



LHCb status report

Paolo Gandini

On behalf of the LHCb Milano group

12th July 2022

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Outline

LHCb experiment:

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

Website

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



ABOUT US

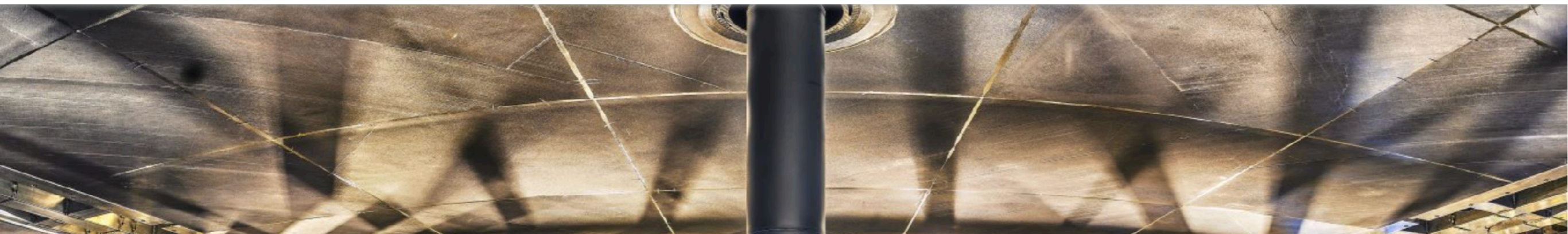
RESEARCH

PUBLICATIONS

CONFERENCE CONTRIBUTIONS

THESIS

EVENTS

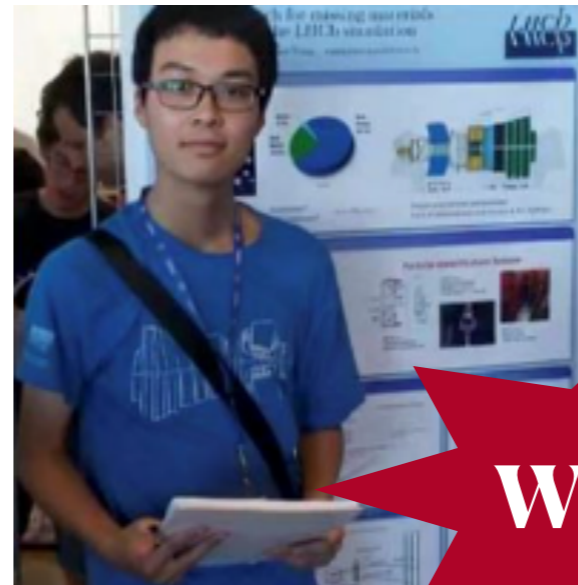


New members of the group

We welcome:

Postdoc:

- Mengzhen Wang (INFN postdoc per stranieri)
- Winner of "POST-DOCTORAL SENIOR LEVEL 3 RESEARCH GRANT IN EXPERIMENTAL PHYSICS"
- Winner of LHCb thesis award 2022:



Winner!

PhD Students:

- Giorgia Tonani (cotutela with Valencia)
- Chiara Mancuso (cotutela with Orsay)

} Very important to maintain fruitful collaboration with other institutions in our collaboration!

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

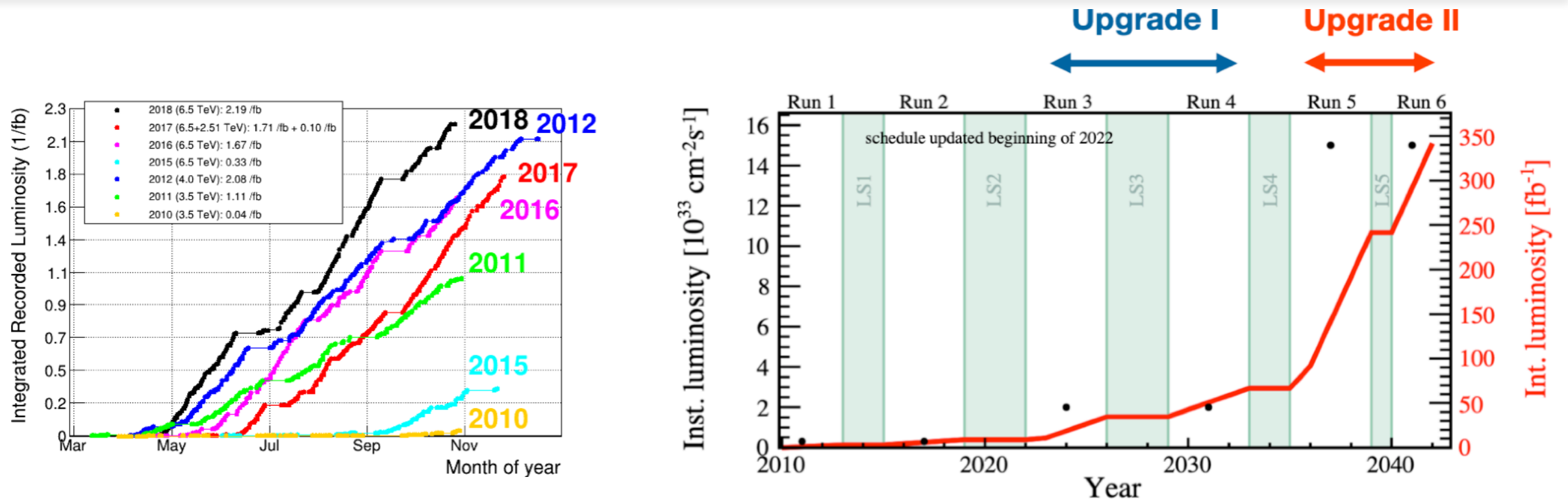
Z^0 , W^+ , top, Dark photons, Long-lived particles, ...

Ion, Fixed-target

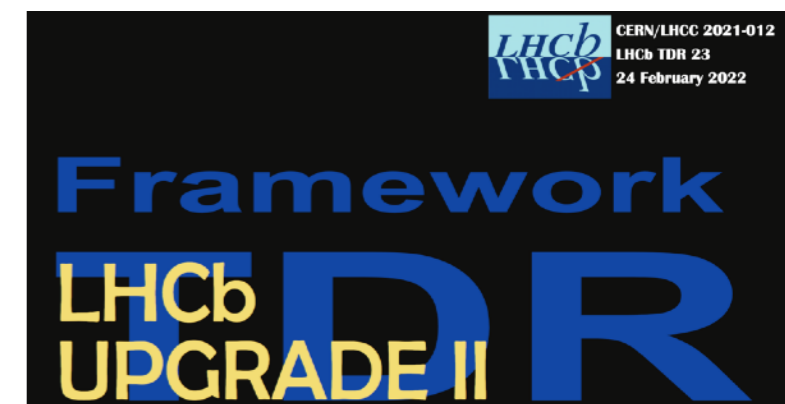
Heavy ions, p-Gas, nuclear effects, ...

Active on several topics,
but expanding...

