Data-driven estimation of the $Z \to \nu\bar{\nu} + jets$ background in SUSY searches using $\gamma + jets$

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Motivation

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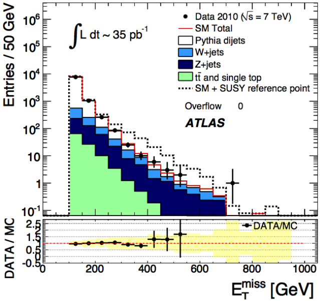
$Z \rightarrow \nu\bar{\nu} + jets$ is one of the **dominant** Standard Model backgrounds to new physics signals in the form of:

Missing Transverse Energy (E_T^{miss}) + jets

This is the case for many popular **SUSY** models.

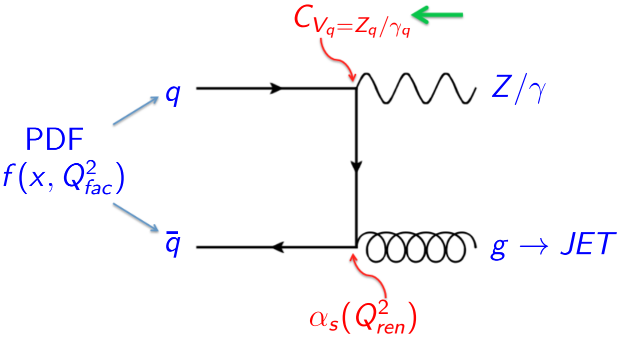


Experimentally, $Z \rightarrow \nu\bar{\nu}$ **escapes detection**, only seen as E_T^{miss}

Data-driven methods exist to calibrate this background using Z, W and γ data samples.

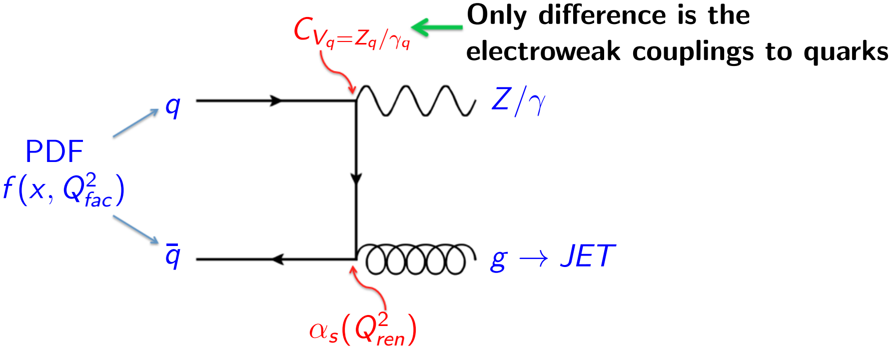
However, the one with γ **data** gives the most **precise** estimate (largest statistics)

- At high p_T ($\gg M_Z$), γ and Z production are very similar:



Theory

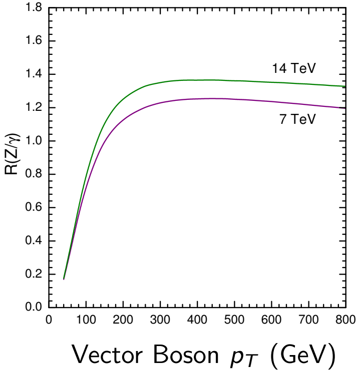
- At high p_T ($\gg M_Z$), γ and Z production are very similar:



$$C_{Z_q} = \frac{-ie}{2\sin\theta_W\cos\theta_W}\gamma^\mu(v_q - a_q\gamma^5) \qquad C_{\gamma_q} = -ieQ_q\gamma^\mu$$

- Indeed the Z to γ cross sections ratio **converges** to a value given by the **ratio** of these couplings:

$$\frac{d\sigma_{Z+jets}/dp_T}{d\sigma_{\gamma+jets}/dp_T} \rightarrow R_{C_Z/C_\gamma}$$



