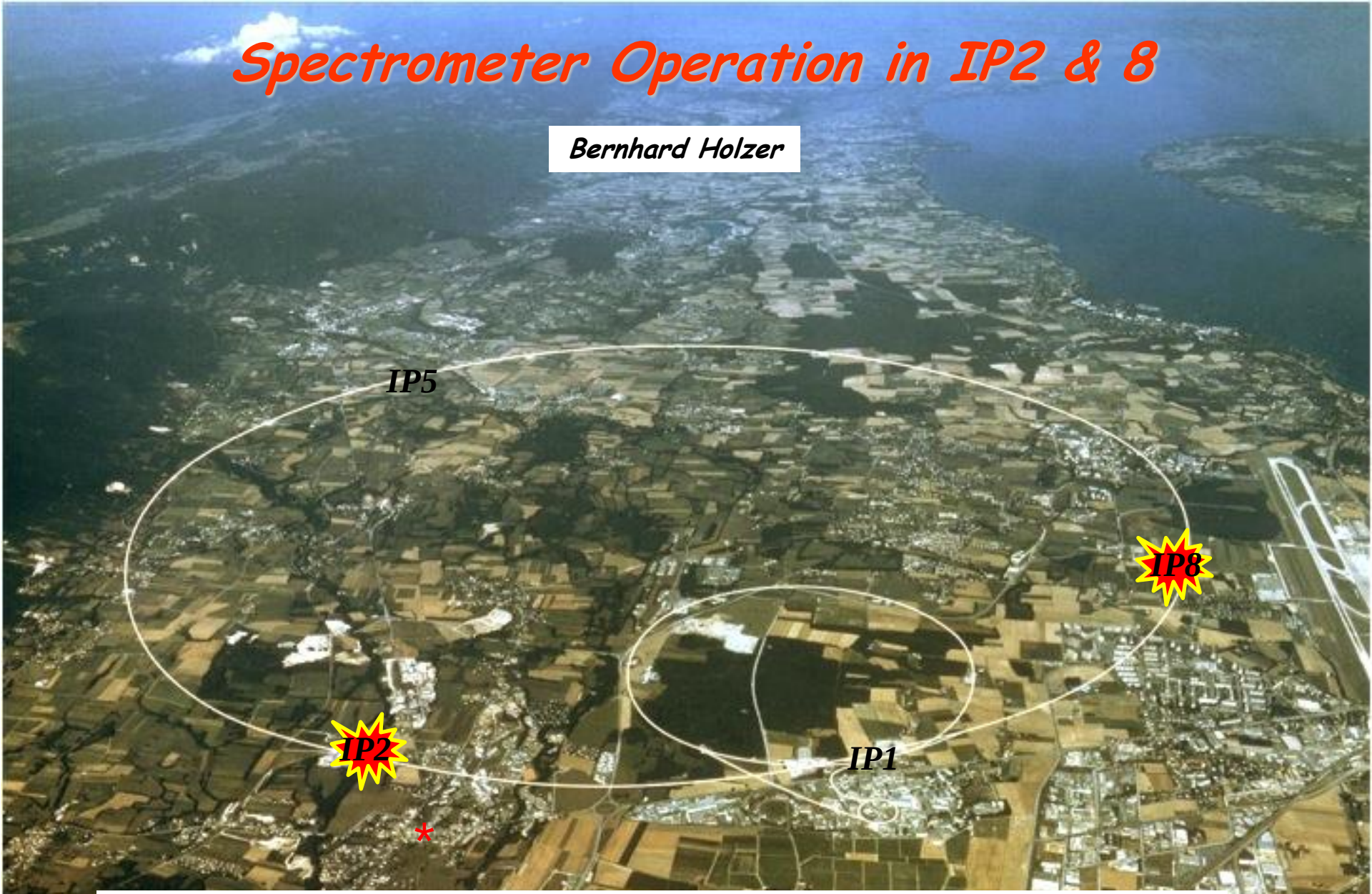
Spectrometer Operation in IP2 & 8

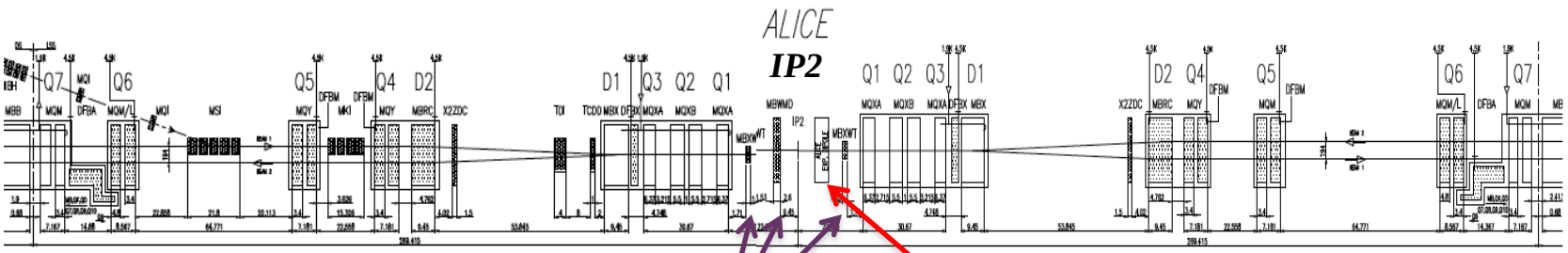
Bernhard Holzer



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' = +/- 1089 µrad***
**** " at 4 TeV: y' = +/- 122.5µrad***

ALICE *spectrometer & ext. bumps*

court. Reine Versteegen

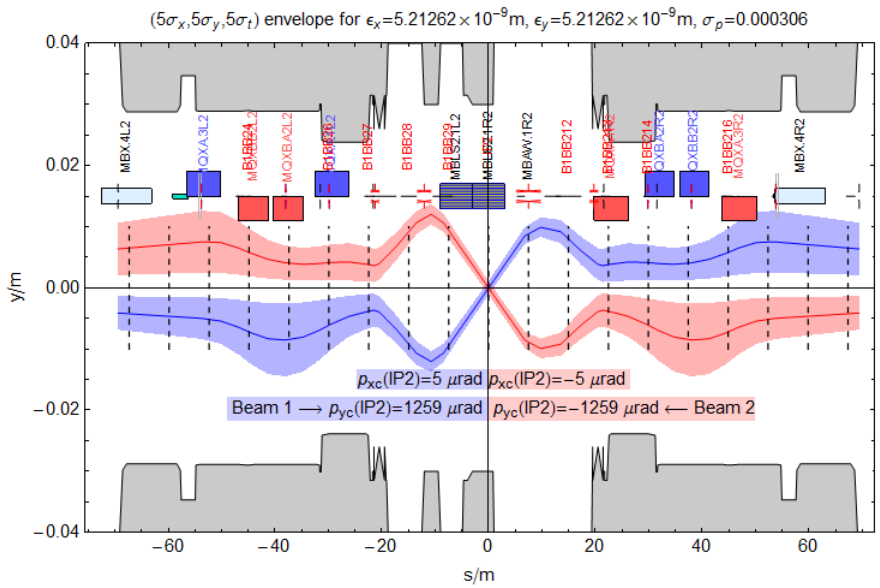
Injection, 450 GeV:

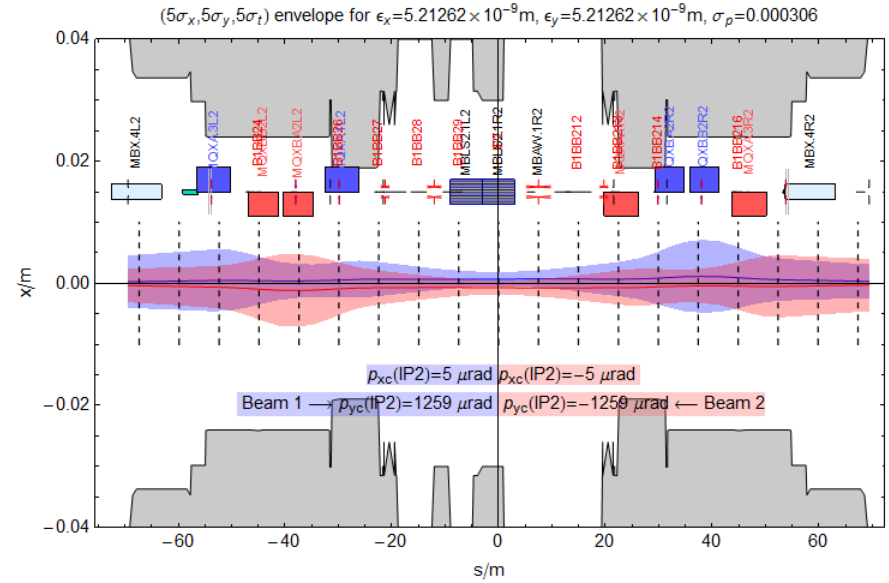
beam separation at any encounter required
The vertical bump, created by the spectrometer dipole is combined with an external vertical crossing angle bump and a horizontal separation bump:

**** spectrometer dipole: vert. crossing angle at : y' = +/- 1089 μrad***
**** external vert. crossing angle bump: y' = +/- 170μrad***
**** external hor. separation bump: Δx=+/- 2mm***

IR2, p-p physics in 2012 - $\gamma\varepsilon_p$ = 2.5 μmrad

Injection – β*= 10 m, θ_y = +170 + 1089 μrad





ALICE spectrometer & ext. bumps

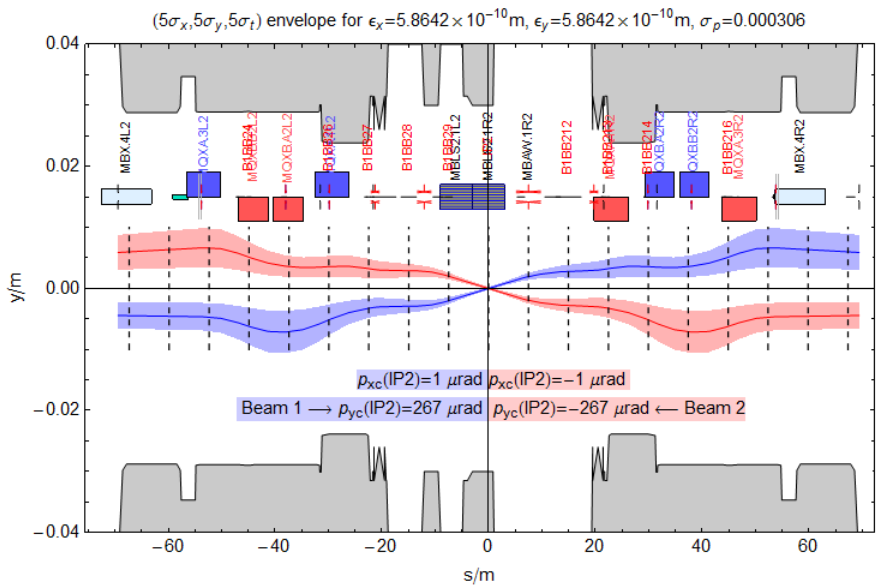
Collision, 4000 GeV:

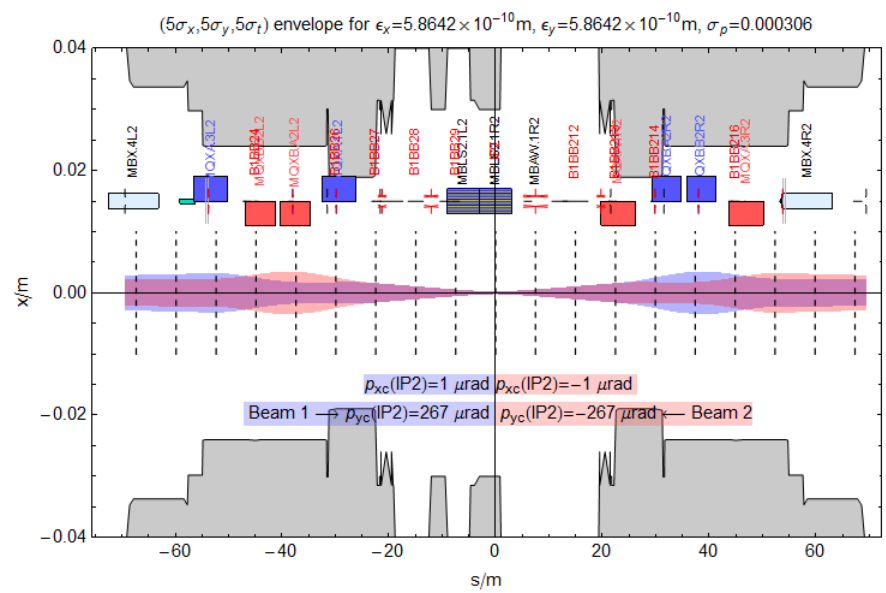
beam separation at IP2 collapsed,
beam separation at parasitic encounters via vert. crossing angle bump,
Crossing angle due to the spectrometer scales down as 1/E

**** spectrometer dipole: vert. crossing angle at : y' = +/- 122.5 μrad***
**** external vert. crossing angle bump: y' = +/- 145μrad***

IR2, p-p physics in 2012 - $\gamma\varepsilon_p$ = 2.5 μmrad

Physics – β^*= 3 m, θ_y = 145 + 122.5 μrad



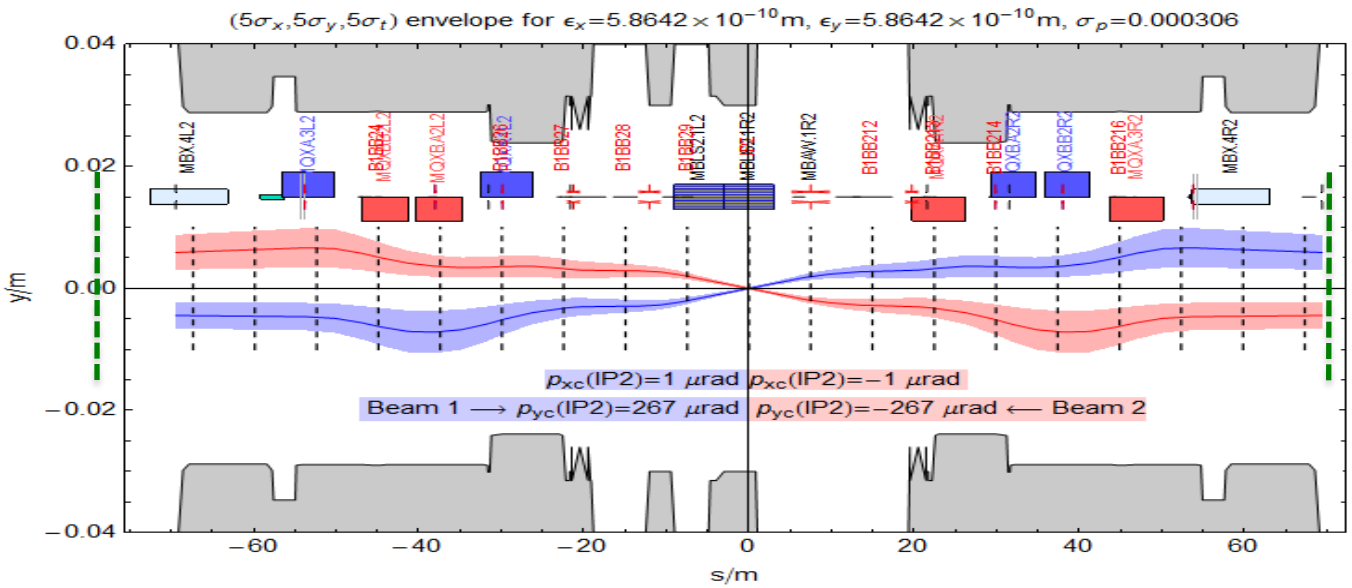


ALICE *Polarity Change p-p*

"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 – β^*= 3 m, θ_y = 145 + 122.5 μrad

