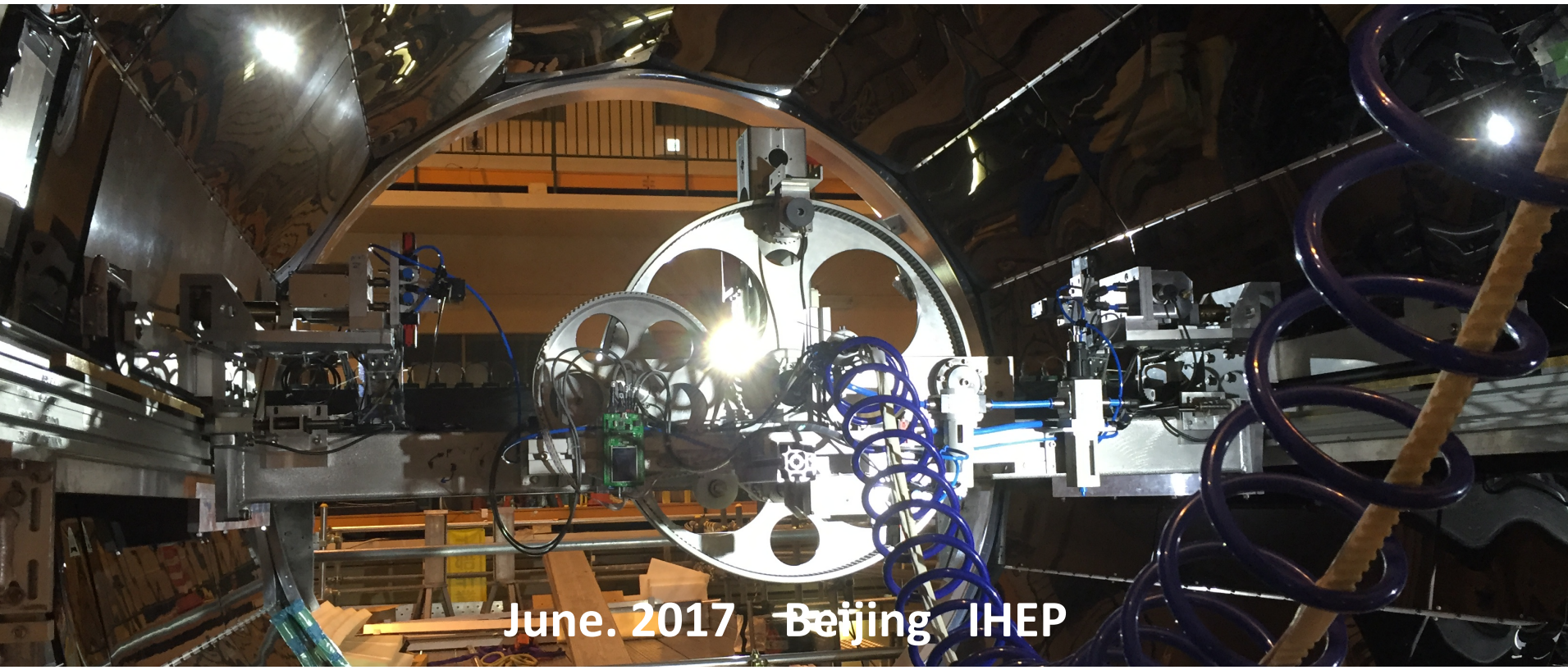
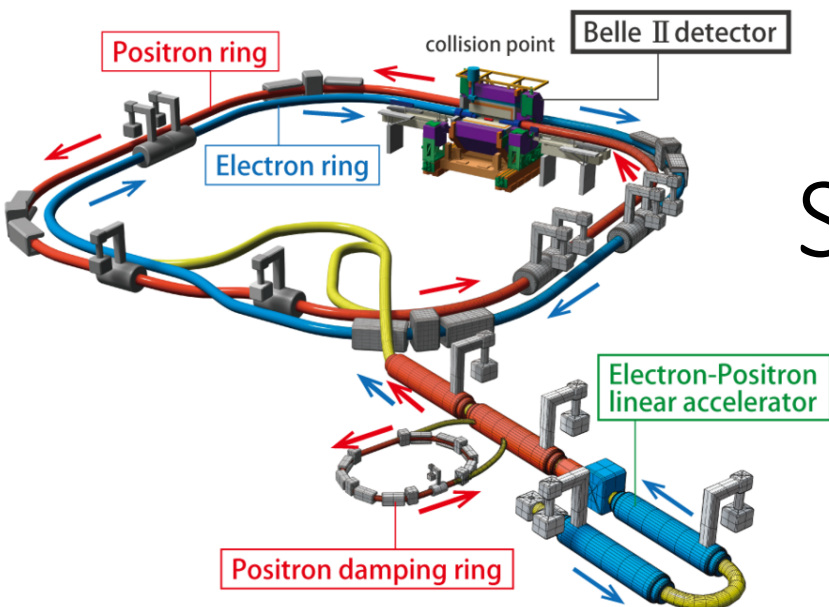


BelleII B field measurement

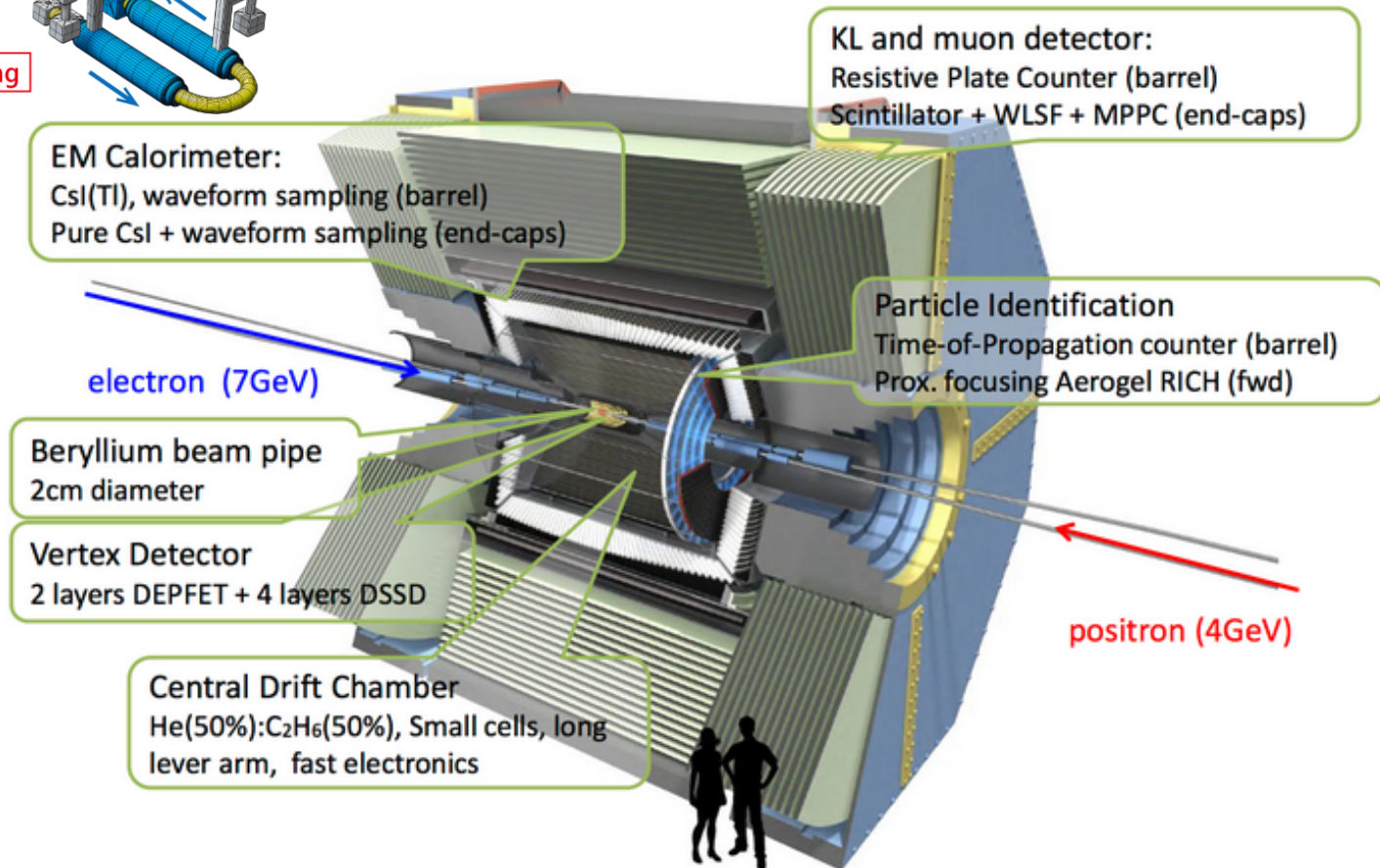
Aiqiang Guo
IHEP & DESY



June. 2017 Beijing IHEP

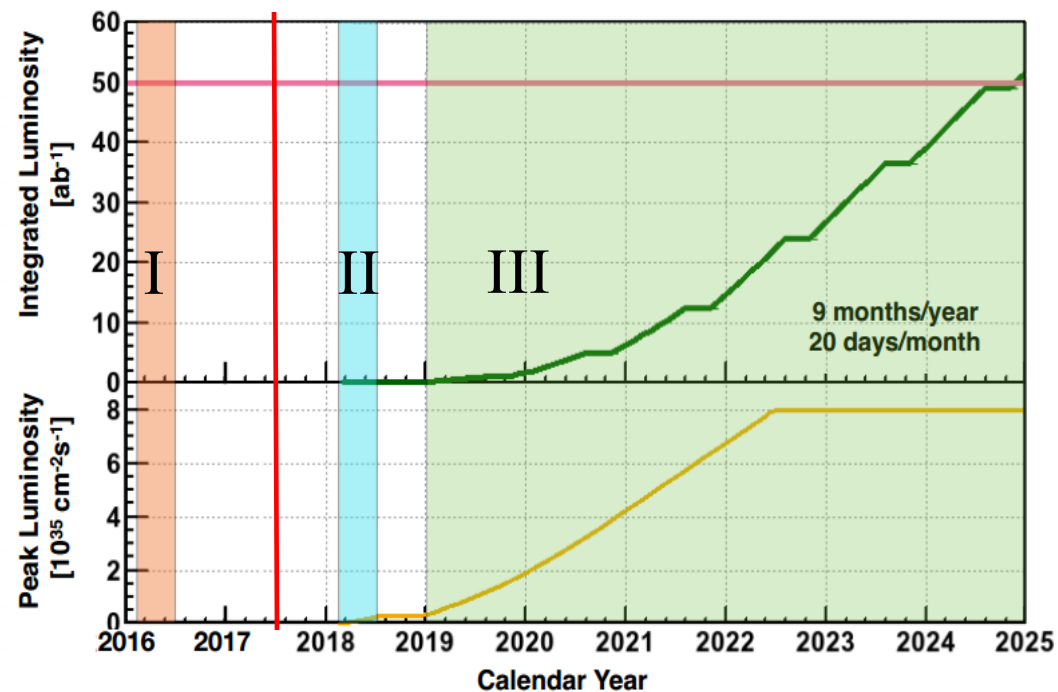
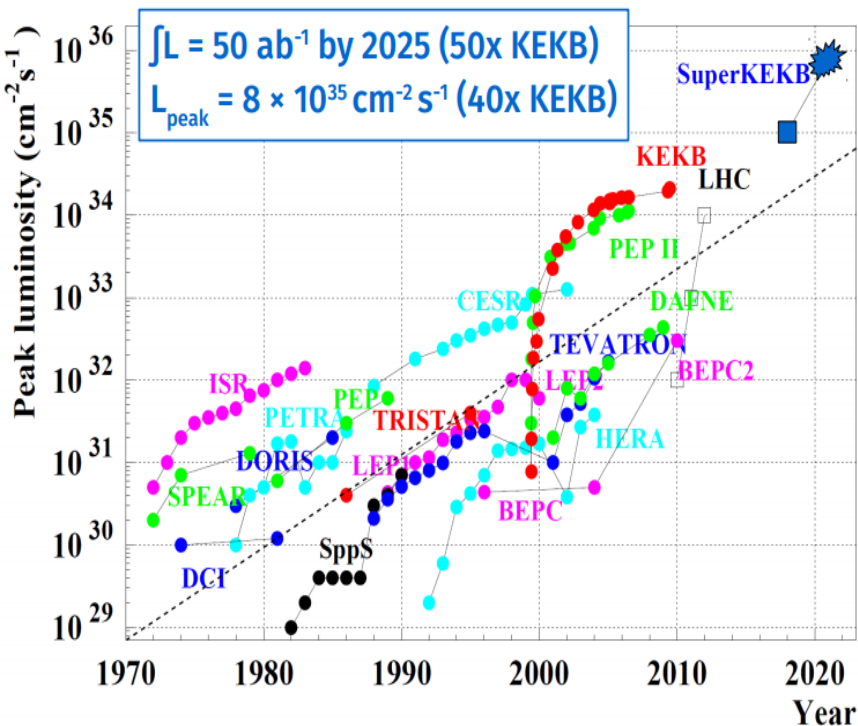


Super KEKB and Belle II



Schedule of BelleII experiment

- Phase I: Beam commissioning, without collisions & Belle II
- Phase II: partial Belle II is rolled in (without full VXD)
- Phase III – Physics Run: Full Belle II with VXD

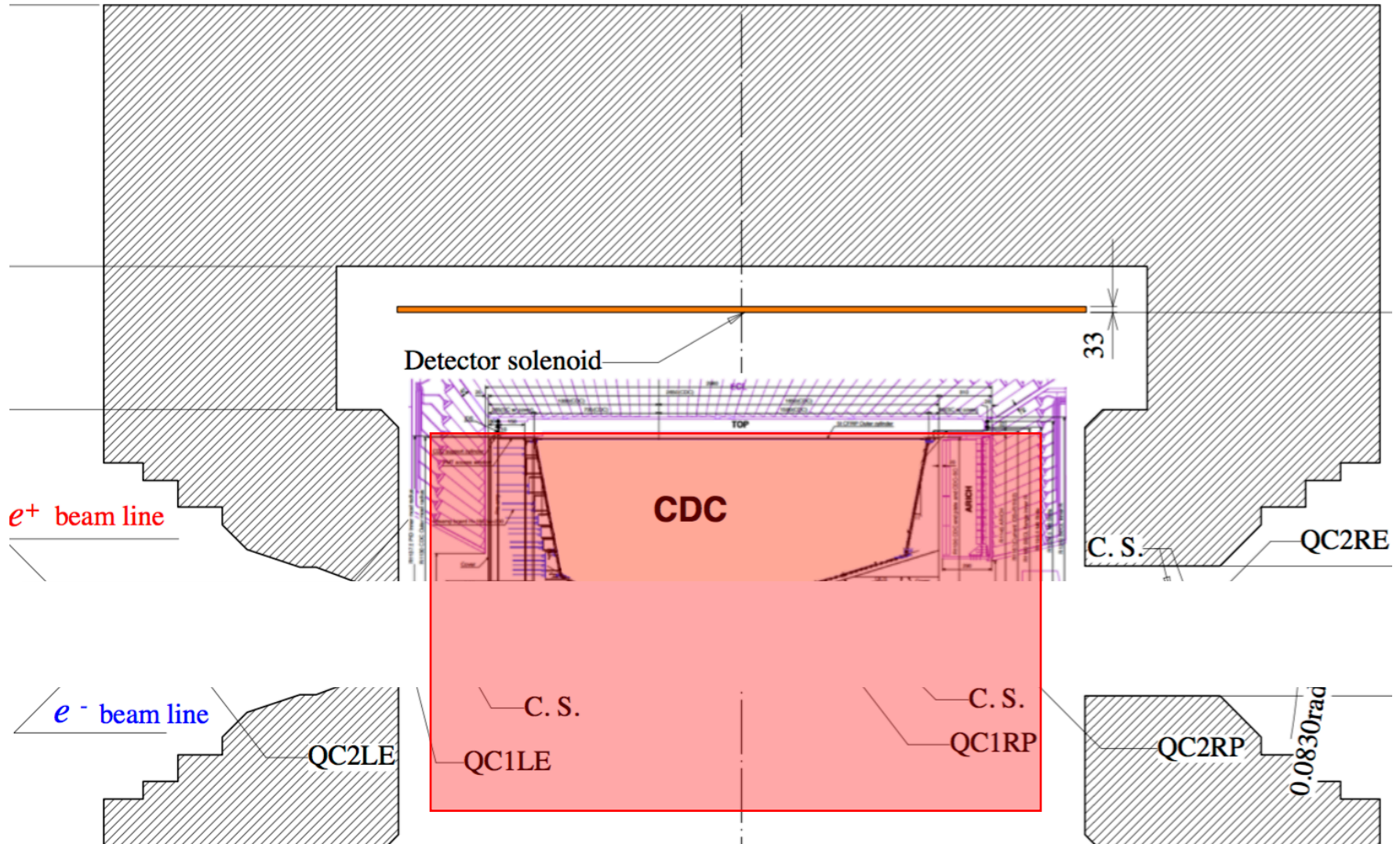


We are here

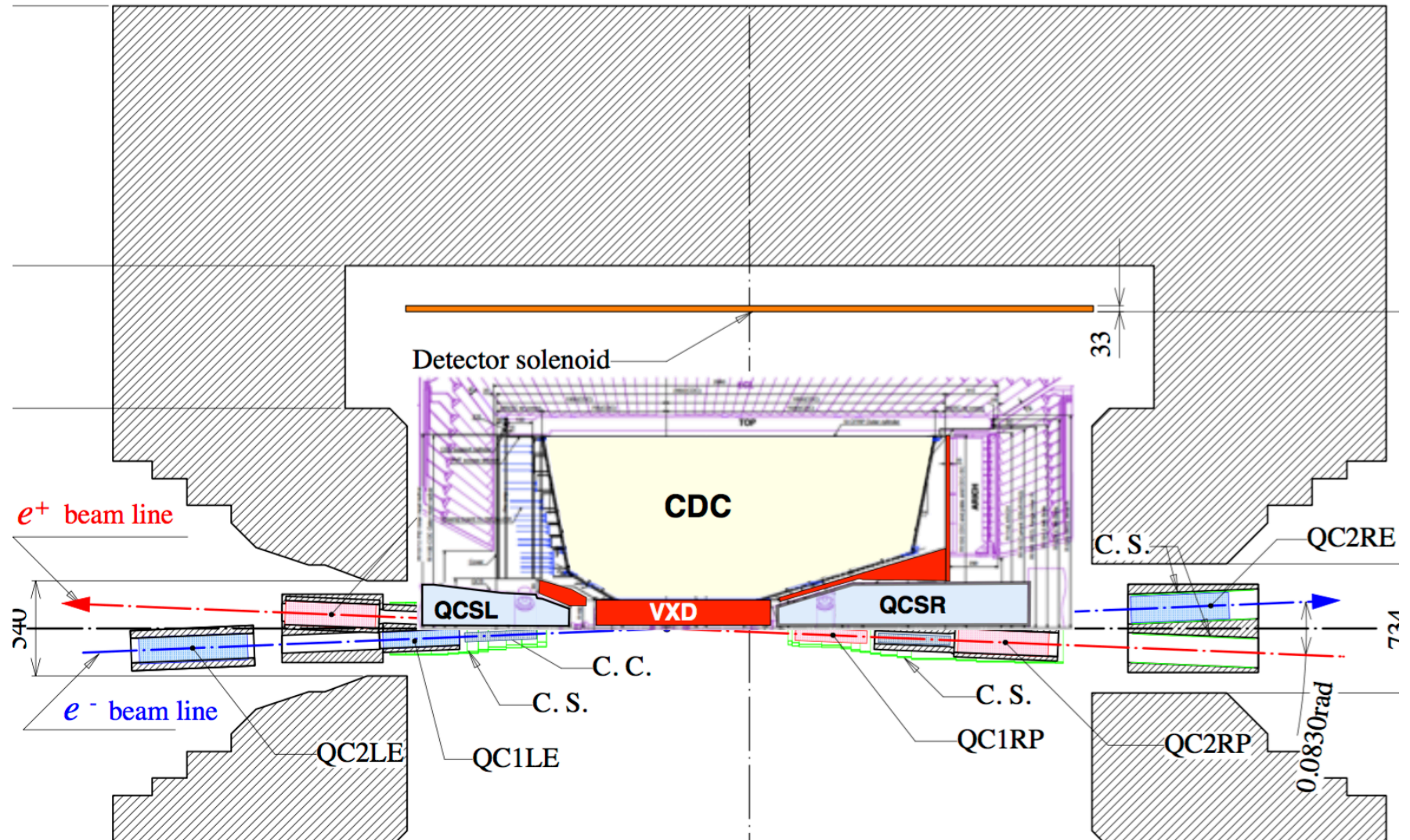
27.11.17



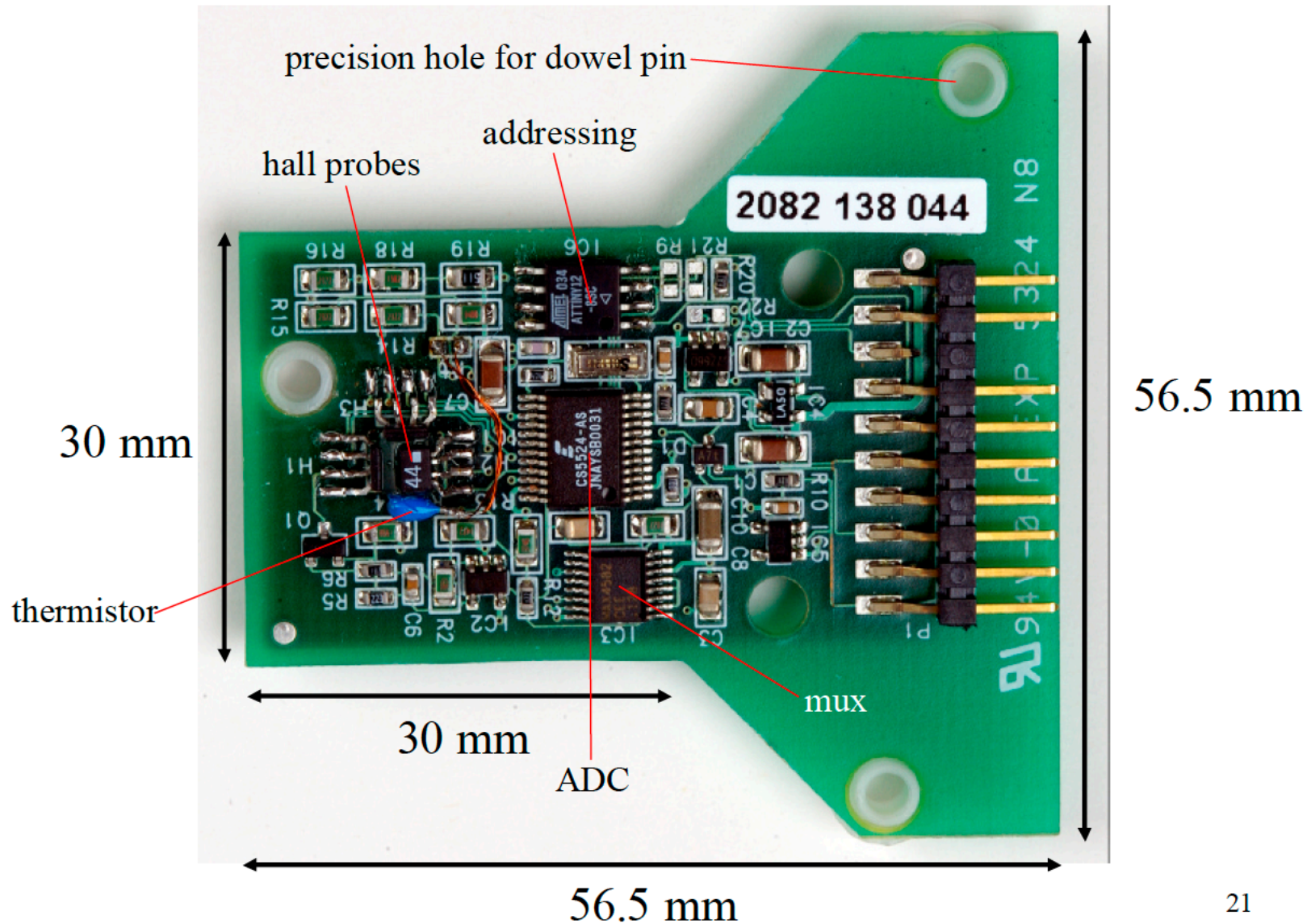
Overview of the B measurement



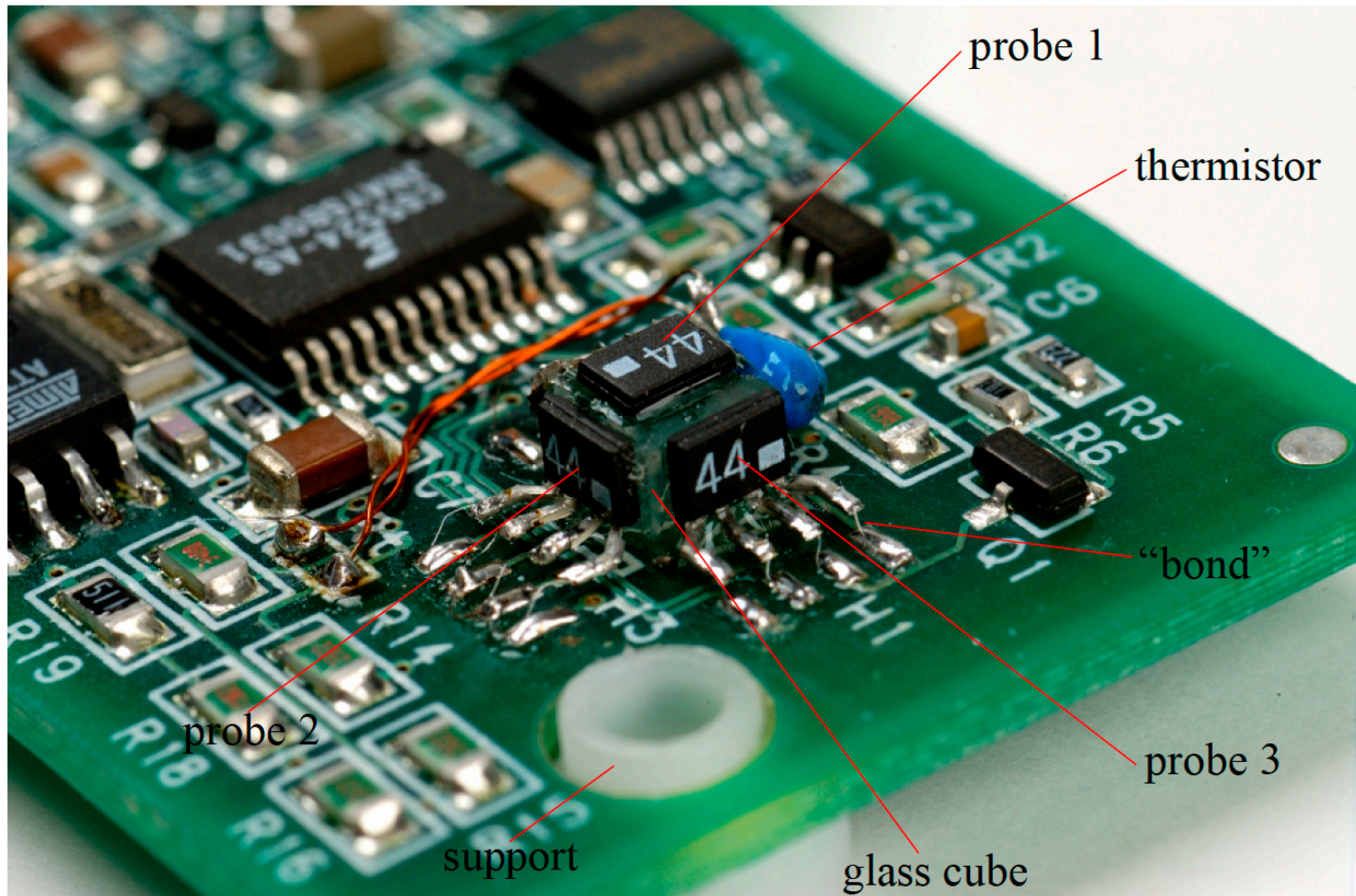
Overview of the B measurement



3D hall prober



3D hall prober



Calibration of Hall probes

3D sensor with 10^{-4} precision

for example:

Ideal Hall probe:

$$V = \text{constant } |B| \cos \theta$$

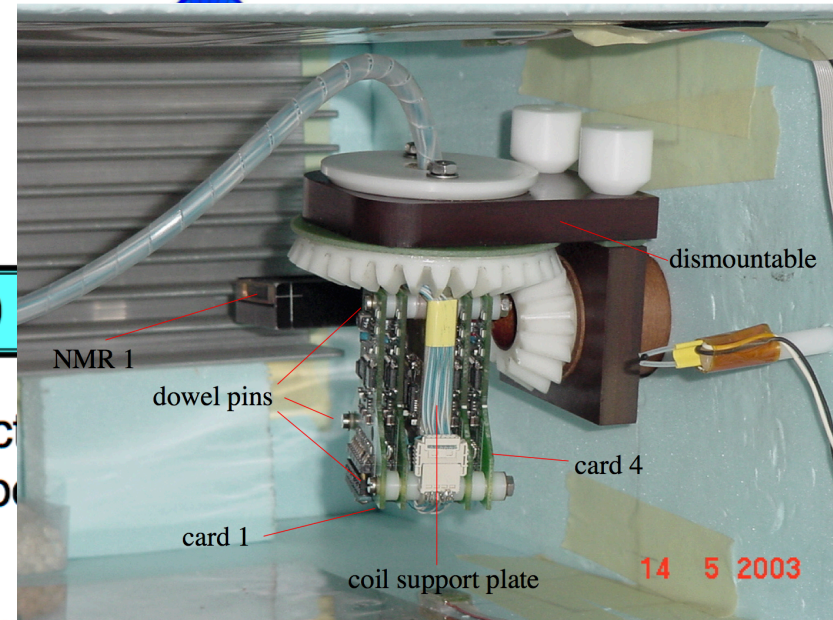
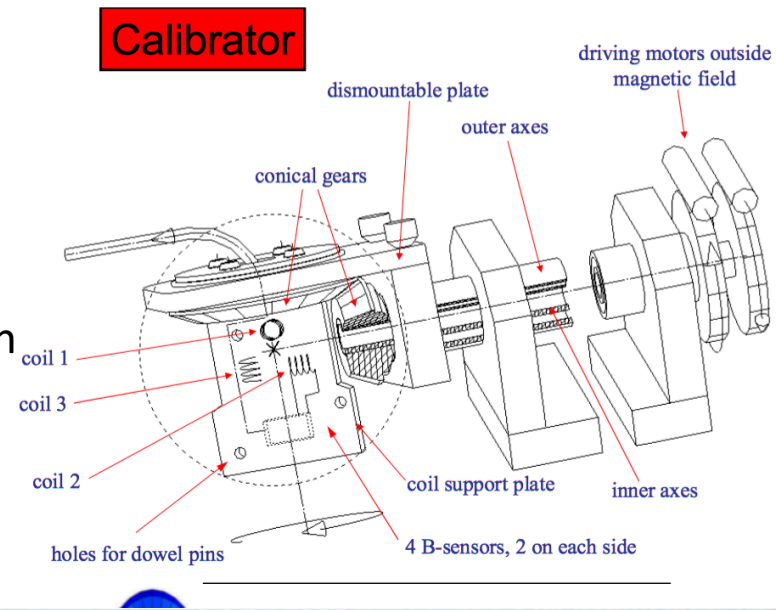
More realistic Hall probe:

$$V = (a + b|B| + c|B|^2 + d|B|^3 + \dots) \cos \theta$$

many reasons: material type, geometrical effects, resistance, etc. $a, b, c, d \dots$ depend on temperature

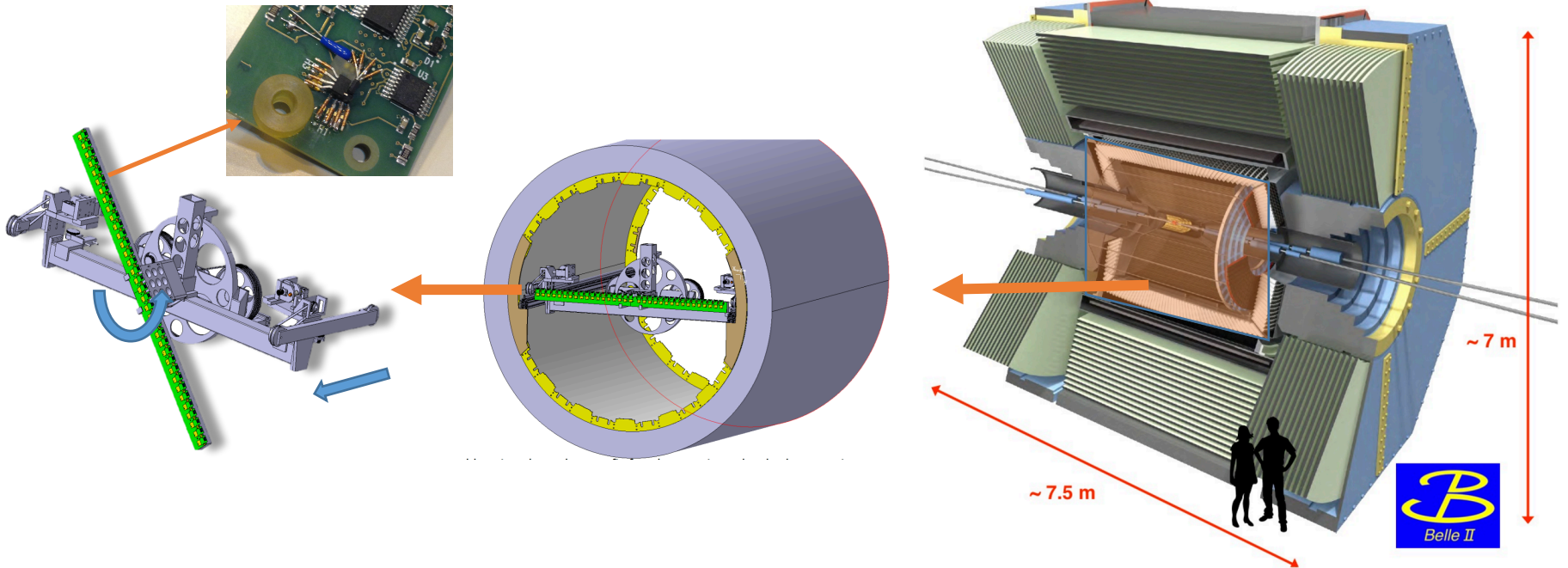
=> You can not simply use 3 single axis calibrations in 3D

$|B|$ during calibration

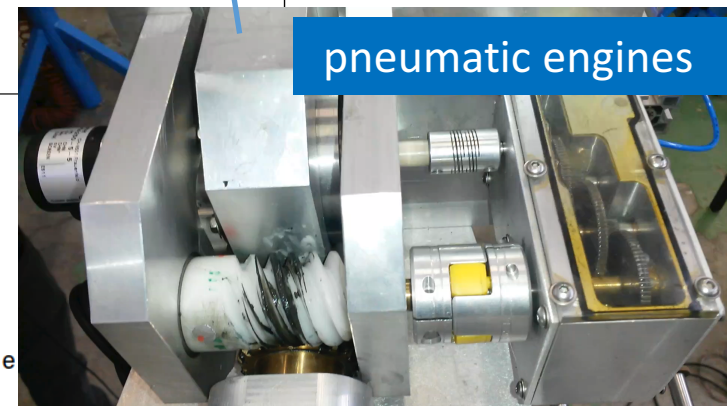
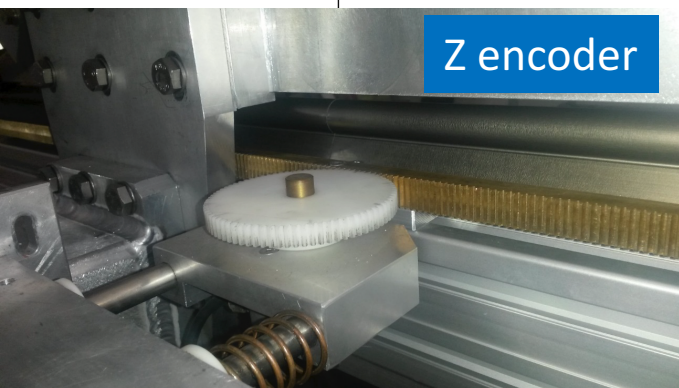
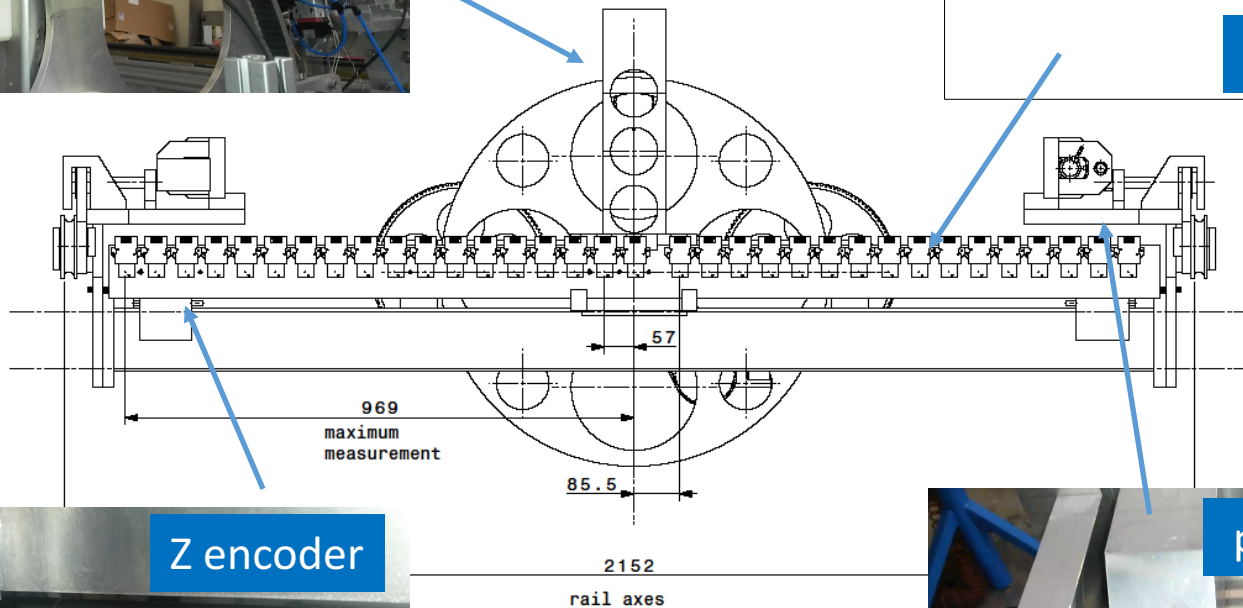
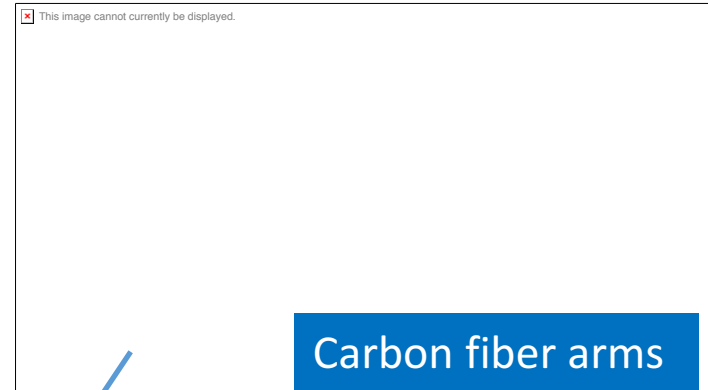


The first B field mapping campaign

- B field of 1.5T produced by solenoid only.
- Mapper is made of nonferrous materials and driven by pneumatic engines.
- B_z B_r B_ϕ were measured simultaneously by Hall probe.
- Requested accuracy <0.1%.



Mapper for CDC volume



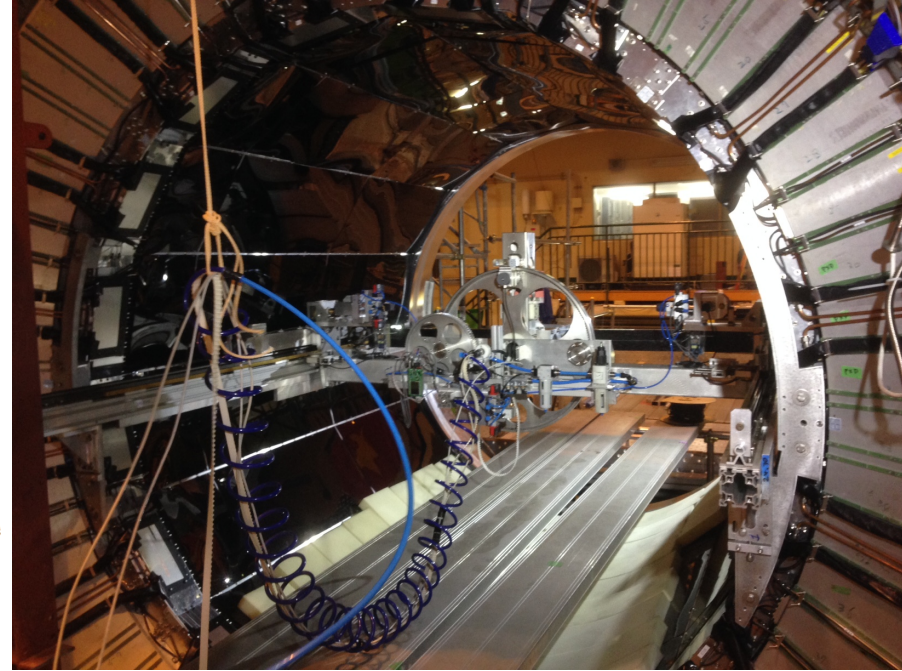
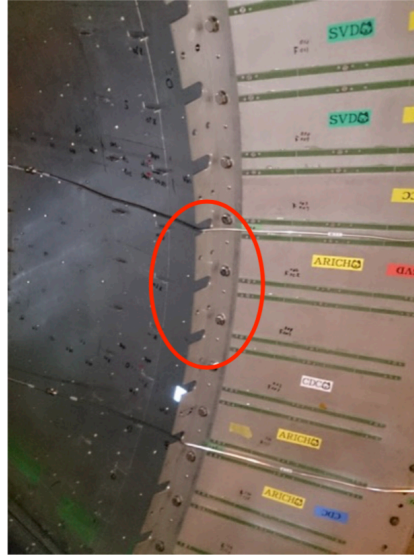
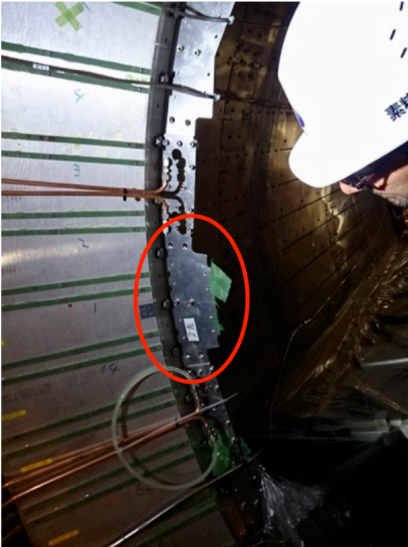
sitions
he middle
eft each 57mm
ight the first at 85.5mm and after

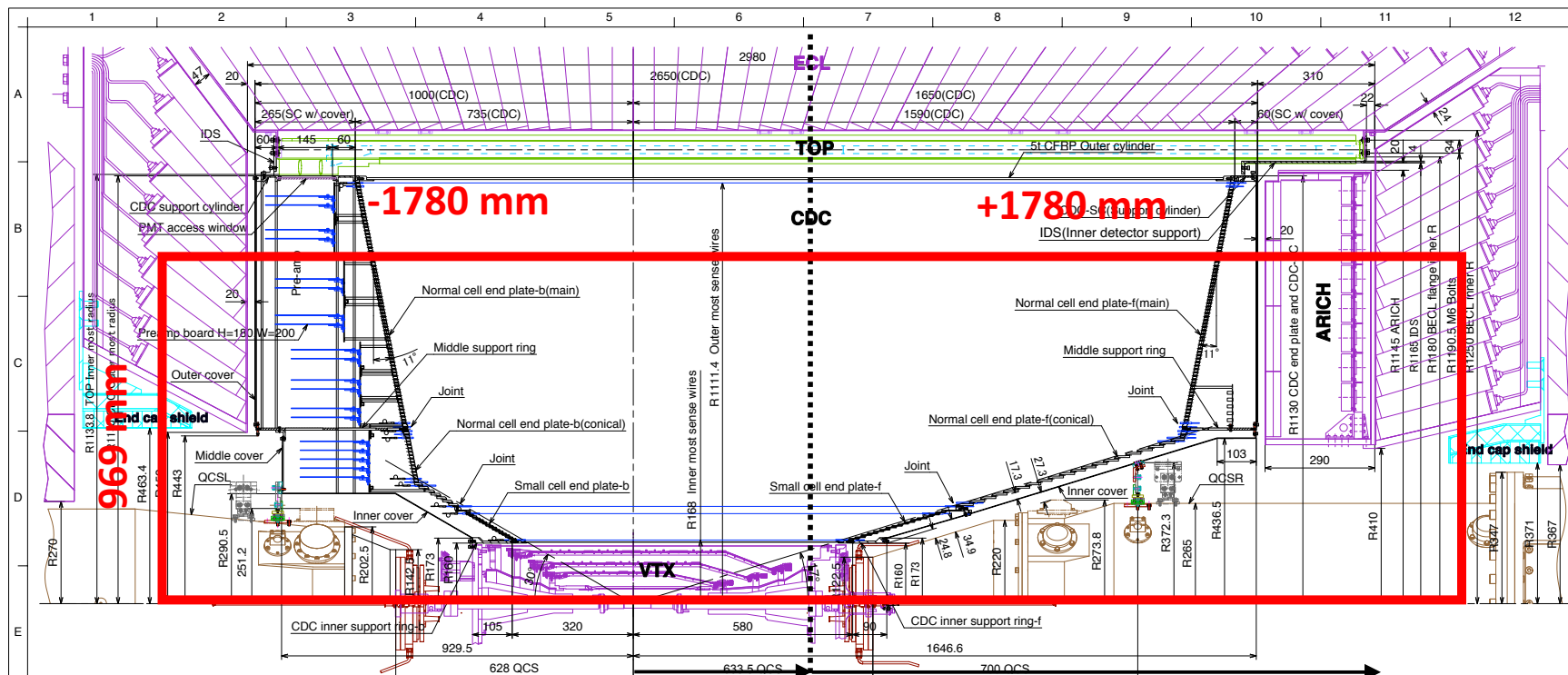
B field crew



Installation

- ECL flange (FWD-BWD) will be used.
- Mapping will be done after forward IDS is placed.





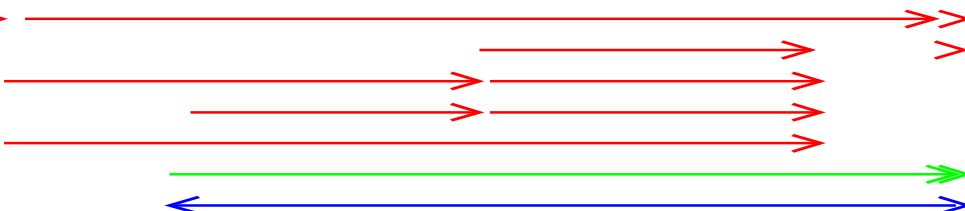
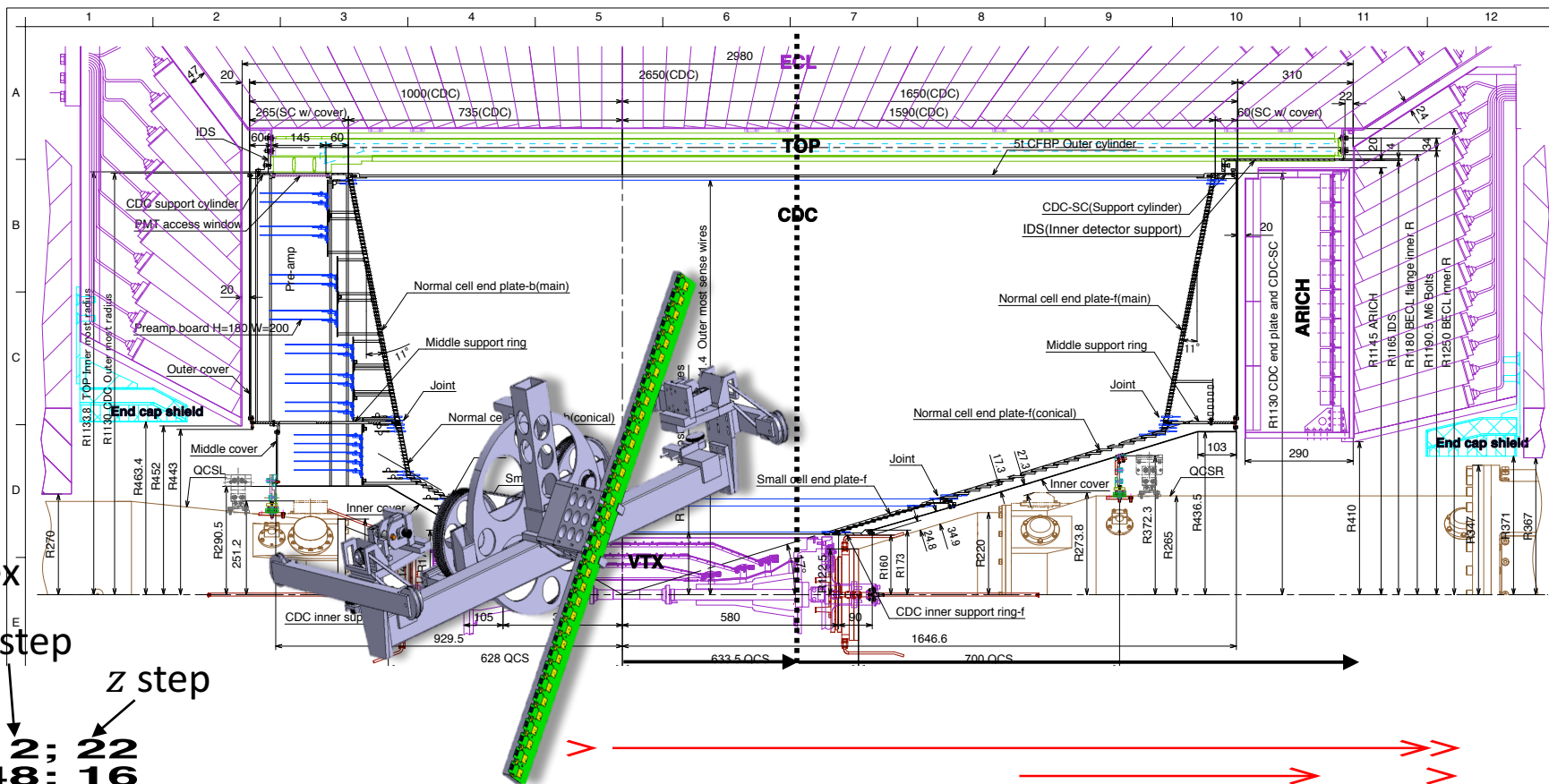
File index

ϕ step

z step

10:	12:	22
11:	48:	16
12:	48:	46, 16
13:	48:	28, 16
14:	48:	79
15:	48:	38
16:	48:	38

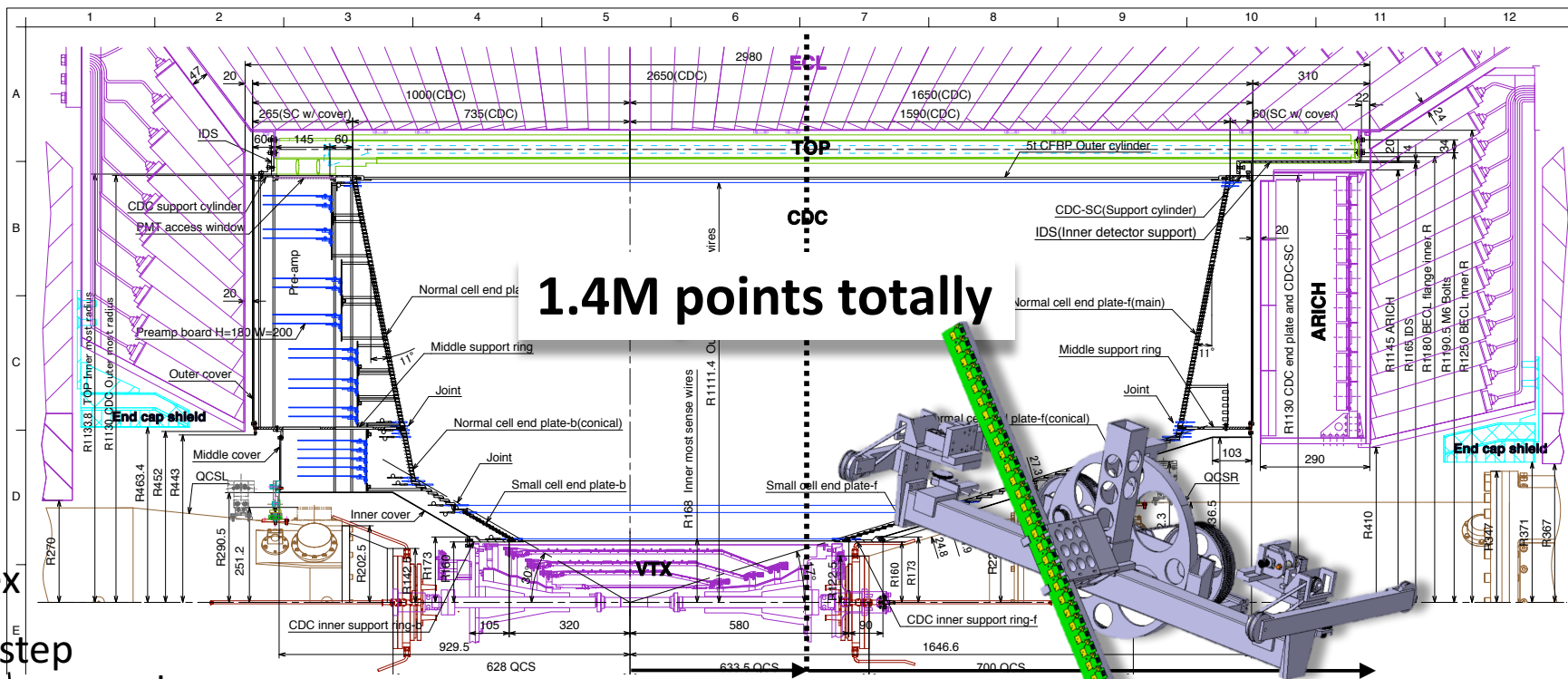
27-28 June



1.50 T

1.25 T

1.00 T



File index

ϕ step

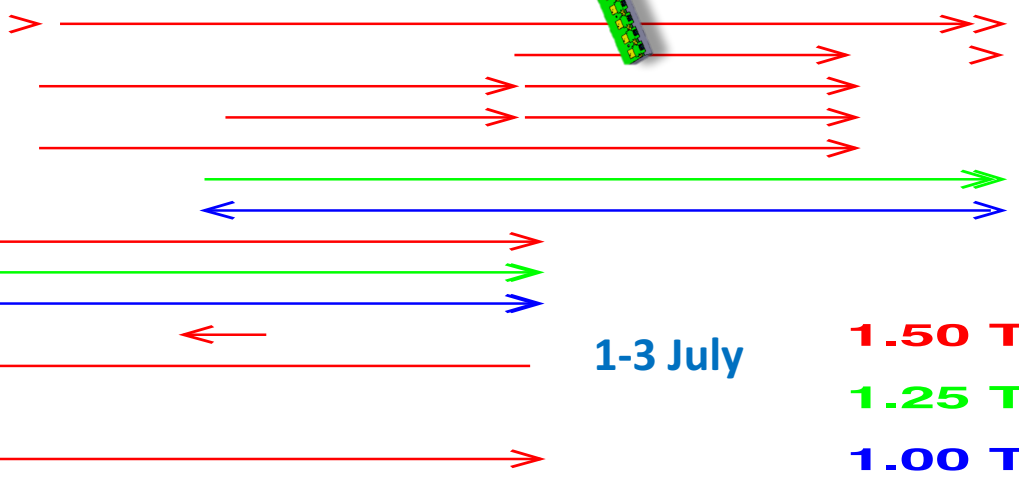
z step

10:	12:	22
11:	48:	16
12:	48:	46, 16
13:	48:	28, 16
14:	48:	79
15:	48:	38
16:	48:	38
17:	48:	92
18:	48:	46
19:	48:	46
20:	180:	8
21:	48:	91
22:	96:	40
23:	96:	40
24:	60:	67

