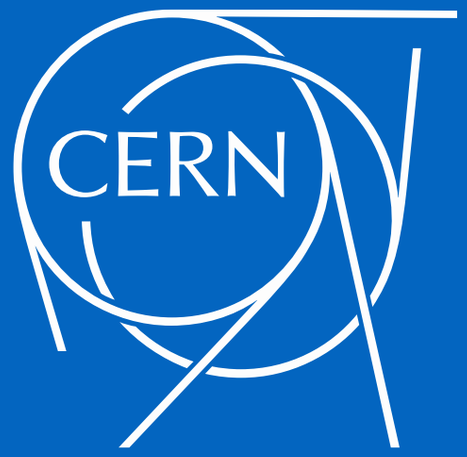


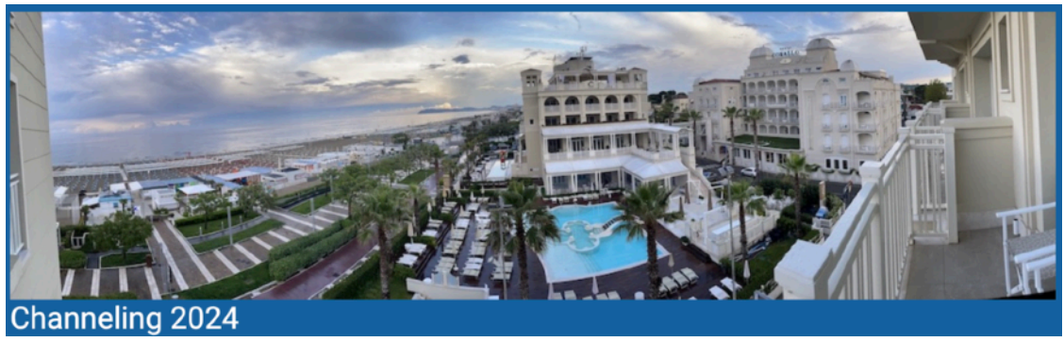
www.cern.ch

TWOCRYST: a proof-of-principle machine test for a double-crystal fixed-target experiment at the Large Hadron Collider (LHC)

S. Redaelli, CERN, BE department

on behalf of the TWOCRYST team

Channeling 2024
8-13 September 2024
Riccione, Italy



TWOCRYST team

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J. Fu, H. Miao

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Warsaw University of Technology, Poland
M. Patecki

See two recent contributions to ICHEP2024 (P. Hermes + F. Vidal)

TWOCRYST collaboration

TWOCRYST Collaboration

Memorandum of Understanding signed

CERN with 7 teams involved

INFN, Italy

IJCLab, France

IFIC, University of Valencia-CSIC, Spain

University of Malta, Malta

Warsaw University of Technology, Poland

Future collaboration member

University of Chinese Academy of Sciences, China

Acknowledgments for financial support

European Research Council
Established by the European Commission

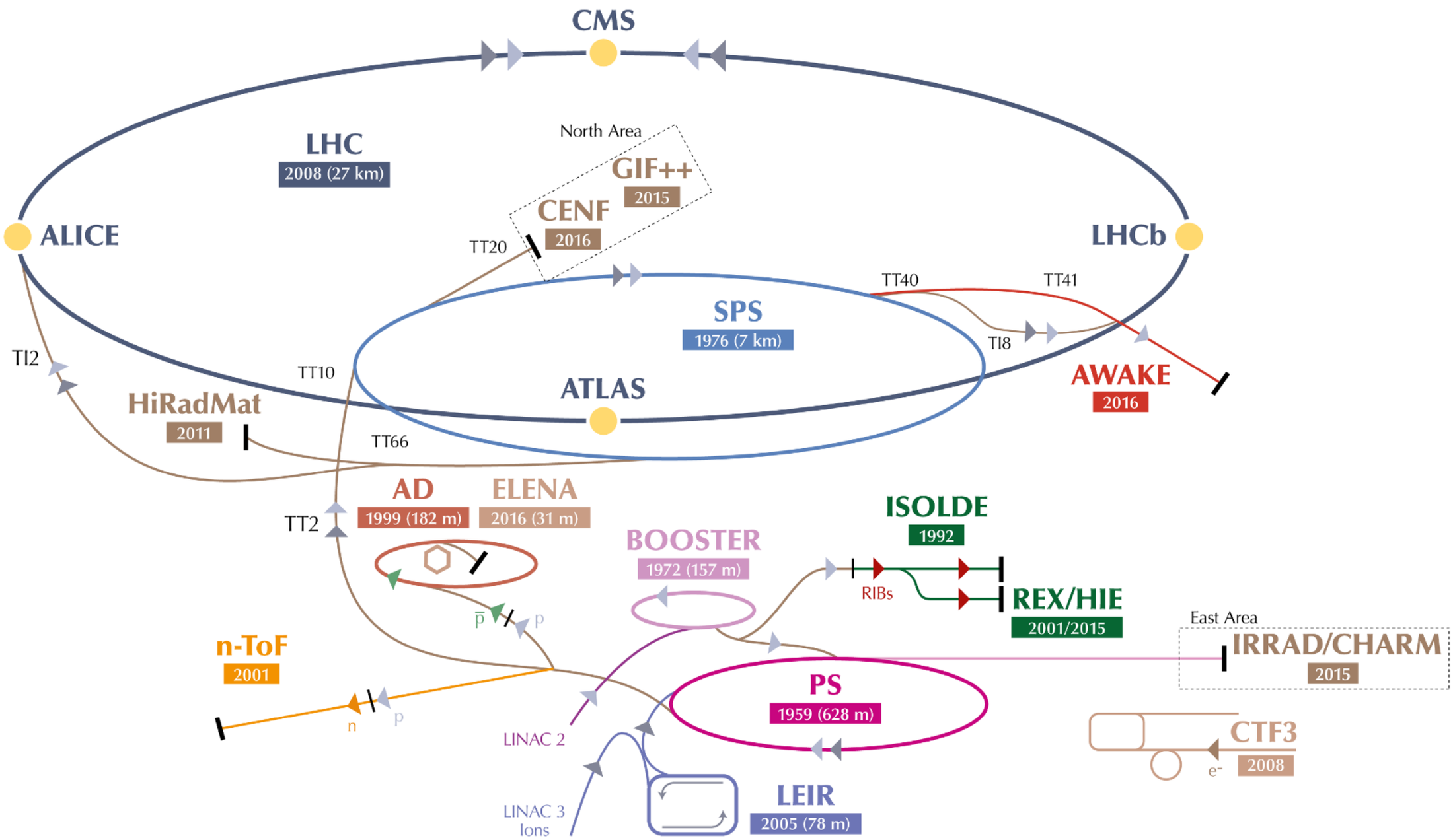
project G.A. 771642

CERN has signed so far 4 Addenda to the TWOCRYST MoU for hardware and manpower agreements.

Table of Content

- Introduction — PBC at CERN
- LHC fixed-target (FT) studies
- Double-crystal setups for LHC-FT
- The TWOCRYST proof-of-principle
- Conclusions

The PBC study at CERN



The PBC study at CERN

HOME ▾ WORKING GROUPS ▾ RESOURCES ▾

The Physics Beyond Colliders Study Group

Overview

Physics Beyond Colliders (PBC) is an exploratory study aimed at exploiting the full scientific potential of CERN's accelerator complex and technical infrastructure, as well as its know-how in accelerator and detector science and technology. PBC projects complement the goals of the main experiments of the Laboratory's collider programme. They target fundamental physics questions that are similar in spirit to those addressed by high-energy colliders, but require different types of beams and experiments. The PBC mandate is available **here**.

Organization

The kick-off workshop held in September 2016 identified a number of areas of interest. Working groups have been set-up to pursue studies in these areas. See '**Organization**' for a detailed breakdown of the current structure.

New Ideas

The Physics Beyond Colliders study remains open to further ideas for new projects. Instructions to submit new ideas are given **here**.

Stay informed

Should you wish to receive general announcements and updates, please subscribe to the e-group PBC-info **here**. (If you do not have a CERN account, you will first need to create a **lightweight account**. CERN Lightweight Accounts provide limited access to certain applications)

