

# Impact of Longitudinal Displacement of Low-Beta Triplets

- Thanks to our colleagues from AT for discussions, the measurements and adjustments of the triplet magnets, in particular: P. Bestmann, L. Bottura, D. Missiaen, R. Ostojic, H. Prin
- The analysis has been done by ABP members:
  - S. Fartoukh: Matching of IR1 & IR5
  - J. Jowett: Matching of IR2
  - M. Giovannozzi: Going into Squeeze
  - R. Tomás: Beta-Beating Correction

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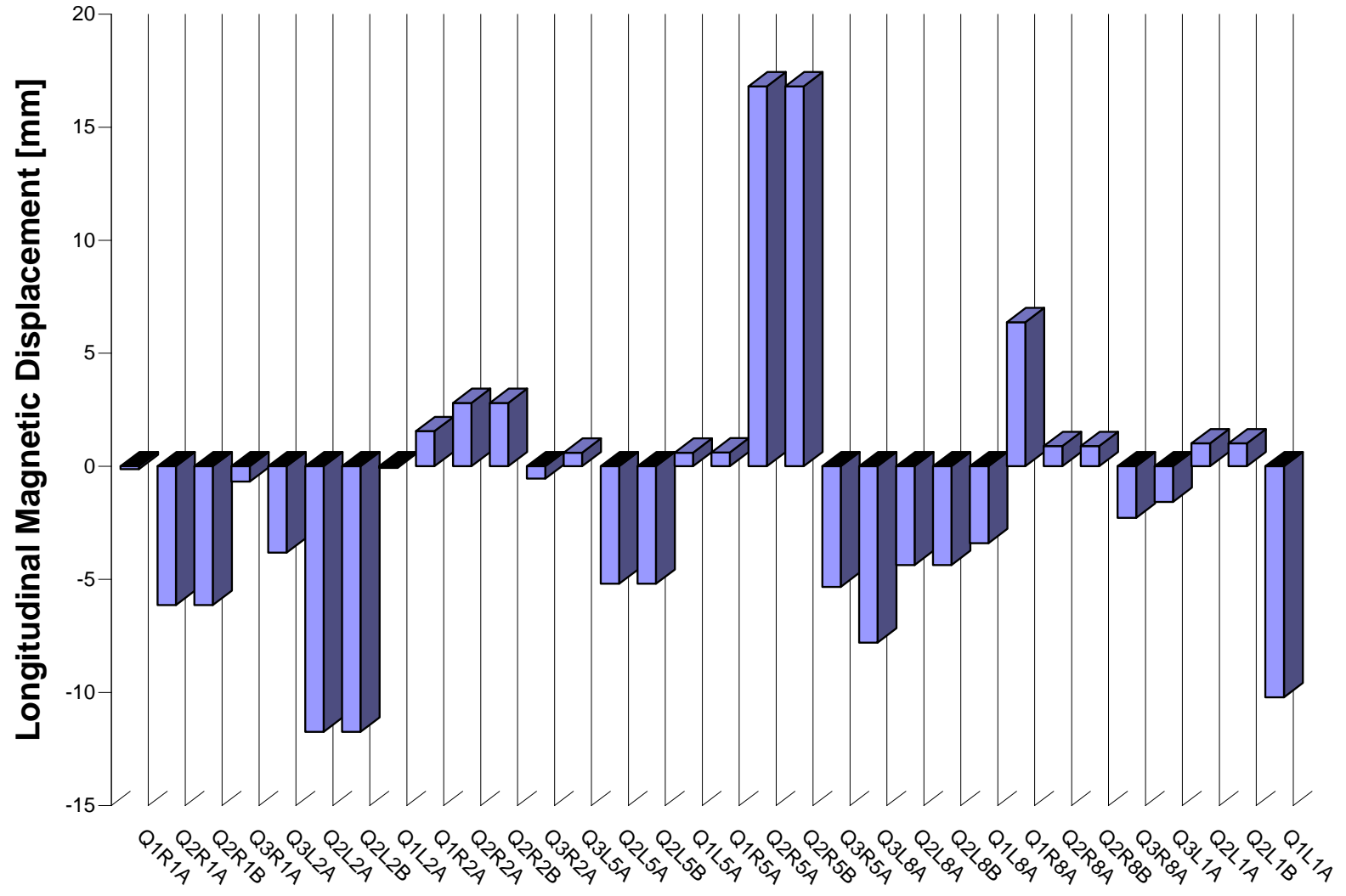
# Uncorrected Magnetic Shift in IR5R

IP5	HCLQXA_001-FL000005			HCLQXB_001-FL000003			HCLQXC_001-FL000007		
	I	IP side Q1R5	NIP side	I	IP side Q2R5	NIP side	I	IP side Q3R5	NIP side
Deviation of Beam Screen		-1.84	9.31		-9.08	-7.85		9.7	9.45
Interconnection default	-1.84			-18.39			17.55		
already applied shift		-4			7			-6	
Interconnection with applied shift	-5.84			-7.39			4.55		
cold mass displacement (due to repair)		-0.79			6.6			-0.74	
shifted intercon. incl. CM-displacement	-5.84 (*)		0.00				-2.79		
shift of the magnetic origine		-4.79			13.6			-6.74	
Cryostat shift due to insulation vacuum		5.4			3.2			1.4	
Total shift in cold conditions		0.61			16.8			-5.34	
<b>Difference magnetic position at cold</b>				<b>-16.2</b>			<b>22.14</b>		

