

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

(without hardware changes)

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Reminder: What is the issue ?

- Present crossing in LHCb in horizontal plane
- Crossing scheme in LHCb (IP8) includes spectrometer:
 - Produces (large) crossing angle in horizontal plane
 - Must be integrated in crossing scheme
 - Regular change of spectrometer polarity required



Crossing in horizontal planes

- Sign of the crossing angle and sign of the external angle are 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^* , settings and squeeze depend on polarity (disadvantage for operation)

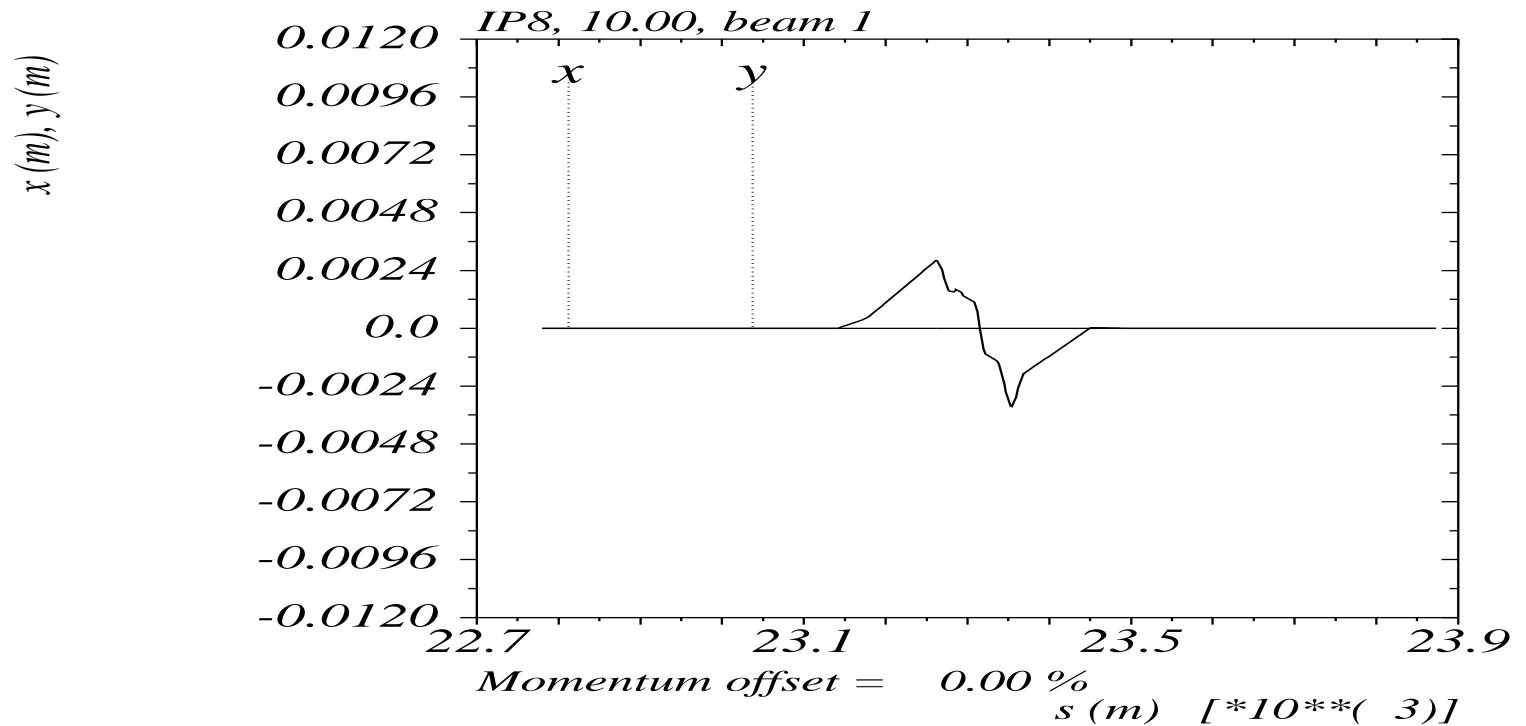


Base-line crossing parameters in LHCb (7 TeV)

Spectrometer	$\beta_{x,y}^*$ (m)	α_s (μrad)	α_x (μrad)	$\alpha_{eff} = \alpha_s + \alpha_x$ (μrad)
–	10.0	∓ 135.0	∓ 65.0	∓ 200
+	10.0	± 135.0	∓ 210.0	∓ 75
–	2.0	∓ 135.0	∓ 125.0	∓ 260
+	2.0	± 135.0	∓ 210.0	∓ 75

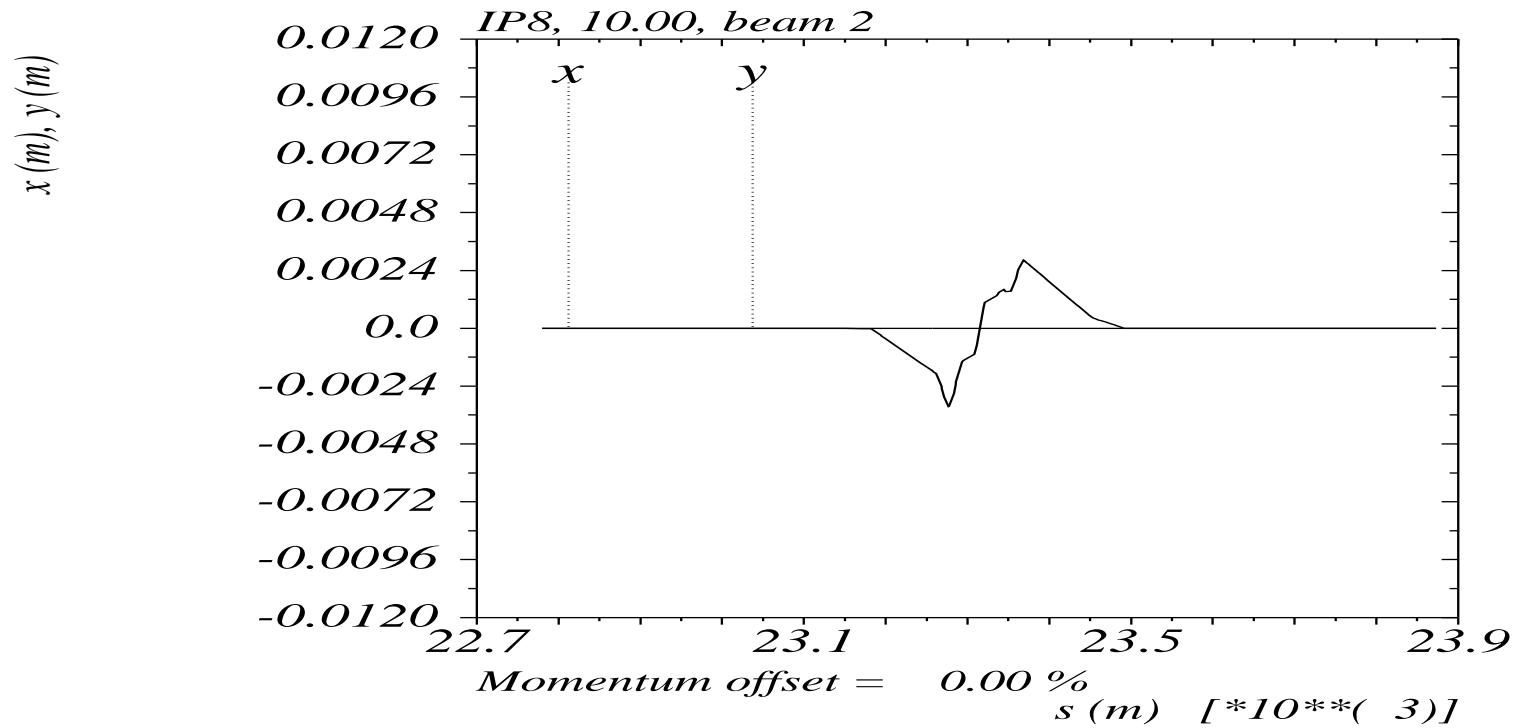
- ➔ External angle α_x very different for the two polarities
- ➔ Effective angle α_{eff} very different for the two polarities

