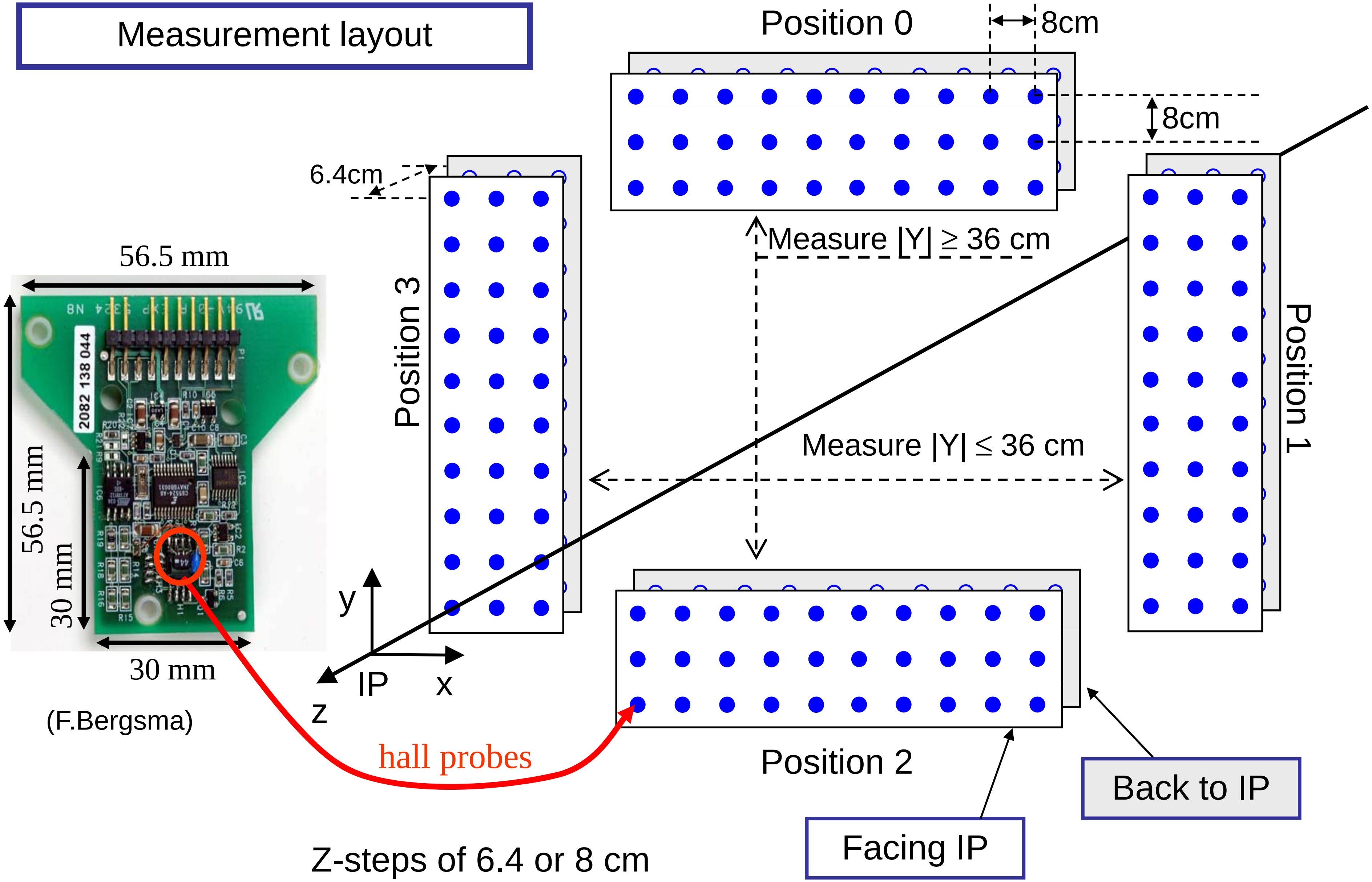
Status of the dipole magnetic field analysis

- introduction
- problems found in the data
- methods used to remove distortions

R.Shahoyan, 12/10/2007 Alice offline week

Measurement layout



Z-steps of 6.4 or 8 cm

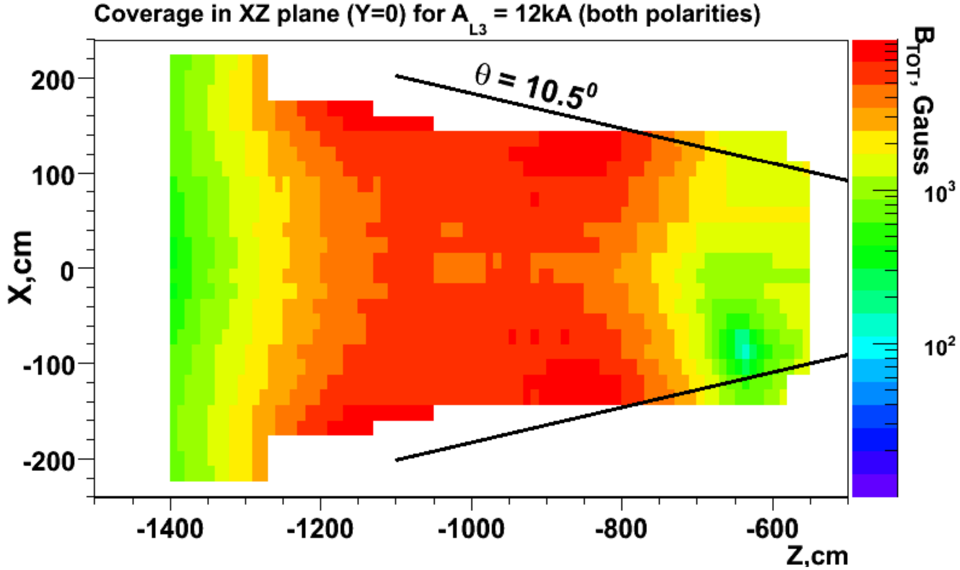
-1392.8 <Z< -1047.2

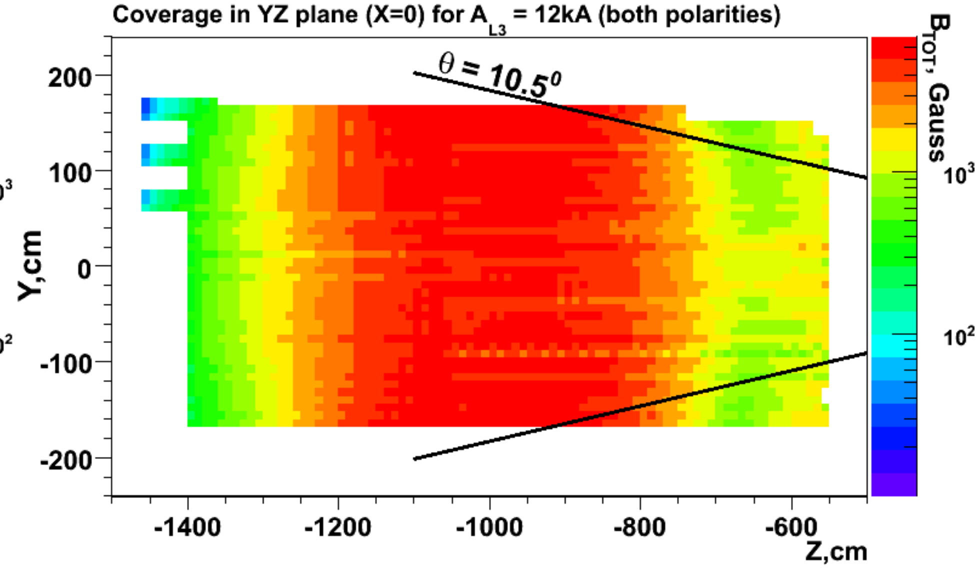
-1058.3 <Z< -555.9

Coverage

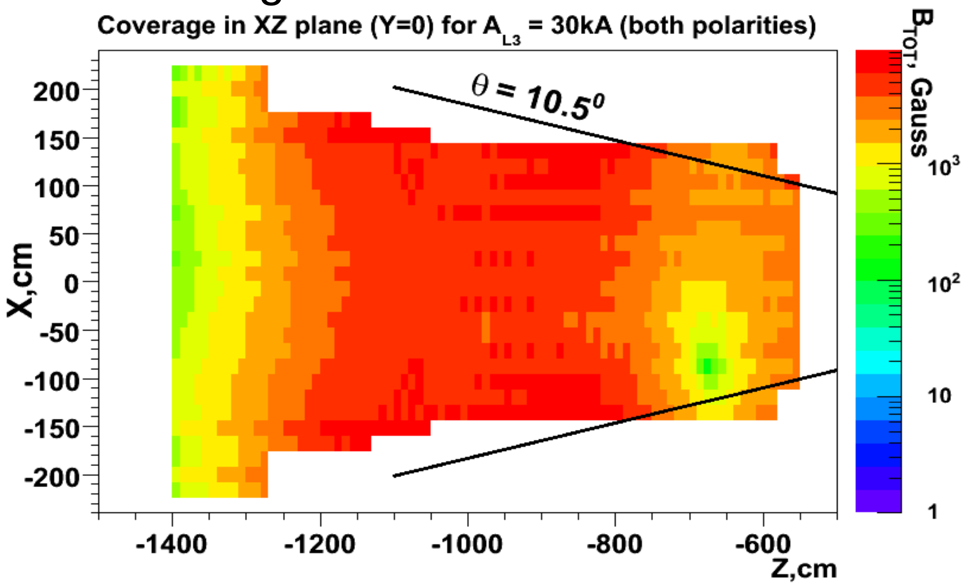
+ and – polarities have to be summed to minimize uncovered regions

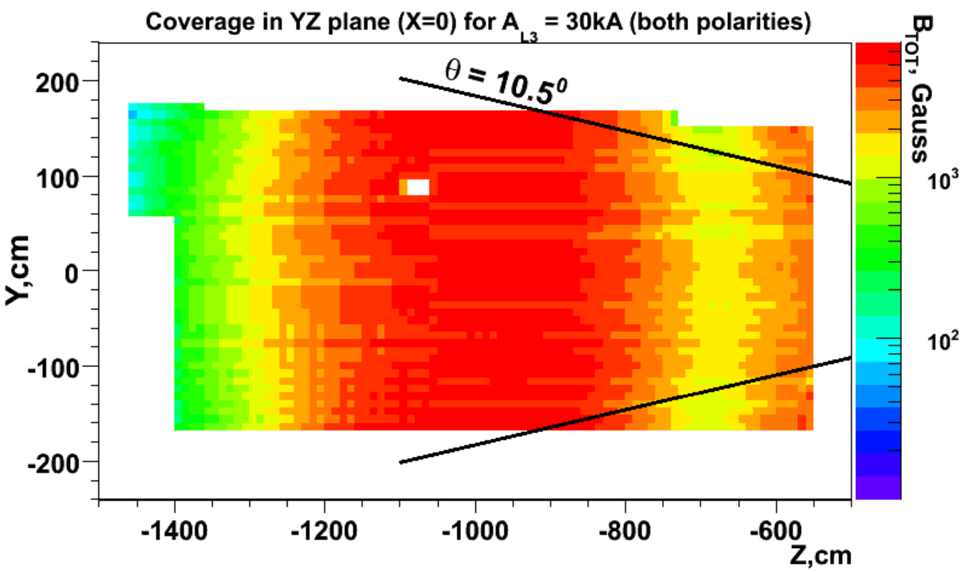
L3 Low





L3 High





Data selection and cleaning

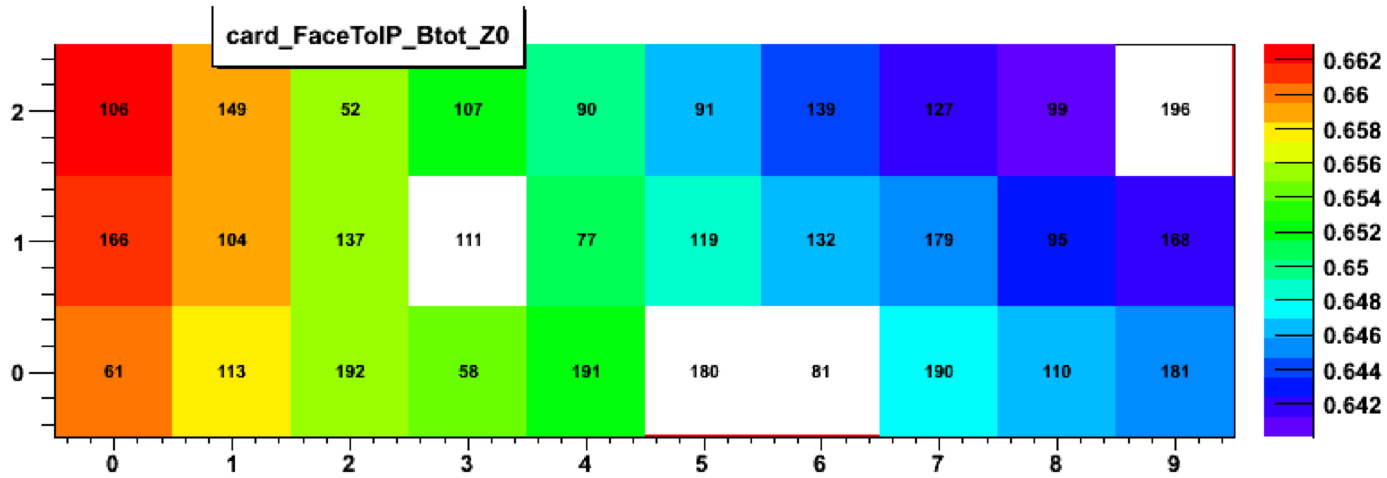
- More than 1000 scans recorded, ~900 survive trivial selection cuts: empty/corrupted data, constant field etc. Part of selection was done by A.Morsch.
- Probe-map (location of each probe ID on the vetronite plates) check.
- Log-book and Scan Header information: Z coverage of each scan (~70 files have wrong labels for starting Z position), measuring head transverse location (wrong for ~20 scans), head position (wrong for ~100 scans)
- Loss of probe ID's : from time to time some probe ID's are not correctly recorded. Recovered by matching to probe-unique calibration constants from the header (see L3 note ALICE-INT-2007-12)
- Probes stability: in normal conditions probes measurements are reproducible on ~0.2 Gauss level and declared calibration precision (F.Bergsma) of ~1 Gauss holds (for most of them…).
  Nevertheless sometimes the probes record completely wrong values.
- Consistency of field measured in different scans and by the FIP and BIP cards within the same scan: probes alignment (unique for given probe-map validity period) and scan-by-scan measuring head distortions (still not finished)

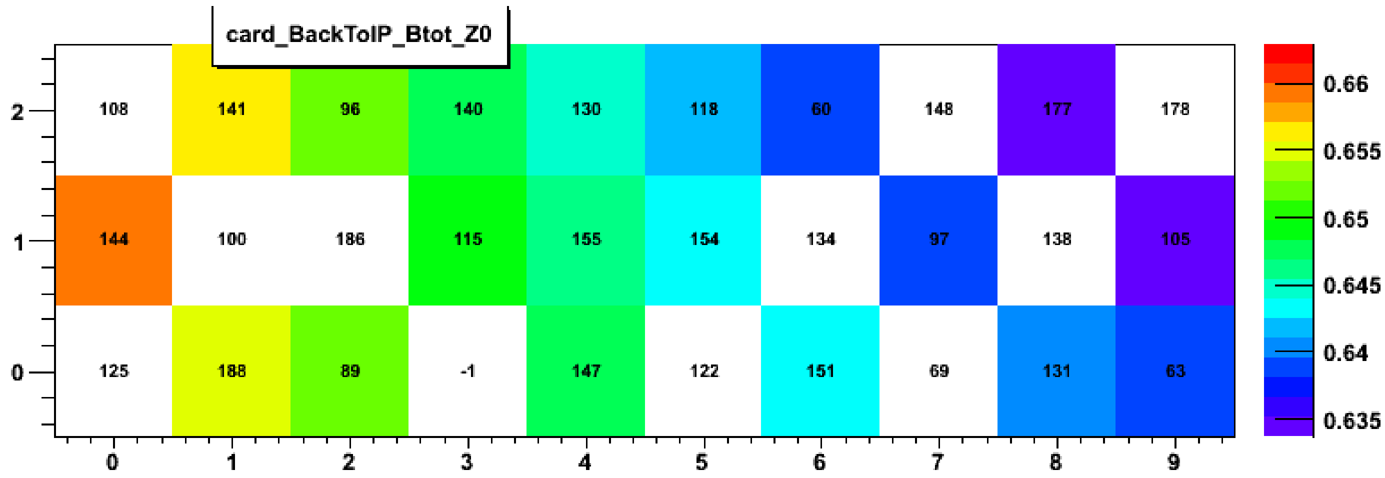
Probe-maps

Just 1 probe-map was provided, which failed to describe most of the data:

- some probes mentioned in the map are not found in the data
- instead the data contains the probes not mentioned in the map.

