

Magnetic field studies

- ❖ **Simulation:** TOSCA model and CMSSW map
- ❖ **Measurements:** NMR, Hall Probes, Flux loops
- ❖ Measurement with tracks **from CRAFT data**

Magnetic Field Task Force: Dietrich Liko, Gigi Rolandi, Slava Klyukhin, Martijn Mulders, Sorina Popescu, Alain Herve, Ugo Gasparini, Alicia Calderon, Sara Bolognesi, Lorenzo Bianchini, Jeremy Andrea, Michael Schmitt, Didar Dobur, Jim Pivarski, Jake Ribnik, Nahn Tran, Ivan Mikulec, Vassili Maroussov, Nicola Amapane, Valeri Andreev, Wolfram Zeuner, Benoit Cure, Alberto Benvenuti, Marco Dallavalle, ...

Plots and numbers in this talk

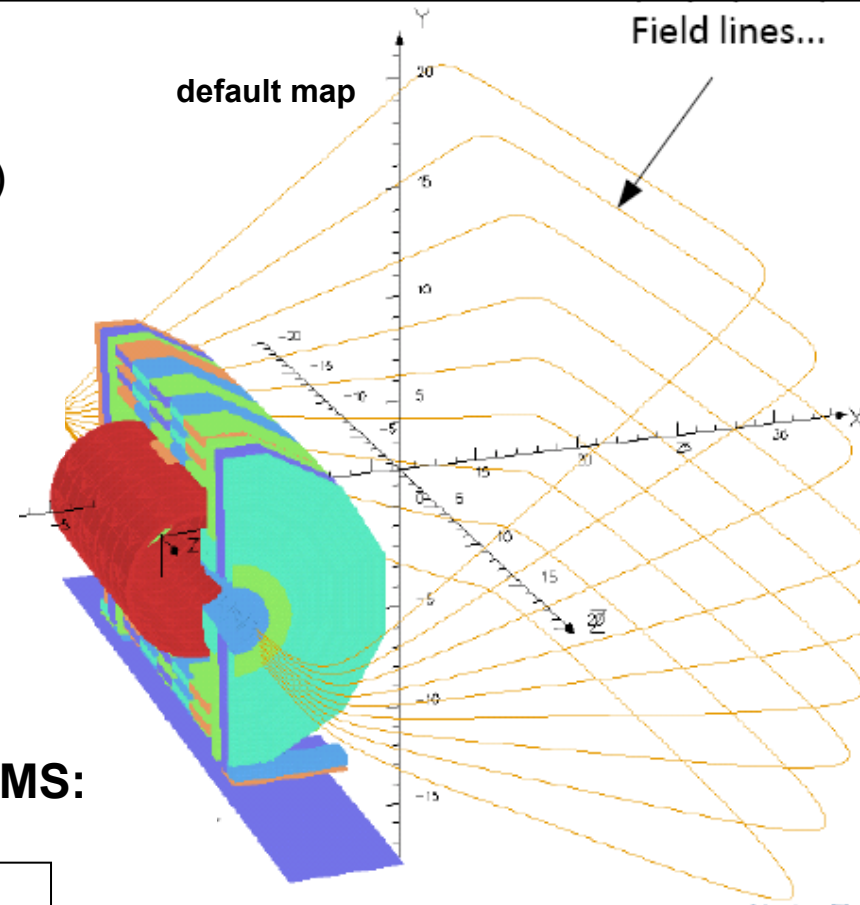
B field simulation: TOSCA

(unphysical)
Field lines...

- ❑ Very detailed description of
 - full solenoid
 - half muon system ($x > 0$, full z length)including shielding, HF, chimneys, feet ...
- ❑ No 'tunable' parameters:
 - field determined by
 - Maxwell's equations
 - geometry
 - current
 - B-H curves

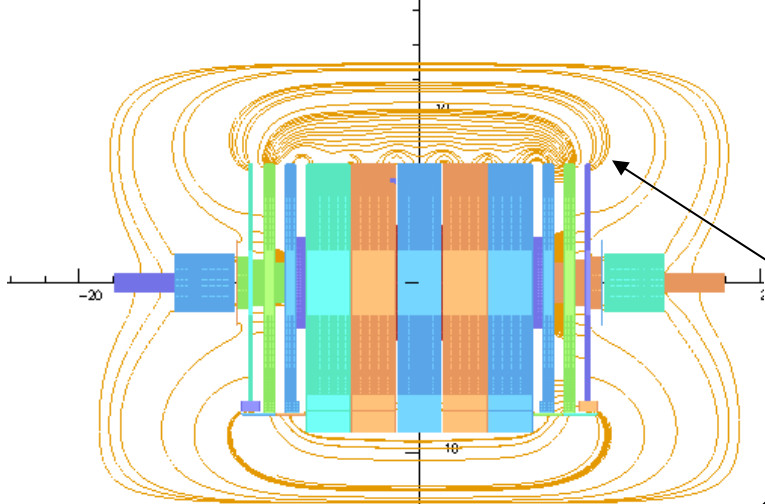
➔ However **improvement obtained increasing R, Z bounds**
i.e. enlarging air volume surrounding CMS:

- | | | |
|------------------------------|----------|----------|
| ▪ <u>default</u> : | R = 13 m | Z = 20 m |
| ▪ <u>increased R</u> : | R = 30 m | Z = 20 m |
| ▪ <u>increased R and Z</u> : | R = 30 m | Z = 30 m |

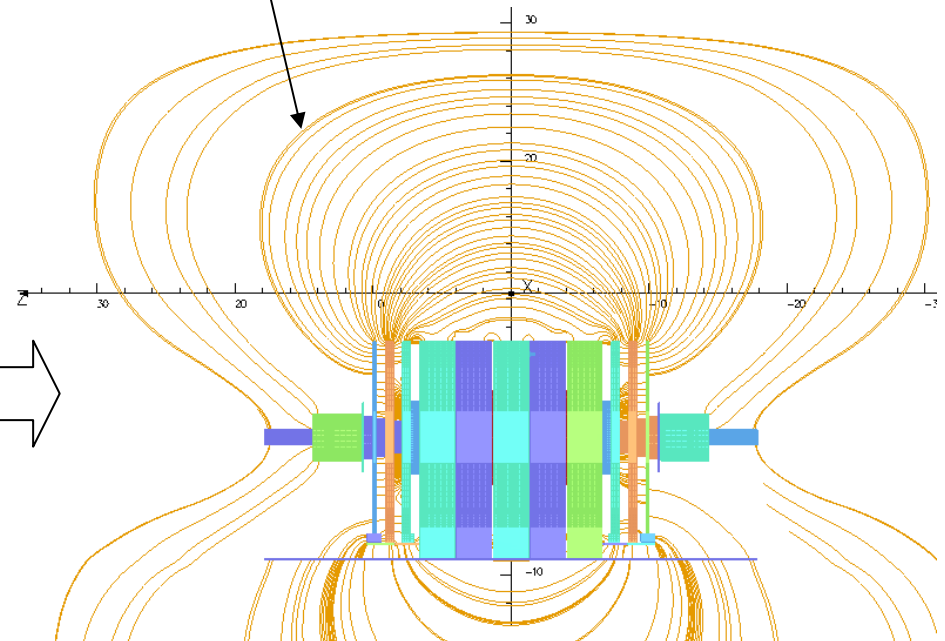
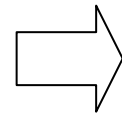
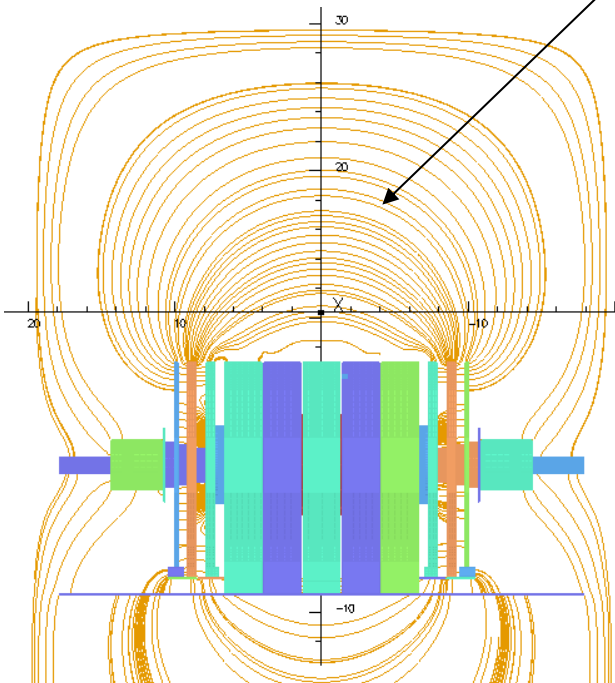


(floor iron plate also added)

Flux lines



- default: R = 13 m Z = 20 m
- increased R: R = 30 m Z = 20 m
- increased R and Z: R = 30 m Z = 30 m



Increased R map

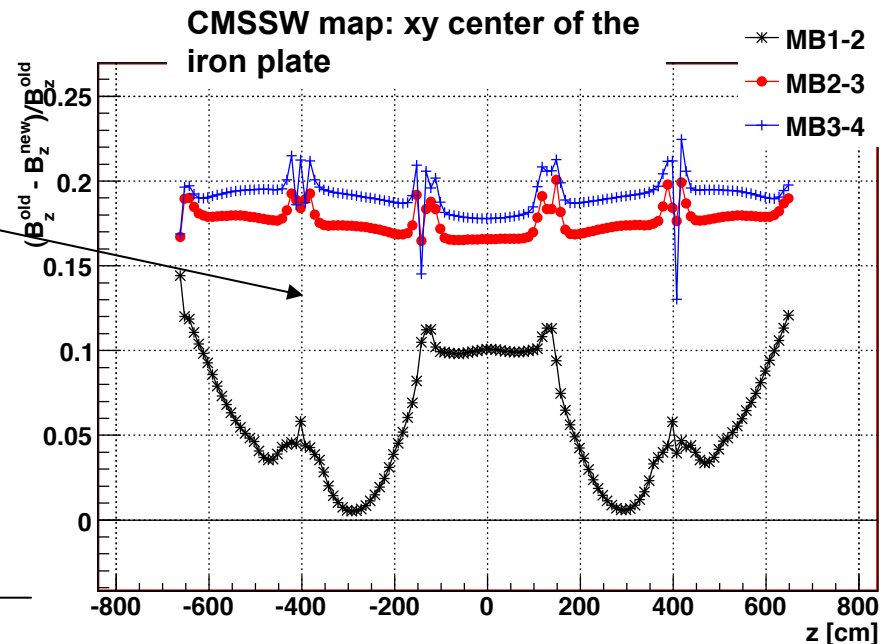
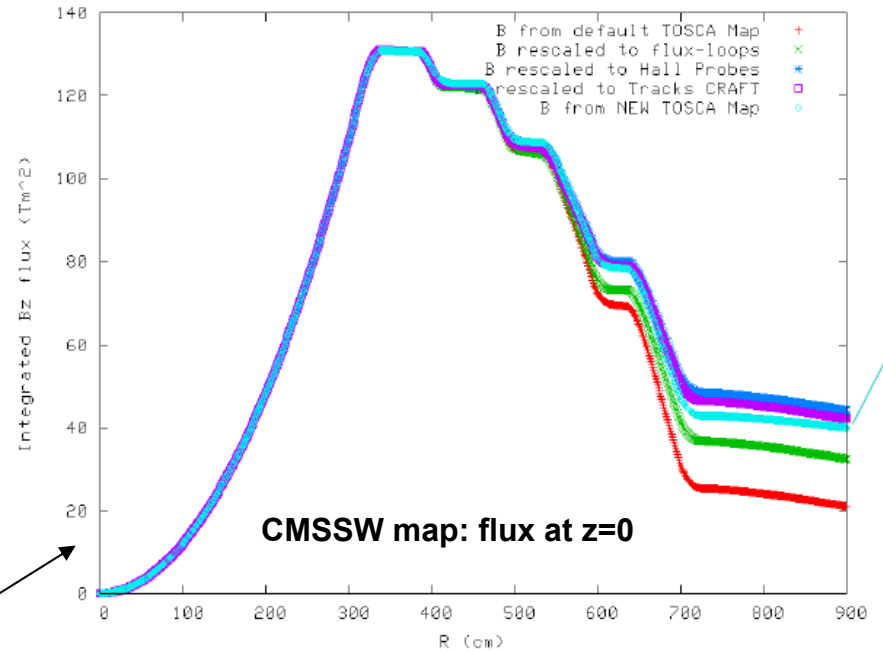
Comparison between default map and R increased map:

