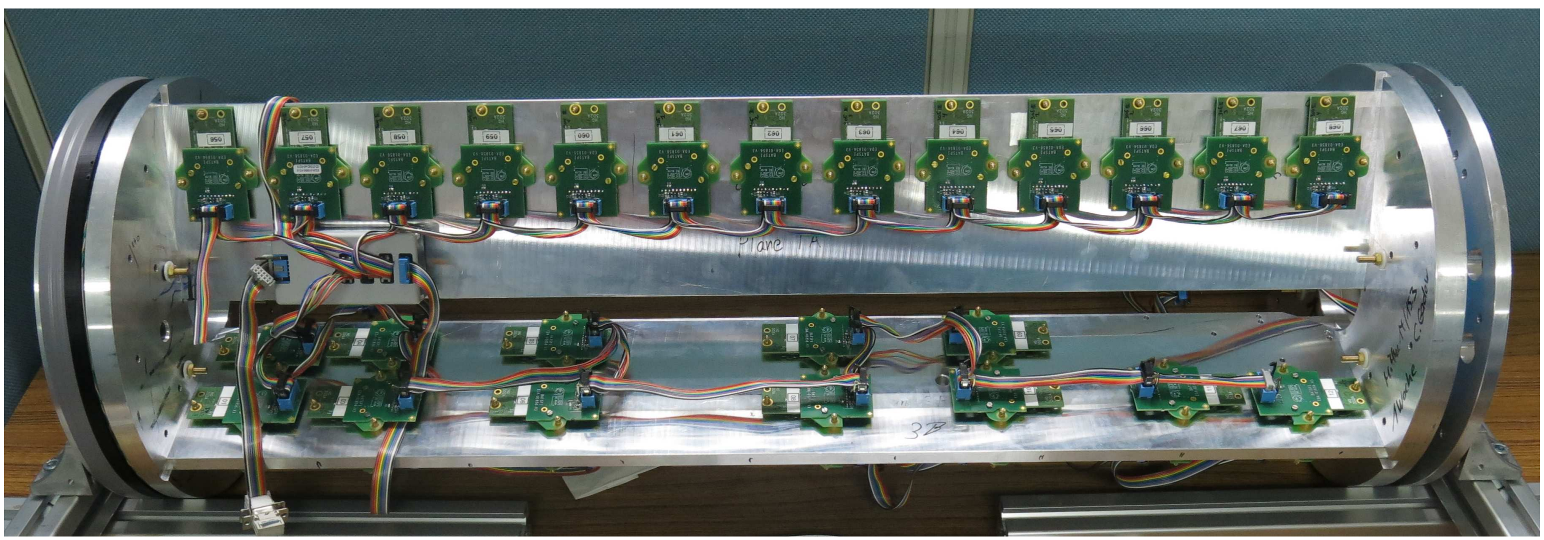
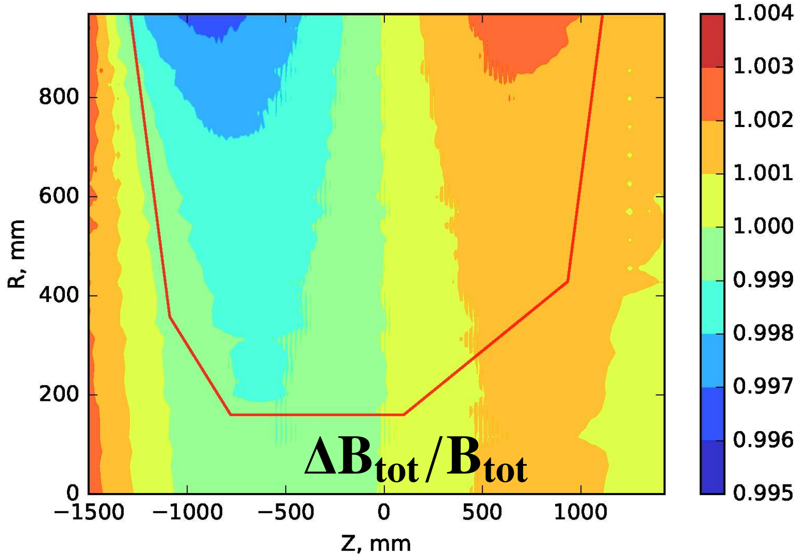
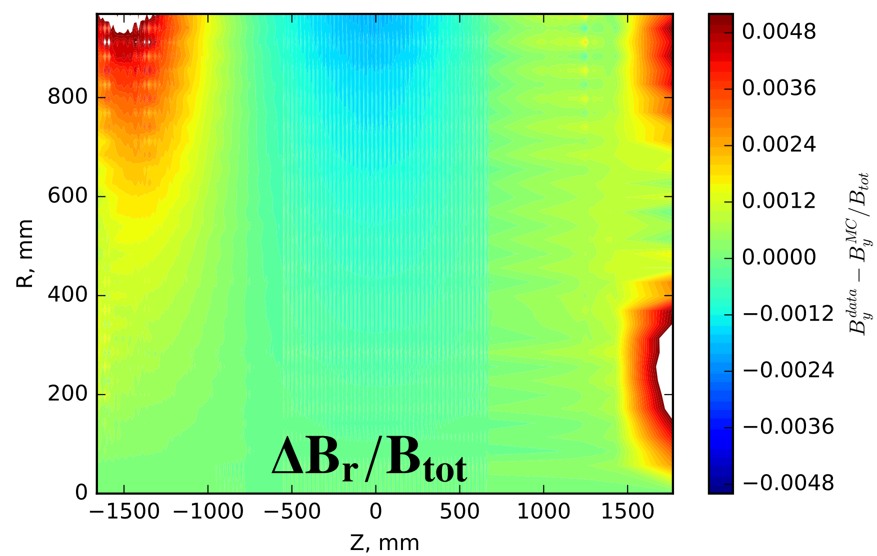
# Measurement of the magnetic field in the VXD volume

