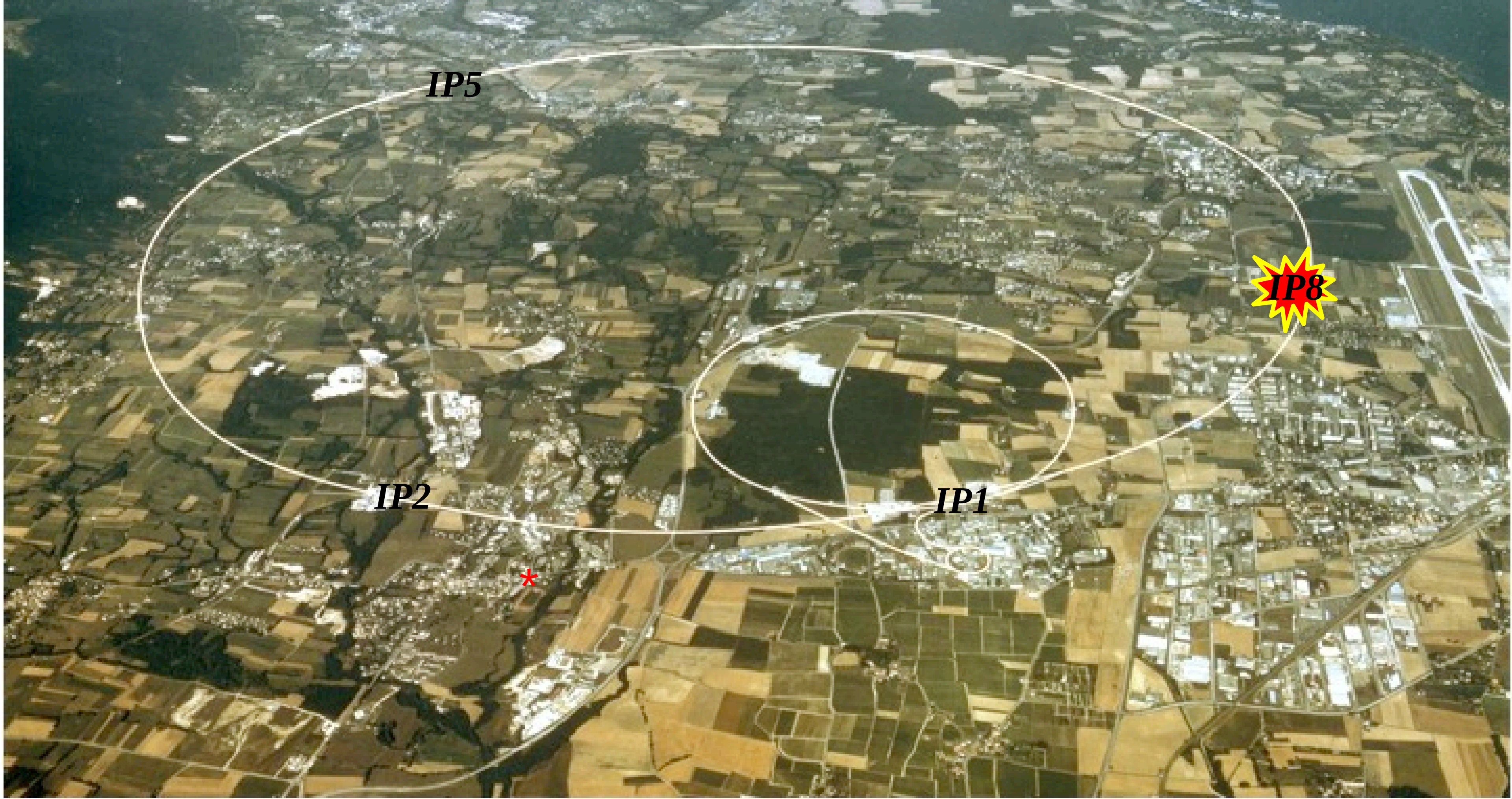
Vertical Crossing at IP8
Parameter Space for 450 GeV

Bernhard Holzer,
CERN-LHC

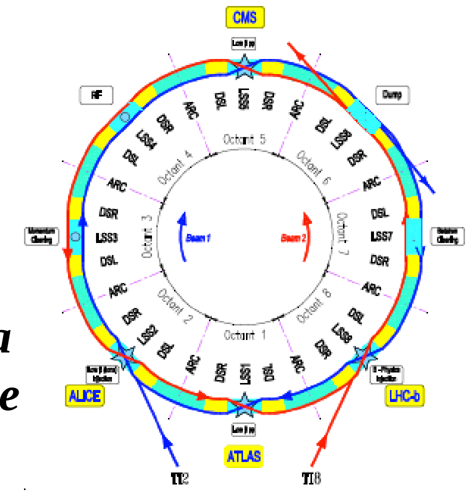


LHC Lattice Layout in IP8

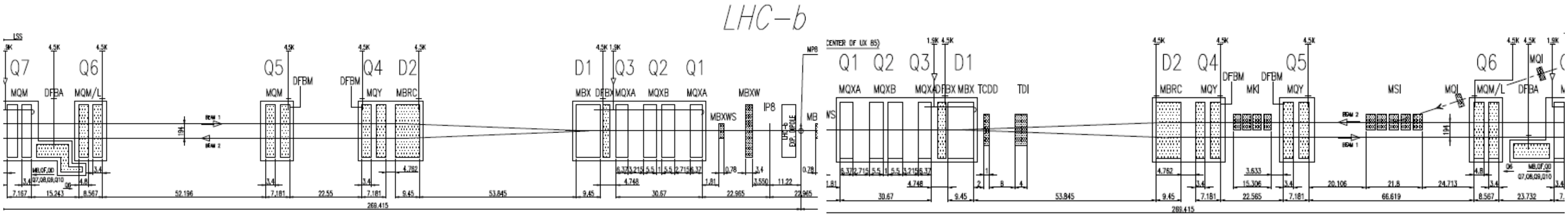
IP8: “natural LHC geometry and the LHCb spectrometer effect

Design Orbit: ***Beam1 crosses at IP8 from ring outside to inside***

-> negative horizontal angle provided by D1 & D2.



To avoid parasitic crossings this natural crossing is supported by a so-called “external (hor.) crossing angle bump” using the Q4/Q5 correctors.



At injection and on the ramp we have in addition to separate the beams vertically by 2mm using again an “external separation bump using the Q4/Q5 correctors.

LHC Lattice Layout in IP8

Situation at Luminosity:

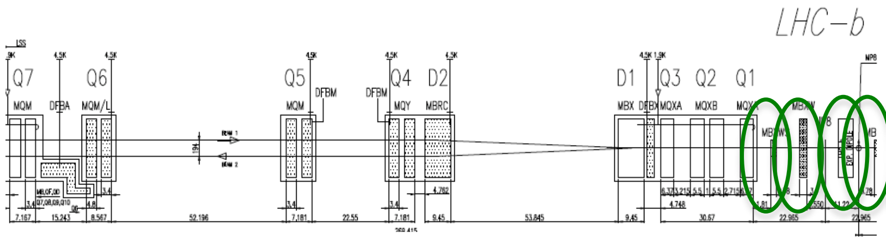
E=7 TeV

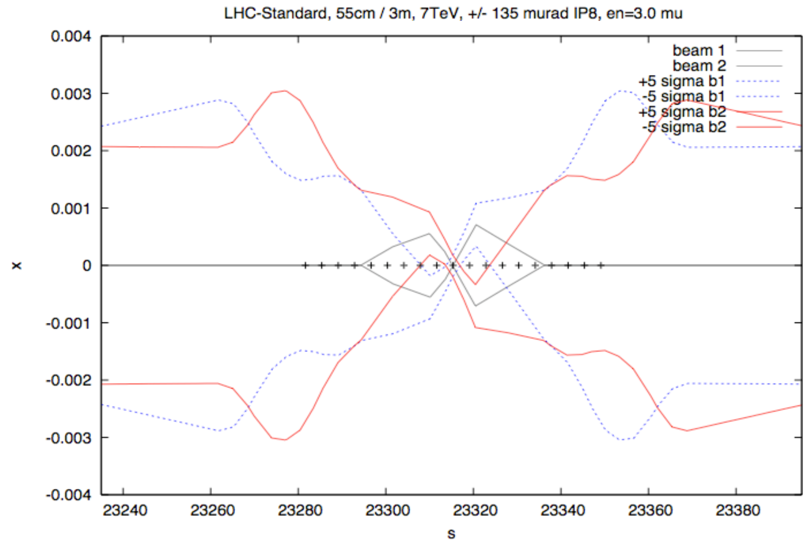
ε=3.0μrad

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

external hor. crossing angle = 0

parasitic encounters are avoided by vertical external crossing of y'=90μrad

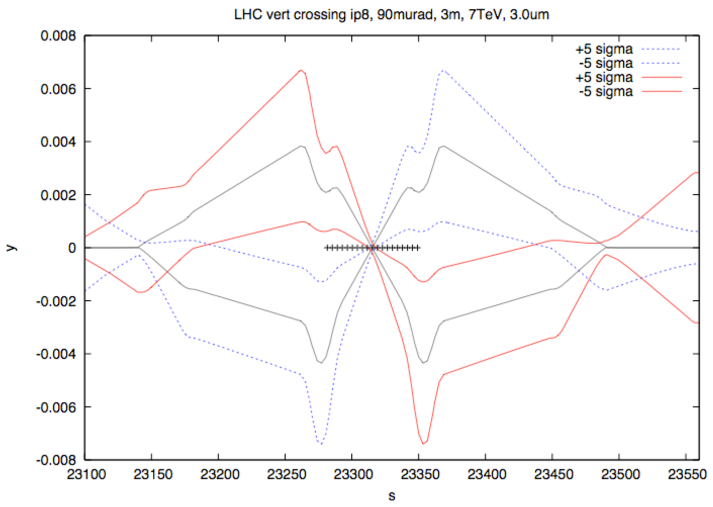




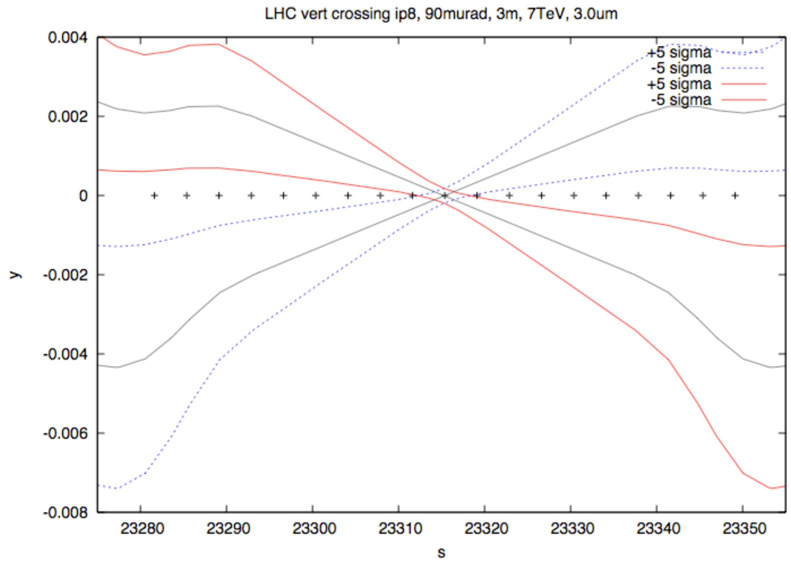
LHC Lattice Layout in IP8

Situation at Luminosity:

