

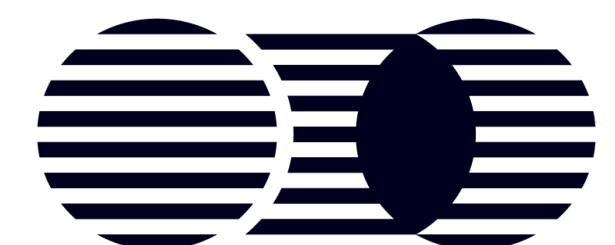
LHCb and Codex- β IGFAE-USC

IGFAE-USC

IGFAE retreat 2026
22 June 2026



INSTITUTO GALEGO
DE FÍSICA
DE ALTAS ENERXÍAS



Research Team 2025-2026

9 Senior Staff:

Paula Álvarez, Xabier Cid (now at CMS and Codex- β), Abraham Gallas, Antonio Romero, Juan Saborido, Cibrán Santamarina, Charlotte Van Hulse (VUB), Pablo Vázquez, María Vieites

Semileptonic B decays

- Julio Nóvoa
- Cristina López
- Bhagyashree Pagare (PostDoc)
- Alessandra Gioventù (PostDoc)

Ions and QCD

- Clara Landesa
- Iván Cambón
- Lidia Carcedo
- Carlos Barbero
- Victoria Valcarce
- Juan A. Teijeiro
- Samuel Belin (PostDoc)

Rare B decays

- Javier Dorta
- Brais Fernández
- Camille Normand (PostDoc)
- Richard Williams (PostDoc)

Very rare/Exotica

- Pablo F. Menéndez
- María Pereira (now at CMS)
- Alberto Martínez
- Alejandro Novo
- Brais Fernández
- Ángel Morcillo
- Miguel Fernández (PostDoc)
- Emilio X. Rodríguez (PostDoc)
- Titus Mombaecher (PostDoc)

Instrumentation

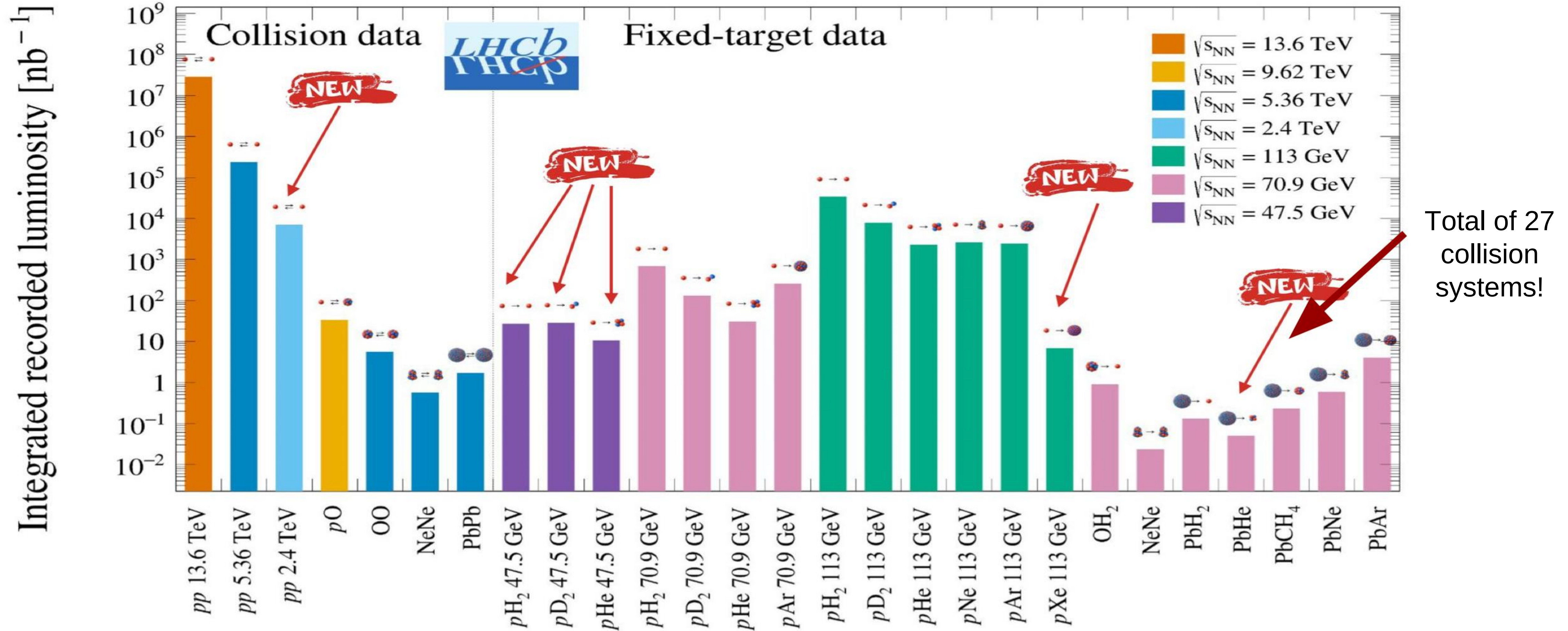
- Federico de Benedetti
- Francisco Piernas
- Efrén Rodríguez
- Juan Pablo Escandón
- Iris García Rivas
- Antonio Fernández (PhD Engineer)
- Eliseo Pérez
- Antonio Pazos

Codex- β

- Many on part time dedication

+ several students working on TFG, TFM projects

LHCb Run 3: Upgraded Detector Data



Reminder: LHCb Runs 1 and 2 pp data sample: (2011 - 2018) $\sim 9 \text{ fb}^{-1}$

Finishing "Run 2" analyses

LHCb Run 3 pp data sample (2022 - 2026) $\sim 27.9 \text{ fb}^{-1}$

Starting "Run 3" analyses, with much increased (or new/better) data samples

Fixed target, injecting different gasses in the collision region

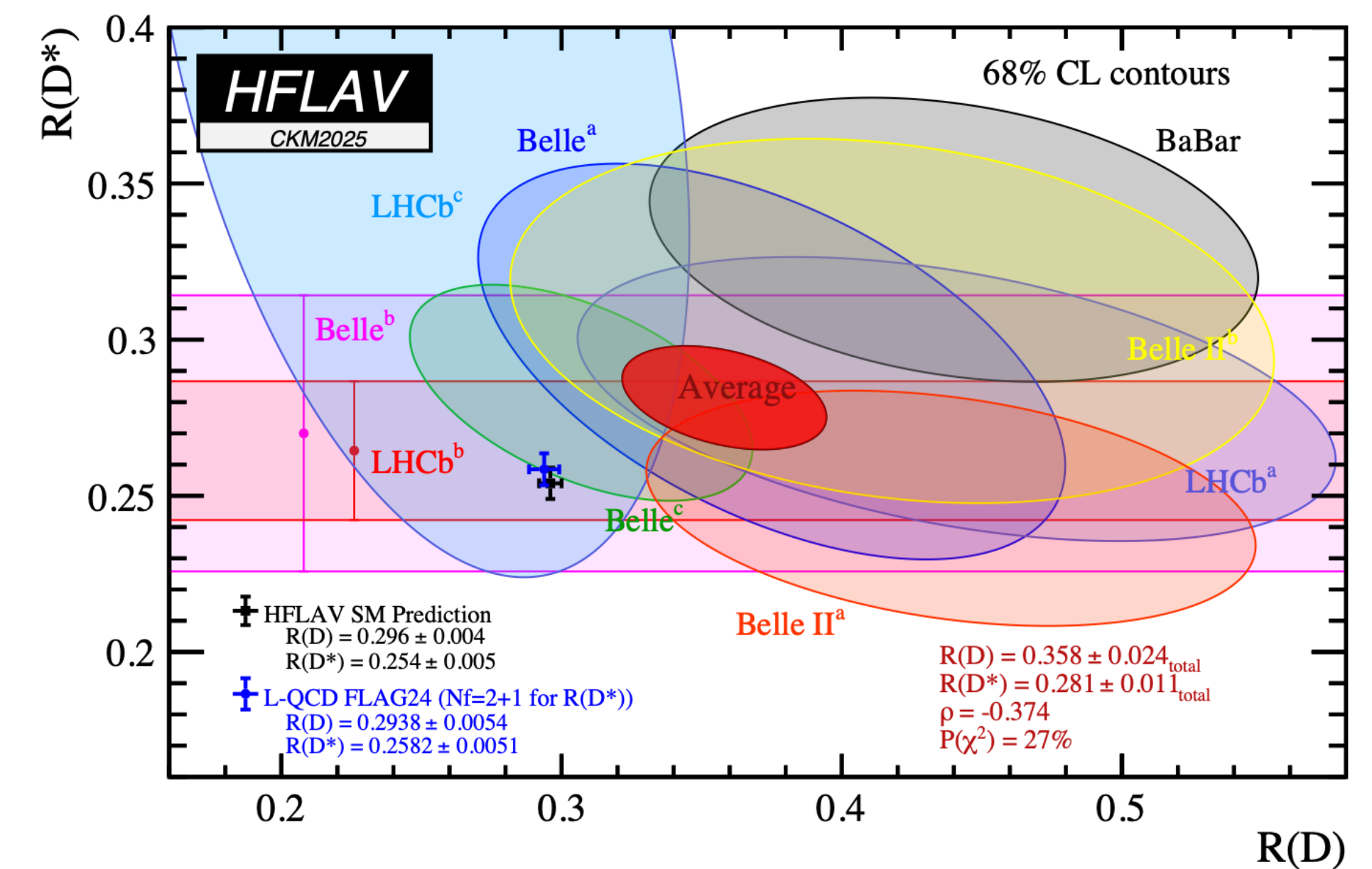
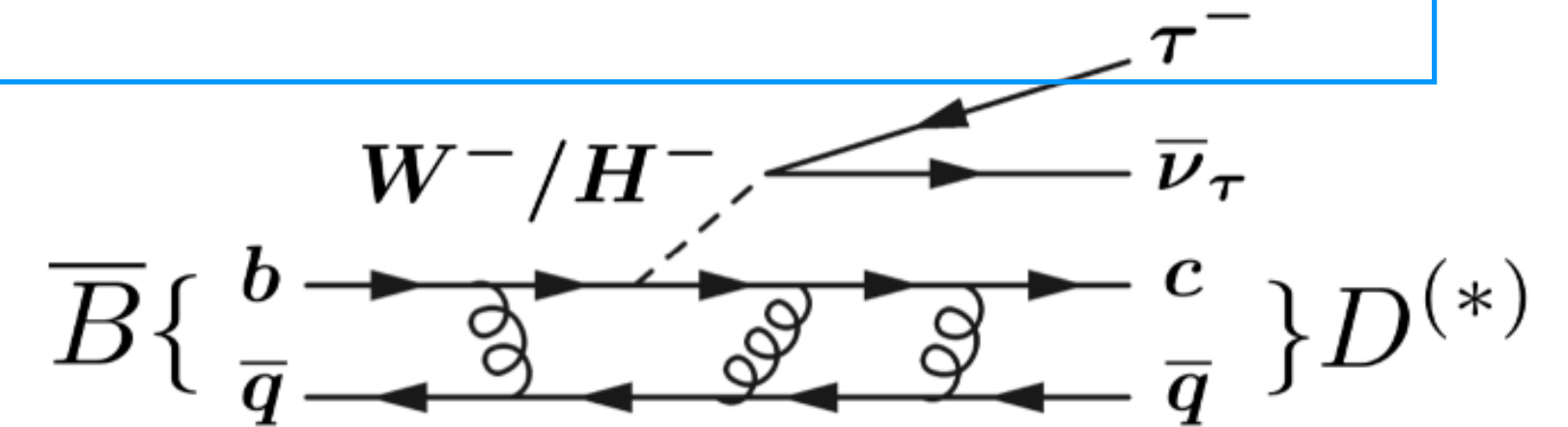
Main physics analysis lines: SL