S. Glazov, Mainz, 18 Sept 2017



# Summary of 2016 field measurement results

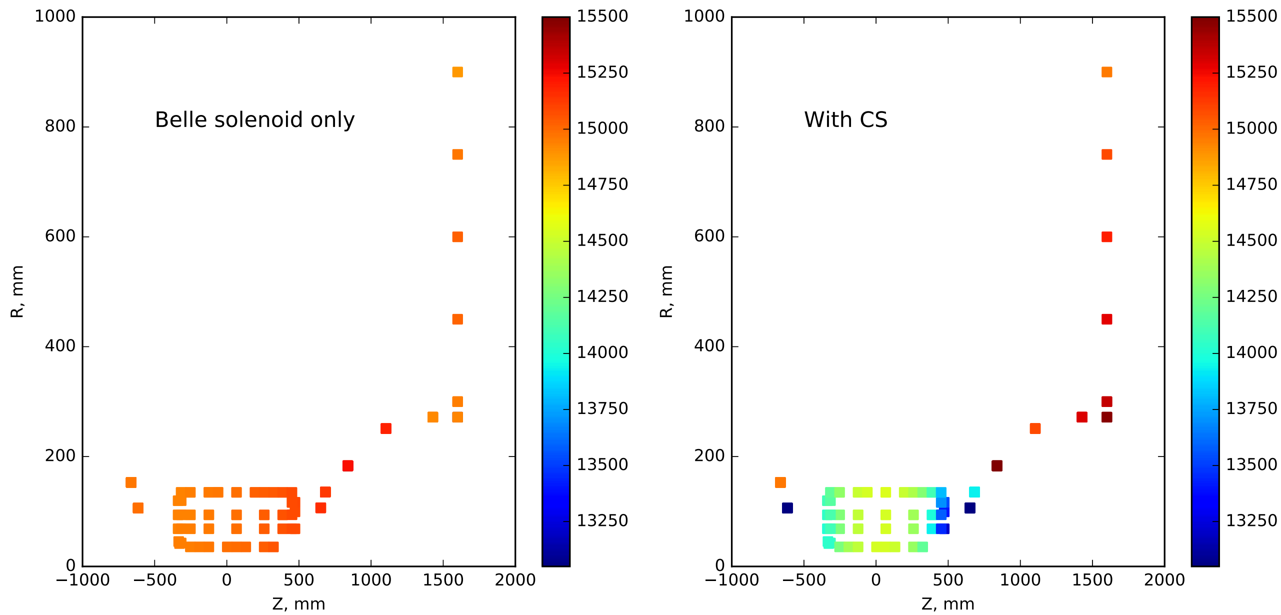



- Detailed 3D B-field map inside Belle solenoid.
- Comparisons with the simulation show reasonable agreement, close to the target 0.1% for the bulk of the volume.

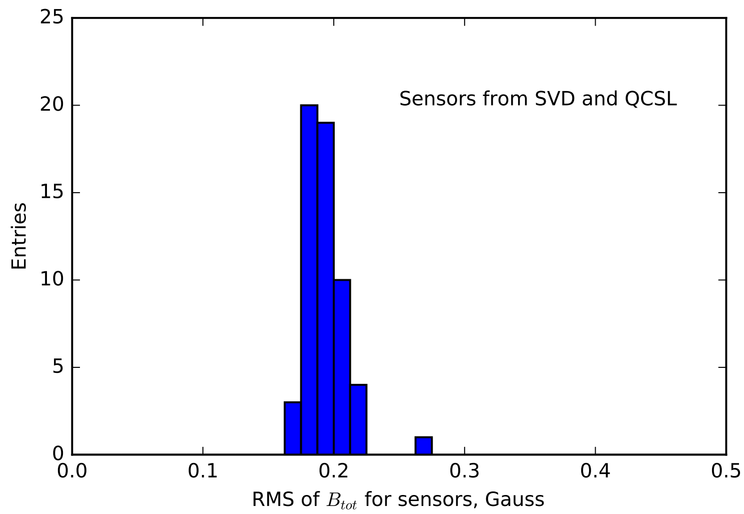
($Z = 0$ corresponds to the center of the solenoid, corresponds to $Z = +480$ in the Belle coordinate system)

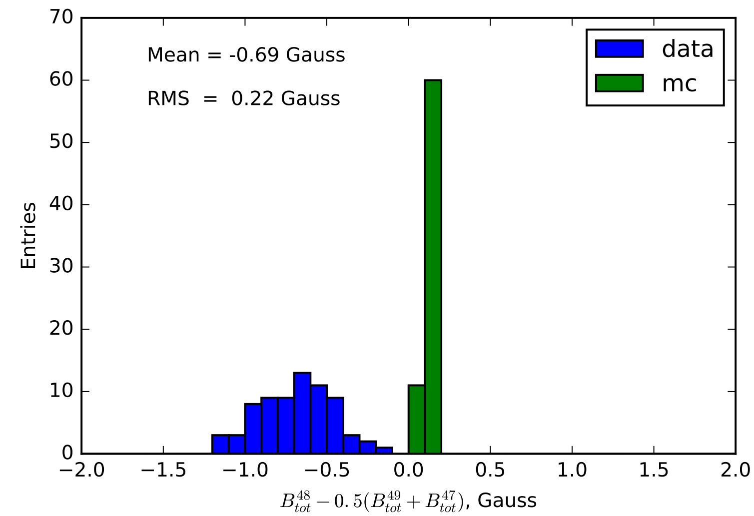
# Magnetic field measurement in 2017




- Measurement of magnetic field using fixed sensors on the surface of QCSL, QCSR, CDC end-plate and using $\phi$ rotating robot in the VXD volume.
- Measurements under different conditions, including Belle solenoid only and nominal conditions (quadruples and compensating solenoids also on).

