



LHCb

SELDOM + TWOCRIST

status report



European Research Council
Established by the European Commission



Paolo Gandini

On behalf of the LHCb Milano group

8th July 2023



Outline

The group is active on many fronts!

Little time so I will cover only the basics

Synergic work on many different projects

- **LHCb**
- **SELDOM**
- **SELDOM_TWOCRIST (sotto dotazioni gr1)**

Website

https://web.infn.it/lhcb_milano/



ABOUT US

RESEARCH

PUBLICATIONS

CONFERENCE CONTRIBUTIONS

THESIS

EVENTS



New members of the group

- Theraa Tork (fondi SELDOM)



- Ziyi Wang (fondi SELDOM)



- Tianyu Xing (fondi PRIN UNIMI)



- Postdoc (fondi PRIN INFN)
Will start early Autumn



LHCb Physics

CKM and
CP violation

$\sin 2\beta$, γ , ϕ_s , $|V_{ub}/V_{cb}|$, CPV in B^0 , B_s^0 , D^0 , b-baryons, etc

Rare decays

$B_{(s)}^0 \rightarrow \mu^+ \mu^-$, $b \rightarrow s \mu^+ \mu^-$, $b \rightarrow s e^+ e^-$, $\Sigma^+ \rightarrow p \mu^+ \mu^-$, etc

Spectroscopy

Tetraquarks, Pentaquarks, Ξ_{cc}^{++} , Ω_c^* , Ξ_b^{*-} , ...

Electroweak
QCD and Exotica

Z^0 , W^+ , top, Dark photons, Long-lived particles, ...

Ion, Fixed-target

Heavy ions, p-Gas, nuclear effects, ...

Active on several topics,
but expanding...

T-Tracks

- We made LHCb a detector for long-lived BSM particles
- Tracking volume extended to 7.6m in z
- Novel technique never used so far in LHCb
- This is one of the goal of SELDOM project (in LHCb)
- Part of the PhD work by Giorgia Tonani for the dipole moment measurements of the Λ

<https://arxiv.org/abs/2211.10920v1>

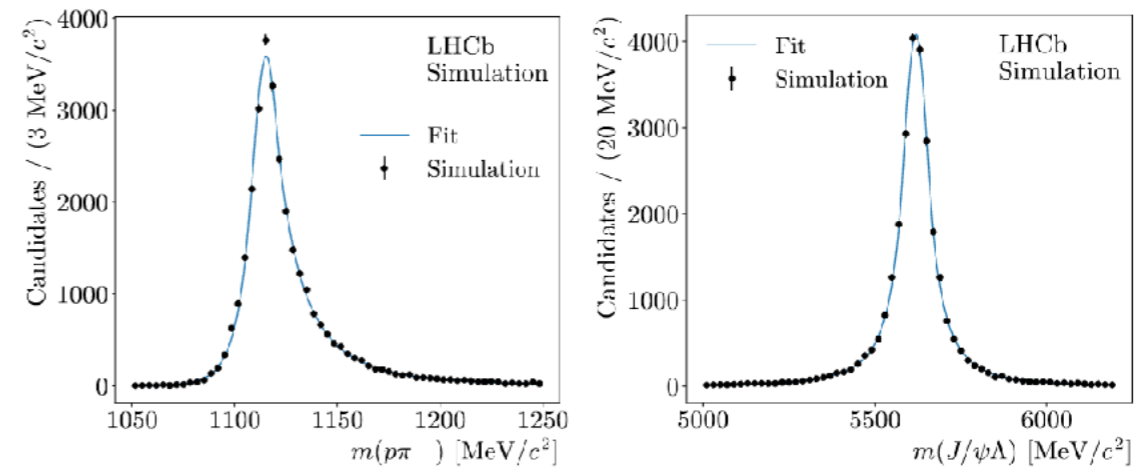
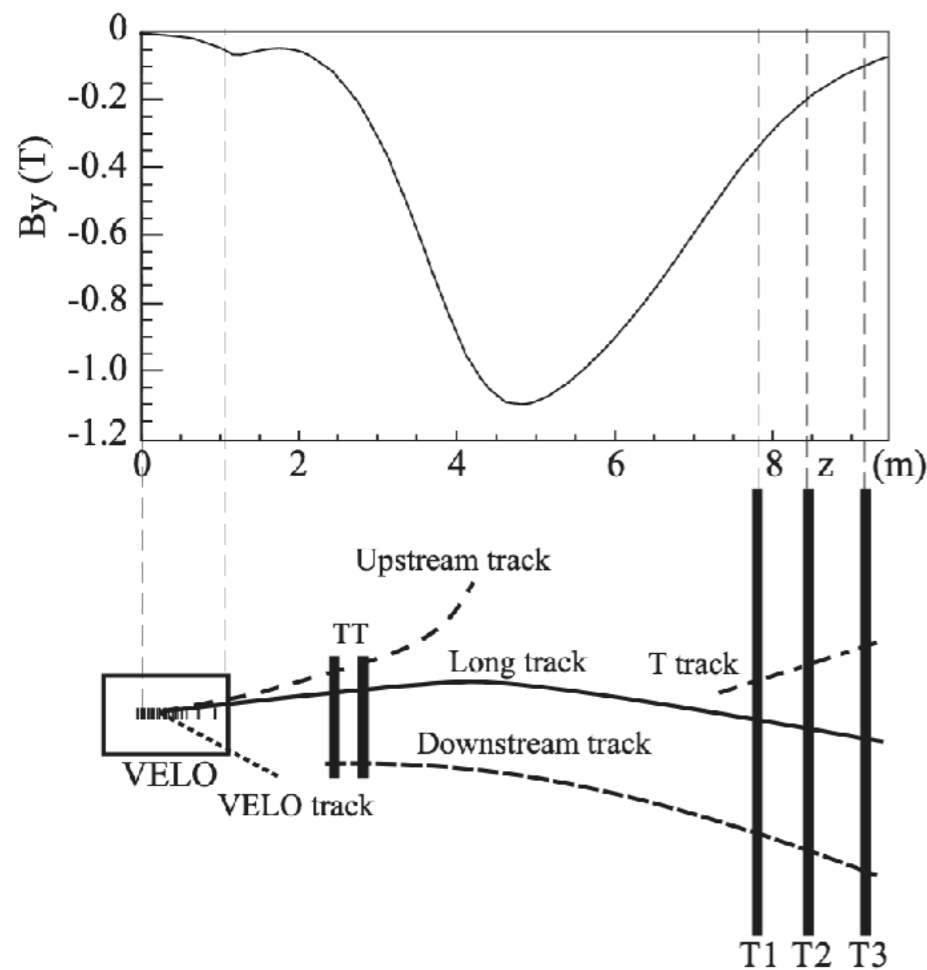


Figure 4: Invariant-mass distribution (left) $m(p\pi^-)$ and (right) $m(J/\psi\Lambda)$ for simulated $\Lambda_b^0 \rightarrow J/\psi\Lambda$ signal decays. Blue points with error bars represent the simulation, and the overlaid (orange) curves are the results of the mass fits.