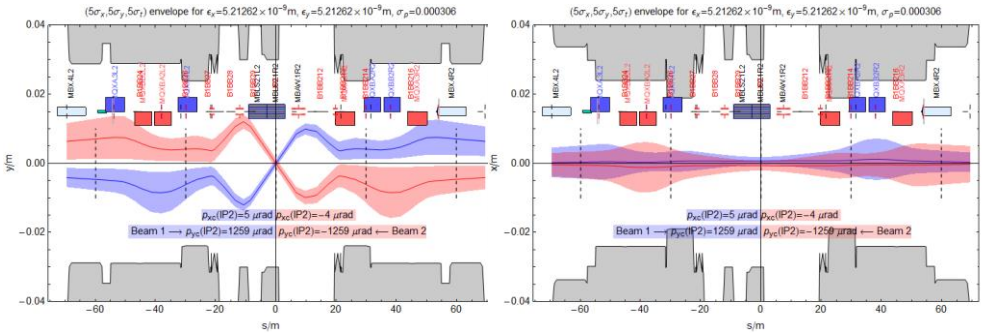


TCTs

ALICE p-PB collisions

Injection: unchanged,

* *spectrometer crossing angle y' = +/- 1089 μrad*
* *external crossing angle: y' = +/- 170μrad (const. !)*
* *external hor. separation bump: Δx = +/- 2mm*

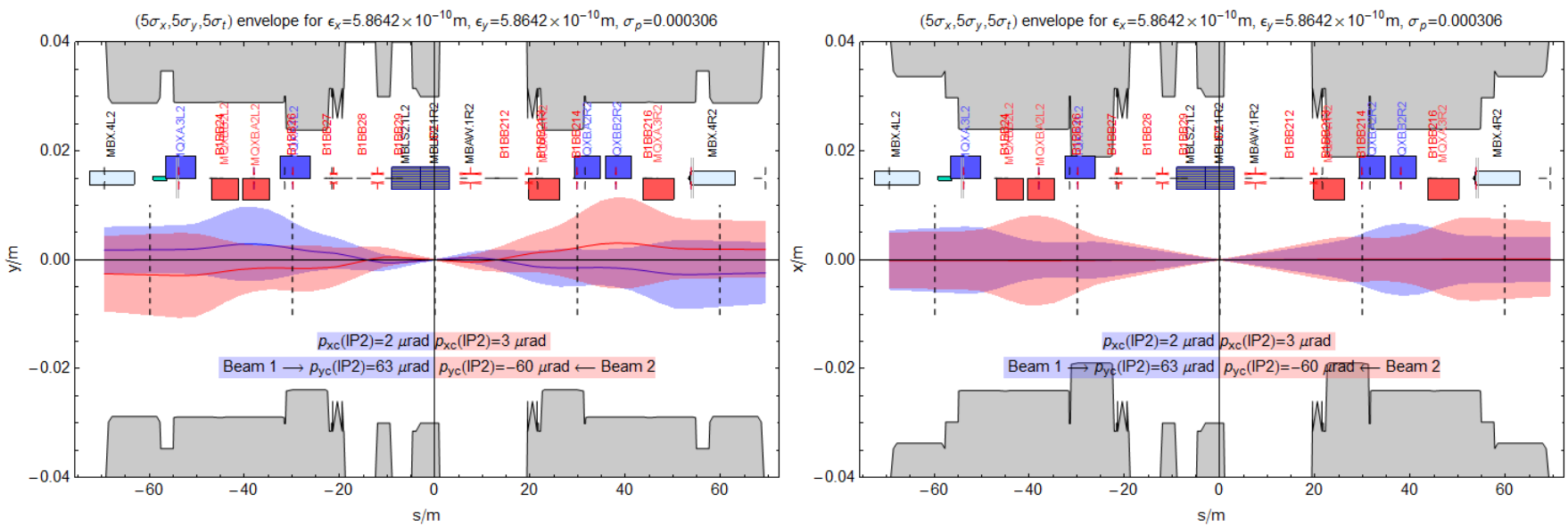


Collision: minimise the net crossing angle,

external crossing angle bump counteracts the spectrometer

IR2, p-Pb physics in 2013 - $\gamma\varepsilon_p$ = 2.5 μm.rad, $\gamma\varepsilon_{Pb}$ = 1.5 μm.rad

***Physics** – β^*= 0.8 m, θ_y = -62.5 + 122.5 μrad*

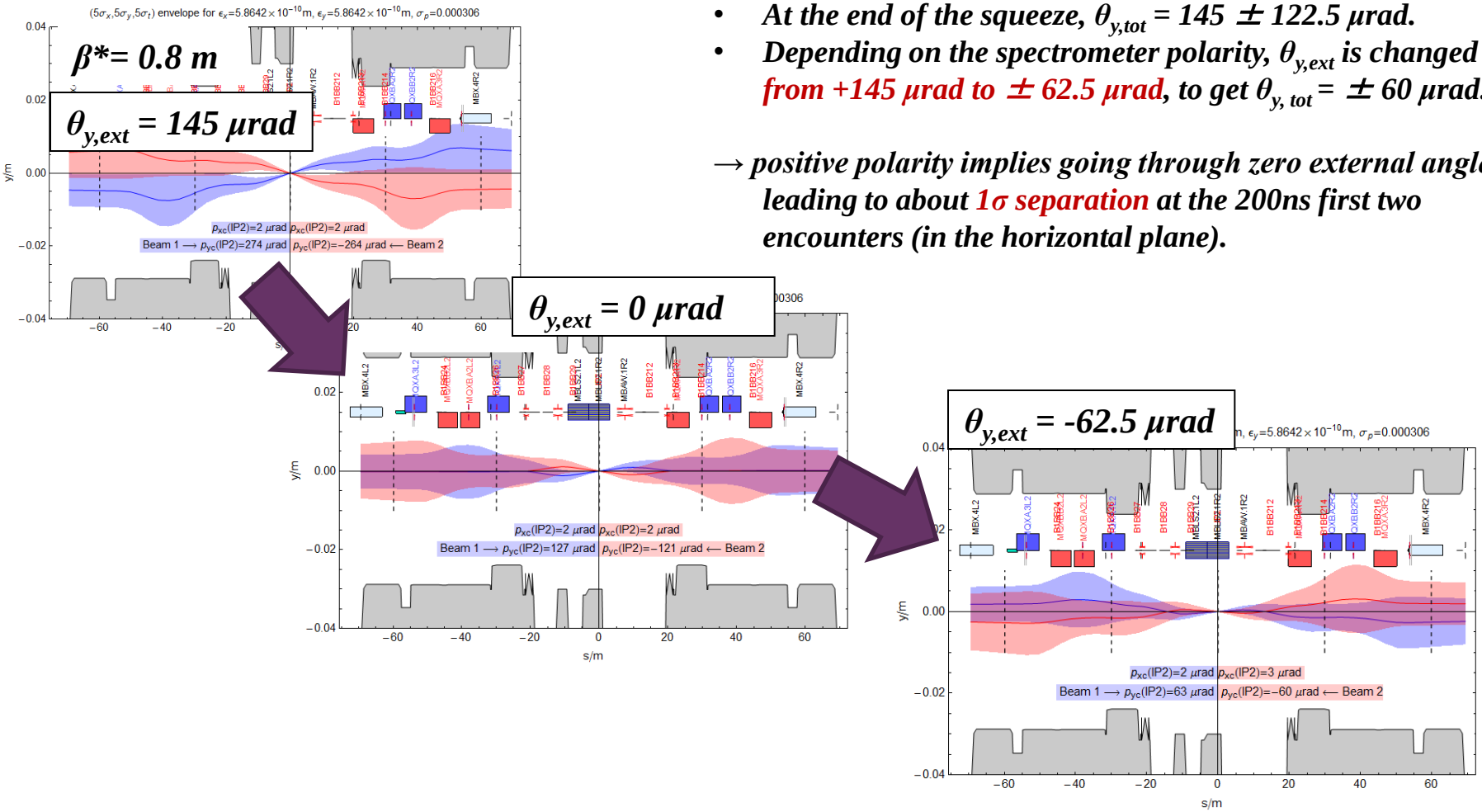


ALICE Polarity Change p-Pb

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 ± 122.5 μrad.***
- ***Depending on the spectrometer polarity, $\theta_{y,ext}$ is changed from +145 μrad to ± 62.5 μrad, to get $\theta_{y,tot}$ = ± 60 μrad.***

→ positive polarity implies going through zero external angle, leading to about 1σ separation at the 200ns first two encounters (in the horizontal plane).

