



# The ALADDIN experiment at CERN

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**Paolo Gandini**

On behalf of the ALADDIN Collaboration

1st October 2026 - QCD@LHC Conference

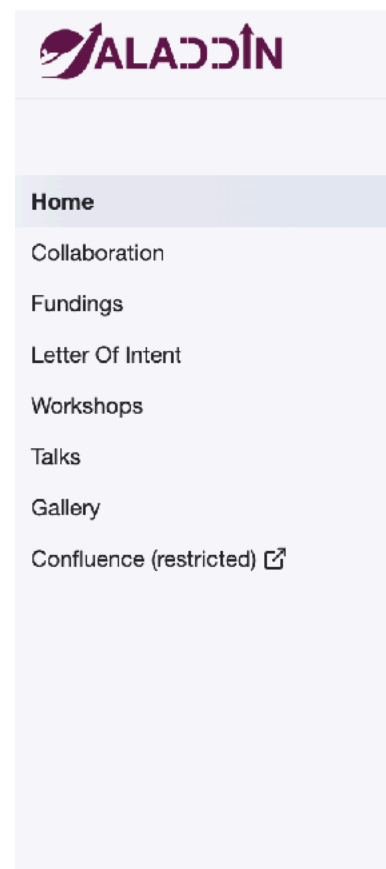
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# Outline

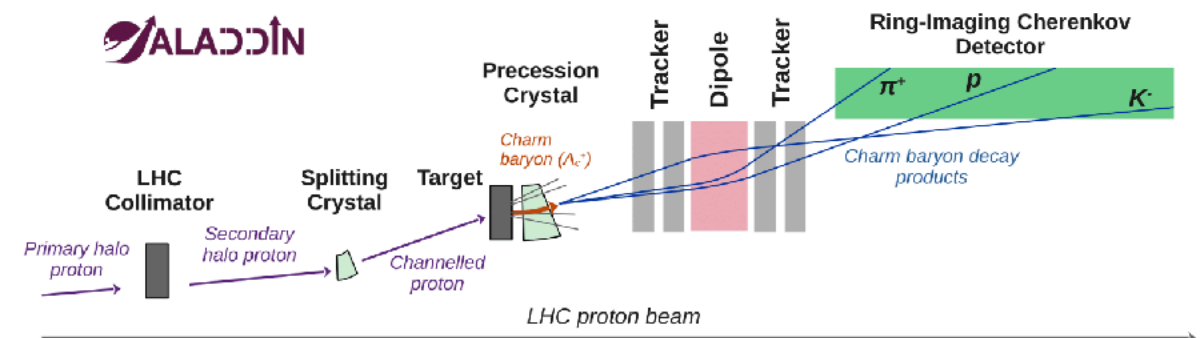
- Theory & Introduction
- The ALADDIN experiment
- The TWOCRIST proof of principle
- Future plans & Conclusions

<https://aladdin.web.cern.ch/>



Search ALADDIN

CERN TWOCRIST



## ALADDIN: A New Experiment to Probe the Dipole Moments of Charm Baryons at the LHC

**ALADDIN** (An LHC Apparatus for Direct Dipole moment INvestigation) is a proposed fixed-target experiment at CERN's Large Hadron Collider (LHC) that aims to open a new frontier in the search for physics beyond the Standard Model. The experiment is designed to measure the **electric (EDM)** and **magnetic dipole moments (MDM)** of **charm baryons**, such as the  $\Lambda_c^+$ , with unprecedented precision.

# Introduction

- Measure electromagnetic dipole moments of unstable particles at LHC
- EDM & MDM are sensitive to BSM physics
- The EDM violates T and P and, via CPT theorem, violates CP

$$\delta = d \frac{q\hbar}{2m} \frac{\mathbf{S}}{\hbar}$$



$\delta$  = electric dipole moment (EDM)  
 $d$  = gyroelectric factor

$$\mu = g \frac{q\hbar}{2m} \frac{\mathbf{S}}{\hbar}$$



$\mu$  = magnetic dipole moment (MDM)  
 $g$  = gyromagnetic factor

MDM of spin-1/2 charm baryons  $\mu_{\Lambda_c^+} = \frac{g_{\Lambda_c^+}}{2} \frac{e}{2m_{\Lambda_c^+}}$  and  $\mu_{\Xi_c^+} = \frac{g_{\Xi_c^+}}{2} \frac{e}{2m_{\Xi_c^+}}$

$g = 2$  for  $e, \mu, \tau$  (point-like),  $g_p = 5.6$  for proton (substructure)

Charge conjugation:  $C\psi = \bar{\psi}$

Parity:  $P\psi(\vec{r}) = \psi(-\vec{r})$

Time reversal:  $T\psi(t) = \psi^*(-t)$

Hamiltonian

$$H = -\mu \cdot \mathbf{B} - \delta \cdot \mathbf{E}$$

Time reversal, Parity:

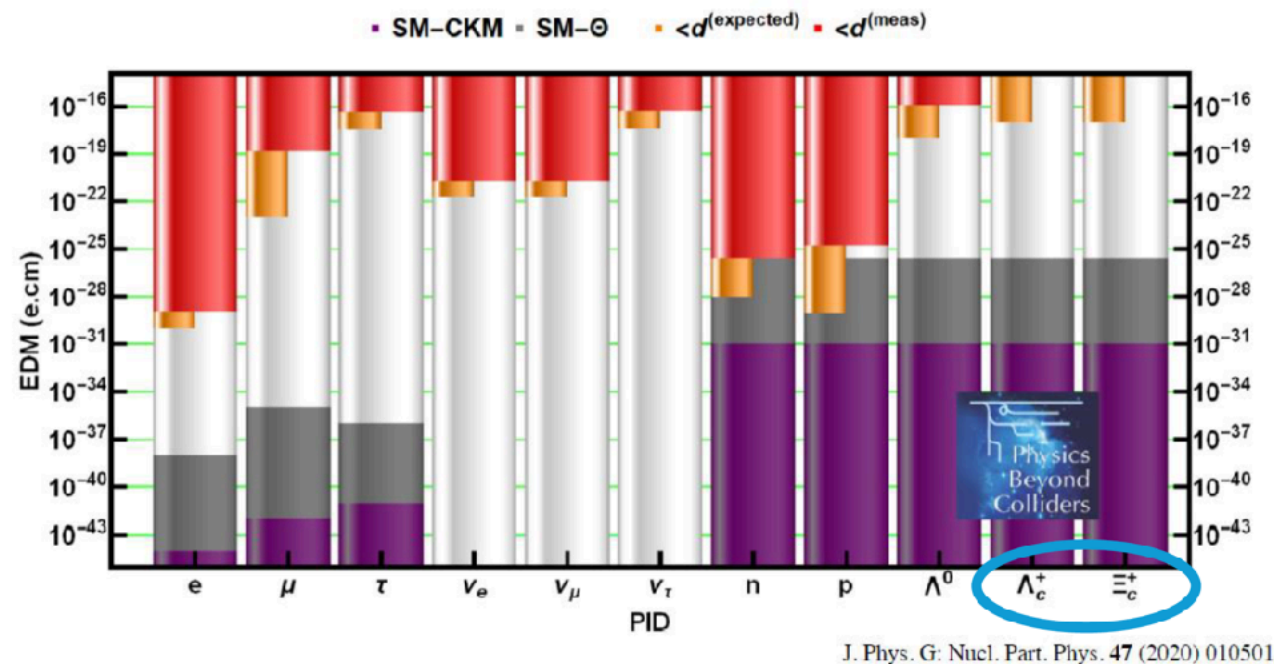
$$d\mu_N \mathbf{S} \cdot \mathbf{E} \xrightarrow{T/P} -d\mu_N \mathbf{S} \cdot \mathbf{E}$$

