LIP seminar
May 2nd, 2012

Diboson Physics in the Search for New Physics

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Outline

- Introduction
- Cross section measurements
  - *$W\gamma$, $Z\gamma$, WW, WZ and ZZ*
- Anomalous triple gauge couplings
- Search for *narrow/wide* diboson resonances
  - *Extra dimension, SSM W', Technicolor and SM Higgs*

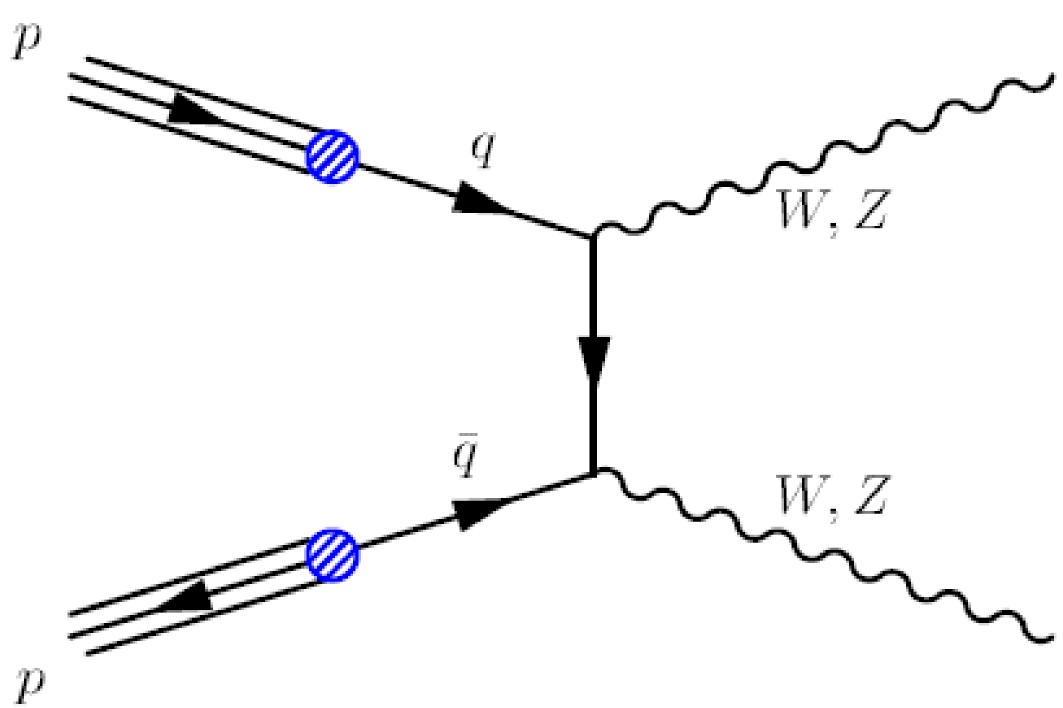
ATLAS and CMS public results:

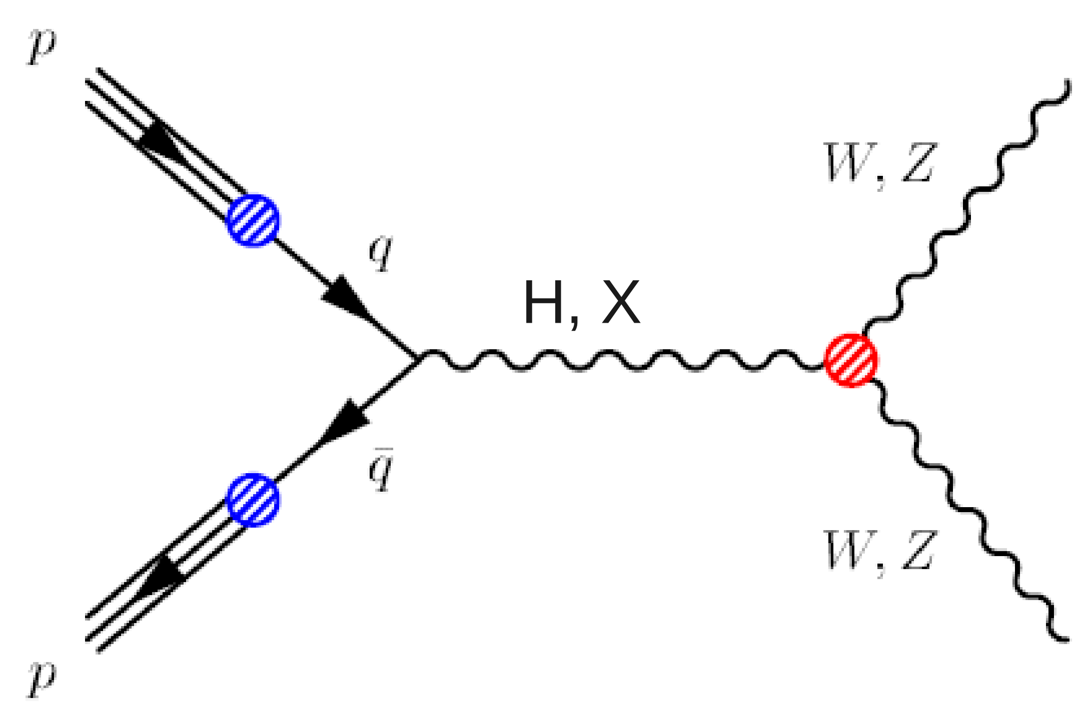
https://twiki.cern.ch/twiki/bin/view/AtlasPublic

https://twiki.cern.ch/twiki/bin/view/CMSPublic/PhysicsResults

Diboson Physics

- Precision test of the Standard Model couplings
- Important background in SM Higgs and BSM searches
- Probe to new physics via triple gauge couplings
- Diboson "resonances" in various BSM scenarios
- Vector boson scattering as production mechanism

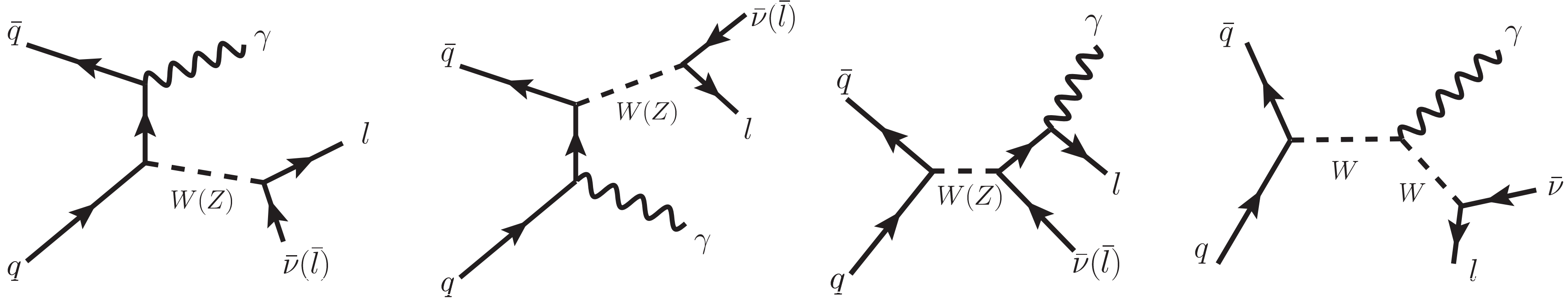




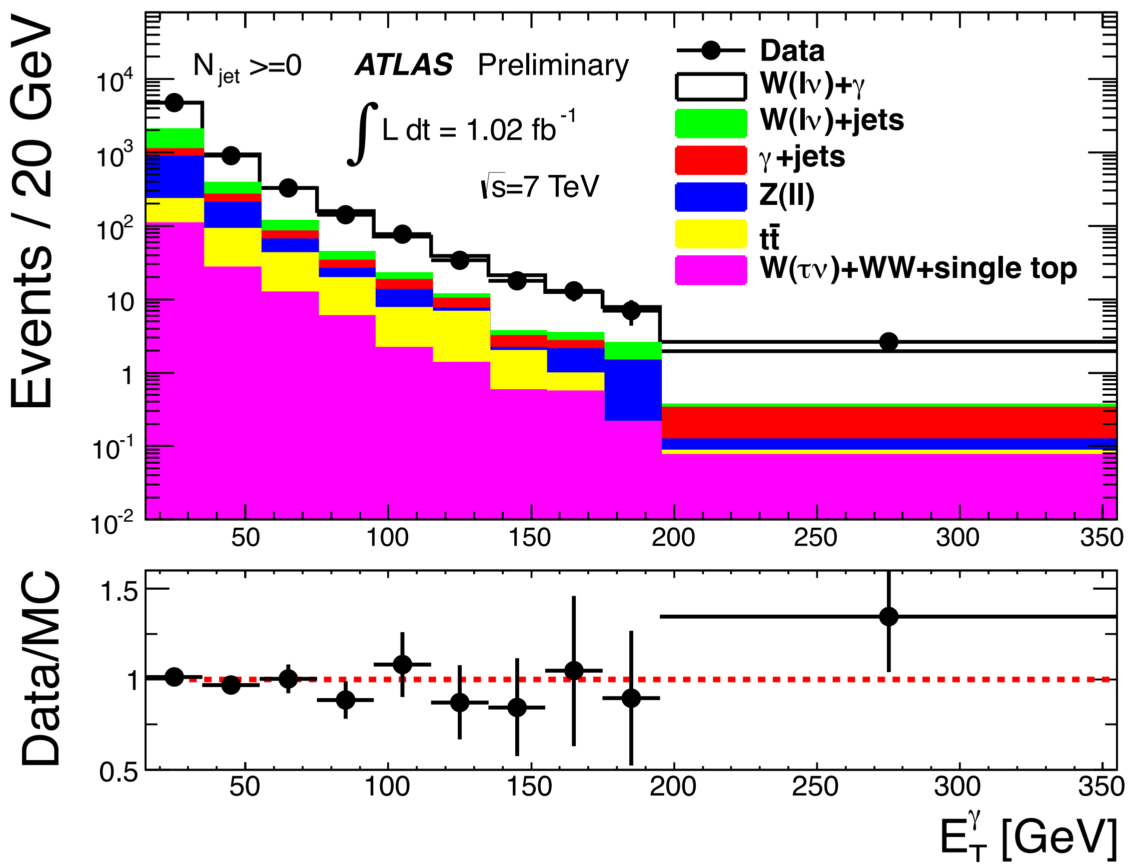
Wγ(→lνγ) Production

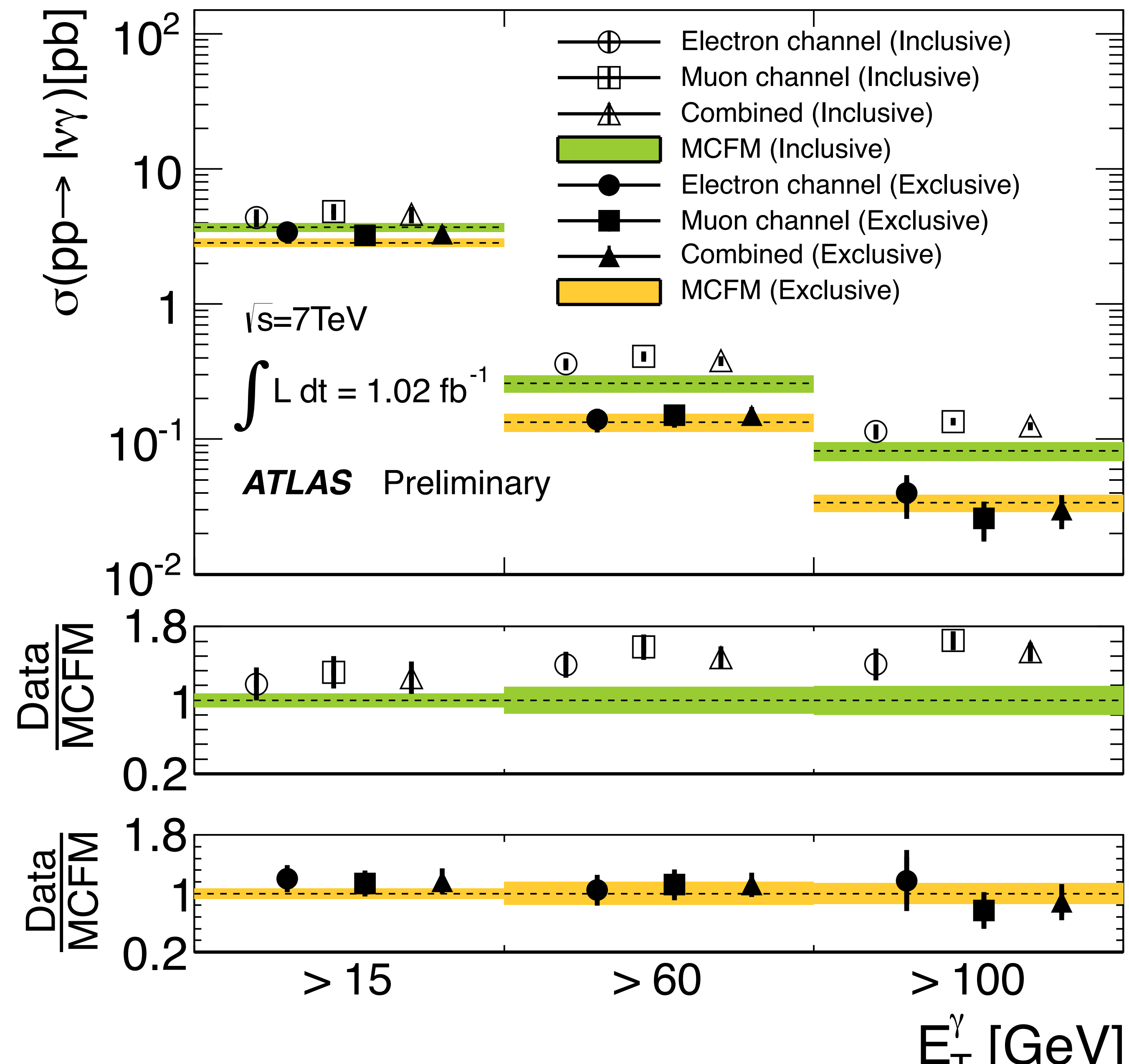
Probe to TGCs

Background to resonance searches



ATLAS Preliminary



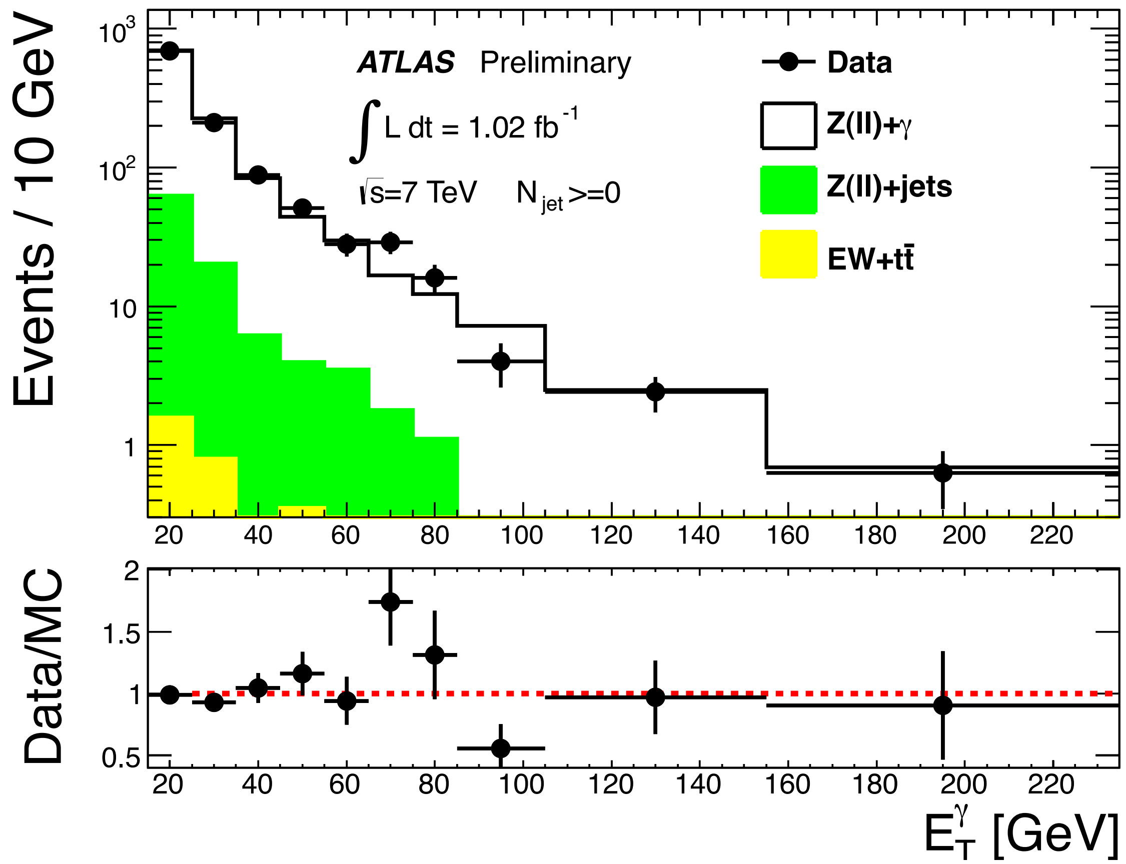


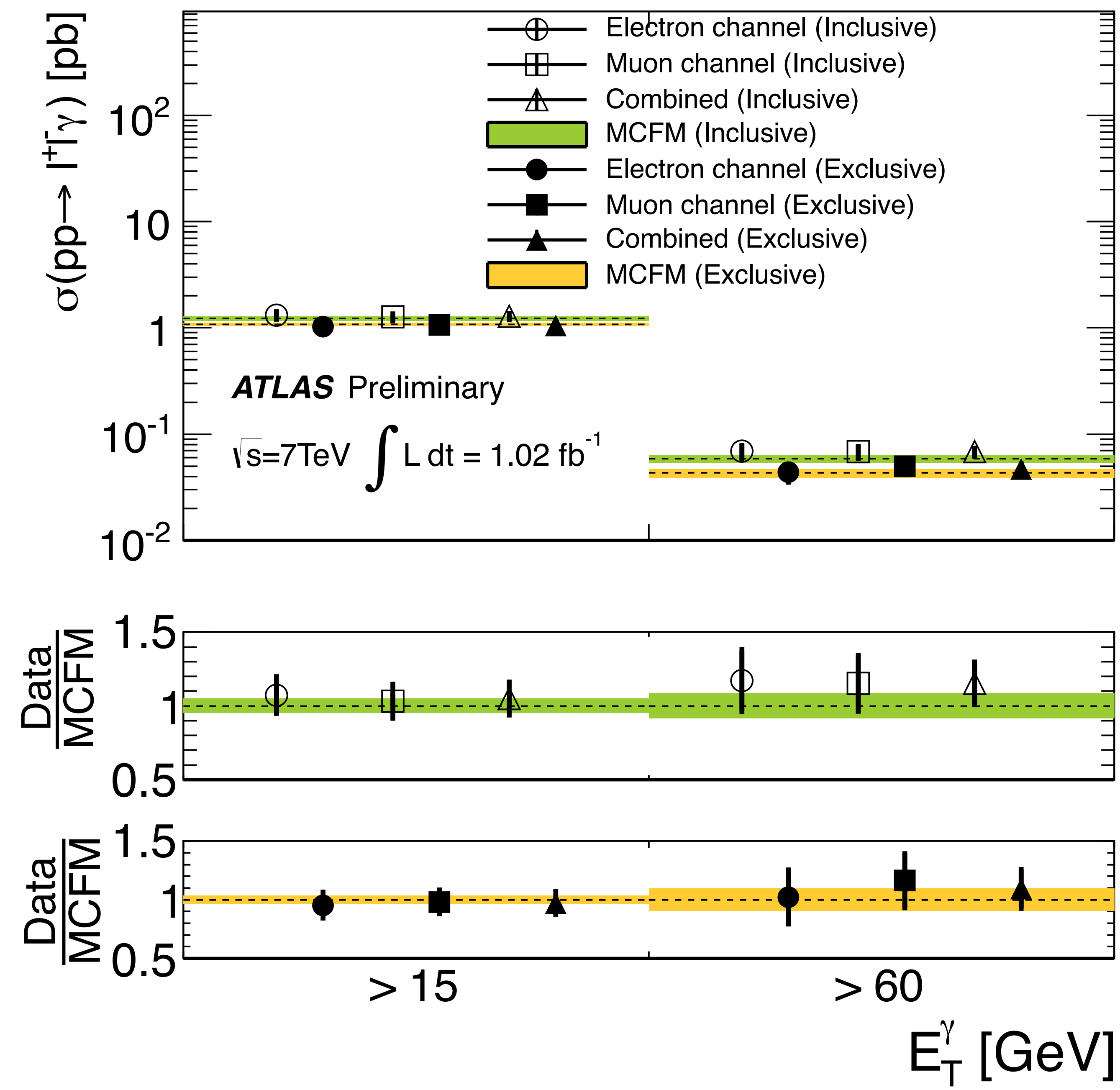
Selection Cuts

- 1 isolated lepton $p_T^{lepton} > 25$ GeV
- Isolated photon $E_T > 15$ GeV
- $\Delta R_{l\gamma} > 0.7$ (suppress FSR)
- $E_T^{miss} > 25$ GeV
- $M_T^W > 40$ GeV

Exclusive ≡ No jet with p_T>30 GeV

$Z\gamma(\rightarrow ll\gamma)$ Production





Probe to anomalous TGCs

Background to resonance searches

Selection Cuts

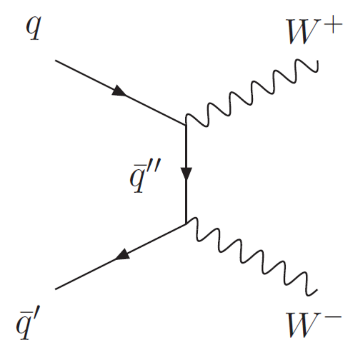
- 2 isolated leptons $p_T^{lepton} > 25$ GeV
- Isolated photon $E_T > 15$ GeV
- $\Delta R_{l\gamma} > 0.7$ (suppress FSR)
- $M_{ll} > 40$ GeV

Higher order QCD corrections important at high E_T^{γ}

(MCFM : only up to one real emission)

WW(→lνlν) Production

ATLAS-CONF-2012-025



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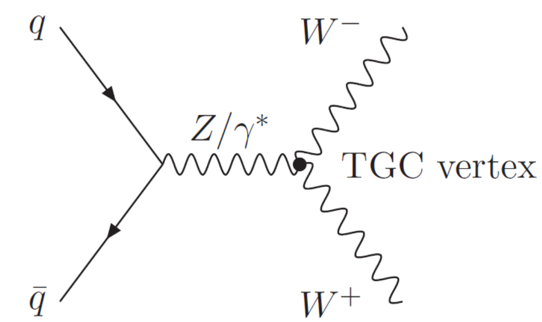

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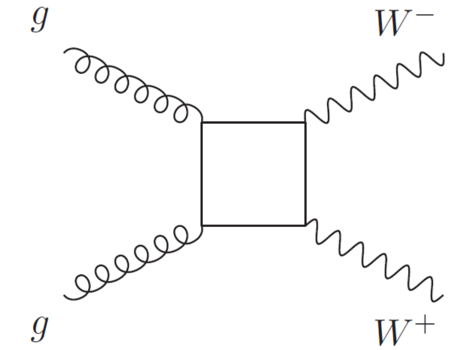

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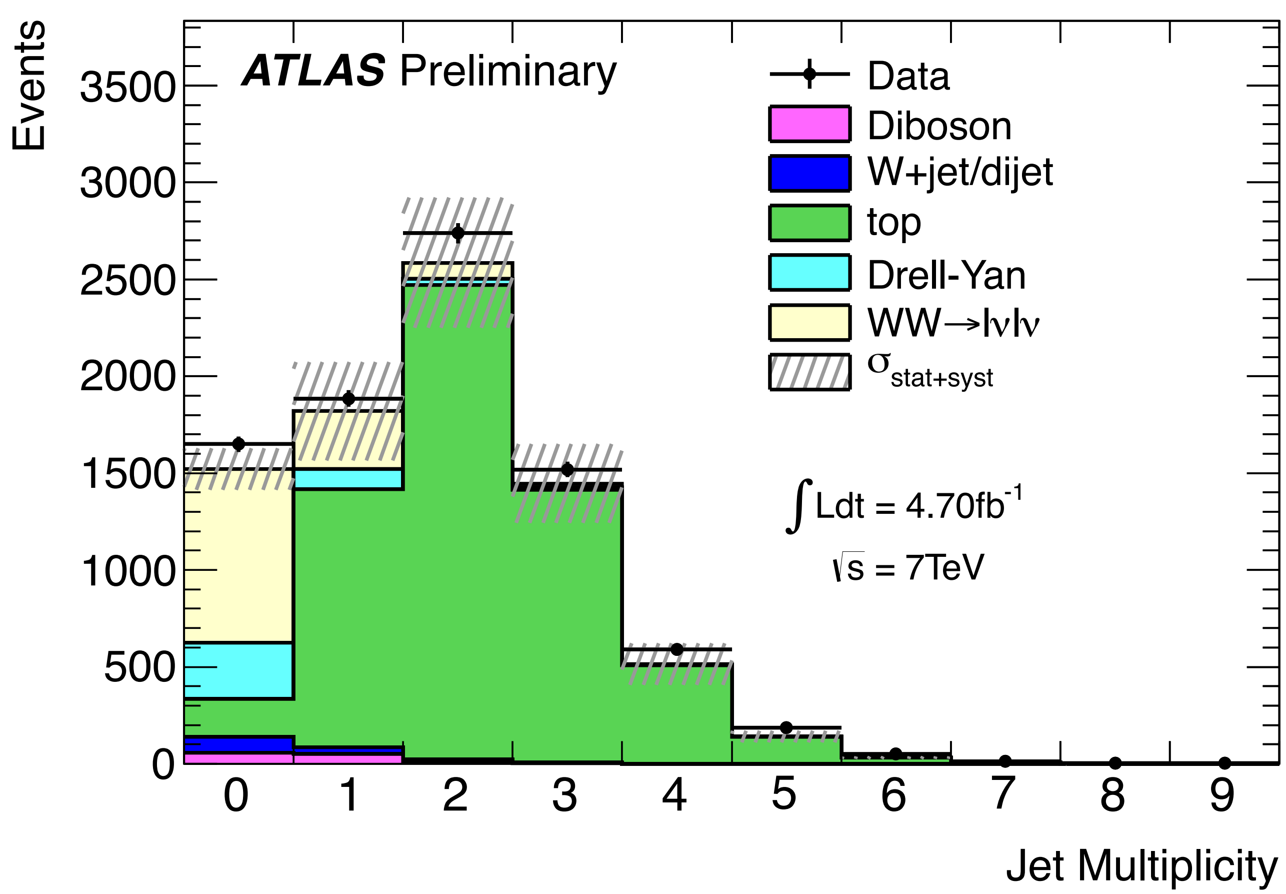
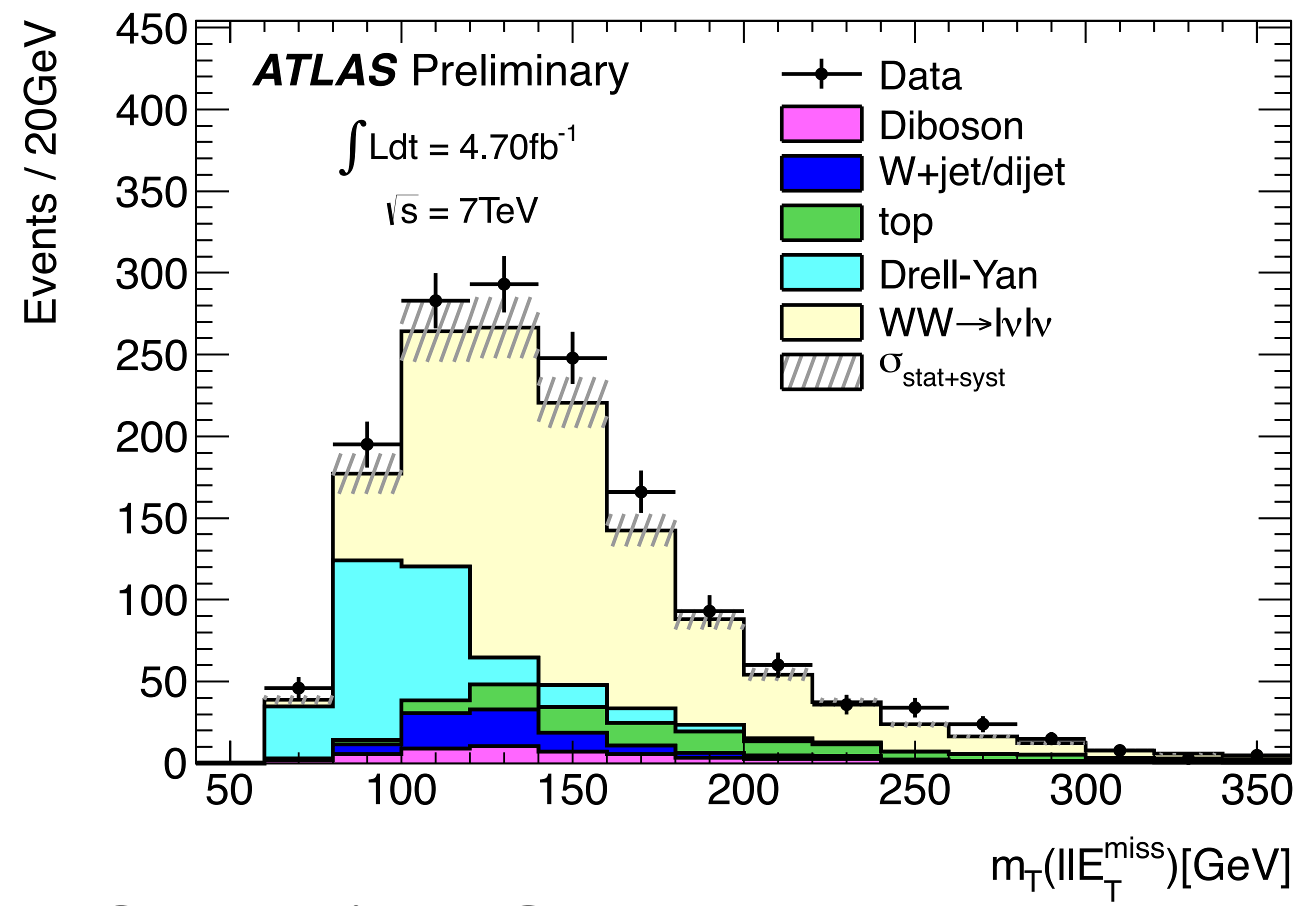




