Ultra-peripheral collisions with the ATLAS detector

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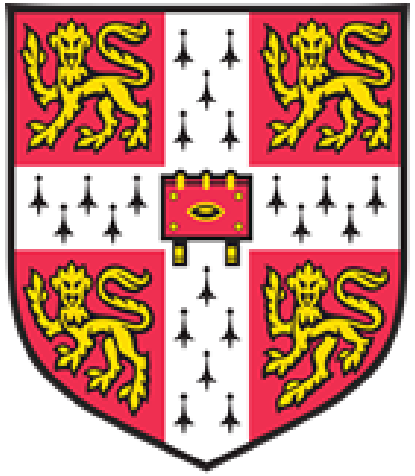
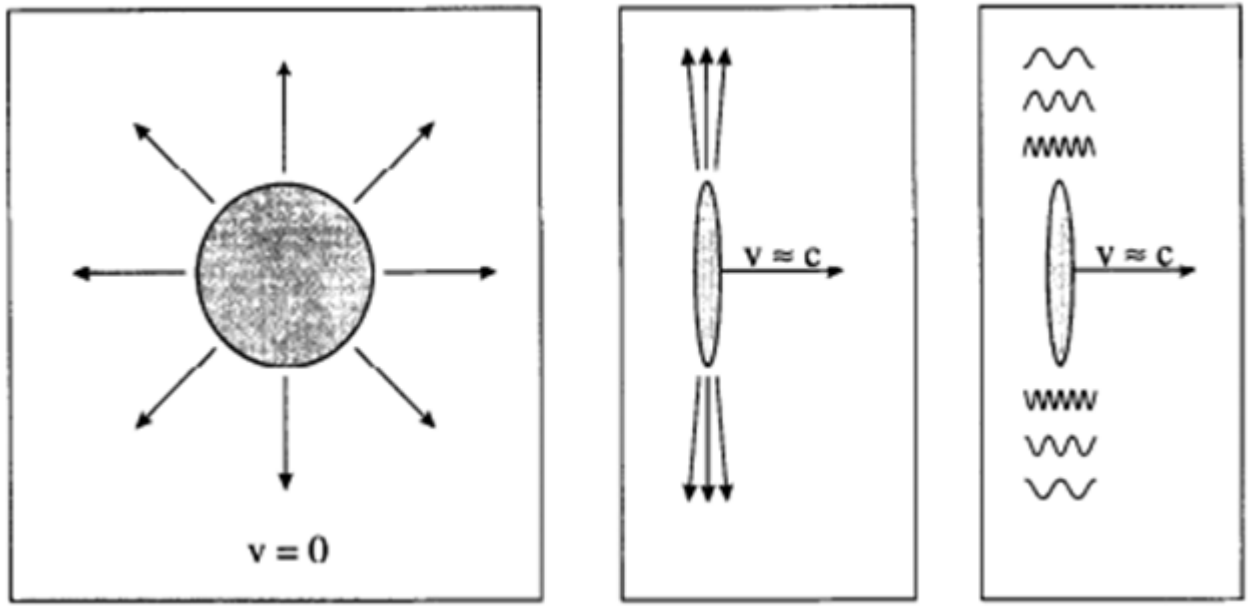
Diffraction 2016, Acireale
September 7th 2016



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

$$Z^4 \approx 5 \times 10^7$$

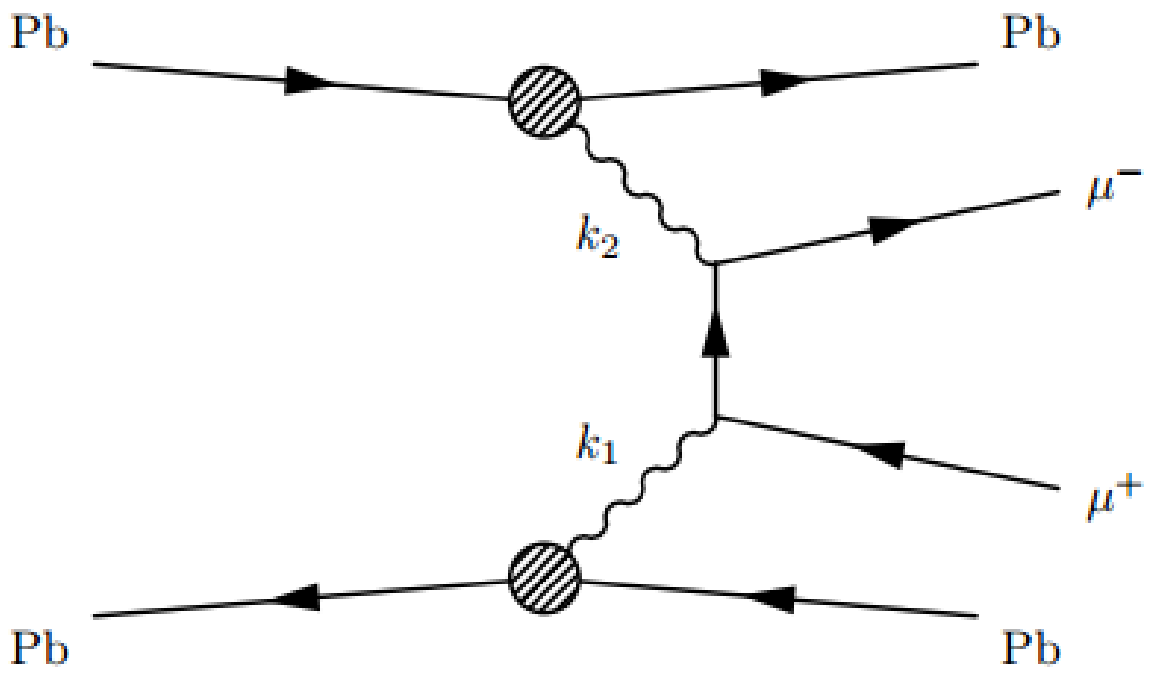
Maximum photon energy given by

$$E < \gamma/R \approx 80 \text{ GeV}$$

The first ATLAS UPC measurement is this:

We can study QED with strong fields.

$\approx 10^{14}$ T



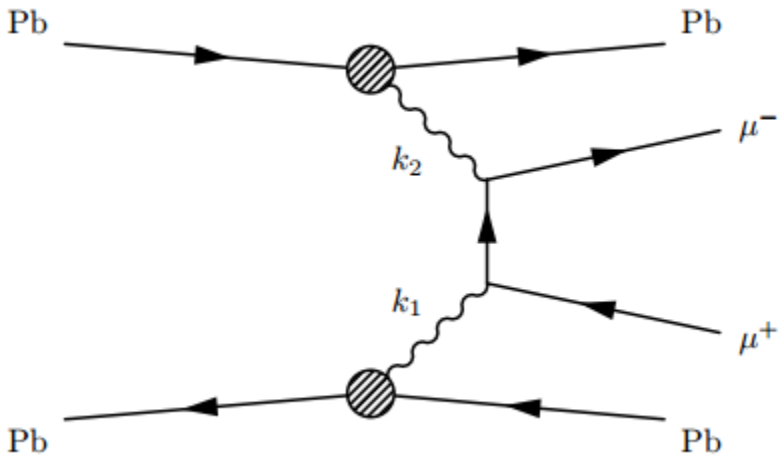
Measurement of high-mass dimuon pairs in ultra-peripheral lead-lead collisions at sqrt(s_NN)=5.02 TeV with the ATLAS detector at the LHC

