

Search for resonances in lepton pairs and photon pairs with the ATLAS detector



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On behalf of the ATLAS collaboration

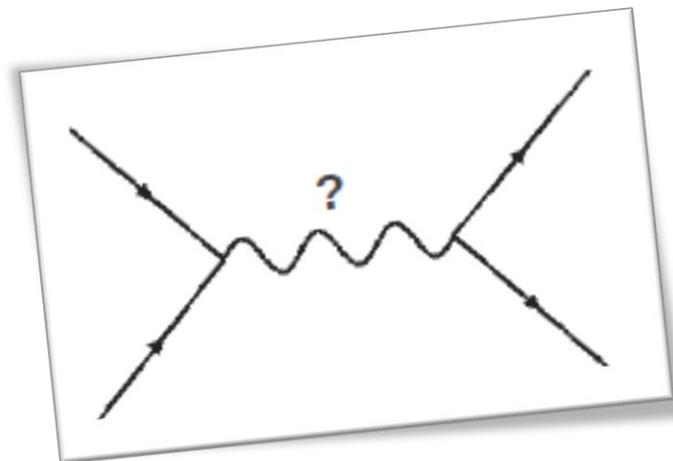
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Outline

- A large variety of models beyond the SM predicts new signals that could be observed at the LHC through the analysis of final states involving two leptons or two photons

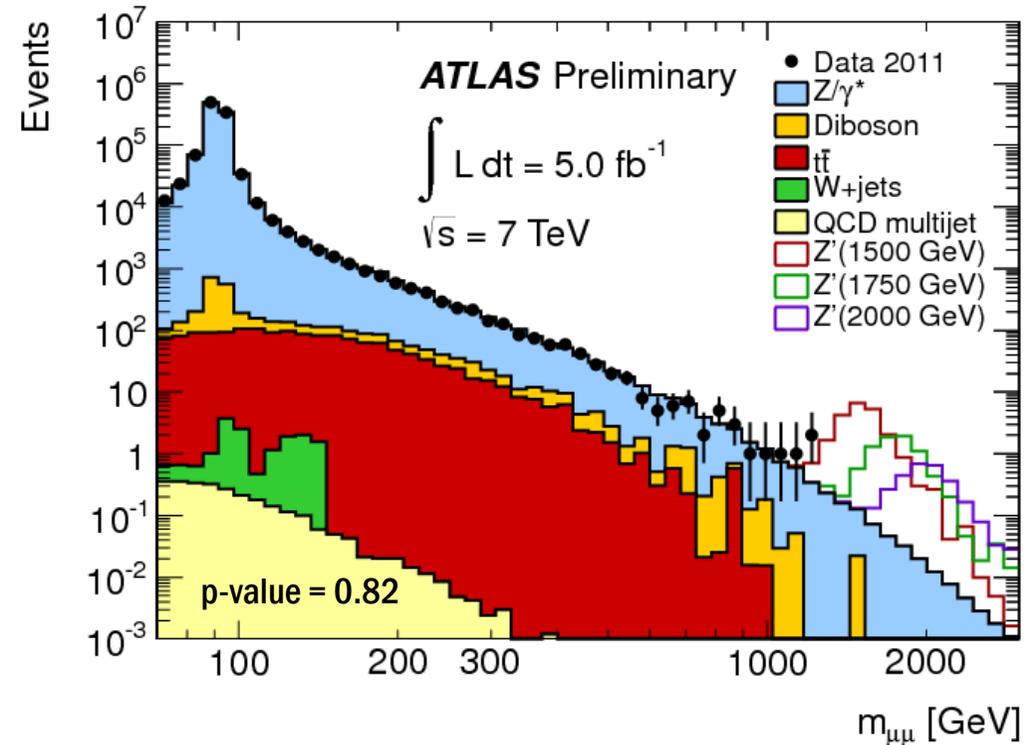
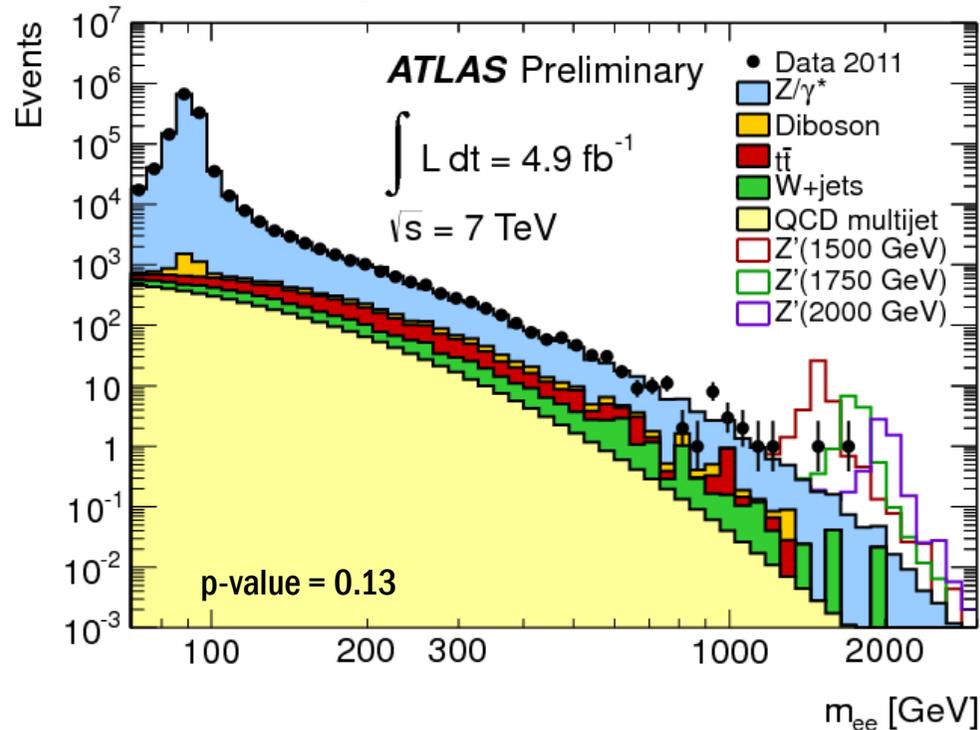


- A summary of several searches in such channels, with proton-proton data from the LHC at $\sqrt{s}=7$ TeV collected by the ATLAS detector during 2011 is presented here.
 - Same data can probe various models
 - References for the details on the slides

Searches on the dilepton final state

Final State	Model	$\int L dt$ [1/fb]	Topology
$ee/\mu\mu$	Heavy spin-1 neutral gauge bosons (SSM, E6): Z'	4.9/5.0 ($\sqrt{s}=7$ TeV)	Resonant
	Spin-2 gravitons (RS): G^*		
$ee/\mu\mu$	Technicolor (LSCT): Techni-hadrons	1.08/1.21 ($\sqrt{s}=7$ TeV)	Resonant
	Quark/Lepton compositeness: Contact-Interactions		Non-resonant
$e\nu_e/\mu\nu_\mu$	Heavy spin-1 charge gauge bosons (SSM): W'	4.7/4.7 ($\sqrt{s}=7$ TeV)	Resonant
	Magnetic-type interacting bosons: W^*		