R bound of air volume around CMS increased from 13m to 30m



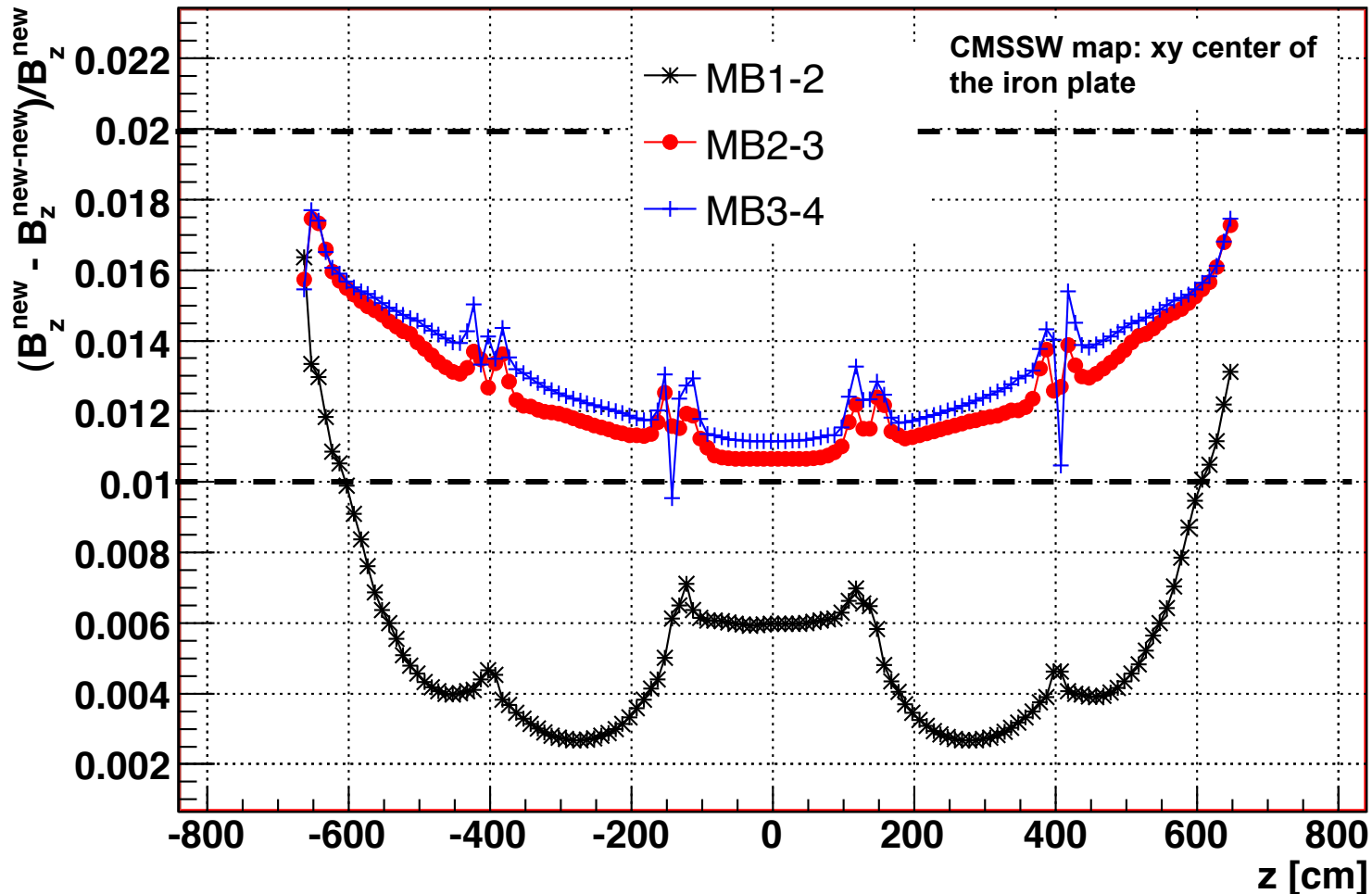
Lower return flux in the iron, more in the air outside CMS

- ~19% less field in MB3-4
- ~17% less field in MB2-3
- 0-15% less field in MB1-2: variation strongly dependent on z



Increased R-Z map

□ Relative difference between increased R map and increased R-Z map



Implementing TOSCA map in CMSSW

- CMSSW map:

only sector 1 from TOSCA used to build a **12-fold ϕ -symmetric** map

- Moving to a non ϕ -symmetric CMSSW map requires a big effort (time scale \sim end of the year)

- How large is the **expected ϕ asymmetry** ?

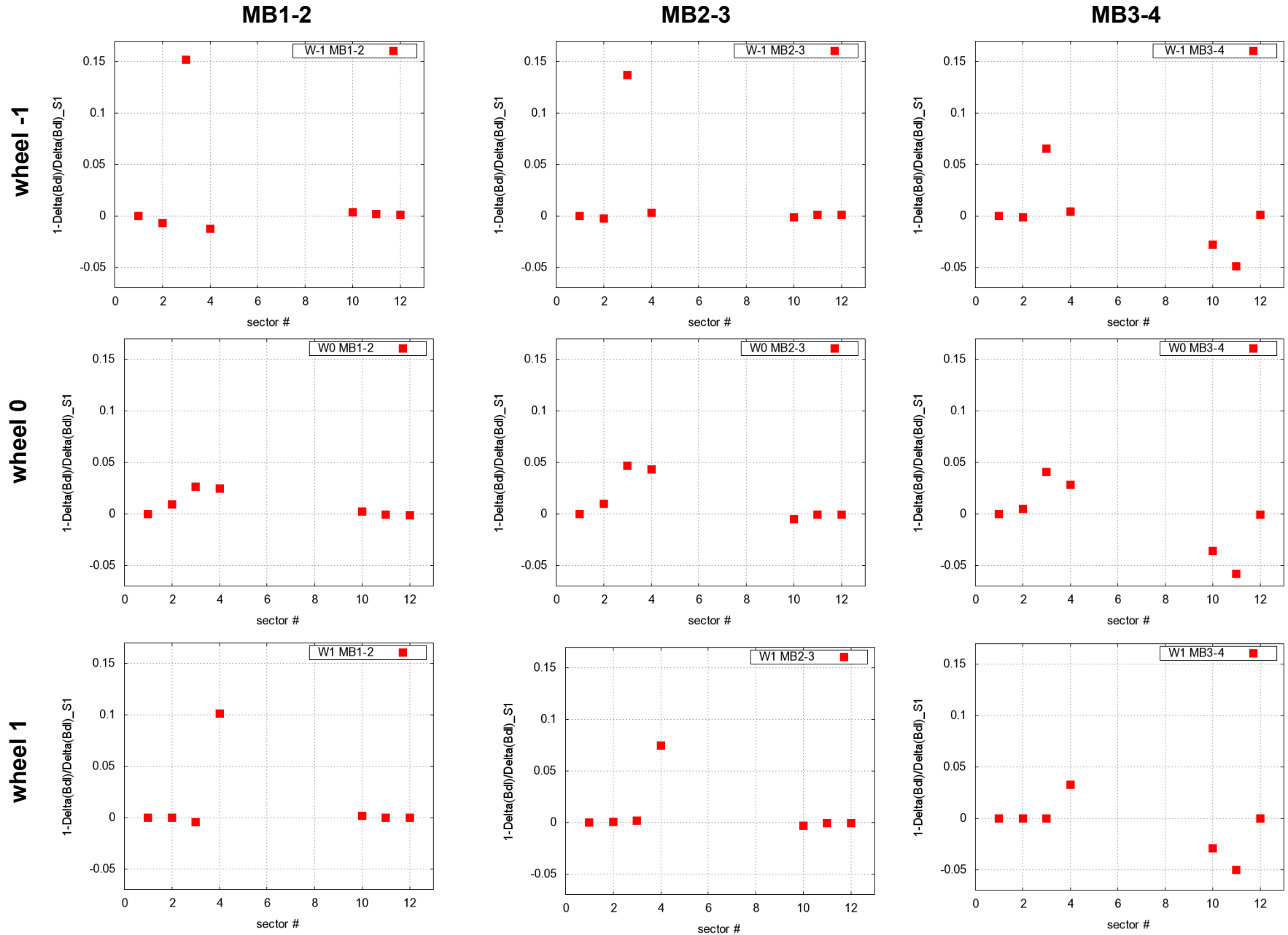
- due to **chimneys and feet**

- next slide: $\int B \times dl$ in TOSCA for pointing muons $\left\{ \begin{array}{l} \text{wheel 0: } |\eta| = 0.43 \\ \text{wheel +/-1: } |\eta| = +/-0.43 \end{array} \right.$

computed for each yoke layer (MB1-2, MB2-3, MB3-4)

normalized to integral in sector1 \rightarrow **relative difference of each sector**

ϕ asymmetry in TOSCA



B field measurements

- **Field Mapper** during **MTCC**

- **CRAFT** status:
 - a few **NMR probes** in the solenoid
 - 22 **flux loops** in the barrel yoke
 - 82 **Hall probes** in barrel/endcaps yoke

- Preparation for **CRAFT09**:
 - 32 more Hall sensors ordered
 - on YB-, sector 4 and possibly other sectors (6,12) and HF-
 - under investigation: automatic readout → data storage on DB

Solenoid: field mapper and NMR probes

□ **2006 MTCC** measurements at various B values with field mapper:
agreement with TOSCA simulation at 0.1%

□ **NMR 2006** data comparison with simulation at 4T:

Bz meas 4 (T)	Bz calc (T)	(calc-meas)/meas (%)	X (m)	Y (m)	Z (m)
4.1263	4.1247	-0.04	2.06345	2.0587	-0.01
4.1262	4.1248	-0.04	-2.06345	2.0587	0.01

□ **NMR** data comparison at 3.8T **between 2006 and 2008**:
agreement better than 0.1%

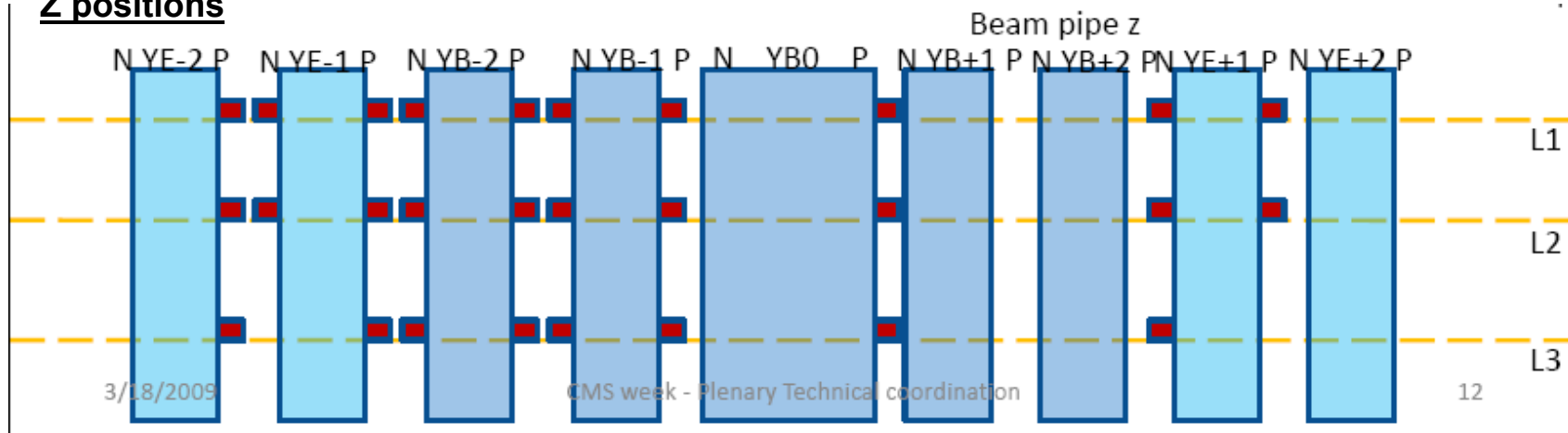
Flux loops

- ❑ Measurement **in iron**
- ❑ Only at **sector 10**, only during fast dump (only at **surface with 4T**)
- ❑ **Big systematics**:
 - subtraction of remnant field (50-80 mT) **<10%**
 - knowledge of flux loop area **<2%**
 - voltage integration **2%**

