

Status of the analysis

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Outline

- Introduction
- Alignment procedure
- Analysis of fit output
- Sensor studies in “DUT mode”
- Recent code development
- Conclusions

Introduction

Test data considered:

- DESY beam tests August 2007
 - 3 GeV data sample - **most of results**
 - 6 GeV data sample
- CERN beam tests September 2007
 - low multiplicity - **for alignment**
 - large multiplicity - **algorithm tests and development**

All results shown are based on the analytical track fitting method implemented in **EUTelTestFitter**. All plots were obtained from two dedicated histogramming processors: **EUTelFitHistograms** and **EUTelDUTHisograms**.

Details of the method were described in my previous presentations, see:

<http://hep.fuw.edu.pl/u/zarnecki/talks/>

In this contribution, I will focus on analysis results.

New code developments will only be mentioned when relevant.

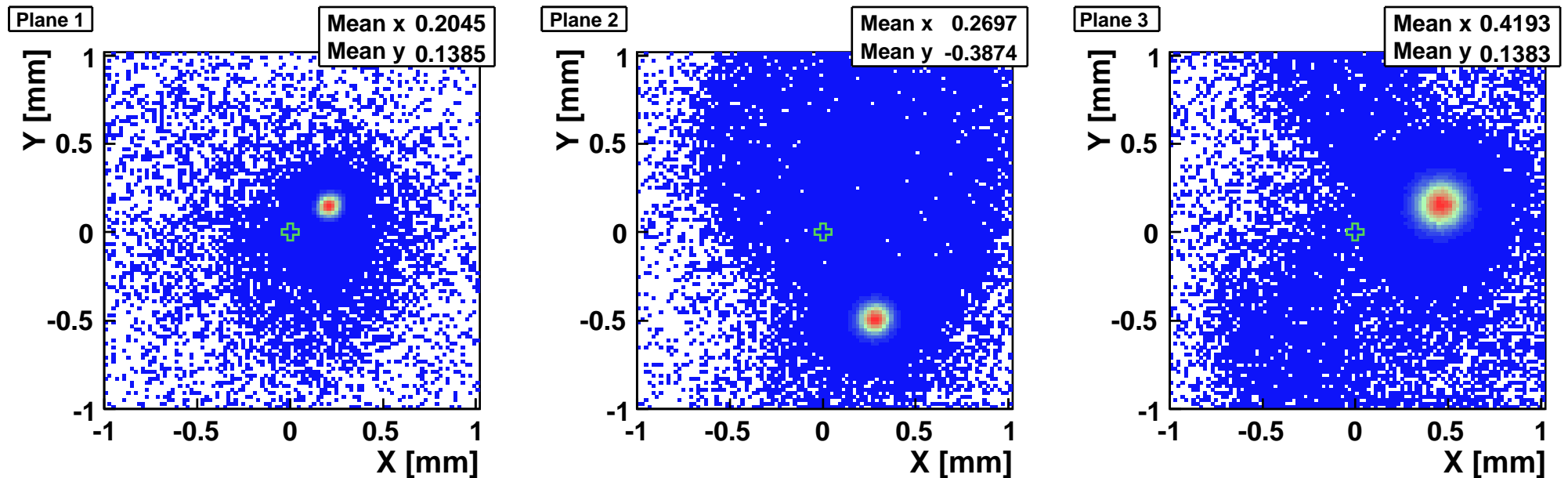
Alignment procedure

Phase I alignment relative to the beam axis

Tracks are reconstructed with very weak χ^2 cut ($\chi^2 < 30000$).

Assuming that the **beam is perpendicular to the first telescope plane** other planes are moved so that the average position difference is zero.

Position difference in X-Y **without alignment**:



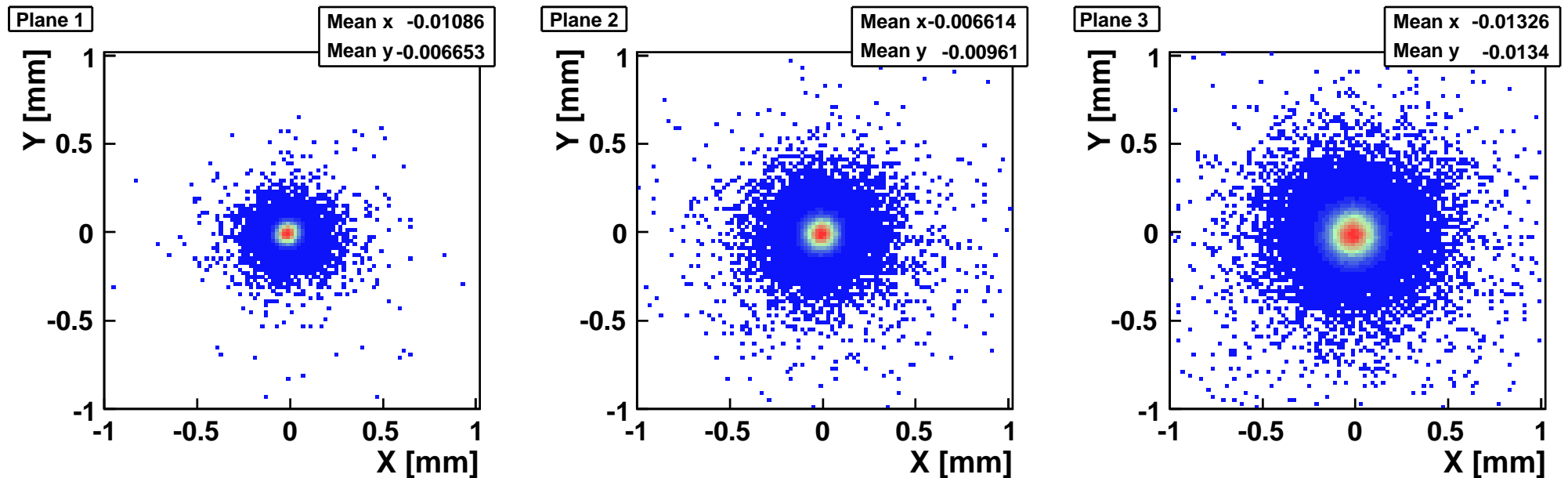
Alignment procedure

Phase I alignment relative to the beam axis

Tracks are reconstructed with weak χ^2 cut ($\chi^2 < 300$).

Assuming that the **beam is perpendicular to the first telescope plane** other planes are moved so that the average position difference is zero.

Position difference in X-Y **after alignment** (Phase I):



Alignment procedure

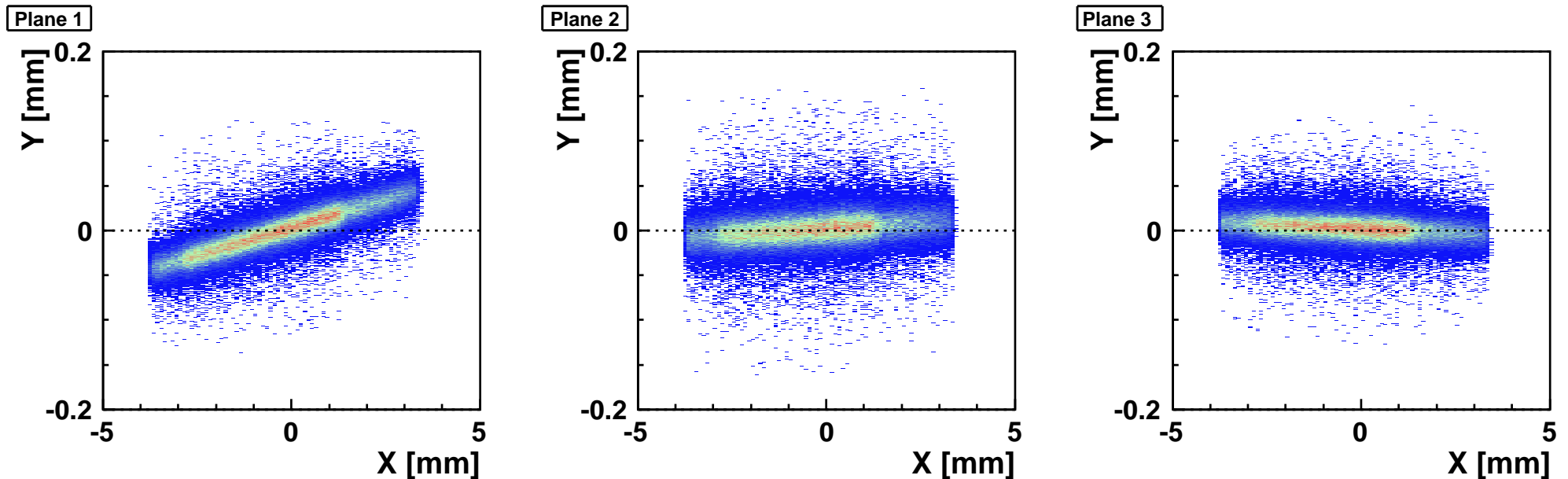
Phase II internal alignment

More precise alignment is obtained using **first and last planes as reference**.

Positions measured in other planes are compared with **interpolated straight line track**.

Plane **rotations** are calculated from position difference **dependence on particle position**.

Position difference in Y as a function of X **before Phase II**:



Alignment procedure

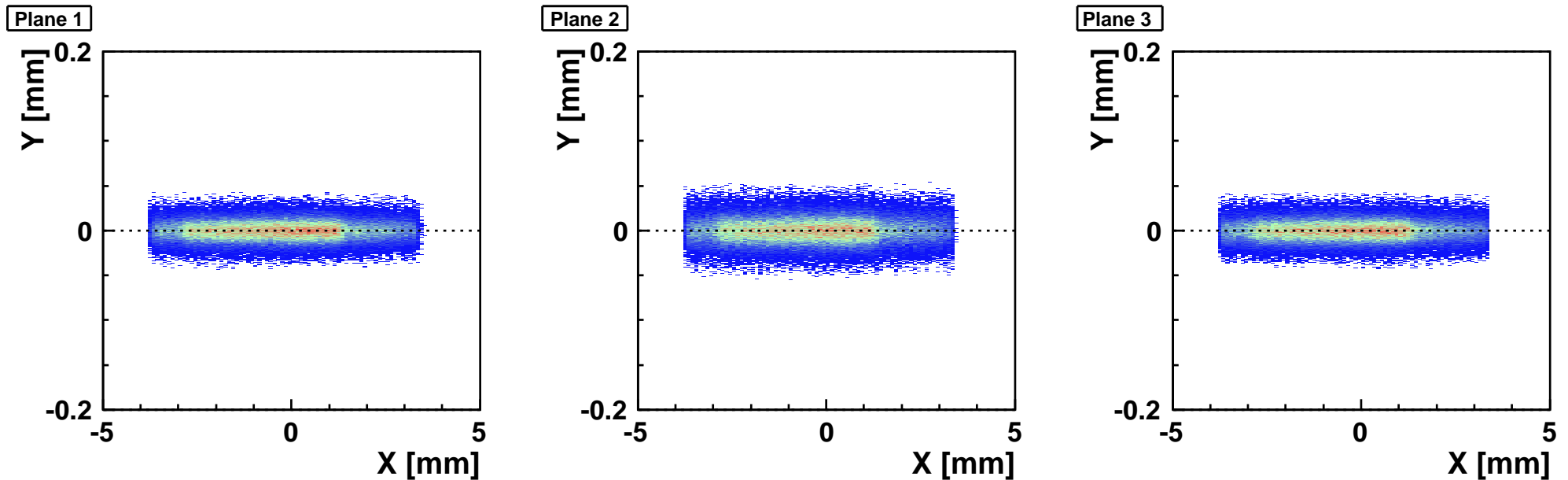
Phase II internal alignment

More precise alignment is obtained using **first and last planes as reference**.

Positions measured in other planes are compared with **interpolated straight line track**.

Plane position can be determined to $0(1)\mu m$, rotation to $0(1)$ mrad.