Such mismatches were corrected manually. In total, 4 different probe-maps were identified (after that the records of the 2nd one were found, confirming already identified map)

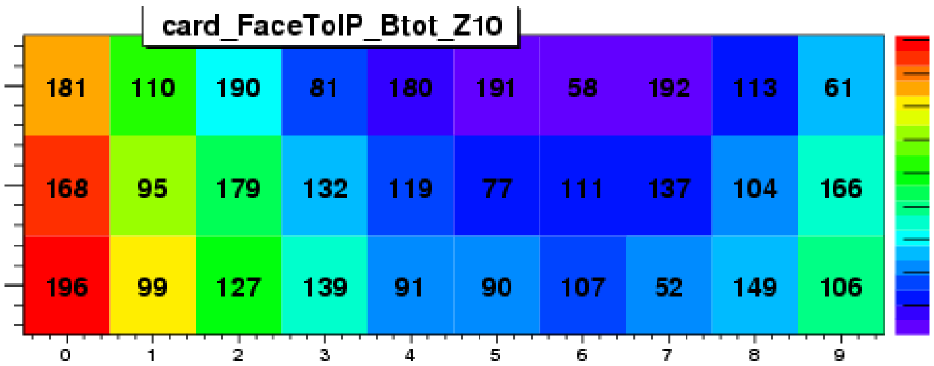


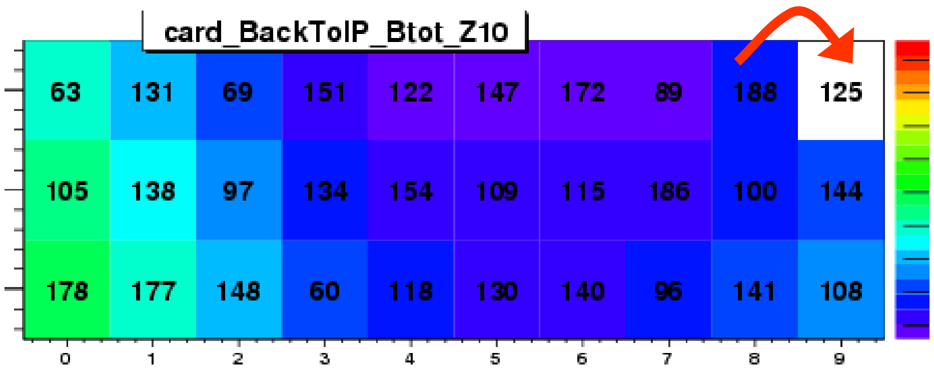


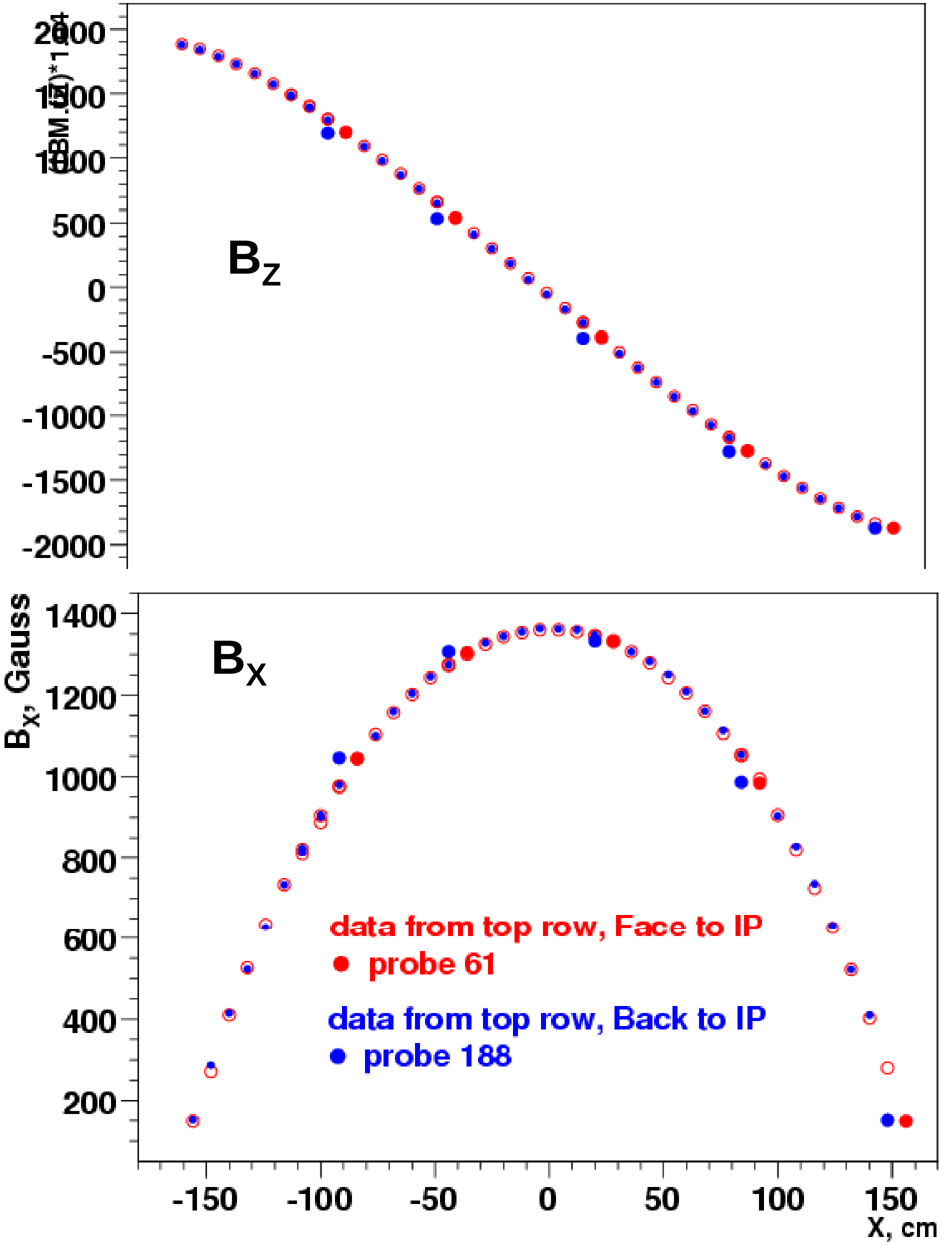
Probe-maps

Example of the probe (#188) not fitting to other measurements when taken at its declared position.

Need to reassign the probe position to make its measurement consistent with other data.







Probe-maps

#100 ⇒ #123

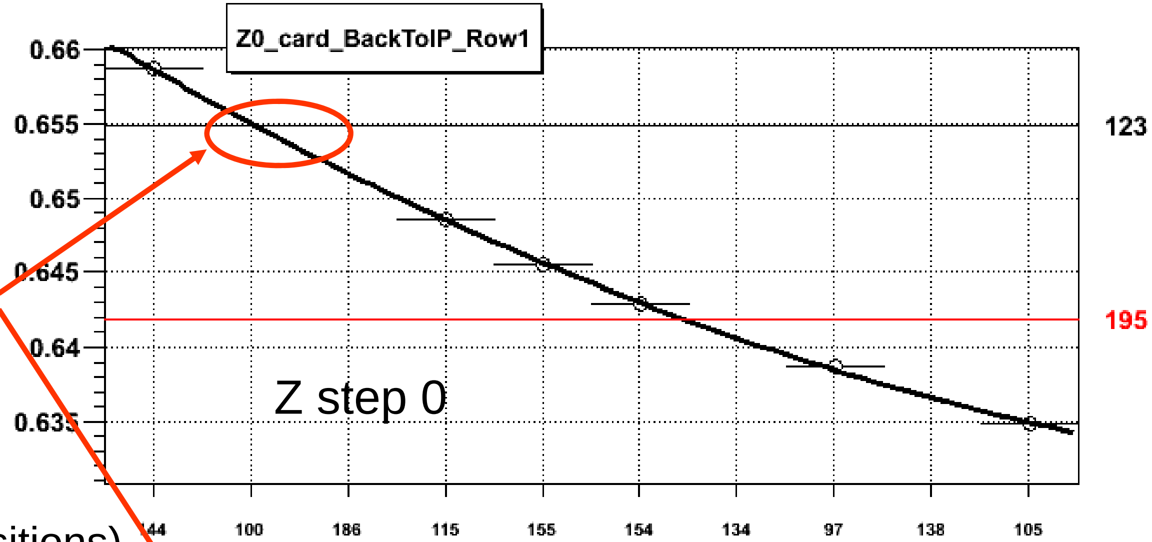
Example of successful probe matching:

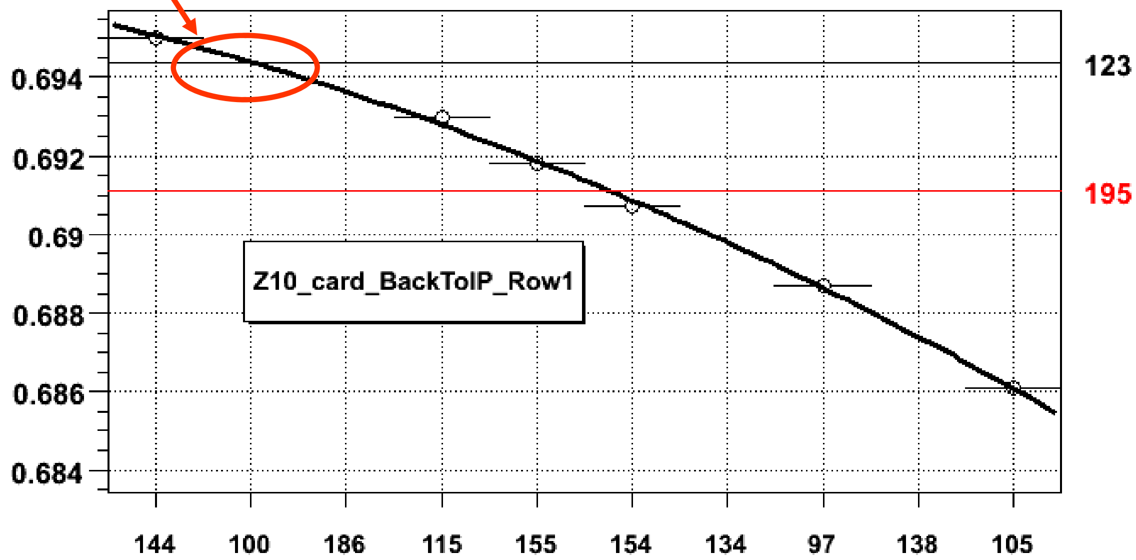
Probe #100 mentioned in the probe-map is not found in the data.

Instead, data sees probes #195 and #123 not mentioned in the probe-map.

Probe #123 is found to match the field expected where #100 should be

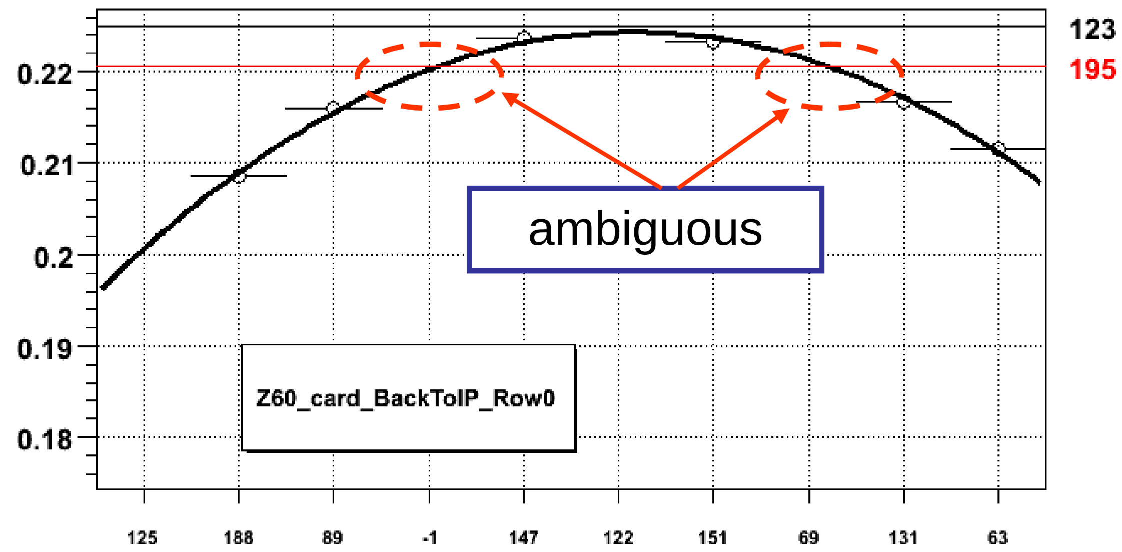
(check is done for multiple Z positions)



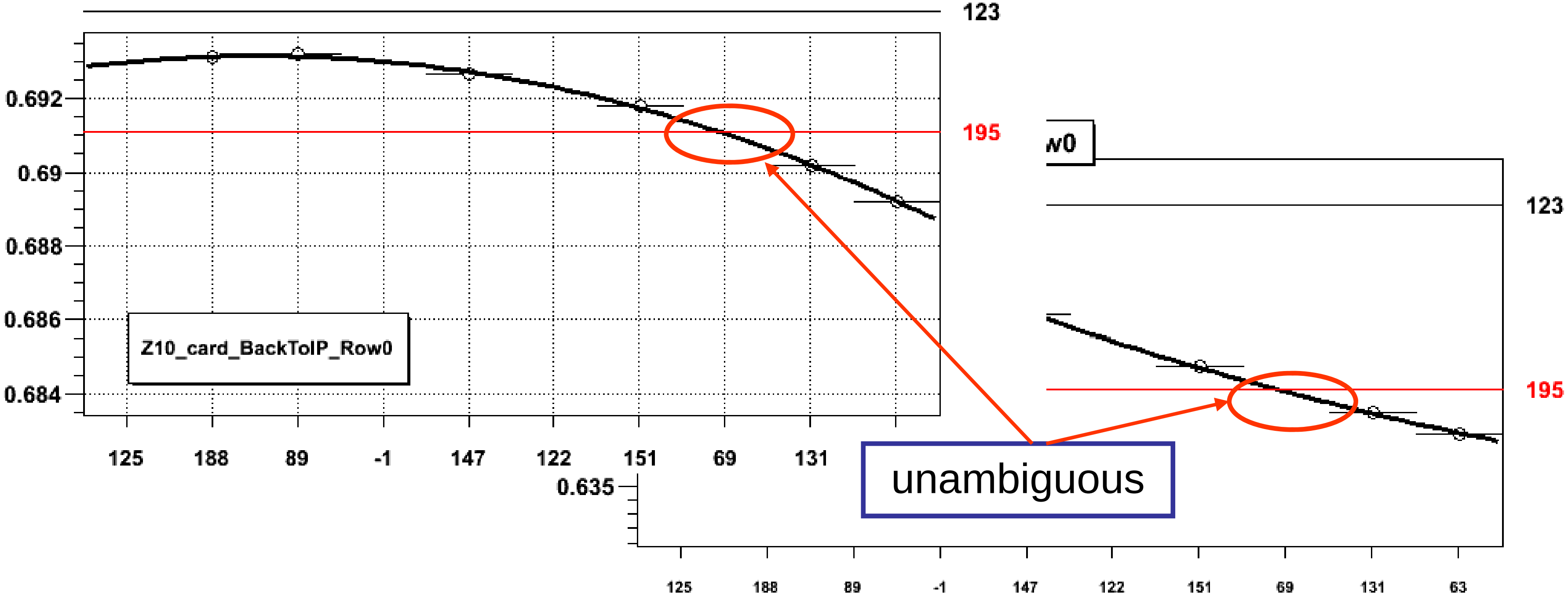


Probe-maps

#69 ⇒ #195



Probe #195 is found to match the field expected where #69 should be



Probe-maps

Declared probe #125 is not found in the data.

Instead #57 is found, but its values don't match to field of other probes.

Tried to find matching probe by using different probe ID's not involved in measurements.