Main background to H→WW and resonance searches

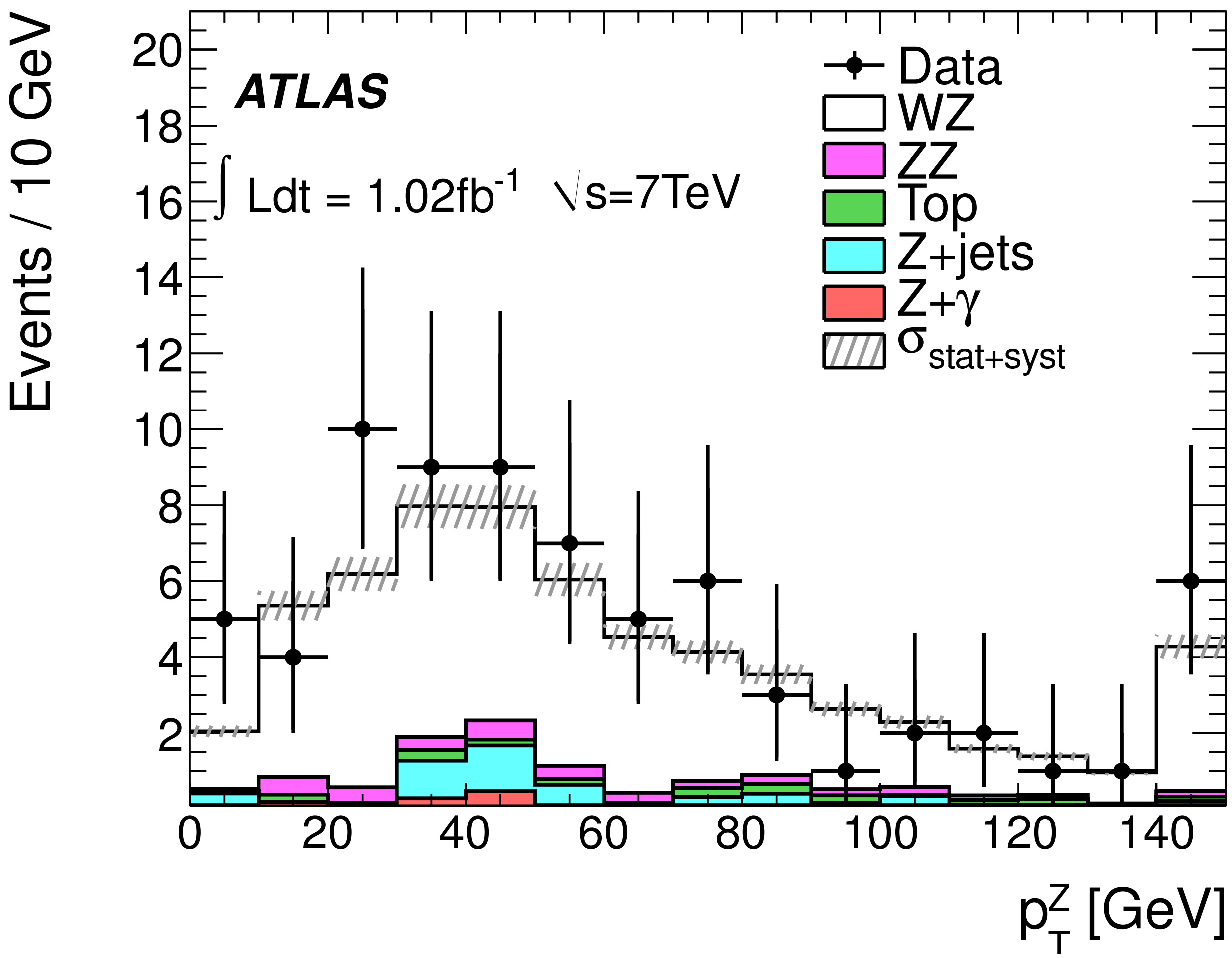
Sensitive to TGCs

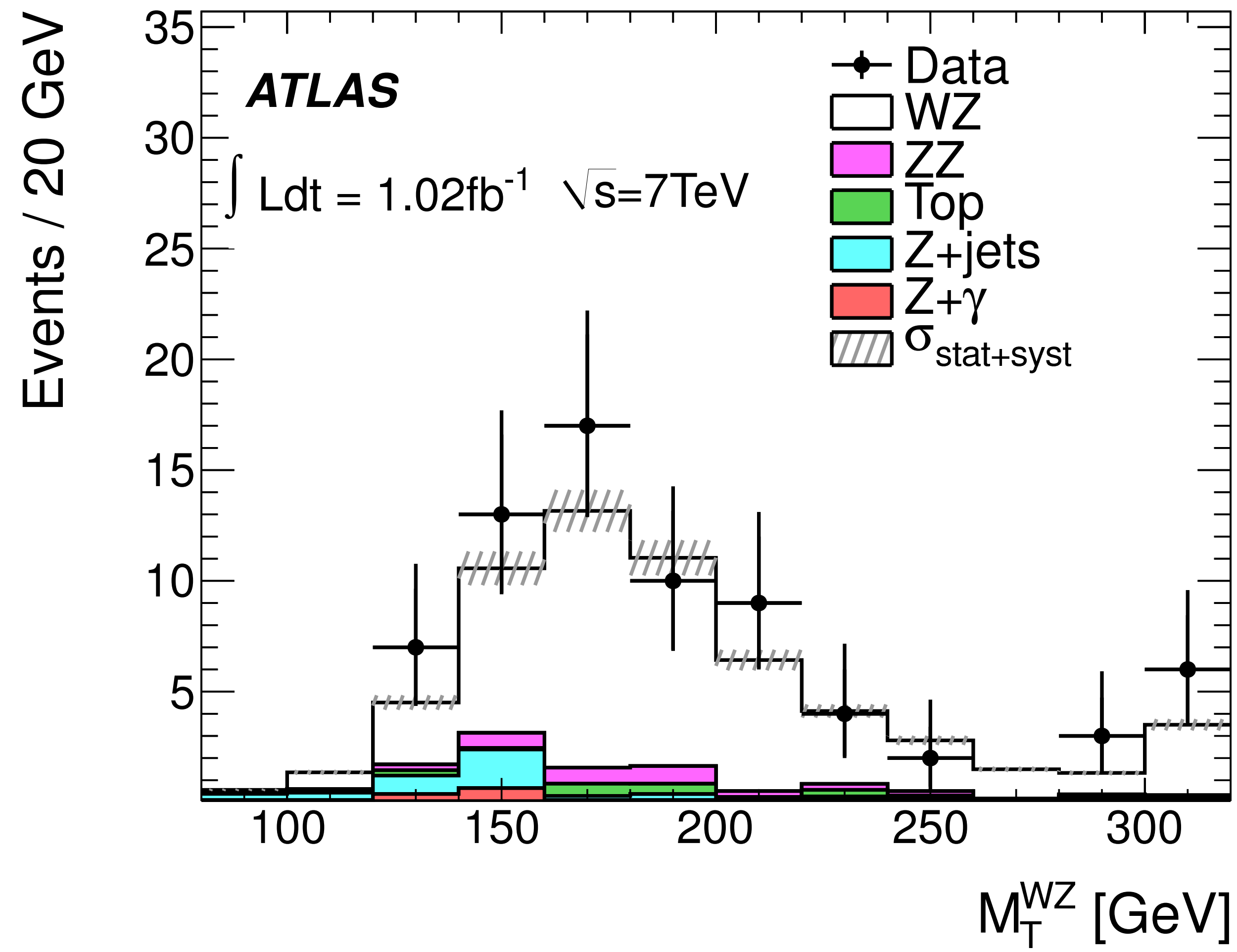
Selection Cuts

- 2 isolated leptons p_T^{lepton} > 20 GeV
- Large relative E_T^{miss}
- Veto events with $|M_{ll} - M_Z| < 15$ GeV
- Veto jets with p_T > 25 GeV
- Veto b-tagged jets with p_T > 20 GeV

WZ(→*lνll*) Production

Phys. Lett. B 709, 341 (2012)





Major background to multi-lepton and resonance searches

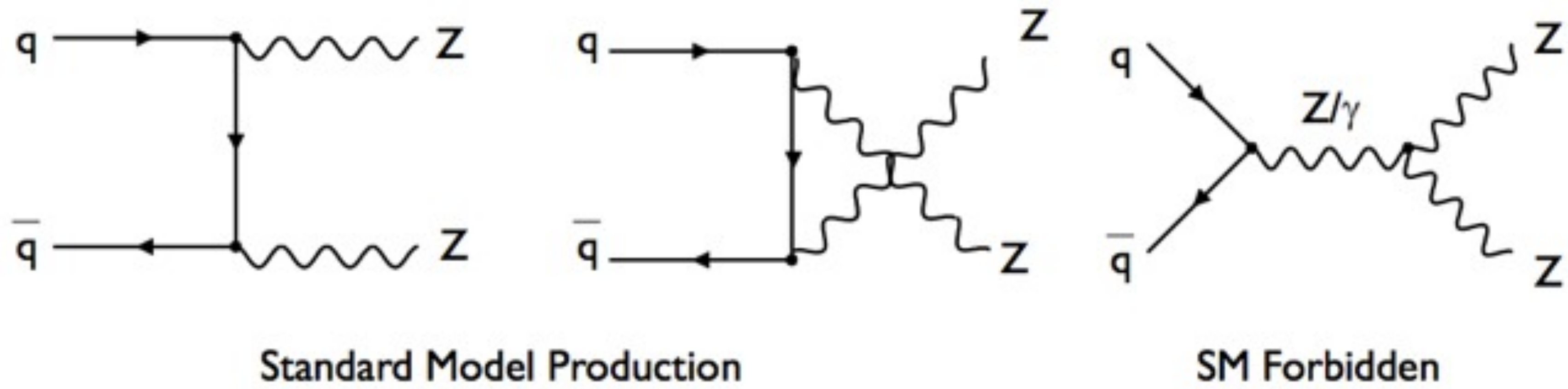
Sensitive to anomalous TGCs

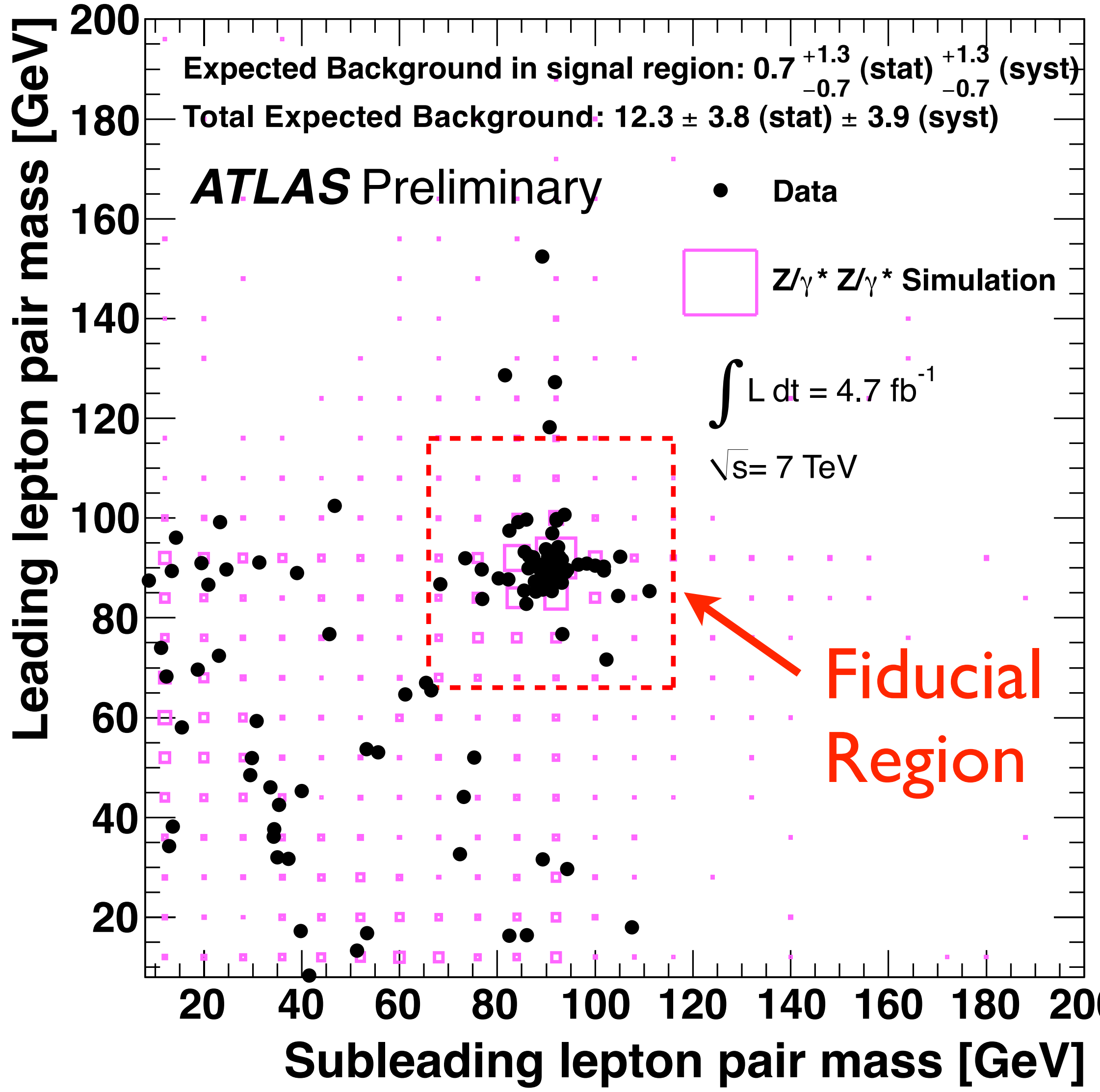
Selection Cuts

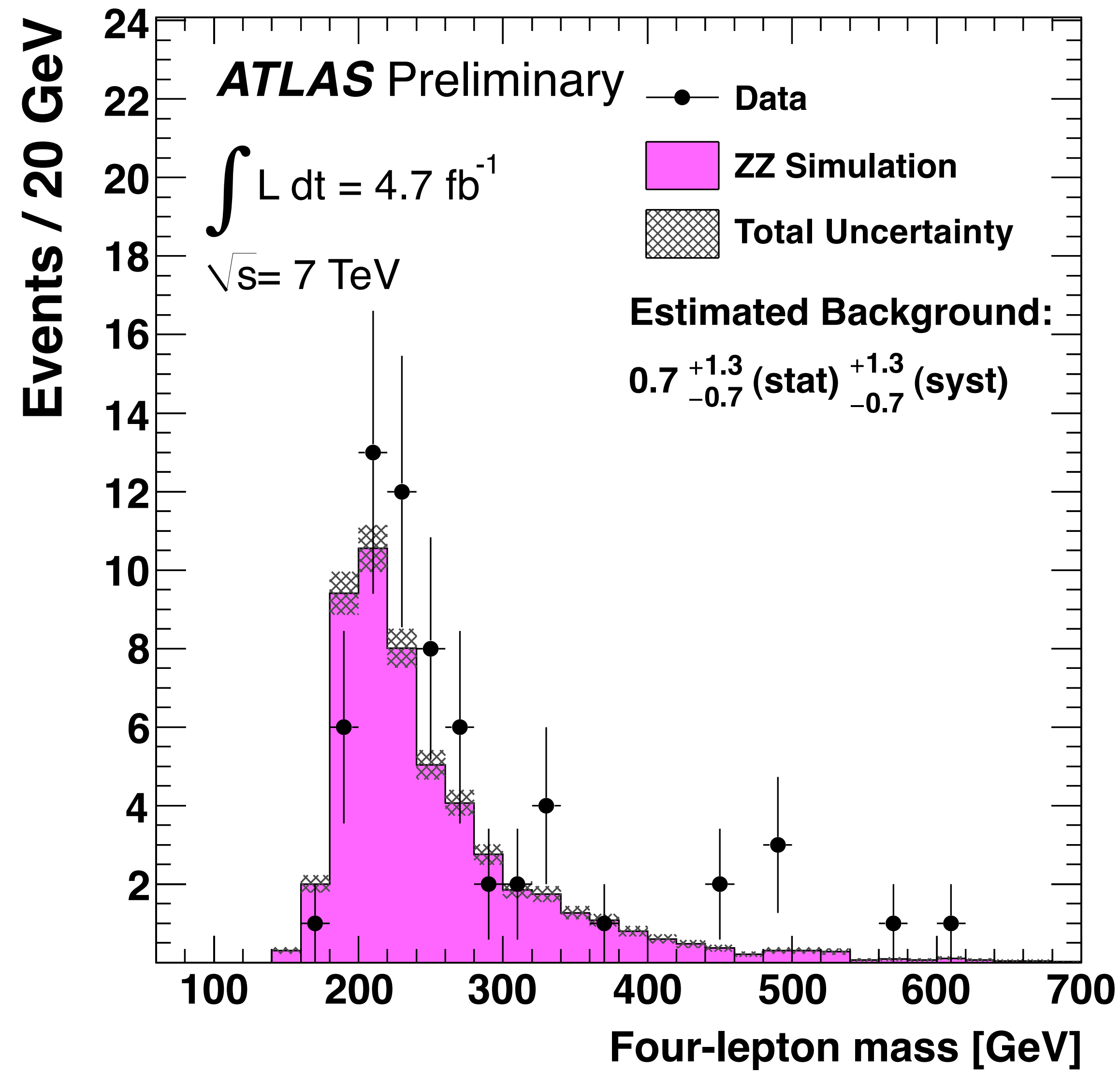
- 2 isolated leptons $p_T^{lepton} > 15$ GeV and $|M_{ll} - M_Z| < 10$ GeV
- 3rd isolated lepton $p_T^{lepton} > 20$ GeV
- $E_T^{miss} > 25$ GeV
- $M_T^W > 20$ GeV

ZZ(→llll) Production

ATLAS-CONF-2012-026







Very clean events (major background to H→ZZ)

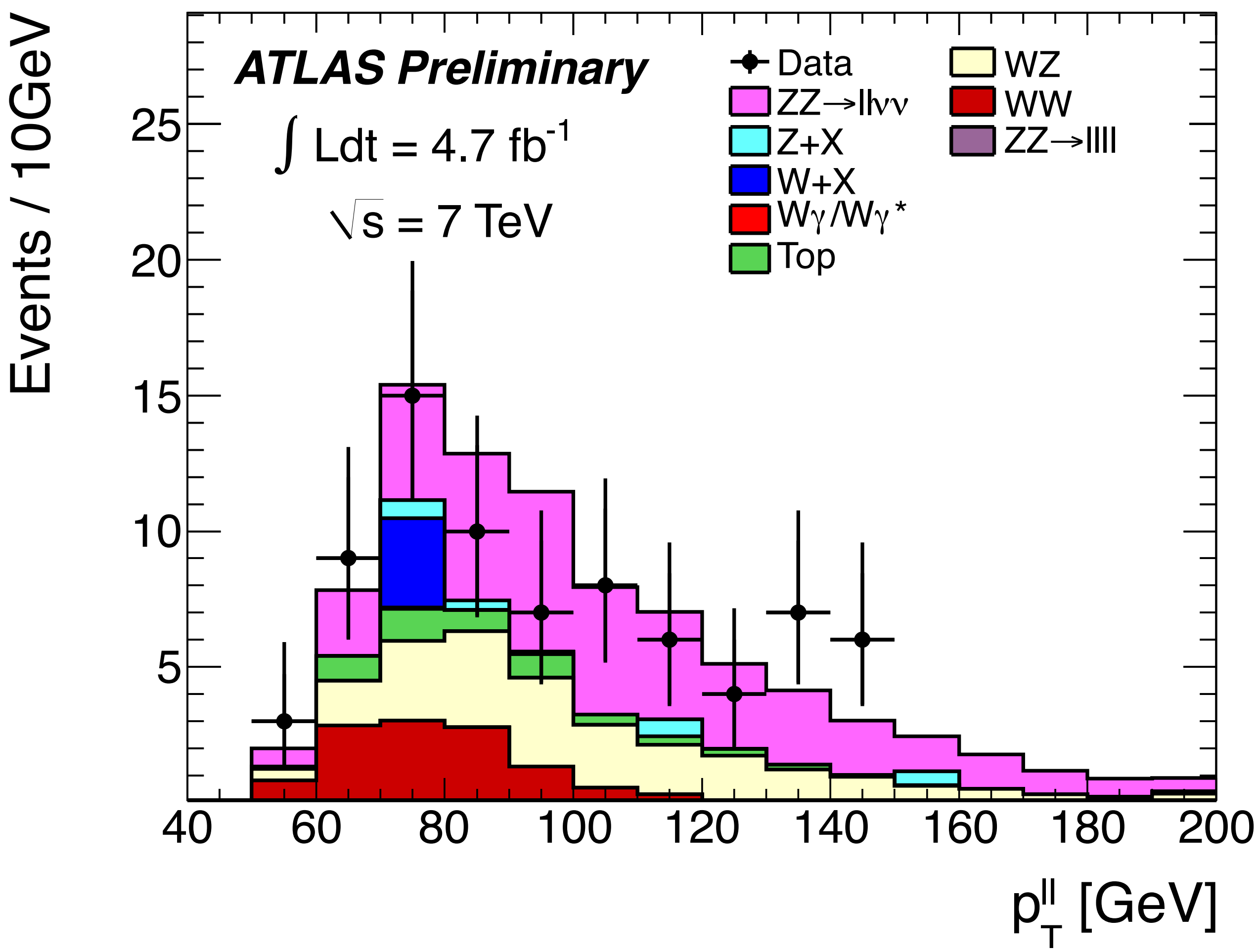
Sensitive to anomalous TGCs

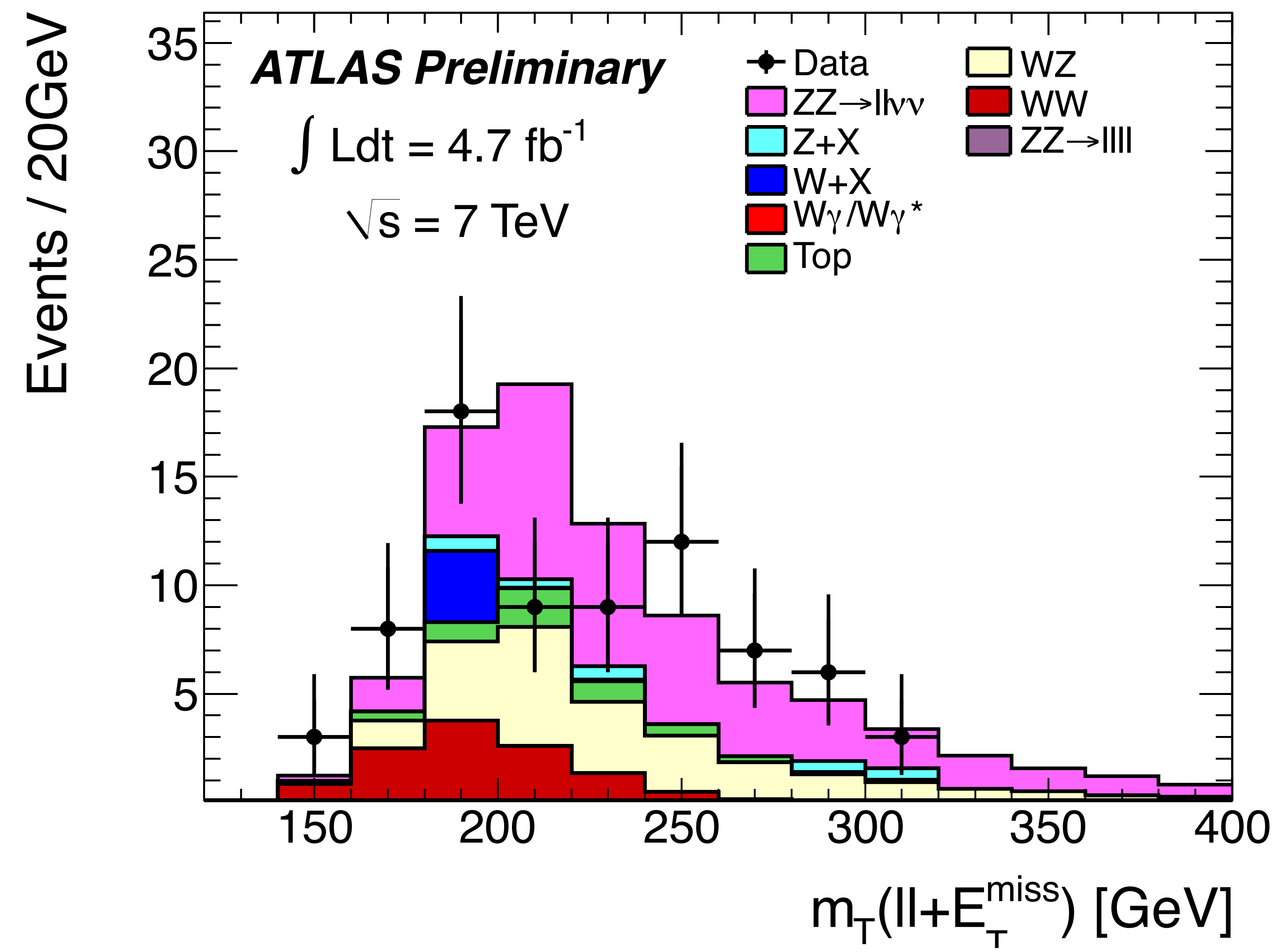
Selection Cuts

- 4 leptons $p_T^{lepton} > 7$ GeV
- Paired to form 2 Z-bosons with $|M_{ll} - M_Z| < 25$ GeV

ZZ(→*llνν*) Production

ATLAS-CONF-2012-027





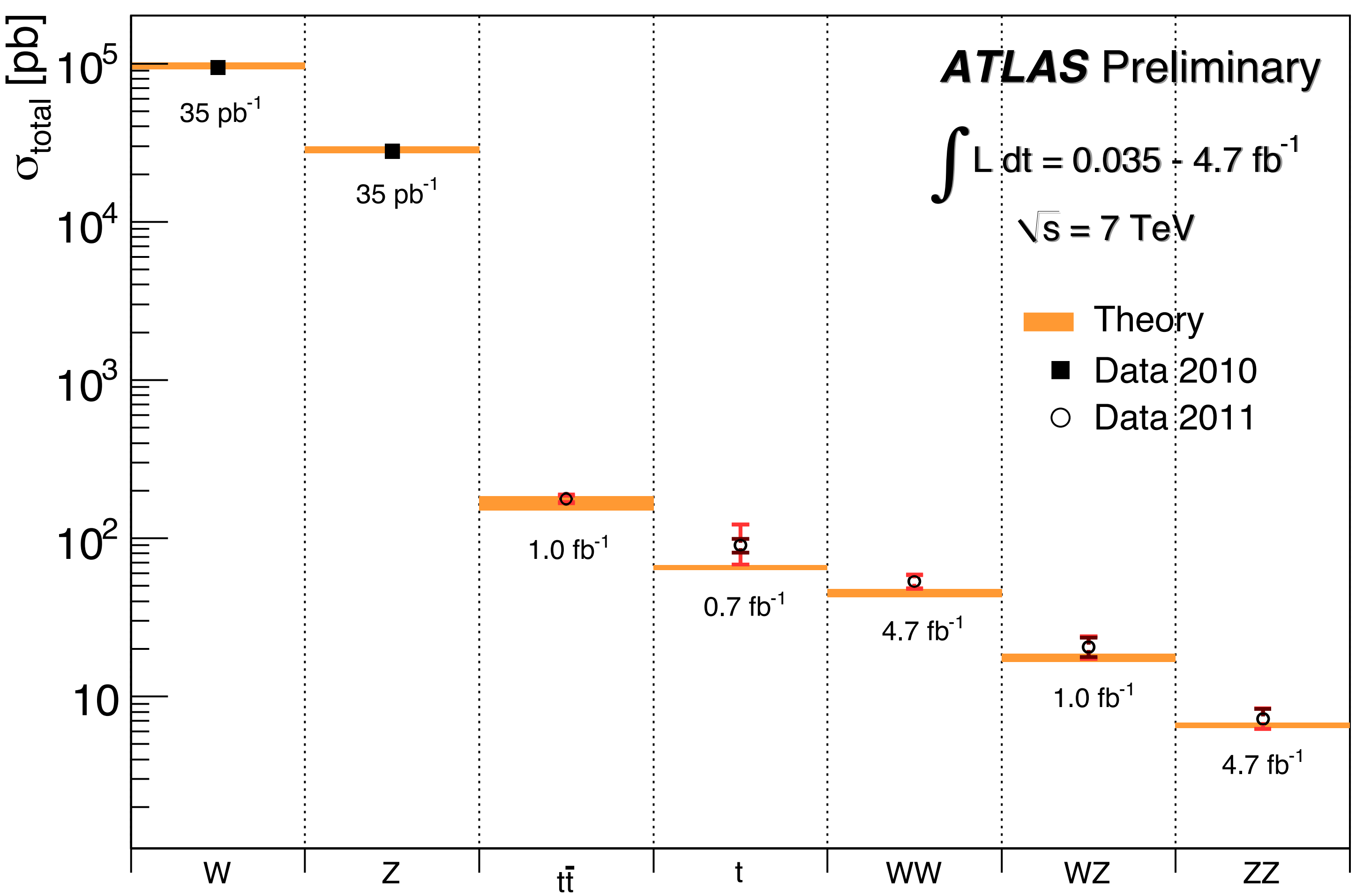
Higher branching fraction but more background than ZZ→4l