ATLAS-CONF-2016-025

24 May 2016

https://cds.cern.ch/record/2157689

Theory

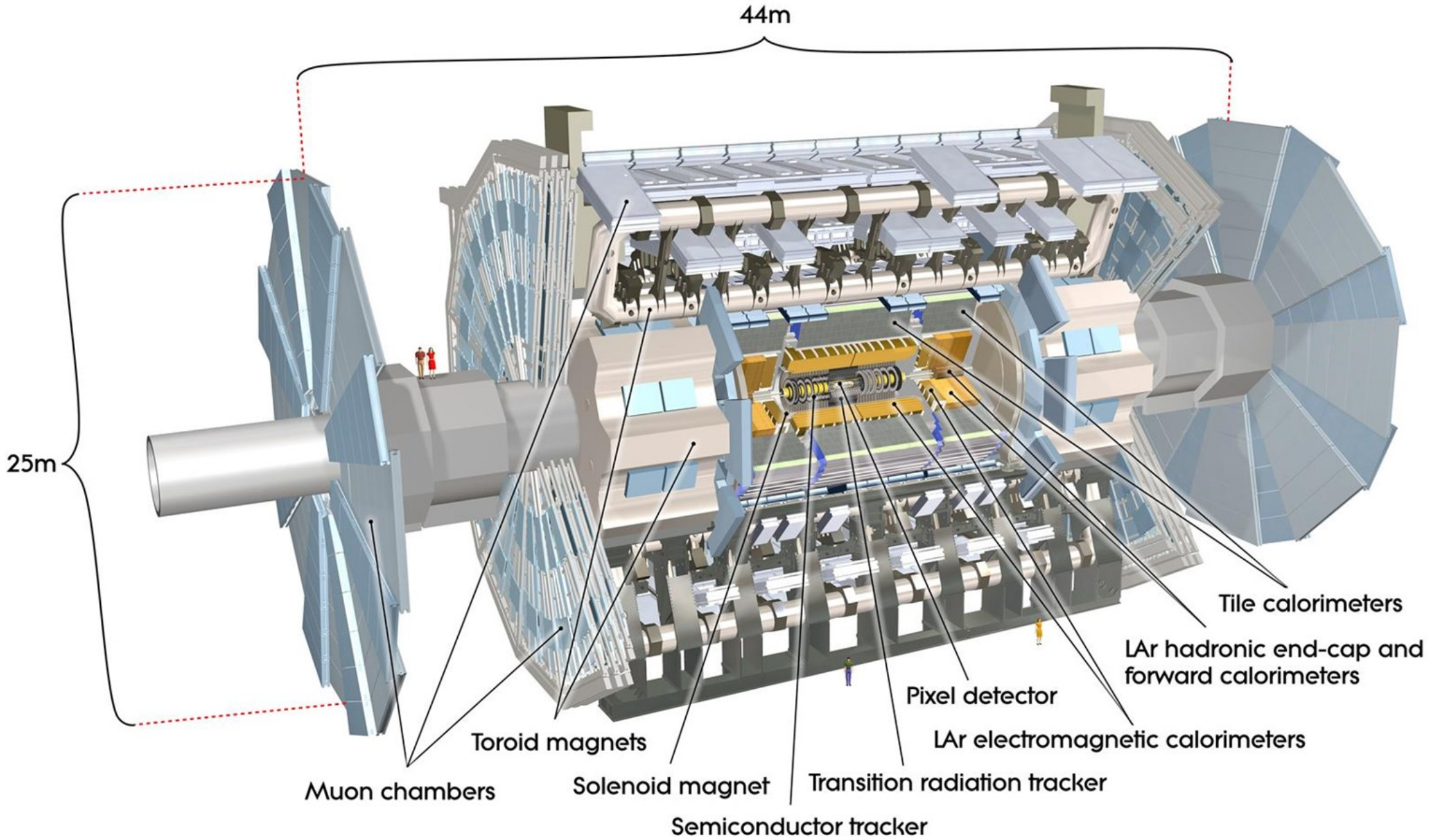


$$\frac{d^2\sigma}{dM_{\mu\mu}dY_{\mu\mu}} = \frac{d^2\mathcal{L}_{\gamma\gamma}}{dMdY} \times \sigma(\gamma\gamma \to \mu\mu)$$

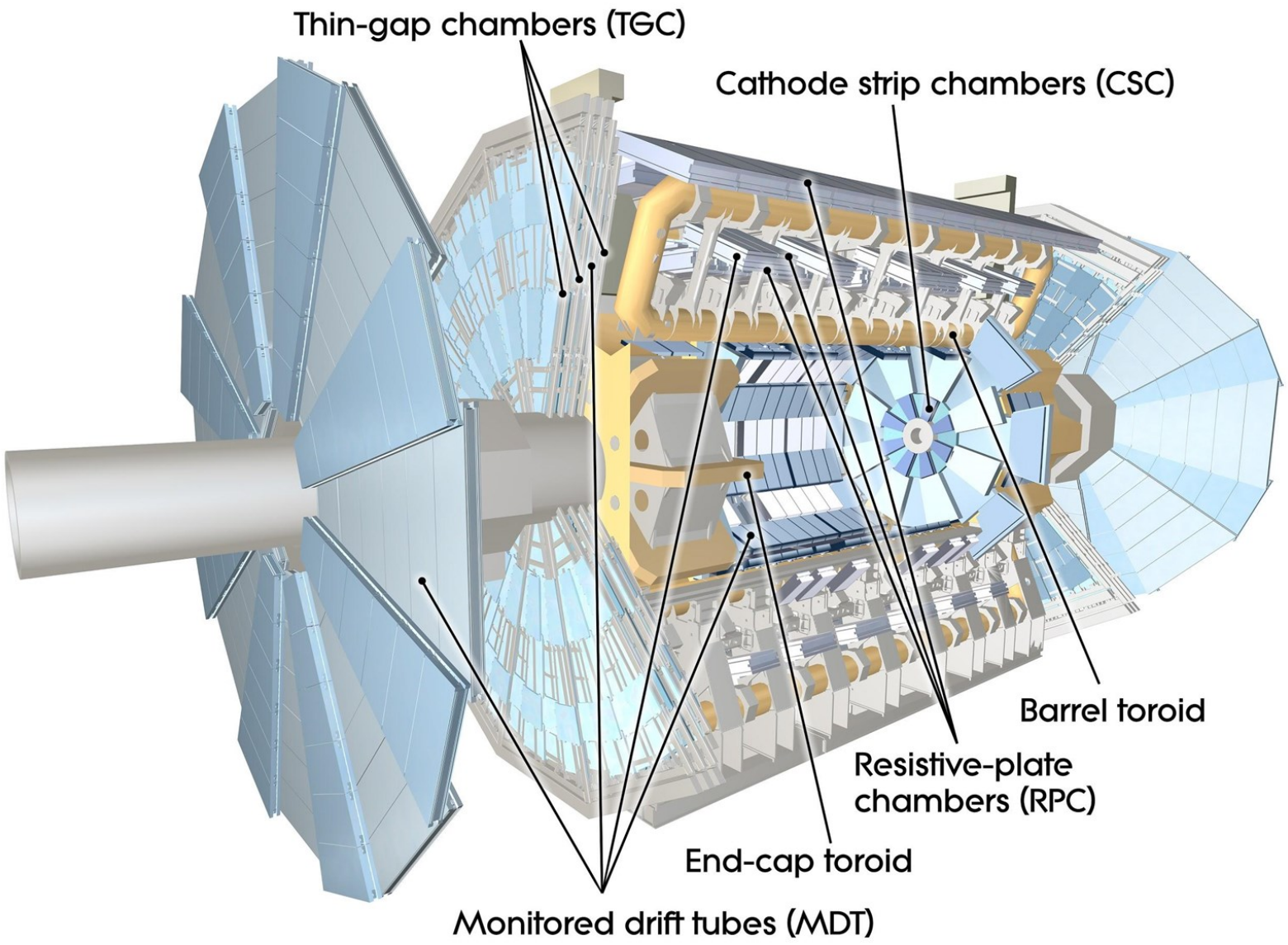
This luminosity also enters photo-nuclear and photon-pomeron reactions

$$\frac{d^2\mathcal{L}}{dMdY} = \mathcal{L}_{\mathrm{AA}} \frac{M}{2} \int_{b_1 > R_\mathrm{A}} d^2b_1 \int_{b_1 > R_\mathrm{A}} d^2b_2 \; n(k_1, b_1) n(k_2, b_2) P(b)[1 - P_H(b)]$$

"Equivalent Photon Approximation": $n(k,b) = \frac{d^3N}{dkd^2b} = \frac{Z^2\alpha}{\pi^2 k b^2} x^2 K_1^2(x)$


44m
25m
Tile calorimeters
LAr hadronic end-cap and forward calorimeters
Pixel detector
LAr electromagnetic calorimeters
Toroid magnets
Transition radiation tracker
Muon chambers
Solenoid magnet
Semiconductor tracker