Comparison between **semitauonic** (τ) and **semimuonic** (μ) decays sensitive to NP, which could **modify branching fractions and angular distributions** → Tensions with the SM seen, strong interest in new measurements to clarify experimental/form factor related effects.

Semileptonic B decays

- Julio Nóvoa
- Cristina López
- Bhagyashree Pagare (PostDoc)
- Alessandra Gioventù (PostDoct)
- 2 Run 2 analyses ongoing. One of them at LHCb Review Committee (RC) stage (publication expected this year)
- Both analyses being updated with Run 3 data.

$$R(D^{(*)+}) = \frac{\mathcal{B}(\bar{B}^0 \rightarrow D^{(*)+} \tau^- \bar{\nu}_\tau)}{\mathcal{B}(\bar{B}^0 \rightarrow D^{(*)+} \mu^- \bar{\nu}_\mu)}$$

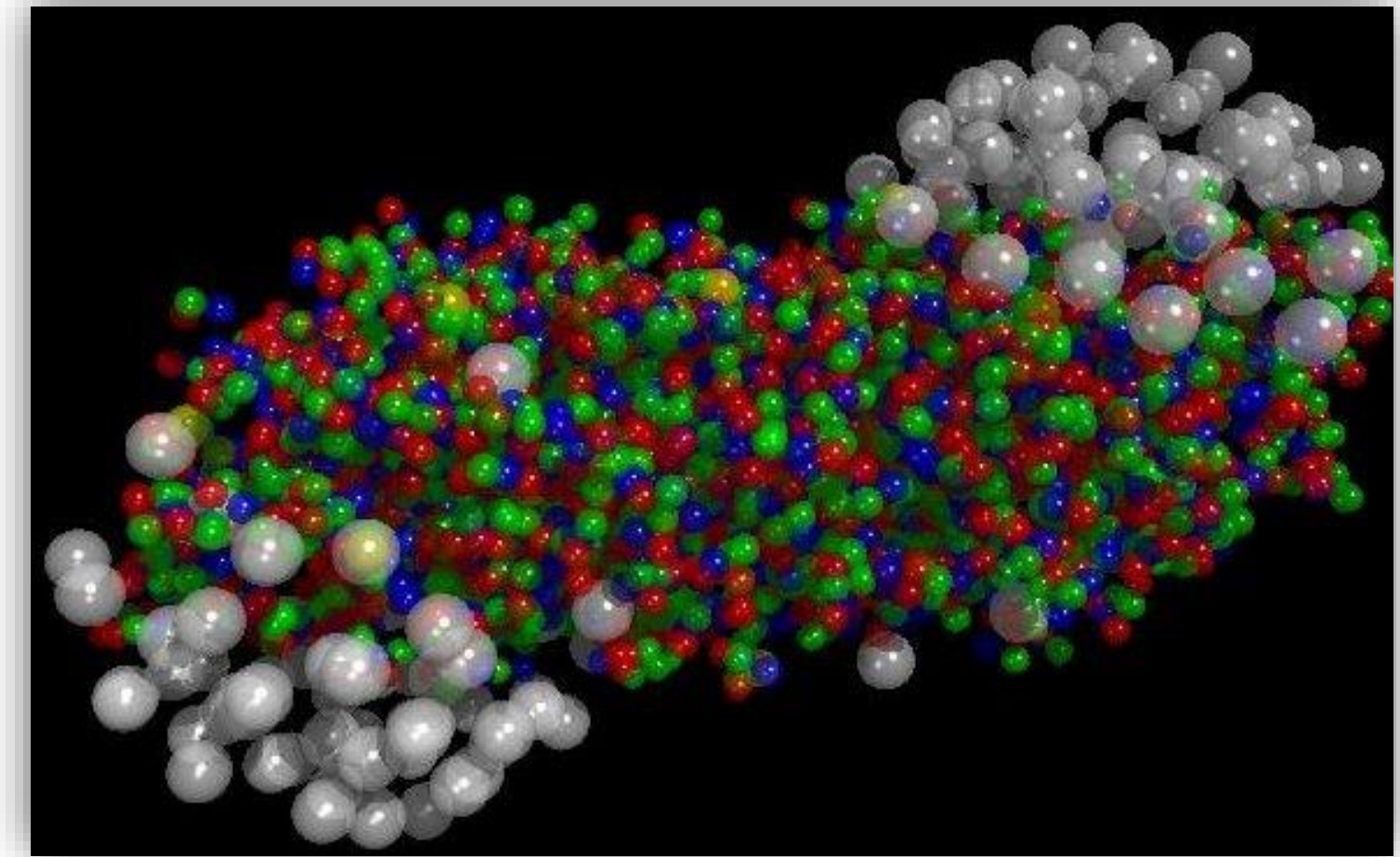


Main physics analysis lines: IFT and QCD

Exploit the very rich and abundant data samples with ions to **pin-point Quark Gluon Plasma phenomenology**, disentangling Cold-Nuclear-Matter effects and isolating newly observed phenomena (collectivity, strangeness suppression, nuclear modification factor, multiplicity dependent observables, temperature of the QGP ...)

Ions and QCD

- Clara Landesa
- Iván Cambón
- Lidia Carcedo
- Carlos Barbero
- Victoria Valcarce
- Juan A. Teijeiro
- Samuel Belin (PostDoc)
- (+Sara Sellam's analysis)



- 1 thesis defended last year / another one to be defended tomorrow
- 3 analyses in RC stage
- Mostly ongoing analyses with Run 2 data samples (lead-lead, p-lead)
- 3 theses in progress with Run 3 data samples
- 2 theses in progress focused on spectroscopy and hadronic properties
- Very significant work on enabling data taking (trigger and reconstruction sequences) as well as on performance improvements (w.r.t. pp data taking algorithms)

Main physics analysis lines: RD

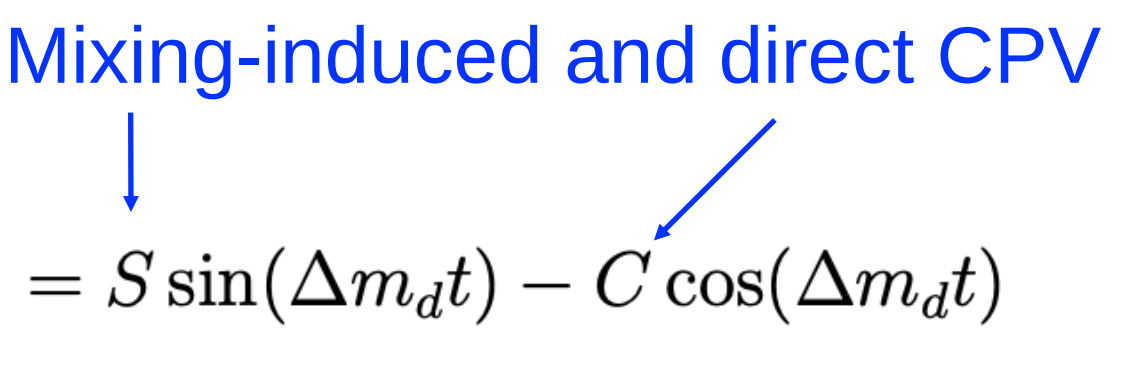
Emerging line, started end of last year. Targeting **time-dependent CP asymmetry** measurements in **rare $b \rightarrow d(s)\mu\mu$ B decays**, particularly, in modes like $B^0 \rightarrow K_S^0 \mu\mu$ and $B_s^0 \rightarrow f^0(980)\mu\mu$.