ALICE *Possible new ideas / improvements*

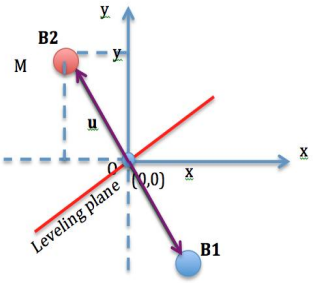
ALICE could ramp the magnet ... what do we win ?

Copy / paste of the LHCb story:

diagonal beam crossing & levelling
**** apply external horizontal crossing angle***
**** combine with vertical spectrometer angle***

Advantage:
orbit at TCTs is not affected, external bump would give same orbit at TCTs
ALICE spectrometer effect is compensated before the triplet.

Disadvantage:
more effort & not an eeeeeasy scheme,
we need it once per year for p-p
for PB mode en external vert. bump is needed anyway to keep crossing angle small.

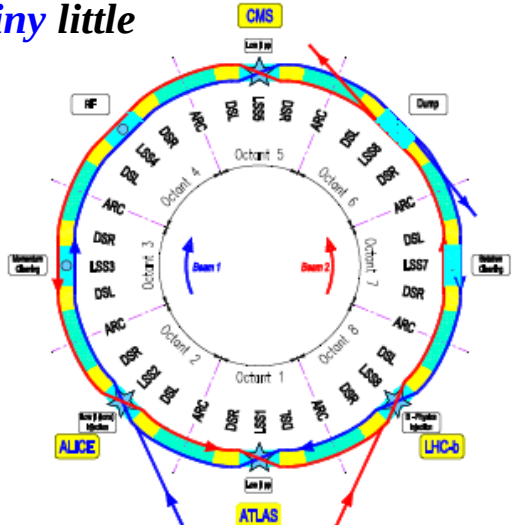


LHCb: The Challenge

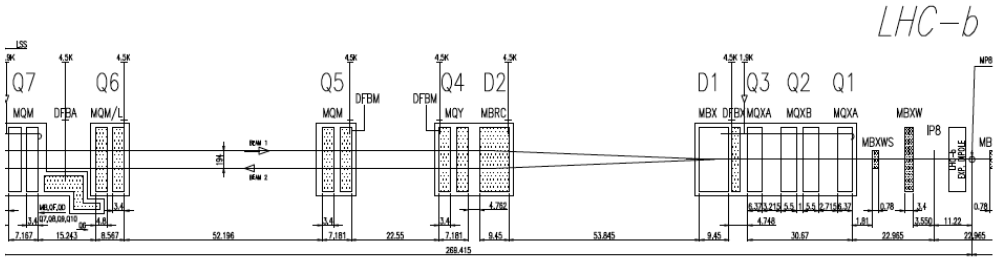
IP8: "natural LHC geometry" and the LHCb spectrometer effect

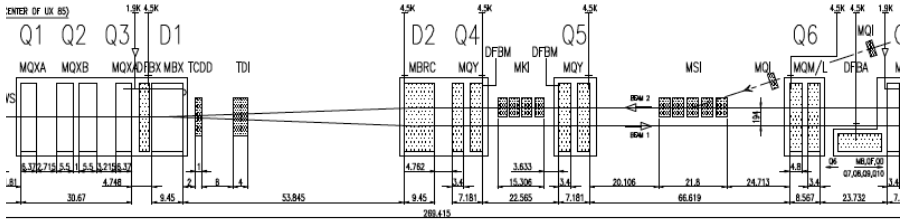
Design Orbit: Beam1 crosses at IP8 from ring outside to inside
-> negative horizontal angle provided by D1 & D2.

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 mrad
* " at 4 TeV: x' = +/- 235μrad
* depending oh the dipole polarity





LHC Lattice Layout in IP8

Situation at Luminosity:

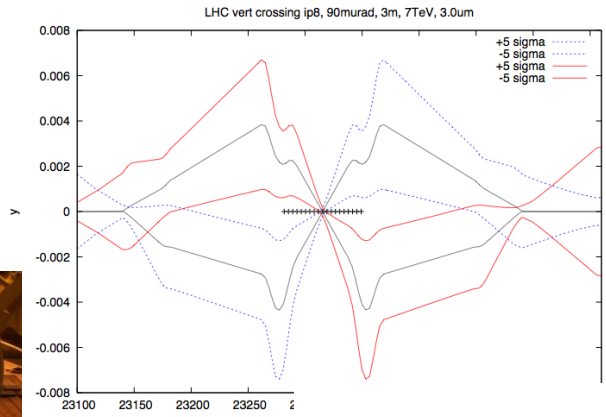
E=7 TeV, ε=3.0μrad

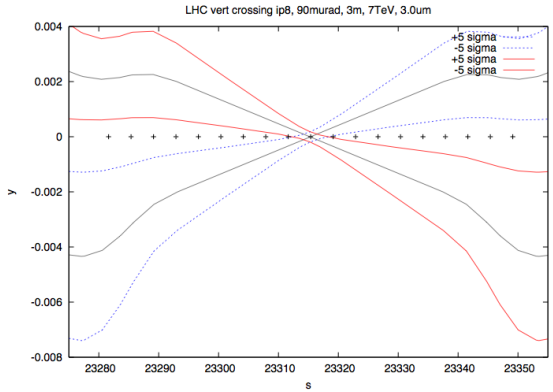
LHCb angle = x'_{int}=+/- 135 μrad, compensated

external hor. crossing angle = 0

parasitic encounters are avoided by

vertical external crossing of y'=90μrad





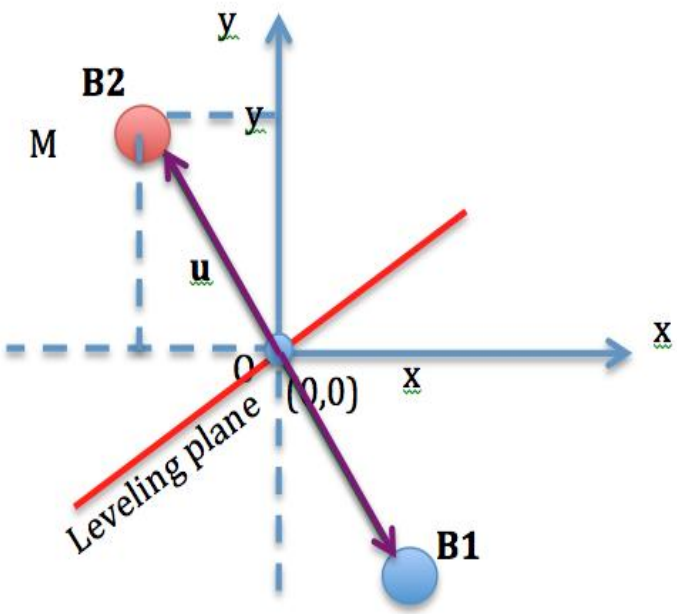
+/- 5σ beam envelope at IP8, in collision mode
crosses mark the 25ns encounters

