Pixel telescope test beam results

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on behalf of JRA1 members

EUDET Annual Meeting – Paris – 8/10 October 2007

Test beam effort

- The JRA1 group organized **three tests on beam** from June to September for a total of **~ 6 weeks** of data taking out of **12 working weeks**... a real effort!

TB-DESY-JUNE (11 / 24 June 2007)
TB-DESY-AUGUST (13 / 24 August 2007)
TB-CERN-SEPTEMBER (17 / 27 September 2007)

1 ½ week ago!

TB-DESY-JUNE: *the integration test*

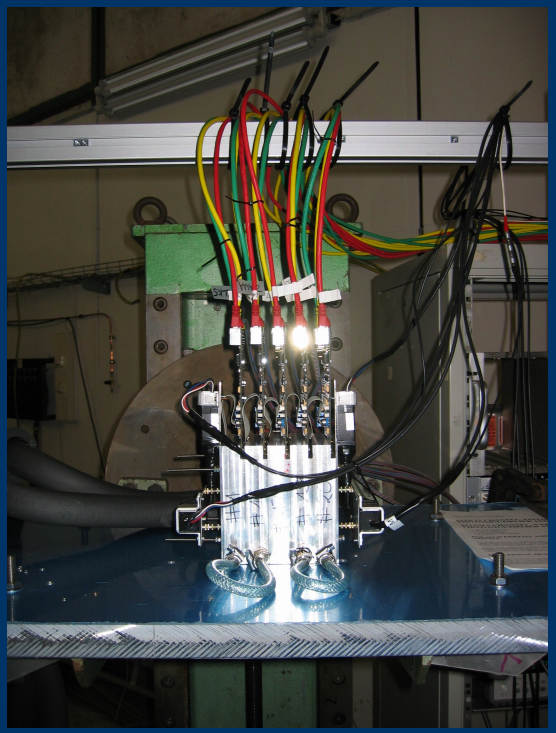
- Main objectives
  - Commissioning a single arm of the telescope connecting together all the hardware pieces.
    - This was the first time ever three EUDRBs were plugged to the sensors and readout synchronized by the TLU.

- Main outcomes:
  - More than 150k events acquired and fully processed.
  - Stable and smooth data taking
  - The acquisition rate was ~ 1 Hz.
  - Room for improvements for the mechanics and the cooling system.

✓ **Smoke test: successful!**

TB-DESY-AUGUST: *testing the telescope*

- Main objectives
  - Acquire enough statistics to characterize the telescope itself.
  - Increase the acquisition rate and the number of planes.
  - Test the on board zero suppression



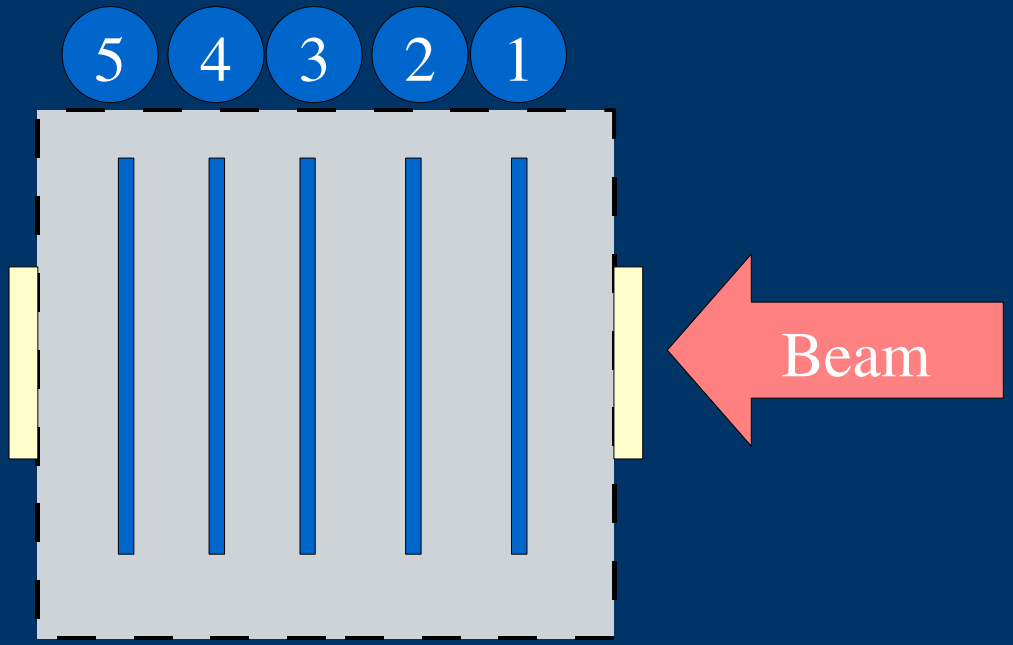
- Main outcomes:
  - More than 200k events in RAW mode
  - More than 100k events in MIXED mode
  - More than 450k events in ZS mode
  - All RAW data processed already while MIXED and ZS analysis still on going

Web logbook available at

http://spreadsheets.google.com/pub?key=pDtQLOmk3OPAVDsodhPTKbA

TB-DESY-AUGUST: *detailed setup*

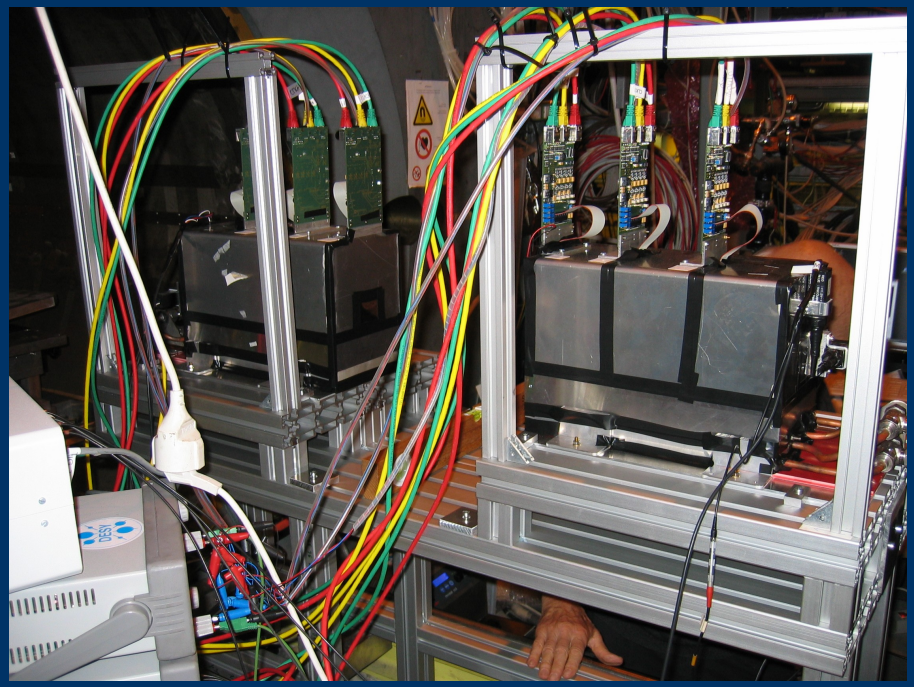
- All sensors are in one single box.
- Distance between sensors is 25 mm
- 4 trigger scintillators defining an acceptance area smaller than the sensor surface.
- The first sensor in the beam has the 14 um epi layer, all the other have 20 um epi layer.



- Plane number 4 has some problem of noise, still to be solved.
- When working in Mixed mode “odd” planes were readout in RAW mode while “even” planes in ZS.
- During the analysis the central plane was treated as a DUT, i.e. not considered in the fit.

TB-CERN-SEPTEMBER: *testing the first DUT*

- Main objectives
  - Study the achievable resolution with a high energy π beam.
  - Integrate an external device in the DAQ system.
  - Testing the tracking software with a high track multiplicity



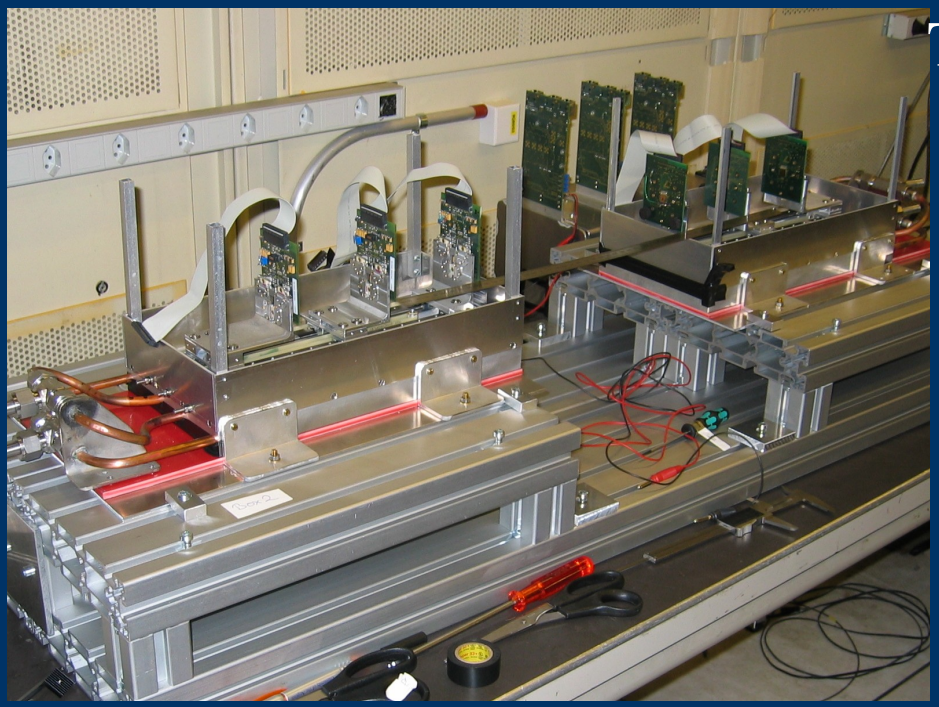
- Main outcomes:
  - More than 4 million tracks acquired in RAW mode
  - Comparable amount of tracks in ZS mode
  - Successful integration of 2 DEPFET sensors