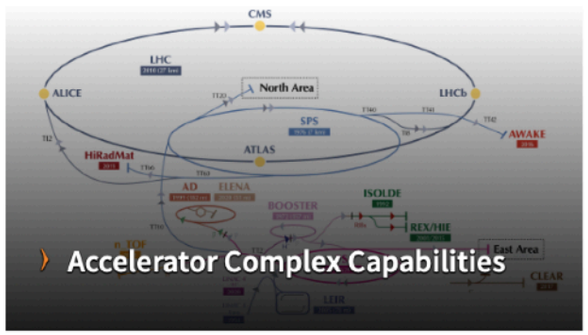
https://pbc.web.cern.ch/

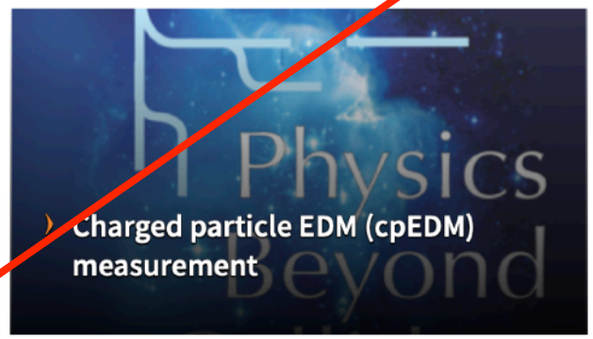
The active PBC studies

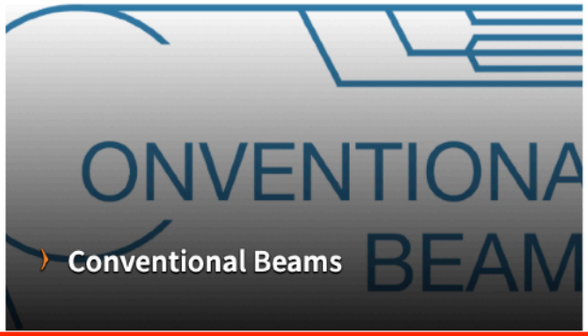
Accelerators & Technology Domain

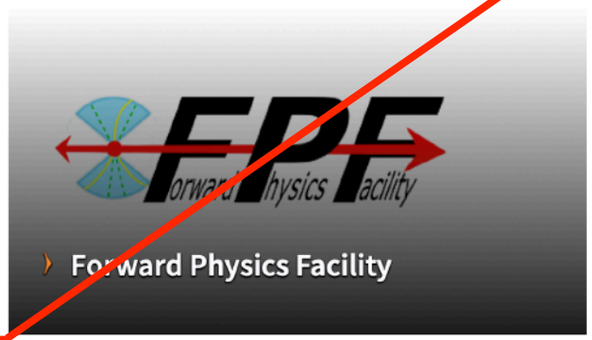
The Working Groups in the Accelerators & Technology Domain are coordinated through the PBC Accelerators & Technology Committee, a steering committee which meets around once per month. The steering committee includes the CERN conveners of the various Working Group in the Accelerators & Technology Domain. The Working Group's core members include accelerator experts and representatives of the projects. Requests from the Working Groups (tests, prototypes, manpower) are discussed by the steering committee.

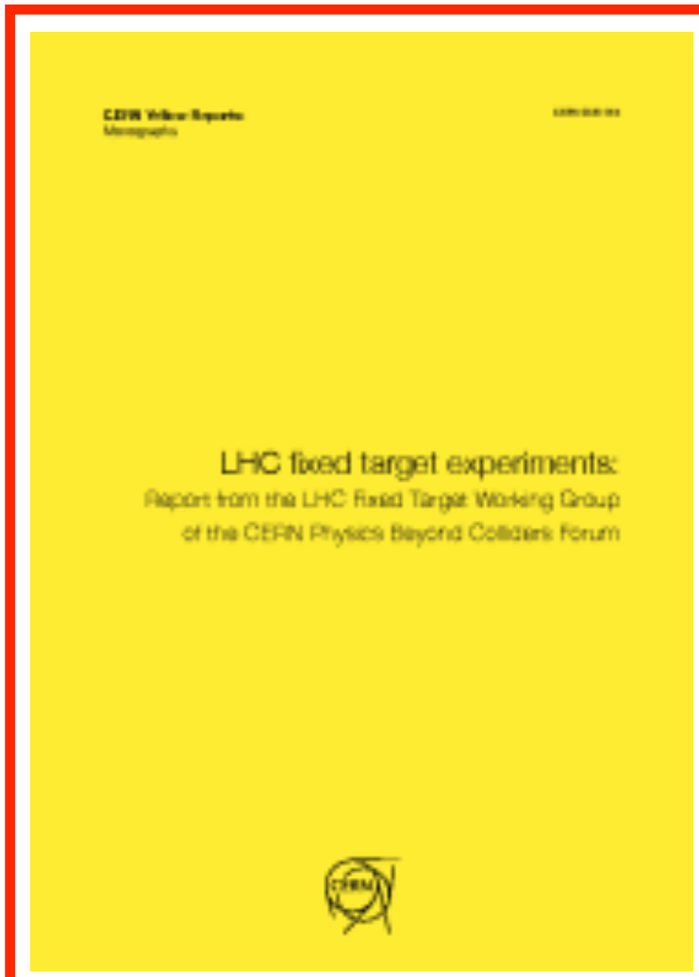
ACCELERATORS & TECHNOLOGY WORKING GROUPS











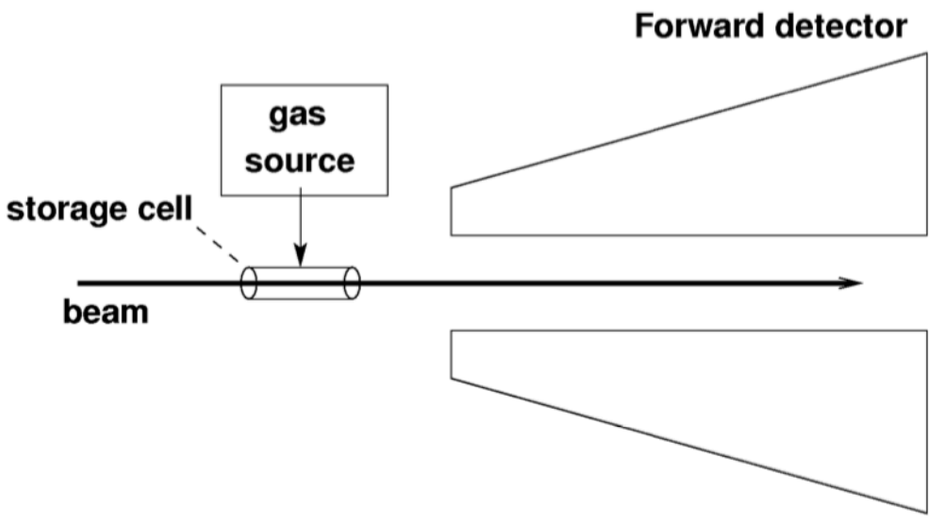
CERN Yellow Report
CERN-2020-004

Focus on proposals supported by experimental teams and compatible with the LHC's main physics programme
Chairs: M. Ferro-Luzzi, S. Redaelli

LHC fixed target (LHC-FT) studies

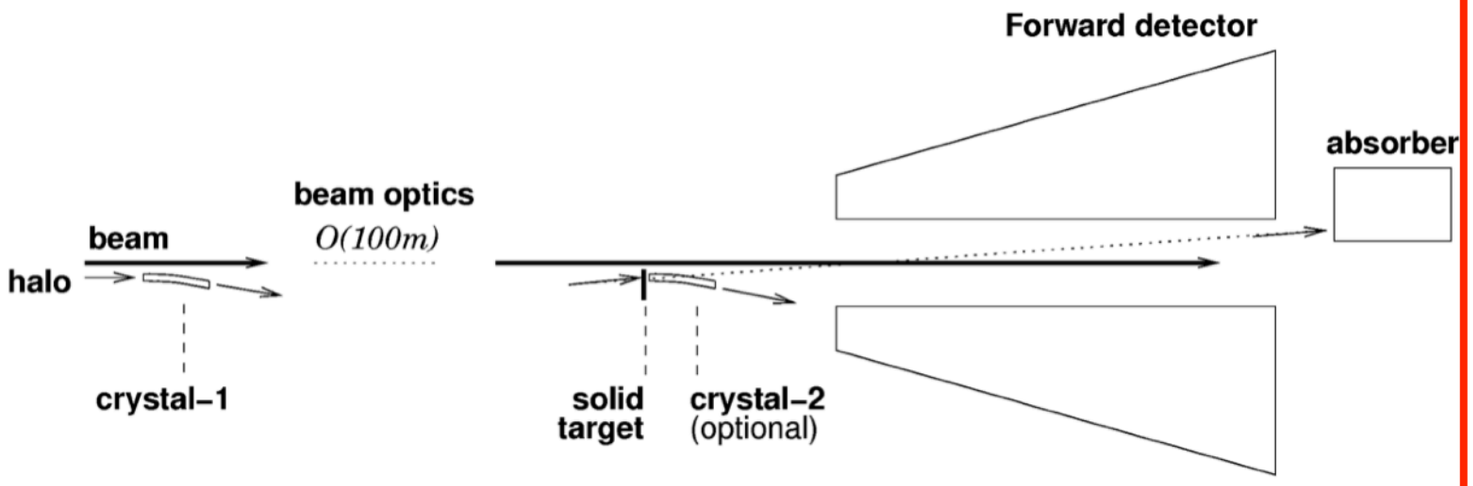
After initial assessments, the PBC LHC FT focused on two solutions compatible with the LHC stored beam energies and with the main proton physics programme:

Gaseous targets



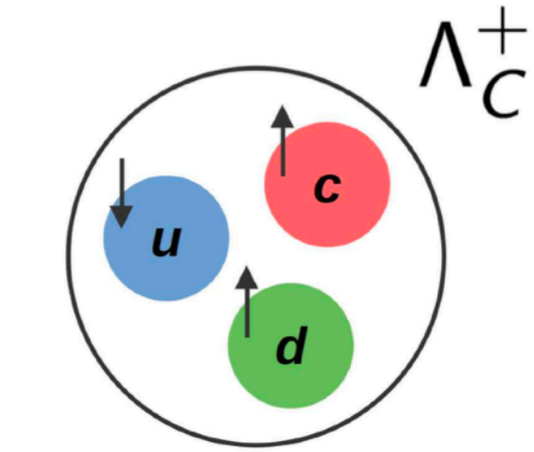
SMOG-2 deployed in LHCb for Run 3. Studies now focused on future integrations of polarised gaseous targets. Not discussed here.

