

# *Spectrometer Operation in IP2 & 8*

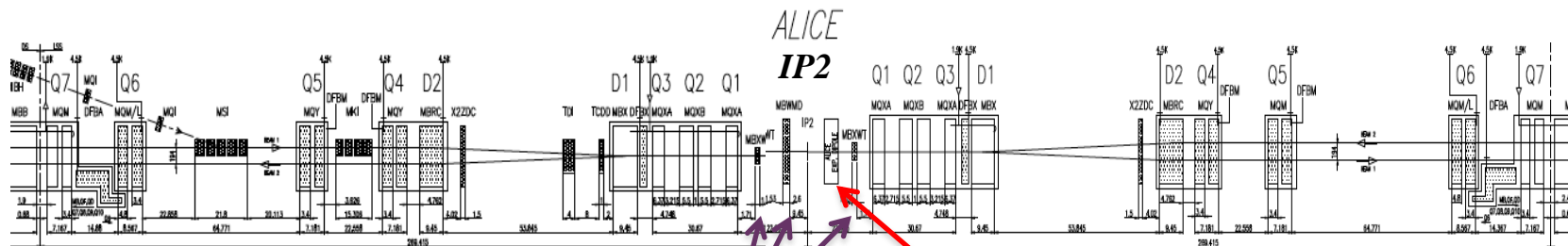
*Bernhard Holzer*



*with a lot of help from Reine Versteegen, John Jowett,  
Richard Jacobson, Burkhard Schmidt, Gilda Scioli, Werner Herr  
CERN-LHC*

# ALICE

## The Straight Forward One



*compensators*

*Spectrometer Dipoles*

*The ALICE Spectrometer Dipole and Compensators form a tiny little crossing angle bump in the vertical plane ... at constant field.*

\* *vert. crossing angle at 450 GeV:*  $y' = \pm 1089 \mu\text{rad}$

\* " " *at 4 TeV:*  $y' = \pm 122.5 \mu\text{rad}$







# ALICE spectrometer & ext. bumps

**Collision, 4000 GeV:**

*beam separation at IP2 collapsed,*

*beam separation at parasitic encounters via vert. crossing angle bump,*

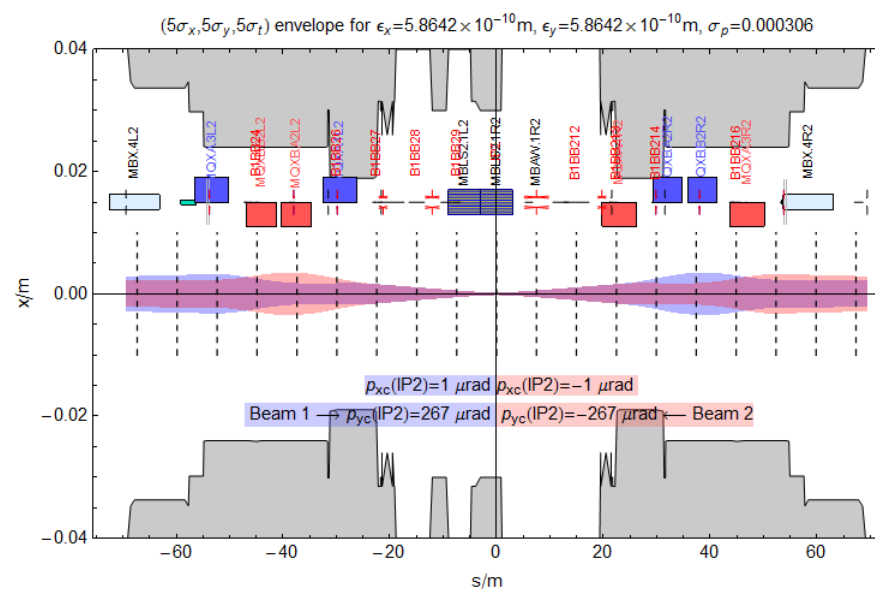
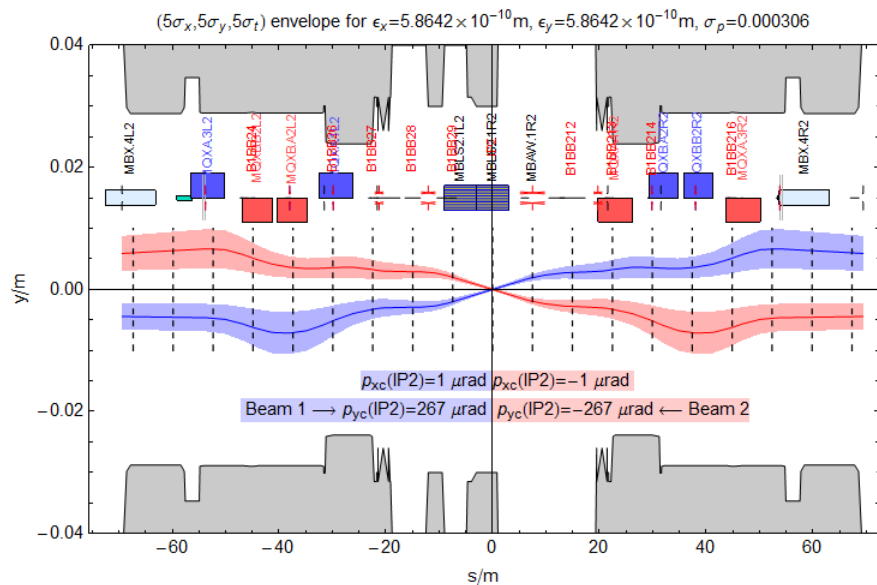
*Crossing angle due to the spectrometer scales down as  $1/E$*

\* spectrometer dipole: vert. crossing angle at :  $y' = \pm 122.5 \mu\text{rad}$

