SEARCHES FOR SUPERSYMMETRY IN EVENTS CONTAINING A Z BOSON, JETS AND MISSING TRANSVERSE MOMENTUM

NExT Workshop

29 April 2015

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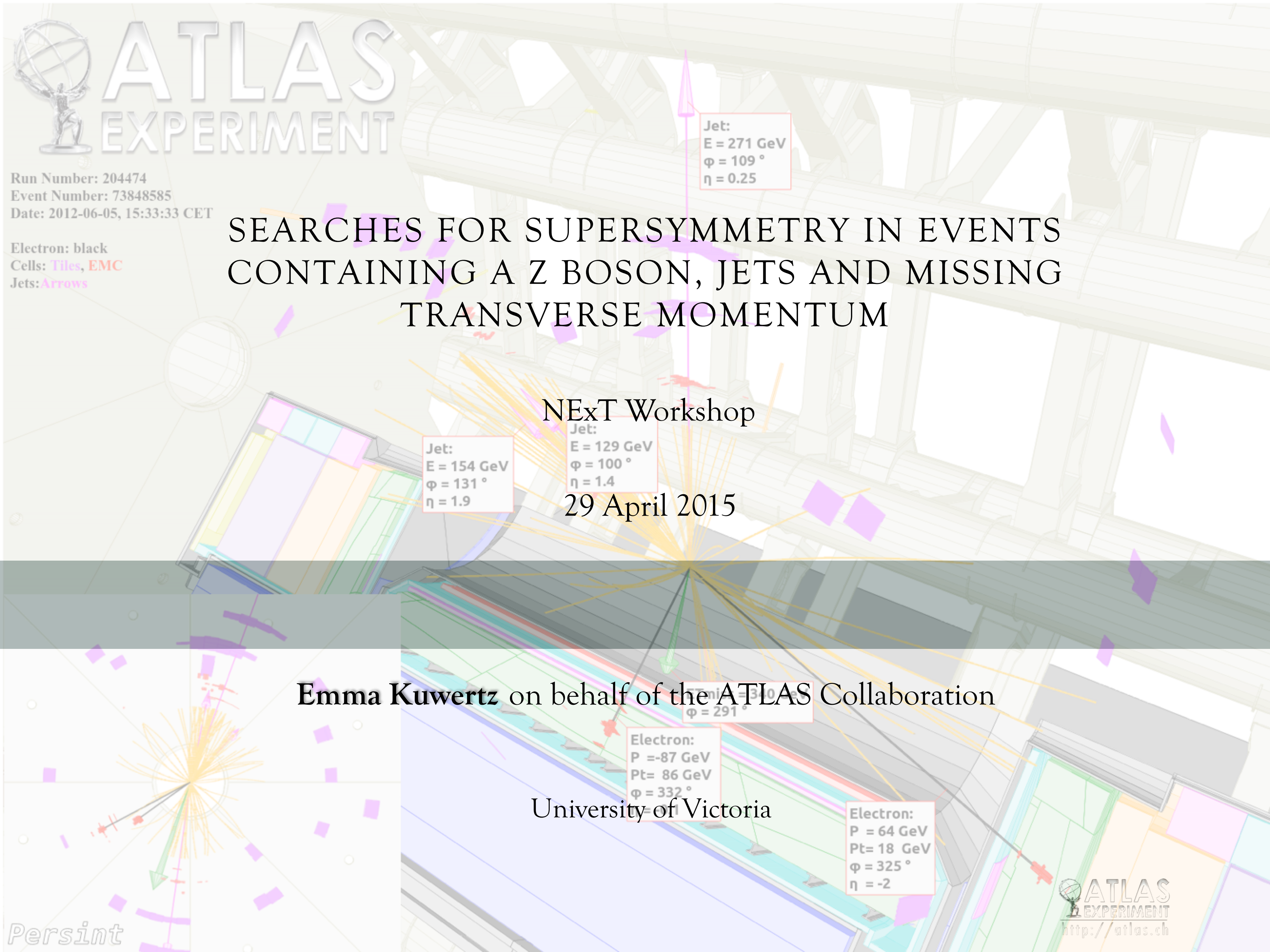
University of Victoria

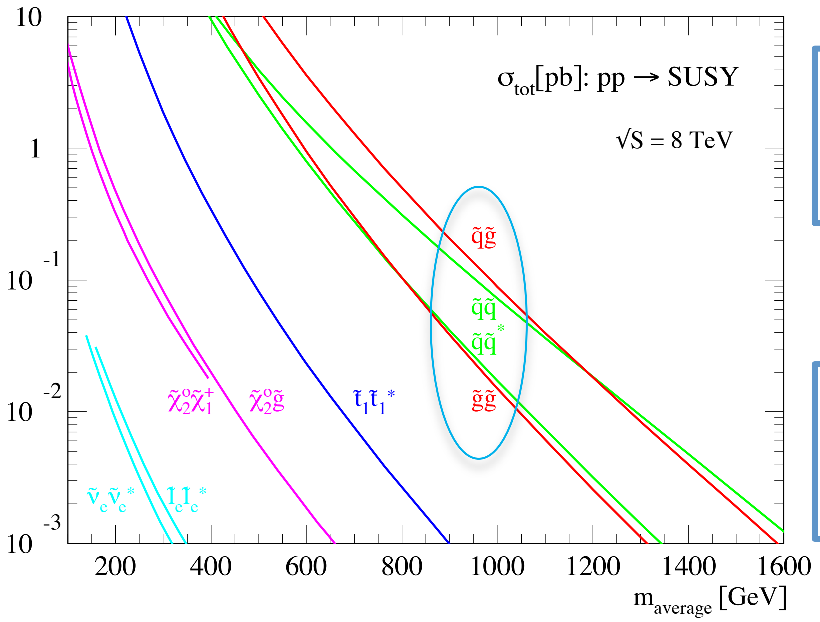


Overview

Presenting a search for SUSY in final states with a leptonically decaying Z boson, at least two jets and missing transverse energy (MET).

