Can we collide in LHCb in the x-y plane ?

(without hardware changes)

Werner Herr, Y. Papaphilippou
AB/ABP

What is the issue ?

- **Crossing scheme in LHCb (IP8) includes spectrometer:**
  - → **Produces (large) crossing angle in horizontal plane**
  - → **Must be integrated in crossing scheme**
  - → **Constrains choice of parameters**
  - → **Regular change of spectrometer polarity required**
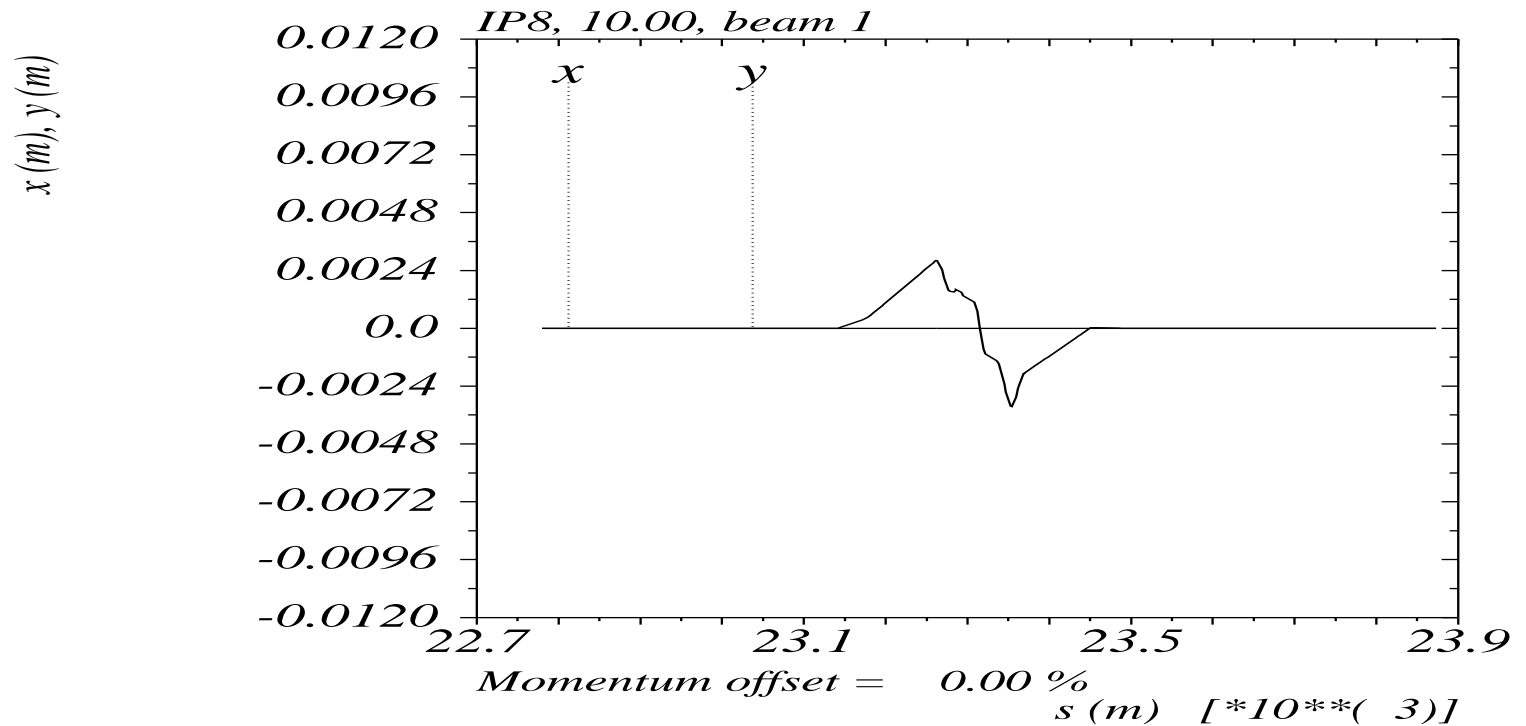
Crossing in horizontal planes

- Crossing angle in horizontal plane is special:

- → For crossing angle and therefore external angle sign is fixed to avoid double crossing

- → Effective crossing angle depends on spectrometer polarity (disadvantage for LHCb)

- → External crossing angle depends on spectrometer polarity (... and on β^*, required for luminosity control → squeeze depends on polarity, disadvantage for us !)

Base-line crossing parameters in LHCb (7 TeV)

Spectrometer	$\beta^*_{x,y}$ (m)	α_s (μrad)	α_x (μrad)	$\alpha_{eff} = \alpha_s + \alpha_x$ (μrad)
$-$	10.0	$\mp$135.0	$\mp$65.0	$\mp$200
$+$	10.0	$\pm$135.0	$\mp$210.0	$\mp$75
$-$	2.0	$\mp$135.0	$\mp$125.0	$\mp$260
$+$	2.0	$\pm$135.0	$\mp$210.0	$\mp$75

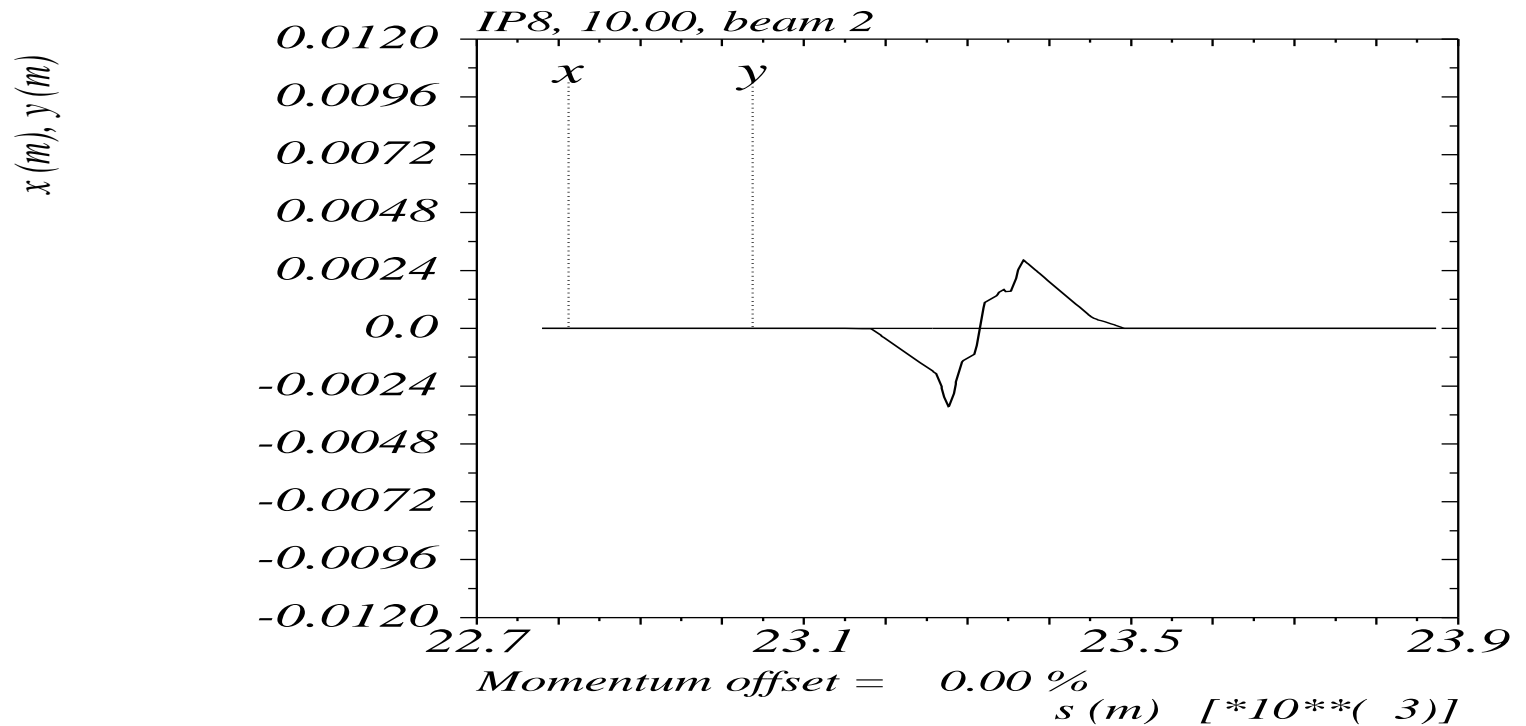➡ External angle α_x very different for the two polarities

