LHCb crossing scheme for Run II & III

S. Fartoukh BE/ABP

Acknowledgements: M. Lamont, R. Lindner, B. Schmidt, R. Versteegen

→ **Description of the problem and boundary conditions**

→ **Complete solutions for**

- **Injection**
- **Ramp**
- **Flat top or end of squeeze**

→ **Conclusions (... please do NOT rotate the IT beam-screen in IR8)**

The problem

→ In a scenario where **the LHCb spectrometer is not ramped** (i.e. full strength from 450 GeV to 6.5 TeV), establish functions for the **external crossing scheme** which

0) With an external crossing angle always <0 for beam1 (for the H plane only to avoid head-on collisions in D1).

1) Does **not depend on the polarity of the LHCb spectrometer**

2) Fulfills the **aperture requirements at injection** (triplet and beam pipe)

3) Warrants **enough beam-beam separation** (≥ 10 σ), for **ANY** bunch spacing, e.g. 25 ns (20+5 ns,..) or in the presence of moving LR encounters (P-Pb run, RF cogging)

→ Assumption and method

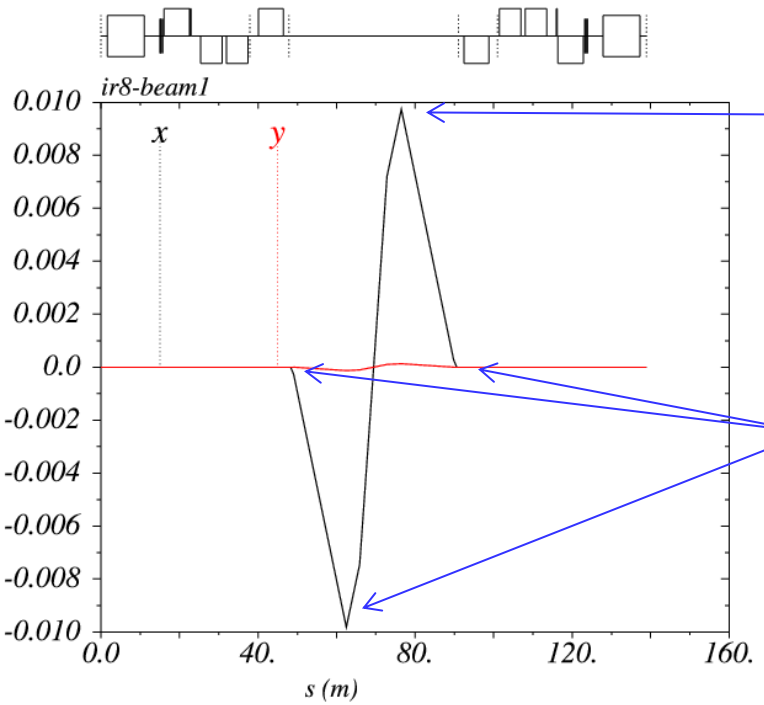
1) **Nominal beam emittances** (3.75 μrad)

2) Aperture evaluated with the **conservative n1 approach** with design tolerances (20% β-beat, 4 mm closed orbit budget), i.e. a "raw aperture" of about 13 σ for n1=7 in the IT, and up to 30 σ for n1=10 in the experimental beam pipe.

The 2012 running scenario and immediate conclusions for 450 GeV

- LHCb spectro full strength and both polarities:

→ **+/- 2.1 mrad at the IP at 450 GeV, leading to +/- 10 mm H orbit excursion at +/ 5m from the IP !**



Spectrometer (+/- 2.8 mrad)
in the H plane (with very slight roll angle)

3 compensator magnets
+/- 0.7 mrad
-/+ 2.8 mrad
-/+ 0.7 mrad

→ Any HORIZONTAL parallel separation, typically of a few mm, will systematically vanish at 450 GeV on one side at a few meters from the IP, where any hypothetical VERTICAL external crossing angle, typically of 150-200 μrad would be too small to generate enough bb separation at 450 GeV (... not mentioning IT aperture for vertical crossing)

→ **The parallel separation can only be vertical at injection, as nominal**

→ **The external crossing angle can only be horizontal at injection, as nominal**

