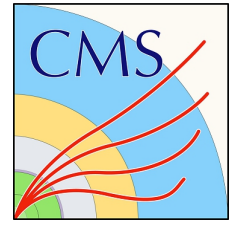
Light-by-light scattering and high mass dilepton production in UPC

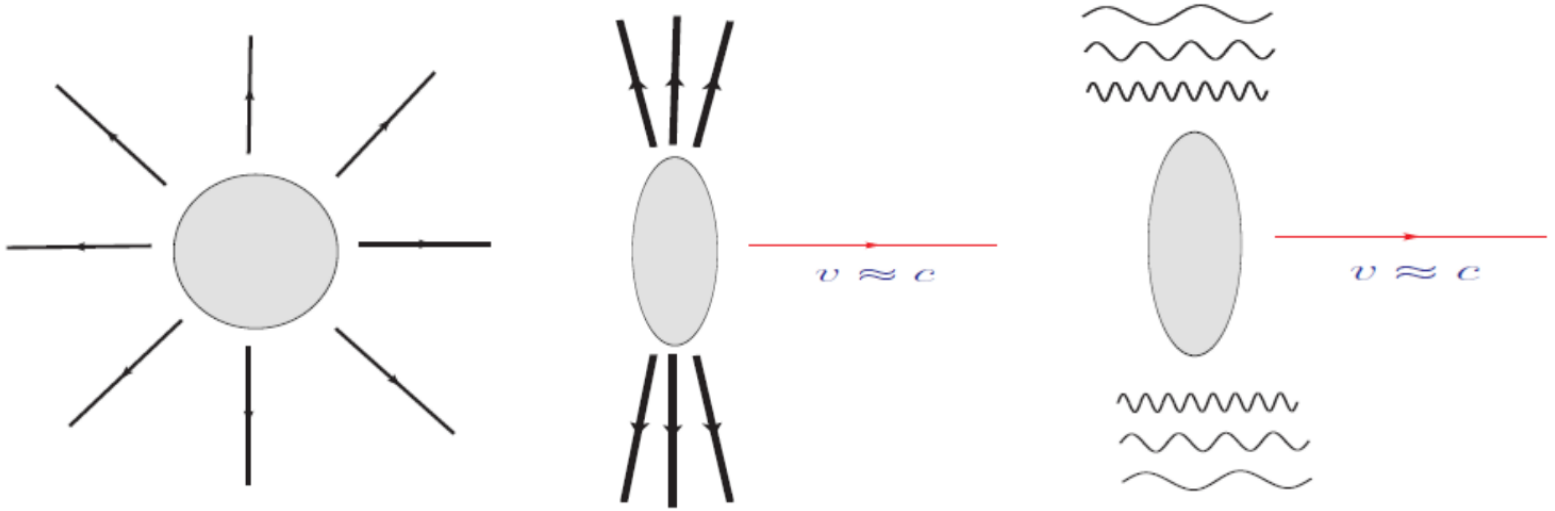
Krzysztof Cieśla

on behalf of the ATLAS and CMS collaborations

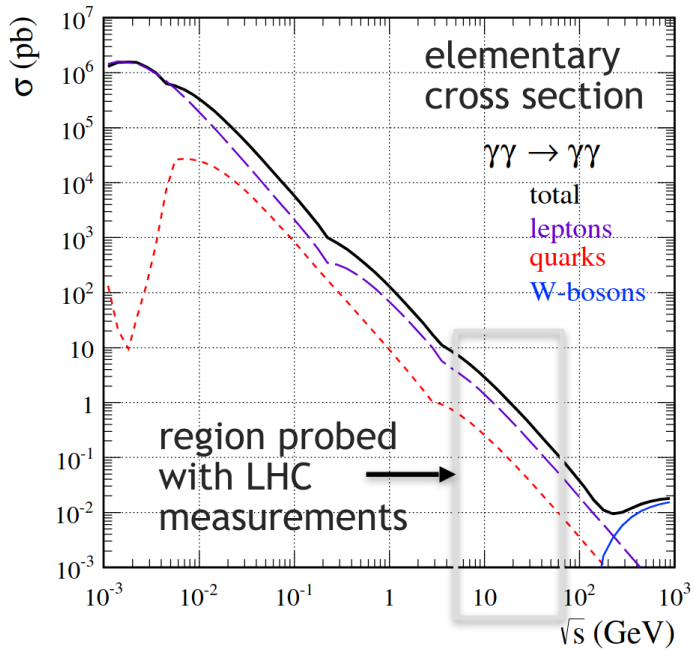


11^{th} Large Hadron Collider Physics Conference
22-26 May 2023

Photon-induced processes in heavy ions



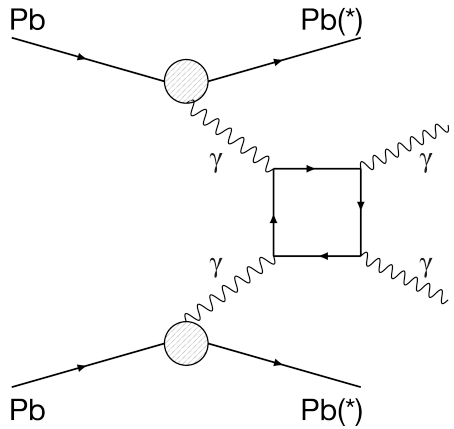
- Accelerated particles surrounded by photons
- Equivalent photon approximation
- Photon-photon interactions possible in Pb+Pb collisions at the LHC
  - Cross-section scales with Z^4
  - Cleaner events (compared to pp)

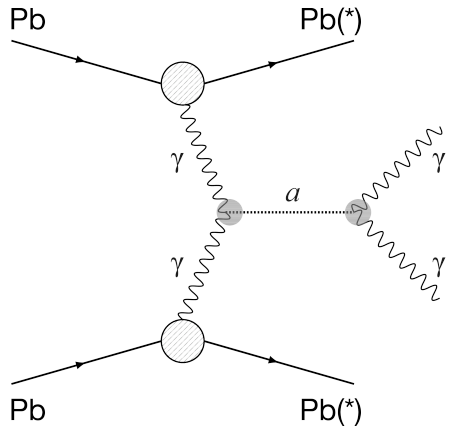


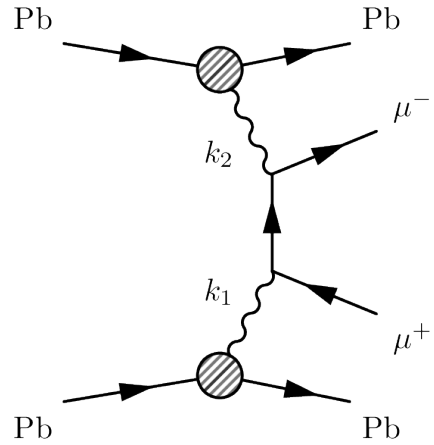
pp results @ TeV scale: see Anna's talk

Motivation

- Various types of photon-photon interactions possible, including:

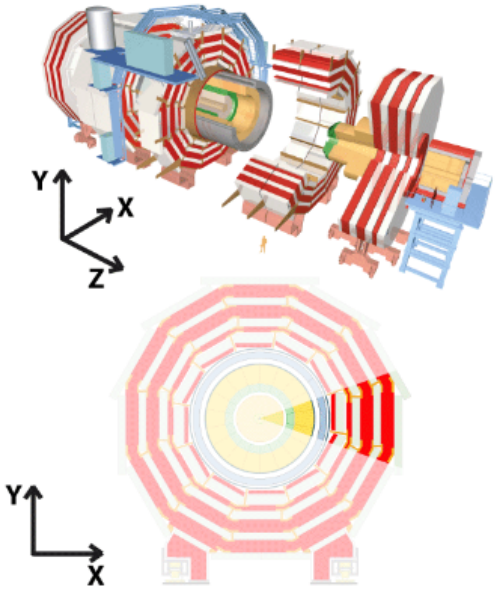


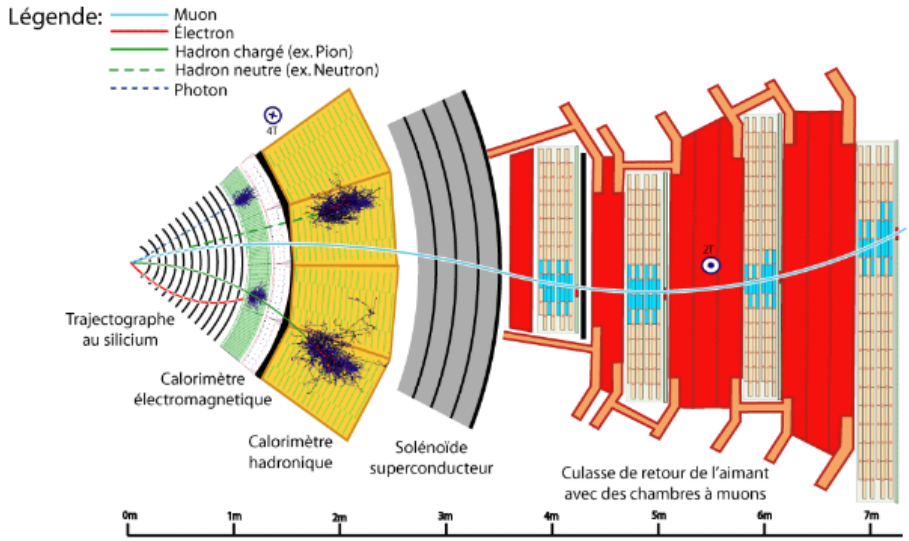


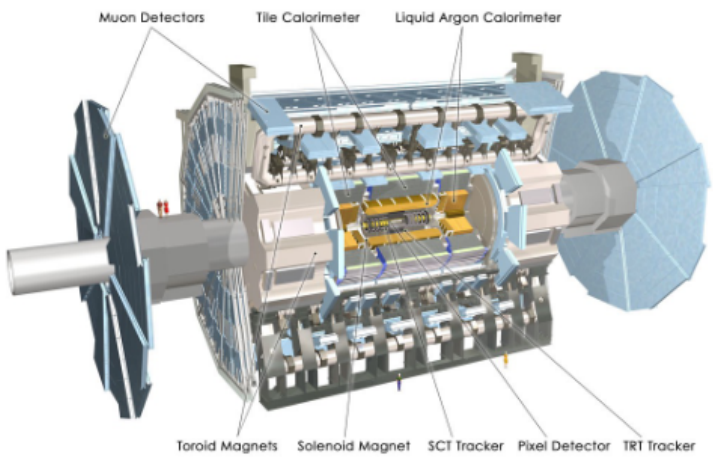


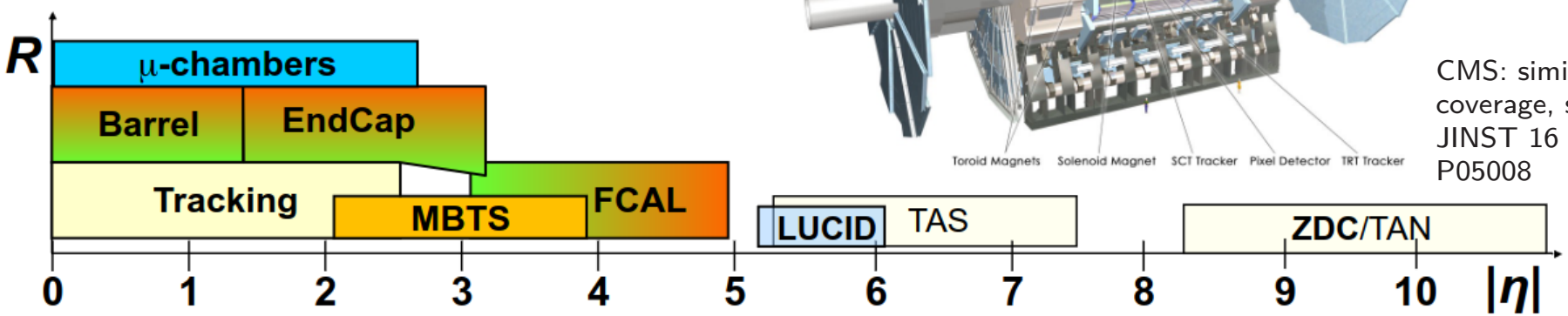
- Light-by-light ($\gamma\gamma \to \gamma\gamma$) scattering:
  - Forbidden at tree-level
  - Tested indirectly in electron/muon g-2 measurements
  - Clean channel to study anomalous gauge couplings and BSM searches
- Dilepton ($\gamma\gamma \to l^+l^-$) production:
  - Abundant rate $\to$ precision test of QED and initial photon flux modelling
  - Background for other processes

ATLAS and CMS detectors





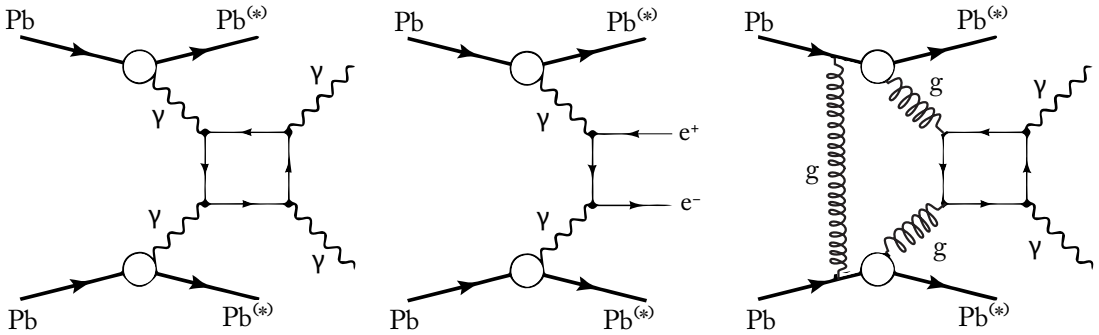




CMS: similar ZDC coverage, see: JINST 16 (2021) P05008

Measurement of light-by-light scattering

Phys. Lett. B 797 (2019) 134826



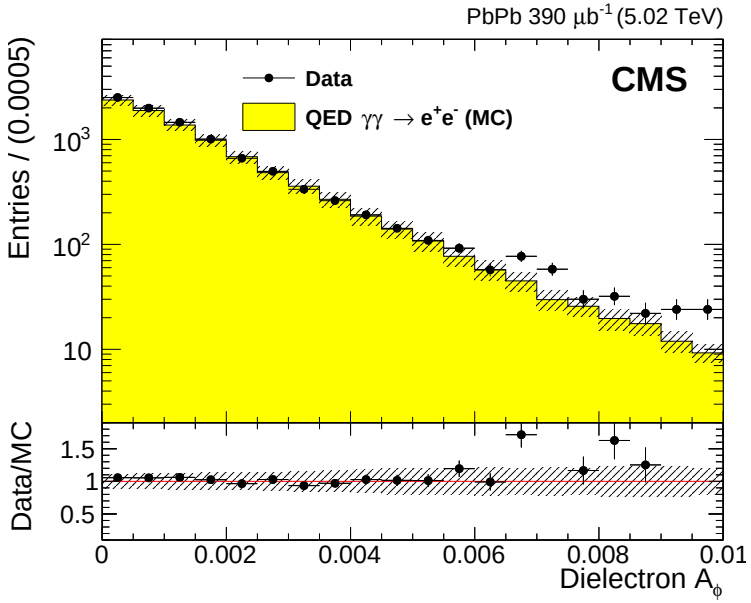
Main background:

