LHCb status report

157th LHCC meeting
Open session

- Physics
- YETS 2023-2024
- Preparation to 2024 data taking

Valeriia ZHOVKOVSKA
28/02/2024

WARWICK
THE UNIVERSITY OF WARWICK

Physics results

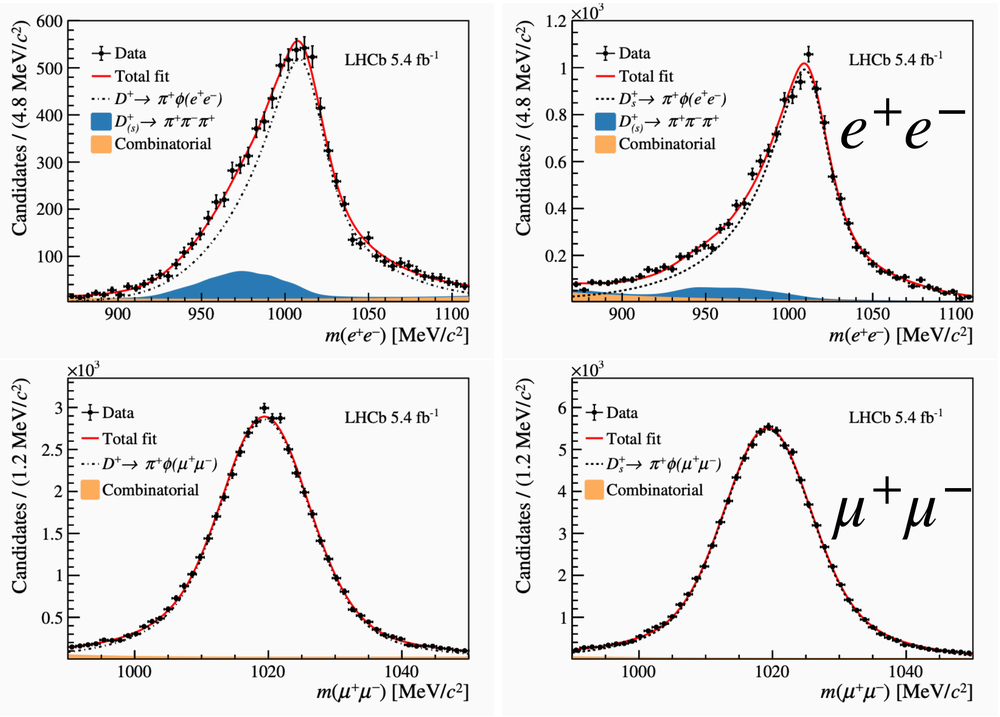
Paper	Title
	Submitted since the November 2023 LHCC
PAPER-2023-024	Prompt and nonprompt $\psi(2S)$ production in pPb collisions at $\sqrt{s_{NN}} = 8.16$ TeV
PAPER-2023-026	Modification of $\chi_c(3872)$ and $\psi(2S)$ in pPb
PAPER-2023-031	Long range charged hadron correlations in PbPb at 5 TeV
PAPER-2023-032/033	Amplitude analysis of the $B \to K^* \mu^+ \mu^-$ decay
PAPER-2023-034	Measurement of the relative BF of $\Lambda_b^0 \to \Lambda_c^+ \bar{D}^{(*)0} K^-$ and $\Lambda_b^0 \to \Lambda_c^+ D_s^{*-}$ decays
PAPER-2023-035	Multiplicity Dependence of $\sigma_{\psi(2S)}/\sigma_{J/\psi}$ in pp collision at $\sqrt{s} = 13$ TeV
PAPER-2023-037	Search for $B_c^+ \to \pi\mu\mu$
PAPER-2023-038	Test of lepton flavour universality using $D_{(s)}^+ \to \pi^+ \phi(\ell^+\ell^-)$ decays
PAPER-2023-039	Study of the $B_c \to \chi_c \pi$ decays
PAPER-2023-040	Search for CPV in $B_s^0 \to DK^*(892)$
PAPER-2023-041	Study of the $B \to J/\psi\pi^0$
PAPER-2023-046	Observation of the decay $B_c^+ \to J/\psi\pi\pi^0$
DP-2023-003	Momentum scale calibration of the LHCb spectrometer
	Preliminary results since the Novembre 2023 LHCC
PAPER-2023-042	Observation of the $\Lambda_b^0 \to D^+ D^- \Lambda$ decay

LHCb has submitted 714 papers to arXiv, of which 682 are published

Measurement of $\mathcal{B}(\phi \to \mu^+\mu^-)/\mathcal{B}(\phi \to e^+e^-)$

LHCb-PAPER-2023-038

- First LFU test in ϕ-meson decays in LHCb:



- A complementary q^2 region to the existing measurements for keeping control over systematics
- LFU observable in charm decays

$$\mathcal{R}^{(d,s)}_{\phi\pi} = \frac{\mathcal{B}(D^+_{(s)} \to \pi^+\phi(\to \mu^+\mu^-))}{\mathcal{B}(D^+_{(s)} \to \pi^+\phi(\to e^+e^-))}$$

- Combined result:

$$\mathcal{R} = 1.02 \pm 0.01_{stat.} \pm 0.05_{syst.}$$

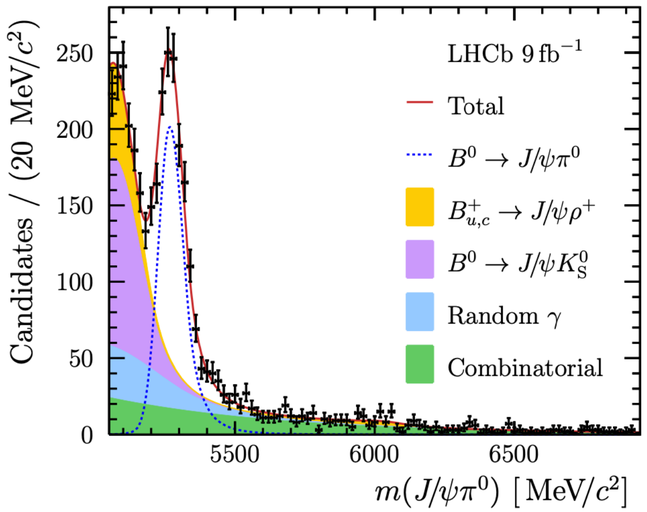
- **The most precise to date**: $\mathcal{B}(\phi \to \mu^+\mu^-) = (3.045 \pm 0.049_{stat} \pm 0.148_{syst}) \times 10^{-4}$

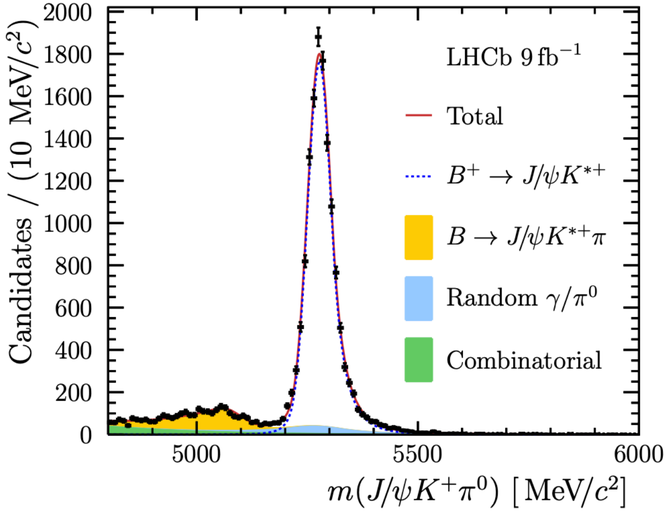
Result is in agreement with SM

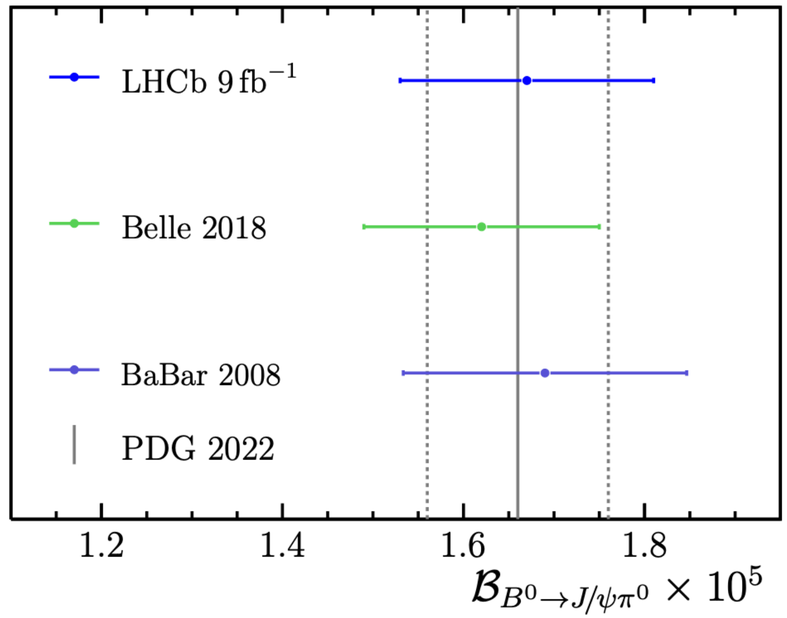
Branching ratio of $B^0 \to J/\psi\pi^0$

LHCb-PAPER-2023-041

- A probe of final-state interaction effects in weak non-leptonic B-decays





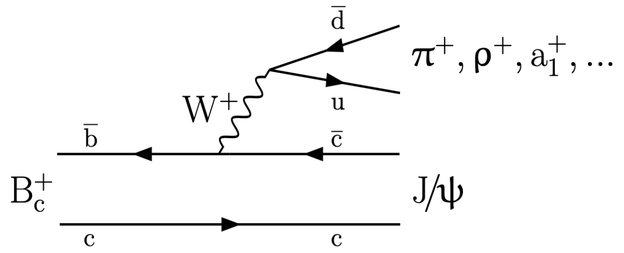


$$\mathscr{R} = (1.153 \pm 0.053_{stat.} \pm 0.048_{syst.}) \times 10^{-2}$$

$$\mathscr{B}(B^0 \to J/\psi\pi^0) = (1.670 \pm 0.077_{stat.} \pm 0.069_{syst.} \pm 0.095_{ext.}) \times 10^{-5}$$

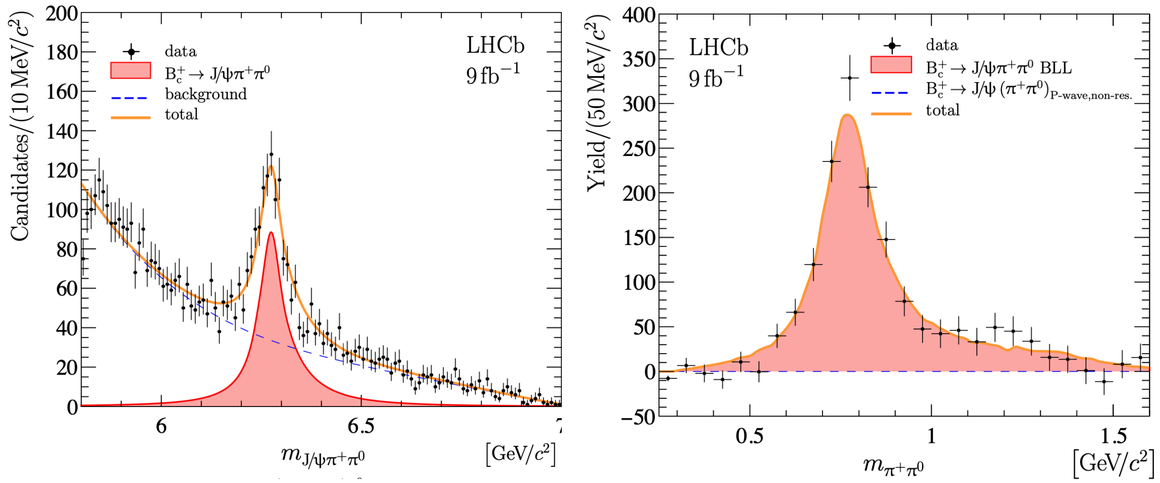
A first step towards CP-violation studies in this decay