No probe is found to match at all Z's

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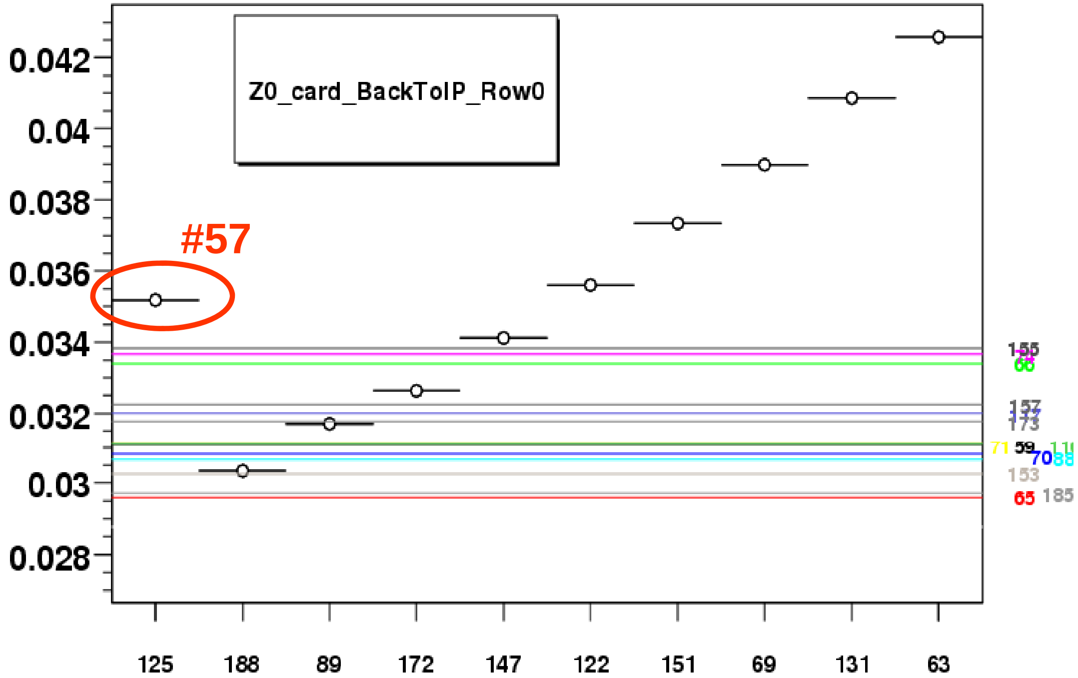
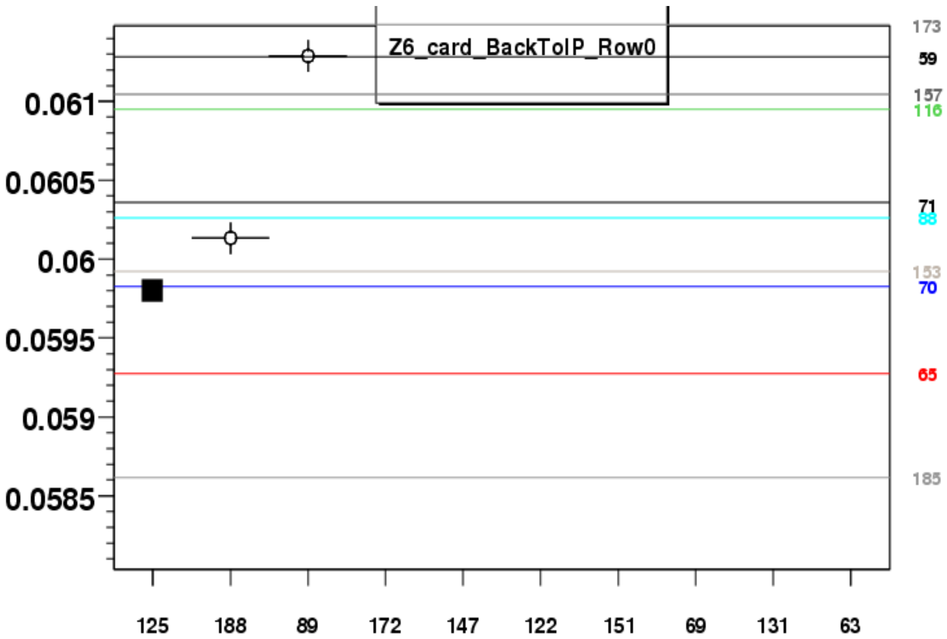
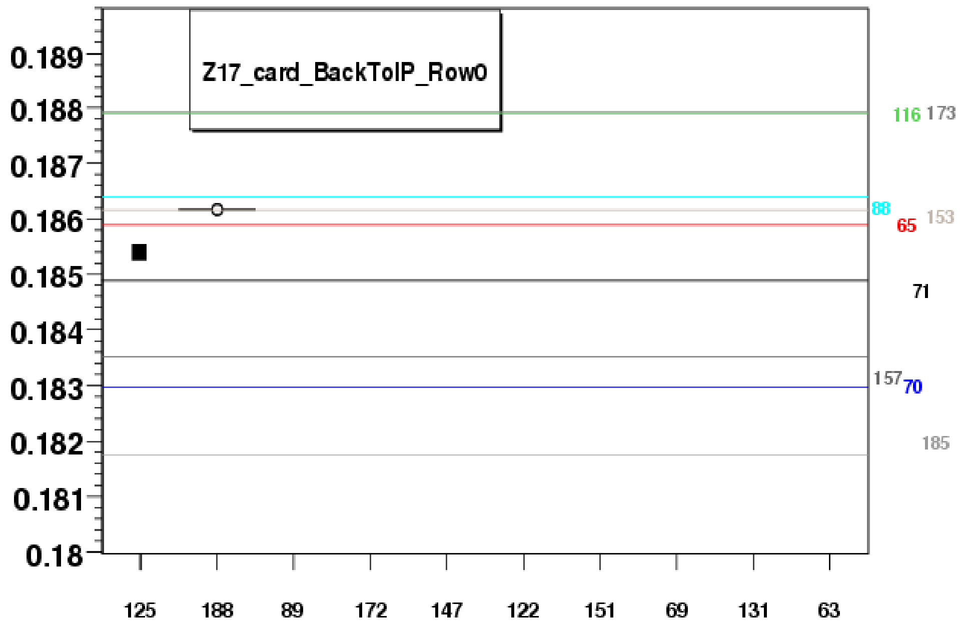
the "correct probe" is not calibrated

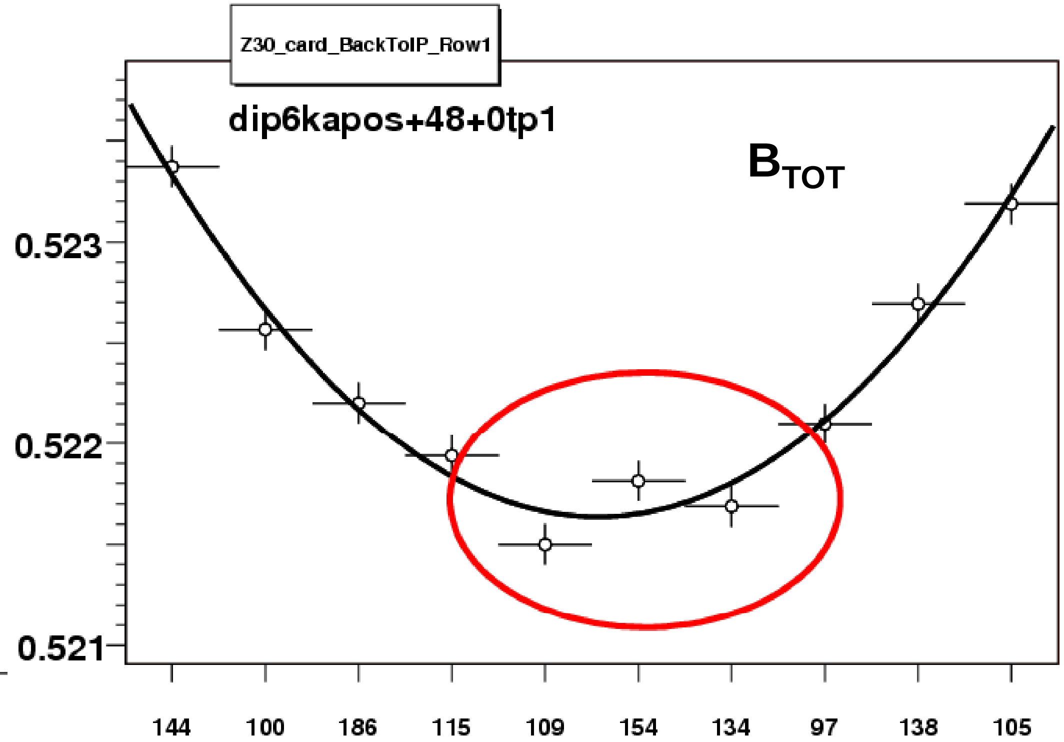


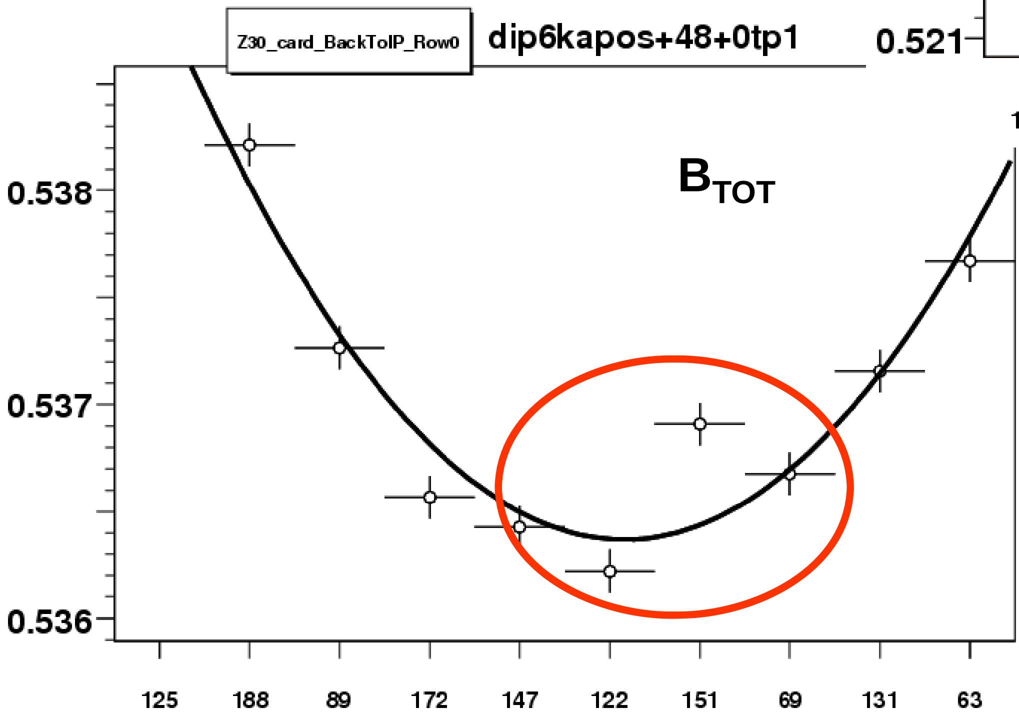




Data quality

Probes calibration is in general very good (≤ 1Gauss) but there are a few ones which show 3-4 Gauss deviations from the expected field

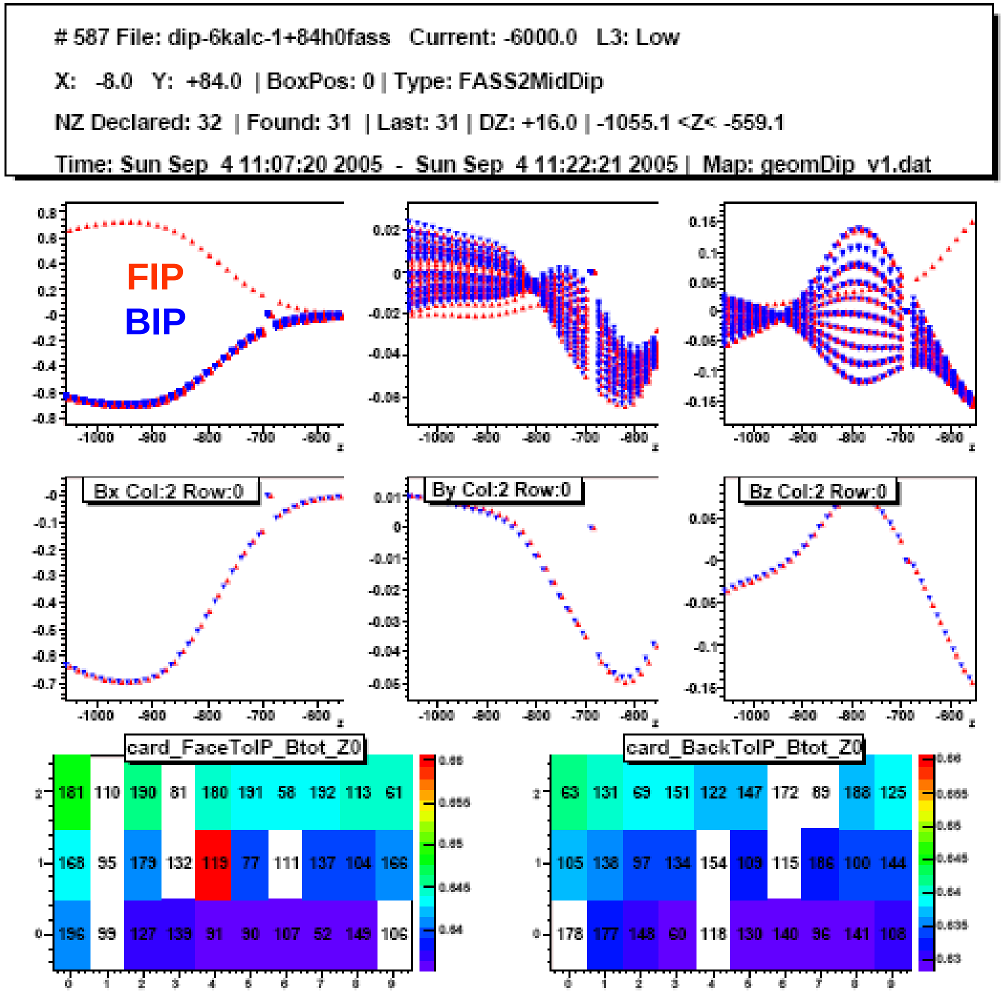


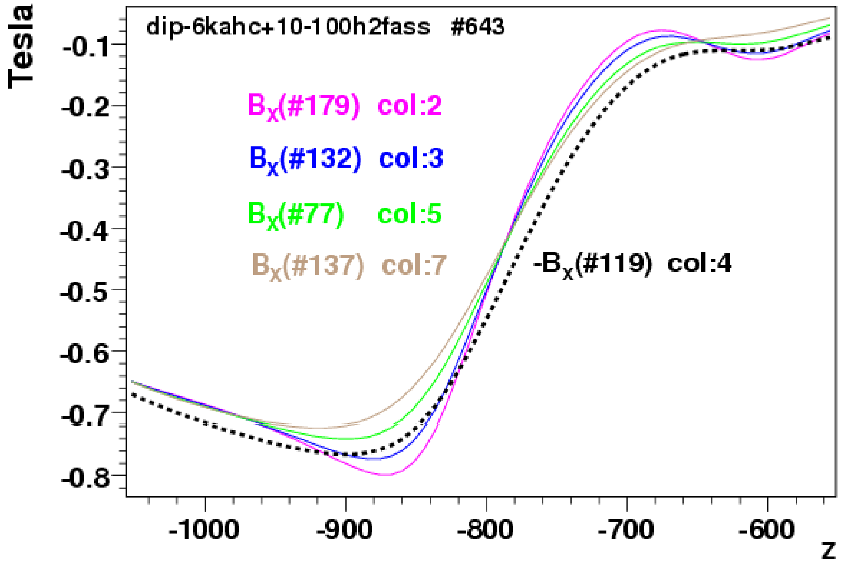


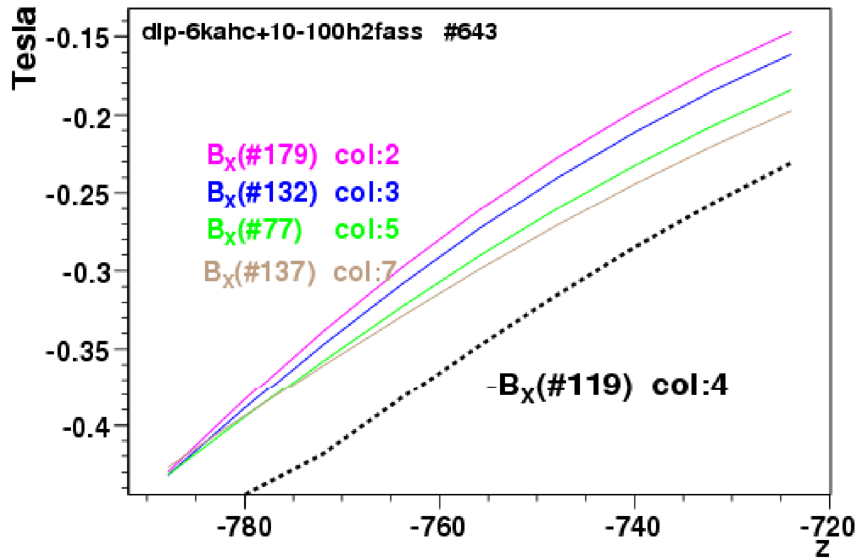
Data quality

Some probes suddenly change their sign.
Comparison of their inverted measurements with the field measured by their neighbors show that apart from the sign flip the calibration is also lost.

In worst case (#119) such behaviour
is observed in ~20% of scans.







Data quality

From time to time some probes measure completely wrong field just for a few Z-steps.

~ in half of cases such behaviour is associated with anomalous temperature.

Tracked by visual inspection of each data measurement, the anomalous values are excluded from the analysis

