

LHC Injection and transfer lines

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On behalf of all contributors

In particular: K.Fuchsberger, S.Fartoukh, V.Mertens, J.Uythoven, M.Barnes, E. Carlier, W.Bartmann, C.Hessler, L.Jensen, R.Jones, M.Lamont, R.Giachino, G.Mueller, S.Redaeli, W.Herr, F.Schmidt, OP crews on shift...

Scope

1. LHC transfer lines – 2009 optics studies
 - Trajectory
 - Dispersion
 - Kick response
 - Aperture
2. Injection regions
 - Injection steering
 - MKI wave form
 - Injection protection
 - Injection aperture
3. List of subjects to follow-up

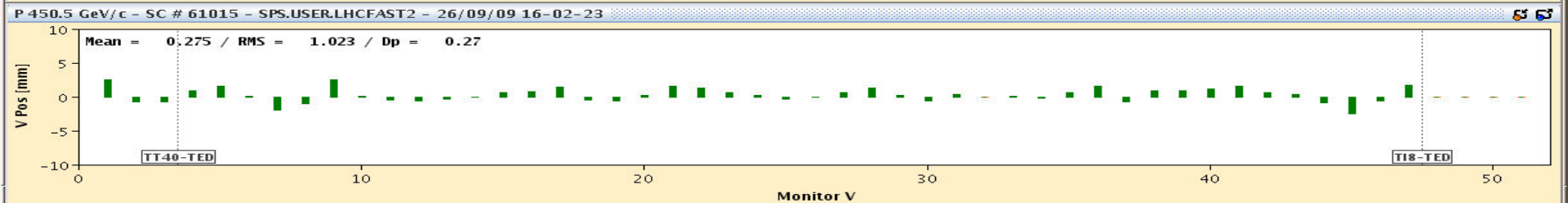
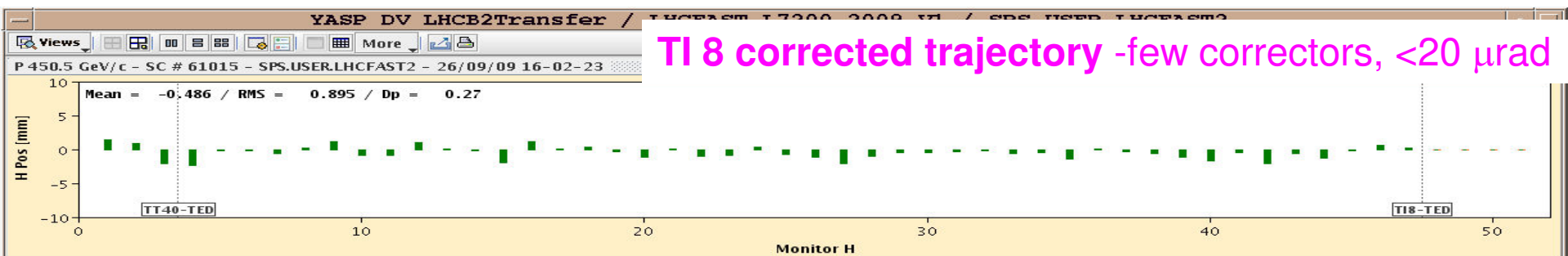
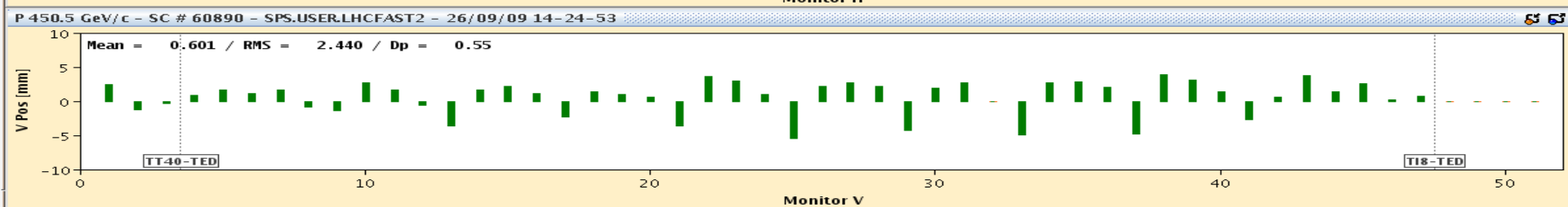
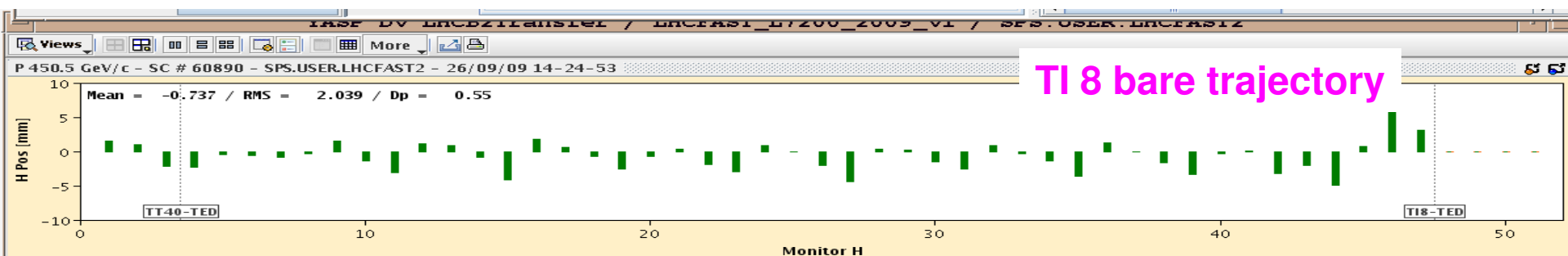
1- LHC Transfer line

Main outcomes from all transfer line beam time measurements – trajectory, kick response and dispersion measurements:

Transfer line BPMs:

