Beam-based measurements


Thanks to E. Calvo Giraldo, N. Catalán Lasheras, O. Brüning, R. Jones, Y. Papaphilippou, S. Peggs, F. Schmidt, R. Steinhagen

Chamonix 2009
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• Motivation: Aperture, simulations, observation and tolerances.
• Polarity checks in sectors 23 & 78
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Motivation: Aperture (see previous talk)

MQ.7L3.B1 clear. $\approx 12\text{mm} + 3\sigma_y$

Design $= 17\text{mm}$

LHC has a tight aperture but so far so good!

S. Redaelli et al
LHCB2 2008
12th Sep.

Measured $b_2 + 5$ units
Sext. misalignments 2mm

LHCB2 optics not in great shape, but let’s fix it!
Polarity tests: a good one! (QT12R2B1)

Sector 23, beam 1

MCBCH.6R2 = 40 µrad

Model
Measured

7th Sep. 08
R. Calaga et al
Polarity tests: a disagreement

Sector 78, beam2

**Model**

**Measured (δp/p=0.003)**

MCBCV.A5L8.B2 = 40 μrad
KSS.A78B2 = -KSS.A78B2

MSS.78 (Polarity Opposite)

24th Aug. 08

R. Calaga et al

Beam2 skew sextupoles polarity conventions?!
Polarity tests: summary

- **Polarity disagreement:** MQS23B1, MQS78B2 and MSS78B2
- **Already fixed:** QT11.R2B1
- **Inconclusive:** QT13.L8B2 and KOD.A23B1

→ Only skew circuits show polarity disagreement...
(details in a coming LHC-PerfN)
Measuring $\beta$: 3 algorithms

Longitudinal location [km]
Performance comparison

SVD wins (R. Calaga’s thesis)
The measurement of $\alpha$

$\alpha$ is measured as $\beta$ but typically ignored.
The impact of the measured closed orbit in the beta-beating is negligible.
Error reconstruction methods

- **Standard matrix inversion correction**: Not suitable due to too large errors

- **Segment-by-segment new**: Use of measured \((\beta, \alpha)\) as initial conditions to split the LHC into segments and reduce problem dimensions (presently under development by myself).

- **Iterative (model) correction new**: Iterate correction subtracting model betas to measured betas at every step (implemented by Masamitsu).
Segment-by-segment in IR3

LHCB2

$K_{1L}$

$\beta_x [m]$ vs. $s [m]$

$\beta_y [m]$ vs. $s [m]$

Model kqt7.r3/10

Meas.

error?

mqtlr73b2 off ?!
Segment-by-segment in IR3

**Hypothesis:** cabling swapping between apertures mqtli7r3b2 & mqtli7r3b1 since mqtli7r3b2 $\approx 10 \times$ mqtli7r3b1

At the same time elsewhere:

- M. Lamont publishes LHC-PerfN-009 concluding that mqtli7r3b2 seems to be unpowered from dispersion measurements
- N. Catalán Lasheras observed an inversion on voltage taps RQLT7.R3 and was seeking for beam-based information

→ “Non-conformity report” 985231 initiated.
<table>
<thead>
<tr>
<th>Segment</th>
<th>$\frac{\Delta \beta_x}{\beta_x}$ peak [%]</th>
<th>$\frac{\Delta \beta_y}{\beta_y}$ peak [%]</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>IR3</td>
<td>17</td>
<td>54</td>
<td>mqtli7r3b2 (/10)</td>
</tr>
<tr>
<td>IR2</td>
<td>9</td>
<td>5</td>
<td>mqya4l2b2 (+14%)</td>
</tr>
<tr>
<td>IR7</td>
<td>6</td>
<td>6</td>
<td>mqt5[rl]7 (×-2,3)</td>
</tr>
<tr>
<td>IR6</td>
<td>5</td>
<td>4</td>
<td>mq4l6b2 (+1%)</td>
</tr>
<tr>
<td>ARC23</td>
<td>0</td>
<td>3</td>
<td>mqd23 (+0.4%)</td>
</tr>
</tbody>
</table>

red: confirmed source, orange: not confirmed and “best fit”
mqya4l2b2 could be a cabling problem.
mqt5[rl]7 have low current, could be in unknown state.

→ Further verifications and studies ongoing
Red magnets indicate that cable swapping was found and fixed. Could IR2 still be affected? IR1 and IR5 are powered with B1-B2 symmetry: IR1/5 Optics are blind to cable swapping!
Segment-by-segment + Iterative

Iteration #1
Segment-by-segment + Iterative

Iteration #2
Segment-by-segment + Iterative

Iteration #3
Segment-by-segment + Iterative

Iteration #4
Segment-by-segment + Iterative

Iteration #5
Effective correctors (integrated)

IR3, perfect after mqtli7r3!
IR2, ARC23 and IR4 seem to need further studies
IR1, IR5 and IR8 are in great optics shape!
Simulations, observation and tolerances

Measured $b_2+5$ units Sext. misalignments 2mm

LHCB2 2008 12th Sep.

First beam in 2009?

Tolerances: total

on-momentum

Measured $b_1$ and $b_2$
This verifies that the integer tune split is 5. Sources are unclear. The coupling is correctable.
Summary & outlook I

• The excellent instrumentation has allowed beam-based measurements from day 1
• Need more aperture and polarity checks (maybe more automatic?)
• Decent beta measurements just with a single file with 90 turns
• Off-momentum information missing
• 2 new powerful methods implemented or under development to localize and correct errors
• mqtli.7r3.b2 cabling problem identified via the segment-by-segment approach as the leading error of the machine
• Unclear error sources in IR2, ARC23, IR4, IR7. Maybe other beam measurements (response measurements, dispersion) could be used for further analysis.

• IR1, IR5, and IR8 in great optics shape

• However IR1 and IR5 are transparent to B1-B2 cable swapping problems. Important check for next run:
  • Systematic checks of B1/2 swap by changing quad strengths in one aperture and monitor optics of the other beam.

• Coupling is correctable but needs understanding
Polarity check: QT13L8B2 Inconclusive

But big problem discarded from the $\beta$ measurement.
Polarity check: KOD23B1 Inconclusive

MCBCV.B5R2.B1 = 60 µrad
KOD.A23B1 = 100

Model
Measured (δp/p=0.0025)

KOD
Model
Measured, (δp/p=0.0025)
IR2, segment-by-segment

LHCb2

IP2

K_{1L}

β_{x}[m]

β_{y}[m]

s [m]
IR6, segment-by-segment
IR7, segment-by-segment

![Graph showing βx and βy measurements over s [m].]
Arc 23, segment-by-segment

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure}
\caption{Beam-based measurements}
\end{figure}