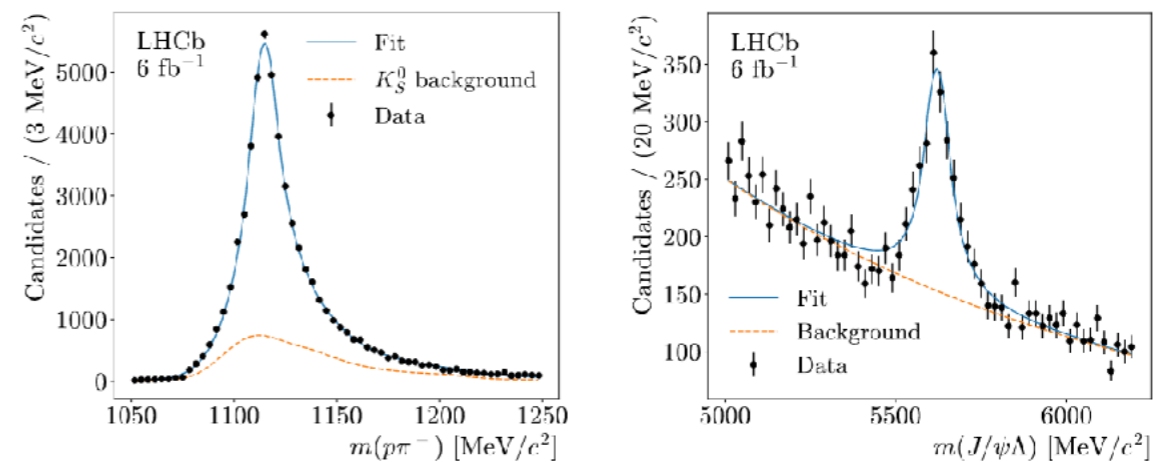


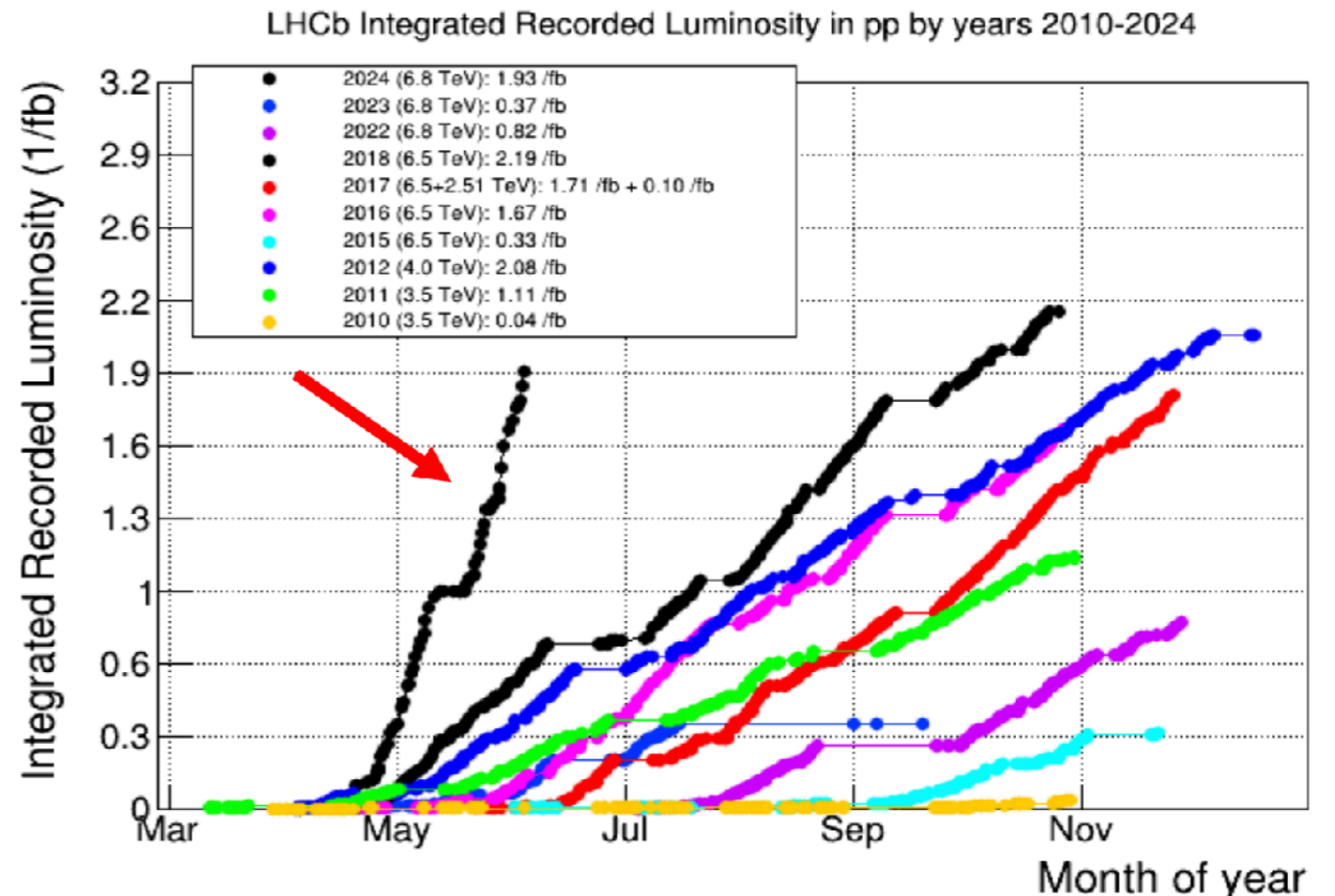
Figure 5: Invariant-mass distribution (left) $m(p\pi^-)$ and (right) $m(J/\psi\Lambda)$ for $\Lambda_b^0 \rightarrow J/\psi\Lambda$ candidates reconstructed using Run 2 data after all selection criteria. The results of the mass fits are superimposed.

LHCb

Slide taken from LHCb week, as 7th June 2024

- Not yet at the final steepness, but already quite impressive
- Remember that in 2023 we recorded a few hundred pb^{-1} , and in 2024 we are already now an order of magnitude above and with much improved data quality (and closed VELO)

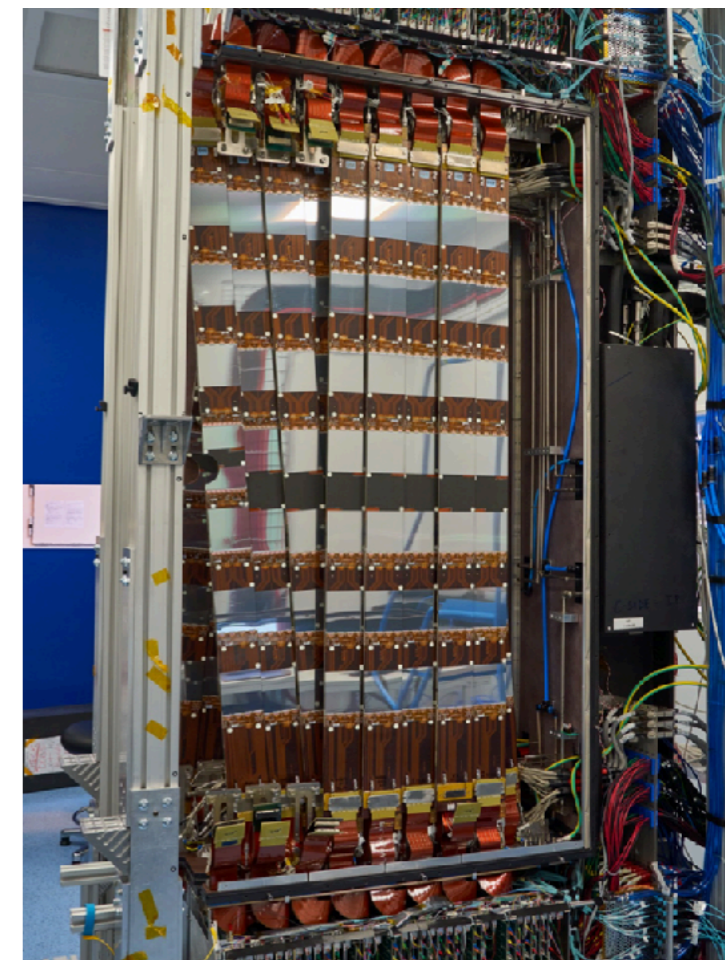
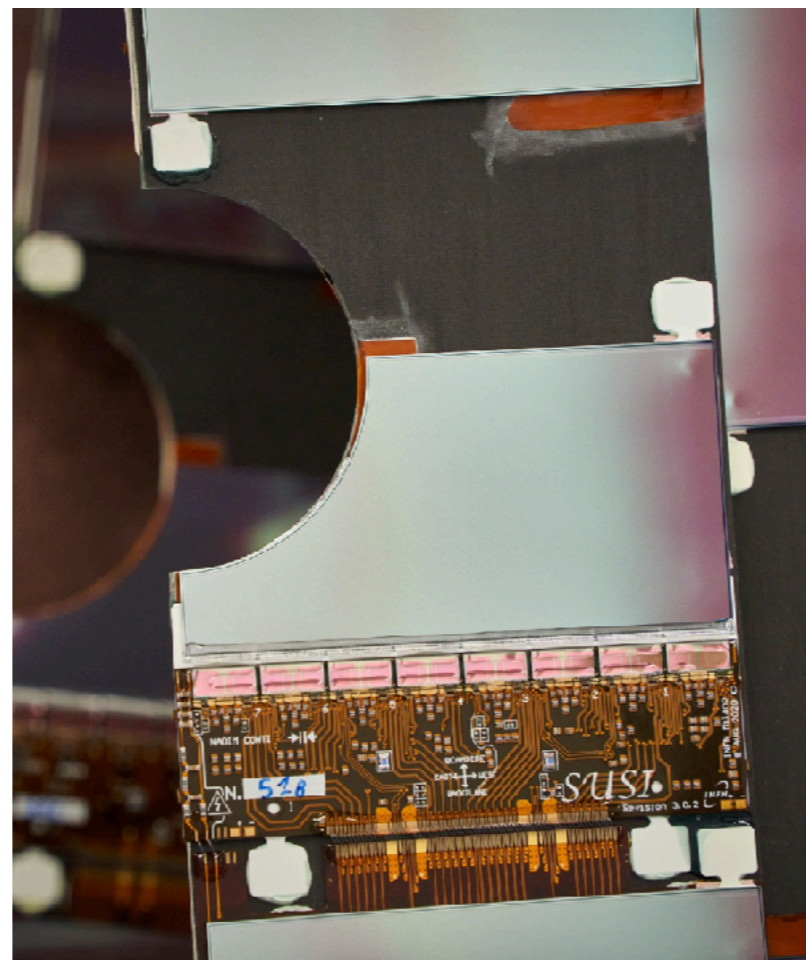
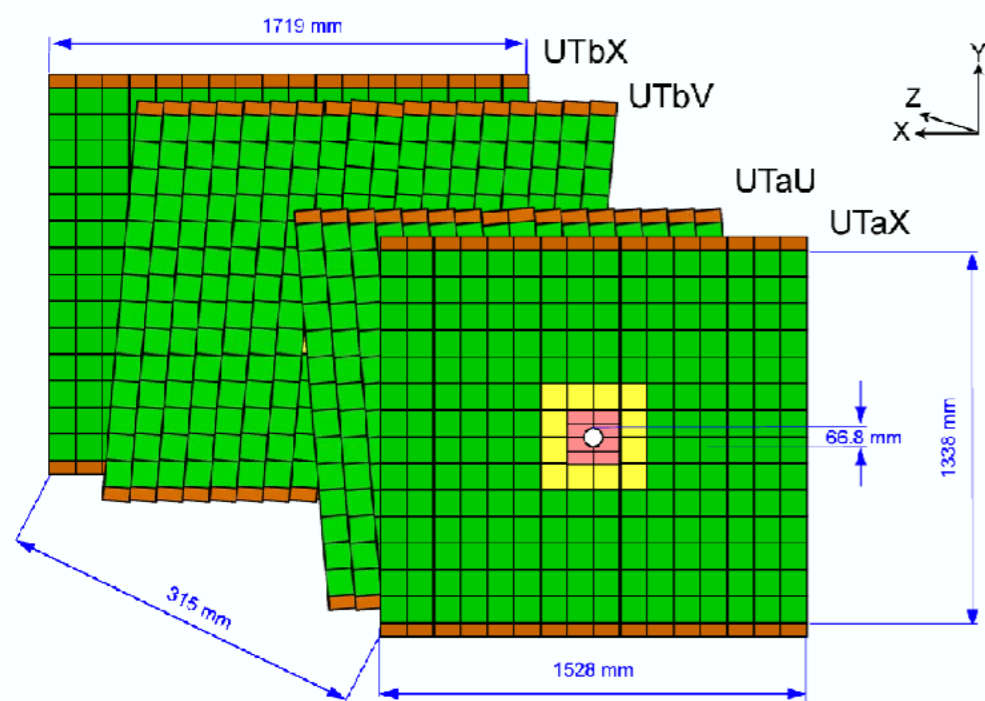
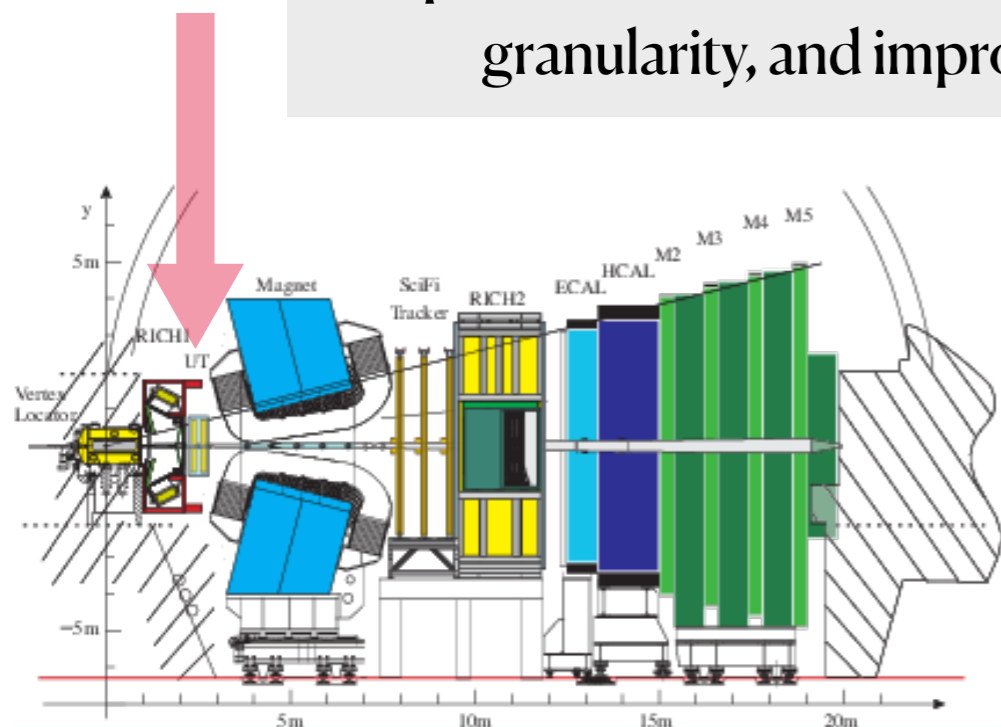
+UT is working
(See later in the talk)