\* external vert. crossing angle bump:  $y' = \pm 145 \mu\text{rad}$

**IR2, p-p physics in 2012 -  $\gamma\epsilon_p = 2.5 \mu\text{mrad}$**

**Physics -  $\beta^* = 3 \text{ m}$ ,  $\theta_y = 145 + 122.5 \mu\text{rad}$**



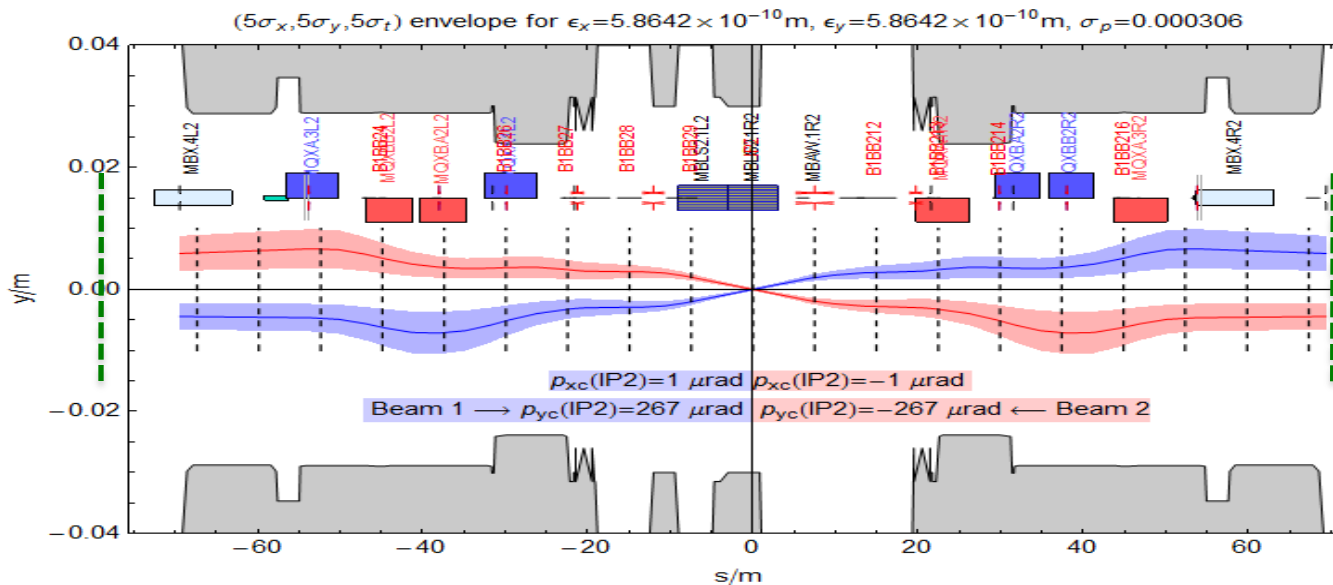
# ALICE Polarity Change p-p

“Wish List”: change polarity **once** per collision mode  
p-p, p-Pb, Pb-p

Overall beam geometry is not affected: mirror symmetric situation

however: TCT re-alignment required, a bit time consuming

Physics –  $\beta^* = 3\text{ m}$ ,  $\theta_y = 145 + 122.5\ \mu\text{rad}$

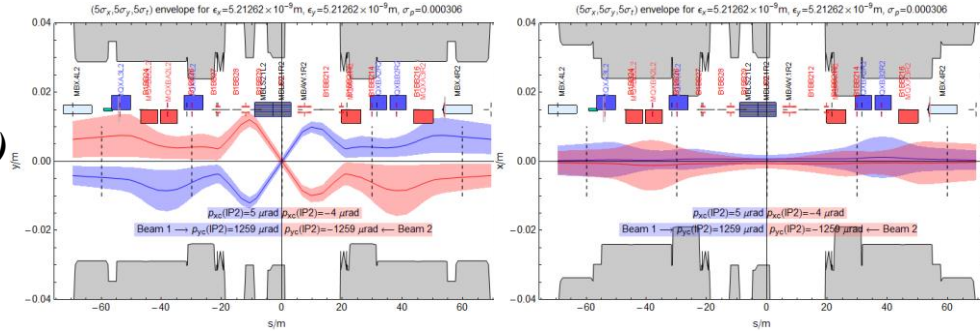


TCTs

# ALICE $p$ -Pb collisions

**Injection: unchanged,**

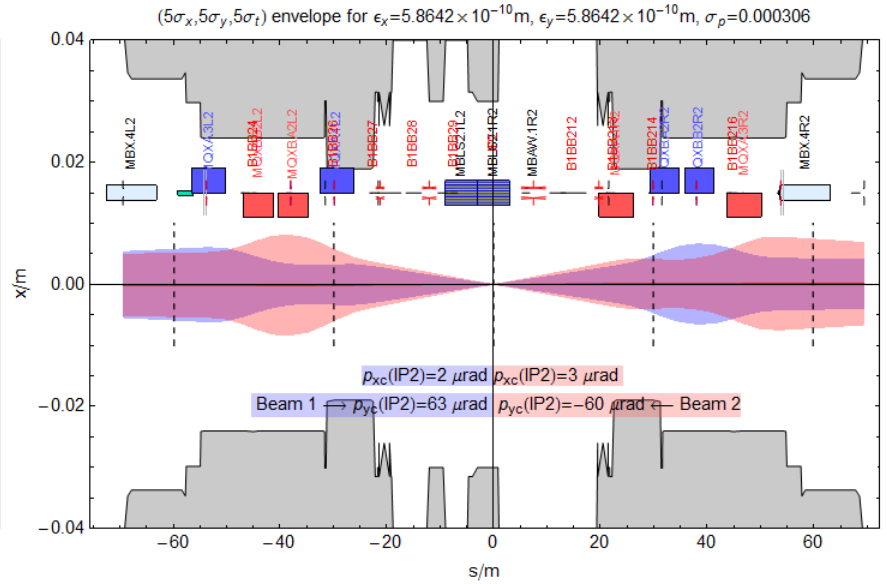
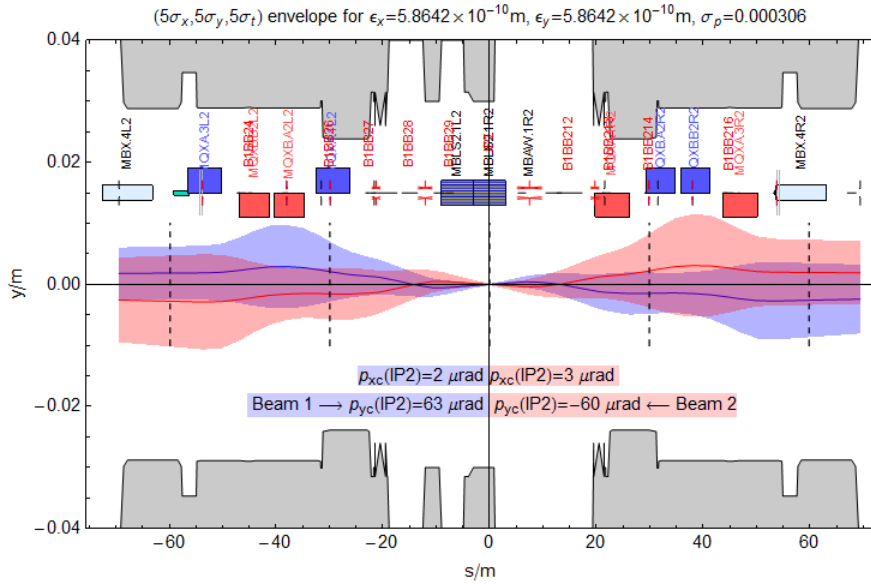
- \* spectrometer crossing angle  $y' = \pm 1089 \mu\text{rad}$
- \* external crossing angle:  $y' = \pm 170 \mu\text{rad}$  (const. !)
- \* external hor. separation bump:  $\Delta x = \pm 2 \text{mm}$



**Collision: minimise the net crossing angle,  
external crossing angle bump counteracts the spectrometer**

IR2, p-Pb physics in 2013 -  $\gamma\epsilon_p = 2.5 \mu\text{m}\cdot\text{rad}$ ,  $\gamma\epsilon_{\text{Pb}} = 1.5 \mu\text{m}\cdot\text{rad}$

