Search for Resonant Diboson Production with the ATLAS Detector

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on behalf of the ATLAS Collaboration

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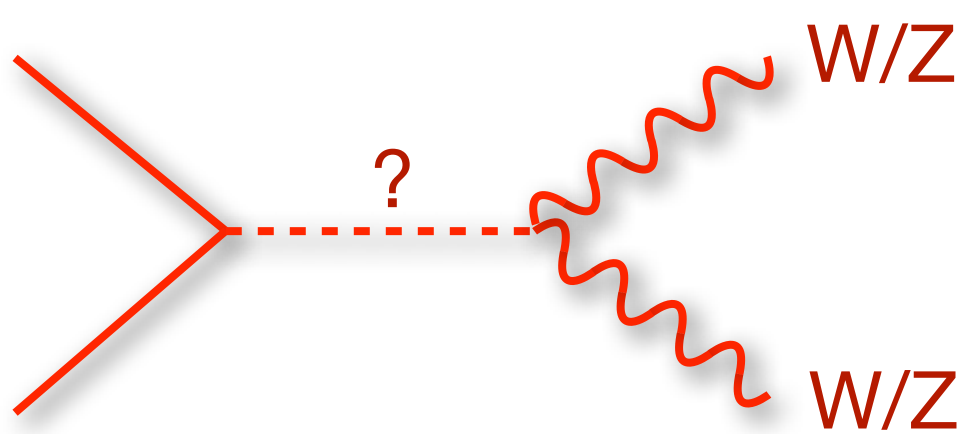
WW, WZ, ZZ Resonance Searches

Several extensions to the Standard Model predict new massive particles which can decay to heavy boson pairs

- The only diboson resonance in the SM is the Higgs

Review and discuss ATLAS results on the search for new particles decaying to WW, WZ, ZZ final states

- Use 1 to 4.7 fb^{-1} of 7 TeV proton-proton collisions
- Focus on masses larger than 300 GeV

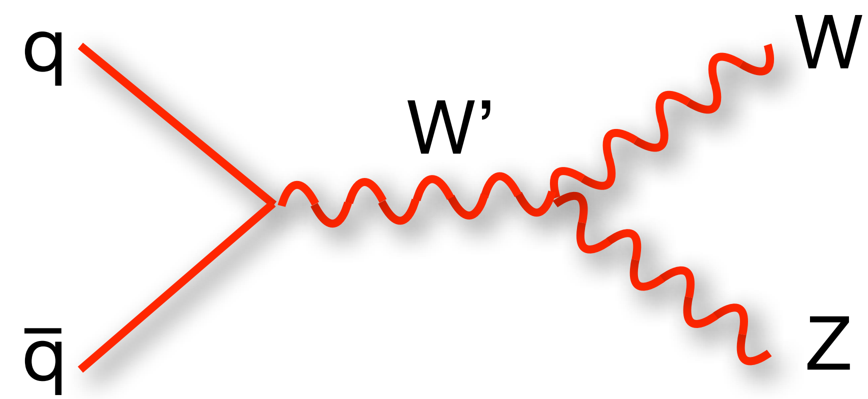


Resonance Models

Charged (WZ)

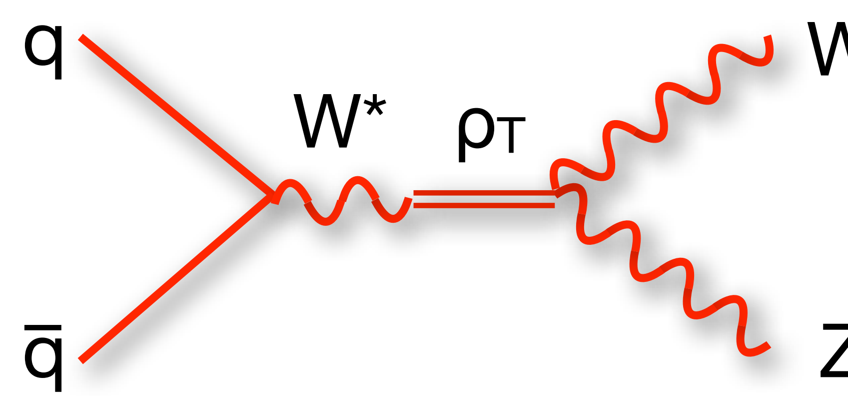
Sequential Standard Model (W', spin-1)

- Trilinear W'WZ coupling set by Extended Gauge Model: $\sim M_W M_Z / M_{W'}^2$



Low-scale Technicolor (ρ_T, spin-1)

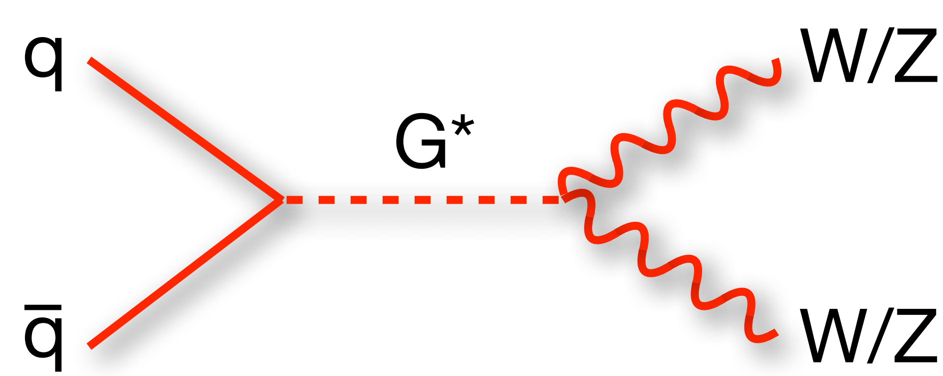
- ρ_T (with $M_\rho < 2^* M_\pi$) can decay to $W+\pi_T$ or W+Z
- $M_\rho = M_\pi + M_W$ choice maximizes ρ_T --> W+Z



Neutral (WW and ZZ)

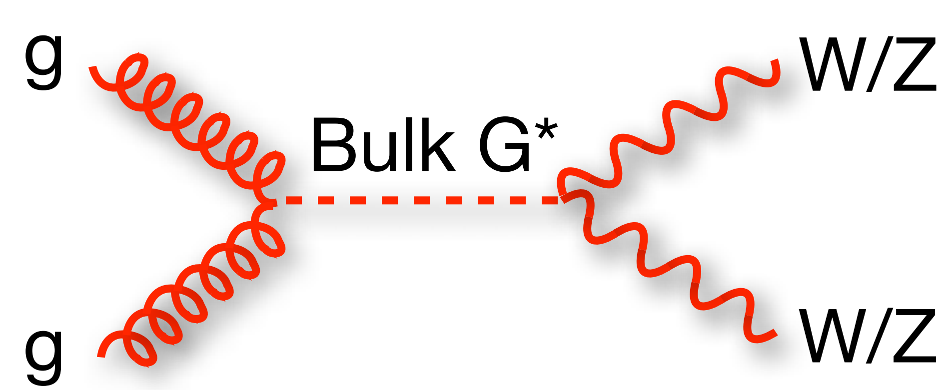
Randall-Sundrum graviton (RS G*, spin-2)

- Traditional benchmark model with extra dimensions



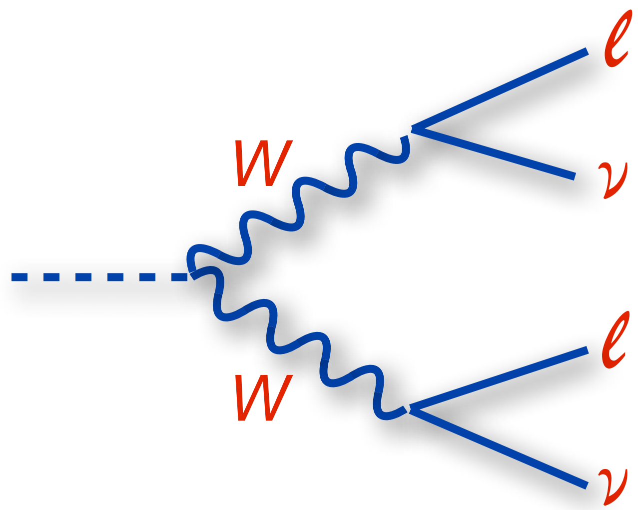
Bulk RS graviton (Bulk G*, spin-2)

- Graviton couples more with heavy particles (W, Z, t)
- Smaller σ, but larger branching ratio to WW, ZZ



Diboson Final States

WW (5 fb^{-1})



2 leptons

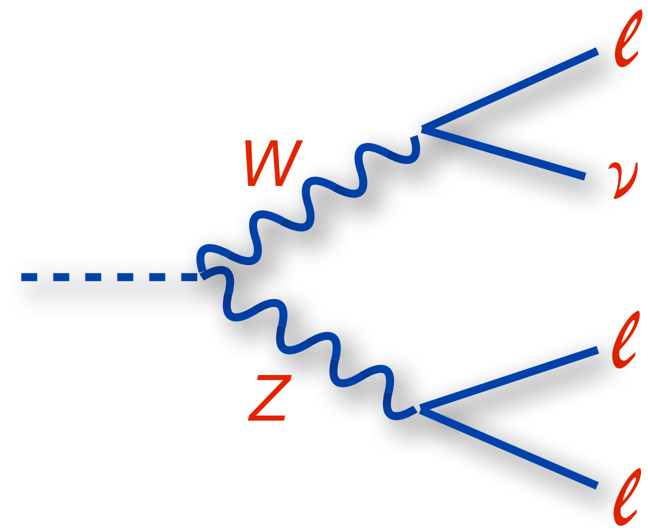
E_T^{miss}

$m(l_1,l_2) \neq m_Z$

No b-jets

[ATLAS: ATLAS-CONF-2012-068]

WZ (1 fb^{-1})



3 leptons

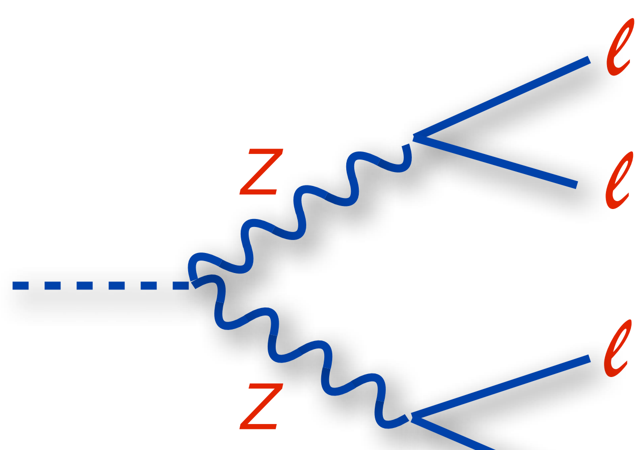
E_T^{miss}

$m(l_1,l_2) \sim m_Z$

$m_T(l_3,\nu) \sim m_W$

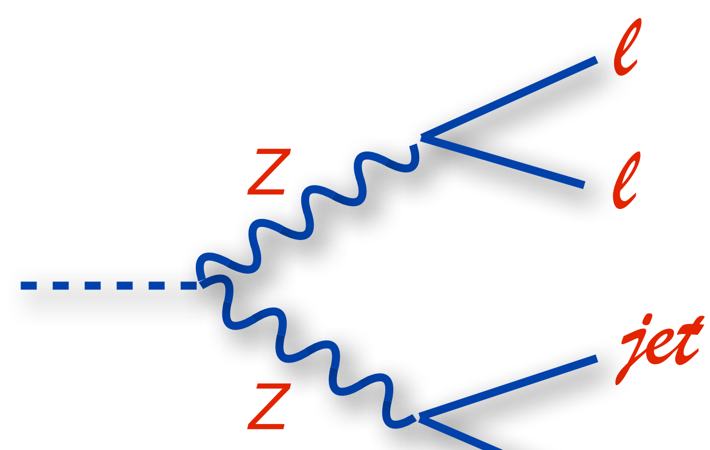
[ATLAS: arXiv:1204.1648v1]

ZZ (1 fb^{-1})



4 leptons

$m(l_1,l_2) \sim m(l_3,l_4) \sim m_Z$



2 leptons, 2 jets

$m(l_1,l_2) \sim m(j_1,j_2) \sim m_Z$

[ATLAS: Phys. Lett. B712 (2012) 331-350]

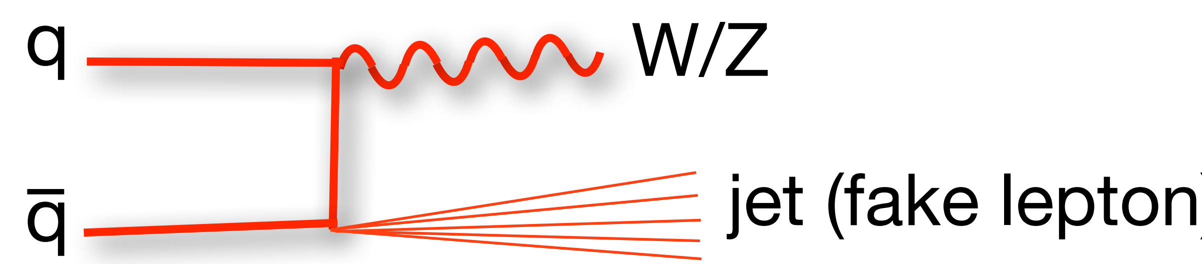
Cross Sections at 7 TeV [pb]