Muon Spectrometer

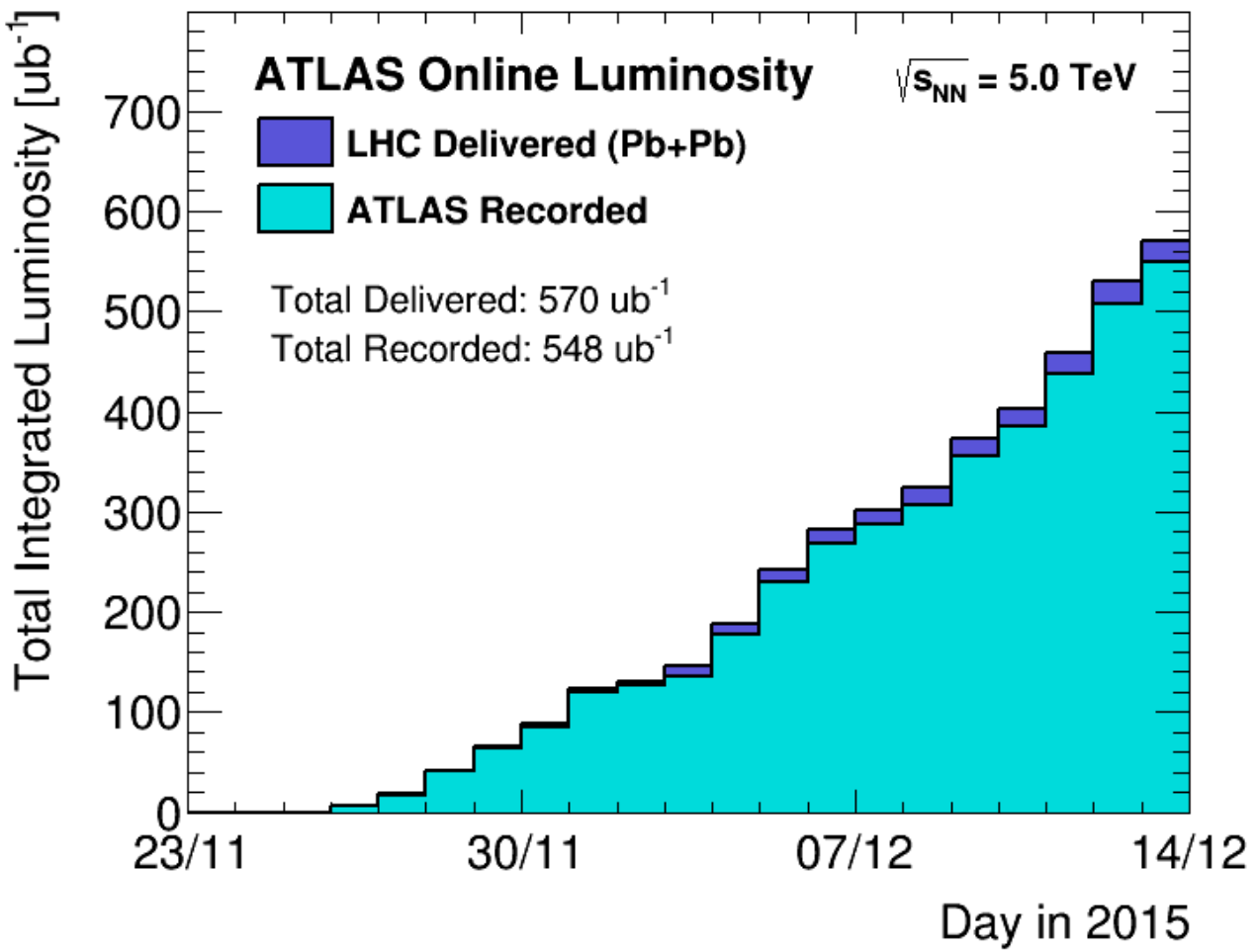


Multiple layers of tracking and trigger chambers that cover $|\eta| < 2.4$

Momentum measurement with bending from azimuthal magnetic field.

Standalone operation (can do tracking, vertexing without inner detector)

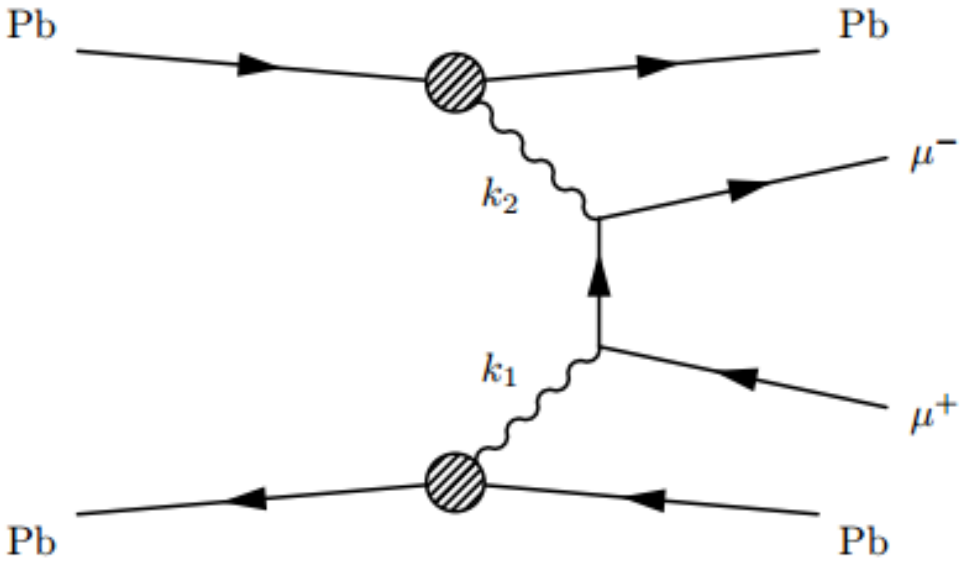
The 2015 lead—lead run



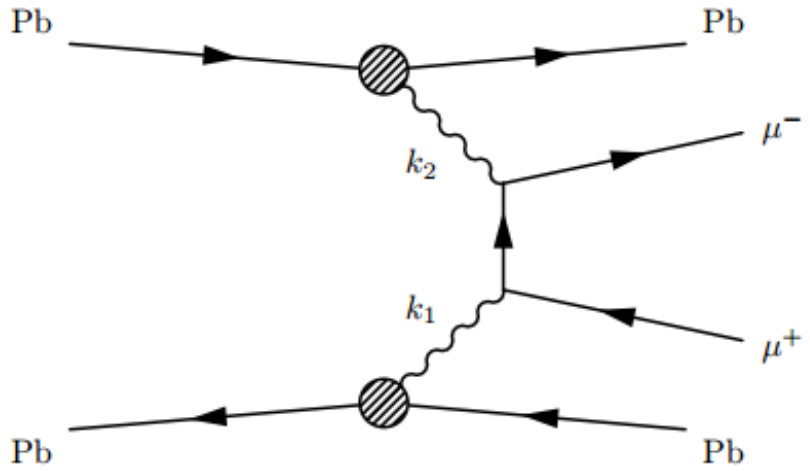
Luminosity calibrated with van der Meer scan with a 7% systematic uncertainty.

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



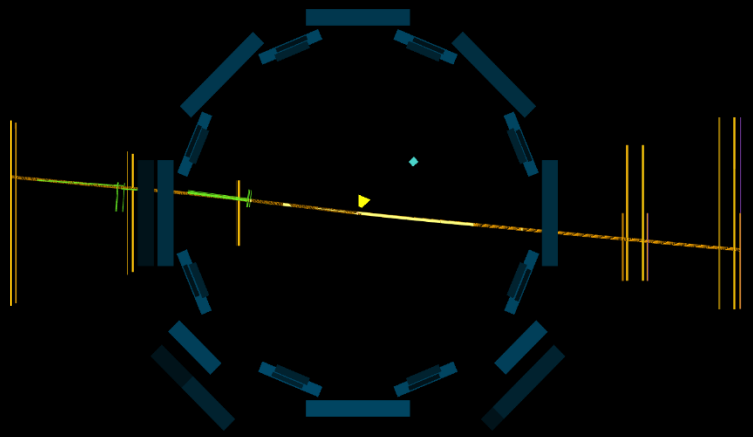
Total number of triggered events is 248k

- 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

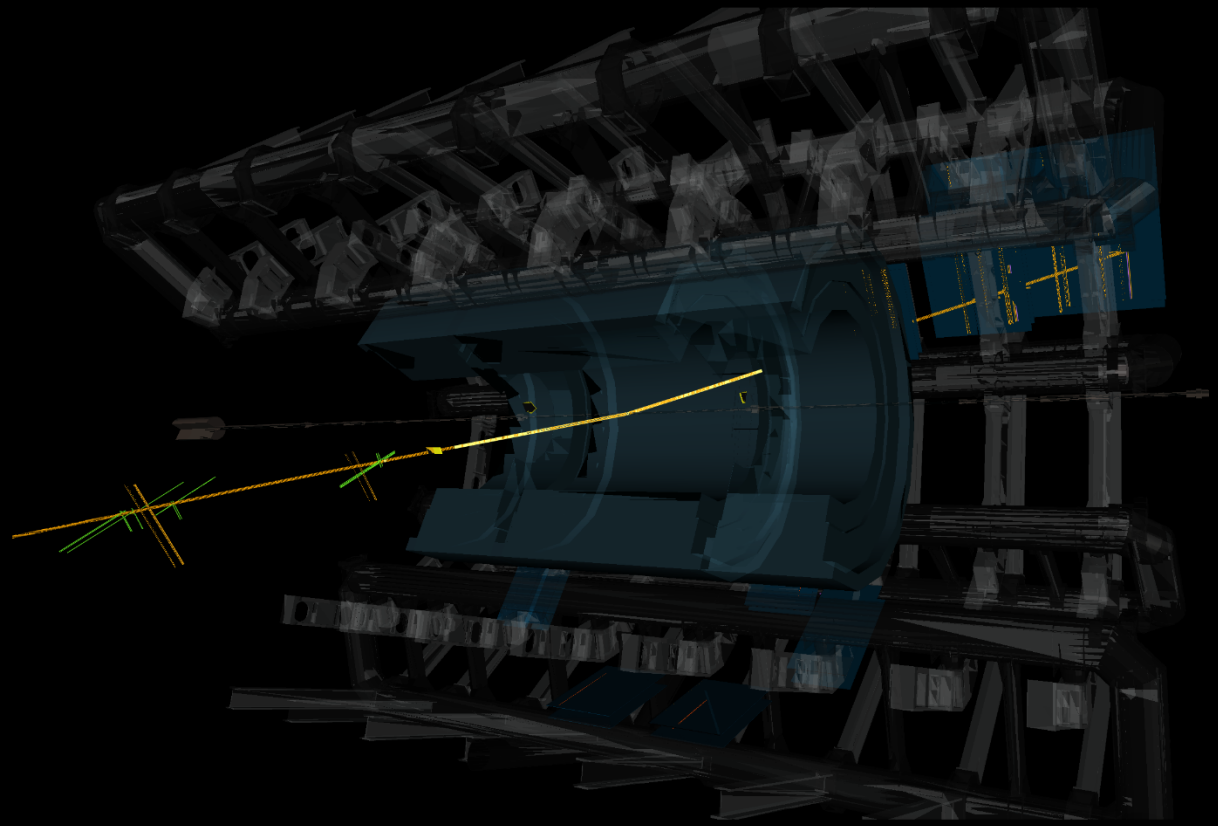
Total number of events selected is **12069**