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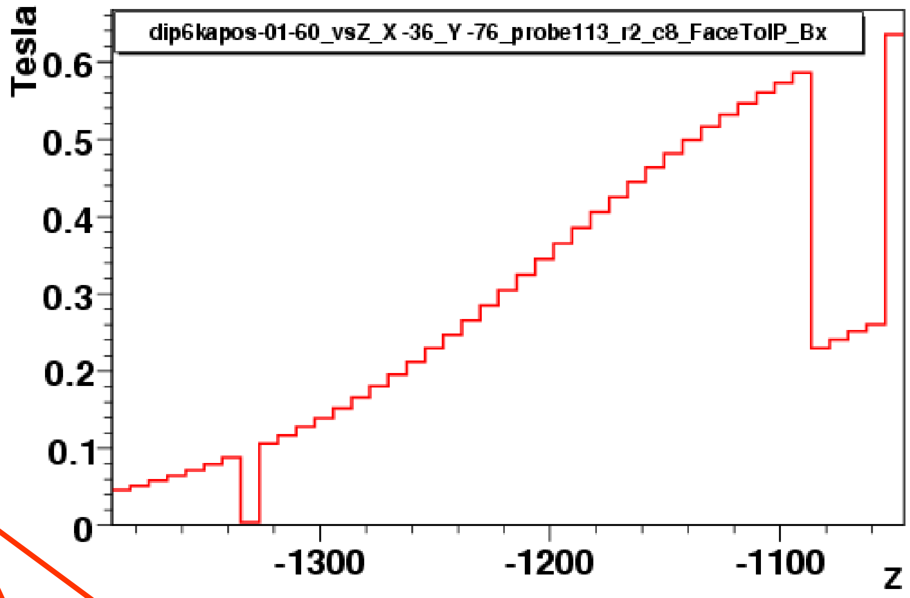
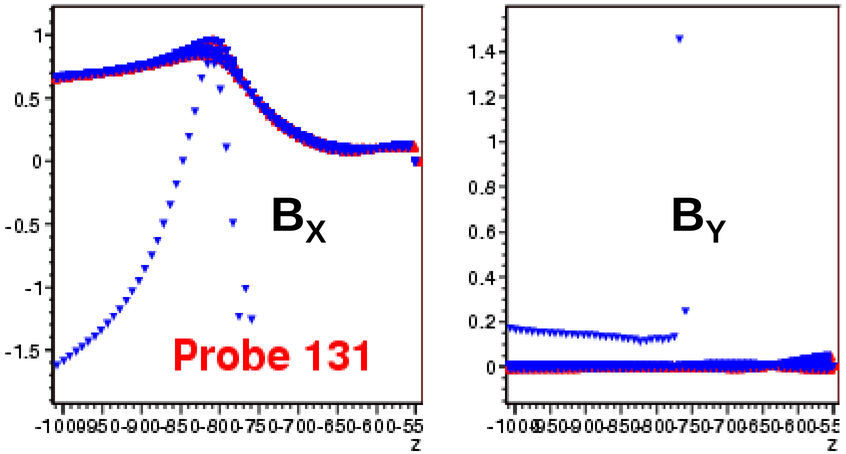
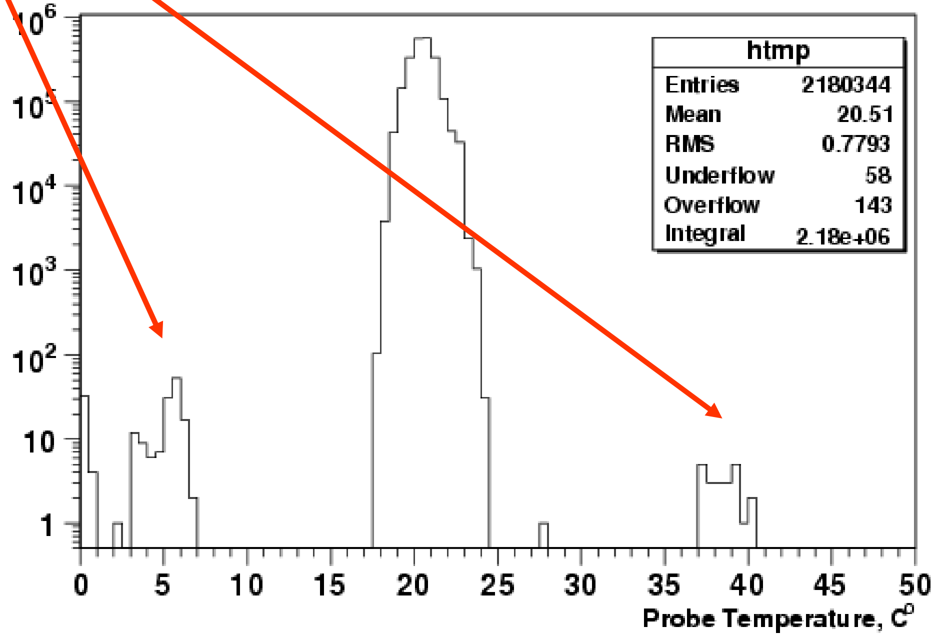
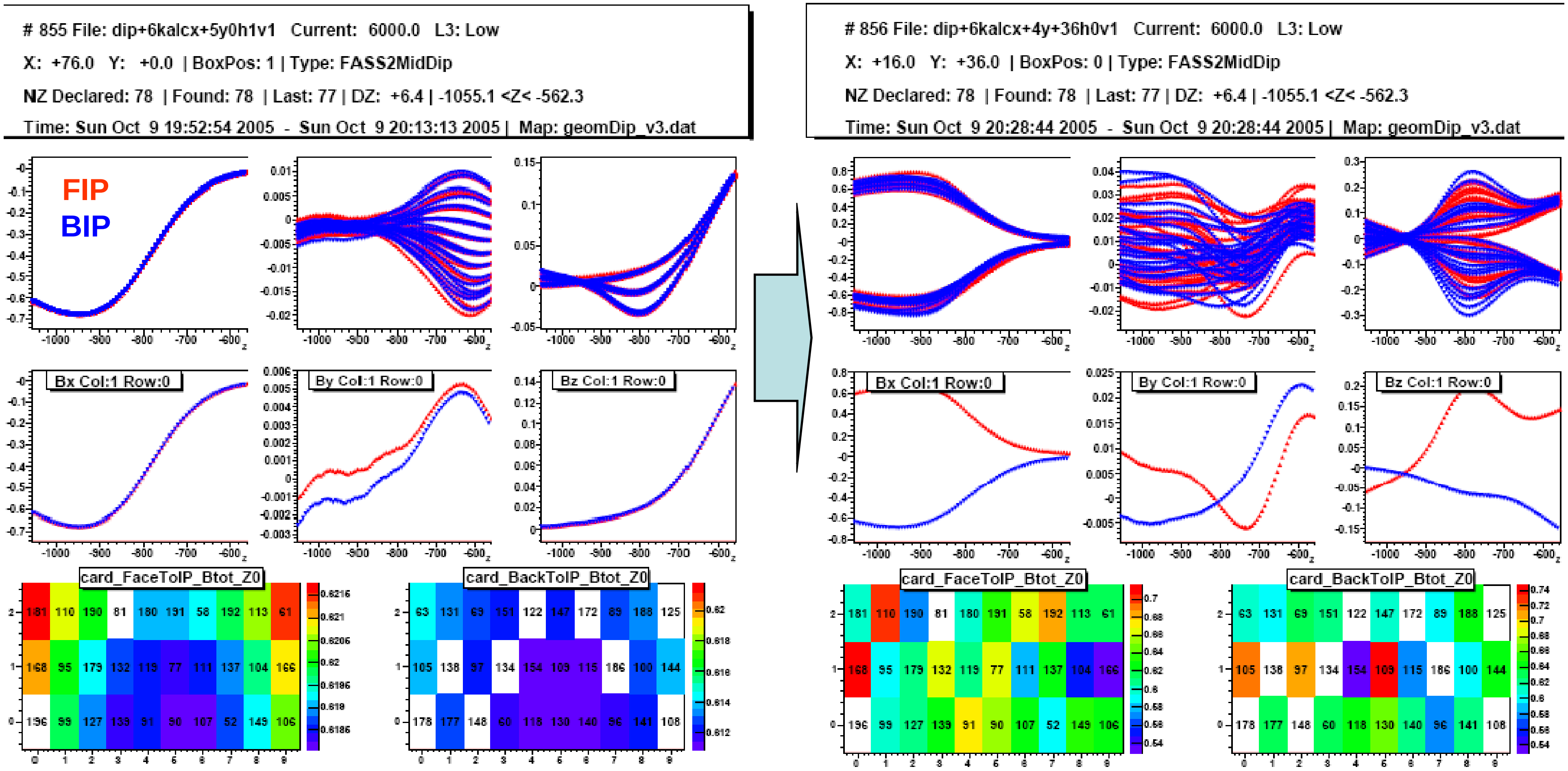






Data quality

In some scans the sign of the field measured by different probes gets random (cabling?).

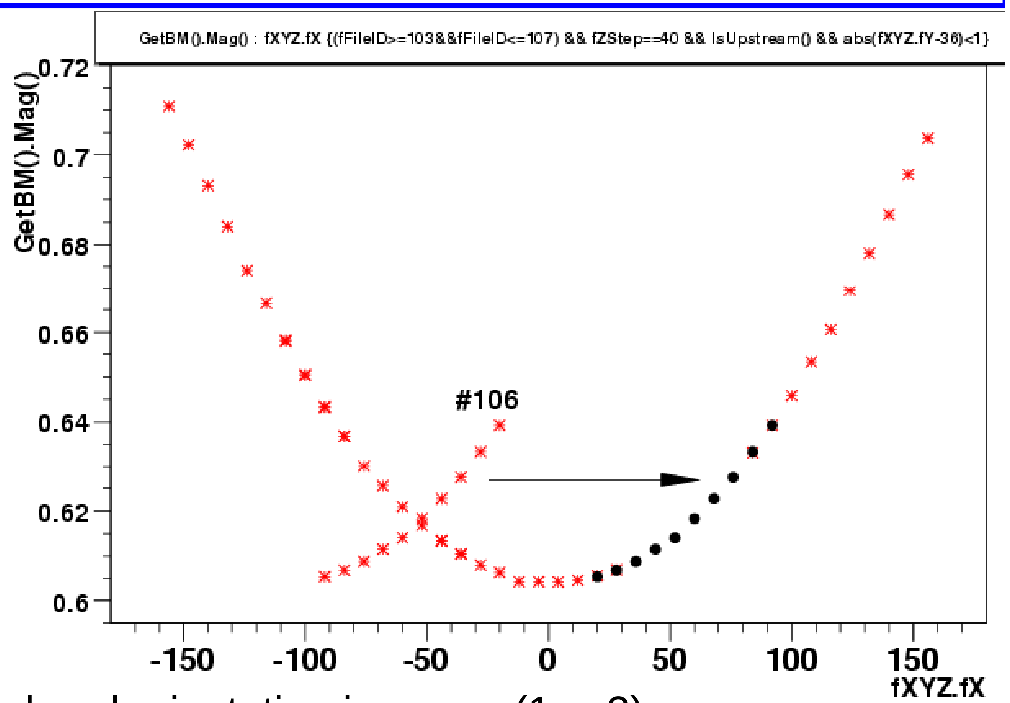


Data taking conditions information

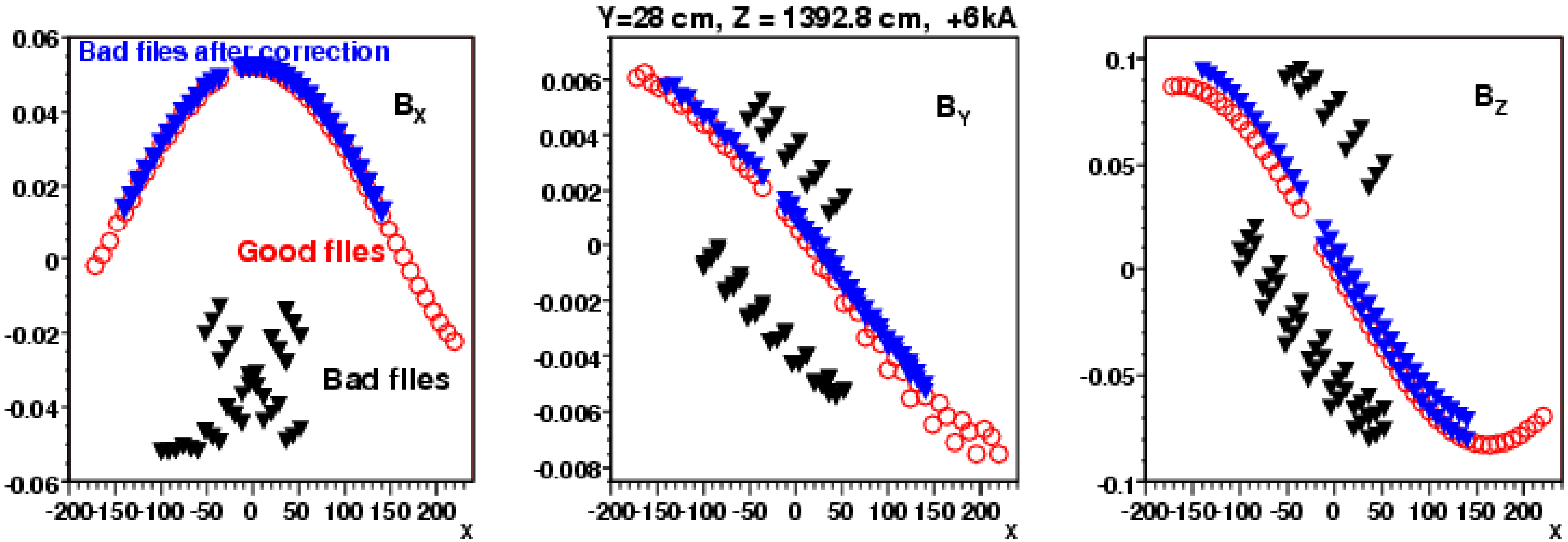
Lot of files with measuring head location wrongly recorded.

Part of problematic data was fixed by A.Morsch.

Sometimes trivial to track down since the mentioned coordinates are not possible but often the comparison with other measurements is needed.

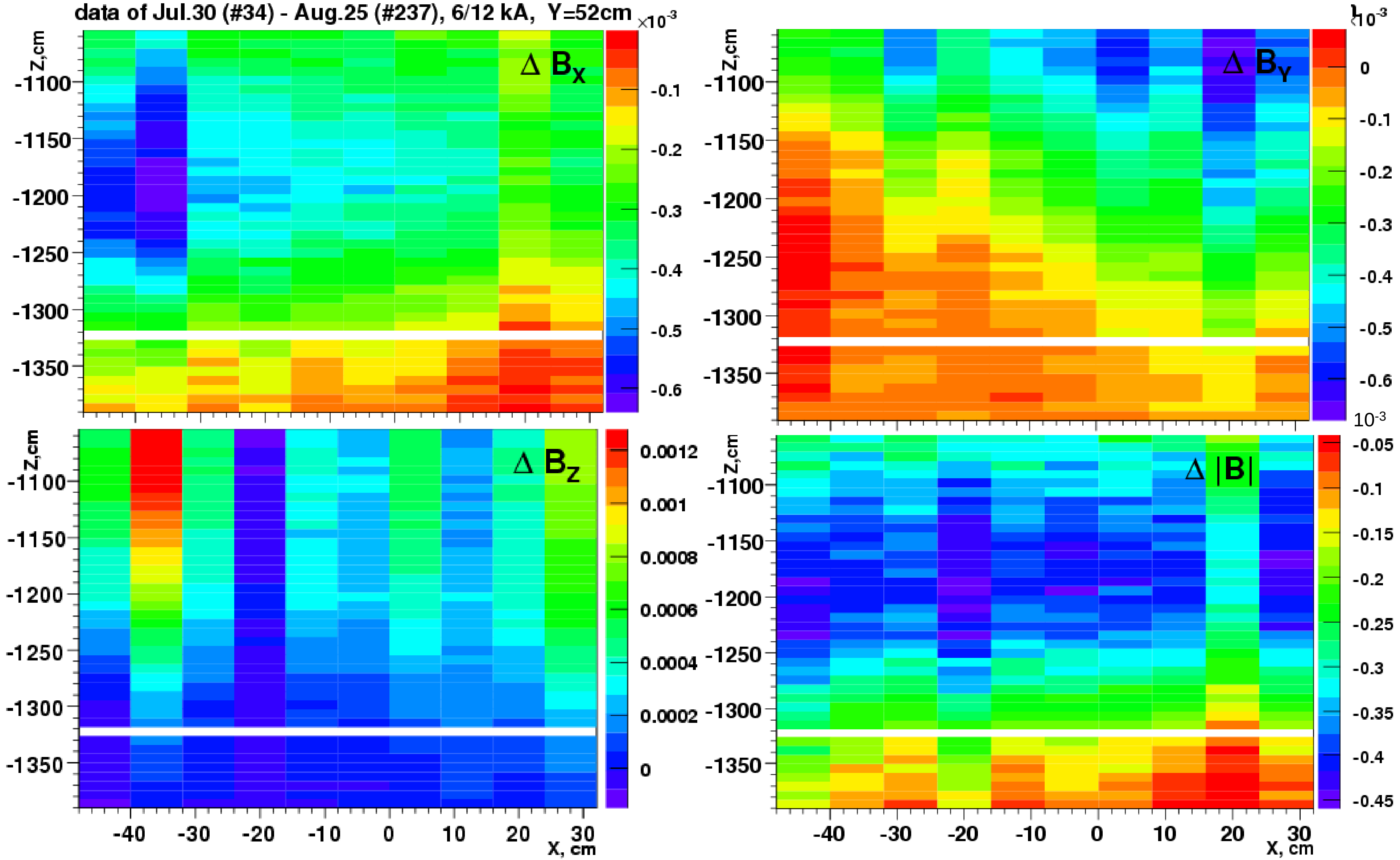


For ~10% of the data the head orientation is wrong (1 ↔3)



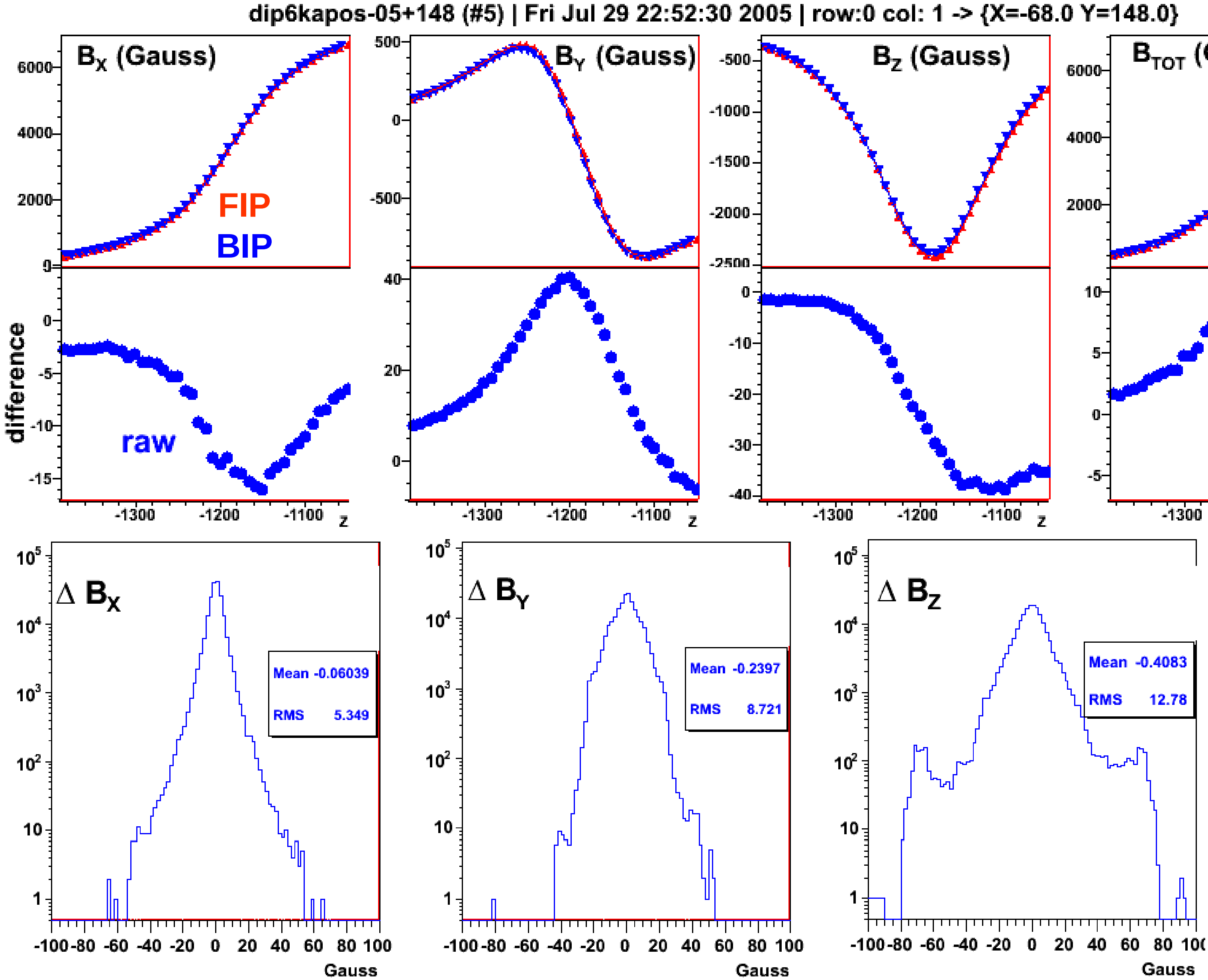
Difference between various data sets (same probes, same head orientation/position)

B_{TOT} is reproduced on the level <4 Gauss.
Similar differences are observed between the data for opposite polarities.



