Light by light scattering in UPC collision with ATLAS detector

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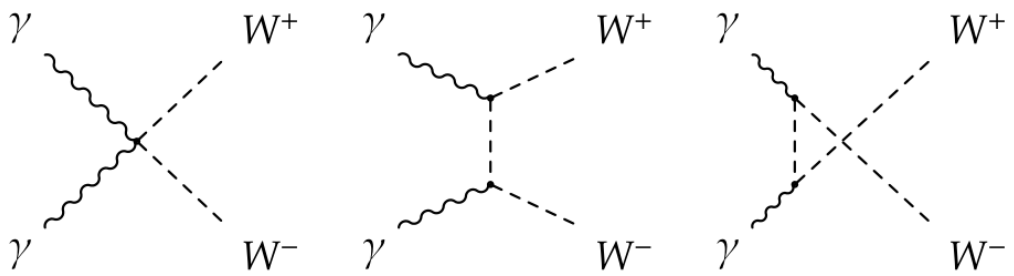
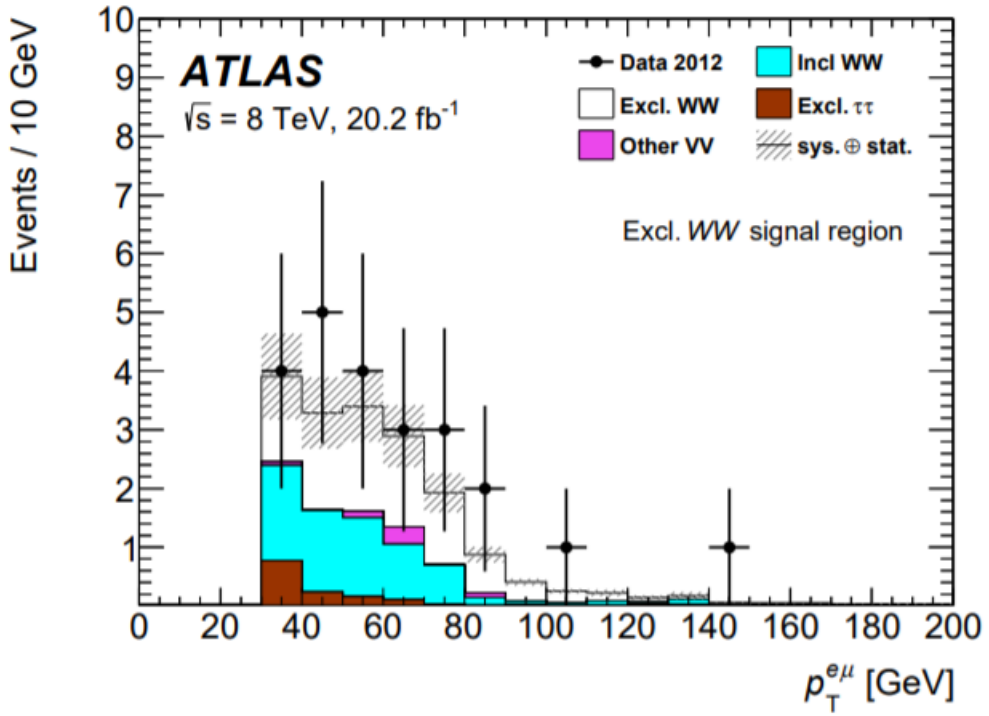
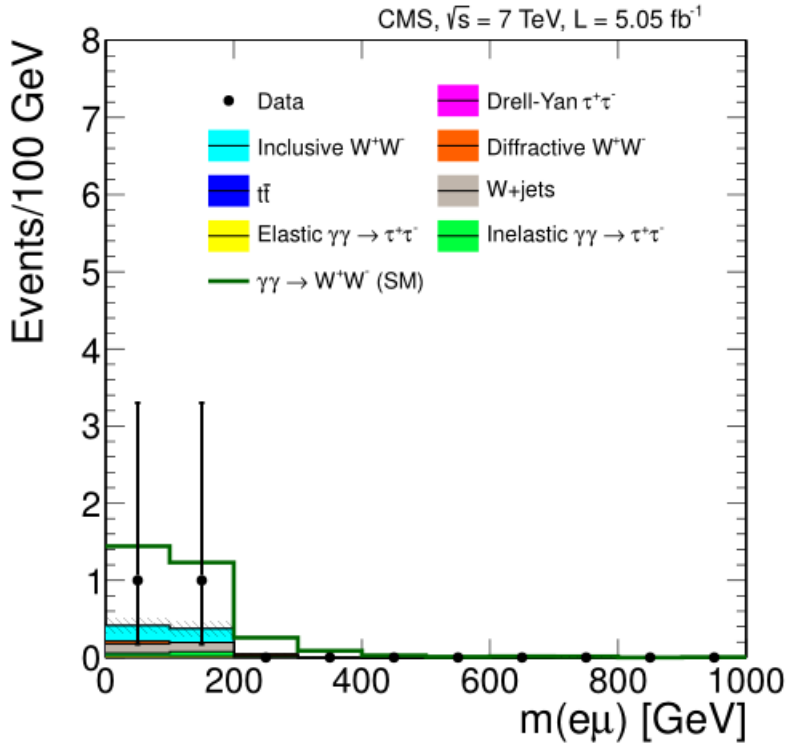
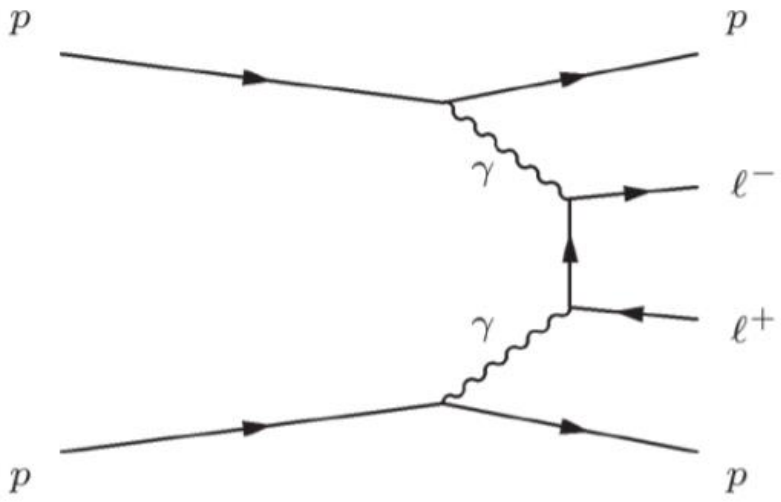
Exclusive WW Productions

