SELDOM

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

European Research Council

Established by the European Commission

PI: Nicola Neri

Proposal n° 771642 SELDOM

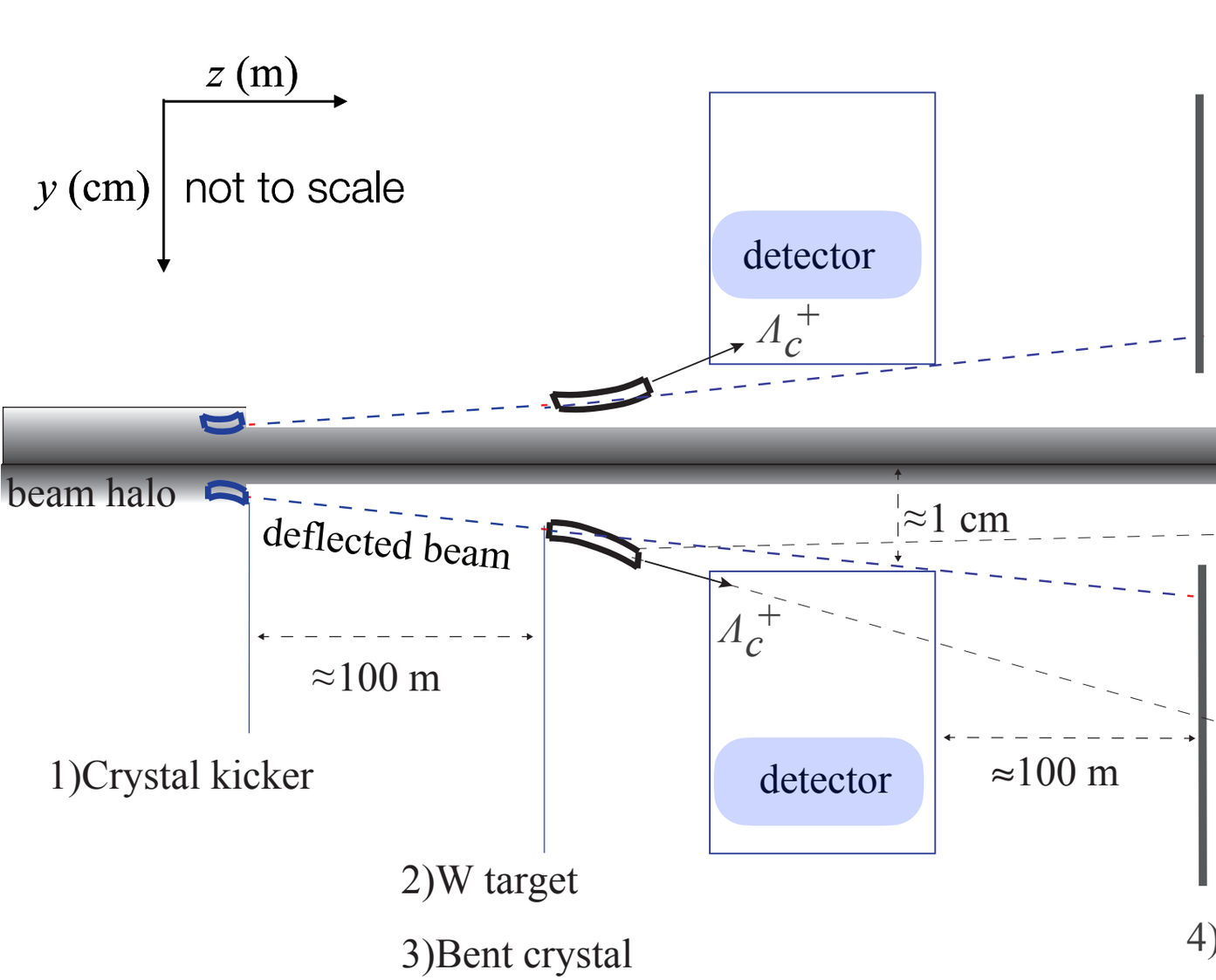
ERC CoG PE2

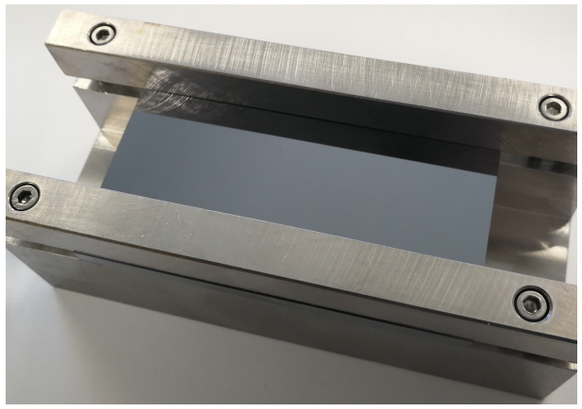
https://web.infn.it/SELDOM/

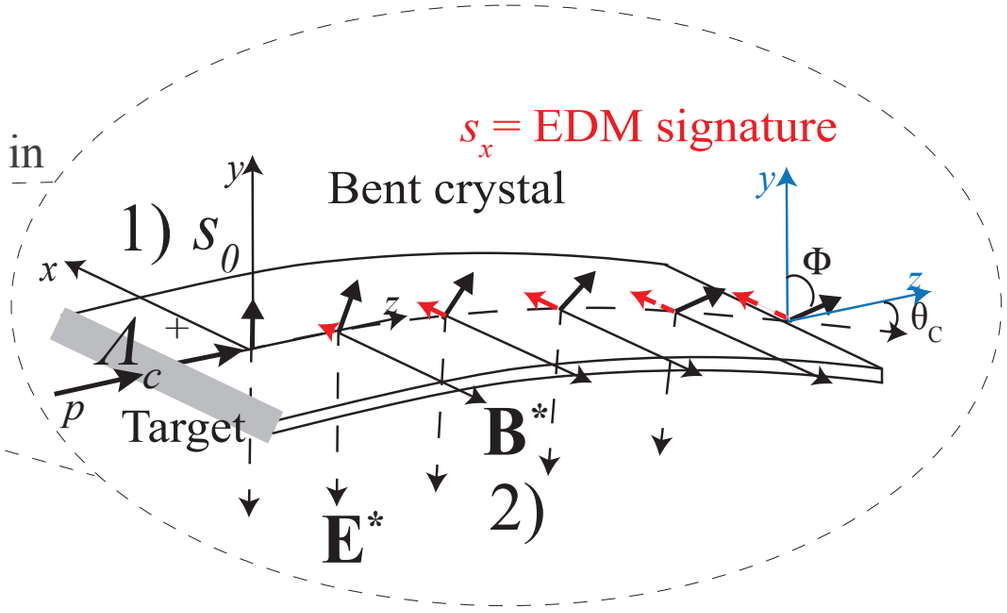
https://twitter.com/SeldomTeam

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

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



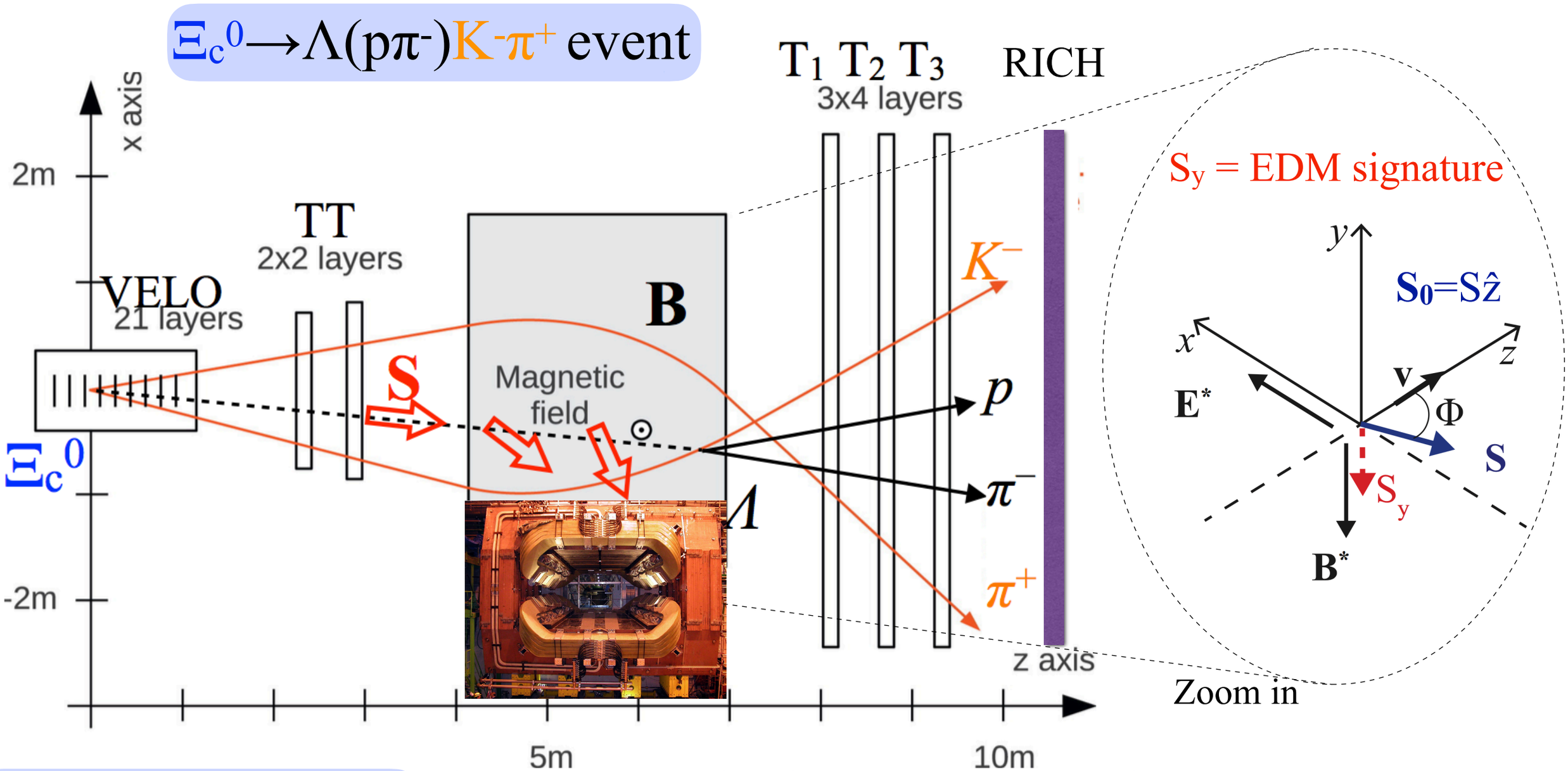




p extraction | Λ_c^+ polarised production | channeling | spin precession | event reconstruction

