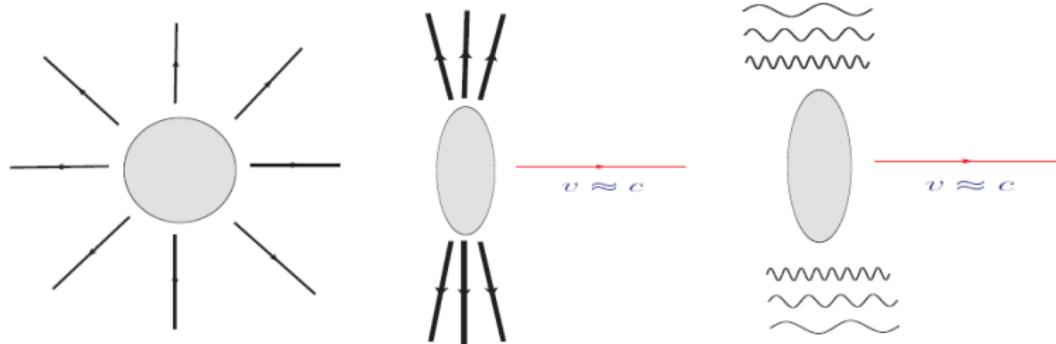


Photon–photon fusion and ultra-peripheral physics with ATLAS

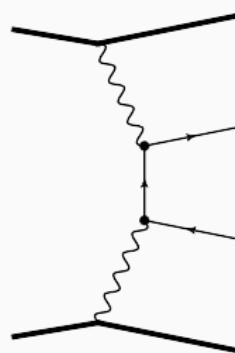
Rafał Staszewski
on behalf of the ATLAS Collaboration

ISMD 2021
50th International Symposium on Multiparticle Dynamics
12 – 16 July 2021

Two-photon processes

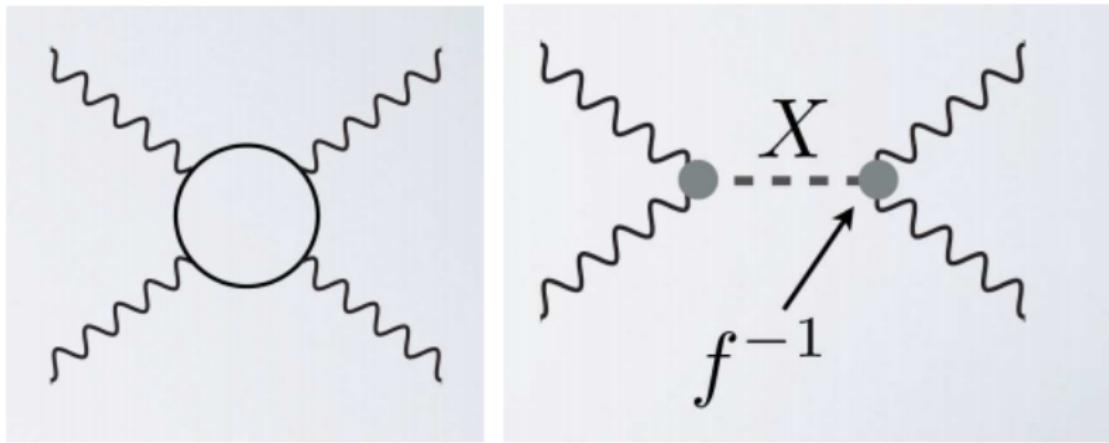


- Accelerated charged particles surrounded by photons
- Equivalent photon approximation
- Two-photon processes can be computed within QED

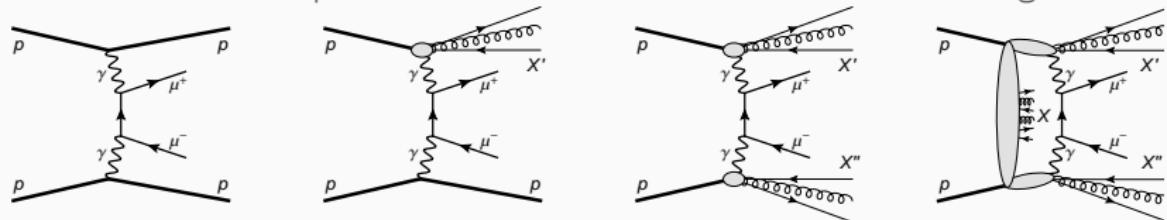


Motivation for research

EWK motivation – possible new particles:



QCD motivation – proton dissociation and additional exchanges:

