Semi-leptonic ZZ/ZW Diboson Final State Search at 8 TeV with ATLAS

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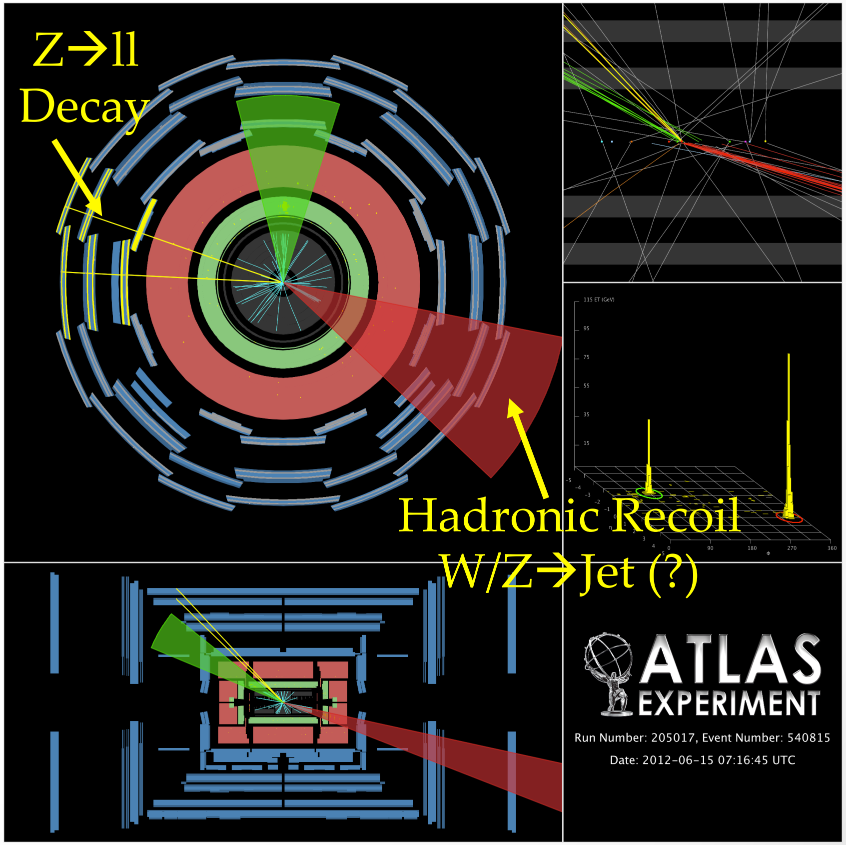
USLUO Meeting

November 2013

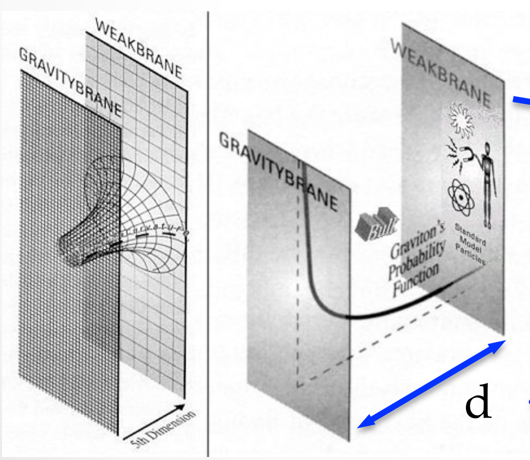
Based on work in
ATLAS-CONF-2012-150

THE UNIVERSITY OF CHICAGO



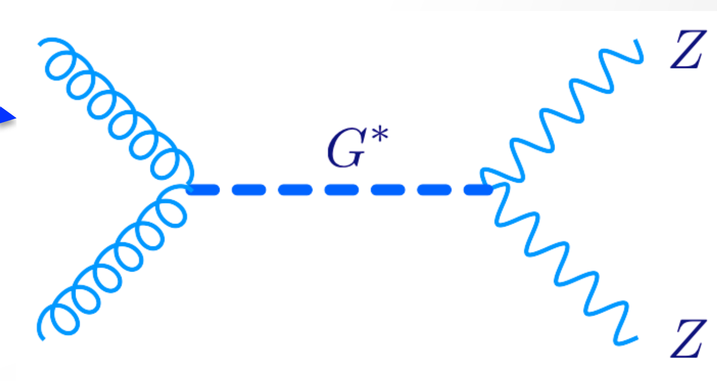
Introduction

- Is there new BSM physics that couples to massive W/Z bosons as a resonance?
  - Can we see it at 8 TeV using 7.1 fb^{-1} of data collected in 2012?
  - If not there, how well can it be constrained?
- Benchmark Signal: Kaluza-Klein (KK) modes of the graviton from Randall Sundrum (RS) model (arXiv:hep-ph/0701186)
  - Offers *one* solution to the weak hierarchy problem – best solution?
  - RS → warped extra dimensions, KK modes → massive excitations of graviton
  - Looking at k/M_{Pl}=1.0 we have σ ($G^* \rightarrow ZZ$)~[60 pb, 0.02 fb] @ M=[300,2000] GeV



