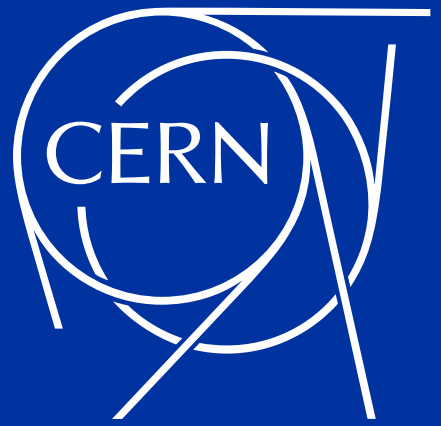


Status of the TWOCRYST project for a double-crystal fixed-target experiment in the LHC

R. Cai and P. Hermes on behalf of the TWOCRYST Collaboration

10th of July at EPS-HEP 2025

CERN
O. Aberle, F. Alessio, C. Antuono, G. Arduini, M. Calviani, V. Coco, M. D'Andrea, Q. Demassieux, K. Dewhurst, M. Di Castro, L. Esposito, M. Ferro-Luzzi, H. Havlikova, P. Hermes, S. Jakobsen, C. Maccani, E. Matheson, D. Mirarchi, A. Perillo Marcone, S. Redaelli, B. Salvant, R. Seidenbinder, S. Solis Paiva, E. Soria, C. Zannini

IJCLab, Orsay, France
A. Fomin, P. Robbe, A. Stocchi

INFN Milano and University of Milano
S. Cesare, S. Coelli, P. Gandini,
D. Marangotto, A. Merli**, N. Neri, E. Spadaro Norella*, G. Tonani, F. Zangari

Warsaw University of Technology, Poland
M. Patecki

IFIC, University of Valencia-CSIC, Spain
S.J. Jaimes Elles, S. Libralon, F. Martinez Vidal,
J. Mazorra de Cos, I. Sanderswood, S. Vico Gil

INFN Ferrara and University of Ferrara
L. Bandiera, V. Guidi, L. Malagutti, A. Mazzolari, R. Negrello, M. Romagnoni, M. Tamisari

INFN Padova and University of Padova
M. Benettoni, G. Simi, A. Triossi, M. Zanetti

INFN Legnaro Labs and University of Padova
D. De Salvador

INFN Pisa and Pisa University
G. Lamanna, J. Pinzino, M. Sozzi, N. Turini

UCAS, China
J. Fu, H. Miao, T. Xing

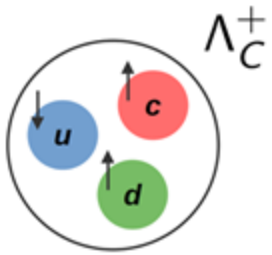
University of Malta
L. Grech, G. Valentino

Institute of Nuclear Physics - Polish Academy of Sciences
K. Korcyl

TWOCRYST is carried out under the Physics Beyond Colliders (PBC) Fixed-Target Working Group and is a collaboration of the institutes CERN, INFN (Italy), IFIC (University of Valencia-CSIC, Spain), IJCLab (France), the University of Malta, the Institute of Nuclear Physics of the Polish Academy of Sciences, Warsaw University of Technology (Poland), and UCAS (China). The project acknowledges support from the PBC project; the HL-LHC project; the ATLAS-ALFA collaboration; the ERC SELDOM Grant No. 771642; the INFN CSN5 project OREO; the Italian Ministry of University and Research (MUR), funded by the European Union – NextGenerationEU under Project Title PRIN 202277EWLW; contributions from the AICRYSCON project funded by Xjenza Malta through the FUSION: R&I Research Excellence Programme; support from MICIU, AEI, and GVA (Spain) under projects PID2022-139842NB-C22, CIPROM/2022/36, ASFAE/2022/030, and NextGenerationEU; and funding from the National Science Centre, Poland (project No. 2021/43/D/ST2/02761).

TWOCRYST

Overview of this talk



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

A concept on a direct measurement of magnetic and electric dipole moments of short-lived charm particles.

ALADDIN : a possible experimental setup in the LHC

TWOCRYST: LHC test stand operated 2025

Developed in the framework of the
Physics Beyond Colliders Fixed-Target Working Group

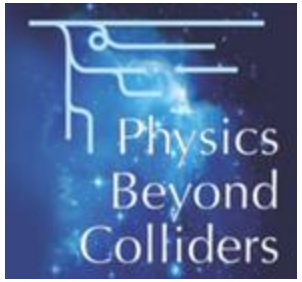


Table of content

Introduction

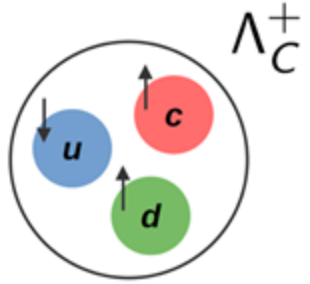
Magnetic and Electric Dipole Moments (MDM & EDM)

Insights to baryon internal quark dynamics → QCD

Charm baryon MDM	Test of heavy quark dynamics in QCD
Charm baryon EDM	Test of physics beyond SM

Very short lifetimes: no direct measurements so far

Conventional **magnets** produce fields **~ T**



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

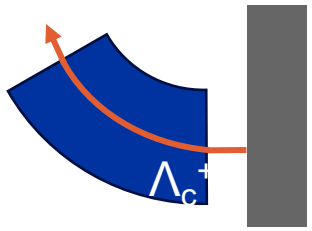
More details in "The ALADDIN experiment at LHC" – S. Cesare

- **LHC double-crystal based fixed-target experiment.**
- **Bent crystals used to split and induced precession.**
  - "The original idea for spin precession in a curved channeling crystal was suggested independently by V.G. Baryshevskii in Byelorussia and Lee Pondrom of Wisconsin"
  - "First observation of magnetic moment precession of channeled particles in bent crystals"

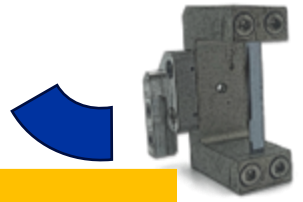
Precession Crystal (TCCP)
Bending angle: 7 mrad
Length: 7 cm
Radius: 10 m

Equivalent to hundreds of Tesla magnet

Target



Splitting Crystal (TCCS)
Bending angle: 50 μrad
Length: 4 mm
Radius: 80 m



Machine safety
requires ~1cm

680 MJ Beam

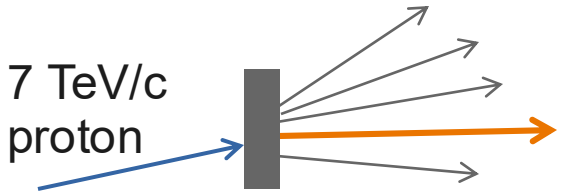
Letter of Intent

Open questions

TCCP Performance

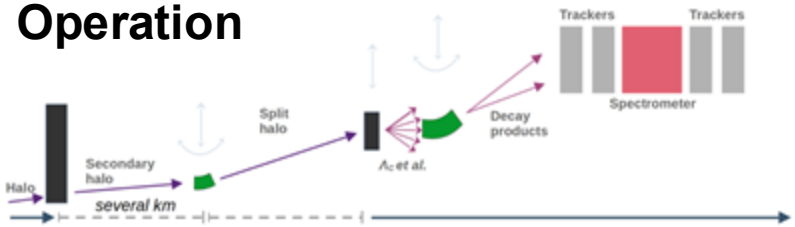
Never tested in LHC:
Efficiency at TeV energy?

Statistics



Requires 1.4 × 10^{13} protons on target:
Can this be reached?

Operation



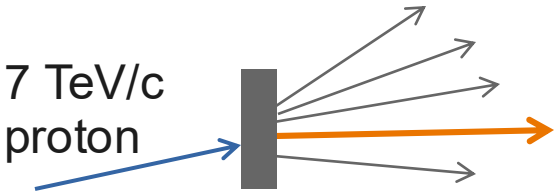
Two high precision devices:
Operationally feasible?

Open questions

TCCP Performance

Never tested in LHC:
Efficiency at TeV energy?

Statistics



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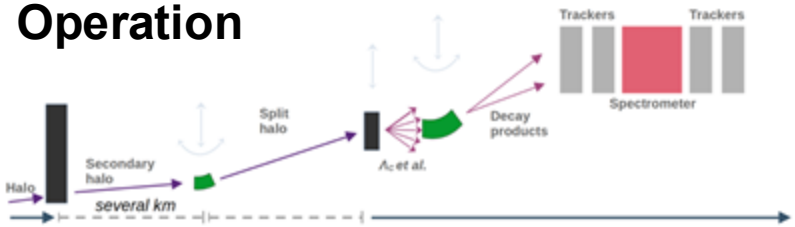


Two high precision devices:
Operationally feasible?

