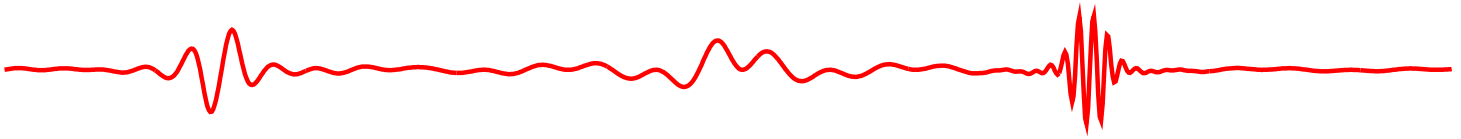
The LHC optics in practice



R. Tomás, C. Alabau, O. Brüning, R. Calaga, M. Giovannozzi, P. Hagen, V. Kain, M. Lamont, R. Miyamoto, F. Schmidt, M. Strzelczyk, and G. Vanbavinckhove

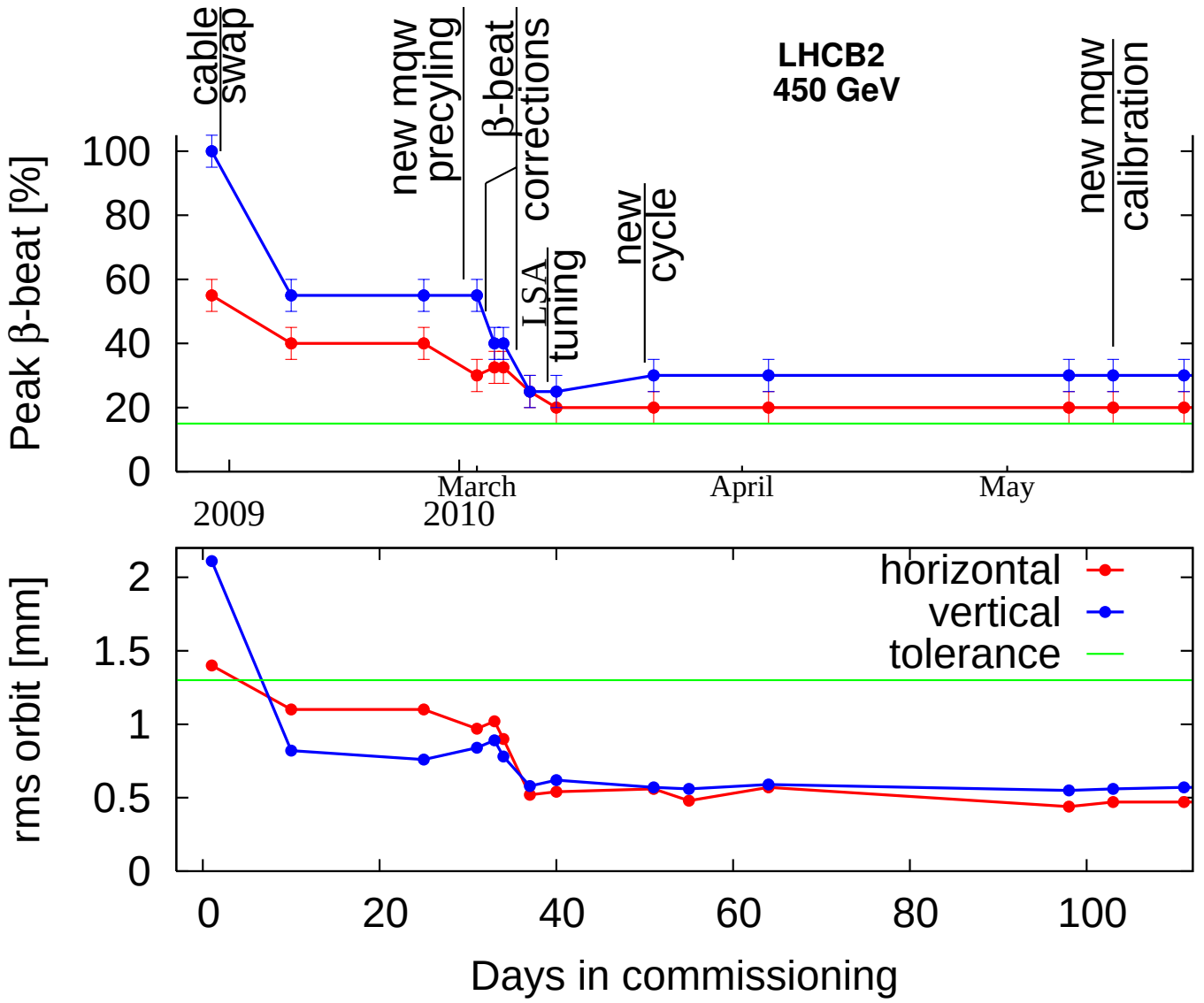
Thanks to BI, CO, FiDeL, LCU, OP and TIMBER

Evian, December 2010

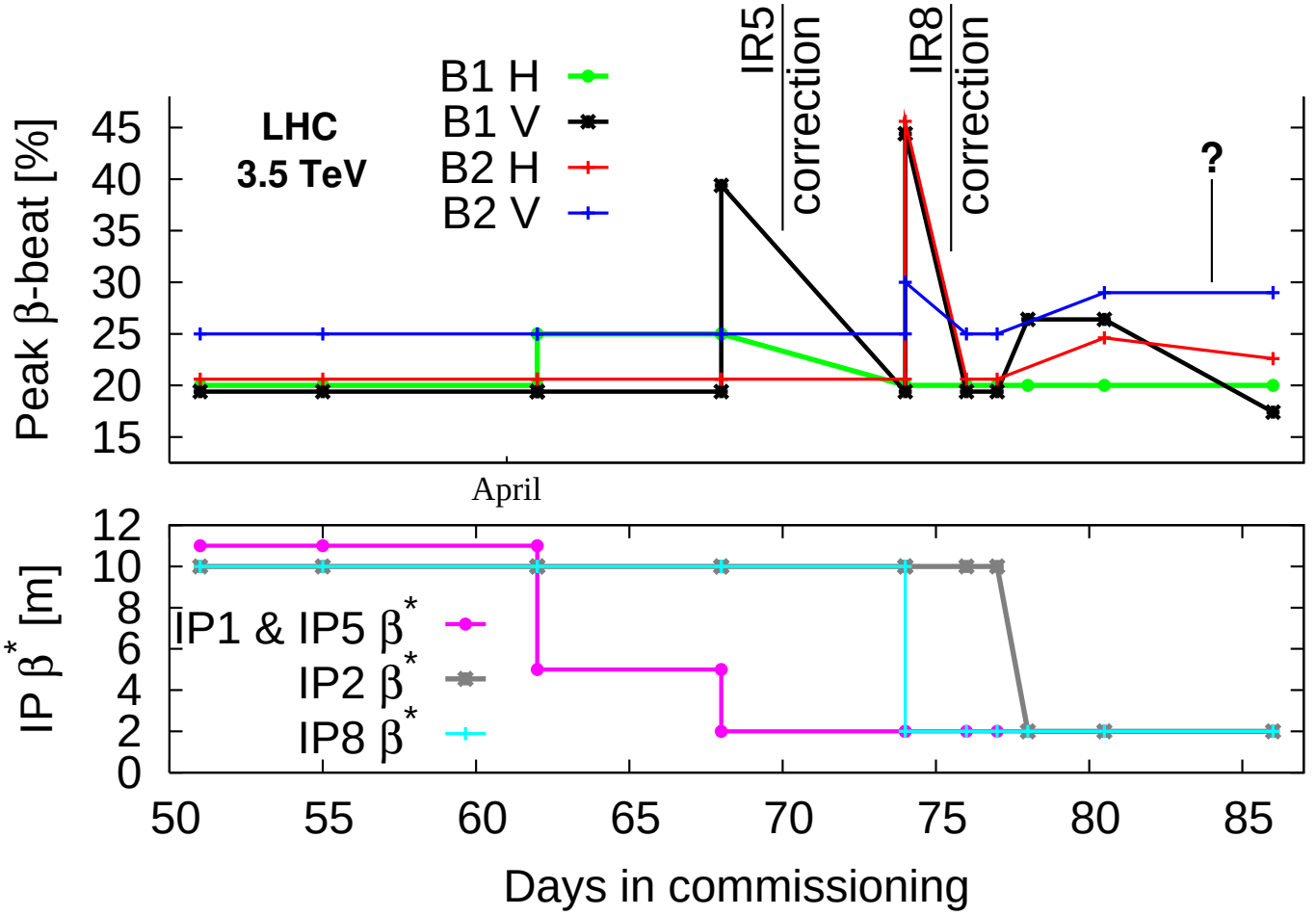
Contents

- 2008-2010
- The $\beta^* =$2m mystery
- Trim versus incorporation
- Stability and measurement error
- K-modulation?
- Consequences of reducing β^*
- Coupling
- Higher order corrections in the triplets?