E=7 TeV, ε=3.0μrad
LHCb angle = x'_{int}=+/- 135 μrad, compensated
external vert. crossing angle, y'=90μrad



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



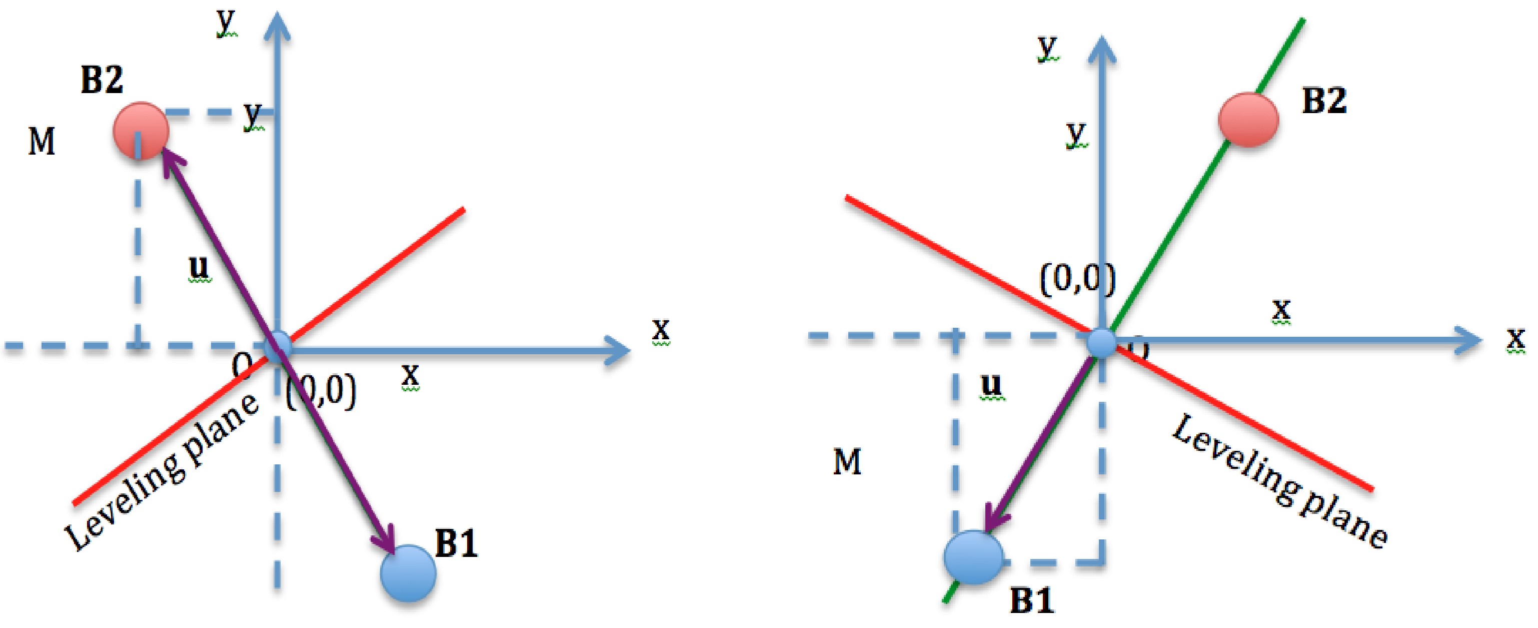
As no external hor. crossing bump is applied the beam envelopes overlap after the LHCb compensators.
Parasitic encounters are avoided by the external vertical bump. (diagonal leveling scheme).

LHC Lattice Layout in IP8

Situation at Luminosity:

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=3.0μrad,

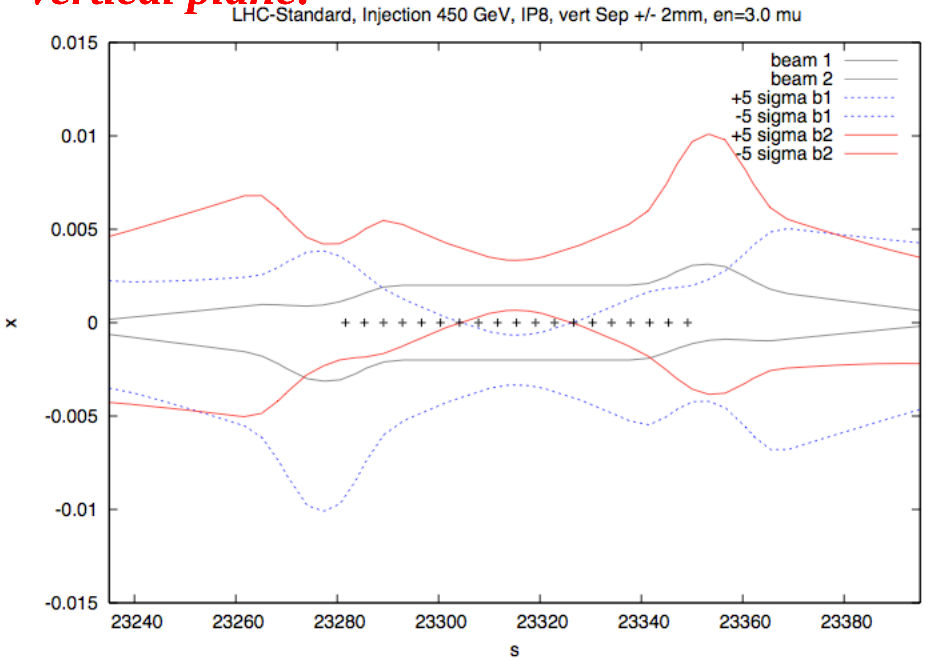
LHCb Effect: "internal" horizontal crossing angle = x' = +/- 2.1 mrad

"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:



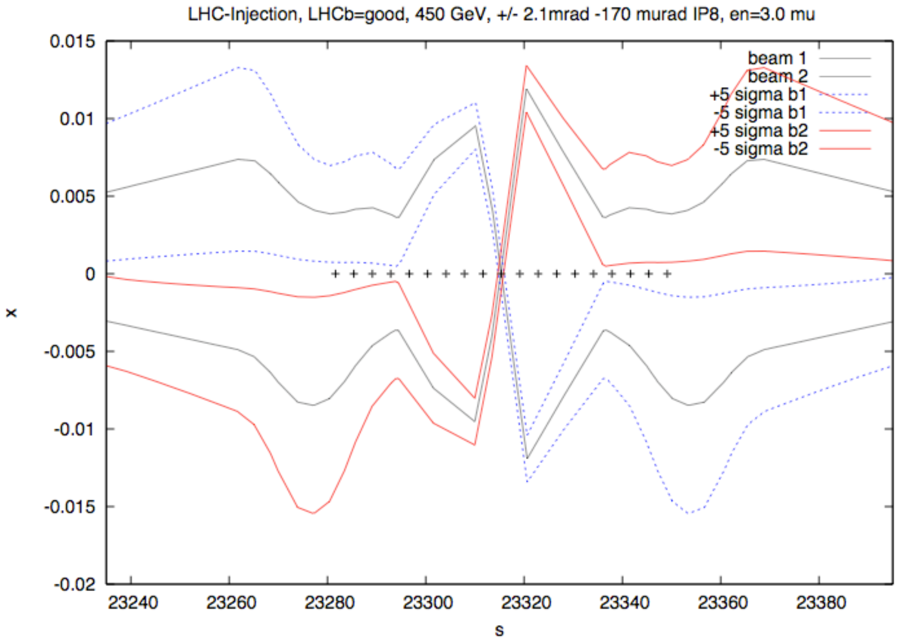
+/- 5σ beam envelope at IP8, injection
crosses mark the 25ns encounters
Beams are separated at IP and the first encounters #1 ... #4

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

Situation in IR8 at Injection:

E=450 TeV, ε=3.0μrad,
LHCb Effect: "internal" horizontal crossing angle = x' = +/- 2.1 mrad
"external" hor. crossing angle to avoid parasitic encounters – 170 μrad const.
vertical separation bump Δy = 2mm
This combination has to avoid encounters at any position.

Horizontal plane: LHCb = GOOD



+/- 5σ beam envelope at IP8, injection
crosses mark the 25ns encounters
Beams are separated at any encounter

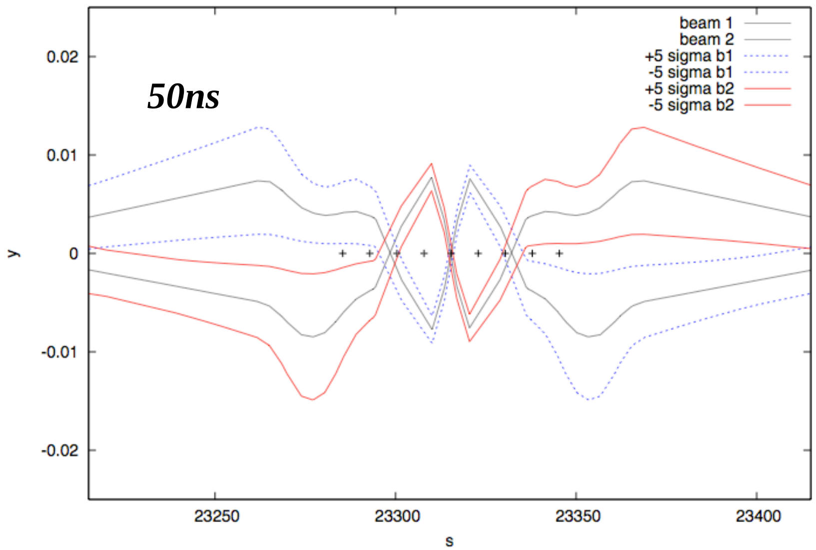
x'=-2.1mrad -170μrad = 2.27 mrad

No Problem.

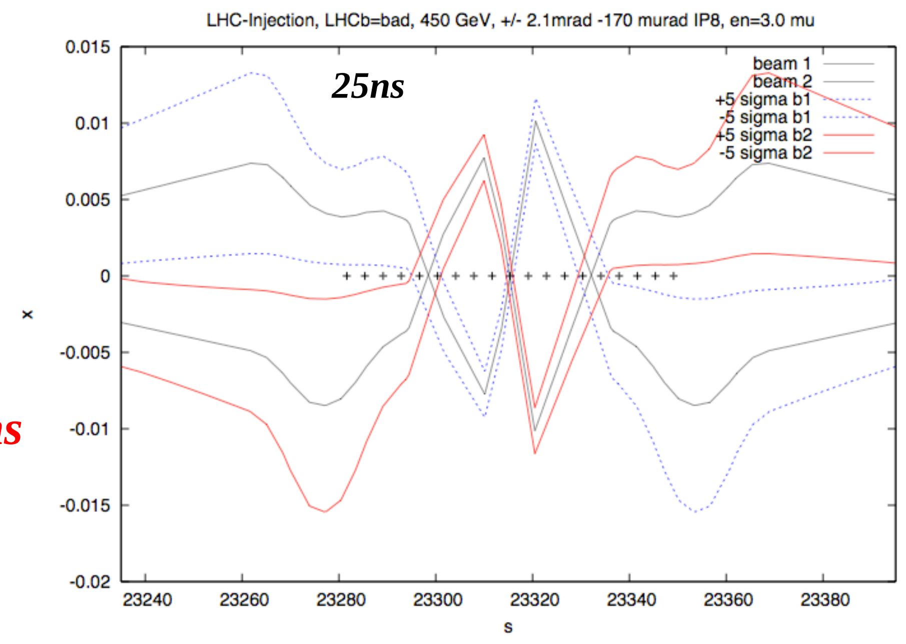
Situation in IR8 at Injection:

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.