Upstream Tracker installed successfully

A reminder of what that is:

4 planes of silicon detectors with improved radiation hardness, finer readout granularity, and improved acceptance coverage at small polar angles



Upstream Tracker installed successfully

- UT installation completed in March 2023 + initial commissioning (but beam-time was limited)
- Commissioning resumed again with 2024 beam
- Milan put on the online monitoring + piquets + bad channel monitoring
- Initial problems with stability of DAQ → fixed and/or mitigated with several daq strategies
- Improvements in every aspect of the data acquisition + time alignment OK+ spatial alignment OK

- **Now we are able to be included in global → great (and fast) achievement**
- **Upstream Tracker is successfully operating**
- **Milan has contributed to the design & construction of the detector in the last 10 years:**
- **Flex cables, hybrids, module construction, CO2 cooling**

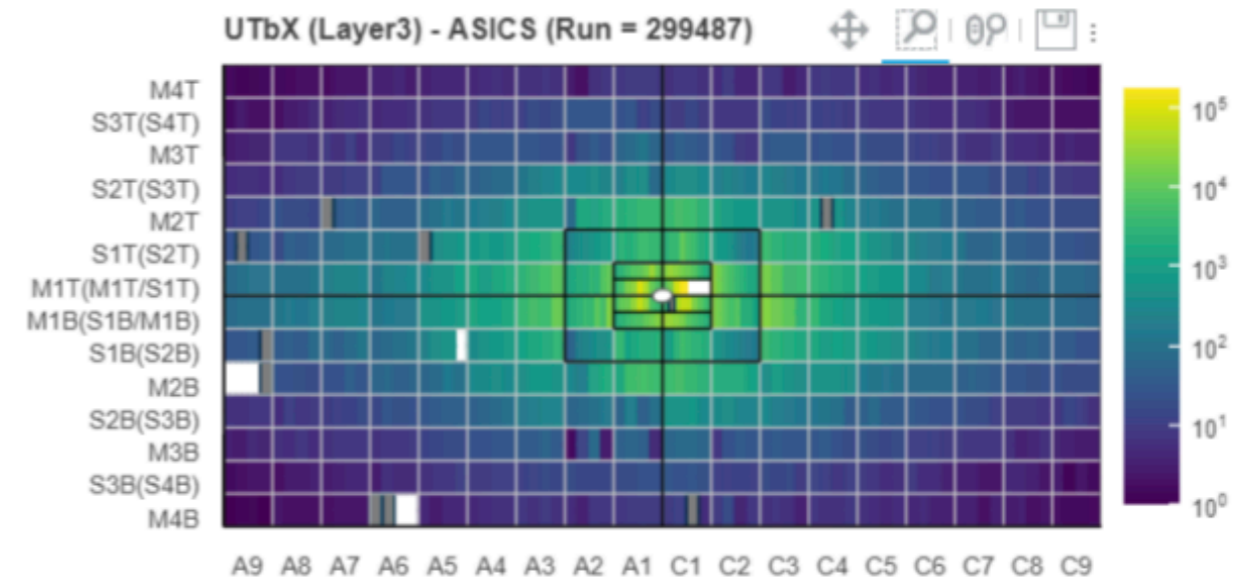
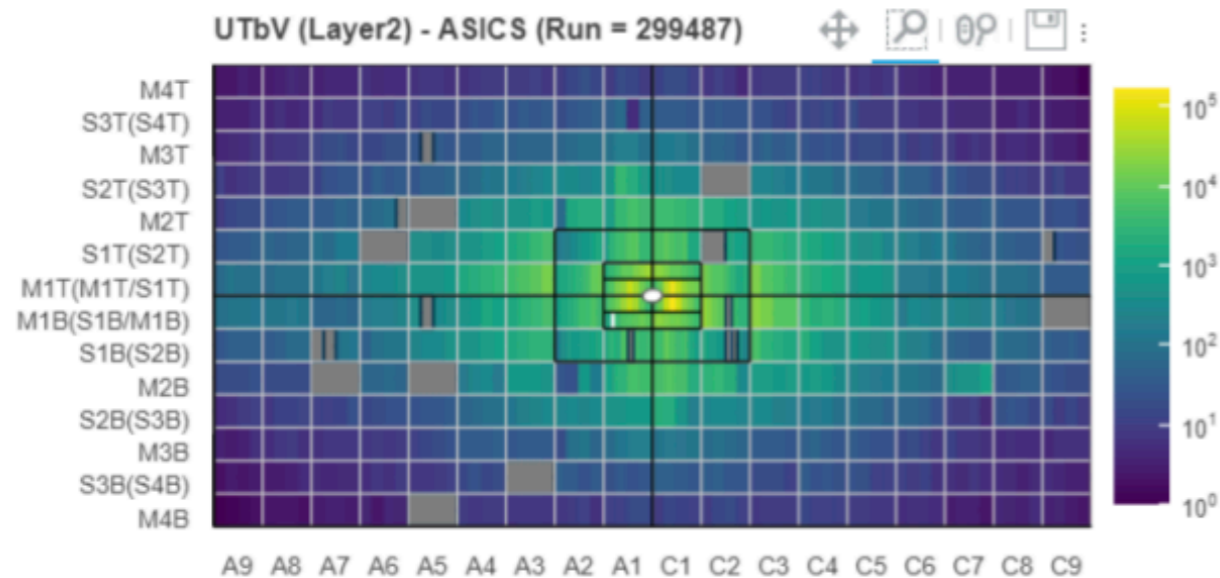
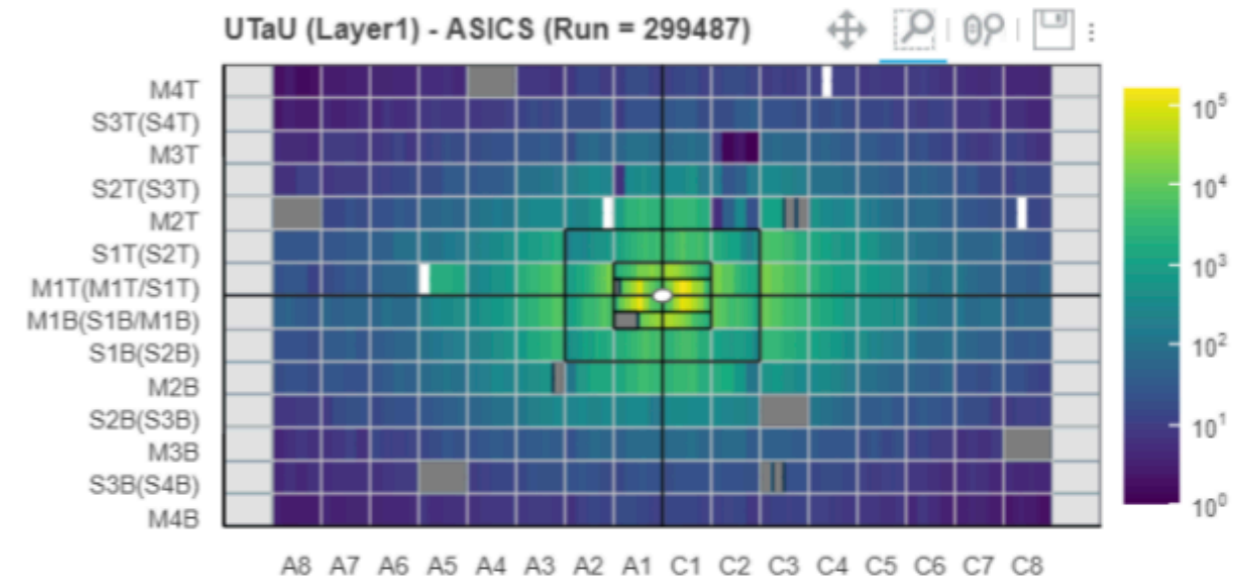
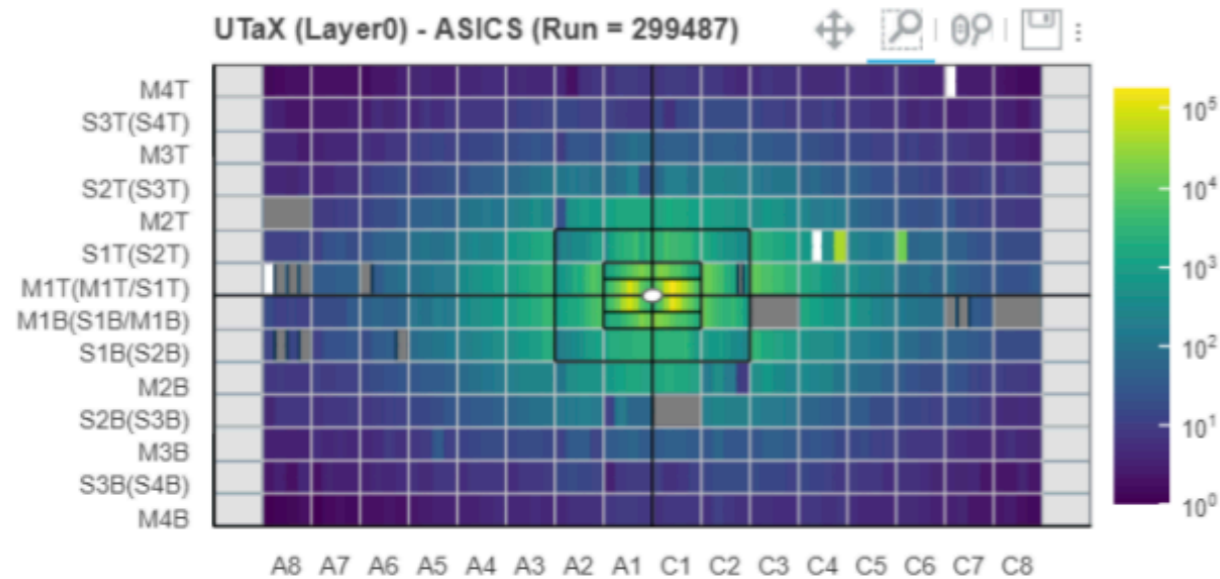
- As for now, all work delivered by Milan is showing reliable operation
- E.g. not a single bond by Milano failed!
- UT is crucial for the whole LHCb collaboration → effort recognized by LHCb management