Crystal-based in-vacuum targets

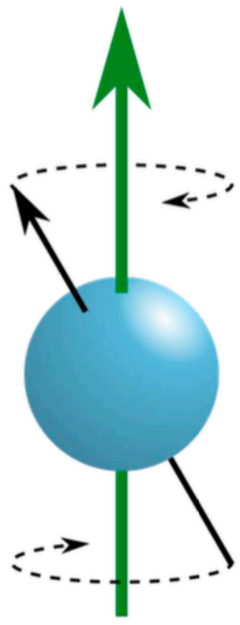


Focus of this presentation!
Relies on the usage of bent crystal for advanced beam manipulations

Physics motivation and crystal solution

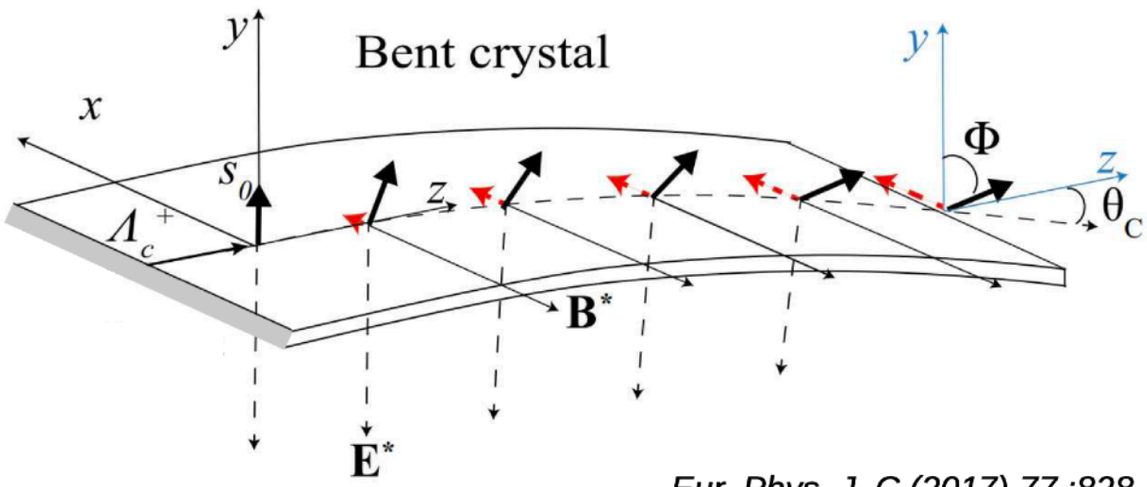


$\tau \approx 10^{-13}$ s



Short-lived baryons: Lifetime too short to measure electrical and magnetic dipole moments with conventional magnets.

Bent crystals can be used instead!



Eur. Phys. J. C (2017) 77 :828

Electric fields ~ GV/m (~500T) → induce measurable precession!

- Fermilab: Nucl. Instrum. Meth.B 90 (1994)
- Idea to use LHC beams: Phys. Lett. B 757 (2016)
- 2016 PBC kick off meeting: pioneer presentations on LHC integration (Stocchi; Scandale; Redaelli)
- EU SELDOM funding to study an LHCb implementation: Eur. Phys. J. C 77 (2017)
- TWOCRYST proof of principle at the LHC
- ALADDIN: LoI submitted to LHCC (Jul. 2024)

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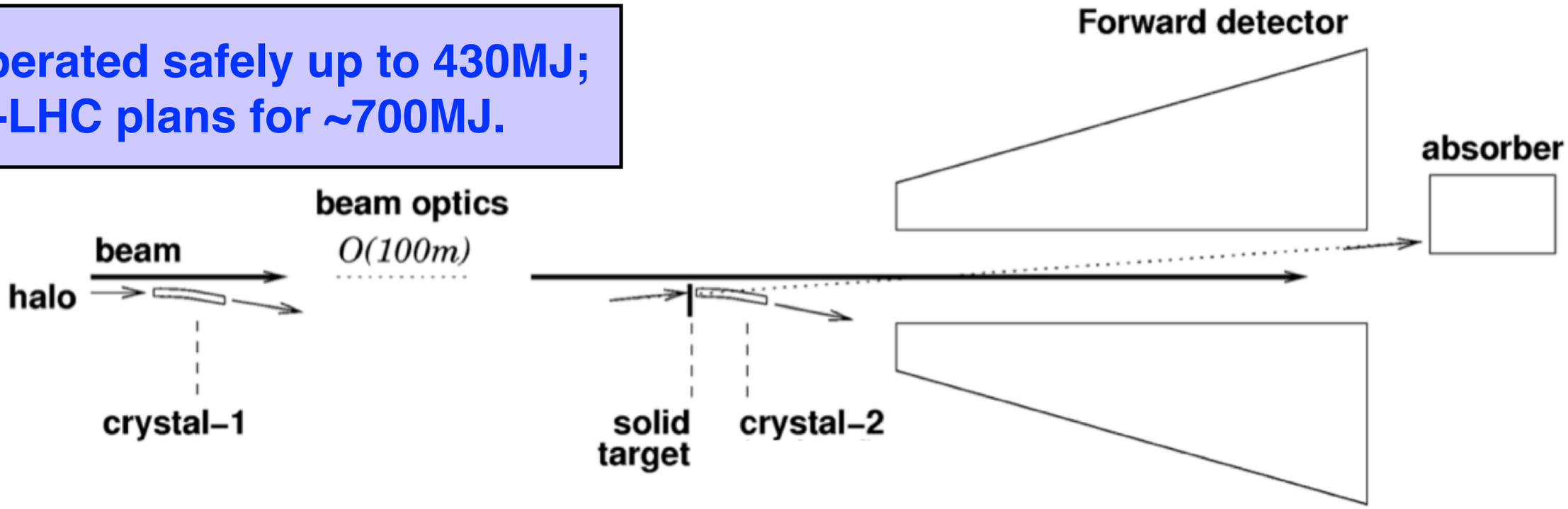
The double-crystal setup

for circular accelerators

LHC operated safely up to 430MJ;
HL-LHC plans for ~700MJ.



Bent crystal for halo splitting
Parasitic splitting of halo from collimator: must be integrated in collimation hierarchy

Rare baryon generation

Bent crystal to induce precession

Detector incl. spec. dipole

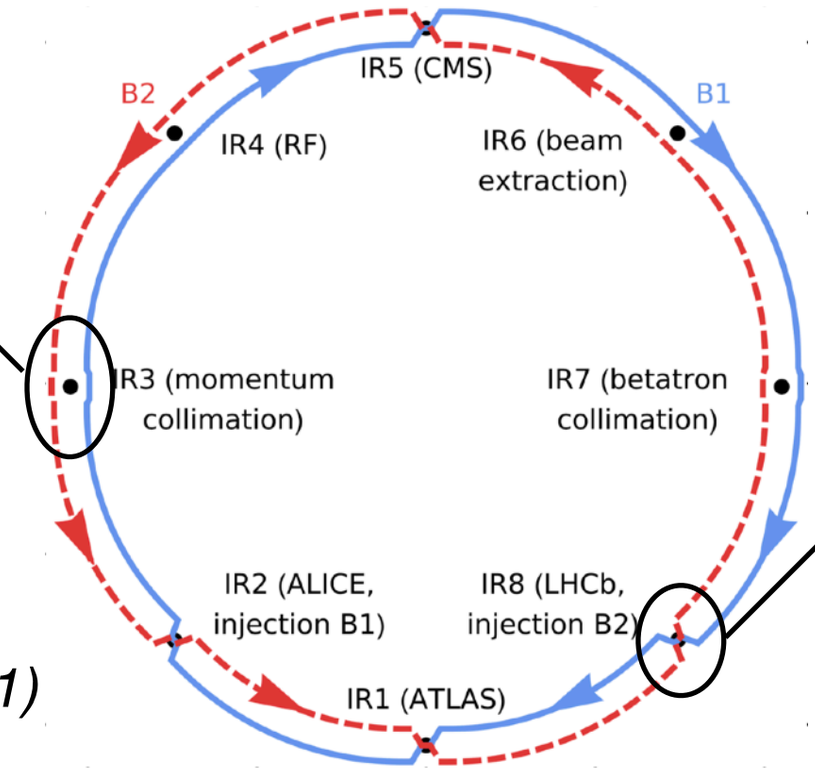
- Halo-splitting to hit a target at sufficient distance from the LHC beams
- Designed to operate parasitically to high-intensity operation
  - *Integration in the transverse hierarchy of the LHC collimation system*
- Evidently very challenging, but feasible according to simulations!