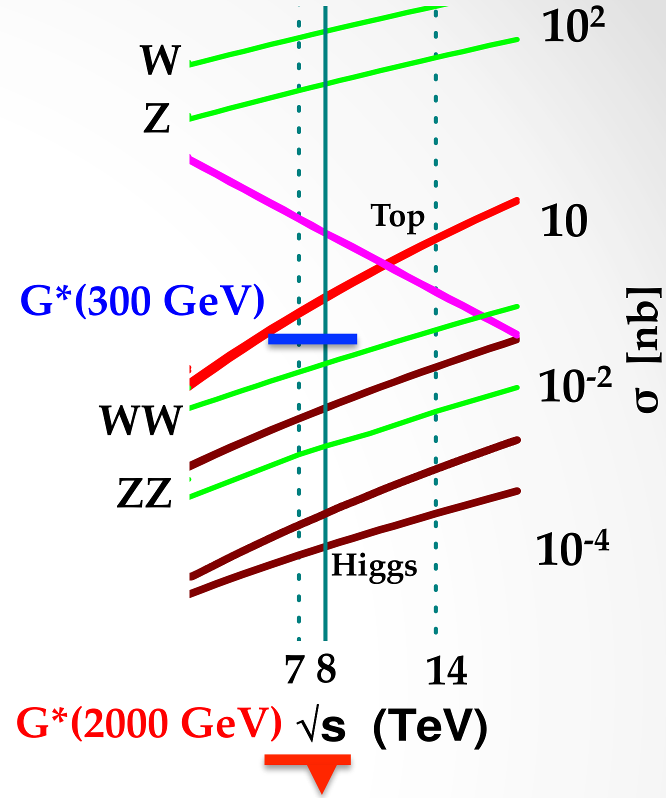
d

RS1→ d~ finite
RS2→ d~ ∞



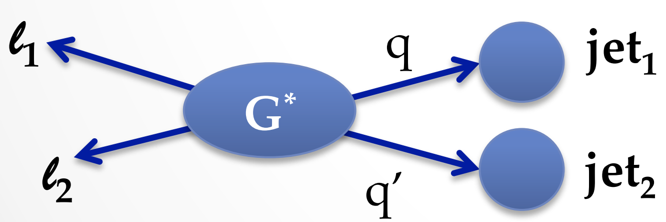
Broad Overview

- Search for generic llqq resonance
  - M_{signal}=300 GeV – 2 TeV
  - "Bump-Hunt" strategy → ~ model independent
- Have to contend with large backgrounds from standard model processes (mainly Z+jets)



(1) Trigger on and tag $Z \rightarrow ll$ decay ($\ell = e,\mu$)

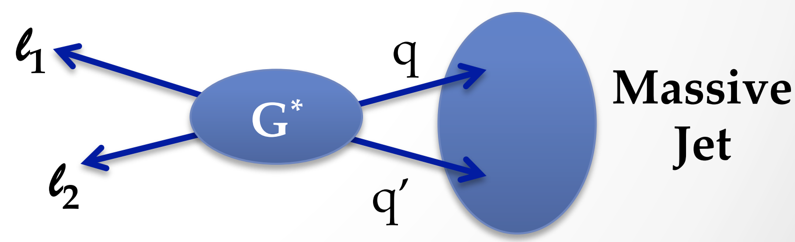
Resolved Regime
M(G)~500 GeV → 4 body system



(2) Select with $p_T(\ell\ell)$, $\Delta\phi(jj)$, M(jj)

(3) Search in $M(\ell, \ell, j, j)$

Boosted Regime (J = merged jet)
M(G) > 1 TeV → 3 body system



(2) Select with $p_T(\ell\ell)$, $p_T(J)$, M(J)

(3) Search in $M(\ell, \ell, J)$

Selection Details

Hadronic Jets

- anti-K_t R=0.4
- p_T > 30 GeV
- $|\eta|$ < 2.1
- |JetVertexFraction| > 0.5 - to fight min-bias pileup interactions
- Removed if close (ΔR<0.3) to a reconstructed lepton

Electrons

- p_T > 20 GeV
- $|\eta|$<2.47
- Well isolated
- Prompt

Muons

- Combined tracking+muon system reconstruction
- p_T > 20 GeV
- $|\eta|$<2.4
- Well isolated
- Prompt

Baseline Selection

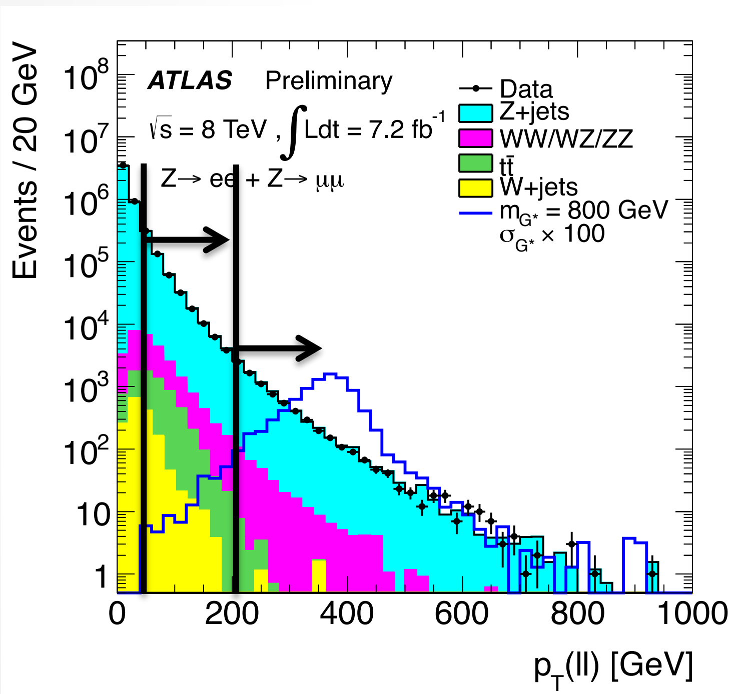
- Trigger : Single lepton of ≥ 24 GeV N_{tracks}(primary vertex) > 3
- Detector level run quality criteria

Leptonic Z

- N_{lep}== 2
- Same Flavor
- Opposite sign for $\mu\mu$
- 66GeV < M(ll) < 116GeV

Optimizing Sensitivity

- Optimize sensitivity in two mass regimes
  - Kinematic cuts chosen to maximize signal efficiency and background rejection for low and high mass signals for different topologies
  - Negligible gain in sensitivity when tuning resolved regime cuts for higher masses → need to change



Final Signal Regions

Resolved Regime:
$p_T(ll) > 50$ GeV
$\Delta\phi(j,j) < 1.6$
66 GeV $< M(jj) <$ 116 GeV