Novel experimental technique for **strange baryons**

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

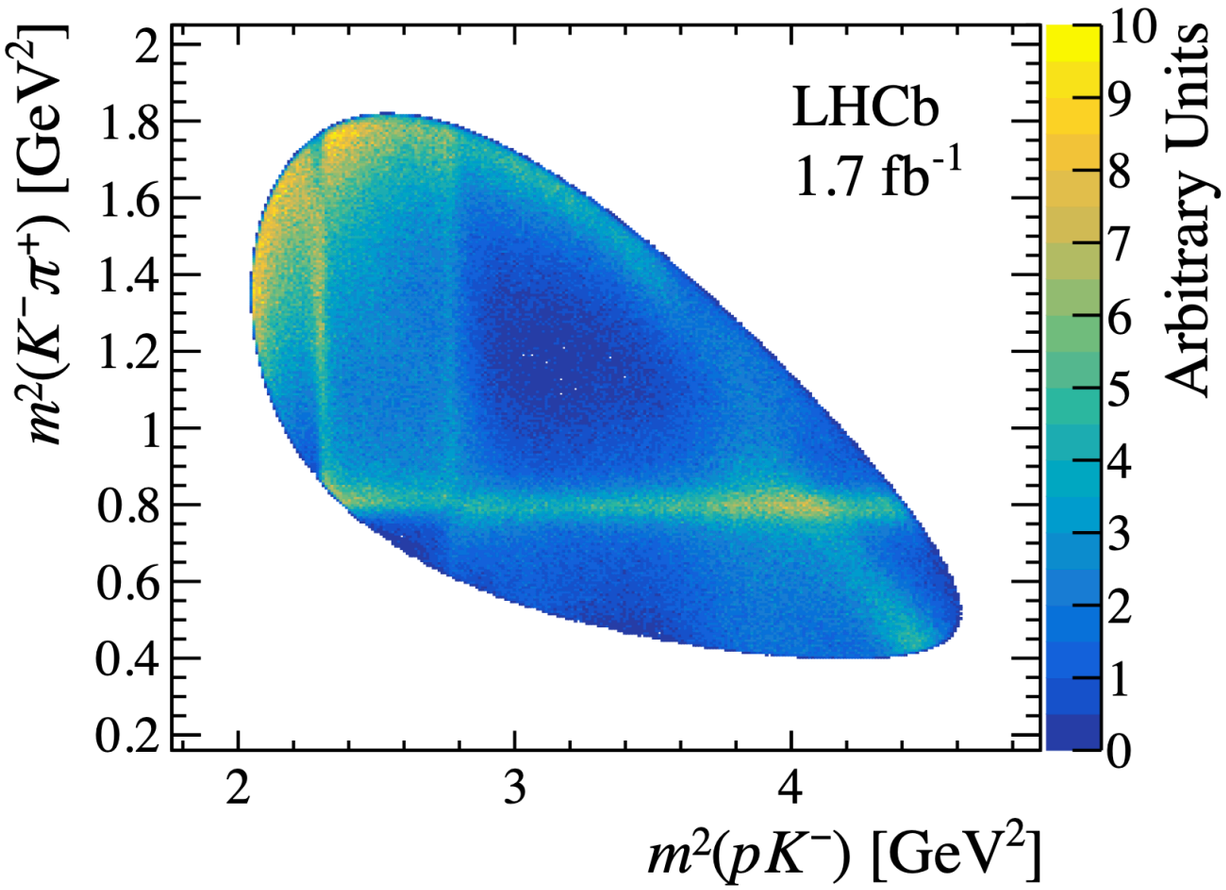


Λ polarised production | spin precession | event reconstruction

Update on last year results

Amplitude analysis and polarisation measurement for $\Lambda_c^+ \to pK^-\pi^+$ decays

- arXiv: 2208.03262, accepted by *Phys. Rev. D*.



Resonant composition

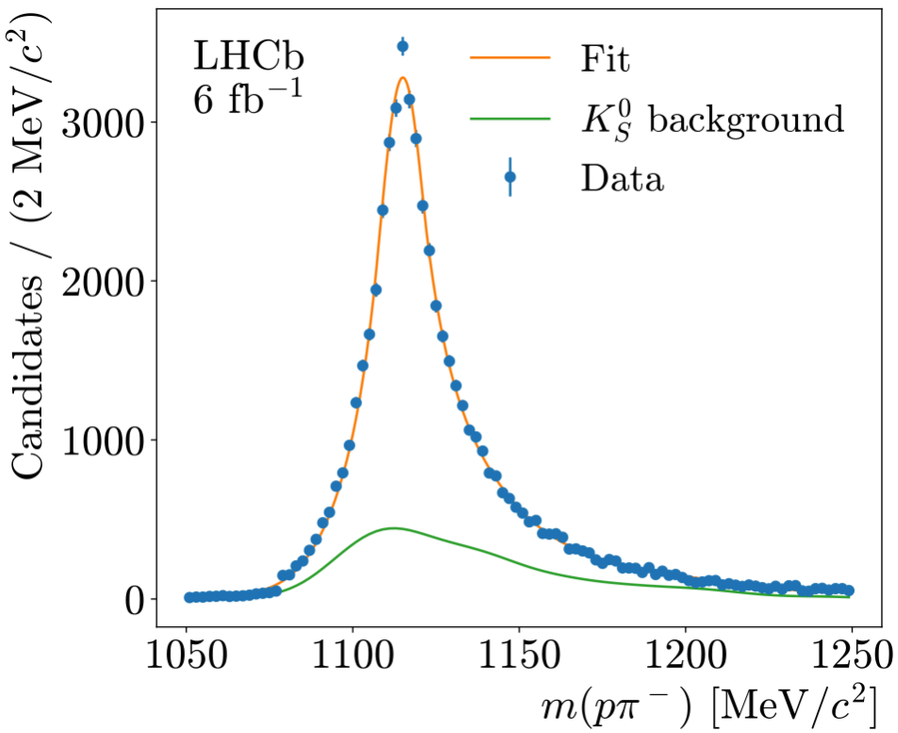
Resonance	J^P	Mass (MeV)	Width (MeV)
$\Lambda(1405)$	$1/2^-$	1405.1	50.5
$\Lambda(1520)$	$3/2^-$	$1515 - 1523$	$10 - 20$
$\Lambda(1600)$	$1/2^+$	1630	250
$\Lambda(1670)$	$1/2^-$	1670	30
$\Lambda(1690)$	$3/2^-$	1690	70
$\Lambda(2000)$	$1/2^-$	$1900 - 2100$	$20 - 400$
$\Delta(1232)^{++}$	$3/2^+$	1232	117
$\Delta(1600)^{++}$	$3/2^+$	1640	300
$\Delta(1700)^{++}$	$3/2^-$	1690	380
$K_0^*(700)$	0^+	824	478
$K^*(892)$	1^-	895.5	47.3
$K_0^*(1430)$	0^+	1375	190