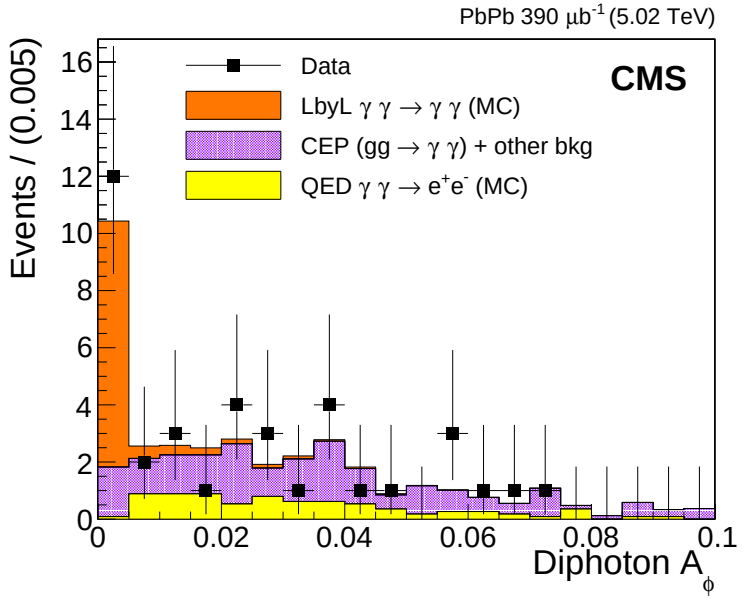
- Central exclusive production $gg \to \gamma\gamma$
- Misidentified electrons from $\gamma\gamma \to ee$
- Dedicated control regions used

Integrated fiducial cross-section:

- Measurement: $\sigma_{fid} = 120 \pm 46\ (stat.) \pm 28\ (syst.) \pm 12\ (theo.)$ nb
- Prediction[a]: $\sigma_{fid} = 116 \pm 12\ (stat.)$ nb

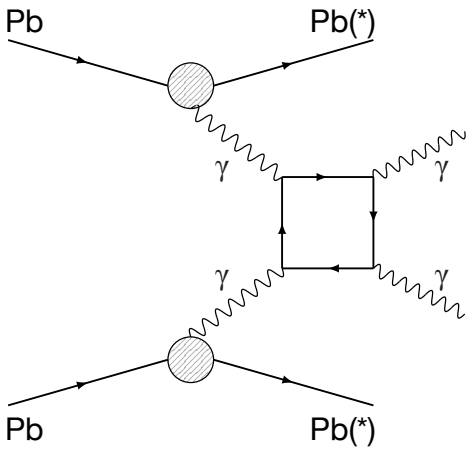
[a] PRL 111, 080405 (2013)





Measurement of light-by-light scattering

JHEP 03 (2021) 243



Integrated fiducial cross-section:

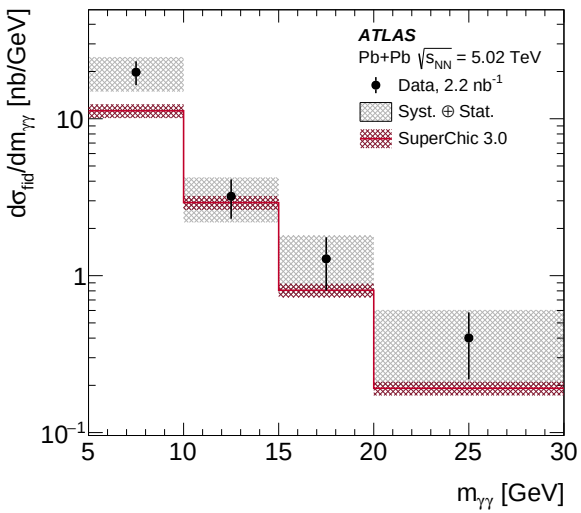
- Measurement:

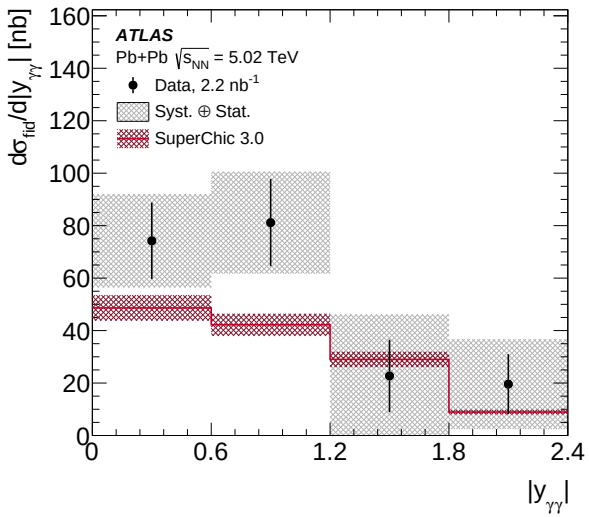
$$\sigma_{fid} = 120 \pm 17(stat.) \pm 13(syst.) \pm 4(lumi.) \text{ nb}$$

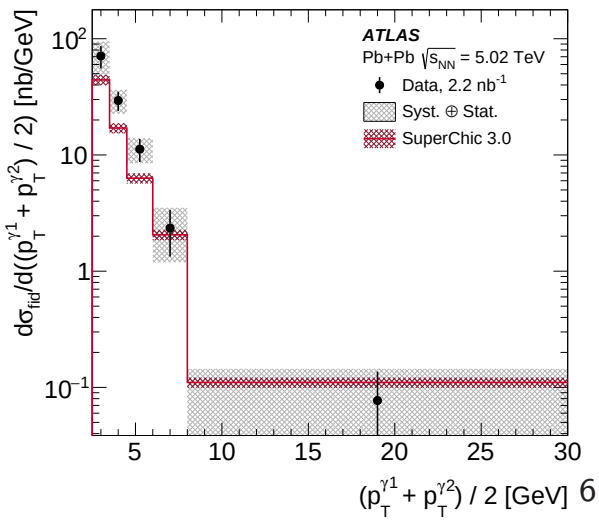
- SuperChic prediction: 78 ± 8 nb
- Data to SuperChic ratio: 1.54 ± 0.32

Differential cross-section:

- Uncertainties dominated by statistics
- No significant differences between predictions and data