Merged Regime:
$p_T(ll) > 200$ GeV
$p_T(j_1) > 200$ GeV
$M(j_1) > 40$ GeV

High p_T New Physics

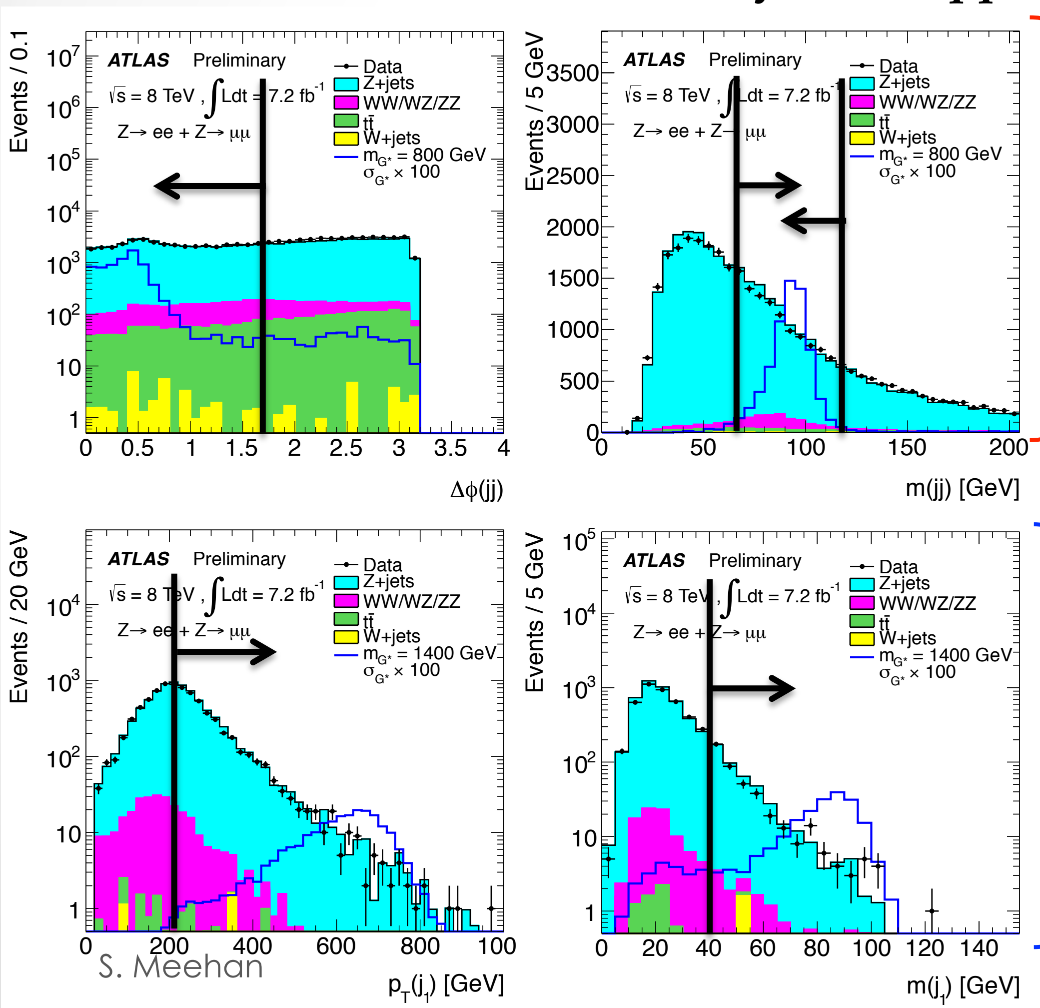
Hadronic Boson Decay

→ = Signal Region

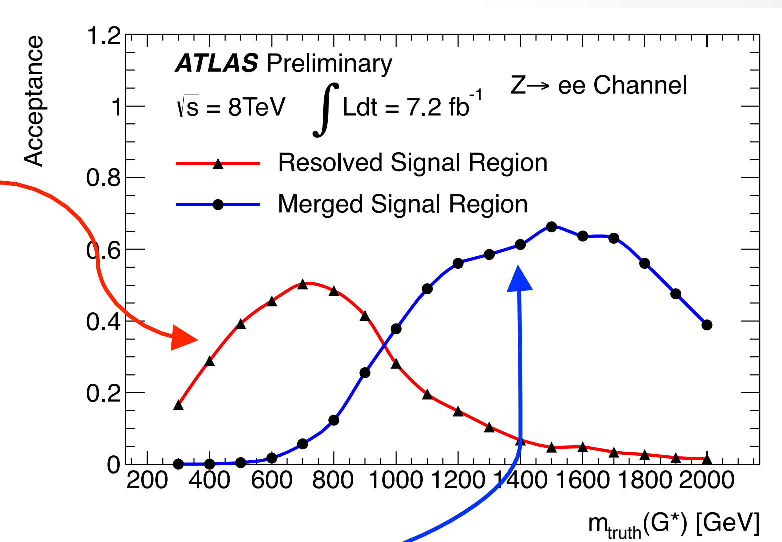
Kinematics for Selection

- Two sets of kinematic handles exploit final state topologies created by massive resonance