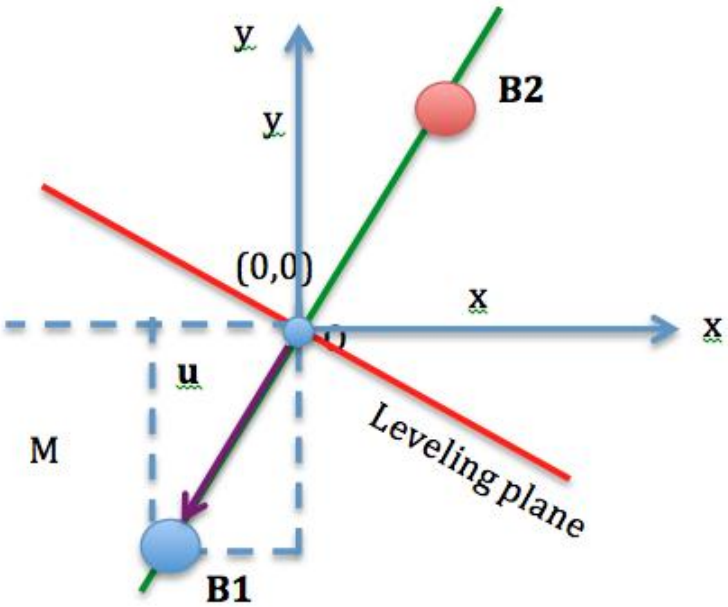
LHC Lattice Layout in IP8

Situation at Luminosity: combination of hor. & vert. crossing anbgles

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 TeV, ε=3.0μmrad,

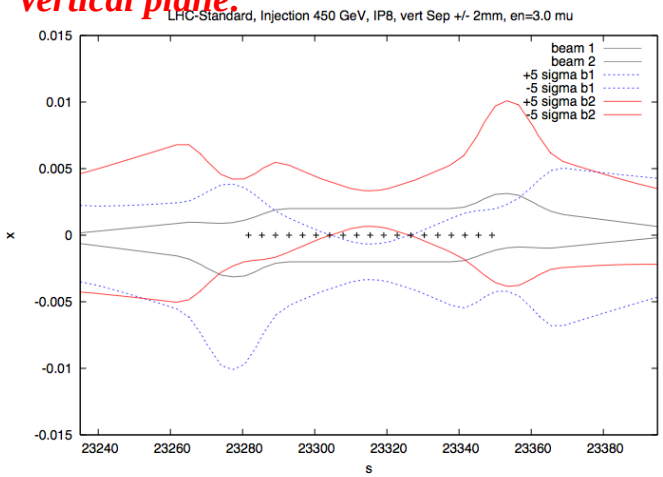
LHCb Effect: "internal" horizontal crossing angle = x' = +/- 2.1 mrad

"external" hor. crossing angle to avoid parasitic encounters x'= – 170 μrad const.

vertical separation bump Δy = 2mm

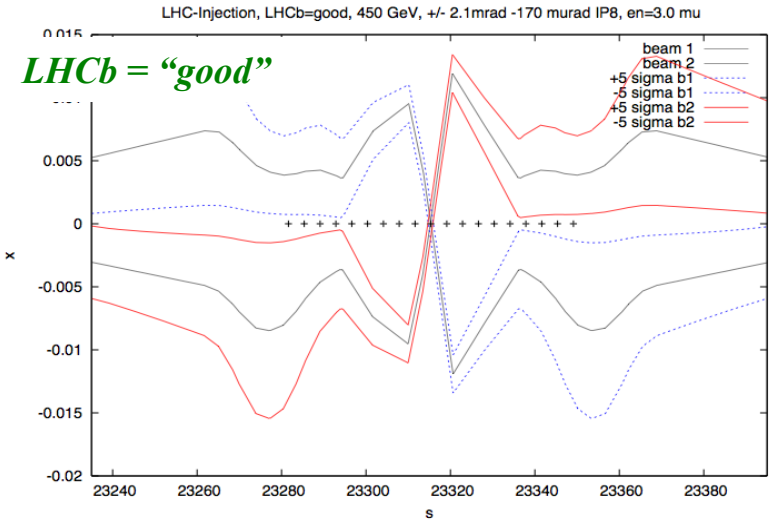
This combination has to avoid encounters at any position.

Vertical plane:



+/- 5σ 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.

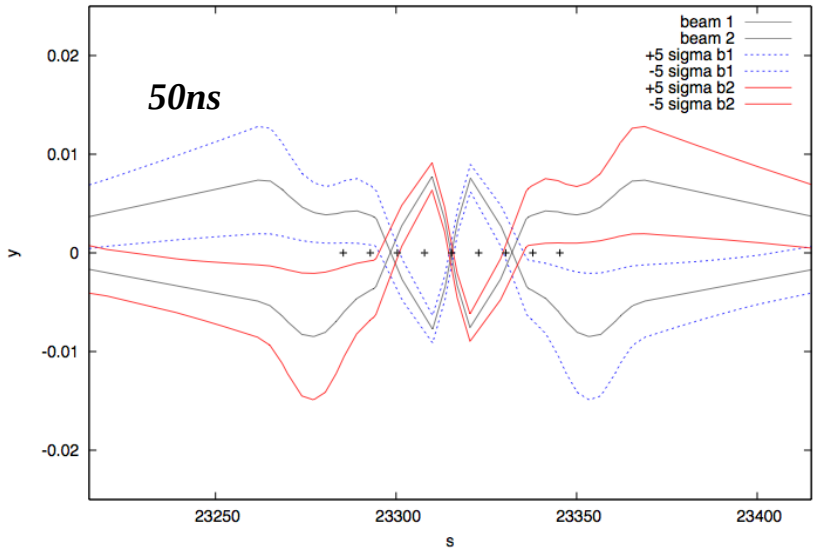


From encounter #5 on the horizontal crossing bump has to do the job.

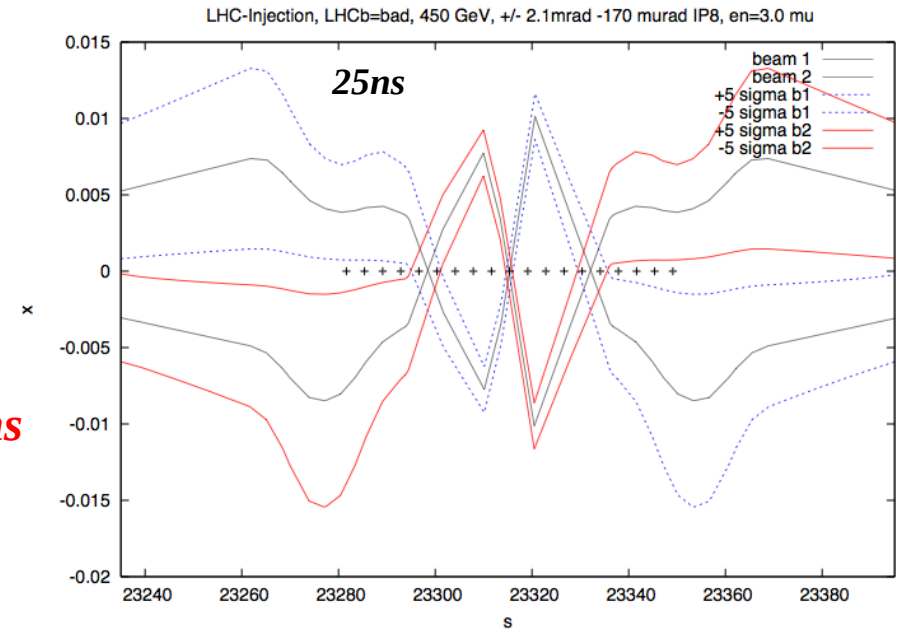
Situation in IR8 at Injection:

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.



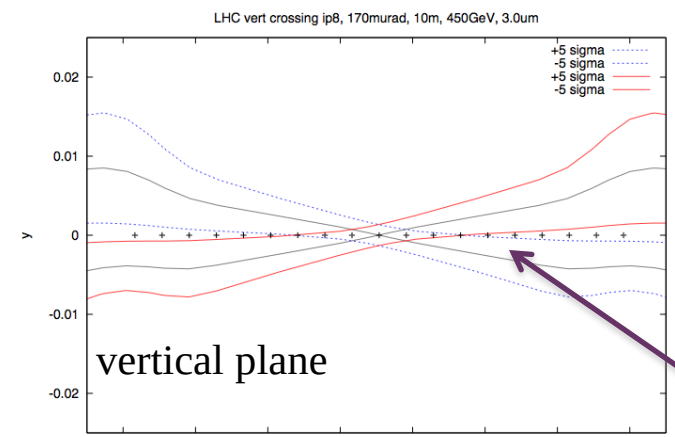
+/- 5σ beam envelope at IP8
Beams are crossing over between two 50ns encounters
x'= +2.1mrad -170μrad = +1.93 mrad
cross over between two 50ns encounters.



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

Swapping the Planes ... ?

