PBC LHC Fixed Target WG report

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on behalf of the PBC LHC FixT working group
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Outlines

- Reminder of scope and organization
- 2018 progress highlights
- Status of documentation
- Outlook
Reminder of scope and organization

Several proposals for fixed-target experiments at the LHC are being actively studied by physics communities. For example, the use of splitting of beam halos from the core with bent crystals for internal targets and the use of internal gas (possibly polarised) or solid targets. The working group will address the technical feasibility and impacts on the LHC machine with the aim of bringing together the various initiatives (UA9, LHC collimation team, AFTER collaboration, ...) and presenting a report to the update of the European Strategy for Particle Physics (ESPP).

Caveats:

- **Resources:**
  - No resources created for this scope
  - Thus, based on “best effort” of a few people

- Several proposals mention LHCb/ALICE as a possible place to perform their experiment. This does **not** automatically imply that LHCb/ALICE have approved these proposals.

Ongoing work... Some conclusions drawn.

**e-groups:** PBC-acc-FT-core, PBC-acc-FT, see https://cern.ch/egroups
Reminder of scope and organization

i) No second crystal, solid target only
   (see D. Kikola in QCD session)

ii) With second crystal, for dipole precession experiments
    (see N. Neri in QCD session)
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ii) With second crystal, for dipole precession experiments
(see N. Neri in QCD session)

Issues with machine protection (collimators hierarchy, beam intensity).
Not further looked at.
Reminder of scope and organization

UNPOLARIZED GAS TARGETS
He, Ne, Ar, H₂, D₂, N₂ ...

At LHCb: SMOG upgrade (SMOG2)
(see G. Graziani & P. di Nezza in QCD session yesterday)
Reminder of scope and organization

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**POLARIZED GAS TARGETS**

H, D, ³He

LHCspin.
Farther in future.
More R&D needed
(see same)
2018 progress highlights

Splitting proton halo with crystal:

Layout at IP8
Daniele Mirarchi

Crystal-2 of 14-15 mrad

Layout at IP2
Francesca Galluccio

No crystal-2
2018 progress highlights

Splitting proton halo with crystal for IP8: Daniele Mirarchi
(expected similar for IP2)

Beam intensity: \( I(t) = I_0 e^{-t/\tau} \)

Crystal-1 at location 1

Loss ratio: \( F_1 = \frac{\text{losses at 1}}{\text{losses at TCP}} \)

Flux at 1: \( \phi_1(t) = \frac{I(t)}{\tau} F_1 \frac{1}{2} \)

Target/crystal-2 at location 2

Flux at 2: \( \phi_2 = \phi_1 \eta_1 \)

- Evaluation of POT fluxes (ongoing)
  - seems limited to \( \phi_1 \sim \mathcal{O}(10^6) \) p/s for crystal-1 @ TCTP
  - considering also other locations in the LHC
- Optimisation of settings and optics (to be done)
- Disposal of halo, absorber design (to be done)
2018 progress highlights

Double crystal setup:

- Sorting out channeling efficiency for a long and large angle crystal
- Two independent measurements at the SPS north hall (analysis ongoing)

Observables:
- the incoming trajectory of each particle
- the outgoing trajectory of each particle
- the inelastic interaction events

LONG CRYSTALS FOR SELDOM

<table>
<thead>
<tr>
<th>Crystal Material</th>
<th>Silicon or germanium, preferably germanium.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal length along the beam</td>
<td>~9 cm in case of silicon</td>
</tr>
<tr>
<td></td>
<td>~6 cm in case of germanium</td>
</tr>
<tr>
<td>Crystal + support height</td>
<td>≤ 55 mm</td>
</tr>
<tr>
<td>Crystal + support weight</td>
<td>To be determined</td>
</tr>
<tr>
<td>Channeling plane</td>
<td>(110) or (111)</td>
</tr>
<tr>
<td>Channeling axis</td>
<td>&lt;111&gt;, &lt;110&gt; or &lt;100&gt;</td>
</tr>
<tr>
<td>Miscut for planar channeling</td>
<td>To be determined</td>
</tr>
<tr>
<td>Torsion</td>
<td>&lt; 1 urad/mm</td>
</tr>
<tr>
<td>Bending angle</td>
<td>~16 mrad</td>
</tr>
<tr>
<td>Dislocation density</td>
<td>&lt; 1 cm²</td>
</tr>
</tbody>
</table>

Bent silicon and germanium crystals with respective holder.

- Bent silicon (8 cm long, bent @16 mrad) or germanium crystal (5 cm long, bent @14.5 mrad).
- Silicon telescope allows reconstruction of single particle trajectory before and after interaction with the crystal (angular resolution ~ 5 urad).
- State of the art goniometer with 5 degrees of freedom.
- Lateral positioning with 1 um accuracy, angular accuracy 1 urad.
2018 progress highlights

Double crystal setup:
(presented by W. Scandale at oct2018 SPSC)
in SPS: crystal-1 channeled protons onto W target with a crystal-2

Next step: double channeling with a target
- A 3 mm long W target was inserted in SPS LSS5 in September 2018
- The W target totally shadows the second crystal
- Reference data have been taken in double channeling without the target, and final analysis is in progress
- We need now to complete the data set with same data with target in order to evaluate the process efficiency and the relative background

Extra run of 10 h requested in October/November 2018

A similar crystal half covered by a Tungsten target, as measured at our H8 test-beam, and bending in the vertical direction

(analysis ongoing)
2018 progress highlights

**Gas targets:**
Guidelines for aperture contraints in the case of a Storage Cell at IP8
Caterina Boscolo Meneguolo, Roderik Bruce
SC adjustable (left, 0.1 mm) or not adjustable (right, 2 mm excursions)

![Graph 1](image1)
![Graph 2](image2)

Takes into account $\beta^*$, crossing angles, separation for leveling and various (pushed!) scenarios in HL-LHC era.

