252nd LHC Collimation Working Group joint with 195th LHC Machine Protection Panel meeting

October 26th, 2020

CERN, Geneva, CH

Strategy for Crystal Collimator Interlocks and Operation in Run 3

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Many thanks to D. Wollmann for inputs

Outline

- ☑ Introduction
- ☑ Planned Run 3 layouts
- ☑ Old and new interlocks
- ☑ Conclusions

Introduction

At the end of 2019, crystal collimation was added to the upgrade baseline of HL-LHC as part of the WP5 (baseline 4.0)

— Pb ion runs: risk mitigation for schedule concerns with 11 T dipoles
  → important to have the crystal collimation operational in Run 3!
— Instrumental: Russian's in-kind contributions for mechanical parts (PNPI/IHEP)
— Crystals from production contracts with INFN and PNPI. Controls at CERN.

Comparison to conventional collimation: Gain in Pb ion cleaning at 6.37 Z TeV, 2018 configuration.

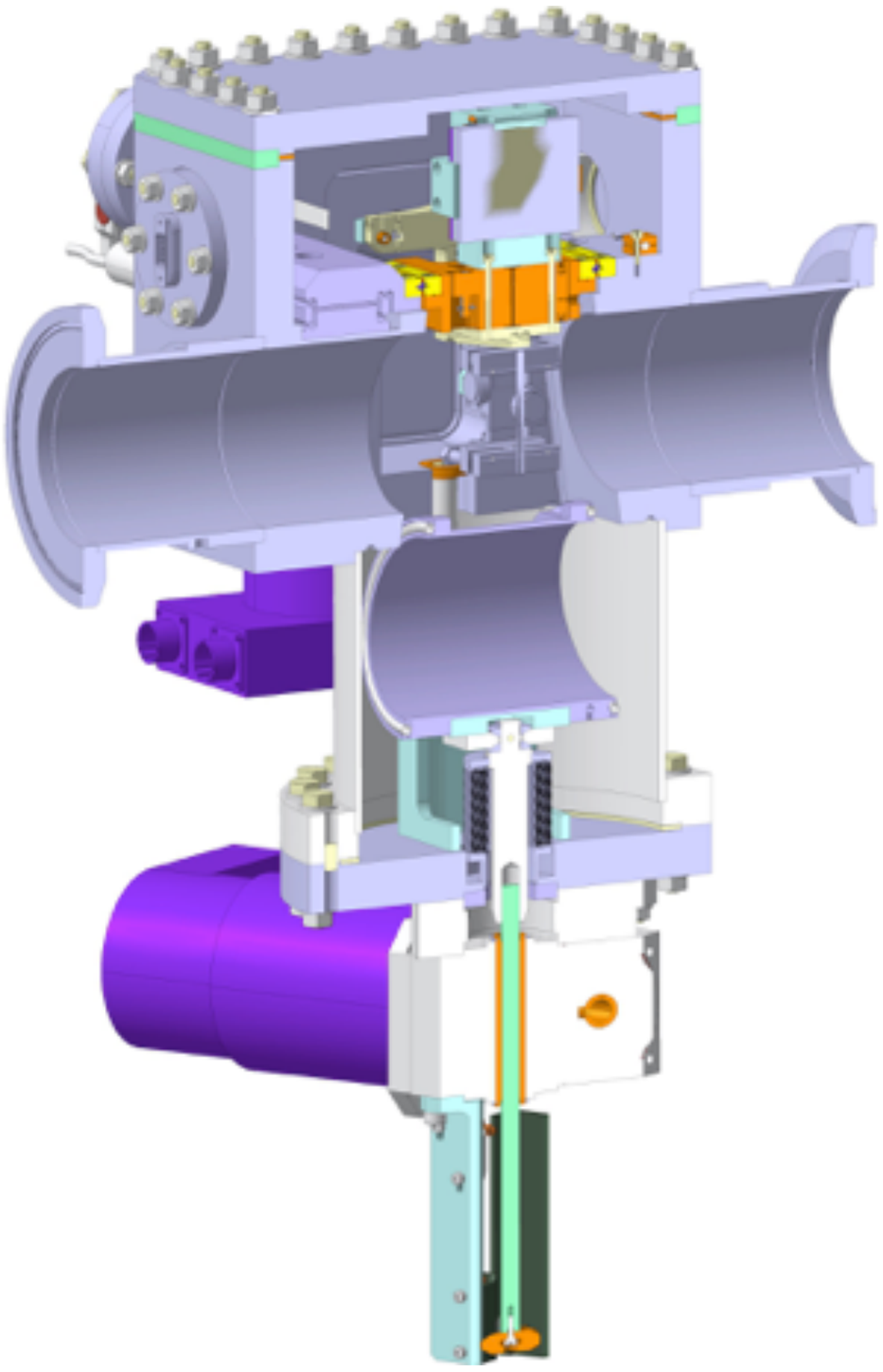
B1H	B1V	B2H	B2V
7.50	3.09	3.61	1.65

- In MDs, gained up to more than a factor 50 at some limiting locations in
- Present crystal assemblies (TCPCs) are devices for tests: HW not i ved for long-term reliable operation. Control system also needs an u ng].

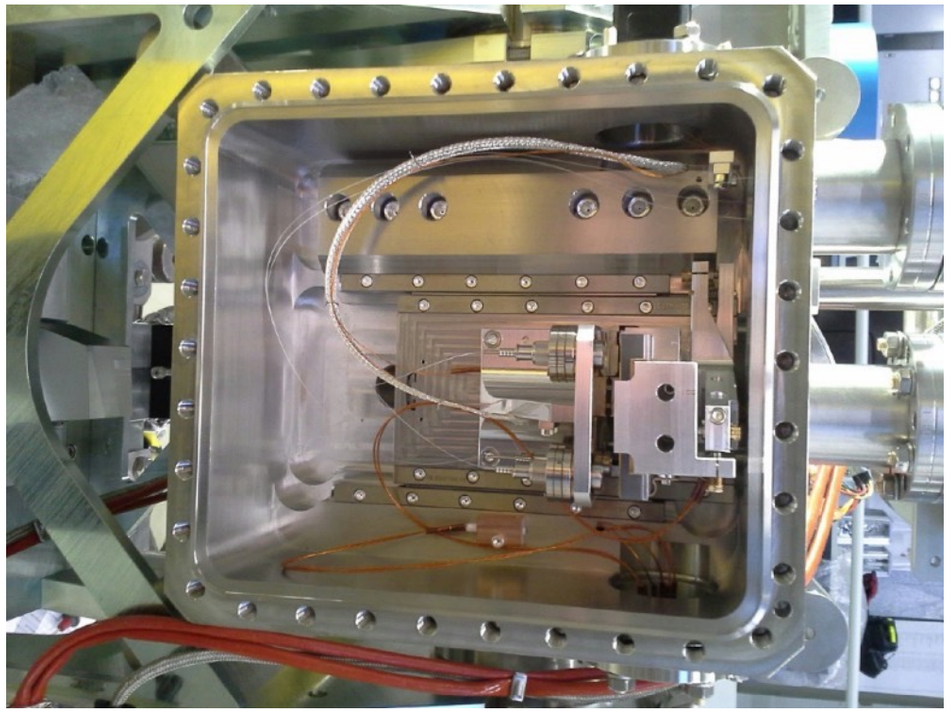
LS2 target upgrade: change all 4 TC devices, for operation in the ic ew un 3.

Successfully used in special runs: functionality that must be kept!