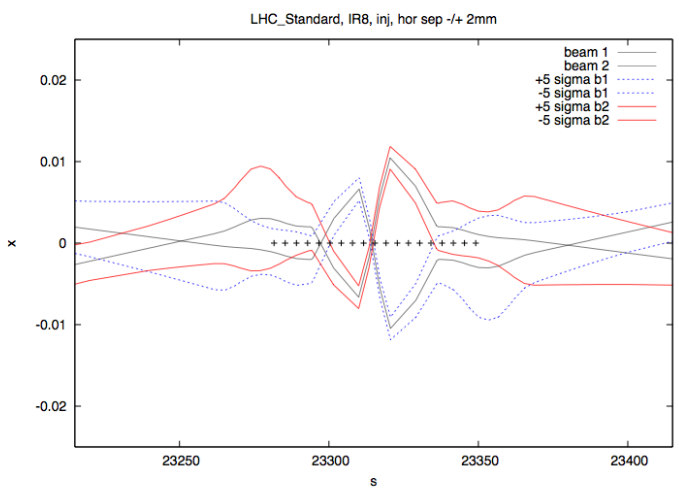
The horizontal crossing angle bump always will have to fight against the bad LHCb polarity.
A vertical crossing angle bump does not !



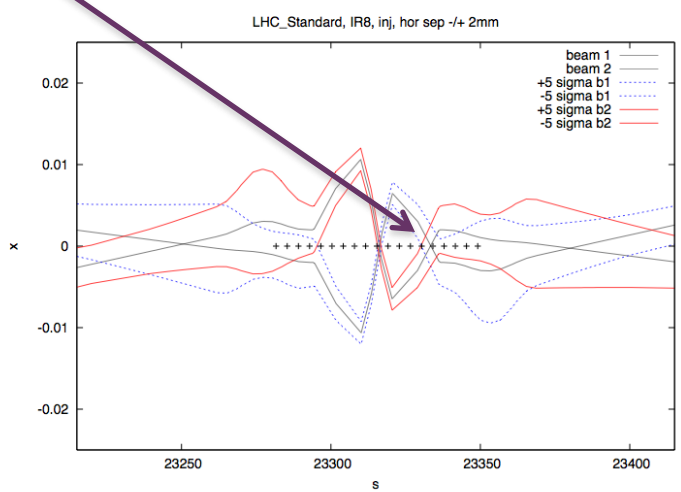
calculate orbits & envelopes for
Δx = 2.0 mm,
y' = 170 µrad, LHCb = on = bad

vert. crossing angle separates the beams from encounter #4

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



horizontal plane: LHCb = good

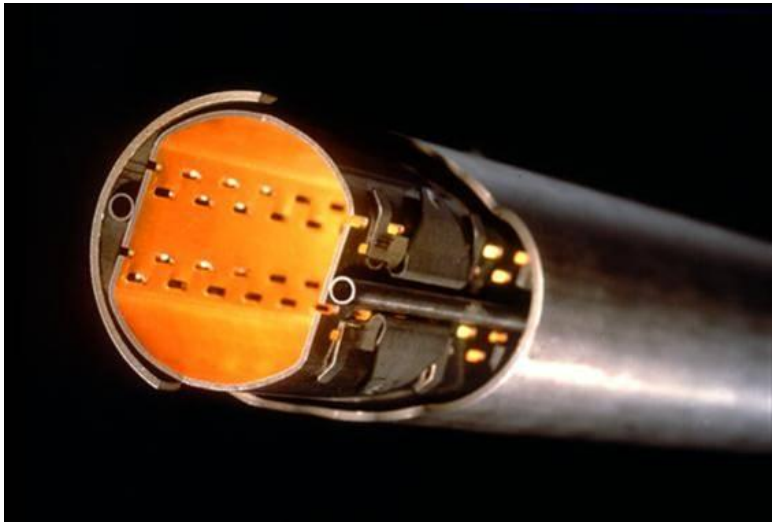


LHCb = bad

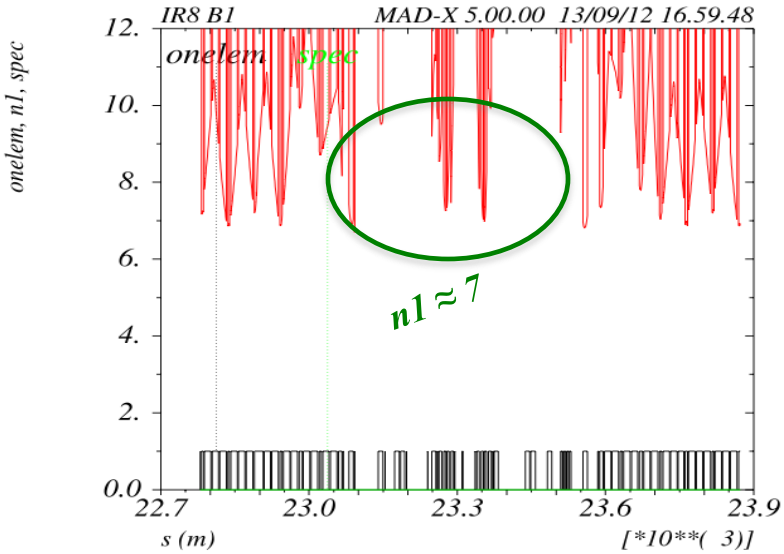
The scheme works for any LHCb polarity and guarantees sufficient separation at ANY encounter !!

But ...

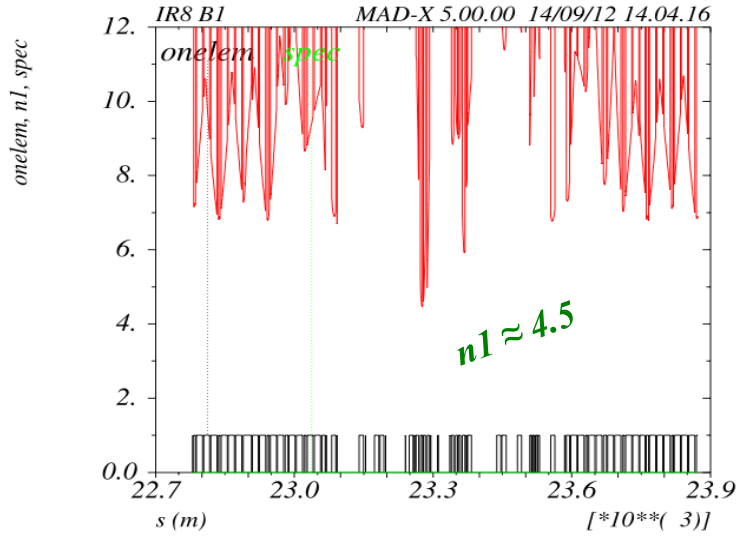
LHC beam screen is not symmetric hor. / vert.



Aperture Model for present situation
n1 ≈ 7



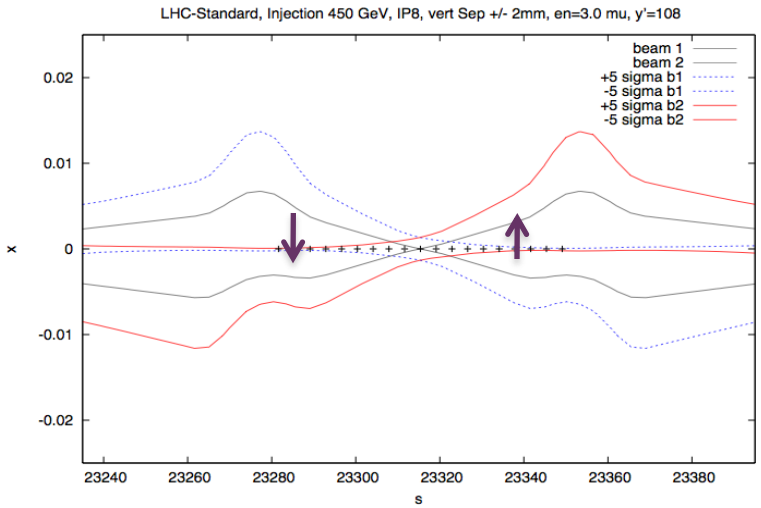
Aperture Model for swapped situation
n1 ≈ 4.5



