LHCb France input to GT08 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, $2 \times 10^{33}\,\text{cm}^{-2}\text{s}^{-1}$, 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 and in order to fully exploit the flavour-physics opportunities of the HL-LHC, 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 $10^{34}\,\text{cm}^{-2}\text{s}^{-1}$ 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.

A full flavour physics program cannot be complete without an efficient and precise calorimeter. We can mention for example as physics cases:

- $b \to s e^+ e^-$ transitions like $B^0 \to K^{*0} e^+ e^-$,

- the radiative decays such as $B^0 \to K^{*0}\gamma$,
- adding independent information for the determination of the γ angle of the CKM matrix by applying the ADS/GLW and GGSZ techniques to B decay modes containing a π^0 meson,
- spectroscopy of multiquark states,
- study $1P$ charmonium and bottomonium states in heavy ion collisions, such as $\chi_c \to J/\psi\gamma$ and $\chi_b \to \Upsilon(1S)\gamma$,
- as well as to study the production of flavour species (some of which require secondary vertexing capabilities) up to very large multiplicities (where collective-like effects were observed in Run-1+2).

In the extremely high multiplicity environment as the one expected during the high luminosity phase of the LHC (HL-LHC), it is crucial to provide a timing information to be used in the data processing (either in the electronics data acquisition chain or in the software trigger processing) and during the reconstruction of the events. In a first approach, this information is needed to be able to reject the clusters in the calorimeter where energy deposits from several pile-up interactions contribute and would degrade significantly the neutral object selection efficiency. In particular, this will forbid the identification of the low-energy bremsstrahlung photons which is crucial for an important part of the LHCb physics program. In a second approach, we could also use this precise timing information in the cluster reconstruction and try to disentangle the different pile-up energy deposits, using the information from the neighbouring cells.

An area where the French community could play an important role is the development of the Front-End electronics. Depending on the characteristics of the hardware used for the calorimeter, the Front-End electronics could either simply provide a high granularity timing information (wave-forms of the signal at a given sampling rate) or even perform some data processing in order to reduce the bandwidth to the DAQ and provide starting points for the future reconstruction. This development would then be tightly coupled to the back-end processing and the real time reconstruction of neutral objects, where also French groups already involved in LHCb have the expertise to contribute.

What can be achieved in the data processing depends on the performances of the calorimeter hardware: geometry and granularity of the detector and technological choices of the modules (affecting time resolution, which should be better than 100 ps for the goals mentioned above, and the Moliere radius). Studies based on fast simulations were initiated and coordinated by the French groups, in particular in tight relation with the LHCb Chinese groups via the FCPPL. The goal of these studies is to select the best design to reach the physics goals, in particular the preliminary results confirm the necessity of a precise timing information to overcome the huge challenge of the high-luminosity environment.

French researchers played important roles in the development, construction, operation, calibration and physics analyses with the LHCb calorimeters during the Run 1 and 2 of the experiment, as well as being in charge of the Upgrade 1 calorimeter project. Their involvement at the early stage of the design of a calorimeter for the Phase II Upgrade of LHCb is the natural continuation of these activities.

References

[1] LHCb collaboration, *Expression of Interest for a Phase-II LHCb Upgrade: Opportunities in flavour physics, and beyond, in the HL-LHC era*, CERN-LHCC-2017-003, 2017.

[2] LHCb collaboration, *Physics case for an LHCb Upgrade II — Opportunities in flavour physics, and beyond, in the HL-LHC era*, arXiv:1808.08865.