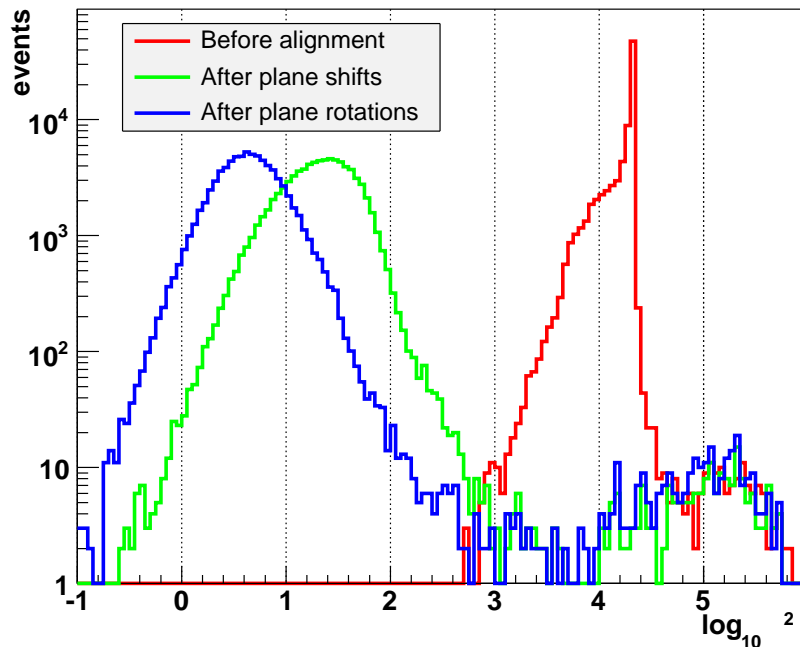
Position difference in Y as a function of X **after Phase II**:



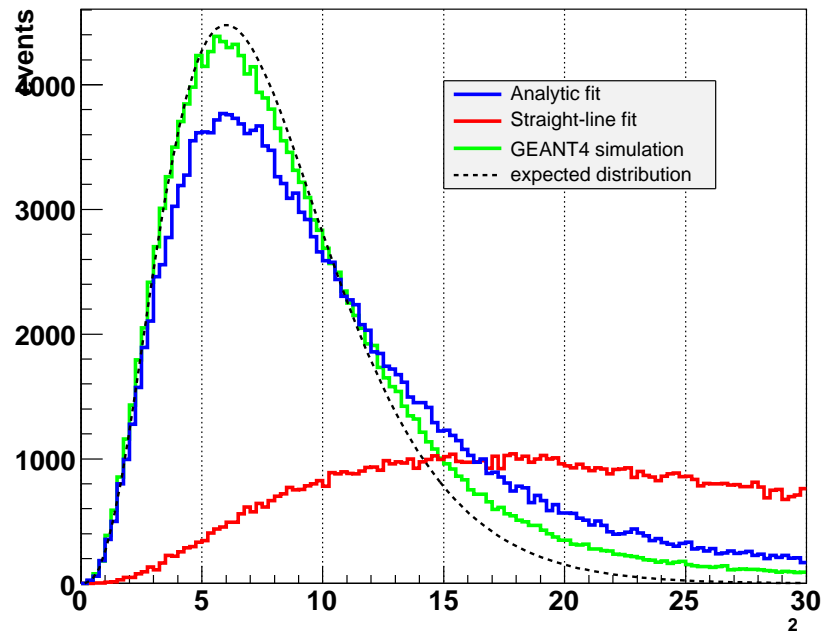
Alignment procedure

Fit quality

χ^2 improvement due to alignment
(Phase I and Phase II)



χ^2 distribution after alignment
very close to the expected one



DESY 3 GeV data, fit to 5 planes including beam direction constraint ($N_{df} = 8$).

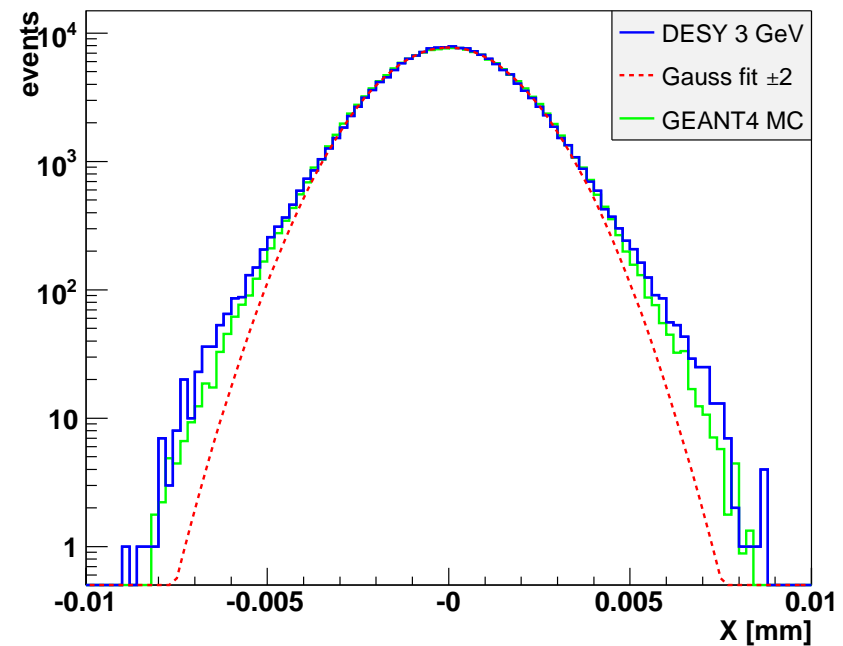
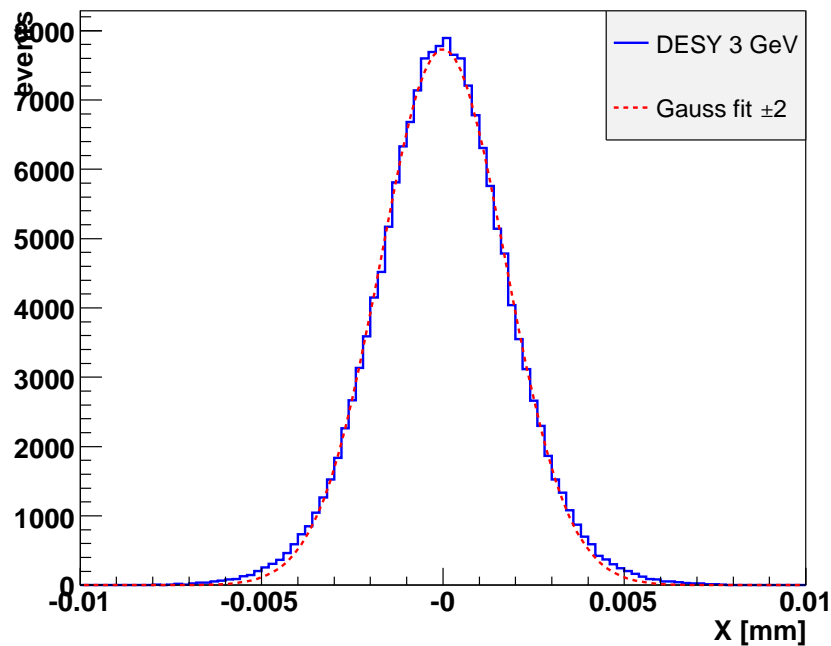
GEANT 4 simulation assuming $\sigma = 3\mu m$.

Fit results

Residuals

Difference between the measured cluster position and fitted track position.

DESY 3 GeV data, **middle telescope plane**, fit to 5 planes including beam constraint:



Analytical expectations: $1.74\mu\text{m}$, MC: $1.75\mu\text{m}$

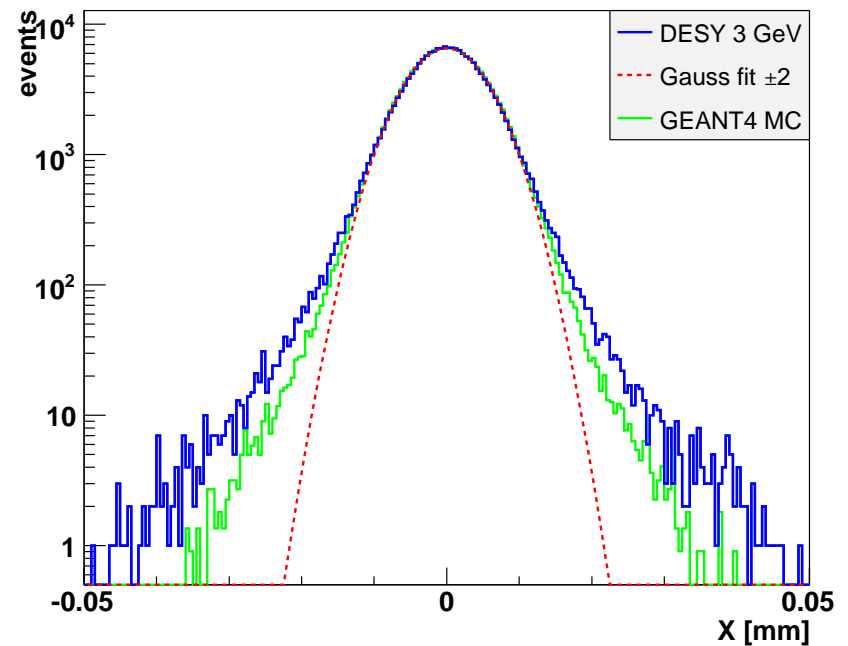
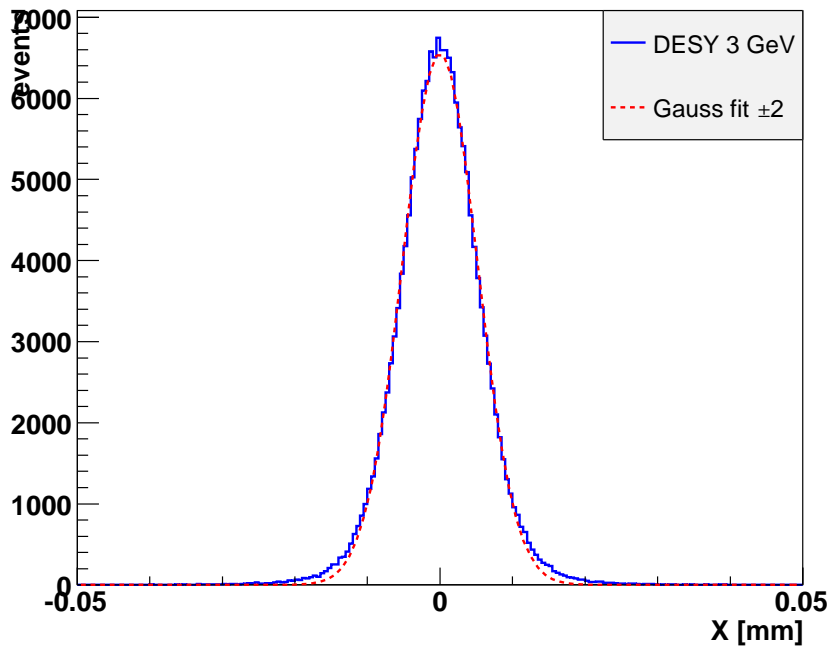
Measured: $1.72\mu\text{m}$ (X) $1.80\mu\text{m}$ (Y) (gaussian curve fitted within $\pm 2\sigma$)

Non-gaussian tails are well described by simulation (multiple scattering)

Fit results

"DUT mode"

One telescope plane is used as DUT.
Its response is compared to the track fitted to 4 remaining layers.
Results for the middle telescope plane:



Analytical expectations: $5.18\mu m$ MC: $5.29\mu m$

Measured: $5.16\mu m$ (X) $5.40\mu m$ (Y) (gaussian curve fitted within $\pm 2\sigma$)

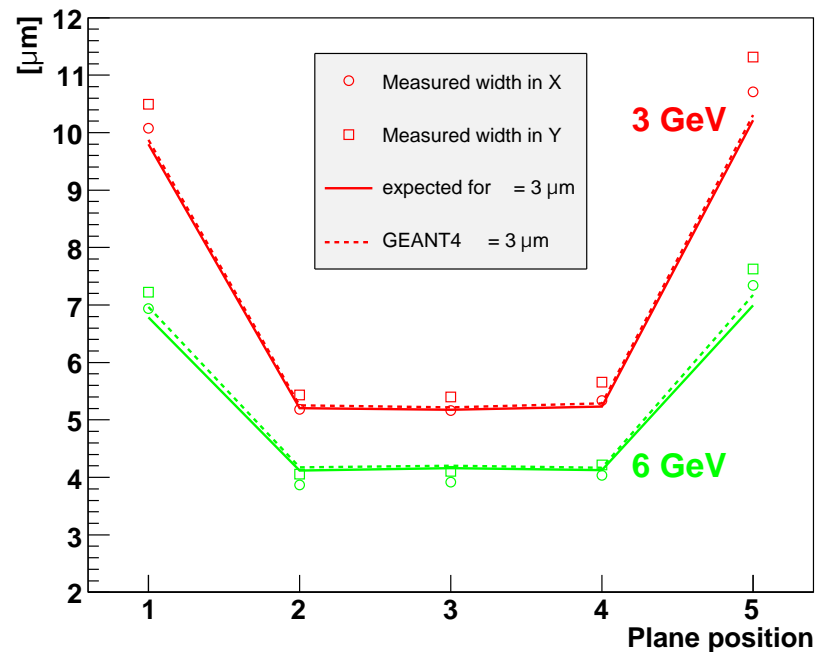
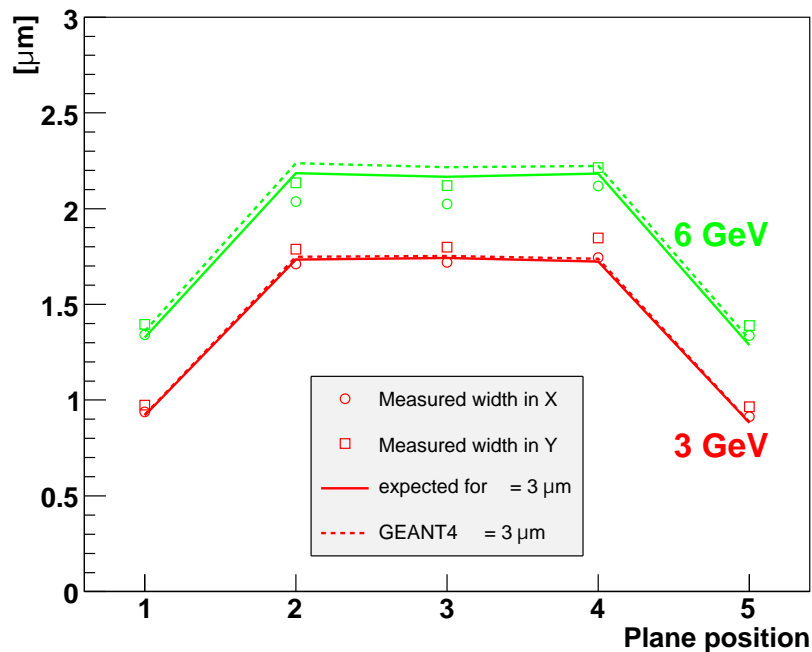
Fit results

Residuals

Comparison of the observed distribution widths with expectations from analytic calculations and GEANT 4 simulation.