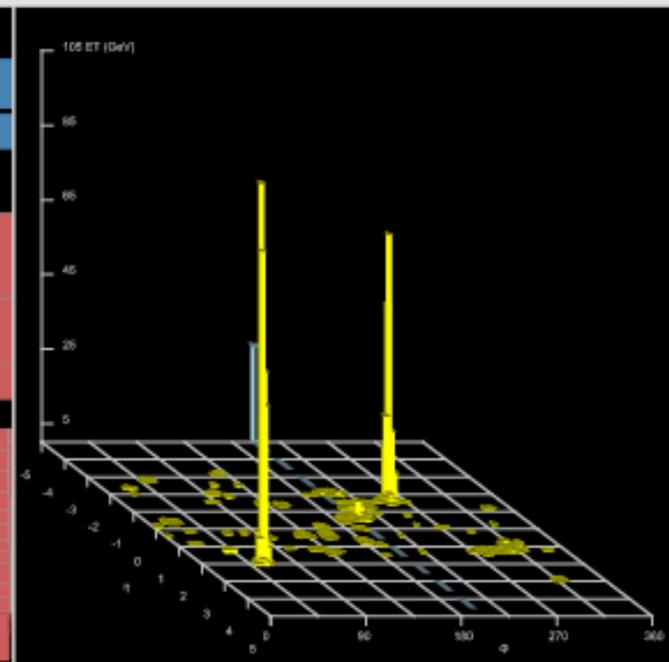
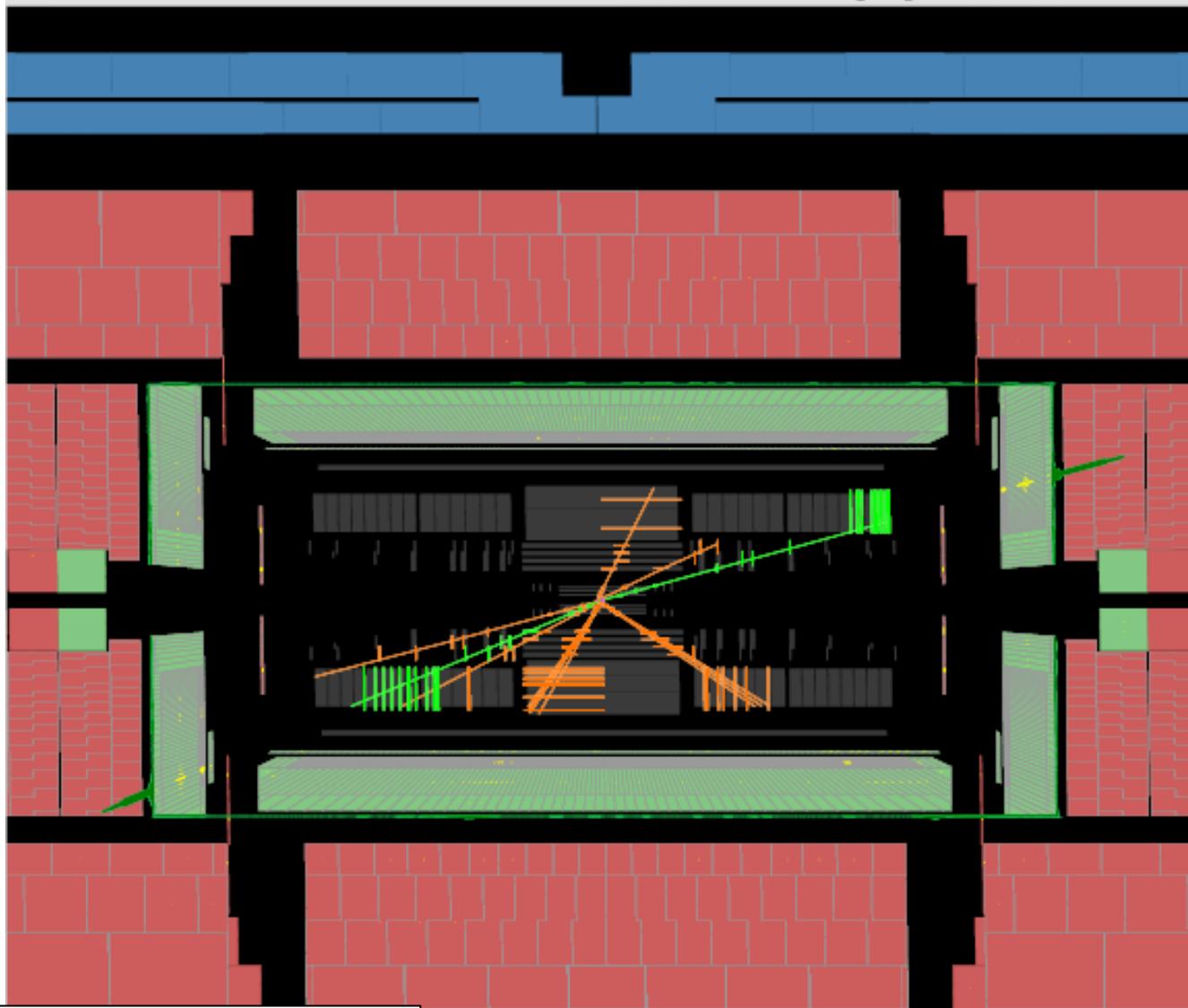
* For $\tau\tau$ final state see presentation by Peter Wagner .

$ee/\mu\mu$ (i) ee - channel Z' / G^* $\mu\mu$ - channel $p_T^{1,2} > 25$ GeV $p_T^{1,2} > 25$ GeV

Background Estimate

- Z/γ^* - Diboson - $t\bar{t}$ - W+jets: from simulations (@NNLO, approx-NNLO, @NLO)
- QCD: data-driven reverse id technique (negligible contributions in the $\mu\mu$ channel)
normalization from low mass control region [70-110] GeV
- Dominant systematic uncertainty arise from theory (PDFs & scales ~20 %)

ATLAS 2011-10-04 05:39:53 UTC source:liveXML_190300_75300042 run:190300 ev:75300042 lumiBlock:388



ATLAS

EXPERIMENT

Run Number: 190300, Event Number: 75300042

Date: 2011-10-04 05:39:53 UTC

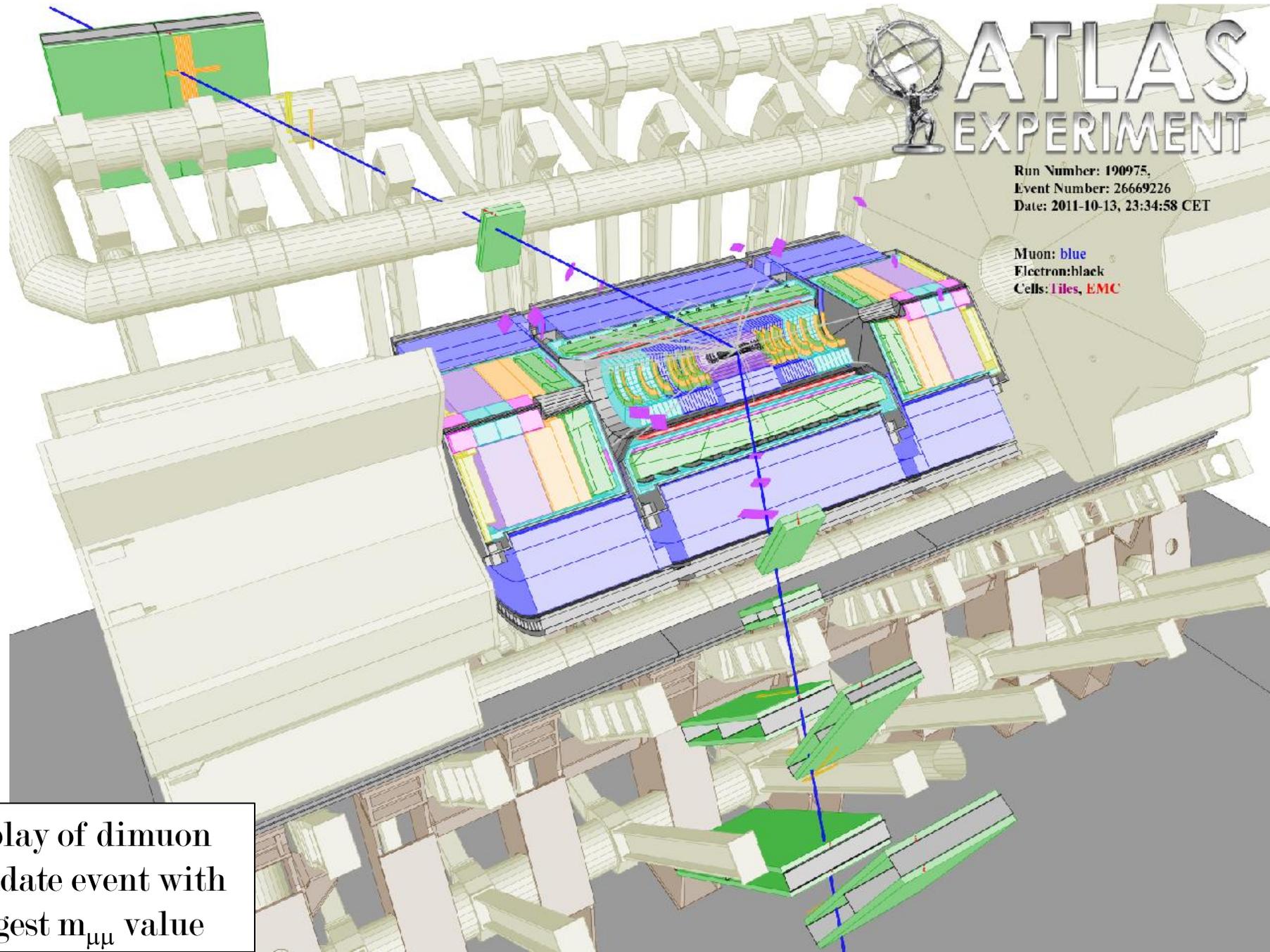
Display of dielectron
candidate event with
largest m_{ee} value



