Forward physics and diffraction results of the ATLAS experiment

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QCD at LHC: forward physics and UPC collisions of heavy ions

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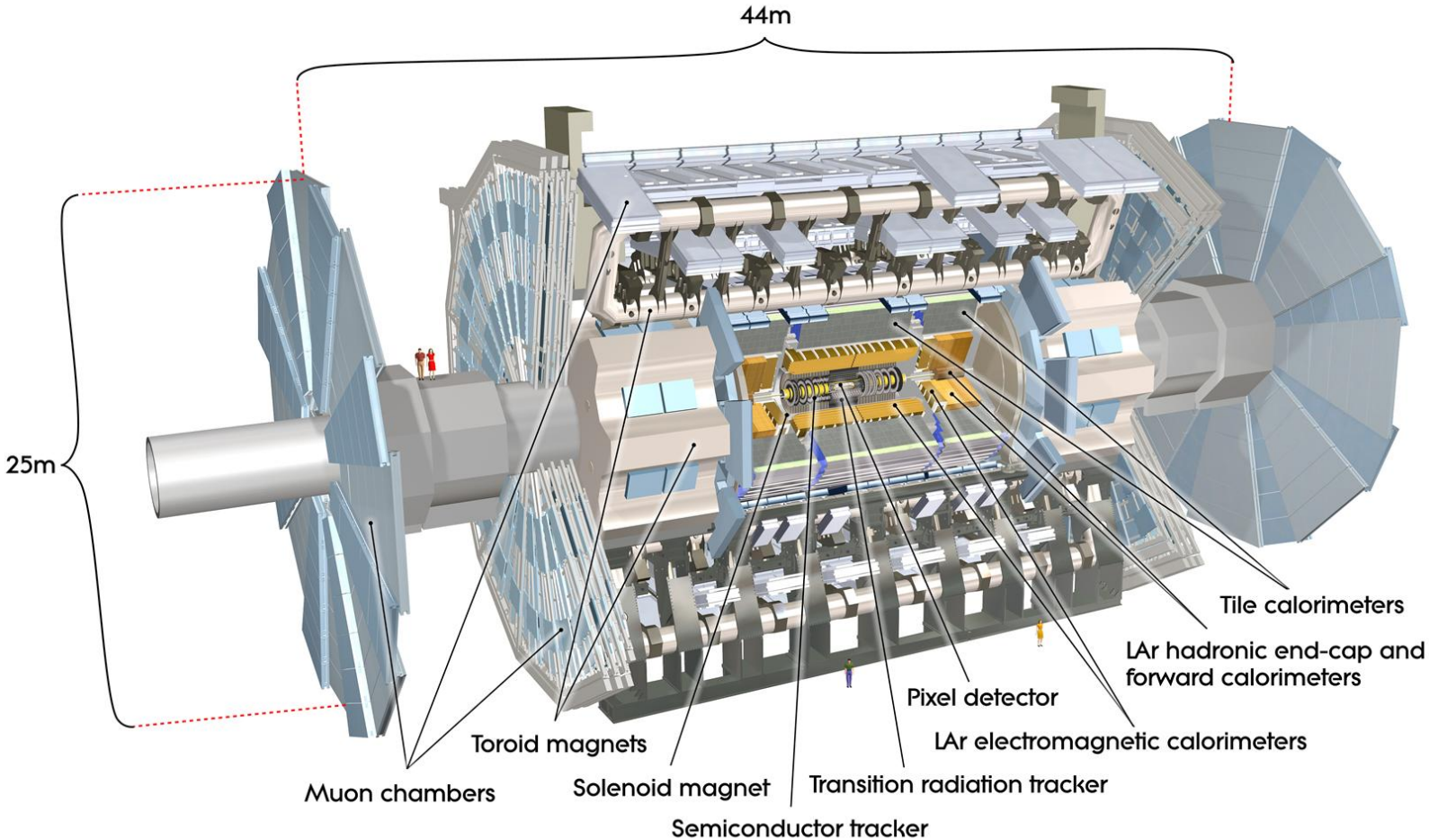
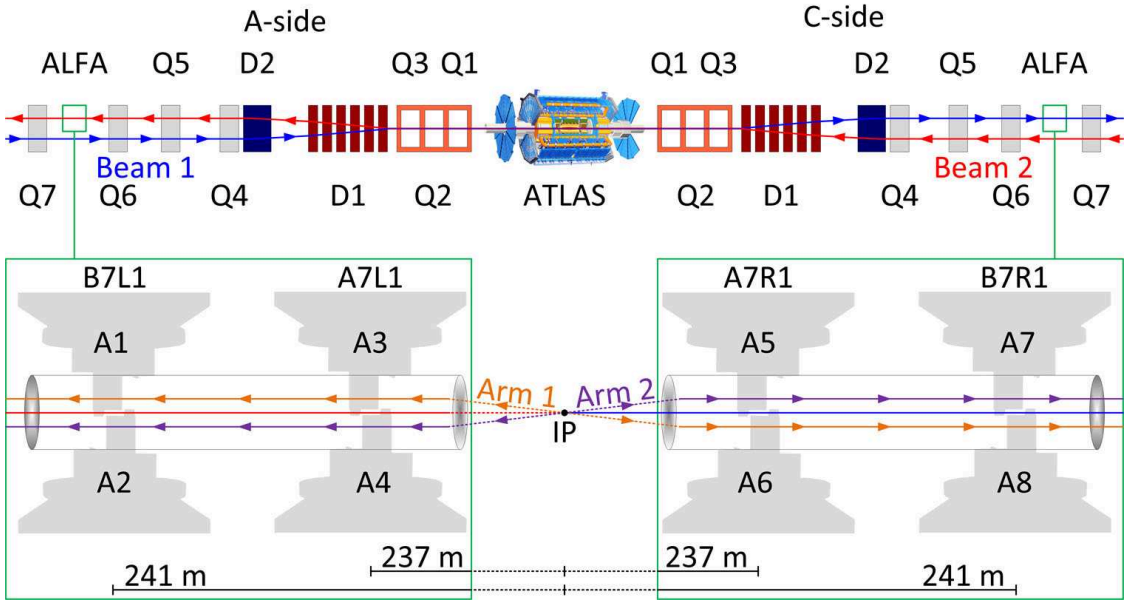
Contents

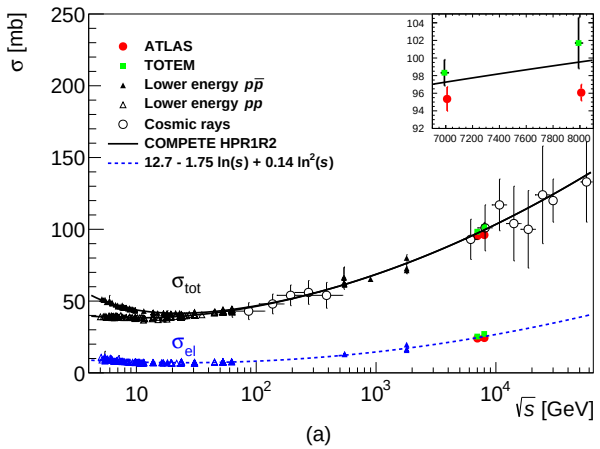
Introduction



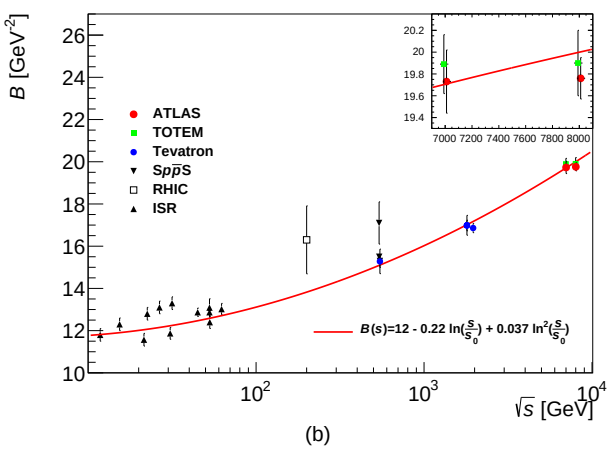
...but also forward detectors providing measurements of forward intact protons: **ALFA** and **AFP**