β-beating at injection



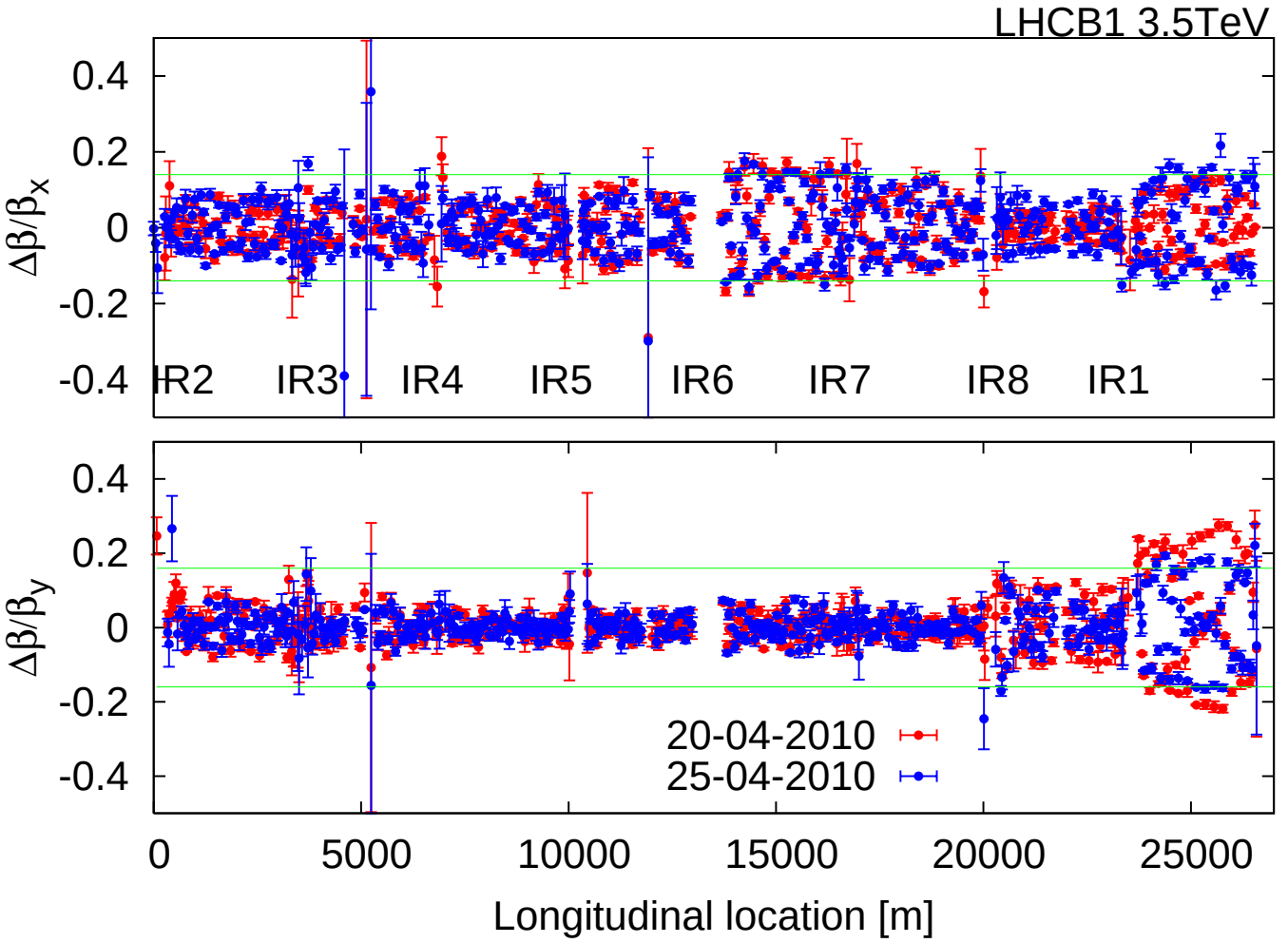
β-beating during β^* =2m squeeze



Very effective local corrections.

Not understood reduction of B1V β-beating.

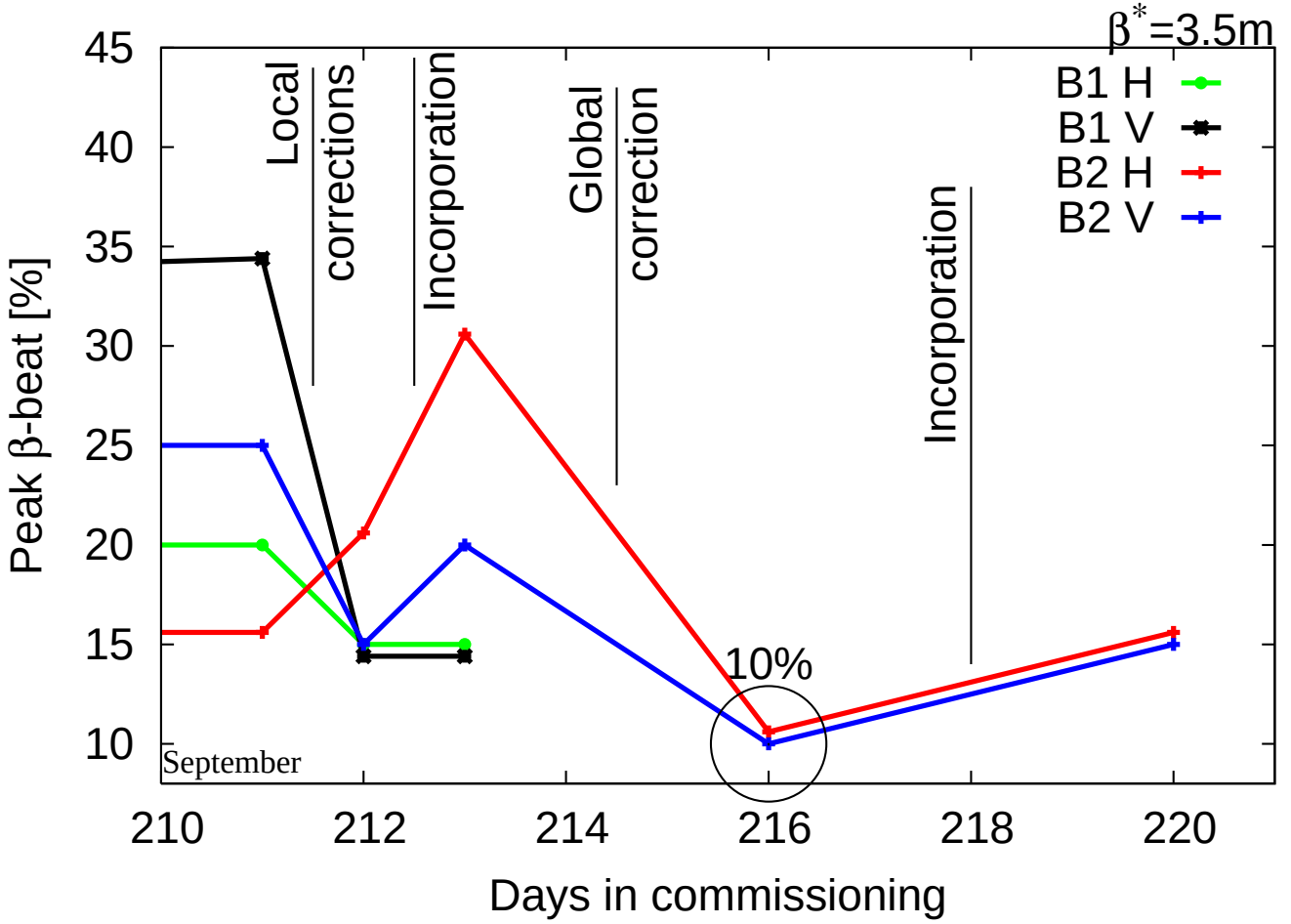
What happened at β^*=2m?



Exactly same quad I_MEAS on 20-4 and 25-4.

Only difference is that the 25-4 was a 30 hours fill...