Compatibility of measurements by FIP and BIP plates

All scans show systematic differences between the measurements by the FIP and BIP probes in the same location (even for the total field, which should be robust against the probes rotations)



Rotations?
Shifts?
Calibration?

Model to fit the field distortions

Field seen by the 3D probe in its local frame (≡ lab.frame for FIP probes in position 0):

$$\vec{B}^m(\vec{r}) = R_{\vec{\theta}}\, R_p\, \vec{\hat{B}}(\vec{r} + R_p^{-1}\, \vec{\delta}) + \vec{\epsilon} \approx R_{\vec{\theta}}\, R_p\, \vec{\hat{B}}(\vec{r}) + R_p\, \frac{\partial \vec{\hat{B}}}{\partial \vec{r}} R_p^{-1} \vec{\delta} + \vec{\epsilon}$$

$\vec{\epsilon}$ - vector of residual miscalibration

$\vec{\delta}$ - vector of probe's displacements wrt its ideal position

R_p - rotation matrix bringing vector from lab to local frame

$$\frac{\partial \vec{\hat{B}}}{\partial \vec{r}} = \begin{pmatrix} \frac{\partial B_X}{\partial x} & \frac{\partial B_X}{\partial y} & \frac{\partial B_X}{\partial z} \\ \frac{\partial B_Y}{\partial x} & \frac{\partial B_Y}{\partial y} & \frac{\partial B_Y}{\partial z} \\ \frac{\partial B_Z}{\partial x} & \frac{\partial B_Z}{\partial y} & \frac{\partial B_Z}{\partial z} \end{pmatrix}$$

- gradients of field components in lab. frame (calculated numerically from the difference of neighboring measurements for the dominant components and exploring $\vec{\nabla} \times \vec{B} = 0$ and $\vec{\nabla} \cdot \vec{B} = 0$ for minor ones

$$R_{\vec{\theta}} = I + Q_{\vec{\theta}} = I + \begin{pmatrix} 0 & \theta_z & -\theta_y \\ -\theta_z & 0 & \theta_x \\ \theta_y & -\theta_x & 0 \end{pmatrix}$$

- rotation matrix accounting the probe's inclinations $\vec{\theta} = \{\theta_x, \theta_y, \theta_z\}$ wrt its ideal position on the plate

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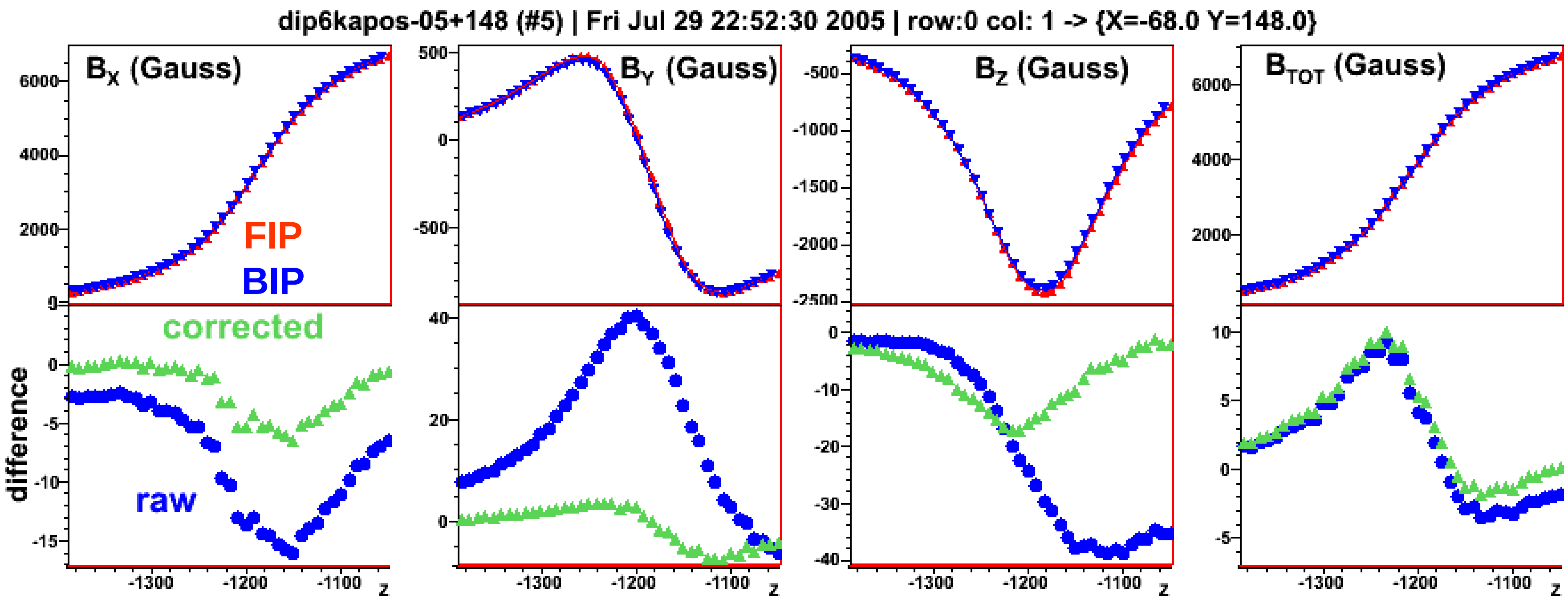
Difference between the local measurement and the reference value (other probe):

$$\Delta \vec{B} = Q_{\vec{\theta}} R_p \vec{\hat{B}} + R_p\, \frac{\partial \vec{\hat{B}}}{\partial \vec{r}} R_p^{-1} \vec{\delta} + \vec{\epsilon} \cdot \qquad (1)$$

Correcting distortions

Fit to (1) shows some improves consistency of FIP and BIP measurements, but not always (almost no effect at all for the last period of data taking, when the probes fixation was improved)



Correcting distortions

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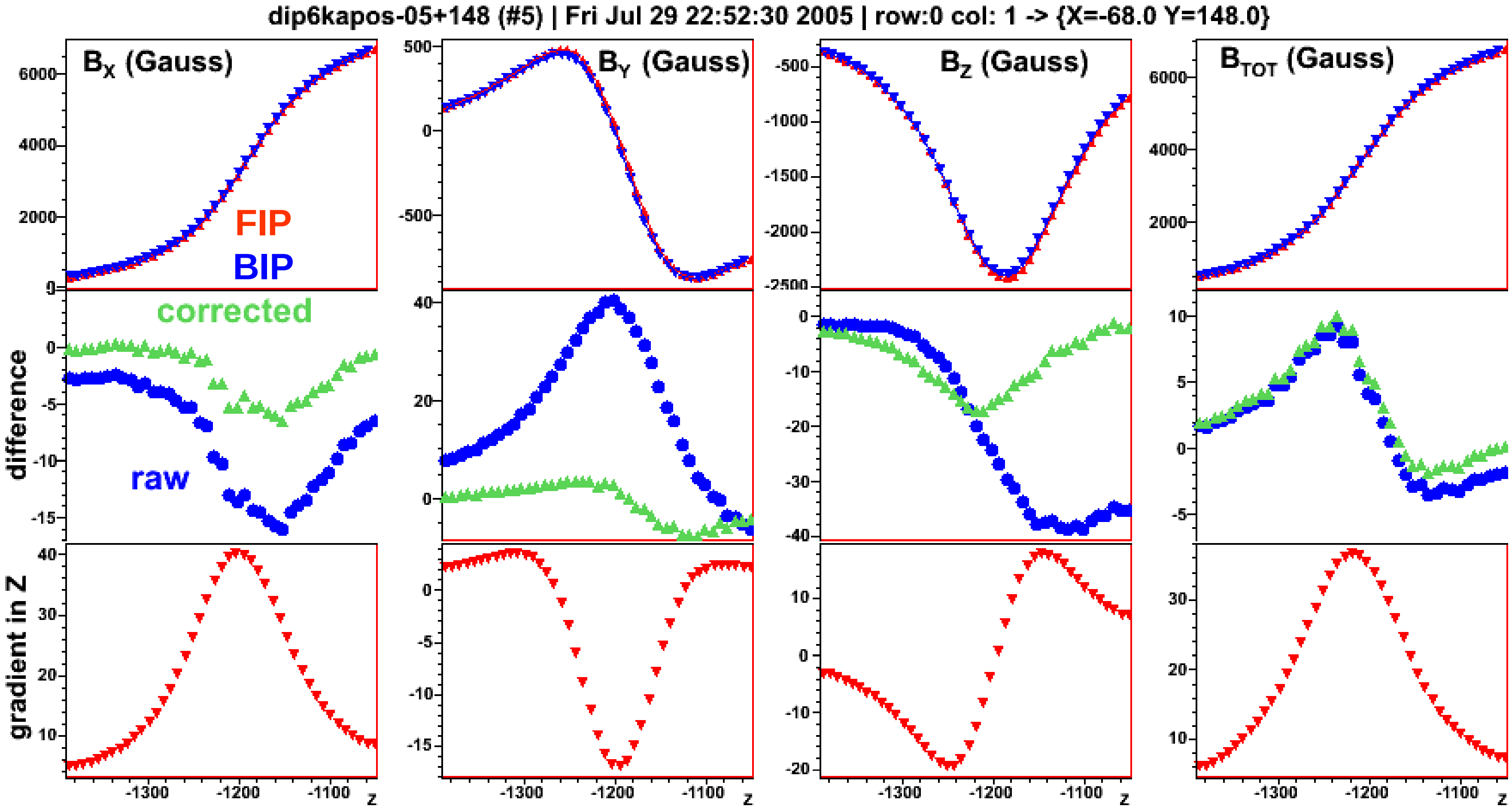
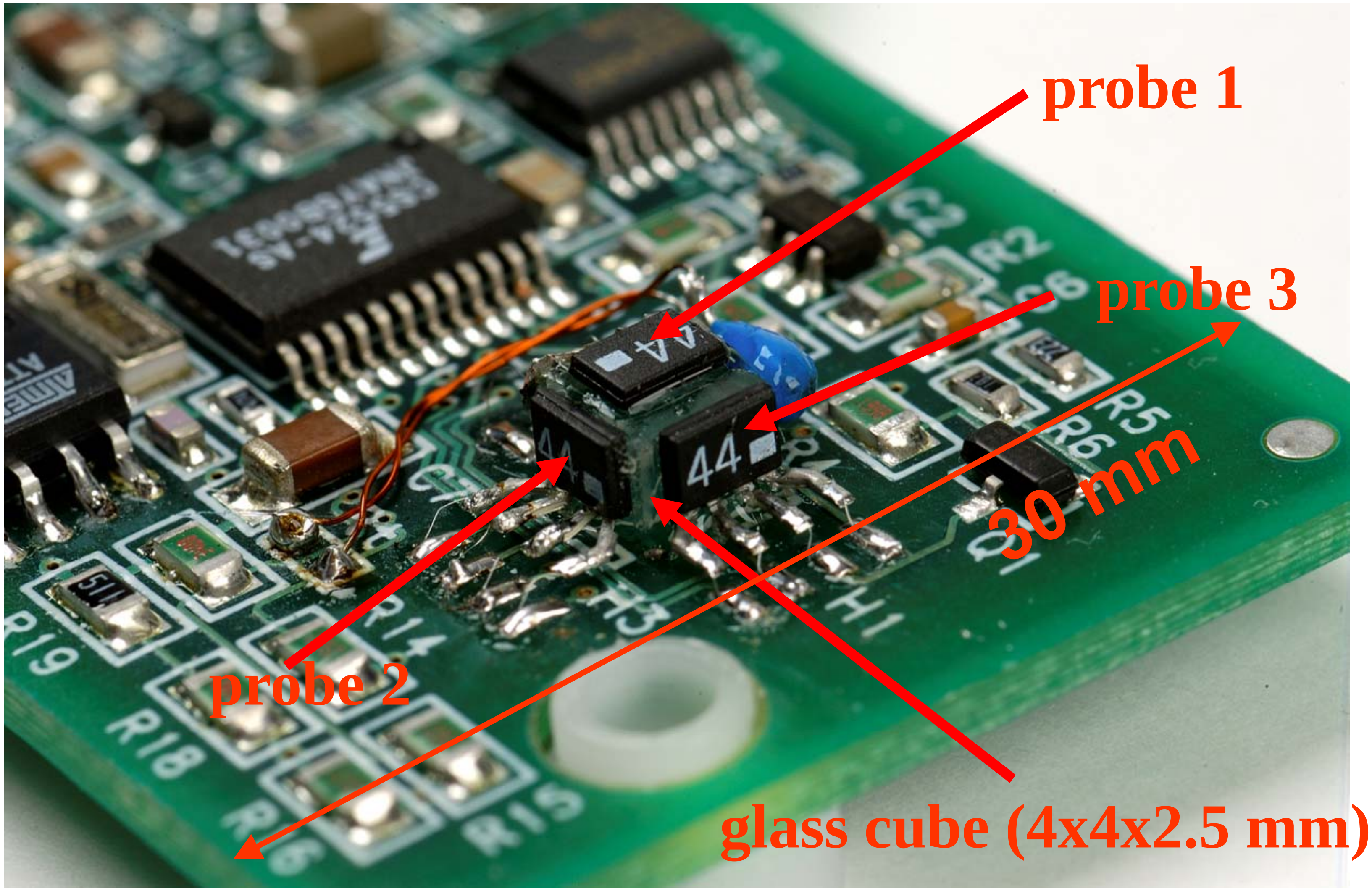


The field gradients are quite strong (reaching > 100 Gauss/cm)



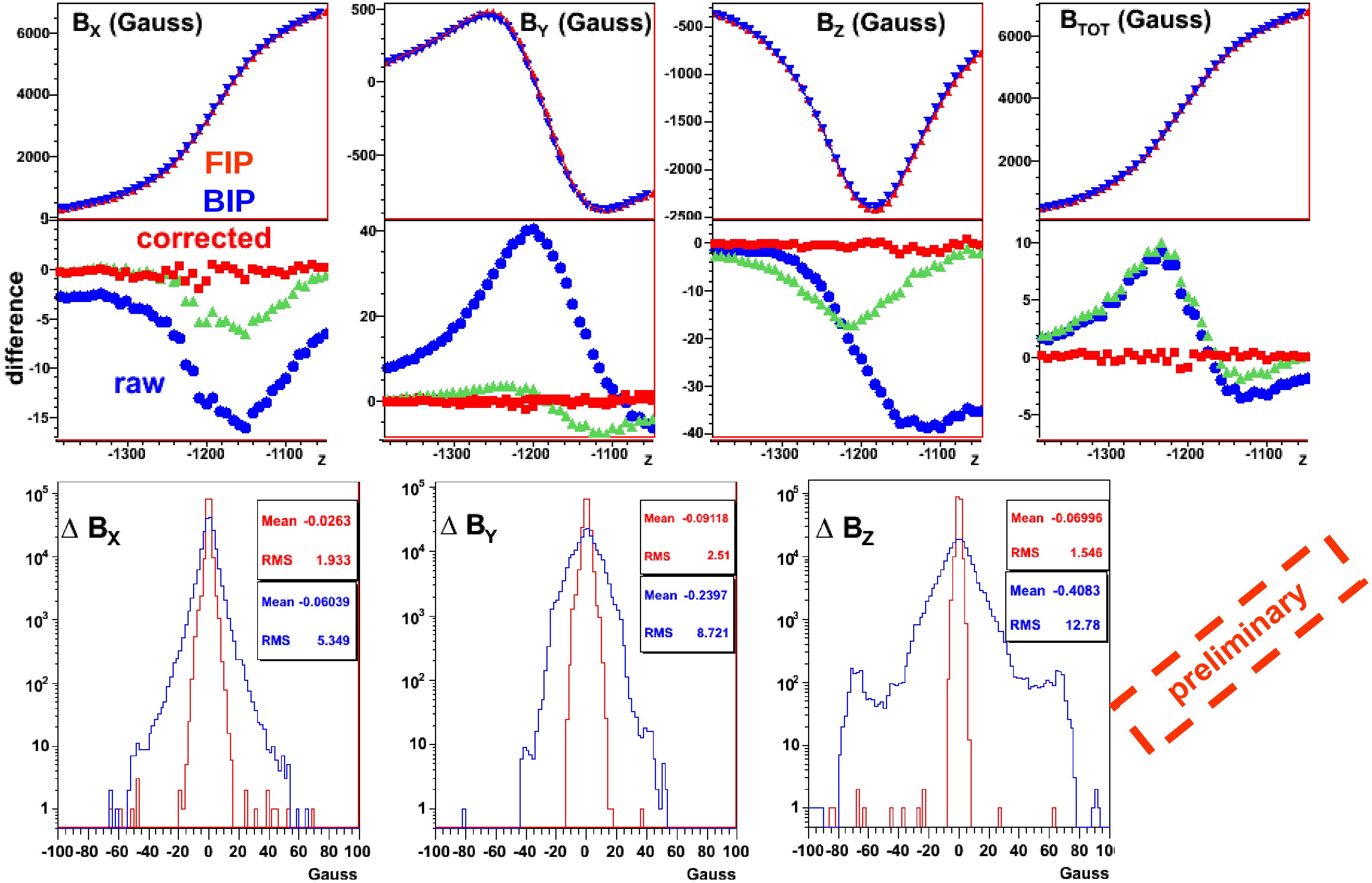
Probes are not point-like : ⇒ their size does matter!