- ❑ **Discrepancies 5-20% w.r.t. default TOSCA model**
 - ➔ **with R increased TOSCA model** (version with 4T, on-surface configuration) general improvement:
discrepancies <10% for 19/22 measurements

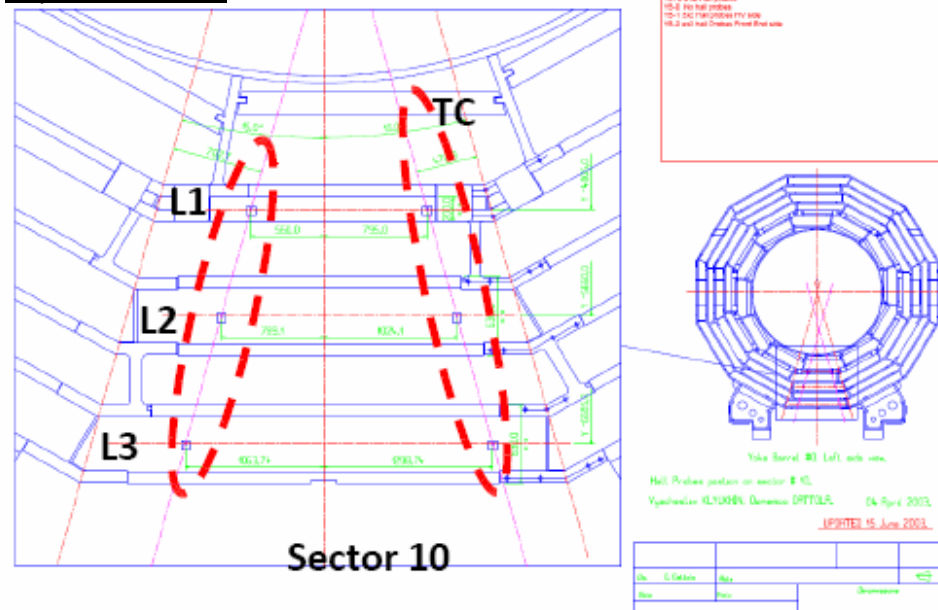
Hall probes

Z positions

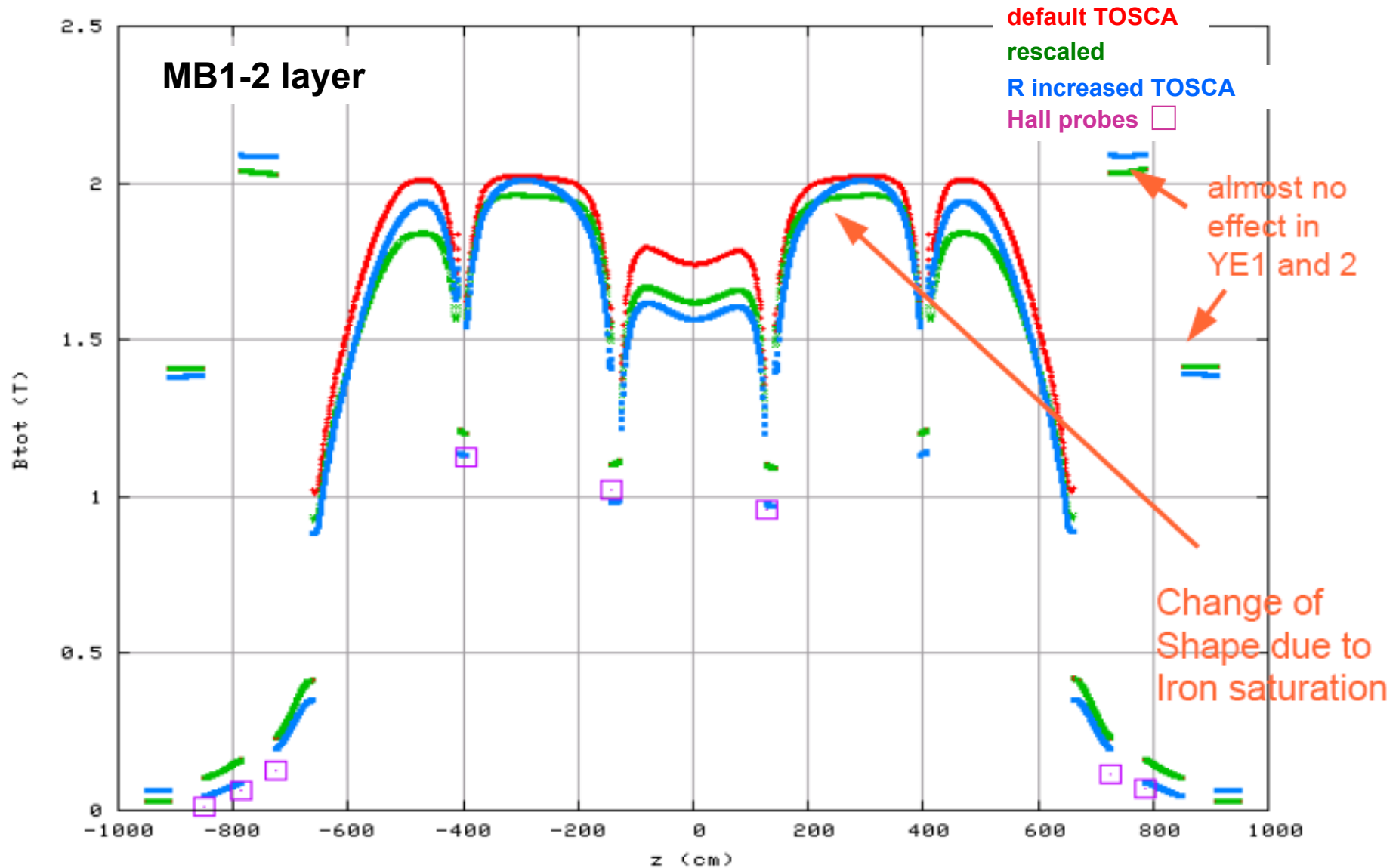


- Not all still working
- Measurement in air

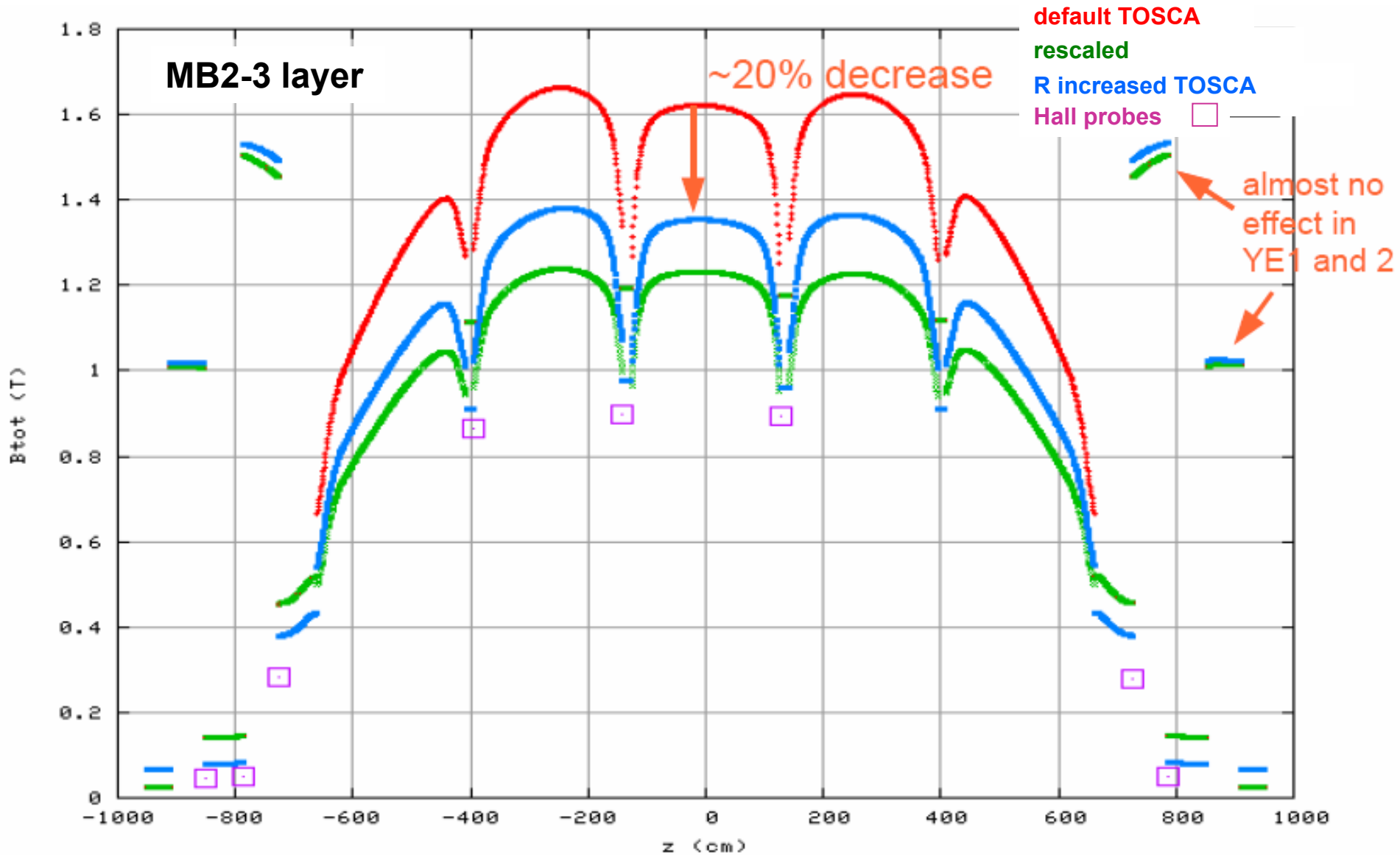
Rφ positions



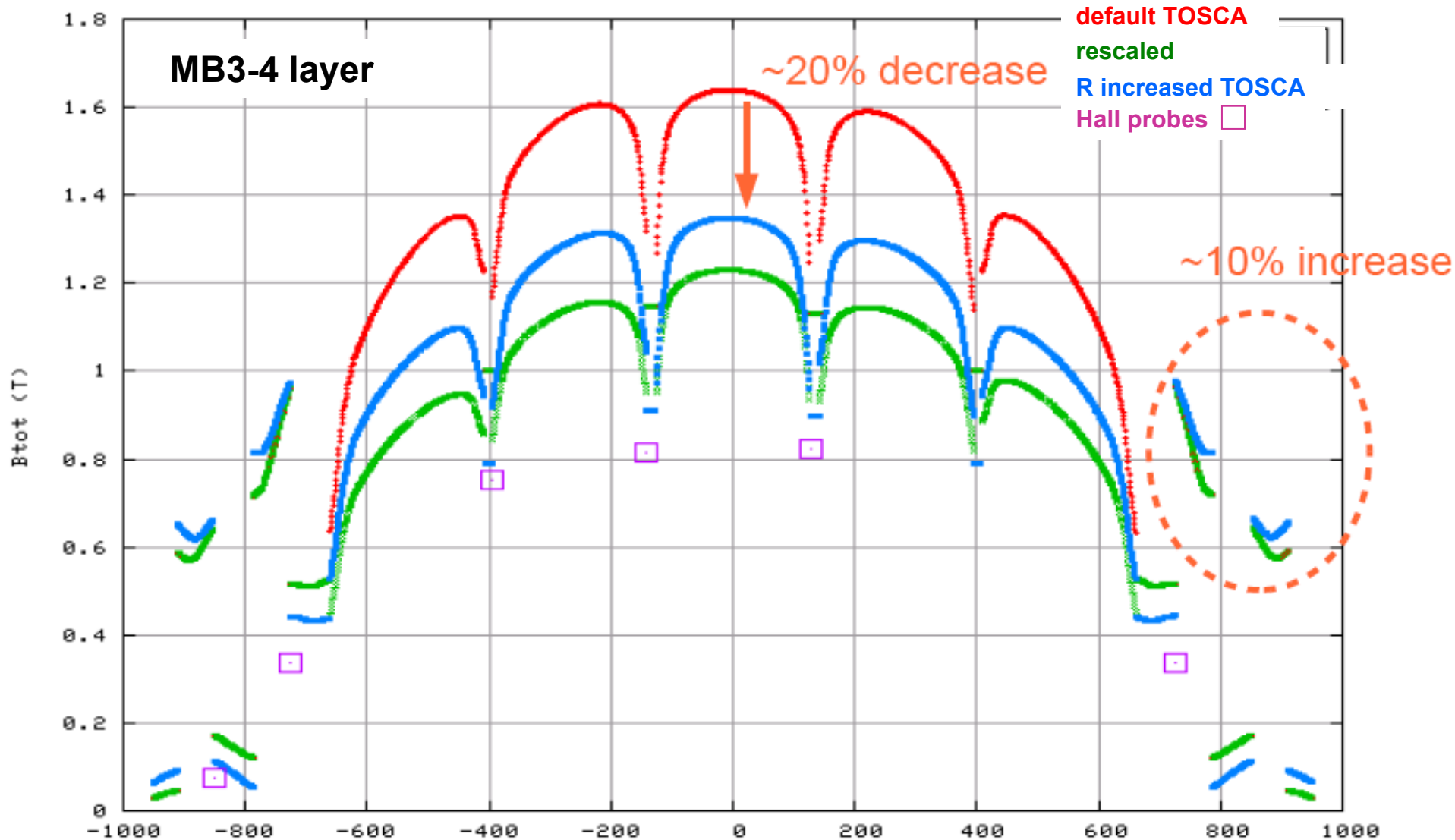
Comparison: Hall probes - TOSCA



Comparison: Hall probes - TOSCA



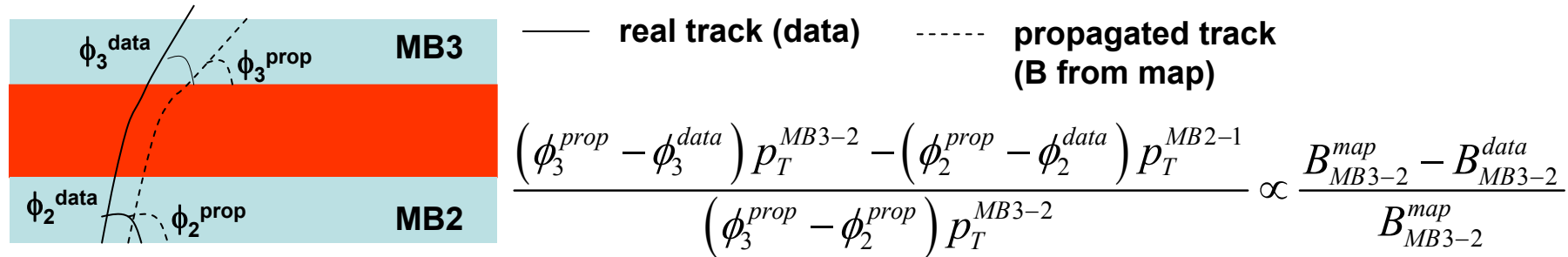
Comparison: Hall probes - TOSCA



CRAFT track analysis

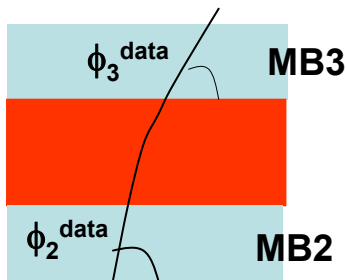