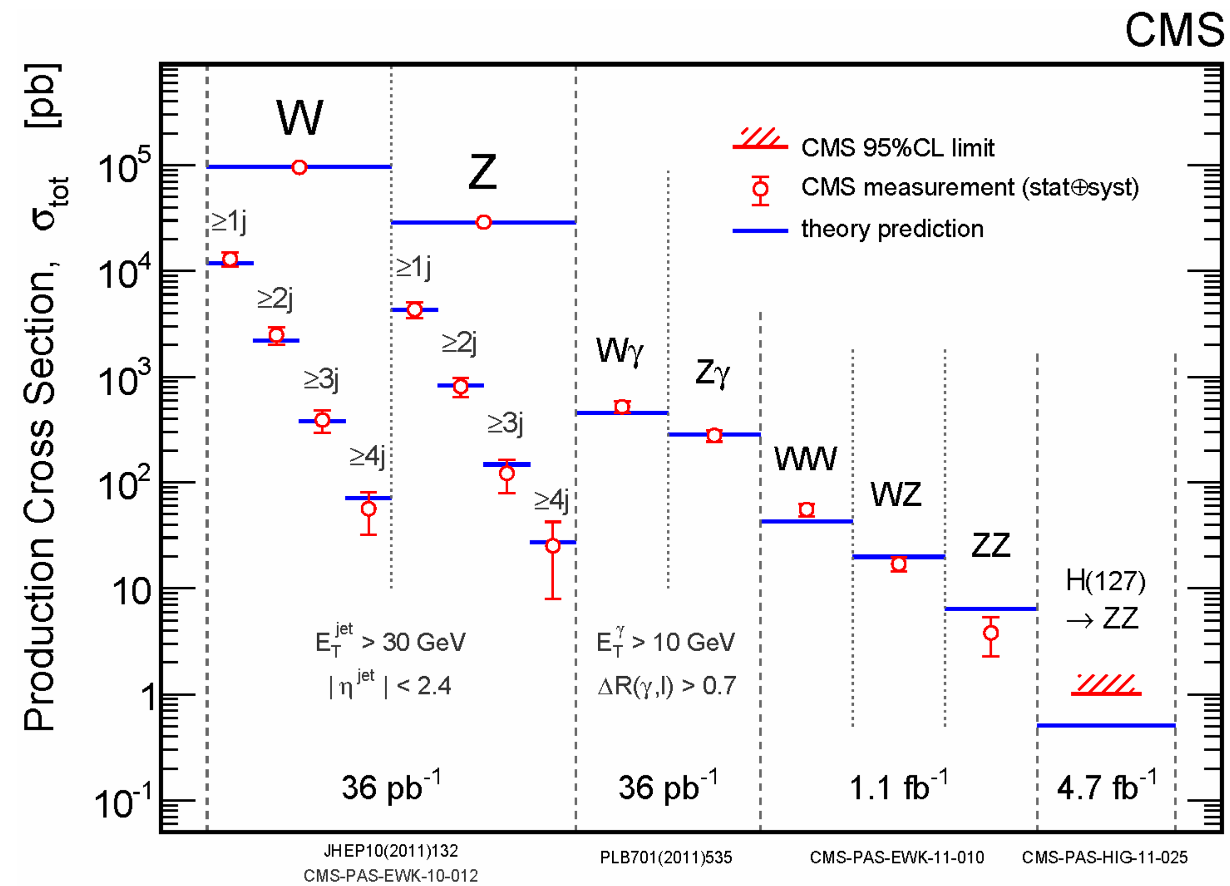
Important background for H→ZZ, ZH(invisible), SUSY

Selection Cuts

- 2 isolated leptons $p_T^{lepton} > 20$ GeV with $|M_{ll} - M_Z| < 15$ GeV
- Axial $E_T^{miss} = E_T^{miss} \cdot \cos \Delta\Phi(E_T^{miss}, p_T^{ll}) > 80$ GeV
- Veto jets with $p_T > 25$ GeV
- $|E_T^{miss} - p_T^{ll}|/p_T^{ll} < 0.6$

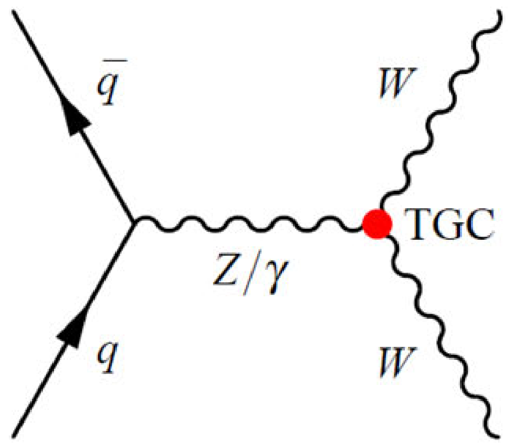
Summary of Diboson Measurements

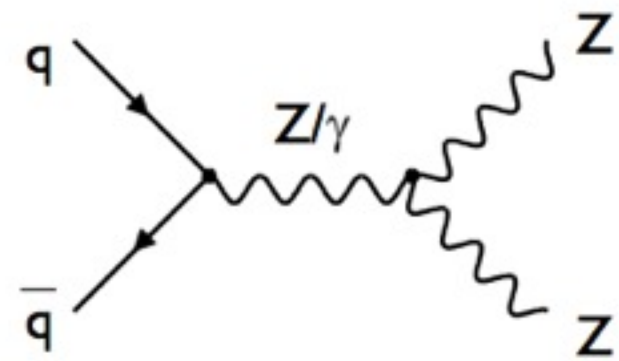


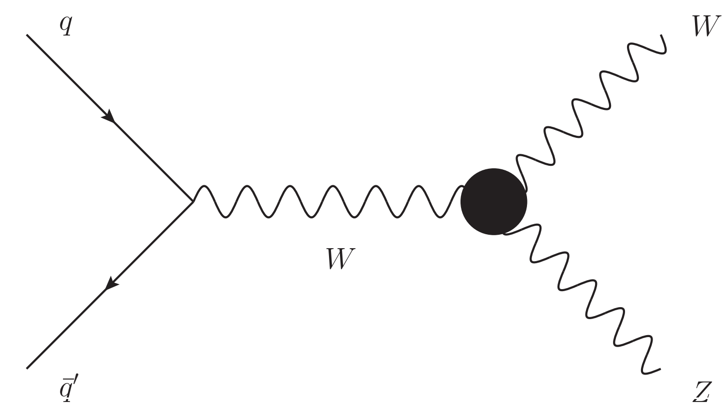


Process	Lumi	σ_{fid} [fb]	stat	syst	lumi	σ_{tot} [fb]	stat	syst	lumi	Reference
WW	5 fb^{-1}	*See reference for each channel*				53.4	±2.1	±4.5	±2.1	ATLAS-CONF-2012-025
WZ	1 fb^{-1}	102	+15 -14	+7 -6	±4	20.5	+3.1 -2.8	+1.4 -1.3	+0.9 -0.8	Phys. Lett. B 709, 341 (2012)
ZZ (→llll)	5 fb^{-1}	21.2	+3.2 -2.7	+1.0 -0.9	±0.8	7.2	+1.1 -0.9	+0.4 -0.3	±0.3	ATLAS-CONF-2012-026
ZZ (→llνν)	5 fb^{-1}	12.2	+3.0 -2.8	±1.9	±0.5	5.4	+1.3 -1.2	+1.4 -1.0	±0.2	ATLAS-CONF-2012-027

Anomalous Triple Gauge Couplings







SM Forbidden

Alternative probe to New Physics : NP contributions to TGCs
➔ Increased x-section at high VV mass

Use effective Lagrangian at low energy << Λ_{NP} (NP scale)

Look for deviation of dimensionless couplings from SM predictions

- Charged TGCs : $g_1^V = k_V = 1, \lambda_V = 0$ for WWV ($V=Z, \gamma$)
- Neutral TGCs : f_4^V (CP-violating), f_5^V (CP-conserving) for $ZZZ, ZZ\gamma$
  $h_{1,2}^V$ (CP-violating), $h_{3,4}^V$ (CP-conserving) for $Z\gamma Z, Z\gamma\gamma$

A suppression factor that depends on Λ_{NP} introduced to conserve unitarity

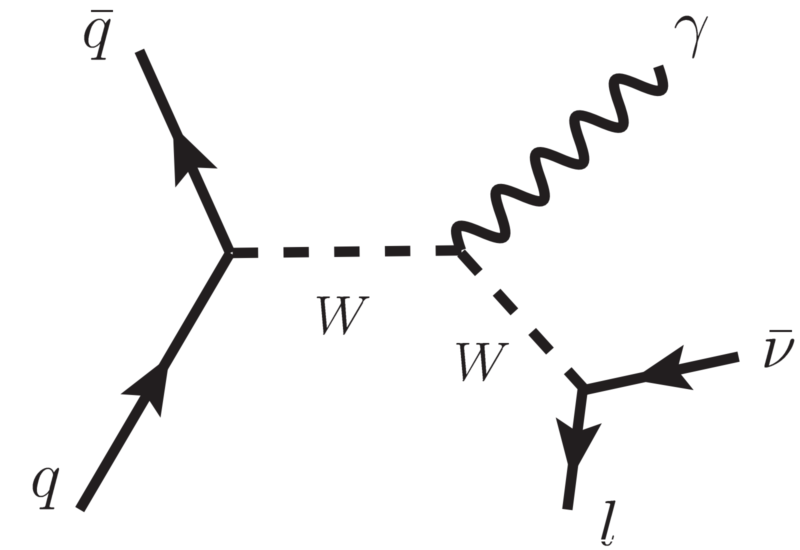
$$\lambda(\hat{s}) = \frac{\lambda}{(1+\hat{s}/\Lambda_{NP}^2)^2}$$

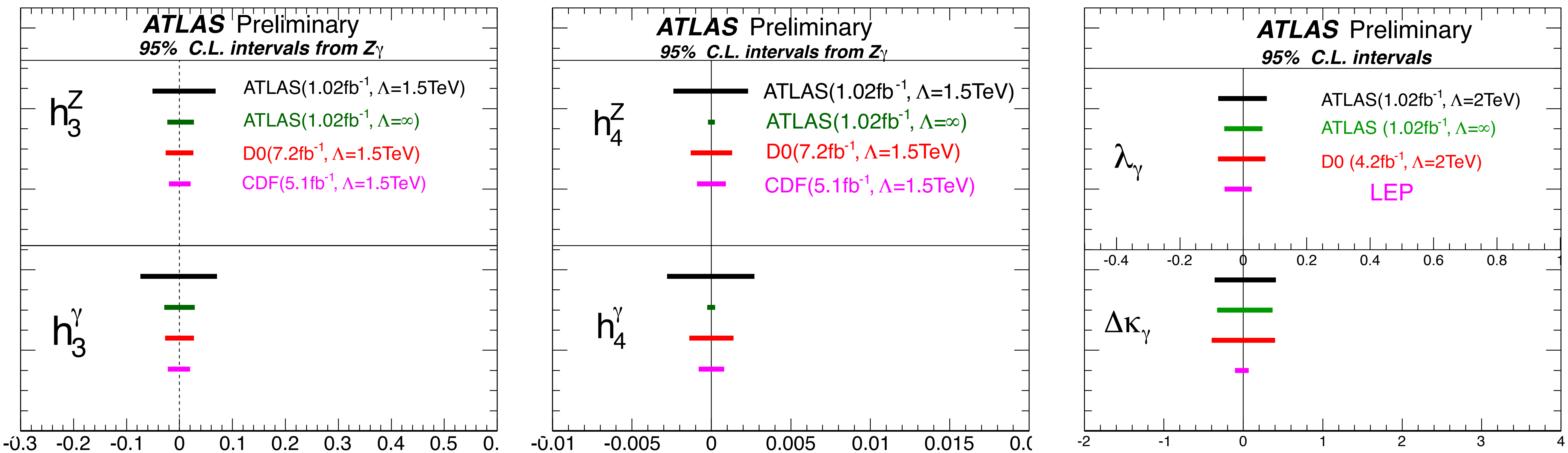
for $\Delta g_1^V = g_1^V - 1$,
$\Delta k_V = k_V - 1$, and λ_V

Results presented for each parameter (fixing others to SM predictions) under different Λ_{NP} assumptions

Anomalous TGCs from Wγ/Zγ

ATLAS Preliminary



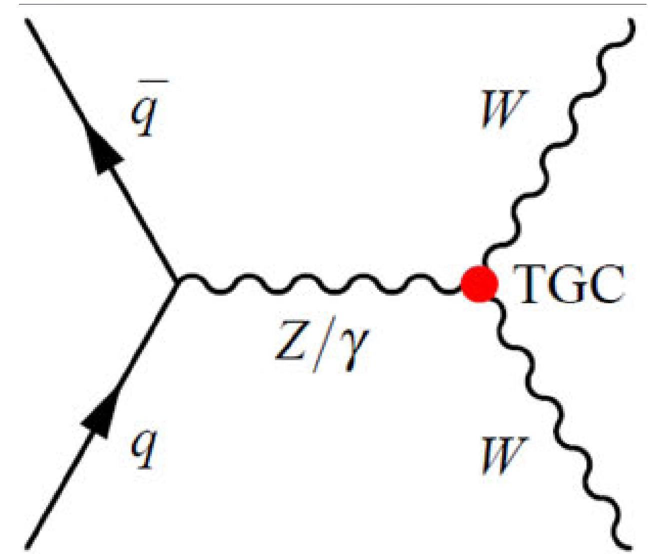


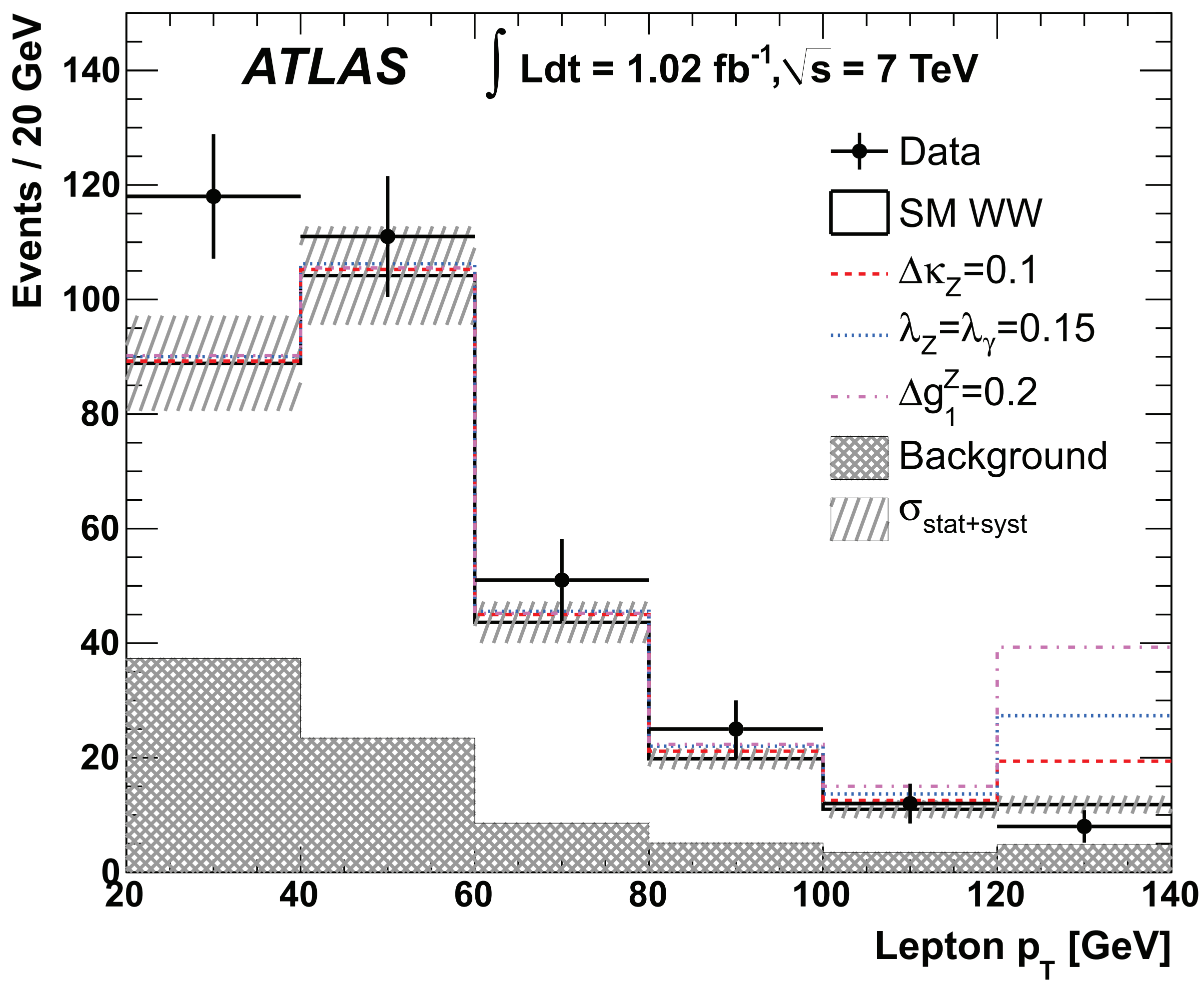
Cross sections of high E_T^γ events (>60 GeV for Zγ, >100 GeV for Wγ) used to extract limits on aTGCs

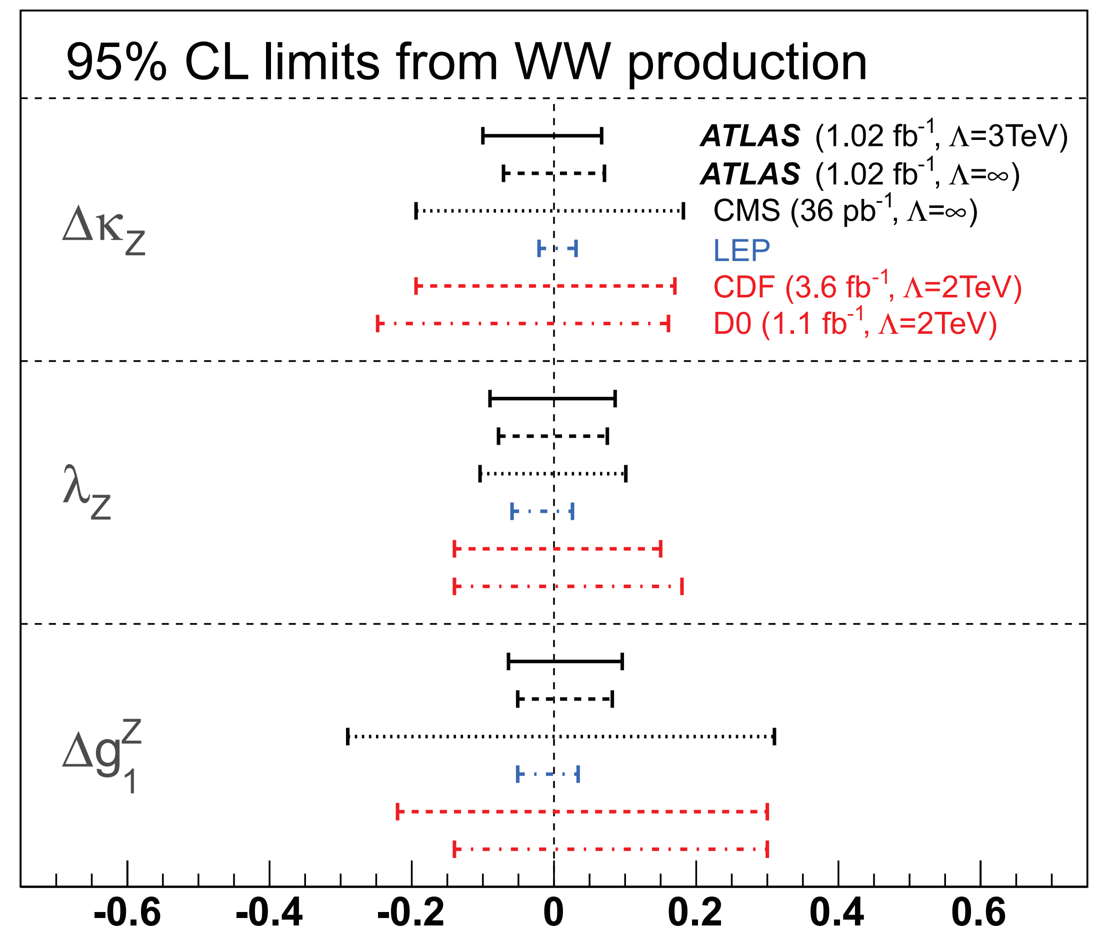
- *NLO predictions with different TGC assumptions simulated using MCFM*
- *Bayesian used to set limits*

Anomalous TGCs from WW

Submitted to PLB
arXiv : 1203.6232



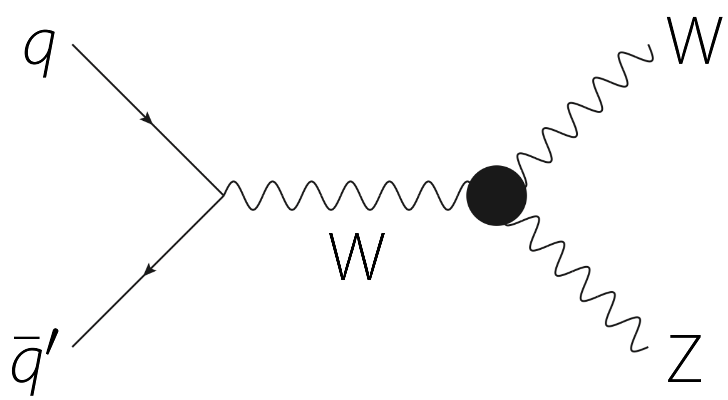


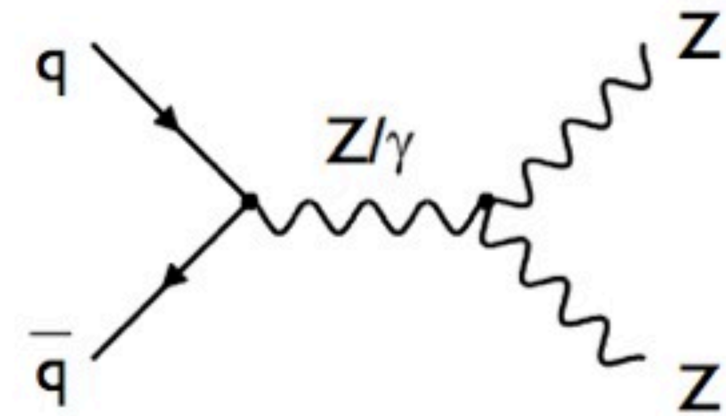


Leading lepton p_T spectra used to place limits on aTGCs from WW

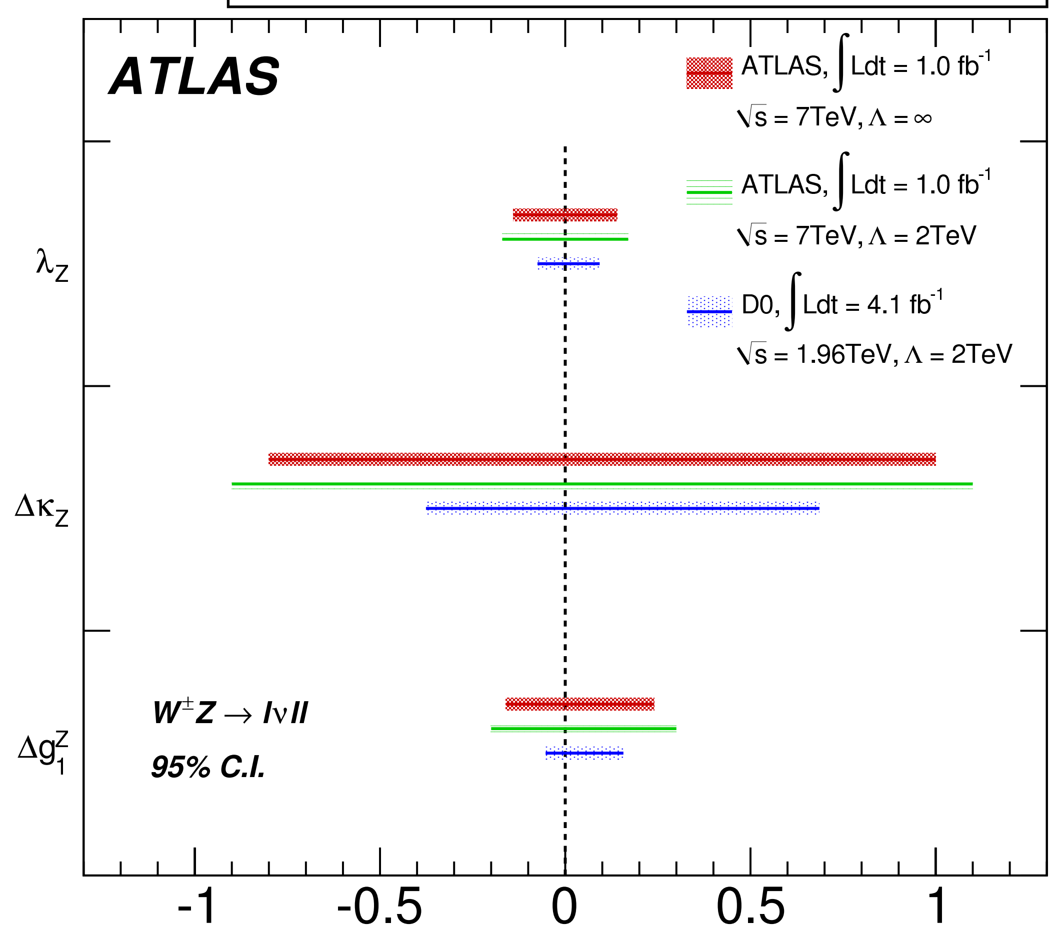
- *Re-weighting used to predict lepton p_T spectra with different TGC assumptions*
- *Binned likelihood fit performed to extract the limits*

Anomalous TGCs from WZ/ZZ

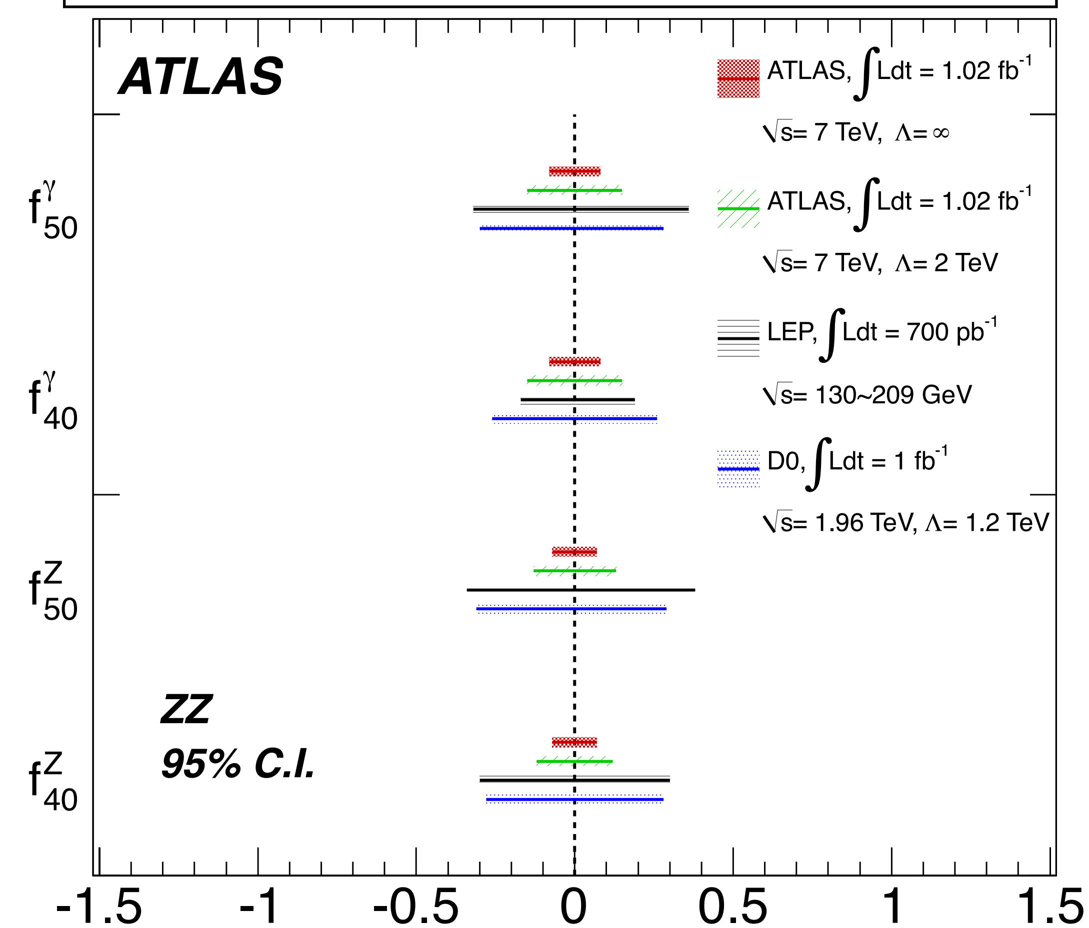




Phys. Lett. B 709, 341 (2012)



Phys. Rev. Lett. 108, 041804 (2012)



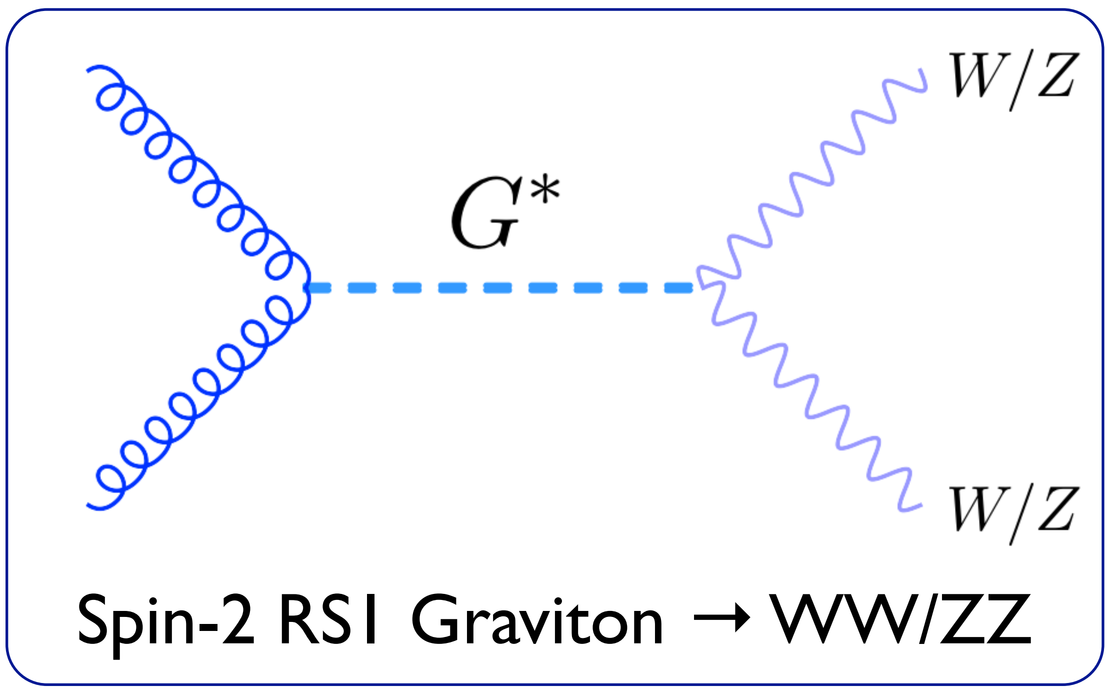
Cross sections used to extract limits on aTGCs