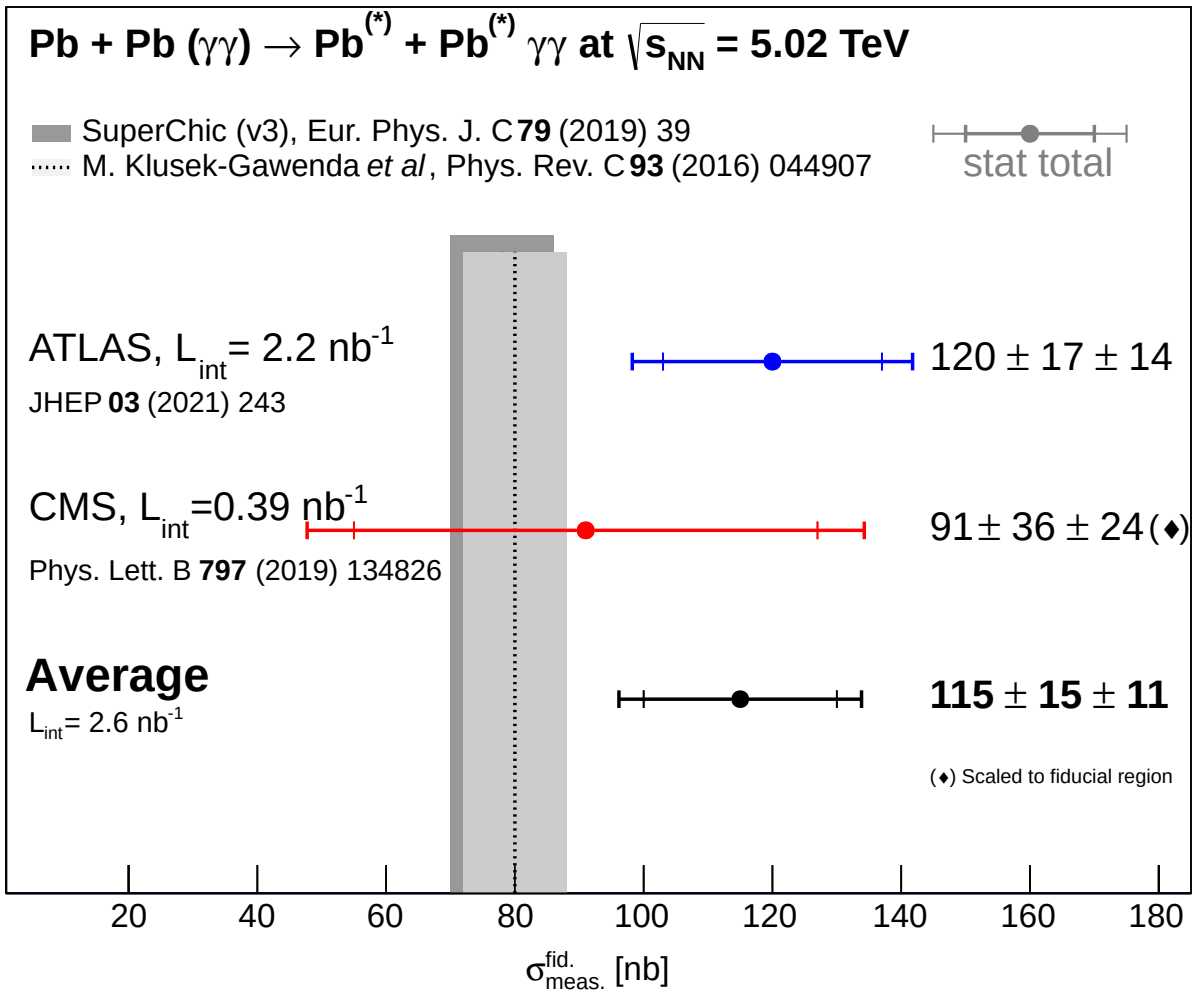




Measurement of light-by-light scattering

arXiv:2204.02845, G. K. Krintiras, et al.

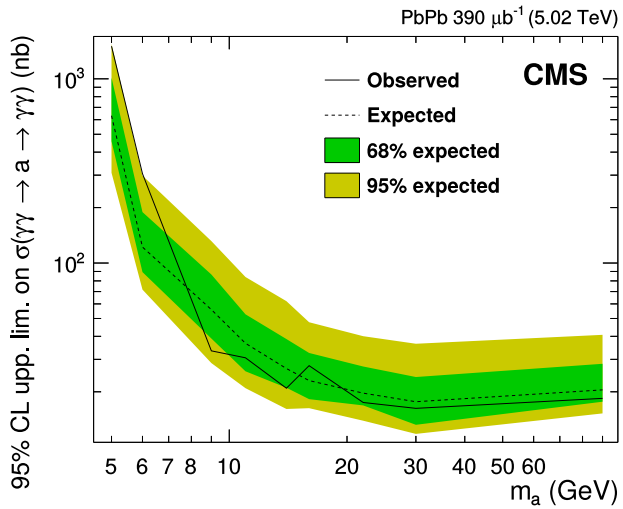
- Combining ATLAS+CMS measurements in a „common" fiducial phase-space
- The averaged cross-section consistent within about two standard deviations with the SM predictions

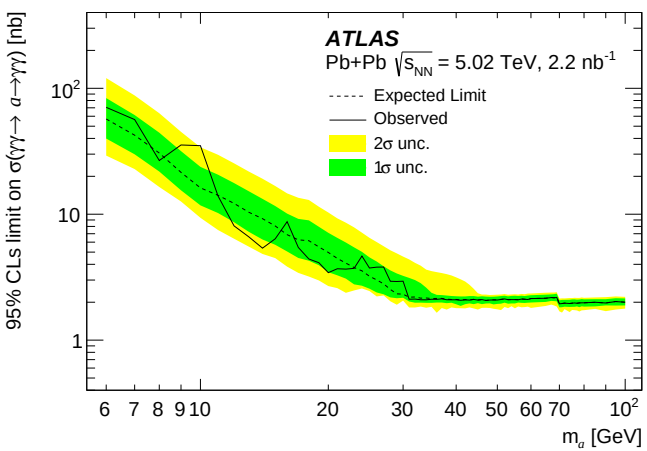


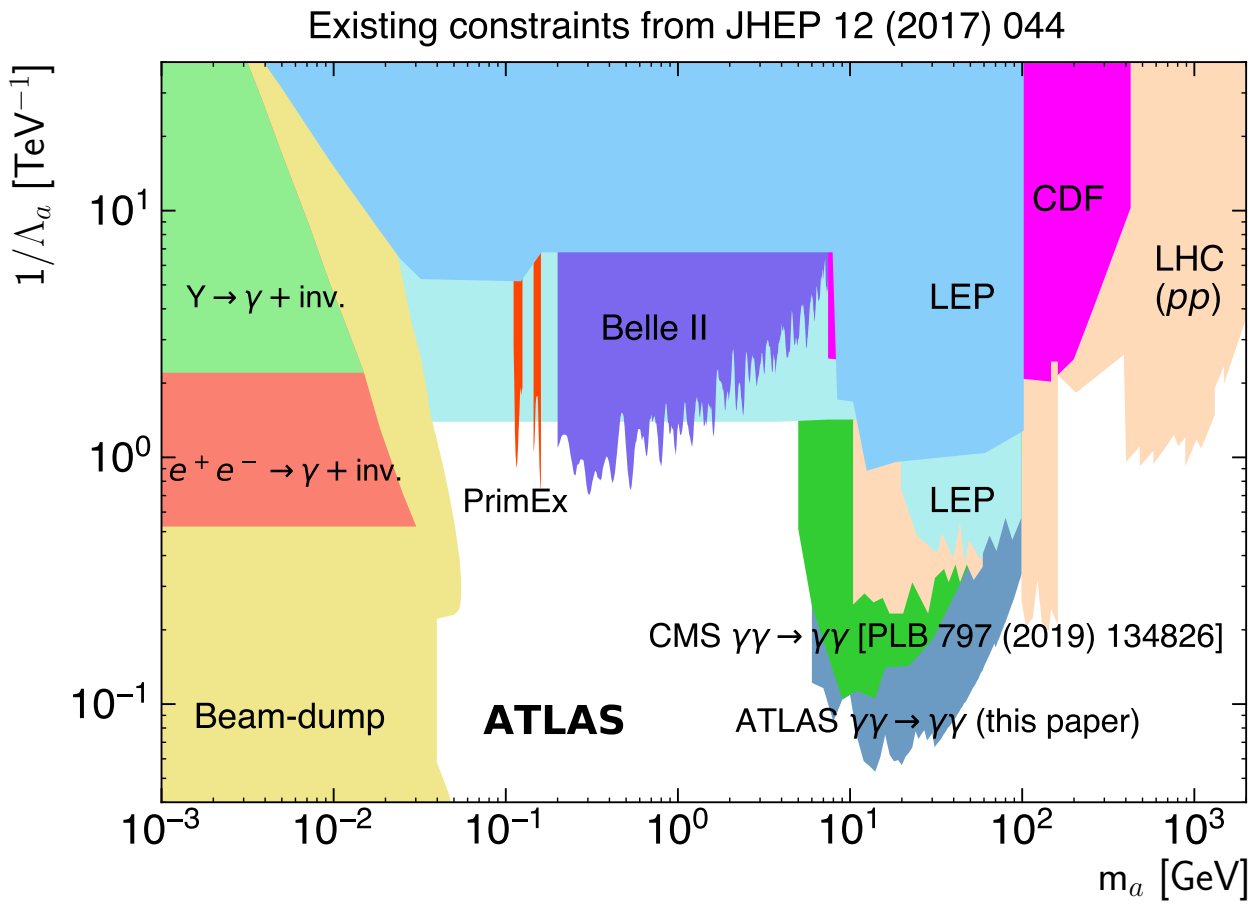
Axion-like particle search

JHEP 03 (2021) 243

- Main background: $gg \to \gamma\gamma$, $\gamma\gamma \to l^+l^-$, SM $\gamma\gamma \to \gamma\gamma$
- MC prediction with STARlight
- ALP mass range: 5-90 GeV (CMS) and 6-100 GeV (ATLAS)