Observation of $B_c^+ \to J/\psi\pi^+\pi^0$



[LHCb-PAPER-2023-046]

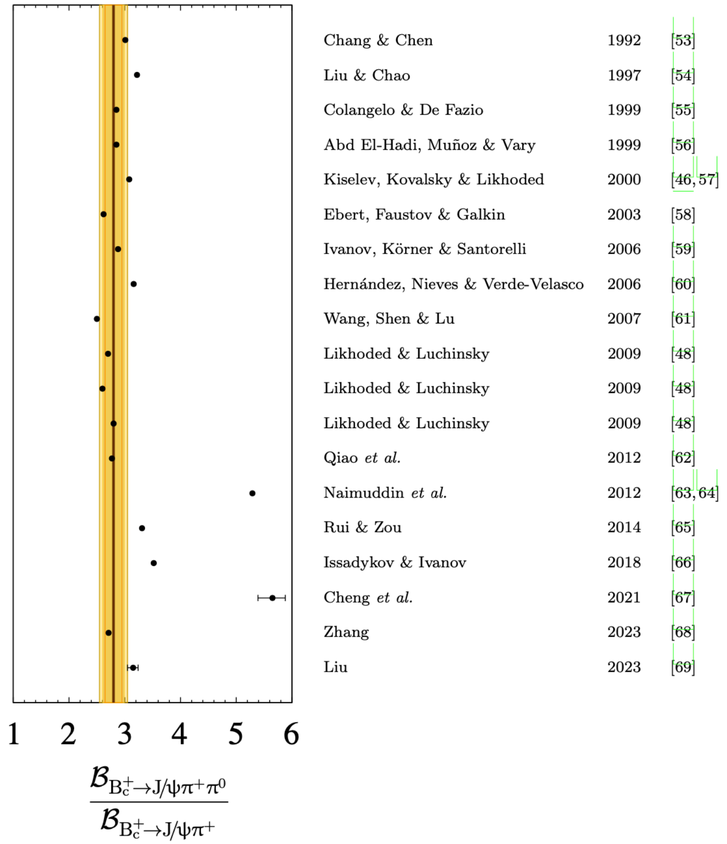
- Important for QCD factorisation test; source of background for other B_c^+ decays and rare decays of B^0



- Decay is saturated with $B_c^+ \to J/\psi\rho^+$ with a small admixture of $B_c^+ \to J/\psi\rho(1450)^+$

$$\mathscr{R} = \frac{B_c^+ \to J/\psi\pi^+\pi^0}{B_c^+ \to J/\psi\pi^+} = 2.80 \pm 0.15_{stat.} \pm 0.12_{syst.} \pm 0.16_{ext.}$$

First observation of the decay mode



Outreach

https://lhcb-outreach.web.cern.ch/

Link to the article

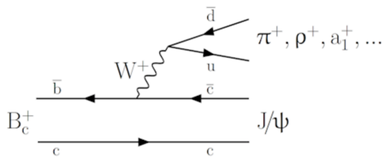
LATEST POSTS | OTHER | PHYSICS RESULTS

Observation of the Bc+→J/ψπ+π0 decay

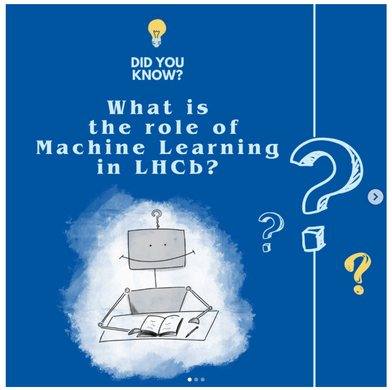
By **pietrzyk**

FEB 9, 2024 #Bc

The LHCb collaboration today submitted for publication a paper reporting the first observation of the $B_c^+ \to J/\psi\pi^+\pi^0$ decay with overwhelming significance. The $\pi^+\pi^0$ mass spectrum is consistent with the dominance of an intermediate ρ^+ contribution.



The B_c^+ meson is composed of two heavy quarks, b and c. It is the heaviest meson that can only decay through the weak interactions via the decay of one heavy constituent, with the other quark playing the role of spectator. Its decay into charmonium and light quarks proceeds through the quark diagram shown in the image to the left. The decays of the B_c^+ mesons into charmonium and odd-numbered light hadrons, such as $B_c^+ \to J/\psi\pi^+$, $B_c^+ \to J/\psi K^+$, $B_c^+ \to \psi(2S)\pi^+$, $B_c^+ \to J/\psi\pi^+\pi^+\pi^-$, have been studied intensively and found to be in a remarkable agreement with the theoretical expectations. The $B_c^+ \to J/\psi\pi^+\pi^0$ decay reported today is the simplest decay into charmonium and an even number of light hadrons. It has never been observed before.



LHCb Instagram

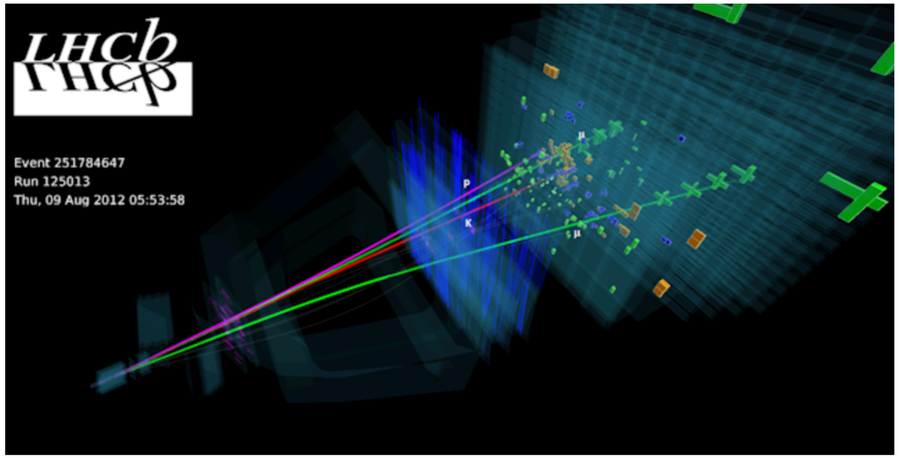
LHCb and CERN articles

LHCb releases the entire Run I dataset

By **pietrzyk**

DEC 20, 2023

Today the LHCb collaboration complete the release of data collected throughout the Run I of the Large Hadron Collider at CERN. The sample made available amounts to approximately 800 terabytes (TB) of data. These data, collected by the LHCb experiment in 2011 and 2012, contain information obtained from proton-proton collisions[1] . The format made available provides pre-filtered data, suitable for a wide range of physics studies. The image below displays an event recorded during 2012.



Check out the LHCb outreach website!

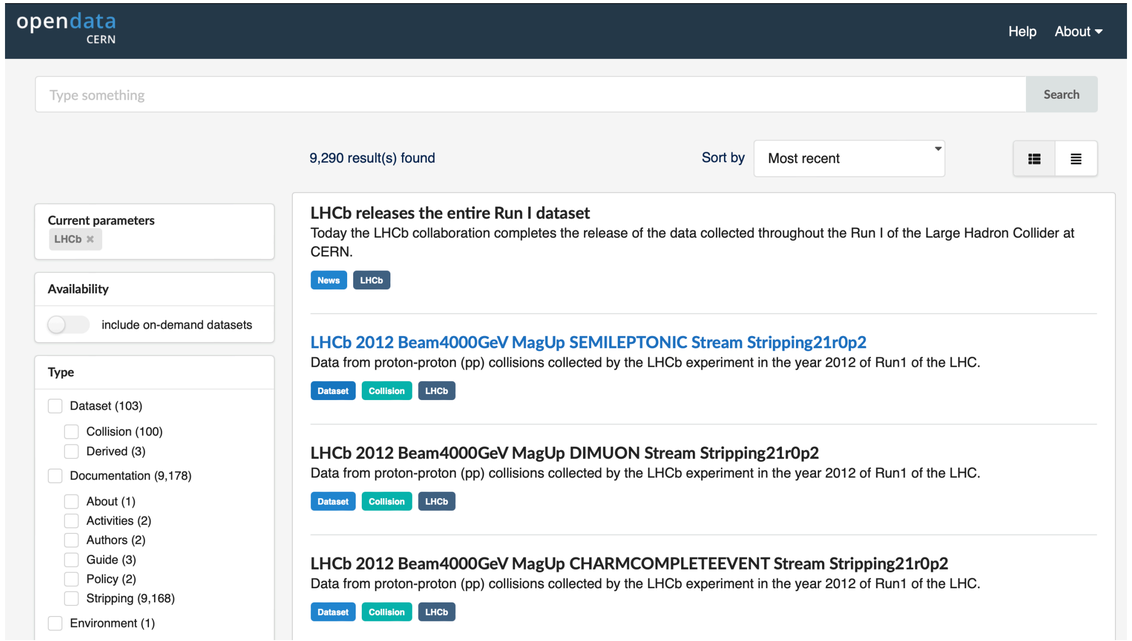
Open Data

Entire Run I dataset is available to the public

Press releases

Date	Article title	Link(s)
2024/01/11	LHCb experiment releases all of its Run 1 proton–proton data	CERN news
2023/12/20	LHCb releases the entire Run I dataset	LHCb news, CERN Open Data news
2022/12/08	LHCb releases first set of data to the public	CERN news
2022/12/02	LHCb data released to the public	LHCb news, CERN Open Data news
2022/07 & 08	First studies with Quantum Machine Learning at LHCb	Padova University Department of Physics and As Maastricht University news, Nikhef news (NL) University of Liverpool news / Department of Ph

https://lhcb-dpa.web.cern.ch/lhcb-dpa/press-outreach.html



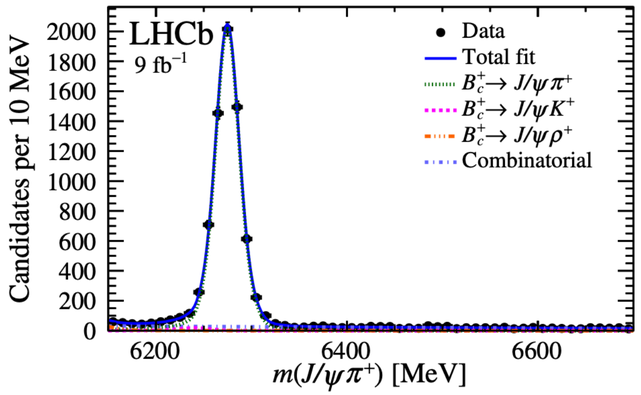
https://opendata.cern.ch/

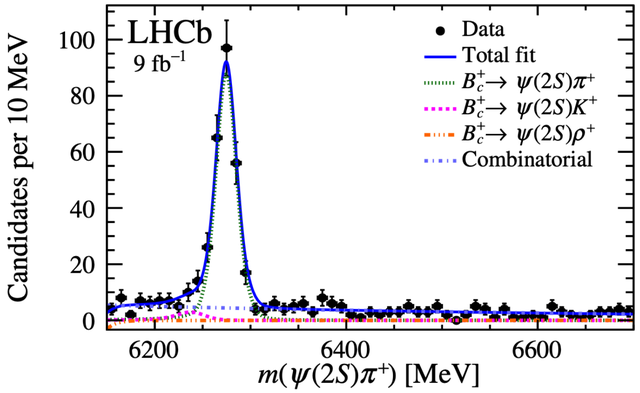
Important milestone to give accessibility of our data to the outside world

Search for $B_c^+ \to \pi^+\mu^+\mu^-$, $\mathcal{B}(B_c^+ \to \psi(2S)\pi^+)/\mathcal{B}(B_c^+ \to J/\psi\pi^+)$