**Physics** -  $\beta^* = 0.8 \text{ m}$ ,  $\theta_y = -62.5 + 122.5 \mu\text{rad}$

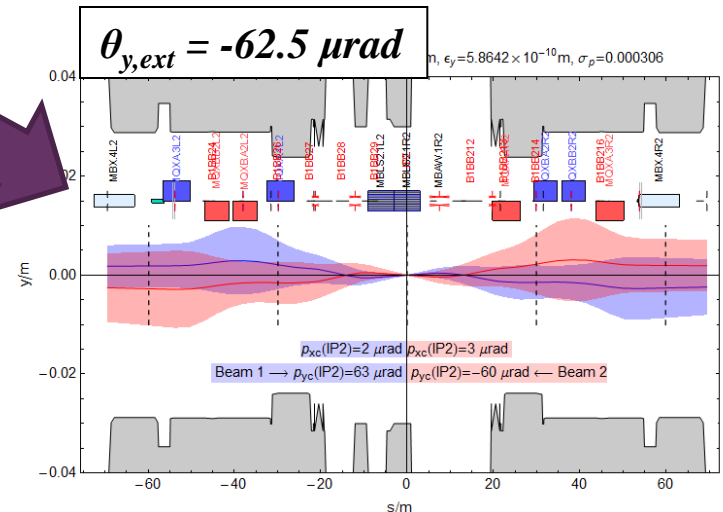
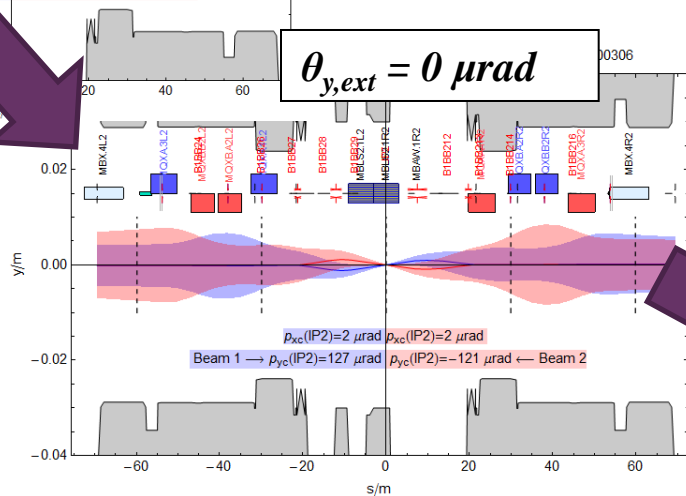
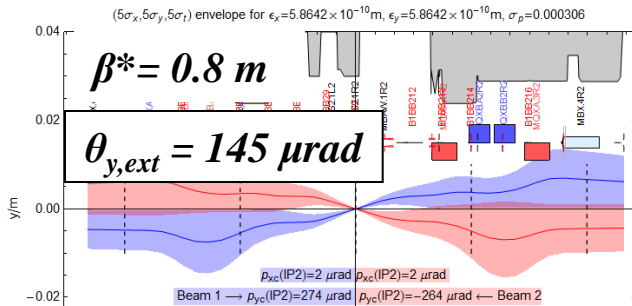


# ALICE Polarity Change p-Pb

CERN-ATS-Note-2012-039 MD

avoid TCT re-alignment at injection & on the ramp (a bit time consuming)

IR2, p-Pb physics in 2013 - going into physics



- At the end of the squeeze,  $\theta_{y,tot} = 145 \pm 122.5 \mu\text{rad}$ .
  - Depending on the spectrometer polarity,  $\theta_{y,ext}$  is changed from  $+145 \mu\text{rad}$  to  $\pm 62.5 \mu\text{rad}$ , to get  $\theta_{y,tot} = \pm 60 \mu\text{rad}$ .
- $\rightarrow$  positive polarity implies going through zero external angle, leading to about **1 $\sigma$  separation** at the 200ns first two encounters (in the horizontal plane).

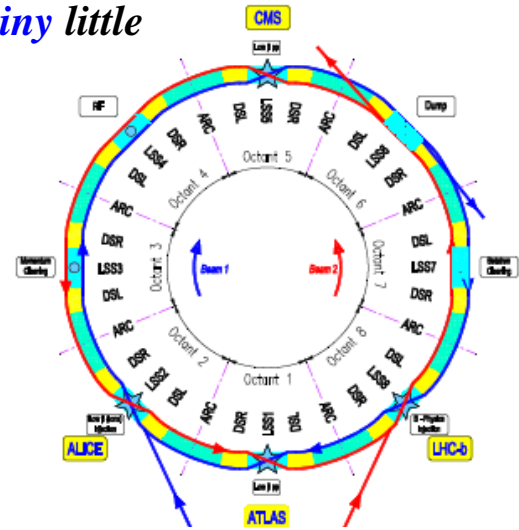
# LHCb: The Challenge

## IP8: “natural LHC geometry” and the LHCb spectrometer effect

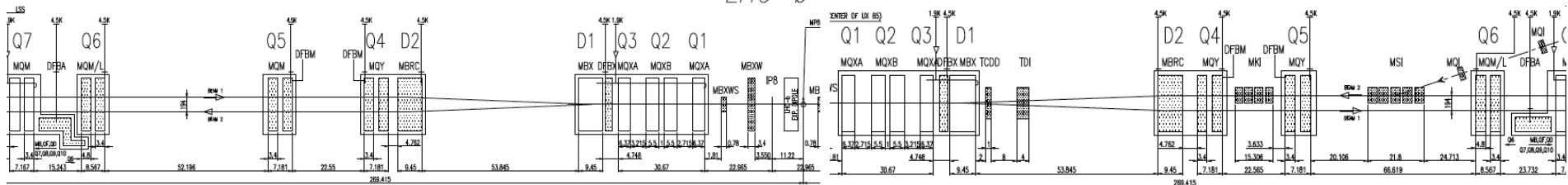
**Design Orbit:** *Beam 1 crosses at IP8 from ring outside to inside*  
 -> *negative horizontal angle provided by D1 & D2.*

*The LHCb Spectrometer Dipole and Compensators form a not really tiny little crossing angle bump in the horizontal plane ... at constant field.*

- \* *hor. crossing angle at 450 GeV:  $x' = +/- 2.1 \text{ mrad}$*
- \* *“ at 4 TeV:  $x' = +/- 235 \mu\text{rad}$*
- \* *depending on the dipole polarity*



LHC-b





# LHC Lattice Layout in IP8

## Situation at Luminosity:

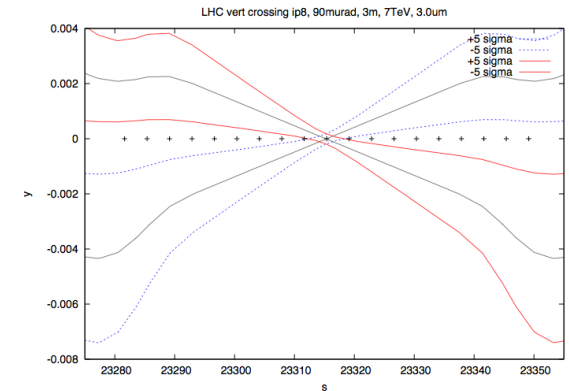
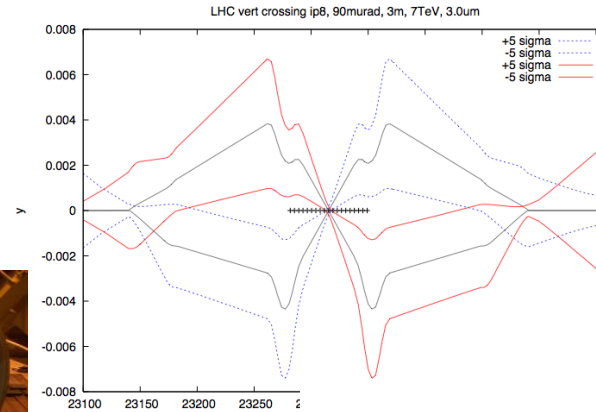
$E=7\text{ TeV}$ ,  $\varepsilon=3.0\mu\text{rad}$