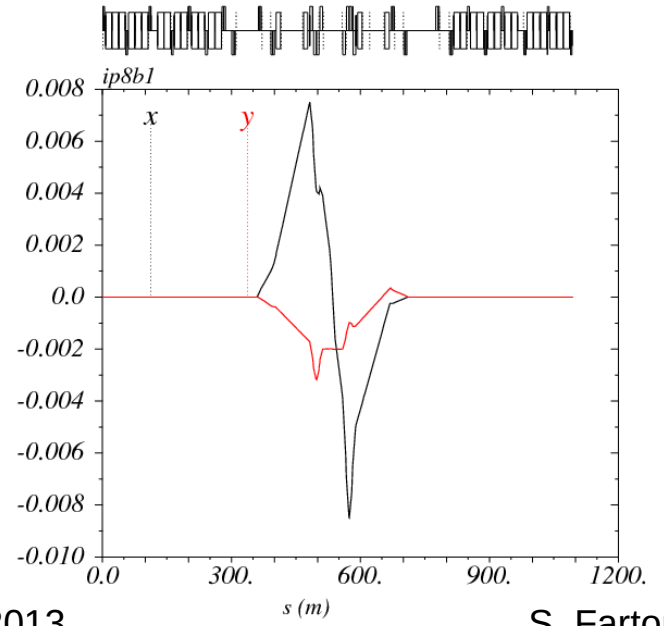
Please do NOT rotate the IT beam-screen in IR8 !

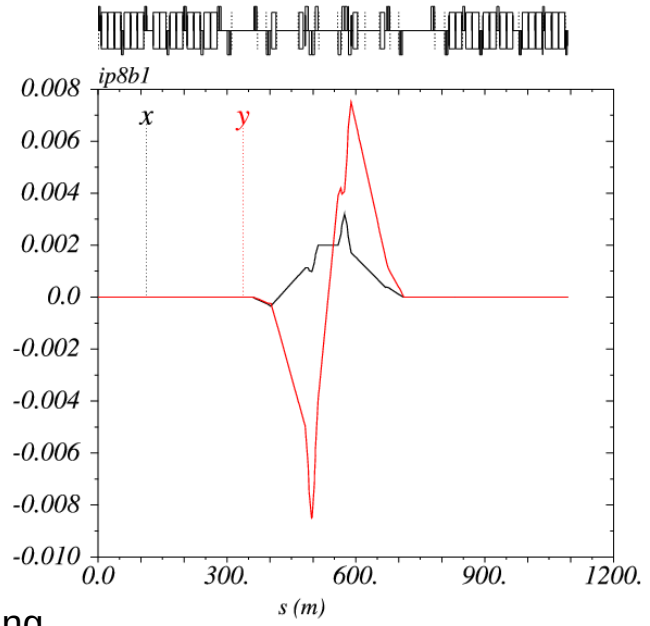
→ A few illustrations with **"bad" (>0) spectrometer polarity**

a) **Case 1**: **Nominal** with H external crossing (-170 μrad for beam1), and V parallel separation (-2 mm for beam1)

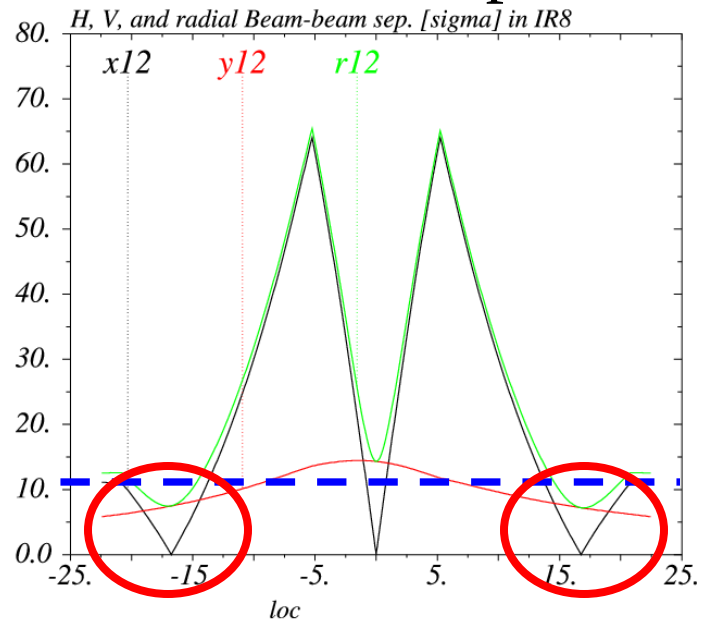
b) **Case 2: Just to try** with V external crossing (170 μrad for beam1), and H parallel separation (+2 mm for beam1)

External crossing bumps for Cases 1 and 2 (spectrometer switched off for clarity of the plots)

