

Activities of the LHCb group

Paolo Gandini

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on behalf of the Milano LHCb group
INFN - Sezione di Milano

2nd July 2020
Consiglio di Sezione



Outline

- The LHCb-Milano group is active on many fronts, from data analysis to hardware

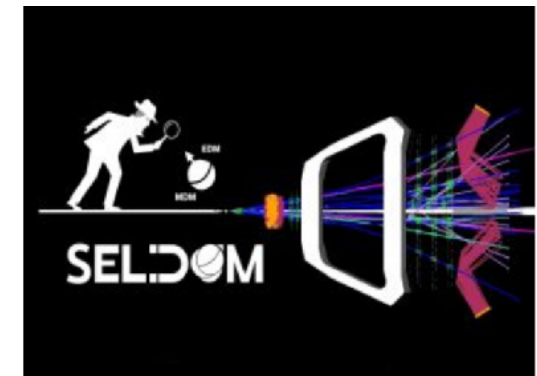
- LHCb experiment

- Physics results
- LHCb upgrade
- Contributions of the group members



- SELDOM ERC project

- Status update



- Timespot (in backup, CSN5)



The Group

- New website: https://web.infn.it/lhcb_milano/



The LHCb Physics program

- The LHCb Physics program is wide and increases year-by-year
- Our detector has proven to be extreme versatile, both on operating strategy and physics reach
- Several outstanding results, e.g.



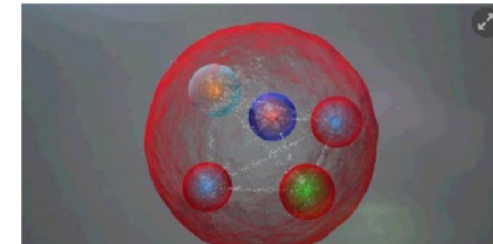
and the same in 2015....

Large Hadron Collider discovers new pentaquark particle

BBC Online

Scientists at the Large Hadron Collider have announced the discovery of a new particle called the pentaquark.

It was first predicted to exist in the 1960s but, much like the Higgs boson particle before it,



TOP NEWS

- Total Covid-19 infections nearing 1.5 lakh, 43.27% fatality for the elderly
- Latifur Rahman no more
- Mangroves from Kankamati's Naniarchar: being exported to Europe for the first time
- Factbox: Covid-19 vaccine candidates with early human-trial data

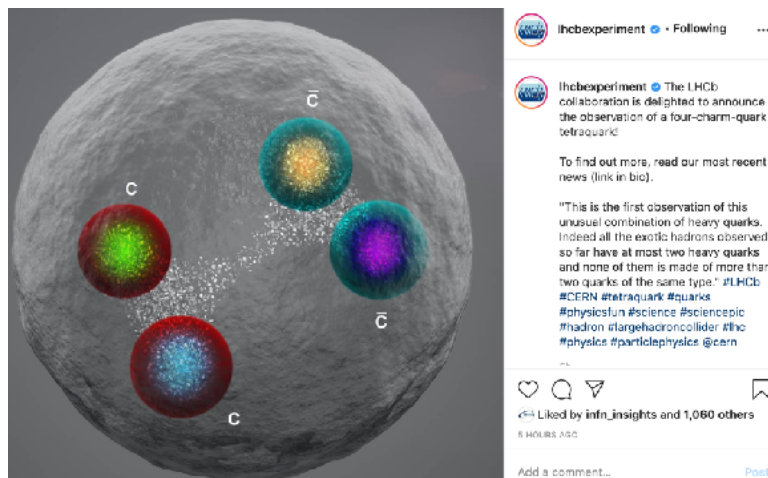
- European Physics Strategy: specific mention on Flavour Physics

2020 UPDATE OF THE EUROPEAN STRATEGY FOR PARTICLE PHYSICS

by the European Strategy Group

A. The quest for dark matter and the exploration of flavour and fundamental symmetries are crucial components of the search for new physics. This search can be done in many ways, for example through precision measurements of flavour physics and electric or magnetic dipole moments, and searches for axions, dark sector candidates and feebly interacting particles. There are many options to address such physics topics including energy-frontier colliders, accelerator and non-accelerator experiments. A diverse programme that is complementary to the energy frontier is an essential part of the European particle physics Strategy. **Experiments in such diverse areas that offer potential high-impact particle physics programmes at laboratories in Europe should be supported, as well as participation in such experiments in other regions of the world.**

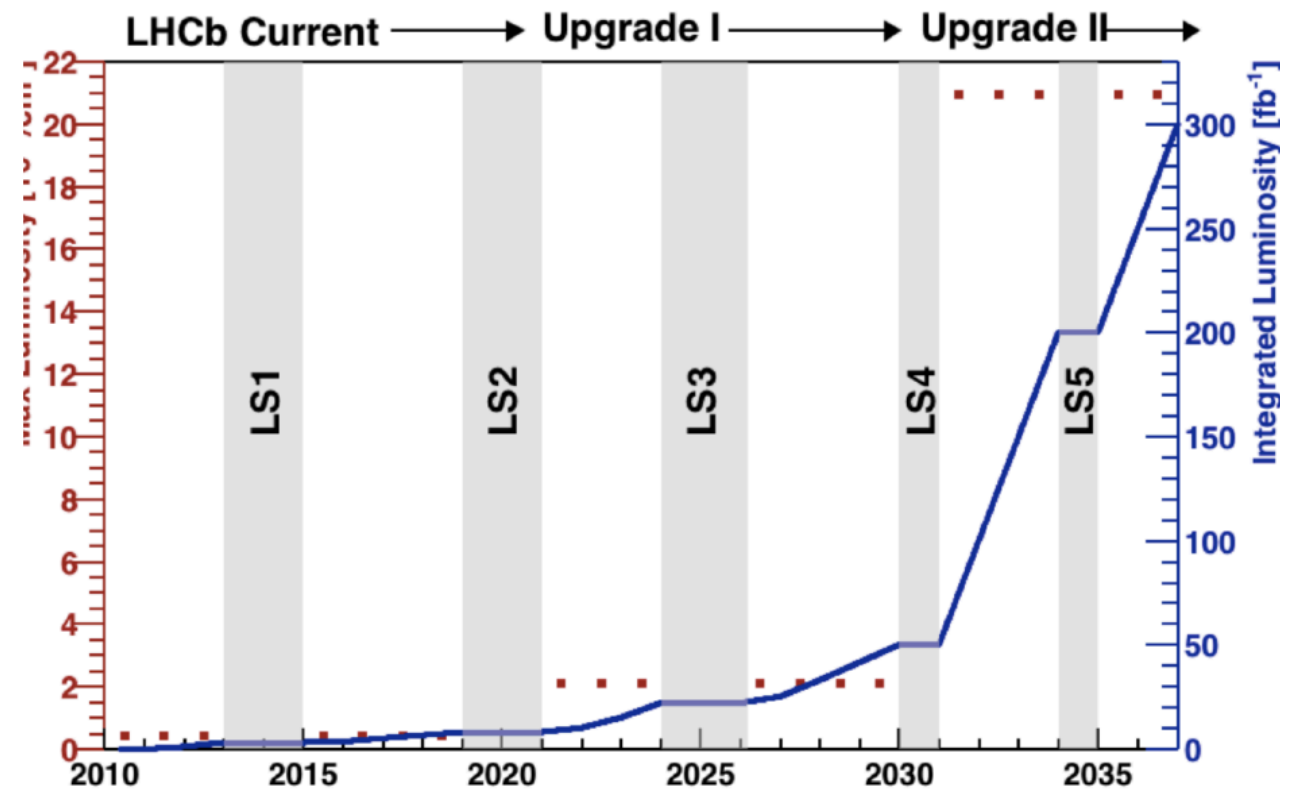
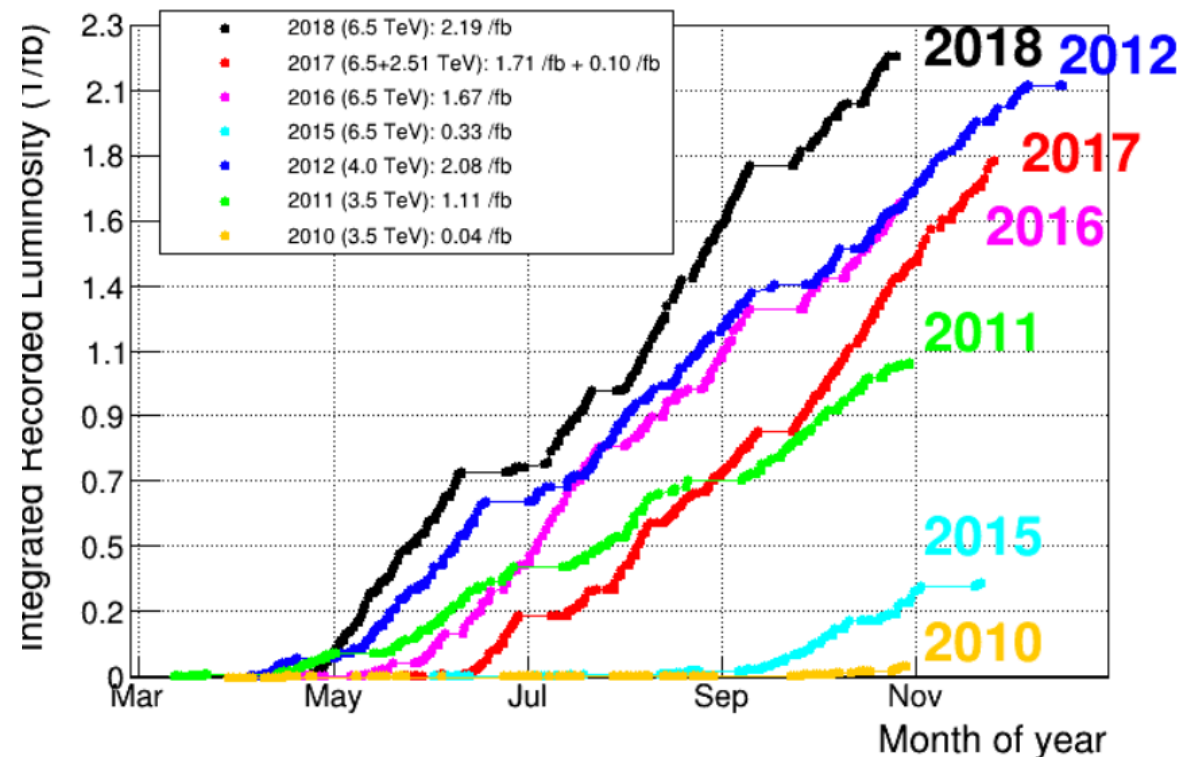
- We are also very active on Social Media and scientific outreach press



> 1k likes in 24h

Data Samples & Upgrade plans

- Plan is to collect about 50fb⁻¹ in Upgrade phase



- Collected 9.23 fb⁻¹ (2010-2018). Major detector upgrade
 - during LS2 (Upgrade I- 2020). Aim at 50 fb⁻¹ before 2030
 - First detector improvements in PID, tracking, and ECAL
 - during LS3 (Upgrade 1b - 2025)
 - Major detector upgrade during LS4 (Upgrade II - 2030)
 - Aim at >300 fb⁻¹ after 2030