The EDM violates T and P and, via CPT theorem, violates CP

|              | <b>C</b> | <b>P</b> | <b>T</b> |
|--------------|----------|----------|----------|
| $\mu$        | -        | +        | -        |
| $\delta$     | -        | +        | -        |
| $\mathbf{E}$ | -        | -        | +        |
| $\mathbf{B}$ | -        | +        | -        |
| $\mathbf{S}$ | +        | +        | -        |

**Heavy baryon  
EDM observation:  
clear signature  
of new physics!**

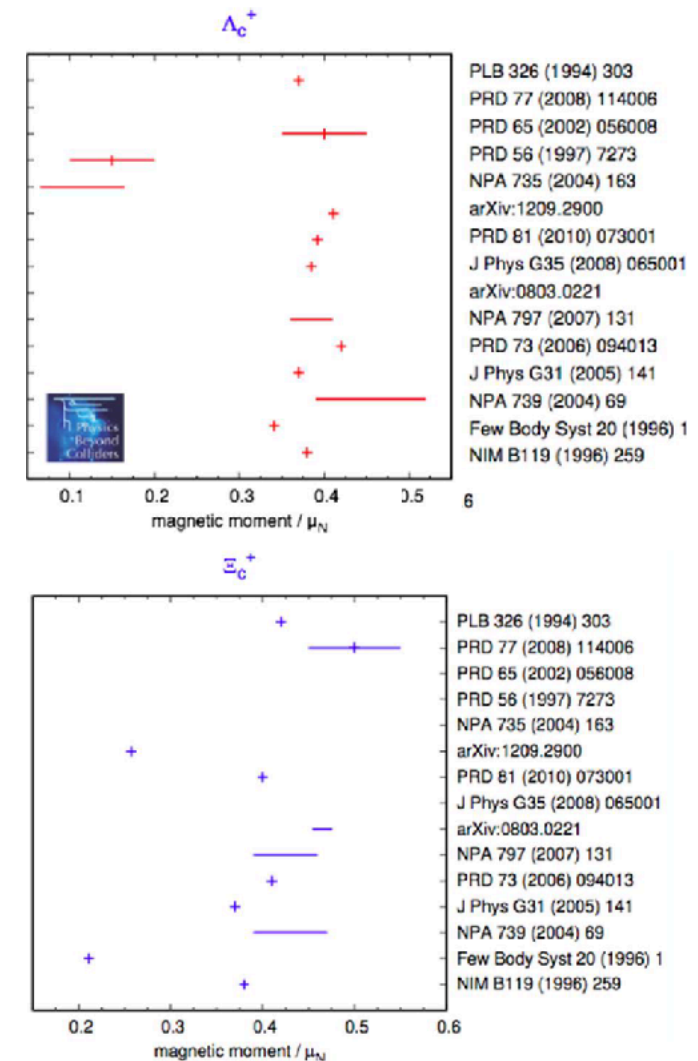
# Introduction



No measurement for charmed baryons due to their short lifetime ( $\tau \sim 10^{-13}$  s)

- SM prediction (from neutron EDM): **EDM**  $< 10^{-26}$  e cm [1]  $\rightarrow$  sensitive to physics **Beyond the Standard Model** at the current experimental sensitivity
- **EDM** violates T and P symmetries  $\rightarrow$  **CP violation** via CPT theorem

[1] Phys. Lett. **B** 291 (1992) 293



- **MDM** measurement  $\rightarrow$  experimental test of low-energy **QCD models**, related to non-perturbative QCD dynamics + sensitive to internal baryon dynamics [1]
- Lattice QCD studies in progress [2]

[1] Eur. Phys. J. **C** (2017) 77:181  
 [2] C. Alexandrou et. al., PRD111: 054505 (2025)  
 [3] CERN-PBC-REPORT-2018-008

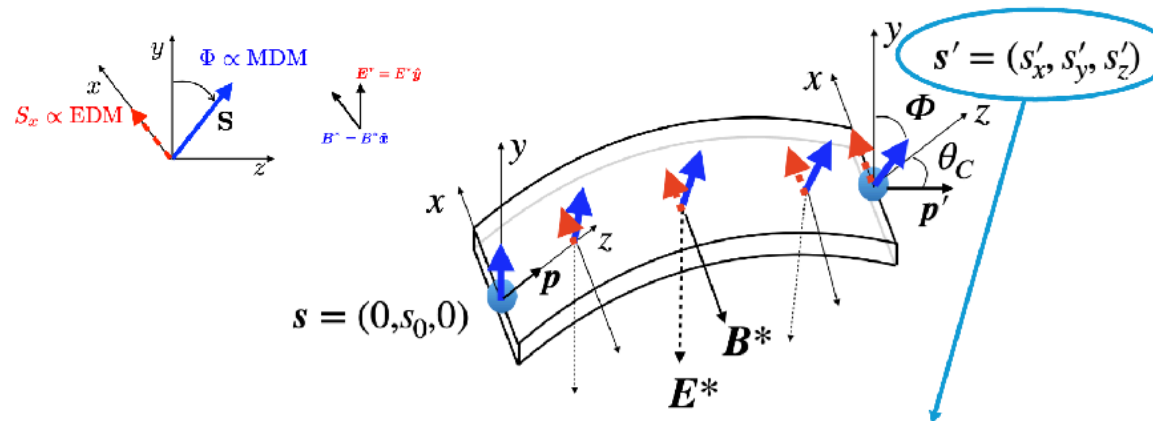
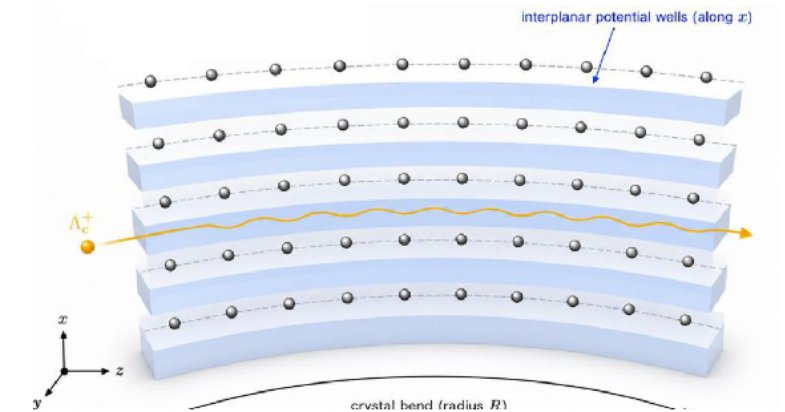
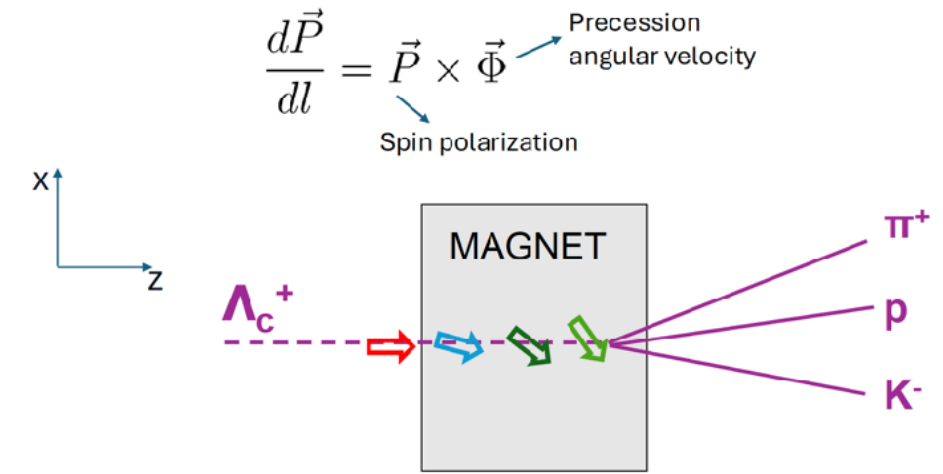
Need of experimental measurement of 10% precision

# Experimental Strategy

- Very short lifetimes: no direct measurements so far (only indirect estimations)
- Conventional magnets produce fields of orders of 1T
- Example: proton in 1T magnet has a Larmor frequency of about 107 Hz
- Need to bridge 6 orders of magnitude!