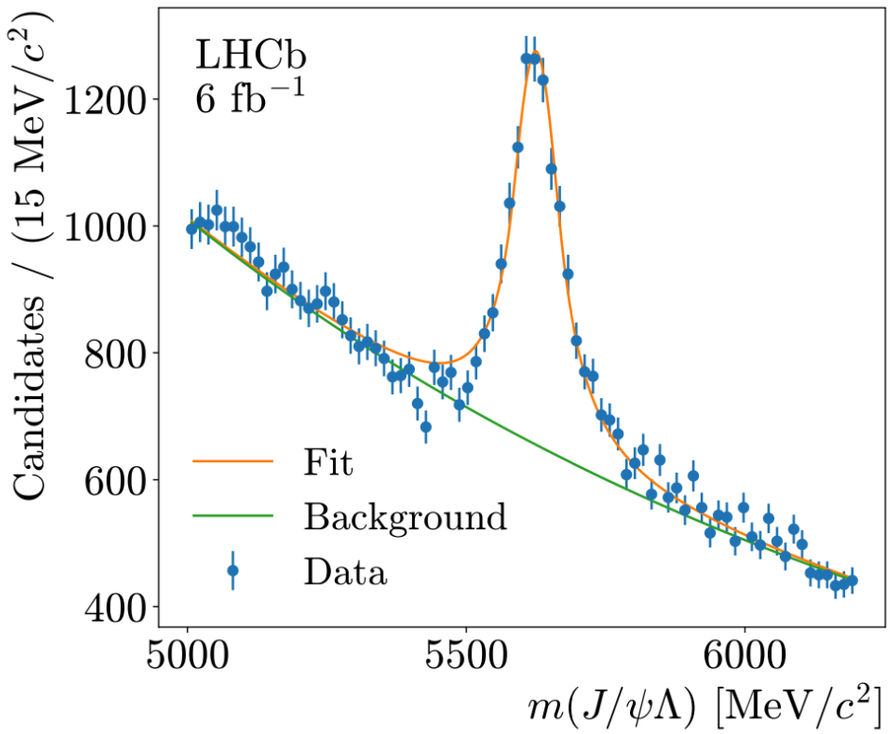
Polarisation measurement

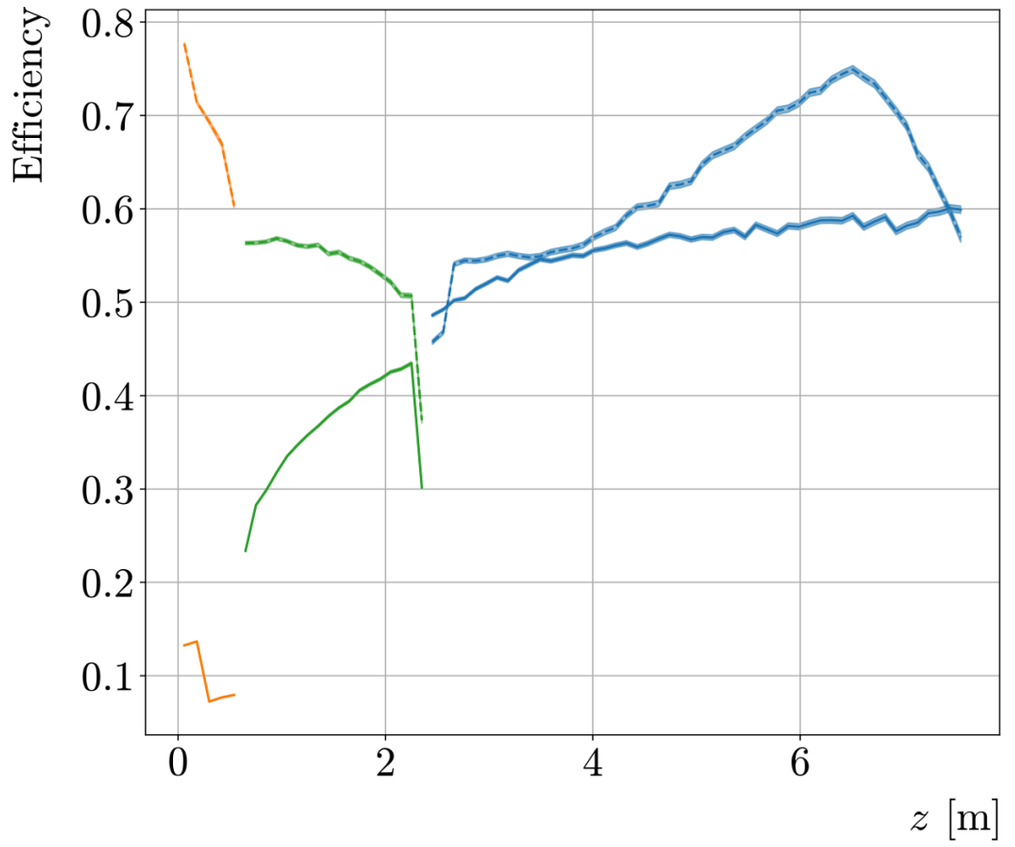
Component	Value (%)
$P_x\ (lab)$	$60.32 \pm 0.68 \pm 0.98 \pm 0.21$
$P_y\ (lab)$	$-0.41 \pm 0.61 \pm 0.16 \pm 0.07$
$P_z\ (lab)$	$-24.7 \pm 0.6 \pm 0.3 \pm 1.1$
$P_x\ (\tilde{B})$	$21.65 \pm 0.68 \pm 0.36 \pm 0.15$
$P_y\ (\tilde{B})$	$1.08 \pm 0.61 \pm 0.09 \pm 0.08$
$P_z\ (\tilde{B})$	$-66.5 \pm 0.6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

Long-lived particle reconstruction downstream of the LHCb magnet

arXiv:2211.10920 **[hep-ex]**

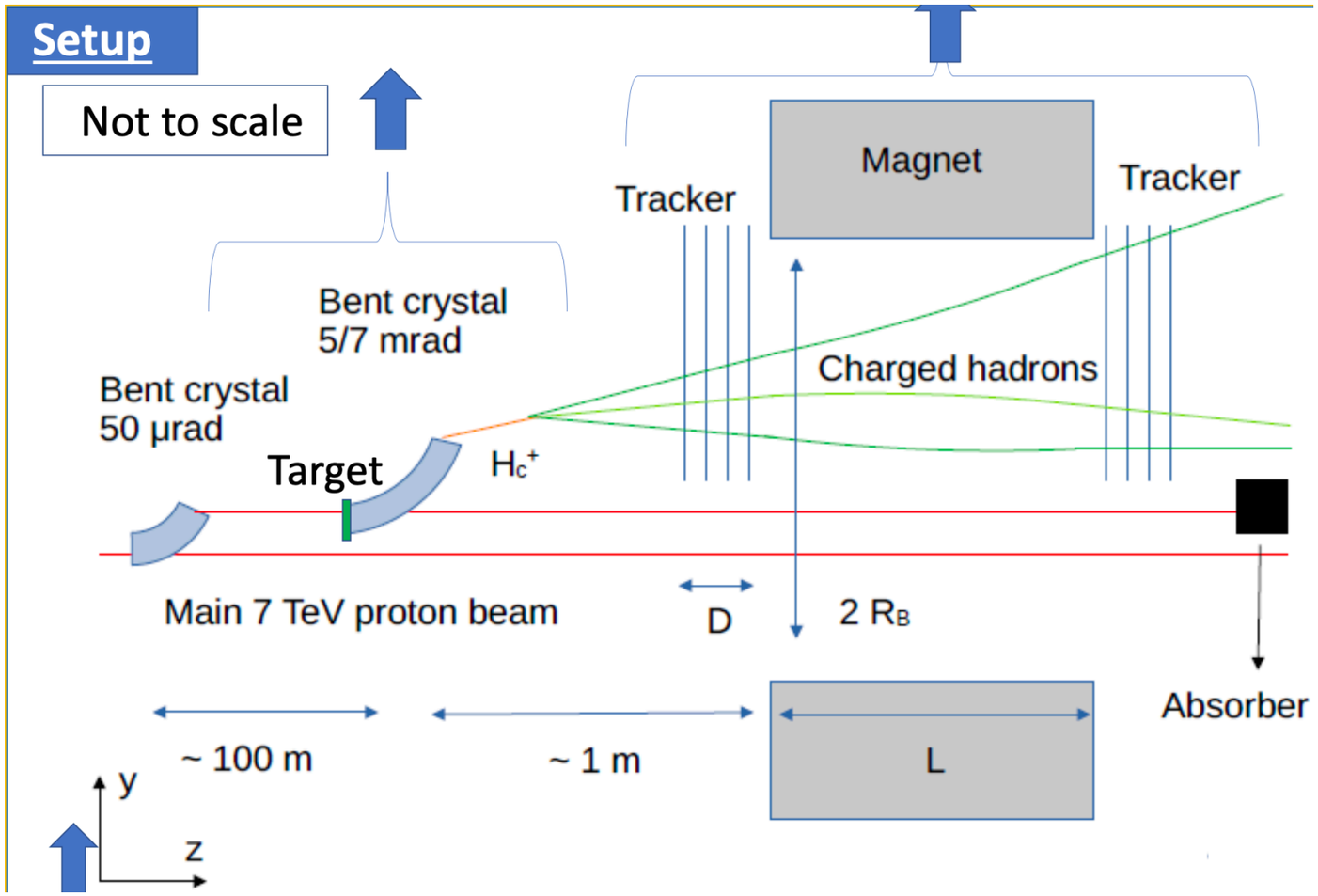


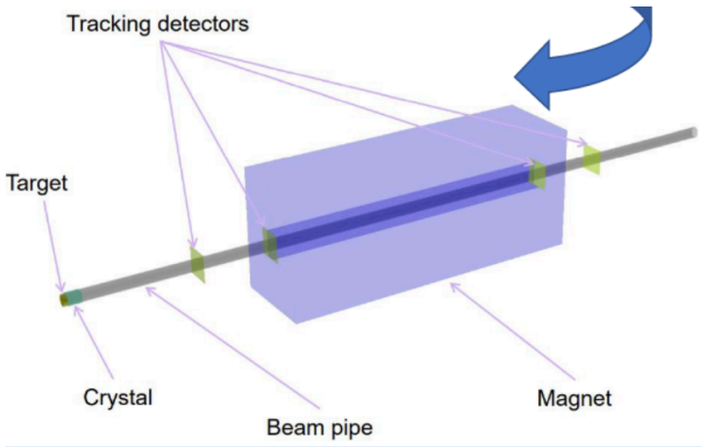




- Crucial milestone for SELDOM
- Analysis for EDM/MDM measurement for Λ baryons started
- Opens further possibilities for long-lived particle studies and searches beyond the SM