Can be tested with an operational test stand

TWOCRYST

An operational test stand

Collaboration

Collaboration est. in 2023

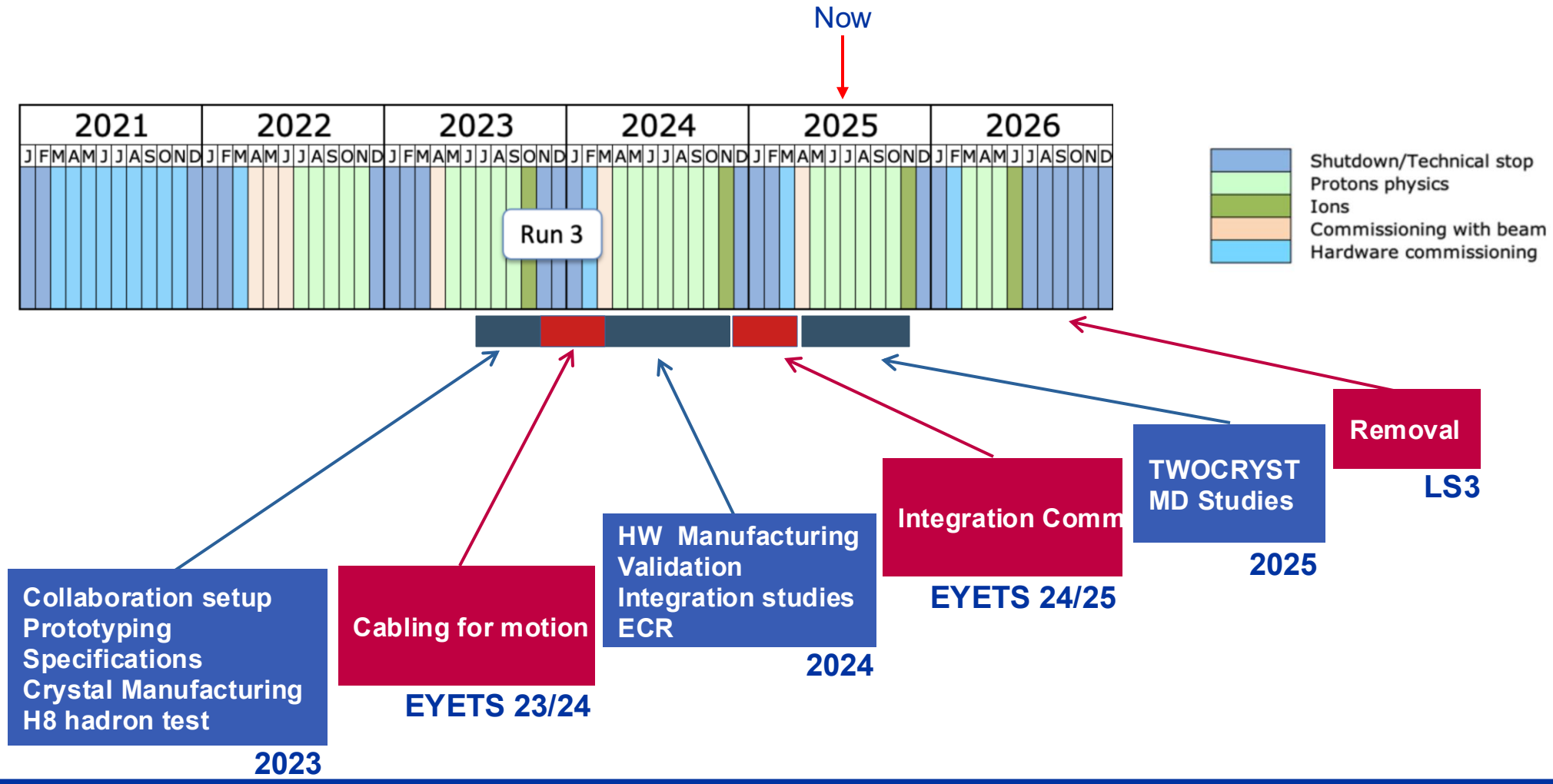
Eight institutes in 7 countries

More than 60 scientists

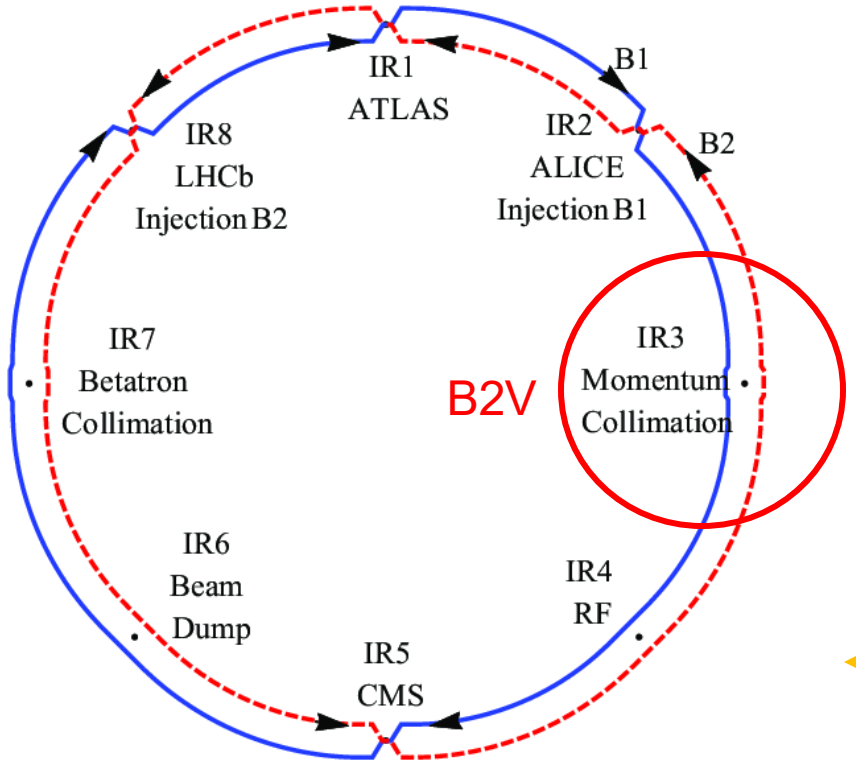
Broad range of expertise

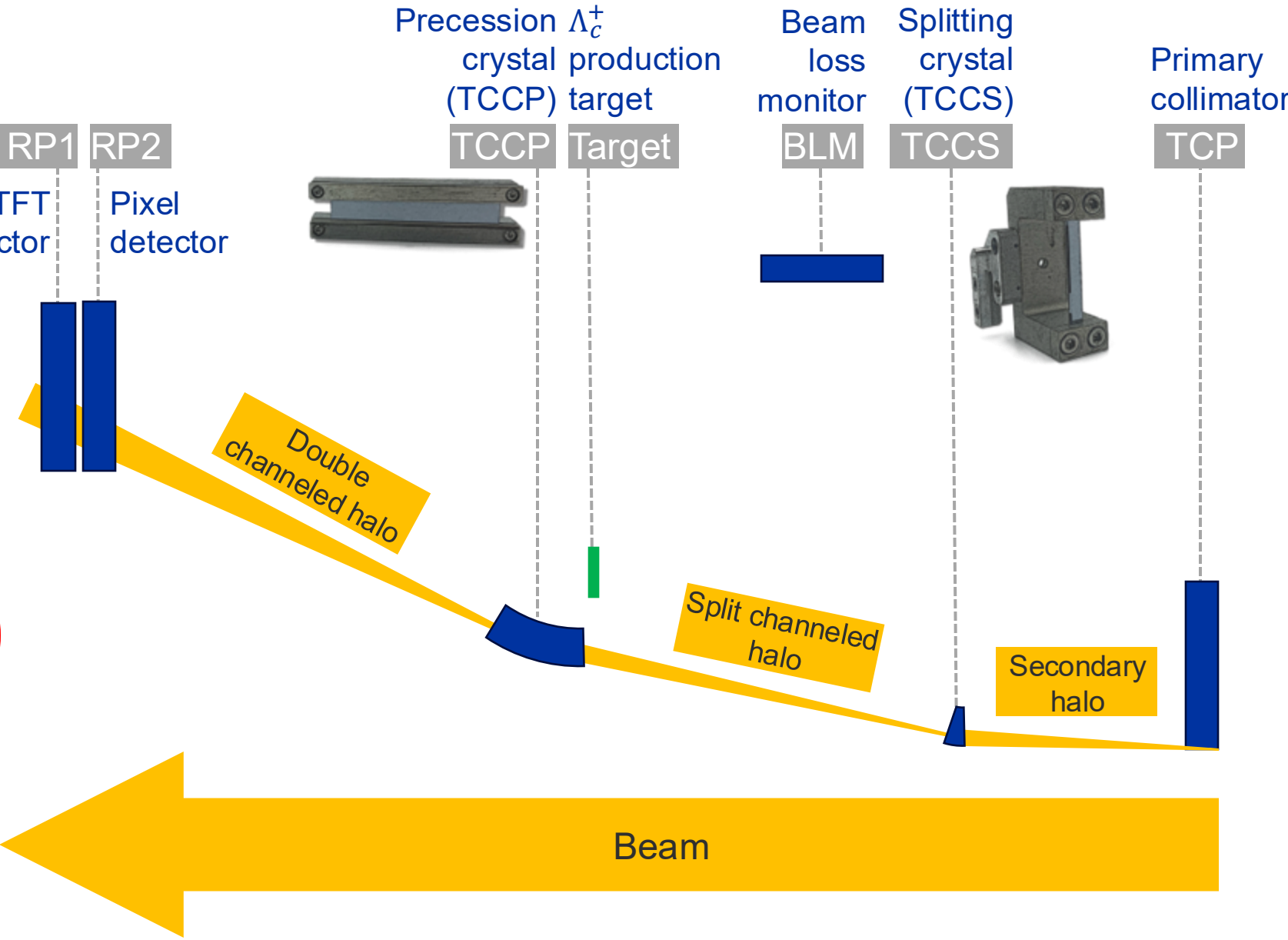
TWOCRYST

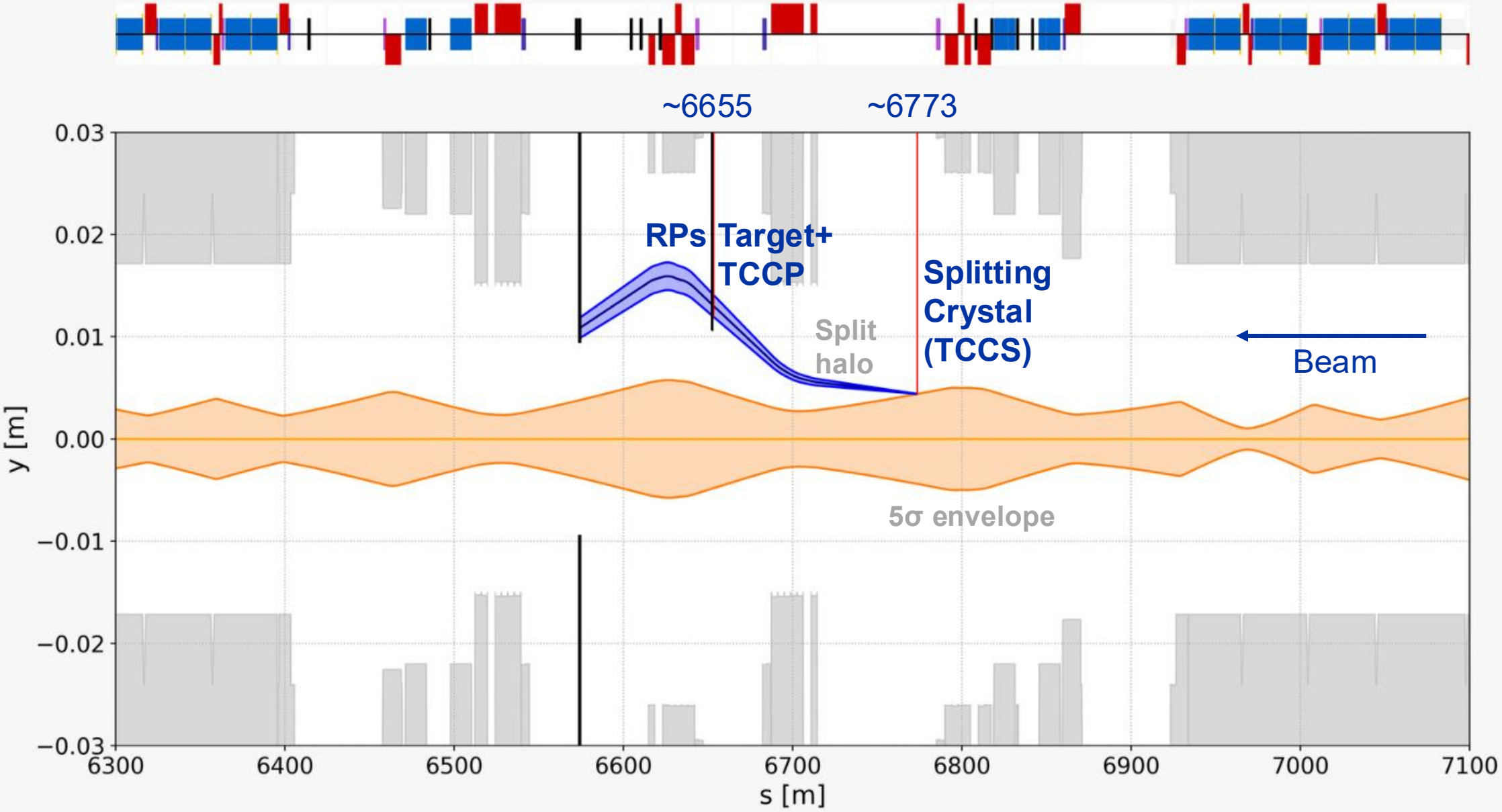
Project schedule

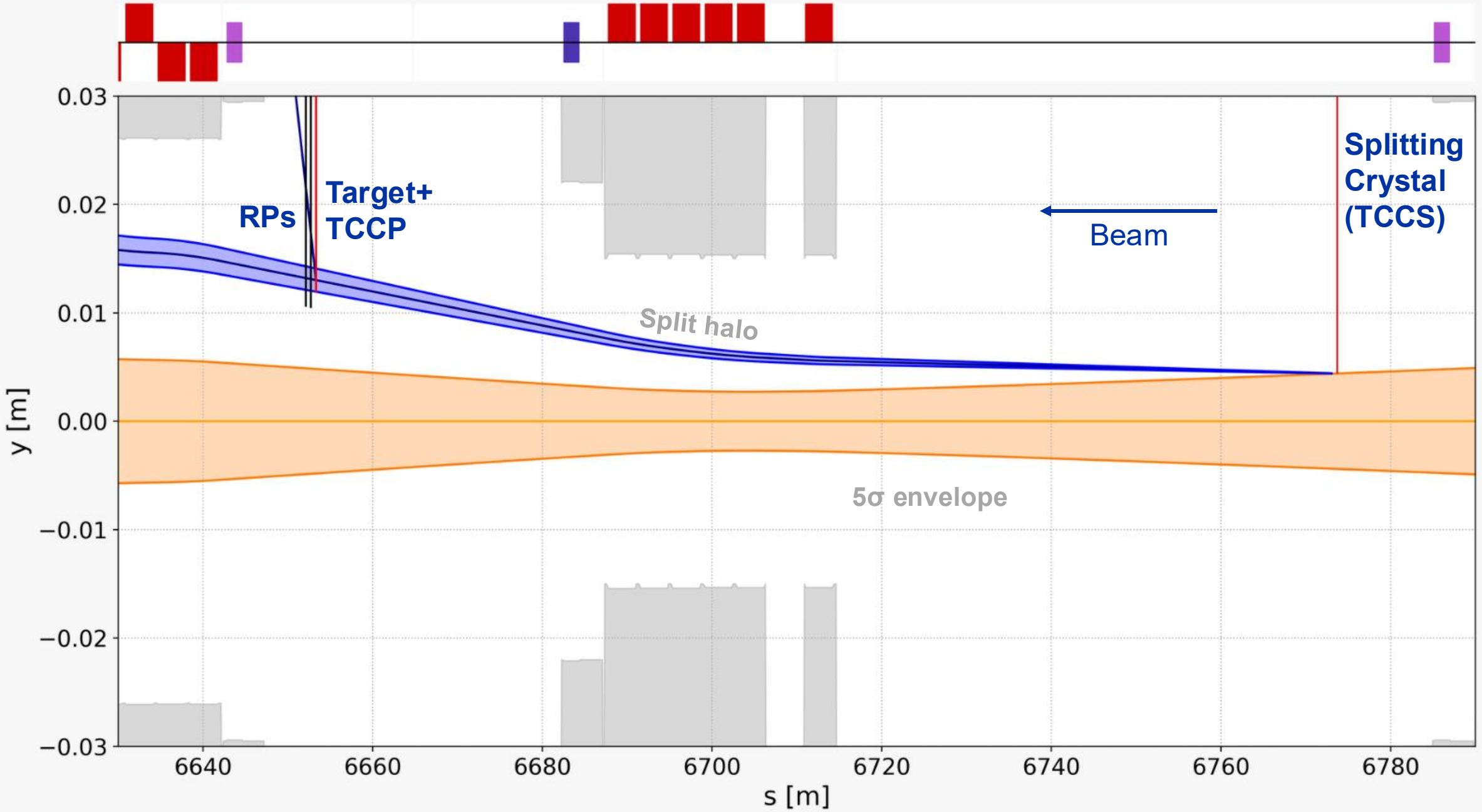


Experimental setup






~6655
~6773
RPs
Target+ TCCP
Splitting Crystal (TCCS)
Split halo
Beam
5σ envelope
y [m]
s [m]
0.03
0.02
0.01
0.00
−0.01
−0.02
−0.03
6300
6400
6500
6600
6700
6800
6900
7000
7100