LHCb plans



- Upgrade I: Major detector upgrade during LS2. Aim at 50 fb^{-1} before 2032
- VELO, RICH, SciFi full in, UT planned to go in winter technical stop
- Upgrade Ib: First detector improvements in PID, tracking, and ECAL during LS3
- Upgrade II: Major detector upgrade during LS4. Aim at $>300 \text{ fb}^{-1}$
- Framework TDR: <https://cds.cern.ch/record/2776420?ln=en>



First LHCb week in person



LHCb Experiment at CERN ✓

18 giugno alle ore 16:54 · 🌐



This week was the 104th LHCb week, the first in-person LHCb week since February 2020. It was a fantastic opportunity for LHCb members to meet, discuss physics and have friendly chats. The high attendance allowed for a new LHCb group picture in the garden in front of CERN's Restaurant 1 (R1).

LHCb organised its traditional BBQ, where the whole collaboration thanked Rolf Lindner for his amazing twelve years as technical coordinator. The general public knows Rolf from the many... **Altro...**



First Collisions in 2022



LHCb Experiment at CERN

5 luglio alle ore 18:01

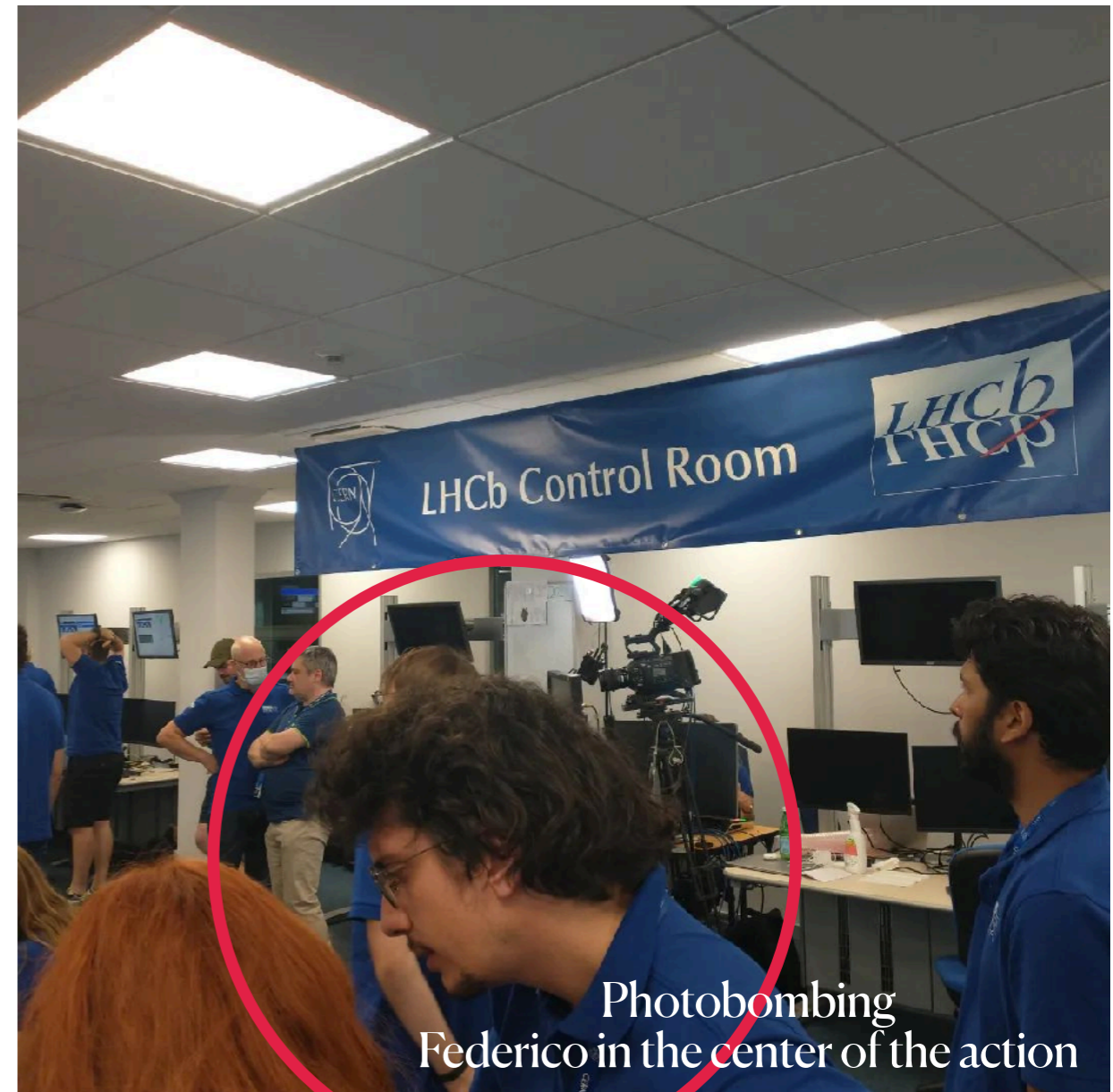


Fantastic day for LHCb! We recorded the first collisions at a world record energy of 13.6TeV!

You can see a 3D image of the detector after the first collisions on the second picture.

The last picture shows the crew behind the scenes at LHCb responsible for the livestream and the social media posts.

We hope you celebrated this special day with us. You can rewatch the livestream on the @cern Youtube channel [#UpgradingLHC](#) [#RestartingLHC](#) [#LHCRun3](#) [#FollowTheProtons](#)



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!

Observation of new Pentaquarks and Tetraquarks

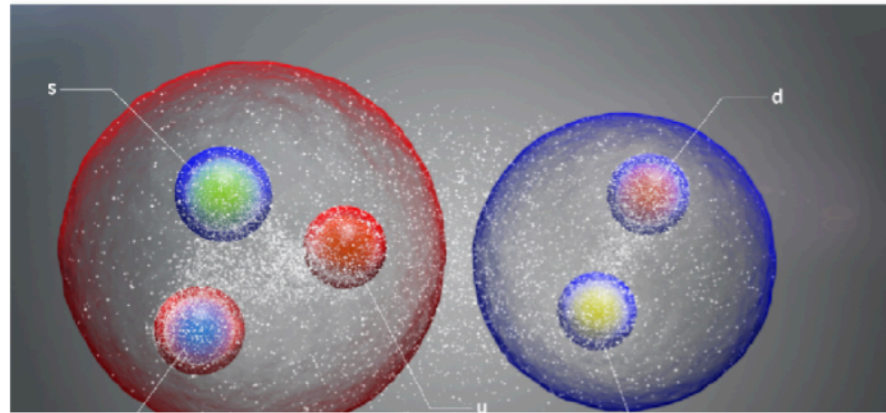


Voir en français

LHCb discovers three new exotic particles

The collaboration has observed a new kind of “pentaquark” and the first-ever pair of “tetraquarks”

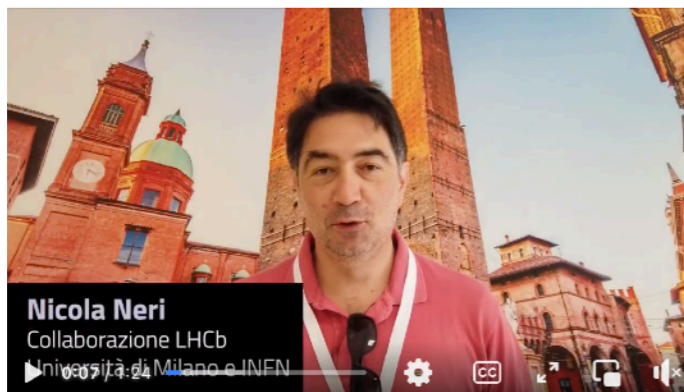
5 JULY, 2022



INFN - Istituto Nazionale di Fisica Nucleare
9 luglio alle ore 15:30

Volet scoprire di più sulle nuove particelle esotiche osservate da LHCb Experiment at CERN? Ascoltate le parole di Nicola Neri, ricercatore INFN e docente di Fisica Sperimentale all'Università degli Studi di Milano.