- Idea: use the spin precession in strong electromagnetic fields
- EDM/MDM from spin precession of channeled baryons in bent crystals
- Physics program started with preparatory measurements with LHCb data

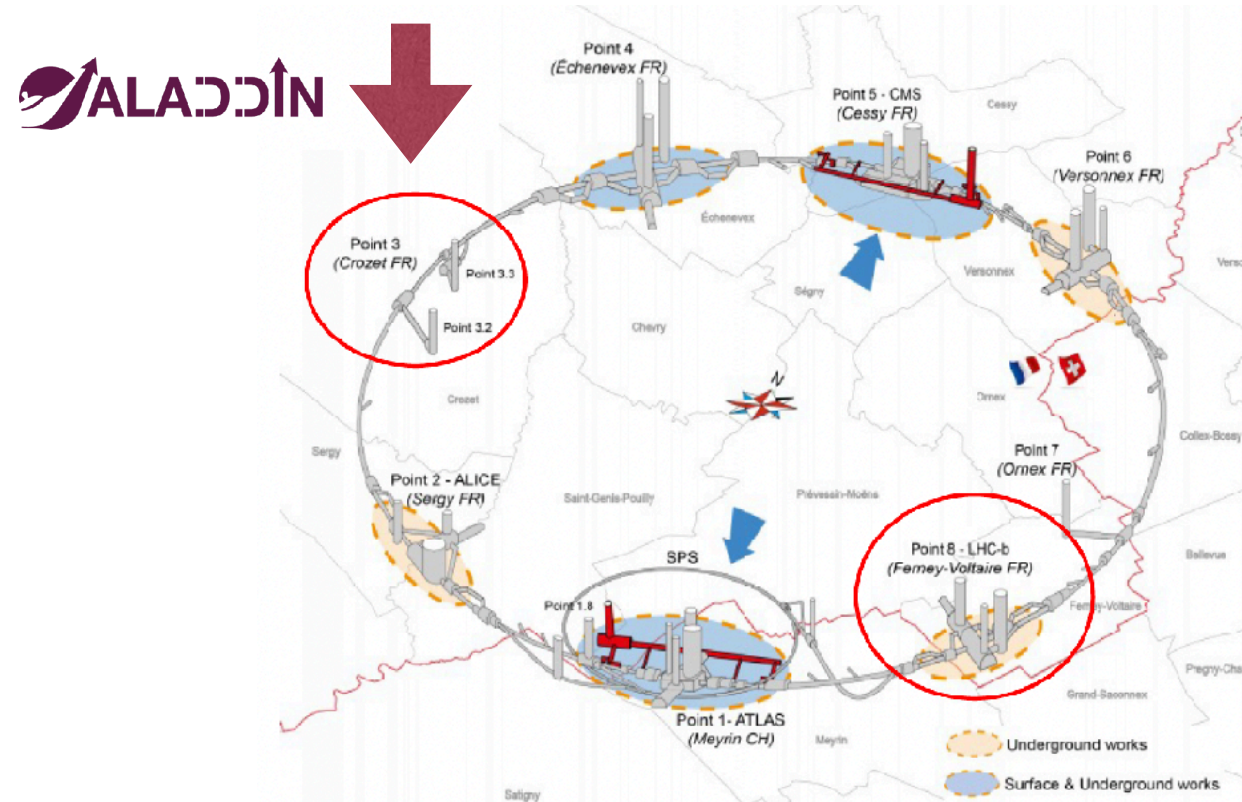
- Potential well between crystal planes
- Well understood phenomenon (Lindhard 1965)
- Bent crystals used already to steer high-energy particle beams
- We use 2 crystal to do both steer & precession



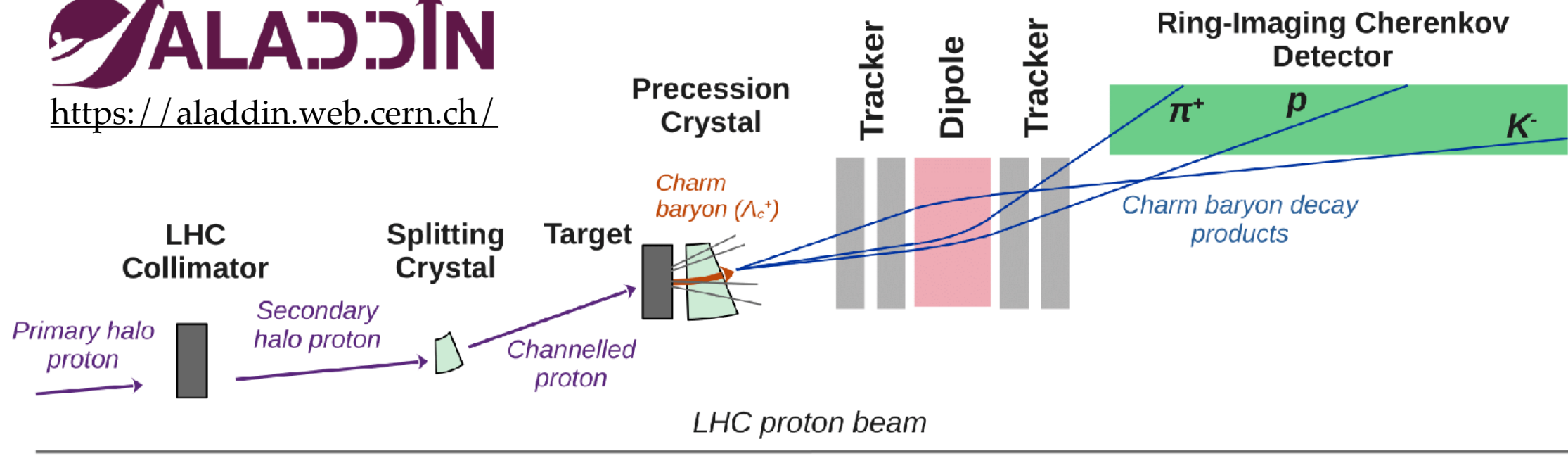
Polarization after the precession extracted from the angular distribution of the decay particles:

$$\mathbf{s}' \approx s_0 \left( \frac{d}{g-2} (\cos \Phi - 1), \cos \Phi, \sin \Phi \right), \quad \Phi \approx \frac{g-2}{2} \gamma \theta_c \approx \pi$$

