COLUMBIA UNIVERSITY
IN THE CITY OF NEW YORK

ATLAS EXPERIMENT

# Measurement of $\gamma\gamma \rightarrow \mu^+\mu^-$ Pairs in non-ultra peripheral Pb+Pb Collisions with the ATLAS Detector

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For the ATLAS Collaboration

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# Photoproduction in Pb+Pb Collisions



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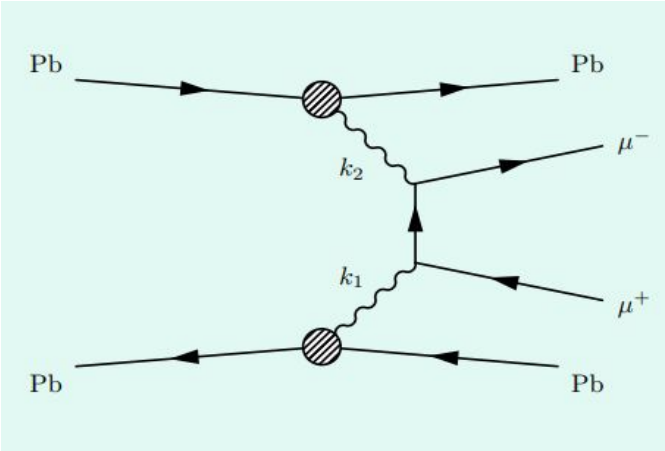

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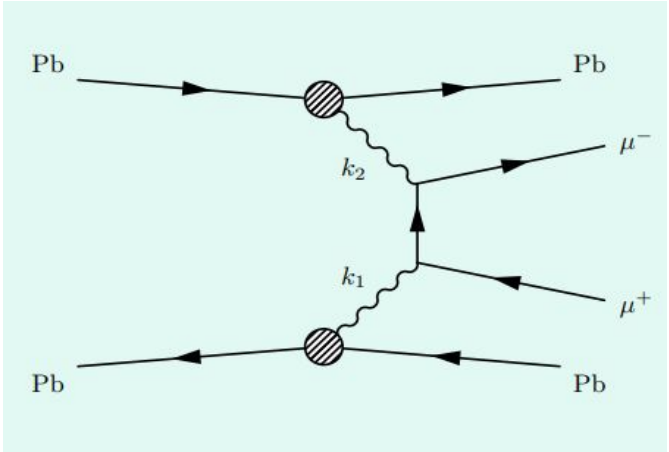
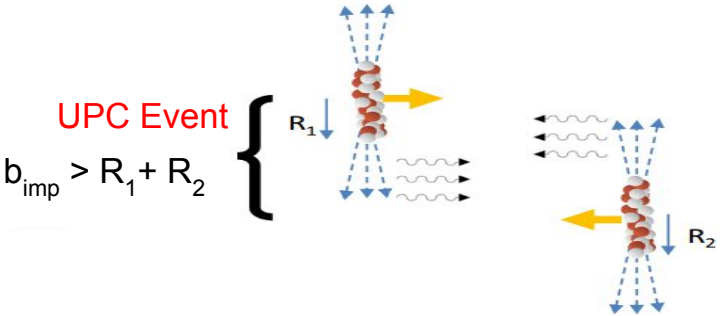
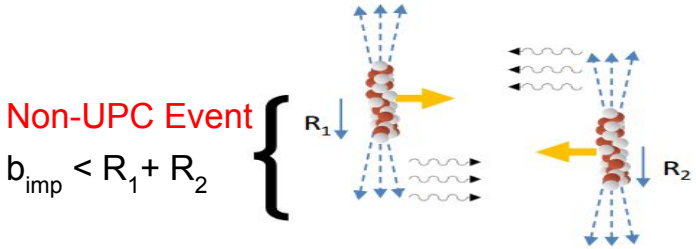