Promising results on double-channeling observed by the UA9 collaboration at the CERN SPS at 270 GeV: Nucl. Instrum. Meth. A 975 (2020) 164175

Possible solutions and open points

Studies to optimise performance and machine aspects; detector to be built

Detailed layout comparisons:
Eur. Phys. J. C 80, 929 (2020)
Phys. Rev. D 103, 072003. (2021)



Initial proposal, relying on the LHCb detector
(CERN-SPSC-2016-030; SPSC-EOI-012; Eur. Phys. J. C 77 (2017))

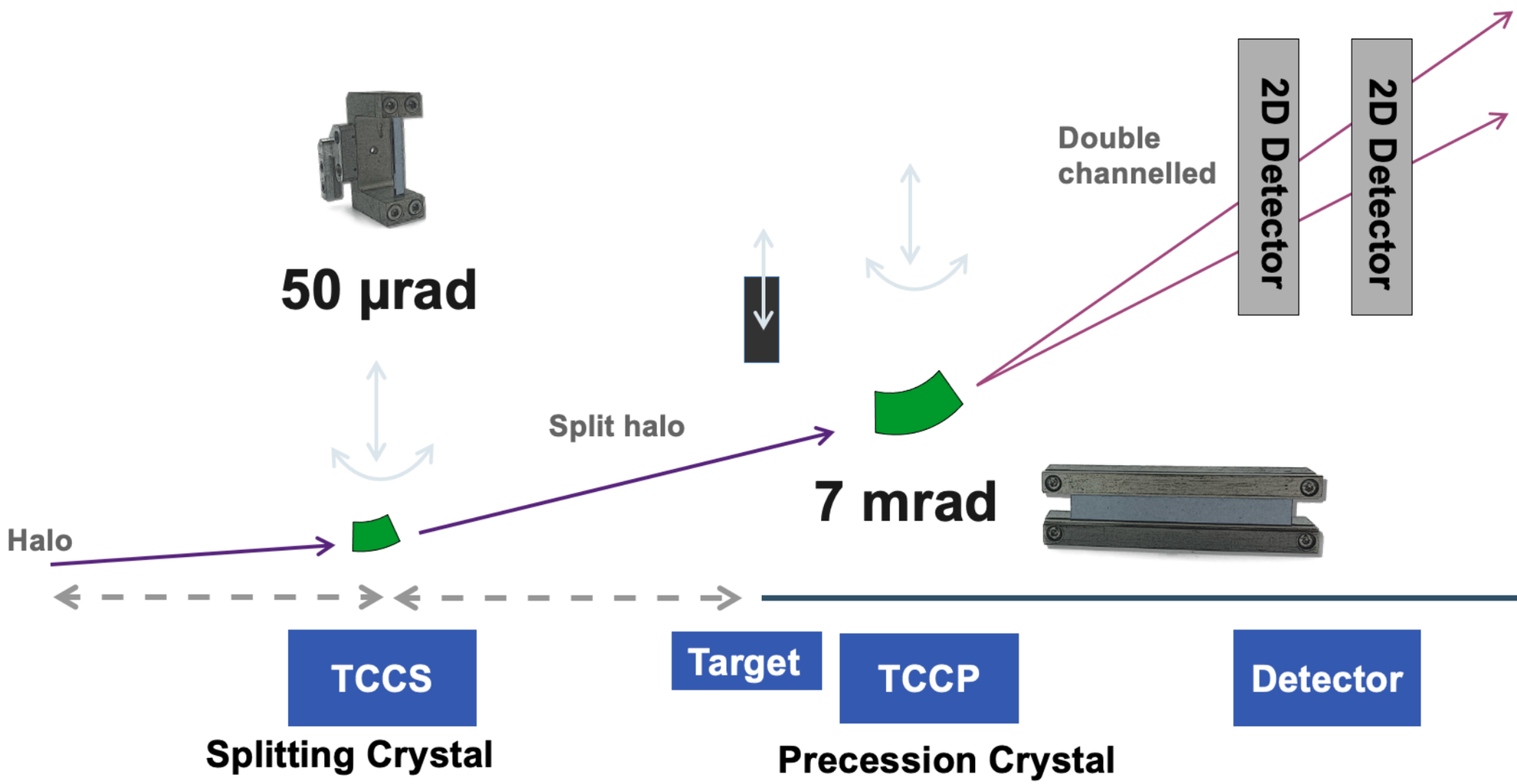
Open points calling for experimental validation:

- Need to validate the long-crystal properties in the relevant TeV range
- Reliable operation of the double-crystal scheme to be demonstrated

  Achievable performance is a key input for final experiment design
- Experimental validation of simulation-based performance estimates

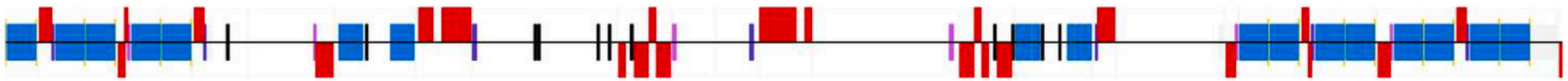
  Performance in simulation relies on the complex dynamics of multi-turn collimation halos

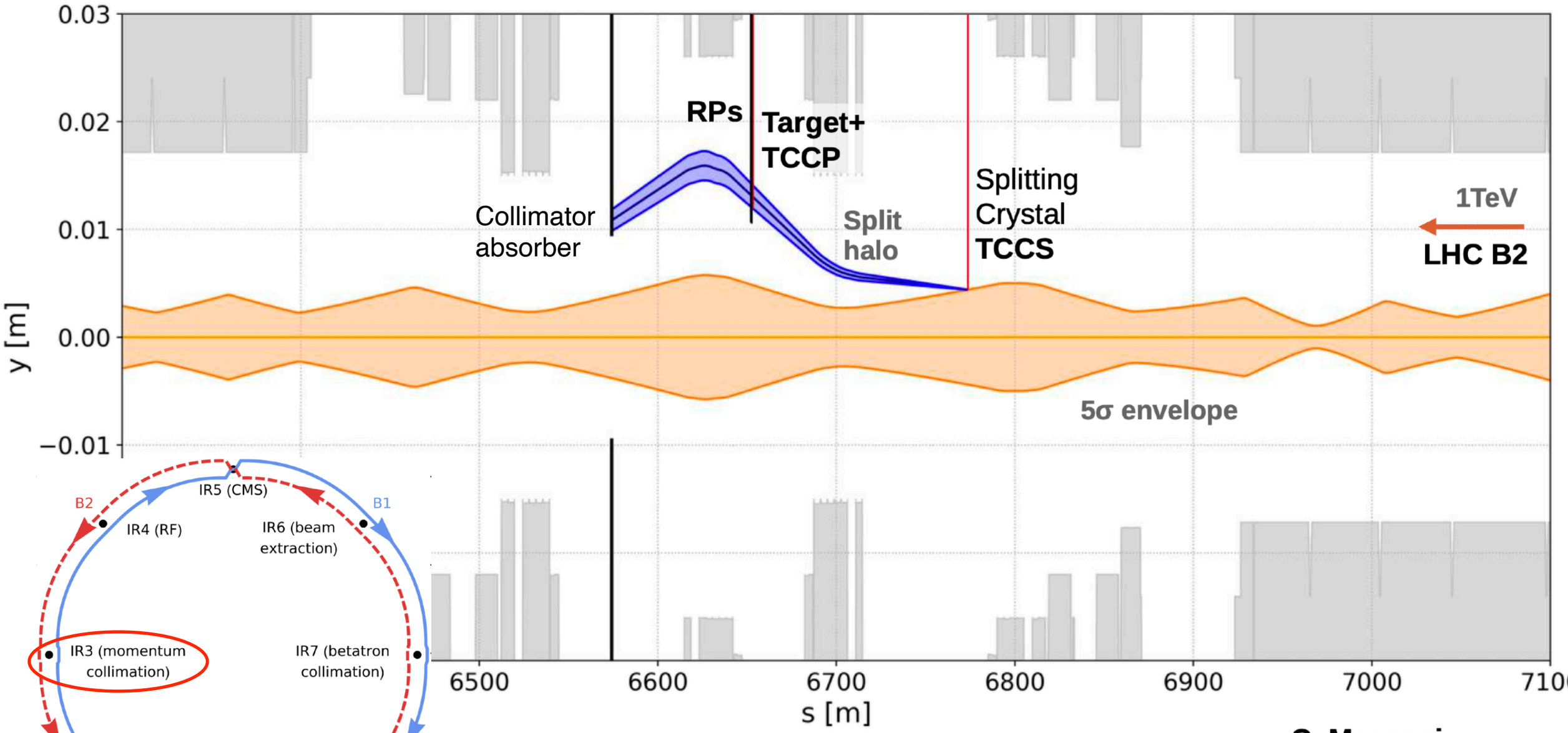
TWOCRYST: proof-of-principle



- Layout integration in the LHC IR3 (off-momentum collimation):
  Available space and infrastructure; low radiation levels; existing collimators
- Test stand conceived for low beam intensities: flexibility vs collimation and safety constraints, simplify designs (impedance considerations)
- Compatible with measurements at different beam energies
- Crystal specifications and layout positions optimised for a final experiment!

