LHCb status report

Paolo Gandini

On behalf of the LHCb Milano group

4th July 2023

INFN MILANO
Istituto Nazionale di Fisica Nucleare
Sezione di Milano

Outline

LHCb experiment:

- Physics results
- Group News
- LHCb upgrade news
- Requests for 2023

Website

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

New members of the group

We welcome:

PhD student
Sara Cesare started now (master at Padova)

She won an award at her first talk with us

RTDB at Università di Bergamo
Federico Redi (will associate to INFN Milano)
Now CERN fellow & Convener of EW working group

PhD Students:

- Giorgia Tonani (cotutela with Valencia)
- Chiara Mancuso (cotutela with IJCLab, University of Paris-Saclay)

LHCb Physics

CKM and CP violation ← $\sin2\beta$, γ, ϕ_s, $|V_{ub}/V_{cb}|$, CPV in B^0, B_s^0, D^0, b-baryons, etc

Rare decays → $B_{(s)}^0 \to \mu^+\mu^-$, $b \to s\mu^+\mu^-$, $b \to se^+e^-$, $\Sigma^+ \to p\mu^+\mu^-$, etc

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

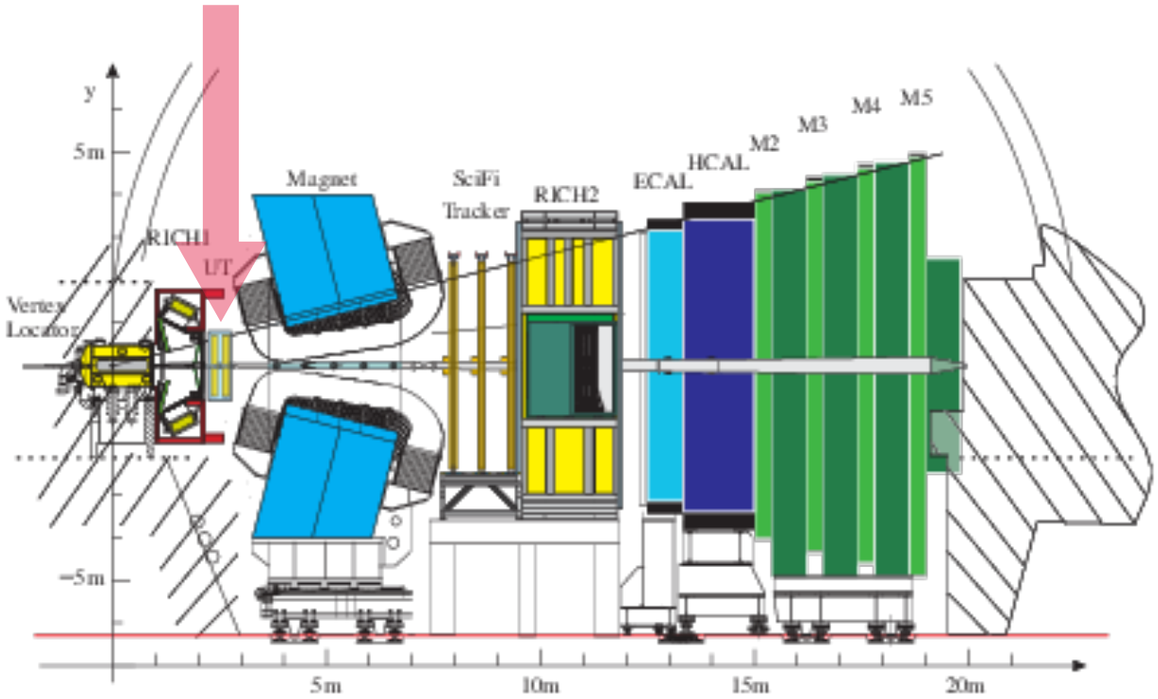
Electroweak QCD and Exotica ← Z^0, W^+, top, Dark photons, Long-lived particles,..

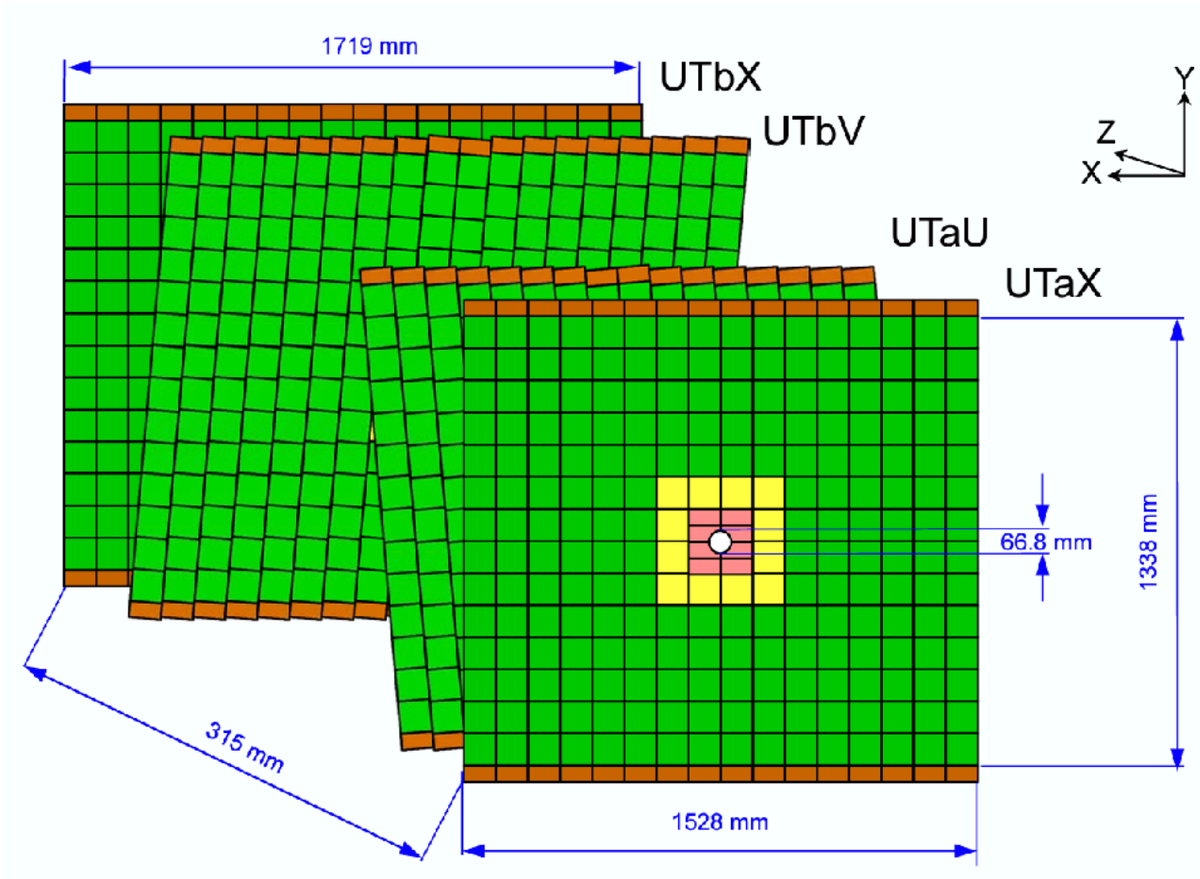
Ion, Fixed-target ← Heavy ions, p-Gas, nuclear effects,...

Active on several topics, but expanding...

