

SELDOM

Search for the electric dipole moment of
the strange and charm baryons at LHC



European Research Council
Established by the European Commission

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Proposal n° 771642 SELDOM

ERC CoG PE2

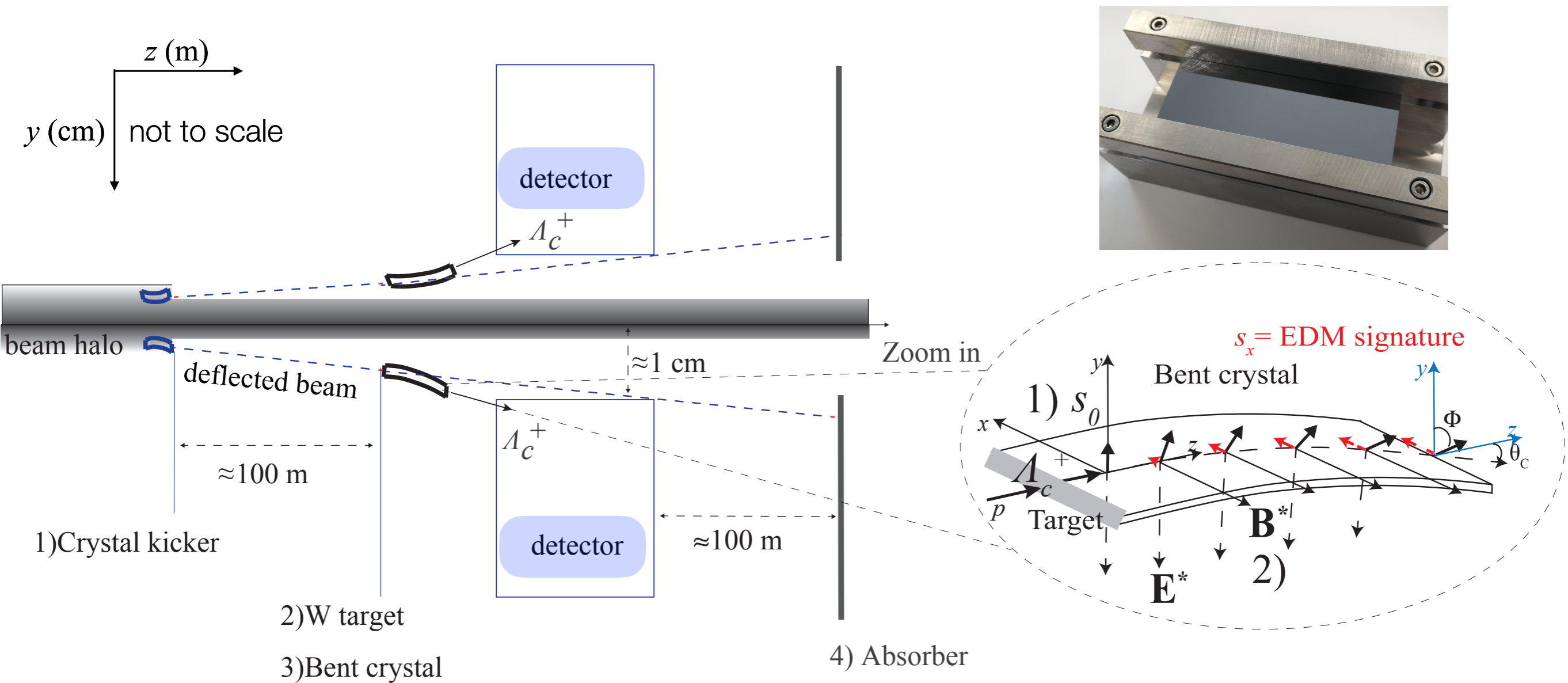


<https://web.infn.it/SELDOM/>

<https://twitter.com/SeldomTeam>

Novel fixed-target experiment at LHC for **charm baryons**

- ▶ EDM/MDM from spin precession of channeled baryons in **bent crystals**

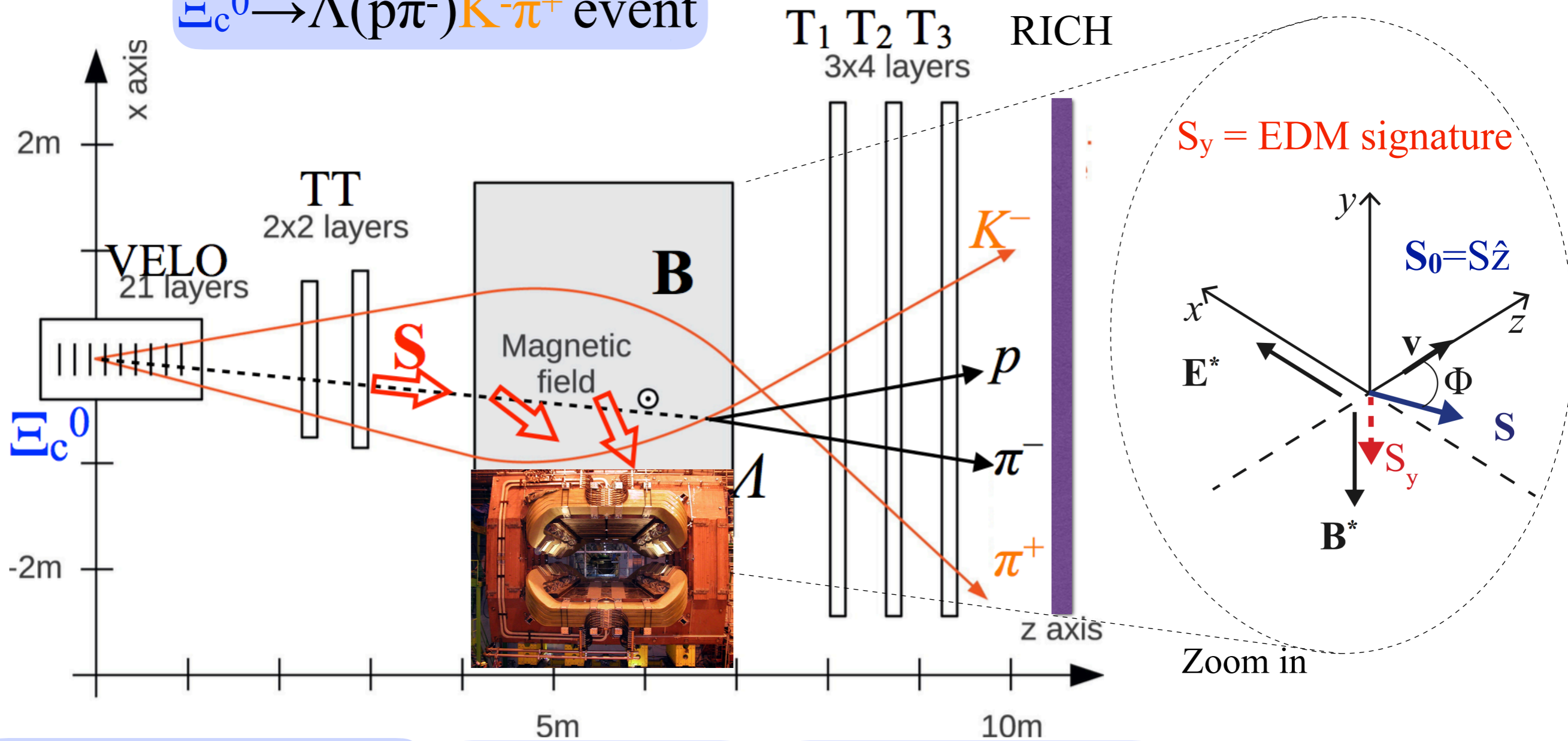


p extraction Λ_c^+ polarised production channeling spin precession event reconstruction