R-parity conservation → MET from escaping LSPs

Quarks from gluino and squark decays → jets in the final state



Recent results from ATLAS:
http://arxiv.org/abs/1503.03290 $20.3\ fb^{-1}, \sqrt{s} = 8$ TeV

Presented here

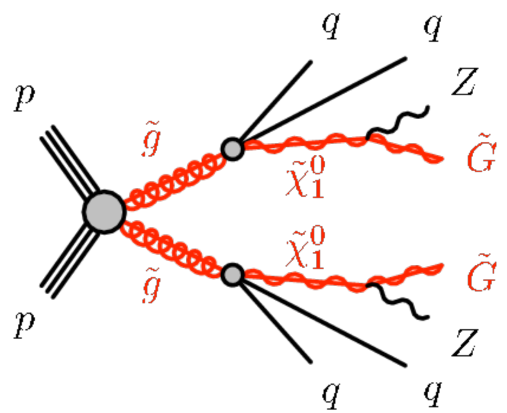
Recent results from CMS:
http://arxiv.org/abs/1502.06031 $19.4\ fb^{-1}, \sqrt{s} = 8$ TeV

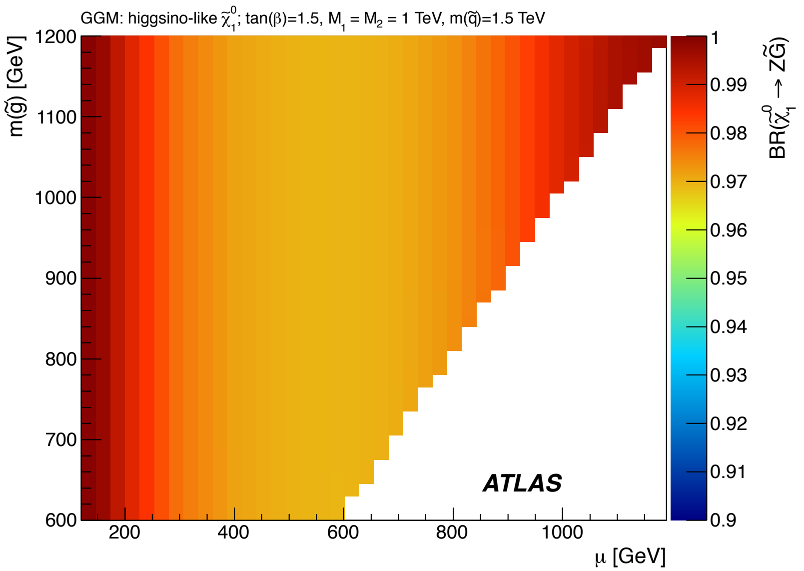
SUSY signal scenarios

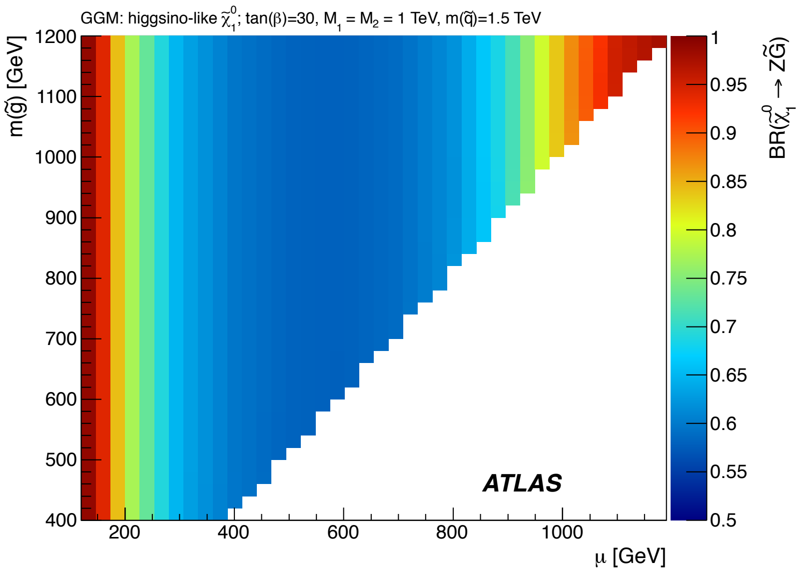
Analysis is optimised towards **general gauge mediated** SUSY models (GGM)

- Gravitino LSP
- *Prompt* higgsino NLSP

Max NLSP decay length ~ 2mm

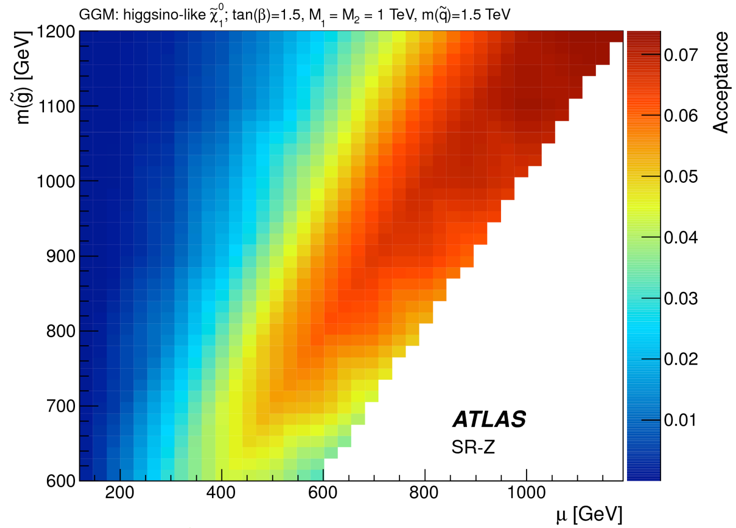






Event selection

- At least 2 *isolated* leptons
- At least 2 jets
- 2 same-flavour opposite-sign (SFOS) leptons with $81<m_{ll}<101$ GeV