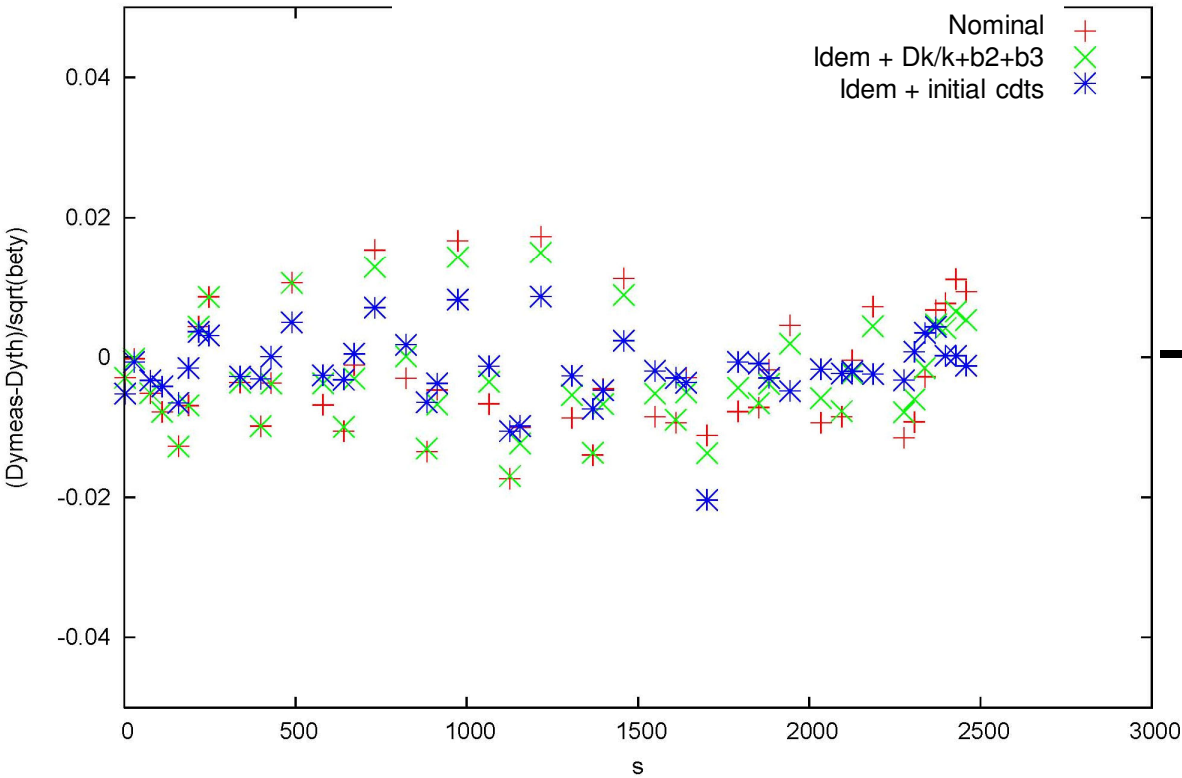
- calibration performed and included in the measurements -Rhodri, Lars and team
+ essential data from kick response measurements (Kajetan)
- request for additional BPMs upstream of TT60 – hidden trajectory bump – available for 2011 start-up
- more robust dispersion measurements in TI 8 thanks to the dual plane reading and the additional BPMs in the LHC injection area
in TI 2, same improvements will be available for the 2011 start-up – BI teams

Trajectory examples



Transfer line magnetic model:

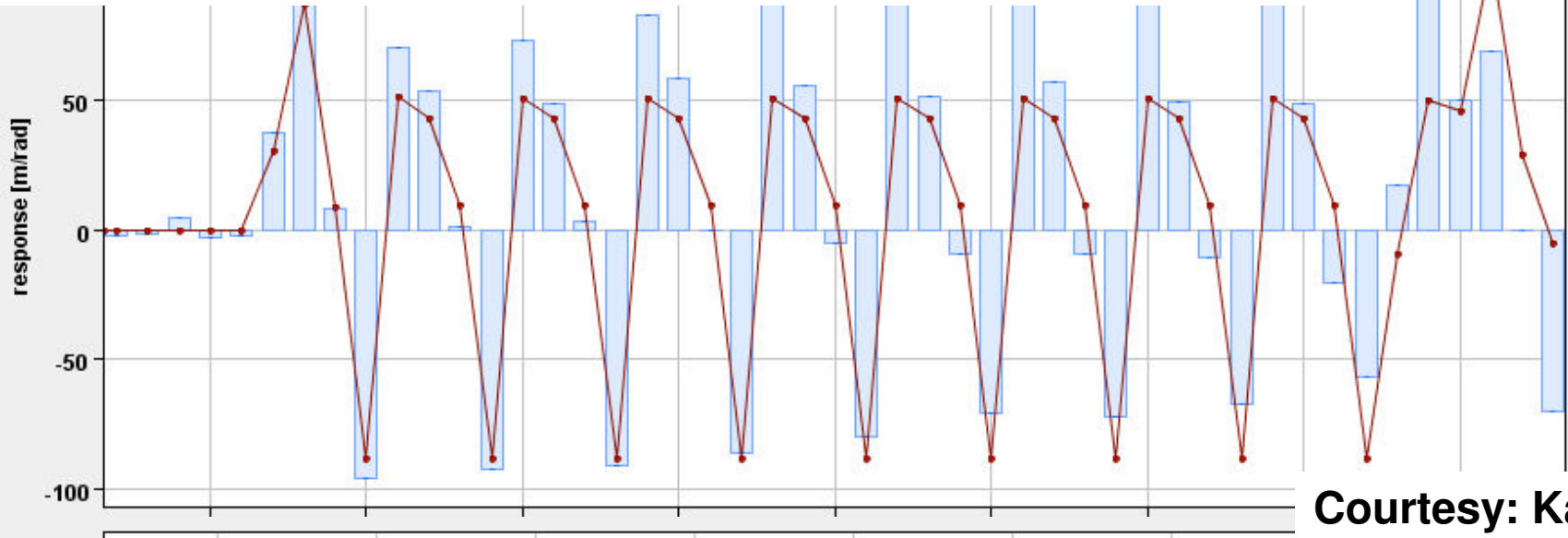
- TT60 MBE CC switched to MBB – vertical bare trajectory as expected
- MQIs $DK/K = \sim 1.006$
 - MQI measurements by magnet group
- MBI sext. component of $\sim -4.5e-4$ @ $r=25mm$ (idea from S.Fartoukh)
 - Confirmed by magnet group from 2D calculations
- MBI quad. component of $\sim 1.35e-4$ @ $r=25mm$
 - Feed-down from systematic horizontal offset in MBI