ATLAS EXPERIMENT

Run Number: 190975,
Event Number: 26669226
Date: 2011-10-13, 23:34:58 CET

Muon: blue
Electron: black
Cells: 11es, EMC

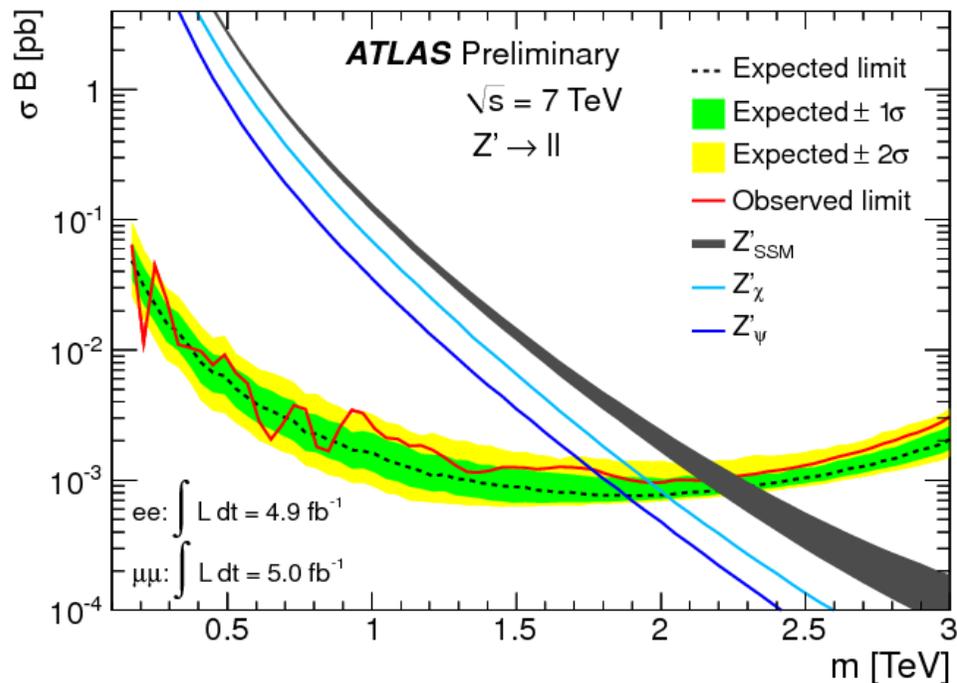


Display of dimuon
candidate event with
largest $m_{\mu\mu}$ value

$ee/\mu\mu$ (ii) 95% CL exclusion limits

Z'

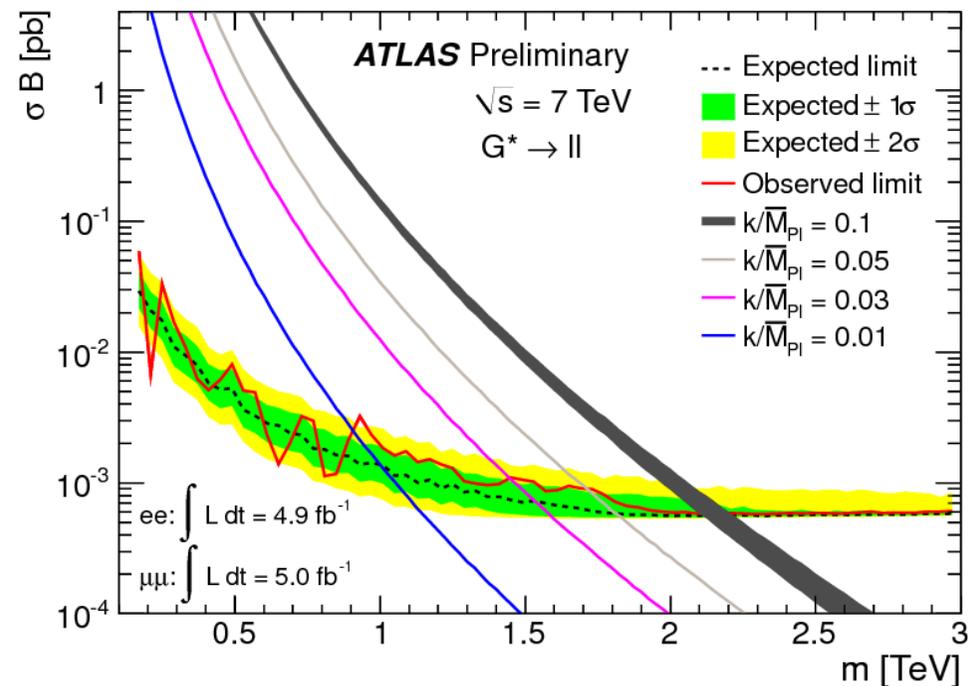
(heavy spin-1 neutral gauge bosons)



Model	Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ	Z'_{SSM}
$M_{Z'}$ limit [TeV]	1.76	1.78	1.84	1.84	1.90	1.96	2.21

G^*

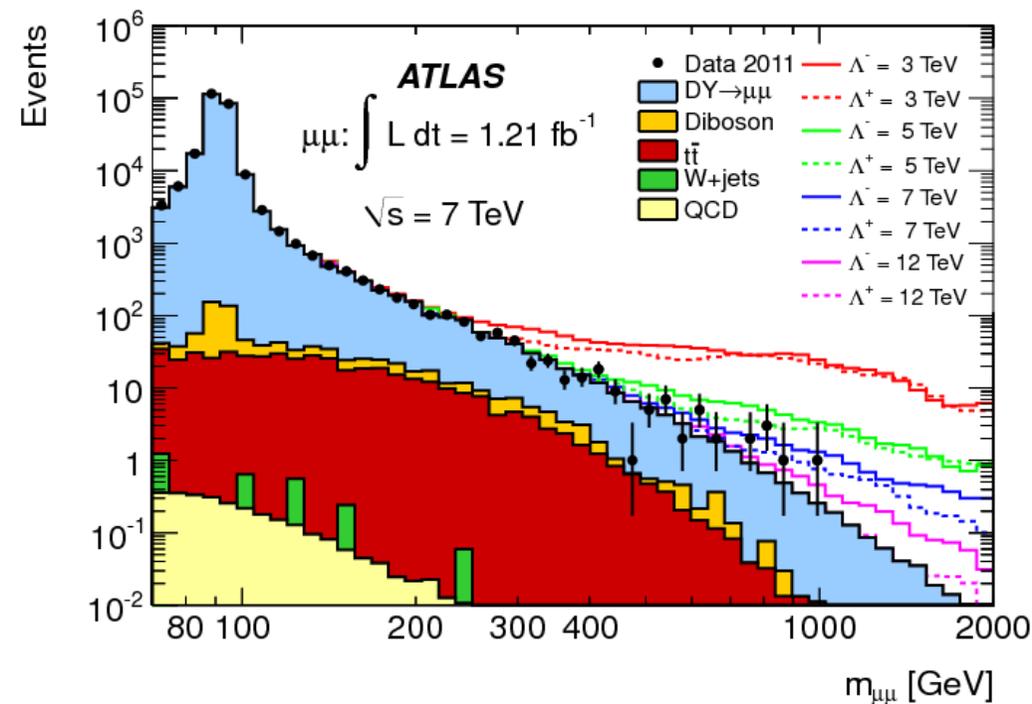
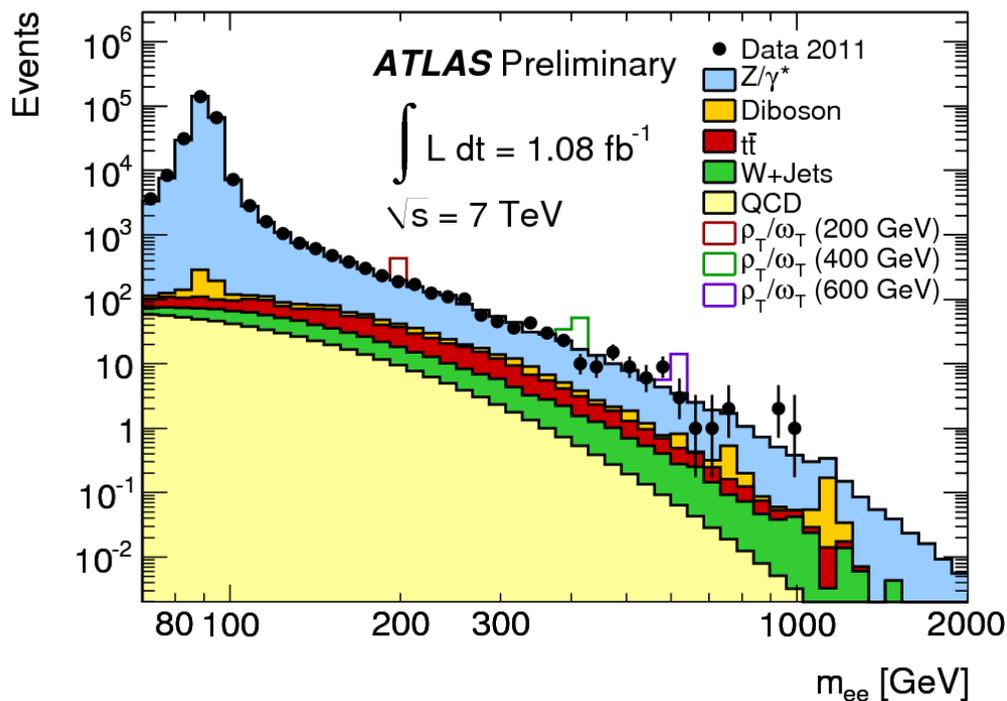
(spin-2 gravitons)