➡ Effective angle α_{eff} very different for the two polarities

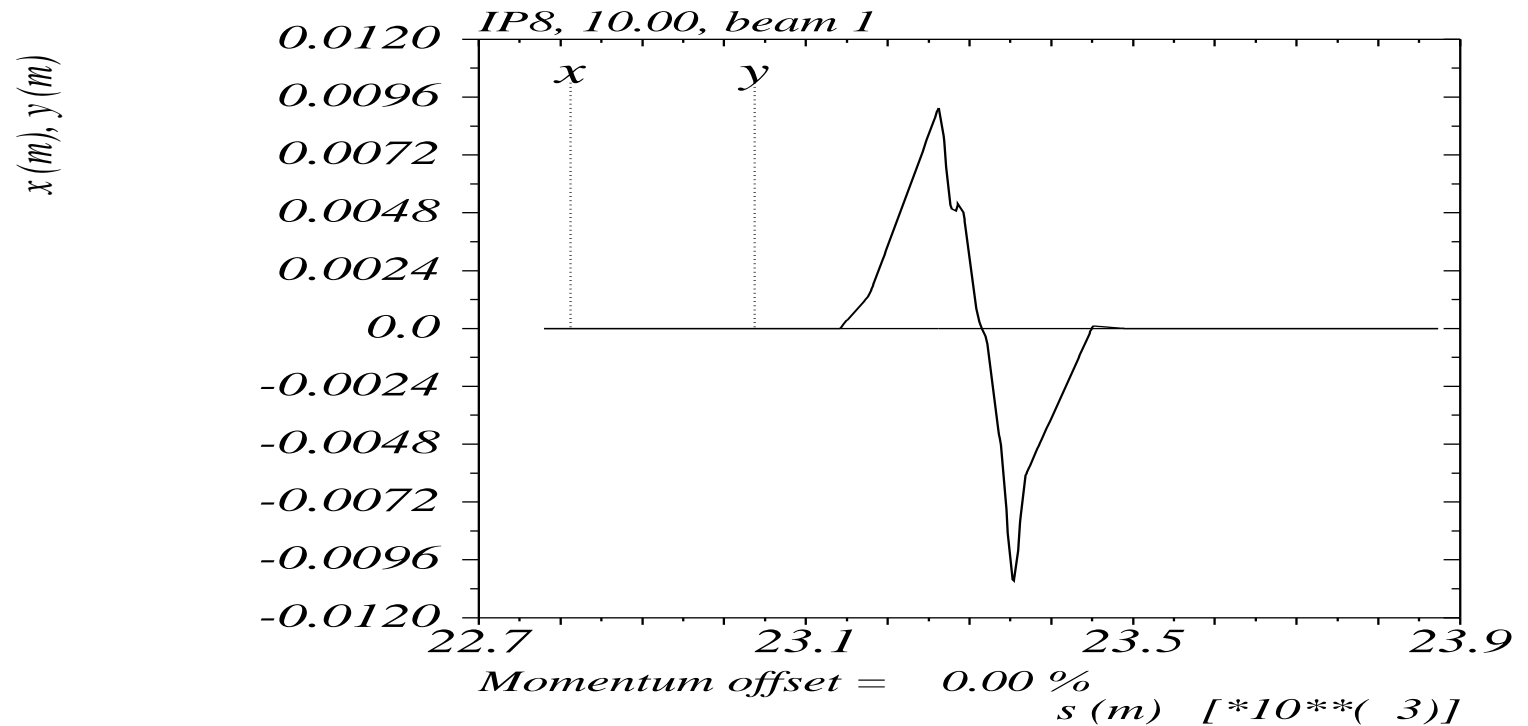# Crossing scheme (Beam 1, β^*=10 m, 7 TeV)

Spectrometer negative: $\alpha_{x,1} = -65 \ \mu$rad
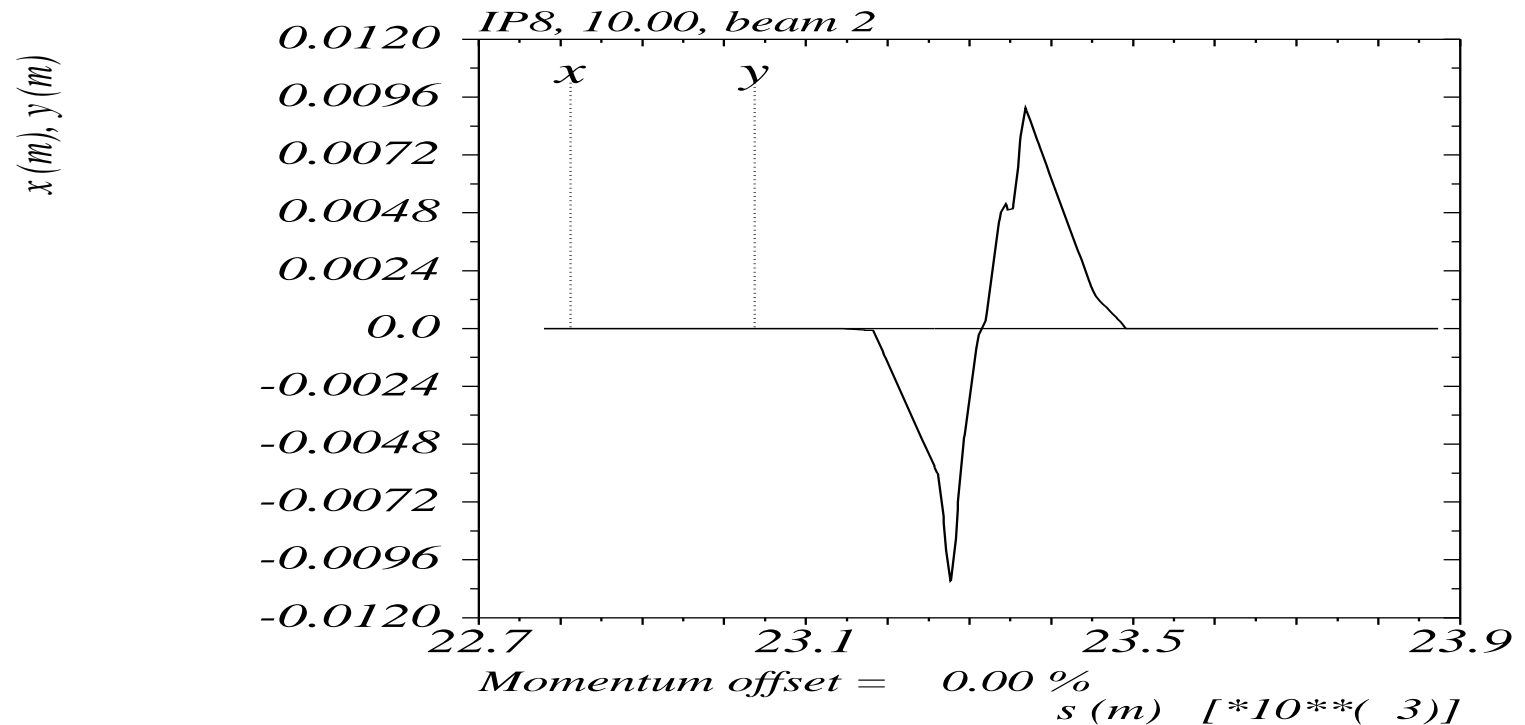
Crossing scheme (Beam 2, β^*=10 m, 7 TeV)