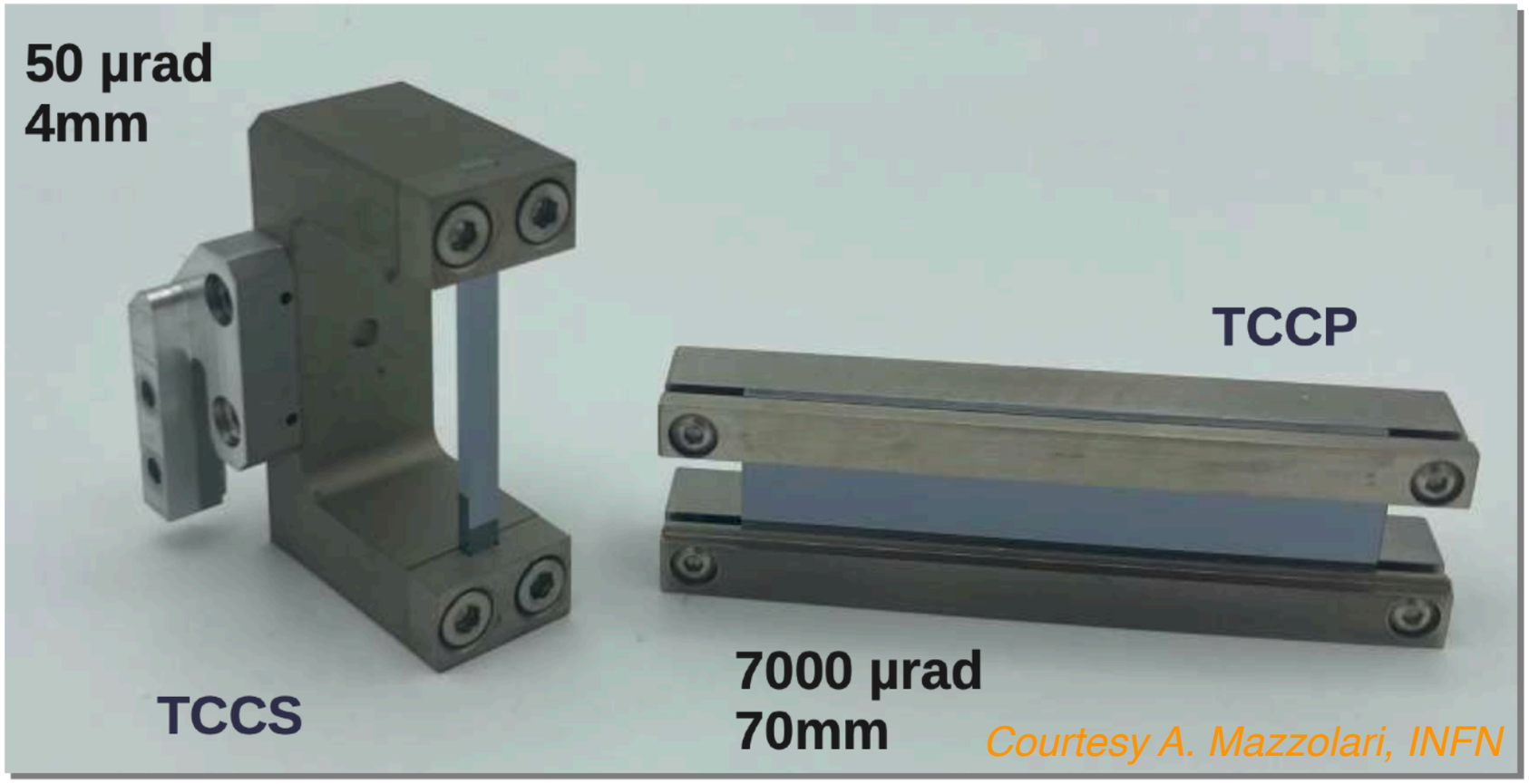
Detailed IR3 layouts





C. Maccani

TWOCRYST crystals

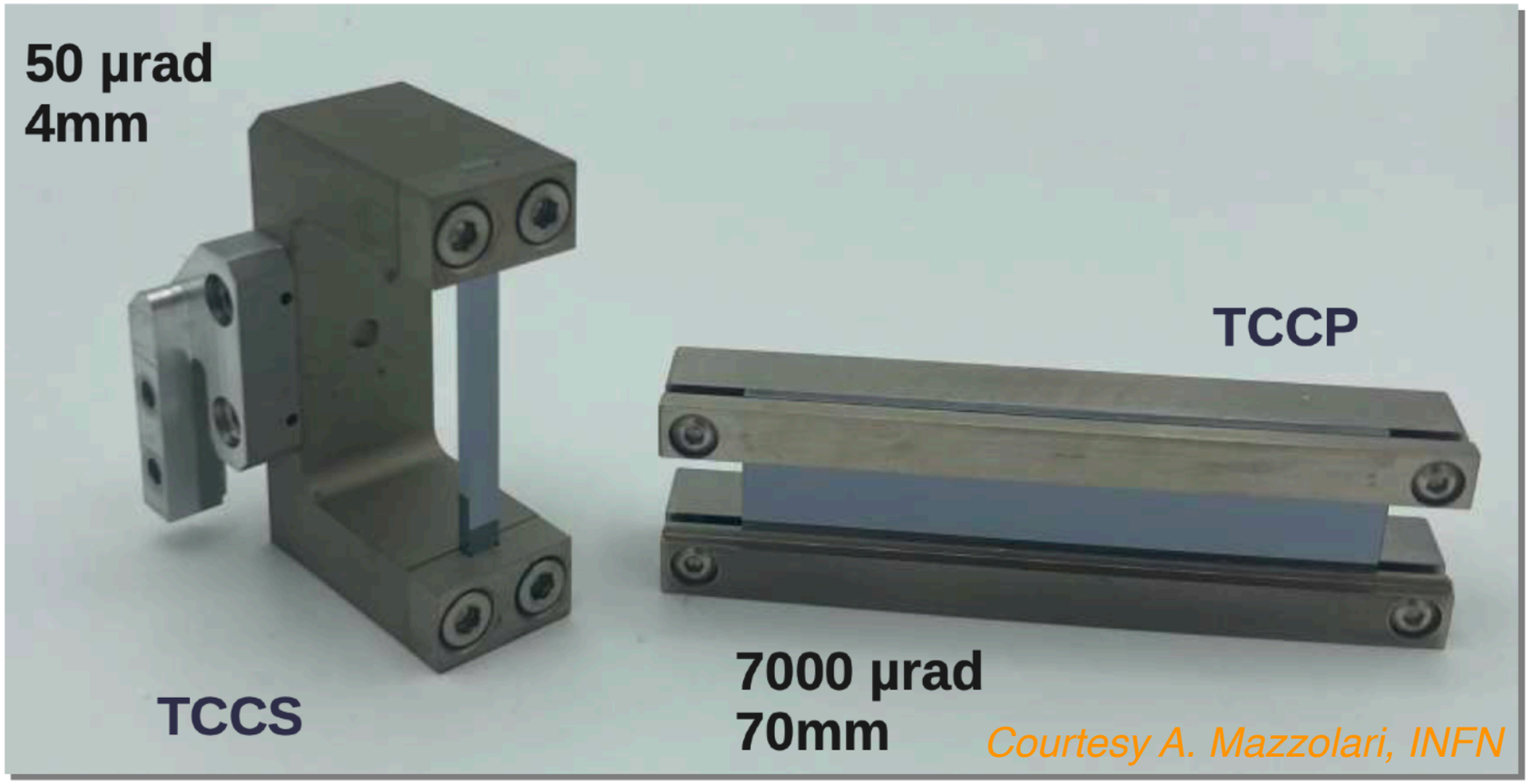


Crystals for splitting and precession delivered to CERN and successfully tested in the SPS-H8 (Aug. 2023).
Well in specs!

Crystal	TCCS	TCCP
Holder type	clamp	clamp
Crystal material	Si	Si
Bending planes	110	110
Length [mm]	4	70
Width [mm]	35	8
Height [mm]	2	2
Bend radius [m]	80	10
Bend angle [mrad]	0.05	7.0
Lindhard angle at 180 GeV [µrad]	13.3	12.9