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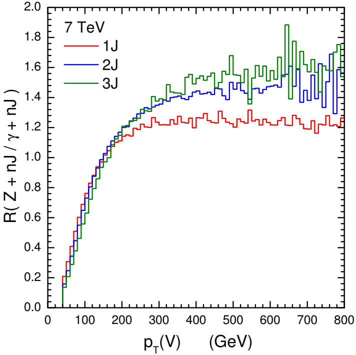
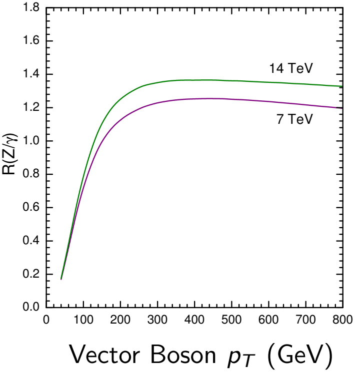
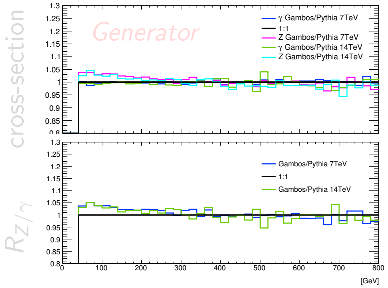
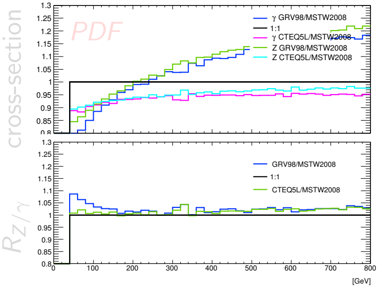


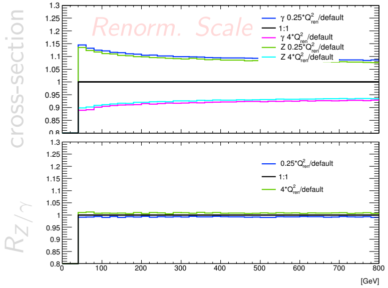


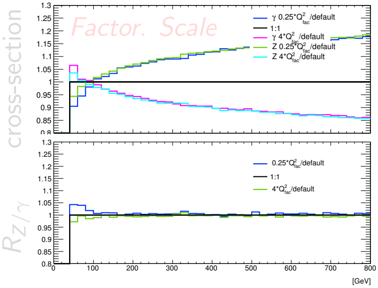
- Moreover, this ratio is relatively **robust** to kinematic variations and theoretical uncertainties.

Theoretical Uncertainties - Effects on the cross-section and Ratio









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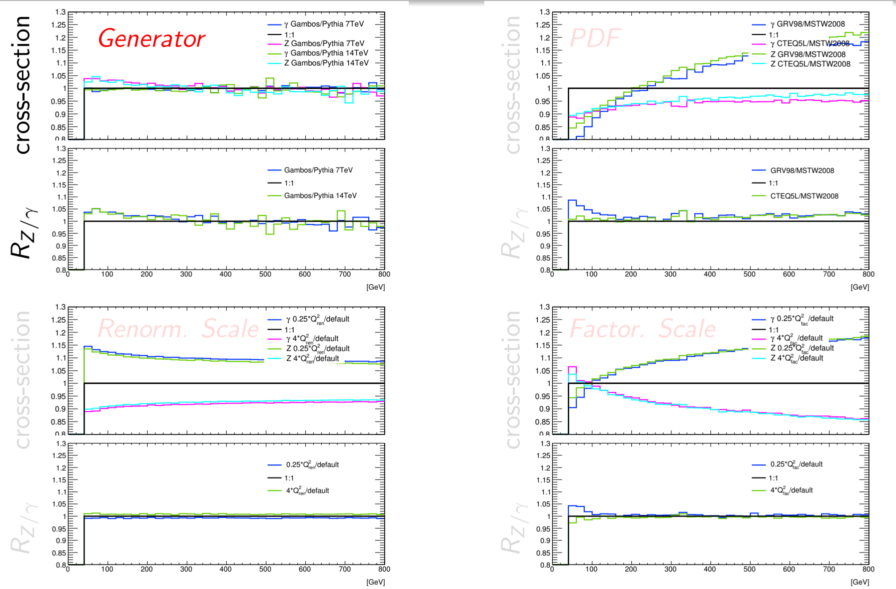

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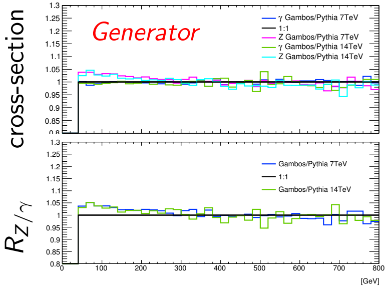