ALFA (Absolute Luminosity For ATLAS) detectors





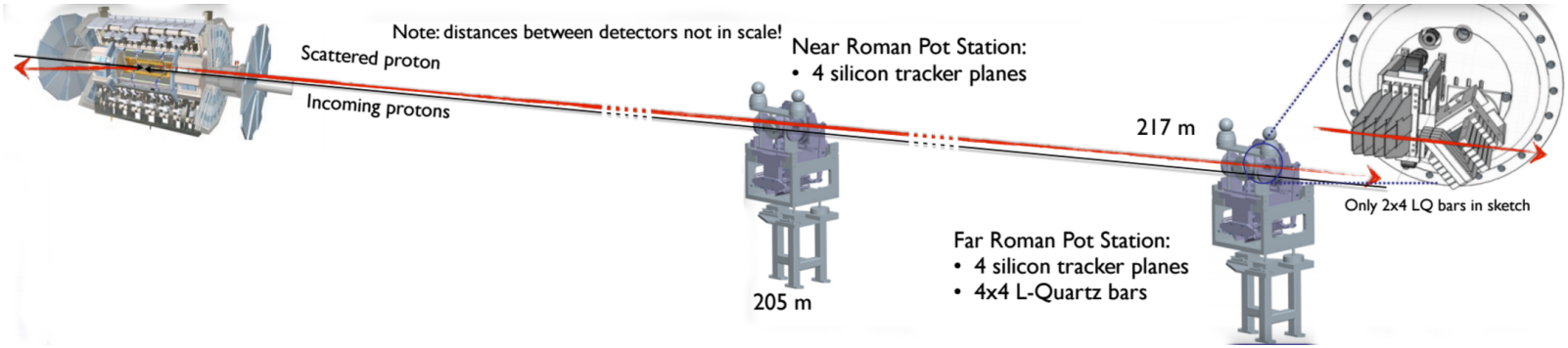
(a)

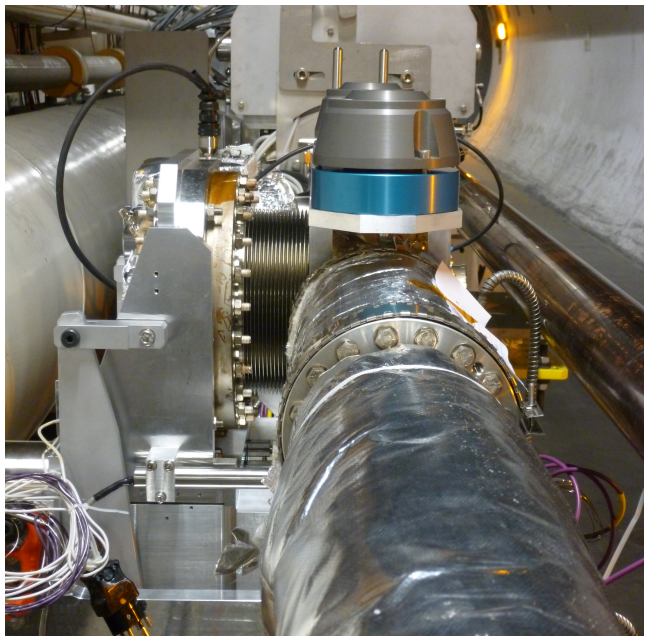


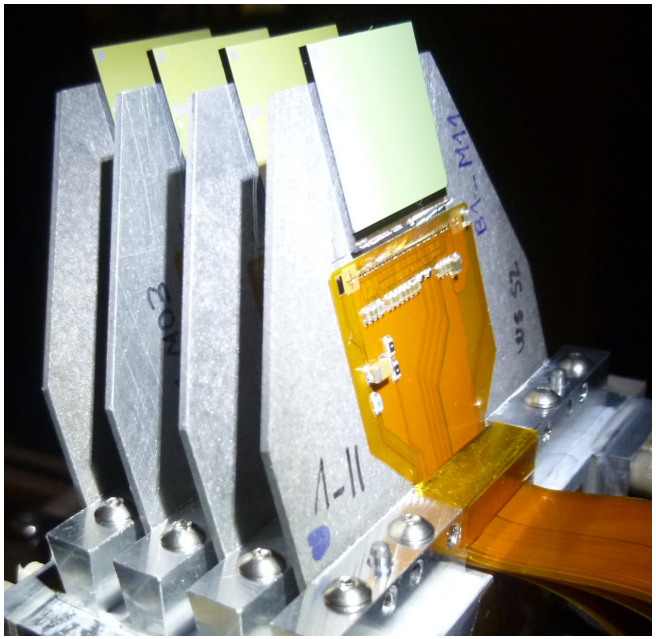
(b)

More in Per's talk later today

AFP (ATLAS Forward Proton) detectors







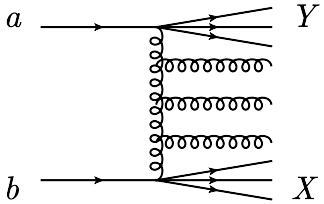
More in Maciej's talk on Thursday

Contents

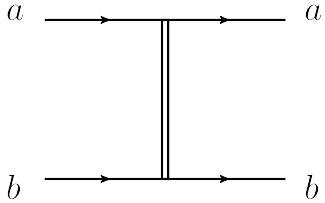
Contents

Early measurements – soft diffraction

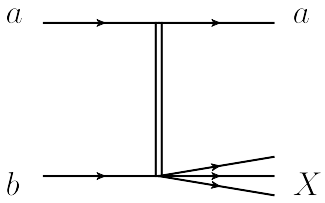
non-diffractive interaction



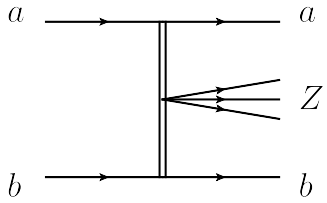
elastic scattering



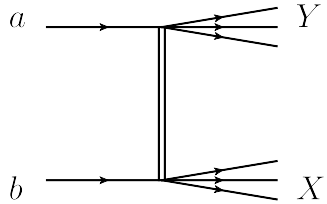
single diffraction

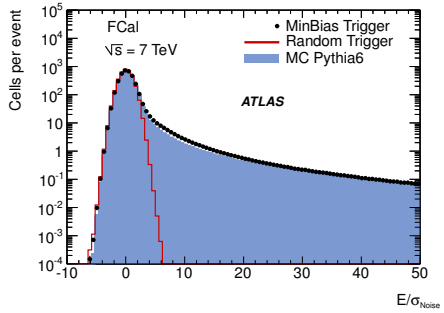


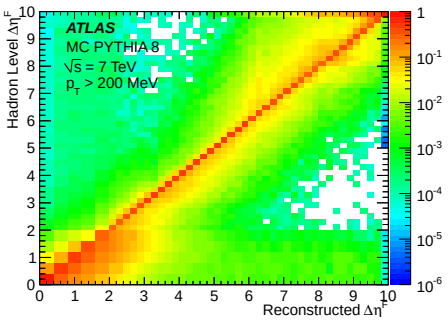
central diffraction



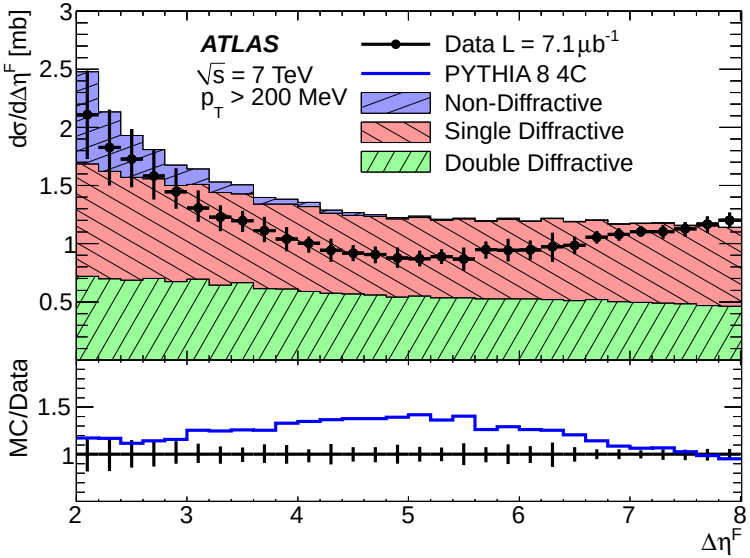
double diffraction







- Calorimeter used to measure rapidity gaps

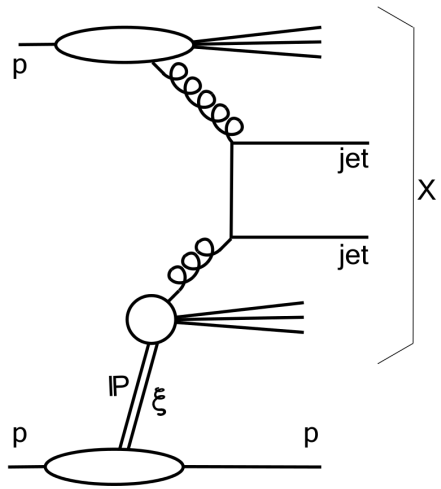


- Separation of diffractive processes from non-diffractive processes
- Full separation of single and double diffraction not possible