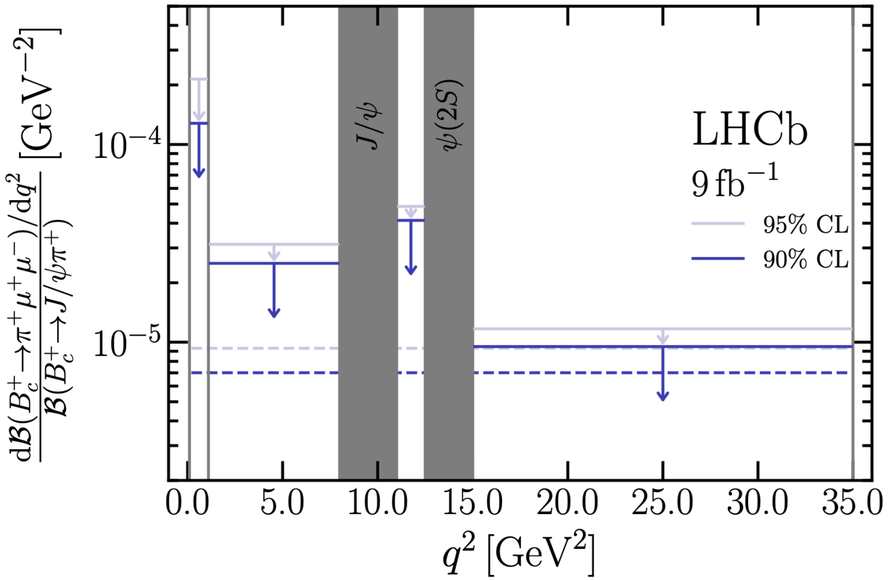
LHCb-PAPER-2023-037

- First search for B_c^+ decay into leptons mediated only by annihilation diagrams
- Possible probe for BSM effects





$$\frac{\mathcal{B}(B_c^+ \to \mu^+\mu^-\pi^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} < 2.1 \times 10^{-4} @ 90\,\%\,CL$$



- **The most precise to date**

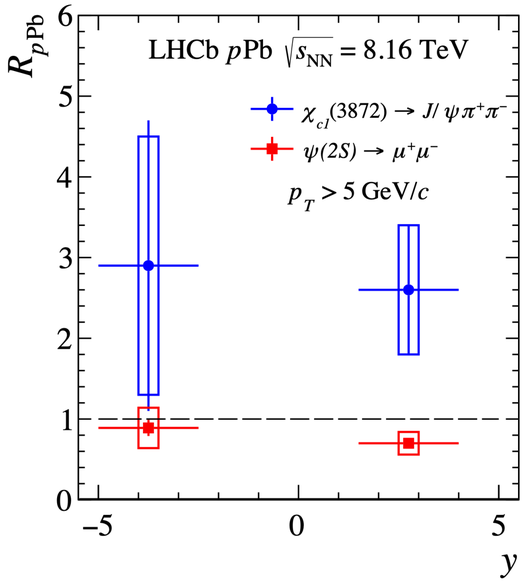
$$\frac{\mathcal{B}(B_c^+ \to \psi(2S)\pi^+)}{\mathcal{B}(B_c^+ \to J/\psi\pi^+)} = 0.254 \pm 0.018_{stat.} \pm 0.003_{syst} \pm 0.005_{BF}$$

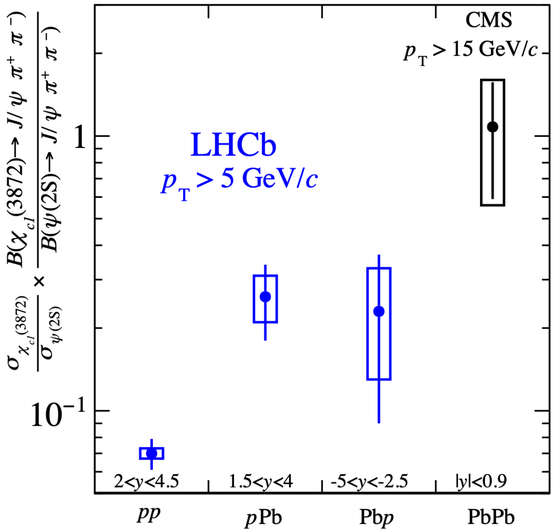
Modification of $\chi_{c1}(3872)$ and $\psi(2S)$ production in *p*Pb at $\sqrt{s_{NN}}$=8.16 TeV

LHCb-PAPER-2023-026

- Nuclear modification factor:

$$R_{pA}^{\chi_{c1}(3872)} = \frac{\sigma_{pA}^{\chi_{c1}(3872)}}{A \times \sigma_{pp}^{\chi_{c1}(3872)}} = R_{pA}^{\psi(2S)} \frac{\sigma_{pA}^{\chi_{c1}(3872)} / \sigma_{pA}^{\psi(2S)}}{\sigma_{pp}^{\chi_{c1}(3872)} / \sigma_{pp}^{\psi(2S)}}$$





- Enhancement from *pp* to PbPb collisions may indicate different dynamic in the nuclear medium for exotic $\chi_{c1}(3872)$

$$R_{p\mathrm{Pb}}^{\chi_{c1}(3872)} = 2.6 \pm 0.8 \pm 0.8$$

$$R_{\mathrm{Pb}p}^{\chi_{c1}(3872)} = 2.9 \pm 1.8 \pm 1.6$$

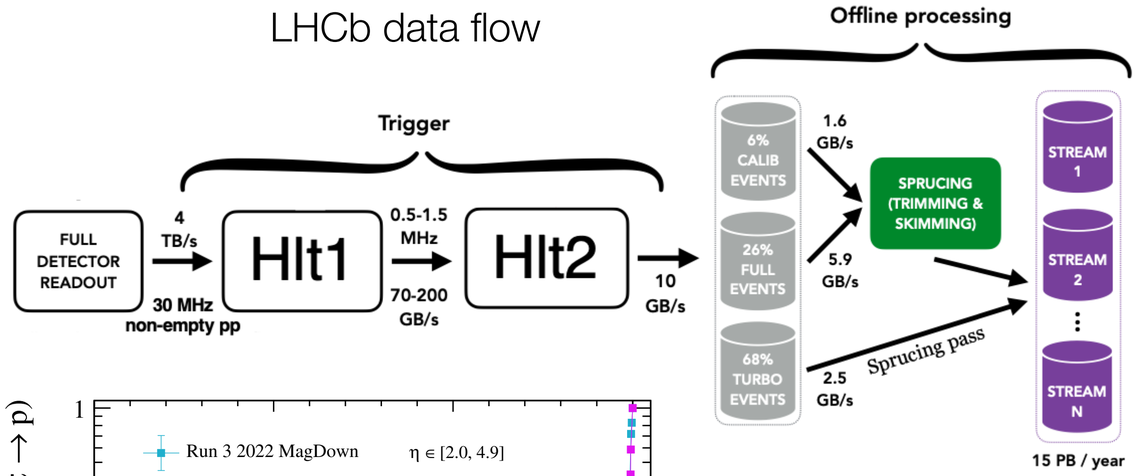
First measurement of the nuclear modification factor of an exotic hadron in *p*Pb collisions

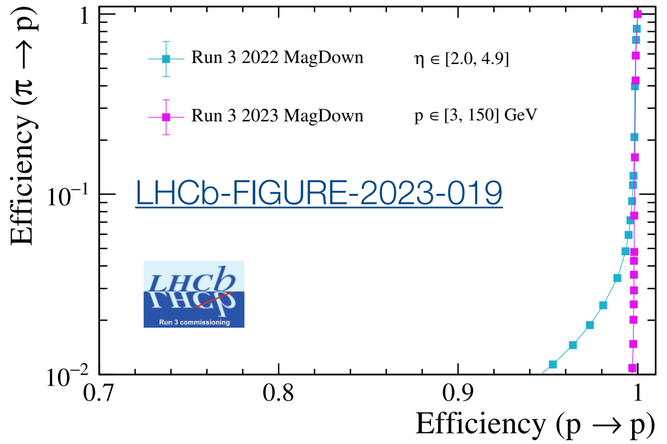
LHCb Run 3

Processing of 2022 and 2023 data

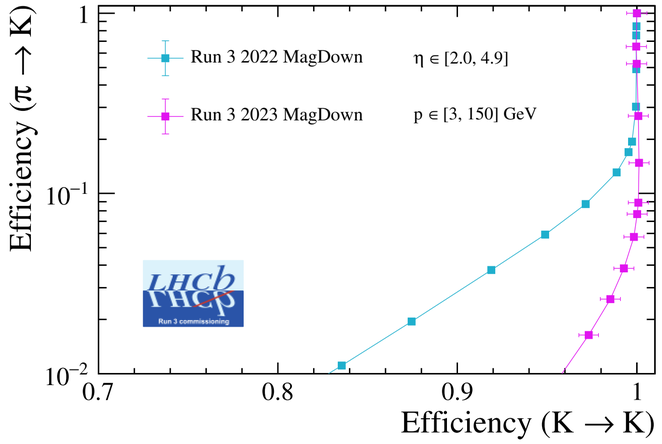
- All processing is done for 2022-2023 data:
  - HLT2: online full quality reconstruction and selections
  - Sprucing: offline streaming of the data
- Annual end-of-year re-sprucing campaign
- Data Quality evaluation is almost completed
- **Collected data are widely used**:
  - to evaluate detector performance
  - improvements for alignment and calibration
  - for Physics analysis
  - for luminosity-related studies