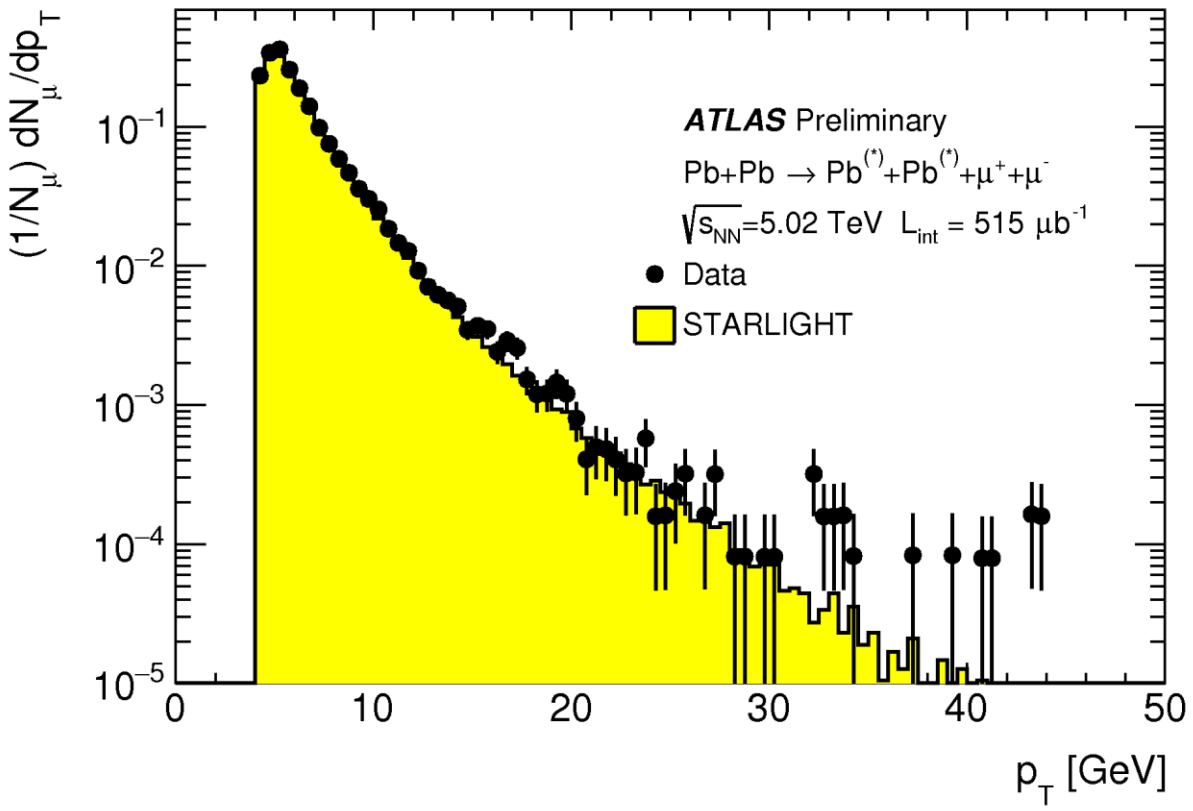
ATLAS EXPERIMENT

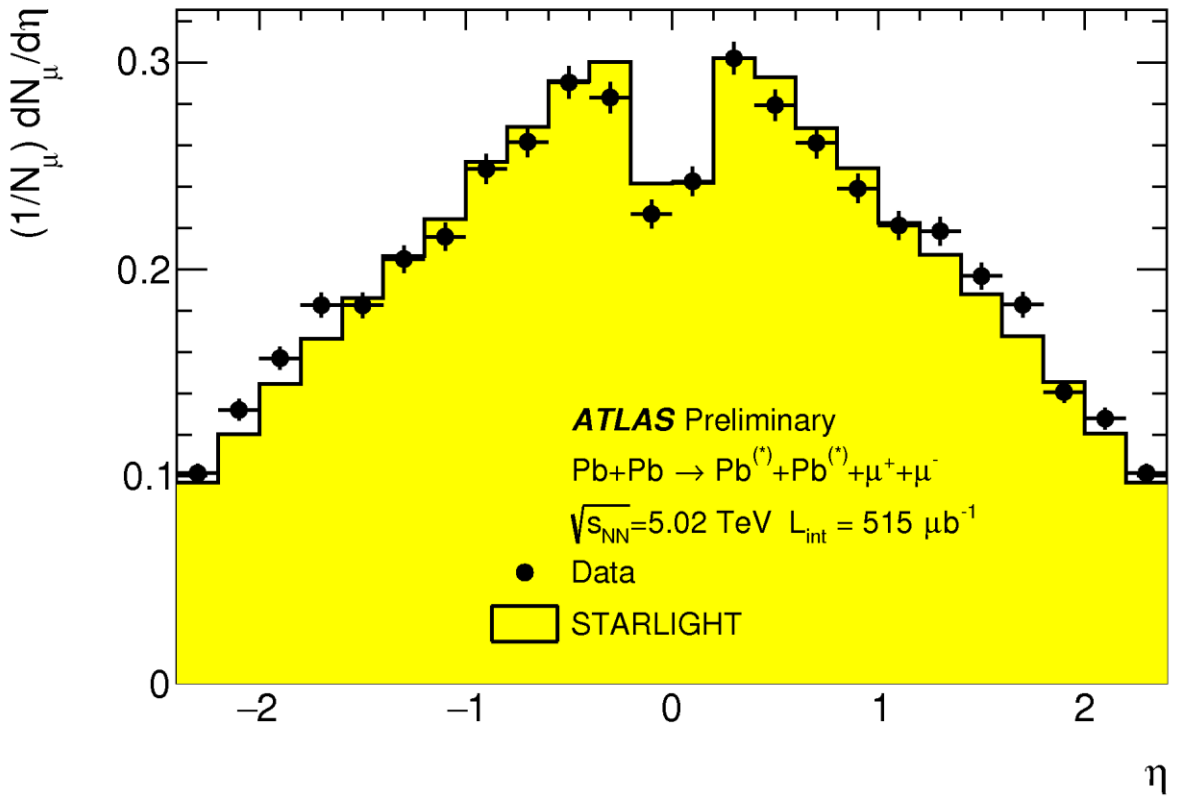
Run: 287038
Event: 71765109
2015-11-30 23:20:10 CEST

Dimuons UPC Pb+Pb 5.02 TeV



(Uncorrected) single-muon distributions

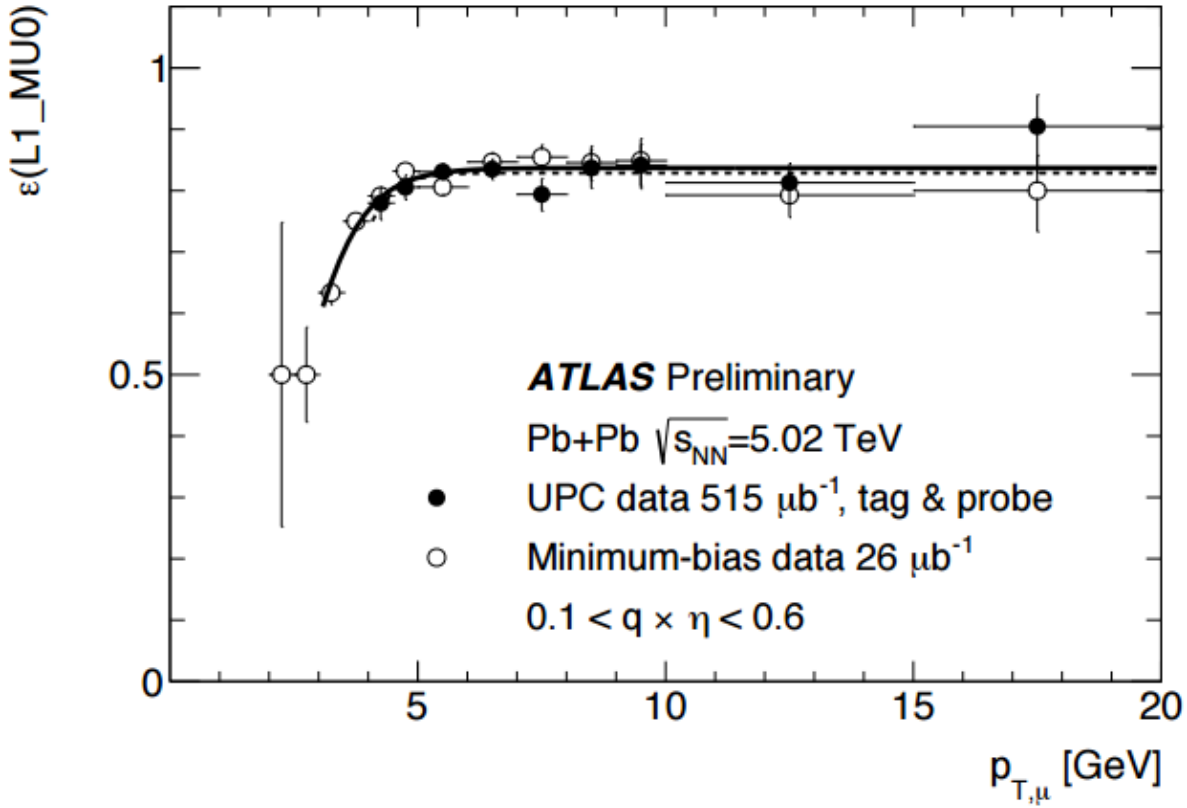




- Starlight 1.1 MC is used to generate exclusive dimuon pairs. Leading order QED calculation.
- Good MC description of distributions of reconstructed muons