Scalar sum of jet and lepton p_T

p_T>35 GeV

On-Z Region	E_T^{miss} [GeV]	H_T [GeV]	n_{jets}	$m_{\ell\ell}$ [GeV]	SF/DF
Signal regions					
SR-Z	> 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF
Control regions					
Seed region	-	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF
CReμ	> 225	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	DF
CRT	> 225	> 600	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF
Validation regions					
VRZ	< 150	> 600	≥ 2	$81 < m_{\ell\ell} < 101$	SF
VRT	150–225	> 500	≥ 2	$m_{\ell\ell} \notin [81, 101]$	SF
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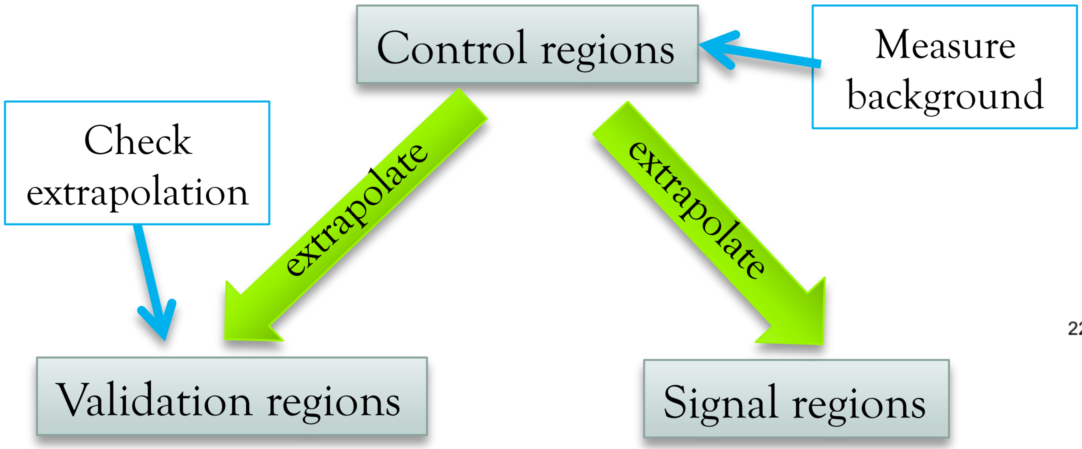
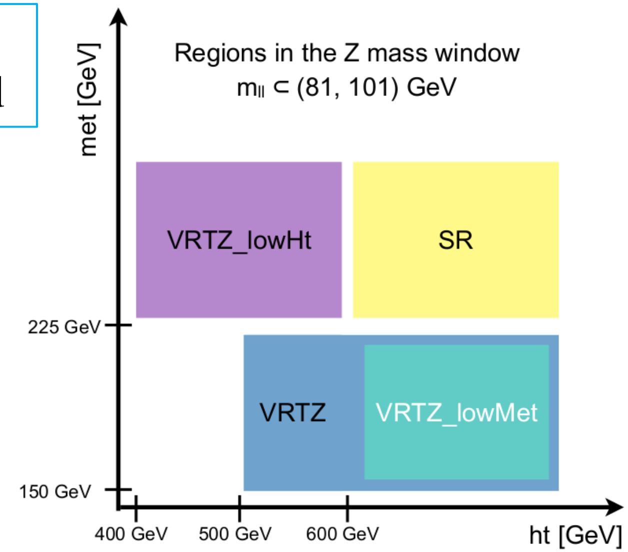
Control regions are used for background estimations

Validation regions are used to check background estimates

Event selection





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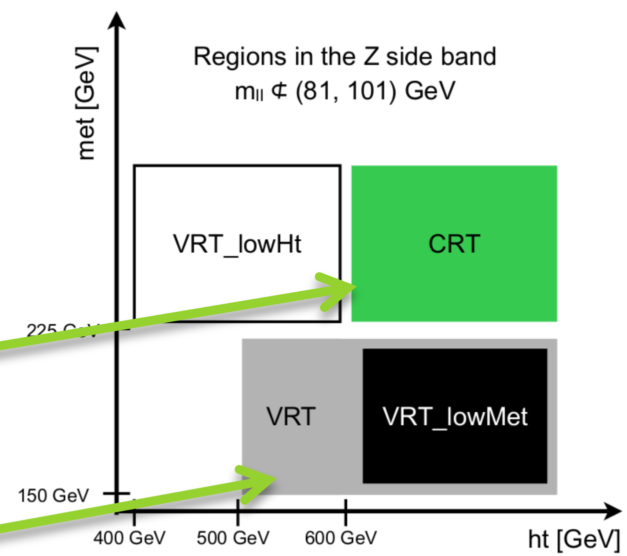


Background estimation overview

Instrumental MET

Dominant backgrounds

Background	Estimation method	Generator
Fake leptons: Multi-jets	Matrix method	-
W → lnu	Matrix method	-
Z → nunu Single top	Matrix Method	-
DY/Z → ll	Jet smearing	Sherpa
ttbar	Flavour-symmetry	Powheg+Pythia Powheg+Jimmy Alpgen
Single top (Wt)	Flavour-symmetry	Powheg+Pythia
WW	Flavour-symmetry	Powheg
WZ	MC	Powheg+Pythia8
ZZ	MC	Powheg+Pythia8
tt+W, tt+WW, tt+Z, t+Z	MC	MadGraph+Pythia