Novel experimental technique for **strange baryons**

- ▶ **EDM/MDM** from spin precession of Λ baryon in LHCb **dipole magnet**

$\Xi_c^0 \rightarrow \Lambda(p\pi^-)K^-\pi^+$ event



Λ polarised production

spin precession

event reconstruction

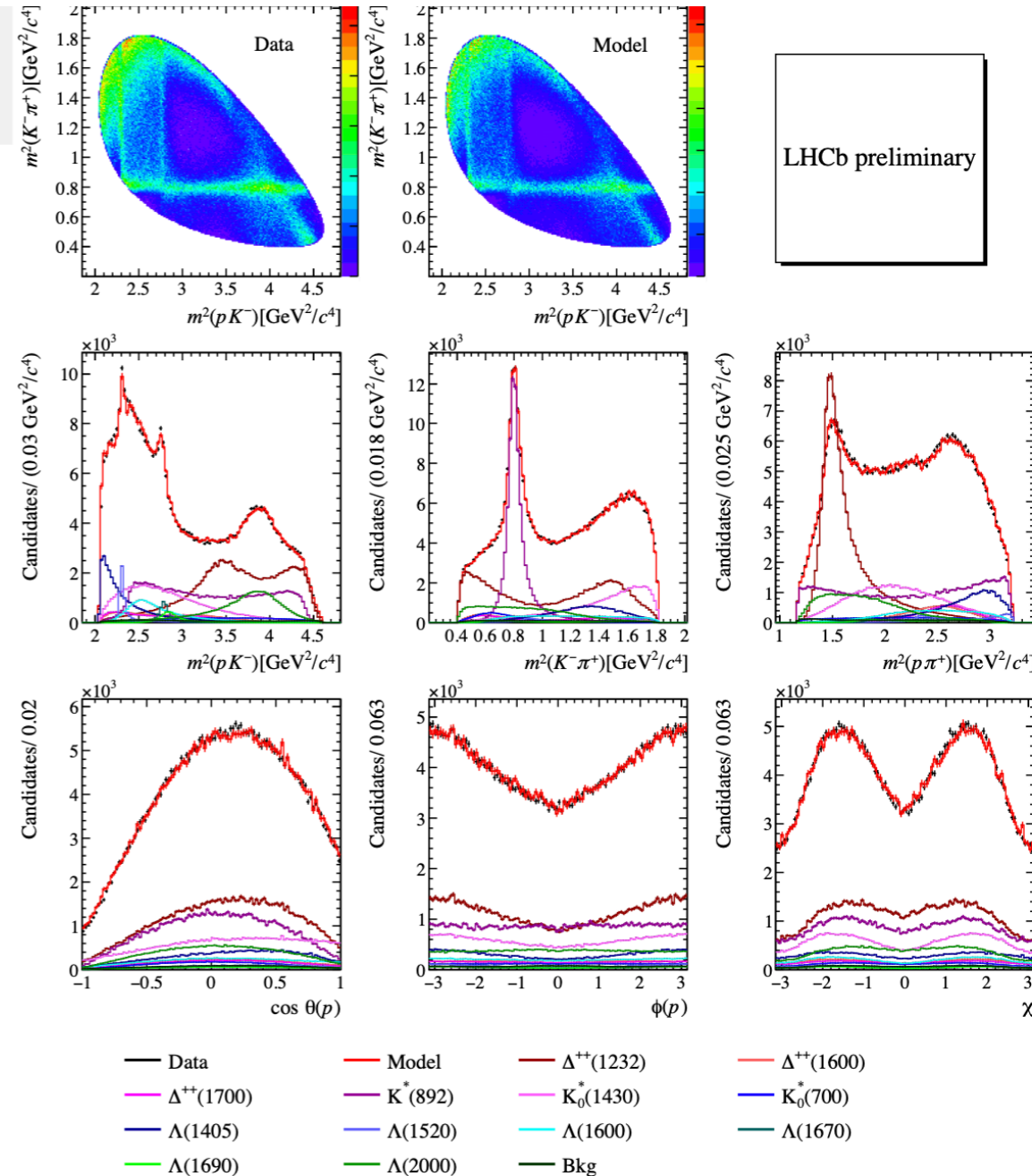
Update on last year results

Developed decay model for $\Lambda_c^+ \rightarrow pK^-\pi^+$ decays

- ▶ Results presented at La Thuile conference by Daniele Marangotto.
Paper in preparation

$\Lambda_c^+ \rightarrow pK^-\pi^+$ amplitude analysis

- Decay model written in terms of helicity amplitudes with general method for matching final particle spin states among different decay chains [AHEP \(2020\) 6674595](#)
- Built amplitude model, measured all parameters



LHCb preliminary

Main contributions	Fit Fraction (%)
$\Delta^{++}(1232)$	$28.60 \pm 0.29 \pm 0.76 \pm 0.16$
$K^*(892)$	$22.14 \pm 0.23 \pm 0.64 \pm 0.04$
$K_0^*(1430)$	$14.7 \pm 0.6 \pm 2.7 \pm 0.1$

Uncertainties divided in statistical, amplitude model choice, systematic

Measurement of Λ_c^+ polarisation from weak decays

- ▶ Results presented at La Thuile conference by Daniele Marangotto.
Paper in preparation