→ **Rematched optics with b2,b3 components and use new MQI CC**

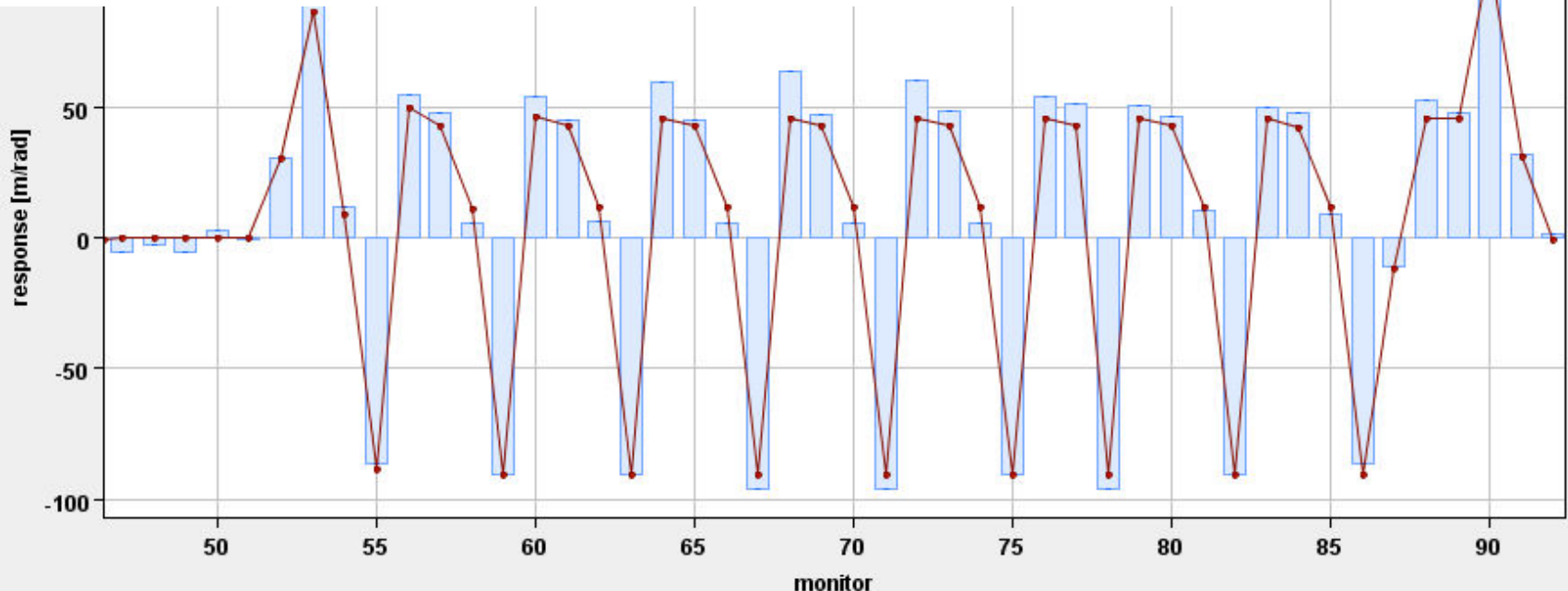
Kick response measurements – TI 8 - V plane – Before rematching

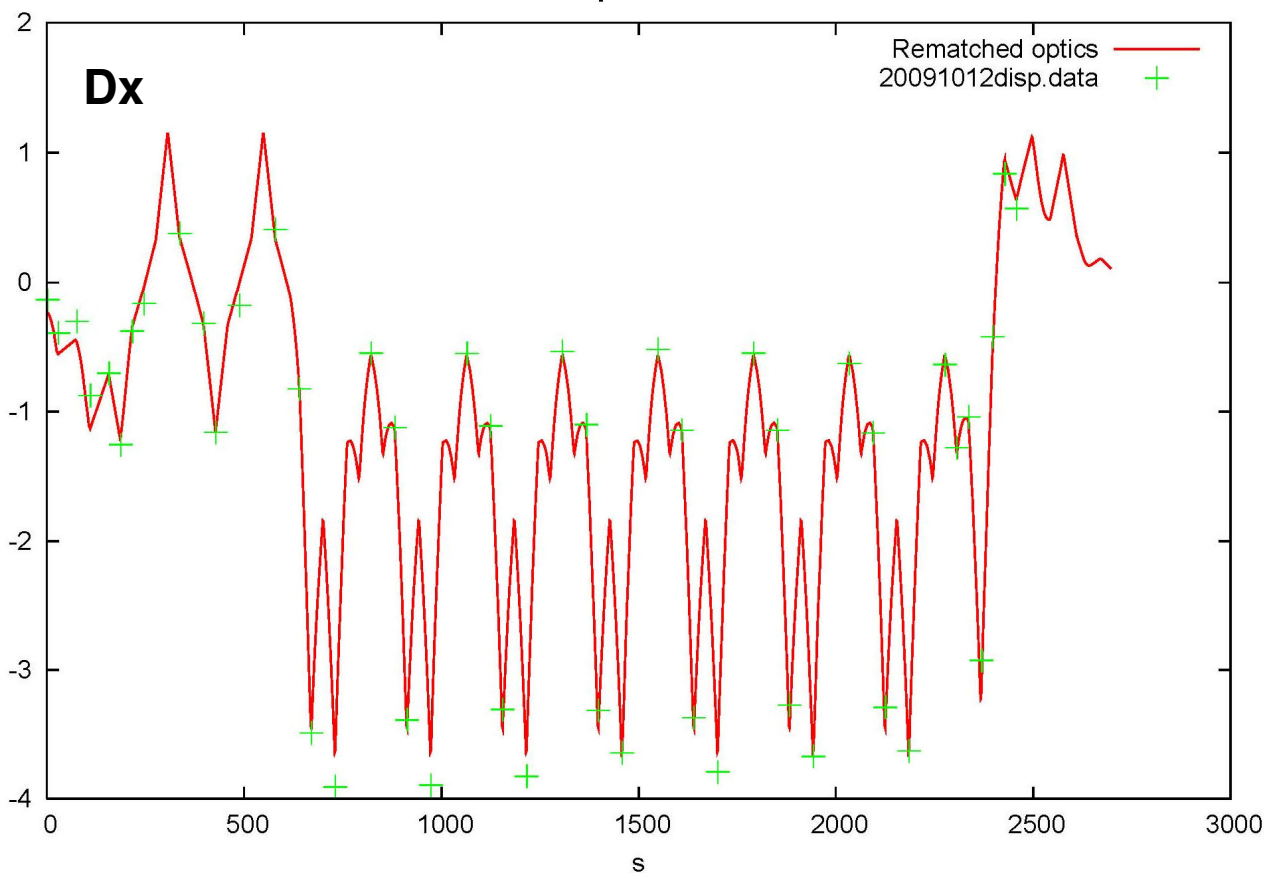
~ 0.7% over-focussing in vertical plane apparent cf model



