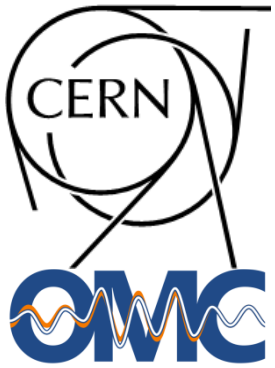
Polarity checks of non-linear circuits

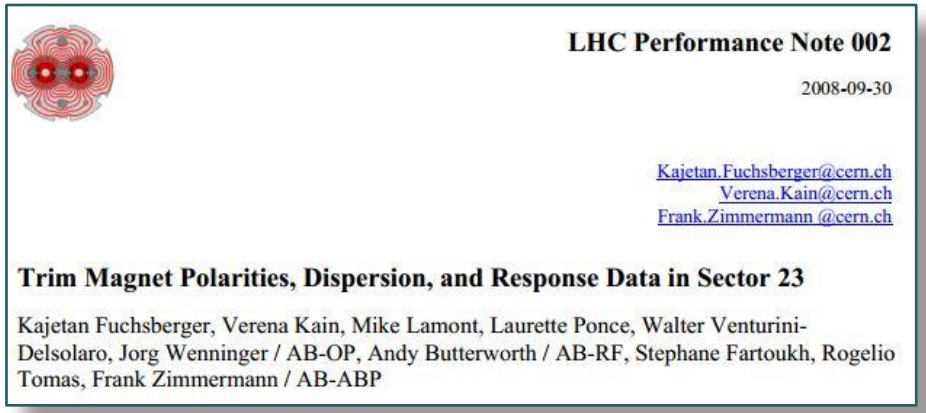
Meghan McAteer
on behalf of OMC team



Contents

- 2008/2009 polarity checks summary
- 2012 polarity checks-methods and results
  - Octupoles MOF, MOD, MCO
  - Sextupoles MSS, MCSSX, MCSX
- Plans for measurements during commissioning in 2015

Recap of 2008 and 2009 polarity checks



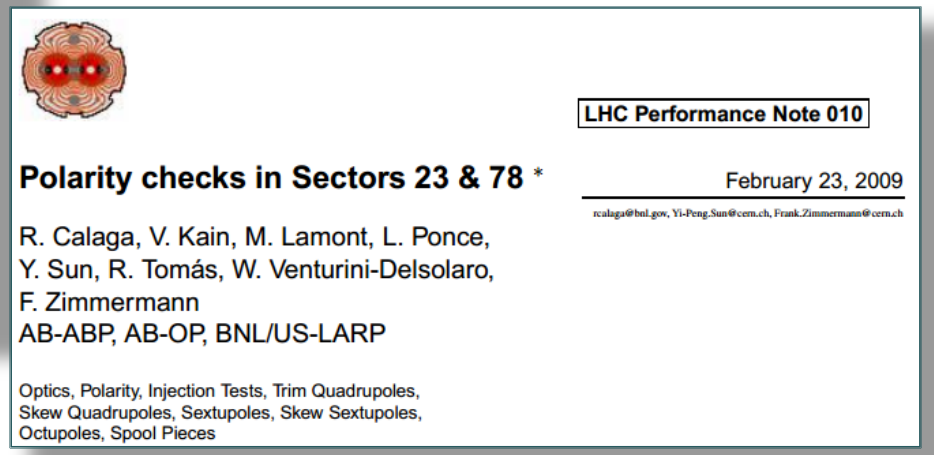
LHC Performance Note 002

2008-09-30

Kajetan.Fuchsberger@cern.ch
Verena.Kain@cern.ch
Frank.Zimmermann @cern.ch

Trim Magnet Polarities, Dispersion, and Response Data in Sector 23

Kajetan Fuchsberger, Verena Kain, Mike Lamont, Laurette Ponce, Walter Venturini-Delsolaro, Jorg Wenninger / AB-OP, Andy Butterworth / AB-RF, Stephane Fartoukh, Rogelio Tomas, Frank Zimmermann / AB-ABP