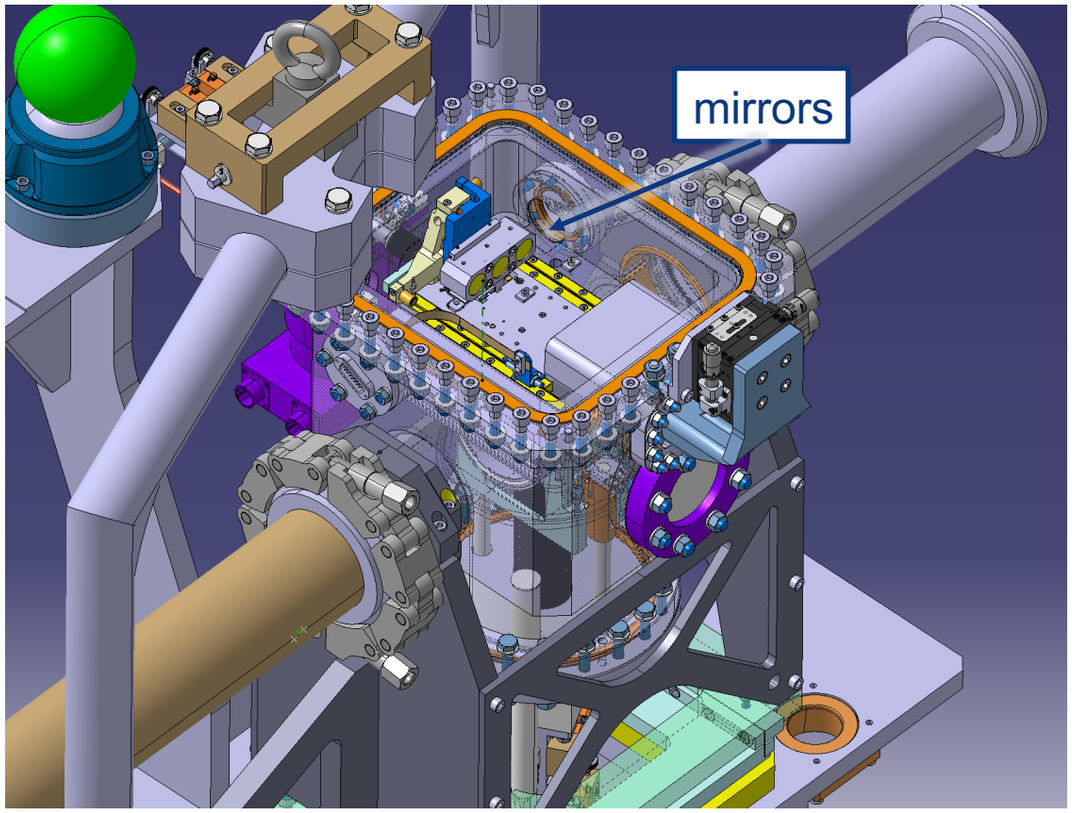
TCPC hardware

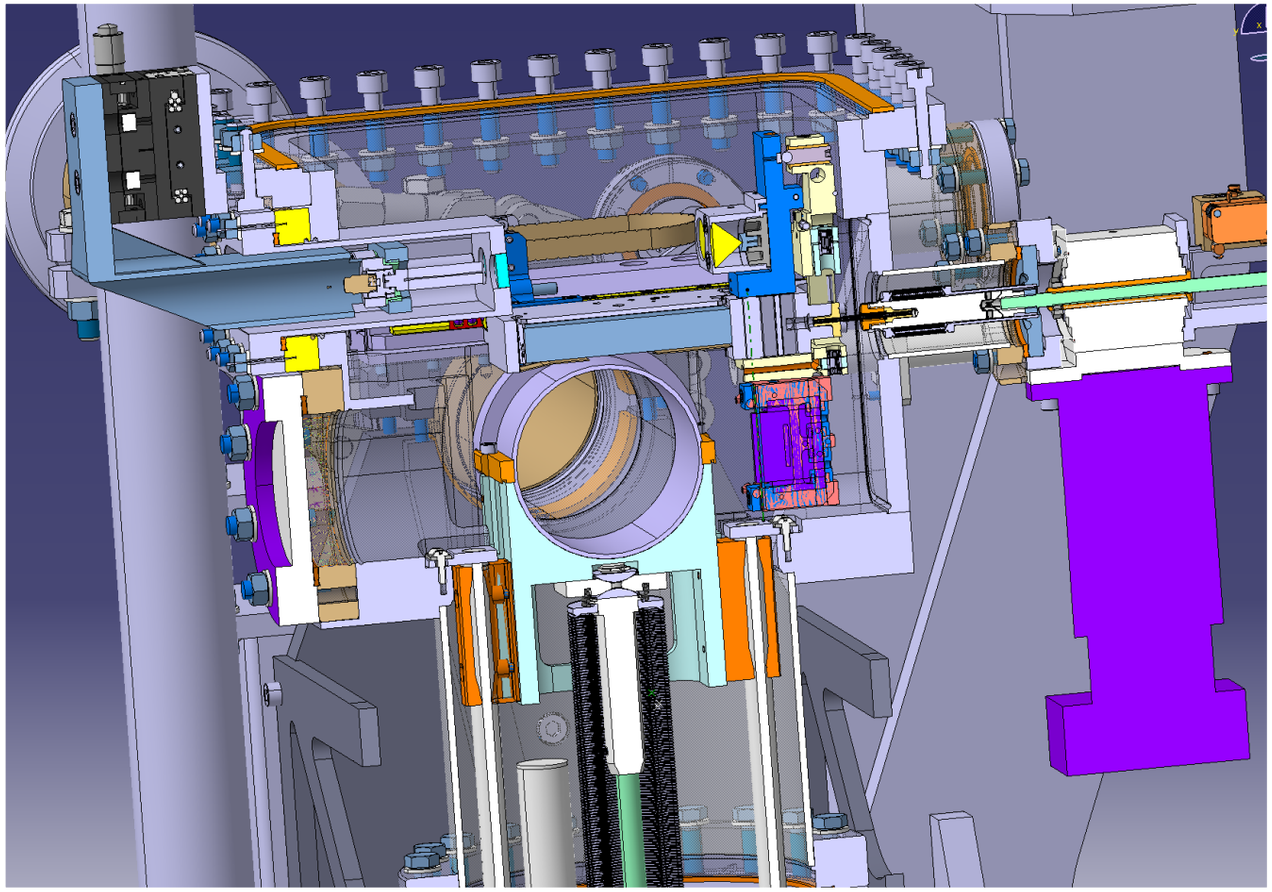


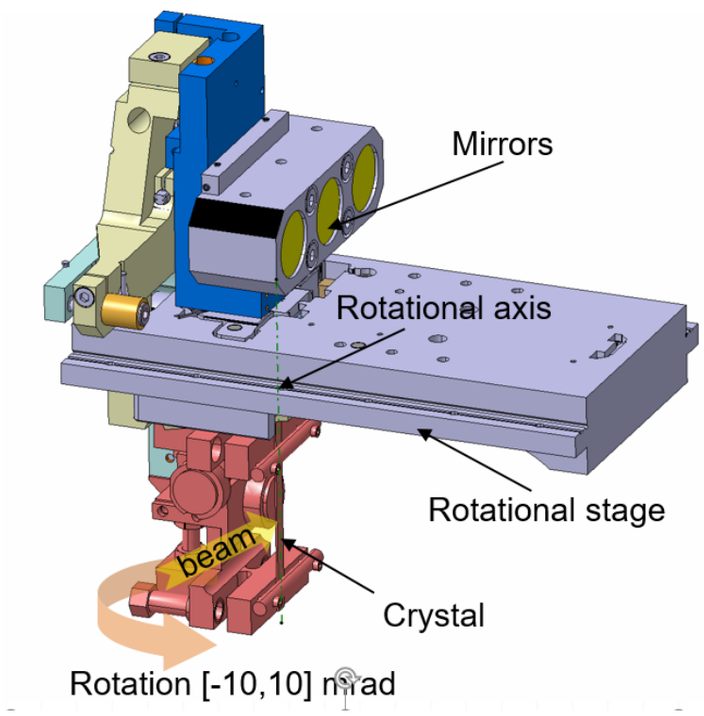
- V1 used for beam 1 (2015)
- Improved hardware V2 installed on B2 (2016, 2017)
- Baseline for Run 3: “V3 design”
  See dedicated 130th ColUSM
- Basic design features same for V3: replacement chamber for high-intensity proton operation. Added redundancy in angle measurements.