Upstream Tracker installed successfully

- Milano has responsibilities in the construction and installation of the LHCb UT
- 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



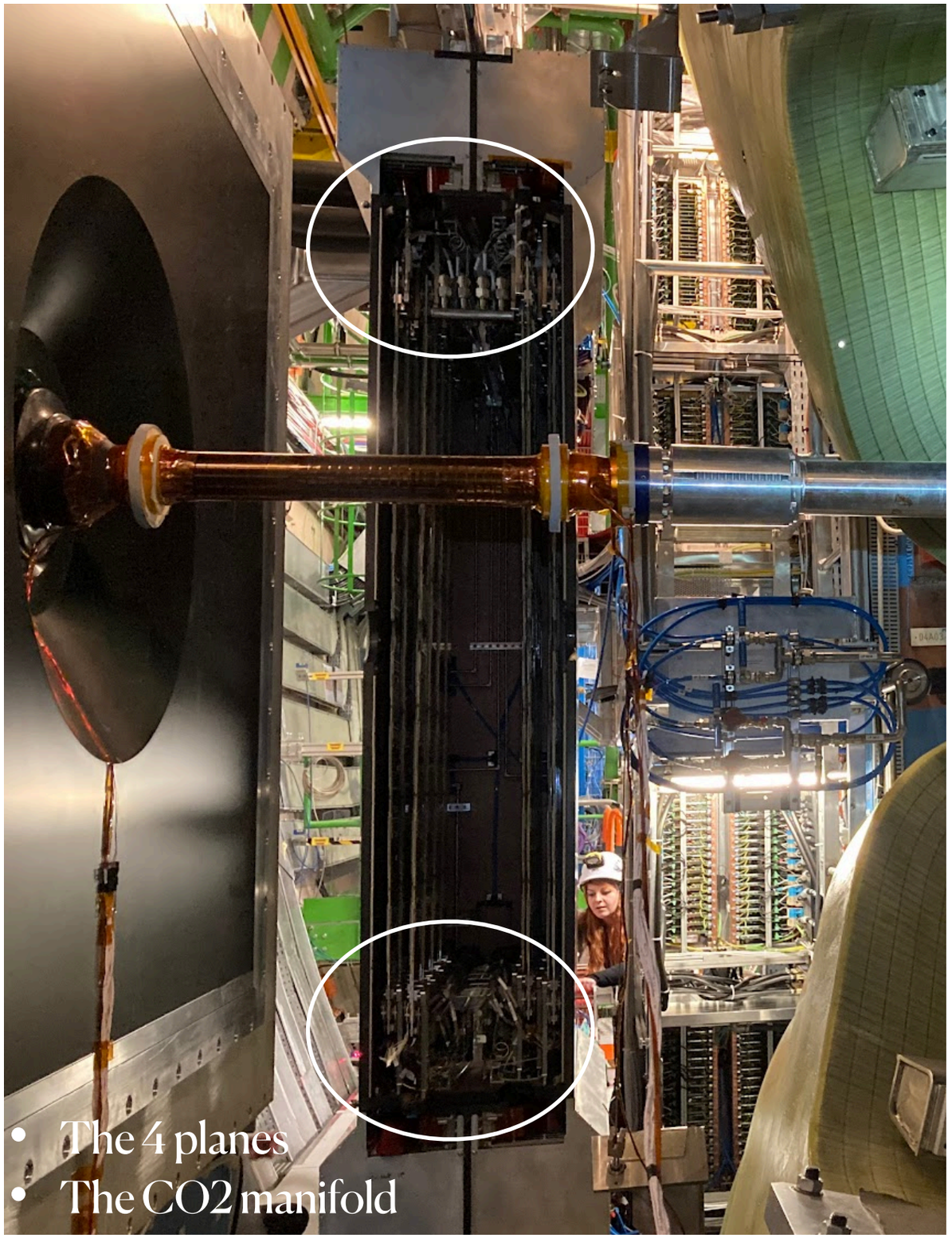


Upstream Tracker installed successfully

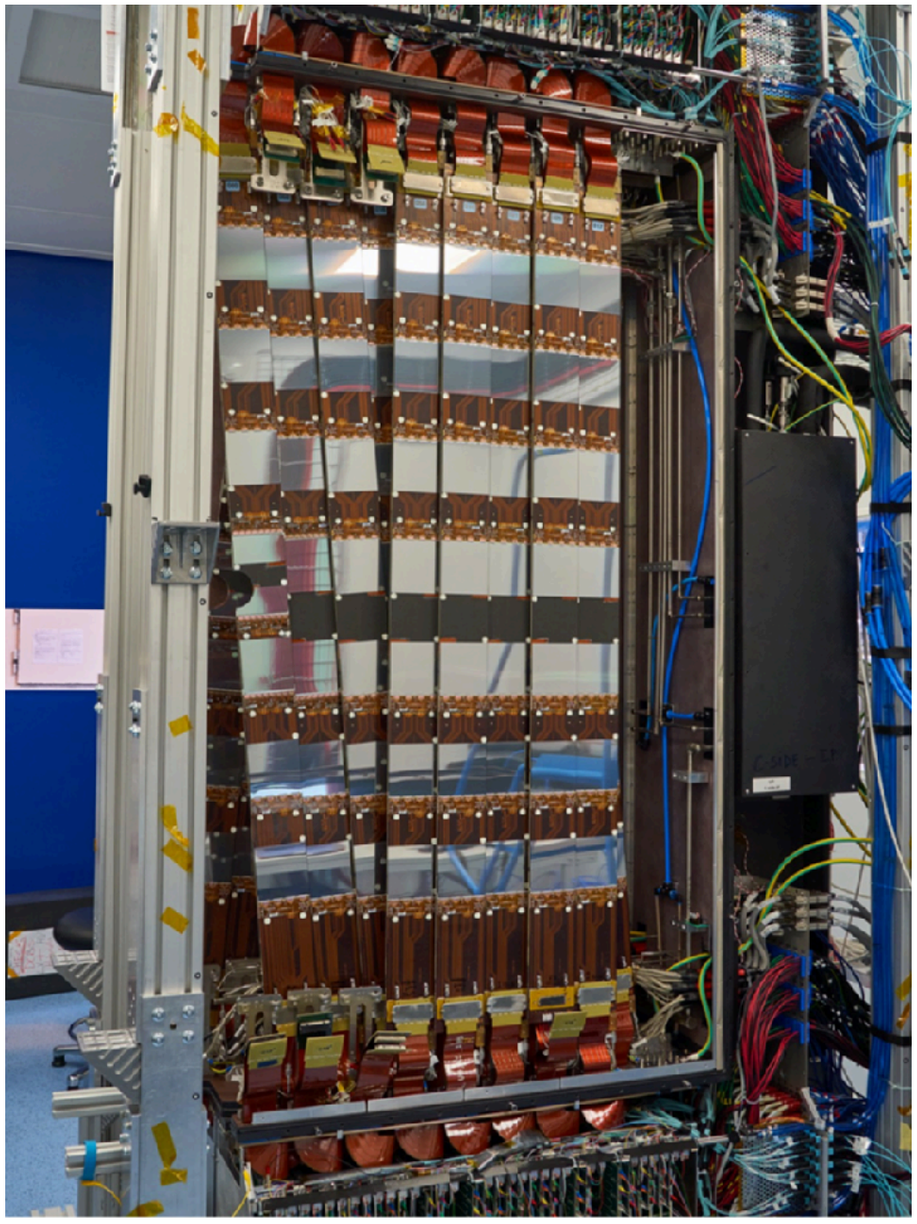
- UT installation completed
- Two weeks in advance!
- Now commissioning started
- Milan has now important responsibilities:
    - Software & Monitoring
    - Data Quality online & offline