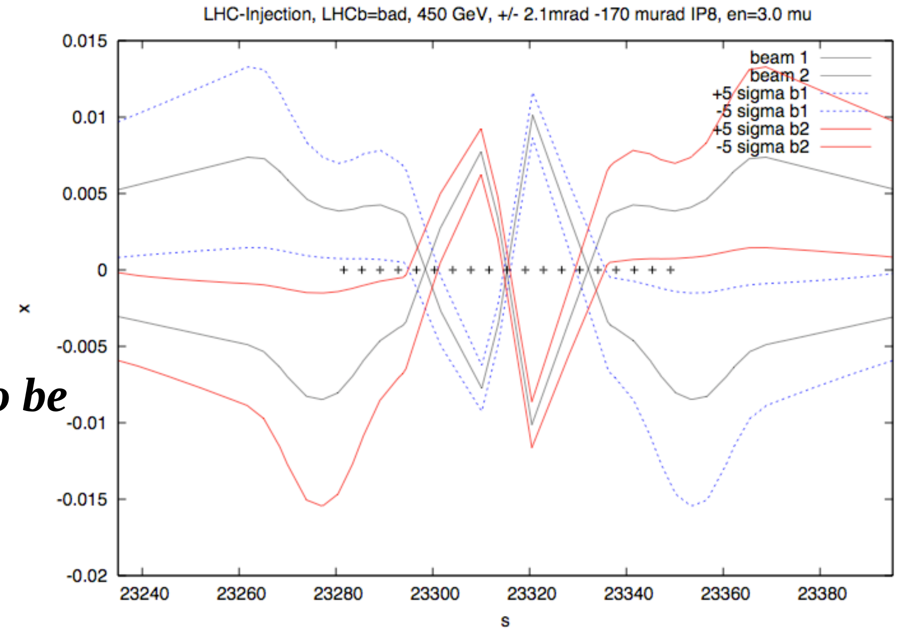


+/- 5σ beam envelope at IP8
Beams are crossing over between two 50ns encounters
x'= +2.1mrad -170μrad = +1.93 mrad
cross over between two 50ns encounters.



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

Situation in IR8 at Injection:



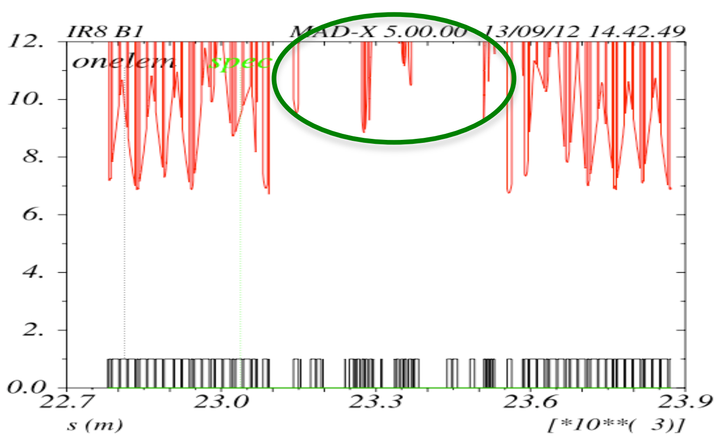
Horizontal plane: LHCb = BAD

Nota Bene:

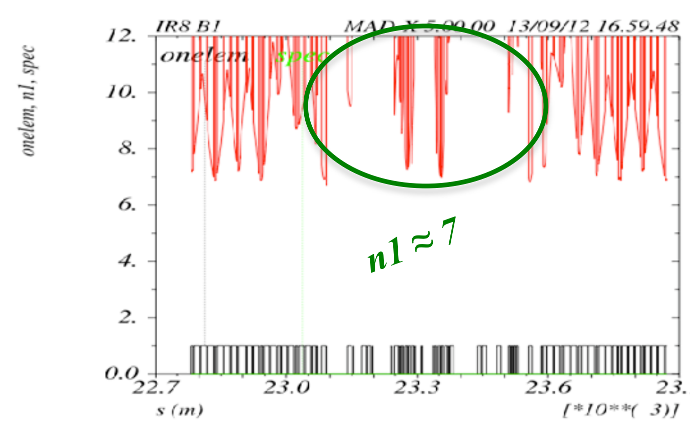
- ***additional hor. Separation wil not help it shifts just the problem between IP8 left / right.***
- ***a larger vertical separation would have to be HUGE to avoid encounters at #5, #6***
- ***and then there is the aperture limit ...***

Aperture Model: for present situation

all flags =0, flat orbits



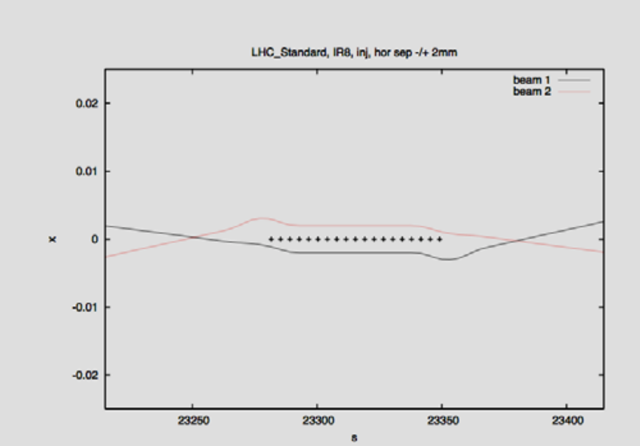
all flags = on



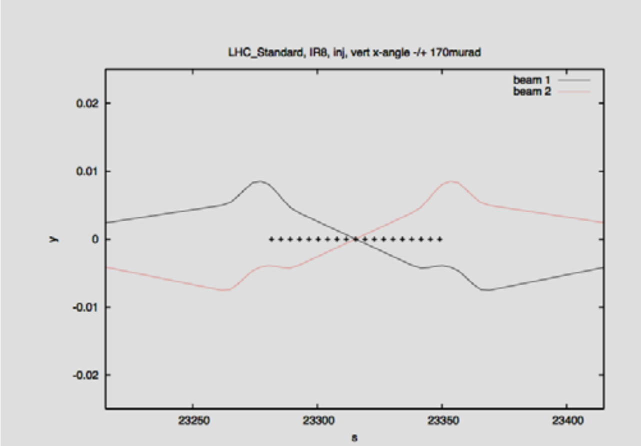
Swapping the Planes ... ?

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

Idea: hor separation $\Delta x = 2.0$ *mm*
vert. crossing angle $y' = 170\ \mu rad$



hor.separation = +/- 2mm

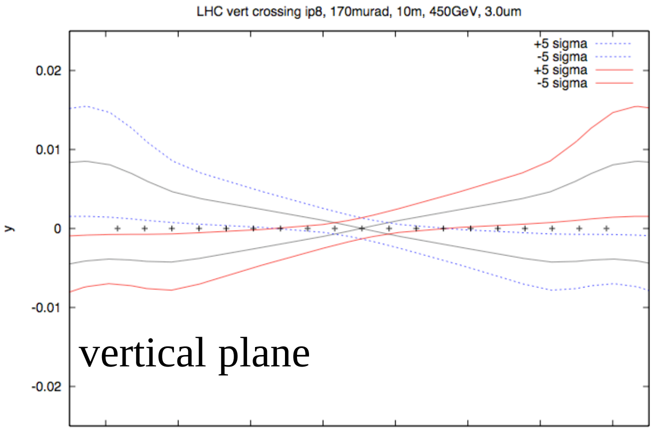


vert. angle = 170μrad

Swapping the Planes ... ?

Beam Envelopes:

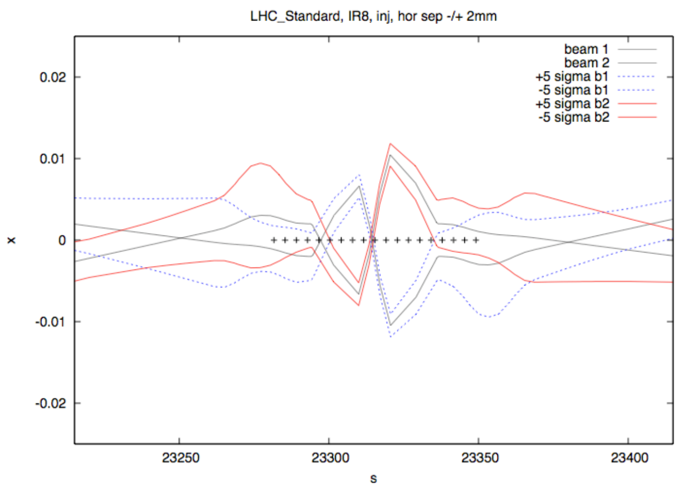
Δx = 2.0 mm, y’ = 170 μrad, LHCb = on



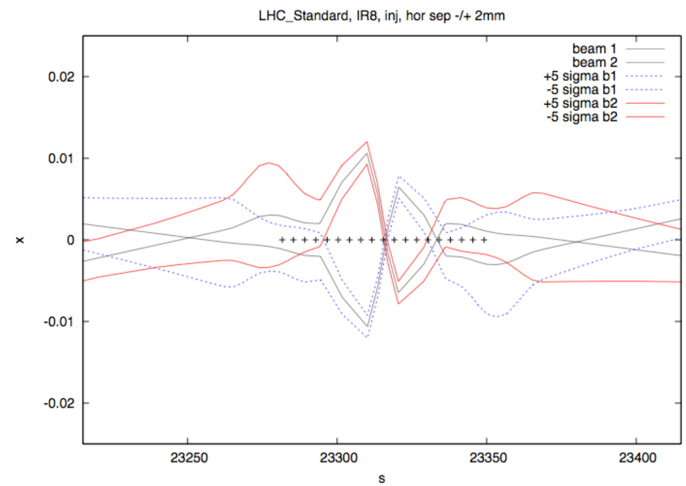
vertical plane

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)