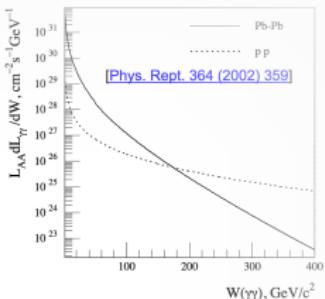


Plan of the talk

	PbPb	pp
EWK	$\gamma\gamma \rightarrow \gamma\gamma$ JHEP 03 (2021) 243	$\gamma\gamma \rightarrow WW \rightarrow e\mu$ PLB 816 (2021) 136190
QCD	$\gamma\gamma \rightarrow ll$ arxiv: 2011.12211	$\gamma\gamma \rightarrow ll$ PRL 125 (2020) 261801

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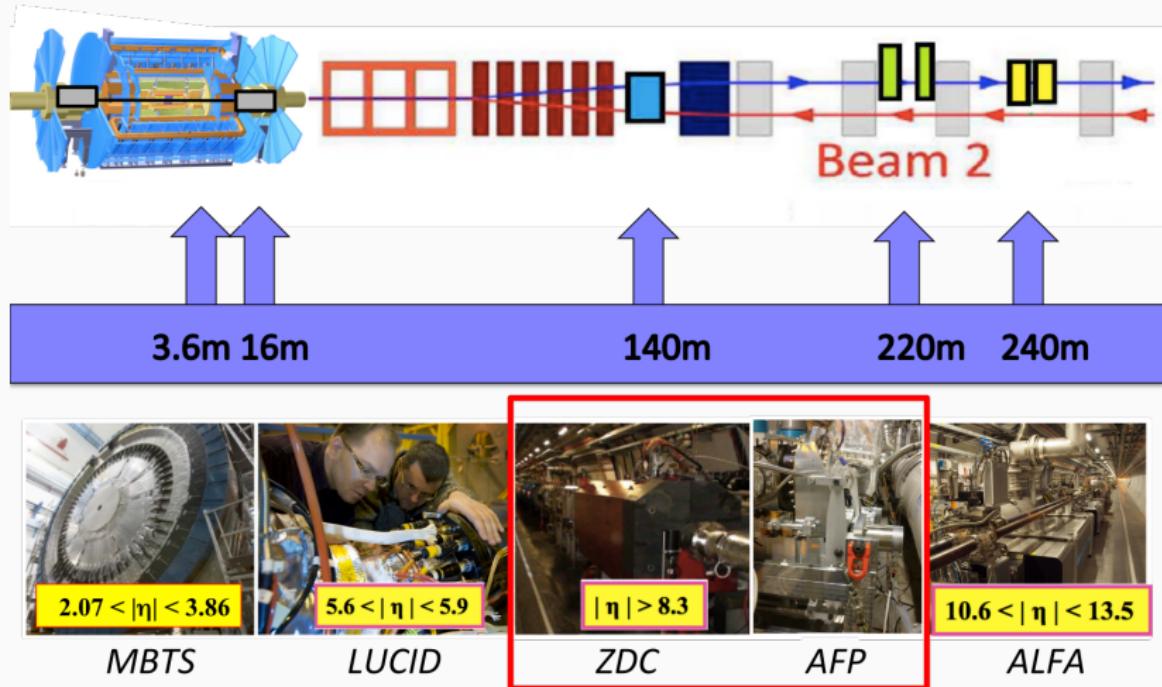
PbPb

- high charge
- low pile-up
- clean events

pp

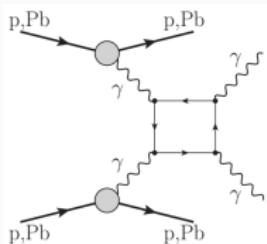
- high luminosity
- high pile-up
- busy events

