



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



European Research Council
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Proposal n° 771642 SELDOM

ERC CoG PE2

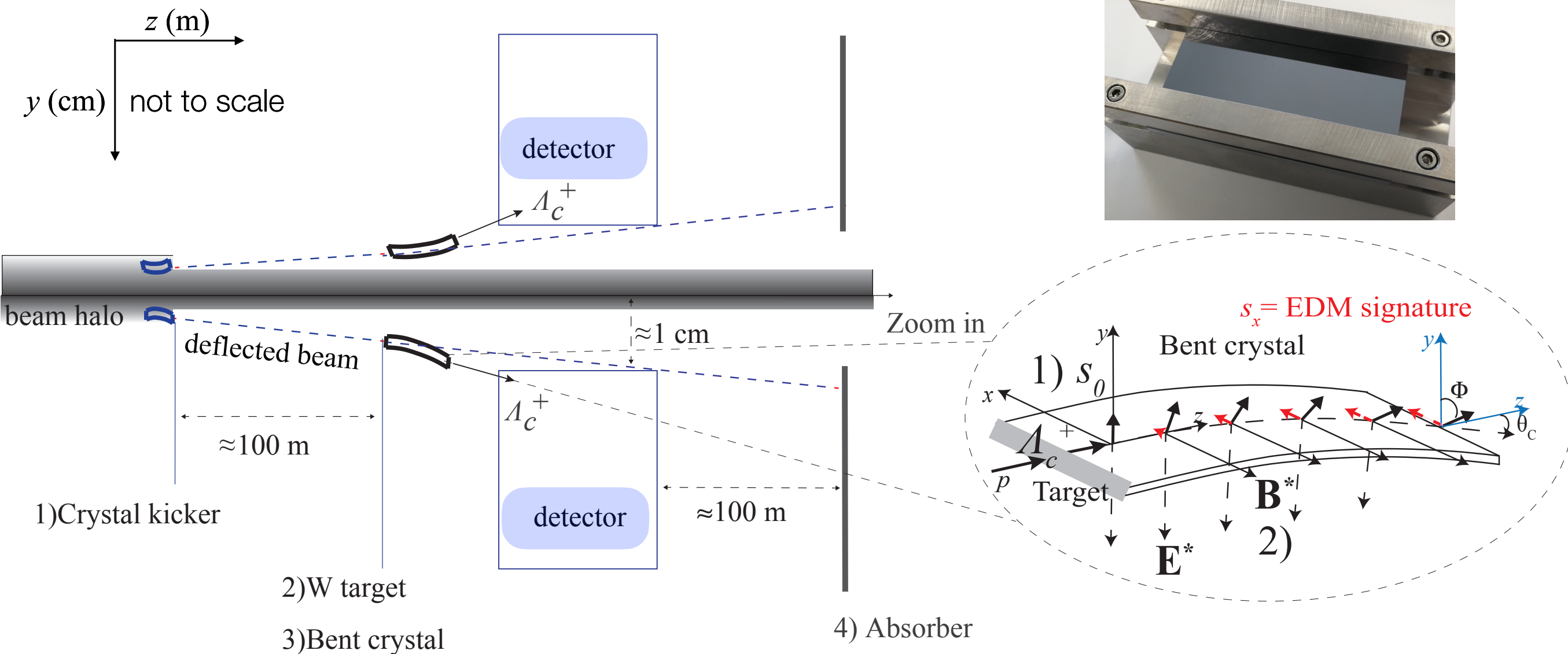


<https://web.infn.it/SELDOM/>

<https://twitter.com/SeldomTeam>

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

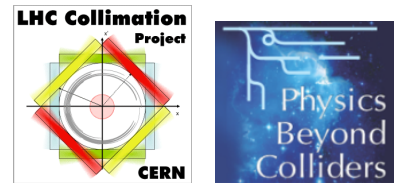
- EDM/MDM from spin precession of channeled baryons in **bent crystals**



