PC Interlock
status, next steps and feasibility of optics interlocking

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Outline

- PC Interlock
- Optics Interlocking
  - Quadrupole families
  - Current variations
    - Fill-to-fill
    - Trims
  - Phase advance change and interlock limits

Motivation for Interlock on Phase

In case of an asynchronous beam dump, the dump kicker fires when beam passes.

Kicked beam could damage TCTs and triplets.

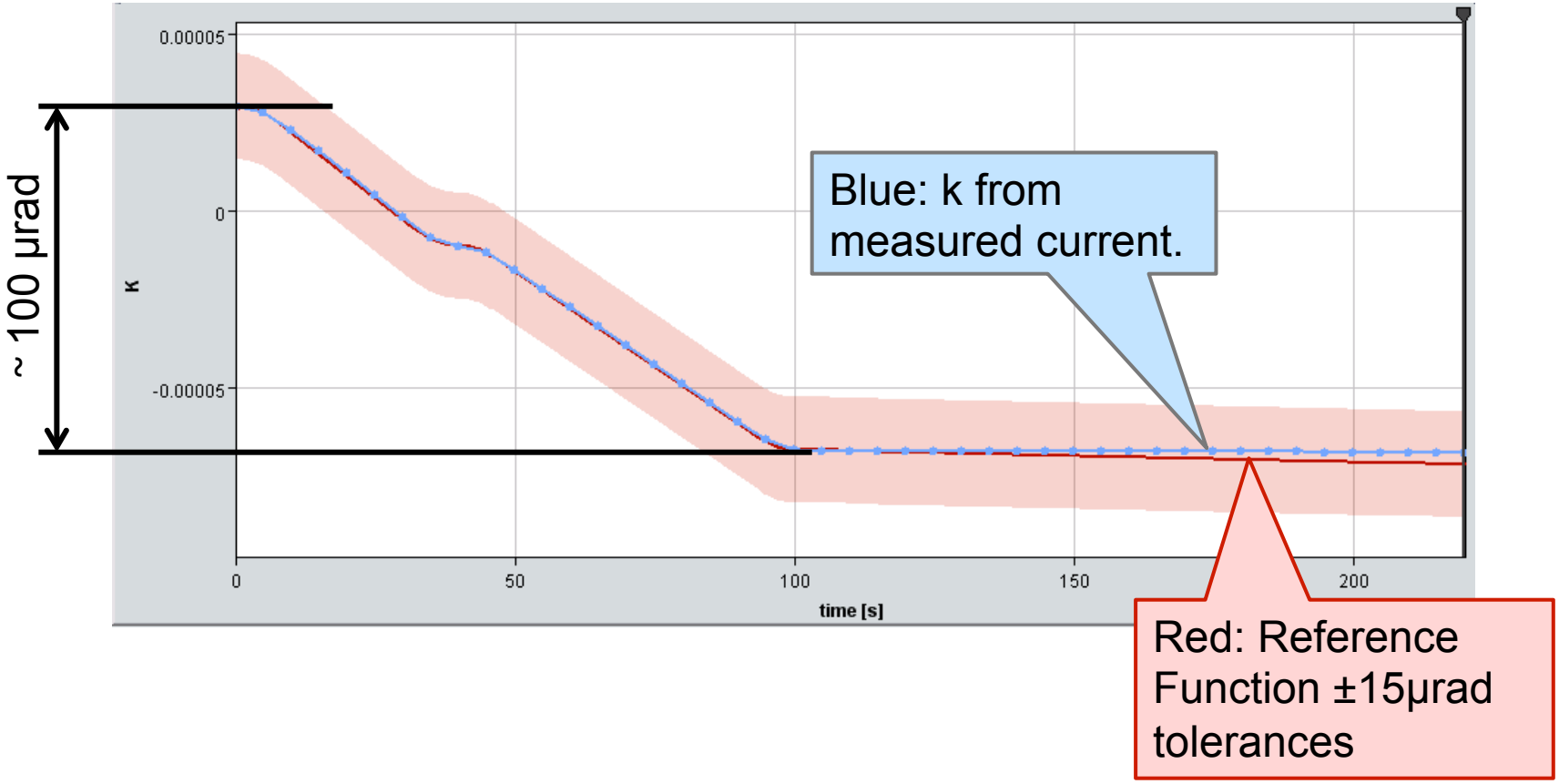
In order to protect the TCTs, it has to be ensured that phase advance between MKD (IR6) and TCTs in IP5/IP1 is < 20˚.