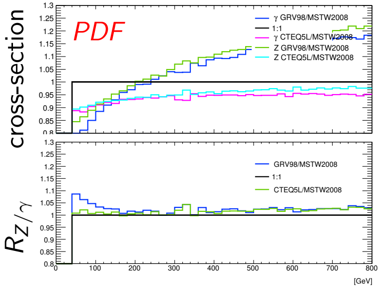

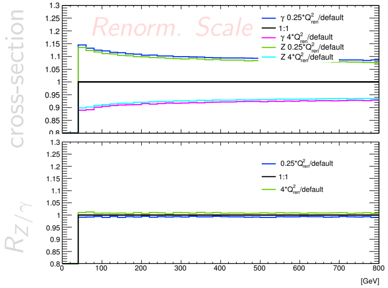

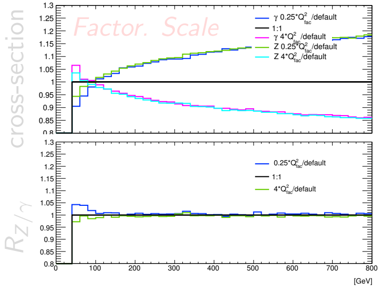

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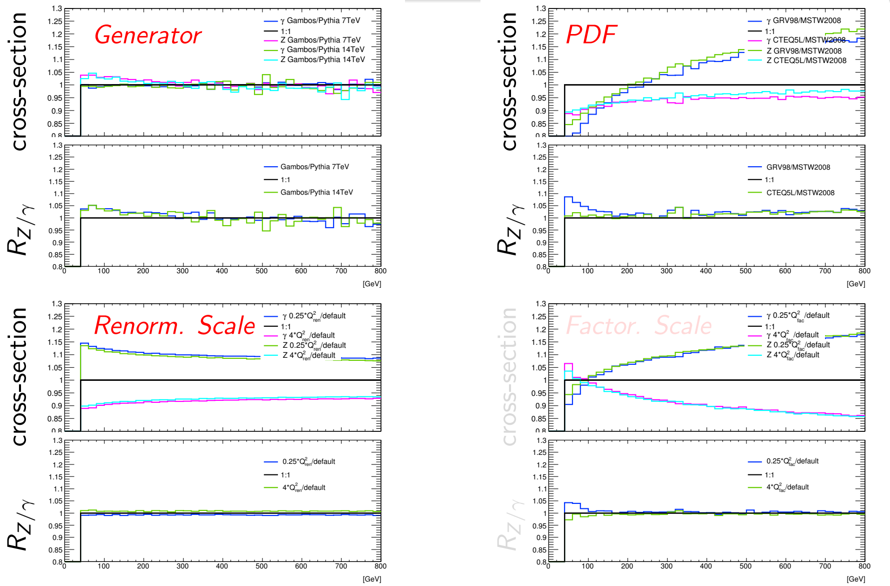

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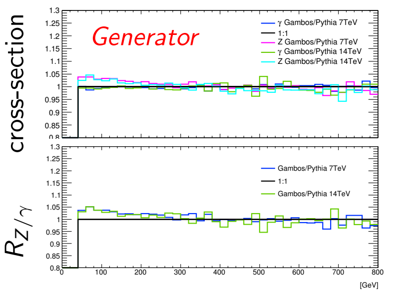
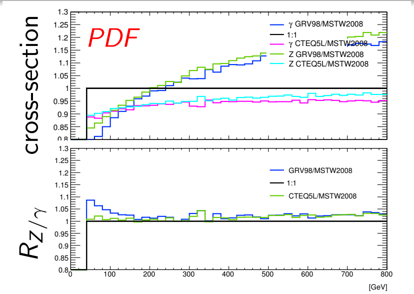
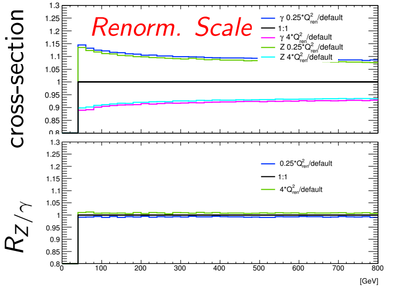
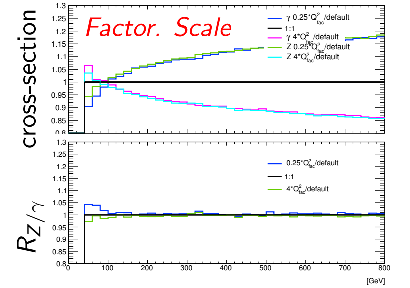