Crossing scheme (Beam 1, $\beta^*=10$ m, 7 TeV)



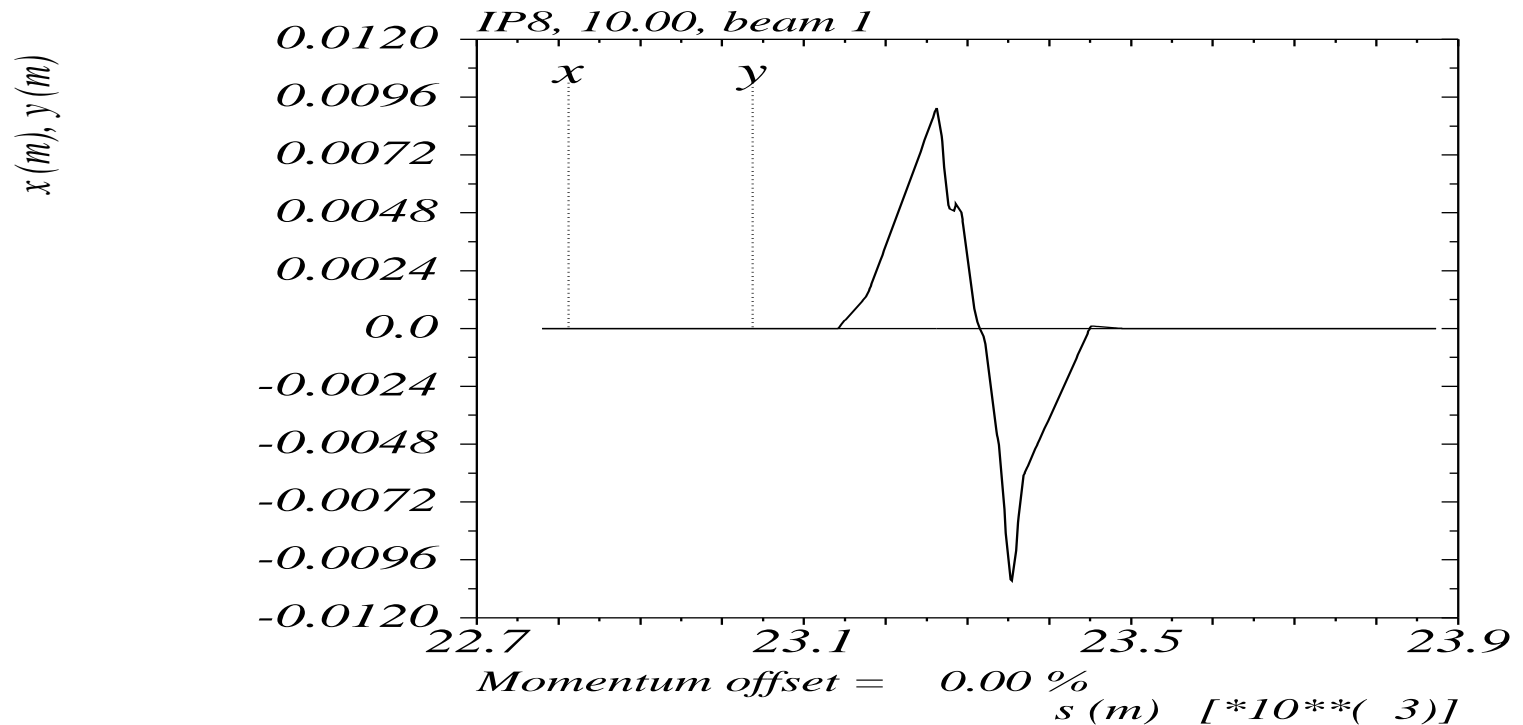
→ Spectrometer **negative**: $\alpha_{x,1} = -65 \mu\text{rad}$

Crossing scheme (Beam 2, $\beta^*=10$ m, 7 TeV)