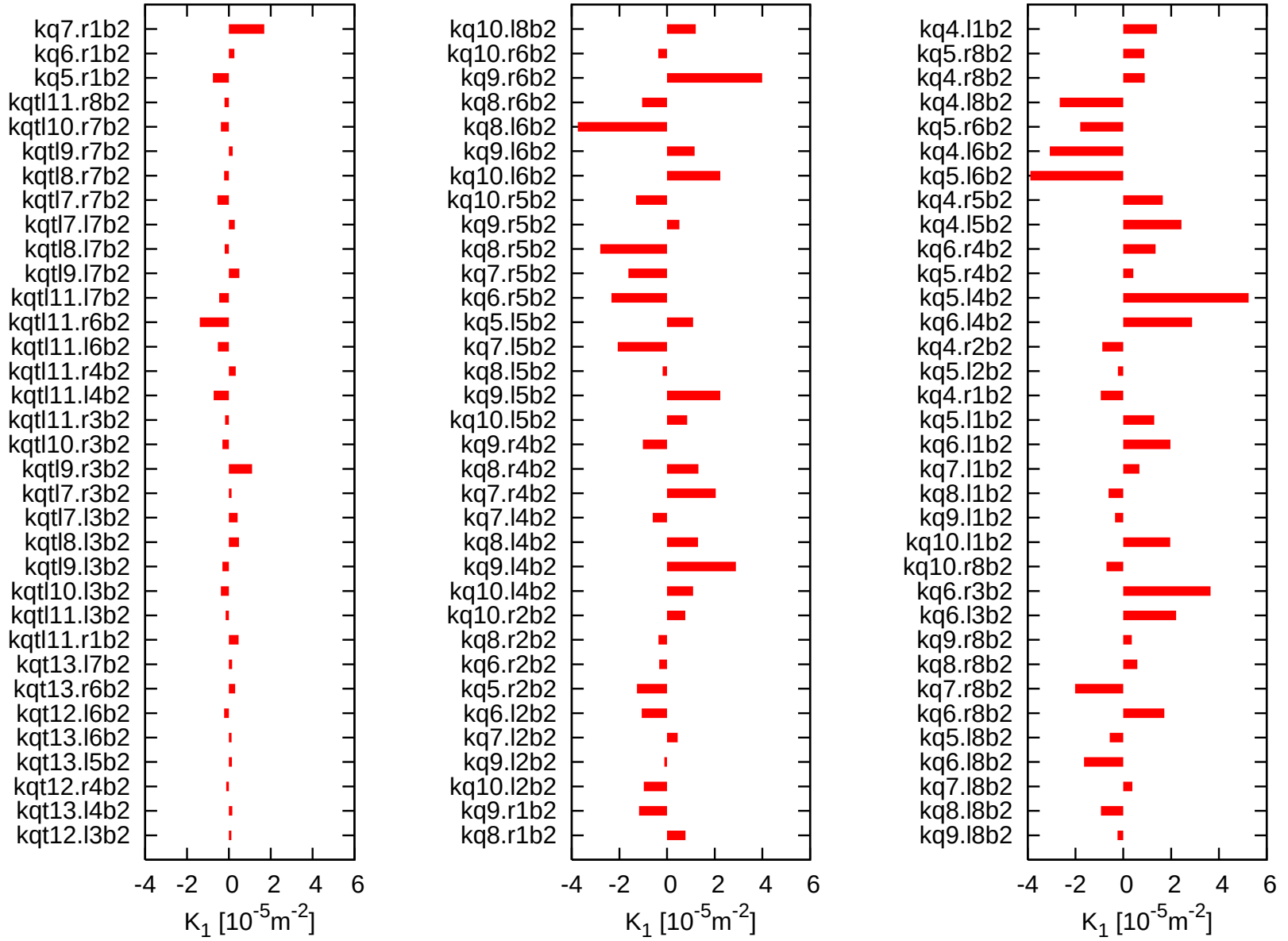
β-beating corrections at β^* =3.5m



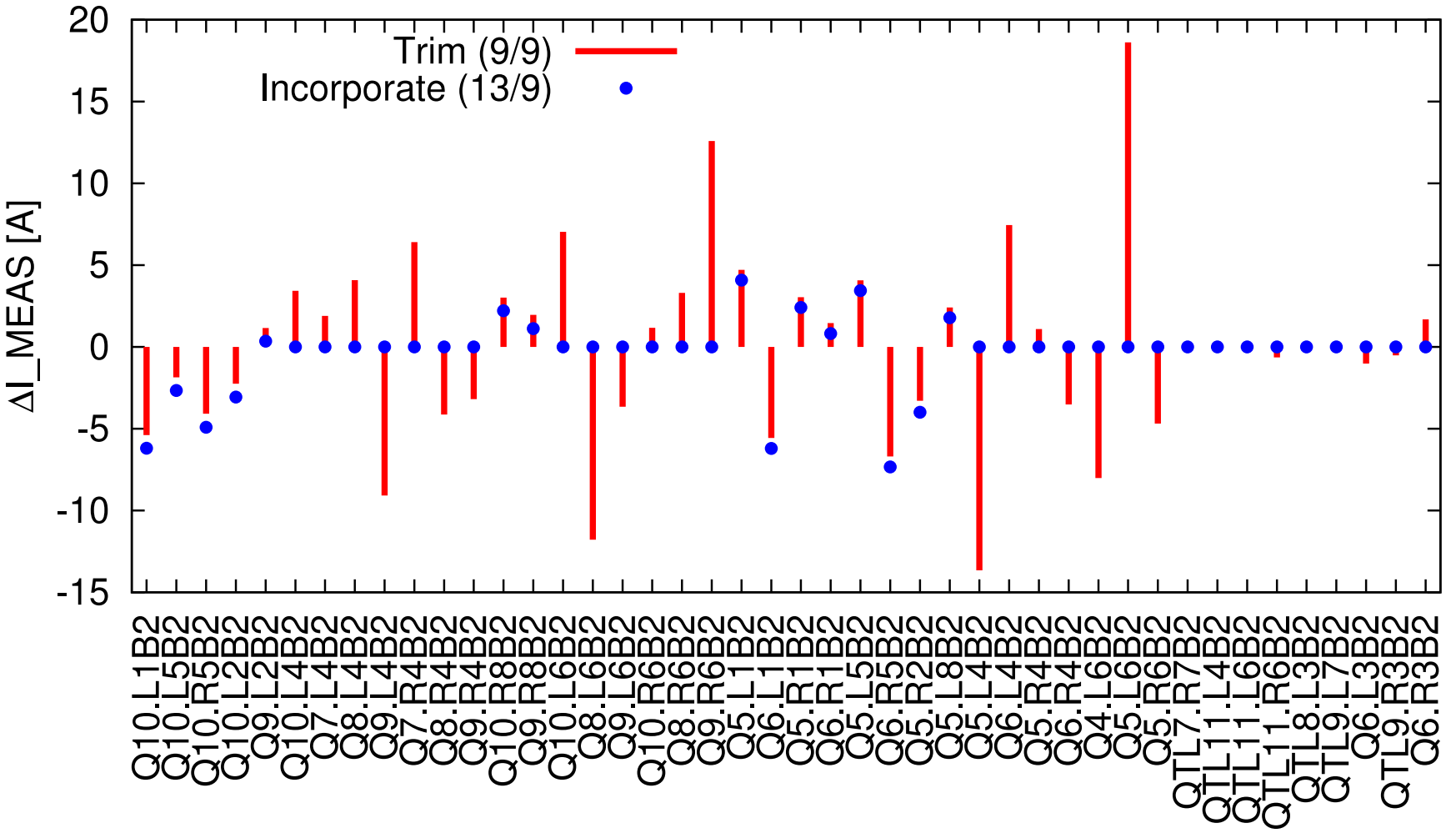
Issue between trim and incorporation...

Yet 10% β-beating has been achieved!