➔ Interlock on quadrupole currents during collisions with the aim to keep $\Delta\mu < 5^{\circ}$-10°.

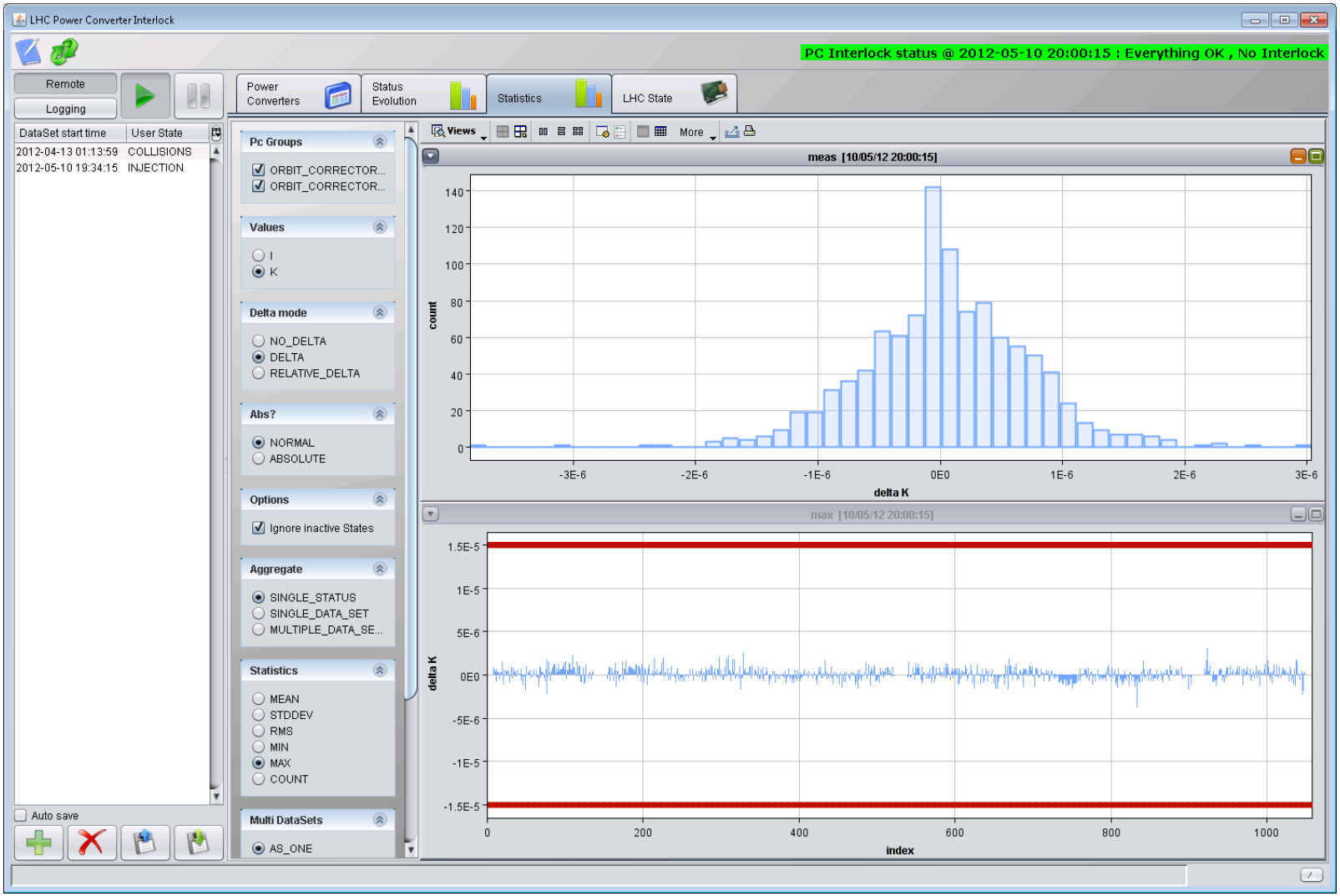
PC Interlock - Principle

Principle: Subscribes to Power Converters and compares current to reference ***functions*** ± tolerances (1 Hz).