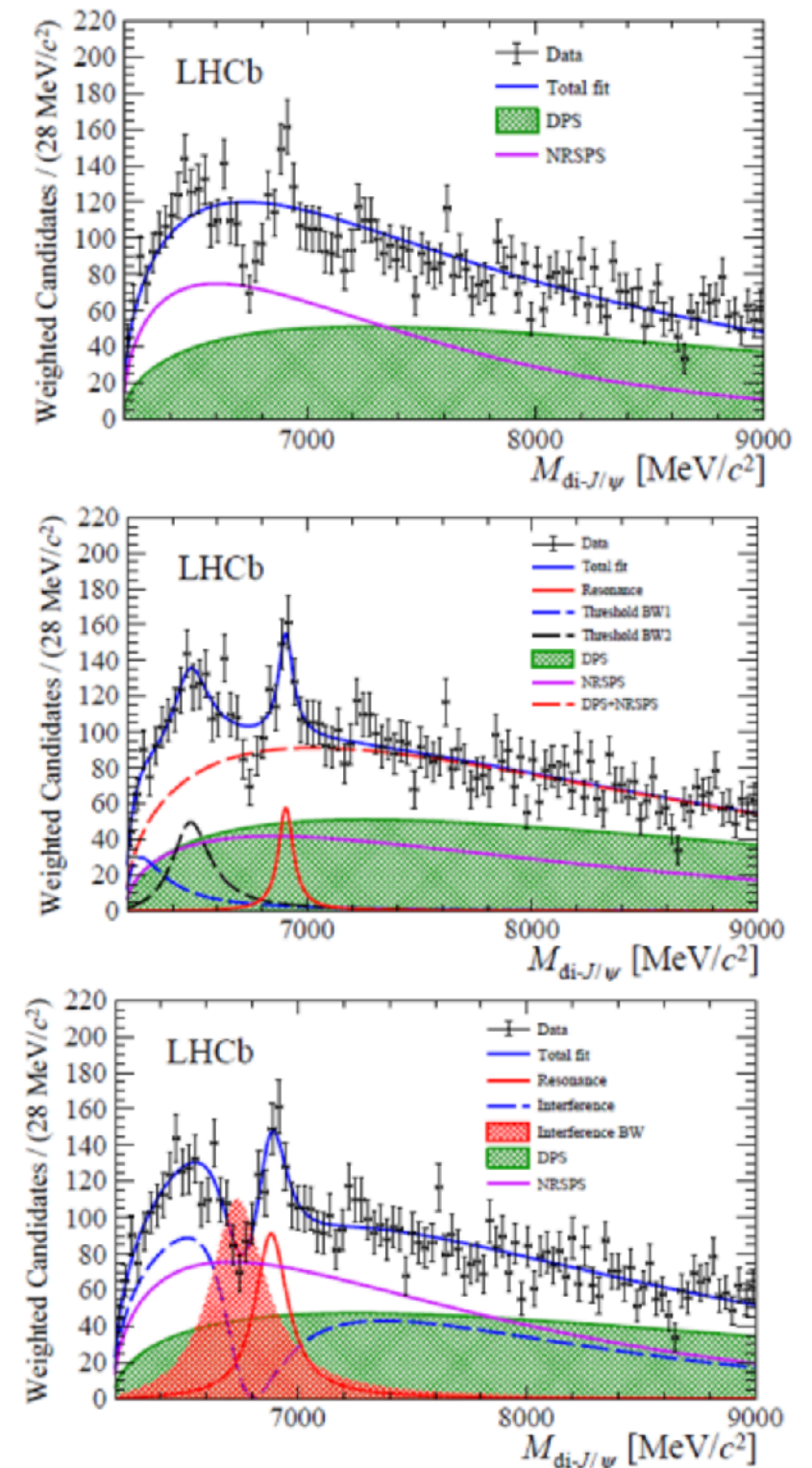
Very selected recent results

including contributions from the group

$J/\psi J/\psi$: a tetraquark candidate?

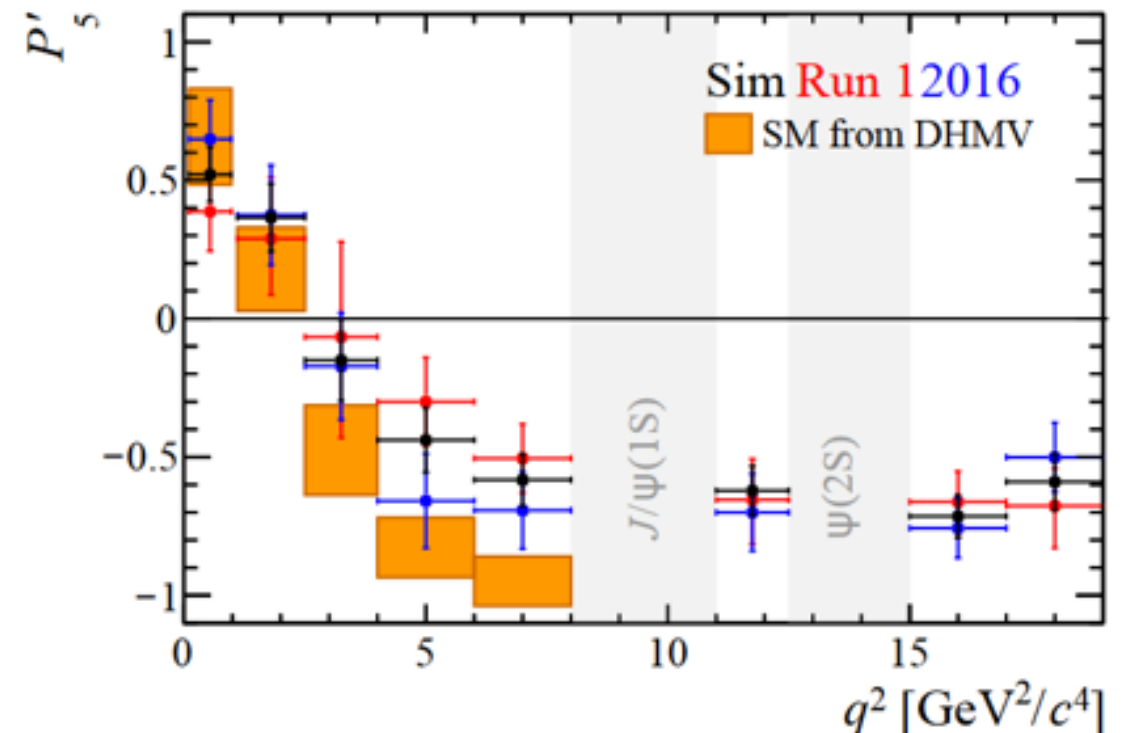
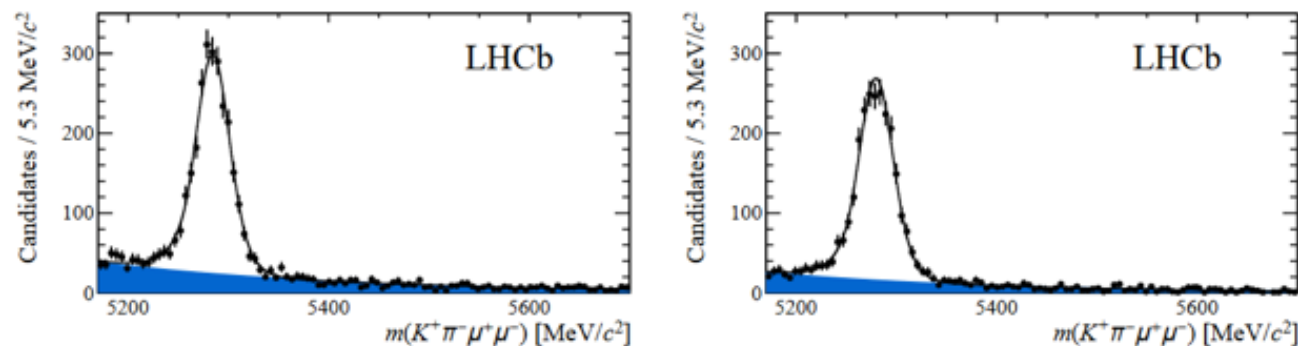
- Just appeared yesterday on [arXiv:2006.16957](https://arxiv.org/abs/2006.16957)
- These results have been presented at a CERN seminar on June 16th
- A lot of interest generated... with several theory papers appearing
- The full Run 1 and Run 2 data sets are used in this analysis
- The invariant-mass spectrum of prompt- J/ψ pairs is investigated
- A narrow peaking structure at $6900 \text{ MeV}/c^2$, matching the expected signature of the production of a new particle, and a broader structure around $6400\text{-}6600 \text{ MeV}/c^2$, close to the threshold, are observed
- Null hypothesis of only continuum J/ψ pair production is inconsistent with the data by more than 5σ in the mass range $6200\text{-}7400 \text{ MeV}/c^2$
- The decay of the new particle into the J/ψ pair suggests a minimum quark content of cccc, consistent with a T_{cccc} tetraquark interpretation

Null hypothesis of only continuum J/ψ pair



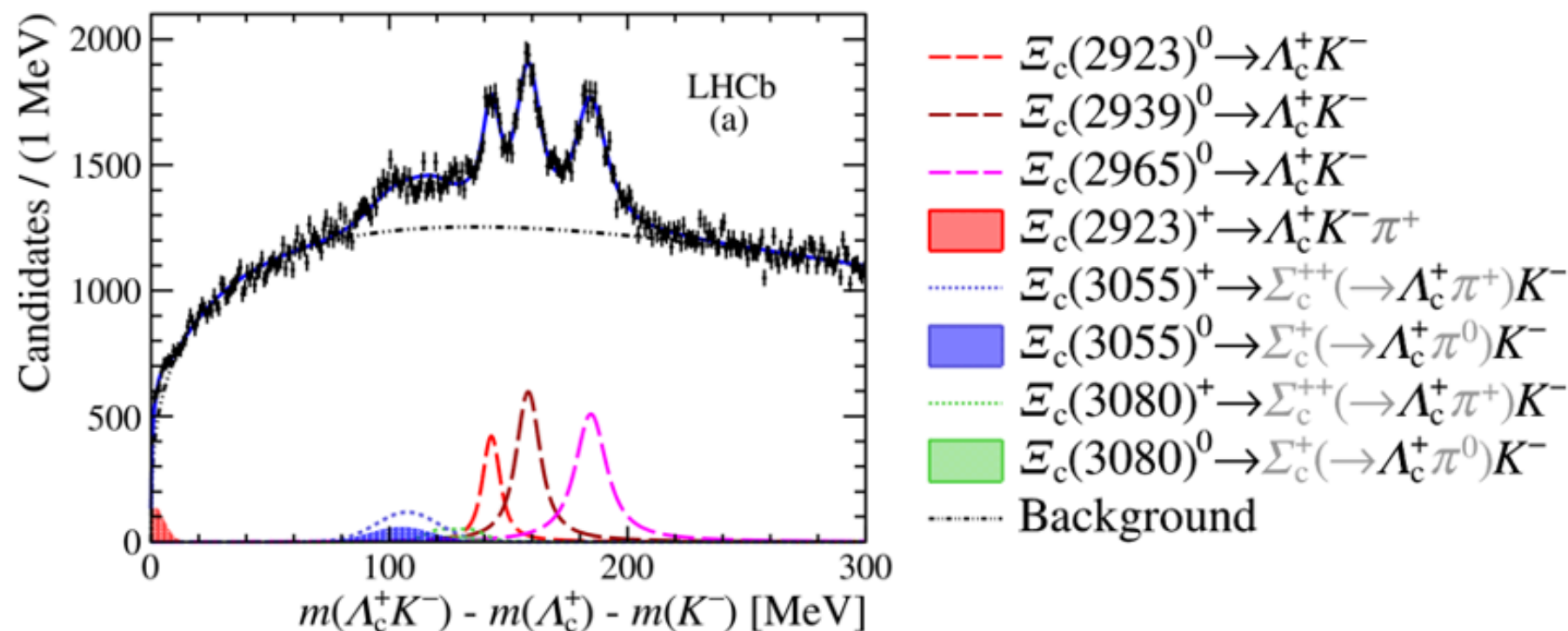
$B^0 \rightarrow K^* \mu^+ \mu^-$: more data confirm old puzzle