E questa sera alle 19:00 seguitemi in diretta su Twitter Spaces da ICHEP 2022: <https://twitter.com/i/spaces/1rmGPggRQIQKN?s=20>



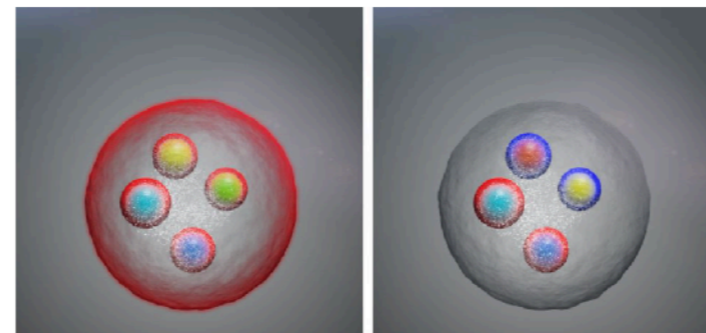
Received considerable press coverage



Pentaquarks: scientists find new "exotic" configurations of quarks

By Pallab Ghosh
Science correspondent

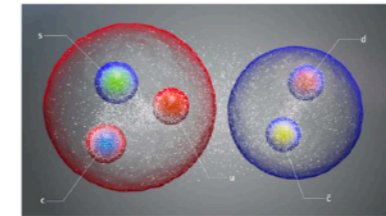
3 days ago



Comunicati stampa

09 LUGLIO 2022

LHCb OSSERVA TRE NUOVE PARTICELLE ESOTICHE. LA PRESENTAZIONE AD ICHEP 2022 IN CORSO A BOLOGNA



La collaborazione internazionale LHCb ha osservato un nuovo tipo di 'pentaquark' e la prima coppia di 'tetraquark', formati da due quark e due antiquark, che a sua volta include un tetraquark mai osservato prima. La scoperta realizzata grazie a un'analisi interamente condotta da ricercatori italiani dell'INFN Istituto Nazionale di Fisica Nucleare e dell'Università degli Studi di Milano.

Tre nuovi componenti si vanno ad aggiungere al sempre più ricco elenco di particelle rare conosciute. A contraddistinguerli, un numero di costituenti elementari, quark, superiore rispetto a quello che caratterizza i

LA STATALE
news




Innovazione e ricerca

La collaborazione LHCb osserva tre nuove particelle esotiche

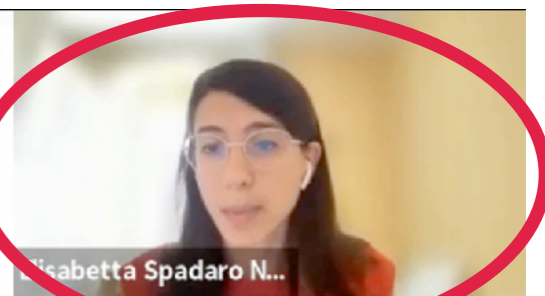
La scoperta, grazie a un'analisi interamente condotta da ricercatori italiani dell'INFN e della Statale, è stata annunciata alla conferenza ICHEP 2022, il più importante appuntamento mondiale dedicato alla fisica delle particelle, che si tiene quest'anno a Bologna.

Observation of new Tetraquarks

- Analysis proposed and performed in the Milano Group
- CERN seminar given by Elisabetta Spadaro Norella (PhD and now postdoc in Milano)
- Long tradition of Dalitz plot analyses with exotic states!



Outline



New exciting results!

- ✓ First pentaquark with s quark content in $J/\psi\Lambda$ ($B^- \rightarrow J/\psi\Lambda\bar{p}$ decays) [LHCb-PAPER-2022-031]
- ✓ Tetraquark isospin pair in $D_s^+\pi^+$ and $D_s^+\pi^-$ ($B^{0(+)} \rightarrow D^{0(-)} D_s^+ \pi^{+(-)}$ decays) [LHCb-PAPER-2022-026, LHCb-PAPER-2022-027]
- ✓ Tetraquark candidate in $D_s^+D_s^-$ ($B^+ \rightarrow D_s^+ D_s^- K^+$ decays) [LHCb-PAPER-2022-018, LHCb-PAPER-2022-019]

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Observation of new Tetraquarks

- All started with the observation of the charmonium-like $X(3872)$ resonance
- In recent years over a dozen exotic states have been observed by LHCb
- Notable examples are:
 - The pentaquark $P_c(4312)^+$
 - 4-charm-state $T_{cccc}(6900)$
 - open charm $X(2900)$
 - doubly charmed $T_{cc}(3875)^+$

