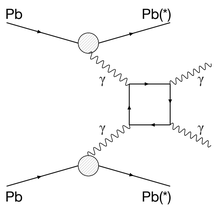
Light-by-light scattering in ultra-peripheral Pb+Pb collisions in the ATLAS experiment

Klaudia Maj, for the ATLAS Collaboration

HP2020, 31.05-05.06.2020

MOTIVATION



Light-by-light scattering is a rare $O(\alpha_{EM}^4)$ QED process
→ can be observed in heavy-ion collisions due to large EM fields associated with relativistic ions
→ sensitive to NEW Physics (axion-like particles, aQGC, ...)

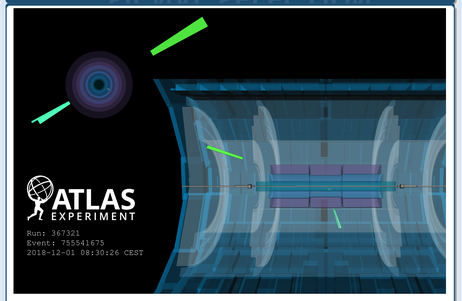
Previous LHC measurements:

- ATLAS Nat. Phys. 13 (2017) 852 ($\sim 4\sigma$ evidence)
- CMS Phys. Lett. B 797 (2019) 134826 ($\sim 4\sigma$ evidence)
- ATLAS Phys. Rev. Lett. 123 (2019) 052001 (8.2σ observation)

This analysis:

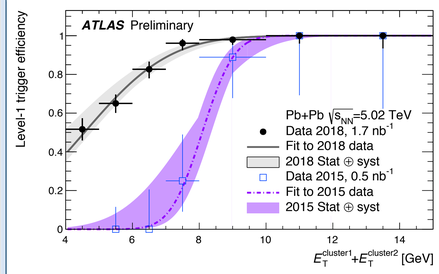
- **Combine 2015 and 2018 Pb+Pb data with 2.2nb^{-1}**
- Differential cross-section measurements
- BSM interpretation: search for the production of axion-like particles (ALP)

SIGNAL SELECTION



- Exactly two photons with $E_T > 2.5$ GeV and $|\eta| < 2.37$
- Invariant diphoton mass $m_{\gamma\gamma} > 5$ GeV
- Veto extra activity in ID
  → No tracks with $p_T > 100$ MeV
  → No pixel tracks with $p_T > 50$ MeV and $|\Delta\eta(\gamma, track)| < 0.5$
- Back-to-back topology
  → $p_T^{\gamma\gamma} < 1$ GeV (2 GeV for $m_{\gamma\gamma} > 12$ GeV)
  → Acoplanarity $(= 1 - \frac{|\Delta\phi|}{\pi}) < 0.01$

TRIGGER PERFORMANCE



Level-1 trigger efficiencies determined using $\gamma\gamma \to e^+e^-$ process in data

- Triggered by independent support triggers
- Efficiency at Level-1 improved in 2018 wrt. 2015
- Applied to simulated events to correct yields

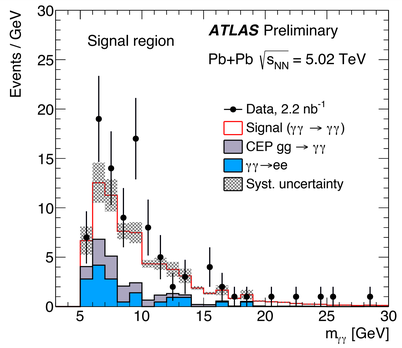
High Level Trigger (HLT) efficiency is higher than 99%

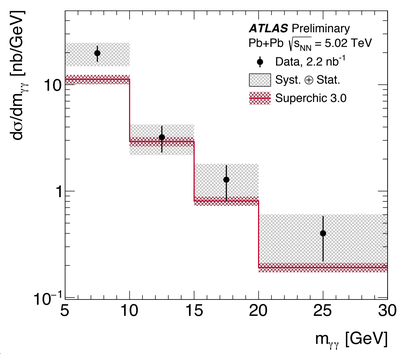
RESULTS

ATLAS-CONF-2020-010

ANALYSIS OF 2015+18 Pb+Pb DATA WITH 2.2 nb^{-1}

97 events observed, **45** signal and **27±5** background events expected





Measured fiducial cross section:
$\sigma_{\text{fid}} = 120 \pm 17\,(\text{stat.}) \pm 13\,(\text{syst.}) \pm 4\,(\text{lumi.})$ nb
Theory predictions:
$\sigma_{\text{fid}}^{\text{theory1}} = 78 \pm 8$ nb (SuperChic 3 MC)
$\sigma_{\text{fid}}^{\text{theory2}} = 80 \pm 8$ nb (Phys. Rev. C 93 (2016) 044907)