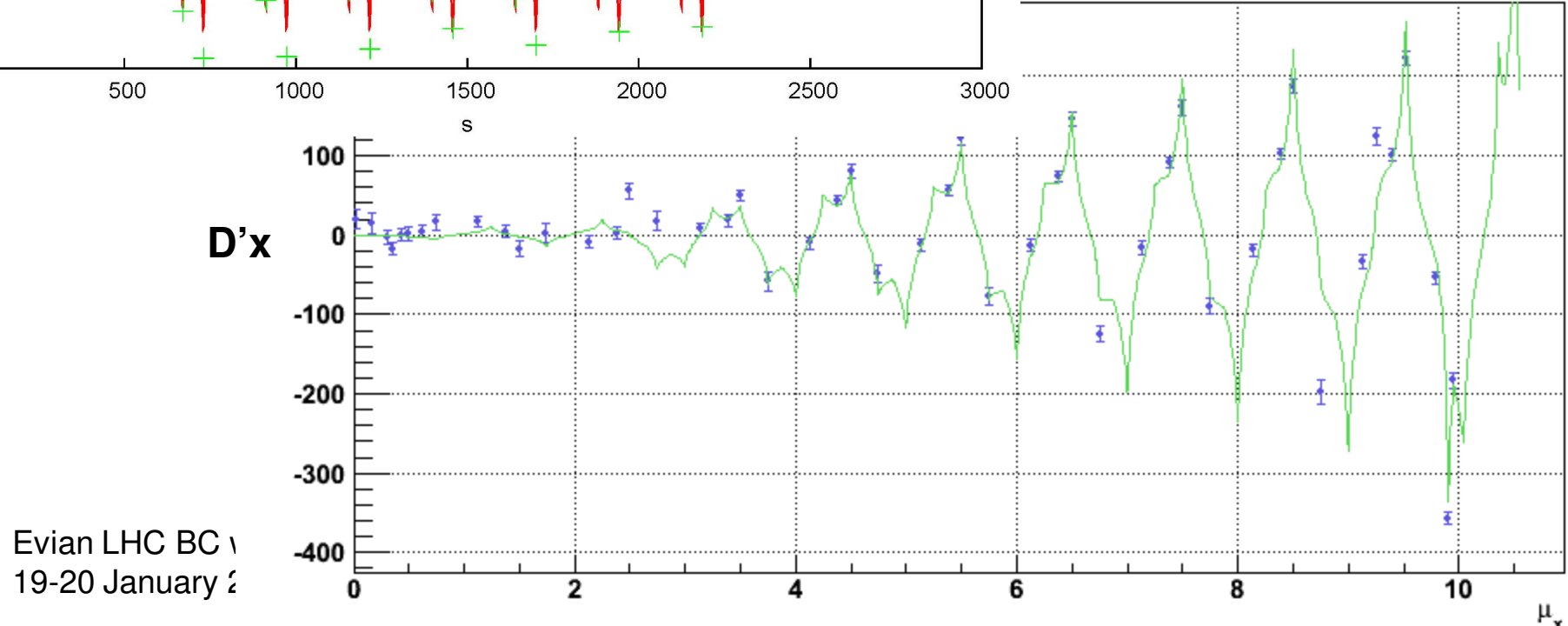
Courtesy: Kajetan

Kick response measurements – TI 8 - V plane – After rematching



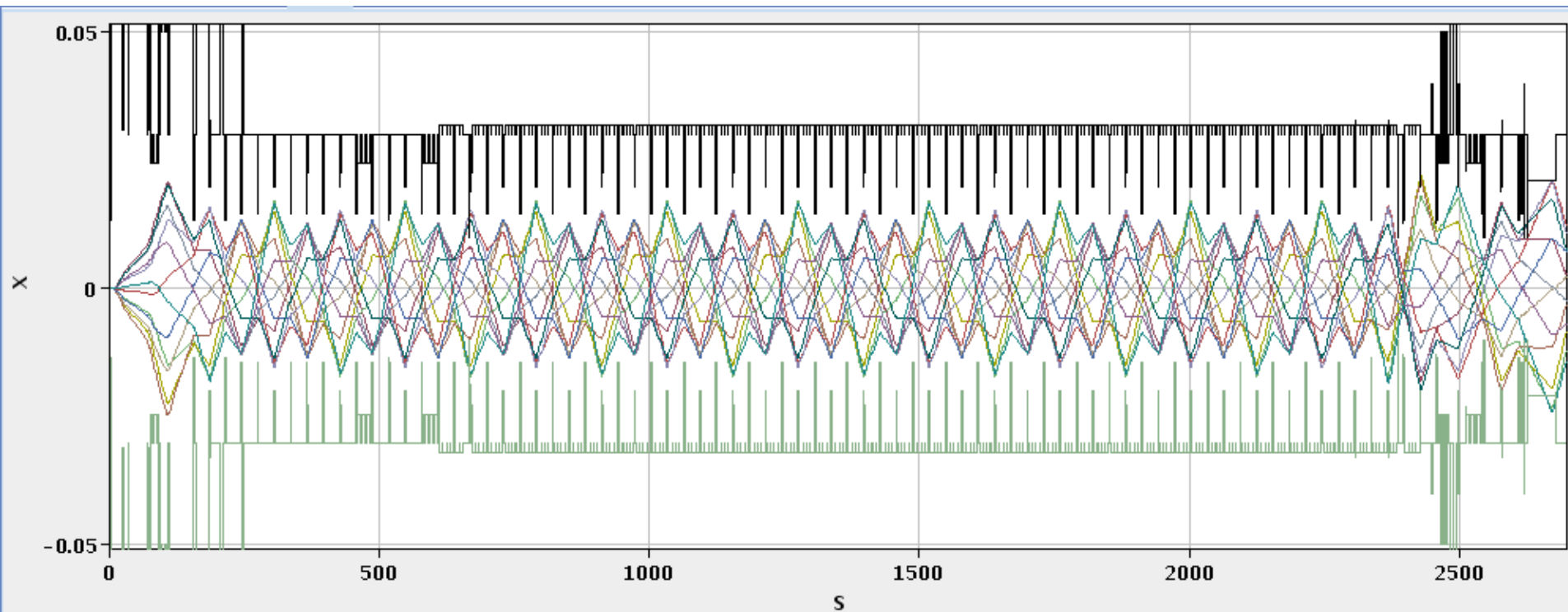


TI 8 1st and 2nd order dispersion with rematched optics



TI 2 and TI 8 aperture studies

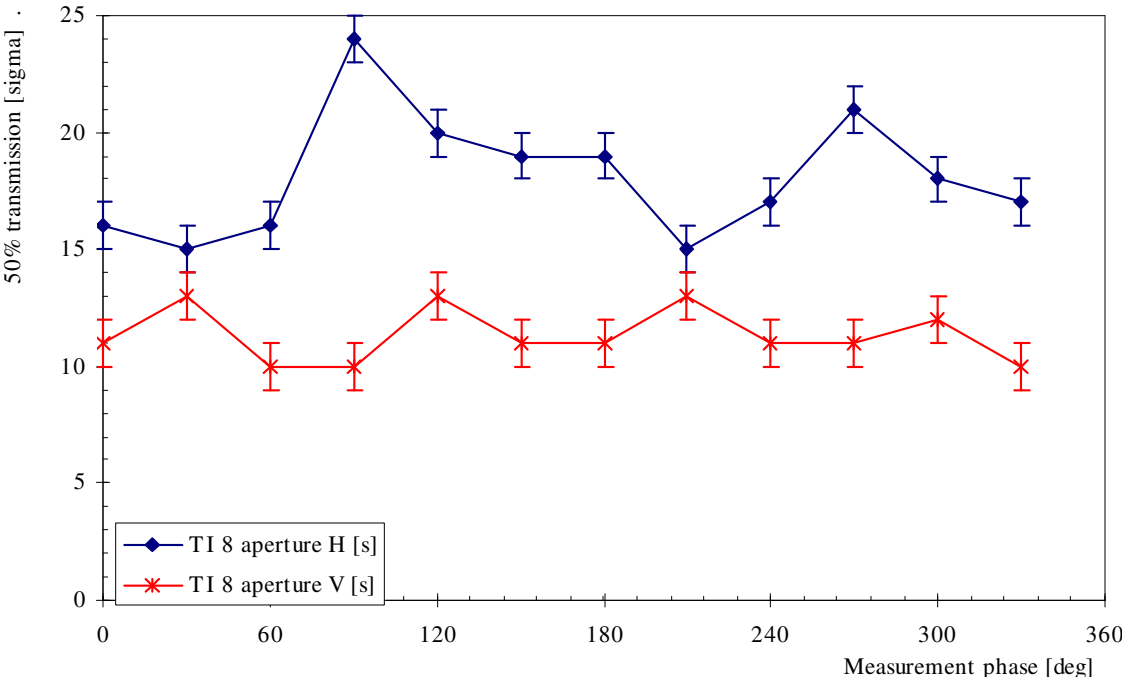
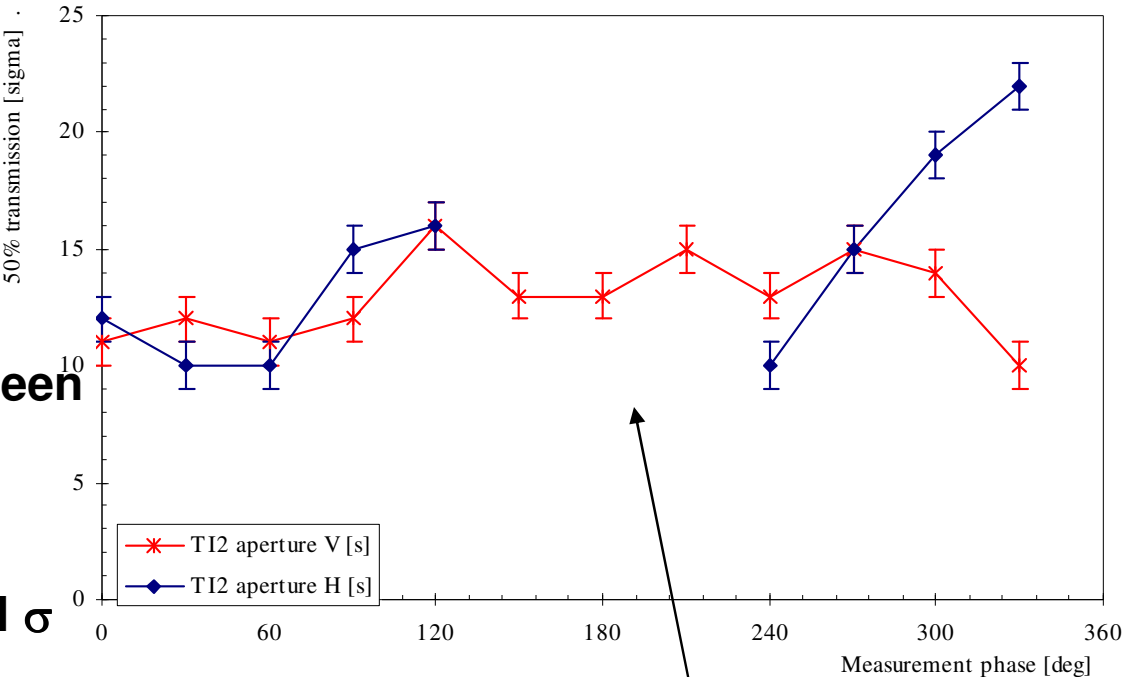
- Momentum aperture: +/- 0.35 to 0.4%, as expected.
- Physical aperture explored in both lines in H and V, at different phases, 30 deg intervals, using on-line model and dedicated knobs



In both planes in both lines:

-No bottlenecks
Note: aperture restriction between P8 MSI and Q5 solved after re-alignments