RPs
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y [m]
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0.03
0.02
0.01
0.00
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6640
6660
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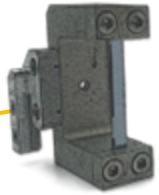
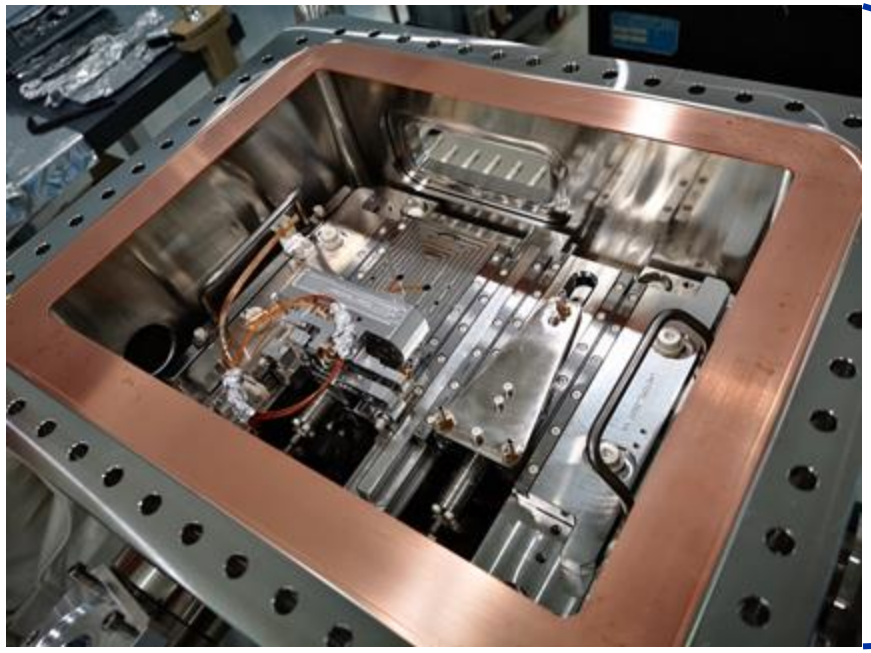
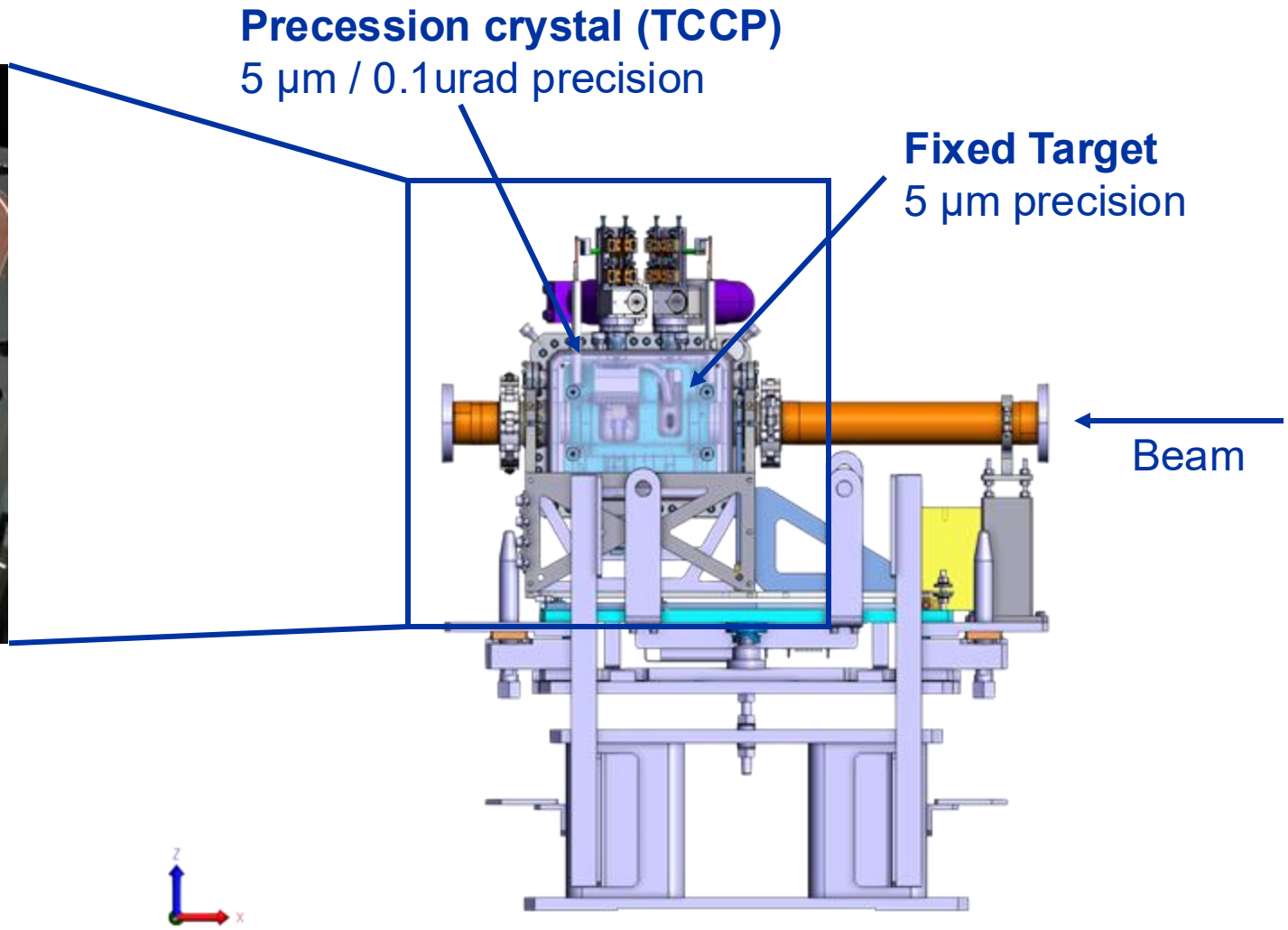
6720
6740
6760
6780

TCCS Assembly



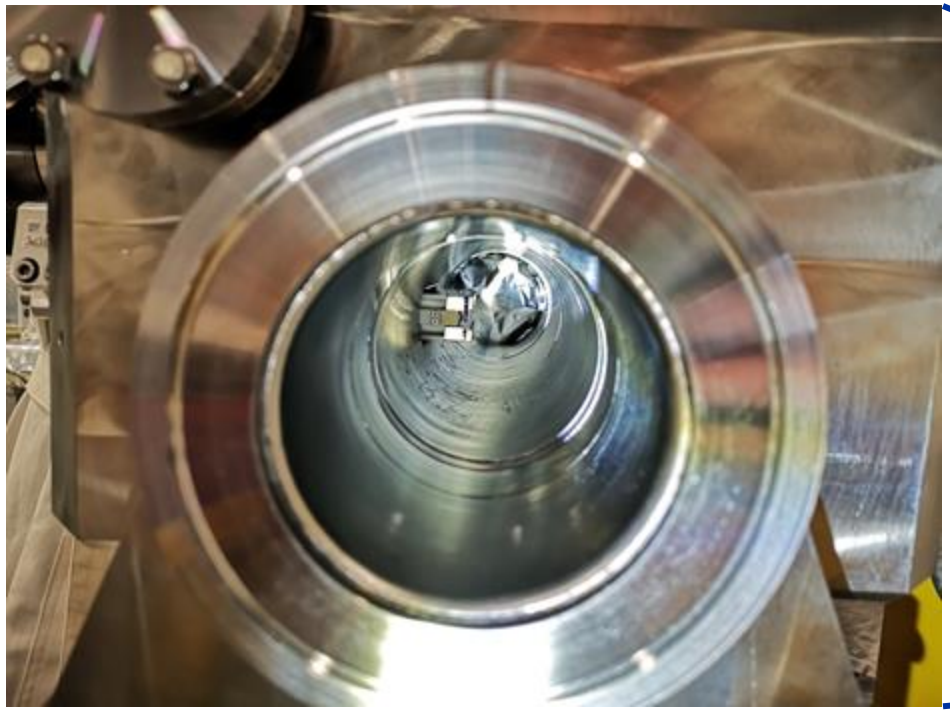
TCCP Assembly





Design started in 2023 (CERN SY/STI and BE/CEM)
Installation in January 2025!

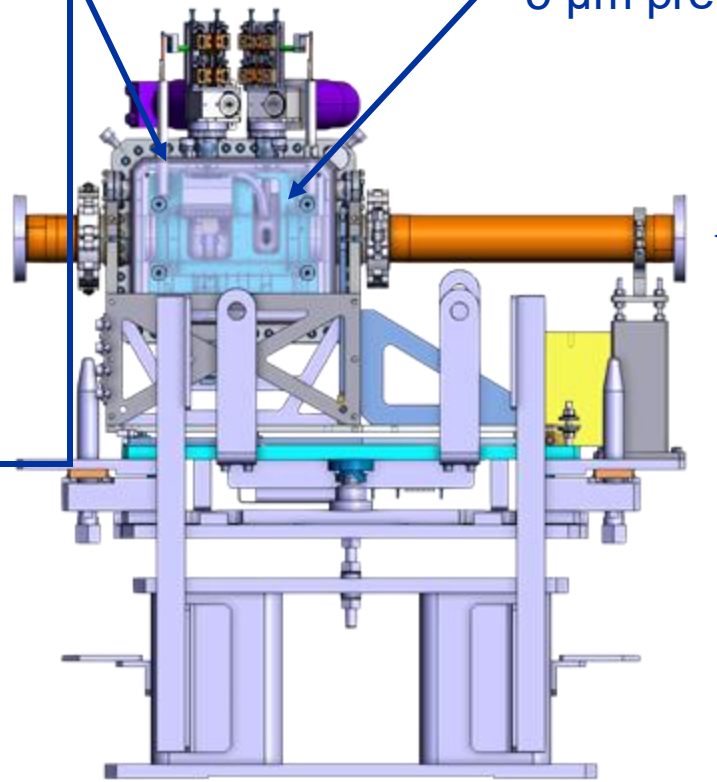
TCCP Assembly



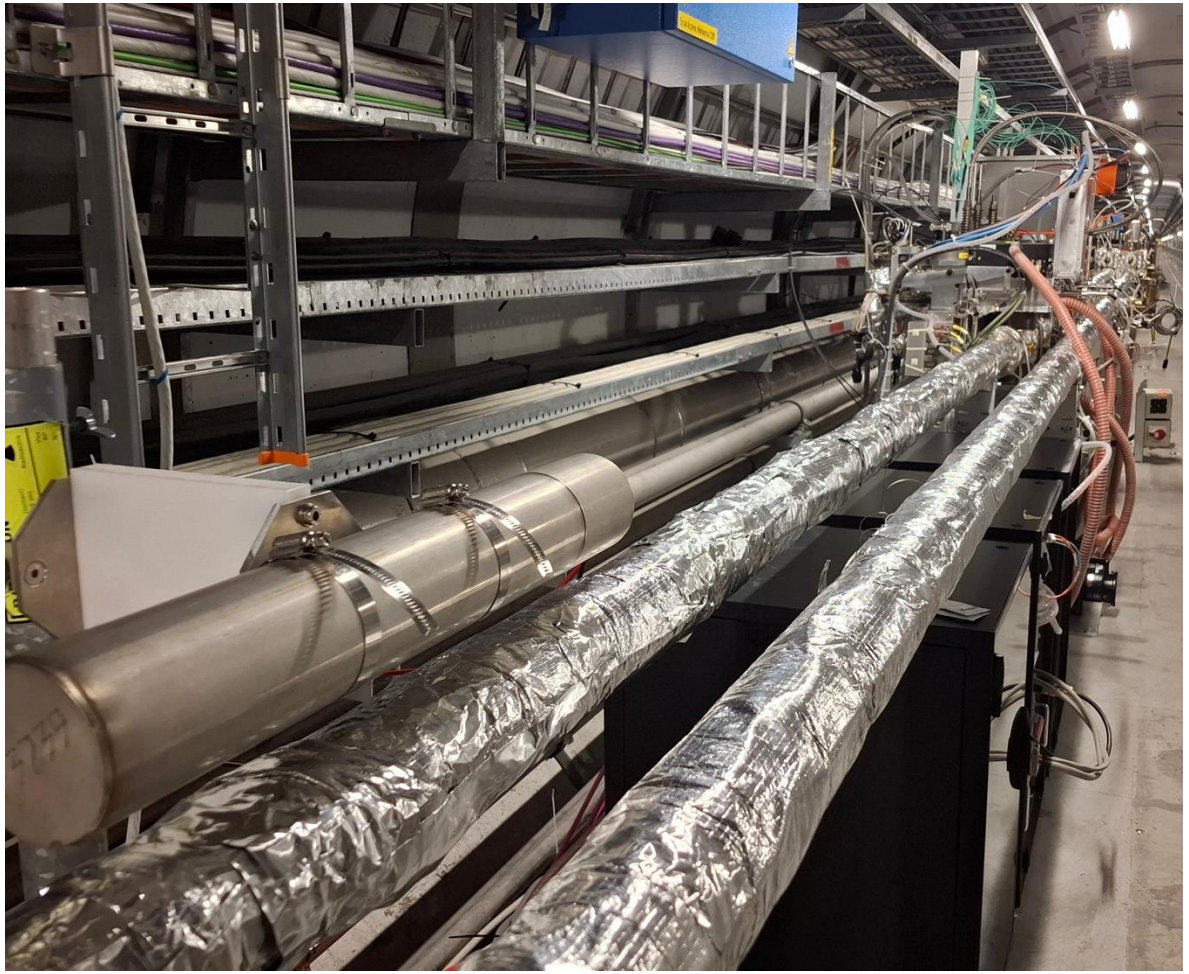
Precession crystal (TCCP)
5 μm / 0.1urad precision

