CERN-RRB-2025-027

Status of LHCb

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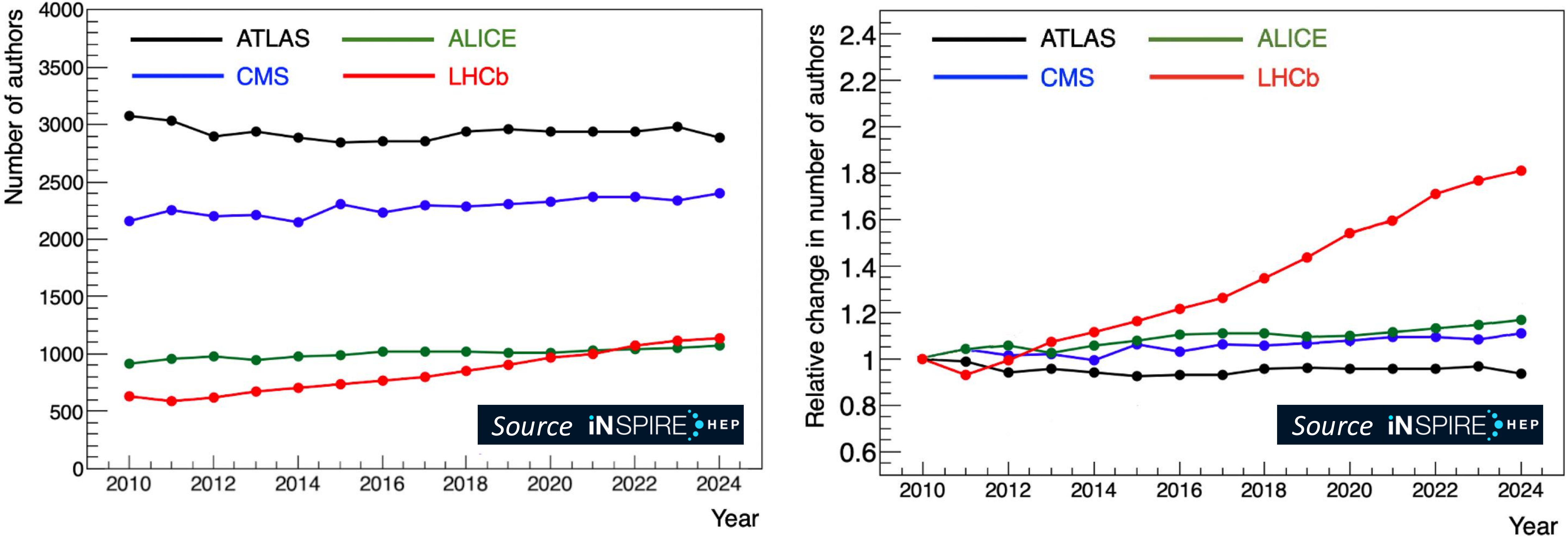
for the LHCb collaboration

29th April 2025, CERN RRB meeting

LHCb collaboration

- As of today, 1784 members from 102 institutes in 24 countries
  - There were 1771 from 108 institutes in 25 countries when we met last October → the reduction in the number of affiliates, following the end of the ICA with the Russian Federation (last December), has been already absorbed by new members

Number of authors in LHC collaborations



- 1204 LHCb authors as of today, which make LHCb the third experimental collaboration at CERN in terms of size

New groups which joined LHCb during last 12 months

Full members

1. IRFU CEA Saclay, France
2. Freiburg University, Germany

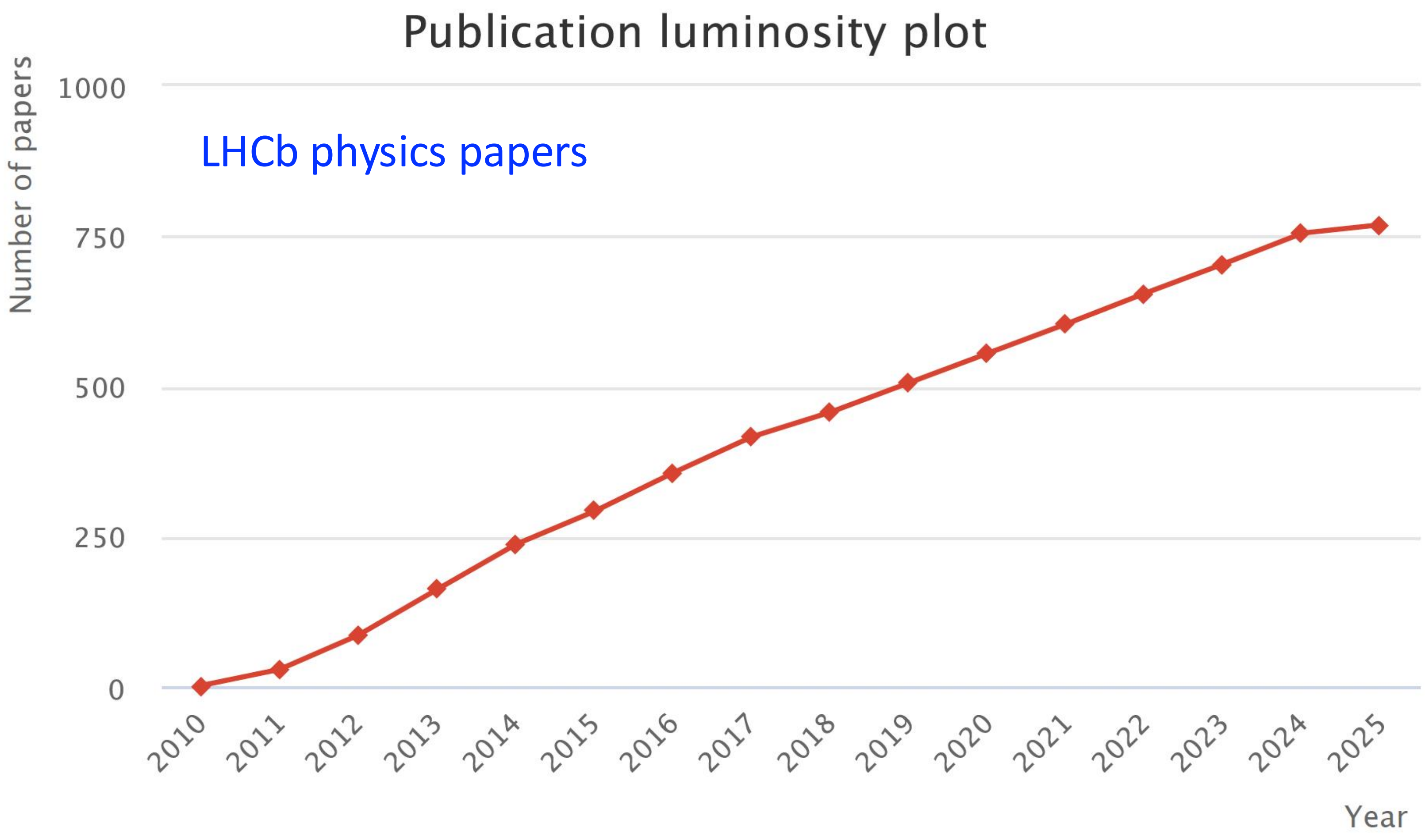
Associate Members

3. Bochum University, Germany
4. Andres Bello University, Chile — New Country
5. Vilnius University, Lithuania — New Country
6. Henan Normal University, China

Technical Associate Members

7. GSI Darmstadt, Germany
8. Subatech Nantes, France
9. Institute of Nuclear Physics (INP), Kazakhstan — New Country
10. Jagiellonian University, Poland
11. University of Napoli and INFN, Italy
12. University of Science and Technology, China
13. University of Leicester, United Kingdom
14. Northwestern Polytechnic University, China
15. Laboratoire de Physique Corpusculaire Caen, France
16. INFN TIPFA, Italy

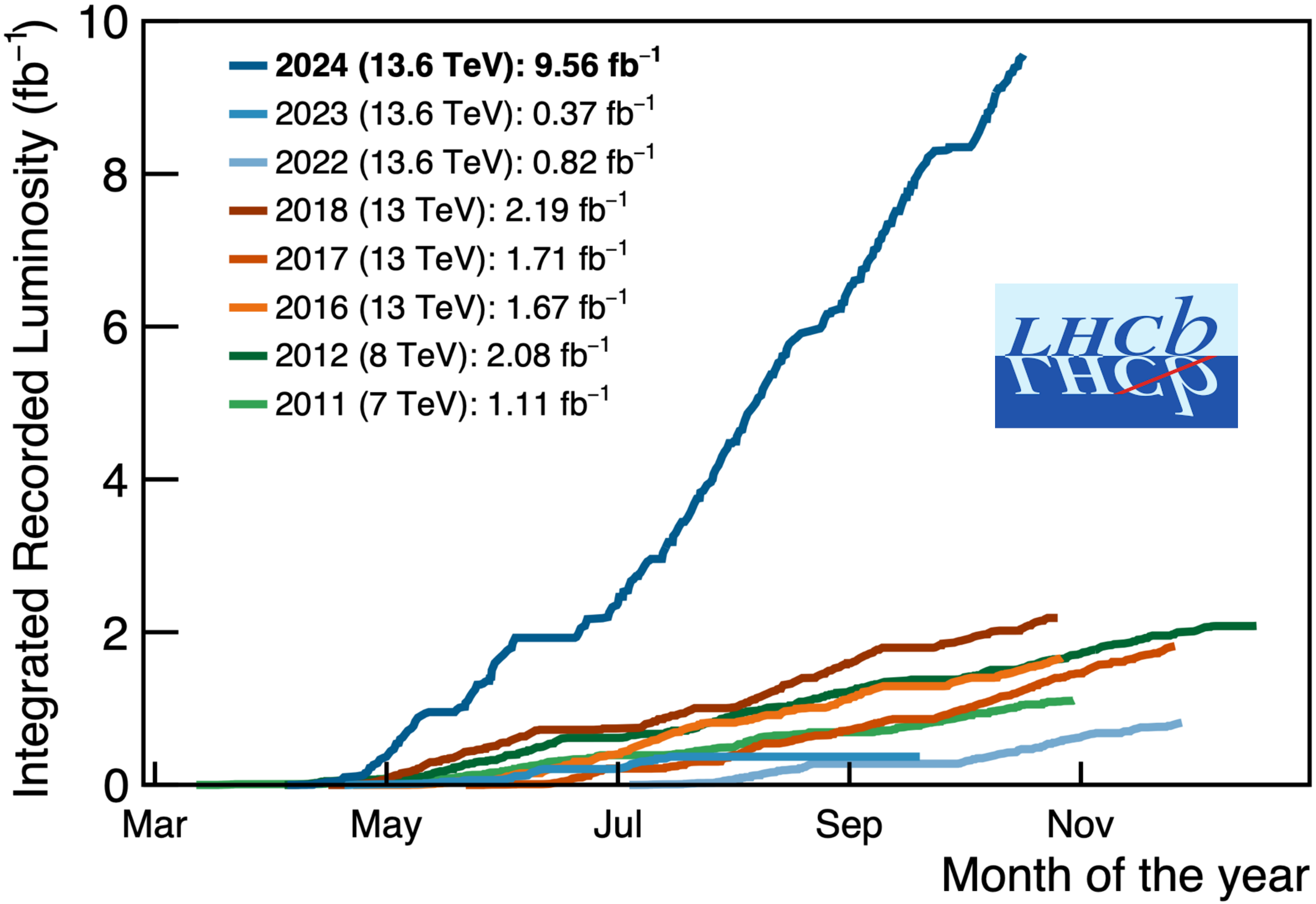
LHCb publication rate



- 769 physics papers produced by LHCb as of today
  - Not including collaboration-wide performance papers
- Steady rate with only Run-1 and Run-2 data so far

