Vert Crossing Angle Operation in IR8

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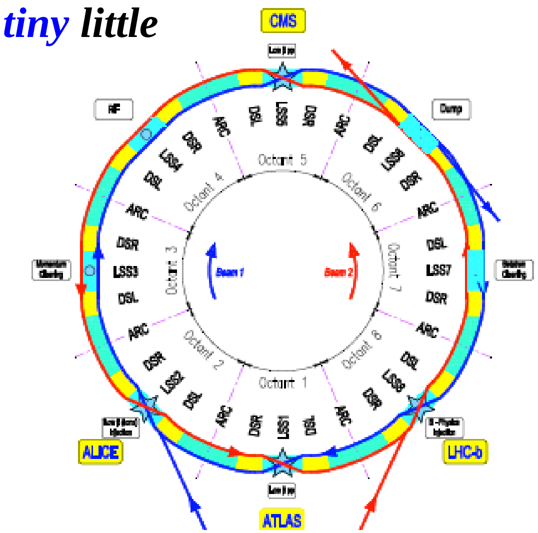
LHCb: The Challenge

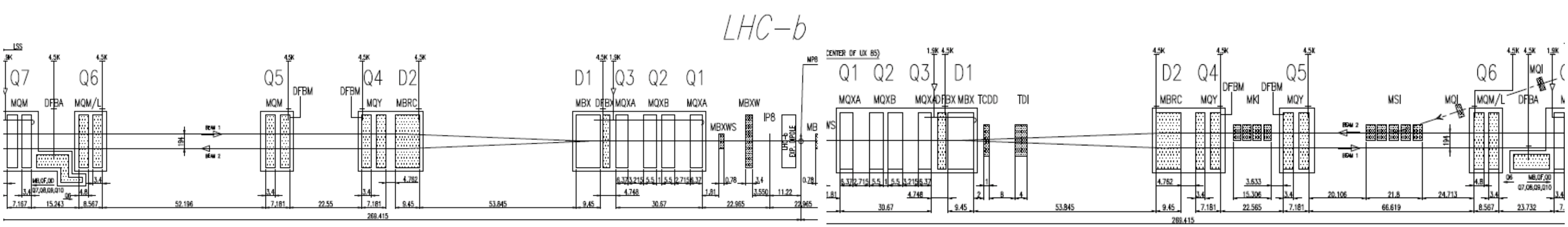
IP8: "natural LHC geometry" and the LHCb spectrometer effect

***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.



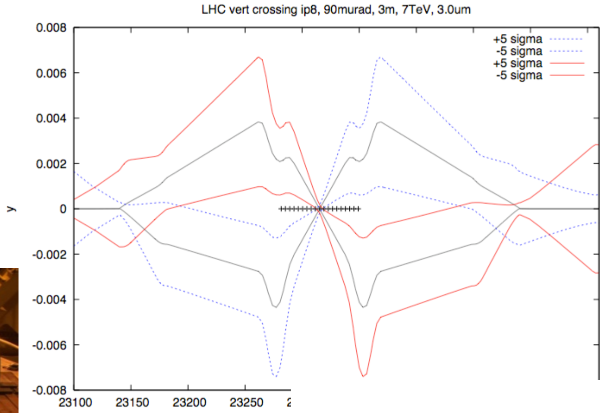
**** hor. crossing angle at 450 GeV: x' = +/- 2.1 mrad***
**** " at 4 TeV: x' = +/- 235μrad***
**** depending on the dipole polarity***



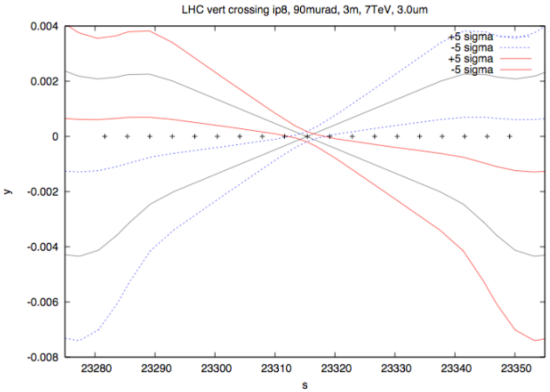
LHC Lattice Layout in IP8

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



hor plane



vert. plane

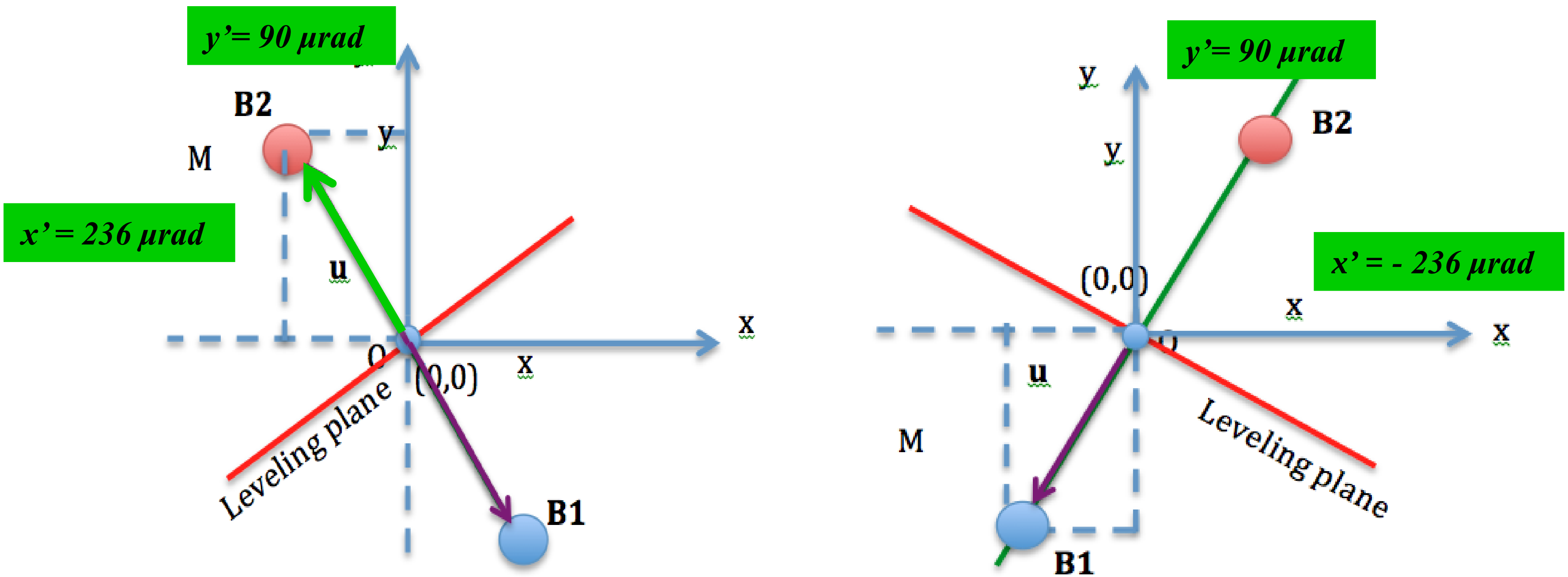
+/- 5σ beam envelope at IP8, in collision mode
crosses mark the 25ns encounters