S. Cesare, K. Dewhurst, to be published.

TWOCRYST crystals



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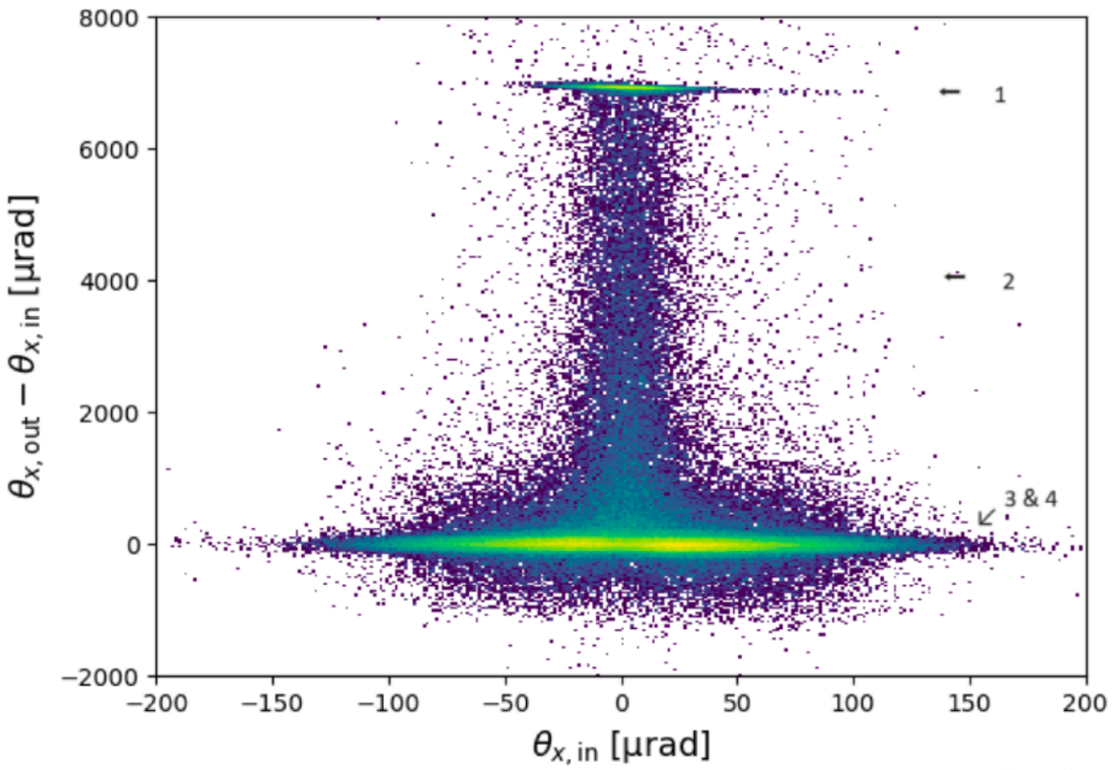
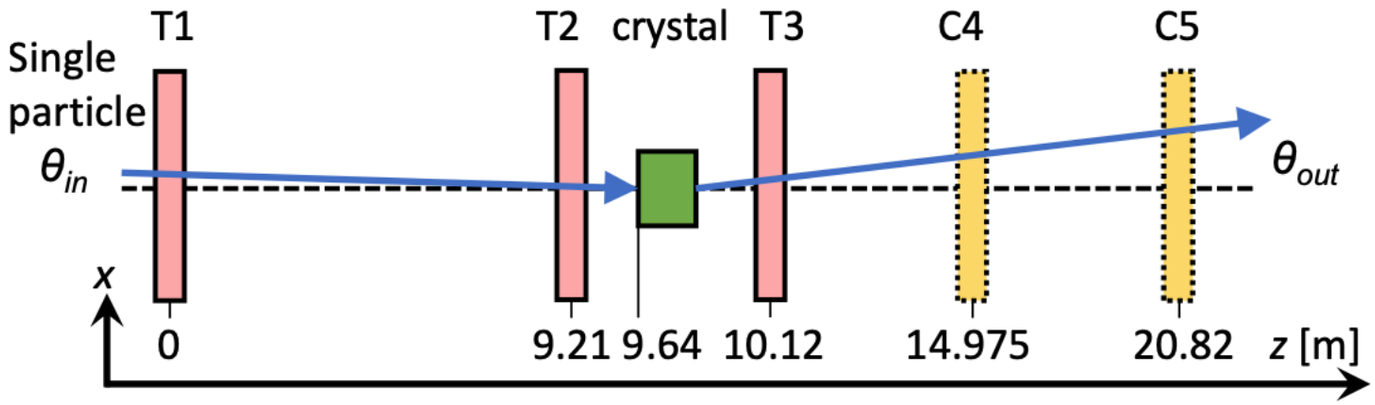


M. Prest, E. Vallazza et al.

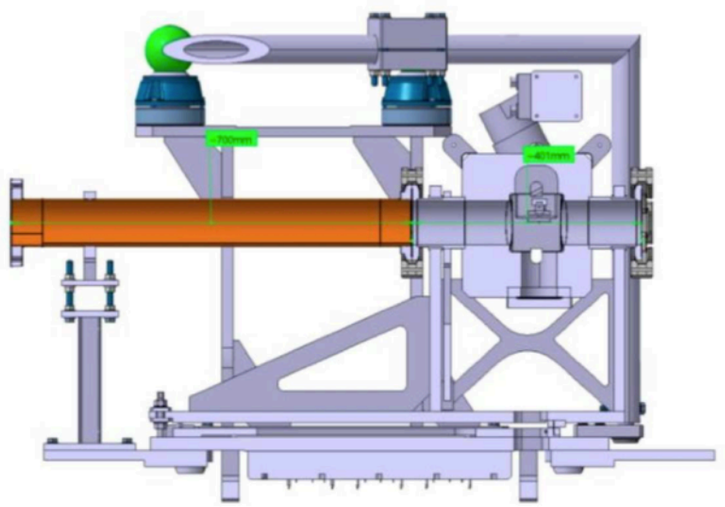


Crystal	ϵ_{ch} [%]	θ_b [µrad]	τ_y [µrad/mm]
TCCS	61.9 ± 0.5	48.2 ± 0.1	-
TCCP	15.8 ± 0.1	6921.3 ± 0.6	24.4 ± 0.2