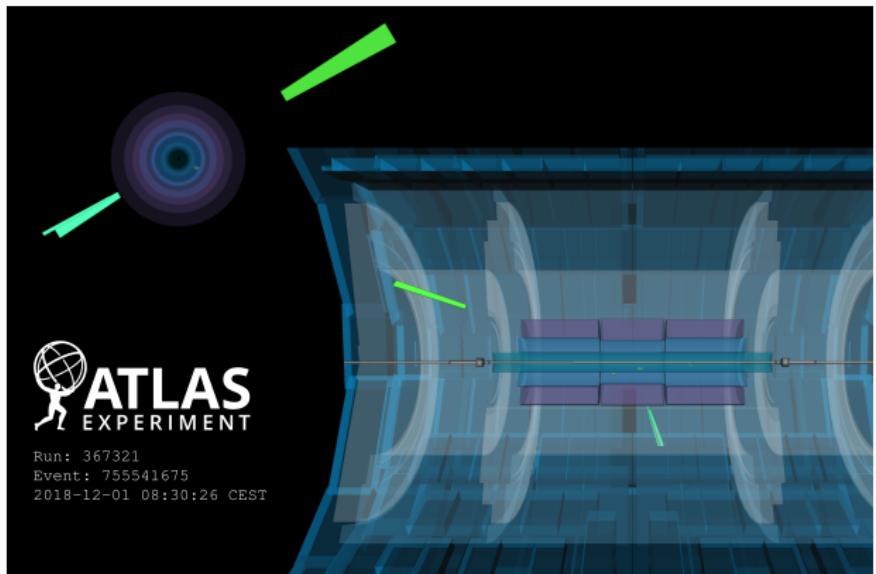
ATLAS forward detectors



ZDC = Zero Degree Calorimeter

AFP = ATLAS Forward Proton detectors

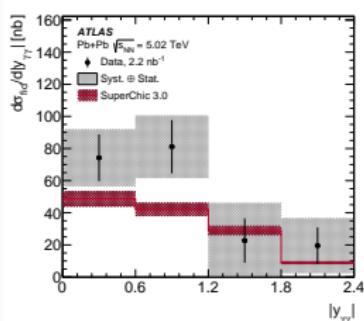
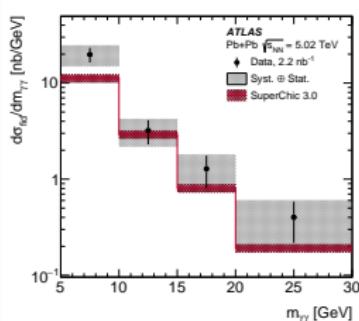
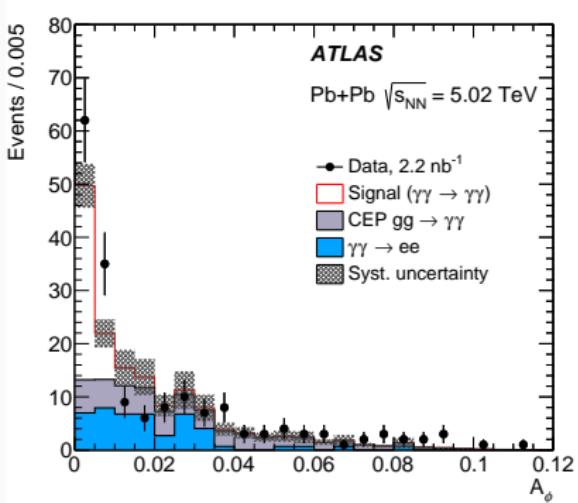


$$\gamma\gamma \rightarrow \gamma\gamma \text{ in PbPb}$$


Evidence: Nature Physics 13 (2017) 852

Observation: Phys. Rev. Lett. 123 (2019) 052001

Measurement of light-by-light scattering



Acoplanarity:

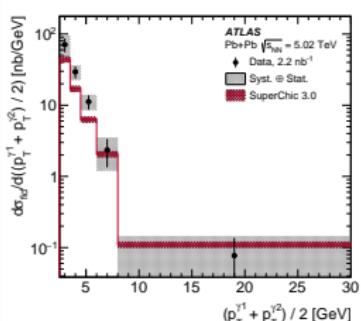
$$1 - |\Delta\phi|/\pi$$

Measured cross section:

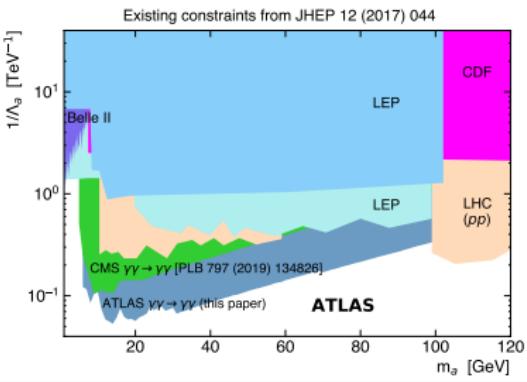
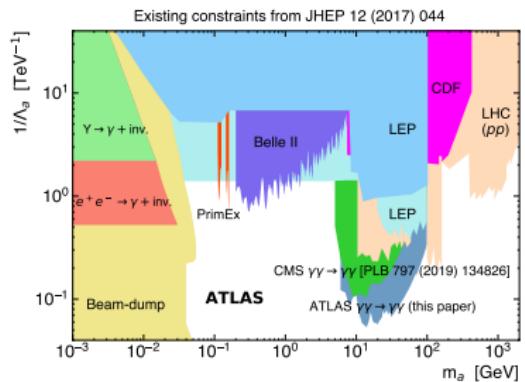
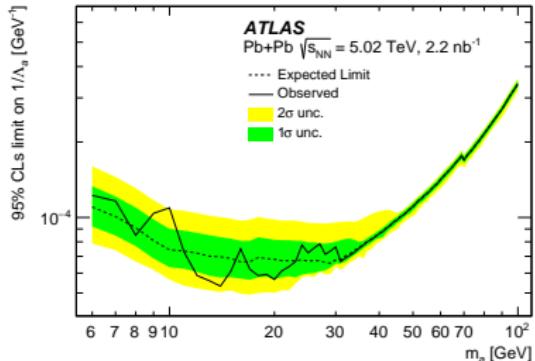
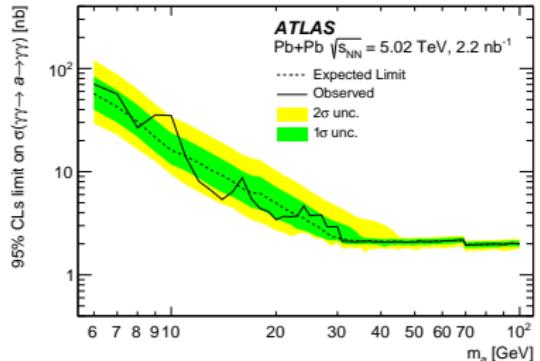
$$\begin{aligned} \sigma_{\text{fid}} &= 120 \pm 17 \text{ (stat.)} \\ &\pm 13 \text{ (syst.)} \pm 4 \text{ (lumi.)} \end{aligned}$$

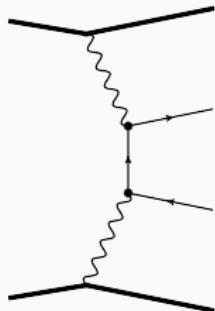
Data to SUPERCHIC 3 ratio:

$$1.54 \pm 0.32$$

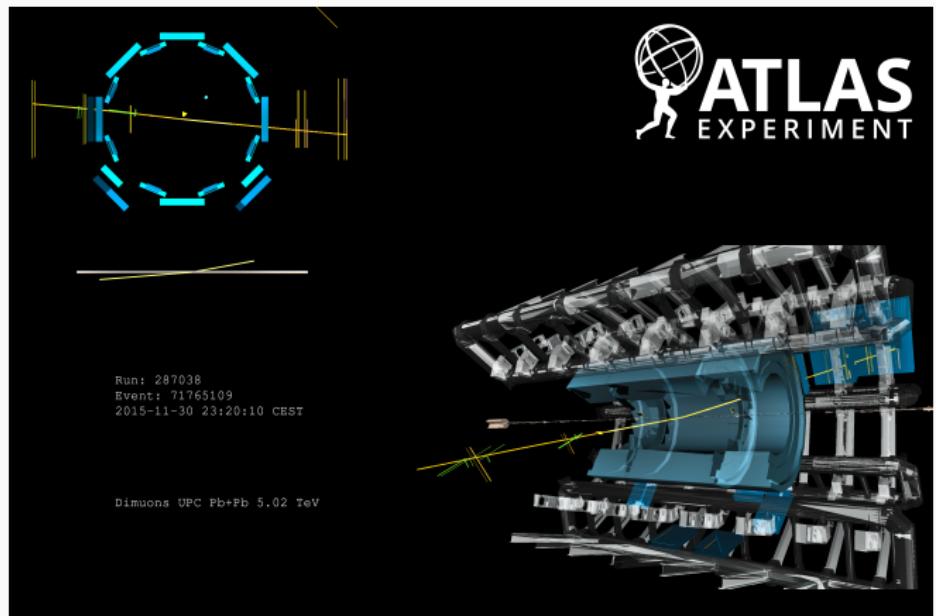


Search for ALP

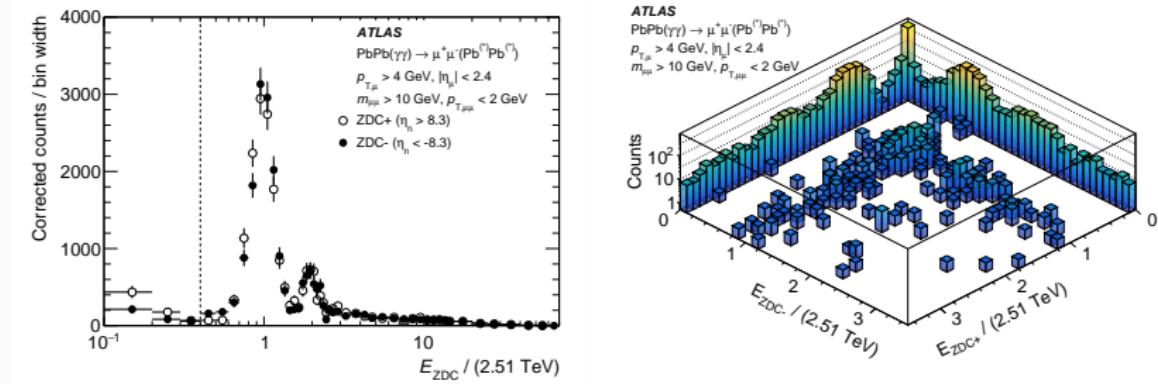




$\gamma\gamma \rightarrow ll$ in PbPb



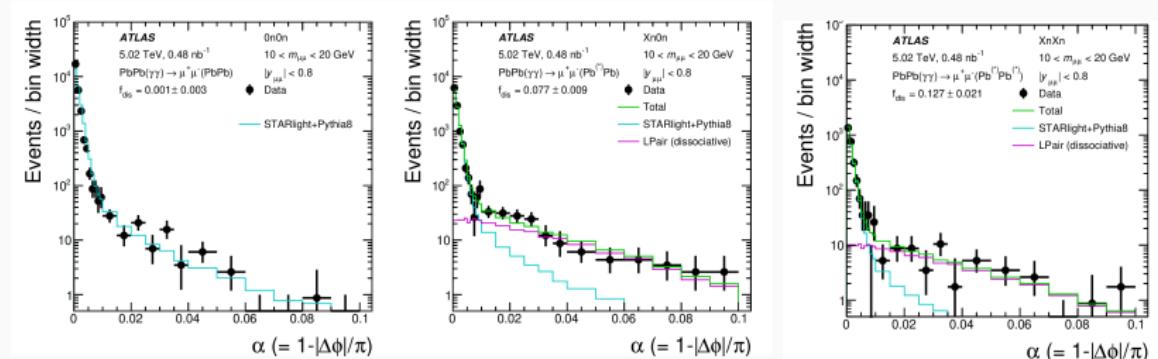
Using ZDC for identifying dissociation



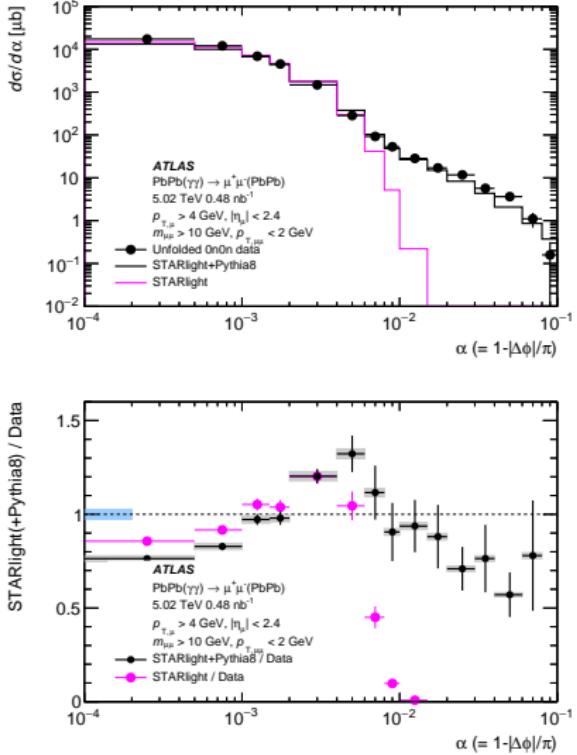
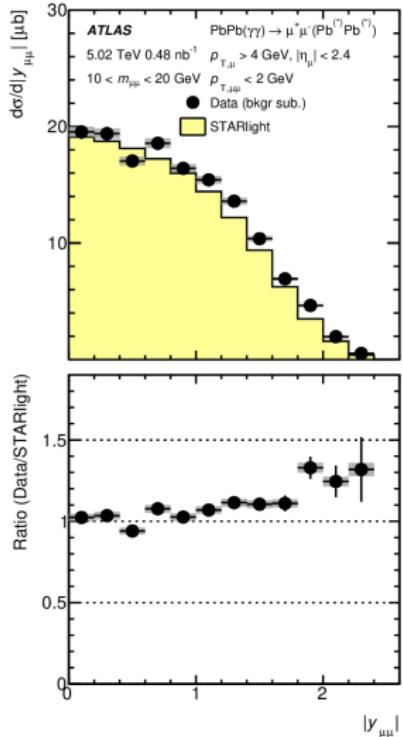
On + On