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,

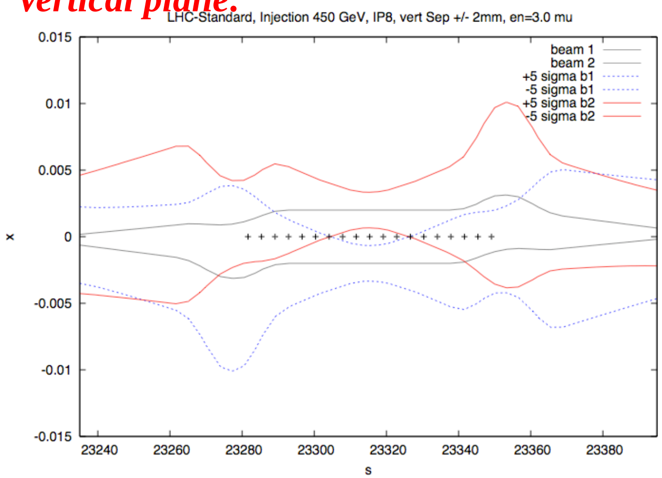
***LHCb Effect:** "internal" horizontal crossing angle x' = +/- 2.1 mrad*

***"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.

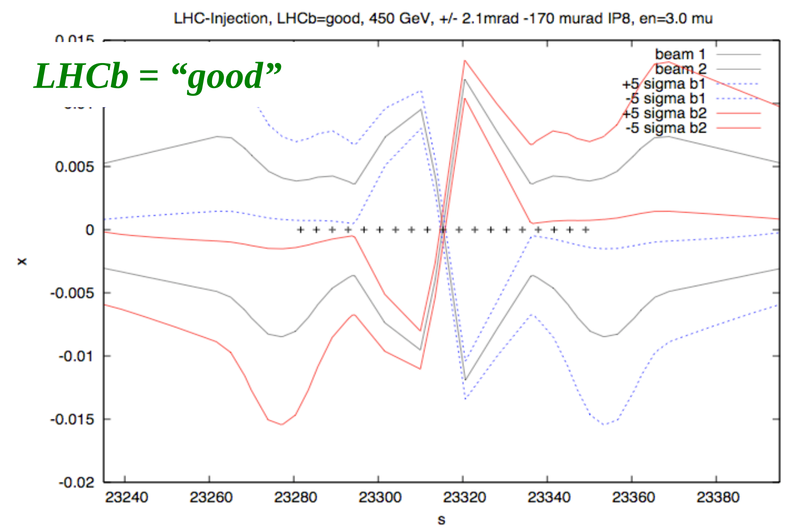
Vertical plane:



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

Beams are separated at IP and the first par. encounters #1 ... 3 due to vert. separation.

LHCb = "good"

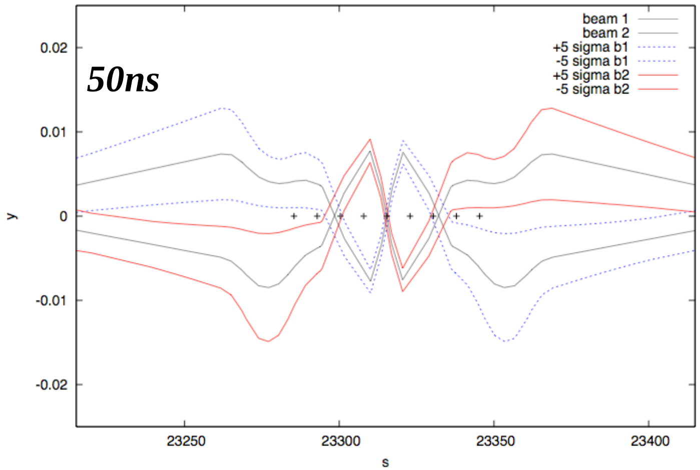


From par. encounter #4 on the horizontal crossing bump has to do the job.

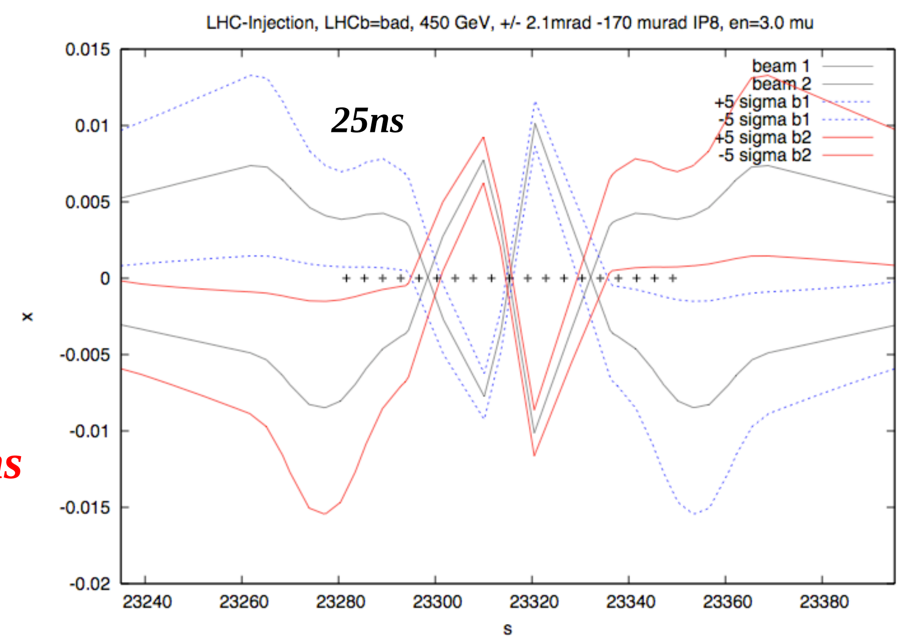
Situation in IR8 at Injection:

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.



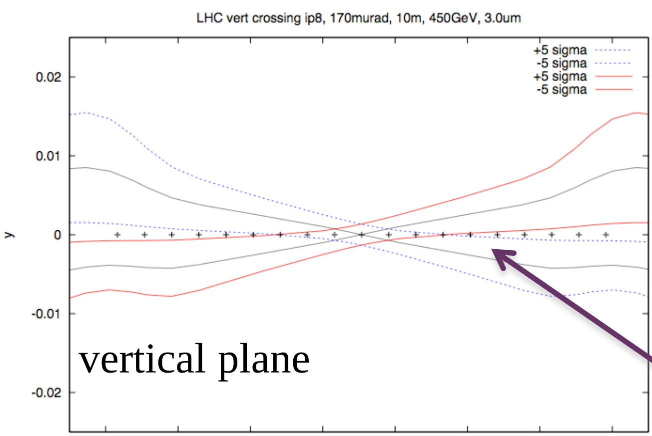
+/- 5σ beam envelope at IP8
Beams are crossing over between two 50ns encounters
x'= +2.1mrad -170μrad = +1.93 mrad
cross over between two 50ns encounters.



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

Swapping the Planes ... ?

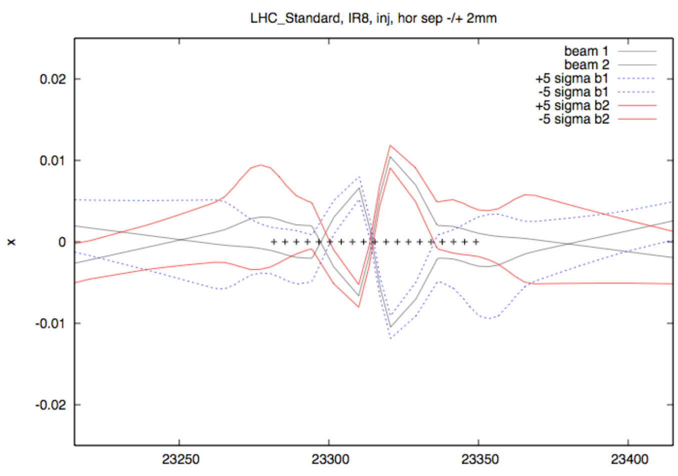
The horizontal crossing angle bump always will have to fight against the bad LHCb polarity.
A vertical crossing angle bump does not !

