Di-Boson production at ATLAS

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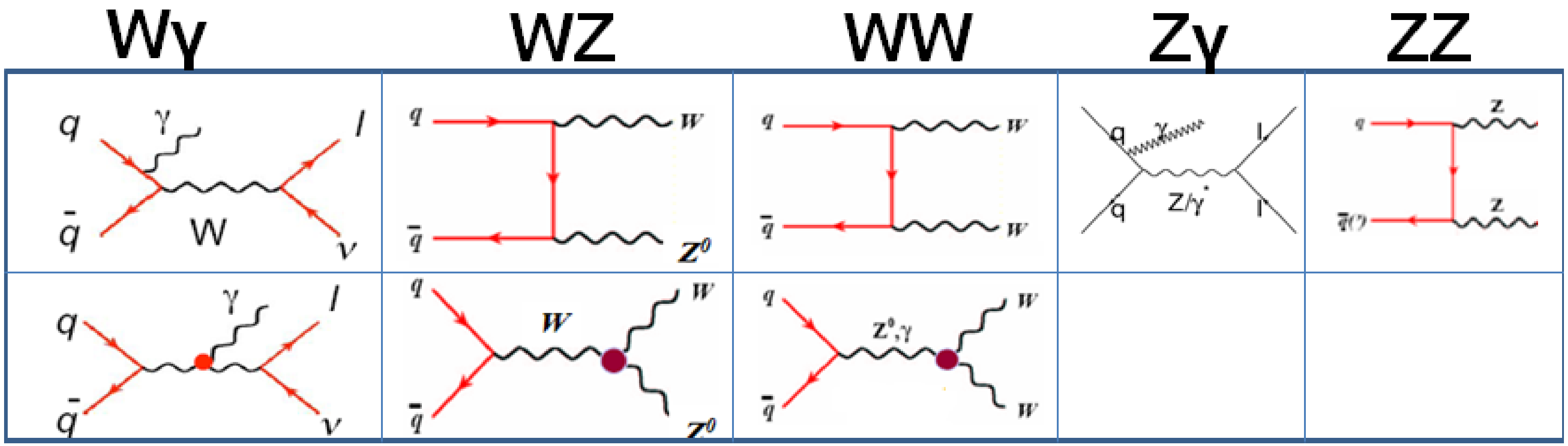
Outline

