Exclusive $\gamma\gamma \to l^+l^-$ production at $\sqrt{s} = 7$ TeV with ATLAS experiment

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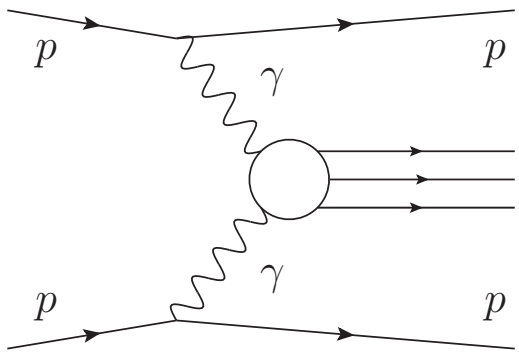
Elastic and Diffractive Scattering, Corsica

Introduction

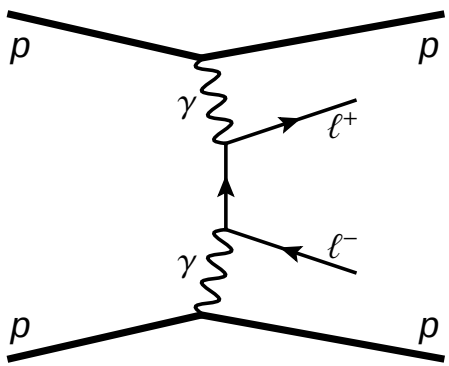
- High energy proton beams $\rightarrow$ high probability initial state photon
- Use LHC as an effective $\gamma\gamma$ collider
- Very nice laboratory to study coupling of vector bosons
- Higher sensitivity to $\gamma\gamma \rightarrow WW$ in photon interactions than in inclusive measurements

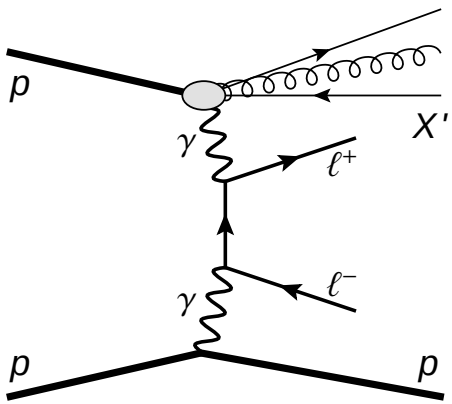


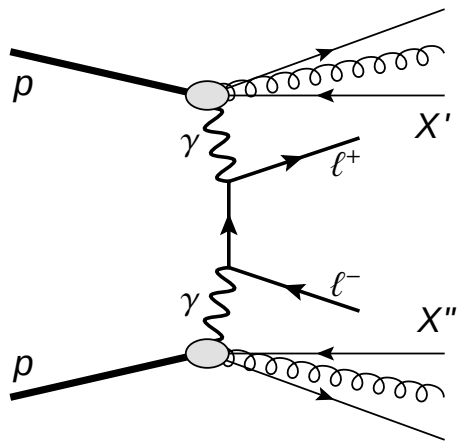
- Measurement of dilepton production - standard candle for photon physics
  - 2011 data $\mathcal{L} = 4.6\,\text{fb}^{-1}$
  - More data than in previous measurements but larger rate of pp collisions ($\langle\mu\rangle \sim 6$)
  - Precise probe of photon induced production predictions

Dilepton exclusive production

- Elastic - signal
  - Precise calculation using Equivalent photon approximation (elmag. formfactors)
- Single dissociation
  - Brase and Suri-Yennie structure function for proton dissociation
- Double dissociation
  - Resolved proton structure: $q \to q\gamma$, NNPDF2.3QED