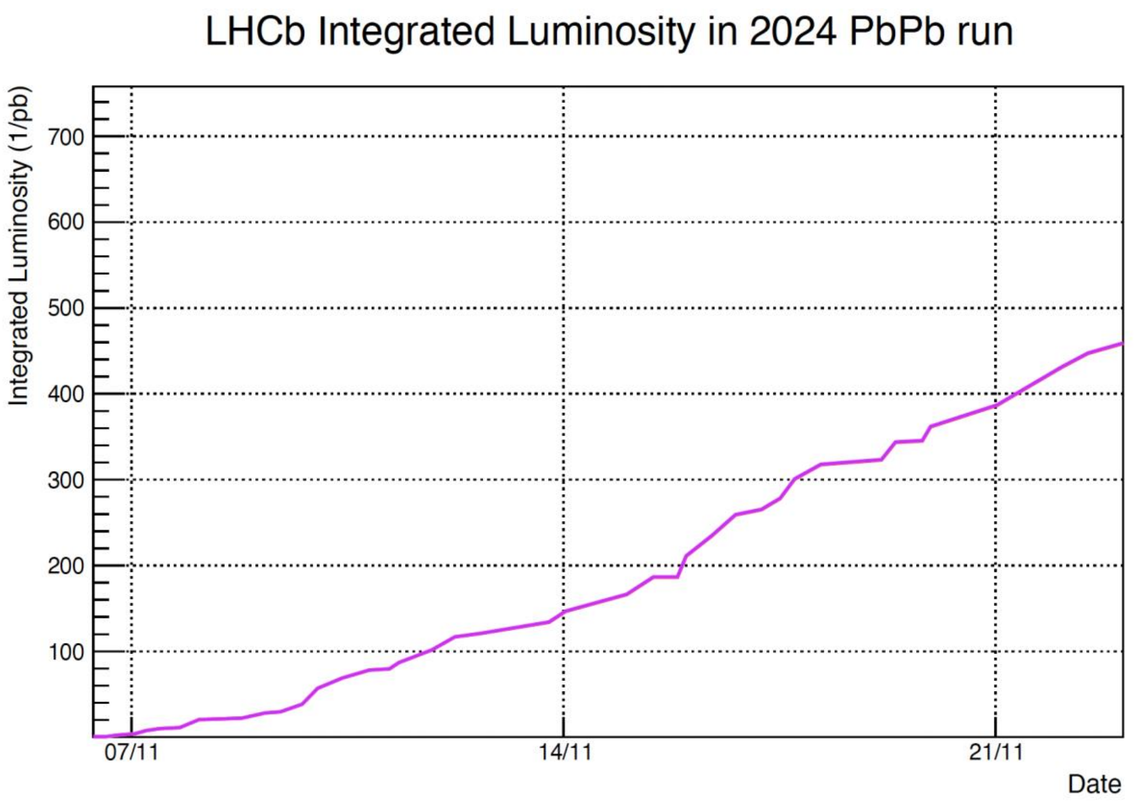
Reminder: 13.6 TeV *pp* data taking in 2024

- Total integrated luminosity: 9.56 fb^{-1}
  - Run-1 and Run-2 combined was 9 fb^{-1}
- Surpassed in a single year the integrated luminosity of all previous years, with more efficient trigger
  - Trigger efficiency for hadronic beauty and charm decays two/three times larger



And also a successful 2024 PbPb run

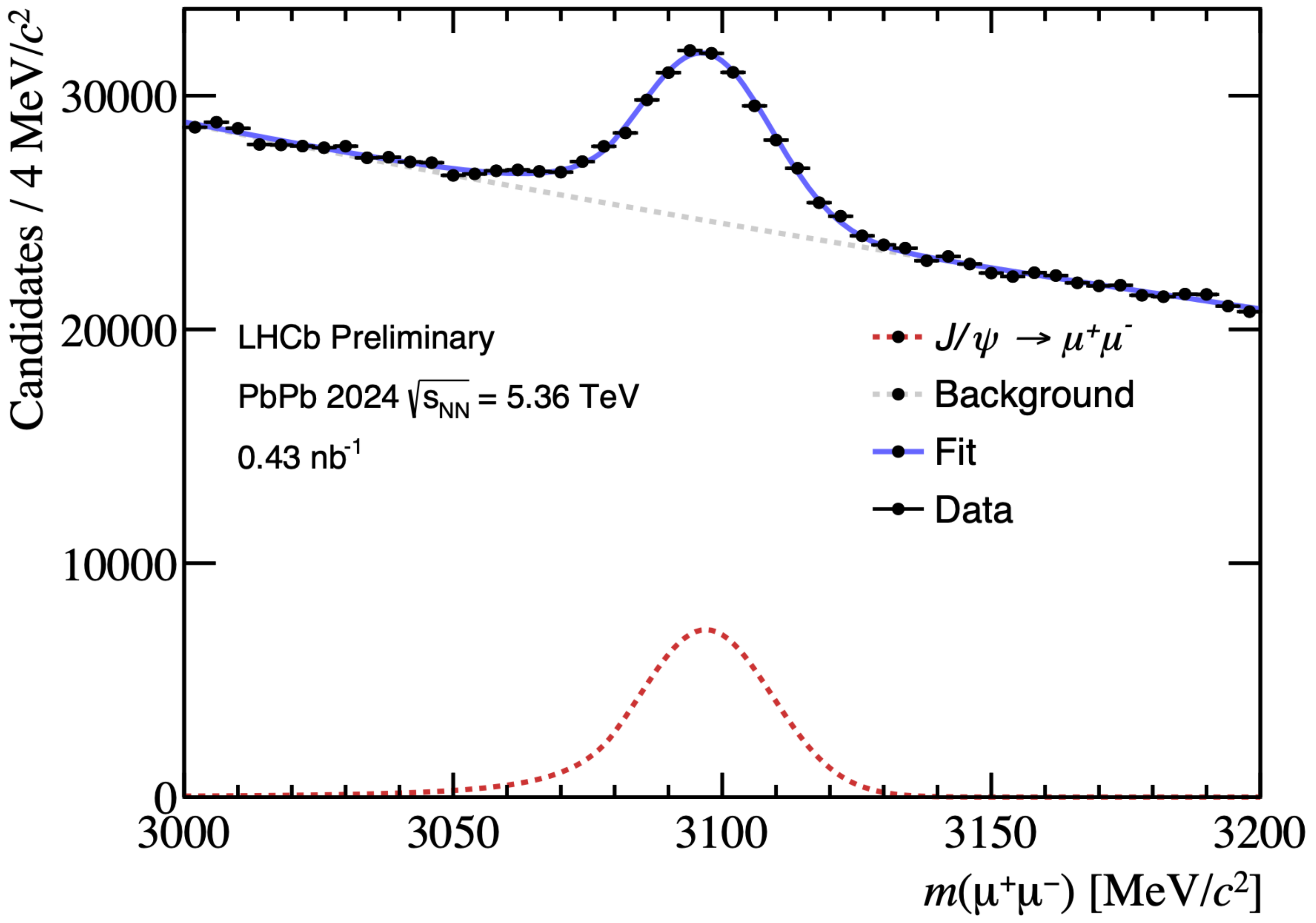
- Pb-Pb collision data collected with the nominal LHCb Upgrade I detector for the first time (closed VELO, UT included)
- The Upgrade I detector reaches much lower centrality than the first LHCb detector, covering the 100%-30% centrality range



- Furthemore, we got a ~70% increase in instantaneous luminosity, allowing us to gather a data sample larger than all previous PbPb runs