Fit to 5 telescope layers

“DUT mode” (fit to remaining 4 layers)



Very good agreement with expectations

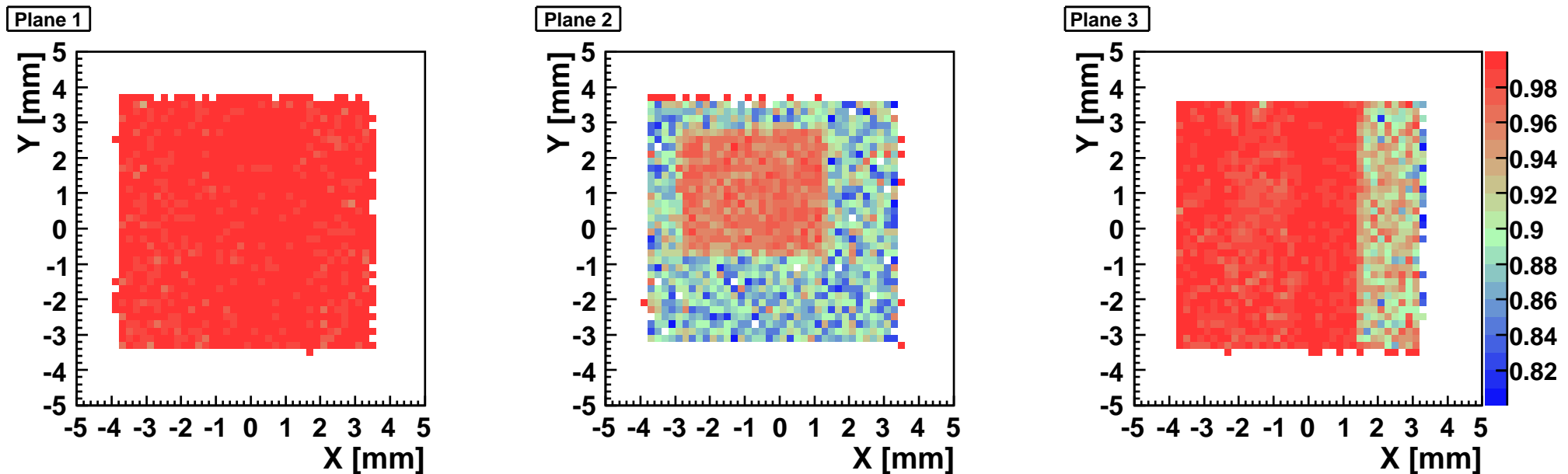
(for the assumed single sensor resolution of $\sigma = 3 \mu\text{m}$)

DUT mode studies

DUT efficiency

Efficiency can be estimated as a **fraction of tracks**, for which a **hit is found in DUT** close to the expected particle position (**track is fitted to the remaining 4 planes**).

Plot for 3 (out of 5) planes at 3 GeV:



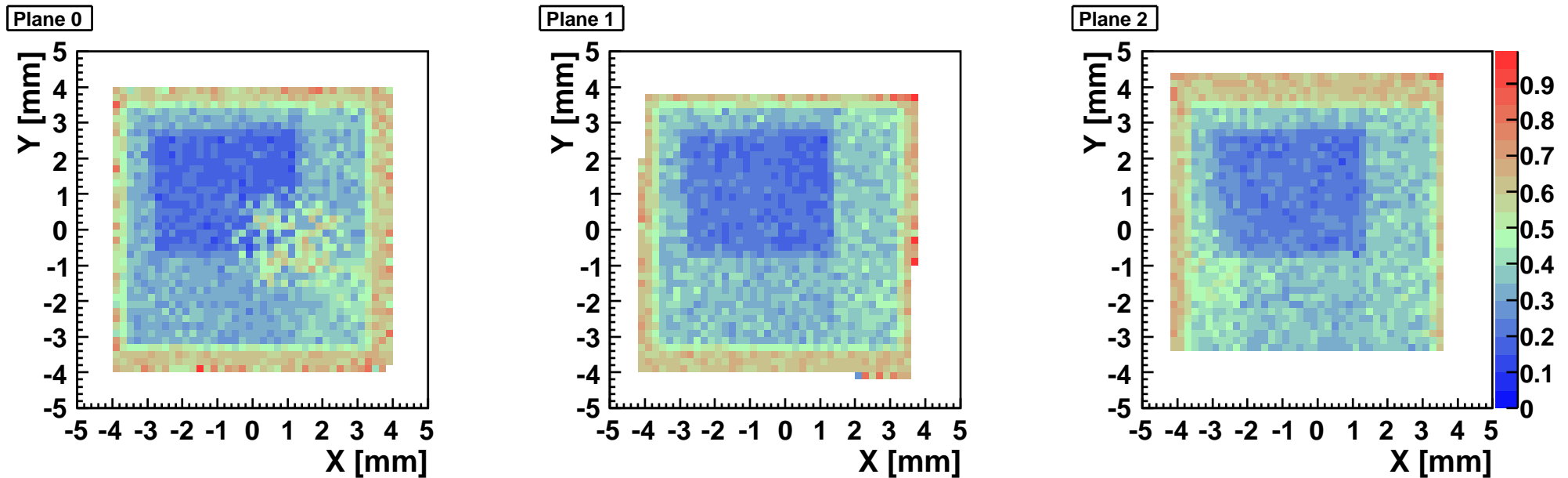
High performance of plane 1. One noisy matrix in plane 3.

Strange behaviour of plane 2 (high efficiency for triggering particles only)

DUT mode studies

DUT noise

Noise can be estimated as a fraction of hits, which are not matched to any track:



However, this estimate is **biased**, as the track reconstruction efficiency is not 100%.

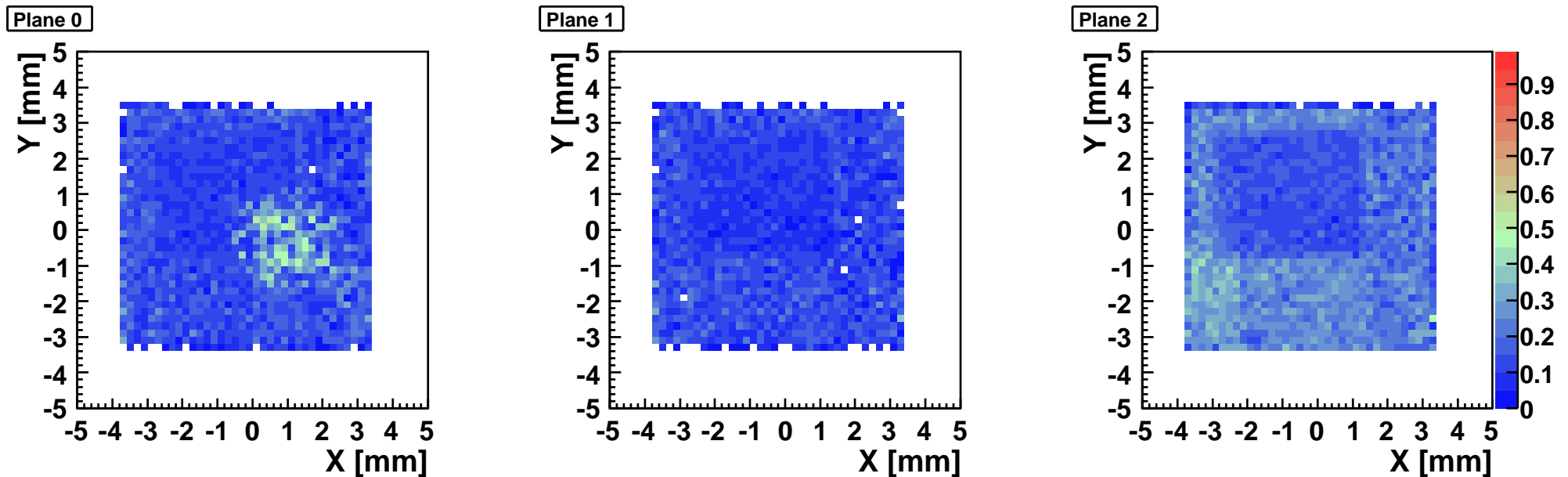
High fraction of unmatched hits at sensor edges is due to plane miss-alignment.

DUT mode studies

DUT noise

Noise estimate can be corrected for track finding efficiency (calculated as a product of plane efficiencies).

Fraction of unmatched hits, after correction for unreconstructed tracks:



Average noise level 10-20%.

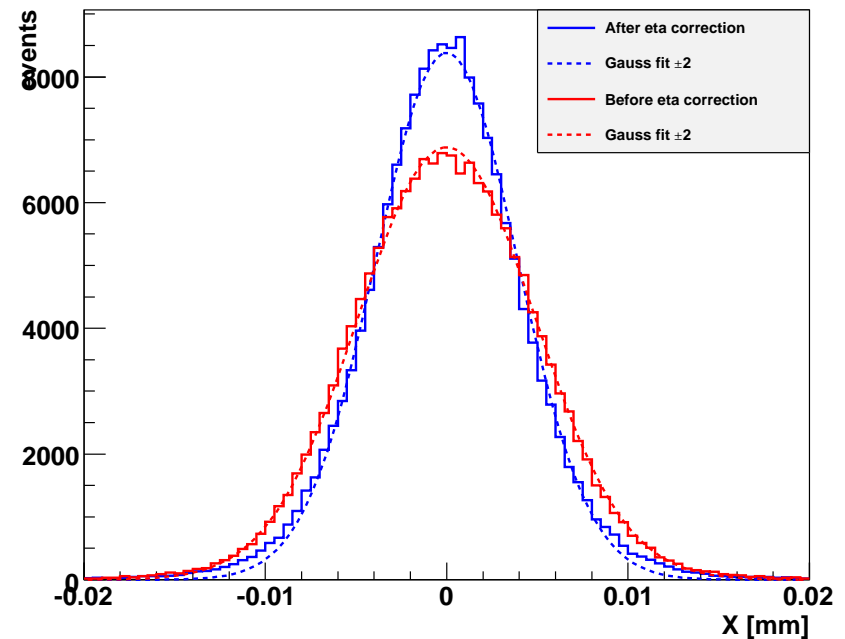
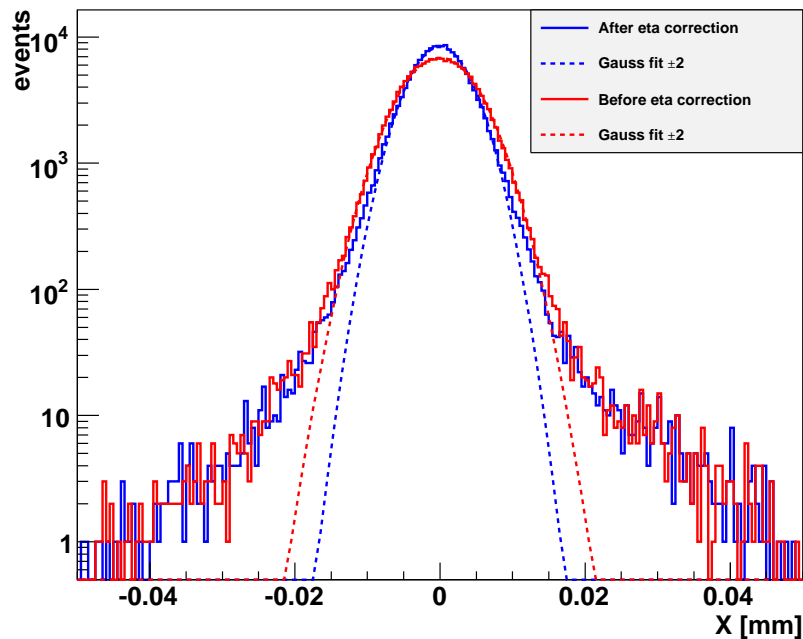
Particles going at large angles, not crossing all planes, also contribute to “noise”.

DUT mode studies

Eta corrections

All results presented so far were based on final cluster positions, calculated including [Eta function correction](#).