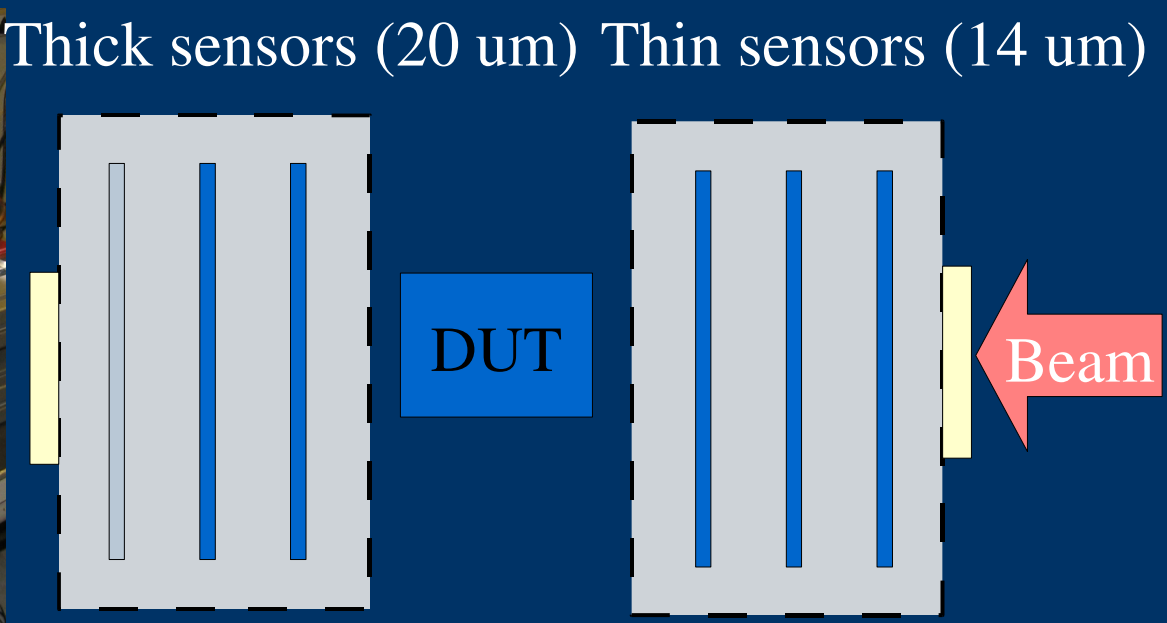
Web logbook available at

http://spreadsheets.google.com/pub?key=pDtQLOmk3OPBD1CC4uKCIeQ

TB-CERN-SEPTEMBER: *detailed setup*

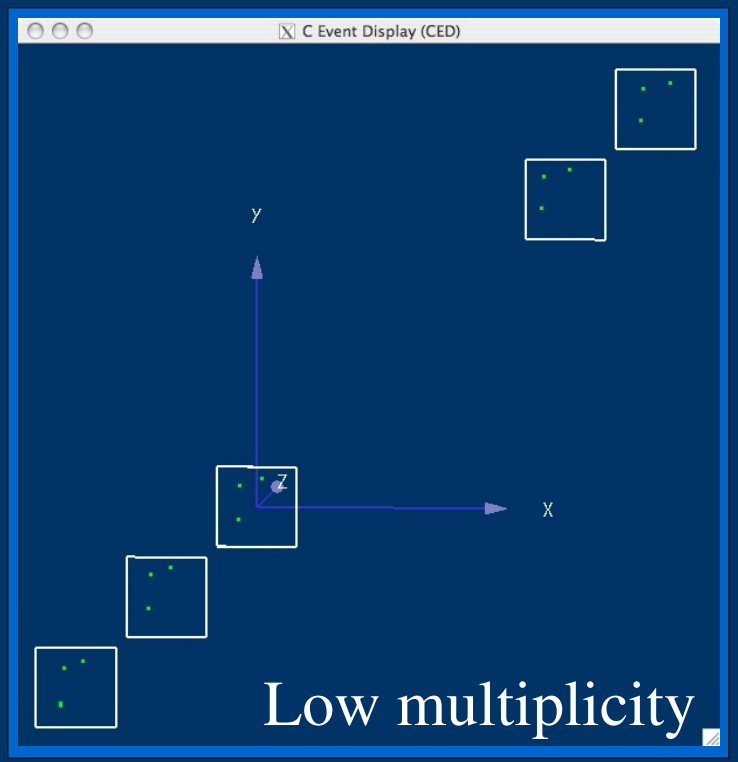
- Two arms with 3 sensor planes each:
  - Only 5 planes were readout due to a failure of one DAQ board.
  - Distance between the two arms: 340 mm
  - Distance between two following sensors in the same arm: 100 mm

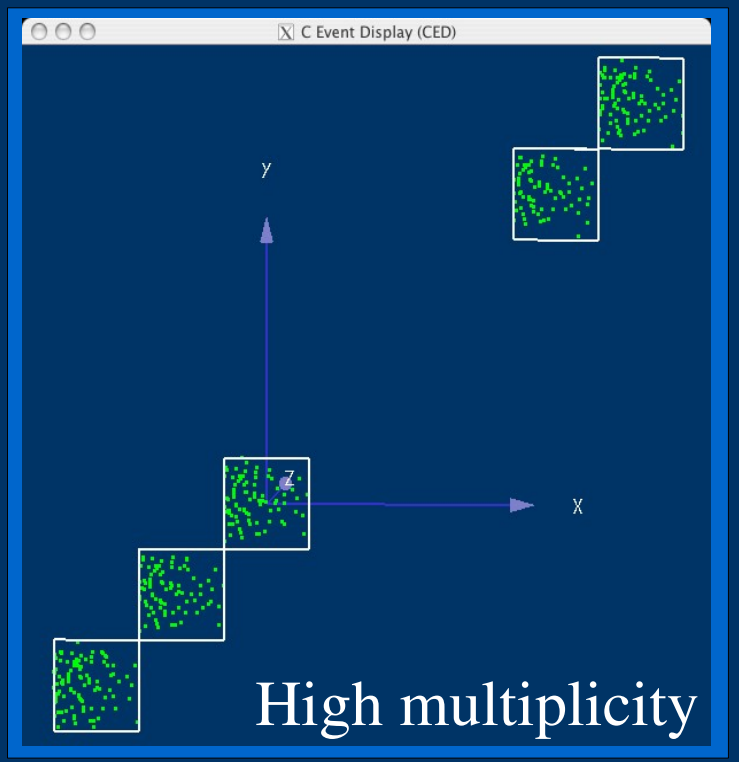




TB-CERN-SEPTEMBER: *data samples*

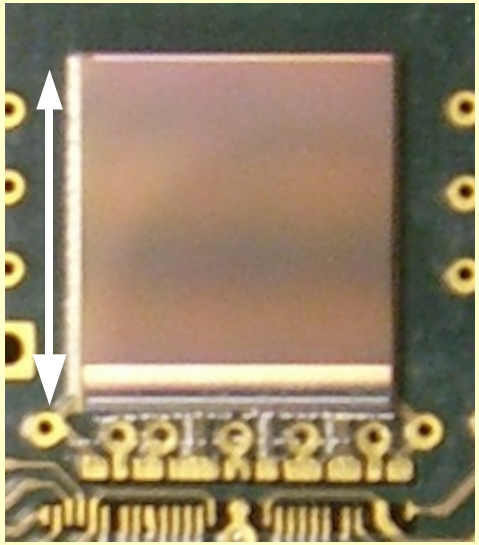
- Data samples divided according to hit multiplicity
  - **Low multiplicity** (3.5 hits/plane) ideal sample for track debugging and alignment
  - **Medium multiplicity** (5.5 hits/plane) No DUT.
  - **High multiplicity** (40 hits/plane) ideal to collect statistics but requires pattern recognition and track finding before fitting.



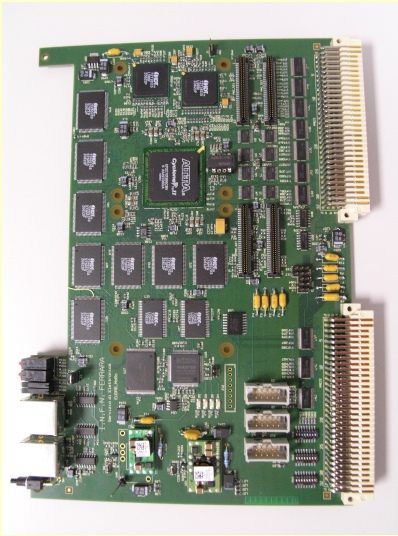


Setup details

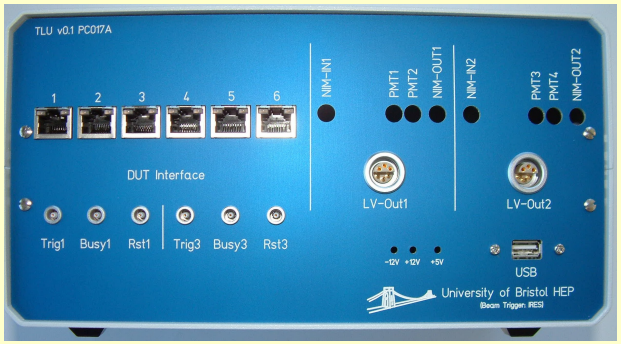
- MAPS sensor with SB structure
- 65k pixels with 30 um pitch
- Four parallel output channels
- Clock @ 10 MHz



- VME 64x and USB2.0 DAQ board
- 1 board for each detector plane
- Two acquisition modality:
  - RAW mode
  - **ZS mode**