Corrections

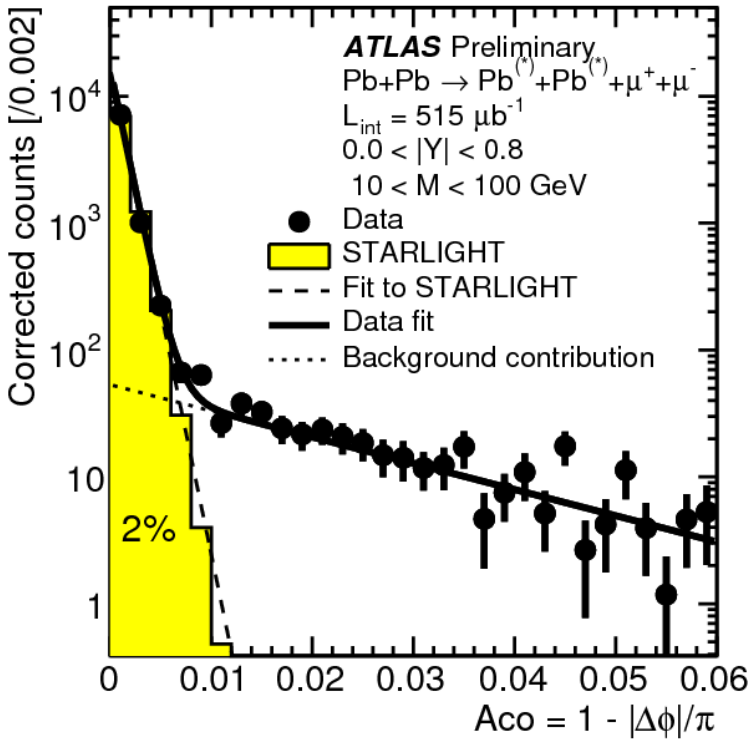
- Muon trigger efficiency **> 80%** (data)
- Muon reconstruction efficiency **> 90%** (data)
- Vertex efficiency ~97% (MC)
- Muon resolution negligible

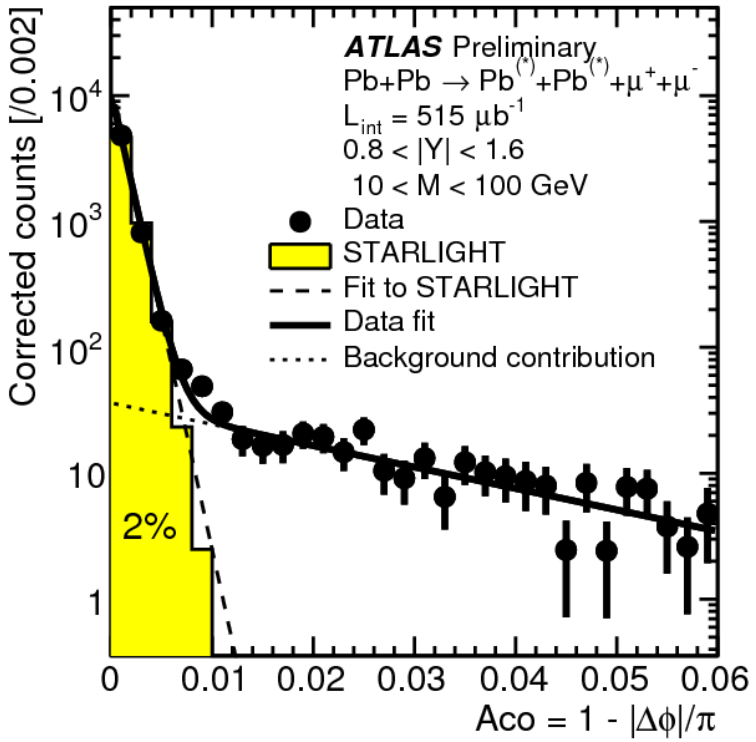


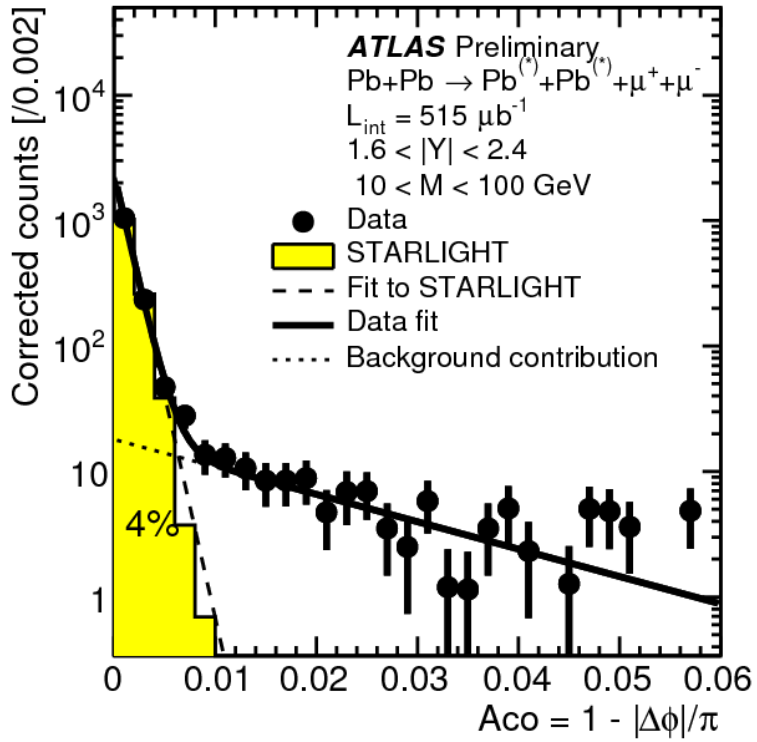
Event-by-event weight for total dimuon efficiency, assuming factorization, is given by:

$$\frac{1}{w} = \epsilon_R(\mu_1)\epsilon_R(\mu_2)(1-(1-\epsilon_T(\mu_1))(1-\epsilon_T(\mu_2)))$$