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Polarity checks in Sectors 23 & 78 *

February 23, 2009

rcalaga@bnl.gov, Yi-Peng.Sun@cern.ch, Frank.Zimmermann@cern.ch

R. Calaga, V. Kain, M. Lamont, L. Ponce,
Y. Sun, R. Tomás, W. Venturini-Delsolaro,
F. Zimmermann
AB-ABP, AB-OP, BNL/US-LARP

Optics, Polarity, Injection Tests, Trim Quadrupoles, Skew Quadrupoles, Sextupoles, Skew Sextupoles, Octupoles, Spool Pieces

- Selected quadrupole, sextupole, and octupole circuits in A23.B1 and A78.B2 examined
- Polarities determined from free oscillations of single-pass beam with magnet circuit trim
- Lattice skew sextupoles MSS found to be reversed w.r.t. MADX model

Type	Magnets	Polarity
Sextupoles	MCS.A78.B2	OK
	MSS.A78.B2	Reversed
	MSF[1,2].A23.B1	OK
	MSF[1,2].A78.B2	OK (?)
	MSD[1,2].A78.B2	OK
Octupoles	MOD.A23.B1	Inconclusive
	MOD.A78.B2	OK
	MOF.A78.B2	OK

August 2012 polarity checks

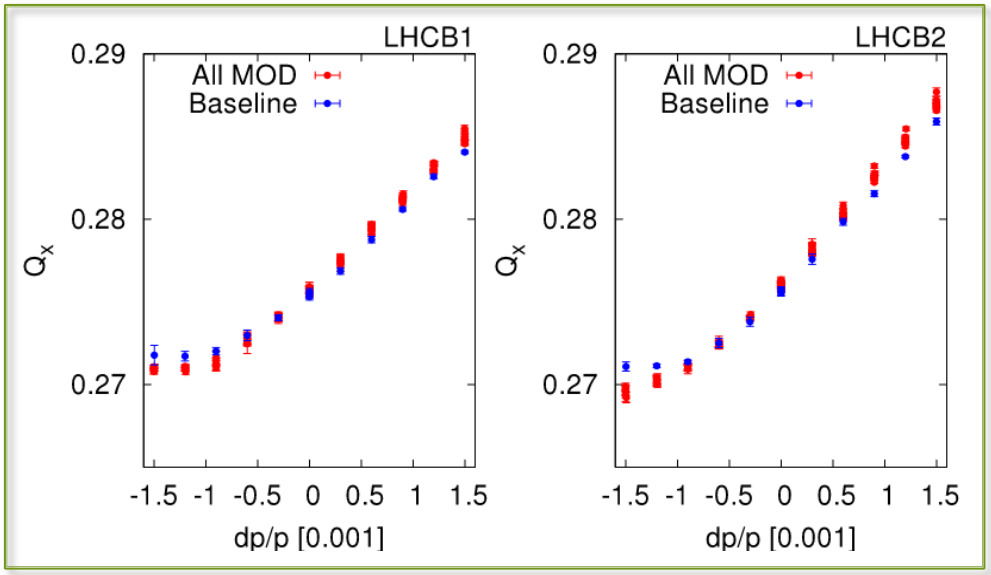
- Selected sextupole and octupole circuits examined using circulating beam
  - Octupoles (MOF, MOD, MCO): polarity determined from change to second order chromaticity due to trimming magnets in each arc
  - Lattice skew sextupoles (KSS): polarity determined from change to chromatic coupling due to trimming magnets in each arc
  - Triplet sextupoles (MCSX and MCSSX): polarity determined from tune shift due to magnet trim

2012 polarity checks
Octupoles

- MOF and MOD circuits contain 8-13 magnets, MCO contain 77 magnets
- MOF, MOD, and MCO circuits were checked in all arcs (except MCO in A12.B1, A12.B2, A78.B2, A81.B2)
- Octupole circuit trims were calculated to give ~3000 units ΔQ''
- Data analysis was done offline to allow for more precise tune determination

2012 polarity checks
Octupoles

Figure: Measured Chromaticity with (red) and without (blue) MOD trims.