Rare B decays

- Javier Dorta
- Brais Fernández
- Camille Normand (PostDoc)
- Richard Williams (PostDoc)

$$\mathcal{A}^{CP}(t) = \frac{\Gamma(\bar{B}^0(t) \rightarrow K_S^0 \mu^+ \mu^-) - \Gamma(B^0(t) \rightarrow K_S^0 \mu^+ \mu^-)}{\Gamma(\bar{B}^0(t) \rightarrow K_S^0 \mu^+ \mu^-) + \Gamma(B^0(t) \rightarrow K_S^0 \mu^+ \mu^-)} = S \sin(\Delta m_d t) - C \cos(\Delta m_d t)$$

Mixing-induced and direct CPV



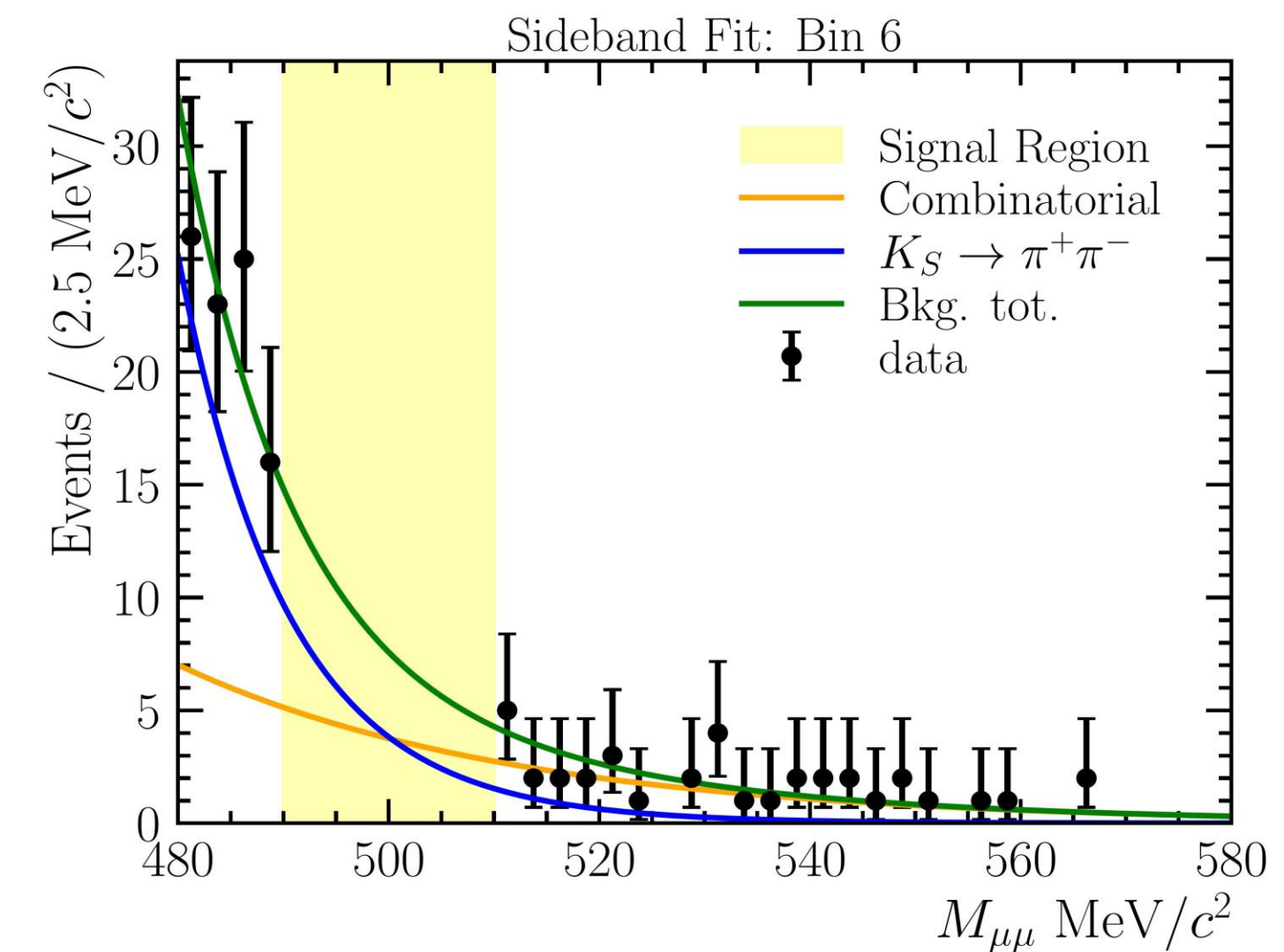
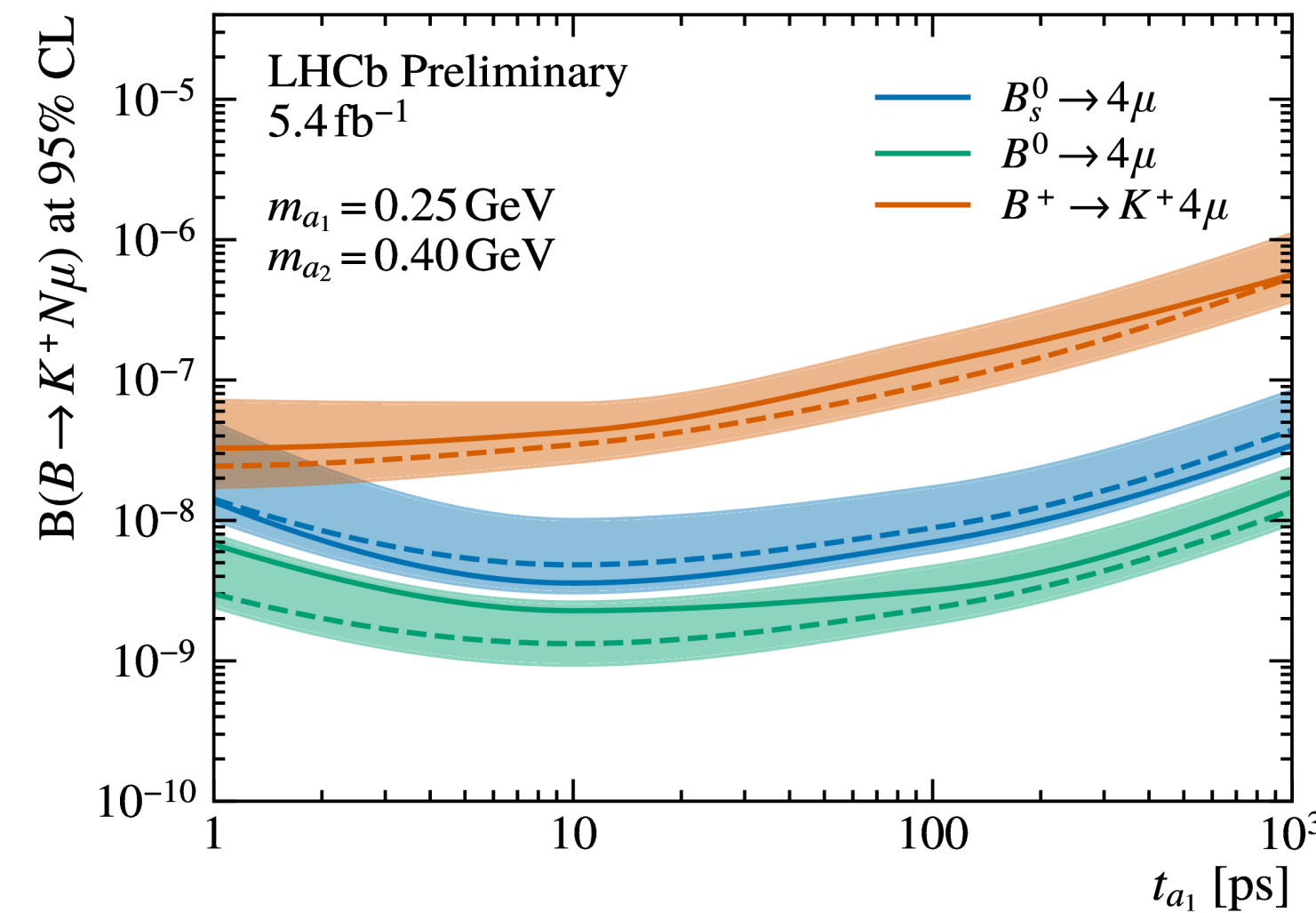
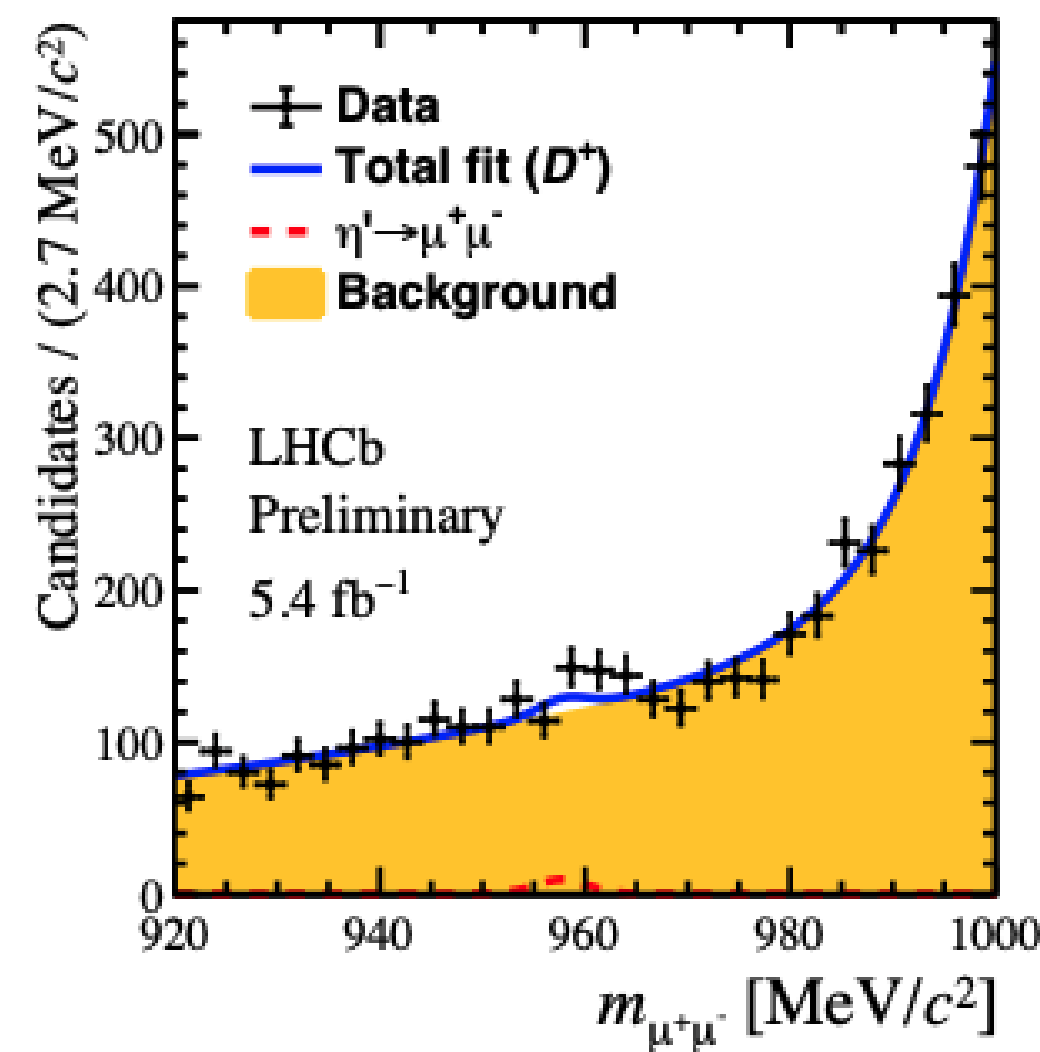
- 2 ongoing theses
- Targeting early analysis of Run 3 data (test of sensitivity and overall data quality for time-dependent studies)
- Work on flavour tagging for Run 3
- Plan to extend line to $b \rightarrow s\tau\tau$ final states with Richard (new PostDoc)