Upstream Tracker in global: hitmaps

UT is GLOBAL from Run #299487

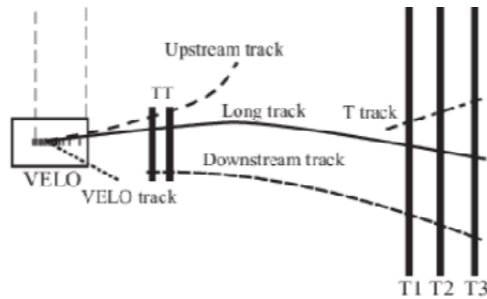
Online monitoring developed and managed by P. G.

OnlineMon/UT/ZS/Occupancy_Chips

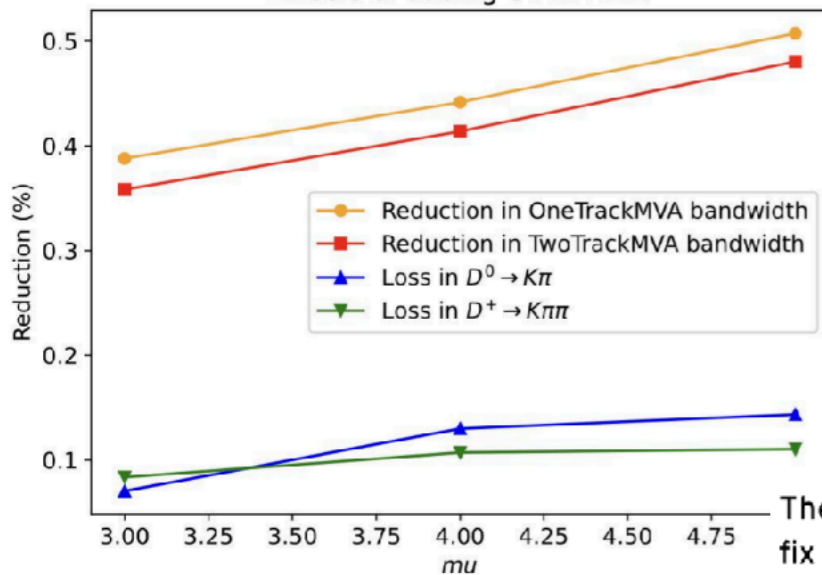


Upstream Tracker in global: performance

- In brief: UT is now in global with little to none close supervision
- **After June TS, UT has been included in HLT2 in Upstream and Downstream, and via Match approach in Long tracks**
- All WGs are requested to check the impact on control samples
- DQ is now active on UT quantities

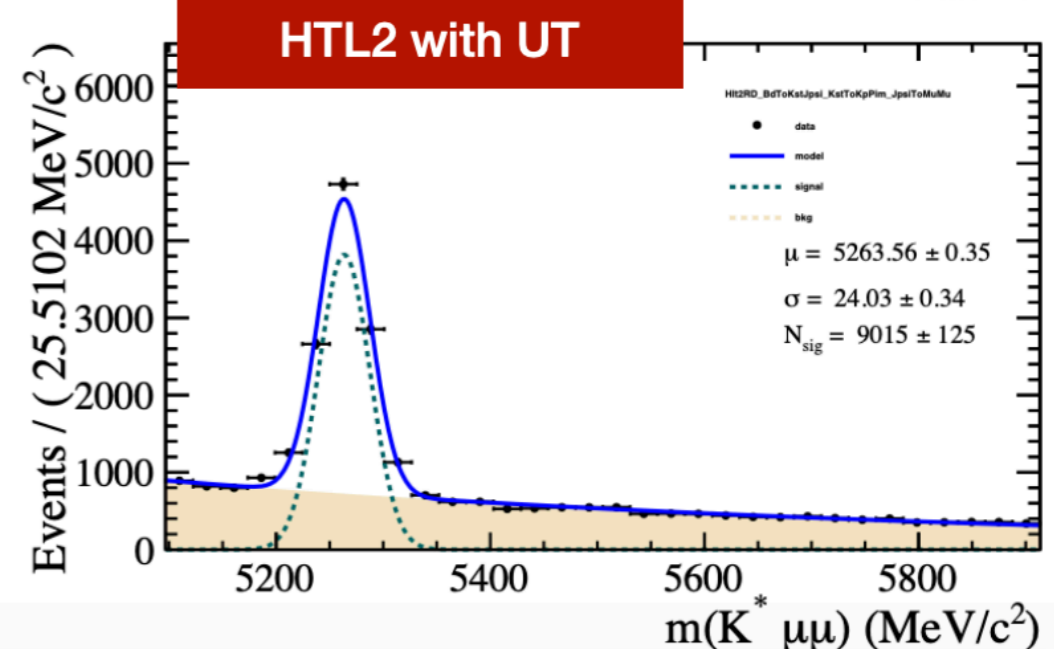
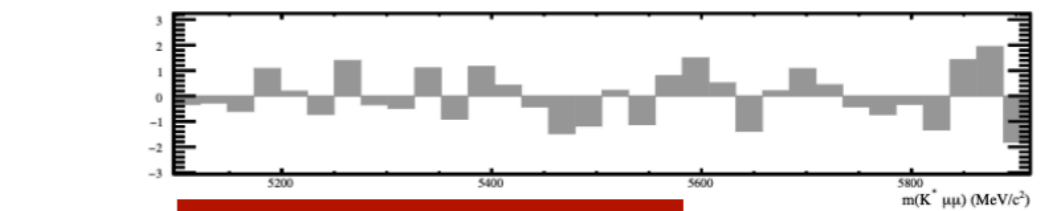
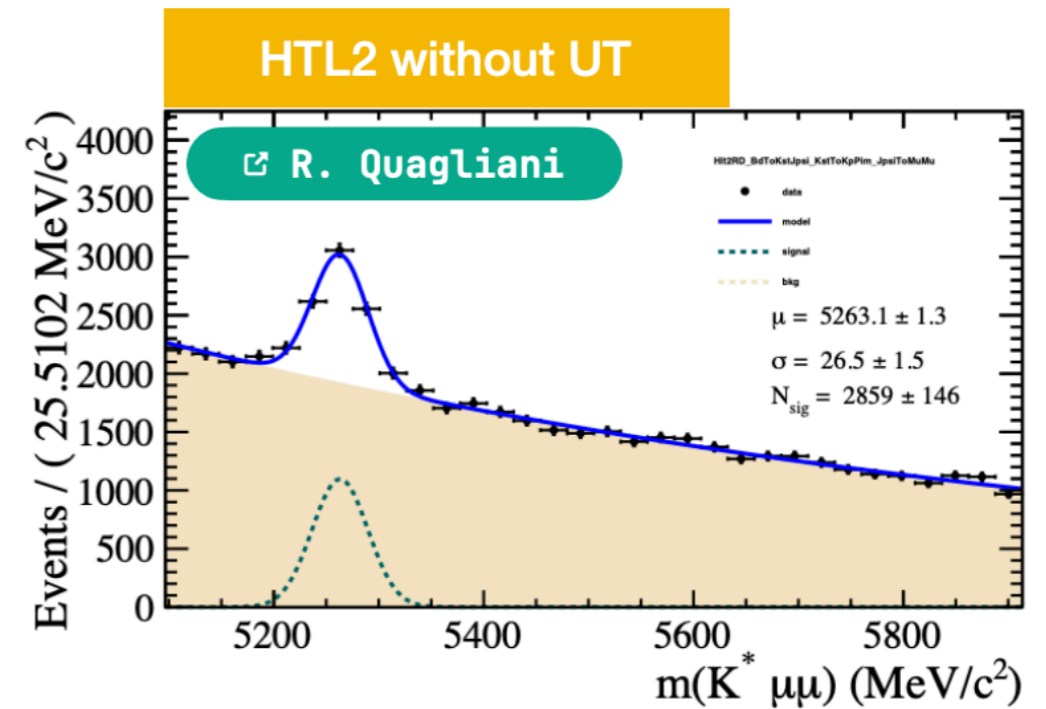


Effects of adding UT in HLT1



The efficiency loss has been understood, and its fix is in the way.