Experimental proof-of-principle at IR3





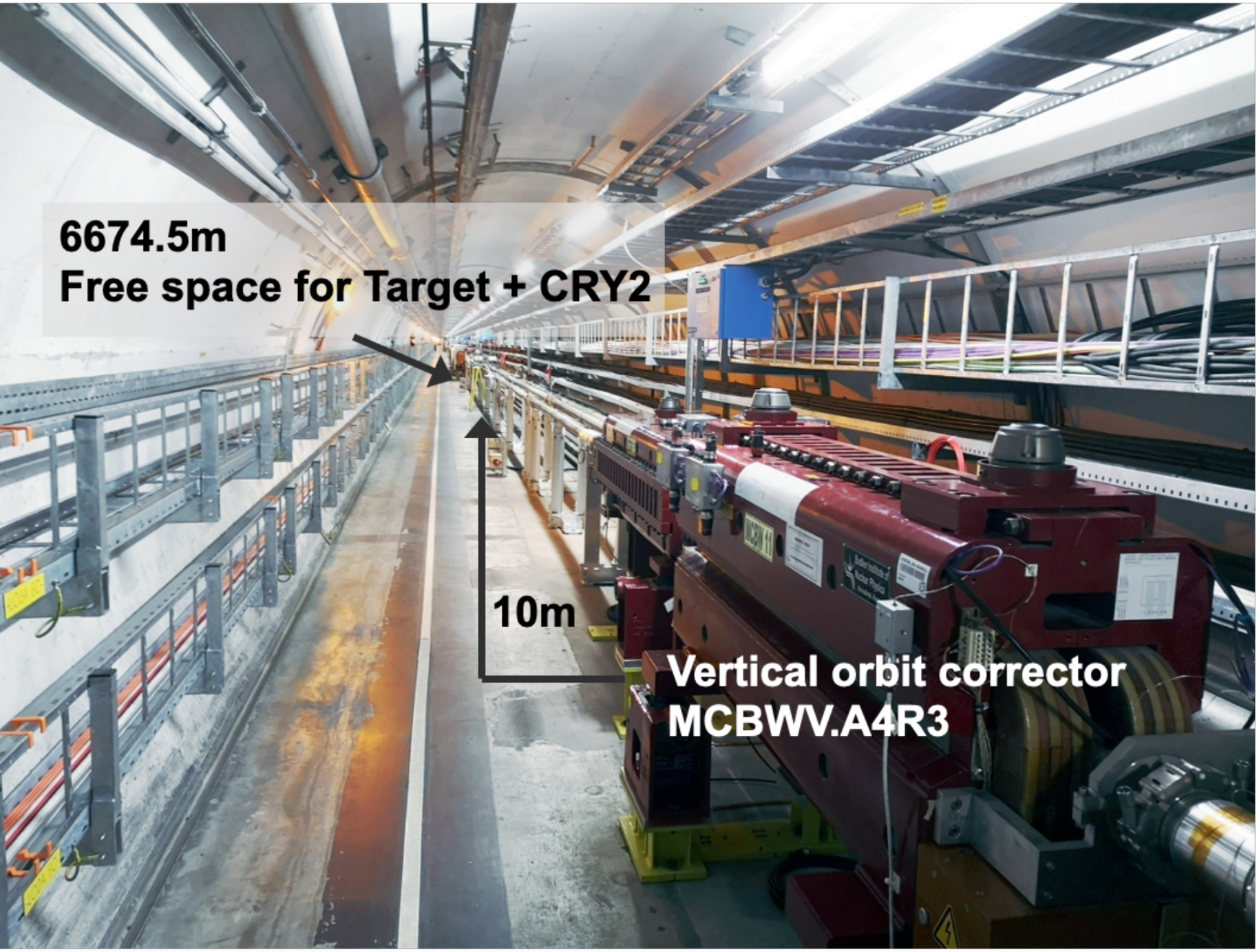
Ongoing study

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

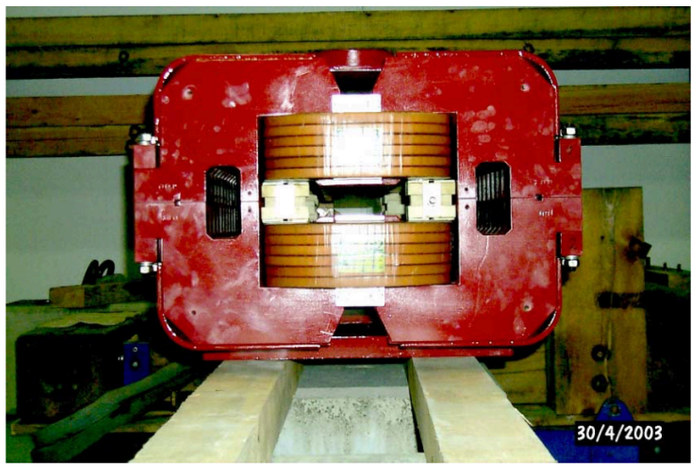
- Goal: demonstrate feasibility of charm baryon EDM/MDM at LHC
  - channeling in bent crystals
  - reconstruction
  - background
  - LHC machine studies
- Test planned at LHC IR3 (intersection region 3) during Run 3

Location at IR3 for the experimental setup

Use MCBWV dipole magnet (L=1.7m, B=1.1T) for the spectrometer

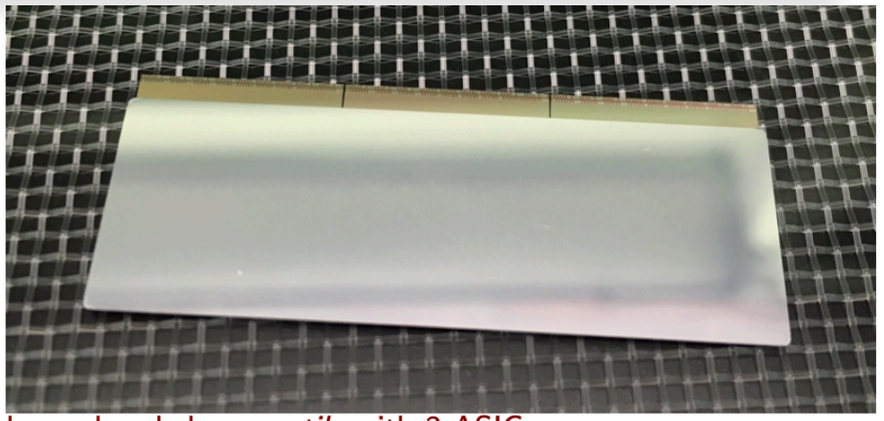


LHC orbit correction dipole MCBW ≈90% acceptance for channeled Λ_c^+ baryons
(Credits: Pascal Hermes, CERN)



Pixel detector for IR3 spectrometer

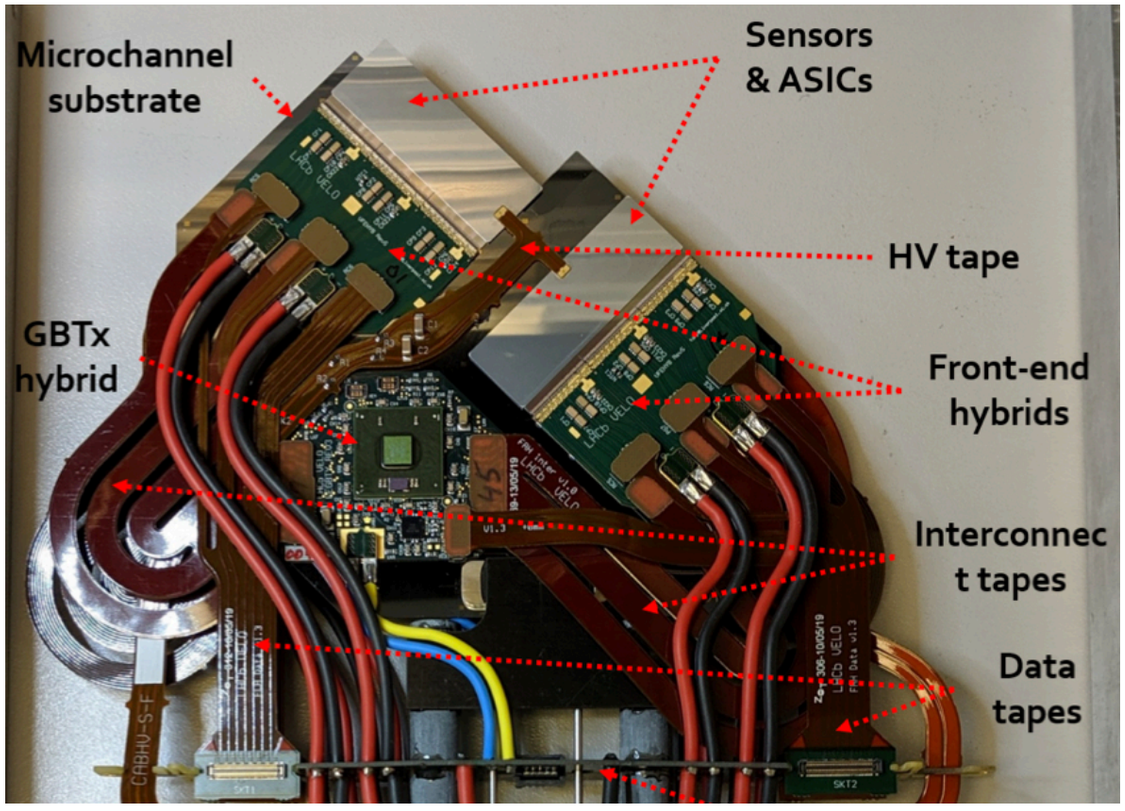
- **8 VeloPix tiles:** tile = silicon sensors bump-bonded to 3 ASICs (1.4x4.2 cm^2)