Signal ($k/M=0.1$)	M_{G^*} limit [TeV]
$G^* \rightarrow e^+e^-$	2.03
$G^* \rightarrow \mu^+\mu^-$	1.90
$G^* \rightarrow l^+l^-$	2.16

$ee/\mu\mu$ (iv)* Results based on a subsample of the 2011 data ($\sim 1/\text{fb}$)

TechniHadrons/ Contact Interactions

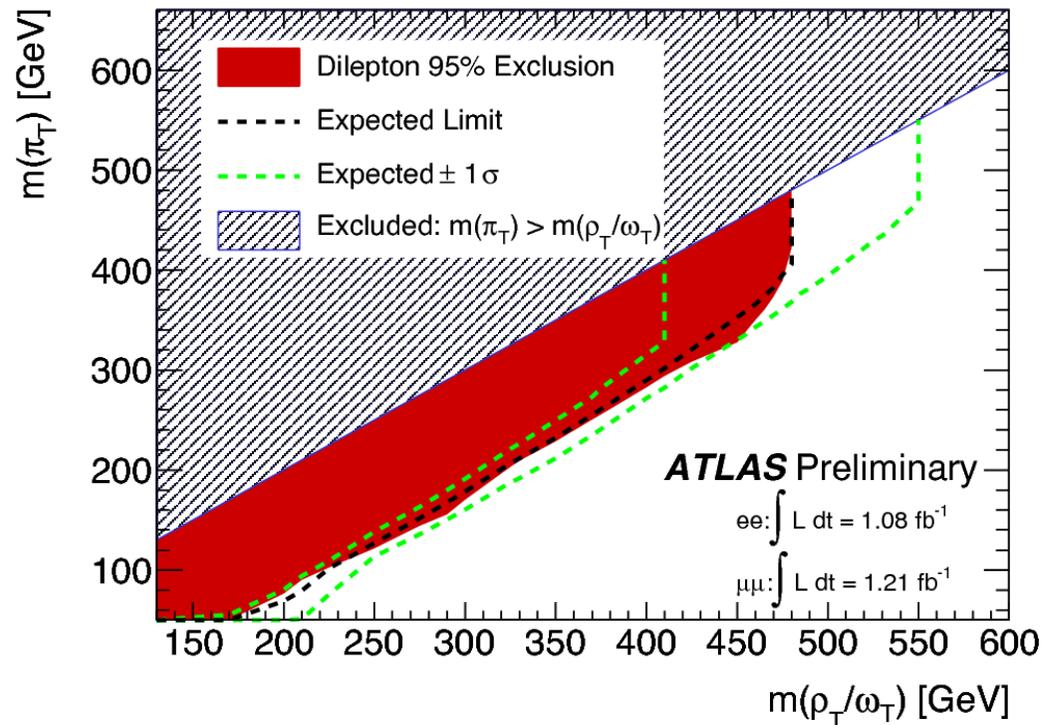
 ee - channel $p_T^{1,2} > 25 \text{ GeV}$ $\mu\mu$ - channel $p_T^{1,2} > 25 \text{ GeV}$ 

Search methodology identical to Z/G^*
 (same event selection criteria, backgrounds, systematics)

$ee/\mu\mu$ (ν) 95% CL exclusion limits

LSCT

(Low Scale Technicolor)



Signal ($M(\rho_T) - M(\pi_T) = 100 \text{ GeV}$) M_ρ limit [TeV]

$\rho_T/\omega_T \rightarrow l^+l^-$ 0.47

Contact Interactions

Left-Left Isoscalar Model

$$\eta_{LL} = \pm 1 \quad \eta_{LR} = \eta_{RR} = 0$$

$$\frac{d\sigma}{dm_{\ell\ell}} = \frac{d\sigma_{DY}}{dm_{\ell\ell}} - \eta_{LL} \frac{F_I(m_{\ell\ell})}{\Lambda^2} + \frac{F_C(m_{\ell\ell})}{\Lambda^4}$$

Channel	95% CL limits [TeV] on Λ ($1/\Lambda^2$ prior)	
	$\eta_{LL} = -1$	$\eta_{LL} = 1$
e^+e^-	10.1	9.4
$\mu^+\mu^-$	8.0	7.0
l^+l^-	10.2	8.8

$$e\nu_e/\mu\nu_\mu (i)$$

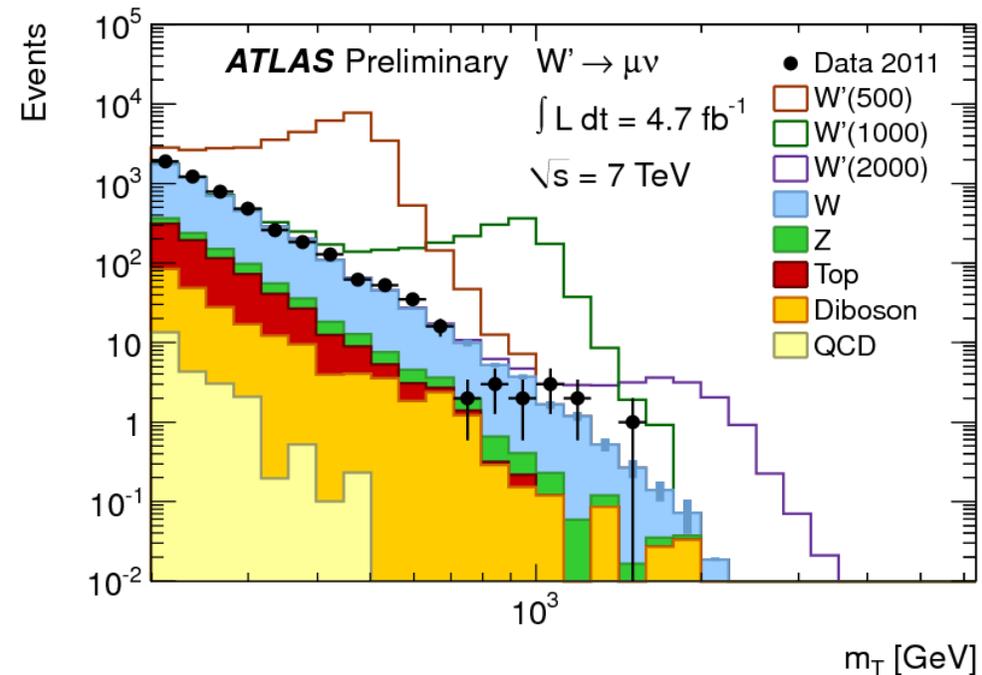
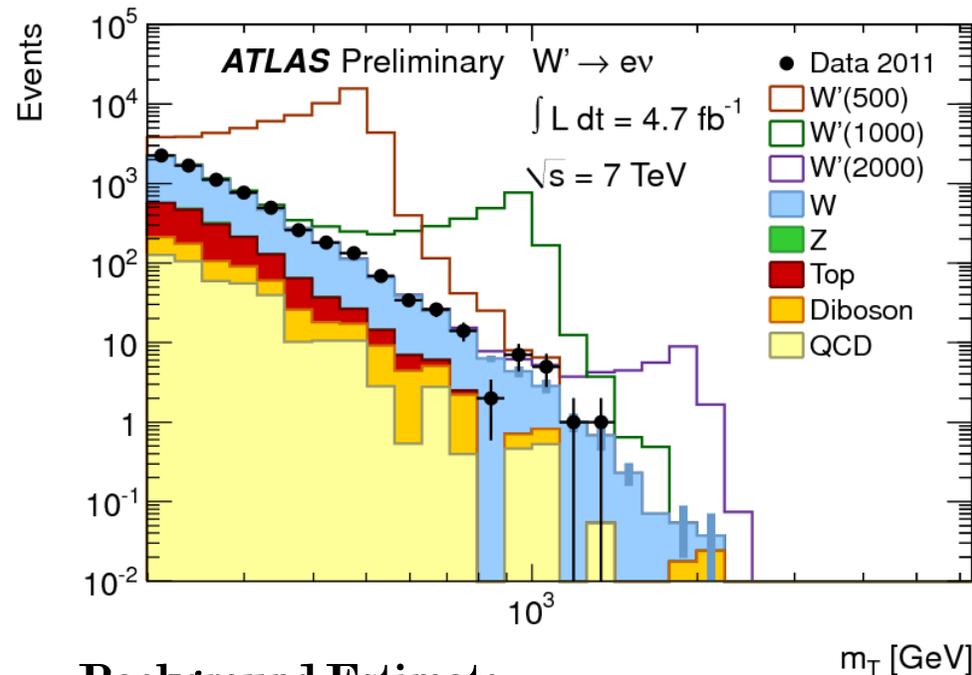
$$\text{Observable} \quad m_T = \sqrt{2p_T E_T^{\text{miss}} (1 - \cos \theta_{l\nu})}$$