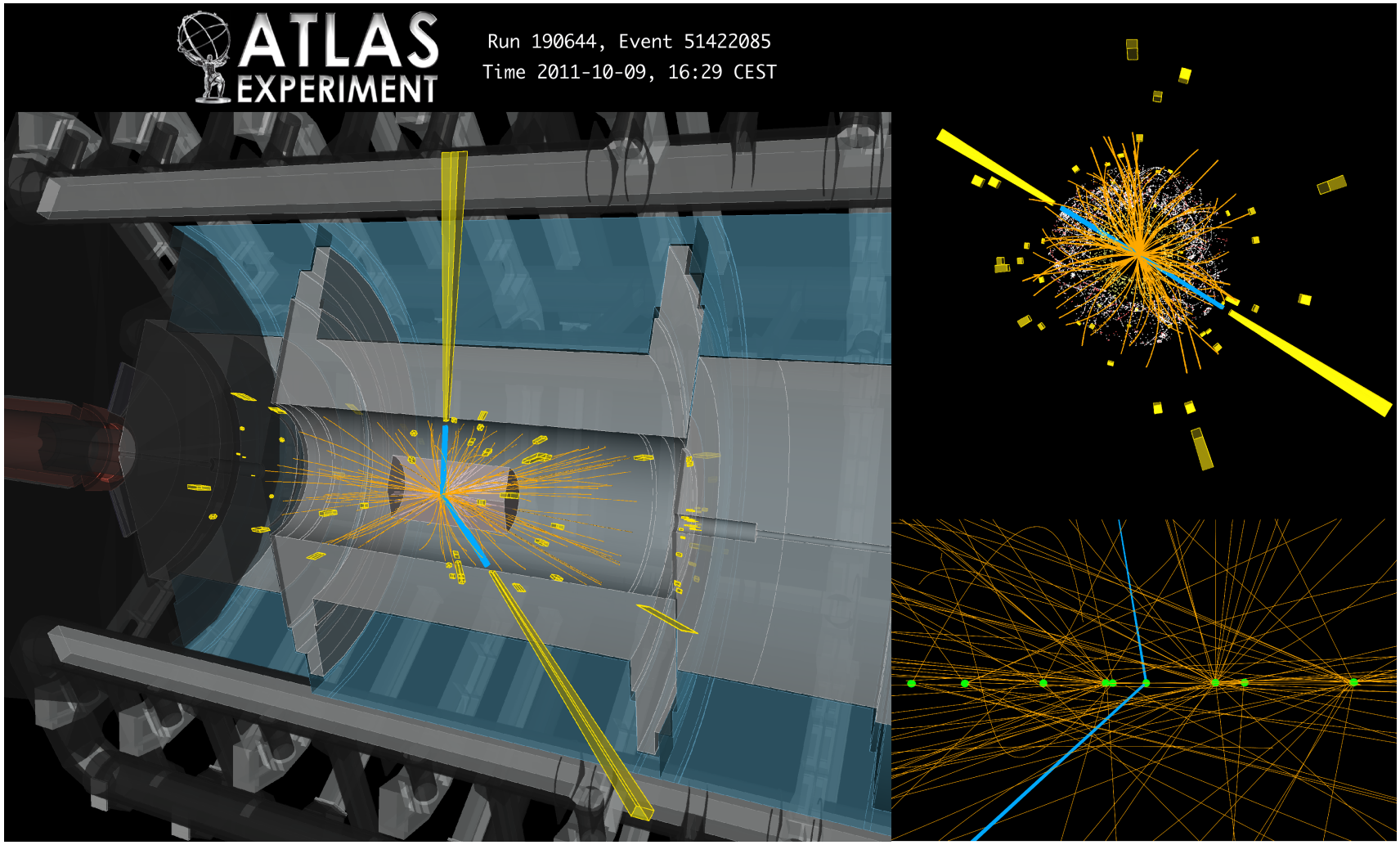






- Modeling respectively by: Herwig++, LPAIR, Pythia8
- MC do not include absorbtive corrections due to QCD

Exclusive dielectron event



Event selection

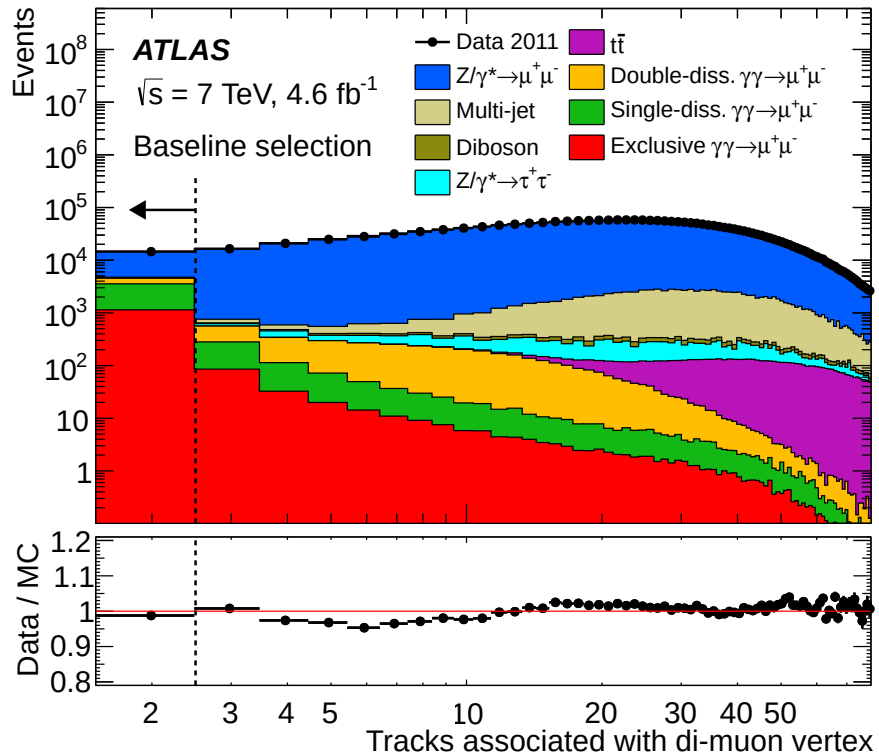
- Same selection as in standard low-mass Drell-Yan measurement
- Isolated e^+e^- and $\mu^+\mu^-$ candidates

