

LHCb Experiment at CERN Run / Event: 263132 / 5940637 Data recorded: 2023-05-11 13:50:49 GMT

## LHCB Run 3 status report on the detector commissioning

[LHCb reports at CSN1:  $\rightarrow$ <u>Detector</u> and  $\rightarrow$ <u>Physics</u>] [Previous LHCb report at CSN1-LNF:  $\rightarrow$ <u>here</u>]

Marco Santimaria on behalf of the LHCb-LNF group CSN1-LNF meeting Frascati, 20/09/2023





Laboratori Nazionale di Fisica Nucleare





## The LHCb Upgrade I detector

- Run 3 : Major upgrade of all subdetectors completed on-budget and near schedule
- Aiming at Run 2 (or better) performance with  $L_{peak} = 2x10^{33} \text{ cm}^{-2} \text{ s}^{-1} \text{ (pile-up}^{-5)}$

« Se vogliamo che tutto rimanga come è, bisogna che tutto cambi » (Il Gattopardo)

- New silicon pixel detector (VELO) at 5 mm from the beam
- New **RICH** optics and photodetectors
- New silicon strip Upstream Tracker (UT)
- New scintillating fibres tracker (SciFi)
- New electronics for MUON and Calorimeters
- Installation of a luminometer (PLUME) and a gas storage cell (SMOG2)
- All subdetector readout at 40 MHz with fully software trigger: HLT1 (GPU) + HLT2 (CPU)  $\rightarrow$  Real Time Analysis (RTA)

### Upgrade-I LHCb detector



[LHCb-DP-2022-002]



Marco Santimaria / LHCb Run 3



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### <u>VELO 1/2</u>

### • Aluminium RF foils (min thickness ~150 μm)



• On Jan 2023, a failure of the LHC vacuum protection system caused an overpressure in the RF foils enclosing the VELO.  $\rightarrow$  provoked an outward deformation: no damage to the sensors



• Instead of closing at each fill, set the VELO position to the minimum one allowed by injection and keep it fixed until 2023 YETS, when the RF foils will be replaced

### • VELO sensors





### VELO 2/2

- Impact of the VELO open position:
  - Reduced acceptance  $\eta \in [2,5] \rightarrow \eta \in [2,3.7]$
  - Degraded impact parameter resolution
  - To limit the VELO radiation dose we'll mostly run at low luminosity ( $\mu \sim 0.1-0.2$ )
- The schedule is reshuffled but the commissioning does not stop:
  - $10\% \rightarrow 0.38\%$  inefficiency after time-
- Long tracks still delivered







### Upstream tracker

- UT installation completed during the 2022 YETS
- Intense activity underground during CERN closure to meet the schedule:
  - LV, HV, CO2 cooling, closure test 🗹
  - Firmware & ECS development ongoing 📒
  - Data-quality & HLT1 decoding ongoing 📒
  - Flexible trigger allows UT exclusion in the tracking
  - [The UT is primarily used to reconstruct downstream tracks & to reduce the ghost rate at high occupancy]
- Noise level in the cavern acquired & found compatible with surface
- Threshold determination ongoing, noisy channels ~0.16 %
- Procedure for coarse time alignment in place, needs collisions to test it









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### <u>SciFi tracker</u>

- Very large system, just-in-time installation before Run 3 data-taking
- Good time-alignment reached and hit efficiency close to the 99% target
- Good 2022 runs used to perform spatial alignment with huge tracking improvements
- Approaching the  $D^0 \rightarrow K^- \pi^+$  resolution expected from simulation (~8 MeV)













- (~ few per fill) implemented

- multiplicity) already better than Run 2!



LHCb Run 3

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## PID: ECAL, HCAL, MUON

- CALO and MUON detectors are running well despite their age!
- HCAL energy calibration with <sup>137</sup>Cs scan
- Developed a  $\pi^0 \rightarrow \gamma \gamma$  HLT1 line for ECAL online calibration
- MUON: Tell40 (DAQ boards) desynchronisation caused inefficiencies in 2022. Developed firmware & software patch to mitigate this issue to negligible level
- The cause is still being investigated (by all subdetectors) but is not affecting MUON performance anymore
- MUON: good time-alignment, to be refined with tracks (see  $\rightarrow$  <u>backup</u>)





• 07/2023 calibration data

Jhr





### PLUME

- PLUME is an array of 24 PMTs with quartz windows for online luminosity measurement, used in particular to level the luminosity at IP8
- PLUME was ready since the first collisions in April



- Non-linearity of the luminosity measurement was observed in 2022  $\rightarrow$  10-20% bias of the nominal  $\mu$  due to high rate of random coincidences
- A new paradigm to measure luminosity was developed during the winter break: use the mean value of the integrated charge from a single PMT  $\rightarrow$  new Tell40 firmware ready, to be tested in the coming weeks