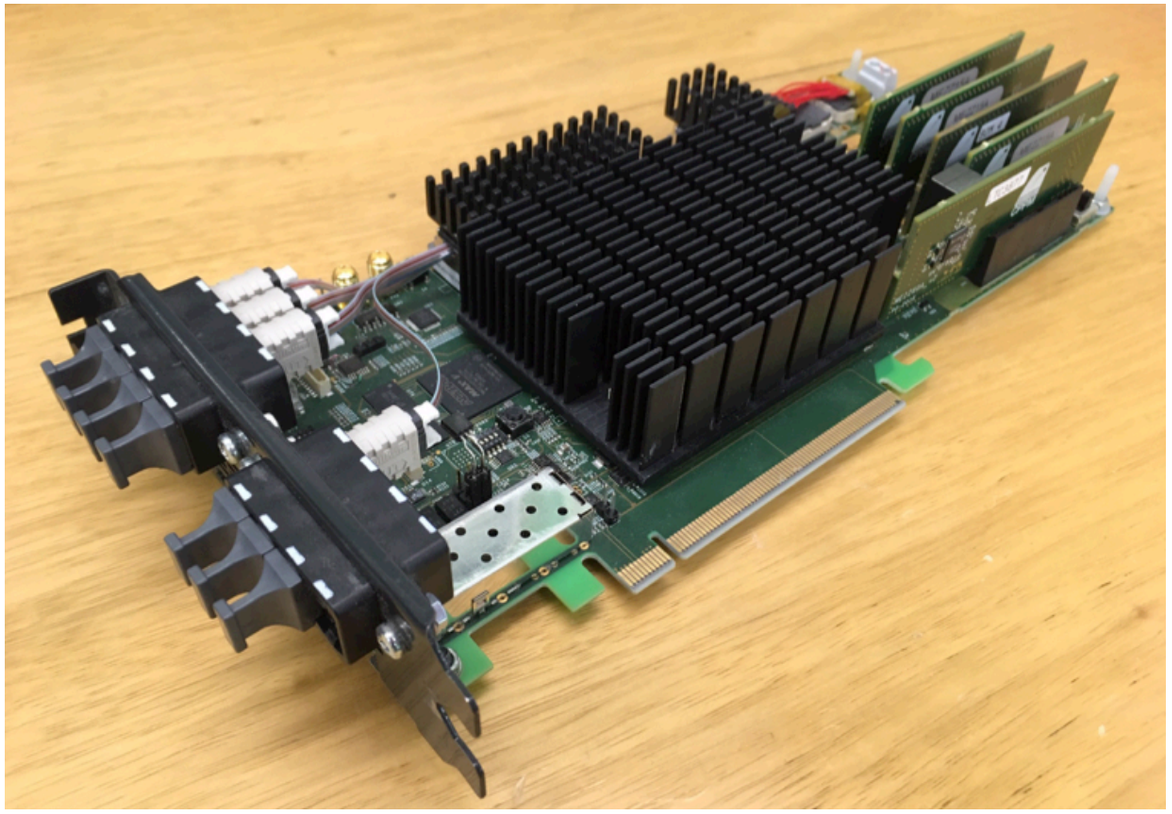


bump-bonded sensor *tile* with 3 ASICs

VeloPix modules inside Roman Pots
for Vertex and Tracker stations ~1 cm from the beam
55x55 μm^2 pixel, pixel hit rate 600 MHz/cm^2,
12 μm hit resolution

PCIe40 VeloPix readout board
FPGA Intel Arria 10
24 optical links
PCIe Gen3, max throughput 100 Gbit/s

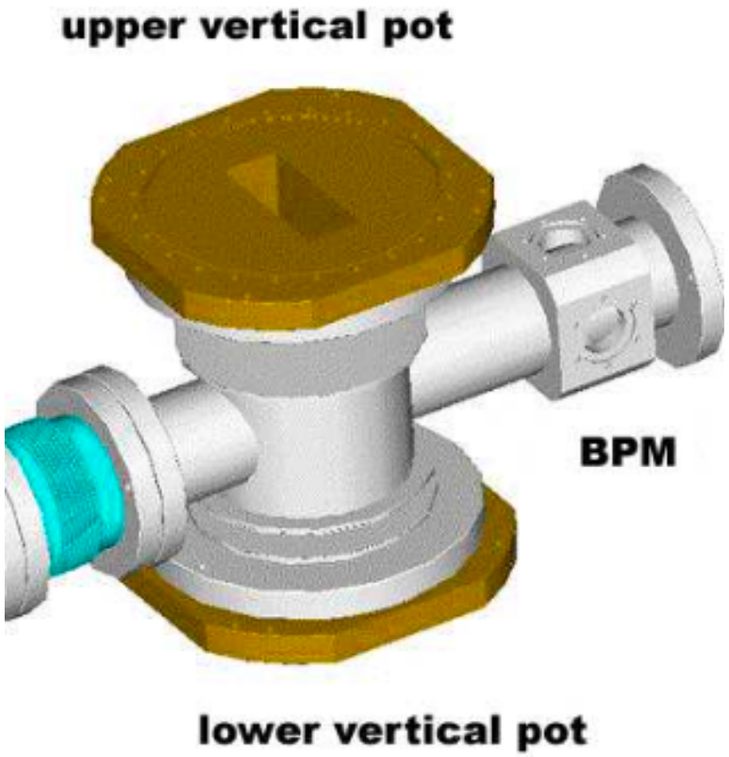


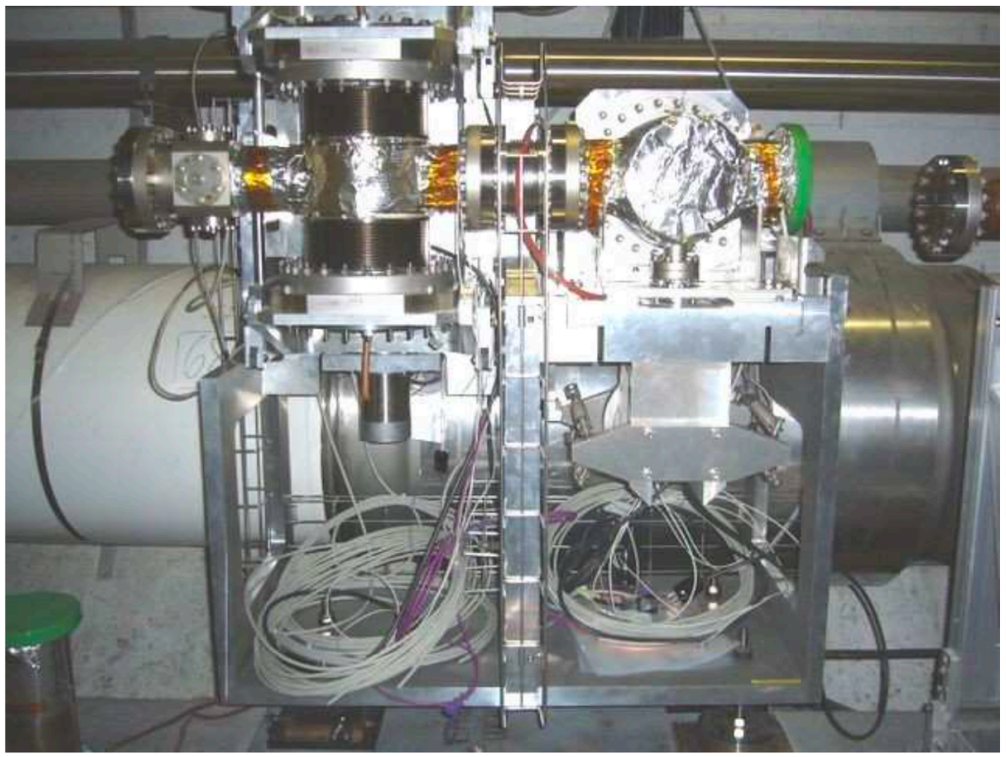


TOTEM Roman Pots

- 1 vertical unit equipped with micro-stepping motors is necessary for the proof-of-principle test at IR3
- 4 vertical units are required to build the spectrometer for the experiment. 2 stations before and 2 stations after the magnet

Roman Pot (50x124x105 mm^3)

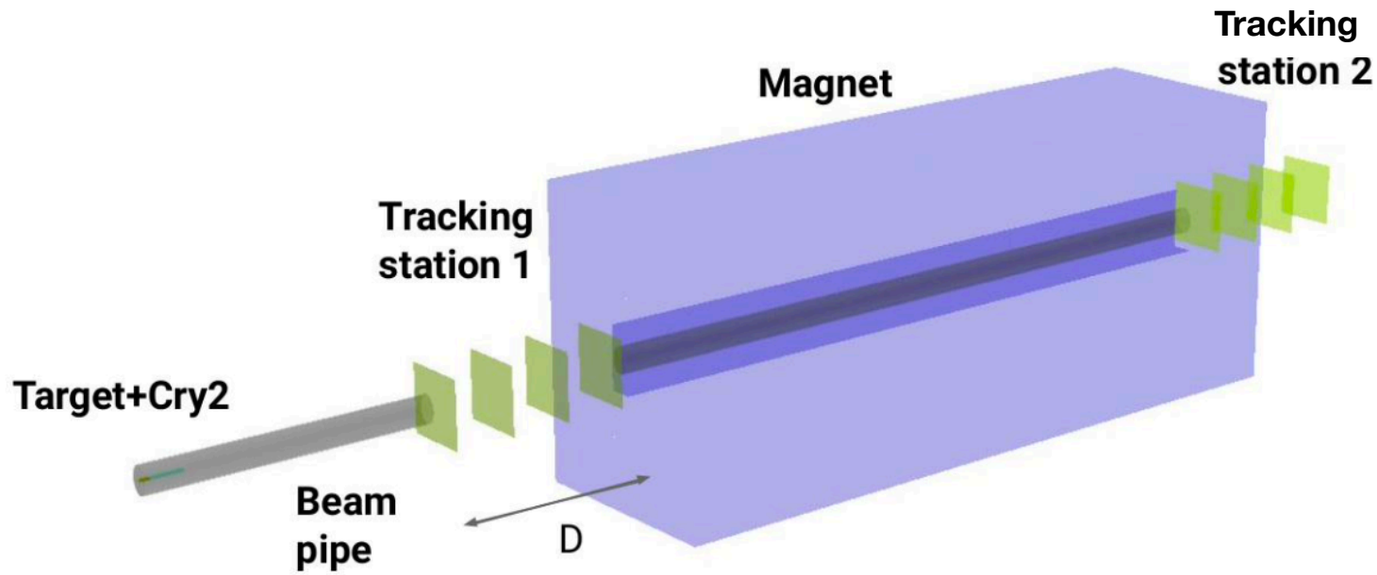




Simulation of IR3 test

Simulation framework

- Geometry based on DD4Hep
- Generators: Phythia/Angantyr model, particle gun, general particle source
- Visualisation: geoDisplay
- Event model: DDG4
- Channeling: Geant4
- Tracking: GenFit