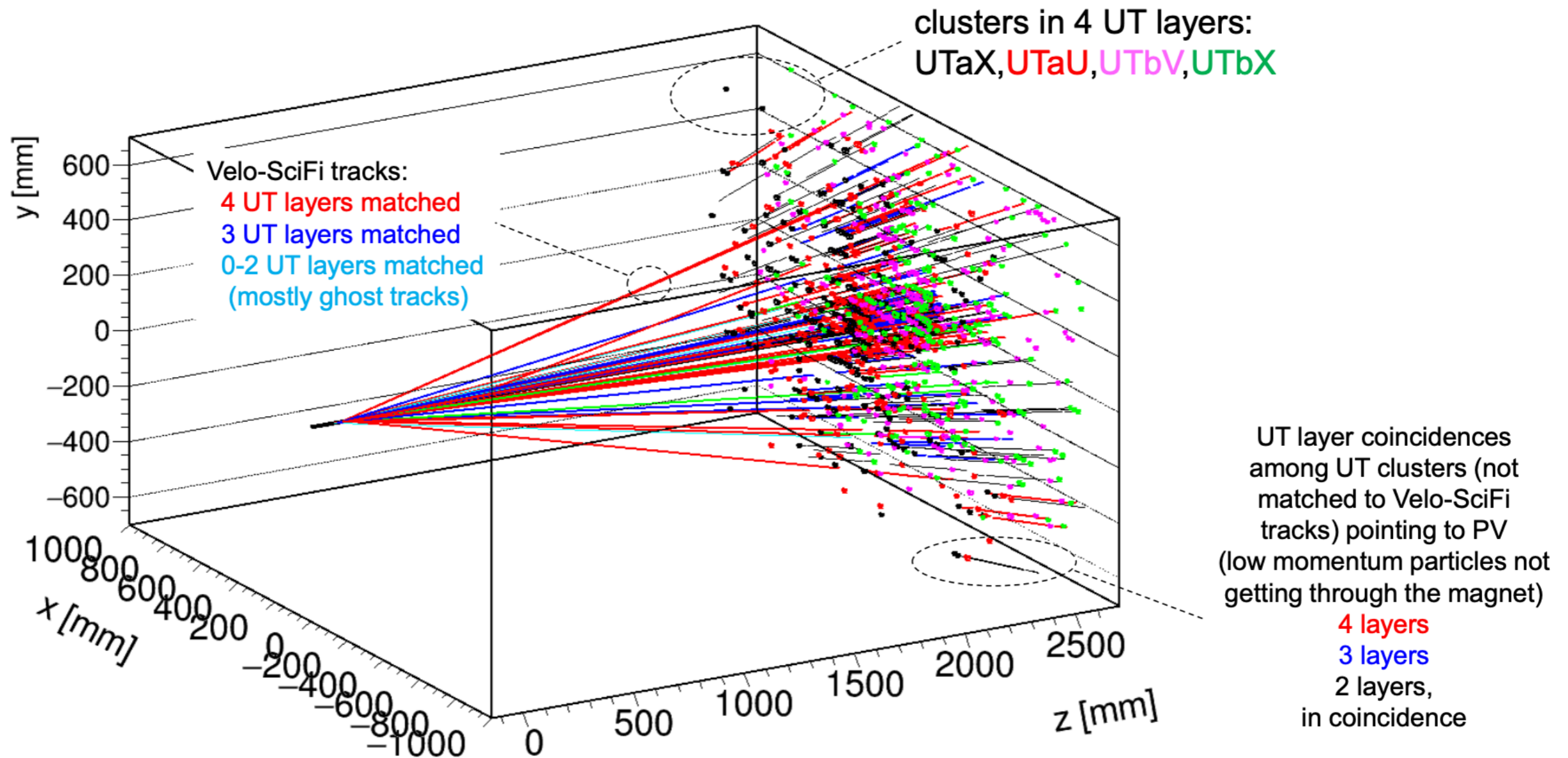
- HLT1 tracking very sensitive to space alignment. Efficiency loss likely due to hardcoded geometrical constants. Now adding implementation to respect space alignment conditions.



Upstream Tracker in global: events

3 PVs, 50 Velo-SciFi tracks (high momentum charged particles getting through the magnet)

Run 295293 Event 9782243 nPv 3 zPv -3 mm nTr 50 nUT 1126 BXType 3 BXID 2782



Published/Completed results since last CdS

- R. Aaij et al. (LHCb Collaboration)
Observation of a $J/\psi\Lambda$ Resonance Consistent with a Strange Pentaquark Candidate in $B^- \rightarrow J/\psi\Lambda^- p$ Decays
Phys. Rev. Lett. 131, 031901 – Published 17 July 2023
- R. Aaij et al. (LHCb Collaboration)
Amplitude analysis of the $\Lambda_{c^+} \rightarrow pK^-\pi^+$ decay and Λ_{c^+} baryon polarization measurement in semileptonic beauty hadron decays
Phys.Rev.D 108 (2023) 1, 012023 - Published: Jul 1, 2023
- Amplitude analysis of the $\Xi_{c^+} \rightarrow pK^-\pi^+$ decay and Ξ_{c^+} baryon polarization measurement in semileptonic beauty hadron decays
(completata) analisi di Daniele Marangotto
- R. Aaij et al. (LHCb Collaboration)
The LHCb Upgrade I
JINST 19 (2024) 05, P05065 - Published: May 23, 2024

PRL
Editor's Suggestion

Thesis

- Tesi di laurea magistrale in Fisica
M. Andre' Botas, Universidade de Lisboa, Portogallo (studentessa Erasmus)
Simulations for charm baryon dipole moment experiment at the LHC

Conference contributions

P. Gandini. Invited talk. LHCb on technical aspects how to search and find resonances, also using AI technique

WPCF 2023, Catania, Italy

<https://agenda.infn.it/event/33324/contributions/214266/>

N. Neri. Prospects for future experiments: physics reach and experimental challenges

Novembre 2023, Roma. Workshop italiano sulla fisica ad alta intensità.

D. Marangotto. Classical and Exotic Spectroscopy at LHCb

La Thuile, Italy, 03 - 09/03/2024. Plenary talk <https://agenda.infn.it/event/38205/>

G. Tonani Measurement of dipole moments of Lambda baryon at LHCb EDMs Complementary experiments and theory connections workshop

4-8/03/2024, ECT* Trento

<https://indico.ectstar.eu/event/199/contributions/4485/>

G. Tonani. Progress towards the measurement of the electromagnetic dipole moments of the Λ baryons at LHCb,

NSTAR 2024, 17-21/06/2024, York (UK), <https://indico.jlab.org/event/729/contributions/14458/>

N. Neri. Advancements in Experimental Techniques for Measuring Dipole Moments of Short-Lived Particles at the LHC

16th Pisa Meeting on Advanced Detectors, La Biodola - Isola d'Elba, 27 May 2024

N. Neri. Measurements of electromagnetic dipole moments of unstable particles

LHCPBC Meeting 2024, Physics Beyond Collider Annual Workshop, CERN, 25-27 March 2024.

P. Gandini. Hadron spectroscopy and hadron-hadron interactions Plenary talk at LHCP2024, Boston

<https://indico.cern.ch/event/1253590/contributions/5814187/>

P. Gandini. Heavy flavor spectroscopy studies at LHCb

Parallel talk at LHCP2024, Boston

<https://indico.cern.ch/event/1253590/contributions/5839207/>

N. Neri. Prospects for direct measurement of Lambda baryon dipole moments at LHCb

10th International Conference on Quarks and Nuclear Physics, Barcelona (Spain) 8-12 July

<https://indico.icc.ub.edu/event/180/>

S. Cesare. EDMs: Complementary experiments and theory connections - Trento 4-8 Mar 2024

<https://indico.ectstar.eu/event/199/contributions/4471/>

S. Cesare TREDI workshop on Silicon Sensors - Torino 20-22 Feb 2024

<https://agenda.infn.it/event/39042/contributions/221975/>

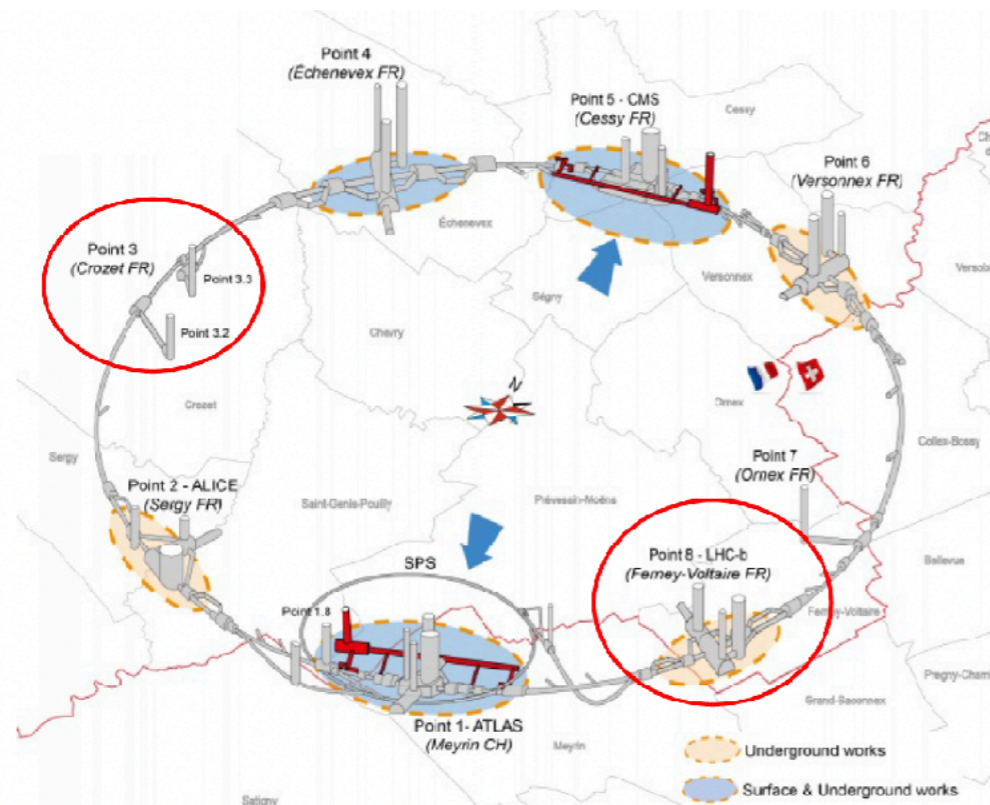
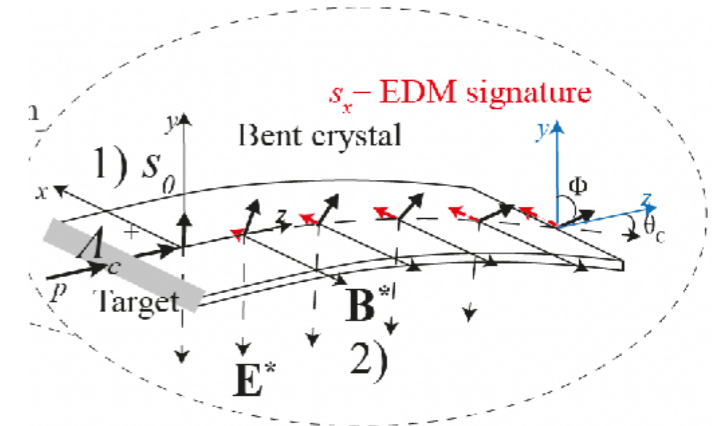
C. Mancuso. Search for CP violation in Baryons