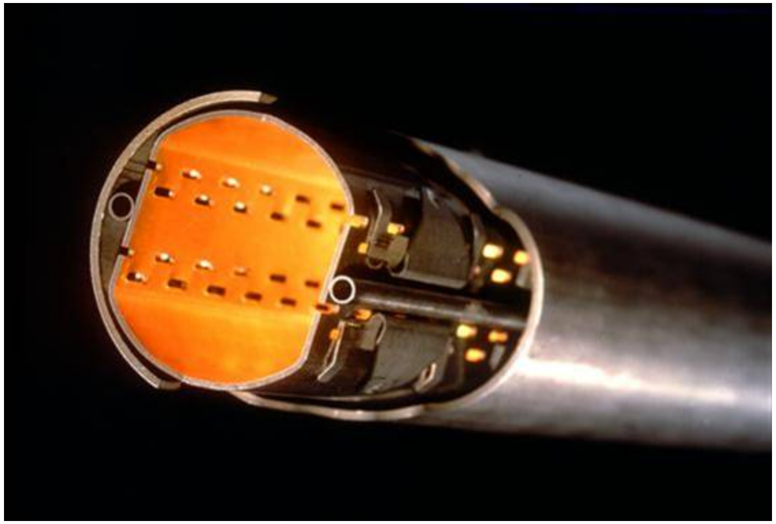
horizontal plane: LHCb = good



LHCb = bad

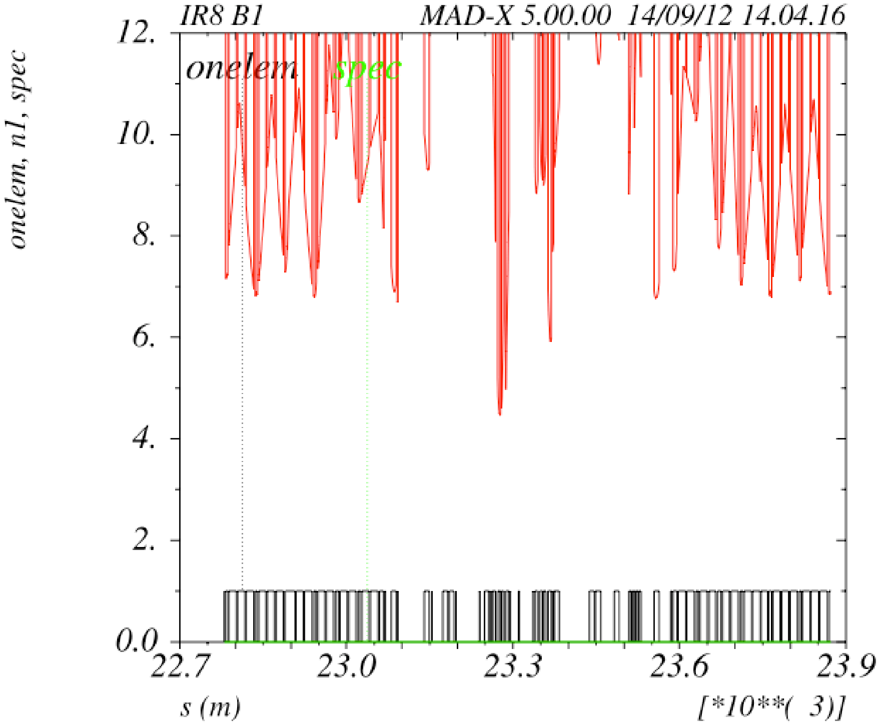
The scheme works for any LHCb polarity and guarantees sufficient separation at ANY encounter !!

But ...



LHC beam screen is not symmetric hor. / vert.

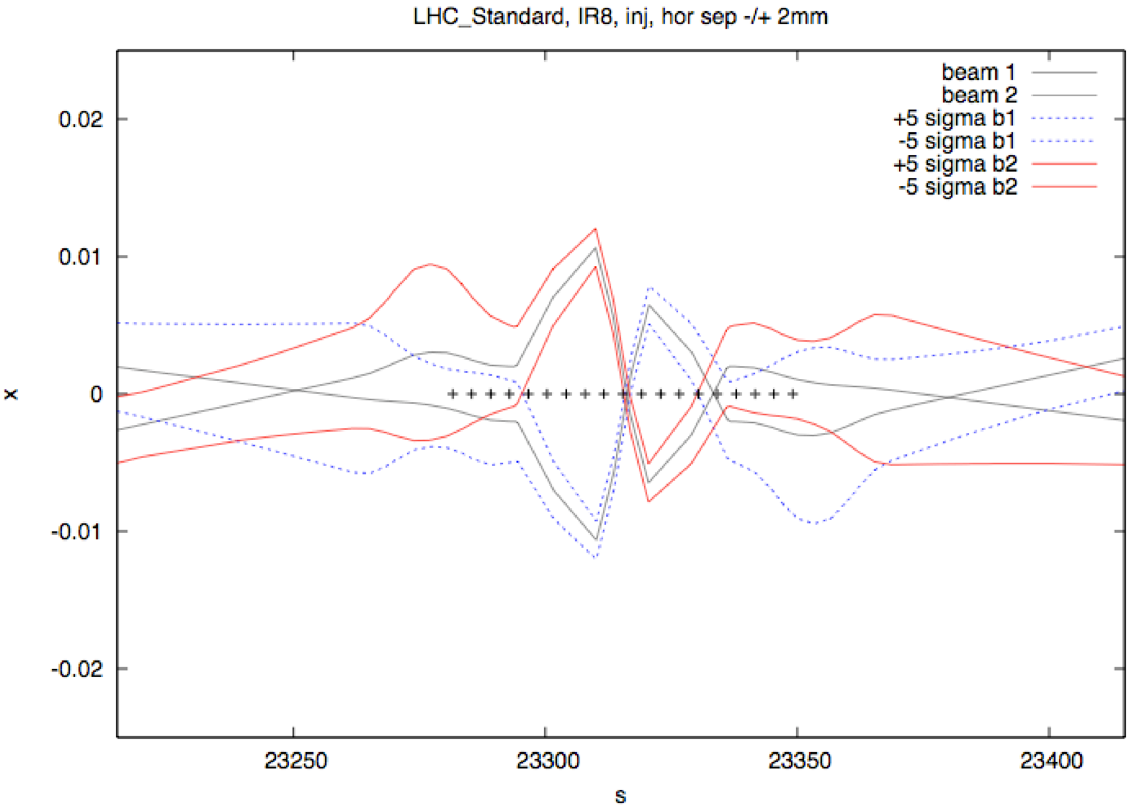
Aperture Model
n1 ≈ 4.5



Optimisation between

realistic emittance (-> determines crossing angle)
assumptions for aperture calculations "ε, cor"
reducing the crossing angle to the minimum
new ideas ??

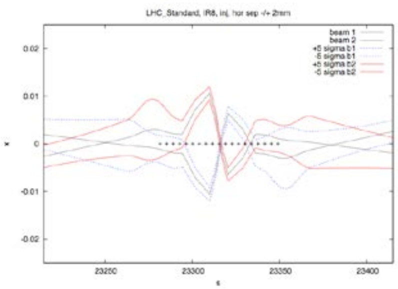
I). Installation of new magnets to close the vert. crossing bump before the inner trip



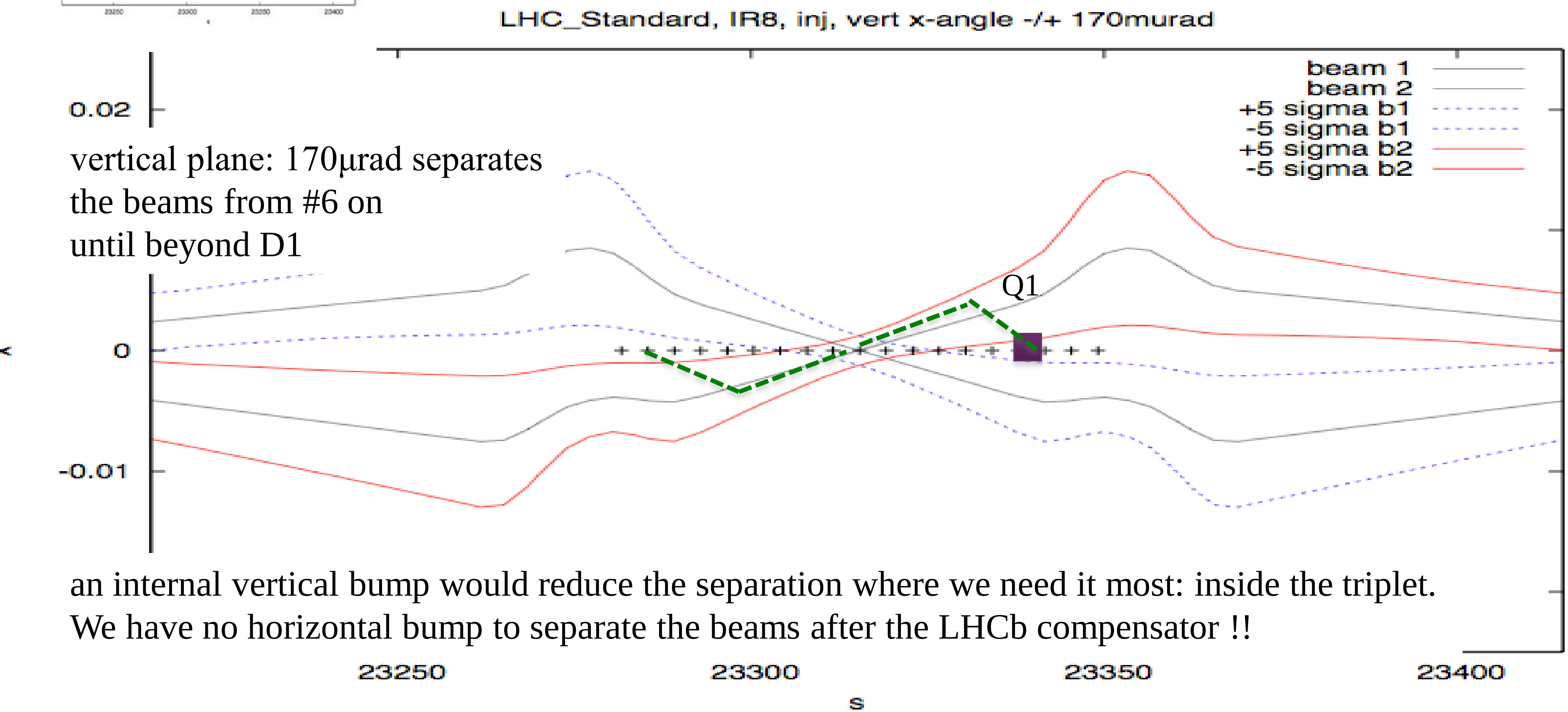
horizontal plane:
we need separation from #6 on

I). Installation of new magnets

to close the vert. crossing bump before the inner triplet ?