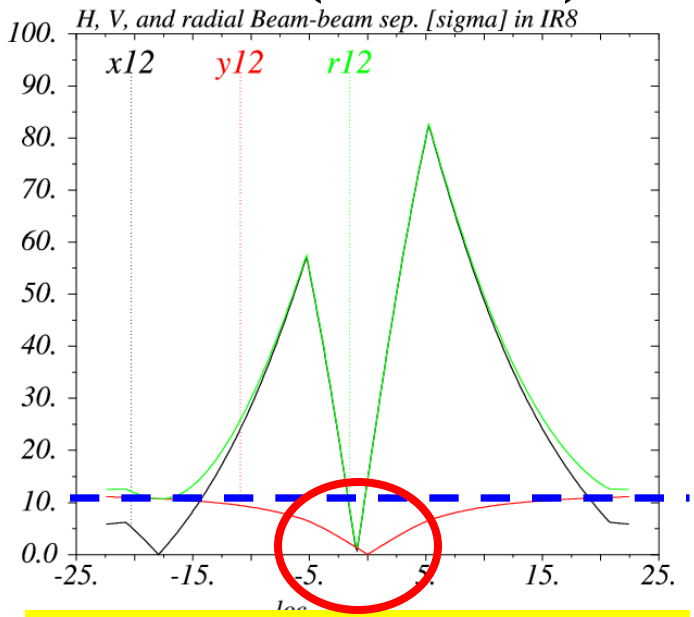




H, V and radial bb sep [σ] at 450 GeV till Q1 (+/-23 m)



Case 1: V||, H-X,"bad" polarity



Case 2: H||, V-X, "bad" polarity
... similar for "good" polarity

→ **Already not that bad !**

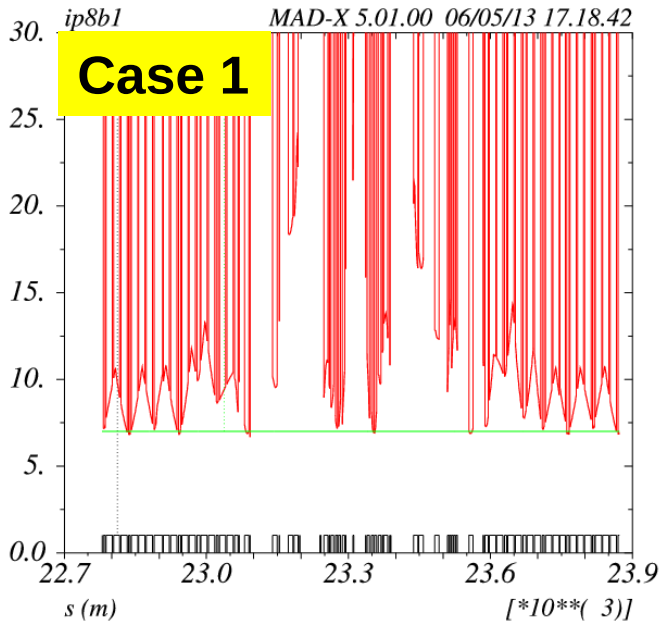
... with only a short zone at about 7.5 σ (for worst polarity only)

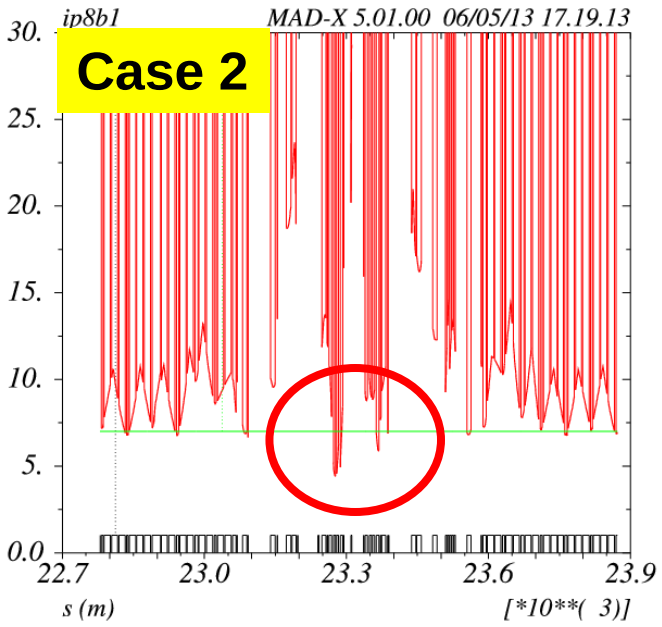
→ **Does NOT work for P-Pb** (head-on expected with moving LR encounters).