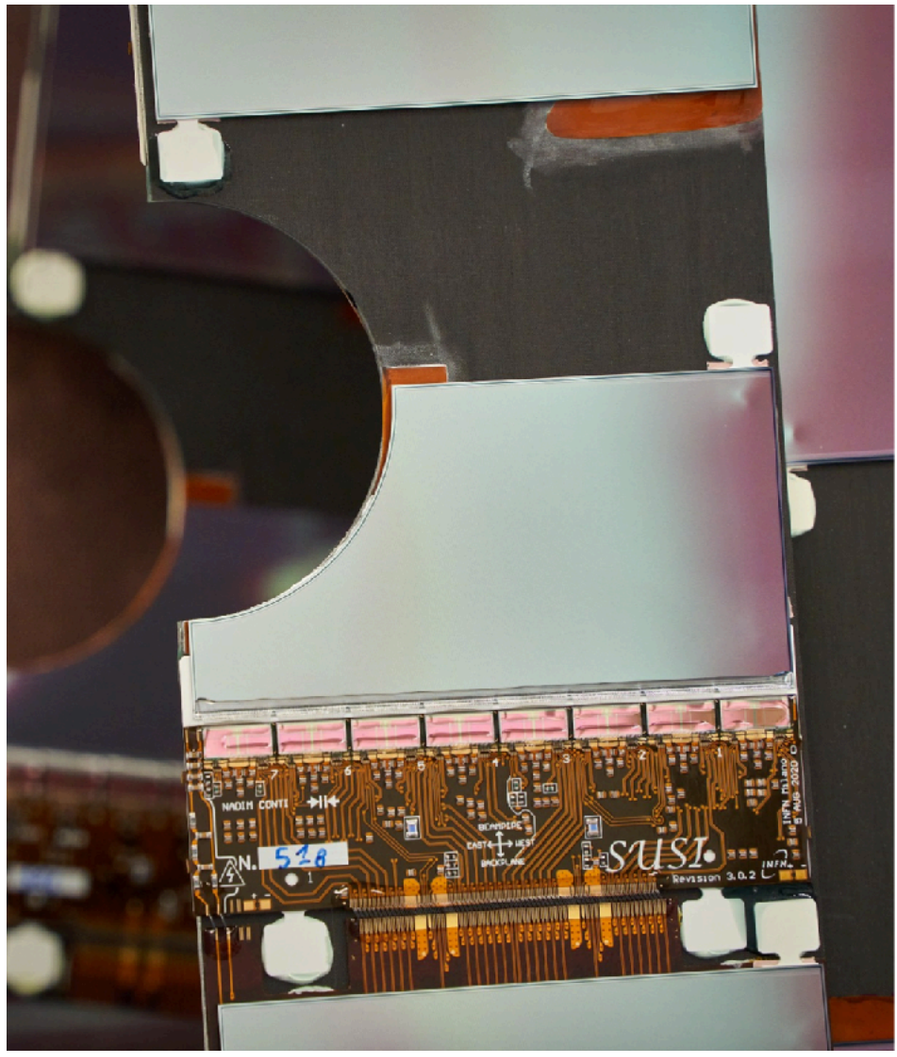
- Milano responsibilities in UT construction:
    - Flex cables ✔
    - Hybrid circuits ✔
    - Glueing, bonding, burn-in ✔
    - CO2 distribution system ✔
    - Federico De Benedetti: project electrical engineer
    - Nicola Neri: deputy project leader
    - Paolo Gandini: monitoring coordinator
    - Simone Coelli: cooling expert

Many thanks to our Officina Meccanica!
(Capsoni,Coelli,Monti,Gesmundo,Trotta,Viganò, Viscione)



