

Searches for new fermions and gauge interactions with ATLAS

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(LAPP, Annecy le Vieux)

on behalf of the ATLAS collaboration

Implications of LHC Results for TeV-Scale Physics, CERN

30 August 2011



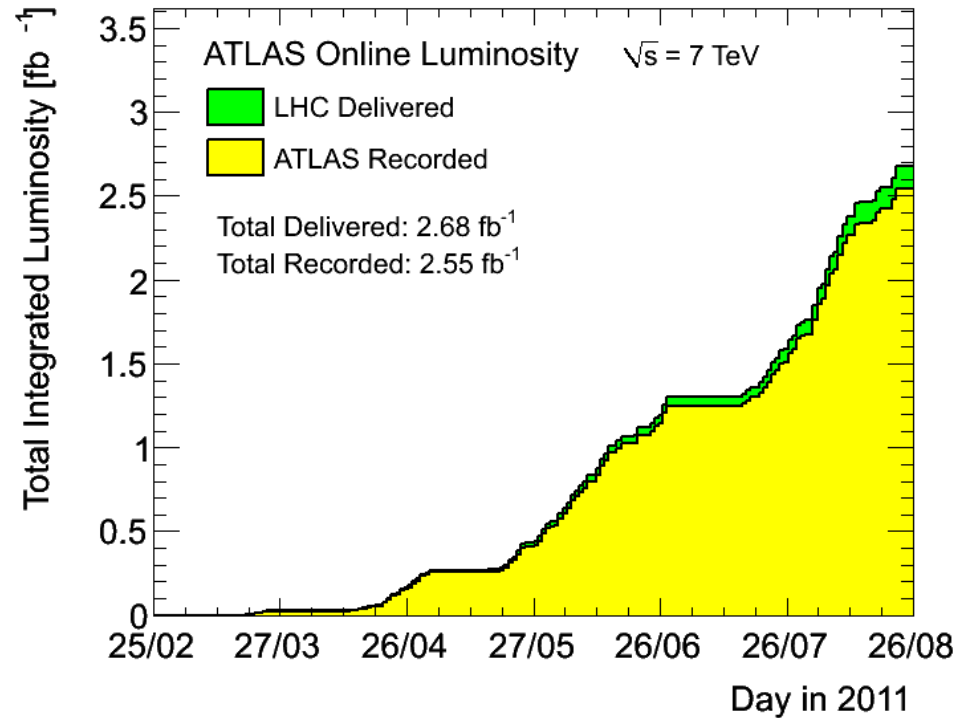
Introduction

Standard Model describes data very well, but is only low energy effective theory

New Physics is needed at the weak scale $\sim 1\text{TeV}$

Searching for New Physics:

- New Gauge Interactions:
 - W-like gauge bosons
 - Z-like gauge bosons
 - Contact Interactions ($\mu\mu, \text{di-jet}$)
- New particles:
 - Doubly Charged Higgs
 - LeptoQuarks
 - $l\nu jj$ spectrum
 - Di-jet spectrum