→ **Still not easy for 25 ns proton run**: the min. will drift during the ramp and coincide with the first 25ns LR at ~1.6 TeV with ~7.5 σ bb separation at cst V external X-angle .... so gymnastic needed anyway

...Why not simply increasing the V parallel separation?

Quick inspection (anyway) of the IT aperture

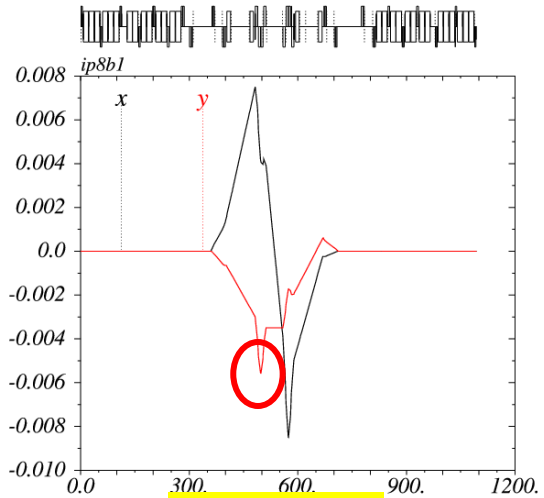


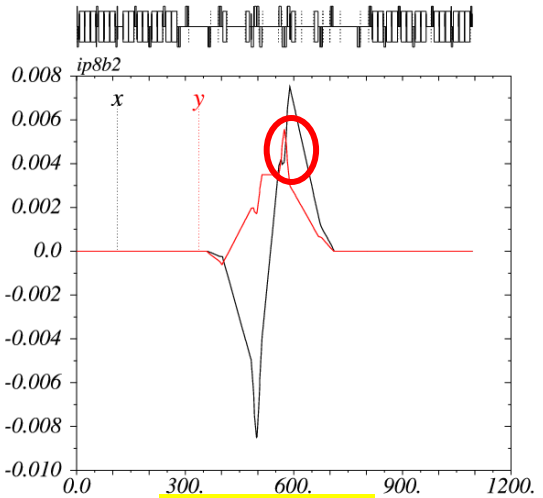


... I would not risk

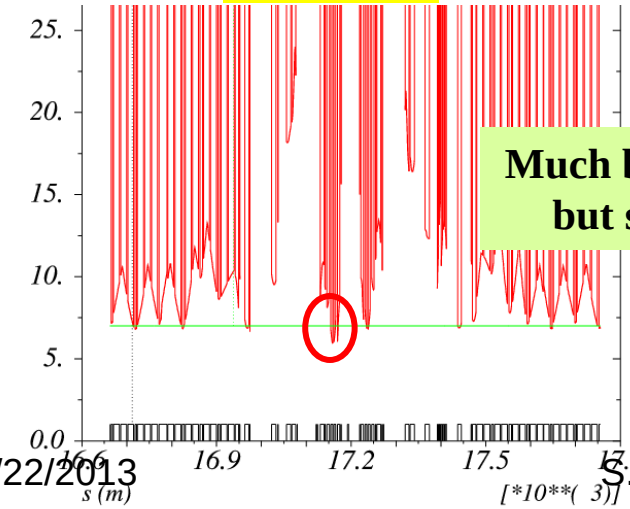
Solution at Injection (1/4)