IP8, 10.00, beam 2

x (m), y (m)

Momentum offset = 0.00 %

s (m) [*10**(3)]

➡ **Spectrometer negative:** $\alpha_{x,2} = +65 \ \mu\mathrm{rad}$

Crossing scheme (Beam 1, β^*=10 m, 7 TeV)

➤ **Spectrometer positive:** $\alpha_{x,1} = -210 \ \mu\text{rad}$

➤ **Large aperture needed in horizontal plane !**
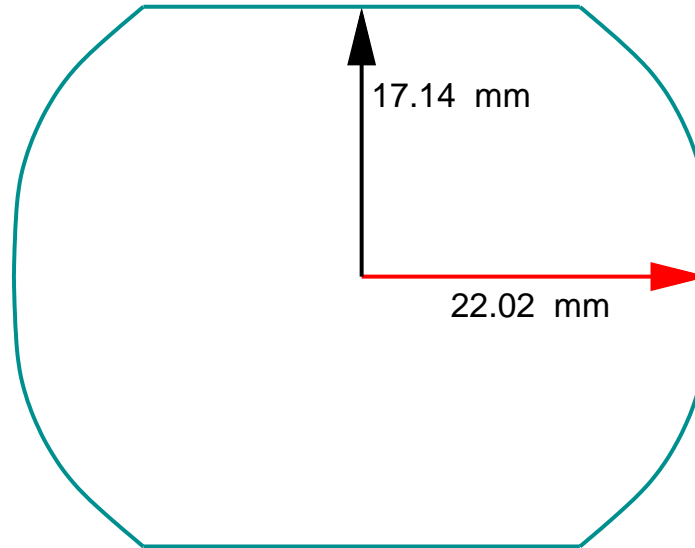
Crossing scheme (Beam 2, β^*=10 m, 7 TeV)

➡ **Spectrometer positive:** $\alpha_{x,2} = +210$ μrad

➡ **Large aperture needed in horizontal plane !**

Alternative: crossing in tilted planes

■ Spectrometer angle horizontal, external angle vertical

➤ Effective crossing in x-y plane

➤ Effective crossing angle independent of spectrometer polarity (advantage for LHCb)

➤ External angle decoupled from spectrometer polarity (advantage for us)
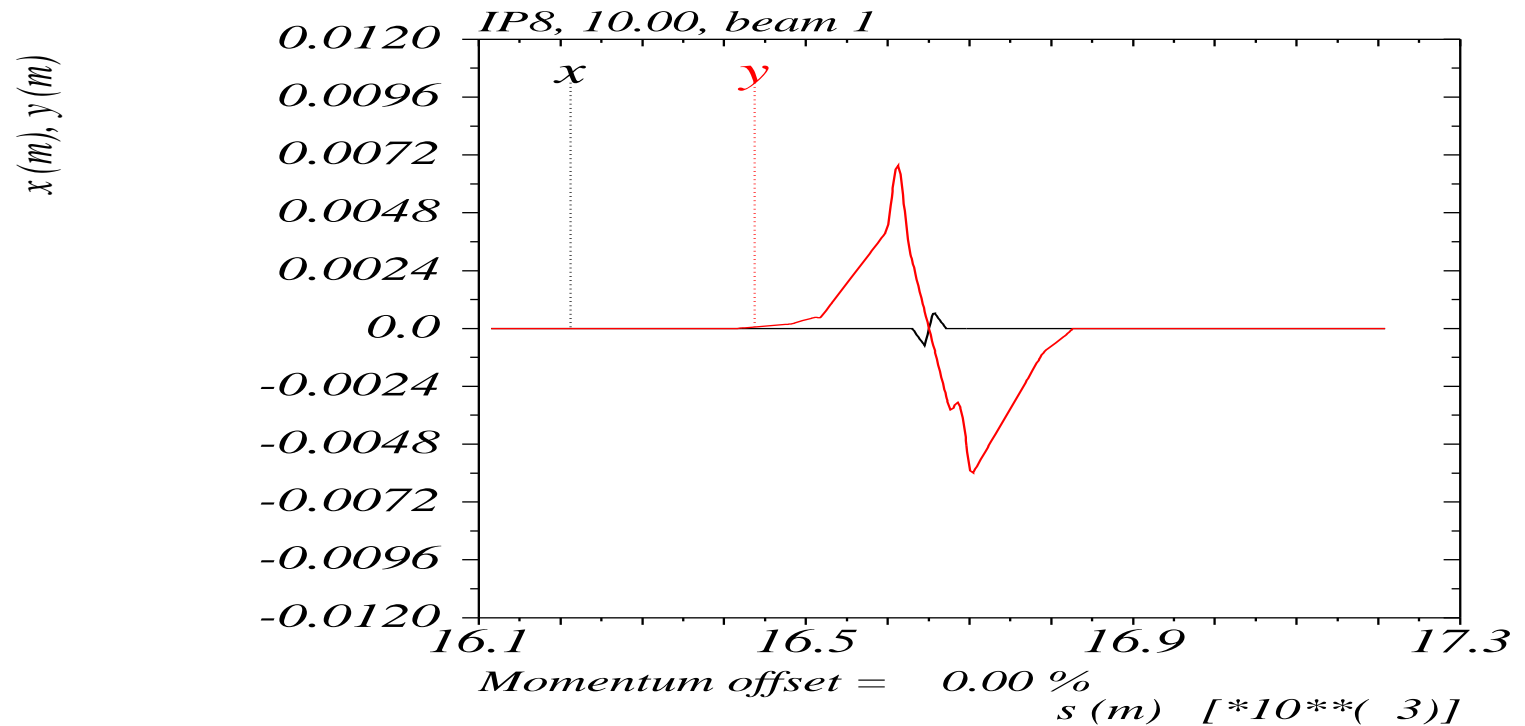
➤ Problem: available aperture