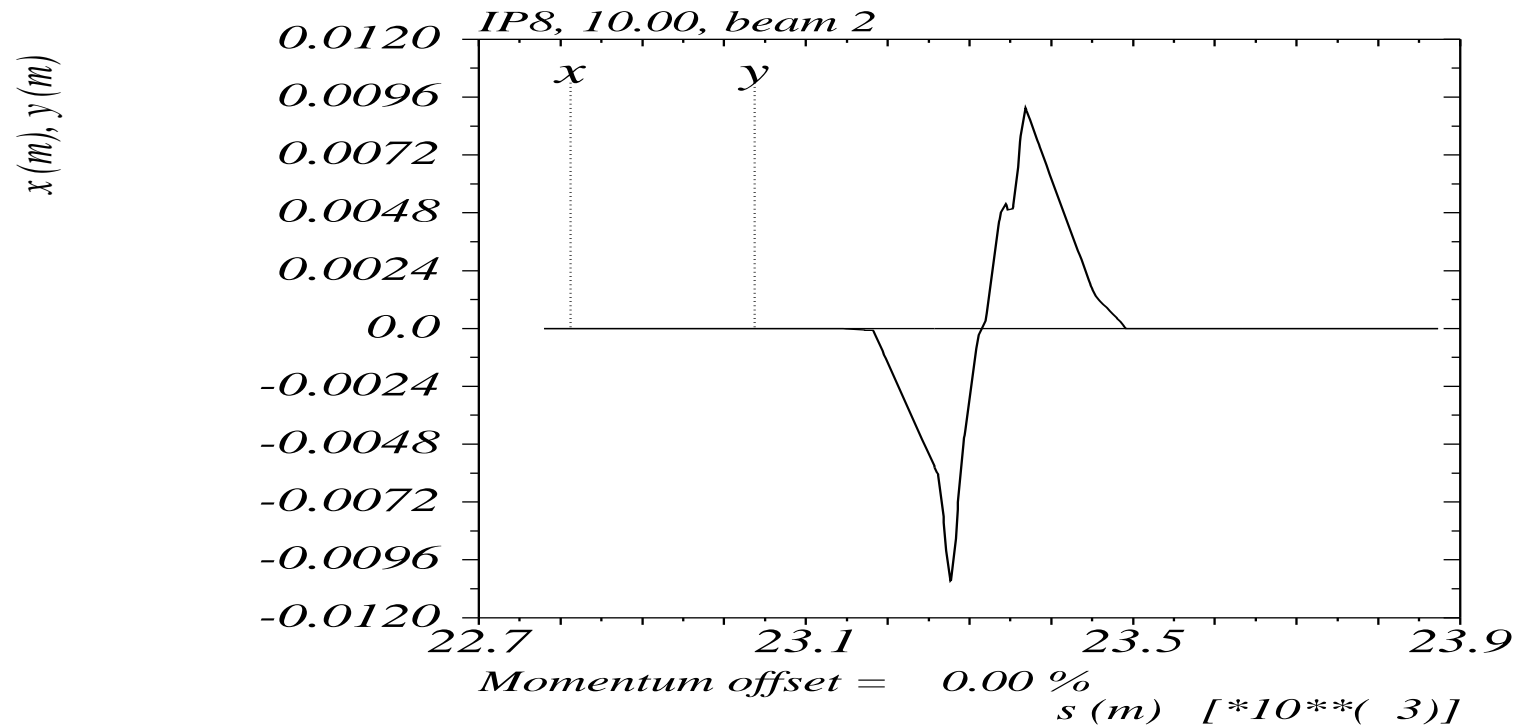
→ Spectrometer **negative**: $\alpha_{x,2} = +65 \mu\text{rad}$

Crossing scheme (Beam 1, $\beta^*=10$ m, 7 TeV)



- Spectrometer **positive**: $\alpha_{x,1} = -210 \mu\text{rad}$
- Large aperture needed in horizontal plane !

Crossing scheme (Beam 2, $\beta^*=10$ m, 7 TeV)

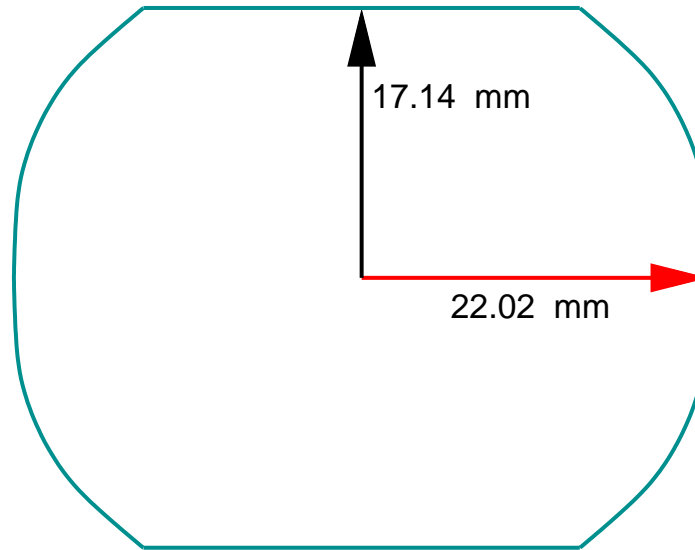


- Spectrometer **positive**: $\alpha_{x,2} = +210 \mu\text{rad}$
- Large aperture needed in horizontal plane !

Alternative: crossing in tilted planes

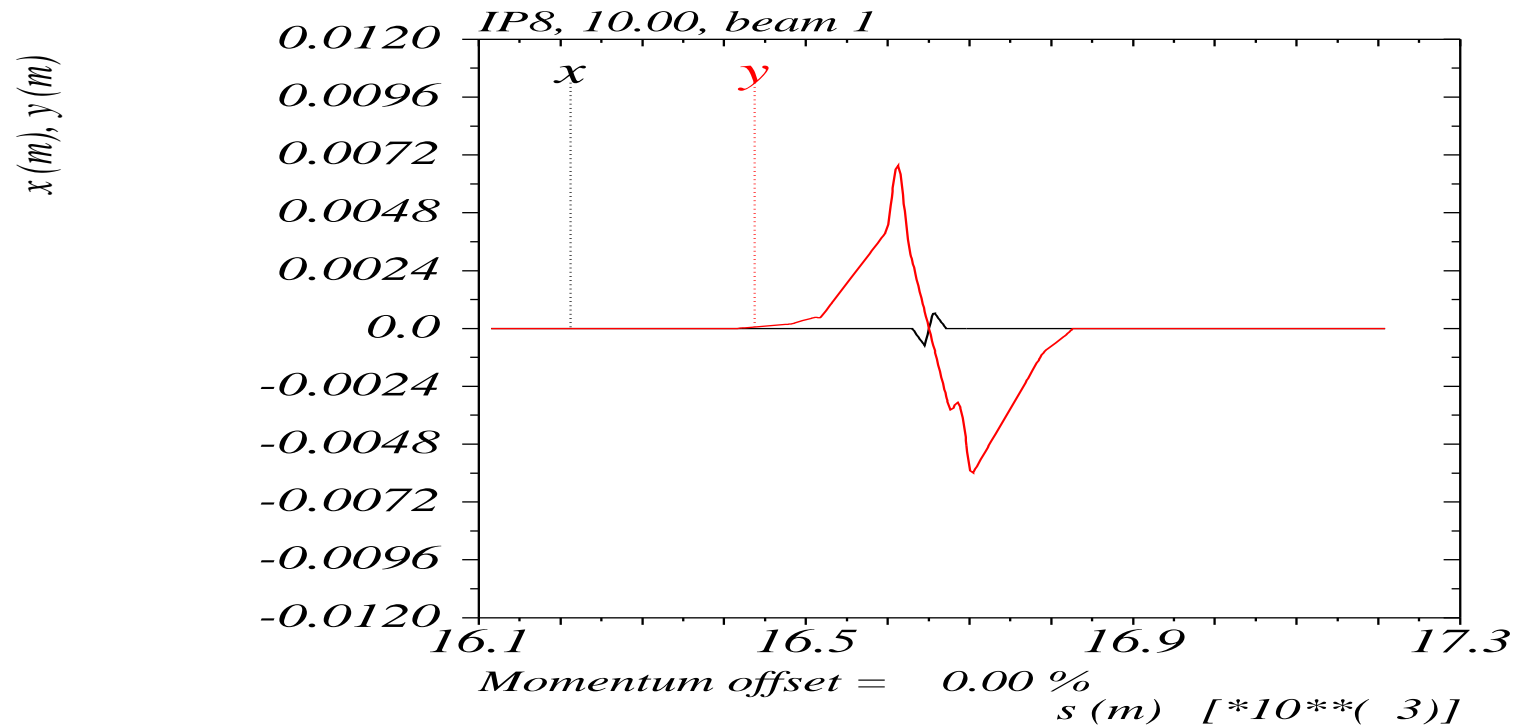
- Spectrometer angle horizontal, external angle vertical
 - Crossing would be in x-y plane
 - Effective crossing angle independent of spectrometer polarity (advantage for LHCb)
 - External angle decoupled from spectrometer polarity (advantage for operation)
 - Problem: available aperture
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Beam screen - IP8