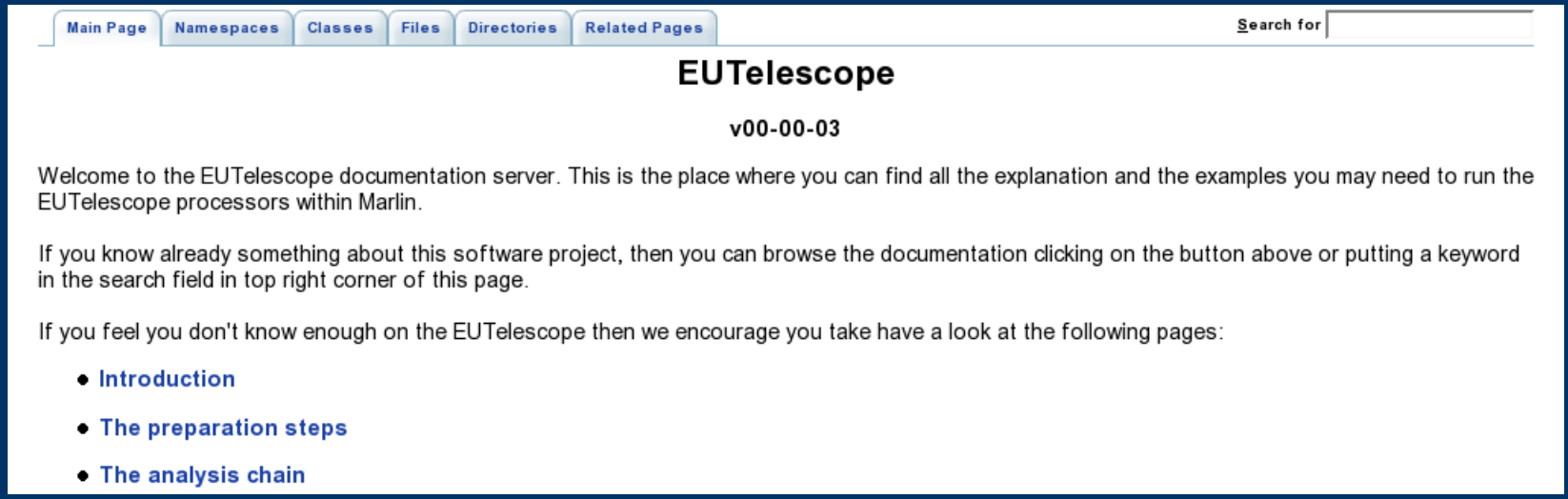
- TLU used to synchronize all the telescope boards
- The DUT receive the trigger signal and the trigger number from the TLU



Analysis software

EUTelescope: a Marlin package

- All the data have been processed using EUTelescope that is a set of Marlin processors coded by the JRA1 software / analysis group and made available for the community.
- DOC: http://www.roma3.infn.it/~bulgheroni/Eutelescope/head/index.html
- CVS:http://www-zeuthen.desy.de/lc-cgi-bin/cvsweb.cgi/Eutelescope/?cvsroot=eutelescope



Data storage and processing

- More than 1 TB of raw data:
  - TB-DESY-JUNE: 250 GB
  - TB-DESY-AUGUST: 630 GB
  - TB-CERN-SEPTEMBER: 430 GB
  - Plus all the intermediate analysis steps...
- All data are stored on tape at DESY and accessible via GRID to “ilc” vo members. Everybody (you too!) can access the data and helping in the analysis!
- All the CPU intensive analysis steps have been executed on the GRID in particular on DESY (HH and Zeuthen) and Manchester computing elements.
- **W/o the GRID (computing and storing) would have been impossible to have results on a so short time scale!**

Track fitting

- Two procedures currently available
  - Simple straight line fit suitable for high energy particles where the MS is negligible
  - Analytical fit (see EUDET-Report-2007-1) by A.F. Zarnecki to take into account the MS contribution.

Alignment

- Very simple procedure based on Minuit, minimizing the distance between the measured position and the reconstructed one (2 offsets and three angles)

Test beam results

Sensor planes characterization

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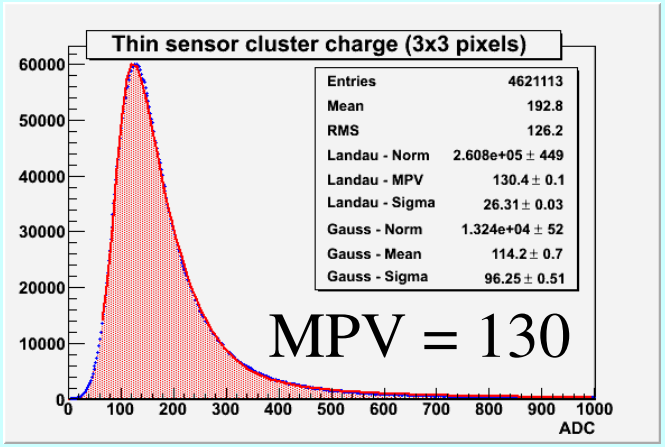
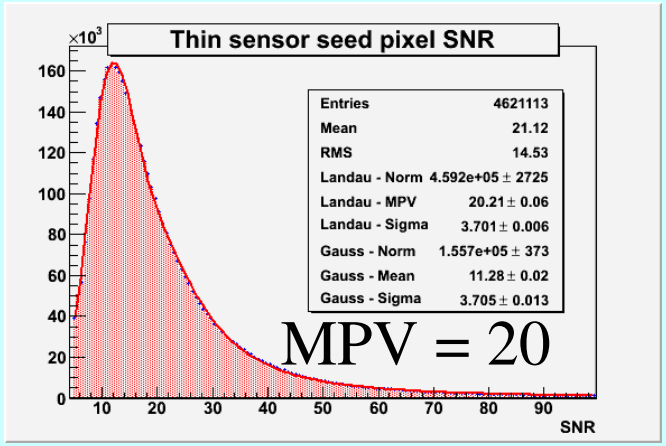
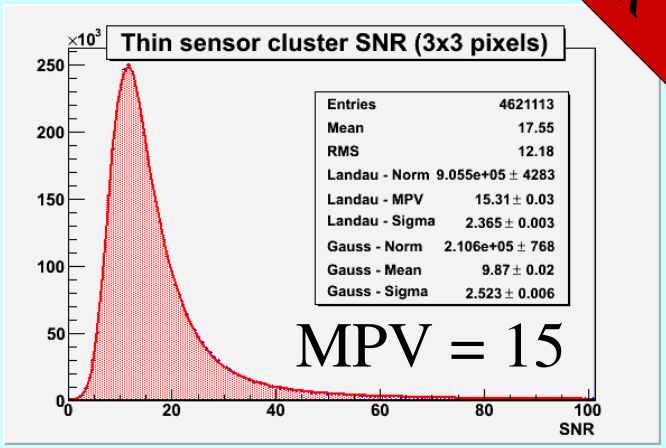
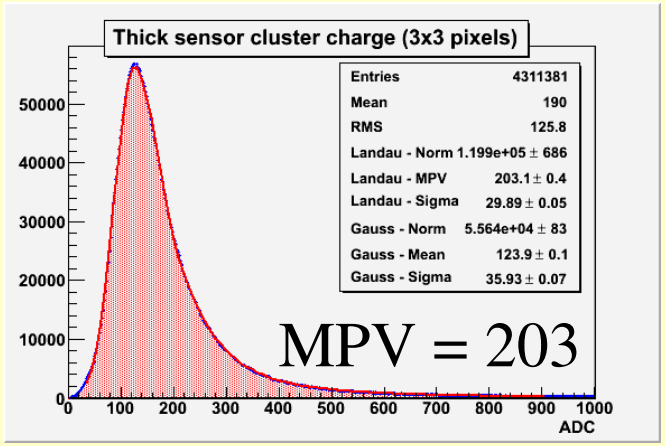
Thin sensor (14 um epi layer thickness)

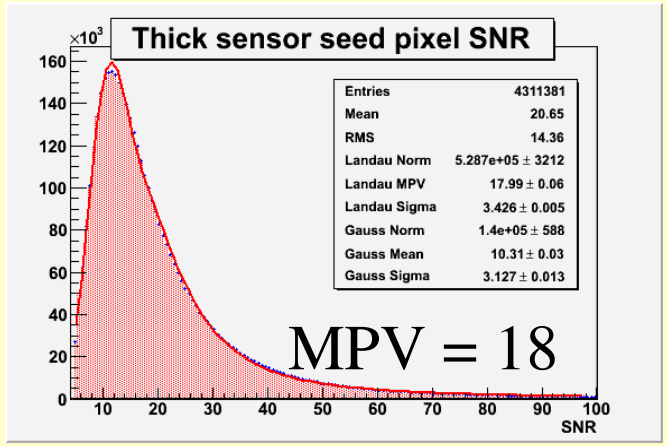


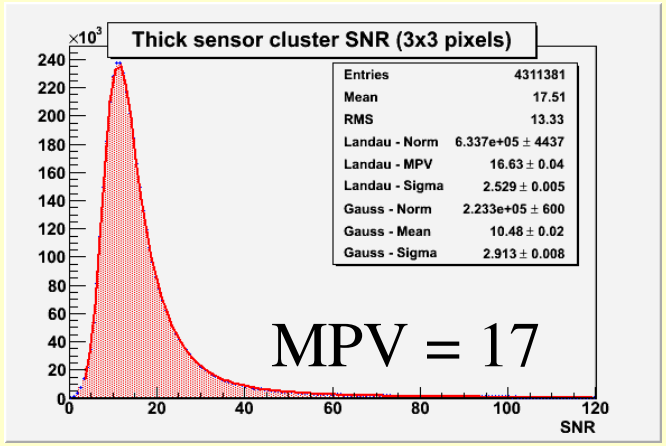




Thick sensor (20 um epi layer thickness)