High-p_T Z→qq **Identify M(Z→qq)**



Need merged regime to pick up signal above M(G*) ~ 1 TeV

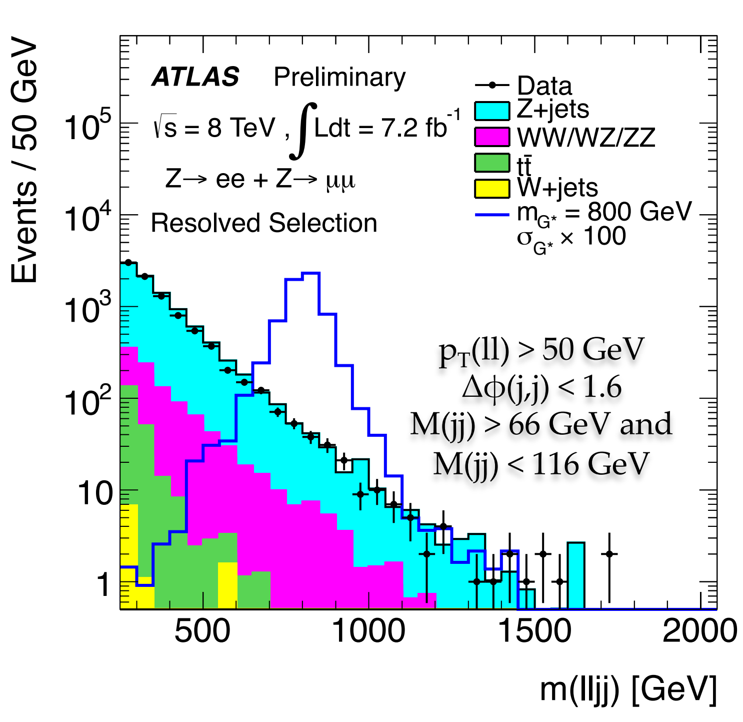


→ = Signal Region

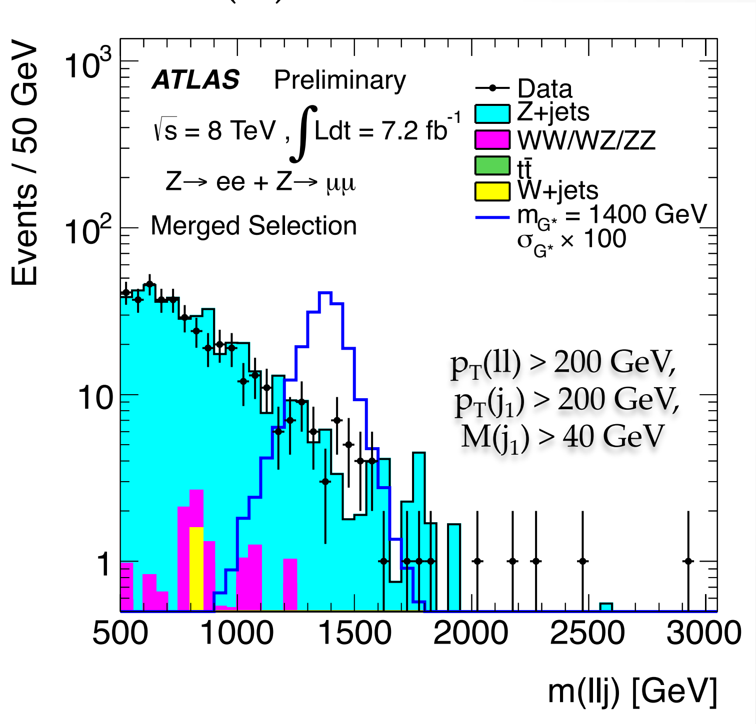
And the signal region …

- After all signal region cuts, **no apparent resonant-like deviation** from the standard model hypothesis
  - Final background estimation is taken from fit to data
  - This is to demonstrate understanding of main background composition