Contents

Event selection

- Low pile-up data sample from 2010 ($\sqrt{s} = 7$ TeV)
- Integrated luminosity: 6.8 nb
- Anti-kT algorithm
  - pT > 20 GeV
  - $|\eta| < 4.4$
  - R $= 0.4, 0.6$
- Rapidity gap based on
  - tracks ($|\eta| < 2.5$, pT > 200 MeV)
  - calorimeter cells ($|\eta| < 4.8$)



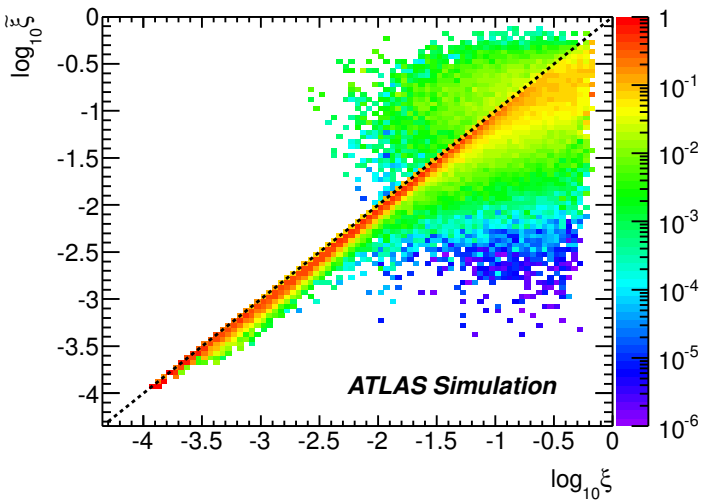
Reconstruction of diffractive proton kinematics

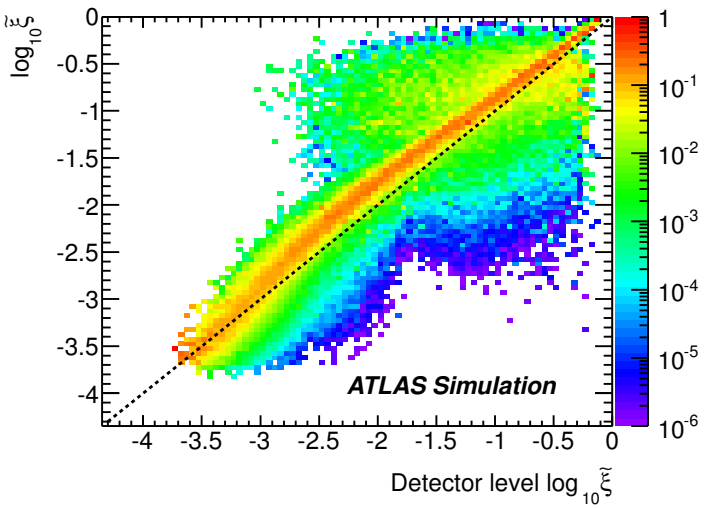
- Proton energy loss and diffractive mass

$$\xi = M_X^2/s$$

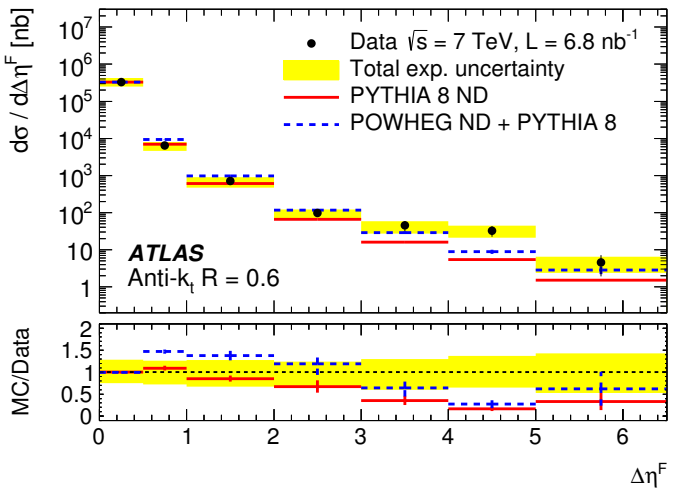
- Reconstruction:

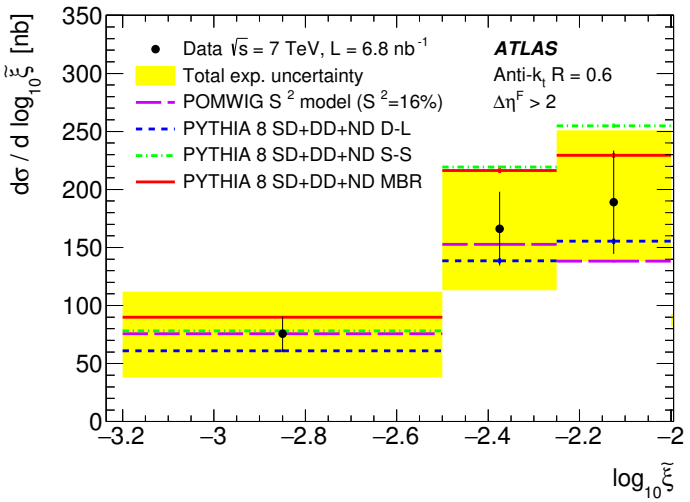
$$\tilde{\xi} = \frac{\sum p_T e^{\pm\eta}}{\sqrt{s}}$$





Results





- Evidence of diffractive component
- Good description by Pythia8
- Gap survival probability: 0.16 ± 0.04 (stat) ± 0.08 (exp. syst.)