LHCb angle =  $x'_{int} = \pm 135\mu\text{rad}$ , compensated

external hor. crossing angle = 0

parasitic encounters are avoided by

**vertical external crossing of  $y'=90\mu\text{rad}$**



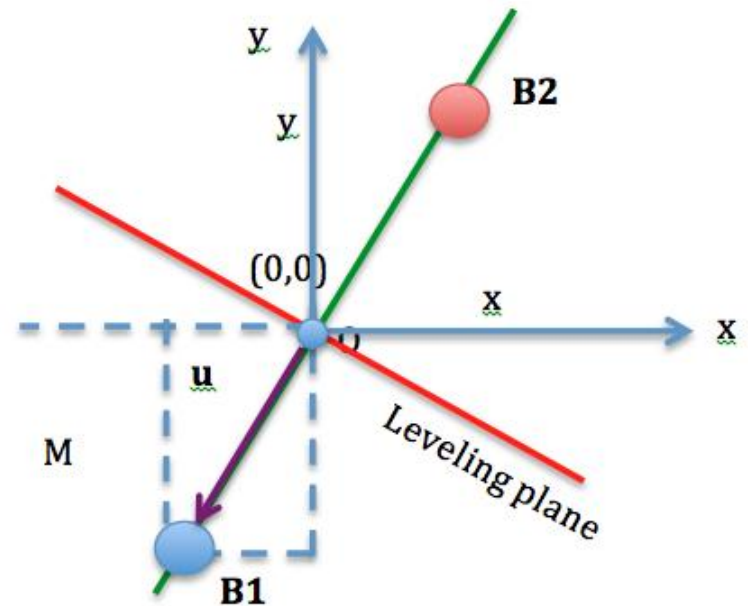
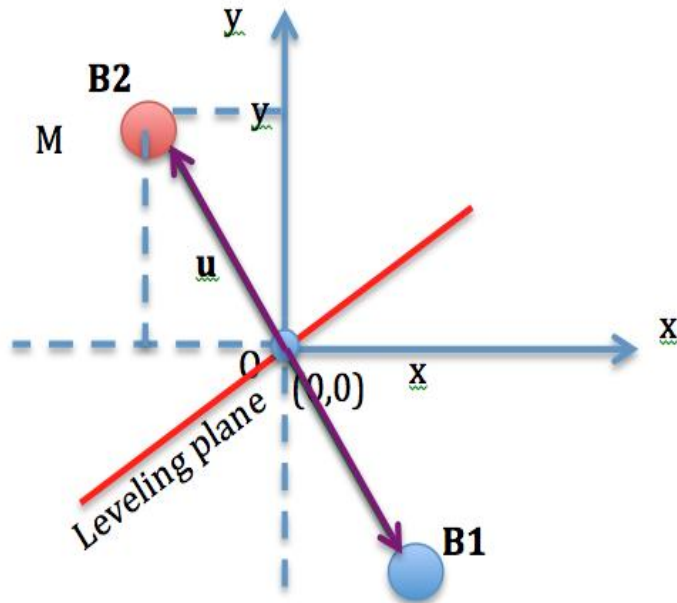
$\pm 5\sigma$  beam envelope at IP8, in collision mode  
crosses mark the 25ns encounters

# LHC Lattice Layout in IP8

*Situation at Luminosity: combination of hor. & vert. crossing angles*

*Present Situation at collisions ... The diagonal leveling scheme*

- *Eliminate the External H crossing angle*
- *Introduce an External V crossing angle that combines with LHCb spectrometer to the “diagonal leveling plane”*



# Situation in IR8 at Injection:

Situation at Injection:

$E=450\text{ TeV}$ ,  $\varepsilon=3.0\mu\text{mrad}$ ,

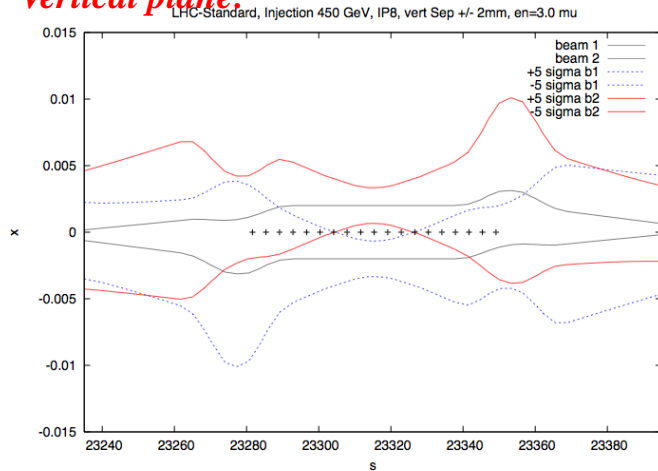
**LHCb Effect: “internal” horizontal crossing angle  $= x' = \pm 2.1\text{ mrad}$**

**“external” hor. crossing angle to avoid parasitic encounters  $x' = -170\mu\text{ rad const.}$**

vertical separation bump  $\Delta y = 2\text{ mm}$

*This combination has to avoid encounters at any position.*

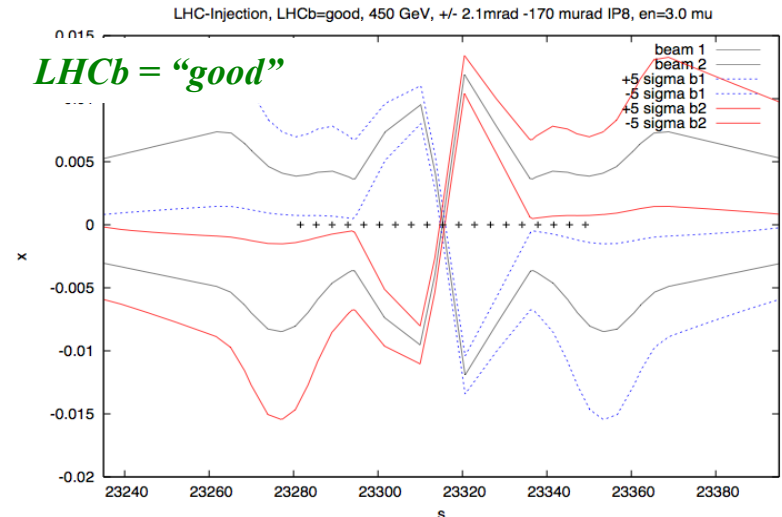
## Vertical plane:



+/-  $5\sigma$  beam envelope at IP8, injection, crosses mark the 25ns encounters

Beams are separated at IP and the first encounters #1 ... #4 due to vert. separation.