Data driven backgrounds

MC backgrounds

"Flavour-symmetric" backgrounds

Estimation strategy

ttbar, Wt, WW, Z→tautau

Flavour symmetric

$$\mathsf{ee} : \mu\mu : \mathsf{e}\mu = 1 : 1 : 2$$

Electron-muon channel → same-flavour channel

Estimate in SF channel

Data e-mu channel

$$N_{ee}^{\textsf{est.}} = \frac{1}{2} N_{e\mu}\, k_{ee}\, \alpha$$

$$N_{\mu\mu}^{\textsf{est.}} = \frac{1}{2} N_{e\mu}\, k_{\mu\mu}\, \alpha$$

Reconstruction efficiency scale factor

Trigger efficiency scale factor

Almost exclusively data-driven method

“Flavour-symmetric” backgrounds

Reconstruction efficiency scale factors

$$k_{ee} = \sqrt{\frac{N_{ee}^{\mathsf{VRZ}}}{N_{\mu\mu}^{\mathsf{VRZ}}}}, \qquad k_{\mu\mu} = \sqrt{\frac{N_{\mu\mu}^{\mathsf{VRZ}}}{N_{ee}^{\mathsf{VRZ}}}}$$

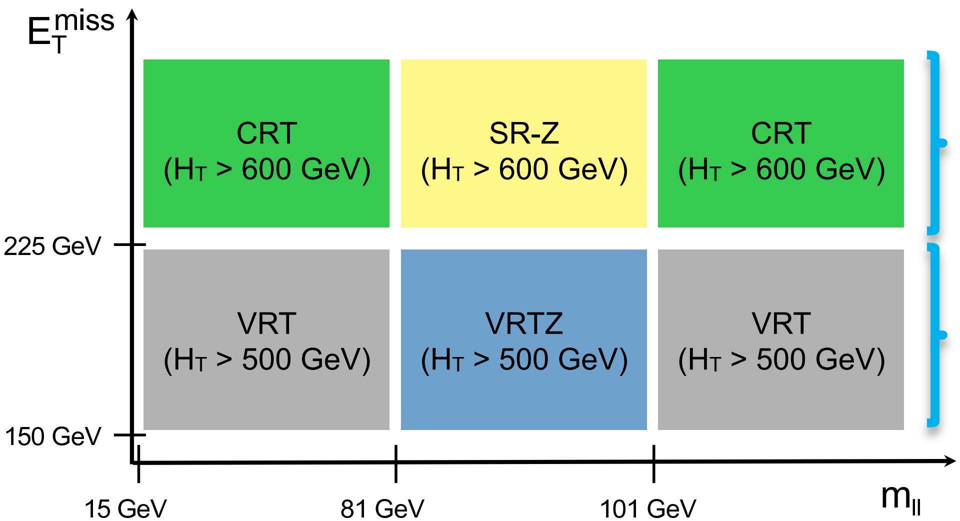
Use the number of events selected in Z dominated event samples in data

Trigger efficiency scale factors

$$\alpha = \frac{\sqrt{\epsilon_{ee}^{\mathsf{trig}}\epsilon_{\mu\mu}^{\mathsf{trig}}}}{\epsilon_{e\mu}^{\mathsf{trig}}}$$

Different channels use different triggers
→ need to account for this in efficiency correction

Side band fit



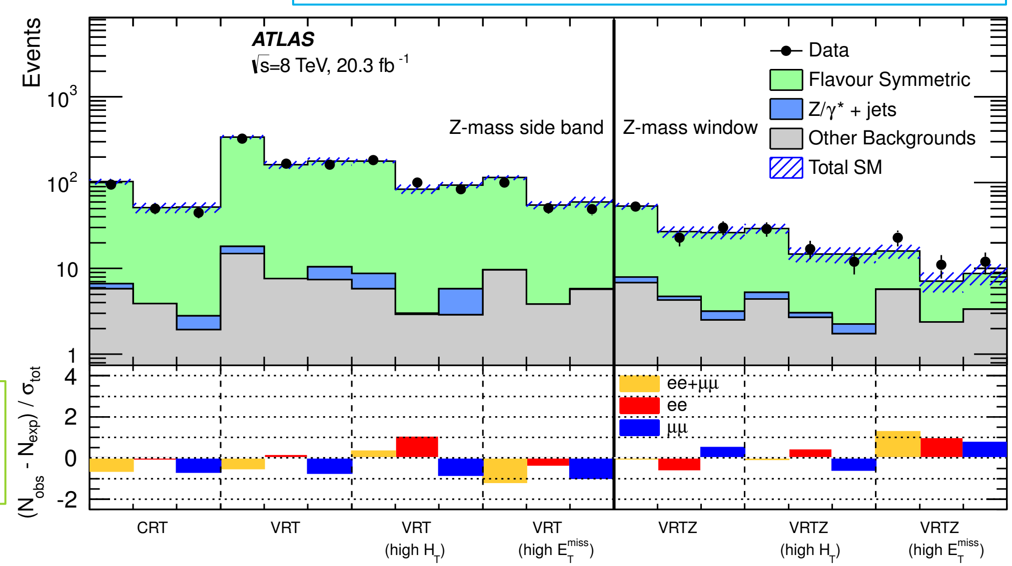
Normalise ttbar MC in Z side bands

- *Alpgen+Pythia, Powheg+Pythia, Powheg +Jimmy*

Cross check this cross check using identical regions at lower MET

Flavour-symmetry method also checked!