Experimental Method

1. Select **prompt** γ events in data ($p_T^\gamma > 45$ GeV), passing "Tight" identification and isolation requirements (to reduce background, mainly from $\pi^0 \to \gamma\gamma$).
2. Then, obtain the number of these γ's that also pass our **SUSY Selection**:

ATLAS 0 Lepton Channel, 4 Signal Regions

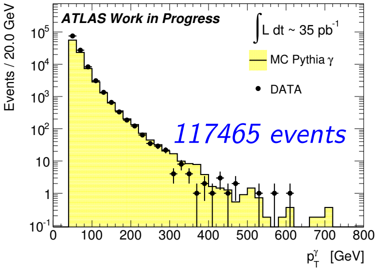
		A	B	C	D
Pre-selection	Number of jets	≥ 2	≥ 2	≥ 3	≥ 3
	Leading jet p_T [GeV]	> 120	> 120	> 120	> 120
	Other jet(s) p_T [GeV]	> 40	> 40	> 40	> 40
	E_T^{miss} [GeV]	> 100	> 100	> 100	> 100
Final selection	$\Delta\phi(jet, E_T^{\text{miss}})_{\text{min}}$	> 0.4	> 0.4	> 0.4	> 0.4
	$E_T^{\text{miss}}/M_{\text{eff}}$	> 0.3	–	> 0.25	> 0.25
	M_{eff} [GeV]	> 500	–	> 500	> 1000
	M_{T2} [GeV]	–	> 300	–	–

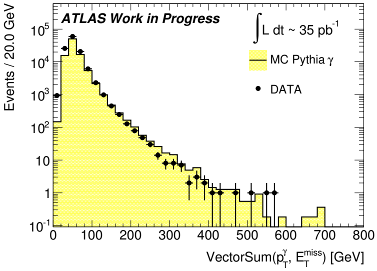
referred as **"Dijet Selection"**

Here the E_T^{miss} is replaced by:

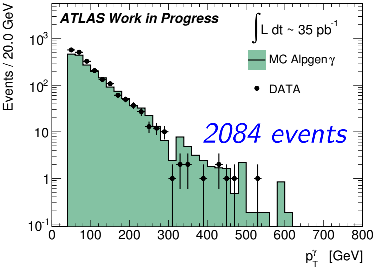
VectorSum(p_T^γ, E_T^{miss})

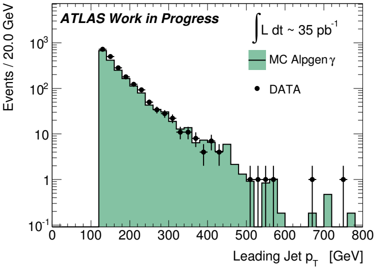
After Photon Selection





After Susy Dijet Selection





Experimental Method

3. Convert the photon events passing to the 4 Signal Regions (SR) into $Z_{\nu\nu}$:

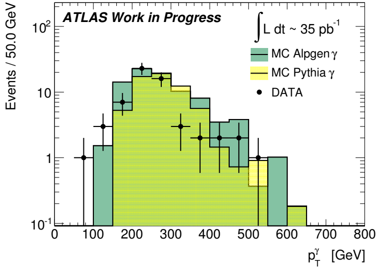
Photon Purity ($> 90\%$)

Theory cross-section ratio

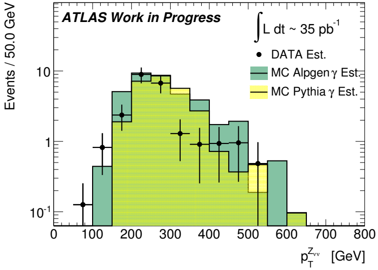
$$N^{Z_{\nu\nu}}(p_T) = \frac{N^{\gamma}(p_T) \cdot (1 - f^{\gamma}_{bkg})}{\epsilon^{\gamma} \cdot A^{\gamma}(p_T)} \cdot R_{Z/\gamma}(p_T) \cdot Br(Z \rightarrow \nu\nu)$$

Photon Efficiency and Acceptance ($\sim 80\% \times 75\%$)