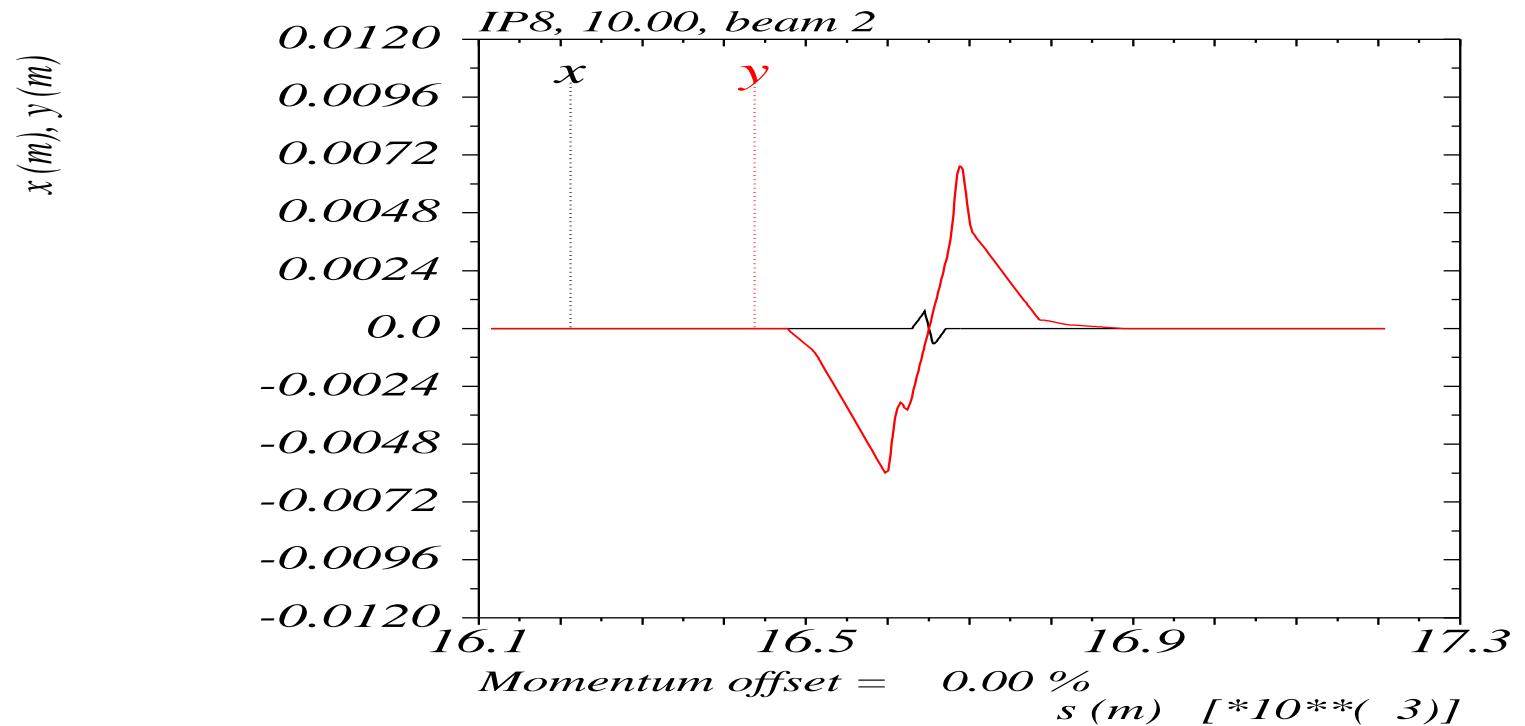
- Orientation in IP8 for horizontal crossing, already installed
- Vertical aperture reduced

Crossing scheme (Beam 1, $\beta^*=10$ m, 7 TeV)



- ➔ External angle: $\alpha_{y,1} = -(\mp)135 \mu\text{rad}$
- ➔ Smaller (or larger) values possible

Crossing scheme (Beam 2, $\beta^*=10$ m, 7 TeV)