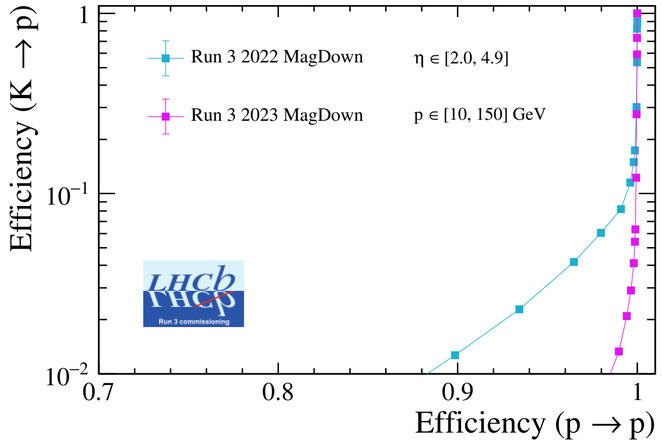
LHCb data flow





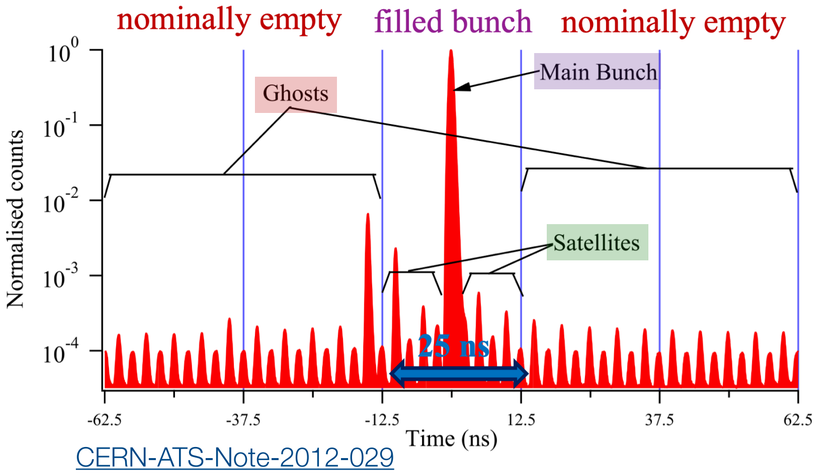
LHCb PID performance



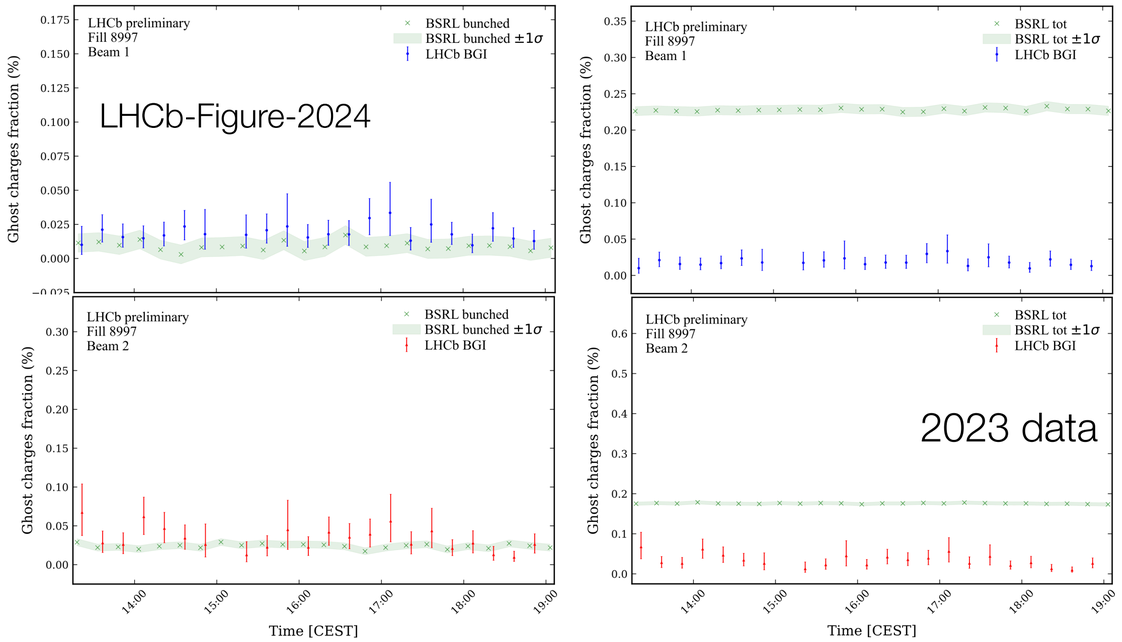


Ghost charge measurements

- Information about bunch content is required for the luminosity measurement
  - **Main Bunch** population (N_1, N_2) is directly used $\mathscr{L} \sim N_1 \cdot N_2$
  - **Satellite** charges: in filled bunch slot, outside filled RF bucket (2.5 ns)
  - **Ghost** charges: circulating in LHC, outside filled bunch slots (25 ns)



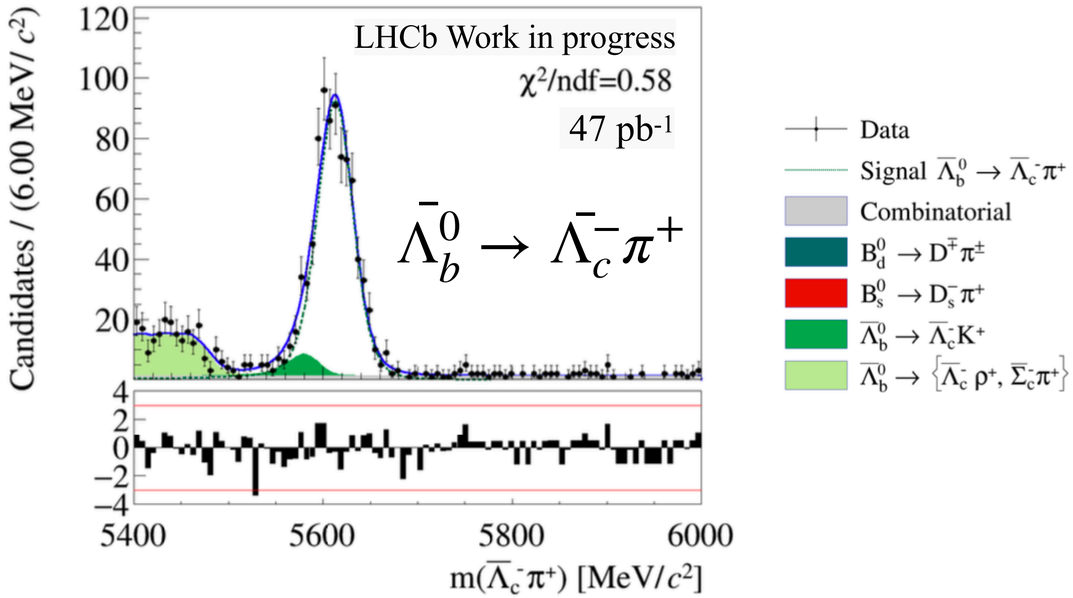
CERN-ATS-Note-2012-029

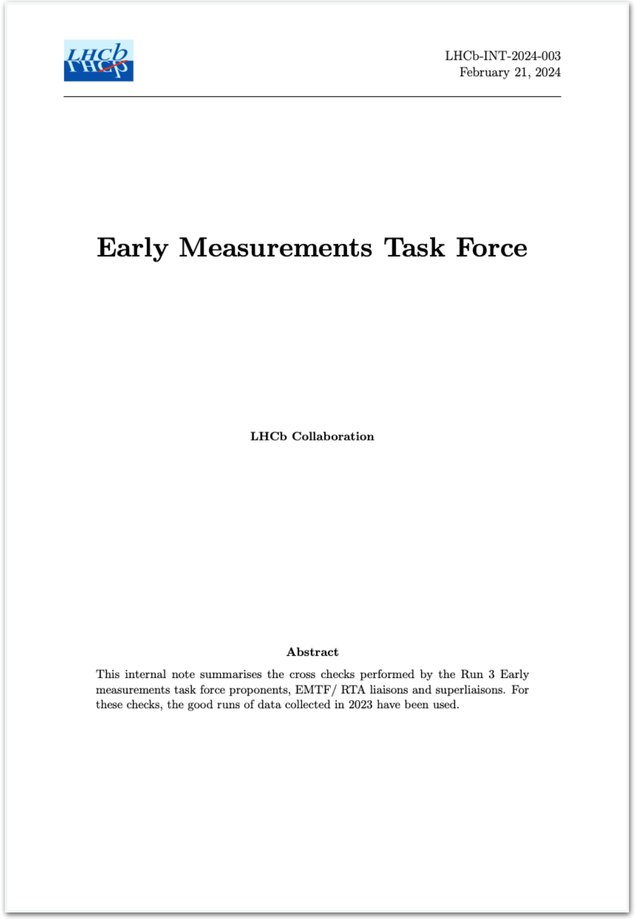


- Satellite and Ghost charges are measured by Beam Synchrotron Radiation Longitudinal (**BSRL**):
  - per bunch: baseline subtracted
  - total: no subtraction
- **LHCb provides a unique ghost charge measurement**:
  - reconstruct PVs produced from ghost charges interacting with gas injected with SMOG
  - results are in agreement with per bunch BSRL
  - low ghost charges fraction => contribution to vdM negligible
  - important for ATLAS and CMS luminosity measurement

From 2023 to 2024

- There has been a large amount of work dedicated to understanding the 2023 data:
  - Internally documented
  - Data are also being used for PhD and master theses




LHCb-INT-2024-003
February 21, 2024

Early Measurements Task Force

LHCb Collaboration

Abstract

This internal note summarises the cross checks performed by the Run 3 Early measurements task force proponents, EMTF/ RTA liaisons and superliaisons. For these checks, the good runs of data collected in 2023 have been used.

- In parallel, a lot of effort going to the preparation of the 2024 dataset

From 2023 to 2024

YETS activities

Improvement of the calibration system

Maintenance, stability improvements and performance studies

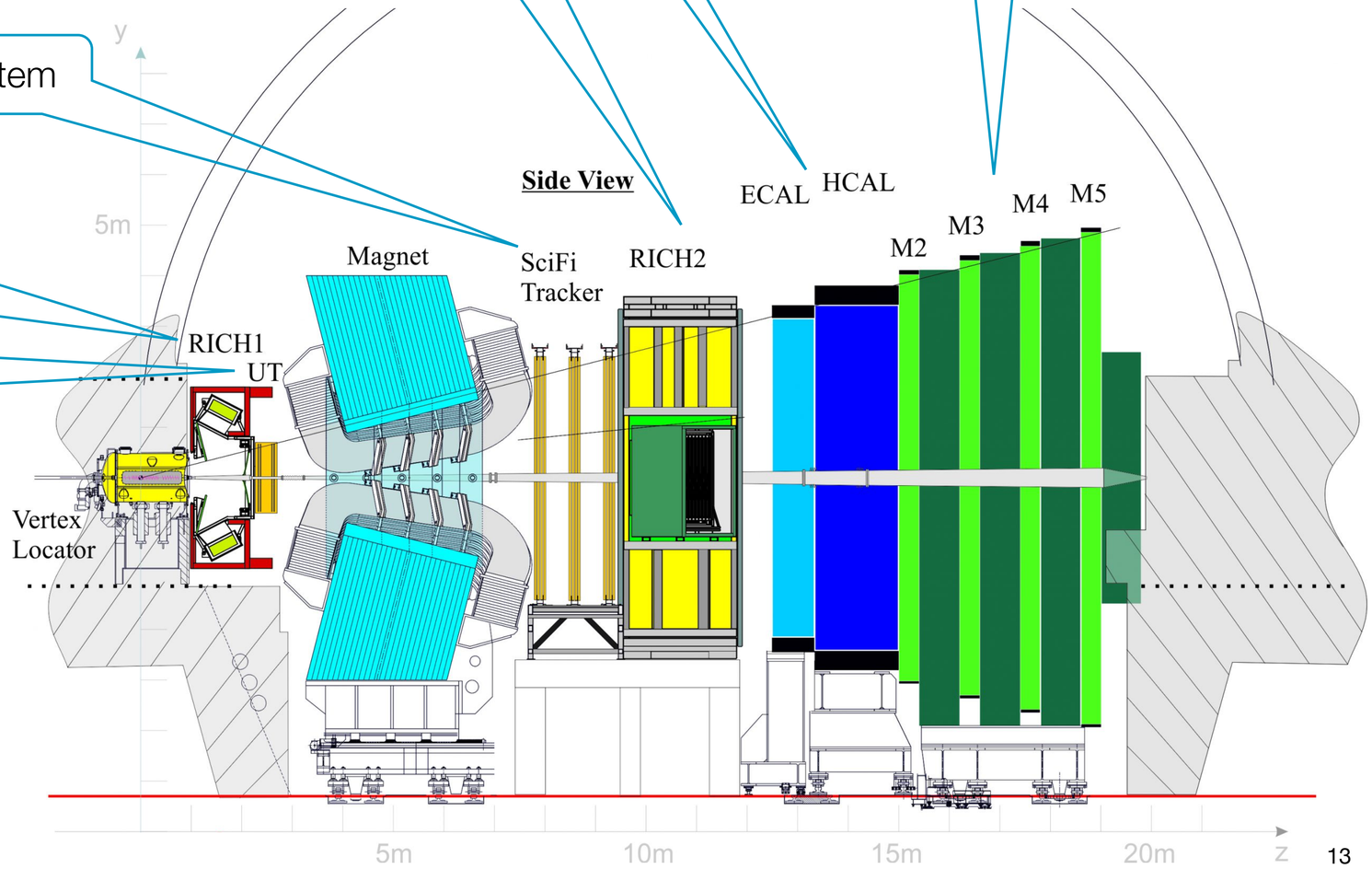
Chamber replacement, calibration and performance studies

Calibration, improved cooling system

Maintenance, stability improvements and performance studies

Hardware interventions, DAQ improvements, first tests

RF-foil replacement, re-installation and re-commissioning



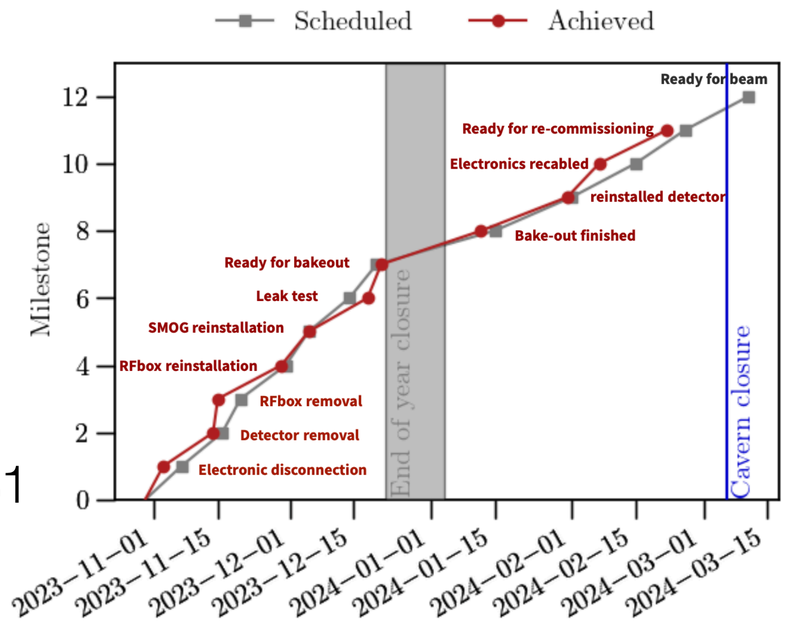
A lot of maintenance, calibrations and studies!

