LHC transfer lines and injection: results from beam commissioning

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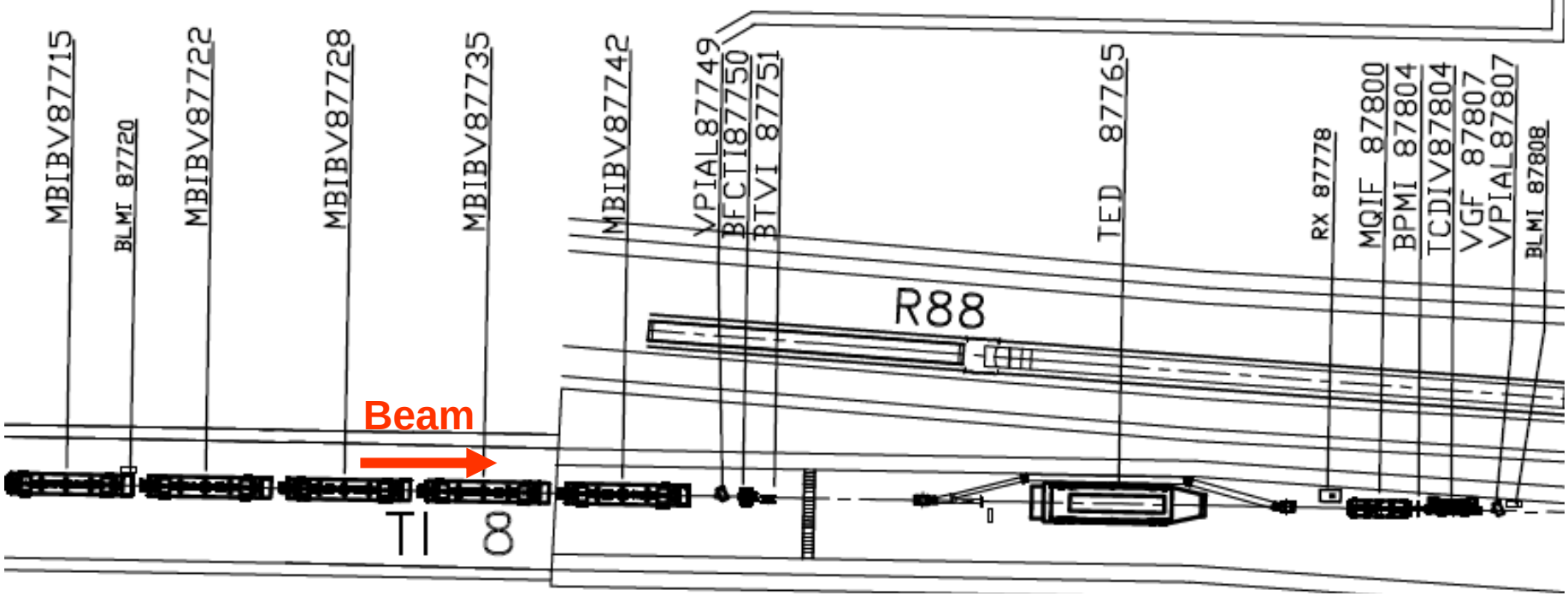
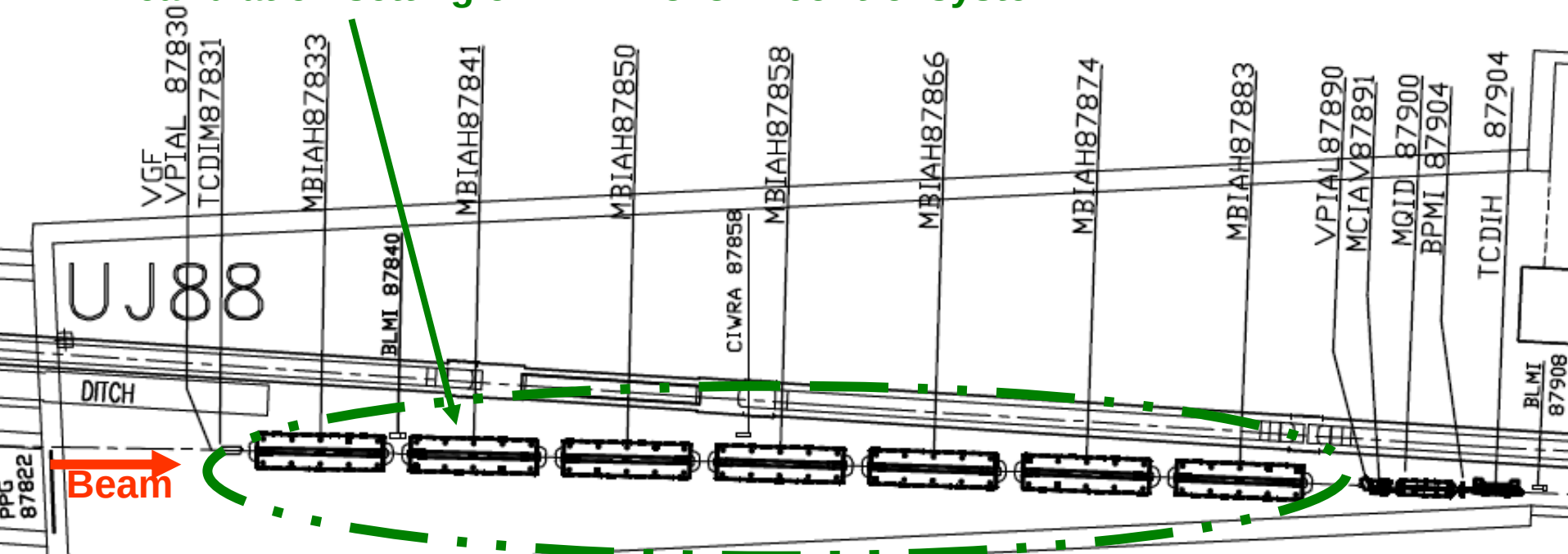
Commissioning through summer 08