10^5	W
10^4	Z
200	tt
50	WW
20	WZ
10	ZZ

Backgrounds

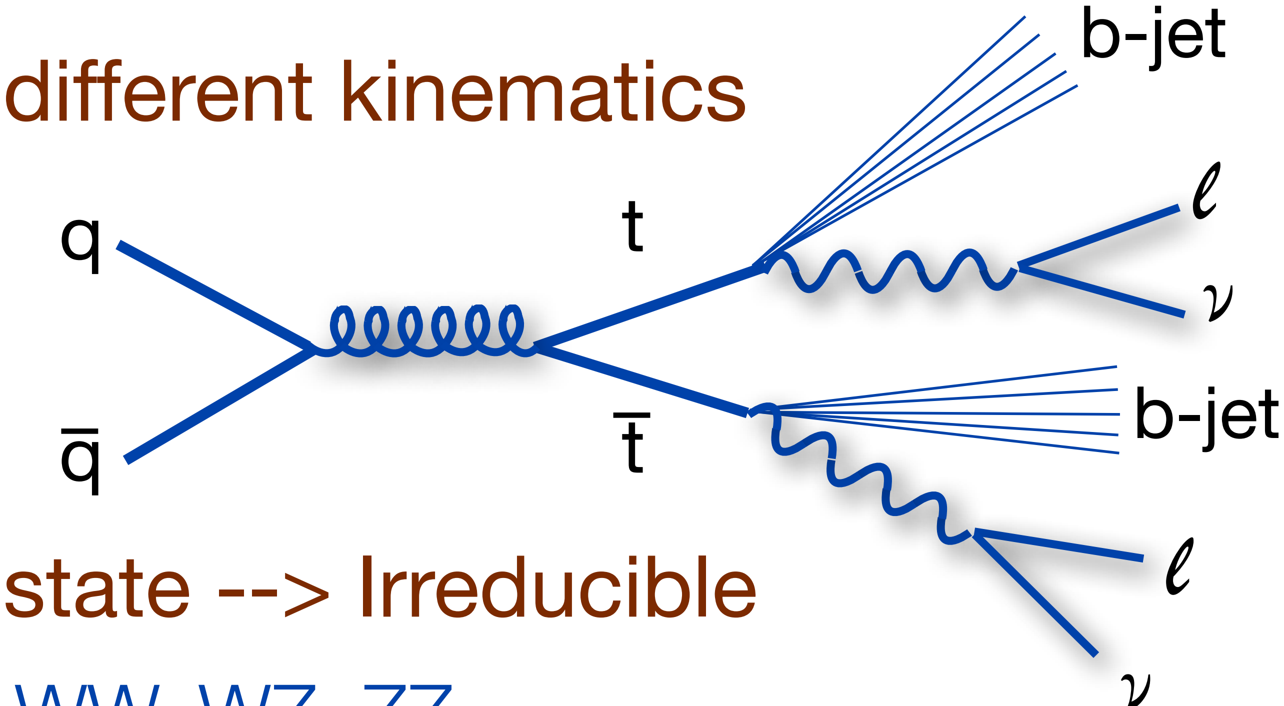
1. Fake (and non-prompt) leptons

W+jets, Z+jets, tt



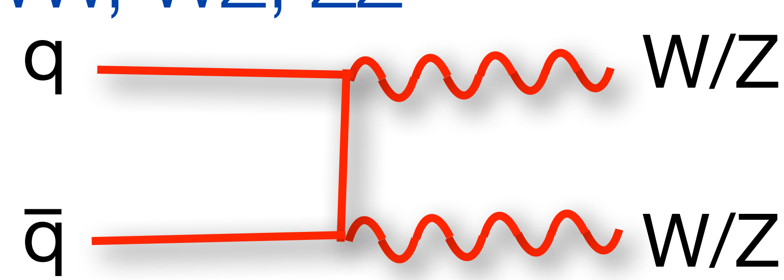
2. Real leptons, different kinematics

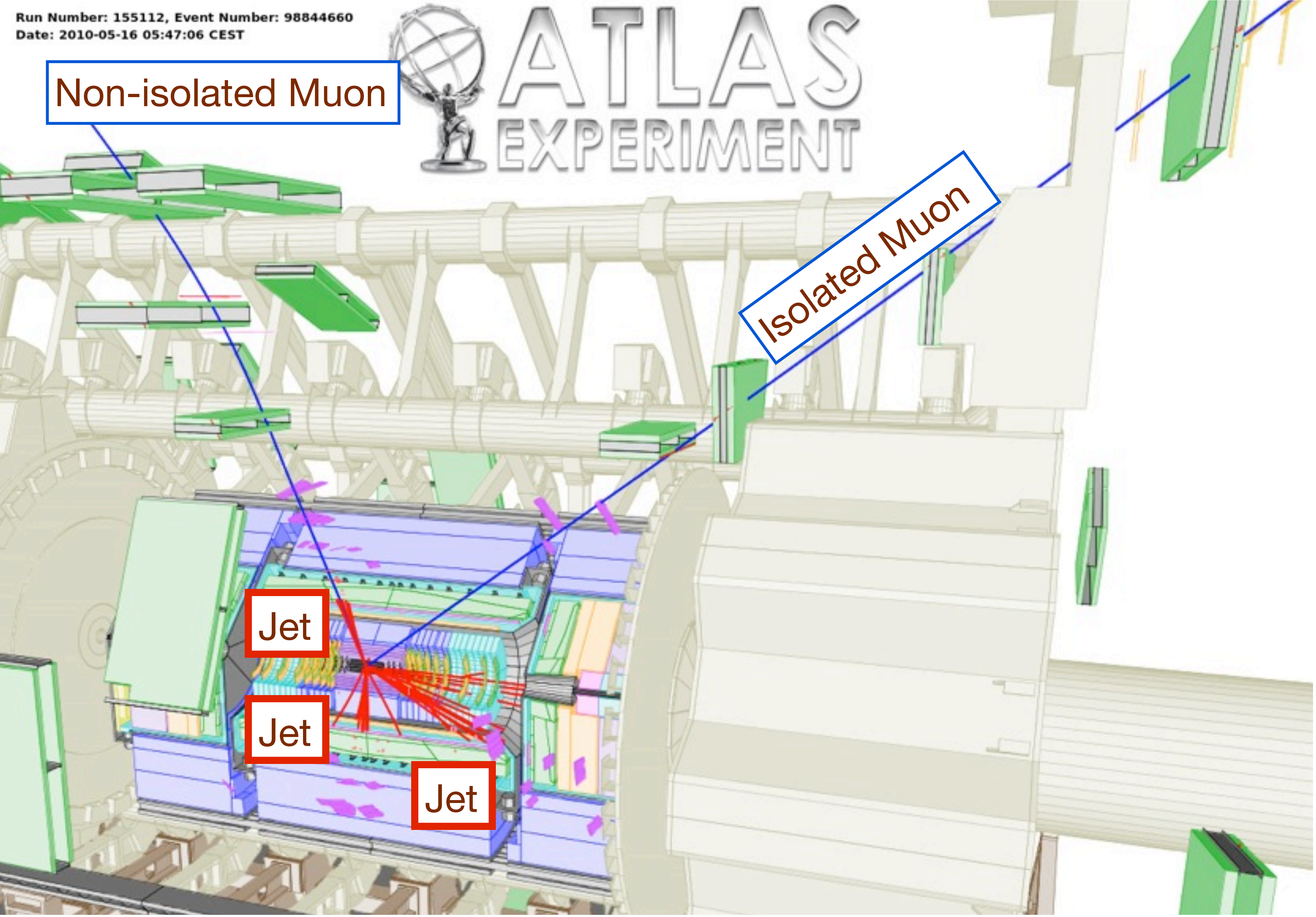
tt (ll), Z (ll)

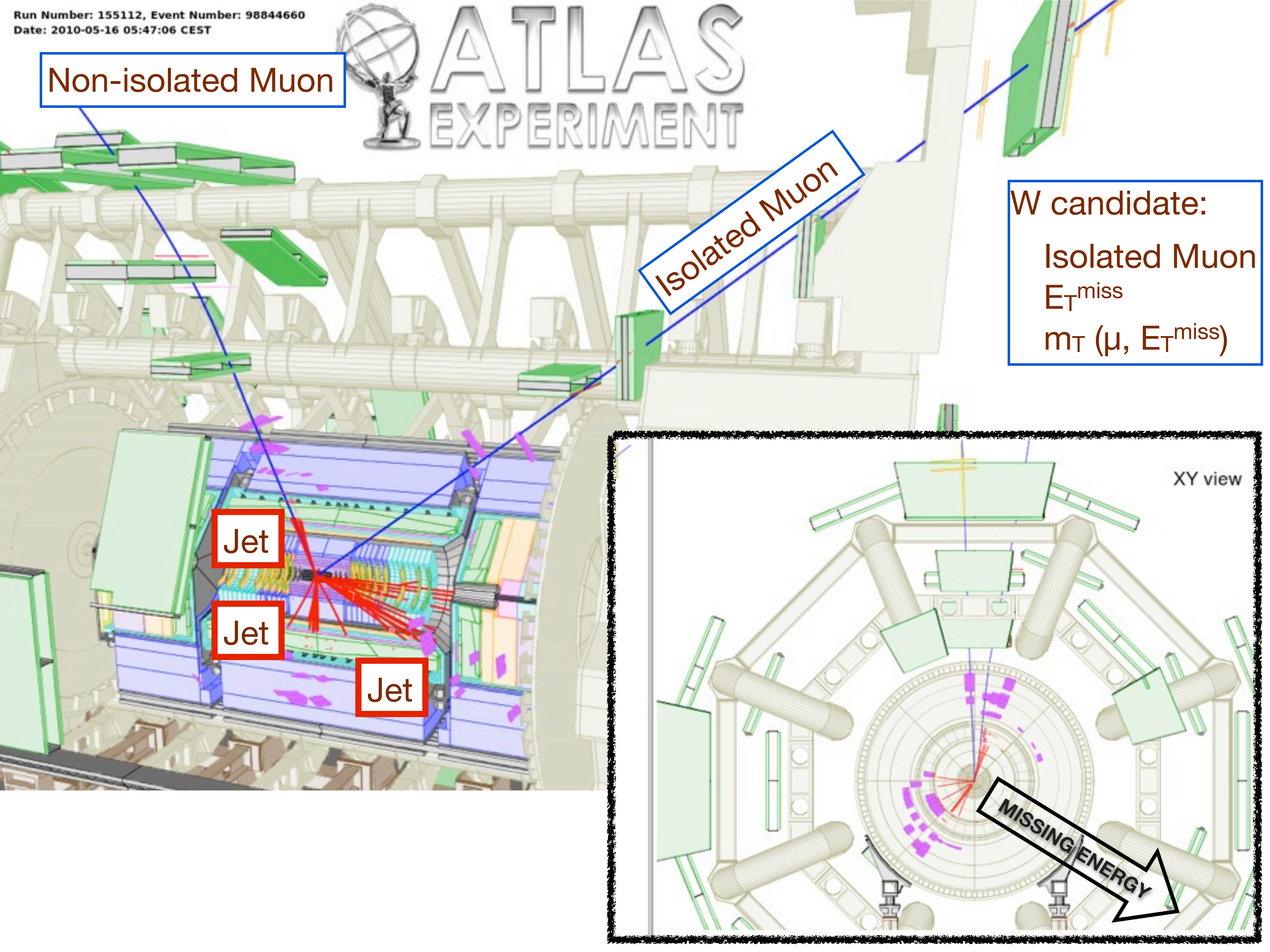


3. Diboson final state --> Irreducible

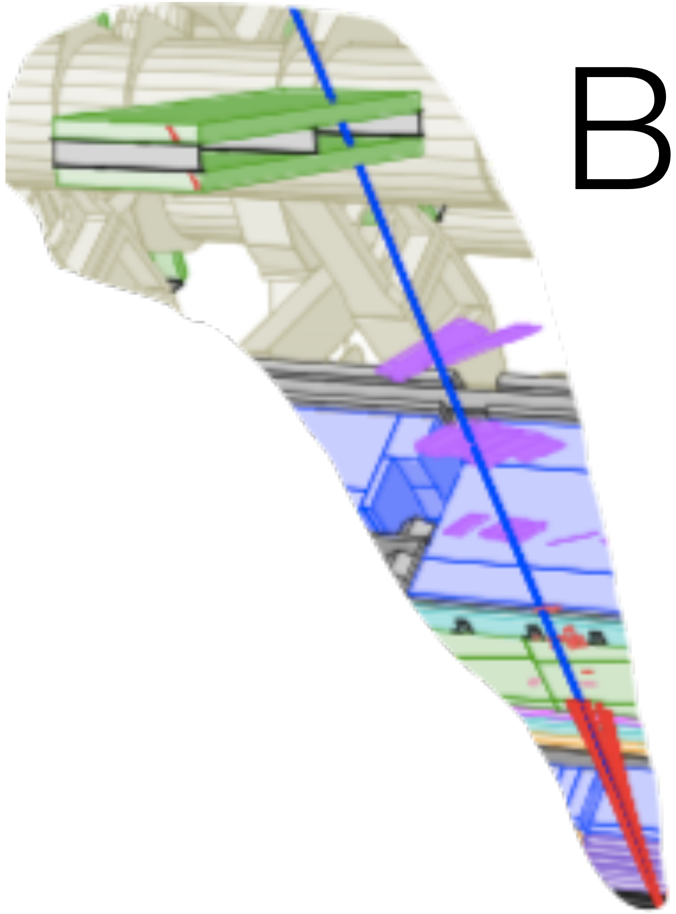
Non-resonant WW, WZ, ZZ




Run Number: 155112, Event Number: 98844660
Date: 2010-05-16 05:47:06 CEST
ATLAS EXPERIMENT
Non-isolated Muon
Isolated Muon
Jet
Jet
Jet



Run Number: 155112, Event Number: 98844660
Date: 2010-05-16 05:47:06 CEST
ATLAS
EXPERIMENT
Non-isolated Muon
Isolated Muon
W candidate:
Isolated Muon
E_T^{miss}
m_T (μ, E_T^{miss})
Jet
Jet
Jet
XY view
MISSING ENERGY



Bkg. 1: Fake Leptons

"Fake" leptons are ...