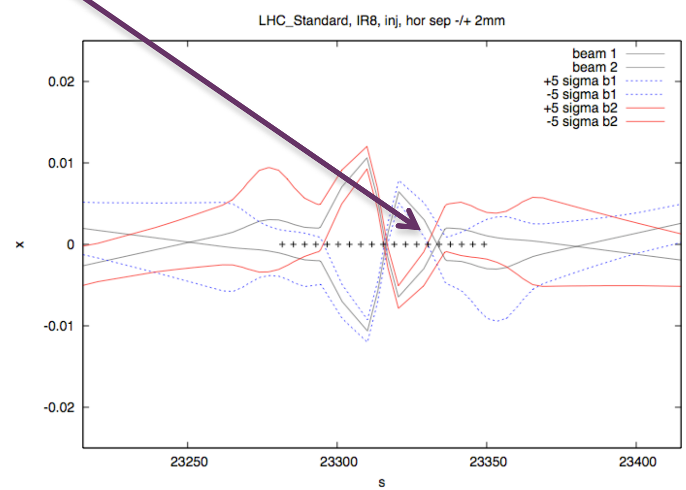


calculate orbits & envelopes for
$\Delta x = 2.0$ mm,
$y' = 170\ \mu rad$, LHCb = on = bad

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)



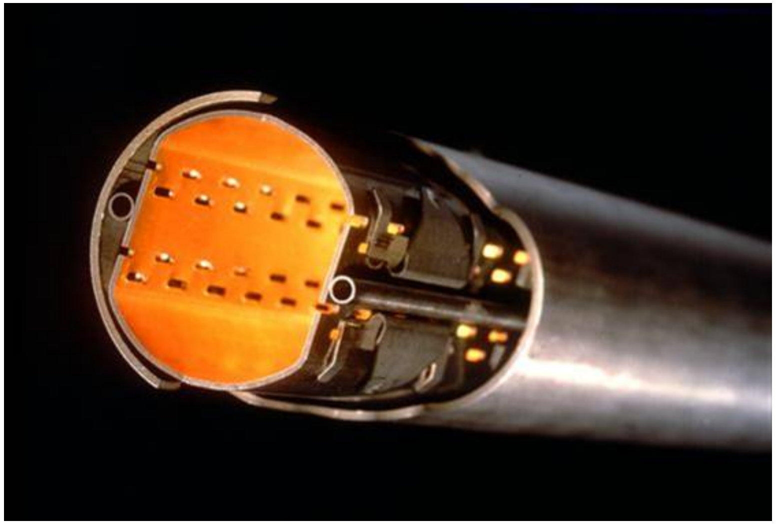


horizontal plane: LHCb = good LHCb = bad

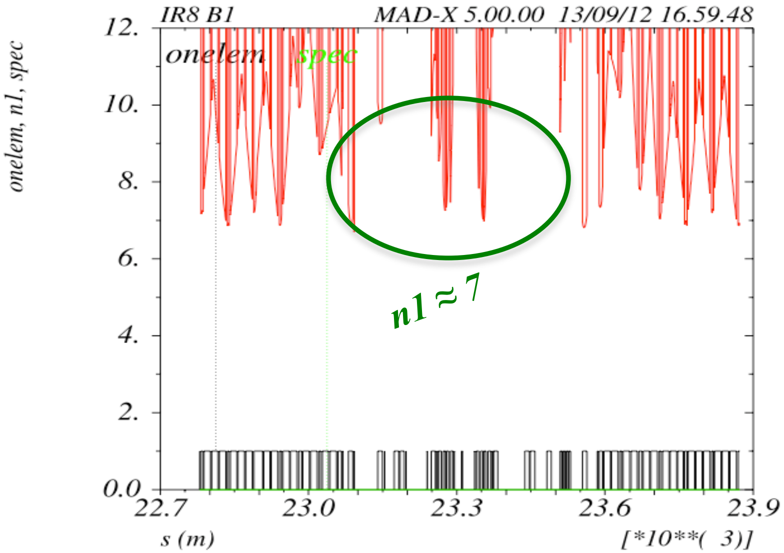
The scheme works for any LHCb polarity and guarantees sufficient separation at ANY encounter !!

But ...

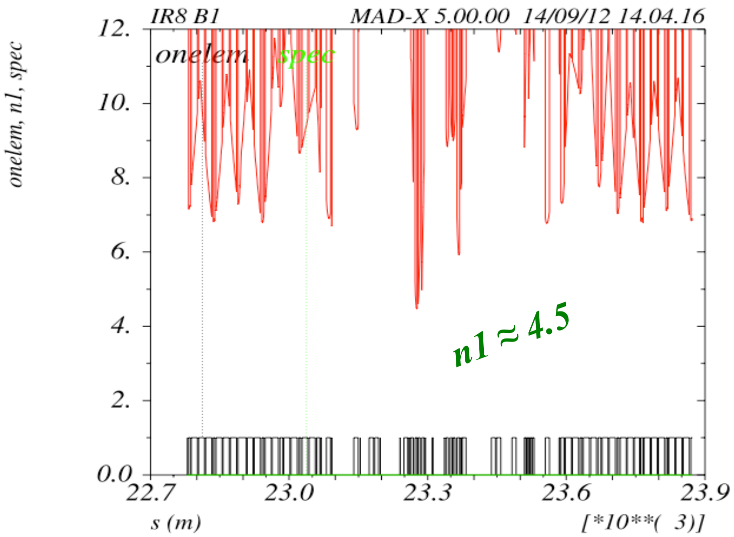
LHC beam screen is not symmetric hor. / vert.



Aperture Model for present situation
n1 ≈ 7



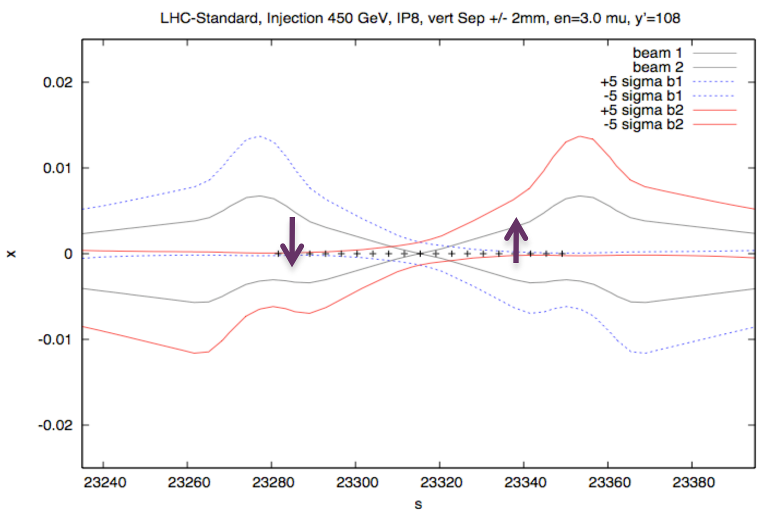
Aperture Model for swapped situation
n1 ≈ 4.5