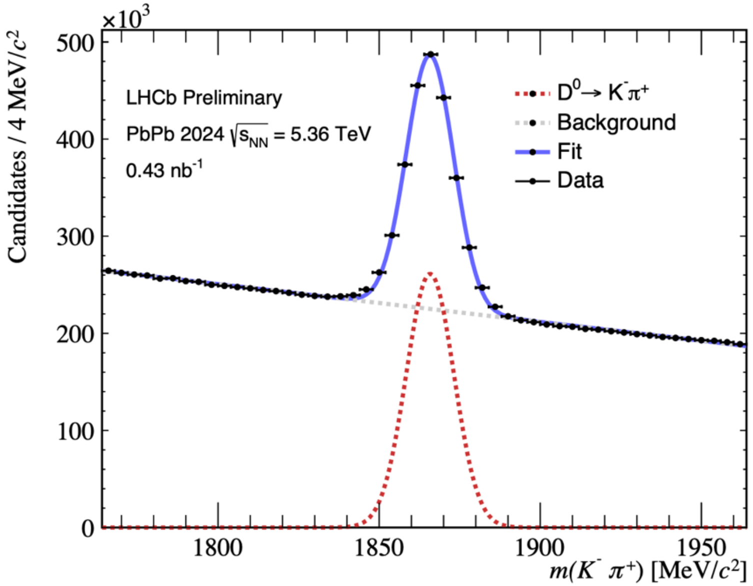
First look at 2024 PbPb data: J/ψ

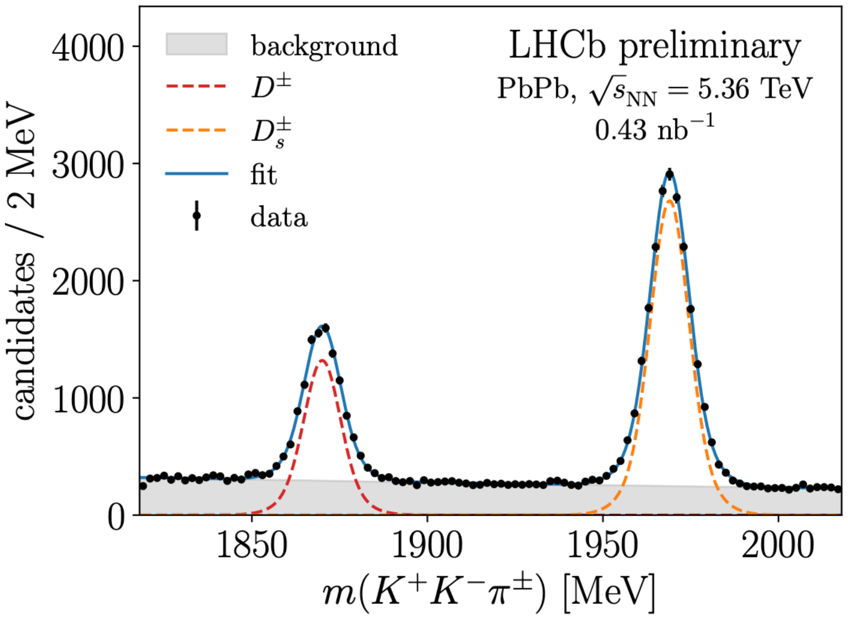
- Clear J/ψ signal decaying to two muons observed with excellent mass resolution
- The sample will allow us to separate prompt and non-prompt components to measure beauty production

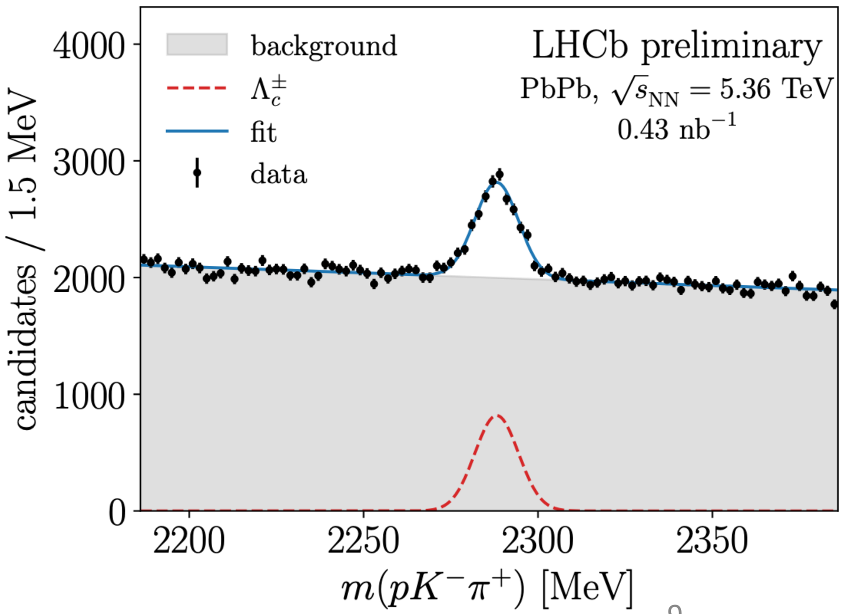


First look at 2024 PbPb data: open charm

- Invariant mass spectra for open-charm hadronic decays: $D^0, D^\pm, D_s^\pm, \Lambda_c$
- Large samples of hadronic decays also in PbPb collisions!



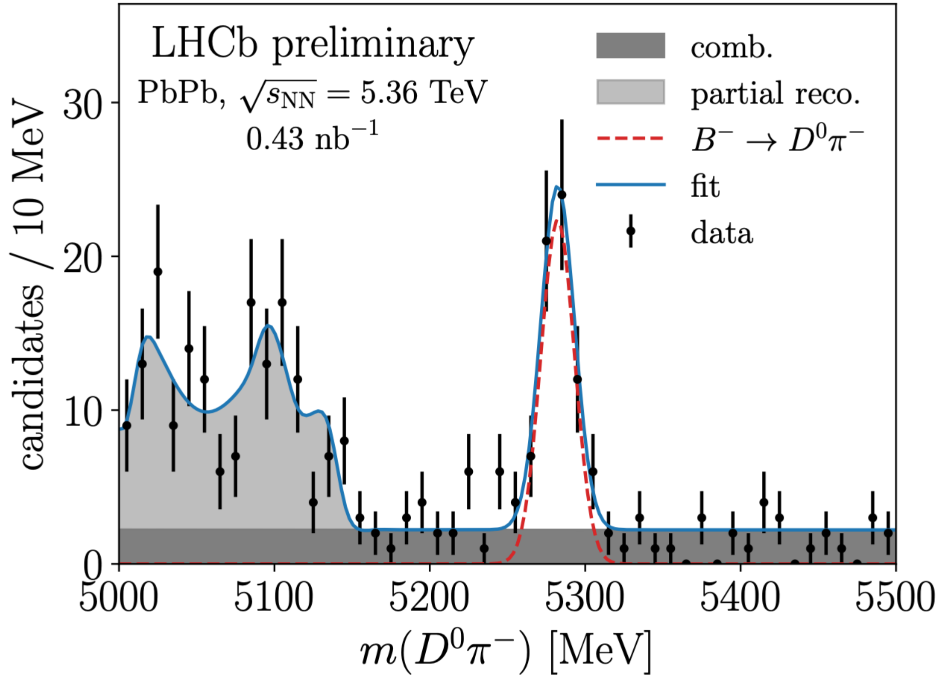


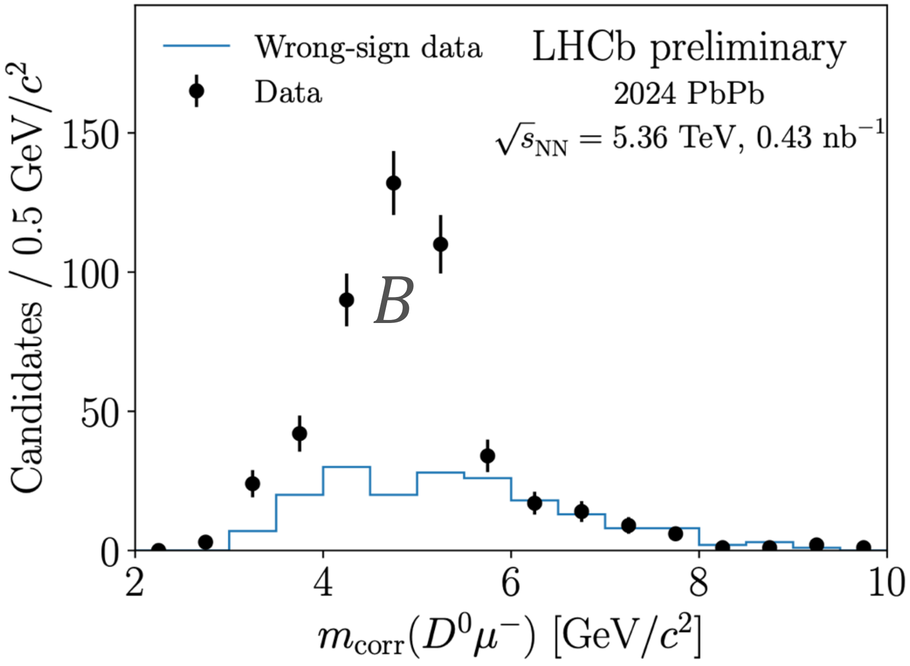


First look at 2024 PbPb data: open beauty

- Invariant mass spectra for the $B^{\pm}$ hadronic and semileptonic decays
- First hadronic decay of a B meson ever observed in PbPb collisions!

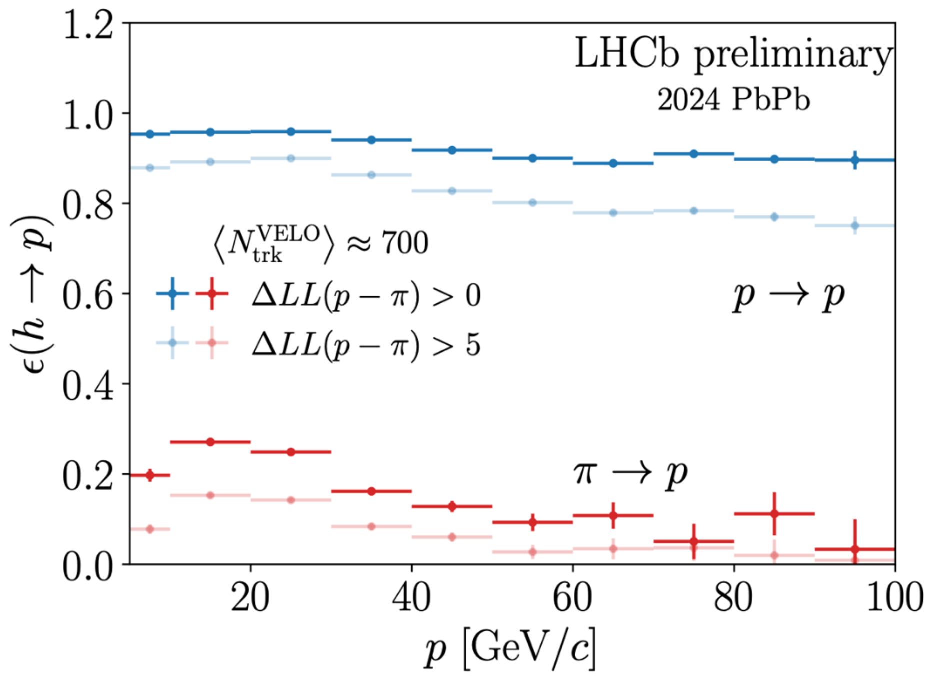
$$m_{corr} = \sqrt{m^2 + p_{\perp}^2} + p_{\perp}$$