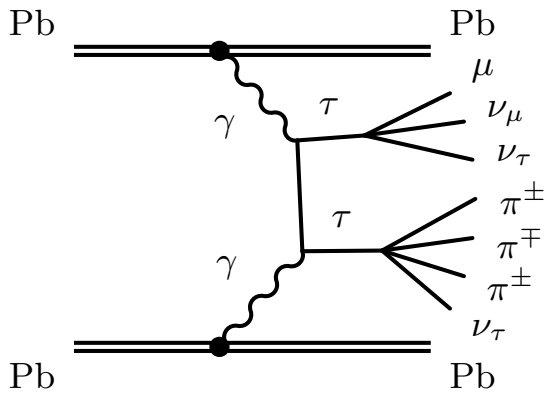


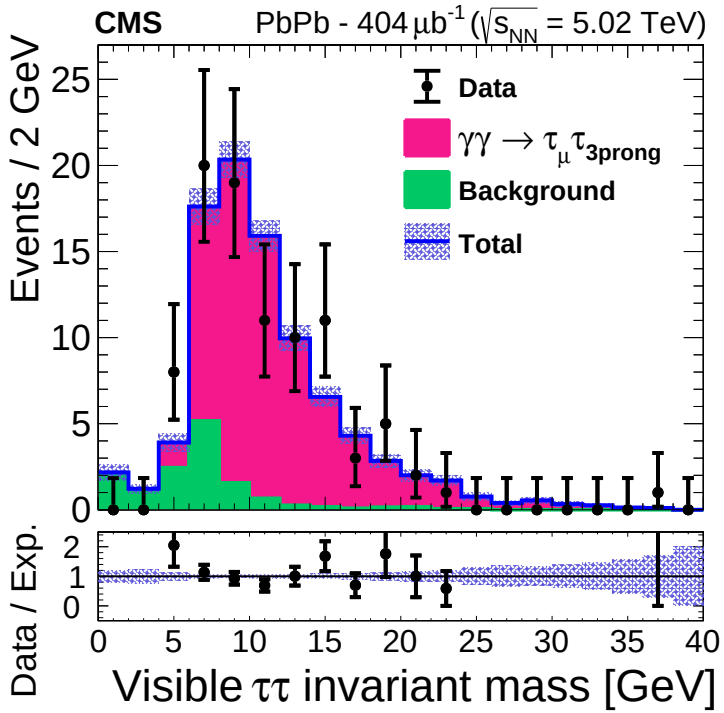
* Does not include newest pp results: arXiv:2304.10953

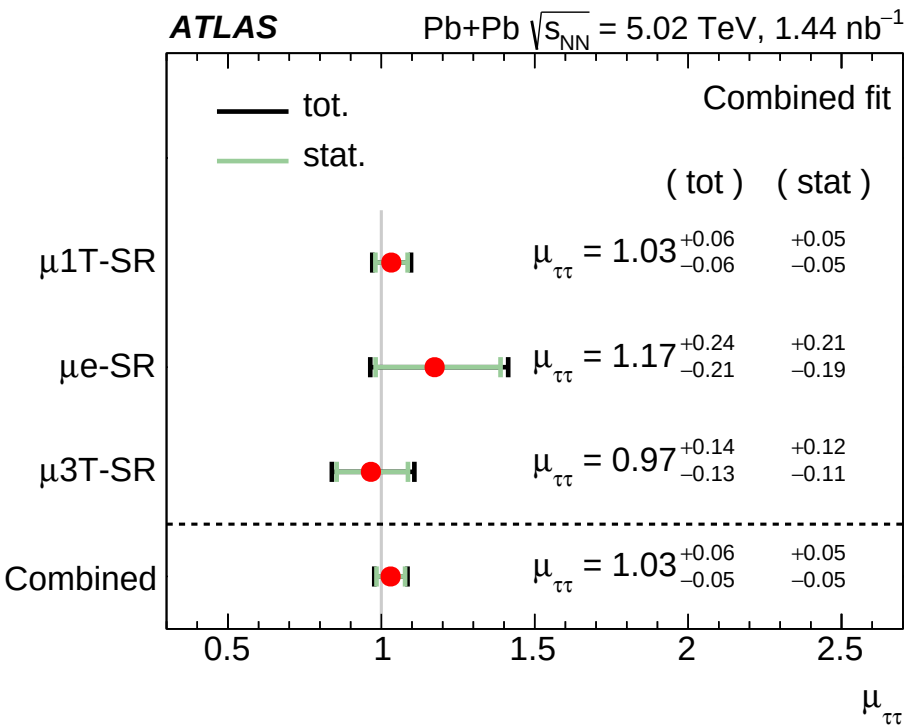
$\gamma\gamma \to \tau\tau$ production

ATLAS: CERN-EP-2022-079, CMS: CERN-EP-2022-098

- First observation of $\gamma\gamma \to \tau\tau$ production in hadron collisions by ATLAS and CMS.
- Targets μ+3prong (CMS) or μ+3prong, μ+1prong and μ+e (ATLAS) decays
- CMS: $\sigma_{fid} = 4.8 \pm 0.6(stat.) \pm 0.5(syst.)$ mb
- ATLAS: $\mu_{\tau\tau} = 1.03^{+0.06}_{-0.05}$