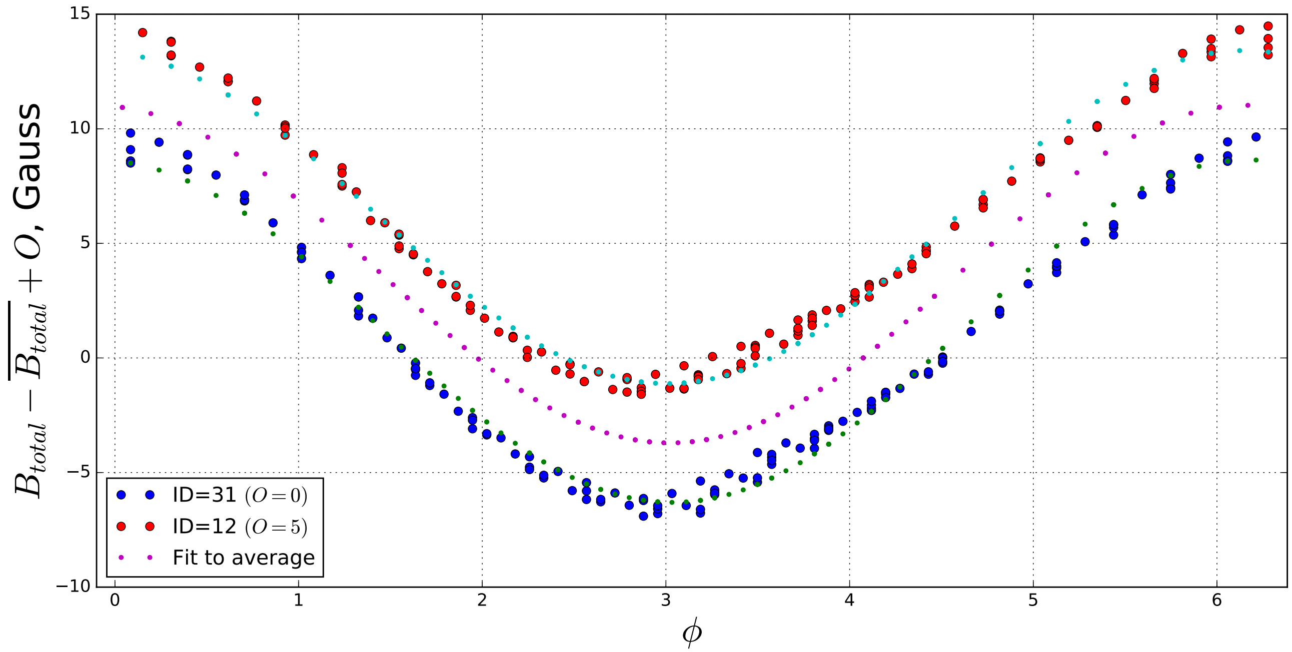
# $B$ field sensors properties



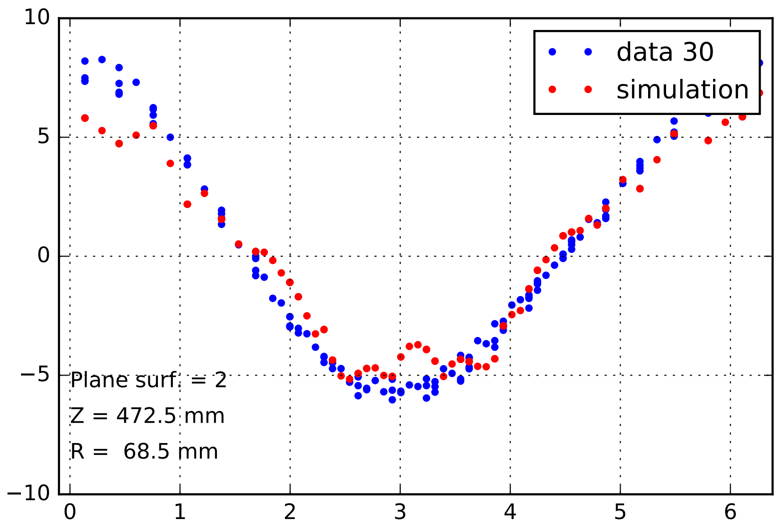

- Goal: check MC to 0.1% accuracy ($\sim$ 15 Gauss).
- Hall probes measuring all 3 components of the field.
- Stability to better than 0.3 Gauss.
- Cross-calibration to better than 1 Gauss.
- For VXD robot, sensors are mounted using precision pins with 1 mrad design accuracy, however somewhat larger misalignment is observed.