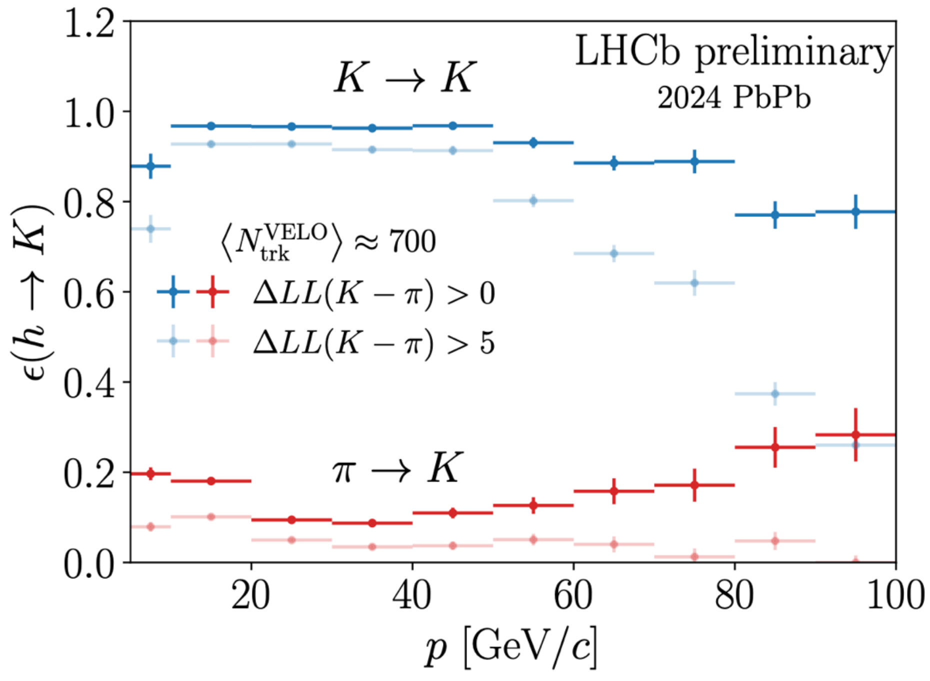




First look at 2024 PbPb data: hadron PID

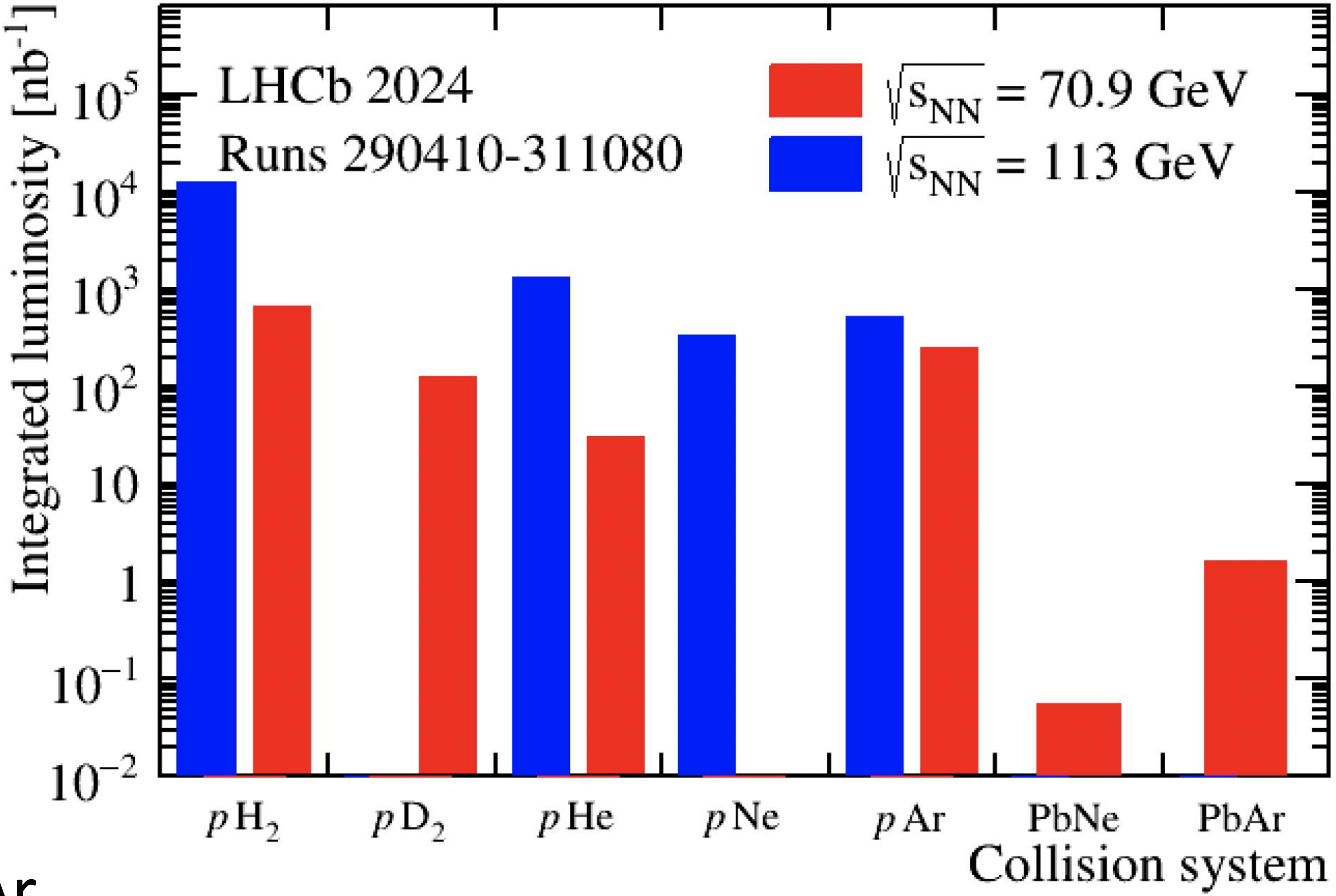
- Hadronic decays become now accessible in PbPb collisions too thanks to the LHCb RICH detector, unique at the LHC
- Excellent performances are found, here shown for proton and kaon identification





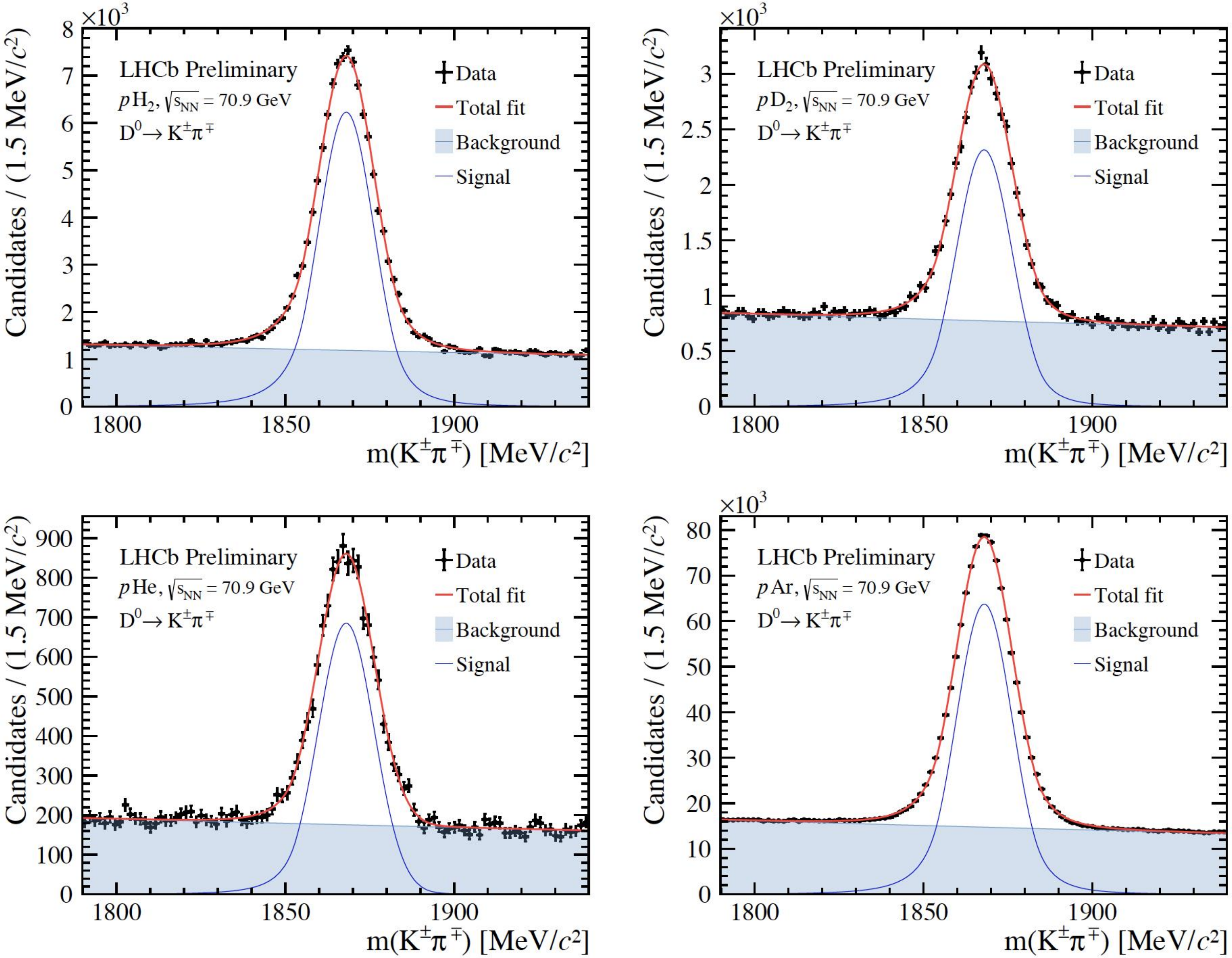
Fixed-target programme with injected gas

- Gas injection into the SMOG2 storage cell allows LHCb to run in fixed-target mode in parallel to *pp* and heavy ion collisions
- This is a unique feature at the LHC, enabling measurements with a range of gases
  - In 2024, SMOG2 was fed with H_2, D_2, He, Ne and Ar
  - Unprecedented samples now available!