# The ALADDIN experiment



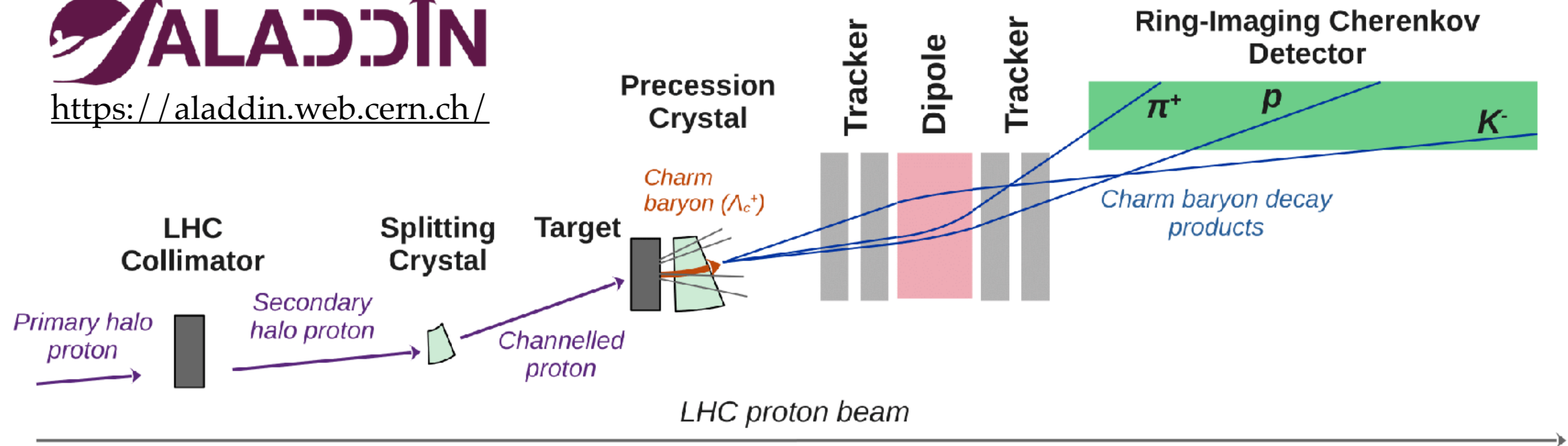
<https://aladdin.web.cern.ch/>



# The ALADDIN experiment



<https://aladdin.web.cern.ch/>



ALADDIN: fixed target experiment proposed at the LHC for the measurement of MDM/EDM of charm baryons

Charmed baryons produced very forward, with momentum of the O(1) TeV

Pseudorapidity coverage:  $5 < \eta < 9$

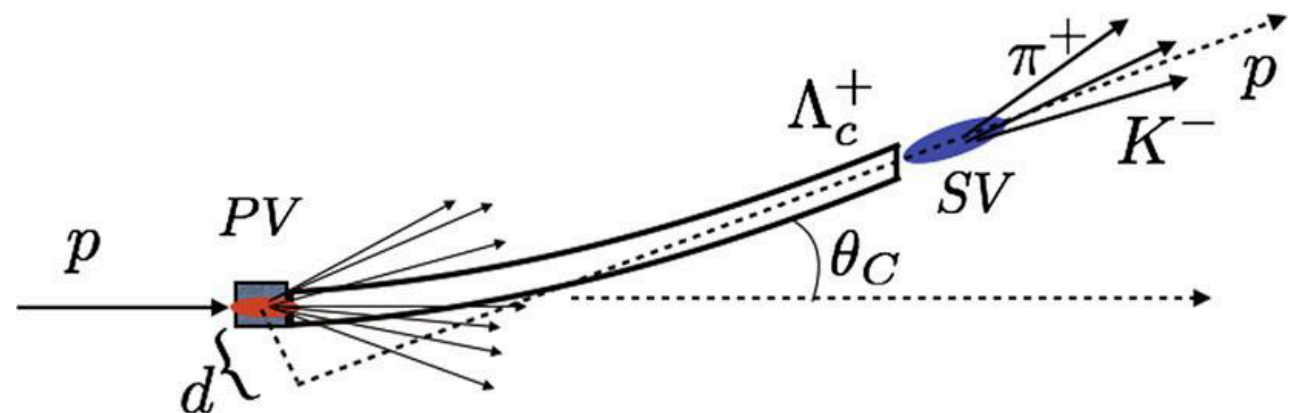
parallel to LHC data-taking

W target: 2 cm thickness

Instantaneous luminosity  $L=0.9 \times 10^{31} \text{cm}^{-2}\text{s}^{-1}$

Requirements:

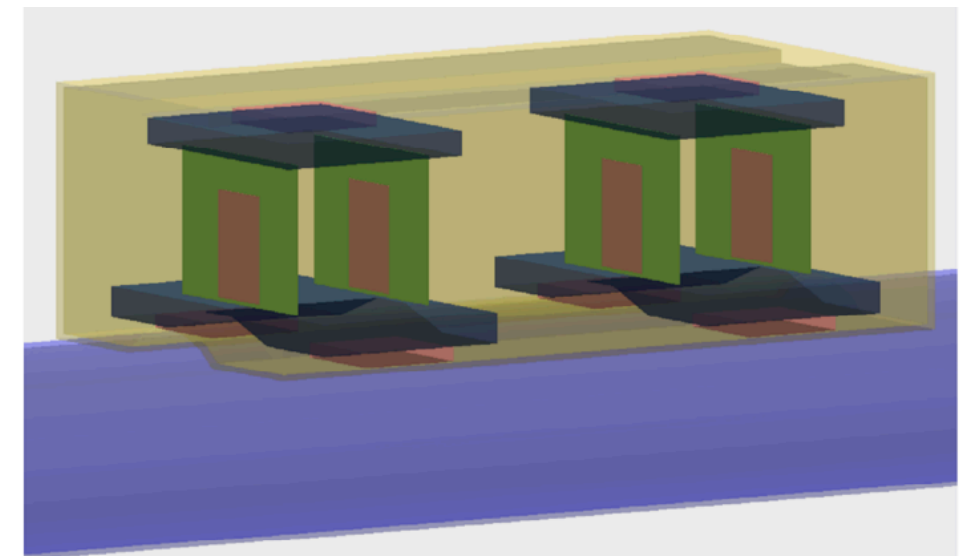
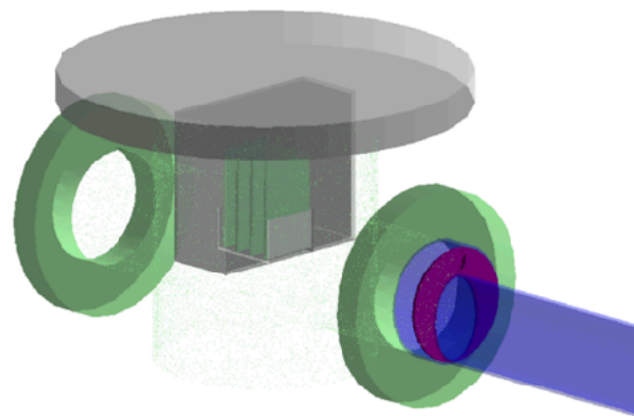
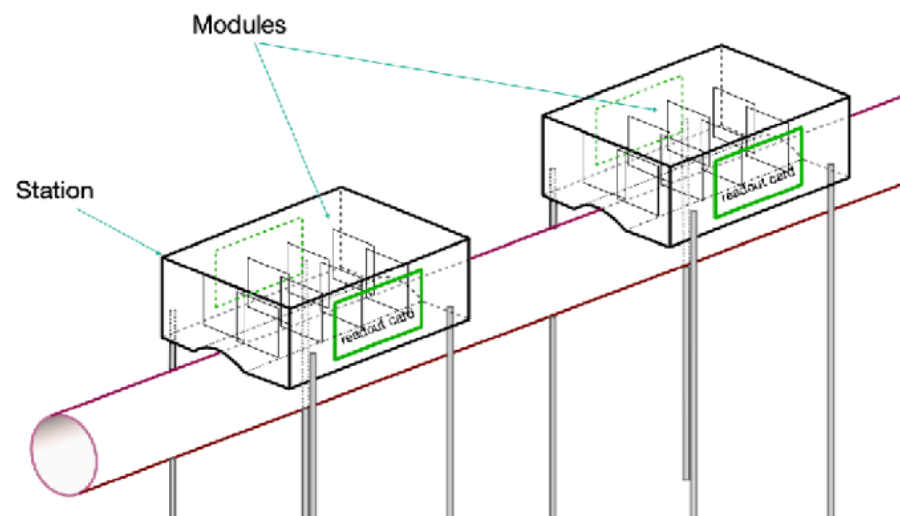
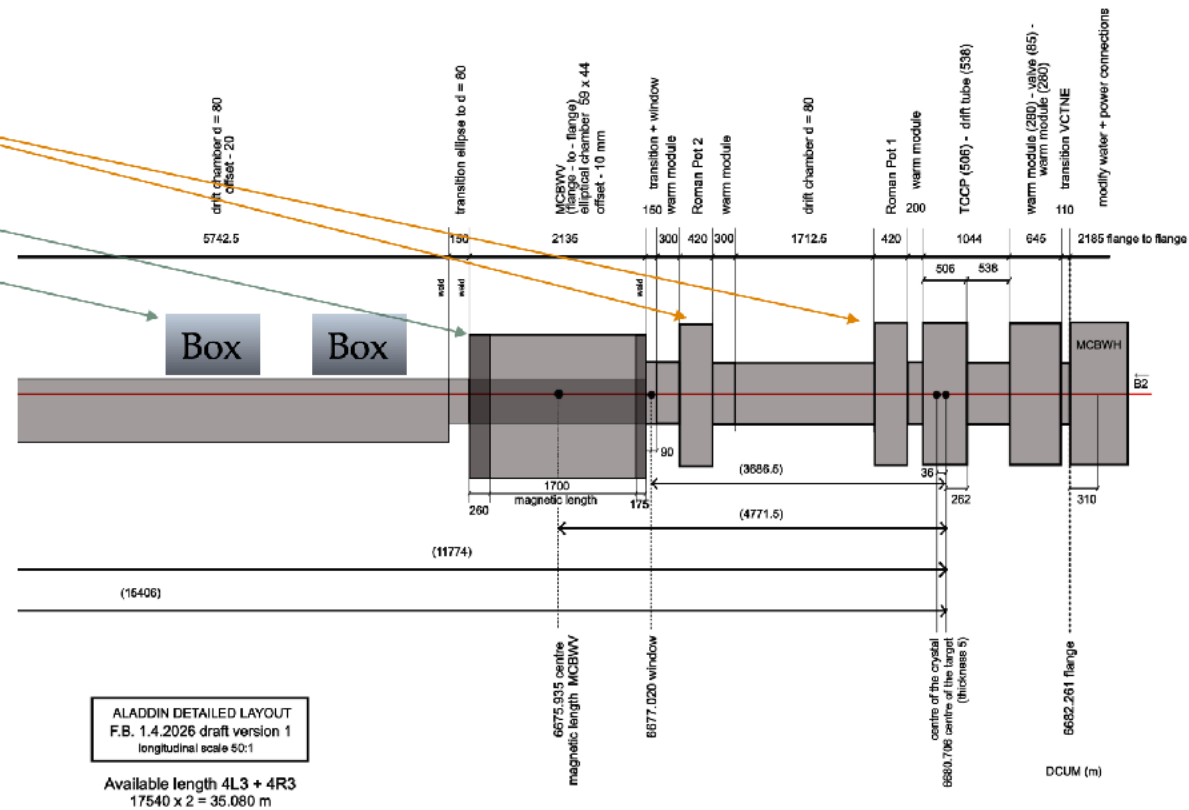
- Excellent angular resolution:  $\approx 15 \mu\text{rad}$
- Good momentum and mass resolution
- Tracker: 4 tracking stations: 2 upstream the magnet
- Excellent RICH resolution for tracks with momentum of up to 1 TeV