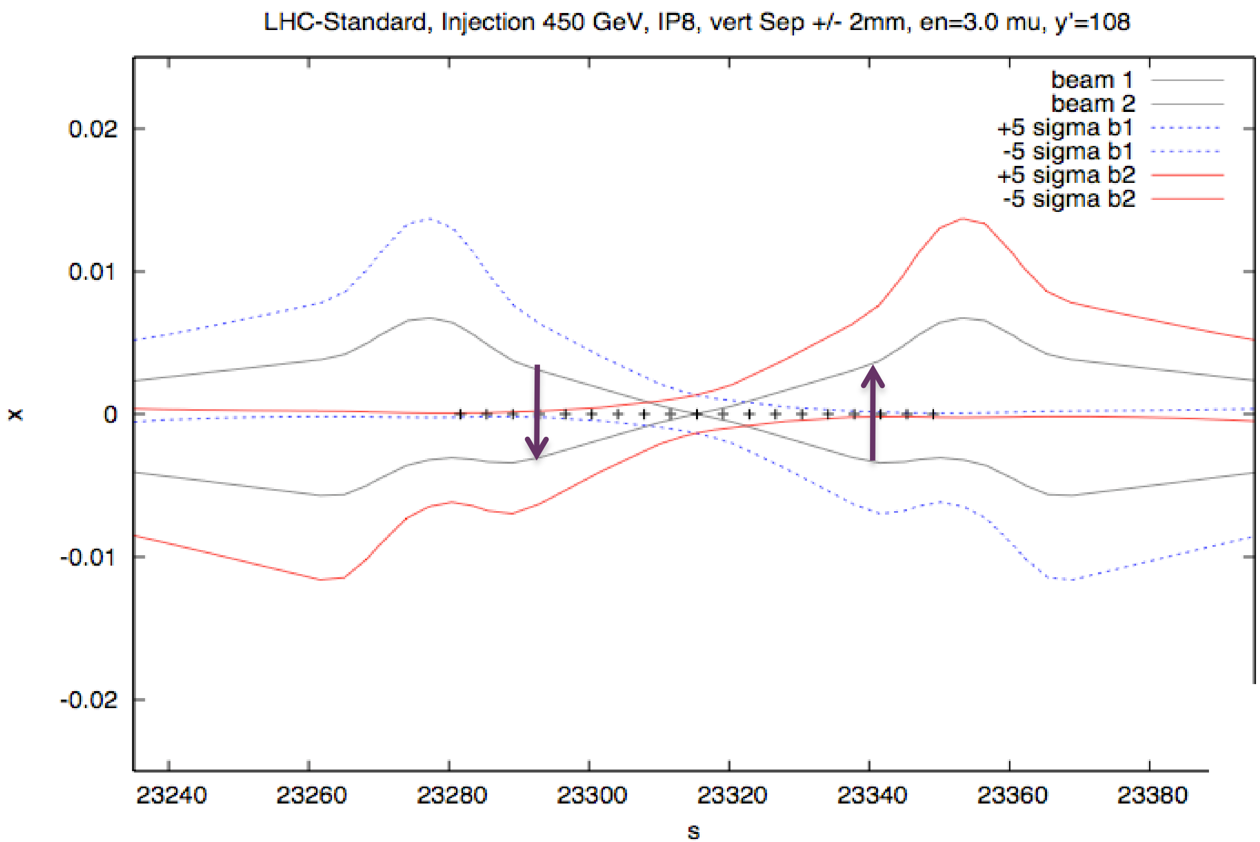
horizontal plane



vertical plane: 170μrad separates the beams from #6 on until beyond D1

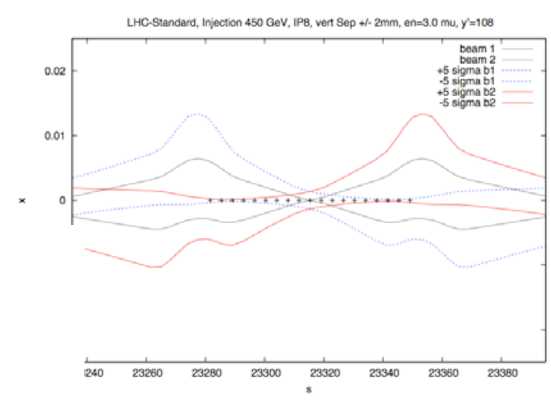
an internal vertical bump would reduce the separation where we need it most: inside the triplet.
We have no horizontal bump to separate the beams after the LHCb compensator !!

II). *Using the mcbx coils to flatten the vert. crossing bump inside the triplet?*
Reducing the crossing angle to the bare minimum ...



vertical plane:

y'=108 µrad
ε=3.0µrad
mcbx1= -/+ 1.1 10^{-5}
to flatten the orbit

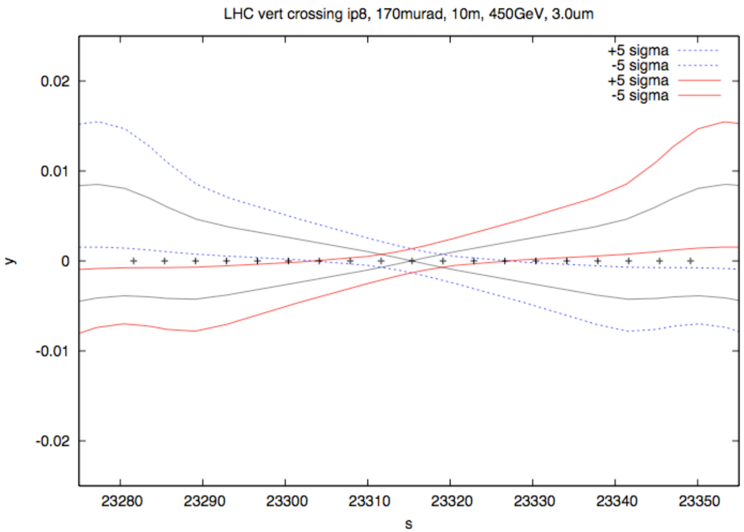


bad example: too strong
mcbx1= -/+ 5 10^{-5} i.e. too strong

III). Optimising Y’

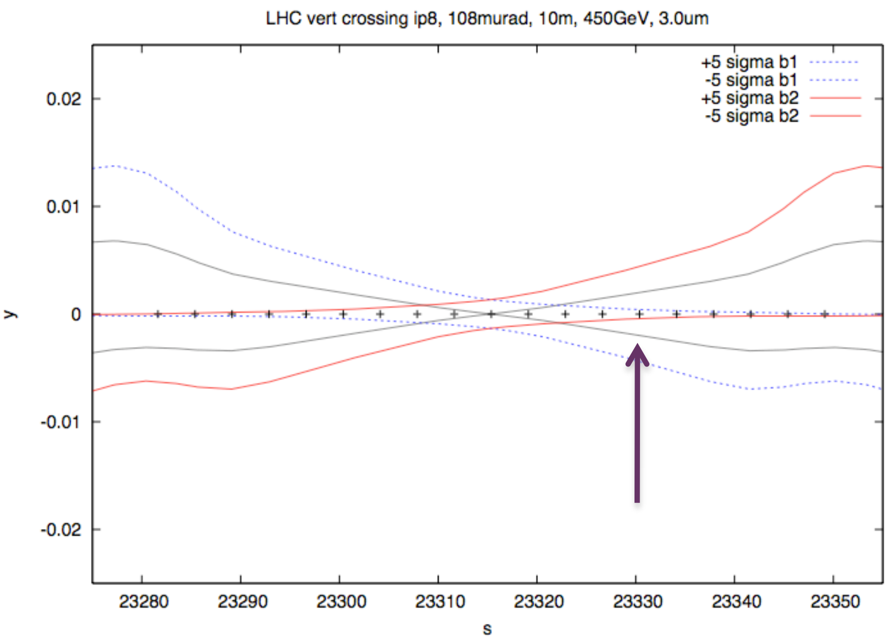
Reducing the crossing angle to the bare minimum ...

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

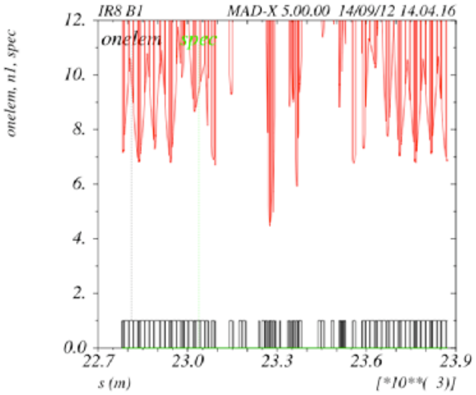


on_xvi=1.0 = 170 μrad

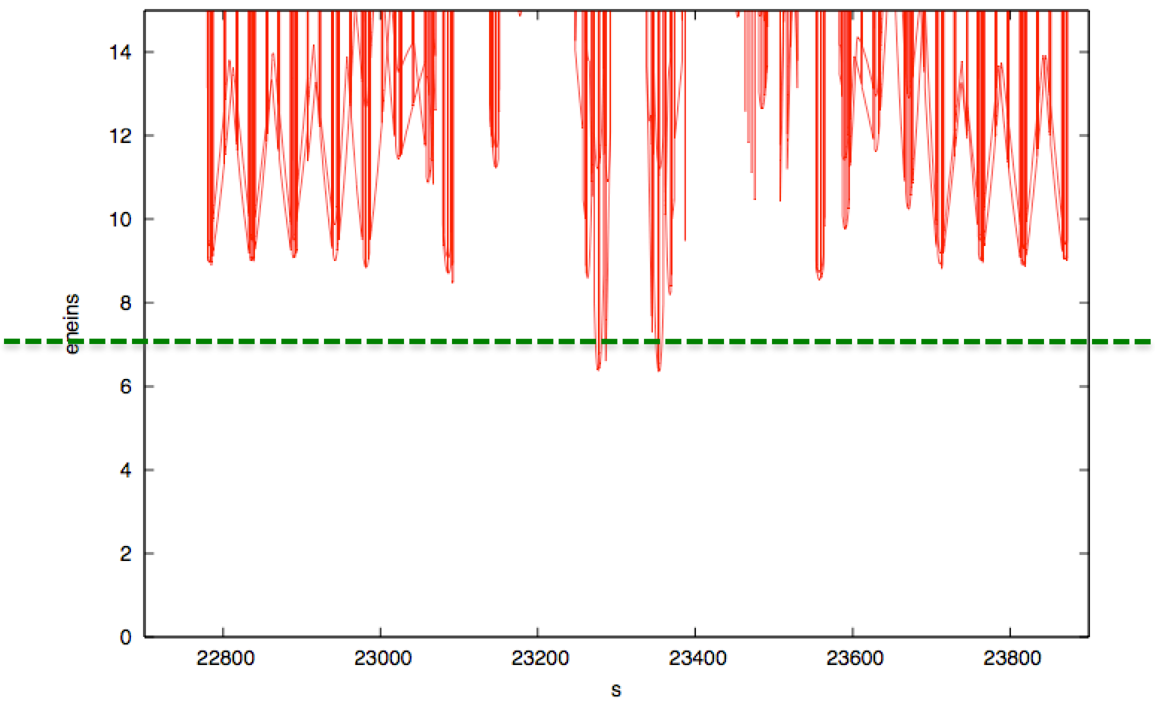
on_xv i= 0.8 = 136 μrad + LHC b= 108 μrad



IV). And again the Aperture
... for the pre-defined "Aperture Settings"