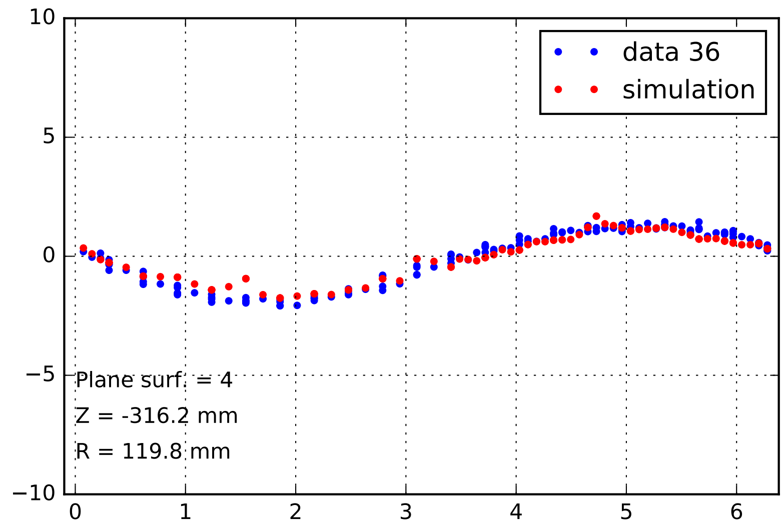
# $B_{\rm tot}$ vs $\phi$ in data




- Estimate gradient of the B-field vs $R$ as $g = \Delta\bar{B}_{\rm tot}/\Delta R$ using two sensors at the same $Z$ but different $R$.
- Fit variation of $B_{\rm tot}$ vs $\phi$ as $\bar{B}_{\rm tot} + A\sin(\phi + \phi_0)$.
- Estimate the magnitude shift of the beam axis vs the beam of the B-field mapper as $A/g$.
- Gradient is only significant for the configuration with compensating solenoids on.