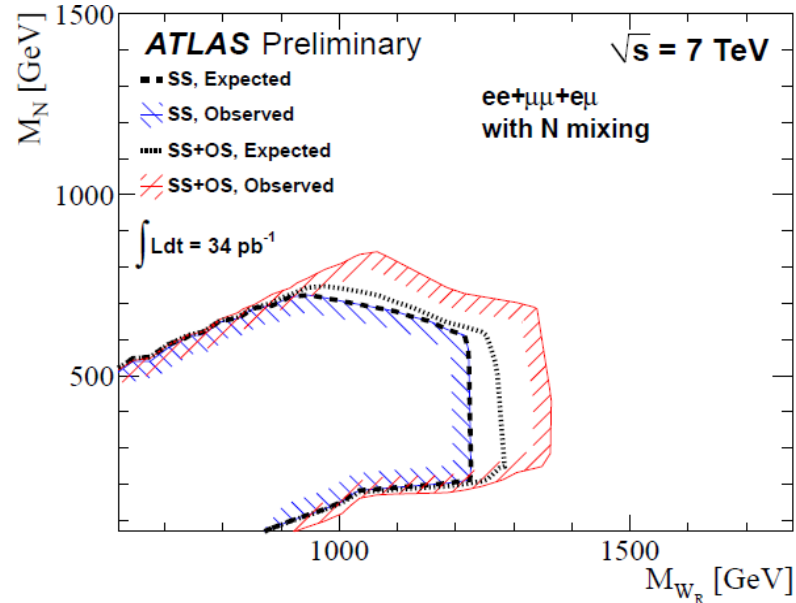
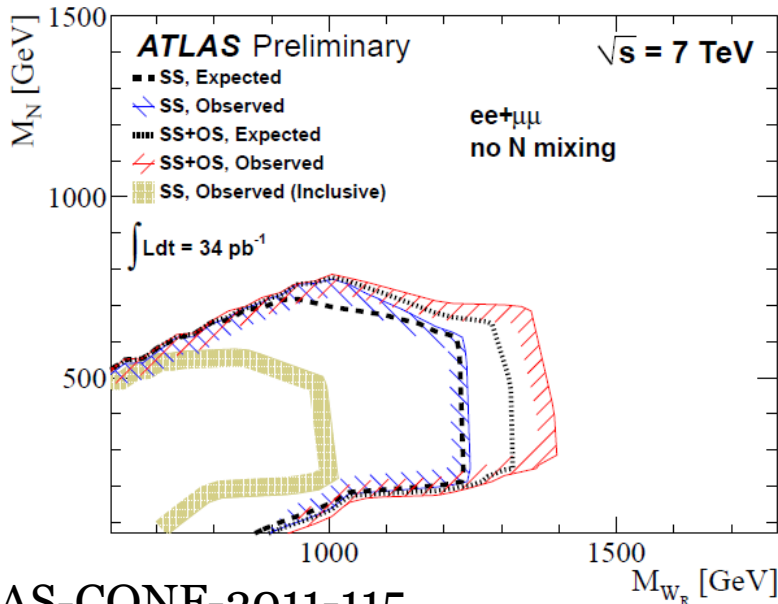
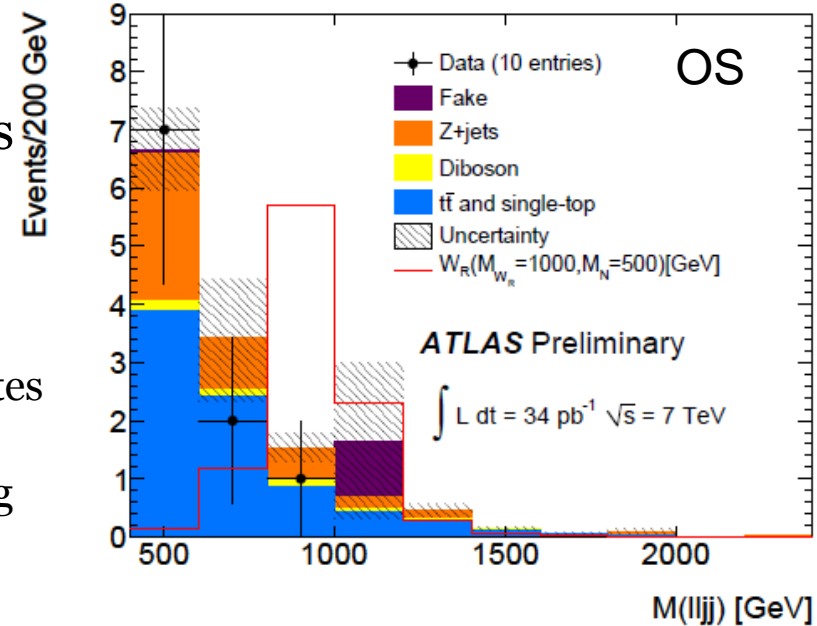


- 2010: 45 pb^{-1} recorded
- 2011 (till 26/08): 2.55 fb^{-1} recorded
- Peak Lumi of $2.37 \cdot 10^{33}\text{ cm}^{-2}\text{s}^{-1}$
- 6 interactions per BC on average

New Heavy Gauge Bosons

Search for Right-Handed W boson

- Benchmark: Left-Right Symmetric Model
- New gauge boson W_R and Heavy neutrinos (N)
 - $q\bar{q} \rightarrow W_R \rightarrow lN, N \rightarrow lW_R^* \rightarrow ljetjet$
 - Non-Majorana N : only l^+l^- (OS) final state
 - Majorana N: both l^+l^\pm (SS) and l^+l^- (OS) final states
 - neutrino masses explained via sea-saw mechanism
 - N can mix if masses are different both no-mixing and 100% mixing cases considered
- Data consistent with SM predictions