- *Re-weighting used to predict # of expected events with different TGC assumptions*
- *Profile likelihood ratio used to extract the limits*

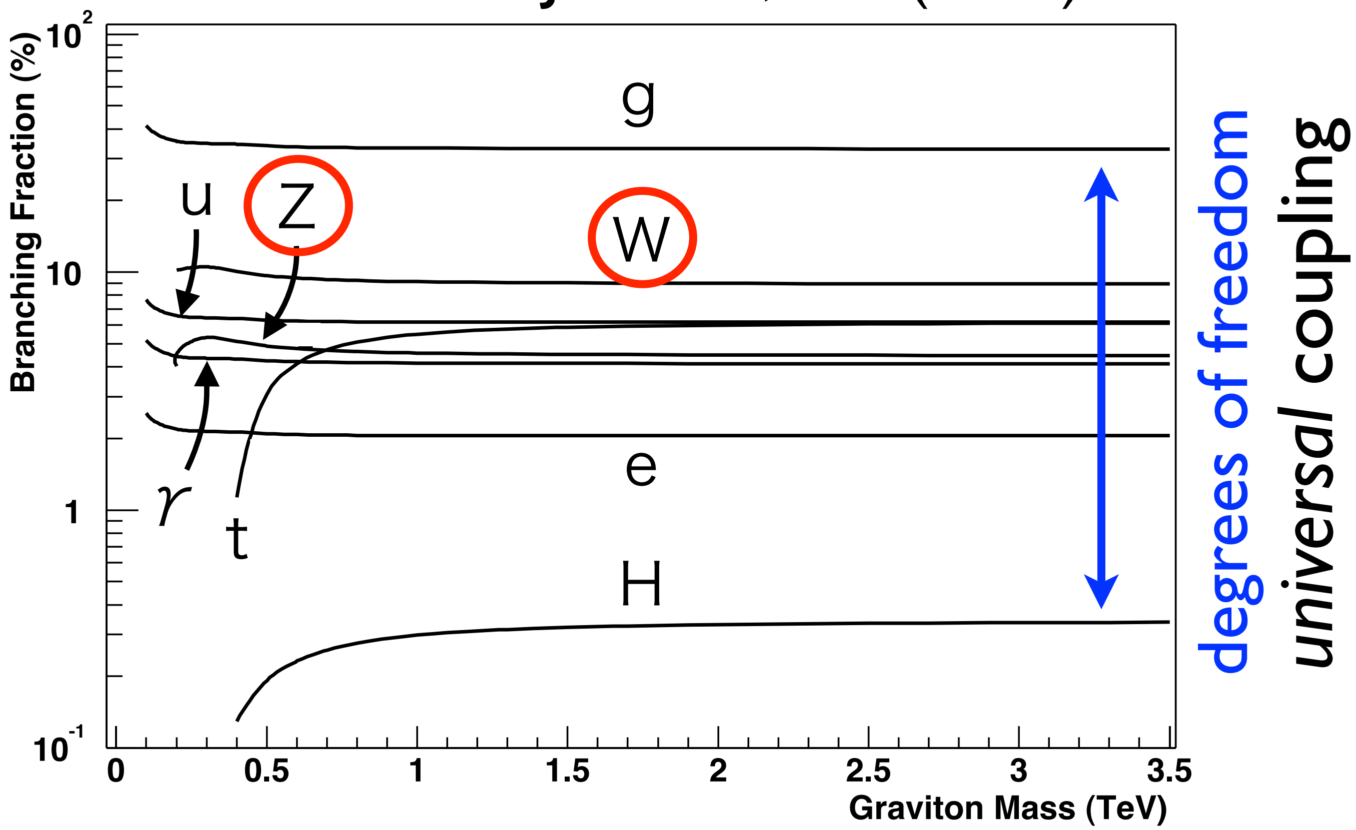
Diboson Resonances

Many BSM models predict new heavy particles that decay to diboson final states for a sizable fraction of time

L. Randall and R. Sundrum (RS1)
Phys. Rev. Lett. 83, 3370 (1999)



B. C. Allanach et al.,
JHEP 12, 039 (2002)

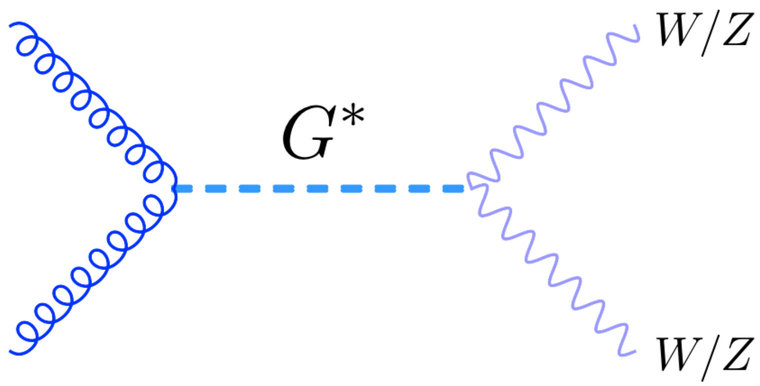


Experimental sensitivity depends a lot on background, detector resolution, systematics, resonance shape, ...

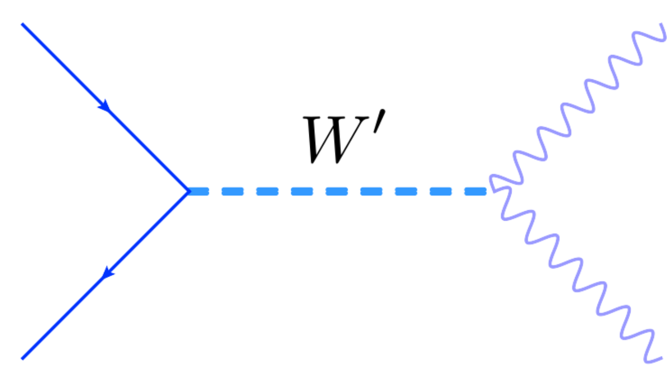
- *Typically dilepton/diphoton final states are more sensitive to RS1*

Diboson *Narrow* Resonances

Use benchmark models in PYTHIA as a baseline

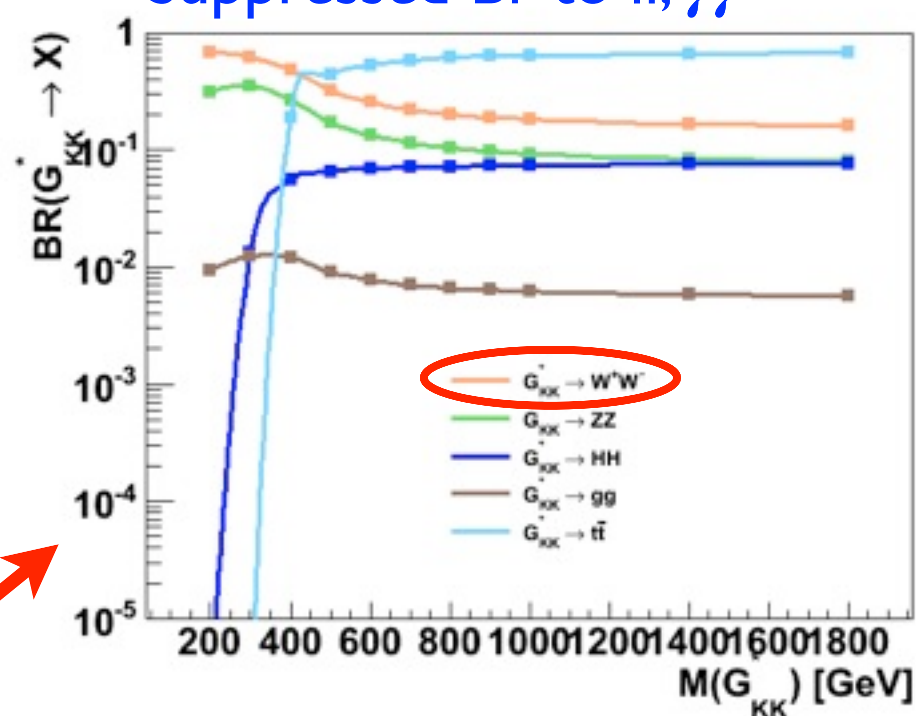


Spin-2 RS1 G* → WW/ZZ



Spin-1 SSM W'-boson → WZ

Br : WW~20%, ZZ~10%
Suppressed Br to ll, $\gamma\gamma$

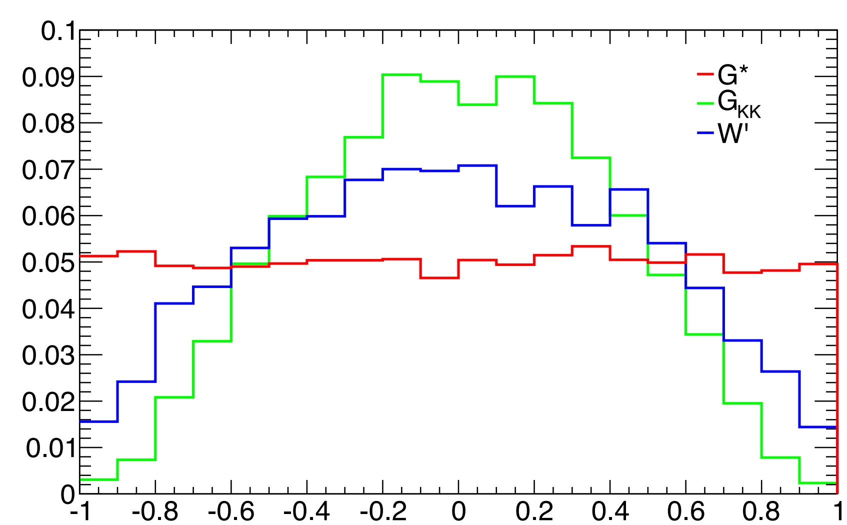


Other interesting models that predict *narrow* diboson resonances

- RS with "SM fields in the bulk" : G* → WW, ZZ, KK Z' → WW (CalcHEP)
- Low-scale technicolor : ρ_T/a_T → WZ, WW, Wγ/Zγ (PYTHIA)
- Minimum walking technicolor : R → WZ, WH, ZH (MadGraph)
- VV resonances in VBS : e.g, qq → qqWW (WHIZARD)

Note:

Spin correlation not implemented in G* decay of PYTHIA RS1



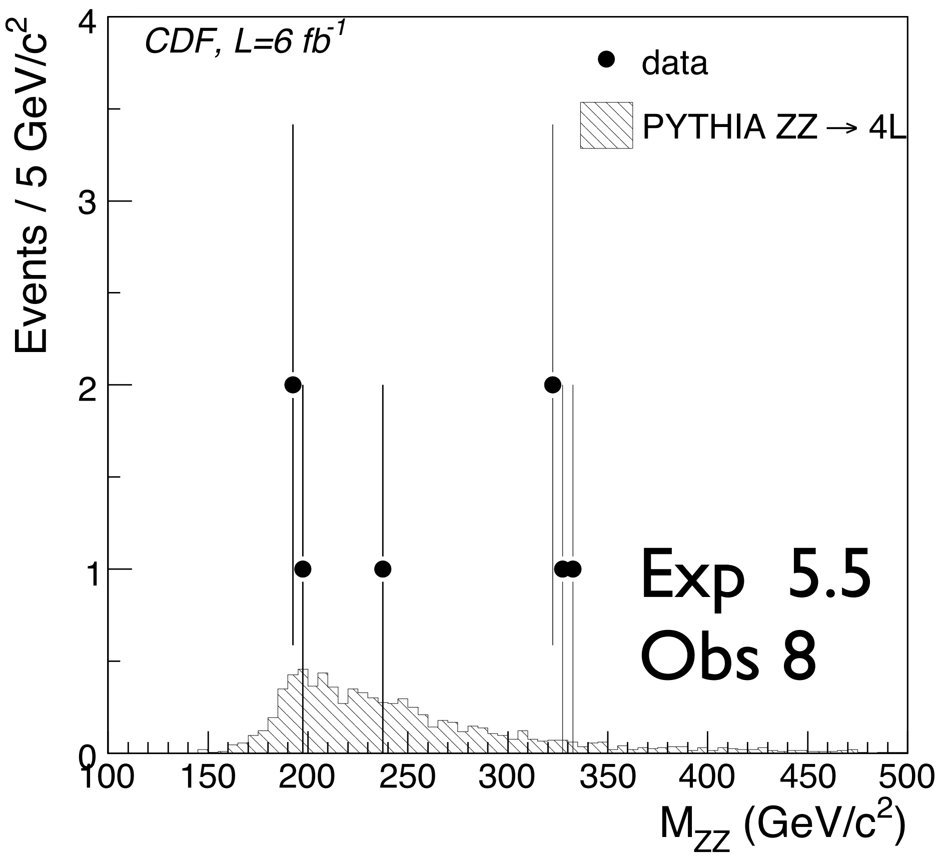
cosθ*

RS1 G* (PYTHIA)
Bulk RS G* (CalcHEP)
SSM W' (PYTHIA)

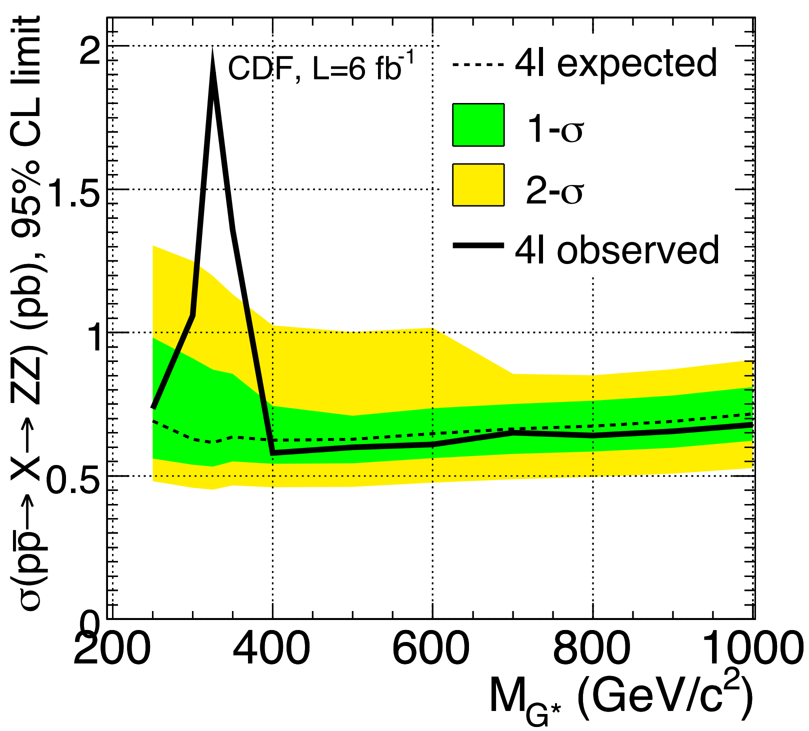
ZZ (→*llll*, *llqq*) Resonance

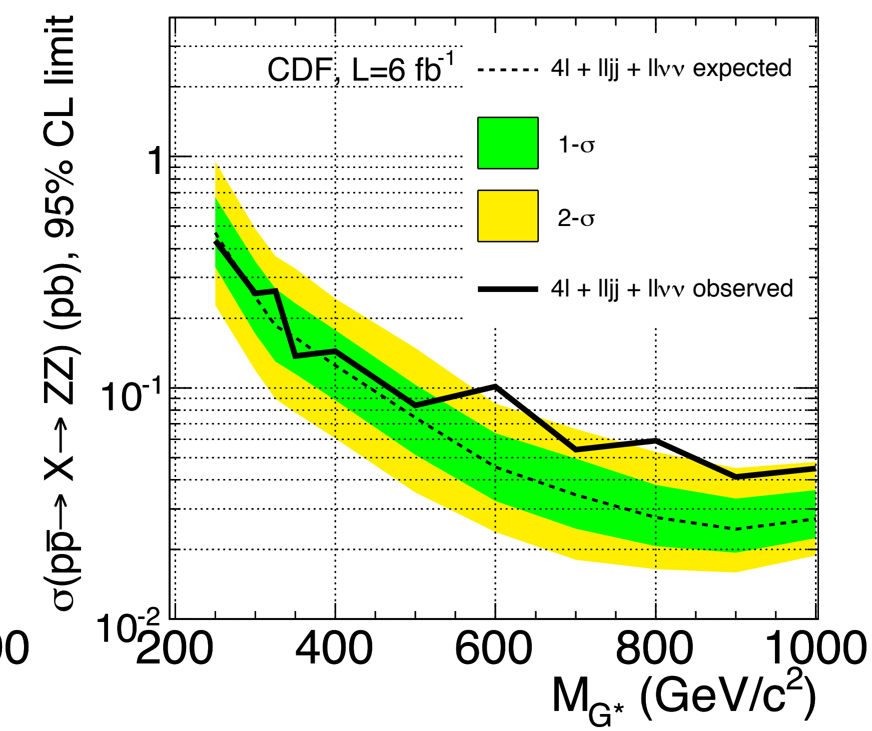
Sensitive to high-mass ZZ resonances over wide mass range
Motivated by CDF 4l events at ~325 GeV (not confirmed by other channels)

M_{ZZ}



CDF 6 fb^{-1} : PRD 85, 012008 (2012)





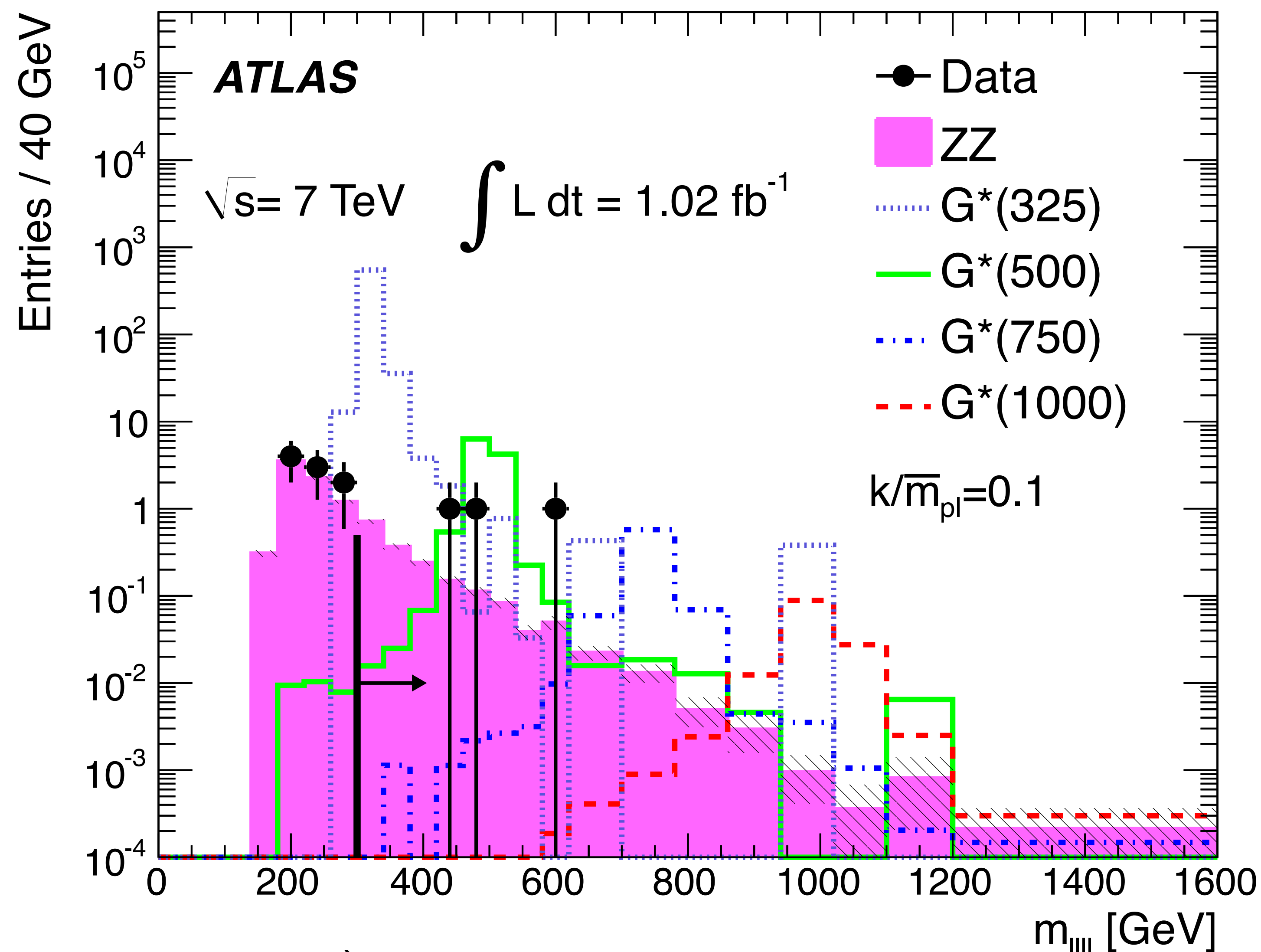
ZZ → ll+ll ➔ Clean signal; very small background; sensitive at low mass
ZZ → ll+qq ➔ Larger branching fraction; sensitive at high mass

Aim to provide fiducial cross section limits for ZZ → ll+ll

ZZ→*llll* : Selection

Submitted to PLB
arXiv : 1203.0718

Process	Events
ZZ	$1.9 \pm 0.1 \pm 0.1$
Fake Leptons	$0.02\ ^{+1.0}_{-0.01}\ ^{+0.8}_{-0.02}$
Total BG	$\mathbf{1.9\ ^{+1.0}_{-0.1}\ ^{+0.8}_{-0.1}}$
Signal M_{G*} = 325 GeV 500 GeV 750 GeV 1000 GeV	 $590 \pm 40 \pm 30$ $71 \pm 3 \pm 4$ $12 \pm 0.5 \pm 0.6$ $1.5 \pm 0.1 \pm 0.1$
Data	**3**



Selection Cuts

- 2 OS SF leptons pairs (eeee, eeμμ, μμee, μμμμ) with $p_T^{lepton} > 15$ GeV
- $|M_{ll} - M_Z| < 25$ GeV
- $M_{ZZ} > 300$ GeV

$ZZ \rightarrow llll$: Background and Systematics

Background

- SM ZZ from MC
- Misidentified leptons from data
  - WZ+jets
  - Z+X (jets or photons)
  - $t\bar{t} \rightarrow bb + l\nu l\nu$

Systematics

- Luminosity
- Lepton efficiency : 3-6% for e, 1-2% for μ
- Misidentified leptons
  - Limited WZ(→3l)+jets sample
  - heavy vs light flavor jets

Misidentified lepton background estimated by

- selecting events with 3 real leptons + "lepton-like" jet
- applying *fake factor = Prob(jet → lepton cut) / Prob.(jet → "lepton-like" jet cut)* obtained from jet-dominant control sample
- correcting for real lepton contamination and double counting

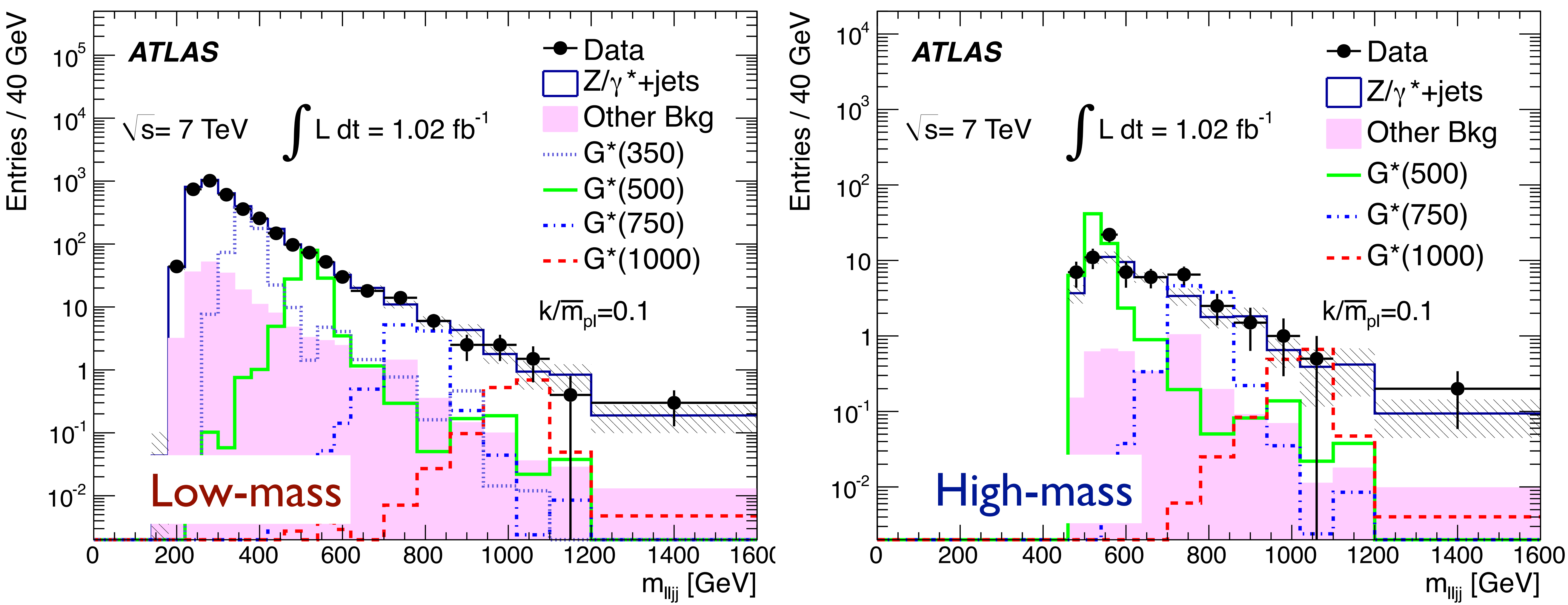
ZZ background modeling checked at M_{ZZ} < 300 GeV

Process	eeee	μμμμ	eeμμ
ZZ	1.3 ± 0.1 ± 0.1	2.5 ± 0.1 ± 0.1	3.6 ± 0.1 ± 0.1
Fake Leptons	$0.01\ ^{+0.02}_{-0.01}\ ^{+0.02}_{-0.01}$	$0.3\ ^{+0.9}_{-0.3} \pm 0.2$	$0.0\ ^{+1.0}_{-0.0}\ ^{+0.8}_{-0.0}$
Total BG	**1.3 ± 0.1 ± 0.1**	**$2.7\ ^{+0.9}_{-0.3} \pm 0.3$**	**$3.6\ ^{+1.0}_{-0.1}\ ^{+0.8}_{-0.1}$**
Data	**2**	**6**	**1**

$ZZ \rightarrow llqq$: Selection

Selection Cuts

- 2 SF leptons with p_T > 20 GeV and $|M_{ll} - M_Z| < 25$ GeV
- $65 < M_{jj} < 115$ GeV
- Low-mass selection = $p_T^{ll} > 50$ GeV + $p_T^{jj} > 50$ GeV
- High-mass selection = $p_T^{ll} > 200$ GeV + $p_T^{jj} > 200$ GeV



ZZ→*llqq* : Background and Systematics

Background

- Z+jets from data-driven method
  - Define control regions :
    M_{jj}<65 GeV or M_{jj}>115 GeV
  - Use M_{jj} sidebands to determine MC (ALPGEN) normalization
  - Systematic uncertainty from normalization difference between M_{jj} sidebands
  - Cross check with SHERPA and MCFM
- Top, Diboson, W+jets from MC

Process	Low-mass	High-mass
Z+jets	3530 ± 190	60 ± 27
Top	81 ± 25	0.4 ± 0.3
Diboson	92 ± 14	4 ± 1
W + jets	9 ± 5	1 ± 1
Multijet	14 ± 14	0.2 ± 0.2
Total BG	**3720 ± 200**	**66 ± 27**
Signal	680 ± 120 (M_{G^*} = 350 GeV)	21 ± 4 (M_{G^*} = 750 GeV)
Data	**3515**	**85**

Systematics

- Z+jets background modeling (~40%)
- Top (~25%), Diboson (7%), W+jets (40%)
- JES (~13%)
- Lepton efficiency, scale & resolution (1-2%)
- PDF, ISR/FSR (signal)

$ZZ \to llll$: Fiducial Limits

Signal acceptance and selection efficiency to get limits on new theory

Fiducial Region

- $p_T > 15$ GeV, $|\eta| < 2.5$
- 2 OS SF pairs leptons (e, μ)
- $66 < M_{ll} < 116$ GeV
- $M_{ZZ} > 300$ GeV

Cross section limits within fiducial region

$$\sigma_{ZZ}^{Fid} < \frac{N_{ZZ}}{\varepsilon_{ZZ} \times Br(ZZ \to llll) \times L} = \frac{5.7}{0.61 \times 0.01 \times 1.02} = 0.92 \text{ pb}$$