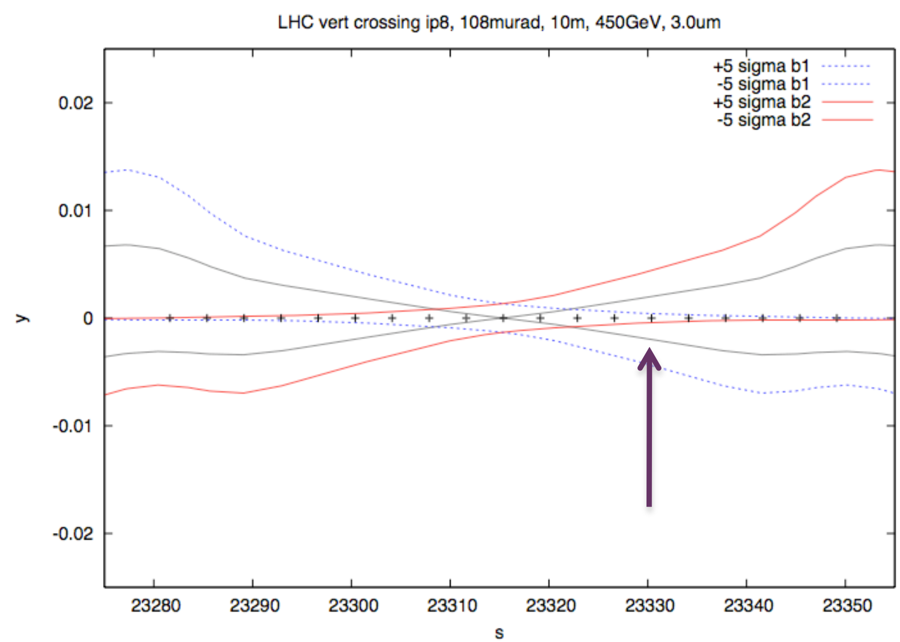
III). Optimising Y':

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

Reducing the crossing angle to the bare minimum ...

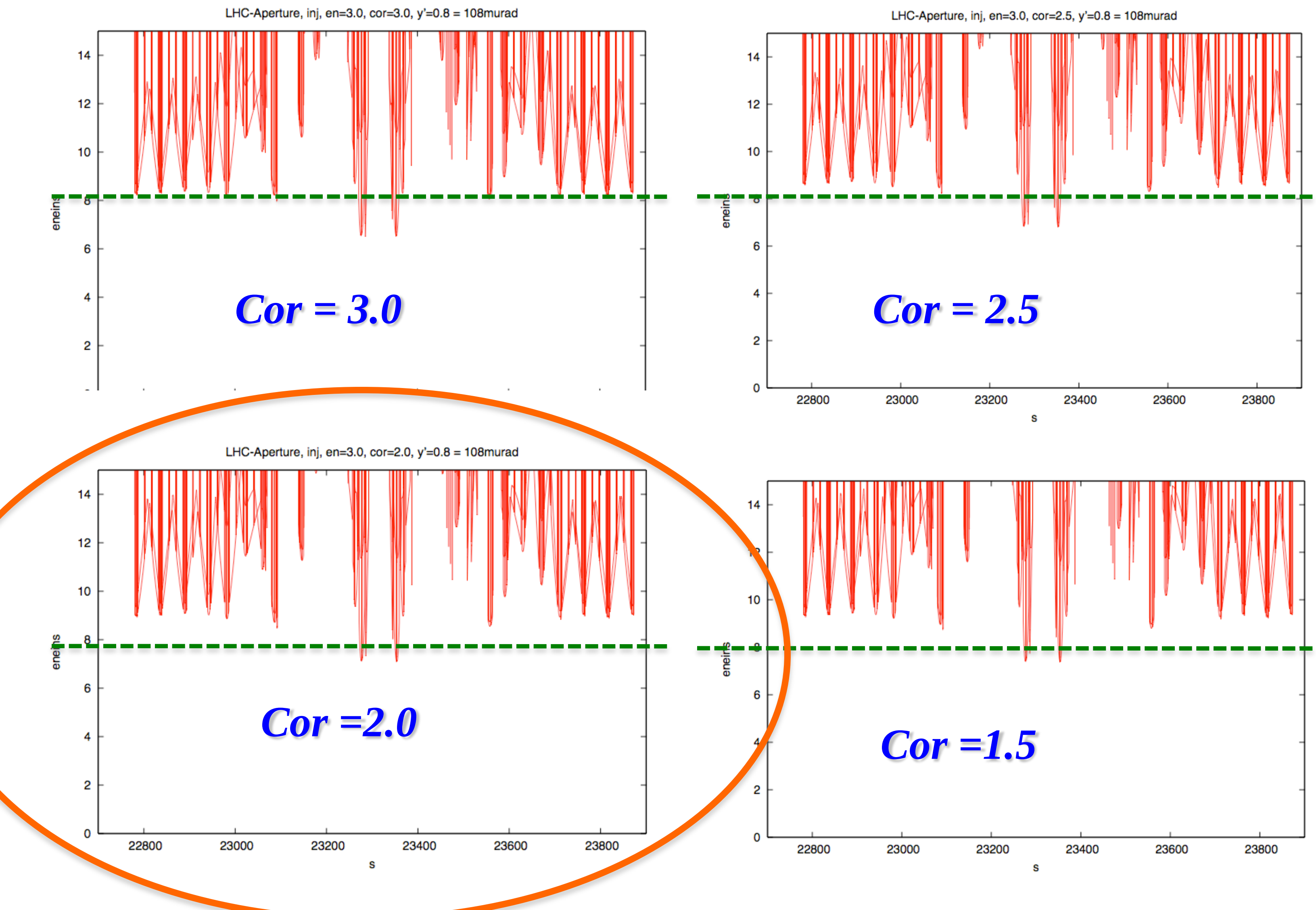


For ε = 3.0, scanning the vertical crossing angle
... with slight optimism.
on_xv i= 0.8 = 136 μrad + LHC b= 108 μrad