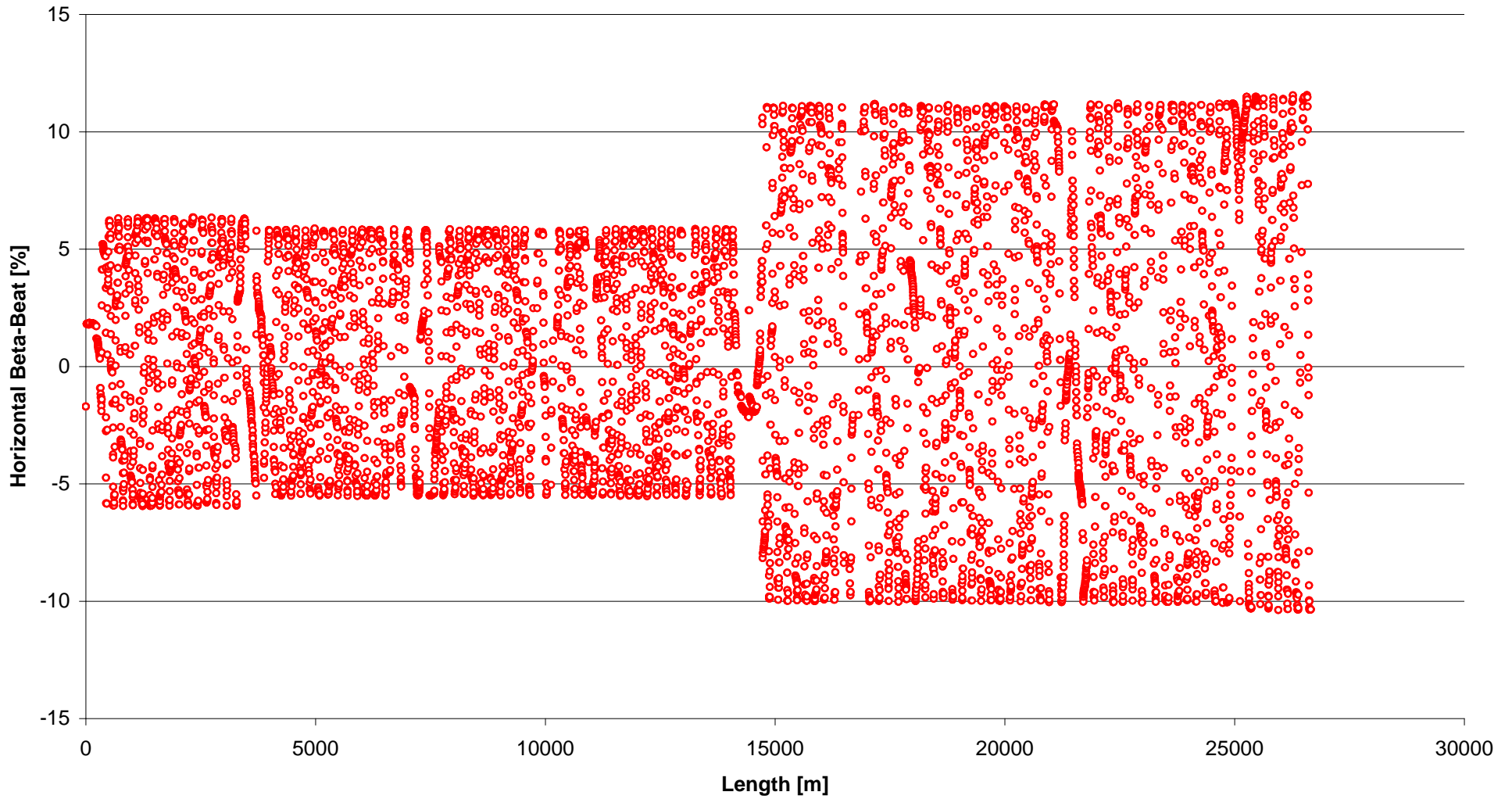
negative displacements are indicating a shift towards the IP  
 negative interconnections are indicating a too short interconnection

(\*) IP flange of Q1 is rigid with the cryostat and doesn't move with the coldmass

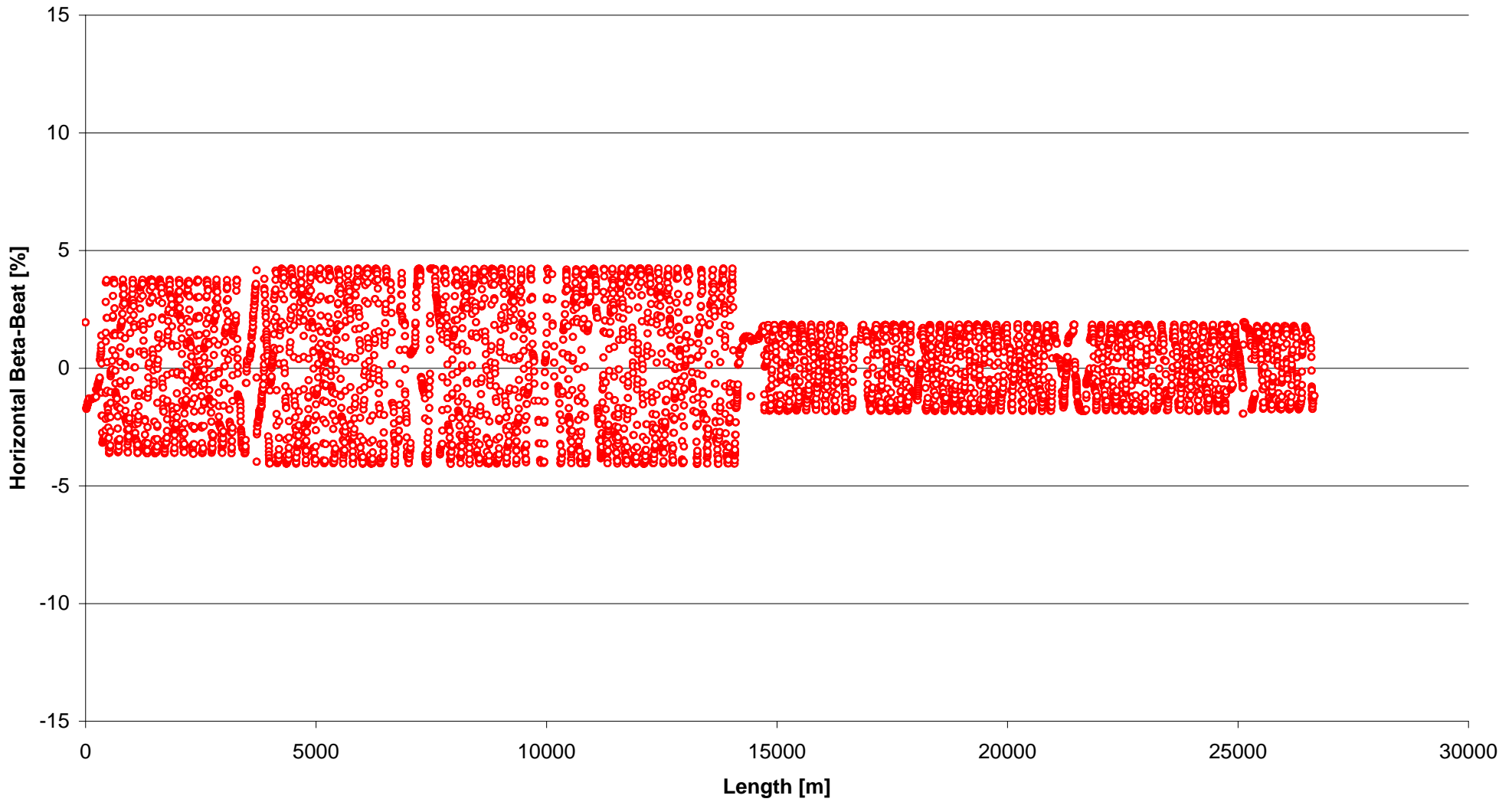
# Measured Longitudinal Displacements (Dec. 2007)



