LOC meeting

Spectrometer compensation in IR2 and IR8 during the 450 GeV collision run

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Thanks to S. Fartoukh, W. Herr, B. Jeanneret, M. Giovannozzi

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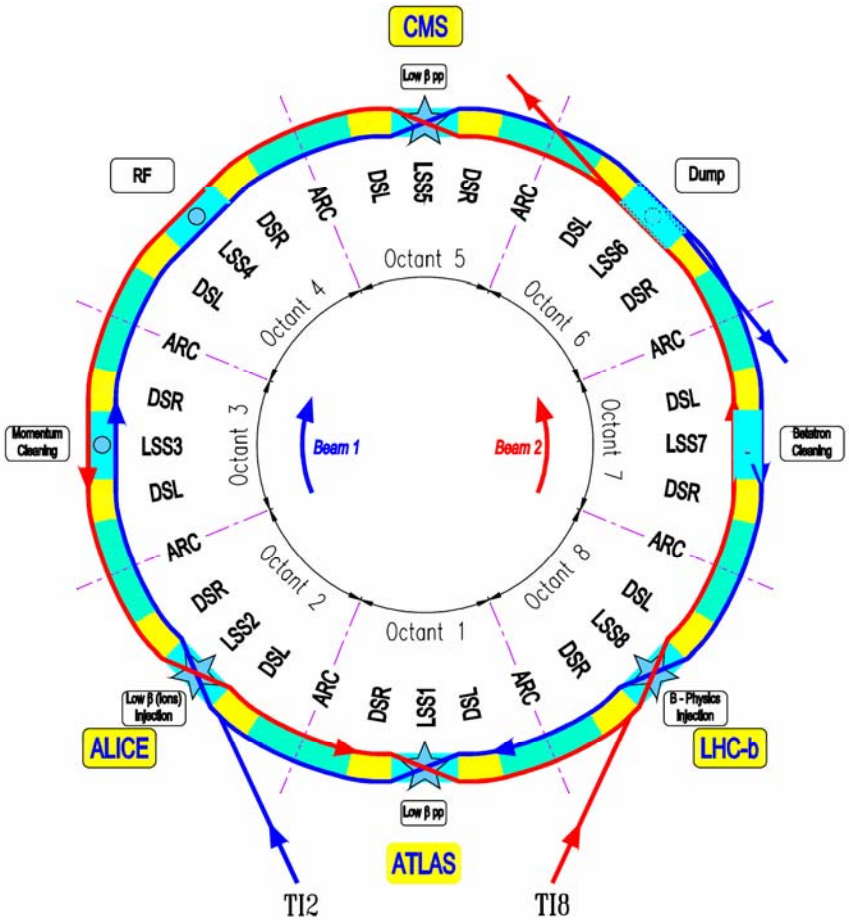
Outline

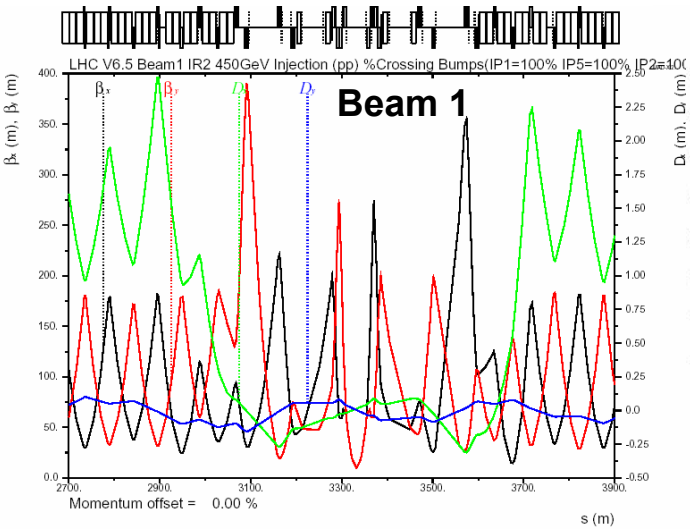
- Can the spectrometer magnets of IR2 and IR8 have their maximum (corresponding to 7TeV) field during the **450 GeV collisions run?** (LTC action)
- IR2/8 nominal injection optics and crossing schemes
- IR2/8 spectrometer magnets and internal crossing angles
- Nominal aperture with different configurations
  - With/without external crossing
  - With + or – spectrometer polarities
- Available aperture when spectrometer ramped to its max value at 450 GeV.
  - Analytical estimates and MADX simulations

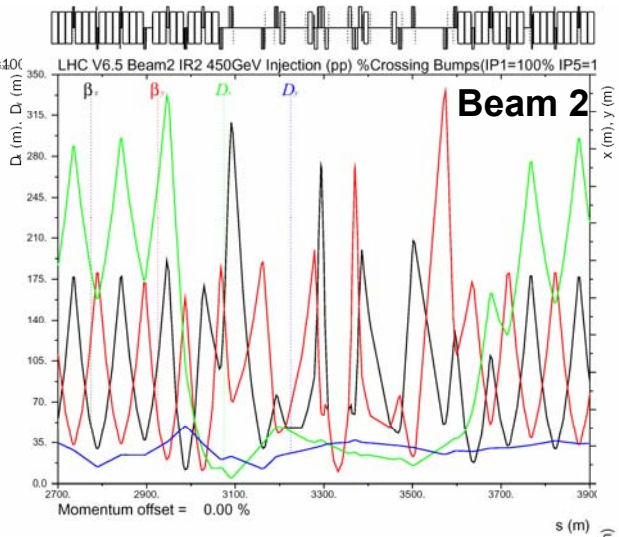
LHC experimental IRs

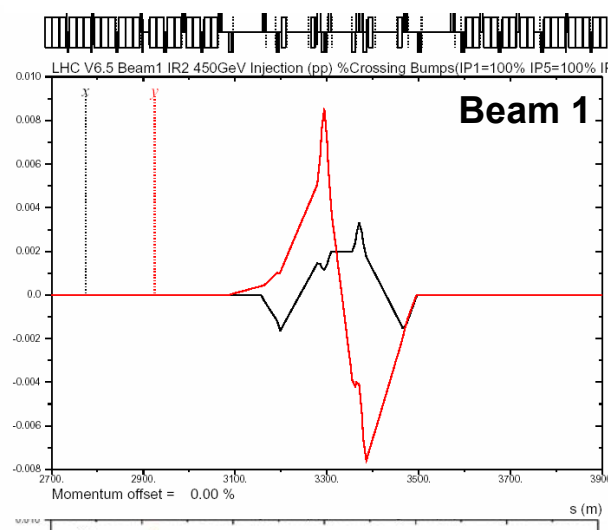


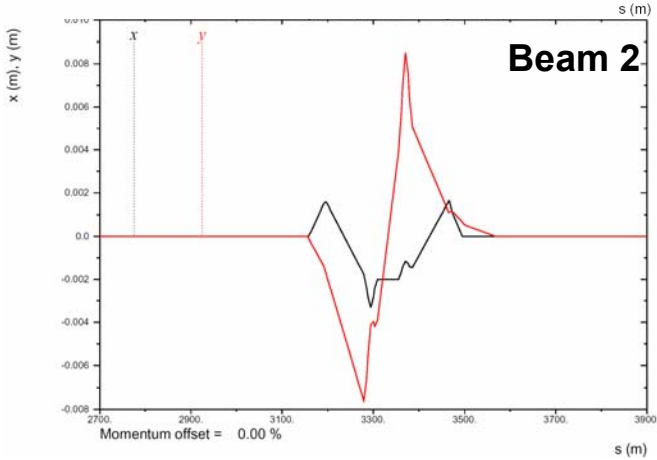
- Two high luminosity experiments
  - **ATLAS** in IP1 (vertical crossing)
  - **CMS** in IP5 (horizontal crossing)
- B-physics with lower luminosity in asymmetric IP8
  - **LHCb** (horizontal crossing)
  - Injection of beam 2
- Heavy ion experiment (and p-p collisions with offset beams)
  - **ALICE** (vertical crossing)
  - Injection of beam 1

IR2 Injection optics (O. Brüning et al. LHC Project rep 367)