- ... jet reconstructed as leptons (e)
- ... non-prompt leptons produced in jets (e, μ)

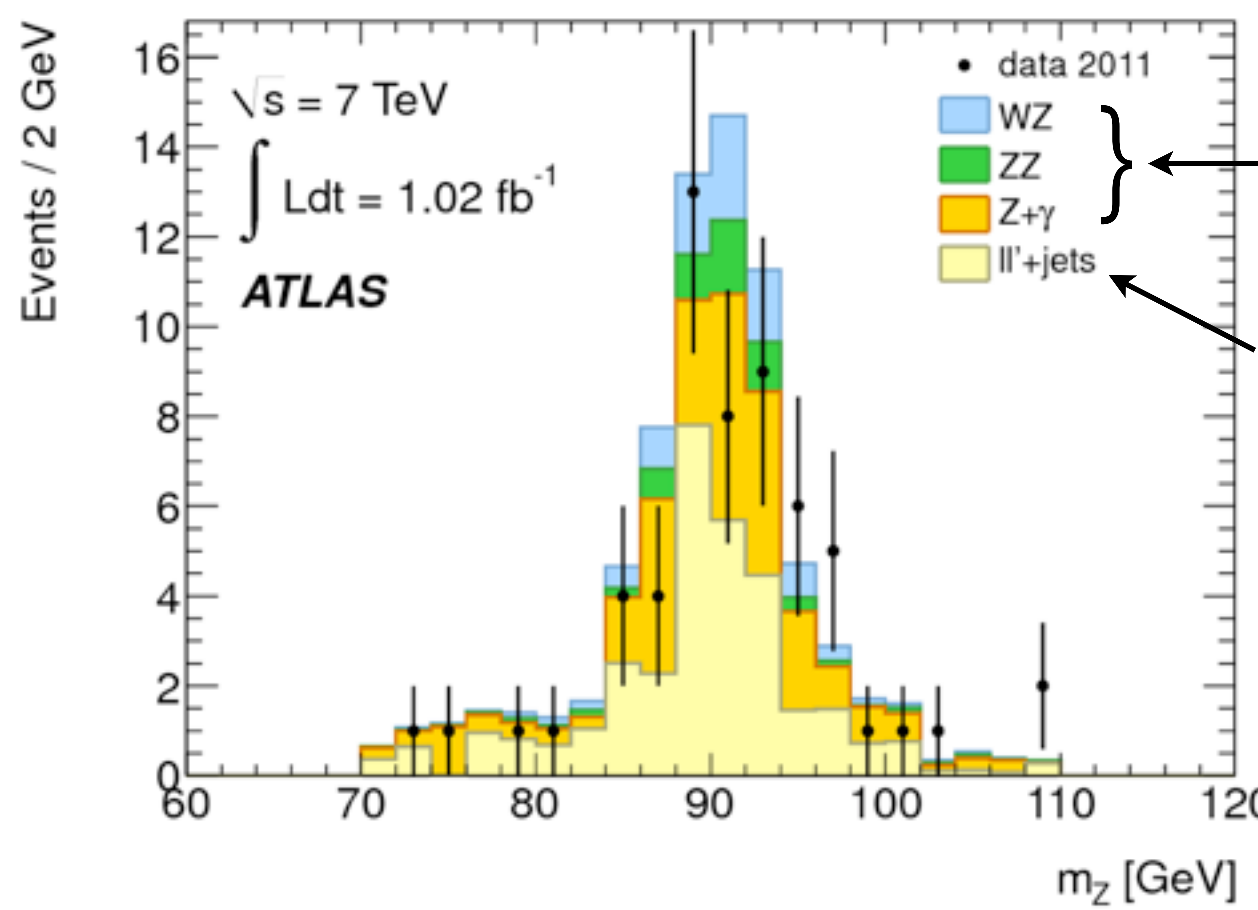
Reduce using tight lepton selection

- track quality and calorimeter signal shape
- isolation, small impact parameter

Estimate remaining background using data-driven methods

Fake 3rd lepton control region (3-leptons, low E_T^{miss})

Used in WZ analysis to cross check the data-driven fake lepton model



Simulation

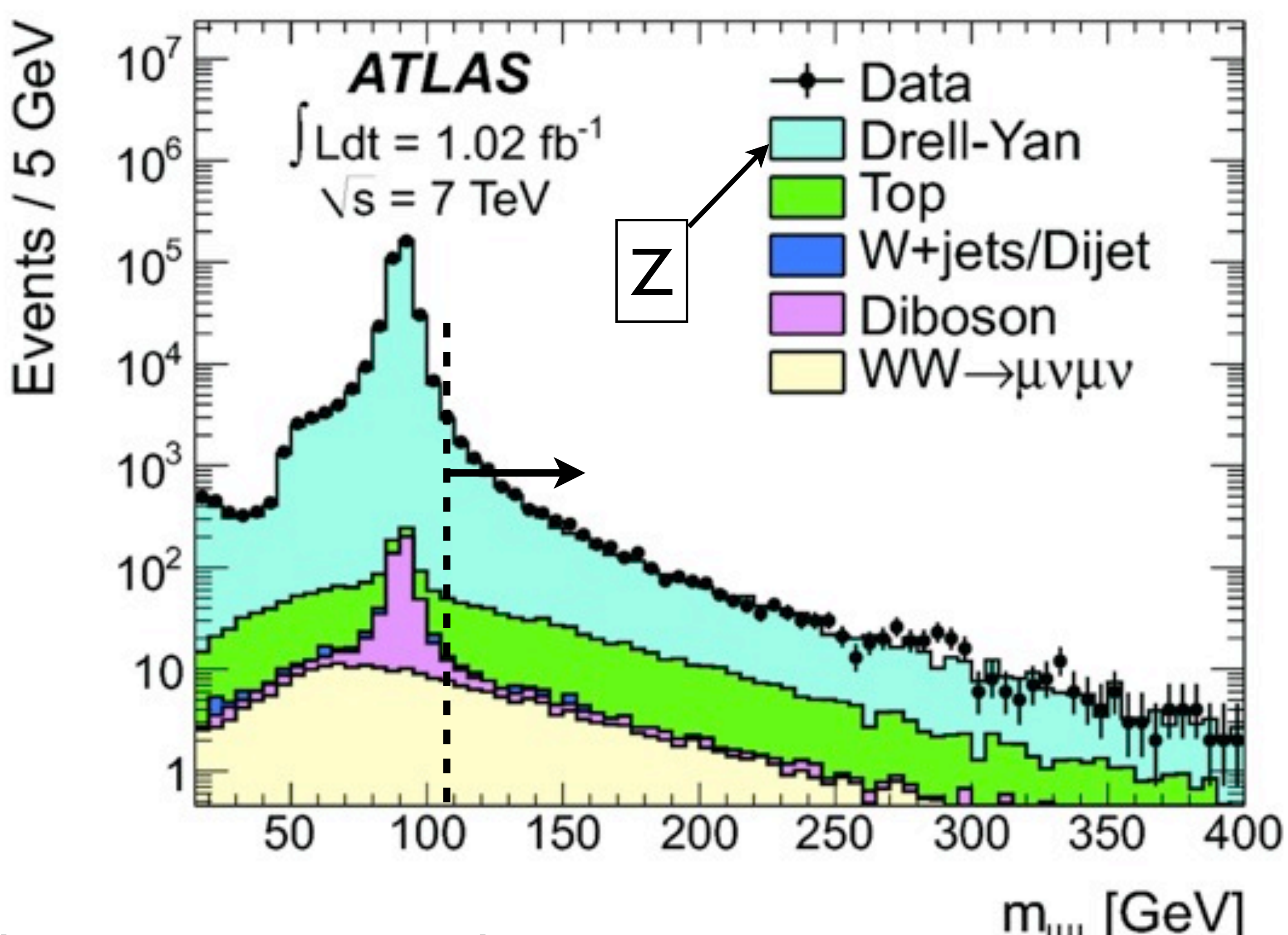
Data driven model

Bkg. 2: Different Kinematics

Real leptons, but with kinematics different from signal (Z+jets, tt)

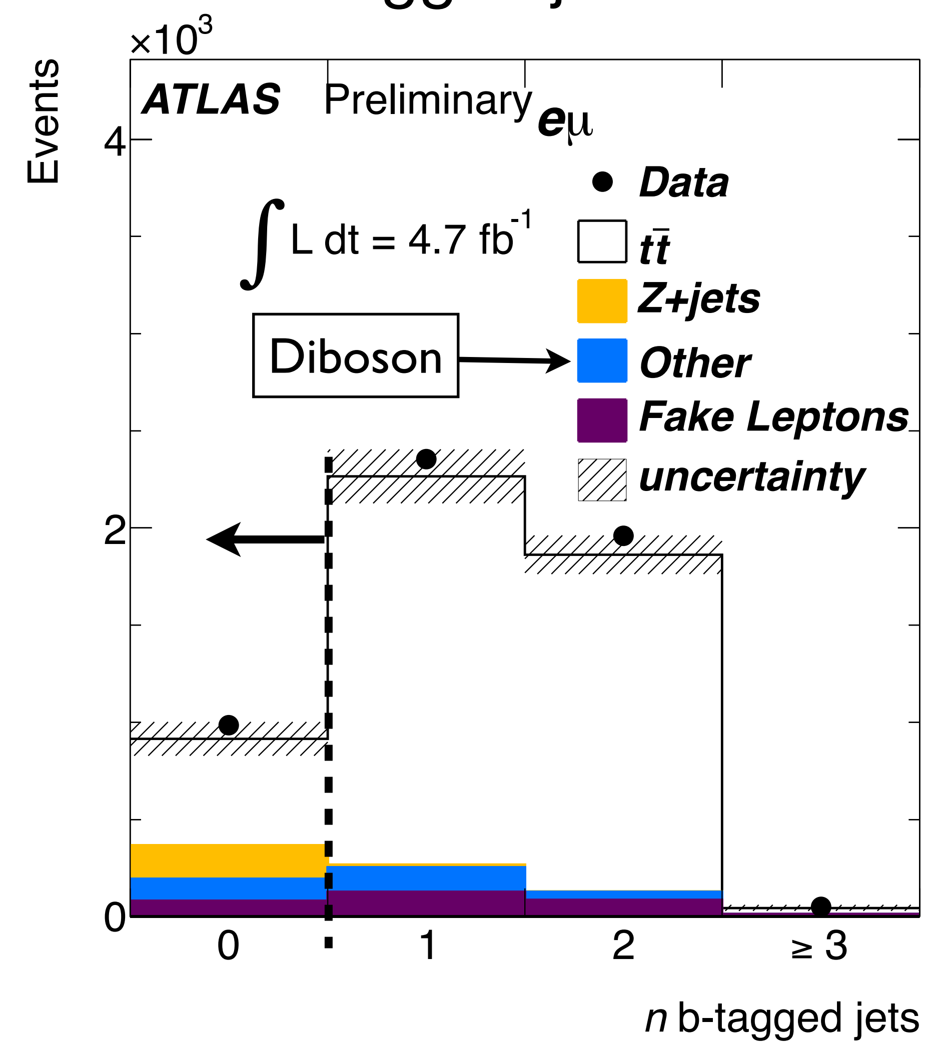
- Can be reduced using cuts on E_T^{miss}, jets, invariant mass
- Inverting these cuts results in control regions

Z+jets cuts for WW analysis:
exclude Z peak, require E_T^{miss}



[WW cross section measurement]

Top cut in WW analysis:
no b-tagged jets



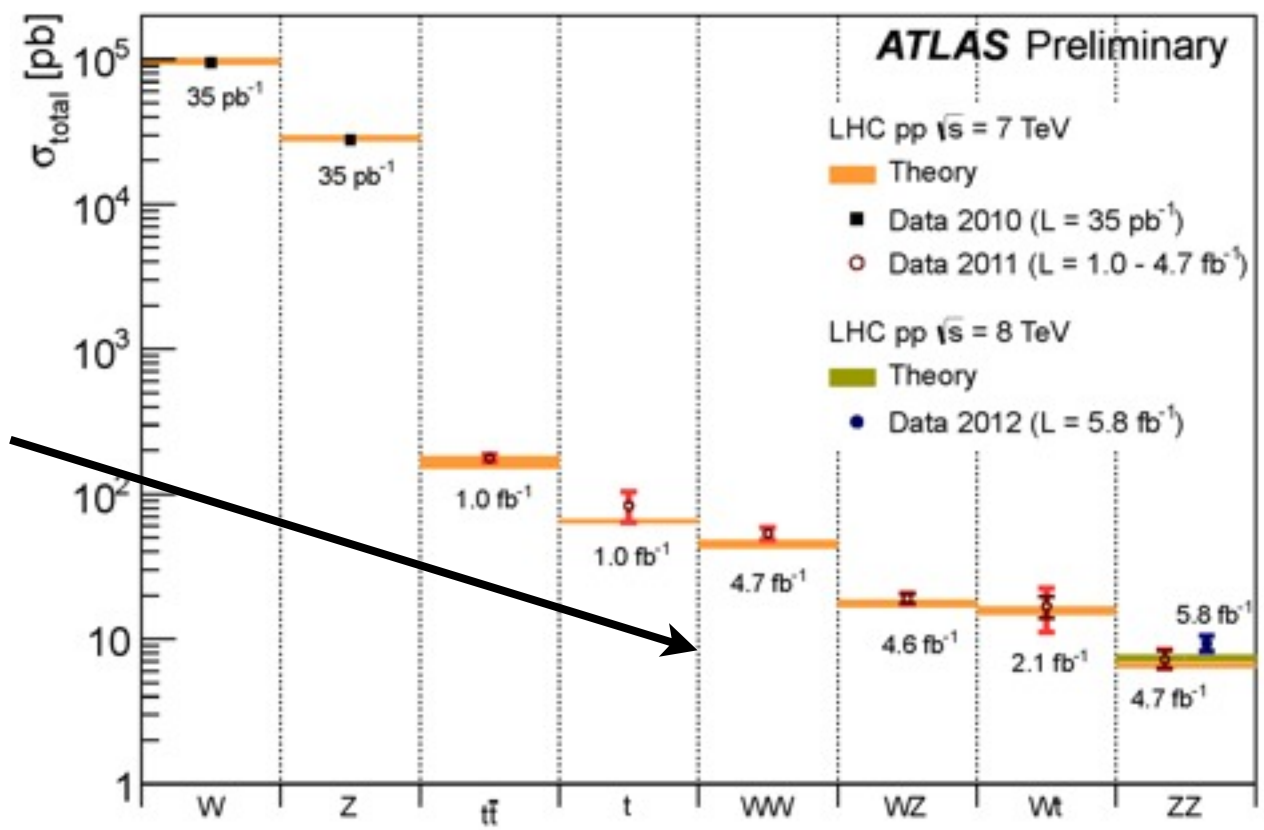
[b-tag efficiency measurement using top pair events]