Family	Trim (m^{-4})	# of Magnets	ΔQ''_x Model	ΔQ''_x Meas.	Standard Error	Discrepancy (σ)
MOD.A12 B1	-54	13	3060	2860	190	-1.05
MOD.A23 B1	-86	8	2981	3400	200	2.10
MOD.A34 B1	-65	11	3120	3120	180	0.00
MOD.A45 B1	-86	8	2981	2860	100	-1.21
MOD.A56 B1	-54	13	3060	2900	200	-0.80
MOD.A67 B1	-86	8	2981	2890	100	-0.91
MOD.A78 B1	-54	13	3060	3010	140	-0.36
MOD.A81 B1	-86	8	2981	2560	190	-2.22

Table: Measured and expected ΔQ'' due to MOD trims in Beam 1, and standard error of chromaticity fit.

2012 polarity checks
Individual octupoles on circuit

- Large discrepancy with model ΔQ'' may indicate incorrect polarity of individual magnets on circuit
- For MOF or MOD with large ΔQ'' discrepancy (> ~2σ), polarity of each magnet in the arc was verified by introducing a closed orbit bump through each magnet in that arc and measuring resulting tune shift
- MCO in many arcs had 3 or 4 σ discrepancy, which can possibly be attributed to hysteresis effects. Orbit bumps through all 77 magnets in these arcs is not practical.

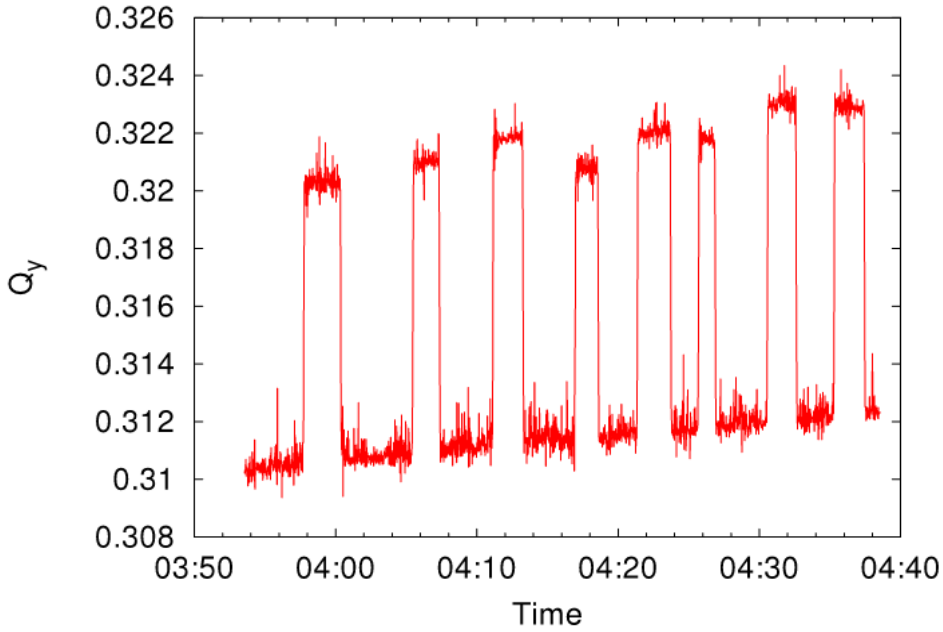
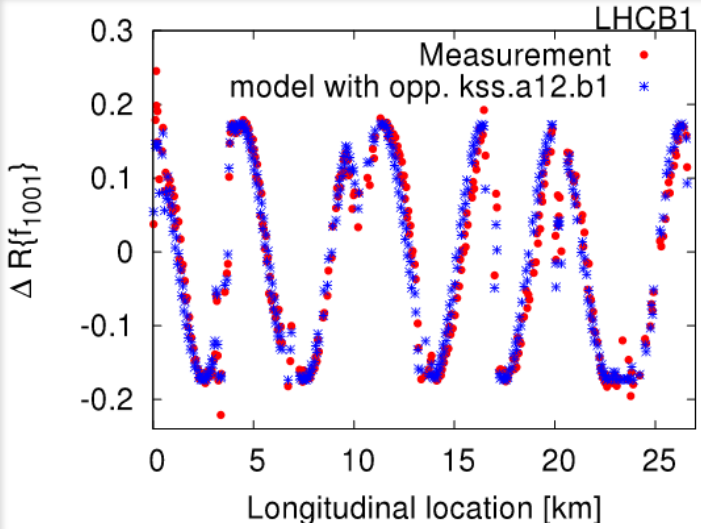


