Crystal H Beam 2 Alignment Check

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Previous observation

During MD1 slot the new crystals installed on B2 were characterised (results presented in [LSWG MD#1 & MD#2 Results](#) and at [ColUSM #90](#)). As reported B2-H showed some puzzling results.

- @450 GeV: very small reduction factor and angular scan width
- @6.5 TeV: very strange angular scan shape, CH orientation too far from injection
In September, within just two hours, we confirmed the observation of skew planes

1. Observed in angular scan
2. Skew planes produce lower deflection, measured with collimator scans
3. Different loss pattern compatible with lower deflected beam halo
Angular Bump Test

Other ordered structures called skew planes are present in a crystal. Skew planes could produce beam with a smaller deflection with respect to the planar channeling.

Skew planes appear closer to planar channeling, when crystal is well aligned to the crystalline axis direction.

Goniometers doesn’t have a rotational stage dedicated for this direction.

A 4 corrector bump in the vertical plane can misalign the crystal and make the skew plane move away from planar channeling orientation.
## Beam Set Up and procedure

<table>
<thead>
<tr>
<th>Number of MD’s</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time required per MD [h]</td>
<td>4</td>
</tr>
<tr>
<td>Beams required [1, 2, 1&amp;2]</td>
<td>2</td>
</tr>
<tr>
<td>Beam energy [GeV]</td>
<td>450</td>
</tr>
<tr>
<td>Optics (injection, squeezed, special)</td>
<td>Injection optics</td>
</tr>
<tr>
<td>Bunch intensity [#p]</td>
<td>standard pilot (or nominal, if needed) at 450GeV</td>
</tr>
<tr>
<td>Number of bunches</td>
<td>10-15 b (total intensity &lt;3e11 charges)</td>
</tr>
<tr>
<td>Transv. emittance [m rad]</td>
<td>&gt;1.5um</td>
</tr>
<tr>
<td>Bunch length [ns @ 4s]</td>
<td>1</td>
</tr>
<tr>
<td>Optics change [yes/no]</td>
<td>No</td>
</tr>
<tr>
<td>Orbit change [yes/no]</td>
<td>No</td>
</tr>
<tr>
<td>Collimation change [yes/no]</td>
<td>Yes: open (see appendix [7.1]) most B2 secondary collimators in IR7, upstream the crystal.</td>
</tr>
<tr>
<td>RF system change [yes/no]</td>
<td>No</td>
</tr>
<tr>
<td>Feedback changes [yes/no]</td>
<td>No</td>
</tr>
<tr>
<td>What else will be changed?</td>
<td>Crystals moved into the beam and set as primary collimators.</td>
</tr>
<tr>
<td>Are parallel studies possible?</td>
<td>Yes</td>
</tr>
<tr>
<td>Other info/requests</td>
<td>No</td>
</tr>
</tbody>
</table>

### Procedure:
1. Align crystal
2. Perform angular scan and check
3. Prepare and activate the 4 corrector bump to have an angle in the vertical plane of ~10÷20 μrad
4. Re-Align crystal to the beam and repeat the angular scan
5. Repeat point 3 and 4 with opposite angle
Conclusion

This test is important to prepare an intervention in the tunnel, with the lowest impact possible.

The idea is to misalign the whole TCPC tank with respect to the beam direction. Knowing in which direction the axis is (upward or downward with respect to the beam direction) a tank misalignment of just 0.5 mrad in the opposite direction to the axis can be sufficient to make the crystal fully operational for 2018 tests.
backup
crystal aligned @ 5.7 \sigma 
best channeling angle @ -298.2 \mu rad 
Reduction factor \( (L_{AM}/L_{CH}) = 10.6 \)

Planar CH

Skew ?

Hor Crystal BLM / Beam Flux [a.u.]

Skew planes confirmed
Channeled halo scan with TCSG.B4R7.B2

The error function fit shows how the channeled beam is different:

Broader and closer to beam core

Circulating beam
The drop is due to the normalization
One more confirmation from Loss Pattern: In case of low deflection beam does not hit B4R7, but pass through all the aperture of the machine and hit at 2\textsuperscript{nd} turn the 6L7.

Crystal in Left Skew
-370 urad

Crystal in Channeling
-295 urad
B2-V showed clearly skew planes near the main planar channeling. This is a known phenomena that happens when the beam is close to the axis. 
- What if with B1-H we are even closer to the axis wrt B2-V crystal?

Other ordered structures called skew planes are present in a crystal. Skew planes could produce beam with a smaller deflection with respect to the planar channeling.
Crystal was fixed in the two minimum and extracted beam was sampled with TCSG.B4R7.B2 (1st Turn), and TCSG.6L7.B2 (2nd turn).