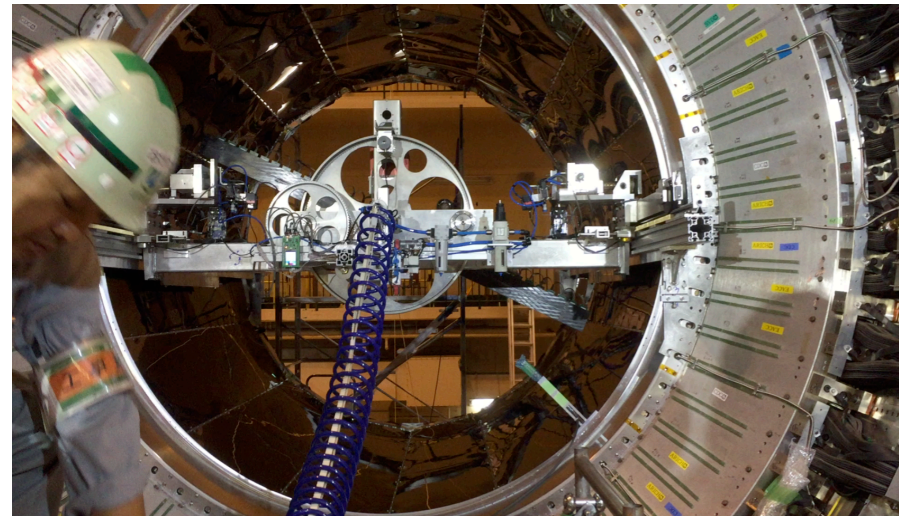
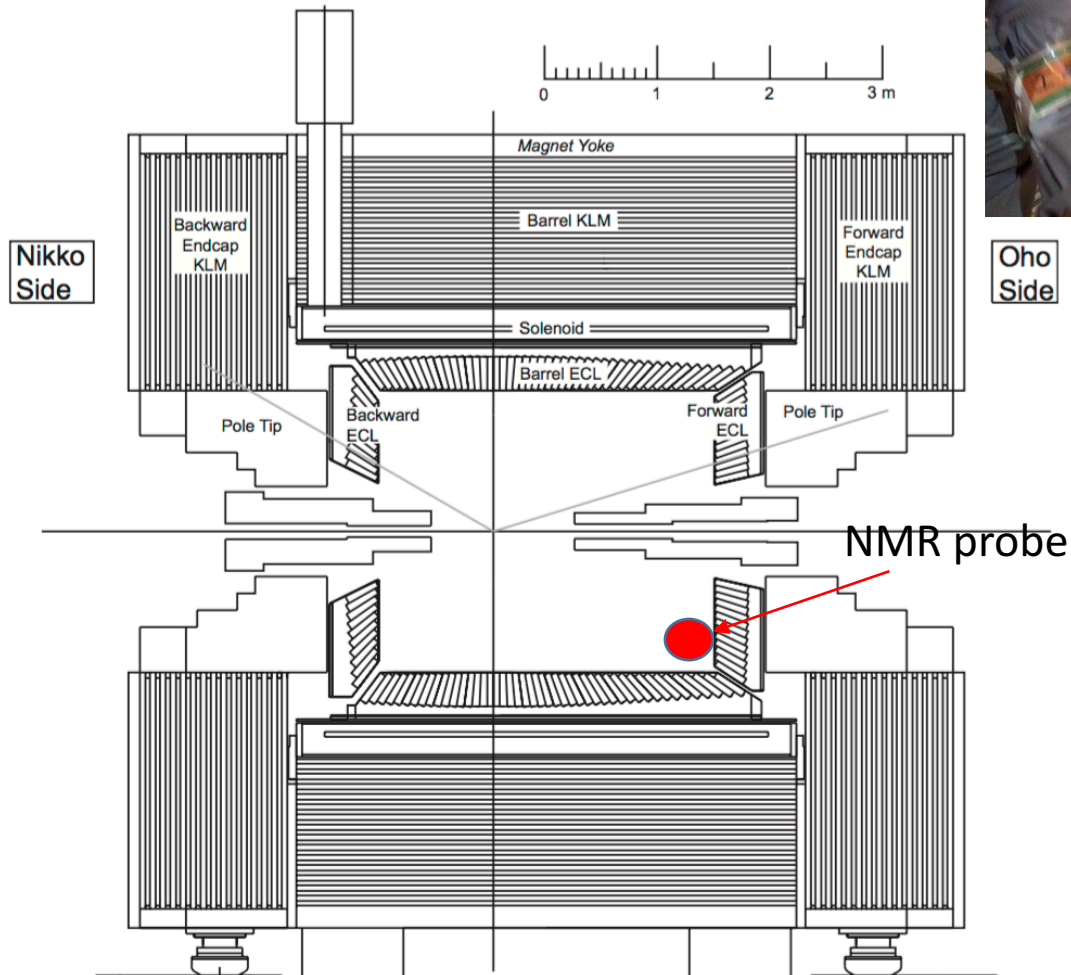
27-28 June

1-3 July

1.50 T
1.25 T
1.00 T



NMR probe



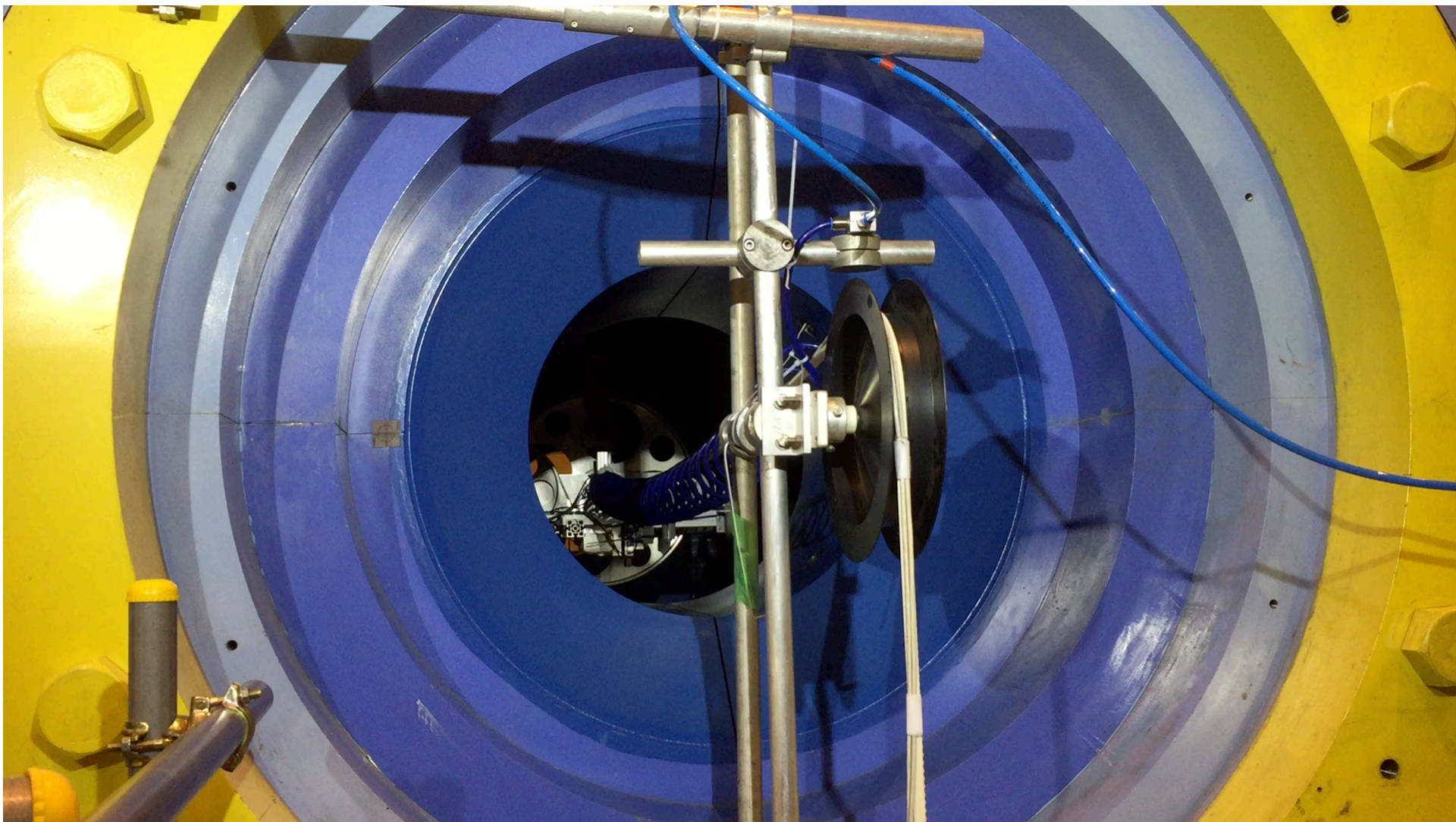
Location: Near the inner fringe of Forward IDS and near the inner surface of TOP.

$z = \sim +1580$ mm (to forward from IP)

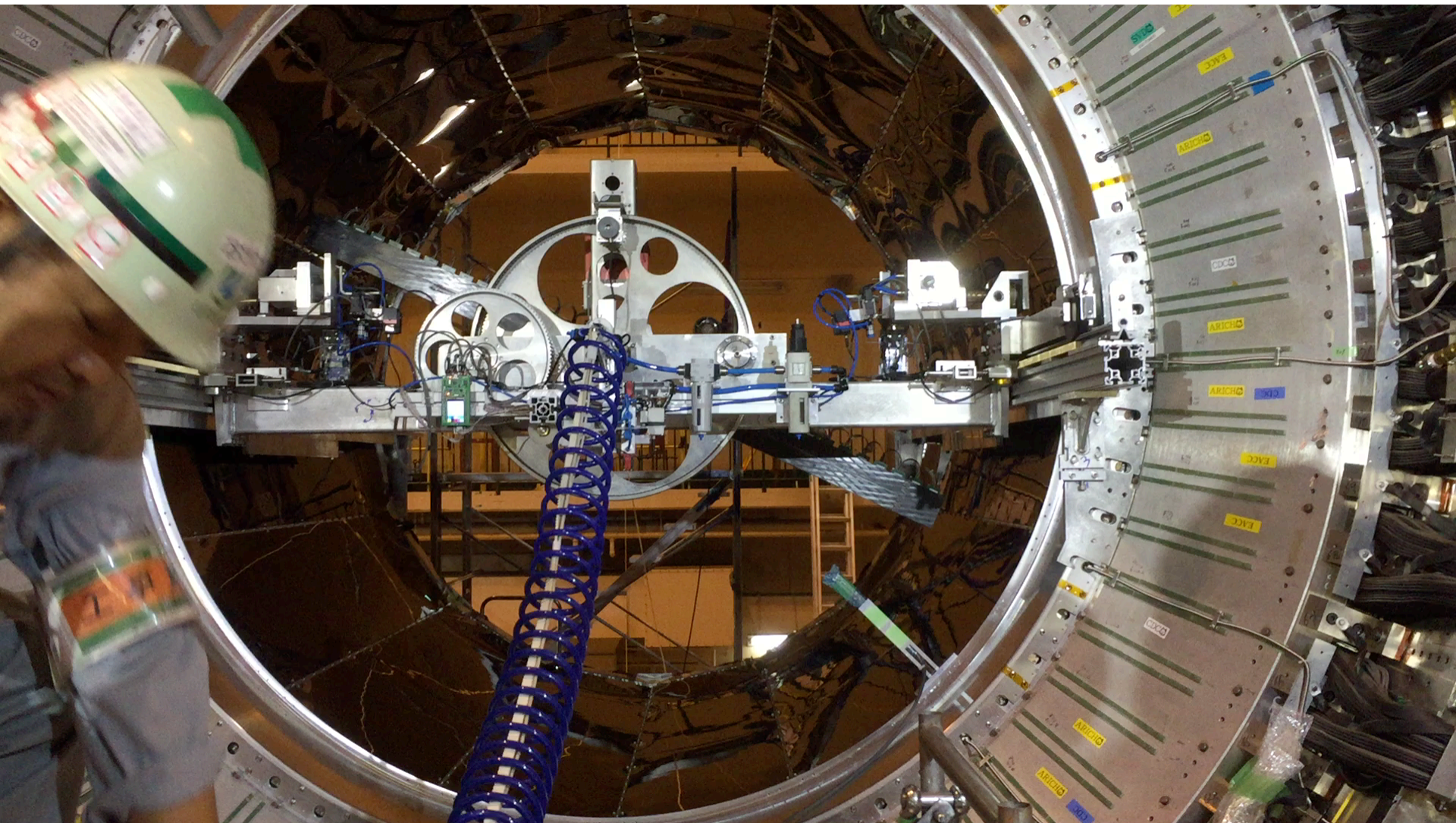
$r = \sim 1150$ mm

$\phi = \sim 335$ deg (lower-right looking from the forward endyoke)

Measurement movie



Measurement movie



Technical drawing of the CDC detector end cap, showing a cross-section with a color-coded stress distribution. The drawing includes dimensions, labels for components, and a color bar indicating stress levels.

Dimensions (mm):

- Top: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12
- Left: R270, R463.4, R452, R443
- Right: R1145 ARICH, R1163 IDS, R1180 BECL flange inner R, R1190.5 M6 Bolts, R1250 BECL inner R
- Bottom: 105, 320, 580, 929.5, 628 QCS, 633.5 QCS, 1646.6, 700 QCS

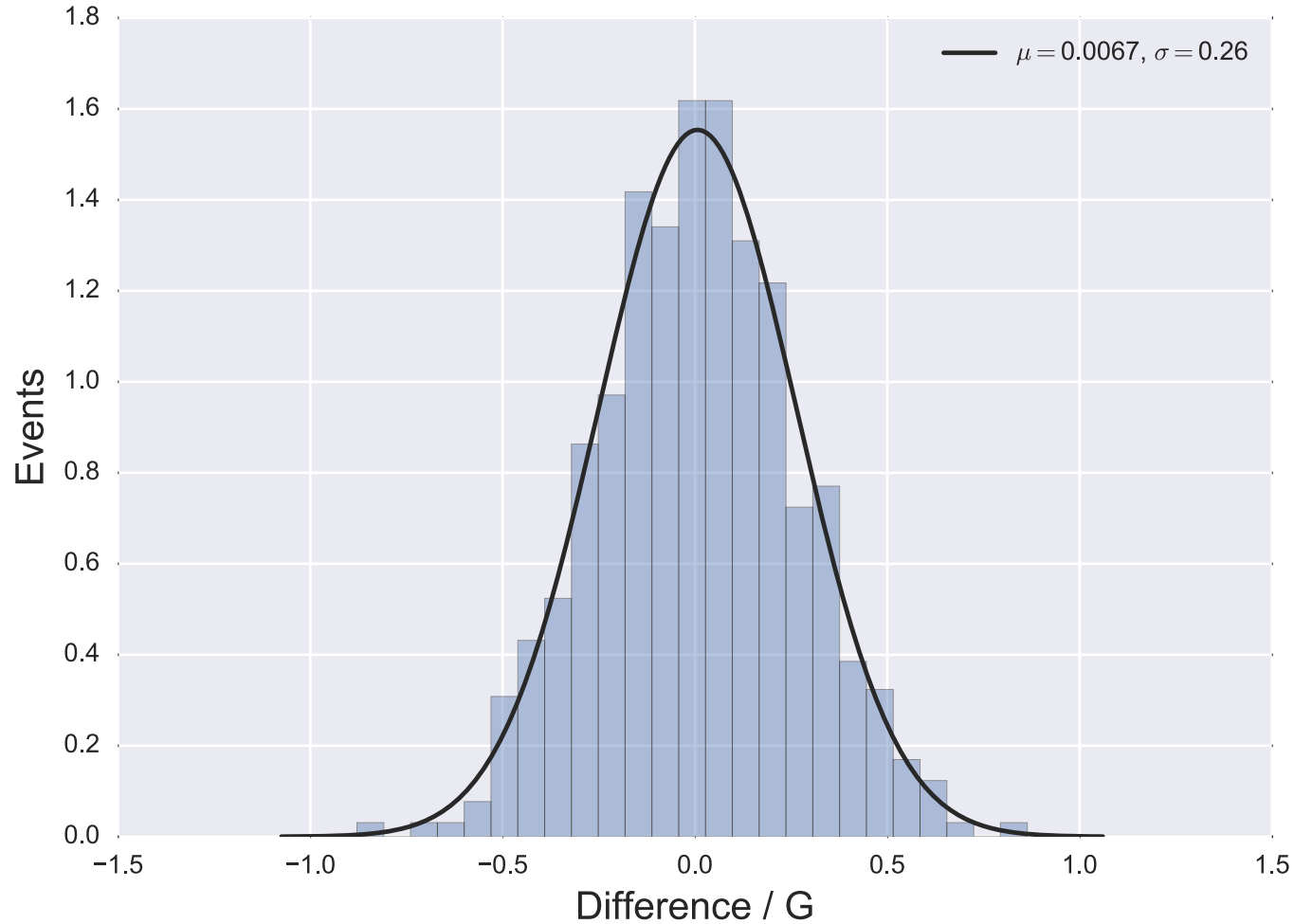
Labels:

- IDS
- CDC support cylinder
- PMT access
- Preamp box
- Outer
- End cap shield
- CDC inner support ring
- CDC inner support ring
- 5t CFBP Outer cylinder
- CDC-SC(Support cylinder)
- IDS(inner support)
- Normal cell end plate (inner)
- Normal cell end plate (outer)
- Small cell end plate
- Inner support
- End cap shield

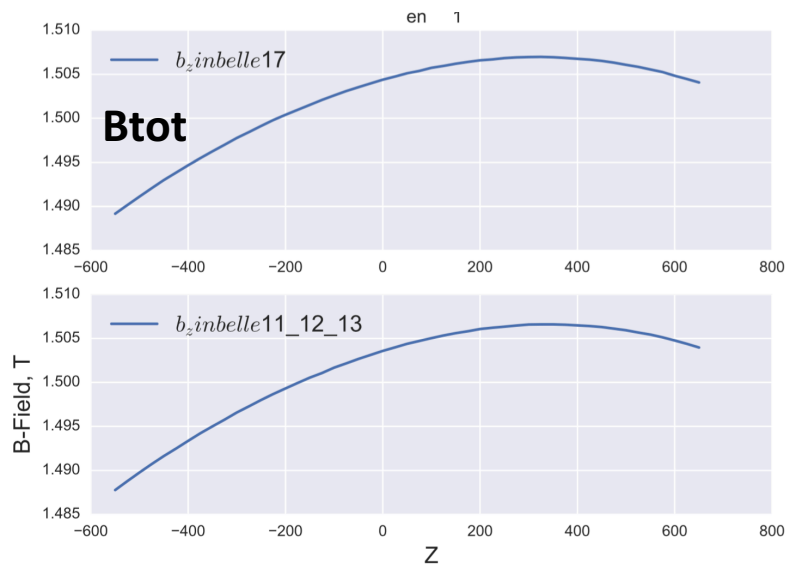
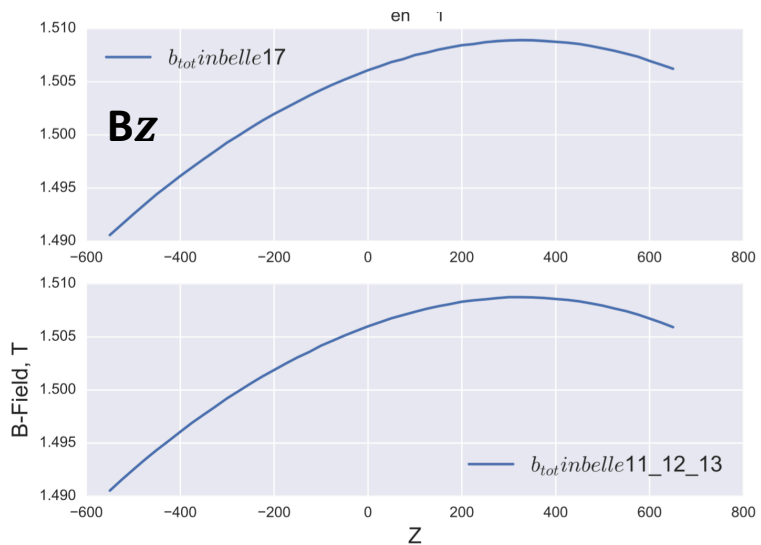
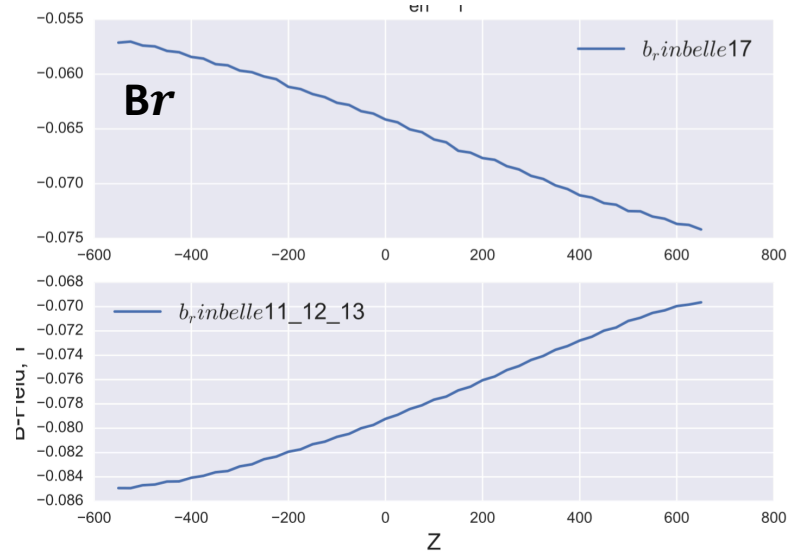
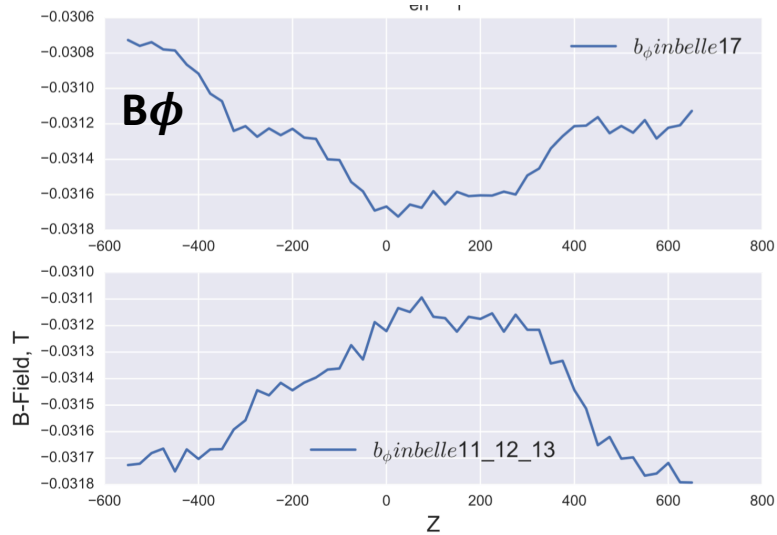
Color Bar (Stress Levels):

- 1.274
- 1.266
- 1.308
- 1.350
- 1.392
- 1.434
- 1.476
- 1.518
- 1.560
- 1.602

Repeatability of Hall

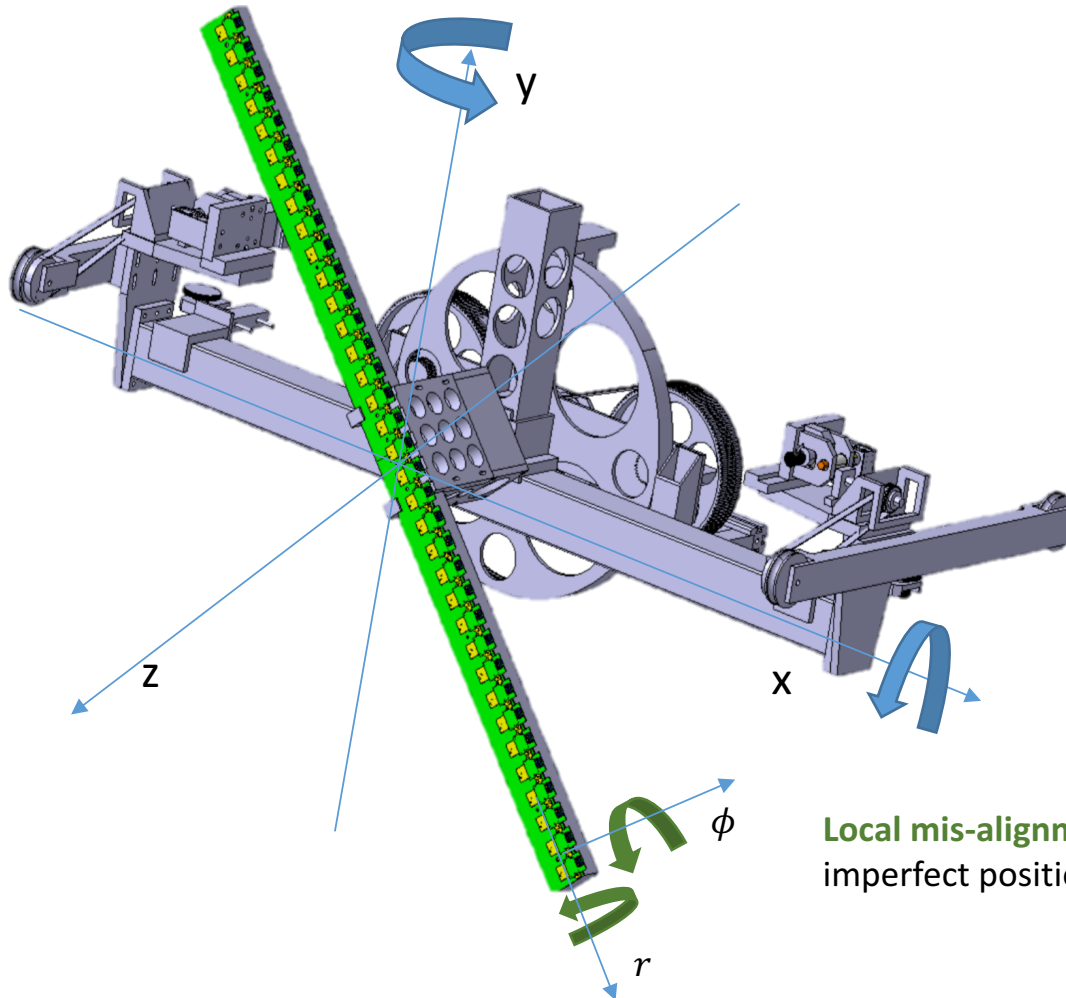


Comparison before and after reversing



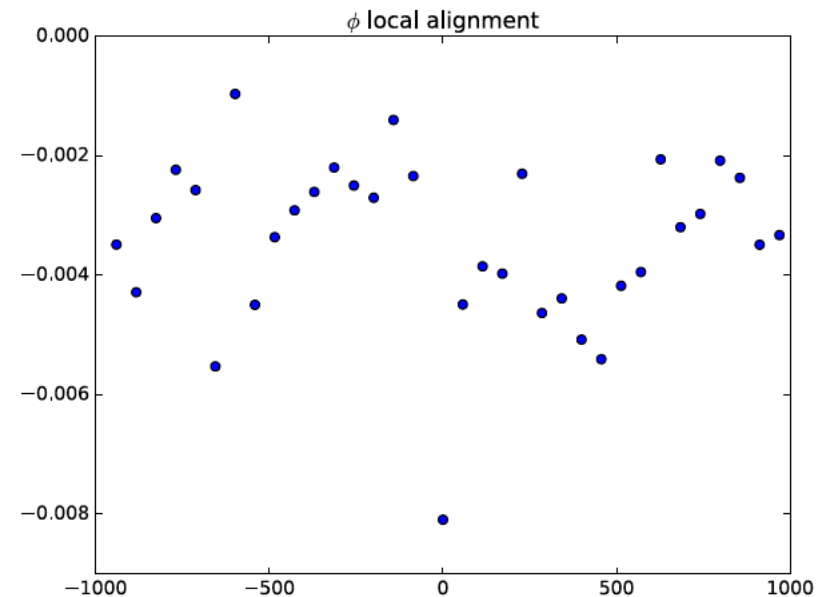
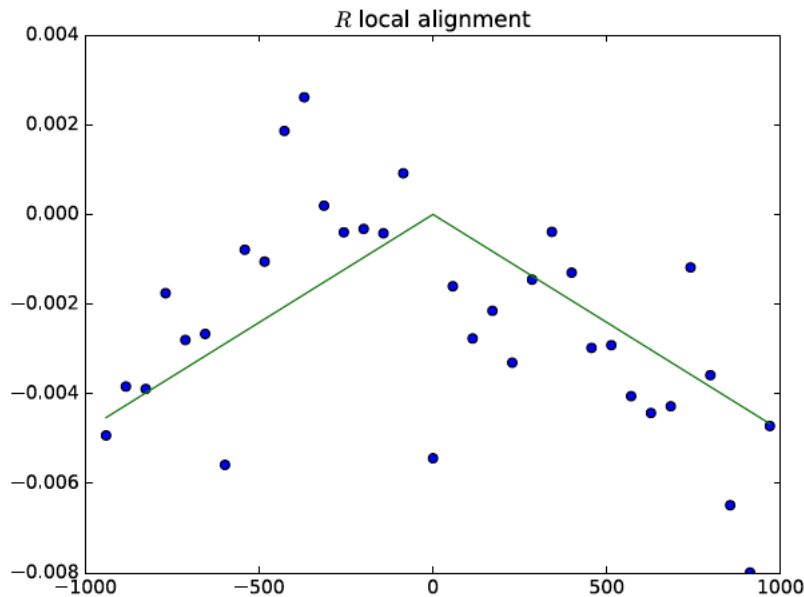
Mis-alignment corrections