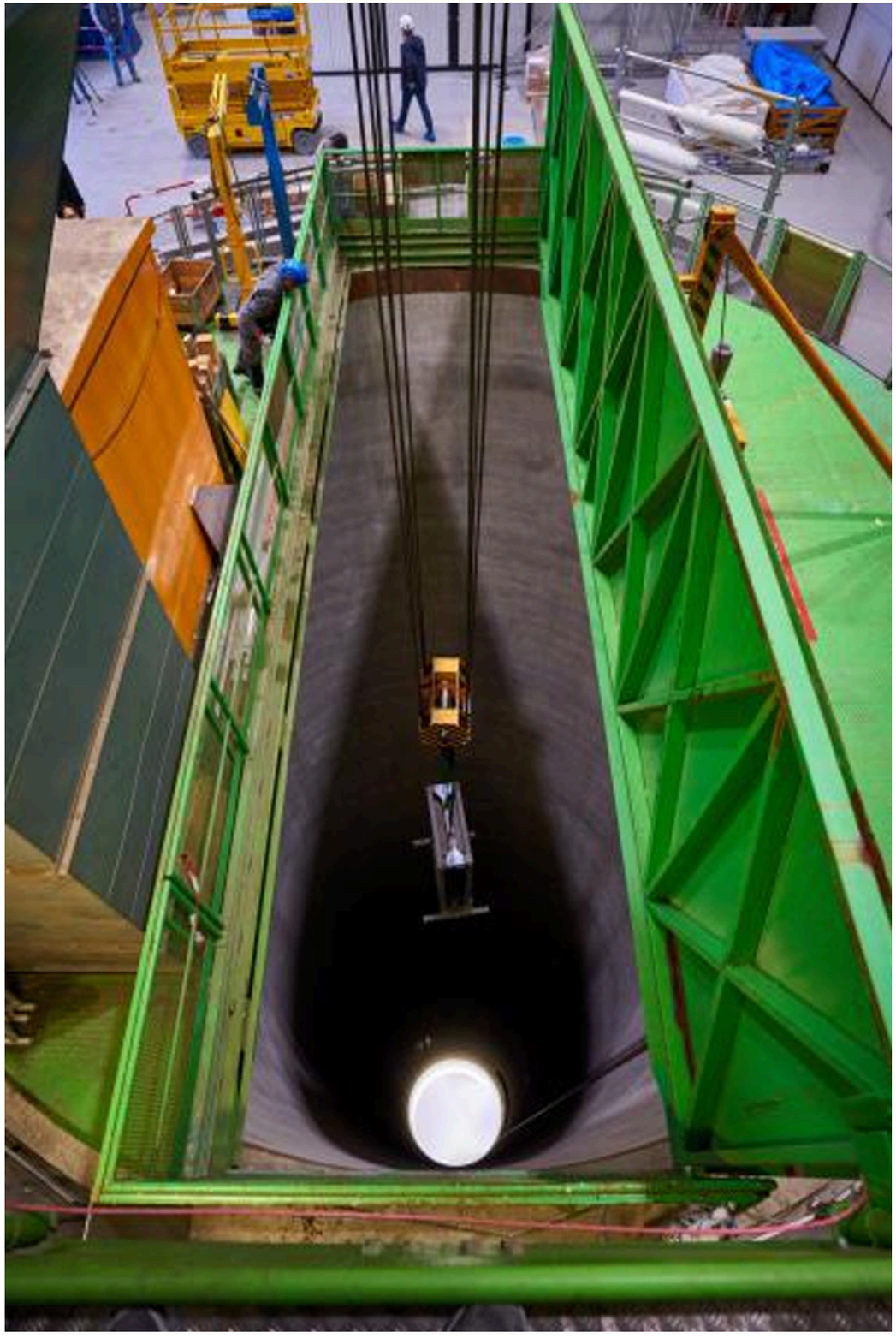
Upstream Tracker installed successfully

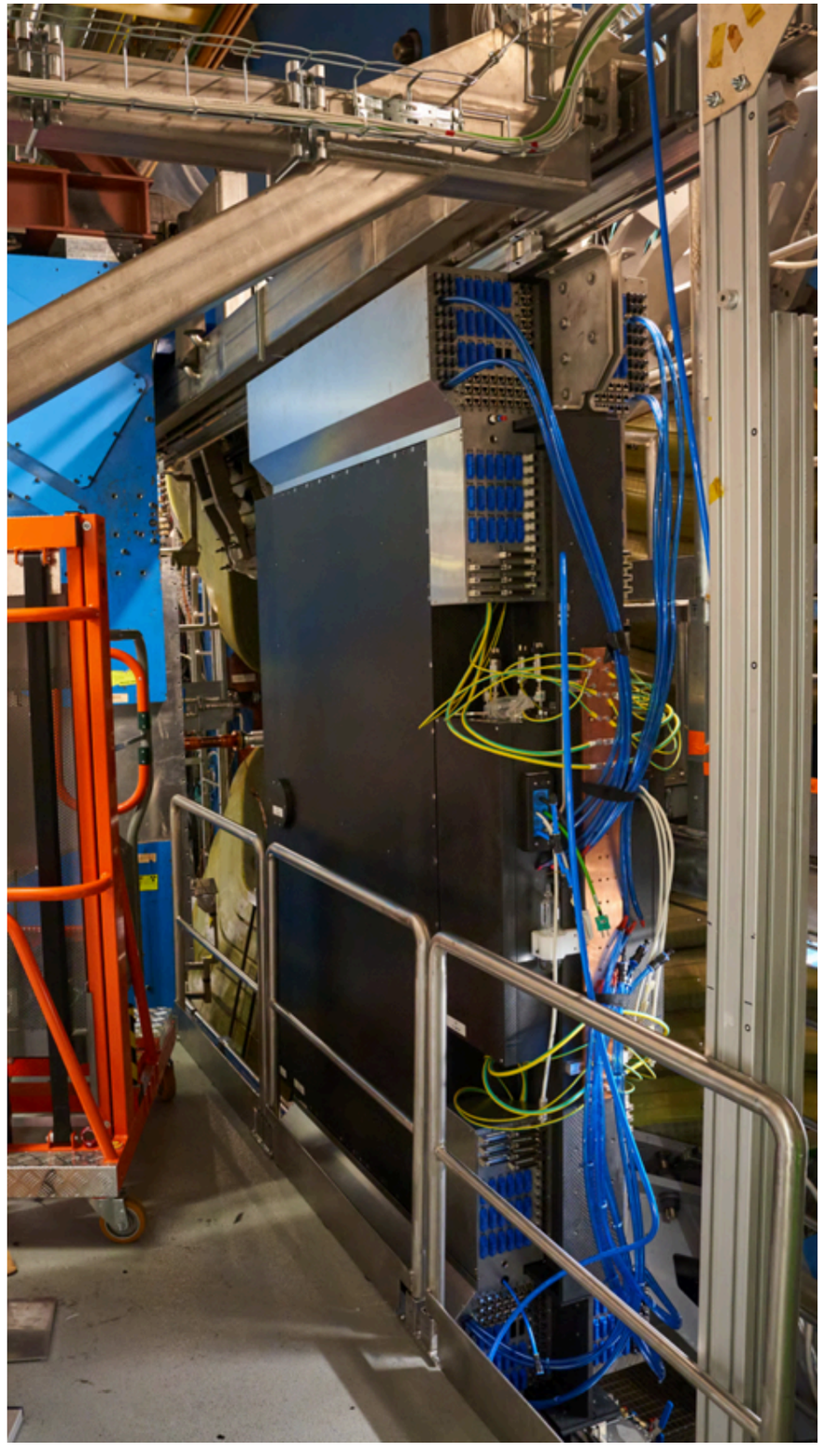




Many thanks to our Servizio Elettronica!
(Citterio, Conti, Sabatini, Andreani)

Upstream Tracker installed successfully



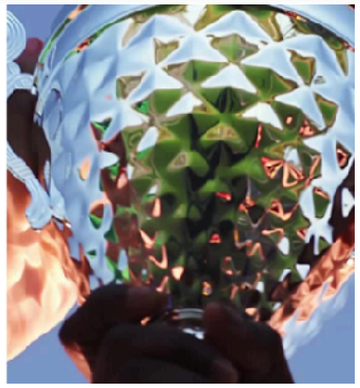


Technical Award 2023 to Federico De Benedetti

- Milan was a key player
- Recognized by the LHCb management

LHCb Technical Award 2023

Committee: Jean-Pierre Cachemiche, Paula Collins, Niko Neufeld, Eric Thomas (chair), Uli Uwer



Federico de Benedetti (INFN)

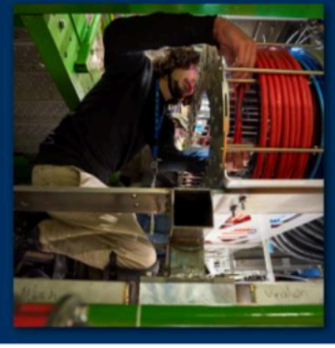
For his outstanding contribution to the construction and installation of the UT detector

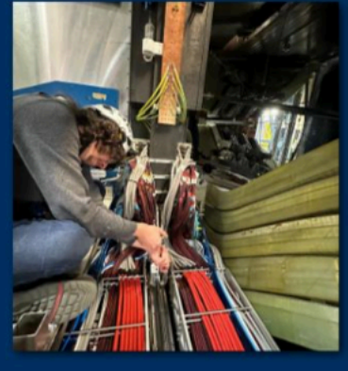
UT PEPI construction, Installation coordinator

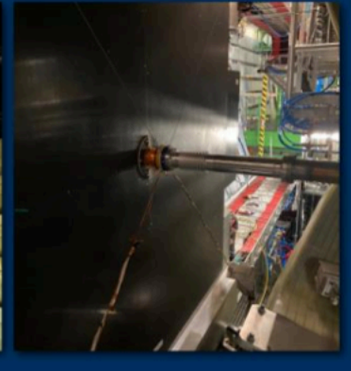
LHCb INFN

UPSTREAM TRACKER INSTALLATION

- Construction and testing of the A side and C side Periphery Electronics (PEPI), validation of the low voltage and high voltage
- Installation and testing of A side and C side front end staves
- Commissioning of the underground services, low voltage and high voltage power supply installation and testing
- Cable chains services installation
- Design of a dedicated hardware system to verify the high voltage and low voltage mapping in the cavern
- Closure of the UT around the beampipe
- Coordination of the UT installation team underground during the YETS
- **UT fully installed underground in March 2023!**







FEDERICO DE BENEDETTI - LHCB TECHNICAL AWARD

Group News

LHCb Italia 2023

Milano hosted the 2023 LHCb Italia meeting with about 50 people over 2 days

Meeting di Collaborazione 2023: LHCb Italia

La collaborazione italiana che partecipa all'esperimento LHCb al CERN si riunirà nei giorni 1 e 2 febbraio presso il Dipartimento di Fisica "Aldo Pontremoli" dell'Università degli Studi di Milano. L'evento è organizzato in collaborazione con l'Istituto Nazionale di Fisica Nucleare e prevede la partecipazione di circa 70 ricercatori e studenti di diverse università e centri di ricerca italiani che si riuniranno per discutere i recenti risultati dell'esperimento e i piani per il futuro. L'esperimento LHCb e' uno dei quattro grandi esperimenti del Large Hadron Collider al CERN che si propone di studiare l'asimmetria tra materia e antimateria e contribuire a risolvere il puzzle dell'assenza di antimateria nell'universo nel quale abitiamo.

Agenda del meeting (protetta): https://indico.cern.ch/event/1239781/

Contributions by Vicini and Forte → overlap with LHCb physics!

11:30 **Theory talk: Evidence for intrinsic charm quarks in the proton (25+5)'**
Speaker: Stefano Forte (Università degli Studi e INFN Milano (IT))
lhcbcharm.pdf

12:00 **Study of Z bosons produced in association with charm and W boson mass measurement**
Speaker: Lorenzo Sestini (Universita e INFN, Padova (IT))
zjet_wmass_lhcb_m...

New convener

Physics Analysis WG conveners

APPROVED

Lorenzo Capriotti 31.03.2025
Mengzhen Wang 31.03.2025

Selection of Recent Results

Highlighting the contributions of the members of the Milano - Group
As usual... very difficult to summarize lots of results in just a few minutes!