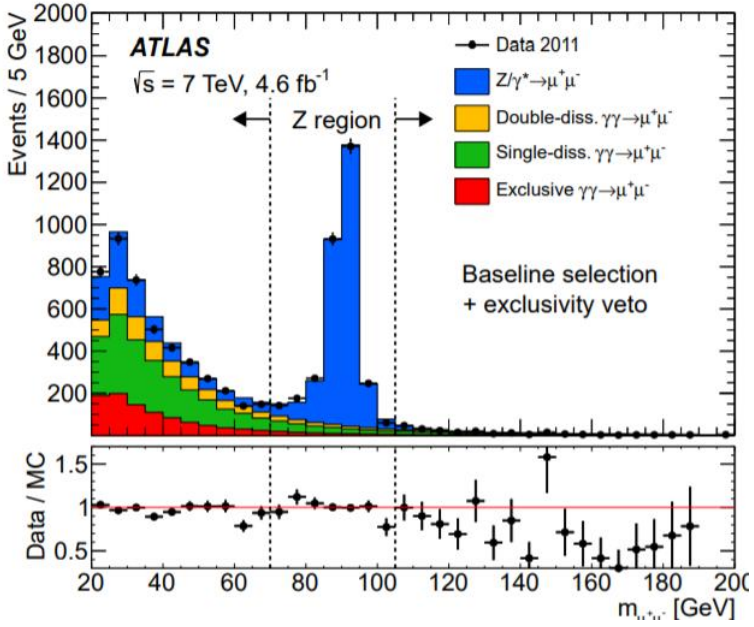


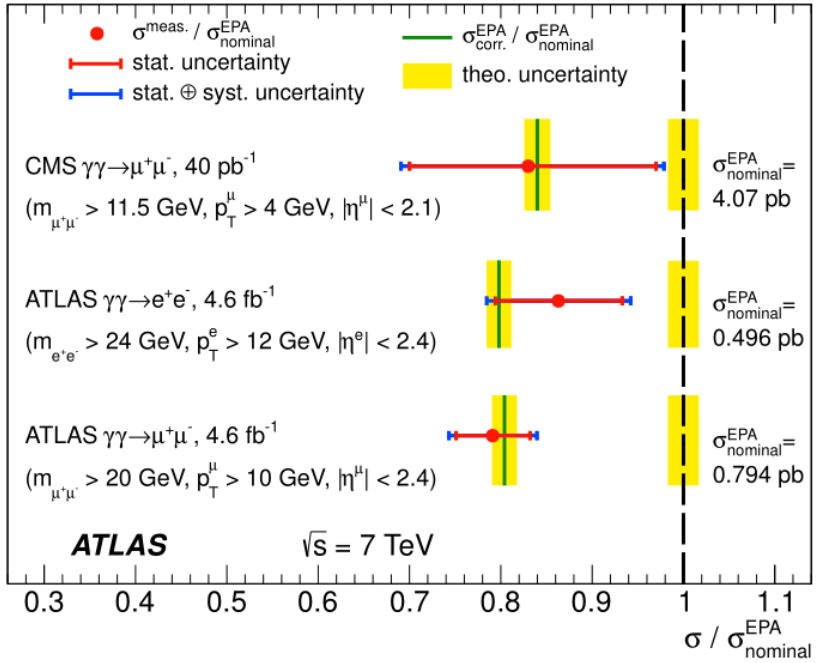


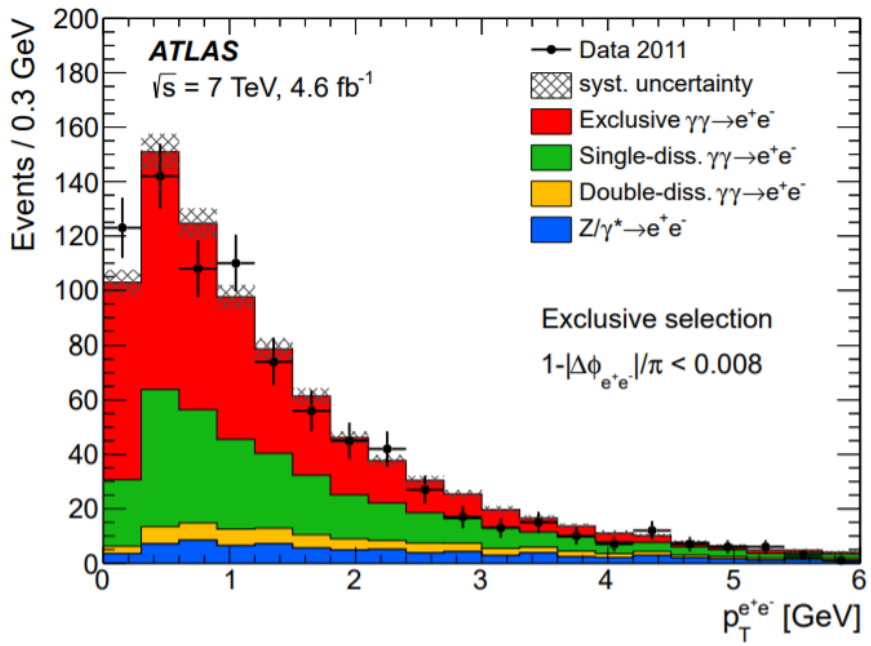


Exclusive lepton Productions









Theoretical setup

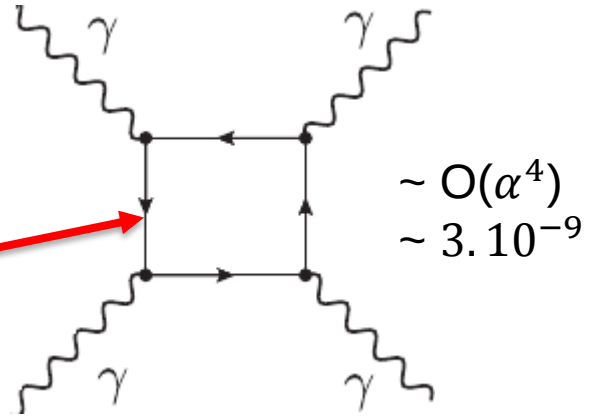
Elastic two-photon collision : a fundamental quantum-mechanical process which remained experimentally unobserved for a long time

Loop contains virtual charged particles (q,ℓ,W ±) from the SM.

Possible BSM :

New ch. particles (sparticles)?

New resonances (axions, monopoles,...)? ……



$\sim O(\alpha^4)$

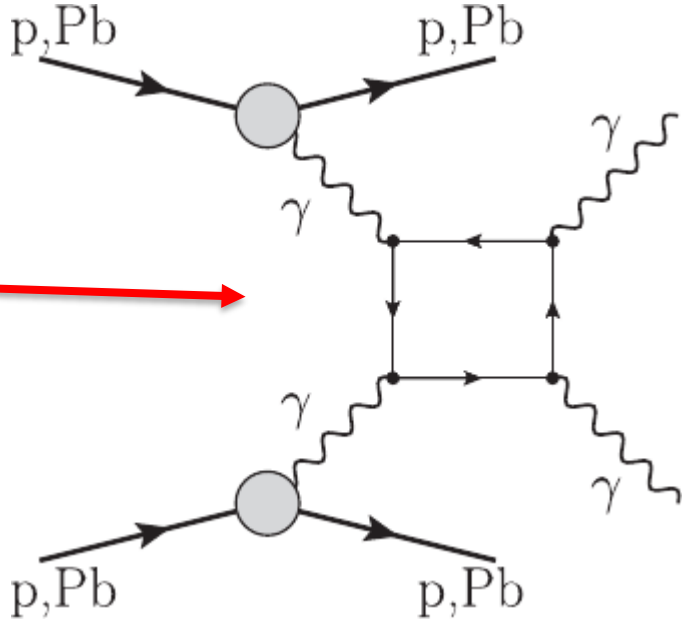
$\sim 3.10^{-9}$

Why UPC ?