S. Cesare, K. Dewhurst, to be published.

Crystal assemblies — splitting

TCCS

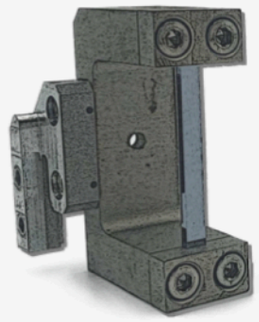


TCCS goniometer

Recovered from IR7

Formerly used for crystal collimation

TCPC - STI device in collaboration with CEM

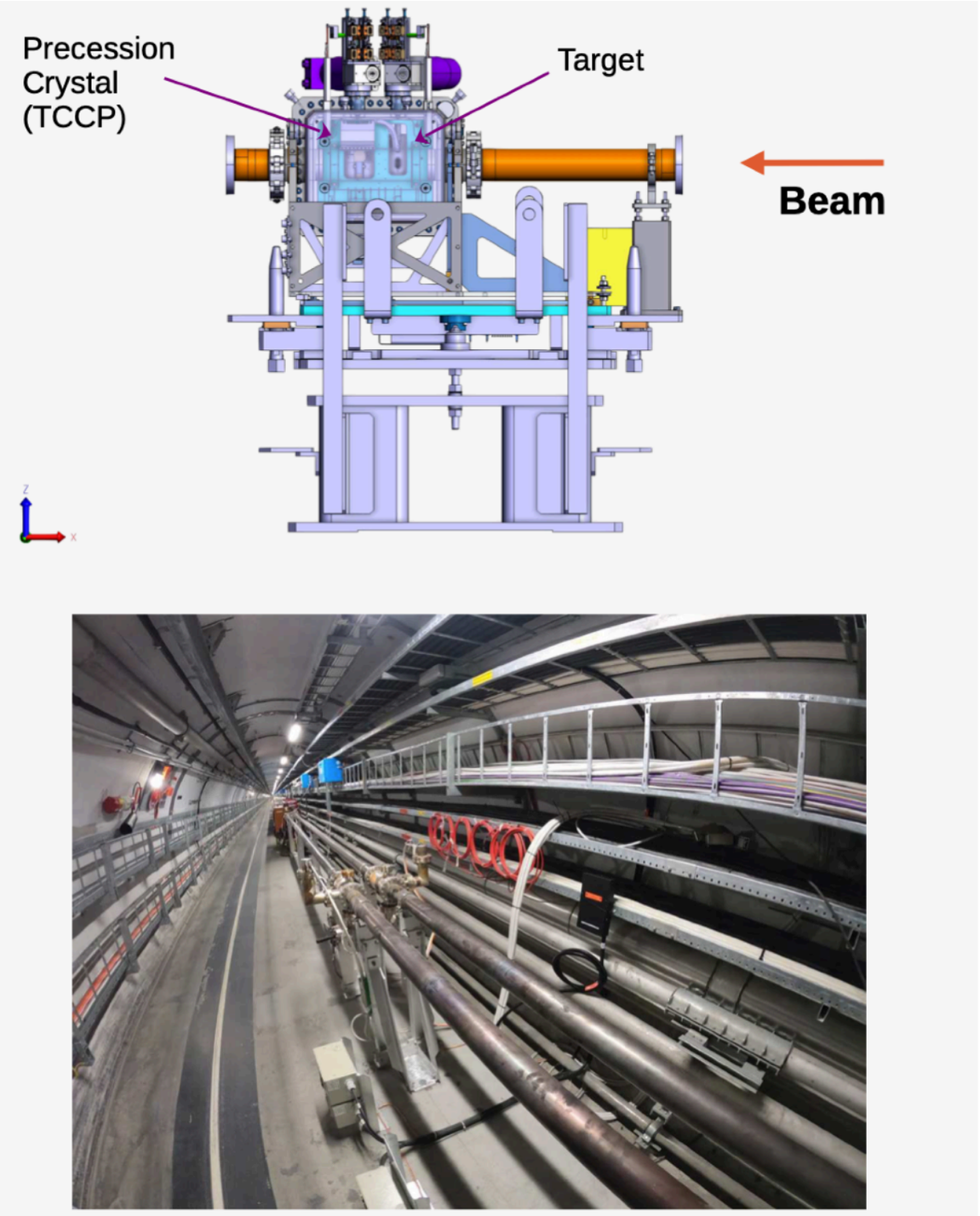


50µrad / 4mm

TCCS crystal for splitting of beam particles

Installation slot in IR3

Crystal assemblies — precession

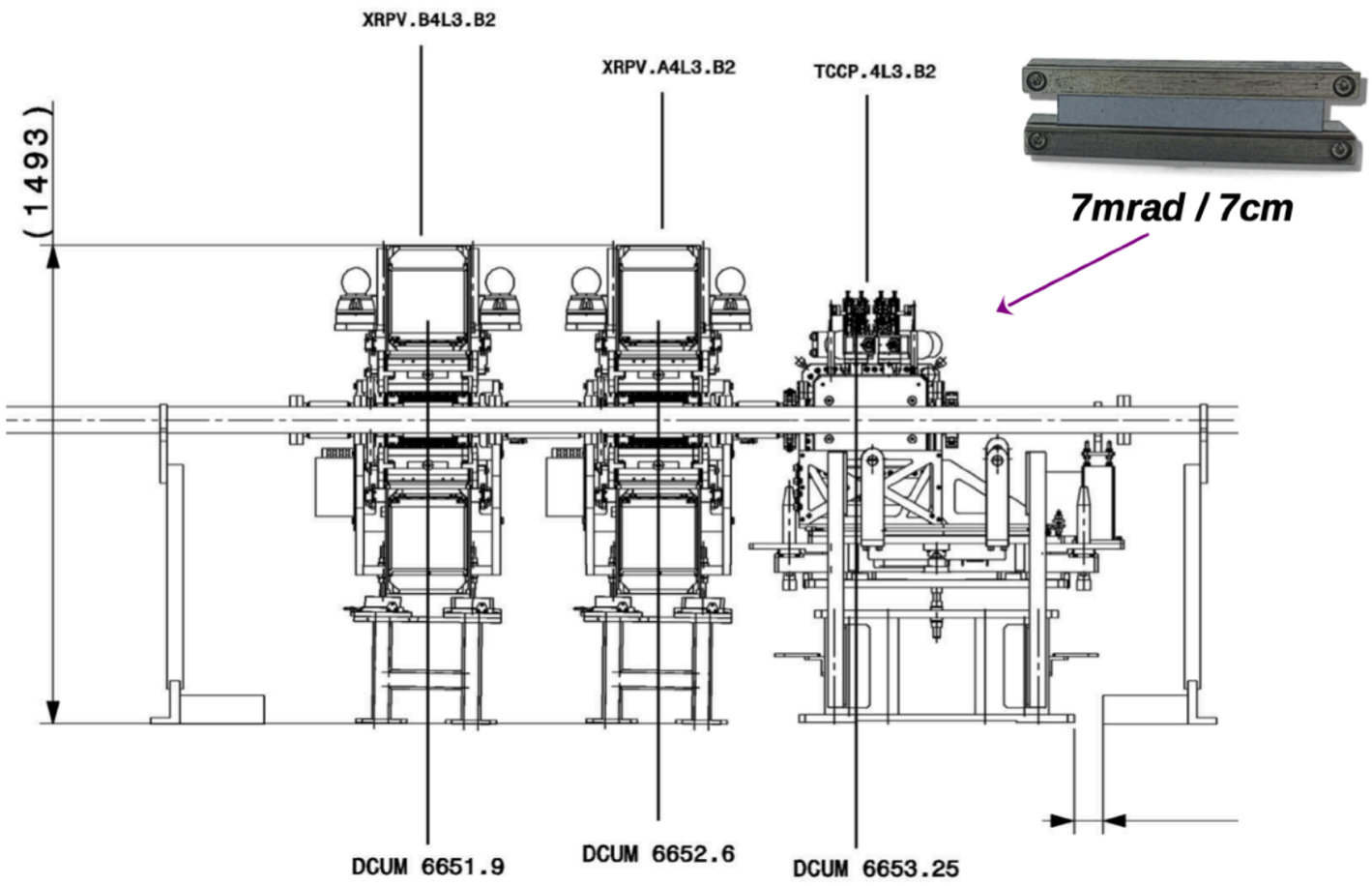


Target - TCCP Assembly

Assembly designed for TWOCRYST

Independent motion of target and TCCP crystal

Construction and validation within 2024



TCCP: custom design by CERN groups for TWOCRYST (STI/CEM, with inputs by ABP on specifications and impedance aspects).

TWOCRYST instrumentation

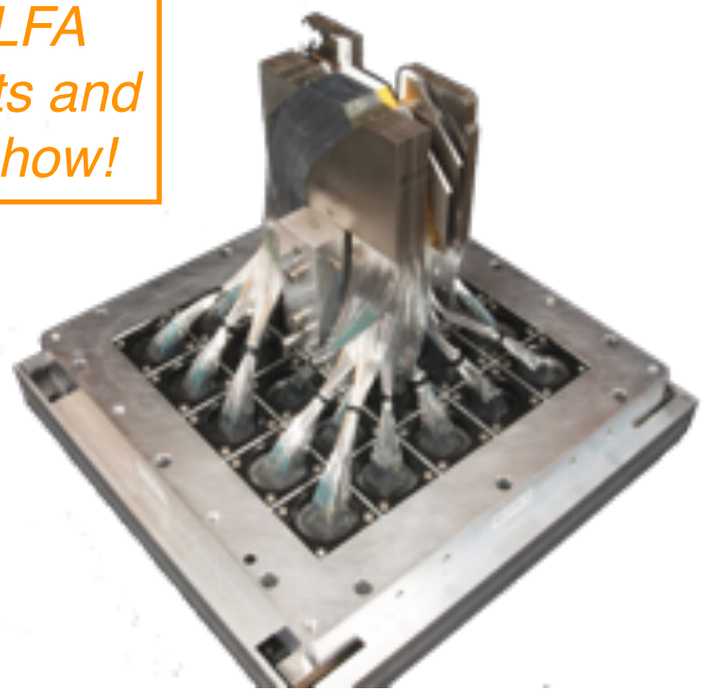
Removal of two ATLAS-ALFA stations after high-β run 2023

ALFA detectors removed

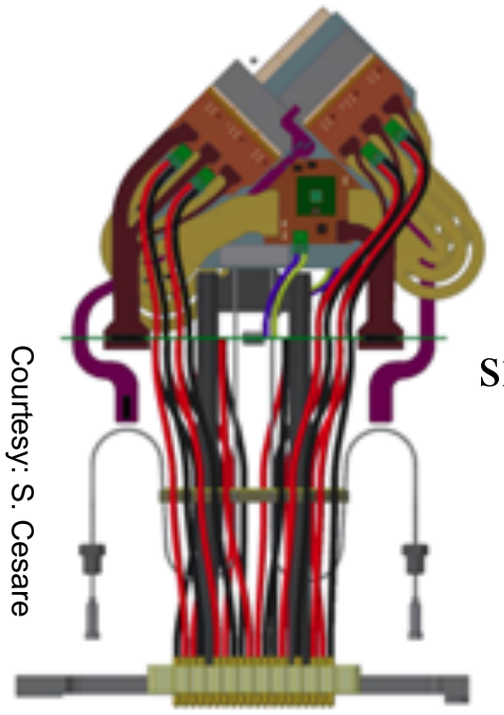
Station refurbishment ongoing

Many thanks to ATLAS-ALFA for giving us 2 Roman pots and supporting with the know how!