The global knob



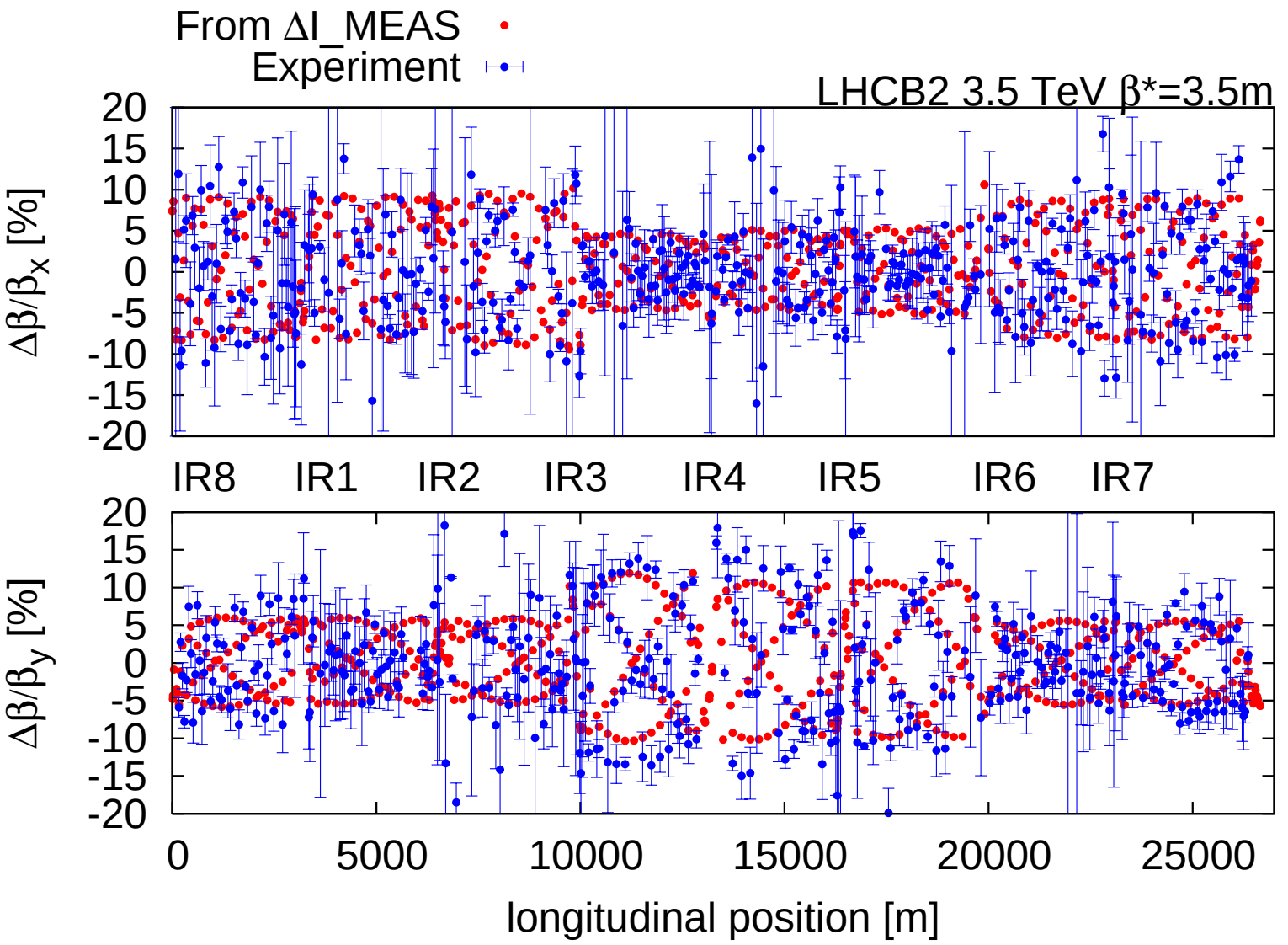
Trim versus incorporation



IR3, IR4, IR6 & IR7 settings were not driven.

$\approx$1 A difference in some quads due to ‘branching’

