

Proposal for an Internship for the Master 2 IMAPP 2025

**“Studying the sensitivity of the Upgrade Phase II LHCb Calorimeter
for the rare decay $B^0 \rightarrow \pi^0\pi^0$,
where one π^0 decays to the Dalitz $e^+e^-\gamma$ channel”**

Introduction to the CKM angle α and to the future LHCb PicoCal calorimeter

The decay $B^0 \rightarrow \pi^0\pi^0$, which occurs with a small probability of 1.6×10^{-6} , its precise study allows to strongly constraint the CKM angle α [1]. Multiples approaches are mandatory to be sensitive to physics beyond the Standard Model of Particle Physics, at energy scale above few tens of TeV, when challenging the global coherence of the KM mechanism [2].

The reconstruction of the rare decay $B^0 \rightarrow \pi^0\pi^0$, where one π^0 decays to the Dalitz $e^+e^-\gamma$ channel, offers a clean signature to perform a time dependent CP violation measurement at LHC with the LHCb detector. The LHCb experiment will be operated by the next decade at a luminosity of about $1.5 \times 10^{34} \text{ cm}^{-2} \cdot \text{s}^{-1}$, corresponding to more than 50 proton-proton collisions at a frequency of 40 MHz. To be able to cope with such a high rate the LHCb calorimeter must be upgraded, and a design has been proposed to the LHCC committee in 2022 [3,4]. A fine granularity and radiation hard layout has been proposed, which has a longitudinal readout through 2 compartments able to measure the timing of electromagnetic showers at a few ten picoseconds precisions in addition to an accurate energy measurement. The name of the next generation LHCb Upgrade II calorimeter is PicoCal.


The LPC laboratory has a long expertise on all the above subject, both physics and instrumental sides. We are being designing an ASIC prototype (the so-called SPIDER project) to achieve the timing precision at a few 10 picoseconds, which is a novel challenging project. Such a timing accuracy allow to distinguish with the least possible ambiguity among the more than 50 collision occurring every 25 ns, which reducing in a very efficiency way the enormous combinatorial background to select the true 3 photons and the e^+e^- pair produced in the final state of the decay $B^0 \rightarrow \pi^0\pi^0$ in order to fully exploit the hundred billions of $B^0\bar{B}^0$ pairs to be produced and detected by LHCb at HL-LHC in the next decade (by year 2035 data corresponding to an integrated luminosity of about 300/fb will be recorded). This corresponds to a few hundreds of final states $B^0 \rightarrow \pi^0(\gamma\gamma)\pi^0(e^+e^-\gamma)$.

Description of the internship topic and its environment

The internship student will work on the reconstruction of the above-described physics channel and will employ LHCb collaborative software tools. A full Geant 4 based simulation of the decay will be performed. The student will contribute to the sensitivity study of the channel $B^0 \rightarrow \pi^0(\gamma\gamma)\pi^0(e^+e^-\gamma)$ with the proposed upgraded II calorimeter design. The student will also perform studies to characterize the kinematics and the tracking nature of the electron-positron pair. This internship will be followed by a PhD thesis proposal.

Vincent Tisserand,
Aubière, les Cézeaux, on 22 Oct 2024.

Contacts

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References

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[hep-ph: <https://arxiv.org/abs/1501.05013>]
- [3] Physics case for an LHCb Upgrade II - Opportunities in flavour physics, and beyond, in the HL-LHC era, LHCb-PUB-2018-009; CERN-LHCC-2018-027 <https://cds.cern.ch/record/2636441>
- [4] Framework TDR for the LHCb Upgrade II - Opportunities in flavour physics, and beyond, in the HL-LHC era, CERN-LHCC-2021-012; LHCb-TDR-023 <https://cds.cern.ch/record/2776420>