III). *Optimising Y':*

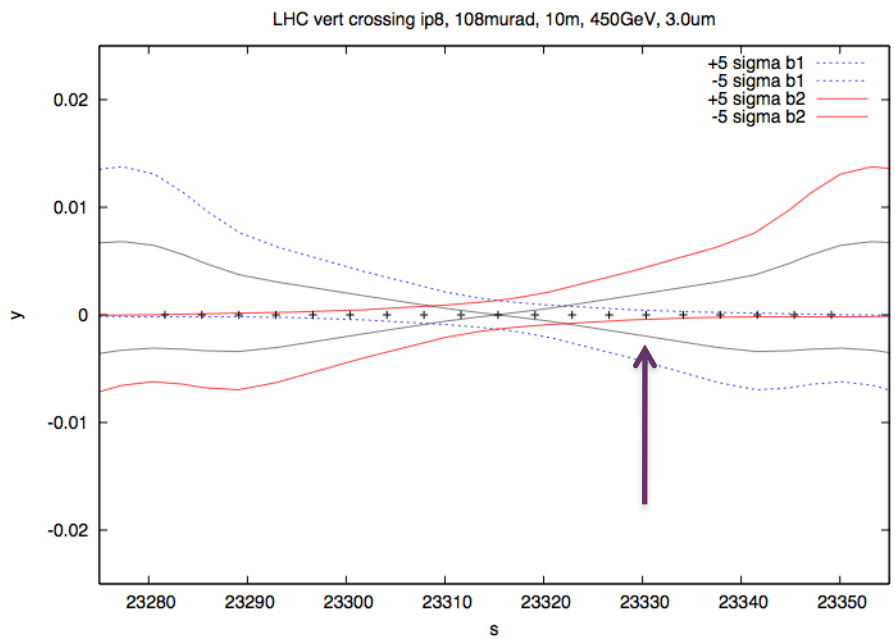
Using the mcbx coils to flatten the vert. crossing bump inside the triplet?

Reducing the crossing angle to the bare minimum ...



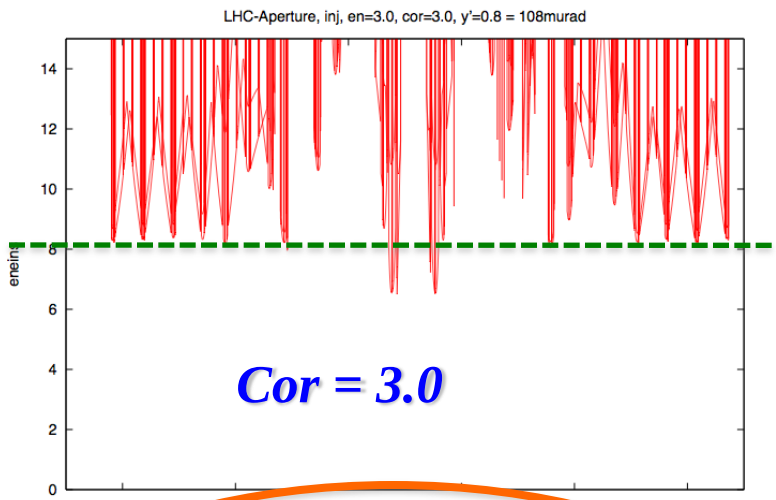
For ε = 3.0, scanning the vertical crossing angle ... with slight optimism.

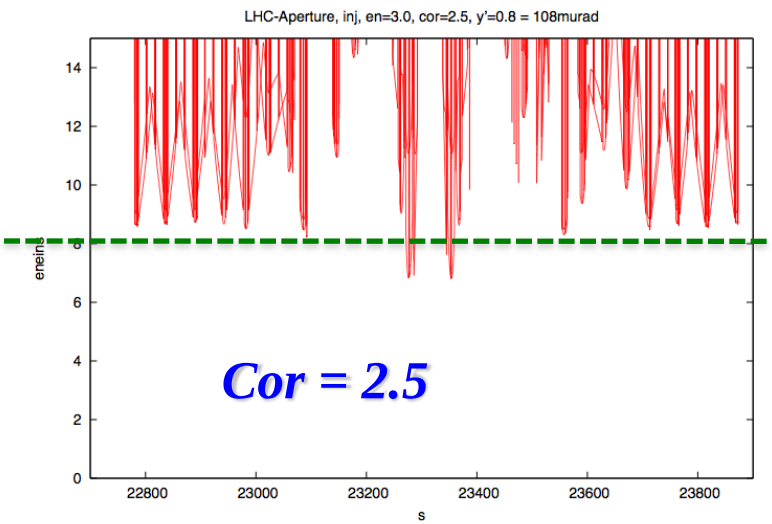
on_xv i= 0.8 = 136 μrad + LHC b= 108 μrad