Example: RCBYVS4.L8B2 **(Orbit corrector)** during COLLISIONS Beam Process:

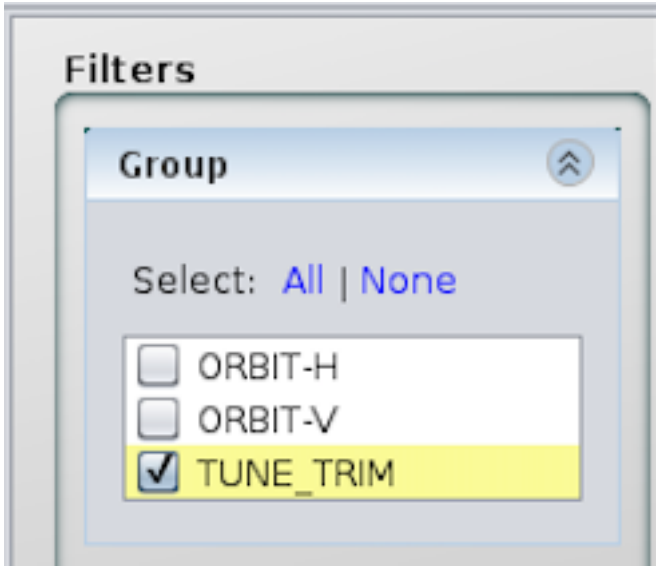


PC Interlock - GUI



PC Interlock – Latest Improvements

- Bugfixes: Following RDA2 to RDA3 changes.
- Made it simpler to add new circuits.
- Preparation for adding different interlocking strategies for different circuits.
- To Do: Prepare for nested power converters (triplets)



Feasibility of Optics Interlocking

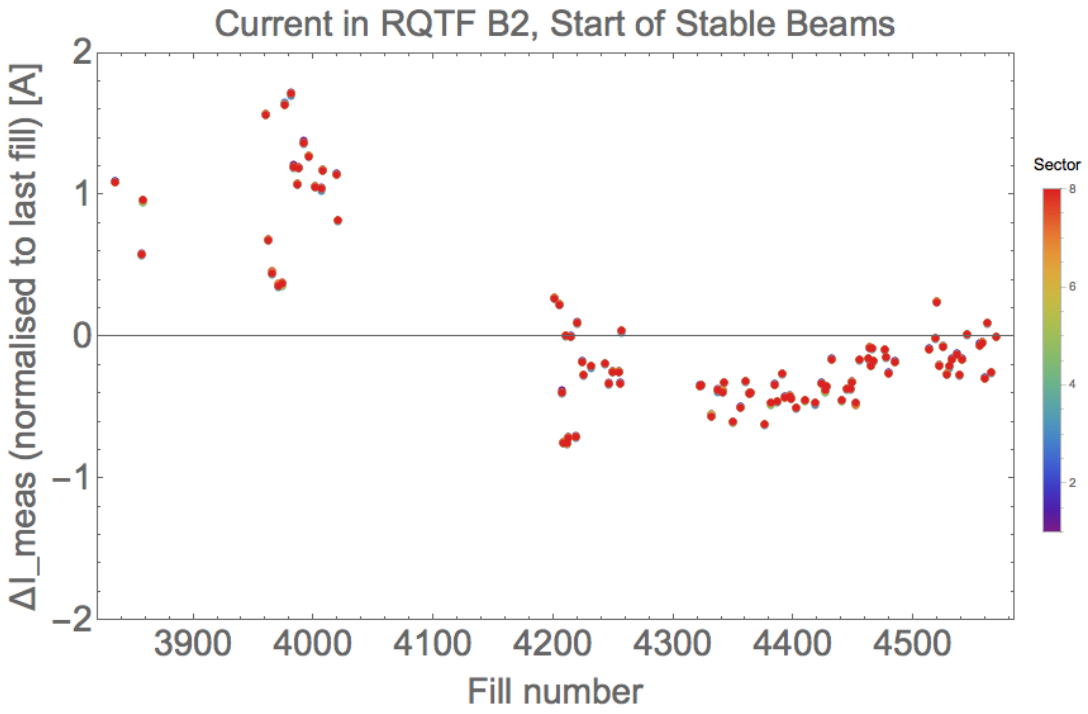
Try simple strategy: Interlock all quadrupole PC individually

Quadrupole Families	Names	Number of Power Converters (PC)
Main Quadrupols	RQD, RQF	each 1 PC/sector
Main Trim Quadrupols	RQTD, RQTF	each 1 PC/sector
Triplets	RQX, RTQX1, RTQX2	6 PC/IP
Individually Powered Quadrupols (IPQ)	RQ4-RQ10, RQTL11, RQT12, RQT13…	1 PC each (total count >300)

Main quadrupoles, Triplets and IPQs have very stable currents from fill to fill and during collisions: **$\Delta I \approx \pm 0.02A$**