Main physics analysis lines: Very rare/Exotica

Exotica searches: very active line with many complementary analyses. Focusing on signatures of **direct DM production** as well as very searches for **rare/suppressed decays and of long-lived particles**: rare charm decays, direct DM production, very rare B decays, ALPs, ...

Very rare/Exotica

- Pablo E. Menéndez
- María Pereira
- Alberto Martínez
- Alejandro Novo
- Brais Fernández
- Ángel Morcillo
- Miguel Fernández (Postdoc)
- Emilio X. Rodríguez (Postdoc)
- Titus Mombaecher (Postdoc)



- 2 theses defended in 2025. 3 analyses in completed/advanced stage:
 - Rare η/η' decays LHCb-PAPER-2025-047.
 - B meson decays to MultimMuon final states LHCb-PAPER-2026-014.
 - Run 3 search of Kaon decays to dimuons (Working group circulation).
- Search for invisible DM decays and direct searches for Dark Sector decays.
- New Machine Learning trigger techniques for exotic topologies.

Instrumentation: LHCb Upgrade and CODEX-b

Instrumentation

- Federico de Benedetti
- Francisco Piernas
- Efrén Rodríguez
- Juan Pablo Escandón
- Antonio Fernández (PhD Engineer)
- Eliseo Pérez
- Antonio Pazos
- Iris García Rivas

LHCb instrumentation: VELO project. Very significant contributions to the **electronics and read-out systems** of the current VELO, plan to work on **consolidation and maintenance** of this detector during **LS3**.

Broad lines for **VELO Upgrade II (4D tracking)**: contribute to the construction of detector modules, develop data acquisition and control systems, and verify Front-End ASICs and sensors.

Codex-β

- Alejandro Novo
- Alberto Martínez

COmpact Detector for EXotics at LHCb : new proposal for off-axis search of LLPs.

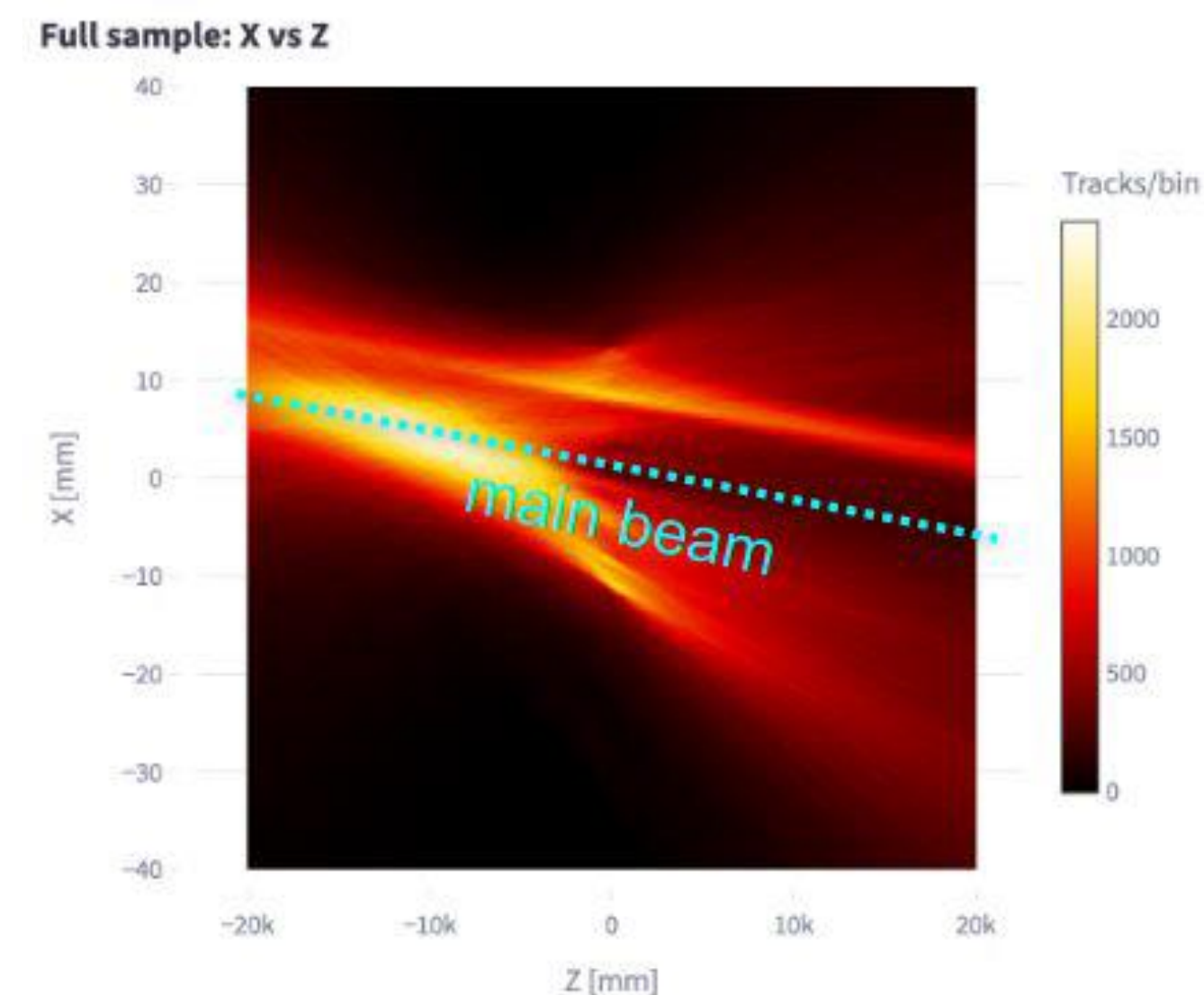
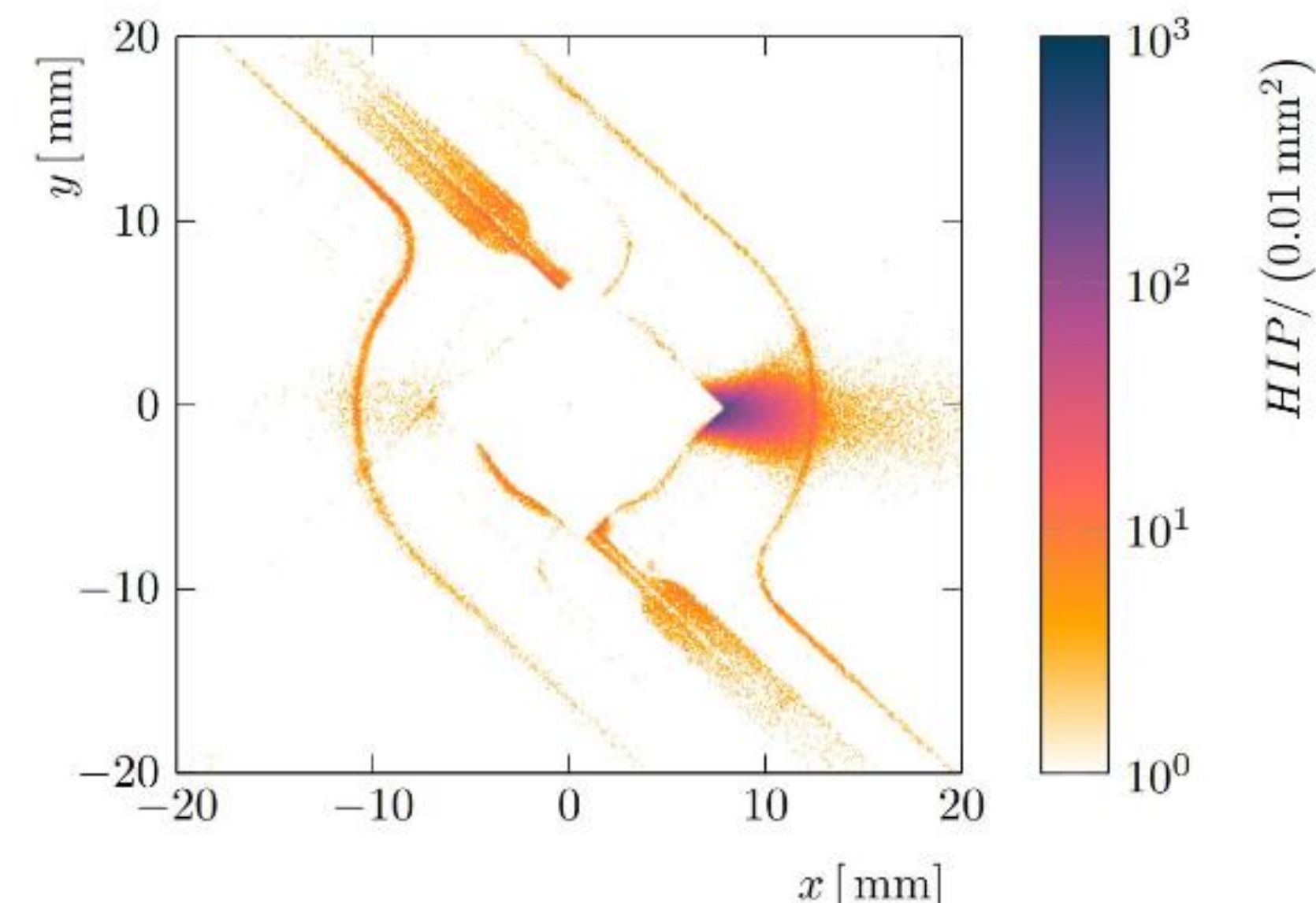
Very different picture from a year ago! **Demonstrator at the LHCb cavern essentially built** and work on commissioning and integration into the LHCb online system already ongoing. **Large involvement** from both USC and UdC groups, with very **substantial on-site presence** in 2024-2026.