Signal region	Flavour-symmetry	Sideband fit
SR-Z ee	2.8 ± 1.4	4.9 ± 1.5
SR-Z $\mu\mu$	3.3 ± 1.6	5.3 ± 1.9



Consistent results from cross-checks
Good agreement in validation regions

Jet smearing method

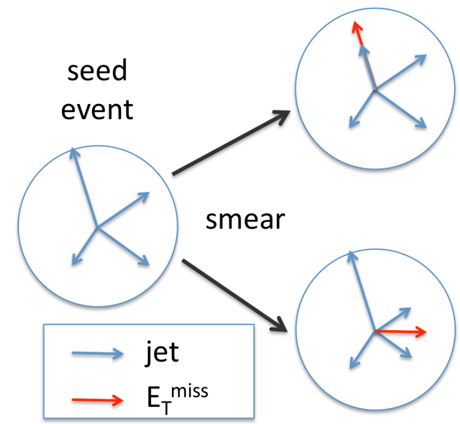
No real MET in Z → ll events

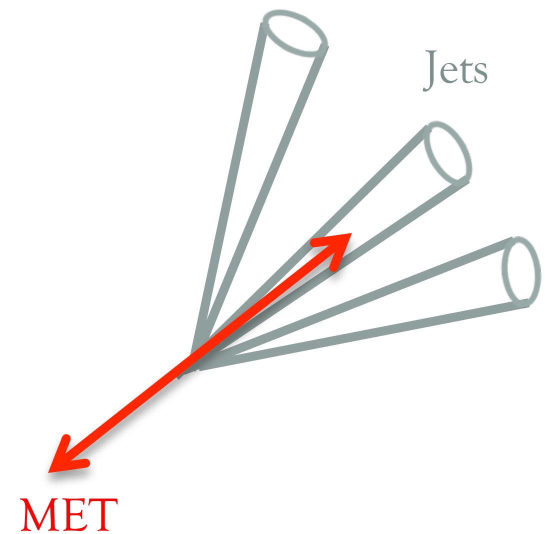
Define a **seed** region → well measured jets low MET

Smear jet p_T and phi with jet response function → Bulk tuned to data using di-jet analysis

→ Non-Gaussian tails tuned to data using 3-jet analysis

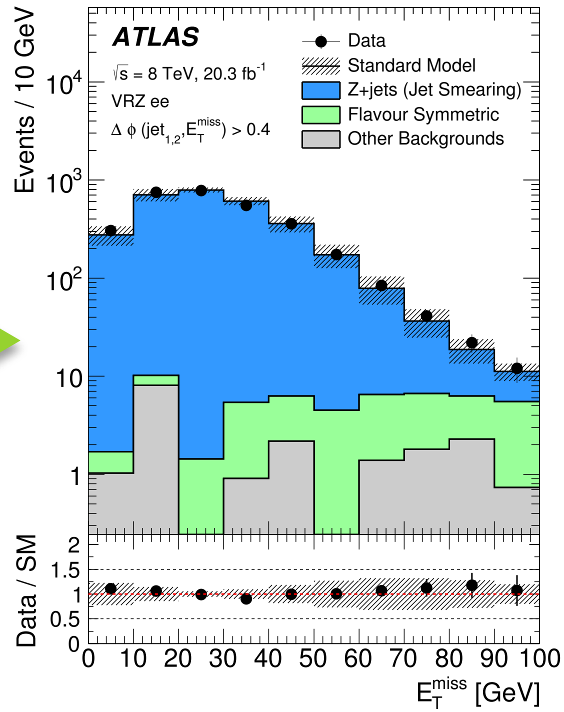
→ “Pseudo-data”

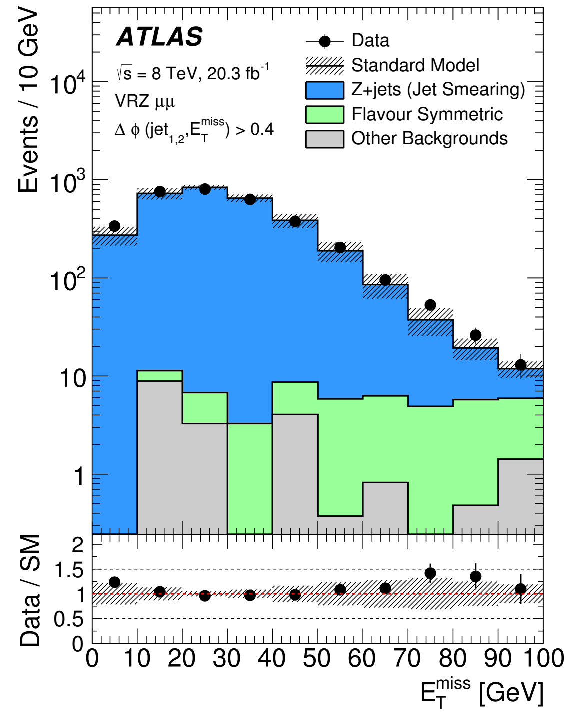




Jet smearing – Z+jets background

Jet smearing tested on data in Z validation region





MC closure test applying jet smearing to Z+jets MC

Use high statistics Sherpa Z+jets MC to cross check data driven estimate

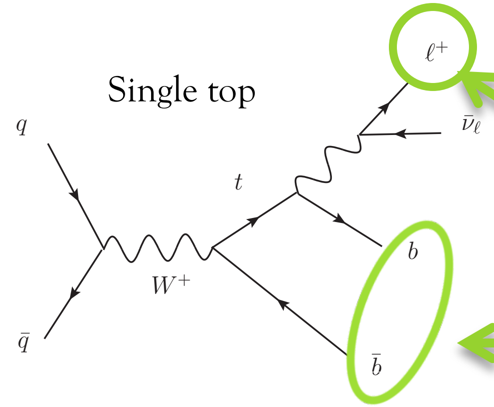
Signal region	Jet-smearing	Z+jets MC
SR-Z ee	0.05 ± 0.04	0.05 ± 0.03
SR-Z $\mu\mu$	$0.02^{+0.03}_{-0.02}$	0.09 ± 0.05

Results are consistent

Fake leptons

"**Fake**" lepton background:

- lepton from heavy flavour decay,
- electron from photon conversion,
- muon from meson decaying in flight,
- mis-identified hadron.