# $B_{\mathrm{tot}}$ vs data vs simulation

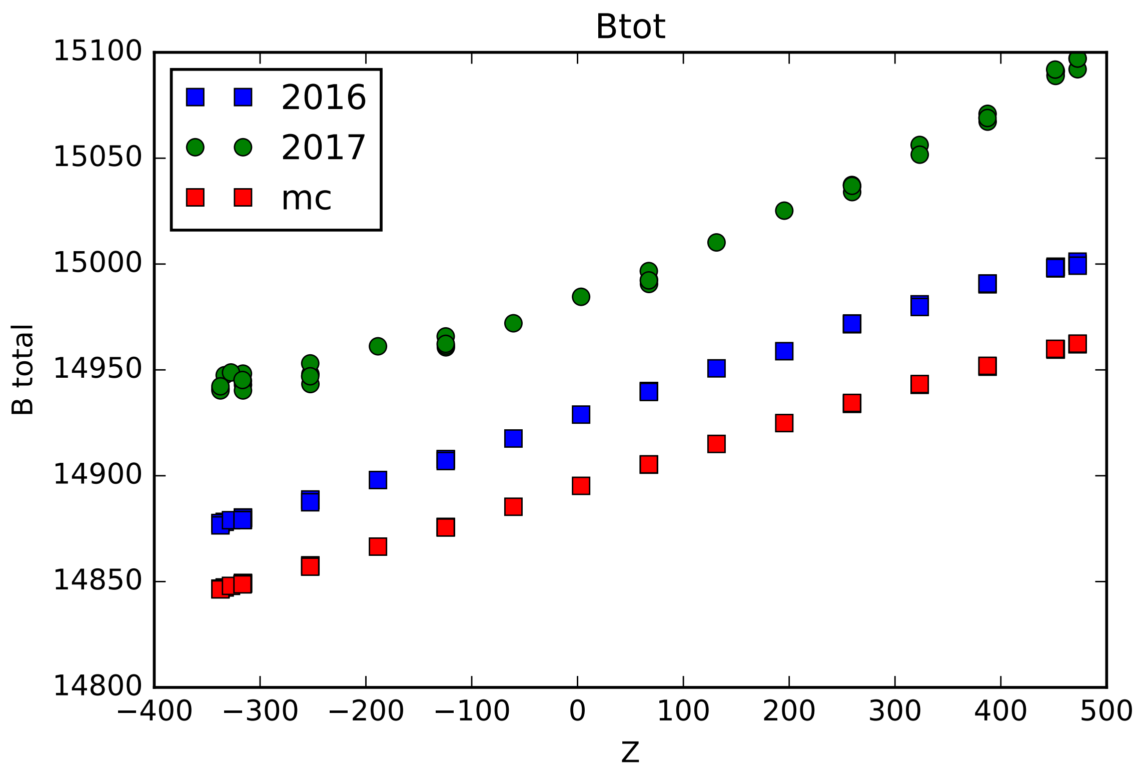



- Estimate shifts at both Nikko and Oho sides using pairs of sensors at the same $Z$ coordinate.
- Assume linear dependence vs $Z$.