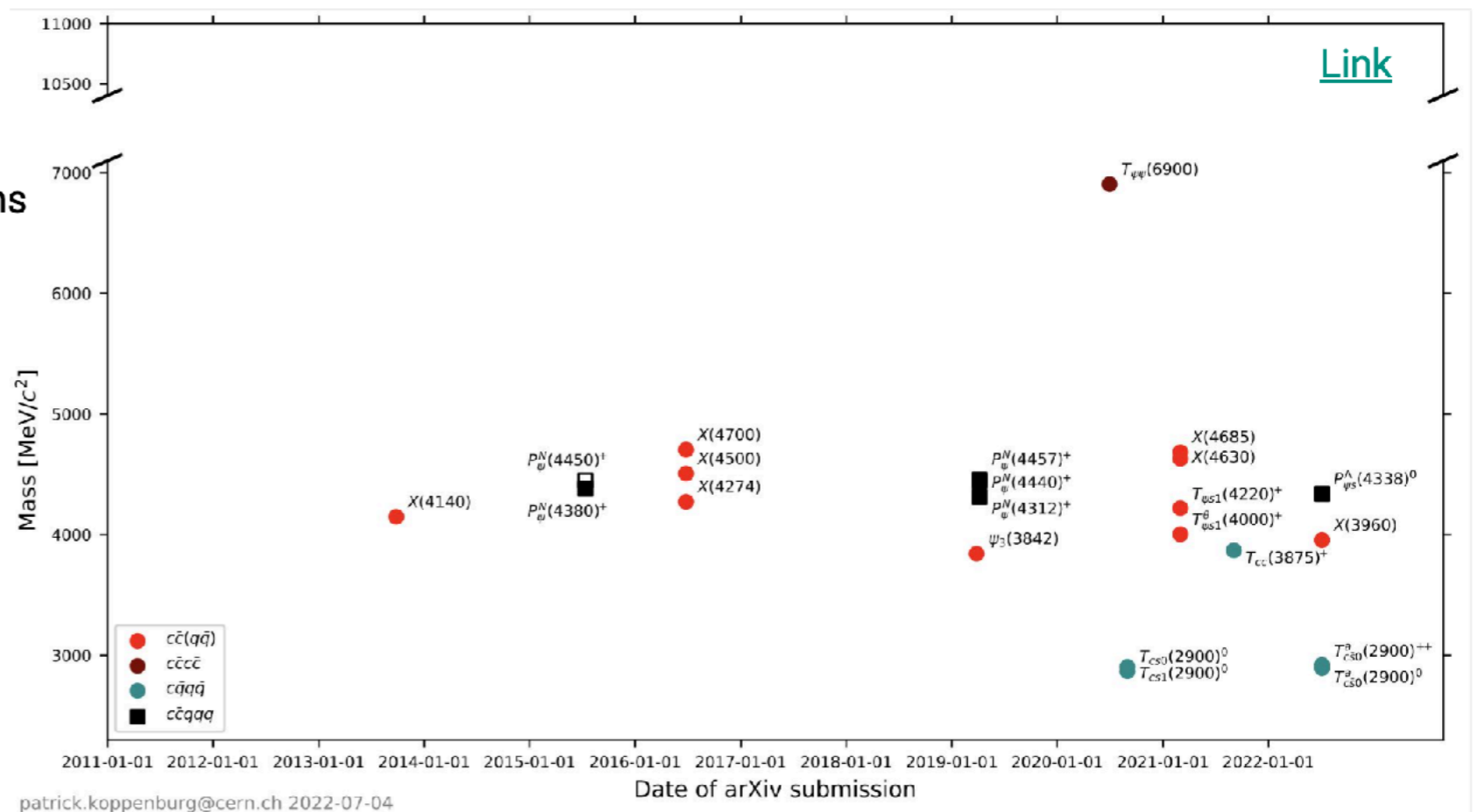
Over the past 10 years more than 60 new hadrons discovered at LHC

More than 15 states are exotics:

⇒ New naming scheme

[arxiv2206.15233](https://arxiv.org/abs/2206.15233)

59 hadrons have been observed by LHCb



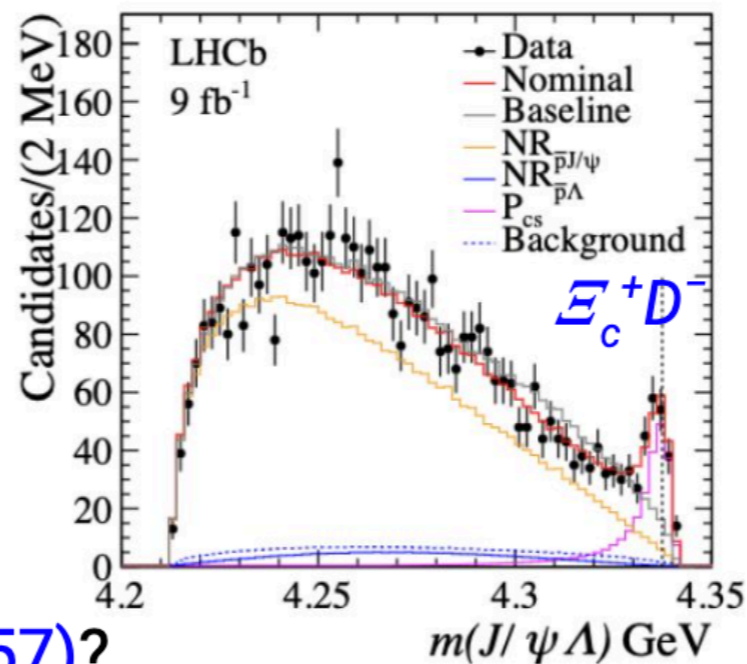
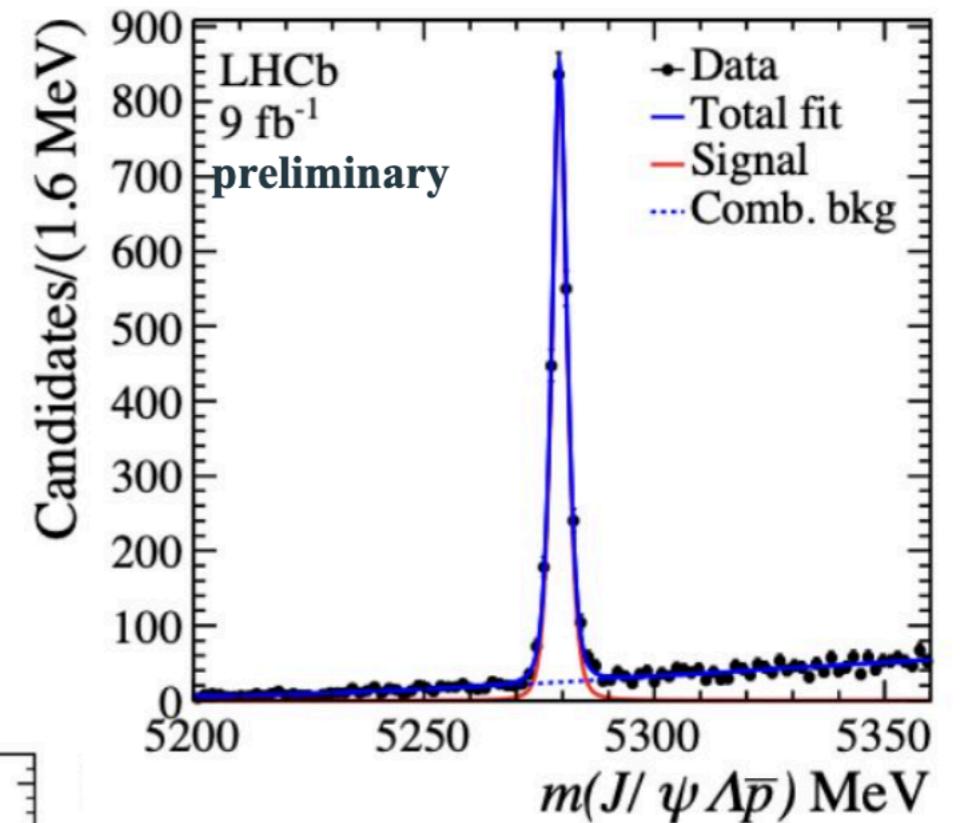
Observation of new Tetraquarks