Bkg. 3: Irreducible

SM diboson production

Total cross section is known

- Theory: small uncertainties (5-7%)
- Experiment: ATLAS meas. with 7 TeV



Resonance searches explore high tails of mass distributions

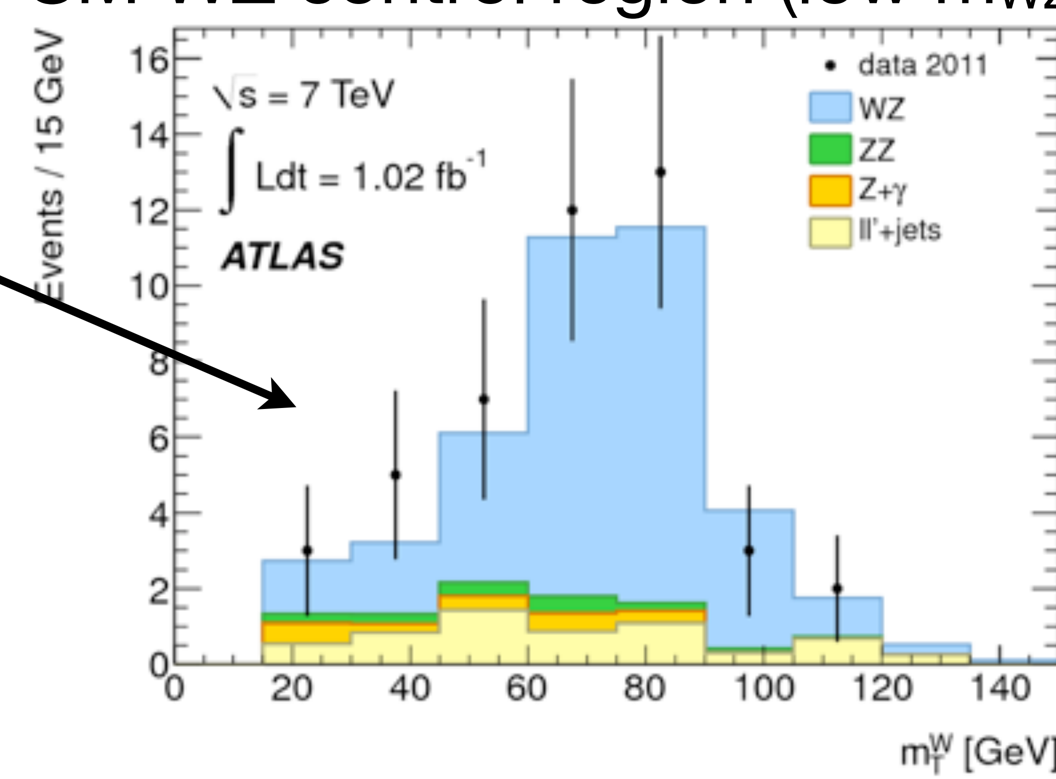
Can use the bulk of distributions as a cross check

- For example m_{ZZ} or m_{WZ} < 300 GeV

Simulation used for high mass tail

- See Tobias Kasprzik talk yesterday for interesting corrections to σ(WW) at large m_{WW}

SM WZ control region (low m_{WZ})



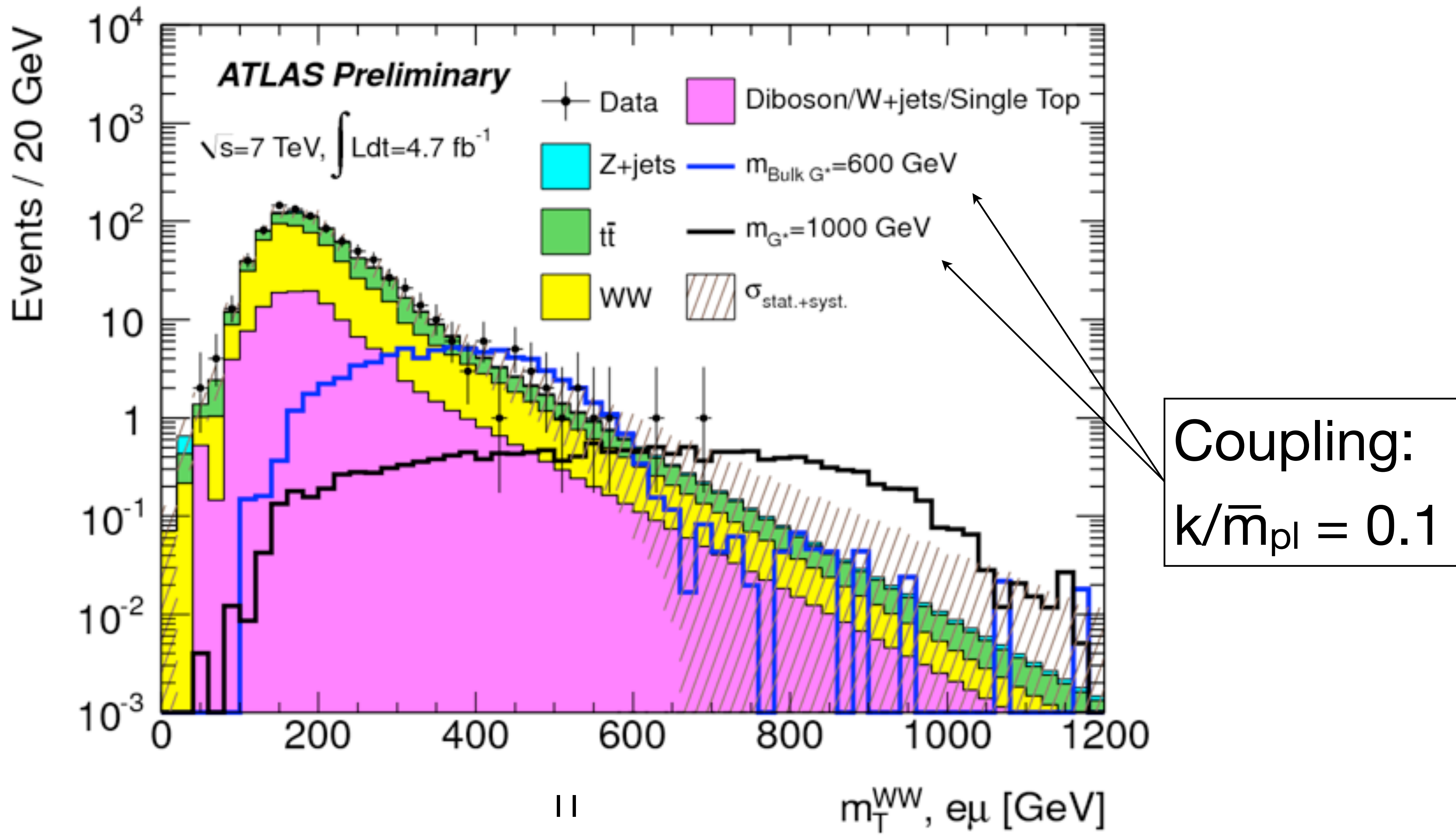
Results

1 to 4.7 fb^{-1} collected in 2011 at $\sqrt{s}$ = 7 TeV

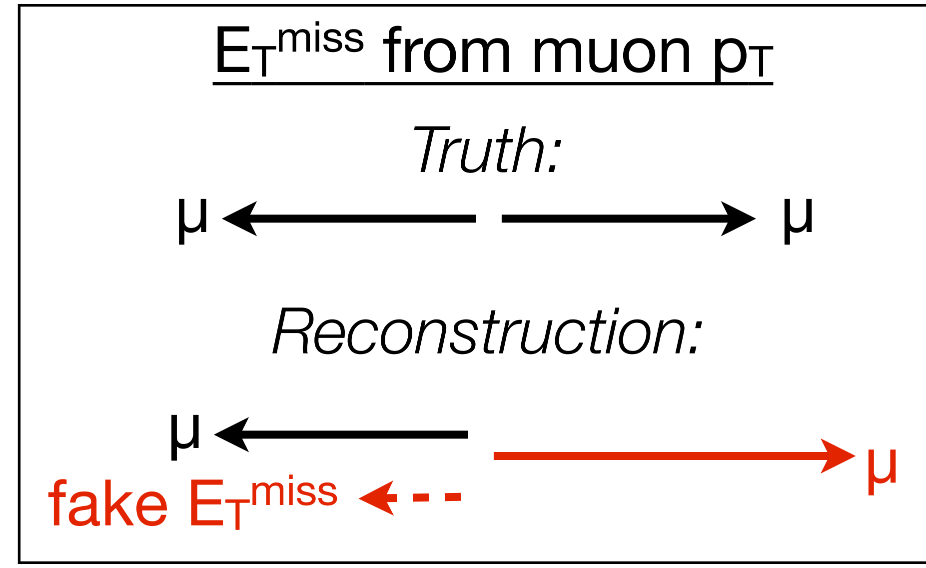
WW (eμ) in 4.7 fb^{-1}

Observed and predicted m_T(WW) distribution in the WW --> eνμν channel

Highest statistics due to combinatorics (e**μ** + **μ**e) and looser cuts used (no Z+jets background)



WW (μμ, ee) in 4.7 fb^{-1}



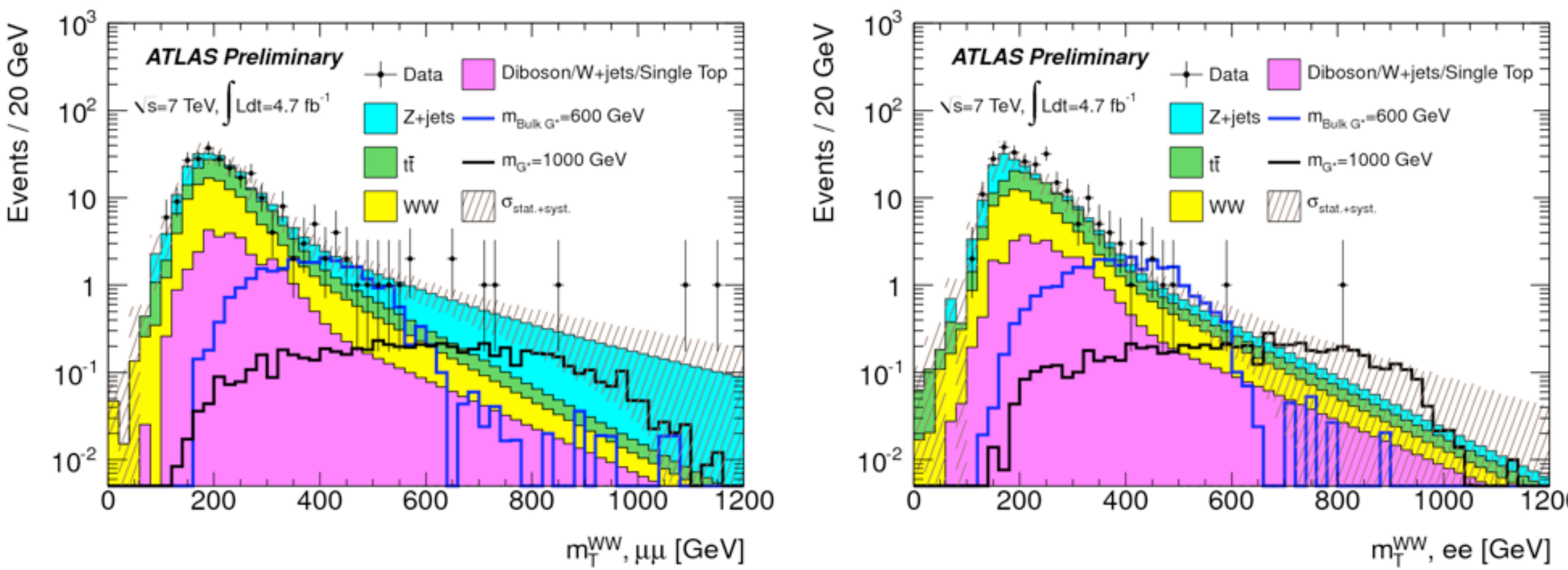
μμ channel (left)

Z+jets event in high tail

- ✳ Muon p_T is part of the E_T^{miss} calculation
- ✳ Muon resolution at 1 TeV is ~ 10%

ee channel (right)