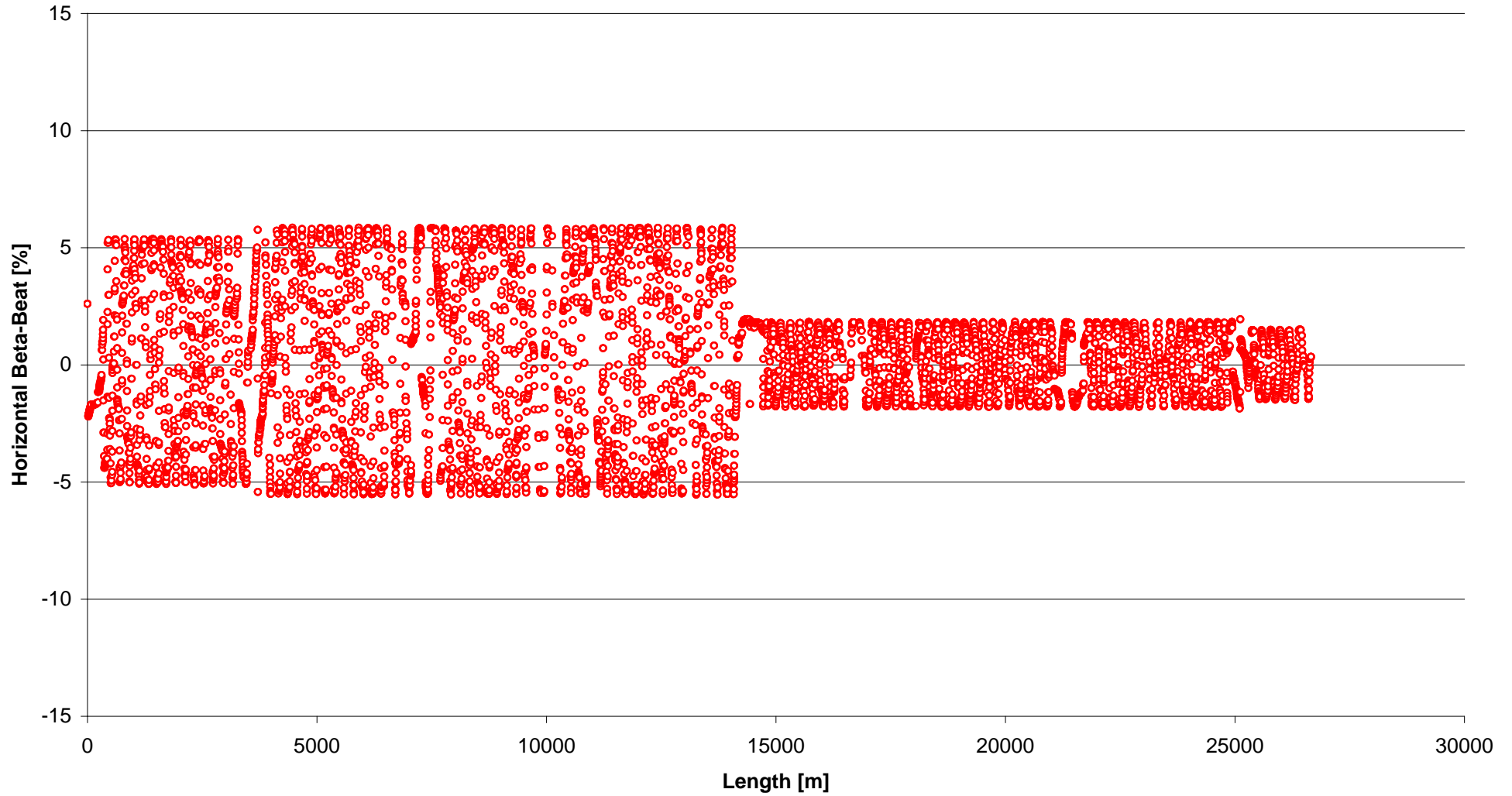
# Measured Longitudinal Shifts



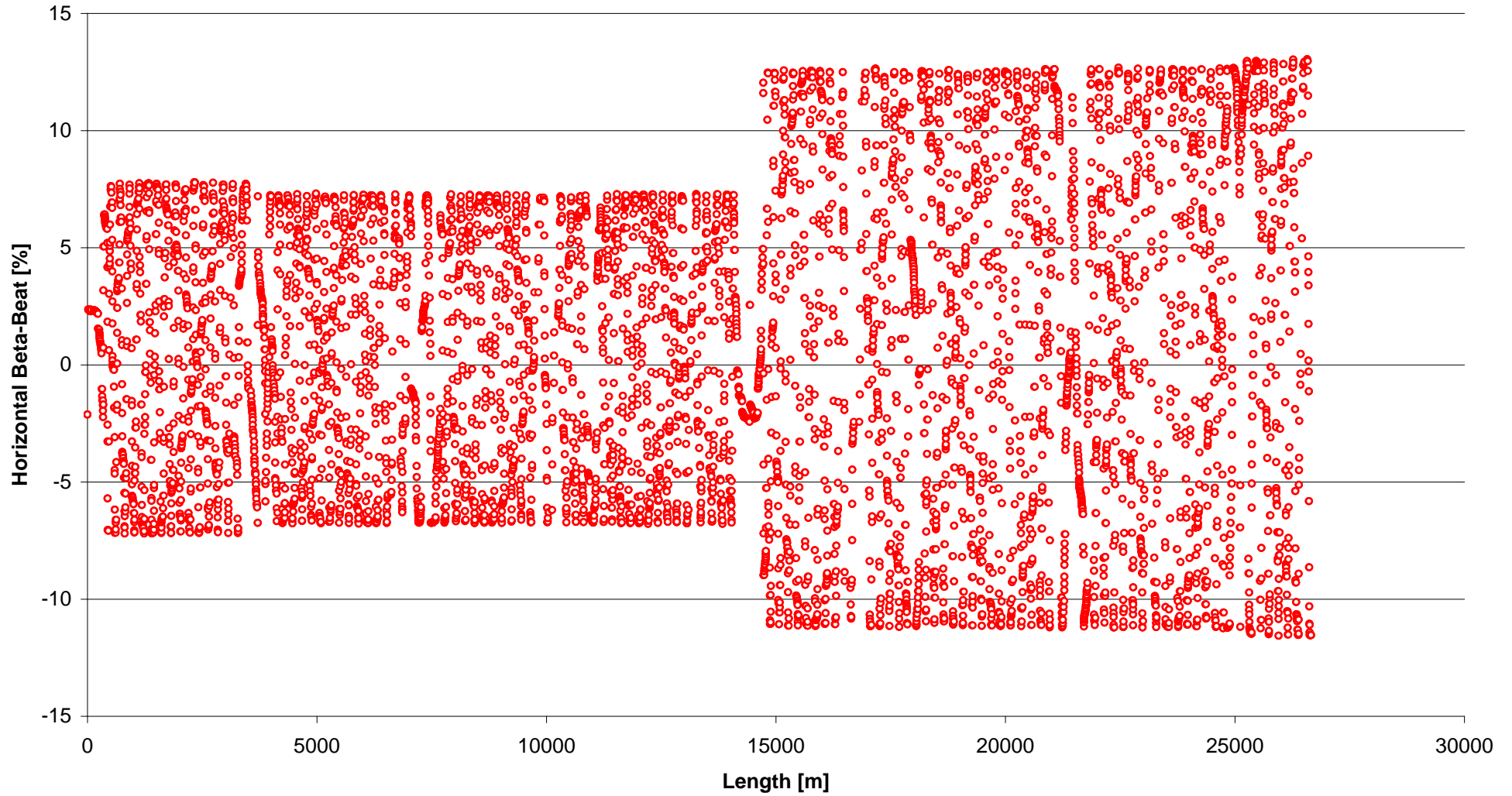
# Measured Longitudinal Shifts, except IR5R set to zero



