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Pranati Jana for the CMS Collaboration

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Ultraperipheral lead-lead collisions produce very large photon fluxes that permit fundamental quantum-mechanical processes to be observed and studied. The first measurement of τ lepton pair in ultraperipheral PbPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV with data collected by CMS during the LHC Run 2 will be presented. The study paves the way for the determination of the anomalous magnetic moment of the τ lepton, currently poorly constrained.

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Observation of $\gamma\gamma \to \tau^{\pm}\tau^{\mp}$ production in PbPb collisions with the CMS experiment

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Abstract

Ultraperipheral lead-lead collisions produce large photon fluxes that permit fundamental quantum-mechanical processes to be observed and studied. The first measurement of τ lepton pair in ultraperipheral PbPb collisions at $\sqrt{s_{\mathrm{NN}}} =$ 5.02 TeV with data collected by CMS[1] during the LHC Run 2 was presented. The study paves the way for the determination of the anomalous magnetic moment of the τ lepton, currently poorly constrained [2].

1 Introduction

In ultraperipheral collisions, lead ions do not disassociate but scatter, leading to final state that may contain τ leptons. The cross-section for producing τ lepton pairs increases like Z^4. Recent theoretical studies have proposed that the production cross section and τ kinematics from the $\gamma\gamma \to \tau^{\pm}\tau^{\mp}$ process, can be studied to measure the anomalous magnetic moment of τ, $(g-2)_\tau$. The value of $a_\tau = (g-2)_\tau/2$ predicted by standard model is 0.00117721(5). The current best measured value of a_τ is from DELPHI, with a constraint (95% CL) of $-0.052 < a_\tau < 0.013$ [3]. The a_τ measurement is one of the fundamental tests of QED, as well as a novel way to probe for BSM physics, for example, lepton compositeness and supersymmetry.

The CMS experiment can trigger on $\tau\tau$ events by requiring a single muon from one of the τ decays as well as a veto on minimum bias activity in the forward hadronic calorimeter ($3 < |\eta| < 5$). The data sample collected at $\sqrt{s} = 5.02$ TeV corresponds to an integrated luminosity of 404.3 μb^{-1} by the CMS experiment is used for this analysis. Further details on the first CMS measurement of the $\gamma\gamma \to \tau\tau$ process are reported in [2].

2 Analysis strategy

Events are selected with one single muon, at least one pixel track, and a minimum amount of event activity above the noise threshold in the forward hadron (HF) calorimeter. To select only UPC events, the threshold of the energy deposit in the leading tower of HF is required to be below 4 GeV.

In the signal phase-space region, selected events must contain one muon and three charged tracks. The selection criteria on the muon and charged tracks are shown in table 1. τ leptons decaying to three charged particles ($\tau_{3\text{prong}}$) are reconstructed by requiring three high-purity charged tracks (pions) that share a common vertex. This vertex must be within 2.5 mm of the primary vertex in the z-direction [4]. The analysis selection requirements for the $\tau_{3\text{prong}}$ and τ_μ candidates are shown in table 1.

Table 1: Analysis selection requirements

Muon	$p_T > 3.5$ for $\eta < 1.2$
	$p_T > 2.5$ for $1.2 < \eta < 2.4$
Pions	$p_T^{\text{leading}} > 0.5$ & $p_T^{\text{subleading}} > 0.3$ for the (sub-)subleading
	$\eta < 2.5$
$\tau_{3\text{prong}}$	$p_T^{\text{vis}} > 2$ and $0.2 < m_\tau^{\text{vis}} < 1.5$

3 Background estimation

The Monte Carlo (MC) signal sample is generated with MADGRAPH5_aMC@NLO(v2.6.5)[5], PYTHIA8 [6] is used for the hadronization and decay, and GEANT4[7] is used to model the detector effects. Background contamination is estimated in a data-driven way, using control regions composed of the phase space with higher numbers of charged hadron tracks per event or higher energy deposits in HF.

4 Uncertainties

The uncertainty on the cross section due to the HF energy scale measurement is 0.9%, and is measured by varying the HF scale by 10%. An additional uncertainty of 0.6% is introduced due to the background shape estimate changing as a function of variations of the n_{ch} parameter. The uncertainty on the muon reconstruction scale factors, including the trigger response, identification and tracking efficiency, results in a 6.7% of uncertainty. The pion tracking scale factor adds an uncertainty of 3.6%. The uncertainty due to MC sample size is 4.2%. An overall systematic uncertainty of 9.7% was determined.

5 Signal extraction

The signal extraction process involves a binned maximum likelihood fit of both the signal and background components. Specifically, the binned distribution of the difference in azimuthal angle between the τ_{μ} and τ_{3prong} candidate is used for the fitting. In addition to bin by bin variations of the signal and background templates, systematic uncertainties are taken into account through the incorporation of nuisance parameters in the fit. The negative of the log likelihood function is minimized by adjusting the nuisance parameters in accordance with their uncertainties and by scaling the signal using a multiplicative factor μ.
The best fit value of the signal strength is given by the minimum, which corresponds to $\mu = 0.99^{+0.16}_{-0.14}$ with $\mathrm{N}^{\tau\tau}_{\mathrm{sig}} = 77 \pm 12$ signal events in the integral of the postfit signal component. The fit result is shown in Fig. 2, here the signal template is represented by the magenta histogram, the background by the green histogram, and the data by the black points. The contributions are stacked with their total uncertainty represented by the blue hatched area.