- Introduction
- W/Zγ Analysis
- WW Analysis
- Summary

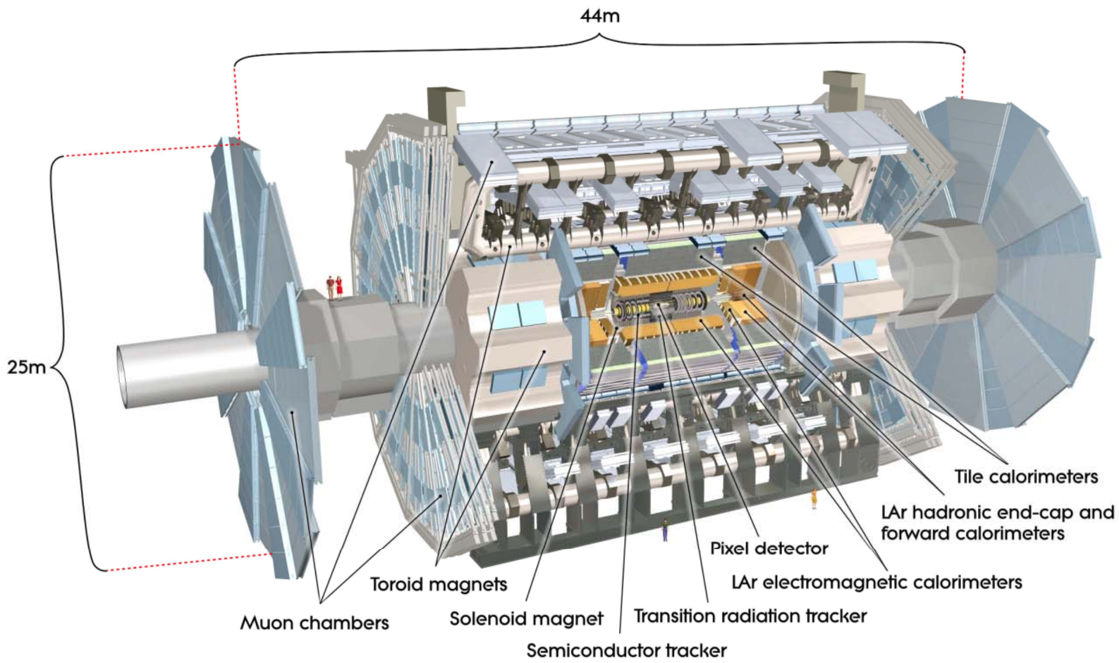
Di-Boson Production

- Standard Model diagrams for di-boson production includes
  - t-channels: qqbar annihilation
  - s-channels:Triple Gauge Boson couplings
    - * Due to non-abelian nature of SU(2)L x U(1)Y, SM predicts vector-boson self coupling
    - * SM only allows WWγ and WWZ couplings in the s-channel
      - Neutral TGC forbidden in SM



ATLAS detector

- Multi-purpose detector
  - coverage up to |η| = 5;
  - design to operate at L= $10^{34}cm^{-2}s^{-1}$
- Inner Detector (tracker)
  - Si pixel & strip detectors + TRT;
  - 2 T magnetic field;
  - coverage up to |η|< 2.5.
- Calorimetry
  - highly granular LAr EM calorimeter (| η |< 3.2);
  - hadron calorimeter – scintillator til
    - * LAr for endcap&forward (| η |< 4.9).
- Muon Spectrometer
  - air-core toroid system (| η | < 2.7)

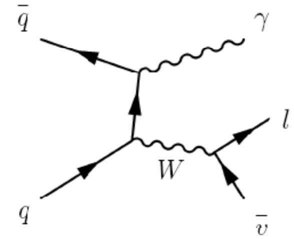


W/Zγ production

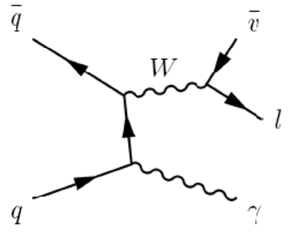
Signal definition

- Signature
  - Wγ
    - * One isolated lepton + photon and missing ET.
  - Zγ
    - * Two isolated leptons + photon
- Signal contributions
  - Initial State Radiation (ISR)
  - WWγ Triple Gauge Coupling (TGC)
  - Final state photon radiation from W(Z) inclusive production.
  - Photons from fragmentation of jets produced in association with a W or a Z boson.
    - * consider only part of fragmentation photon that satistify
      - particle level truth isolation:

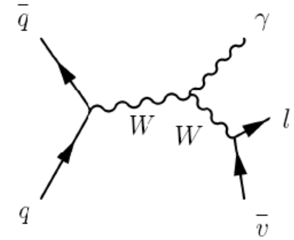
$$\Sigma E_T^{had} < 0.5 \cdot E_T^{\gamma}$$



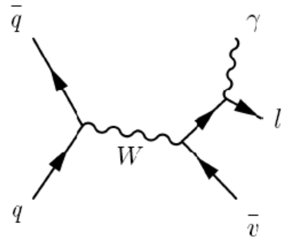
(a) u channel



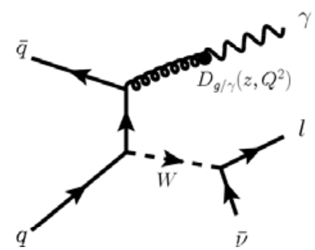
(b) t channel

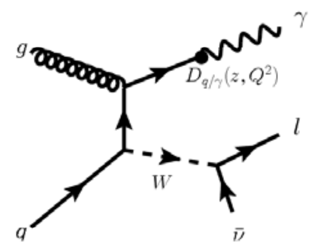


(c) s channel



(d) FSR





Event Selection

W selection

- One lepton with ET > 20 GeV
- $|\eta| < 2.47$ (e) $|\eta| < 2.4$ (μ)
- MET> 25 GeV
- $m_T(W) > 40$ GeV
- Veto on a second lepton