Beam screen - IP8

17.14 mm

22.02 mm

➡ **Orientation in IP8 for horizontal crossing**

➡ **Vertical aperture reduced**

Crossing scheme (Beam 1, β^*=10 m, 7 TeV)

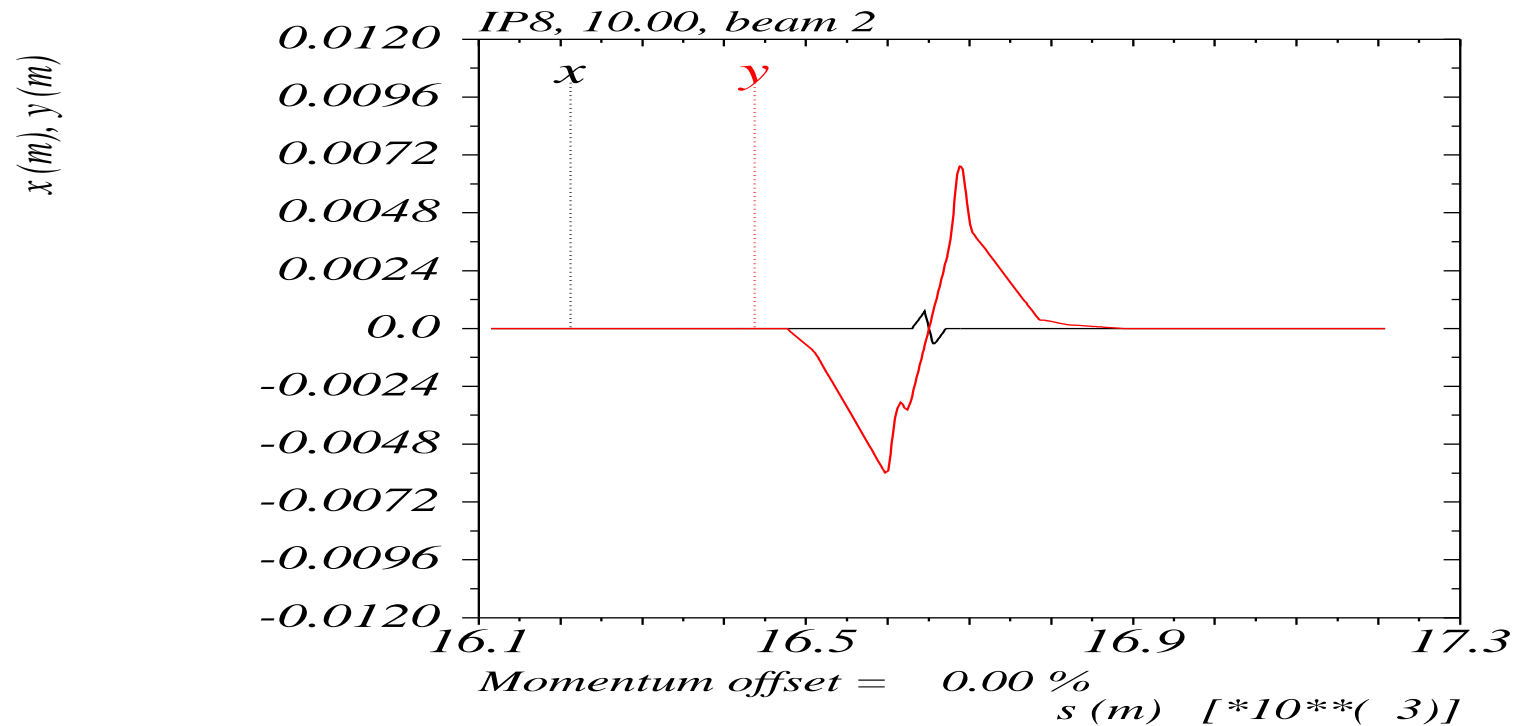

- External angle: $\alpha_{y,1} = -(\mp)135 \ \mu$rad

- Aperture needed in vertical plane
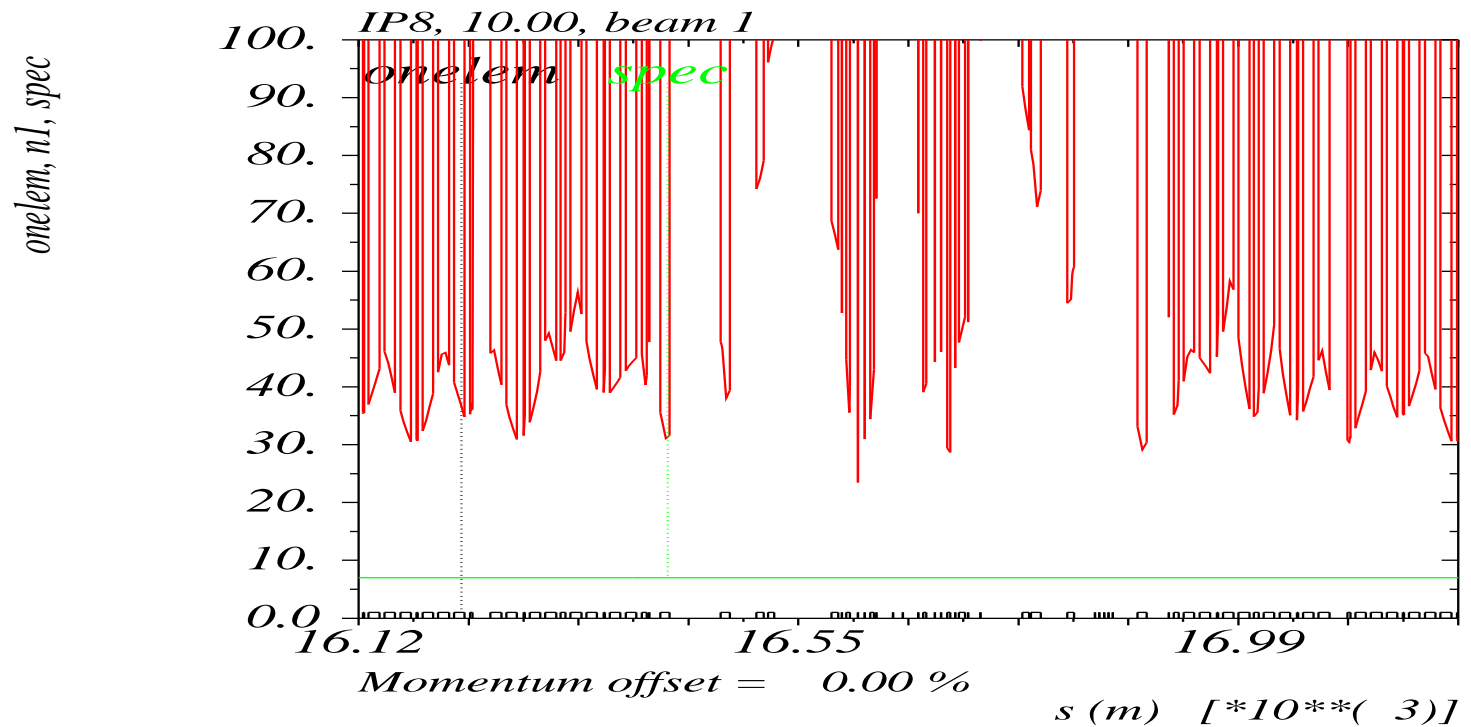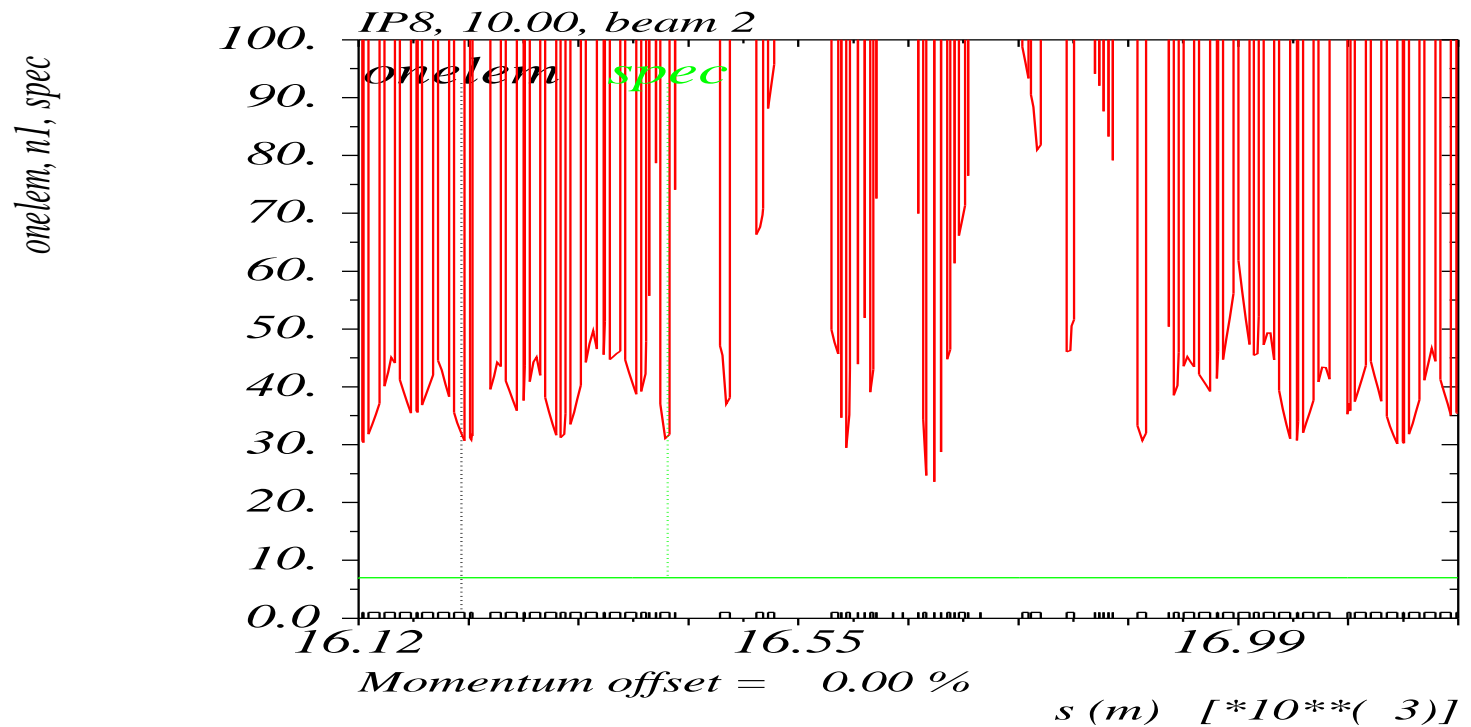
Crossing scheme (Beam 2, β^*=10 m, 7 TeV)

IP8, 10.00, beam 2

Momentum offset = 0.00 %

➤ **External angle:** $\alpha_{y,2} = +(\pm)\mathbf{135}$ μrad

➤ **Aperture needed in vertical plane** ➤

Aperture (Beam 1, β^*=10 m, 7 TeV)

IP8, 10.00, beam 1

onelem   *spec*

Momentum offset =   0.00 %

s (m)   [*10**(3)]

➡ **Sufficient aperture available for $\beta^* = 10$ m**

Aperture (Beam 2, β^*=10 m, 7 TeV)

IP8, 10.00, beam 2

onelem *spec*

onelem, n1, spec

100.
90.
80.
70.
60.
50.
40.
30.
20.
10.
0.0

16.12   16.55   16.99

Momentum offset =   0.00 %

s (m)   [*10**(3)]

➡ **Sufficient aperture available for $\beta^* = 10$ m**

Crossing scheme (Beam 1, β^*=2 m, 7 TeV)

External angle: $\alpha_{y,1} = -(\mp)135 \ \mu$rad

Crossing scheme (Beam 2, β^*=2 m, 7 TeV)