Variable	Electron channel	Muon channel
p_{T}^{ℓ}	> 12 GeV	> 10 GeV
$\lvert\eta^{\ell}\rvert$	< 2.4	< 2.4
$m_{\ell^+\ell^-}$	> 24 GeV	> 20 GeV

- Enhance exclusive signal
  - Exclusive selection - 2 tracks ($p_{\mathrm{T}} > 400\,\mathrm{MeV}$) associated to vertex, vertex isolated
  - Veto Drell-Yan events
  - Require dilepton $p_{\mathrm{T}}^{ll} < 1.5$ GeV
  - Alternative selection: acoplanarity $1 - |\Delta\phi_{ll}|/\pi < 0.008$

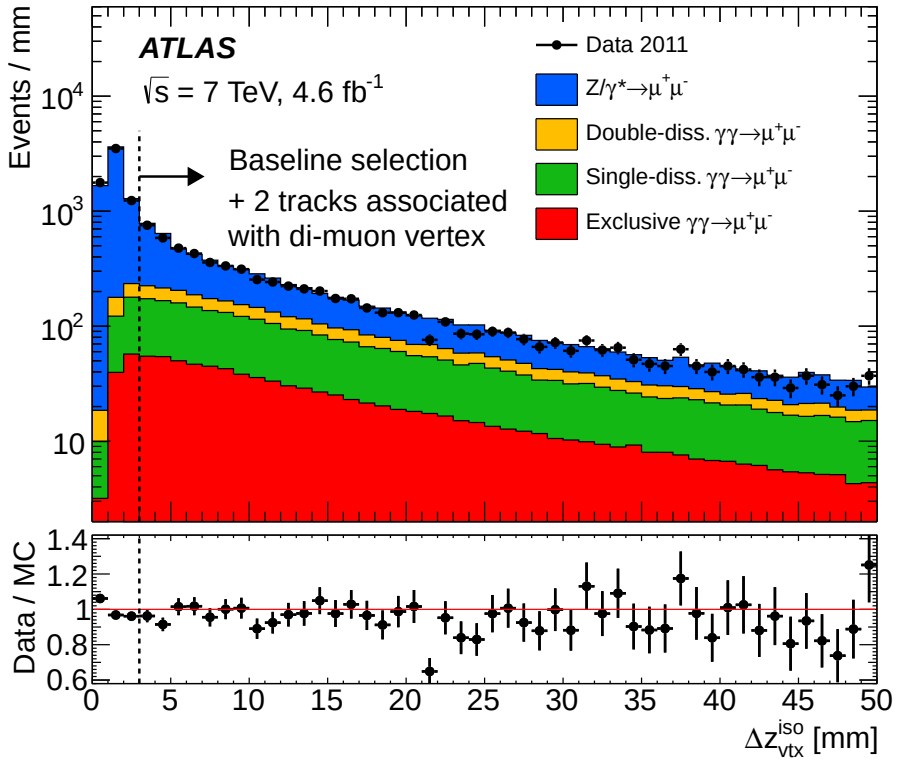
Exclusivity requirement

- Exclusivity requirement: multijet, diboson, $t\bar{t}$ background negligible
- Drell-Yan - modelled by POWHEG+PYTHIA6
  - Not reliable modelling of particle activity, overestimate by 50% for low multiplicity
  - Charged particle multiplicity measured in $70\,\text{GeV} < m_{l^+l^-} < 105\,\text{GeV}$ (corrected for PU and track reconstruction)
- Drell-Yan events re-weighted at particle level