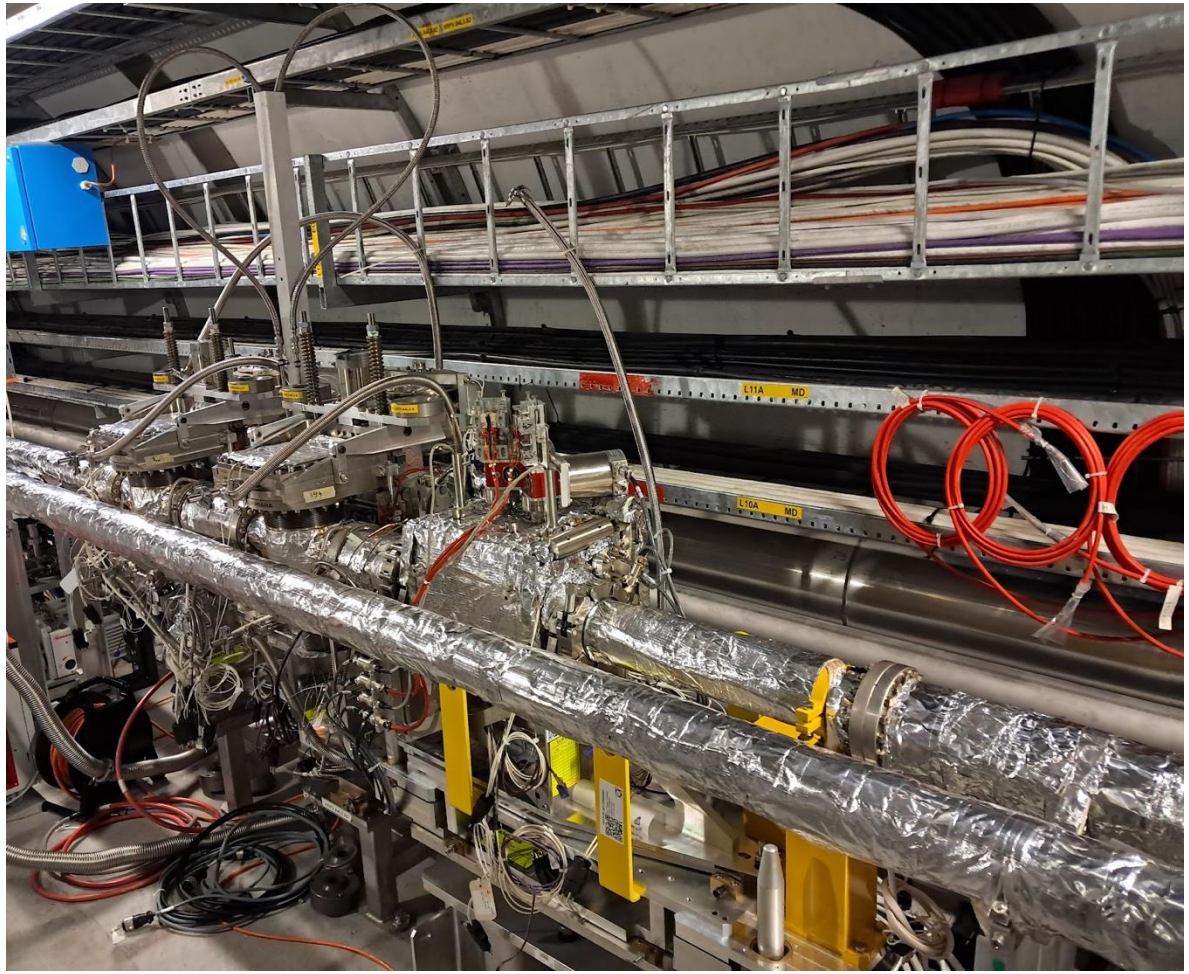
Fixed Target
5 μm precision

Beam



TCCP Assembly





Roman Pot stations

2023: Recovery of ATLAS-ALFA RP stations: physics program concluded

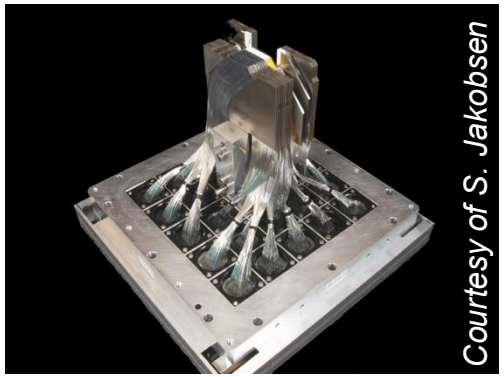
Refurbishment 2024

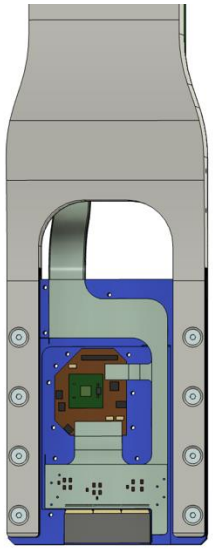
Installation 2025

Photographs: Courtesy of S. Jakobsen

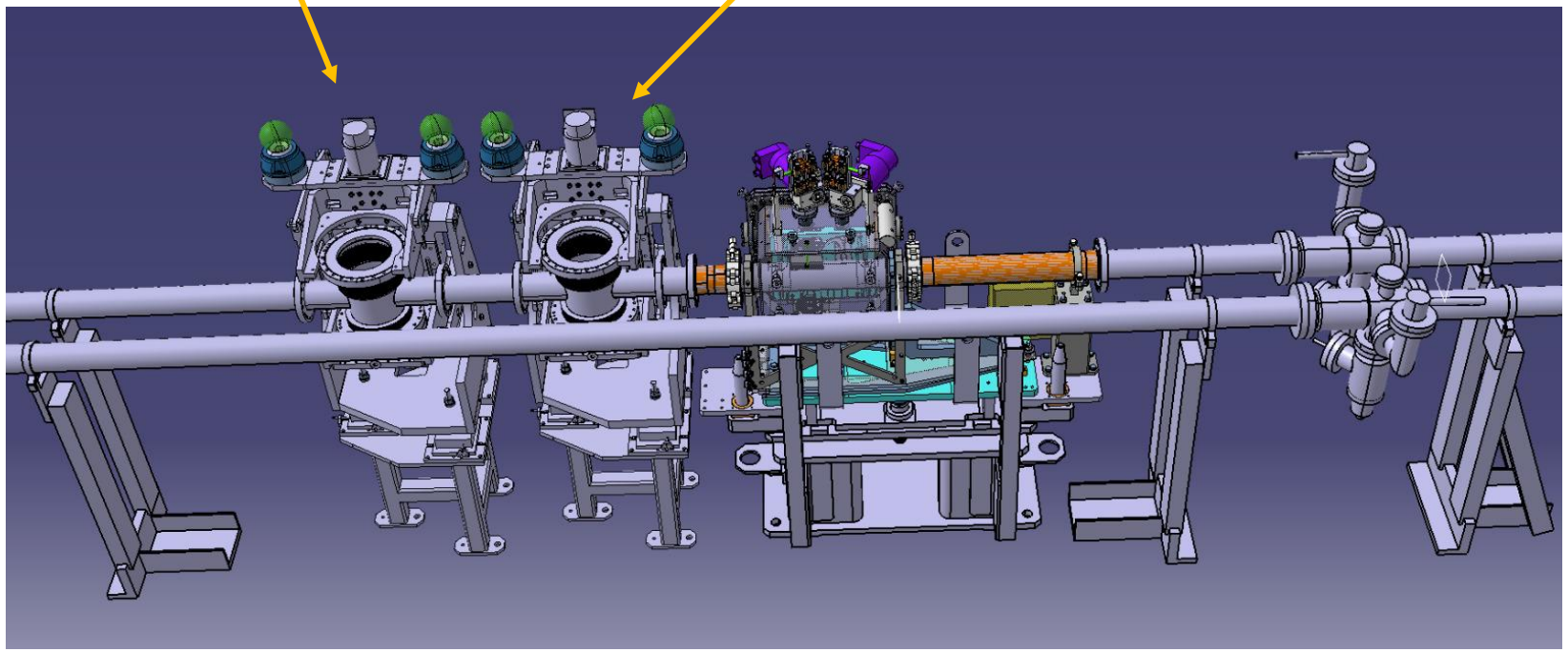
Detectors

Fibre tracker
Recovered from
ATLAS-ALFA





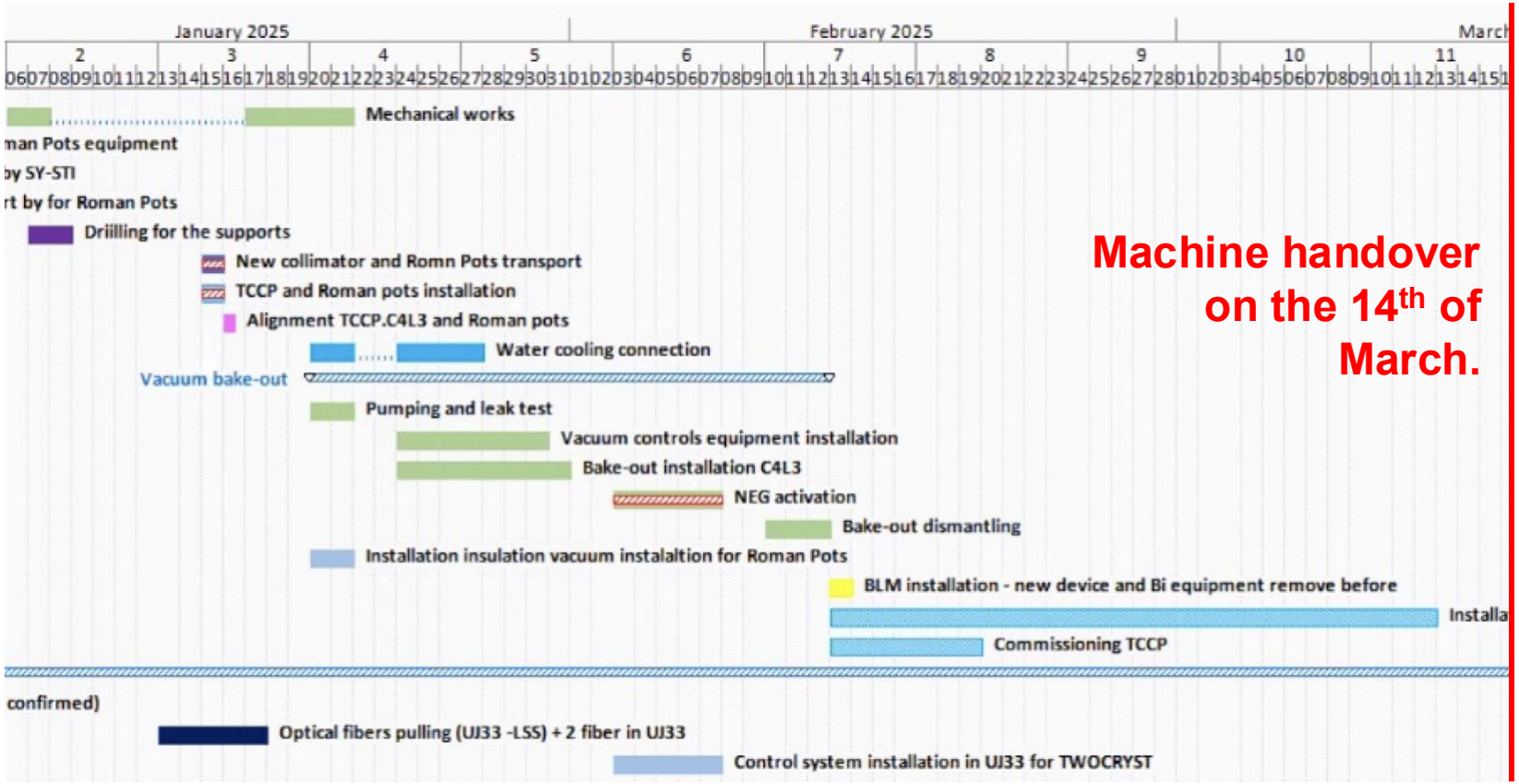
VELO silicon
pixel detector



Beam

Installation complete

- Successfully installed in 2025
- All hardware commissioned and operational
- First beam tests conducted



Machine handover on the 14th of March.

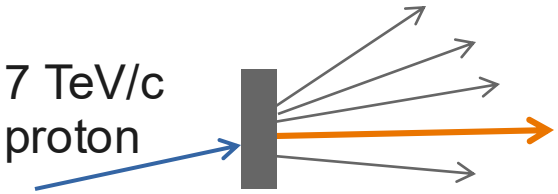
TWOCRYST test campaign

Open questions

TCCP Performance

Never tested in LHC:
Efficiency at TeV energy?

Statistics



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Can this be reached?

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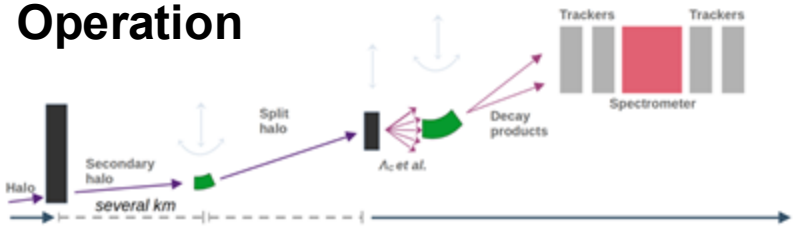

Two high precision devices:
Operationally feasible?

Open questions

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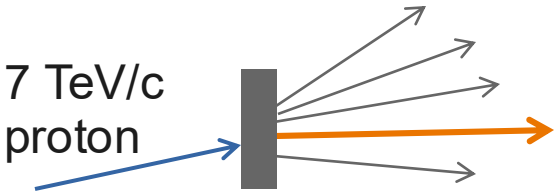

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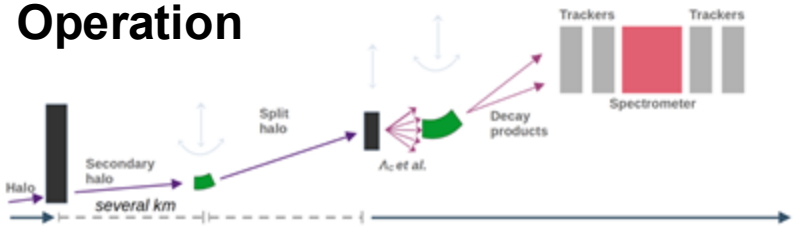
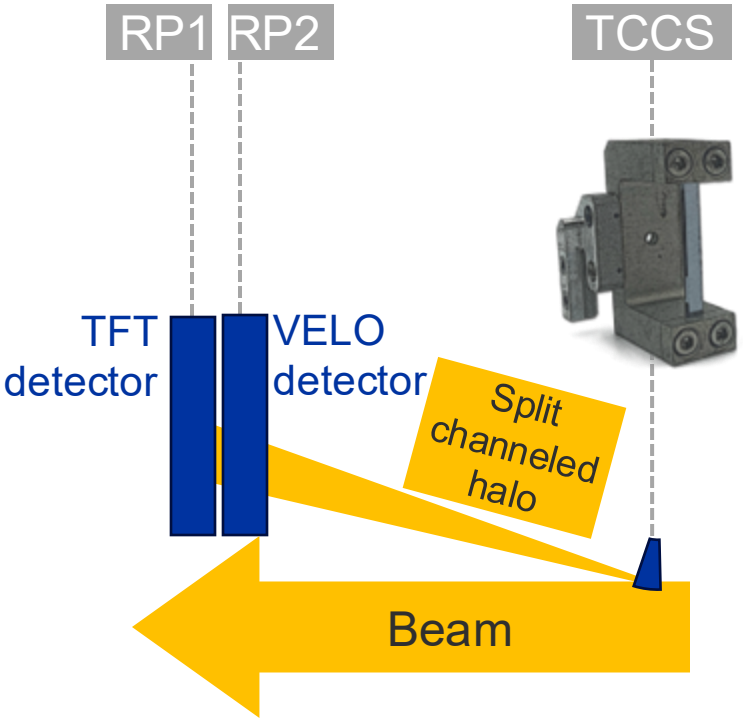