# Measured Longitudinal Shifts, except all IR5R triplets shifted by 16.8mm

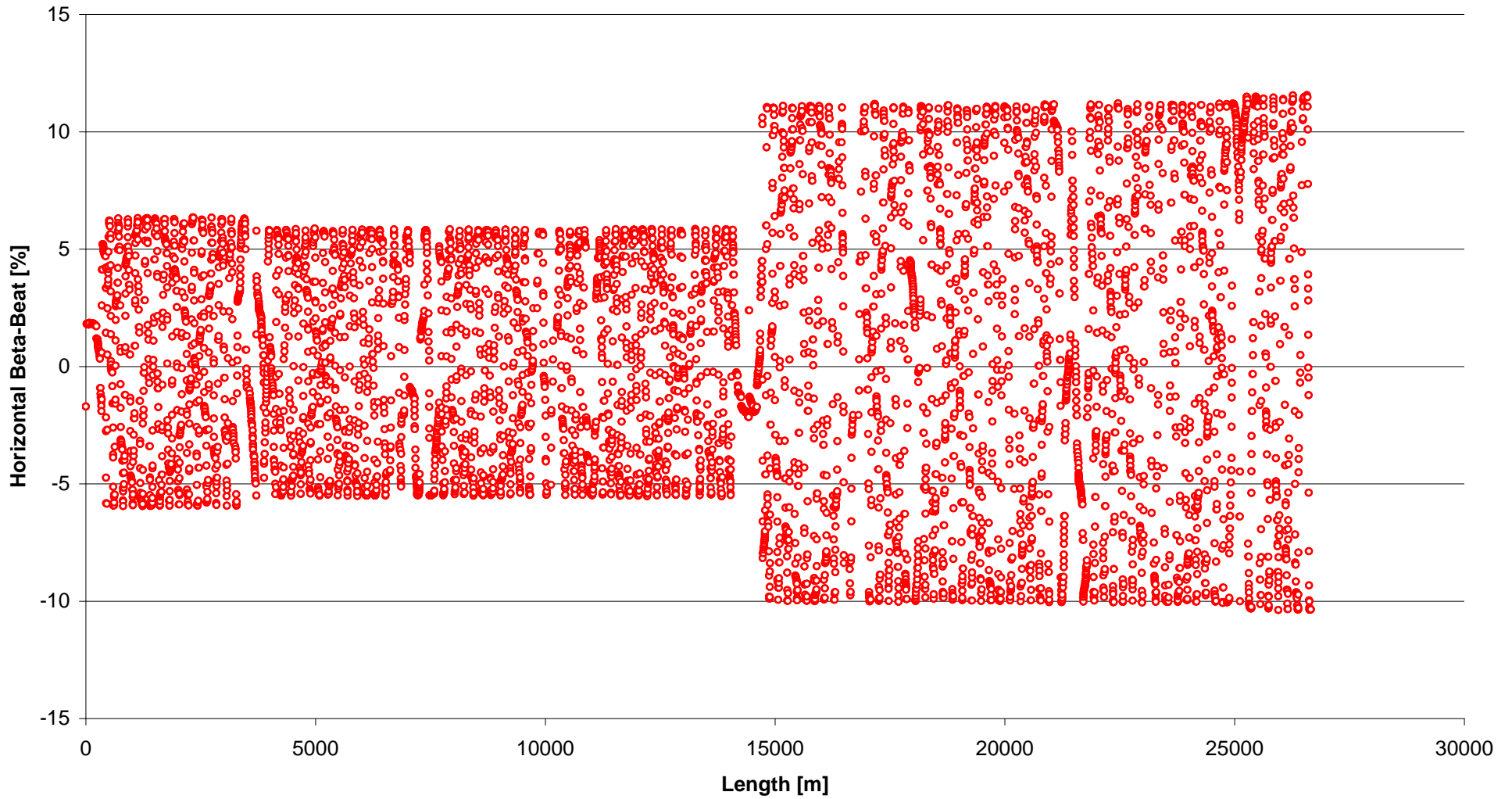


# Measured Longitudinal Shifts, except IR5L set to zero





# Measured Longitudinal Shifts



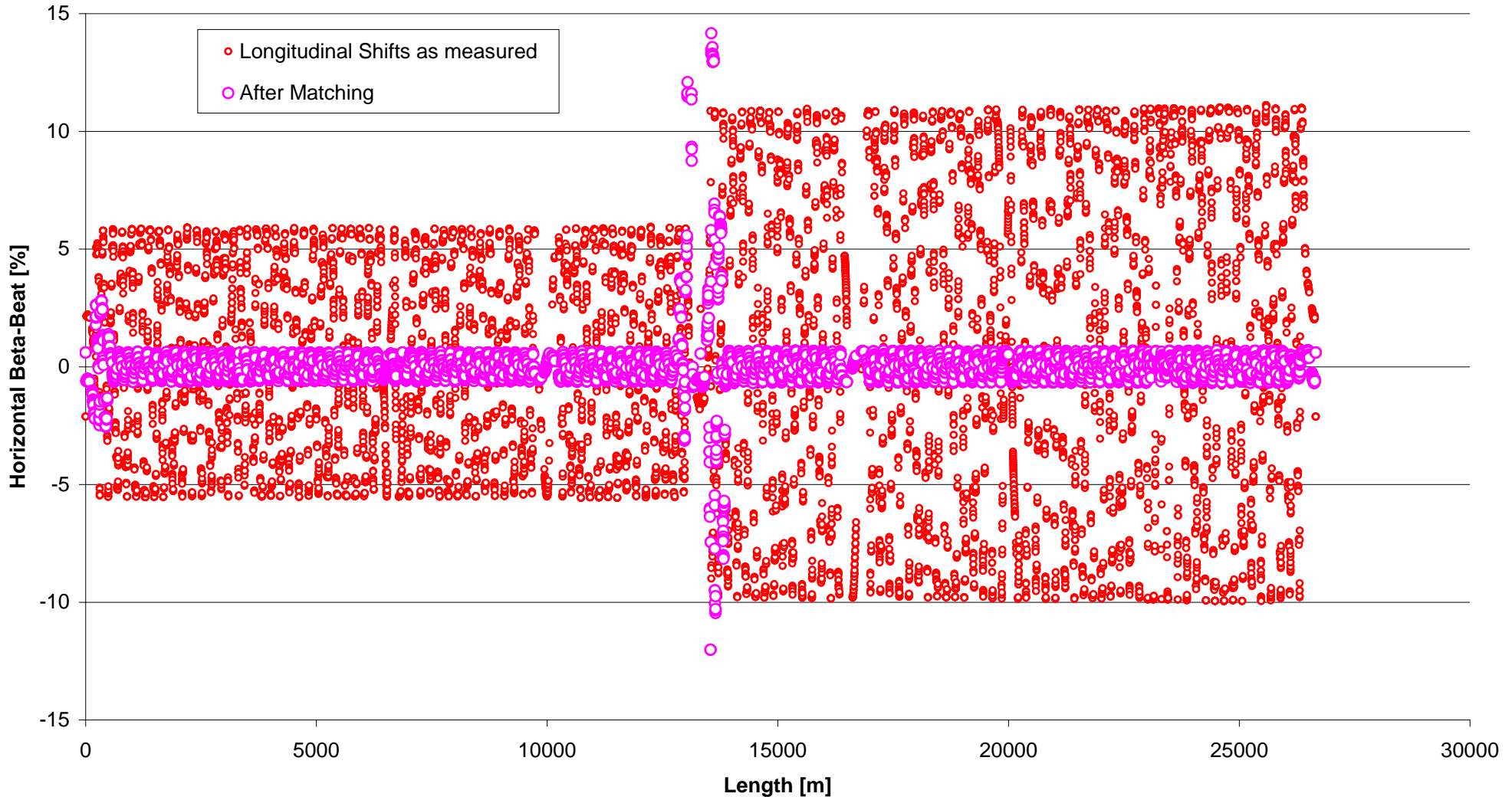
# Intermediate Summary

- Measurement and Adjustment of Longitudinal Displacement is a complex matter
- Unfortunately the chance was missed to re-adjust IR5R
- Half of the Beta-Beating Budget of 25% is used up just for IR5R
- ➔ Matching is required
- The goal was to stay below 5% which is the case without IR5R
- There may be cancellation of the Beta-Beating from one side of the IR to other. However, one should not rely on it!
- What counts is not a shifting of all 3 triplet assemblies but rather the relative differences