TCPC design version 3

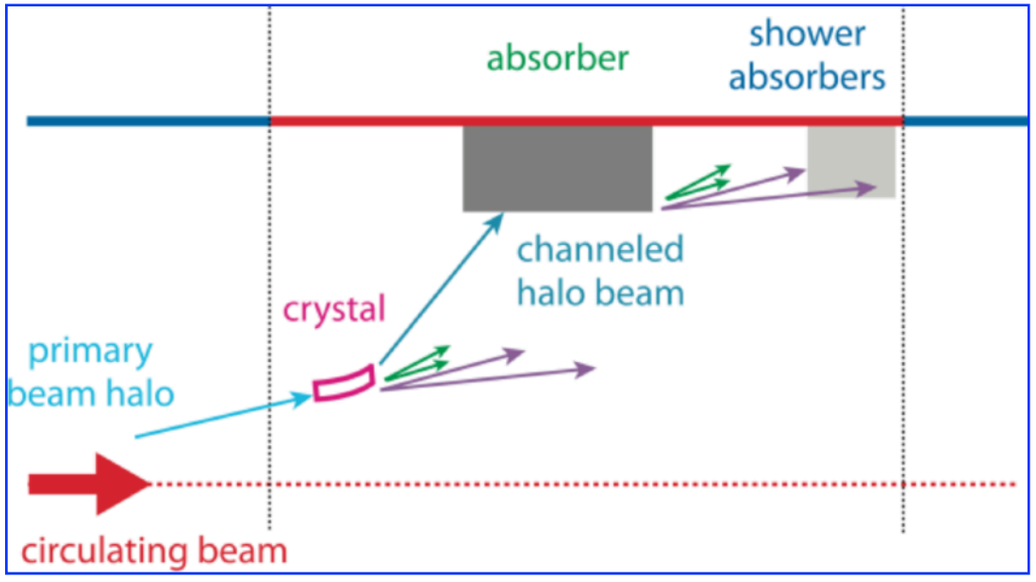


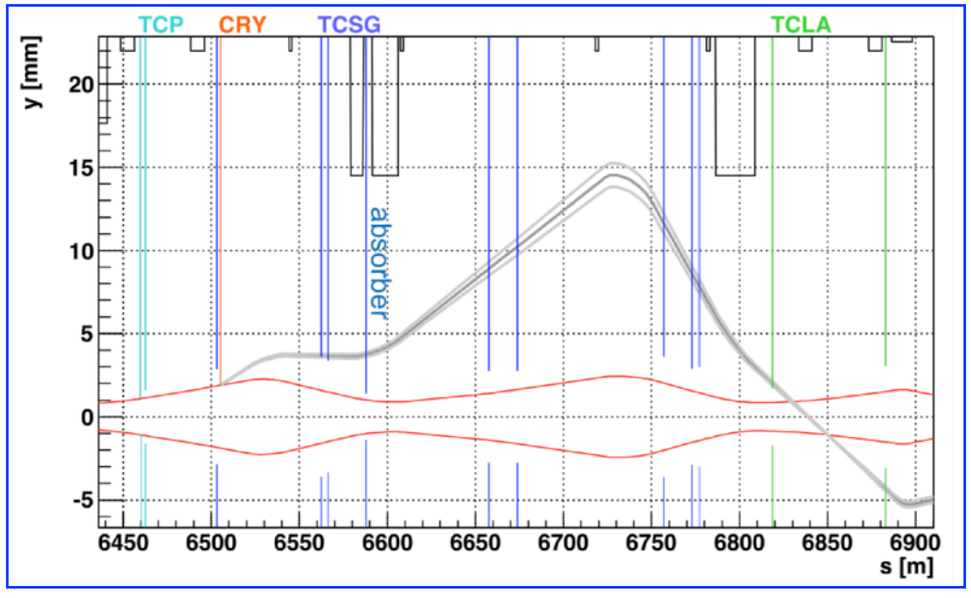




From slides by I. Lamas, 130th ColUSM

IR7 layouts





	Beam 1		Beam 2	
Name	TCPCH.A4L7	TCPCV.A6L7	TCPCH.A5R7	TCPCV.A6R7
Plane	Horizontal	Vertical	Horizontal	Vertical
s [m]	19918	19842	20090	20145
β_x [m]	342.1	30.5	201.6	30.5
β_y [m]	64.9	281.1	135.0	281.1
α_x [rad]	-2.05	0.24	-3.53	0.24
α_y [rad]	0.84	-2.63	2.36	-2.63
D_x [m]	0.03	0.15	-0.28	0.01
D_y [m]	0.10	0.12	0.22	0.32
Absorber	TCSG.B4L7	TCSG.D4L7	TCSG.B4R7	TCSG.D4R7

Updated plan (first phase): replace the existing 4 devices

Operational modes

- Proton beam operation: MDs and low intensity runs
  - OUT (replacement chamber IN) for standard operation
    a. Discrete position limits enforcing parking positions
    b. Injection prevented by SIS if chamber moving
    c. Check status as part of the LHC sequencer
    d. Beam interlock while moving
  - MD mode of operation as in Run 2
  - Dedicated runs like forward physics: to be discussed
- Ion beam operation: baseline usage for collimation.
  - Replacement chamber OUT for all operation
  - To be decided: TCPC in or out during injection?
  - Part of the ramp functions and kept in channeling at 7TeV

Controls strategy

Available in Run 2, to be kept:

- Discrete position limits triggering interlocks
- Ramp functions for position / angle settings
- “Moving” status for SIS purposes.

Planned change for Run 3:

- Ramp functions for linear-position limit interlocks

Comments:

- No interlock on beam angle because at top energy, RMS noise too close to critical angle: ~ 1µrad RMS vs ~ ±2µrad.
- Plan validation loss maps in amorphous configuration.
- BLM thresholds will need important adjustments in IR7.
- Improvements identified following the incident in 2018:
  a. Need a sequence’s recovery/check task in nominal sequence
  b. Movements and checks done through sequences

Conclusions

- Crystal collimation of heavy ion beams needs to be made operational in 2022
  - Aim for 4 new crystals (challenging)
  - Backup: re-use some of the existing.
- New hardware will enable reliable operation and redundant angular measurements
- Planned controls update will enable using the TCPC in high-intensity operation for ion beam.
  - Main focus is on the new ramp functions for linear-position interlock limits
- For the rest, we need to tighten the operational procedures and the integration in the operational sequence to make a successful operation
  - A series of improvements was identified: to be implemented.