Eta function correction

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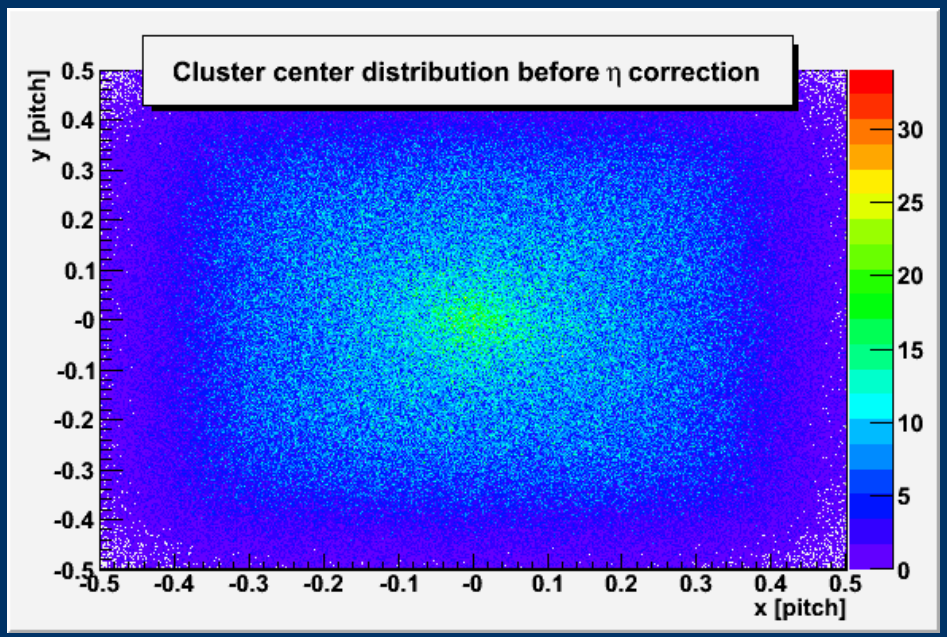
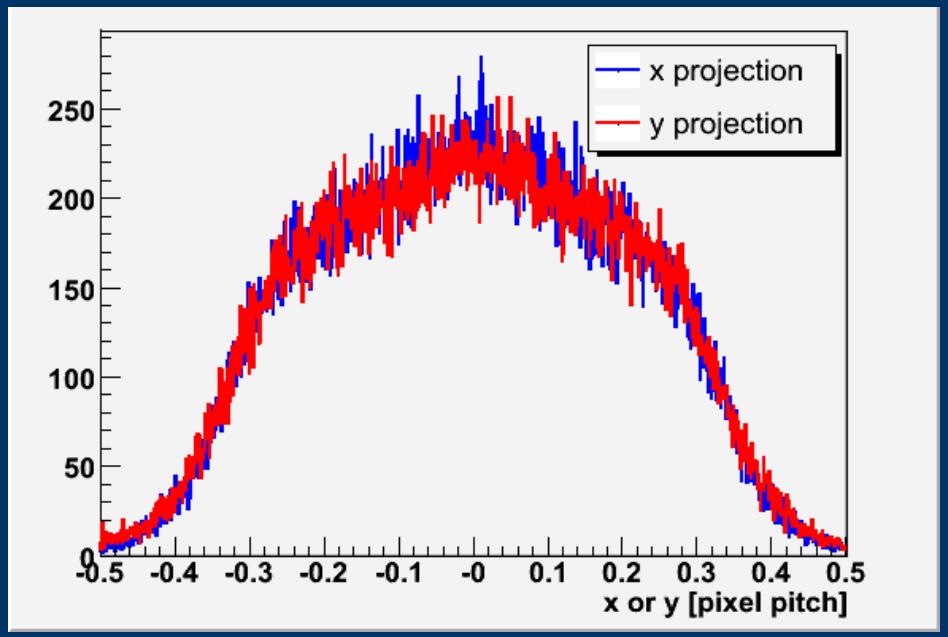
- **Assumption:** the cluster center distribution should be flat within the central pixel.
  - If not, it means the definition of cluster center is inappropriate and we have to correct for.
  - Use a non-linear weighting function





Eta function calculation

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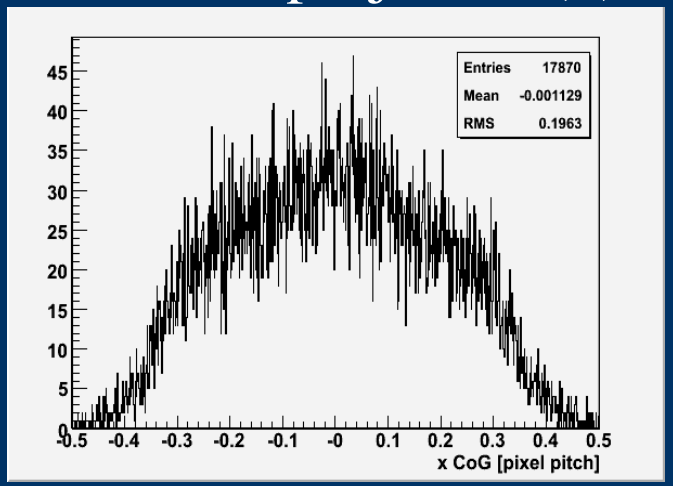
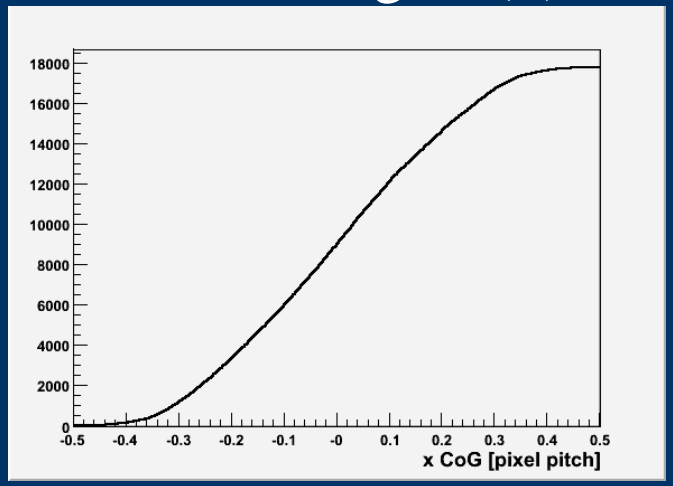
- Used only a subset of data with optimum cluster selection.
- The two projections are treated independently
- For all clusters, the CoG is calculated and a histogram is filled with the corresponding value (1)
- When the loop is over, histogram (1) is integrated as shown in (2).
- The integral is normalized by the highest value and shifted down by half. This is the η function (3)!

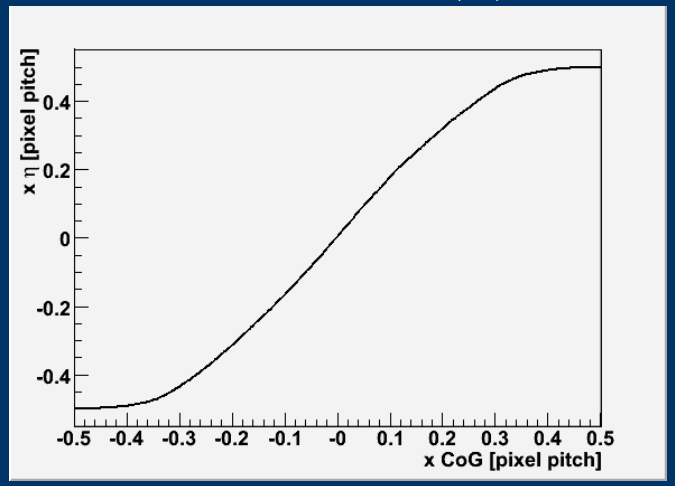
CoG – x proj histo (1)



CoG – integral (2)



Eta function (3)



After Eta function

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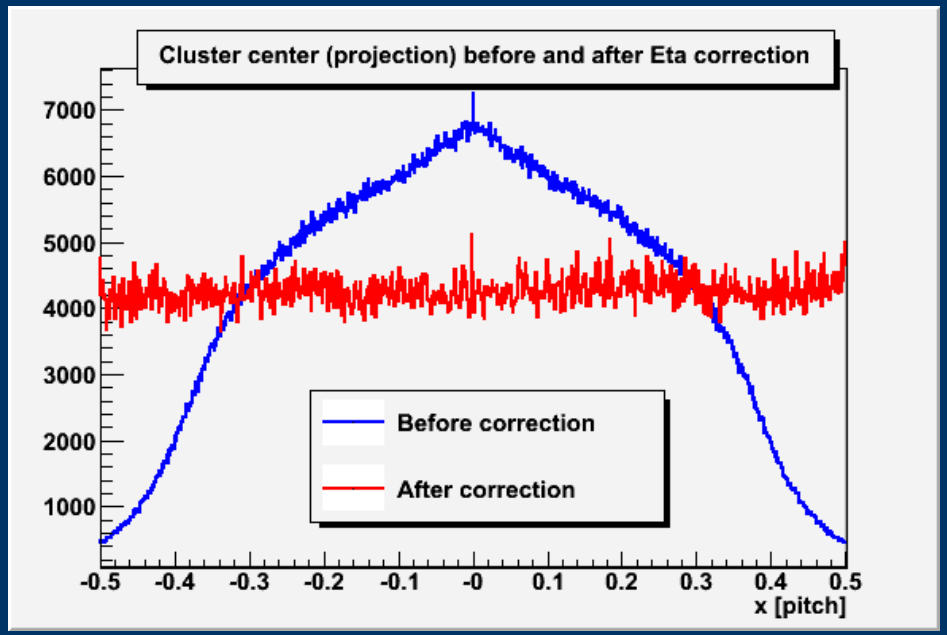
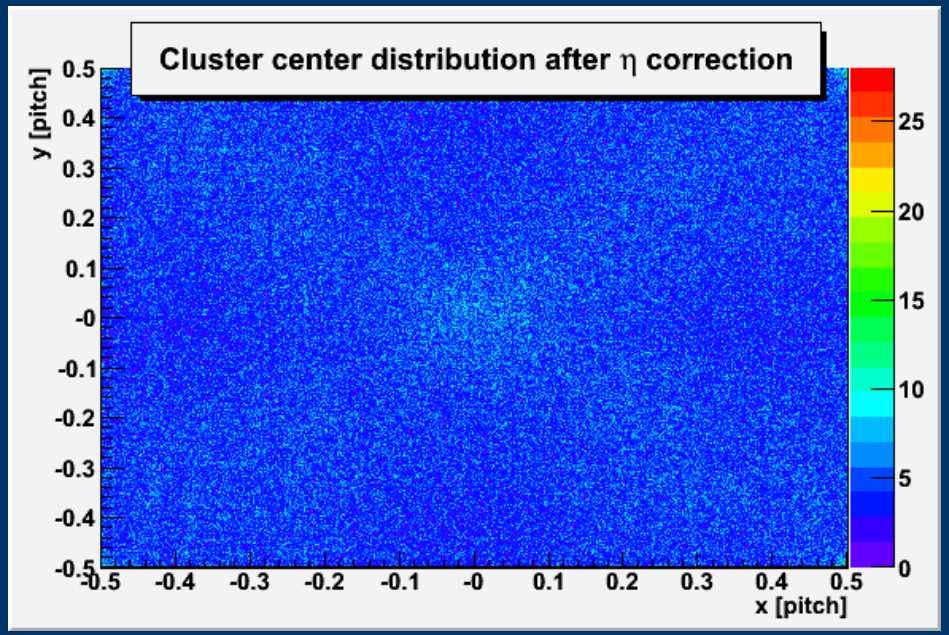
- The application of such an algorithm has to flat the cluster center distribution within the central pixel