- ➔ 10 mm seems okay while 22 mm is clearly too much

## Matching of IR1 & IR5

- The goal is to restore the Twiss parameters at the IP
- And minimize Beta-Beating outside the IR
- The matching is achieved with quadrupoles in the IR however excluding the triplets themselves
- The required powering of these quadrupoles remains well within their limits

# Curing Beta-Beating with Matching

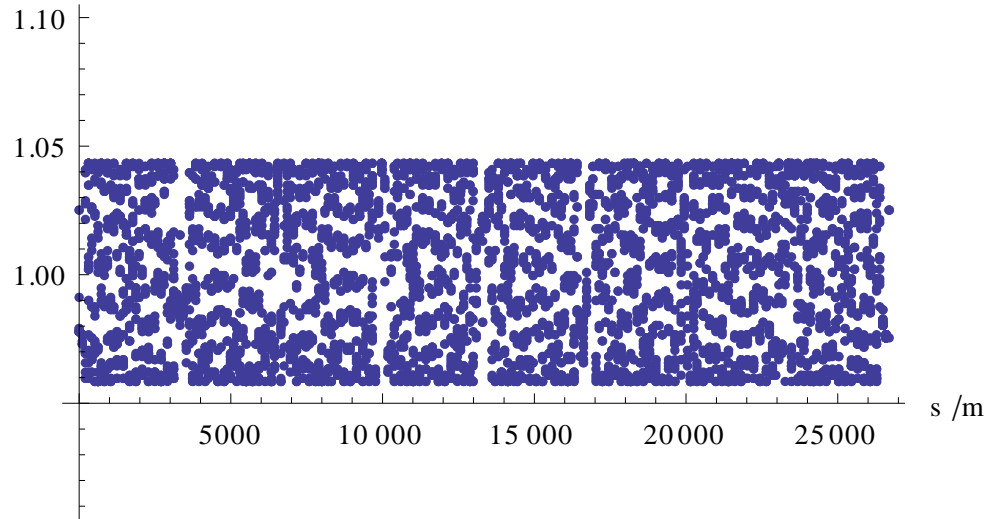


# Matching of IR2

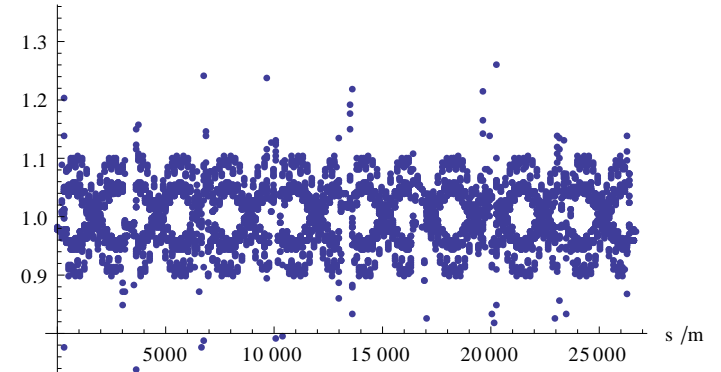
- Fully squeezed ION physics optics with  $\beta^* = 0.5 \text{ m}$
- The matching in IR2 is less demanding since the longitudinal displacements are smaller, although still in access of **10mm**
- The matching goals are similar
- Matching can be done with small changes of a few percent of the quadrupole strength