Residua for position at DUT reconstructed without and with Eta correction:

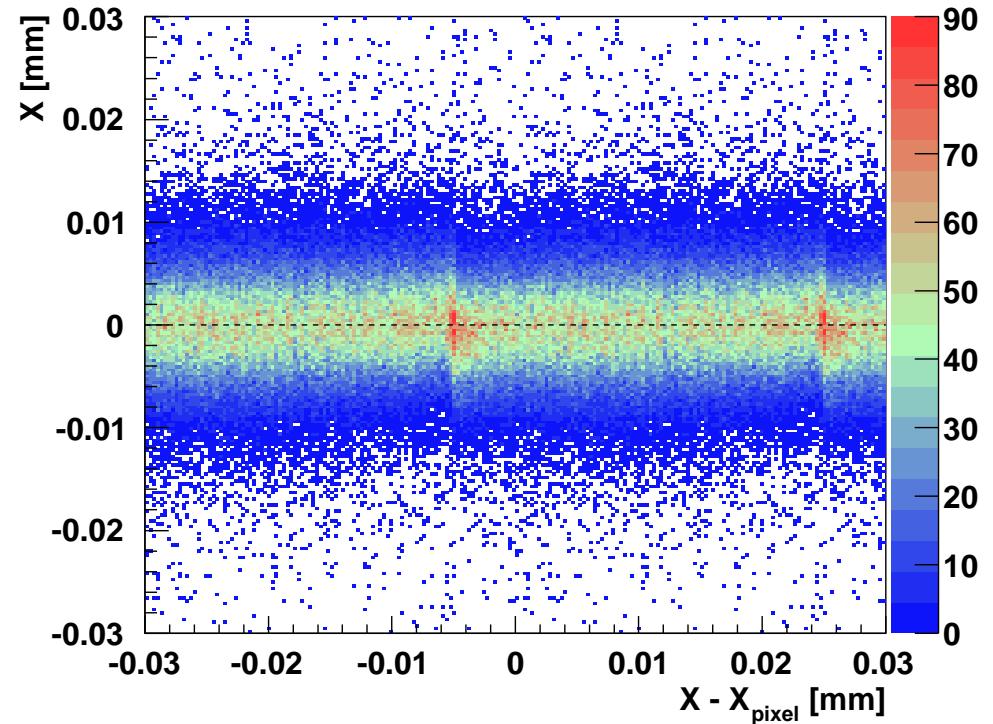
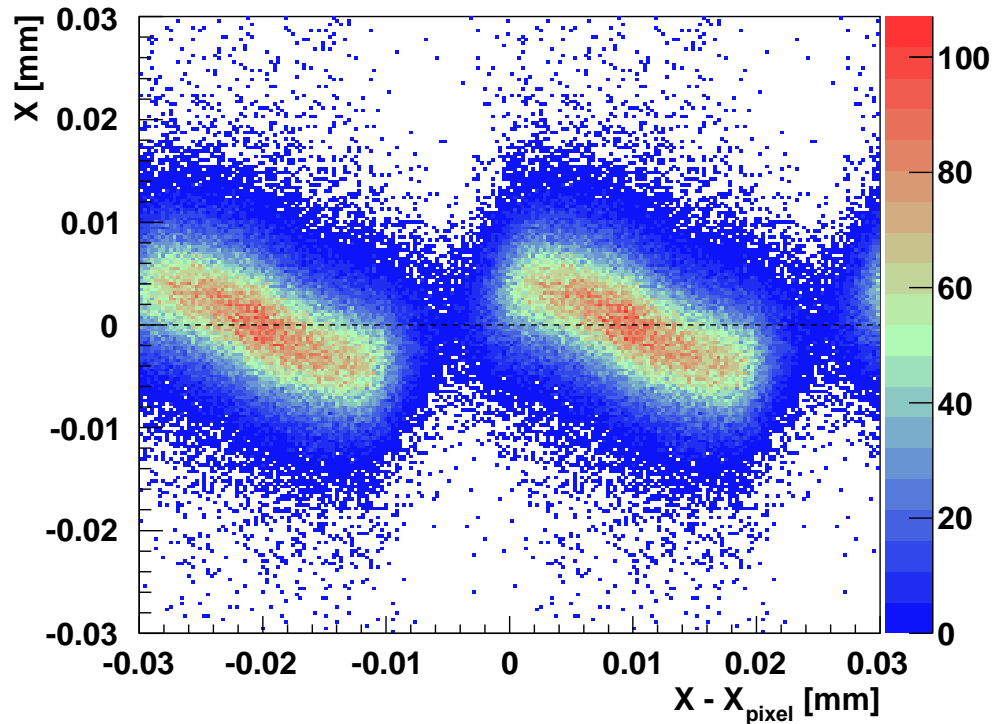


Eta correction reduces the width of the distribution from $4.9\mu\text{m}$ to $3.9\mu\text{m}$ (DESY 6 GeV)

DUT mode studies

Eta corrections

Position shift (**measured - fitted position**) as a function of the measured position in sensor frame modulo the pixel width, before and after applying Eta correction:



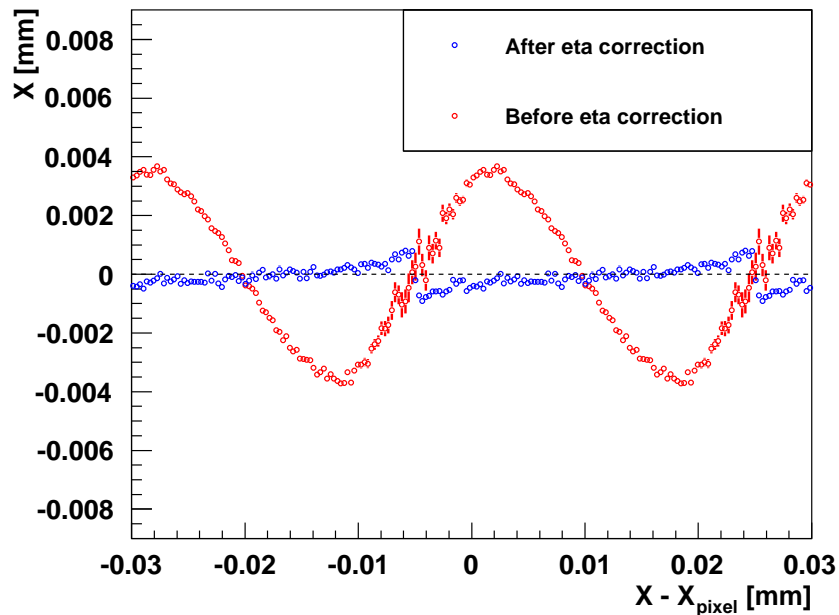
DESY, 6 GeV

DUT mode studies

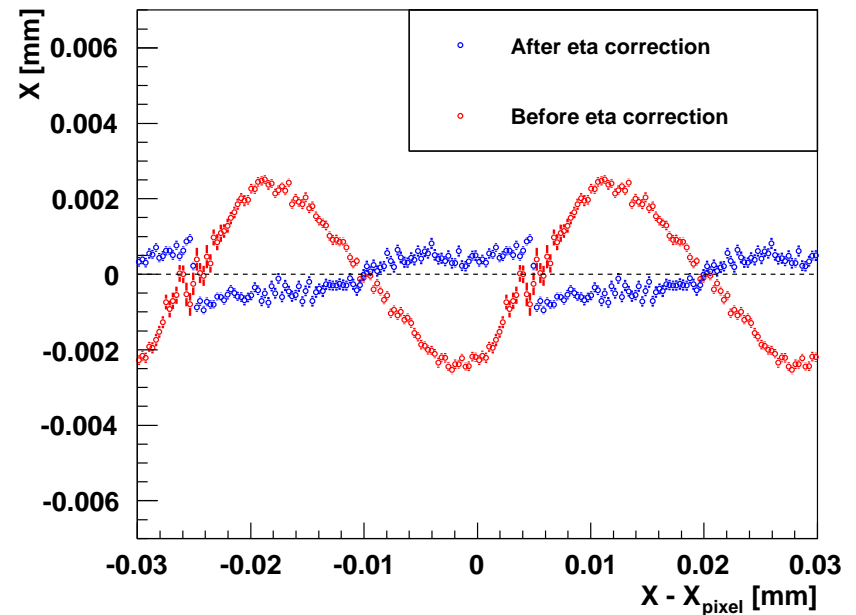
Eta corrections

Average position shift in bins of position (modulo pixel width)

DESY e^- 6 GeV



CERN π^\pm 180 GeV



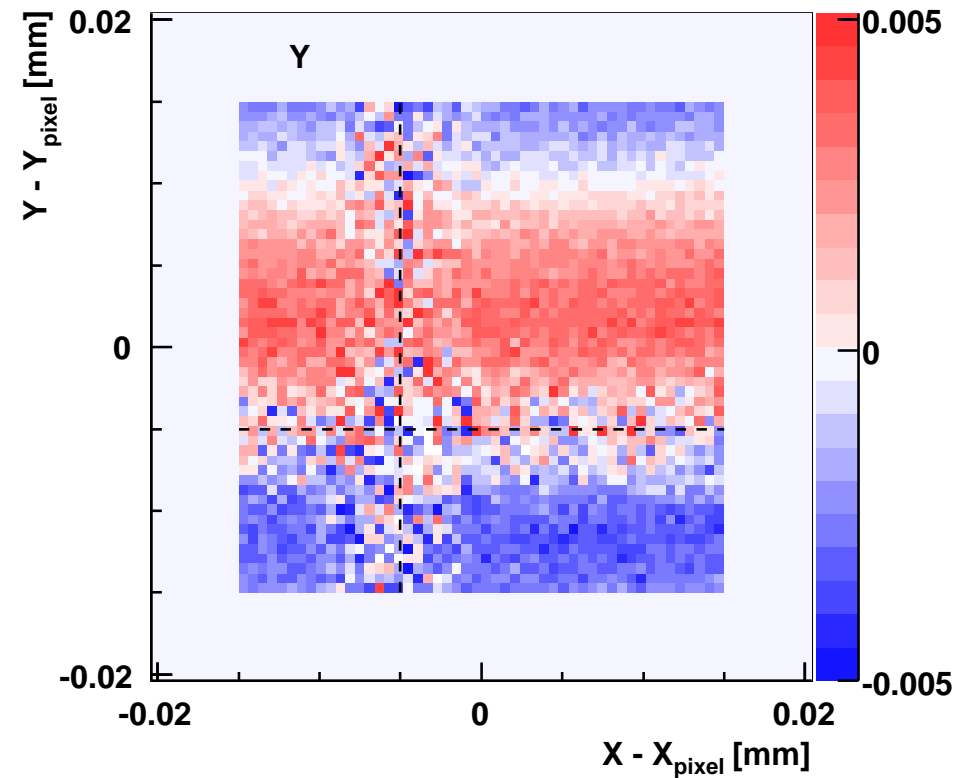
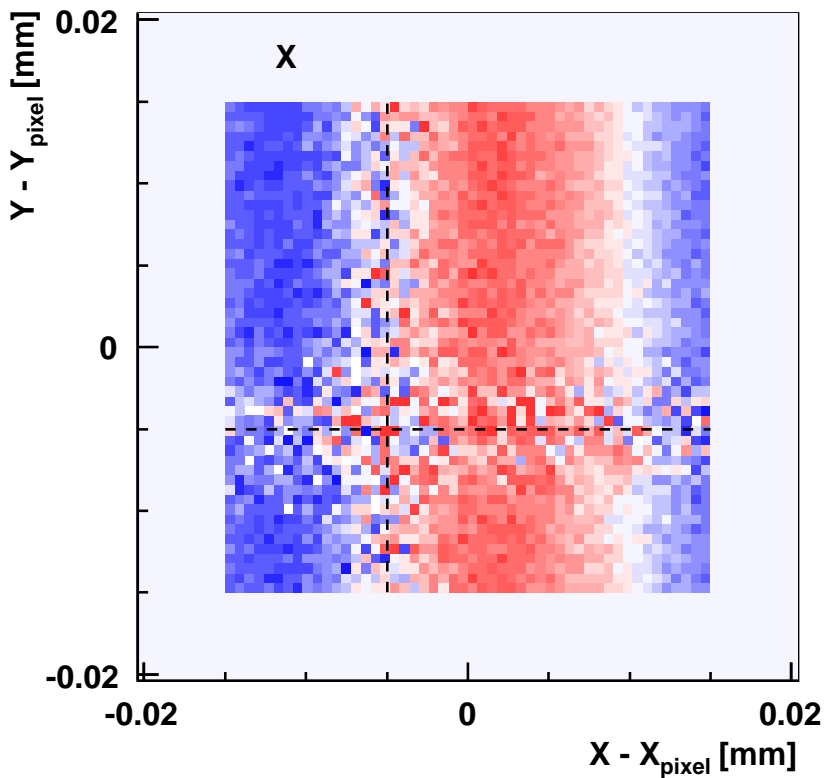
Eta function applied seems to 'overcorrects' the data...

DUT mode studies

Eta corrections seem to be uncorrelated

No clear correlation between position shift and position in perpendicular direction.