Zero suppression

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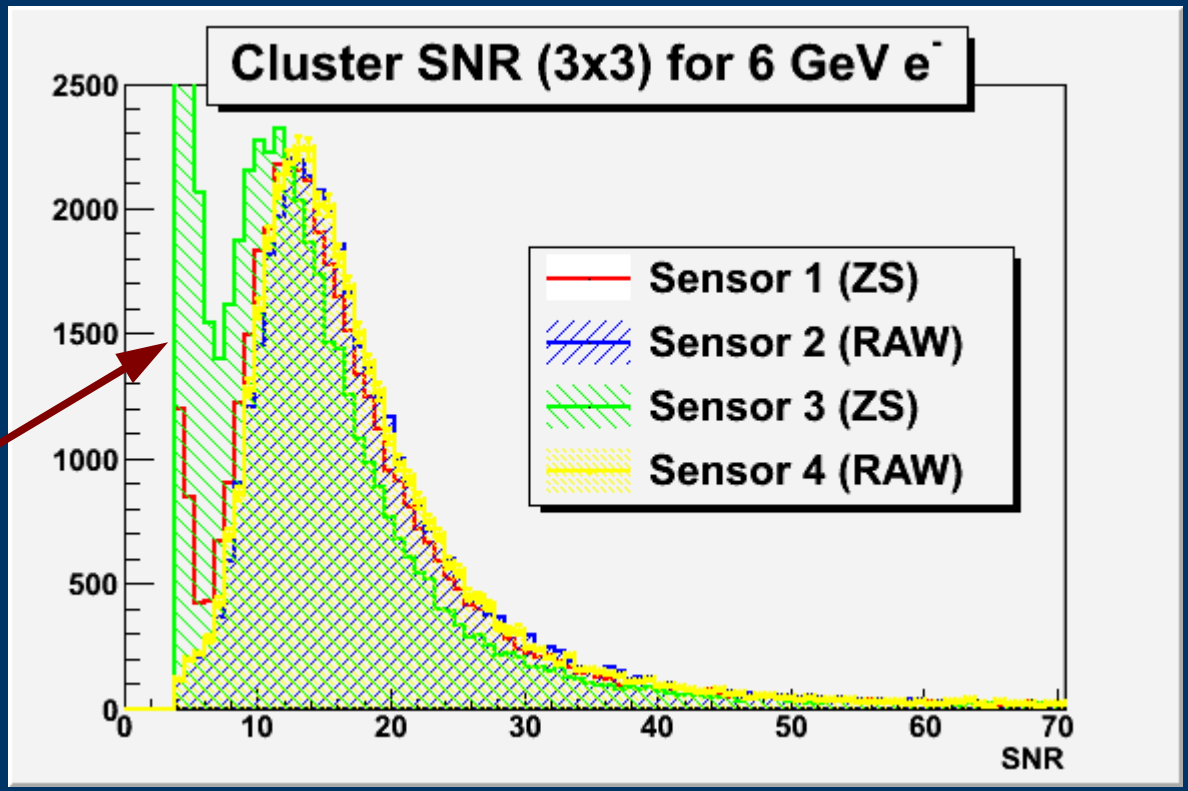
- The analysis of Mixed and ZS suppressed data is just started
  - Requires some more coding in the software
  - First we would like to have some results from the good old raw data.
- Preliminary results look very interesting...



Noisy plane

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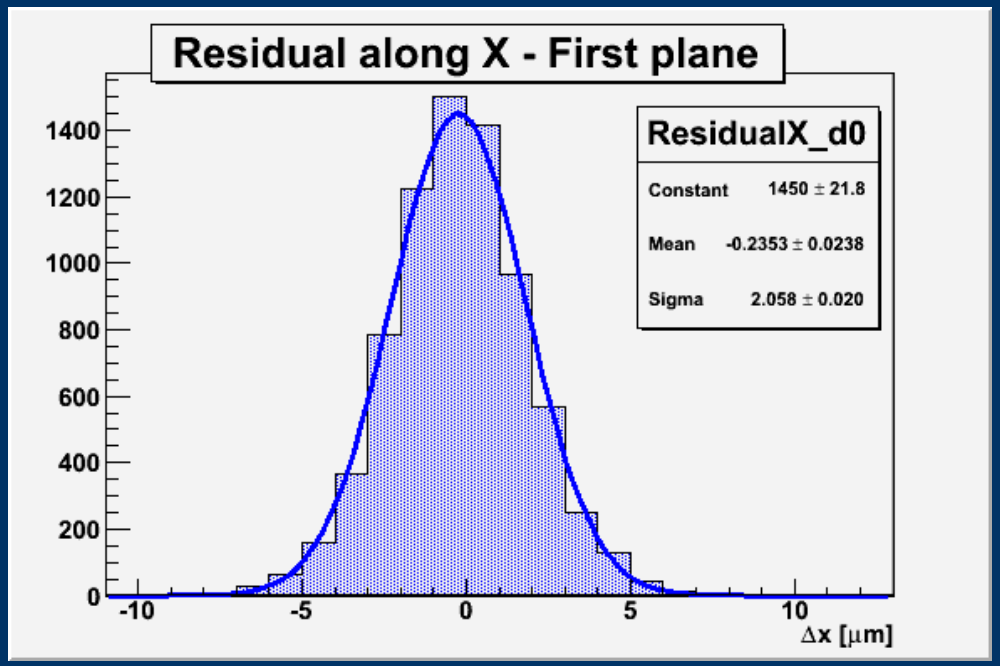
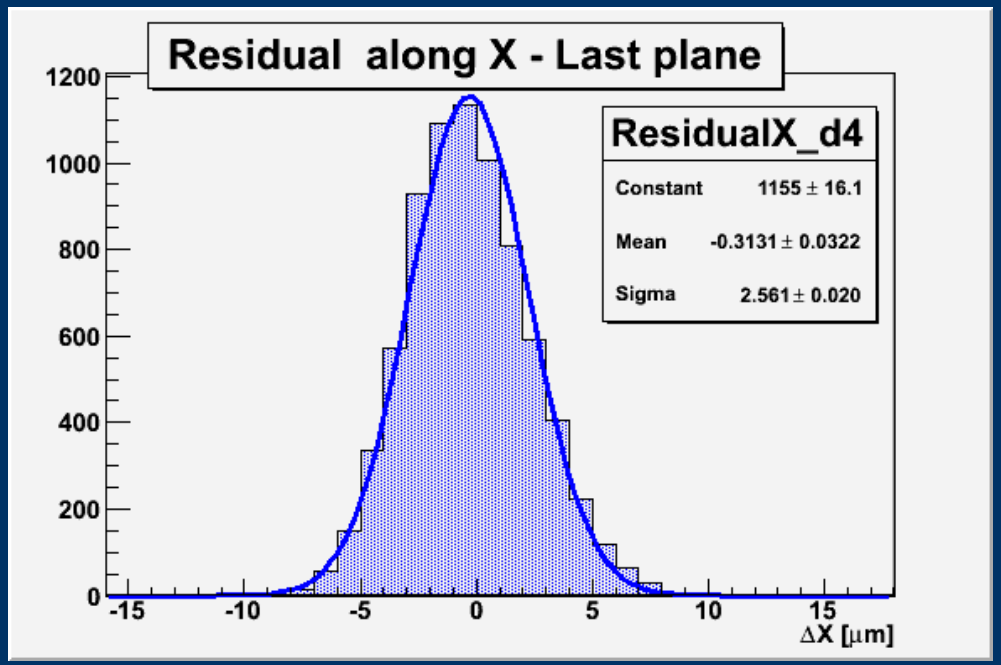
Telescope alignment

- Alignment performed on the low multiplicity data sample and then used for high multiplicity track fitting.
- Telescope aligned better than half a micron!