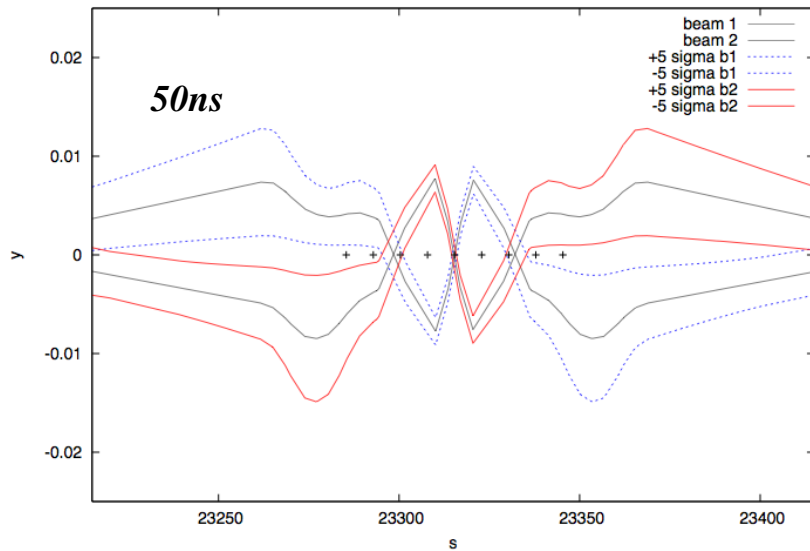
From encounter #5 on the horizontal crossing bump has to do the job.



# Situation in IR8 at Injection:

## Horizontal plane: LHCb = BAD

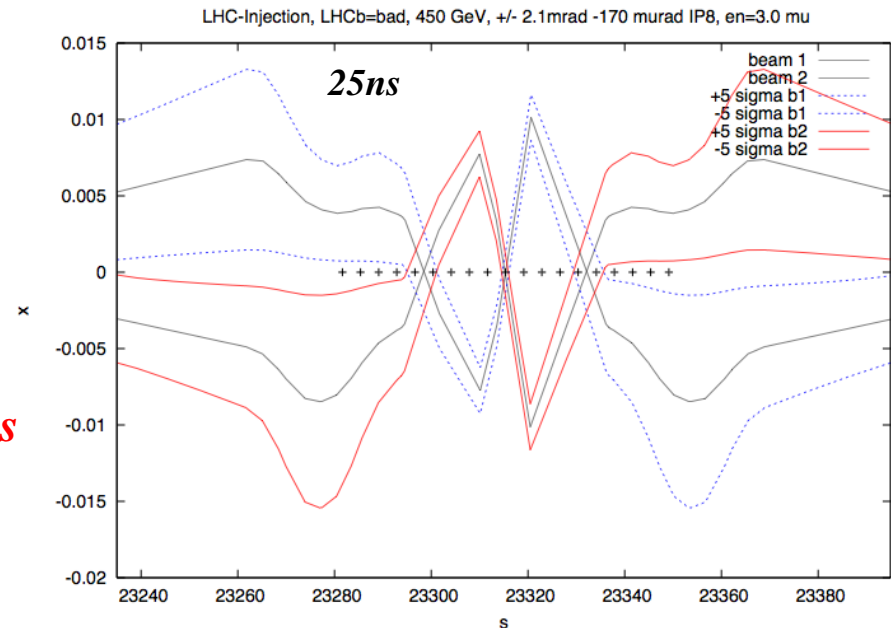
*beam 1 is deflected towards outer side of LHC,  
the compensators are bending back the orbit -> cross over !! and the external bump is  
used to deliver after the compensators sufficient separation at the parasitic encounters.*



+/- 5 $\sigma$  beam envelope at IP8

Beams are crossing over between two 50ns encounters  
 $x' = +2.1\text{ mrad} - 170\mu\text{rad} = +1.93\text{ mrad}$   
cross over between two 50ns encounters.

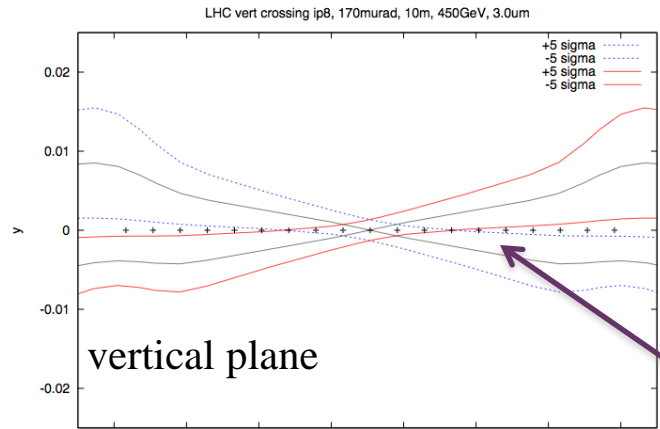
*... for 25 ns bunch spacing parasitic collisions  
are unavoidable !!*





# Swapping the Planes ... ?

*The horizontal crossing angle bump always will have to fight against the bad LHCb polarity. A vertical crossing angle bump does not !*



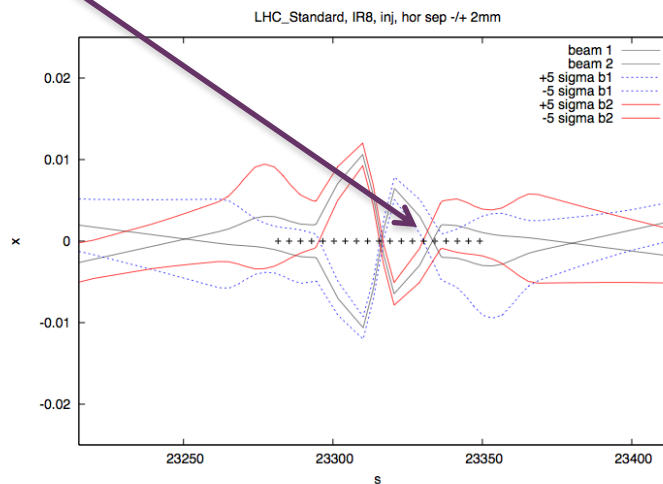
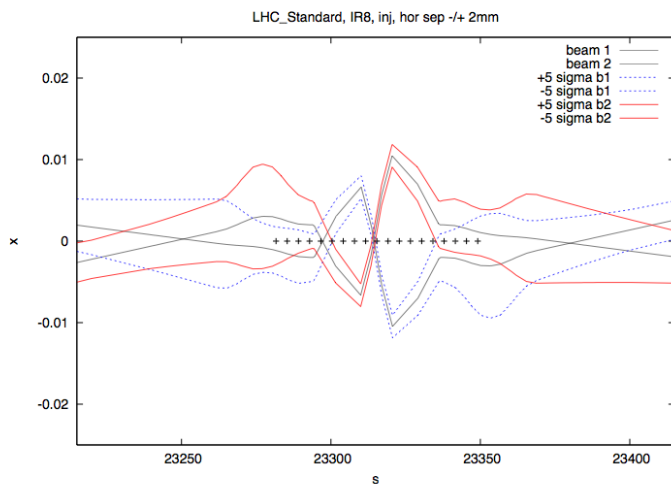
*calculate orbits & envelopes for*