Average shift as a function of X-Y position **before eta correction** (DESY 6 GeV)

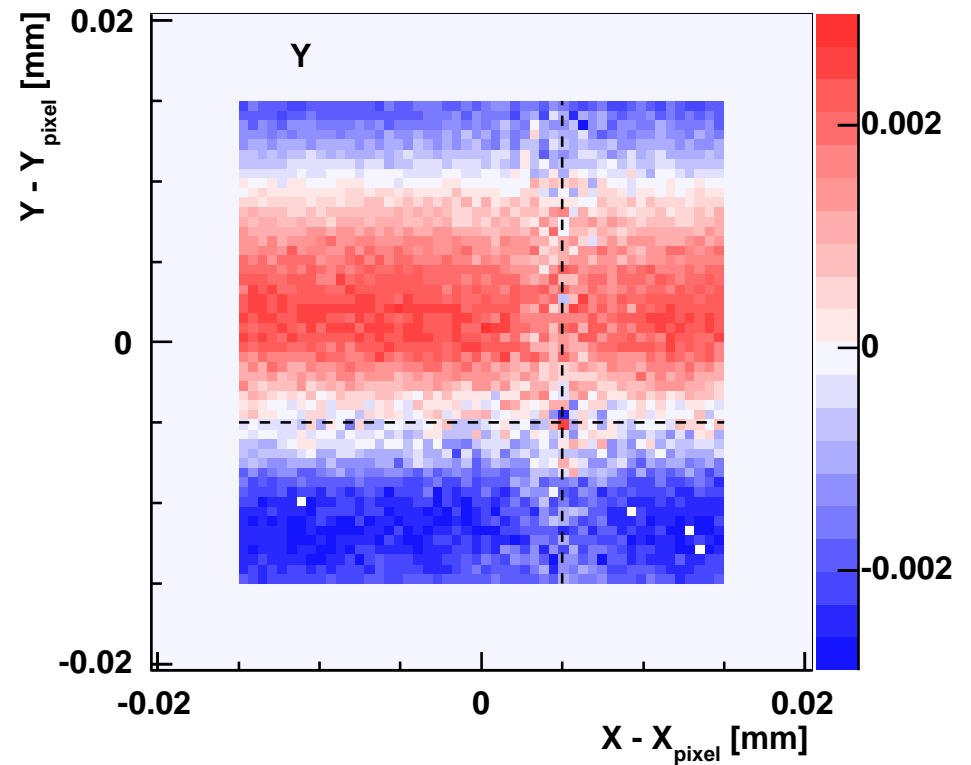
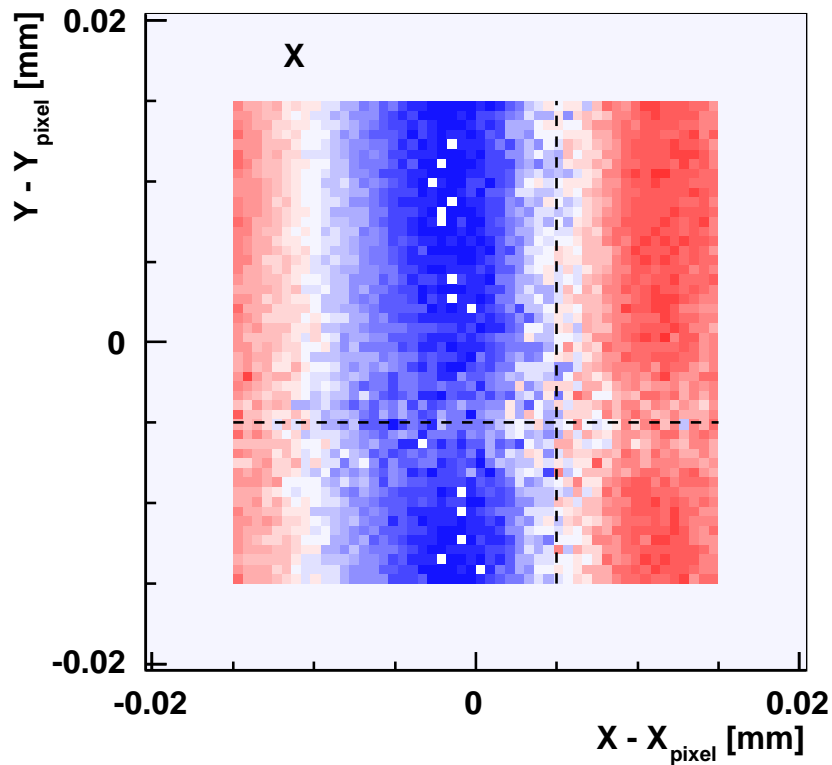


DUT mode studies

Eta corrections seem to be uncorrelated

No clear correlation between position shift and position in perpendicular direction.

Average shift as a function of X-Y position **before eta correction** (CERN)

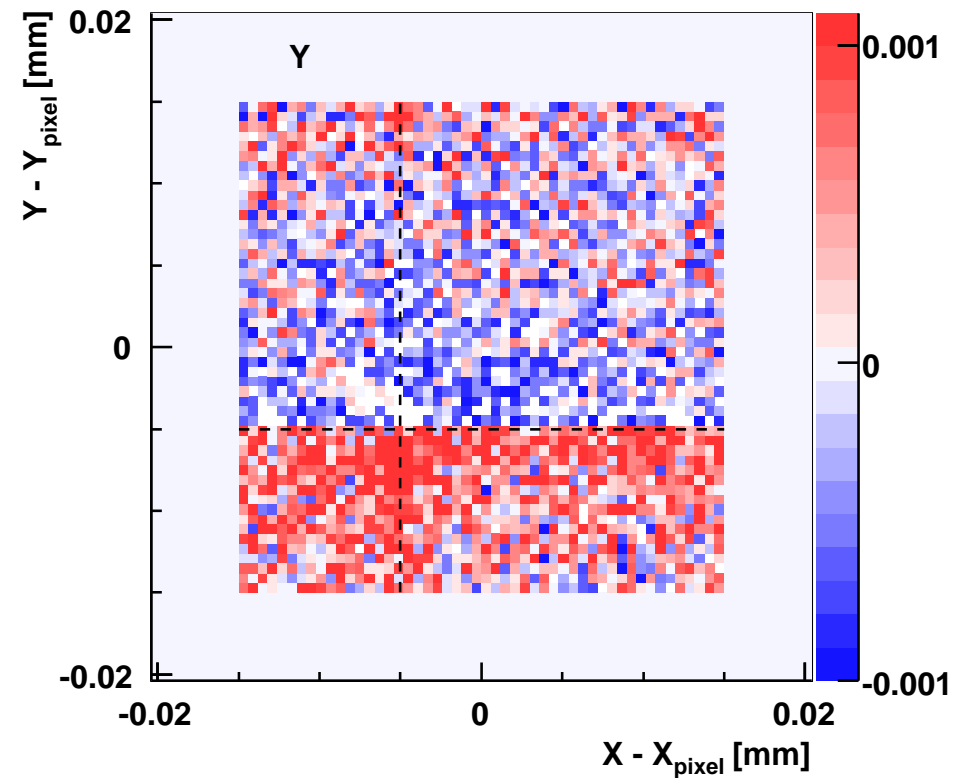
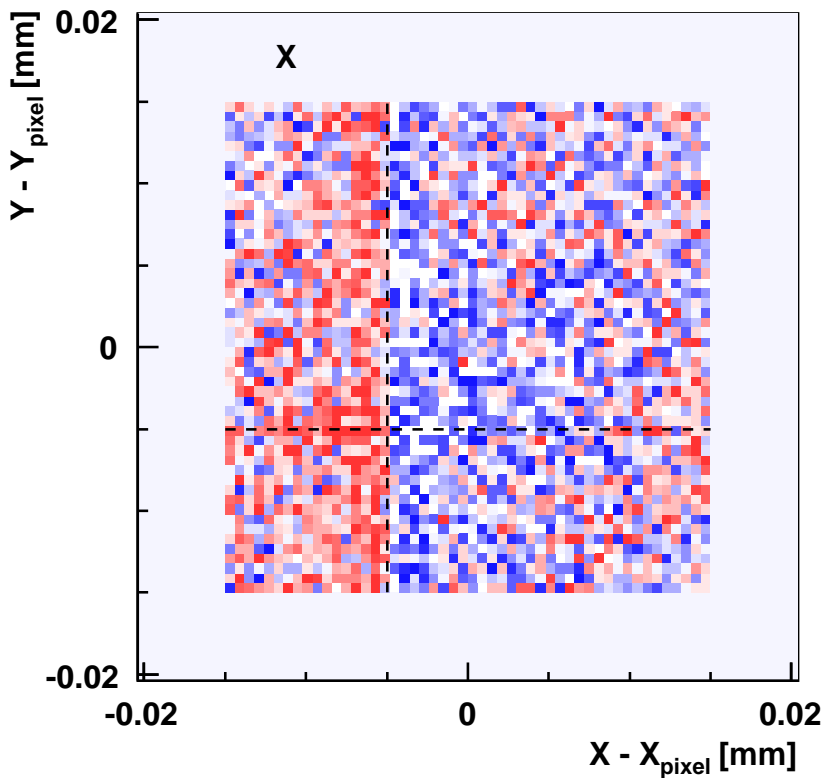


DUT mode studies

Eta corrections seem to be uncorrelated

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Average shift as a function of X-Y position **after eta correction** (DESY 6 GeV)

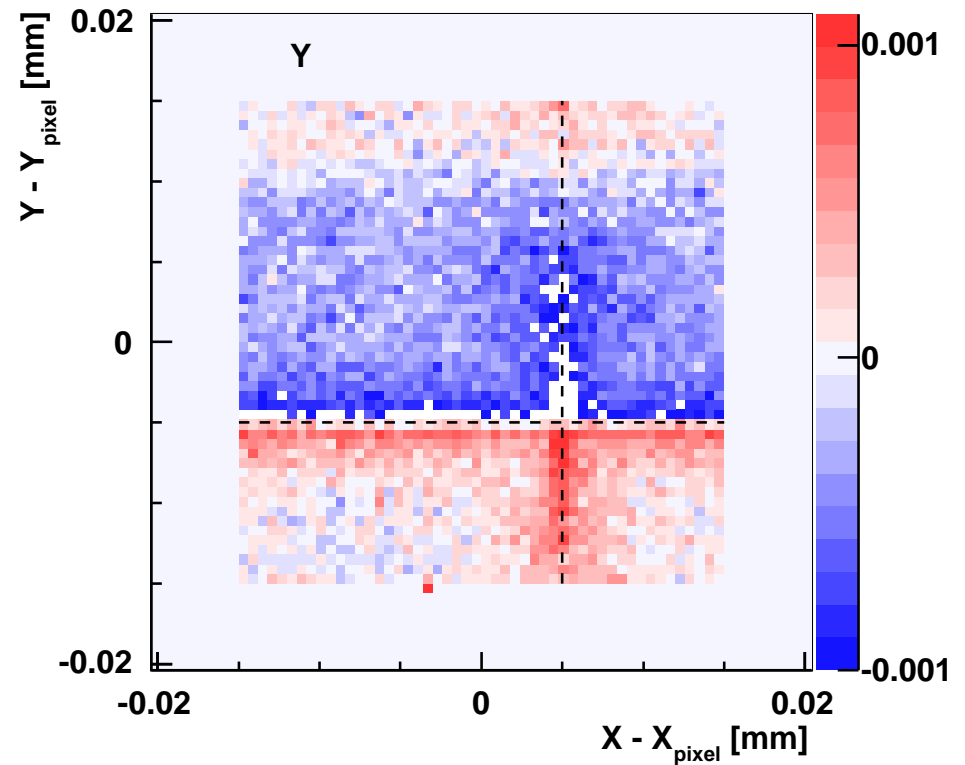
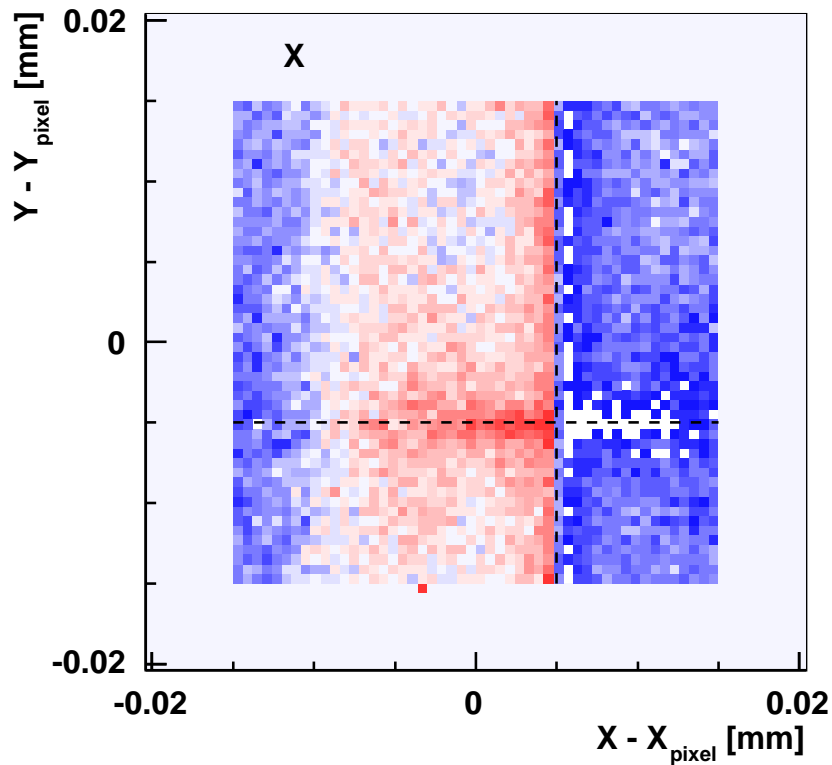