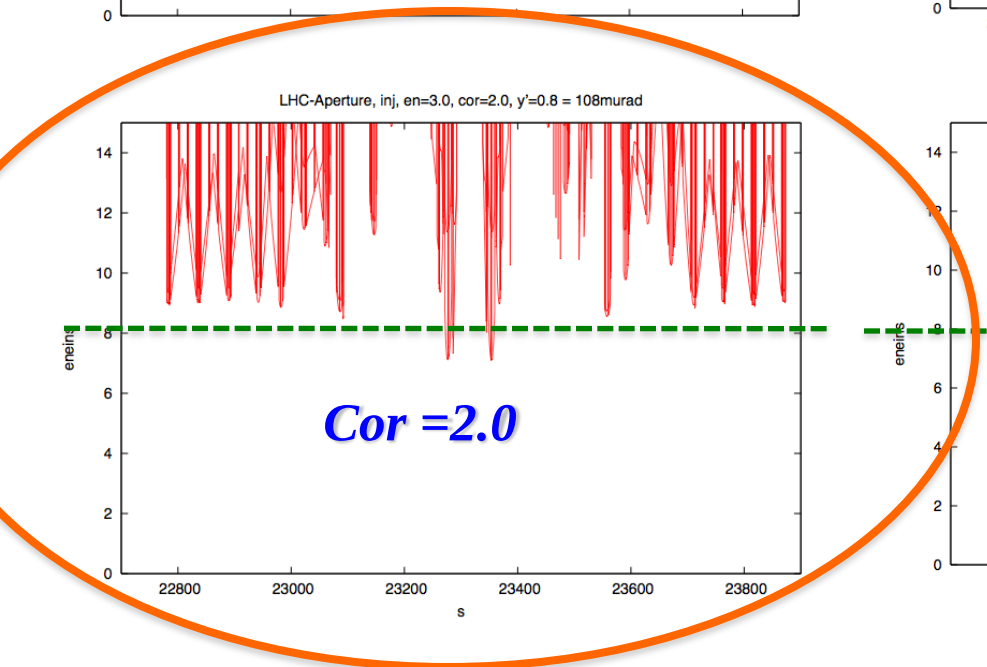


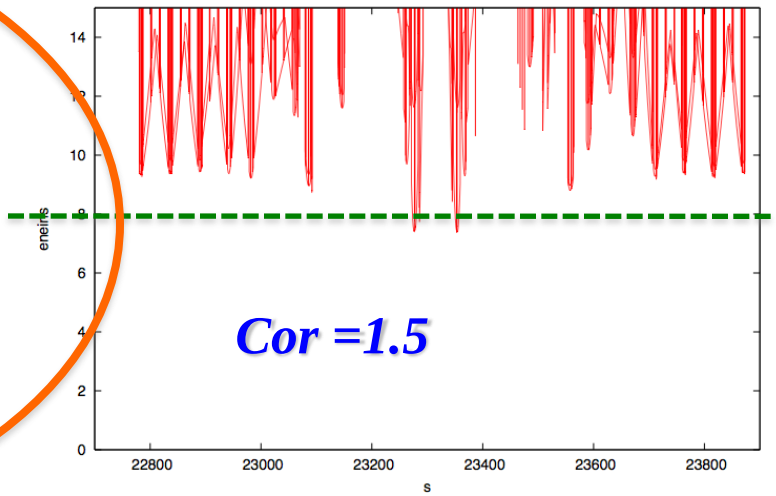
V) Aperture Scans

ε = 3.0urad





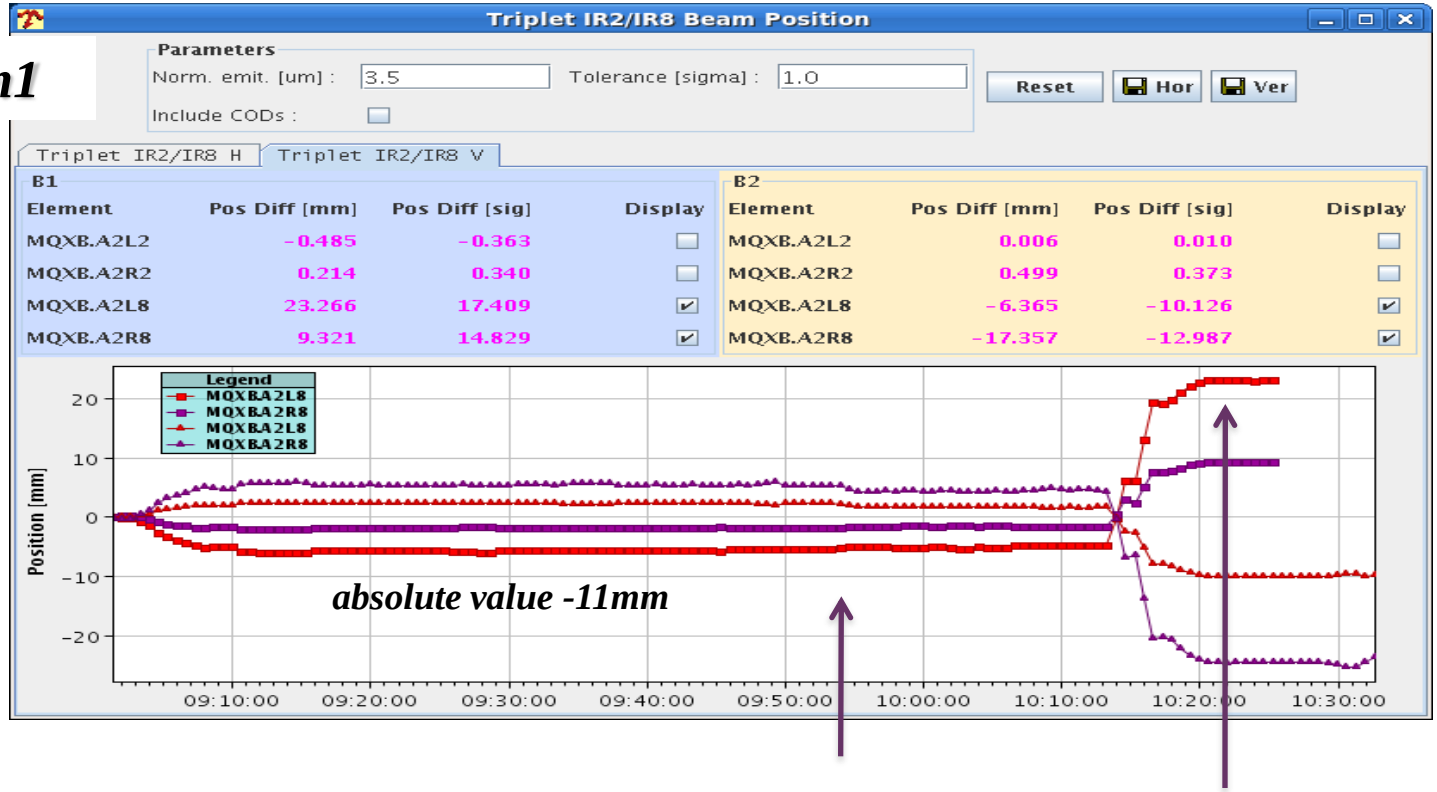




VI.) ... and finally the measurements

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

28.7mm + 2* 4σ

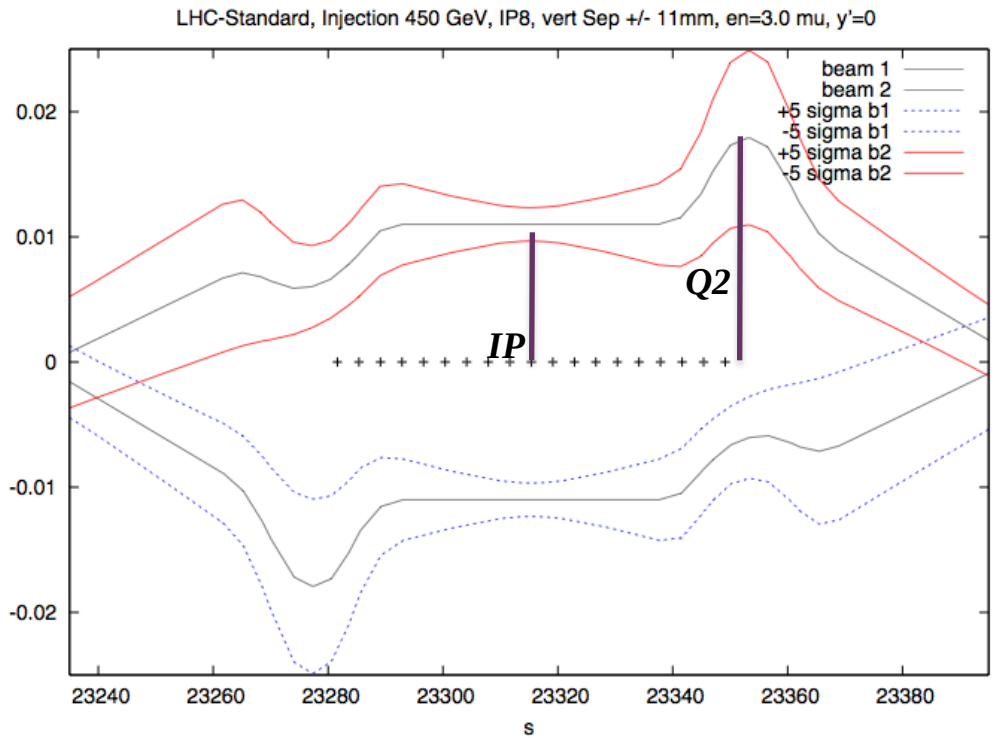
β=270m, ε_n=3.5 -> σ=1.5mm

aperture radius = 20.4 mm

cross check & summary

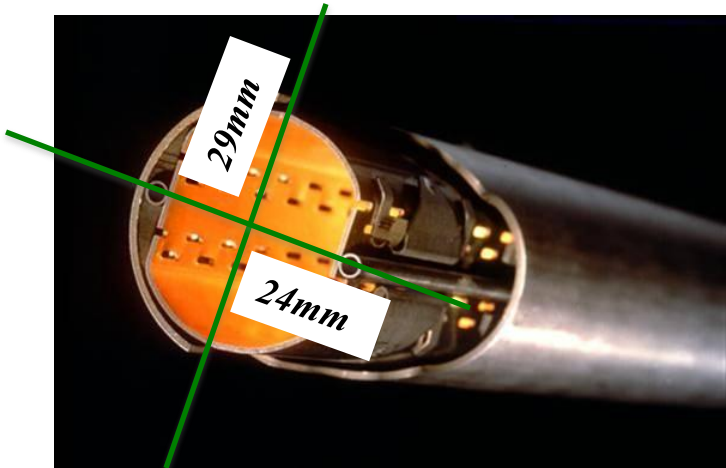
Referring to the IP settings of the bump:
aperture limits obtained at $\Delta y \approx +/- 11$mm corresponds to 17.8mm at Q2.
Overall Aperture: 17.8mm + 4σ = 23.8mm ×

Compared to theoretical expected value: ...
Beam Screen Geometry in IP8
hor * vert. = 29mm * 24mm
uffffff ... ?????



vert. Separation Bump +/- 11 mm

Aperture Need:
y'=108 μrad -> Δy = 6.8mm at Q2
Overall Aperture Measured = 24 mm
In other words: applying 108μrad gives us still margin for 17 mm ... corresponding to 12σ (ε = 3.0)



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, ε = 1.5 μrad