Acoplanarity distributions



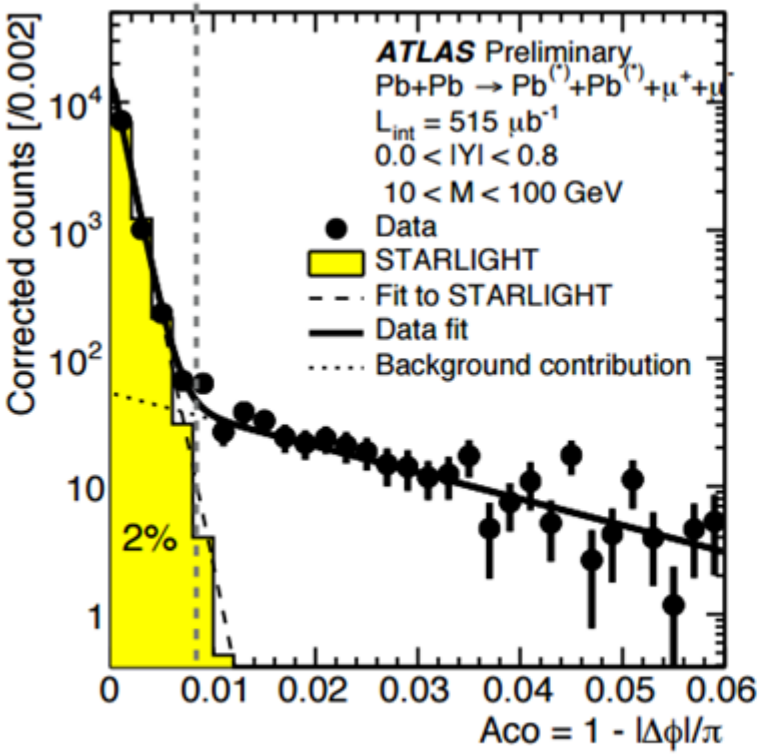


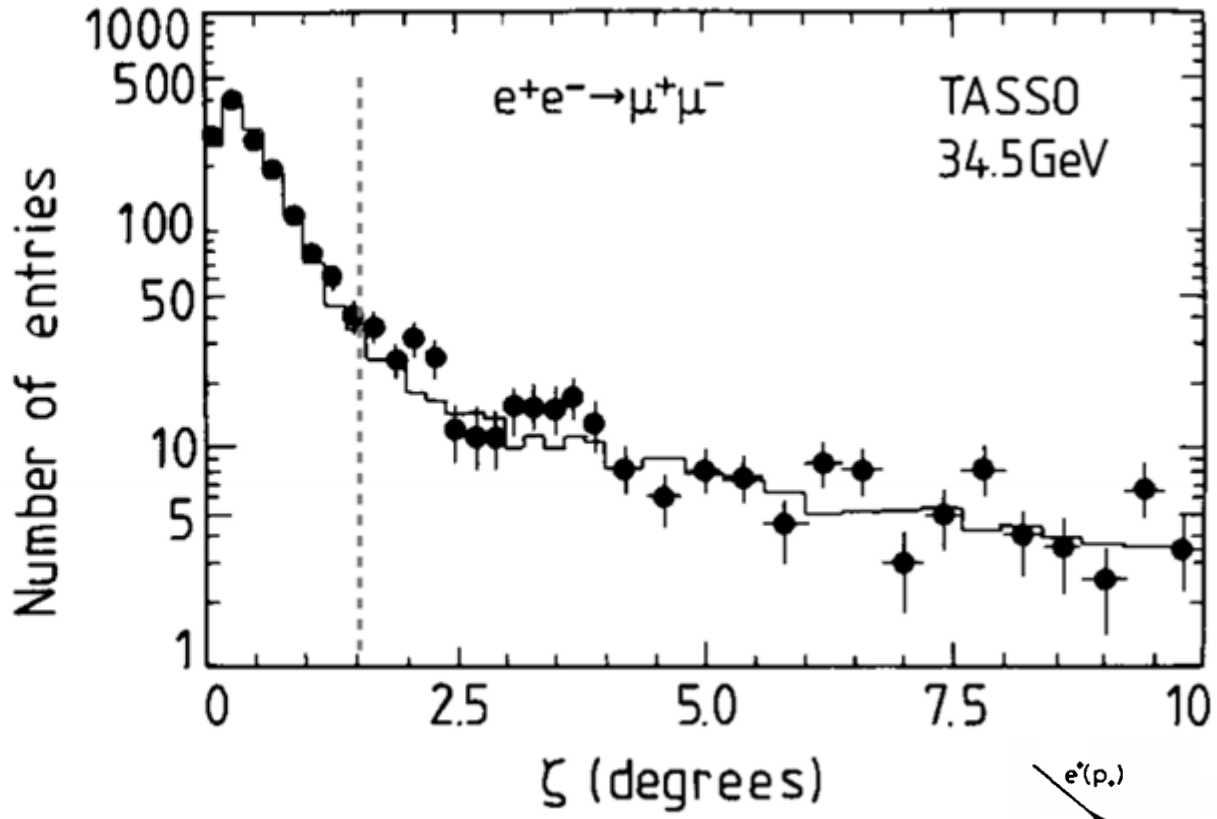


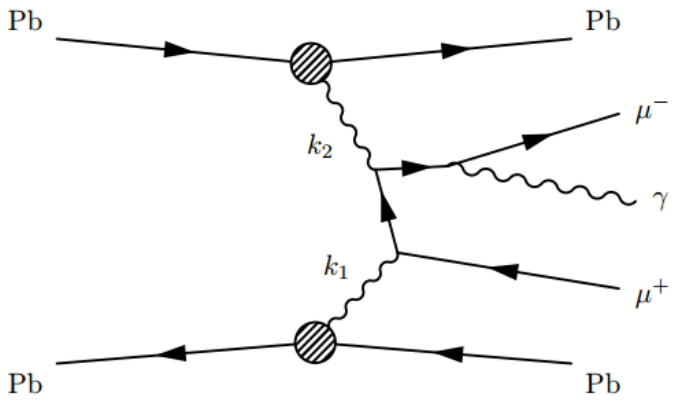
Most of dimuon pairs are produced mostly back to back, as expected

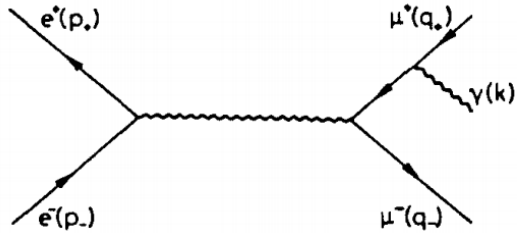
Higher-order QED corrections ?