V) Aperture Scans

ε = 3.0µrad, y'=108 µrad

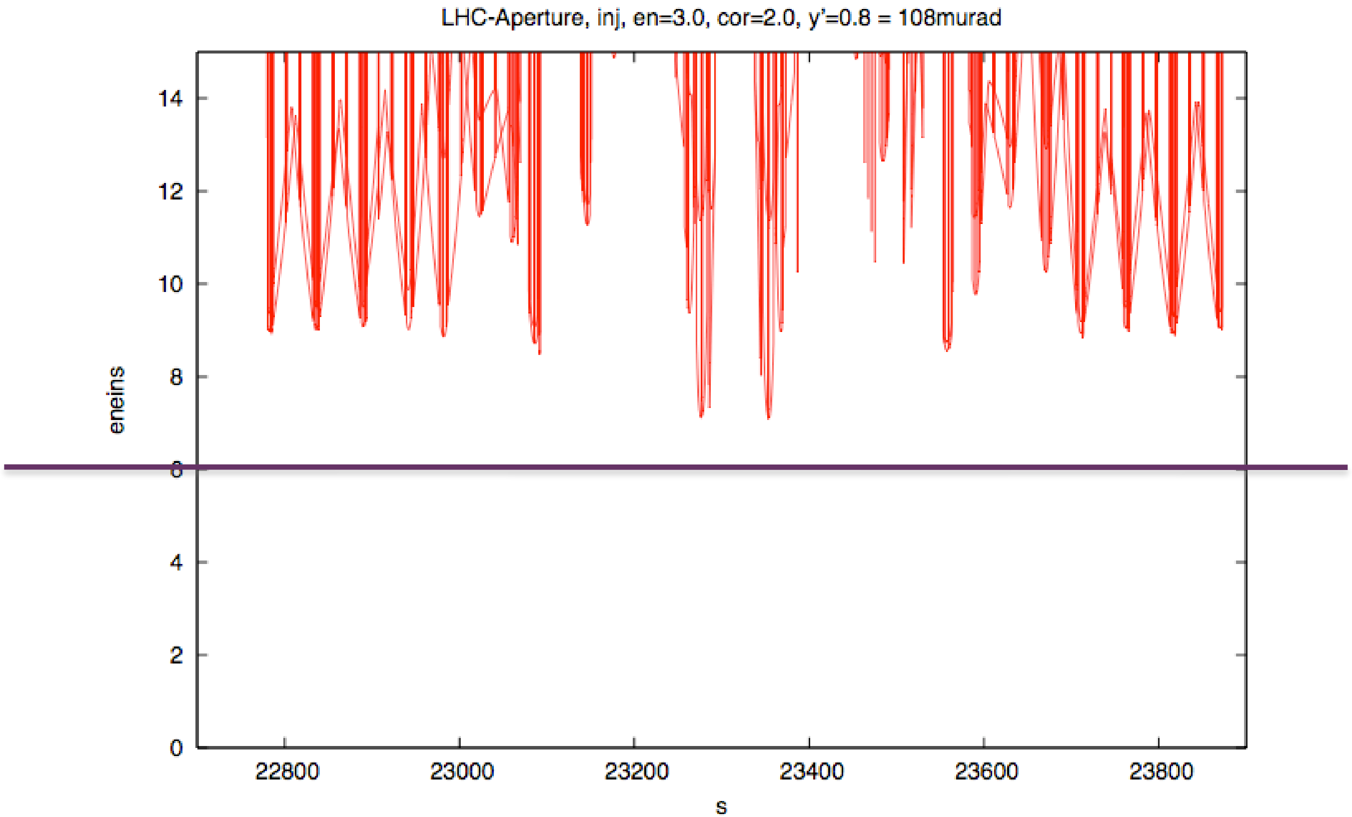


for comparison and careful contemplation ...

V) Aperture Scans: Optimistic Proposal:

ε = 3.0μrad, y'=108 μrad

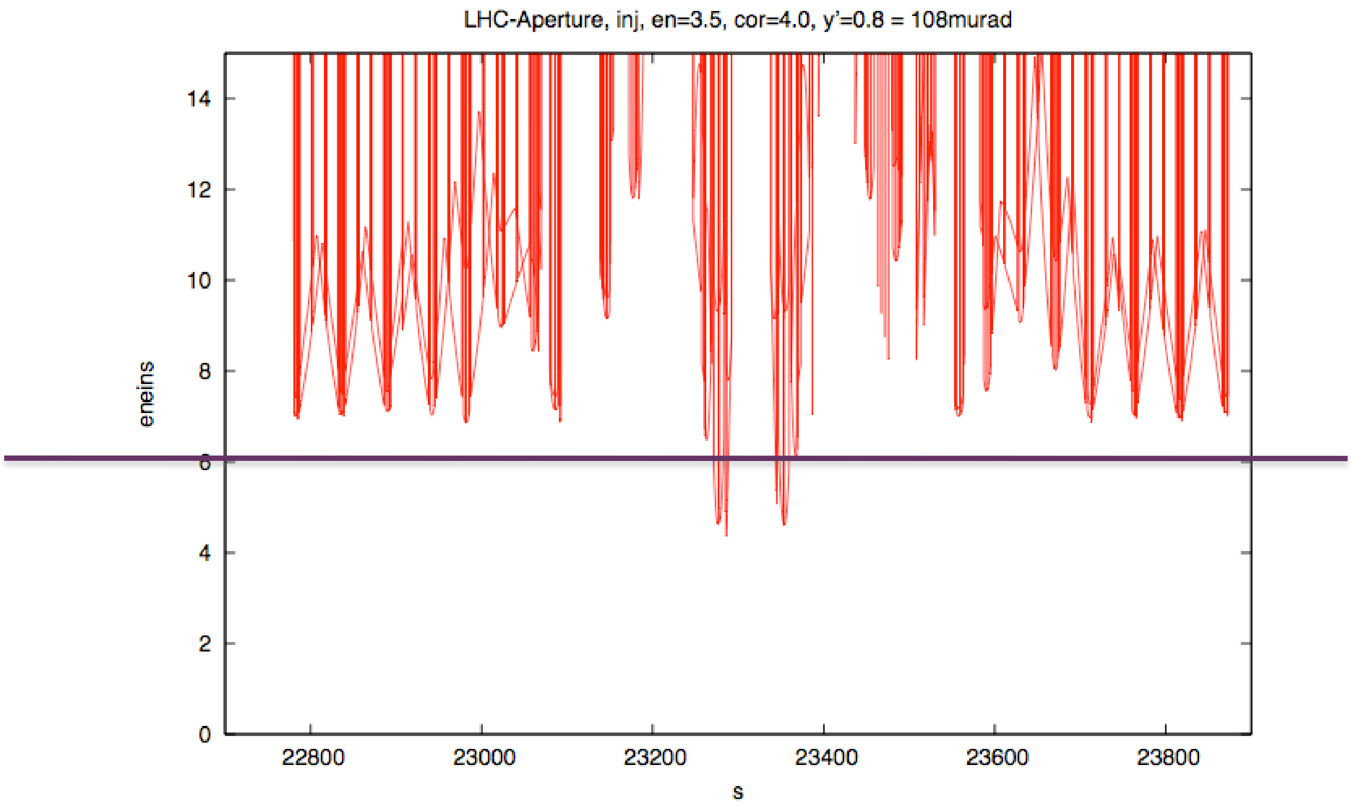
cor=2mm



V)) Aperture Scans: Reference calculations
proposed scheme

ε = 3.5μrad, y'=108 μrad

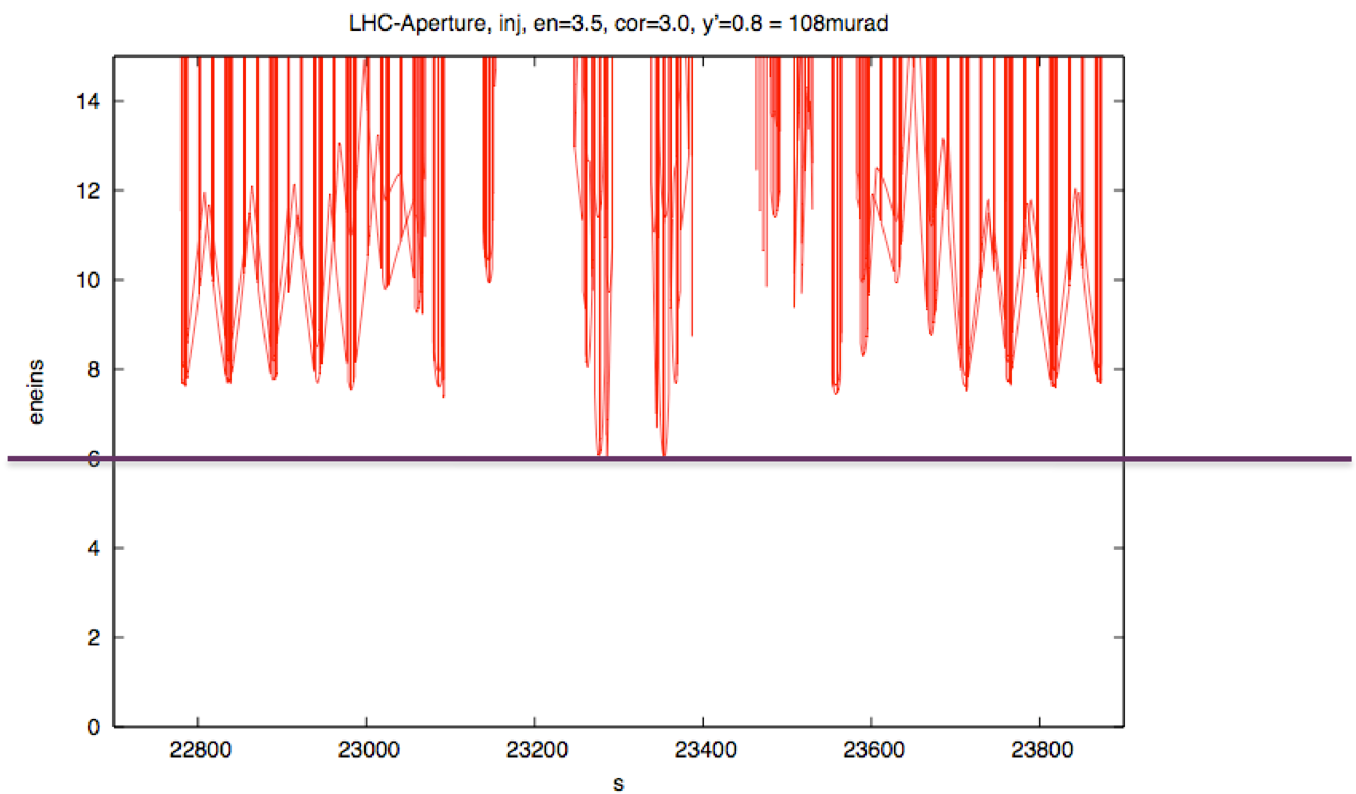
cor=4mm



V) Aperture Scans: Reference calculations: proposed scheme

ε = 3.5µrad, y'=108 µrad

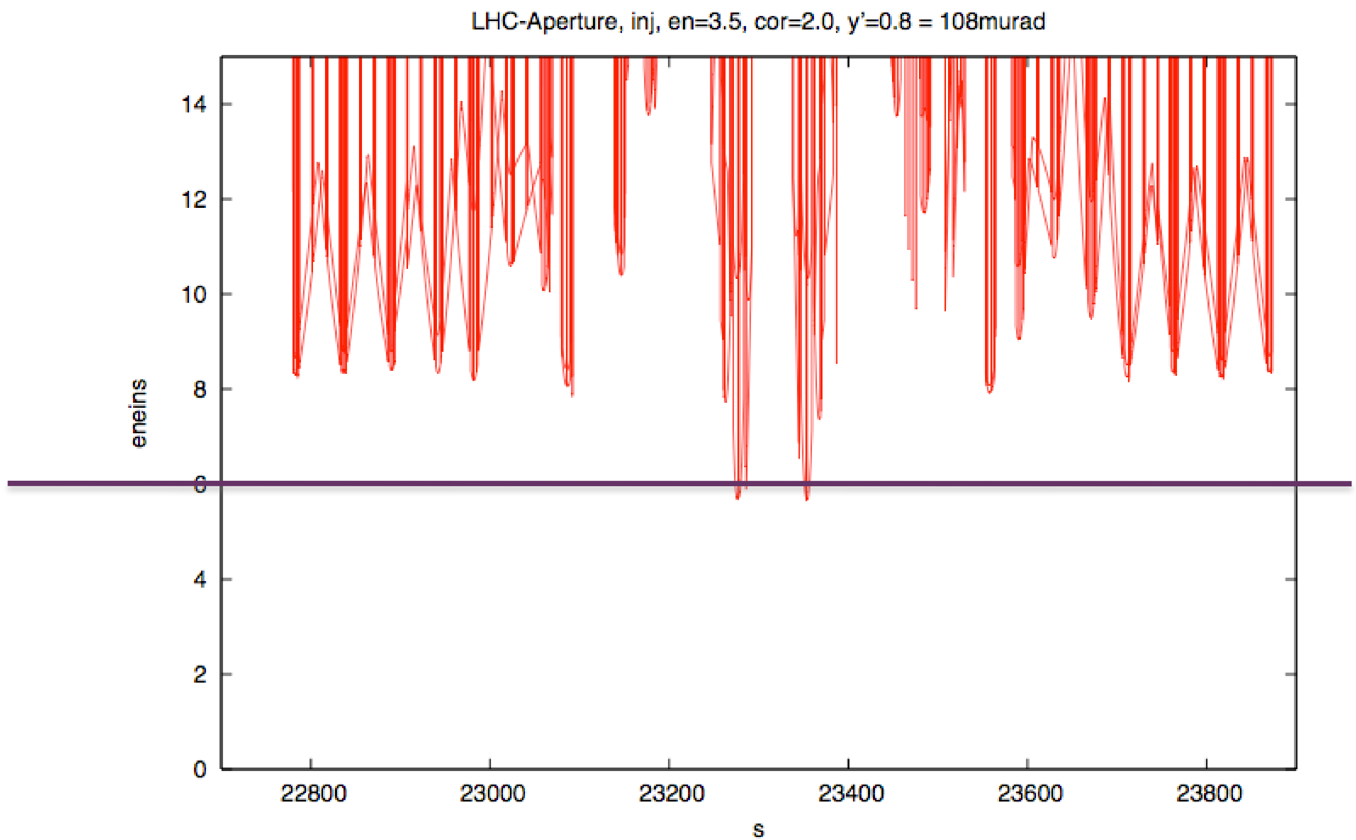
cor=3mm



V) Aperture Scans: himmi kreiz deifi no emol wie oft denn nocchchchch: proposed scheme