Global mis-alignment is due to imperfect movement of mapper



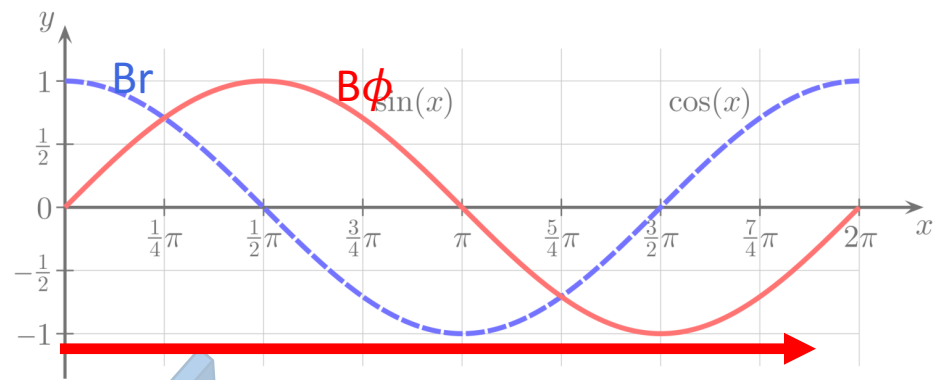
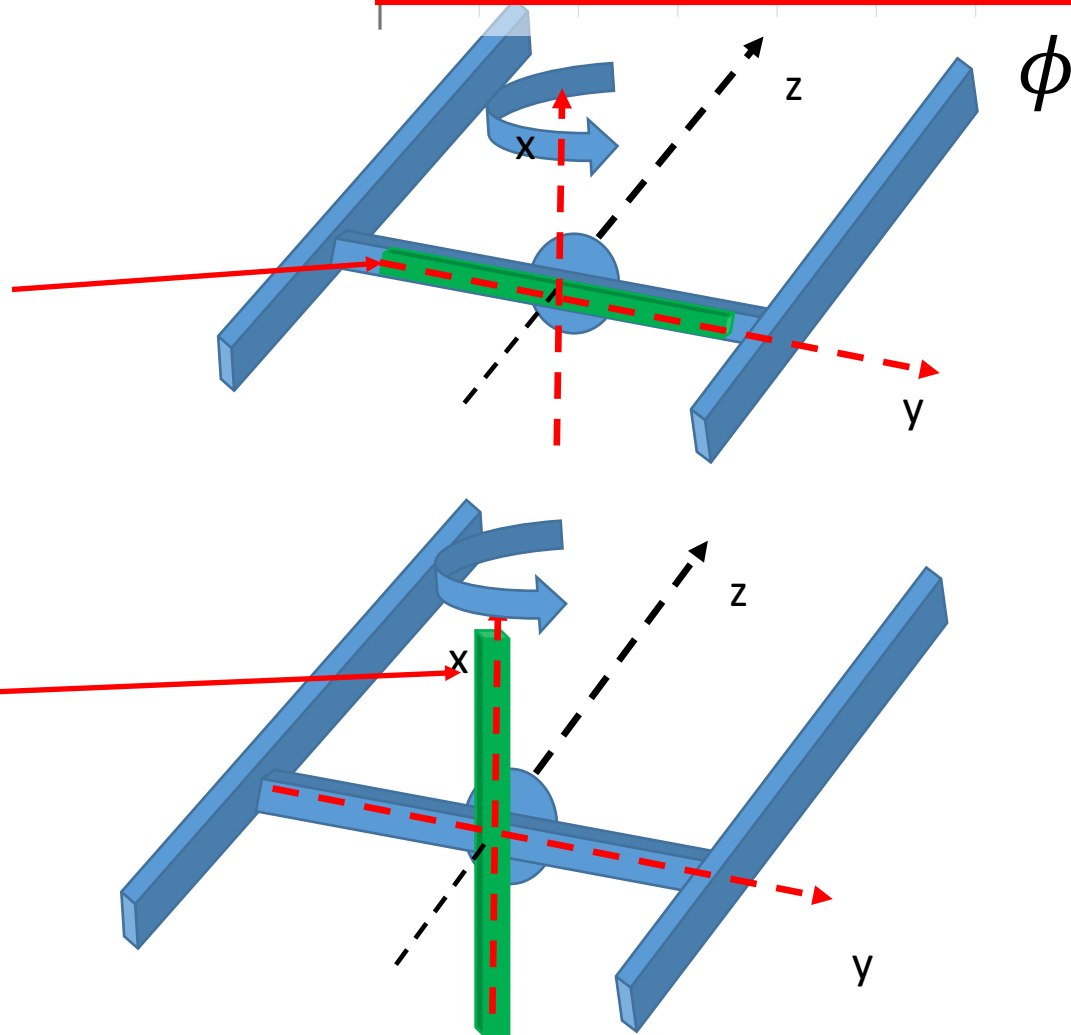
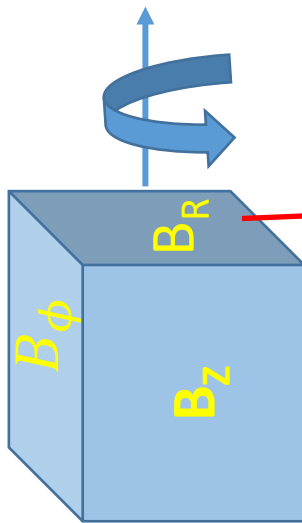
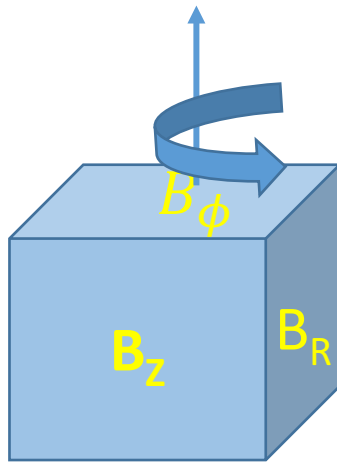
Local mis-alignment is due to imperfect position of sensor mounted on the arm

Local misalignment

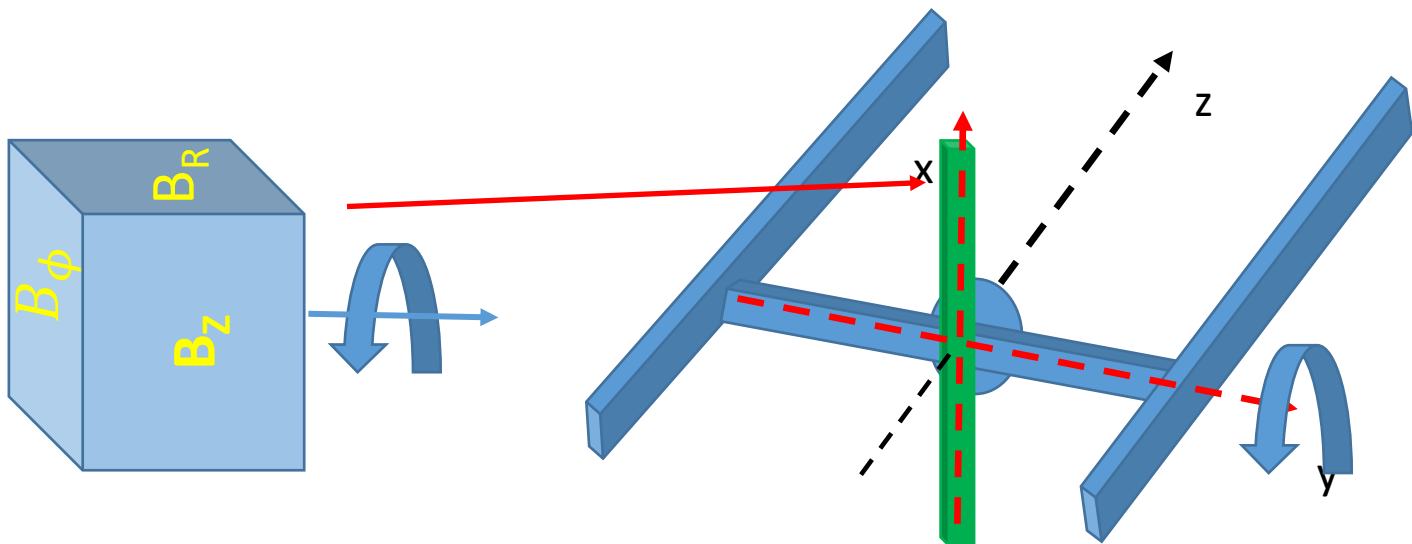
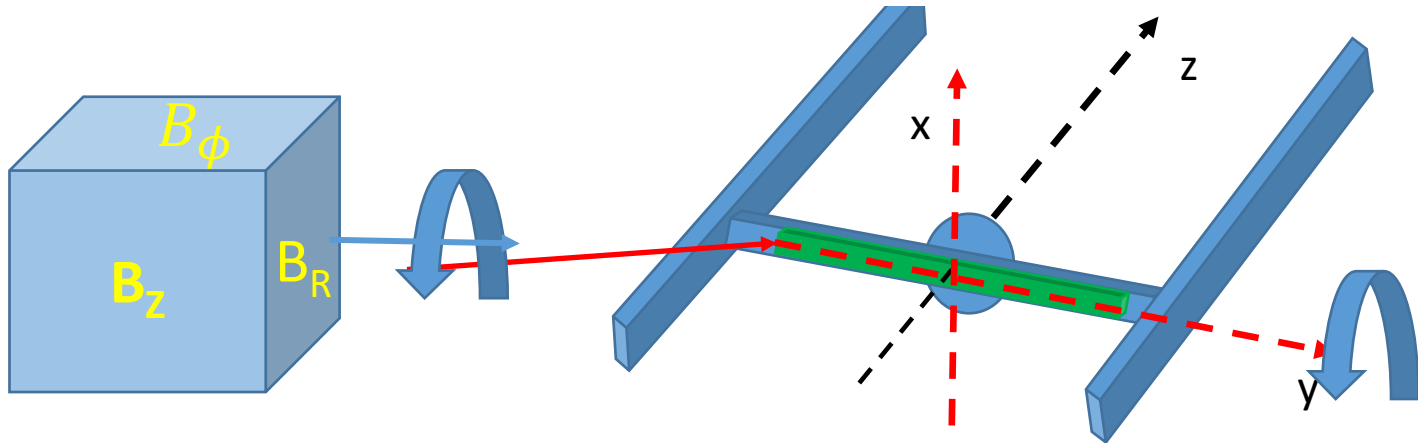
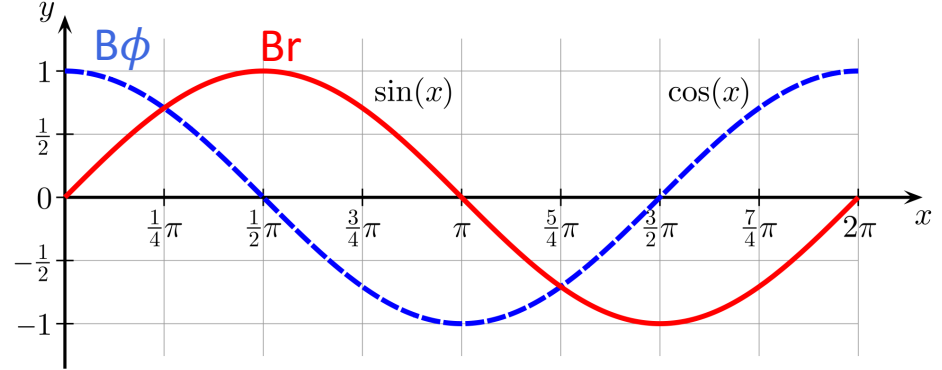


- $\bar{B}_r = \bar{B}_r^{loc} + \bar{B}_r^{glo} + \bar{B}_r^{true}$ MC expectation is a linear increase of BR vs $|R|$, use this model for the data.
- $\bar{B}_\phi = \bar{B}_\phi^{loc} + \bar{B}_\phi^{glo}$
- Use average B_R and B_ϕ for $|Z| < 100$ mm range.

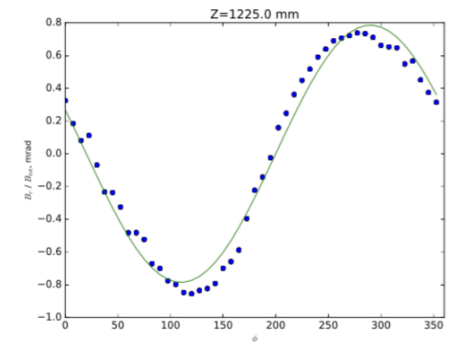
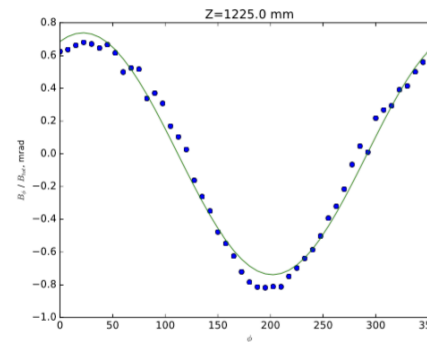
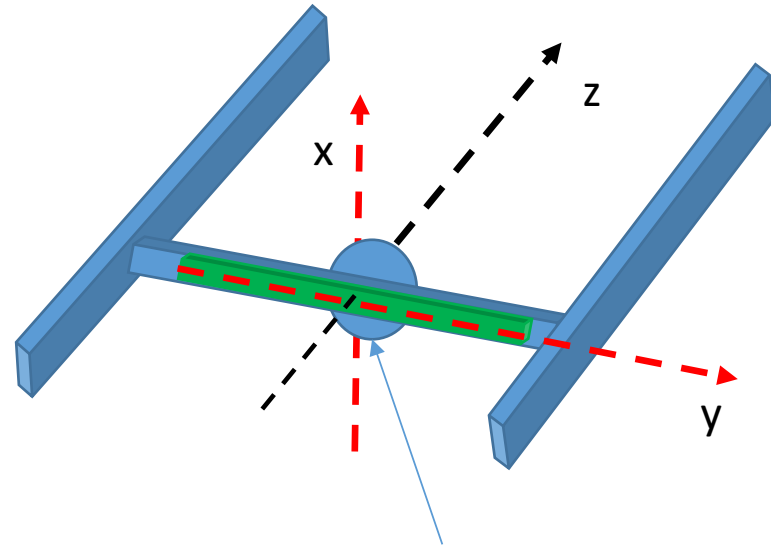
Global Misalignment



Global Misalignment

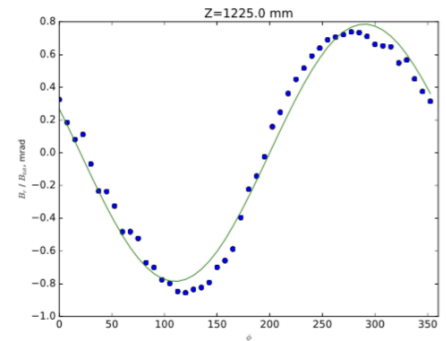
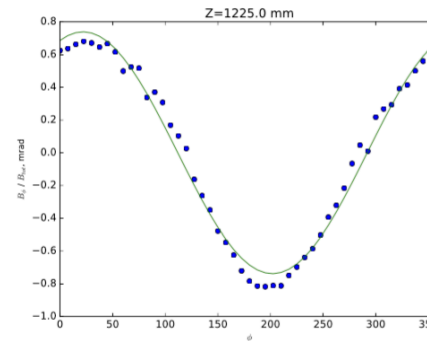
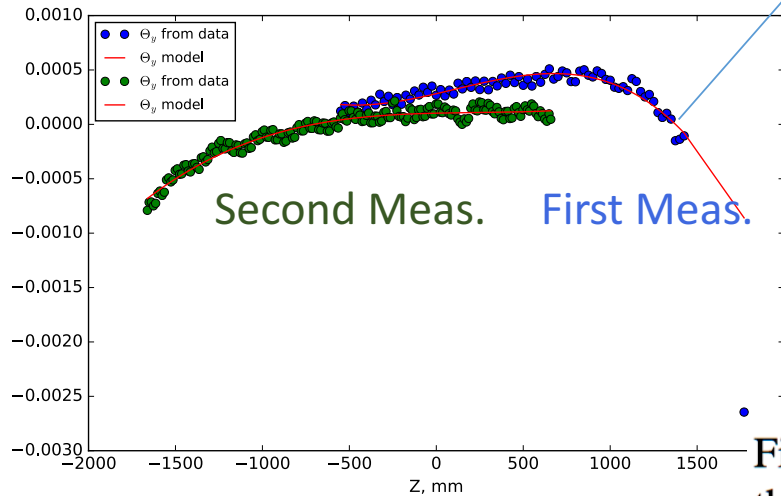
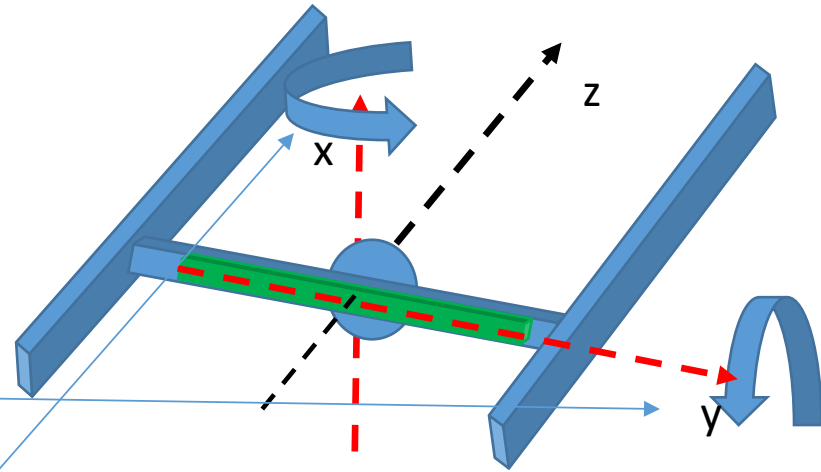
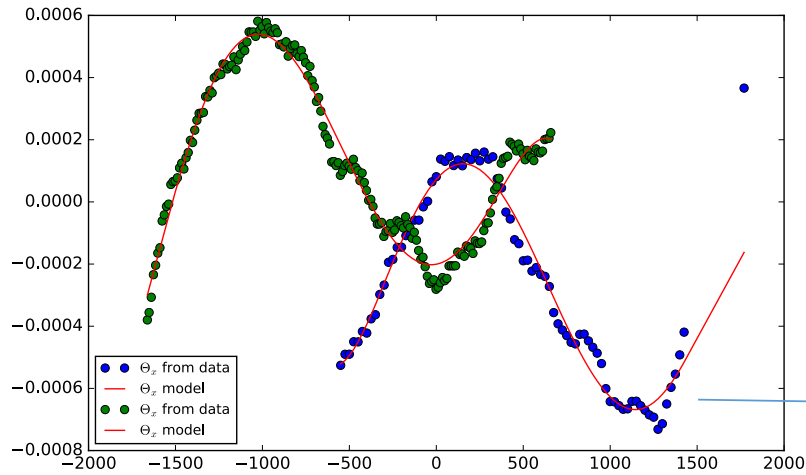


Observed rotation of the arm



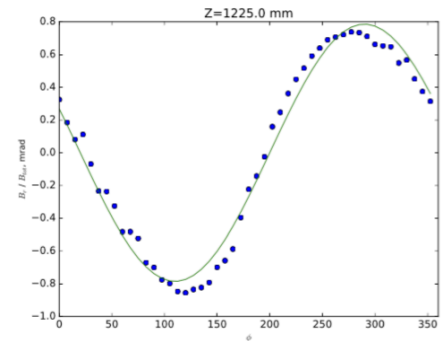
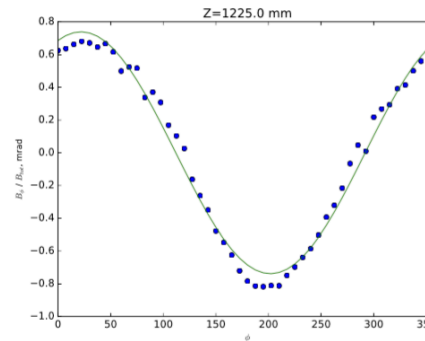
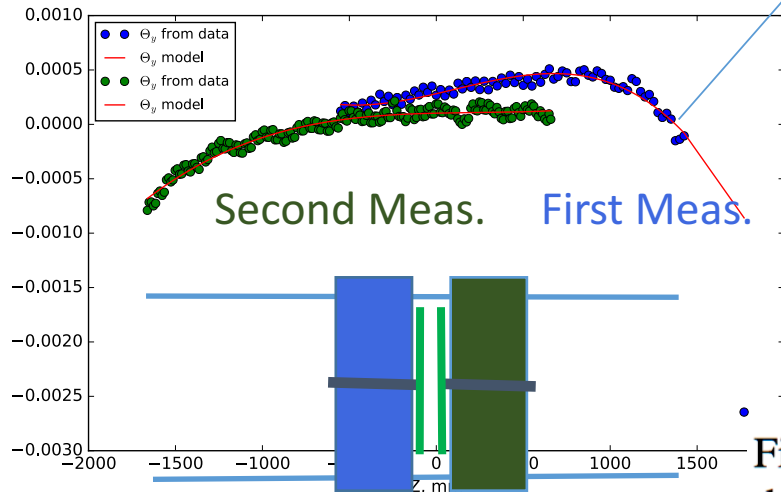
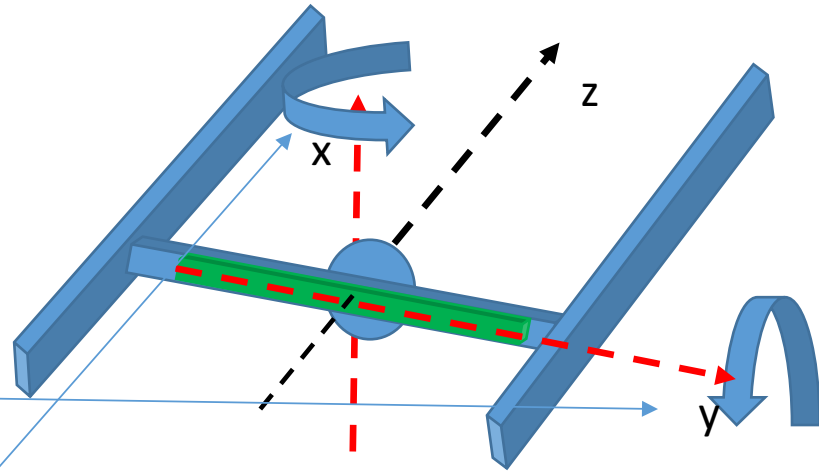
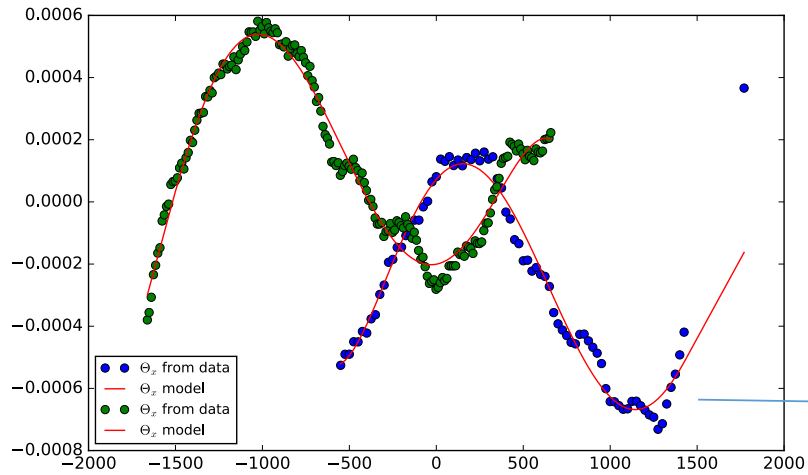
Fit $f(\phi) = A \sin(\phi + \phi_0)$ to B_r/B_{tot} and B_ϕ/B_{tot} distributions for the sensor 17 in Z slices.