Cleaner high tail (electron res. at 1 TeV ~ 1%), lowest statistics



WZ and ZZ (leptonic) in 1 fb^{-1}

WZ --> lllν

48 events observed, 45±5 expected

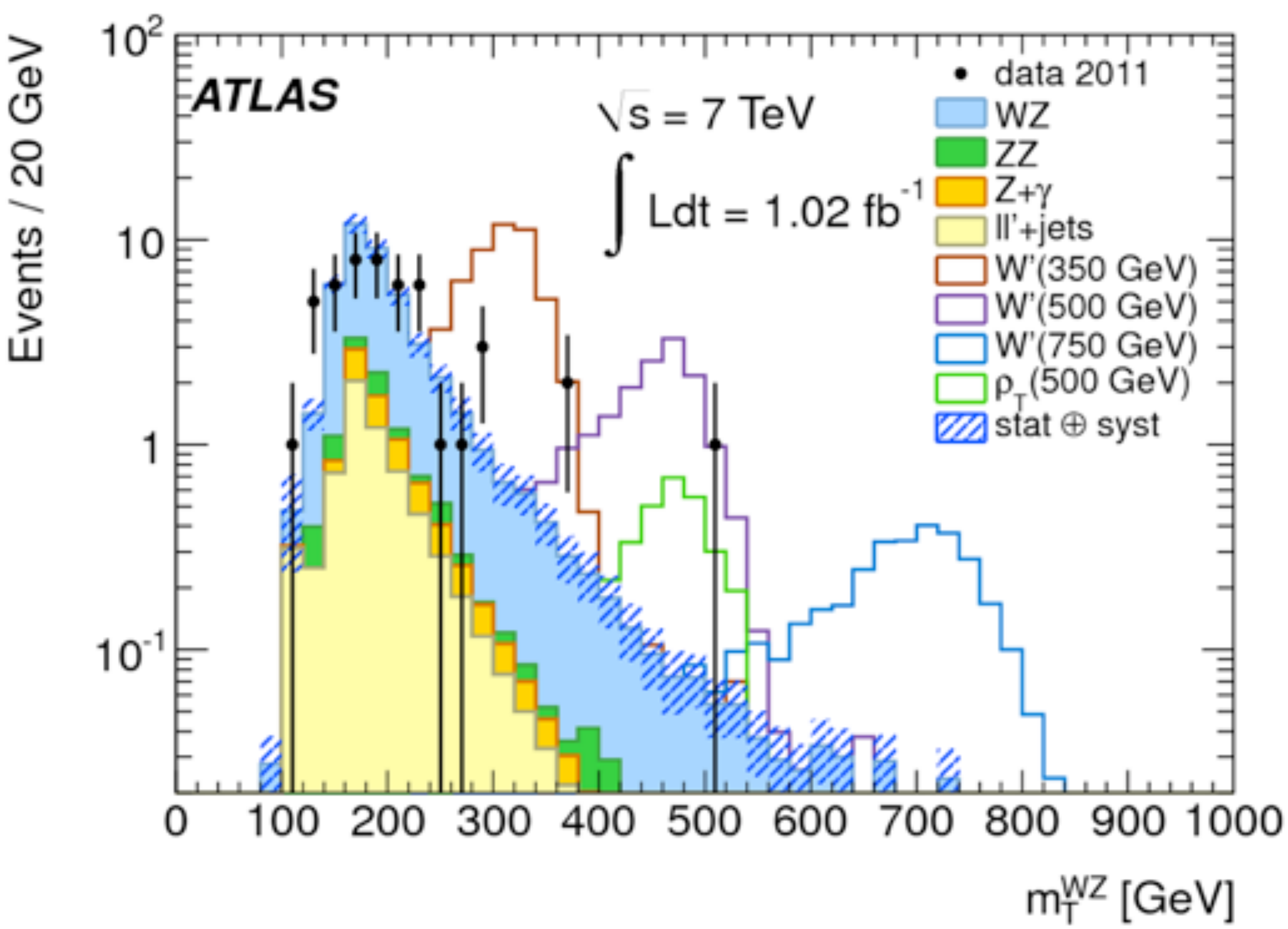
No significant excess found in data

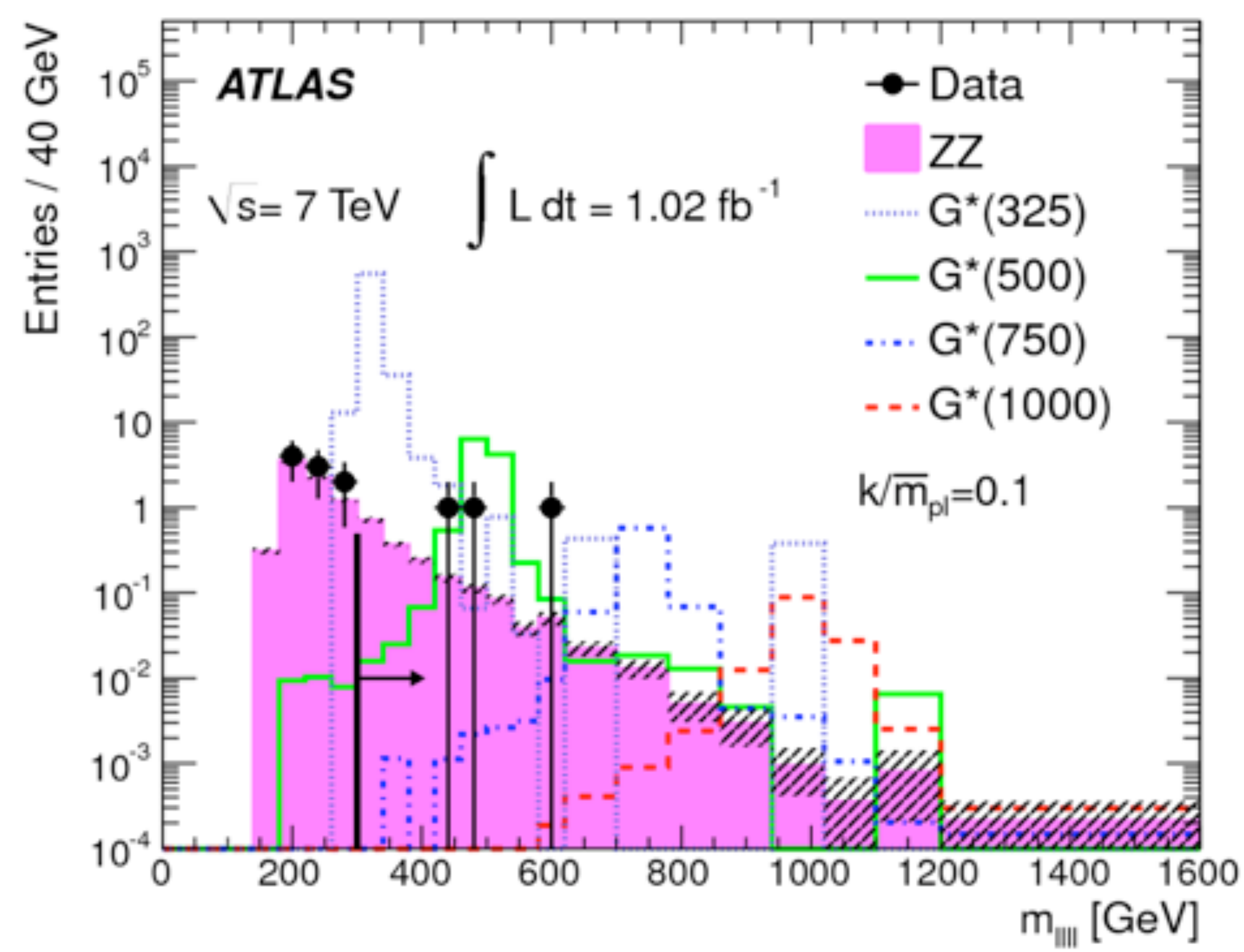
ZZ --> llll

3 events observed, 1.9±1.3 expected

Set model independent limit on fiducial cross section at high mass:

σ_{ZZ} (m_{ZZ} > 300 GeV) < 0.92 pb



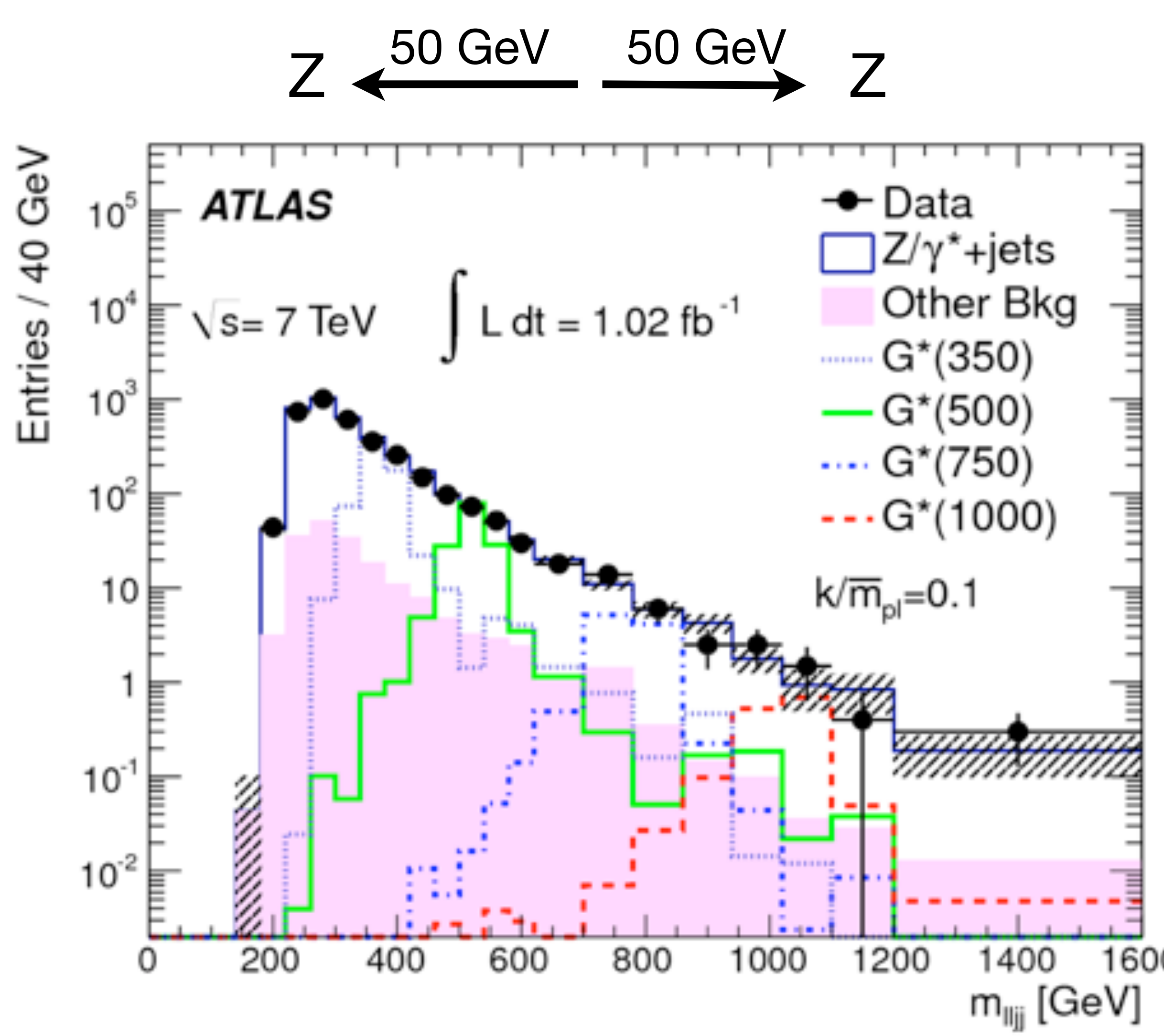


ZZ (leptons+jets) in 1 fb^{-1}

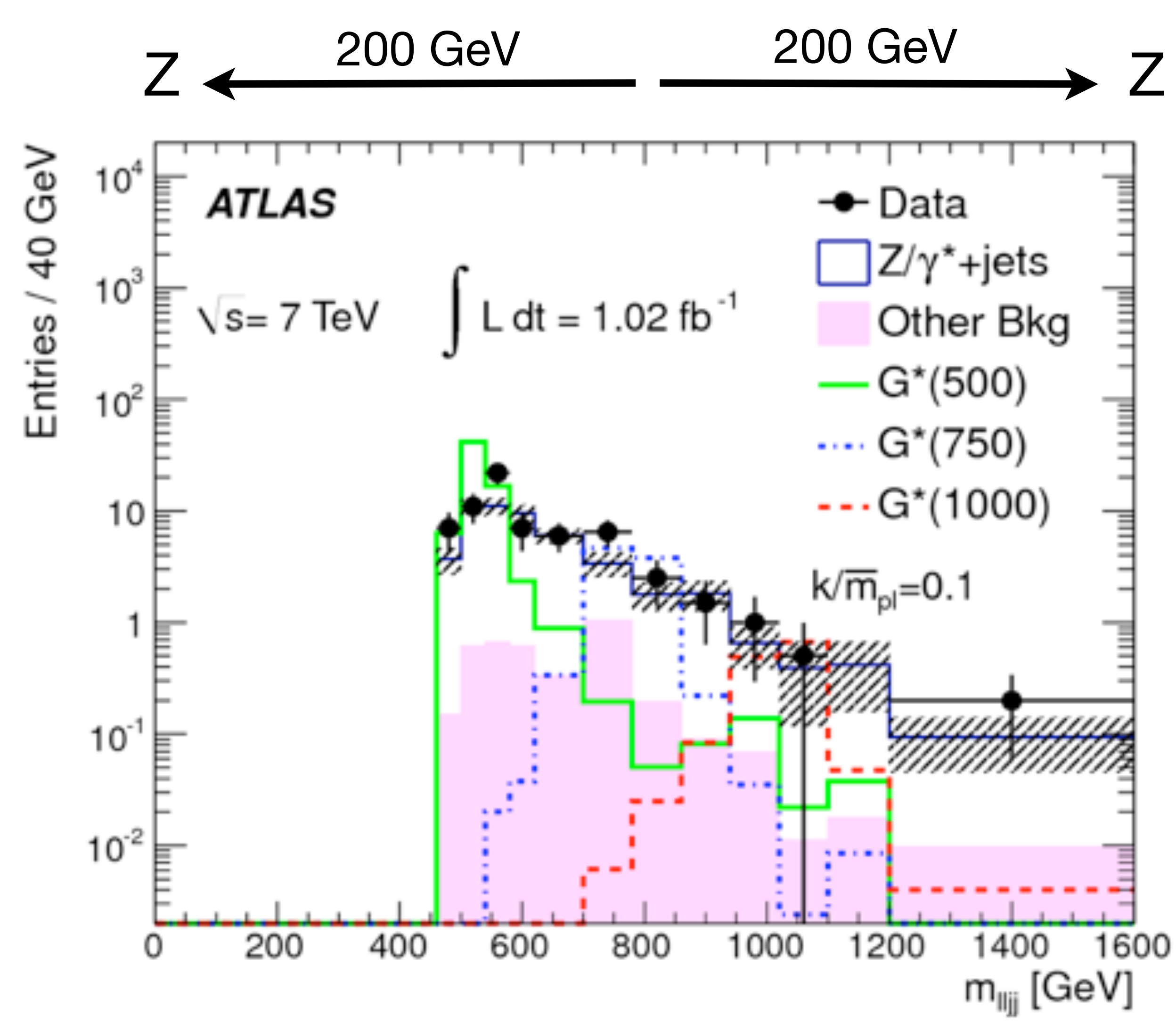
ZZ --> lljj

- Highest statistics, signal events predicted up to m_{G^*}~1TeV
- Two search regions: p_T^Z>50 GeV and p_T^Z>200 GeV

ZZ --> lljj (p_T^Z > 50 GeV)



ZZ --> lljj (p_T^Z > 200 GeV)



