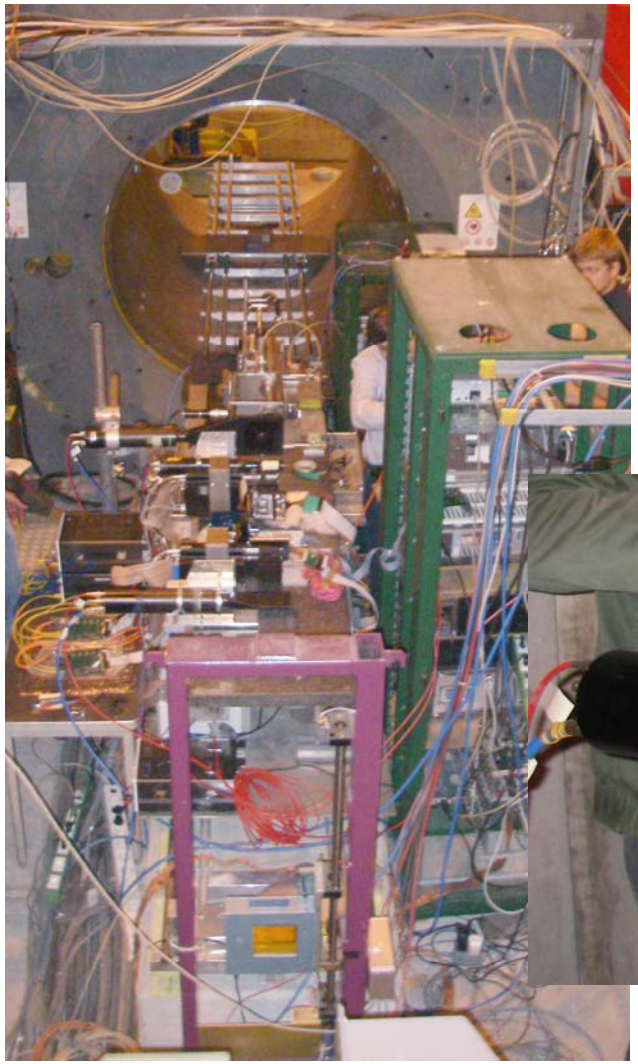
FZ p-type

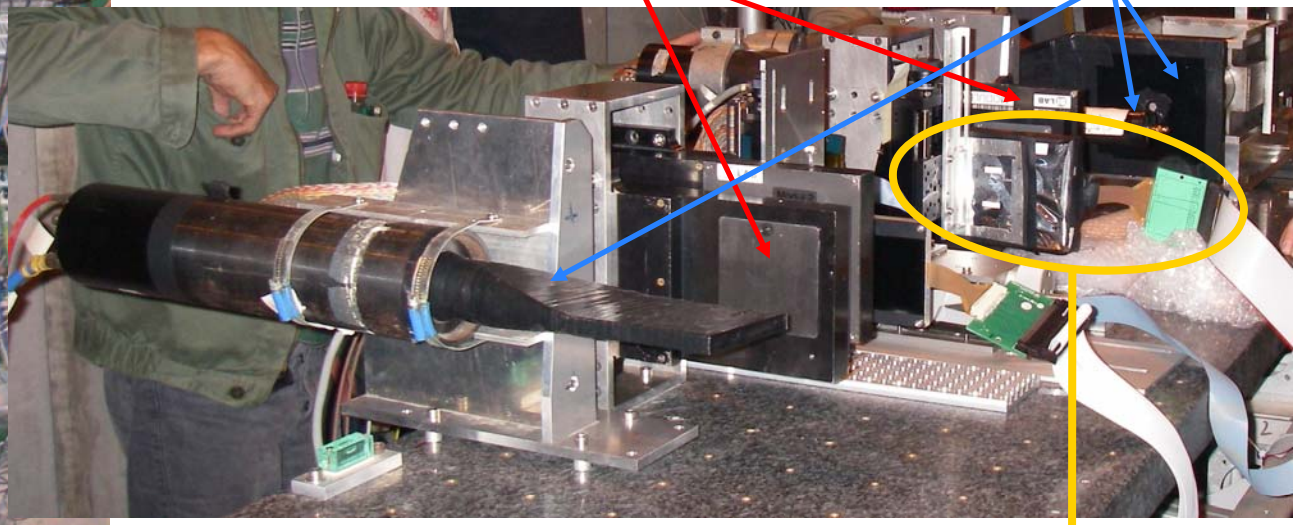
- Total depletion unreachable due to onset of micro discharge
- Note high annealing T will move into reverse annealing regime
- Due to reverse annealing N_{eff} increases
  -> less charge after annealing due to smaller depleted volume underneath the columns.