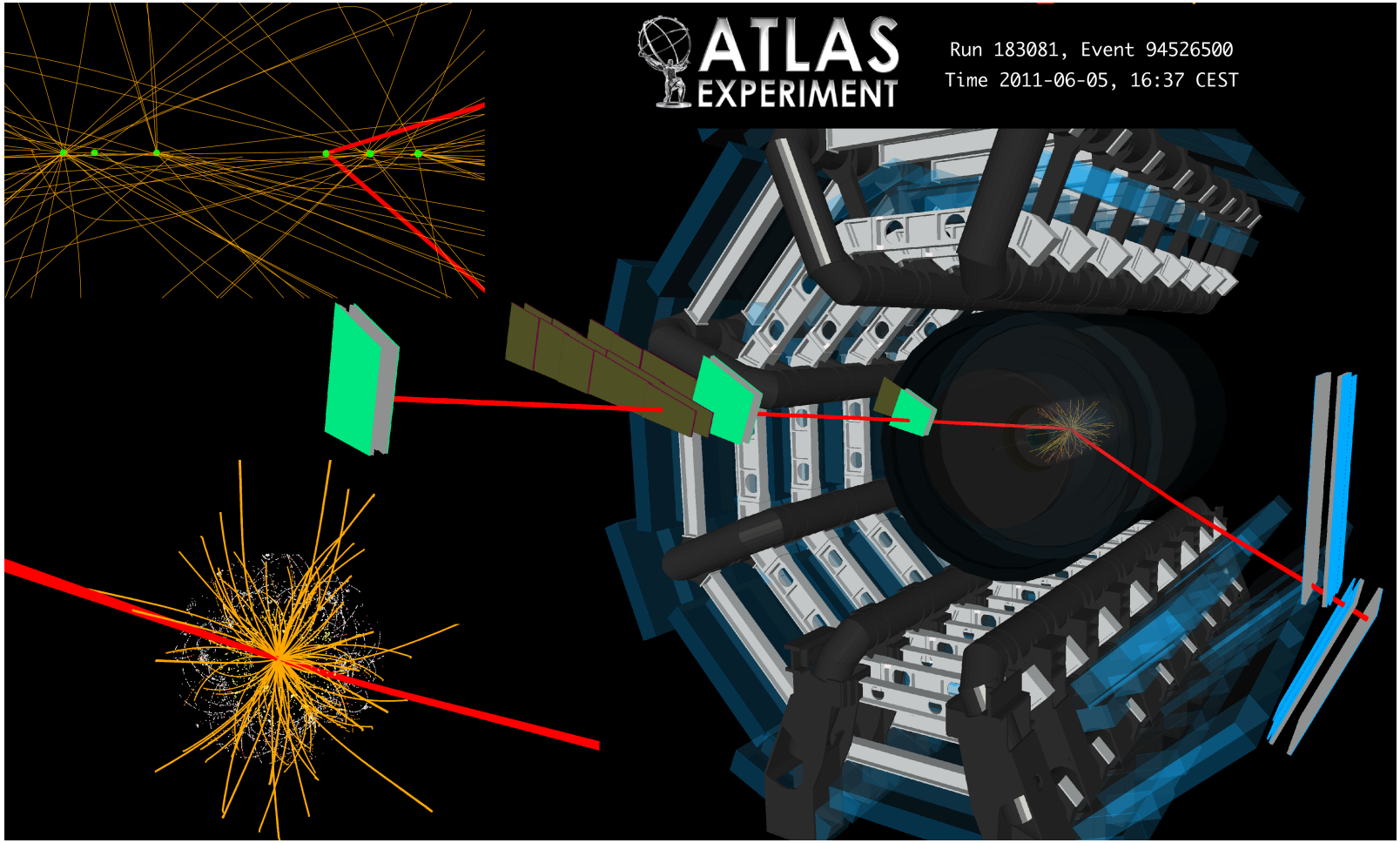
Contents

Motivation

- Two-photon processes can be computed within QED
- Absorptive corrections (gap survival probability)
- Exclusive $\gamma\gamma \to ll$
  - Standard candle for photon-induced physics
  - Non-negligible background to Drell-Yan like reactions
- Test of SM γWW and $\gamma\gamma WW$ couplings
- Searches for new physics

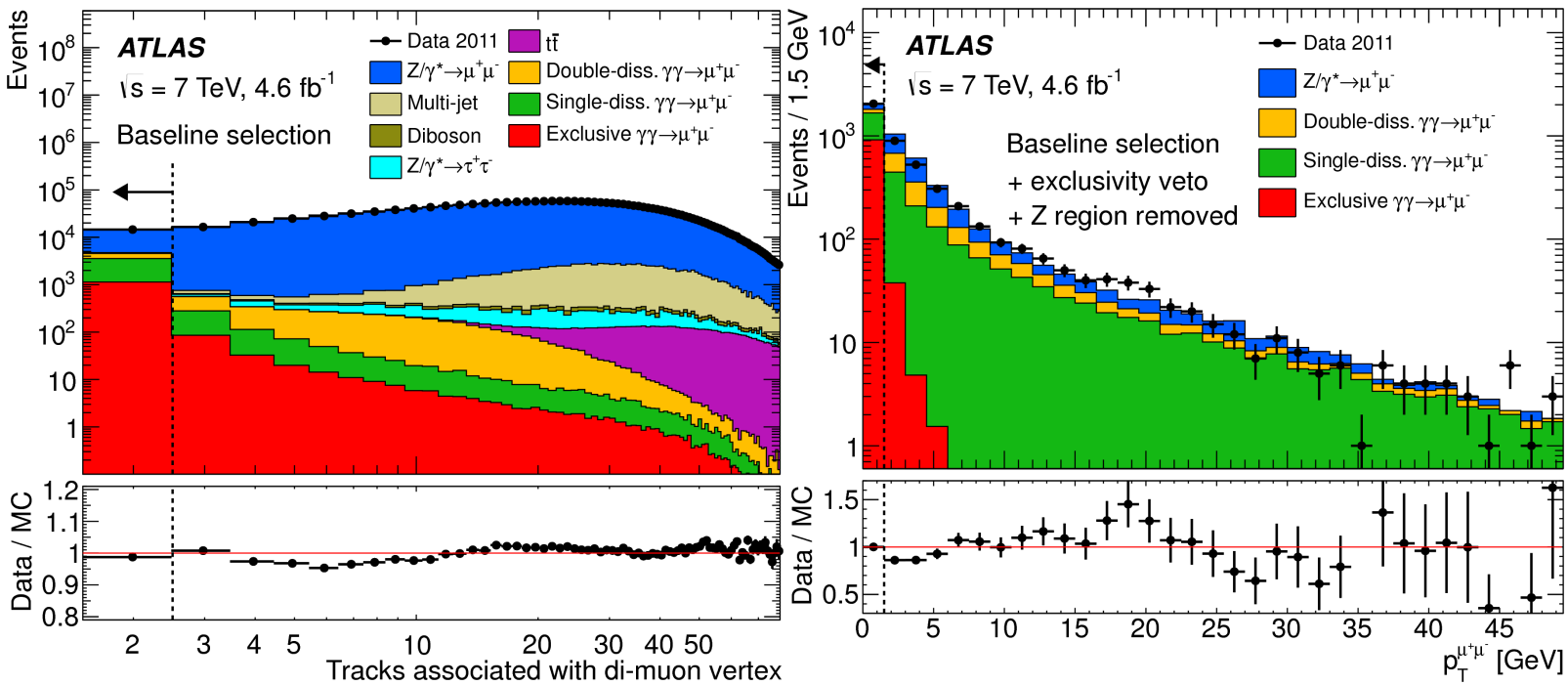
Contents

$\gamma\gamma \to \mu\mu$ event

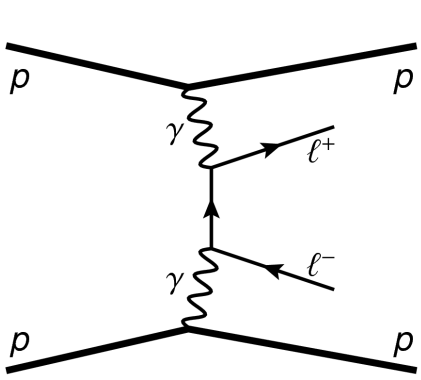


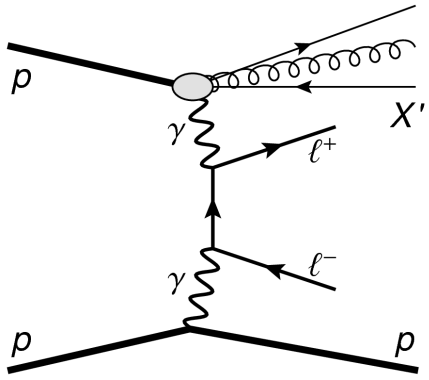
Event selection

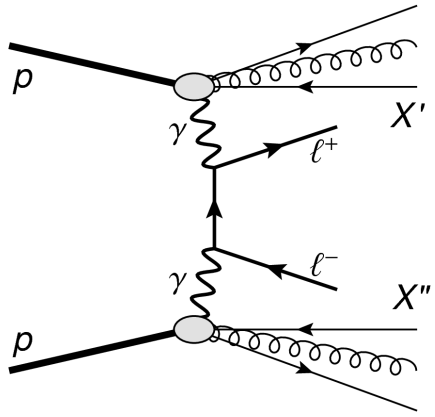
- Preselection:
  - muons: $p_T > 10$ GeV, $|\eta| < 2.4$, $M_{\mu\mu} > 20$ GeV
  - electrons: $p_T > 11$ GeV, $|\eta| < 2.4$, $M_{ee} > 24$ GeV
- Exclusive selection:
  - 3 mm vertex longitudinal isolation (efficiency = 74%)
  - p_T of the pair below 1.5 GeV