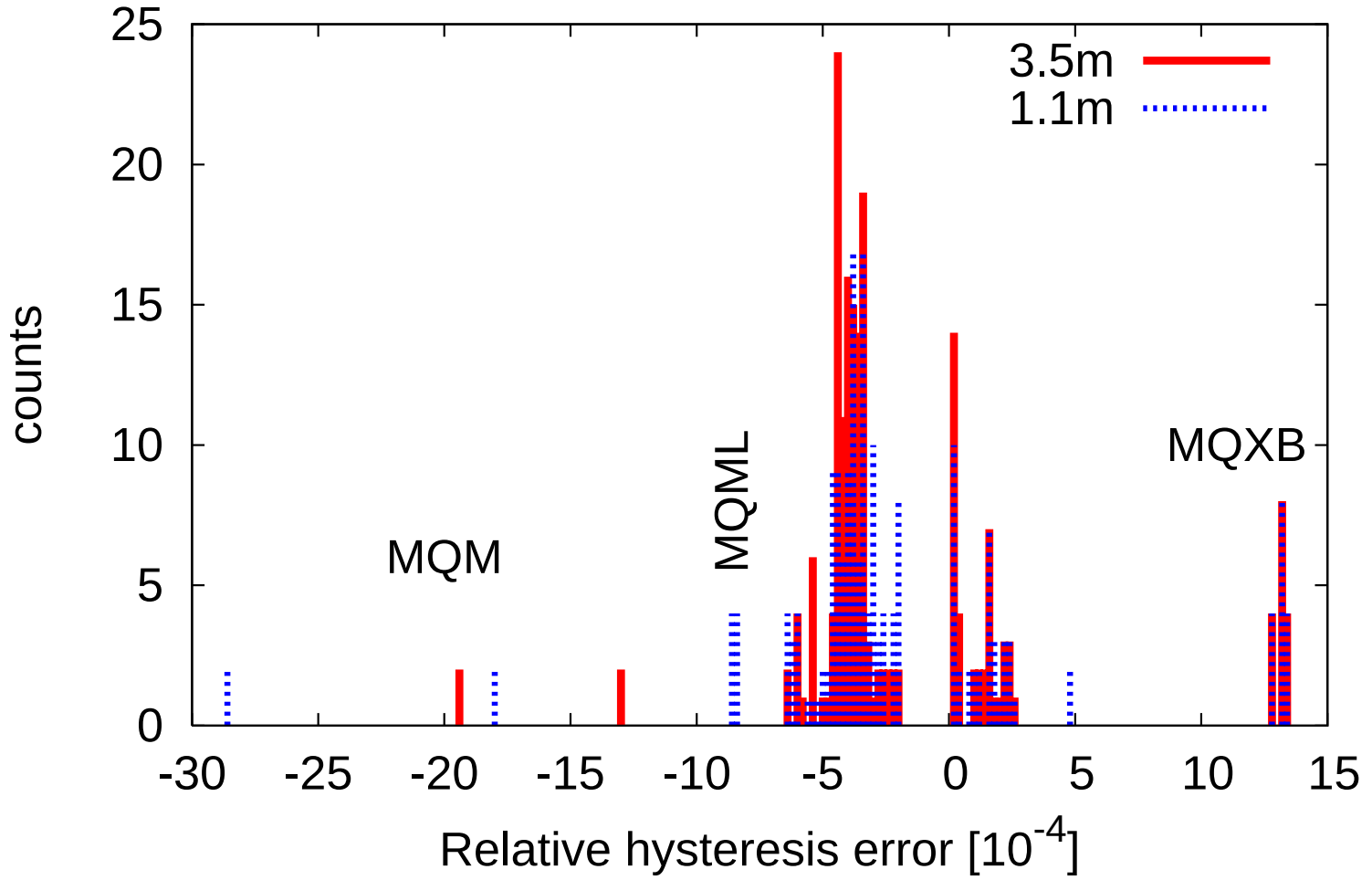
Prediction versus experiment



Not driving $\rightarrow$ 8-10%

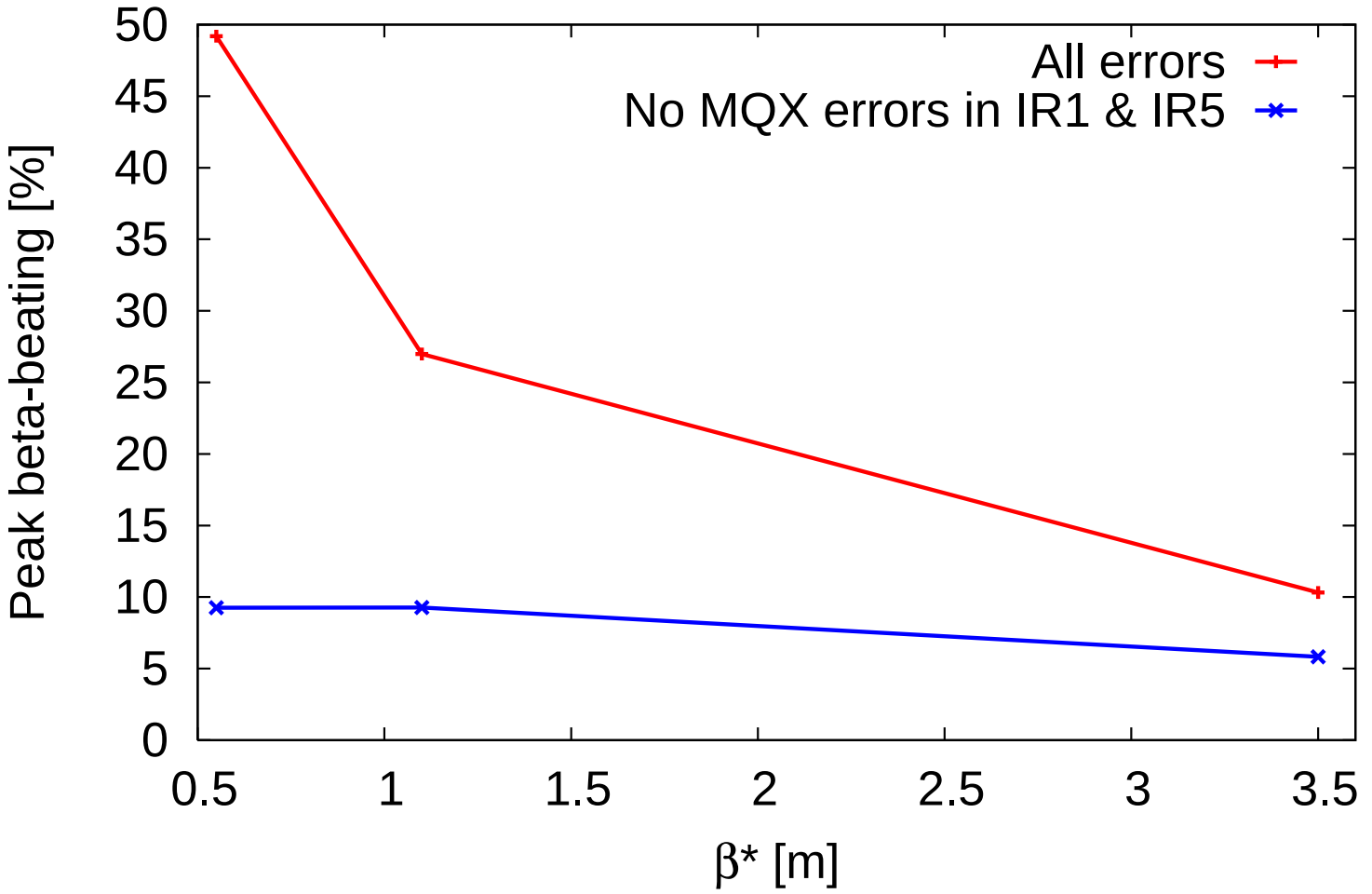
Branching $\rightarrow$ 4-2%

Hysteresis errors at 3.5 TeV from P. Hagen



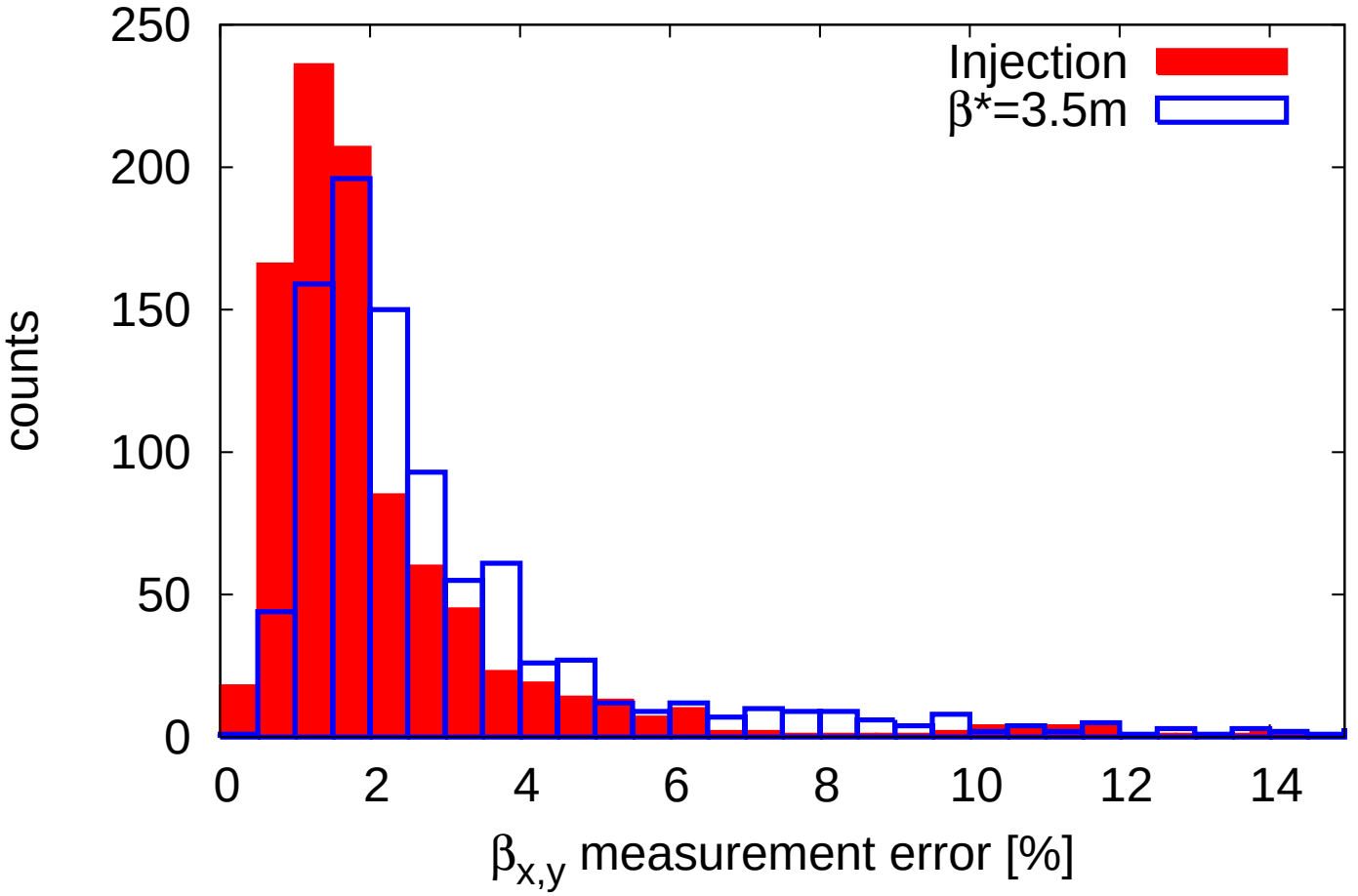
Few magnets have large hysteresis errors

Estimates from hyst. errors at 3.5 TeV



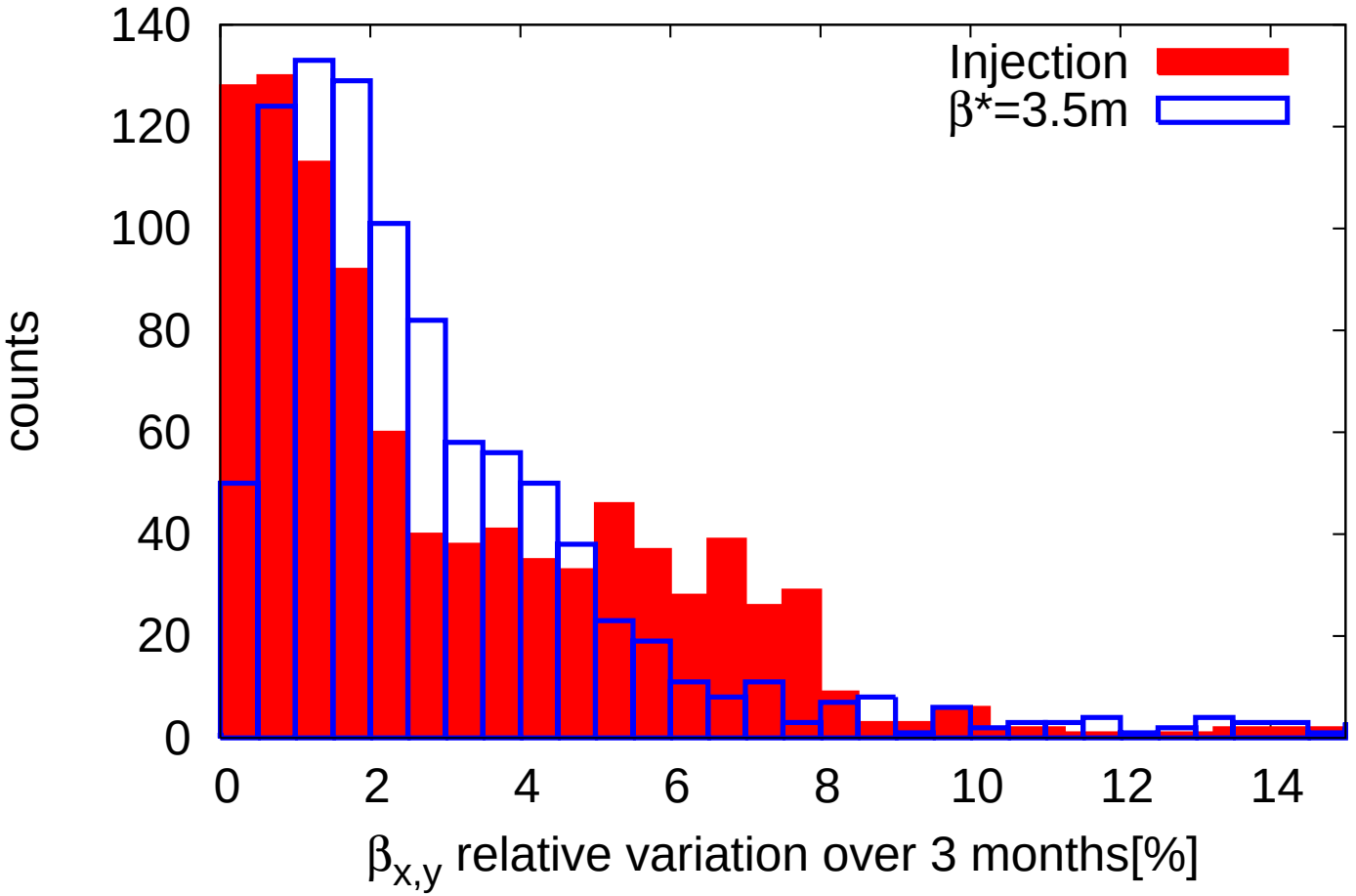
Optics error from hysteresis doubles between 3.5m and 1.1m. Expected to be 10% in 2011.