- ❑ **Discrepancy up to 20% in the scale** of standalone muons w.r.t. inner tracker
 → 2 parallel analyses to **measure the B field in barrel yoke from CRAFT data**:

- **“Method 1”**:

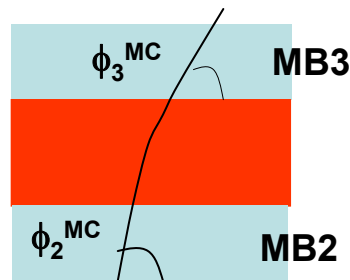


- **“Method 2”**:

Event from CRAFT



Event from MC

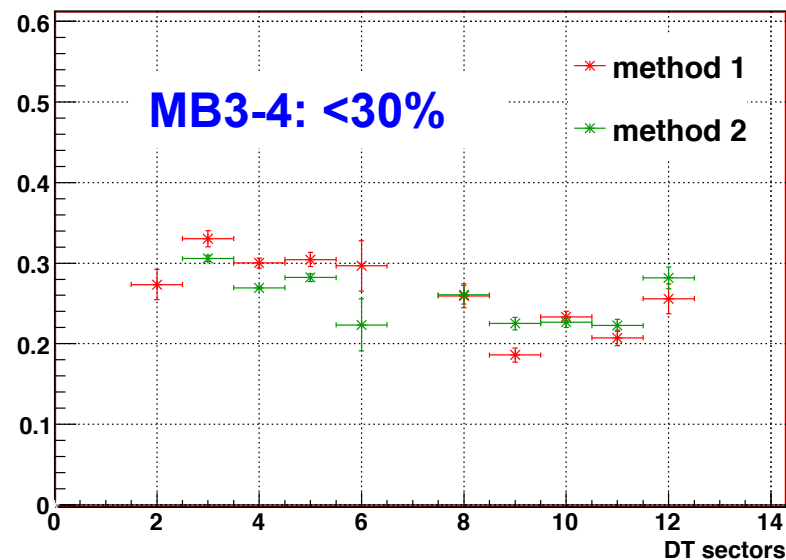
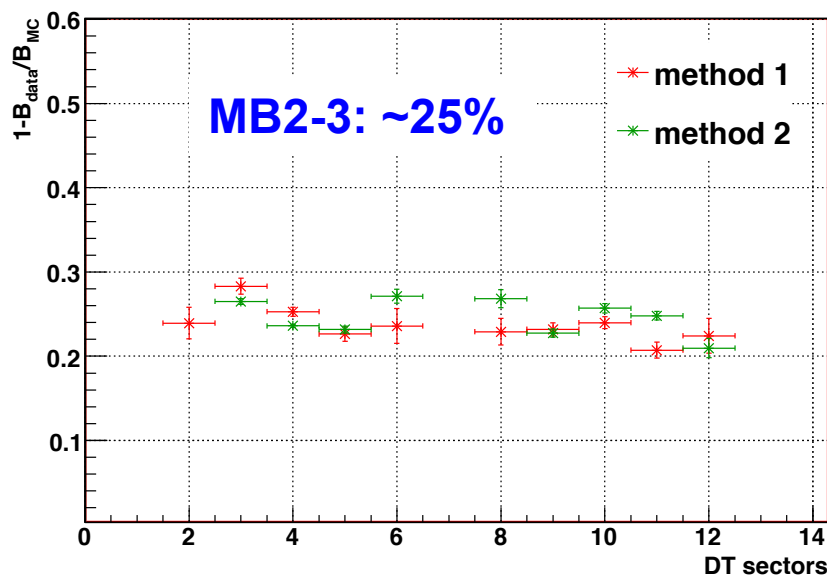
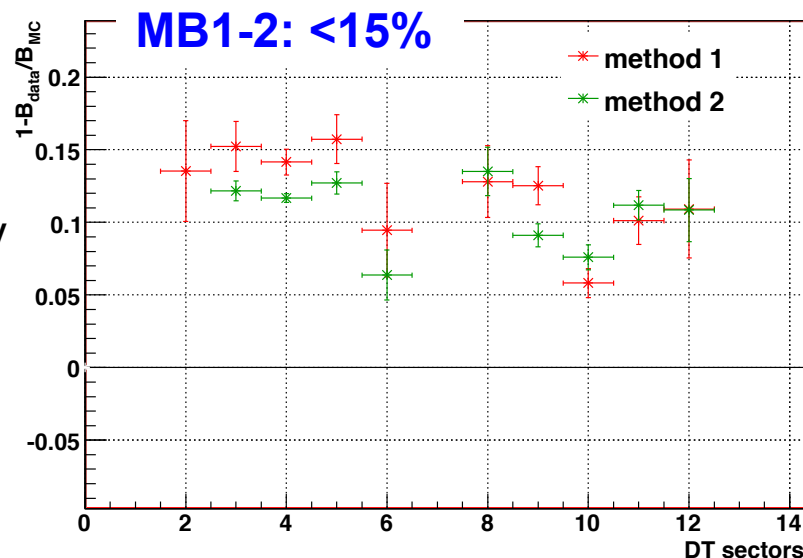


$$\frac{(\phi_3^{MC} - \phi_2^{MC}) p_T^{MB3-2} - (\phi_3^{data} - \phi_2^{data}) p_T^{MB3-2}}{(\phi_3^{MC} - \phi_2^{MC}) p_T^{MB3-2}} \propto \frac{B_{MB3-2}^{map} - B_{MB3-2}^{data}}{B_{MB3-2}^{map}}$$

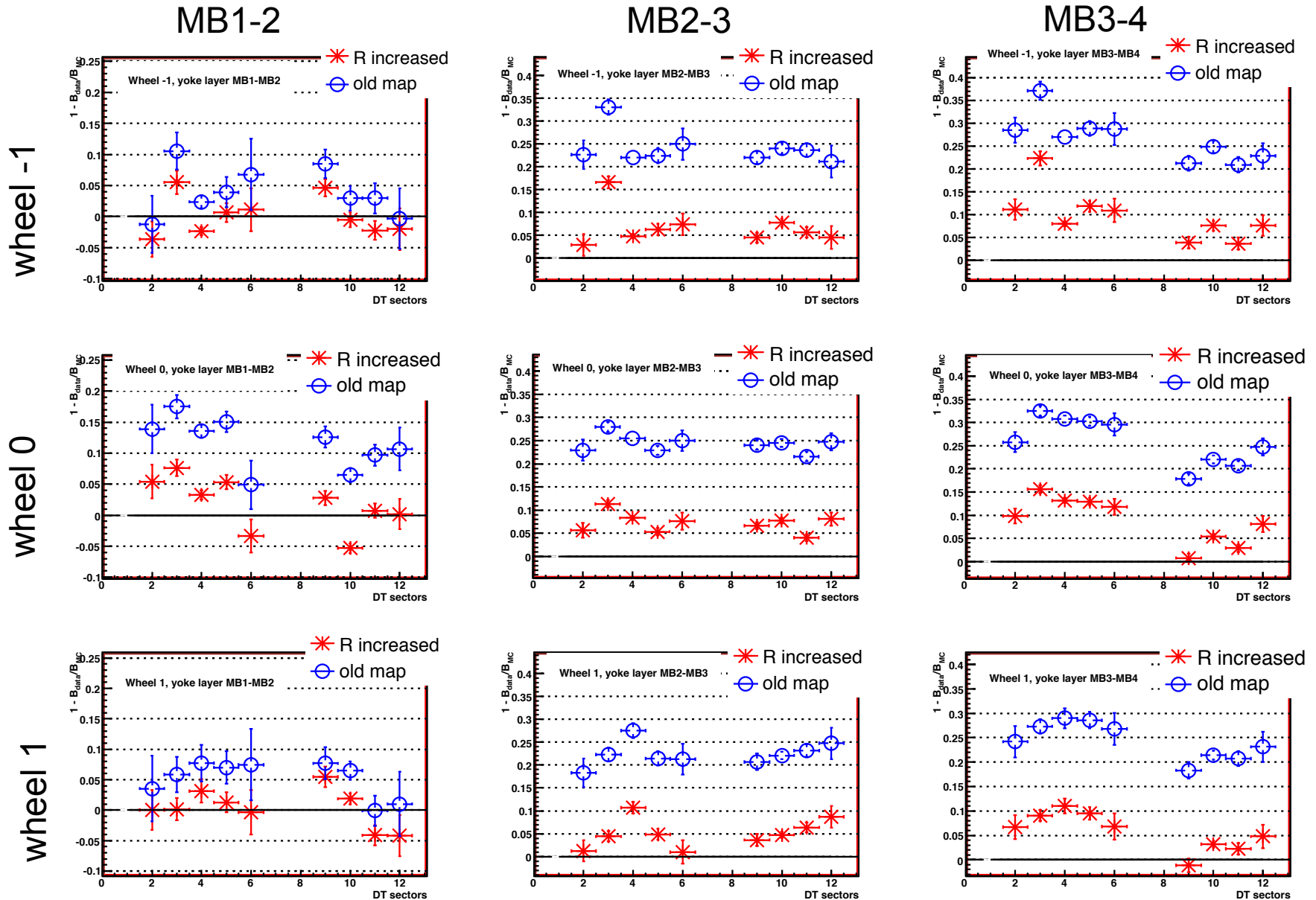
- **antisymmetric part between opposite charge** → misalignment effect