3D Test beam

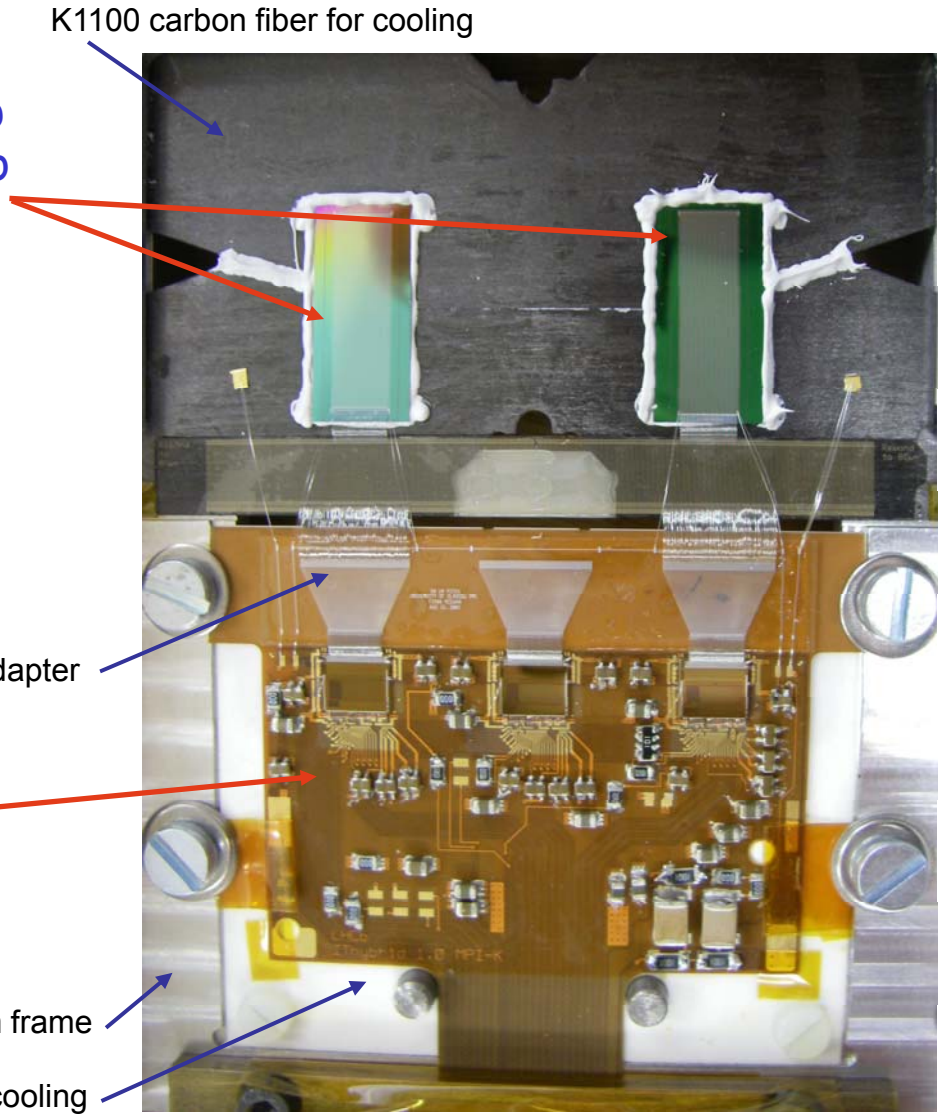
- ATLAS 3DSi test beam 2007 at CERN H8 area
- This work: close collaboration with Glasgow
- 180 GeV π beam
- Bonn ATLAS Telescope (BAT), 5µm resolution





Testbeam Module

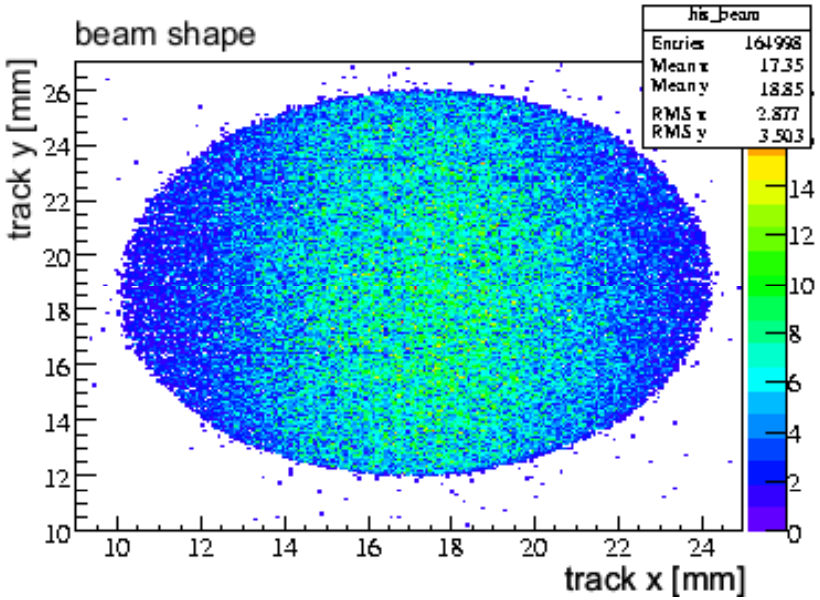
- Sensors
  - 3D-STC n^+-on-p mCz microstrip devices from fbk-IRST, Trento
  - Thickness: 300µm / 380µm
  - Strips: 64 per sensor, length 18.4mm, pitch 80µm
  - Isolation: p-spray / moderated p-spray
  - Columns: pitch 100µm / 80µm, depth 150µm
- Readout
  - Analogue 40MHz LHCb hybrid
  - Beetle ASICs (~25ns shaping)
  - 5 consecutive time bins