- Different components are measured at different space points.
- Probes on the BIP plate are not measuring the same points as their partners on FIP, even in case of ideal alignment

Correcting distortions

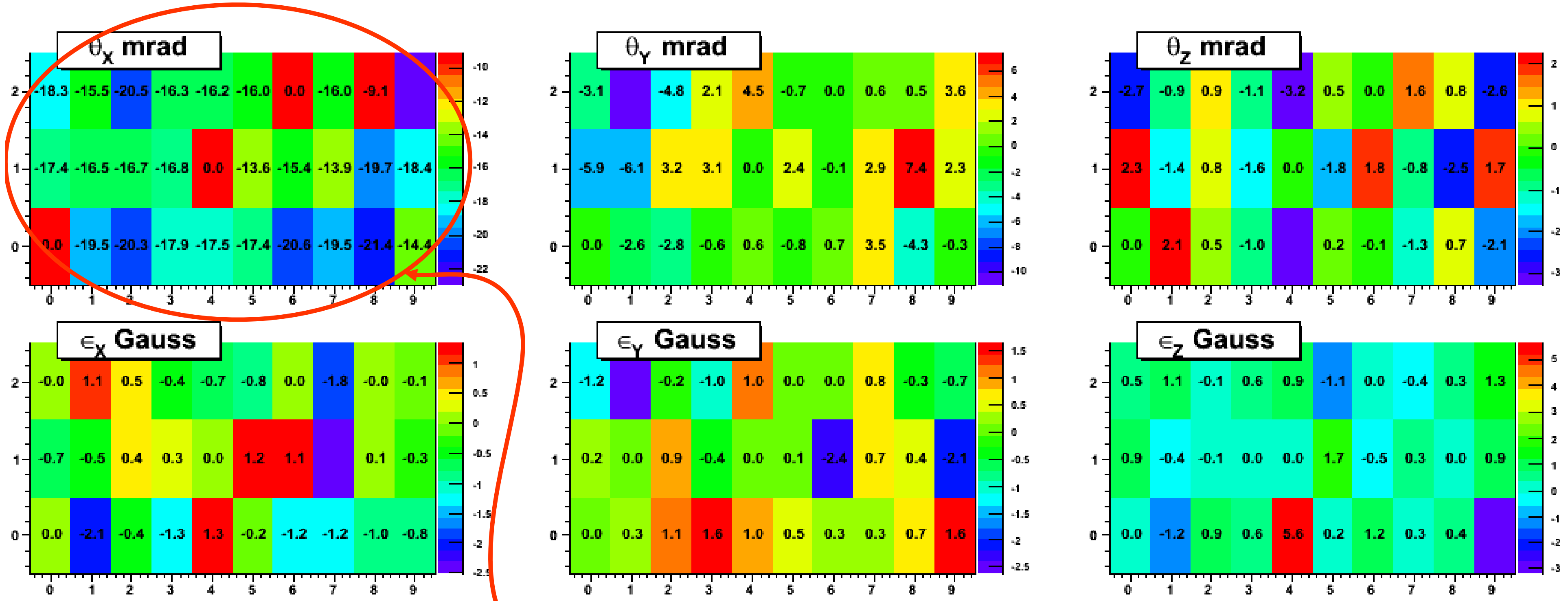
Modify fit model to account for the individual displacement of 1D probe for each projection

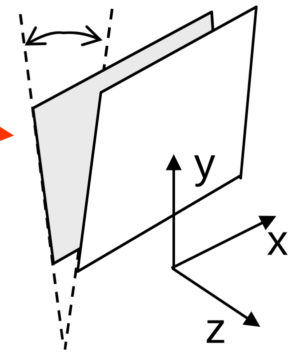
$$\begin{bmatrix} \Delta B_X \\ \Delta B_Y \\ \Delta B_Z \end{bmatrix} = Q_{\vec{\theta}} R_p \vec{\hat{B}} + R_p \frac{\partial \vec{\hat{B}}}{\partial \vec{r}} R_p^{-1} \begin{vmatrix} \vec{\delta_X} \\ \vec{\delta_Y} \\ \vec{\delta_Z} \end{vmatrix} + \vec{\epsilon}$$



Correcting distortions

Example of obtained rotations and miscalibrations probe-map valid for the majority of scans: 19 Aug–10 Sep
(0 means that fit/comparison is not possible :one of the FIP/BIP probes is missing)



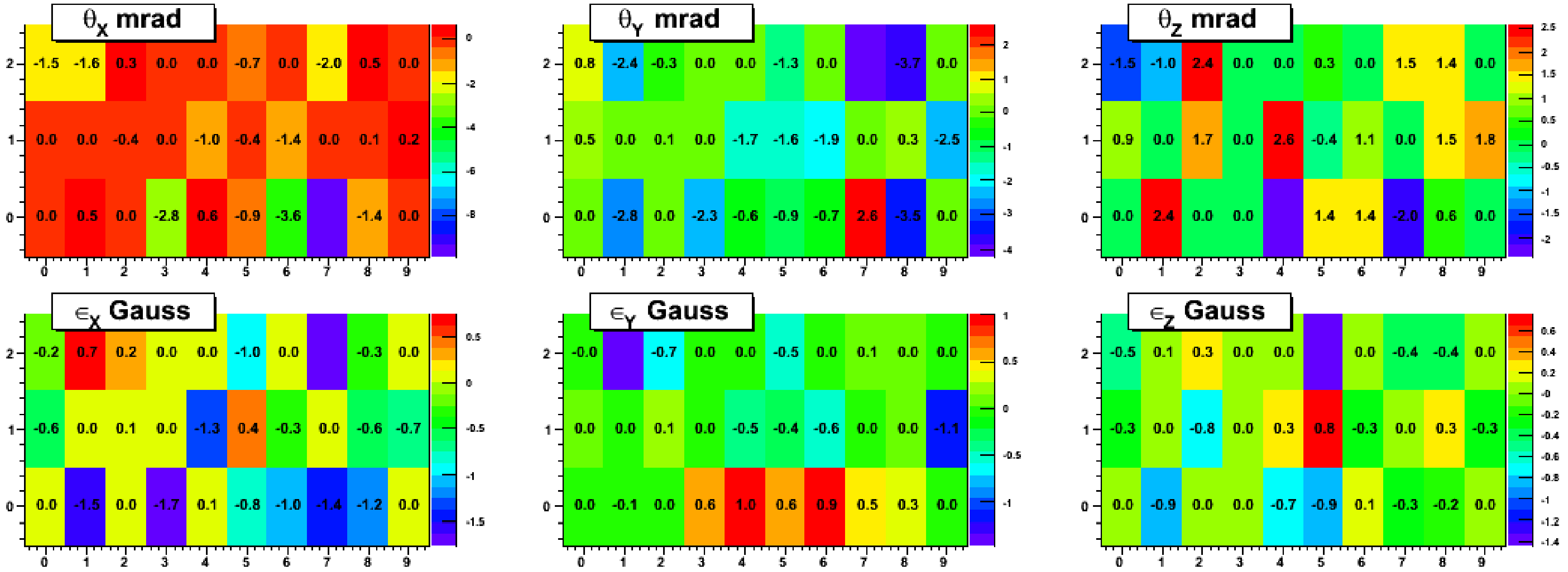


~17 mrad relative tilt between FIP and BIP plates

NOTE: these fits show only the relative alignment between the pairs of FIP and BIP probes

Correcting distortions

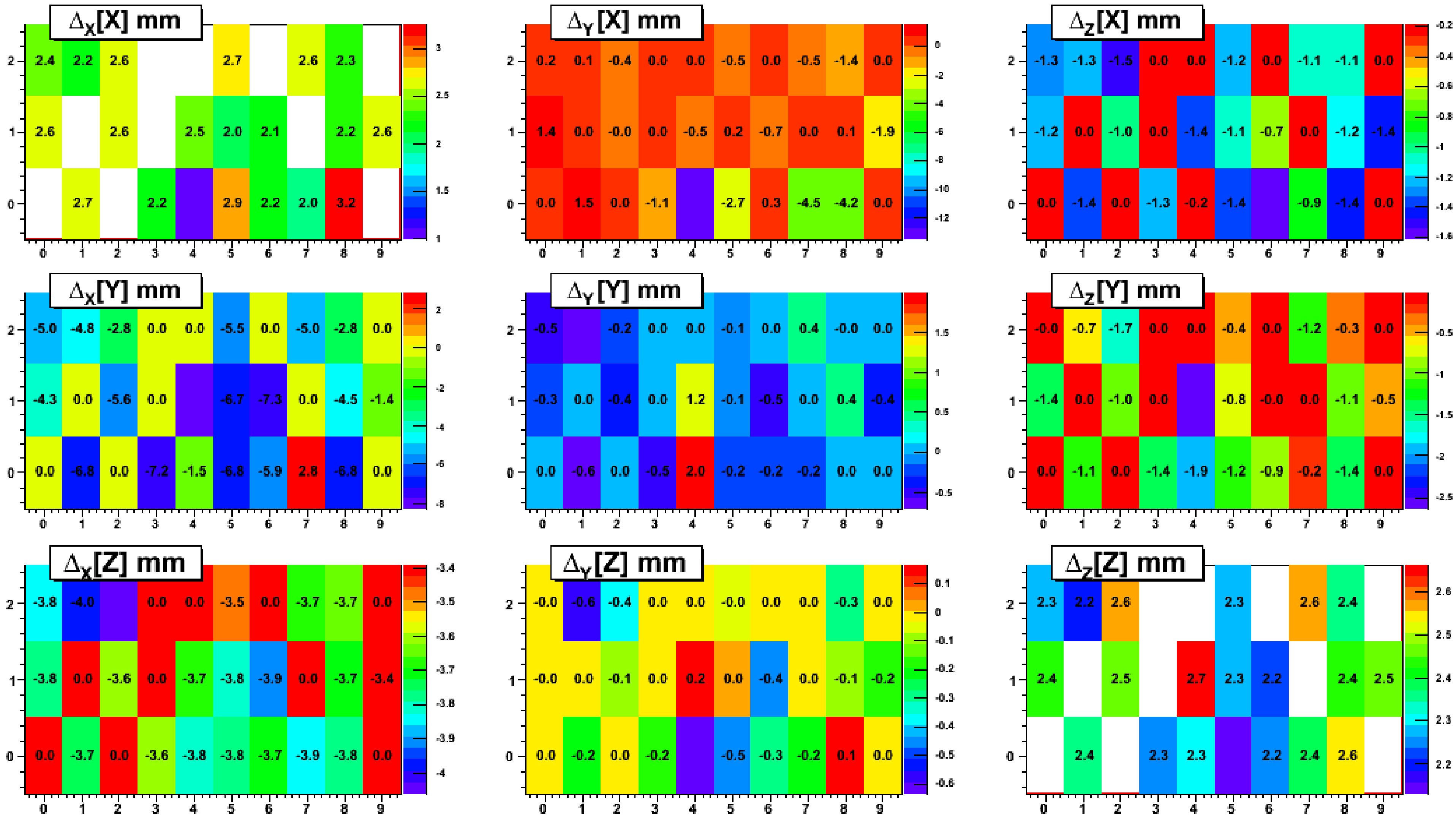
Example of obtained rotations and miscalibrations
(last probe-map: 9-23 Oct. : probes were readjusted)



The common tilt has been removed

Correcting distortions

Example of obtained offsets for each 1D probe
(last probe-map: 9-23 Oct)



Correcting distortions

How the absolute probes/plates alignments wrt lab system can be done?
(work in progress)

To do this we need to know the “reference” correct field at least in some restricted region.

Suppose we are able to describe the distorted field on the surface of the volume by the solution of the Laplace equation.

Explore the fact that :

- both “distorted fitted**”** and correct fields are the solutions of the Laplace equation
  $\Rightarrow$ their difference (“fake field”) too.
- the solution of the Laplace equation has its extremum on the surface of the volume

$\Downarrow$

As we go further from the surface inside the volume the error (“fake field”) may only decrease $\Rightarrow$ the fitted field becomes closer to the correct field.

$\Downarrow$

Do few iterations by minimizing (as a function of the alignment parameters) the difference between the distorted measurements deep in the volume and the fitted field.

Field parameterization method (based on H.Wind, NIM 84 (1970) 117)

In the absence of currents all magnetic field components and scalar potential must obey Laplace equation $\Delta\Psi = 0 \quad \Delta B_i = 0$ $\Rightarrow$ fully defined by their values on the volume surface.

The general solution in Cartesian coordinates for the box with sides ***X***,***Y*** and ***Z*** is:

$$\Psi(x,y,z) = \sum_{m,k} C_{mk} \begin{bmatrix} \sin\left(m\frac{\pi x}{X}\right) \\ \cos\left(m\frac{\pi x}{X}\right) \end{bmatrix} \begin{bmatrix} \sin\left(k\frac{\pi y}{Y}\right) \\ \cos\left(k\frac{\pi y}{Y}\right) \end{bmatrix} \begin{bmatrix} \sinh\left(z\pi/\sqrt{\left(\frac{mx}{X}\right)^2 + \left(\frac{ky}{Y}\right)^2}\right) \\ \cosh\left(z\pi/\sqrt{\left(\frac{mx}{X}\right)^2 + \left(\frac{ky}{Y}\right)^2}\right) \end{bmatrix} \qquad (1)$$

Since the field main component ($\boldsymbol{B_X}$ for Alice dipole) is the most robust against the measurements errors, one can

- fit $\boldsymbol{B_X}$ values measured on the surface of the box to (1)
- integrate along ***X*** to obtain the Ψ
- compute the field inside the volume as $\vec{B} = \vec{\nabla}\Psi$

Caveats:

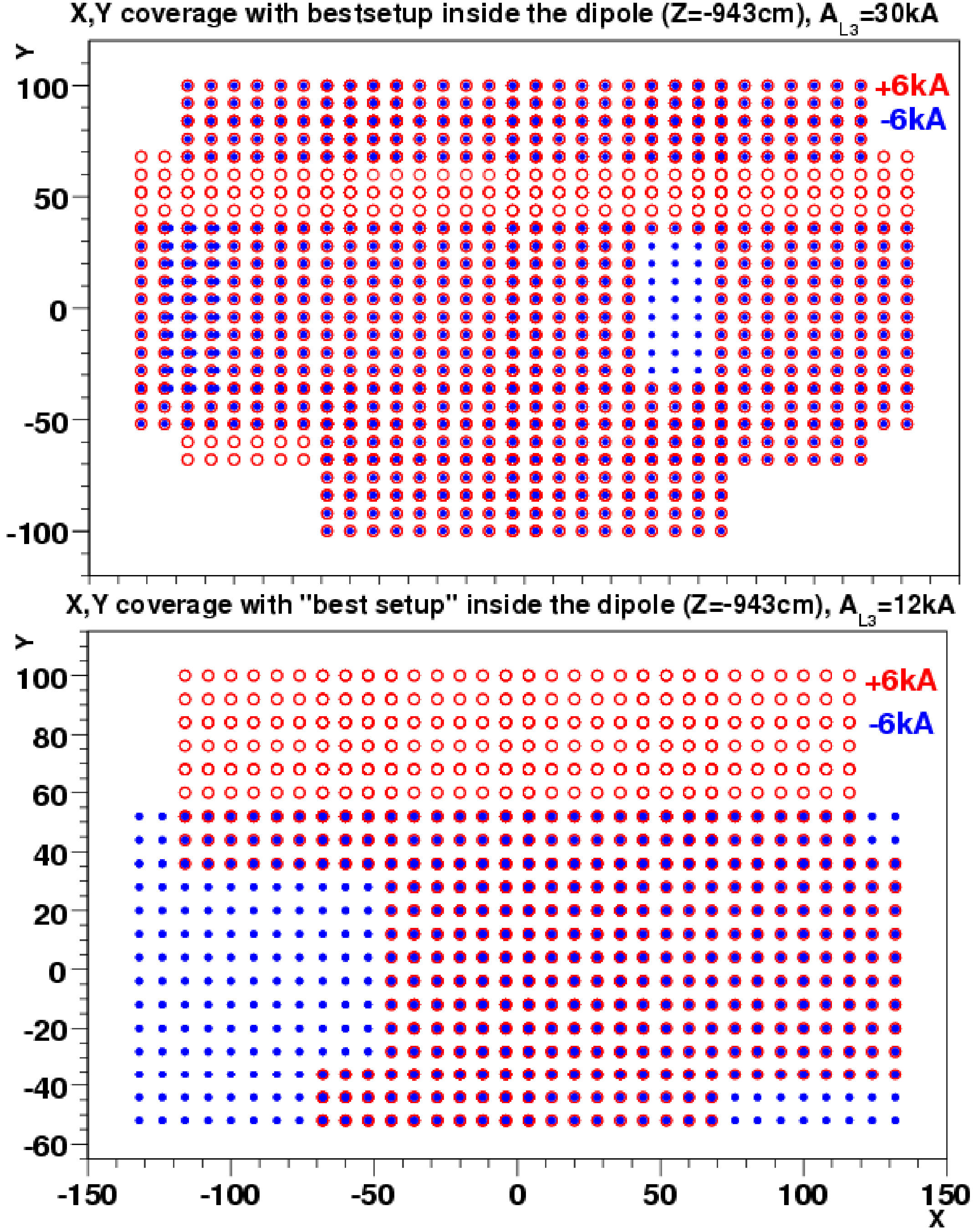
- for the fit to be convergent, the measurements should be done in the points equidistant in each dimension (no missing points are allowed).
- since the Ψ is obtained by integrating in one dimension, it is precise up to a function of two other dimensions (also obeying to 2D Laplace equation):

$$B_Y = \frac{\partial\Psi}{\partial y} + F_Y(y,z) \qquad\qquad B_Z = \frac{\partial\Psi}{\partial z} + F_Z(y,z)$$

These missing functions must be obtained by fitting the difference between the measured and calculated minor components to 2D version of (1).