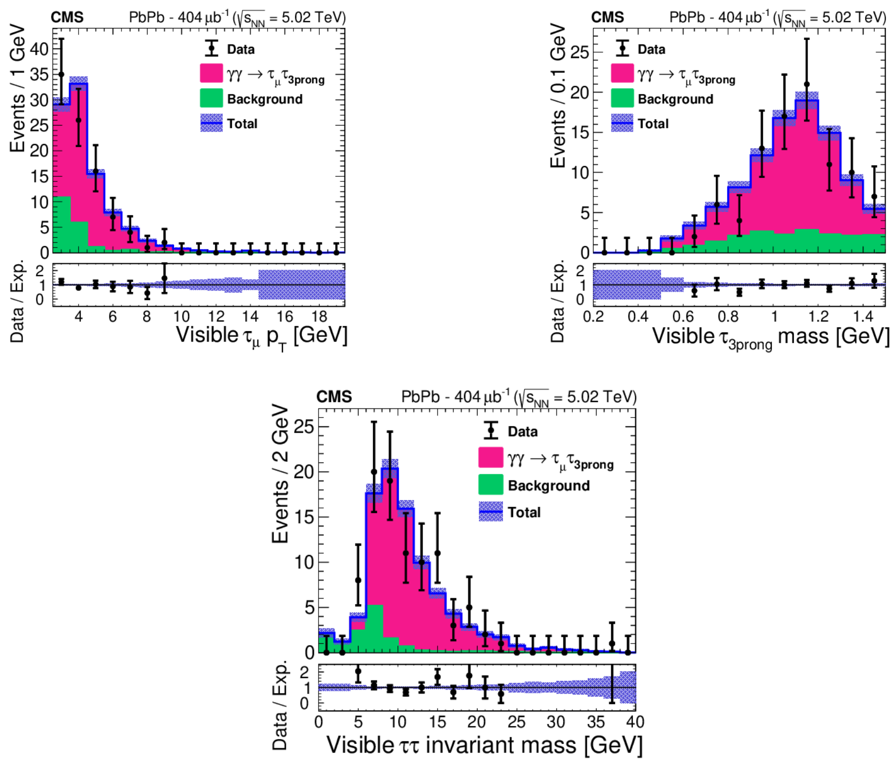

Figure 1: Top left: Transverse momentum of the τ_μ candidate. Top right: Invariant mass of the three pions forming the $\tau_{3\text{prong}}$ candidate. Bottom: $\tau\tau$ invariant mass

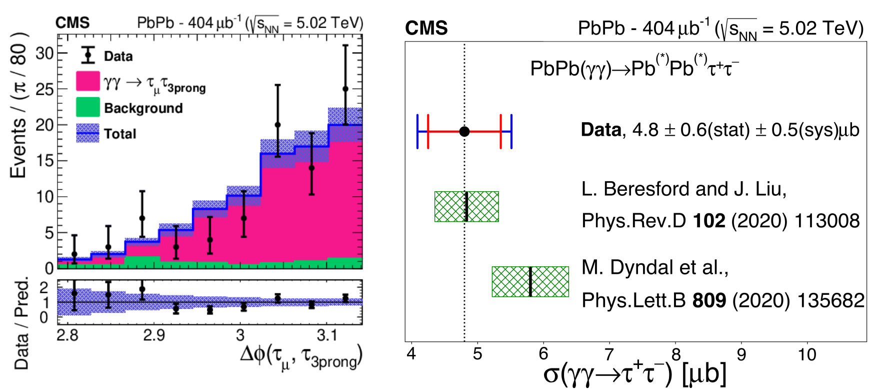

Figure 2: Left:Difference in azimuthal opening angle between the τ_μ and $\tau_{3\text{prong}}$, Right: The cross section, σ measured in a fiducial phase space region

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6 Results

The fiducial cross-section is measured as $\sigma(\gamma\gamma \to \tau^\pm\tau^\mp) = 4.8 \pm 0.6(stat) \pm 0.5(syst)$ μb, which is in agreement with predictions from quantum electrodynamics at leading-order accuracy[8, 9]. The significance of this process exceeds five standard deviations. To impose limits on model-dependent a_τ, variations of $\sigma(\gamma\gamma \to \tau^\pm\tau^\mp)$ are utilized. Limits on a_τ corresponding to a 68% confidence level are set at $(8.8 < a_\tau < 5.6)\times 10^{-2}$.

7 Summary

This proceeding summarizes the first observation of τ lepton production in lead-lead collisions at $\sqrt{s} = 5.02$ TeV by the CMS collaboration, making use of an integrated luminosity of $404\mu b^{-1}$, and measured in the final state with one τ lepton decaying to a muon and the other decaying to three charged pions. The cross section is measured to be $\sigma(\gamma\gamma \to \tau^\pm\tau^\mp) = 4.8 \pm 0.6(\text{stat}) \pm 0.5(\text{syst})$ μb. Using the measured cross-section, the model-dependent limits on a_τ are found to be $(8.8 < a_\tau < 5.6) \times 10^{-2}$ at 68% confidence level.

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