*$\Delta x = 2.0$  mm,*

*$y' = 170$   $\mu$ rad, LHCb = on = bad*

vert. crossing angle separates the beams from encounter #4

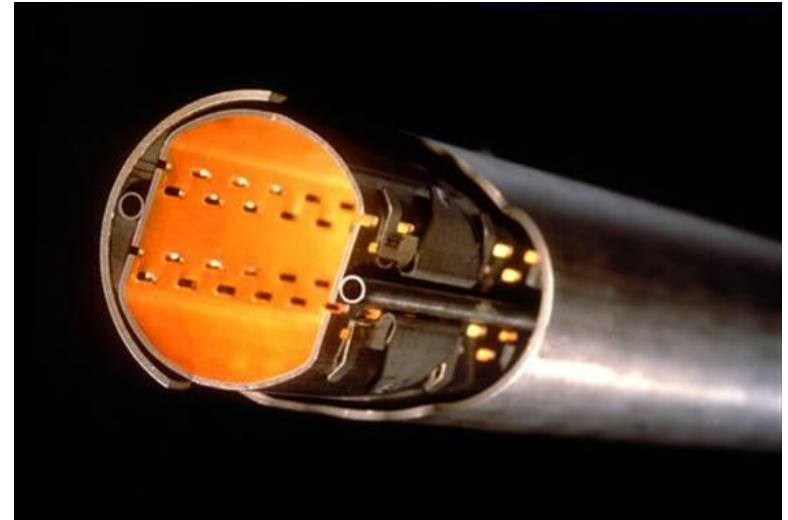
LHCb internal crossing angle separates the beams at #2 ... #5  
 $\Delta x = 2$ mm separates the beams at #1 (i.e. IP)



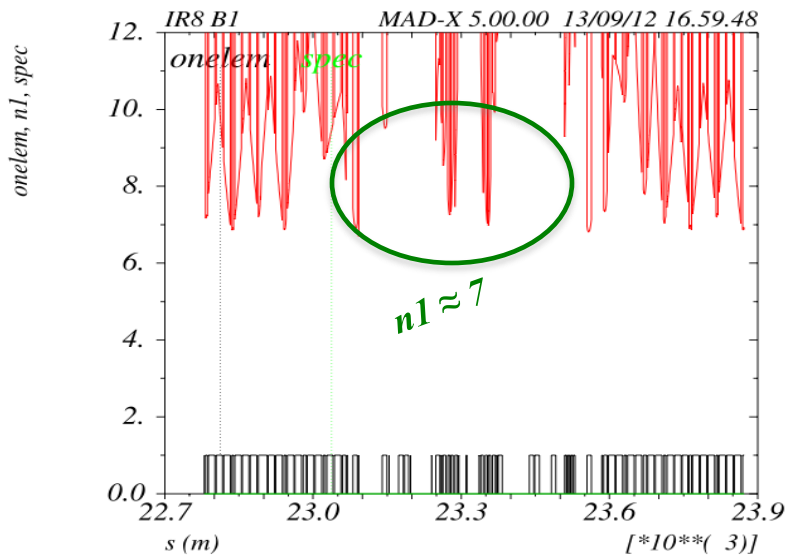
*The scheme works for any LHCb polarity and guarantees sufficient separation at ANY encounter !!*

**But ...**

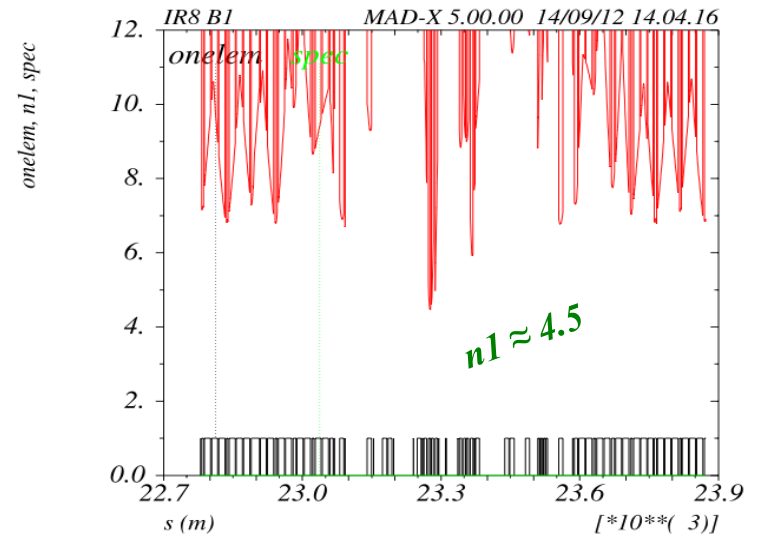
*LHC beam screen is not symmetric  
hor. / vert.*



*Aperture Model for present situation  
 $n1 \approx 7$*



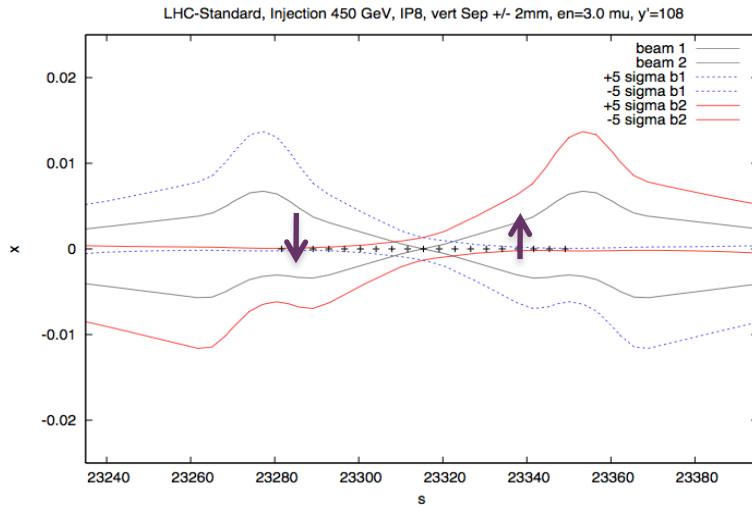
*Aperture Model for swapped situation  
 $n1 \approx 4.5$*



### III). Optimising Y':

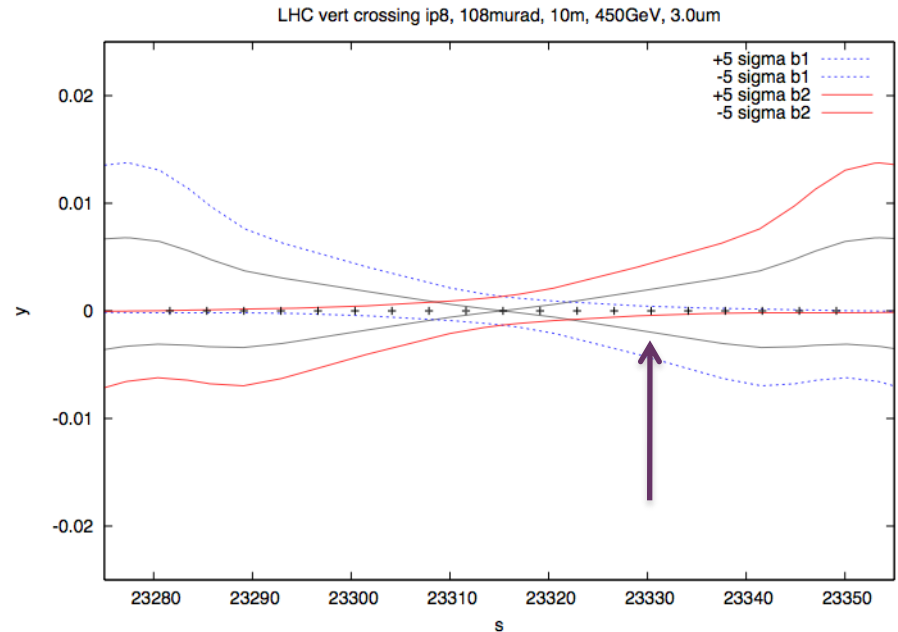
*Using the mcbx coils to flatten the vert. crossing bump inside the triplet?*