Results with default B map (wheel 0)

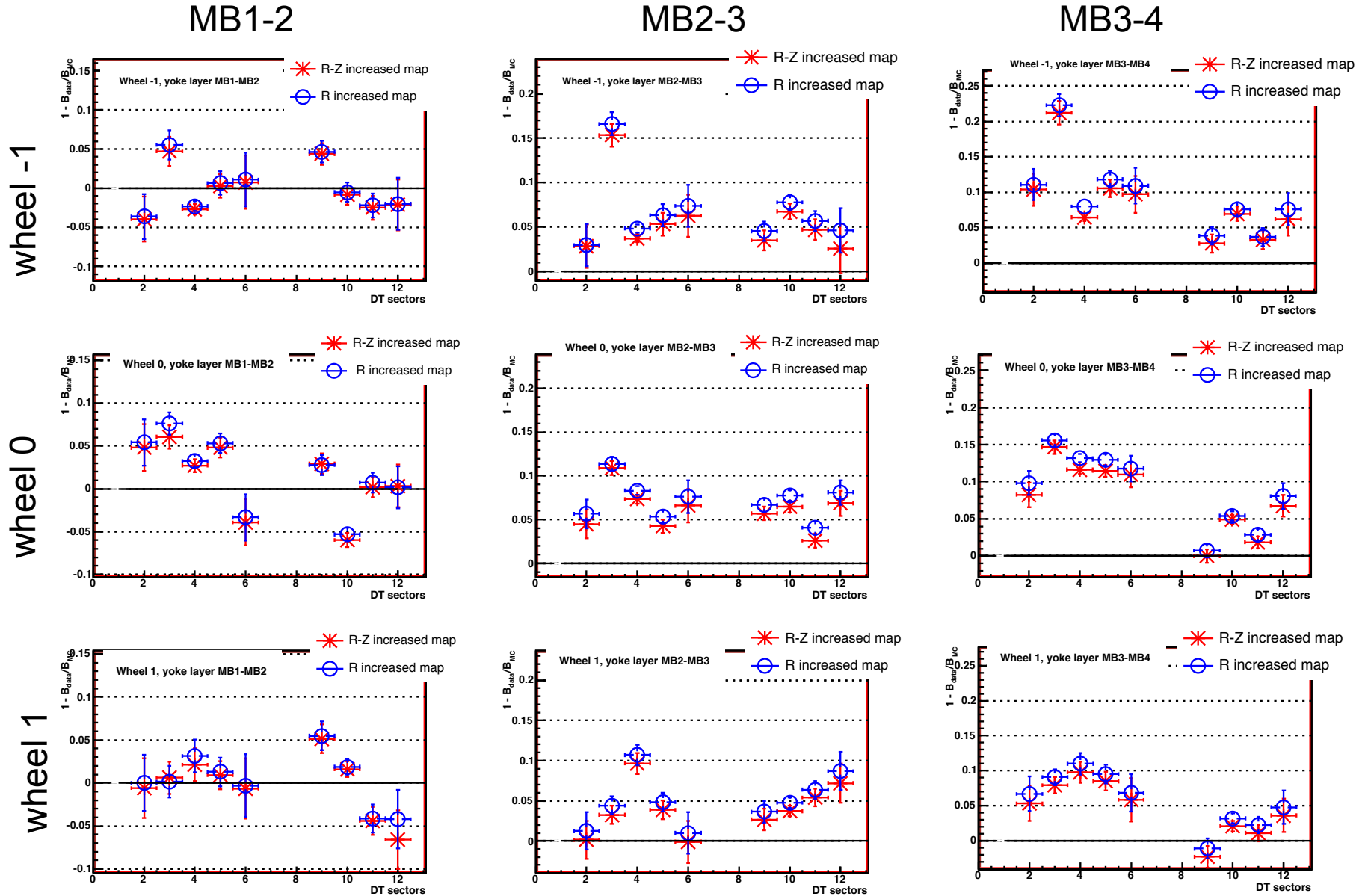
- ❑ Data-map discrepancy increases from inner to outer yoke layer
- ❑ Agreement between method satisfactory → better understanding of uncertainties needed
(see next slides about systematics on rescaling factors)



Results with R increased map



Results with R-Z increased map



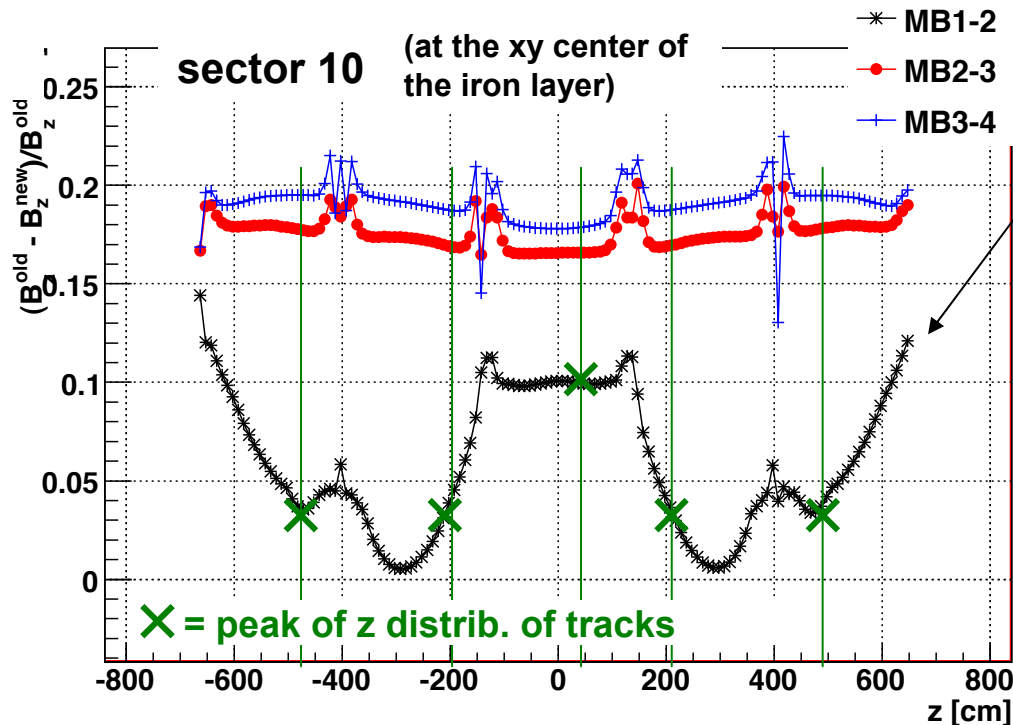
A new approach is needed to improve further the simulation!!

Systematics on rescaling factors

❑ Rescaling factors measured from data can be compared to **B bias** estimated considering:

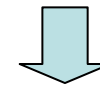
increased R map = real field, default = our knowledge

❑ We assume B bias uniform in each sector/wheel (→ one rescaling factor) but ...



B bias is NOT uniform VS z in layer MB12, wheels $\pm 1, \pm 2$

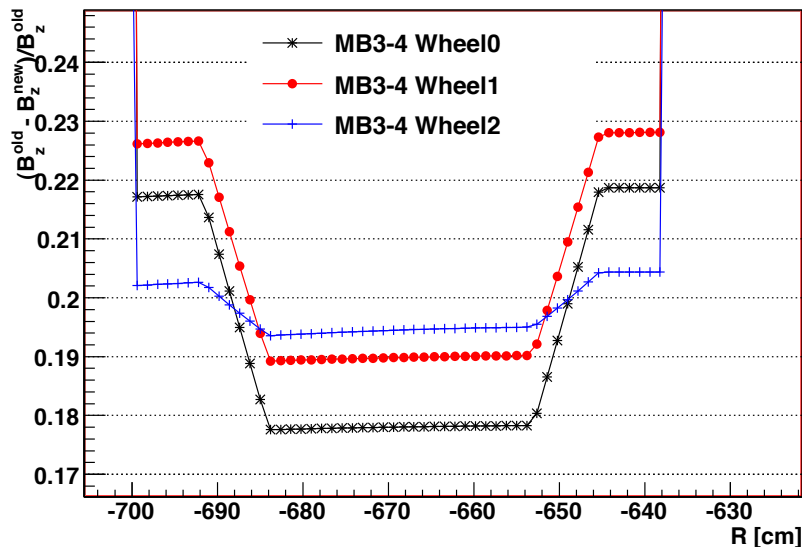
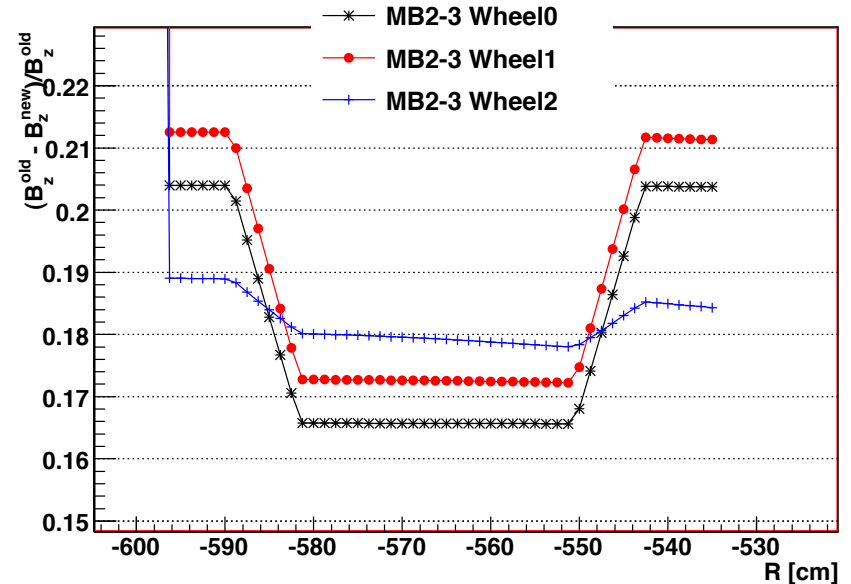
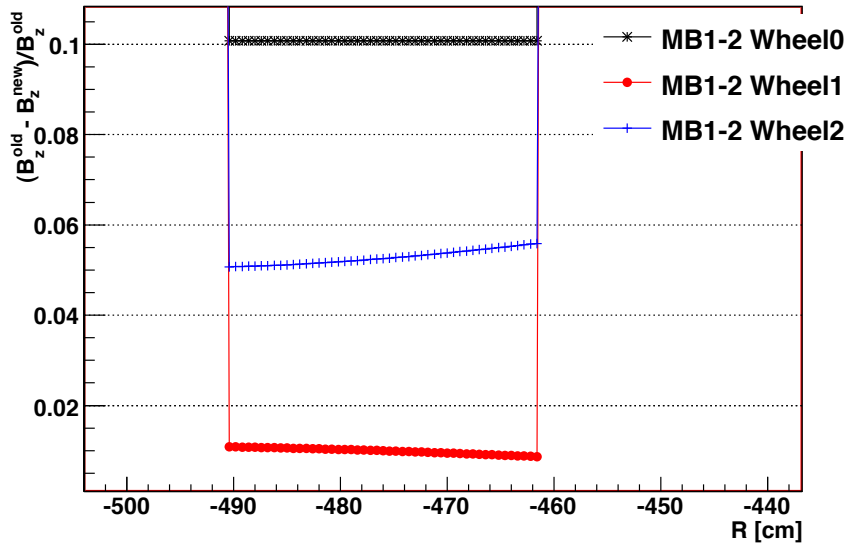
(large cosmic statistics is needed to measure this kind of effect from data)



In these regions rescaling factors under/over-estimated, depending on the z distribution of cosmic tracks!

