Ultra-peripheral collisions with the ATLAS detector

Miguel Arratia
Cavendish Laboratory, University of Cambridge

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The LHC is a Large Photon Collider

...it produces, at that point, a variable electric field. If we decompose this field, via a Fourier transform, into its harmonic components we find that it is equivalent to the electric field at the same point if it were struck by light with an appropriate continuous distribution of frequencies...

Nuovo Cim., 2:143-158, 1925

With lead beams, electromagnetic cross-sections scale by

\[ Z^4 \approx 5 \times 10^7 \]

Maximum photon energy given by

\[ E < \gamma/R \approx 80 \text{ GeV} \]
The first ATLAS UPC measurement is this:

\[ \approx 10^{14} \, \text{T} \]

We can study QED with strong fields.

Measurement of high-mass dimuon pairs in ultra-peripheral lead-lead collisions at $\sqrt{s_{\text{NN}}}=5.02$ TeV with the ATLAS detector at the LHC
Theory

This luminosity also enters photo-nuclear and photon-pomeron reactions

\[
\frac{d^2 \sigma}{dM_{\mu\mu} \, dY_{\mu\mu}} = \frac{d^2 \mathcal{L}_{\gamma\gamma}}{dM \, dY} \times \sigma(\gamma\gamma \rightarrow \mu\mu)
\]

"Equivalent Photon Approximation":

\[
n(k,b) = \frac{d^3 N}{dkd^2b} = \frac{Z^2 \alpha}{\pi^2 b^2} x^2 K_1^2(x)
\]
Muon Spectrometer

Multiple layers of tracking and trigger chambers that cover $|\eta| < 2.4$

Momentum measurement with bending from azimuthal magnetic field.

Standalone operation (can do tracking, vertexing without inner detector)
The 2015 lead—lead run

Luminosity calibrated with van der Meer scan with a 7% systematic uncertainty.
Trigger strategy

• Require 1 muon
• Veto activity by requiring $ET < 50$ GeV,
  No more than one hit in forward scintillators
• At least one track with 400 MeV
Event Selection

Total number of triggered events is 248k

- Two opposite-sign and good-quality muons with:
  \[ p_{T1}, p_{T2} > 4 \text{ GeV}, \, |\eta_1|, |\eta_2| < 2.4 \]

- At least one muon compatible with trigger particle
- Muons form a vertex
- There are no other good tracks in the event

Total number of events selected is 12069
Run: 287038
Event: 71765109
2015-11-30 23:20:10 CEST

Dimuons UPC Pb+Pb 5.02 TeV
(Uncorrected) single-muon distributions

- Starlight 1.1 MC is used to generate exclusive dimuon pairs. Leading order QED calculation.
- Good MC description of distributions of reconstructed muons
Corrections

- Muon trigger efficiency > 80% (data)
- Muon reconstruction efficiency > 90% (data)
- Vertex efficiency ~97% (MC)
- Muon resolution negligible

Event-by-event weight for total dimuon efficiency, assuming factorization, is given by:

\[
\frac{1}{W} = \epsilon_R(\mu_1)\epsilon_R(\mu_2)(1 - (1 - \epsilon_T(\mu_1))(1 - \epsilon_T(\mu_2)))
\]
Acoplanarity distributions

Most of dimuon pairs are produced mostly back to back, as expected
Higher-order QED corrections?

- TASSO data well described when considering radiative corrections
- Maybe is the same for ATLAS data, we are investigating this.
Acoplanarity tails

• Starlight1.1 does not include radiative corrections. So we can't compare.

• Two options:
  1) Assume tail is background
  2) Assume tail is due radiative corrections

• The background fraction with acoplanarity<0.08 is 2–4%.

• Our preliminary result is average of 1) and 2).
  Difference is taken as systematic uncertainty
Good agreement with Starlight MC.
Surprising given that this is the first measurement in this kinematic region.
Good agreement with Starlight MC.
This is the first measurement in this kinematic region
Verifies $Z^4$ scaling of cross-section and photon flux
• First-order QED (Starlight) seems enough to describe the data in wide kinematic regime.
Conclusions and future prospects

• First ATLAS measurement of dimuon pairs from exclusive photon—photon fusion.

• Good agreement with Starlight MC (first order QED) suggesting good model of photon flux, which in turn will be useful for photonuclear or photo—pomeron studies (dijets, J/psi, rho, etc.)

• Using ZDC we will explore neutron emission and its effect on photon spectrum.