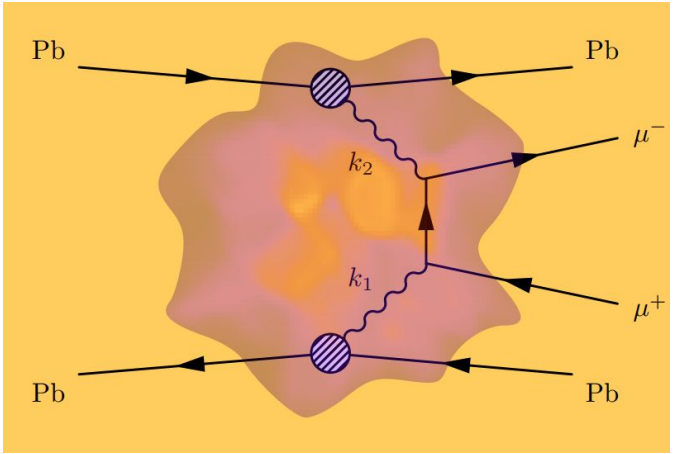



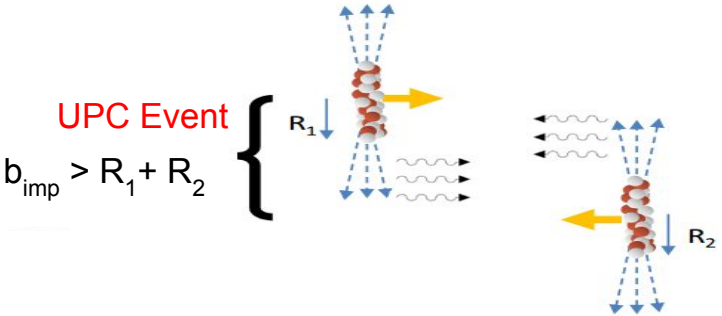



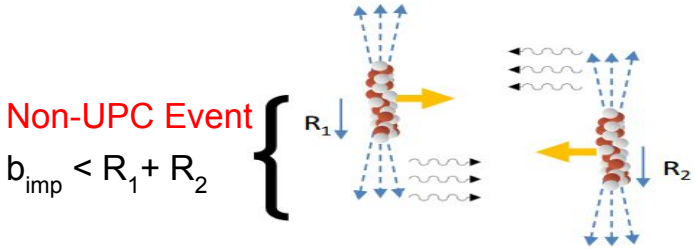
# Photoproduction in Pb+Pb Collisions



- The intense electromagnetic fields surrounding Lead ions in heavy ion collisions provide a flux of quasi-real photons for $\gamma\gamma$ processes.
- These photoproduction processes studied in Ultra-Peripheral Collisions (UPCs) are also present in hadronic Pb+Pb collisions.
- Dimuons produced via $\gamma\gamma$ scattering could provide a useful electromagnetic probe of the Quark-Gluon Plasma.