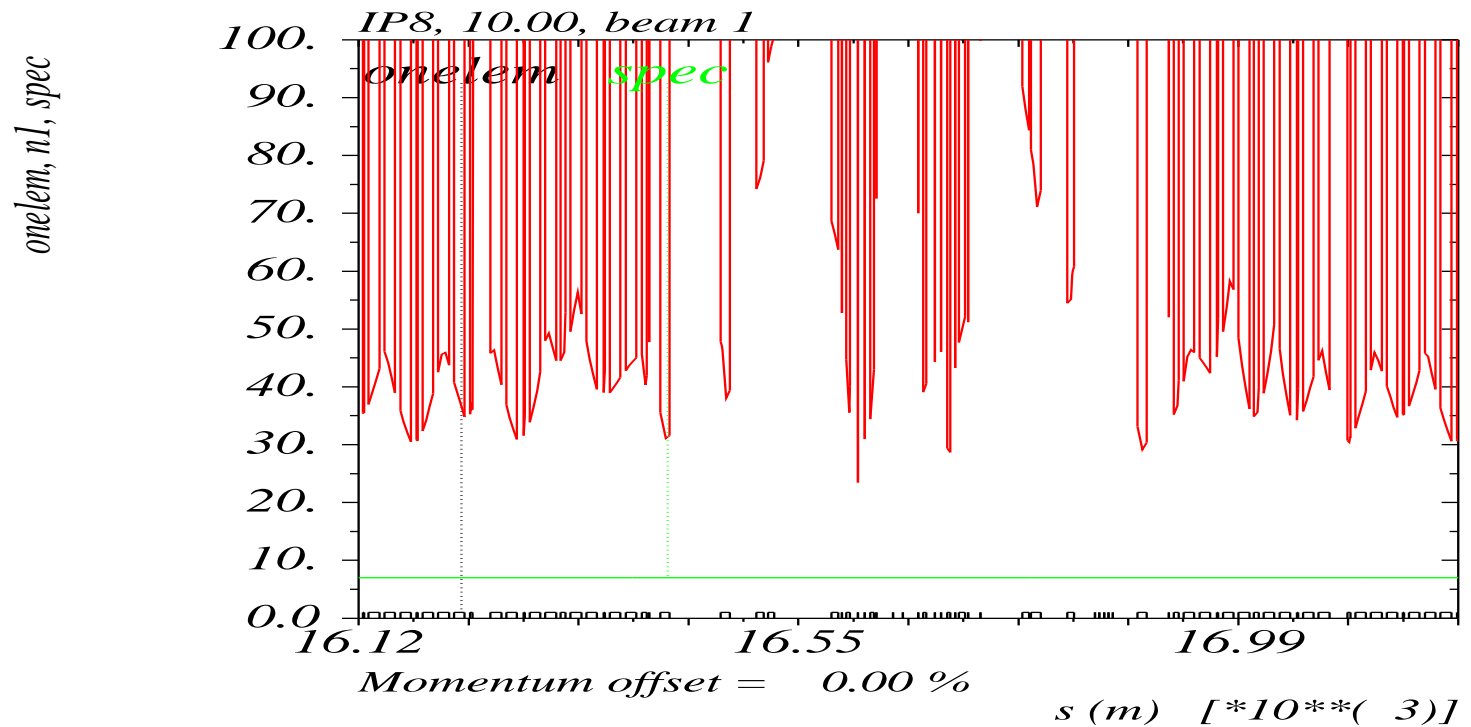


→ External angle: $\alpha_{y,2} = +(\pm)135 \mu\text{rad}$

→ Aperture needed in vertical plane →

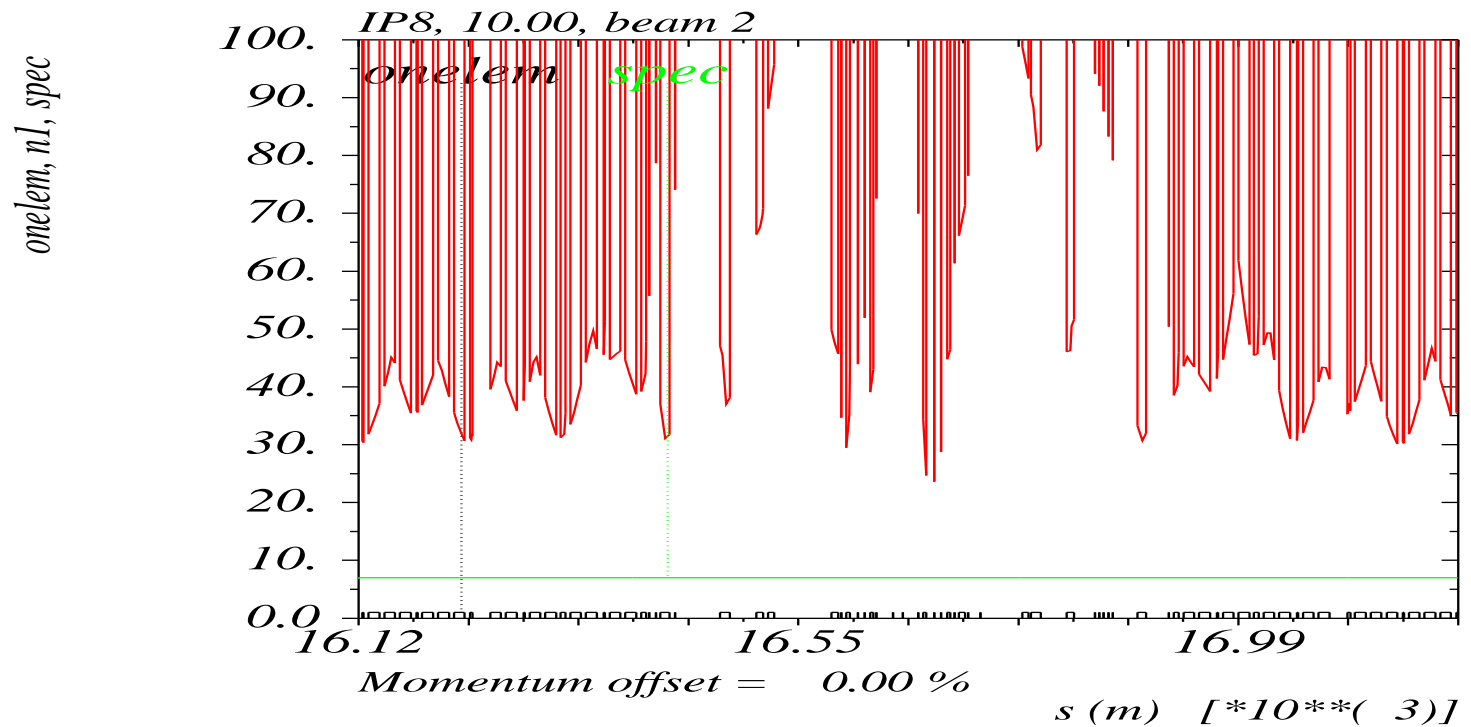


Aperture (Beam 1, $\beta^*=10$ m, 7 TeV)



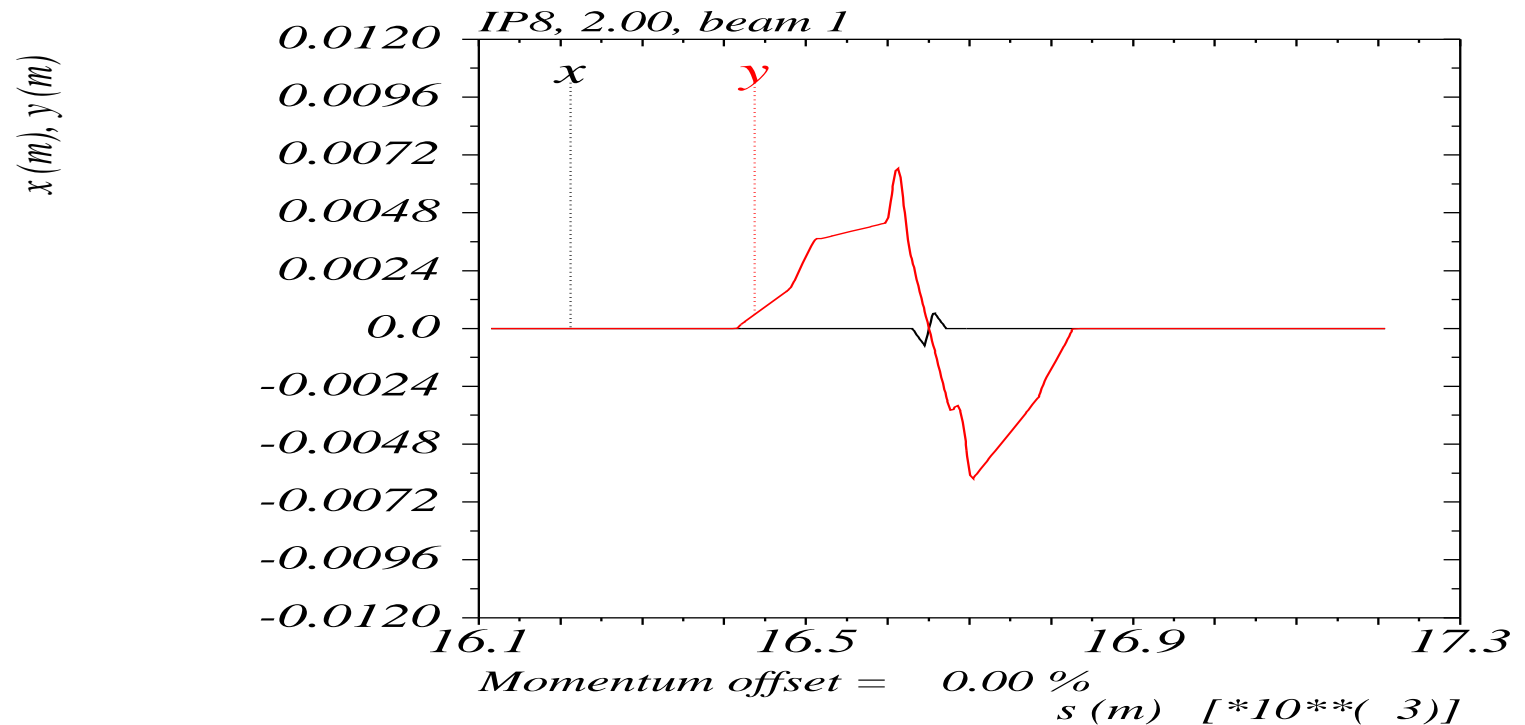
→ Sufficient aperture available for $\beta^* = 10$ m