Xn + On

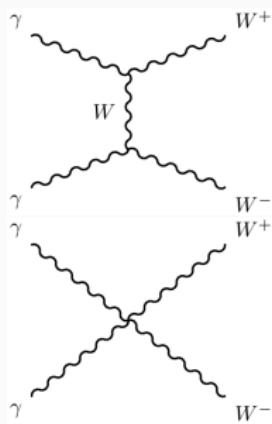
Xn + Xn

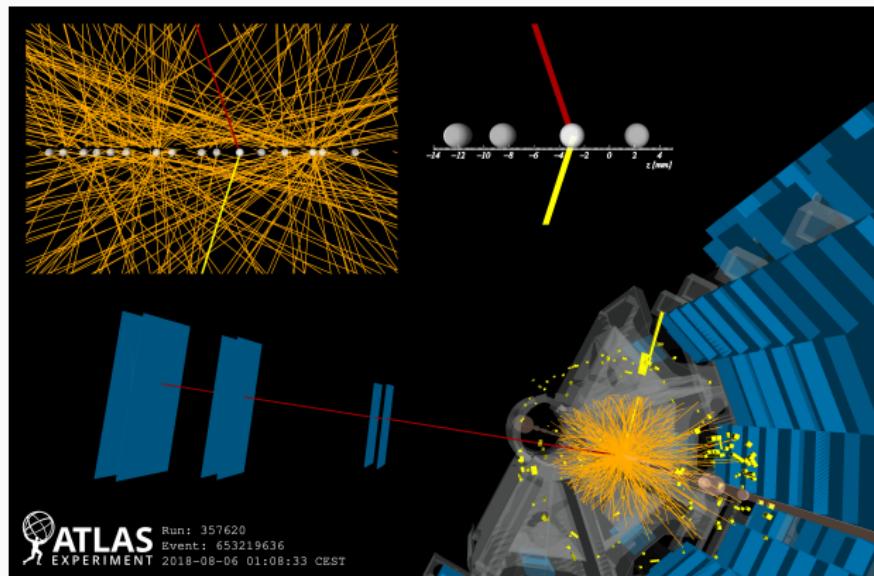


Differential measurements



Measurements also in different mass bins, as a function of mass, and as a function of $\vartheta_{\mu\mu}^*$ in different mass and rapidity bins

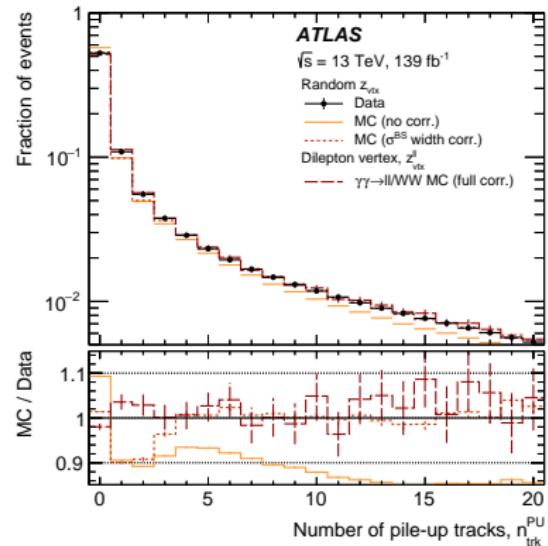


$$\gamma\gamma \rightarrow WW \rightarrow e\mu \text{ in pp}$$


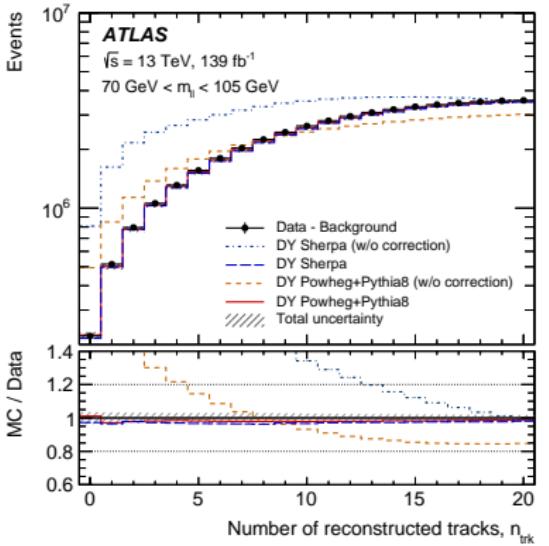
Evidence: Phys.Rev.D 94 (2016) 3, 032011