Electromagnetic ultra-peripheral collisions (UPC): $b_{min} > R_A + R_B$

Heavy ions create huge EM fields (10^{14}T) from coherent action of Z protons: cross section Z^4

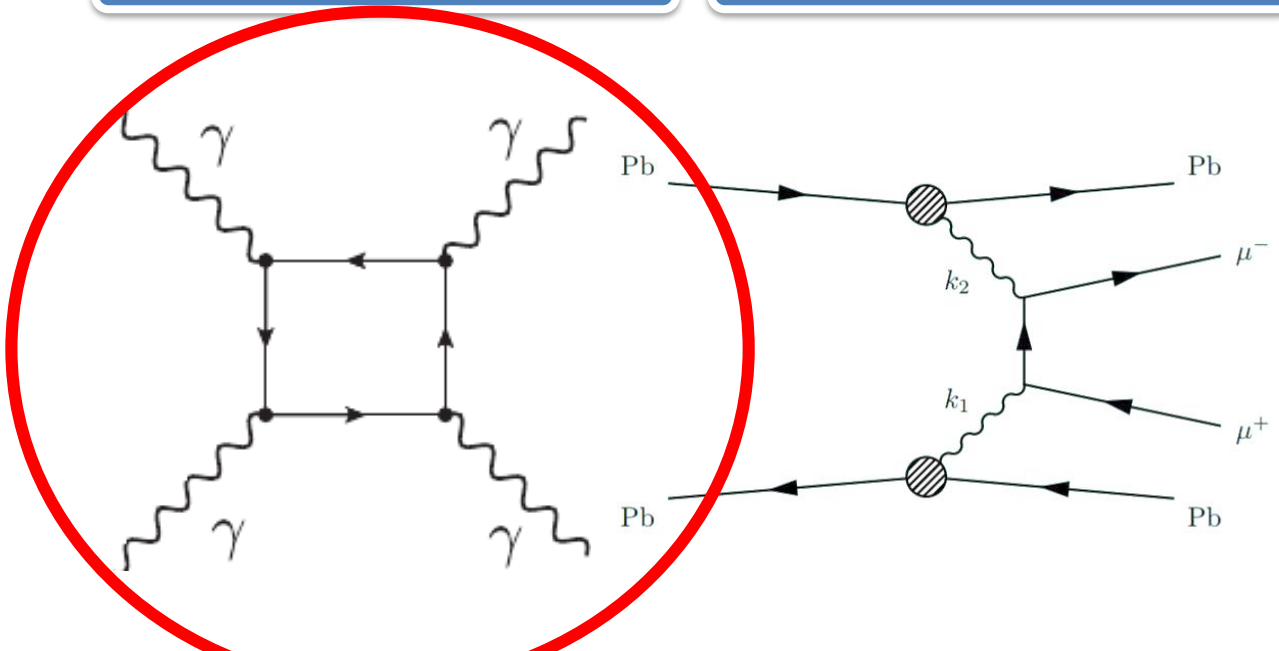
- UPC provide a flux of quasi-real photons probing the nuclear structure
- No pileup !
- PbPb and pPb collisions exploit the large γ flux ∝ Z 2
- For exclusive production of heavy flavour states, pQCD calculations are possible
- Sensitive to nPDF down to x ~ 10 −5 (for y up to 5)



Ultra Peripheral collisions

Pure EM processes

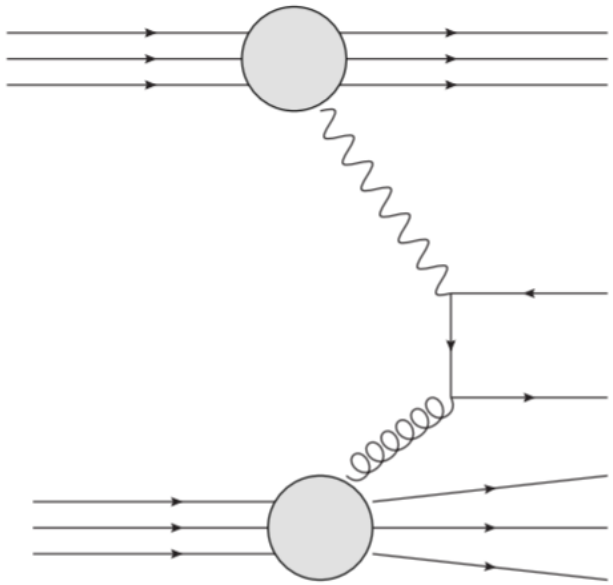
LbyL scattering



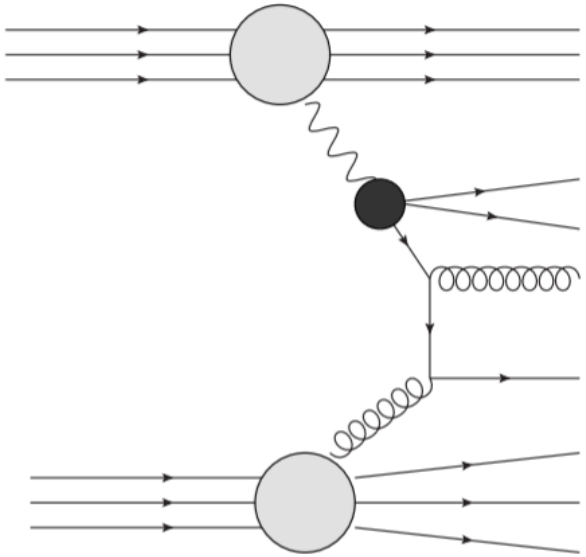
Lepton pair production

Photo-nuclear interactions

Direct



Resolved



First ATLAS LbyL result (Evidence)

2015 Pb+Pb data 0.48 nb-1

Signal selection :