ε = 3.5μrad, proposed scheme, y'=108 μrad

cor=2mm

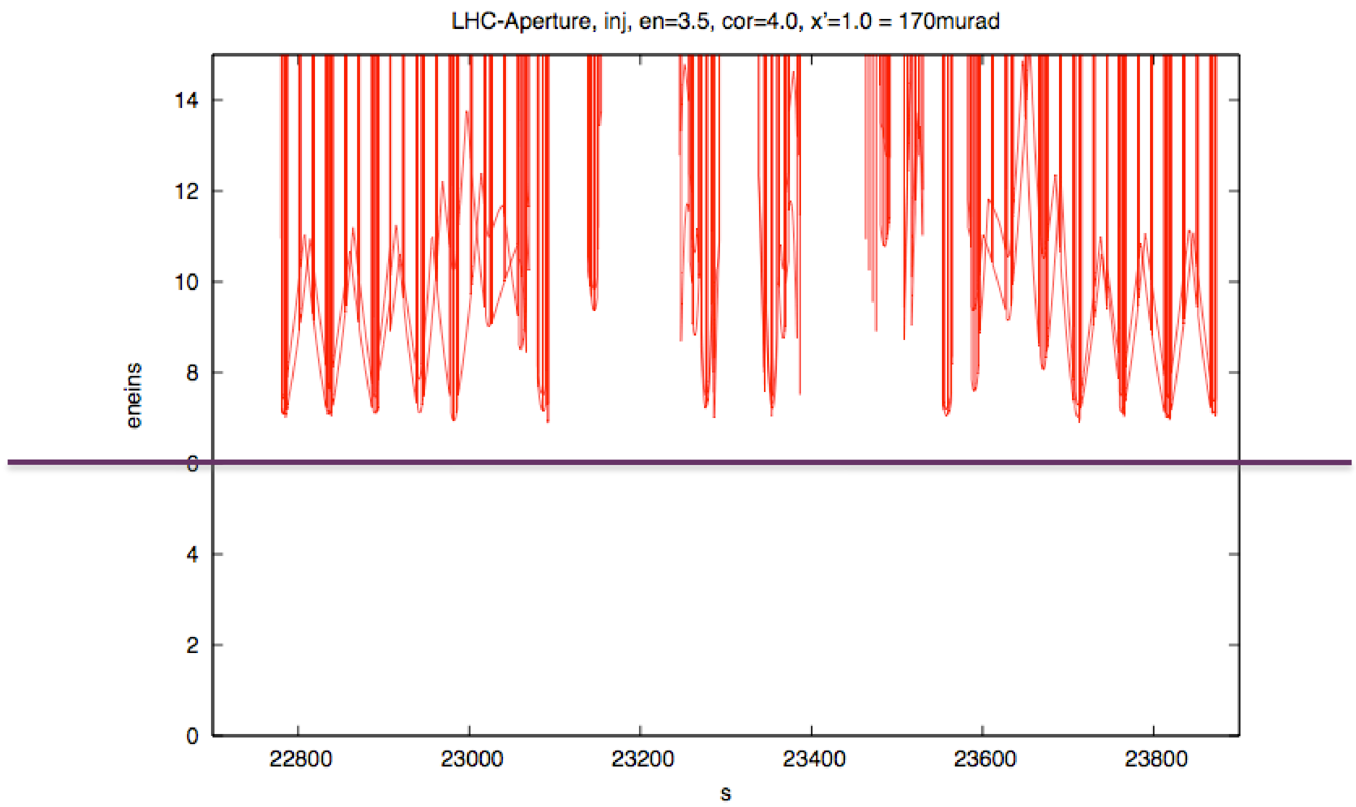


V) Aperture Scans: Reference calculations:

nominal scheme

ε = 3.5μrad, x'=170μrad

cor=4mm
LHCb pos

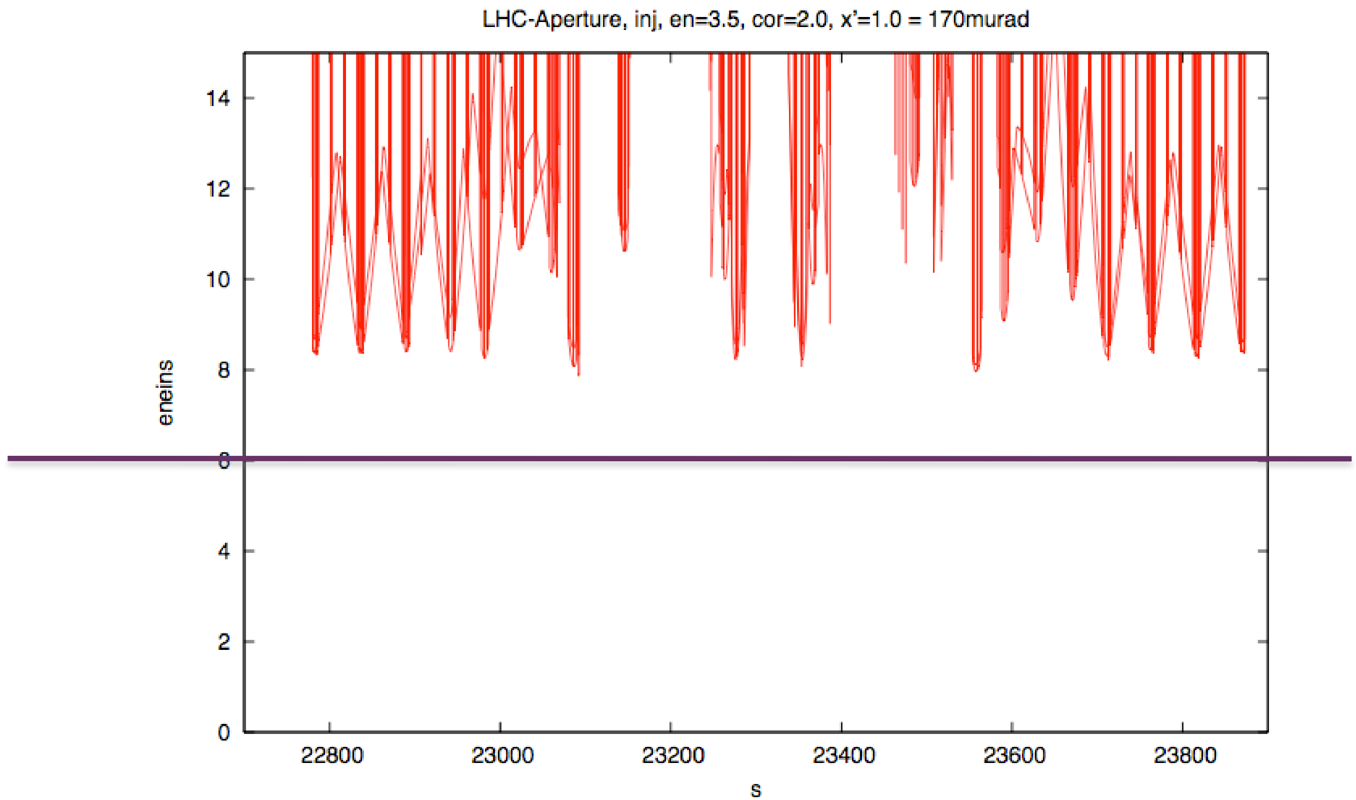


V) Aperture Scans: Reference calculations:

nominal scheme

ε = 3.5μrad, nominal scheme, x'=170μrad

cor=2mm
LHCb pos



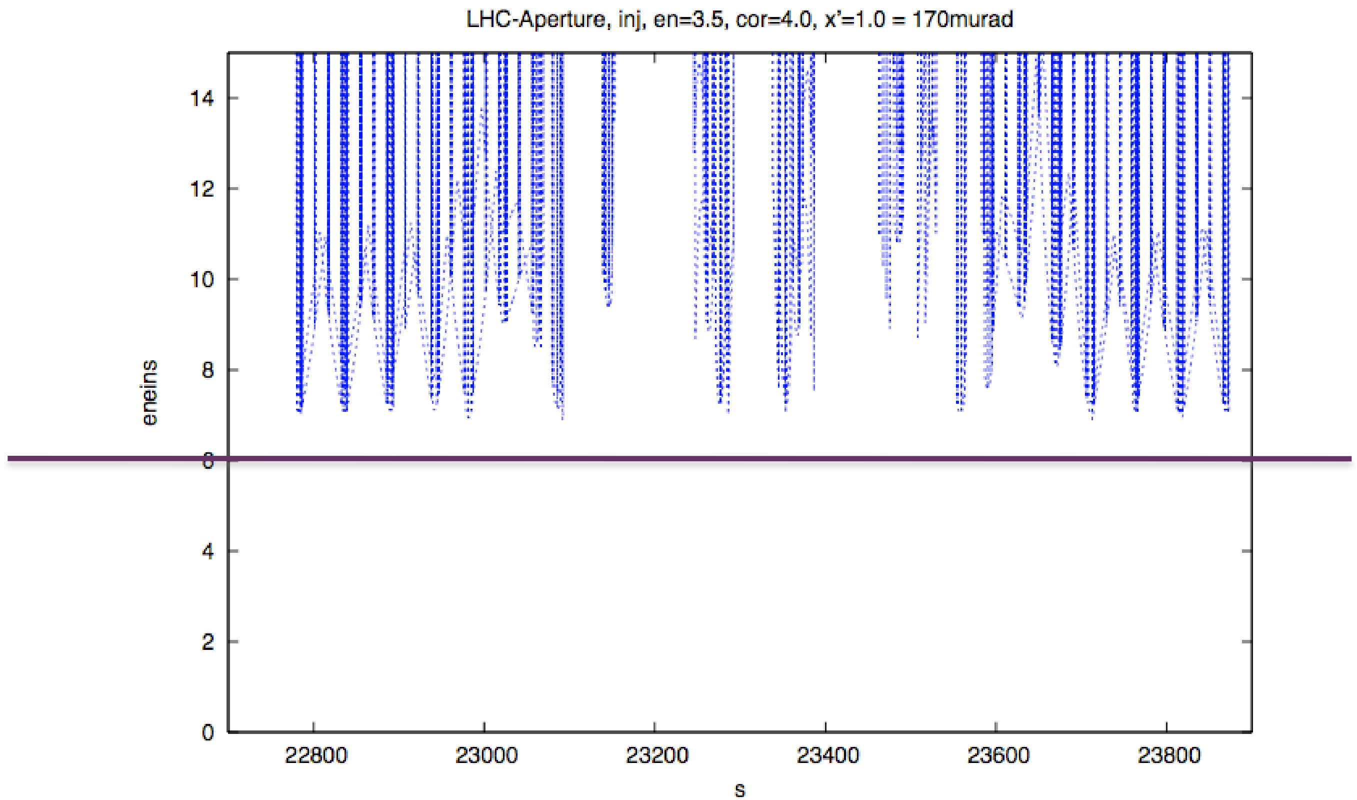
V) Aperture Scans: Reference calculations:

nominal scheme

ε = 3.5μrad, x'=170μrad

cor=4mm

LHCb neg



V) Aperture Scans: Reference calculations:
nominal scheme

ε = 3.5μrad, x'=170μrad

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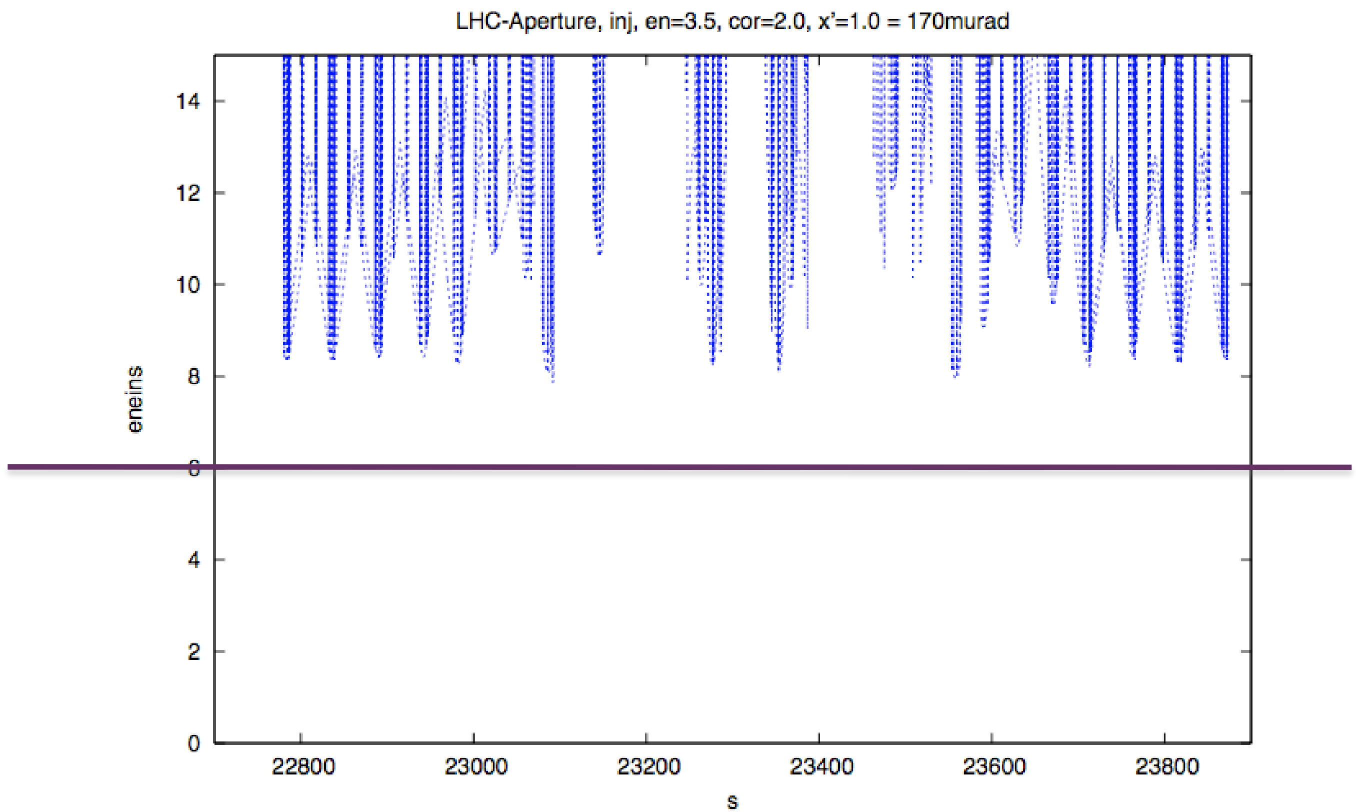
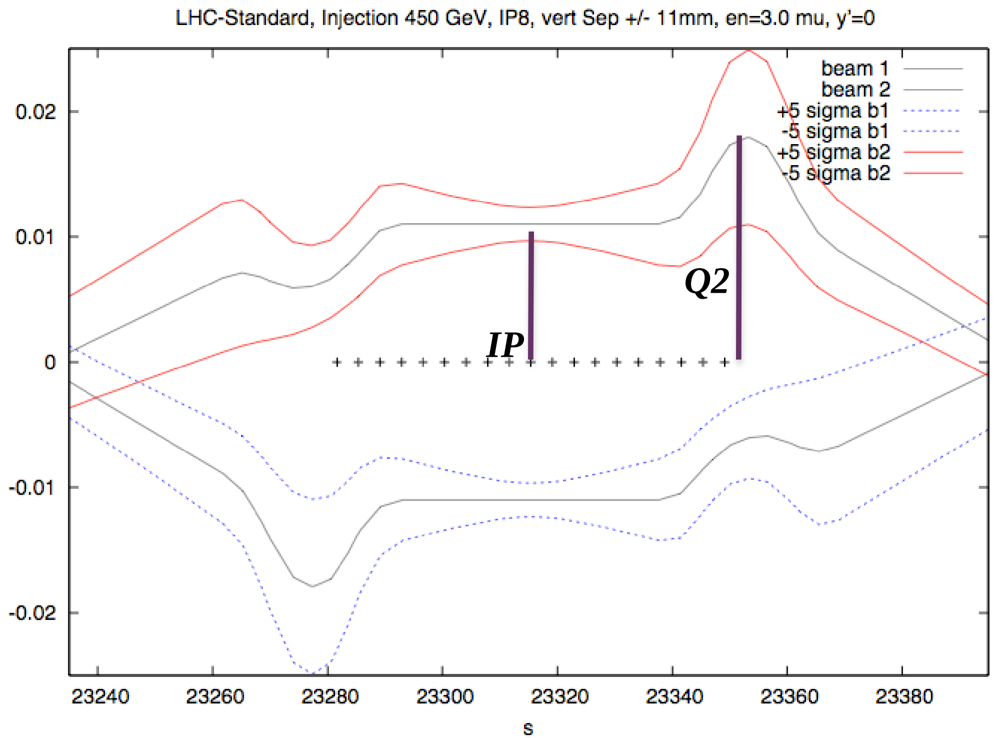


Apertures

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



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)