Z selection

- Two leptons with ET > 20 GeV
- $|\eta| < 2.47$ (e) $|\eta| < 2.4$ (μ)
- $M_{ll} > 40$ GeV

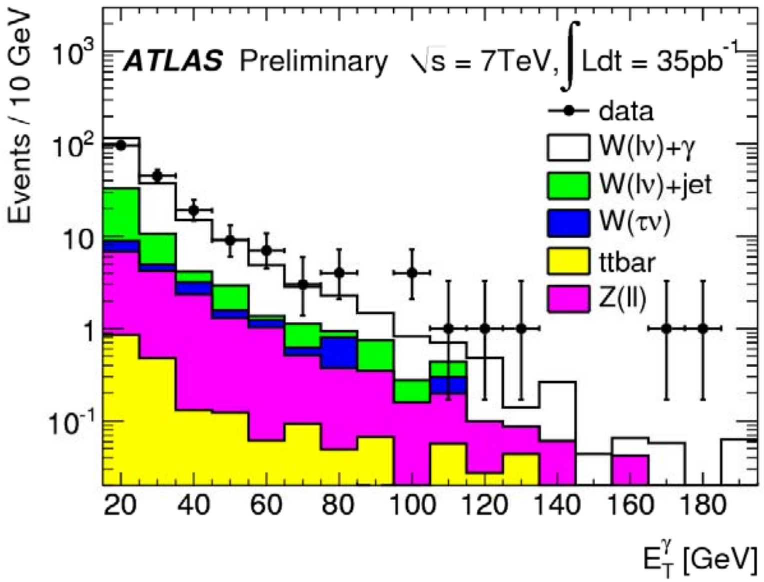
Photon selection

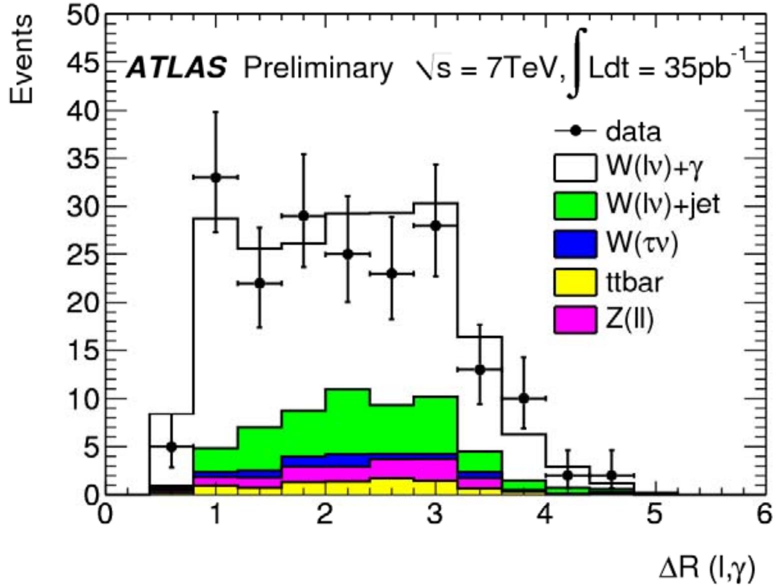
- One photon with ET > 15 GeV and $|\eta| < 2.37$
- $\Delta R(l,\gamma) > 0.7$
- Isolation energy Et (iso) < 5GeV