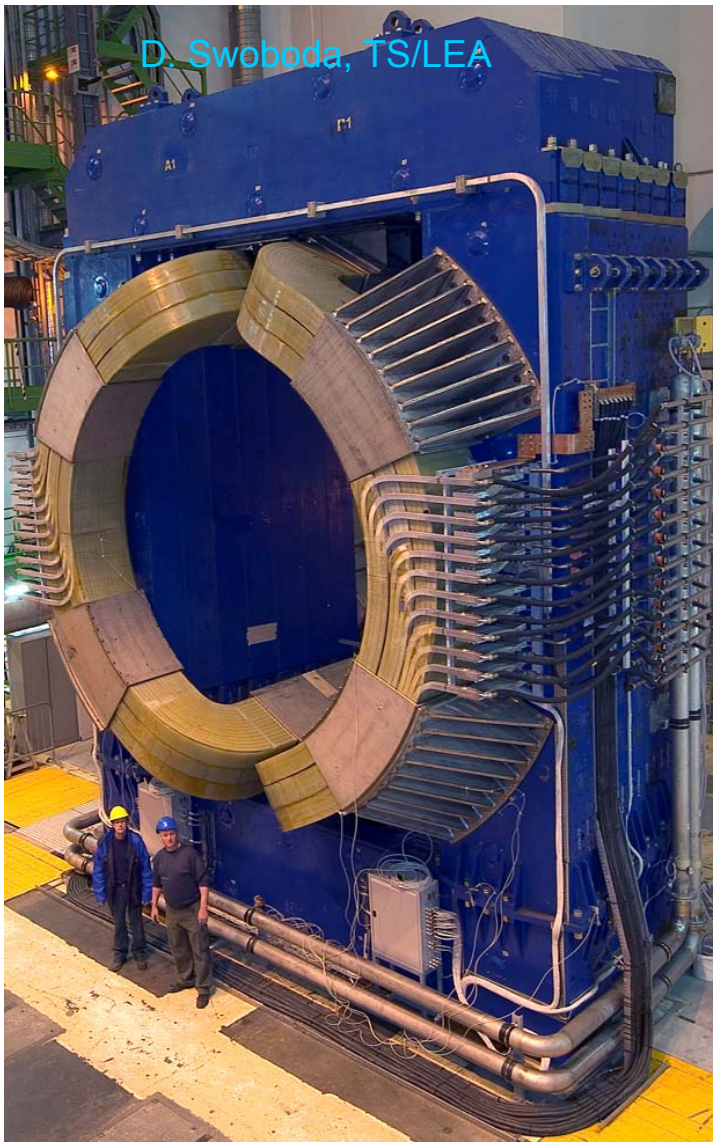






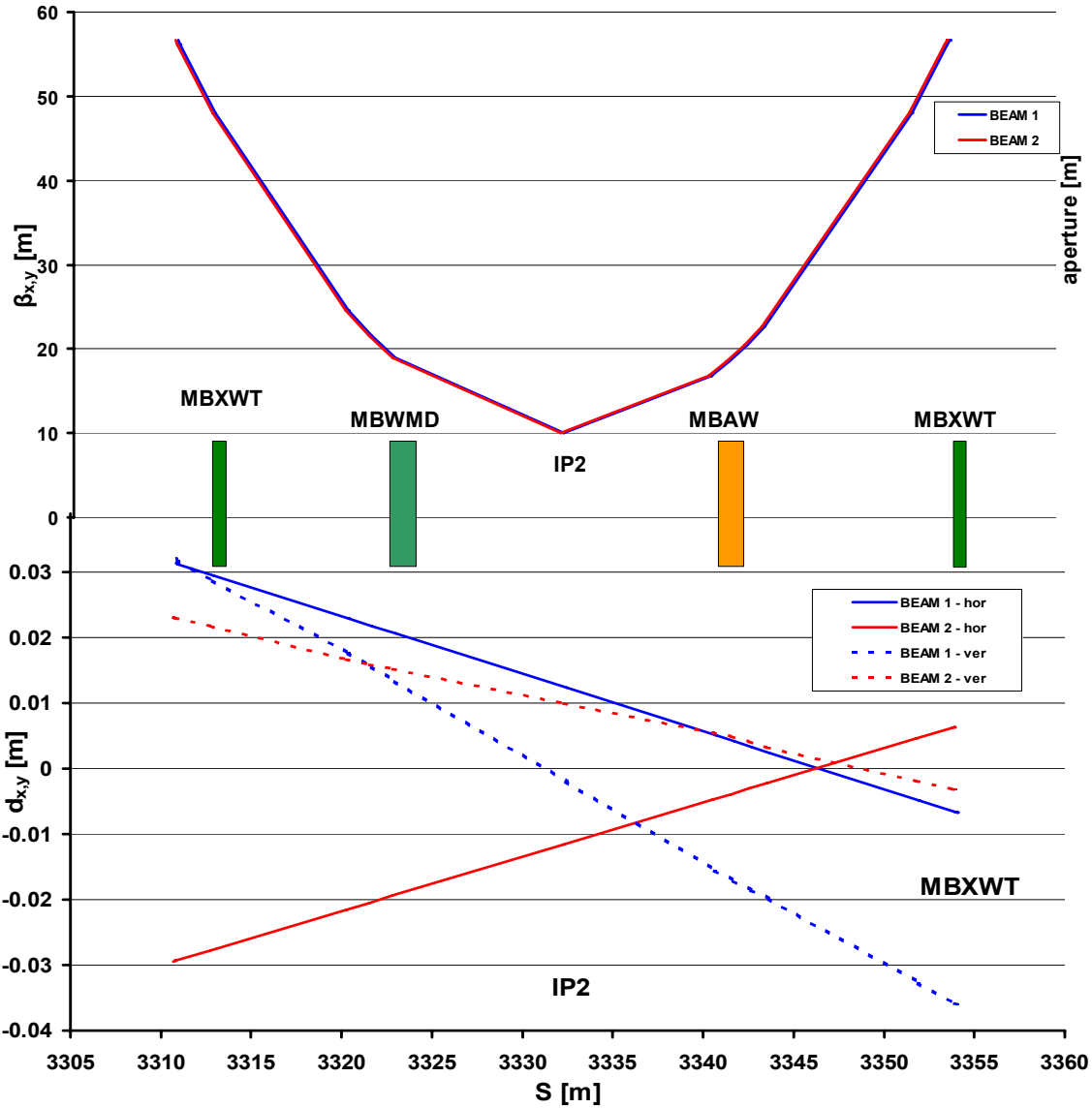
- β*=10m, vertical crossing angle of ±150μrad and horizontal parallel separation of ± 2mm
  - External angle of ±80μrad for reducing the long range beam-beam effect
  - Internal angle of ±70μrad for compensating spectrometer orbit distortion
  - Horizontal separation positive for Beam 1 and negative for Beam 2
  - Angle sign can be chosen arbitrarily (following spectrometer polarity)

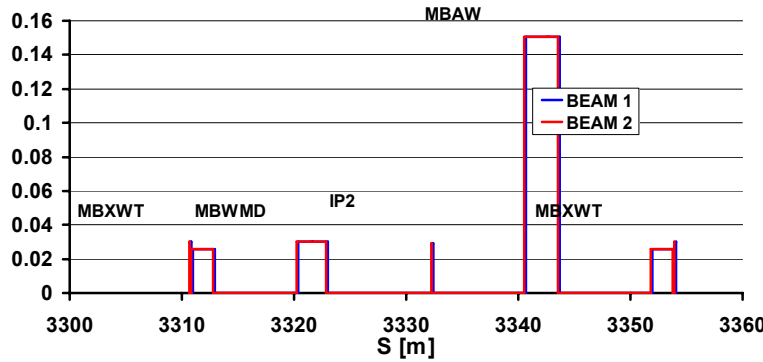
ALICE dipole magnet and its compensators



- 3m-long spectrometer dipole (MBAW) @ 10m to the right of the IP
- Vertical deflection with nominal integrated field of 3Tm (deflection of 130μrad @ 7TeV)
- The resulting orbit deflection is compensated by three dipole magnets
  - Two 1.5m-long magnets of type MBXWT @ 20m left and right of the IP
  - One 2.6m-long magnet of type MBWMD @ 10m to the left of the IP
- Two Beam Position Monitors (BPMWS) are located upstream and downstream of the two MBXWT to monitor the internal bump closure

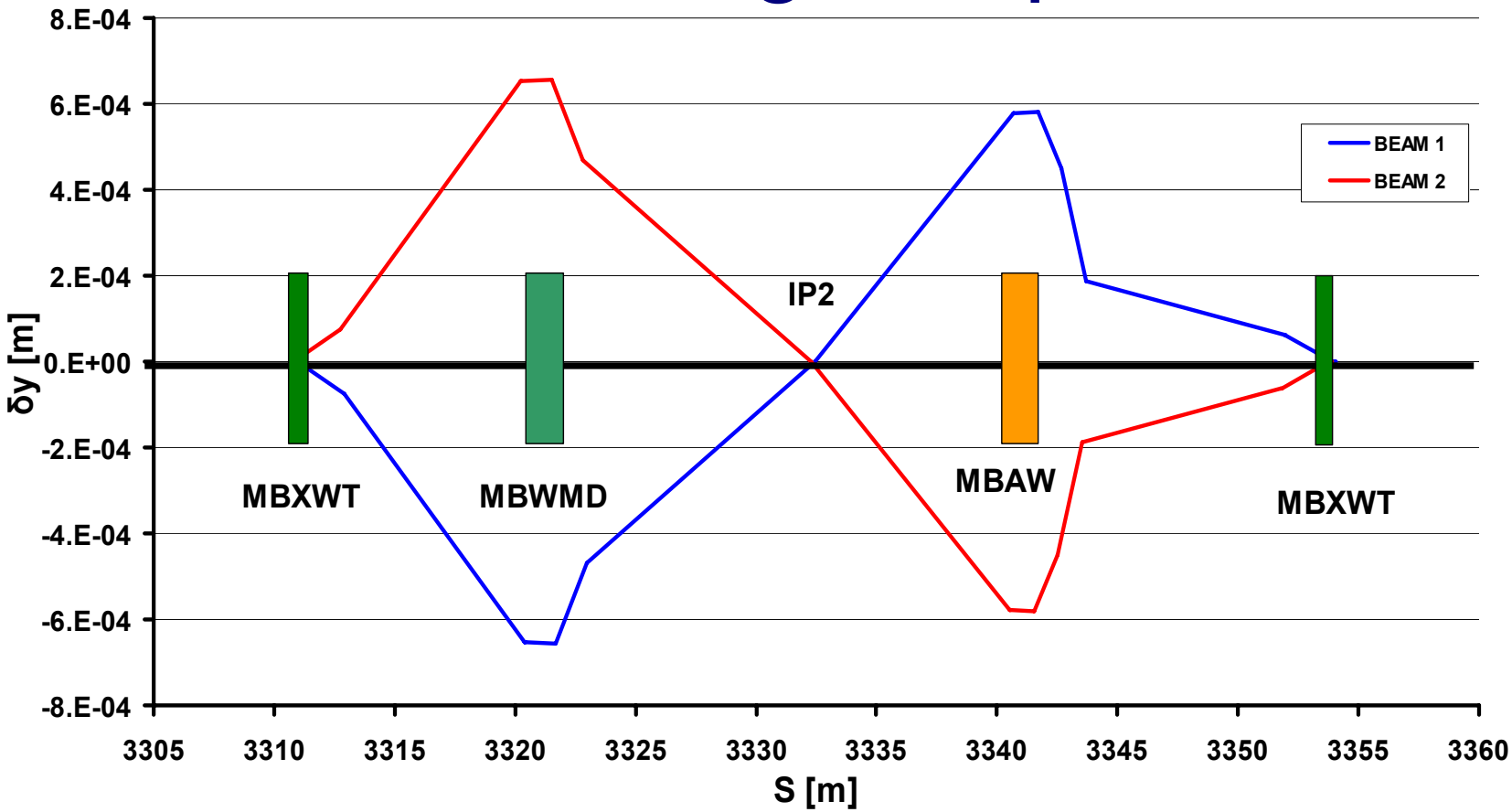
Injection optics around the IR2





Equipment	Aperture [m]	β [m]
BPMSW.1L2	0.030	57
MBXWT.1L2	0.026	56 - 48
MBWMD.1L2	0.030	24 - 19
IP2	0.029	10
MBAW.1R2	0.151	17 - 23
MBXWT.1R2	0.026	48 - 56
BPMSW.1R2	0.030	57