Target to take background (calibration) data during the last months of Run 3 → see dedicated talk for the updated status and plans.

VELO operations

- In 2025 at the beginning of the ion run several ASICs (across 7 modules) were damaged during the operation
 - Run until the 2026 long shutdown of the LHC at 400V.
 - Impact on data quality
- Issue involve a mix of the high voltage, sensor behaviour, ASIC and beam background condition
 - On-going studies to understand the failure
- Module replacement during LS3
- VELO piquet Shifts (Kudos to Cristina, Adrián)

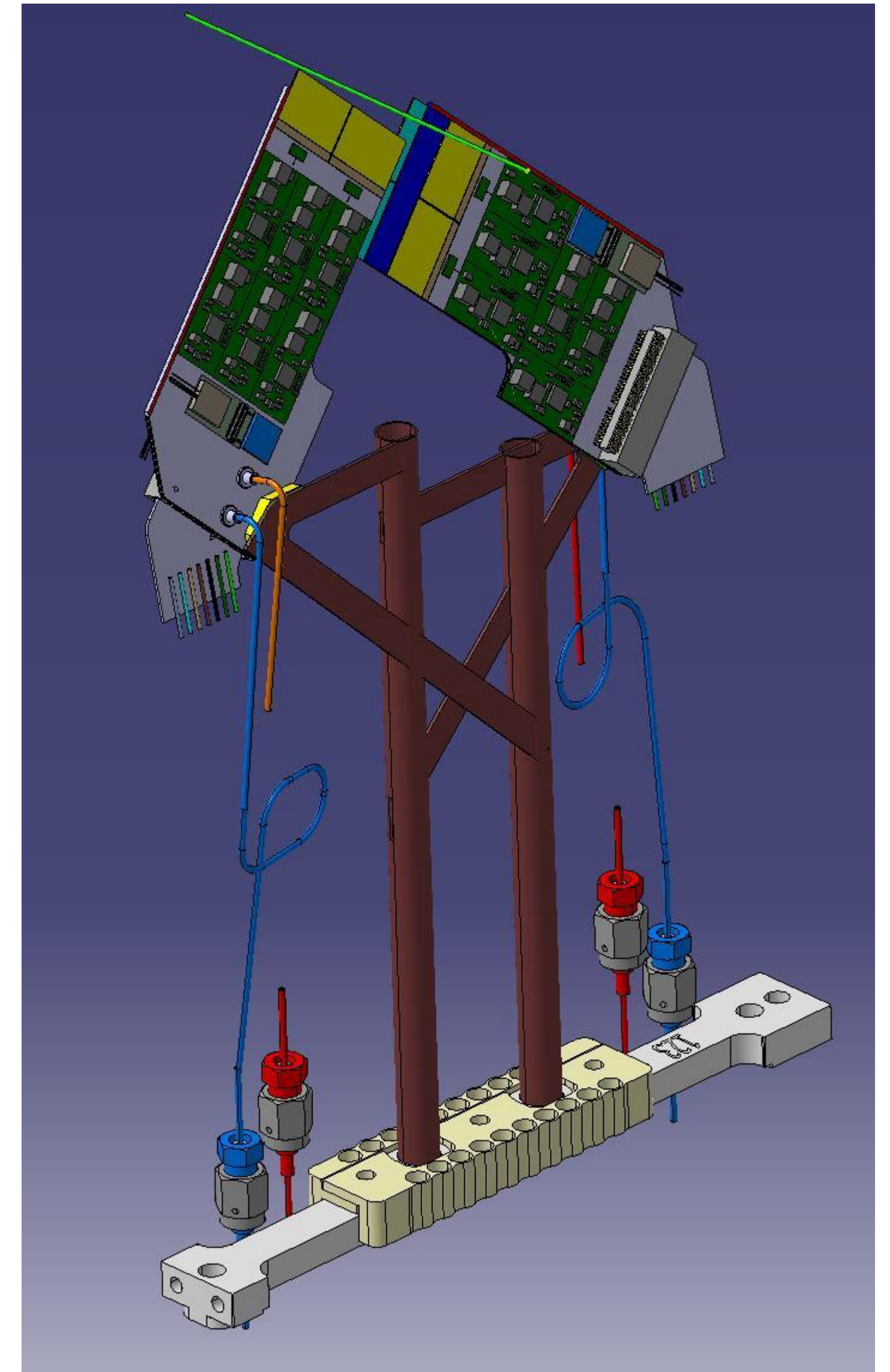
X,Y intercept of tracks made >5 hits of >5 pixels in PbPb 2025



VELO Upgrade II

Converging different R&D lines towards TDR (Q1 2027)