Search for New Heavy Charged Boson

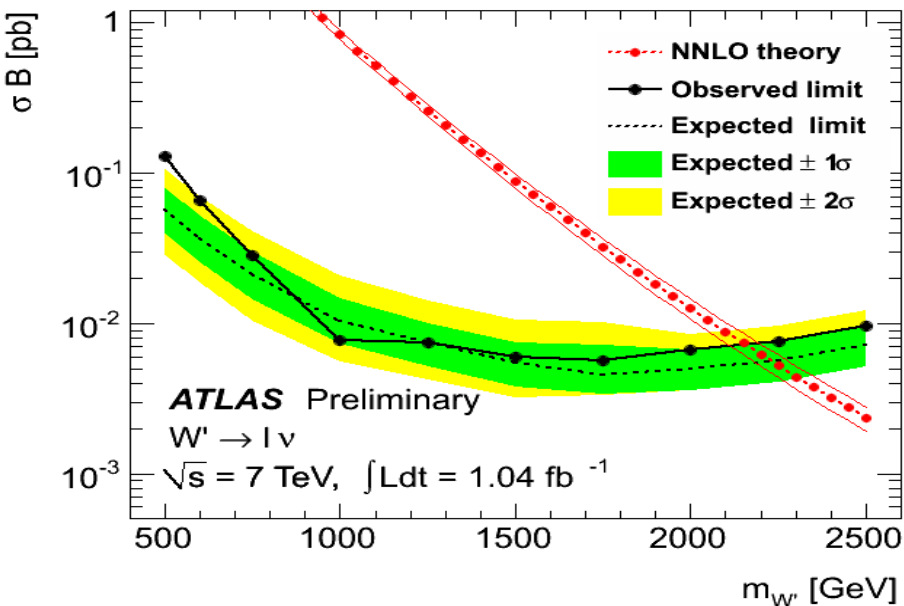
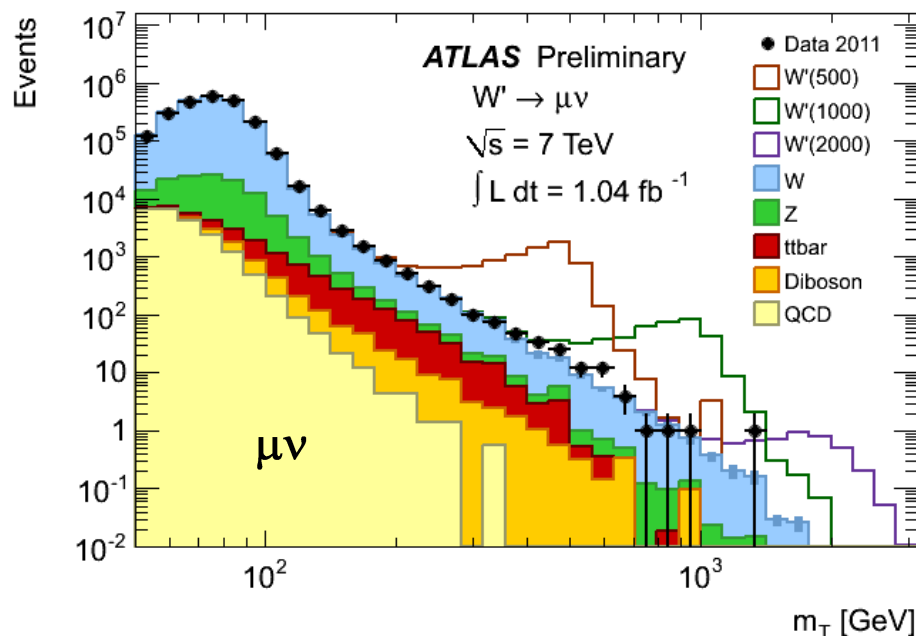
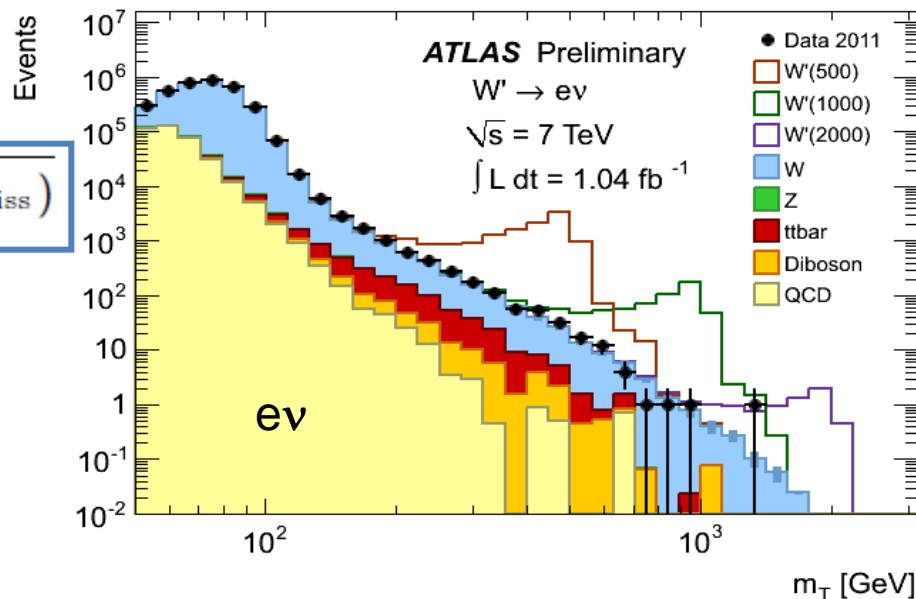
- Benchmark Signal: $W' \rightarrow l\nu$