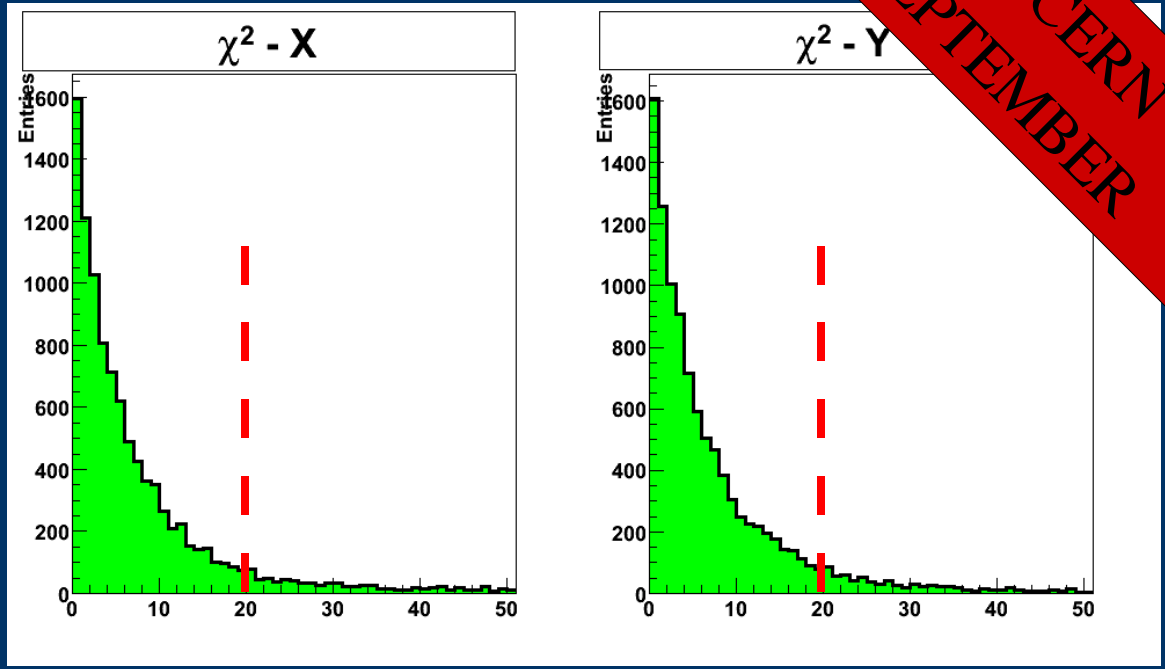


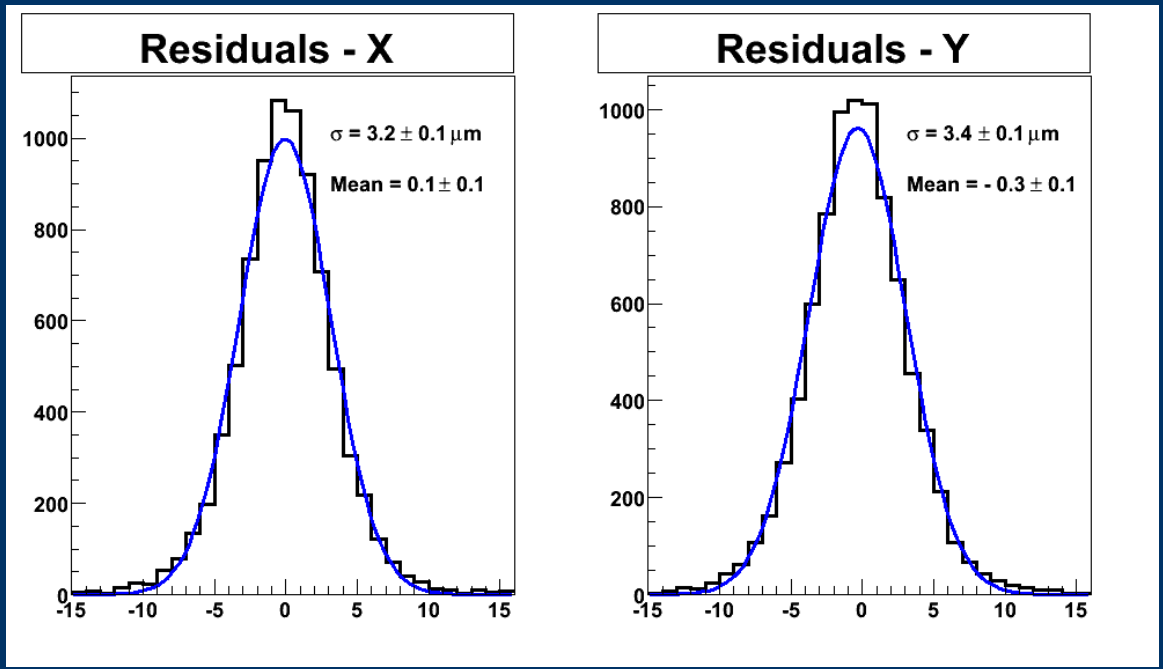
DUT resolution

Straight line fitting procedure using the only four planes and extrapolating on the central one.

Fitting on x and y separately

Chi^2 cut < 20





Measured resolution is **3.4 um** (intrinsic + telescope). The same figure has been obtained also with the analytical fit.

This is very well in agreement with the expected resolution of the sensor of 3 um

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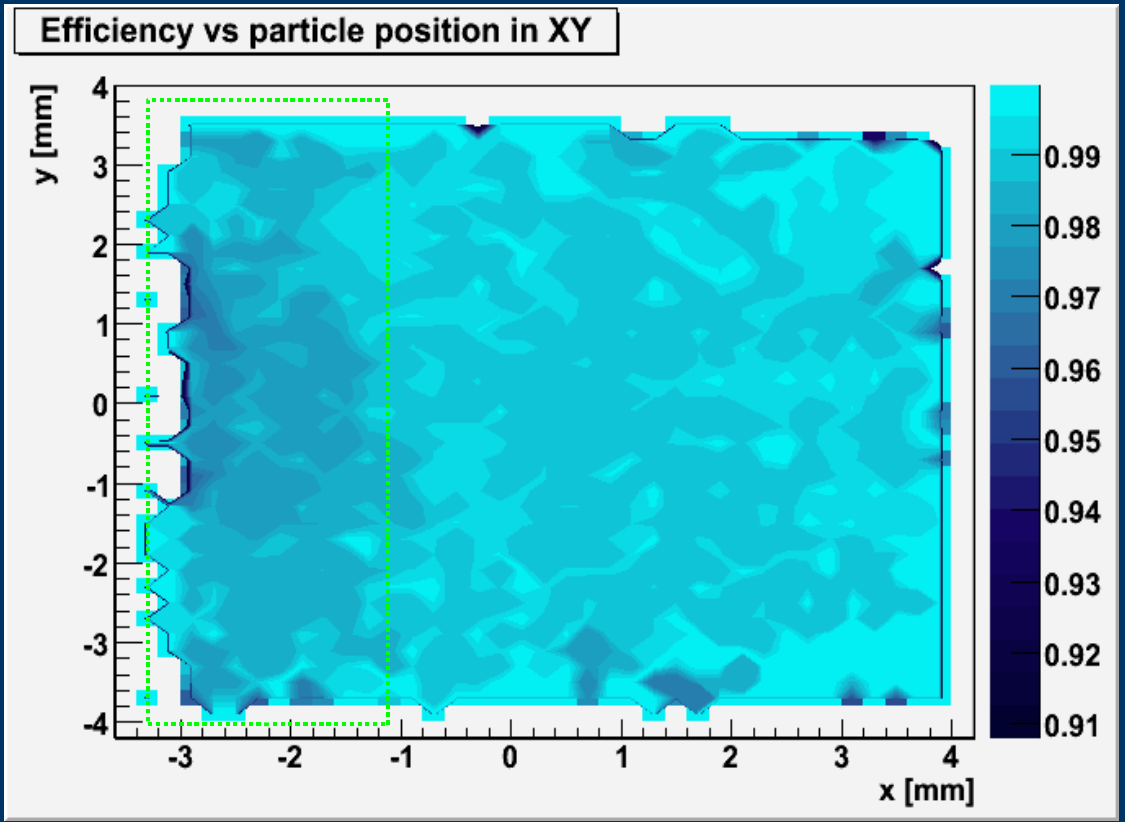
Efficiency

- **Very preliminary**, no adhoc studies and no information about purity.
- Mean efficiency is higher than 95%



Beam shape

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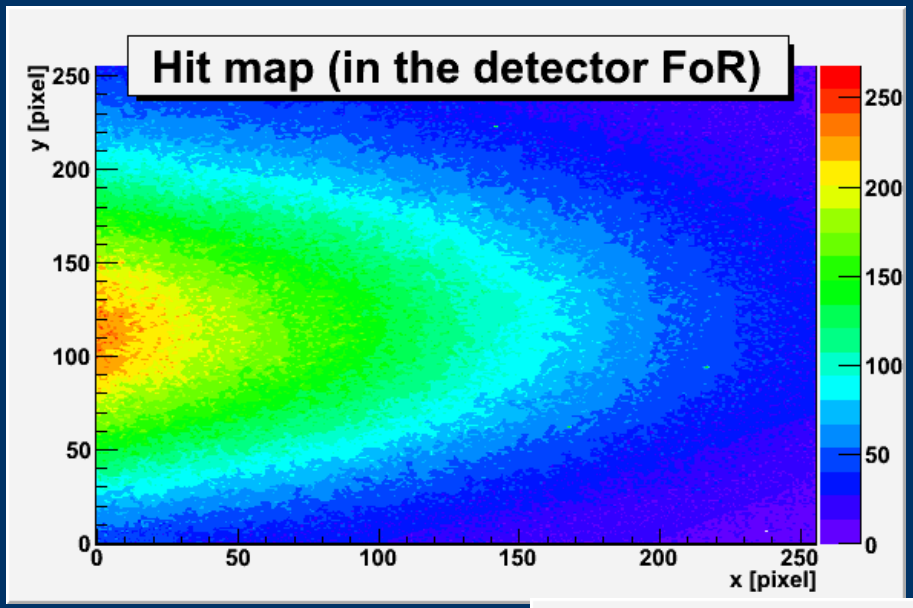