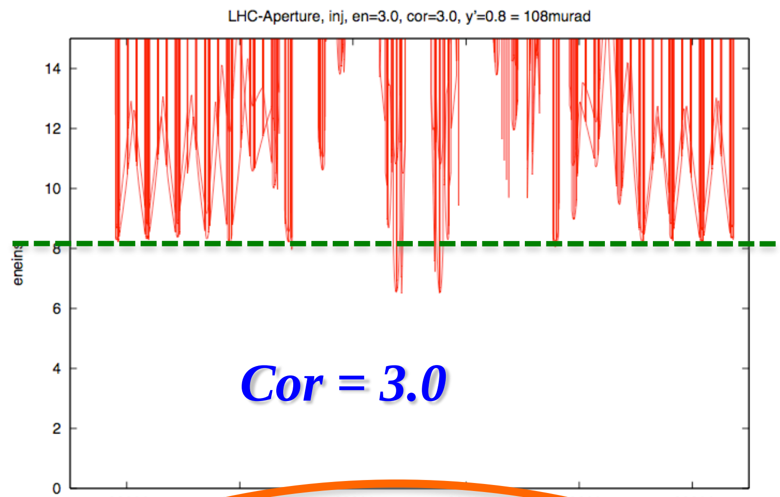
y'=170μrad

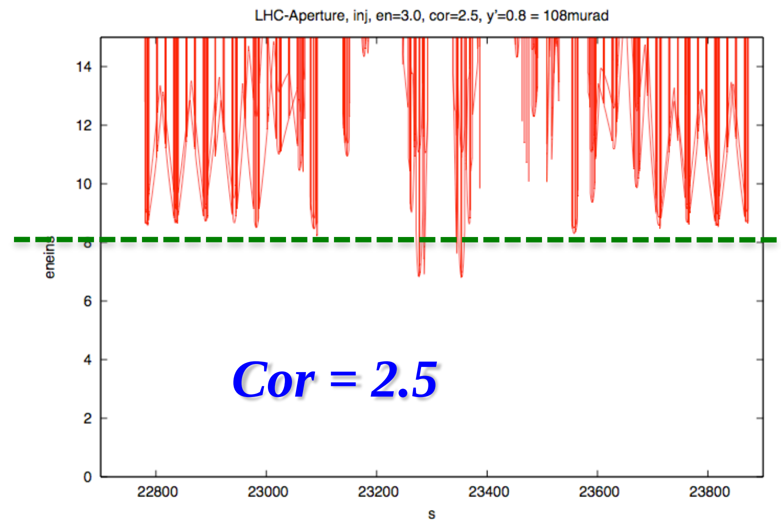


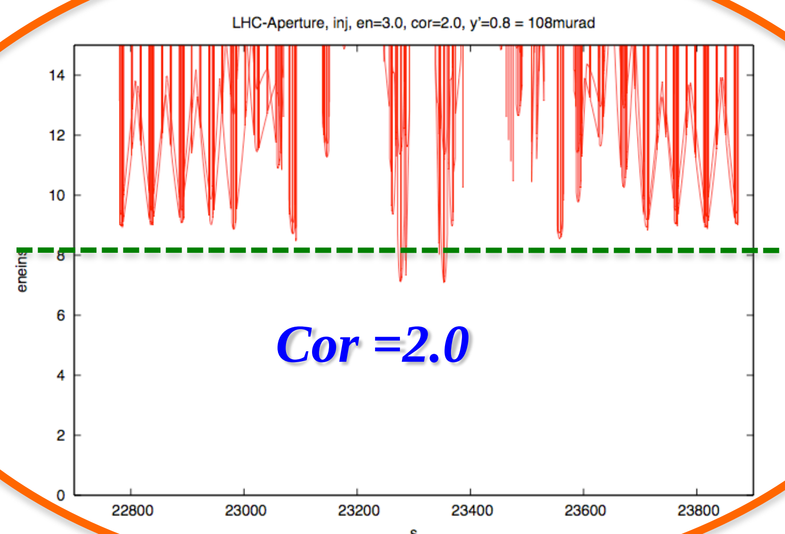
y'=108μrad

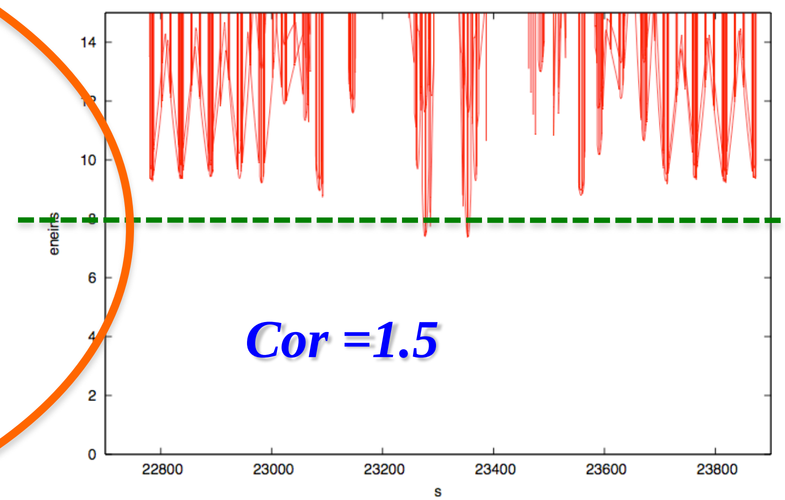
V) Aperture Scans

$\varepsilon = 3.0\mu rad$



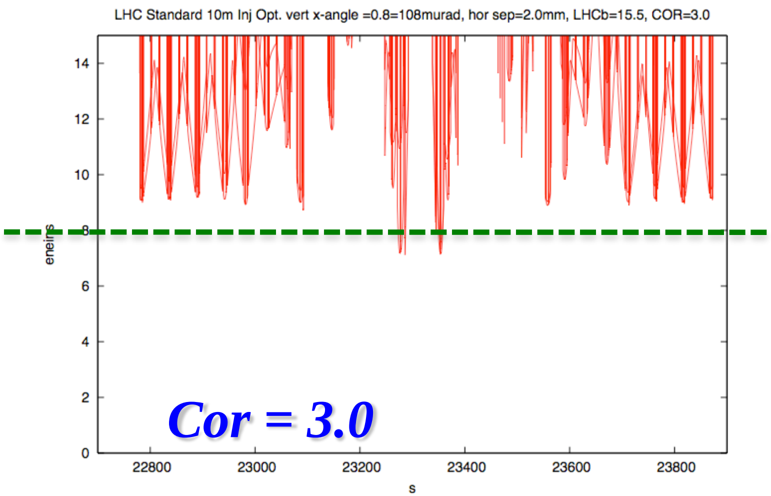


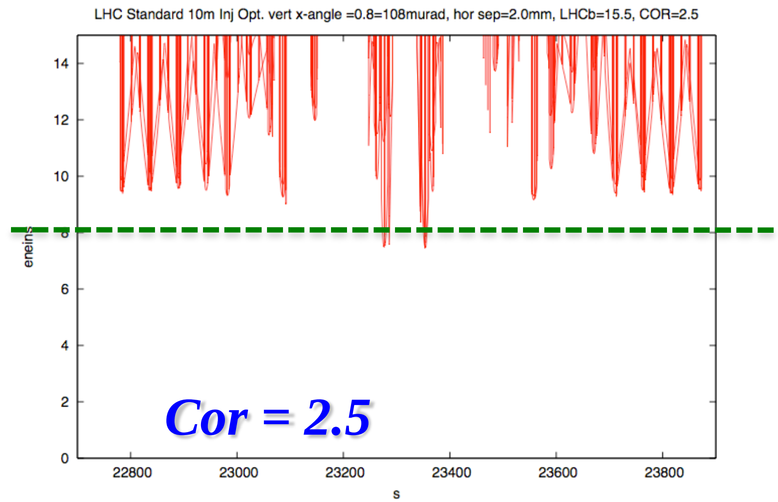


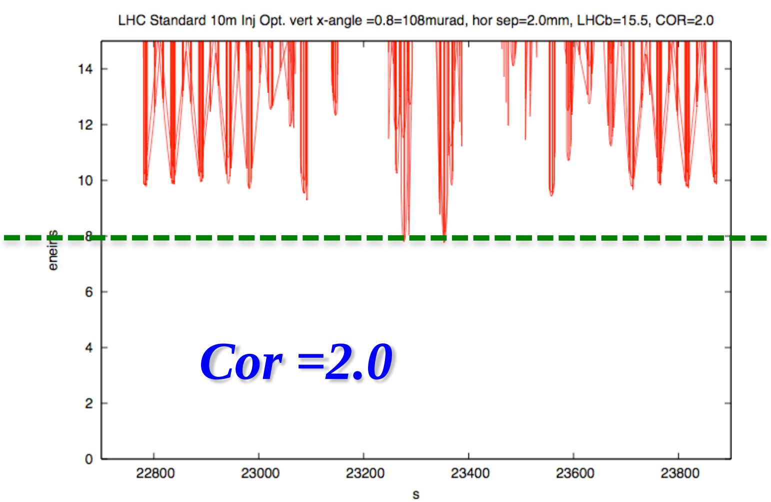


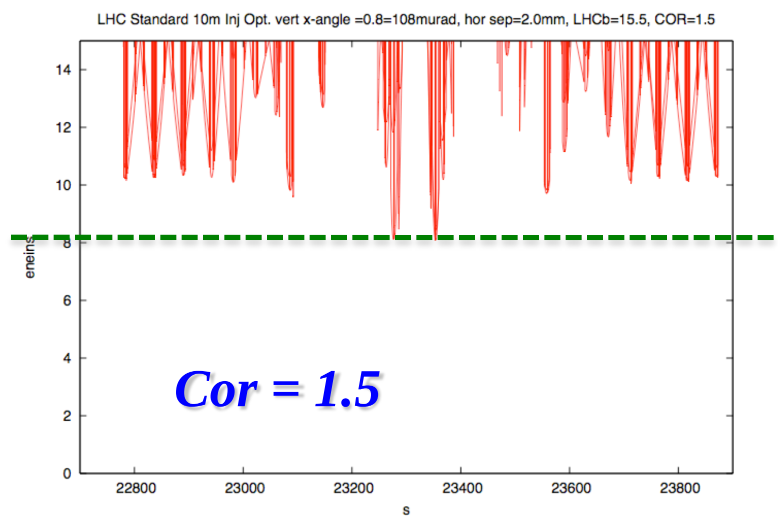
V) Aperture Scans

ε = 2.5μrad



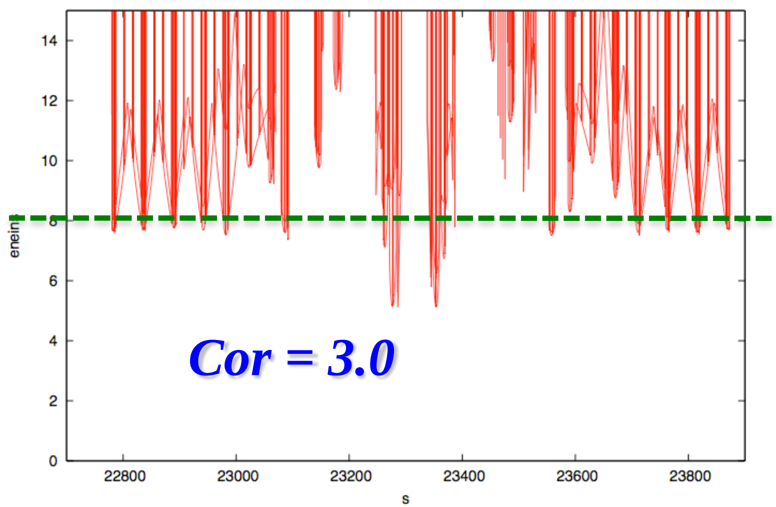


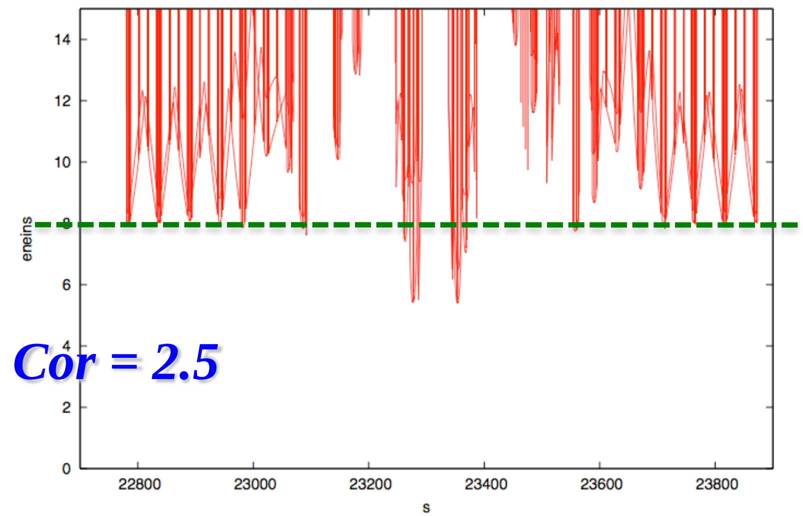


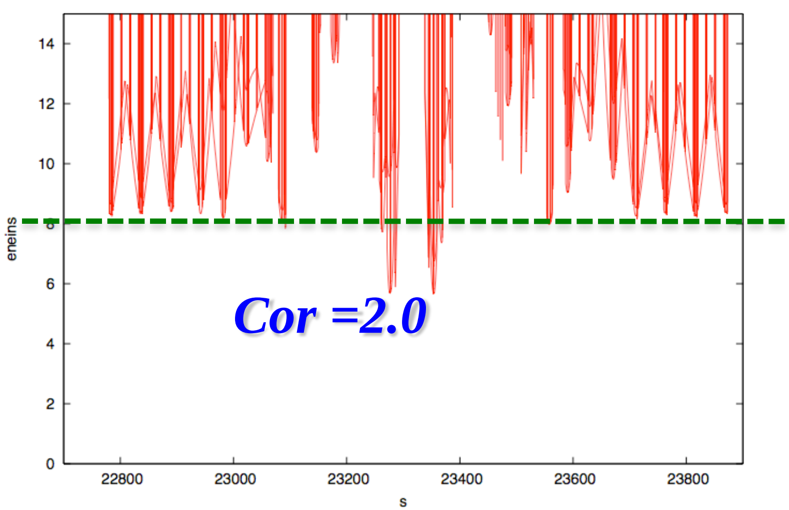


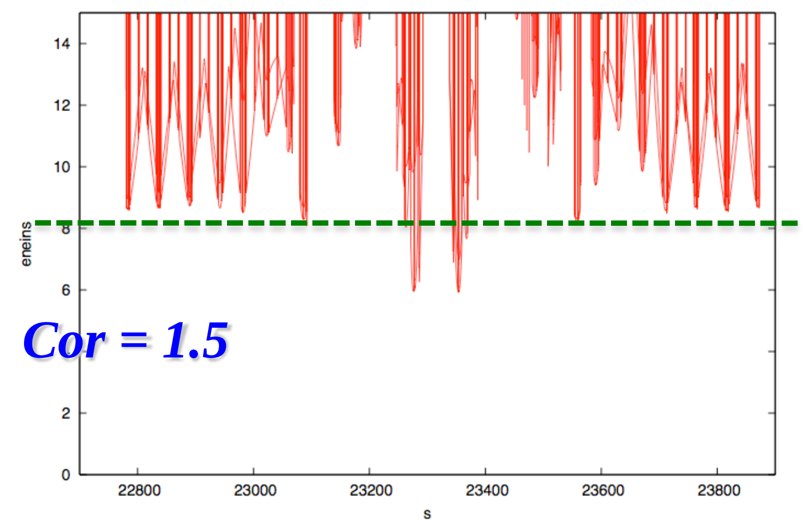
V) Aperture Scans

ε = 3.5μrad









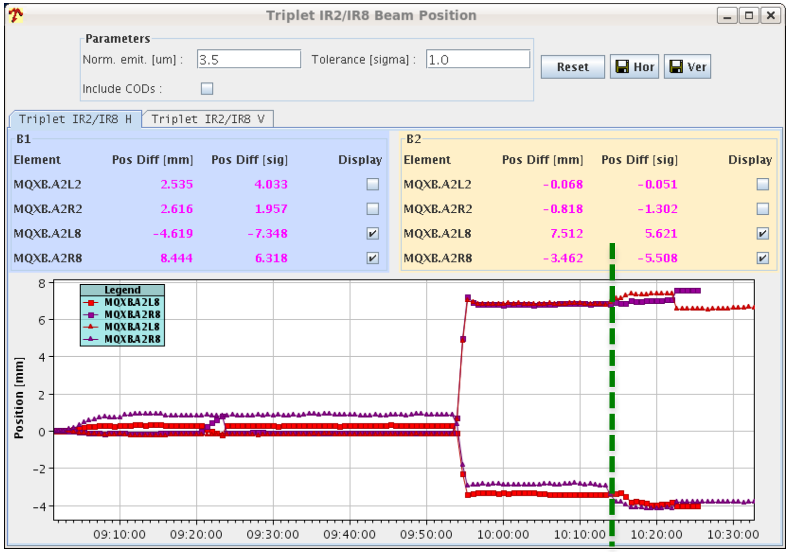
VI.) ... and finally the measurements

MD: 29-Nov-2012, 9:00-10:34h
Logbook plots: 6-Dez-2012

hor. VdM bump ...
to avoid artificial limitations of vert. aperture.

+6mm

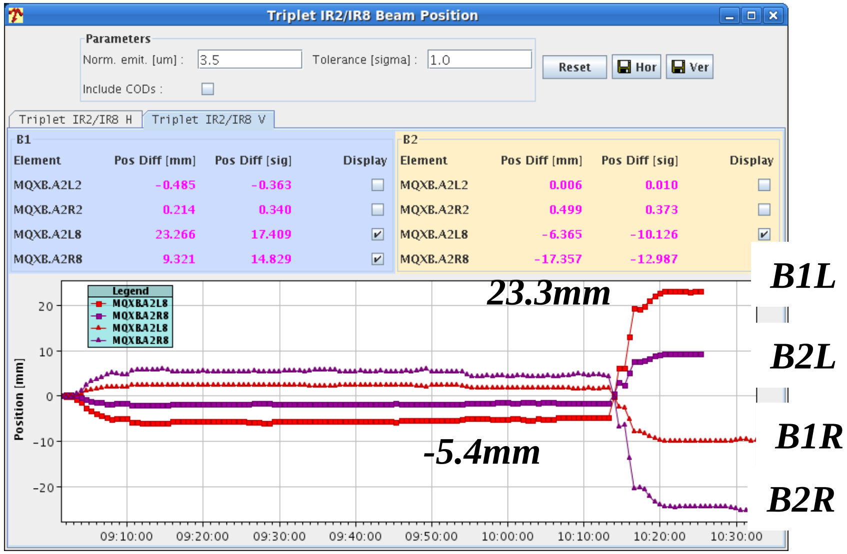
-4mm



vert. VdM bump ...
to measure vert. aperture.