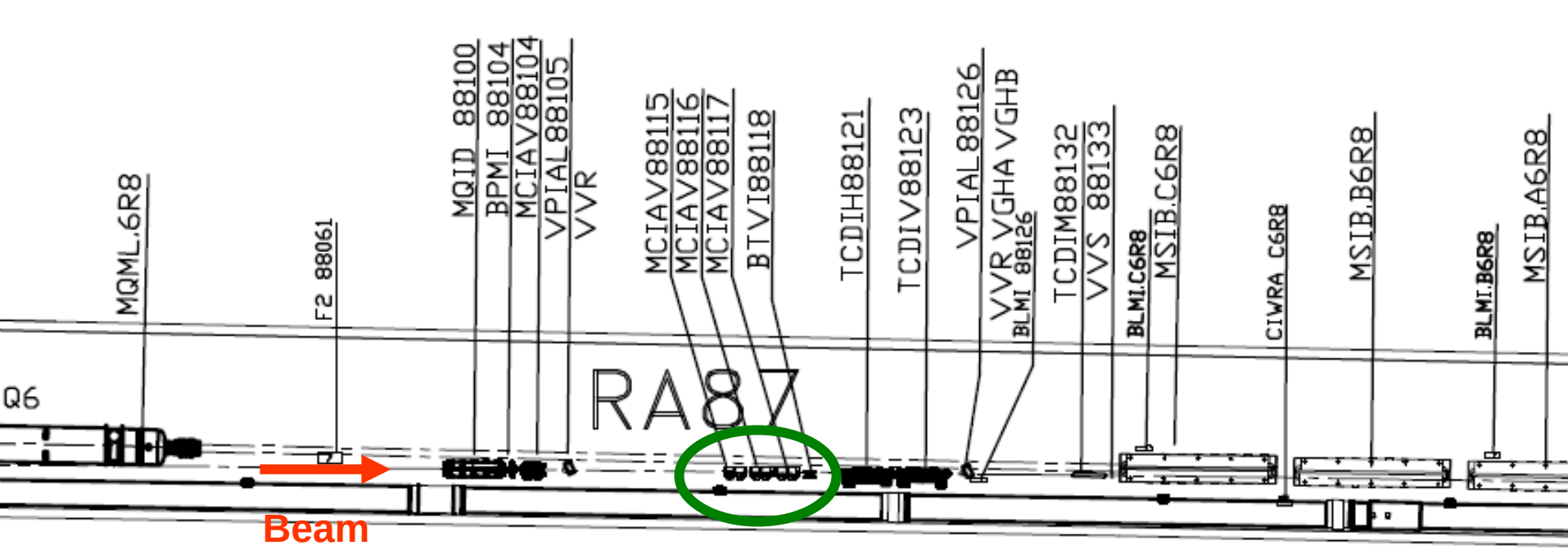
- Previous transfer line commissioning performed over the last years
- Very detailed analysis of beam trajectory, beam dynamics…
- Beam lines to last TED were performing as expected

- For the first time: go beyond last TED
- Got first measurements of the injected beam into the LHC: beam trajectory, beam parameters, beam stability…
- Compare with expectation