- **Step 1:** Increase the **V parallel sep. from +/- 2 mm to +/- 3.5 mm**

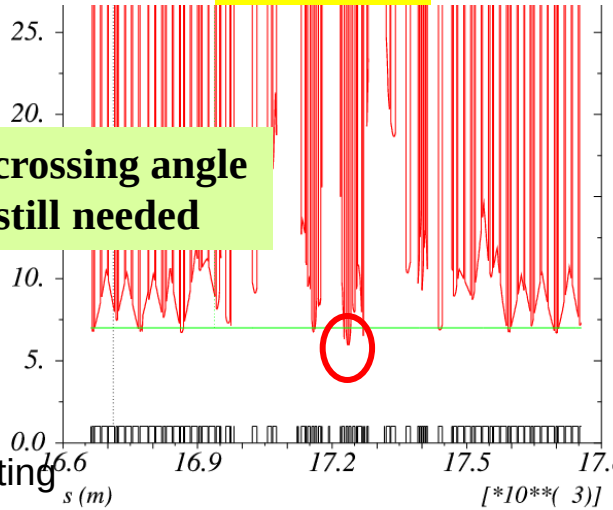




Beam1



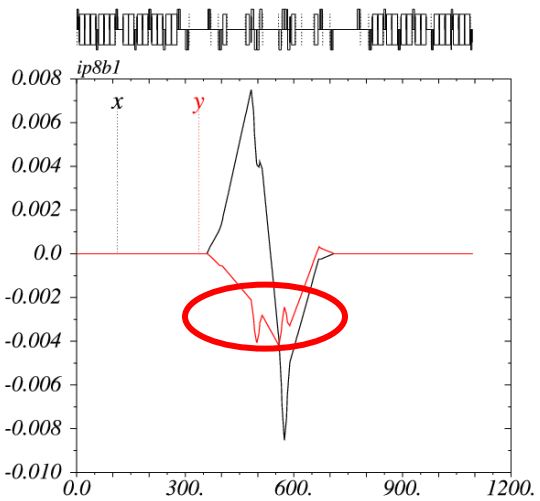
Beam2

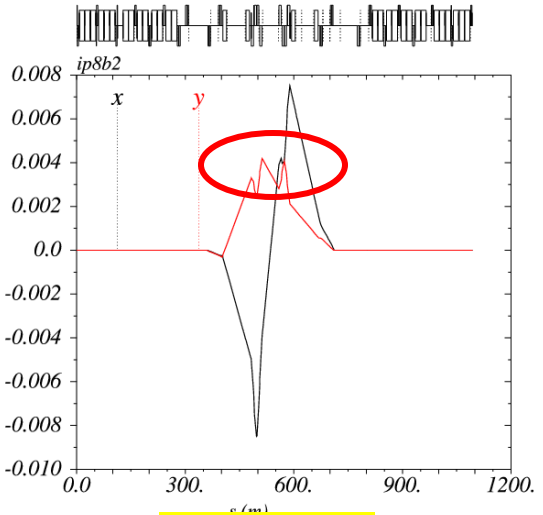


Much better than with V crossing angle but some optimization still needed

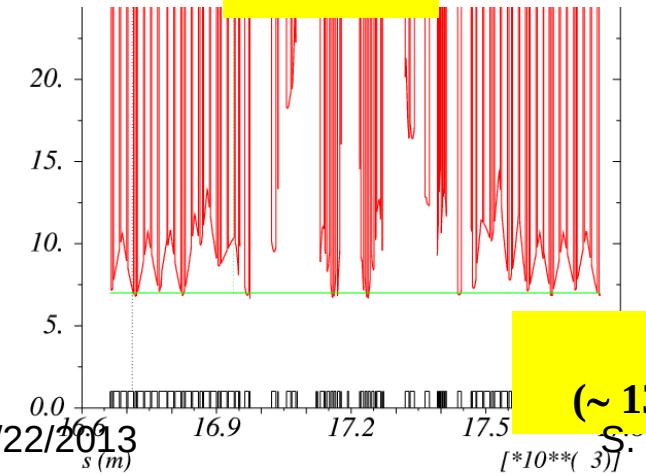
Solution at injection (2/4)

- **Step 2:** Add a **small V crossing angle (-30 µrad)**, **with same sign for both beams** (no impact on the bb sep.) to recover the full IT aperture