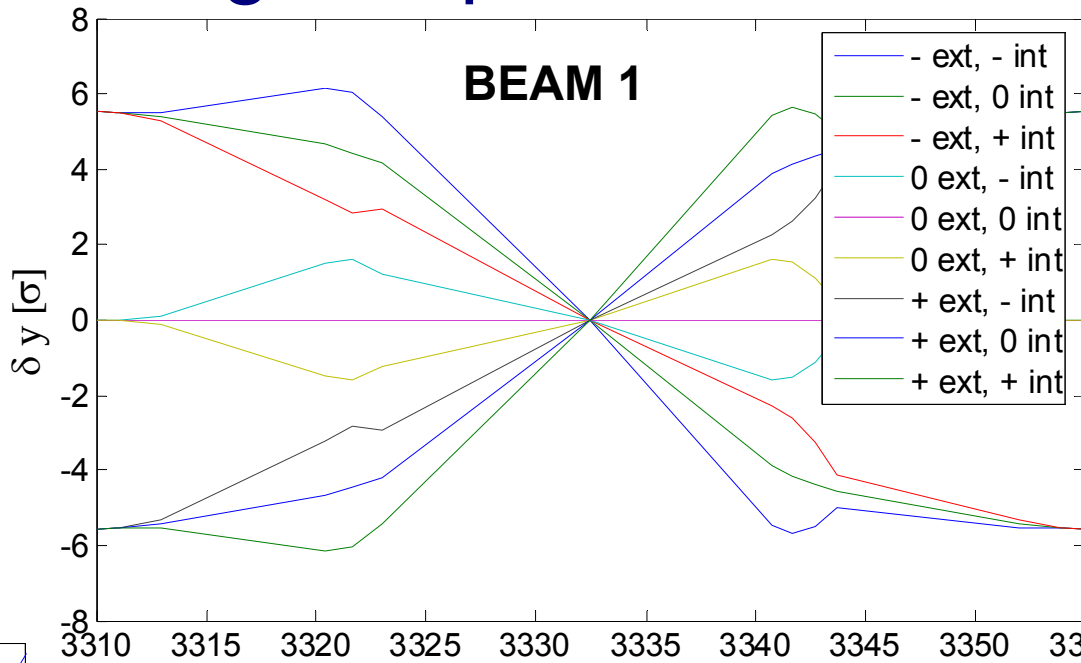
Internal crossing bump of IR2

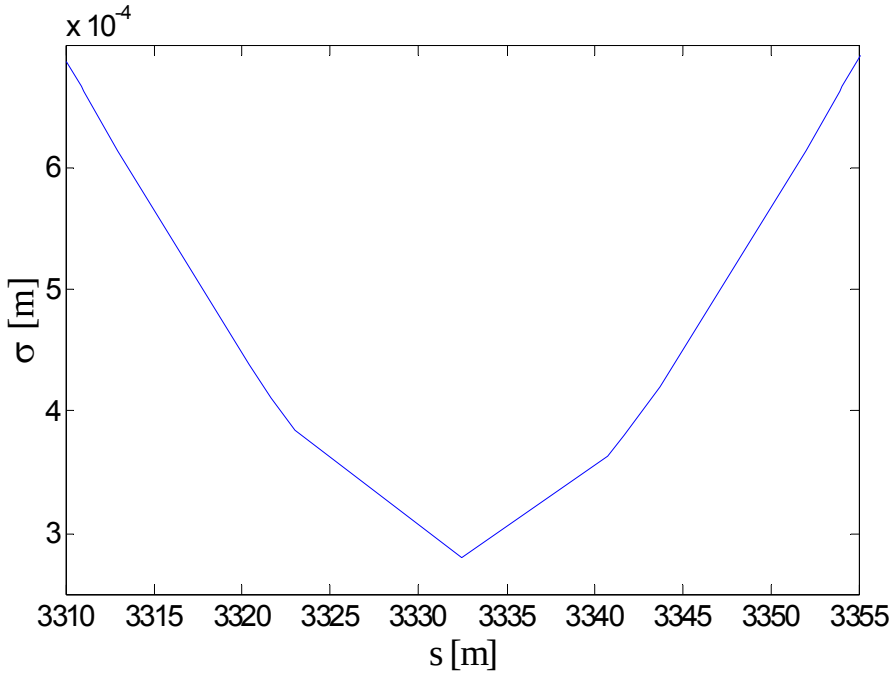


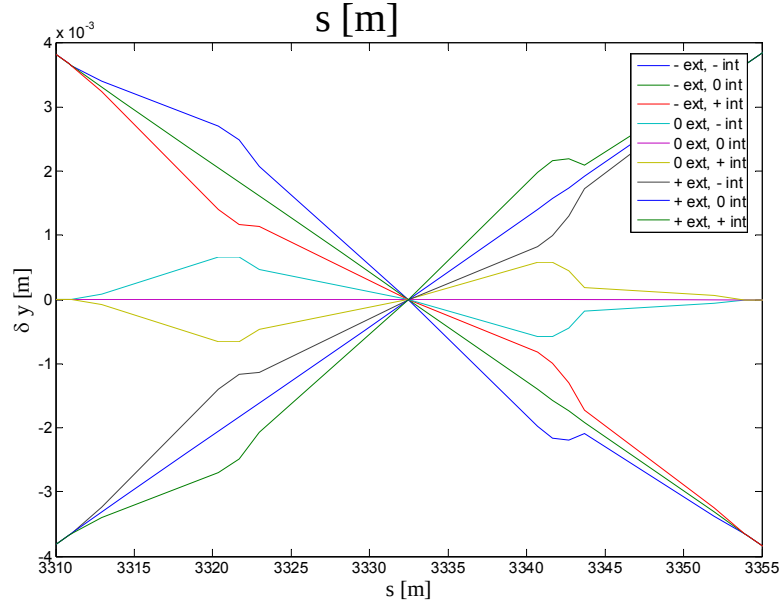
- Internal crossing angle of ±70μrad in the vertical plane (maximum deflection of ±0.7mm at MBWMD)
- External crossing angle follows spectrometer dipole polarity

Nominal injection crossing bump of IR2

- External crossing angle of ±80μrad in the vertical plane added giving an effective crossing angle of ±150μrad, when polarity of spectrometer follows the sign of the external angle
- Beam size varies between 0.8 and 0.3mm
- Deflection maximum of 6σ at MBWMD

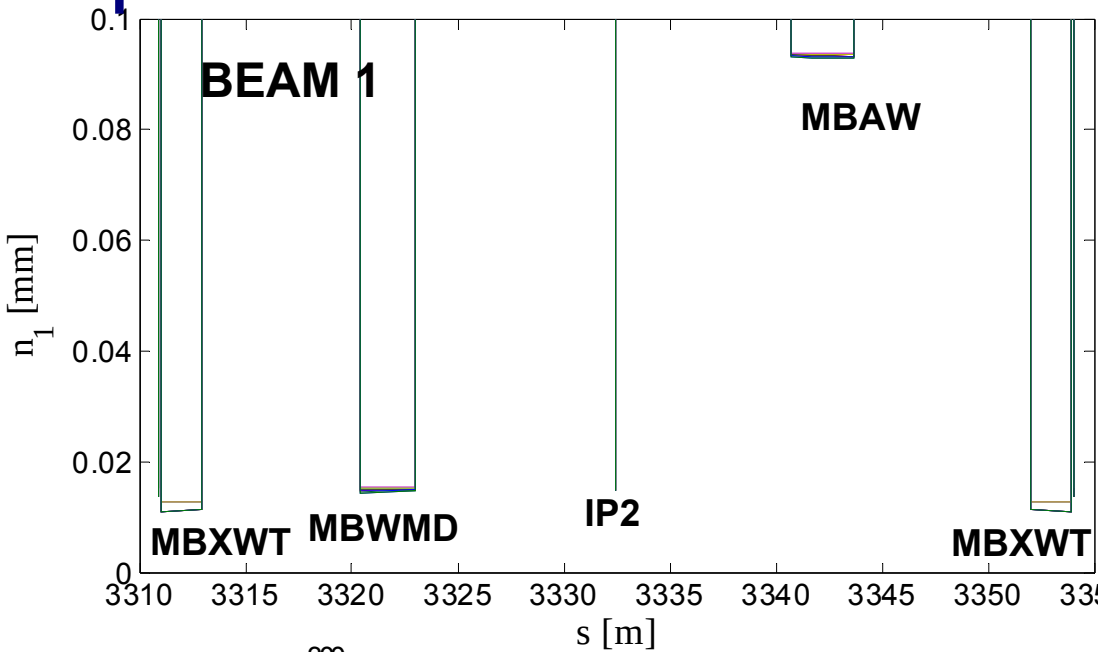




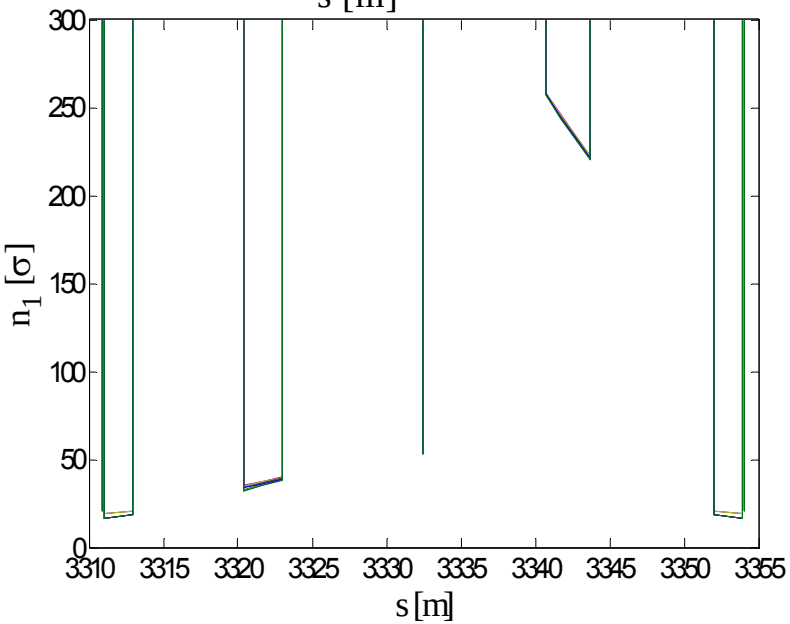


Nominal injection aperture in IR2

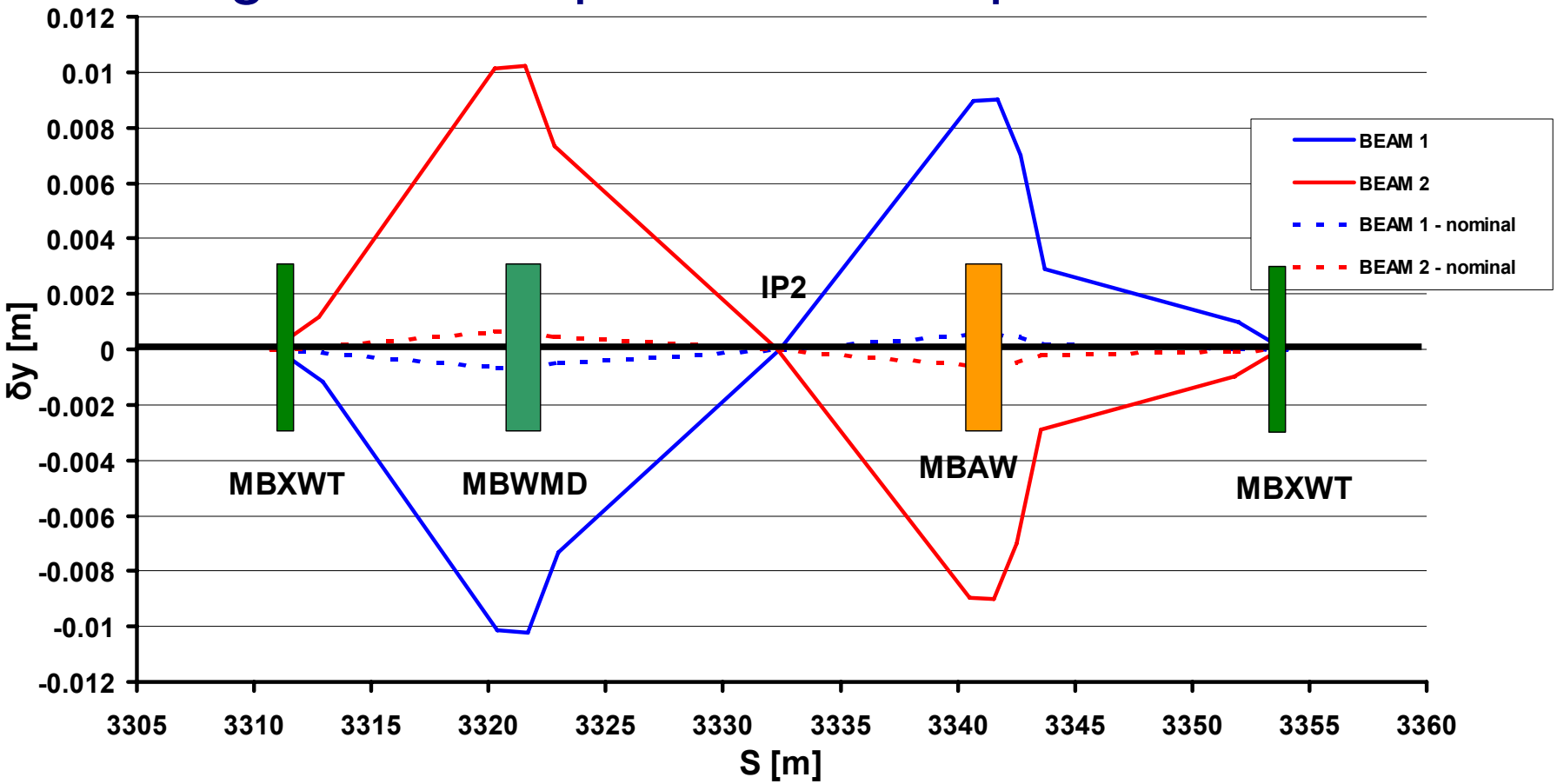
Equipment	n_1 [σ]	n_1 [m]	n_1 [%]
BPMSW.1L2	**20**	**0.014**	**47**
MBXWT.1L2	**17**	**0.011**	**42**
MBWMD.1L2	**33**	**0.014**	**47**
IP2	**53**	**0.015**	**52**
MBAW.1R2	**221**	**0.093**	**58**
MBXWT.1R2	**17**	**0.011**	**42**
BPMSW.1R2	**20**	**0.014**	**47**