+20mm

-20mm



VI.) ... *and finally the measurements*

(vert.) orbits beam1

data_set 194, 9:50:25h
at aperture limit
(1st direction)

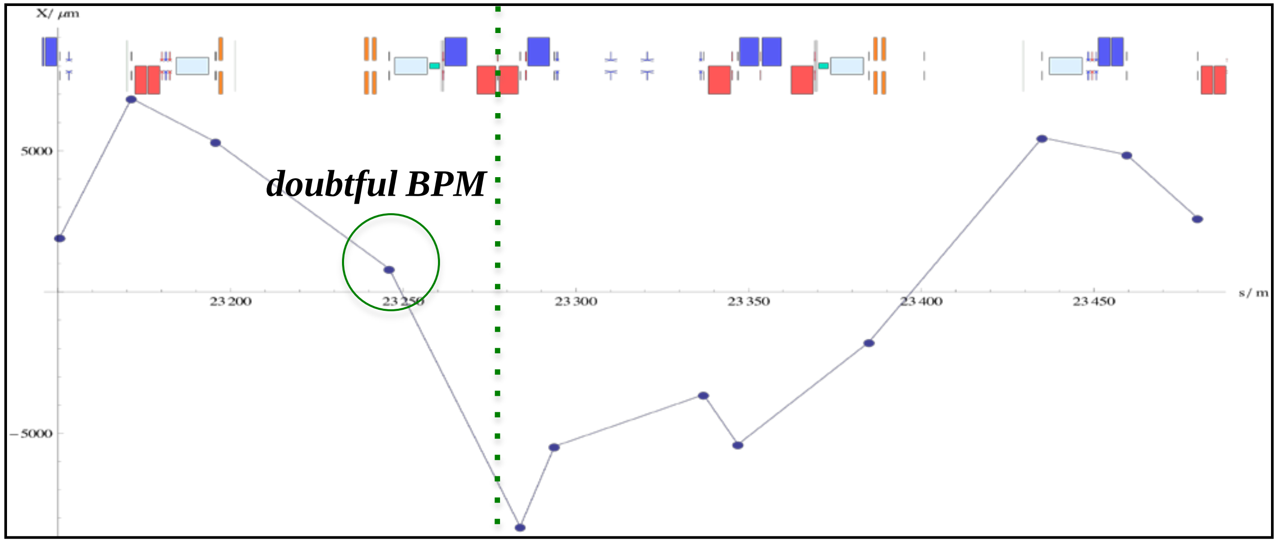
BPM.8L8.B1	V	1	772.3	0.0	0.0	0	0	OK
BPM.7L8.B1	V	1	174.0	0.0	0.0	0	0	OK
BPMR.6L8.B1	V	1	-315.5	0.0	0.0	0	0	OK
BPM.5L8.B1	V	1	2056.2	0.0	0.0	0	0	OK
BPMYB.4L8.B1	V	1	9010.8	0.0	0.0	0	0	OK
BPMWB.4L8.B1	V	1	6950.5	0.0	0.0	0	0	OK
BPMSX.4L8.B1	V	1	820.0	0.0	0.0	134217729	1	
BPMS.2L8.B1	V	1	-12684.9	0.0	0.0	0	0	OK
BPMSW.1L8.B1	V	1	-9128.2	0.0	0.0	0	0	OK
BPMSW.1R8.B1	V	1	-6708.6	0.0	0.0	0	0	OK
BPMS.2R8.B1	V	1	-7460.4	0.0	0.0	0	0	OK
BPMSX.4R8.B1	V	1	-2243.4	0.0	0.0	0	0	OK
BPMWB.4R8.B1	V	1	8625.7	0.0	0.0	0	0	OK
BPMYB.4R8.B1	V	1	7669.6	0.0	0.0	0	0	OK
BPMYB.5R8.B1	V	1	3463.4	0.0	0.0	0	0	OK
BPM.6R8.B1	V	1	-94.6	0.0	0.0	0	0	OK
BPM_A.7R8.B1	V	1	-1201.8	0.0	0.0	0	0	OK
BPM.8R8.B1	V	1	-810.1	0.0	0.0	0	0	OK

data_set 295, 9:50:25h
at aperture limit
(2nd direction)