Aperture (Beam 2, $\beta^* = 10$ m, 7 TeV)



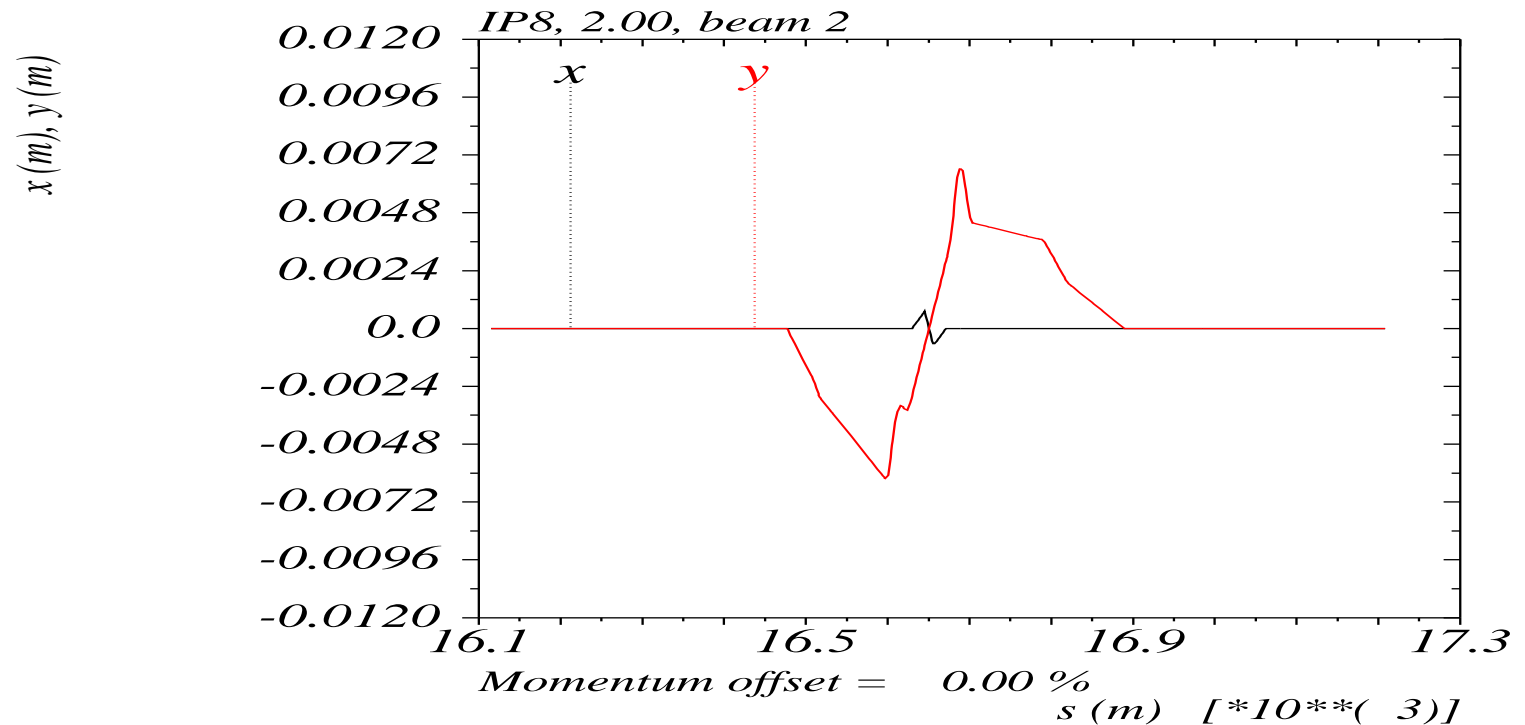
→ Sufficient aperture available for $\beta^* = 10$ m

Crossing scheme (Beam 1, $\beta^*=2$ m, 7 TeV)



- ➔ External angle: $\alpha_{y,1} = -(\mp)135 \mu\text{rad}$
- ➔ Smaller (or slightly larger) values possible