- Aperture varies for less than 3σ between the scheme with only internal and full crossing scheme
- Around half of the available aperture is lost for all compensators and 40% for the spectrometer (but a lot of margin in that area)

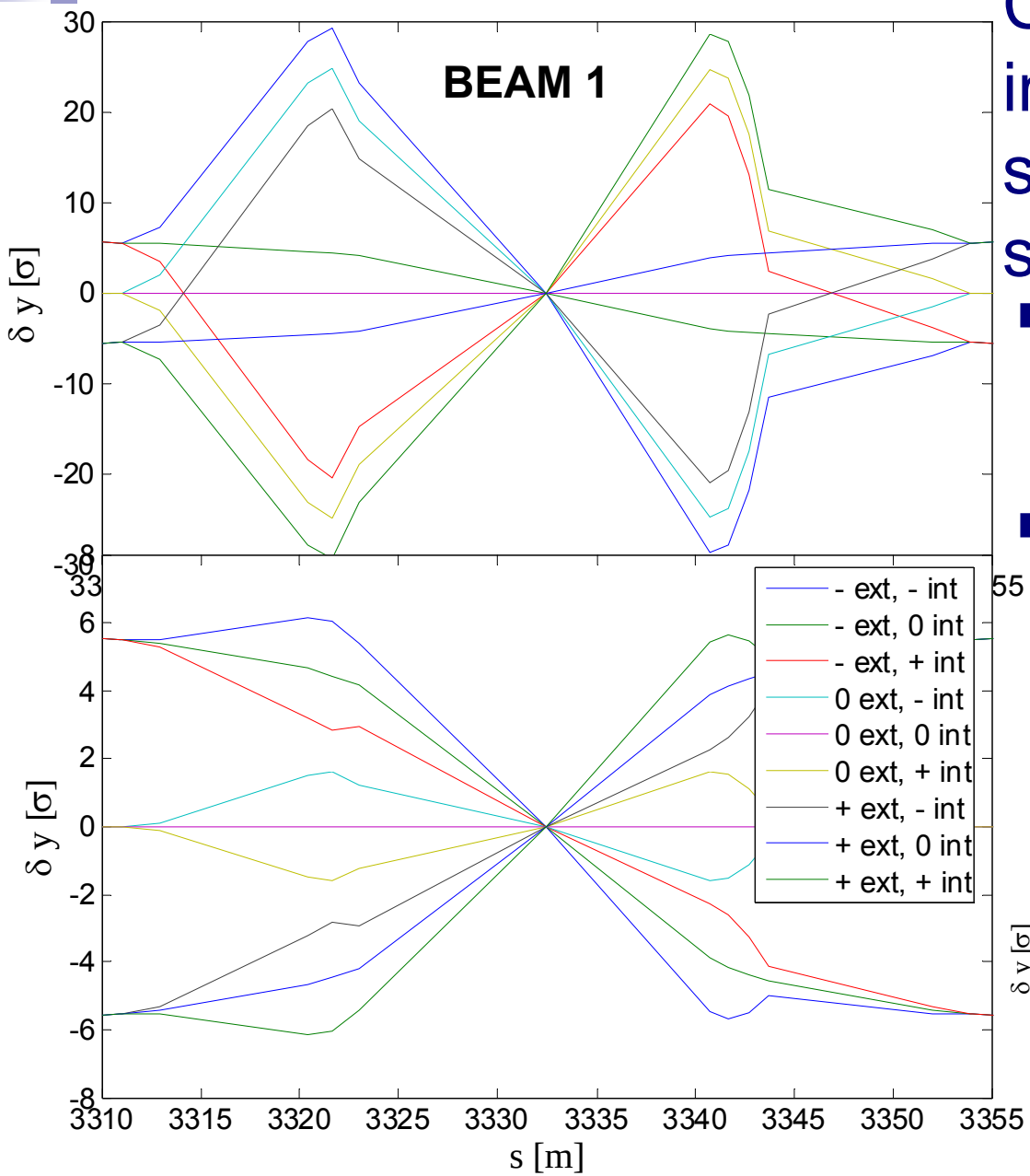


Internal crossing bump of IR2 with collision strength for the spectrometer dipole

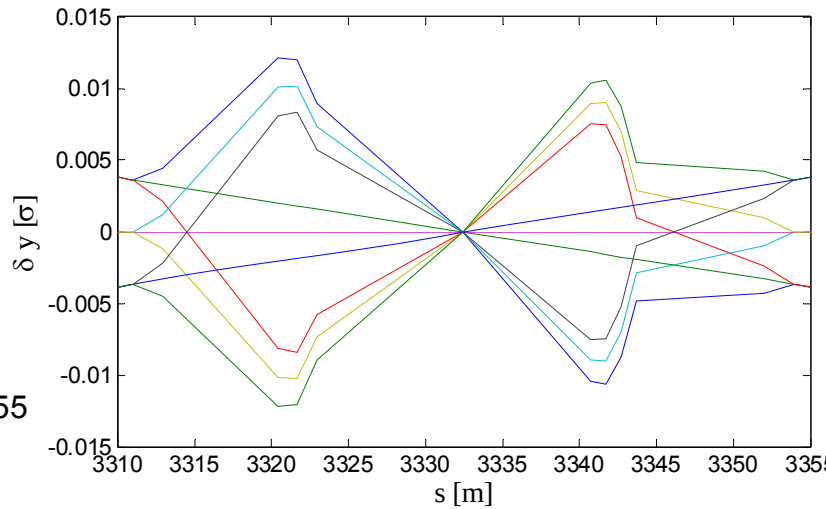


- Internal crossing angle of ±1089μrad in the vertical plane
- Maximum deflection of ±0.011m at MBWMD, corresponding to 25σ, as compared to 0.0007m (1.6σ) of the nominal bump

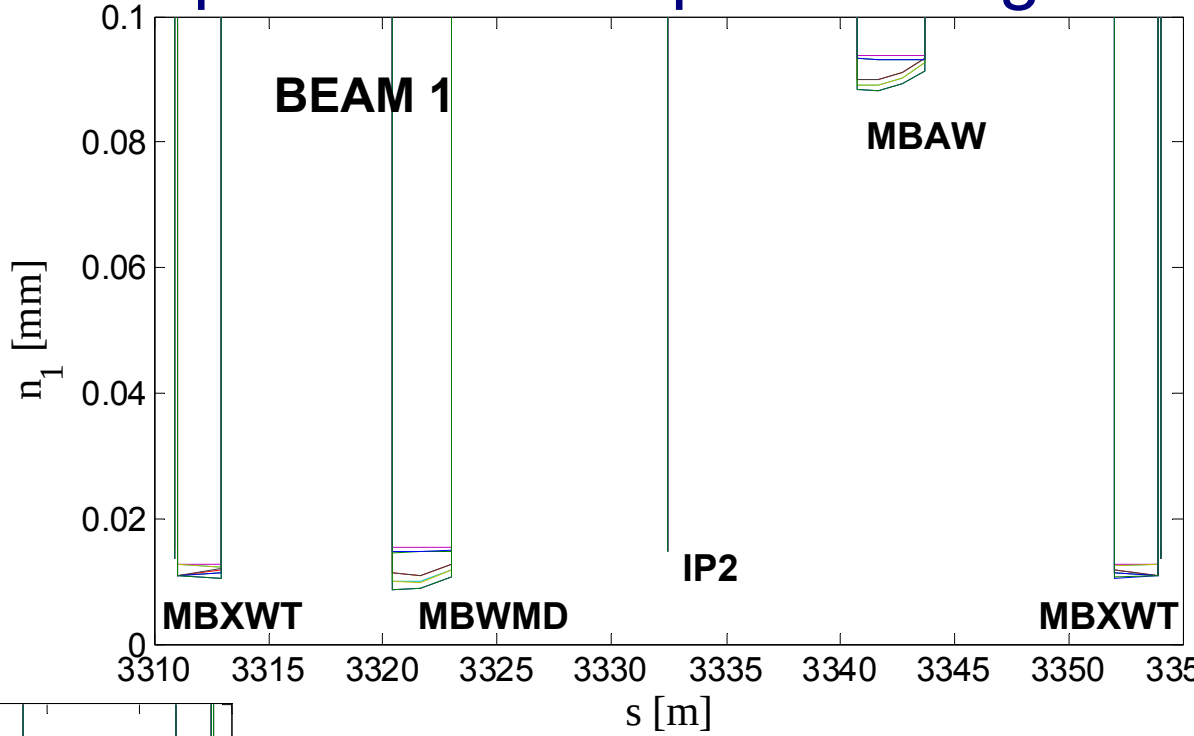
Crossing bump in IR2 at injection with collision strength for the spectrometer dipole

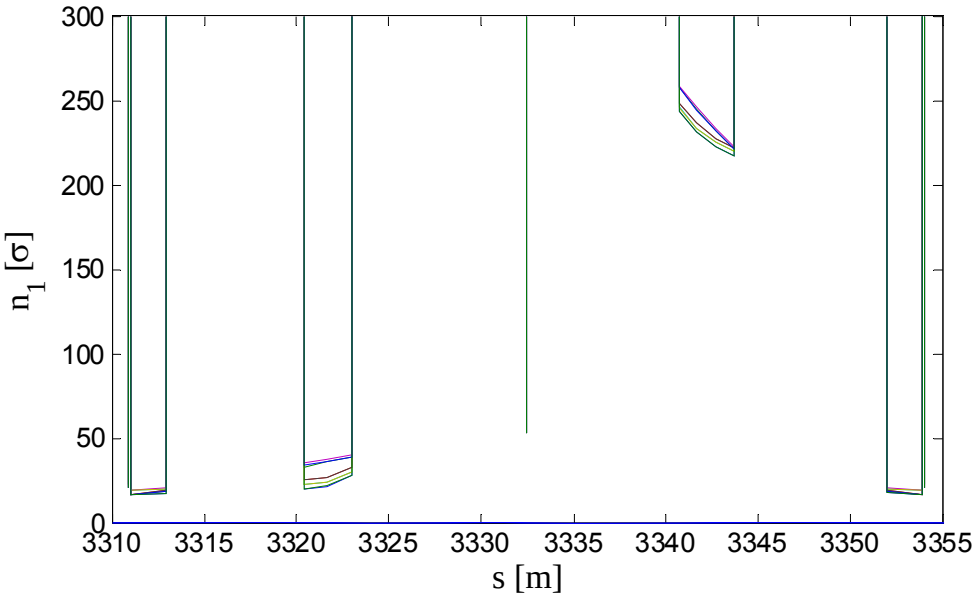


- Maximum beam excursion of 0.012m (30σ) at MBWMD, as compared to 0.0004m (6σ) for the nominal scheme
- When polarity and external crossing angle sign are mismatched, two additional crossings occur ~15m left and right of the IP (W. Herr, Chamonix 2006)