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

R&D and preparatory studies

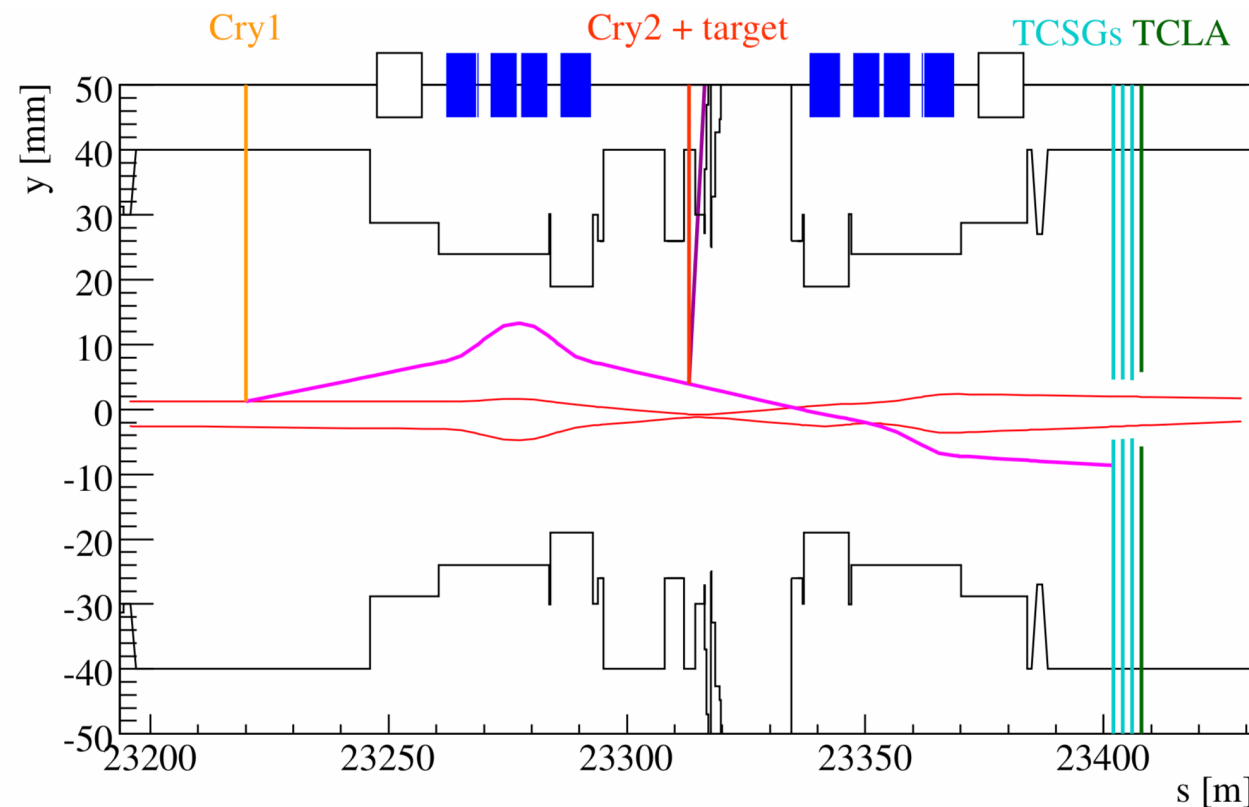
LHC (SPS) machine studies



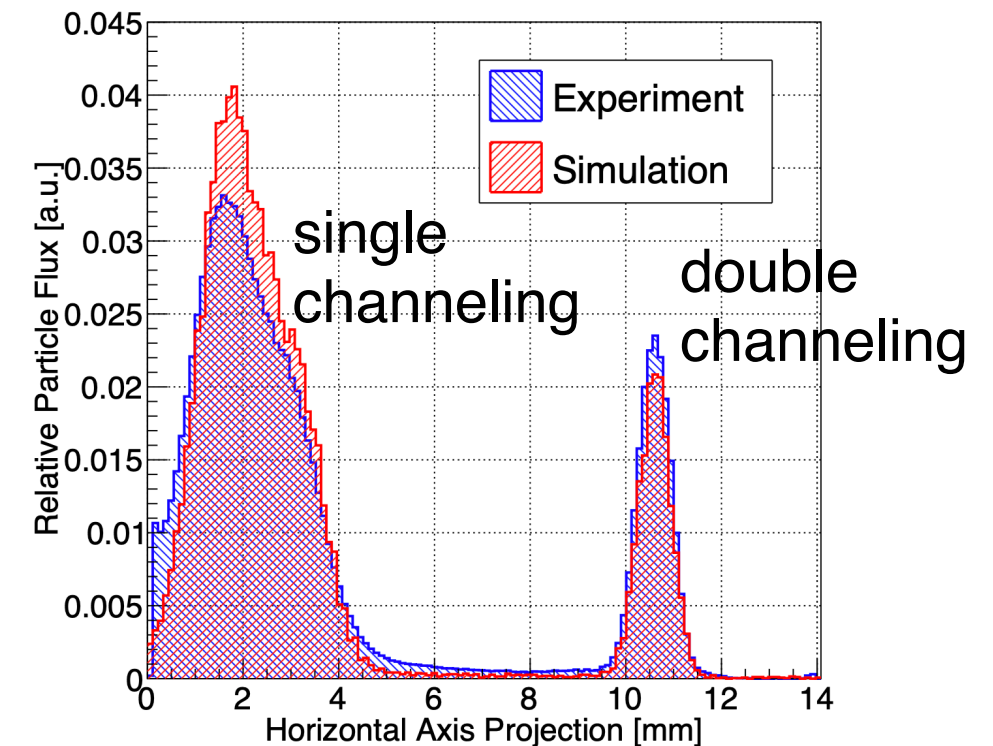
D. Mirarchi, A. S. Fomin, S. Redaelli, W. Scandale,
EPJC 80 (2020) 10, 929

W. Scandale et al., arXiv:2103.14681

LHC machine layout simulations



Experimental results at SPS



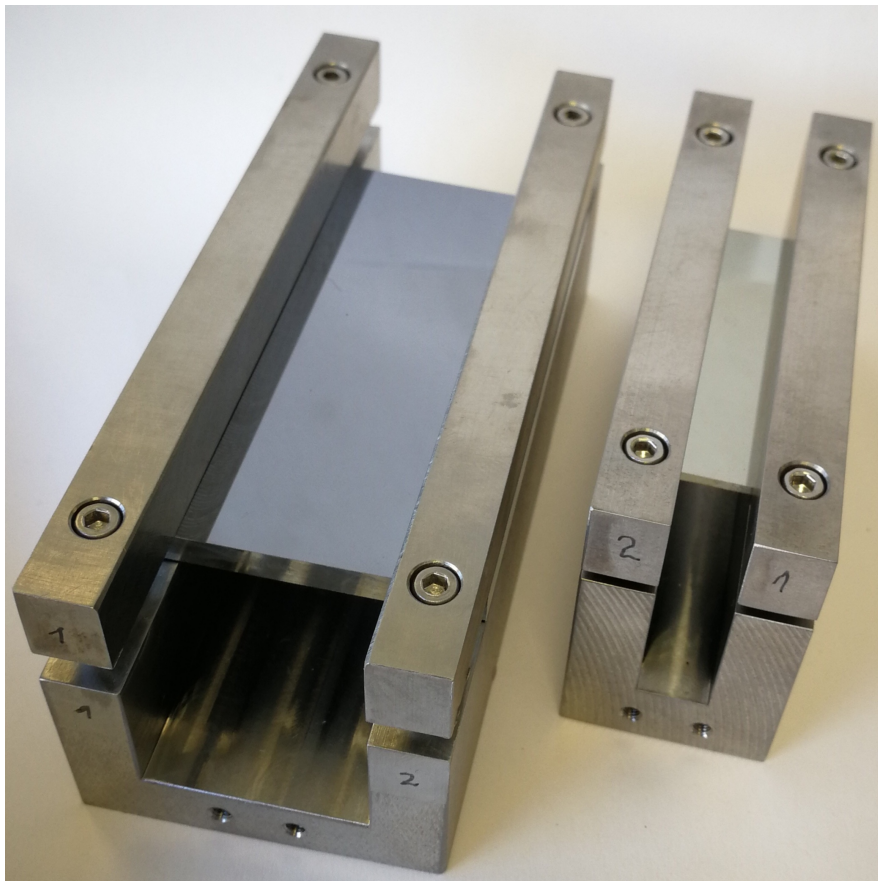
W. Scandale et al., PLB 758 (2016) 129–133

- **Channeling** of 6.5 TeV at **LHC** already **demonstrated** by UA9
- **Viable layout:** 10^6 p/s on target close to LHCb. Possibility to improve performance with a dedicated experiment at LHC
- Successful **layout test** done at SPS. Test in **LHC** possibly during Run3