- Include the shifts in MC simulation: reasonable agreement with the data for all sensors.

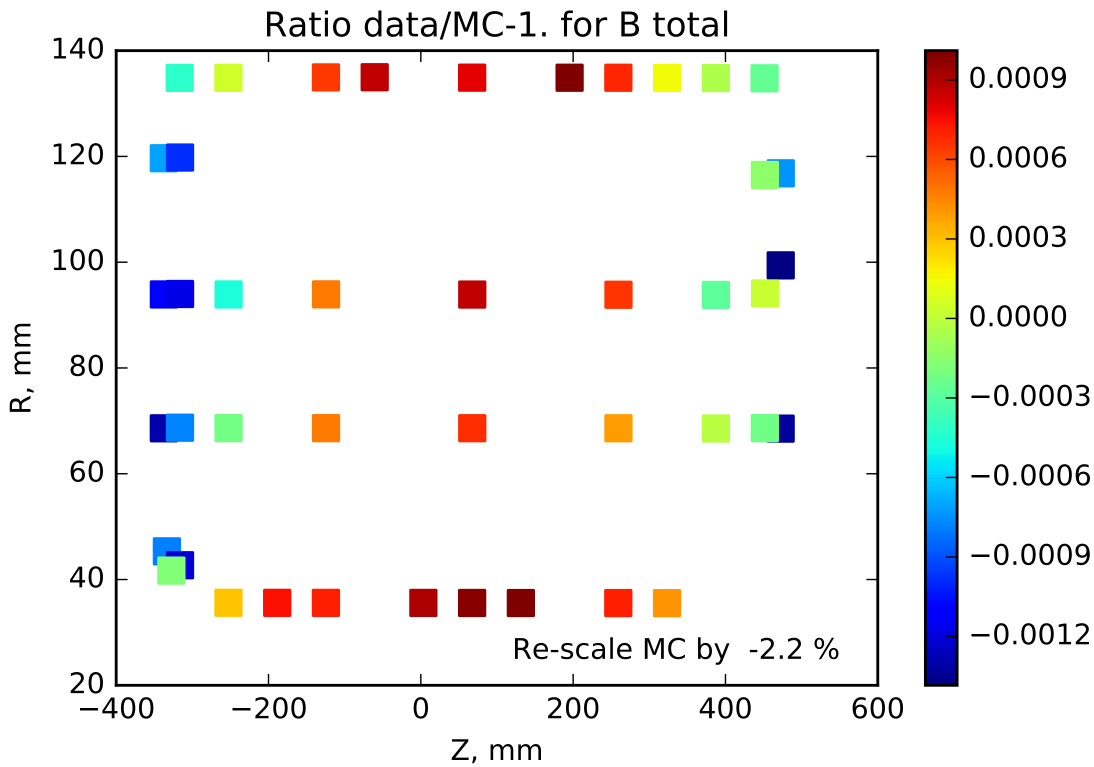
$\rightarrow$ potential misalignment of VXD and $B$ field axis, up to 0.5 mm level.