Exotica searches in Milano

- Bs → J/Ψ $p\bar{p}$ was published last year as Editor' Suggestions on PRL
- CERN seminar by Elisabetta Spadaro Norella in 2022

- Searches on pentaquarks with strangeness will be published on PRL 17th July
- Editor's suggestion + first page!
- Also selected to be published on APS as outreach to press

https://arxiv.org/abs/2210.10346

Observation of a $J/\psi\Lambda$ resonance consistent with a strange pentaquark candidate in $B^- \to J/\psi\Lambda\bar{p}$ decays

LHCb collaboration

An amplitude analysis of $B^- \to J/\psi\Lambda\bar{p}$ decays is performed using about 4400 signal candidates selected on a data sample of pp collisions recorded at center-of-mass energies of 7, 8 and 13 TeV with the LHCb detector, corresponding to an integrated luminosity of 9 fb^{-1}. A narrow resonance in the $J/\psi\Lambda$ system, consistent with a pentaquark candidate with strangeness, is observed with high significance. The mass and the width of this new state are measured to be $4338.2 \pm 0.7 \pm 0.4$MeV and $7.0 \pm 1.2 \pm 1.3$MeV, where the first uncertainty is statistical and the second systematic. The spin is determined to be 1/2 and negative parity is preferred. Due to the small Q-value of the reaction, the most precise single measurement of the B^- mass to date, $5279.44 \pm 0.05 \pm 0.07$MeV, is obtained.

Spectroscopy measurements

- The Milano group is active in many different searches for spectroscopy
- Exotica but even conventional hadrons
- Analysis on observation of two new baryons presented to Moriond + CERN seminar + Munich workshop
- In 2022 CERN seminar → 2023 CERN seminar (4th seminar so far by members of Milano group)

Reviewing a decade of spectroscopy at LHCb
and
the observation of new baryonic structures

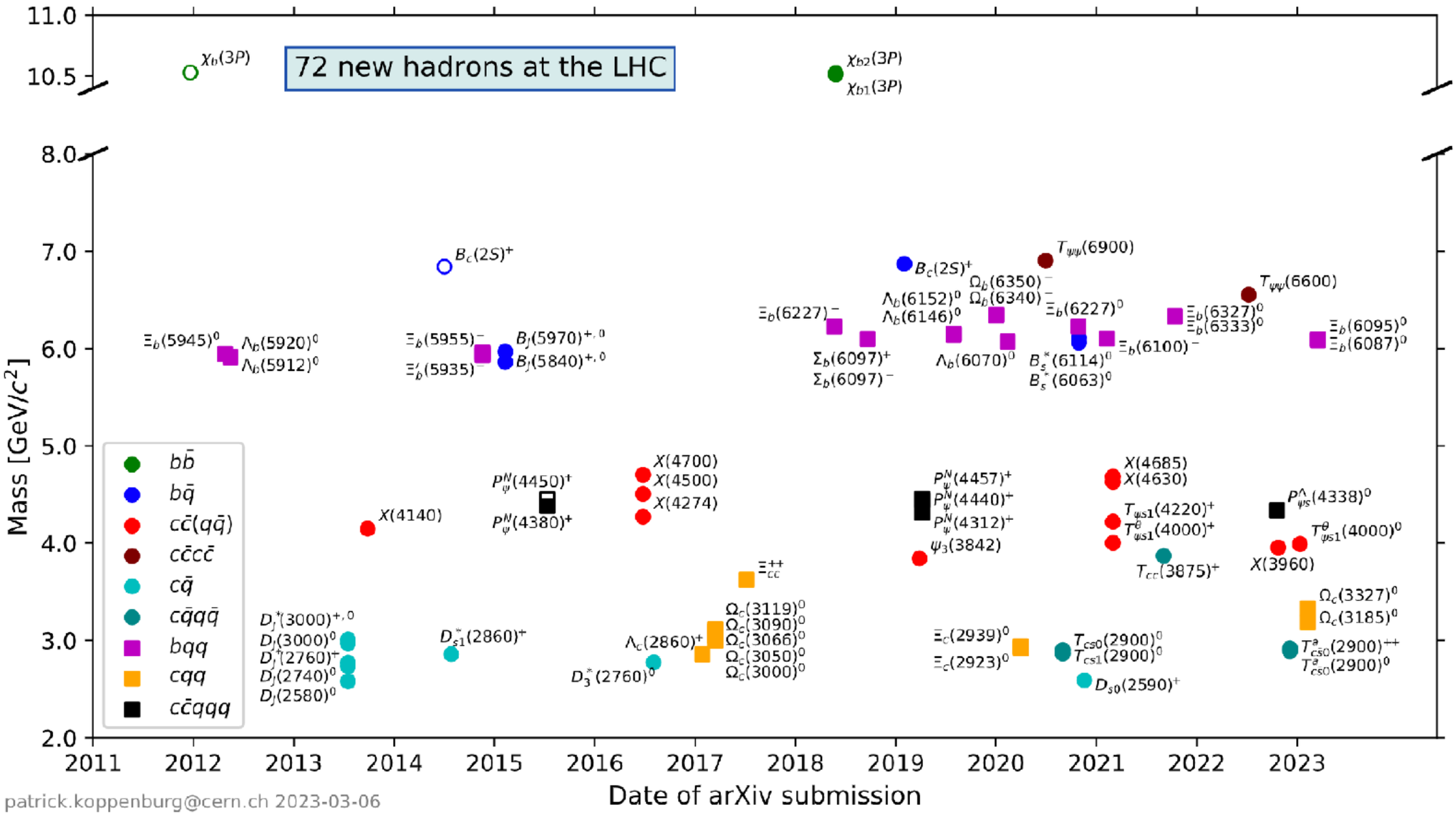
Paolo Gandini
INFN - Sezione di Milano
On behalf of the LHCb collaboration

25th April 2023
CERN Seminar

Image celebrating the observation of Tcc in 2021 by the LHCb collaboration... an intrinsic exotic state!

Spectroscopy measurements

- **Spectroscopy is a super-active field at LHC and all the experiments are contributing!**
- So far 72 hadrons have been discovered at the LHC, of which 64 by LHCb
- The list is growing... All sector represented



LHCb collaboration, P. Koppenburg, List of hadrons observed at the LHC, LHCb-FIGURE-2021-001, 2021, and 2023 updates.

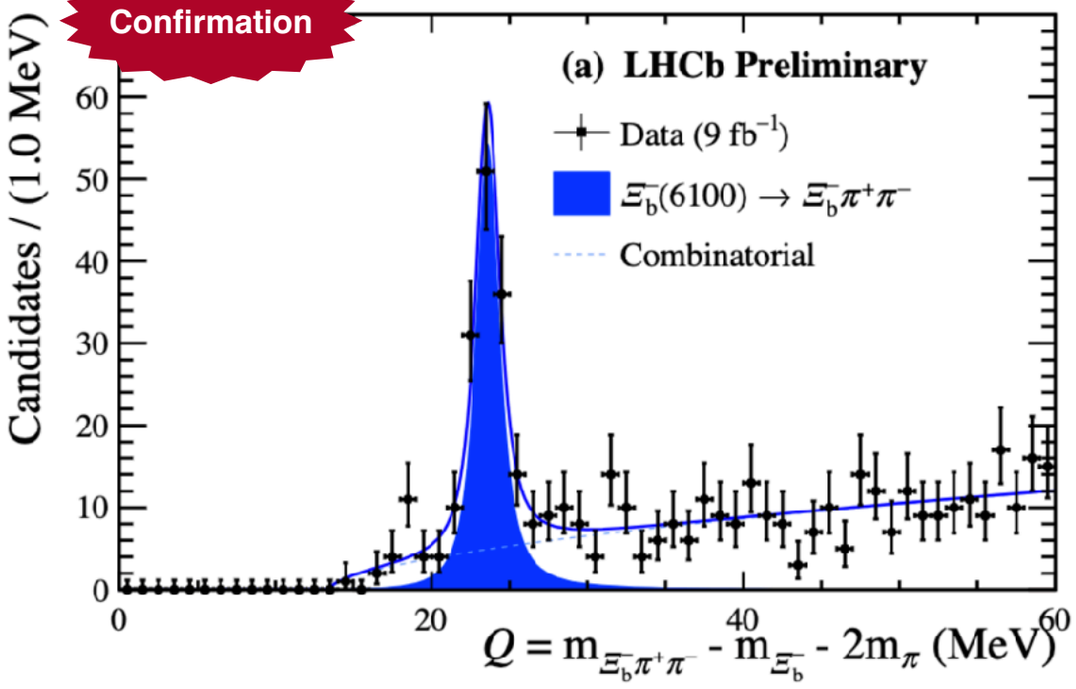
New baryons in $\Xi_b^-\pi^+\pi^-$ and $\Xi_b^0\pi^+\pi^-$

LHCb-PAPER-2023-008
In preparation

New!

