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Warsaw University of Technology

Faculty of Physics
WARSAW UNIVERSITY OF TECHNOLOGY

LHC Collimation Project
CERN

Status of layout studies for fixed-target experiments in ALICE based on crystal-assisted halo splitting

Marcin Patecki[1,a]

Daniel Kikoła[1], Alex Fomin[2,3], Daniele Mirarchi[2], Stefano Redaelli[2]

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Cynthia Hadjidakis[4], Laure Marie Massacrier[4], Rihan Haque[1]

[1]Warsaw University of Technology, Faculty of Physics
[2]CERN, European Organization for Nuclear Research
[3]Kharkiv Institute of Physics and Technology
[4]Université Paris-Saclay, CNRS, IJCLab
[a] Marcin.Patecki@pw.edu.pl

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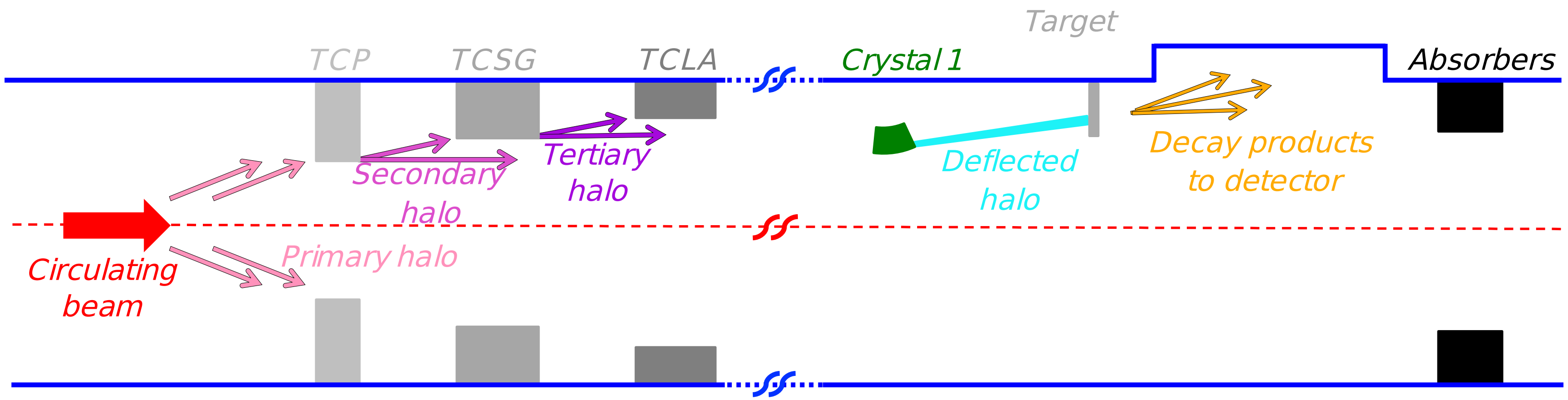
Context

- Publications:
  - A fixed-target programme at the LHC: Physics case and projected performances for heavy-ion, hadron, spin and astroparticle studies https://doi.org/10.1016/j.physrep.2021.01.002
  - LHC fixed target experiments: Report from the LHC Fixed Target Working Group of the CERN Physics Beyond Colliders Forum https://doi.org/10.23731/CYRM-2020-004
  - Physics opportunities for a fixed-target programme in the ALICE experiment https://cds.cern.ch/record/2671944
  - Layouts for fixed-target experiments and dipole moment measurements of short-lived baryons using bent crystals at the LHC https://doi.org/10.1140/epjc/s10052-020-08466-x

- Presentations:
  - F. Galluccio, W. Scandale Proposal for beam splitting in LHC IR2 https://indico.cern.ch/event/853688/contributions/3620725/
  - A. Fomin Updates on IP2 FT layouts https://indico.cern.ch/event/981210/contributions/4132813
  - D. Kikoła A fixed-target program in the ALICE experiment https://indico.cern.ch/event/1002356/contributions/4229546/
  - M. Patecki, Status of the crystal based ALICE fixed target layout https://indico.ijclab.in2p3.fr/event/7201/contributions/22532/

Layout for crystal based fixed-target experiments



Graphics: D. Mirarchi

- Halo particles are intercepted and disposed by the collimation system.
- Part of the secondary halo is intercepted by the crystal and deflected towards the target.
- Local absorbers capture additional losses coming from the crystal+target assembly.
- Parasitic operation means that fixed-target collisions occur in parallel to beam-beam collisions
- Parasitic operation of fixed target experiment is possible only if new loss spikes stay within acceptable limits (e.g. not larger than usual losses).
- The setup is optimized to provide a maximum flux of protons on target (PoT) that can be handled by the detector acquisition system.