Reco & ID efficiency

- Largely process independent

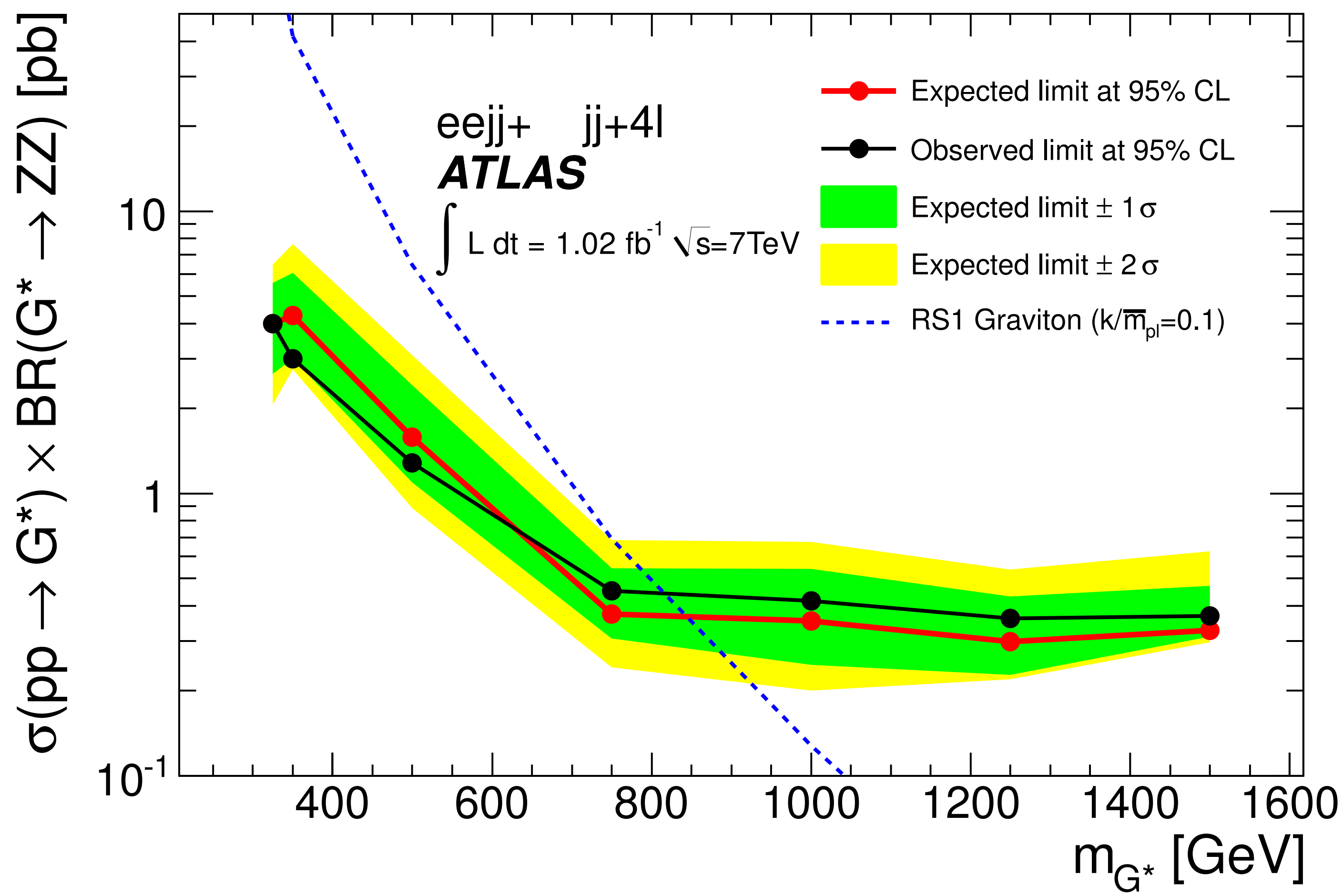
Graviton Mass [GeV]	Theory [pb]	Fid. Acceptance	Sel. Efficiency	Exp. Limit [pb]	Obs. Limit [pb]
325	950	23%	61%	4.0	4.0
350	42	27%	61%	3.3	3.3
500	6.5	28%	63%	3.2	3.2
750	0.69	31%	66%	2.9	2.9
1000	0.13	32%	66%	2.8	2.8
1250	0.03	33%	67%	2.7	2.7
1500	0.01	35%	66%	2.6	2.6

Need parton-level fiducial acceptance for new theory

ZZ→*llll, llqq* : Limits

95% CL observed limits on σ·Br

Graviton Mass [GeV]	eejj [pb]	μμjj [pb]	lljj [pb]	llll [pb]	llll + lljj [pb]
325	-	-	-	4.0	4.0
350	8.9	11.6	10.9	3.3	3.0
500	2.3	1.8	2.1	3.3	1.3
750	0.9	0.5	0.5	2.9	0.5
1000	0.6	0.7	0.5	2.8	0.4
1250	0.7	0.6	0.4	2.8	0.4
1500	0.7	0.9	0.4	2.6	0.4



Set 95% CL limits on σ·Br for the RS1 G^* signal ($k/\overline{m}_{Pl}$ = 0.1)

- *Modified frequentist approach with LLR test statistic*

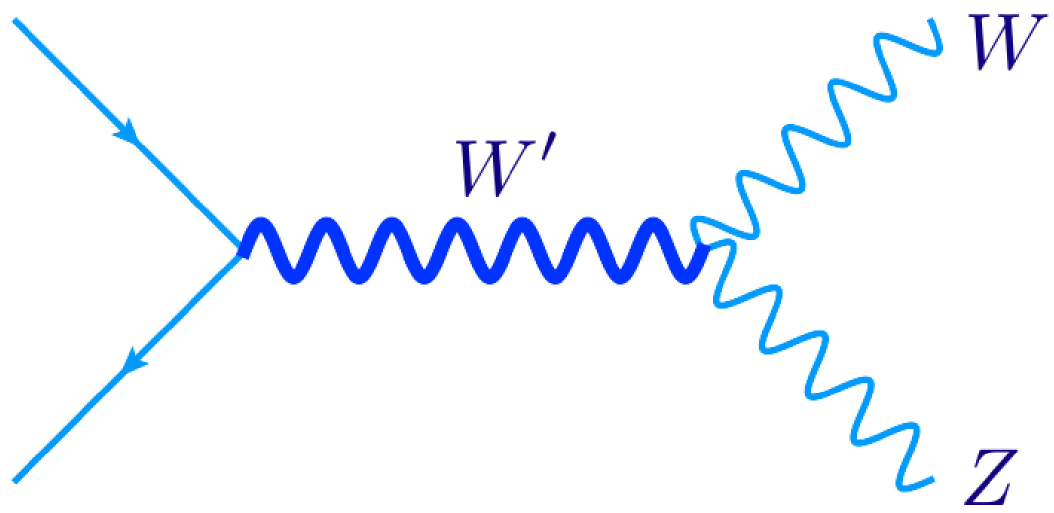
RS1 Graviton ($k/\overline{m}_{Pl}$ = 0.1) excluded within 325-845 GeV at 95% CL

WZ (→*lνll*) Resonance

Submitted to PRD
arXiv : 1204.1648

Resonance search in WZ → 3-lepton final state

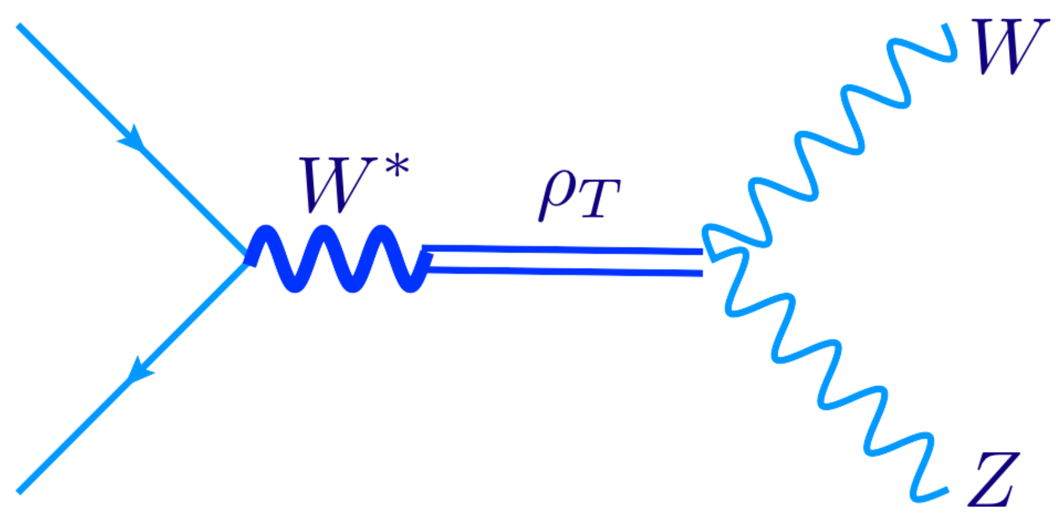
Small branching fraction but also small background (dominated by SM WZ)



G. Altarelli et al., Z. Phys. C 45, 109 (1989)

EGM W' → WZ

- Predominantly longitudinal W/Z
- W'WZ coupling is given by SM WWZ coupling × $M_{W'} M_Z / M_{W'}^2$



LSTC ρ_T/a_T → WZ

W/Z polarization not accounted for in ρ_T decay in PYTHIA
➔ slightly lower A×ε than W'

Analysis strategy

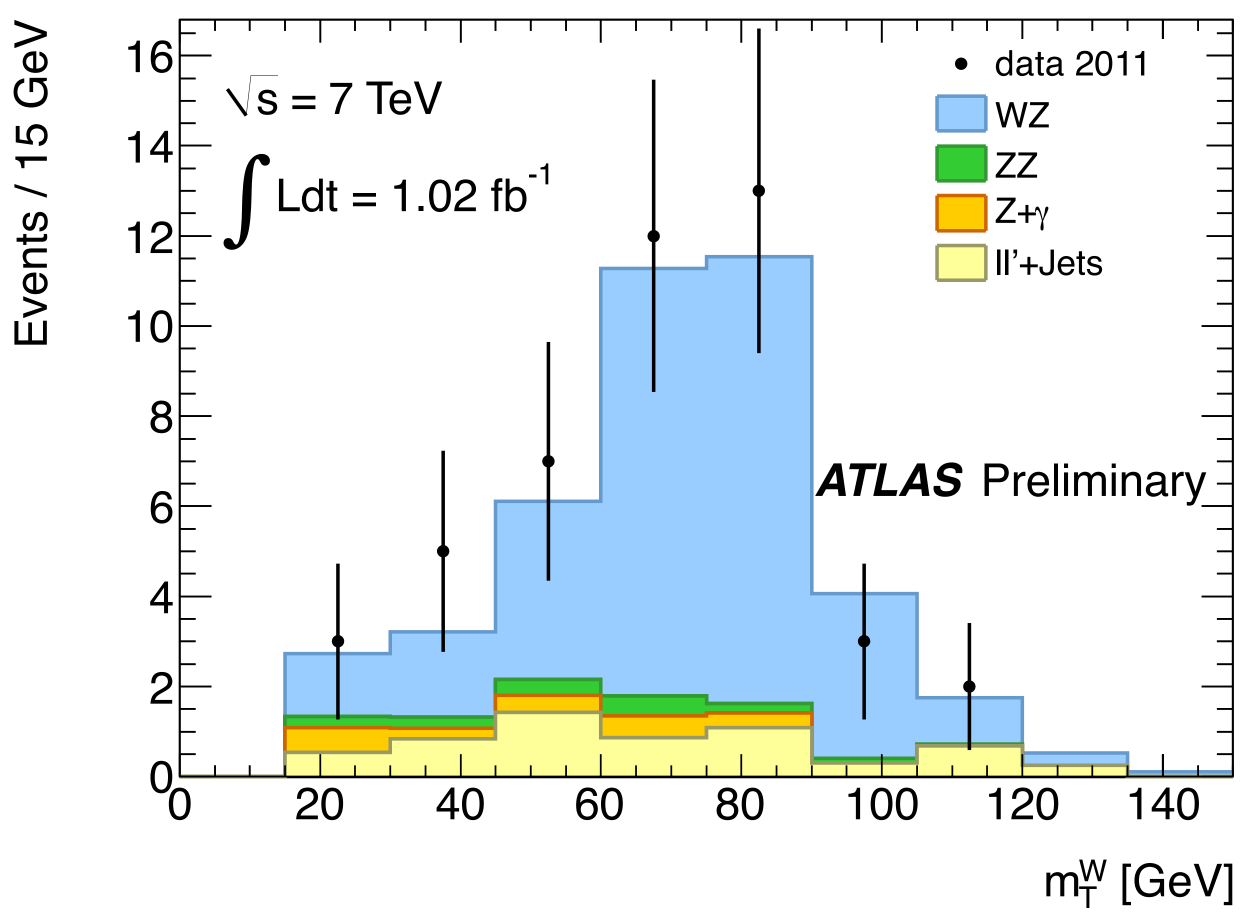
- Select events with 3 leptons and E_T^{Miss}
- Background modeling checked in control region data
- Look for excess events in M_T^{WZ}

WZ→*lνll* : Selection

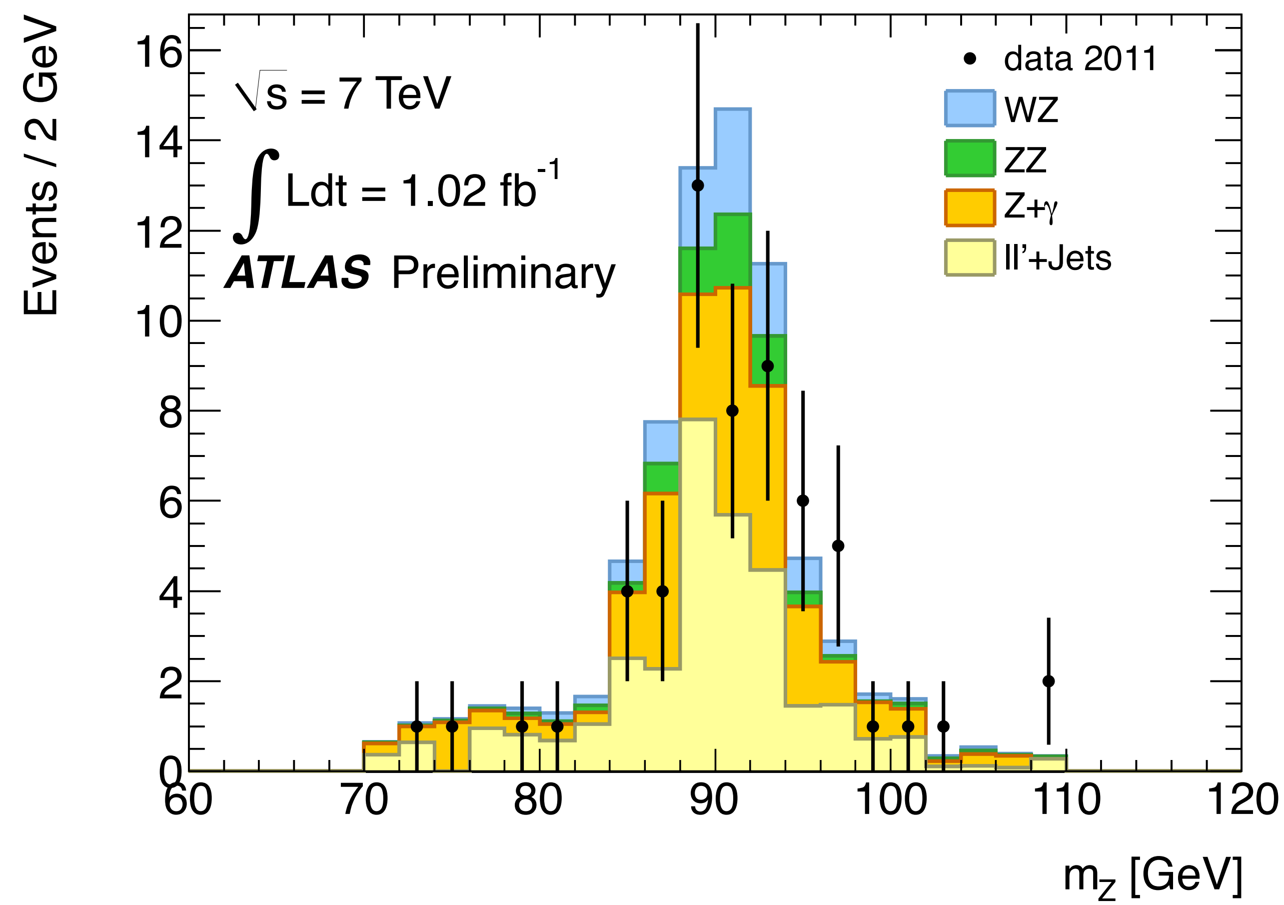
Selection Cuts

- Exactly 3 leptons $p_T^{lepton} > 25$ GeV (veto 4th one)
- At least one pair of $|M_{ll} - M_Z| < 20$ GeV
- $E_T^{Miss} > 25$ GeV
- $M_T^W > 15$ GeV

Background modeling checked in control regions



WZ background (MC@NLO)
➔ $M_T^{WZ} < 300$ GeV



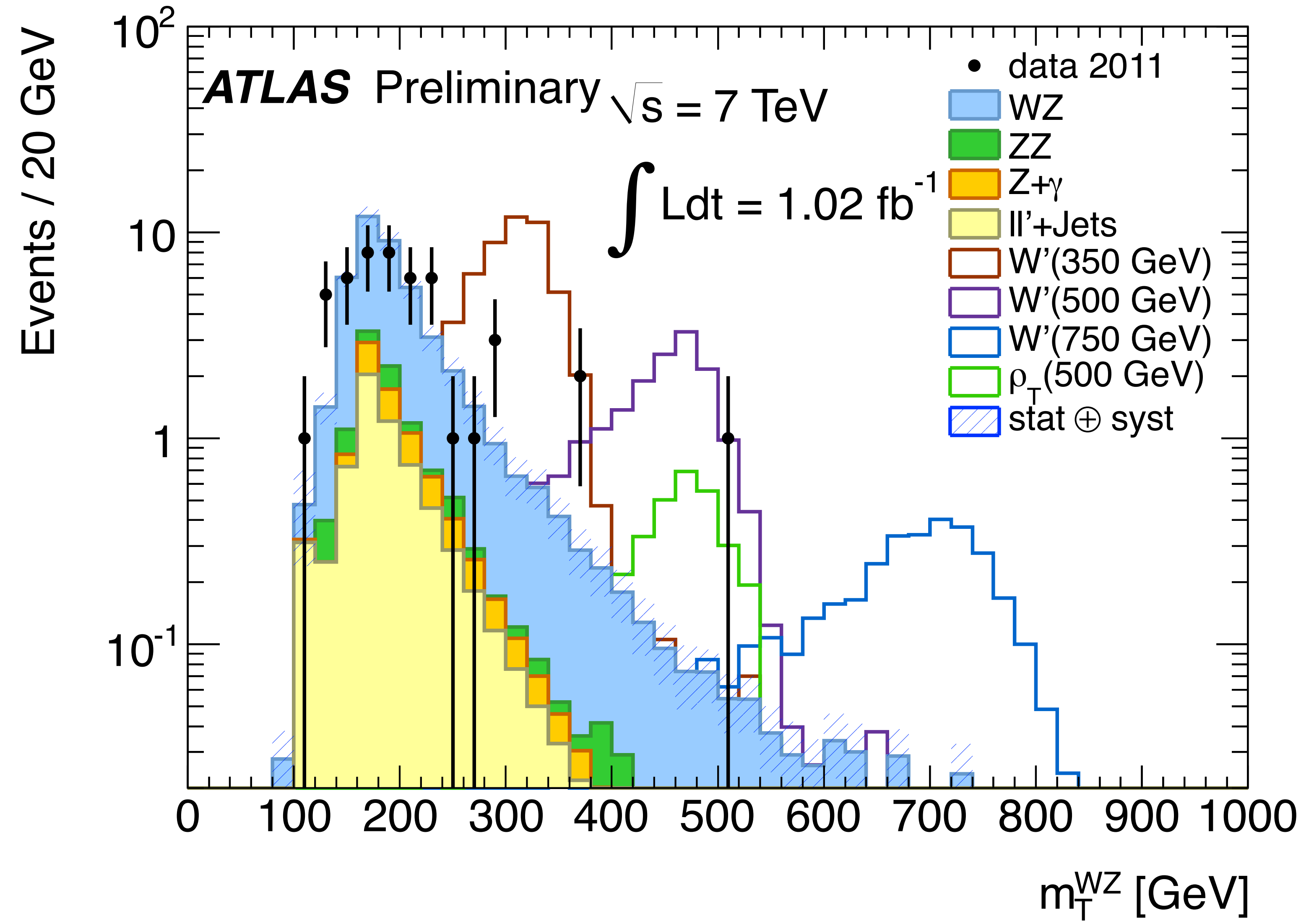
ll'+jets background (data-driven)
➔ $E_T^{Miss} < 25$ GeV

WZ→*lνll* : Data

Statistical significance of data assessed using log-likelihood ratio built from M_T^{WZ} and pseudo-experiments

Lowest p-value (= 1 − CL_b) = 0.19 at M_T^{WZ} = 550 GeV

➔ No significant excess found in data

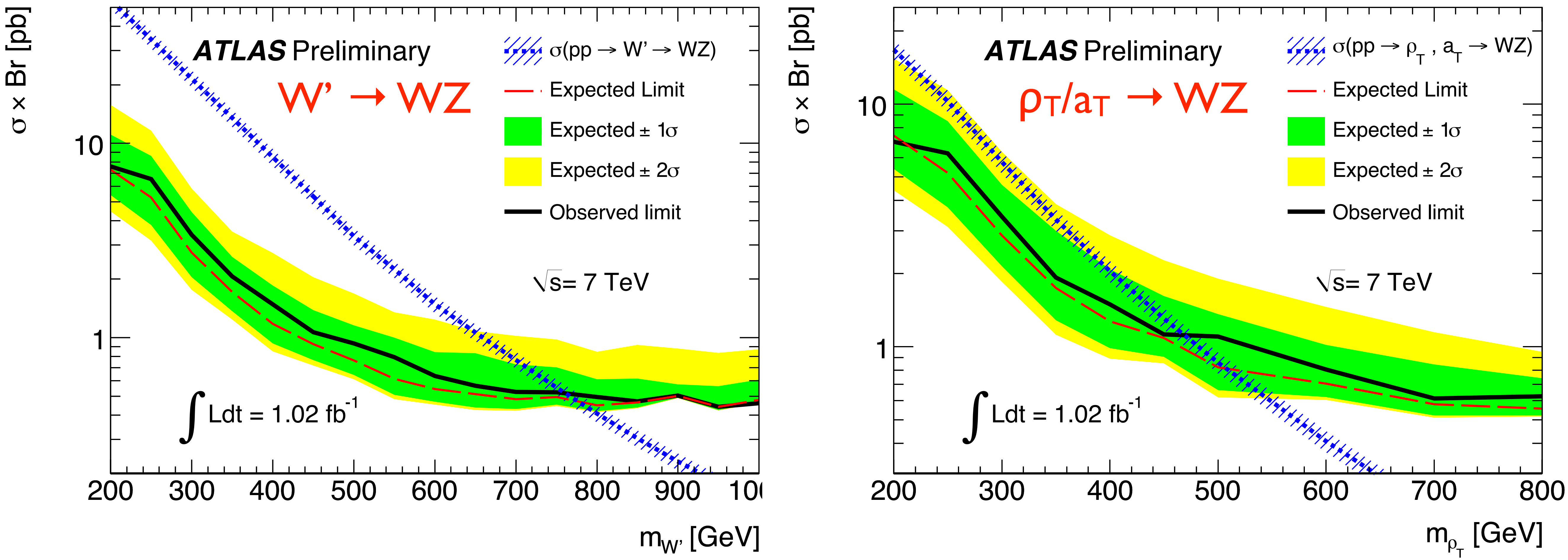


Process	eνee	μνee	eνμμ	μνμμ	Combined
WZ	6.2 ± 0.2 ± 0.5	7.6 ± 0.2 ± 0.5	9.2 ± 0.2 ± 0.5	11.6 ± 0.2 ± 0.6	34.6 ± 0.4 ± 1.9
ZZ	$0.25 \pm 0.06^{+0.04}_{-0.09}$	$0.48 \pm 0.09^{+0.11}_{-0.09}$	$0.37 \pm 0.07^{+0.13}_{-0.09}$	$0.63 \pm 0.10^{+0.13}_{-0.04}$	$1.7 \pm 0.2^{+0.4}_{-0.2}$
Zγ	1.3 ± 0.6 ± 0.4	-	1.0 ± 0.4 ± 0.8	-	$2.3 \pm 0.7^{+1.1}_{-0.6}$
ll'+jets	1.1 ± 0.4 ± 0.7	$1.3 \pm 0.5^{+0.6}_{-0.8}$	$3.0 \pm 0.7^{+1.6}_{-1.9}$	$1.0 \pm 0.4^{+0.5}_{-0.6}$	$6.4 \pm 1.0^{+3.2}_{-4.0}$
Total BG	**8.9±0.8±1.0**	$\mathbf{9.3 \pm 0.5^{+0.8}_{-1.0}}$	$\mathbf{13.6 \pm 0.8^{+2.0}_{-2.2}}$	$\mathbf{13.2 \pm 0.5^{+0.9}_{-1.0}}$	$\mathbf{45.0 \pm 1.3^{+4.2}_{-4.7}}$
Data	**9**	**7**	**16**	**16**	**48**

WZ→*lνll* : Limits

$\rho_T(A\times\varepsilon)$ as implemented in PYTHIA

$M_{aT} = 1.1 M_{\rho T}$

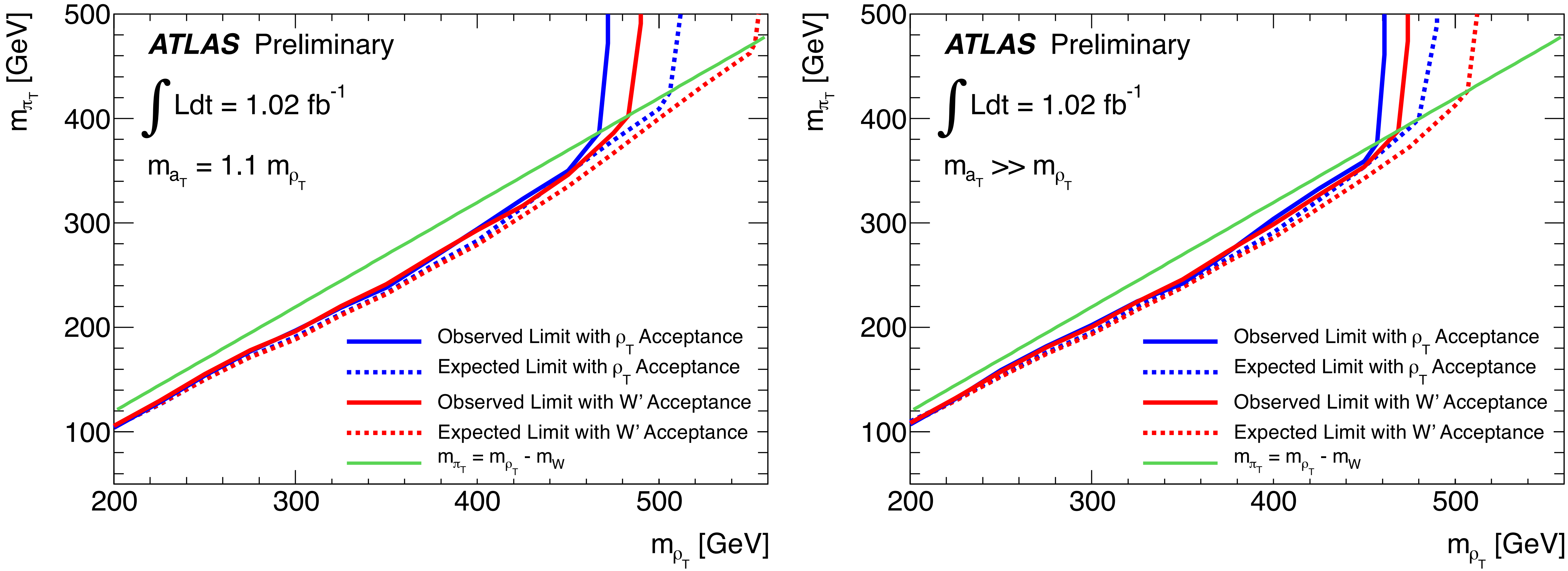


Set 95% CL limits on $\sigma\cdot$Br for the W' and ρ_T signal using

- *Finely binned signal templates*
- *Modified frequentist approach with LLR test statistic*

$\sigma\cdot$Br < 0.5 pb for $M_{W'}$=800 GeV, < 0.6 pb for $M_{\rho T}$ =700 GeV

WZ→*lνll* : Limits on ($M\rho_T$, $M\pi_T$)



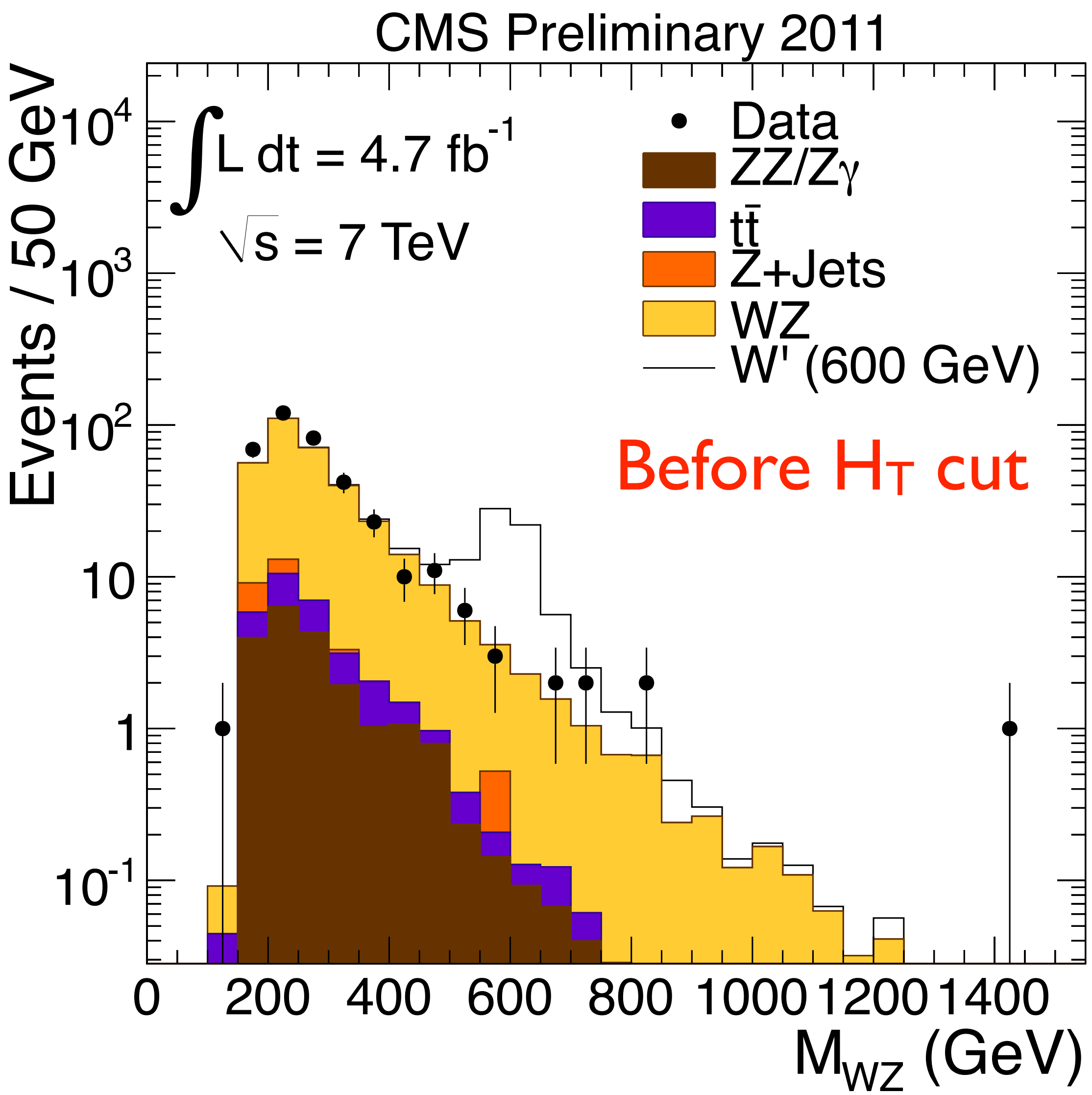
95% CL excluded mass regions in ($M_{\rho T}$, M_{aT}) plane assuming acceptance for W' and ρ_T as implemented in PYTHIA