Added lower deflection trajectories, to compare the lower deflection trajectories.
Overview from single pass experiment

Long scan several Skew Distant from Planar

Skew deflection = smaller X deflection + low Y deflection

In this case (QM crystal) is closer to the axis, Then the skew planes are closer to the planar channeling
The scan on the left is vertically displaced by -1040 urad from -> standard channeling is observed with no contamination by skew + axial effects.
B2 H Crystal – Injection September

Comparison with single pass

Skew

Planar CH

Skew

Horizontal Crystal Angle

-600 -400 -200 0 200

Horizontal Crystal Angle

-14 10

-13 10

rad[m]
crystal aligned @ 5.5 $\sigma$ (TCP H re-aligned)
best channeling angle @ -294.5 $\mu$rad
Reduction factor ($L_{AM}/L_{CH}$) = 4.75
crystal aligned @ 5.23 σ (TCP H re-aligned)
5 angular scan measured, no one clean enough for analysis
Losses recorded with BLM at goniometer position normalized to beam. The X axis is converted in deflection angle using

\[ \theta_k(s_{coll}) = \frac{x(s_{coll}) - \sqrt{\beta_{coll}/\beta_{cry}} \cdot x_{cry} \cdot \cos(\Delta \phi)}{\sqrt{\beta_{cry}/\beta_{coll} \cdot \sin(\Delta \phi)}} \]

Hor Crystal Scraping @ 6.5 TeV

A bit low, but may be consistent with difference from optic functions
Or it may be a skew plane, since it is too far away from injection orientation
Crystal in best channeling orientation and scan with TCSG.B4R7.B2 for horizontal plane

The angle is not good at injection, the evaluation is done to understand the relative difference with the following if it is.

Hor Crystal Scraping @ 450 GeV

Hor Absorber BLM / Beam Flux [a.u.]

Absorber position [mm]

0 -9.5 -9 -8.5 -8 -7.5 -7 -6.5 -6 -5.5

Deflection angle @ absorber position [ rad ]

-200 -190 -180 -170 -160 -150 -140 -130 -120

Hor Absorber BLM / Beam Flux [a.u.]

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B2 H Injection - September

Crystal in best channeling orientation and scan with TCSG.B4R7.B2 for horizontal plane

Slightly different, but is due to the different alignment (Jul 5.5 / Sep 5.7)
B2 H Injection – Sep Skew L (1st turn)

Crystal in left skew orientation and scan with TCSG.B4R7.B2 for horizontal plane

Hor Crystal Scraping @ 450 GeV

Hor Absorber BLM / Beam Flux [a.u.] vs Absorber position [mm]

Hor Crystal Scraping @ 450 GeV

Hor Absorber BLM / Beam Flux [a.u.] vs Deflection angle @ absorber position [rad]

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B1 H Injection – Sep Skew L (1\textsuperscript{st} turn)

Seems to be consistent with a smaller deflection
On B4L7 deflection smaller of about 20 urad
Crystal in left skew orientation and scan with TCSG.6L7.B2 for horizontal plane
B1 H Injection – Sep Skew L (2\textsuperscript{nd} turn)

Seems to be consistent with a smaller deflection
Crystal in right skew orientation and scan with TCSG.B4R7.B2 for horizontal plane
Seems to be consistent with a smaller deflection
On B4L7 deflection smaller of about 20 urad, again
Crystal in right skew orientation and scan with TCSG.6L7.B2 for horizontal plane
B1 H Injection – Sep Skew L (2\textsuperscript{nd} turn)

Seems to be consistent with a smaller deflection
B2 H Vertical Angle Bump

Test with vertical angle added to the beam direction with a 4 knobs bump

Unfortunately we lost the channeling orientation

Two possible explanation
1. Losses are very low, with respect to angular scan which is normalized in the same way -> beam away from crystal
2. Moving vertically may put the channeling far away in the angular horizontal range -> out of scanned range

The second hypothesis is not so strong: by geometrical construction, if we move of 25 urad, on vertical, the horizontal displacement must be lower than this value...

\[ \theta_x, \theta_y \]

\[ \text{(111)} \]
Conclusion

✓ Program to understand the B2-H behaviour completed in about 2 hours
✓ We got consistent results with respect to July
  ✓ CH orientation around -297 urad, reduction factor of about 10.6
✓ Measured possible skew planes very close to planar CH orientation
  ✓ The two depressions correspond to a deflected beam, with a characteristic loss pattern
  ✓ Sampled at both 1st and 2nd turn, showed a relative reduction of deflection
✓ Results compatible with skew plane observation

Outlook:

☐ Evaluate better the deflection angle from the linear scans
  ○ A quantitative evaluation is possible with measured optic values at injection
☐ Next MD:
  ○ Test with local vertical angular bump to move away from axis
  ○ Scan at flat top with planar channeling orientation