- Presented at CERN seminar: analysis of the angular distributions of $B^0 \rightarrow K^* \mu^+ \mu^-$ decays.
- Twice the luminosity wrt previous result (which received much attention due to tensions with SM)
- Compared with the previous LHCb results, the overall tension with the Standard Model (SM) is observed to mildly increase
- The analysis of $B^0 \rightarrow K^* \mu^+ \mu^-$ decays is considered to be a very promising way to search for effects of NP
- The best sensitivity to new particles comes from the study of the angular distribution of the kaon and pion from the K^* decay and the muons.
- Several hadronic form factors involved: tension with the most promising observable P_5'



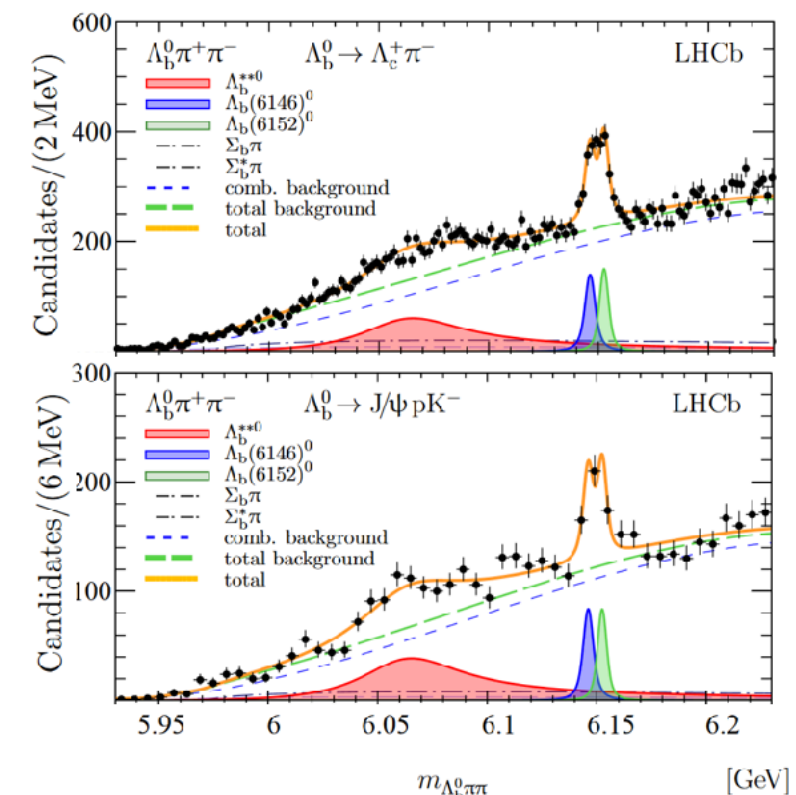
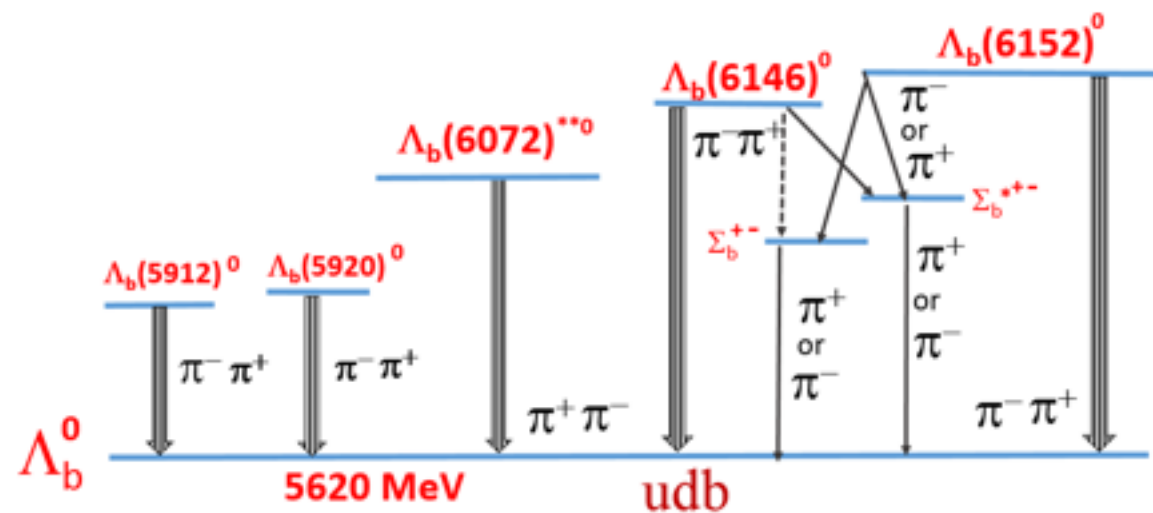
Observation of new Ξ_c baryons

- Observed a system of three particles interpreted as three narrow excited Ξ_c - states <https://arxiv.org/abs/2003.13649>
- Decays into a Λ_c^+ baryon and a K- meson.
- Three narrow structures are clearly visible
- They represent an observation, with large statistical significance, of three excited states of the Ξ_c baryon
- While other excited Ξ_c states have been reported before, the $\Xi_c(2923)^0$ and $\Xi_c(2939)^0$ are observed as new narrow states for the first time.
- The $\Xi_c(2965)^0$ seen by LHCb is close to a previously known state, the $\Xi_c(2970)^0$, but its measured mass and width properties differ significantly from the average of existing Belle and BABAR results for the $\Xi_c(2970)^0$.
- Further studies will be required to determine whether more than one state is present in the 2965-2970 MeV region, and, if so, the relation between them.
- This adds up to the discovery of new states in the Λ_b , Σ_b , Ω_c and Ω_b multiplets! (Milano is involved)



Observation of a new beauty baryon particle

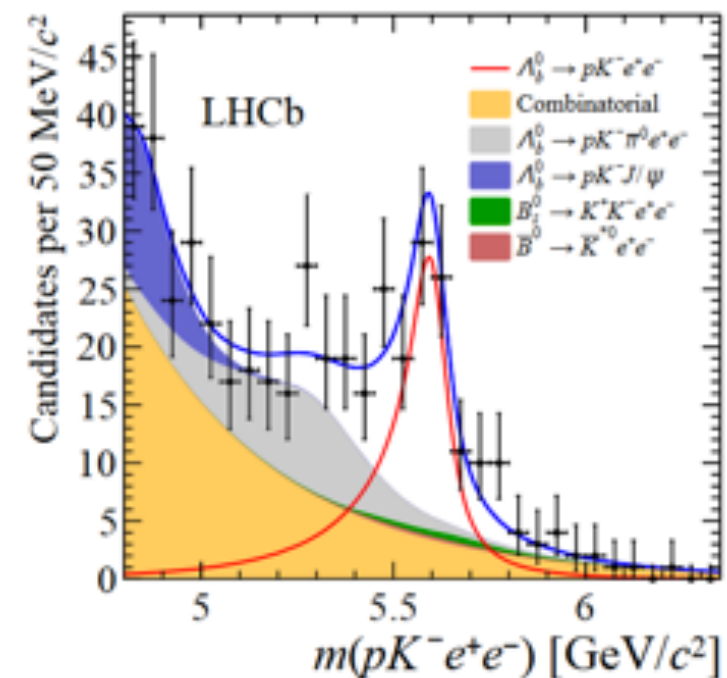
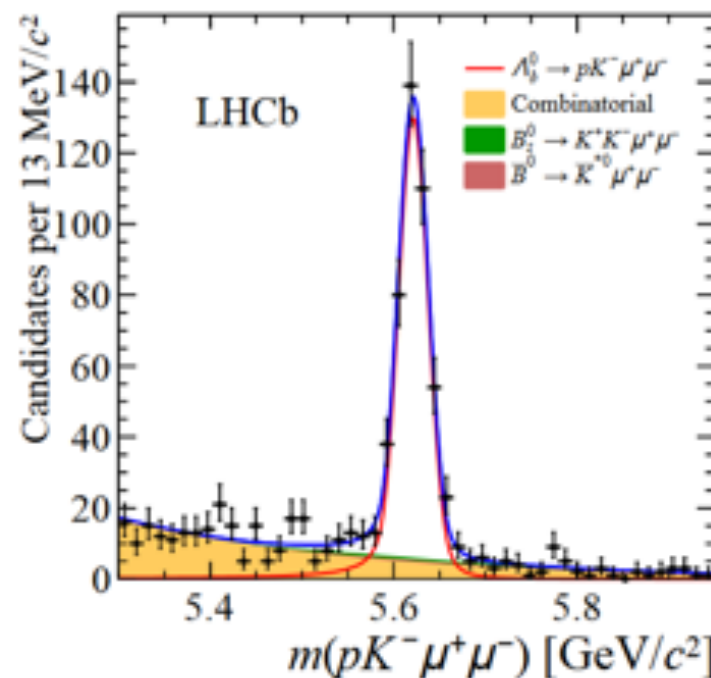
- Work done in Milano -> the latest of a long list of new discoveries
- Very fruitful exploitation of huge dataset collected so far, Milano is leading this effort
- Presented by Paolo Gandini for the first time at Bormio2020 in January
 - LHCb has already announced the observation of the two excited states of Λ_b baryon in 2012
 - Another discovery followed more recently, with the existence of two additional excited states (last year), $\Lambda_b(6146)0$ and $\Lambda_b(6152)0$, being announced six months ago
 - All these particles were discovered in the $\Lambda_b\pi^+\pi^-$ invariant mass spectrum
 - This new particle adds another brush stroke to the painting and is interpreted as the 2S state
- Each discovery saw the participation of the Milan group as proponent and corresponding author