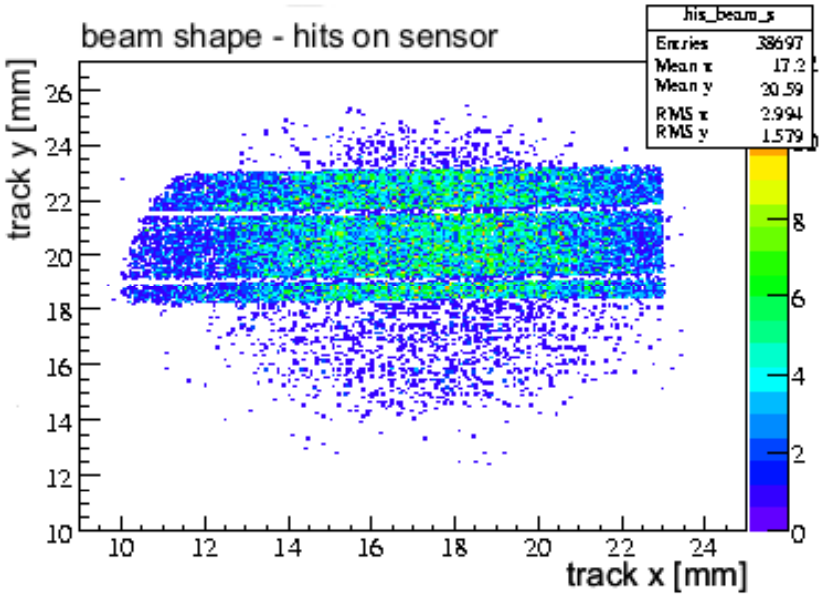


Test Beam Data

Track information (Ole Rohne)

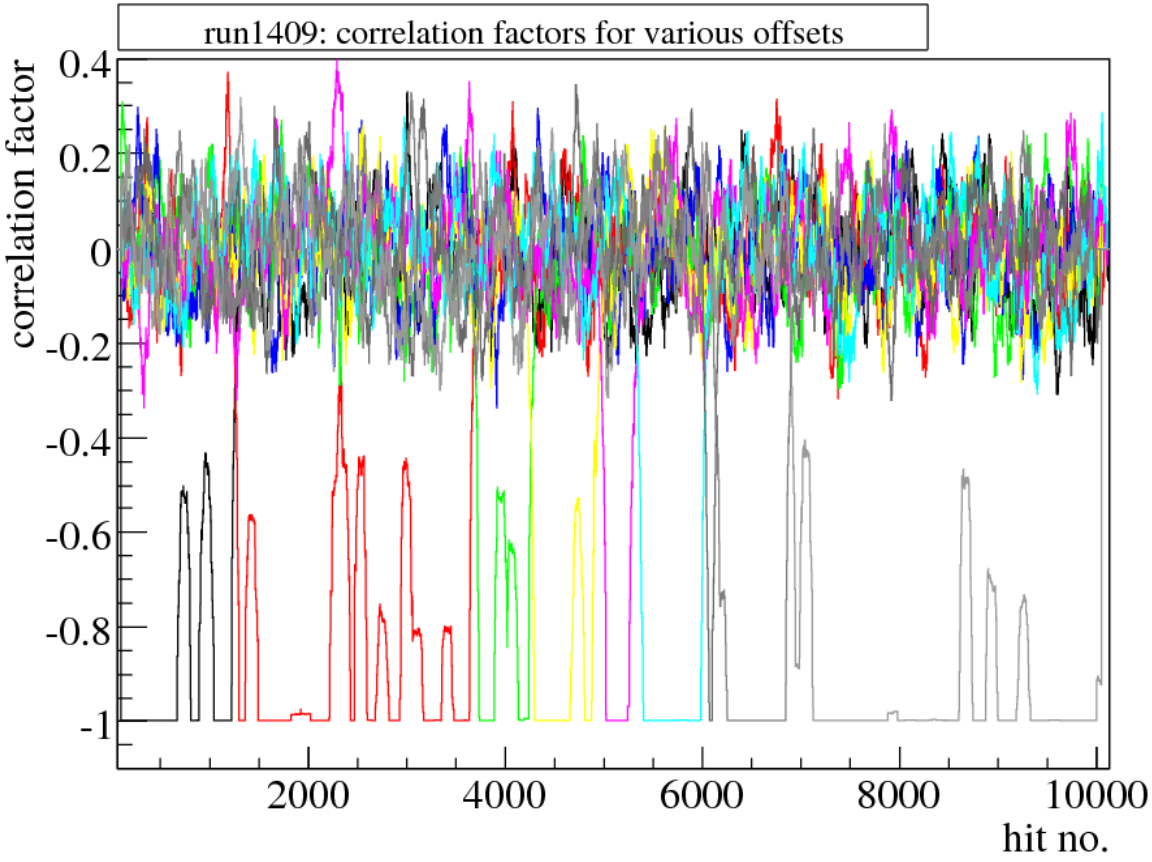
- Starting point: x, y track coordinates
- Beam shape: track y vs. track x (left plot)
- Track x,y for events where the 3D sensor registered a hit





