Measurement of H→ $\gamma\gamma$ fiducial cross sections with 13.6 TeV CMS data

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The Higgs boson, discovered in 2012, remains a cornerstone of the Standard Model, and precision studies of its properties are a major goal of the LHC physics program. One of the most important final states for these measurements is the diphoton decay channel ($H \to \gamma\gamma$). Although the branching ratio is only about 0.02%, the channel benefits from the excellent energy resolution of the CMS electromagnetic calorimeter, which provides a sharp mass peak and allows for precise extraction of the Higgs signal over a large background.

The results presented here are based on $34.7\,\text{fb}^{-1}$ of proton–proton collision data collected in 2022 at $\sqrt{s} = 13.6$ TeV, corresponding to the first year of Run 3. This measurement is the first step in Run 3 towards increasingly precise results, with the much larger 2023 and 2024 datasets currently under validation.

The extraction of cross sections relies on fitting the diphoton invariant mass distribution, where the Higgs boson appears as a narrow resonance on top of a smooth continuum background. The signal is modeled using Monte Carlo simulations of Higgs production and decay, while the background is described by analytic functions constrained directly from data. Systematic uncertainties play a crucial role in the overall precision of the result. The leading contributions arise from detector effects, such as photon energy scale and resolution, photon identification efficiency, and category migrations, as well as from the integrated luminosity determination. Controlling these sources of uncertainty is essential given the statistical power of Run 3 data.

A key challenge is the rejection of background from non-prompt photons produced inside jets. CMS employs multivariate photon identification algorithms, based on shower-shape and isolation variables, to separate genuine photons from hadronic backgrounds. Work is ongoing to develop new identification strategies that exploit lower-level detector information, such as calorimeter images and particle-flow candidates, with the aim of improving performance and reducing mismodeling effects in simulation. These developments are particularly important since detector mismodeling is currently the dominant systematic uncertainty in the diphoton channel.

Beyond inclusive cross sections, differential measurements provide insight into the production dynamics of the Higgs boson and are especially sensitive to deviations from the Standard Model in the tails of kinematic distributions. Such measurements also enable interpretations in terms of Effective Field Theory, including constraints on light-quark Yukawa couplings, which are otherwise very difficult to access. The transverse momentum spectrum of the Higgs boson is particularly valuable in this context, complementing results obtained in other decay modes.

In summary, the $H \to \gamma\gamma$ channel remains one of the cleanest and most precise probes of Higgs boson properties. The first Run 3 measurements from CMS already demonstrate excellent performance and underline the importance of reducing detector-related systematics. With upcoming larger datasets and improved photon identification, increasingly precise and interpretable results will become possible, strengthening the program of precision Higgs physics at the LHC.