• 2 back to back photons and nothing else in the central detector

•E_T<3 GeV and |η| < 2.4, mγγ > 6 GeV

•pTγγ < 2 GeV

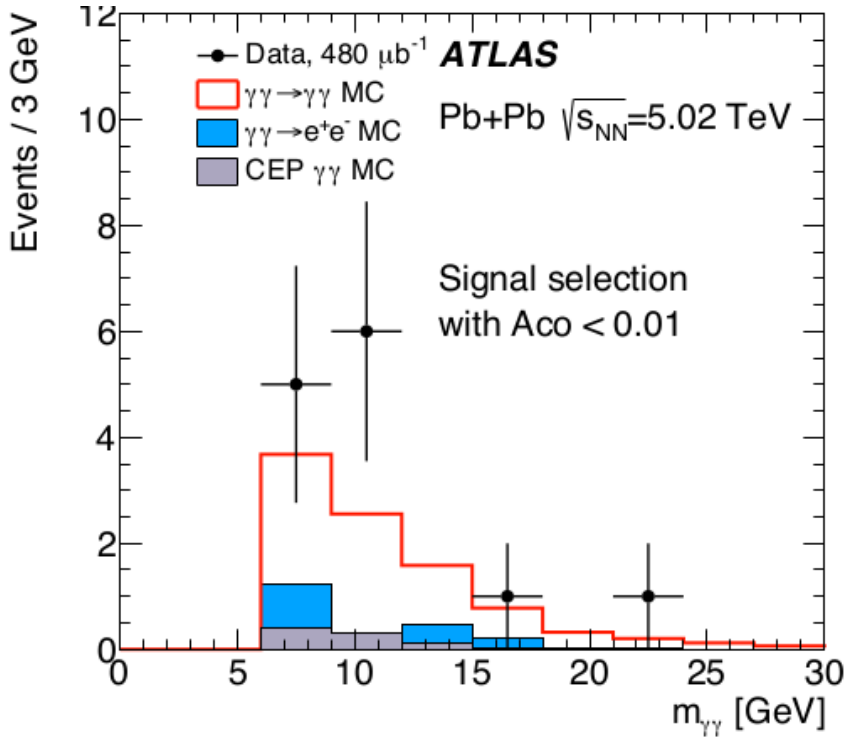
•Acoplanarity $= 1 - \frac{|\Delta\varphi|}{\pi} < 0.01$

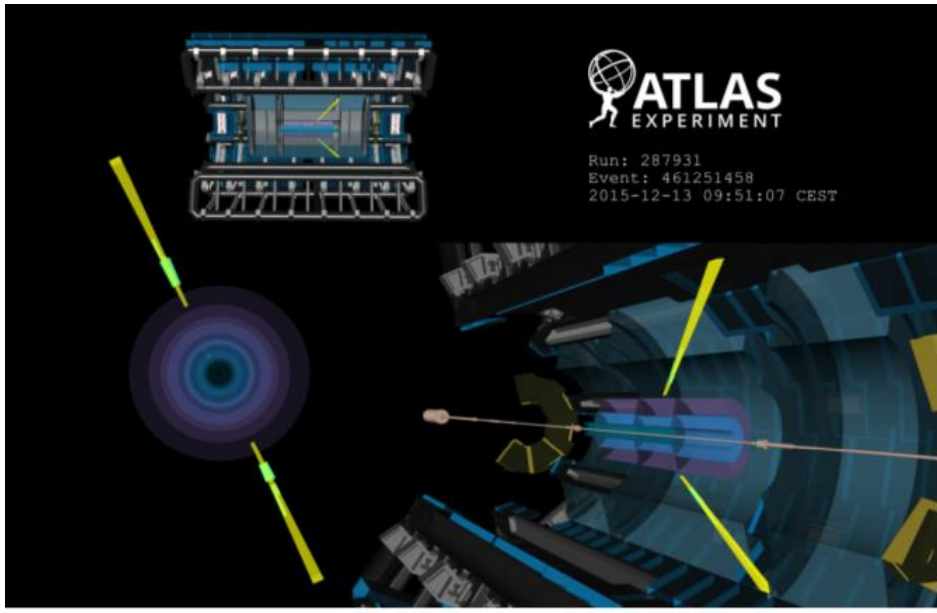
Results :

•13 events observed (7.3 signal events and 2.6 background events are expected)

•Excess corresponds to **4.4σ** statistical significance over background only hypothesis

• Confirmed later in the same year from CMS experiment





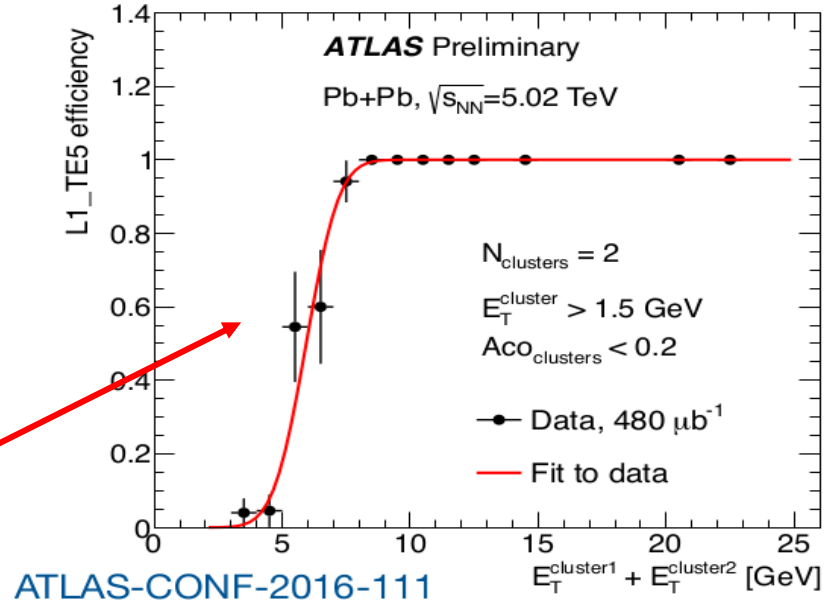
Second ATLAS LbyL result (Observation)

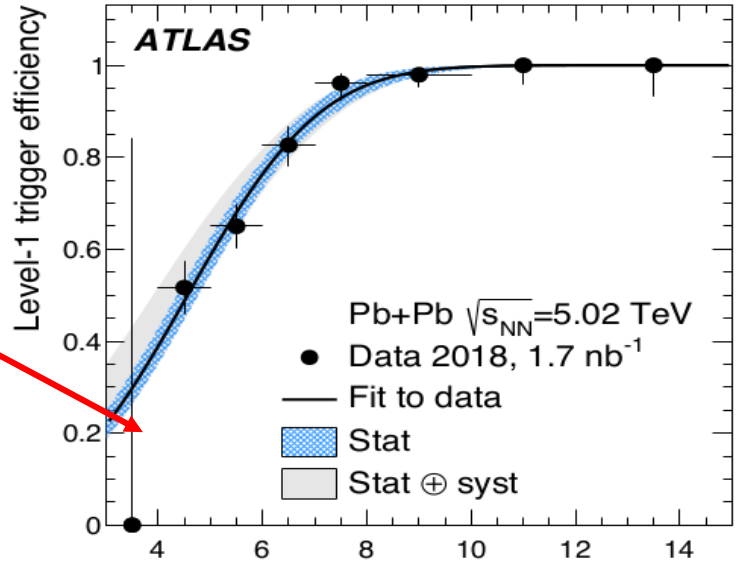
❖ **2018 data** :

- New measurement performed using 1.73 nb -1 of data
- collected in November 2018 (end of Run2)
-

❖ **Improvement :**

- More than 3 times stat w.r.t 2015 dataset
- Trigger with higher efficiency at low E_T
- NN Photons PID instead of cut based
- Better background rejection