### SMOG2

- Fixed-target physics is performed at LHCb since 2015 by injecting noble gases into the VELO (SMOG). See our  $\rightarrow$  publications
- A gas storage cell with precise flux and temperature measurements has been installed for Run 3 (SMOG2)  $\rightarrow$  Luminosity precision  $\sim 1\%$
- The injected gas has a negligible impact on the LHC beam lifetime & the LHCb trigger load
- Early data: beam-gas and beam-beam <u>simultaneous data-taking</u> with same resolution is demonstrated!
- Clean signals with few minutes of data-taking, also exploiting a new muonID operator [JINST 15 (2020) T12005]





## Online









## <u>Real Time Analysis (RTA)</u>

- The (software) trigger is split into:
  - HLT1  $\rightarrow$  partial reconstruction, bandwidth division across ~100 lines. This already provides offline-quality objects in real time! (right plots)
  - $HLT2 \rightarrow$  selections via ~2000 lines

Automatic rate tests deployed for stream optimisation

- First HLT2 signals of the year (05/2023) shown below
- 2023 processing ongoing (e.g. calibration data shown on slide 8)









## <u>Conclusions & prospects</u>

- The LHCb collaboration is growing and now facing:
  - 1. Run 2 analyses LNF: semileptonics and rare decays
  - 2. Run 3 commissioning LNF: Key roles in MUON and SMOG2
  - 3. Upgrade II R&D (next slide)
- Huge effort to commission the detector with 2022 data:
  - Full functionality of all installed subdetectors has been demonstrated
  - Calibration & alignment are rapidly improving performance, in some cases reaching the expectation
- 2023 data are crucial to achieve full performance:
  - UT installed & closed, priority to firmware development
  - Achieving stability of the operations
  - VELO incident has a sizeable impact but does not prevent commissioning
  - LHC cryo incident during summer voids physics possibilities for 2023
  - A leak at TDIS further hampered the commissioning and postponed the p-preference run (for Pb-Pb) to next year

### Ruoli di coordinamento in LHCb attivi nel 2024

- E. de Lucia: **WP-D Simulation Coordinator L2b** [01/2022 - 12/2024] - P. de Simone: Muon Software Coordinator **L2b** [01/2017 - 12/2024] - P. Di Nezza: SMOG2 Project Leader L1 [04/2019 - 12/2024] - M. Palutan: U2 Planning Group Chair L1 [07/2023 - 06/2024]

- M. Pepe Altarelli: Chair of Membership Committee L1 [07/2023 - 12/2024]

- M. Rotondo: Speakers Bureau Member L2b [07/2022 - 06/2024]
- B. Sciascia: Muon Project Leader L1 [01/2021 - 12/2024]
- B. Sciascia: Membership Committee Member **L2b** [01/2021 - 12/2024]

	People			
Sezione	Pers.	FTE	FTE/Pers	
BA	13	8.1	0.62	
во	14	9.5	0.68	
СА	17	15.8	0.93	
FE	23	15.8	0.69	
FI	7	6.7	0.96	
GE	6	3.3	0.55	
LNF	16	12.1	0.76	
МІ	15	10.5	0.70	
MIB	13	8.7	0.67	
PD	11	6.7	0.61	
PI	12	10.0	0.83	
RM1	6	2.7	0.45	
RM2	3	2.1	0.70	
PG	7	1.2	0.61	
Totale	163	116.3	0.71	

		Ре	ple	
Sezione	Pers.	FTE		FTE/Pers
BA	12		7.7	0.64
во	14		9.9	0.71
СА	18		12.4	0.69
FE	27		20.9	0.77
FI	7		6.7	0.96
GE	7		4.9	0.70
LNF	16		13.1	0.82
МІ	16		12.2	0.76
MIB	13		9.7	0.75
PD	13		7.6	0.58
PI	18		15.7	0.87
RM1	6		2.5	0.42
RM2	4		3.1	0.78
PG	v		5.3	0.66
Totale	179	1	31.7	0.74



## Upgrade II

- Many key observables will be statistically limited after LHCb Upgrade I
- LHCb Upgrade II is a major detector change to fully exploit HL-LHC
- $L_{peak} = 2x10^{34}$  cm<sup>-2</sup> s<sup>-1</sup>,  $L_{int} = 300$  fb<sup>-1</sup> in Run 5 + Run 6
- The LNF group is committed to:
  - <u>MUON Upgrade II:</u>
    - Inner regions (R1-R2) where R ~ 1 MHz/cm<sup>2</sup>  $\rightarrow$  muRwell
    - Outer regions (R3-R4) where R < 50 KHz/cm<sup>2</sup>  $\rightarrow$  keep current MWPCs
    - More details:  $\rightarrow \underline{performance}$  and  $\rightarrow \underline{hardware}$  talks @ U2 workshop
  - LHCspin project (SMOG3):
    - A polarised gas target to bring spin physics at the LHC
    - More details: <u>[EPJ WoC 276, 05007 (2023)]</u>





### <u>[CERN-LHCC-2018-027]</u>



<u>[CERN-LHCC-2021-012]</u>





# backup

## MUON: time alignment

- which we look at +-10 BXIDs
- applied at the nODE level
- level with 1.5 ns steps
- channels