Measurement error



≈1.5% error at injection and ≈2% at store

Stability of β over 3 months



Excellent long-term stability!

Non-negligible drift $\approx$8% observed at injection!

β^* measurements

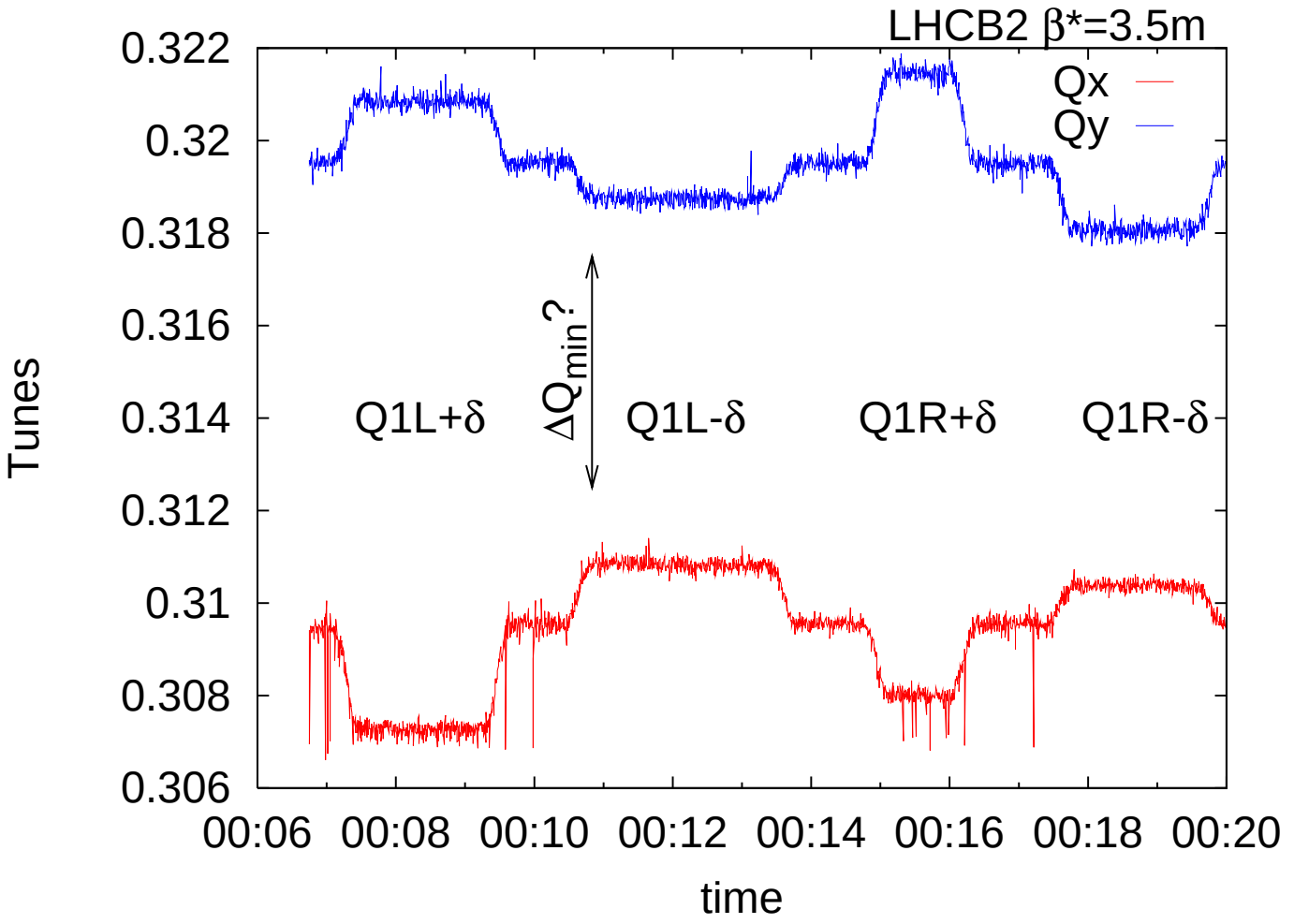
	β_x^1	err	β_y^1	err	β_x^2	err	β_y^2	err
IP1	3.6	0.1	3.9	0.6	3.4	0.1	3.6	0.2
IP2	3.4	0.2	3.2	0.1	3.9	0.1	3.7	0.1
IP5	3.8	0.1	3.7	0.2	3.5	0.1	3.6	0.1
IP8	3.6	0.1	3.7	0.1	3.6	0.1	3.3	0.1

$$\left|\frac{\Delta\beta^*}{\beta^*}\right| \leq 11\%$$

So far distributed via web and/or upon request.

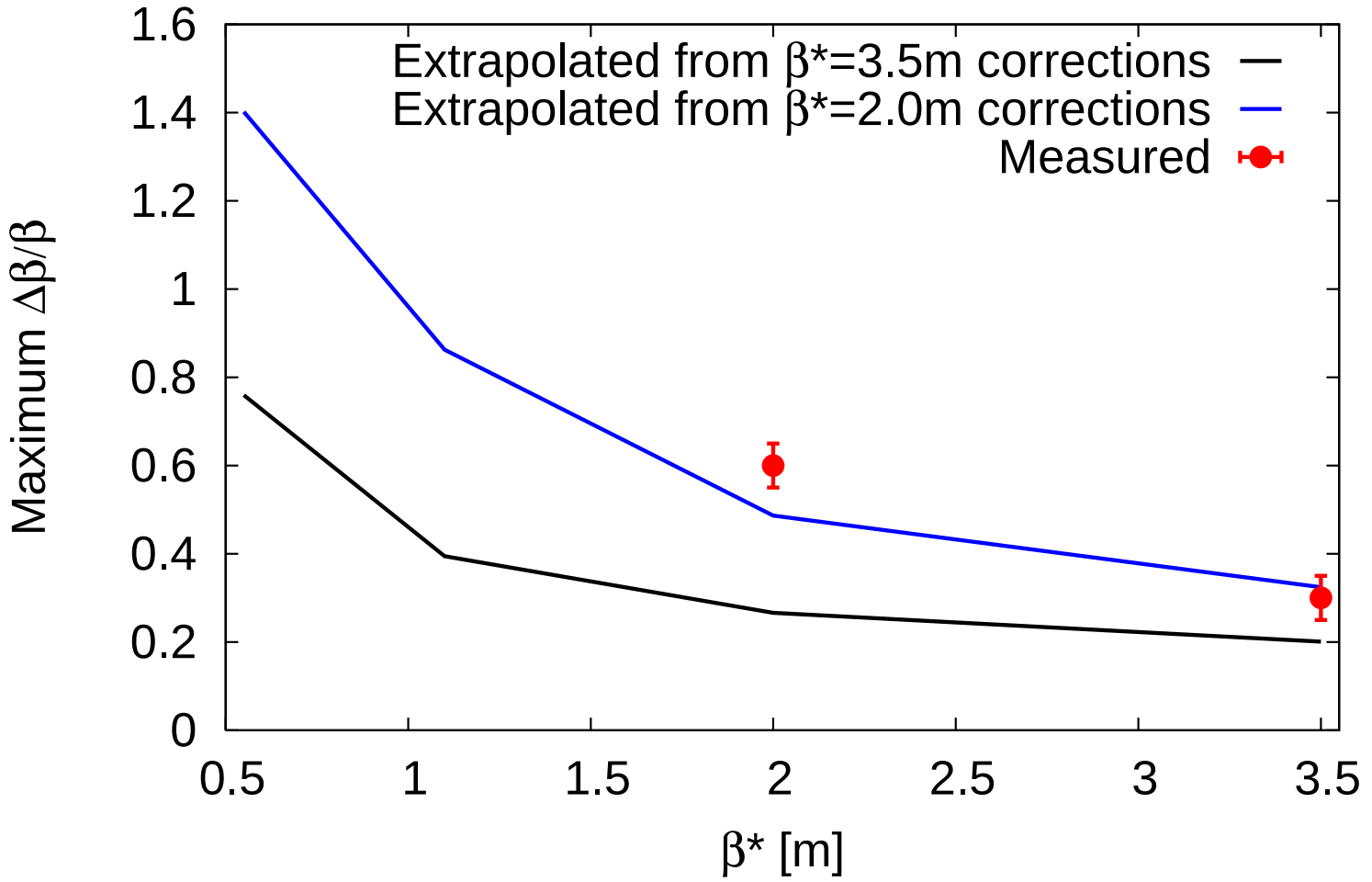
To be improved in 2011 (preferences?).