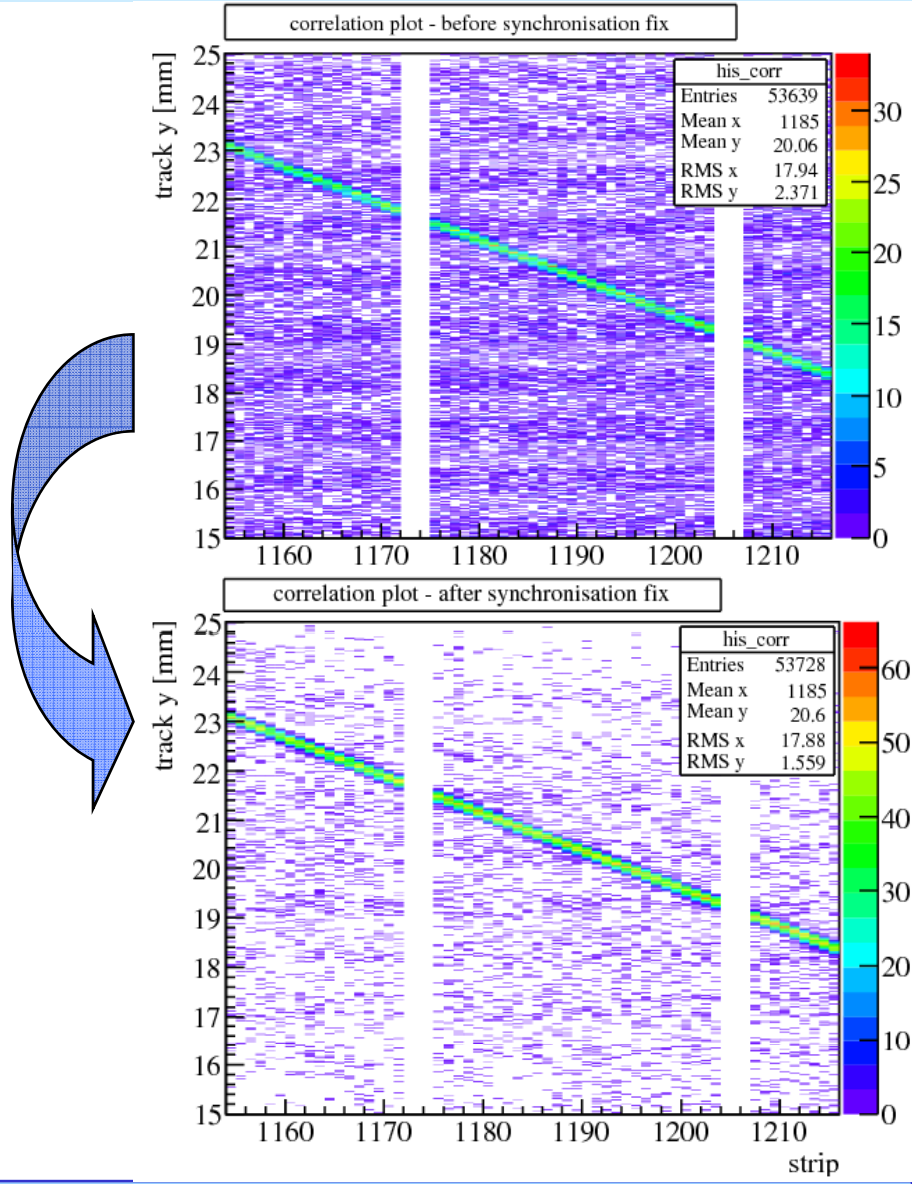
Desynchronisation

- So far the data look promising
- But data analysis proved very problematic
- Caused by two paralell DAQ systems that frequently loose synchronisation
- Event offset between DAQs must be found from data (using correlation between telescope and 3D sensor)
- Typical length of clean run sequence ~500 events
- In addition to that, main DAQ has internal trigger losses