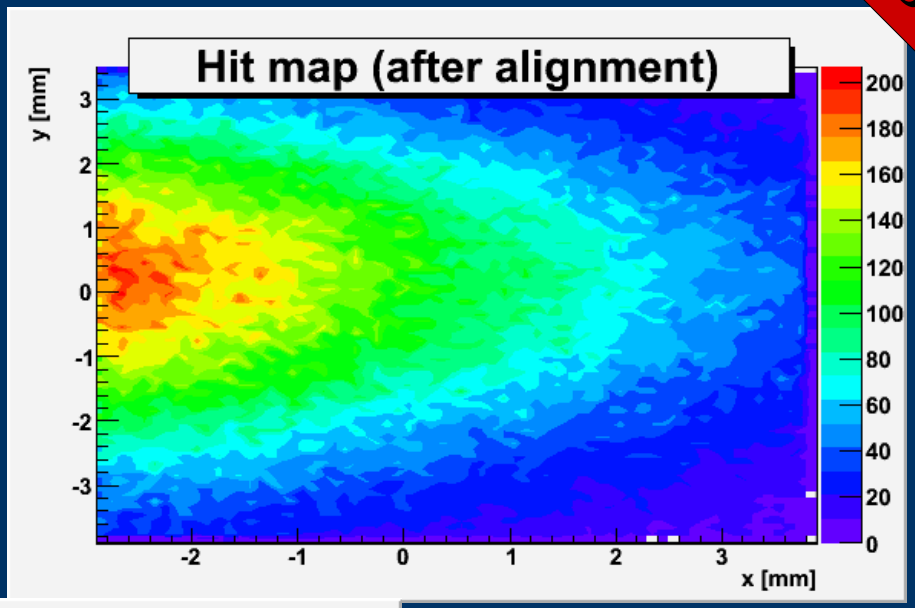

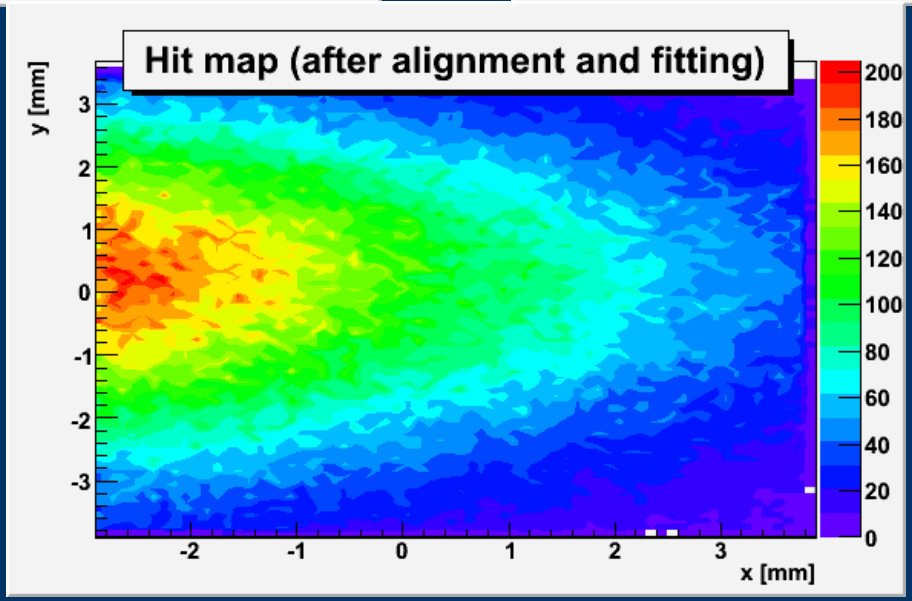

Tracking code performance

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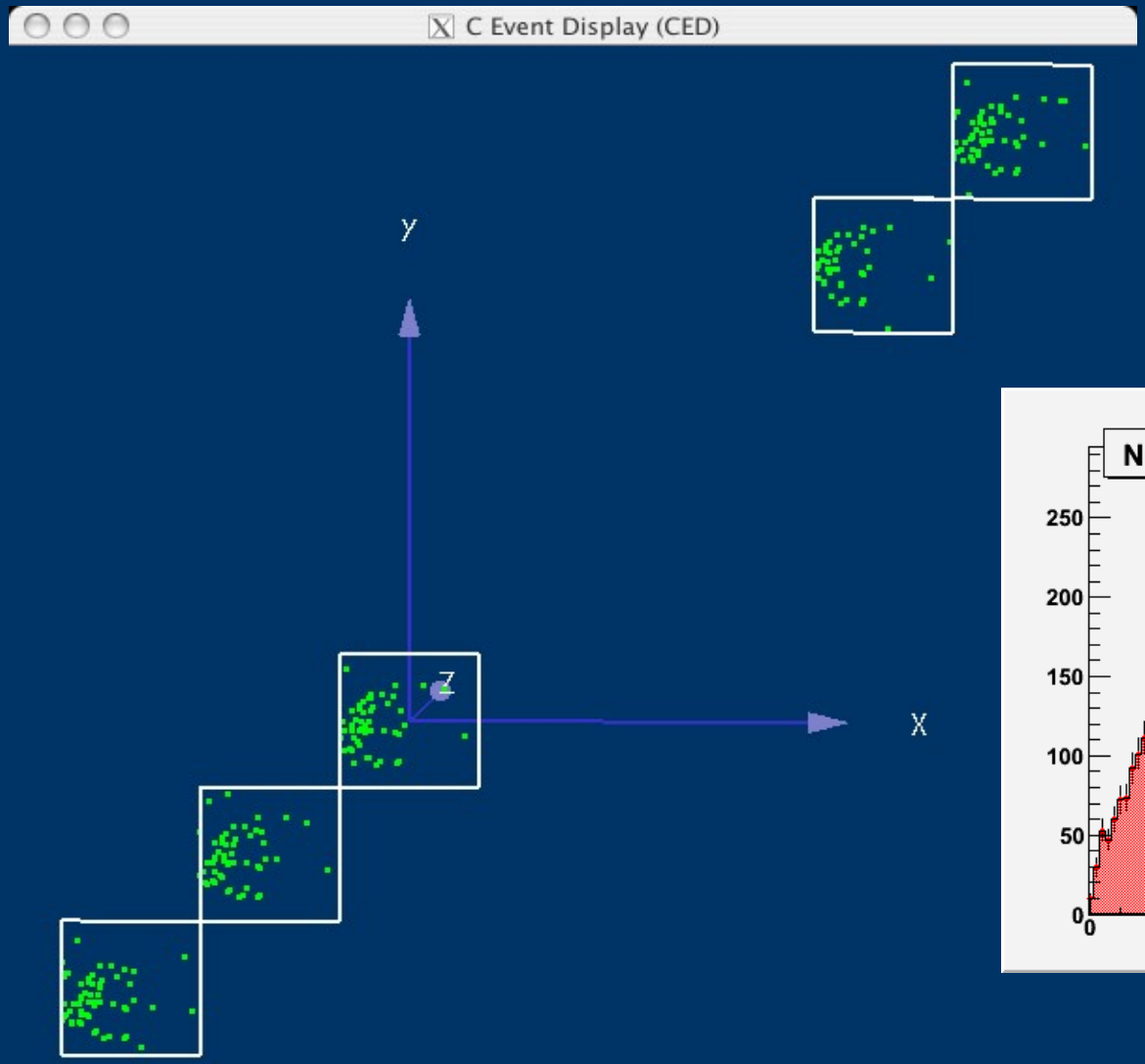

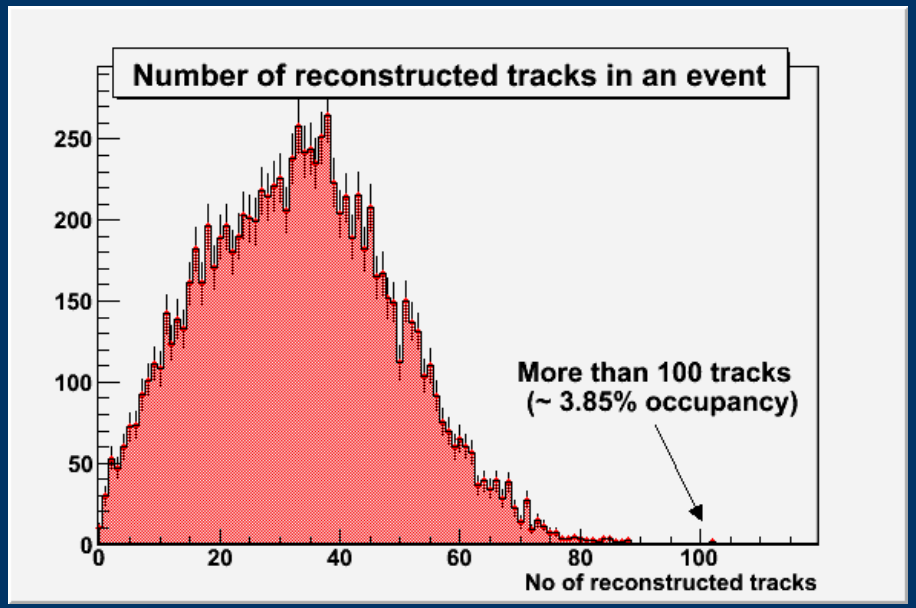

When the MS does matter

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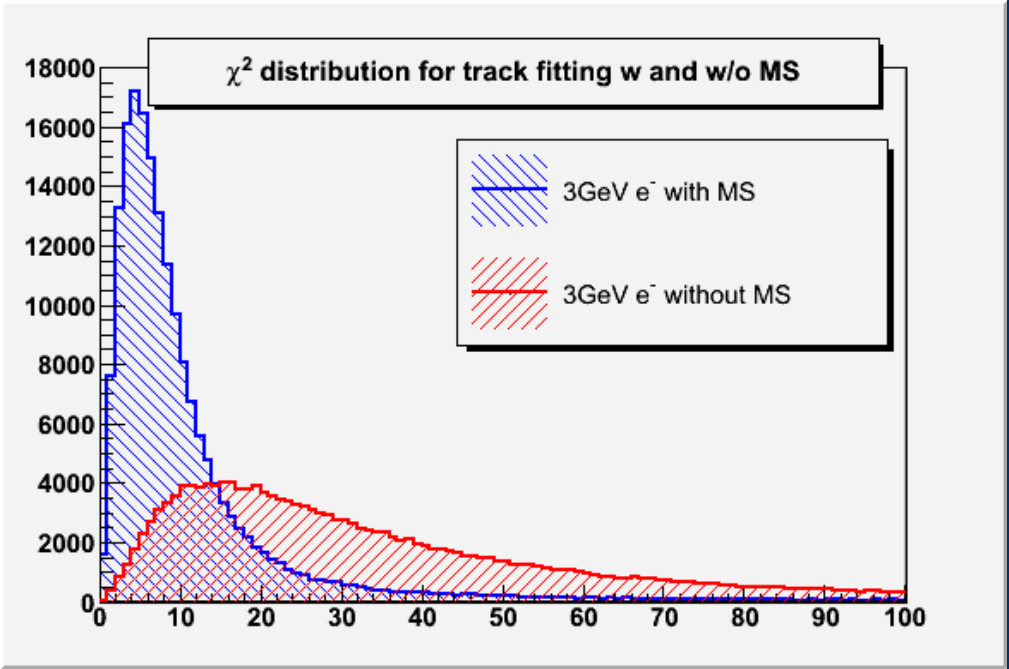
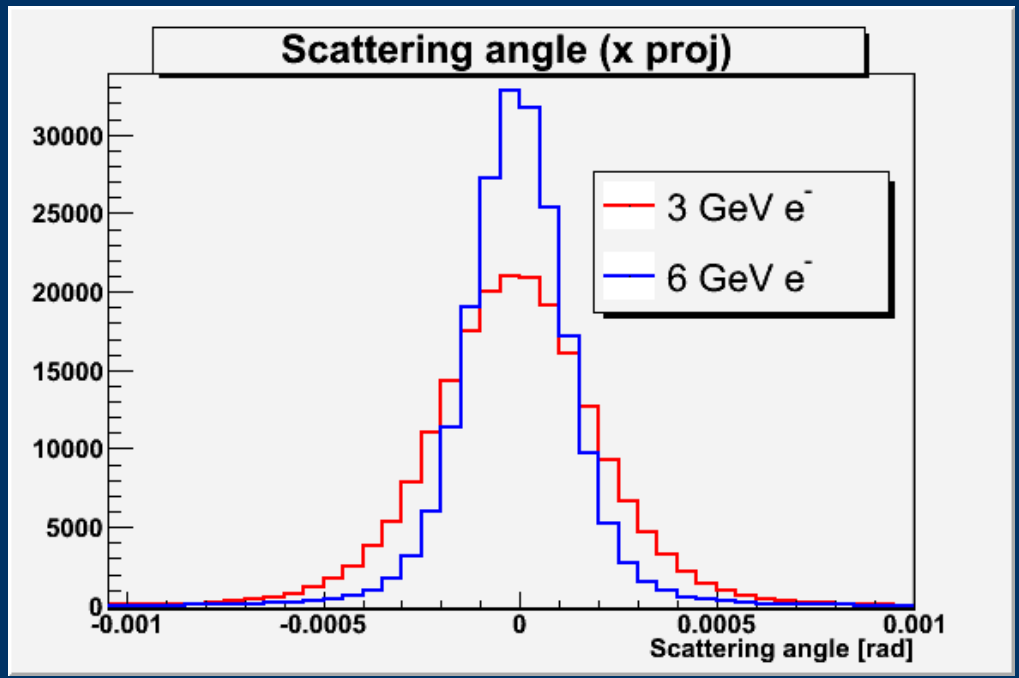
- When working with 3 and 6 GeV e^-, multiple scattering does play a role.
- To obtain good resolution you need to take care of MS, so forget about straight lines and use the analytical fitting function (see A.F. Zarnecki EUDET report)