Figure: Measured tune while local orbit bumps were made through each of the MOD in A23 B1, verifying correct polarity of each of 8 magnets on the circuit.

2012 polarity checks
Arc skew sextupoles

- Polarity was determined from change to chromatic coupling (see talk by Y. I. Levinsen) in response to trimming MSS circuit in one arc
- Data analysis can be done quickly during measurement session
- Comparison with MADX shows opposite polarity for MSS



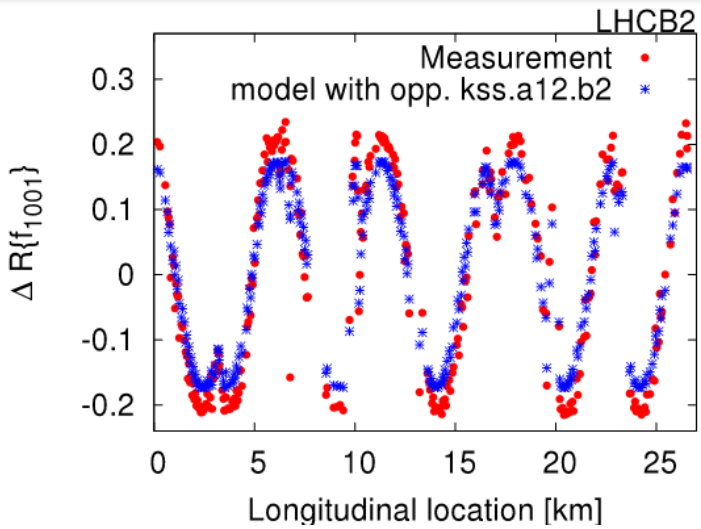


Figure: Chromatic coupling from measurement (red) and model with MSS reversed (blue).

2012 polarity checks
Triplet sextupoles

- Triplet sextupoles MCSX in IP5 and MCSSX in IP1 were examined
- Polarities were determined from tune shift due to magnet trim (with nominal crossing angle orbit bump left in)
- All found to be consistent with MADX

