LHCb France input to GT09 of the IN2P3 national prospects 2020-2030

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The LHCb detector is being upgraded during the ongoing long shutdown LS2 (2019-2020) in order to run at a luminosity 5 times higher, $2 \times 10^{33}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, than the current one. The new detector has been funded and approved to take data until 2029. Motivated by the lack of evident systematics limitations to its key measurements, the LHCb collaboration prepared an expression of Interest [1] and a physics case [2] for further upgrades of the detector during LS3 (2024-2026) and LS4 (2030), eventually culminating in the ability to run above an instantaneous luminosity of $10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and aiming to collect at least 300 fb^{-1} of integrated luminosity during the High Luminosity HL-LHC period. These documents were very well received by the LHCC and the collaboration will deliver a Framework TDR by the summer 2021.

These upgrades of the LHCb detector lead to some of the greatest data challenges faced not only in High Energy Physics, but also science more generally. A key requirement of LHCb's real-time processing is to perform tracking for every LHC bunch crossing. This is a necessary ingredient to classify, at 30 MHz, the presence of charm and beauty hadrons and even of their specific decay modes; calorimetry and muon-system information are not sufficient to discriminate between charm and beauty hadron decays and QCD background. Since most of LHCb's data rate comes precisely from the tracking system, this requirement leads to the triggerless readout processing being implemented for the upgrade. The first LHCb upgrade will therefore require that a data rate of 40 Tb/s is processed using variable latency commodity processors. This is comparable to the volume of data after the ATLAS and CMS hardware triggers in HL-LHC but must be delivered approximately 6 years earlier. The second LHCb upgrade would increase this data rate to at least 400 Tb/s, comparable to today's worldwide internet dataflow [3]. This data volume must be processed economically, both in terms of money and energy consumption, but also with a full flexibility which permits LHCb to achieve its physics objectives.

To meet this challenge the LHCb collaboration has formed a "Real Time Analysis" project, bringing together specialists in high-throughput computing, hybrid architectures, physics analysis frameworks, detector alignment and calibration, and data quality. The French LHCb groups played a key role in proposing and forming this project, and are deeply involved across the project's work packages to deliver a functioning system for the first LHCb upgrade in 2021. In particular, a French LHCb member (Vava Gligorov) is the Project Leader, and other French LHCb members are responsible for the calorimeter reconstruction, the vertex detector reconstruction, and have authored two of the three main tracking algorithms used by LHCb. In addition, French LHCb researchers have demonstrated that the entire first stage of the real-time reconstruction could be implemented on GPUs instead of CPUs. This could not only be a more cost-effective solution, but the developed expertise in hybrid processing architectures will be crucial when designing a solution for the even bigger challenges of the second upgrade.

Indeed the competences which French LHCb researchers have developed in multi-threaded and vectorized agorithms running on hybrid architecture is crucial for the future (see page 199 of Ref. [4], and Ref. [5]). French LHCb researchers played crucial roles in tracking and triggering since the beginning of LHCb, but we have now trained a new generation of researchers who can write highly performant code optimized for modern computing architectures. This effort has already paid off in concrete ways: enabling an all software trigger for Run 3 which will gain factors in efficiency for hadronic decay modes and charm physics, and developing a GPU trigger with the potential to save factors in cost to the collaboration compared to the CPU trigger. But they will become even more crucial for the future upgrades, which will have to deal with an order of magnitude more complex data processing problem. All these developments also fit well with the fact that data processing is fundamentally driven by the development of commercial architectures, which are increasingly hybrid. Looking towards upgrade 2, French LHCb groups will aim to reinforce these competences by creating close collaborations with computing laboratories, as already done between LPNHE and LIP6 for example.

References

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