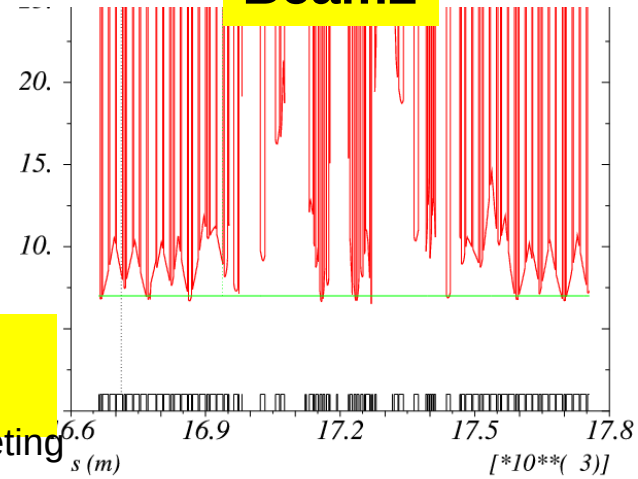




Beam1



Beam2

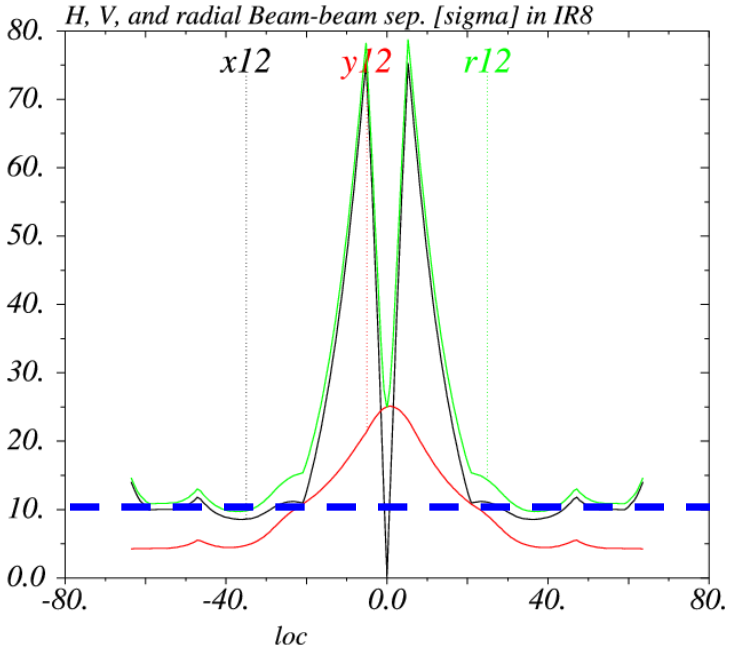


n1~ 6.5 !
(~ 13 σ raw aperture)

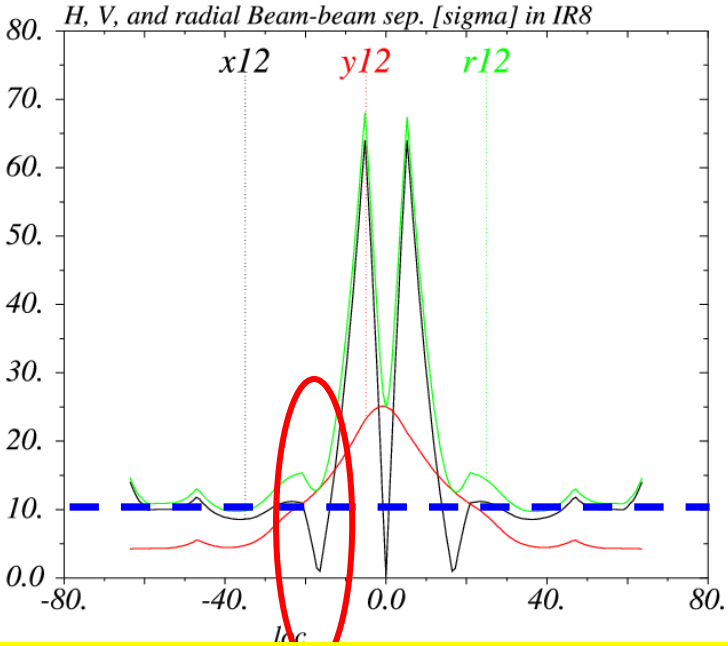
Solution at injection (3/4)

→ A radial 10 σ beam-beam sep. can be preserved for both polarities of the spectrometer, nominal emittance and any bunch spacing (in particular moving LRs with P-Pb at 450 GeV) GeV)