Observed rotation of the arm



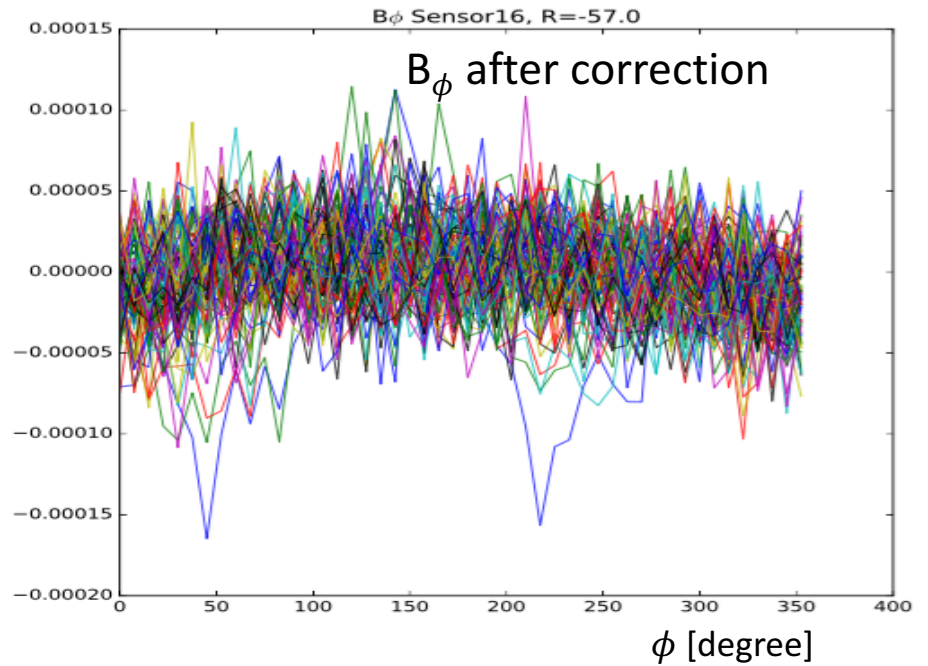
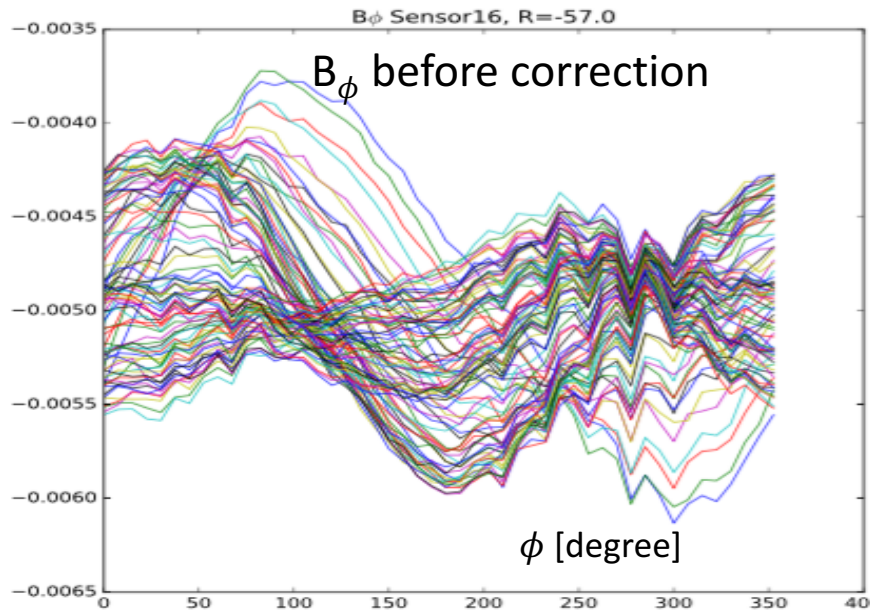
Fit $f(\phi) = A \sin(\phi + \phi_0)$ to B_r/B_{tot} and B_ϕ/B_{tot} distributions for the sensor 17 in Z slices.

Observed rotation of the arm

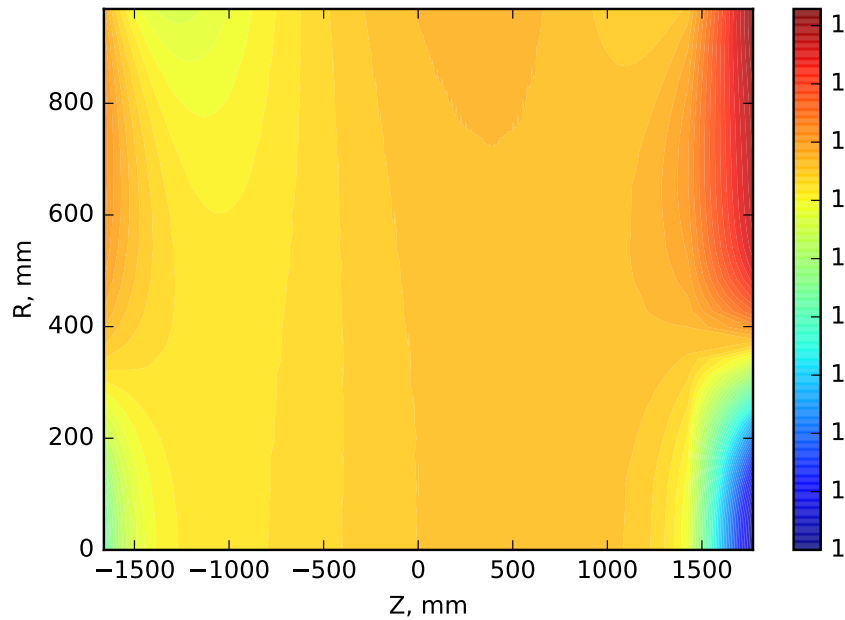


Fit $f(\phi) = A \sin(\phi + \phi_0)$ to B_r/B_{tot} and B_ϕ/B_{tot} distributions for the sensor 17 in Z slices.

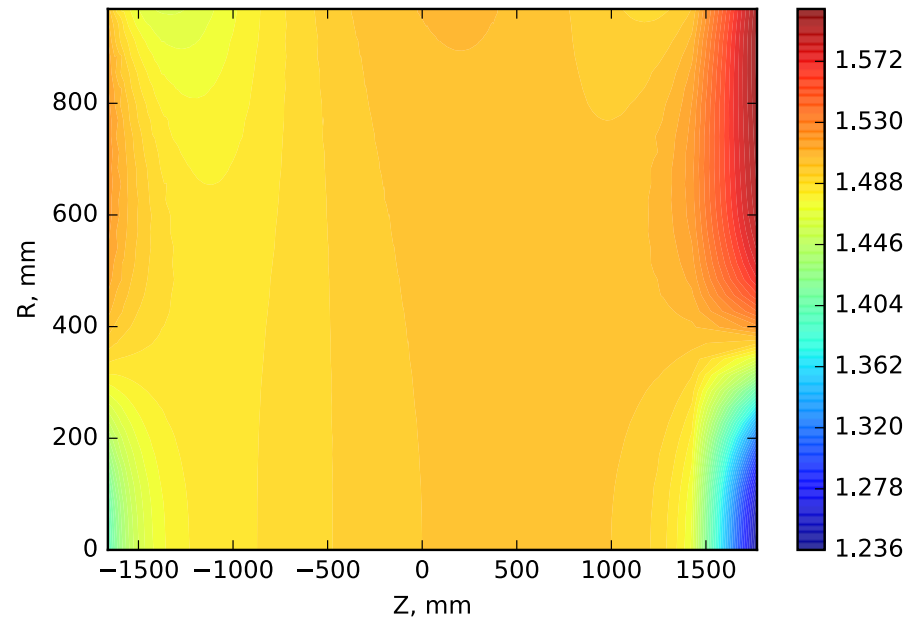
Mis-alignment corrections



Comparison between meas. & simul.

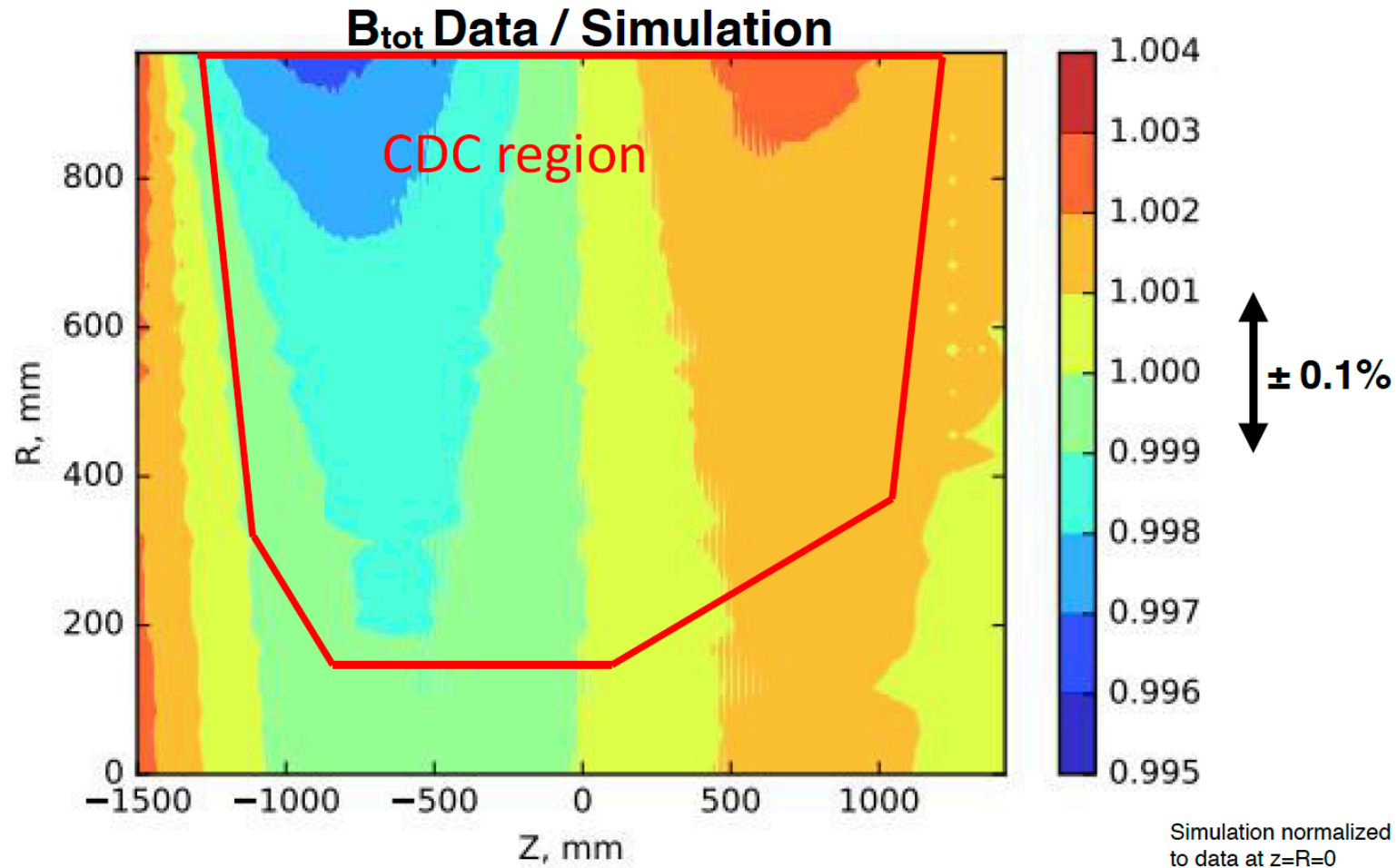


Measurement



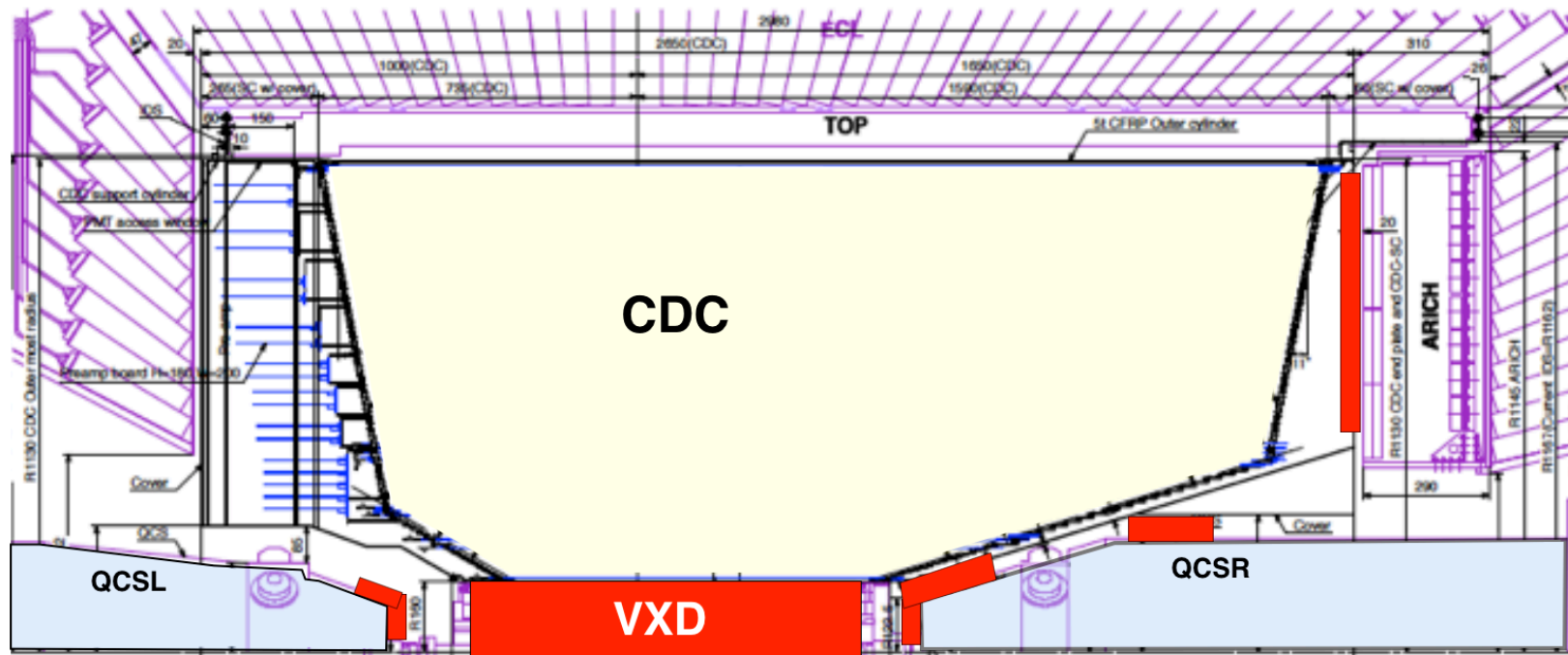
Simulation

Comparison between meas. & simul.

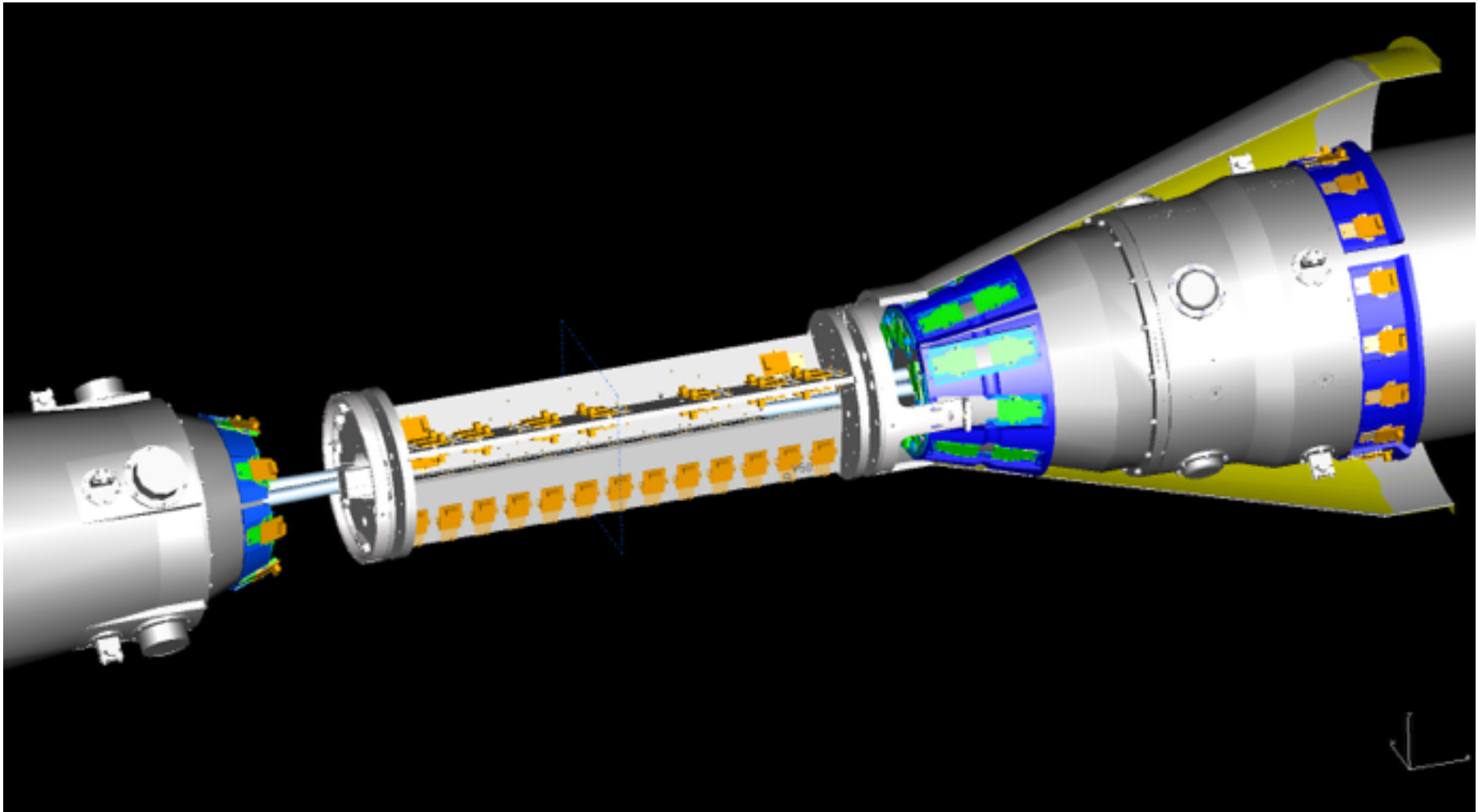


- $|\Delta B|/B > 0.1\%$ in large part of the CDC volume
- Map can be used as input for parameter tuning of Opera model (KEK magnet group)

Second measurement campaign



Second measurement campaign



Differences compared to 1st B-Field Measurement

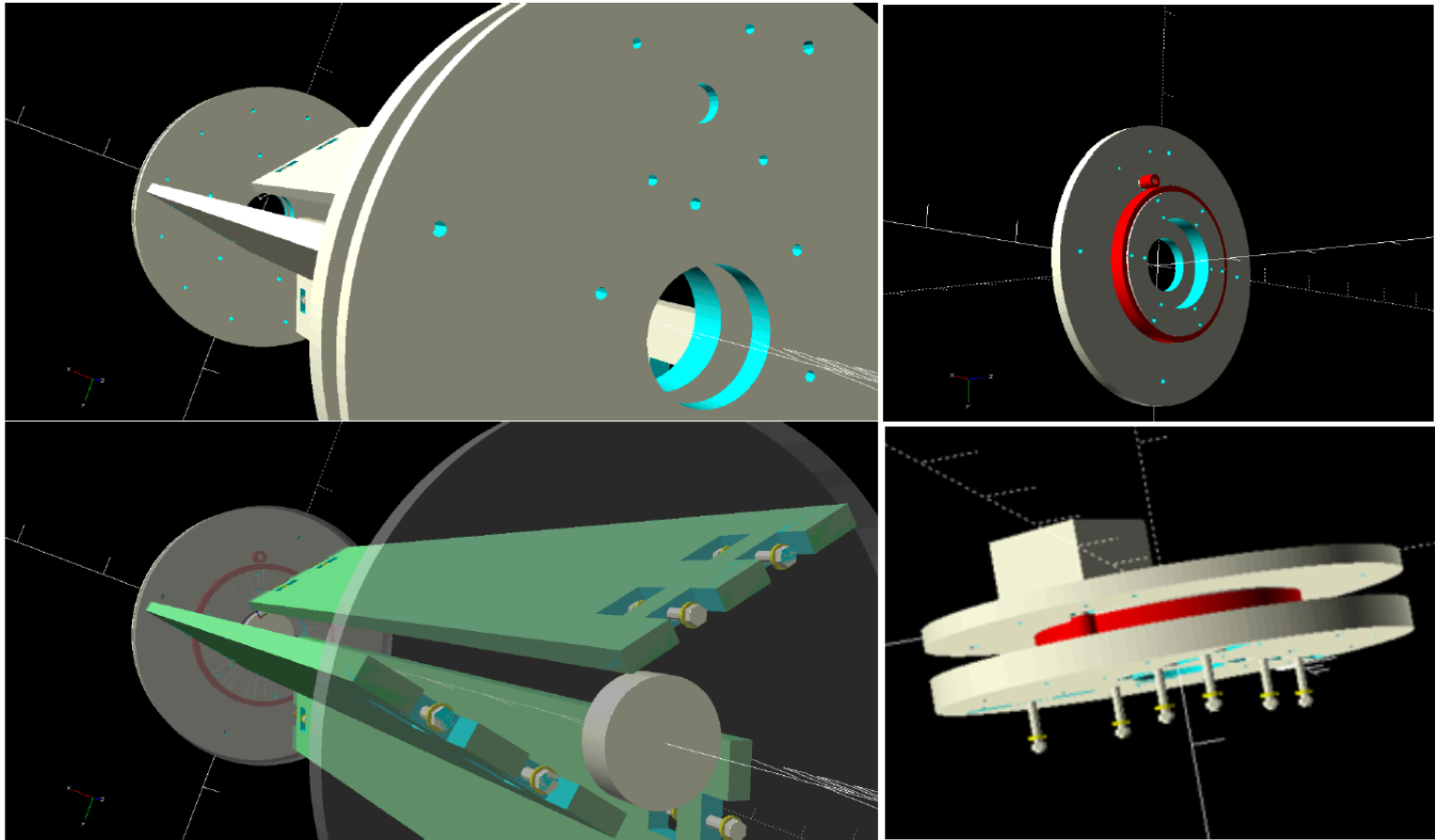
Systematics

- accessible measurement volume is very limited
- finally will have to extrapolate results into inaccessible tracking volume
- can only use stationary sensors in most interesting regions

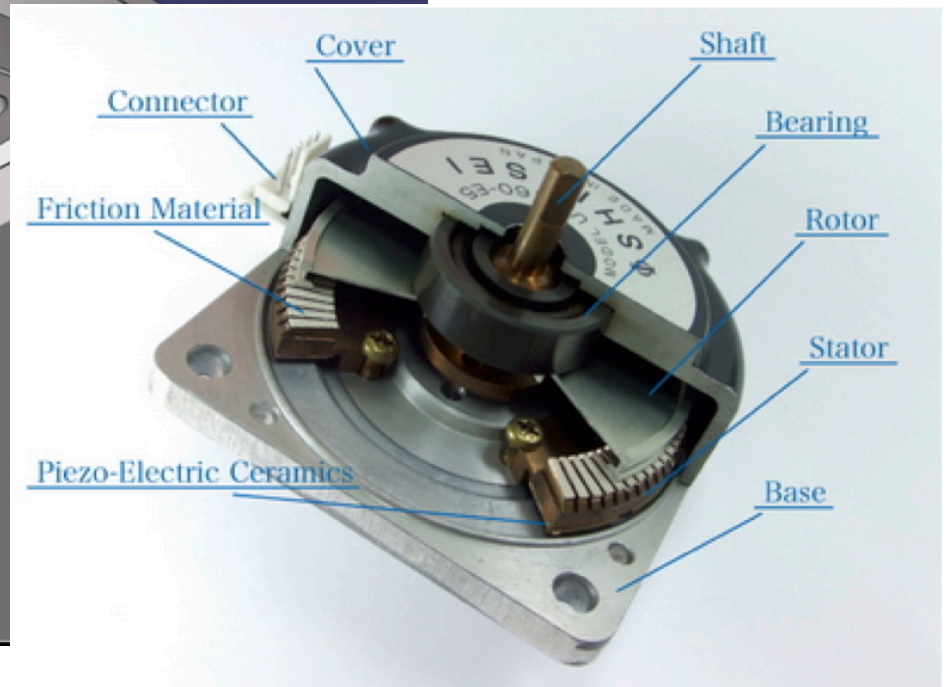
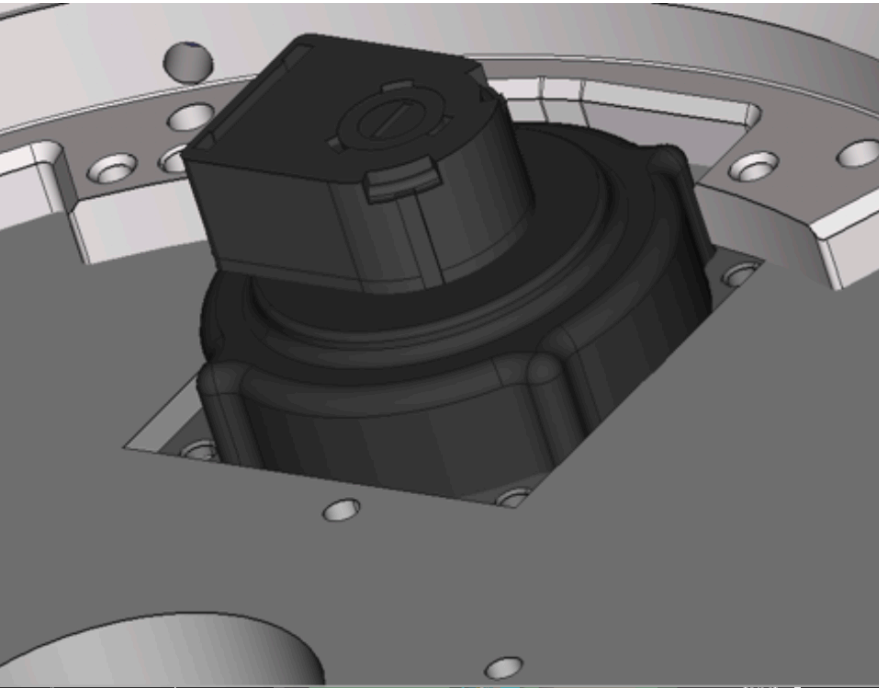
Operational challenges

- once QCS magnets are in place B-field sensors are inaccessible
- very tight schedule allows only parasitic data taking in parallel to most important and demanding QCS measurement program
- continuous operation must be guaranteed over ~ 8 weeks