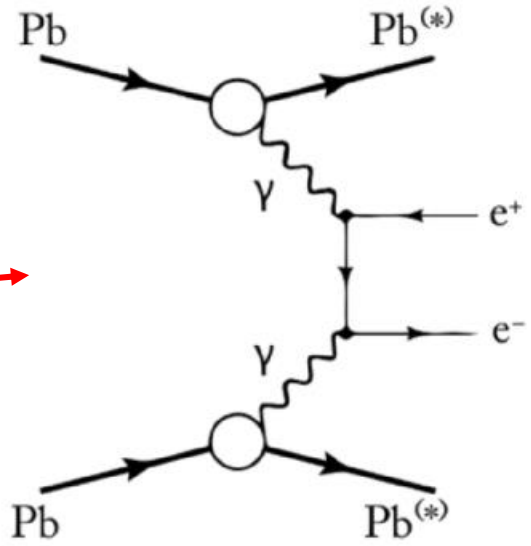




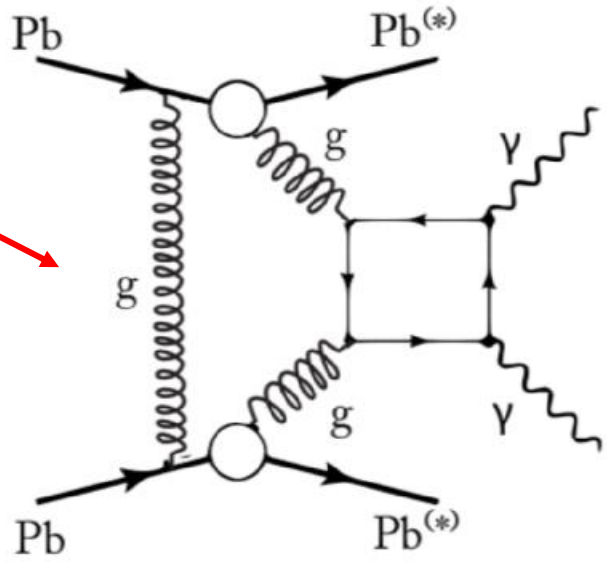
Backgrounds

❖ **Considered :**

- Exclusive dielectron production γγ → e+e-



- Central Exclusive Production (CEP) gg → γγ



❖ **Negligible**

- Fakes (calo noise, cosmics)

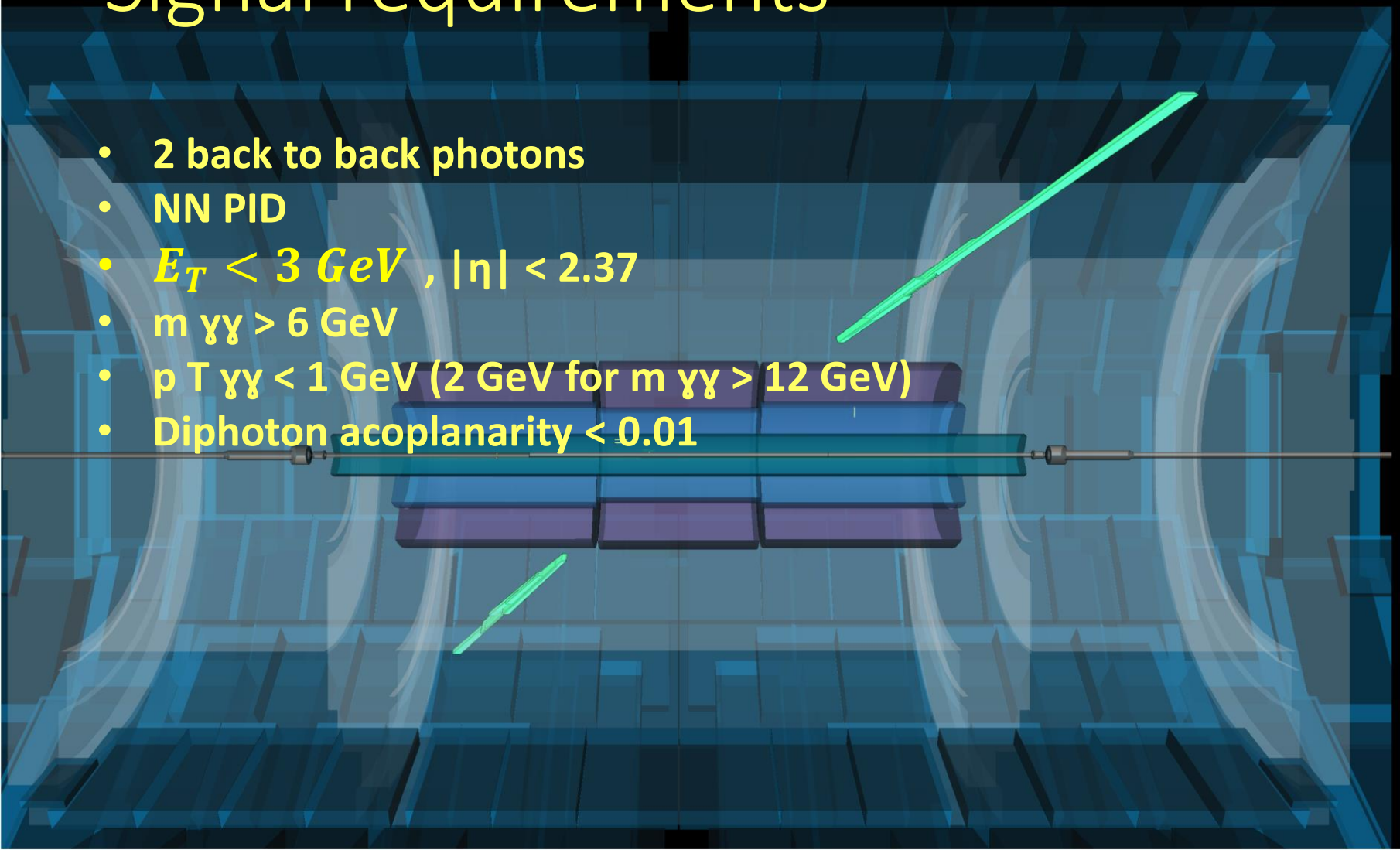
- Others (exclusive di-meson
- production (e.g. π 0 π 0), γγ → ττ, γγ → qq,
- γγ → eeγγ, γγ → η b → γγ, γPb → Υ → 3γ,
- ion bremsstrahlung)