- Observation of a $J/\psi\Lambda$ resonance in $B^- \rightarrow J/\psi\Lambda p$ decays (LHCb-PAPER-2022-031 in preparation)
- Multibody decays of B meson
 - good invariant mass resolution
 - high signal purity
 - good place to search for narrow resonances
 - Exotic states in the projections of the Dalitz plot
 - Look for strange pentaquarks
- Complicate Amplitude Analysis

narrow, close to $\bar{E}_c^+ D^-$ threshold and in S-wave

pentaquark with strangeness, due to SU(3) symmetry

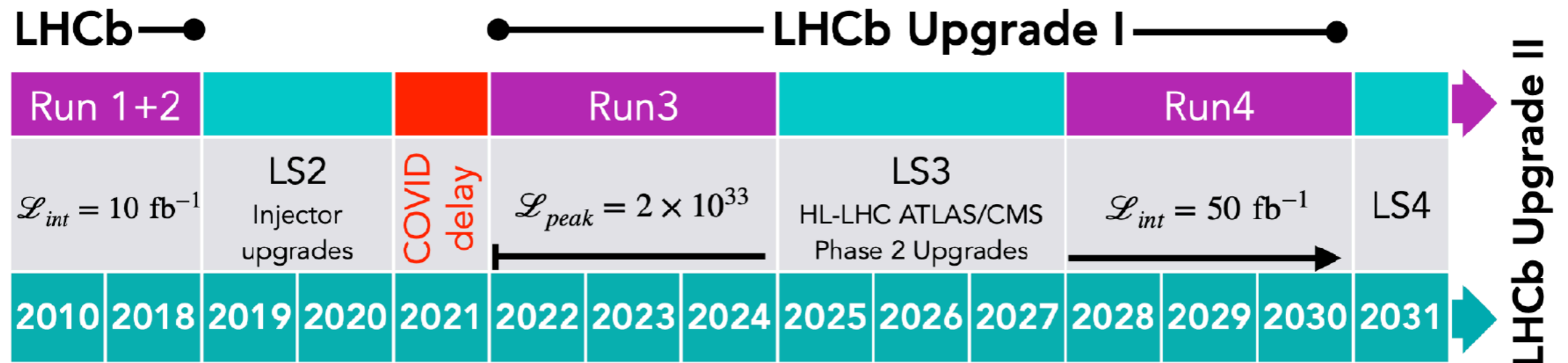
at same mass of $P_\psi^N(4337)$:
analogy to $P_{\psi_s}^\Lambda(4459)$ & $P_\psi^N(4457)$?



Ongoing Analyses in the group

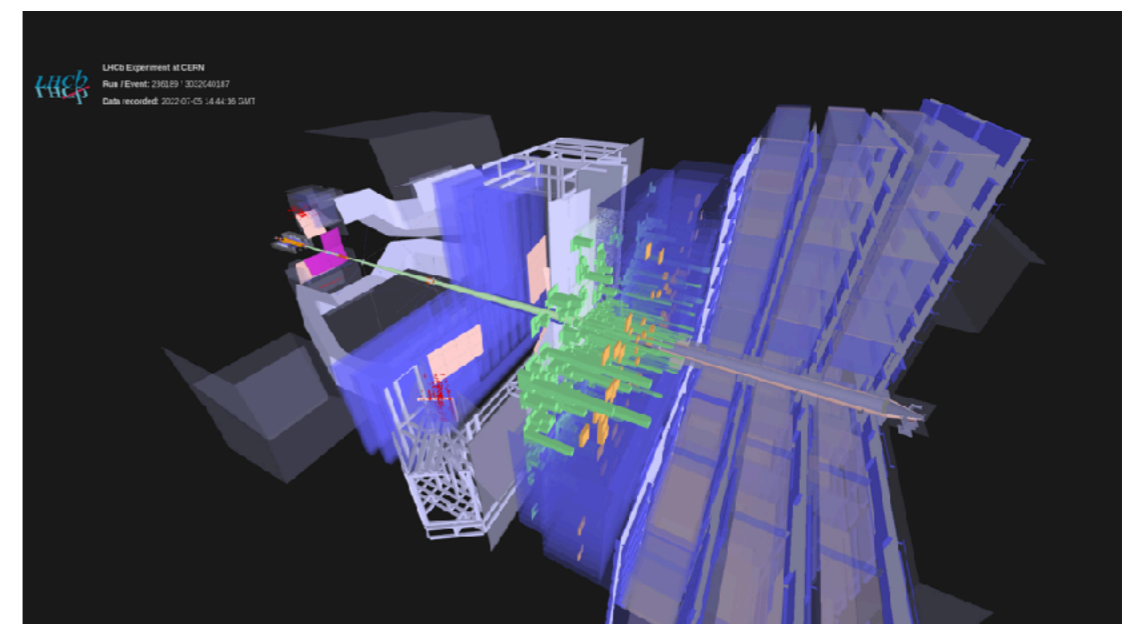
- Amplitude analysis of charm baryon decays from semileptonic production. Daniele Marangotto
- Λ_c^+ polarisation measurement in p-Ne collisions at $\sqrt{s}=68$ GeV. Merli (ongoing)
- Λ polarisation measurement in $\Xi_c^0 \rightarrow \Lambda K^- \pi^+$ decays. Tonani, Merli, Neri (ongoing)
- $B_s \rightarrow J/\Psi p \bar{p}$ with evidence of pentaquark in $J/\Psi p$ PRL 128, 062001 (2022). Spadaro, Fu, Neri
- Amplitude analysis of B decays for exotic state searches. Spadaro, Fu, N. N. (in review)
- Studies of excited Ξ_b baryons. Gandini (ongoing)
- 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 $\Lambda_b^0 \rightarrow D^0 p K^-$ decay. Mancuso
- $\Lambda_b \rightarrow J/\Psi p K$ 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