*Reducing the crossing angle to the bare minimum ...*



*For  $\epsilon = 3.0$ , scanning the vertical crossing angle  
... with slight optimism.*

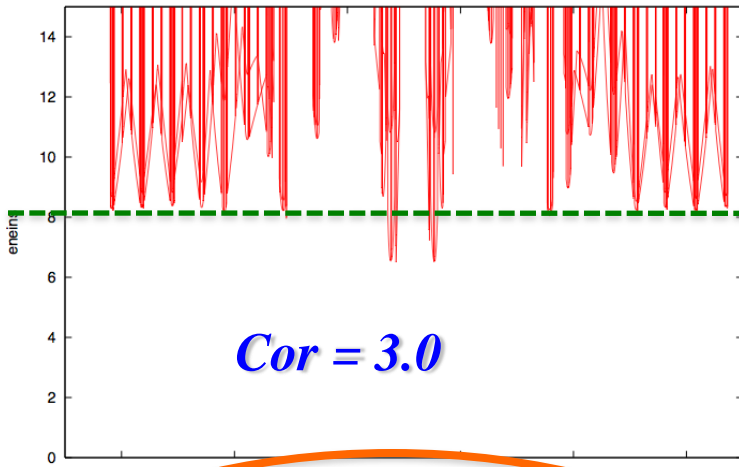
*on\_xv i= 0.8 = 136  $\mu$ rad + LHC b= 108  $\mu$ rad*



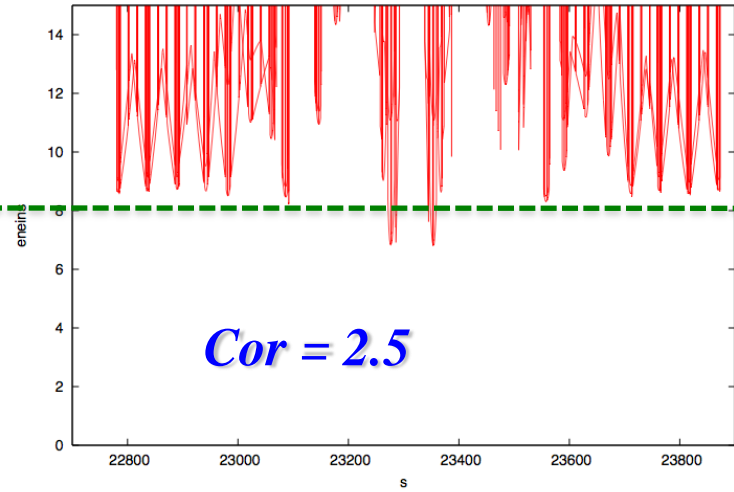
# V) Aperture Scans

$$\varepsilon = 3.0 \mu\text{rad}$$

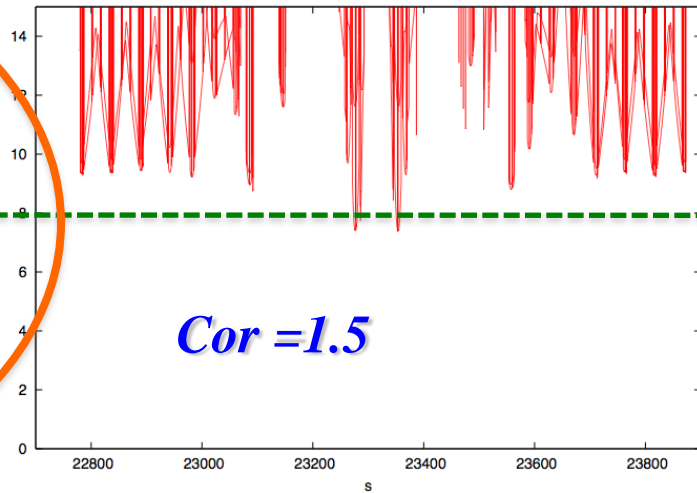
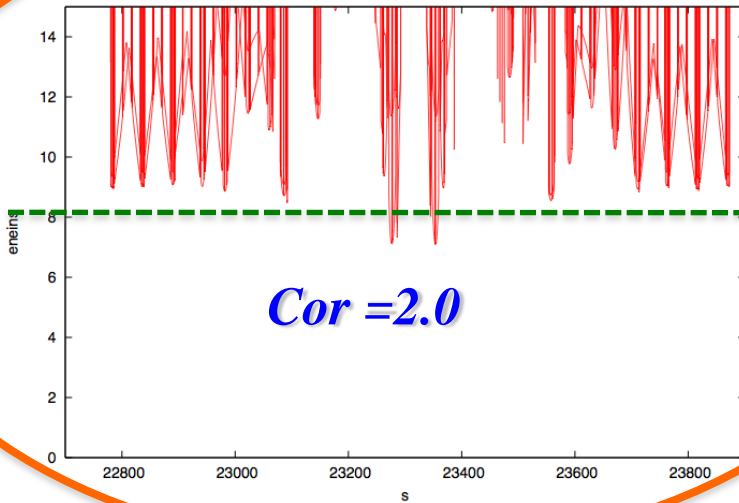
LHC-Aperture, inj, en=3.0, cor=3.0, y'=0.8 = 108murad