Field parameterization

Data with 12 kA and 30 kA in L3 were taken with both polarities, but the coverage by each polarity is quite incomplete.



Field parameterization

Data with 12 kA and 30 kA in L3 were taken with both polarities, but the coverage by each polarity is quite incomplete.
Need to take together + and – (inverting the field) currents data to improve the coverage.
This allows to define large enough rectangular surfaces for the potential reconstruction (only 30kA is shown)
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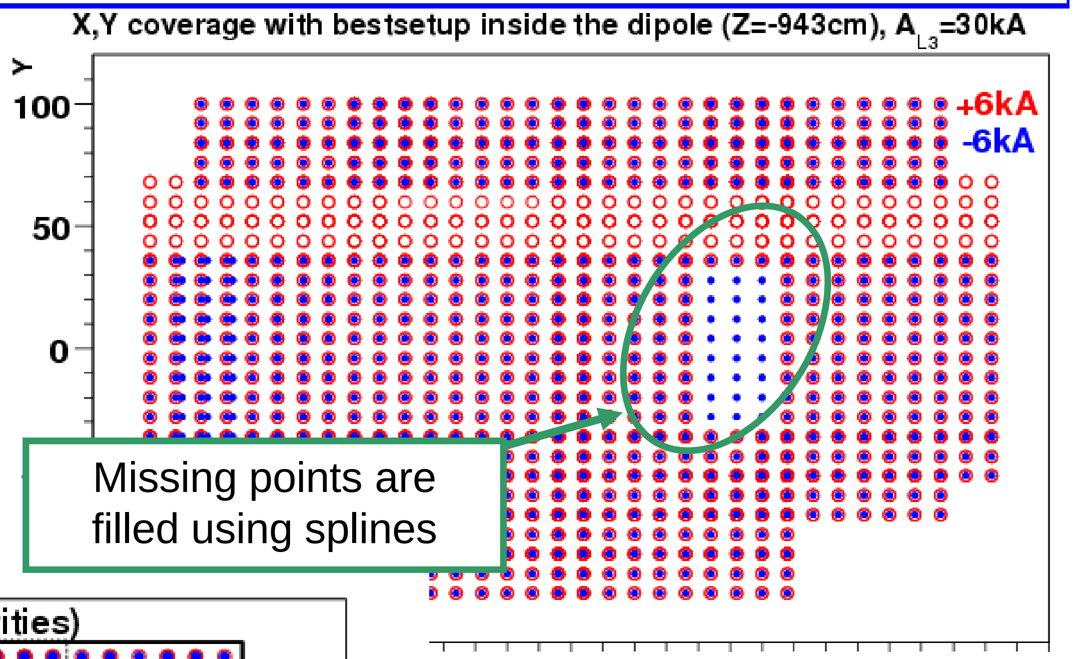
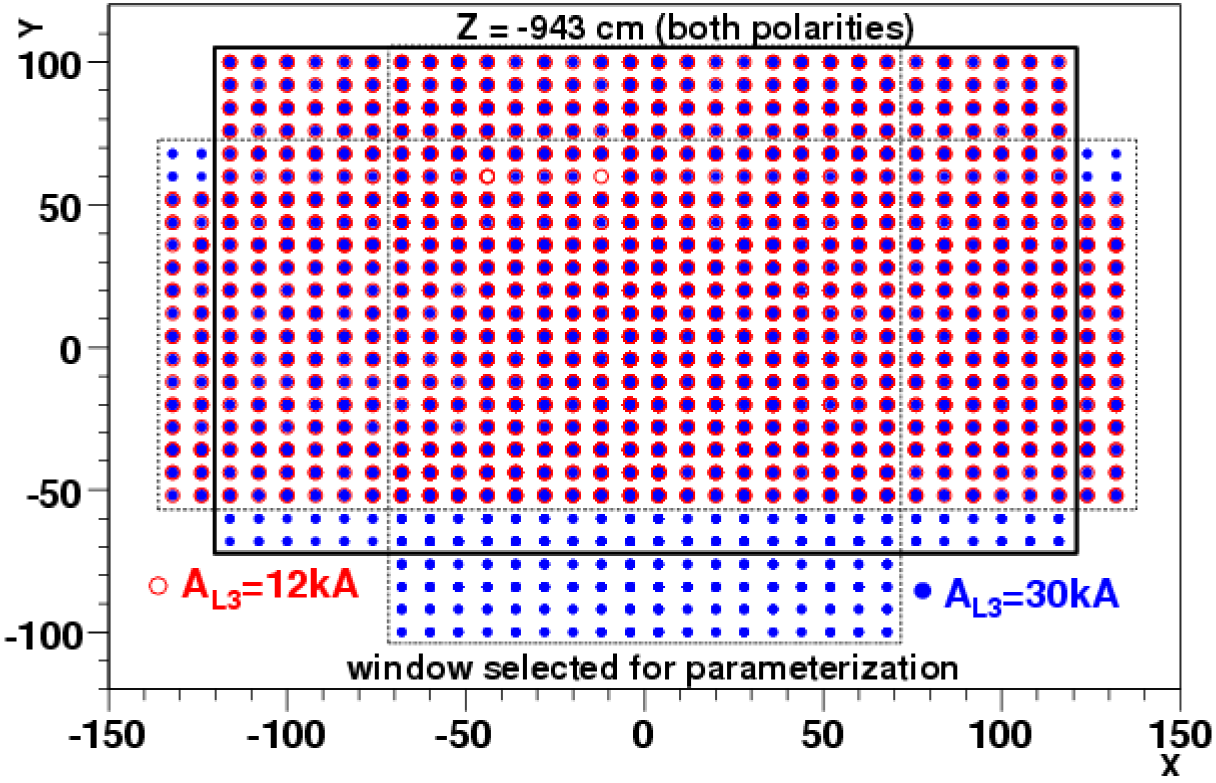
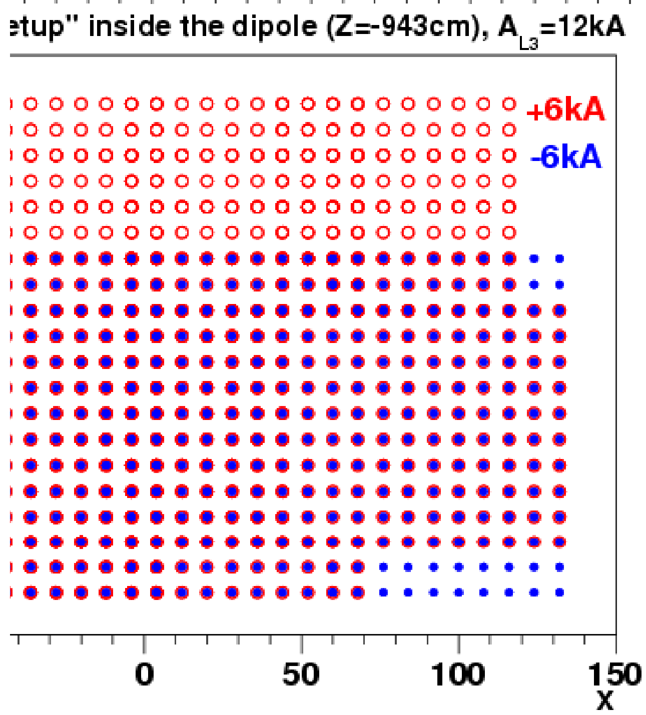
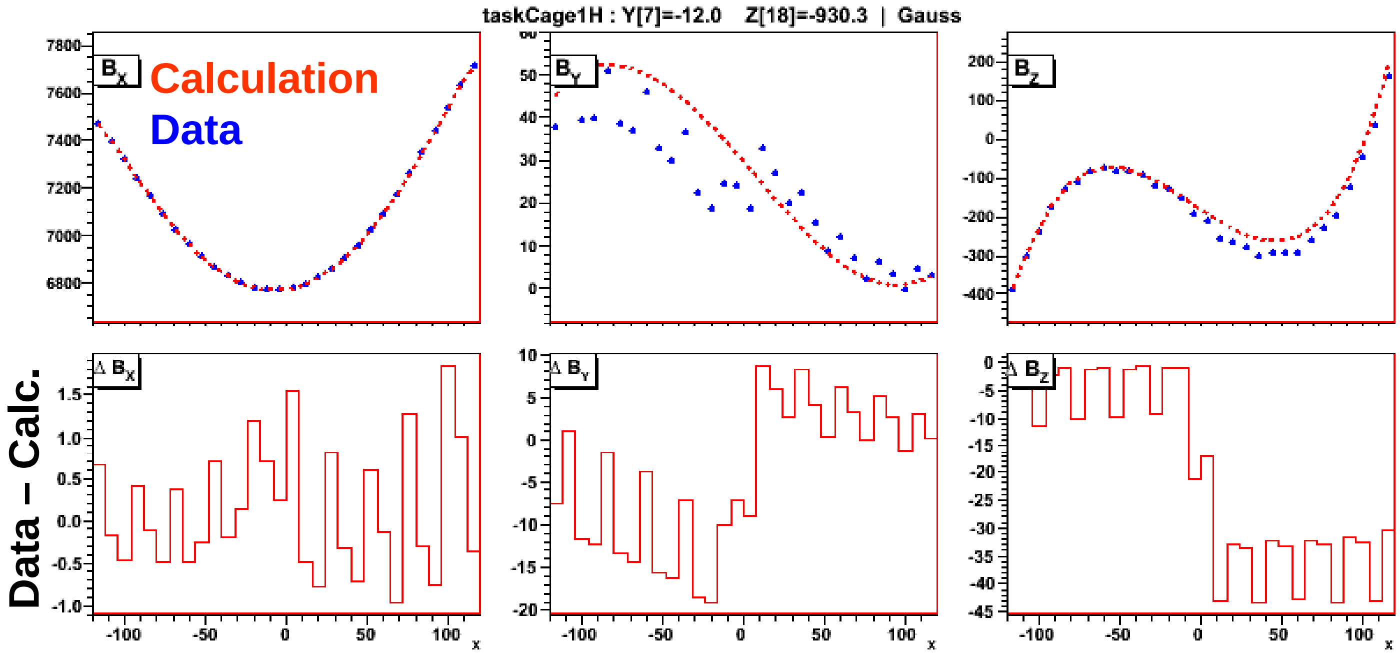