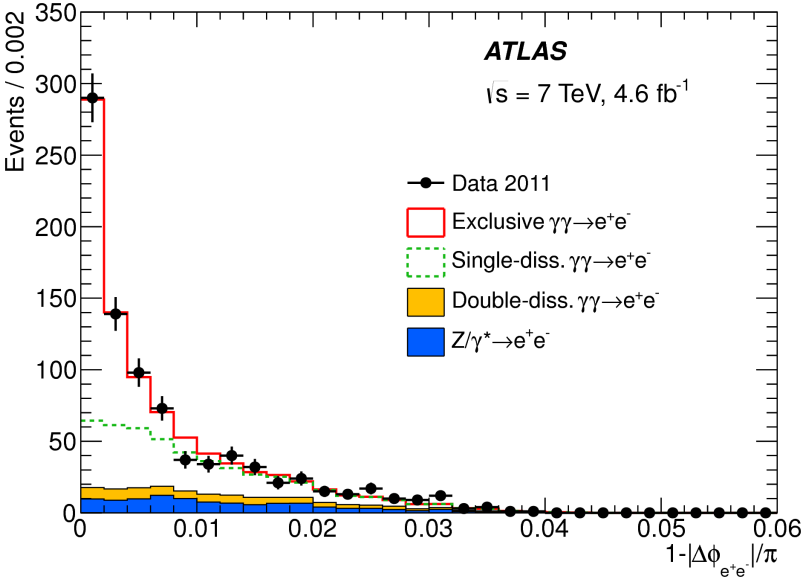


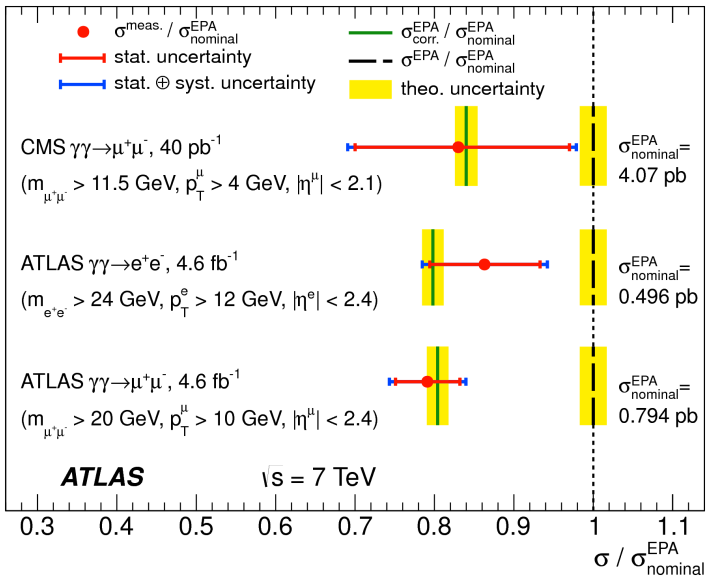
Results









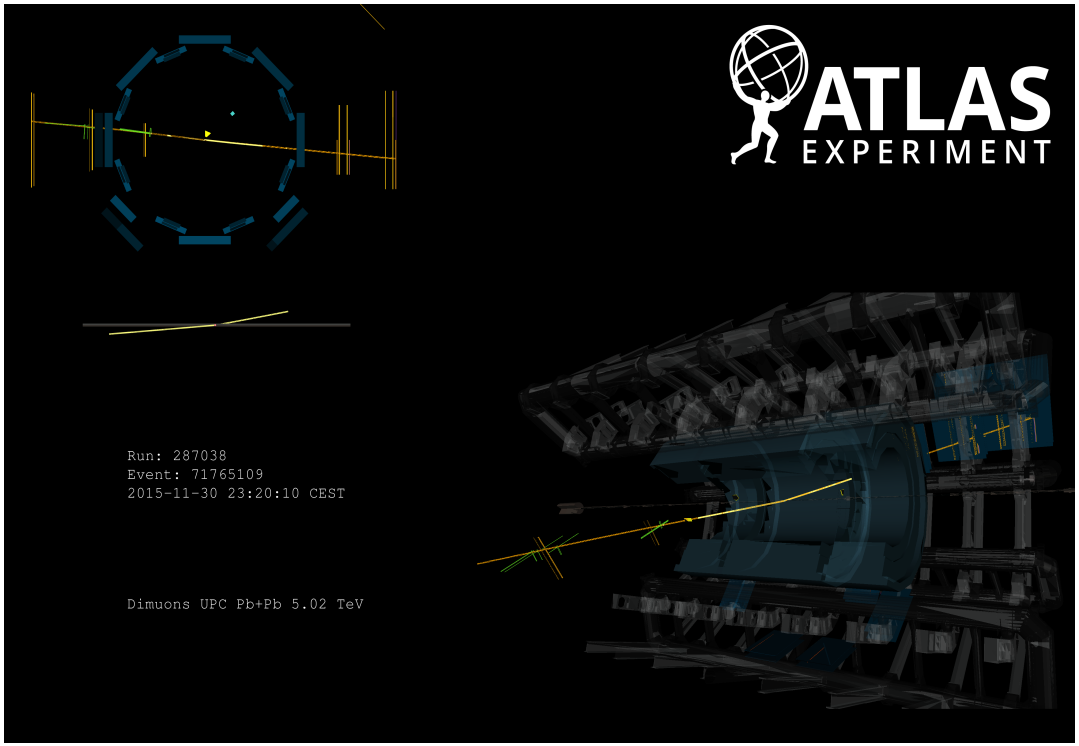


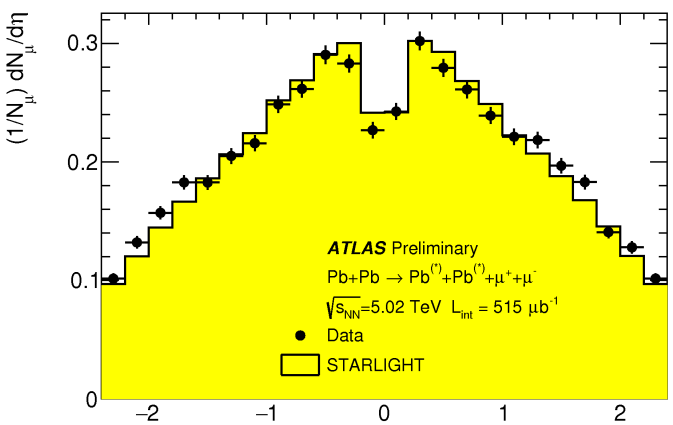
- Agreement with calculations (absorptive corrections are important)
- Agreement with CMS measurement

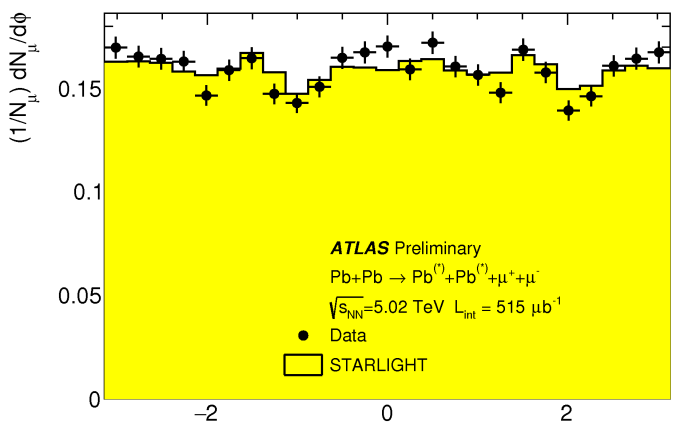
Contents

Event selection

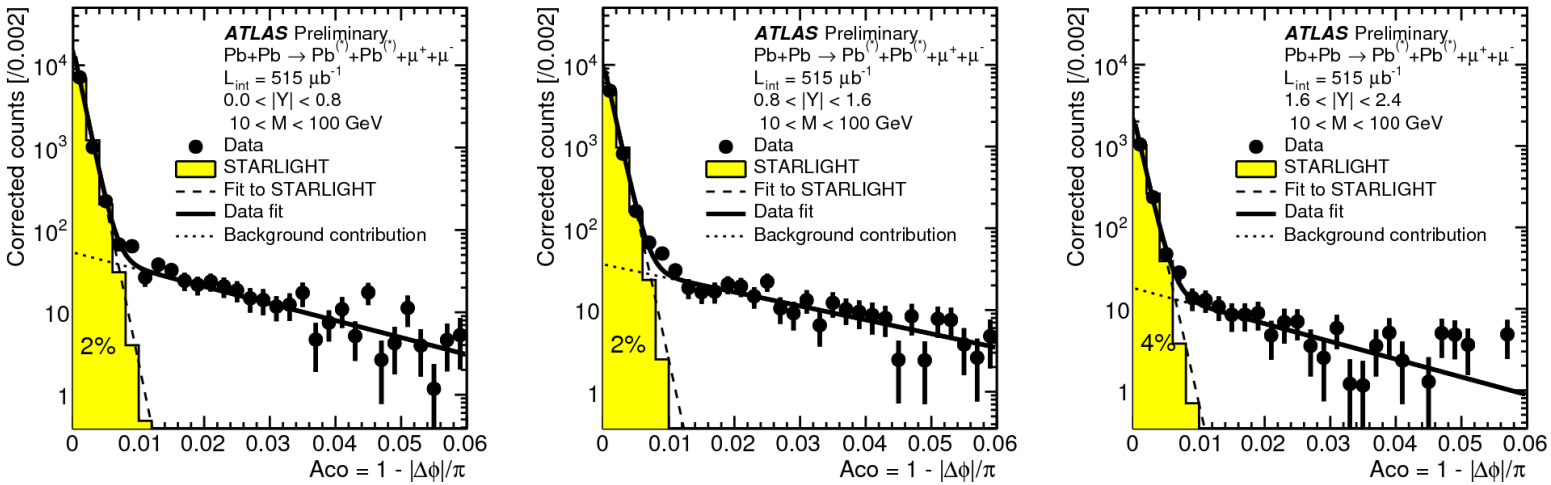
- $p_T > 5$ GeV
  $|\eta| < 2.4$
  (both muons)
- $M_{\mu\mu} > 10$ GeV
- Muons form a vertex
- No other tracks
- 12069 events after selection