Aperture in IR2 with full spectrometer dipole strength





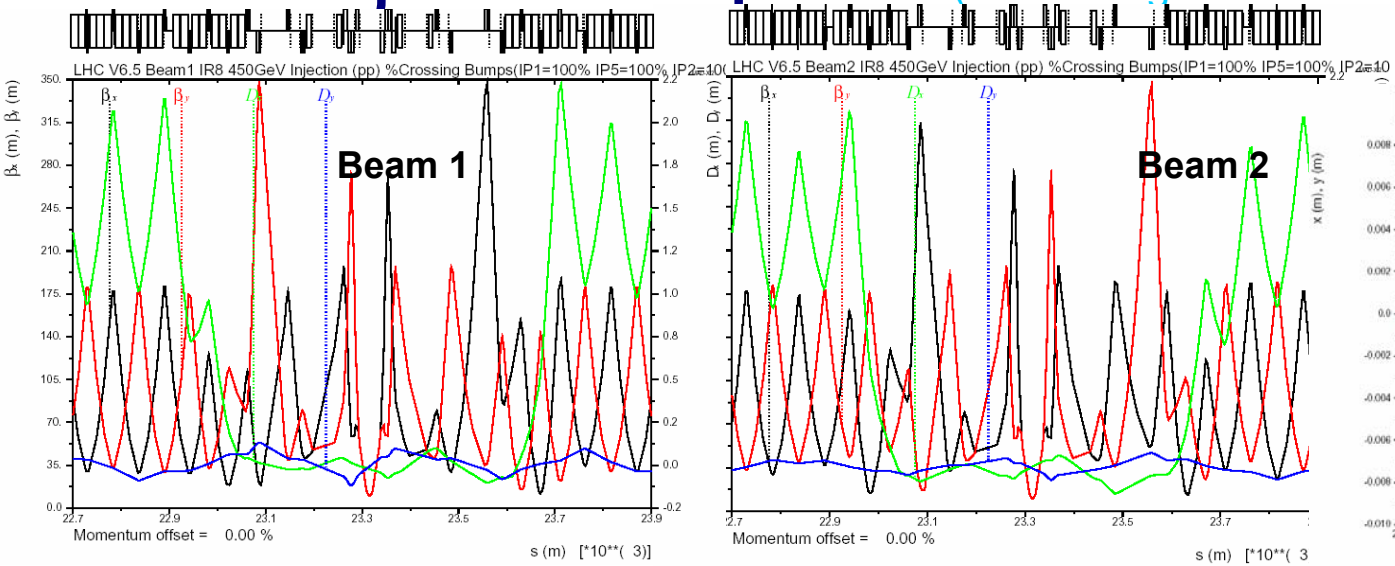
- Biggest loss in aperture around MBWMD
- n_1 takes equivalent values with MBWXT and IP2 in σ and even smaller in mm

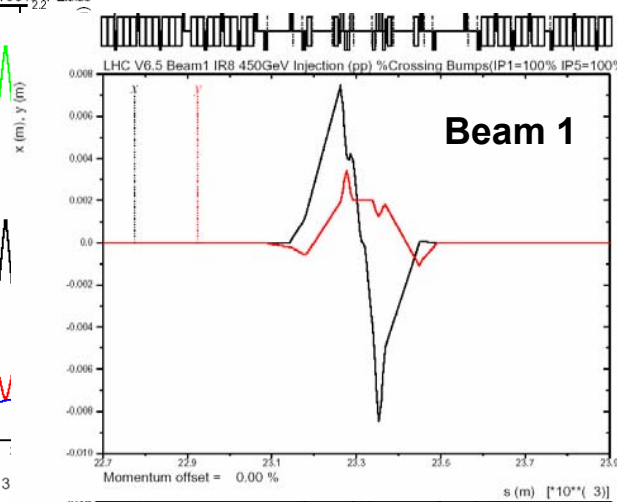
Aperture loss in IR2 by element

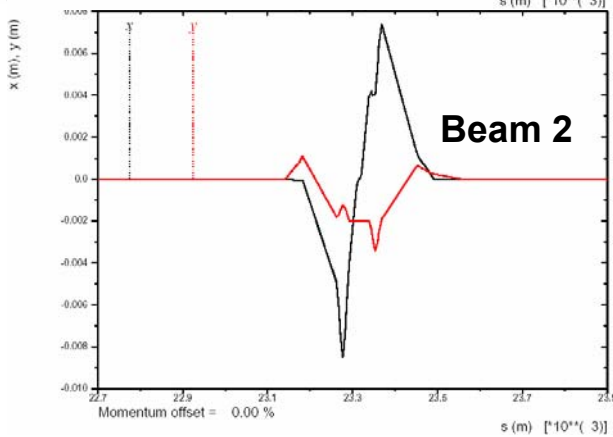
Equipment	n_1 nominal [σ]	n_1 full [σ]	n_1 nominal [m]	n_1 full [m]	n_1 nominal [%]	n_1 full [%]
BPMSW.1L2	20	20	0.014	0.014	47	47
MBXWT.1L2	17	17	0.011	0.011	42	42
MBWMD.1L2	33	20	0.014	0.009	47	30
IP2	53	53	0.015	0.015	52	52
MBAW.1R2	221	217	0.093	0.088	62	58
MBXWT.1R2	17	17	0.011	0.011	42	42
BPMSW.1R2	20	20	0.014	0.014	47	47

- Not important impact in any element apart MBWMD
  - Available aperture of 9mm (with respect to 14mm), corresponding to 13σ of aperture loss
  - Remaining aperture is 30% of the available

IR8 Injection optics (O. Brüning et al. LHC Project rep 367)

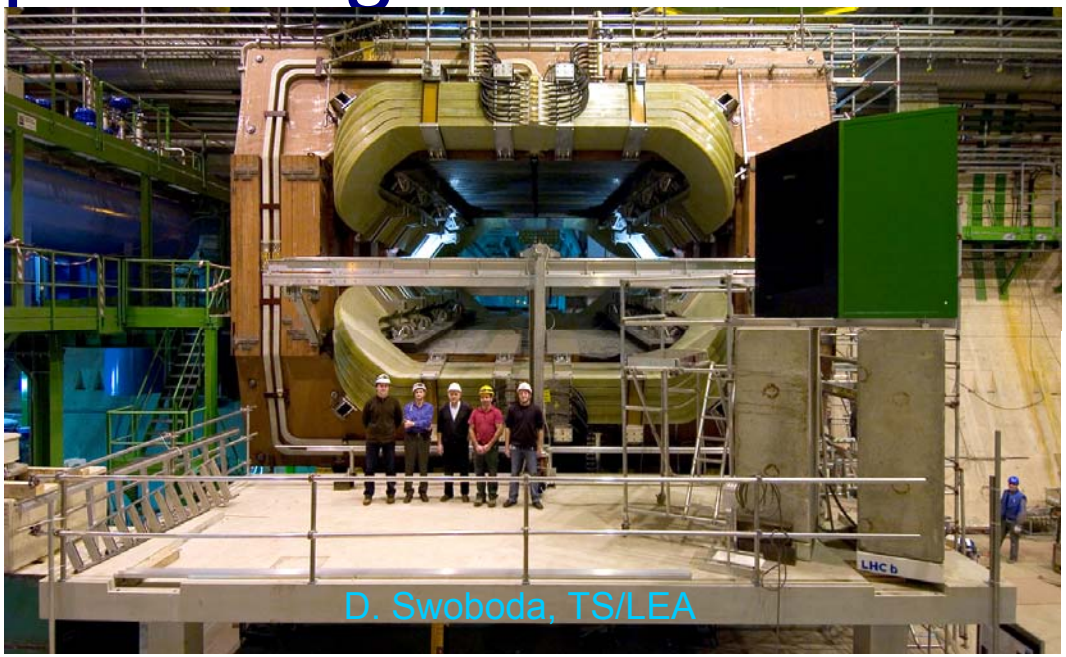






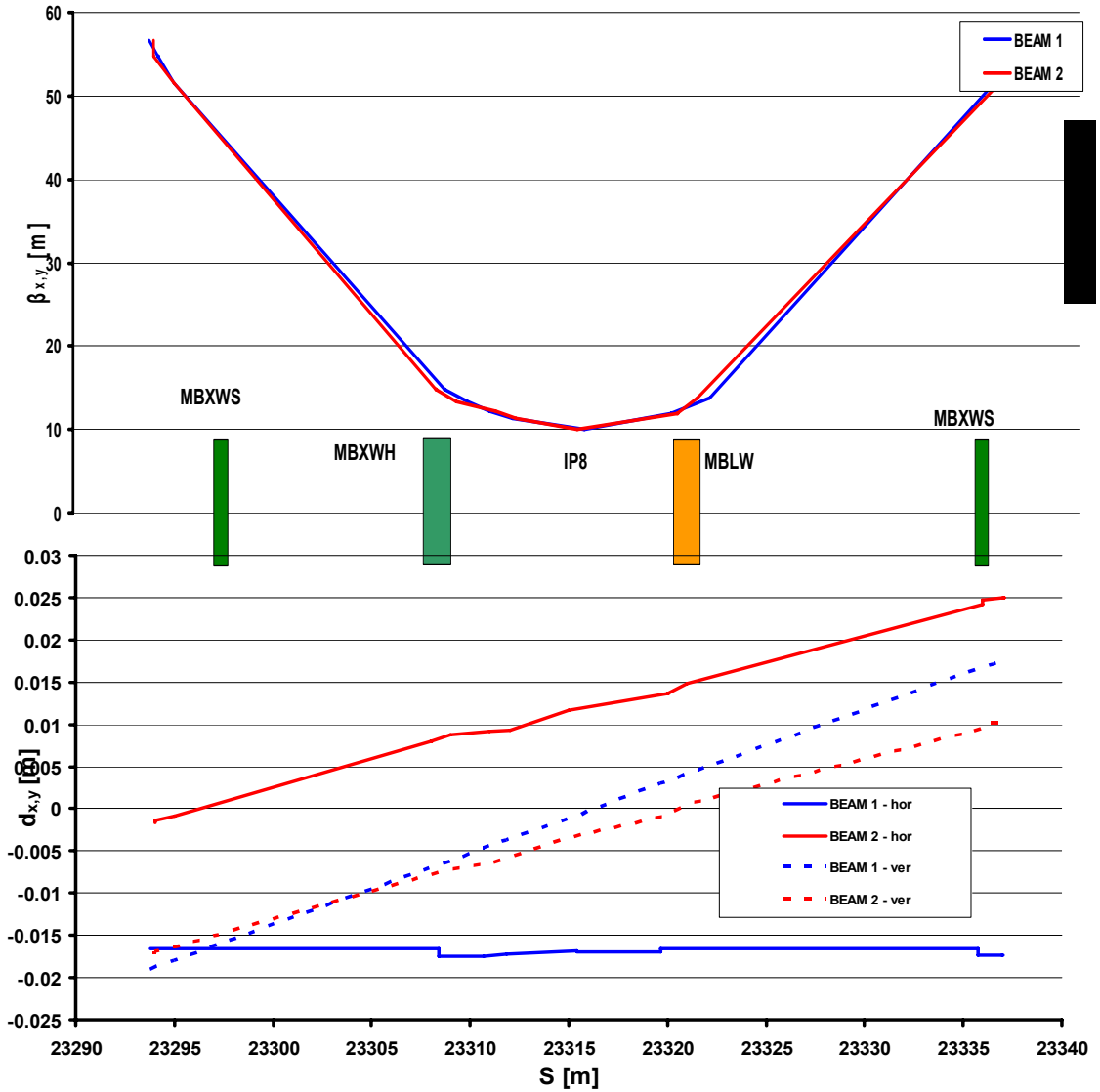
- β*=10m, horizontal crossing angle of ±200 or ±75 μrad depending on the polarity and vertical parallel separation of ± 2mm
  - External angle of ±65 (- polarity) or ±210 μrad (+ polarity)
  - Internal angle of ±135 μrad for compensating spectrometer orbit distortion
  - Horizontal crossing angle always negative for Beam 1 and positive for Beam 2
  - Vertical separation sign can be chosen arbitrarily