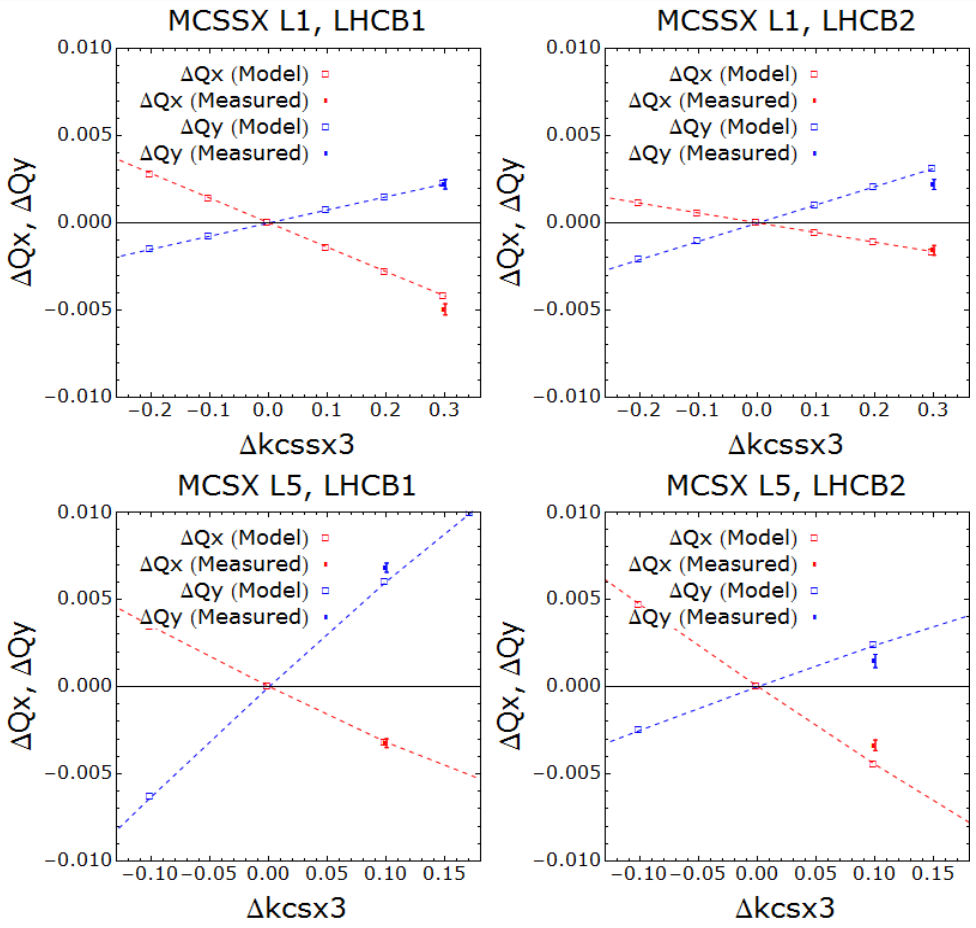


Figure: Measured and model tune shifts resulting from MCSSX trim in IP 1 and from MCSX trim in IP5 .

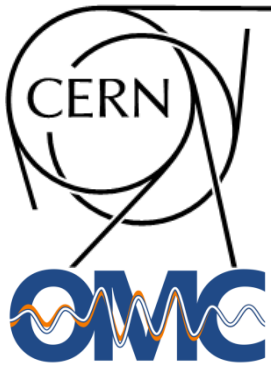
2012 polarity checks
Summary of findings

- Lattice octupoles MOF and MOD:
  - consistent with MADX polarities
- Spool piece octupoles MCO :
  - Several circuits showed ~3 or 4 σ difference from model ΔQ'', possibly due to hysteresis
  - Difficult to confirm whether all magnets on a circuit are correct
  - Four MCO circuits (A12.B1, A12.B2, A78.B2, A81.B2) not functional
- Lattice skew sextupoles MSS:
  - polarities reversed with respect to MADX
- Triplet sextupoles MCSX IP5 and MCSSX IP1:
  - consistent with MADX polarities

2015 polarity checks plans

- Checks should be repeated during 2015 commissioning period to ensure that magnet polarities are unchanged
- Methods will be the same as used in August 2012 measurements
- Magnet circuits to measure:
  - Spool piece octupoles MCO (from ΔQ'')
  - Lattice octupoles MOF, MOD (from ΔQ'')
  - Triplet octupoles MCOX3, MCOSX3 (from ΔQ)
  - Spool piece sextupoles MCS (from ΔQ')
  - Lattice sextupoles MS, MSS (from ΔQ', chromatic coupling)
  - Triplet sextupoles MCSX, MCSSX (from ΔQ)
- Should MSS polarity in LSA and MADX be synched during LS1?