Only the **trim quadrupoles have large variations** …

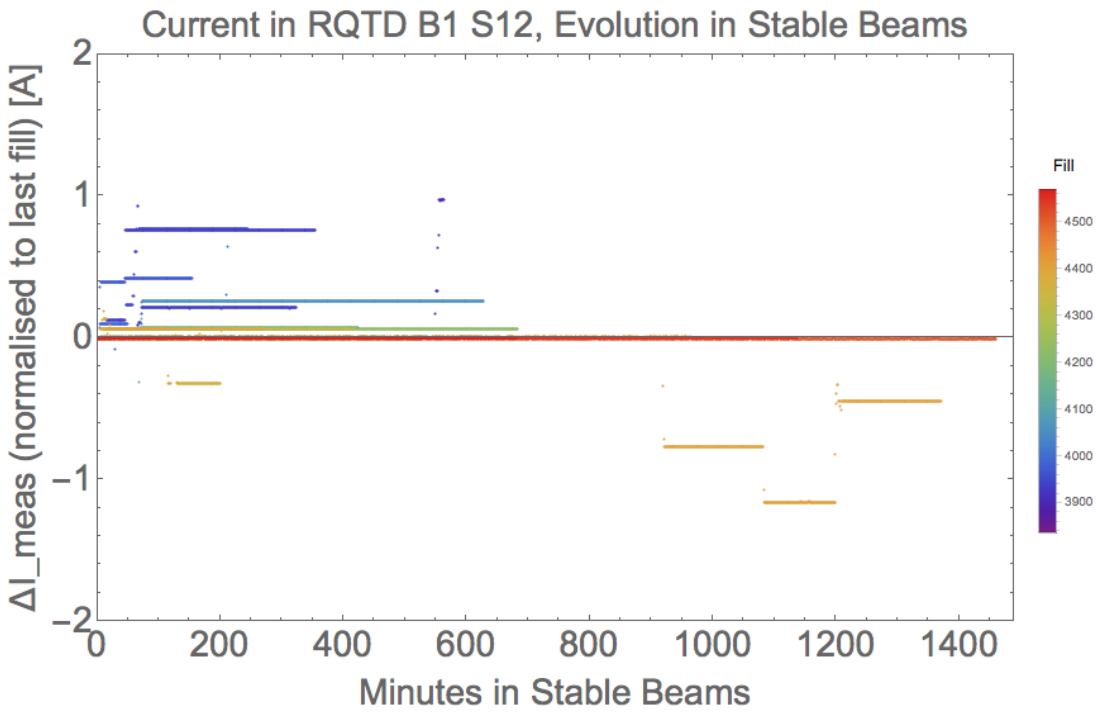
Current variations: RQTs (1)



Current variation **from fill to fill**

- Example RQTF-B2 (family with the largest spread, see back up slides for the other families)
- All sectors are similar (color code)
- Data normalized to last fill (arbitrary)
- **|Max – Min| ≈ 3A**

Current variations: RQTs (2)



Current variation **during Collisions**

- Example RQTD-B1 (family with the largest spread, see back up slides for the other families)
- All sectors are similar (color code)
- Data normalized to initial value of each fill
- **ΔI ≈ ±1.5A**

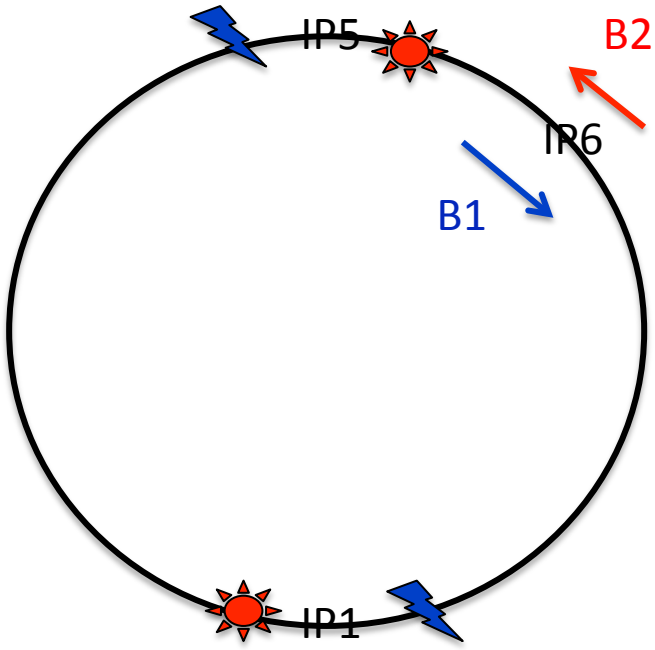
Phase Advance Changes

Optics used (40cm, 2015):
/afs/cern.ch/eng/lhc/optics/runII/2015/opt_400_10000_400_3000_coll.madx