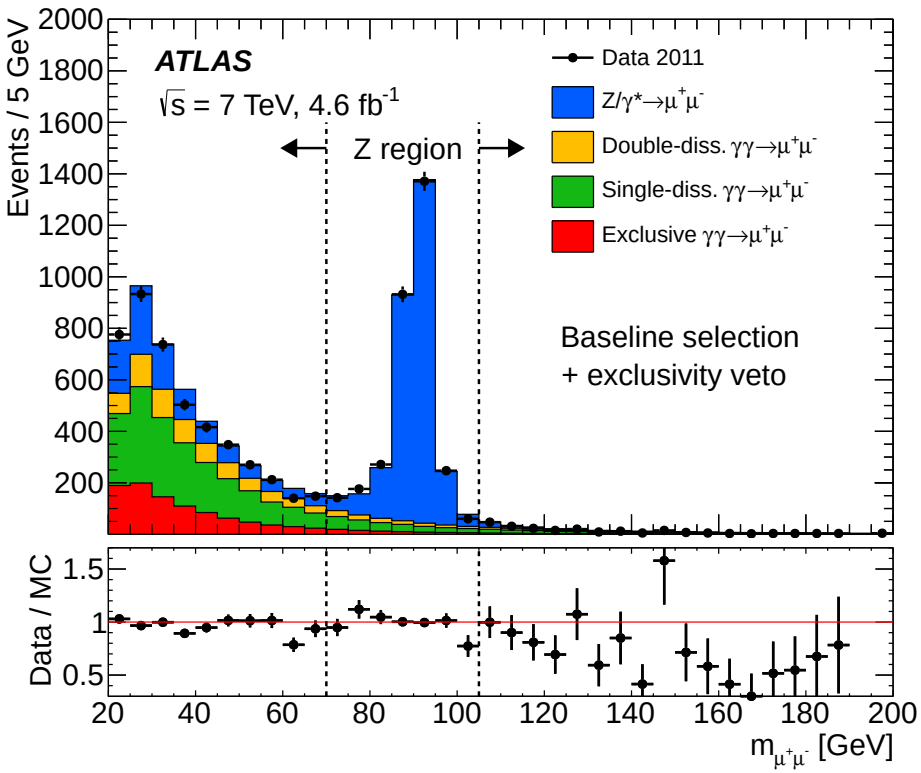
Vertex isolation

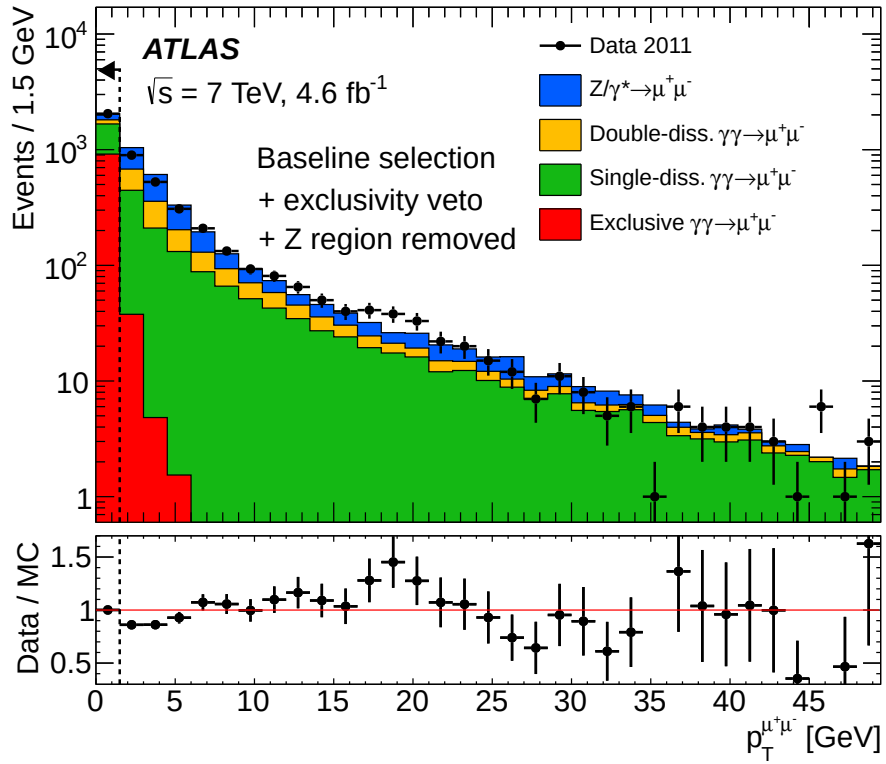
- Exclusive event vertex required to be isolated $\Delta^{\mathrm{iso}}_{\mathrm{vtx}} > 3\,\mathrm{mm}$
- Reject Drell-Yan events - mostly split vertices - event with high particle multiplicity reconstructed with more than 1 vertex
- At cost of 26% of signal - vertices due to additional pp interactions