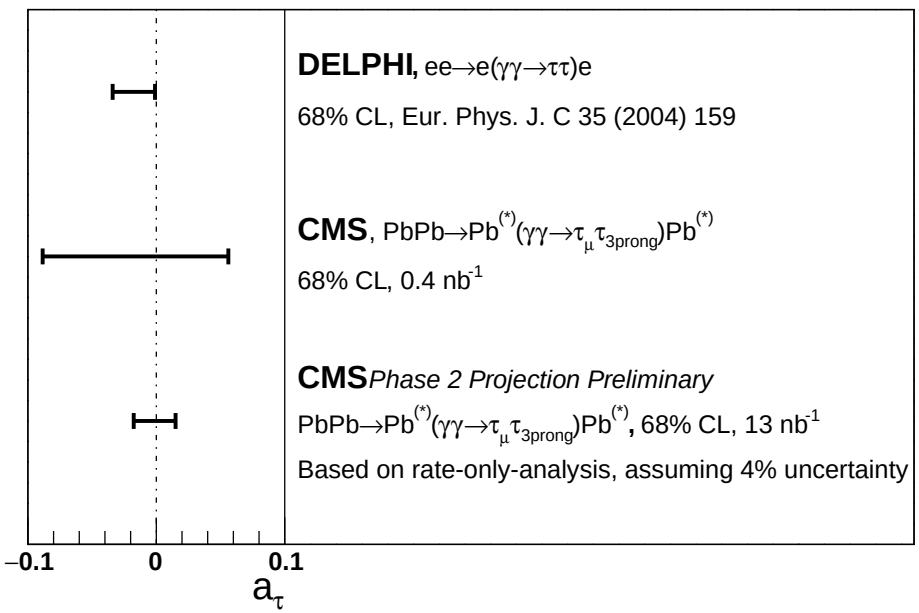


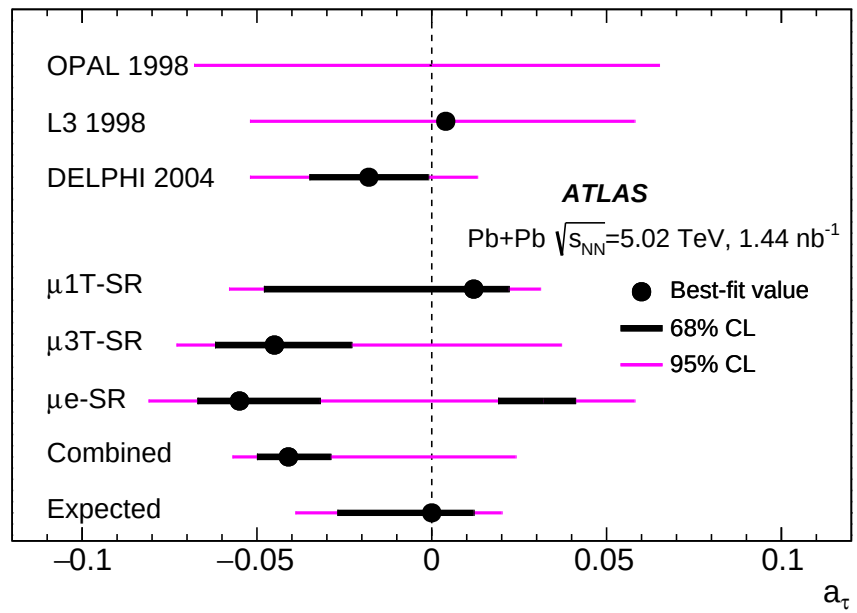


Constraints on τ anomalous magnetic moment

ATLAS: CERN-EP-2022-079, CMS: CERN-EP-2022-098

- $a_\tau = (g_\tau - 2)/2$ poorly constrained experimentally $\rightarrow$ can be sensitive to BSM
- ATLAS and CMS provide their first constrains on a_τ
- ATLAS precision competitive with DELPHI@LEP limits

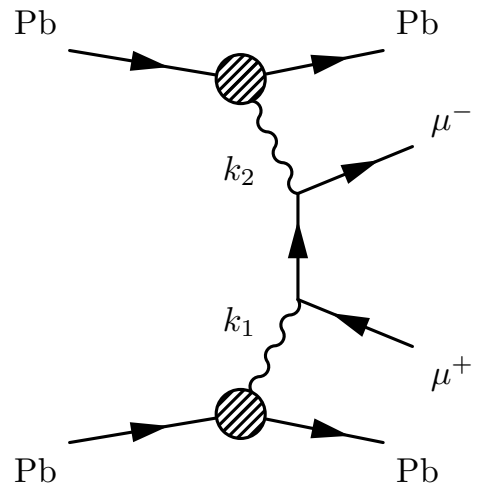


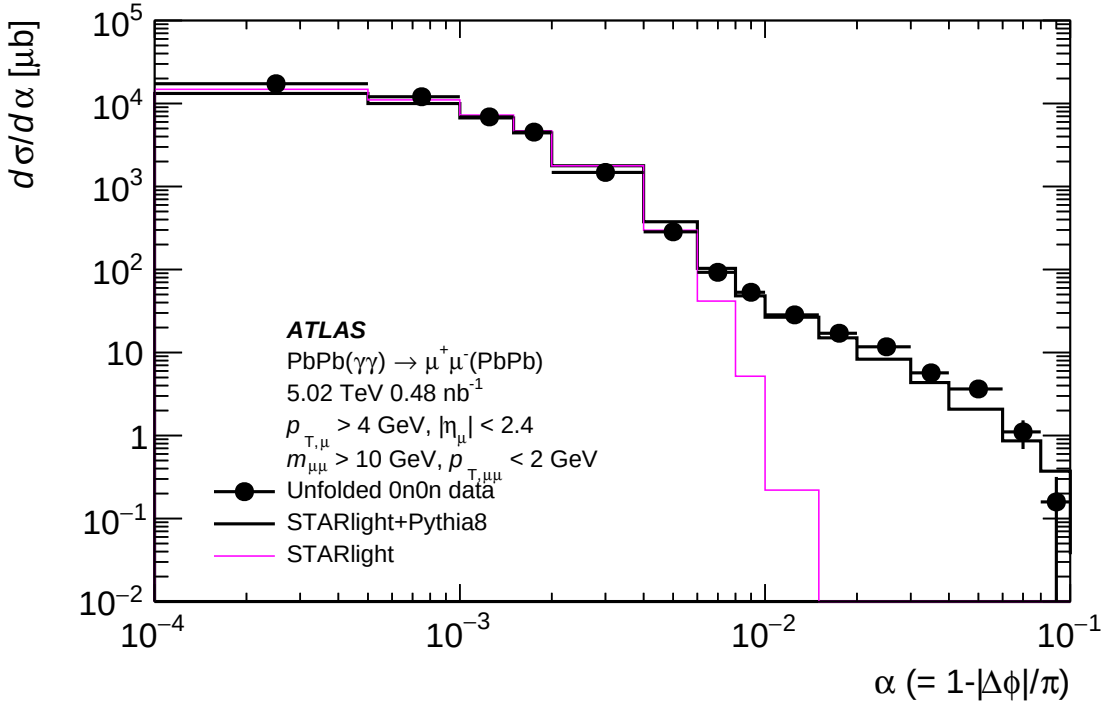


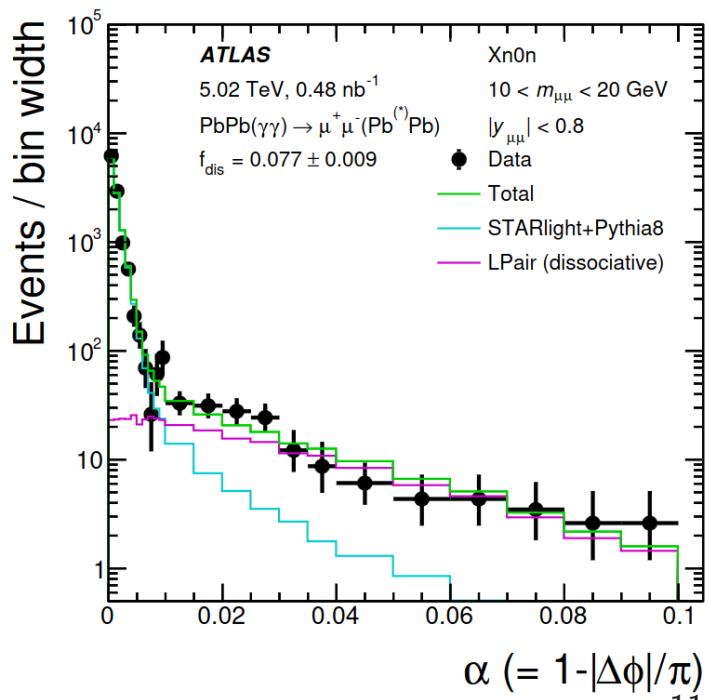
$\gamma\gamma \to \mu\mu$ production

Phys. Rev. C 104 (2021) 024906

- Background: dissociative dimuon production → emission of forward neutrons → importance of ZDC
- Presence of forward neutrons affects the impact parameter dependence of the two-photon flux
- Modelling with STARlight+Pythia (FSR) and LPair (dissociation)