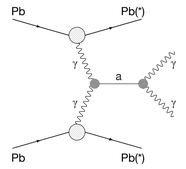
Differential distributions:

- cross sections for diphoton: $m_{\gamma\gamma}$, $|y_{\gamma\gamma}|$, $(p_T^{\gamma 1} + p_T^{\gamma 2})/2$ and $|cos\theta^*|$
- **Good agreement in shape**, differences in the normalisation

SEARCH FOR ALP $\gamma\gamma \to a \to \gamma\gamma$ PRODUCTION

Axion like particles (ALP):

- (pseudo-) scalar particles with typically weak interactions with SM particles
- have identical signature as SM Light-by-light scattering

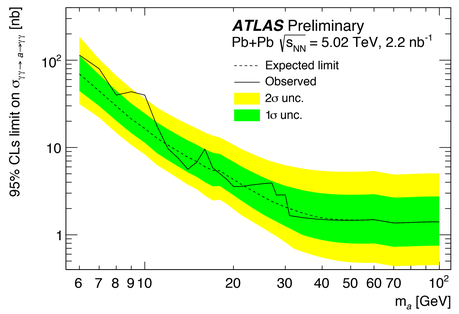


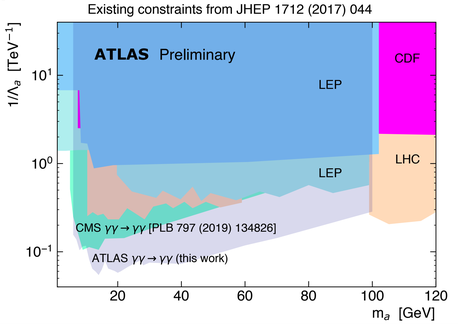
Idea:

- search for new narrow resonances via $\gamma\gamma \to a \to \gamma\gamma$ reaction using cut-and-count method
- Signal: $\gamma\gamma \to a \to \gamma\gamma$, BR($a \to \gamma\gamma$)=100%
- Background: LbyL, $\gamma\gamma \to e^+e^-$, CEP gg→ $\gamma\gamma$

Results:

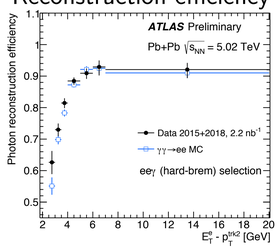
- 95% CL limits on ALP production cross section and ALP coupling to photons
- Largest excess observed around 10 GeV ($\sim 2.1\sigma$)
- **The most stringent limit established for diphoton masses of $6 < m_a < 100$ GeV**





PHOTON IDENTIFICATION

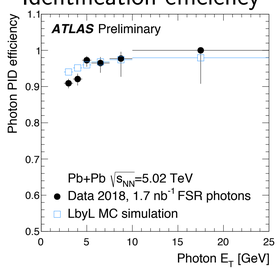
Reconstruction efficiency



Photon reconstruction:

- Using e+e- events where a hard bremsstrahlung photon was radiated
- Efficiency is 60% for E_T=2.5 GeV, and reaches 90% at E_T=6 GeV

Identification efficiency



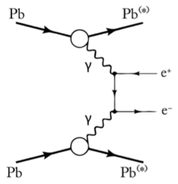
Photon identification:

- Using $\gamma\gamma \to l^+l^-\gamma$ events
- Neutral network based PID, optimized for low-E_T photons
- Efficiency exceeds 90%

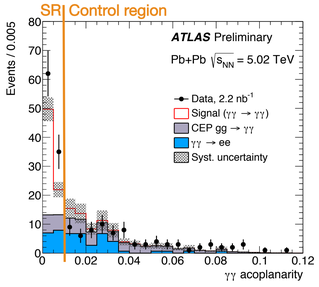
Good modelling in MC simulation

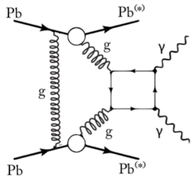
- Differences between data and MC simulation included in dedicated corrections

BACKGROUND PROCESSES



Exclusive production of electron pairs $\gamma\gamma \to e + e-$
→ evaluated using a data-driven method





Central Exclusive Production (CEP) $gg \to \gamma\gamma$

- Gluonic initial state → nuclear breakup, larger initial transverse momentum and broader shape of acoplanarity distribution
- Evaluated from a control region in data (acoplanarity>0.01)
- **Total background in SR: 27±5 events**

AGH University of Science and Technology

This work was supported in part by the National Science Centre, Poland, grant DEC-2016/23/B/ST2/01409 and by PL-Grid Infrastructure