Resolved Regime
M(G) ~ 300-1000 GeV

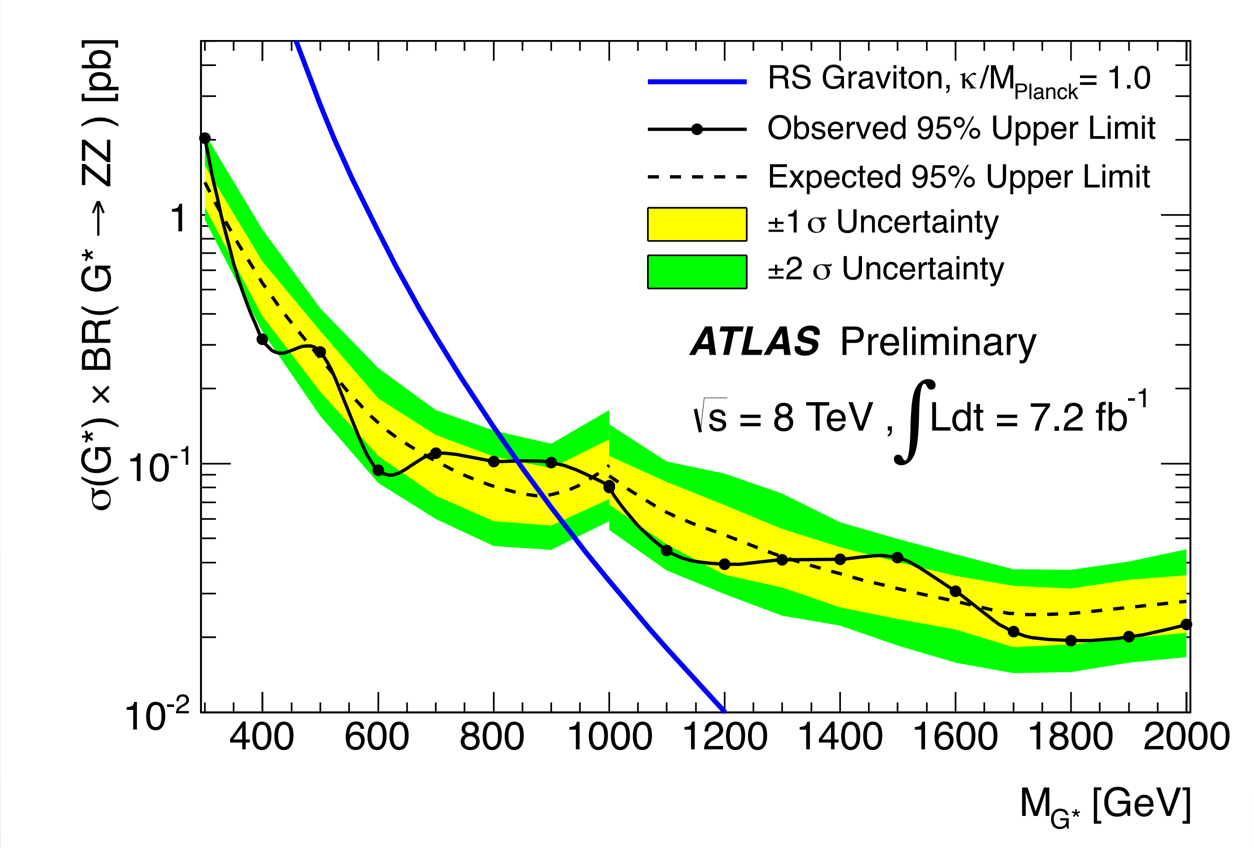


Merged Regime
M(G) ~ 1000-2000 GeV



Final Result

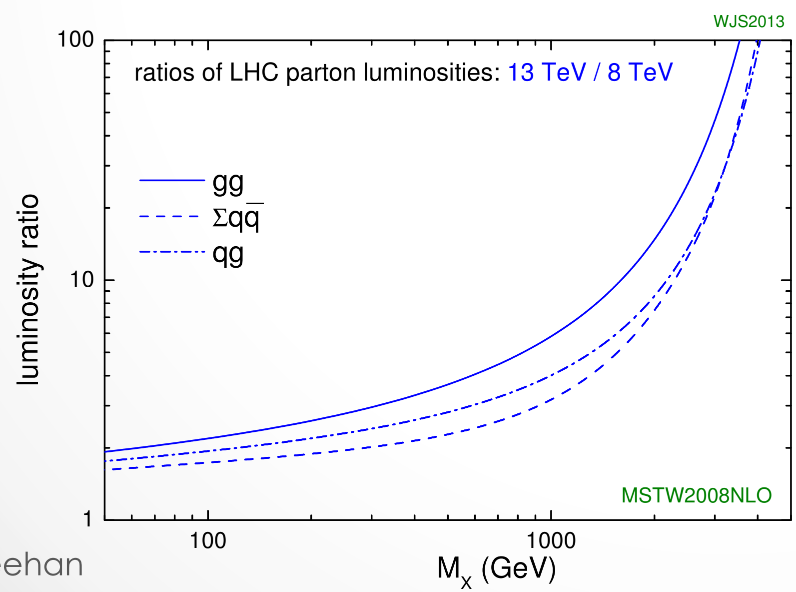
- Final limits quoted on $\sigma(G^*) \times BR(G^* \rightarrow ZZ)$
  - Comparable to other final states (eg G*→4l, G*→4q)



Mass Limit for G*:
Expected = 880 GeV
Observed = 840 GeV

Conclusions

- A portion of the total 8 TeV dataset collected by Atlas has been analyzed to search for ZZ/ZW resonances
  - No deviation from the smooth (standard model) hypothesis found
- Very exciting to get to open the box again – this time with the full 2012 data set
- Doubly exciting when considering such searches with the LHC turns back on in 2015



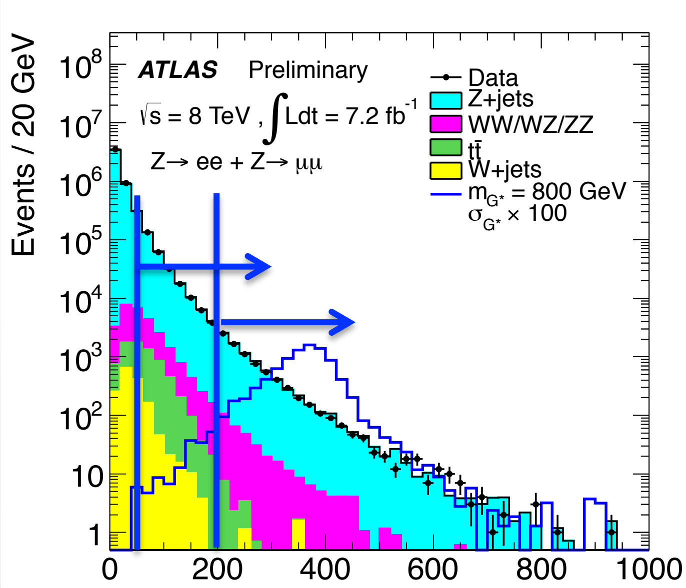
Thank You!

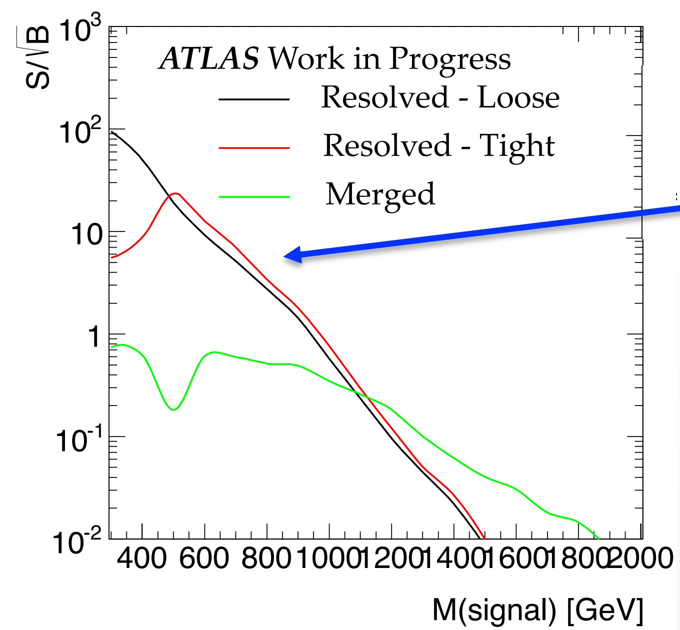
Optimize Sensitivity

- Optimize sensitivity in two mass regimes
  - Kinematic cuts chosen by using signal efficiency versus background rejection curves with qualitative bias of M(lljj) and M(llJ) spectra

Resolved Regime:
$p_T(ll) > 50$ GeV, $\Delta\phi(j,j) < 1.6$, 66 GeV < M(jj) < 116 GeV