Long bent crystal prototypes

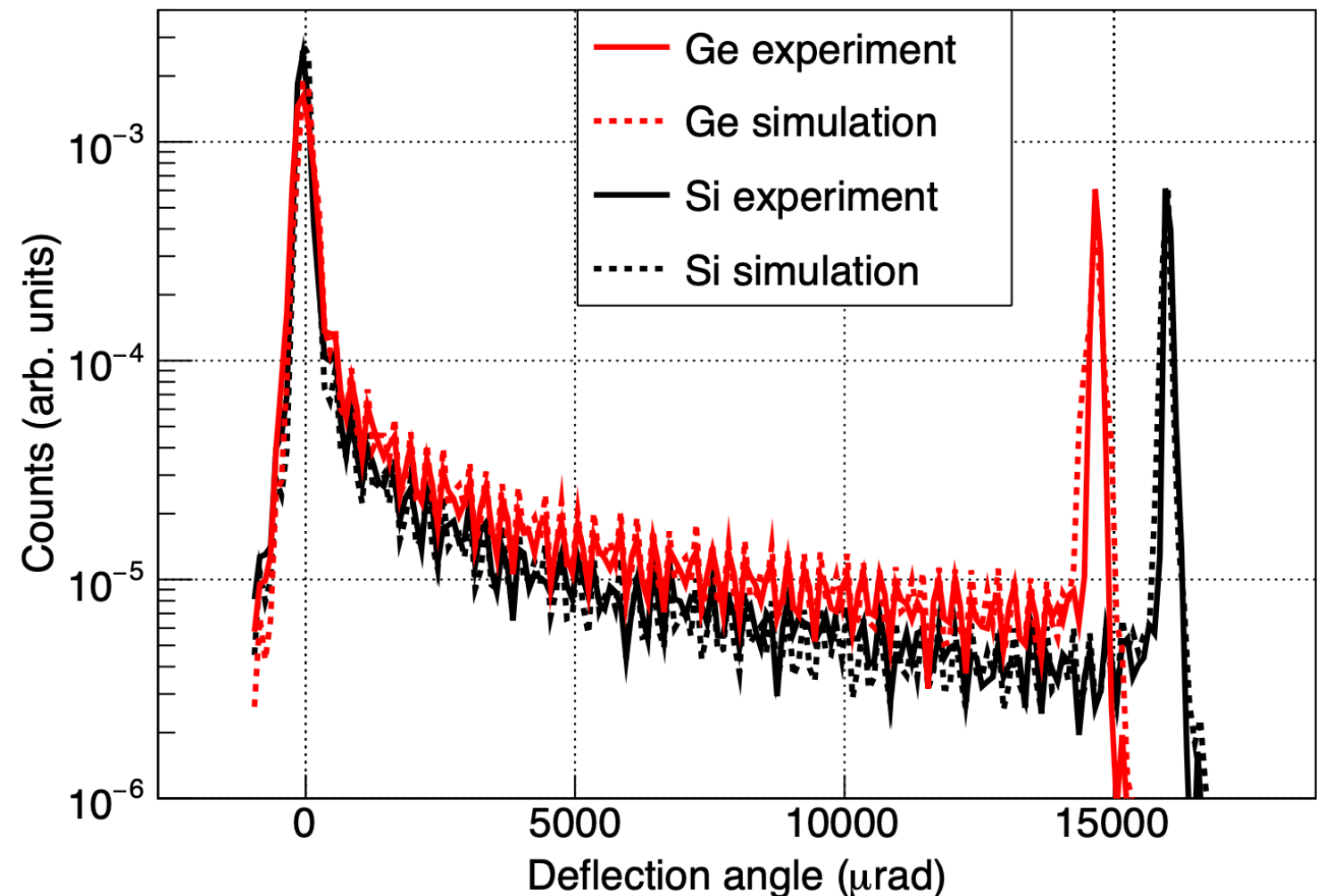
Si: 8 cm long, bent @16.0 mrad

Ge: 5 cm long, bent @14.5 mrad



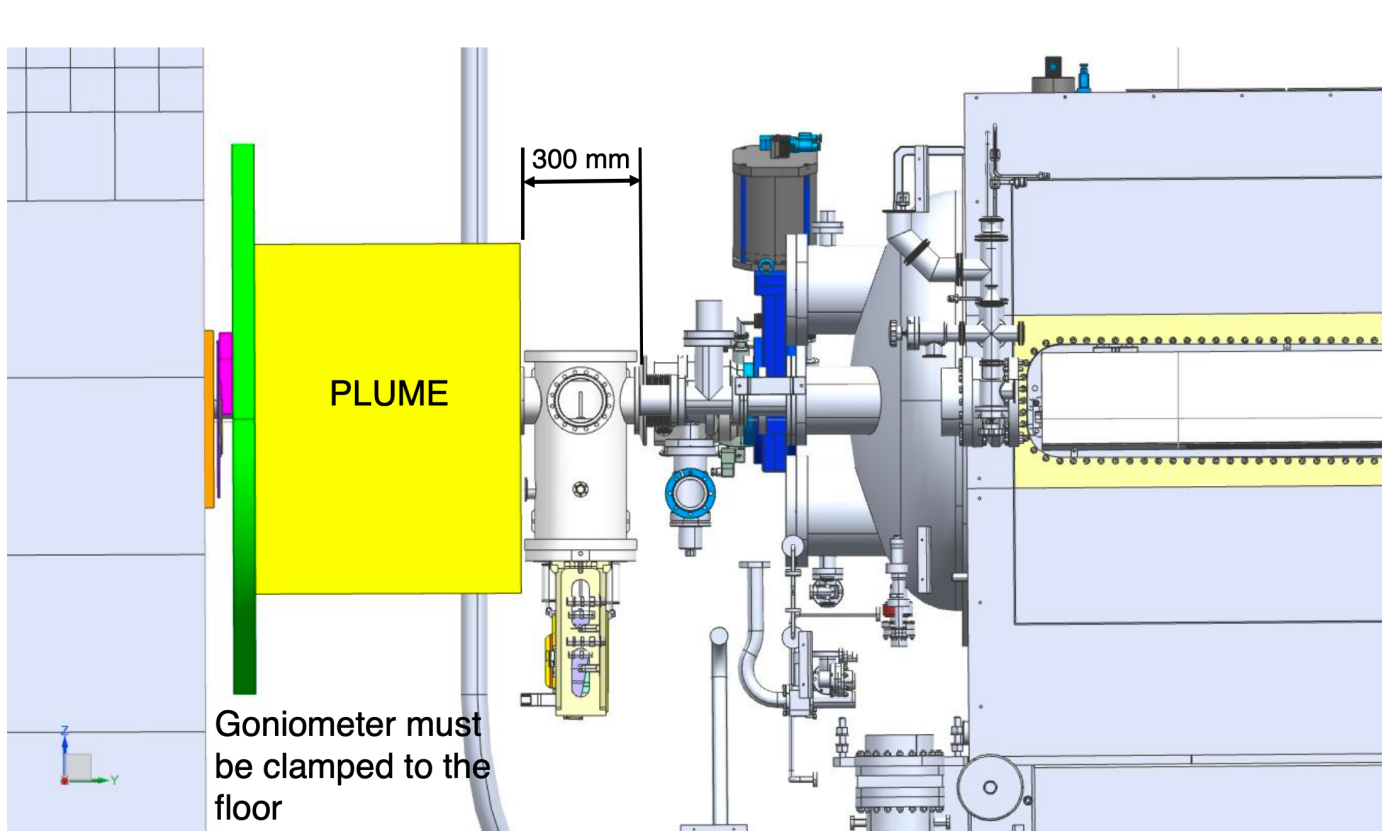
Courtesy of A. Mazzolari

S. Aiola *et al.*, PRD 103, 072003 (2021)



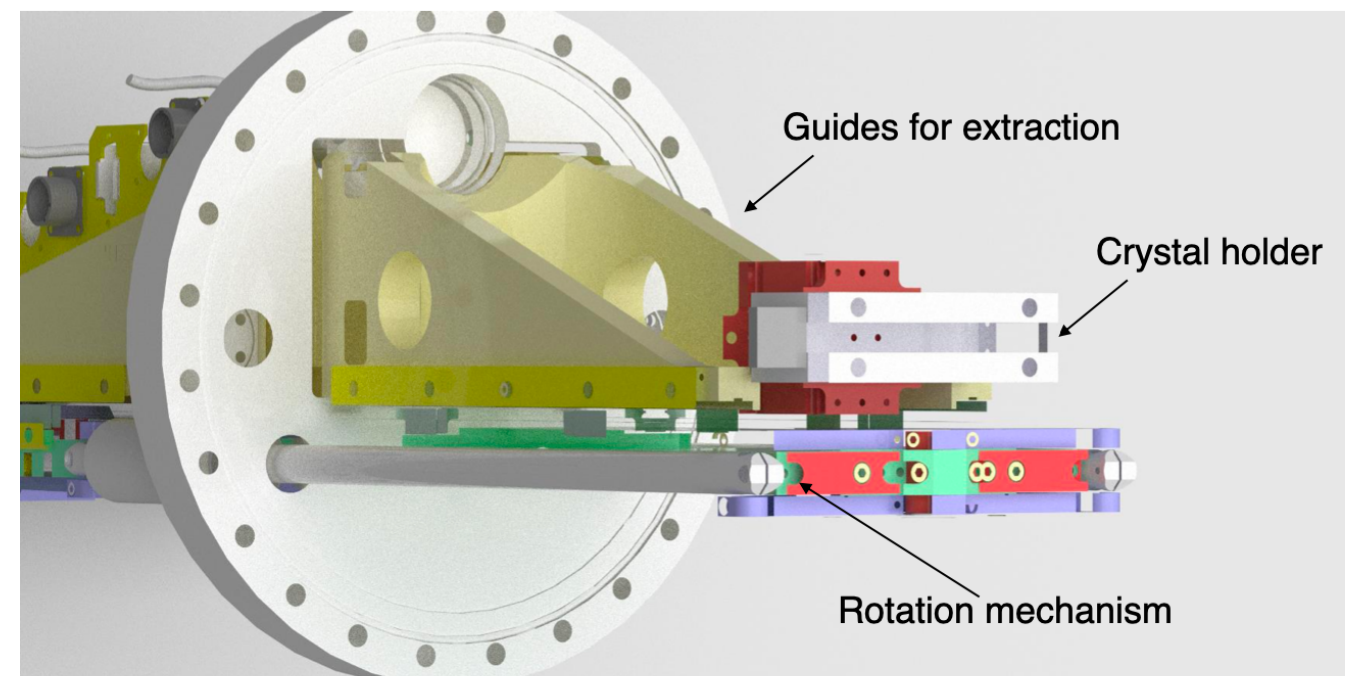
- **Si** and **Ge** long bent crystals developed at INFN-Ferrara.
Channeling efficiency $>10\%$ for 180 GeV/c pions

Fixed-target setup upstream of LHCb



- ▶ Goniometer for target+crystal positioned in the region upstream of the LHCb detector

- ▶ Goniometer internal structure: compatible with operations in ultra-high vacuum
- ▶ Accuracy on position $\sim 20 \mu\text{m}$, rotation angle $\sim 20 \mu\text{rad}$