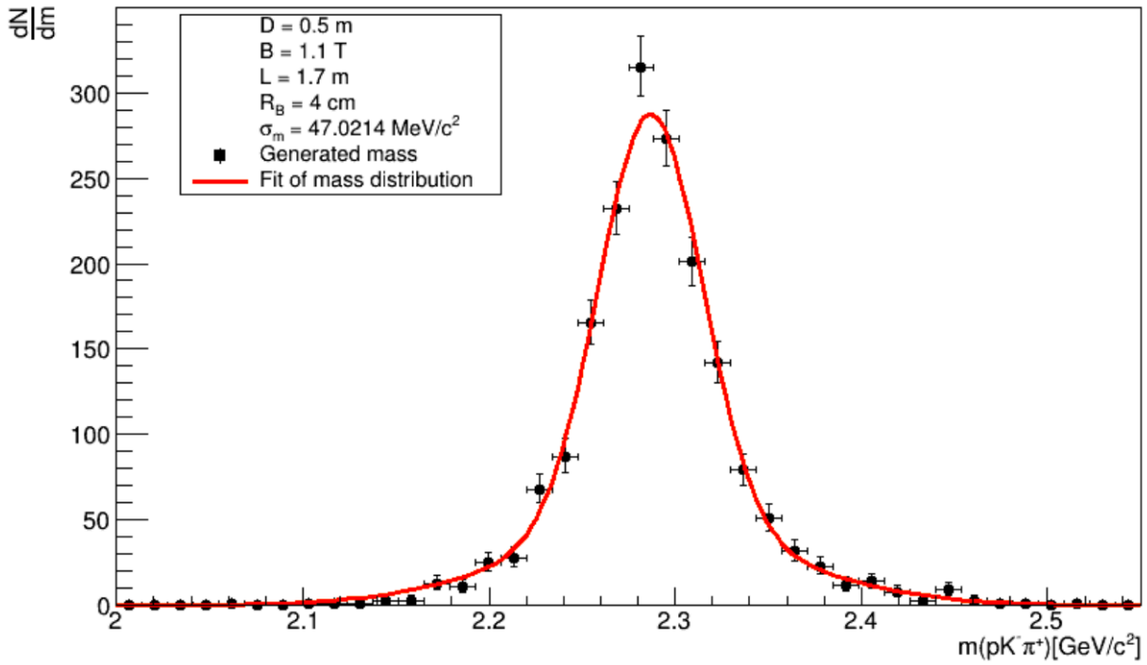
8 VeloPix modules: 4 before - 4 after magnet