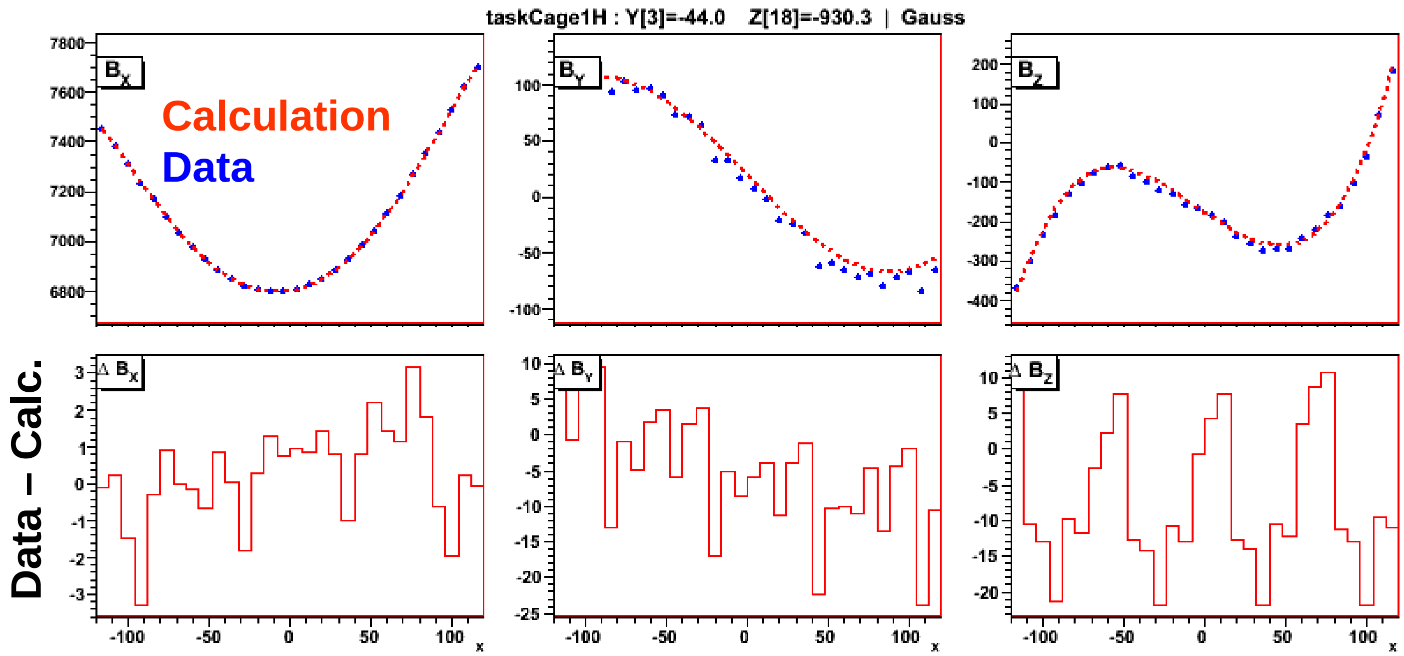


Comparison of data (averaged over different scans) with calculation

X dependence

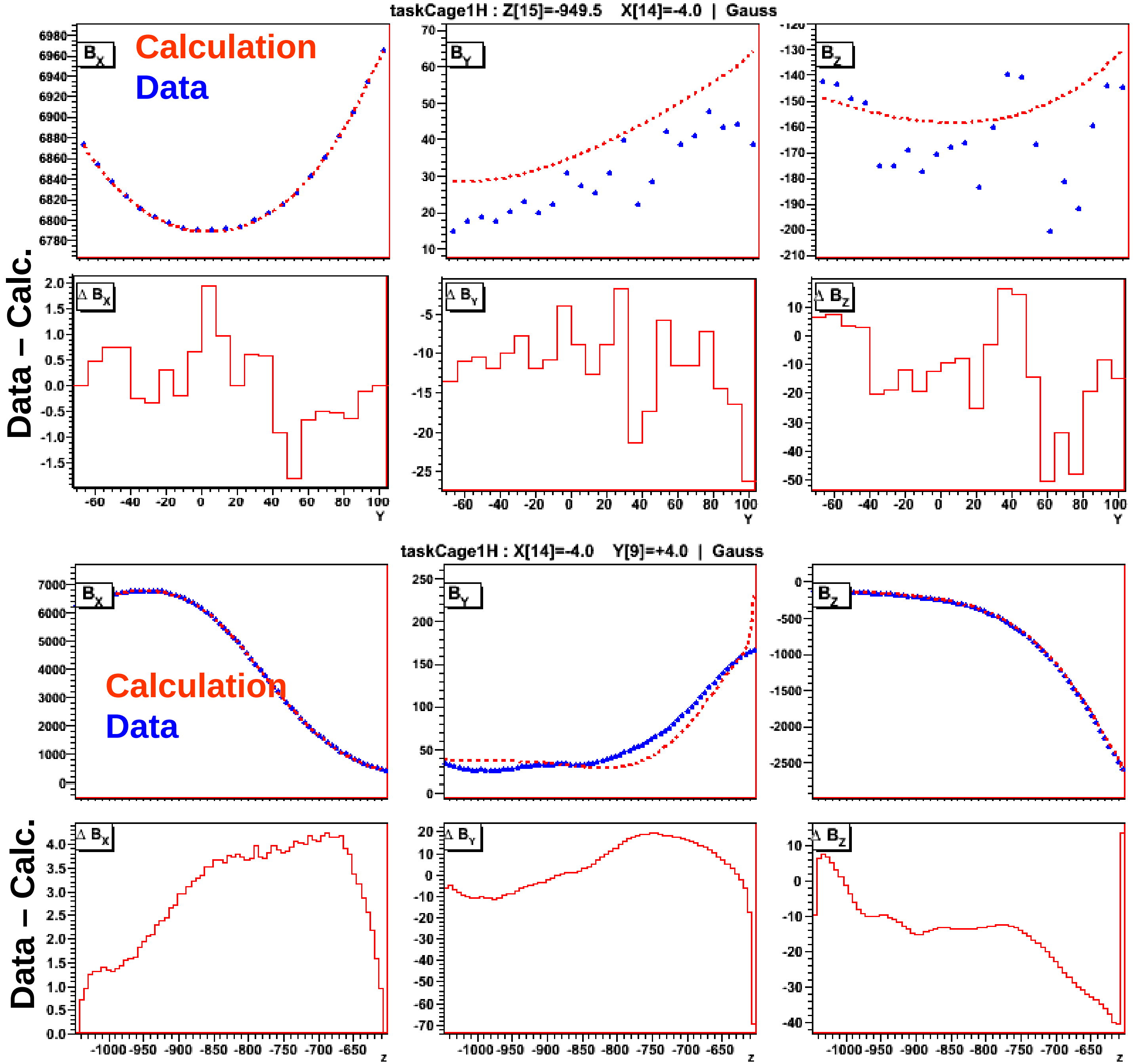


Center of the dipole box positions: 1 and 3



Above the center box positions: 0 and 2

Comparison of data (averaged over different scans) with calculation

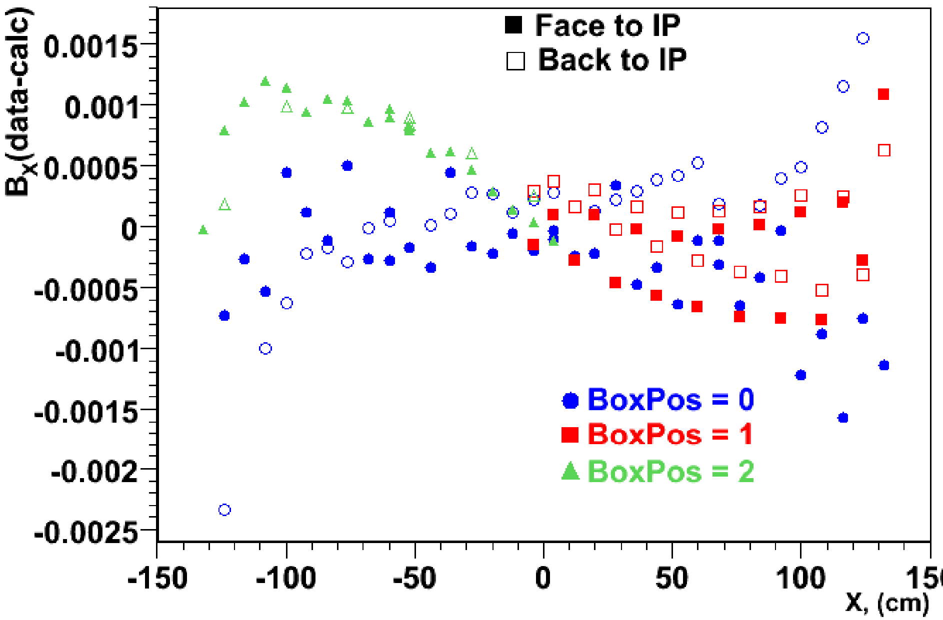


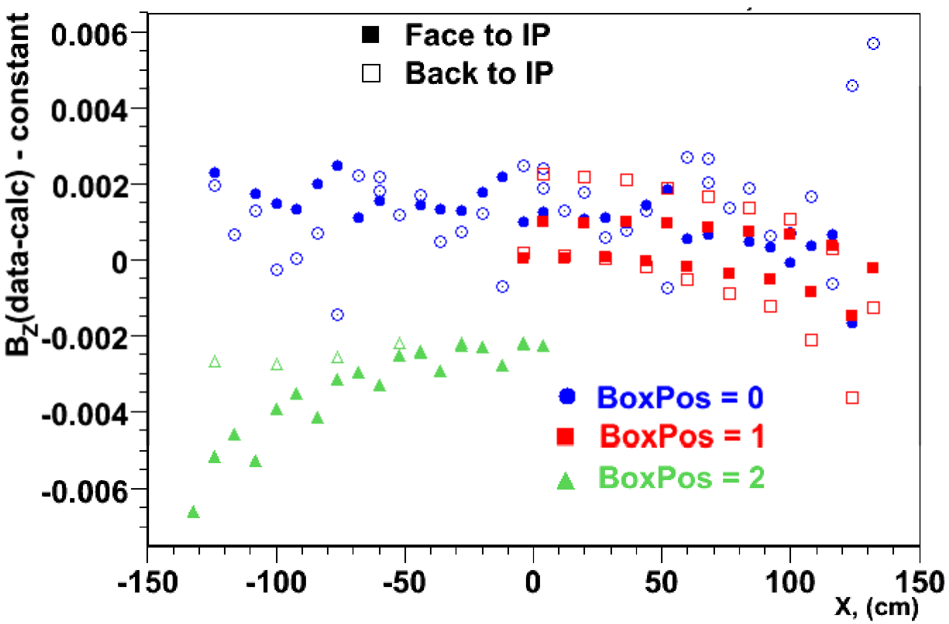
Y dependence

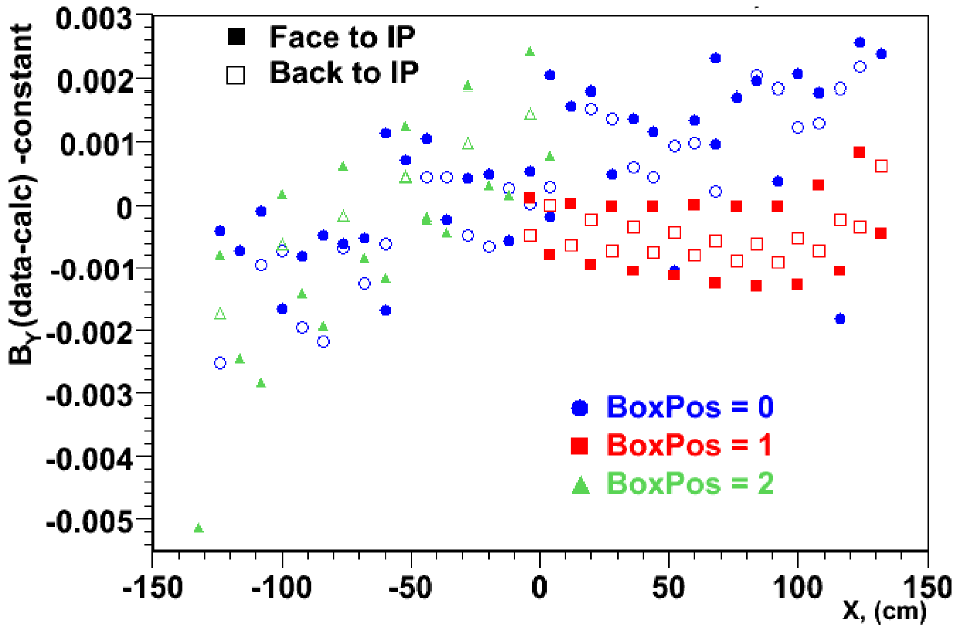
Z dependence

Comparison of individual measurements with calculation (Y=36 cm, Z=-853)

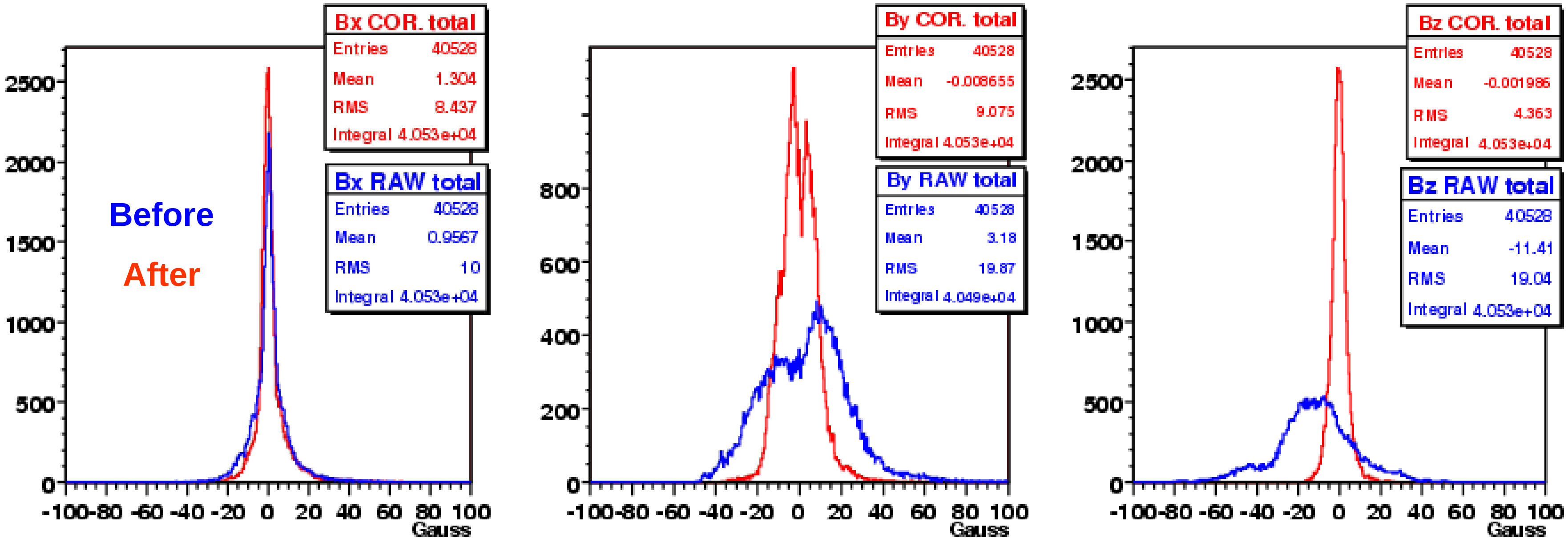
There are apparent systematic differences between the deviations of measurements with different plates orientations: still to be seen if they are scan dependent







Very preliminary: example of minimization of the differences between the data and the fitted field (probe size is not accounted)



Data – Fit (for points 24 cm from the surface in X and Y and 80 cm in Z)

Summary

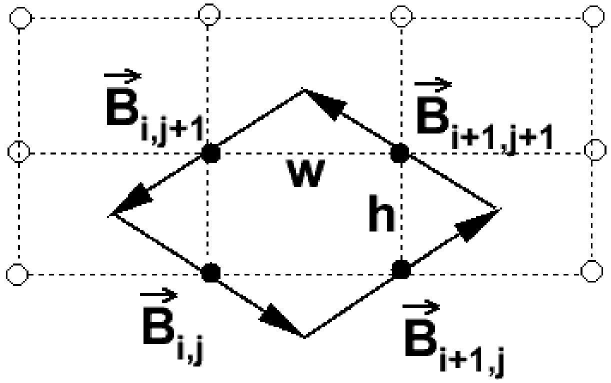
- Lot of problems with data quality and the information on data taking conditions, seem to be mostly solved
    - All probe-maps are identified
    - Data are cleaned
    - Effects caused by the finite probe's size are accounted (still have to do some check on compatibility of the offsets obtained by the measurements with different measuring head orientations)
- The field parameterization routines are working
- The probes alignment is being done

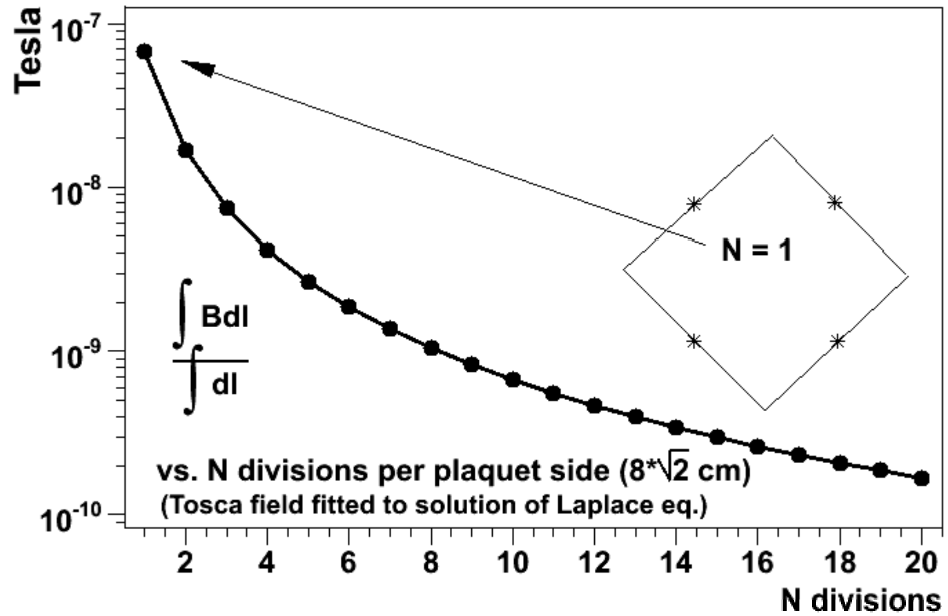
Tentative time estimate to get the field map for the measured data and filling the uncovered regions by Tosca calculations: ~ 1 month (if no new problem found)

Failed attempt of probes alignment exploring Biot-Savart law

Fit deviation of $\oint \mathbf{Bdl}$ from 0 for all possible plaquets as a function of probe's misalignments…

$$\oint \mathbf{Bdl} \approx w(B^x_{i,j}+B^x_{i,j+1}-B^x_{i+1,j+1}-B^x_{i,j+1}) + h(-B^y_{i,j}+B^y_{i,j+1}+B^y_{i+1,j+1}-B^y_{i,j+1}) \approx 0$$



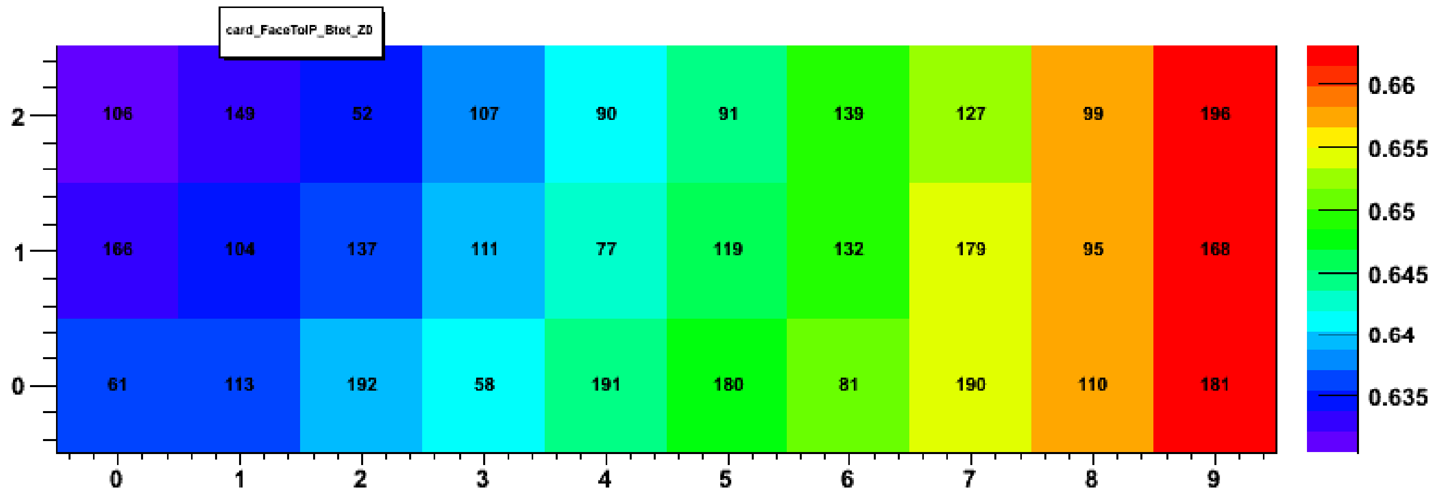


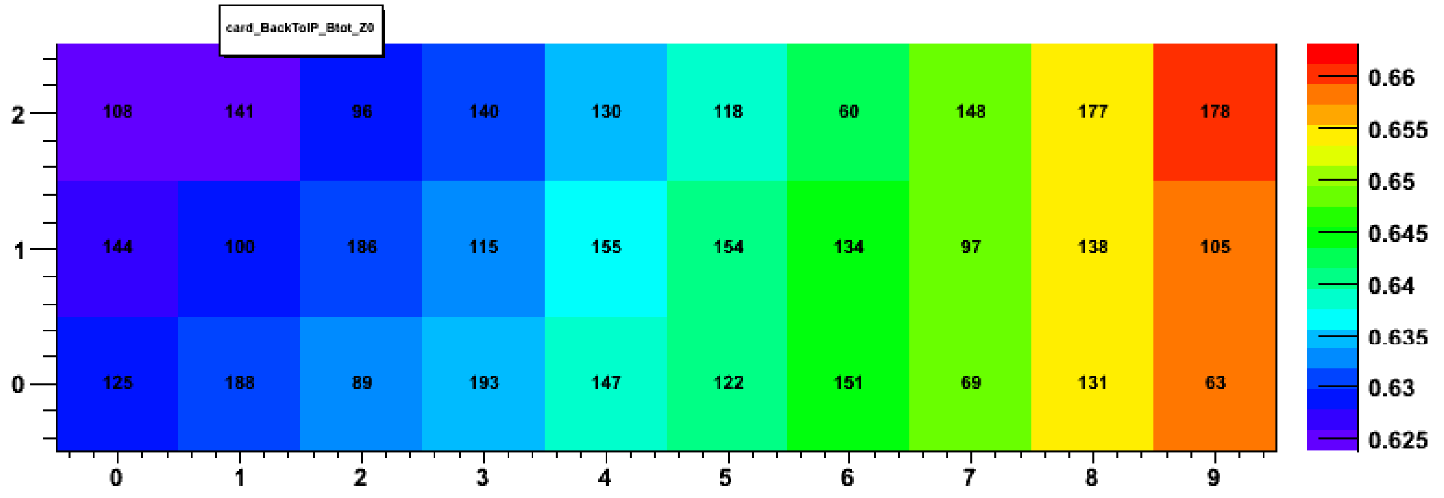
Fails because even in the case of the ideal alignment such rough $\oint \mathbf{Bdl}$ computed on the loop of 4 points is far from 0 due to the non-linearity of the field.

Tried to account for this by subtracting the $\oint \mathbf{Bdl}$ calculating by Tosca, but it did not work because:

- Tosca does not respect Maxwell equations with needed precision.
- Used too crude mesh leads to field fluctuations on the level of a few Gauss...

The only complete probe map (used for ~30 very short scans)





dip+6kah+7-84h2fass2 (#765) | Fri Sep 16 06:15:21 2005 | row:0 col: 0 -> {X=92.0 Y=-84.0}