ATLAS EXPERIMENT

Run: 366994
Event: 453765663
2018-11-26 18:32:03 CEST

Signal requirements

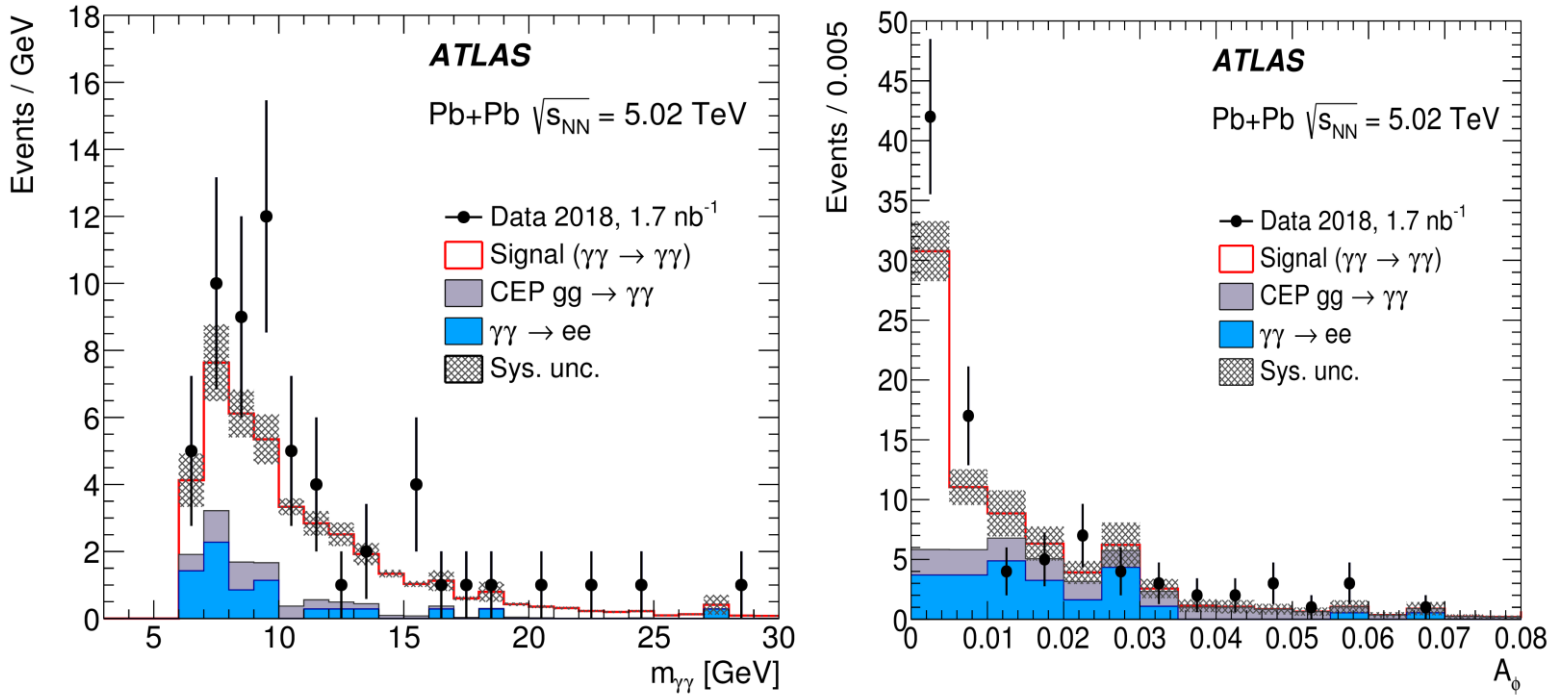
- 2 back to back photons
- NN PID
- $E_T < 3\ GeV$, |η| < 2.37
- m γγ > 6 GeV
- p T γγ < 1 GeV (2 GeV for m γγ > 12 GeV)
- Diphoton acoplanarity < 0.01