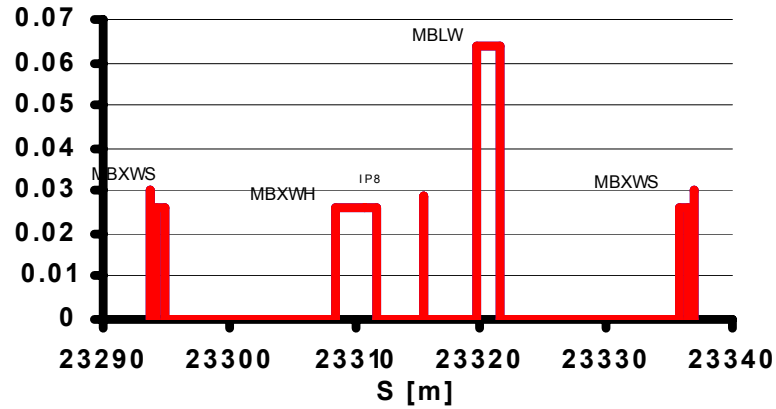
LHCb dipole magnet



- 1.9m-long spectrometer dipole (MBLW) @ 4.9m to the right of the IP
- Horizontal deflection with nominal integrated field of 4.2Tm (deflection of 180μrad @ 7TeV)
- The resulting orbit deflection is compensated by three dipole magnets
  - Two 0.8m-long magnets of type MBXWS @ 20m left and right of the IP
  - One 3.4m-long magnet of type MBXWH @ 5m to the left of the IP
- Two Beam Position Monitors (BPMWS) are located upstream and downstream of the two MBXWS to monitor the internal bump closure

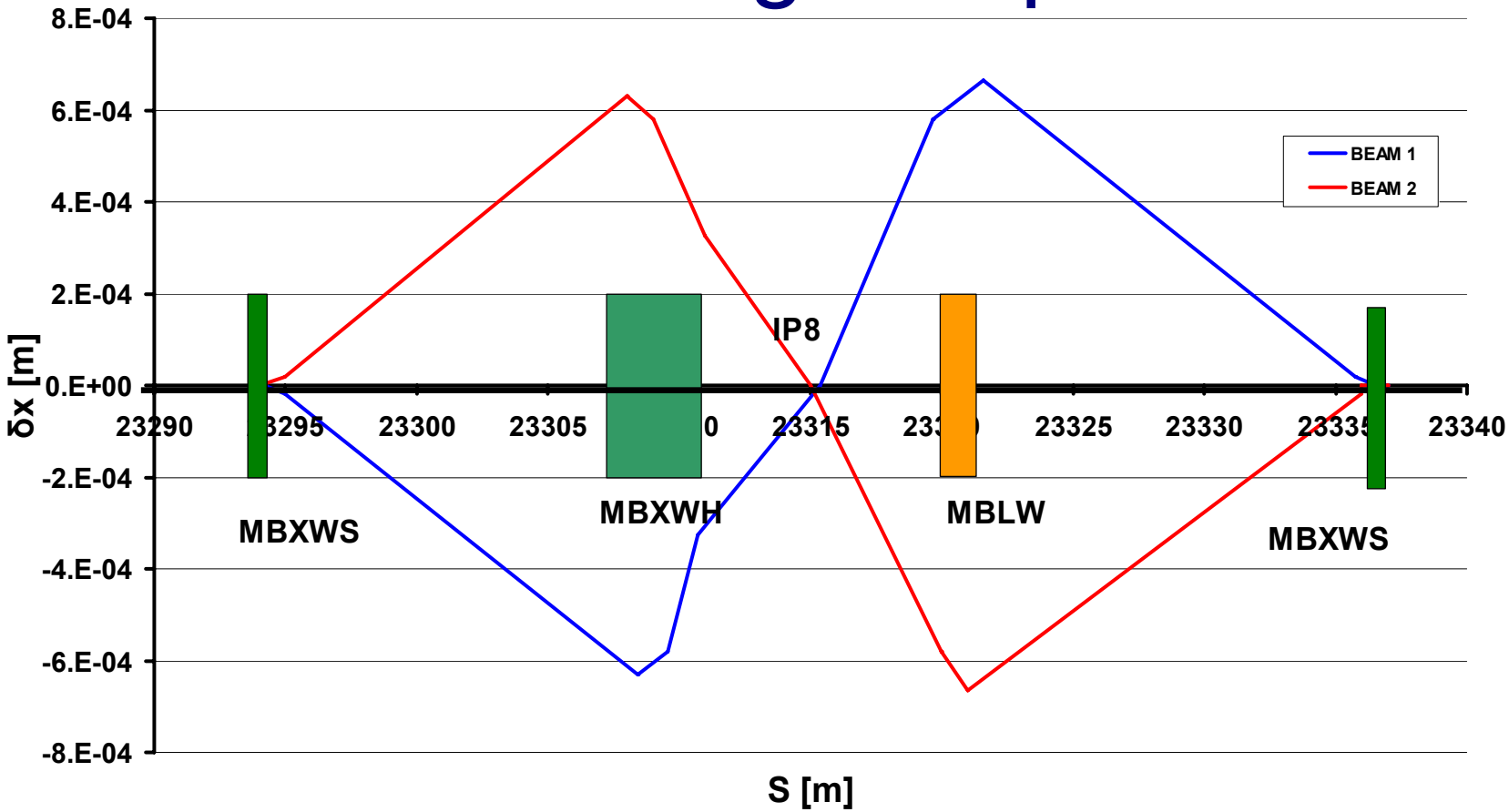
Injection optics around the IR8





Equipment	Aperture [m]	β [m]
BPMSW.1L8	0.030	57
MBXWS.1L8	0.026	55 - 52
MBXWH.1L8	0.026	15 - 12
IP8	0.030	10
MBLW.1R8	0.064	12 - 14
MBXWS.1R8	0.026	52 - 55
BPMSW.1R8	0.030	57

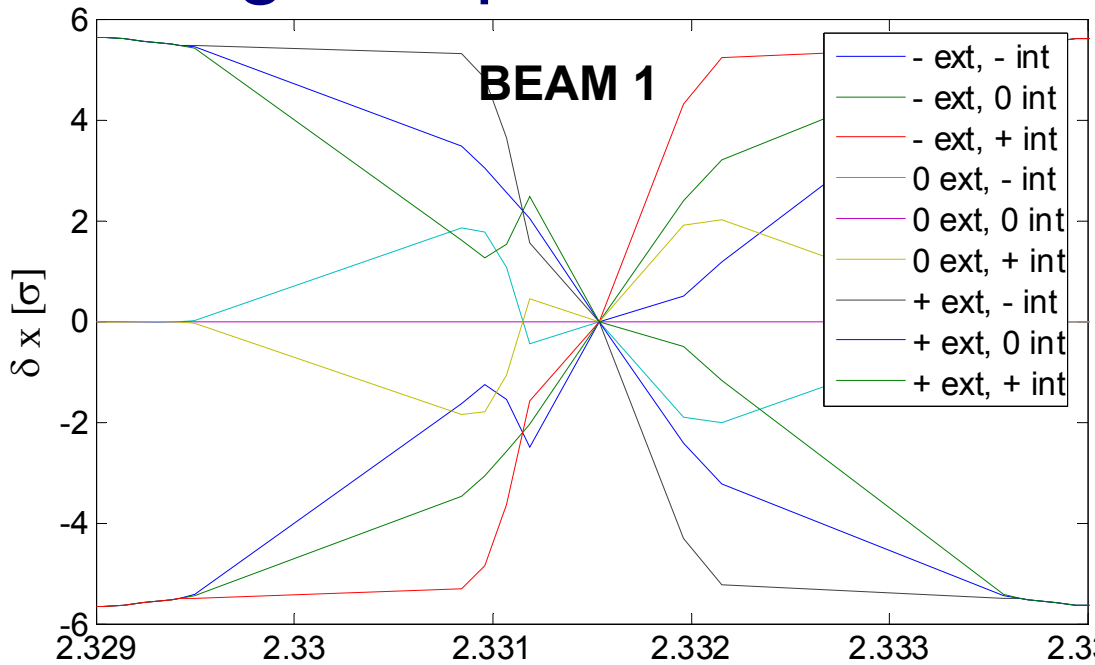
Internal crossing bump of IR8

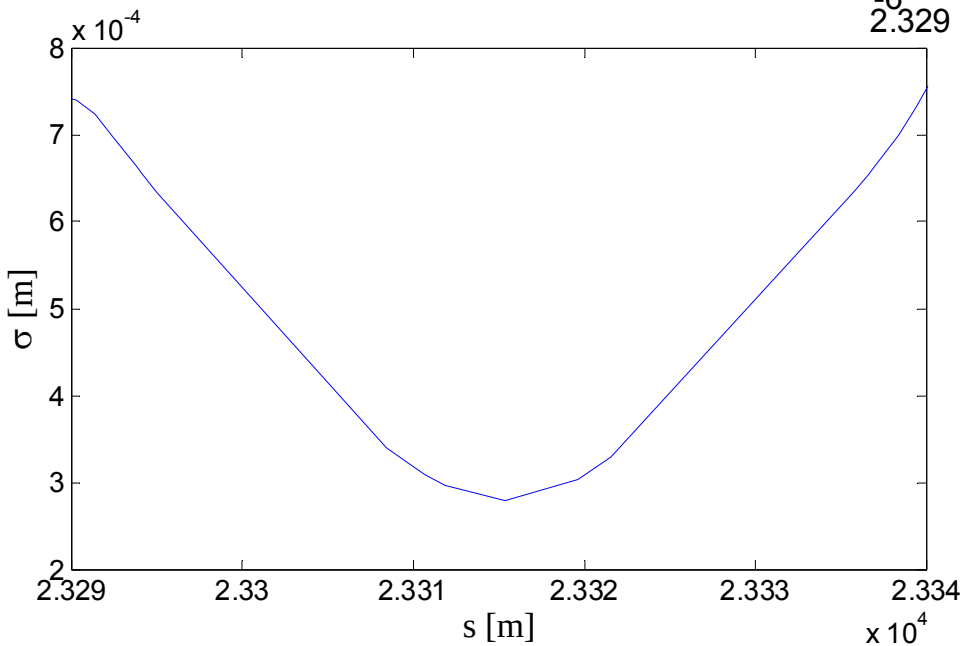


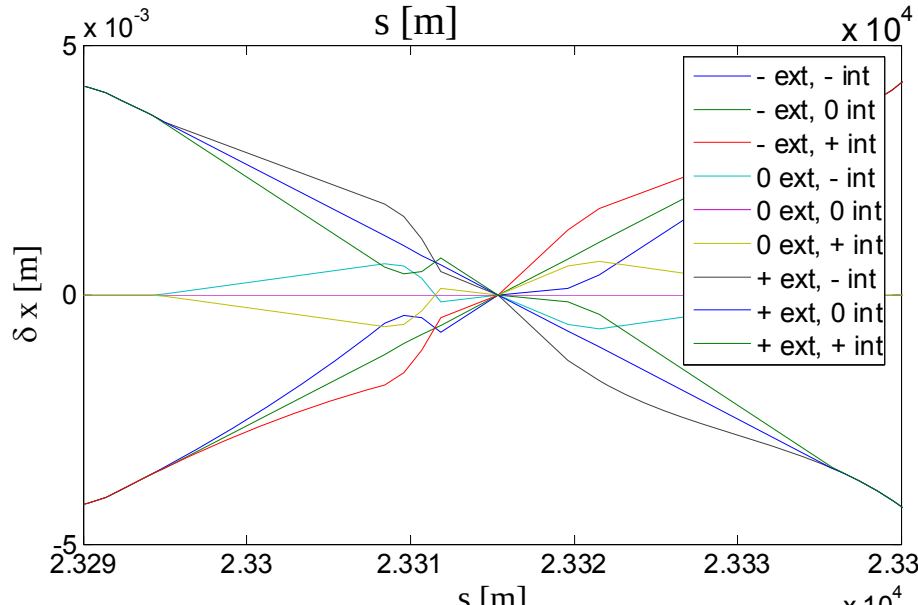
- Internal crossing angle of ±135μrad in the horizontal plane (maximum deflection of ±0.6mm at MBXWH)
- External crossing angle does not follow spectrometer dipole polarity
- Note additional crossing at the edge of MBXWH(???)