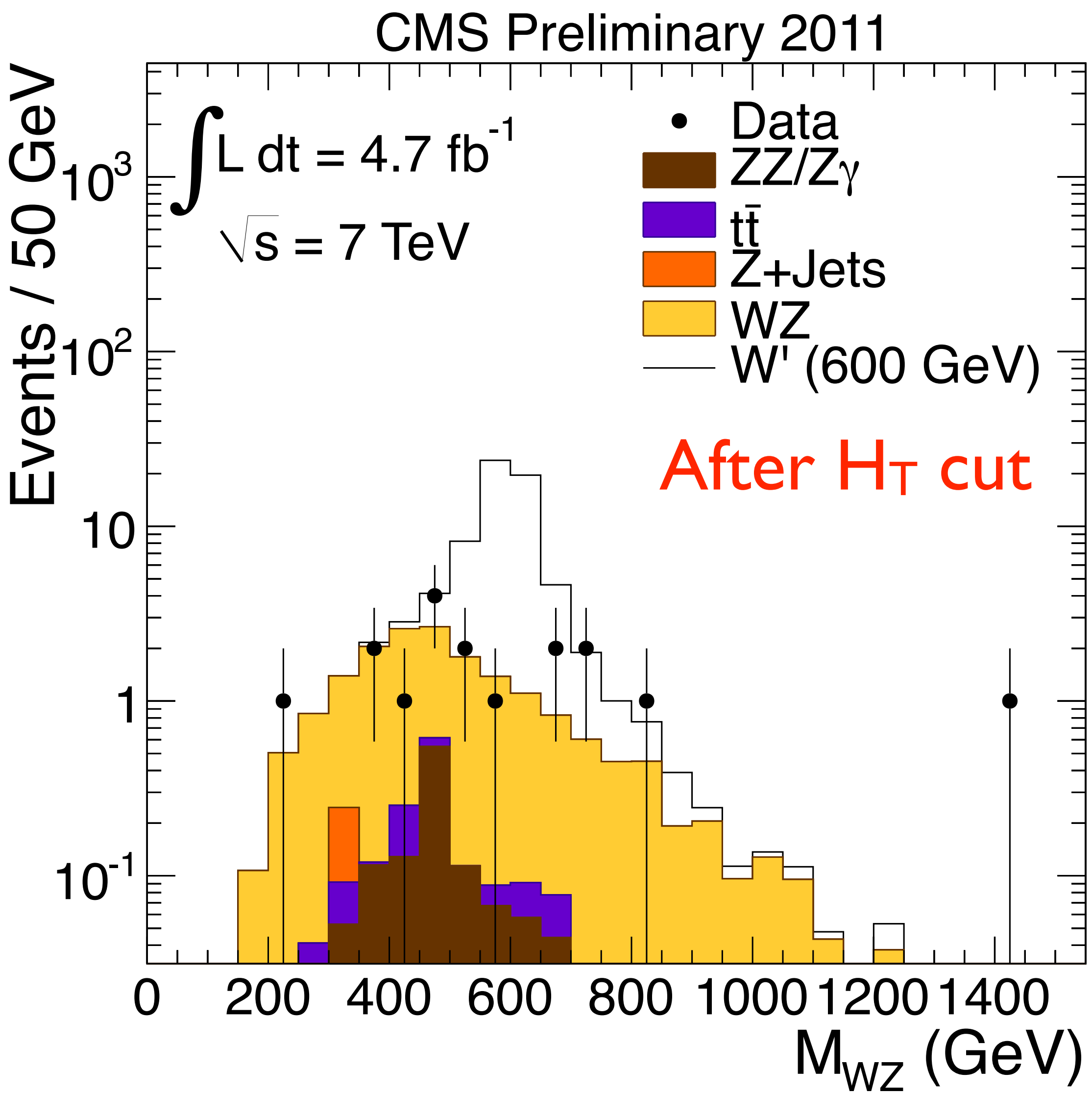
- *with 2 mass assumptions for a_T and ρ_T*

Acceptance × Efficiency from	$M_{aT} = 1.1 M_{\rho T}$	$M_{aT} >> M_{\rho T}$
EGM W'	**483** (553)	**469** (507)
LSTC ρ_T (PYTHIA)	**467** (506)	**456** (482)

WZ (→*lνll*) Resonance

CMS-PAS-EXO-11-041

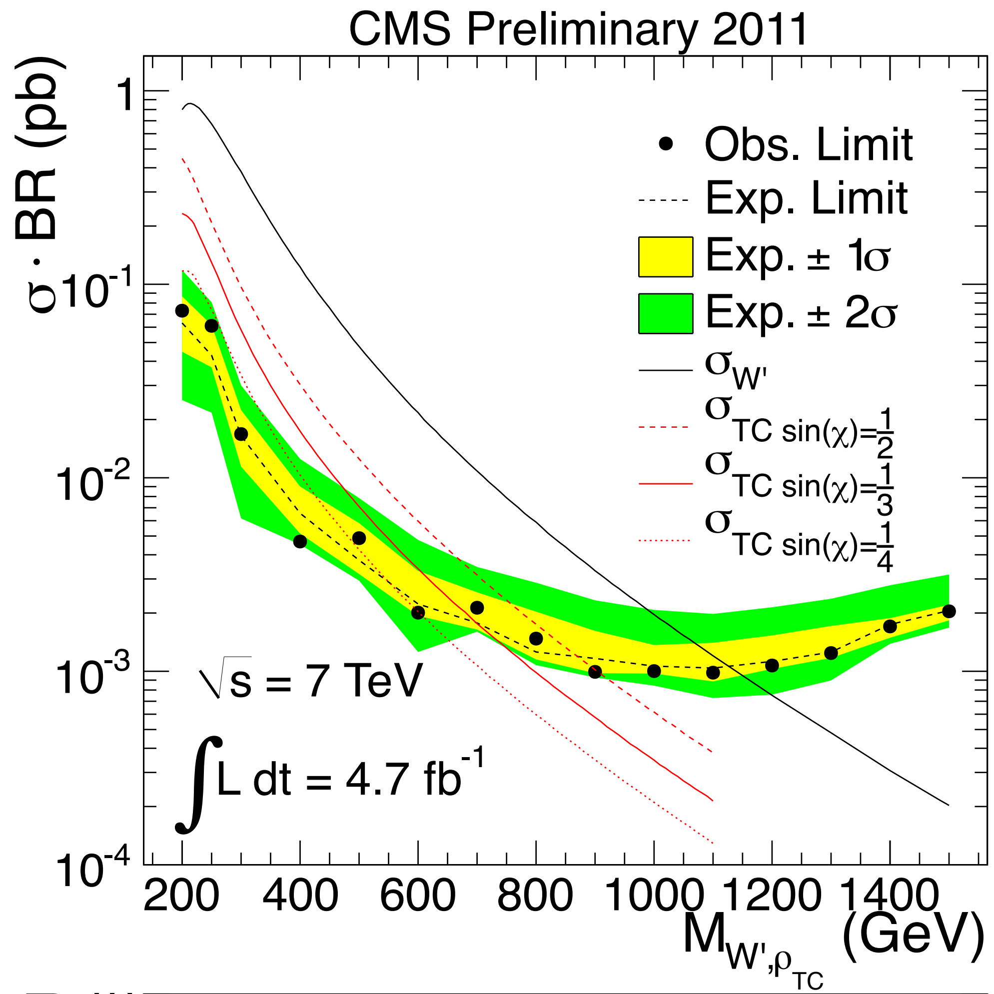


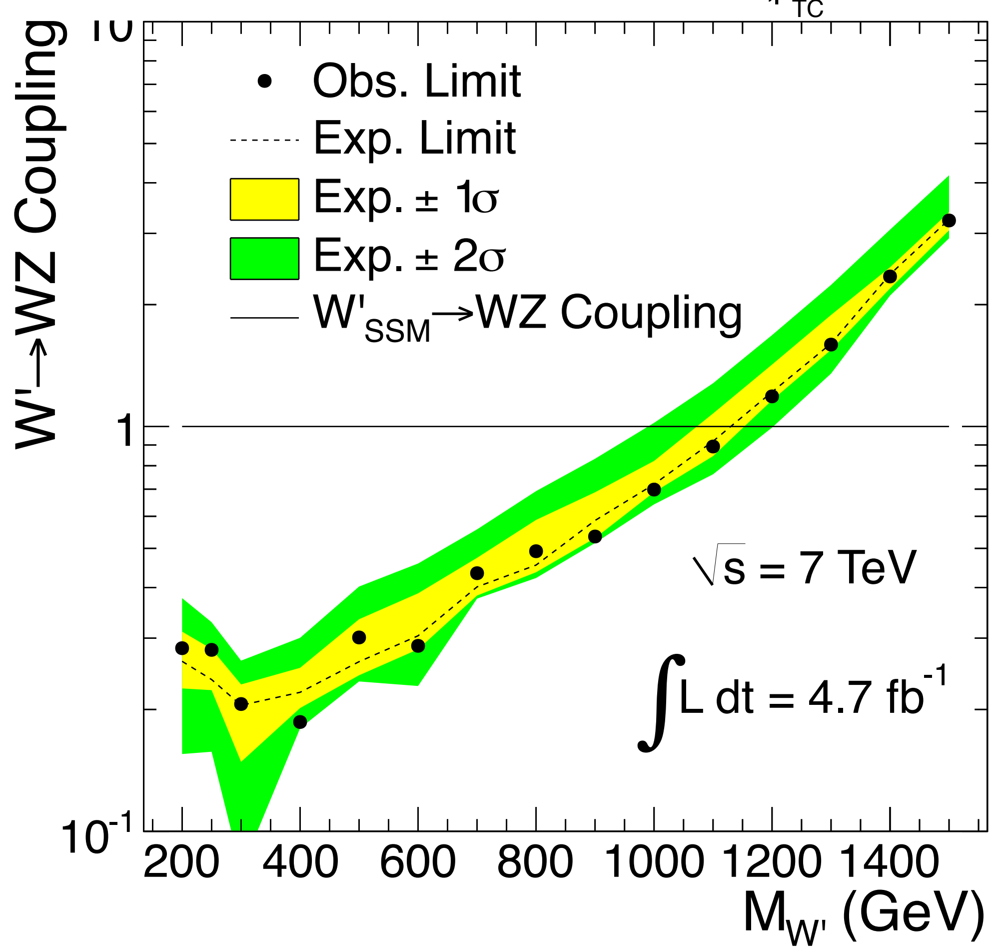


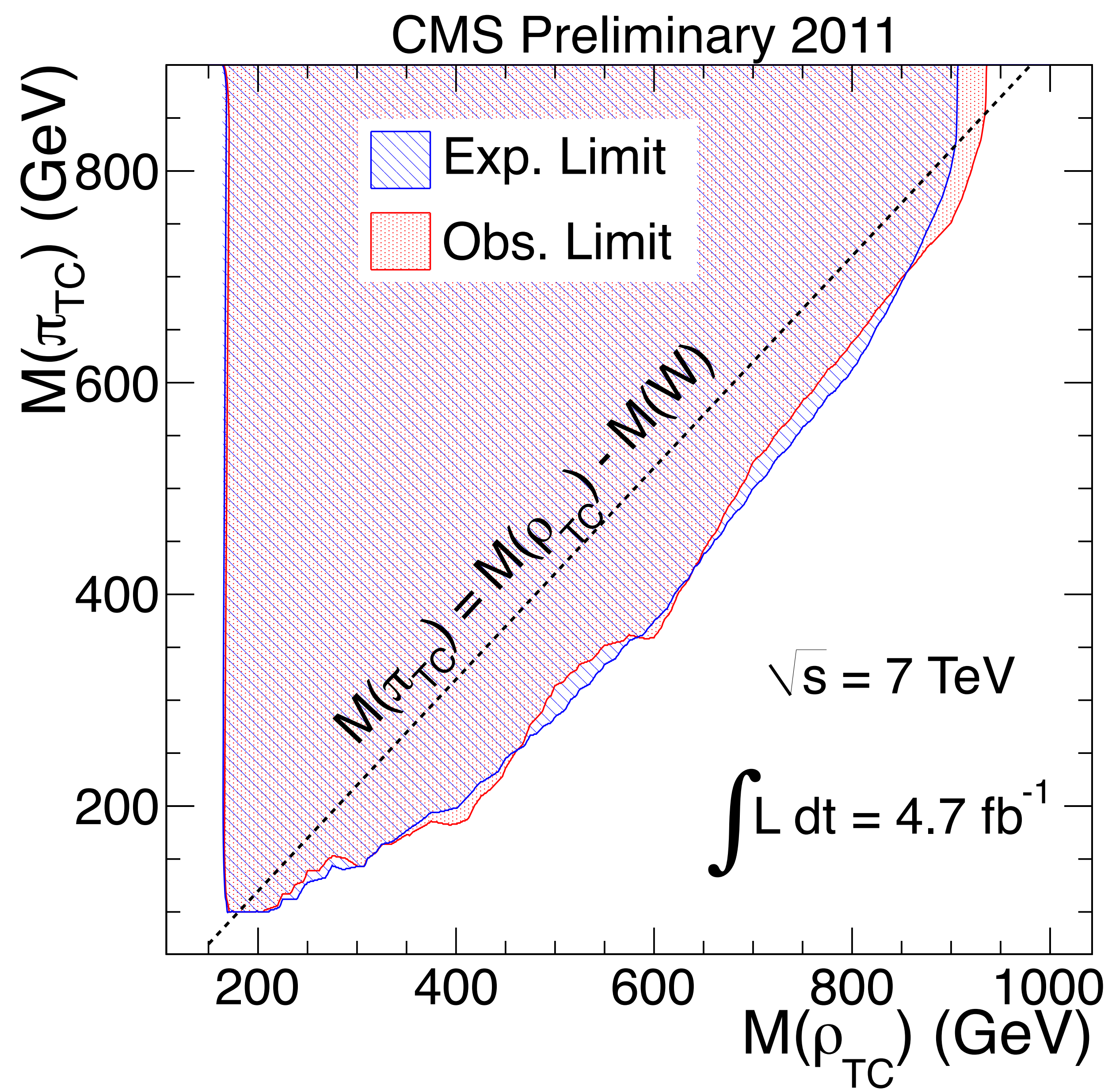
Selection Cuts in 1 fb^{-1} analysis

- Z-cand. leptons $p_T^1 > 20(15)$ GeV, $p_T^2 > 10(15)$ GeV for e (μ) channel
- $60 < M_Z^{ll} < 120$ GeV
- W-cand. lepton $p_T > 20$ GeV, $E_T^{Miss} > 30$ GeV
- $H_T = \sum p_T^{lepton}$ cut

WZ→*lνll* : Limits





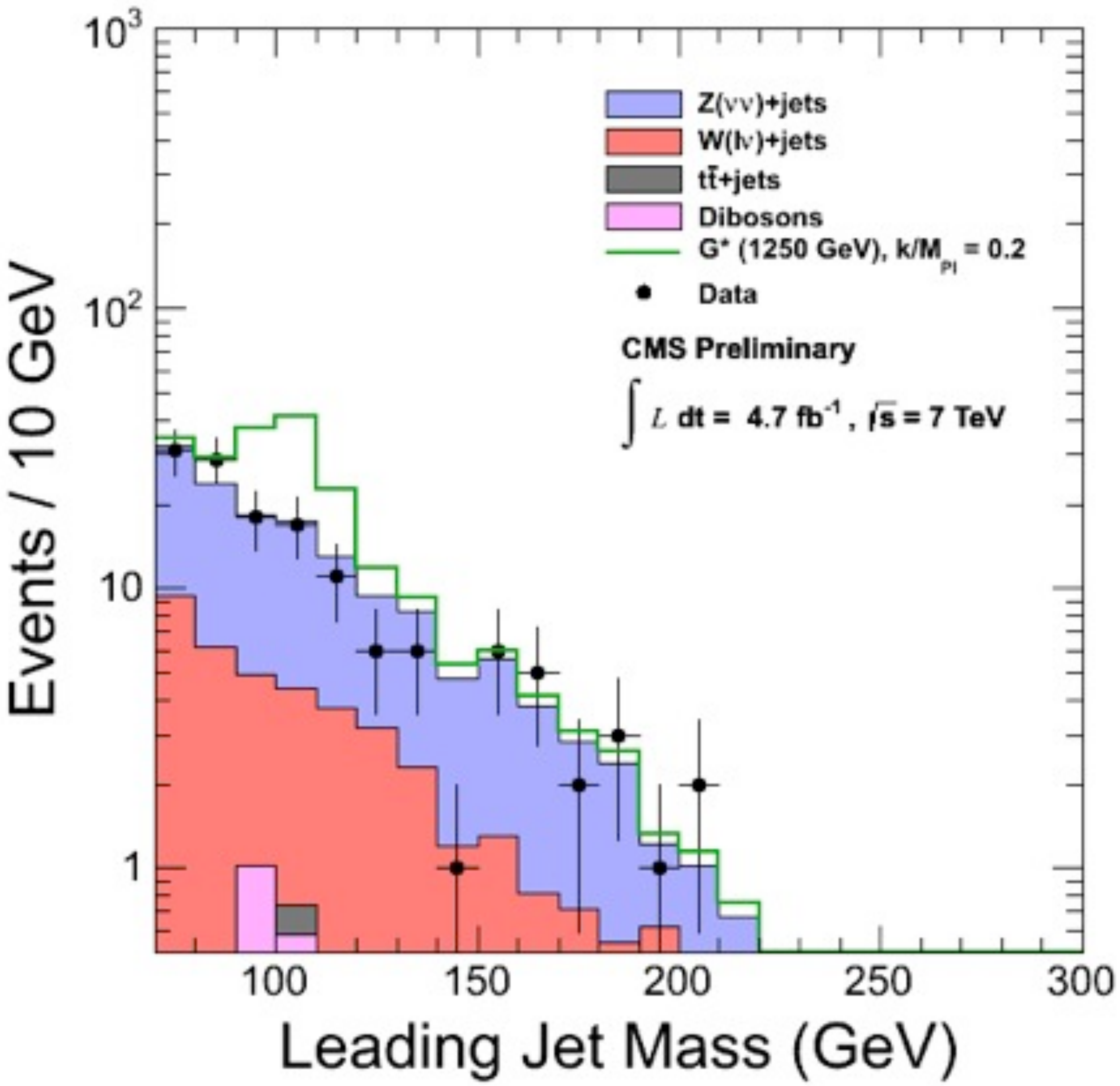


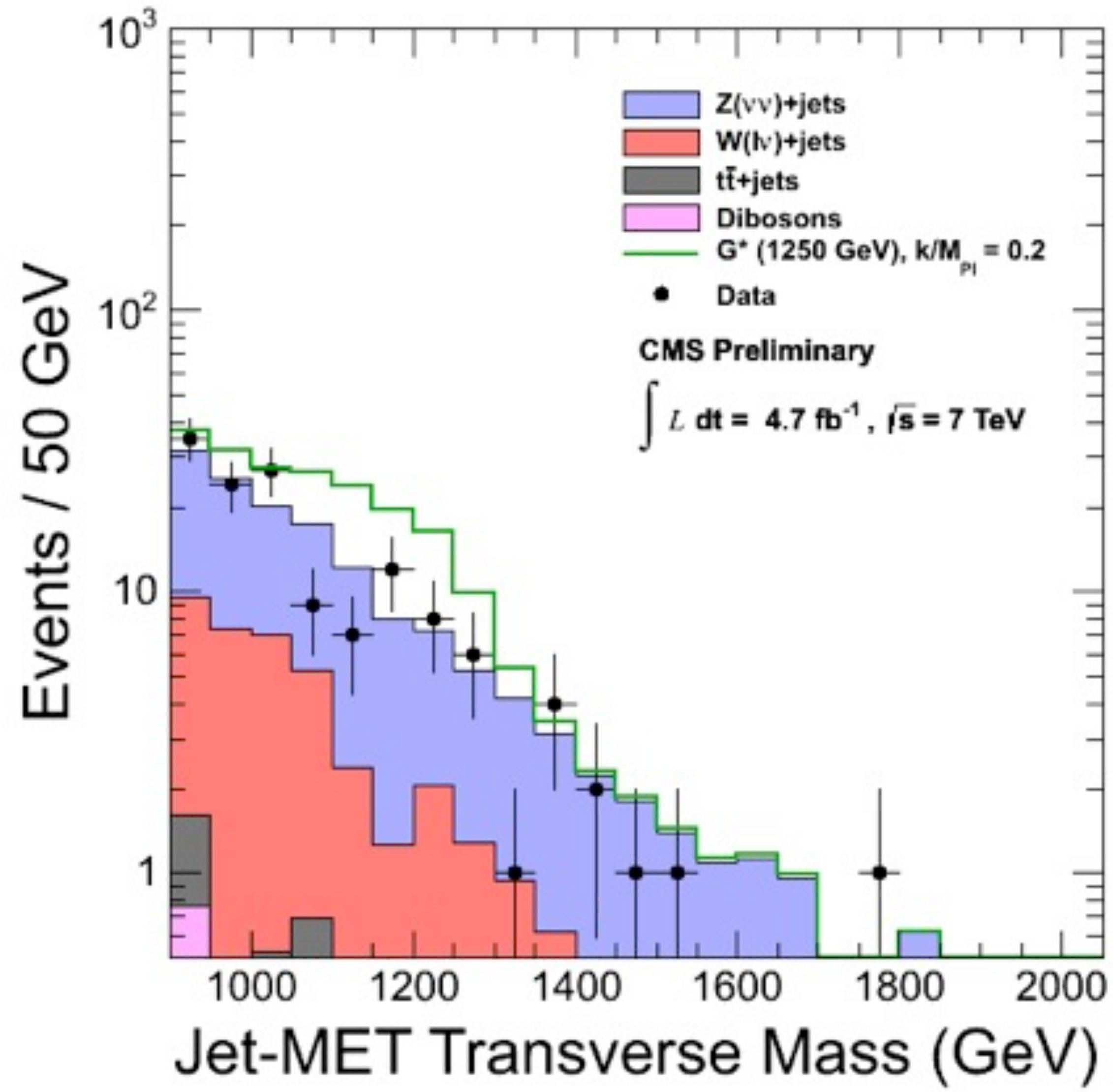
PYTHIA	95% CL Obs. Mass Limit
SSM W'	**1141 GeV**
LSTC ρ_T	**935 GeV**

"optimal choice for model parameters" in LSTC

ZZ ($\rightarrow \nu\nu qq$) Resonance

CMS-PAS-EXO-11-061





Selection Cuts

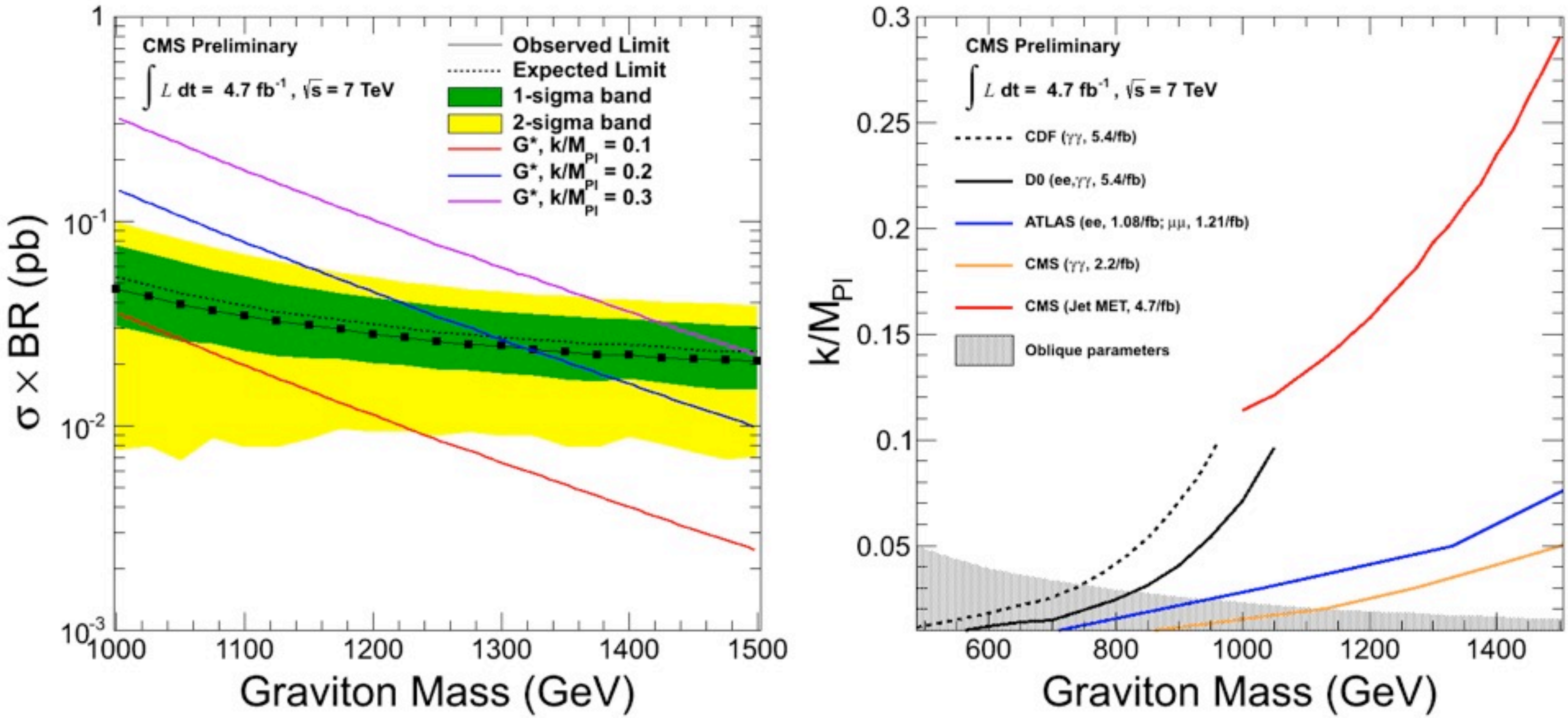
- p_T^{jet1} > 300 GeV, E_T^{miss} > 300 GeV
- Veto events with isolated leptons or ≥3 jets (p_T>30 GeV)
- $\Delta\Phi_{jj}$ < 2.8
- M_{jet1} > 70 GeV
- M_T(jet, E_T^{miss}) > 900 GeV

Background

- Determined with MC using (M_{jet1}, M_T) sideband regions

Yield	Run2011 Data	SM Prediction	Ratio
N_A	138	131 ± 3	1.05 ± 0.02
N_B	125	125 ± 3	1.00 ± 0.03
N_C	542	579 ± 7	0.94 ± 0.01
N_D	283	259 ± 5	1.09 ± 0.02

ZZ→$\nu\nu qq$: Limits



Set 95% CL limits on $\sigma \cdot Br$ for RS1 Graviton signal using

- *Profile likelihood ratio for nuisance parameters*
- *Modified frequentist CL_S approach*

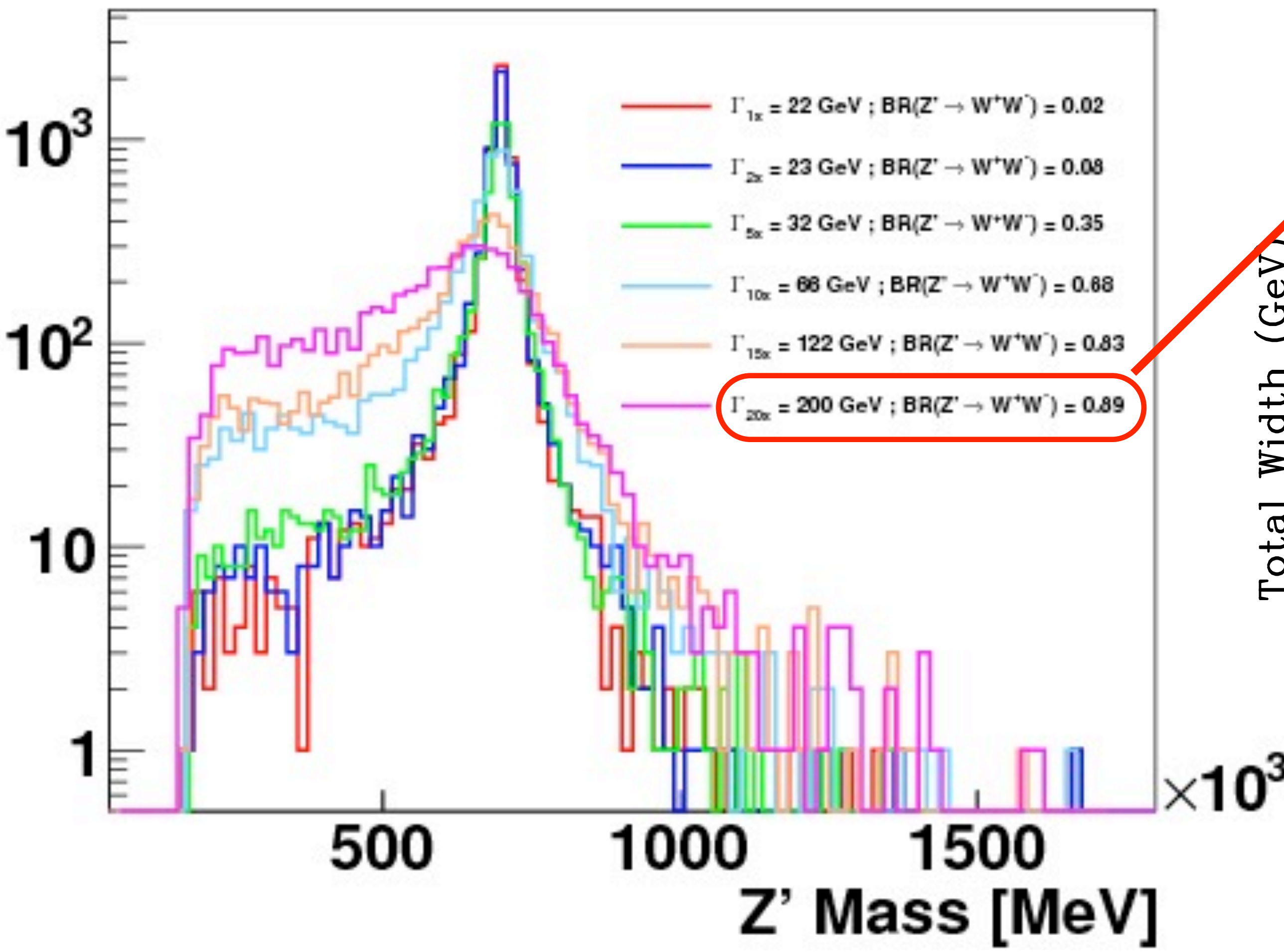
$\sigma \cdot Br$ < 47(21) fb and $k/\overline{m}_{pl}$ < 0.11(0.29) for M_{G*}=1.0(1.5) TeV