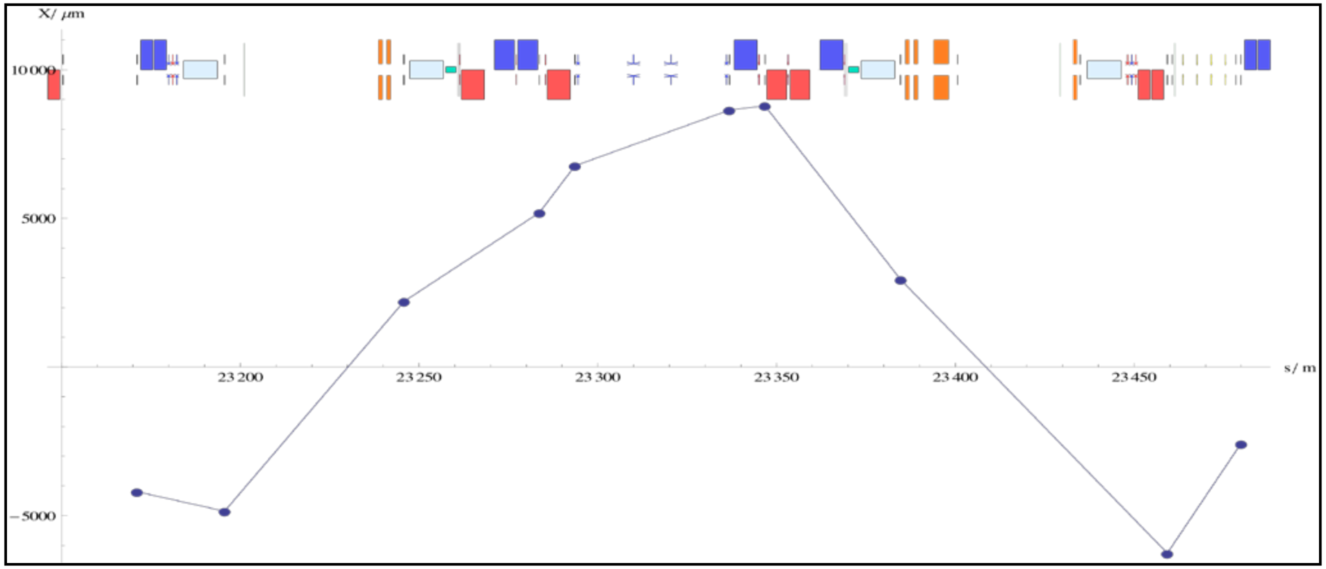
BPMR.6L8.B1	V	1	-1211.0	0.0	0.0	3	1	FEC_BPM_ACQ_FAILURE,FEC_BPM_ERROR_RATE_H
BPM.5L8.B1	V	1	1970.2	0.0	0.0	1	1	FEC_BPM_ACQ_FAILURE
BPMYB.4L8.B1	V	1	-8635.0	0.0	0.0	0	0	OK
BPMWB.4L8.B1	V	1	-7091.8	0.0	0.0	0	0	OK
BPMSX.4L8.B1	V	1	820.0	0.0	0.0	134217729	1	FEC_BPM_ACQ_FAILURE,REMOVED_OP
BPMS.2L8.B1	V	1	11800.9	0.0	0.0	0	0	OK
BPMSW.1L8.B1	V	1	9607.5	0.0	0.0	0	0	OK
BPMSW.1R8.B1	V	1	11003.4	0.0	0.0	0	0	OK
BPMS.2R8.B1	V	1	6013.2	0.0	0.0	0	0	OK
BPMSX.4R8.B1	V	1	2462.8	0.0	0.0	0	0	OK
BPMWB.4R8.B1	V	1	-7598.4	0.0	0.0	0	0	OK

VI.) ... *and finally the measurements*

(vert.) orbits beam1



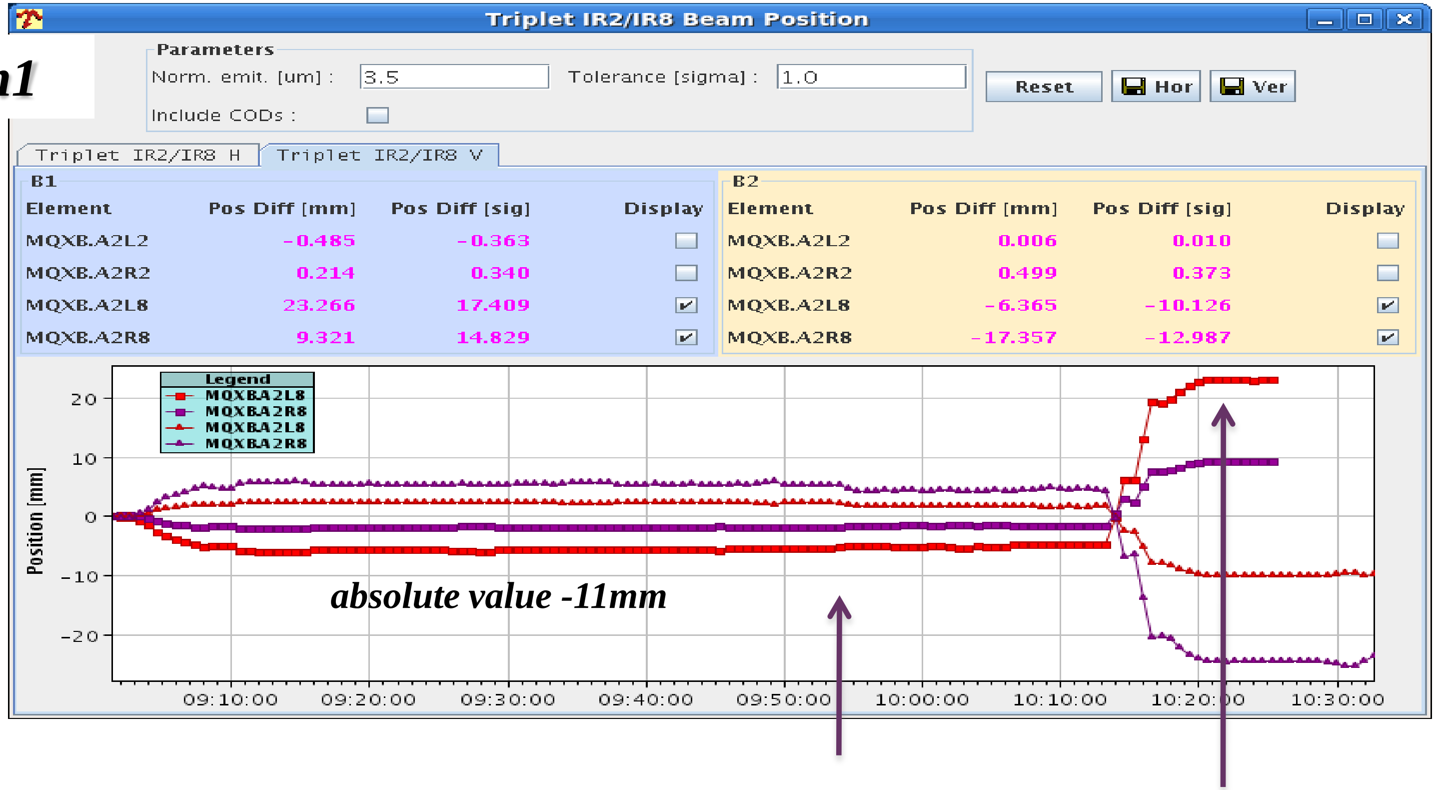
beam2



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

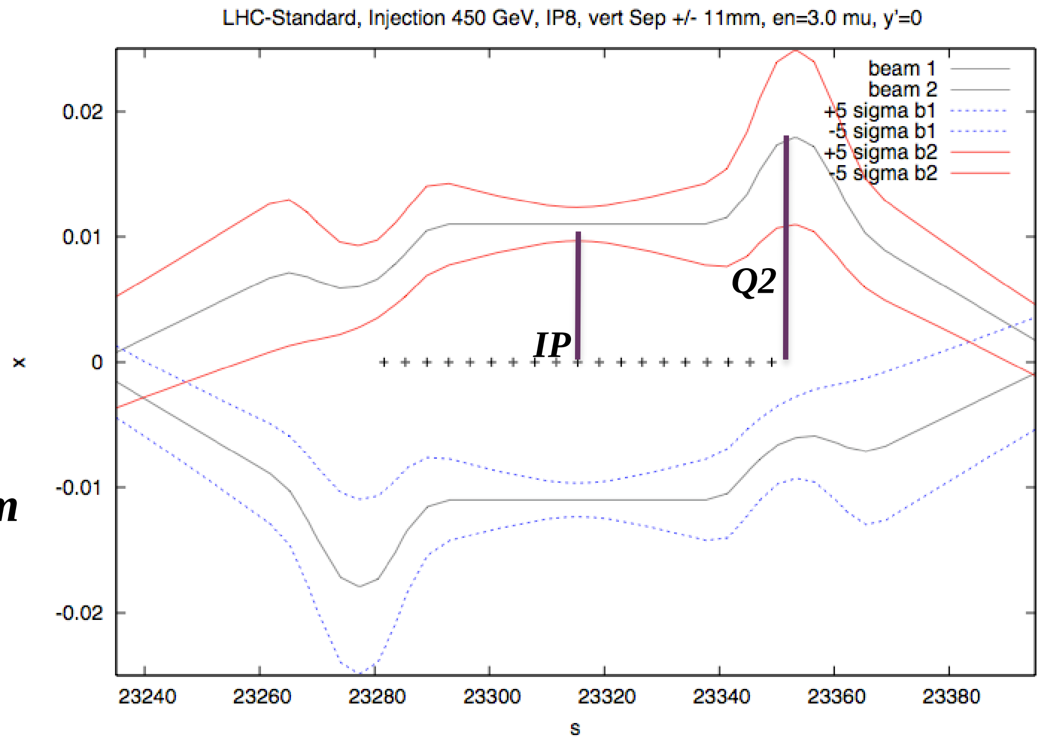
28.7mm + 2* 4σ

β=270m, ε_n=3.5 -> σ=1.5mm

aperture radius = 20.4 mm

cross check & summary

" never trust the BPM readings "
- non-linearity problem –

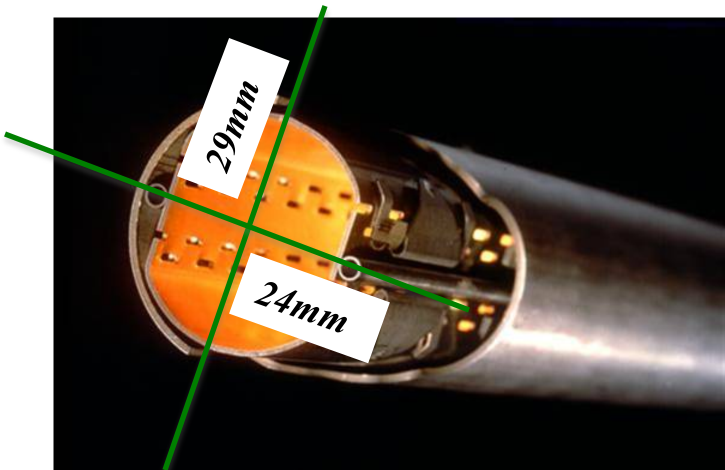


vert. Separation Bump +/- 11 mm

Referring to the IP settings of the bump:
aperture limits obtained at $\Delta y \approx +/-$ 11mm
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

ufffff ... ?????



cross check & summary

Aperture Need:
y'=108 μrad -> Δy = 6.8mm at Q2
resulting n1 margin: n1 = 7
Overall Aperture Measured = 24 mm

In other words: applying 108μrad gives us still margin for 17 mm
... corresponding to 12σ.