$\Lambda_c^+ \rightarrow pK^-\pi^+$ amplitude analysis & polarisation

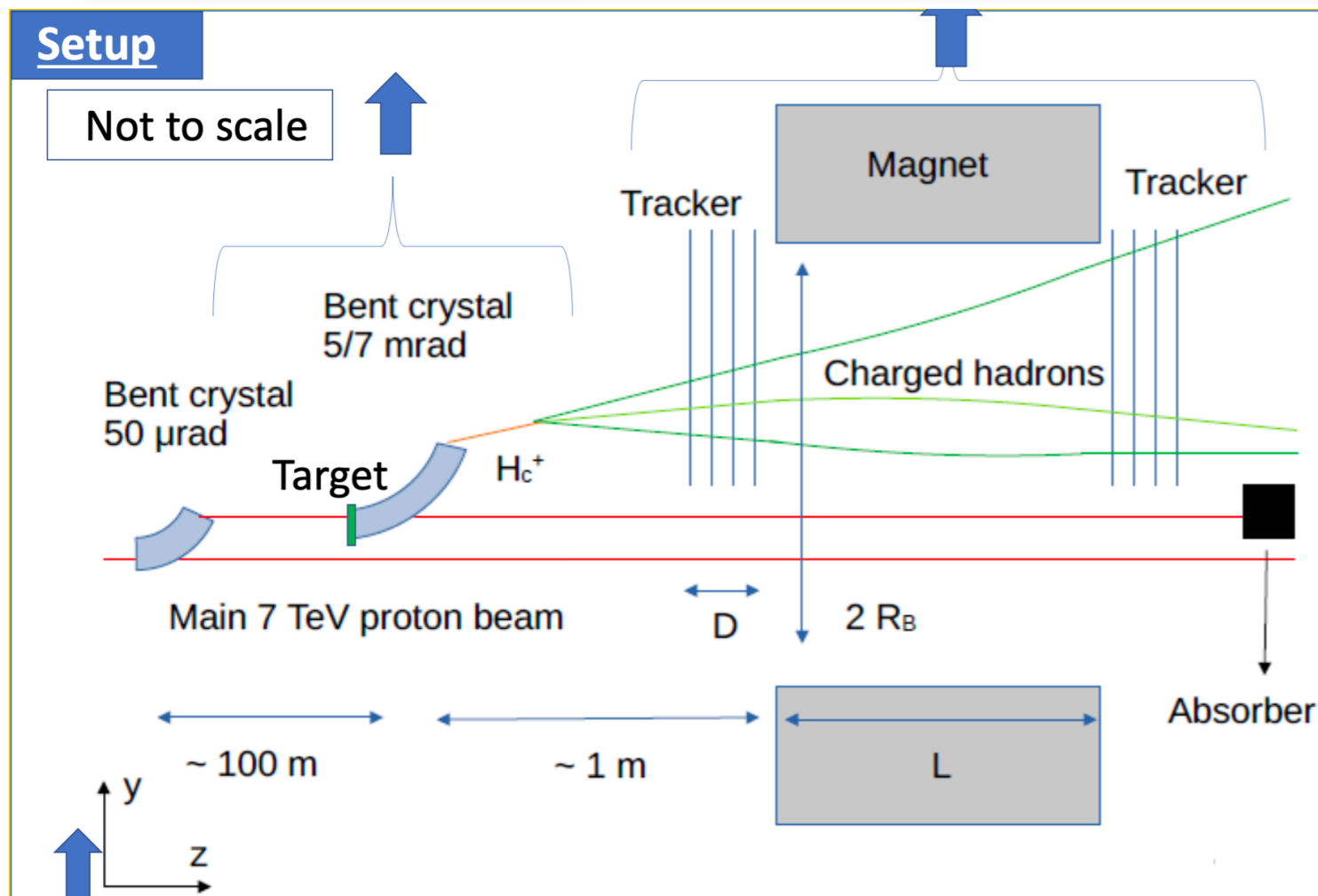
LHCb-PAPER-2022-002, in preparation

- Large polarisation precisely measured in Λ_c^+ helicity systems
- Normal \hat{T} -odd polarisation (P_y) compatible with zero

Component	Value (%)
P_x (lab)	$60.32 \pm 0.68 \pm 0.98 \pm 0.21$
P_y (lab)	$-0.41 \pm 0.61 \pm 0.16 \pm 0.07$
P_z (lab)	$-24.7 \pm 0.6 \pm 0.3 \pm 1.1$
P_x (approx B)	$21.65 \pm 0.68 \pm 0.36 \pm 0.15$
P_y (approx B)	$1.08 \pm 0.61 \pm 0.09 \pm 0.08$
P_z (approx B)	$-66.5 \pm 0.6 \pm 1.1 \pm 0.1$

- Established large contribution in $m(pK^-) \approx 2$ GeV region
 - Described as single $J^P = 1/2^-$ state, with Breit-Wigner parameters
 $m = 1970 \pm 4 \pm 13$ MeV and $\Gamma = 148 \pm 7 \pm 18$ MeV
- Closest resonance reported by the PDG is $\Lambda(2000)$

Experimental proof-of-principle at IR3



► Goal: demonstrate feasibility of charm baryon EDM/MDM at LHC

– channeling in bent crystals

– reconstruction

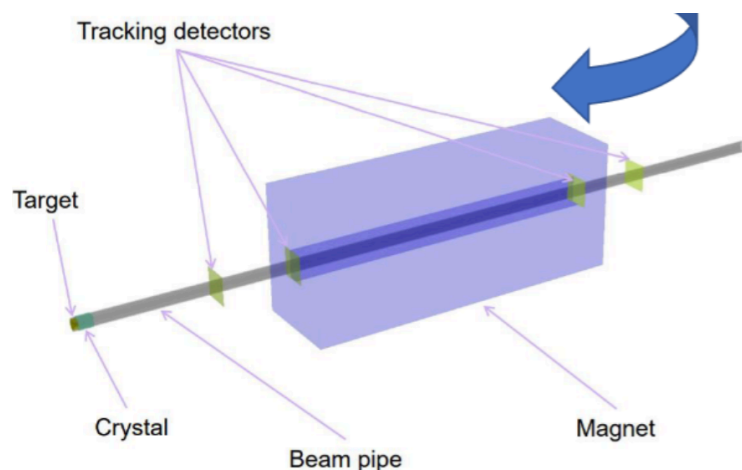
– background

– LHC machine studies

► Test planned at LHC IR3 (intersection region 3) during Run 3

Ongoing study

Full simulation with DD4HEP (detector geometry) + GEANT4 to optimize the setup



Reconstruction of Λ decays after the magnet

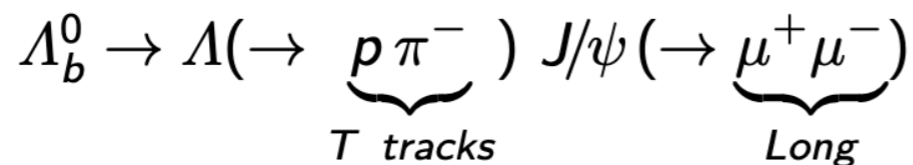
Reconstruction challenges (I)