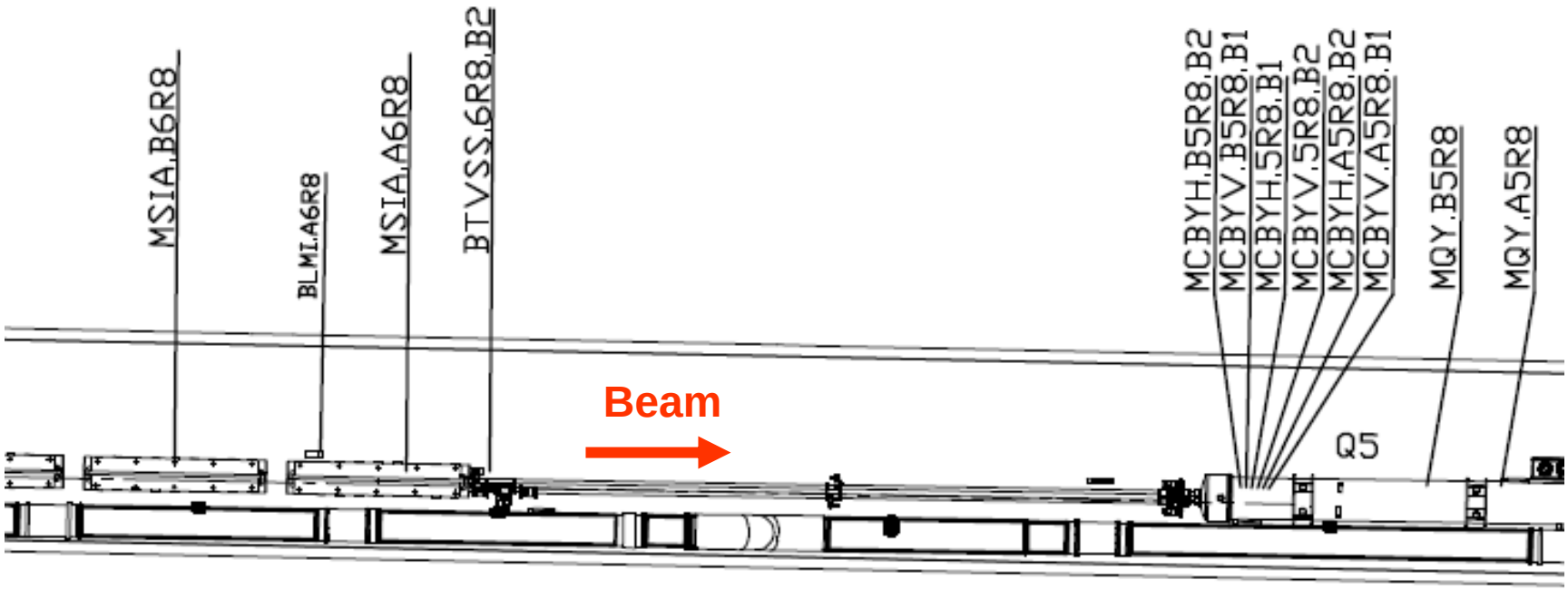


calibration setting of MBIAH878 in control system

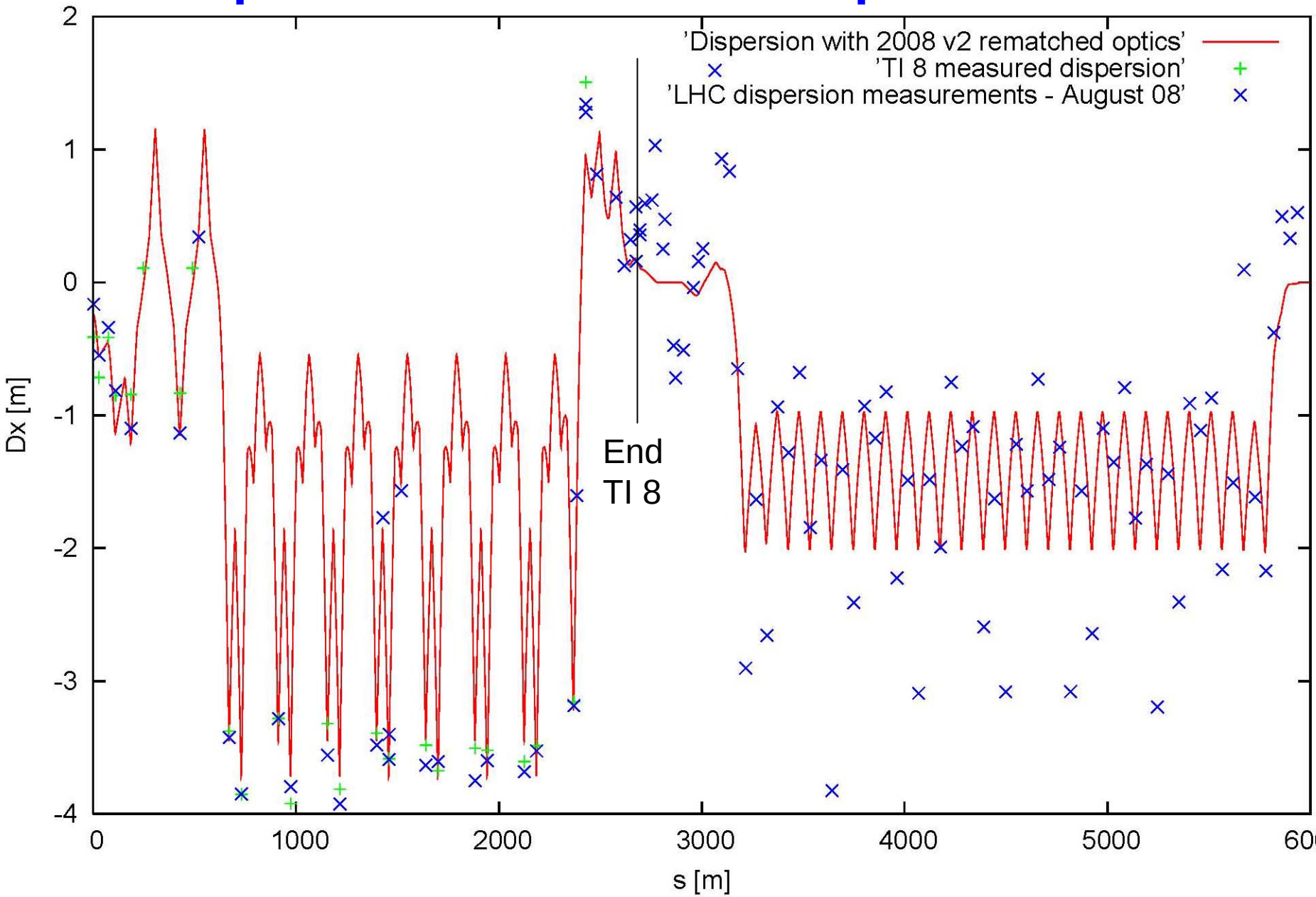




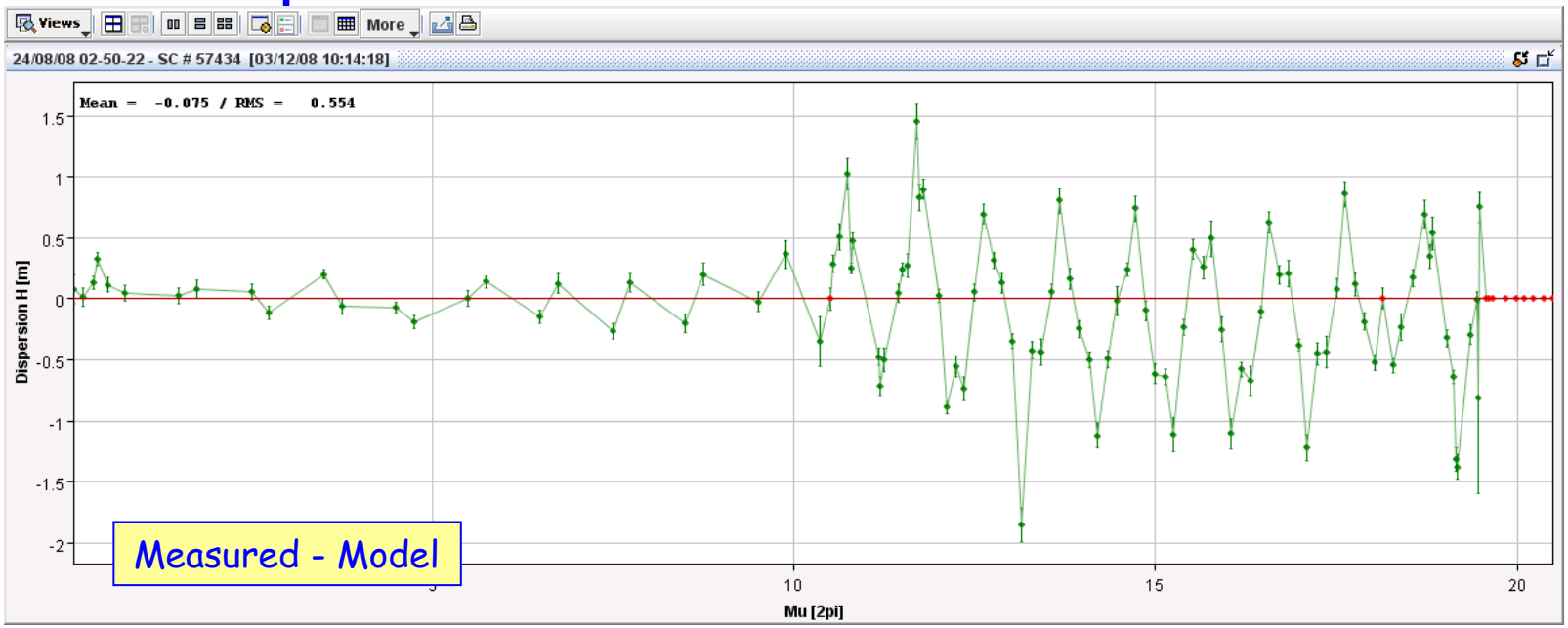
MCIAV88 polarity

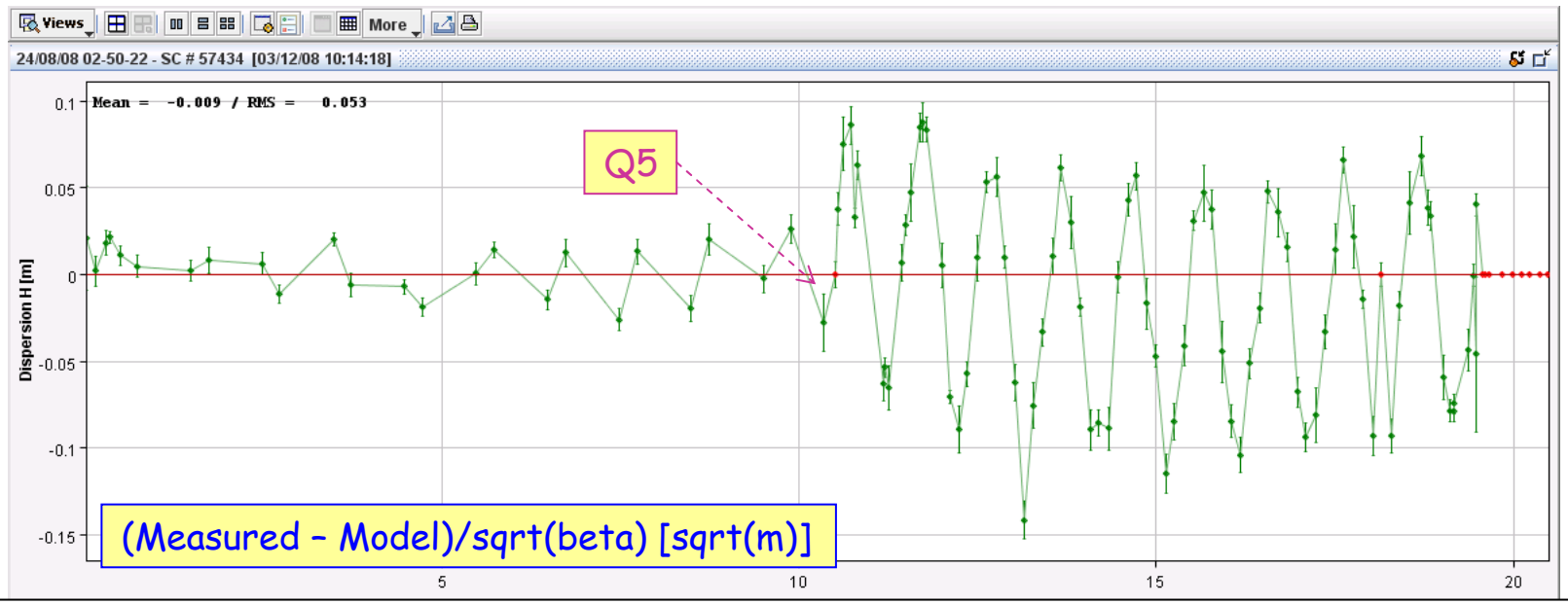


Optics checks: Dispersion



Dispersion : measurement - model



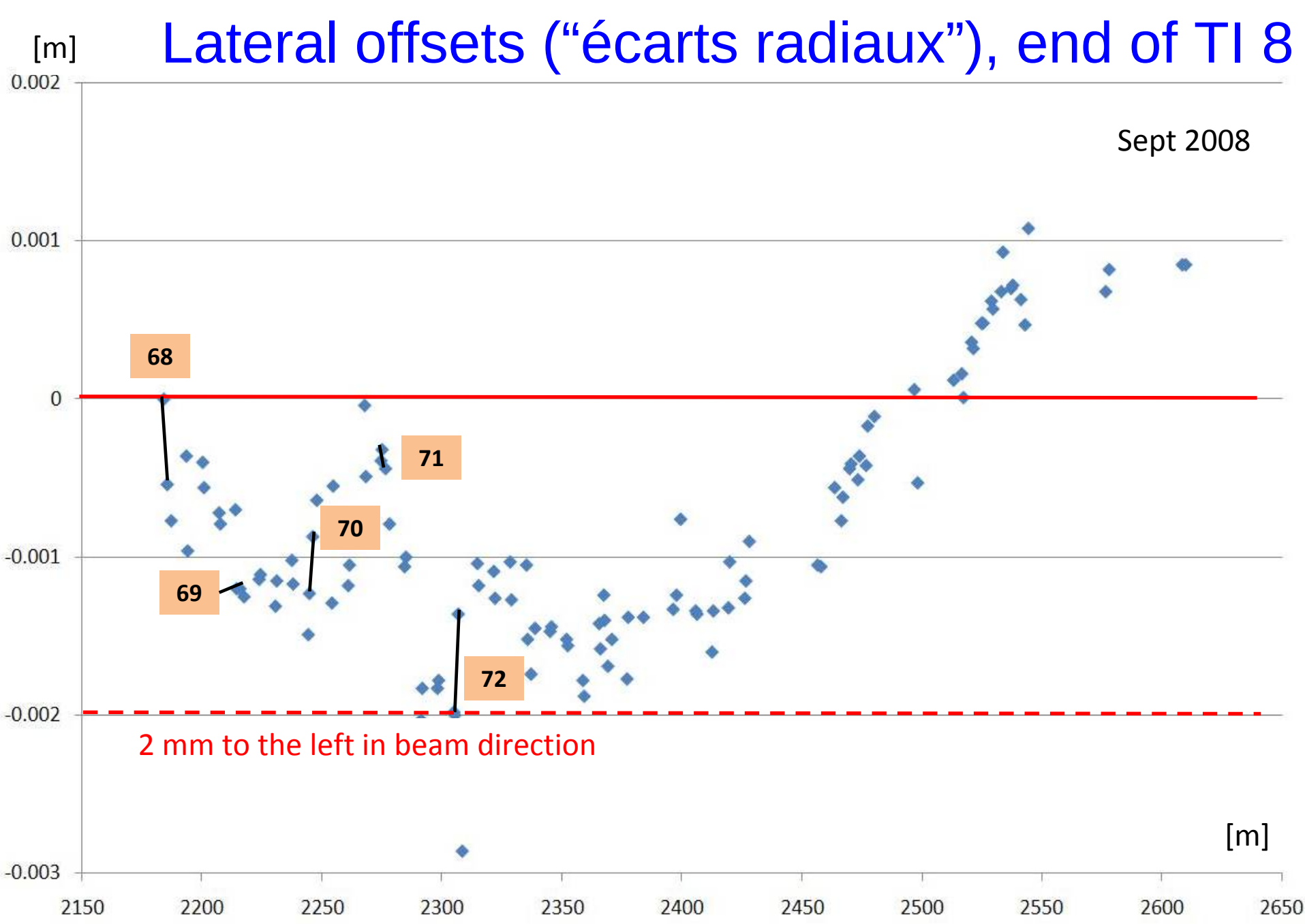


Courtesy J. Wenninger

Magnet related checks

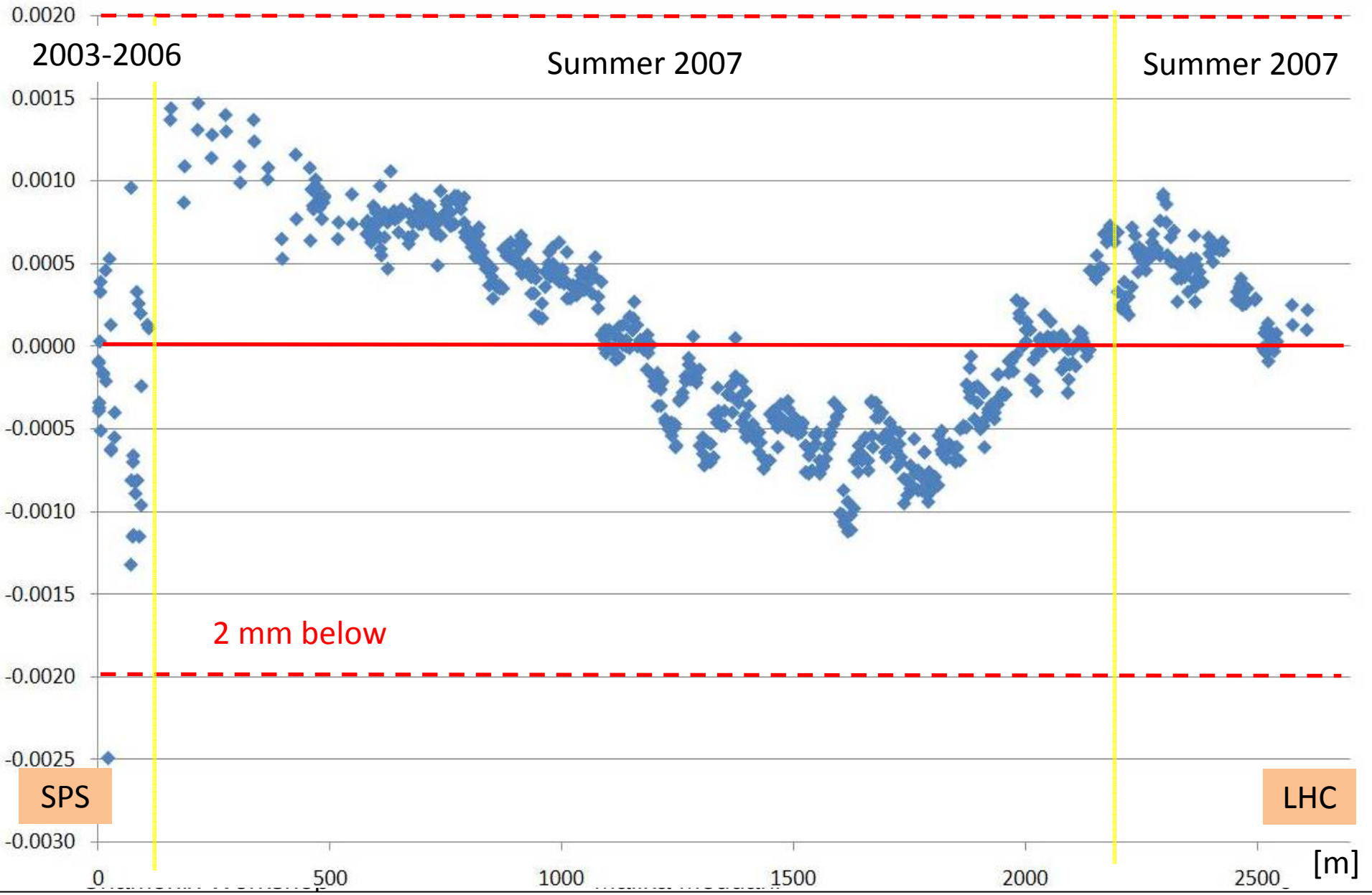
- **Alignment/control campaigns:**
  - TT40 aligned in 2003, then controlled/re-aligned at various occasions 2004-2006
  - TI 8 re-aligned in Summer 2007
  - Bottom of TI 8 controlled in August/September 2008
- **Magnetic checks:**
  - TI 8 matching quad settings in the trim editor of the control system and what is read back via EquipState
  - Set values w.r.t. to the calibration curves
  - The peak field between the poles -measured with a Hall probe
  - The response of the field to the current rise along the cycle
  - One suspected magnet was subjected to a capacitive discharge measurement at 150 V, no significant difference was observed
  - Magnetic field with one inverted pole – with doublet MQID874 (J. Borburgh)
- **Other checks done:**
  - MBIT alignment gauge: no significant systematic error found
  - MBIT dimensions of groove/holes to access laminations: no error found
  - BPMI values not significantly different from the MQI on which they are fixed