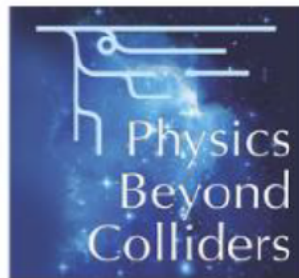
# Detectors

Major reoptimization effort to improve experiment layout, beam pipe and RICH ongoing

- Pixel technology
- 2 RP upstream
- Magnet
- Downstream a solution with detectors outside beampipe



# TWOCRIST



The TWOCRIST Proof-of-Principle was installed in 2025 at IR3 (same as ALADDIN)

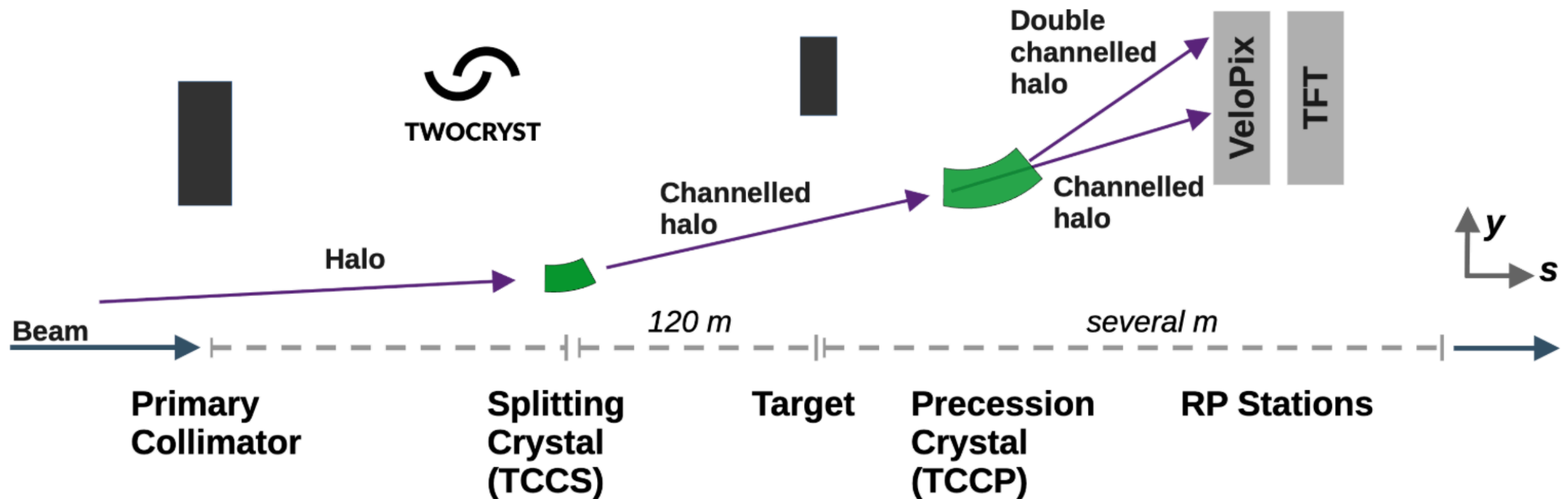
It took data with several dedicated MD runs in 2025 & 2026

Layout is similar to that of ALADDIN, but simplified

Goals of the proof-of-principle:

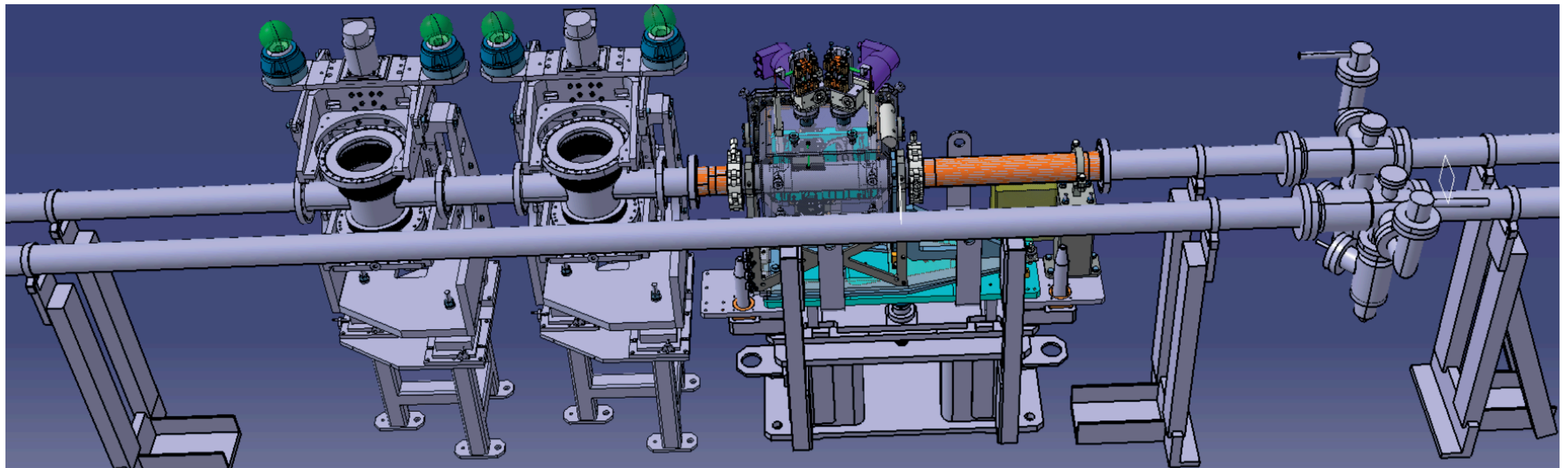
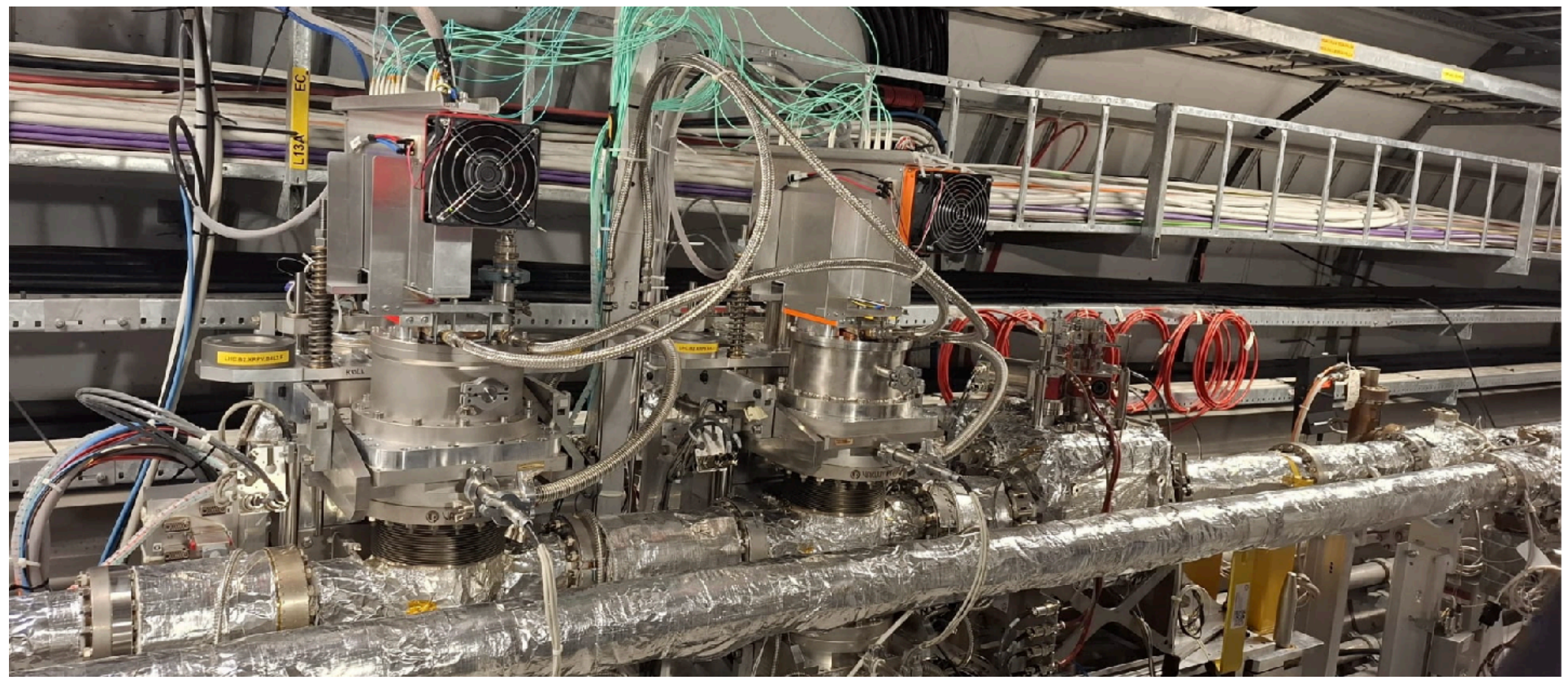
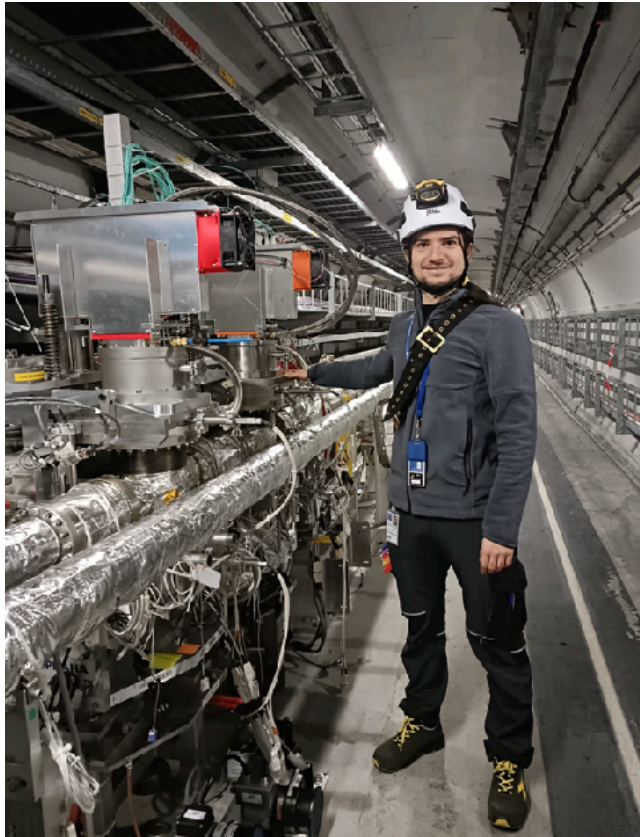
- Demonstration of operational feasibility
- Measurement of channeling efficiency for long crystals at TeV energies
- Study of proton beam intensity on target and background studies