September 18 to 22, 2023 in Santiago de Compostela, Spain.

<https://indico.cern.ch/event/1184945/contributions/5531347/>

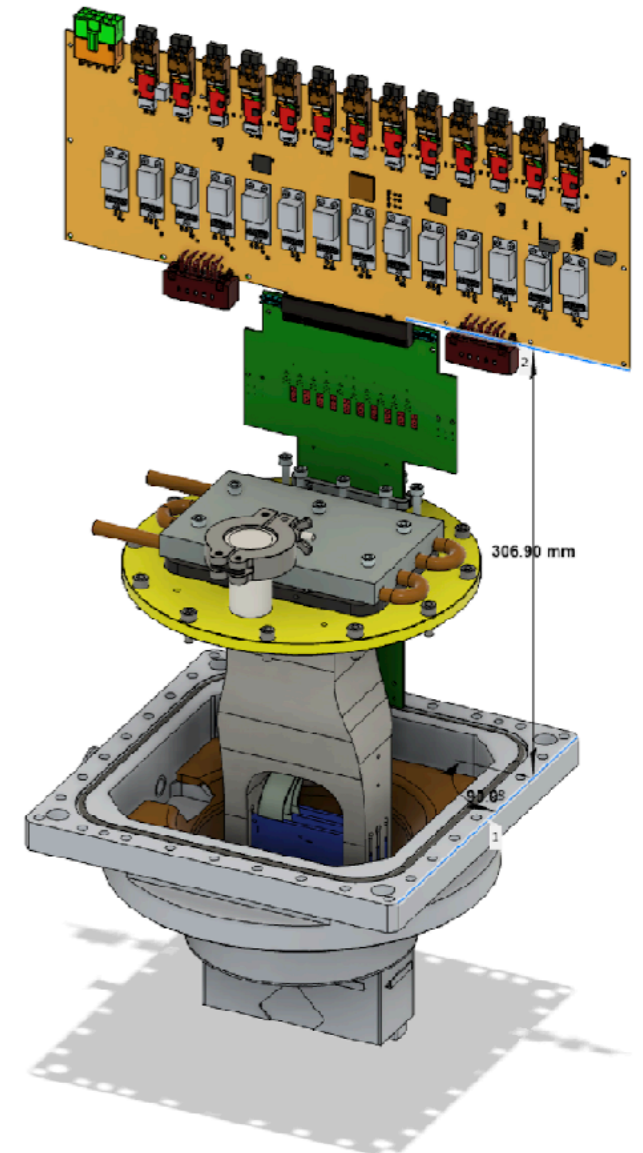
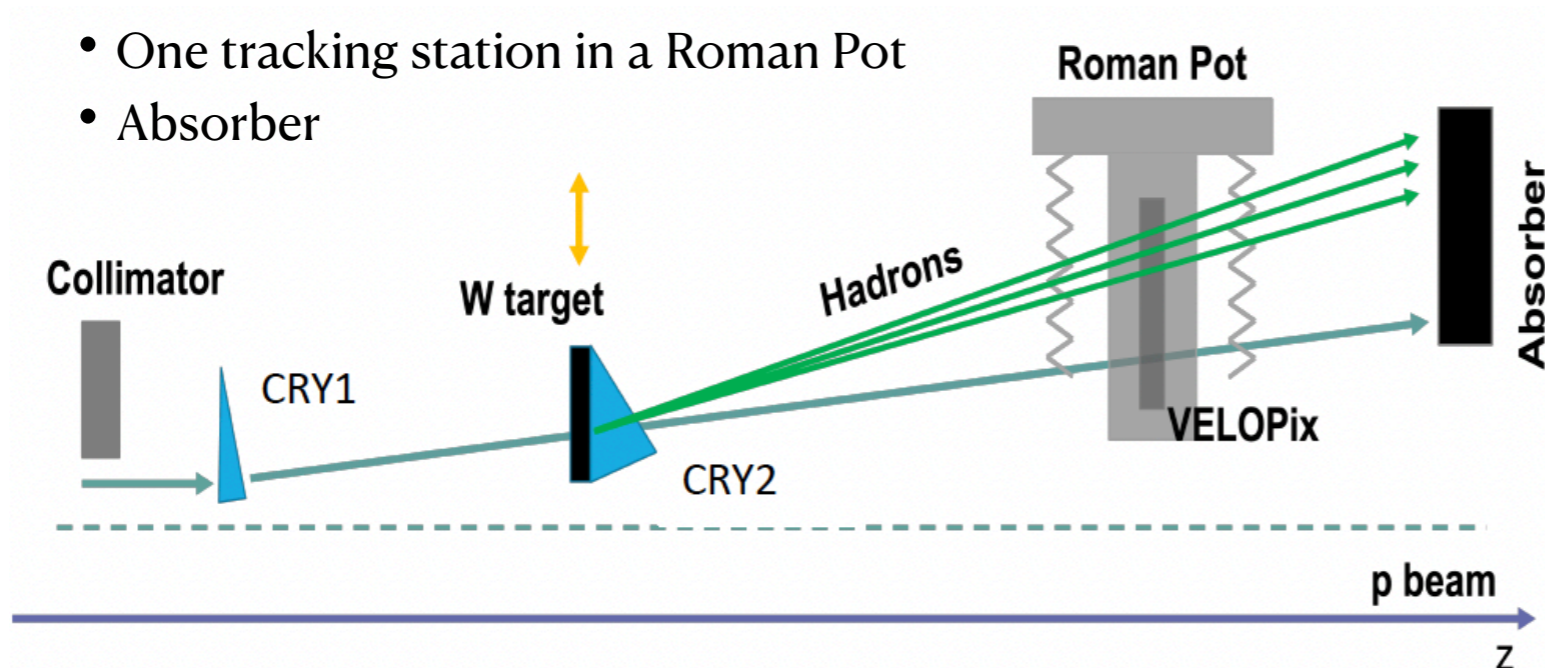
SELDOM + TWOCRIST + ALADDIN

- Recap: SELDOM (ERC) → EDM/MDM from spin precession of channeled baryons in bent crystals
- Triggered an international collaboration with several groups towards a proposal for a new experiment
- Idea is to use the spin precession, now physics program has expanded considerably
- Two approaches:
 - put experiment before LHCb (and use it)
 - New experiment at LHC IR3 region
- In 2025 we will install a proof of principle experiment at IR3: TWOCRIST