B bias depends on R

Estimated considering: R increased map = real field, default = our knowledge



- B bias changes in each iron type following different magnetization curves
- forget to measure B_z VS R from data!

❑ Rescaling factor corrects average
→ correct bending...

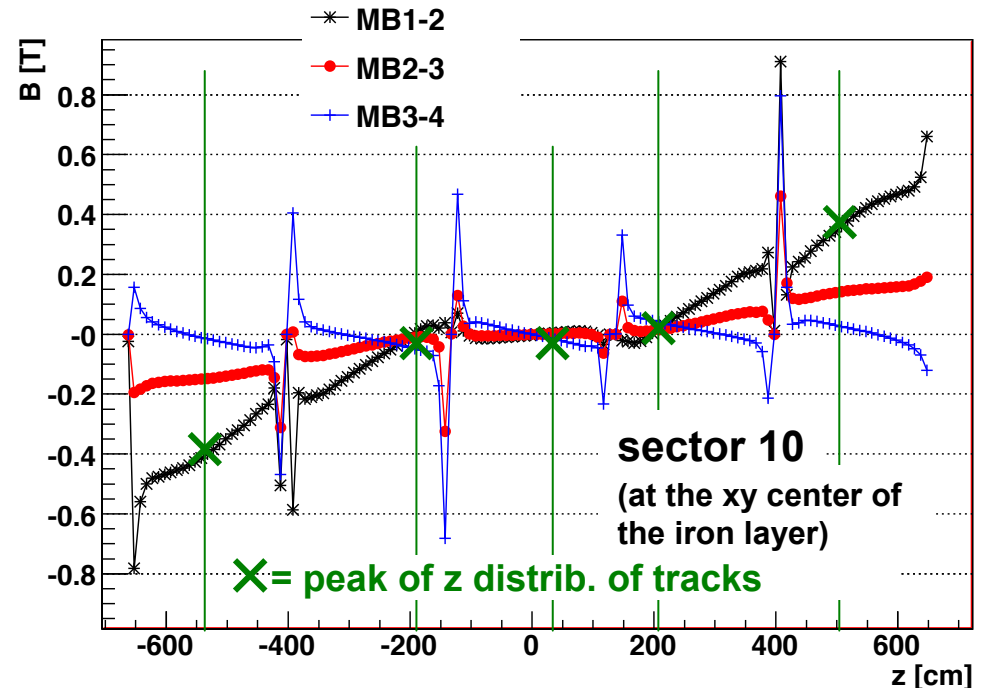
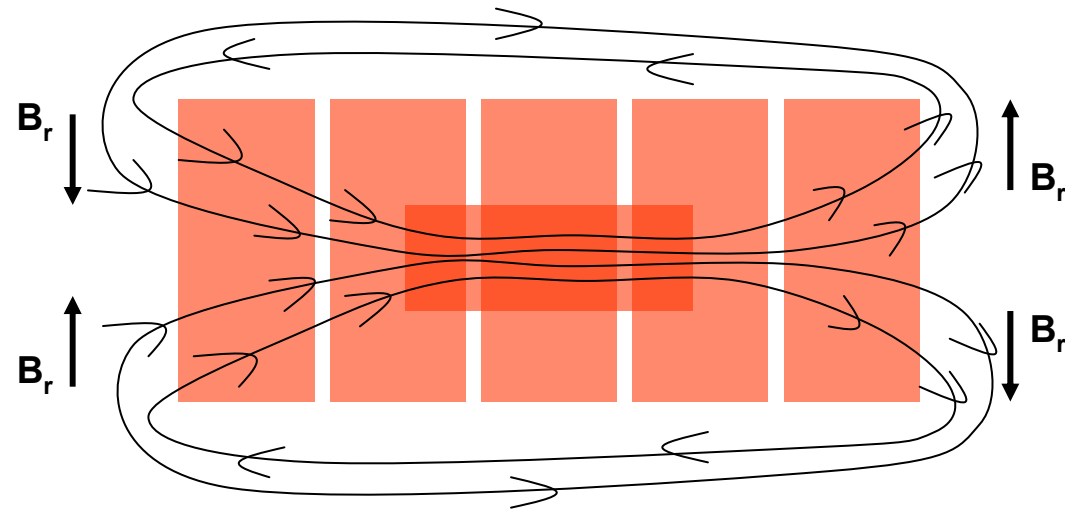
... but different distribution affects the position of the muon after having traversed the iron layer!!

Effect of B_r (1)

□ Radial component gives curvature with same sign and direction of B_z

$$\Delta\varphi \cdot p_T \propto B_z L + B_r L \cot\theta$$

□ $B_z \gg B_r \rightarrow \theta$ must be big to see some effects \rightarrow mainly in external wheels



Effect of B_r (2)

- Fraction of bending due to radial component:

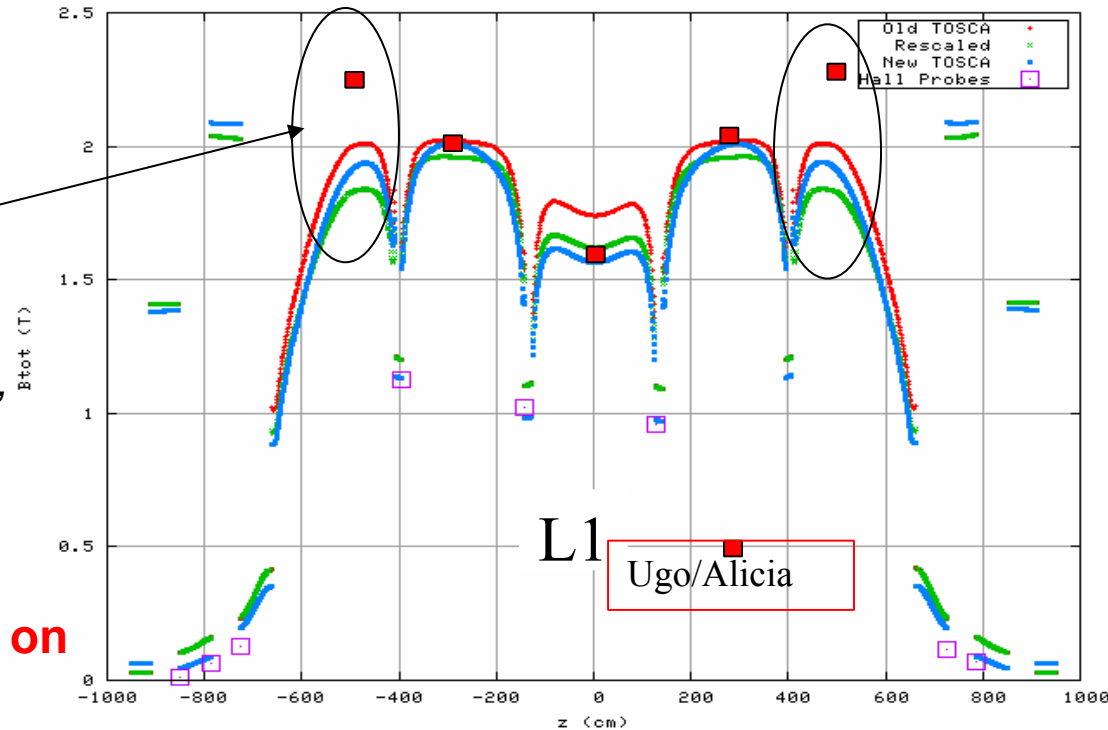
$$B_r L \cot \theta / (B_r L \cot \theta + B_z L)$$

Wheel -2, sec 10: MB1-2: ~ **13%**

MB2-3: ~ **5%**

- If we want to measure directly B_r , without normalizing to propagator (or MC), there are sizable systematics effects !!!

- These become **2° order effects on rescaling factors (1-2%)**



❑ **Rescaling factors**, while improving the matching of the map with data, **introduce systematics (up to few % in some regions):**

- useful in chimney sectors
- systematic effects in external wheels

➡ In any case it is **essential to start from a map as realistic as possible** to minimize variation of rescaling factors with z , B component, etc...

Conclusions for barrel region

❑ It is worth to break the ϕ symmetry in CMSSW?

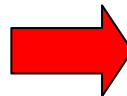
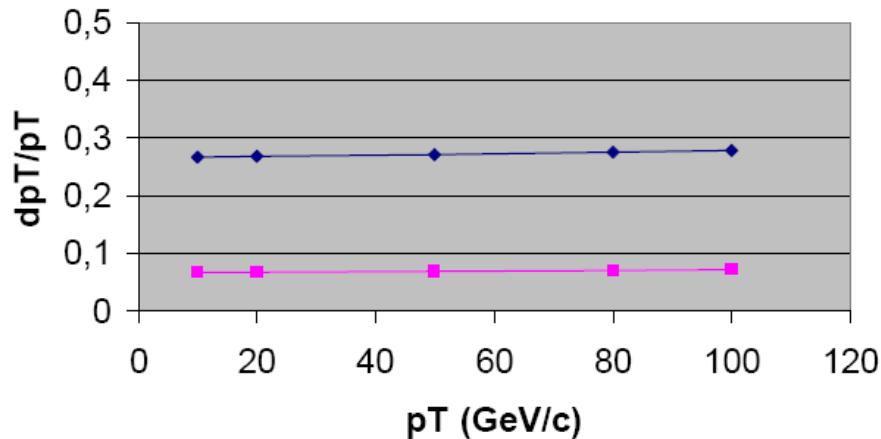
- deeper study of the ϕ asymmetry in TOSCA just started
- to be compared with the ϕ asymmetry in the rescaling factors

→ **short term: better modeling of chimney sectors**

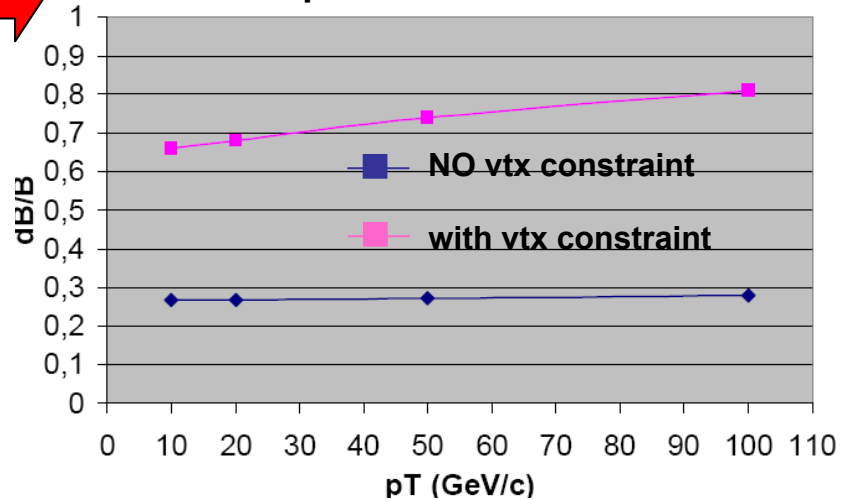
❑ At which precision on B we should aim?