Number of Candidates in 35/pb

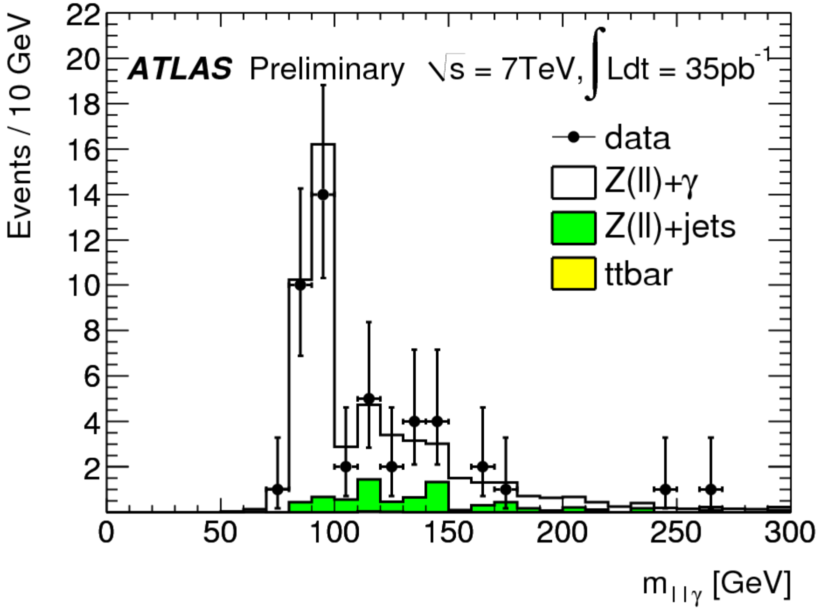
- Wγ: 192
  - 95 (eνγ) + 97(μ νγ)
- Zγ: 48
  - 25 (eeγ) + 23(μμγ)

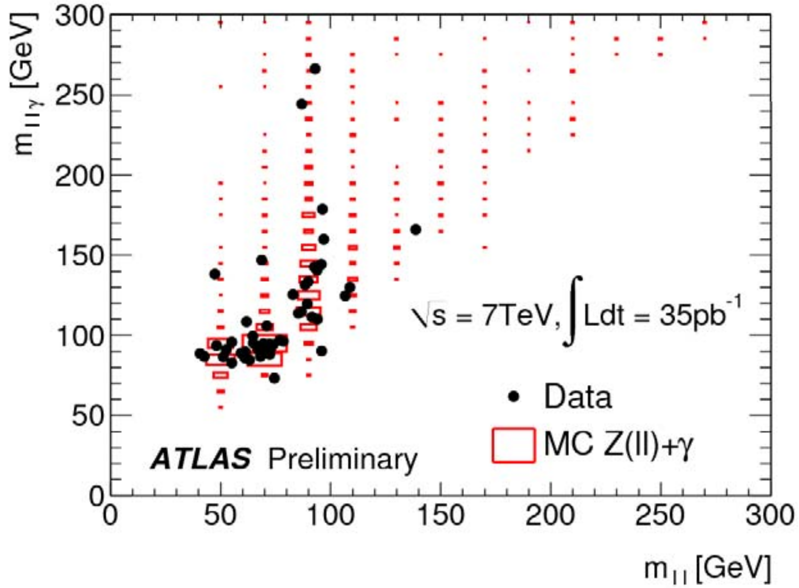
Kinematic Distributions of the Wγ candidates





Kinematic Distributions of the Zγ candidates





Cross section calculation

- Fiducial cross section
  - Performed within phase space defined by kinematic cuts of event selection in analysis.

$$\sigma^{fid}_{pp\to l\nu\gamma(l^+l^-\gamma)} = \frac{N^{sig}_{W\gamma(Z\gamma)}}{C_{W\gamma(Z\gamma)} \cdot L_{W\gamma(Z\gamma)}}$$

  - N^{sig} is the number of the extracted signal events
  - $C_{W\gamma\,(Z\gamma)}$ summarizes the reconstruction and identification efficiency for signal events

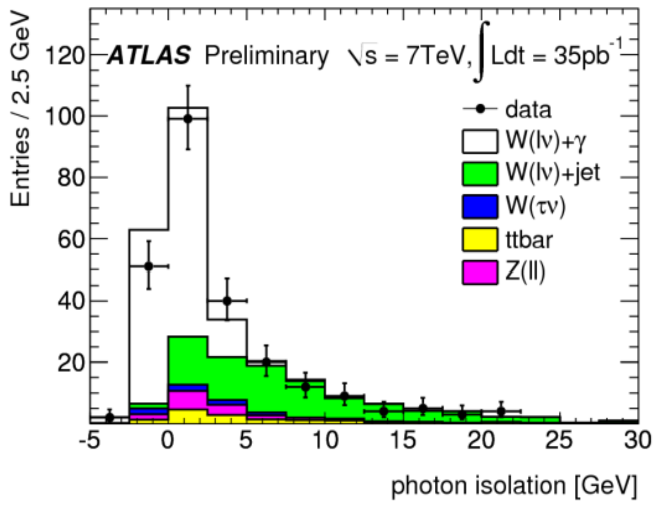
- Total cross section
  - extraploting from fiducial phase space to full W/Z decay space.

$$\sigma^{total}_{pp\to l\nu\gamma(pp\to l^+l^-\gamma)} = \frac{\sigma^{fid}_{pp\to l\nu\gamma(pp\to l^+l^-\gamma)}}{A_{W\gamma(Z\gamma)}}$$

  - $A_{W\gamma\,(Z\gamma)}$ is the acceptance of total phase space with respect to the fiducial one.