Test of lepton universality with beauty baryons, R_{pK}

- Test of “lepton universality”, which states that the laws of physics treat the three charged leptons identically
- This time use uses baryons: R_{pK} describes how often a Λ_b^0 baryon decays to $(pK^-\mu^+\mu^-)/(pK^-e^+e^-)$
- This process is highly suppressed in the SM, could be affected by New Physics
- This adds up to decays to other similar searches (see [R_K](#), [R_{K^{*0}}](#), [R\(D^{*}\)](#) and [R\(J/ψ\)](#))
- These results revealed hints of deviations from lepton universality, none of which was significant enough to constitute evidence of new physics
- However, according to theorists who study possible extensions of the Standard Model, taken together these deviations suggest an interesting and coherent pattern

$$R_{pK}^{-1} = 1.17_{-0.16}^{+0.18} \pm 0.07$$

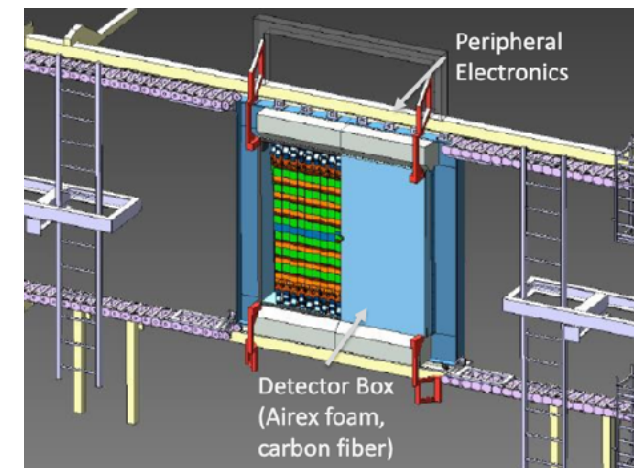
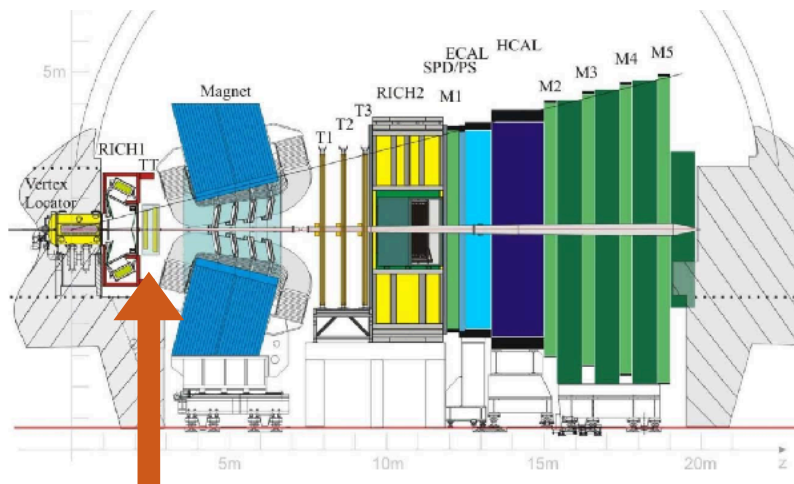


LHCb Upgrade

including contributions from the group

General Overview

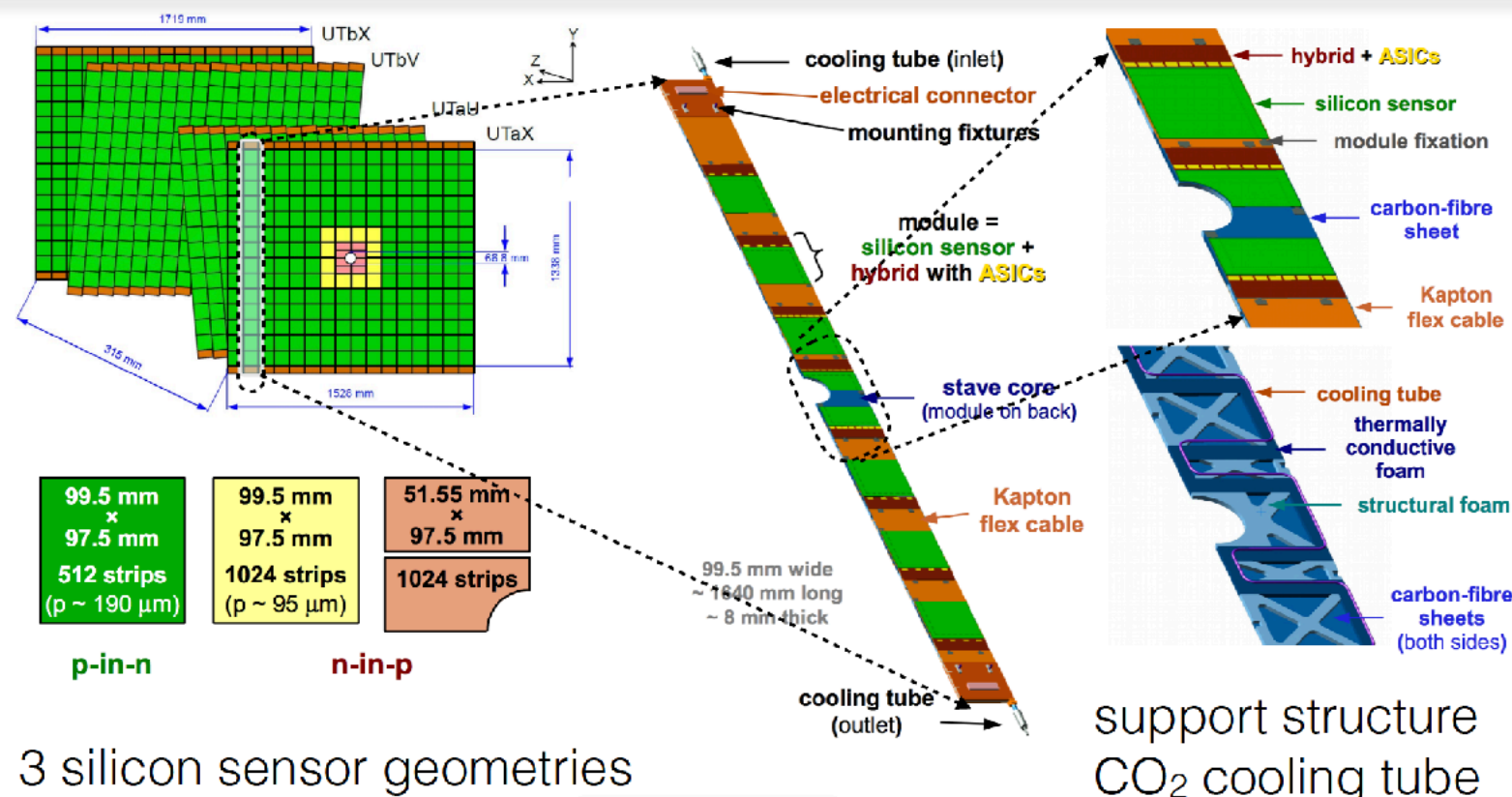
- The LHCb Milano group is a major contributor to the construction of the Upstream Tracker
- Silicon detector to be placed before the magnet, with high acceptance and high efficiency
- Detector organized in “staves”, “modules” and sensors



4 detection layers

stave design

module design



UT responsibilities

- Personnel

- Marco Petruzzo, Andrea Merli, Federico De Benedetti, Nadim Conti, Fabio Manca, Paolo Gandini