Thank you
for your attention!



Extra slides

MOF Landau damping octupoles

- All MOF in an arc are powered in series
- Change to Q'' from MOF group trim was measured to determine polarity
- In most cases, measured ΔQ'' is within ~2σ of model prediction
- Shift between reference and trimmed measurements is due to machine tuning, which is not expected to have a significant effect on higher-order chromaticity.
- Conclusion: all MOF polarities are CORRECT

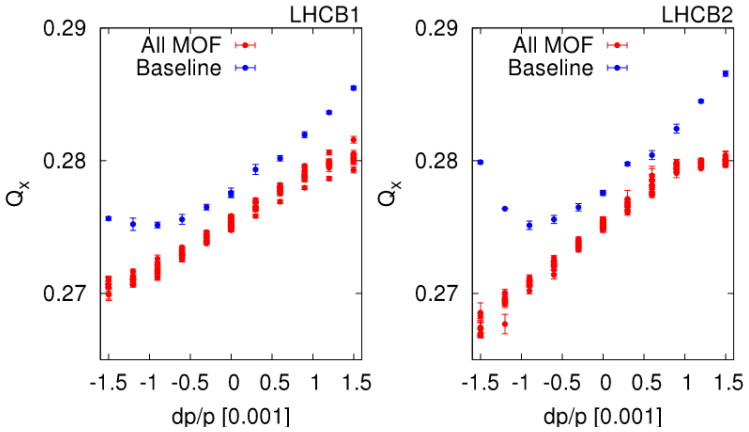


Figure 1. Measured chromaticity with (red) and without (blue) MOF trims.

Family	Trim (m^-4)	# of Magnets	ΔQ''_x Model	ΔQ''_x Meas.	Standard Error	Discrepancy (σ)
A12 B1	-15	8	-2125	-2120	180	0.03
A23 B1	-12.5	13	-2875	-2700	190	0.92
A34 B1	-20	8	-2833	-2700	180	0.74
A45 B1	-12.5	13	-2879	-2510	180	2.05
A56 B1	-20	8	-2833	-2700	200	0.67
A67 B1	-12.5	13	-2879	-2670	190	1.10
A78 B1	-20	8	-2833	-2560	180	1.52
A81 B1	-12.5	13	-2879	-2600	200	1.40
A12 B2	-15	13	-3450	-3300	200	0.75
A23 B2	-24	8	-3400	-3500	200	-0.50
A34 B2	-18	11	-3504	-3770	170	-1.56
A45 B2	-24	8	-3368	-3400	200	-0.16
A56 B2	-15	13	-3450	-3300	300	0.50
A67 B2	-33	8	-4675	-4000	200	3.38
A78 B2	-15	13	-3455	-3300	200	0.78
A81 B2	-24	8	-3400	-3700	200	-1.50

Table 1. Measured and model ΔQ''_x in response to MOF trims. Reduced number in A34 B2 is due to 2008 incident.

MOD Landau damping octupoles

- All MOD in an arc are powered in series
- Change to Q'' from MOD group trim was measured to determine polarity
- In most cases, measured ΔQ'' is within ~2σ of model prediction
- Some outliers were investigated further to ensure that no single magnets in a group were reversed
- Conclusion: all MOD polarities are CORRECT