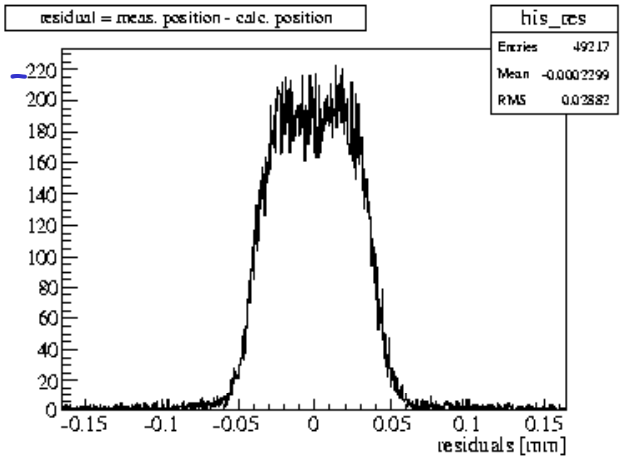
Re-Synchronisation

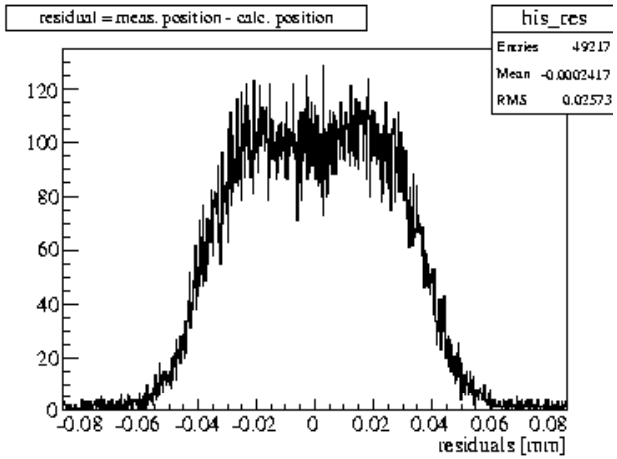
- Re-Synchronisation fix improves data sample massively
- Fix cannot recover all events → uncorrelated hits make alignment difficult and need to be excluded
- Fit correlation line by slicing 2D histogram and retrieving the y maximum for each strip from Gauss fit
- Use only hits within 3σ ≈ 200μm for alignment (≈ 91%)

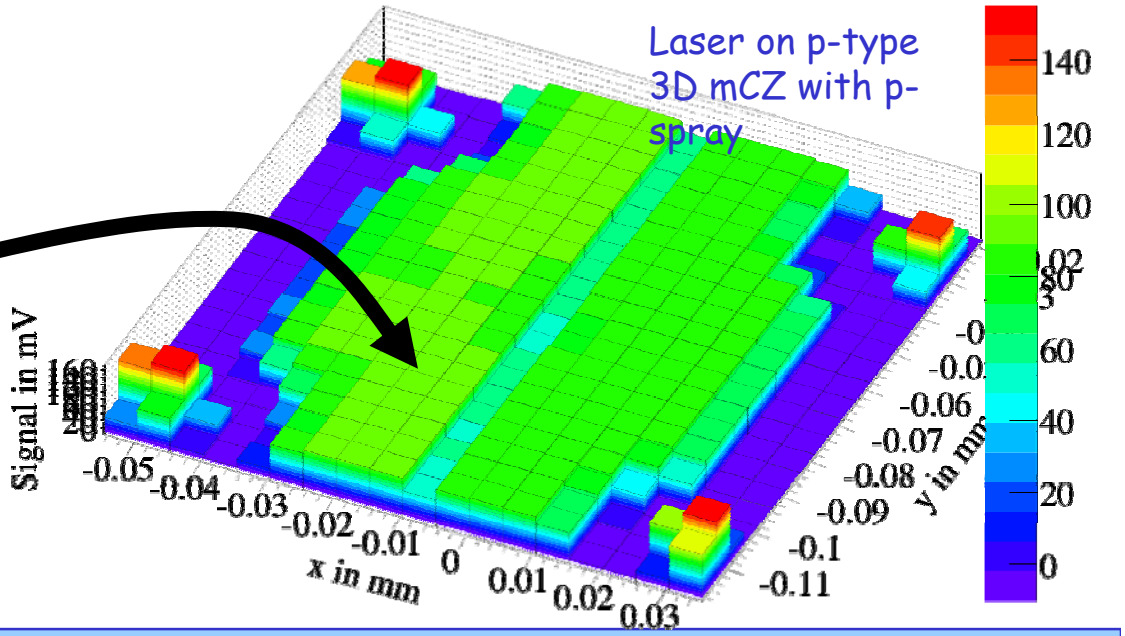


Alignment

- Calculate residual (extrapolated track position – measured hit position)
- Minimize it
- Alignment converges
- Residual: ~26µm (c.f. binary: 23µm from 80µm/√12)
- So far only small sub-set of data analysed. Requires effort from central DAQ (Ole Rohne)
- Strategy: fold all data onto one unit cell to look for local variation of CCE as expected from simulation & Laser tests
- Results expected in autumn after Gregor Pahn finishes his thesis