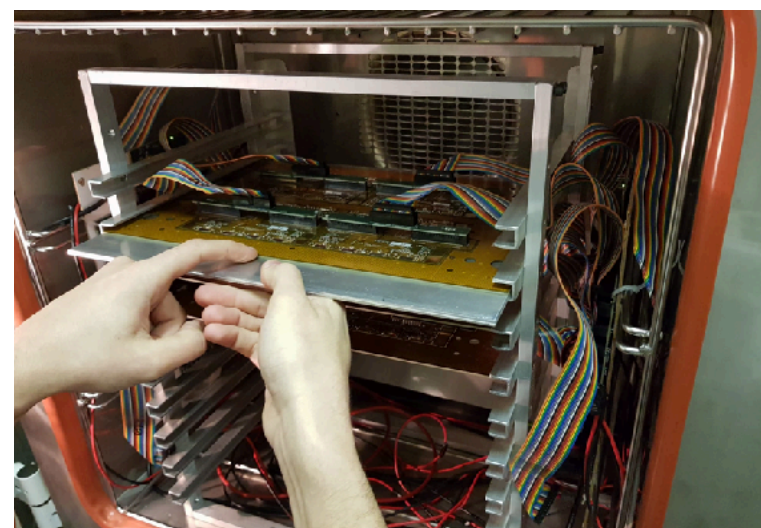
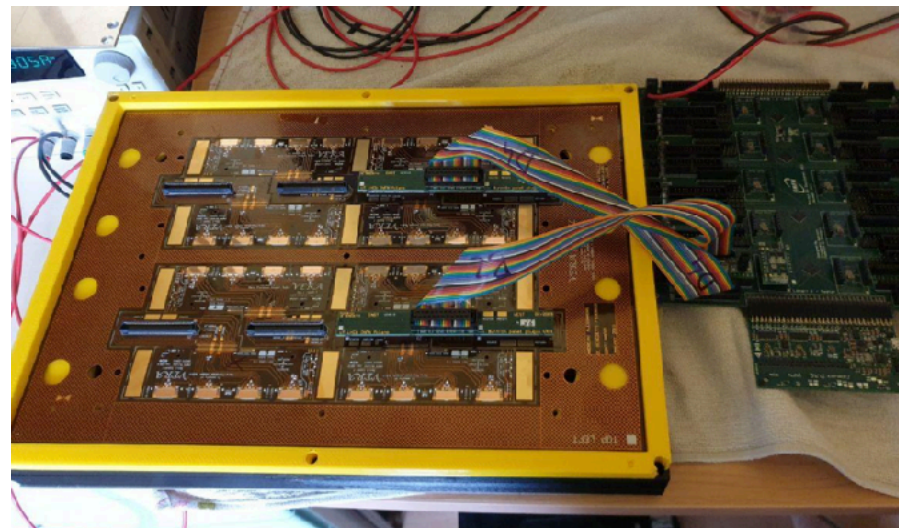
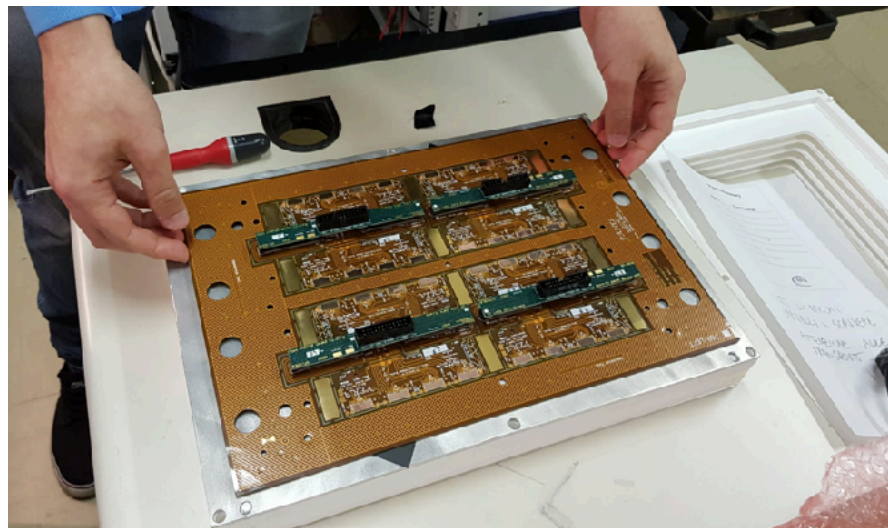
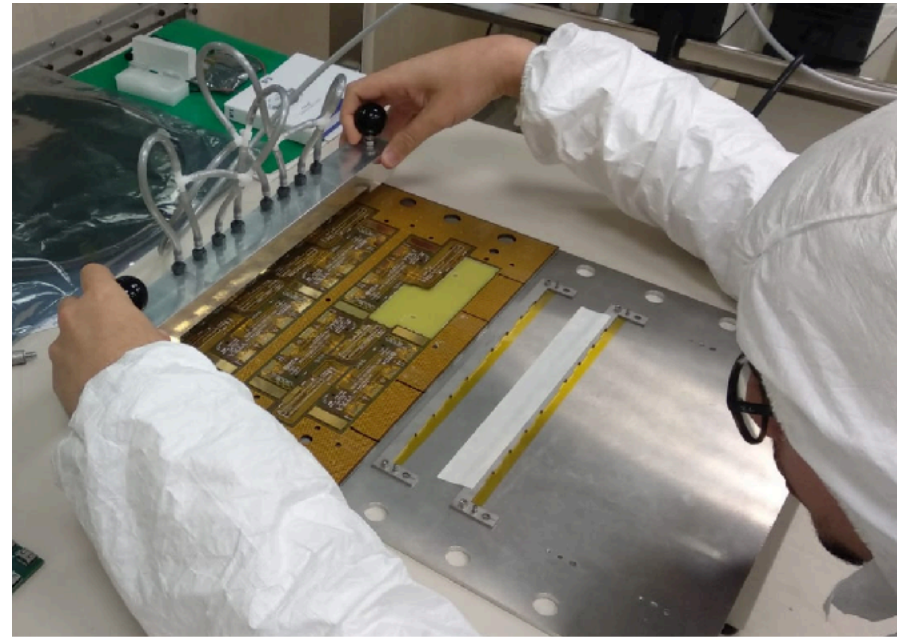
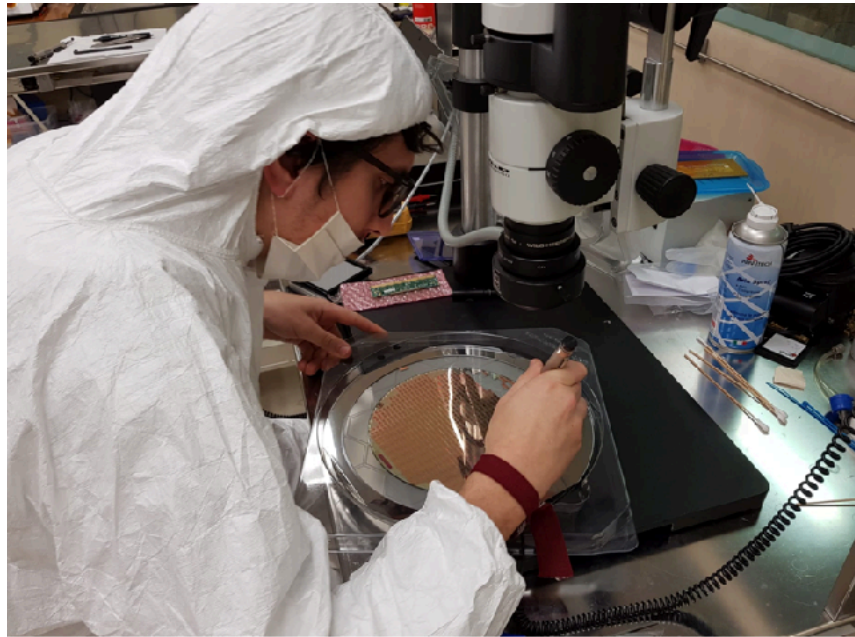
- Milano responsibilities in UT project:

- Flex cables. Production and test (in progress at CERN, on hiatus due to travel restrictions)
- Hybrid circuit for ASIC. Production in house so far (50% complete)
- Production of the 8-chip hybrid in the central region of the detector
- CO₂ distribution system in production

- Milano coordination roles in UT project:

- Deputy project leader: Nicola Neri
- Hybrid production responsible: Paolo Gandini
- Sensor and hybrid WG co-convener: Mauro Citterio
- Mechanics and cooling WG co-convener: Simone Coelli

Selected images

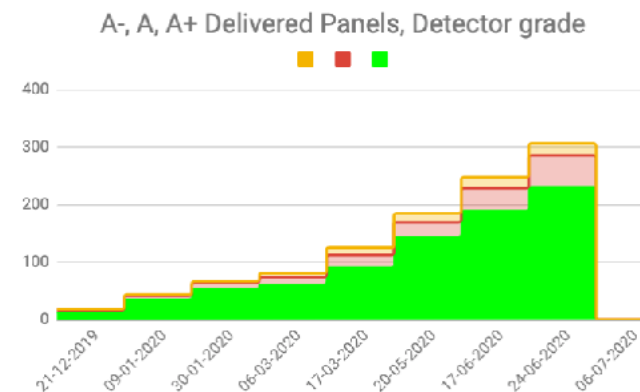


Hybrid production status

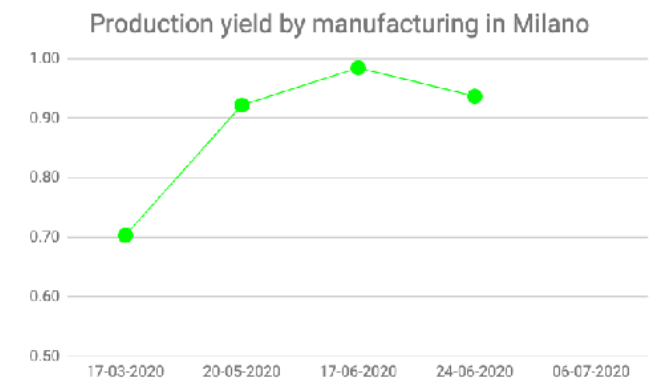
- Just to give an idea, we need to produce > 1000 hybrid circuits, 888 for detector, 1070 including spares
- We received all flexes now assembling with a very tight organized schedule
- Production involves several delicate steps (all performed in Milan)
- Evaluating the possibility to outsource part of the production to an external company

- Glueing
- Assembling
- Burn-in in climate chamber (to find early failures)
- Full mechanical characterization
- Full electrical tests and characterization
- Detector grading for installation
- Shipping and handling

Delivered 50% of the hybrids
DETECTOR GRADE



Improving yield
Currently > 95%



Numbers according to grading done in Milan

Sometimes grades change depending on tests done at Syracuse (so minor discrepancies could occur between the two numbers)

TARGET HYBRIDS	1070	1.20	20% spares	Preproduction + EES																					
TOTAL HYBRIDS	888	Delivered before Christmas										117	Target number of hybrids												
6 shipping before quarantine (1 for stave test, 5 for production)										SUM of delivered				1070	1070										
date	tot pan	ship	Panels	Hybs	Good	%	A+	A	A-	Sum A+	Sum A	Sum A-	Yield%	All A	production% new prod only	production% incl preprod	B+	B	B-	C	D	E	F	Start new batch	
21-12-2019		1.1					12	4	2	12	4	2													
09-01-2020		1.2					23	2	0	35	6	2													
30-01-2020		1.3					19	3	1	54	9	3													
06-03-2020		2.1					7	3	4	61	12	7													
17-03-2020	24	2.2	8	64	64	1.00	30	9	6	91	21	13	0.70	125	0.12	0.23	0	2	0	1			8	Covid-19 crisis	
20-05-2020	32	2.3	8	64	64	1.00	53	4	2	144	25	15	0.92	184	0.17	0.28	2	0	0				3		
17-06-2020	40	2.4	8	64	64	1.00	46	13	4	190	38	19	0.98	247	0.23	0.34	1								
24-06-2020	48	2.5	8	64	63	0.98	41	16	2	231	54	21	0.94	306	0.29	0.40	2	1					1		
06-07-2020	48	2.6	8	64																				<<<	

To be updated with the latest shipment

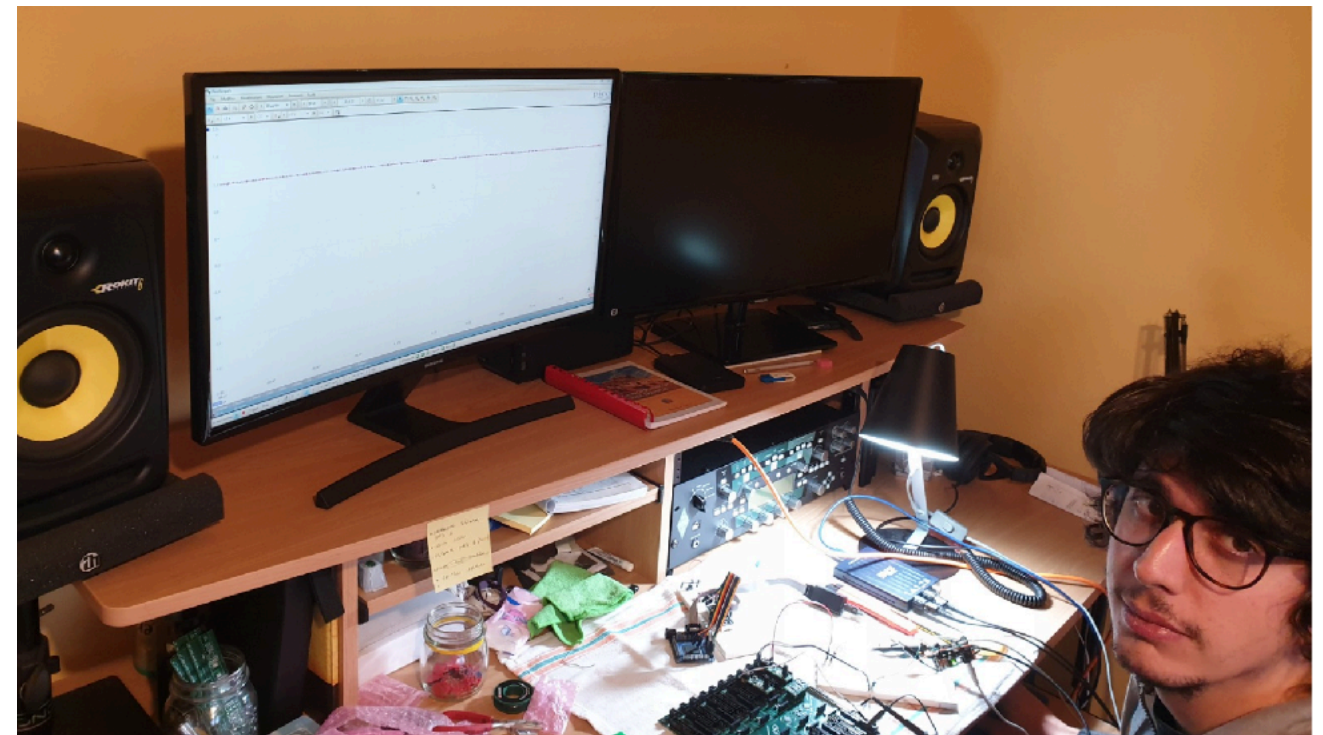
Work during the Pandemic

- All activities were highly affected by COVID-19 lockdown
- Actually, Italy was hit first and we had to shut down activities before anyone else
- **However, we managed to keep some activities ongoing even during shutdown**
- Now quickly ramping up, but spaces are limited to one person per room