Signal yield

- Background for Wγ: W → τν, t¯t, and Z → l+l− and W+jets.
- Background for Zγ: t¯t and Z+jets.
- W+jet background: data driven estimation
  - 2D sideband method is applied. The two dimensions are defined by the isolation energy on one axis, and the photon identification "quality" of the photon candidate on the other axis.
- Z+jets background contribution, as well as the non W+jets background, is estimated from Monte Carlo.



Process	Observed events	non W+jets background	W+jet background	Extracted Signal
$pp \to e\nu\gamma$	95	$10.1 \pm 0.8 \pm 1.2$	$16.9 \pm 6.4 \pm 7.3$	$67.9 \pm 9.5 \pm 7.3$
$pp \to \mu\nu\gamma$	97	$12.4 \pm 0.9 \pm 1.4$	$16.8 \pm 4.7 \pm 7.3$	$67.8 \pm 9.3 \pm 7.4$
Process	Observed events	Total Background		Extracted Signal
$pp \to e^+e^-\gamma$	25	3.8 ± 3.8		$21.2 \pm 5.8 \pm 3.8$
$pp \to \mu^+\mu^-\gamma$	23	3.4 ± 3.4		$19.6 \pm 4.8 \pm 3.4$

Results

- Fiducial cross section

	experimental measurement	SM model prediction
	$\sigma^{fid}[pb]$(measured)	$\sigma^{fid}[pb]$(predicted)
$pp \to e\nu\gamma$	$5.1 \pm 0.7(stat) \pm 0.9(syst) \pm 0.6(lumi)$	4.6 ± 0.3(syst)
$pp \to \mu\nu\gamma$	$4.2 \pm 0.6(stat) \pm 0.7(syst) \pm 0.5(lumi)$	4.9 ± 0.3(syst)
$pp \to e^+e^-\gamma$	$2.0 \pm 0.6(stat) \pm 0.5(syst) \pm 0.2(lumi)$	1.7 ± 0.1(syst)
$pp \to \mu^+\mu^-\gamma$	$1.3 \pm 0.3(stat) \pm 0.3(syst) \pm 0.1(lumi)$	1.7 ± 0.1(syst)

- Total cross section

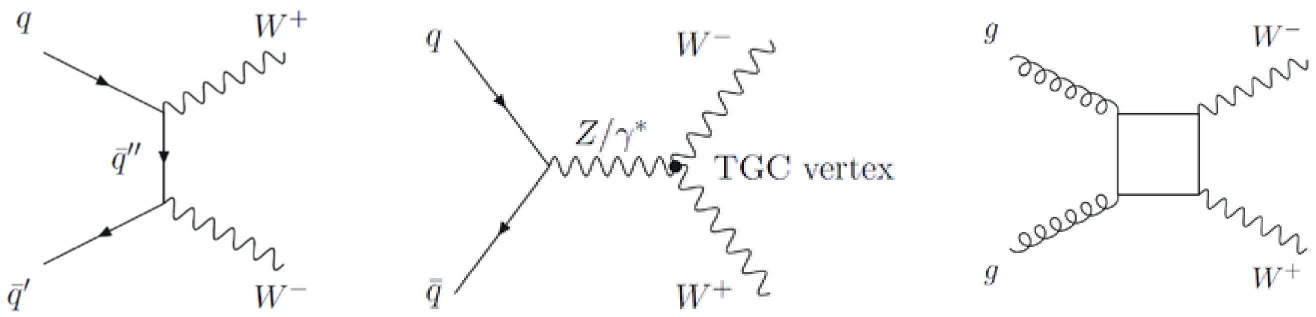
	$\sigma^{total}[pb]$(measured)	$\sigma^{total}[pb]$(predicted)
$pp \to e\nu\gamma$	$73.9 \pm 10.5(stat) \pm 14.6(syst) \pm 8.1(lumi)$	69.0 ± 4.6(syst)
$pp \to \mu\nu\gamma$	$58.6 \pm 8.2(stat) \pm 11.3(syst) \pm 6.4(lumi)$	69.0 ± 4.6(syst)
$pp \to e^+e^-\gamma$	$16.4 \pm 4.5(stat) \pm 4.3(syst) \pm 1.8(lumi)$	13.8 ± 0.9(syst)
$pp \to \mu^+\mu^-\gamma$	$10.6 \pm 2.6(stat) \pm 2.5(syst) \pm 1.2(lumi)$	13.8 ± 0.9(syst)