Selection

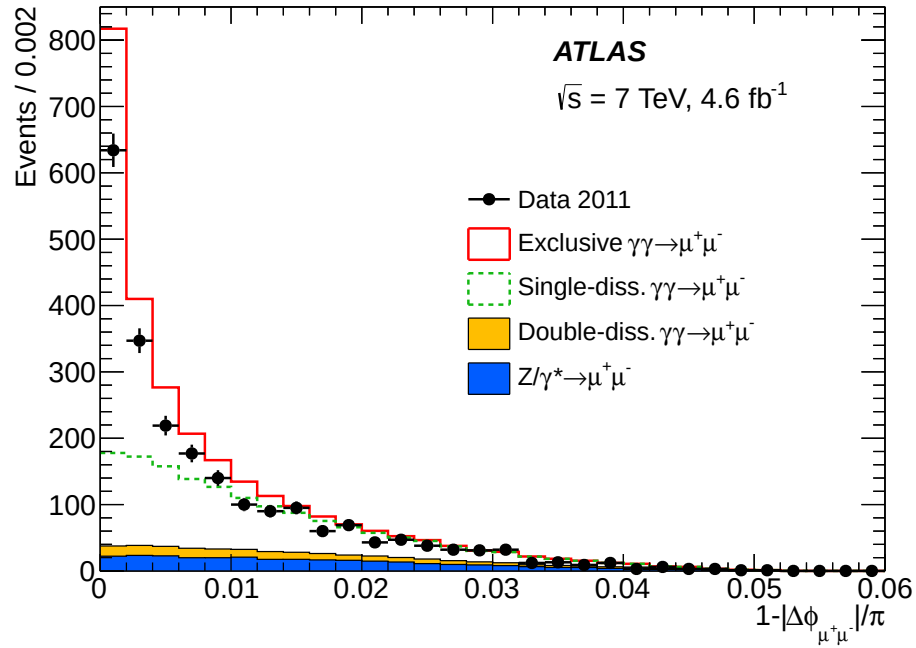
- Drell-Yan suppression
- Signal selection $p_{\mathrm{T}}^{ll} < 1.5$ GeV - thanks to low virtuality of incoming photons





Final selection

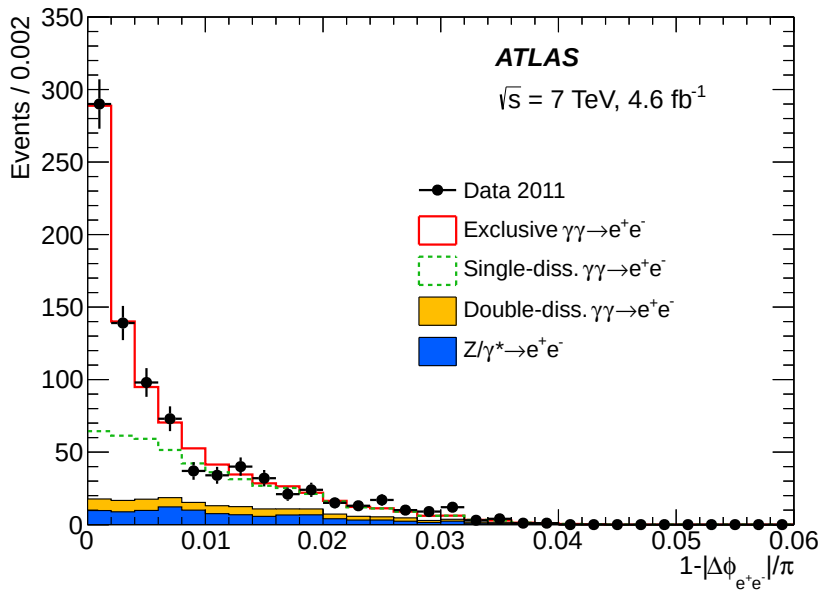
- 869 and 2124 events selected in $ee/\mu\mu$ channel
- Background (SD) approximately 50%
- MC does not include absorbtive corrections $\rightarrow$ data $\sim$ 80% of prediction