Negative ("good") polarity



Positive ("bad") polarity



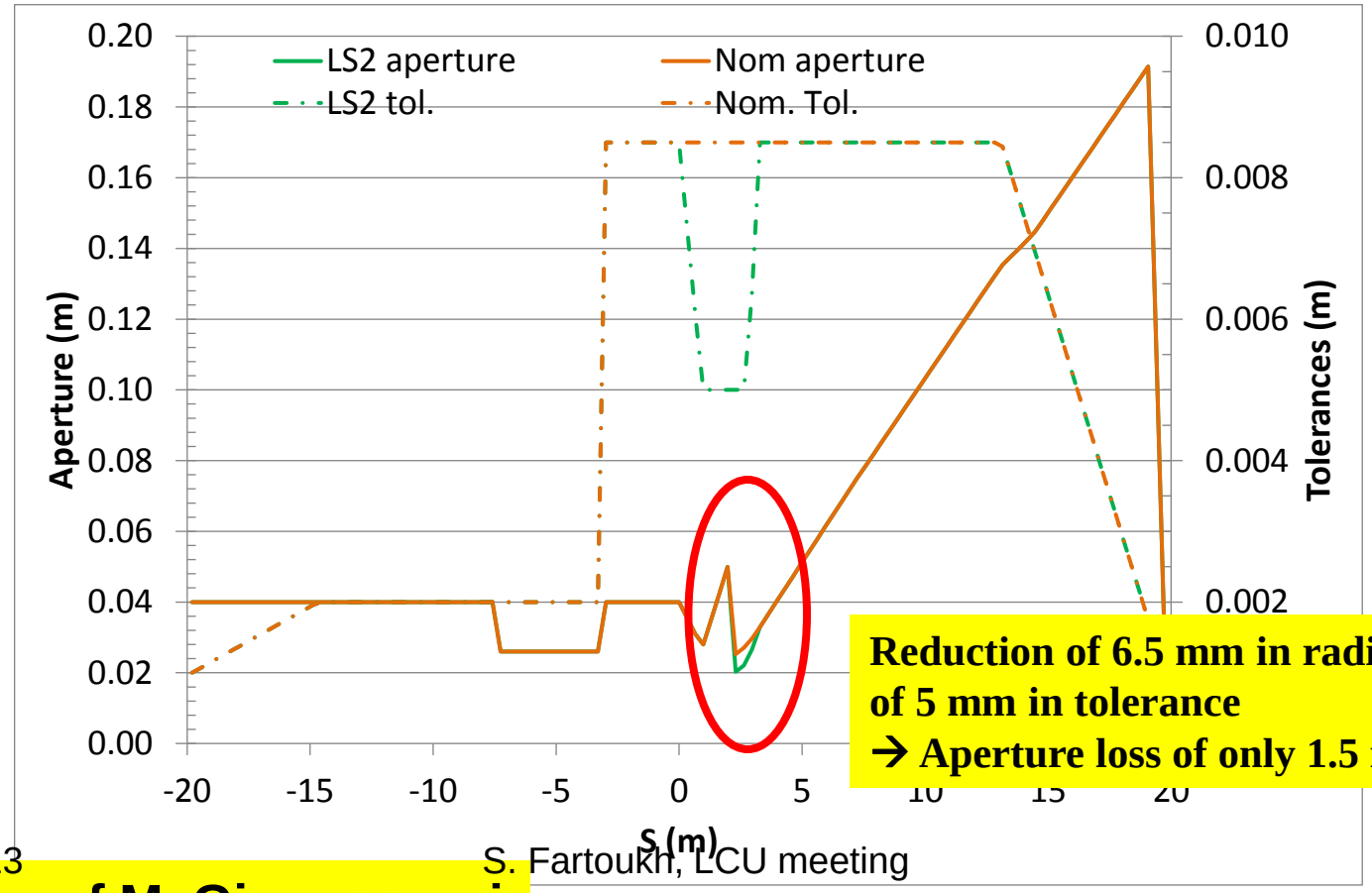
The min. of course still exists but "safe" thanks to the parallel separation.

Solution at injection (4/4)

→ Experimental beam pipe aperture looks also very OK !

1) n1=13.7 for the existing beam pipe (~37 σ raw aperture)

2) n1=10.3 for the postLS2 beam pipe (~ 31 σ raw aperture)



Reduction of 6.5 mm in radius but gain of 5 mm in tolerance
→ Aperture loss of only 1.5 mm after LS2

Courtesy of M. Giovannozzi

Solution for the ramp

→ Very similar to 2012 since most of the bb sep. in the zone of the spectrometer bump is provided by the parallel sep.

- external (H) crossing angle linearly increased up to 250 μrad

→ MCBX/Y/C strength checked and found OK up to 7 TeV

→ Aperture checked and found OK (n1~10 at β^*=3 m)