- Measured aperture ≥ 10 nominal σ



Few phases in TI 2 to complete

2- Injection region

Much injection checks and setting-up work performed through the LHC beam commissioning

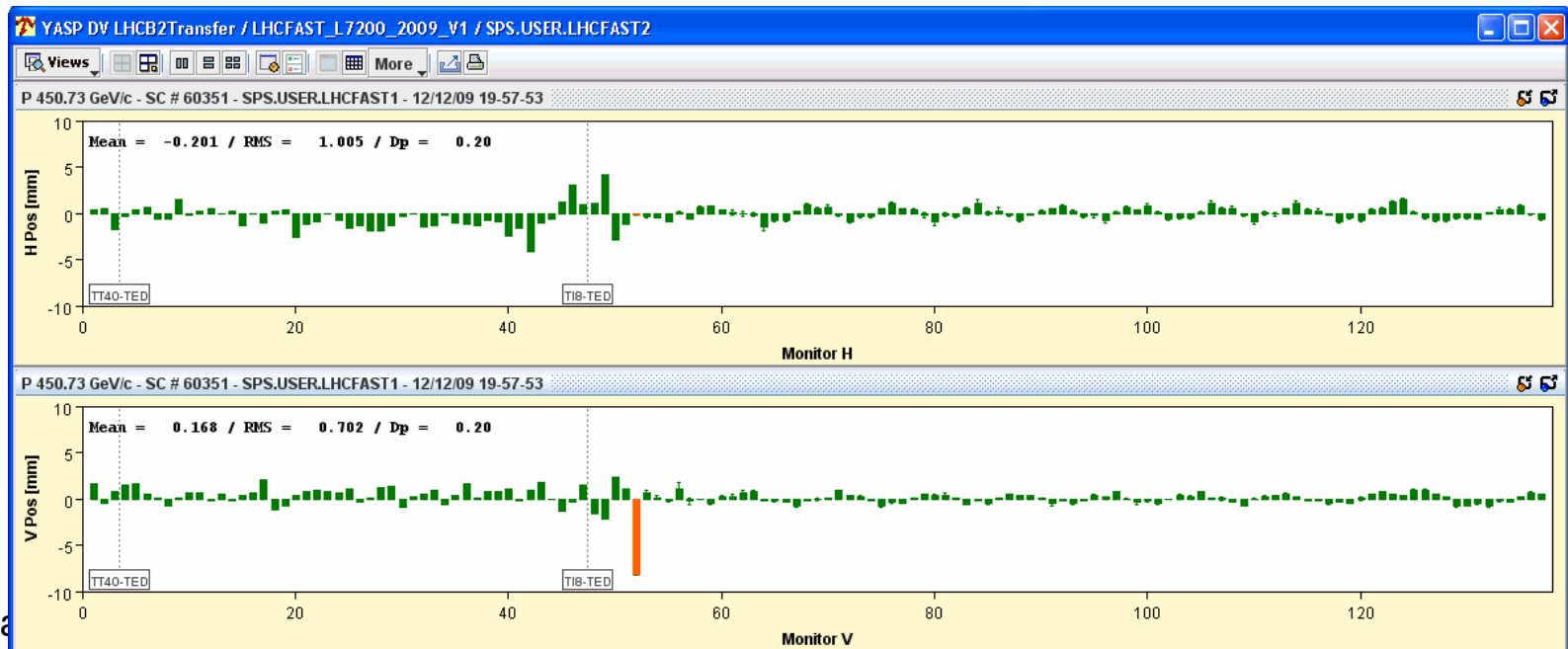
- Injection steering
- Injection region aperture
- Kick response – dispersion measurements
- MKI waveform
- TDI and TCLIA/B setting up around orbit, LHCb BeamCdtMonitor, setup of TDIs to golden orbit – see Wolfgang's talk
- Checked losses on TDI & IR8 for MKI off/over-injecting – see Christos' talk
- Tests of injection and matching with xing/sep bumps on – see Werner's talk
- Injection kicker timing in
- Injection of multiple bunches
- ...