VXD mapper

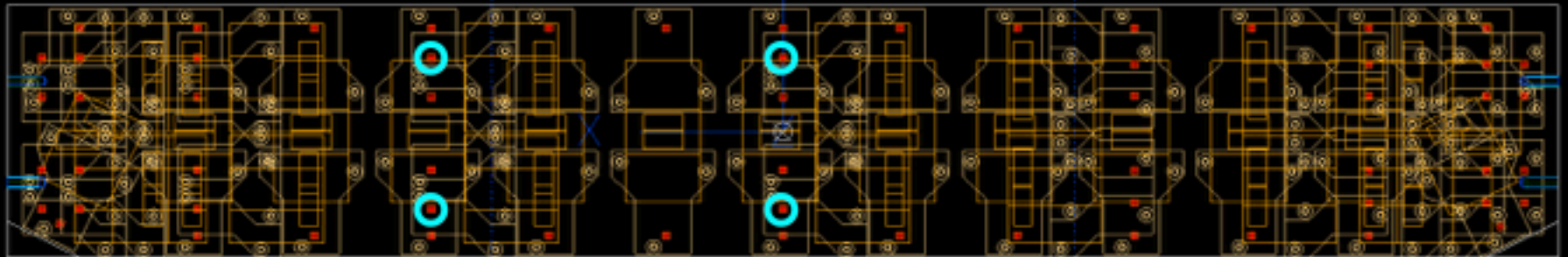
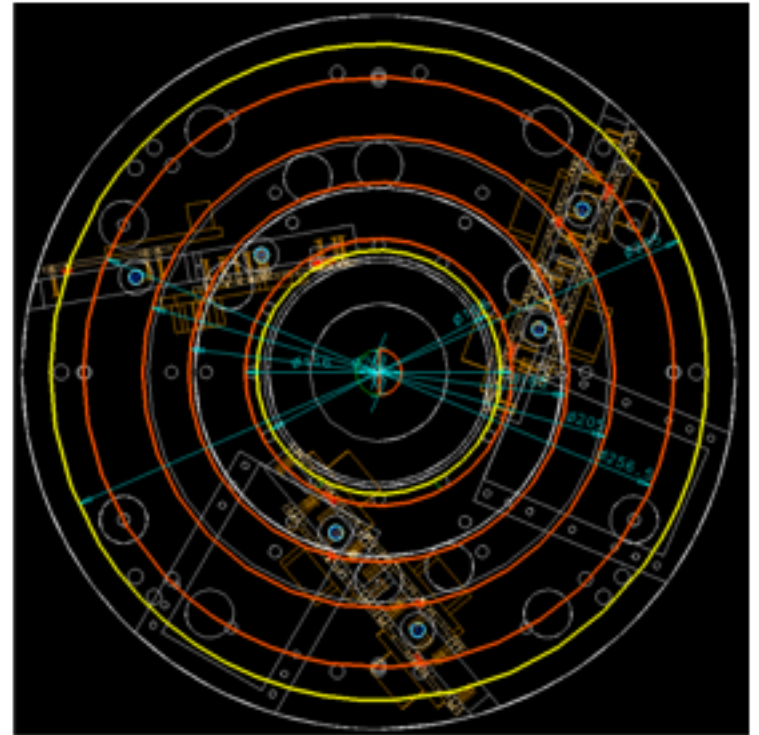
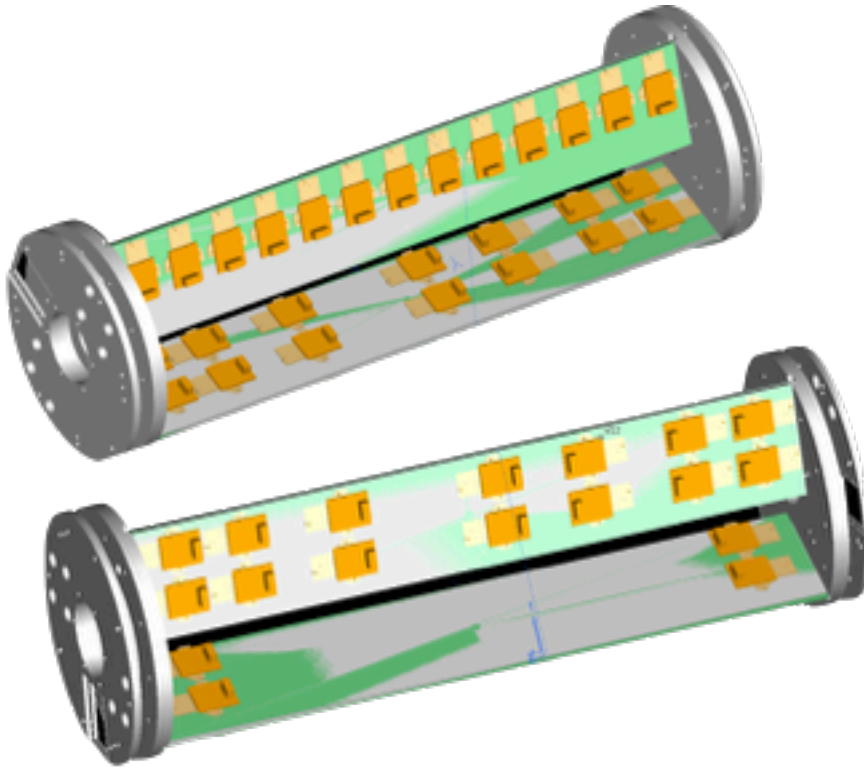


VXD mapper

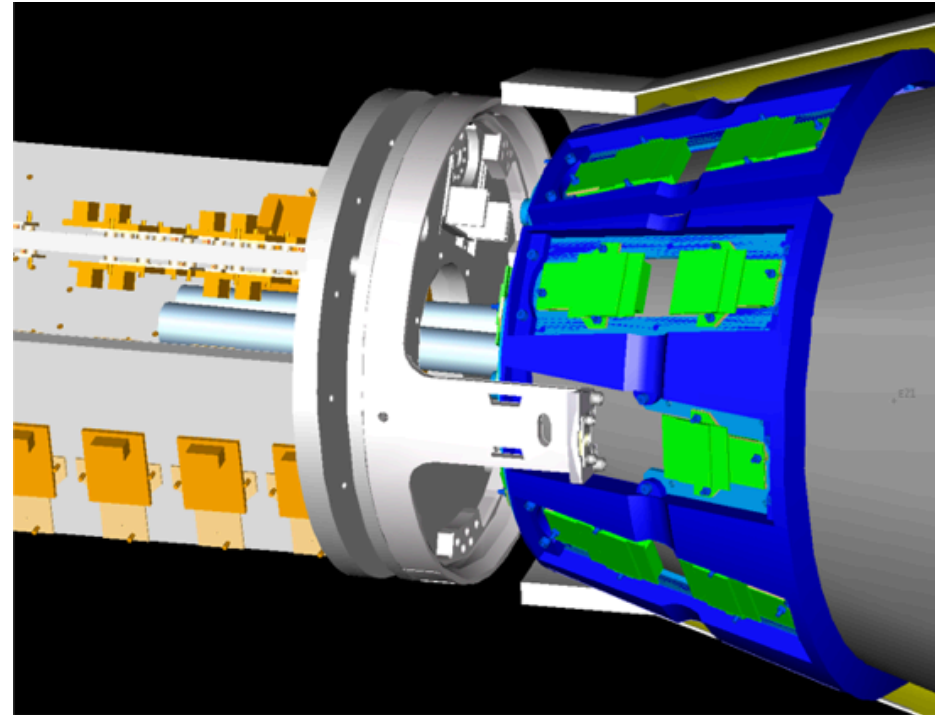
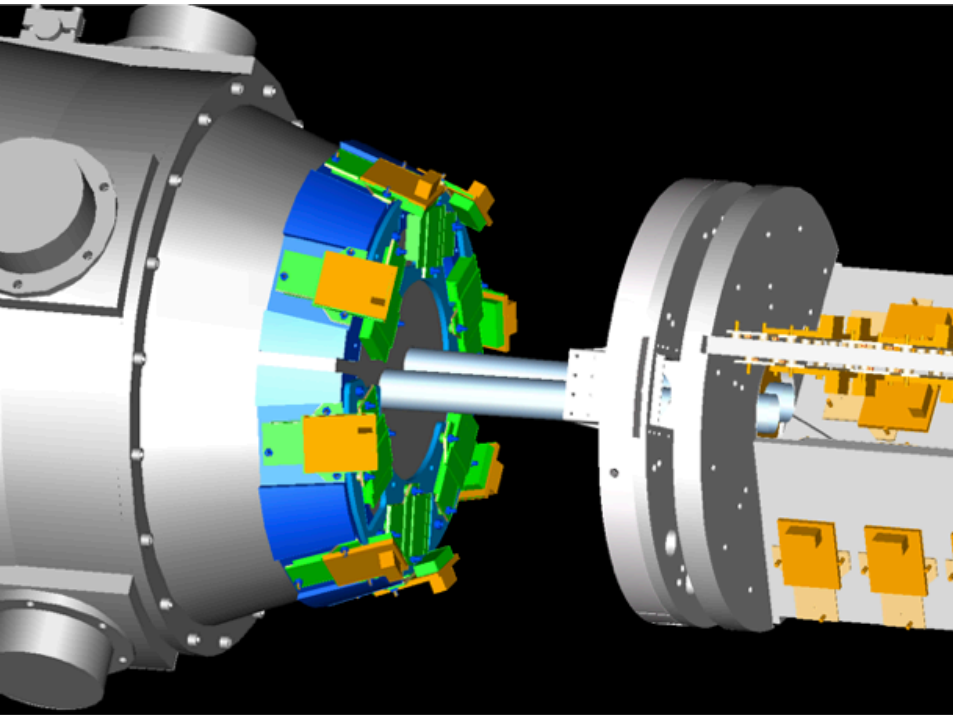


Large holding power without the need to use gears
Stable operation in strong magnetic field environment

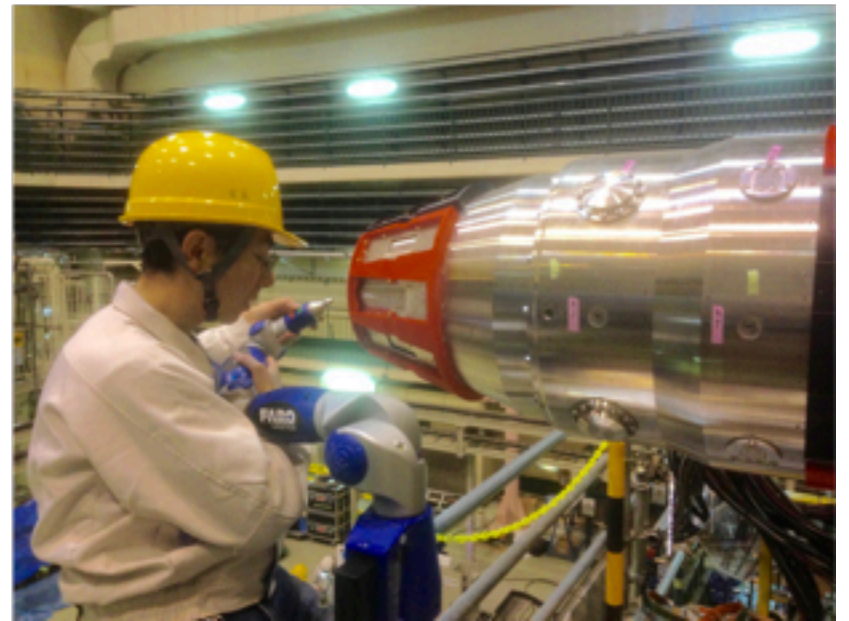
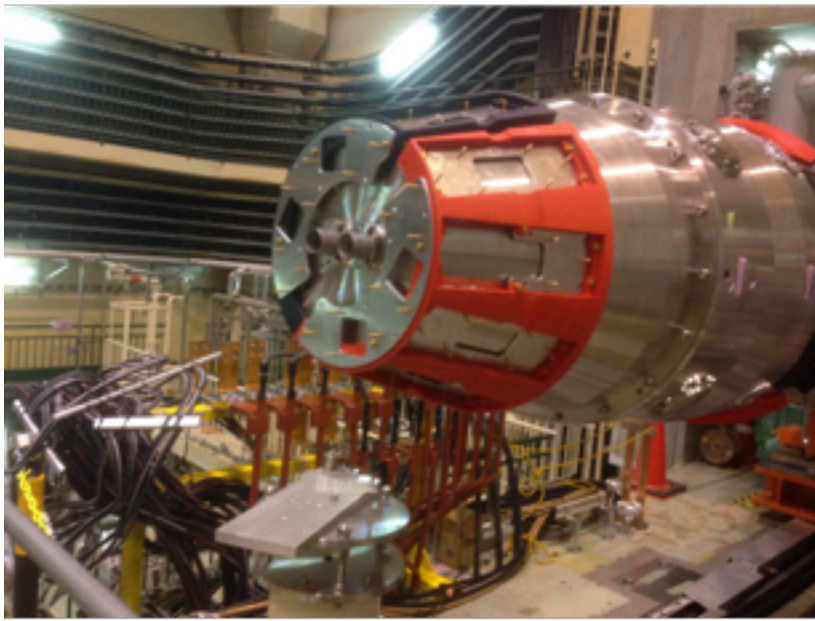
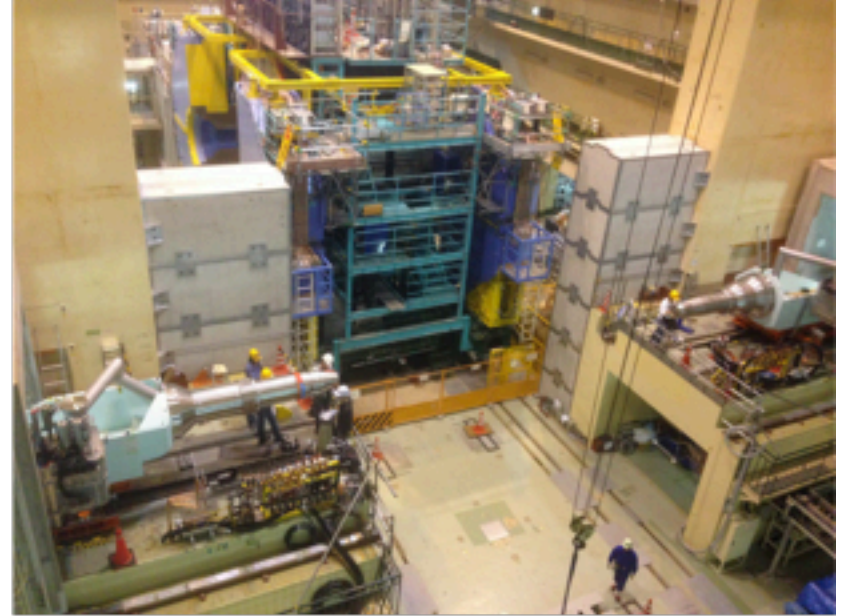
Sensor distribution



Sensors on QCSL and QCSR

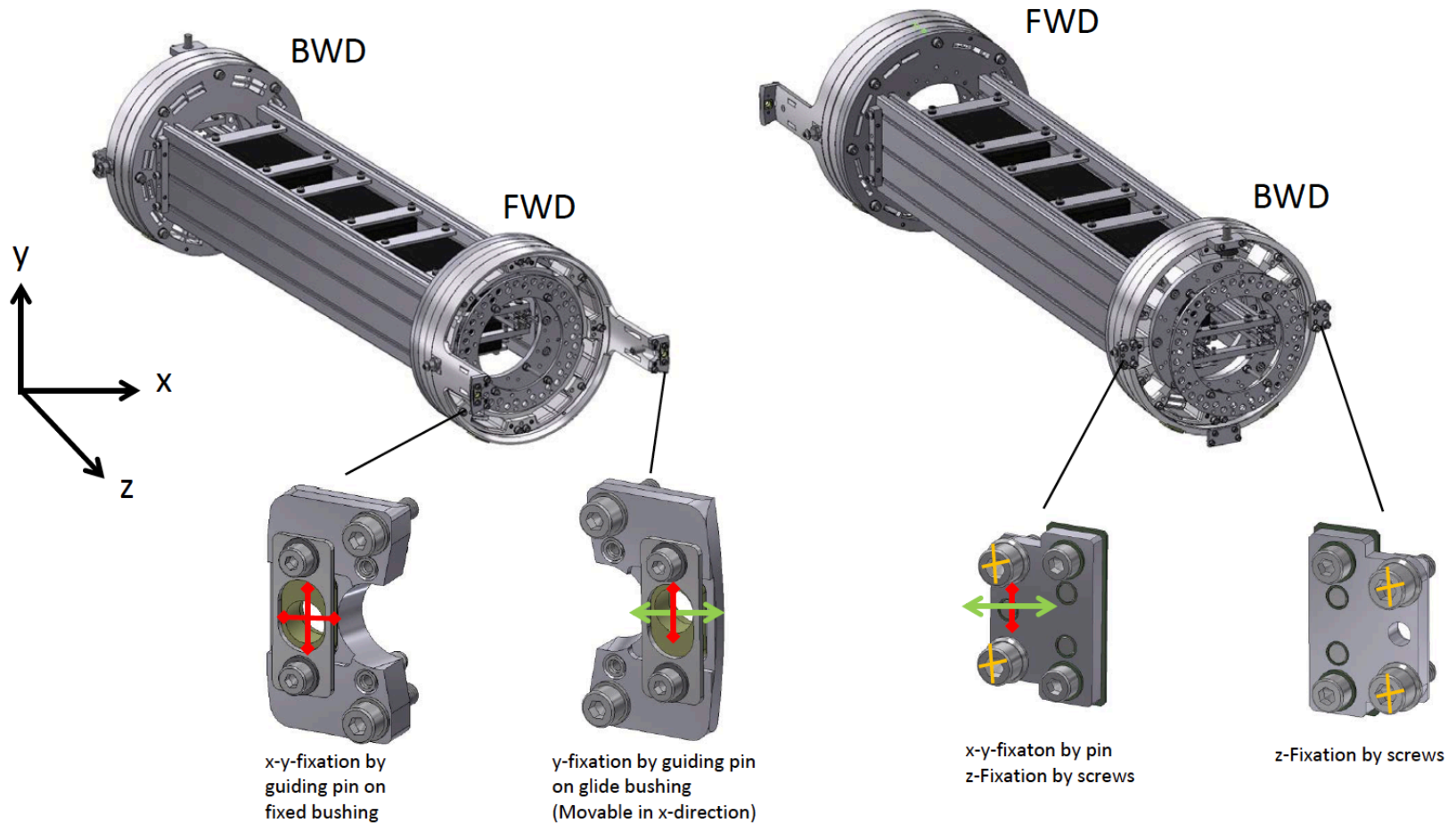


Installation and survey



Installation ring and bracket

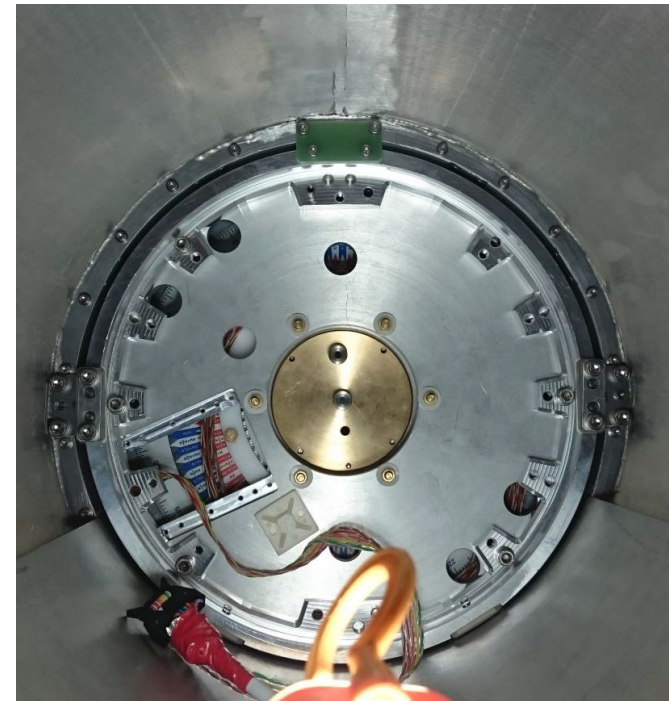
- Use standard VXD installation rings



VXD mapper installation

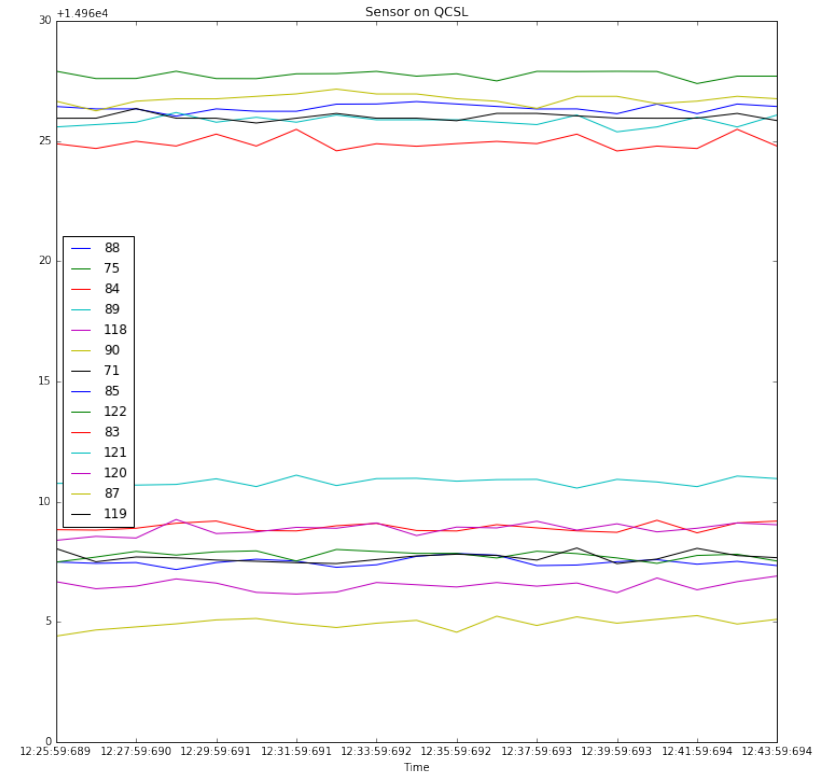
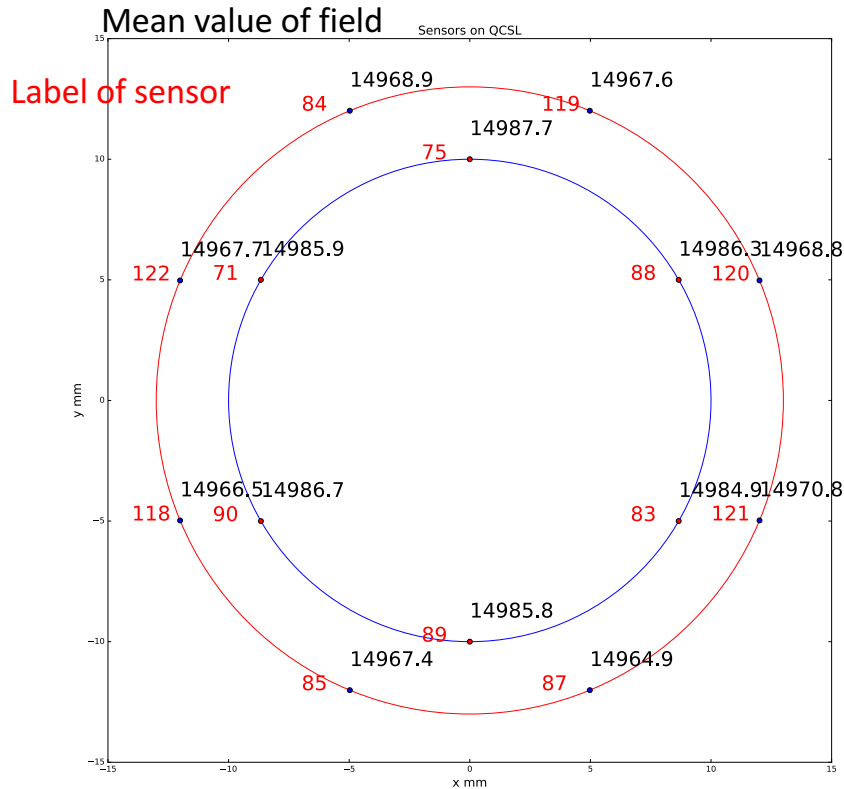


Installed mapper from the FWD-side

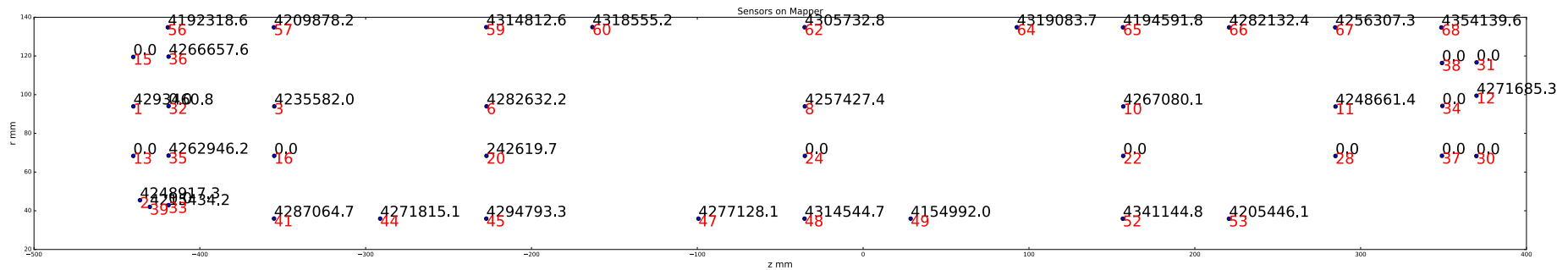


Installed mapper from the BWD-side

B field measured by QCS sensors



B field measured by VXD mapper



Before calibration

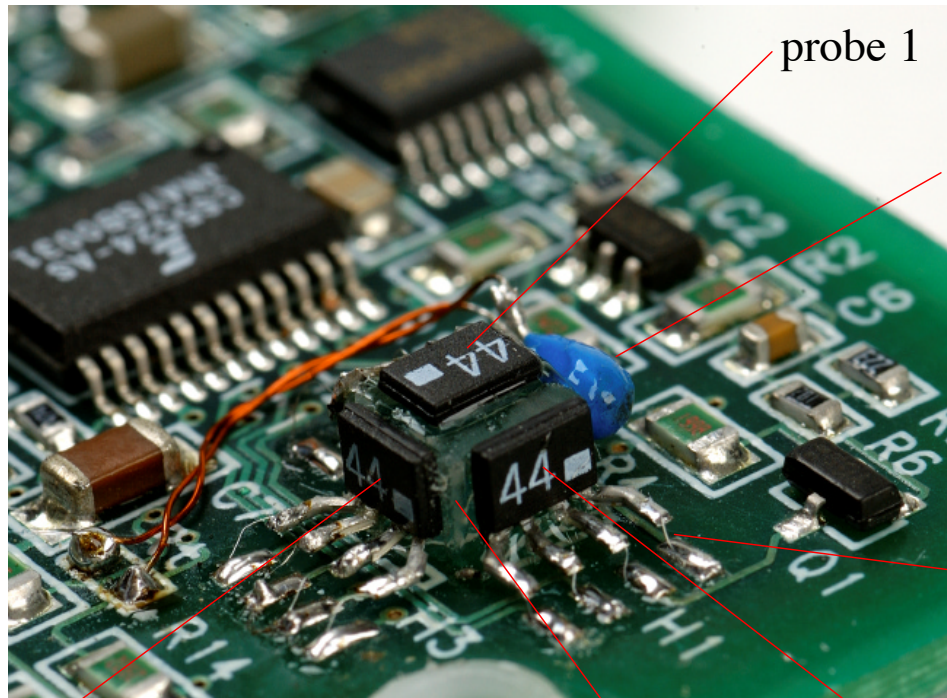
Summary

- Data taken in CDC volume in Summer 2016 are of excellent quality and overall show reasonable agreement with the simulation.
- Mapper for the measurement in the VXD volume with QCS magnets is successfully installed end of April.
- Issues during mapper commissioning in June
 - - lost connection to part of the sensors - under investigation
 - - software issues
- Final measurement scheduled for end of August
 - - in parallel to QCS Hall Probe measurement
 - - Belle II plus all QCS systems at nominal field
- Interpretation of data and proper combination with data taken in 2016.