Track multiplicity at DESY

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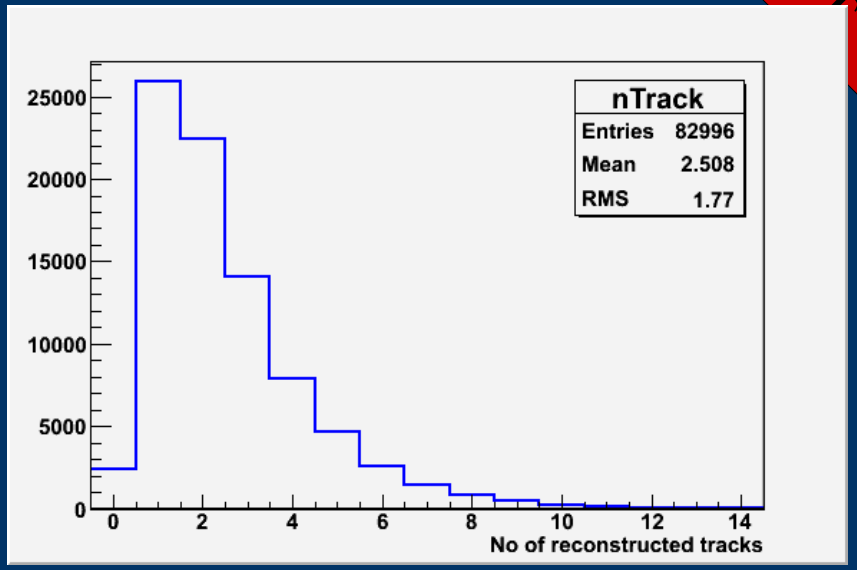
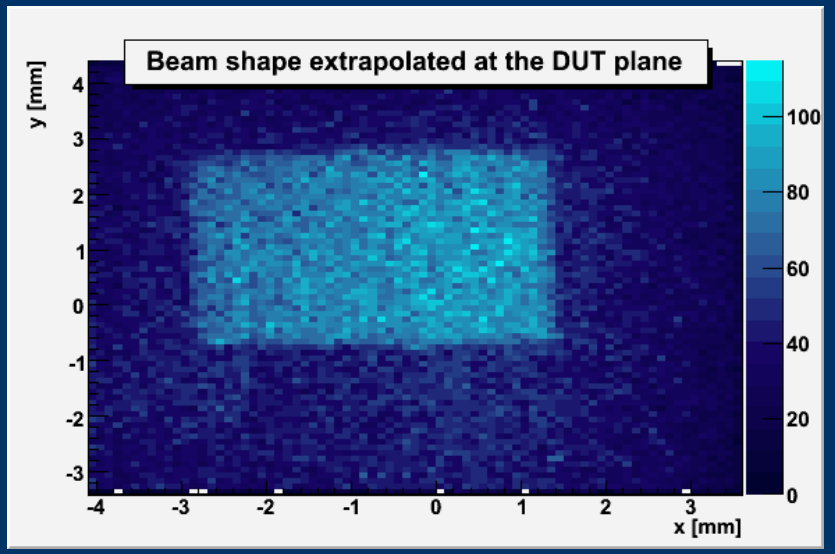
- At DESY the multiplicity was lower (2.5 tracks)
- This was making possible to see the trigger shape.
- Even with so low multiplicity the alignment is a bit more difficult.





Resolution with e^-

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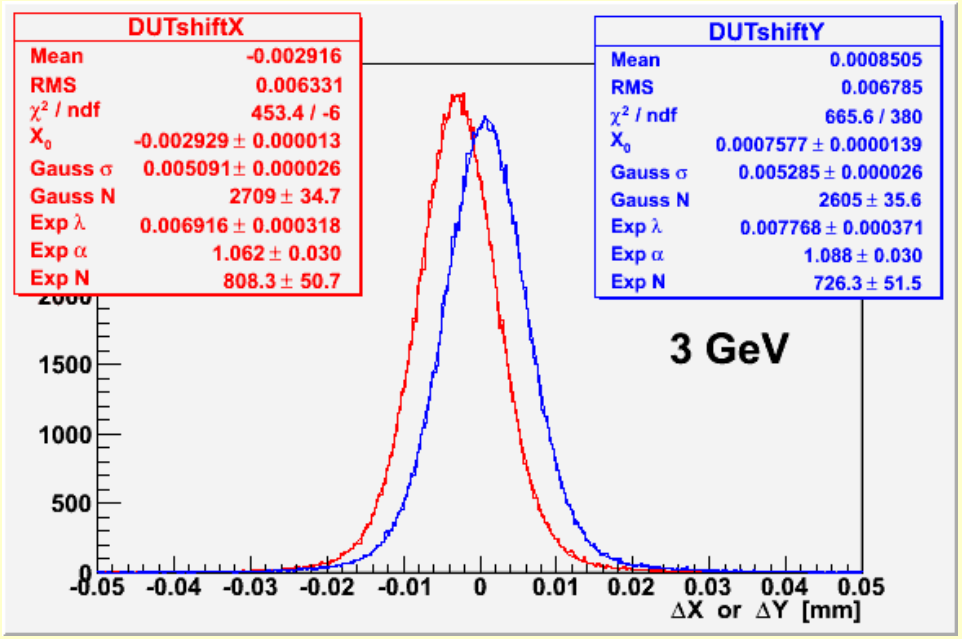
- Using the analytical fit, it is possible to take MS into account. Due to MS the telescope resolution is slightly worse at lower energies. But the observed widths are in very good agreement with expectations.

expected fit precision at DUT = 4.22 um

expected DUT width = 5.12 um

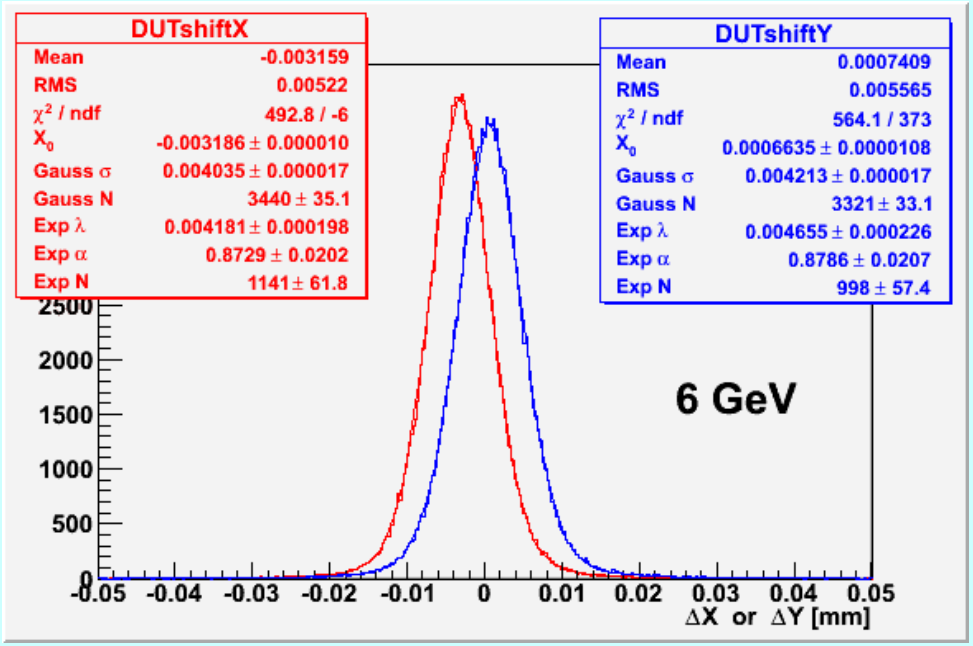
measured width = 5.09 um / 5.28 um



expected fit precision at DUT = 2.89 um

expected DUT width = 4.16 um

measured width = 4.03 um / 4.21 um



Summary and conclusion

- The JRA1 group was organizing three data taking period in the last months.
  - Two at DESY and one at CERN.
  - All of them were a big success and a lot of fun!
- The data analysis is still on going but preliminary results are very good and in agreement with the expectations.
- The telescope demonstrator and the rest of the DAQ system worked almost “out of the box”.
- The tracking software proves to work very well even if there are still some issues that can be improved.
- More results will appear soon and they will be published into a EUDET memo.
- Next beam tests? See the talk of the **new boss!**

Thanks!