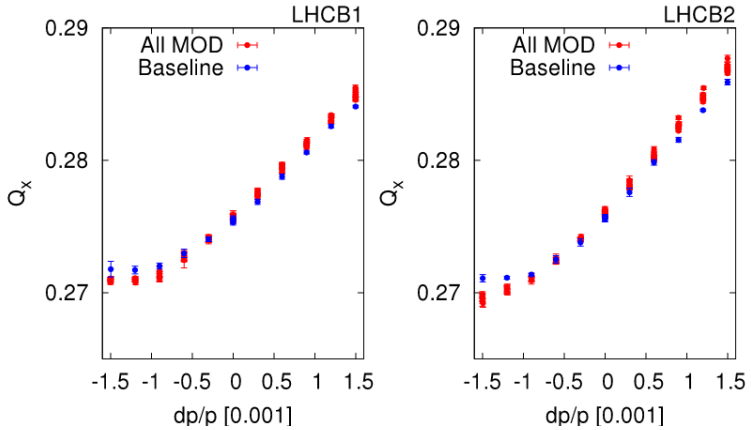


Figure 1. Measured chromaticity with (red) and without (blue) MOD trims.

Family	Trim (m^-4)	# of Magnets	ΔQ''_x Model	ΔQ''_x Meas.	Standard Error	Discrepancy (σ)
A12 B1	-54	13	3060	2860	190	-1.05
A23 B1	-86	8	2981	3400	200	2.10
A34 B1	-65	11	3120	3120	180	0.00
A45 B1	-86	8	2981	2860	100	-1.21
A56 B1	-54	13	3060	2900	200	-0.80
A67 B1	-86	8	2981	2890	100	-0.91
A78 B1	-54	13	3060	3010	140	-0.36
A81 B1	-86	8	2981	2560	190	-2.22
A12 B2	-43	8	1491	1570	90	0.88
A23 B2	-27	13	1530	1410	300	-0.40
A34 B2	-43	8	1491	1590	70	1.41
A45 B2	-27	13	1530	1520	100	-0.10
A56 B2	-43	8	1505	1570	100	0.65
A67 B2	-27	13	1530	1670	100	1.40
A78 B2	-43	8	1505	1720	90	2.39
A81 B2	-27	13	1530	1960	70	6.14

Table : Measured and model ΔQ''_x in response to MOD trims. Reduced number in A34 B1 is due to 2008 incident.

MCO spool piece corrector octupoles

- All MCO in an arc are powered in series
- Change to Q'' from MCO group trim was measured to determine polarity
- Some magnet groups were not operational at the time of measurements
- In many cases, measured ΔQ'' is more than ~2σ away from model prediction
- Discrepancy may be due to hysteresis effects (no pre-cycling in these magnets)
- Conclusion: all measured MCO polarities are CORRECT

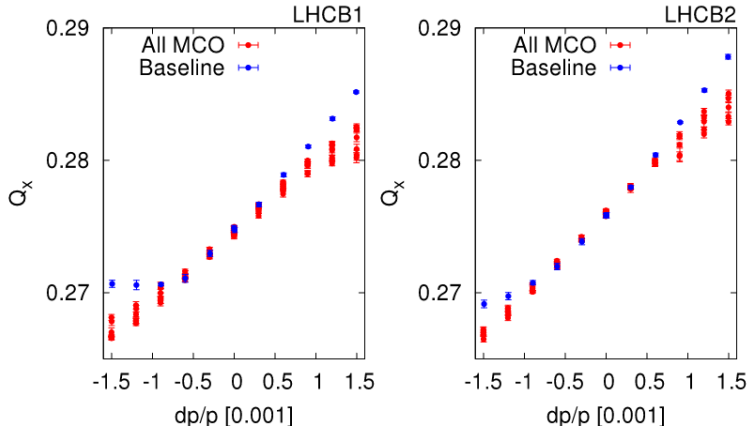
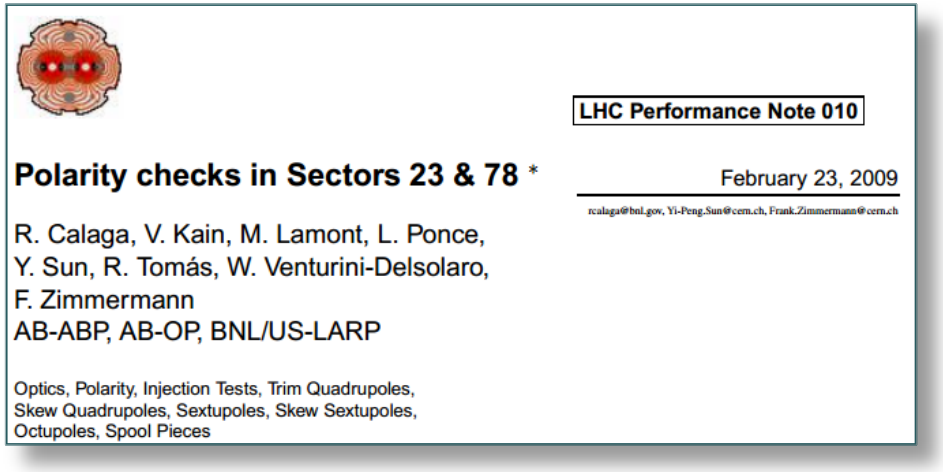