External angle: $\alpha_{y,2} =+(\pm)\mathbf{135}\ \mu\mathrm{rad}$

Aperture needed in vertical plane
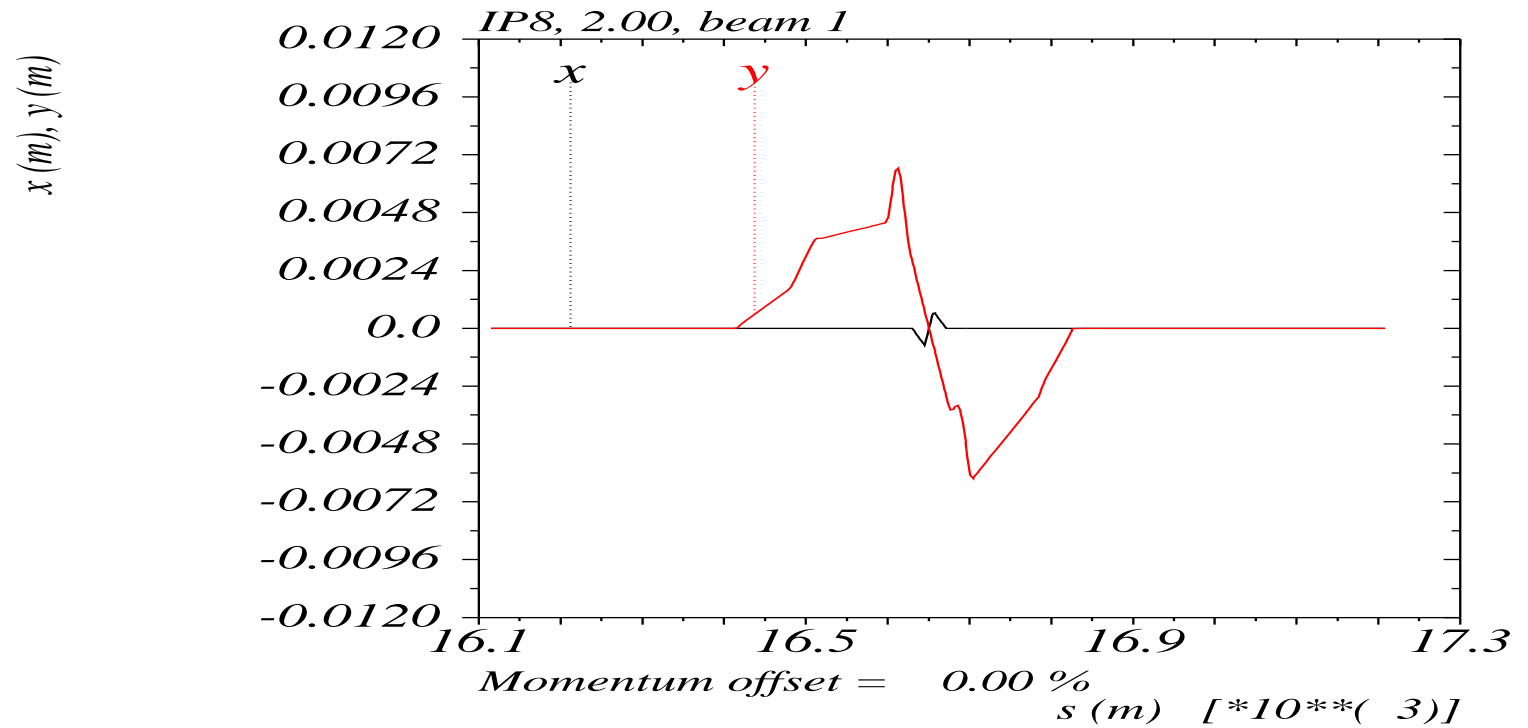