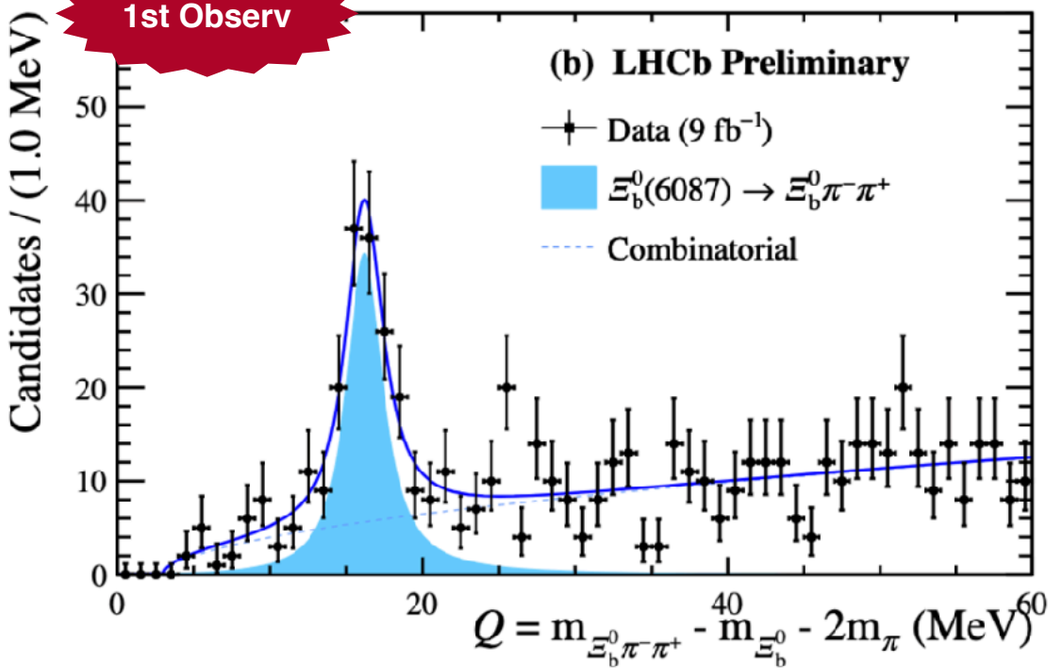
Significance 18σ

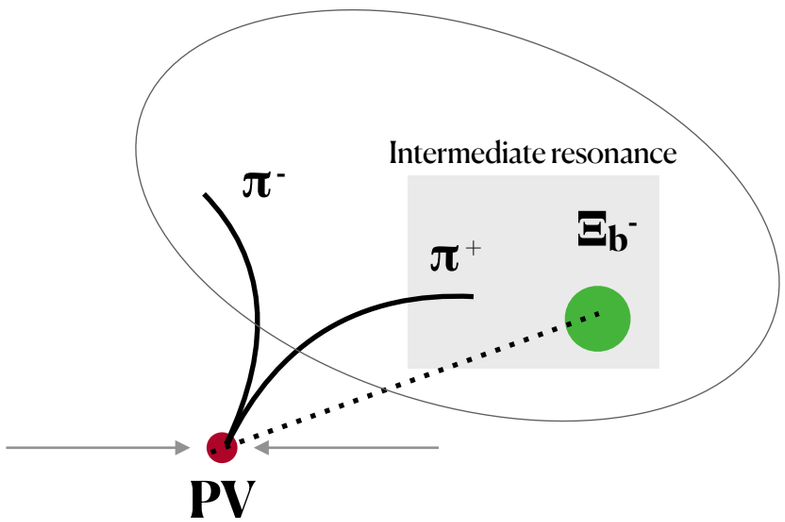
Confirmation



Significance 15σ

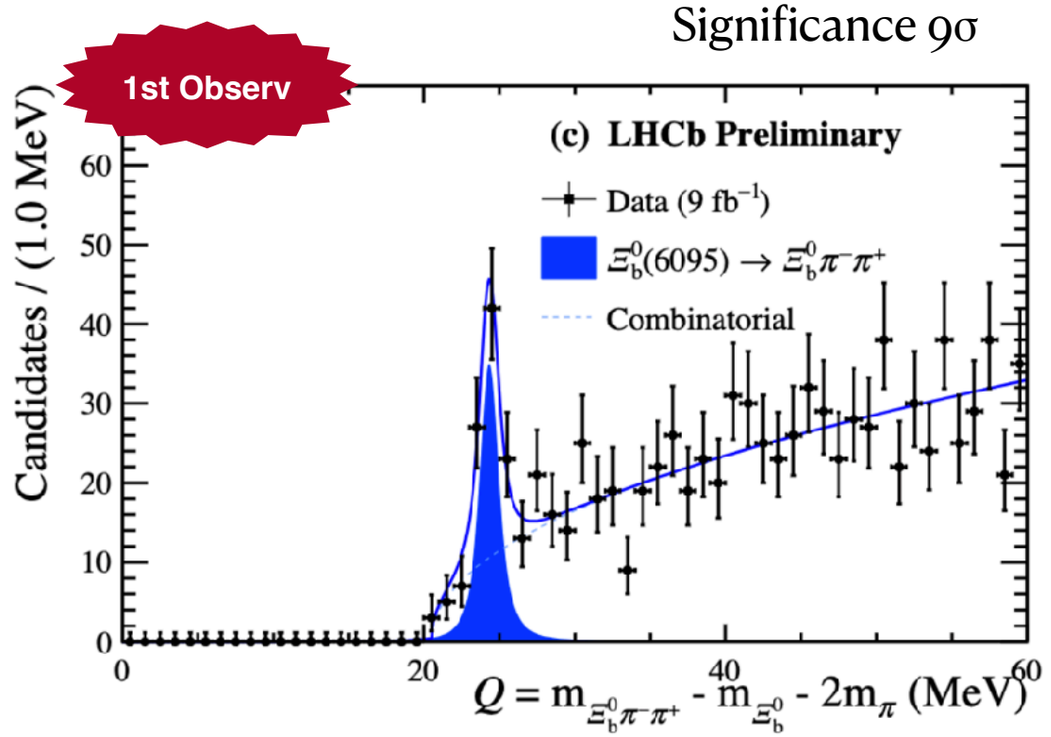
1st Observ





Significance 9σ

1st Observ



New baryons in $\Xi_b^- \pi^+ \pi^-$ and $\Xi_b^0 \pi^+ \pi^-$

LHCb-PAPER-2023-008
In preparation

New!

In summary:

- **Observation of two new *bsq* baryons is reported: $\Xi_b(6100)^-$**
- **One state is confirmed (and measured): $\Xi_b(6087)^0$ $\Xi_b(6095)^0$**
- Best measurement on the known Ξ_b' and Ξ_b^* states
- This measurement uses final states with up to 9 tracks (record in LHCb
- Possible thanks to the excellent performance of the LHCb tracking, PID and trigger systems
- First observation of $\Xi_b^0 \to \Xi_c^+ \pi\pi\pi$
- Seems like resonances go predominantly via their intermediate resonances
- Situation similar in the charm sector (but threshold there are different and so e.m. decays)

A naive interpretation would be that the new states are P-wave states ($l = 1$ between b and qs diquark) coupling to the b quark ($s = \frac{1}{2}$) to give a pair of states $J^P = (\frac{1}{2})^-$ and $(\frac{3}{2})^-$, respectively. One might expect the dominant decay mode of the lighter one to be $\Xi_b^{\prime(0,-)}\pi$ and for the heavier one $\Xi_b^{*(0,-)}\pi$. The lighter $\Xi_b^-(1\mathrm{P}, 1/2)$ state is not observed as it would likely decay primarily through the intermediate $\Xi_b^{\prime 0}$ resonance which is below threshold to decay to $\Xi_b^-\pi^+$. However, hints of such $\Xi_b^-(6100) \to \Xi_b^{\prime 0}(\Xi_b^0\pi^0)\pi^-$ decay could be observed in the $\Xi_b^0\pi^-$ spectrum as a partially reconstructed feed-down component.