YETS activities

VErtex LOcator (VELO)

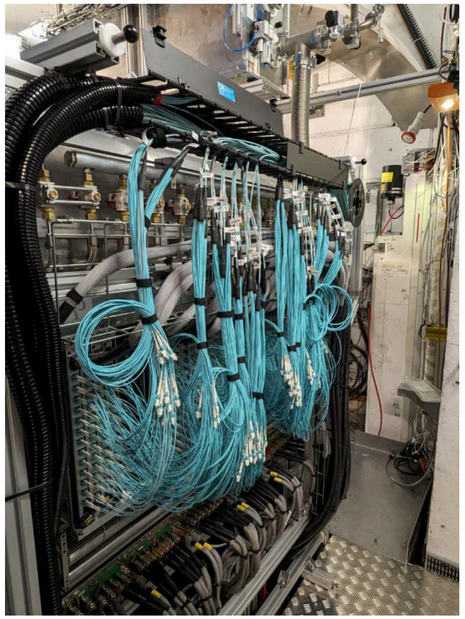
- RF-foil replacement and detector re-installation went smoothly
  - 0.5 mm shims are installed on each side, to be removed during TS1
- Electronics is re-cabled
- Post reinstallation check-out:
  - Cooling performances
  - Modules functionalities
  - Calibration with and without beams
  - Validation of new monitoring tools
  - VELO closing at each intensity step

Intense re-commissioning schedule



VELO A-side transportation

VELO installation

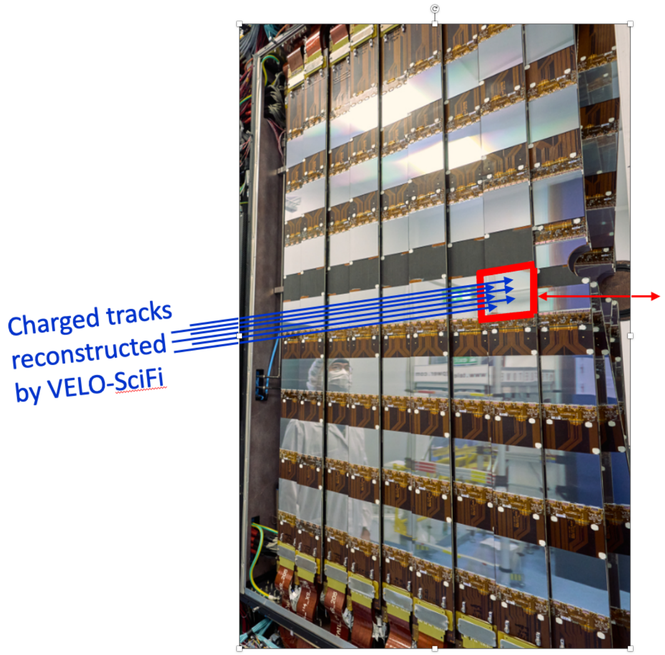


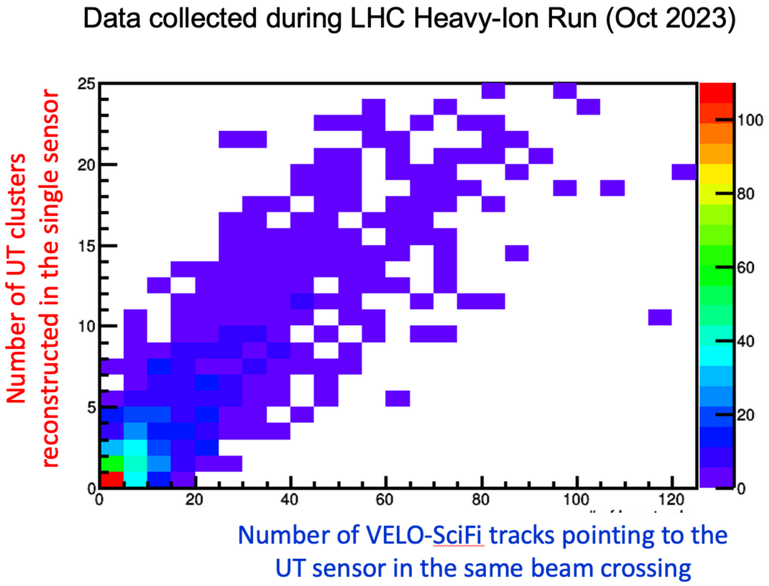
VELO re-cabling

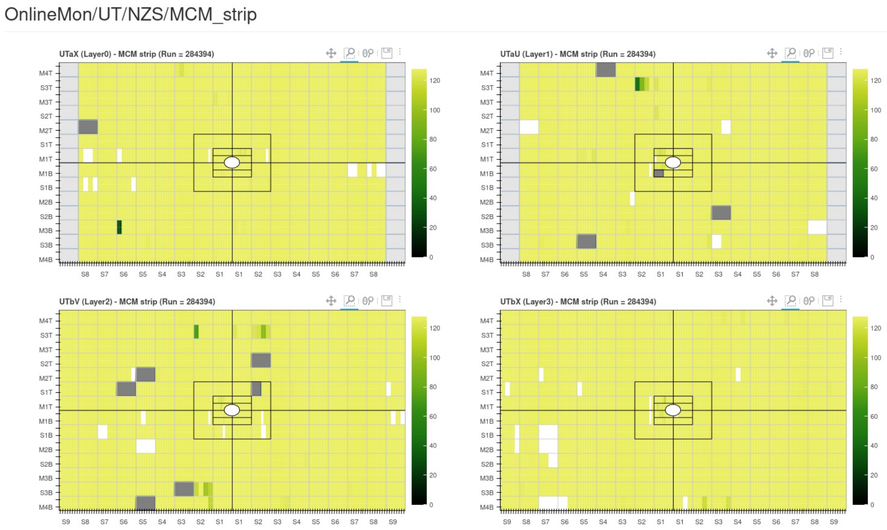
YETS activities

Upstream Tracker (UT)

- Great progress achieved during YETS
- All hardware issues were addressed
- Improved DAQ stability
- Detector calibration steps are ready







Detector response during the first tests

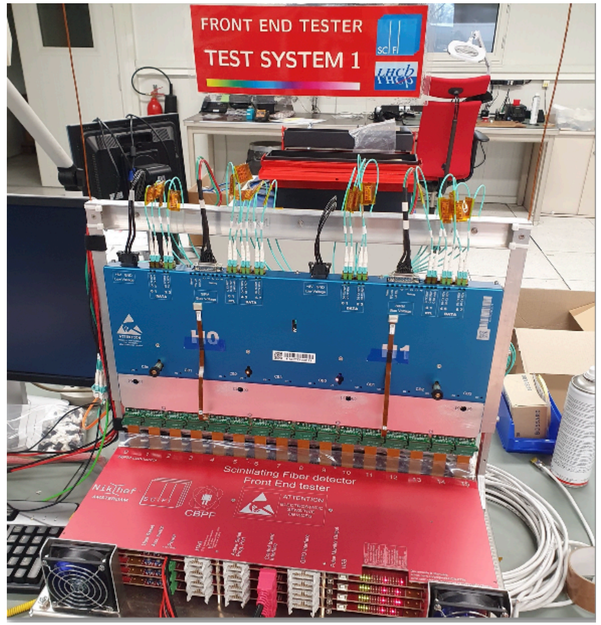
- First test running UT is satisfying
  - Long stable runs
  - Expected clusters behaviour
  - >97% of channels are working, to be improved
- Offline Software ready: refinement stage

First data taking period dedicated to commissioning

YETS activities

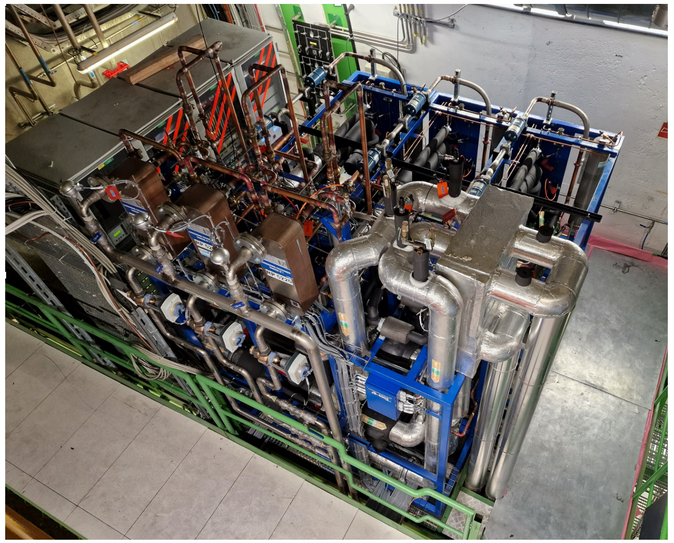
SciFi

- Detector calibration:
  - Gain for different temperatures and bias
  - Charge threshold scan
- Upgraded FE-Tester to reproduce problems in the lab



FE-Tester

SciFi



New cooling system

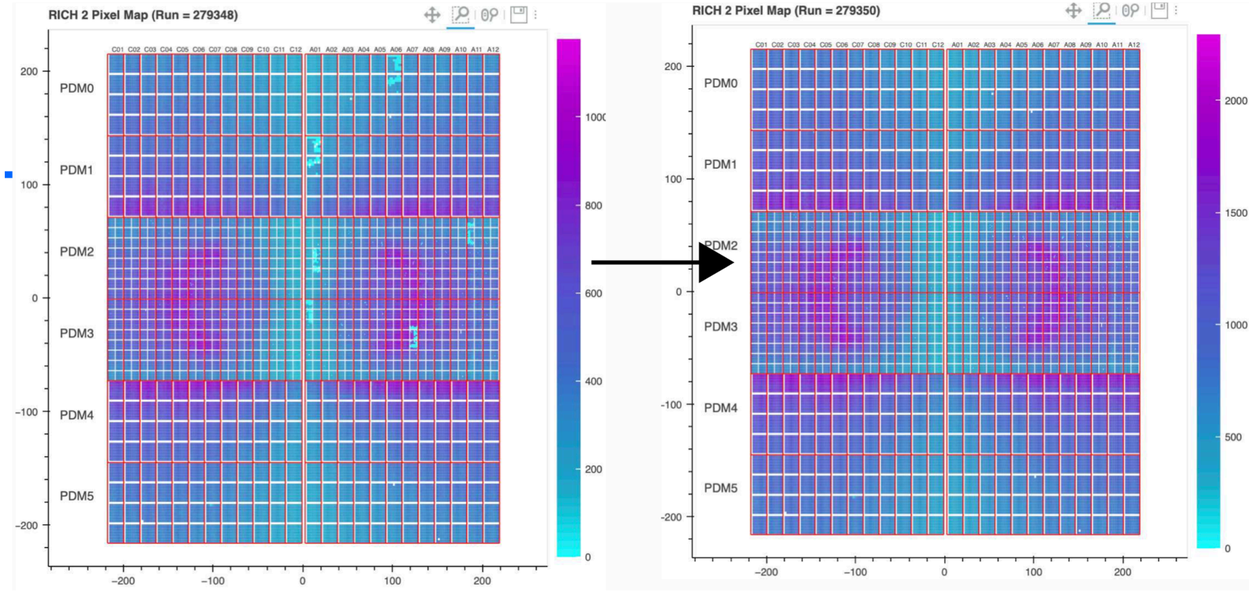
- Improved cooling system:
  - Cooling plant upgraded
  - Condensation Prevention System upgraded
- Only 2 Data Links excluded (out of 4096) and 100% of the 1024 Control Links