LHCb Upgrade



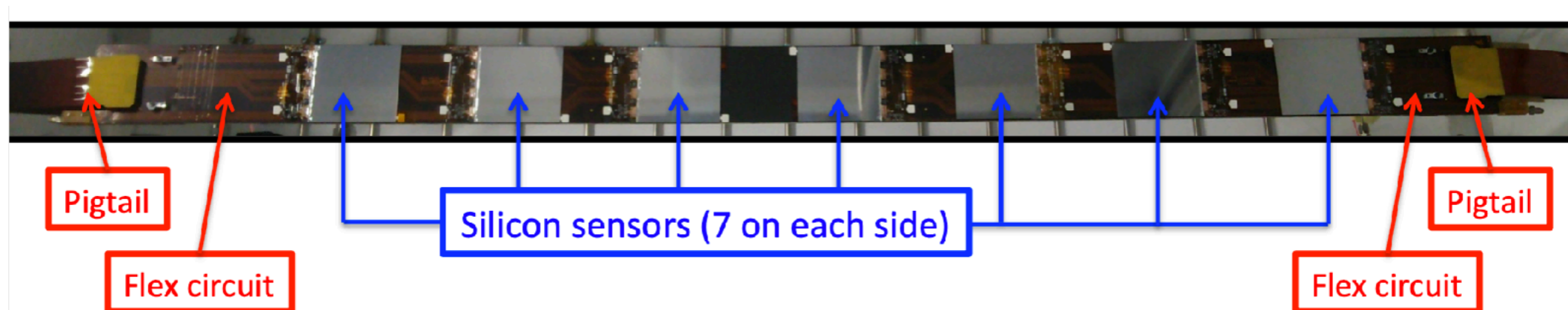
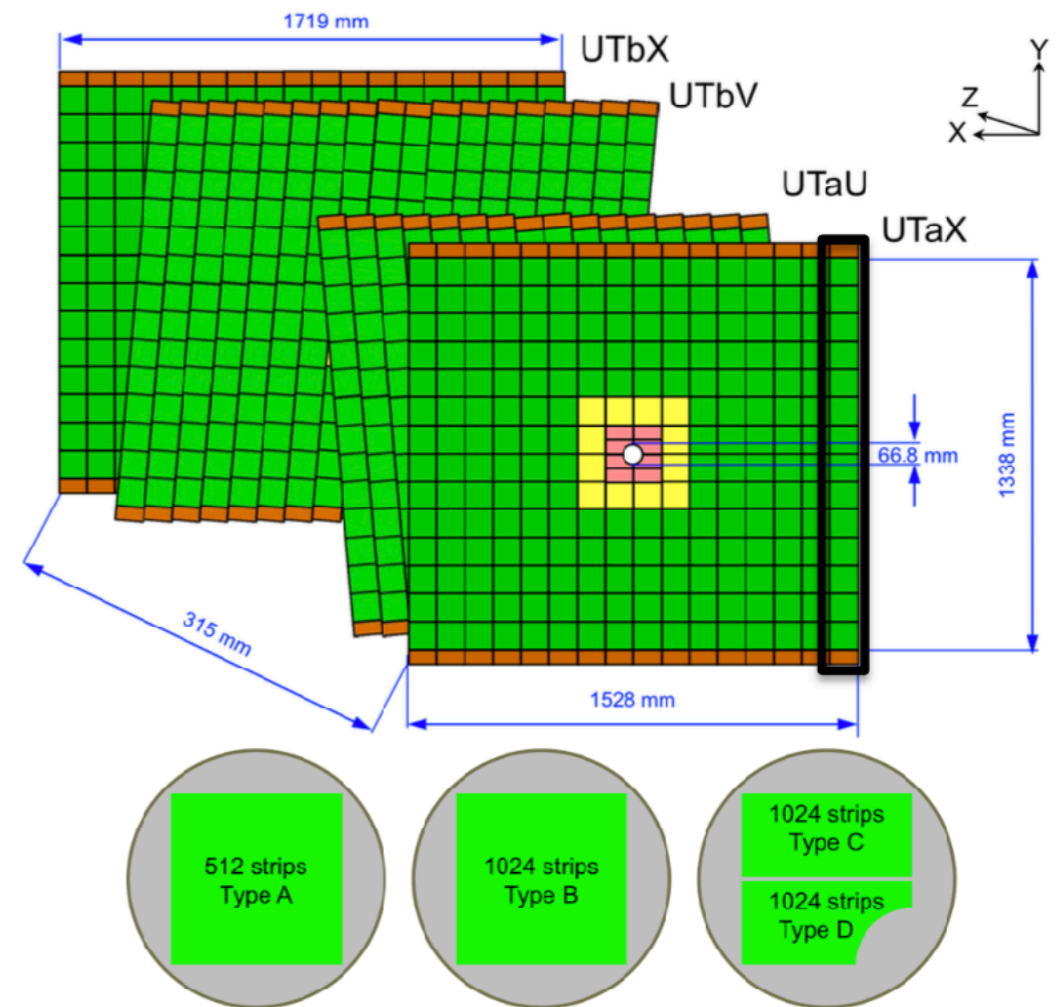
- Increase instantaneous luminosity 5 times wrt Run2
- Now full software based trigger → Removed LO bottle neck

Event taken in 2022-07-05



Upstream Tracker

- **Silicon micro-strip detector**
 - 4 layers (x, u, v, x) upstream of magnet
- 4 types of sensors
 - 968 sensors of type A, B, C, D: 888, 48, 16, 16
 - n- and p-type with 512 or 1024 strips
 - 320/250 μm thick; 187.5/93.5 μm pitch
- Modules mounted on double-sided staves
 - 68 staves / 968 modules
 - CO₂ cooling pipe integrated in stave
- ASIC (SALT) and hybrid circuits
 - 128 channels with 6-bit ADC.
 - 4192 ASICs mounted on hybrid circuits
 - 888 4-chip hybrids; 80 8-chip hybrids
- Read-out electronics mounted on detector frame



Upstream Tracker

- Milano responsibilities in UT project:
 - Flex cables. Production and test completed ✓
 - Hybrid circuits. Production completed ✓
 - Integration of hybrid and SALT chip: glueing, bonding, burn-in ✓
 - CO2 distribution system completed and installed ✓
- LHCb management asked extra commitment by the Milano group to speed the installation process
- Federico De Benedetti as project electrical engineer
- Major involvement in the cavern commissioning, high voltage, and low voltage
- Involved in the installation of the A side, scheduling is on time
- Cable chain preparation and installation
- Making hardware and software for the detector integration underground