Polarization of Λ_c^+ and amplitude analysis

- Very complex analysis, now published on PRD arXiv:2208.03262 (Marangotto)

Amplitude analysis of the $\Lambda_c^+ \to pK^-\pi^+$ decay and Λ_c^+ baryon polarization measurement in semileptonic beauty hadron decays

LHCb collaboration

An amplitude analysis of $\Lambda_c^+ \to pK^-\pi^+$ decays together with a measurement of the Λ_c^+ polarization vector in semileptonic beauty hadron decays is presented. A sample of 400 000 candidates is selected from proton-proton collisions recorded by the LHCb detector at a center-of-mass energy of 13 TeV. An amplitude model is developed and the resonance fractions as well as two- and three-body decay parameters are reported. The mass and width of the $\Lambda(2000)$ state are also determined. A significant Λ_c^+ polarization is found. A large sensitivity of the $\Lambda_c^+ \to pK^-\pi^+$ decay to the polarization is seen, making the amplitude model suitable for Λ_c^+ polarization measurements in other systems.

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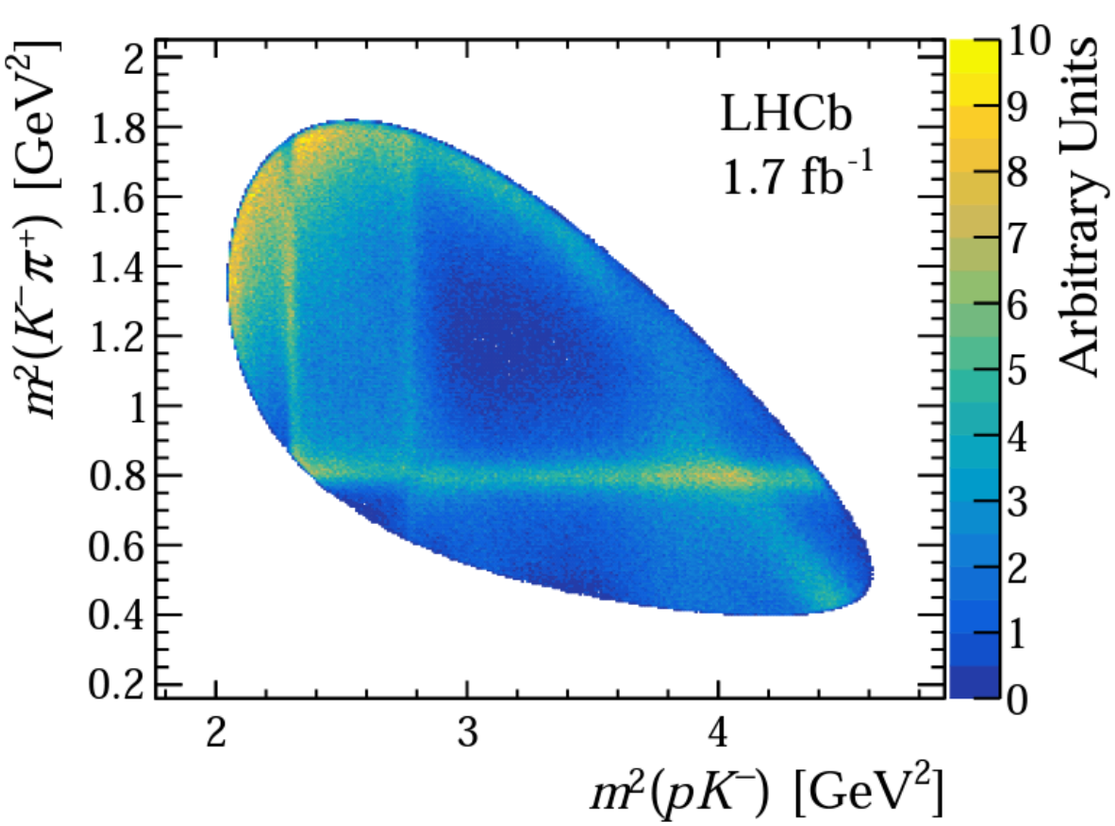
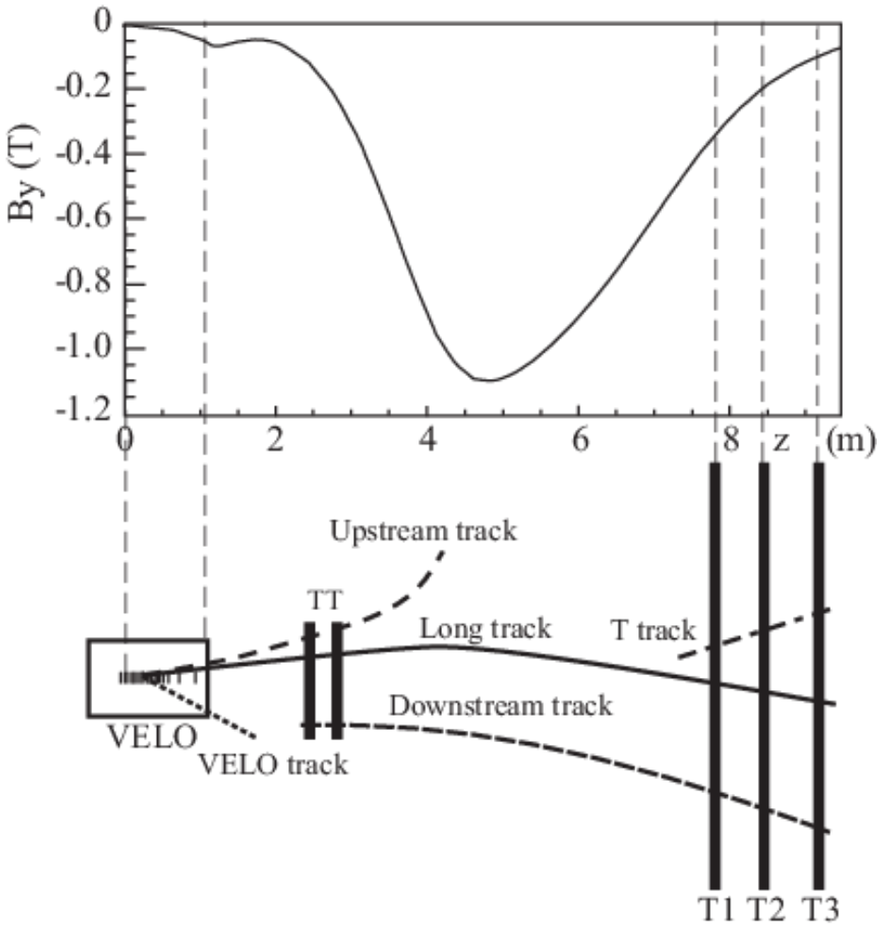


Figure 2: Dalitz plot for the total sample of $\Lambda_c^+ \to pK^-\pi^+$ candidates.