Production of Λ_c^+ baryons

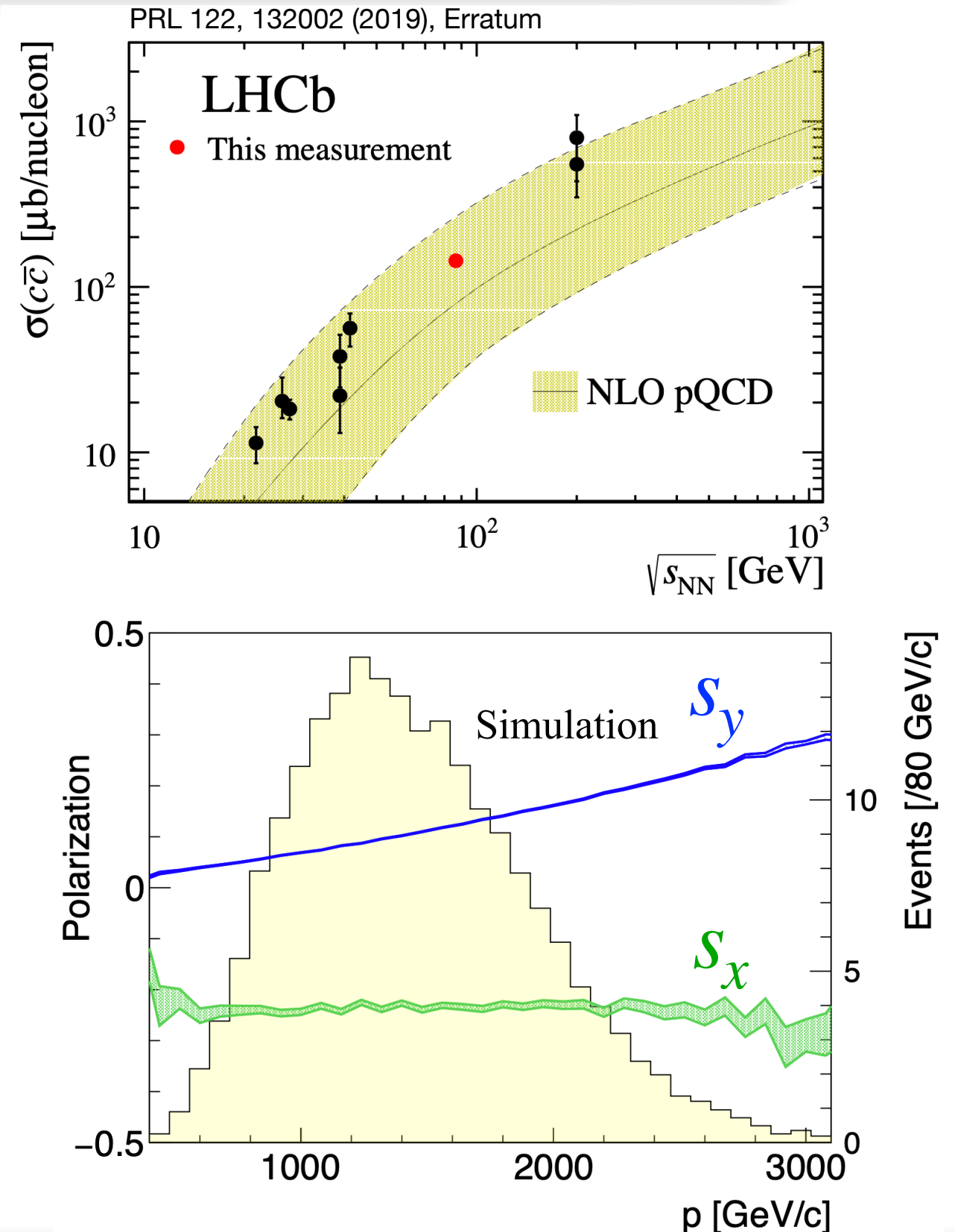
Measured $c\bar{c}$ cross-section at $\sqrt{s_{NN}} = 86.6$ GeV - $\sigma_{c\bar{c}} = 144 \pm 12.1 \pm 3.5$ $\mu\text{b}/\text{nucleon}$

Expected Λ_c^+ **cross-section** at $\sqrt{s}=115$ GeV: $\sigma(\Lambda_c^+) \sim 11$ μb

Λ_c^+ **polarization** measurements ongoing using p-Gas collisions (signal yield of few hundreds)

Momentum and polarization for Λ_c^+ baryons produced in fixed-target (Ge crystal at 293 K)

S_y and S_x polarisations for Λ_c^+ baryons with $\theta_{y,C}=0.3$ mrad between impinging p and crystal

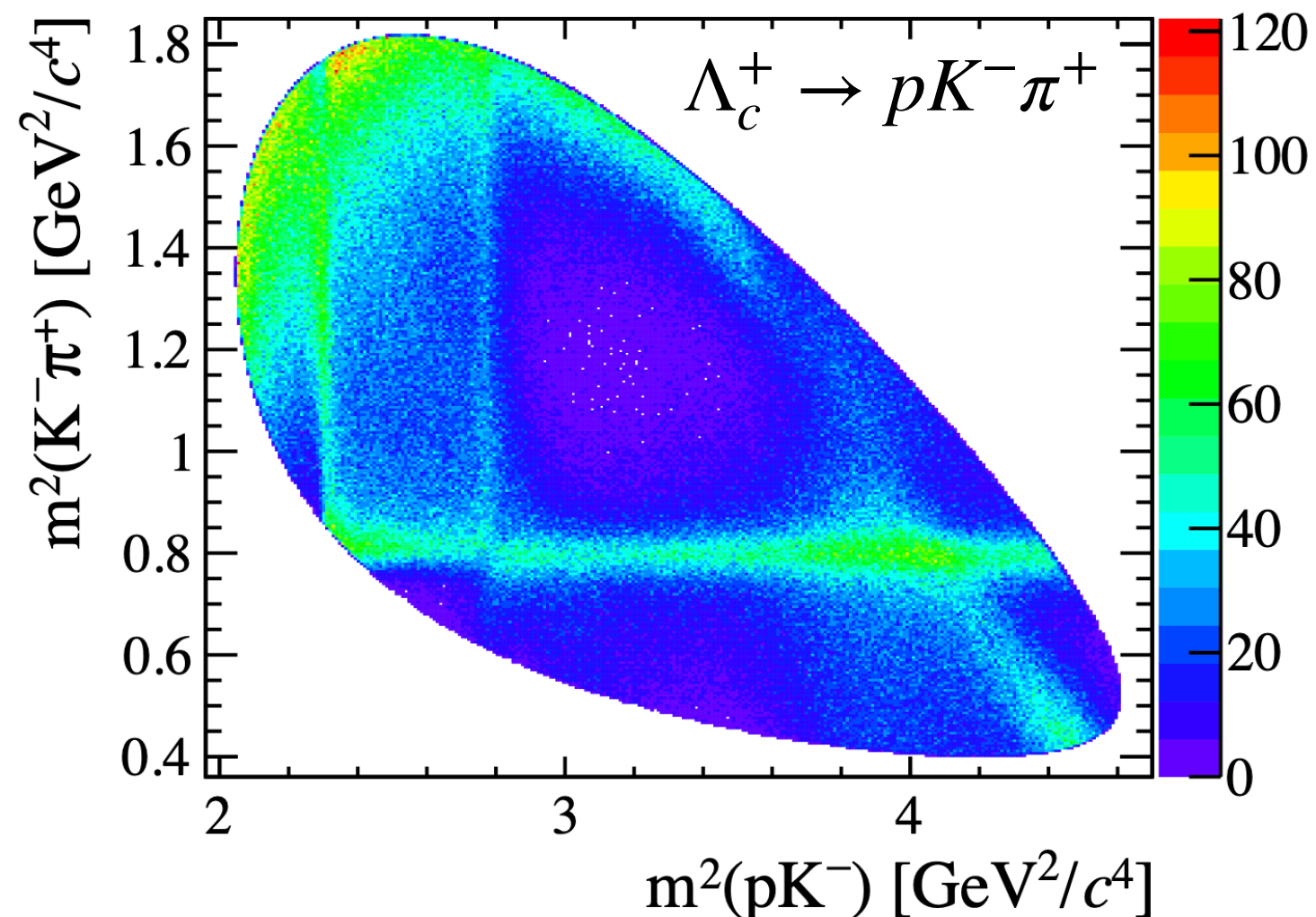


Use copious Λ_c^+ , Ξ_c^+ 3-body decays

- ▶ Use many 3-body decays to increase the signal yield
- ▶ Extract maximum information via full amplitude analysis of the 3-body decays D. Marangotto, AHEP (2020) 7463073