Layout at IR2

<u>Layout:</u>

- Two ALICE polarities (“negX” and “posX”)
- HL-LHC v1.5 optics

<u>Gaps:</u>

- IR7 betatron coll. (TCP/TCS/TCA): 6.7/9.1/12.7 σ
- Crystal: 7.3 - 8.3 σ

<u>Crystals:</u>

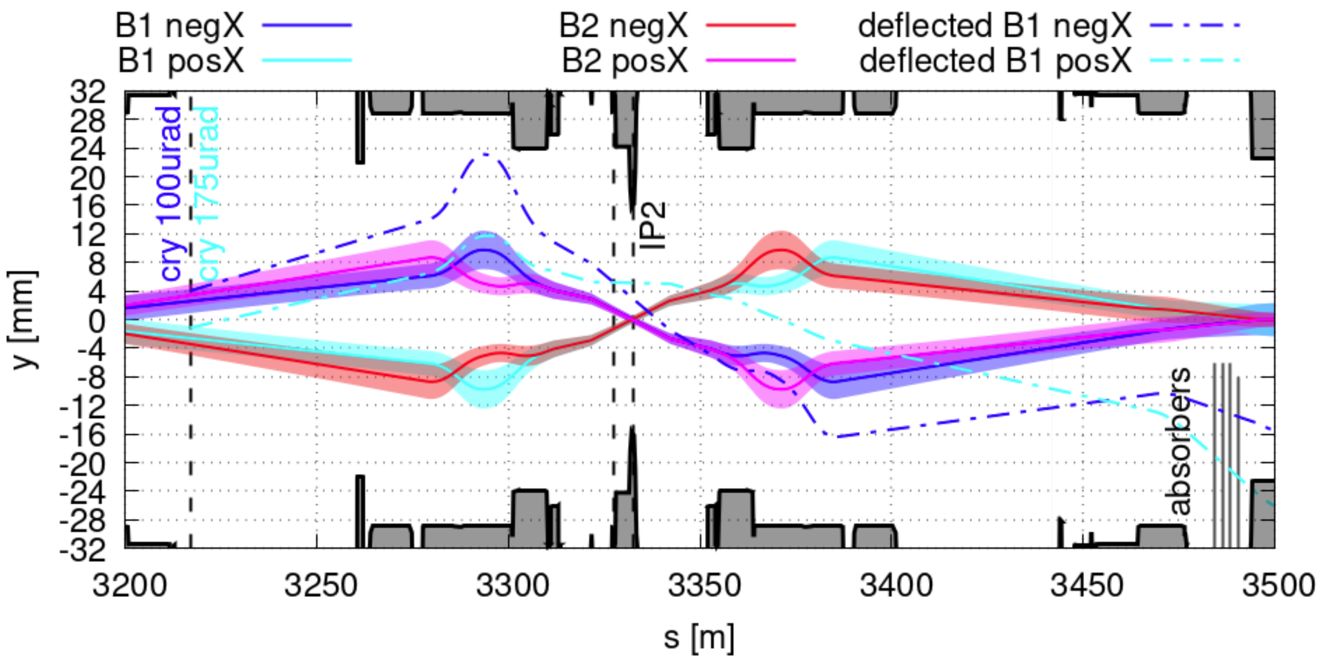
- bending radius: 80m
- bending angle: 100μm, 175μm
- length: 8mm, 14mm
- long. position: 3217.5m