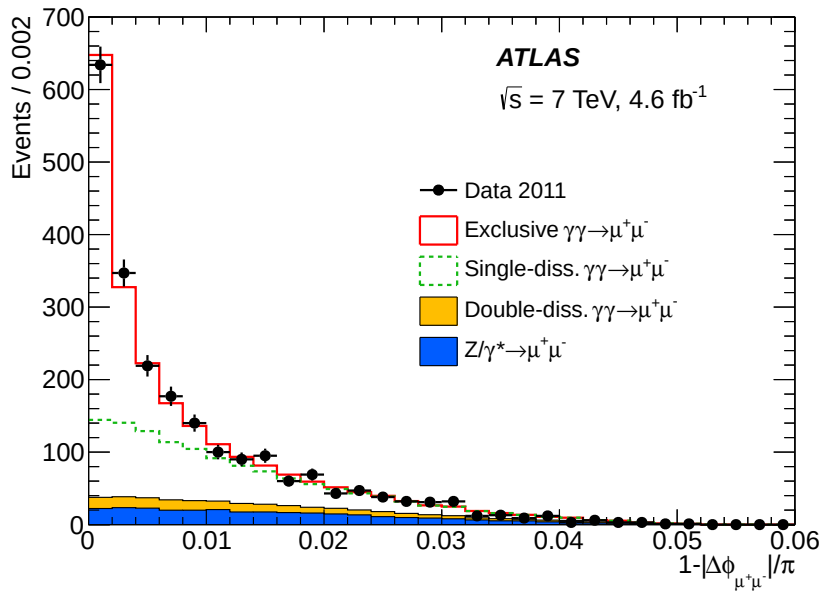


Selection	$\gamma\gamma \rightarrow \ell^+\ell^-$ Signal	$\gamma\gamma \rightarrow \ell^+\ell^-$ S-diss.	$\gamma\gamma \rightarrow \ell^+\ell^-$ D-diss.	$Z/\gamma^* \rightarrow \ell^+\ell^-$	Multi-jet	$Z/\gamma^* \rightarrow \tau^+\tau^-$	$t\bar{t}$	Di-boson	Total predicted	Data
Electron channel ($\ell = e$)										
Preselection	898	2096	2070	1 460 000	83 000	3760	4610	1950	1 560 000	1 572 271
Exclusivity veto	661	1480	470	3140	0	9	0	5	5780	5410
Z region removed	569	1276	380	600	0	8	0	3	2840	2586
$p_{\mathrm{T}}^{\ell^+\ell^-} < 1.5$ GeV	438	414	80	100	0	2	0	0	1030	869
Muon channel ($\ell = \mu$)										
Preselection	1774	3964	4390	2 300 000	98 000	7610	6710	2870	2 420 000	2 422 745
Exclusivity veto	1313	2892	860	3960	3	8	0	6	9040	7940
Z region removed	1215	2618	760	1160	3	8	0	3	5760	4729
$p_{\mathrm{T}}^{\ell^+\ell^-} < 1.5$ GeV	1174	1085	160	210	0	3	0	0	2630	2124

Signal extraction

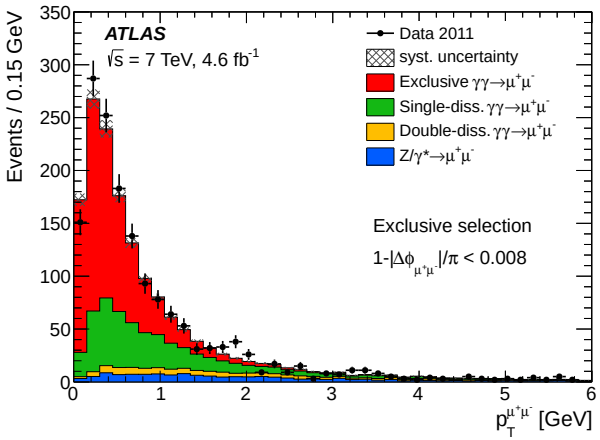
- Binned likelihood fit of signal (exclusive) and background (single dissociation)
- Drell-Yan and double dissociation fixed
- Both exclusive and single dissociation requires scaling down:
  - $R^{\mathrm{excl.}}_{\gamma\gamma\to e^+e^-} = 0.863 \pm 0.070$ $\quad R^{\mathrm{s-diss}}_{\gamma\gamma\to e^+e^-} = 0.759 \pm 0.080$
  - $R^{\mathrm{excl.}}_{\gamma\gamma\to \mu^+\mu^-} = 0.791 \pm 0.041$ $\quad R^{\mathrm{s-diss}}_{\gamma\gamma\to \mu^+\mu^-} = 0.762 \pm 0.049$
- Fitted scaling factors anti-correlated

