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Enhancing Signal Identification in Rare Higgs Boson Decay to Zγ and Complex Decay Processes at LHC Energies

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Higgs Boson is characterized by $J^{\pi} = 0^{+}$ and fundamentally forms the cosmos by interacting with other particles to impart mass in standard model discovered in 2012 at CERN. This study is focused on Zγ channel of Higgs with branching ratio of $\beta(H \rightarrow Z\gamma) = (1.57 \pm 0.09) \times 10^{-3}$. Feynman diagram for Z$\gamma$ channel is similar to $\gamma\gamma$ channel and loop diagrams in this process are particularly sensitive to BSM physics. Recent studies have measured $\kappa_{Z\gamma} = 1.65^{+0.34}_{-0.37}$ indicating a uncertainty 40\% . Deviation in standard model prediction $\kappa_{Z\gamma} = 1$ can affect the decay rate $H \rightarrow Z\gamma$ and the Higgs production cross-section indicating the need for thorough research into $Z\gamma$. We have used PYTHIA8 Monte Carlo (MC) event generator for the analysis of $H \rightarrow Z\gamma \rightarrow \mu^{+}\mu^{-}\gamma$ or $e^{+}e^{-}\gamma$ in proton-proton collisions at centre-of-mass energy $\sqrt{s}$ = 13 TeV. This research further explores a novel method to address challenges such as complex background noise and pile-up in dense media, as well as the detection of heavy resonance signals within the domain of heavy-ion physics. By employing an angular correlation technique, the study aims to enhance the Higgs signal-to-background ratio in both heavy-ion and proton-proton experiments. Higgs mass is reconstructed by employing selection criteria focused on certain kinematic variables at various stages and signal-to-background ratio computed. Further analysis involves examining relation between P_Z vs $\theta_{\ell^+\ell^-}$ and P_H vs $\theta_{Z\gamma}$ - refers to 1^{st} and 2^{nd} angular correlation respectively both were applied up to 1σ, which significantly increased the signal-to-background ratio by several orders of magnitude. Utilizing this approach in conjunction with several kinematic cuts is expected to improve signal detection in complex data sets. Furthermore, this study has also taken into the acceptance and efficiency to incorporate these factors into the cross-section calculation.

Author: Ms KUMARI, Manisha (Indian Institute of Technology Mandi)

Co-author: Dr SARKAR, Amal (Indian Institute of Technology Mandi)

Presenter: Ms KUMARI, Manisha (Indian Institute of Technology Mandi)

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