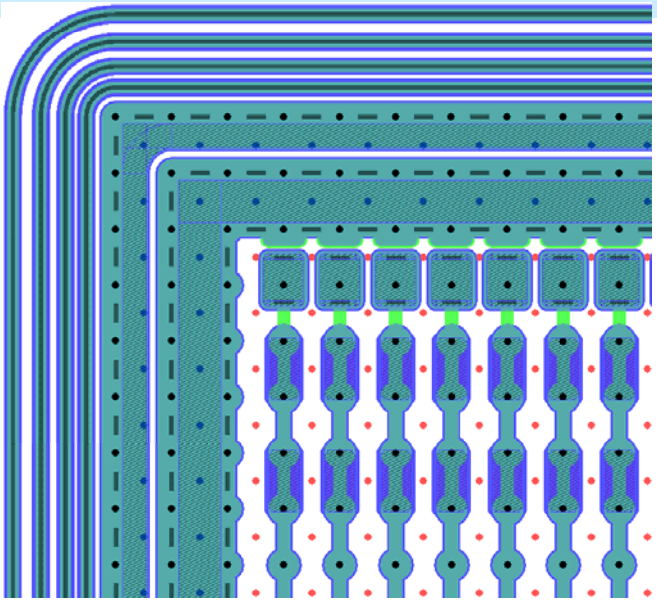


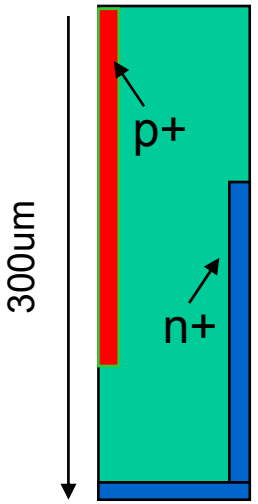




Ongoing work: Double Type Column

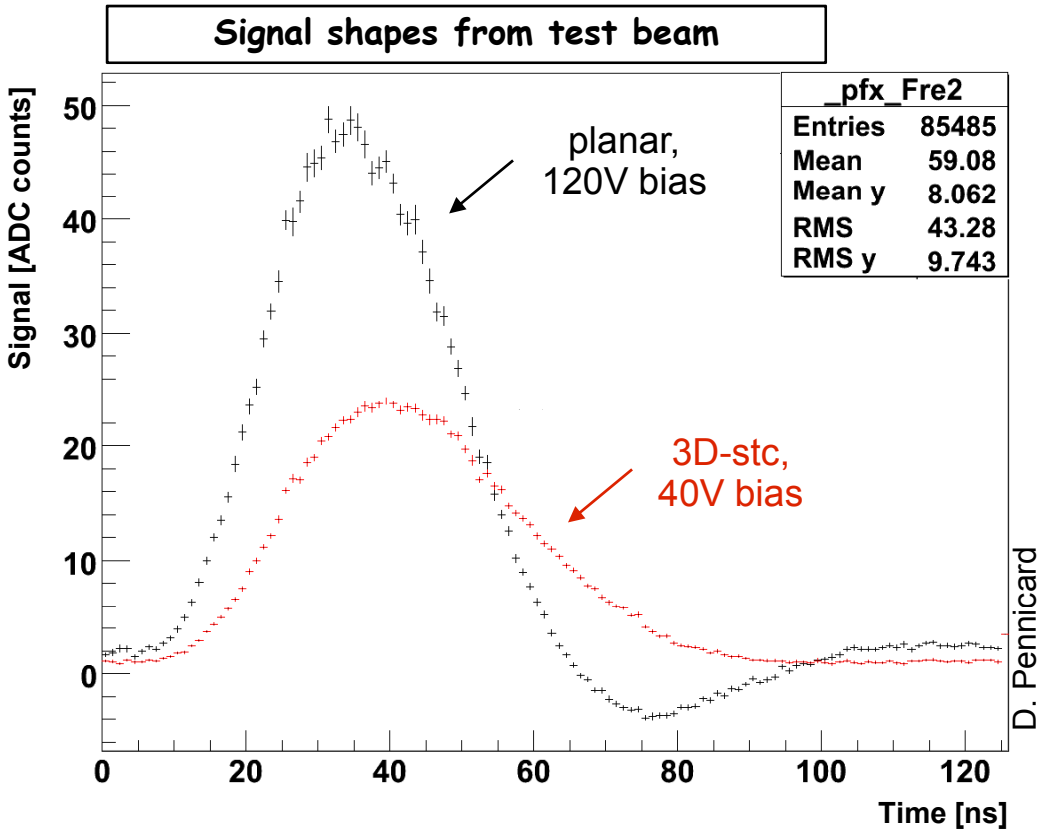
- The new geometry is an important step as for CCE and radiation hardness
- In Freiburg: 4 DDTC p-in-n strip sensors from first batch (again from fbk-IRST)
- 300µm thick, 190 µm column depth
  - Column overlap only 80µm
- Size 1cm x 1cm, 80µm inter/intra column pitch
- 102 strips and 102 col/strip
- Devices show early breakdown, but can be fully depleted
- 2 DDTC modules were made with ATLAS SCT readout, source and laser testing still ongoing





Comments on 3D-STCs

- **Overall charge level low (2.2fC)** due to ballistic deficit arising from 3D-STC field configuration
- **This will be improved with new Double Type Column Designs**
- 3D-STC after irradiation to $10^{15} N_{eq}/cm^2$ are still operational
- Same CCE as unirradiated device, but at much higher bias voltage
- The annealing has affected the CCE:
  - On CZ probably due to trapping of holes between columns
  - On FZ mostly because the annealing was too long and Neff has increased significantly
- **Modules recently taken to another irradiation step, total dose now ~$3.5 \cdot 10^{15} N_{eq}/cm^2$**
- Testing in Sr90-system is running this week



Need to move from STC to DTC!