TI 2-TI 8 Steering

- TI 2+S23 and TI 8+S78 selections of the steering display now by default:
 - TL trajectory
 - Ring First turn - Closed orbit = injection oscillation
 - Closed orbit is estimated from average of 50 first turns
- >> ensures that TL steering always brings beam onto the CO

Trajectory

FT-CO

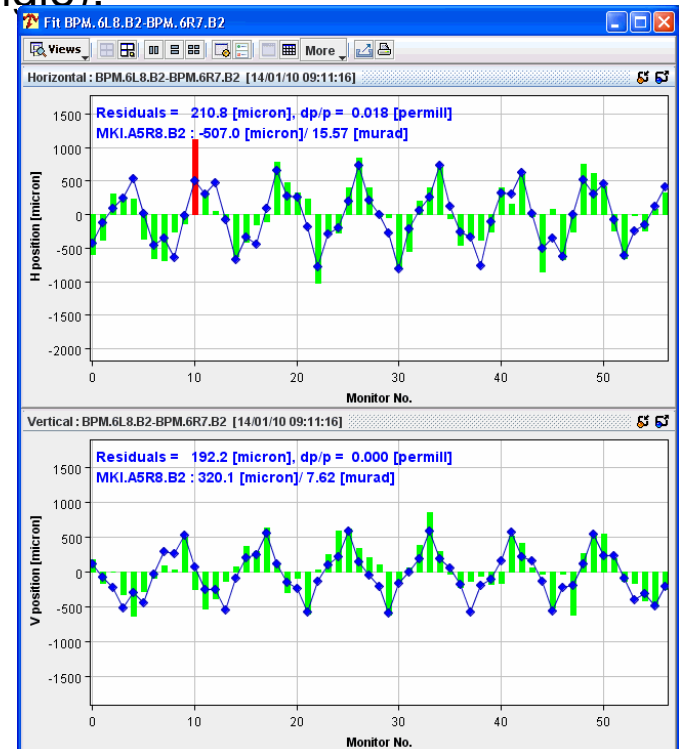


Injection Autopilot

- Feedback tools inside steering program to correct injection oscillations:
 - Same tool used for SPS injection oscillations & SPS target steering.
 - Manually activated.
 - Algorithm can be configured (DB). Presently:
 - Fit a betatron oscillation to the ring FT-CO (in H subtract dp/p error).
 - Interpolate fit to a virtual start point (pos + angle).
 - If pos/angle out of tolerance, correct with 2 correctors at end of line.

>> tested & works well !

- May need to tune algorithm because of TL collimation.
 - Global MICADO (towards ref) better?
- >> need more experience !



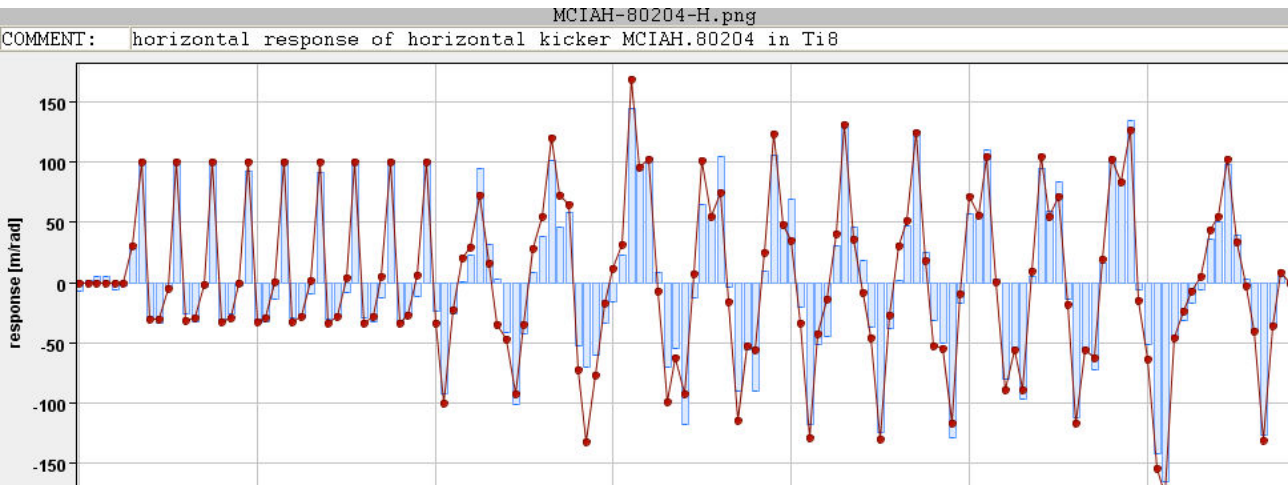
Kick response measurements -1

Data in very good agreement with model.

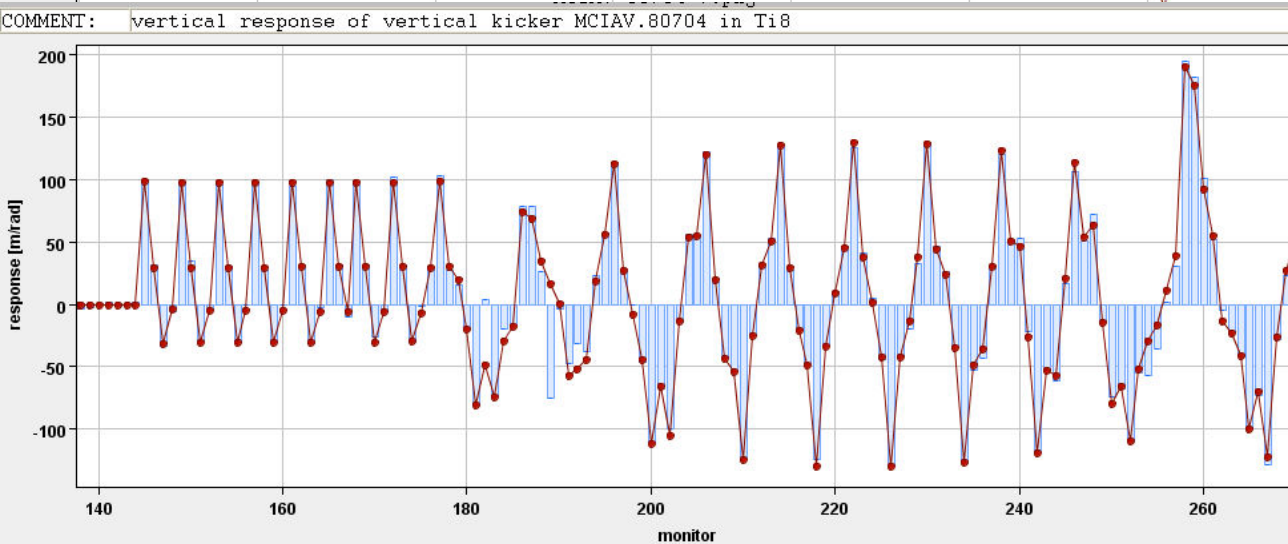
All measurements were done at $\text{deltap/p} = -0.5$ permil.