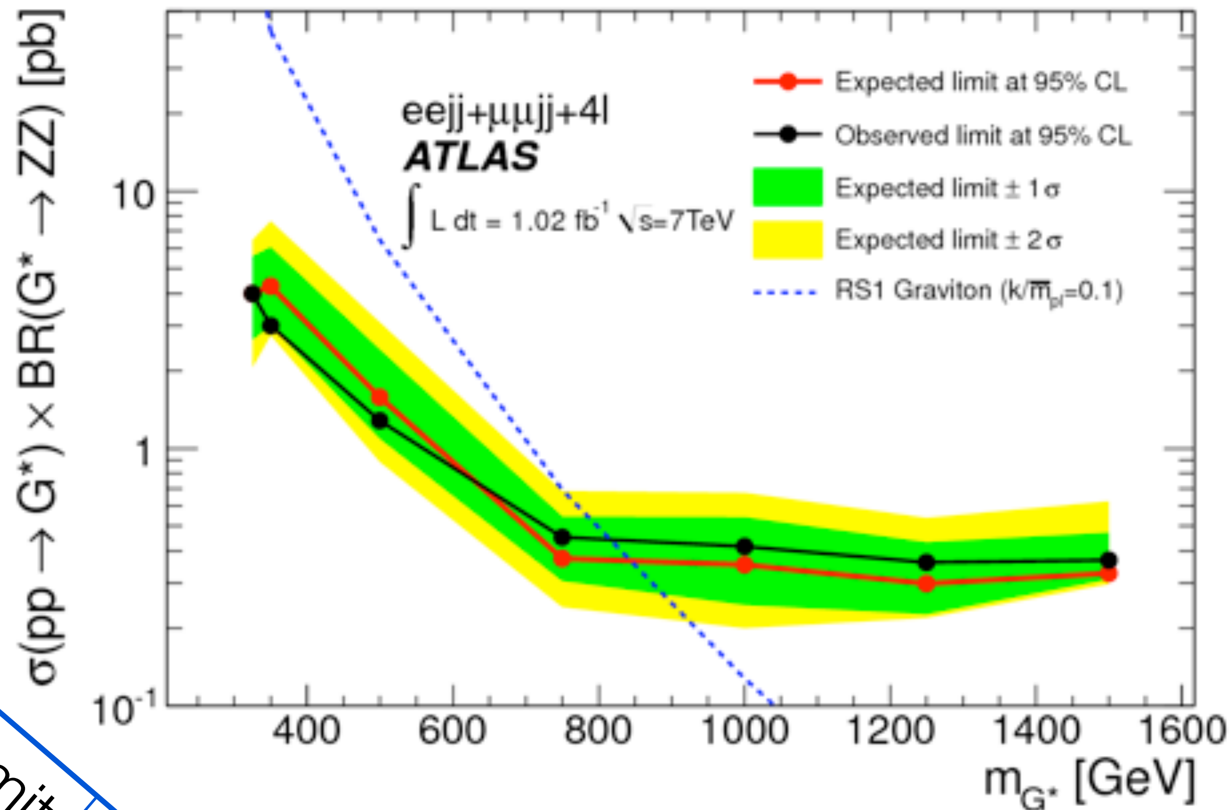
Limits on Graviton Production

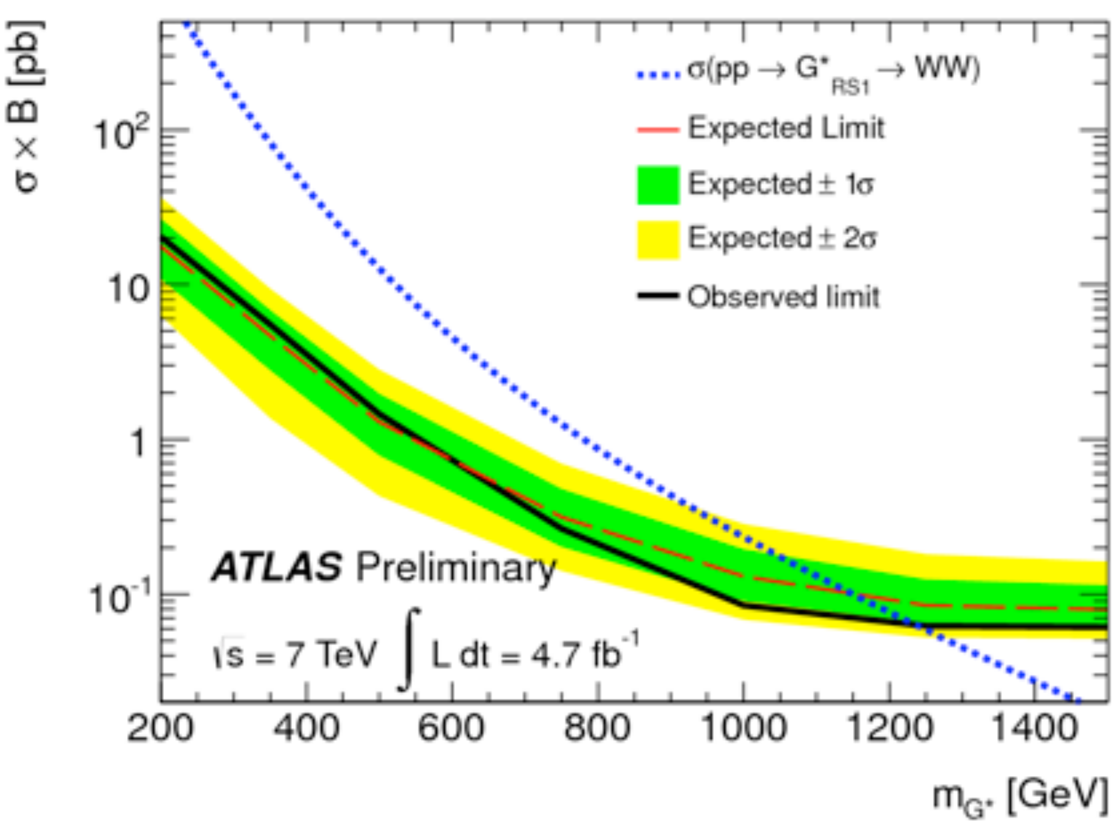
Coupling parameter set to $k/\overline{m}_{pl} = 0.1$ for limits

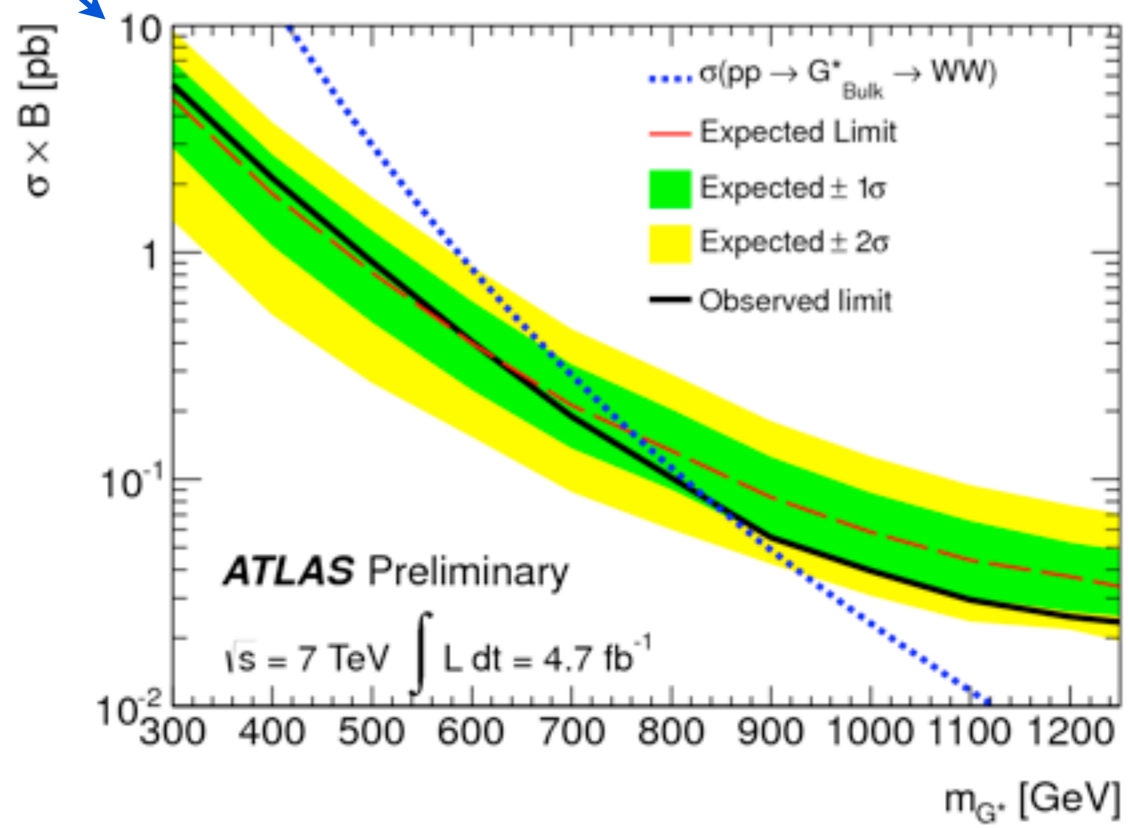
95% Confidence Level lower mass limits [GeV]		
Channel	RS G* Mass	Bulk G* Mass
ZZ (1 fb^{-1})	810	-
WW (5 fb^{-1})	1230	840

Previous limit (D0): 750 GeV

First Limit







Limits on WZ resonances

95% Confidence Level lower mass limits [GeV]		
Channel	W’	Techni-ρ
WZ (1 fb^{-1})	760	467

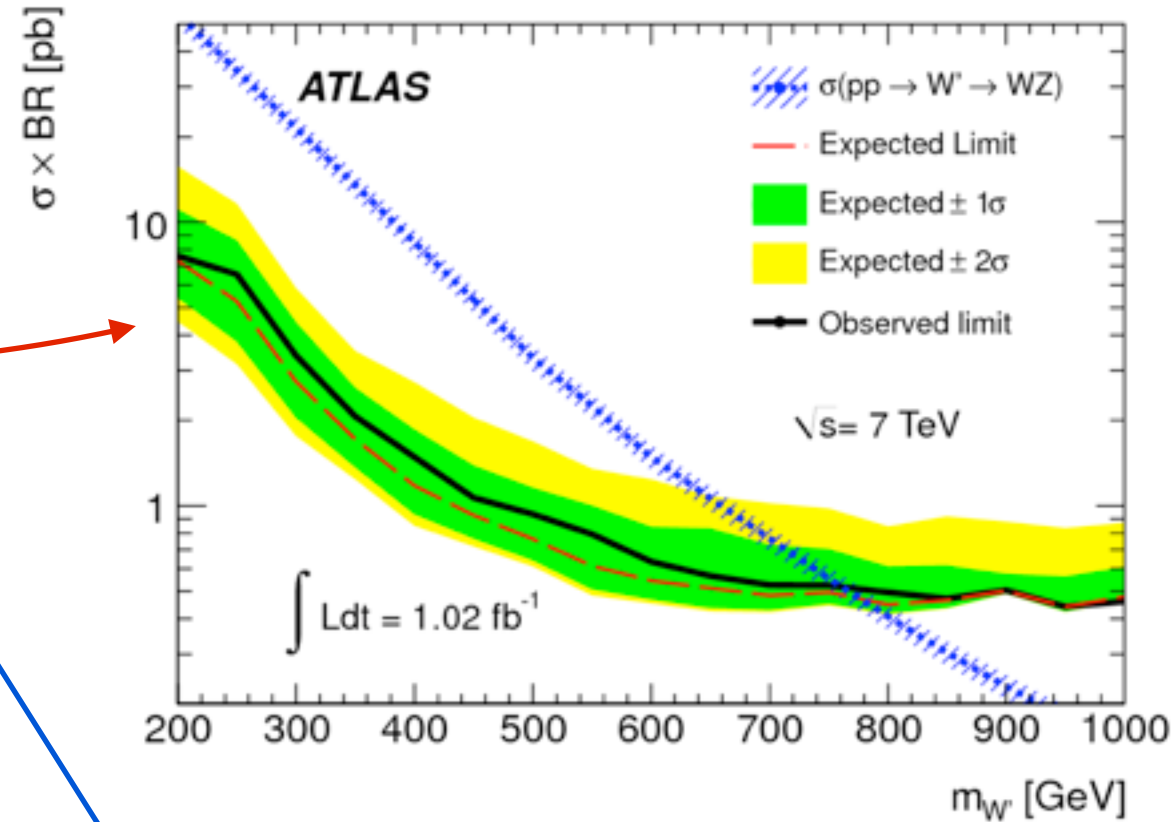
W’:

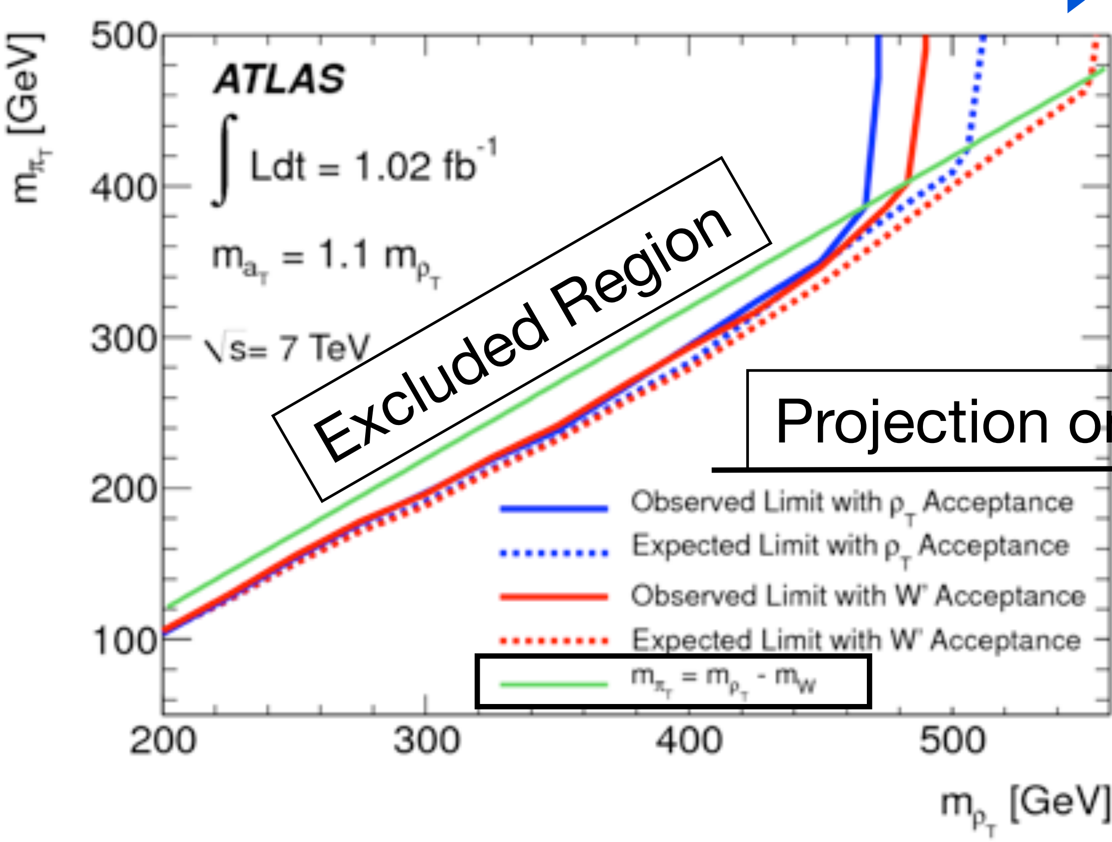
W’WZ coupling ~ $M_W M_Z / M_{W'}^2$

Technicolor:

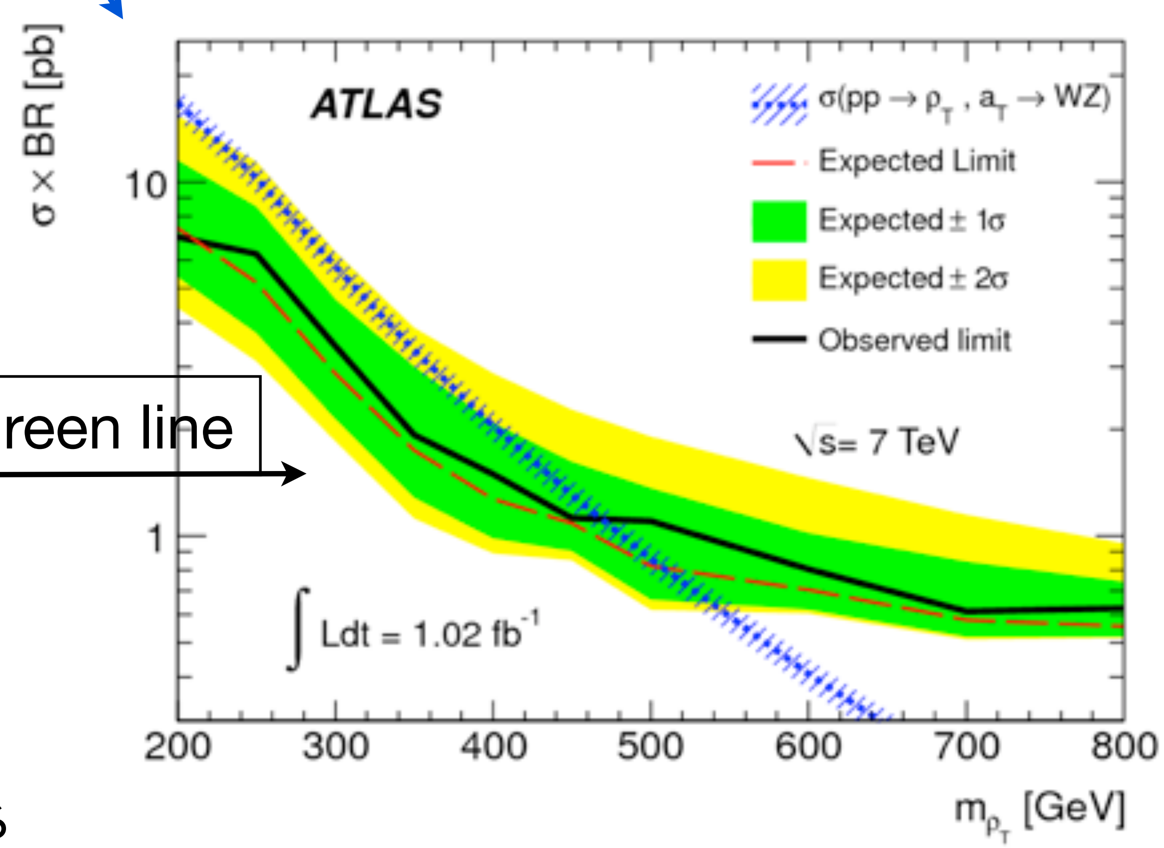
Limits in the full (m_ρ, m_π) plane and projected on the $m_\rho = m_\pi + m_W$ line

Previous (D0, 4-5.4 fb^{-1}): 408 (ρ_T), 690 (W’) GeV





Projection on green line



Conclusions

Reviewed Atlas results for the search of new particles in diboson final states with 1-4.7 fb^{-1} of 7 TeV collisions

Model / Channel	Randall-Sundrum Gravitons	Bulk RS Gravitons	W' (SSM+EGM)	Low-scale Technicolor ($m_\rho = m_\pi + m_W$)
ZZ (1 fb^{-1})	810 (845)			
WW (5 fb^{-1})	1230 (1130)	840 (740)		
WZ (1 fb^{-1})			760 (776)	467 (506)

95% CL lower mass limits in GeV (expected)

No sign of new physics yet. Pushing towards higher masses and smaller cross sections.

More 7 TeV analysis coming soon

- Use full 4.7 fb^{-1} dataset
- Explore other W/Z decay channels (neutrinos, jets)

6.3 fb^{-1} of 8 TeV collisions already collected in 2012

Main References

https://twiki.cern.ch/twiki/bin/view/AtlasPublic

https://twiki.cern.ch/twiki/bin/viewauth/AtlasProtected/PreliminaryApprovedPlots

WW:

- https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-068/

WZ:

- http://arxiv.org/abs/1204.1648
- Submitted to Physical Review D
- Plots: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2011-24/

ZZ:

- http://arxiv.org/abs/1203.0718
- Phys. Lett. B712 (2012) 331-350
- Plots: https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/EXOT-2011-16/

Additional References

Measurement of the WW cross section (4.7 fb^{-1})

http://arxiv.org/abs/1203.6232

Phys. Lett. B712 (2012) 289-308

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PAPERS/STDM-2011-24/

Measuring the b-tagging efficiency using top-pair events (4.7 fb^{-1})

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CONFNOTES/ATLAS-CONF-2012-097/

CDF: Search for high-mass resonances decaying into ZZ

Phys. Rev. D85 (2012) 012008

http://arxiv.org/abs/1111.3432

CMS: Search for exotic particles decaying to WZ (W' and Technicolor limits)

http://arxiv.org/abs/1204.1648

D0: Search for resonant WW and WZ production (Graviton and W' limits)

http://arxiv.org/abs/1011.6278

Phys.Rev.Lett.107:011801,2011

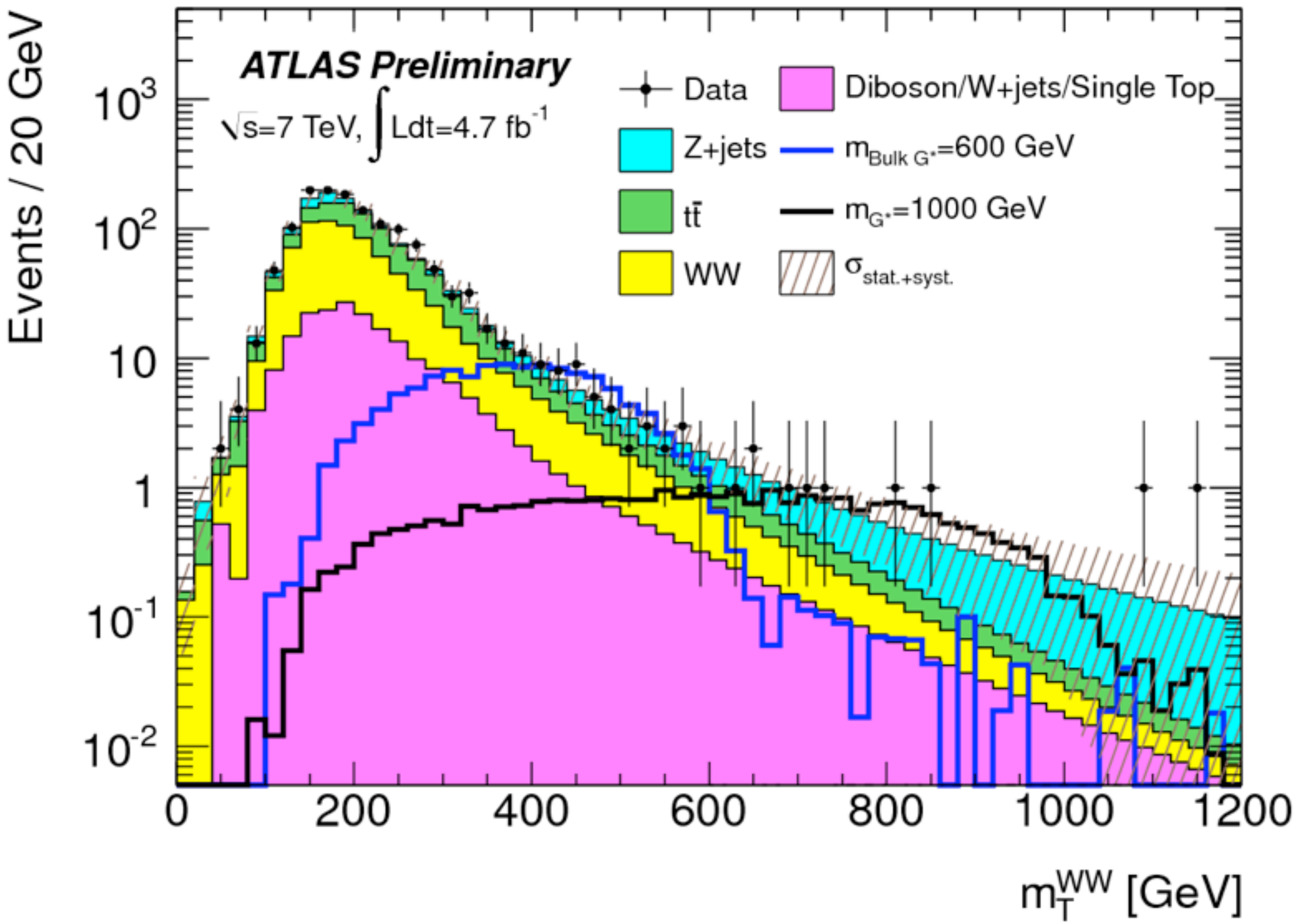
D0: Search for a resonance decaying into WZ boson pairs (Technicolor limit)

http://arxiv.org/abs/0912.0715

Phys.Rev.Lett.104:061801,2010

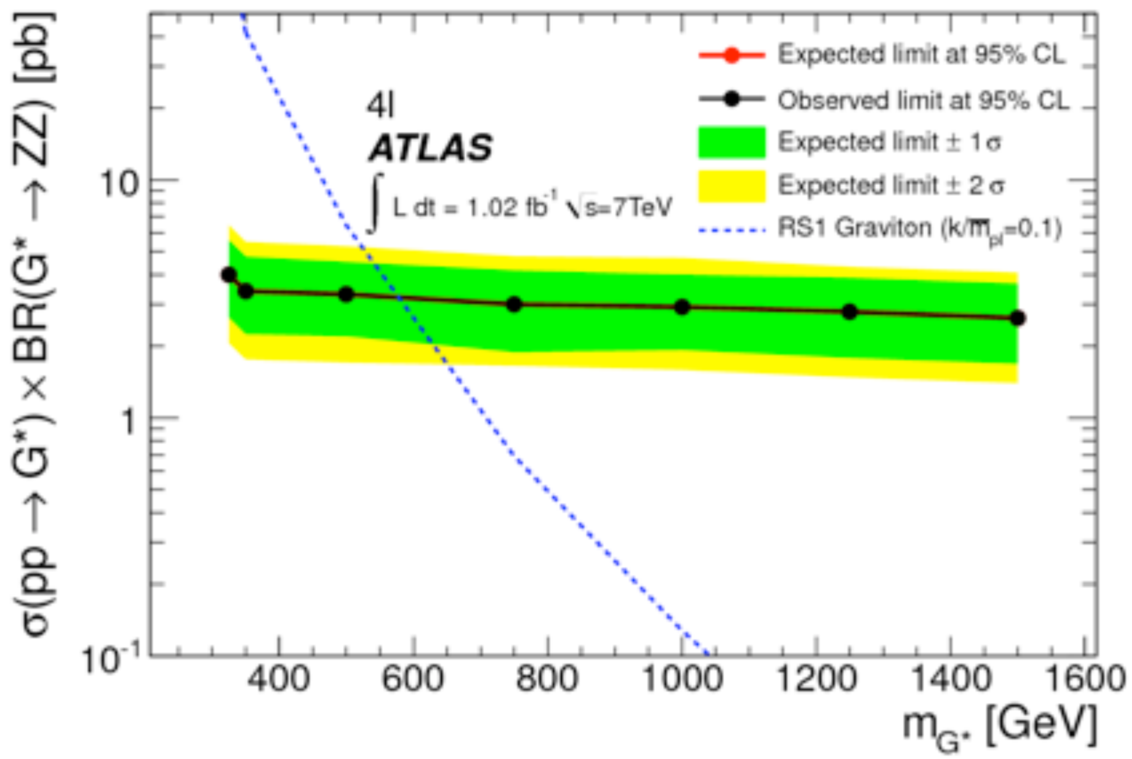
Backup

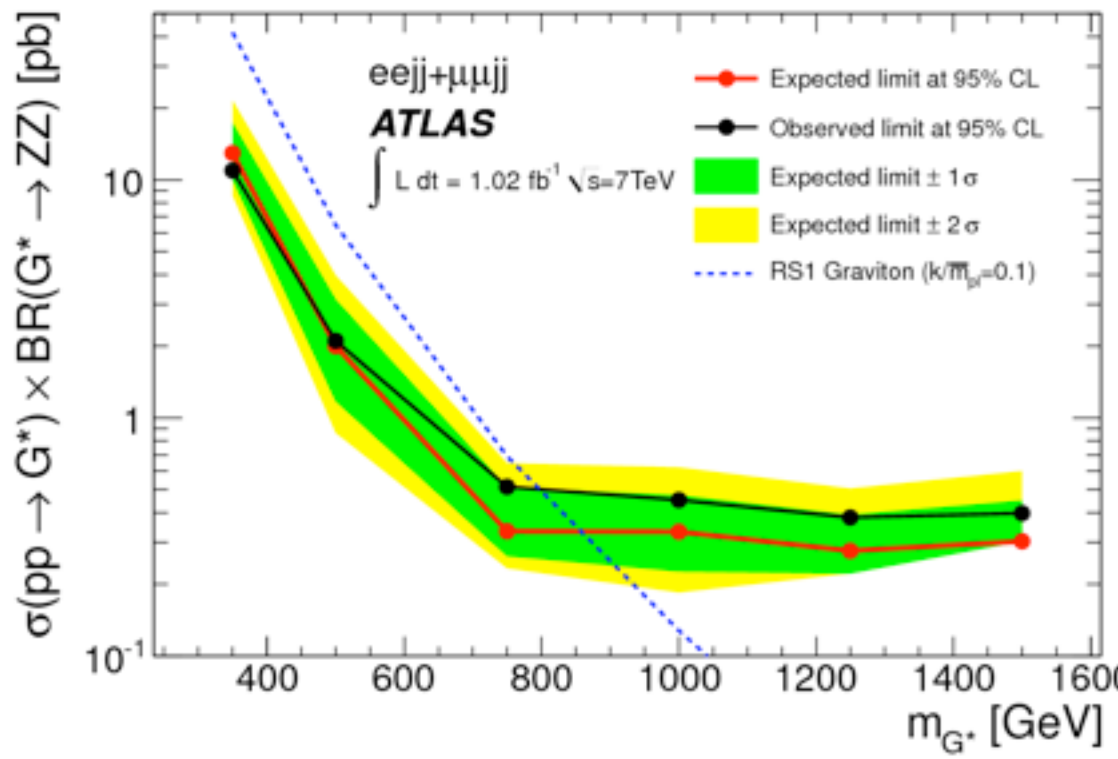
WW (ee+eμ+μμ)