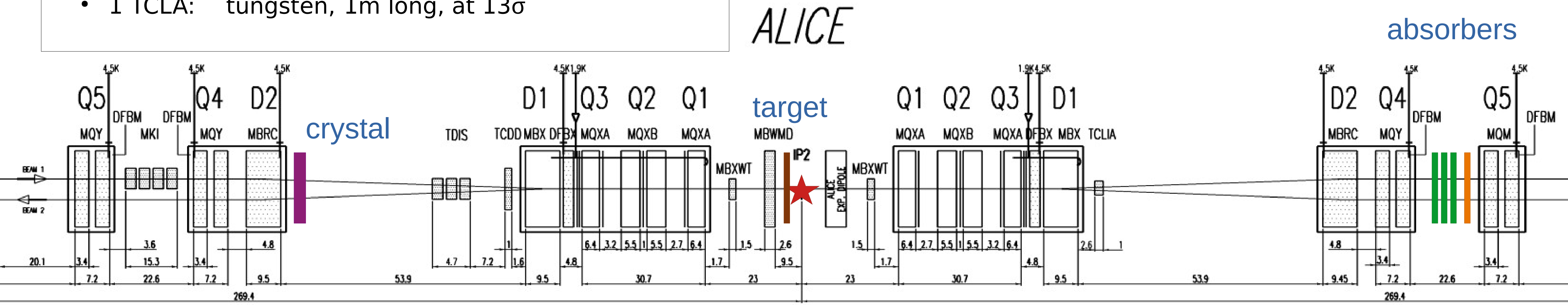
<u>Target:</u>

- 5mm - 10mm long, tungsten
- 4.8m upstream from the IP2

<u>Absorbers:</u>

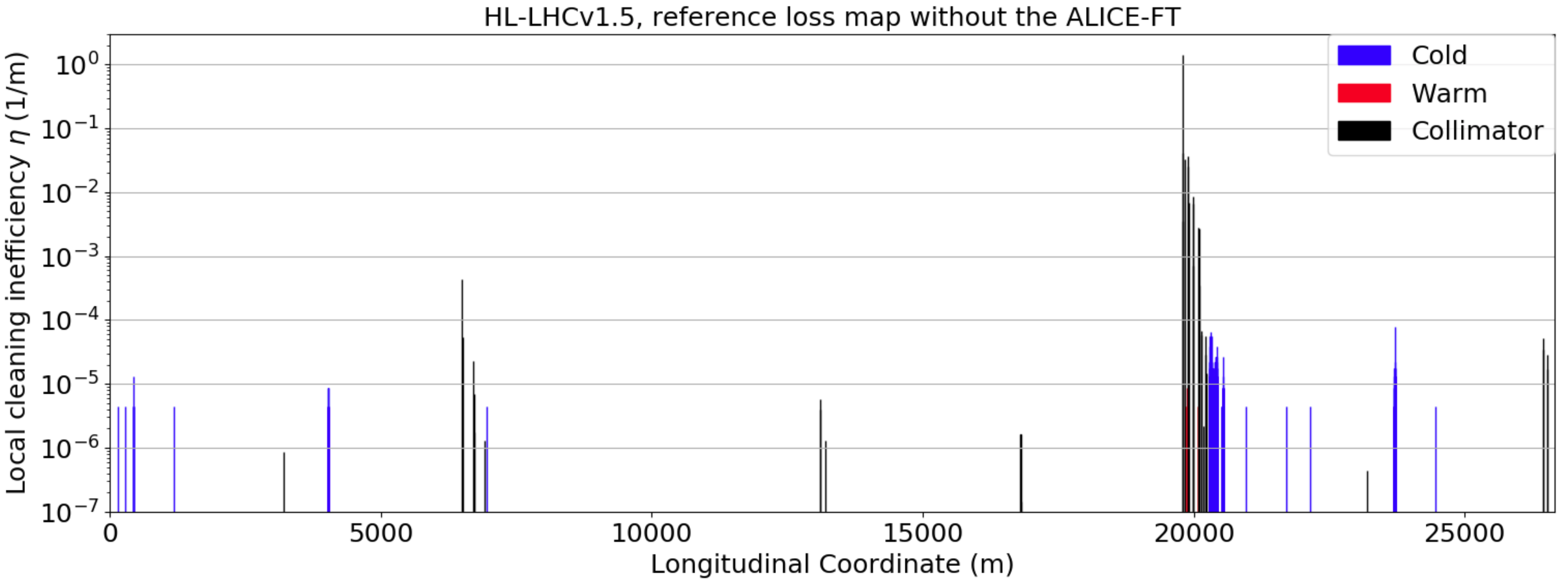
- 3 TCSGs: graphite, 1m long, at 10σ
- 1 TCLA: tungsten, 1m long, at 13σ