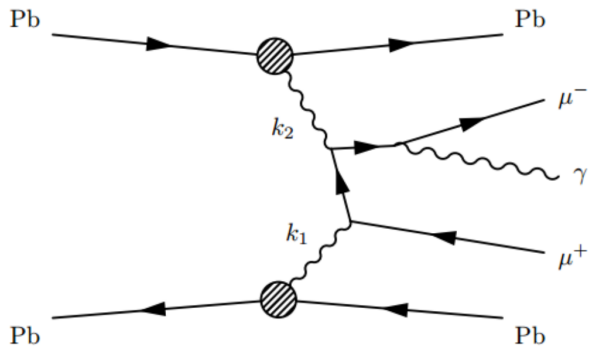




Acoplanarity

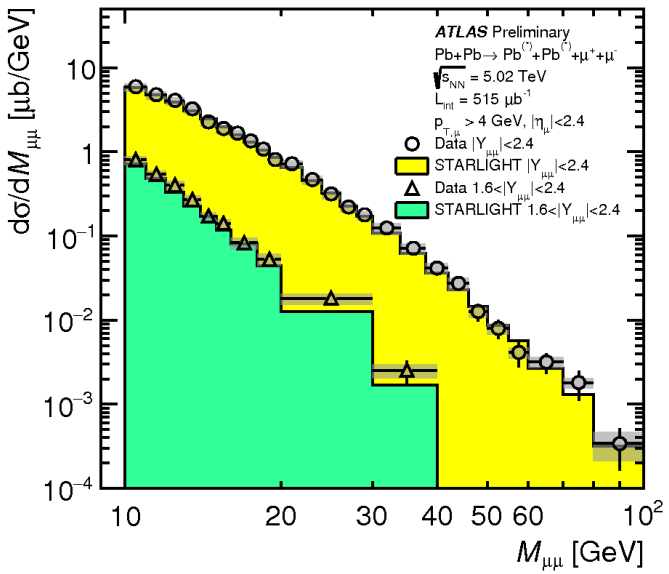


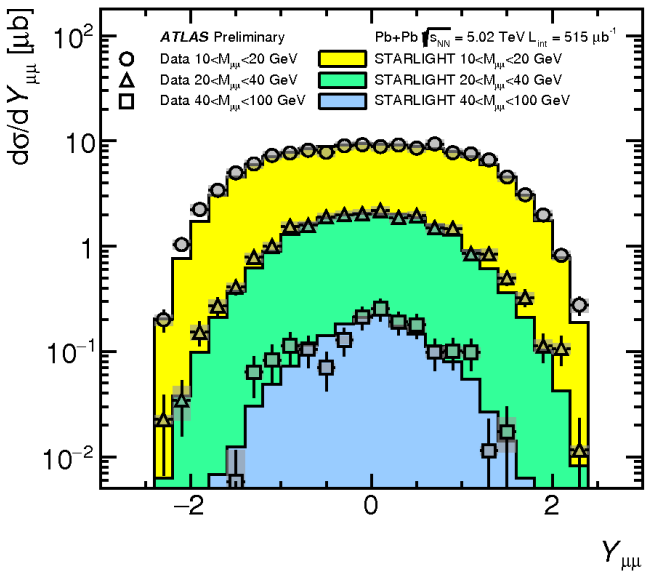
- No QED radiative corrections in MC (Starlight)
- Two variants assumed:
  - tail is background
  - tail is due to FSR

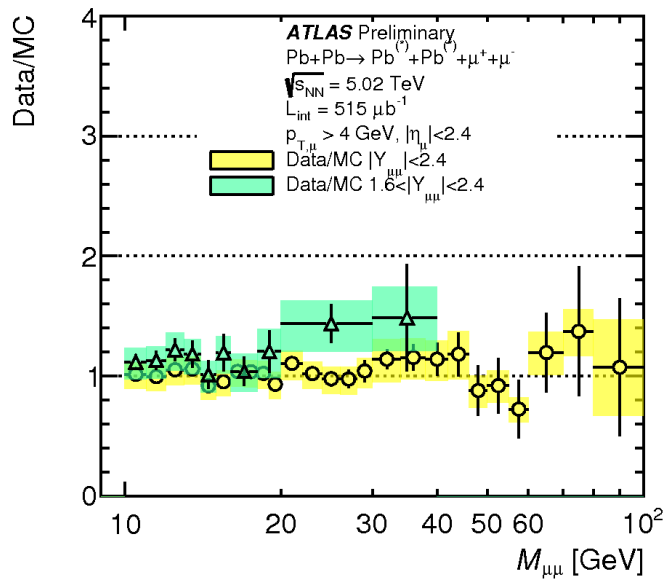


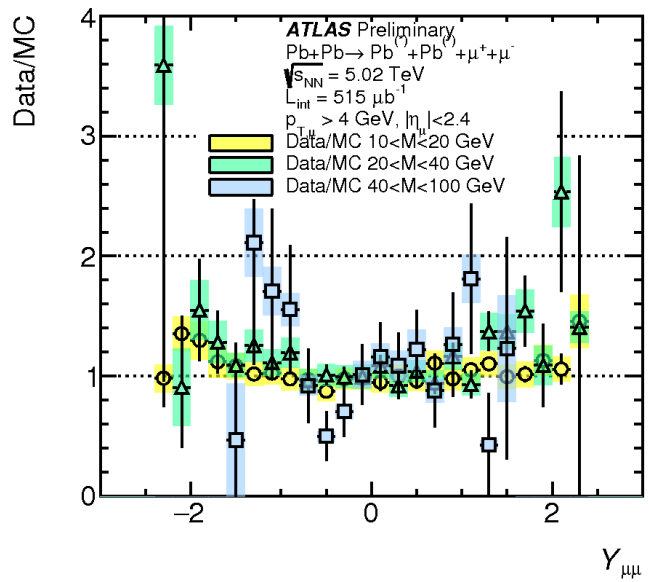
- The background fraction with acoplanarity$<$0.08 is 2 – 4%.
- The result is average of the two possibilities
- Difference is taken as systematic uncertainty