mγγ = 29 GeV

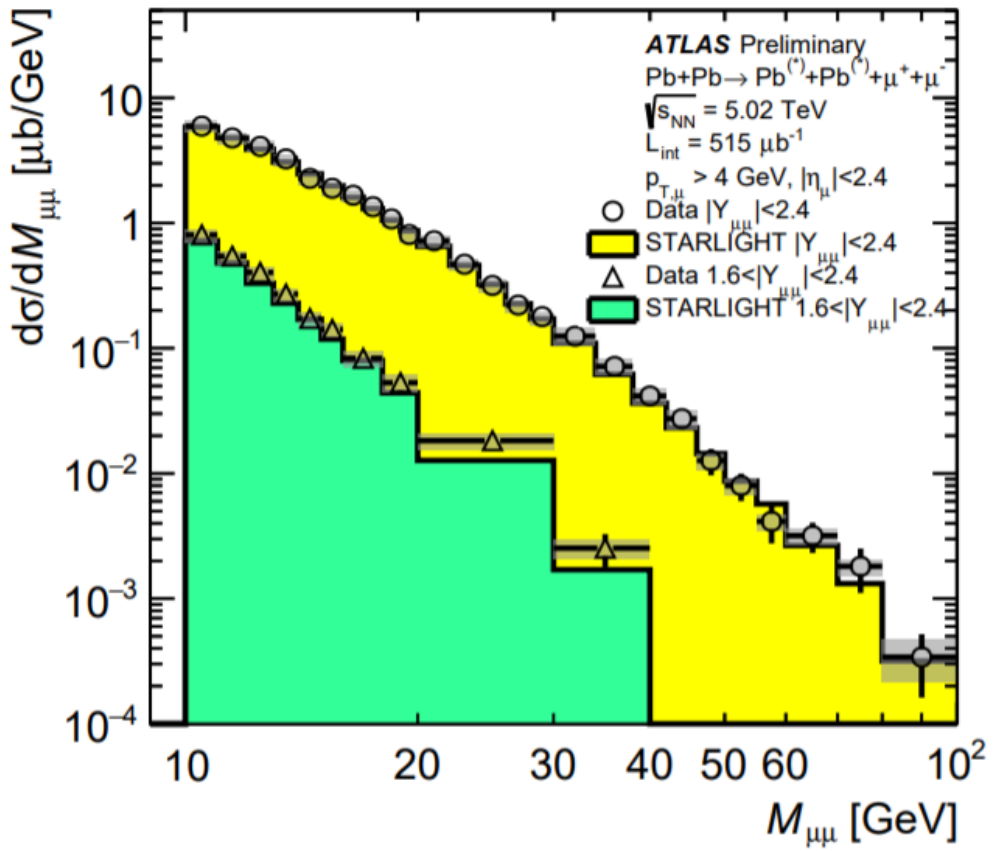
Results

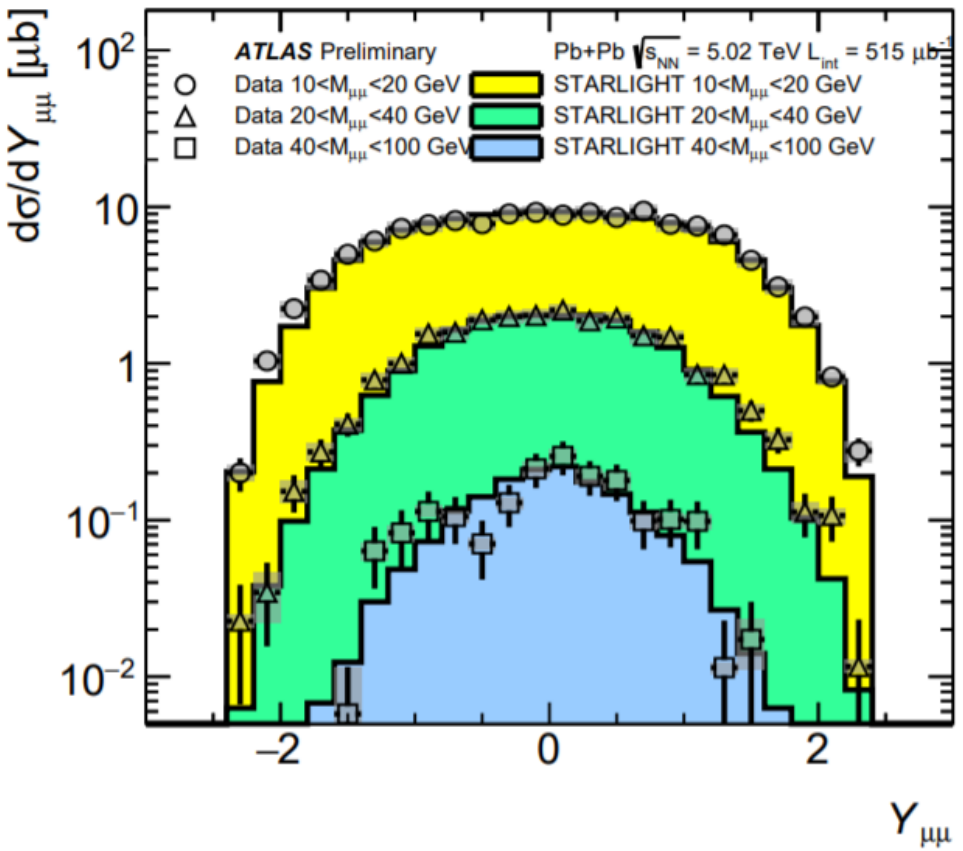
- 59 events observed (where 12 ± 3 events expected)
- Observed signal significance over the background only hypothesis is of **8.2σ** (expected 6.2σ)
- The corresponding fiducial cross section is 78 ± 13 (stat.) ± 7 (syst.) ± 3 (lumi.) nb
- SM predictions: 51 ± 5 nb (Szczurek et al.) and 50 ± 5 nb (SuperChic3)



Di Muon production in UPC

ATLAS-CONF-2016-025





Di Muon production in non-UPC

Phys. Rev. Lett. 121 (2018) 212301

•Dimuons photoproduced on top of hadronic collisions, identified through the acoplanarity α and pT asymmetry A

$$\alpha \equiv 1 - \frac{|\phi^+ - \phi^-|}{\pi}, \qquad A \equiv \left| \frac{p_{\mathrm{T}}^+ - p_{\mathrm{T}}^-}{p_{\mathrm{T}}^+ + p_{\mathrm{T}}^-} \right|,$$

- Significant broadening of the acoplanarity is observed in most central collision

a novel clean probe of the QGP medium!

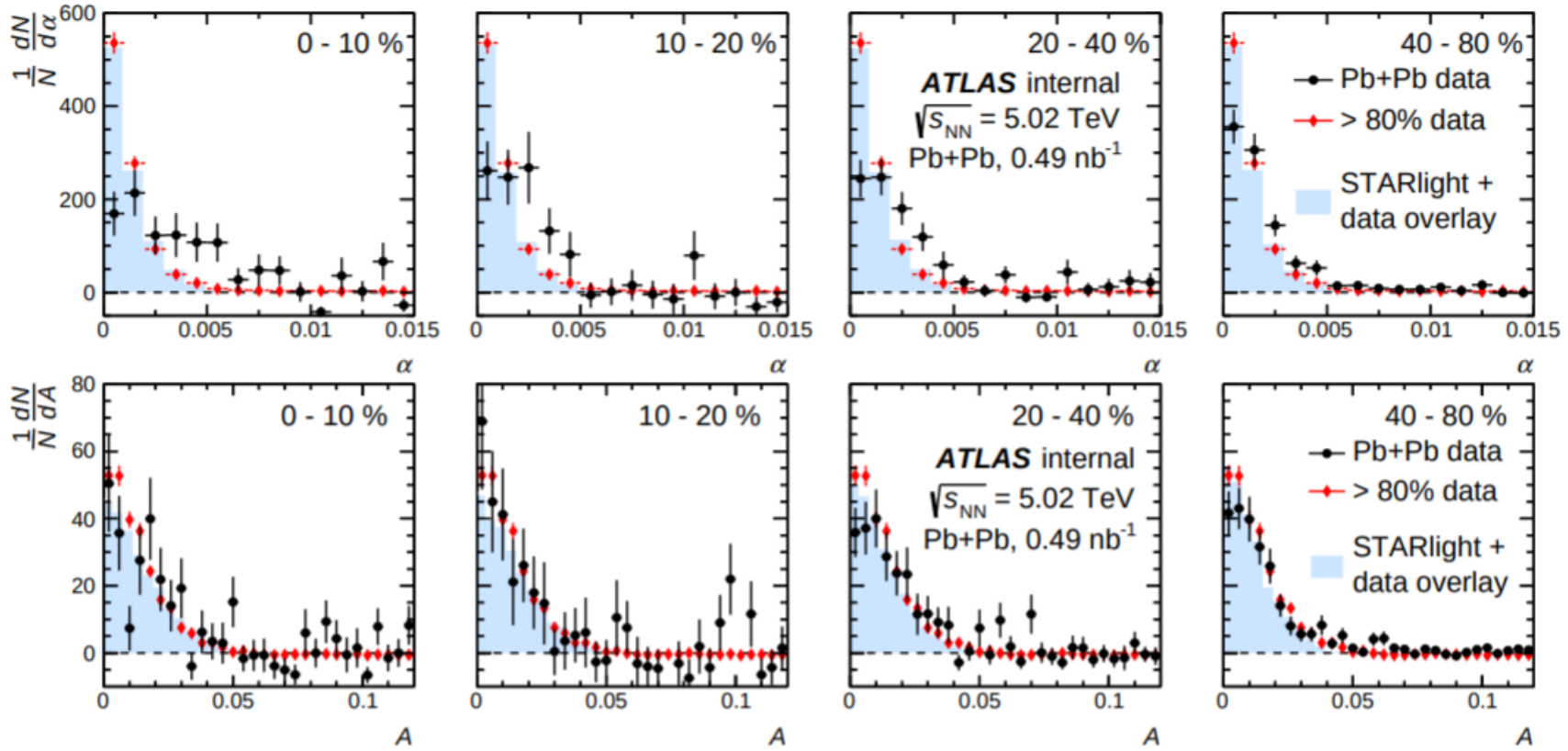
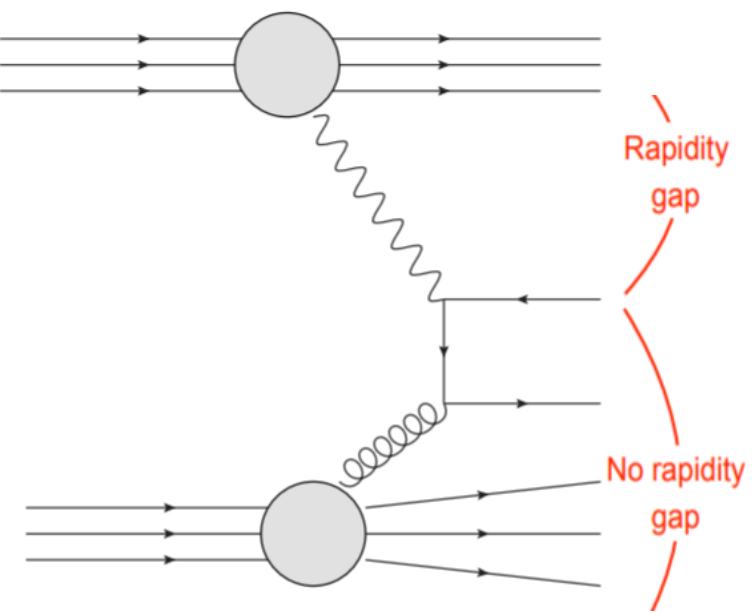
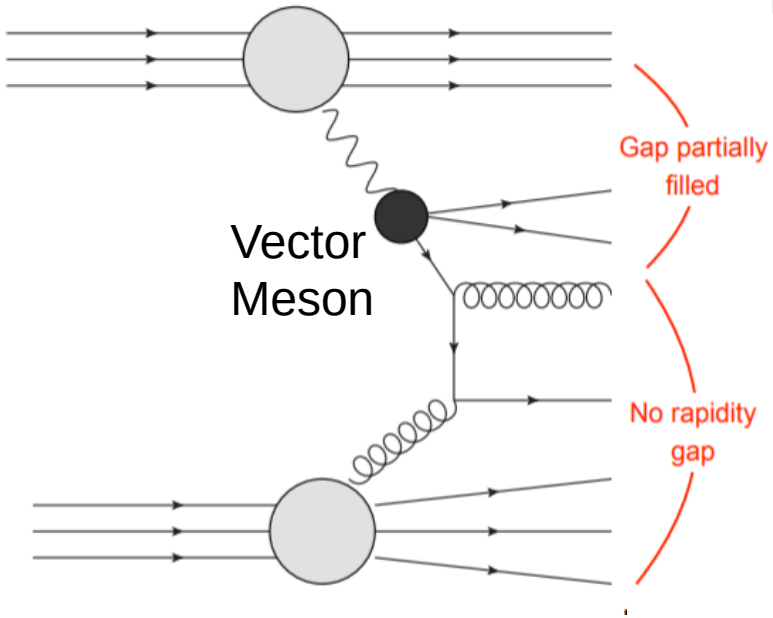