# Global beta-beating caused by displacements, **LHCB1**

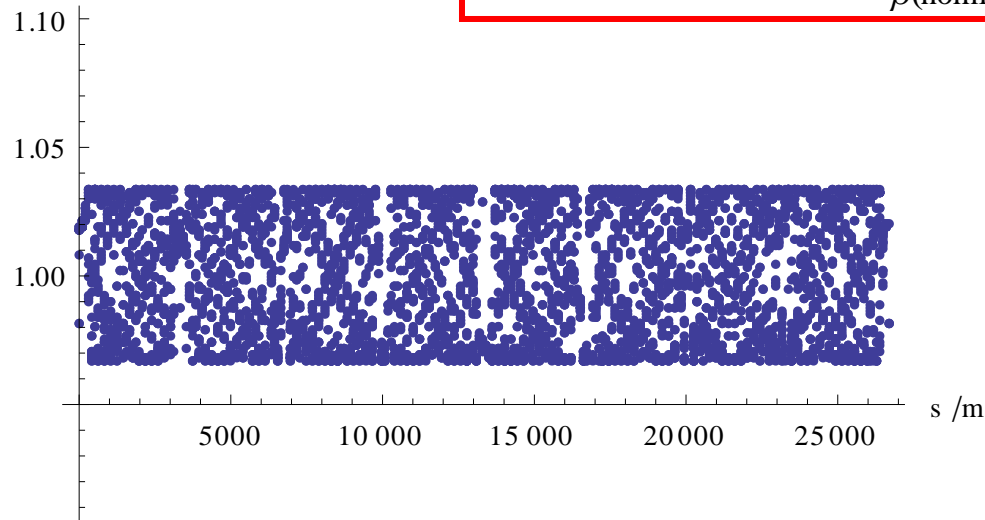
Beating of  $\beta_x$



Beating of  $\alpha_x$

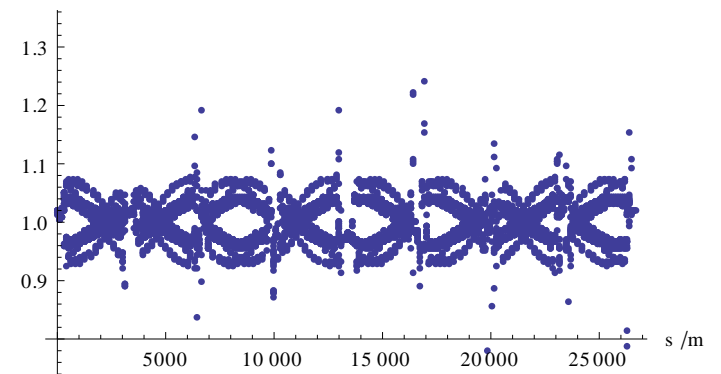


Beating of  $\beta_y$



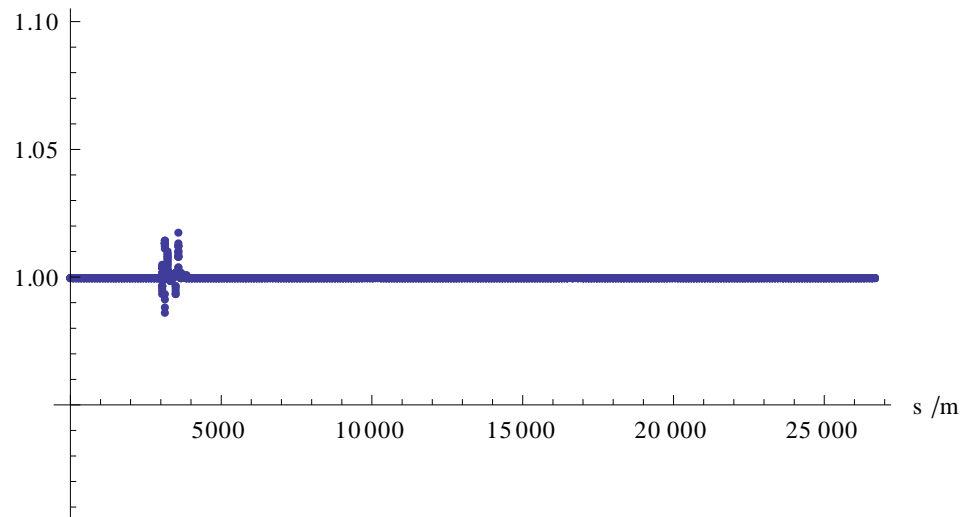
Beating defined as:  $\frac{\beta(\text{displaced})}{\beta(\text{nominal})}$