$$W' / W^*$$

$$W' / W^*$$

$$p_T, E_T^{\text{miss}} > 85 \text{ GeV}$$

$$p_T, E_T^{\text{miss}} > 25 \text{ GeV}$$


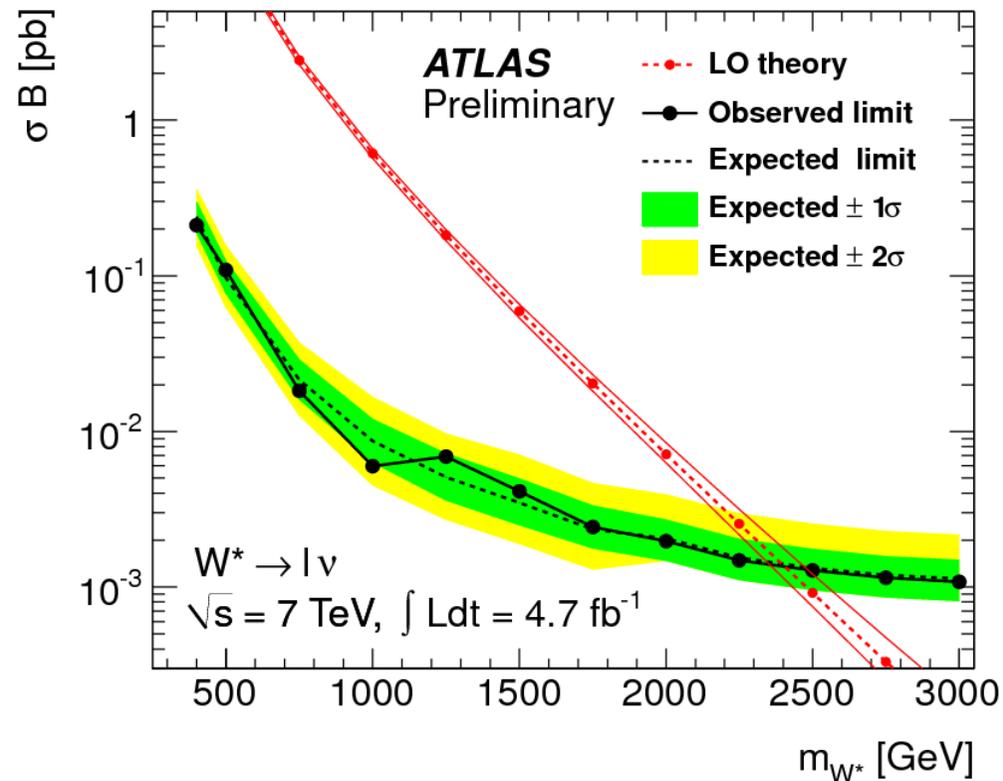
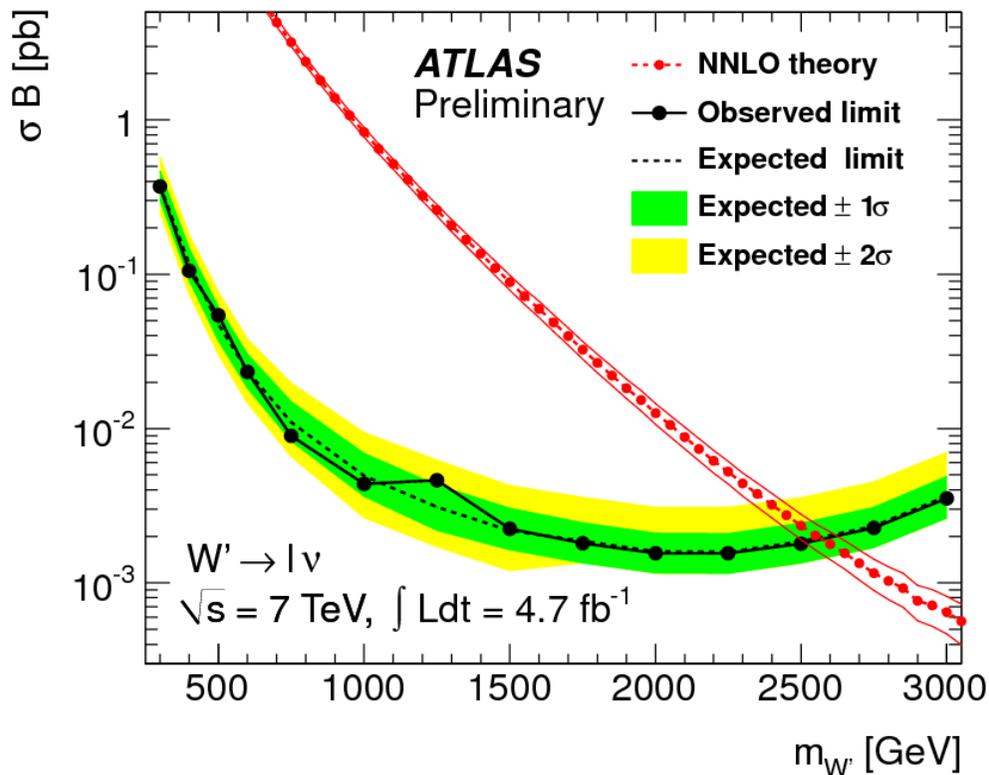
Background Estimate

- **W - Z - Top - Diboson** : from simulations (**@NNLO** , **approx-NNLO**)
- **QCD** : data-driven ABCD technique (negligible contributions in the $\mu\nu$ channel)
- Dominant systematic uncertainty arise from theory (PDFs & scales) $\sim 12\%$ and MC statistics $\sim 10\%$

$e\nu_e/\mu\nu_\mu$ (ii) 95% CL exclusion limits

W'