Merged Regime:
$p_T(ll) > 200$ GeV, $p_T(j_1) > 200$ GeV, $M(j_1) > 40$ GeV



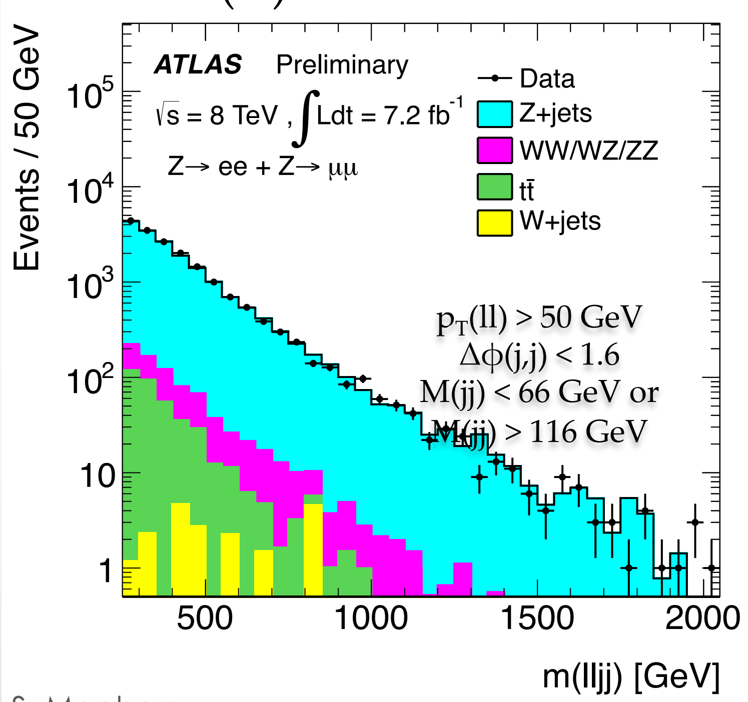


Negligible gain when staying in the same final state topology

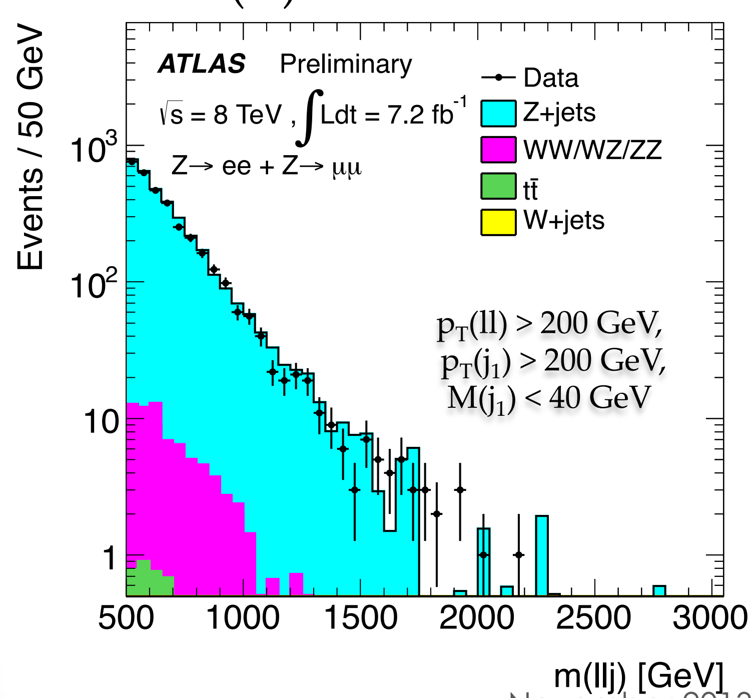
Control Region Modelling

- All signal region cuts applied with **inverted cuts on M(jj) or M(J)** in the resolved and merged selections respectively to deplete signal
  - Data modeled well by MC → gain confidence that smooth function which fits this spectra will model signal region spectra as well

Resolved Regime
M(G) ~ 300-1000 GeV

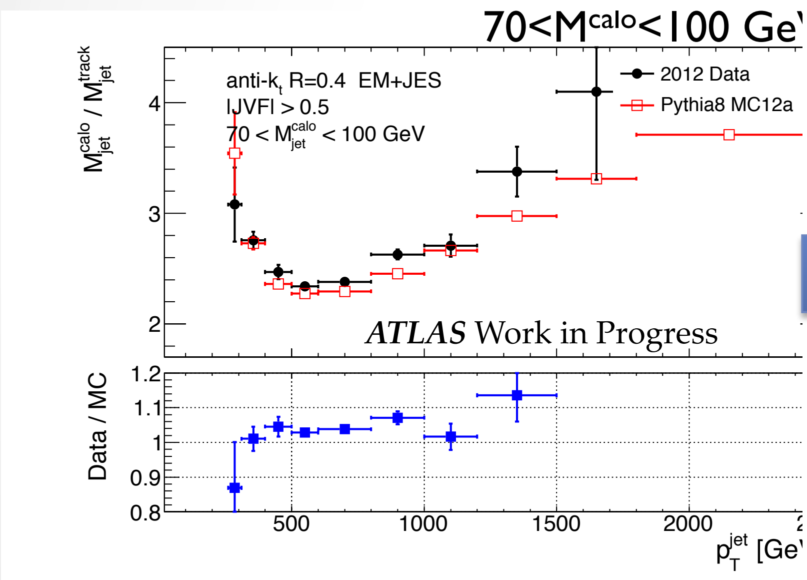


Merged Regime
M(G) ~ 1000-2000 GeV



Uncertainty on Jet Mass

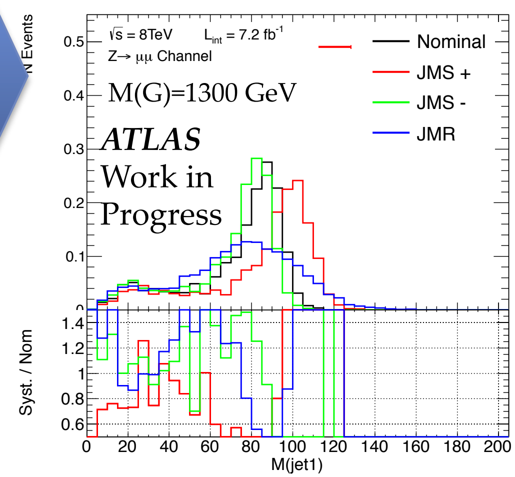
- Cutting on M(J) requires a full evaluation of the jet mass uncertainty
  - Not covered in normal uncertainties on jet energy scale and resolution
  - Inherently topological in nature and connected to the distribution of energy between jet constituents
  - Evaluated (left) by comparison of jet mass measurement with tracker and calorimeter
  - Effect on final M(llJ) signal shape (right) is very small



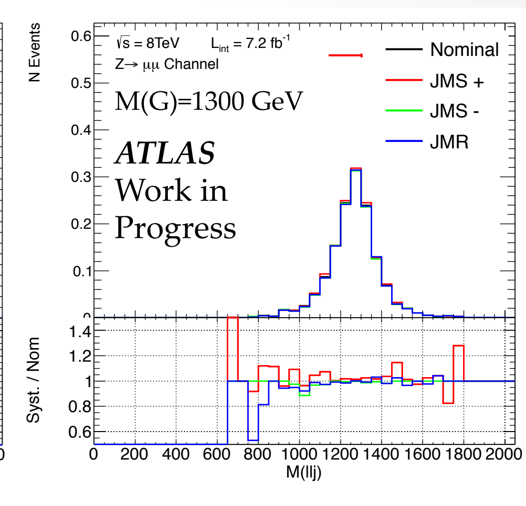
Evaluated in QCD using calorimeter versus track jets and looking at data/MC ratio of M_{calo}/M_{track} and assigning systematic to cover difference.