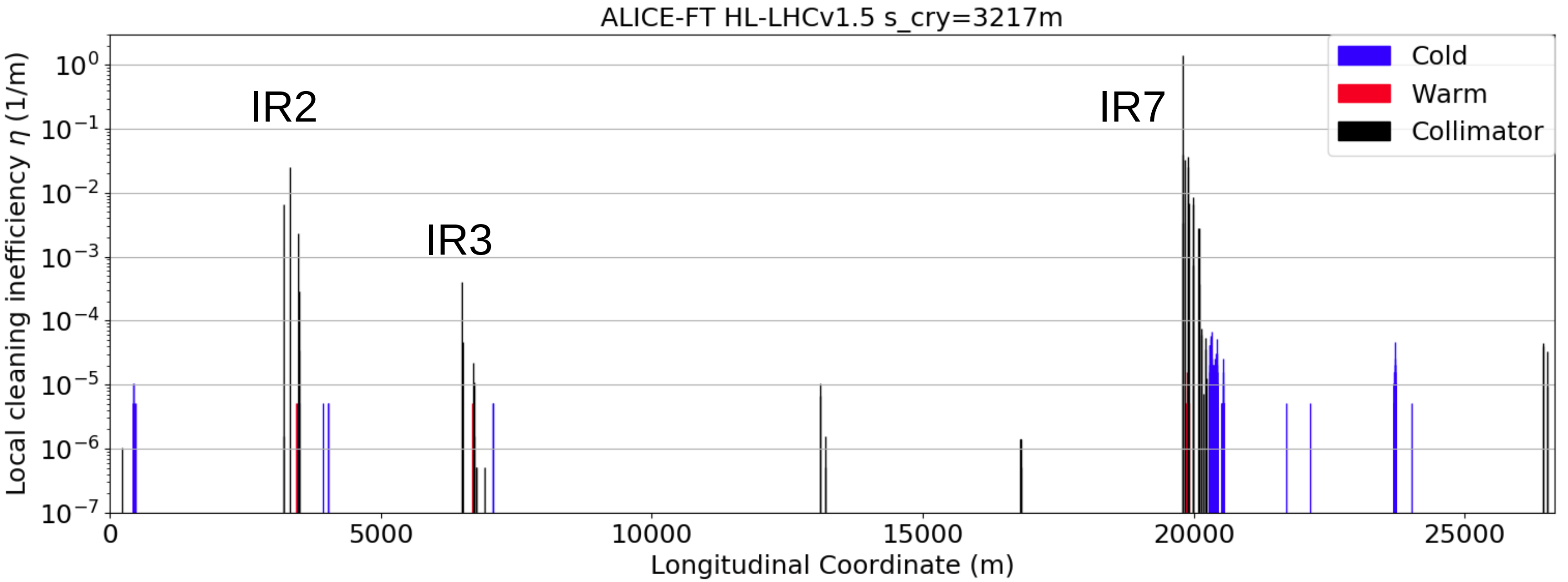




Loss map comparison

- Result of tracking simulations in SixTrack including collimation system and ALICE-FT experiment.
- Local cleaning inefficiency: measure of number of p not intercepted by the coll. system and impacting the machine aperture.
- The simulation limit of 1 proton lost in the machine aperture corresponds to 4.4×10^{-6} m^{-1} in a 10 cm longitudinal bin.
- No issue for cleaning.
- Number of absorbers can be potentially reduced – detailed energy deposition simulations needed.