TWOCRIST: PoP will be installed in 2025

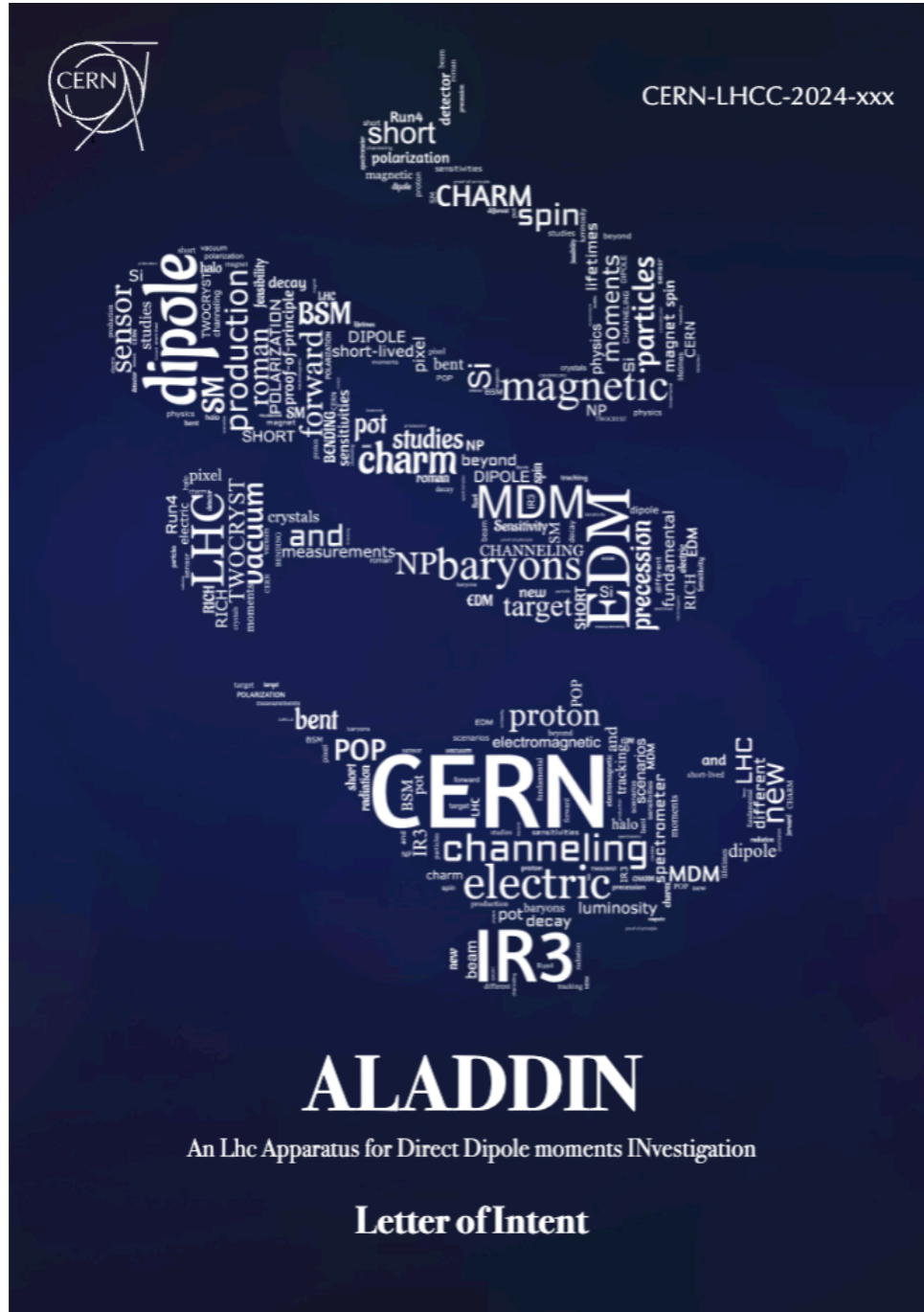
- TWOCRIST is one of the goals of the SELDOM project
- It has been approved by the LHC Machine Committee (LMC) for data taking in 2025
- Goals of the test
 - Demonstrate the operational feasibility of the double crystal and tracking detector setup at the LHC
 - Confirm the estimated achievable rates of proton on target
 - Measure channeling efficiency of long crystals at TeV energies
 - Background studies
- Experimental set-up
 - Short crystal for beam-halo deflection
 - W target
 - Long crystal for Λ^*c channeling
 - One tracking station in a Roman Pot
 - Absorber



ALADDIN proto-collaboration

- Now ALADDIN proto-collaboration established
- LOI almost ready to be submitted to LHCC
- 4th workshop in Valencia this September: <https://indico.ific.uv.es/event/7688/>

19 institutions
8 countries



Letter of Intent [CERN-LHCC-2024-xxx] ALADDIN: An Lhc Apparatus for Direct Dipole moments INvestigation v2 – 5 July 2024 (2nd review)

K. Akiba¹, F. Alessio², M. Benettoni³, A. Bizzetti^{23,24}, F. Borgato^{3,4}, F. Bucci²³, R. Cardinale^{5,6}, S. Cesare^{7,8}, M. Citterio⁸, V. Coco², P. Collins², E. Dall’Occhio⁹, M. Ferro-Luzzi², A. Fomin²¹, R. Forty², J. Fu¹⁰, P. Gandini⁸, M. Giorgi^{11,12}, J. Grabowski¹³, S. J. Jaimes Elles¹⁴, S. Jakobsen², E. Kou²¹, G. Lamanna^{11,12}, H. Li^{10,16}, S. Libralon¹⁴, C. Maccani^{3,4}, D. Marangotto^{7,8}, F. Martinez Vidal¹⁴, J. Mazon de Cos¹⁴, A. Merli¹⁵, H. Miao^{10,16}, N. Neri^{7,8}, S. Neubert¹³, A. Petrolini^{5,6}, A. Pilloni¹⁷, J. Pinzino¹², M. Prest¹⁹, P. Robbe²¹, L. Rossi^{7,8}, J. Ruiz-Vidal^{14,22}, I. Sanderswood¹⁴, A. Sergi^{5,6}, G. Simi^{3,4}, M. Sorbi^{7,8}, M. Sozzi^{11,12}, E. Spadaro Norella^{5,6}, A. Stocchi²¹, G. Tonani^{7,8}, T. Tork^{7,8}, A. Triossi^{3,4}, N. Turini^{18,12}, E. Vallazza^{19,20}, S. Vico Gil¹⁴, Z. Wang⁸, M. Wang⁸, T. Xing⁸, M. Zanetti^{3,4}, F. Zangari^{7,8}

¹Nikhef, National institute for subatomic physics, Amsterdam, Netherlands

²CERN - Geneva, Switzerland

³INFN Sezione di Padova, Padua, Italy

⁴Università degli Studi di Padova, Padua, Italy

⁵Università di Genova, Genoa, Italy

⁶INFN Sezione di Genova, Genoa, Italy

⁷Università degli Studi di Milano, Milan, Italy

⁸INFN Sezione di Milano, Milan, Italy

⁹Technische Universität Dortmund (TU), Dortmund, Germany

¹⁰University of Chinese Academy of Sciences

¹¹Università di Pisa, Pisa, Italy

¹²INFN Sezione di Pisa, Pisa, Italy

¹³University of Bonn, Bonn, Germany

¹⁴IFIC - Universitat de Valencia-CSIC, Valencia, Spain

¹⁵Institute of Physics, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

¹⁶Institute of High Energy Physics, Chinese Academy of Sciences

¹⁷INFN Sezione di Catania, Università degli Studi di Messina, Messina, Italy

¹⁸Università degli Studi di Siena, Siena, Italy

¹⁹INFN Sezione di Milano Bicocca, Milan, Italy

²⁰INFN Sezione di Trieste, Trieste, Italy

²¹IJCLab, Orsay, France

²²Lund University, Sweden

²³INFN Sezione di Firenze, Firenze, Italy

²⁴Università degli Studi di Modena e Reggio Emilia, Italy

ALADDIN

- W target, 4 Roman pots, Reuse 1.1T magnet, RICH detector proposed
- Synergy with Lucio Rossi's group at LASA for the construction of a magnet with HTS technology (for the spectrometer)
- Progetto IRIS → compact HTS dipole 4 Tm (4T x 1 m)
 - 2x in momentum resolution
 - Acceptance up to 90%
 - First HTS magnet in HEP

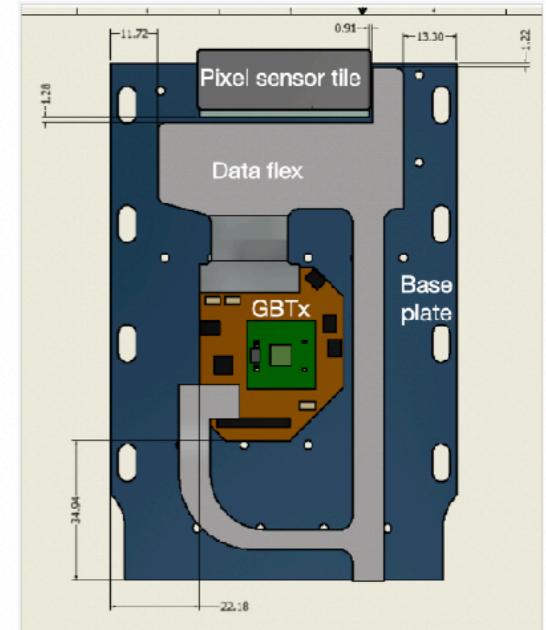
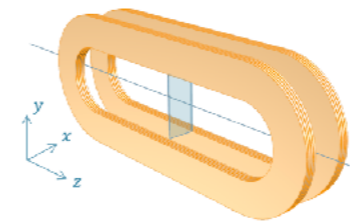


Figure 3: Pixel sensor module developed for the TWOCRIST project. The dimensions reported in the sketch are in mm.

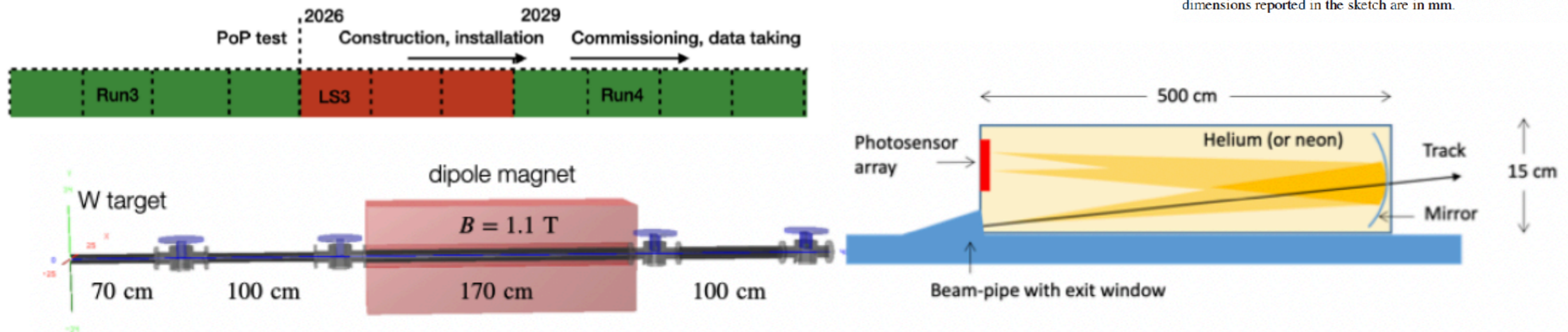


Figure 2: ALADDIN detector side view. The spectrometer is on the left side and the RICH detector on the right.