K-modulation?



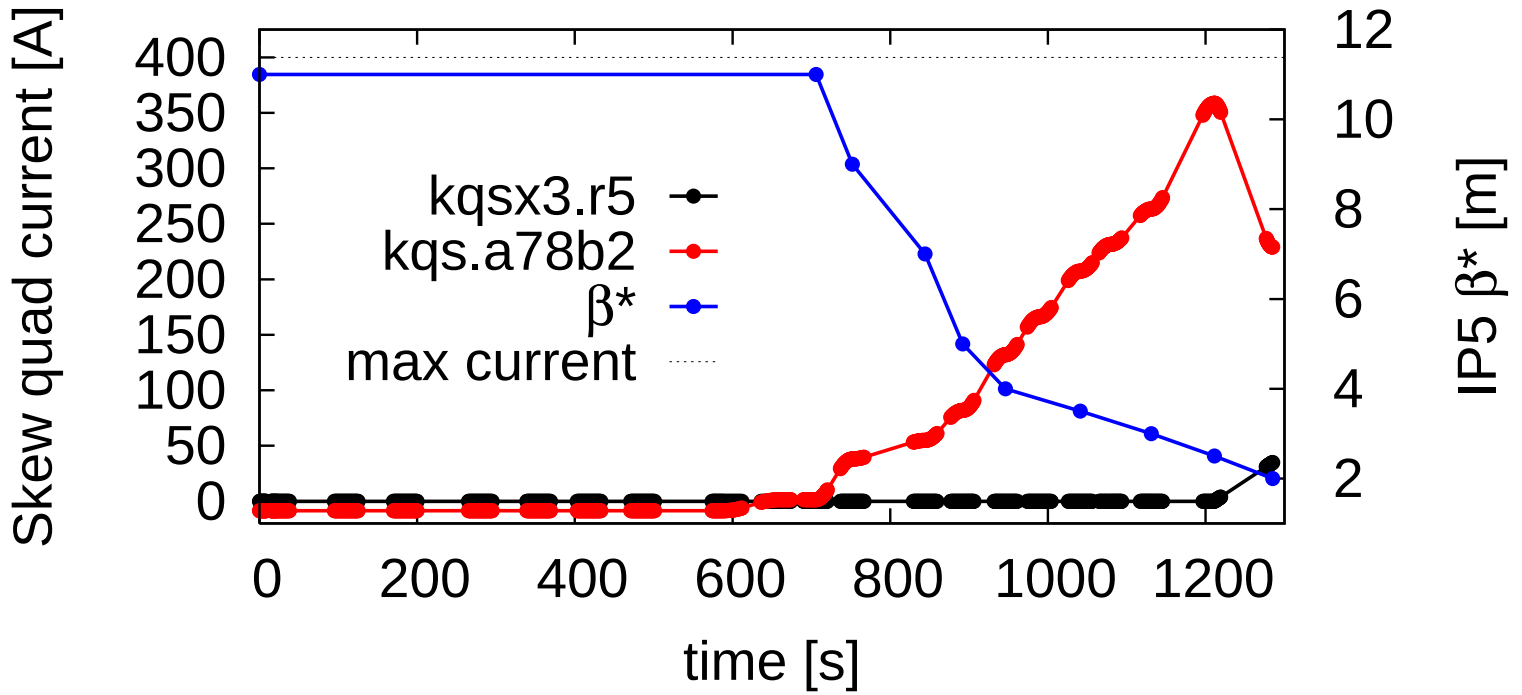
K-modulation needs a good coupling correction!

Extrapolating $\Delta\beta/\beta$ to lower β^* (uncorrected)



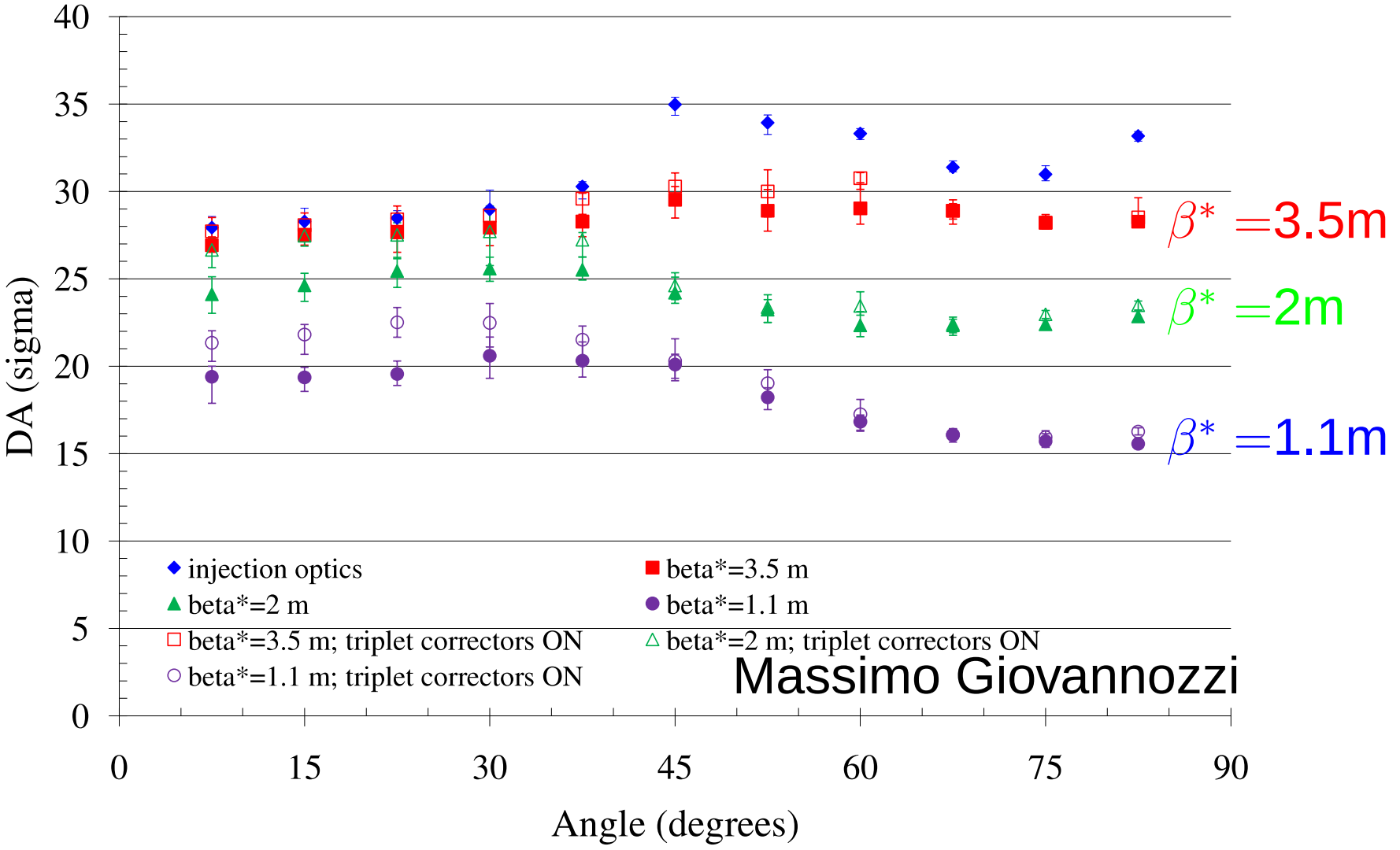
80% peak beat-beating at $\beta^* = 1.1$m?

Coupling



IR coupling correction mandatory for $\beta^* \leq$2m.

When do we need non-linear correctors?