First look at 2024 fixed-target data

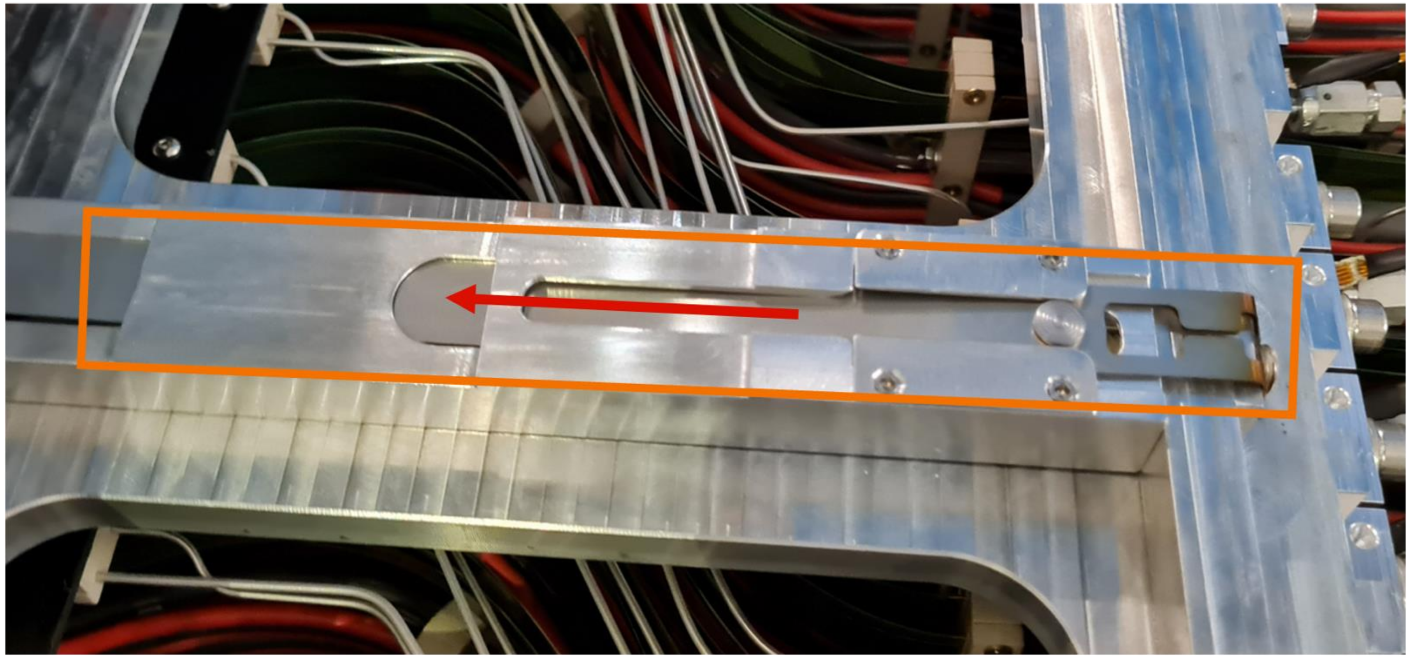
- Very clean charm signals observed, here focusing on the data taken in parallel to the *pp* reference run at $\sqrt{s_{NN}}$=70.9 GeV
- The gas injection durations are only 16 hours for $p\mathrm{H}_2$, 2 hours for $p\mathrm{D}_2$, 4 hours for *p*He and 56 hours for *p*Ar
- First beauty signals in fixed target mode in the pipeline too!

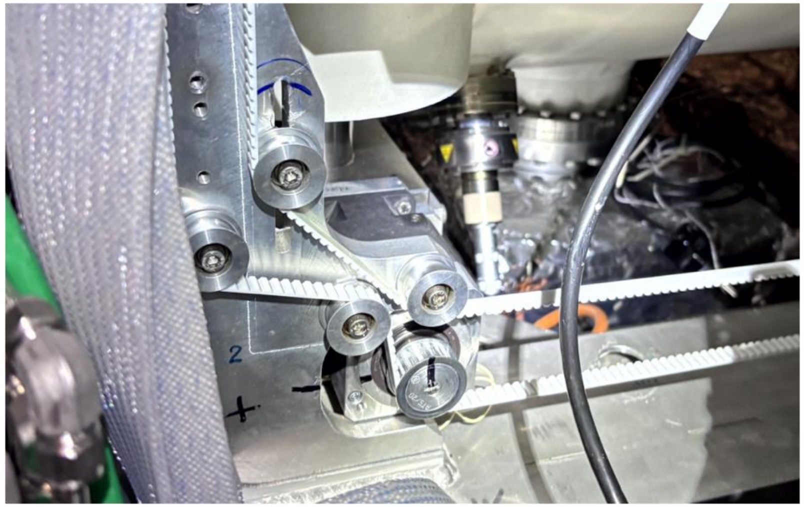


Work done during YETS: VELO and SMOG2

- VELO
  - Installation of new belt in the motion system
  - O-ring replacement to fix minor leak in the secondary vacuum
  - Shims removal to allow the VELO sensors to move closer to the beam (by 0.5 mm) → improvement in IP resolution around 10%
- SMOG2
  - Change gas cylinders from 1.5 to 200 bar, enabling data-taking for the full year without manual replacements, as well as faster injection
  - Consolidation of gas feed system

View of the shim with VELO half retracted

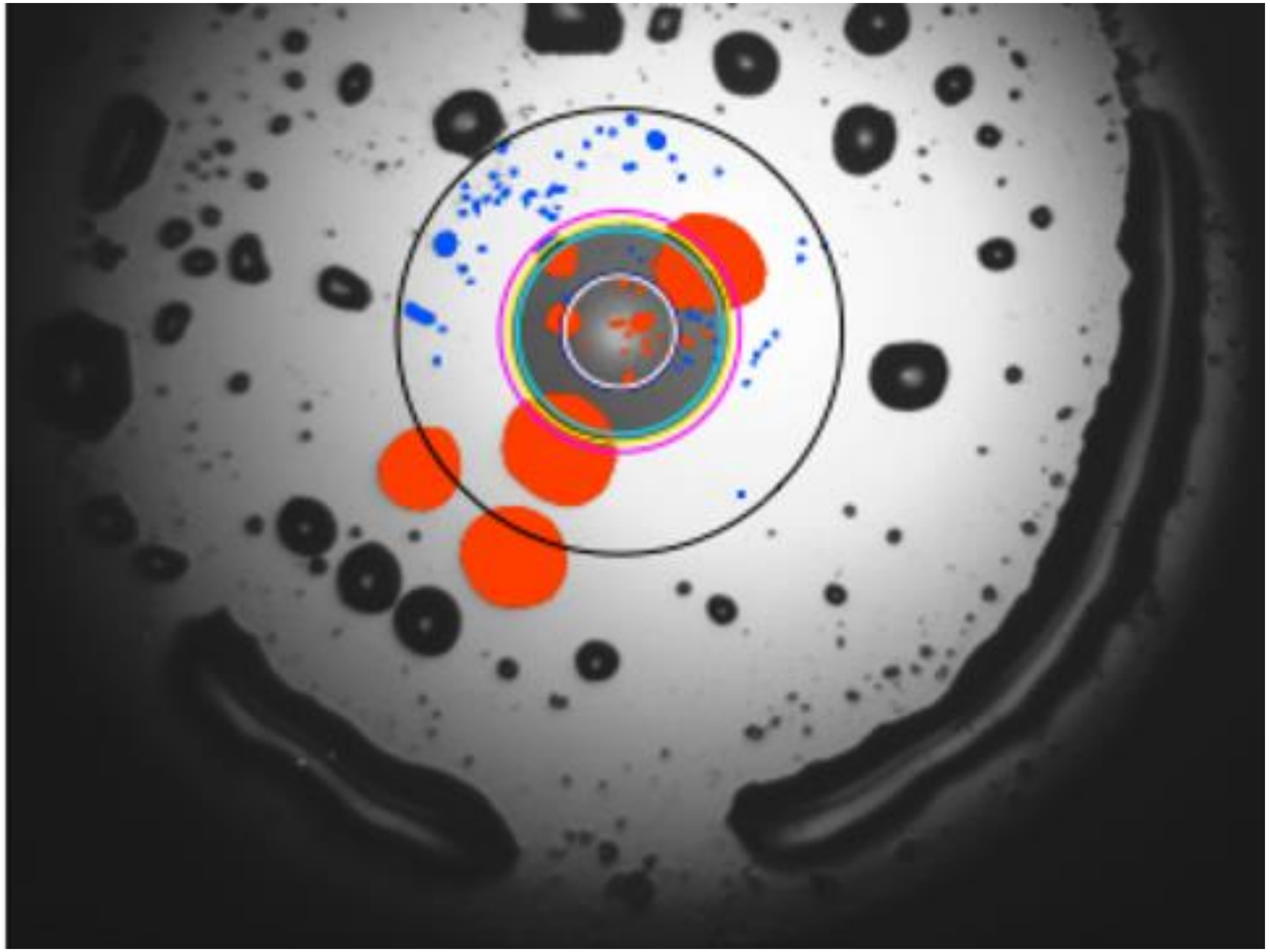




Work done during YETS: SciFi Tracker

- Upgrade of the Condensation Prevention System, a.k.a. heating wires, to improve on redundancy and stability
- Change of the SiPM cooling liquid from C_6F_{14} to NOVEC 7100, 30 times lower greenhouse impact
- Optical fibers affected by (unbaked) VTRx outgassing checked and cleaned with a thorough campaign

Optical fiber with significant VTRx outgassing effects



Work done during YETS: UT and RICH

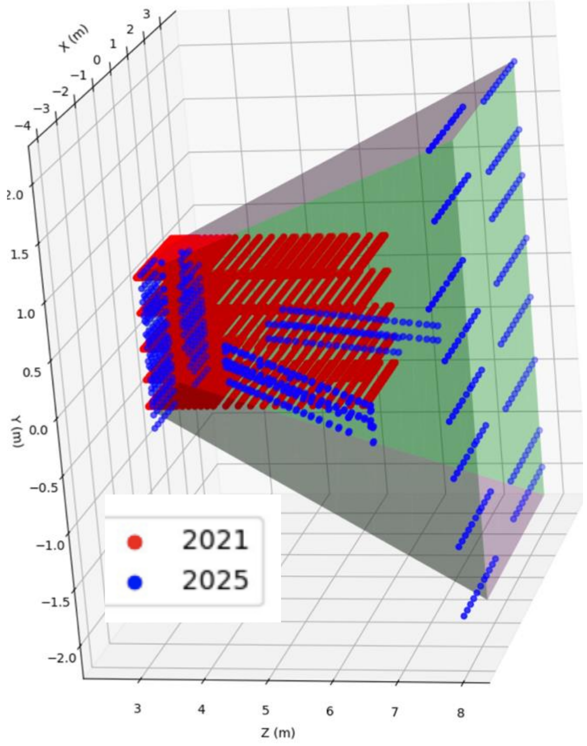
- UT
  - Maintenance and replacement of hardware components
  - Cooling tests to optimise performances → CO_2 cooling lowered from −10°C to −15°C
  - Update of readout firmware to improve speed and stability → more stable operations and UT efficiency expected to increase significantly!
- RICH
  - Inspection and cleaning of RICH1 MaPMT windows
  - Outgassing in optical fibres due to unbaked VTRx → inspection and cleaning