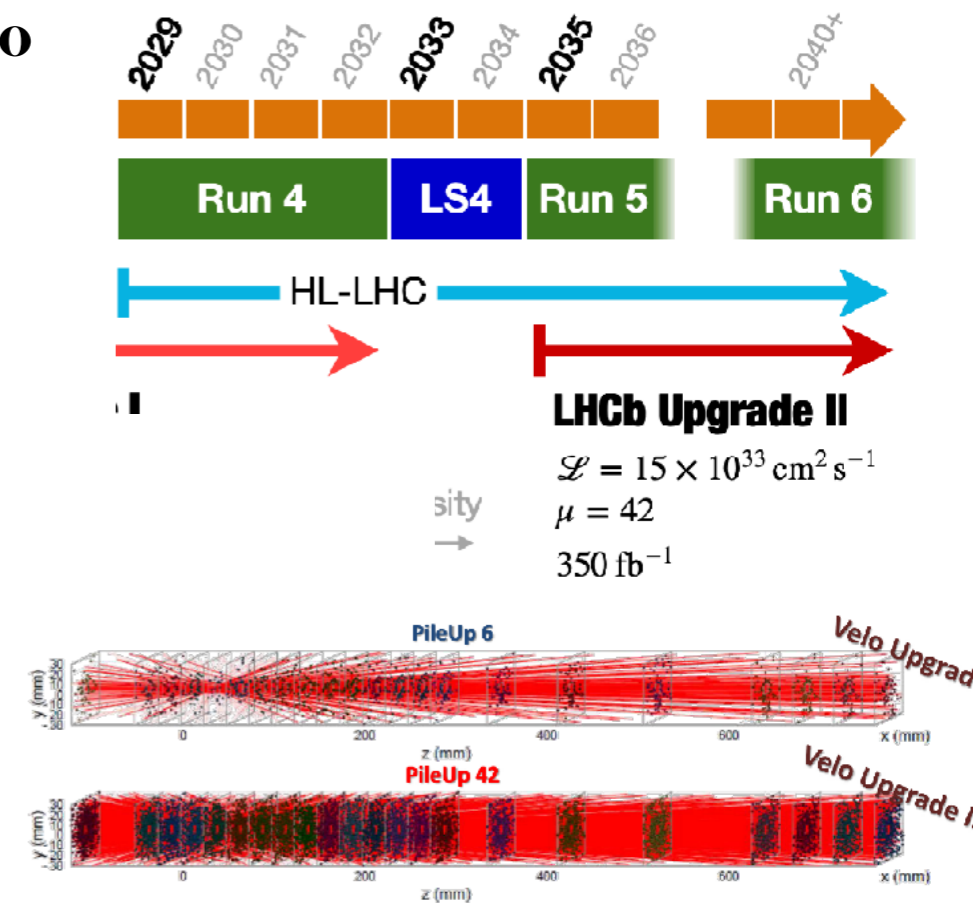
	pitch (μm)	hit rate (MHz/cm ²)	fluence ($n_{\text{eq}}/\text{cm}^2$)	area (cm ²)	tech. solution
Upstream	55	250	3.5×10^{15}	10	Si pixel
Downstream	100	30	9.0×10^{13}	30	Si pixel/strip

VELO: Upgrade phase 2

- **Pixels + Timing** → nice integration with other activities in Milano
- **In 2025** start activities for VELO upgrade 2
- **Milano: Setup for test of silicon sensors**

Milan contributions to VELO U2

- ▶ Milan contribution to VELO U2 could start in January 2025. Need to continue supporting UT operations during next years
- ▶ Current VELO related activities of the group:
 - contributions to IGNITE/Timespot for sensor and ASIC developments
 - using VELO sensors/electronics for CERN TWOCRIST project (PoP test for charm dipole moments experiment)
- ▶ Main interest for VELO U2:
 - detector simulations, performance for TDR
 - detector assembly, construction and test (VELO modules)
 - FEA simulations: thermal, mechanical, thermo-mechanical
 - CO₂ cooling and mechanics (VELO modules)



Composizione del gruppo e preventivi 2025

Personale		LHCb + sigle sinergiche (FTE)	LHCb	IGNITE	SELDOM (ERC UE)	SELDOM _TWOCRYST	PRIN 2022	FERRAD	Inquadramento		Servizio Meccanica	Servizio Elettronica
Bianchi	Antonio					0,5			T3 TD	Attenzione time sheet 100% IRIS INFN --> Sinergia		
Cesare	Sara	1,0	1,0		0,0	0,0			Dottoranda		6 m.u.	6 m.u.
Citterio	Mauro	0,2	0,2		0,0	0,0			Dirigente Tecnologo		0 m.u.	0 m.u.
Coelli	Simone	0,2	0,1		0,1	0,0			Primo Tecnologo		2 m.u.	2 m.u.
Frontini	Luca	1,0	0,0					1,0	AR UNIMI			
Gandini	Paolo	1,0	0,7		0,25	0,0	0,05		Ricercatore			
Liberali	Valentino	0,2	0,0	0,1				0,1	PA		kEuro	
Mancuso	Chiara	1,0	1,0						Dottoranda	Trasferte		125,5
Marangotto	Daniele	1,0	0,7		0,3	0,0			AR UNIMI (UE)	Consumi		18,5
Neri	Nicola	1,0	0,7		0,3	0,0			PA	MOF-B UT		9,5
Redi	Federico Leo	1,0	0,7	0,3					RTD-B UNIBG	Upgrade 2		45
Riboldi	Stefano	0,2	0,2						PA	Altre richieste		7,5
Sorbi	Massimo					0,1			PA			
Stabile	Alberto	0,5	0,0	0,4				0,1	PA UNIMI	Totale		206
Tonani	Giorgia	1,0	1,0		0,0	0,0			Dottoranda (UE)			
Tork	Theraa	1,0	0,7		0,3	0,0			AR UNIMI (UE)			
Wang	Ziyi	1,0	0,7		0,3	0,0			AR UNIMI (UE)			
Xing	Tianyu	1,0	1,0						AR UNIMI (PRIN2022)			
Tot. (FTE)		12,3	8,7	0,8	1,55	0,6	0,05	1,2				

SELDOM (ERC UE finirà il 31 marzo 2025)

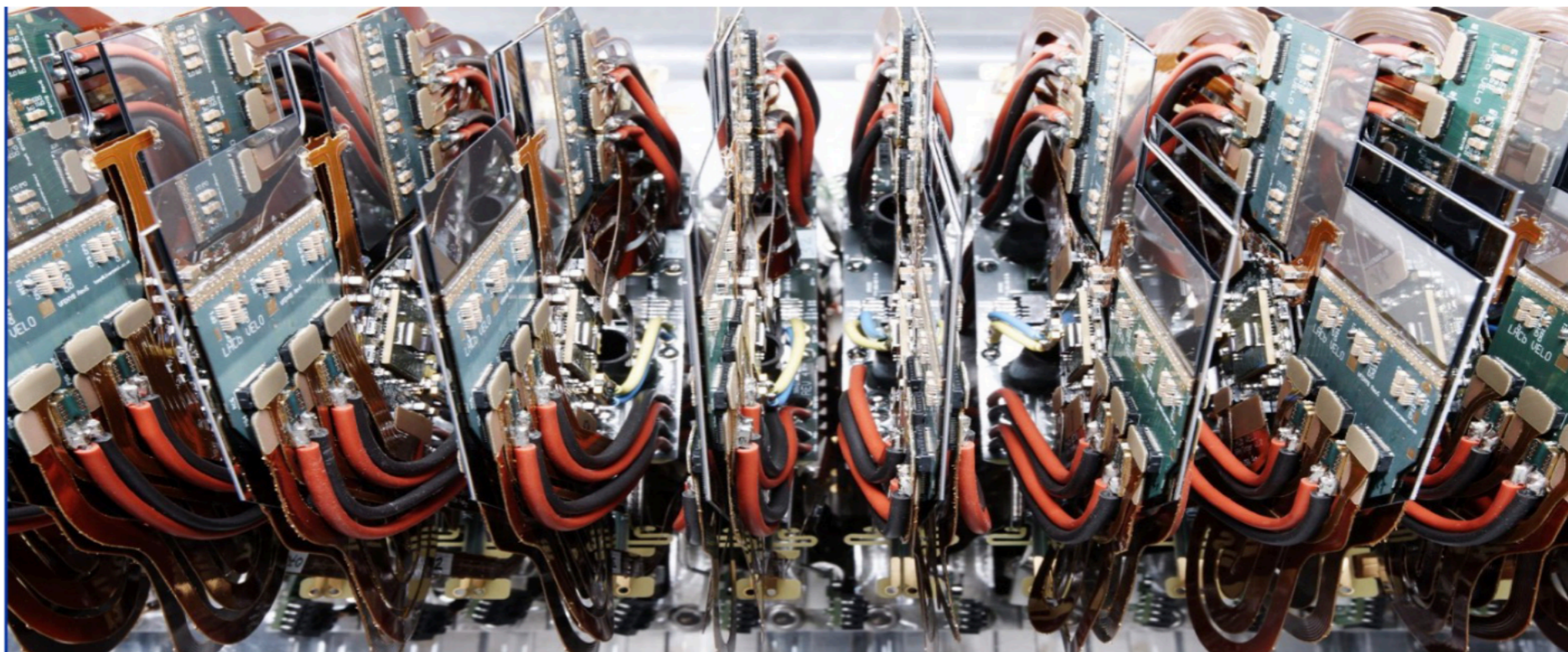
PRIN2022 (finirà il 28 settembre 2025)

FERRAD (Call giovani CSN5 di Frontini)

Richieste Servizi di Sezione (1)

- **Per LHCb (responsabile locale N. Neri)**

- 6 mesi uomo servizio meccanica: 4 m.u. progettazione e simulazioni FEA per VELO + 2 m.u. officina
- 6 mesi uomo servizio elettronica (disegno schede front end per test sensori 3D e circuiti ibridi)
- Attività previste: simulazioni termiche e meccaniche moduli VELO, realizzazione di microcanali con stampante 3D e loro caratterizzazione meccanica e termica
- 5 kEuro costruzione prototipi per microchannel cooling con stampante 3D in titanio (VELO U2)



VELO-U1 modules

Richieste Servizi di Sezione (2)

- **Per SELDOM_TWOCRIST (responsabile locale P. Gandini, prima era Neri da aggiornare)**
 - 2 mesi uomo servizio meccanica: 1 m.u. progettazione e simulazioni cooling nel vuoto secondario della Roman Pot + 1 m.u. officina
 - 2 m.u. servizio elettronica: supporto per testbeam, sistema di acquisizione per moduli sensori VELO, disegno cavi flex