Even for PGT at $2 - 3$ m it’s reasonable to imagine a SC radius $\sim 5$ mm provided it can be adjusted around the beams.
Gas targets:

Studies of loss-induced limitations on beam-gas rates

Caterina Boscolo Meneguolo

- SixTrack and FLUKA used to study loss pattern and the induced power load on magnets resulting from beam-gas interactions in IP8 storage cell
  - Considered inelastic and elastic interactions, H and Xe target with $10^{14}$ atoms/cm$^2$ as limiting cases
- Elastic interactions: No risk of quenching any magnet. Resulting losses are orders of magnitude below quench limit.
- Inelastic interactions on H target: probably safe, but not a huge margin
- Inelastic interactions on Xe target (preliminary):
  - Resulting rate is a factor 6 higher than for $pp$ at LHCb.
  - Losses below quench limit if $\Theta < \sim 1.2 \cdot 10^{13}$ atoms/cm$^2$
2018 progress highlights

Gas targets:
simulations in presence of a pressure bump ($e/\text{ions}$, leading to instabilities)

Kyle Poland, Lotta Mether

Above plot for LHC 16L2 case. For storage cell at IP8: ongoing...

Conclusions and Outlook

First simulations for the LHCb fixed target setup are ongoing
- the importance of electron induced ionization is evaluated
  - we possibly need to add this effect to the simulation model
- currently we are assuming a single beam in the chamber
  - common chamber adds layers of complexity, may enhance build-up
- electron and ion distributions from current studies will be used as input for single-bunch stability studies
- capability for multi-bunch instability studies is being developed, unclear if possible within the time frame of the PBC-FT CDR
2018 progress highlights

Gas targets:
SMOG upgrade = SMOG2 (SC attached to VELO at IP8) V. Carassiti et al.

- detailed review in LHCb with LHC machine experts (15.11.2018)
  - addressed vacuum, wake fields / impedance, aperture, machine protection...
- obtained green light from LHCb to go ahead and build it
- presentation at LHC Machine Committee yesterday
- next: monitor carefully the actual realization of this SC implementation, define running scenarios, studies for new gases (non-He/Ne/Ar), etc.
List of docs in CDS specifically related to PBC LHC FT

- **ESPP (aka EPPS, ESU, EPPSU) 10-pagers:** (will appear soon under CDS PBC Reports)
  - F. Galluccio et al., “Physics opportunities for a fixed-target programme in the ALICE experiment”
  - J.D. Bjorken et al., “Community Support for A Fixed-Target Programme for the LHC”
  - C. A. Aidala et al., “The LHCSpin Project”

- **PBC-acc FT WG notes:**
  - C. Boscolo Meneguolo et al., “Calculation of the allowed aperture for a gas storage cell in IP8”, CERN-PBC-Notes-2018-008. (PDF coming)
  - Someone et al., “The SMOG2 project” CERN-PBC-Notes-2018-007 (PDF coming)

- **PBC-acc FT WG Conference proceedings:**

- **PBC-acc FT WG report:**
  - Someone et al., “Report from the LHC Fixed Target working group of the CERN Physics Beyond Colliders forum”, CERN-PBC-REPORT-2019-001. (PDF due in March)
Status of documentation

More to come

- **Gaseous targets**
  - “Study of beam-gas interaction at the LHC for the Physics Beyond Collider Fixed-Target study”, C. Boscolo Meneguolo et al., draft available
  - Note(s) on polarised gas targets (R&D for coatings, ballistic flow, vac pumping schemes), P.di Nezza, E.Steffens et al
  - e-cloud build-up effects in a storage cell, K. Poland and L. Mether
  - target gas types and implications in LHC, P. Chiggiato et al

- **Solid targets:**
  - Possibly, conceptual design note on solid target in ALICE

- **Double crystal:**
  - SPS double crystal paper (IPAC2018)
  - Note(s) on double-crystal LHC layouts and PoT estimates
  - Long crystal: experimental performance (UA9)
  - Long crystal: experimental performance (SELDOM)
  - Detector simulations: update on implementation at point 8
Outlook

Wrap up WG activity with reporti (by March 2019)
Wrap up WG activity with report (by March 2019)

Gaseous targets

- vacuum: guidelines for various gas types
- beam-gas loss limits: finish simulations
- e-cloud/ions: finish simulations
Outlook

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Gaseous targets

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Crystals

- crys1@TCT: finish simulation & optimization for flux and baseline absorber (conceptual)
- evaluate if (which) other options could be considered beyond WG
- results for long crystals and finalize overall efficiency of dbl-crys experiment