Nominal injection crossing bump of IR8

- External crossing angle of ±65 or ±210μrad in the horizontal plane added giving an effective crossing angle of ±200 or ±75μrad, and polarity of spectrometer does not follow the sign of the external angle
- Beam size varies between 0.7 and 0.3mm
- Deflection maximum of 6σ at MBXWS

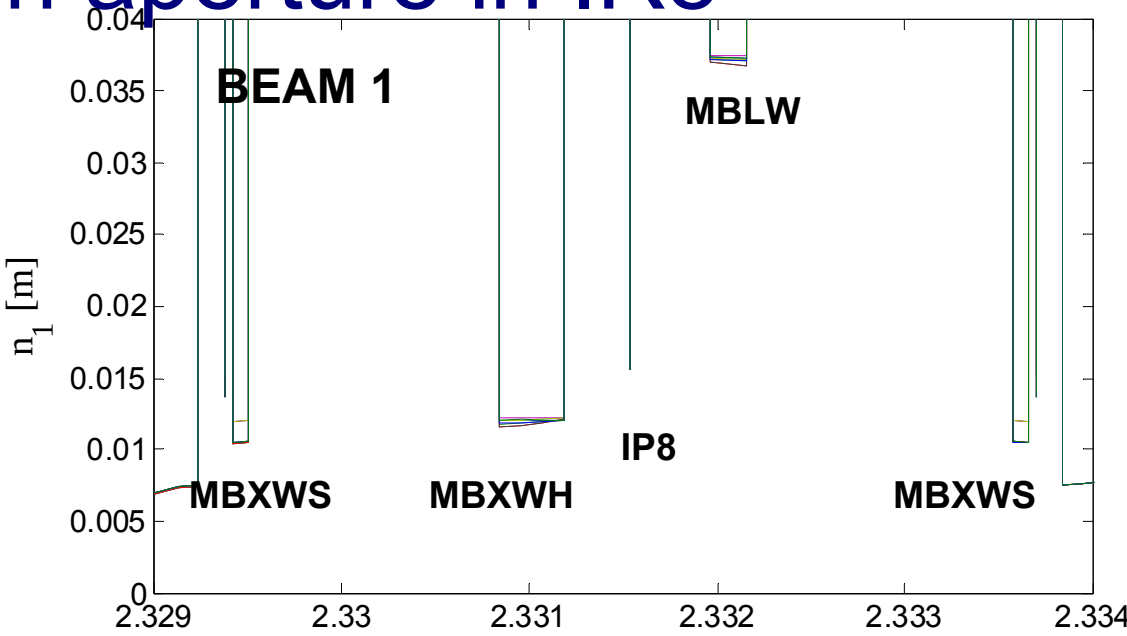




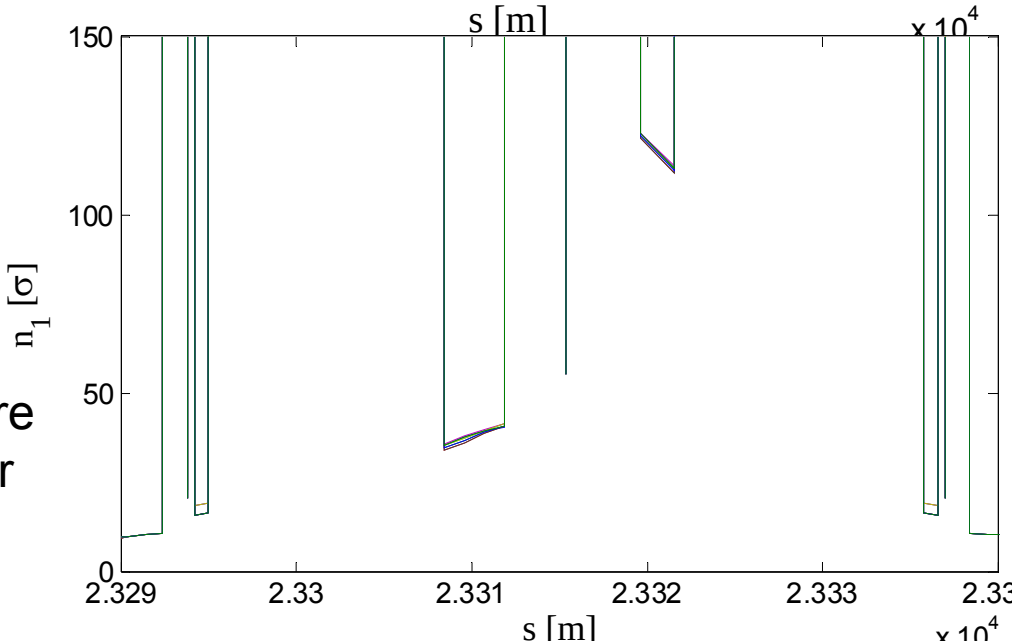


Nominal injection aperture in IR8

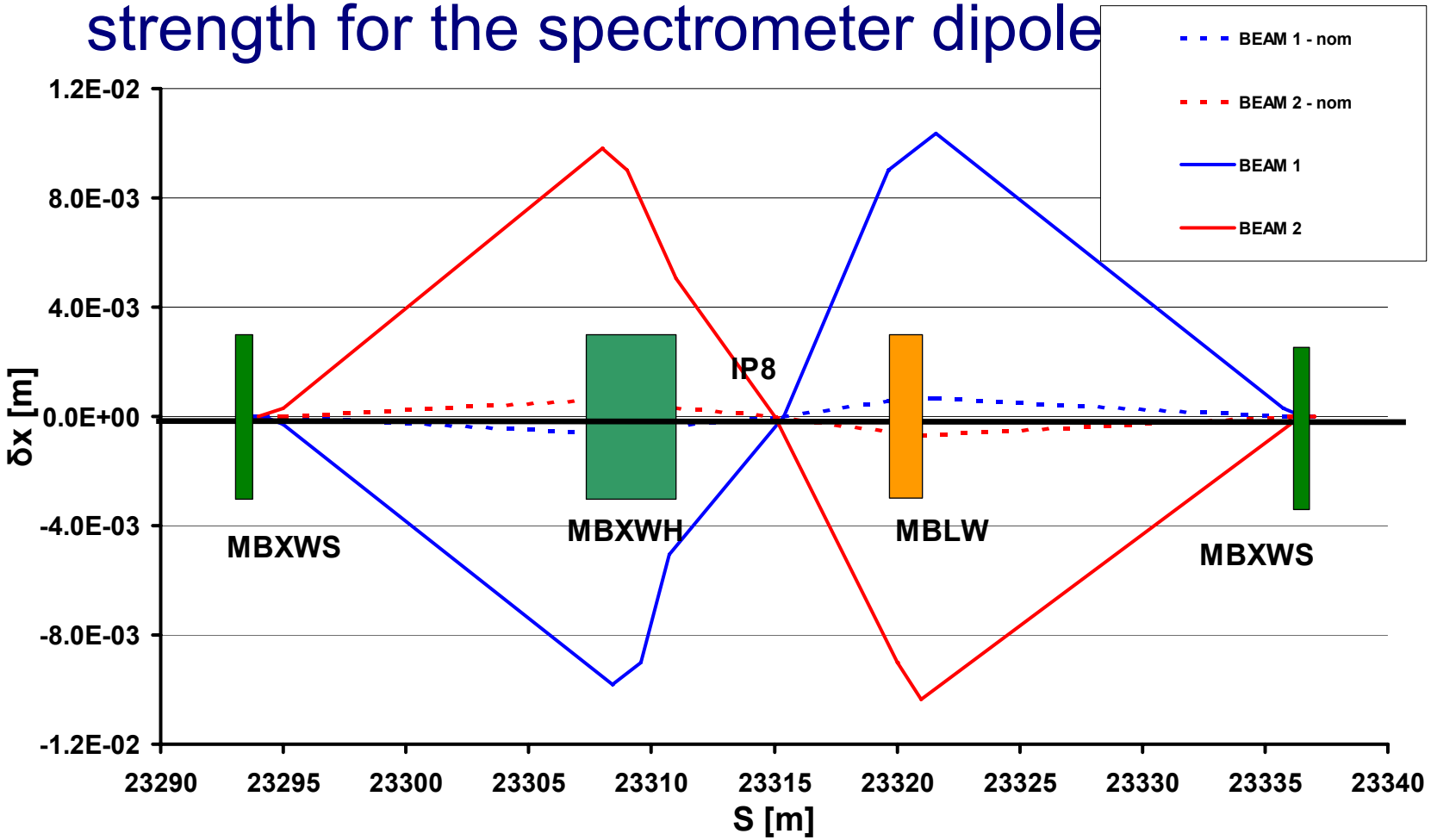
Equipment	n_1 [σ]	n_1 [m]	n_1 [%]
BPMSW.1L8	**20**	**0.014**	**45**
MBXWS.1L8	**16**	**0.010**	**40**
MBXWH.1L8	**34**	**0.012**	**45**
IP8	**56**	**0.016**	**52**
MBLW.1R8	**111**	**0.037**	**58**
MBXWS.1R8	**16**	**0.010**	**40**
BPMSW.1R8	**20**	**0.014**	**45**



- Differences with respect to IP2 on the 2nd compensator (smaller β) and spectrometer (smaller β and aperture)
- Aperture varies for less than 3σ between the scheme with only internal and full crossing scheme
- Around 50-60% of the available aperture is lost for all compensators and 40% for the spectrometer