Later replaced by  
Pixel, can do tracking!  
RP about 1m apart



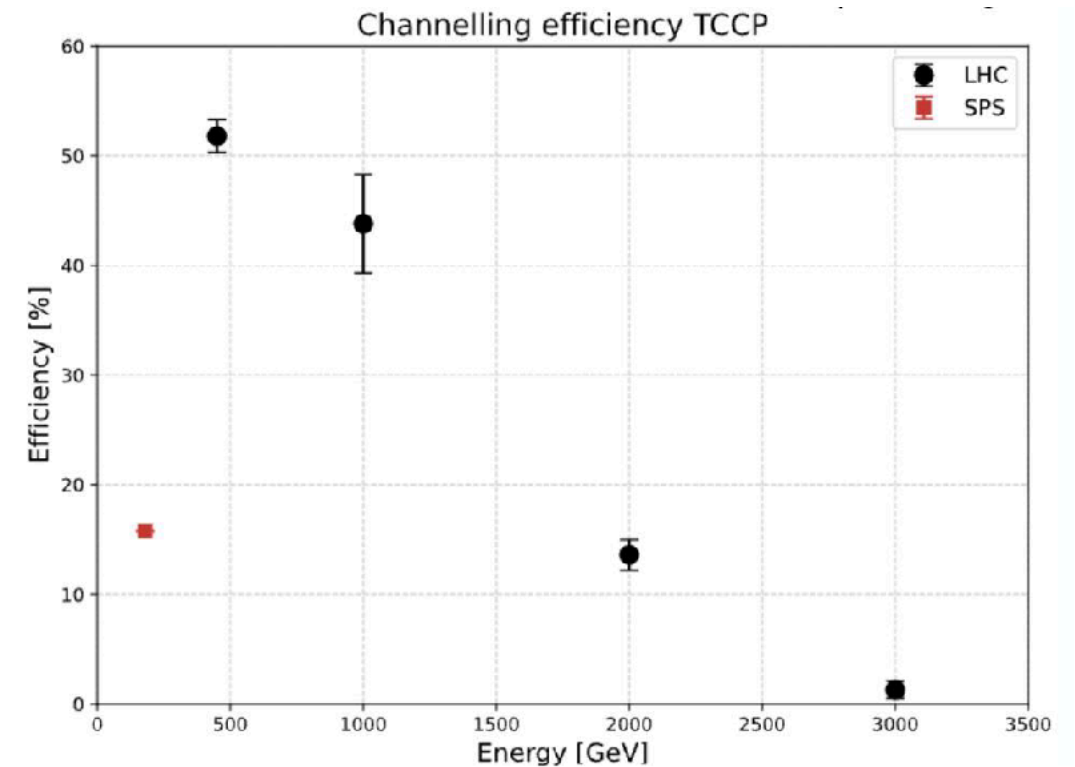
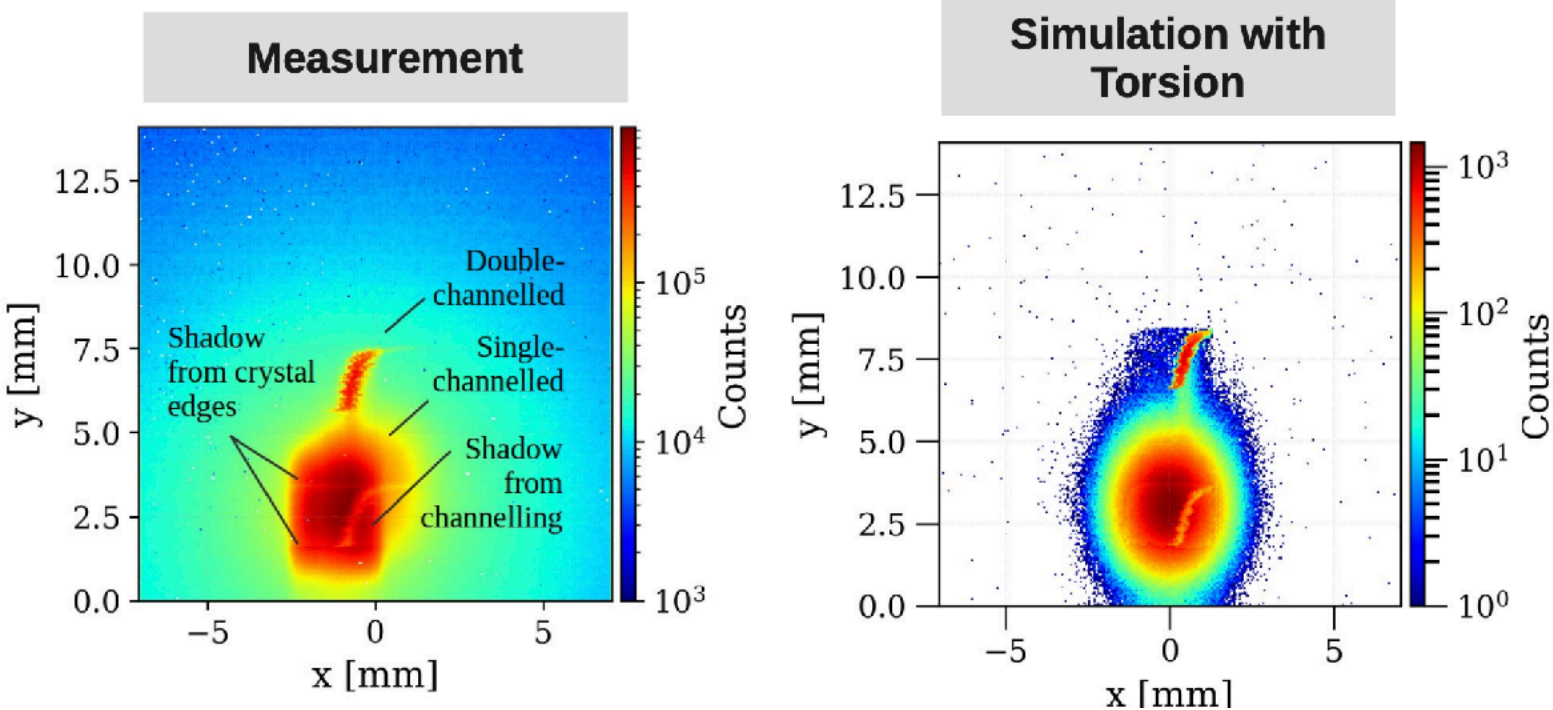
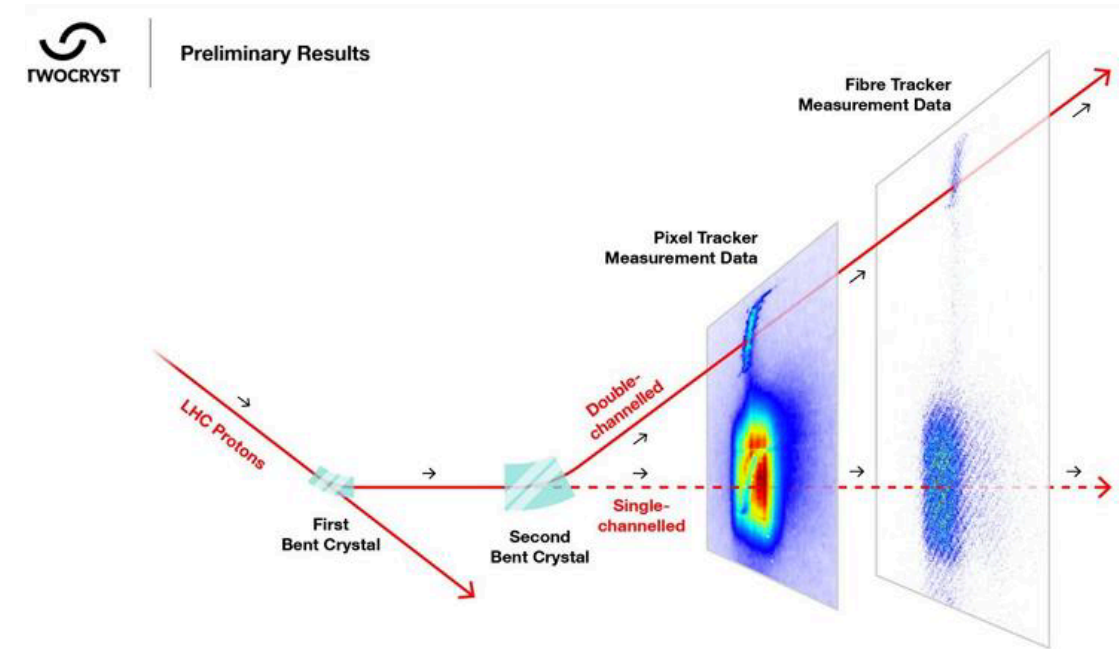
# TWOCRIST