Resolution expected from first principle

L. Bianchini CMS AN 2008/107



Error on the field that gives scale bias \sim previous resolution



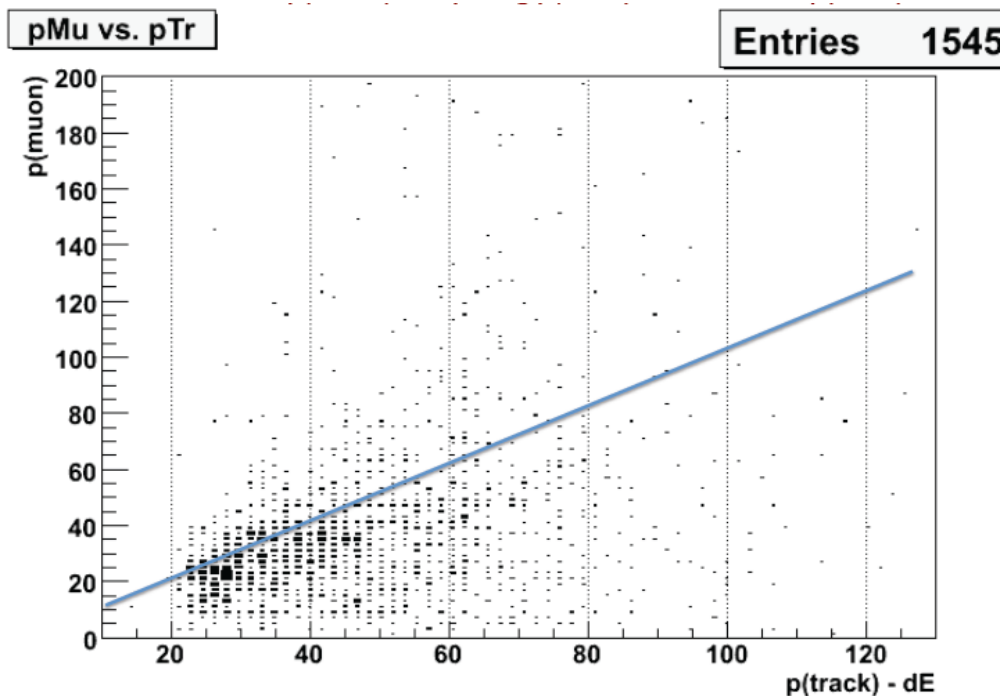
with vertex constraint: 70-80% error \rightarrow 7-9% resolution on STA

Endcap analysis: previous approach

- Comparison between p measured in CSC and in the inner tracker, subtracting energy loss in calorimeters

$$\frac{P_{CSC}}{P_{inntrack} - \Delta E}$$

- But p in CSC is not reliable beyond 25 GeV because of misalignment:



Endcap new approach

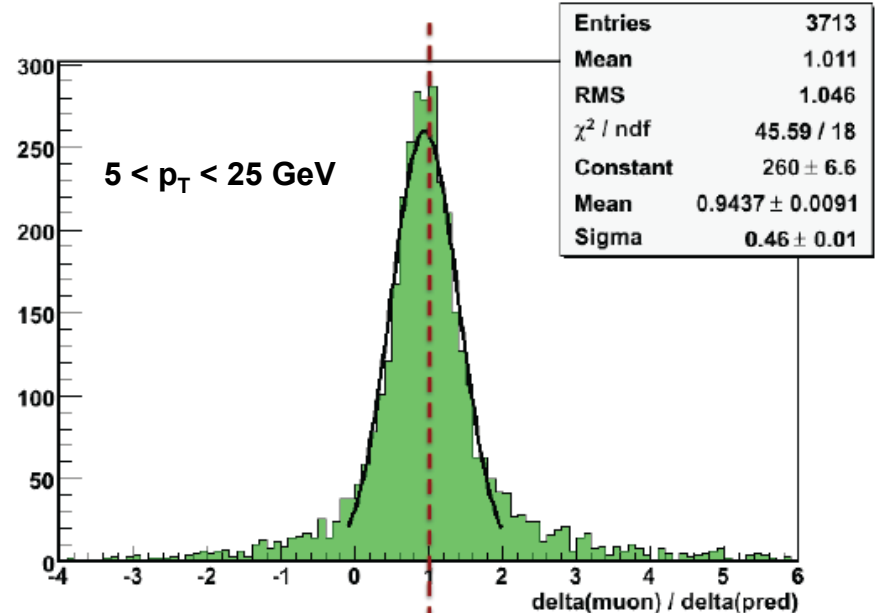
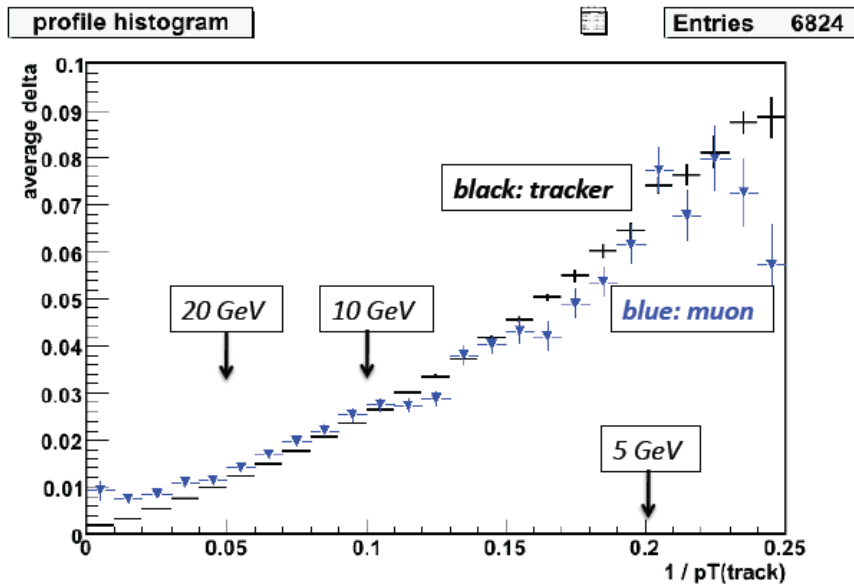
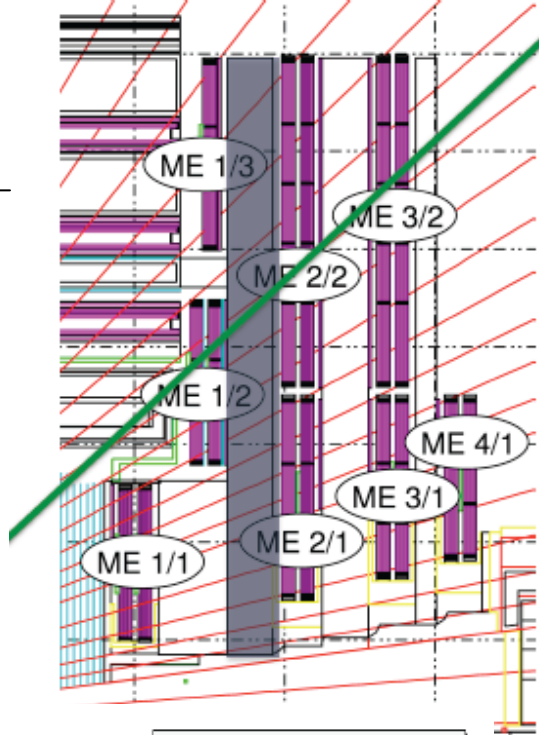
$$\delta = (\vec{s}_1 \times \hat{B}) \cdot \vec{s}_2$$

s_1, s_2 are normalized segments direction in ME1, ME2

B assumed radial for now

- Comparison between δ measured by CSC and δ expected by propagated inner track

(these results refer only to $Y < 0$)

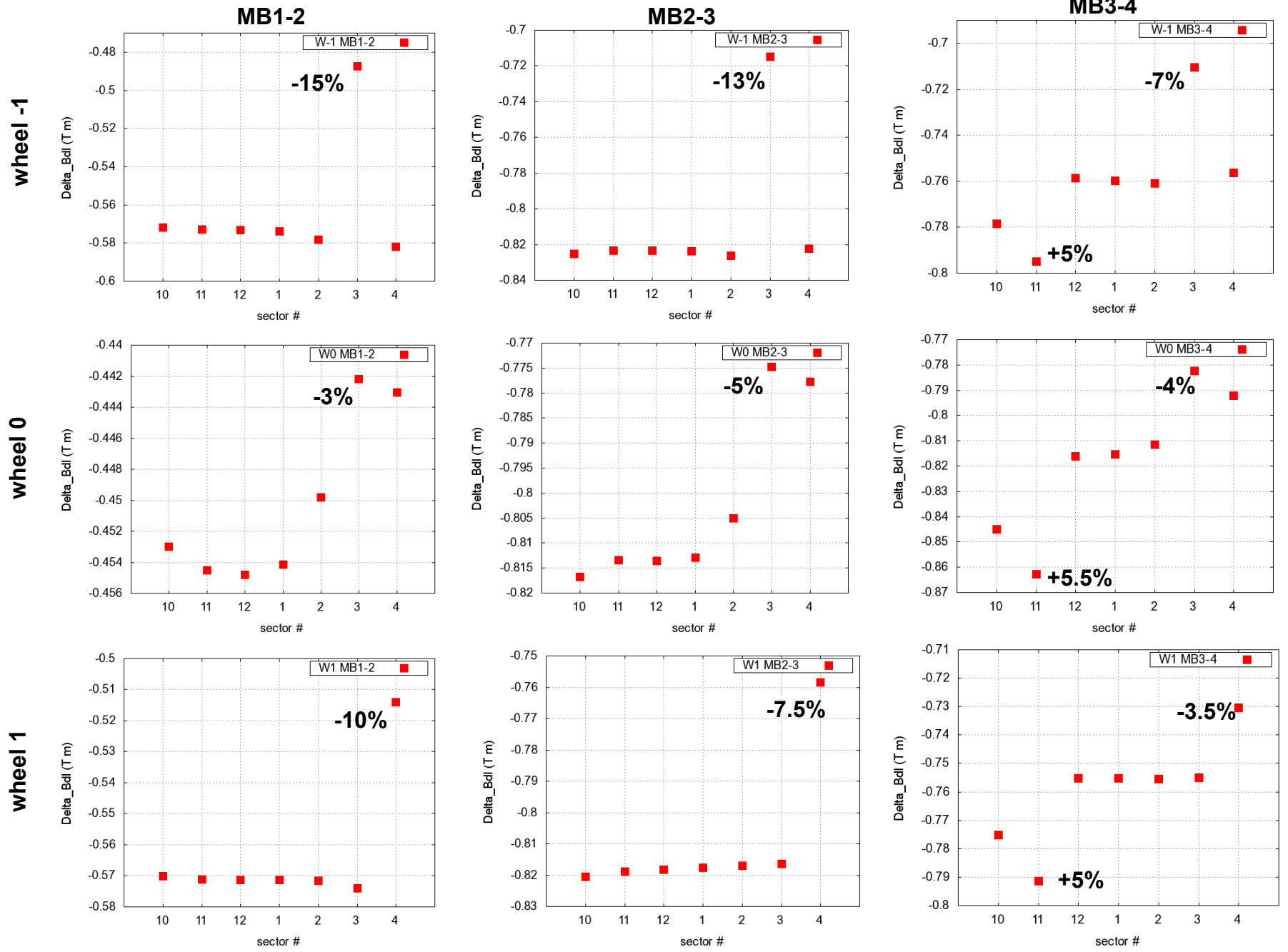


Back-up

Magnetic field studies

Magnetic Field Task Force: Dietrich Liko, Gigi Rolandi, Slava Klyukhin, Martijn Mulders, Sorina Popescu, Alain Herve, Ugo Gasparini, Alicia Calderon, Sara Bolognesi, Lorenzo Bianchini, Jeremy Andrea, Michael Schmitt, Didar Dobur, Jim Pivarski, Jake Ribnik, Nahn Tran, Ivan Mikulec, Vassili Maroussov, Nicola Amapane, Valeri Andreev, Wolfram Zeuner, Benoit Cure, Alberto Benvenuti, Marco Dallavalle, ...

$\int B \times dI$: integral between DT stations from TOSCA



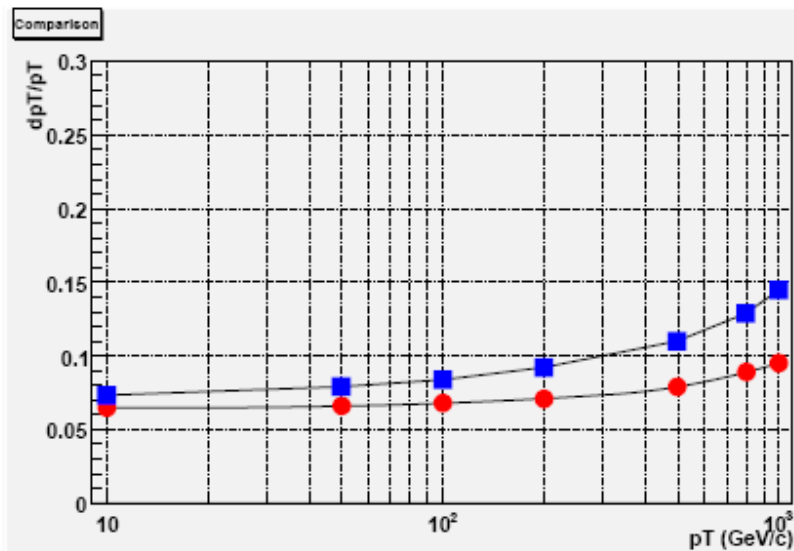


Figure 5: Comparison between p_T -resolution for muons reconstructed with the vertex using CMSSW_2_0_10 (blue boxes) and p_T -resolution from the analytical calculation in Sec. 2.3 (red points).