DUT mode studies

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Average shift as a function of X-Y position **after eta correction** (CERN)



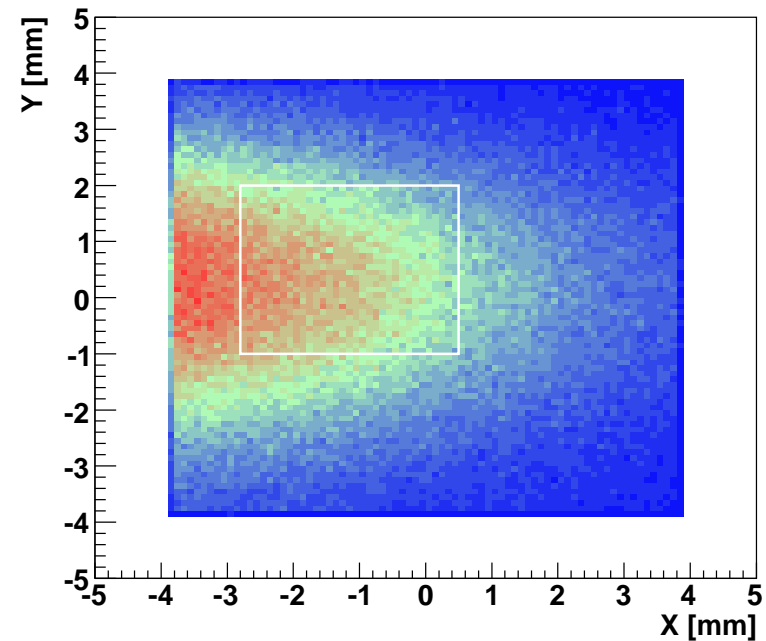
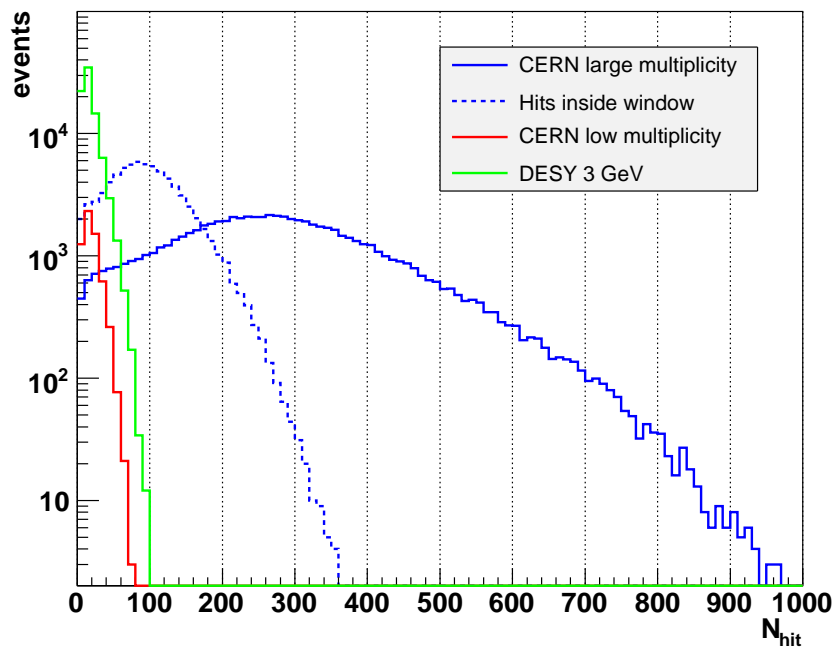
Code development

Box cut

For CERN large multiplicity data, number of hits per event is very large.

Algorithm limits number of hits per plane to 72 (for 5 planes), so many tracks are missed.

To overcome this limitation a possibility to define and active “window” or inactive “mask” on sensor surface was added to EUTelTestFitter

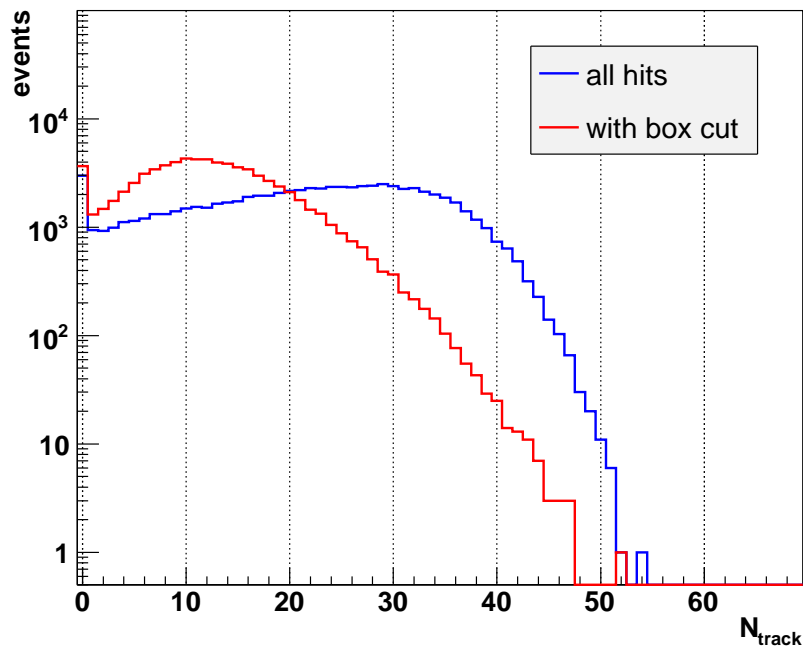


Code development

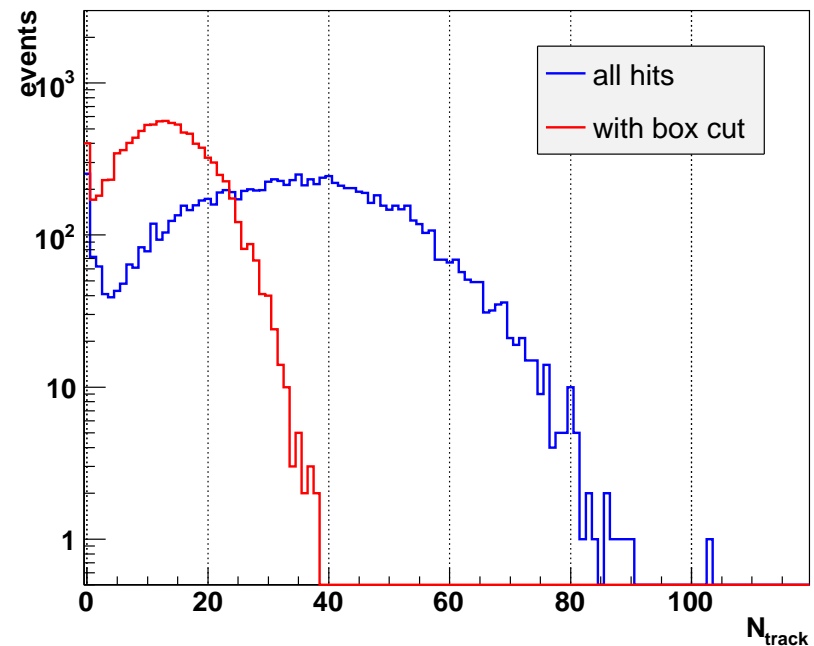
Box cut

Influence of the $3.3 \times 3 \text{ mm}^2$ window
(approximately 1/6 of sensor surface) on track reconstruction:

Tracks fitted to 5 planes



Tracks fitted to 4 planes



CERN large multiplicity data

Code development

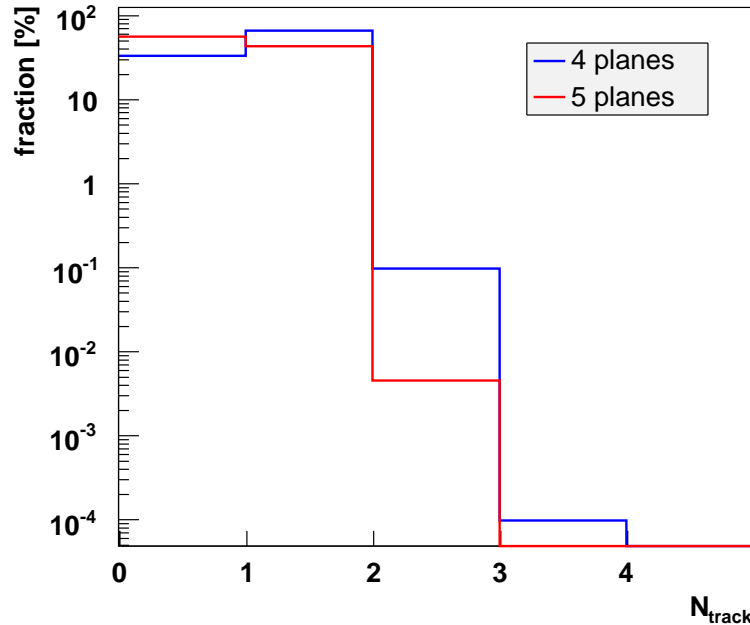
New track finding option

AllowAmbiguousHits true

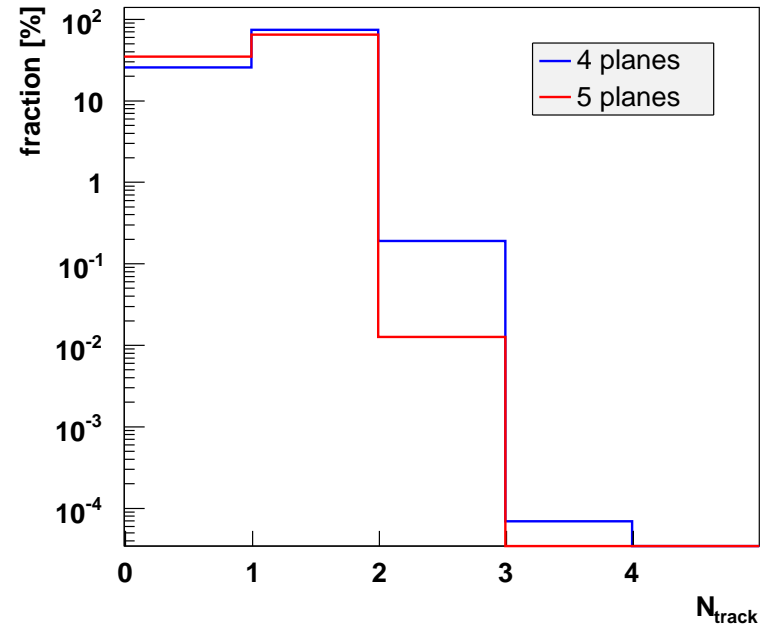
Old track finding algorithm required that each hit can belong to one track only. Track with smallest χ^2 was always chosen.

New option: all tracks passing χ^2 cut are stored \Rightarrow significant gain in CPU time

However, one hit can be used in more than one track \Rightarrow "Hit ambiguity"



CERN data without box cut



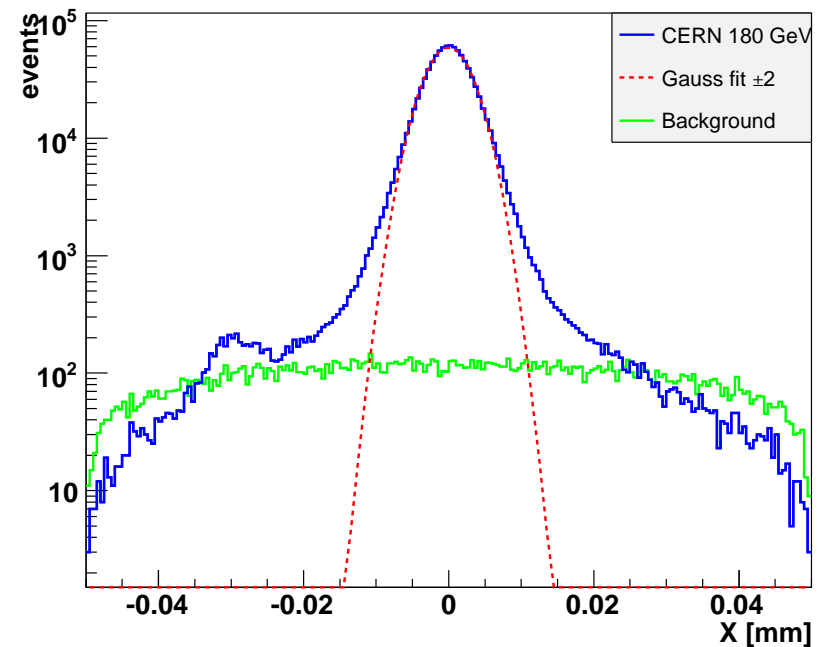
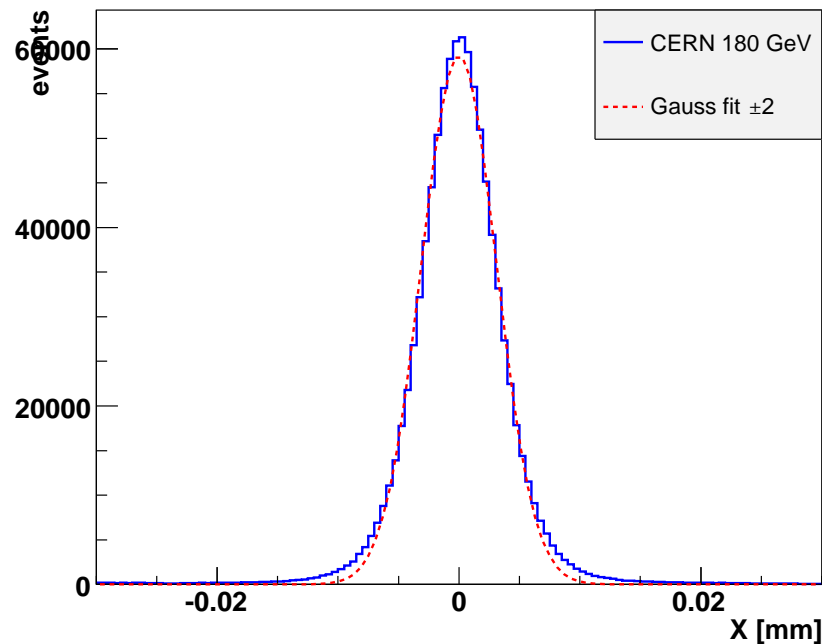
with box cut

Code development

Background estimate for "DUT mode"

Background from accidental hit-track matches is estimated by matching reconstructed tracks with hits from previous event.