Only one true lepton

Heavy flavour "jets"

The matrix method

Analysis selects **isolated** leptons
→ remove isolation criteria

Number of leptons failing isolation

Number of leptons passing isolation

$$N_{\text{fake}} = \frac{N_{\text{fail}} - (1/\epsilon^{\text{real}} - 1)N_{\text{pass}}}{(1/\epsilon^{\text{fake}} - 1/\epsilon^{\text{real}})}$$

Relative identification efficiency for fake leptons

Relative identification efficiency for real leptons

Results

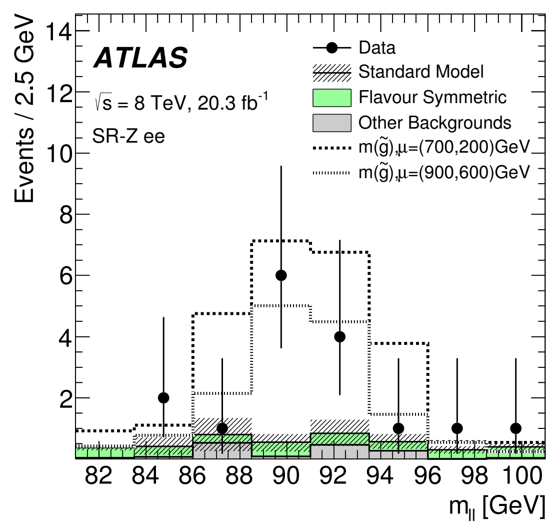
DOCUMENTATION

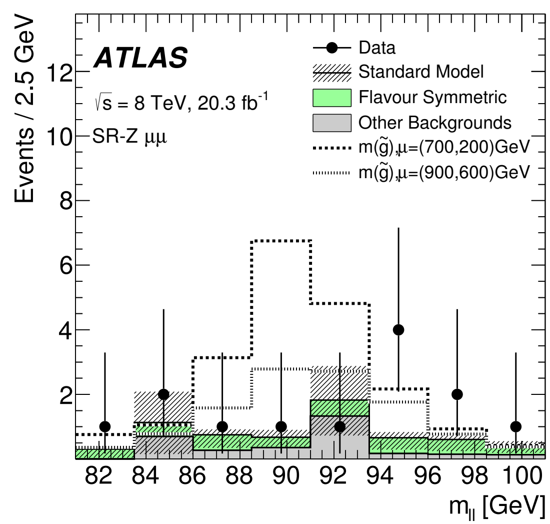
Channel	SR-Z ee	SR-Z $\mu\mu$	SR-Z same-flavour combined
Observed events	16	13	29
Expected background events	4.2 ± 1.6	6.4 ± 2.2	10.6 ± 3.2
1~ Flavour-symmetric backgrounds	2.8 ± 1.4	3.3 ± 1.6	6.0 ± 2.6
$Z/\gamma^* +$ jets (jet-smearing)	0.05 ± 0.04	$0.02^{+0.03}_{-0.02}$	0.07 ± 0.05
Rare top	0.18 ± 0.06	0.17 ± 0.06	0.35 ± 0.12
2 ~ WZ/ZZ diboson	1.2 ± 0.5	1.7 ± 0.6	2.9 ± 1.0
Fake leptons	$0.1^{+0.7}_{-0.1}$	$1.2^{+1.3}_{-1.2}$	$1.3^{+1.7}_{-1.3}$

3 sigma

An excess of events is observed in the signal regions

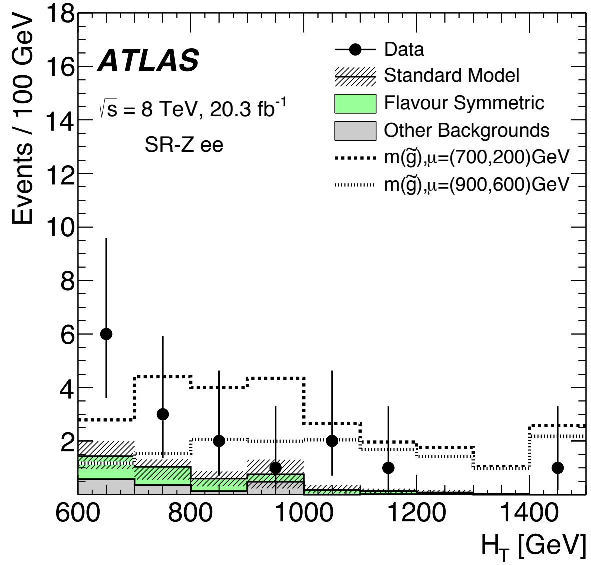
Excess more apparent in dielectron channel