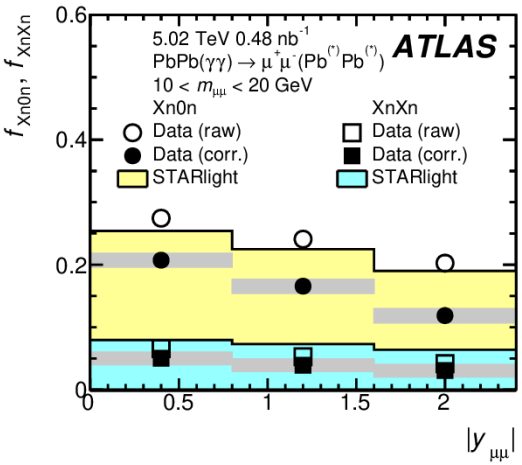


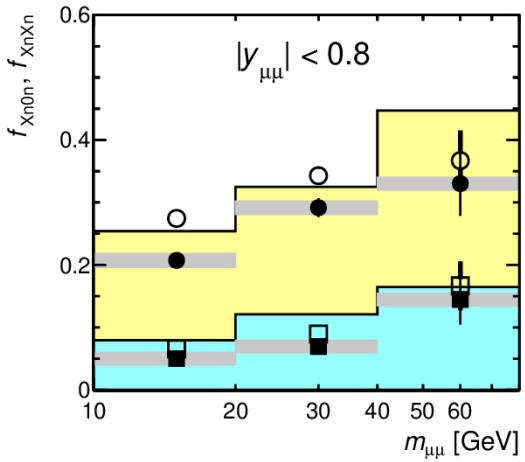


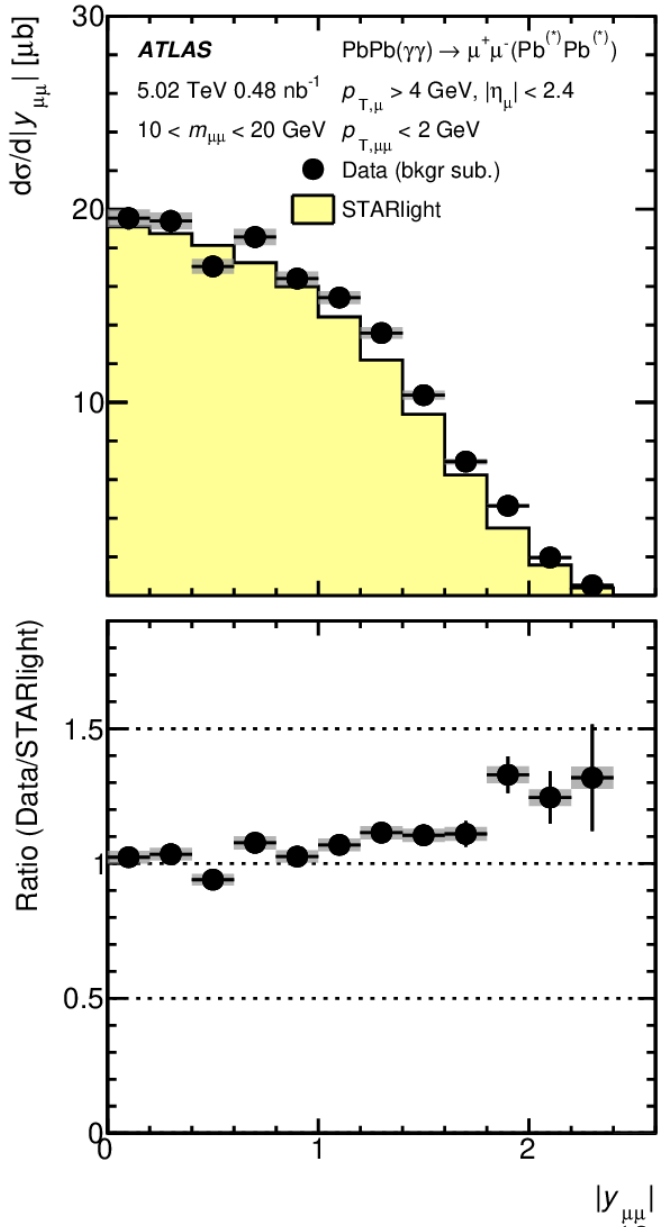
$\gamma\gamma \to \mu\mu$ production

Phys. Rev. C 104 (2021) 024906

- Measurement:
  $\sigma_{fid} = 34.1 \pm 0.3\,(stat.) \pm 0.7\,(syst.)$ µb
- STARlight: 32.1 µb + Pythia: 30.8 µb
- Hints of larger fluxes of photons in the initial state



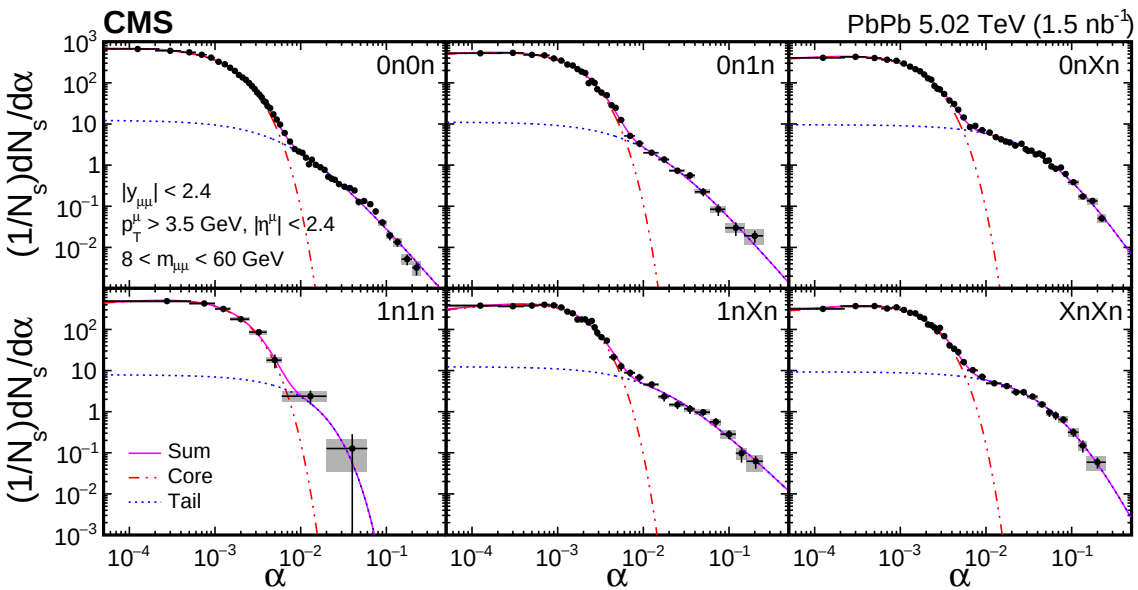


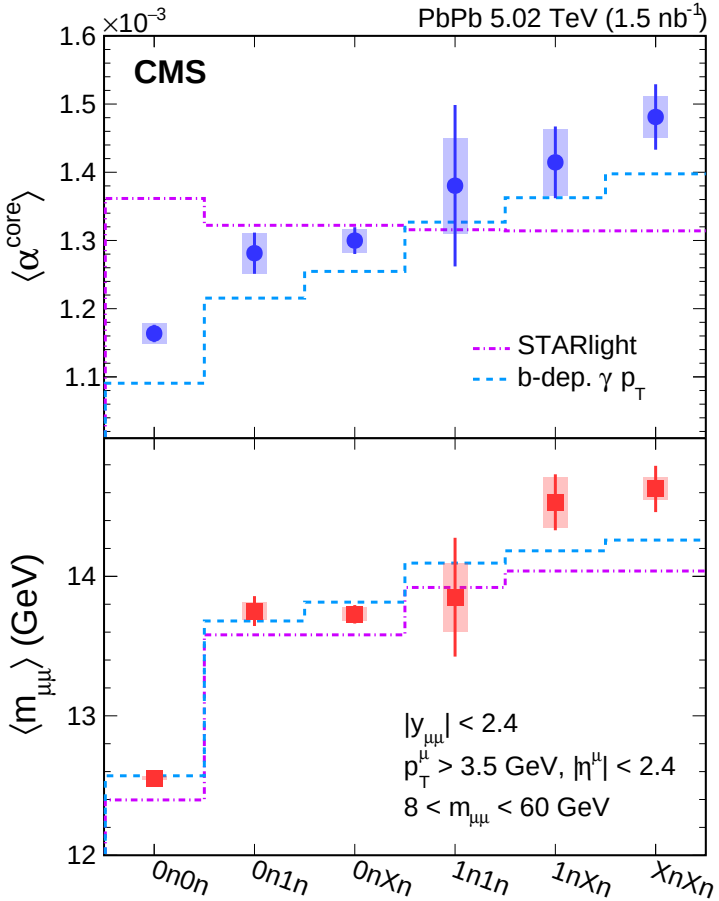


$\gamma\gamma \to \mu\mu$ production

Phys. Rev. Lett. 127 (2021) 122001

- First measurement of the dependence of $\gamma\gamma \to \mu\mu$ production on the multiplicity of forward neutrons
- CMS observes a significant impact parameter dependence of the initial photon p_T (not grasped by STARlight)