Correctors start being effective at β^*=1.1m

Summary

- ⋆ 10% β-beating demonstrated!
- ⋆ Trim Vs incorporation differences understood
- ⋆ Branching errors expected to be 10% in 2011
- ⋆ Shall not forget driving IR3-4, IR6-7 settings.
- ⋆ Not understood 10% drift at $\beta^* =$2m (MQM?).
- ⋆ LHC is very reproducible at injection and at $\beta^* =$3.5m (however drift of 8% at injection).
- ⋆ IR correctors:
  - Skew quads mandatory for $\beta^* \leq$2m
  - Higher order only effective for $\beta^* \leq$1.1m

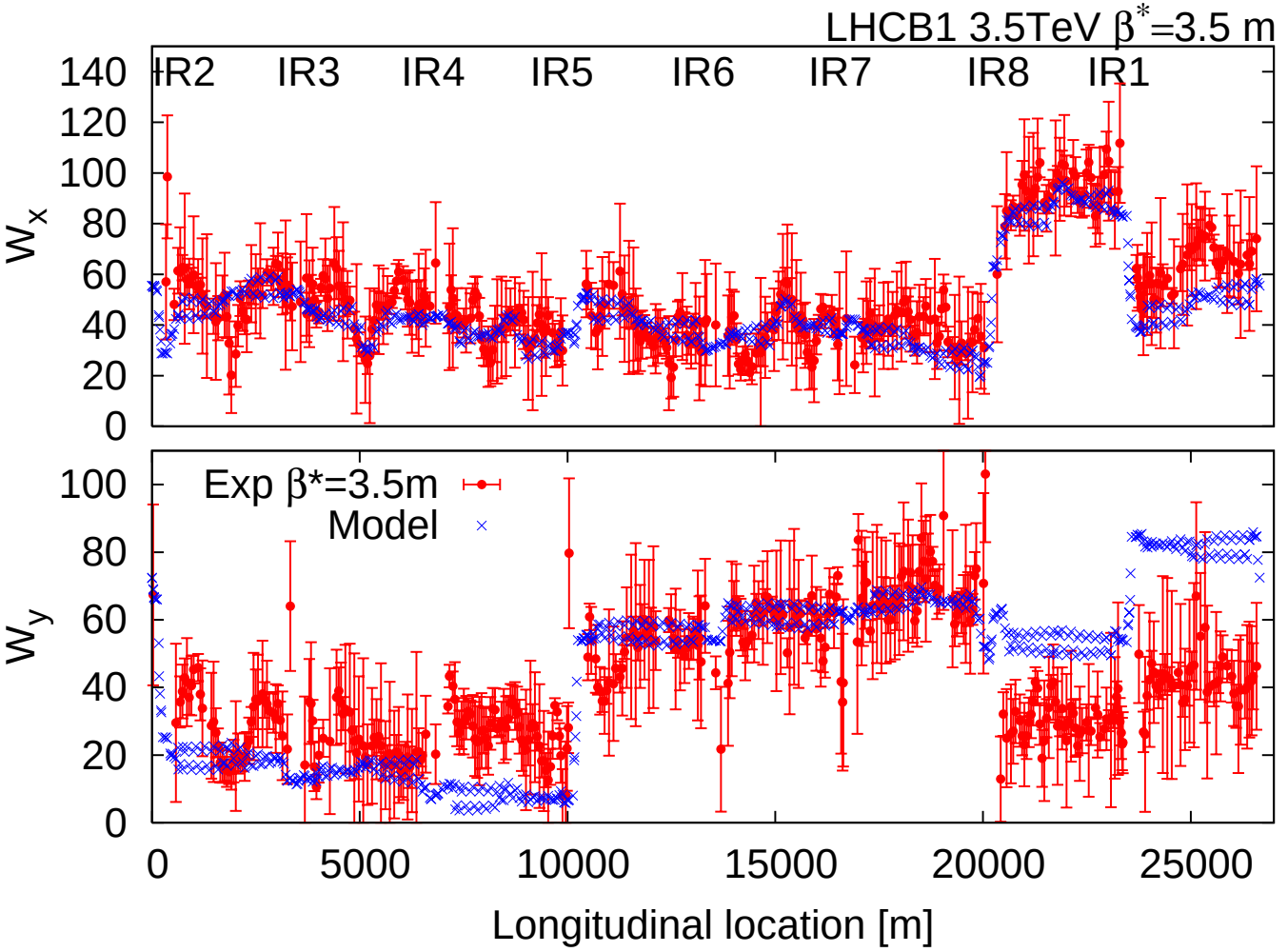
Shopping list

- Periodic measurements at injection
- 1-3 sessions at every matched optics $\beta^* \leq$2m for correction iterations.
- We would like to measure at least once 10h after squeeze $\beta^* \leq$2m with corrections.
- Dedicated collimation settings to allow large oscillations with $\leq 3 \times 10^{10}$ protons.
- High β^* optics (90 m): Exercise higher resolution measurement approaches.

Extra slides

Chromatic β-beating before correction

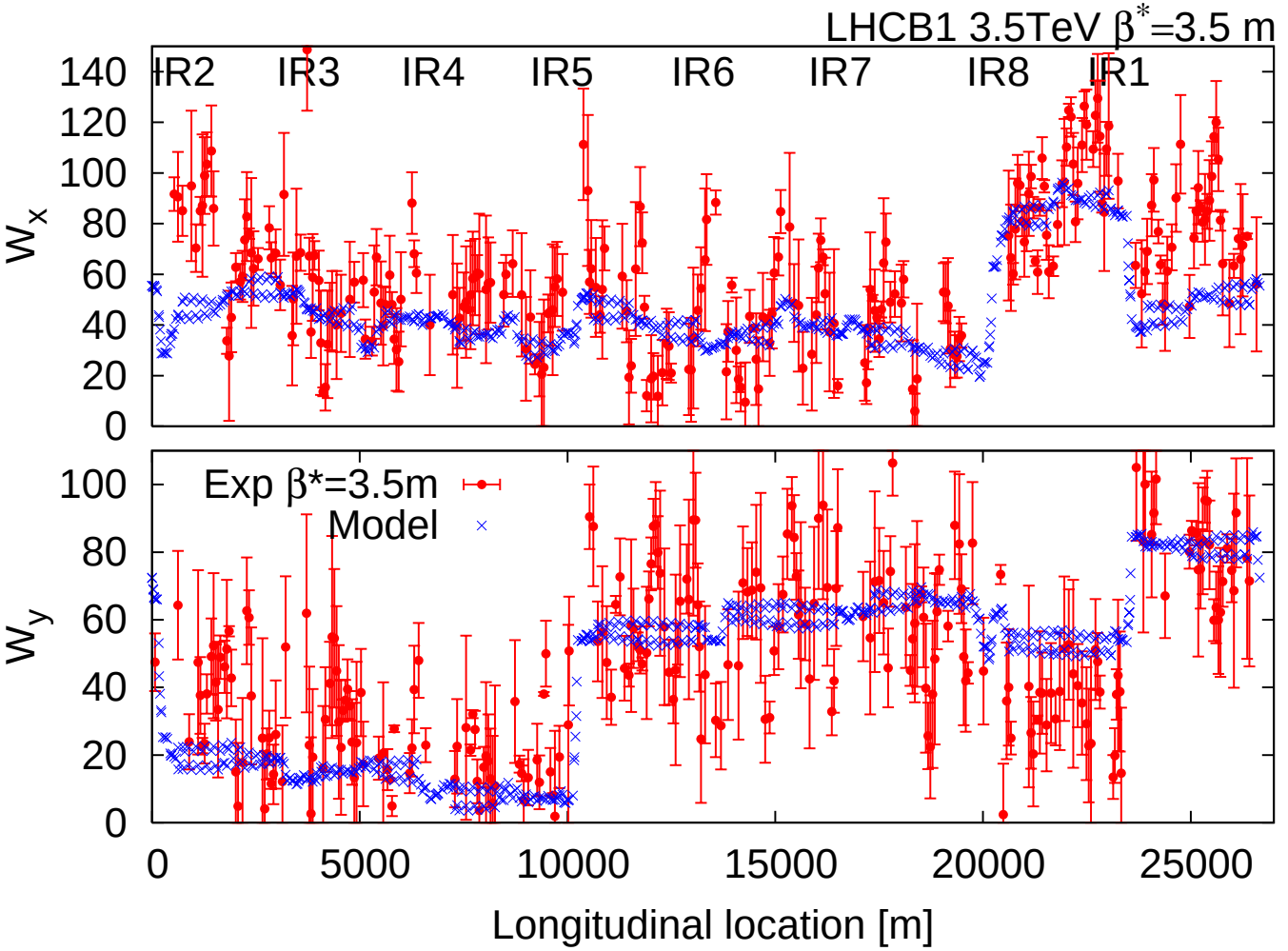
W=100 means $\Delta\beta/\beta = 10\%$ at $\delta p/p$=0.001



Vertical discrepancies between IR8 and IR2.

Chromatic β-beating after optics correction

W=100 means $\Delta\beta/\beta = 10\%$ at $\delta p/p$=0.001



Poorer measurement but discrepancies migth be gone!

Superlocked correctors from Mirko Pojer

```
RCOSX3.R1 - cryo-regulation
RCOSX3.L1 - electrical NC
RCOX3.L1 - cryo-regulation
RCSSX3.L1 - cryo-regulation
RCSX3.L1 - cryo-regulation
RCOSX3.L2 - cryo-regulation
RCTX3.L8 - cryo-regulation
RCSSX3.R8 - cryo-regulation
```