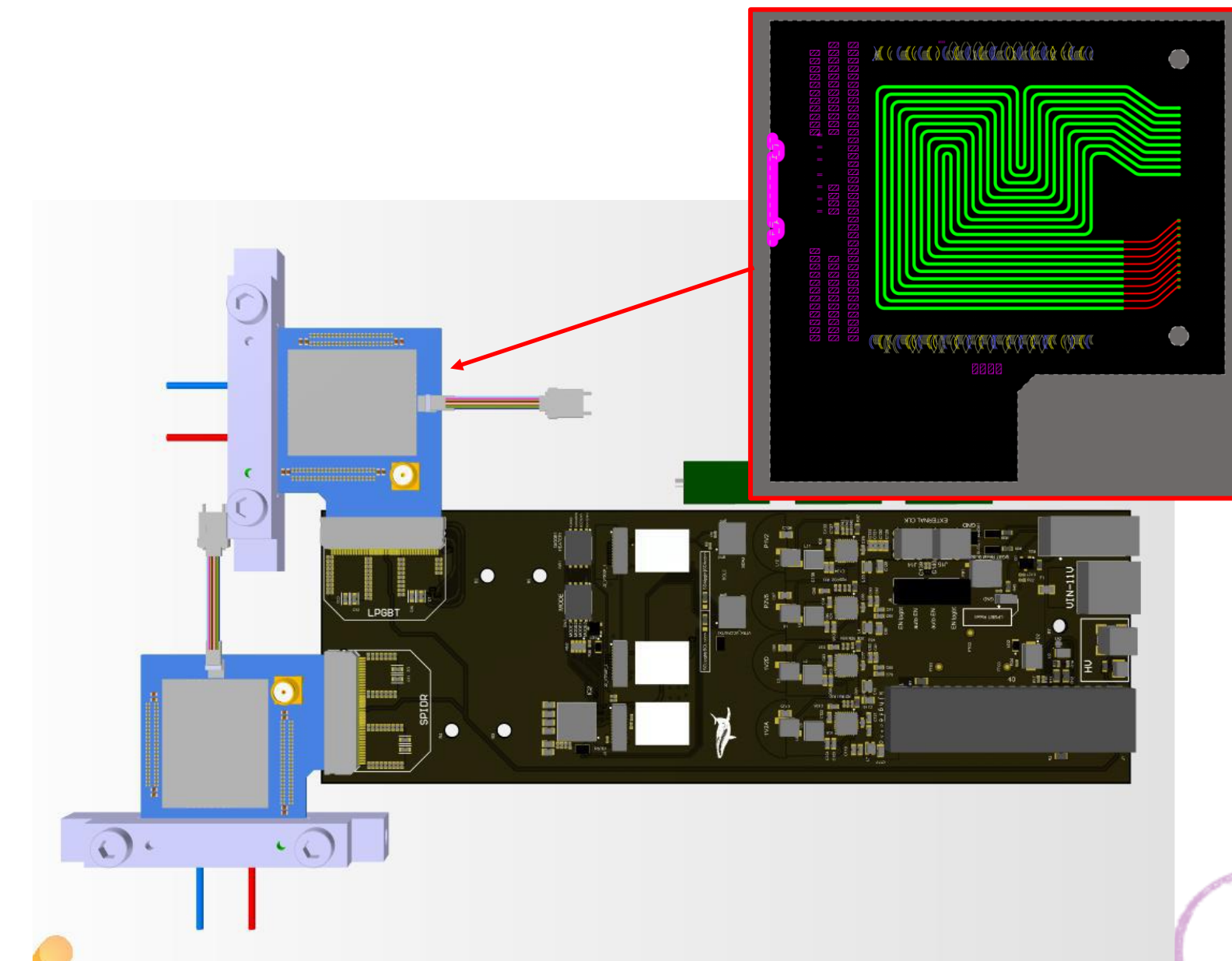
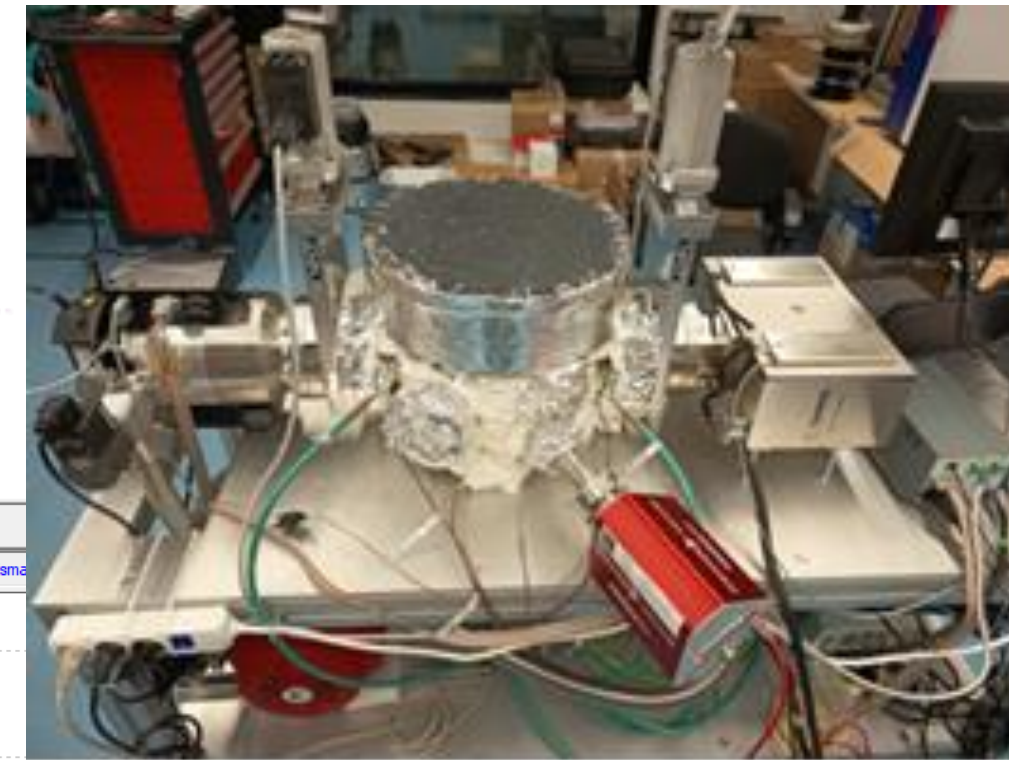
- Mechanics: Considered detector on primary vacuum. Now evaluating secondary vacuum with 300 μ m Beryllium box
- Sensors: 3D
- ASICs: New generation of ASICs taped out by TDR
- Electronics:
 - Designing the first module prototypes
 - Silicon photonics readout preferable solution