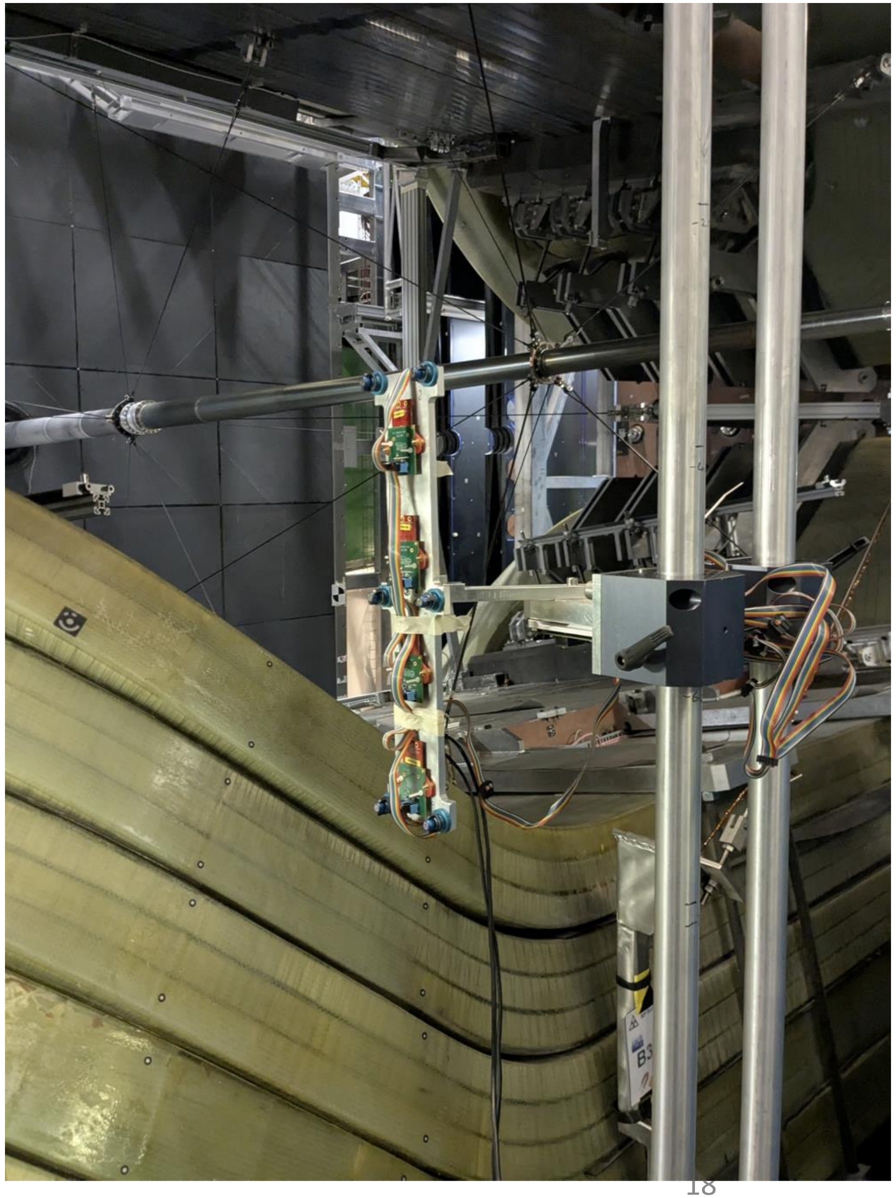
Work done during YETS: CALO and MUON

- ECAL
  - 204 Cockcroft-Walton power bases for the PMTs of the inner ECAL had to be replaced to avoid reaching their expected limits in the accumulated radiation dose during 2025
- HCAL
  - 21 degraded PMTs with high dark current replaced
- MUON
  - Some front-end boards and chambers replaced
  - Shielding layer added in a small acceptance region as a test for Upgrade II (no effect on 2025 performances)

Work done during YETS: B field measurements

- New measurements of magnetic field done in certain acceptance region to improve the map used in the reconstruction
- Reduce dependence on momentum scaling → leading to improvements in mass resolution!



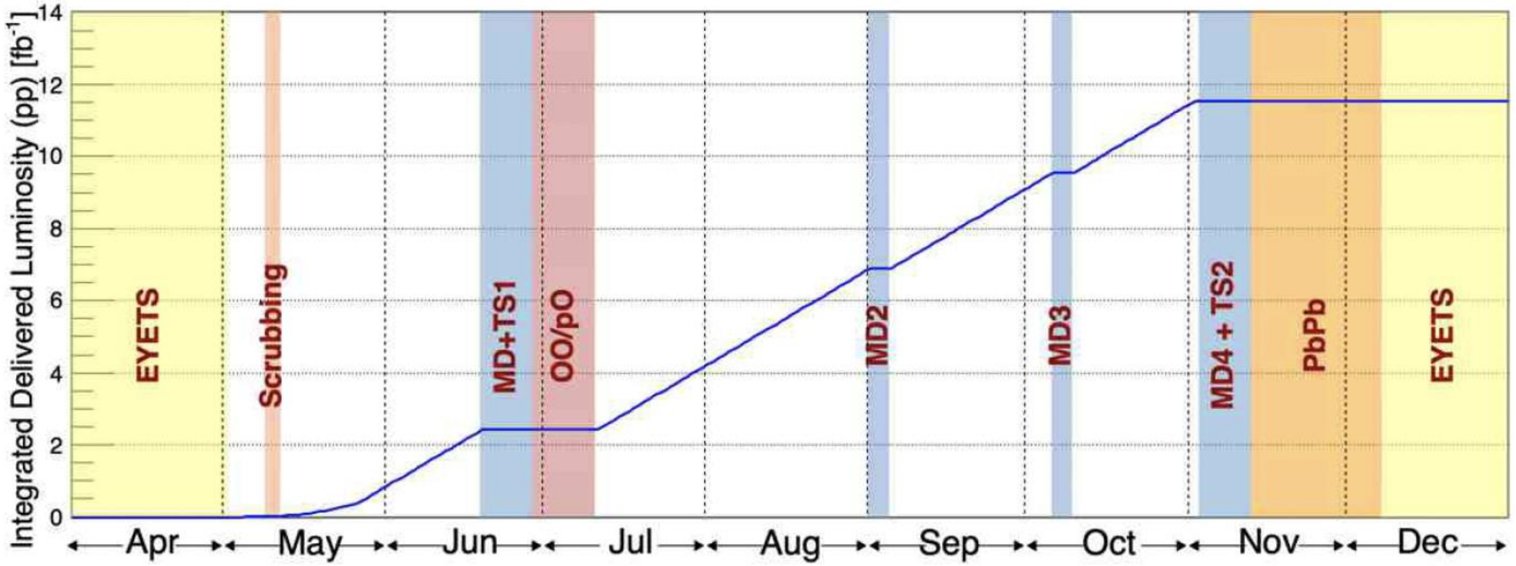


Work done during YETS: progress on software

- Real Time Analysis (RTA)
  - Improvements in both first and second level trigger stages → better reconstruction, with particular attention to UT and low momentum particles
  - VELO track pattern recognition updated to mitigate possible efficiency losses in the event of missing modules → increased robustness
  - Improved calorimeter calibration to cope with aging effects during the run
  - Bandwidth reassessed by optimizing online event selections to meet tape and disk resources
- Significant progress also on Data Processing and Analysis (DPA), Simulation and Offline Computing, e.g.
  - Removal of data duplication allows a reduction of the required disk resources by around 30%
  - Simulation now compiled and tested on the ARM architecture
  - Progress in the development of DIRACx, i.e., the major upgrade of the Data and Workload Management system used to manage offline LHCb computing
- Also great progress in luminosity determination

Data taking plan for 2025

- Top priority is to accumulate large *pp* sample in stable conditions
  - The 2025 target is 12 fb^{-1} (delivered)



- In July there are about 8 days allocated for special runs, in which the LHC will provide both *p*O and O-O collisions, followed by a day of operation devoted to Neon-Neon collisions
  - About 2 nb^{-1} for *p*O and 0.5 nb^{-1} for O-O are expected
- LHCb looks forward to the PbPb data taking at the end of the year, during which we expect to benefit from enhanced levelling times and thus larger integrated luminosity, if the $\beta^* = 1$ m commissioning is successful

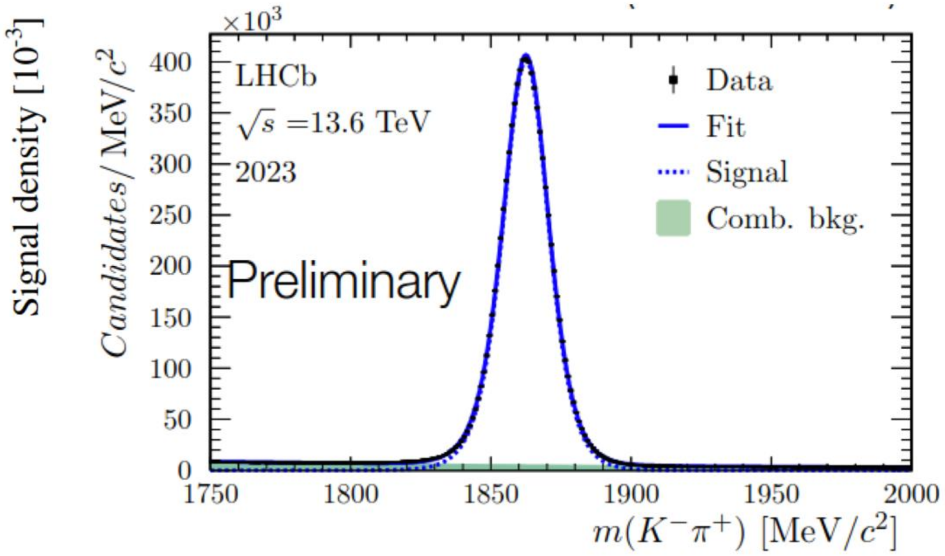
Charm production asymmetry measurements at √s = 13.6 TeV