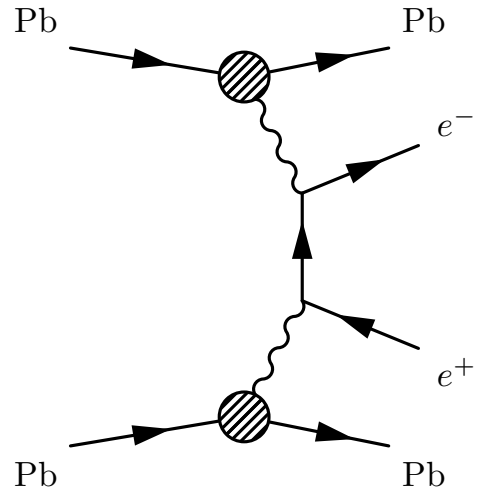


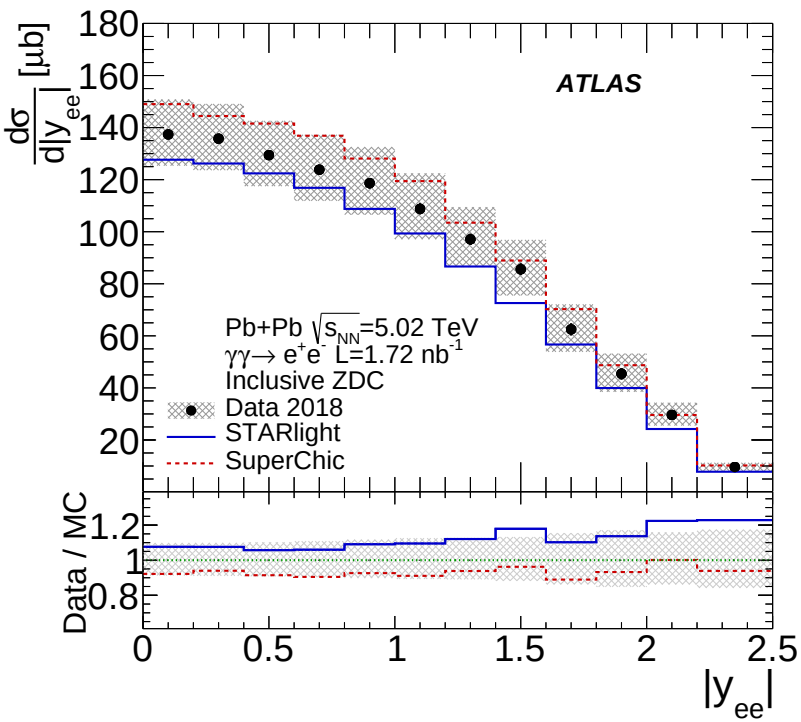
arXiv:2006.07365

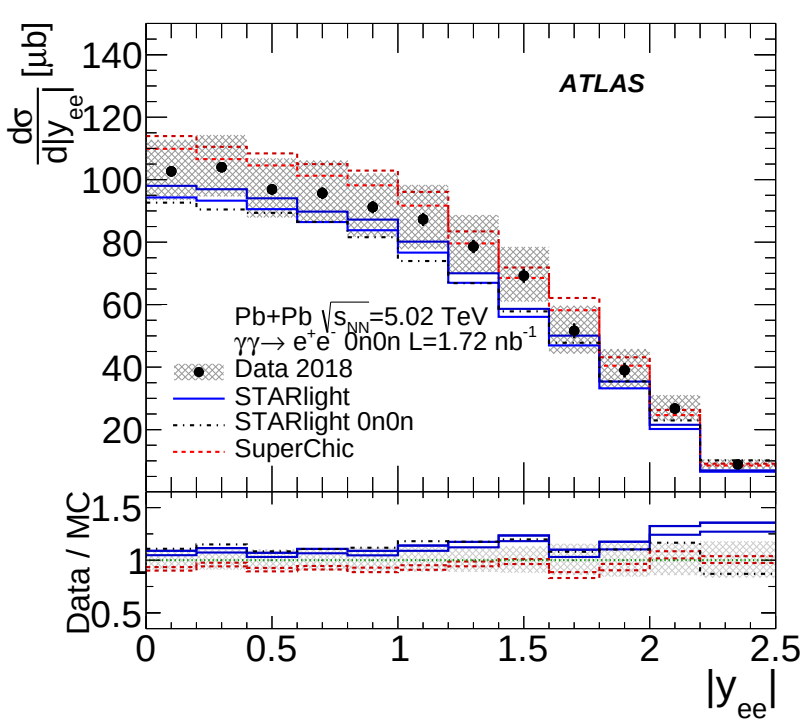
$\gamma\gamma \to ee$ production

CERN-EP-2022-130

- Similar techniques as in ATLAS $\mu\mu$ UPC measurement, but with notable advances:
  - Higher statistics from 2018 data
  - Extended fiducial region
- $\sigma_{fid} = 215 \pm 1(stat.)^{+23}_{-20}(syst.) \pm 4(lumi.)$ µb
- STARlight: 196.9 µb, SuperChic: 235.1 µb

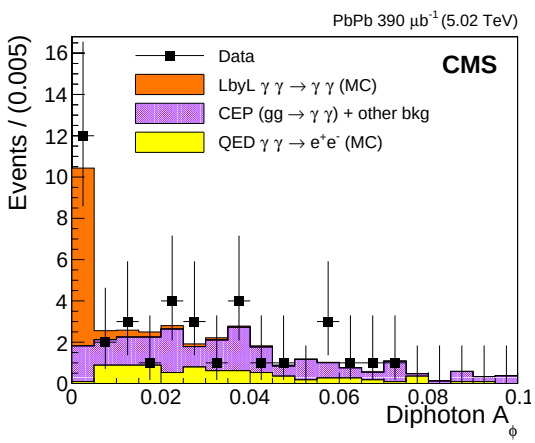


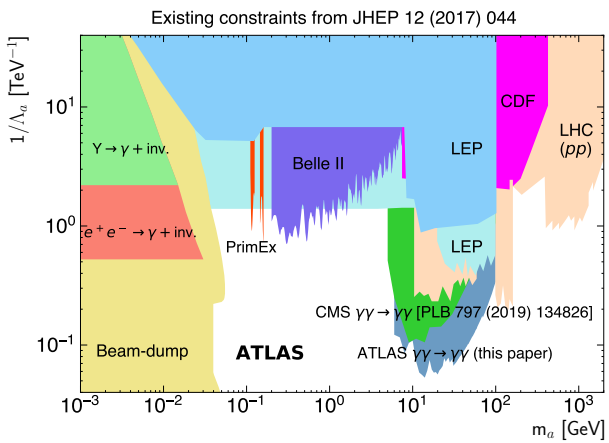


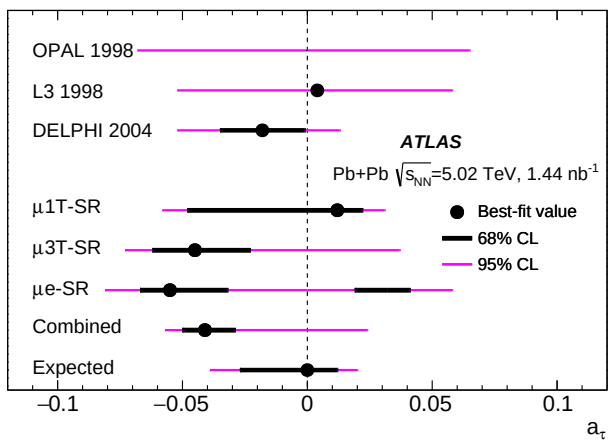


Summary

- Rich physics programme of UPC collisions at the LHC
- Standard Model tests:
  - Observation of LbyL scattering
  - Measurement of $\gamma\gamma \to ll$ processes
  - First constrains on anomalous magnetic moment a_τ
- BSM searches:
  - The best limits on ALP production in mass range 5-100 GeV
- Very good prospects for LHC Run3 and beyond







Backup