Starting from these optics we varied k1 of each family separately and extracted the Δμ/Δk between the first dump kicker the beams see an the TCTs in IP1/5:

Beam 1: MKD.O5L6.B1 ➔ TCTPH4L1.B1
➔ TCTPH4L5.B1

Beam 2: MKD.O5R6.B2 ➔ TCTPH4R5.B1
➔ TCTPH4R1.B1



Assumptions:
➔**Worst case:** effect of all magnets add up.
➔ Ensured that **Δμ < 10°** in all four positions.

Phase Advances and Interlock Limits

preliminary study

	Beam 2		Beam 1			
Families	**$\Delta\mu_h/A$ (6->5)**	**$\Delta\mu_h/A$ (6->1)**	**$\Delta\mu_h/A$ (6->5)**	**$\Delta\mu_h/A$ (6->1)**	**ΔI_{meas}**	**Interlock proposal**
KQD	0.06˚	0.27˚	0.38˚	0.17˚	±0.02A	±0.5A
KQF	0.37˚	1.81˚	2.52˚	1.09˚	±0.02A	±0.5A
KQTD	0.03˚	0.13˚	0.17˚	0.08˚	±4.5A	±5A
KQTF	0.16˚	0.72˚	0.94˚	0.37˚	±4.5A	±5A
IPQ	2.8˚	5.8˚	10.5˚	5.1˚	±0.02A	±0.5A
Triplet	3.87˚	4.72˚	3.05˚	2.25˚	±0.02A	±0.5A
Sum $\Delta\mu_h$ (meas.)	1.0˚	4.1˚	5.3˚	2.2˚	-	-
Sum $\Delta\mu_h$ (Limit)	**4.5˚**	**10.6˚**	**13.8˚ ??**	**6.6˚**	**-**	**-**

Conclusion

- Calculations were done with preliminary 40cm optics.
- Phase changes were obtained from periodic solution with madx.
  - Is this the right approach?

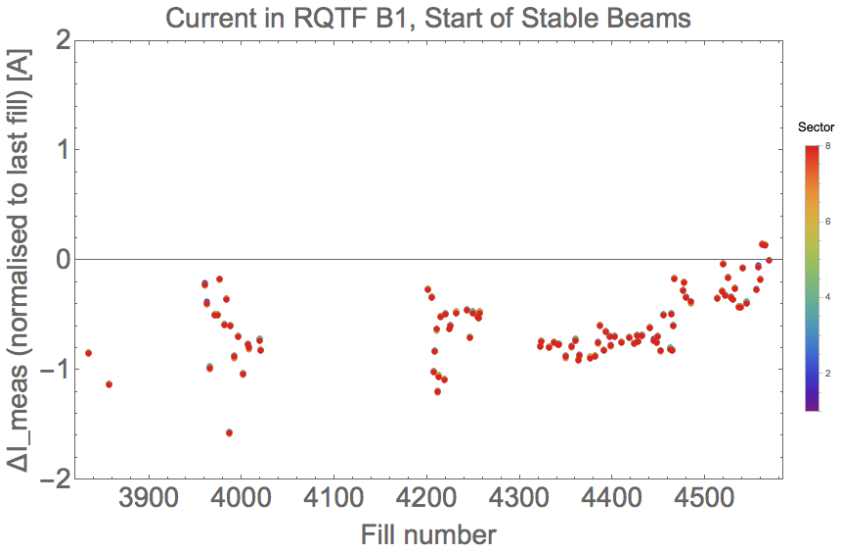
- How to test?
  - Can we put everything on the limit and re-measure the phase advances?