Results







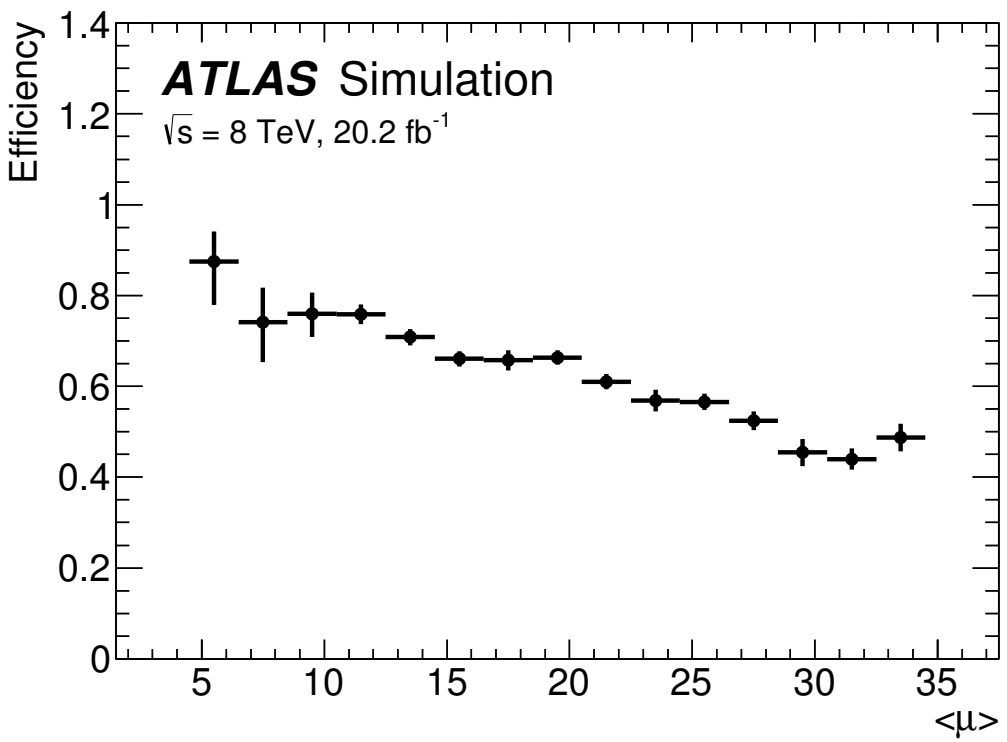


Contents

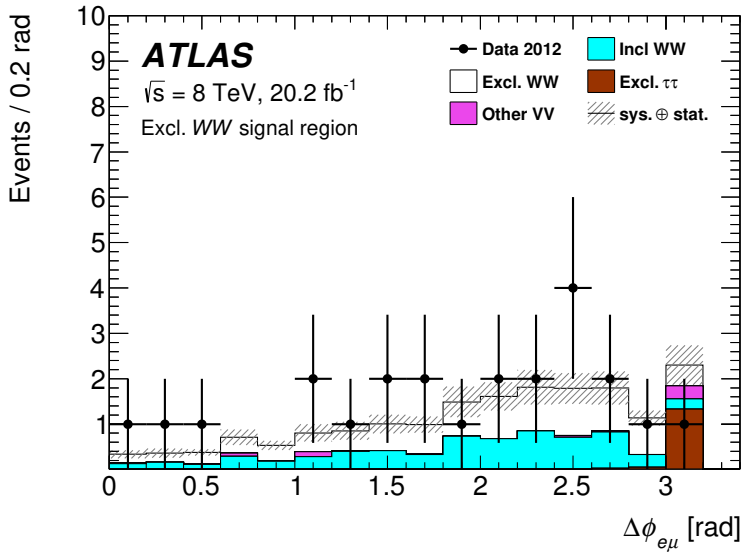
Event selection

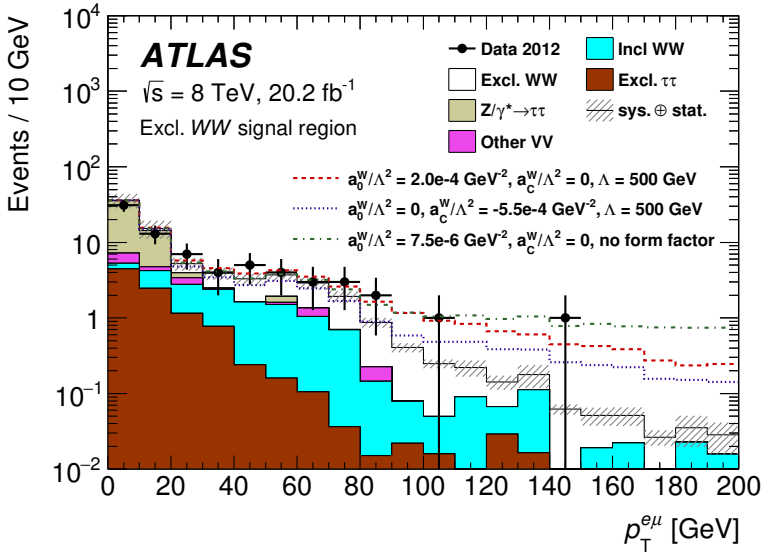
- $\gamma\gamma \to WW \to e\nu\mu\nu$
- exclusive $H \to WW \to e\nu\mu\nu$
- exclusive selection:
  1 mm vertex longitudinal isolation

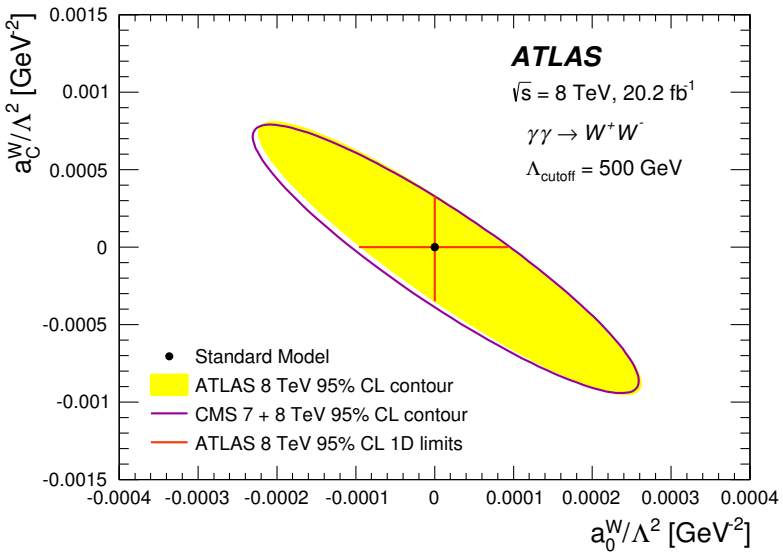
Variable	Excl W^+W^-	Excl Higgs
p_T^{lep}	$> 25, 20$ GeV	$> 25, 15$ GeV
$m_{e\mu}$	> 20 GeV	> 10 GeV
$p_T^{e\mu}$	> 30 GeV	> 30 GeV
Δz_0^{iso}	1mm	1mm
$p_T^{e\mu}$ (aQGC)	> 120 GeV	-
$m_{e\mu}$	-	< 55 GeV
$\Delta\phi_{e\mu}$	-	< 1.8
m_T	-	< 140 GeV



Results for $\gamma\gamma \to WW$



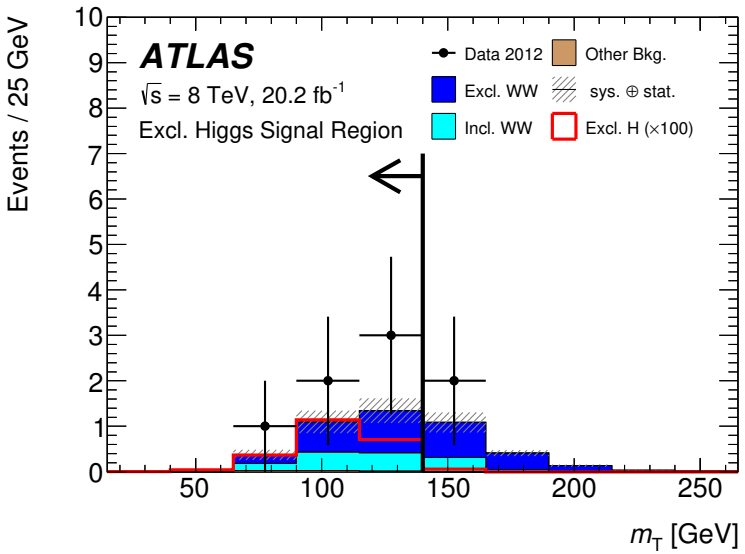


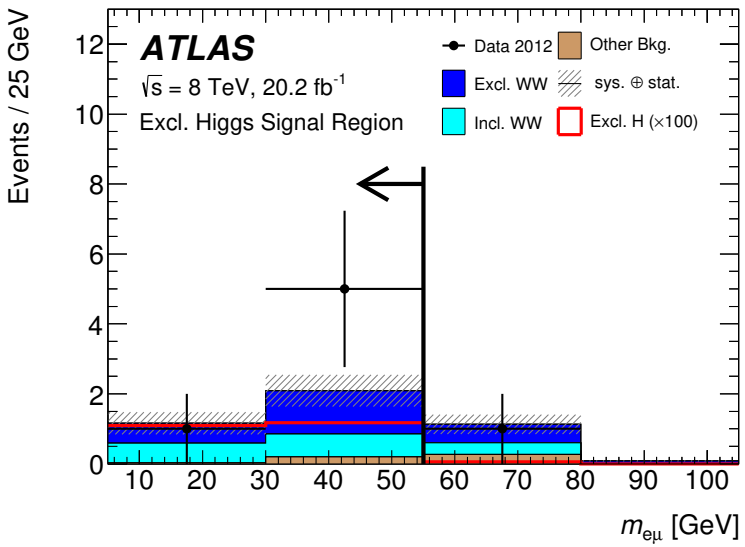


- Standard Model signal
  - 3σ significance
- New physics searches
  - $p_T^{e\mu} > 120$ GeV
  - Data: 1
  - Background: 0.37 ± 0.13
  - SM Signal: 0.37 ± 0.04
  - limits on anomalous $\gamma\gamma WW$ couplings