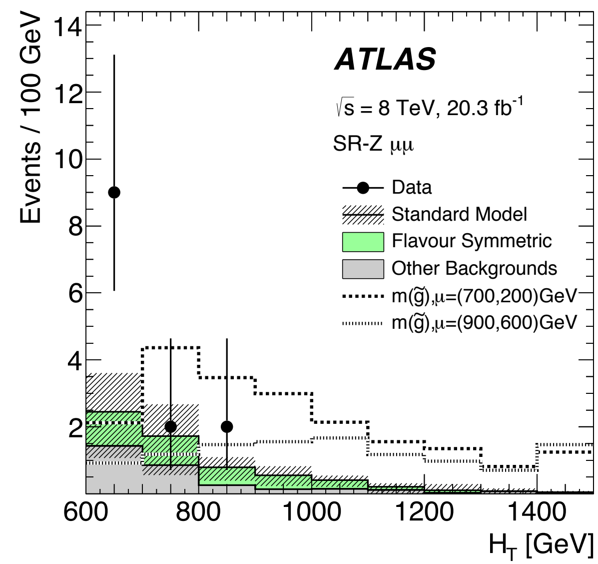




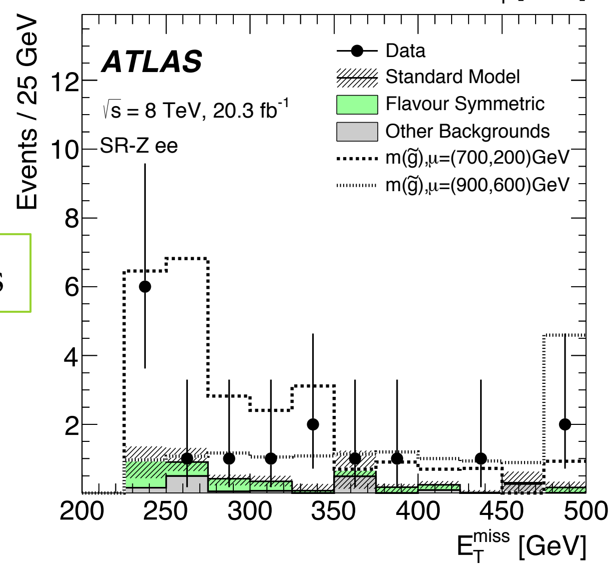
Unblinded distributions

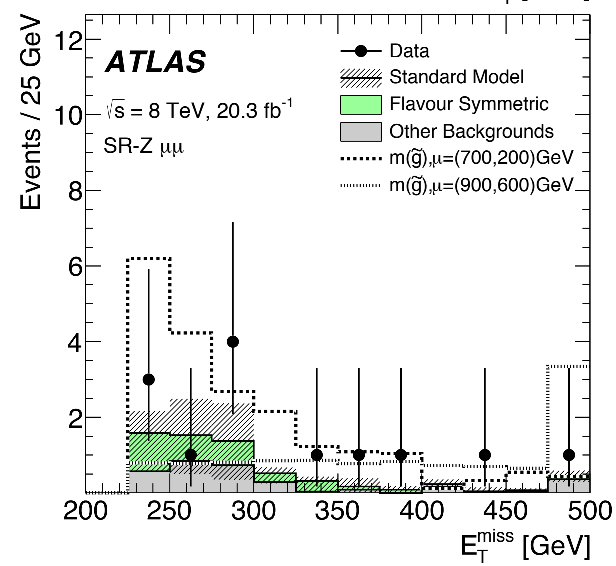
H_T distributions





MET distributions

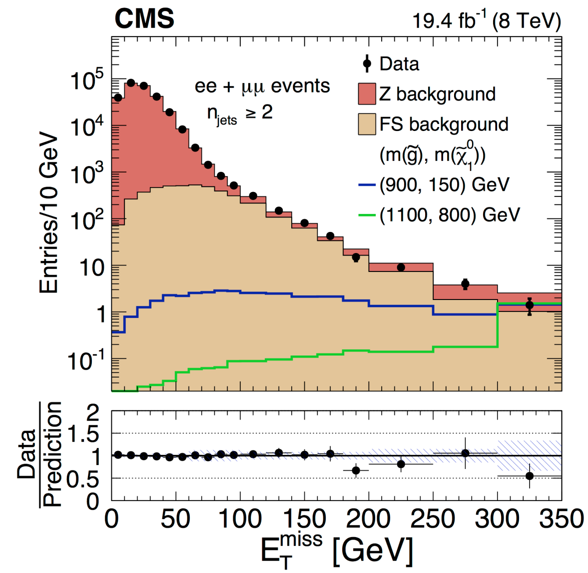


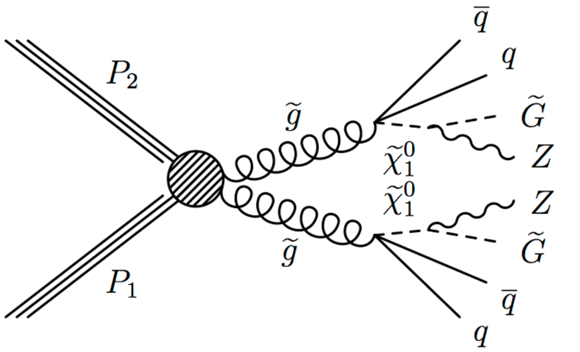


ATLAS vs CMS

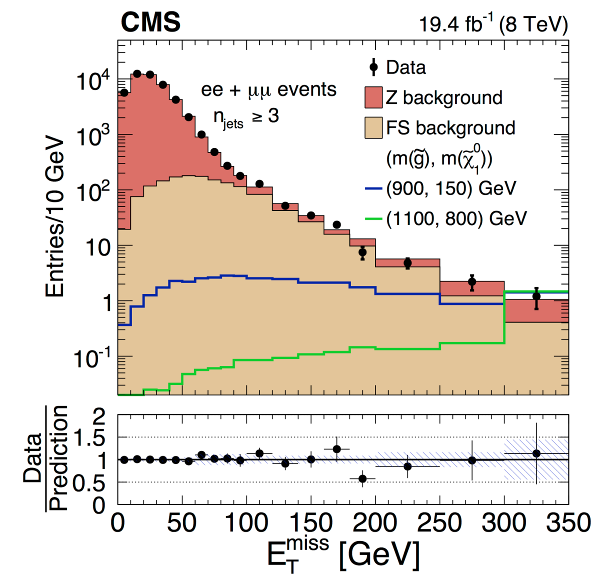
CMS search:
- 2 x 3 SRs binned in MET
- No direct H_T cut