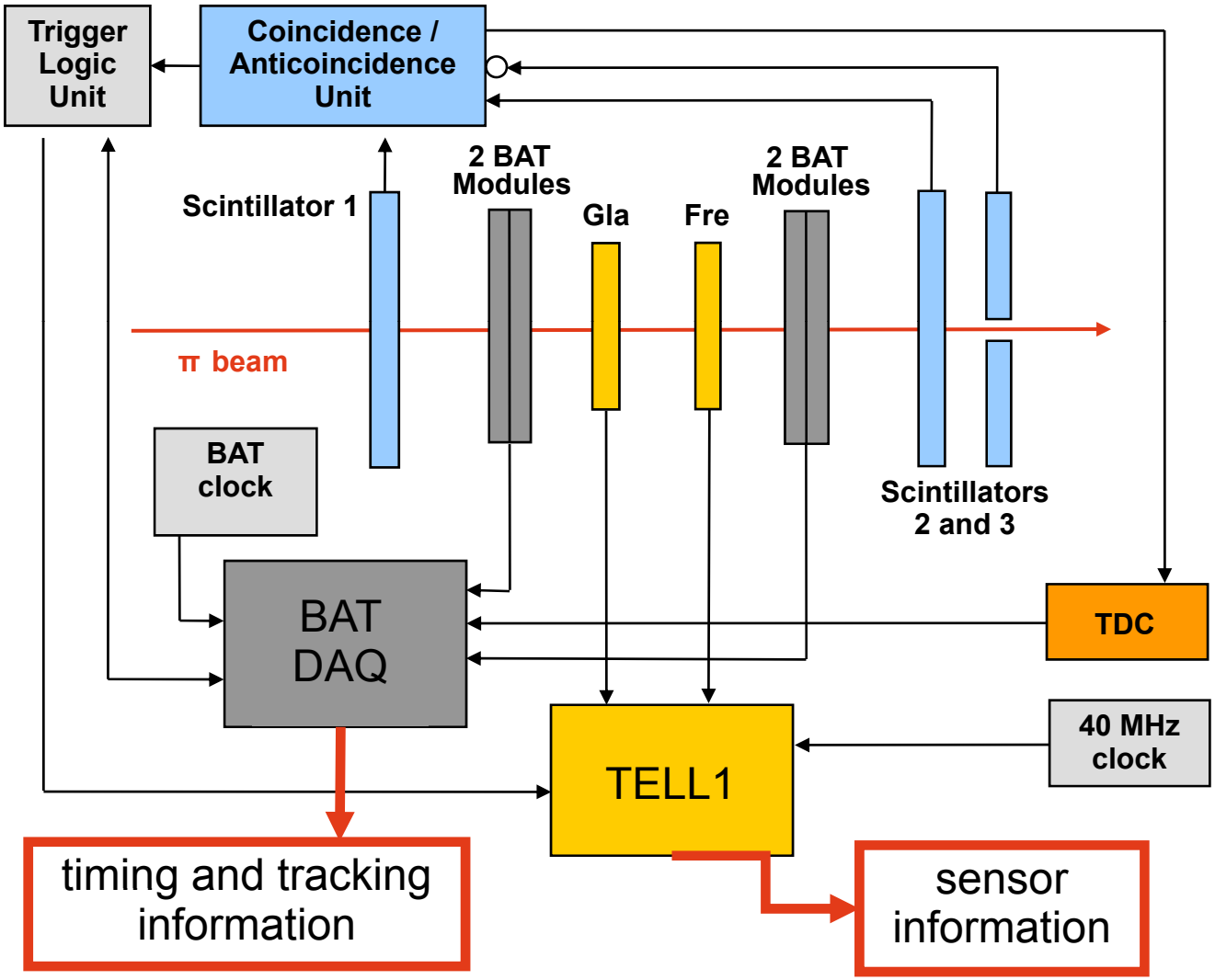
Conclusions & Outlook

- Work on STC 3D devices (originally intended as technology test) is coming to an end.
  - STCs are radiation hard
  - Too slow for a 40 MHz SLHC (field configuration)
  - Still have some STC measurements in the pipeline
    - Two modules irradiated to $3.5 \cdot 10^{15} N_{eq}/cm^2$ in source and laser test systems
    - Completion of 2007 test beam analysis
- Future 3D tests will concentrate on DDTC devices

- Last testbeam analysis has many complications, given by separate DAQs
- We plan to participate in CMS testbeam this summer, in the spirit of RD50