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



Upstream Tracker

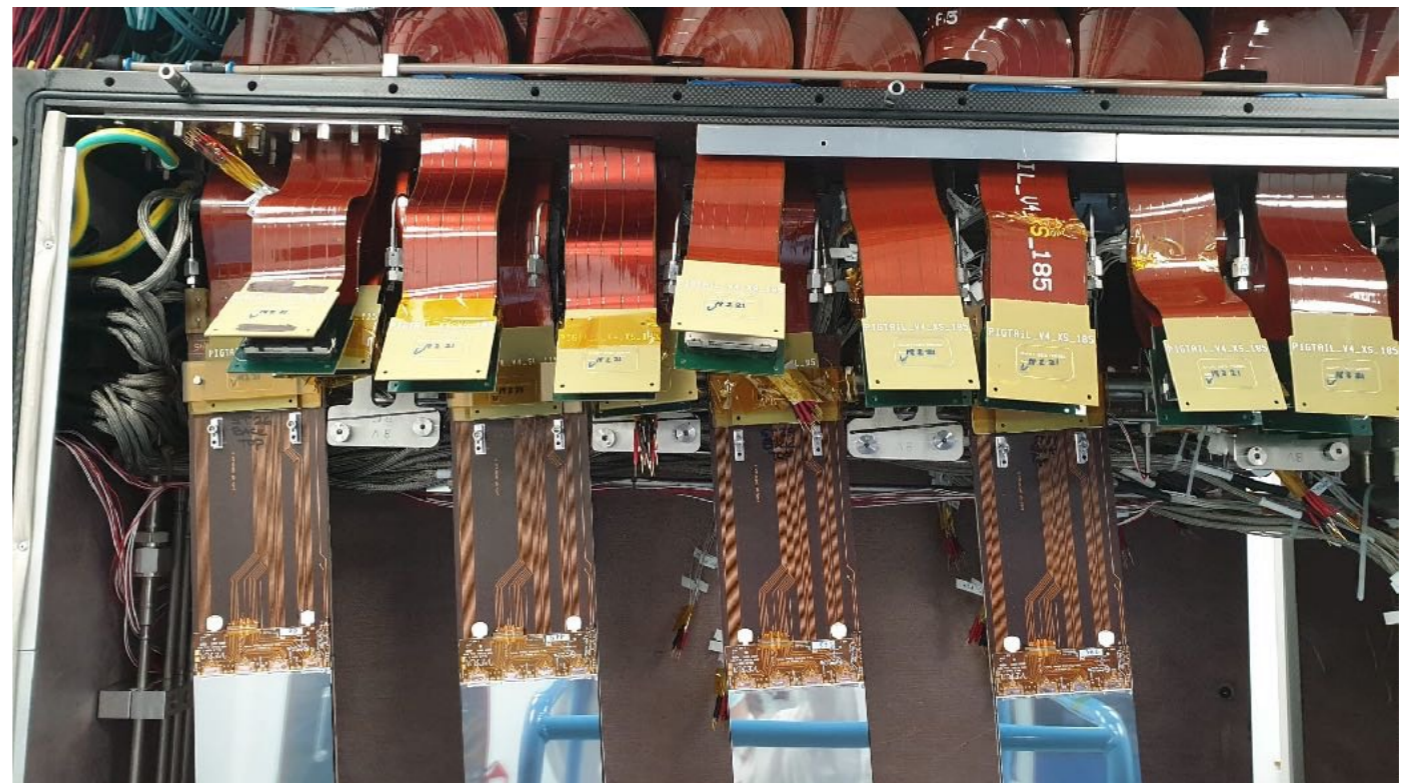
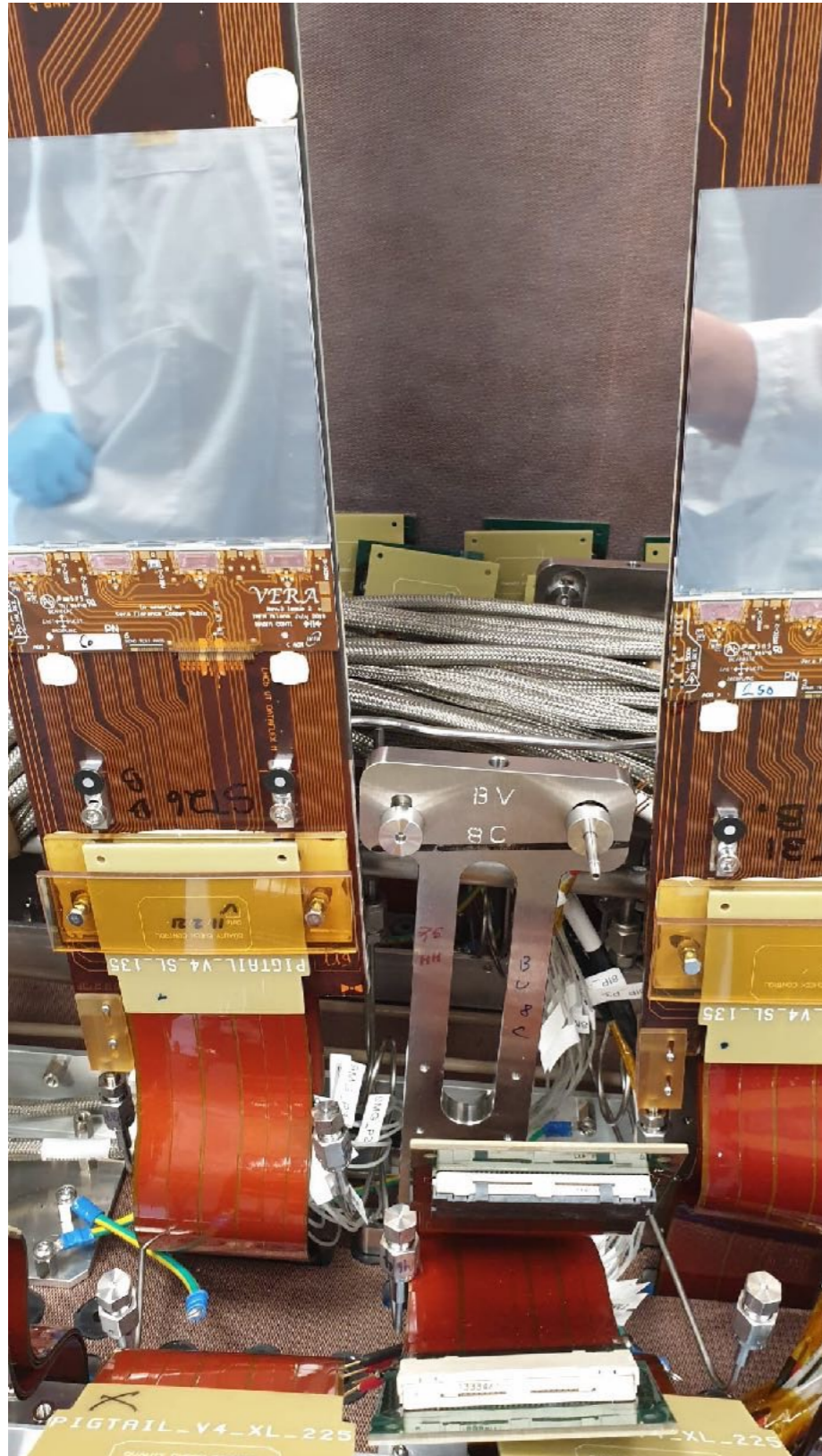
C side