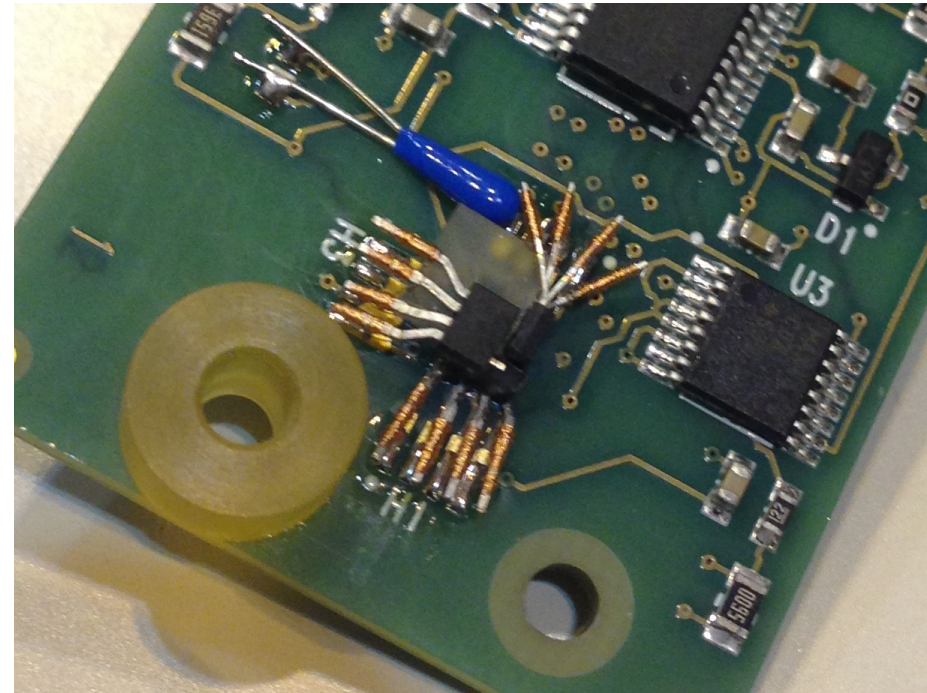
Back Up

Improvement on the Hall probe

Old design

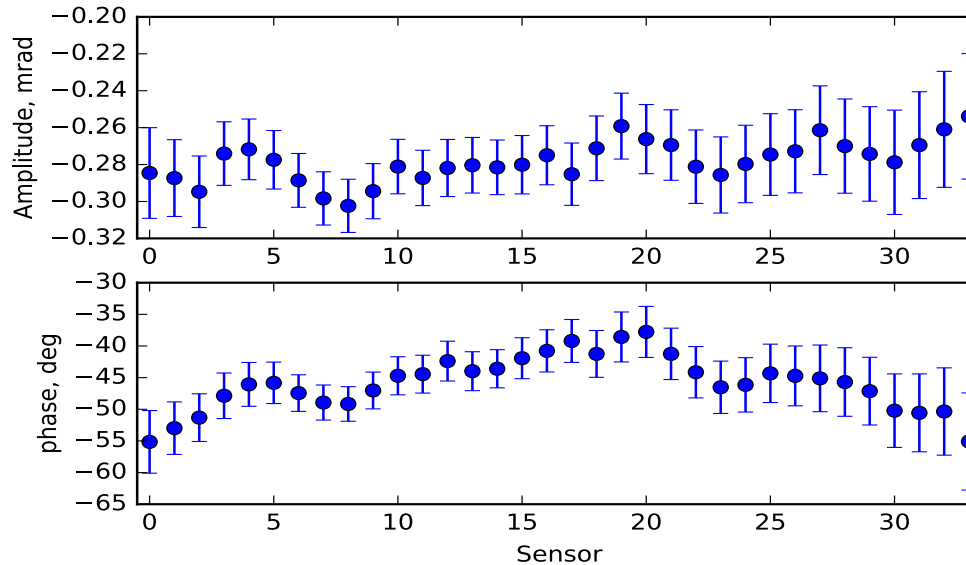


New design

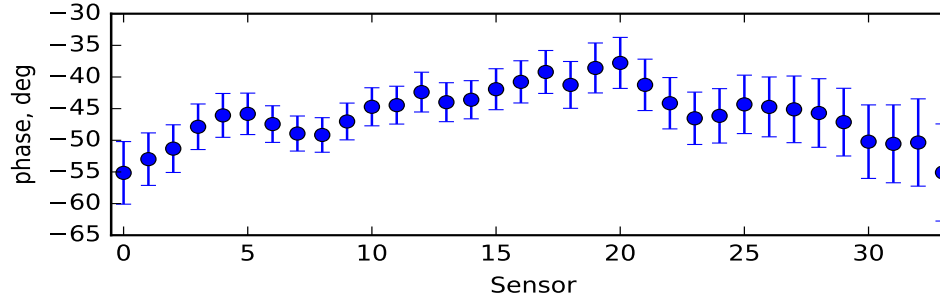


Misalignment observed in data

Amplitude

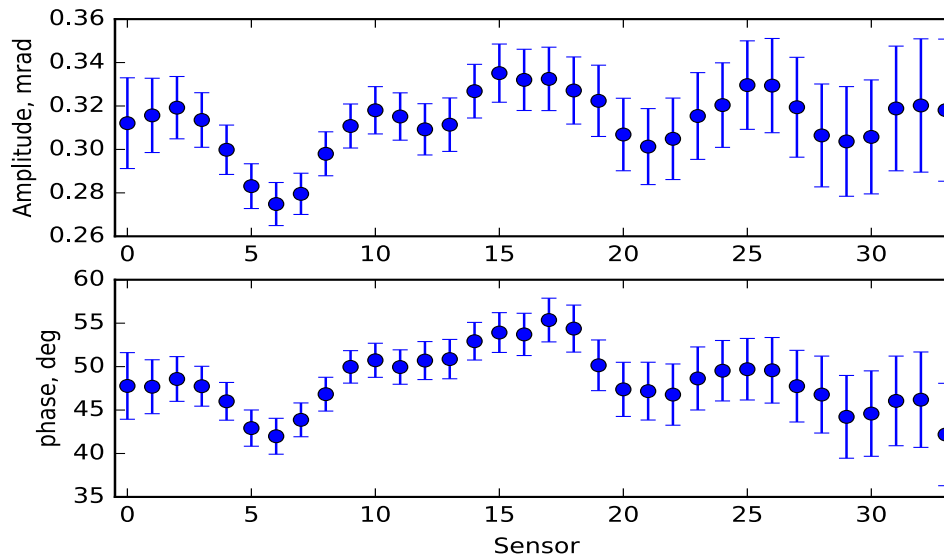


Phase

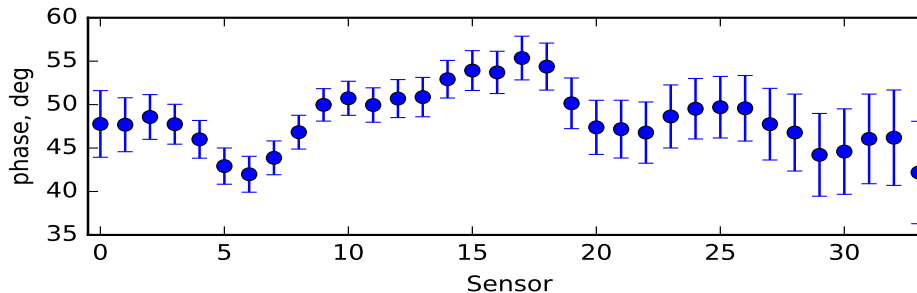


Fitted amplitude and phase
from Br

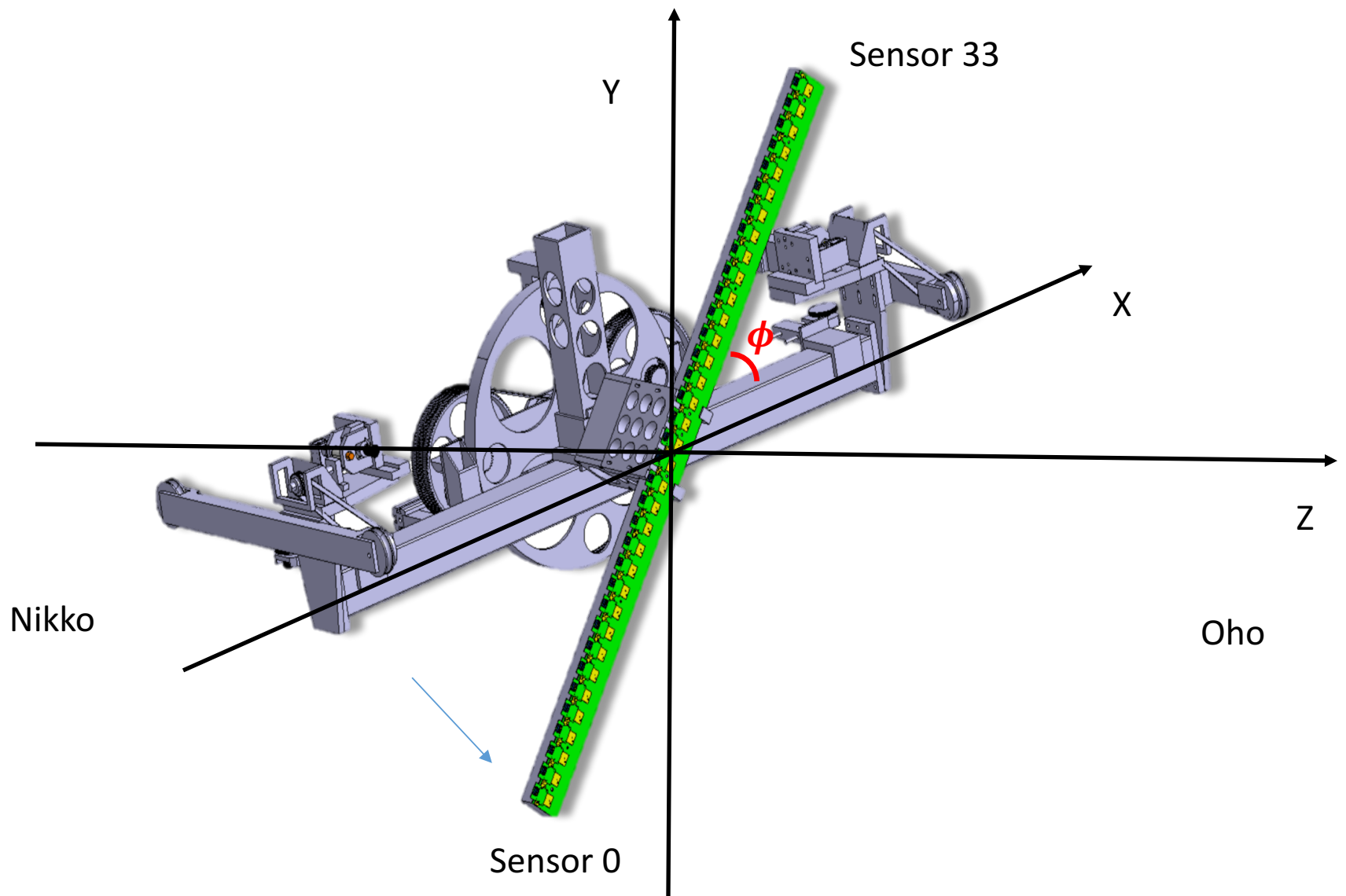
Amplitude



Phase

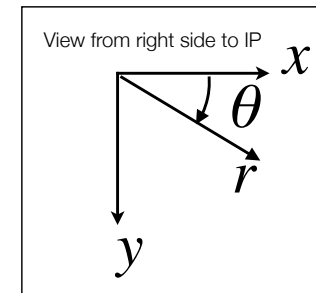
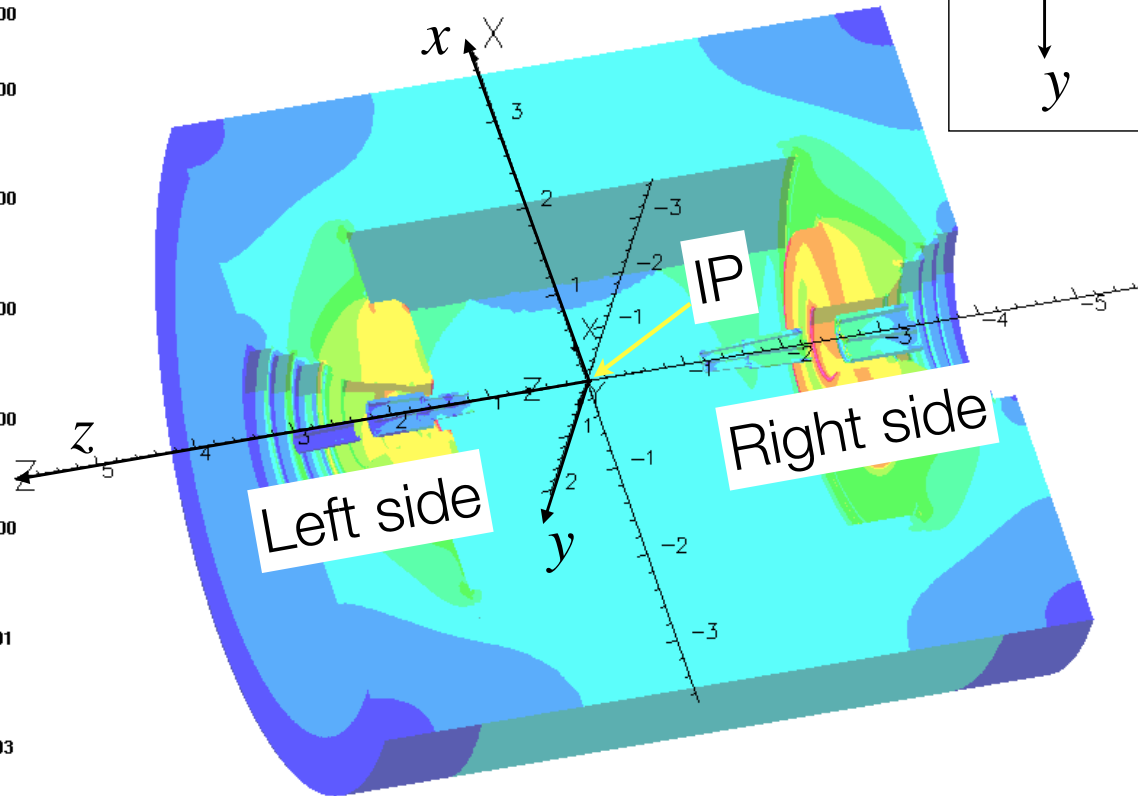
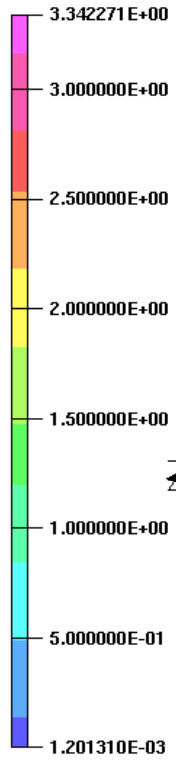


Fitted amplitude and phase
from B_ϕ

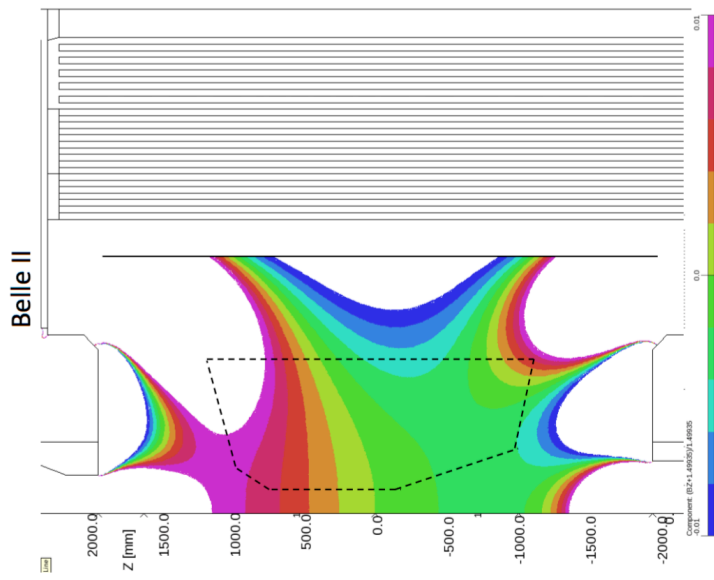
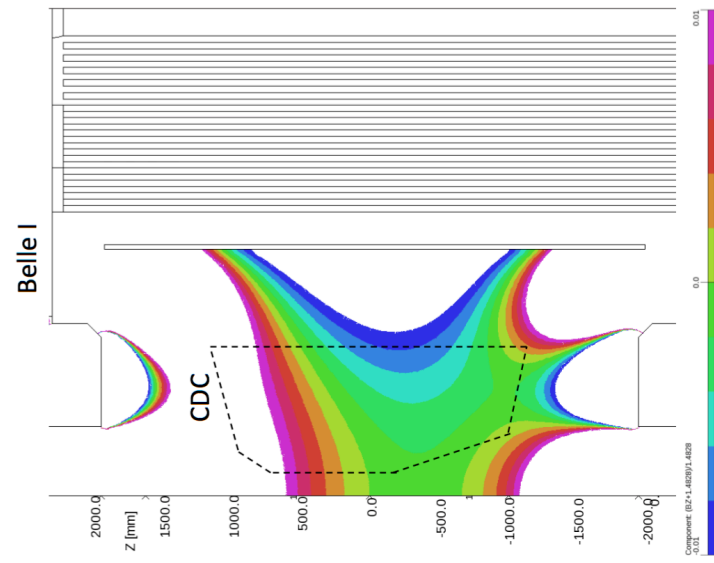