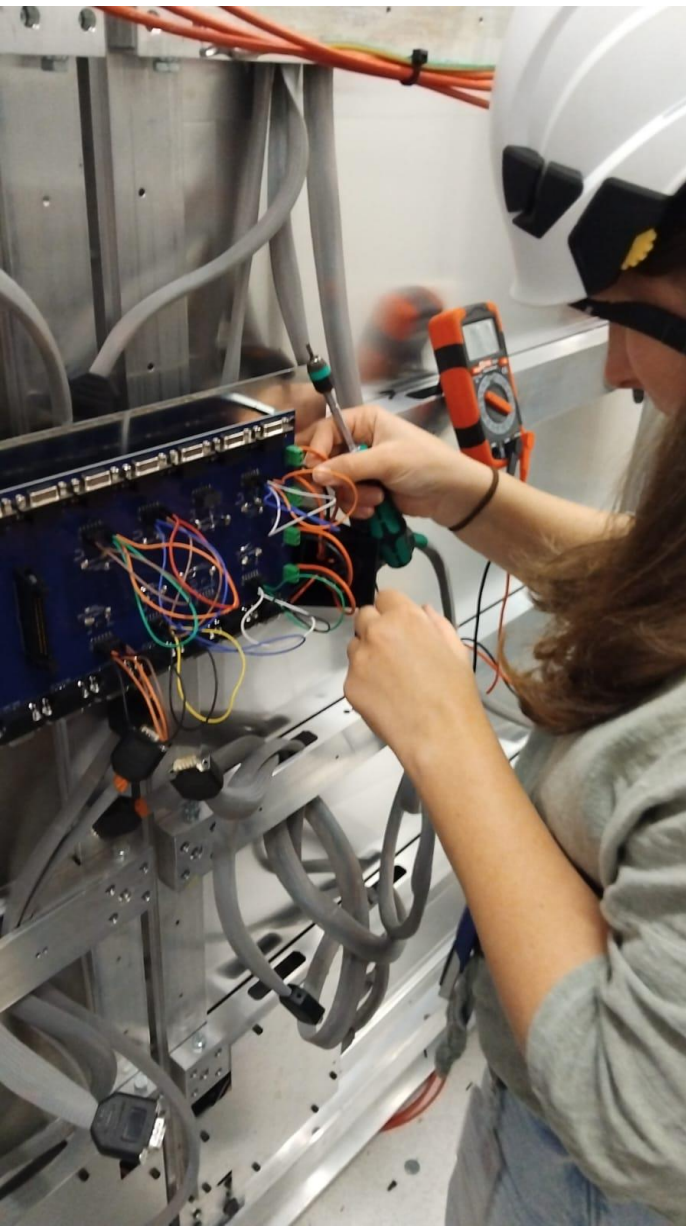
VELO upgrade II

The role of IGFAE for VELO Upgrade II

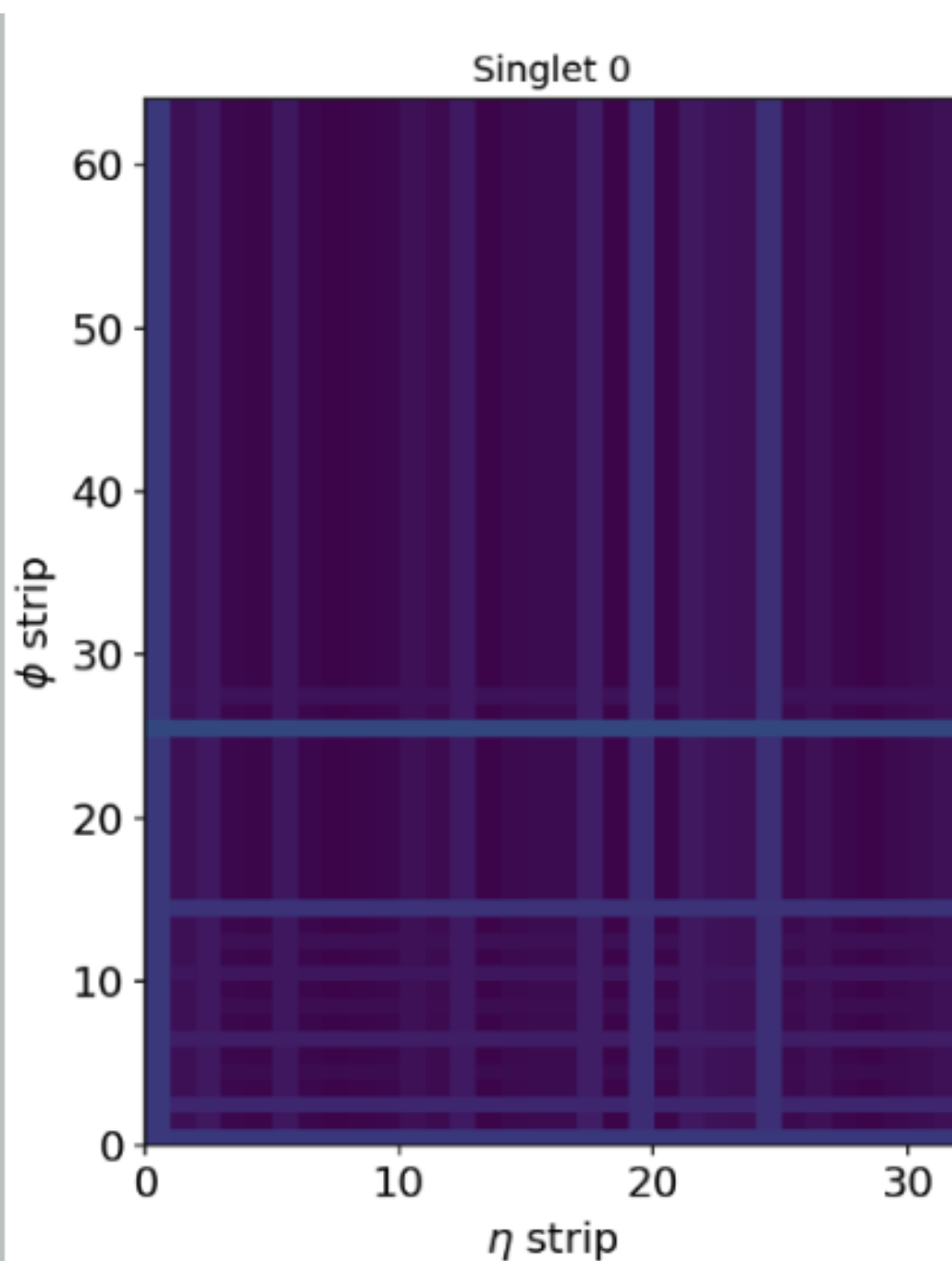
- Sensor development
 - 3D sensor productions running in FBK and Sintef
 - Sensor characterization.
[TimePix 4 beam telescope paper published on NIMA](#)
 - Exploring hybridization and sensor integration at INL (Braga)
 - Developing new sensors (SiEM). *PhD Federico de Benedetti*
- Electronics
 - Setting the specs for ASIC design. Two LHCb technical notes
 - Developing control and DAQ electronics.
Converging to module design
PhD Francisco Piernas Díaz
- Vacuum compatibility
 - Outgassing setup: 10^{-10} mbar, 230°C, gas composition spectrometer (RGA)
 - To test: ceramics, optical fibres, feedthroughs, PCBs, foil samples, etc.



CODEX- β



- Installation of a reduced-size prototype CODEX-beta completed during Run 3.



- Hardware:
 - RPC triplets installed and tested.
 - Service routing (Low Voltage/High Voltage/Gas) completed.
 - DAQ units connected and integrated within LHCb readout.



- Software:
 - Trigger and reconstruction implemented: time alignment in progress.
 - ECS integrated with LHCb.
 - Simulation software.
 - Offline analysis framework COBRA.

Beyond LHCb

Proton therapy. *PhD Iris García Rivas*

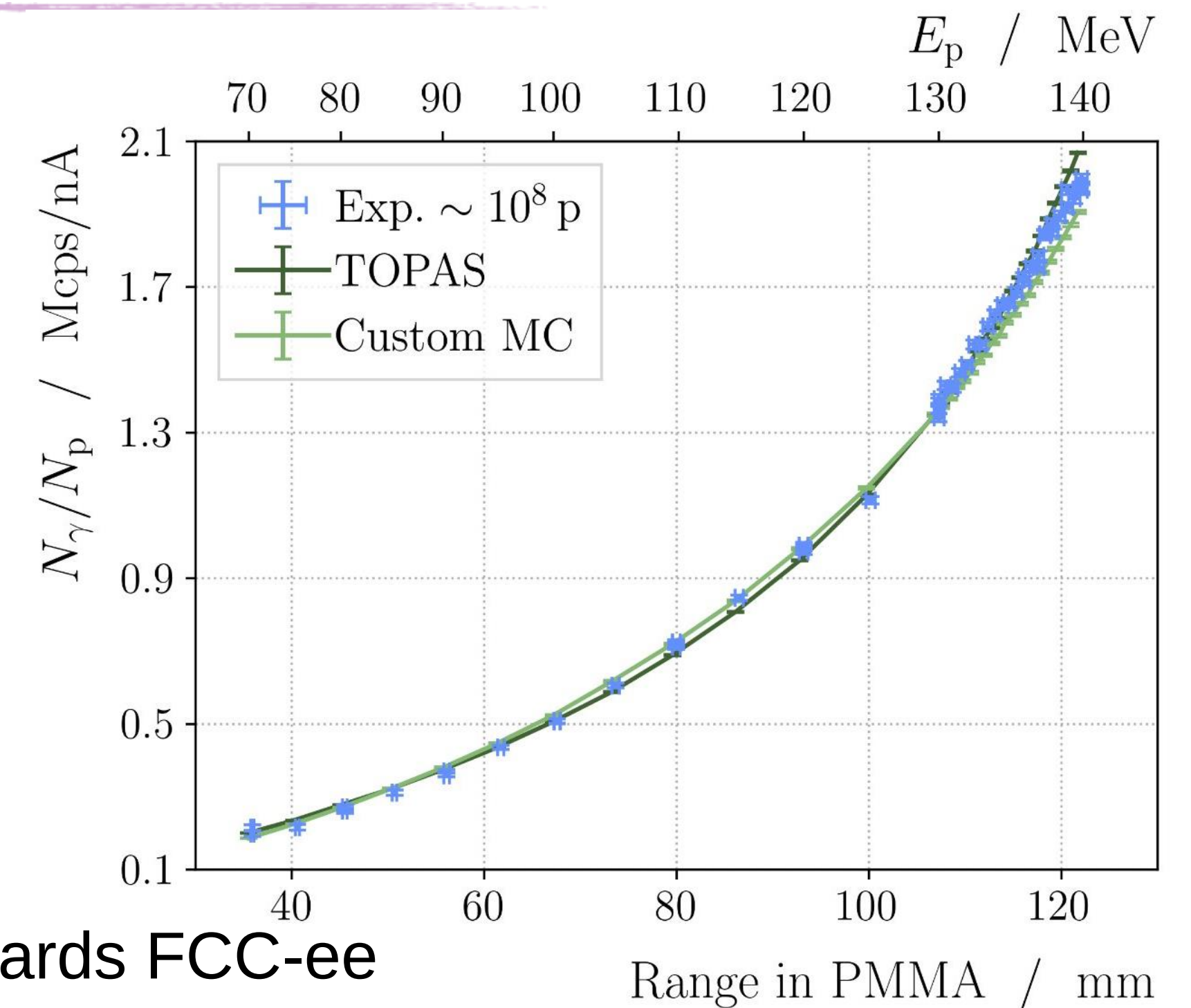
- Proof of principle demonstrated
 - Publication of detector hardware on [JINST](#)
 - Publication with clinical beam submitted in May 2026

DRD3. IGFAE IGNITE.

- Goal is to position the institute on key detector technologies towards FCC-ee (Monolithic Active Pixel Sensors- DMAPS)
- Collaboration with IFIC & IFCA to build a telescope based on Belle II DMAPS ASICs
- IGFAE is focus on system integration and DAQ electronics