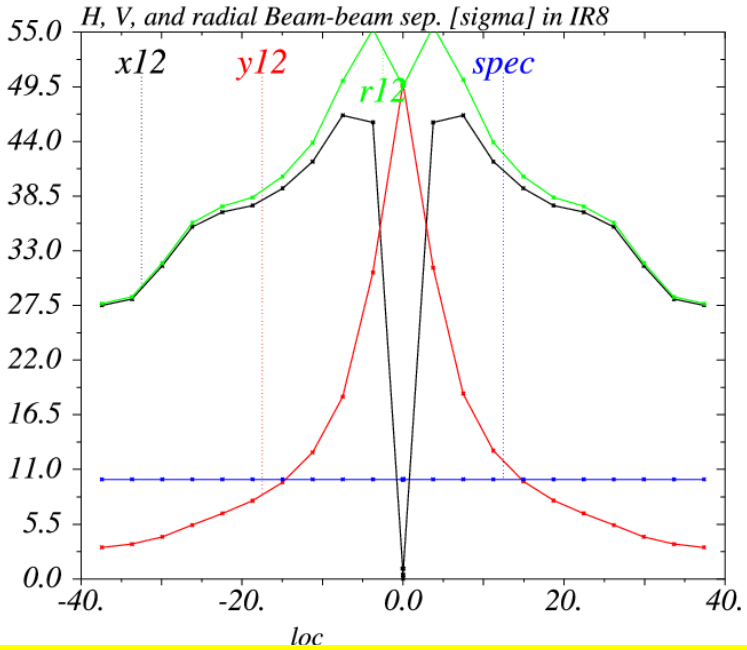
- Parallel sep (V) reduced linearly with time down to +/- 1 mm
- Small (V) tilt angle (for IT aperture) linearly switched off

IP8 parameters for beam1/2 (external bump only)	New 450 GeV setting (2012 settings)	End of Ramp @ 6.5 TeV (2012 settings)
x* [mm]	0/0 (0/0)	0/0 (0/0)
px* [μrad]	-170/+170 (-170/+170)	-250/+250 (-220/+220)
y* [mm]	**-3.5/+3.5** (-2.0/+2.0)	-1.0/+1.0 (-0.65/+0.65)
py* [μrad]	-30/-30 (0/0)	0/0 (0/0)

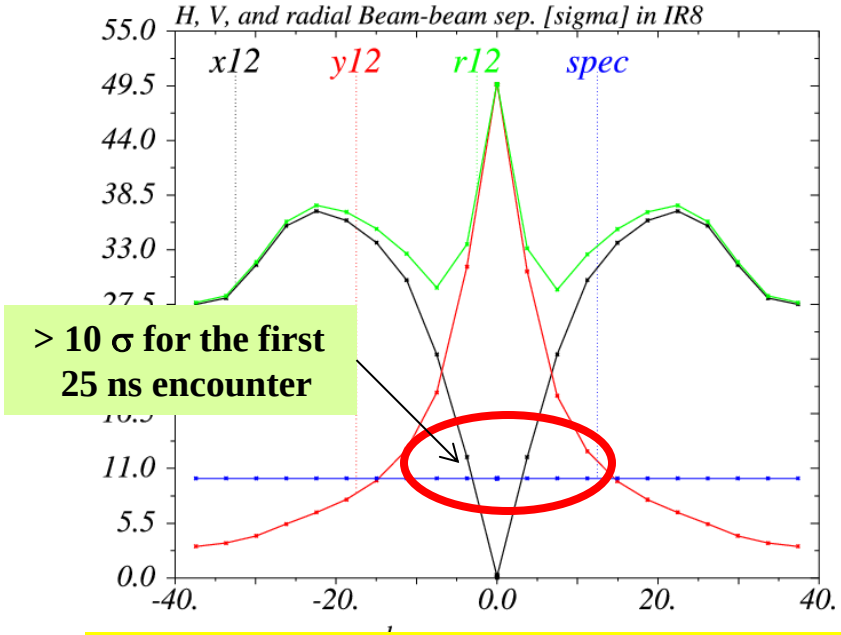
Gymnastic at 6.5 TeV for V external crossing

→ Could be similar to 2012 (see R. Alemany et al. IPAC13)

→ But is it really needed even down to β^*=3 m at IP8:



"Good" polarity
+/- 395 μrad internal half X-angle



> 10 σ for the first 25 ns encounter

"Bad" polarity
+/- 105 μrad internal half X-angle
but still very comfortable !

Conclusions

→ **It is (already almost) working, do not fix it** with a V external crossing at injection, which does not work for P-Pb runs, and only displaces the complexity and the risk from flat top to injection and ramp.

→ **Just a little bit more V parallel separation would do the job at injection, with some external bump sophistication.**

→ ...and (maybe) a reiteration of the 2012 IR8 gymnastic at flat top, should an asymmetry by ~290 μrad (@6.5 TeV) be a problem for LHCb data taking when changing the polarity of the spectrometer.

→ In ALL cases, rotating the IT beam-screen in IR8 could only made things worst, if not unmanageable.