How do we have to ramp the LHCb spectrometer magnet?

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Present scenario

- Spectrometer at 100% field at 7 TeV
- Spectrometer at $\frac{450}{7000} = 6.4\%$ field at 450 GeV
  - Implies ramping the spectrometer $\propto E$
- Q: can we go to more than 6.4% field at 450 GeV??
- Q: can we go to full field for collisions at lower energy?
Reminder: CHAMONIX 2006

IP8 basic facts:

- Crossing angle in horizontal plane
  - Sign of effective crossing angle fixed (to avoid additional crossings)
  - Sign of external crossing angle fixed

- LHCb spectrometer compensated with 3 magnets
  - Creates (internal) crossing angle
  - Polarity change causes change of sign of (internal) crossing angle ➔ must be overcompensated
Spectrometer(-compensator) bump (⊕) at IP8

Orbit from spectrometer

beam 1

beam 2

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Spectrometer(-compensator) bump (⊕) at IP8

Orbit from spectrometer

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For $\oplus$: external angle must be larger than spectrometer angle

At top energy: internal crossing angle is $\pm 135$ $\mu$rad

- For polarity $(\ominus)$: $\mp 65$ $\mu$rad $\pm 135$ $\mu$rad
  ($\rightarrow \mp 200$ $\mu$rad)

- For polarity $(\oplus)$: $\mp 210$ $\mu$rad $\pm 135$ $\mu$rad
  ($\rightarrow \mp 75$ $\mu$rad)

For different polarities: different effective crossing angles (see LHCCWG specification)

We have a preferred polarity $(\ominus)$ for the spectrometer

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Full spectrometer field at injection

- At top energy: crossing angle $\pm 135 \, \mu\text{rad}$
- At injection with ramp: crossing angle $\pm 135 \, \mu\text{rad}$
- At injection without ramp: crossing angle $\pm 2100 \, \mu\text{rad}$
  - For polarity ($\ominus$): maybe difficult
  - For polarity ($\oplus$): is overcompensation possible to avoid additional crossings?
Different scenarios

- **Number of bunches:**
  - For 43 and 156 bunches: no external angle needed
  - For 75 ns, 50 ns, 25 ns: need the external angle superimposed

- **Optics:**
  - No $\beta^*$ smaller than 10 m
Crossing scheme with spectrometer (Θ)

For 43 and 156 bunches: no external angle
Crossing scheme with spectrometer ($\Theta$)

For 43 and 156 bunches: no external angle
Crossing scheme with spectrometer (θ)

With ± 170 μrad external angle: sufficient separation
Crossing scheme with spectrometer ($\Theta$)

With $\pm 170 \mu \text{rad}$ external angle: sufficient separation

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Crossing scheme with spectrometer (⊕)

With ± 170 µrad external angle: insufficient separation

Additional crossings to be avoided

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Crossing scheme with spectrometer (⊕)

With very large external angle: sufficient separation
Crossing scheme with spectrometer (⊕)

With external angle for sufficient separation

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Crossing scheme with spectromter (⊕) at 20%

\[
\begin{array}{cccc}
16.1 & 16.5 & 16.9 & 17.3 \\
10^{10} & 10^{10} & 10^{10} & 10^{10}
\end{array}
\]

-0.0120
-0.0096
-0.0072
-0.0048
-0.0024
 0.0
 0.0024
 0.0048
 0.0072
 0.0096
 0.0120

\text{IP8, 10.00, beam 1}

\[s (m)\]

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Crossing scheme with spectrometer (⊕) at 20%
Which is the maximum field?

- Find the maximum field to fulfil aperture requirements
- Scan field and compute $n_1$
- Try to optimize crossing angle to maximize $n_1$ in this process
Minimum $n_1$ as function of crossing angle

External angle scaling of 1.2 corresponds to 8.2% of maximum field
Minimum $n_1$ as function of crossing angle

External angle scaling of 1.2 corresponds to 8.2% of maximum field
Collisions at lower energy

Collisions at lower energies are discussed ...

At which energy is the full field possible?

Without crossing angle full field is always possible

Depends on $\beta^*$, polarity (of course) and number of bunches:
Collisions at lower energy

\[ 16.390, 16.606, 16.822 \times 10^3 \, \text{m} \]

4 TeV, full field spectrometer \( \oplus \), \( \beta^* = 10 \, \text{m} \)

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At which energy is the full field possible?

- Without crossing angle full field is always possible.
- Depends on $\beta^*$, polarity (of course) and number of bunches:
  - For $\beta^*$ 10 m full field possible around 4000 GeV (both polarities)
SUMMARY

Working scenarios at injection:

→ No angle, no aperture problem
→ For one polarity full field (probably) feasible
→ For second polarity full field excluded, can maybe go from 6.4% to 7.5%

With $\beta^* = 10$ m collisions at 4 TeV (or more):
→ Full spectrometer field is possible for both polarities