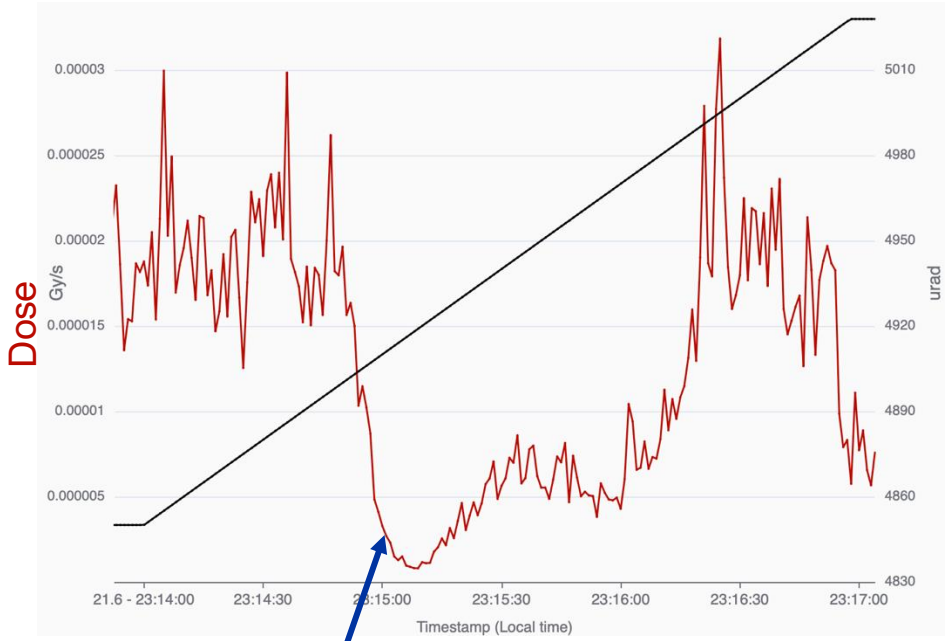
Two high precision devices:
Operationally feasible?

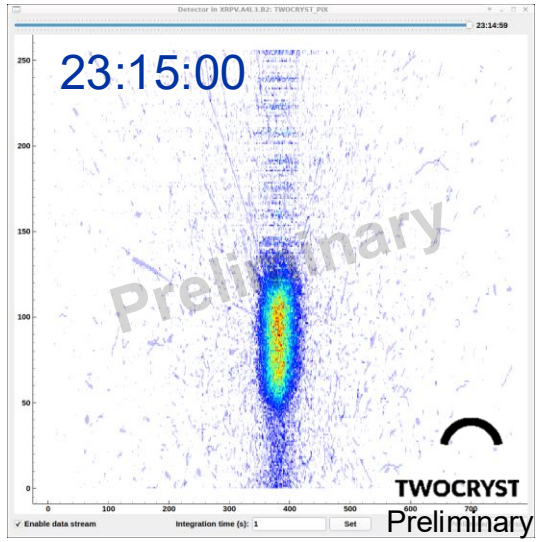
Extensive machine development studies devised

First experience - Success!

TCCS beam splitting

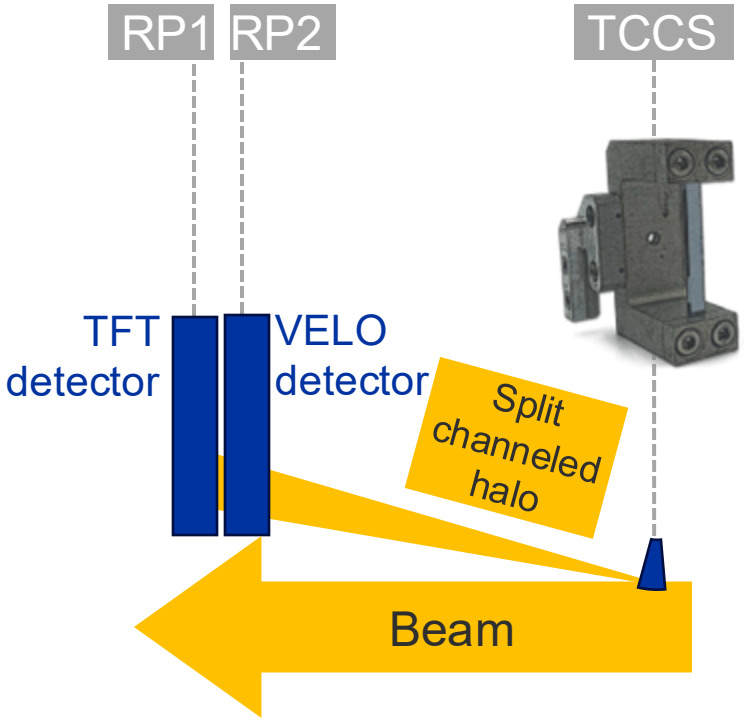


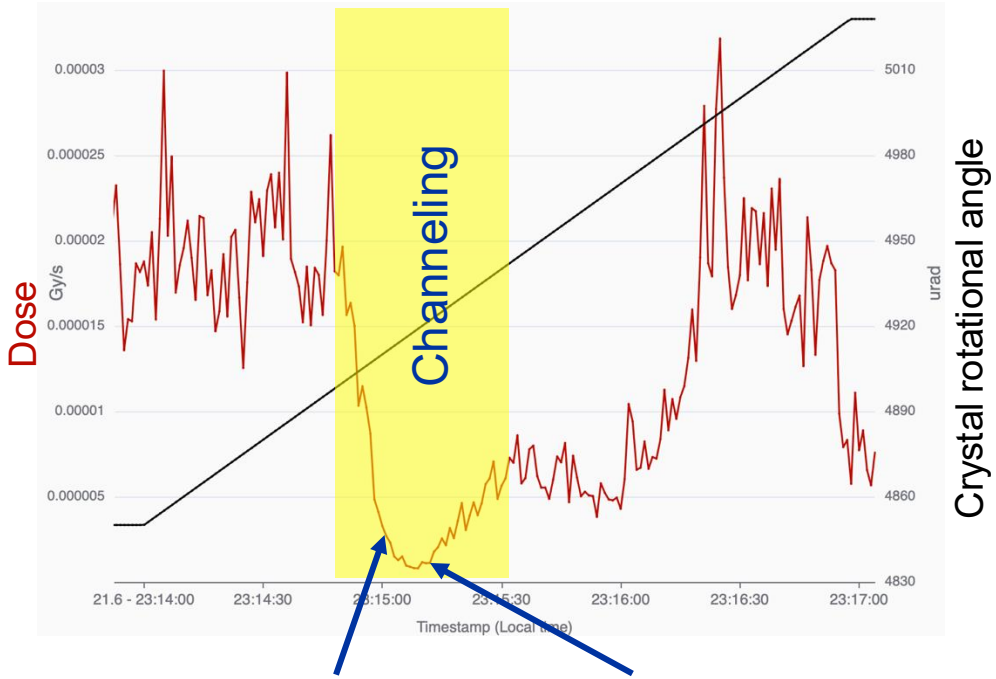


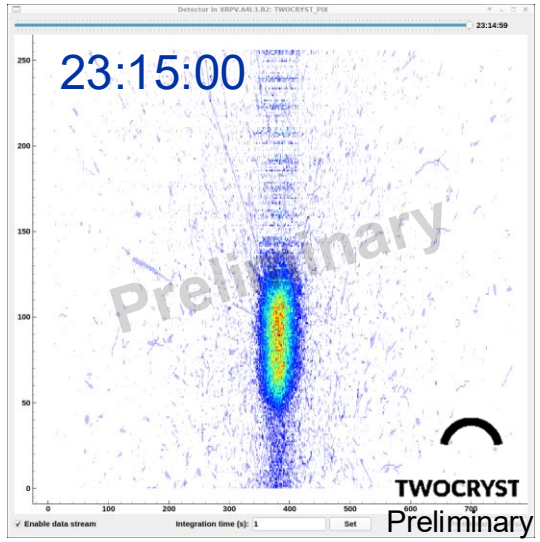


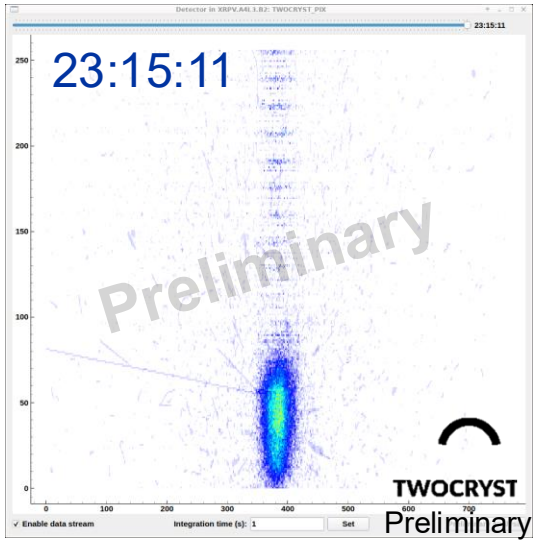
First experience - Success!

TCCS beam splitting



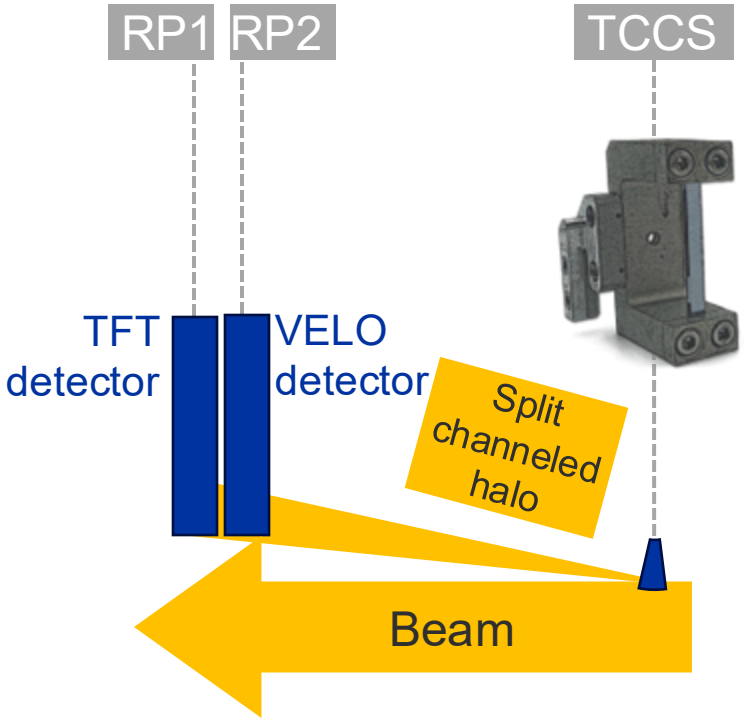


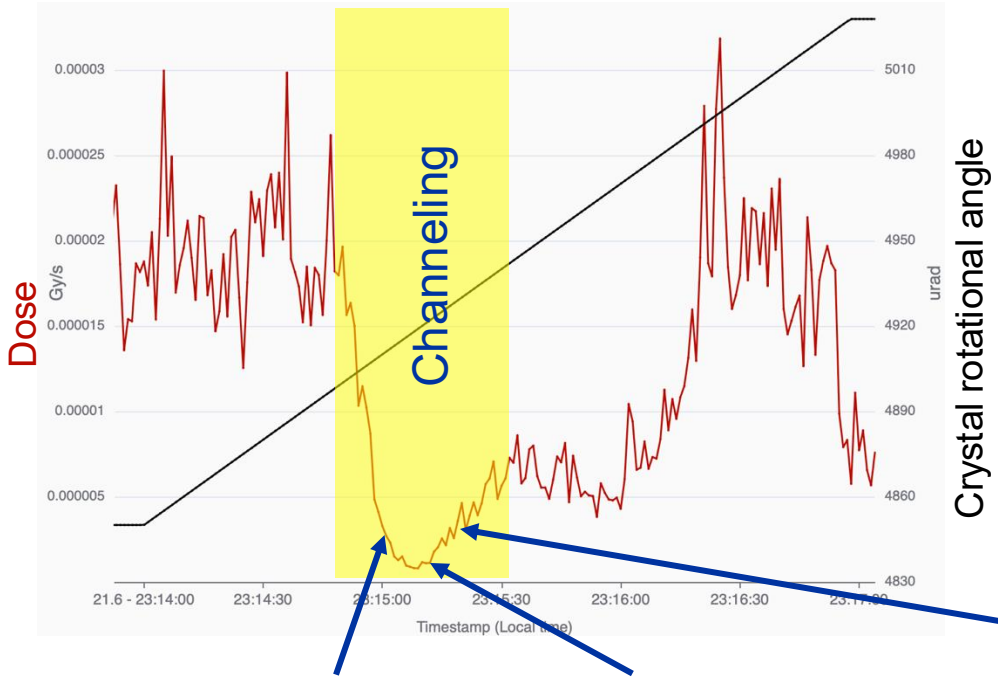


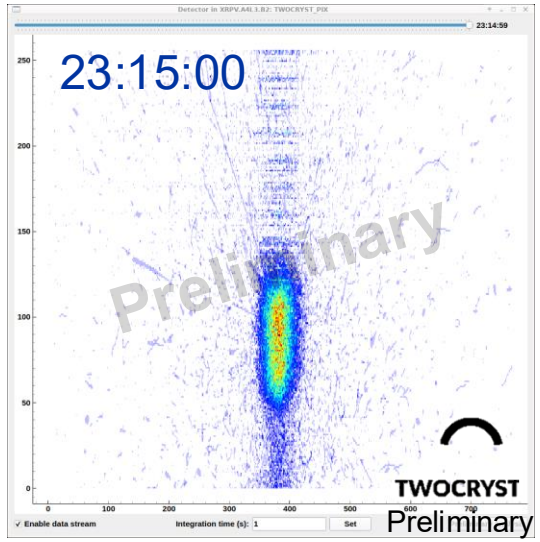


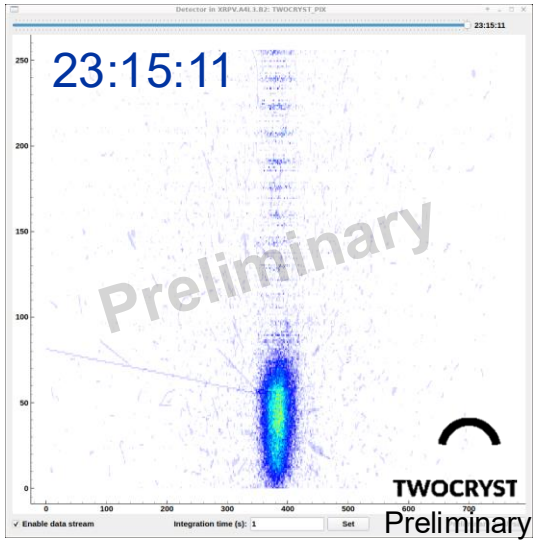
First experience - Success!