Detector is in good shape and ready for 2024 data taking

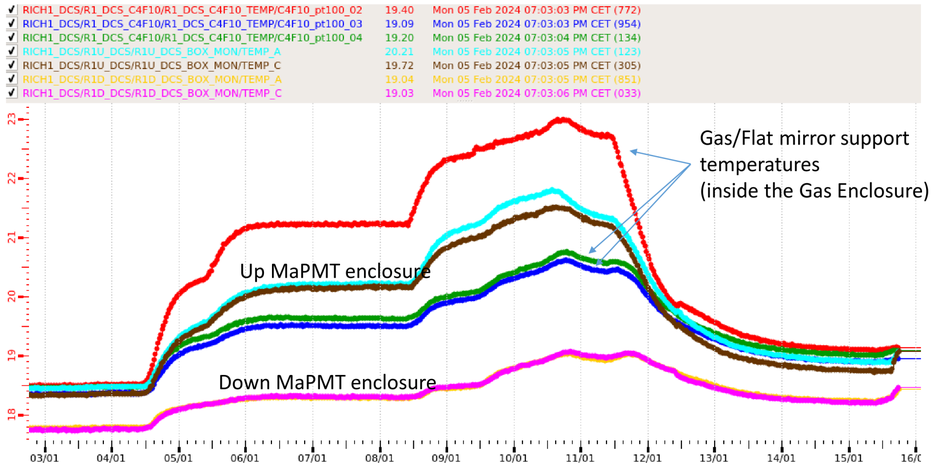
YETS activities

RICH

- Maintenance of the detectors:
  - Replacement of one photon detector module and three digital boards to remove instabilities
- Bake-out to degas the VELO region and beam pipe after the RF-foil replacement: crucial to keep temperatures under control and well monitored



Automated recovery procedure for improved performance



Temperature monitoring during bake-out

- DAQ delays readjusted at run change in automated way
- Detector optimisation to further improve the excellent PID performance:
  - Evolution of performance with different time gates
  - Performance and photon yield studies at different HV values

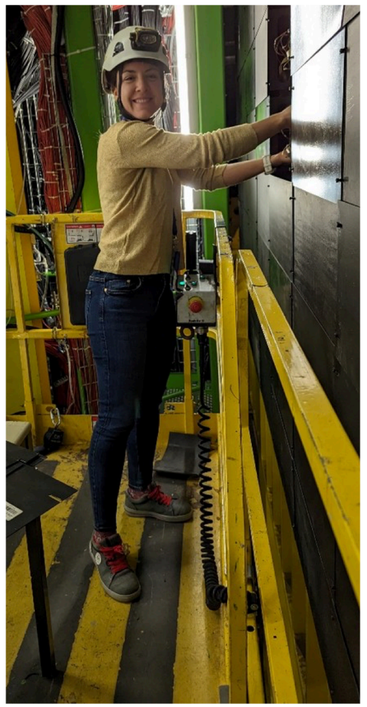
Detector is in good shape and ready for 2024 data taking

YETS activities

ECAL and HCAL

- Changed pedestal subtraction method in 2023:
  - High occupancy mitigation for Run3
  - Beneficial effect on pos. fluctuations (occupancy)
  - Bad effect on neg. fluctuations (undershoot) - triggering signal in many BX, effect occurs with calibration LED pulse shape
- Adaptation of the LED system to remove the undershoot and detector maintenance
  - Access for HCAL was required
  - ECAL LED have to be tuned (no access needed)
- **99% of channels are working** (16/6016 for ECAL and 3/1472 for HCAL), to be improved
- Preparation of calibration and monitoring

Calibration with first beams is required



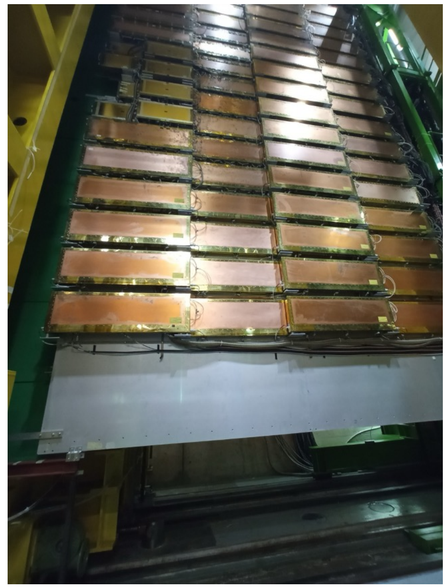
Maintenance

YETS activities

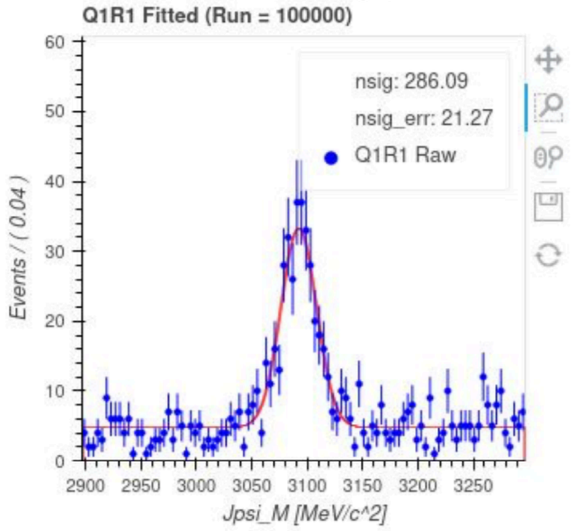
MUON

- Study of 2023 performance
  - Hardware maintenance: replaced 5 chambers
  - Calibration: improved Time Alignment Event (TAE) trigger
  - Hit efficiency studies; high-level online monitoring of the resolution and efficiency

C-side opening

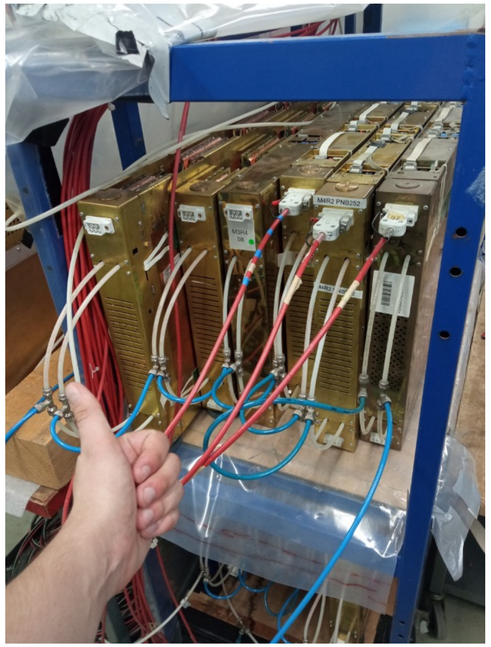


Online monitoring plot



- Data taking during intensity ramp-up:
  - Time alignment with new TAE
  - Improve efficiency

Calibration with first beams is required



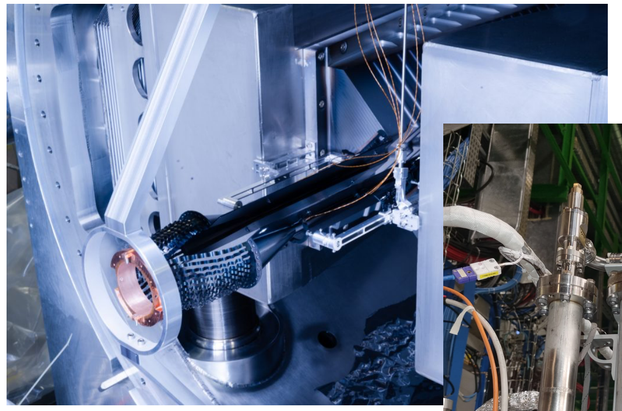
Chambers replacement

YETS activities

SMOG2 and PLUME

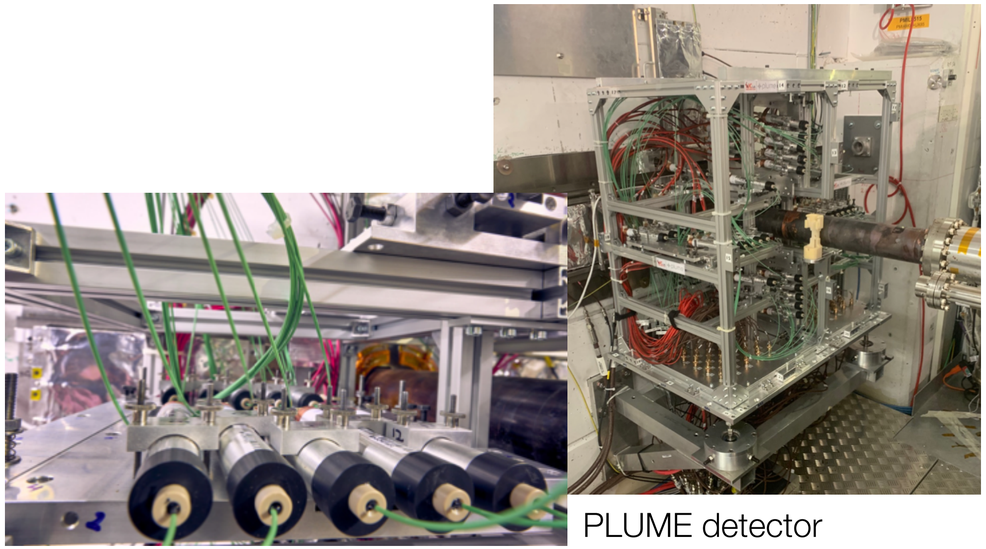
- Both sub-detectors were successfully re-installed
- **SMOG2 (System for Measuring Overlap With Gas)**:
  - **Upgrade of the Gas Feed System**: 3 (He,Ne,Ar) + 3 (H_2,D_2,O_2) gases
  - Implementation of the gas automatic injection system

new!



SMOG2 gas confinement cell

New Gas reservoirs



PLUME detector

- **PLUME (Probe for LUminosity Measurements)**:
  - Updated detector readout to provide luminosity per BX
  - **"Forever" feature**: run independently of the LHCb DAQ, continuous feedback to LHC

New features are useful for both detector performance and physics

YETS activities

Online

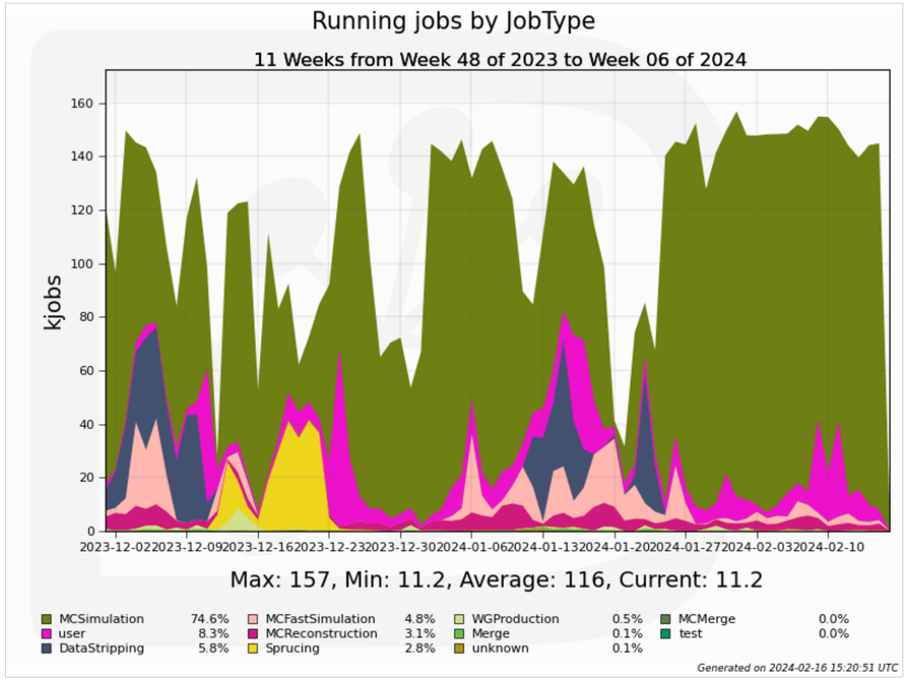
- **WinCC:** ECS projects updated to WinCC 3.19 (and VMs updated to RHEL9)
- **Control firmware**: New release (‘Kharkiv’) deployed last week
- **VHDL**: Common library for portable and verified FW components
- **Event Builder**: New fault tolerant scheduling and Continuous Integration / Continuous Deployment
- **HLT farm**: Successful procurement of +50% of the computing power
- **Disk space**: Doubling of the available disk space for calibration data
- **Data transfer**: Successful transfer of all the 2023 data to offline