$N^{\gamma}(p_T)$ *in SR 'A'*



$N^{Z_{\nu\nu}}(p_T)$ *Estimate in SR 'A'*

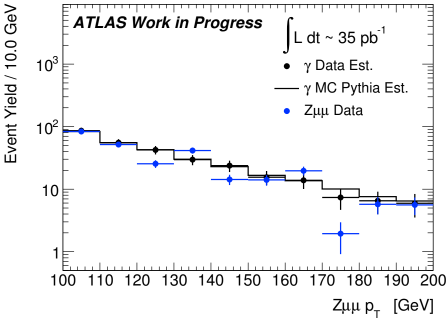


$Z_{\mu^+\mu^-}$ Closure Test

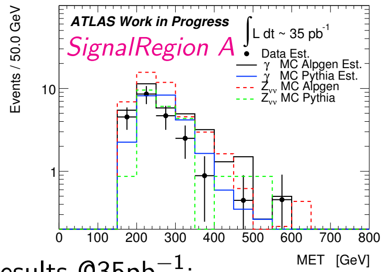
- To validate further this method, another estimate was made for the number of $Z_{\mu^+\mu^-}$ events produced in association with at least 1 jet (leading jet $p_T > 30$ GeV).

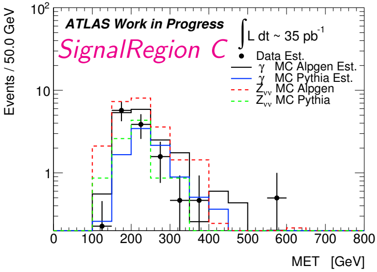
- The result was then compared to real $Z_{\mu^+\mu^-}$ ATLAS data:

100 GeV $< p_T^{Z_{\mu\mu}} <$ 200 GeV		
$Z_{\mu\mu}$ Data	γ Data Est.	γ Pythia Est.
263 $\pm$25(stat) $\pm$30(syst)	286 $\pm$10(stat) $\pm$40(syst)	289



- Here, our variable **VectorSum**$(p_T^{\gamma}, E_T^{\mathbf{miss}})$ is directly comparable to the $\mathbf{E_T^{miss}}$ (MET) in MC $\mathbf{Z_{\nu\nu}}$ events:





Results @35pb^{-1}:

Signal Region	$Z_{\nu\nu}$ Pythia	γ Pythia Est.	Data Est.	$Z_{\nu\nu}$ Alpgen	γ Alpgen Est.
A	24	26	22 ± 5	45	34
C	10	10	13 ± 4	25	18
D	0.0	0.3	0.5	0.8	1.8

→ Pythia Closure Test

→ Closure is less good

→ higher due to harder jets

Summary

- We have performed theoretical studies on the Z/γ x-section ratio.
- Our studies show that this ratio can confidently be used to predict the E_T^{miss} spectrum of invisible Z bosons.
- The experimental method to determine this using ATLAS data has also been implemented and the first results show good agreement with theory predictions.

Outlook

- Comparison with MC Sherpa in progress.
- We aim to increase the precision of this method even further by decreasing the systematics in the correction factors applied in the conversion of γ's to Z.

References I

[1] [3] [2]

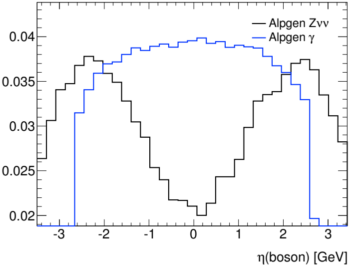
[1] The ATLAS Collaboration. Measurement of the inclusive isolated prompt photon cross section in pp collisions at $\sqrt{s} = 7$ TeV with the ATLAS detector. *CERN-PH-EP-2010-068*, 2010.

[2] The ATLAS Collaboration. Measurement of the cross-section for jets produced in association with Z bosons. *ATL-COM-PHYS-2011-141*, 2011.

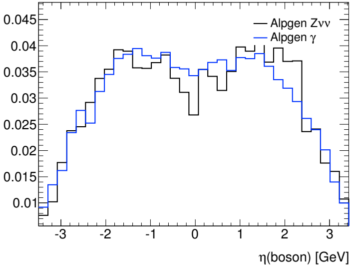
[3] The ATLAS Collaboration. Search for squarks and gluinos using final states with jets and missing transverse momentum with the ATLAS detector in $\sqrt{s} = 7$ TeV proton-proton collisions. ATL-COM-PHYS-2010-1077, 2011.

– Backup Slides –

γ vs $Z_{\nu\nu}$ Pseudorapidity distributions



After Photon Selection



After Susy Dijet Selection

- There's a difference in the η distributions of photons and Z's from different phase-space factors for massive Z's versus massless photons, and differences in their couplings to quarks.
- However, at high p_T , the bosons tend to be found in the central region which mitigates the difference. This can be seen in the figure above.