CERN-LHCb-DP-2022-001

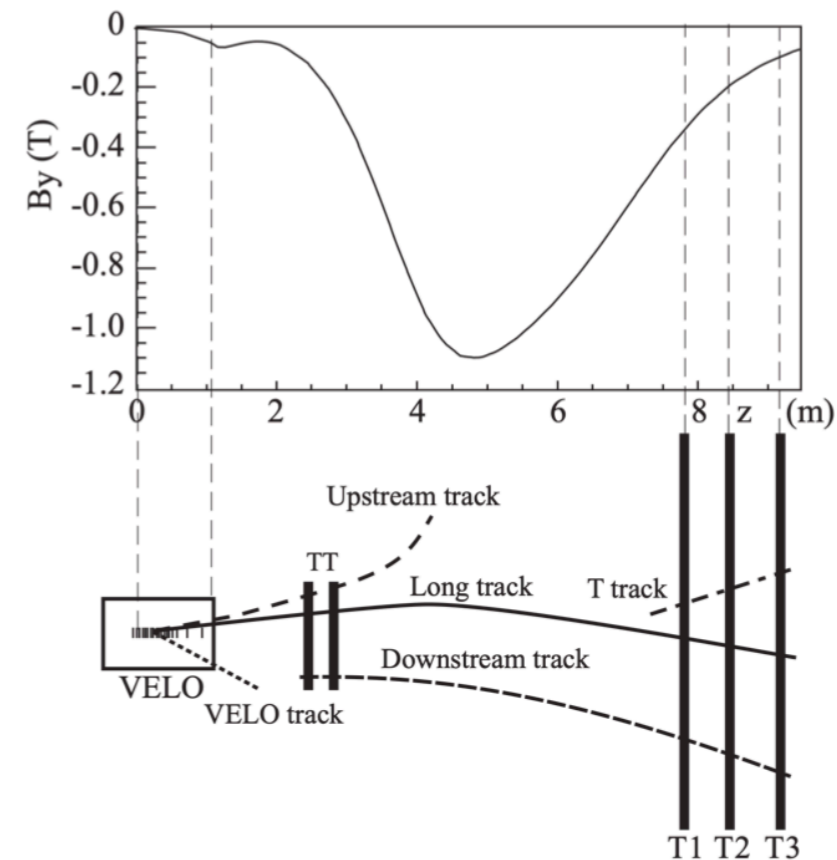
Low momentum resolution
foremost source of challenges

$$\left. \frac{\sigma_p}{p} \right|_{T \text{ track}} \sim 30\% \quad \left. \frac{\sigma_p}{p} \right|_{Long} \sim 0.5\%$$

- Measured **track curvature** induced by residual \mathbf{B} in between T1-T3
- **Improved to 10%** by constraining masses and vertex positions with Decay Tree Fitter (DTF)
 → exclusive Λ production modes