Private house transformed in a shipping hub as department was closed and it was not possible to ship receive goods from US



Federico De Benedetti working in his tavern, transformed in a temporary electronic laboratory

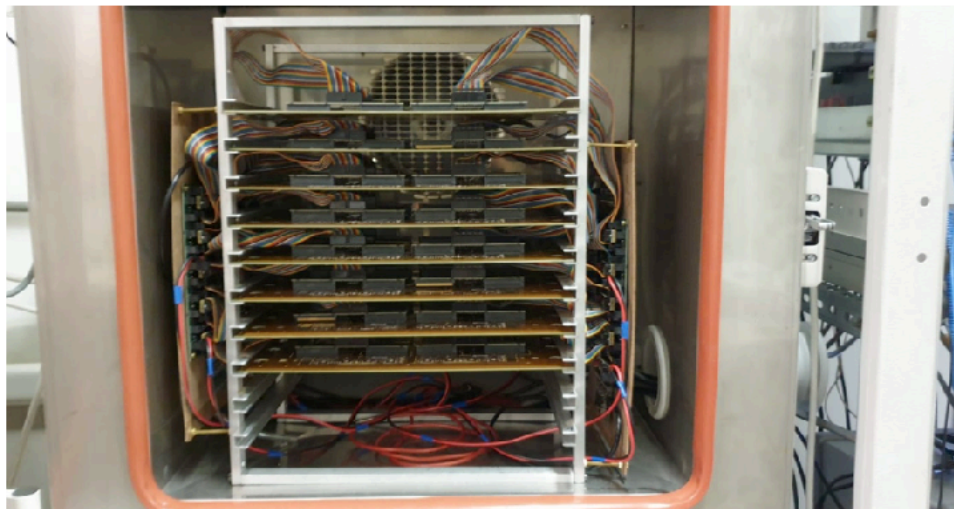


Work during the Pandemic

- This effort and dedication was highly praised and well received by the LHCb management
- From yesterday's LHCb general meeting Spokesperson's talk, we were used as an example

Lab Reopenings

- Augusto will report on installation activities for Upgrade I
- Construction work is active at most of the key laboratories across the collaboration e.g.



Milano for UT Hybrids:
Working at 8 panels/week,
i.e. 80% of its capacity



Manchester for VELO Modules:
Access for preparations for
construction from 29th June

Chris Parkes, Tuesday Meeting

5

Conference contributions Awards & Prizes

Notable achievements of the members of the group since last presentation (July 2019)

Awards & News

- **Paolo Gandini**

- Ettore Pancini Prize, awarded by the Italian Physical Society (SIF)
- Mention: award for his determinant contribution to the activities of the LHCb experiment at CERN, in particular for his measurements on spectroscopy and CP violation

Borsa "Ettore Pancini"

PAOLO GANDINI, laureato all'Università di Milano, dottorato all'Università di Oxford, attualmente ricercatore all'INFN, Sezione di Milano
per il contributo determinante alle attività dell'esperimento LHCb del CERN con particolare riferimento alle misure di spettroscopia e violazione di CP.



- **Nadim Conti**

- awarded with the LHCb Early Career Award, for his leading contributions to the UT project
- CERN PRESS RELEASE

Carlos Abellan Beteta and Nadim Conti



For their leading contributions to the Upstream Tracker (UT) project.

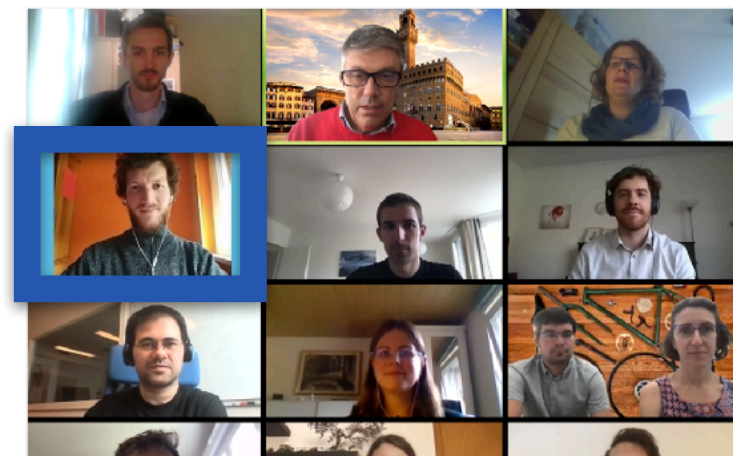
Carlos joined Zurich University in 2014 to work on the Silicon Tracker. He was one of the experts operating and taking care of it until its recent dismantle for LS2. In parallel he has contributed to its upgrade - the Upstream Tracker - doing electronic design, FPGA firmware and helping to make things work in general. One of these tasks was the Quality Assurance tests for the ASICs that are the core of the detector.

Nadim joined LHCb in 2015 with INFN and worked on the UT Upgrade while starting his EE BSc with Polimi. From 2017 he studied how agile techniques improve the R&D process, joined LeCroy's Signal Integrity Academy, and designed UT's front end boards, backbone FPCBs, and DAQ/TDR testing systems, saving a considerable amount of labor during the detector's development. He's now studying microwave testing systems and their medical applications.

LHCb honours its Thesis and Early Career Awards Winners

LHCb celebrated some of its youngest contributors at an unusual but lively virtual ceremony

23 JUNE, 2020



Scientific Roles



- **Nicola Neri:** Upstream Tracker Deputy Project Leader
- **Paolo Gandini:** elected as new member of the LHCb Speakers' bureau
- **Simone Coelli:** UT cooling responsible
- **Jinlin Fu:** convener of Event Selection Subgroup of Charmless Working Group
- **Salvatore Aiola and Louis Henry:** part of the RTA working group, downstream tracking and hybrid seeding
- **Daniele Marangotto:** Stripping liaison for IFT WG

Publications

2020

- R. Aaij et al (LHCb Collaboration), *Observation of a new baryon state in the $\Lambda_b^0 \pi^+ \pi^-$ mass spectrum*, submitted to JHEP, arXiv: [2002.05112](#)
- A. Dainese et al., *Physics Beyond Colliders QCD Working Group Report*, J. Phys. G **47** (2020) 010501, CERN-PBC-REPORT-2018-008, DOI: [10.1088/1361-6471/ab4cd2](#), arXiv: [1901.04482](#)
- J. Beacham et al., *Physics Beyond Colliders at CERN: Beyond the Standard Model Working Group Report*, J. Phys. G **47** (2020) 010501, CERN-PBC-REPORT-2018-007, DOI: [10.1088/1361-6471/ab4cd2](#), arXiv: [1901.09966](#)

2019

- R. Aaij et al (LHCb Collaboration), *Observation of New Resonances in the $\Lambda_b^0 \pi^+ \pi^-$ System*, Phys.Rev.Lett. **123** (2019) 15, 152001, DOI: [10.1103/PhysRevLett.123.152001](#), arXiv: [1907.13598](#)
- R. Aaij et al (LHCb Collaboration), *Search for CP violation and observation of P violation in $\Lambda_b^0 \rightarrow p \pi^- \pi^+ \pi^-$ decays*, submitted to Phys. Rev. Lett., arXiv: [1912.10741](#)
- R. Aaij et al (LHCb Collaboration), *Observation of $B_{(s)}^0 \rightarrow J/\Psi p \bar{p}$ decays and precision measurements of the $B_{(s)}^0$ masses*, Phys.Rev.-Lett. **122** (2019) 19, 191804, DOI: [10.1103/PhysRevLett.122.191804](#); arXiv: [1902.05588](#)
- R. Aaij et al (LHCb Collaboration), *Observation of Two Resonances in the $\Lambda_b^0 \pi^\pm$ Systems and Precise Measurement of $\Sigma_b^\pm$ and $\Sigma_b^{*,\pm}$ properties*, Phys.Rev.Lett. **122** (2019) 1, 012001, DOI: [10.1103/PhysRevLett.122.012001](#), arXiv: [1809.07752](#)

Conferences

2020

- *Dipole moments of unstable particles at LHC(b)*, N. Neri, Kick-off workshop for the search of a muon EDM using the frozen spin technique at PSI, Paul Scherrer Institut, Switzerland, 17-19 February 2020
- *Hadron Physics in LHCb*, P. Gandini, 58th International Winter Meeting on Nuclear Physics (plenary talk), Bormio, Italy, 22 January 2020

2019

- *EDM and MDM measurements of heavy baryons and τ leptons*, S. Aiola, Physics Beyond Colliders Working Group meeting, CERN, 5-6 November 2019
- *SciFi* (LHCb restricted), L. Henry, LHCb Computing Workshop, 18-22 November 2019
- *Amplitude analyses for heavy baryon electromagnetic dipole moment measurements*, D. Marangotto, Issues in Baryon Spectroscopy Workshop, MIAPP, 29 October 2019
- *Searches for CP violation in multibody baryon decays at LHCb*, A. Merli, LHC Seminar, CERN, 22 October 2019
- *CP violation in multi-body final states at LHCb*, L. Henry, LHCb Implication workshop, 18 October 2019
- *Perspectives for measurements of electromagnetic dipole moments of charm and strange baryons at the LHC*, S. Aiola, 105th Congress of the Italian Physical Society, L'Aquila, Italy, 23-27 September 2019
- *Nuovi risultati nella ricerca di pentaquark a LHCb*, E. Spadaro Norella, 105th Congress of the Italian Physical Society, L'Aquila, Italy, 23-27 September 2019
- *Hadron spectroscopy and exotic states at LHCb*, E. Spadaro Norella, Strong dynamics for physics within and beyond the Standard Model at LHC and Future Colliders (LFC19), Trento, Italy, 9-11 September 2019
- *Progress towards an experiment for electromagnetic dipole moment of unstable particles at LHC*, N. Neri, XXXVII International Symposium on Dynamical Properties of Solids (DyProSo2019), Ferrara, Italy, 8-12 September 2019
- *EDM and MDM measurements in LHCb: the SELDOM project*, S. Aiola, Second LHCb Heavy Ion Workshop: Exploring Matter with Precision Charm and Beauty Production Measurements in Heavy Nuclei Collisions, Chia (Cagliari), Italy, 4-6 September 2019