Figures show a comparison between measurements (blue) and model (red).

Beam from left.



H plane

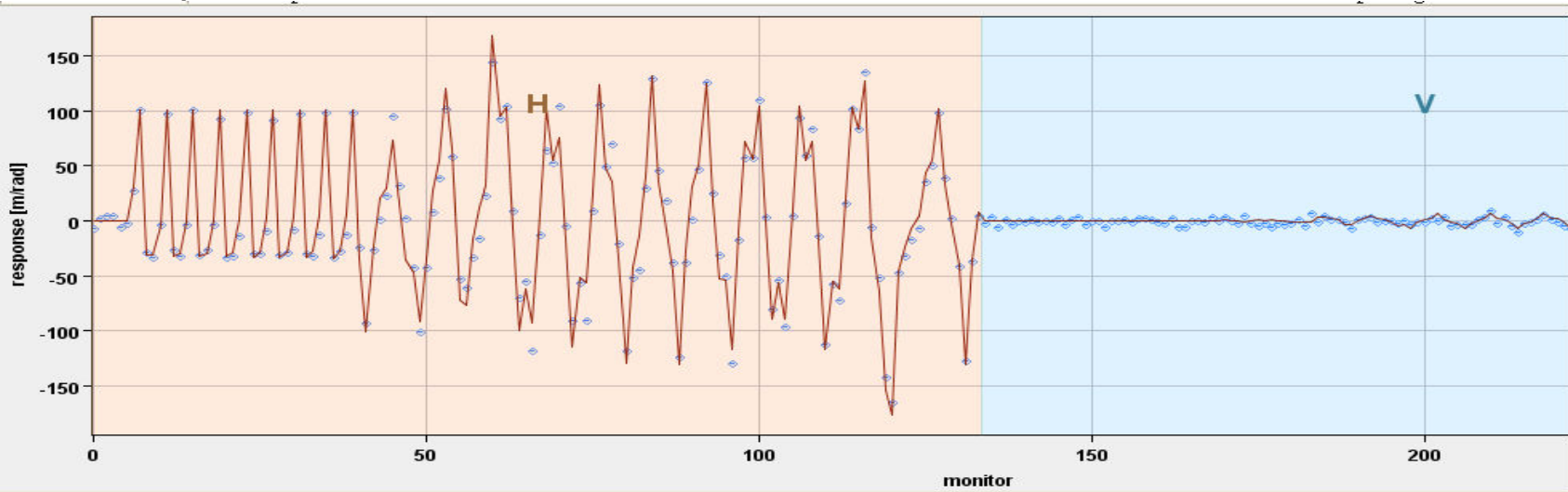


V plane

Courtesy Kajetan

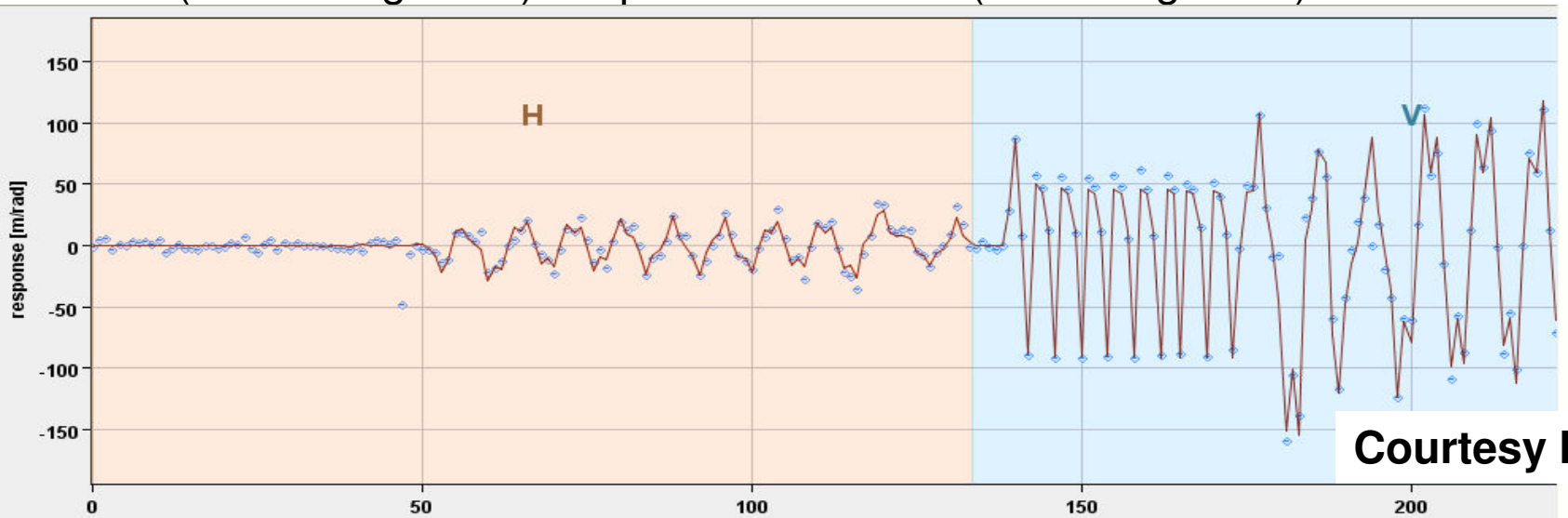
Kick response measurements -2

H+V response of horizontal kicker MCI AH.80204 for TI8 and LHC sector 78.



H+V response for vertical kicker MCI AV.80704 for TI8 and LHC sector 78.

Vertical (blue background) couples to horizontal (red background)