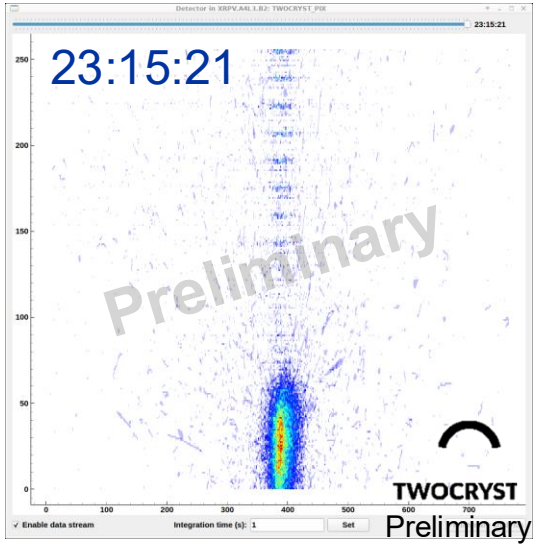
TCCS beam splitting





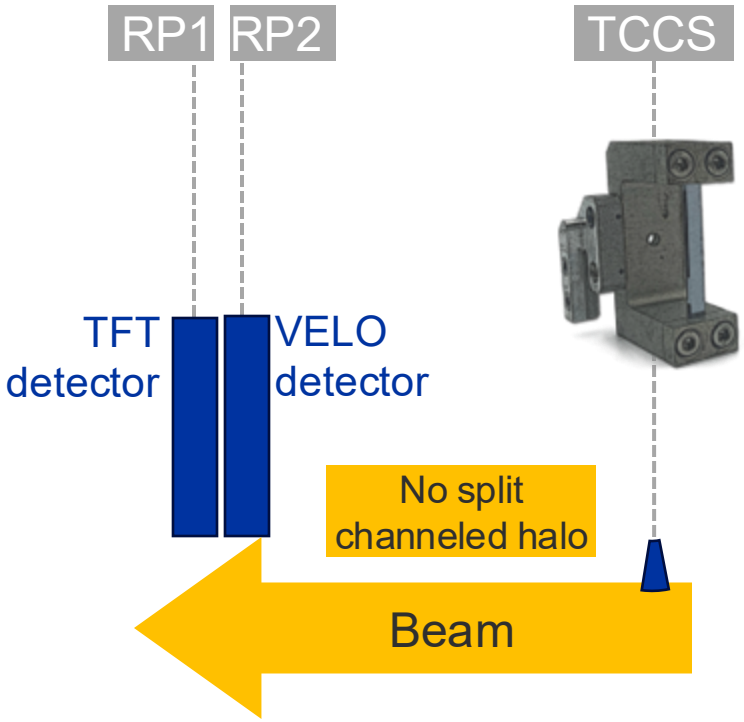


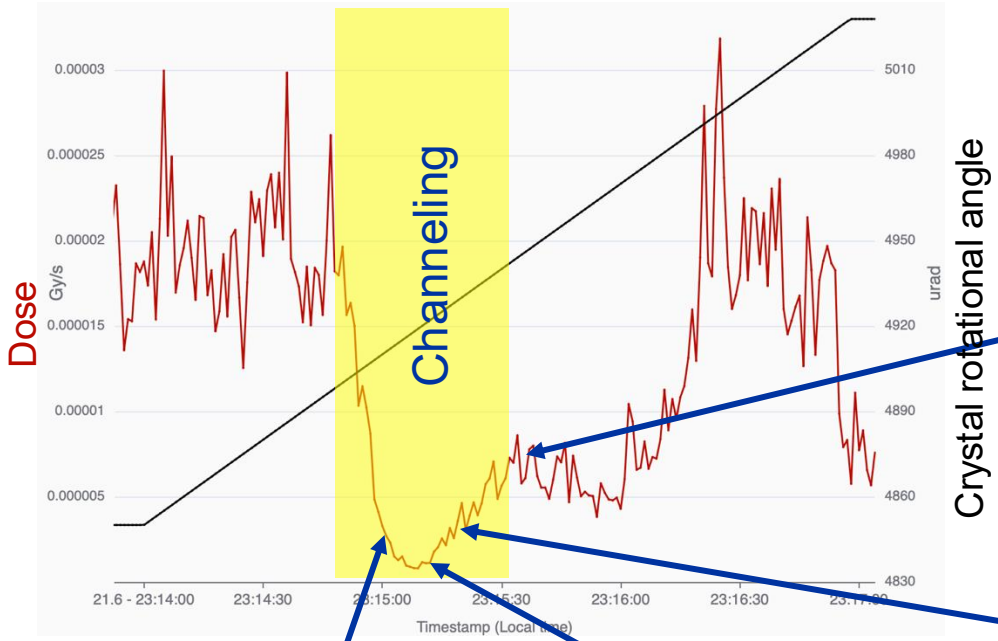


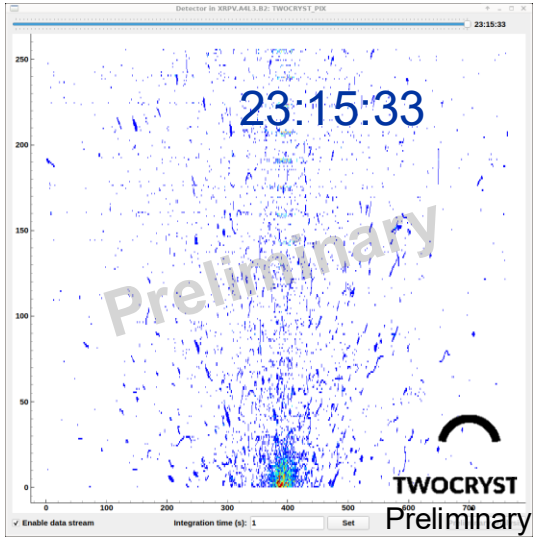


First experience - Success!