# Data 2016, 2017 vs Simulation: solenoid only



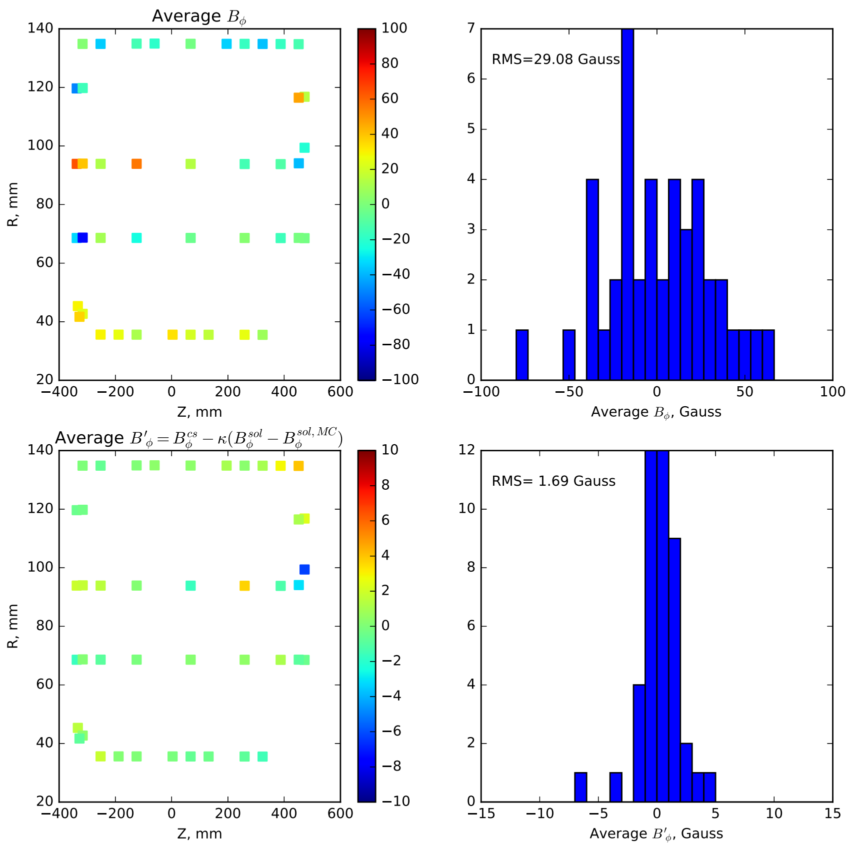

- Compare measurements in 2016, 2017 and MC simulation for Belle solenoid only configuration.
- Some global scale shifts and some shape difference for 2017 result, possibly due to presence of iron inside QCS magnets.

# Data 2017 vs simulation: nominal *B* field




- Compare data and simulation for the nominal field configuration
- Some global 2.2% scaling required.
- Variation of the data/MC ratio over VXD volume is at 0.1% level.