Figure 4. Measured chromaticity with (red) and without (blue) MCO trims.

Family	Trim (m^-4)	# of Magnets	ΔQ''_x Model	ΔQ''_x Meas.	Standard Error	Discrepancy (σ)
A12 B1		77				
A23 B1	-30	77	-2170	-2900	220	-3.32
A34 B1	-30	77	-3260	-3840	130	-4.46
A45 B1	-30	77	-2160	-2590	130	-3.31
A56 B1	-30	77	-3080	-3840	140	-5.43
A67 B1	-30	77	-2130	-2920	180	-4.39
A78 B1	-30	77	-3011	-3540	180	-2.94
A81 B1	-30	77	-2200	-2940	140	-5.29
A12 B2		77				
A23 B2	-30	77	-3200	-3200	120	0.00
A34 B2	-30	77	-2080	-2470	90	-4.33
A45 B2	-30	77	-3050	-3300	160	-1.56
A56 B2	-30	77	-2170	-2500	70	-4.71
A67 B2	-30	77	-3020	-2960	130	0.46
A78 B2		77				
A81 B2		77				

Table: Measured and model ΔQ''_x in response to MCO trims. Where no measurements are given, magnets were not operational.

2009 polarity checks



LHC Performance Note 010

Polarity checks in Sectors 23 & 78 *

February 23, 2009

rcalaga@bnl.gov, Yi-Peng.Sun@cern.ch, Frank.Zimmermann@cern.ch

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AB-ABP, AB-OP, BNL/US-LARP

Optics, Polarity, Injection Tests, Trim Quadrupoles, Skew Quadrupoles, Sextupoles, Skew Sextupoles, Octupoles, Spool Pieces

- Polarities were determined by measuring change in oscillation trajectory in response to magnet trim
- MSF: plot shows reversed polarity, text states correct polarity

Type	Magnets	Polarity	Fixed?
Normal quads	QTL11.R2.B1	Reversed	12/10/08
	QTL11.L8.B2	OK	
	QT12.R2.B1	OK	
	QT12.L8.B2	OK	
	QT13.R2.B1	OK	
	QT13.L8.B2	Inconclusive	
Skew quads	MQS23.B1	Reversed	
	MQS78.B2	Reversed	
Sextupoles	MCS.A78.B2	OK	
	MSS.A78.B2	Reversed	
	MSF[1,2].A23.B1	OK	
	MSF[1,2].A78.B2	??	
	MSD[1,2].A78.B2	OK	
Octupoles	ROD.A23.B1	Inconclusive	
	ROD.A78.B2	OK	
	ROF.A78.B2	OK	
Orbit correctors	MCBCH.6R2.B1	OK	
	MCBCH.6L8.B2	OK	
	MCBXV.3L8.B2	OK	
	MCBXV.3R2.B1	OK	
	MCBCV.A5L8.B2	OK	
	MCBCV.B5R.B1	OK	
	MCBYH.B4L8.B2	OK	
	MCBYH.B4R2.B2	OK	