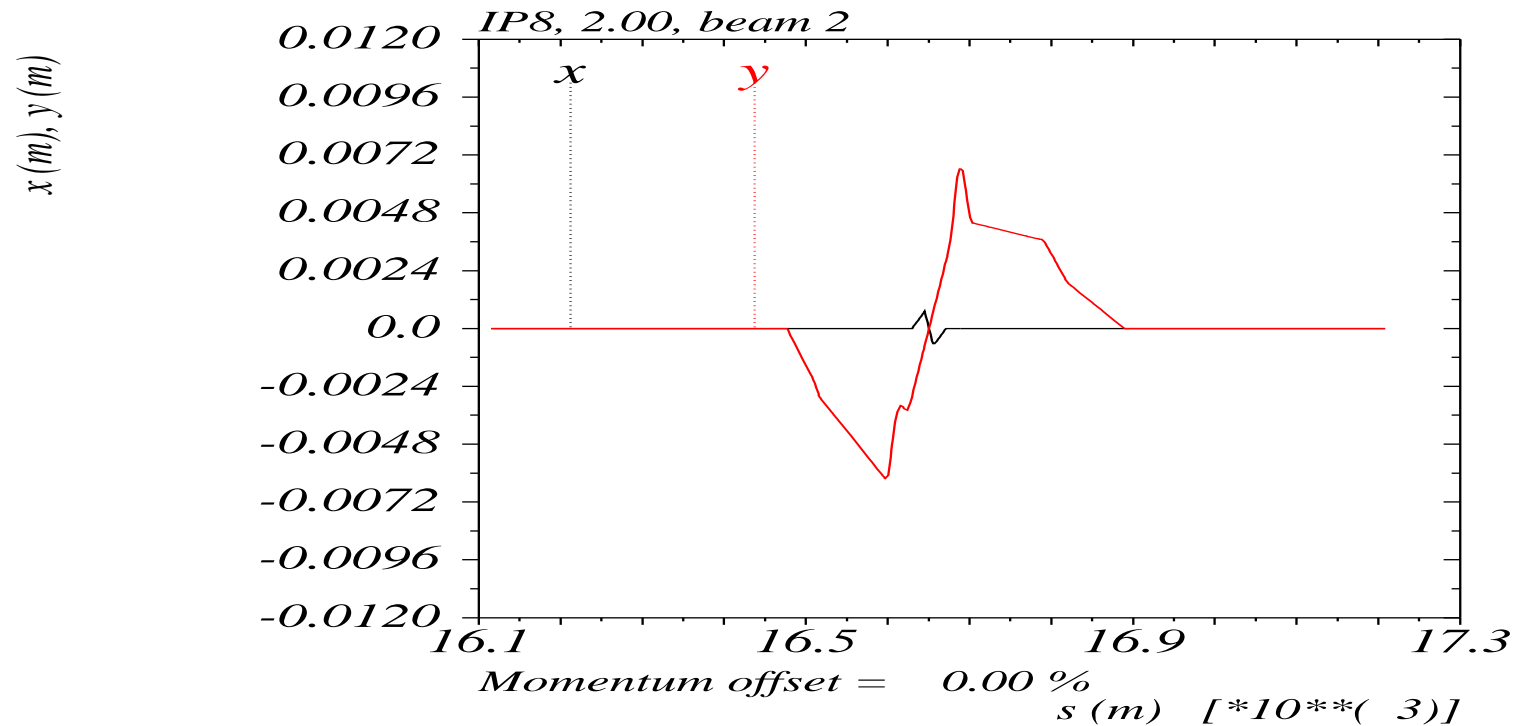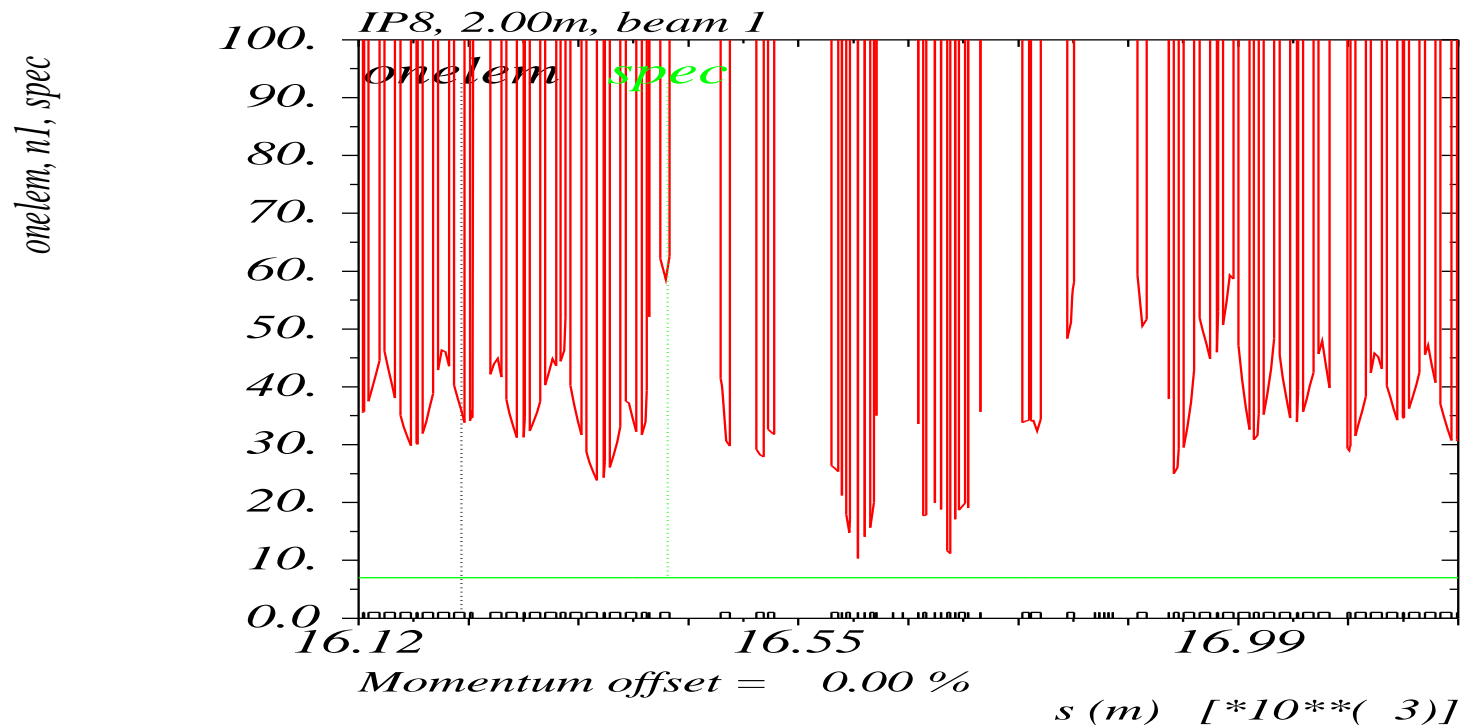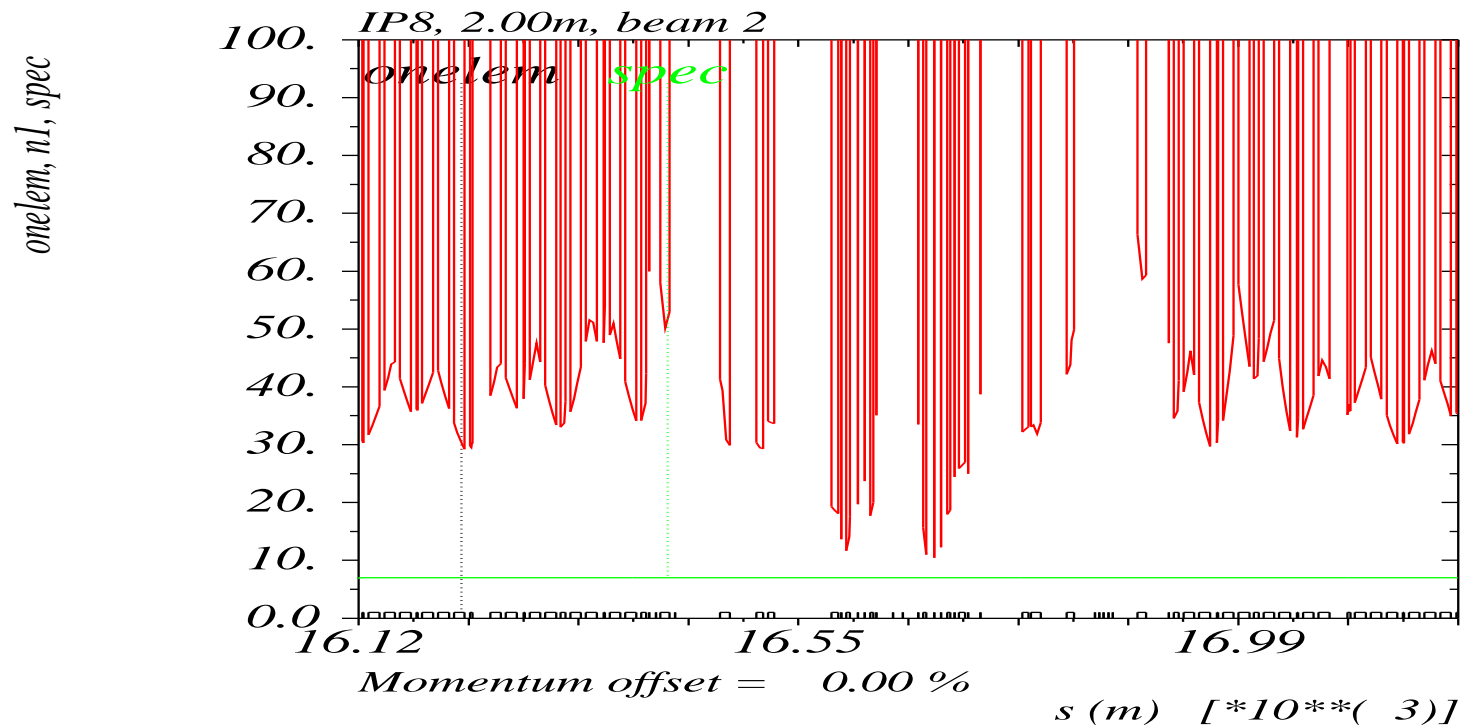
Aperture (Beam 1, β^*=2 m, 7 TeV)