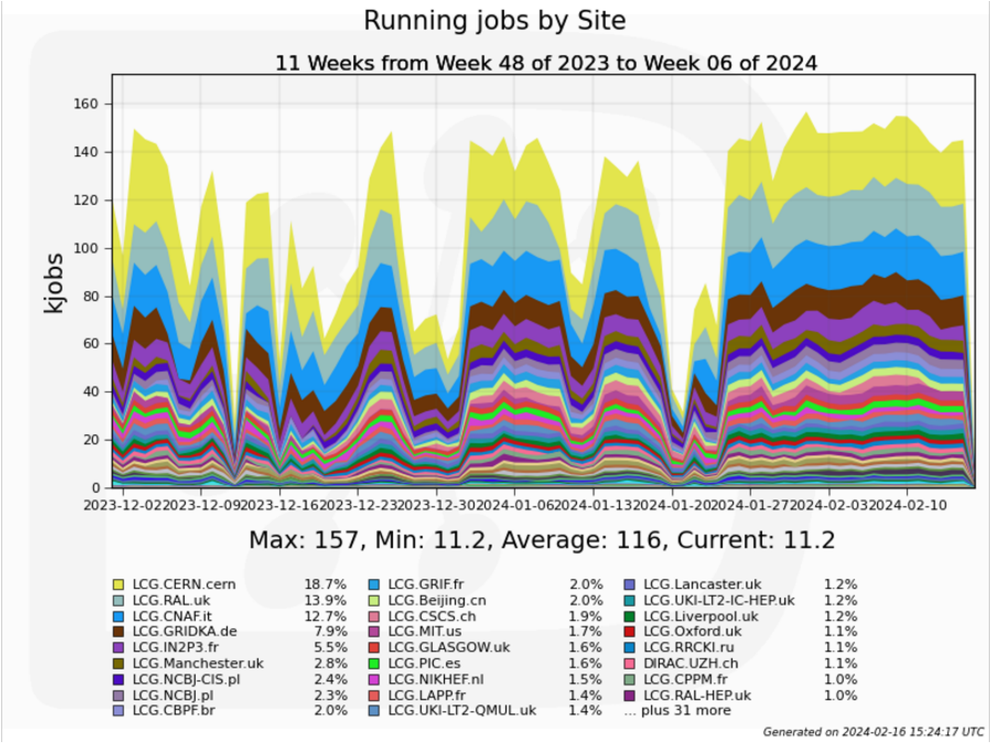
A lot of work and a lot of improvement

Offline computing

Distributed computing operations

- Computing work: MC production (82%), physics analysis (9%), data reconstruction and selection (legacy Stripping 6%, Run-3 campaign Sprucing 3%)



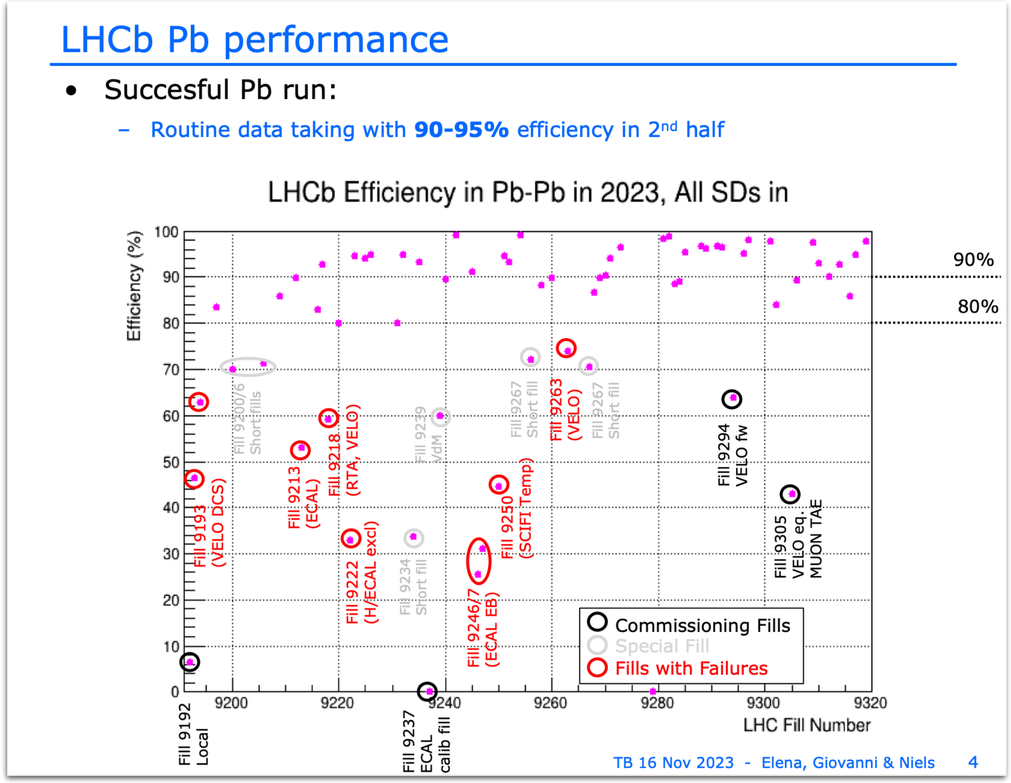


- NCBJ (Swierk) is now officially a new Tier1 for LHCb
- WLGC Data Challenge showed that the infrastructure can support the data transfers planned for 2024

Preparations for 2024 data taking

Plans

- Sub-detectors preparation for luminosity increase is ongoing; propagating experience from 2023
- Achieving nominal conditions:
  - μ scan at beginning of the intensity ramp up
  - increase μ in parallel to the intensity ramp up
  - test VELO closing at each step
- Targeted luminosity is 7 fb^{-1} in *pp (unless the data taking in 2024 is extended),* with >85% efficiency



Looking forward to the first 2024 beams

Preparations for 2024 data taking

New Structures

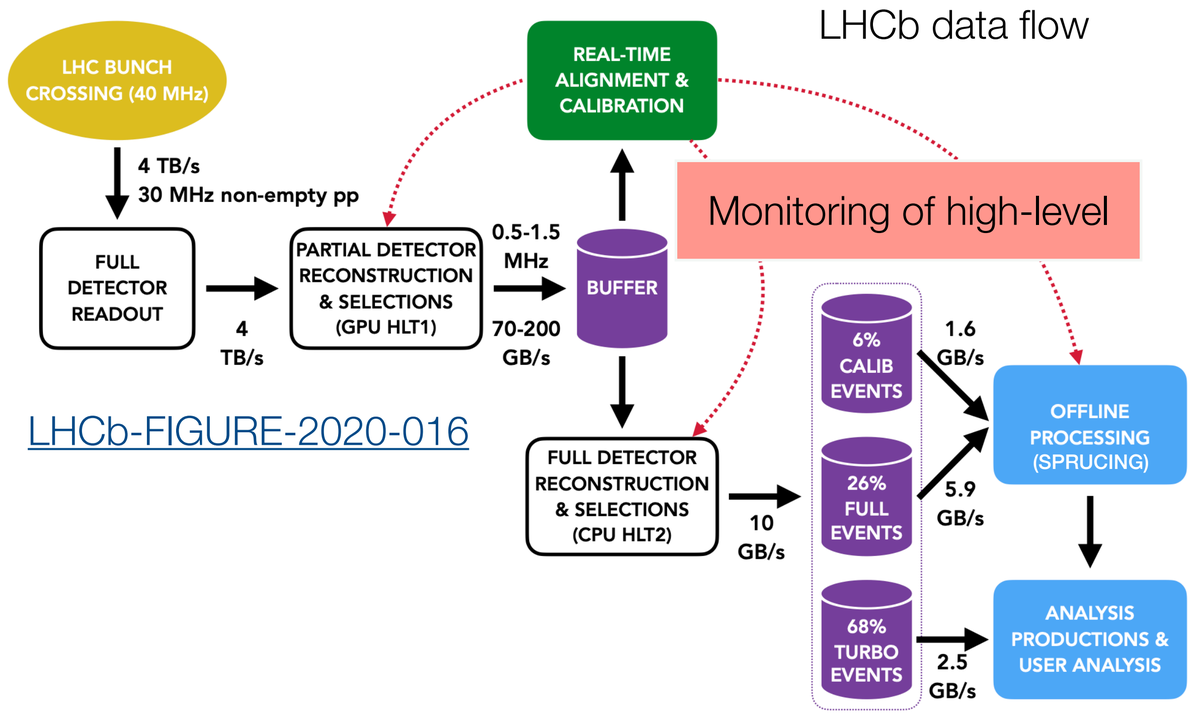
- Two structures were set up to speed-up re-commissioning process:
  - **Technical Board Sub-committee** (TBSC): concentrated on issues **mostly related to online software components of common interest to Real Time Analysis and subsystems**
    - Improved time-alignment strategy
    - Dedicated calibration trigger lines with a possibility of performance evaluation on per-run basis
  - **Detector Electronic Commissioning Task Force** (DECTF): concentrated on issues **mostly related to detector electronics**
    - DAQ improvements
    - GBTx synchronisation issues: understood and mitigated

Both structures operate successfully

Preparations for 2024 data taking

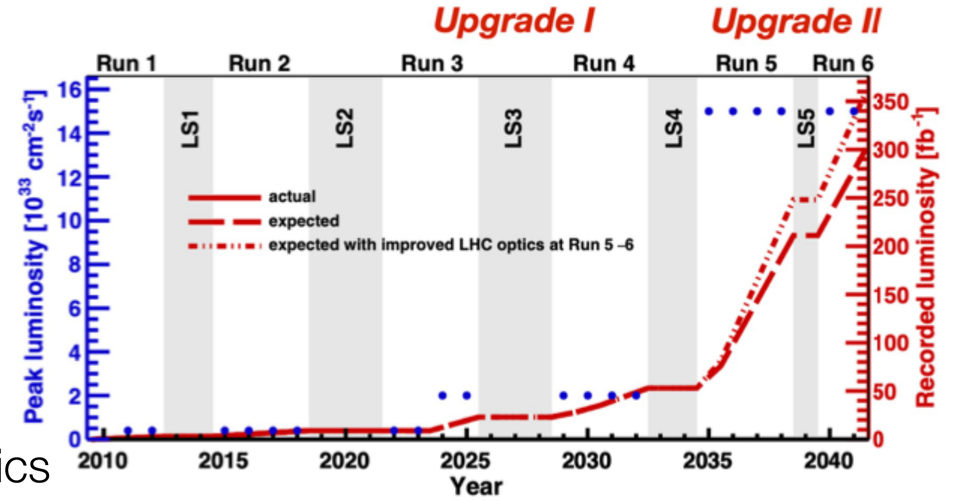
Trigger and data processing

- Tuning reconstruction sequences in HLT1 and HLT2
- Introducing a neural net for killing of fake tracks in HLT1:
  - Reduce ghosts by 50% while keeping more than 98% of the signal
- Tuning of the HLT1 bandwidth division
- Tuning and close monitoring of HLT2 and Sprucing lines bandwidths