Paper in preparation

- Using Run-3 data from 2022 and 2023
- Asymmetry in production of charm and anticharm can arise due to the presence of valence quarks only (no valence antiquarks) in the colliding protons

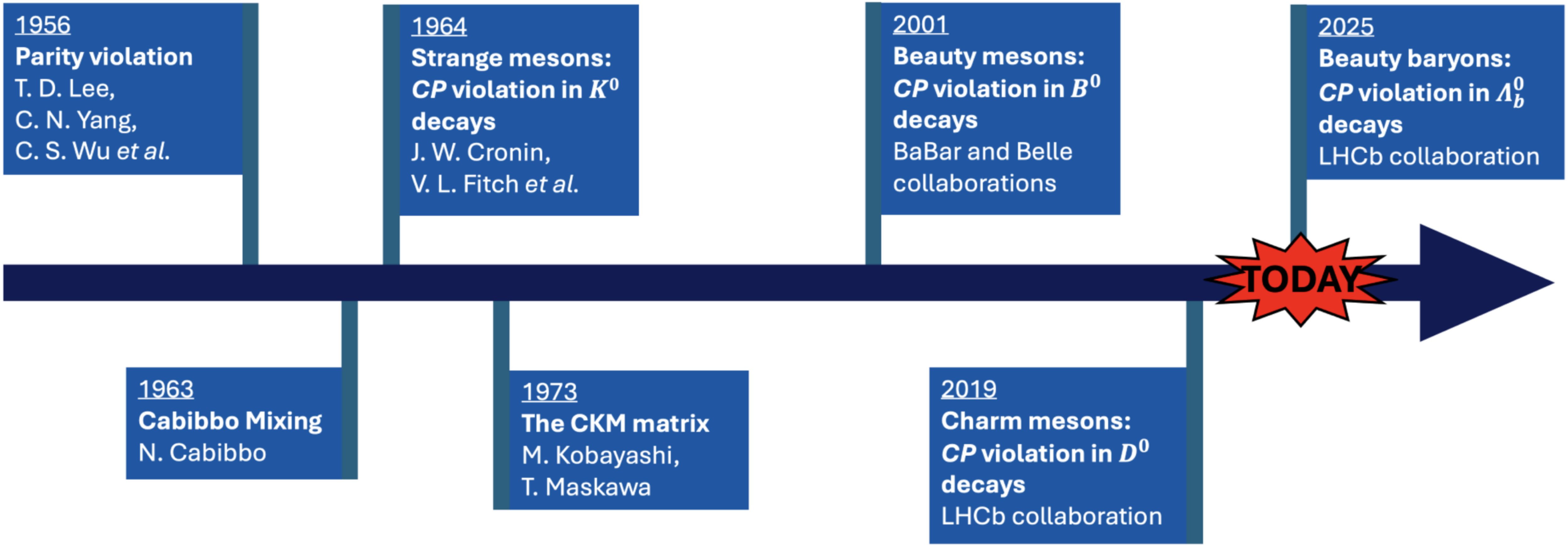
$$A_{\mathrm{prod}}(D) \equiv \frac{\sigma(pp \to DX) - \sigma(pp \to \overline{D}X)}{\sigma(pp \to DX) + \sigma(pp \to \overline{D}X)}$$

$$A_{\mathrm{prod}}(D^0) = (\ \ 0.07 \pm 0.26(\mathrm{stat}) \pm 0.10(\mathrm{syst}))\%$$
$$A_{\mathrm{prod}}(D^+) = (-0.32 \pm 0.29(\mathrm{stat}) \pm 0.13(\mathrm{syst}))\%$$
$$A_{\mathrm{prod}}(D_s^+) = (\ \ 0.18 \pm 0.26(\mathrm{stat}) \pm 0.07(\mathrm{syst}))\%$$



- All compatible with zero at the current level of precision
- Similar statistical precision as in Run-1 with about 1/10 of luminosity thanks to the full software trigger!

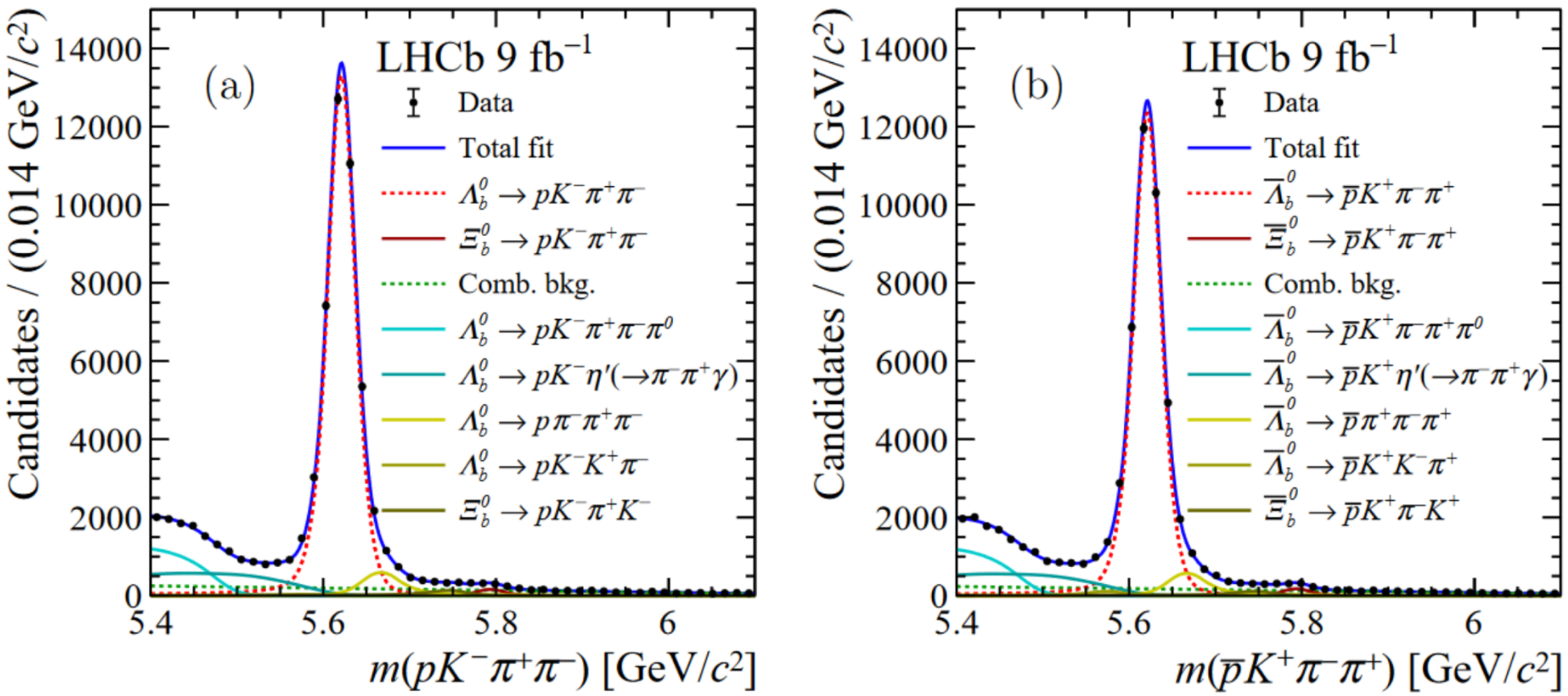
First observation of *CP* violation in baryon decays

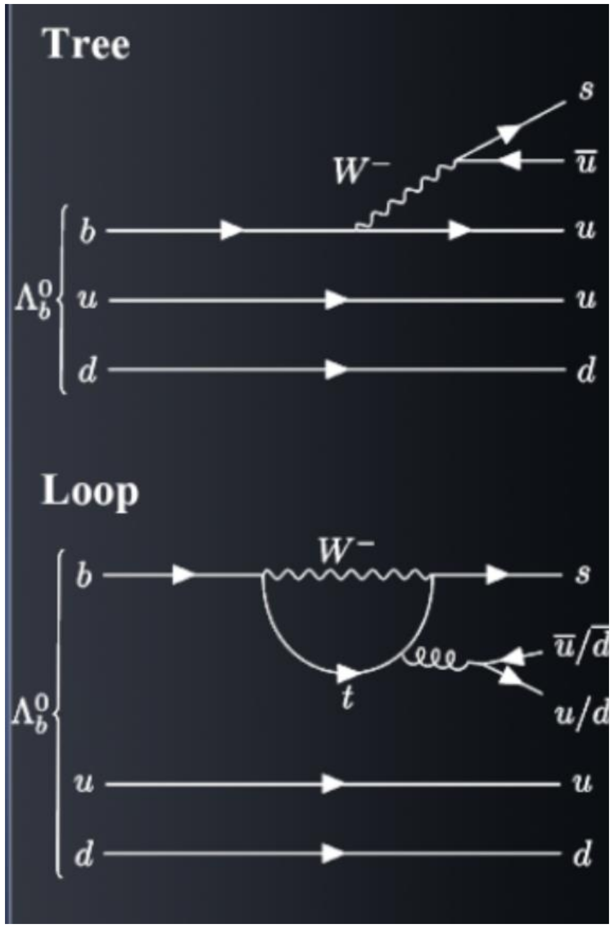


- Since the first observation by Cronin and Fitch in 1964, *CP* violation has so far been observed only in meson decays
- Now LHCb observes *CP* violation in a baryon decay for the first time after 60 years!