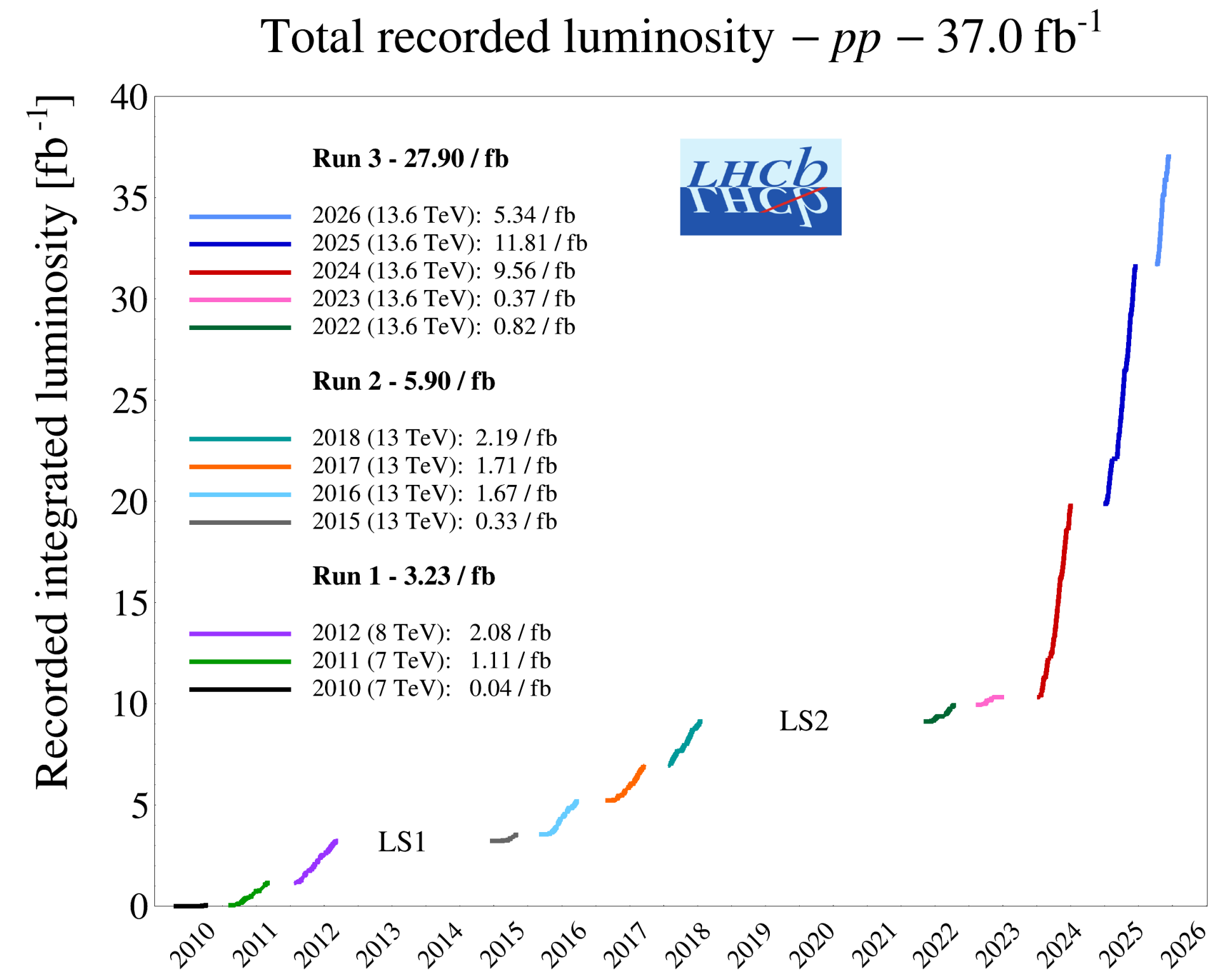
DRD7. IGFAE IGNITE

- Goal is to develop the next gen. of radiation hard high-speed transceivers
- IGFAE is focus on the operation of these devices at extreme environments (like VELO)



Summary

- Very active group, broad physics programme
 - Did not mention every single analysis on this talk, focused on describing strategic lines
 - Physics-output oriented, many developments of tools and internal LHCb/Codex-b software not covered
- Long-term planning and involvement in instrumentation, mainly, through the LHCb VELO system, but also participating in the DRD3 and DRD7 collaborations for future developments.

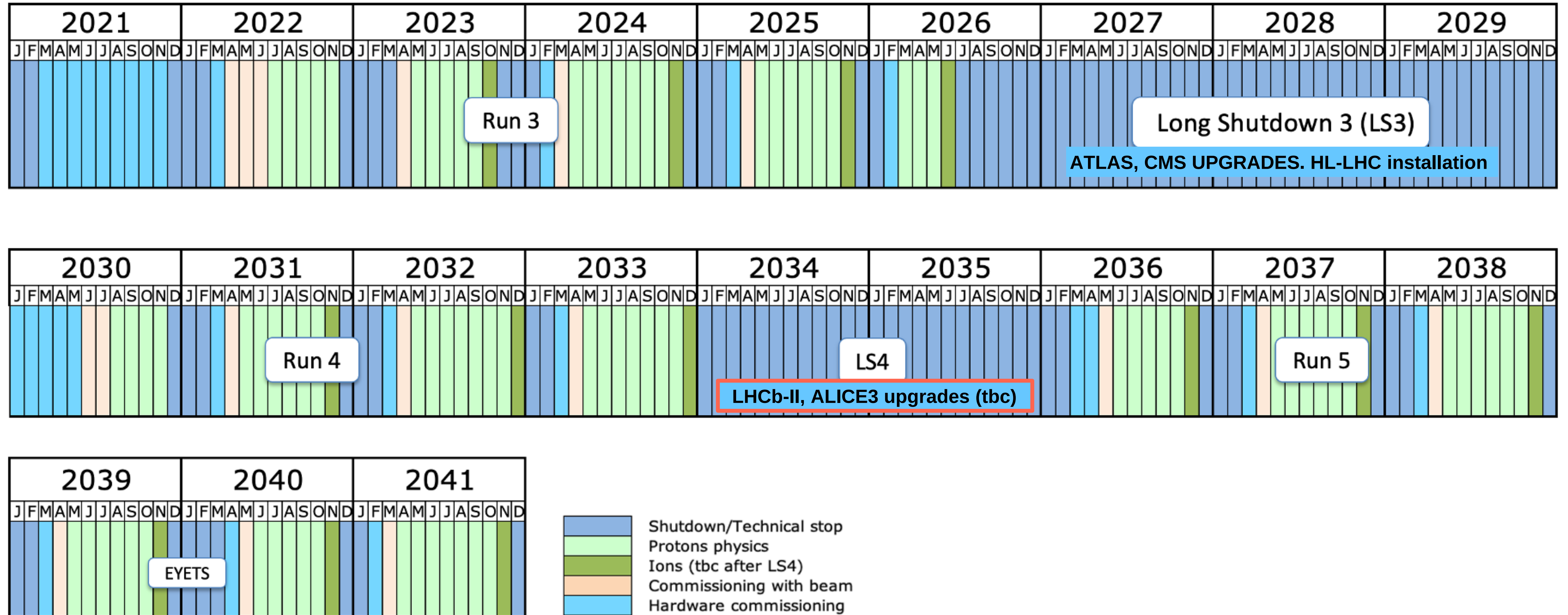


INSTITUTO GALEGO
DE FÍSICA
DE ALTAS ENERXÍAS



Backup slides

LHC Schedule



Last update: September 24

Measurement of $R(D^{(*)0})$ using 3-prong hadronic tau decays

- Ongoing analyses:

1) Simultaneous measurement of:

$$R(D^0) = \frac{\mathcal{B}(B^- \rightarrow D^0 \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B^- \rightarrow D^0 \mu^- \bar{\nu}_\mu)} \quad R(D^{*0}) = \frac{\mathcal{B}(B^- \rightarrow D^{*0} \tau^- \bar{\nu}_\tau)}{\mathcal{B}(B^- \rightarrow D^{*0} \mu^- \bar{\nu}_\mu)}$$

- Using $D^0 \rightarrow K^- \pi^+$ decays and 3-prong hadronic $\tau^- \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$ decays.
- Measurement of $\mathcal{B}(B^- \rightarrow D^0 \tau^- \bar{\nu}_\tau)$ & $\mathcal{B}(B^- \rightarrow D^{*0} \tau^- \bar{\nu}_\tau)$ with respect to the normalisation mode $\mathcal{B}(B^- \rightarrow D^0 D_s^- (\rightarrow \pi^- \pi^+ \pi^-))$.
- Use the best-known values of $\mathcal{B}(B^- \rightarrow D^0 D_s^-)$ and $\mathcal{B}(B^- \rightarrow D^{(*)0} \mu^- \bar{\nu}_\mu)$ to obtain $R(D^0)$ and $R(D^{*0})$.
- 1 analysis using Run 2 data (advanced, in LHCb RC) and 1 analysis using Run 3 data.

2) Measurement of:

$$R(D^{*+}) = \frac{\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau)}{\mathcal{B}(B^0 \rightarrow D^{*-} \mu^+ \nu_\mu)}$$

- Using $D^{*-} \rightarrow D^0 \pi^-$ with $D^0 \rightarrow K^- \pi^+ \pi^- \pi^+$ decays and 3-prong hadronic $\tau^- \rightarrow \pi^- \pi^+ \pi^- \nu_\tau$ decays.
- Measurement of $\mathcal{B}(B^0 \rightarrow D^{*-} \tau^+ \nu_\tau)$ with respect to the normalisation mode $\mathcal{B}(B^0 \rightarrow D^{*-} \pi^- \pi^+ \pi^-)$.
- 1 analysis using Run 2 data and 1 analysis using Run 3 data.

QCD and Heavy-Ion collisions and Spectroscopy

- J/ψ and dimuon pair CEP $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 8.16$ TeV
- Charged hadron flow in $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 8.16$ TeV. Approved
- Λ^0/K_s versus transverse momentum, rapidity and centrality in PbPb collisions 2024
- Multiplicity dependence of $\langle p_T \rangle$ and multiplicity distribution for charged particles in pp and $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 5$ TeV CW review
- Measurement of the production and nuclear modification factor of prompt $\pi^\pm$, $K^\pm$ and $p^\pm$ in pp and $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 5$ TeV Collaboration Review
- Multiplicity-dependent ϕ -meson production in $p\text{Pb}$ collisions at $\sqrt{s_{NN}} = 5$ TeV WG Review
- Measurement of $D_{s1}(2460)^+/D_s^{*+}$ ratio in pp collisions at $\sqrt{s} = 13\text{TeV}$
- X_{c2}/X_{c1} ratio in 2024 OO
- $\rho(770)^0$ -meson mass-shift measurement and $f_0(980)$ nature in pp collisions at $\sqrt{s} = 5$ TeV
- Measurement of the average transverse momentum of charged particles in PbPb 2024
- Production of isolated J/ψ mesons in pp collisions data at 13 TeV in the LHCb experiment