Thesis

Thesis

2020

Daniele Marangotto, PhD Thesis, 2020

- Amplitude analysis and polarisation measurement of the Λ_c^+ baryon in the $pK^-\pi^+$ final state for the electromagnetic dipole moment determination

Massimiliano Luchi, Master Thesis, 2020

- A demonstrator for a 4D real-time tracking device for the LHCb Upgrade II

2019

Andrea Merli, PhD Thesis, 2019

- Search for CP violation in the angular distribution of $\Lambda_b^0 \rightarrow p\pi^+\pi^-\pi^+$ baryon decays and a proposal for the search of heavy baryon EDM with bent crystal at LHCb

Marco Petruzzo, PhD Thesis, 2019

- A 4D real-time tracking device for the LHCb Upgrade II



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

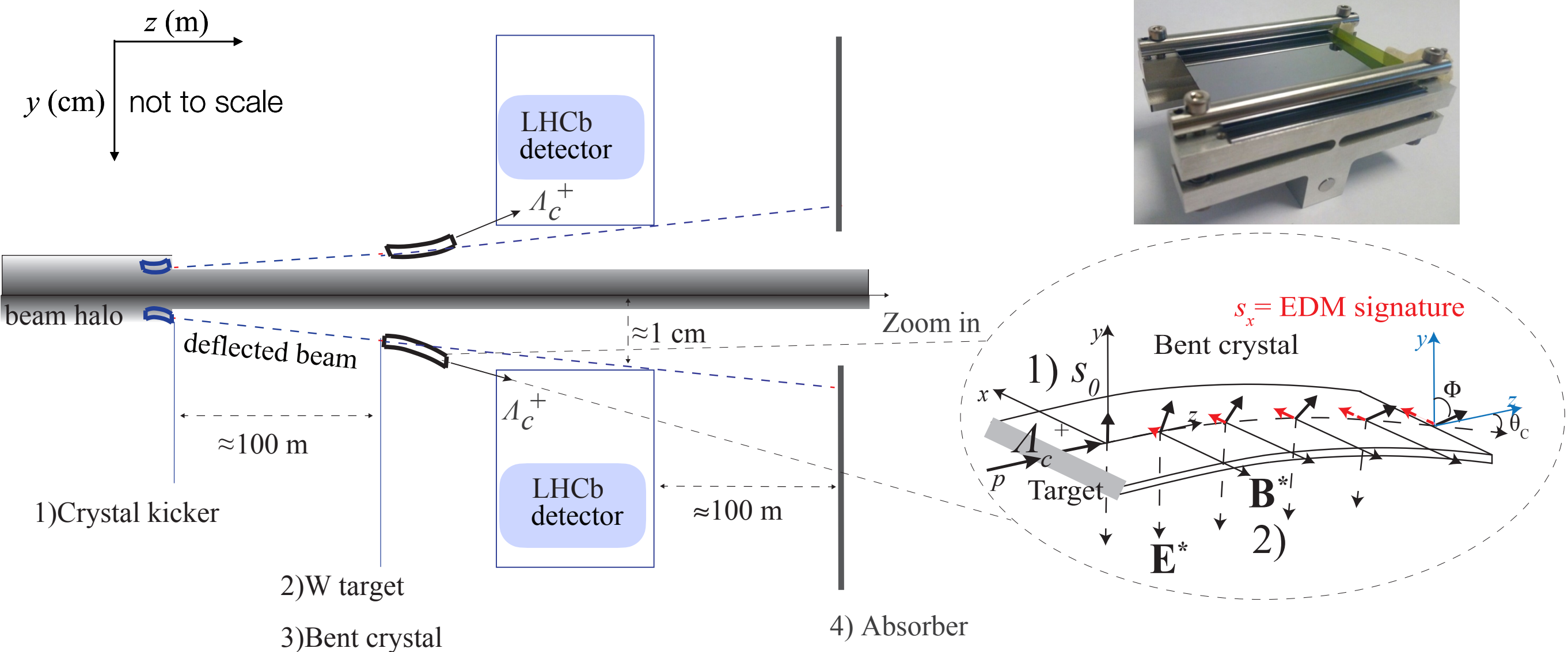
<https://web.infn.it/SELDOM/>



<https://twitter.com/SeldomTeam>

Novel fixed-target experiment at LHC for charm baryons

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

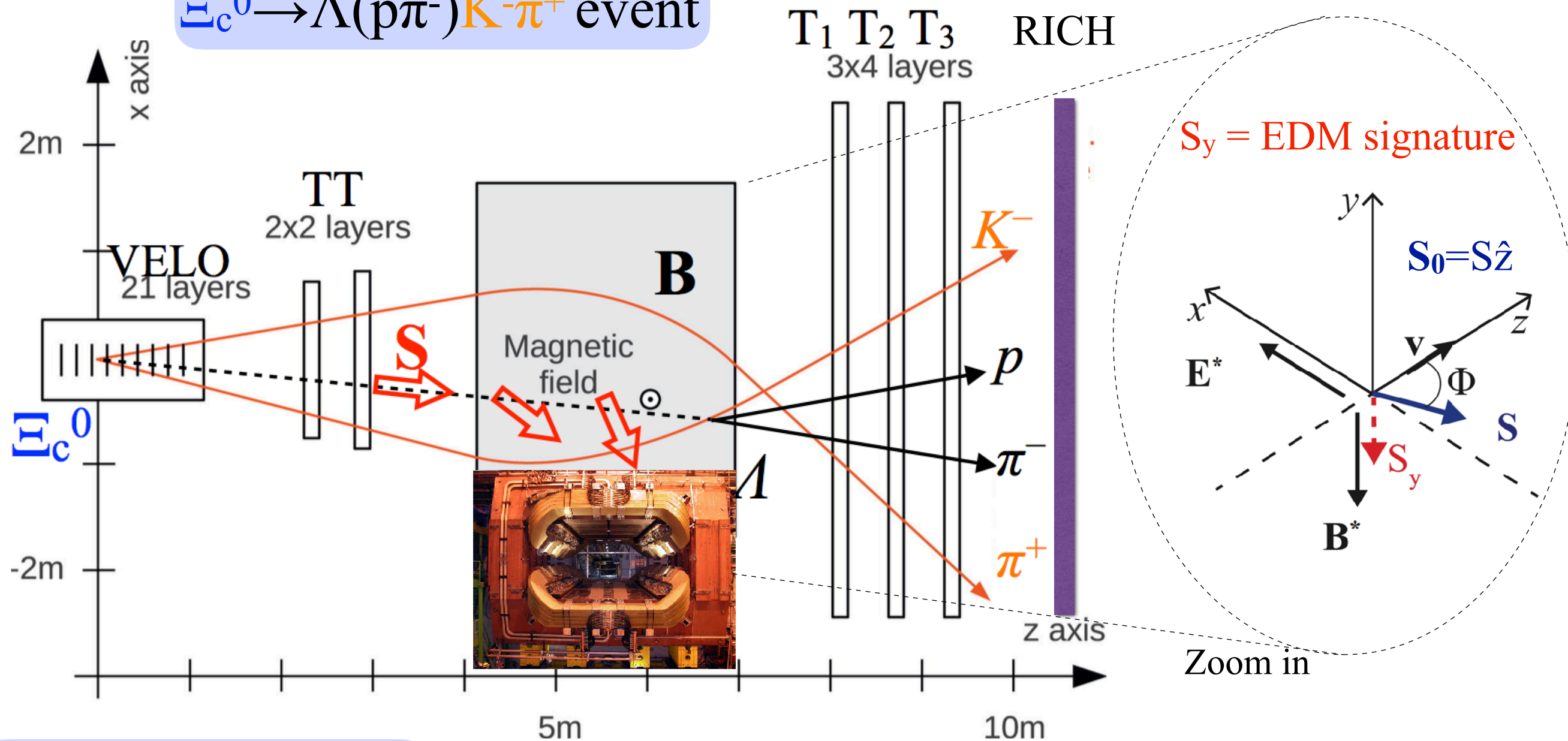


p extraction Λ_c^+ polarised production channeling spin precession event reconstruction

Novel experimental technique for strange baryons

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

$\Xi_c^0 \rightarrow \Lambda(p\pi^-)K^-\pi^+$ event



Λ polarised production

spin precession

event reconstruction

Achievements

- ▶ Reconstruction of long-lived Λ particles using LHCb Run2 data demonstrated (S. Aiola, article in preparation)
- ▶ Improved track reconstruction algorithm using SciFi detector (S. Aiola, L. Henry, article in preparation)
- ▶ Improved simulations and fixed-target setup (A. Merli, CERN-THESIS-2019-108, Internal LHCb Document)
- ▶ $\Lambda_c^+ \rightarrow pK^-\pi^+$ amplitude analysis and polarisation measurement using LHCb data (D. Marangotto, CERN-THESIS-2020-015, article in preparation)
- ▶ Project under review at CERN and included in Physics Beyond Collider report for the European Strategy of Particle Physics (CERN Yellow report)
- ▶ Developed an improved experimental setup and analysis technique for optimal dipole moment sensitivity (article in preparation)

Conferences and workshops

2020

- **Dipole moments of unstable particles at LHC(b)**, N. Neri, Kick-off workshop for the search of a muon EDM using the frozen spin technique at PSI, Paul Scherrer Institut, Switzerland, 17-19 February.

2019

- **EDM and MDM measurements of heavy baryons and τ leptons**, S. Aiola, Physics Beyond Colliders Working Group meeting, CERN, 5-6 November 2019.
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- **Perspectives for measurements of electromagnetic dipole moments of charm and strange baryons at the LHC**, S. Aiola, 105th Congress of the Italian Physical Society, L'Aquila, Italy, 23-27 September 2019.
- **Progress towards an experiment for electromagnetic dipole moment of unstable particles at LHC**, N. Neri, XXXVII International Symposium on Dynamical Properties of Solids (DyProSo2019), Ferrara (Italy), 8-12 September 2019.
- **EDM and MDM measurements in LHCb: the SELDOM project**, S. Aiola, Second LHCb Heavy Ion Workshop: Exploring Matter with Precision Charm and Beauty Production Measurements in Heavy Nuclei Collisions, Chia (Cagliari), Italy, 4-6 September 2019.
- **Perspectives for Electromagnetic Dipole Moment of unstable particles at LHC**, N. Neri, Flavour changing and conserving processes 2019 (FCCP2019), Capri Island (Italy), 29-31 August 2019.
- **Prospects for electromagnetic dipole moments of unstable particles at the LHC**, N. Neri, Lepton Photon 2019, Toronto (Canada), 5-10 August 2019.