DTF Nucl.Instrum.Meth.A 552 (2005) 566-575

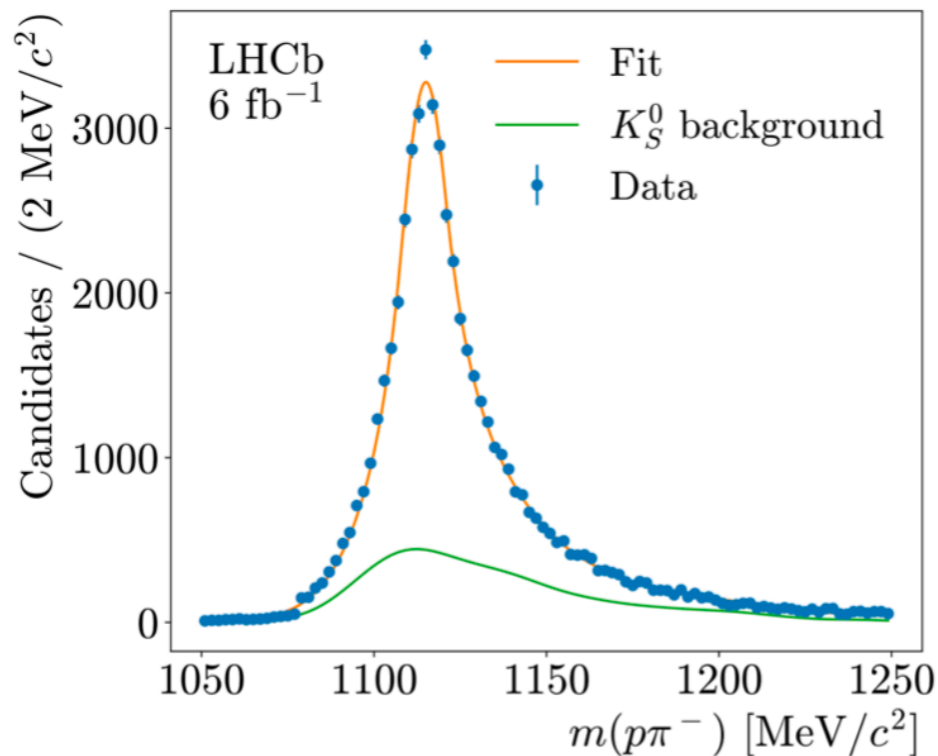


Reconstruction of Λ decays after the magnet

Results presented at ICHEP 2022 conference.
Paper in preparation

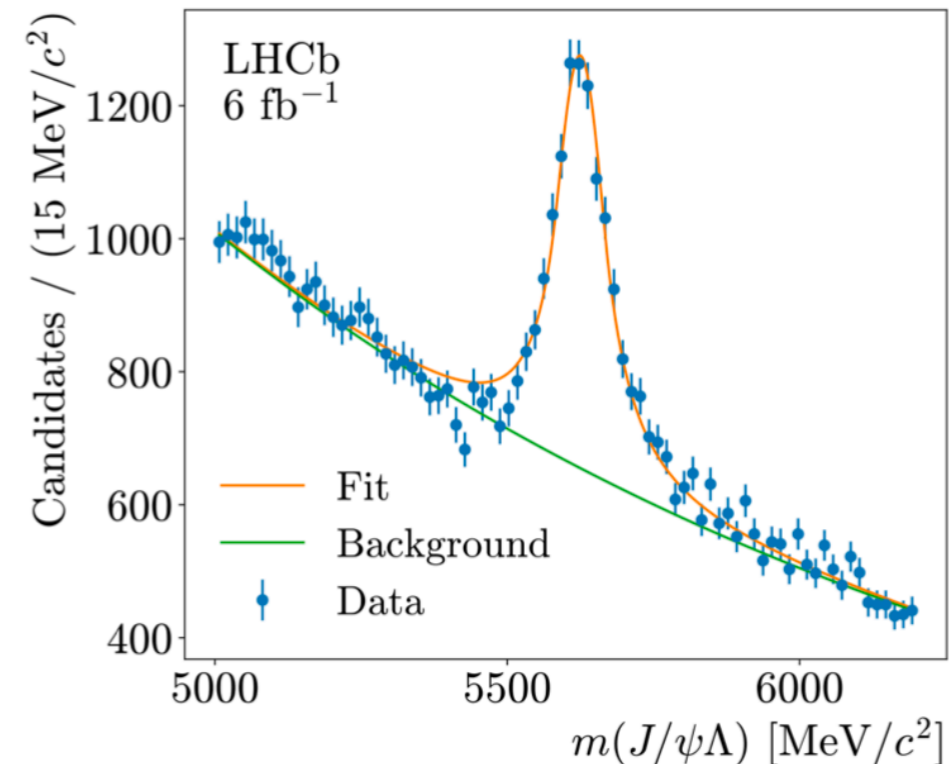
CERN-LHCb-DP-2022-001
LHCb-FIGURE-2022-009

$$\Lambda \rightarrow p\pi^-$$



$$\sigma_{m(\Lambda)} \approx 8 \text{ MeV}$$

$$\Lambda_b^0 \rightarrow \Lambda J/\psi$$



$$\sigma_{m(\Lambda_b^0)} \approx 41 \text{ MeV}$$

Mass peaks with reconstructed and combined T tracks at LHCb