PRD 103, 072003 (2021)

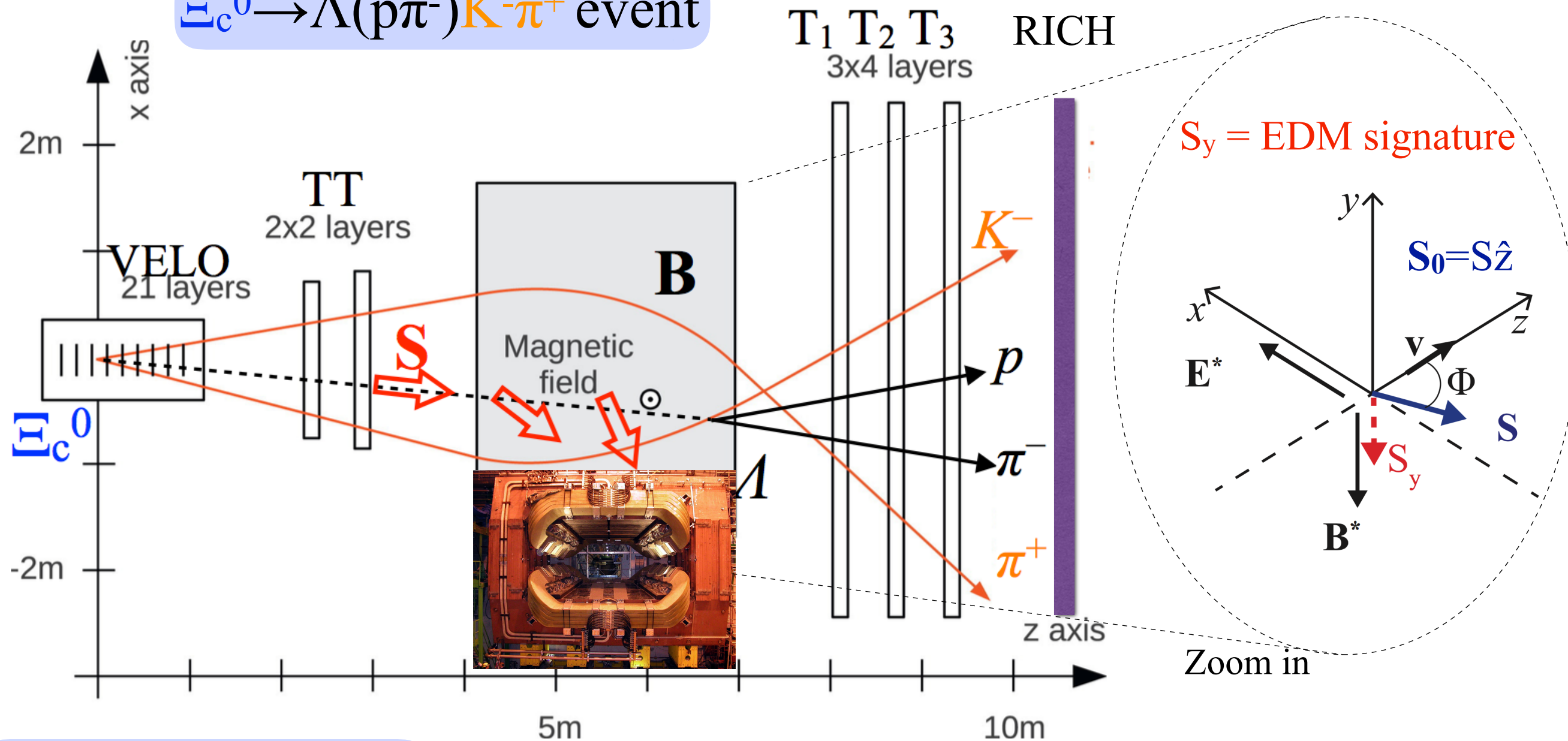
Λ_c^+ final state	$\mathcal{B}$ (%)	$\epsilon_{3\text{trk}}$	$\mathcal{B}_{\text{eff}}$ (%)
$pK^-\pi^+$	6.28 ± 0.32	0.99	6.25
$\Sigma^+\pi^-\pi^+$	4.50 ± 0.25	0.54	2.43
$\Sigma^-\pi^+\pi^+$	1.87 ± 0.18	0.71	1.33
$p\pi^-\pi^+$	0.461 ± 0.028	1.00	0.46
$\Xi^-K^+\pi^+$	0.62 ± 0.06	0.73	0.45
$\Sigma^+K^-K^+$	0.35 ± 0.04	0.51	0.18
pK^-K^+	0.106 ± 0.006	0.98	0.11
$\Sigma^+\pi^-K^+$	0.21 ± 0.06	0.54	0.11
$pK^-\pi^+\pi^0$	4.46 ± 0.30	0.99	4.43
$\Sigma^+\pi^-\pi^+\pi^0$	3.20	0.54	1.72
$\Sigma^-\pi^+\pi^+\pi^0$	2.1 ± 0.4	0.71	1.49
$\Sigma^+[p\pi^0]\pi^-\pi^+$	2.32	0.46	1.06
$\Sigma^+[p\pi^0]K^-K^+$	0.18	0.46	0.08
$\Sigma^+[p\pi^0]\pi^-K^+$	0.11	0.46	0.05
All	...	...	20.2