Protons on target (PoT) per LHC fill

- Protons on Crystal (PoC) is a fraction of beam halo impacting the crystal.
- Protons on Target (PoT) is a fraction of beam halo that received a correct deflection from the crystal (channelling) and hit the target.
- Number of protons on target per fill can be estimated as:

$$N_{PoT}=\frac{1}{2}PoT\int_0^{T_{fill}}\frac{1}{\tau_{coll}}I_0\exp\left(\frac{-t}{\tau_{BO}}\right)\exp\left(\frac{-t}{\tau_{coll}}\right)dt$$

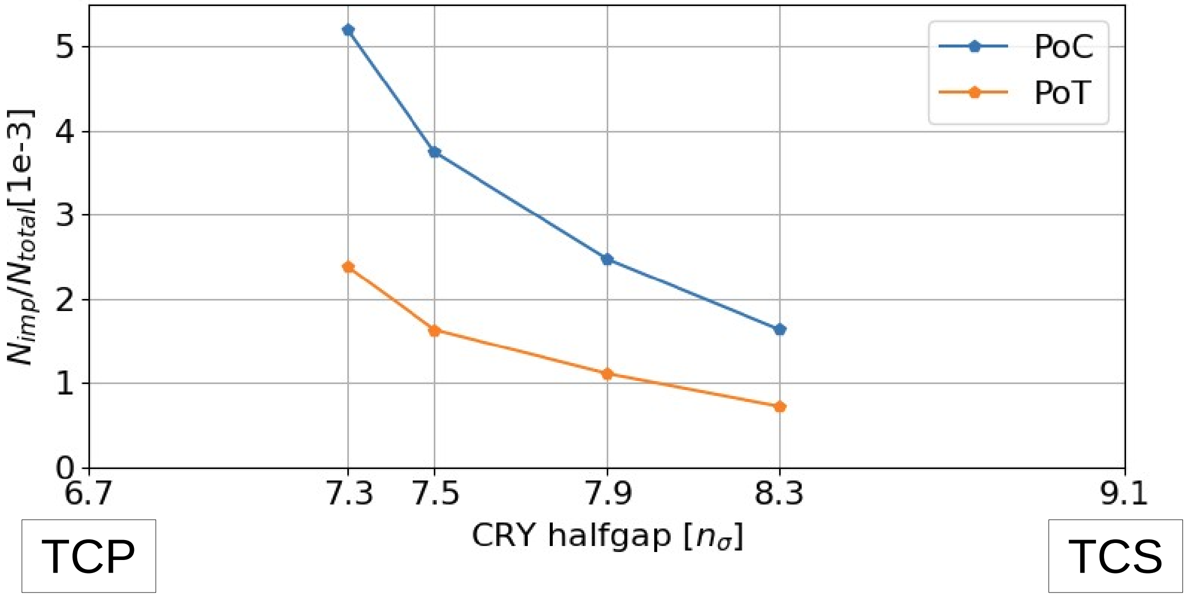
which for 2018 operation would result in about:

10^{10} protons per fill,

assuming [Eur. Phys. J. C (2020) 80:929]:

$$I_0=2556\cdot 1.1\cdot 10^{11}\,p,\ \tau_{BO}=20\,h,\ \tau_{coll}=200\,h,\ T_{fill}=10\,h$$

- HL-LHC beam intensity will be about x2 larger.
- Up to x10 gain in N_{poT} is expected if a special, dedicated beam excitation mode is applied at the end of each fill (details out of the scope of this presentation).



Conclusions

- A conceptual layout of the ALICE fixed-target experiment is ready.
- Integration of crystal and target assemblies in IR2 will be challenging but seems feasible.
- Two different crystals might be needed to cover both ALICE solenoid polarities.
- No issues with extra beam losses. Number of absorbers will be optimised based on E deposition simulations for cost efficiency.
- Parasitic operation allows for about $2x10^{10}$ protons on target per fill in HL-LHC conditions. This is about one order of magnitude less than ALICE acquisition system capabilities.
- Up to x10 more protons on target per fill can be obtained if a special, dedicated beam excitation mode is used. This would allow to use the full capabilities of the ALICE acquisition system.
- The system is planned to be ready for LHC Run 4.
- The Letter of Intend will be submitted in 2022.