W^*

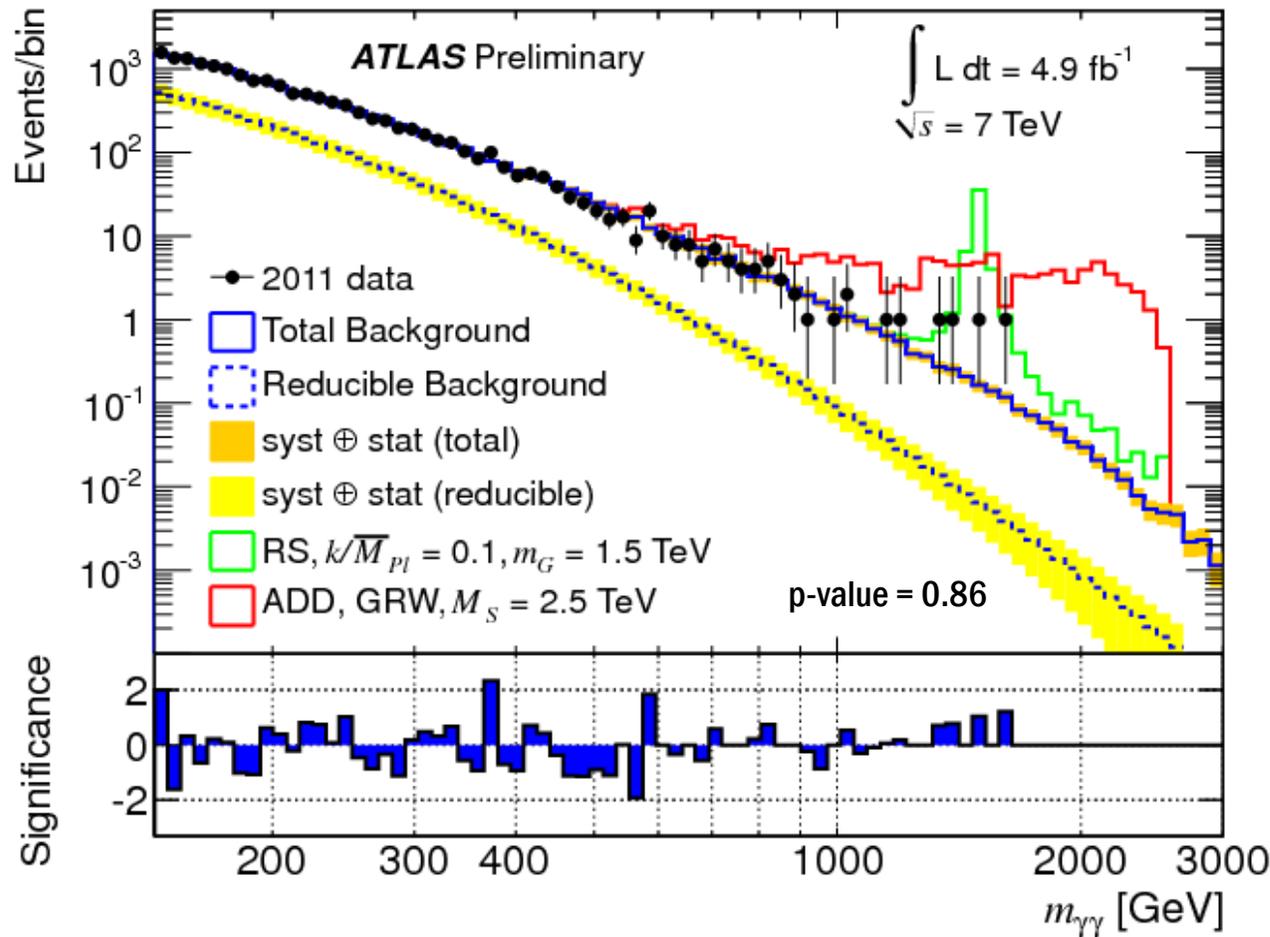


Signal	95% CL limit on mass [TeV]		
W'	$e\nu$: 2.50	$\mu\nu$: 2.28	$l\nu$: 2.55
W^*	$e\nu$: 2.35	$\mu\nu$: 2.04	$l\nu$: 2.40

Searches on the diphoton final state (i)

Final State	Model	$\int L dt$ [1/fb]	Topology
$\gamma\gamma$	Spin-2 gravitons (RS): G^*	4.9	Resonant
	Virtual-graviton exchange: ADD	($\sqrt{s}=7$ TeV)	Non-resonant

* Branching ratio twice the one to any pair of charge leptons

$\gamma\gamma$ (ii) $p_T^{1,2} > 25 \text{ GeV} / m_{\gamma\gamma} > 140 \text{ GeV}$ **Background Estimate**

Irreducible

SM $\gamma\gamma$

(shape from simulation @NLO)

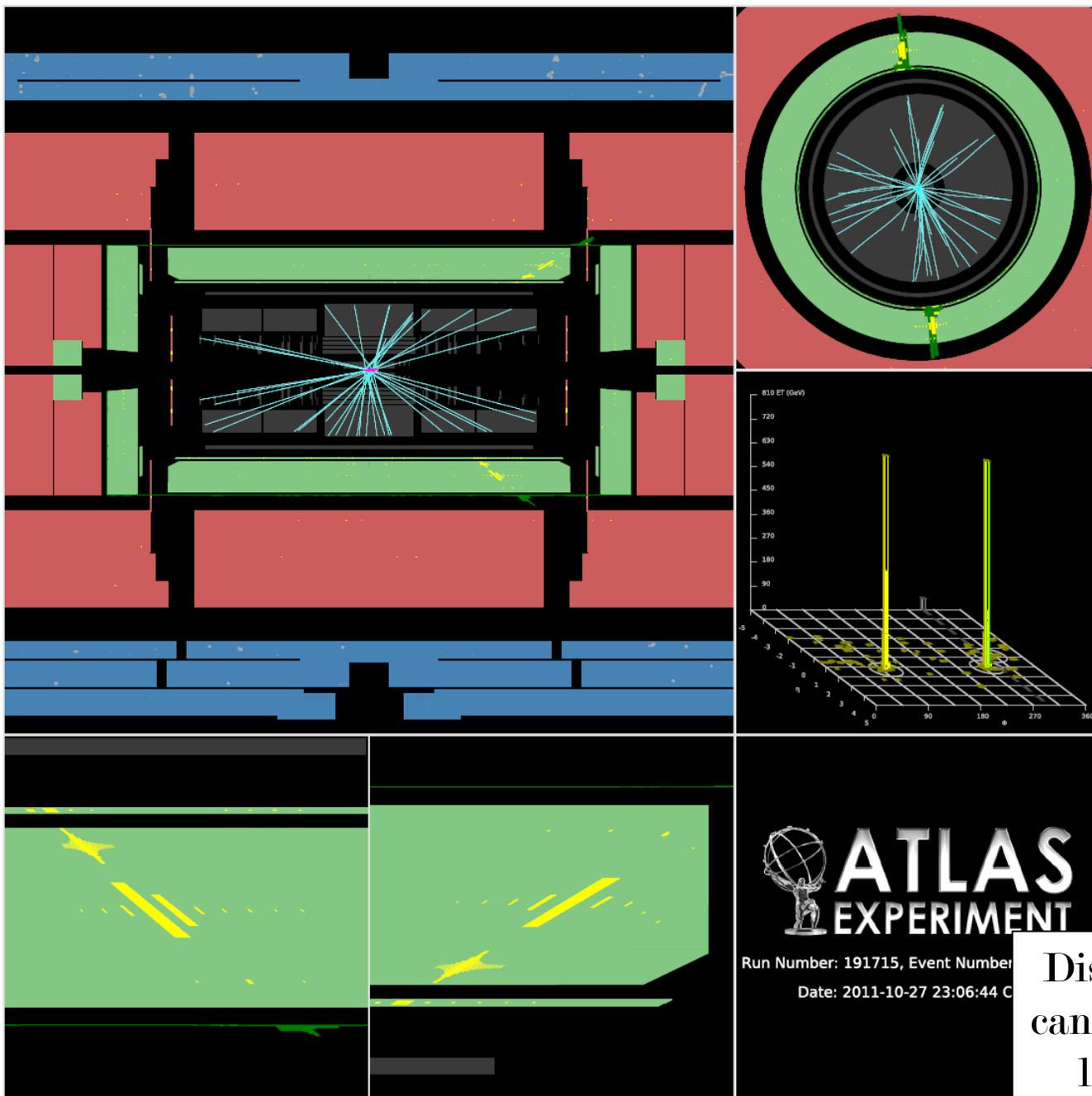
+

Reducible

QCD γ +jet / jet+jet

(shape from data jet enriched samples)

Normalization from low mass control region [142,409] GeV using isolation templates