Fibre tracker recovered from ATLAS-ALFA



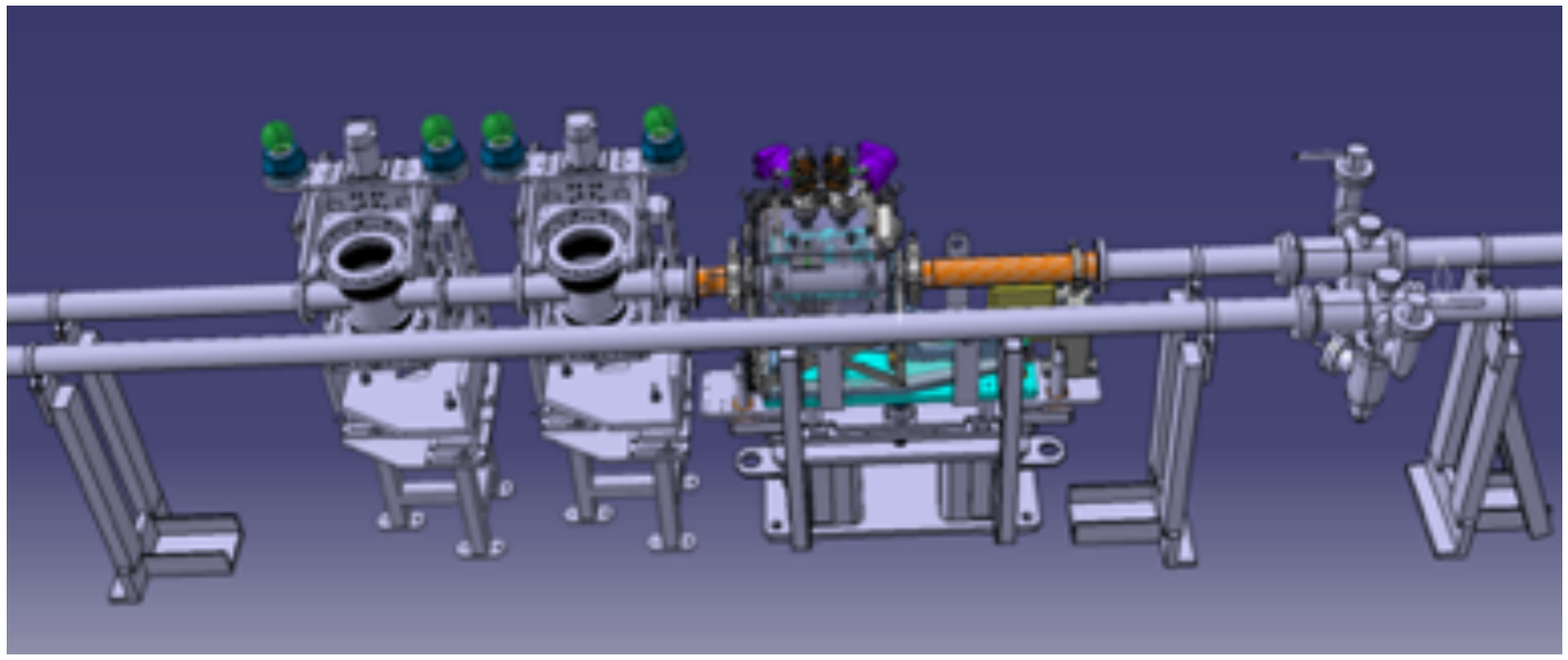
Courtesy: S. Jakobsen

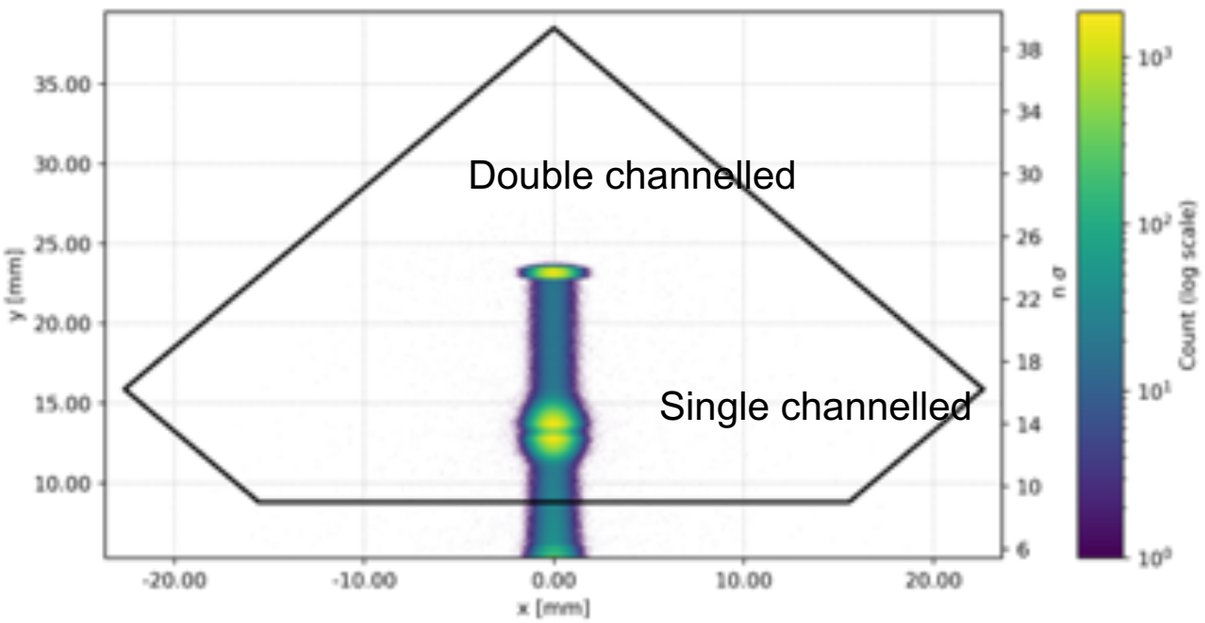


Courtesy: S. Cesare

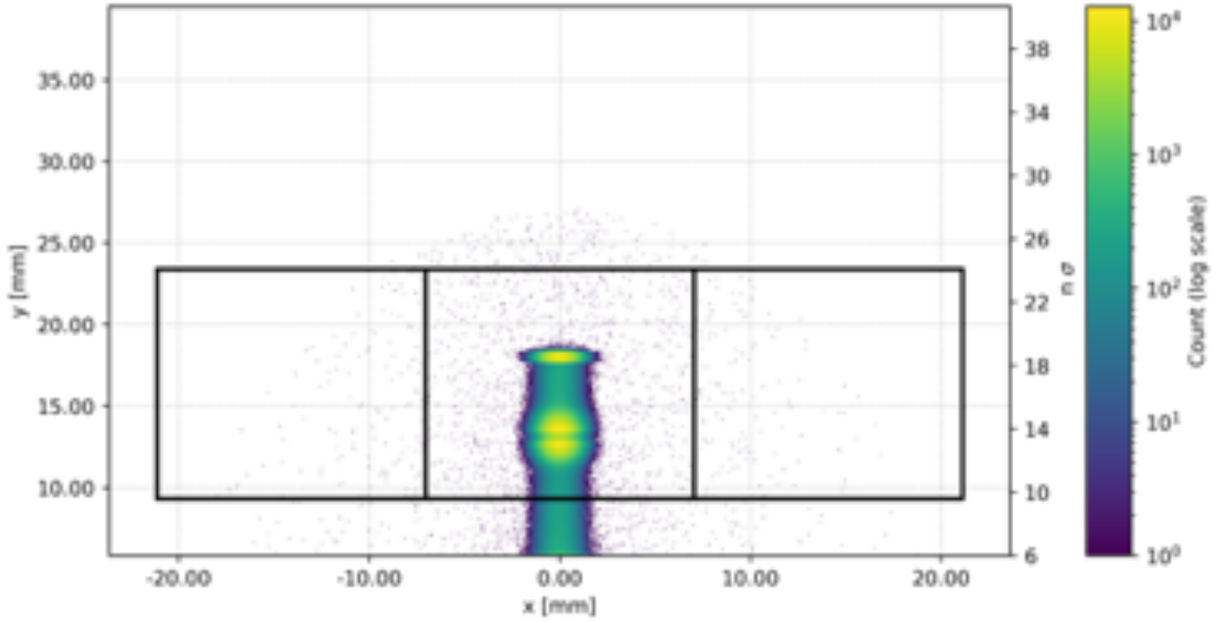
VELO silicon pixel sensor

Final 3D layout



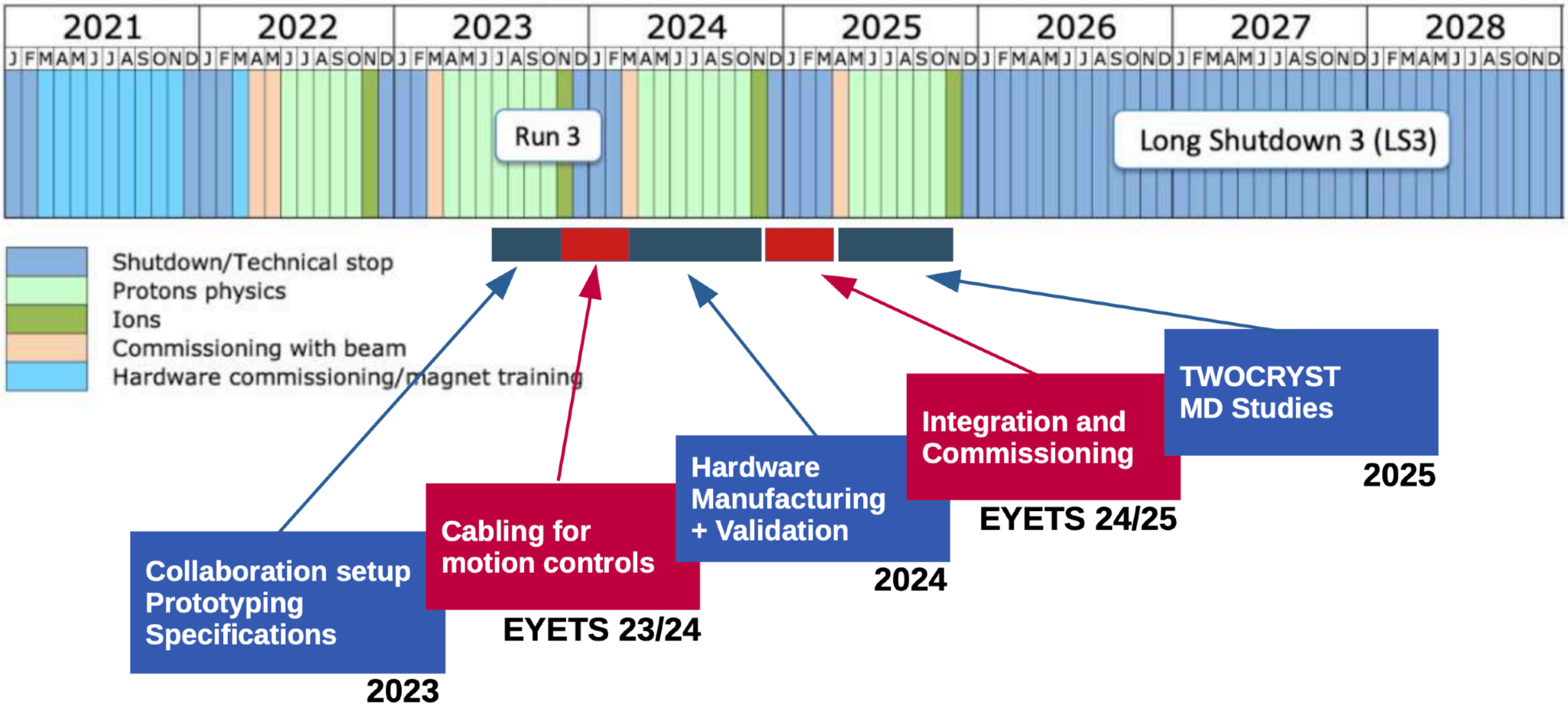


TWOCRYST fiber tracker



TWOCRYST silicon pixel detector

Schedule



Challenging, but on good track so far!

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References

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LHC, in Proc. IPAC'22, Bangkok, Thailand. doi:10.18429/JACoW-IPA

Dewhurst K., *Performance of a double-crystal setup for LHC fixed-t*
Venezia, Italy. doi:10.18429/jacow-ipac2023-mopl048

See two recent contributions to ICHEP2024 (P. Hermes + F. Vidal)