6140 $\Lambda_b^0 \rightarrow \Lambda J/\psi$ signal candidates

Particle identification strategy for Λ and K_S^0

Results presented at ICHEP 2022 conference

Particle identification for Λ / K_S^0

- Misidentified p / π^+ results in cross contamination of

$$\Lambda \rightarrow p\pi^- \text{ and } K_S^0 \rightarrow \pi^+\pi^-$$

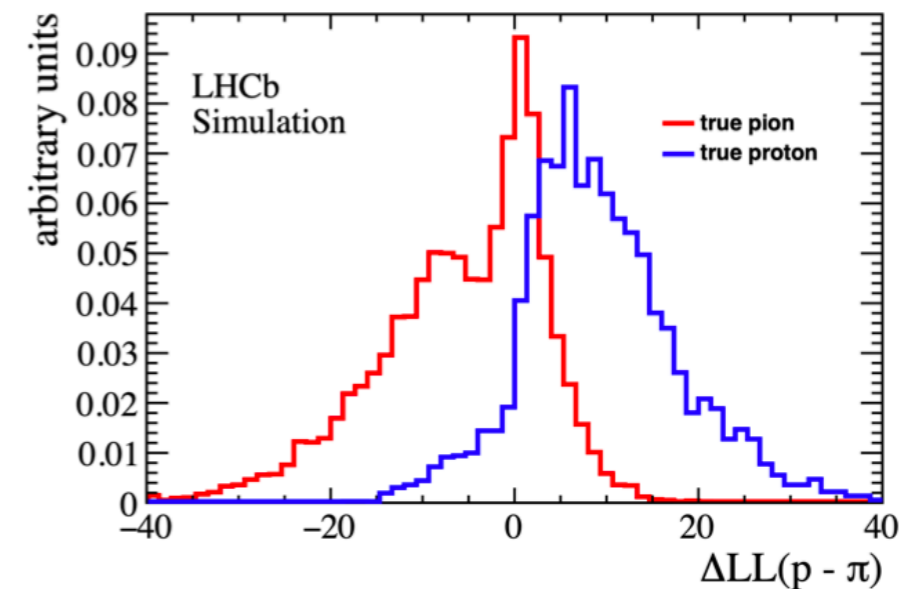
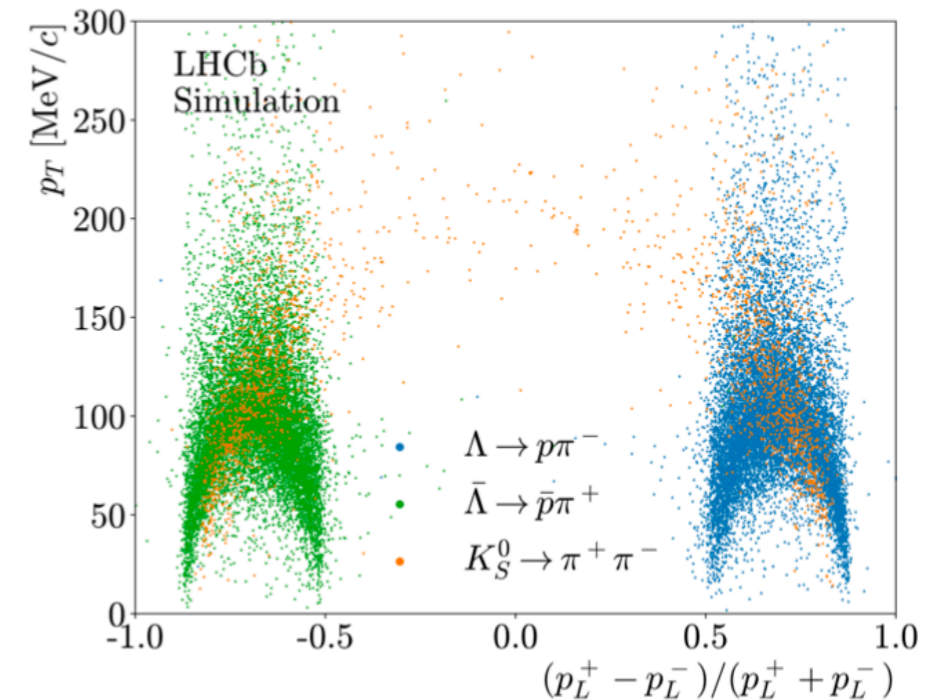
- Low momentum resolution: overlapping mass peaks