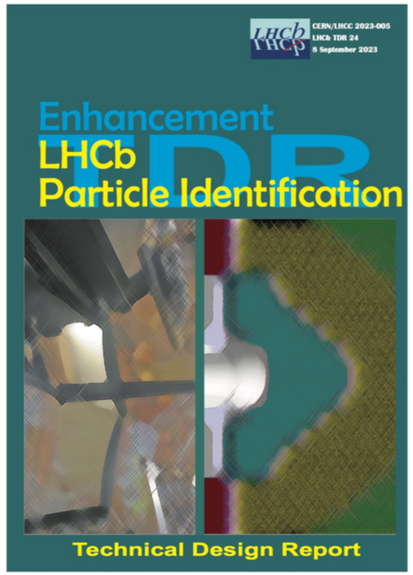


- Improvements to framework to enable use of TAE events in data taking
- **Monitoring of low-level and high-level quantities** being integrated, **including a new high-level monitoring system** for a quick turnaround

Upgrade II



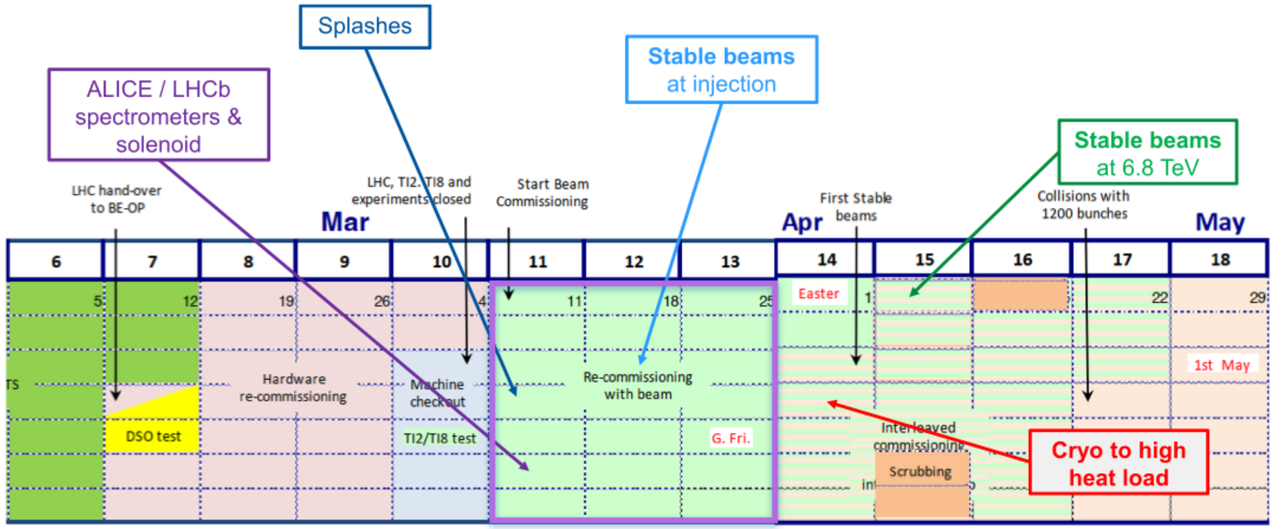
- Upgrade II is the only way to achieve the European Strategy priority of maximising the scientific return from the HL-LHC, including flavour physics
- Preparation for Upgrade II is ongoing
- Waiting for approval of the PID LS3 enhancement TDR
- Online LS3 enhancements TDR has been submitted
- Working hard towards the Scoping Document:
  - Developing different scenarios in terms of physics performance, cost and complexity



25-27 March: Upgrade II workshop! All interested people are welcome to join!

- Registration link: https://indico.cern.ch/event/1377881/

Summary

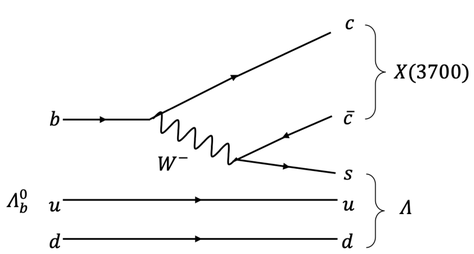


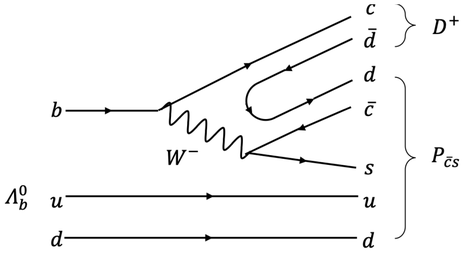
- **Run 1 and Run 2 data being analysed**:
  - 14 papers submitted since the last LHCC
- **2023 data are processed, study is ongoing**:
  - Understanding of detector behaviour
  - Assessing early detector performance
  - Preparation for 2024 data taking
- **YETS activities are finalised, moving towards data taking in the next month**:
  - Successful VELO RF-foil replacement
  - UT commissioning is ongoing
  - Other subsystems are in good state
- **Next steps: getting ready for the first beams**

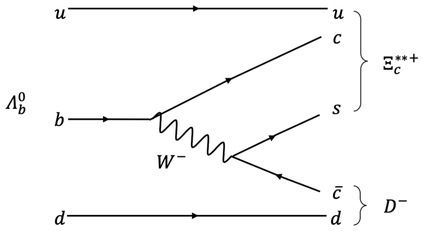
Backup

First observation of $\Lambda_b \to D^+D^-\Lambda$

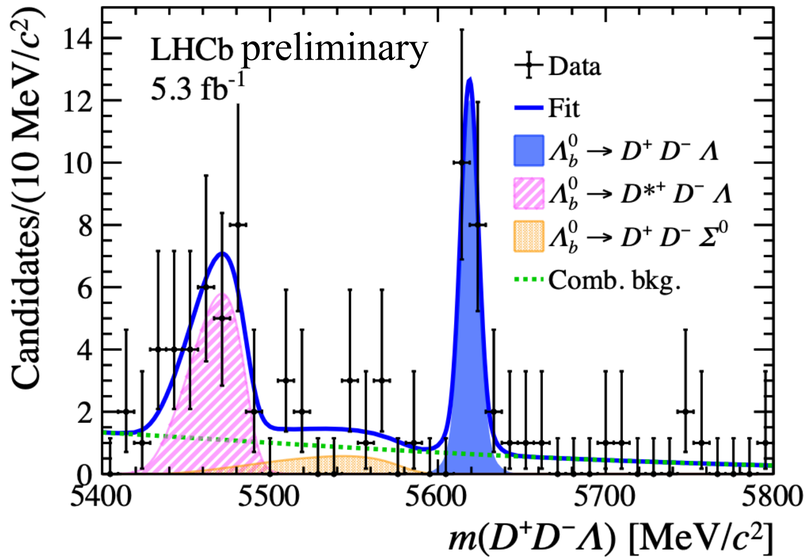
LHCb-PAPER-2023-042, in preparation

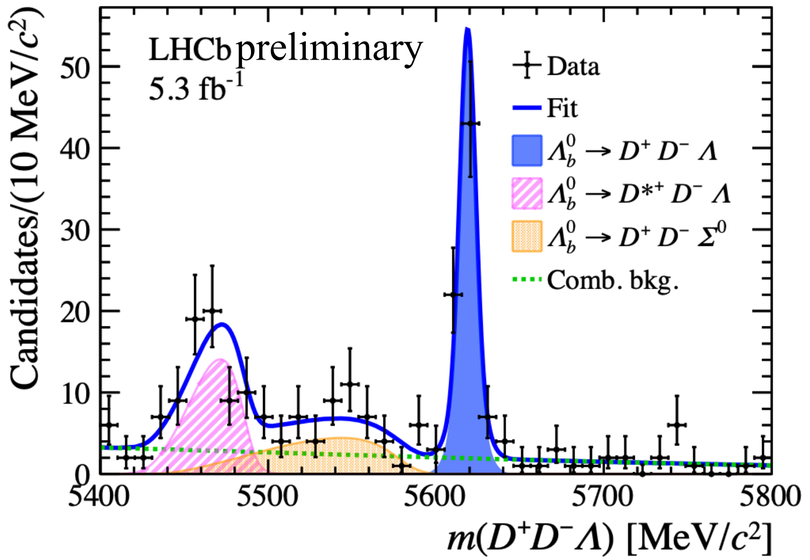






- Possible two-body decay via intermediate charmonium-like state, charm-baryon and anti-charm meson, or pentaquark





$$\mathcal{B}(\Lambda_b \to D^+D^-\Lambda) = (1.24 \pm 0.15 \pm 0.10 \pm 0.28 \pm 0.11) \times 10^{-4}$$

Good probe for $D\bar{D}$ bound states, charmonium-like states and excited Ξ_c^+

Technical Board Sub-committee

Mandate

- The TBSC is created to reduce the latency in:
  - **identifying problems, missing features, and areas for improvement, mostly related to online software components of common interest to RTA and subsystems**
  - scoping the possible solutions to the identified issues, defining the required number of people and the expected timescale
  - identifying the priorities

Technical Board Sub-committee

Current tasks

*Time Alignment Event

- An **improved strategy for time-alignment** using regular TAE* data taking in parallel to Physics
  - wide time window and a dedicated trigger on the central bunch
  - allows improving the purity of the TAE events and analysis time
  - **reduces response time for the detector time-alignment**

Technical Board Sub-committee

Current tasks

- Development of additional **dedicated detector calibration lines** at the first trigger stage:
  - fundamentally possible because of a 30 MHz tracking trigger and its ability to find low-momentum tracks
  - was partially implemented last year for alignment and now being greatly expanded to allow fast real-time evaluation of PID performance
  - a tool for a **coarse evaluation of performance on a per-run basis** and follow-up with a more **fine-grained evaluation** based on offline data **some days later**
  - will help reduce the latency in reacting to varying detector performance

This work is done in close collaboration between the sub-detectors and RTA team

Detector Electronic Commissioning Task Force

Mandate

- A new Task Force was created to:
  - **coordinate the work** on issues related to the detector data taking performance, **mostly related to detector electronics**
  - develop a “critical mass” of LHCb experts
  - create an official list of contributors, with actions, responsibilities and recognition
- The Task Force
  - is taking care of detector electronics, creating interfaces and boundaries to other systems
  - works in tight cooperation with the Run Coordination team

Detector Electronic Commissioning Task Force

Organisation and aims

- Discuss and agree on task priorities
- Break boundaries between sub-systems
- Create a list of “super-experts”
- Organise regular and irregular meetings by topic
- Follow up a list of Issues and Actions and report the progress

#	Description/Title	Assigned to	Status
1	GBT desynchronizations	KW, Online, EP-ESE	
2	LHCb central clock jumps + SOL40 characterization	Online, *help needed*	
3	RICH TELL40 coarse time align	RICH, Online	
4	HCAL TELL40 errors	CALO, GV	
5	MUON TELL40 desynchronizations	MUON, Online, TS, CB, JPC	
6	VELO OPB LV stability	VELO, KW	
7	VELO reconfiguration at injections	VELO, Online	
8	VeloPix GBTs FEC counting	VELO, Online, KW, EP-ESE	
9	SEUs investigations	KW, Online, VELO, RICH, SCIFI	
10	PLUME continuous readout FW	PLUME, GV	
11	SCIFI scans interruptions with FV FW	SCIFI, GV, Online	
12	SCIFI readback functions for scans	SCIFI, Online	
13	UT at nominal threshold	UT	
14	UT 5-flavors fw validations	UT, GV, Online, FL	
15	UT monitoring	UT	
16	UT TELL40 error recovery	UT, GV, Online	
17	UT grounding investigations	UT	

Legend	
To start	
Ongoing	
Mitigated	
Solved	

The Task Force was smoothly set up and successfully started operating

Offline computing

New Tier1 site

- NCBJ (Swierk) is now officially a new Tier1 for LHCb
- IHEP (Beijing) Tier2 site is making progress towards becoming Tier1 sites for LHCb
  - computing HW and SW OK, network ~OK
    - 100Gps available in shared mode, functional tests OK
    - data challenge to be scheduled