

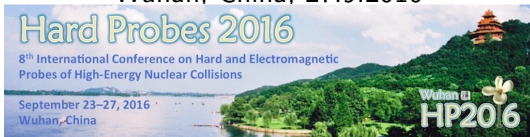
Light-by-light scattering in ultra-peripheral Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector



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Light-by-light scattering in ultra-peripheral Pb+Pb collisions at $\sqrt{s_{NN}} = 5.02$ TeV with the ATLAS detector



Motivation

Elastic scattering of two photons.

- Tested indirectly in measurements of the anomalous magnetic moment of the electron and muon.
- Previous LbyL measurements involve Delbruck scattering and photon splitting process at low-energies.

A possible channel to study:

- Anomalous gauge couplings.
- Contributions from BSM particles.



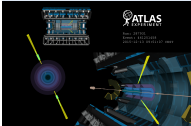
- In SM box diagram involve charged fermions (leptons or quarks) and W bosons.
- Pb ions are a source of strong electromagnetic field.
- Very small Q^2 of initial photons for PbPb results in small p_t of produced photons.



Selection	Data	Signal $\gamma\gamma \rightarrow e^+e^-$	$gg \rightarrow \gamma\gamma$	Hadronic fakes	Other fakes	Total expected
Preselection	105	9.1	74	4.7	6	113
$N_{ch} = 0$	39	8.7	4.0	4.5	6	19
$p_T^{\gamma\gamma} < 2$ GeV	21	8.5	3.5	4.4	3	21
$\text{Acc} < 0.01$	13	7.3	1.3	0.9	0.3	9.9
Uncertainty	1.5	0.3	0.5	0.3	0.1	

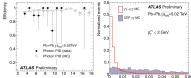
Event characteristics

- Two back-to-back photons ($E_{\gamma 1} = 12$ GeV and $E_{\gamma 2} = 11$ GeV) with an invariant mass of 24 GeV with no additional activity.



Trigger

- Minimal activity in the EM calorimeter (total E_{γ} between 5 GeV and 200 GeV).
- No activity in the forward direction.
- Minimal activity in the tracker.



Selection

- Two photons with $E_{\gamma} > 3$ GeV and $|\eta| < 2.4$
- $m_{\gamma\gamma} > 6$ GeV
- $p_T^{\gamma\gamma} < 2$ GeV
- Diphoton acoplanarity, $1 - \Delta\phi_{\gamma\gamma} / \pi < 0.01$ (back-to-back)
- Optimized photon identification is used to achieve sufficient efficiency in low E_{γ} region.

Background

- Electron final states – two electrons originating from a 1-channel photon-photon annihilation.
- Quark and gluon final states – low p_t dijet events can produce multiple π^0 mesons that could potentially mimic diphoton events.
- Central exclusive production of meson pairs – mesons can fake photons either by their intermediate decay to photons or by misreconstructed charged-particle tracks.
- Other fake backgrounds – fake diphoton events can occur e.g. due to noise in the calorimeter.



Results

- In total, 13 events were observed in data where 7.3 signal events and 0.6 background events are expected.

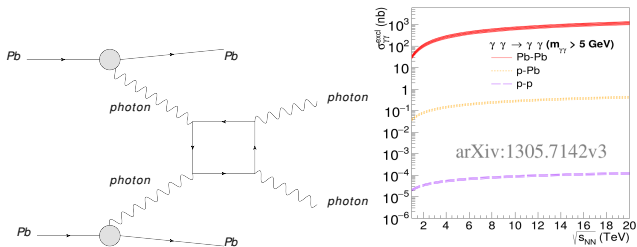
The cross section of $\gamma\gamma \rightarrow \gamma\gamma$ process is measured to be 70 ± 20 (stat) ± 17 (sys) nb, which is in good agreement with the SM prediction of 49 ± 10 nb. The observed signal significance is determined to be 4.4 σ , while the expected significance is 3.6 σ .



Physical motivation

Light-by-light ($\gamma\gamma \rightarrow \gamma\gamma$) scattering:

- elastic scattering of two photons,
- tested indirectly in measurements of the anomalous magnetic moment of the electron and muon,
- no direct measurement so far (very small cross section),
 - first opportunity to measure in PbPb due to Z^4 enhancement
- propose to study anomalous gauge couplings and contribution from BSM.



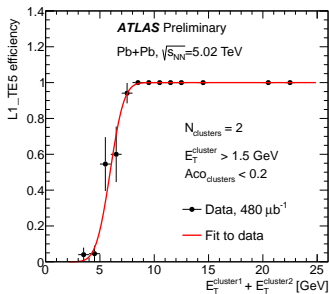
Trigger and fiducial region

Trigger:

- minimal activity in the EM calorimeter (total E_T between 5 GeV and 200 GeV),
- no activity in the forward direction,
- minimal activity in the tracker.

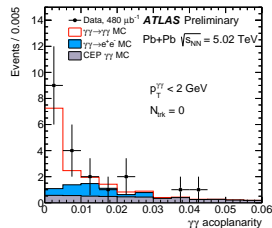
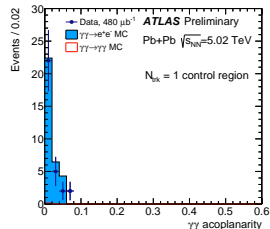
Fiducial region:

- two photons with $E_T > 3$ GeV and $|\eta| < 2.4$,
- $m_{\gamma\gamma} > 6$ GeV,
- $p_T^{\gamma\gamma} < 2$ GeV,
- track veto,
- Diphoton acoplanarity, $1 - \Delta\phi/\pi < 0.01$ (back-to-back).



Background

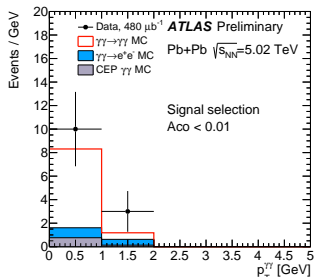
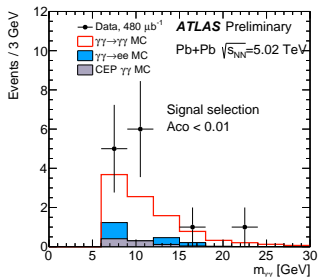
- $\gamma\gamma \rightarrow e^+e^-$ - data and MC prediction in control region (one or two tracks) are comparable
- $\gamma\gamma \rightarrow q\bar{q}$ - negligible contribution as no events out of 10^5 simulated events pass the track veto.
- exclusive two-meson production - cross section is estimated to be very small as compared to diphoton CEP, thus considered to have a negligible contribution
- central exclusive production $gg \rightarrow \gamma\gamma$ - reduced significantly by the requirement on diphoton acoplanarity ($A_{co} < 0.01$). Normalisation performed in the control region $A_{co} > 0.01$ and it is lower 50% than in MC.
- other background (cosmic-ray muons, EM calorimeter noise) - estimated from data using control regions.



Results

- measured cross section $\sigma_{fid} = 70 \pm 20 \text{ stat} \pm 17 \text{ (syst)} \text{ nb}$
- predicted cross section $\sigma_{fid} = 49 \pm 10 \text{ nb}$ (arxiv:1601.07001)

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Uncertainty		1.5	0.3	0.5	0.3	0.1	



Two back-to-back photons ($E_T = 12$ GeV and $E_T = 11$ GeV) with $m_{\gamma\gamma}$ of 24 GeV with no additional activity.