Reserve slides

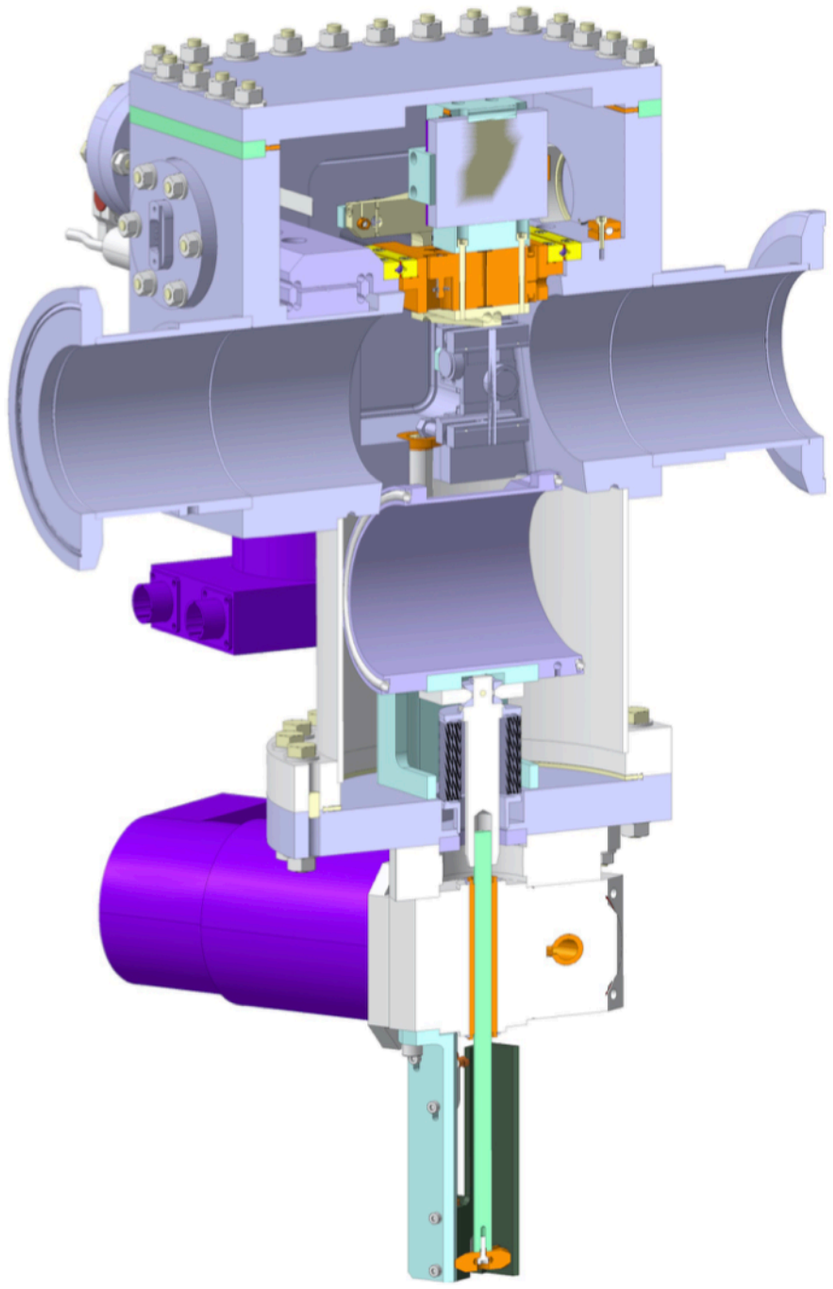
Crystal interlocking

- Key design feature: a replacement “O”-shape chamber moves into the beam to hide the goniometer.
- 2018 operational mode (for high intensity):
  1) Hardware interlock while moving OUT↔IN
  2) Software interlock prevents injection if IN