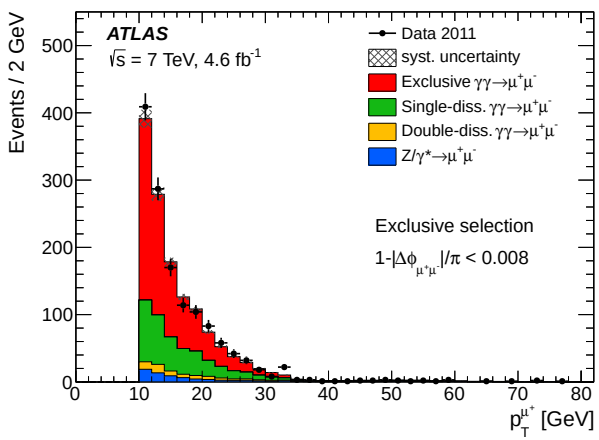


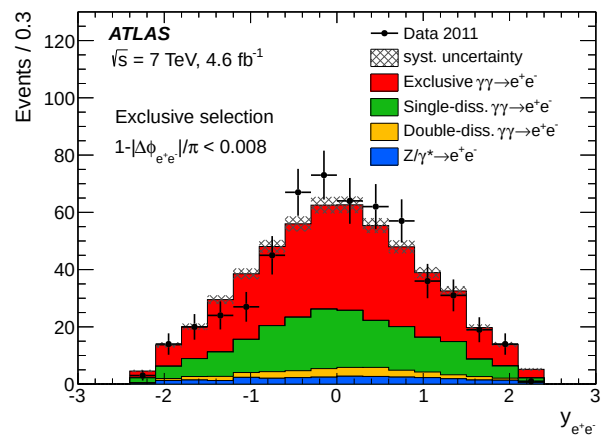


Control distributions

- Apply scaling factors to MC, use $1 - |\Delta\phi_{l+l-}| < 0.008$ instead of $p_{\mathrm{T}}^{l^+l^-} < 1.5\mathrm{GeV}$
- Good modeling of data seen in both channels







Cross section measurement

- Cross section extracted by measuring suppression factor $R^{\text{excl.}}_{\gamma\gamma\to l^+l^-}$, applied to prediction:

$$\sigma^{\text{excl.}}_{\gamma\gamma\to l^+l^-} = R^{\text{excl.}}_{\gamma\gamma\to l^+l^-} \cdot \sigma^{\text{EPA}}_{\gamma\gamma\to l^+l^-}$$

- Measurement performed in fiducial region
  - Includes extrapolation under Z peak

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- $\sigma^{\text{excl.}}_{\gamma\gamma\to e^+e^-} = 0.428 \pm 0.035\ (\text{stat.}) \pm 0.018\ (\text{syst.})$ pb
- $\sigma^{\text{excl.}}_{\gamma\gamma\to \mu^+\mu^-} = 0.628 \pm 0.032\ (\text{stat.}) \pm 0.021\ (\text{syst.})$ pb
- Measurement statistic dominated
  - Systematic uncertainty 4.3/3.3%
  - Statistic uncertainty 8.2/5.1%

Systematic uncertainties

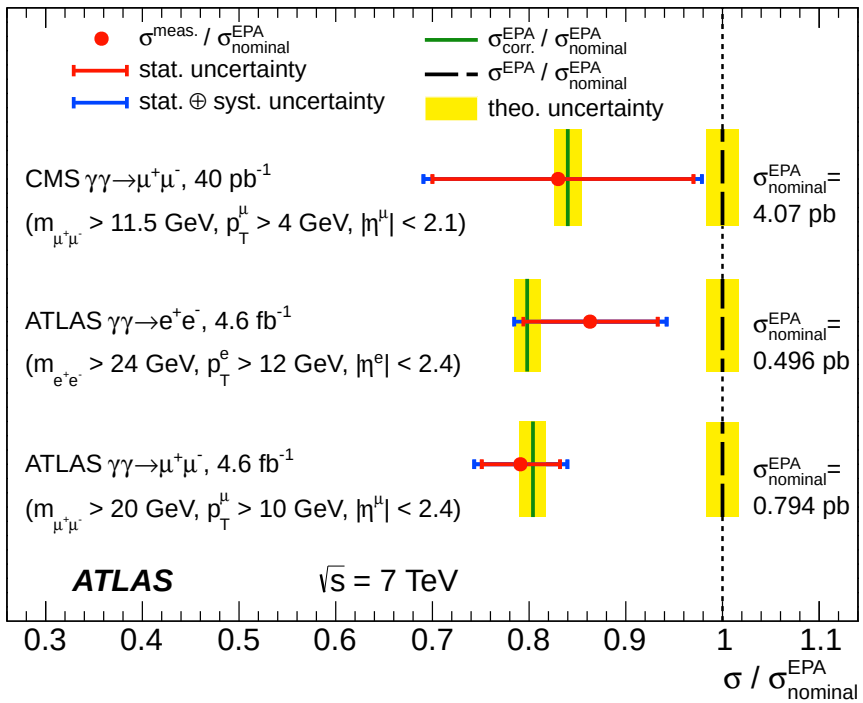
- Backgrounds
  - Drell-Yan - in particular reweighting charged particle multiplicity
  - Double dissociation - variation of NNPDF2.3QED
- Vertex isolation and pile-up modelling
- Electron measurement
- Luminosity

- Very precies measurement overall!