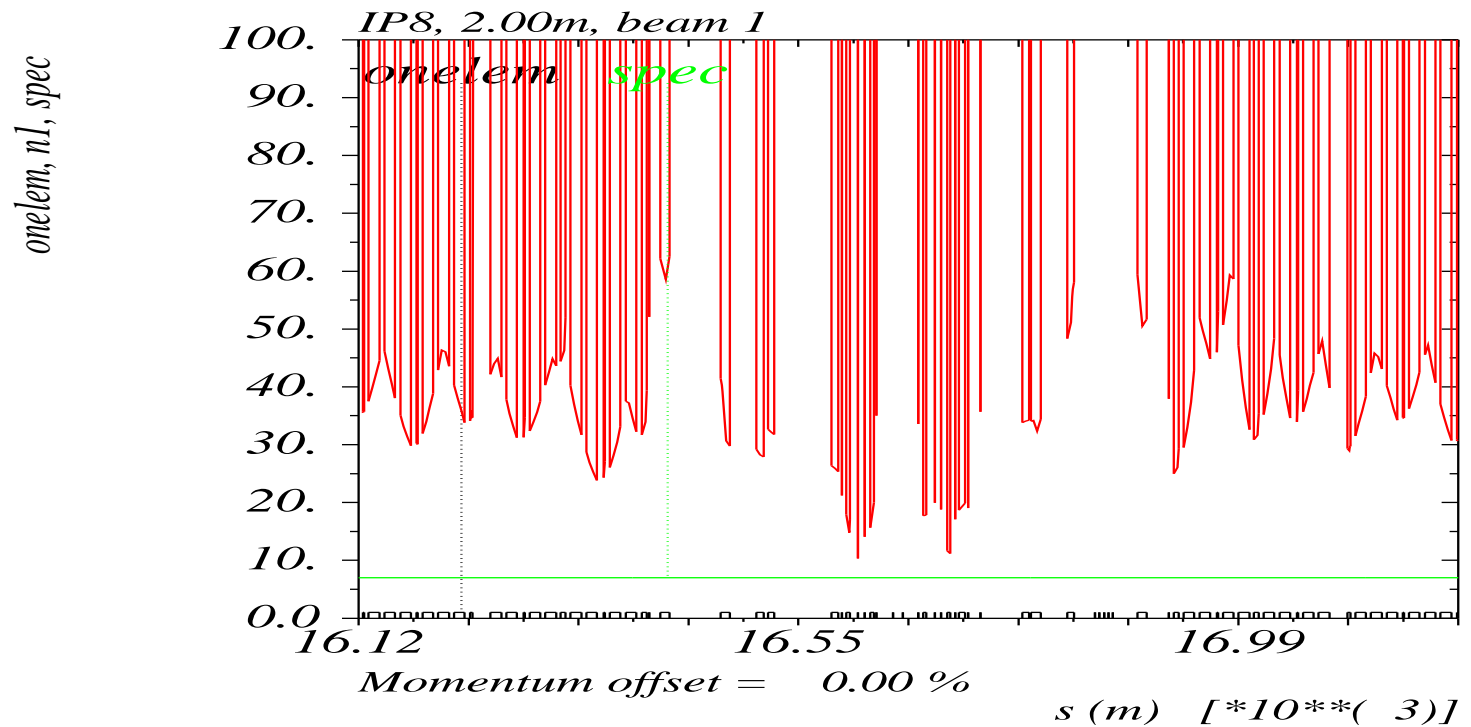
Crossing scheme (Beam 2, $\beta^*=2$ m, 7 TeV)



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

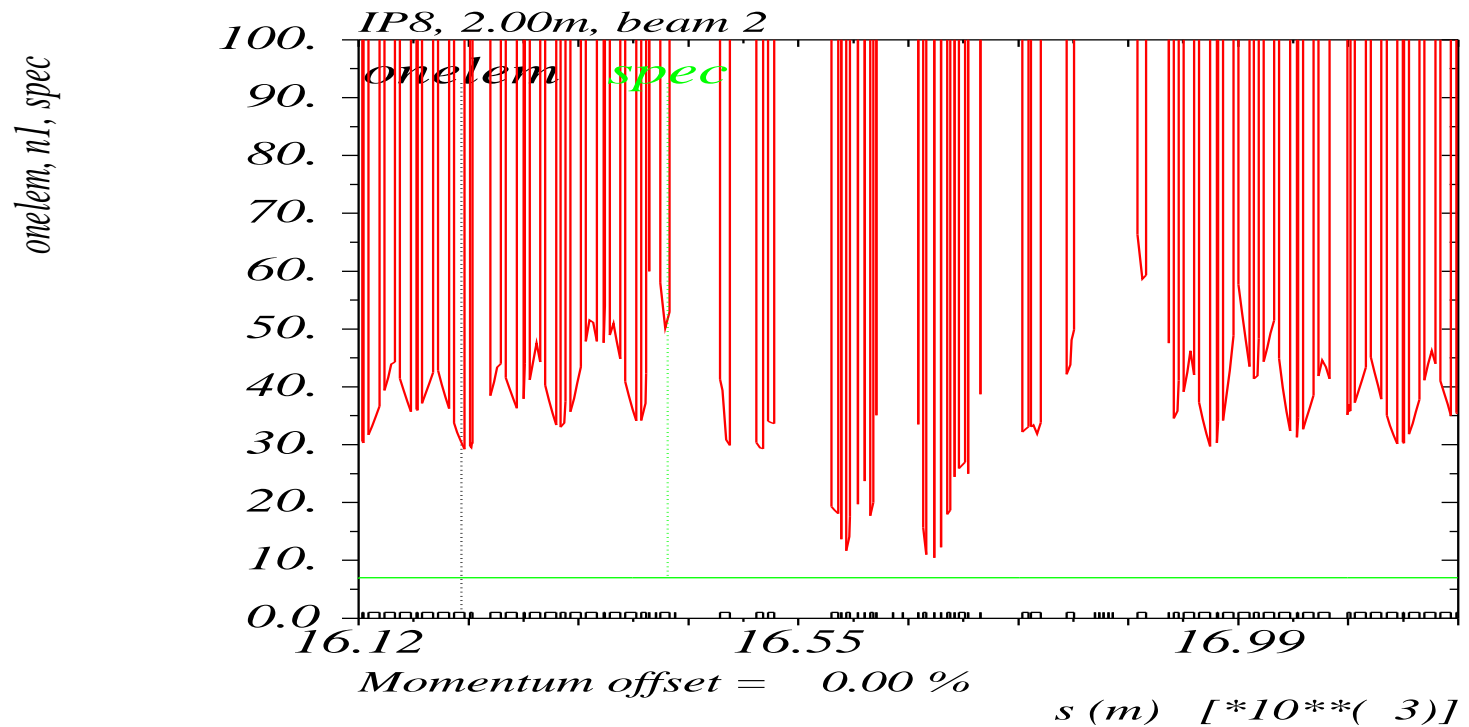
→ Aperture needed in vertical plane →

Aperture (Beam 1, $\beta^*=2$ m, 7 TeV)



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

Aperture (Beam 2, $\beta^* = 2$ m, 7 TeV)



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

Alternative crossing in LHCb at 7 TeV

Spectrometer	$\beta_{x,y}^*$ (m)	α_s (μrad)	α_y (μrad)	α_{eff} (μrad)	sep_{min} ($\sigma_{x,z}$)
–	10.0	∓ 135.0	± 135.0	∓ 190	14 \pm 2
+	10.0	± 135.0	± 135.0	± 190	14 \pm 2
–	2.0	∓ 135.0	± 135.0	∓ 190	13 \pm 2
+	2.0	± 135.0	± 135.0	± 190	13 \pm 2