Modeling charged particles

Pile-up interactions

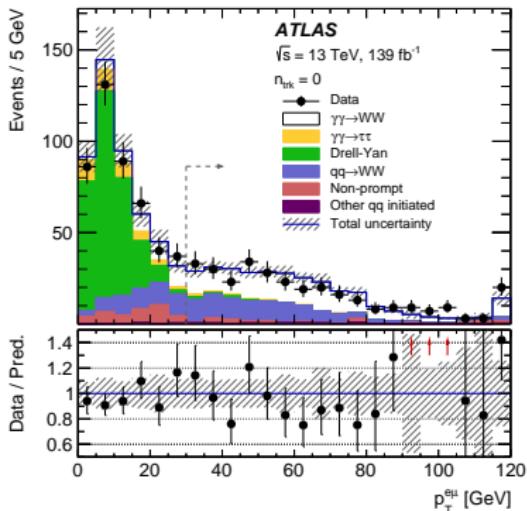
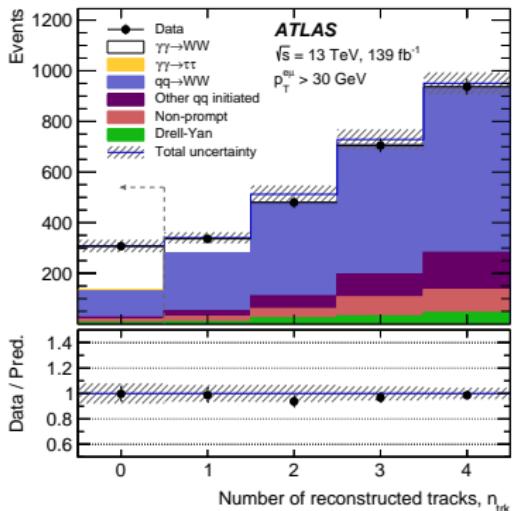


Underlying event

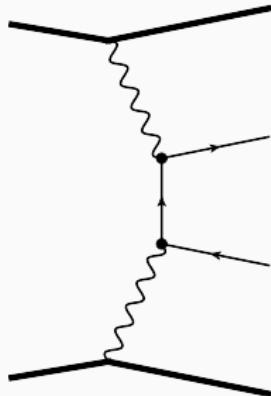


Important for understanding backgrounds and signal efficiency

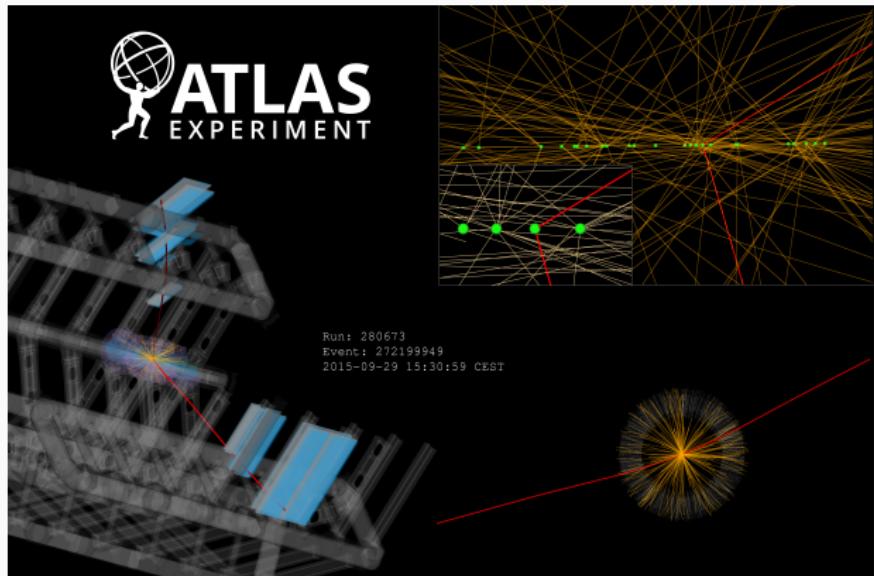
Event selection and results



- Measurement: $\sigma = 3.13 \pm 0.31(\text{stat.}) \pm 0.28(\text{syst.}) \text{ fb}$
- MG5_AMC@NLO+PYTHIA8 MMHT2015qed $\times S^2$: $\sigma = 2.8 \pm 0.8 \text{ fb}$
- MG5_AMC@NLO+PYTHIA8 CT14qed $\times S^2$: $\sigma = 3.5 \pm 1.0 \text{ fb}$
- HERWIG7 elastic rescaled: $\sigma = 2.34 \pm 0.27 \text{ fb}$