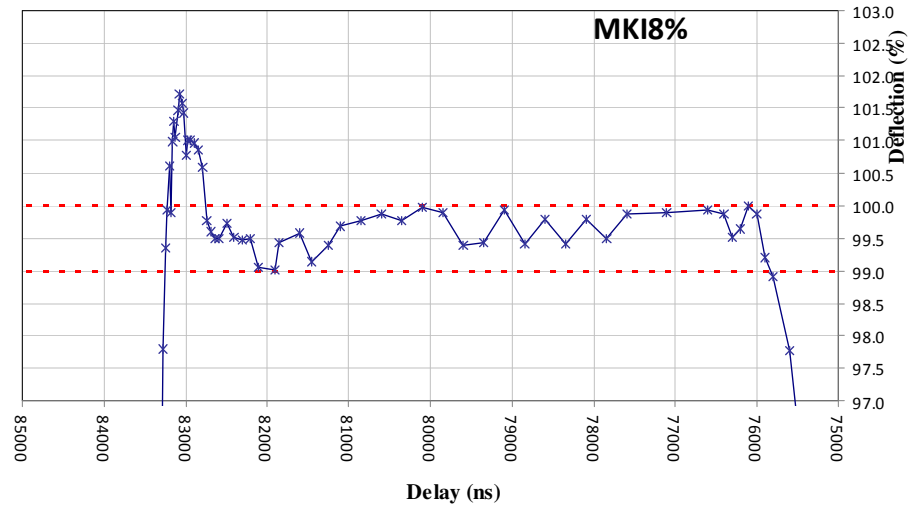
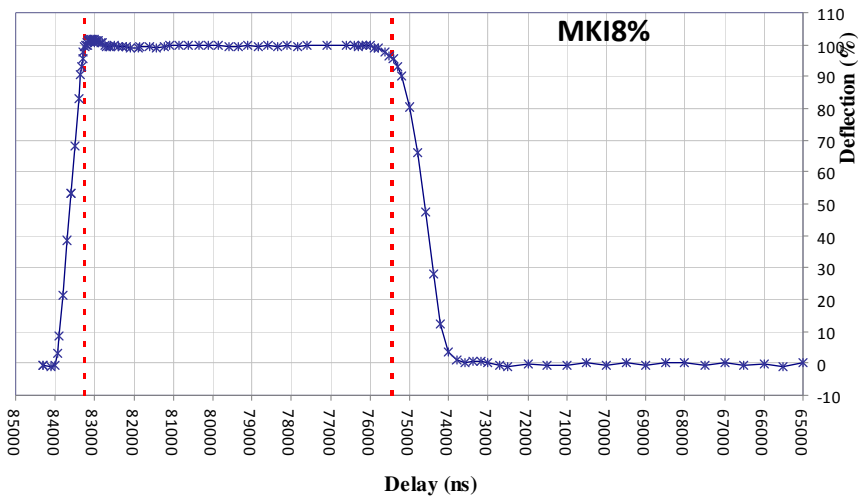


Courtesy Kajetan

Point 2 / 8 TDI and TCLIA/B setting up

- Transfer line protection devices: setting up partially done
- TDI / TCDI : done
 - See Wolfgang Bartmann presentation

MKI 2 and 8 waveform measured

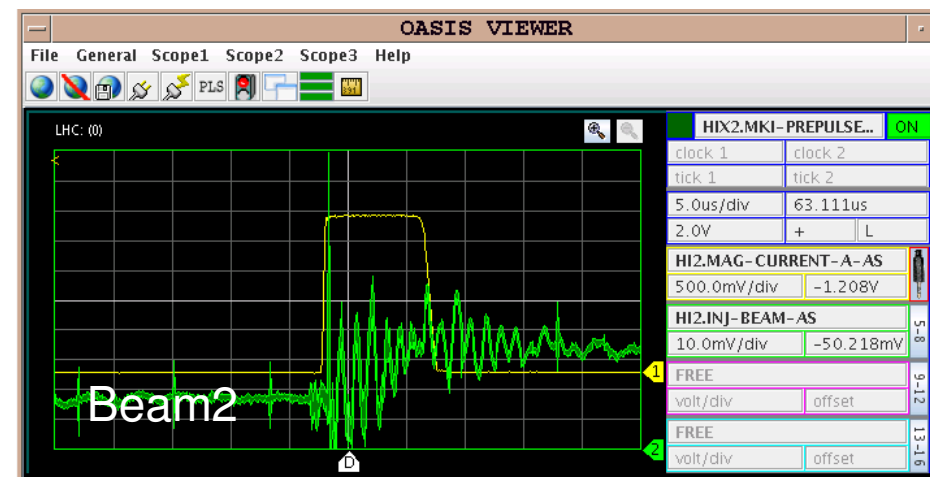
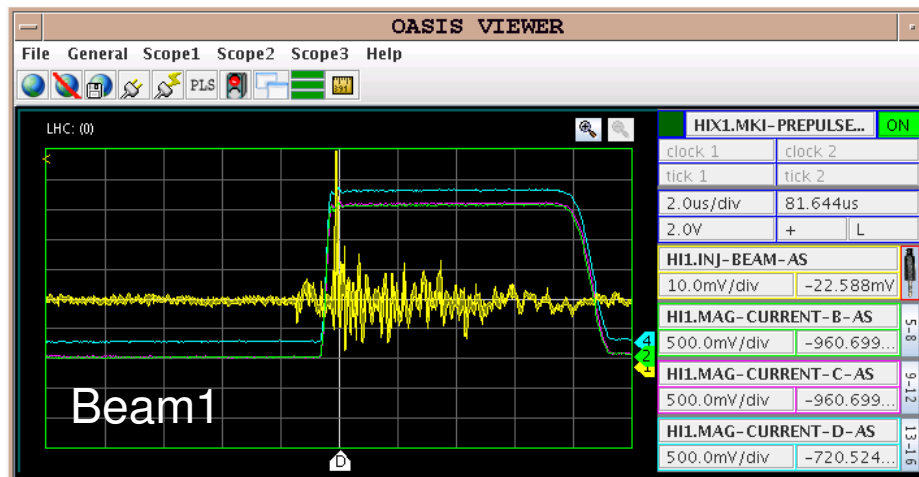


Looks OK except for 2% overshoot, both MKI2 and 8 – being corrected

Courtesy M.Barnes

Injection kicker timing in

- Both beams timed in
 - Adjusted with OASIS signals
 - Configured for abort gap keeper
 - Checked beam injected OK with acceptable oscillations
 - Need to check the fine timing to fit full SPS batch



Multiple bunch injection (and fixes)

- 4 bunch injection sequences worked after timing in MKI and MKD
- Need to be aware that injecting near to abort gap needs consideration
 - bunch is always at the head of the injection kicker pulse – always 11 μs gap as result after last bunch
 - may need to reorder some injection sequences, especially with ‘trailing pilot’
 - may need to change order of injection for some bunches.
- Setting up of protection devices to (re)do for high intensity

3- List of subjects to follow-up

- Transfer lines: Importance of:
 - Regular survey checks and re-alignment
 - Steering with minimum corrector number and strength
 - Accurate characterisation of the main magnets
 - Noise on QPS from TF pulsing? Worry about other EMC sources around ring?
- Injection region:
 - FT-CO evaluation is presently based on FIFO acquisition:
 - Works only when injecting into EMPTY ring.
 - To be able to work on ANY injection (also with circ. beam):
 - FT-CO from capture data. Code written – needs testing.
 - Capture data must be automatically configured and enabled to trigger on the buckets corresponding to the injected bunches (>> injection sequencer).
 - ‘Interference’ with PC interlocks of TLs:
 - Corrector interlock margin presently +/- 10 μ rad (from CNGS experience).
 - Must find a compromise between protection (small tol.) and steering flexibility (larger tol.). Note that shift crews have the right to change the corrector reference settings (not the tolerance).

- Injection region (cont'd):
 - Still investigate how to over-inject without interlocking
 - Puzzle of losses in P8 on MQX – issue of BLM range
 - Fine synchronisation of injection kicker pulse to bucket 1
 - Setting up of TCDIs and TCLIA/Bs
 - Losses on TCDQ/TCSG for B1 at injection– (more) checks to make
 - BQM information for IQC – to be made operational
 - Injection sequences to revisit with ‘trailing pilot’
 - May need to change order of injection for some bunches.
- **Need adequate (re)commissioning time**