➡ **Sufficient aperture available for $\beta^* = 2$ m**

Aperture (Beam 2, β^*=2 m, 7 TeV)

➤ **Sufficient aperture available for $\beta^* = 2$ m**

Alternative crossing in LHCb

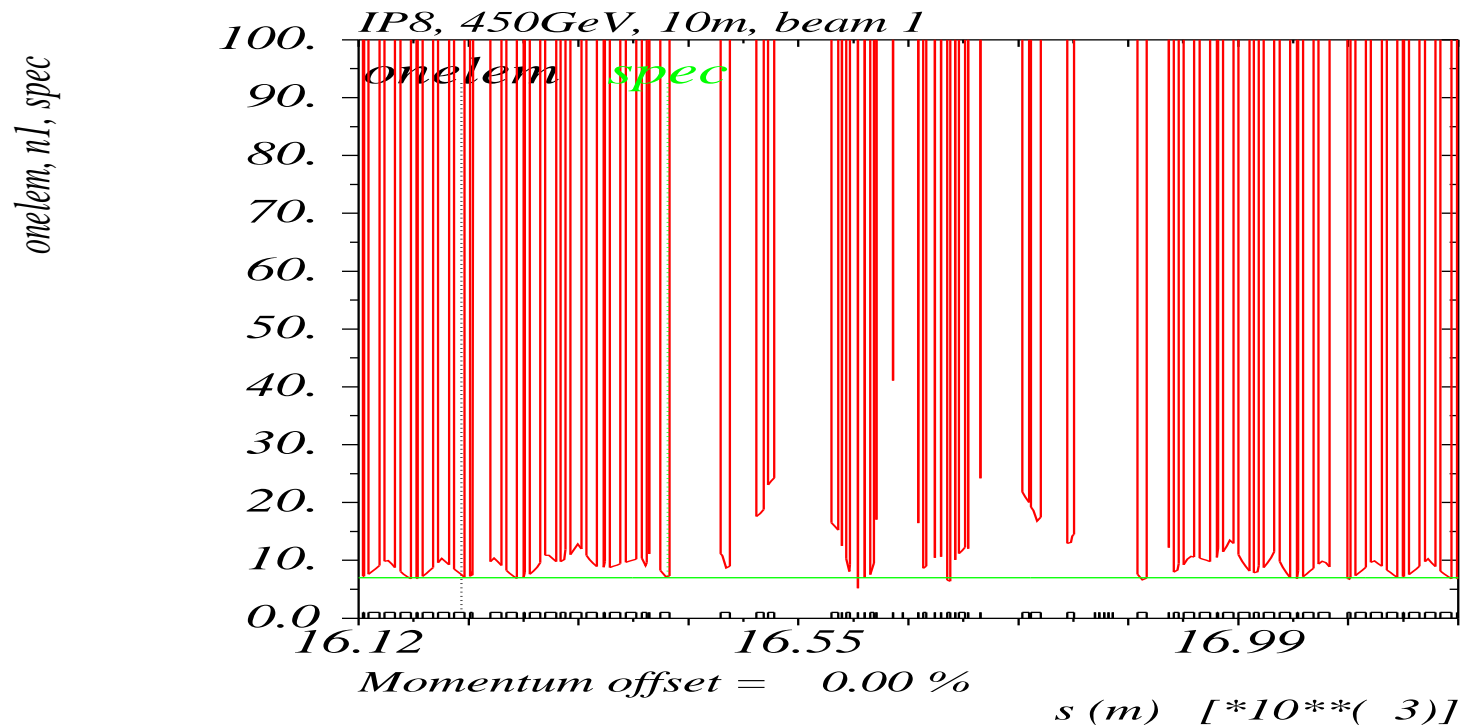| Spec	$\beta^*_{x,y}$ (m)	α_s (μrad)	α_y (μrad)	α_{eff} (μrad)	$\mathbf{sep}_{min}$ ($\sigma_{x,z}$)
$-$	10.0	$\mp$135.0	$\pm$135.0	$\pm$190	14
$+$	10.0	$\pm$135.0	$\pm$135.0	$\pm$190	14
$-$	2.0	$\mp$135.0	$\pm$135.0	$\pm$190	13
$+$	2.0	$\pm$135.0	$\pm$135.0	$\pm$190	13

Crossing in both planes

- Effective crossing angle independent of spectrometer polarity

- External crossing angle independent of spectrometer polarity

- Beam separation sufficient
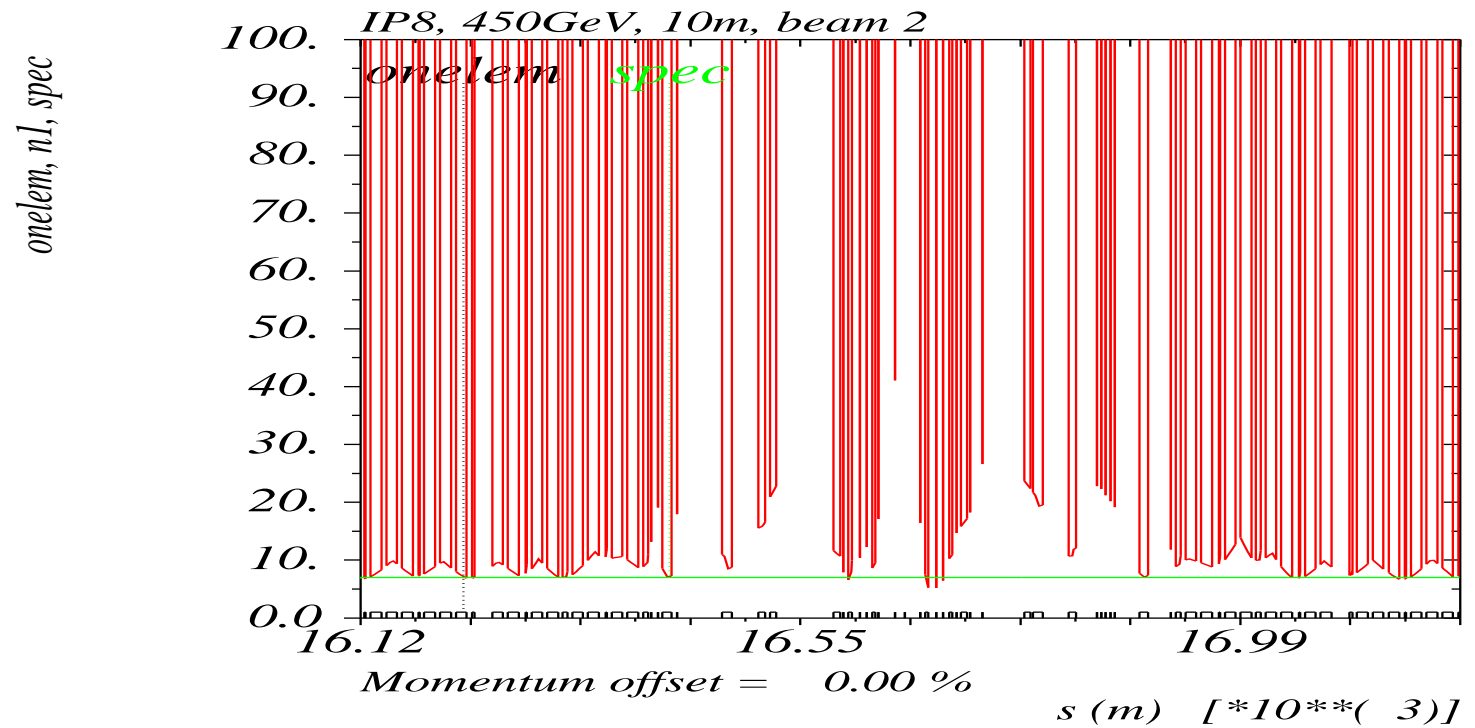
- What about injection ?

Aperture (Beam 1, β^*=10 m, 0.450 TeV)

IP8, 450GeV, 10m, beam 1

onelem   spec

onelem, n1, spec

Momentum offset =   0.00 %

s (m)   [*10**(3)]

➤ **Aperture an injection (probably) insufficient**

Aperture (Beam 2, β^*=10 m, 0.450 TeV)

IP8, 450GeV, 10m, beam 2

onelem, n1, spec

onelem   spec

Momentum offset =   0.00 %

s (m)   [*10**(3)]

Injection and ramping:

▣ Aperture an injection (probably) insufficient

▣ Proposal:

➡ Inject into nominal scheme (horizontal angle)

➡ Switch on vertical angle after ramp

➡ Switch off horizontal angle

➡ Squeeze if necessary ➡ only one squeeze for both polarities !

▣ This excludes spectrometer at full field at injection energy

Summary:

- ▣ Collisions at **7 TeV** are possible without hardware changes

- ▣ $\beta^* = $ **2 m** and **10 m** are possible

- ▣ Injection must be done into base line scheme

- ▣ Ramping as in base line scheme, including spectrometer

- ▣ Setting up of vertical angle at **7 TeV**.