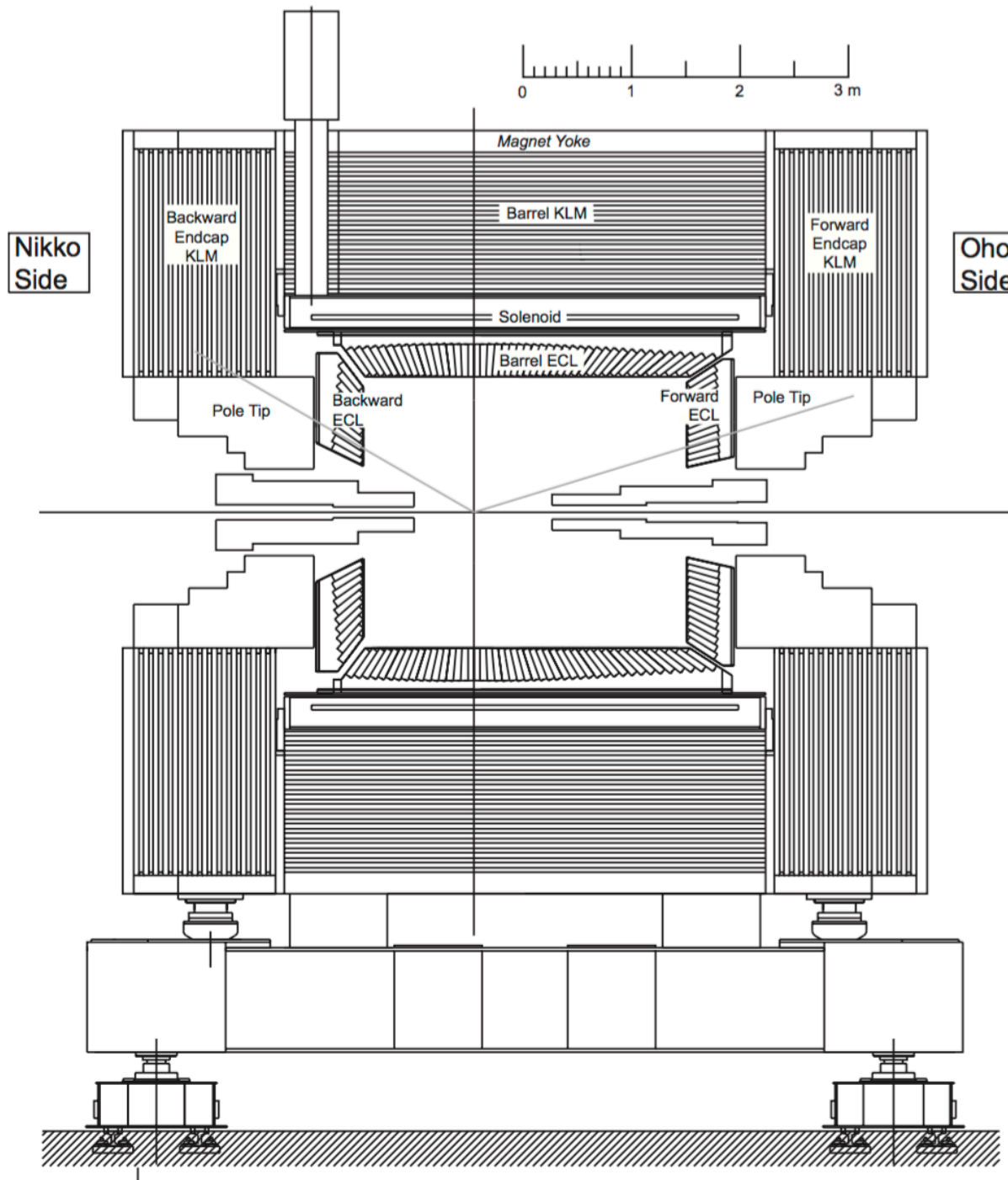
26/Jun/2015 10:45:30

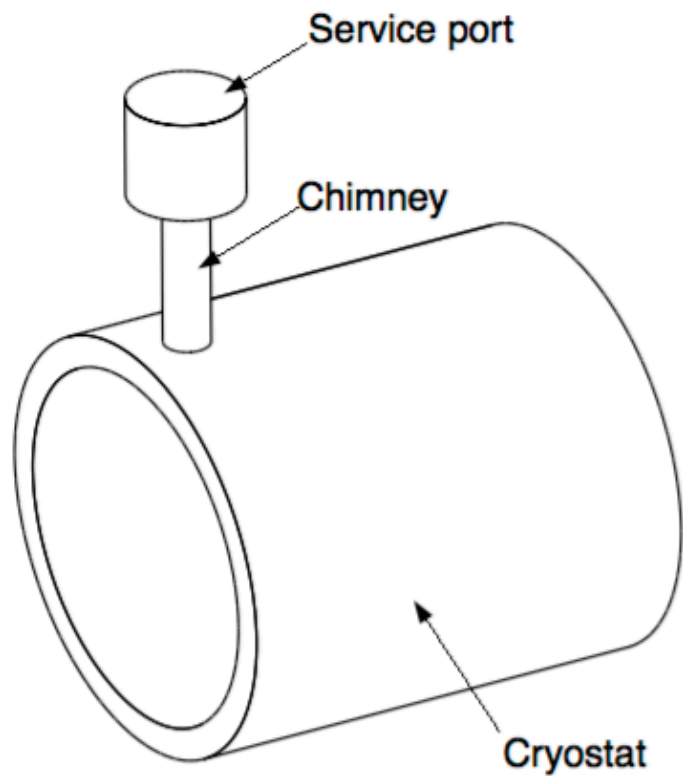
Surface contours: B



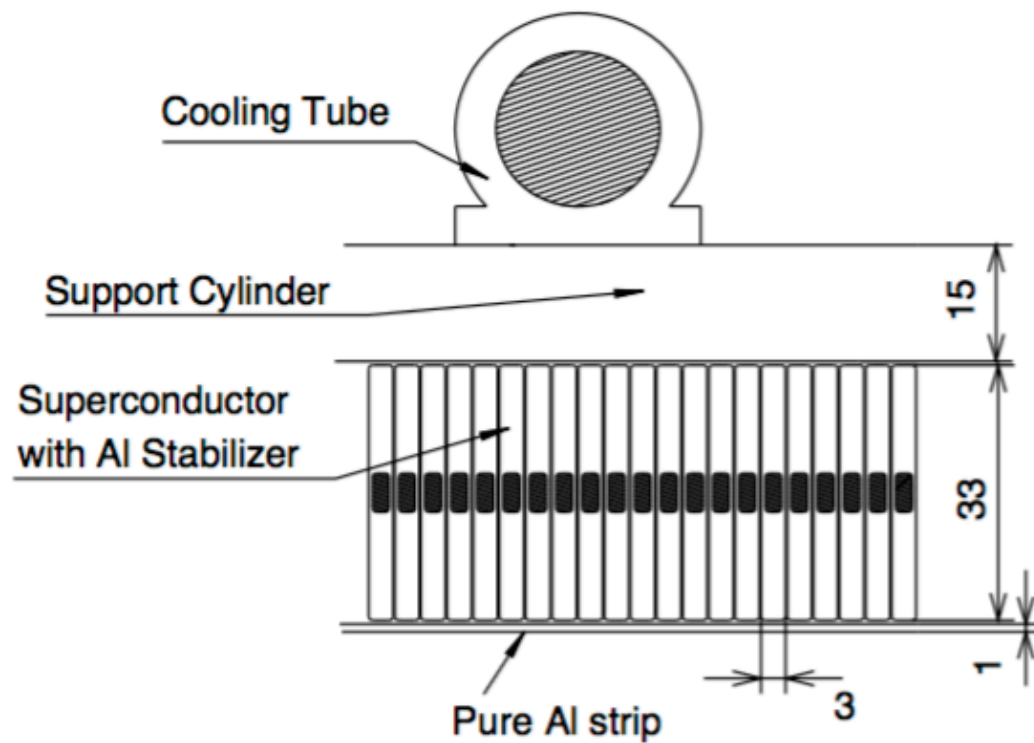
Opera



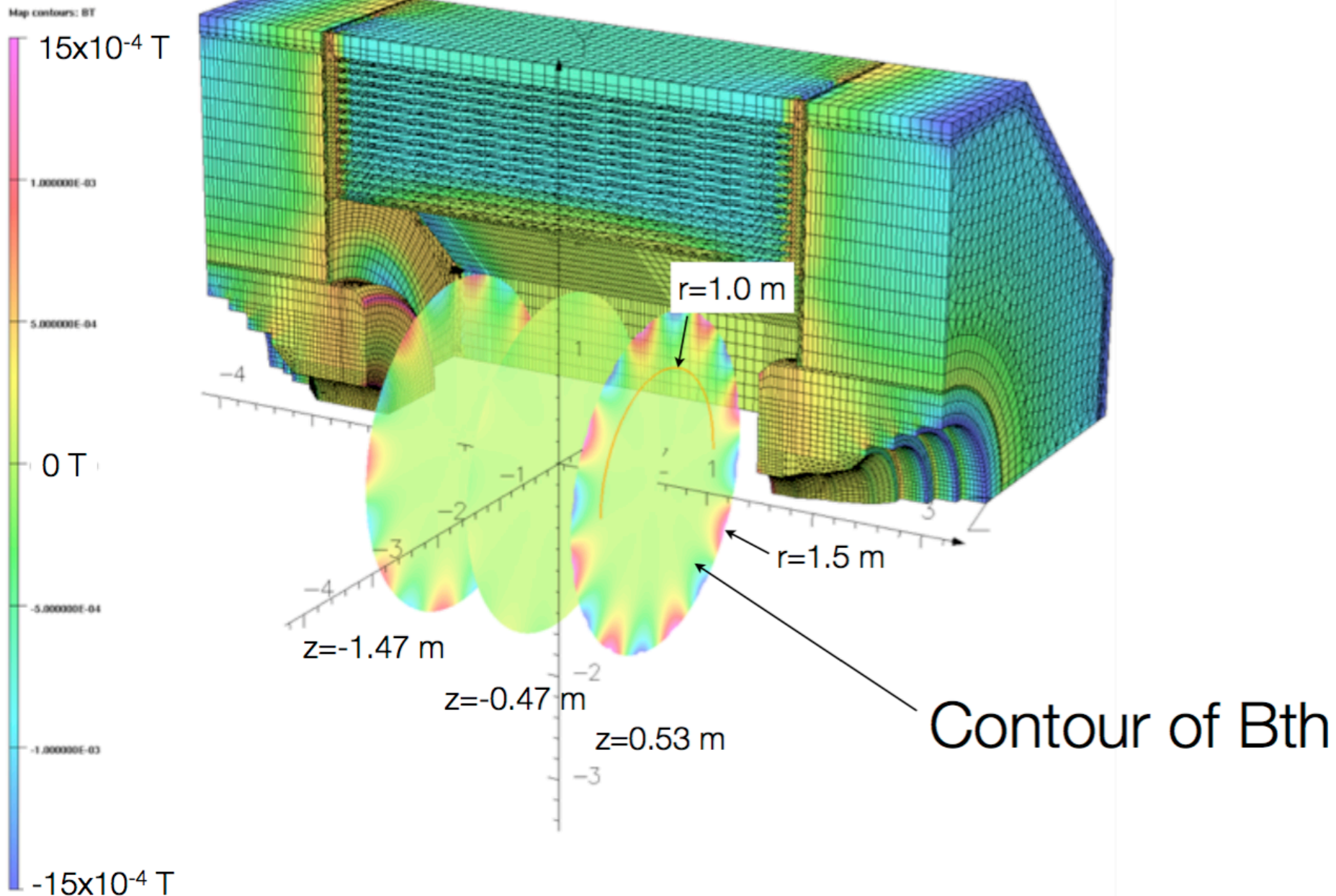




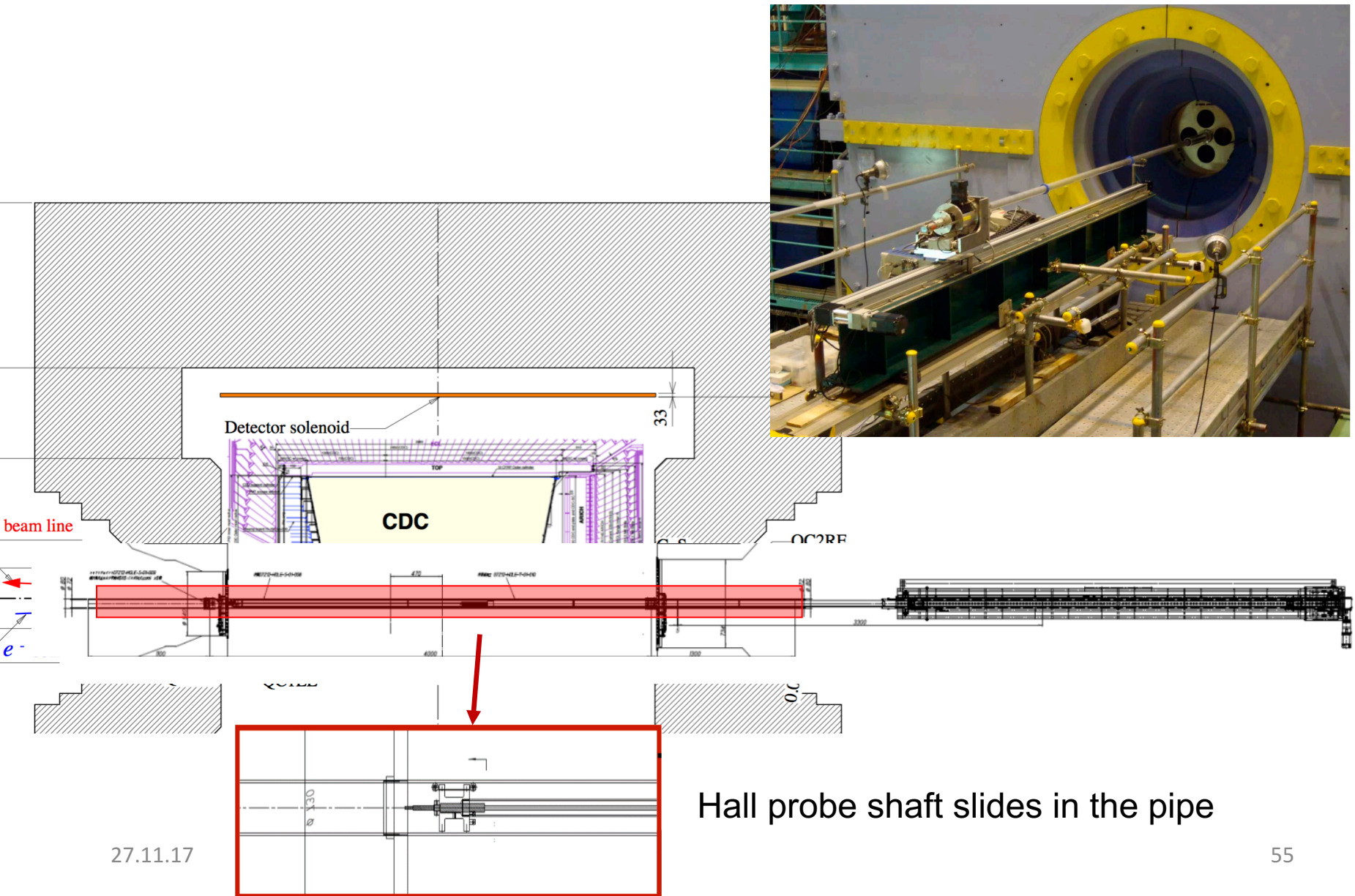
(a) Outlook of the magnet



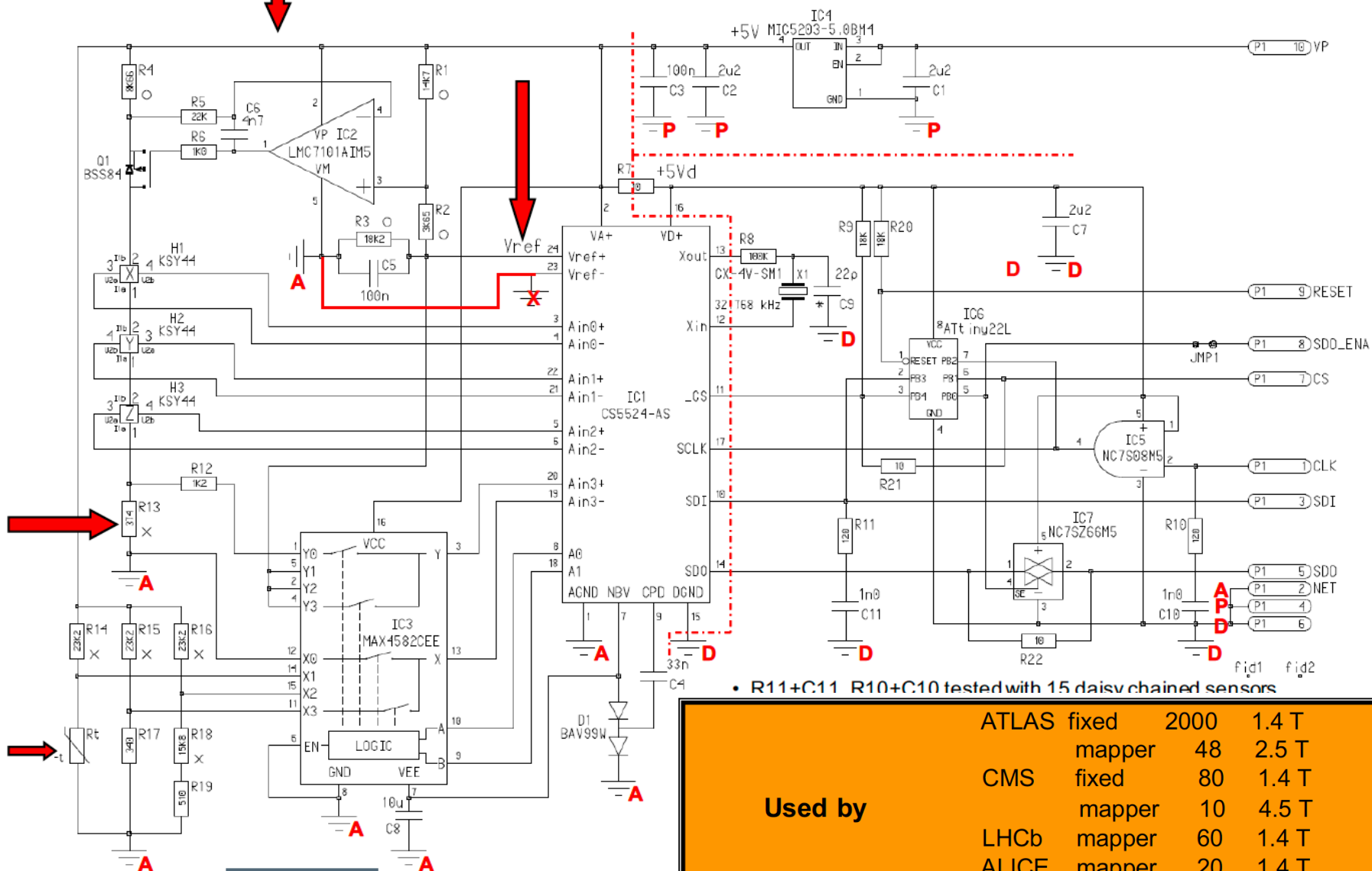
(b) Cross sectional view of the coil



Overview of the B measurement



NIKHEF B-sensor diagram



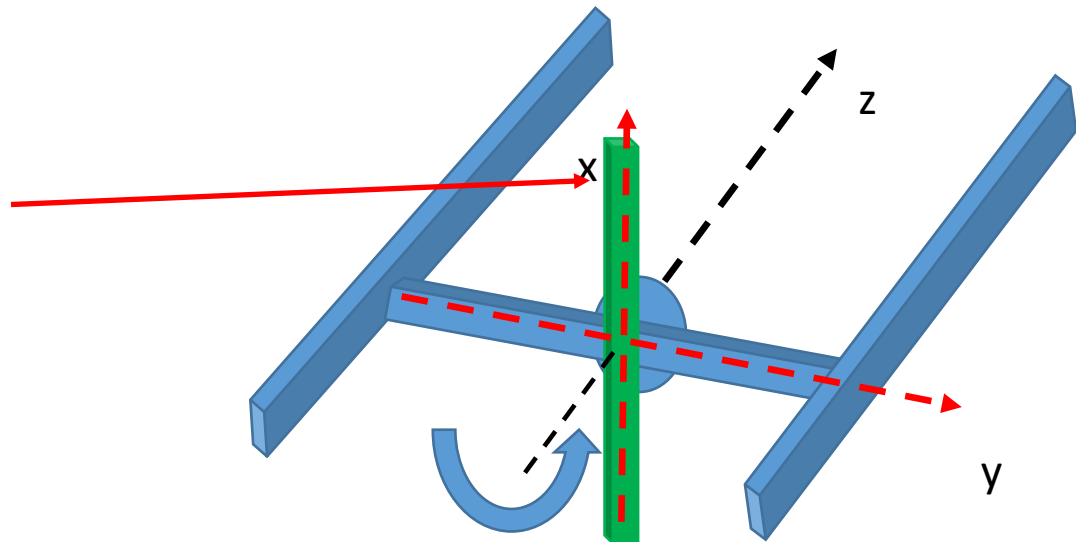
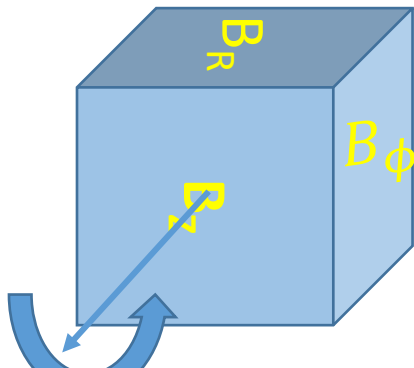
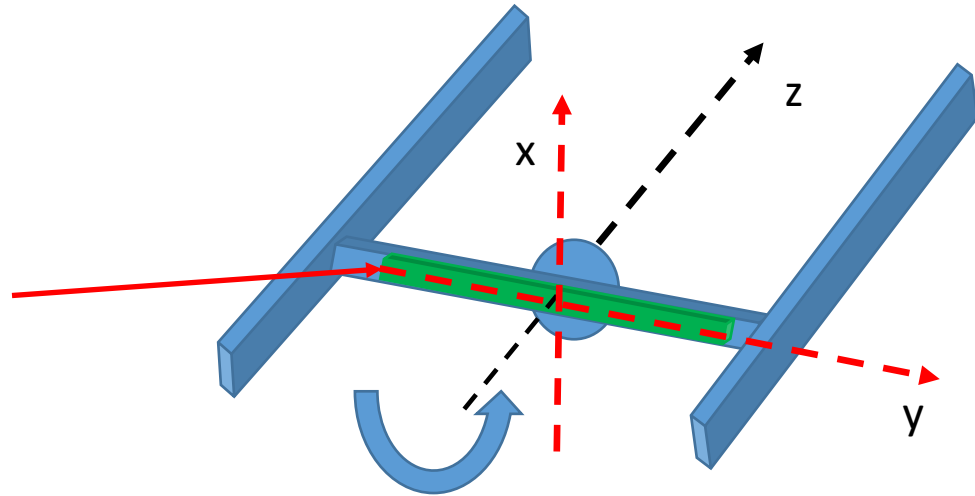
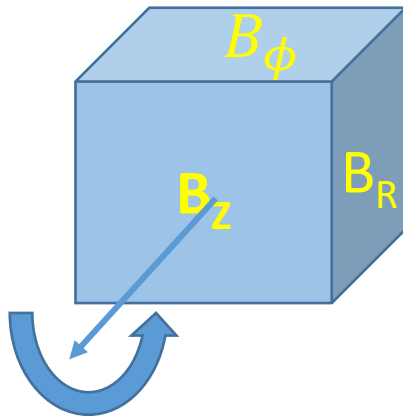
Used by

ATLAS	fixed	2000	1.4 T
	mapper	48	2.5 T
CMS	fixed	80	1.4 T
	mapper	10	4.5 T
LHCb	mapper	60	1.4 T
ALICE	mapper	20	1.4 T
MICE		24	4.5 T

• Identifier has to be added to the μP or extra chip.

Global Misalignment

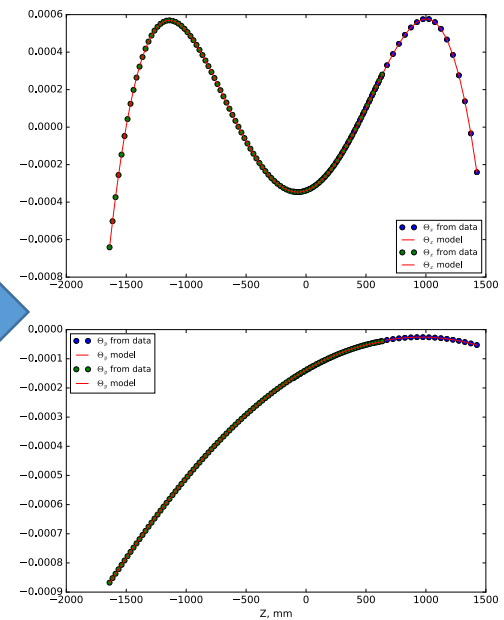
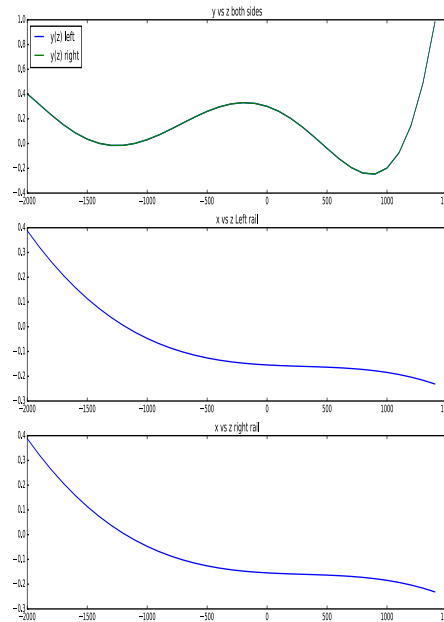
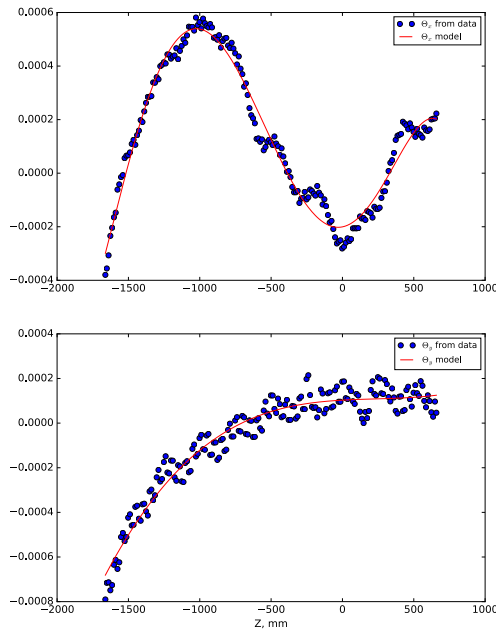
Just affect the ϕ position,
will not change the value of B_r , B_ϕ , B_z



Strategy of mis-alignment simulation

Fit the observed mis-alignment shape with polynomial $p_x(z)$, $p_y(z)$

Obtain their primitive function $F_x(z)$, $F_y(z)$ by indefinite integral

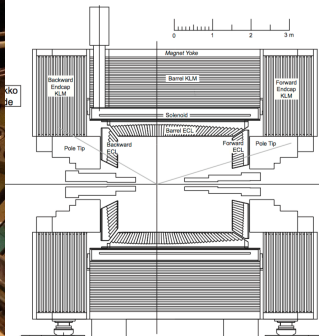
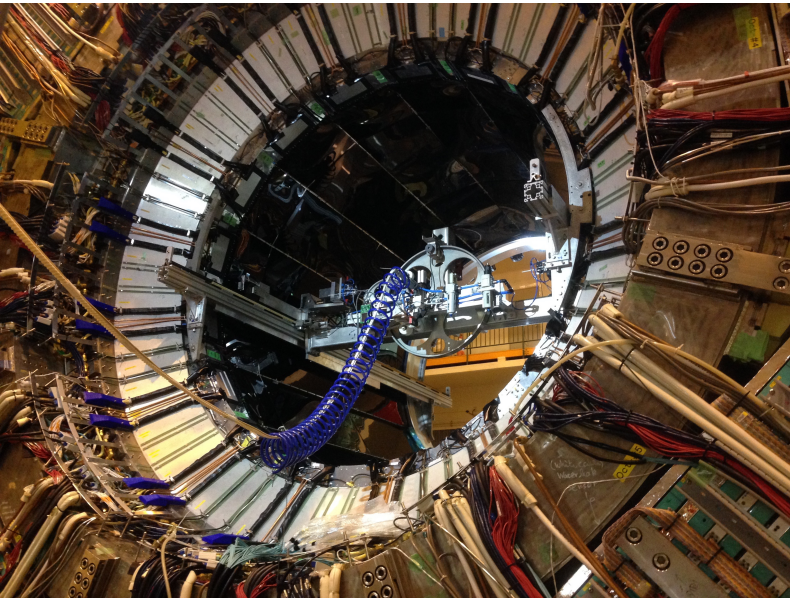


Use $F_x(z)$, $F_y(z)$ as shape of rail, apply rotation on the MC

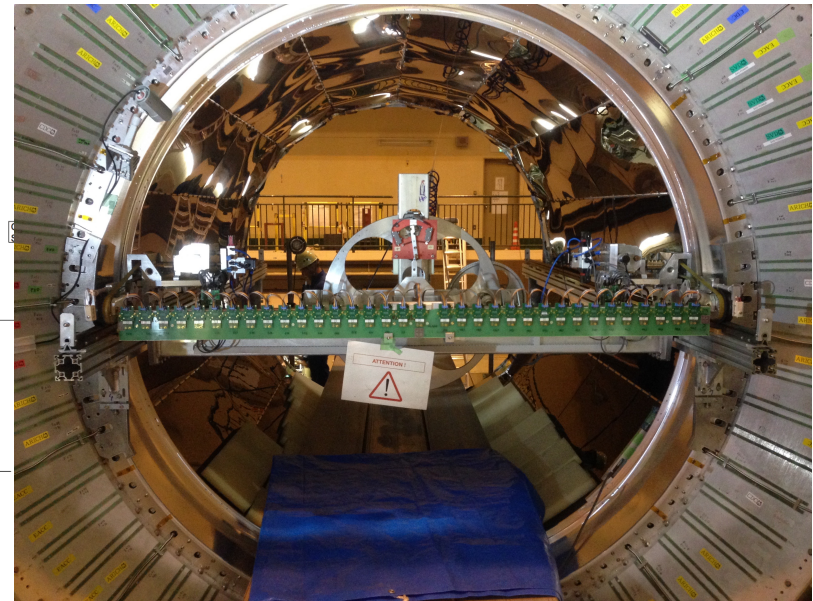
Obtain the mis-alignment of MC

The mapper in the CDC volume

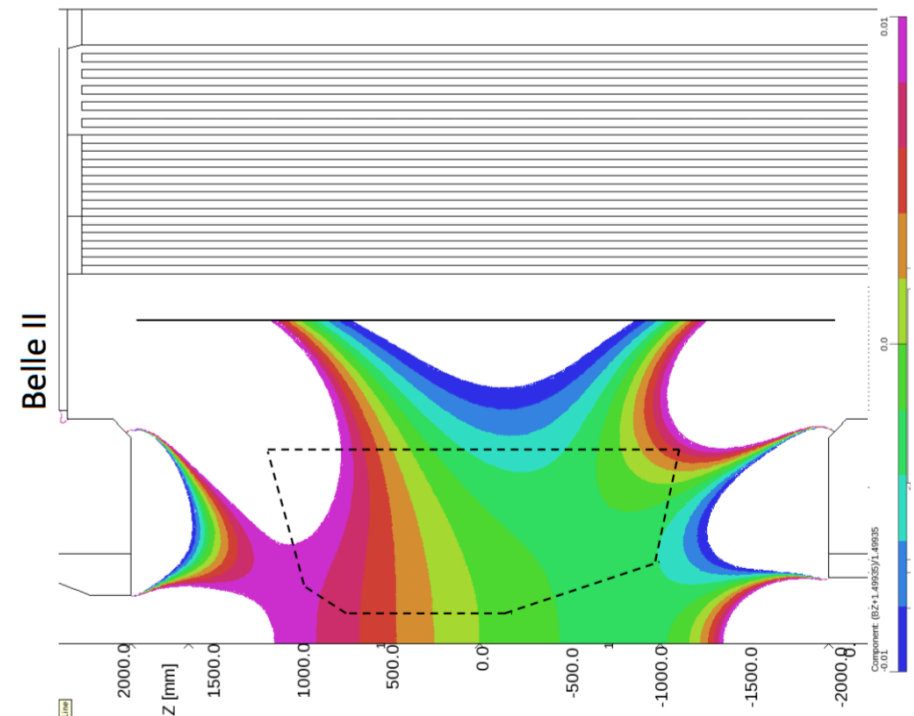
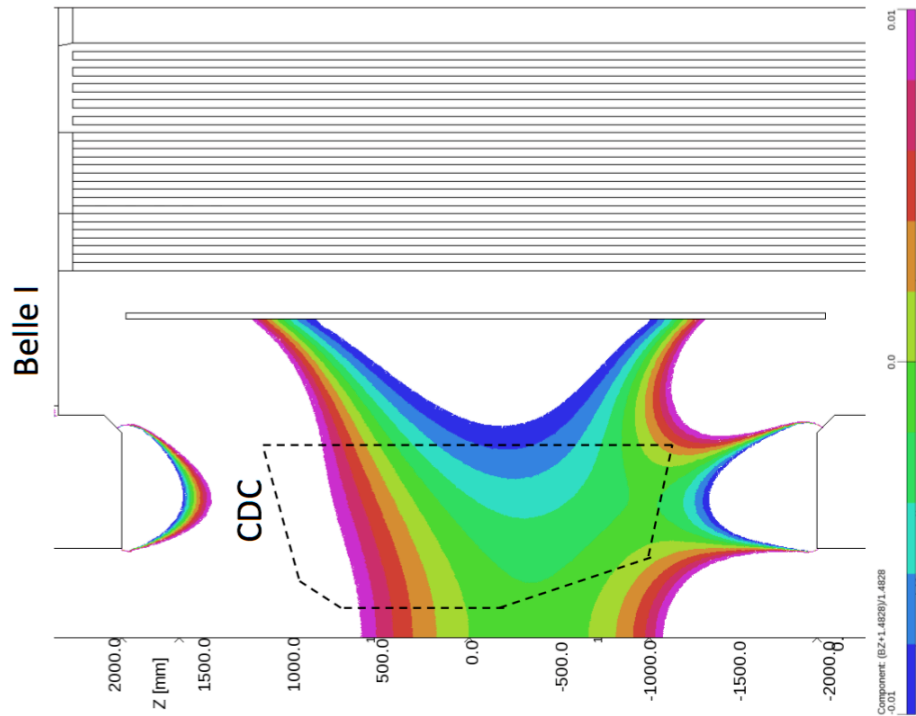
Nikko



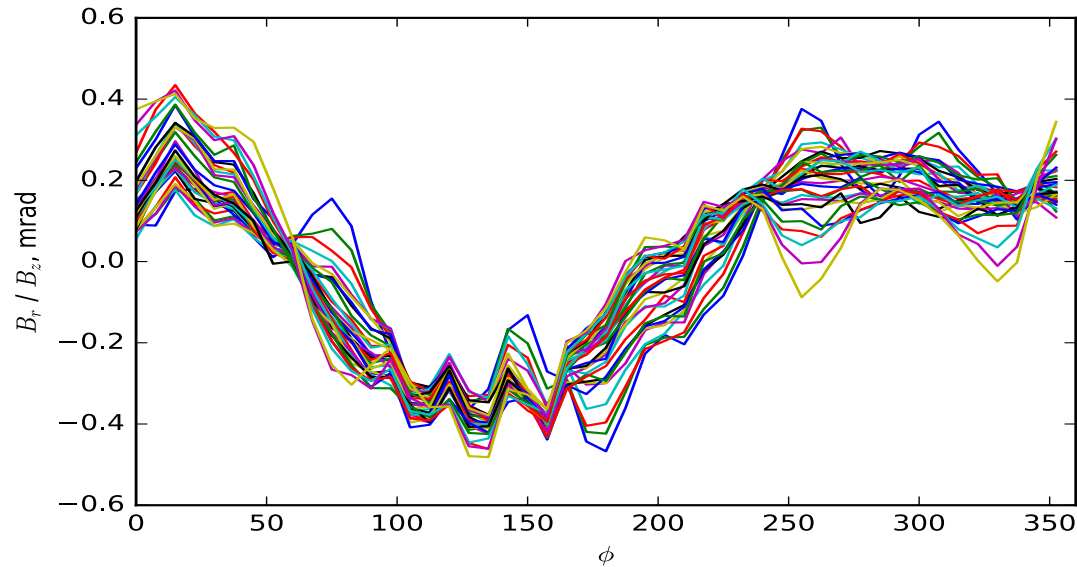
Oho



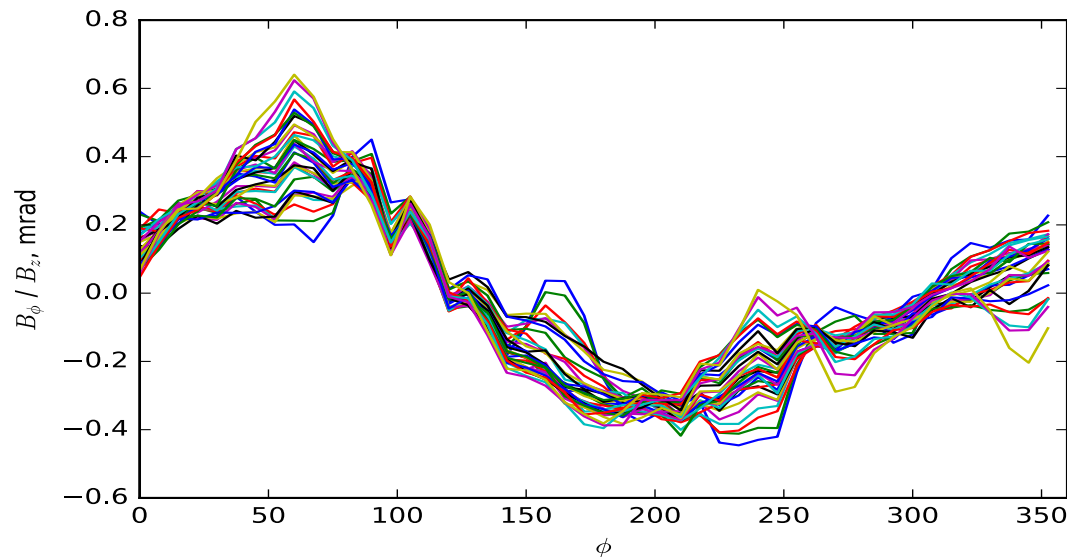
Comparison of solenoid B field



Misalignment observed in data



B_r/B_z
At $Z = 0$ mm
With different R



B_ϕ/B_z
At $Z = 0$ mm
With different R