- All cross section measurements are consistent within their uncertainties with the Standard Model expectations

WW leptonic decay channels

WW signature

- WW signal
  - Two opposite-sign isolated high P_T leptons. Accordingly signal events are split into 3 channels:
    - ee, μμ, eμ
  - Large missing ET and less jet activity



- WW Background
  - W+jets, Drell-Yan, Top and Di-boson (WZ,ZZ,W/Zγ)

Event selection

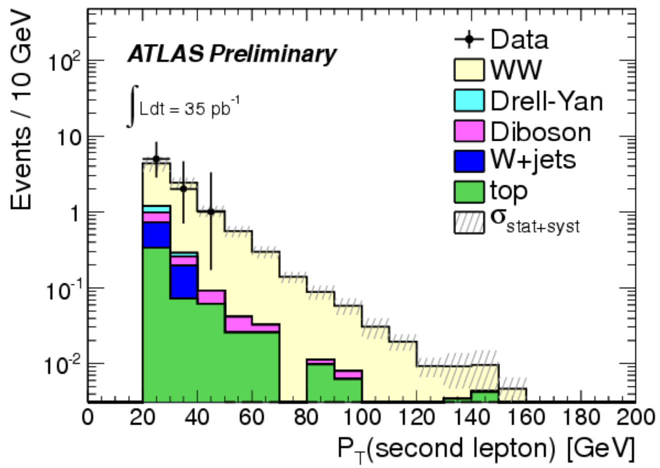
Selection

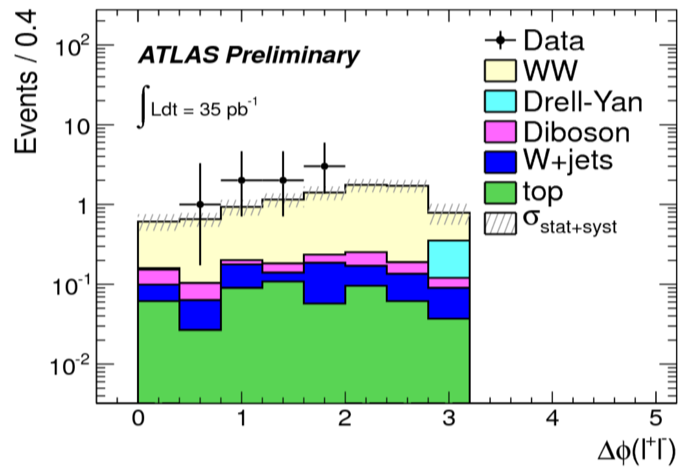
- Exactly two opposite-sign good leptons (*e, μ)*
  - To select di-lepton events
  - To suppress W+jets and di-boson events
- M_{ll}>15GeV && $|M_{ll}-M_Z|$>10GeV for ee and μμ channels
  - Mainly to remove Drell-Yan events
- MET_{rel}> 40GeV in ee and μμ channels, and >20GeV in e*μ* channel
  - To further remove Drell-Yan and di-boson events
- Jet veto : No jets (PT>20GeV,|η|<3) present
  - To remove top events