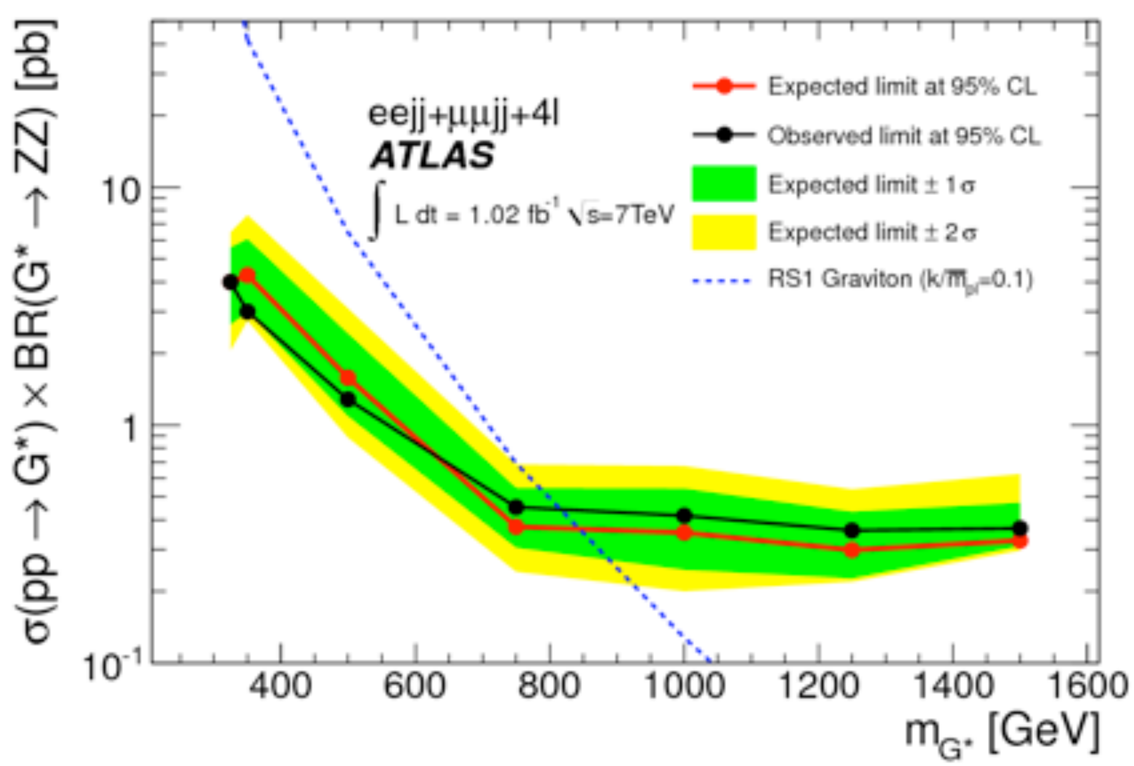


ATLAS Preliminary
√s=7 TeV, ∫Ldt=4.7 fb⁻¹
Data
Diboson/W+jets/Single Top
Z+jets
m_Bulk G*=600 GeV
tt̄
m_G*=1000 GeV
WW
σ_stat.+syst.
Events / 20 GeV
m_T^WW [GeV]

ZZ limits by channel



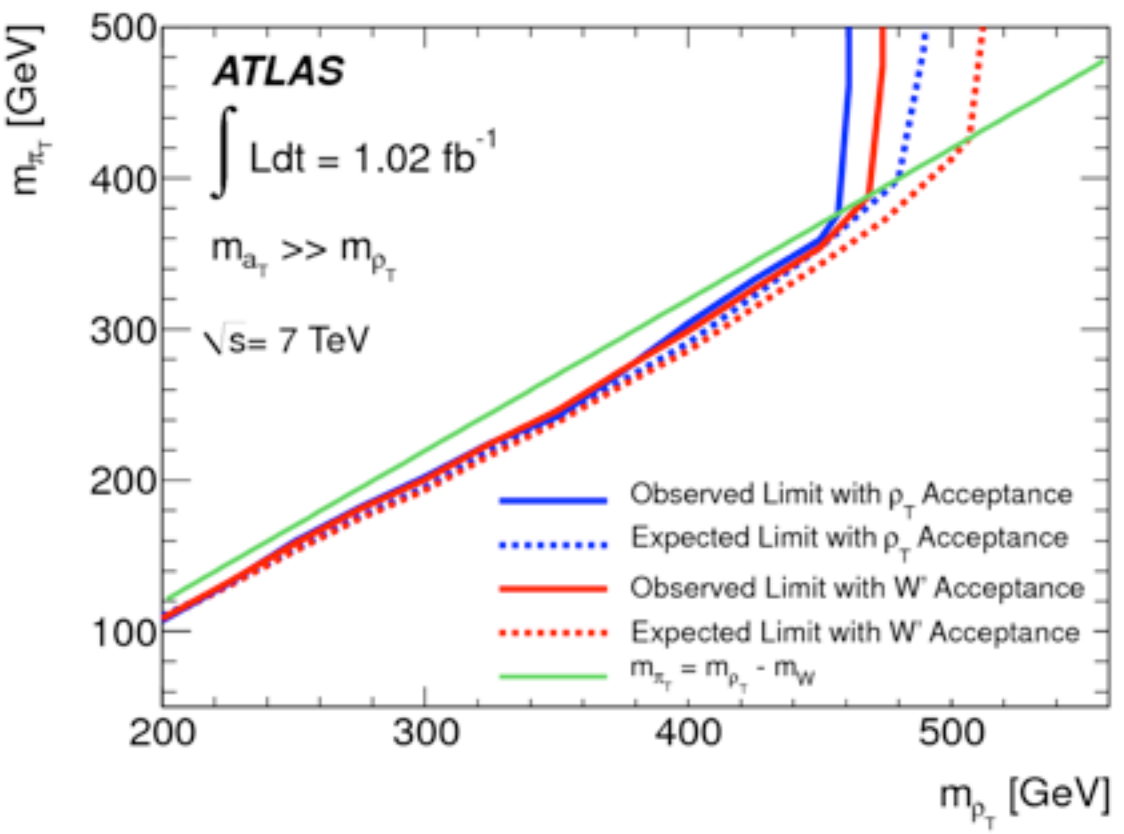


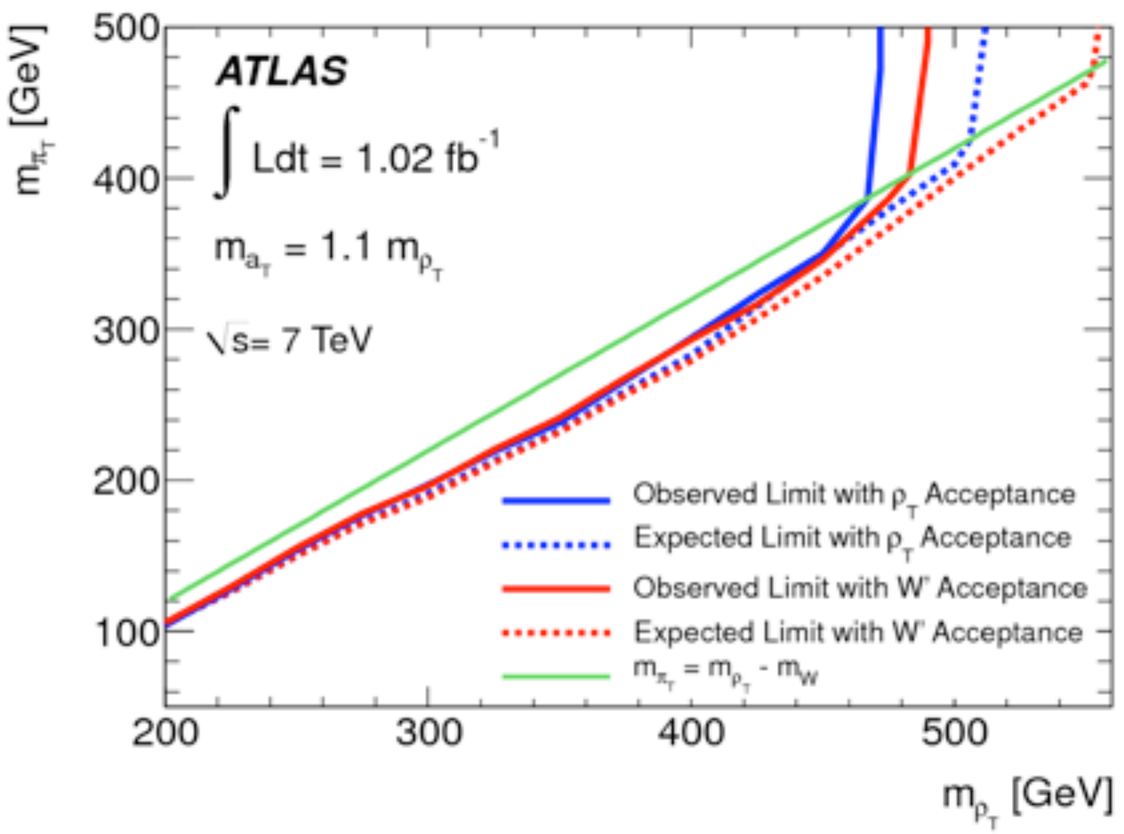


WZ limits

Different assumptions for mass of a_T and ρ_T

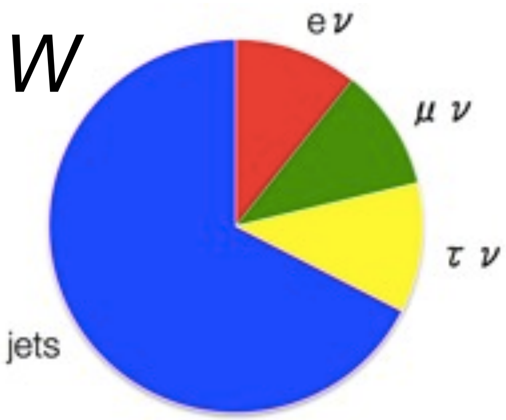
- Very small differences between the two, since a_T has much smaller cross section.
- In the degenerate case, the (ρ_T+a_T) peak is slightly wider.

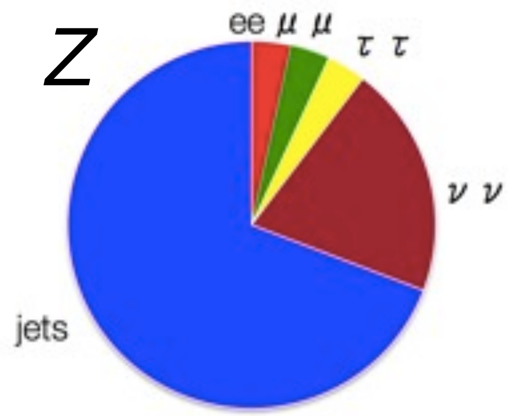




Summary of Cuts Used

Building blocks: W and Z boson



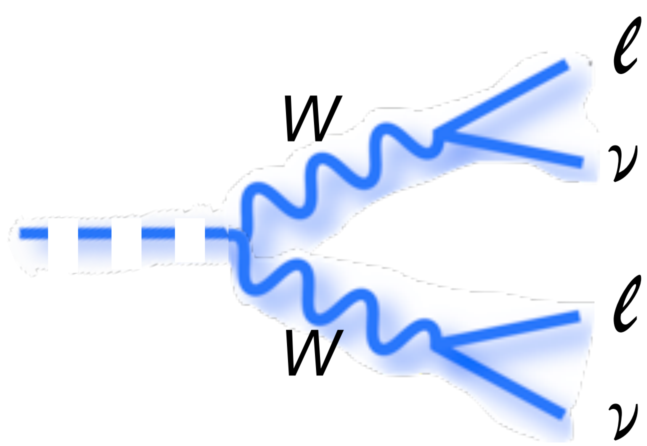


1 lepton, E_T^{miss} , $m_T(l,\nu)$

2 leptons (OS SF), m(l,l)

or: 2 jets, m(j,j)

WW (5 fb^{-1}) <-- NEW RESULT



2 leptons (25 GeV)

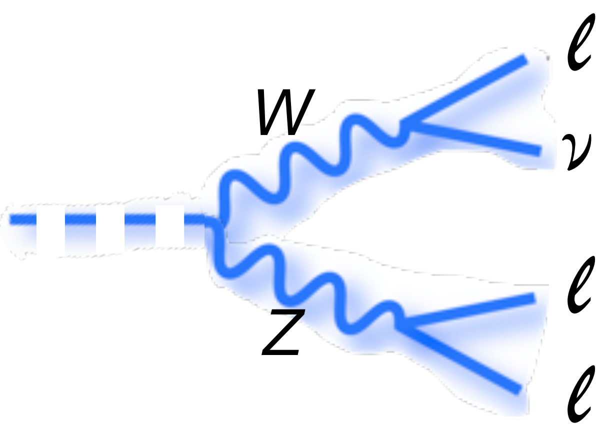
E_T^{miss} > 30 GeV (eμ)

(60/65 GeV for ee/μμ)

m_{ll} - m_Z > 25 GeV

b-jet veto (20 GeV)

WZ (1 fb^{-1})



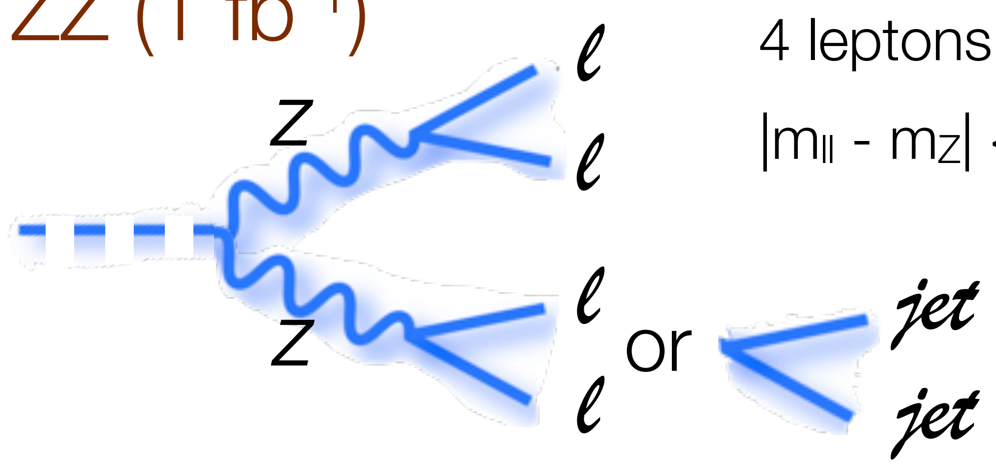
3 leptons (25 GeV)

E_T^{miss} > 25 GeV

$|m_{ll} - m_Z| < 20$ GeV

$m_T(l,\nu) > 15$ GeV

ZZ (1 fb^{-1})



4 leptons (15 GeV)

$|m_{ll} - m_Z| < 25$ GeV (x2)

2 leptons (20 GeV) with $|m_{ll} - m_Z| < 25$ GeV
2 jets (25 GeV) with $|m_{jj} - m_Z| < 25$ GeV
Boost both p_T^{ll} and p_T^{jj} (50 or 200 GeV)