Z.Phys. C22 (1984) 13





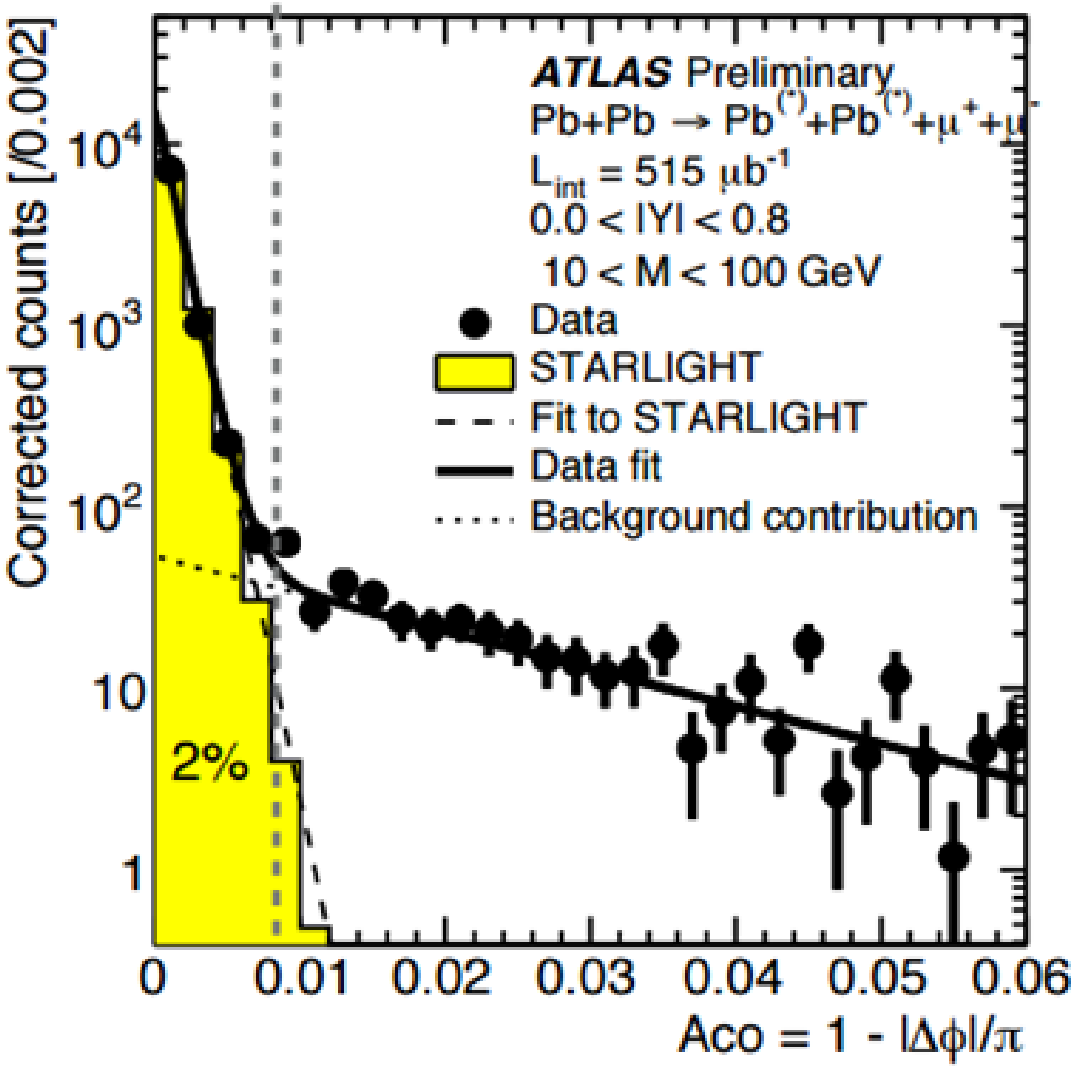




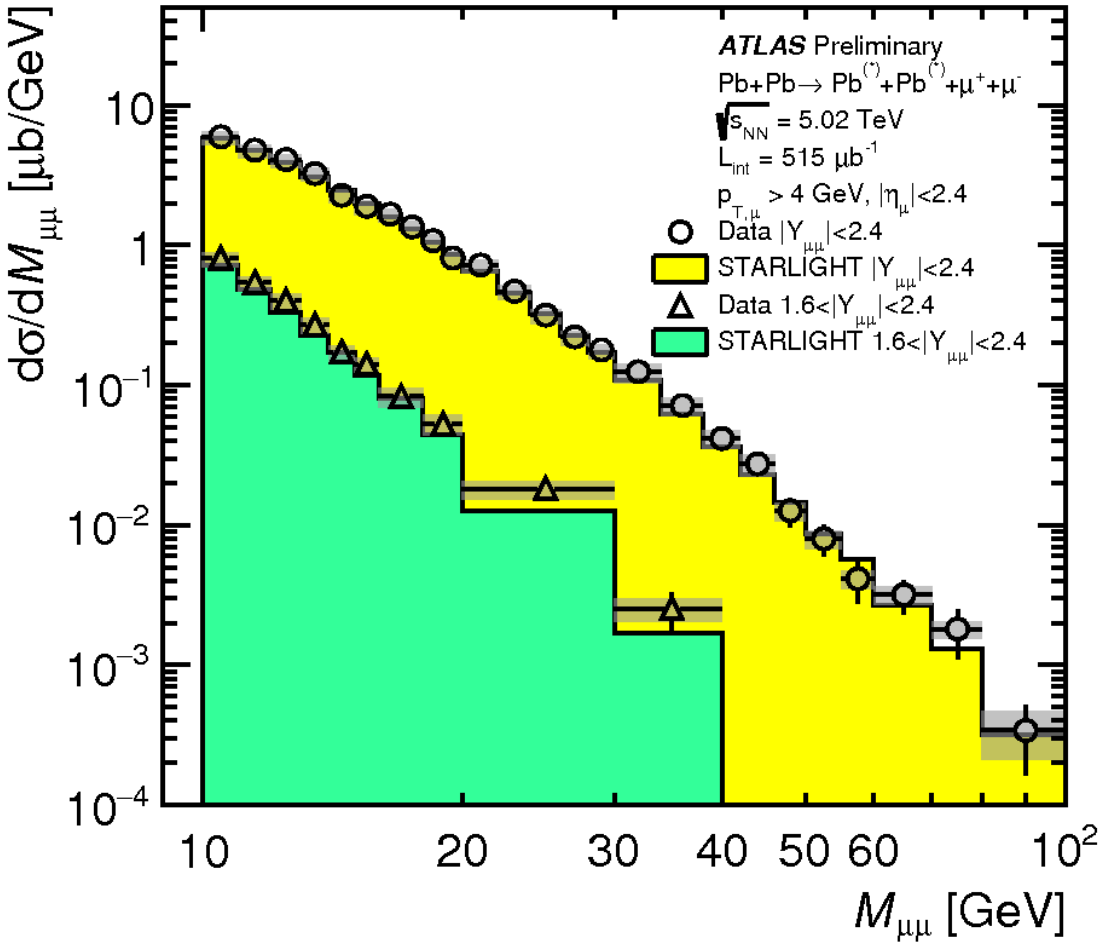
- TASSO data well described when considering radiative corrections
- Maybe is the same for ATLAS data, we are investigating this.

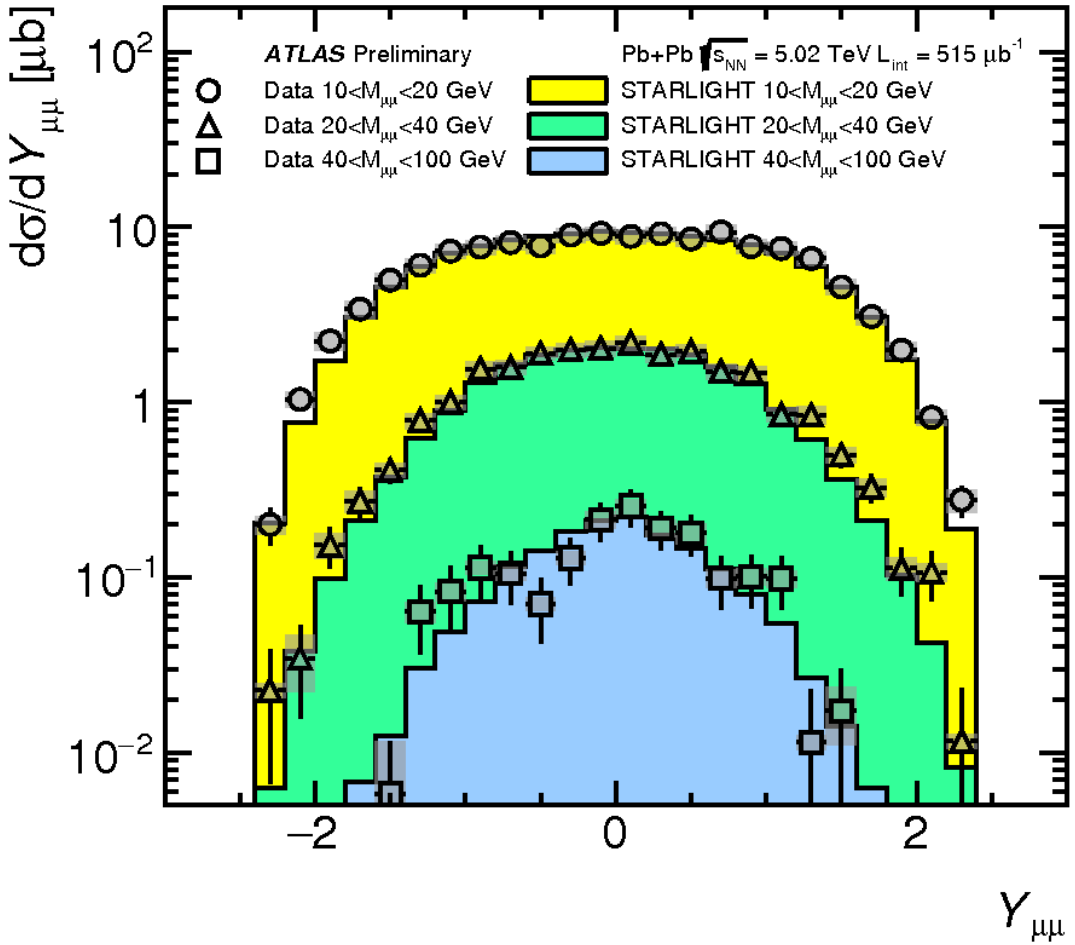
Acoplanarity tails

- Starlight1.1 does not include radiative corrections. So we cant 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