Diboson *Wide* Resonances

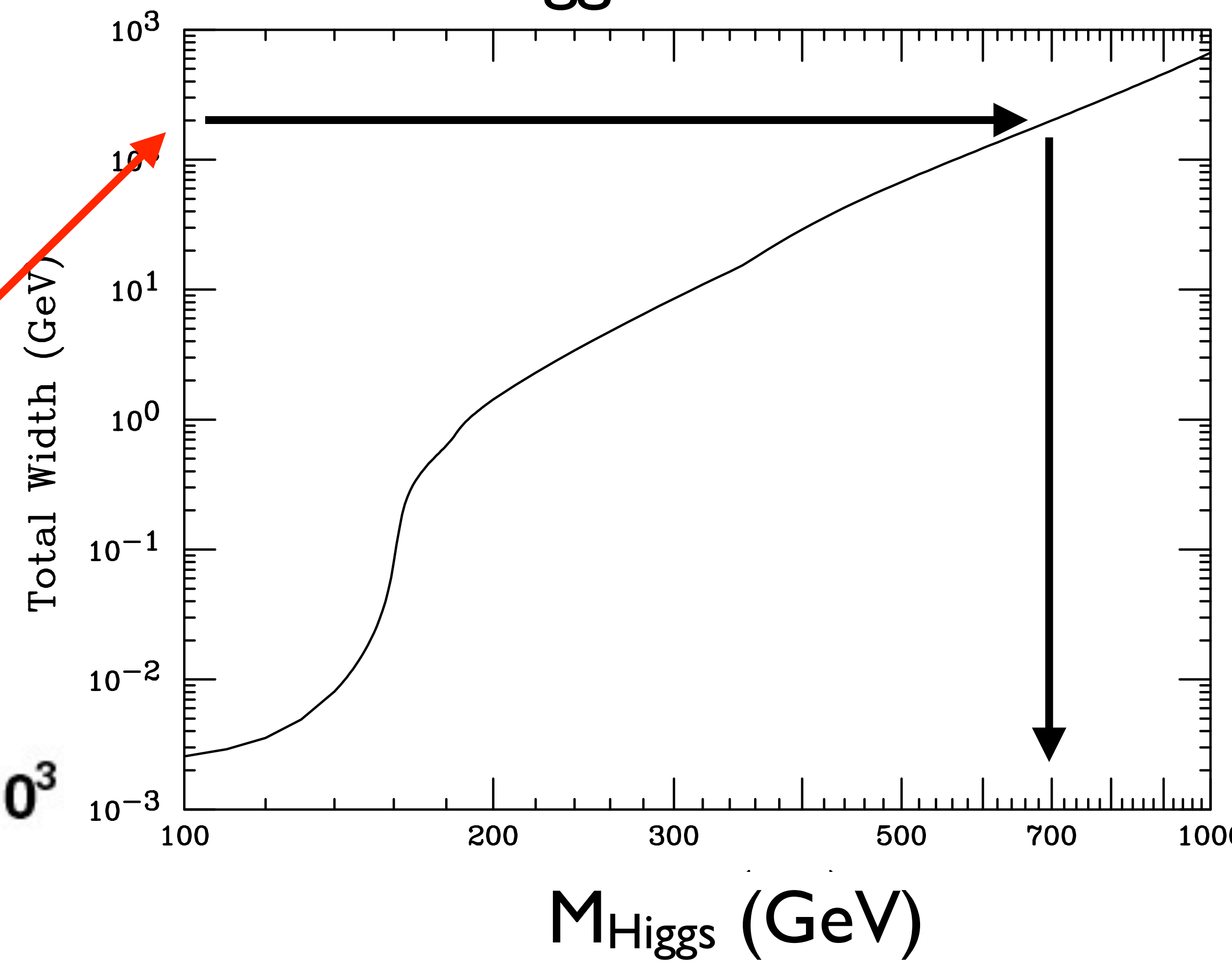
Diboson resonances could be wide in various BSM scenarios

EGM Z'(700 GeV)→WW

$g_{Z'WW}$ coupling = 1~20 x g_{ZWW}



Total SM Higgs width vs M_H



SM Higgs : reasonable benchmark for wide diboson resonances

- *spin difference will need to be accounted for in interpretation*

H→ZZ→*llqq* Search

ATLAS-CONF-2012-017

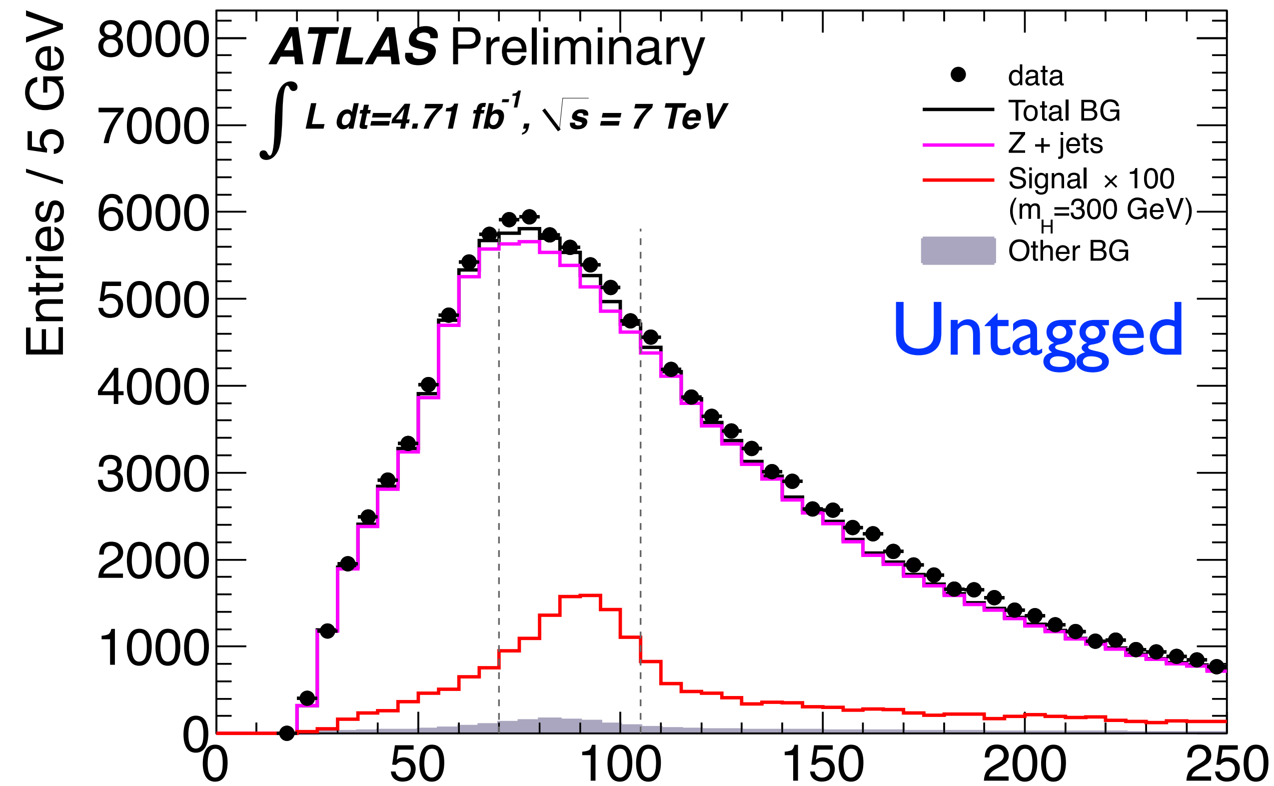
Tagged (2 b-tags) and Untagged (<2 b-tags) analyses

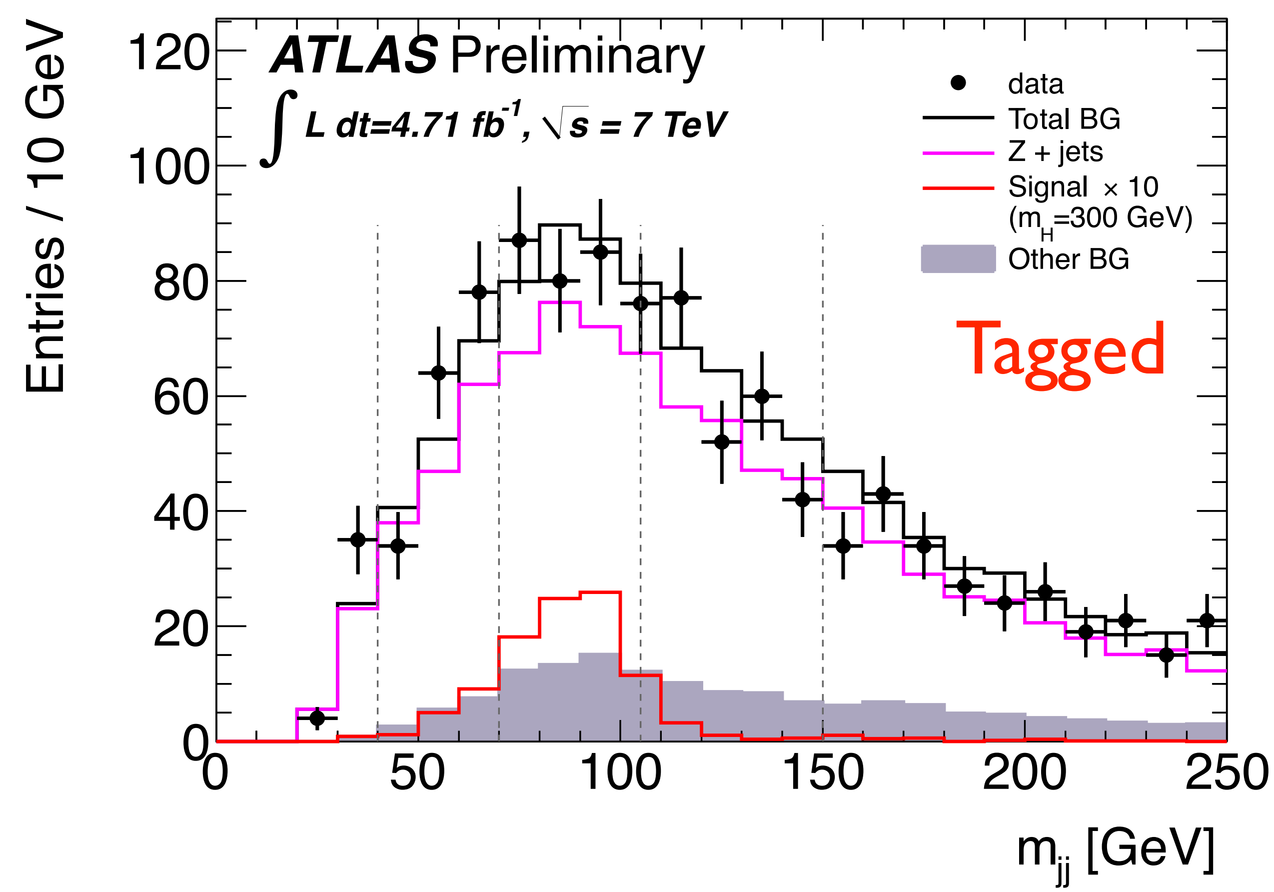
Selection Cuts

- 2 SF leptons with $|M_{ll} - M_Z| < 8$ GeV
- $E_T^{miss} < 50$ GeV
- $70 < M_{jj} < 105$ GeV, $\Delta R_{jj} > 0.7$
- High-mass ($M_H > 300$ GeV) = $p_T^{jet} > 45$ GeV, $\Delta\Phi_{ll} < \pi/2$, $\Delta\Phi_{jj} < \pi/2$

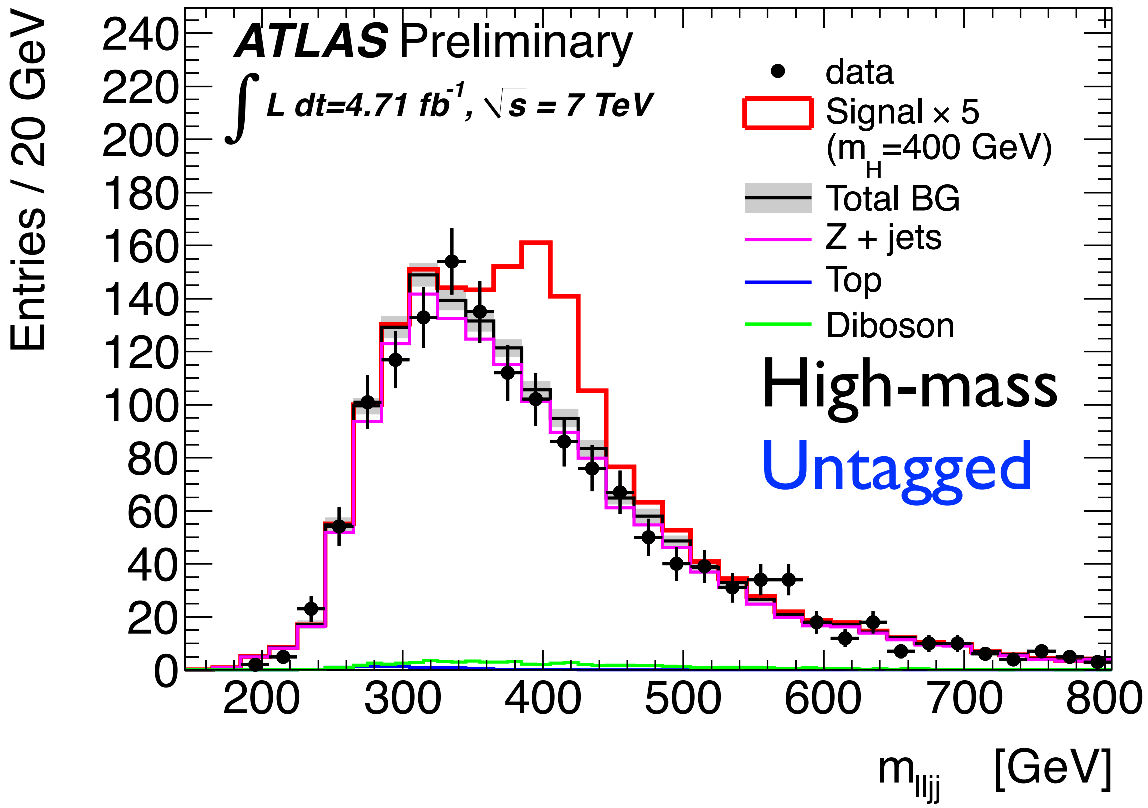
Background

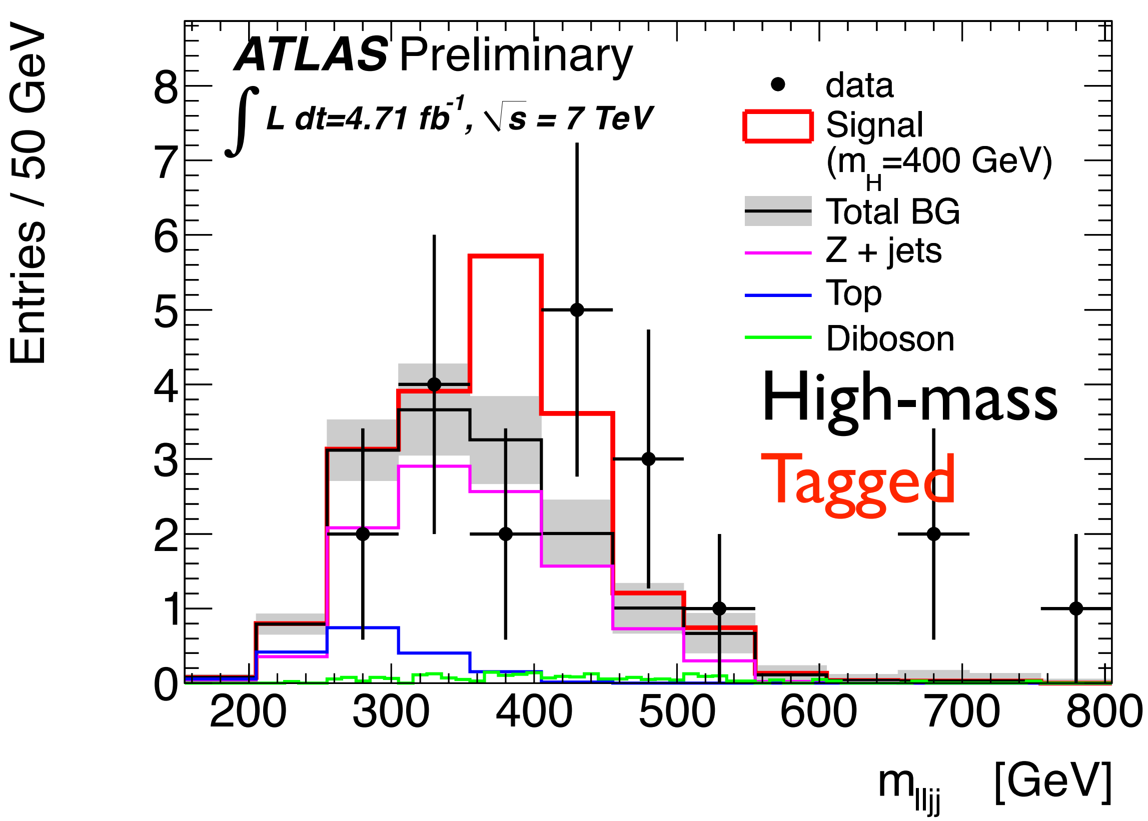
- Z+jets → Data-driven determination of normalization using M_{jj} sidebands
  Shape taken from MC simulation
- Top → M_{jj} sidebands + reversed E_T^{miss} cut
- Diboson (WZ, ZZ, WW) → Determined from MC

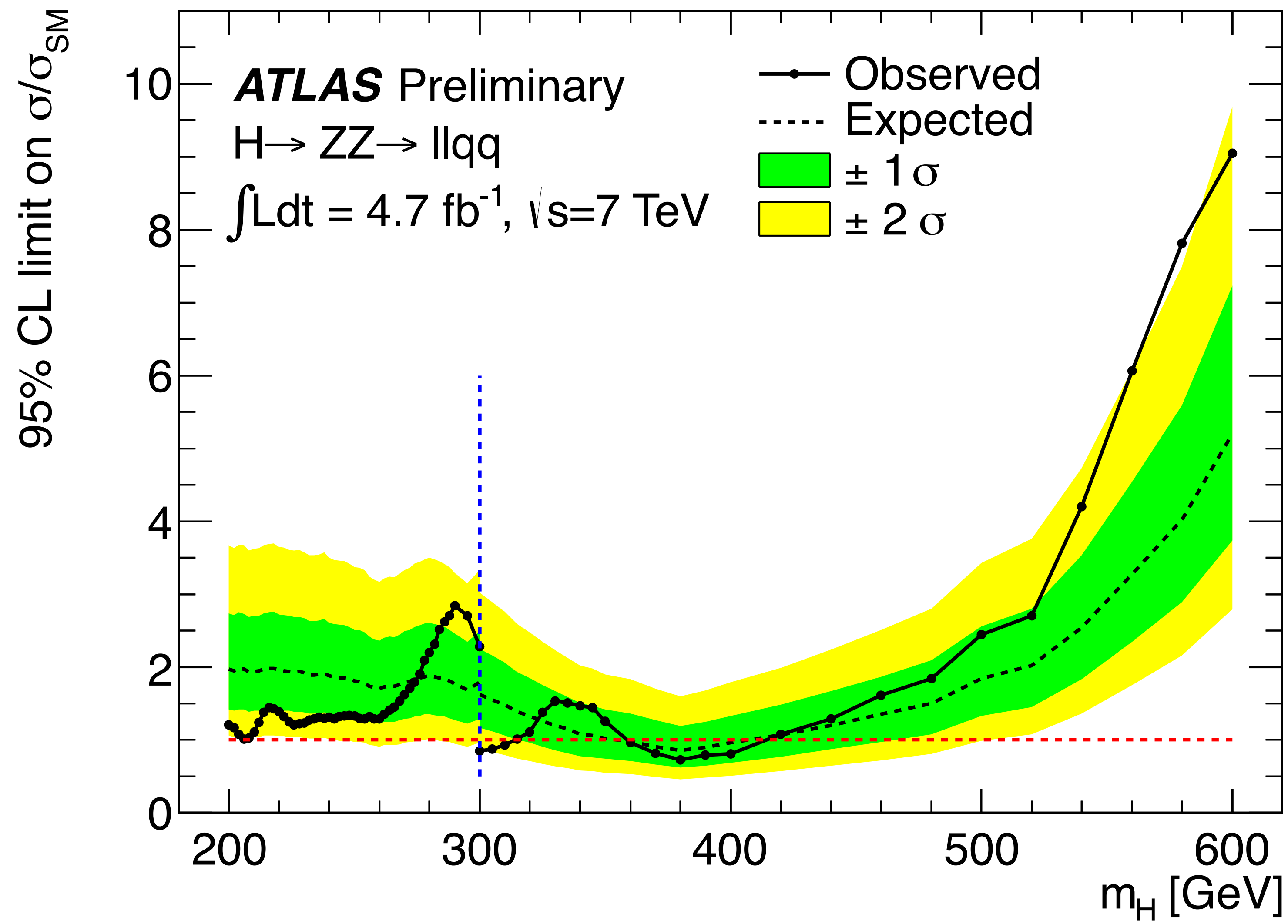




H→ZZ→*llqq* Search





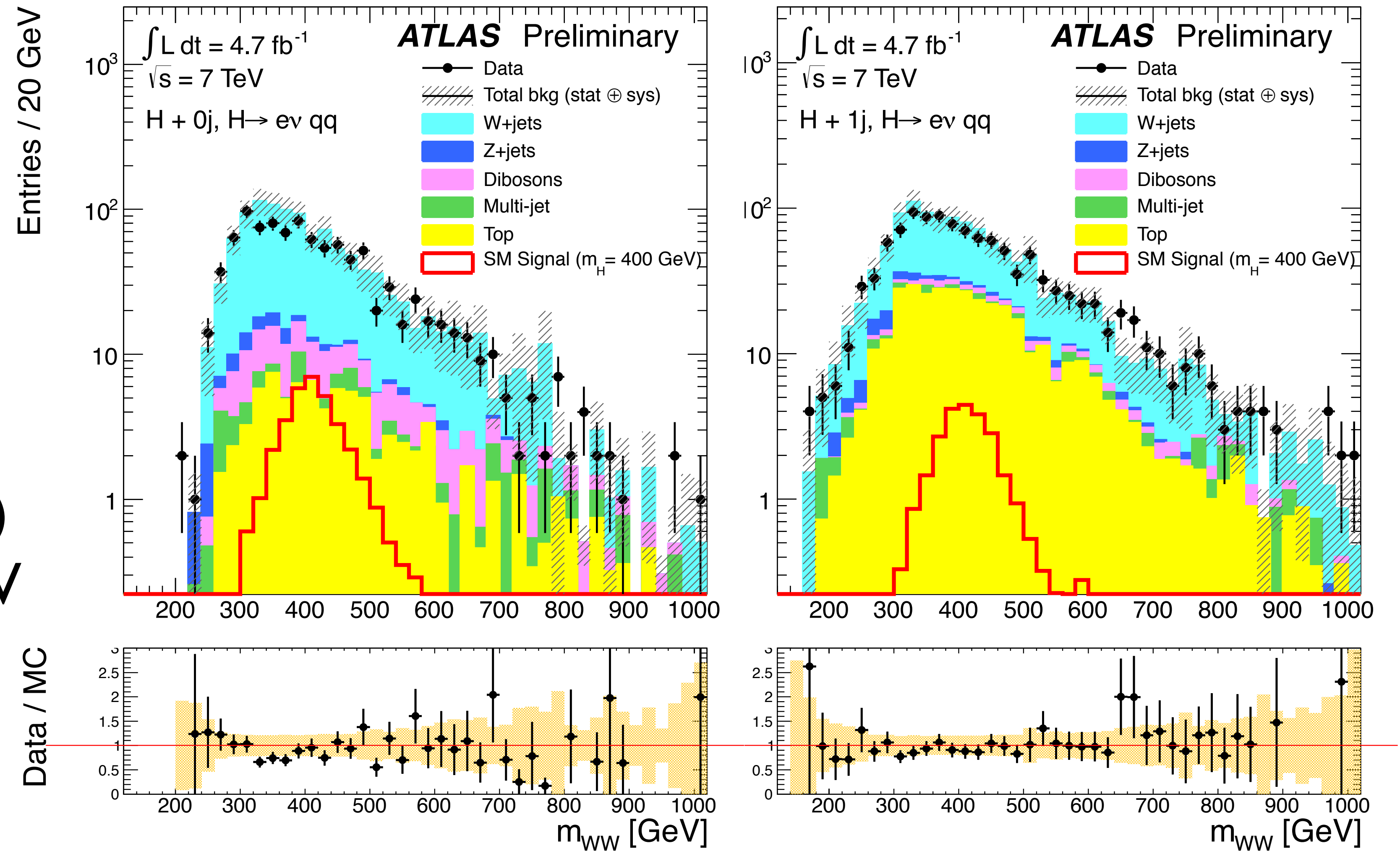


95% CL exclusion for SM Higgs : 300-310 GeV, 360-400 GeV

No significant excess at high mass, or difference between tagged and untagged

H→WW→*lvqq* Search

ATLAS-CONF-2012-018



Selection Cuts (ggF H+0/1 jet)

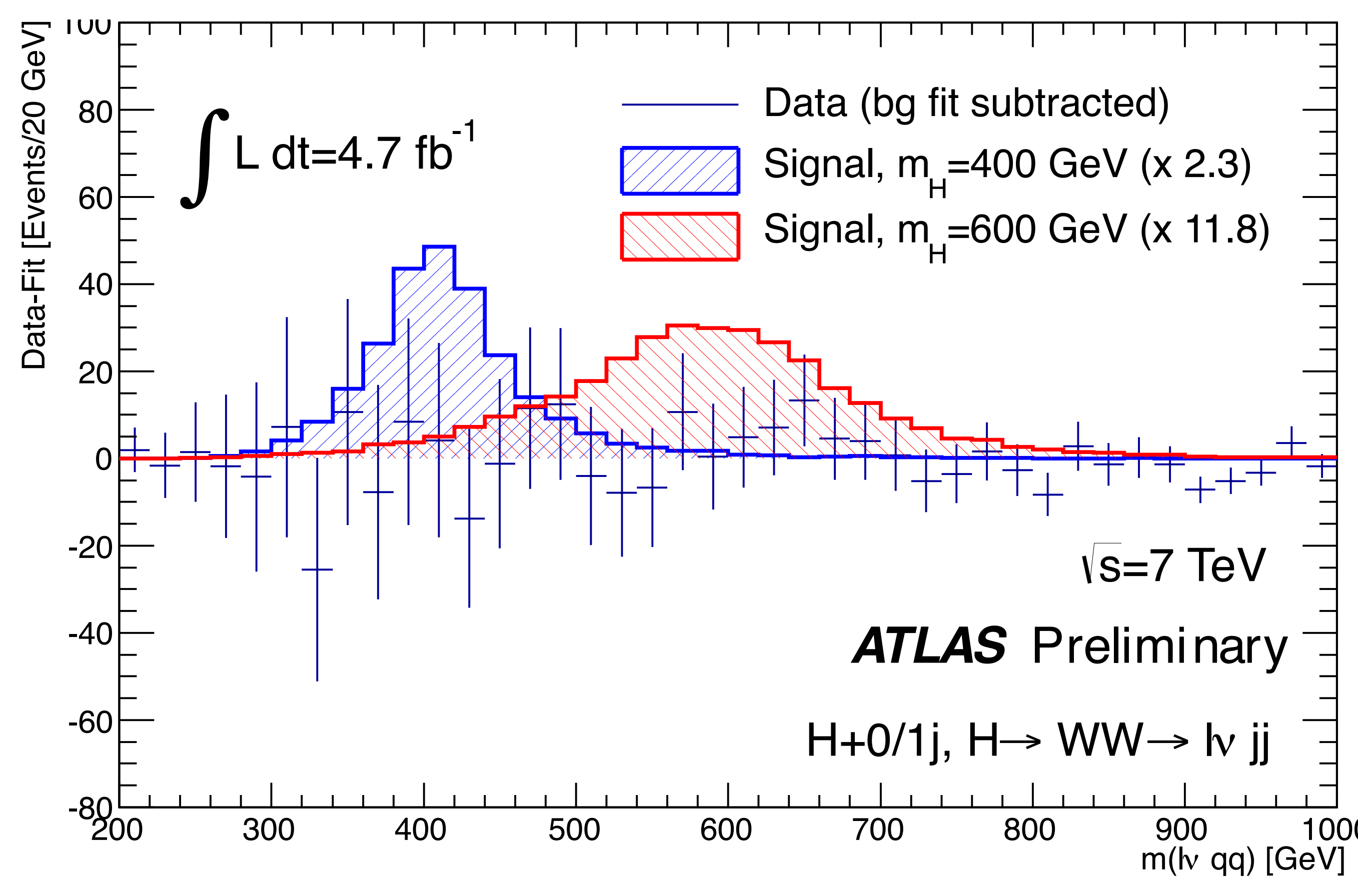
- $p_T^{lepton} > 40$ GeV, $E_T^{miss} > 40$ GeV
- ≥2 jets with $E_T^{jet1} > 60$ GeV
- $71 < M_{jj} < 91$ GeV
- $\Delta R_{jj} < 1.3$, $\Delta R_{l\nu} < 1.3$
- no b-tags