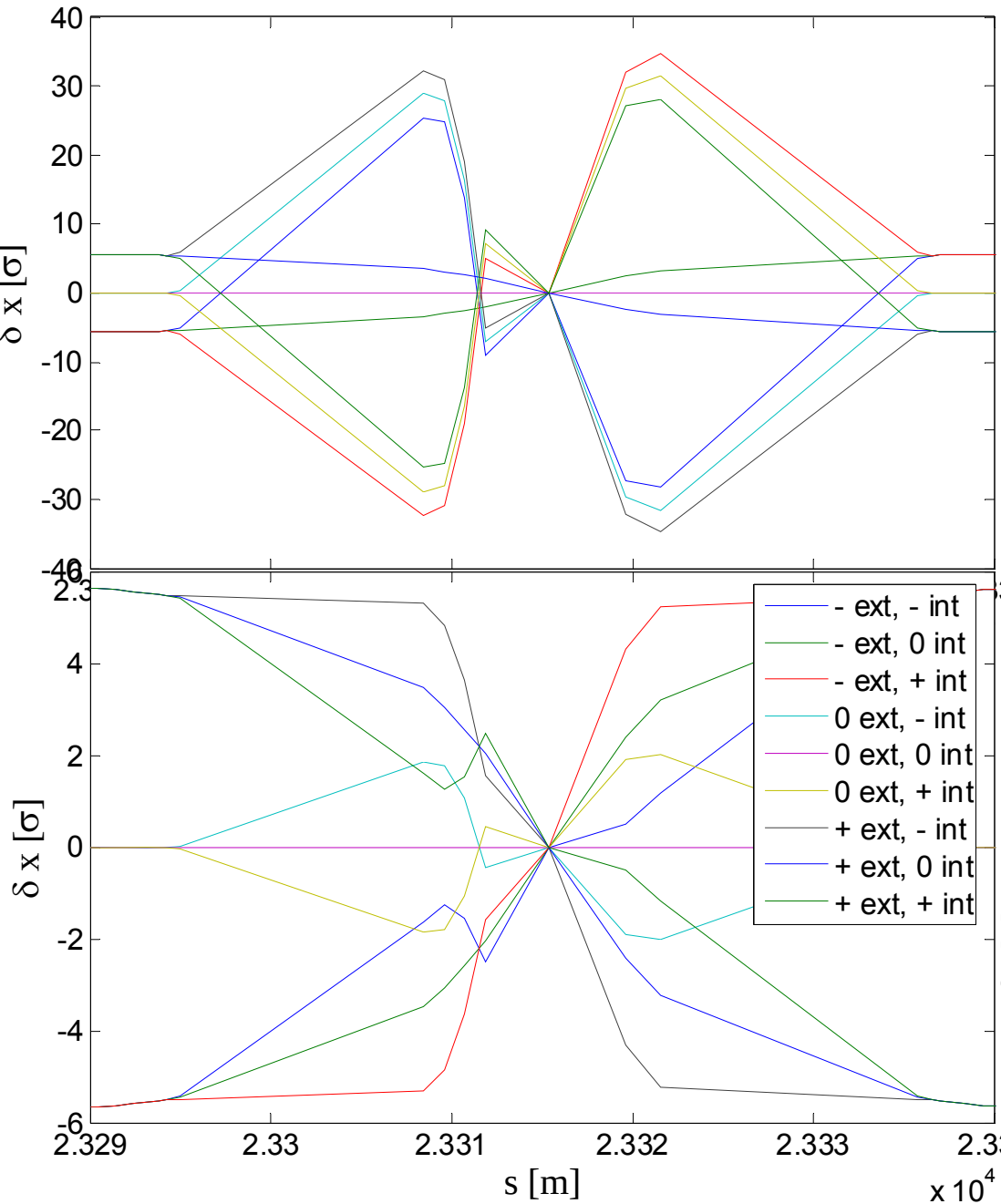
Internal crossing bump of IR8 with collision strength for the spectrometer dipole

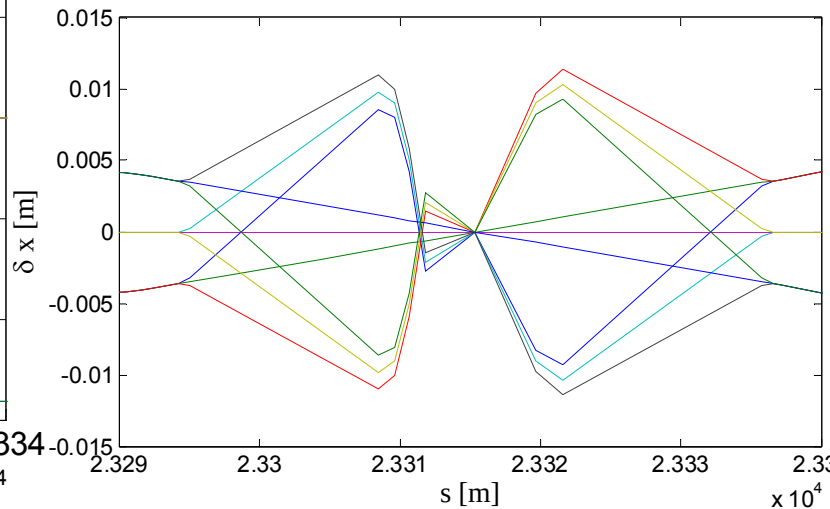


- Internal crossing angle of ±2100μrad in the horizontal plane!
- Deflection of ±0.010m at MBXWH, corresponding to 29σ, as compared to 0.0006m (2σ) of the nominal bump

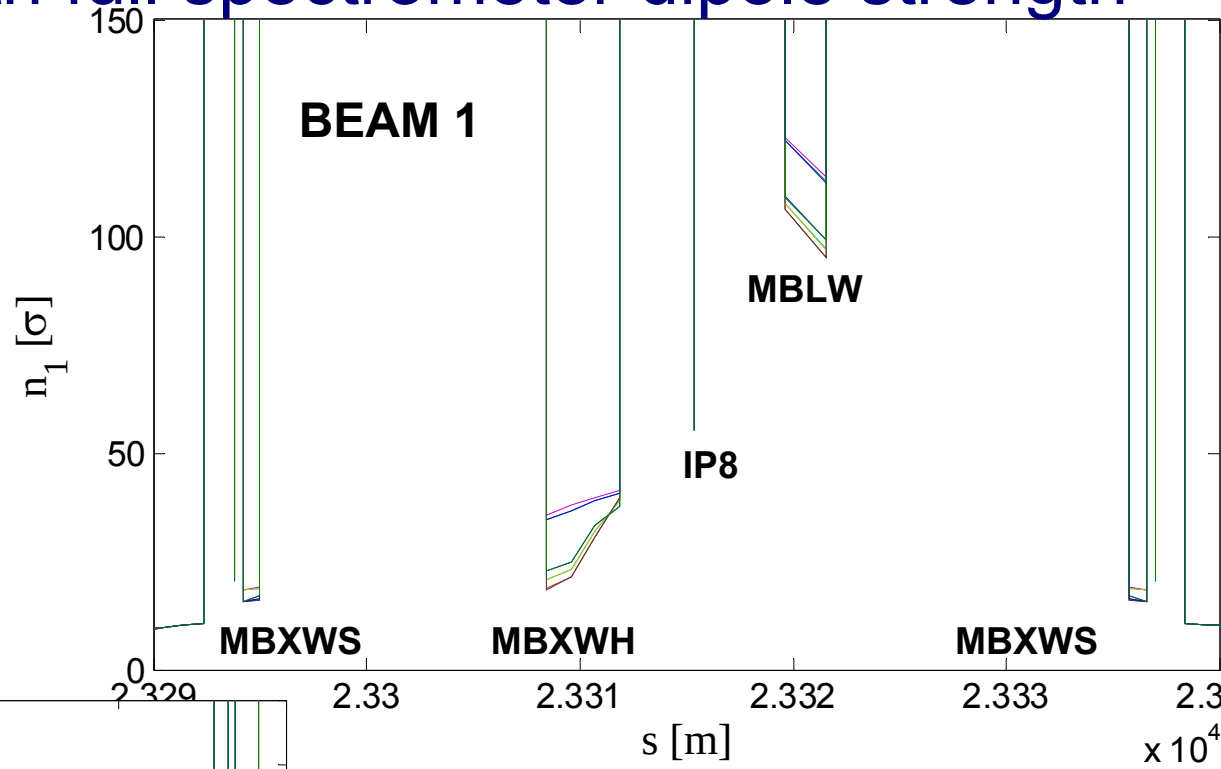
Crossing bump in IR8 at injection with collision strength for the spectrometer dipole

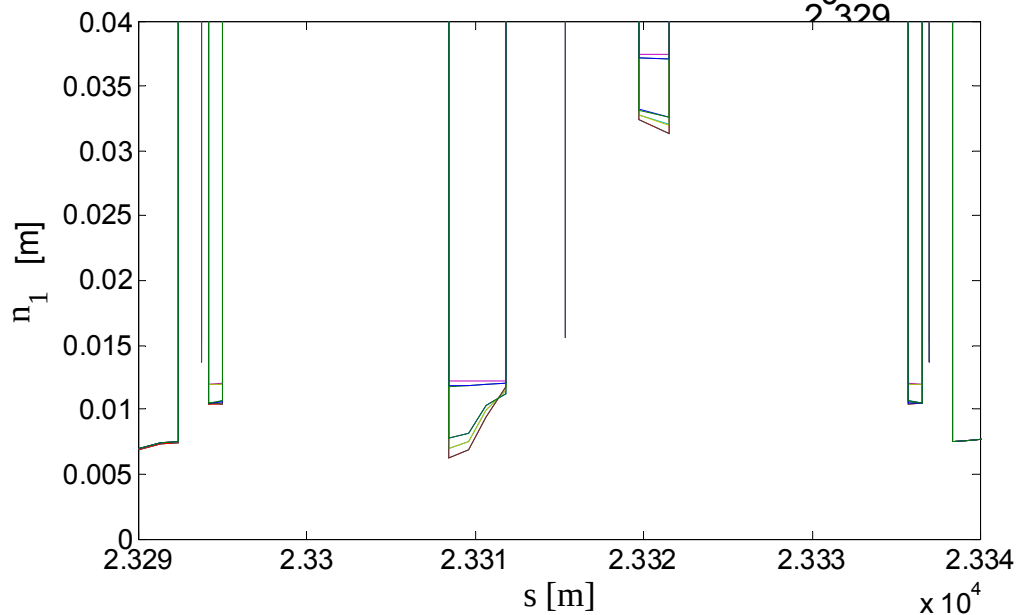
- Beam excursion of 0.011m (33σ) at MBXWH, as compared to 0.0004m (6σ) for the nominal scheme
- When polarity and external crossing angle sign are mismatched, two additional crossings occur ~15m left and right of the IP (in total 4 crossings)





Aperture in IR8 with full spectrometer dipole strength





- Biggest loss in aperture around MBXWH
- n_1 correspond to even smaller values than MBWXS in mm

Aperture loss in IR8 by element

Equipment	n_1 nominal [σ]	n_1 full [σ]	n_1 nominal [m]	n_1 full [m]	n_1 nominal [%]	n_1 full [%]
BPMSW.1L8	20	20	0.014	0.014	45	45
MBXWS.1L8	16	16	0.010	0.010	40	40
MBXWH.1L8	34	19	0.012	0.006	45	24
IP8	56	56	0.016	0.015	52	52
MBLW.1R8	111	95	0.037	0.031	58	50
MBXWS.1R8	16	16	0.010	0.010	40	40
BPMSW.1R8	20	20	0.014	0.014	45	45

- Not important impact in any element apart MBXWH
  - Available aperture of 6mm (with respect to 12mm), corresponding to 15σ of aperture loss
  - Remaining aperture corresponds 24% of the available

Summary

- Main limitations in IR2 and 8 in the aperture of 2nd compensator magnets
  - MBWMD in IR2
    - Available aperture of 9mm (with respect to 14mm), corresponding to 13σ of aperture loss
  - MBXWH in IR8
    - Available aperture of 6mm (with respect to 12mm), corresponding to 15σ of aperture loss
- In both cases, n1 above 7σ, but available aperture quite small, especially in IR8
- Any decision should be based on the ability to control the orbit and optics within the tolerances given for computing the available aperture