	Uncertainty [%]	
Source of uncertainty	$\gamma\gamma \to e^+e^-$	$\gamma\gamma \to \mu^+\mu^-$
Electron reconstruction and identification efficiency	1.9	-
Electron energy scale and resolution	1.4	-
Electron trigger efficiency	0.7	-
Muon reconstruction efficiency	-	0.2
Muon momentum scale and resolution	-	0.5
Muon trigger efficiency	-	0.6
Backgrounds	2.3	2.0
Template shapes	1.0	0.9
Pile-up description	0.5	0.5
Vertex isolation efficiency	1.2	1.2
LHC beam effects	0.5	0.5
QED FSR in DY e^+e^-	0.8	-
Luminosity	1.8	1.8
Total systematic uncertainty	4.3	3.3
Data statistical uncertainty	8.2	5.1

Results comparison

- Summary plot: CMS measurement in different phase-space (lower dilepton masses)
- All measurement give consistent picture of proton absorbtive correction ~ 0.8

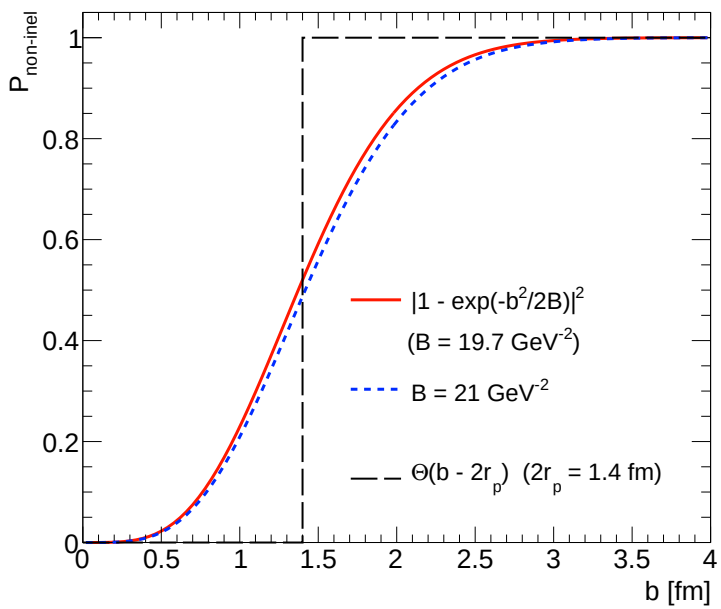


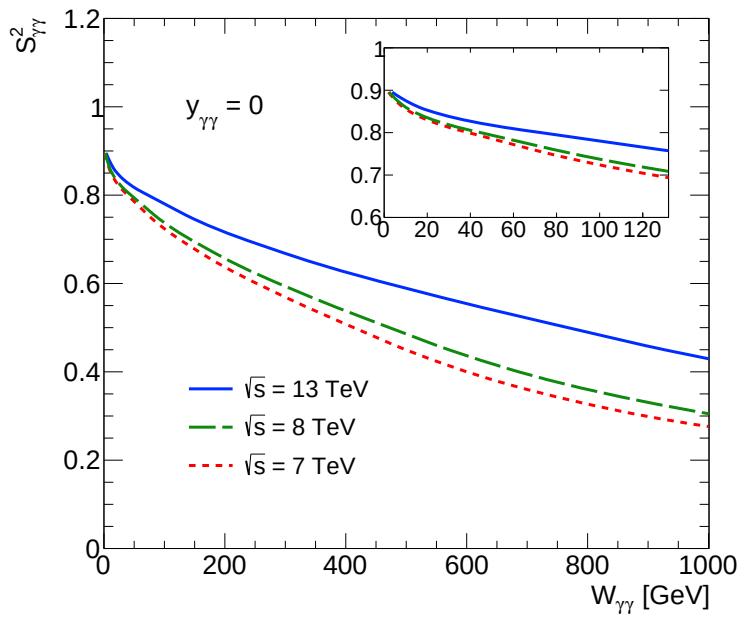
Interpretation

- Size of absorbtive correction can be explained from impact parameter picture
- Probability of non-interaction calculated from elastic amplitude, which is fitted to data
- Naively: proton do not dissociate if scattering at $b > 2r_p$ (for a black disk)

$$f(\omega_1)f(\omega_1) \rightarrow \int\int n(\vec{b}_1,\omega_1)n(\vec{b}_2,\omega_2)P_{\mathrm{non-inel}}(|\vec{b}_1-\vec{b}_2|)\mathrm{d}\vec{b}_1\mathrm{d}\vec{b}_2$$

Dyndal, Schoeffel, Physics Letters B, 741, 66





- Perhaps too simple, might be process dependent (see L. Harland-Lang talk on Tuesday)

Summary

- ATLAS first measurement of exclusive production
- Most precise measurement of two-photon dilepton production
- Measured absorbtive corrections consistent from different measurements
- arXiv:1506.07098

Backup

Fit results

- Fit of accoplanarity distribution