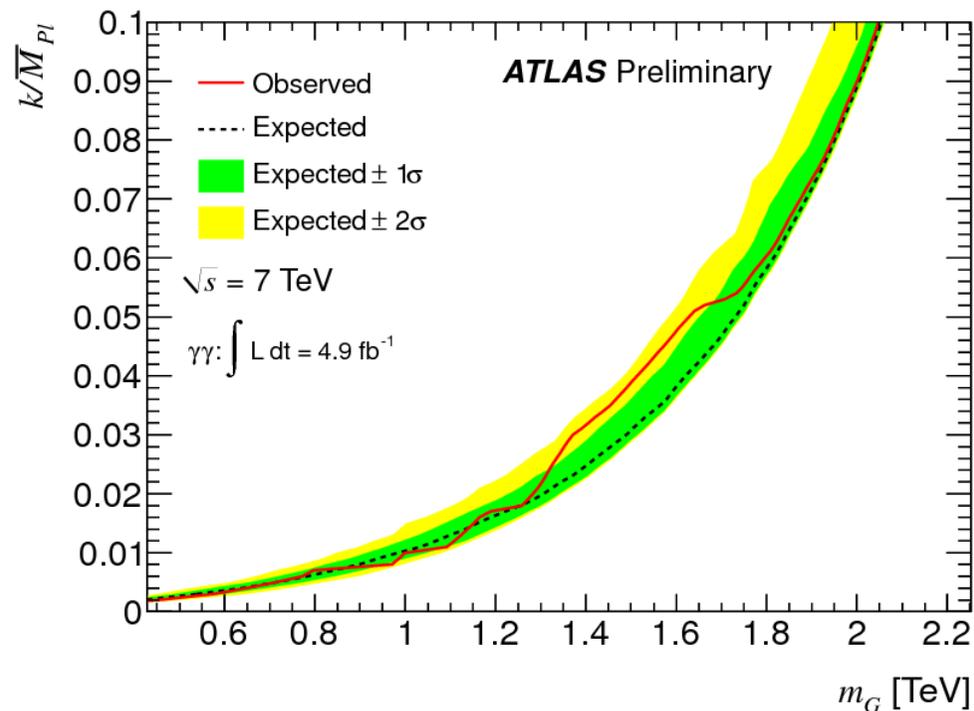


Display of diphoton
candidate event with
largest $m_{\gamma\gamma}$ value

$\gamma\gamma$ (iii) 95% CL exclusion limits

G^*

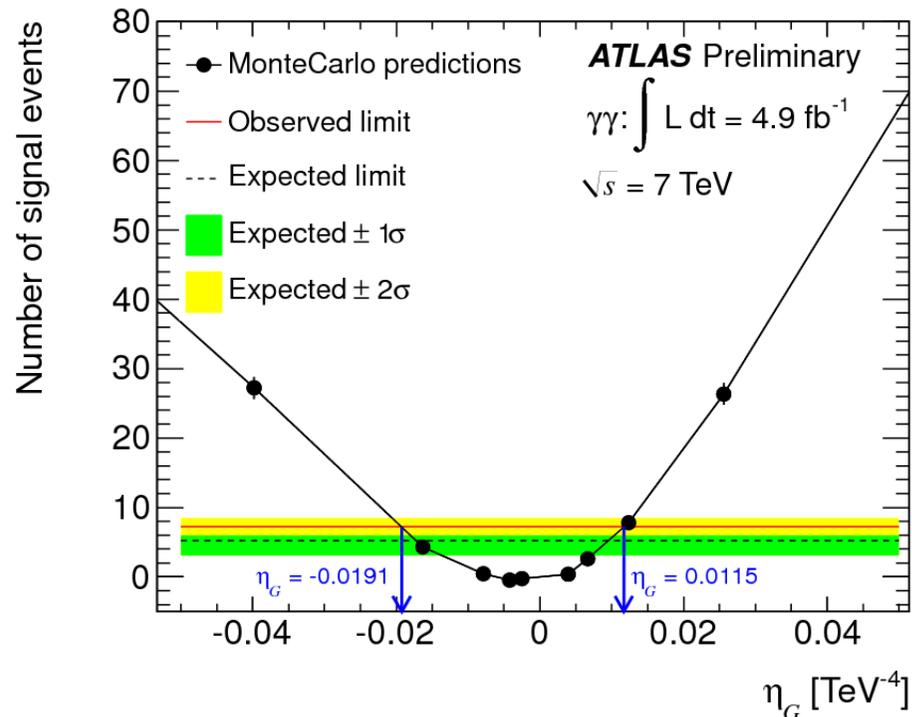
(resonant)



Signal ($k/M=0.1$)	m_{G^*} limit [TeV]
$G^* \rightarrow \gamma\gamma$	2.06

Virtual graviton exchange

(non - resonant)



$$\sigma_{\text{total}} = \sigma_{SM} + A\eta\sigma_{\text{int}} + B\eta^2\sigma_{ED}$$

$$\eta = \mathcal{F}/M_S^4$$

Model	GRW	Hewett	HLZ
M_S limit [TeV]	3.29	2.52 - 2.94	3.92 - 2.62

Conclusions

- Searches for new signals in events with a pair of leptons or photons have been made by the ATLAS experiment for several BSM scenarios.
 - Data consistent with SM expectations : No hint of new physics so far.
 - A widely new region of the parameters space of the models has been explored and 95% CL upper/lower limits were set on them.

- 8 TeV 2012 data is coming very fast
 - Data is being analyzed as we speak
 - **New physics might come very soon!**

ATLAS Exotics Searches* - 95% CL Lower Limits (Status: ICHEP 2012)

Extra dimensions

CI

V

LQ

New quarks

Excit. ferm.

Other

Large ED (ADD) : monojet + $E_{T,miss}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-084]	3.8 TeV	$M_D (\delta=2)$
Large ED (ADD) : monophoton + $E_{T,miss}$	$L=4.6 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-085]	1.7 TeV	$M_D (\delta=2)$
Large ED (ADD) : diphoton, $m_{\gamma\gamma}$	$L=4.9 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-087]	3.29 TeV	M_S (GRW cut-off, NLO) *
UED : diphoton + $E_{T,miss}$	$L=4.8 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-072]	1.41 TeV	Compact. scale 1/R
RS1 with $k/M_{Pl} = 0.1$: diphoton, $m_{\gamma\gamma}$	$L=4.9 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-087]	2.06 TeV	Graviton mass *
RS1 with $k/M_{Pl} = 0.1$: dilepton, m_{ll}	$L=4.9-5.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-007]	2.16 TeV	Graviton mass *
RS1 with $k/M_{Pl} = 0.1$: ZZ resonance, m_{ll} / l_{ij}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.0718]	845 GeV	Graviton mass
RS1 with $k/M_{Pl} = 0.1$: WW resonance, $m_{T,lv}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-068]	1.23 TeV	Graviton mass
RS with $g_{\text{KK}}/g_s = -0.20$: $tt \rightarrow l+jets, m_{tt}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-029]	1.03 TeV	KK gluon mass
RS with BR($g_{\text{KK}} \rightarrow tt$) = 0.925 : $tt \rightarrow l+jets, m_{tt}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [Preliminary]	1.50 TeV	KK gluon mass
ADD BH ($M_{TH}/M_D=3$) : SS dimuon, $N_{\text{ch,part}}$	$L=1.3 \text{ fb}^{-1}, 7 \text{ TeV}$ [1111.0080]	1.25 TeV	$M_D (\delta=6)$
ADD BH ($M_{TH}/M_D=3$) : leptons + jets, Σp_T	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1204.4646]	1.5 TeV	$M_D (\delta=6)$
Quantum black hole : dijet, $F(m_{ij})$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-038]	4.11 TeV	$M_D (\delta=6)$
qqqq contact interaction : $\chi(m_{ij})$	$L=4.8 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-038]	7.8 TeV	Λ
qqll CI : ee, $\mu\mu$ combined, m_{ll}	$L=1.1-1.2 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.4462]	10.2 TeV	Λ (constructive int.) *
uutt CI : SS dilepton + jets + $E_{T,miss}$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.5520]	1.7 TeV	Λ
Z' (SSM) : $m_{ee/\mu\mu}$	$L=4.9-5.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-007]	2.21 TeV	Z' mass *
Z' (SSM) : $m_{\tau\tau}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-067]	1.3 TeV	Z' mass
W' (SSM) : $m_{T,e\mu}$	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-086]	2.55 TeV	W' mass *
W' ($\rightarrow tq, g_s=1$) : m_{tq}	$L=4.7 \text{ fb}^{-1}, 7 \text{ TeV}$ [CONF-2012-096]	350 GeV	W' mass
W'_R ($\rightarrow tb, \text{SSM}$) : m_{tb}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1205.1016]	1.13 TeV	W' mass
Scalar LQ pairs ($\beta=1$) : kin. vars. in eejj, evjj	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.4828]	660 GeV	1 st gen. LQ mass
Scalar LQ pairs ($\beta=1$) : kin. vars. in $\mu\mu jj, \mu\nu jj$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.3172]	685 GeV	2 nd gen. LQ mass
4 th generation : $Q_4 \bar{Q}_4 \rightarrow WqWq$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.3389]	350 GeV	Q_4 mass
4 th generation : $u_4 \bar{u}_4 \rightarrow WbWb$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.3076]	404 GeV	u_4 mass
4 th generation : $d_4 \bar{d}_4 \rightarrow WtWt$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1202.6540]	480 GeV	d_4 mass
New quark b' : $b\bar{b}' \rightarrow Zb+X, m_{Zb}$	$L=2.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1204.1265]	400 GeV	b' mass
TT _{top partner} $\rightarrow tt + A_0 A_0$: 2-lep + jets + $E_{T,miss}$ (M_{T2})	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-071]	483 GeV	T mass ($m(A_0) < 100 \text{ GeV}$)
Vector-like quark : CC, m_{Vq}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.5755]	900 GeV	Q mass (coupling $\kappa_{qQ} = v/m_Q$)
Vector-like quark : NC, m_{Vq}	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.5755]	760 GeV	Q mass (coupling $\kappa_{qQ} = v/m_Q$)
Excited quarks : γ -jet resonance, $m_{\gamma\text{jet}}$	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1112.3580]	2.46 TeV	q* mass
Excited quarks : dijet resonance, m_{jj}	$L=5.8 \text{ fb}^{-1}, 8 \text{ TeV}$ [ATLAS-CONF-2012-088]	3.66 TeV	q* mass
Excited electron : e- γ resonance, $m_{e\gamma}$	$L=4.9 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-023]	2.0 TeV	e* mass ($\Lambda = m(e^*)$)
Excited muon : μ - γ resonance, $m_{e\gamma}$	$L=4.8 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-023]	1.9 TeV	μ^* mass ($\Lambda = m(\mu^*)$)
Techni-hadrons : dilepton, $m_{ee/\mu\mu}$	$L=1.1-1.2 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2011-125]	470 GeV	ρ_T/ω_T mass ($m(\rho_T/\omega_T) - m(\pi_T) = 100 \text{ GeV}$) *
Techni-hadrons : WZ resonance (vlll), $m_{T,WZ}$	$L=1.0 \text{ fb}^{-1}, 7 \text{ TeV}$ [1204.1648]	483 GeV	ρ_T mass ($m(\rho_T) = m(\pi_T) + m_W, m(a_\pm) = 1.1 m(\rho_T)$)
Major. neutr. (LRSM, no mixing) : 2-lep + jets	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.5420]	1.5 TeV	N mass ($m(W_R) = 2 \text{ TeV}$)
W_R (LRSM, no mixing) : 2-lep + jets	$L=2.1 \text{ fb}^{-1}, 7 \text{ TeV}$ [1203.5420]	2.4 TeV	W_R mass ($m(N) < 1.4 \text{ GeV}$)
$H_L^{\pm\pm}$ (DY prod., BR($H_L^{\pm\pm} \rightarrow \mu\mu$)=1) : SS dimuon, $m_{\mu\mu}$	$L=1.6 \text{ fb}^{-1}, 7 \text{ TeV}$ [1201.1091]	355 GeV	$H_L^{\pm\pm}$ mass
Color octet scalar : dijet resonance, m_{jj}	$L=4.8 \text{ fb}^{-1}, 7 \text{ TeV}$ [ATLAS-CONF-2012-038]	1.94 TeV	Scalar resonance mass

