IP2 and IP8 contributions to beam-beam effects: preliminary studies and recommendations

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Repeating a bit what many other people did before working on IP2&IP8 crossing schemes
W. Herr, lannis, S. Fartoukh, J. Jowett.....

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Outlook

- Simulations set-up
- Different scenarios for the 2015 run for IP2 and IP8
- IP2 tune shifts and footprints for squeeze and collision:
  - Spectrometer OFF
  - Spectrometer ON
- IP8 tune shifts and footprints for squeeze and collision
  - Spectrometer POSITIVE polarity
  - Spectrometer NEGATIVE polarity
- Summary
2015 case: Simulations set-up

- Intensity: $1.3\times10^{11}$ protons per bunch
- Emittance: 3.75 $\mu$m
- 25ns bunch spacing
- Energy 6.5 TeV
- IP1/5 beta*=80 cm, IP2 beta*=10 m, IP8 beta*= 3 m

New optics available from Riccardo:

/afs/cern.ch/eng/lhc/optics/runII/opt_med/opt_800_10000_800_3000_thin.madx

Crossing Schemes:

- IP1-V/5-H: 145 $\mu$rad half crossing angle $\rightarrow$ equivalent to 11 $\sigma$ beam-beam separation (proposed at EVIAN 2014 workshop for LHC runII start-up)
- IP2-V: external crossing angle + ALICE spectrometer (+ 75 $\mu$rad)
- IP8-H: external crossing angle + LHCb spectrometer (+/- 145 $\mu$rad)
IP2 and IP8 possible running scenarios for RUNII: end of squeeze

End of betatron squeeze parallel separations on

- **IP2 Vertical x-angle and spectrometer angle in vertical plane (2mm half)**
  - The swap of the spectrometer polarity will always have a change of the sign of the external crossing angle → the effective crossing angle is always the sum of spectrometer and external
  - Have the possibility to **switch off the spectrometer** (request from Massimo) the effective crossing angle will be equal to the external one

- **IP8 Horizontal external x-angle and spectrometer angle in horizontal plane (1mm half)**

  BUT the crossing angle bump interferes with the recombination bump (in H plane) → to avoid multiple head-on collisions external crossing angle has fixed sign
  - the polarity swap of the spectrometer will sum or subtract from the external x-angle
IP2 and IP8 possible running scenarios for RUNII: collisions

In collision

(rough luminosity assumptions private communication J. Wenninger still need experiments official requests)

- IP2 luminosity in the range of $10^{29} - 10^{31} \rightarrow$ separations of 4-6 $\sigma$ at the IP (depending on tails populations)
  - Reconsider the configuration with spectrometer ON and parallel separation at IP of 6 $\sigma$
    - Spectrometer OFF and parallel separation at 6 $\sigma$

- IP8 approximately 4-6 $10^{32}$ with pile-up of 1.6 (key parameter) $\rightarrow$ separation < 3 $\sigma$
  - Spectrometer both polarities with parallel separation at IP of 3 $\sigma$
Some basics

Separation in H plane

IP8 Horizontal crossing
→ LR in H-plane
→ Positive detuning in H-plane
→ Negative detuning in V-plane

IP2 Vertical crossing
→ LR in V-plane
→ Positive detuning in V-plane
→ Negative detuning in H-plane

\( +\Delta Q_lr \)

\( -\Delta Q_lr \)

\( \Delta Q_x \)

\( \Delta Q_y \)

\( \Delta Q_z \)

Beam separation \( d \) (units beam size \( \sigma \))

Graph showing the separation in the H plane with markers for different detunings and crossing points.
Footprints: x-angle scan in IP8

$$d_{sep} = \alpha \cdot \sqrt{\frac{\gamma \cdot \beta^*}{\epsilon}}$$

LR with Horizontal separation

→ Positive detuning in H-plane
→ Negative detuning in V-plane
Zero amplitude particle tune shift: IP8 LR

LR with Horizontal separation

\[ \Delta Q_{lr} \propto \frac{1}{d^2} \]
Zero amplitude particle tune shift: IP8 LR

LR with Horizontal separation

\[ \Delta Q_{lr} \propto \frac{1}{d^2} \]
Footprints: x-angle scan in IP2

LR with Vertical separation

→ Negative detuning in H-plane
→ Positive detuning in V-plane

\[ d_{sep} = \alpha \cdot \sqrt{\frac{\gamma \cdot \beta^*}{\epsilon}} \]
Zero amplitude particle tune shift: IP2 LR