- PID information not used in Run II

- Discrimination possible** with **Armenteros-Podolanski method**
Different \vec{p} carried by p/π^- vs. π^+/π^-

- PID information to be used for Run III

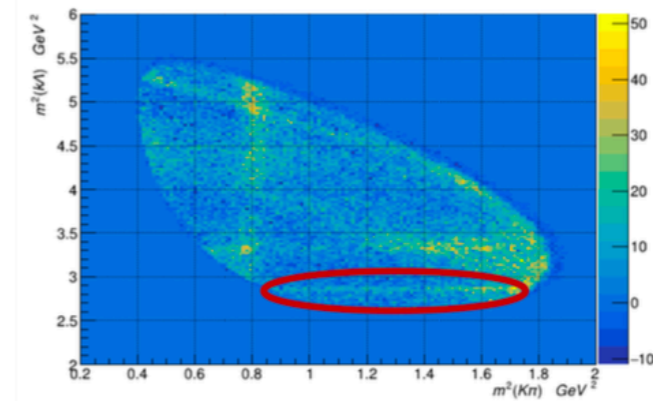
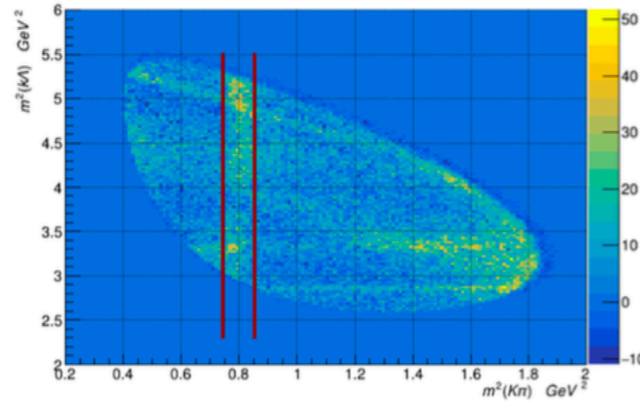
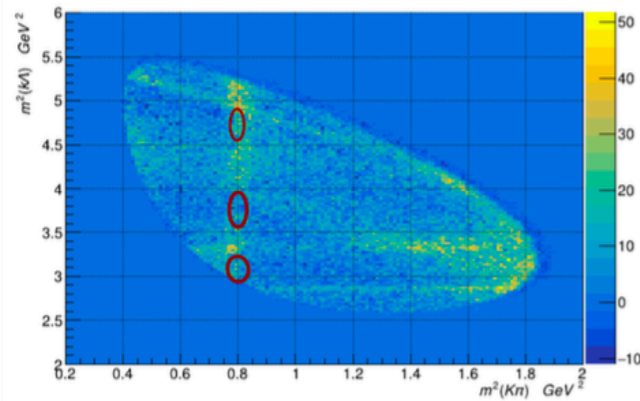
LHCB-FIGURE-2022-008



very preliminary

Measurement of Λ baryon polarisation

Preparatory measurement for EDM/MDM measurement (Giorgia Tonani's thesis)