$$\int L dt = (1.0 - 5.8) \text{ fb}^{-1}$$

$$\sqrt{s} = 7, 8 \text{ TeV}$$

ATLAS Preliminary

* Shown today

Mass scale [TeV]

Backup

Other references (i)

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Other references (ii)

■ W'/W^*

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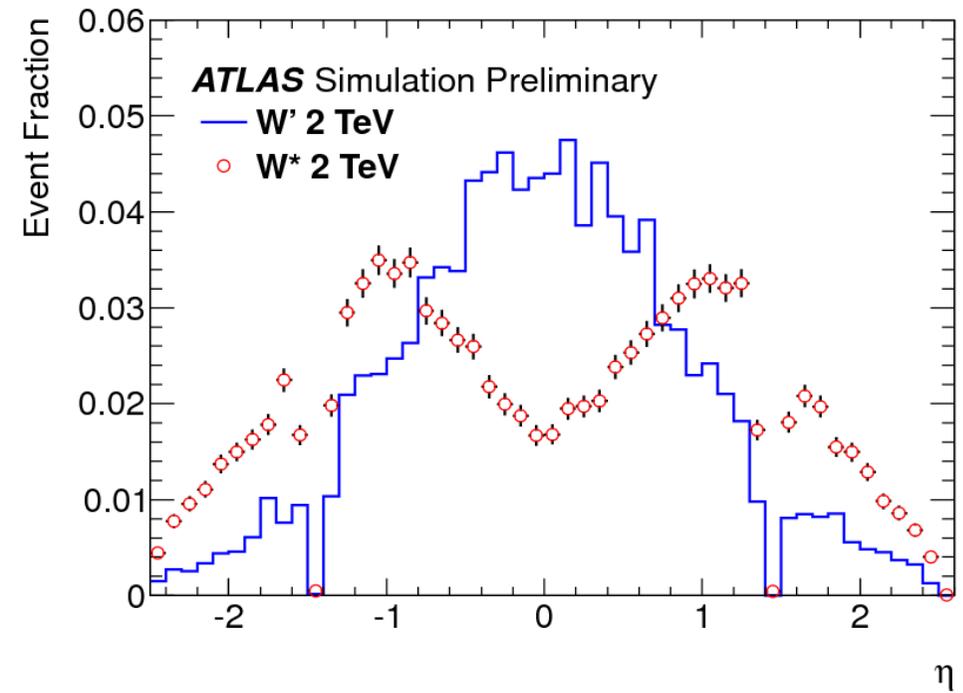
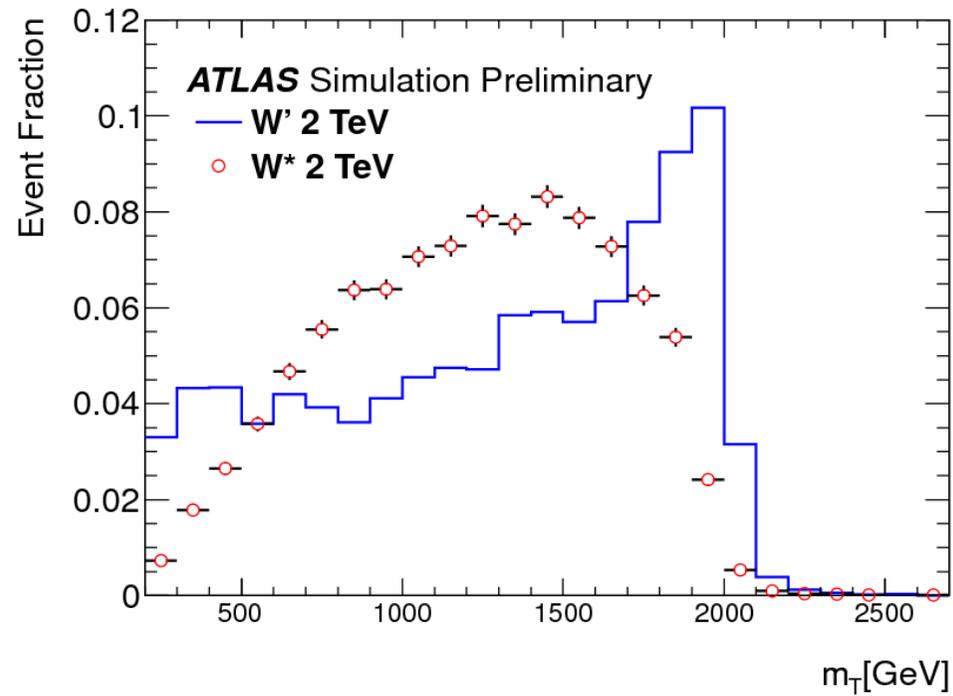
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W'/W^* kinematics



Simulated processes : Generators

- Z' : **PYTHIA** -> NNLO **PHOZPR**
- G^* : **PYTHIA** -> NLO (from dedicated study)
- DY: **PYTHIA** -> NNLO **PHOZPR + HORACE (EW)**
- DIBOSON: **HERWIG** ->NLO **MCFM**
- $t\bar{t}$: MC@NLO -> approx-NNLO (from dedicated study)
- W +JETS : **ALPGEN** -> NNLO **FEWZ**
- DY+CI: **PYTHIA** -> NNLO **PHOZPR + HORACE (EW)**
- Technihadrons : **PYTHIA** -> NNLO **PHOZPR**
- W' : **PYTHIA** -> NNLO **FEWZ**
- W^* : **COMPHEP**
- W/Z : **PYTHIA** -> NNLO **FEWZ**
- DIPHOTON: **PYTHIA** -> NLO **DIPHOX**
- ADD: **SHERPA** -> NLO (dedicated study)