- Pixel size = 55x55 μm^2

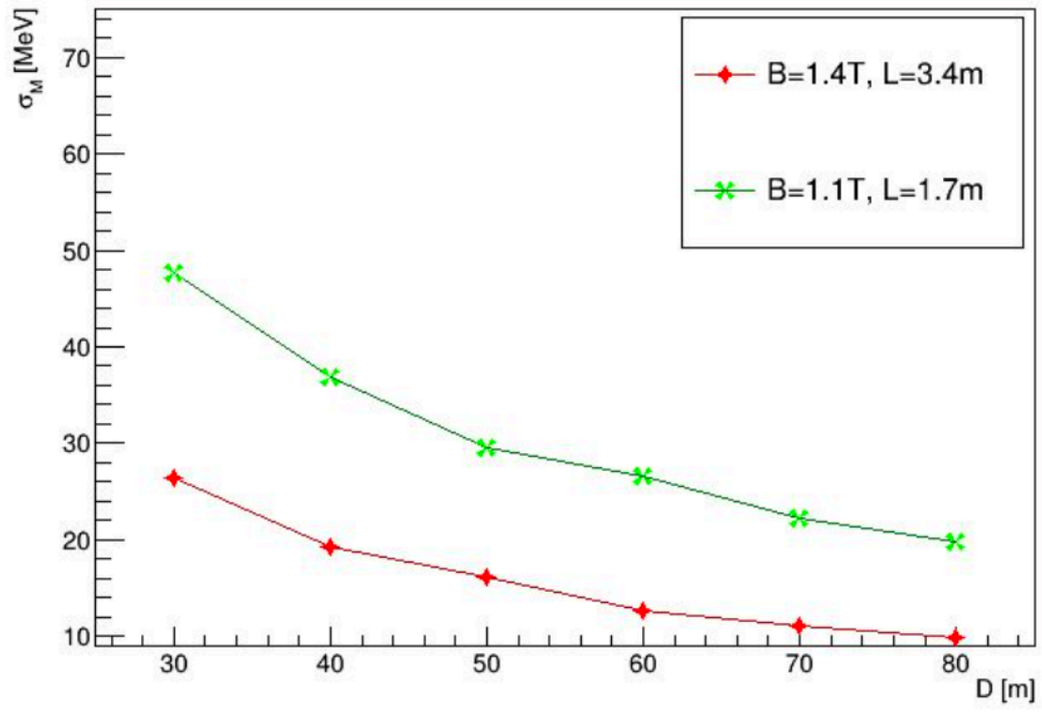
Magnet MCBWV: 1.7m, 1.1T

Simulation studies for IR3

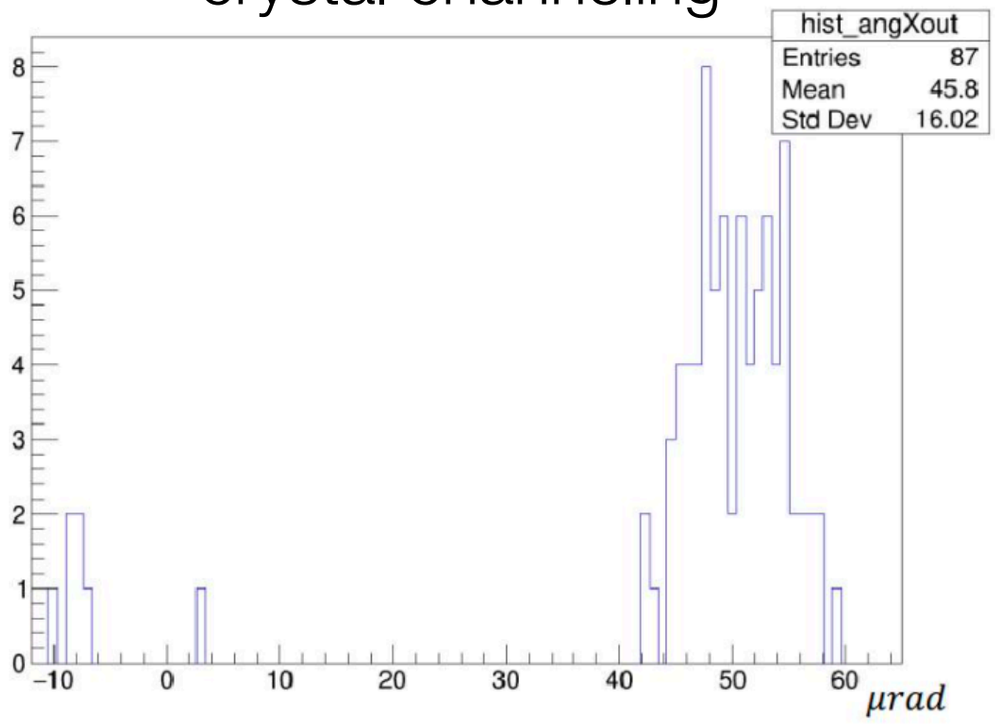
$m(pK^-\pi^+)$ distribution



$m(pK^-\pi^+)$ resolution *vs* spectrometer

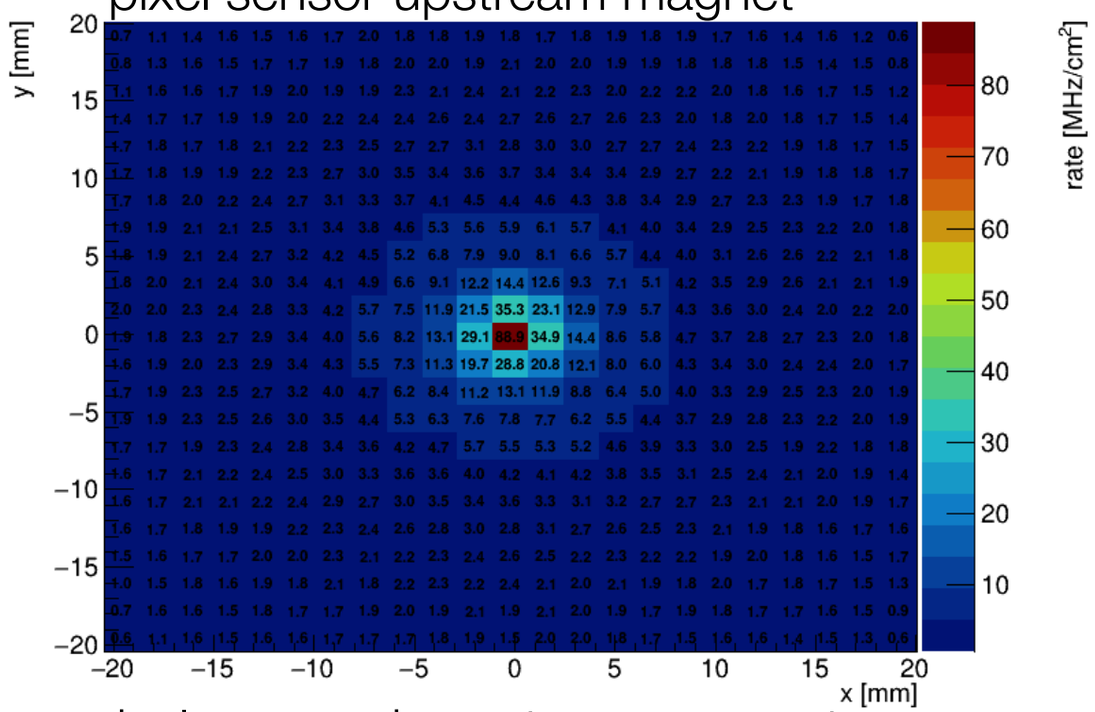


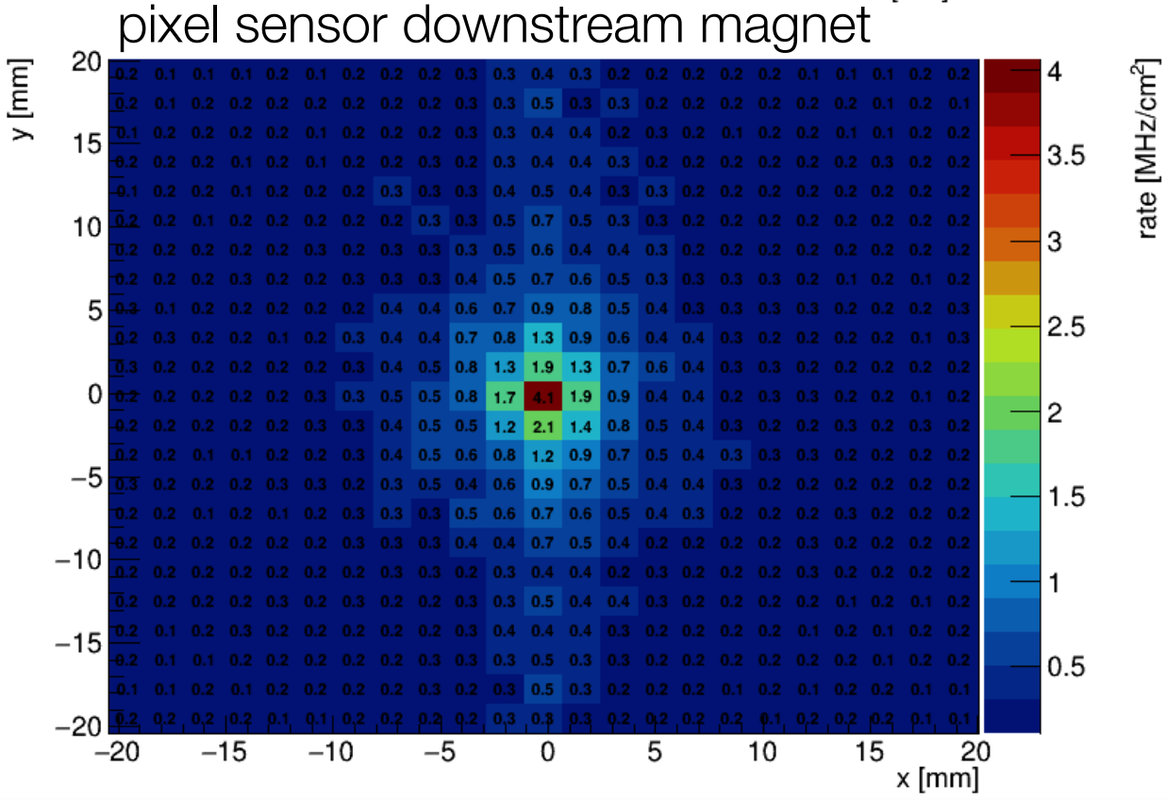
crystal channeling



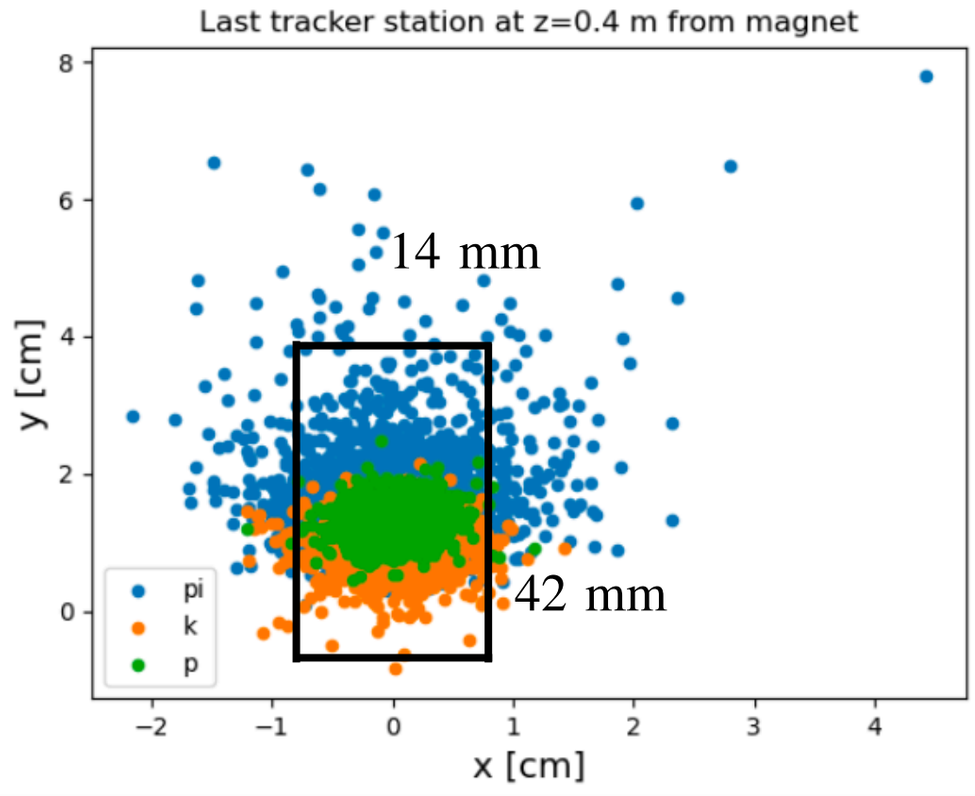
- Parametric simulations to estimate resolution on $m(pK^-\pi^+)$ vs tracker geometry and available in situ dipole magnet solutions
- Crystal channeling based on Geant4 simulations

Pixel sensors hit rate





- Simulations for 10^6 p/s on 2.0 cm W target
- Rate/area in pixel sensors before (top plot, <100 MHz/cm^2) and after the magnet (bottom plot, <10 MHz/cm^2)
- Hit distribution for channeled $\Lambda_c^+ \to pK^-\pi^+$ decays, Area ≈ few cm^2



Status and next steps

- First measurements of Λ baryon EDM/MDM started
- Machine **test in LHC** planned during Run3 for double channeling test (MoU signed between CERN/INFN in Dec 2022)
- Testbeams at CERN SPS for bent crystal validation for IR3 test: i) 23-30 August 2023, ii) summer 2024 (TBD)
- Interest of international scientific community for a **dedicated experiment** at LHC. LoI in progress and to be finalise this year
- Present the status of the activities at CSN1 next week (July 13th)