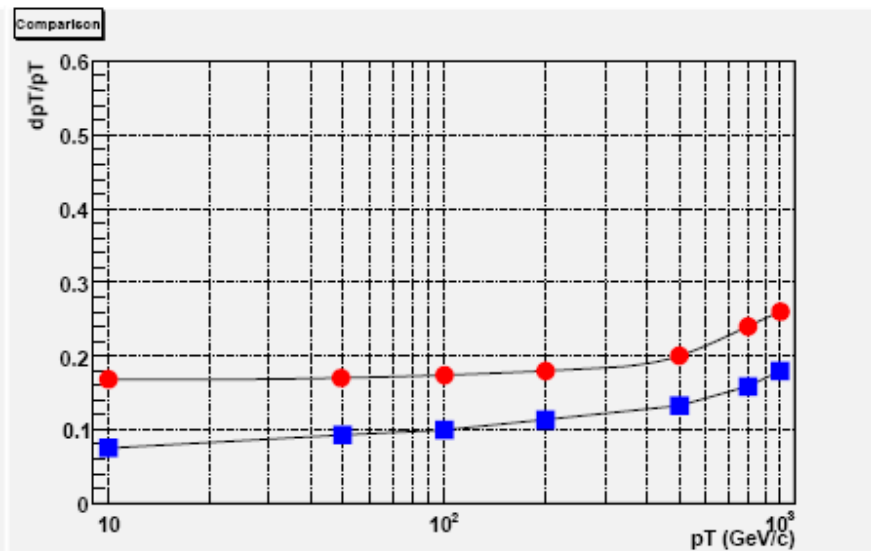


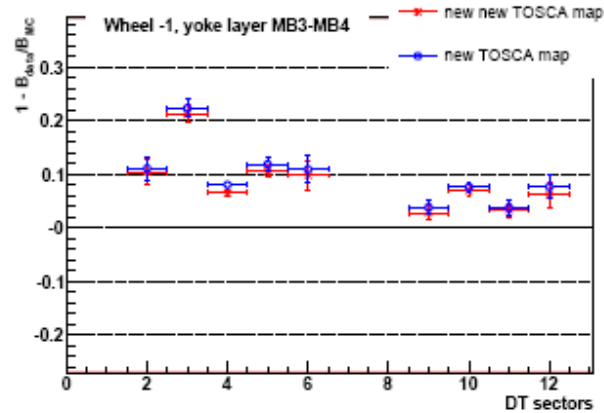
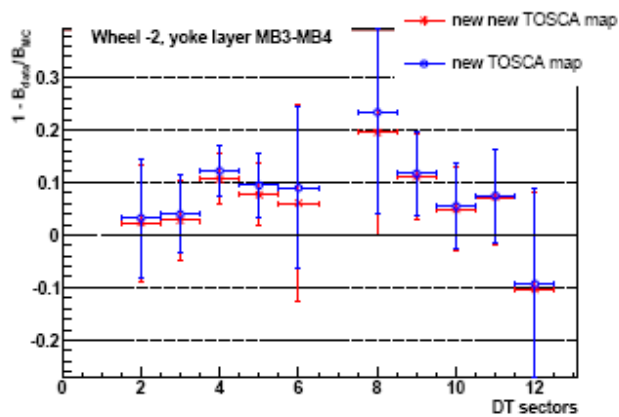
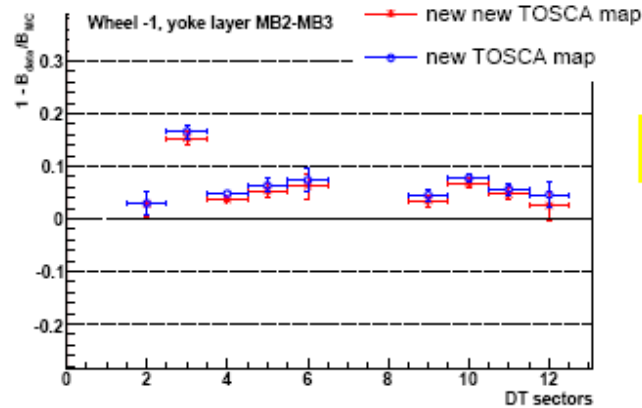
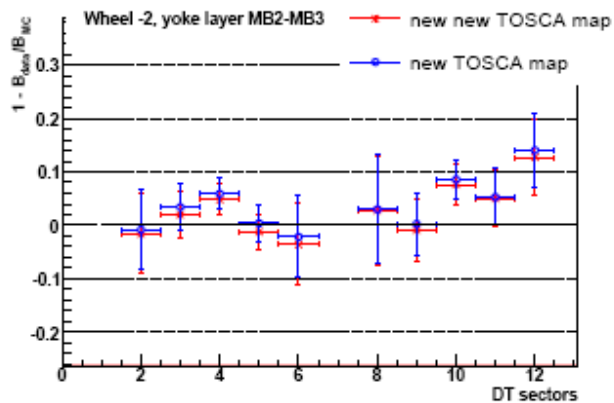
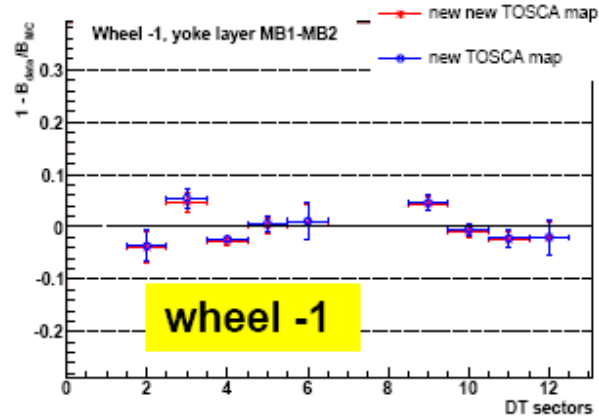
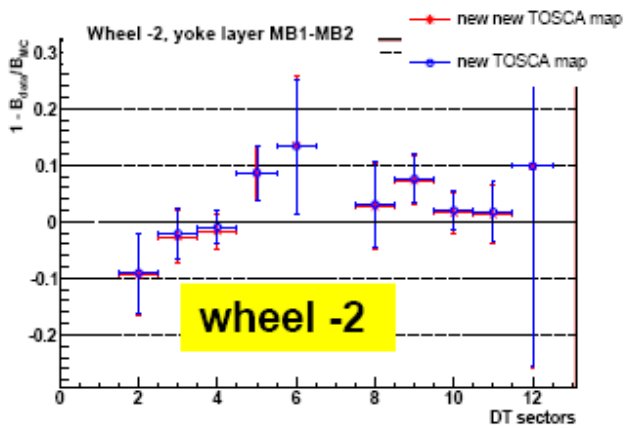
Figure 6: Comparison between p_T -resolution for muons reconstructed without the vertex using CMSSW_2_0_10 (blue boxes) and p_T -resolution from the analytical calculation in Sec. 2.2 (red points).

Rescaling factors wheel -2,-1

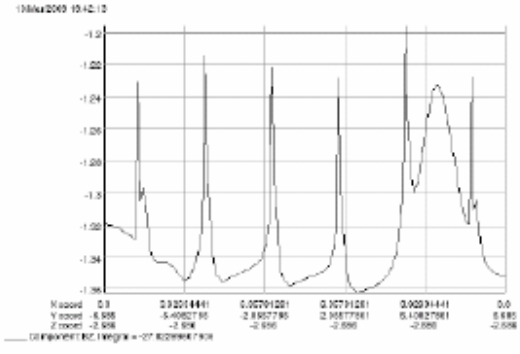
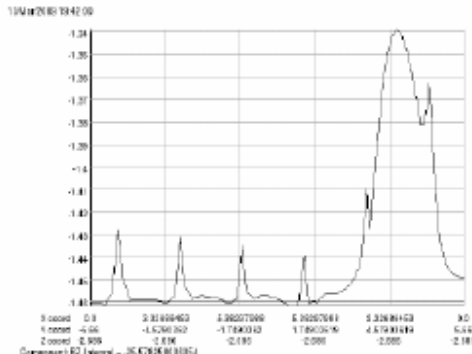
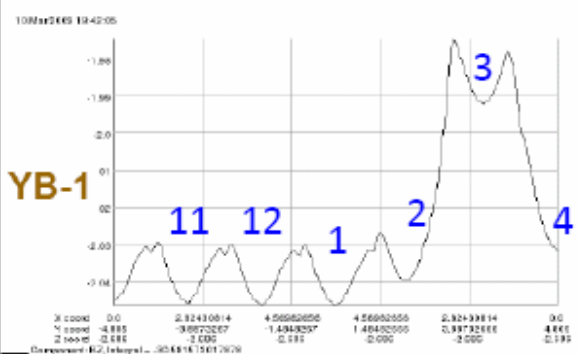
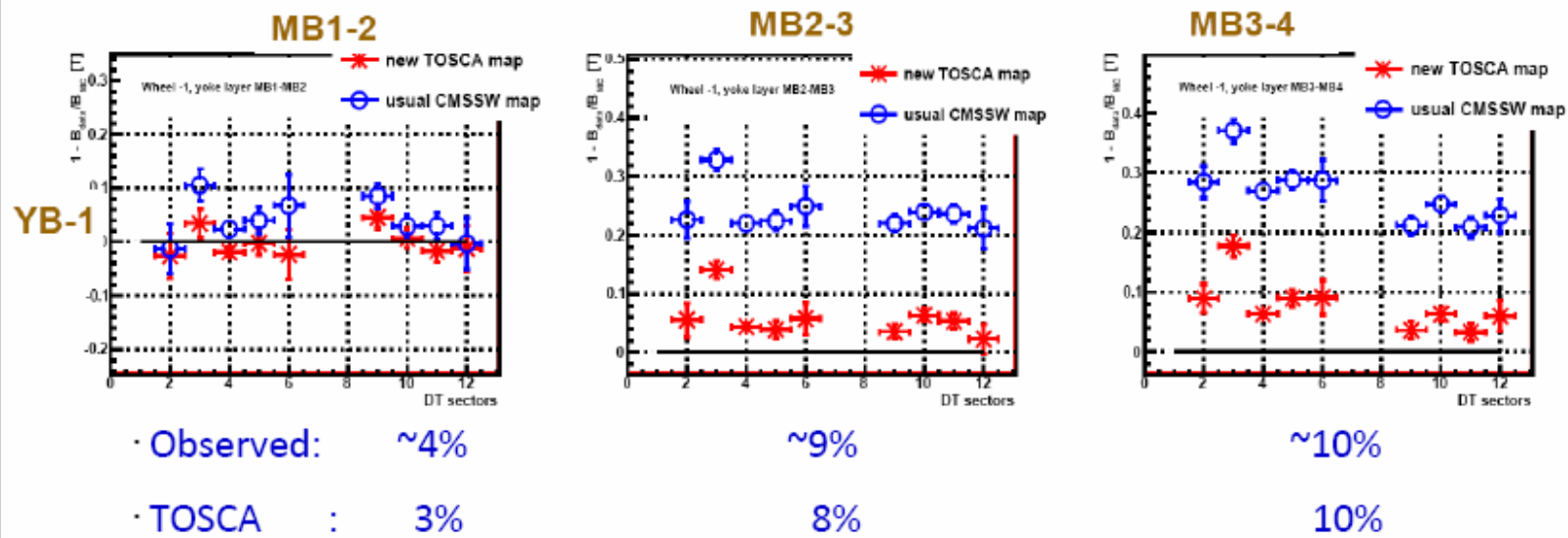
MB1-2

MB2-3

MB3-4



Understanding effect of chimneys:



(Slava Klyukhin) <http://indico.cern.ch/conferenceDisplay.py?confId=54297>