Background

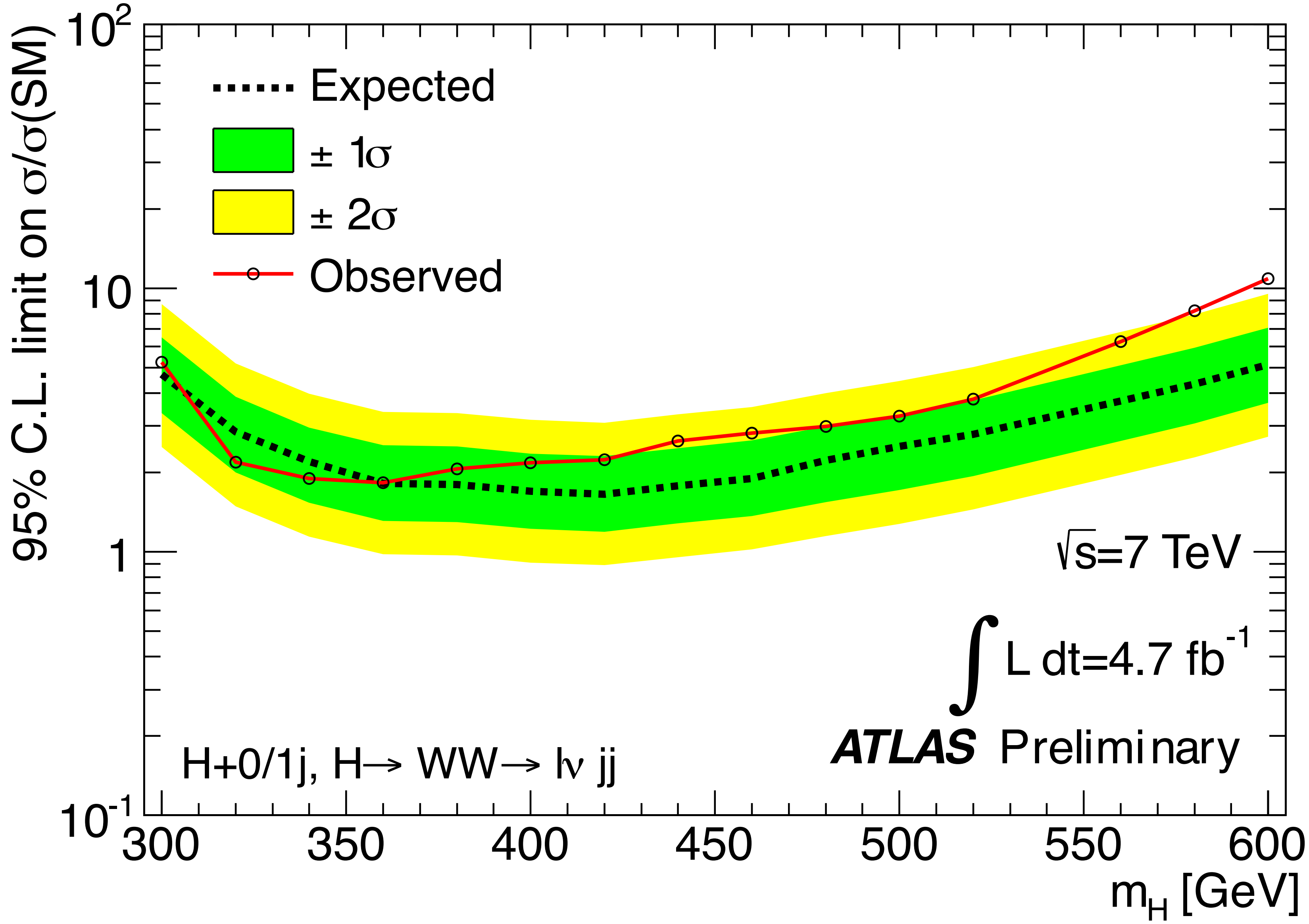
- W+jets
- Top, Z+jets, QCD
- Diboson (WW,WZ, ZZ)

Fit to $M_{l\nu jj}$ spectrum

BG fit: $$f(x) = \frac{1}{1+|a(x-m)|^b} e^{-c(x-200)}$$



H→WW→*lvqq* Search

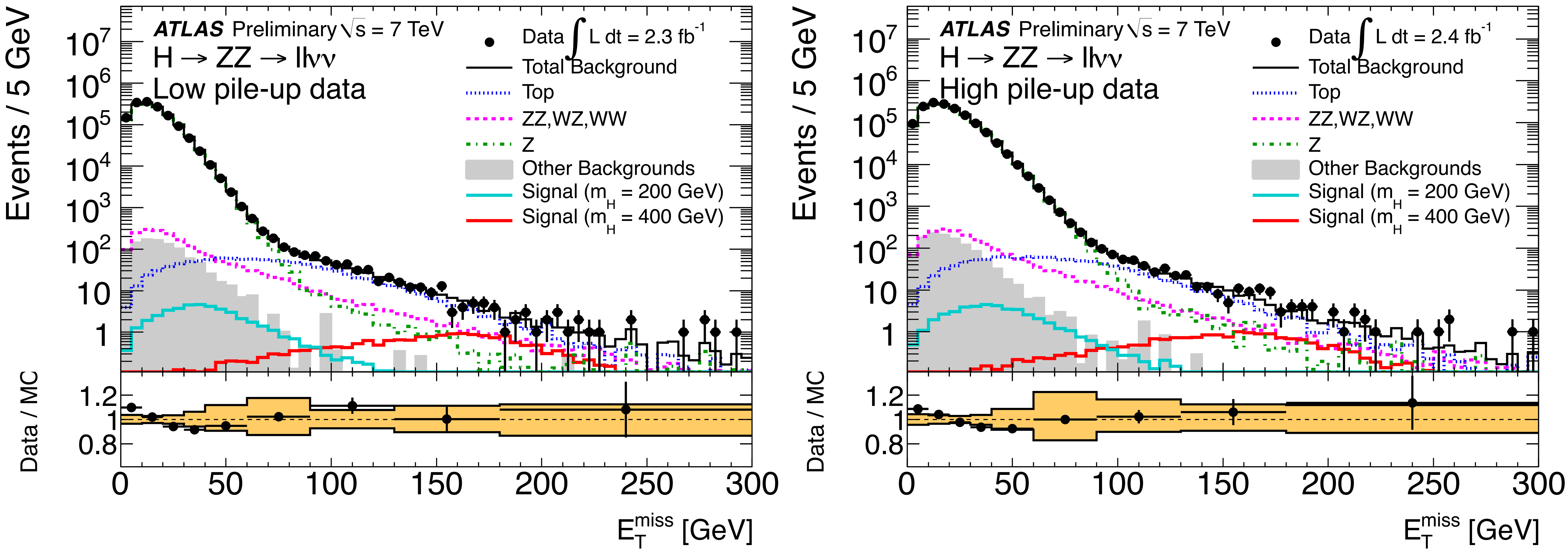


95% CL limit on cross section for ggF :
2.2(10) x σ_{SM} at M_H = 400(600) GeV

No significant excess at high mass...

H→ZZ→*llνν* Search

ATLAS-CONF-2012-016



Low (<280 GeV) and high mass (>280 GeV)

Low and high pile-up conditions

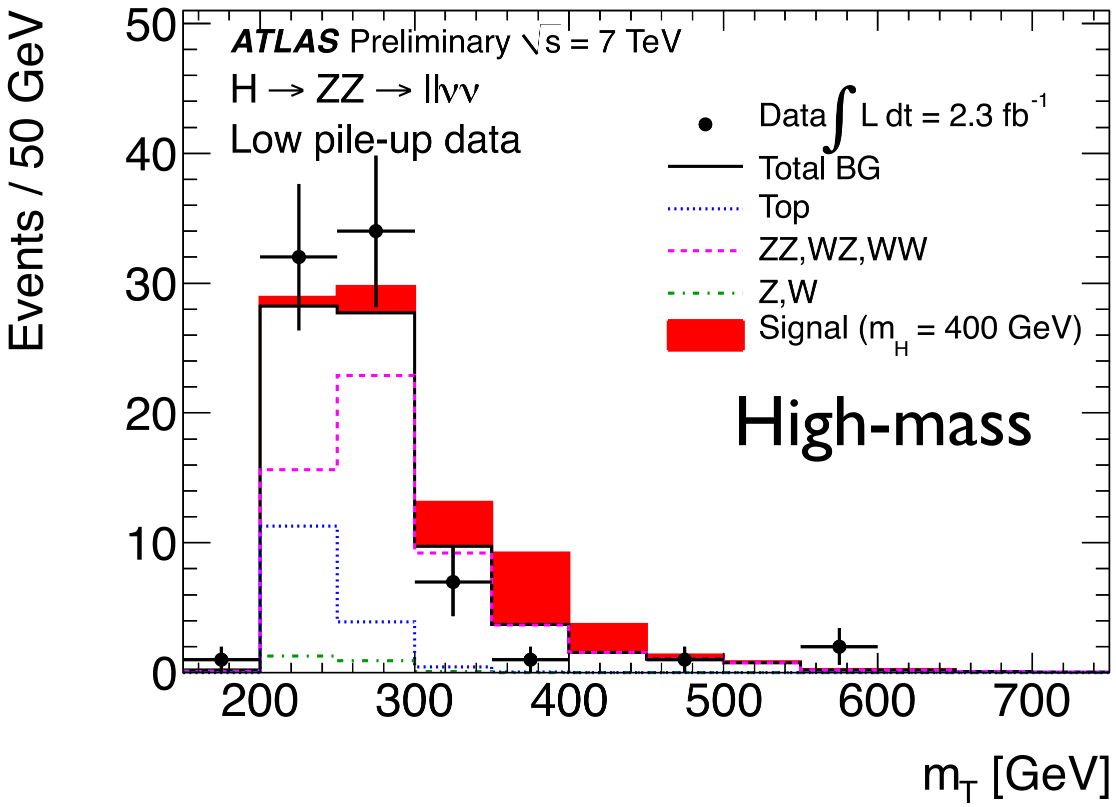
Selection Cuts

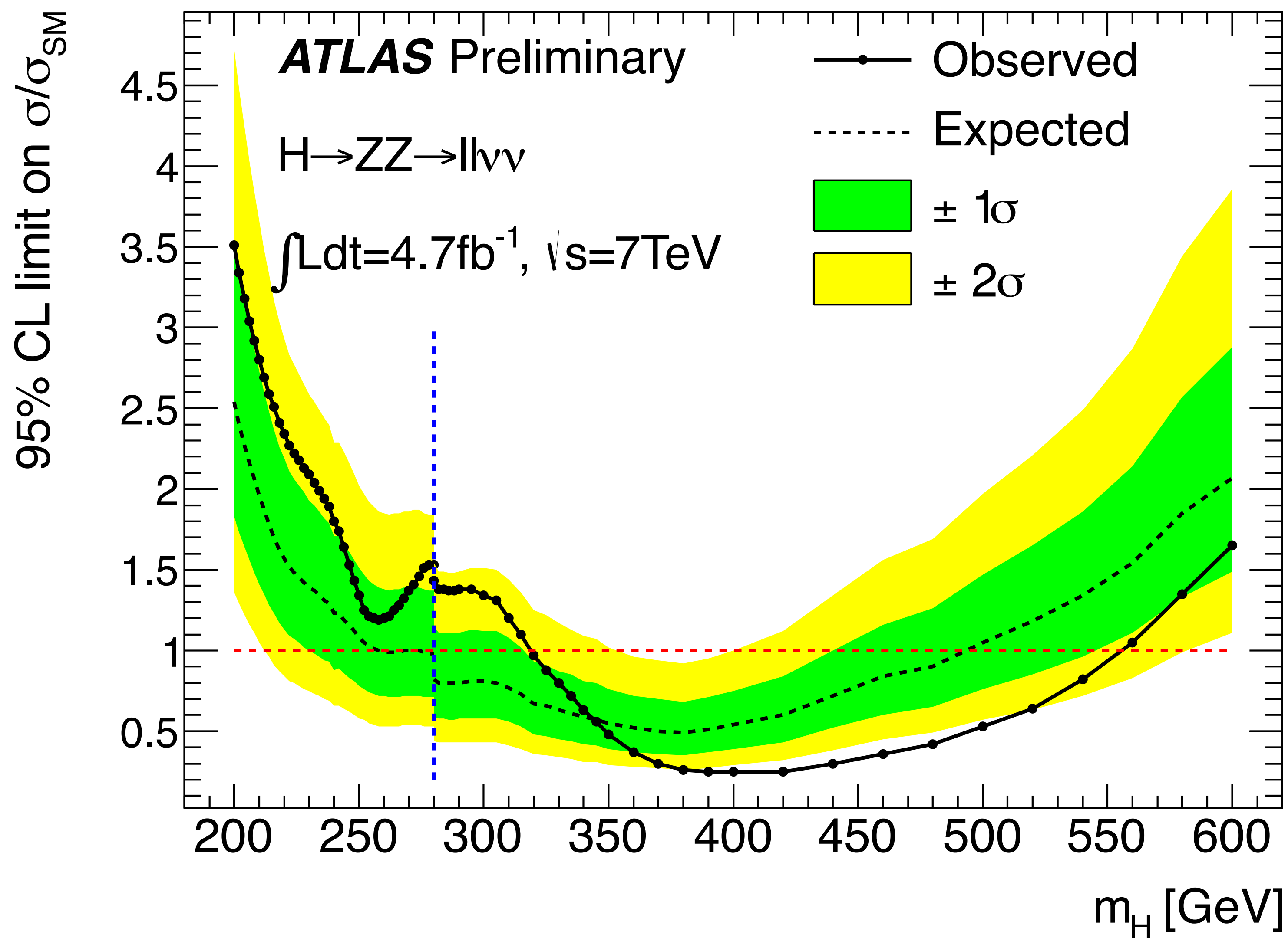
- 2 SF leptons with $|M_{ll} - M_Z| < 15$ GeV
- $E_T^{miss} > 66(82)$ GeV
- $\Delta\Phi(l,l)$ and $\Delta\Phi(ll,E_T^{miss})$ cuts
- no b-tags

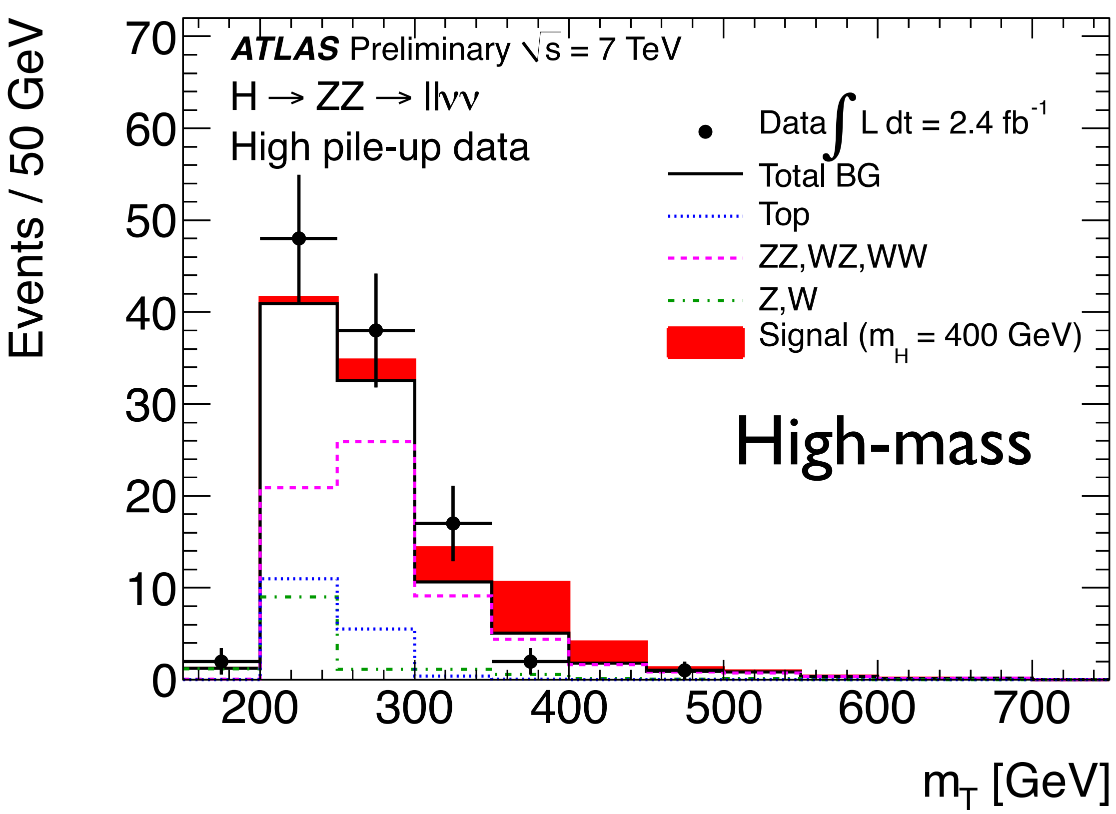
Background

- Z+jets
- Top
- Diboson (ZZ,WZ,WW)

H→ZZ→*llνν* Search





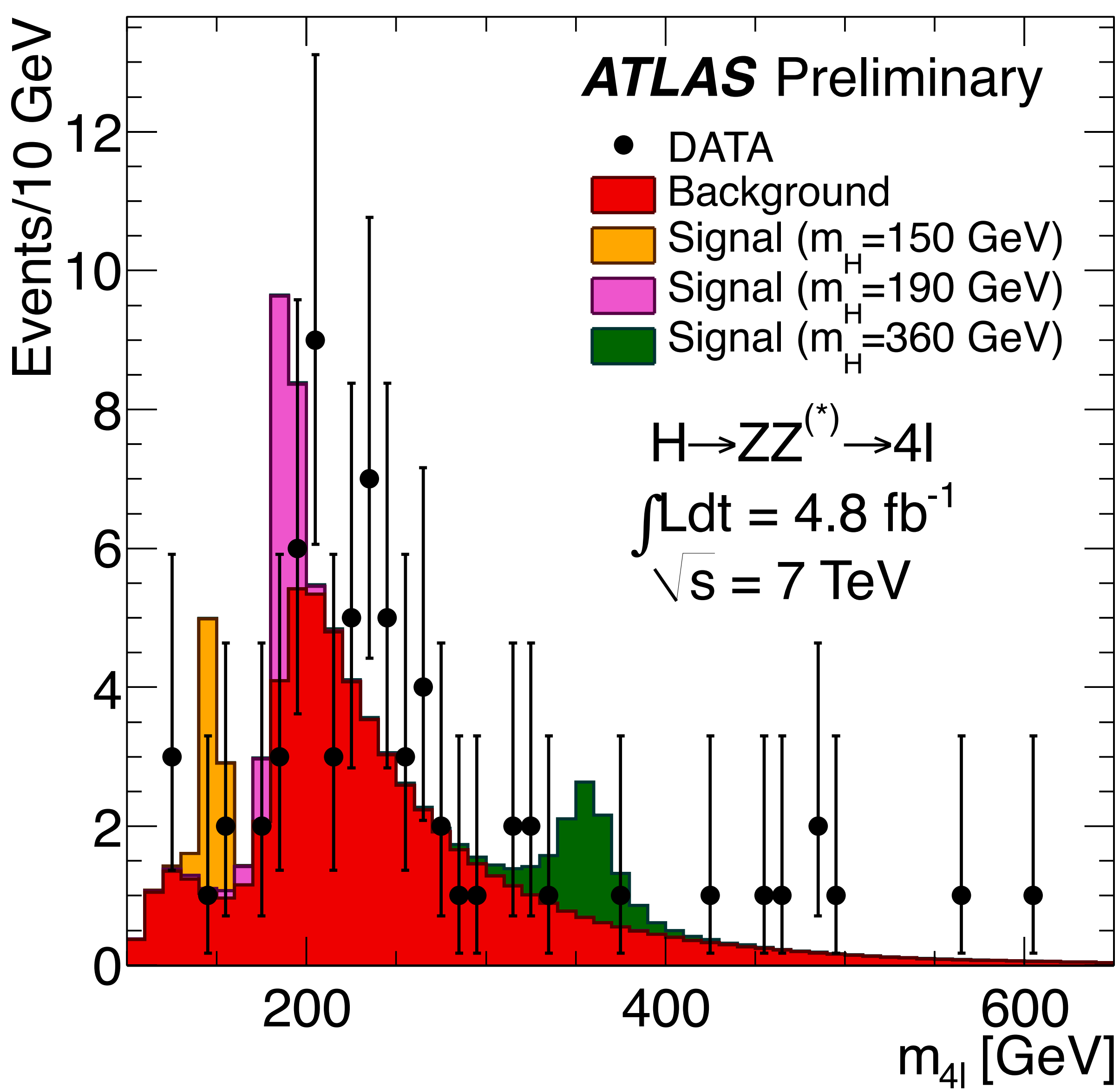


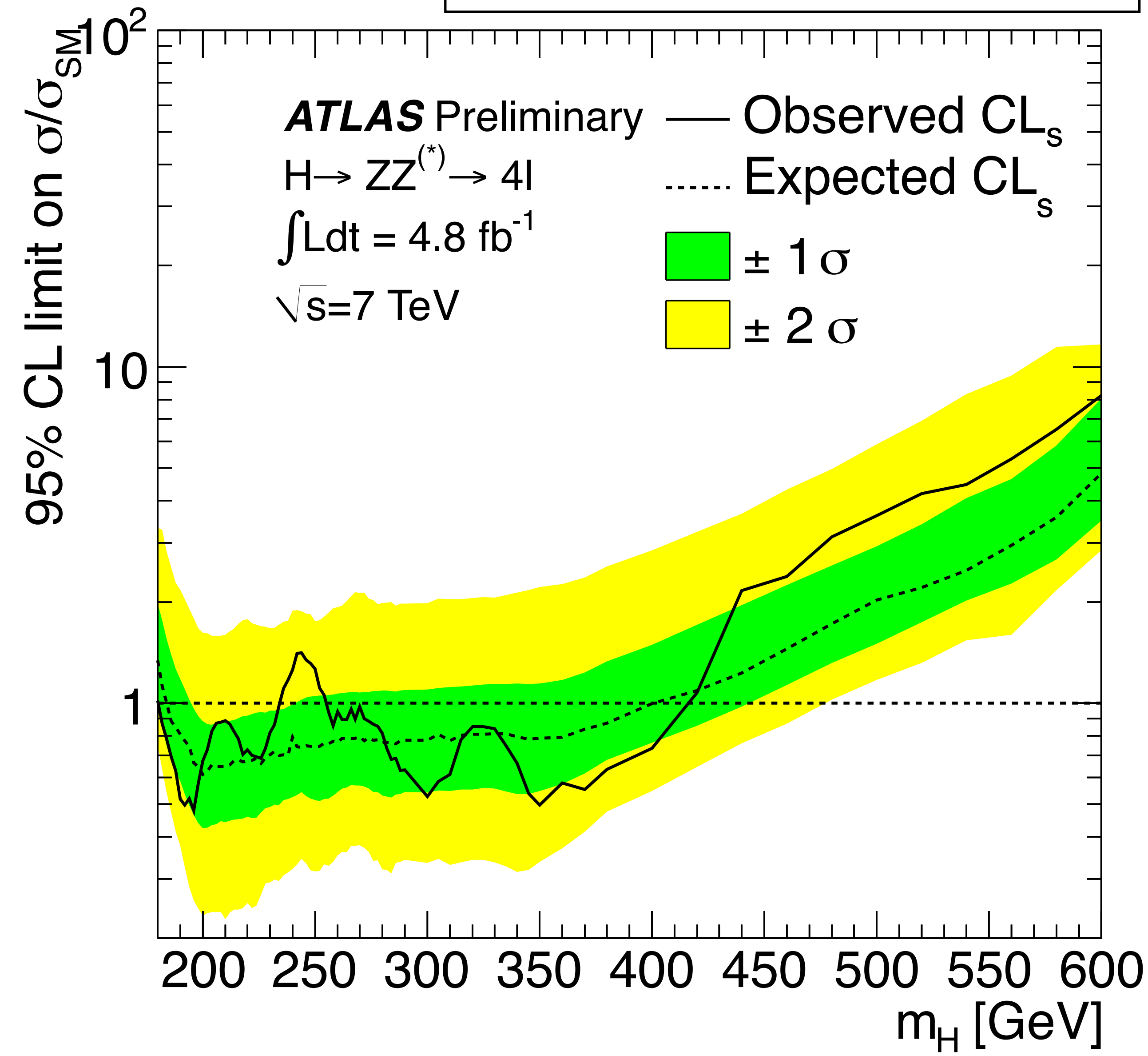
95% CL exclusion for SM Higgs : 320-560 GeV

No significant excess at high mass up to 600 GeV...

H→ZZ→*llll* Search

ATLAS-CONF-2011-162





95% CL exclusion for SM Higgs :
134-156, 182-233, 256-265, 268-415 GeV

Again not very interesting structure at high mass...

Summary

- Making precision tests of the Standard Model at the LHC with ~4.7 fb^{-1} of luminosity in 2011
- Both total and fiducial cross sections measured to provide less model-dependent results
- Limits on anomalous triple gauge couplings becoming competitive with the LEP and Tevatron
- Probing narrow/wide diboson resonances in new physics models; complementary to dilepton/dijet resonances
- Opening up many interesting channels with 8 TeV collisions in 2012!!

Backup

ZZ→*llll, llqq* : Statistical Analysis

Perform counting experiments inside mass windows (M_{ZZ}>300 GeV for ll+ll)
Mass windows optimized using signal predictions
Identical systematics taken to be correlated across channels

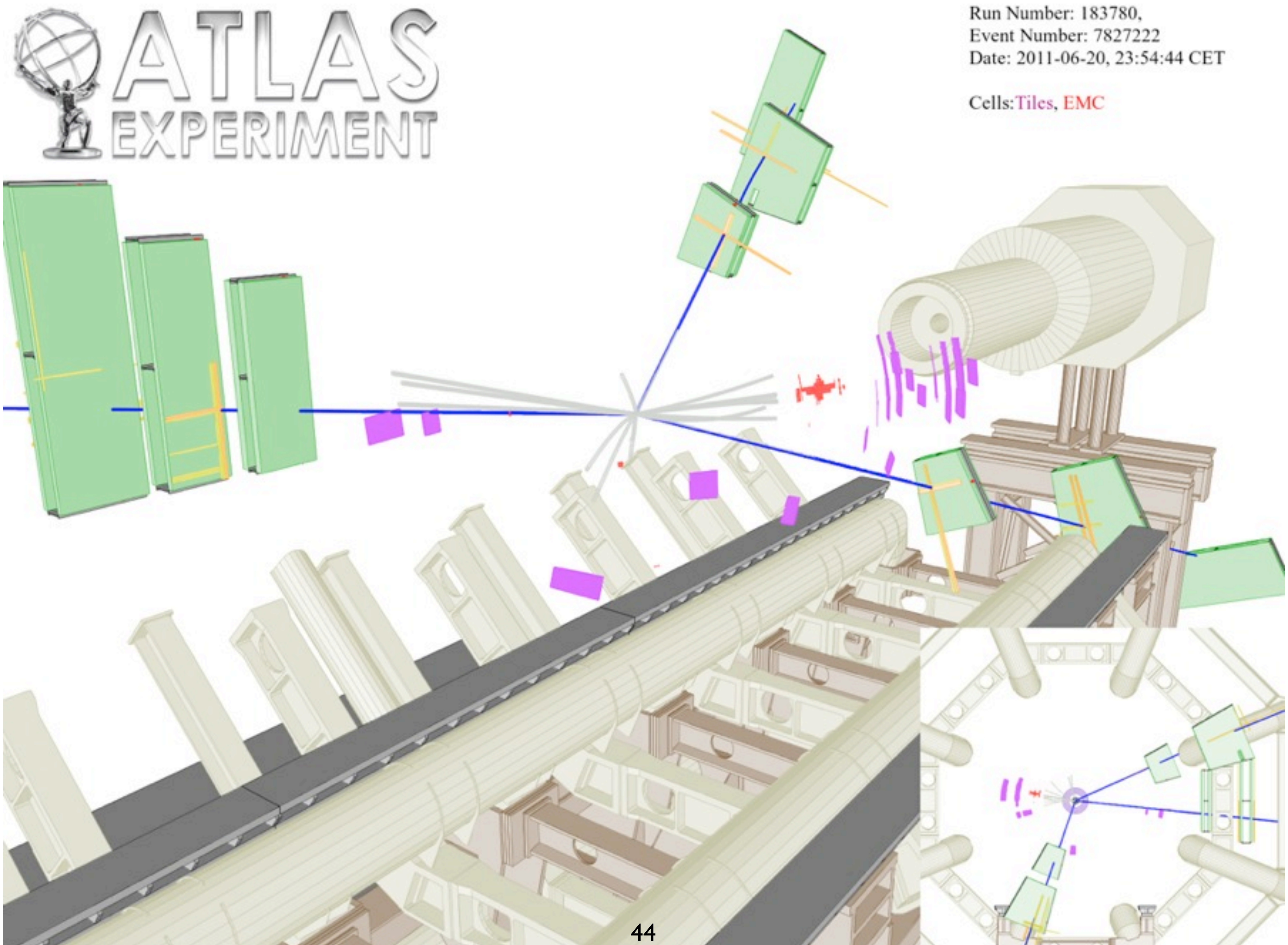
Res. Mass [GeV]	Mass Window [GeV]		Expected Background	Expected Signal	Obs
350	330-360	eejj	116^{+20}_{-15}	161^{+36}_{-14}	109
		μμjj	163^{+28}_{-23}	165^{+19}_{-16}	147
500	480-530	eejj	6^{+4}_{-2}	27^{+3}_{-4}	8
		μμjj	8^{+5}_{-2}	23^{+2}_{-3}	6
750	730-830	eejj	4^{+2}_{-1}	$6.5^{+0.6}_{-0.9}$	6
		μμjj	$1.2^{+0.9}_{-0.5}$	$6.9^{+0.6}_{-0.7}$	2
1000	900-1090	eejj	$2.1^{+1.3}_{-0.9}$	1.2±0.2	2
		μμjj	$1.2^{+0.8}_{-0.5}$	1.2±0.1	3
1250	1150-∞	eejj	$0.4^{+0.4}_{-0.3}$	0.18±0.01	1
		μμjj	$0.5^{+0.5}_{-0.4}$	0.21±0.01	1
1500	1300-∞	eejj	0.1±0.1	0.04±0.01	0
		μμjj	0.4±0.4	0.04±0.01	1

Look for bumps in full mass spectrum using BUMPHUNTER algorithm

➔ Most significant excess

	p-value	Significance
llll	0.07	1.5σ
lljj (Low-mass)	0.08	1.4σ
lljj (High-mass)	0.08	1.4σ

WZ→$\mu\nu\mu\mu$: M_T^{WZ} = 506 GeV



ZZ→μμμμ : M_{ZZ} = 240 GeV