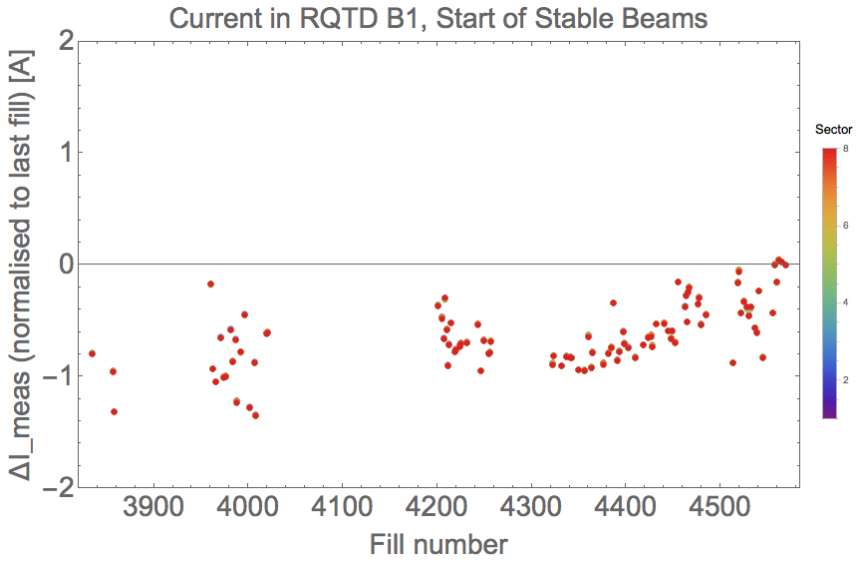
- **± 10° seems feasible but tight!**
  - Current tolerances have to be discussed.
  - B1 6->5 exceeds this limit but has largest margin in initial phase advance.

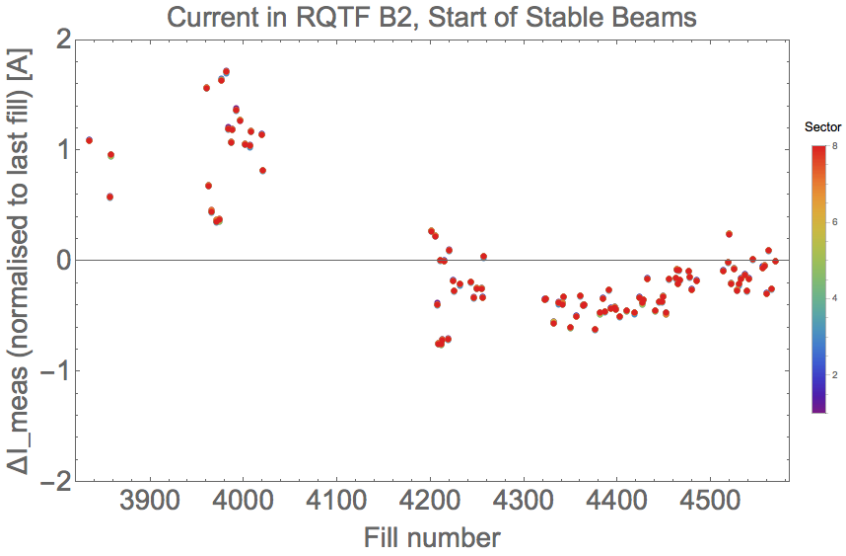
THANK YOU
FOR YOUR ATTENTION

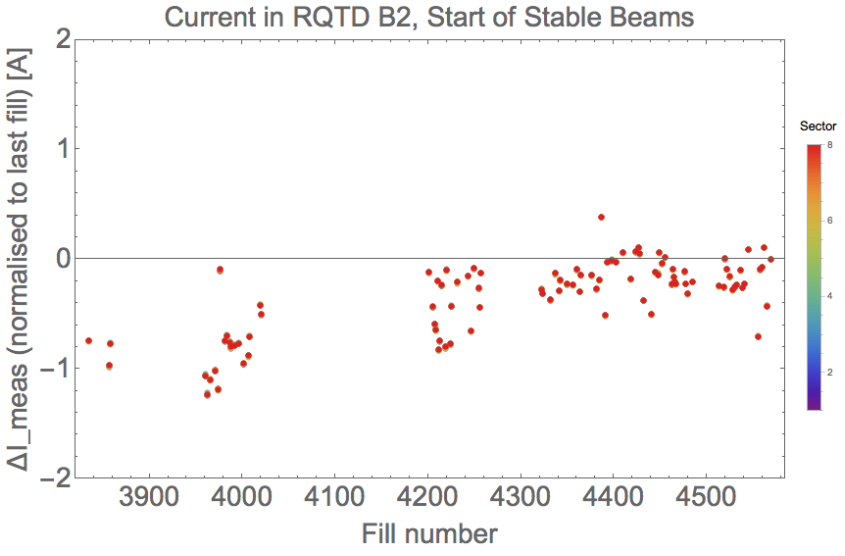
Backup

Fill to Fill variations in Current of RQTs









Current Variations of RQTs in Collisions