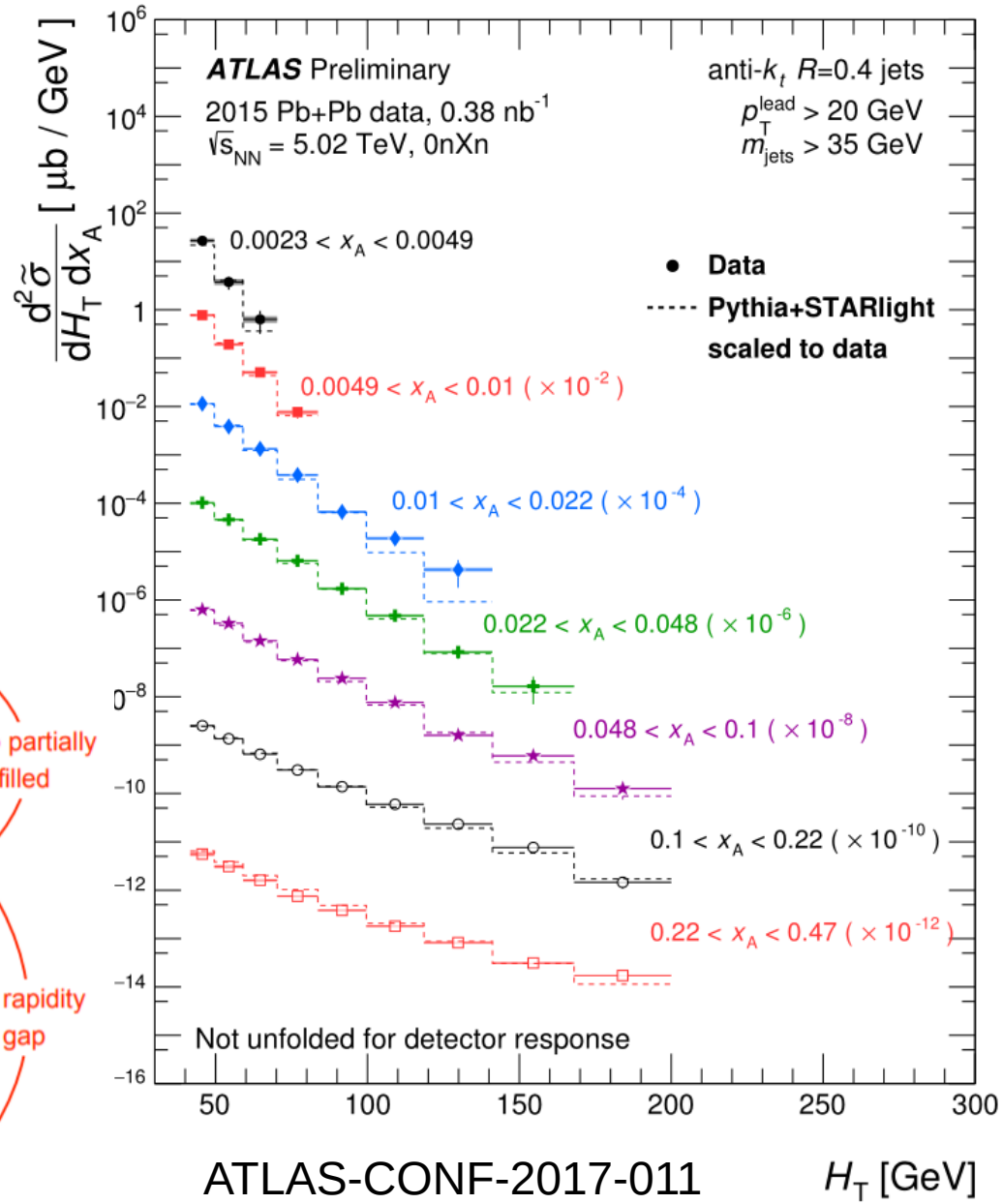
Photo-nuclear dijet production in UPC

$$H_T \equiv \sum_i PT_i \qquad y_{\text{jets}} \equiv \frac{1}{2}\ln\left(\frac{\sum_i E_i + \sum_i p_{z\,i}}{\sum_i E_i - \sum_i p_{z\,i}}\right)$$

$$z_\gamma \equiv \frac{m_{\text{jets}}}{\sqrt{s}} e^{+y_{\text{jets}}}, \qquad x_{\text{A}} \equiv \frac{m_{\text{jets}}}{\sqrt{s}} e^{-y_{\text{jets}}}$$







ATLAS-CONF-2017-011

Conclusion

- Elastic light-by-light scattering well accessible in UPC at the LHC
- UPC provide a flux of quasi-real photons probing the nuclear structure
- Toward differential cross section measurement for light-by-light scattering and Interpretations using the combination of 2015 & 2018 data
- Stay tuned !