Analysis on T tracks

- Novel technique in LHCb (never used so far)
- Interesting for future developments
- Essential for searches of long lived particles
- https://cds.cern.ch/record/2841793?ln=en

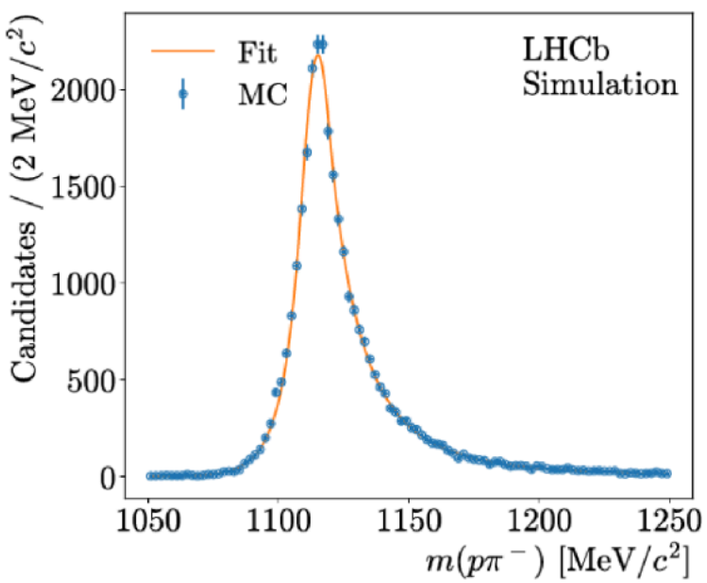


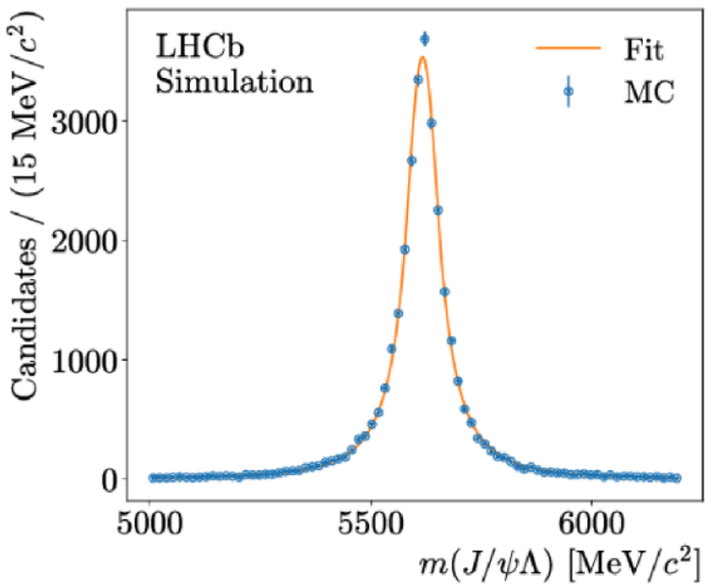
Long-lived particle reconstruction downstream of the LHCb magnet

LHCb collaboration

Abstract

Charged-particle trajectories are usually reconstructed with the LHCb detector using combined information from the tracking devices placed upstream and downstream of the 4 T m dipole magnet. Trajectories reconstructed using only information from the tracker downstream of the dipole magnet, which are referred to as T tracks, have not been used for physics analysis to date due to their limited momentum resolution. The challenges of the reconstruction of long-lived particles using T tracks for use in physics analyses are discussed and a solution is proposed. The feasibility of the experimental technique is demonstrated by reconstructing samples of long-lived Λ and K^0_S hadrons decaying between 6.0 and 7.6 metres downstream of the proton-proton collision point. The long-lived hadrons are selected using a data sample recorded between 2015 and 2018, corresponding to an integrated luminosity of about $6\,\text{fb}^{-1}$. These results open an opportunity to further extend the physics reach of the LHCb experiment.





Ongoing Analyses in the group (riguardare!)

Published / close to publication in red

- Amplitude analysis of Lc->pKpi decays from semileptonic production. Marangotto (completed)
- Amplitude analysis of Xic->pKpi decays from semileptonic production. Marangotto (ongoing)
- Polarisation measurement of Xic->pKpi decays from prompt production. Libralon, Marangotto (ongoing)
- Λc+ polarisation measurement in p-Ne collisions at √s=68 GeV. Merli (ongoing)
- Λ polarisation measurement in Ξc0→ΛK-π+ decays . Tonani, Merli, Neri)
- Amplitude analysis of B decays for exotic state searches. Spadaro, Fu, N. N. (in review)
- Studies of excited Ξb baryons. Paper in Preparation
- Long-lived particle reconstruction downstream of the LHCb magnet (DP-2022-001). Tonani, Neri
- Measurement of the CKM angle γ and of CP asymmetry in Λ_b^0→D^0 pK^- decay. Mancuso
- Λb → J/ΨpK amplitude analysis Run1+2 to study pentaquark properties (on going). Wang
- R(D*)e/mu measurement (on going). Wang
- J/Ψ cross-section measurement using Run3 early data (on going). Wang

Thesis & Publications

Published results

- LHCb Collaboration, **Observation of a $J/\psi \Lambda$ resonance consistent with a strange pentaquark candidate in $ \B^{-}\to J/\psi \Lambda\bar{p}$ decays**, arXiv:2210.10346, accepted by *PRL (Editor's suggestion), APS press for outreach*
- LHCb collaboration, **Amplitude analysis of the Λ+c → pK-π+ decay and Λ+c baryon polarization measurement in semileptonic beauty hadron decays**, arXiv: 2208.03262, accepted by *Phys. Rev. D*
- LHCb collaboration, **Long-lived particle reconstruction downstream of the LHCb magnet**, arXiv: 2211.10920, submitted to *Eur. Phys. C*
- Beteta, C. and others, **The SALT, readout ASIC for silicon strip sensors of upstream tracker in the upgraded LHCb experiment Sensors** (2022) 22(1) 107 DOI: 10.3390/s22010107

Thesis

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

Measurement of Ξ+c baryon polarisation in pp collision at LHCb

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

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

***Alessandro De Gennaro*, Master Thesis, 2022**

A study for the measurement of the Λ baryon electromagnetic dipole moments in LHCb

Conference contributions

2023

- ***A decade of spectroscopy at LHCb" on behalf of the LHCb Collaboration***, **P. Gandini,** CERN Seminars, 25 April 2023. Talk
- ***Momenti di dipolo elettromagnetici di barioni con stranezza e charm a LHC***, **G. Tonani**, Incontri Fisica Alte Energie, Catania,13/04/2023. Talk
- ***Heavy-ion and fixed-target physics at LHCb***, **A. Merli**, 57th Rencontres de Moriond QCD, 25th March – 1st April. Plenary talk
- ***Heavy flavour spectroscopy at LHCb" on behalf of the LHCb Collaboration***, **P. Gandini**, 57th Rencontres de Moriond QCD, La Thuile, Italy, 27 March 2023. Plenary talk

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
- ***Results of hadron spectroscopy at LHCb***, **E. Spadaro Norella**, NSTAR 2022, S. Margherita Ligure, Italy, 17-21 Oct., 2022. Plenary talk.
- ***Charm baryon amplitude analysis and polarization measurements***, **D. Marangotto**, 2nd Workshop on electromagnetic dipole moments of unstable particles, Gargnano del Garda, Italy, 26-28/09/2022. Talk.
- ***Λ+c , Ξ+c amplitude analyses and polarization measurements in pp collisions***, **D. Marangotto**, LHCb Italia meeting, Frascati, Italy, 18-19/07/2022. Talk.
- ***Studies of pentaquark states at LHCb***, **N. Neri**, International Conference of High Energy Physics 2022, Bologna, 6-13 July 2022. Talk
- ***Experiment for direct measurements of short-lived particle dipole moments at LHC***, **G. Tonani**, International Conference of High Energy Physics 2022, Bologna, 6-13 July 2022. Poster
- ***Particle zoo 2.0 at LHCb: New tetra- and pentaquarks at LHCb***, **E. Spadaro Norella**, CERN Seminar, 5th July, 2022, Plenary talk.

Richieste Servizi di Sezione

- Main activities: (LHCb) UT commissioning at CERN + Overlaps with project IGNITE + SELDOM
- Richieste

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				

Servizi LHCb: supporto per operazioni di commissioning del rivelatore in particolare durante l'YETS

	kEuro
Trasferte	147
Consumi	18,5
MOF-B UT	9,5
Upgrade 2	0
Totale	175