First observation of *CP* violation in baryon decays

- *CP* violation observed by using of $\Lambda_b^0 \to pK^-\pi^+\pi^-$ decays in the interference between tree and penguin decay amplitudes

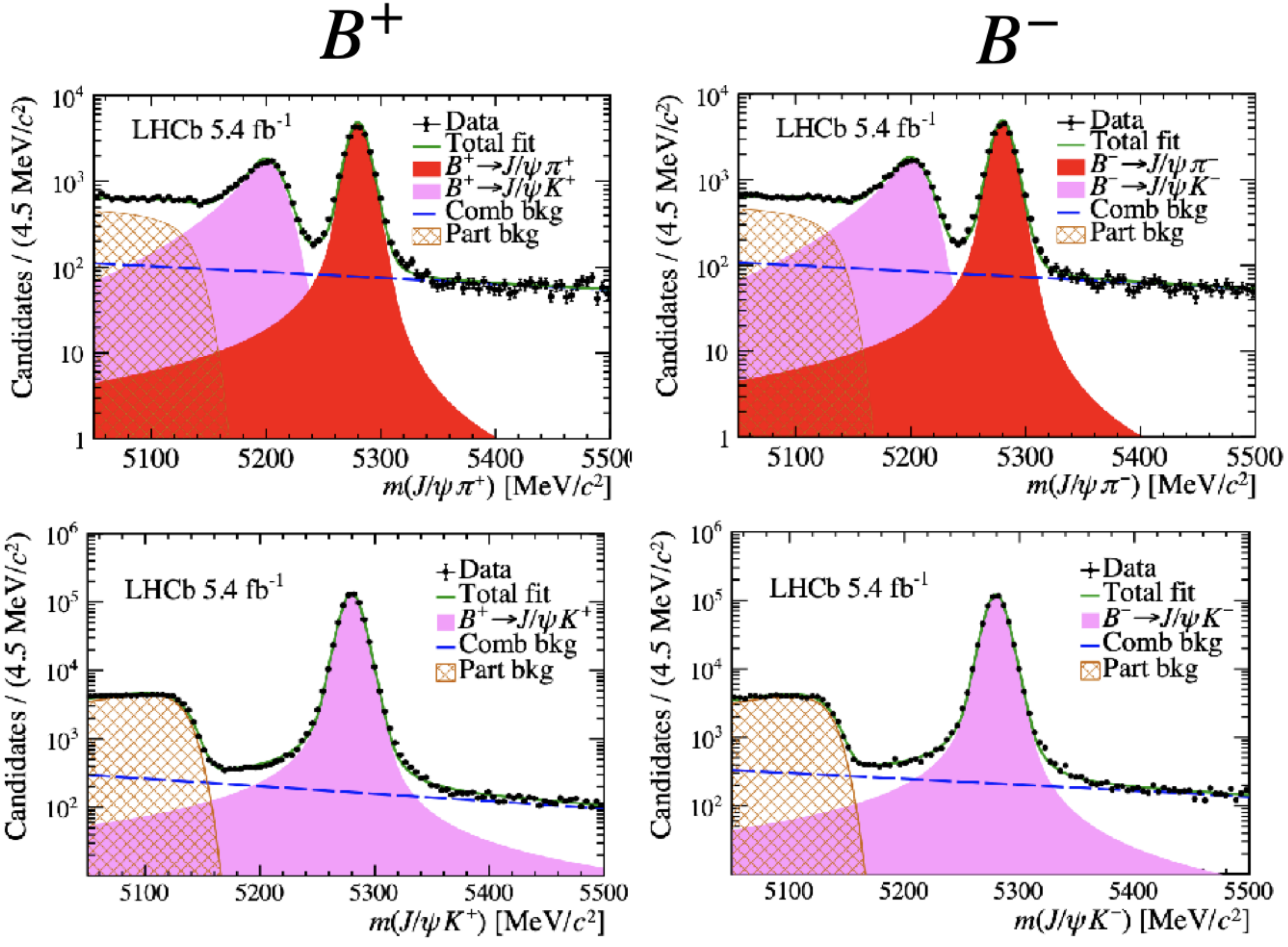


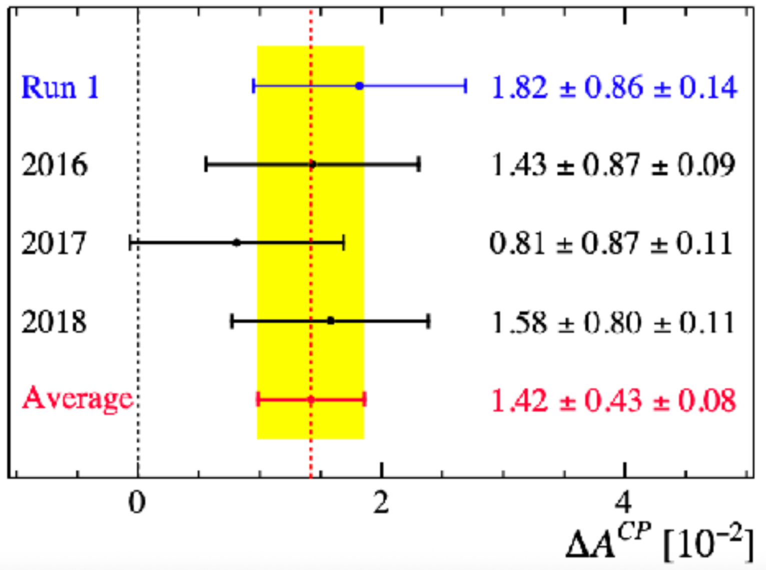


- A_{CP} = (2.45 ± 0.46 ± 0.10)% differing from zero by 5.2 standard deviations
- Paper submitted to Nature

CP violation in beauty to charmonium

- First evidence for direct *CP* violation in beauty to charmonium decays
- Measured with Run-2 data by comparing the suppressed mode $B^+ \to J/\psi\pi^+$ measured with respect to the favoured mode $B^+ \to J/\psi K^+$



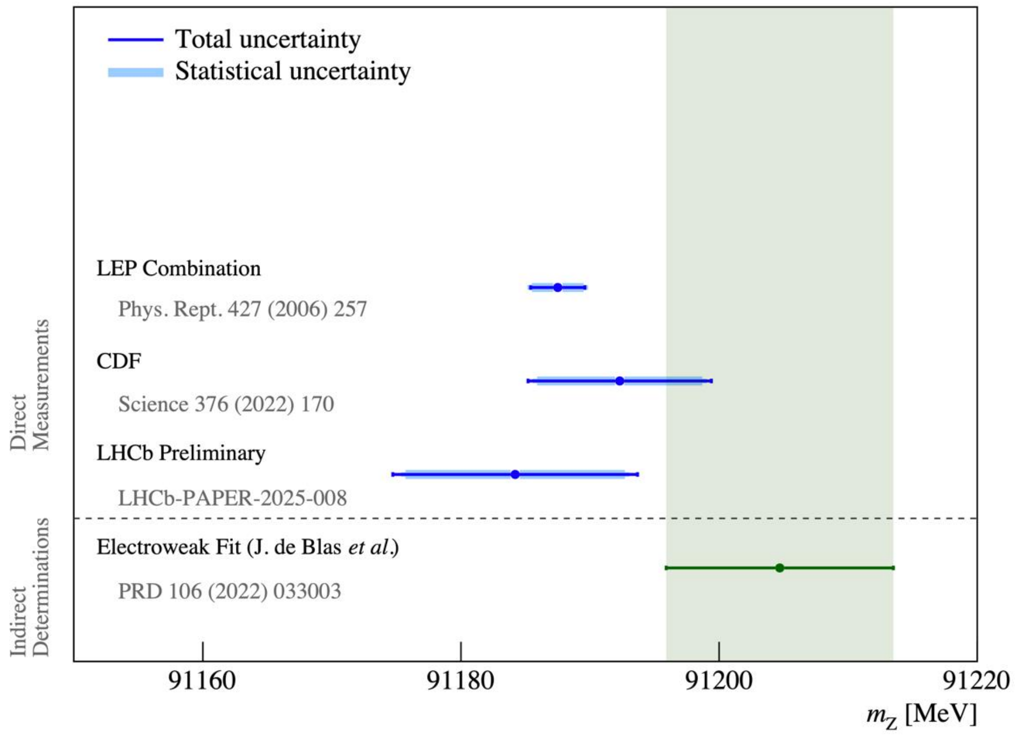


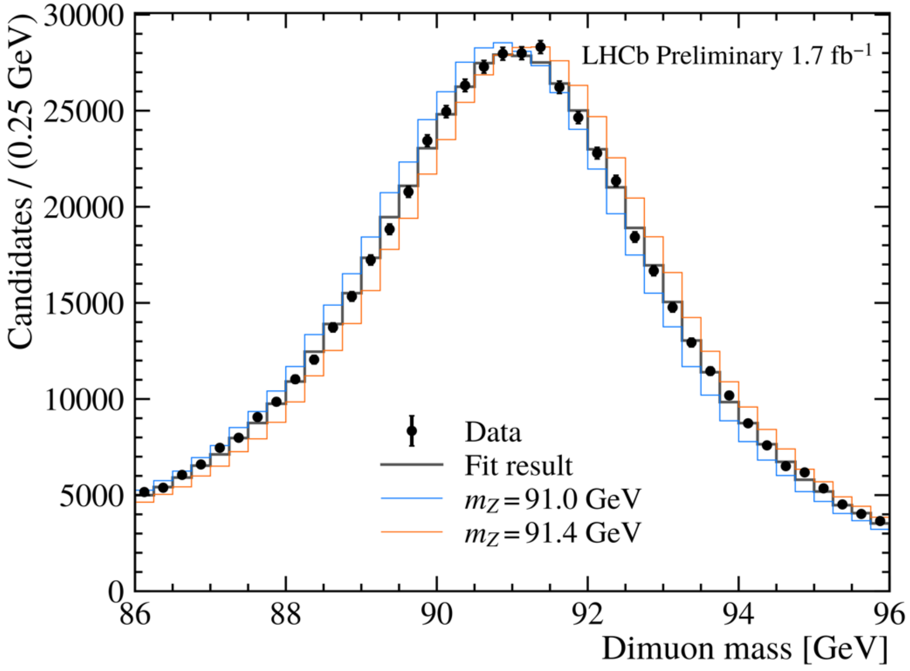
- Combined with Run-1 → $\Delta A_{CP} = (1.42 \pm 0.43 \pm 0.08)\%$
- 3.2σ evidence of nonzero *CP* violation!

First Z^0 mass measurement at the LHC

- *Z* mass never measured at the LHC so far → now we have one!

$$m_Z = 91184.2 \pm 8.5 \pm 4.3\,\mathrm{MeV}$$





- Larger uncertainty if compared with LEP and CDF, but using only 2016 data → room for improvement!

Summary

- The collaboration keeps growing at high pace, with new groups and new countries joining (16 new groups and 3 countries in 12 months)
- After the great success of the 2024 *pp* run at 13.6 TeV, also the PbPb run and the *pp* reference run were very successful
  - In a single year, surpassed all previous runs combined for all configurations: *pp*, PbPb, *p*-gas and Pb-gas
- Work during YETS was smooth and the detector is now in better shape for the 2025 run, where we expect to collect more data than in 2024
- Physics production is in great shape, with some relevant measurements like the first observation of *CP* violation in baryons
- Now important to move forward with the Upgrade II → let's discuss about it in a while