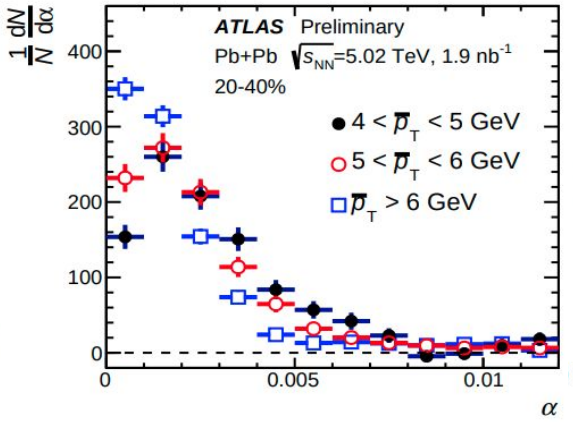



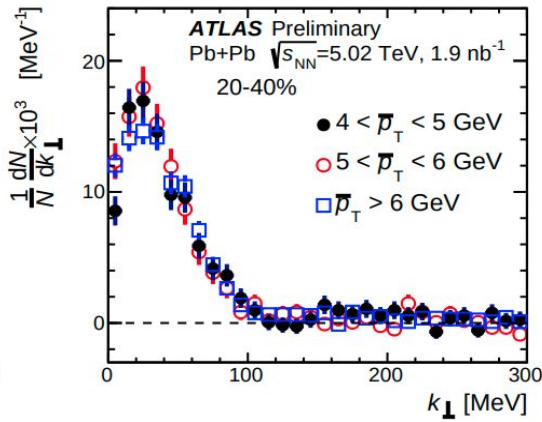
# Main Observables



- The primary background for this analysis is muon pairs produced via decays of heavy flavor quarks, which is subtracted via a template fitting procedure.
- After subtraction, 2 main variables are used to describe the relative deflection the muons:
  - Acoplanarity -- Angular deflection of the dimuon pair: $\alpha \equiv 1 - |\Delta\phi|/\pi$
  - $k_\perp$ -- Transverse momentum deflection of the pair: $k_\perp \equiv (p_{T1} + p_{T2})\,|(\pi - \Delta\phi)|/2$

- The shape of the $k_\perp$ distribution is independent of $p_T$, while the $\alpha$ distribution is $p_T$-independent.
- Since it incorporates $p_T$-dependent effects, $k_\perp$ is our preferred variable.



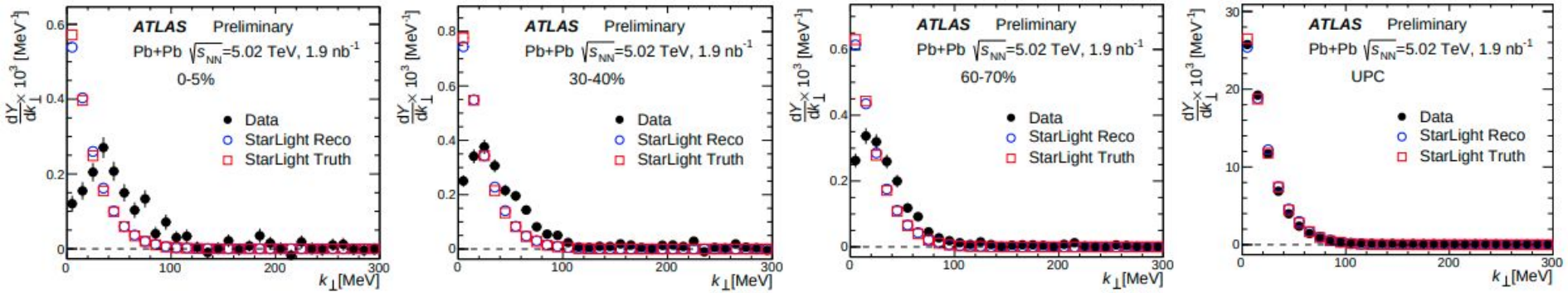



# New Behavior with Run 2 Data



- With the inclusion of LHC Run 2 data, this analysis is now sensitive to a non-zero peak position not observed in previous measurements.
  - The UPC data matches StarLight predictions well, but this depletion at small $k_\perp$ is not predicted in the Monte Carlo.
  - Several recent theoretical predictions offer explanations for the non-zero peak.
    - QED-Based interference effects (Zha, Brandenburg, Tang, Xu): https://doi.org/10.1016/j.physletb.2019.135089
    - Generalized EPA (Klein, Mueller, Xiao, Yuan): https://arxiv.org/abs/2003.02947
- The peak position increases from 0 in the UPC to being largest in the most central collisions.