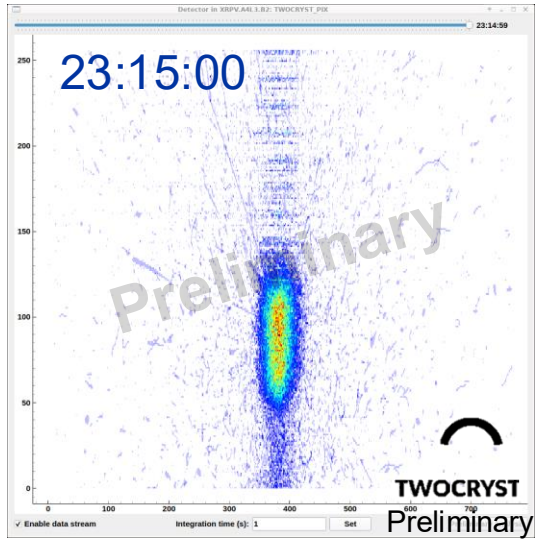
TCCS beam splitting

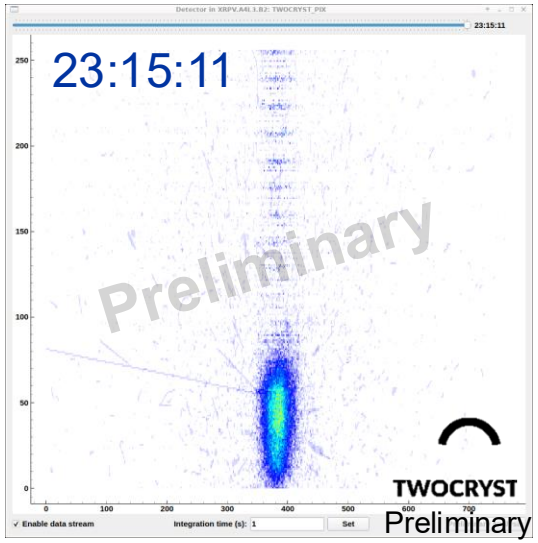


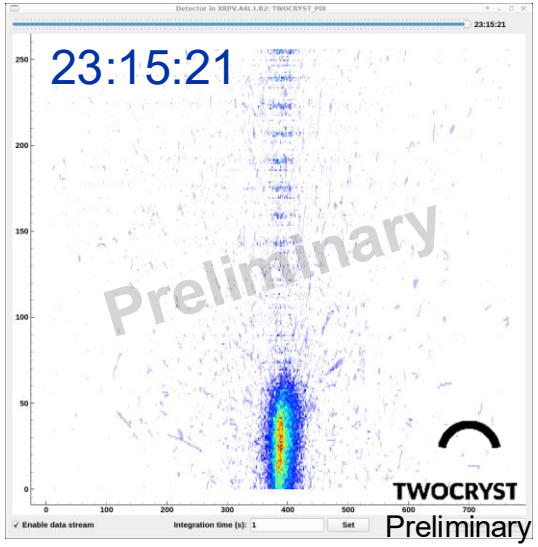




VELO Pixel

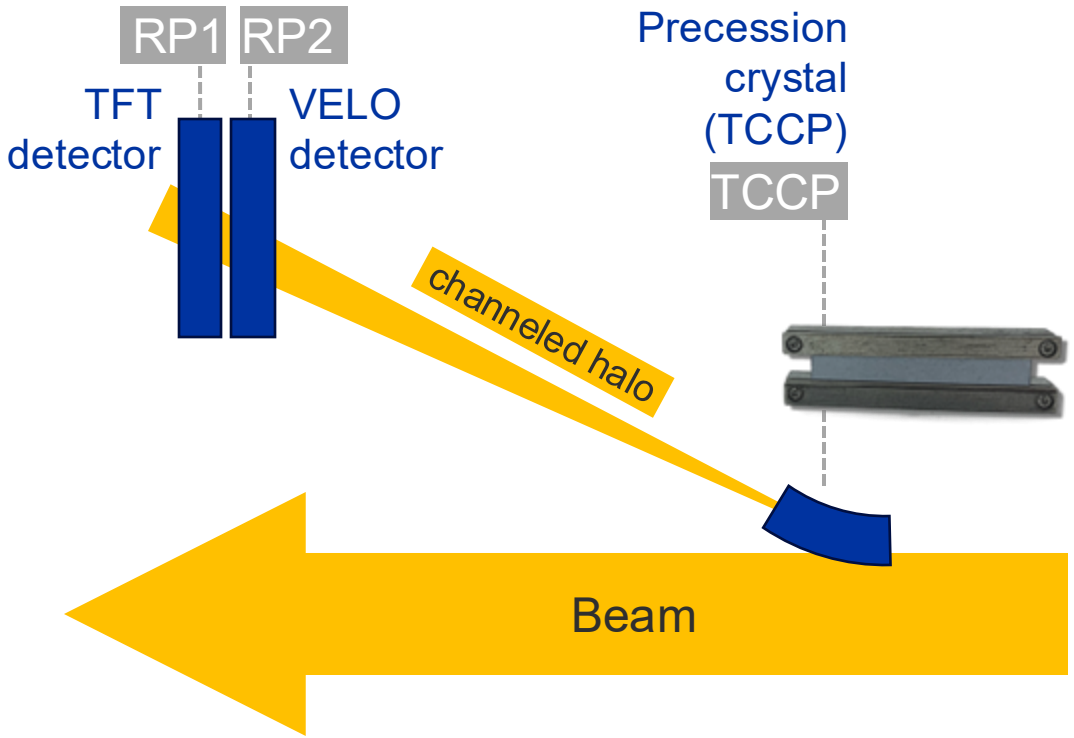


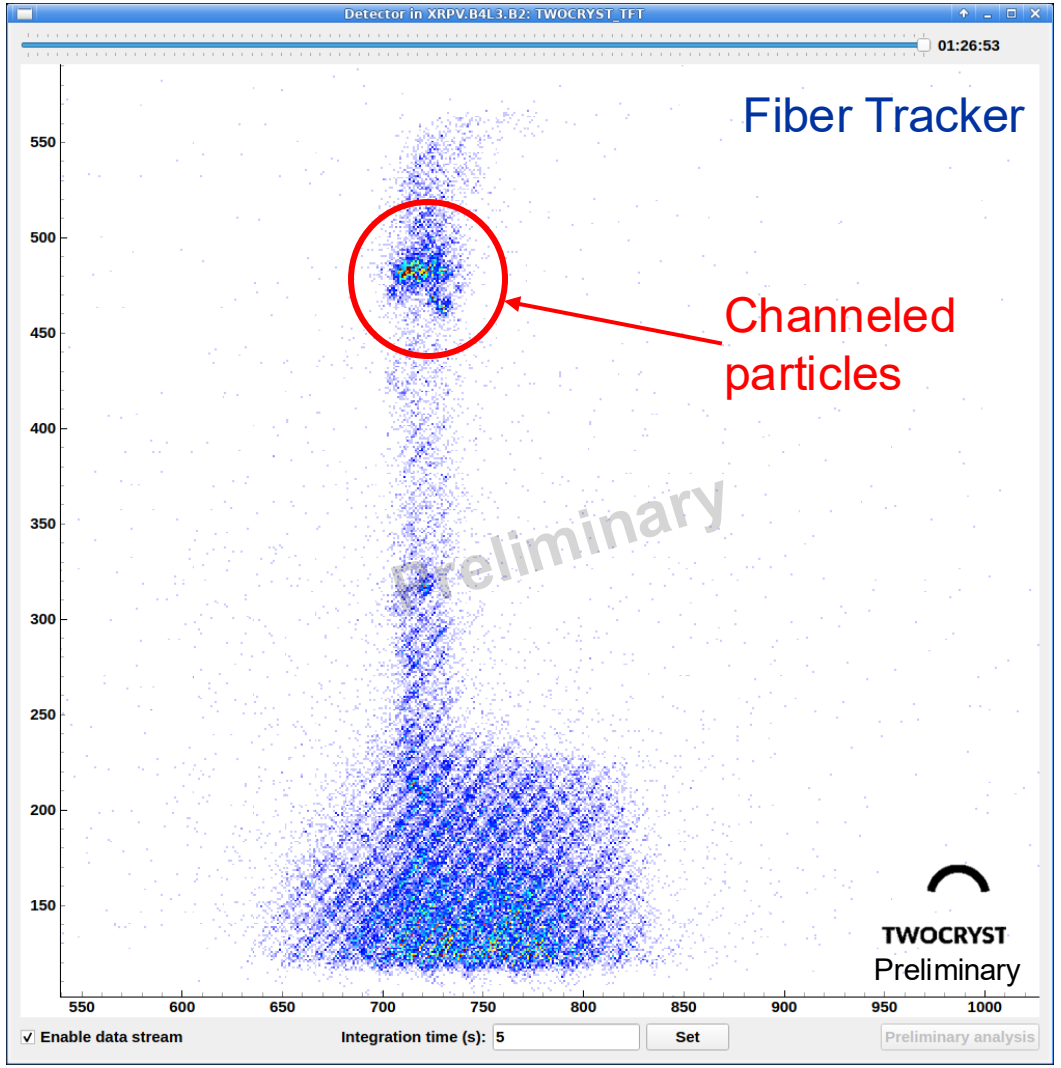




First experience - Success!

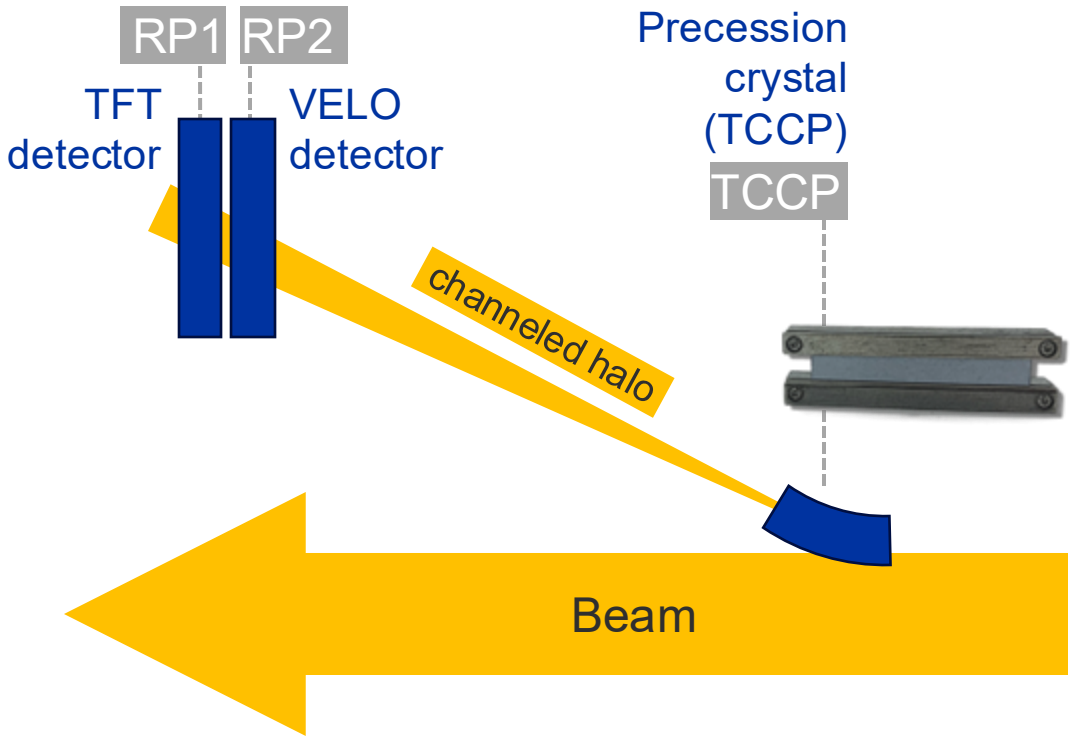
TCCP channeling

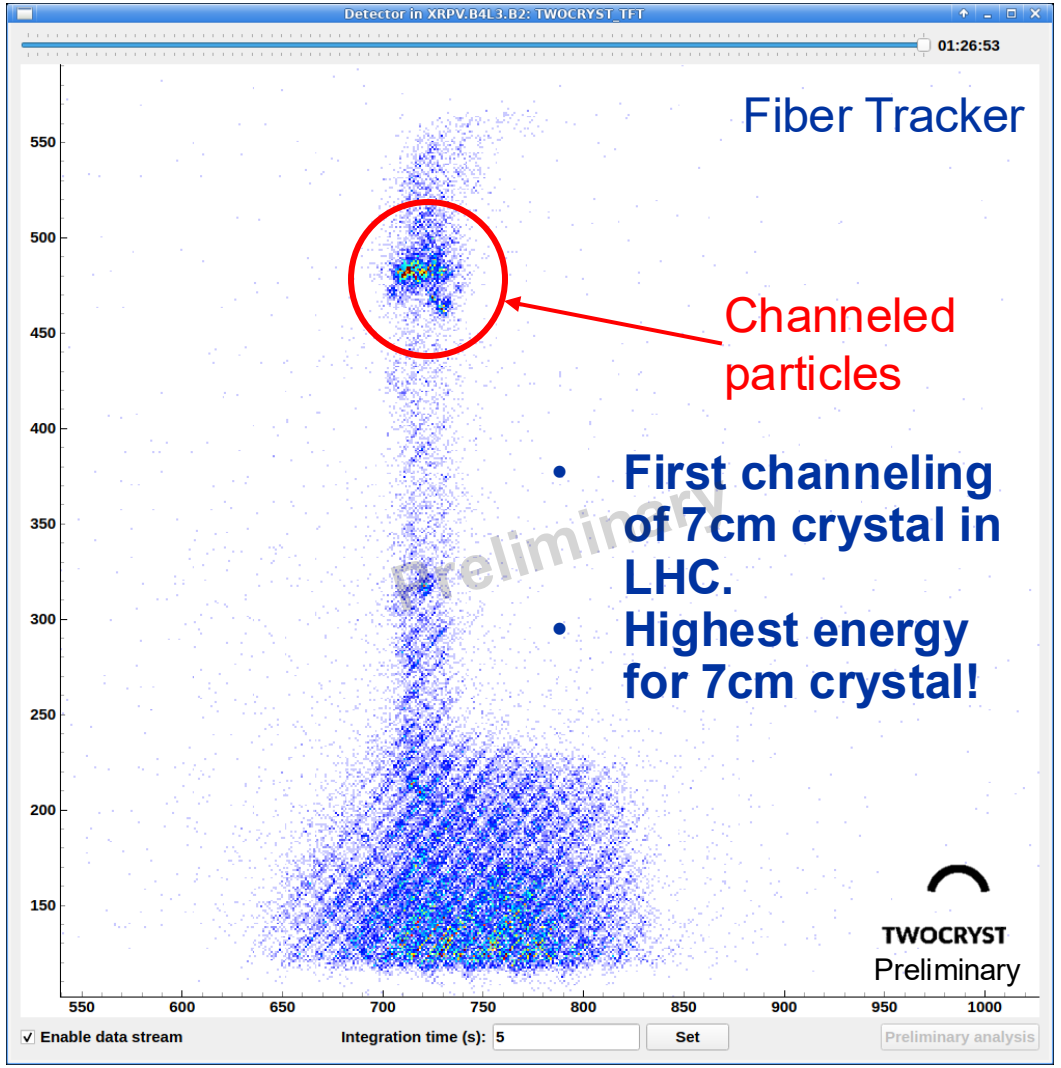




First experience - Success!

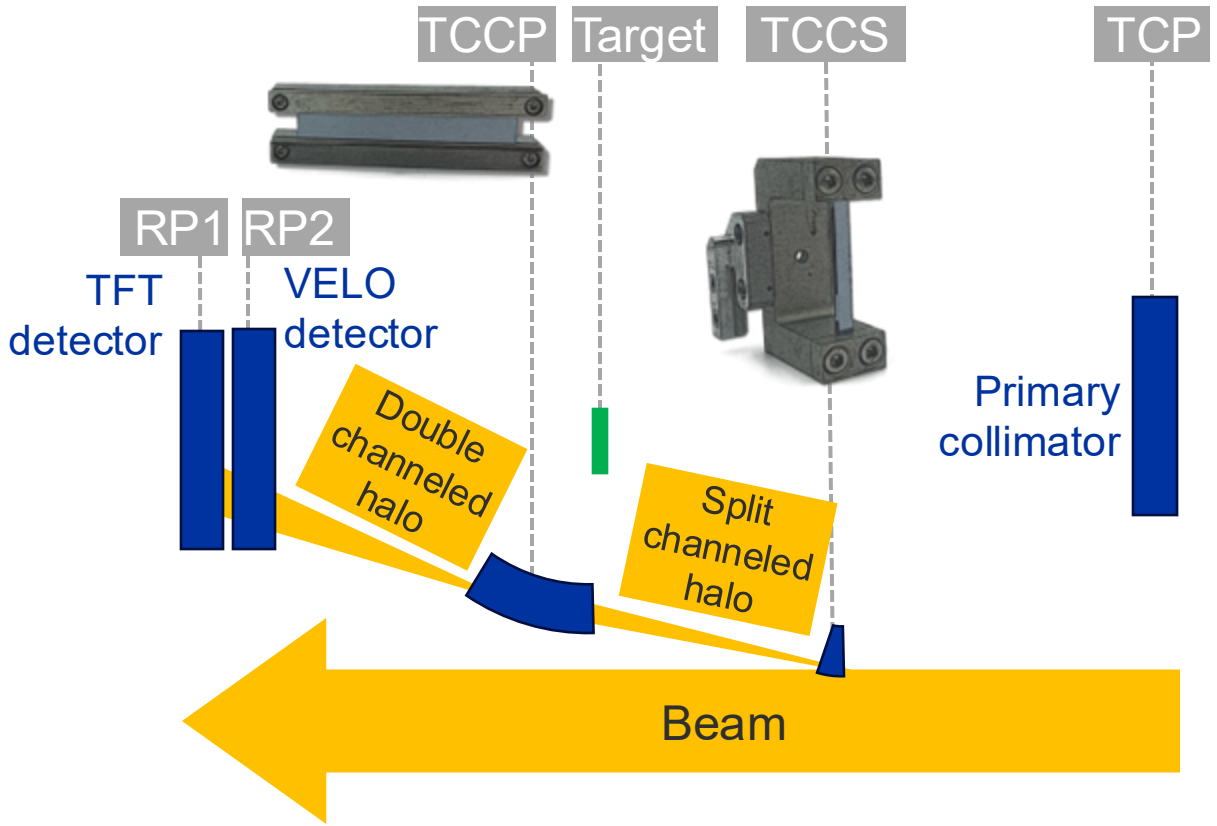
TCCP channeling





First experience - Success!