Richieste di Sezione

per le varie attività del gruppo nel 2021

Composizione del gruppo di ricerca 2021

Personale	FTE	LHCb (FTE)	TIMESPOT (FTE)	SELDOM (FTE)	Inquadramento
Aiola	1,0	0,0	0,0	1,0	AR INFN (UE)
Citterio	0,1	0,1	0,0		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 INFN (Call)
Fu	1,0	1,0		0,0	PostDoc Stranieri INFN
Gandini	1,0	0,7	0,3		Ricercatore
Henry	1,0	0,0		1,0	AR UNIMI (UE)
Lazzaroni	0,1	0,1			PA
Liberali	0,3		0,3		PA
Marangotto	1,0	1,0		0,0	AR UNIMI (UE)
Merli	1,0	0,0	0,0	1,0	AR UNIMI (UE)
Neri	1,0	0,2	0,2	0,6	PA
Palombo	0,0	0,0			PA in pensione
Petruzzo	1,0	0,7	0,3		AR INFN
Riboldi	0,2		0,2		RU
Shojaii	0,25		0,25		Ricercatore Straniero
Stabile	0,2		0,2		RTD UNIMI
Spadaro	1,0	1,0		0,0	Dottoranda
Tot. (FTE)	11,8	5	2,1	4,7	

Attività' 2021 e richieste servizi di sezione



- LHCb: attività di installazione e commissioning di UT al CERN
- Inizio nuova attività 4DLumiTracker: tracker per misura luminosità con sensori a pixel ad alta risoluzione temporale
 - 20% Simone Coelli, responsabile cooling UT
 - 6 m.u. servizio officina e progettazione meccanica
 - 6 m.u. servizio elettronico

Attività' 2021 e richieste servizi di sezione



- ▶ Costruzione telescopio per caratterizzazione di cristalli curvi su fascio
- ▶ Progetto e costruzione prototipo per camera a vuoto e sistema di posizionamento (goniometro) per cristalli curvi in LHC
- ▶ Cooling cristalli di germanio a 77 K
- ▶ **Spazio di laboratorio (già richiesto l'anno scorso)**
- ▶ **3 m.u. servizio elettronico**
- ▶ **3 m.u. servizio progettazione e officina meccanica**
- ▶ **10% Coelli**

Backup Slides



Progetto call CSN5

Consiglio di Sezione

Milano, 2 luglio 2020

Rad-hard pixel detector for 4D real-time tracking

Main target:

Develop and realize a demonstrator consisting of a complete and simplified tracking system, integrating about 100-1000 read-out channels (pixels), satisfying the following characteristics:

- Space resolution: $O(10\ \mu\text{m})$
- Radiation hardness: $> 10^{16}\ 1\ \text{MeV}\ n_{\text{eq}}/\text{cm}^2$ (sensors) and $> 1\ \text{Grad}$ (electronics)
- Time resolution: $< 100\ \text{ps}$ per pixel (target $\approx 30\ \text{ps}$)
- Real time track reconstruction algorithms and fast read-out (data throughput $> 1\ \text{TB/s}$)

Activities are organized in 6 work packages:

RN: A. Lai Cagliari

1. 3D silicon sensors: development and characterization (GF. Dalla Betta Trento)
2. 3D diamond sensors: development and characterization (S. Sciortino Perugia)
3. Design and test of pixel front-end (V. Liberali Milano)
4. Design and implementation of real-time tracking algorithms (N. Neri Milano)
5. Design and implementation of high speed readout boards (A. Gabrielli Bologna)
6. System integration and tests (A. Cardini Cagliari)

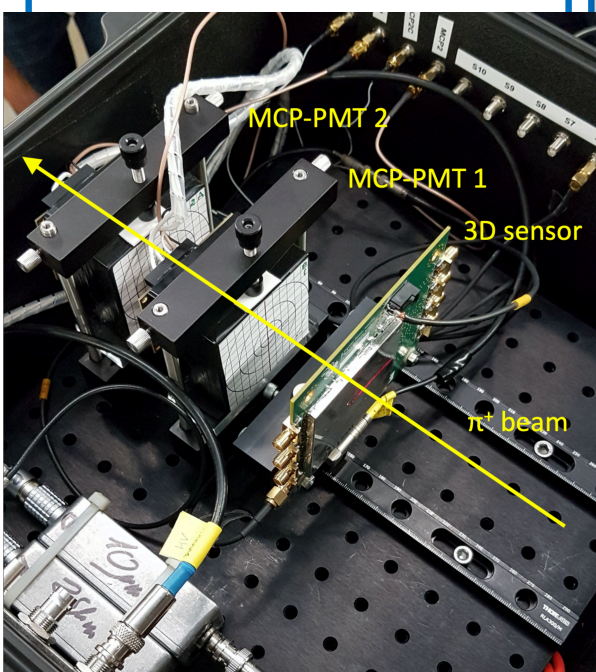
Sezioni INFN: Bologna, Cagliari, Genova, Ferrara, Firenze, Milano (+Bergamo), Padova, Perugia, Torino, TIFPA. ≈ 60 heads, ~ 20 FTE. People from LHCb, ATLAS, CMS + others

Current status of the project

From A. Lai

1.

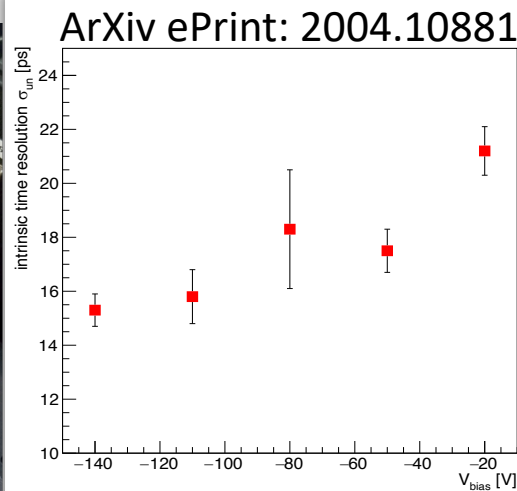
Tests of timing performance of **silicon sensors** designed for timing by our group (**3D-trench sensors**).



Setup under test beam

2.

Intrinsic (sensor only) time resolution σ_t reaches **15 ps** and ≈ 20 ps if the F/E electronics contribution is included

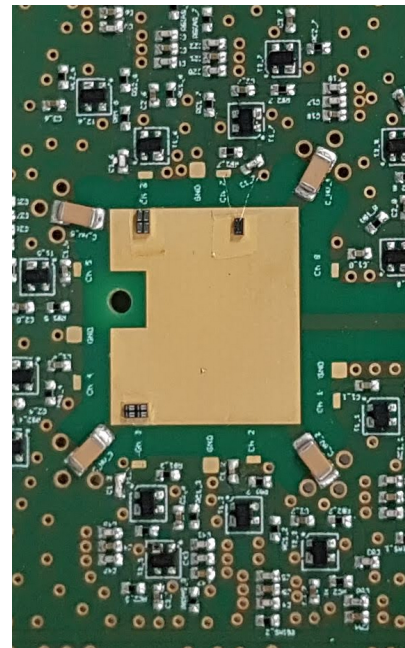


Intrinsic trench sensor jitter, under Minimum Ionising Particle beam

$$\sigma_t \approx 15 \text{ ps}$$

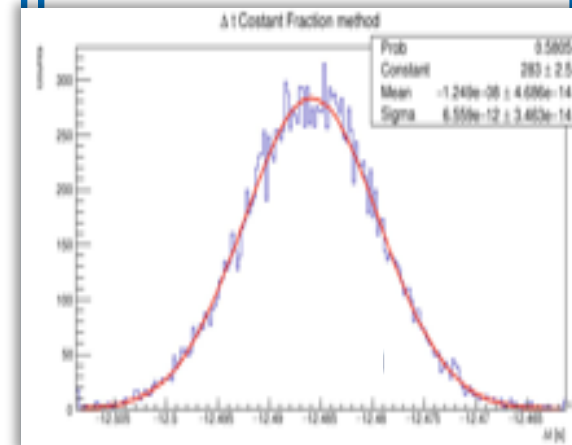
3.

Performances can be improved developing **optimised electronics**, not yet available during first tests.



4.

New electronics development (discrete components) yield better performance!

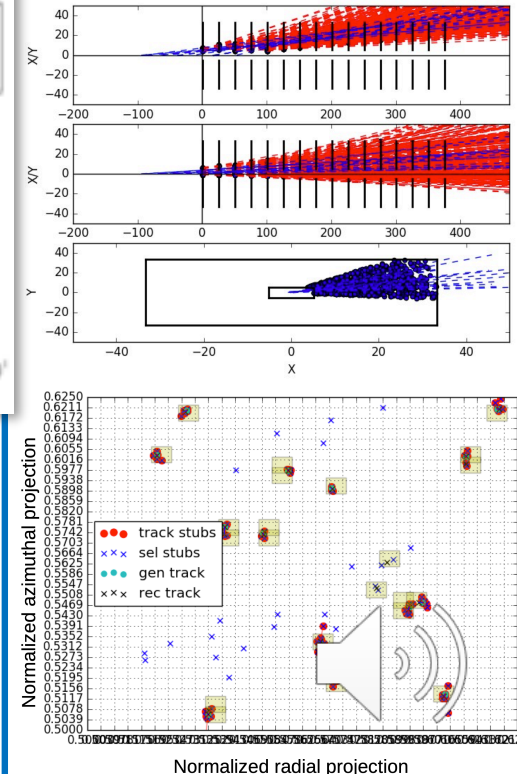


1030 nm laser, single spot, 1 MIP equiv. charge deposit

$$\sigma_t \approx 6.5 \text{ ps}$$

5.

Implementation on FPGA of **real-time image processing** algorithms using timing information.



About 15 ps intrinsic time resolution measured at the testbeam for the 3D sensor

ASIC submission as MPW 29 July in 28nm TSMC technology

Real-time tracking on FPGA using 4D information

Attività a Milano nel 2021

- ▶ Richiesta estensione di 1 anno del progetto Timespot
 - ▶ costruzione dimostratore: telescopio con sensori + elettronica di front-end + real-time tracking
 - ▶ Test su fascio del dimostratore
- ▶ Attività prevista a Milano:
 - ▶ test del ASIC + sensore
 - ▶ finalizzazione dispositivo per real-time tracking
 - ▶ partecipazione a test su fascio del dimostratore

Richieste 2021

- ▶ Spese di consumo per preparazione test del ASIC+sensore 5 kEuro
- ▶ Servizi: 0.5 m. u. servizio elettronico

Composizione gruppo di ricerca Milano

Personale	TIMESPOT(FTE)	Inquadramento
M. Citterio	0,0	Dirigente Tecnologo
L. Frontini	0,35	AR INFN
P. Gandini	0,3	Ricercatore INFN
V. Liberali	0,3	PA UniMi
N. Neri	0,2	PA UniMi, Resp. Loc.
M. Petruzzo	0,3	AR INFN
S. Riboldi	0,2	Ricercatore UniMi
A. Stabile	0,2	RTDA UniMi
S. Seyedruhollah	0,25	Ricercatore straniero
Tot. (FTE)	2,1	