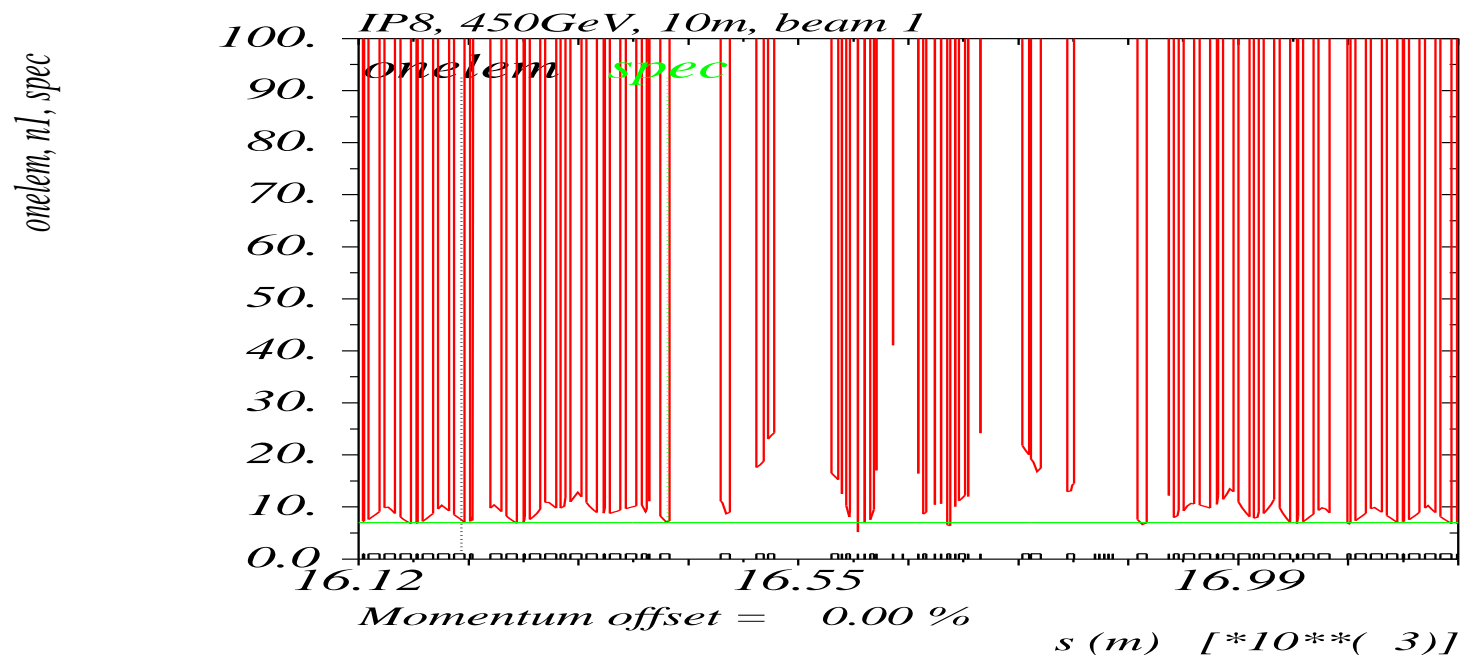
- ➔ External angle α_y can be all the same
- ➔ Effective angle α_{eff} always same absolute value



Crossing in both planes (at 7 TeV)

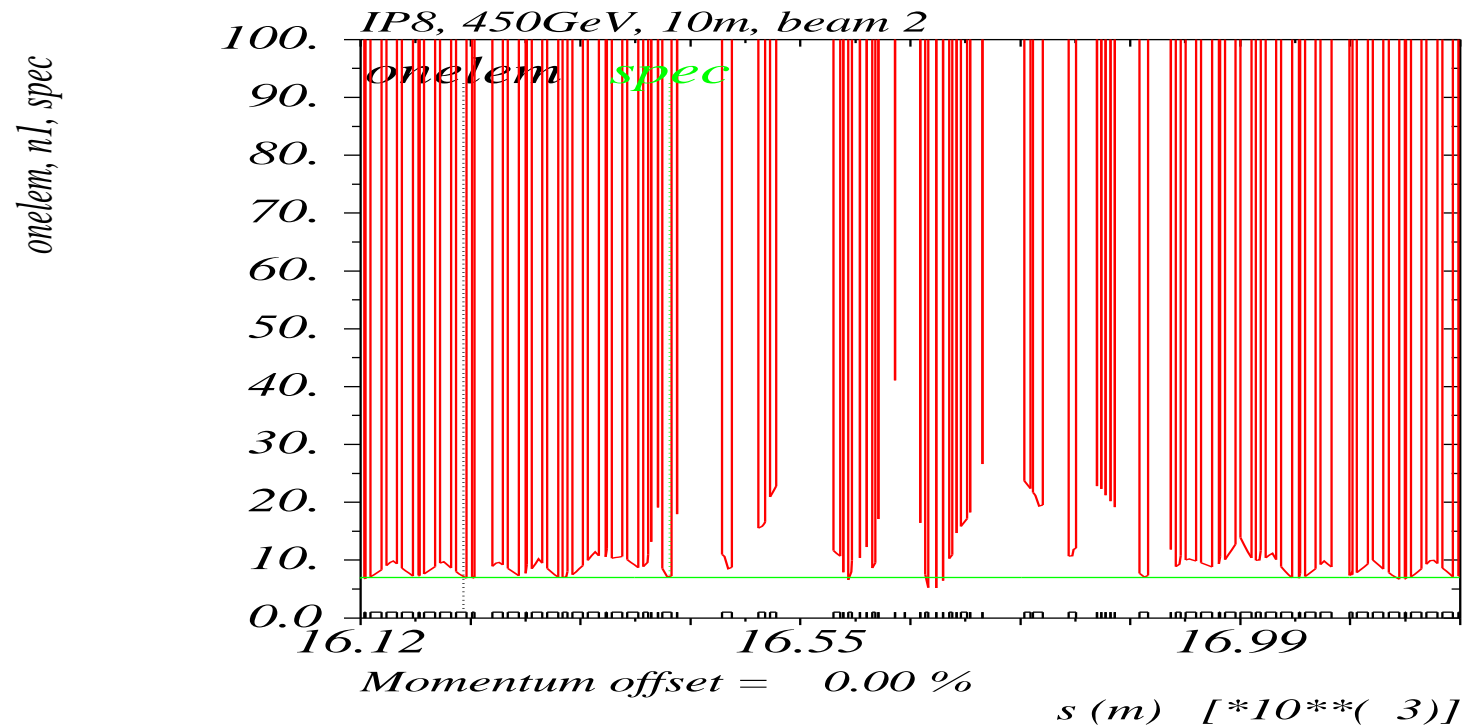
- Effective crossing angle independent of spectrometer polarity
- External crossing angle independent of spectrometer polarity
- Beam separation sufficient
- Transparency of crossing angle and spectrometer bumps
- What about injection ?

Aperture (Beam 1, $\beta^*=10$ m, 0.450 TeV)



- Computed with nominal (pessimistic) assumptions
- Aperture for injection (probably) insufficient

Aperture (Beam 2, $\beta^*=10$ m, 0.450 TeV)



Injection and ramping:

- Assume aperture for injection 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:

- Polarity transparent 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
 - Answer to the original question is YES
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