LHC-Aperture, inj, en=3.0, cor=2.5, y'=0.8 = 108murad



LHC-Aperture, inj, en=3.0, cor=2.0, y'=0.8 = 108murad

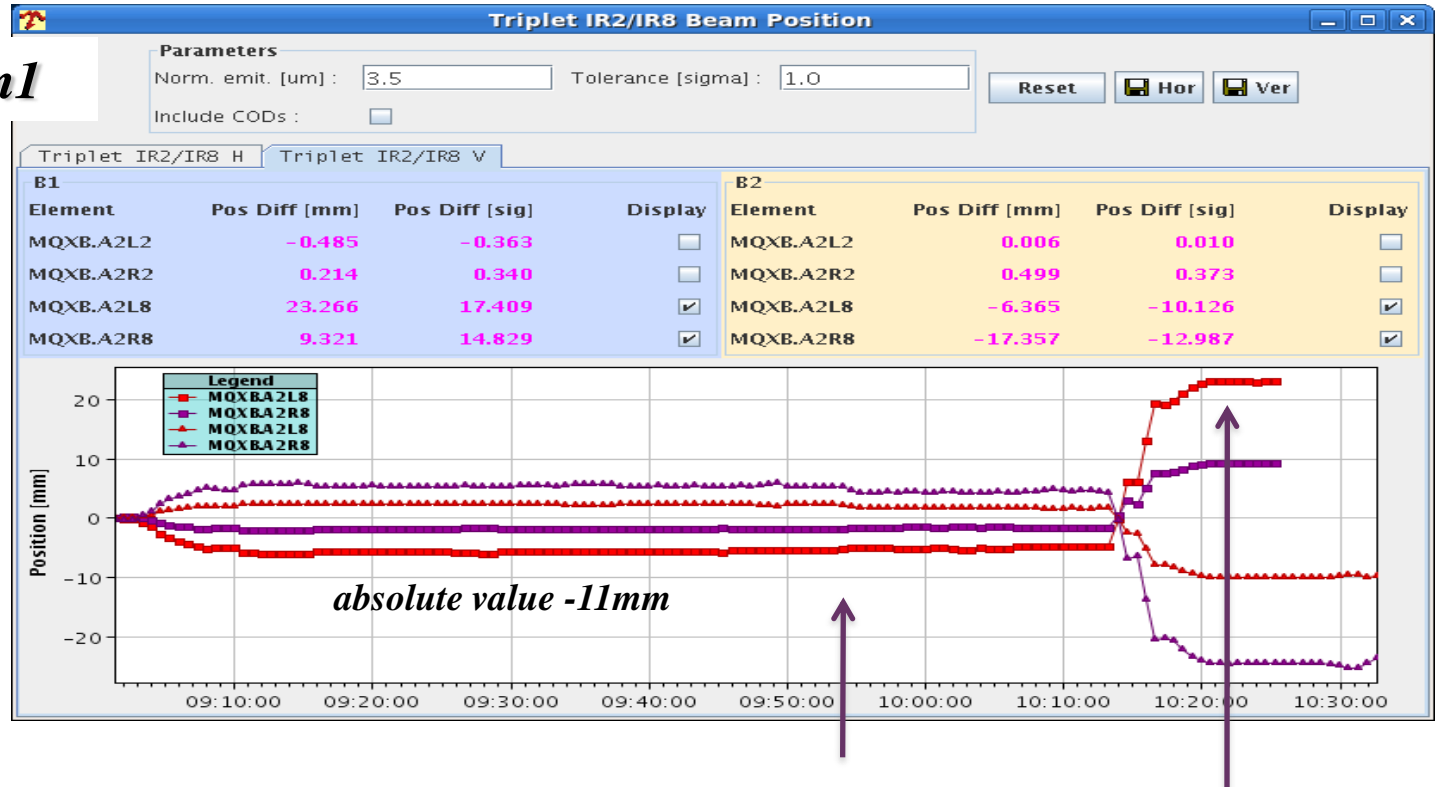




# VI.) ... and finally the measurements

## YASP-Extraction:

(vert.) orbits beam1



reaching the aperture  
limit in 1st direction  
-5.4mm

reaching the aperture  
limit in 2nd direction  
+23.3mm

overall amplitude

$$28.7\text{mm} + 2 * 4\sigma$$

$$\beta=270\text{m}, \epsilon_n=3.5 \rightarrow \sigma=1.5\text{mm}$$

aperture radius = 20.4 mm

## cross check & summary

Referring to the IP settings of the bump:  
aperture limits obtained at  $\Delta y \approx \pm 11\text{mm}$   
corresponds to 17.8mm at Q2.

Overall Aperture:  $17.8\text{mm} + 4\sigma = 23.8\text{mm} \times$

Compared to theoretical expected value: ...

Beam Screen Geometry in IP8

hor \* vert. = 29mm \* 24mm

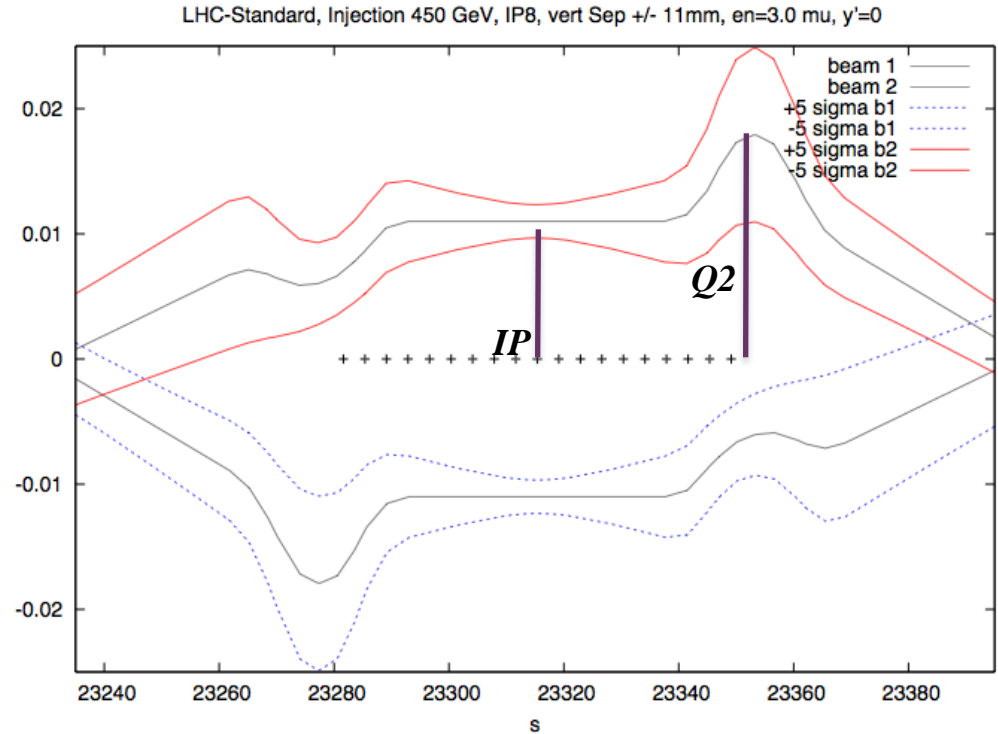
ufffff ... ?????

Aperture Need:

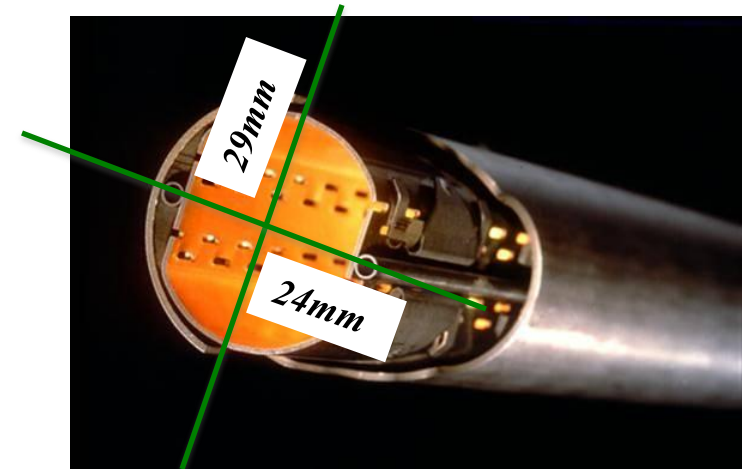
$y' = 108 \mu\text{rad} \rightarrow \Delta y = 6.8\text{mm}$  at Q2

Overall Aperture Measured = 24 mm

In other words: applying  $108\mu\text{rad}$  gives us still margin  
for 17 mm ... corresponding to  $12\sigma$  ( $\epsilon = 3.0$ )



vert. Separation Bump +/- 11 mm



## *cross check & summary*

- \* *ALICE Spectrometer needs polarity switch once per collision mode*  
*TCT re-alignment needed in all machine procedures*  
*fast procedure established (and already used in 2012) for Pb-Pb / p-Pb runs*  
*vertical deflection does not harm operation*
- \* *LHCb Spectrometer needs polarity change every “n” weeks,*  
*horizontal crossing scheme is not compatible with 25ns bunches*  
*new procedure has been established combining the unavoidable hor. crossing with*  
*vertical crossing scheme and a hor. offset.*  
*Problem: Aperture, but seems feasible.*
- \* *h=9 scheme gives us even smaller emittances at 450 GeV and makes the new procedure*  
*quite promising.*

$$h=9, \varepsilon = 1.5 \mu\text{rad}$$