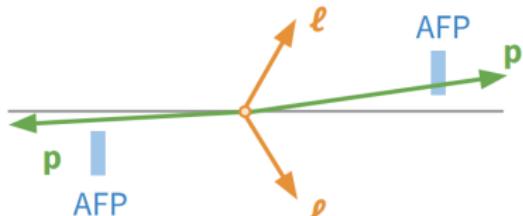


$\gamma\gamma \rightarrow ll$ in pp
with proton tagging



Analysis strategy

Signal:



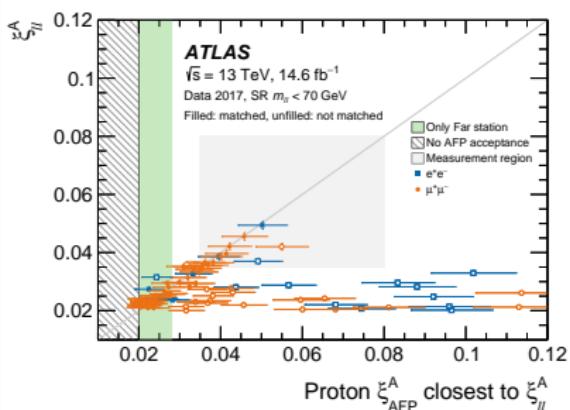
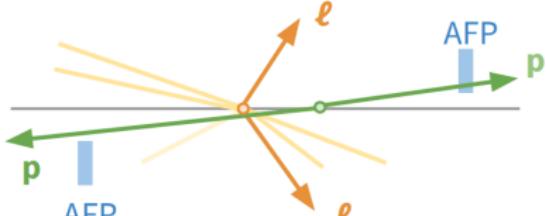
- ξ – fraction of proton energy carried by the photon
- ξ from proton measurement

$$\xi = 1 - E_p/E_{\text{beam}}$$

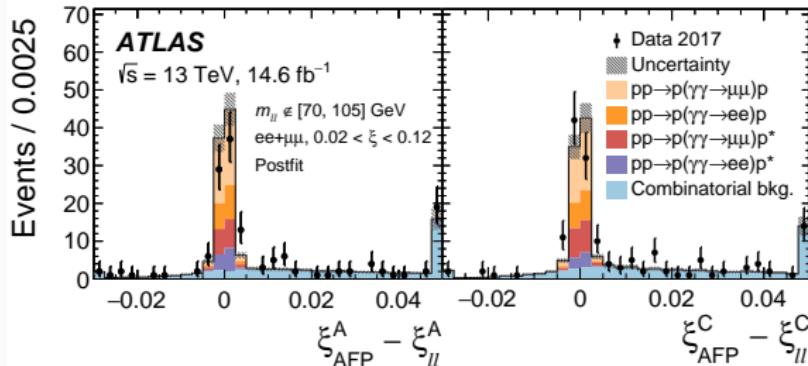
- ξ from $l\bar{l}$ system

$$\xi_{\pm} = \frac{M_{l\bar{l}}}{\sqrt{s}} \cdot e^{\pm y_{l\bar{l}}}$$

Background:



Kinematic matching and measurements



	$\sigma_{ee+p}^{\text{fid.}} [\text{fb}]$	$\sigma_{\mu\mu+p}^{\text{fid.}} [\text{fb}]$
Measurement	11.0 ± 2.9	7.2 ± 1.8
SUPERCHIC 4 predictions		
Exclusive + single-dissociative	12.2 ± 0.9	10.4 ± 0.7
Exclusive	8.6 ± 0.6	7.3 ± 0.5
Single-dissociative	3.6 ± 0.6	3.1 ± 0.5

Summary

- Photon–photon interactions present in hadron collisions
- Interesting both from EWK and QCD points of view
- ATLAS measurements in PbPb and pp collisions
- Important role of forward detectors:
 - ZDC – forward nucleons
 - AFP – forward protons