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



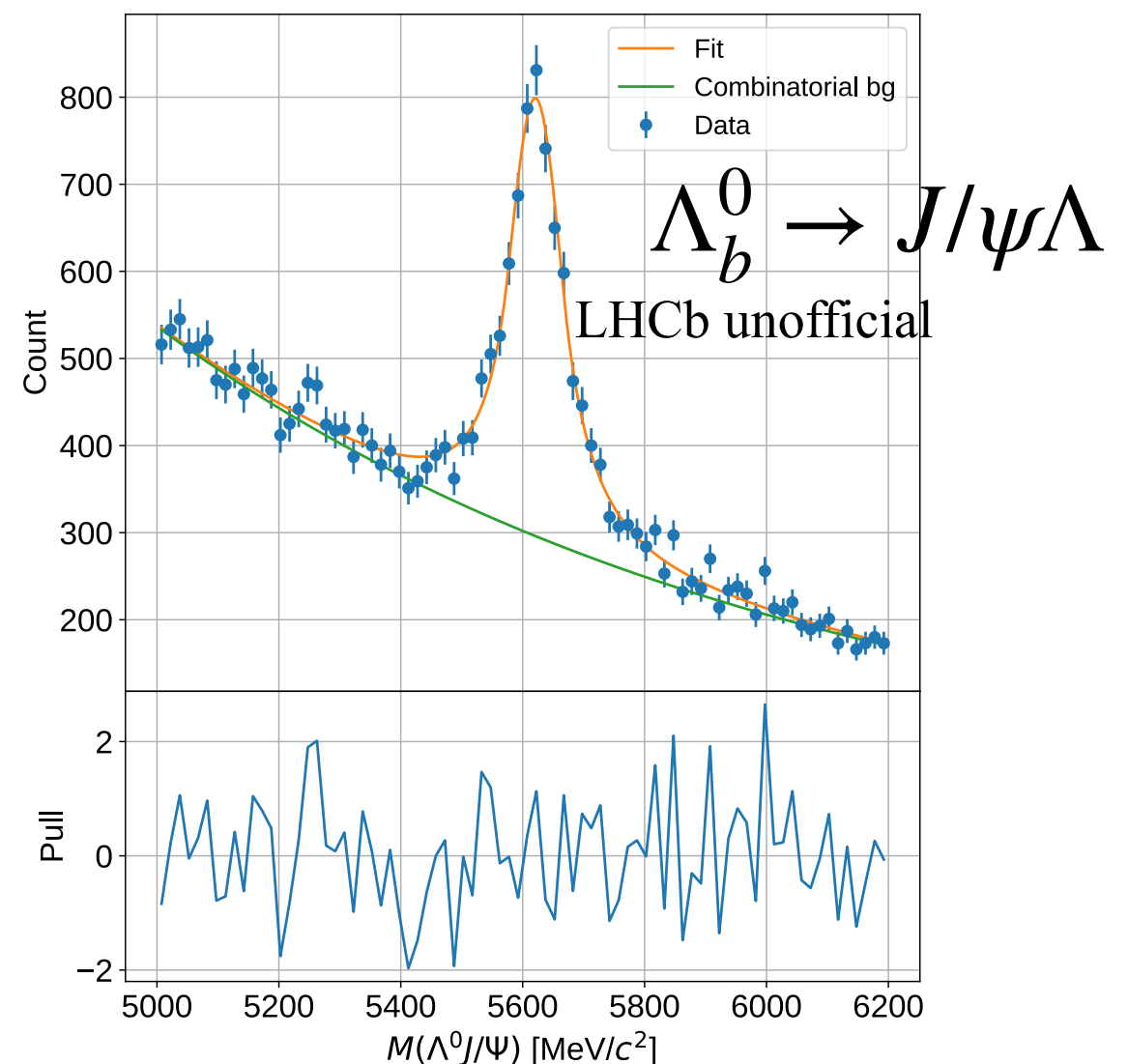
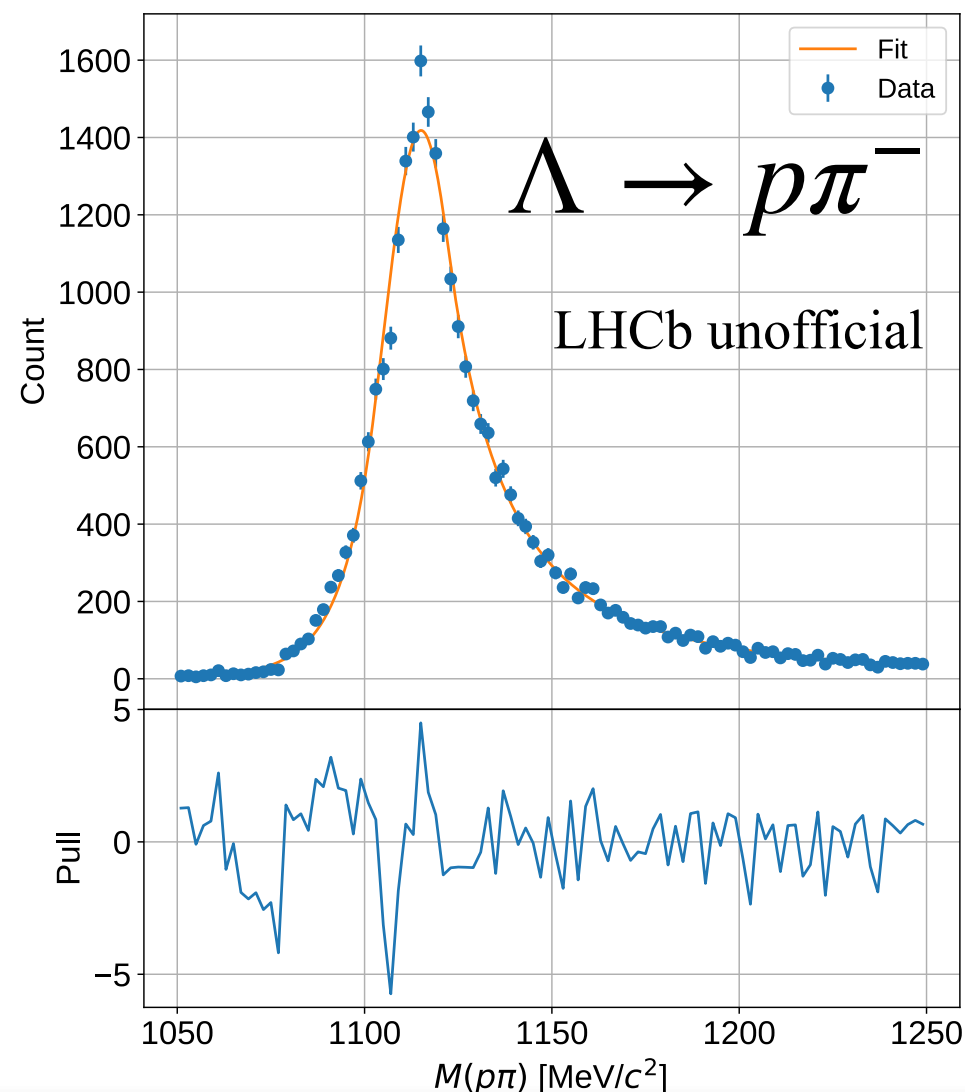
Λ polarised production

spin precession

event reconstruction

$\Lambda_b^0 \rightarrow J/\psi \Lambda$ reconstruction on data

- ▶ Reconstruct the decay $\Lambda_b^0 \rightarrow J/\psi(\mu^+\mu^-)\Lambda(p\pi^-)$ exploiting existing dimuon trigger on Run2 data ✓
- ▶ Λ reconstructed decay vertex after the LHCb magnet (6m) ✓