Decadimento	P_x	P_y	P_z	$ \vec{P} $
$\Xi_c^0 \rightarrow \Lambda K^- \pi^+$	$0.14 \pm 0.01 \pm 0.01$	$0.023 \pm 0.013 \pm 0.005$	$0.042 \pm 0.014 \pm 0.004$	$0.15 \pm 0.02 \pm 0.01$
$\Xi_c^0 \rightarrow \Lambda K^*(892)^0$	$0.28 \pm 0.08 \pm 0.01$	$(3.7 \pm 7.3 \pm 4.5) \cdot 10^{-2}$	$0.34 \pm 0.08 \pm 0.01$	$0.44 \pm 0.11 \pm 0.01$
$\Xi_c^0 \rightarrow \Lambda K^*(892)^0$	$0.19 \pm 0.04 \pm 0.01$	$(-2.7 \pm 3.2 \pm 4.5) \cdot 10^{-2}$	$0.14 \pm 0.03 \pm 0.01$	$0.24 \pm 0.05 \pm 0.01$
$\Xi_c^0 \rightarrow \Xi^*(1690)^- \pi^+$	$0.06 \pm 0.06 \pm 0.01$	$-0.03 \pm 0.05 \pm 0.005$	$-0.20 \pm 0.05 \pm 0.01$	$0.21 \pm 0.09 \pm 0.01$
$\Xi_c^0 \rightarrow \Xi^*(1820)^- \pi^+$	$0.17 \pm 0.03 \pm 0.01$	$-0.01 \pm 0.03 \pm 0.005$	$0.001 \pm 0.03 \pm 0.01$	$0.17 \pm 0.05 \pm 0.01$
$\Xi_c^0 \rightarrow \Sigma^*(1385)^+ K^-$	$0.23 \pm 0.05 \pm 0.01$	$0.07 \pm 0.04 \pm 0.005$	$0.10 \pm 0.05 \pm 0.01$	$0.26 \pm 0.08 \pm 0.01$

- Max polarizzazione per barioni Λ prodotti in **decadimenti deboli**,
- diluizione polarizzazione per effetto di **interferenza catene diverse**,
- diluizione polarizzazione per barioni Λ prodotti in **decadimenti forti**.

Status and next steps

- ▶ **Milestones** achieved: feasibility detector studies, long bent crystal prototypes, preparatory studies in LHCb, machine layout, physics program extended
- ▶ General **meeting** of the project 13-14 January 2022, Milano
- ▶ Machine **test in LHC** possibly during Run3 for double channeling test
- ▶ Data taking in **LHCb** for first measurements in the near future (for Λ baryons)
- ▶ **Workshop** at Villa Feltrinelli, Gargnano del Garda (Brescia) 25-28 September 2022

Conferences and workshops

2022

- [Experiment for direct measurement of short-lived particle dipole moments at LHC](#), G. Tonani, ICHEP 2022, 6-13 July 2022, Bologna, Italy. Poster
- [Reconstruction and physics opportunities of long-lived particles decaying downstream of the LHCb magnet](#), J. Ruiz-Vidal, ICHEP 2022, 6-13 July 2022, Bologna, Italy. Parallel Talk
- [Classical and Exotic Spectroscopy at LHCb](#), D. Marangotto, La Thuile, Italy, 06 – 12/03/2022. Plenary talk.

2021

- [Direct measurement of short-lived particle moments at the LHC](#), N. Neri, Low-x 2021 Workshop, La Biodola Isola d'Elba, Italy, 26 September – 1 October 2021. Invited talk.
- [Prospettive per la misura di momenti di dipolo di barioni \$\Lambda\$ a LHCb](#), G. Tonani, Italian Physical Society conference, online conference, 13-17 September 2021
- [Produzione di heavy flavour e spettroscopia in LHCb](#), D. Marangotto, invited talk, Italian Physical Society conference, online conference, 13-17 September 2021
- [Bent crystals for investigation of charmed baryons electromagnetic dipole](#), M. Romagnoni, Poster, EPS-HEP Conference 2021, Online conference, July 26-30, 2021
- [Bent crystals for investigation of charmed baryons electromagnetic dipole](#), M. Romagnoni, Poster Prize talk, EPS-HEP Conference 2021, Online conference, July 26-30, 2021

Theses

Alessandro De Gennaro, Master Thesis, 2022

- [A study for the measurement of the \$\Lambda\$ baryon electromagnetic dipole moments in LHCb](#)

Bjorn Kerby Dimayuga, Bachelor Thesis, 2021

- [Sensitivity studies for the search of the Lambda baryon electric dipole moment in \$J/\Psi \rightarrow \Lambda \bar{\Lambda}\$ decays at LHCb](#)

Giorgia Tonani, Master Thesis, 2021

- [Study of Lambda baryon polarization in \$Xic0 \rightarrow \Lambda K^- \pi^+\$ decays](#)

Composizione gruppo di ricerca

Personale	FTE	ALTRO	SELDOM (FTE)	Inquadramento
Coelli	0,2	0,1	0,1	Tecnologo
Mancuso	1,0	1,0	0,0	Dottoranda
Marangotto	1,0	0,0	1,0	AR Unimi (UE)
Merli	1,0	1,0	0,0	RTD-A
Neri	1,0	0,4	0,6	PA
Spadaro	1,0	1,0	0,0	AR Unimi
Tonani	1,0	0,0	1,0	Dottoranda (UE)
Wang	1,0	1,0	0,0	PostDoc INFN stranieri
Tot. (FTE)	6,2	3,5	2,7	

- ▶ SELDOM 5.7 FTE in 2021 → 2.7 FTE in 2023
- ▶ Nominal end March 2023. Will ask for extension due to COVID-19 restrictions

Attività' 2022 e richieste servizi di sezione

- ▶ Costruzione telescopio per caratterizzazione di cristalli curvi su fascio
- ▶ Simulazioni FEA per cristalli

- ▶ **3 m.u. servizio elettronico**
- ▶ **3 m.u. servizio progettazione e officina meccanica**
- ▶ **10% Coelli**