Lateral offsets (“écarts radiaux”), end of TI 8



Courtesy V. Mertens

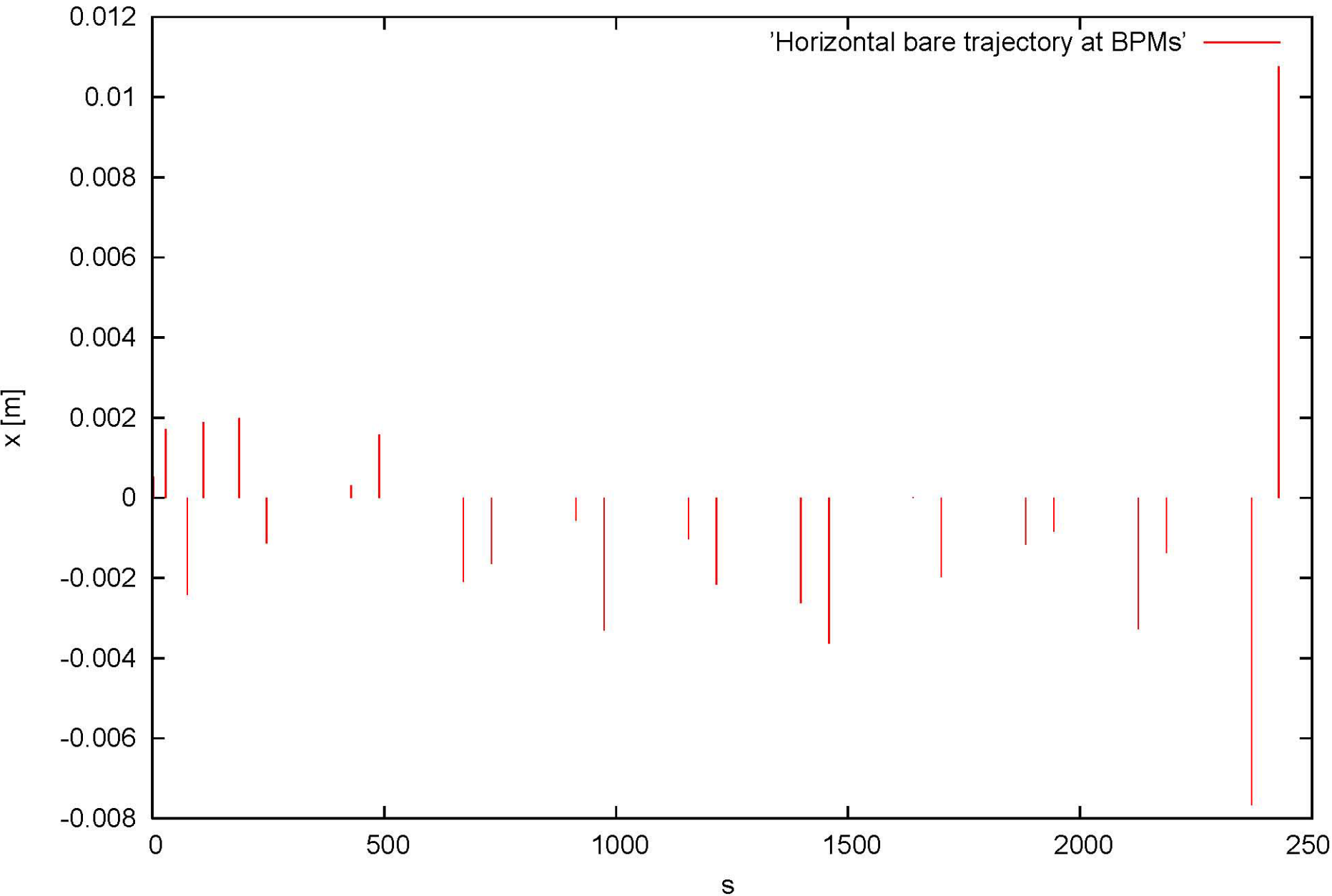
Vertical offsets, TT40 and TI 8

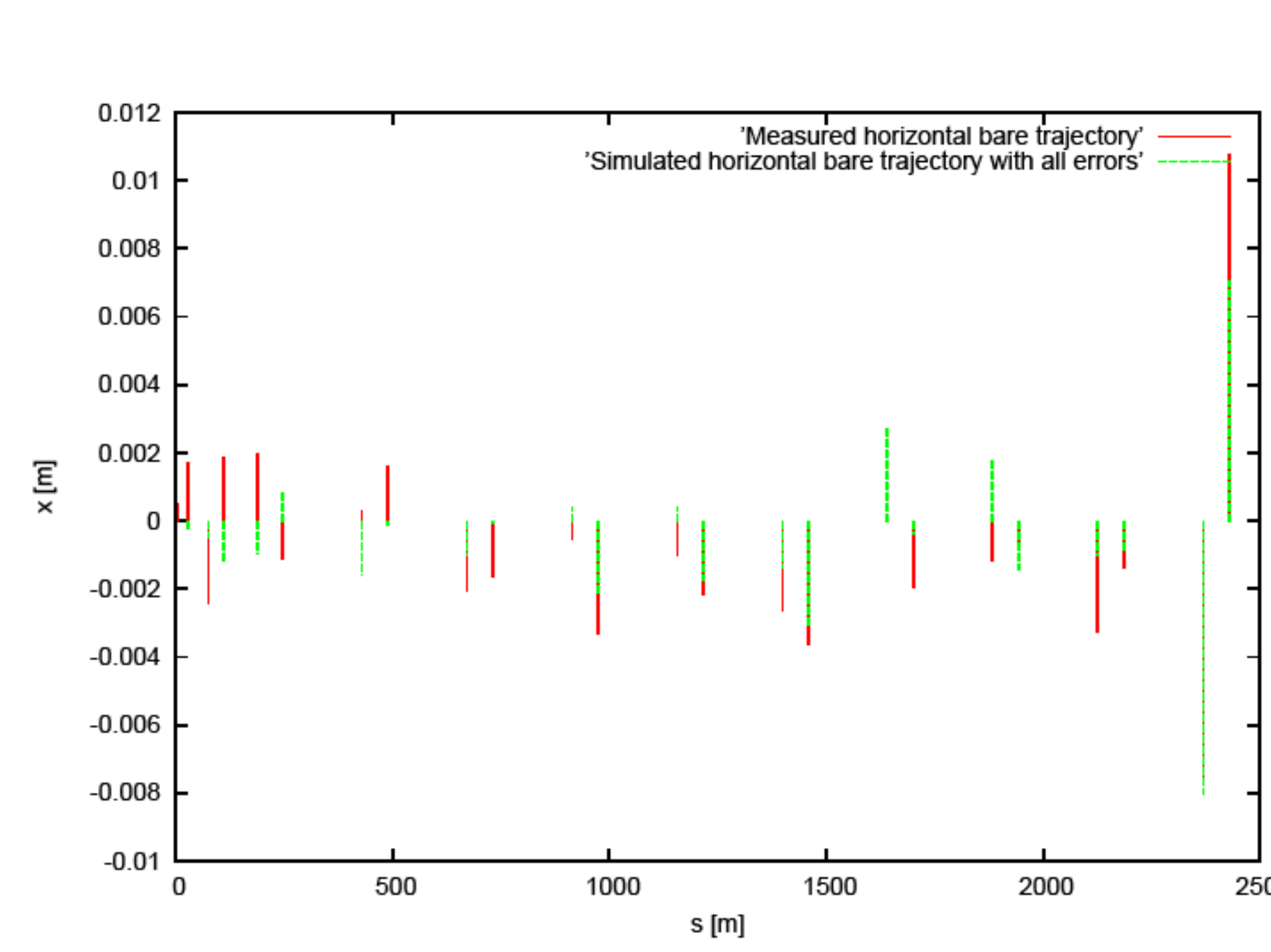


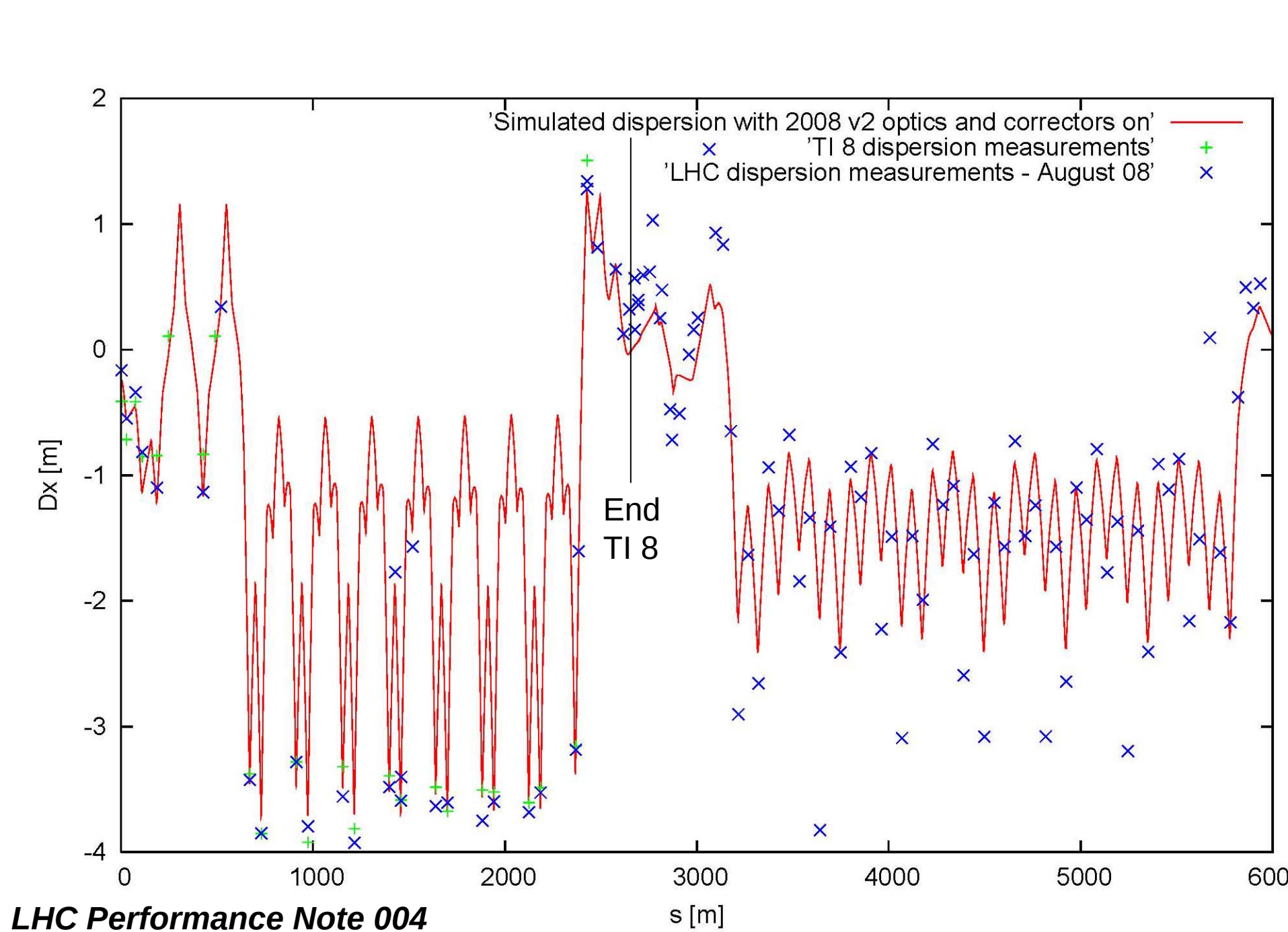
Courtesy V. Mertens

- TI 8 tunnel (relatively new site) still moves quite rapidly.
- Regular alignment checks / re-alignment campaigns needed: Just done for TI 2, in progress for TI 8