Achievements and next steps

- ▶ **Milestones** achieved: feasibility detector studies, long bent crystal prototypes, preparatory studies in LHCb, machine layout, physics program extended
- ▶ **Testbeam** at CERN for characterisation of bent crystals
- ▶ Machine **test in LHC** possibly during Run3 for double channeling test (for charm baryons)
- ▶ Data taking in **LHCb** for first measurements in the near future (for Λ baryons)
- ▶ Design a dedicated fixed-target experiment at LHC at high statistics for an **ambitious physics program**: charm and beauty baryons, and possibly the tau lepton

Conferences and workshops

2021

- New ideas for the direct determination of the electromagnetic moments of charged and neutral fermions, **N. Neri**, FPCP 2021, Shanghai, China (remote participation due to COVID-19), 7-11 June 2021. Invited plenary talk
- Progress towards the charm baryon dipole moments with bent crystals, **A. Merli**, FTE@LHC, Paris, France, 4th June 2021.
- **Prospects for direct Measurements of short-lived Particle Dipole Moments at the LHC**, **N. Neri**, PSI Colloquium, Villigen, CH, Thursday April 15th 2021 (remote due to COVID-19).
- **Direct measurements of short-lived particle dipole moments at the LHC**, **N. Neri**, Excellence Cluster Prisma+ Colloquium, Johannes Gutenberg University Mainz, Germany (remote-only due to COVID-19), 10 February 2021

2020

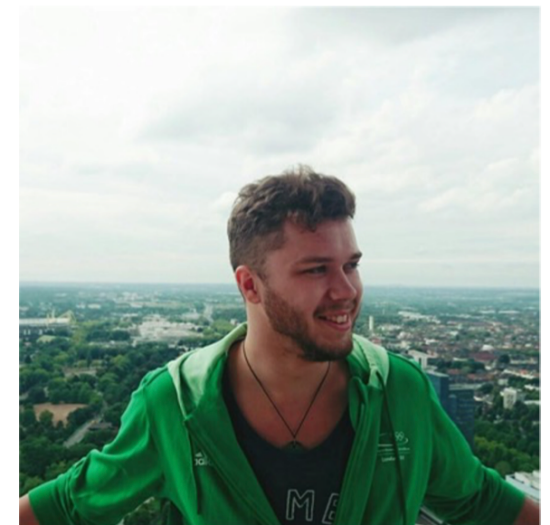
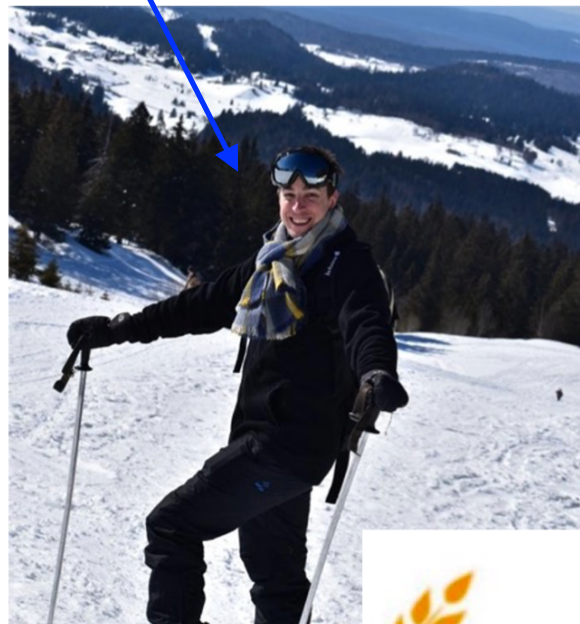
- **DIPOLE-b: direct measurement of dipole moments of short-lived particles at the LHC(b)**, **S. Aiola**, ICHEP 2020: 40th International Conference on High Energy Physics, Prague, Czech Republic (remote-only due to COVID-19), 28 July-6 August 2020
- **The Hybrid Seeding at LHCb**, **L. Henry**, Connecting The Dots 2020, Princeton, NJ, USA (remote-only due to COVID-19), 20-30 April 2020
- **A 30 MHz software trigger and reconstruction for the LHCb upgrade**, **L. Henry**, Connecting The Dots 2020, Princeton, NJ, USA (remote-only due to COVID-19), 20-30 April 2020

Early Career Scientist Award

Louis Henry was a PostDoc in Milano since March 2021, now Research Fellow at CERN

ARTHUR HENNEQUIN, LOUIS HENRY, CHRISTOPH HASSE AND NIKLAS NOLTE

For their achievements and ground-breaking developments for the LHCb software trigger and the real-time analysis system.



Attività' 2022 e richieste servizi di sezione

- ▶ Costruzione telescopio per caratterizzazione di cristalli curvi su fascio
- ▶ Costruzione prototipo per camera a vuoto e sistema di posizionamento (goniometro) per cristalli curvi in LHC
- ▶ Simulazioni FEA e cooling cristalli di germanio a 77 K
 - ▶ **Spazio di laboratorio (richiesto dall'inizio del progetto)**
 - ▶ **3 m.u. servizio elettronico**
 - ▶ **3 m.u. servizio progettazione e officina meccanica**
 - ▶ **10% Coelli**

Composizione gruppo di ricerca

Personale	FTE	LHCb (FTE)	SELDOM (FTE)	Inquadramento
Citterio	0,1	0,1		Dirigente Tecnologo
Coelli	0,3	0,2	0,1	Tecnologo
De Benedetti	1,0	0,0	1,0	AR INFN (UE)
Frontini	0,35	0,35		AR Unimi
Gandini	1,0	1,0		Ricercatore
Liberali	0,3	0,3		PA
Marangotto	1,0	0,0	1,0	AR Unimi (UE)
Merli	1,0	0,0	1,0	AR Unimi (UE)
Neri	1,0	0,4	0,6	PA
Petruzzo	1,0	0,0	1,0	AR INFN
Riboldi	0,2	0,2		RU
Stabile	0,2	0,2		
Spadaro	1,0	1,0	0,0	AR Unimi
Mancuso	1,0	1,0		Dottorando Paris-Milan
TBD	1,0	0,0	1,0	Dottorando (UE)
Tot. (FTE)	10,45	4,75	5,7	

- ▶ LHCb 3.9 FTE in 2021 → 4.75 FTE in 2022
- ▶ SELDOM 5.7 FTE in 2021 → 5.7 FTE in 2022