Beam goes right to left



# TWOCRIST

- 4 dedicated MD during 2025
- First observation of **double channeling** at LHC!
- Measurement of channeling efficiencies at LHC energy
- TFT detector replaced with VeloPix during the 2025-2026 YETS
- Ongoing measurement of proton beam intensity on target
- Real-time reconstruction proof-of-principle
- Based on the LHCb Allen software
- Online monitoring with Grafana
- To be used as a trigger application for ALADDIN



<https://repository.cern/records/y2499-6bf38>

# TWOCRYST

<https://home.cern/towards-new-physics-bent-crystals/>

CERN | Accelerating science

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TOPIC: Experiments

## Towards new physics with bent crystals

Double crystal channelling was observed for the first time at the LHC, a milestone for future short-lived particle research

Written by: Insa Meinke

Celebrations in the CCC (LHC Control Room)



# Status & Schedule



June 2024

- Letter of Intent (LoI) submitted
- Positive review by the LHCC
- Invite to write Technical Proposal

2025-2026

- ALADDIN **proto-collaboration** created and organized
- Simulation framework finalized
- Reoptimization of detector layout & performance
- Detailed studies of integration in LHC

2027

- **Technical proposal** to be presented to the LHCC in Spring

<https://cds.cern.ch/record/2905467>



Construction and installation  
during LS3 & Run 4 YETS  
Data taking during Run 4+

# Conclusions



<https://aladdin.web.cern.ch/>

- Proposed new fixed-target experiment at the LHC
- Physics goal: charm baryon EDM/MDM measurements
- Expected data taking during Run 4+
- Proto-collaboration created
- Technical proposal to be submitted next year at LHCC



<https://twocryst.web.cern.ch/>

- Proof-of-Principle experiment for ALADDIN
- Successful operation during several MD in 2025 and 2026
- First double channeling observation at LHC
- All goals achieved!
- Many papers in preparation with data results

The ALADDIN Collaboration at Elba 2026



The TWOCRIST crew in the CCC



# ALADDIN Collaboration & Acknowledgments

## The ALADDIN Collaboration

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16 Institute of High Energy Physics, Beijing, China  
17 INFN Sezione di Catania, Università degli Studi di Messina, Messina, Italy  
18 Università degli Studi di Siena, Siena, Italy  
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**RICH WG coordinators:** Francesca Bucci, Tonino Sergi

**DAQ WG coordinators:** Marco Sozzi, Federico Alessio

- TWOCRIST 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).
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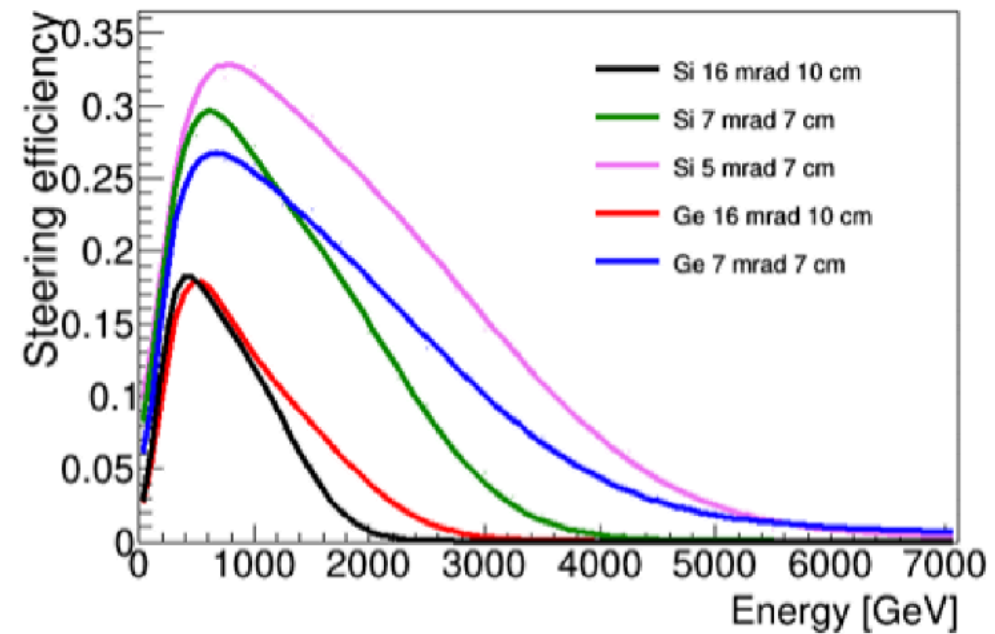
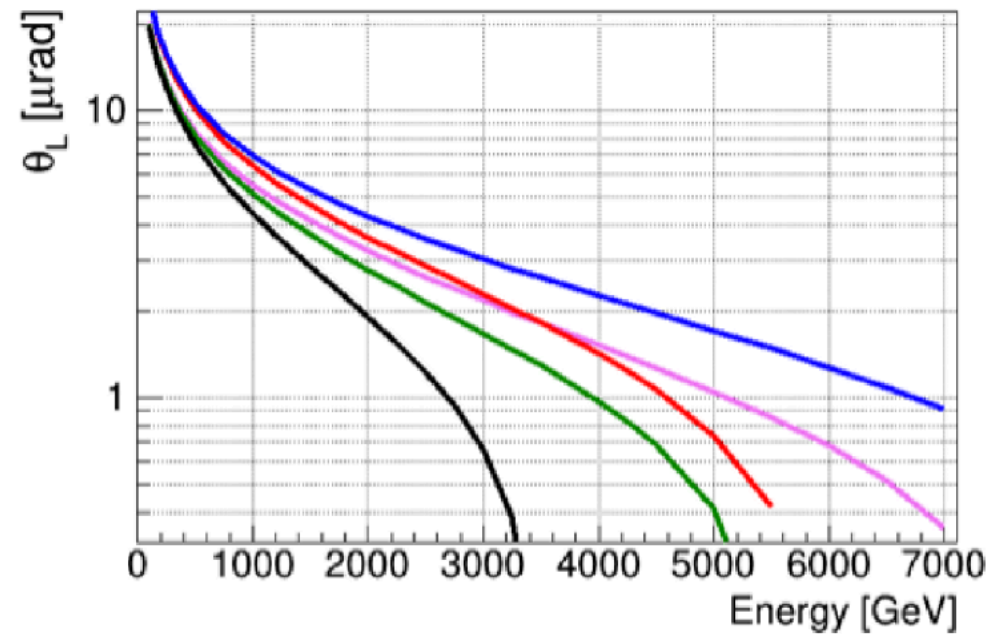
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# Backup Slides

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# Miscellanea

## Lindhard angle



|                                    | ALADDIN                    | LHCb-SMOG                       |
|------------------------------------|----------------------------|---------------------------------|
| $\sqrt{s}$ (GeV)                   | 115                        | 115                             |
| Momentum $p$ (GeV/c)               | $\gtrsim 500$              | $\lesssim 500$                  |
| Transverse momentum $p_T$ (GeV/c)  | $\lesssim 1.3$             | 0.2 to 1.8                      |
| Rapidity $y^*$                     | 1 to 3.5<br>(very forward) | -3.5 to 0<br>(central/backward) |
| Pseudorapidity $\eta$              | 5 to 9                     | 2 to 5                          |
| Four-momentum transfer $Q$ (GeV/c) | 4                          | 15 to 115                       |
| $\log_{10} x_B$ (Bjorken)          | Down to -3.2               | Down to -3                      |
| $x_F$ (Feynman)                    | 0.1 to 0.5, max. at 0.3    | -0.5 to 0, max. at -0.1         |