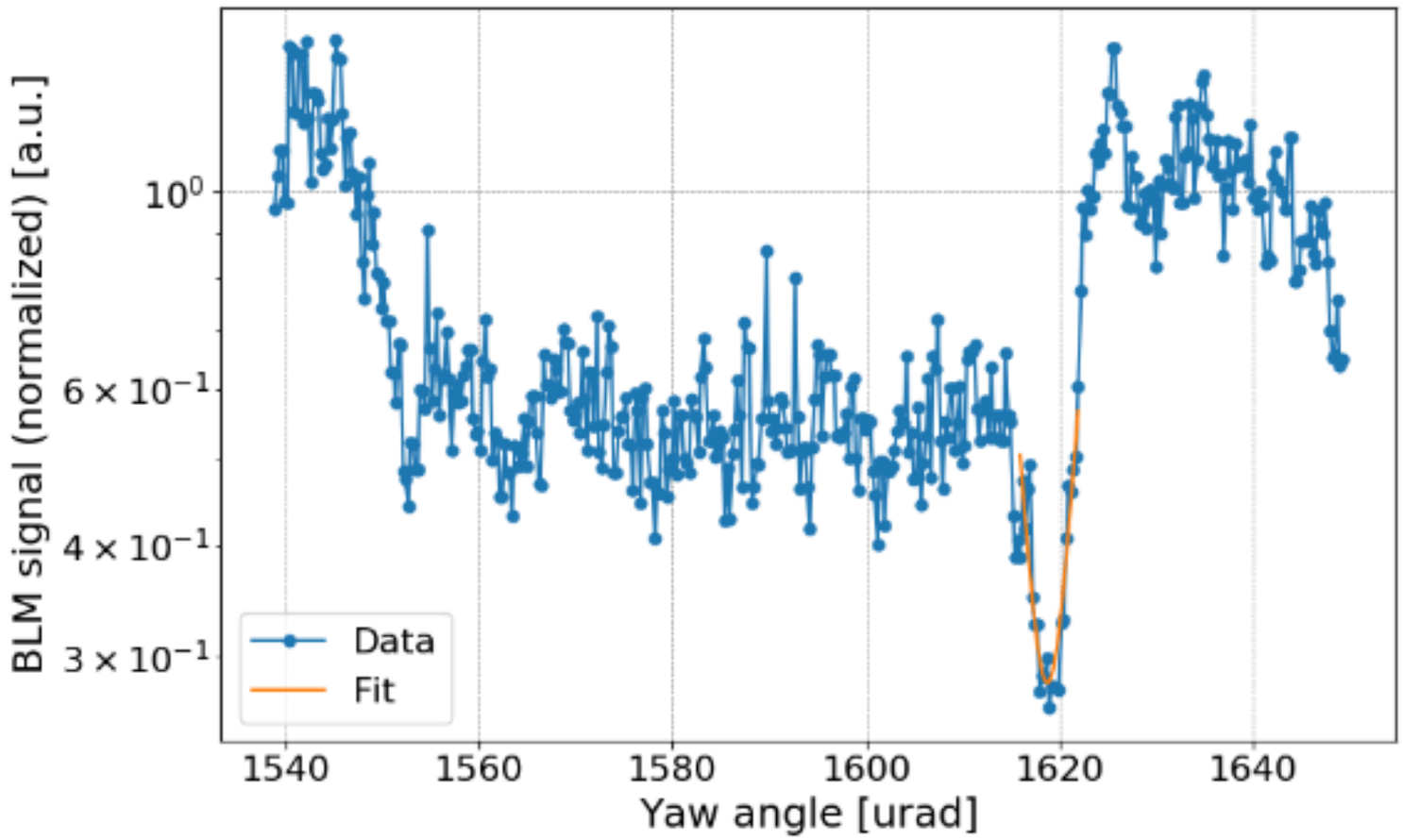
     To be masked to inject with crystals seeing the beam: only in MDs and for high-β* run.
  3) Time position limits, like other collimators

     Not used operationally at start of 2018, deployed to allow EoF tests with ion beams

  High intensity operation in 2018 relied on 1+2.
- High-beta* run in 2018
  - Used in “MD mode” [SIS masked]
  - New specific high-beta* sequence for settings crystal positions (in and out) and angles



Example: angular scan 6.5TeV



(a) B1H