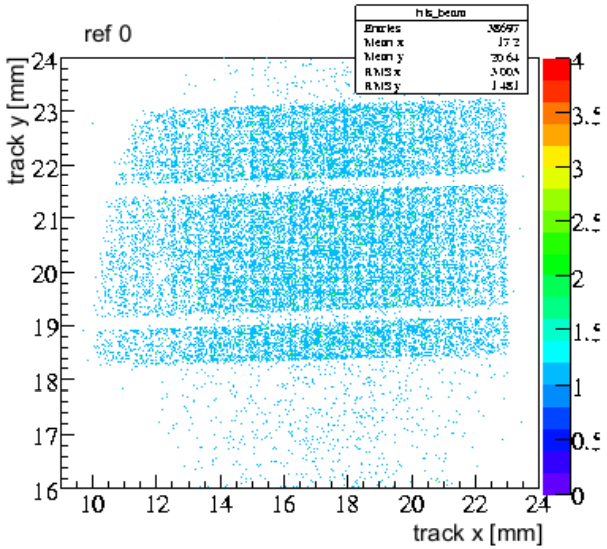
Backup

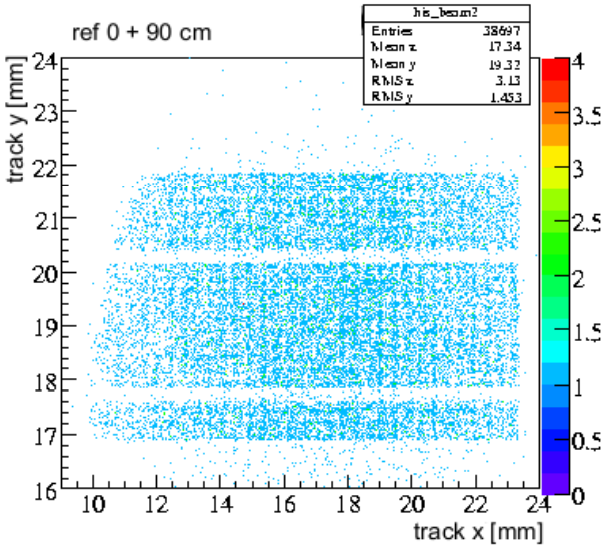
Setup schematic (simplified)



- 3D devices under test on Freiburg module (Fre)
- Telescope/TDC and sensor separately read out
- Triggered by scintillators
- Active sensor area very small →use 3rd scintillator as veto

Finding start values

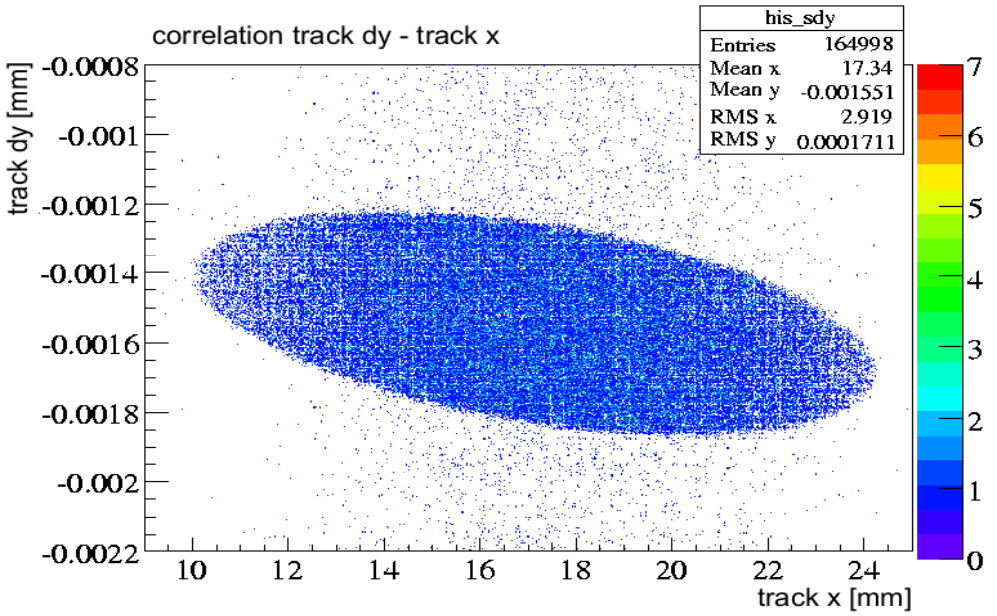




- **Upper left: projection of sensor into track reference system ref 0**
- **Sensors positioned ca. 90cm downstream ref 0**
- **Upper right: tracks extrapolated 90cm downstream in a plane parallel to ref 0**

- **choose sensor system origin in lower right corner →start values for 3 offset parameters**

- **Sensor should only be shifted in x and y**
- **Why is there also a rotation?**
  - **x and dy correlated**
  - **Beam optics or error in**



Exclude uncorrelated hits

- Sychronisation fix cannot recover all events → uncorrelated hits make minimization unreliable and need to be excluded
- Fit correlation line in ref 0 by slicing the 2D histogram and retrieving the y maximum for each strip from Gauss fit
- Use only hits within 3σ ≈ 200μm for alignment (≈ 91%)