Shifting jet mass scale (JMS) up and down by one standard deviation of uncertainty

M(lead jet)



$M(ll,j_1)$

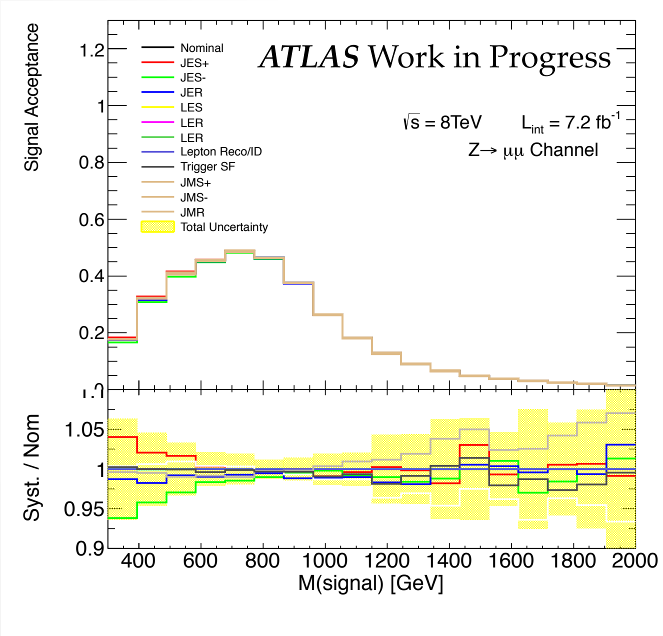


NOTE: Shape variation in M(ll,J) signal is much smaller than JES,JER uncertainties

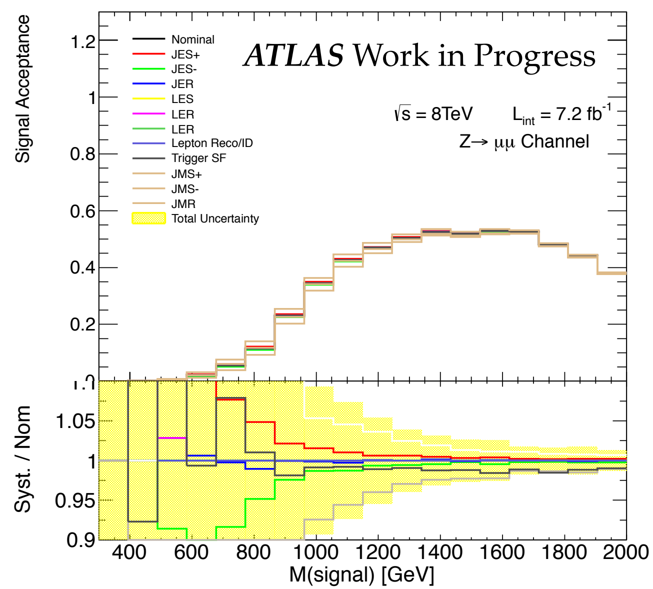
Systematic Uncertainties

- Taken as flat systematic on rate as JES,JER shift mean and RMS by <3%
- Detector uncertainties – between ~7% to <1% dependent on M(G)
- Dominated by jet mass scale uncertainty

Low Mass Selection



Merged Selection



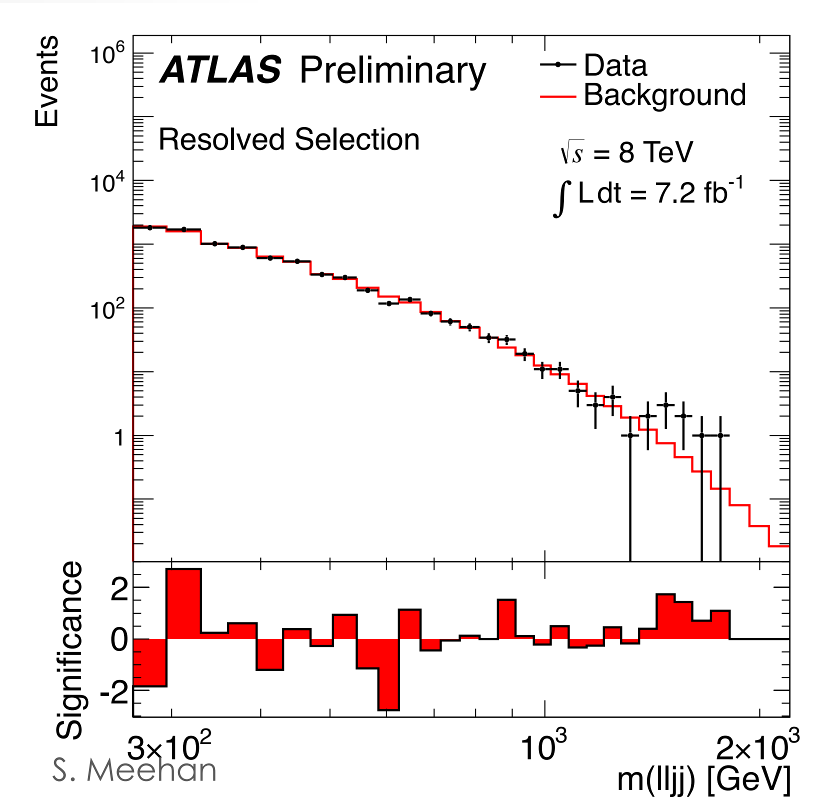
Signal acceptance curves shown with full systematic error bands

- Added in quadrature in calculation of sensitivity and M(G) dependent
  - Luminosity = 3.6%, PDF = 2%, and ISR/FSR = 10% → **TOTAL ~ 15%-11%**