Differential cross-section

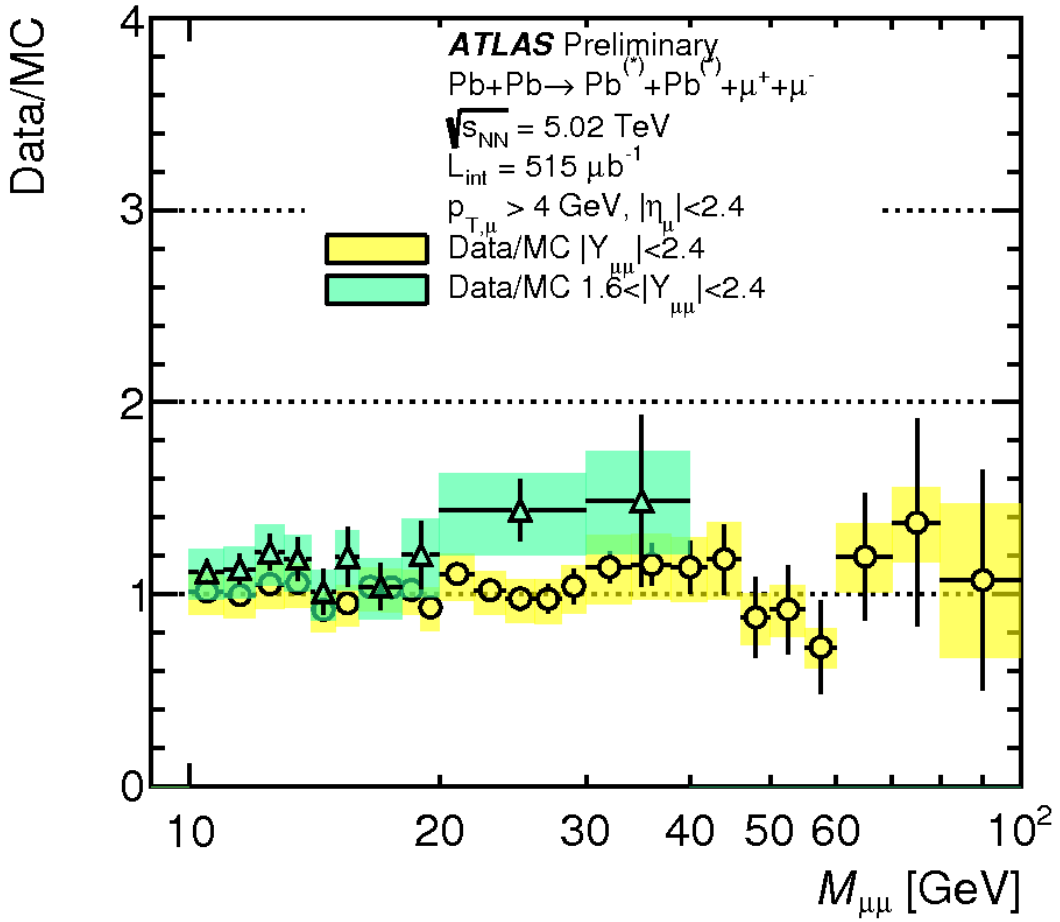


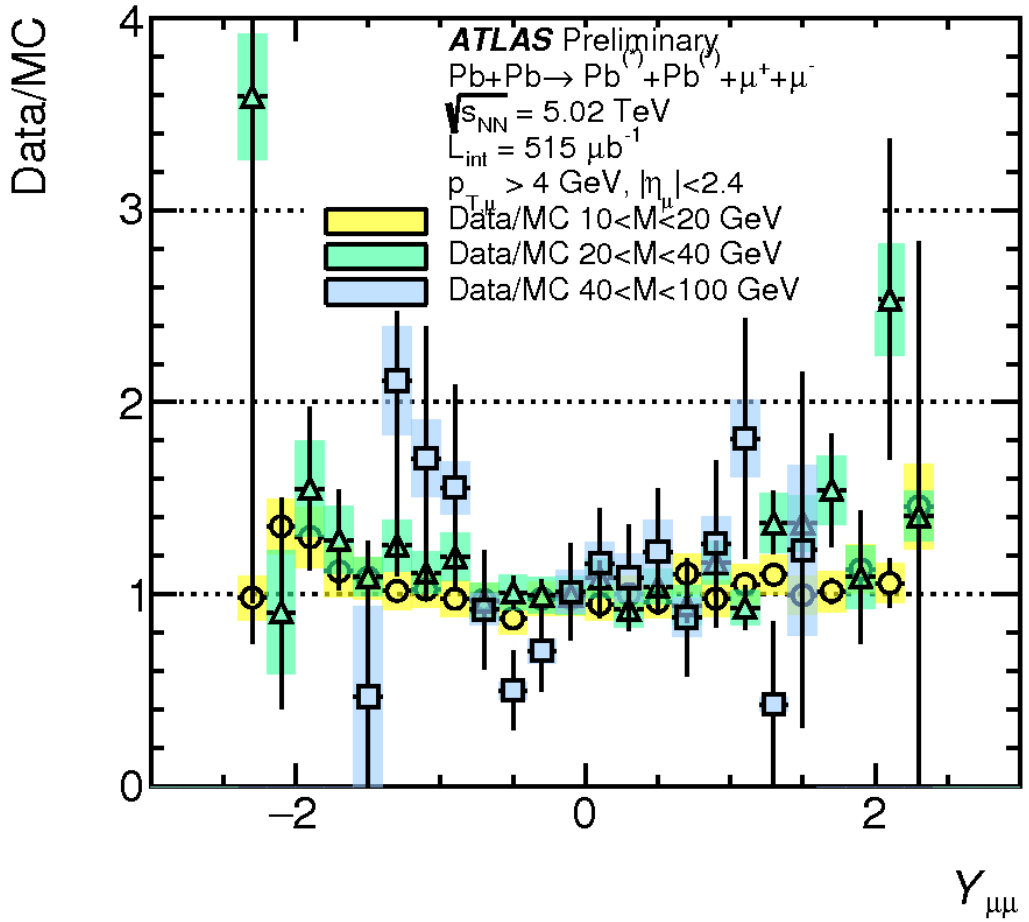


Good agreement with Starlight MC.

Surprising given that this is the **first measurement** in this kinematic region

Ratio to Starlight MC



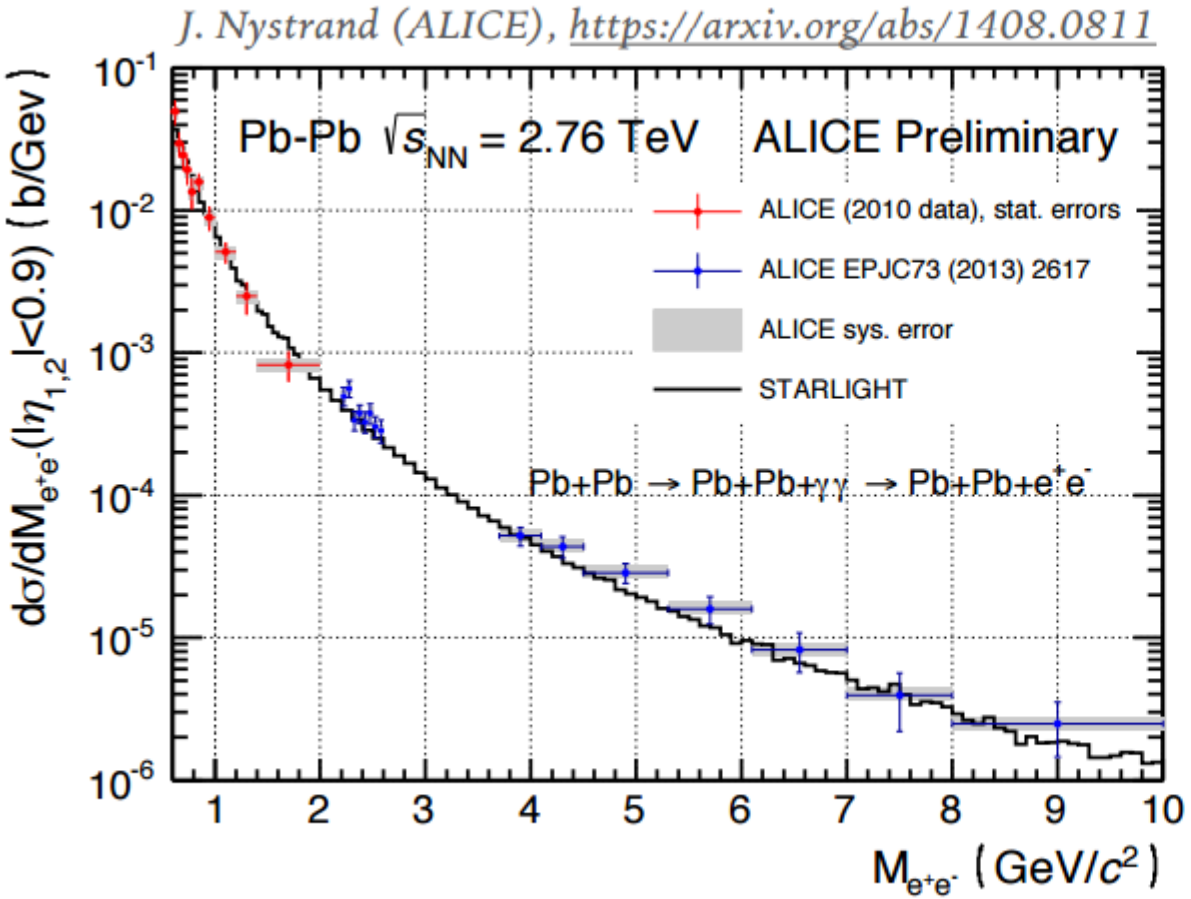


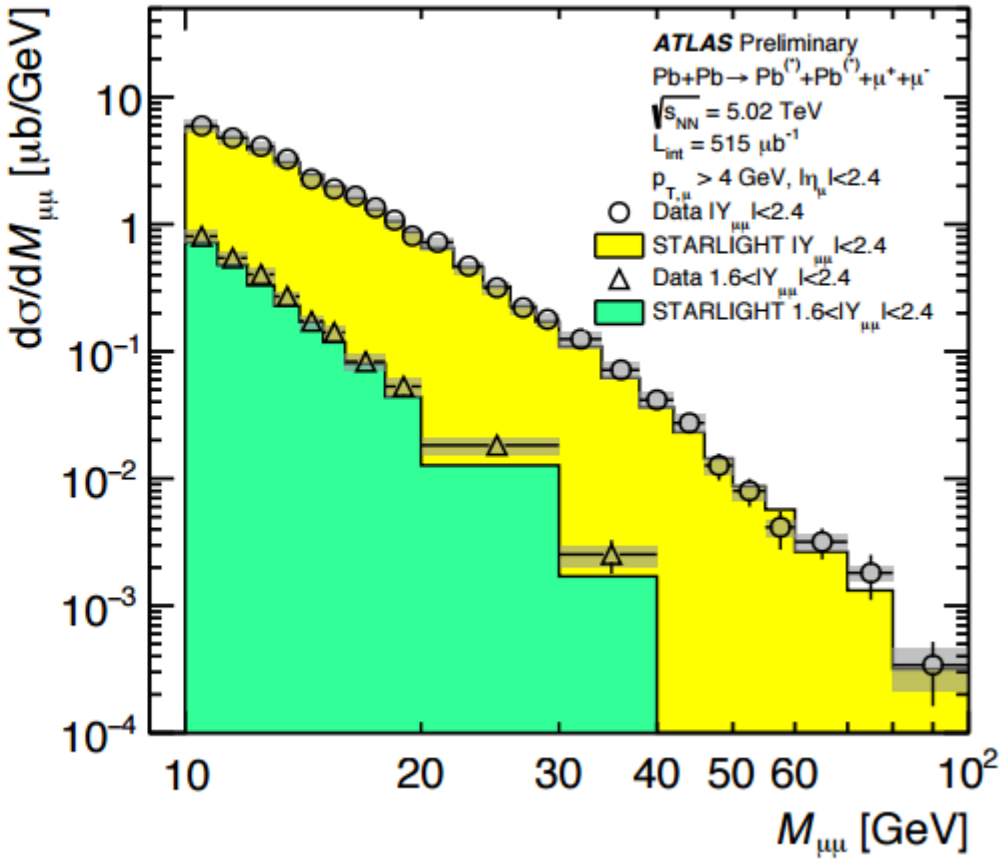
Good agreement with Starlight MC.

This is the **first measurement** in this kinematic region

Verifies Z^4 scaling of cross-section and photon flux

Starlight vs data





- 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.