Beating of  $\alpha_y$

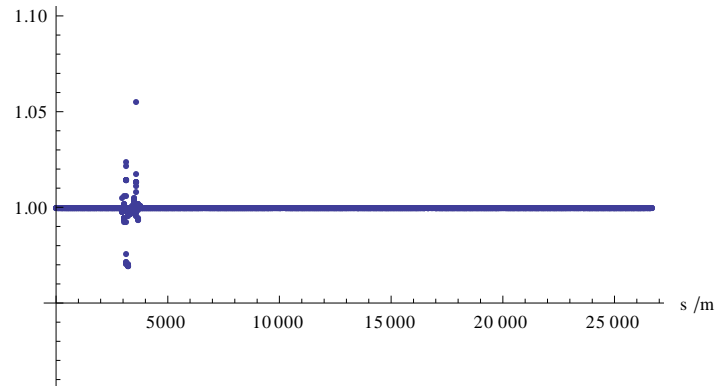


# Global beta-beating after rematching, LHCb1

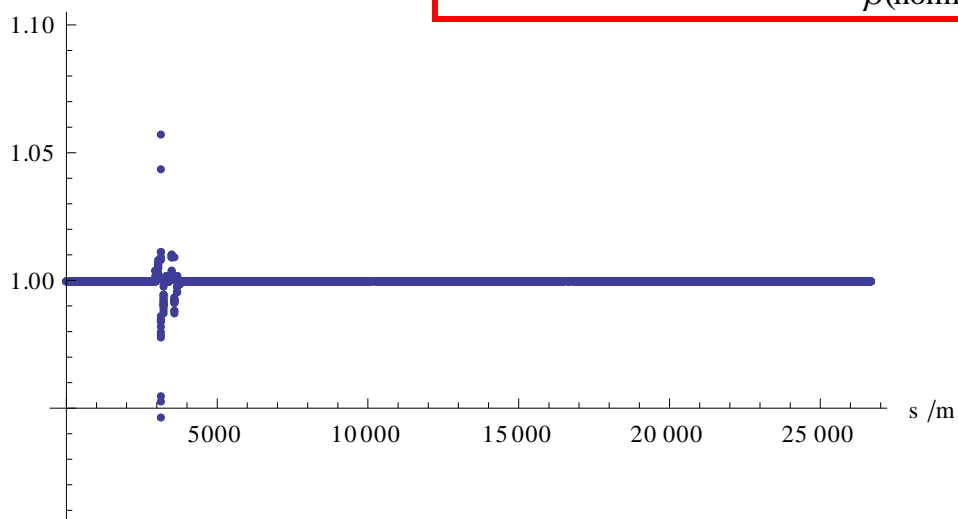
Beating of  $\beta_x$



Beating of  $\alpha_x$

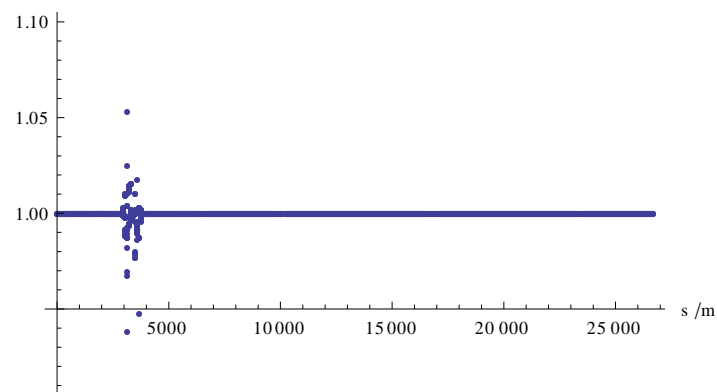


Beating of  $\beta_y$

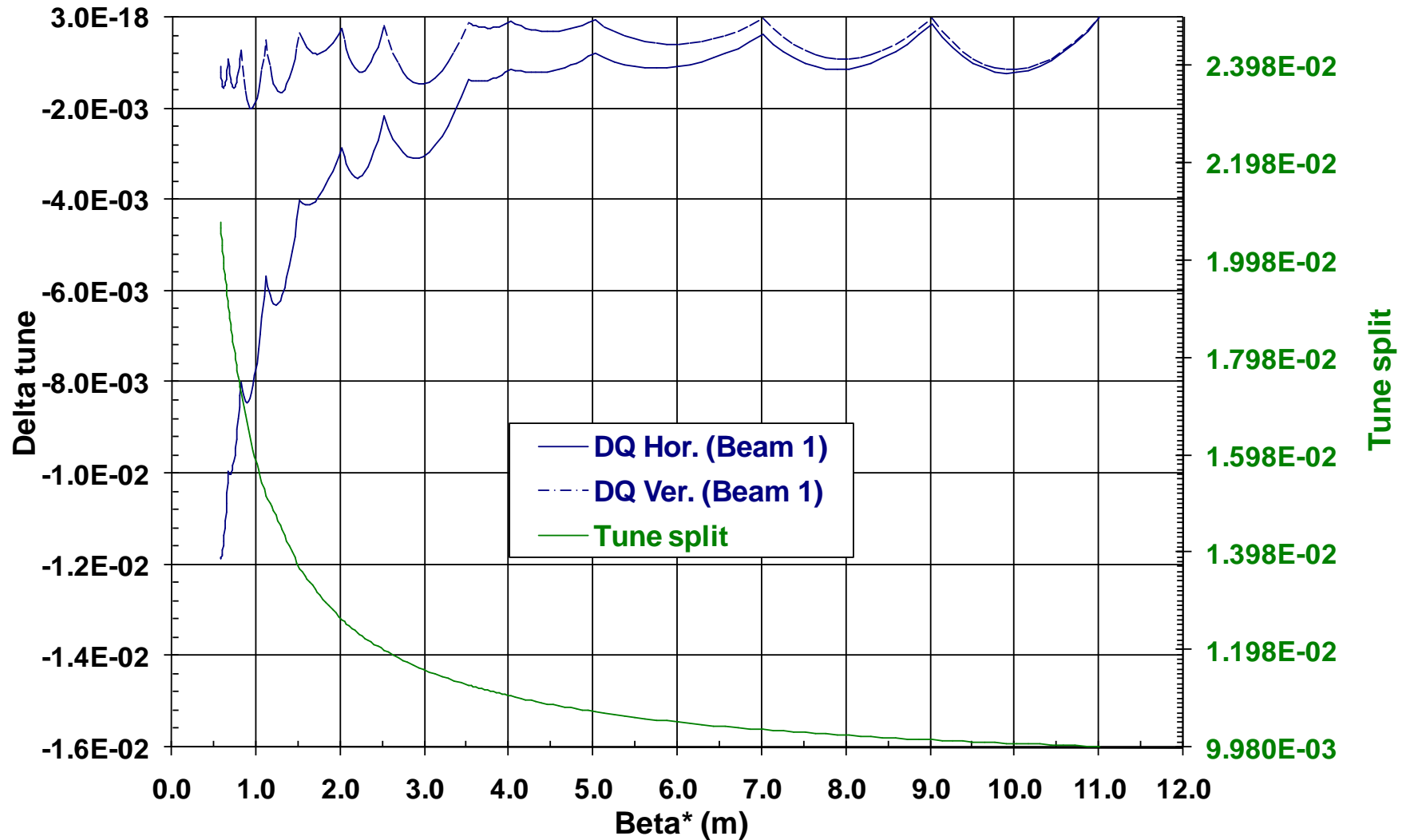


Beating defined as:  $\frac{\beta(\text{displaced})}{\beta(\text{nominal})}$

Beating of  $\alpha_y$

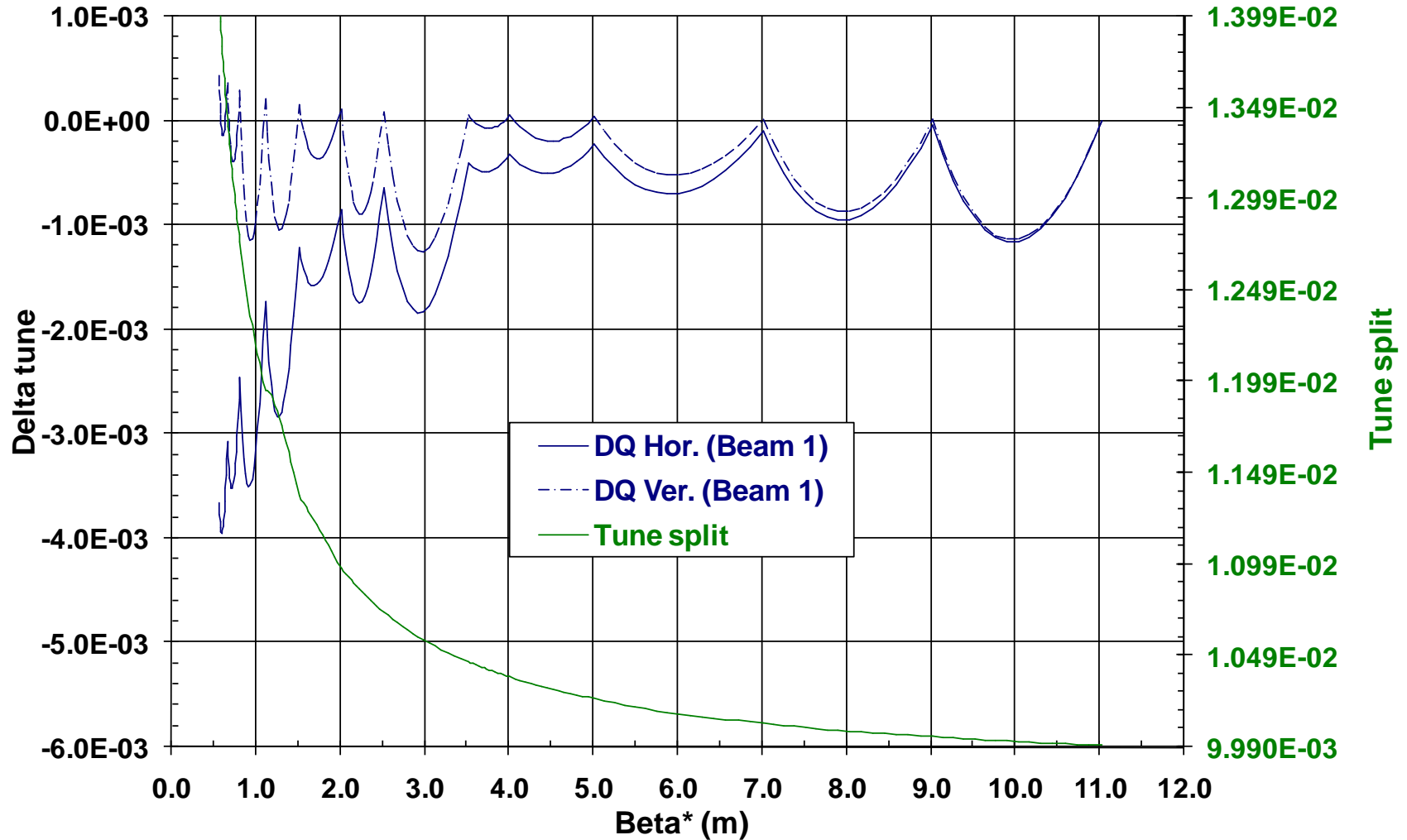


# Squeeze IR5 only





# Squeeze IR1 only



# Squeeze

- As expected the IR5 leads to much larger deviations from the desired behavior than IR1. Effectively due to IR5R.
- Below  $\beta^* = < 4$  m a rematching seems mandatory (done for  $\beta^* = 0.55$  m). At least for IR5.

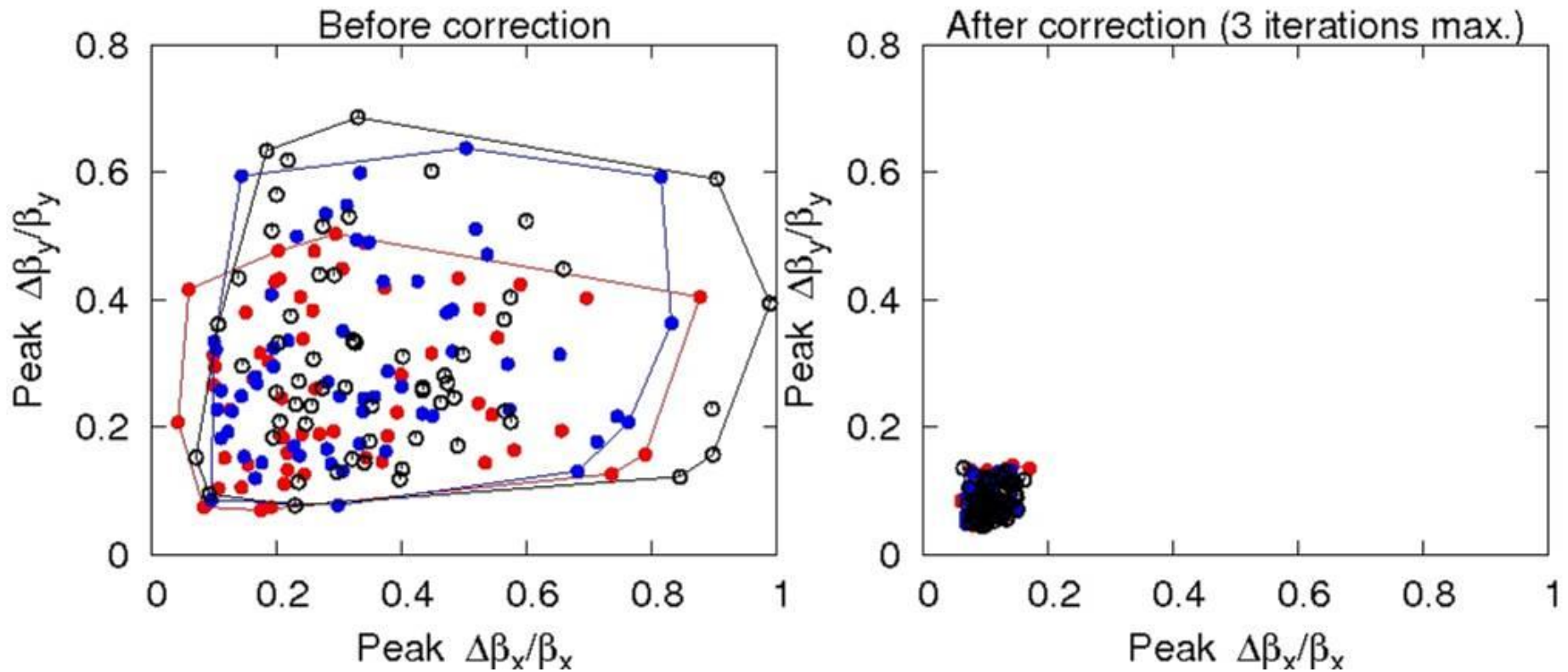
# Beta-Beating Correction

- Up to now the measured longitudinal displacements have been discussed. One also has to consider an uncertainty of +/- 5 mm of the magnetic center measurement.
- Measurement and correction of beta-beating is envisaged to cope with this random effect.
- The measurement requires the expected BPM resolution and an operational AC dipole allowing for a  $4 \sigma$  kick at top energy.

# Beta-Beating Correction

LHC collision optics  
Quad errors, 60 seeds

Matched ●  
Matched and 5mm random Y-misalignment ●  
Unmatched and 5mm random Y-misalignment ○



# Conclusion

- The large relative longitudinal displacement of more than **22 mm** in IR5R is eating **50 %** of the beta-beating budget.
- It is unfortunate that despite a clear request from ABP and many discussions these adjustments have been postponed until it was too late.
- As result a re-matching is required when squeezing below  **$\beta^* = < 4\text{m}$** .
- The longitudinal displacement is about **~12 mm** for IR2 (fully squeezed) and leads to a beta-beating of just **5 %**. A re-matching may not be required.
- Results for IR8 are still preliminary but the longitudinal displacement are much smaller in this IR.
- Lastly, a beta-beating correction has been attempted and shown to work even without a re-matching, albeit under ideal operational conditions.