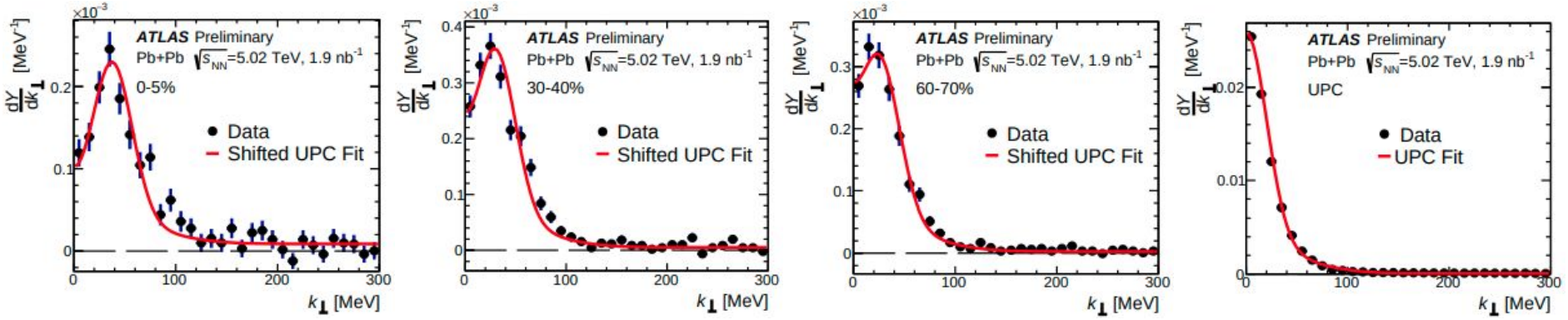
Central ⟵ UPC



# Fitting the Peak Position



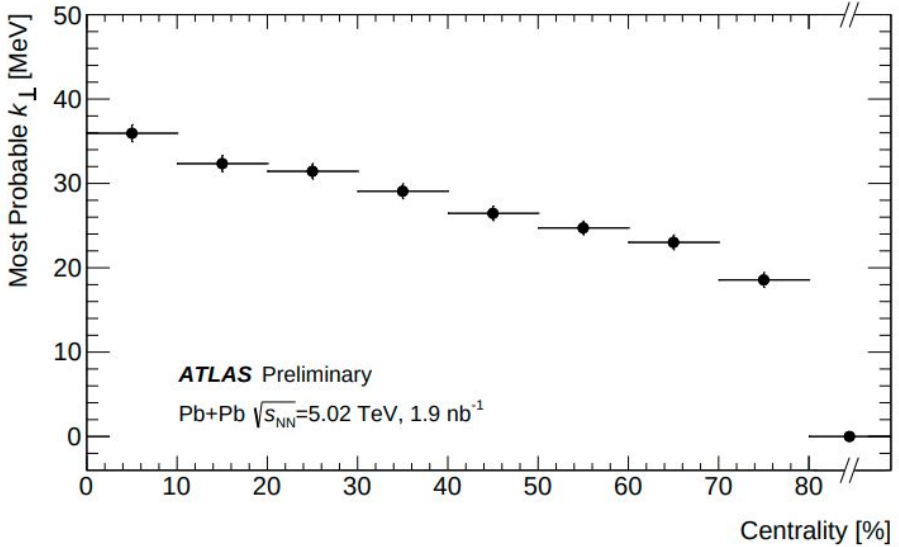
- In order to quantitatively understand the non-zero peak of the $k_\perp$ distribution as a function of centrality, a fitting procedure is applied:
  - First, the UPC bin is fitted with the sum of 2 Gaussians peaked at 0.
  - Next, this fit is symmetrized about 0 to get the “UPC Template”.
  - Finally, the UPC Template is fitted with 2 free parameters, a shift and a constant offset, to the measured $k_\perp$ distribution.
- This fit matches the actual data well and provides an effective characterization of the shift in the distribution as a function of centrality.



# Conclusions



- ATLAS measured non-exclusive dimuon photoproduction in Pb+Pb collisions at 5.02 TeV.
  - The most probable $k_{\perp}$ value measured increases to 36 ± 1 (stat + syst) MeV in the 0-5% interval from 19 ± 1 (stat + syst) MeV in the 70-80% interval and 0 for the UPC.
- Several theoretical predictions exist to explain this shift in the peak, but a more direct theory comparison is necessary in order to distinguish between them.




- For a more detailed description of the full analysis, the original CONF note is available at https://cds.cern.ch/record/2698293
- Thank you for your attention!