LR with Vertical separation

\[ \Delta Q_{lr} \propto \frac{1}{d^2} \]
Zero amplitude particle tune shift: IP2 LR

LR with Vertical separation

\[ \Delta Q_{lr} \propto \frac{1}{d^2} \]
Squeeze IP8 versus external crossing angle
Squeeze: IP8 LR tune shift

Maximum variation $2 \times 10^{-4}$
Squeeze: tune shift IP8 LR

Maximum variation $2 \times 10^{-4}$

$Qy$: $\Delta Qy$ Negative lhcb spectrometer
$\Delta Qy$: Positive lhcb spectrometer

$225:250 \, \mu\text{rad}$
IP8 LR separation

Negative LHCb spectrometer

All separations above 26 $\sigma$
IP8 LR separation

Positive LHCb spectrometer

All separations above 26 $\sigma$
Squeeze: IP2 versus external crossing angle

Separation bump on
Squeeze: tune shift IP2 LR

![Graph showing ΔQ vs half crossing angle in μrad]
IP2 LR separations

All separations above 30 $\sigma$
2015 FPs: IP2-IP8 LR contribution

IP2: 120 µrad
IP8: 250 µrad
2015 FPs: IP2-IP8 HO contribution

IP2 parallel sep: 6 $\sigma$, IP8 parallel sep: 3 $\sigma$

IP2: 120 µrad
IP8: 250 µrad
2015 FPs: IP8 HO contribution vs parallel separation

IP8: 250 µrad

Vertical separation bump → negative detuning in H-plane → positive detuning in V-plane
IP8 versus external angle

Negative LHCb spectrometer

IP8 parallel sep: $3 \sigma$
IP8 LR separations in collision

Negative LHCb spectrometer  IP8 parallel sep: 3 \sigma

All separations above 20 \sigma
IP8 collision: tune shift

![Graph showing ΔQx for Negative LhcB spectrometer (solid line) and Positive LhcB spectrometer (dashed line) as a function of half crossing angle (μrad). The ΔQx values range from 0.300 to 0.3035.]
IP8 collision: tune shift

![Graph showing the tune shift for negative and positive LHCb spectrometers. The y-axis represents the ΔQy values, and the x-axis shows the half crossing angle in μrad. The graph includes two lines, one for negative LHCb spectrometer and another for positive LHCb spectrometer, indicating a gradual increase in ΔQy with the angle.](graph.png)
IP8 versus external angle

Positive LHCb spectrometer

IP8 parallel sep: 3 \( \sigma \)
IP8 LR separations in collision

Positive LHCb spectrometer  IP8 parallel sep: 3 $\sigma$

All separations above 12 $\sigma$
IP2 versus external angle

IP2 parallel sep: 6 σ

ALICE spectrometer on (Positive)
IP2 LR separations in collision

Spectrometer ON

IP2 parallel sep: 6 $\sigma$

All LR at 20 sigma
IP2 versus external angle

IP2 parallel sep: $6 \sigma$  ALICE spectrometer off
IP2 LR separations in collision

Spectrometer OFF

IP2 parallel sep: 6 σ

2 LR at 12 sigma
IP2 collision: tune shift

\[ \sigma \]

\[
\begin{align*}
\Delta Q_y \text{ ALICE spectrometer on} \\
\Delta Q_x \text{ ALICE spectrometer off}
\end{align*}
\]
IP2 collision: tune shift

\[
\Delta Q_y \quad \text{ALICE spectrometer on}
\]

\[
\Delta Q_y \quad \text{ALICE spectrometer off}
\]
Summary

• Several scenarios for IP2 and IP8 have been analyzed to characterize the first order long-range BB effects (tune shifts)

• There is room to reduces the effect of these encounters significantly

• Possible ranges for crossing angles to keep effect smaller than $\Delta Q < 10^{-4}$ level
  • IP2 external half crossing angle of $120 \ \mu$rad gives separations $> 28 \ \sigma$
  • IP8 external half crossing angle at $250 \ \mu$rad will give 2 LR at 12 $\sigma$ separations above 20 $\sigma$

• A scenario with IP2 spectrometer off will not have strong impact impact the LR effects (2 LR at 12 sigma)

• Still some discussions are needed with optics team to define limits on parallel separations and with OP for possible operation mode

• Anything missing? Questions?
2015 FPs: all IPs in collision