A side

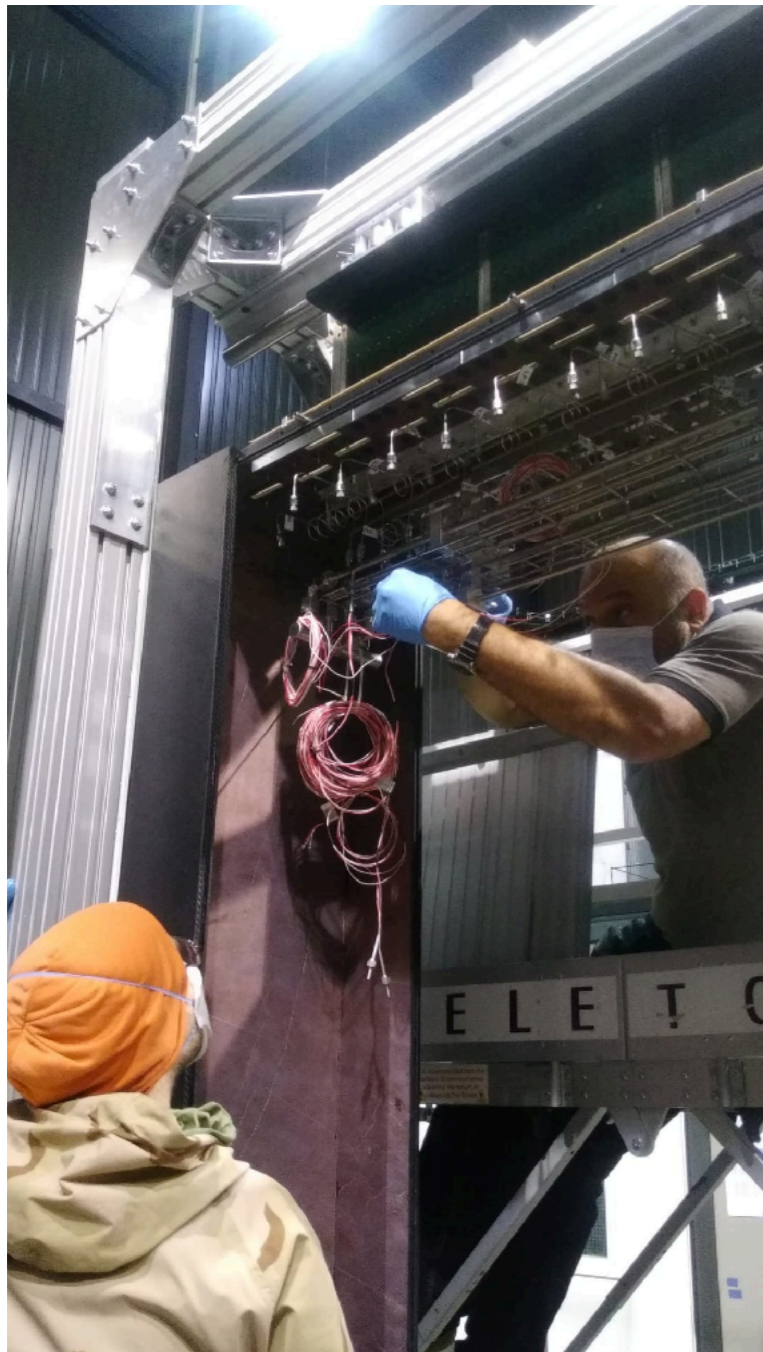


Upstream Tracker: 5 staves



CO2 Cooling

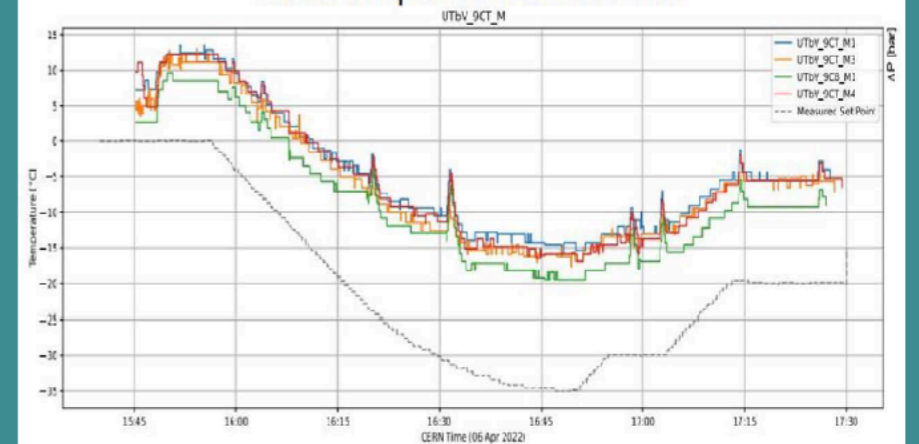
- Designed, assembled and tested in Milano → Installed and tested at CERN
- Constant help provided for daily operation & tests
- Precious contribution by our Officina Meccanica (Capsoni,Coelli,Monti,Gesmundo,Trotta,Viganò, Viscione)



COMMISSIONING MEASUREMENTS, MAY 2022

- LUKASZ cooling unit
- «A» TYPE lateral stave installed
- Characterization from +15/ -35° C set-point
- Stability studies

Stave temperature vs Set Point



Conference Contributions

- N. Neri, “Direct measurement of short-lived particle moments at the LHC”
Low-x 2021 Workshop, La Biodola Isola d’Elba, Italy, 26 September – 1 October 2021. Invited talk.
- N. Neri, “Enabling technologies for measurements of short-lived particle dipole moments”
PM2021- 15th Pisa Meeting on Advanced Detectors, La Biodola, Isola d’Elba (Italy), 22-28 May 2022. Poster.
- N. Neri, “Studies of pentaquark states at LHCb”
ICHEP 2022 XLI International Conference on High Energy Physics, Bologna (Italy), 6-13 July 2022. Parallel.
- P. Gandini, “Exotic hadrons at LHC (experiment)”
LHCP 2022, Taipei (online), 16-20 May
- P. Gandini, “Spectroscopy at LHCb”
20th Lomonosov Conference on Elementary Particle Physics
- P. Gandini, “Hadron Spectroscopy at LHCb”
Workshop PWA/ATHOS, Bristol
- D. Marangotto, “Analysis of $\Lambda_c \rightarrow pK\pi^-$ ”
La Thuile 2022 – Les Rencontres de Physique de la Vallée d’Aoste, La Thuile, Italy, 06 – 12/03/2022,
- E. Spadaro Norella, “QCD spectroscopy and hadronic structure”
LHCP 2022, Taipei (online), 16-20 May
- E. Spadaro Norella, “Particle zoo v2.0: New tetra- and pentaquarks at LHCb”
CERN seminar, 5 July 2022
- G. Tonani, “Direct measurement of electromagnetic dipole moments of strange baryons at LHCb”
Strong2022 workshop.
- S. Coelli, “CO2 evaporative cooling system for the LHCb UT Detector”
Forum on Tracking Detector Mechanics 2022

Thesis

- Alessandro De Gennaro, Master Thesis, 2022
A study for the measurement of the Λ baryon electromagnetic dipole moments in LHCb
- Bjorn Kerby Dimayuga, Bachelor Thesis, 2021
Sensitivity studies for the search of the Λ 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 $\Xi_c^0 \rightarrow \Lambda K^- \pi^+$ decays
- Chiara Mancuso, Master Thesis, 2022
Study of the $\Lambda_b \rightarrow D^0 p K^-$ decay in preparation of a future measurement of the CKM angle γ at LHCb

Composizione Gruppo di Ricerca

Attività 2023

Personale	FTE	LHCb (FTE) Responsabile Neri	SELDOM (FTE) Responsabile Neri	IGNITE (FTE) Responsabile Stabile	Inquadramento	Servizio Meccanica	Servizio Elettronica
Citterio	0,1	0,1			Dirigente Tecnologo	4 m.u.	4 m.u.
Coelli	0,2	0,1	0,1		Primo Tecnologo	2 m.u.	2 m.u.
De Benedetti	1,0	0,7		0,3	AR tecnologico		
Frontini	0,3			0,3	AR UNIMI		
Gandini	1,0	1,0			Ricercatore		
Liberali	0,3			0,3	PA		
Mancuso	1,0	1,0			Dottoranda		
Marangotto	1,0	1,0			AR UNIMI (UE)		
Merli	1,0	1,0			RTD UNIMI		
Neri	1,0	0,4	0,6		PA		
Riboldi	0,2	0,2			RU		
Stabile	0,4			0,4	RTD UNIMI		
Spadaro	1,0	1,0			AR UNIMI		
Tonani	1,0		1,0		Dottoranda (UE)		
Wang	1,0	1,0			PosDoc INFN stranieri		
Tot. (FTE)	10,5	7,5	1,7	1,3			

Per progetto IGNITE
vedi presentazione dedicata

Richieste Servizi di Sezione

- Istallazione UT durante YETS 2022 (fino a marzo 2023)
- Fine tuning del sistema di CO2 cooling

- Development and test of front-end chip for Upgrade (IGNITE)
- R&D e test di elettronica e sensori a pixel per VELO Upgrade 2
- Realizzazione di prototipi di sensore + elettronica per tracciamento 4D
- Integrazione con progetto IGNITE (appena approvato, vedi presentazione Liberali)

- Richieste (ultimare istallazione):
 - 10% FTE Mauro Citterio (6m.u. servizio elettronico)
 - 20% FTE Simone Coelli (6m.u servizio officina e progettazione meccanica)