- Introduce all these alignment data in our transfer line model: Done with 2008 values. To be updated with new 2009 survey data.

Trajectory studies



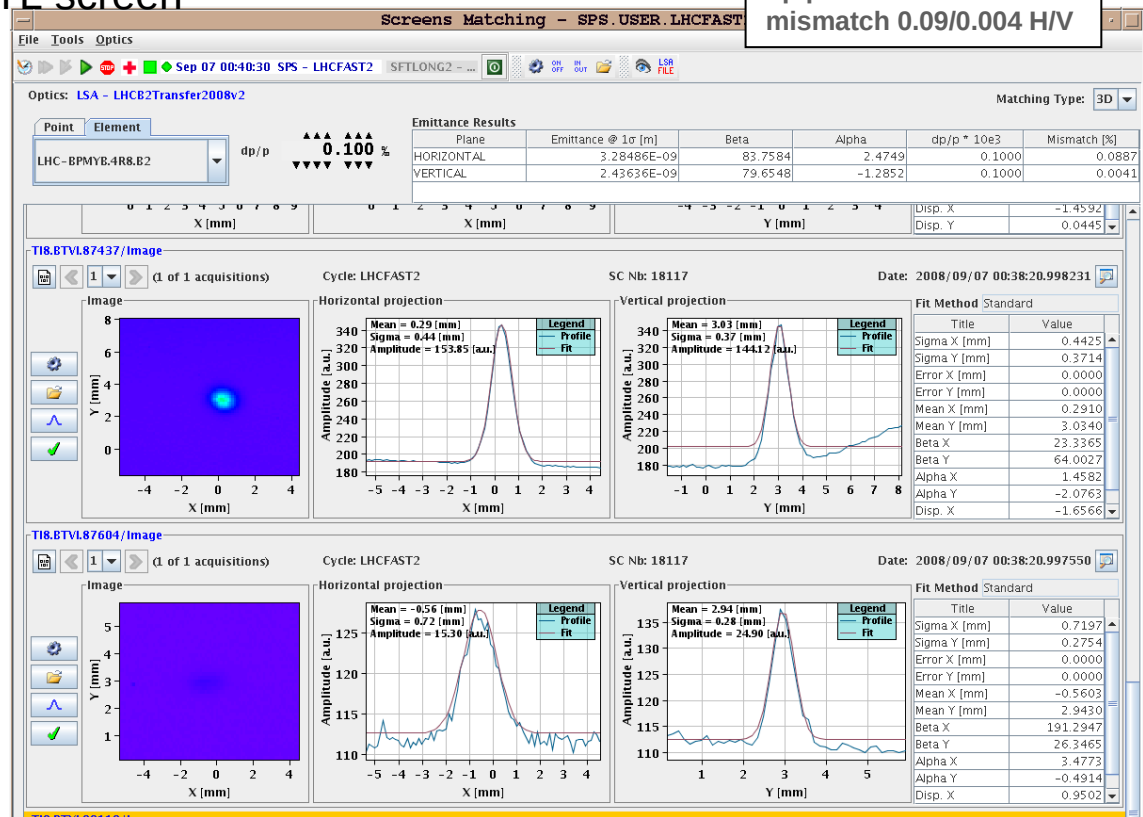

'Measured horizontal bare trajectory'
'Simulated horizontal bare trajectory with all errors'
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
x [m]
0
500
1000
1500
2000
s [m]