Results on exclusive Higgs searches

- Backgrounds: exclusive and inclusive WW
- Exclusive Higgs event yields:
  data: 6, background: 3.0 ± 0.8, signal: 0.023 ± 0.003
- Observed and expected limits:
  $\sigma < 1.2$ pb @ 95% CL (Observed)
  $\sigma < 0.7$ pb @ 95% CL (Expected)
- Upper limit: 400 times expected cross section for elastic process

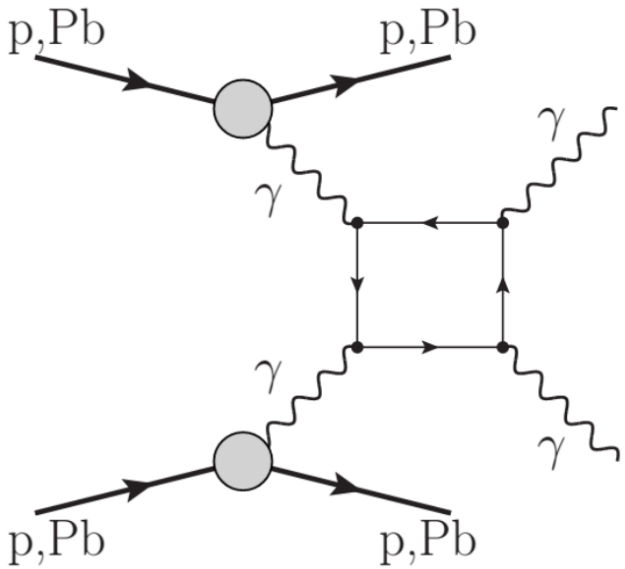




Contents

Light-by-light scattering in $PbPb$

- Elastic scattering of two photons
- Quantum effect: not present in classical theory
- Very small cross section
- No direct observation so far
- Possible channel to study new physics

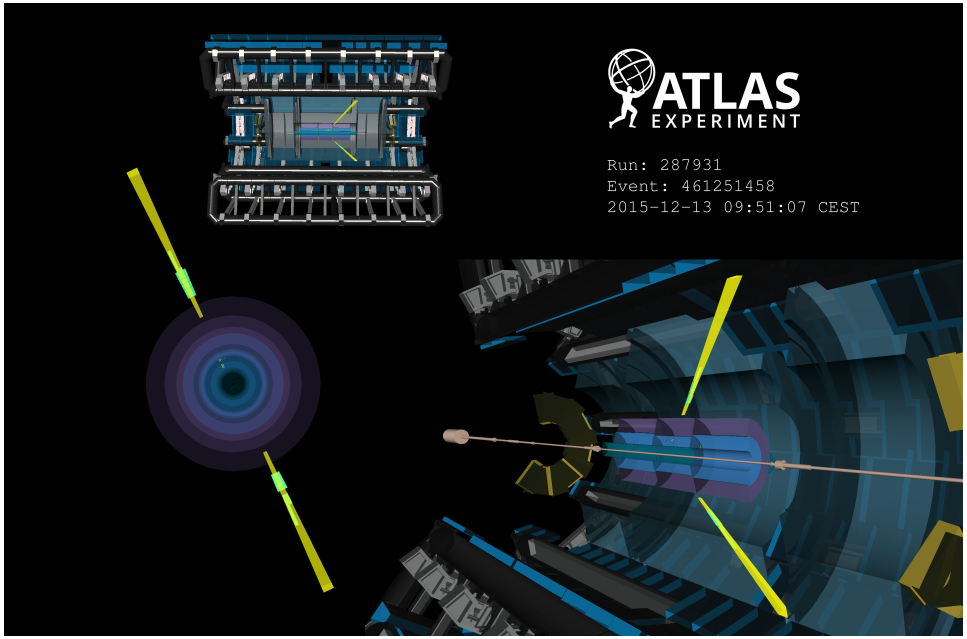


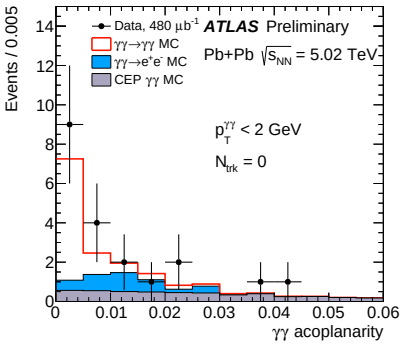
Event selection

- Dedicated trigger: photons + clean event

Selection:

- Two photons, $E_T > 3$ GeV
- $M_{\gamma\gamma} > 6$ GeV
- Exclusivity: no tracks
- $p_T^{\gamma\gamma} < 6$ GeV
- Acoplanarity: $(1 - \Delta\Phi_{\gamma\gamma}/\pi) < 0.01$



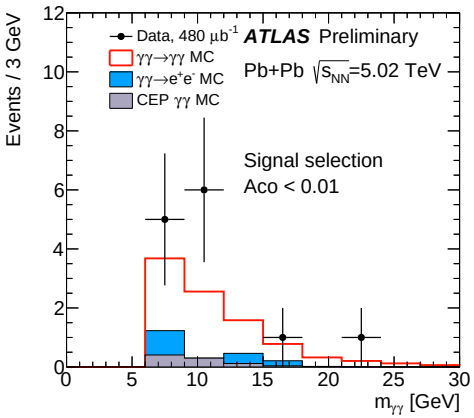


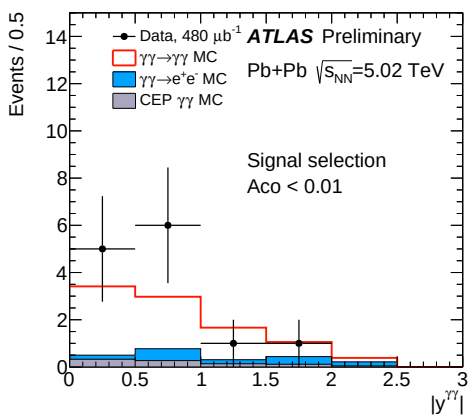
Selection	Data	Signal	$\gamma\gamma \to e^+e^-$	CEP $gg \to \gamma\gamma$	Hadronic fakes	Other fakes
Preselection	105	9.1	74	4.7	6	19
$N_{\rm trk} = 0$	39	8.7	4.0	4.5	6	19
$p_{\rm T}^{\gamma\gamma} < 2$ GeV	21	8.5	3.5	4.4	3	1.3
$Aco < 0.01$	13	7.3	1.3	0.9	0.3	0.1
Uncertainty		1.5	0.3	0.5	0.3	0.1

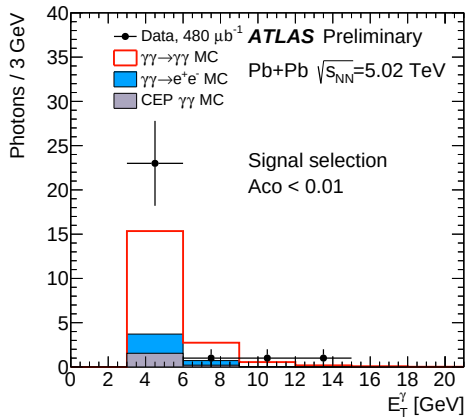
Results

- First direct observation of the light-by-light signal
- Excess in the data consistent with predictions
  (M. Kłusek-Gawenda *et al.*, Phys.Rev. C93 (2016) no.4, 044907)

$$\sigma_{\text{fid}}^{\text{meas}} = 70 \pm 20(\text{stat}) \pm 17(\text{syst}) \text{ nb} \qquad \sigma_{\text{fid}}^{\text{th}} = 49 \pm 10 \text{ nb}$$







- Observed significance: 4.4σ (expected: 3.8σ)
- Signal strength: $\mu = 1.6 \pm 0.6$

Contents

Summary

- Measurements of diffraction with rapidity-gap method exploiting ATLAS calorimetry
  - soft diffraction
  - diffractive jets
- Measurements of elastic scattering and prospects for new measurements with proton taggers:
  - ALFA (Per's talk)
  - AFP (Maciej's talk)
- Two-photon physics
  - In pp and $PbPb$
  - Understanding of absorptive corrections
  - Searches for new physics
  - Observation of light-by-light scattering