CERN large multiplicity data



Analytical expectations: $3.27 \mu m$

Measured: $3.07 \mu m$ (X) $3.16 \mu m$ (Y) (gaussian curve fitted within $\pm 2\sigma$)

Conclusions

Simple alignment method gives good results. Not limited to single track events.

Precision obtained sufficient for detailed telescope studies.

Telescope performance studied for low energy (DESY) and high energy (CERN) data.

Results for low energies in good agreement with expectations.

For CERN data some discrepancies observed - still to be investigated.

DUT analysis tools developed - unbiased sensor studies possible.

Eta function corrections verified - details still to be understood.

Overall code performance significantly improved.

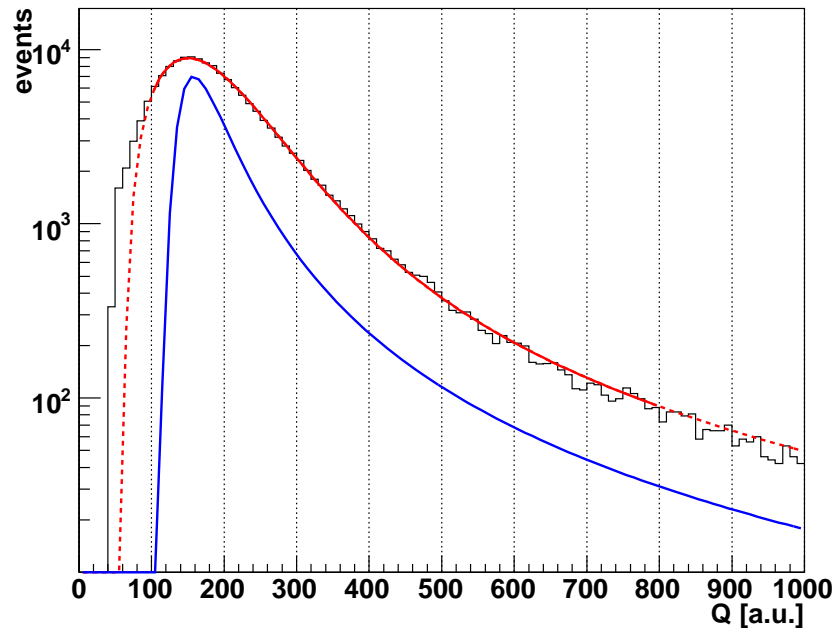
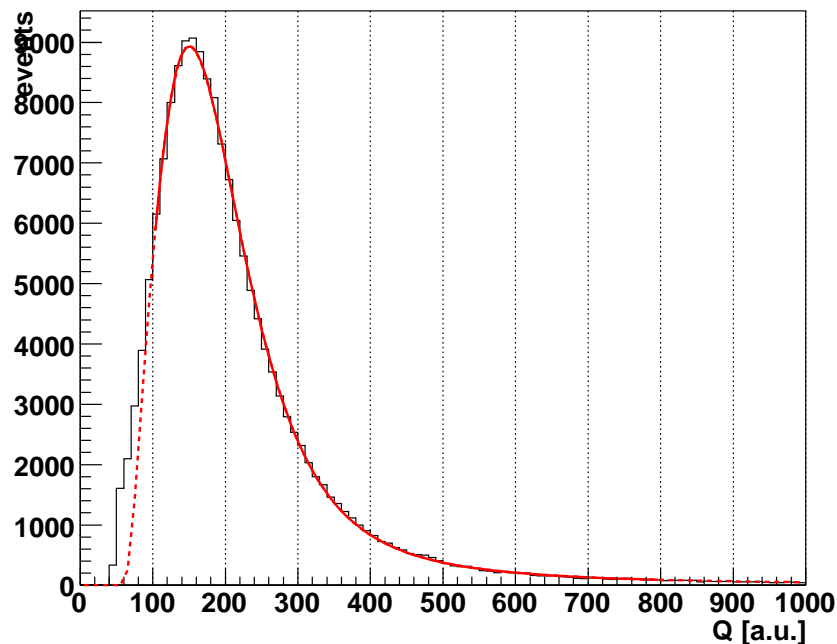
Efficient and fast track finding possible even at high multiplicity.

Hit number limitation for > 4 planes - still to be solved...

Backup slide

Cluster charge

Signal distribution for clusters contributing to the fitted track (one layer):



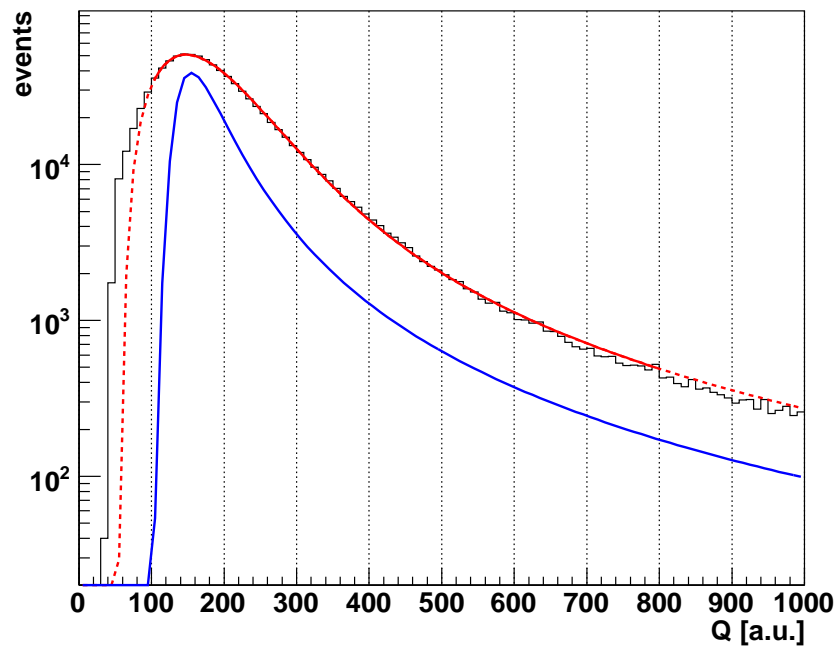
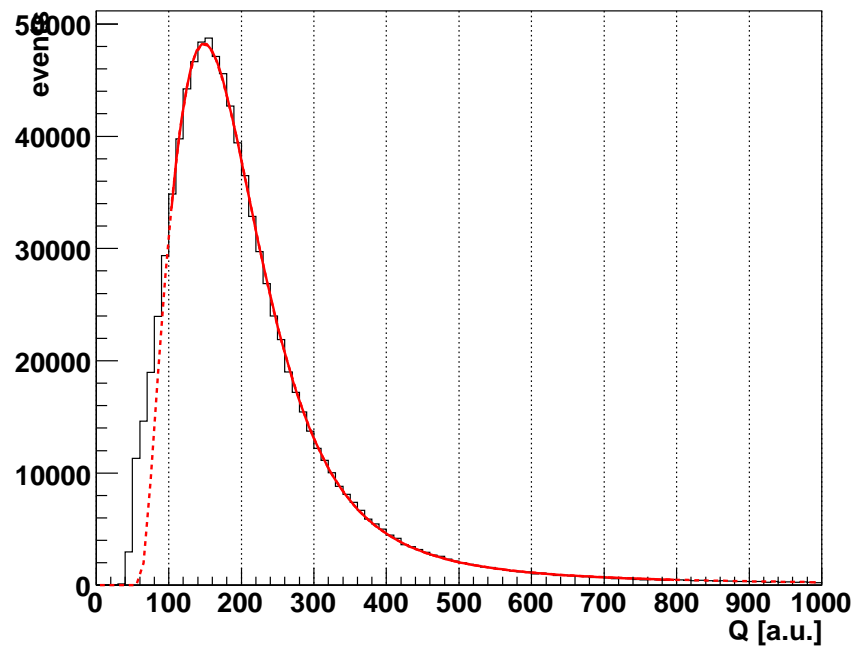
DESY 3 GeV data.

Fitted is the **Landau function** convoluted with **Gamma distribution** for modeling of detector resolution (fitted resolution is $\sim 35\%$).

Backup slide

Cluster charge

Signal distribution for clusters contributing to the fitted track (one layer):



CERN large multiplicity GeV data.

Fitted is the **Landau function** convoluted with **Gamma distribution** for modeling of detector resolution (fitted resolution is $\sim 35\%$).

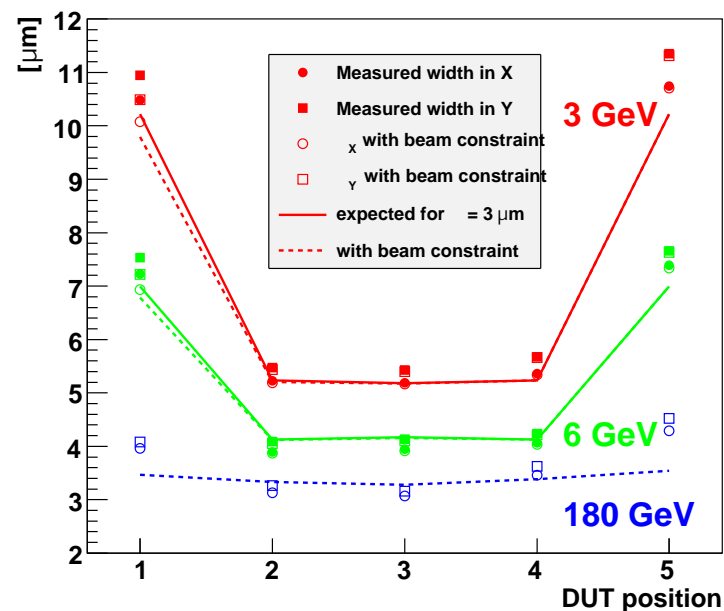
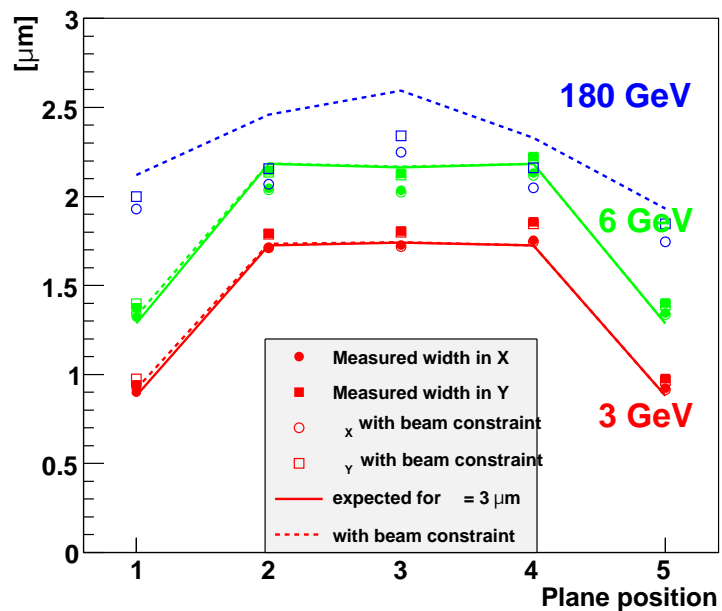
Backup slide

Residuals

Comparison of the observed distribution widths with expectations from analytic calculations.