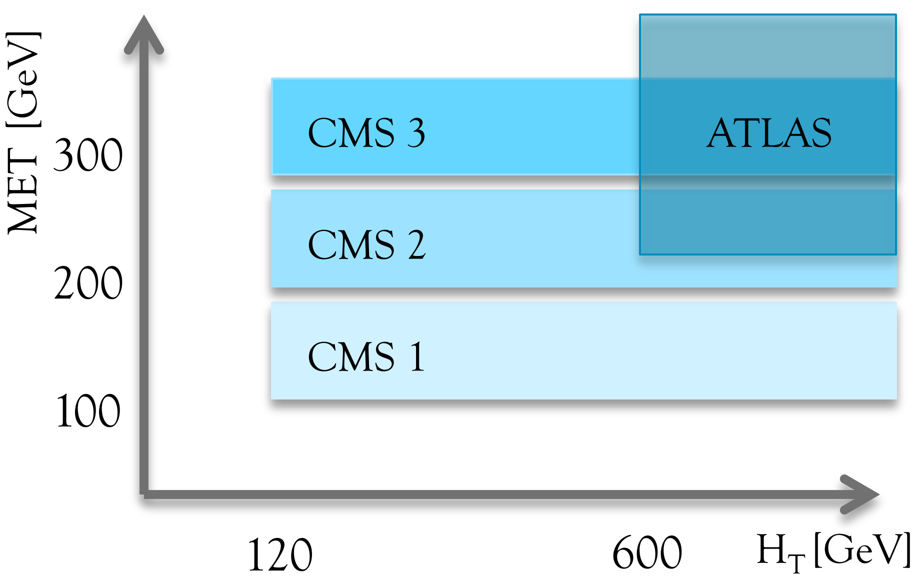
100-200 GeV
200-300 GeV
300+ GeV





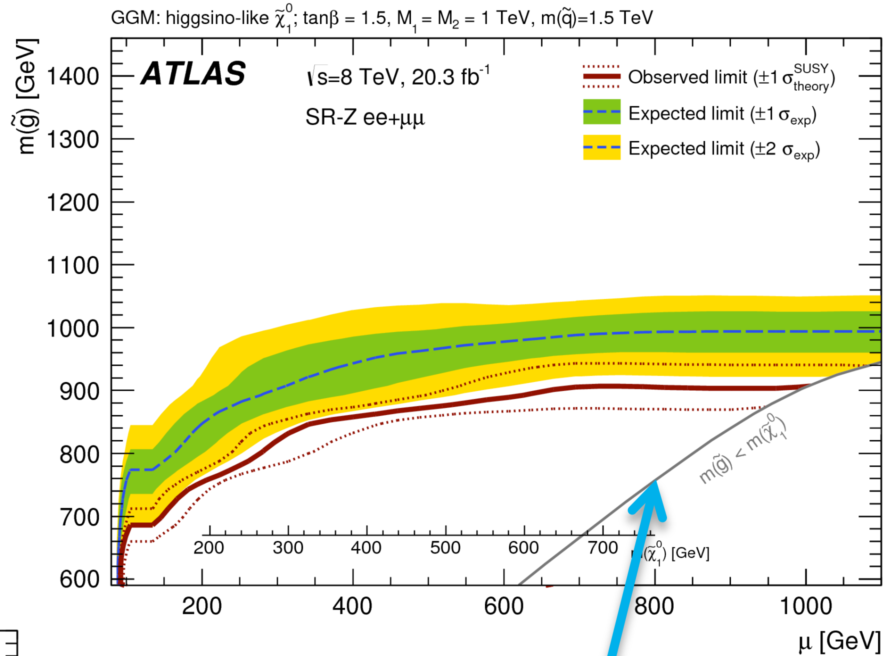
Optimised for similar signal models



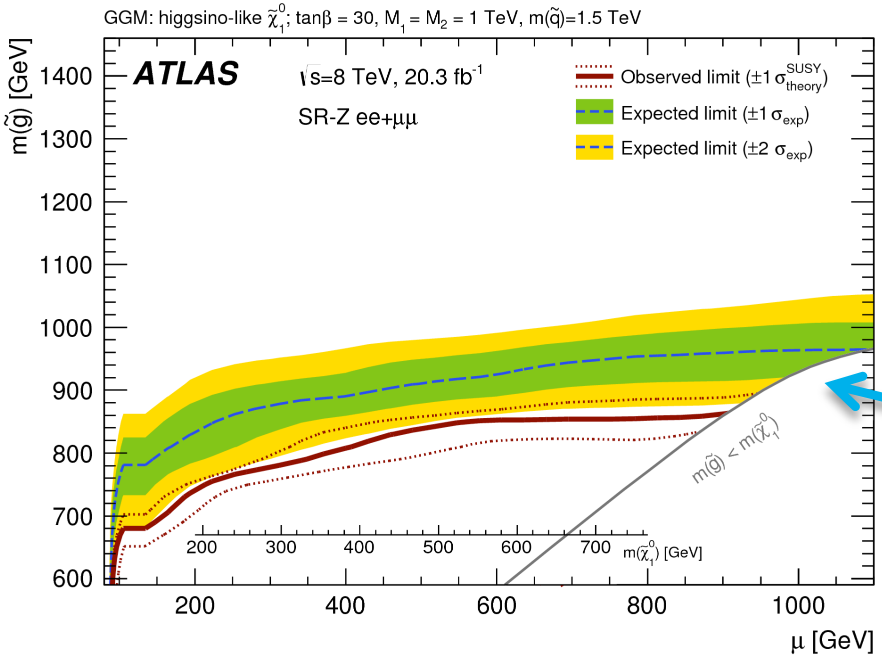


Exclusion limits on GGM models

Limits set on GGM models are weaker than expected



Exclude up to m(gluino) = 900 GeV and mu = 1000 GeV



Exclude up to m(gluino) = 850 GeV and mu = 900 GeV

Conclusion and outlook

- ATLAS search for SUSY in final states with a Z boson, jets and MET presented.
- A 3 sigma deviation from the Standard Model expectation was observed.
- CMS reports good agreement with expectation in the same final state – but phase space cuts are different.
- Something to look out for in Run II.