Conferences and workshops

2023

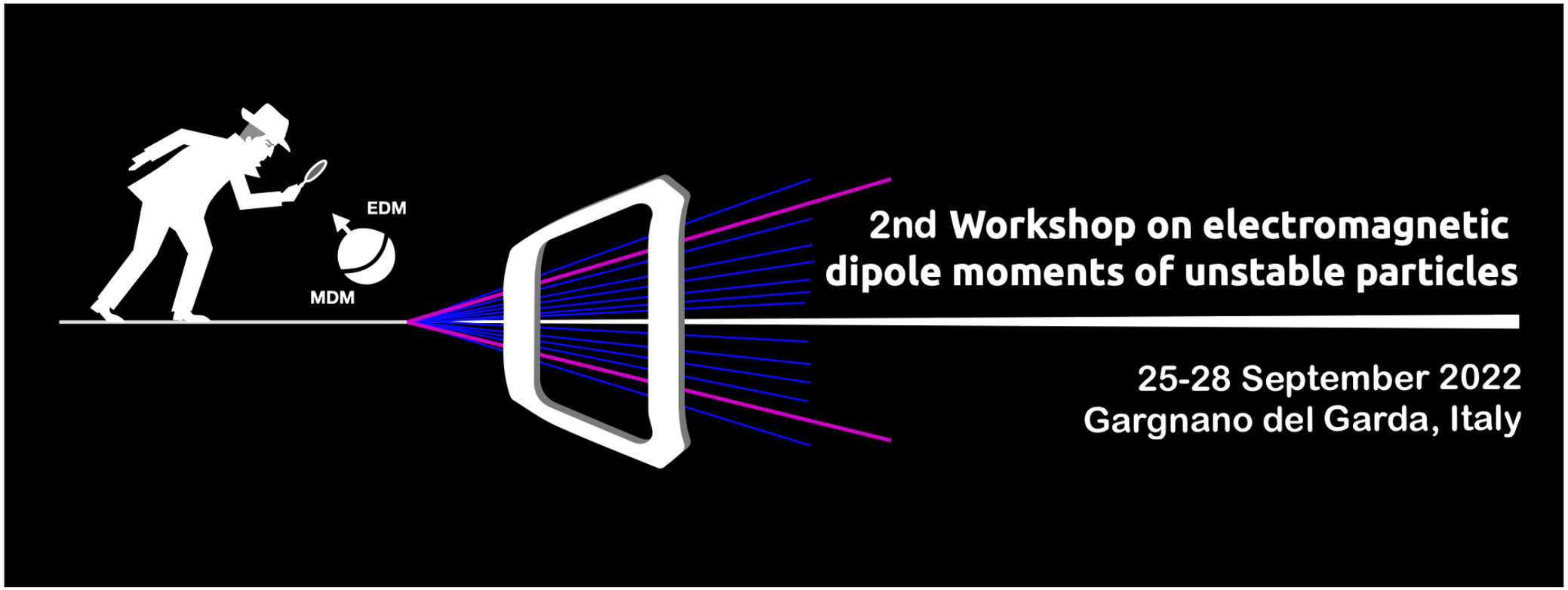
- ***Momenti di dipolo elettromagnetici di barioni con stranezza e charm a LHC***, **G. Tonani**, Incontri Fisica Alte Energie, Catania, 13 April 2023. Talk
- ***Heavy-ion and fixed-target physics at LHCb***, **A. Merli**, 57th Rencontres de Moriond QCD, 31 March 2023. Plenary talk
- **SELDOM (ERC): proposta test con due cristalli**, **N. Neri**, INFN CSN1 Meeting, 20-21 February 2023, Rome (Italy)
- **Electromagnetic dipole moments of strange and charm baryons at LHC**, **N. Neri**, Fixed-target experiments at LHC – strong 2020 workshop, 5-7 January 2023 Aussois (France)

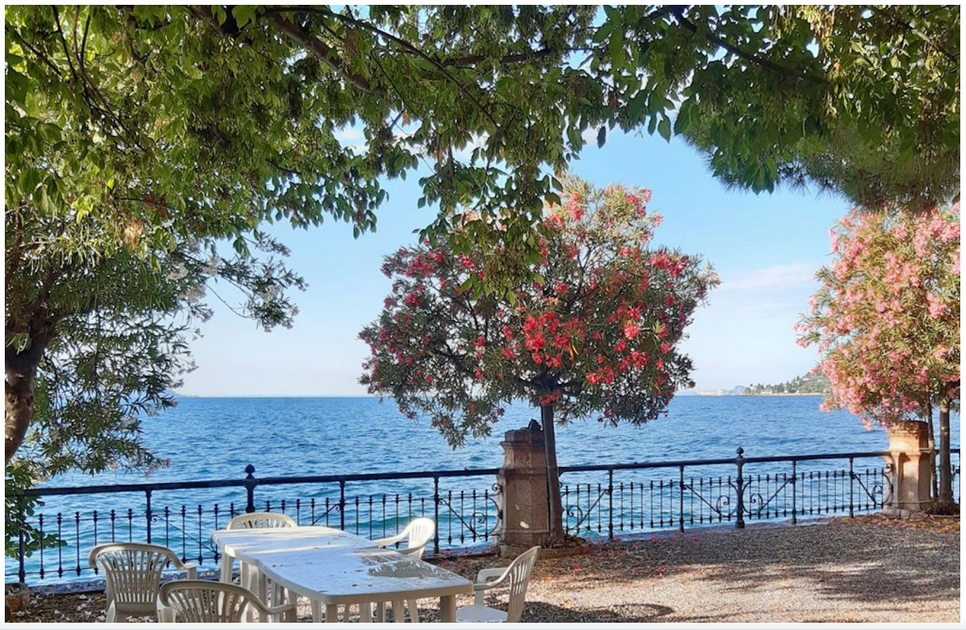
2022

- ***Towards the measurement of electromagnetic dipole moments of strange and charm baryons at LHC***, **G. Tonani**, Baryons 2022 Conference, Sevilla, 7-11 November 2022. Flash Talk
- **Physics opportunities with double crystal fixed-target setup**, **N. Neri**, Physics Beyond Collider Annual Workshop, 7-9 November 2022 CERN
- **Proposed measurements of electromagnetic dipole moments of strange and charm baryons at LHC**, **N. Neri**, NSTAR 2022, 17-21 Oct 2022, Santa Margherita Ligure (Italy)
- ***Charm baryon amplitude analysis and polarization measurements***, **D. Marangotto**, 2nd Workshop on electromagnetic dipole moments of unstable particles, Gargnano del Garda, Italy, 25-28 September 2022. Talk
- **2nd Workshop on electromagnetic dipole moments of unstable particles**, **N. Neri**, 25-28 Sept 2022, Gargnano del Garda (Italy).
- **Reconstruction of decay vertex for long-lived particles**, **G. Tonani**, 2nd Workshop on electromagnetic dipole moments of unstable particles, Gargnano del Garda, Italy, 25-28 September 2022. Talk
- **Overview of the IR3 proof-of-principle test and beyond**, **E. Spadaro Norella**, 2nd Workshop on electromagnetic dipole moments of unstable particles, 25-28 Sept 2022, Gargnano del Garda (Italy). Talk.
- **Possibility of spin precession in high-field magnet**, **A. Merli**, 2nd Workshop on electromagnetic dipole moments of unstable particles, 25-28 Sept 2022, Gargnano del Garda (Italy). Talk
- **Direct measurement of electromagnetic dipole moments of strange and charm baryons**, **N. Neri**, LFC22: Strong interactions from QCD to new strong dynamics at LHC and future colliders, Aug 29 – Sept 2 2022, ECT* Trento (Italy)

Topical workshop in Gargnano

- Agenda of the workshop at this link





Topical workshop in Gargnano

- Agenda of the workshop at this link

Theses

***Simone Libralon*, Master Thesis, 2022**

- Measurement of Xi+c baryon polarisation in pp collisions at LHCb

***Federico Zangari*, Bachelor Thesis, 2022**

- Feasibility study for an experiment to mesure charm baryon dipole moments at LHC

Attivita' 2024

Personale	FTE	LHCb (FTE)	IGNITE (FTE)	SELDOM (FTE)	Inquadramento		Servizio Meccanica	Servizio Elettronica
Cesare	1,0	1,0		0,0	Dottoranda		4 m.u.	4 m.u.
Citterio	0,1	0,1		0,0	Dirigente Tecnologo		0 m.u.	0 m.u.
Coelli	0,2	0,1		0,1	Primo Tecnologo		2 m.u.	2 m.u.
Frontini	0,8	0,3	0,5		AR UNIMI			
Gandini	1,0	0,8		0,2	Ricercatore			
Liberali	0,2	0,1	0,1		PA			
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 UNIMI			
Neri	1,0	0,4		0,6	PA			
Redi	1,0	1,0			RTD-B UNIBG			
Riboldi	0,2	0,2			PA			
Spadaro	1,0	1,0		0,0	AR UNIMI			
Stabile	0,7	0,2	0,5		RTD-B UNIMI			
Tonani	1,0	0,0		1,0	Dottoranda (UE)			
M. Wang	1,0	1,0		0,0	PosDoc INFN stranieri			
Tot. (FTE)	12,2	8,2	1,1	2,9				

- SELDOM 2.7 FTE in 2022 → 2.9 FTE in 2023
- A new PostDoc 100% on SELDOM will be hired in July 2023 (not included in the FTE)
- Project has been extended until 31 March 2025 (24 month extension for the LHC delay in data taking due to the pandemic)

Progetto PRIN 2022

Finanziato dall'Unione europea
NextGenerationEU

Ministero dell'Università e della Ricerca

Segretariato Generale

Direzione Generale della Ricerca

PRIN: PROGETTI DI RICERCA DI RILEVANTE INTERESSE NAZIONALE – Bando 2022
Prot. 202277EWLW

- Finanziato sviluppo per futuro esperimento dedicato a LHC per la misura di momenti di dipolo di fermioni pesanti (231 kEuro)
- Persone coinvolte (mesi uomo): **PI Neri** (8), Spadaro Norella (8), **AI Gandini** (8), Citterio (4), Coelli (6)
- WP1: simulation studies
- WP2: Experimental setup (spectrometer with silicon pixel detectors inside Roman Pots)

Attività 2024 e richieste servizi di sezione

- Costruzione rivelatori a pixel per spettrometro
- Progettazione cavi e circuiti ibridi (modifica disegni esistenti)
- Sistema di cooling per rivelatori ed elettronica di front-end
- Integrazione rivelatori in Roman Pot
- Disegni tecnici per sensori e Roman Pot
  - **2 m.u. servizio elettronico**
  - **2 m.u. servizio progettazione e officina meccanica**
  - **10% Coelli**