Fit to 5 telescope layers

“DUT mode” (fit to remaining 4 layers)



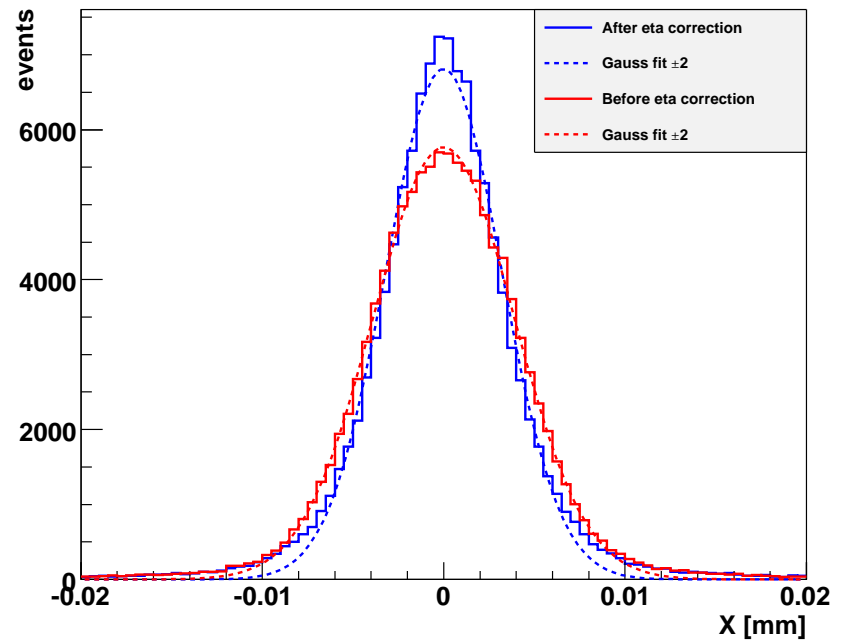
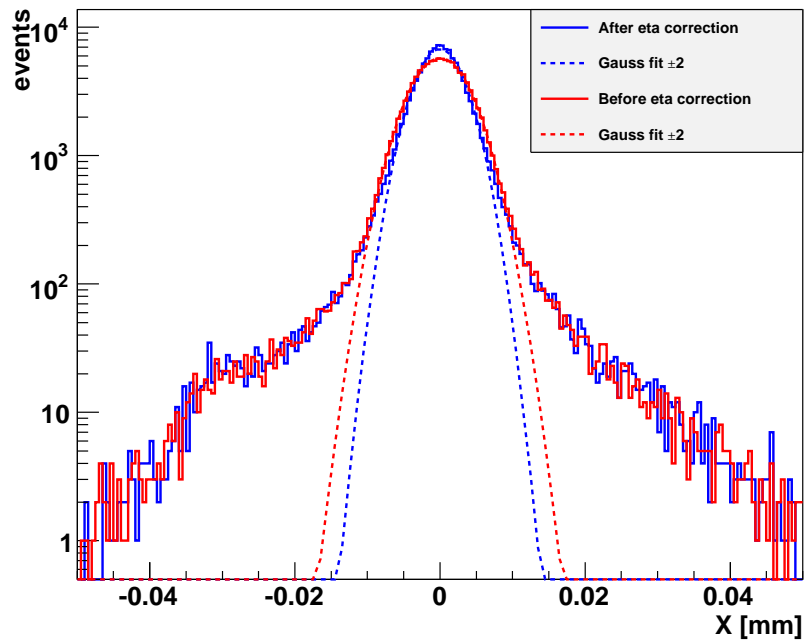
Very good agreement for low energies, not so good for CERN data (for the assumed single sensor resolution of $\sigma = 3\ \mu\text{m}$)

Backup slide

Eta corrections

CERN large multiplicity data

Residua for position at DUT reconstructed without and with Eta correction:

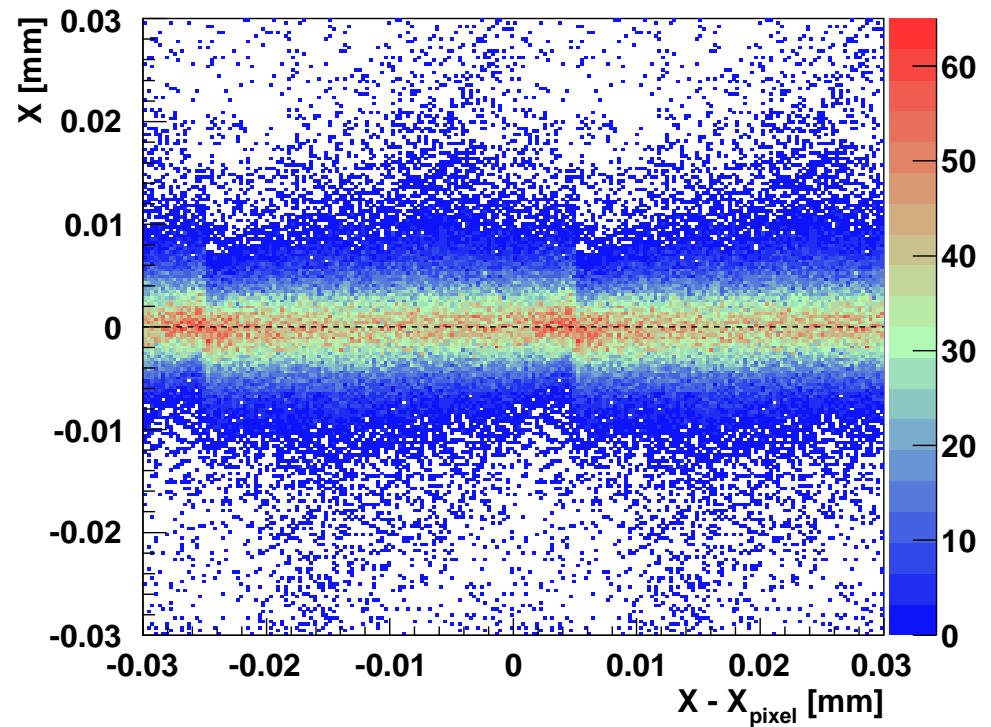
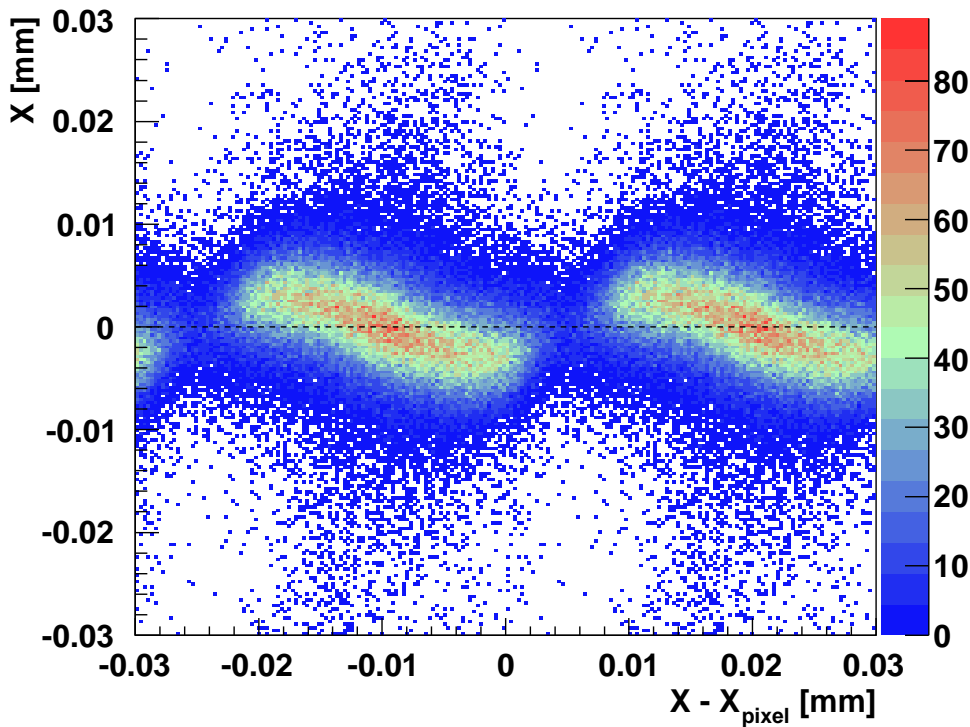


Eta correction reduces the width of the distribution from $3.9\mu\text{m}$ to $3.2\mu\text{m}$

Backup slides

Eta corrections

Position shift (measured - fitted position) as a function of the measured position in sensor frame modulo the pixel width, before and after applying Eta correction:



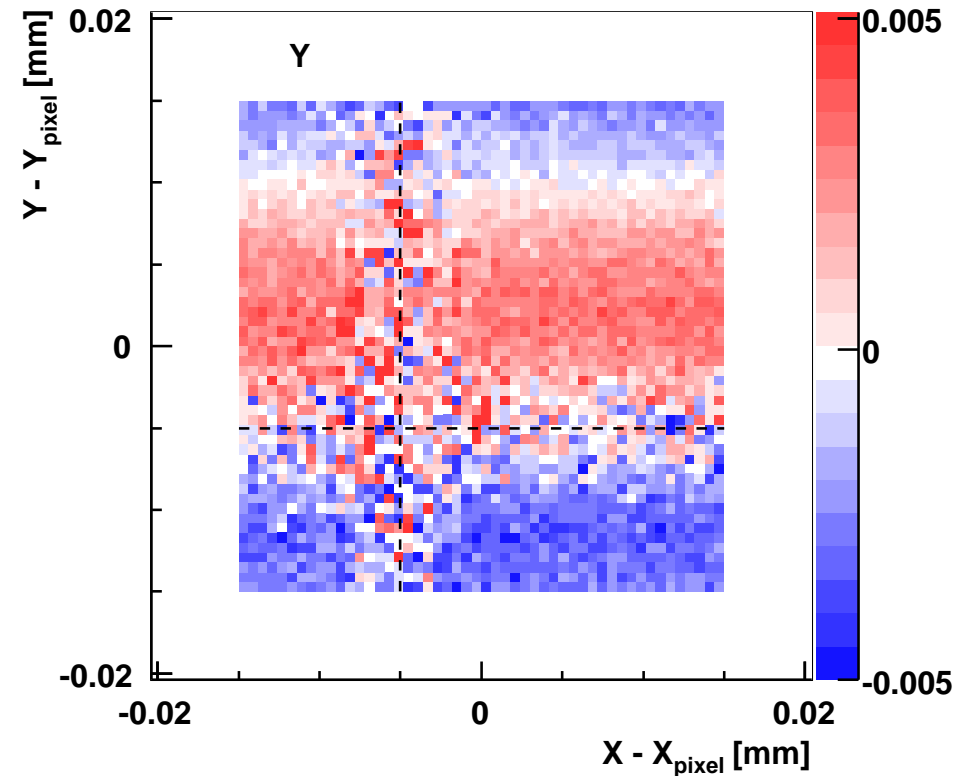
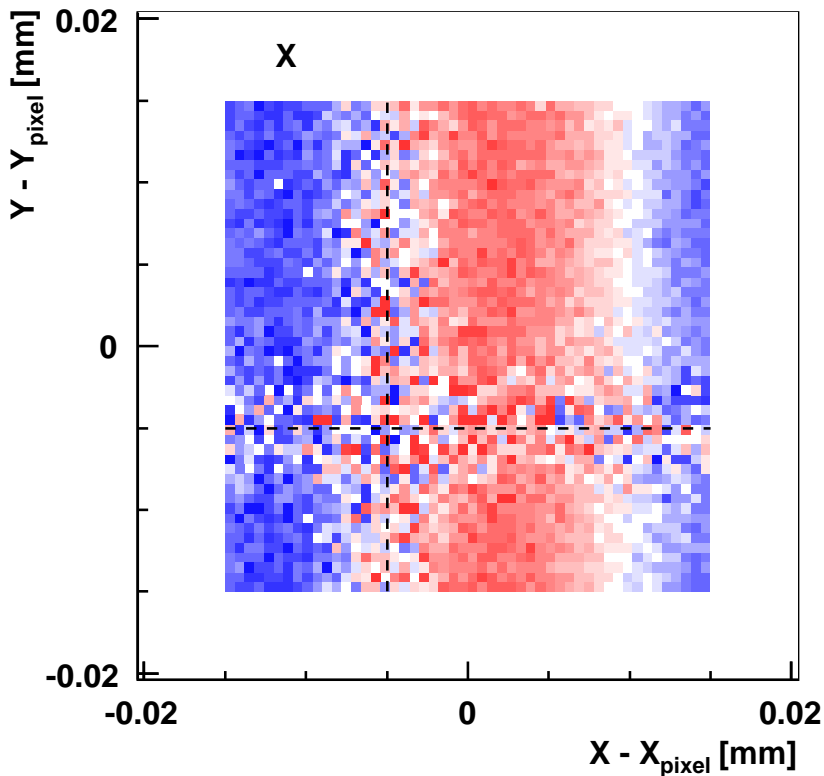
CERN large multiplicity data

Backup slides

Eta corrections seem to be uncorrelated

No clear correlation between position shift and position in perpendicular direction.

Average shift as a function of X-Y position **before eta correction** (DESY 3 GeV)



Backup slides

Eta corrections seem to be uncorrelated

No clear correlation between position shift and position in perpendicular direction.

Average shift as a function of X-Y position **after eta correction** (DESY 3 GeV)