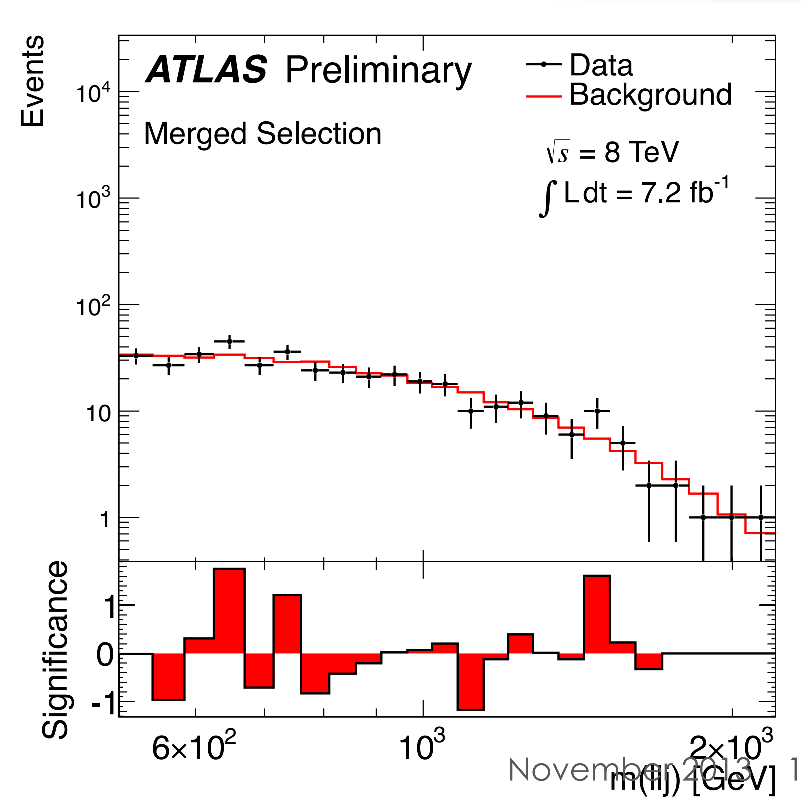
BumpHunt of Spectra

- No resonant excess observed → both spectra are consistent with the smooth background hypothesis

Low Mass Dijet Regime
M(G) ~ 300-1000 GeV

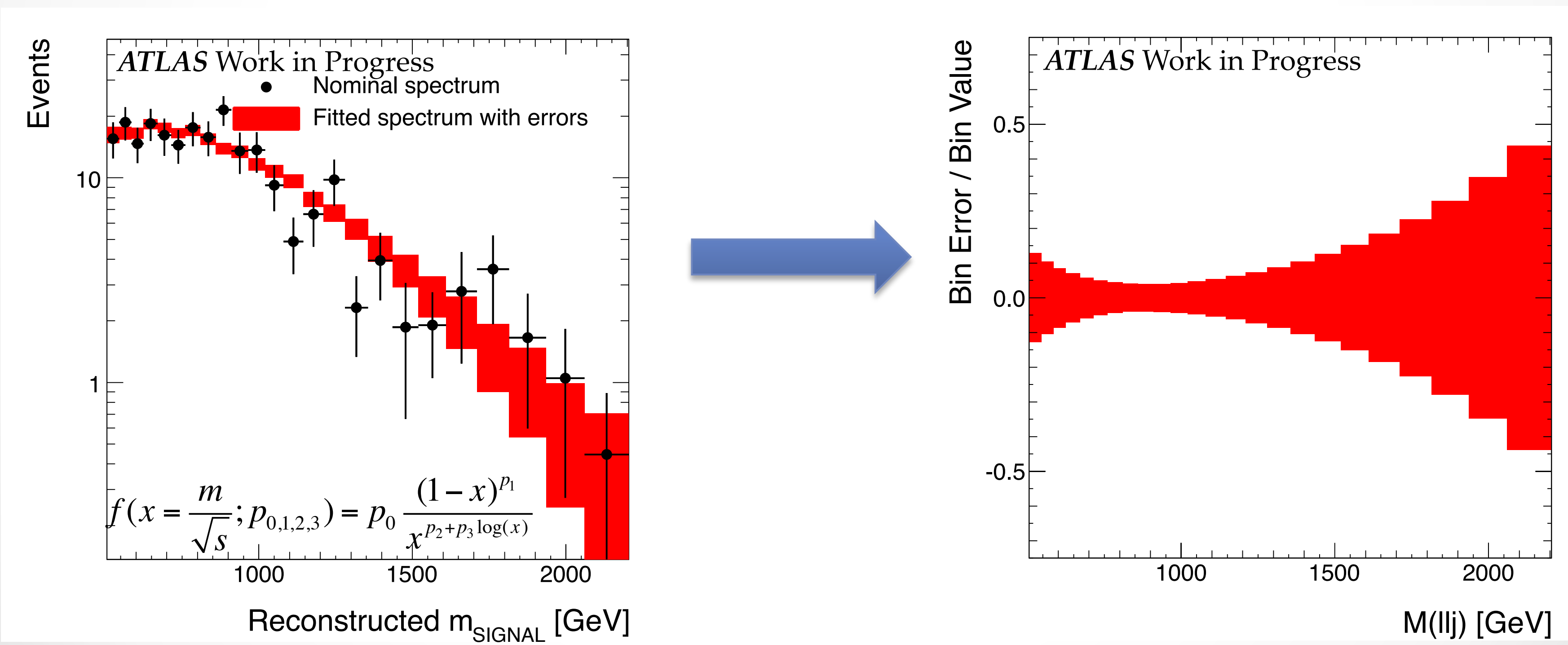


Merged Regime
M(G) ~ 1000-2000 GeV



Background Estimation

- Determined from smooth fit of data: $f(x=\frac{m}{\sqrt{s}};p_{0,1,2,3}) = p_0 \frac{(1-x)^{p_1}}{x^{p_2+p_3\log(x)}}$
  - Four free parameters = "suitably flexible" and used in many analyses from ATLAS and CMS
  - Extensive tests performed on Monte Carlo estimations
- Systematic uncertainty purely from fit
  - Determined from bin-by-bin spread of pseudo-experiment fits
  - Ranges from 5% to 40% depending on reconstructed M(G) and signal region selection



(Z→ee + Z→μμ) Merged signal region shown here