'Simulated dispersion with 2008 v2 optics and correctors on'
'TI 8 dispersion measurements'
'LHC dispersion measurements - August 08'
End
TI 8
Dx [m]
s [m]
2
1
0
-1
-2
-3
-4
0
1000
2000
3000
4000
5000
600

Optics matching at injection point

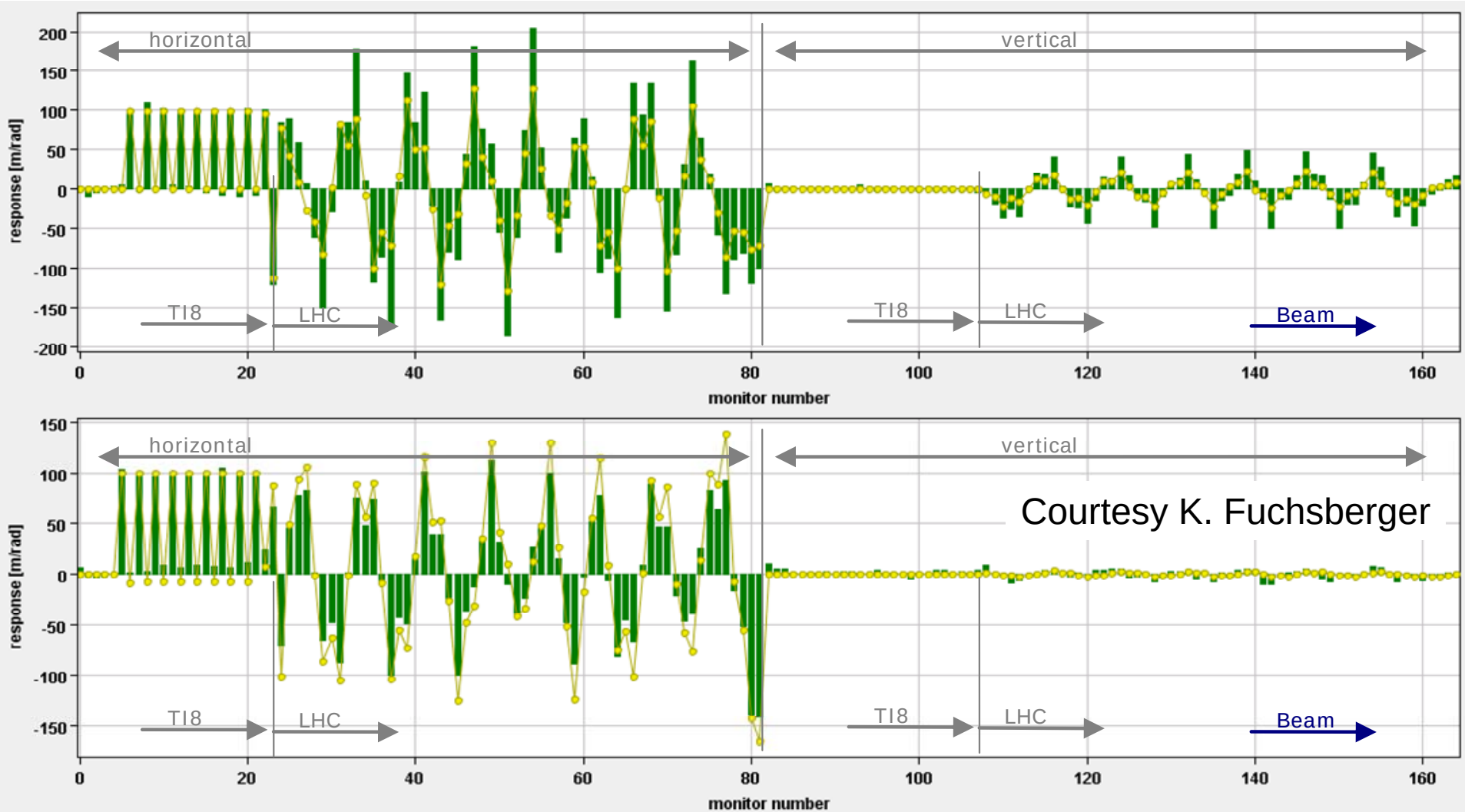
- Screen data taken parasitically during other setting-up and measurement
- High-quality OTR profiles give extremely precise position information
  - Used for dispersion measurements in crucial injection region
  - Would be good to get a way to make this automatic
- Calculation of optics functions at injection point from profiles
  - Looks promising – used online in CCC
  - Needs data from at least one TL screen
  - Will use measured dispersion
  - Improve fitting for δp

Measured 6/09/08:
ex 3.28 nm
ey 2.44 nm
dp/p 0.1%
mismatch 0.09/0.004 H/V



Courtesy V. Kain, E. Benedetto

Coupling from tilt rotation in TI 8



- Explained by tilt mismatch at injection point
- Still ~20% larger than model predicts – more measurement needed

LHC Performance Note 003

Summary

- Linear optics measurements made from TL into LHC. coupling – dispersion TI 8 to LHC
  - Field and alignment errors added to the transfer line model
  - Importance of including the operational corrector settings in the model
  - Measured bare TI 8 trajectory well reproduced with the measured alignment offsets
  - Dispersion behavior with all errors shows same amplitude and phase of perturbation in TI 8 –still difference in beating patterns in LHC but LHC model to be included

- For 2009 start-up:
  - Alignment of the lines prior to 2009 start-up, in progress. Model will be updated accordingly
  - Additional BPMs installed in TI 8. All BPMs will provide dual plane reading
  - Algorithm for “dispersion-free” steering added in YASP
  - Checks of coupling with high statistics
  - Full LHC model linked to TI 8

Thanks to all contributors

- *OP teams (K. Fuchsberger, V. Kain, M. Lamont, J. Wenninger …)*
- *ABP (I. Agapov, O. Brüning, S. Fartoukh, M. Giovannozzi, W. Herr, T. Risselada, ….)*
- *BI (L. Jensen, R. Jones, …)*
- *SU (M. Jones, D. Missiaen …)*
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- *USLARP collaborators (E. Gianfelice, R. Calaga)*
- *Magnet colleagues (D. Smekens, J. Bauche…)*

- *Excellent support from the numerous teams involved in preparing and running the TLs & LHC*