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Proposal for an Internship for the M2 UP & IMAPP (2023)

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

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

The precise study of the decay $B^0 \to \pi^0\pi^0$, which occurs with a small probability of 1.6×10^{-6}, 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 $B^0 \to \pi^0\pi^0$, 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 1.5×10^{34} $cm^{-2}.s^{-1}$, 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 last year [3,4]. A fine granularity and radiation-hard layout has been proposed, which has a longitudinal readout through 2 compartments able to measures the timing of electromagnetic showers at a few ten picoseconds precisions in addition to an accurate energy measurement.

The LPC laboratory has a long expertise on all the above subject, both physics and instrumental sides. We are being designing an ASIC prototype 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 $B^0 \to \pi^0\pi^0$ 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 recorded). This corresponds to a few hundreds of finals states $B^0 \to \pi^0(\gamma\gamma)\pi^0(e^+e^-\gamma)$.

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 $B^0 \to \pi^0(\gamma\gamma)\pi^0(e^+e^-\gamma)$ with the proposed upgraded II calorimeter design, to be described in a future TDR due to the LHCC by sept 2024.

Vincent Tisserand & Olivier Decshamps,
Aubière, les Cézeaux, on 16 Nov 2022.

Contacts

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References

[1] Isospin analysis of charmless B-meson decays, by J. Charles et al. (CKMfitter group), Eur.Phys.J. C77 (2017) no.8, 574 [hep-ph : https://arxiv.org/abs/1705.02981]

[2] Current status of the standard model CKM fit and constraints on ΔF=2 new physics, by J. Charles et al. (CKMfitter group), Phys. Rev. D 91, 073007 (2015) [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