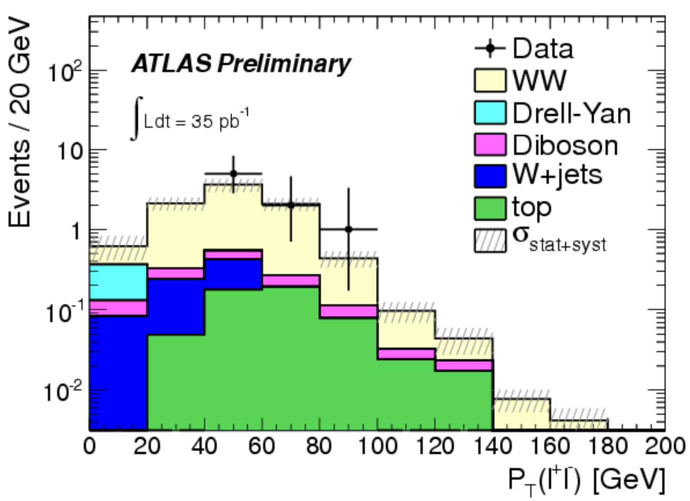
Number of Candidates in 35/pb

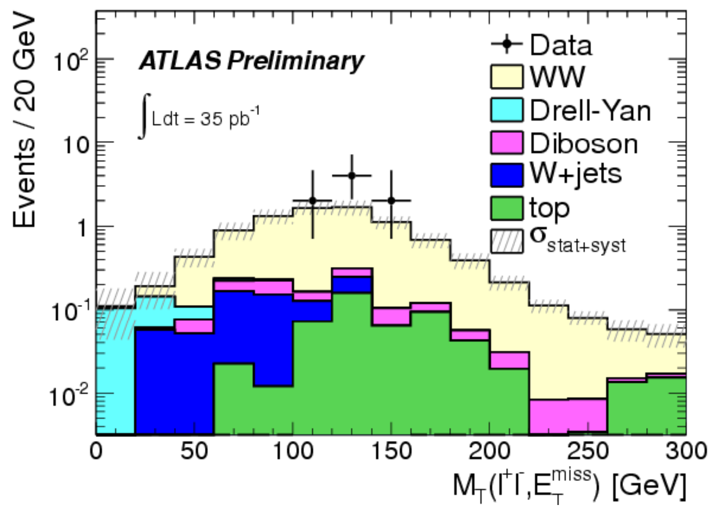
- 8 (ee, μμ,eμ combined)

Kinematic Distributions of the W+W- candidates









Signal yield

- Background estimation:
  - W+jet : Data driven estimation
    - Using W+Jet control sample and di-jet sample in data
  - Drell-Yan
    - Central values are estimated using MC. Systematic uncertainties are estimated using a data driven method on Z control sample
  - Top background estimated using MC and crosschecked using data driven methods.
  - Di-boson (WZ, ZZ, W/Z+γ) backgrounds estimated using MC.

Final State	$e^+e^-E_T^{miss}$	$\mu^+\mu^-E_T^{miss}$	$e^\pm\mu^\mp E_T^{miss}$	combined
Observed Events	1	2	5	8
MC WW Signal	0.85±0.02±0.13	1.74±0.04±0.24	4.81±0.06±0.68	7.40±0.07±1.05
Total Background	0.17±0.11±0.09	0.26±0.31±0.15	1.29±0.17±0.32	1.72±0.37±0.45
Signal / Background	5.0	6.7	3.7	4.3

Cross section

- The combined W+W- production cross-section is determined using the maximum likelihood method. The likelihood function based on Poisson statistics is constructed as

$$F = \ln \prod_{i=1}^{3} \frac{e^{-(N_s^i + N_b^i)} (N_s^i + N_b^i)^{N_{obs}^i}}{N_{obs}^i!} \quad \text{where} \quad N_s^i = \sigma_{WW} \times Br^i \times \mathscr{L} \times A^i$$

$$\sigma_{WW} = 40^{+20}_{-16}(\text{stat}) \pm 7(\text{syst})\ \text{pb}$$

- which is in good agreement with the SM NLO prediction of 46±3pb.

Conclusion

- First measurement of W/Zγ and WW production cross sections at 7 TeV performed by ATLAS using 35/pb of integrated luminosity
- The cross section measurements are in good agreement with SM NLO expectations
- The measurements are limited by statistics. The future analysis with larger dataset will be important for precision test of the SM and new physics searches.