# Check local alignment using $B_\phi$




- Using Amper's law:

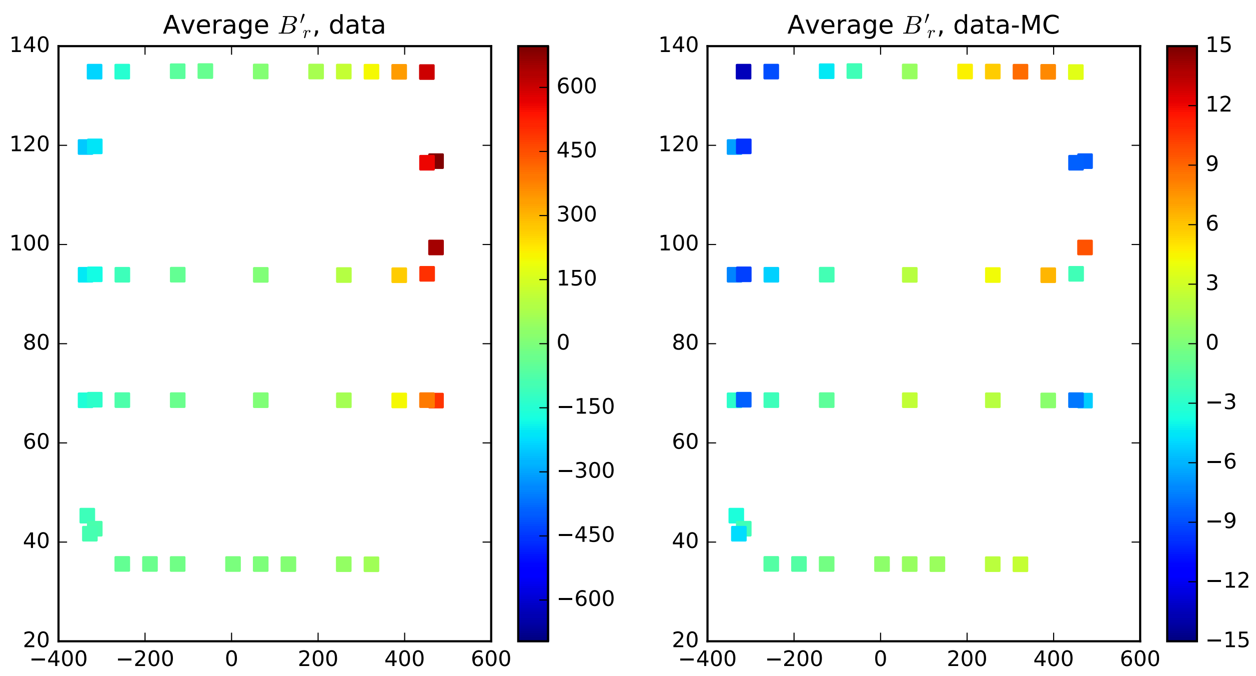
$$I_\phi = \frac{1}{2\pi} \int B_\phi d\phi = 0$$

  Non-zero value of $I_\phi$ is an indication of misalignment, $B_z$ component leaking into $B_\phi$.

- Raw $I_\phi$ shows RMS($I_\phi$) = 29 Gauss
- Misalignment effect can subtracted using difference of the data measurements with different *B*-field configurations, e.g. with all magnets ("cs") on minus Belle solenoid only ("sol").

- Subtracted $I'_\phi = I^{\text{cs}}_\phi - \kappa(I^{\text{sol}}_\phi - I^{\text{sol,MC}}_\phi)$ where $\kappa = \overline{B^{\text{cs}}_{\text{top}}} / \overline{B^{\text{sol}}_{\text{tot}}}$ is a scaling factor based on the total field ratio shows much reduced RMS.

# $B_r$ in data and MC




- Compute $I_r = 1/(2\pi)\int d\phi B_r$ as $I_r^{\mathrm{cs}} - \kappa(I_r^{\mathrm{sol}} - I_r^{\mathrm{sol,MC}})$.
- Smooth field, sizable $B_r$ field close to the quadruple and compensating solenoids.
- Described by MC to $\sim 15$ Gauss.

# Summary

- First results from the measurement of $B$-field in Summer 2017.
- Overall good agreement with the predictions for the VXD volume.
- Further studies in the QCSL, QCSR and CDC region.
- Additional simulation samples required to understand residual discrepancies.