Double channeling



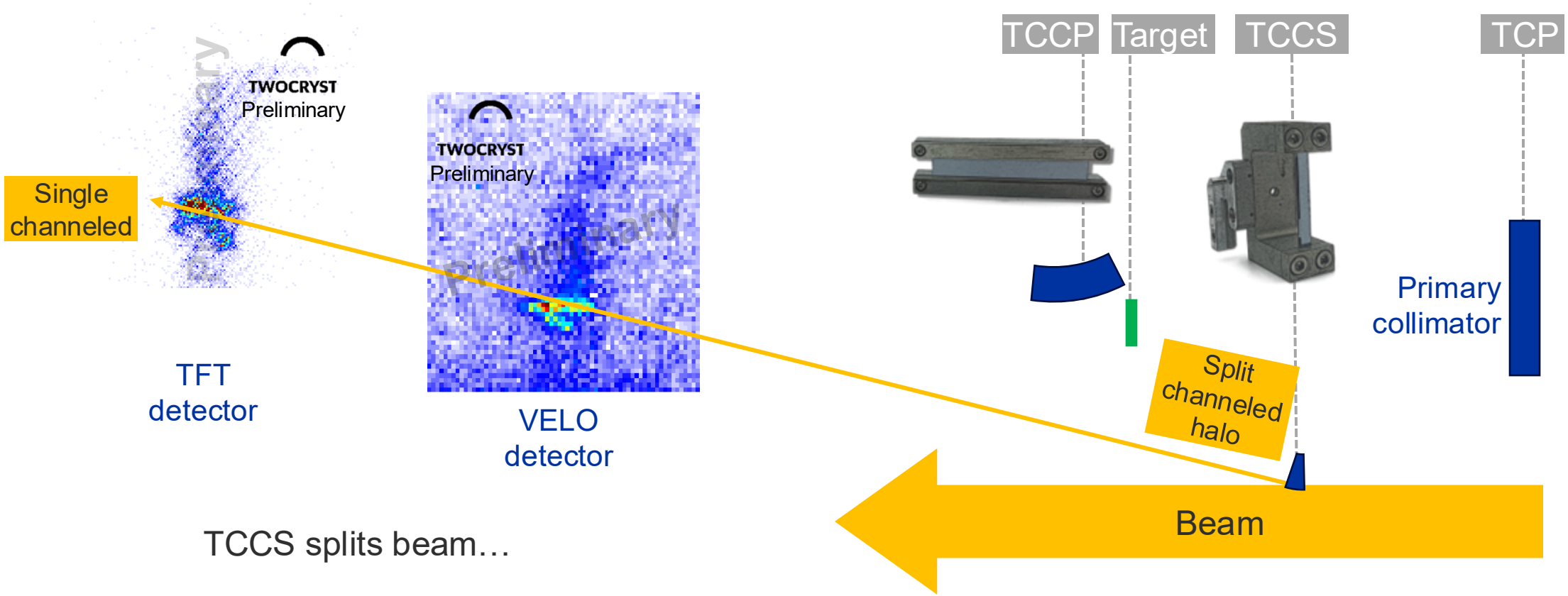
Key setup: Double channeling

Challenges:

- **Never performed previously**
- **Split halo has small intensity ➔ potential weak signal**
- **Both transverse and angular alignment needed.**
- **Potentially large scanning field.**

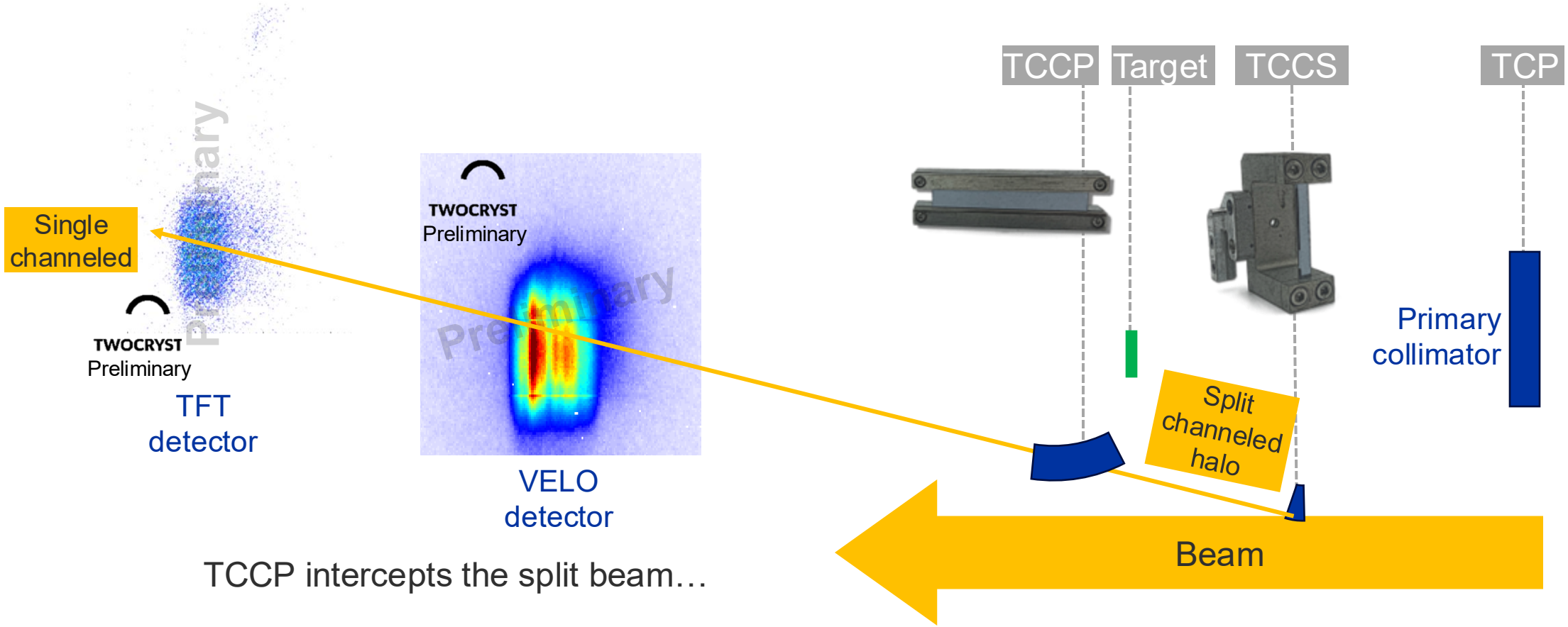
First experience - Success!

Double channeling



First experience - Success!

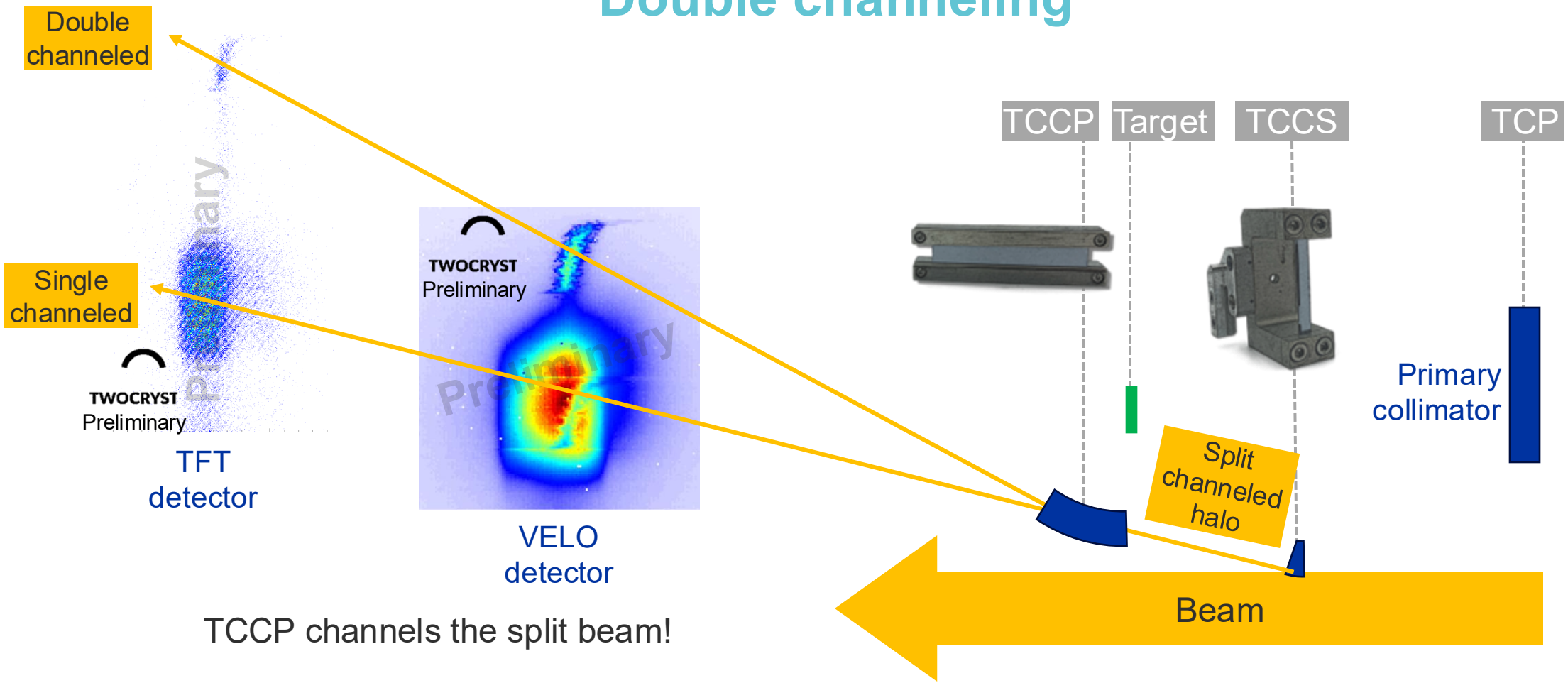
Double channeling



TCCP intercepts the split beam…

First experience - Success!

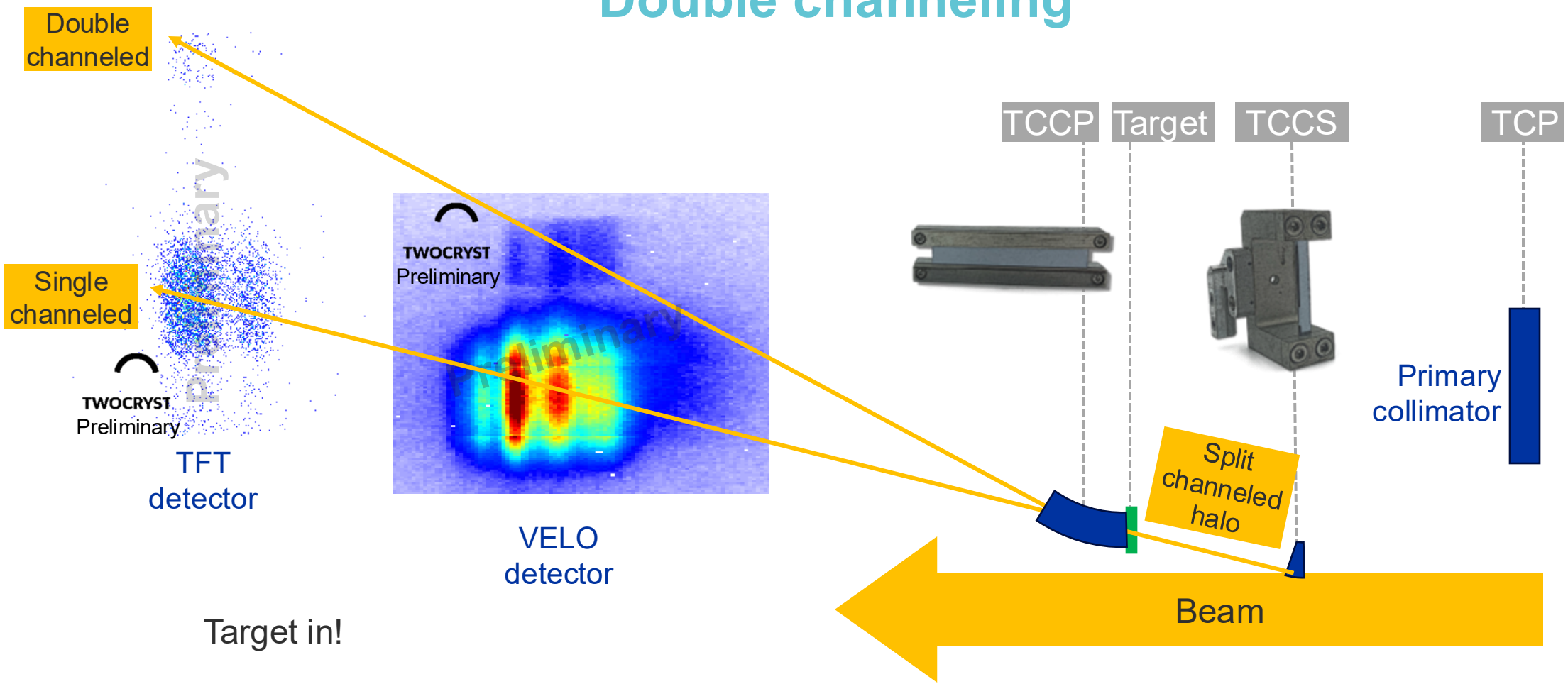
Double channeling



TCCP channels the split beam!

First experience - Success!

Double channeling



Conclusions & next steps

- **TWOCRYST is a proof-of-concept test stand at CERN for the ALADDIN experiment.**
- **Its main goals are:**
  - Explore the characteristics of the long precession crystal;
  - Prove operational feasibility;
  - Estimate proton-on-target.
- **Initial prototyping and testing started in mid-2023.**
- **In the End-of-Year Technical stop of 2024 two detectors, two crystal goniometers, two beam loss monitors, and numerous auxiliary components were installed in the LHC.**
- **All software and data integration tests were completed before the first allocated experiment time.**

Conclusions & next steps

During the first experimental time all planned tests were carried out successfully, in particular:

- Single channeling was found for the splitting and the precession crystals;
- Double channeling was established on the primary beam halo.

<u>Next steps:</u>

Complete the measurement campaign.

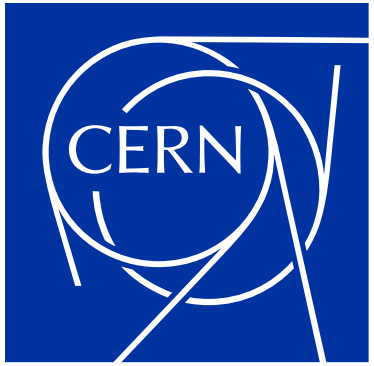
Analyze collected data.

Translate findings for ALADDIN.

Acknowledgements

- **CERN Main Workshop** for design and construction of RP parts
- **BE/CEM** for work on RP controls, low level controls, and interlocks
- **BE/GM** for alignment and fiducialization work
- **BE/OP** for development of TWOCRYST control system
- **EN/ACE** for their excellent integration studies, planning, and coordination
- **EN/CV** for the water connection for detector cooling
- **EN/EL** for the extensive cabling and fiber connection work
- **EN/HE** for their expert handling of our sensitive devices
- **EP/LHCb** for support on the Twocryst Velopix-based module and its readout.
- **EP/DT**
  - DI Controls group for secondary vacuum system
  - Design office (redesign RP station support)
  - Cable & crate workshop
- **EN/MME** for their support in installation and RP preparation
- **SY/BI** for the work on the new TWOCRYST BLMs
- **TE/MPE** for integrating the TWOCRYST devices into the BIS
- **TE/VSC** for their extensive vacuum-related work
- **ATLAS-ALFA** for lending the TFT to the TWOCRYST collaboration and providing the two RP stations
- **HSE/RP, TE/VSC**, and **TE/MPE**, for allowing to use their rack space for the TWOCRYST equipment
- Plus other teams that may not be listed

Thanks to all colleagues who made TWOCRYST possible



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