- Observable

$$M_T = \sqrt{2p_T^l E_T^{\text{miss}} (1 - \cos \Delta\phi_{l, E_T^{\text{miss}}})}$$

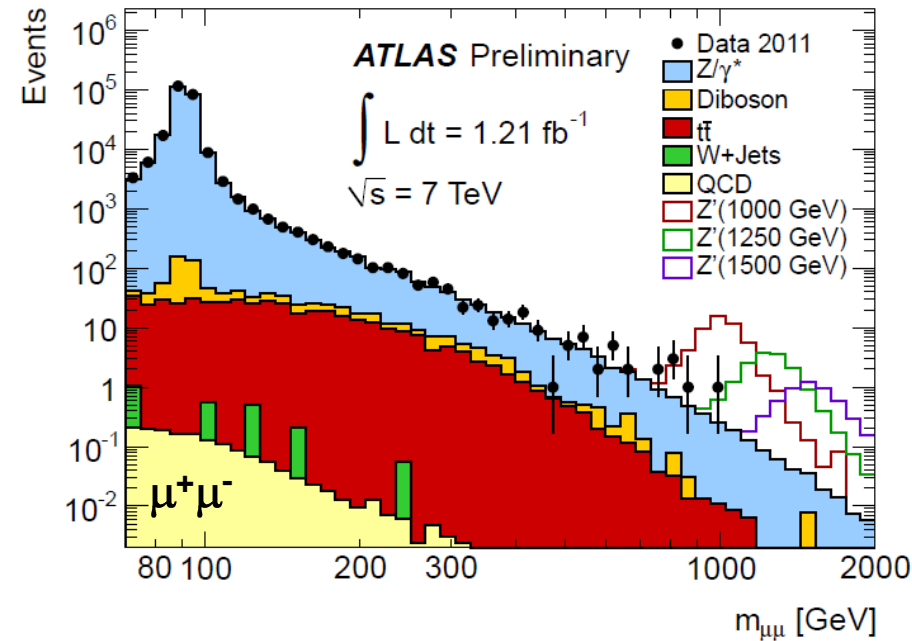
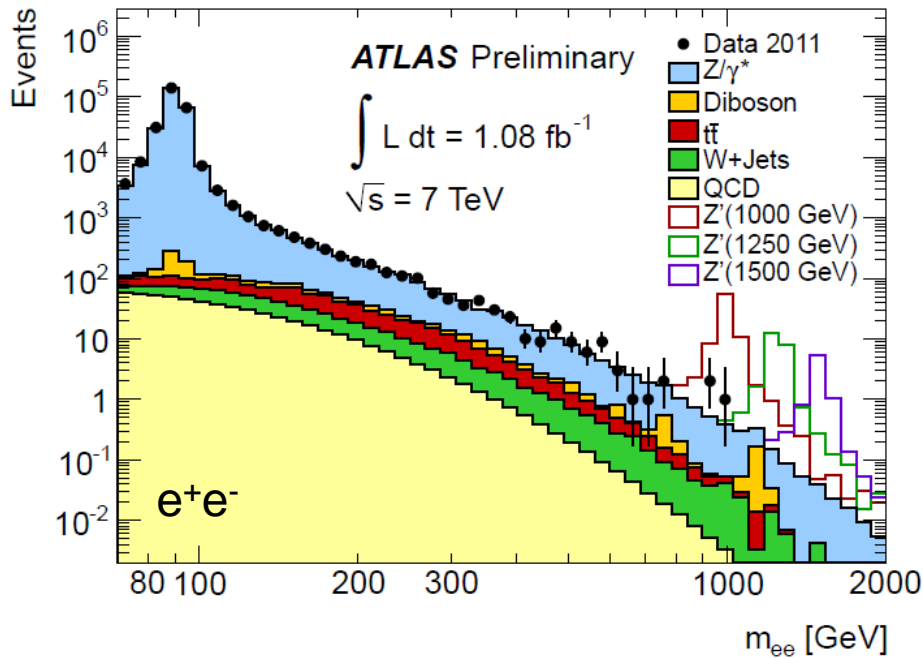
- Data consistent with SM prediction

- Limit @ 95% CL mass of SSM W' $> 2.15\text{TeV}$ (2.08TeV e & 1.98TeV μ)



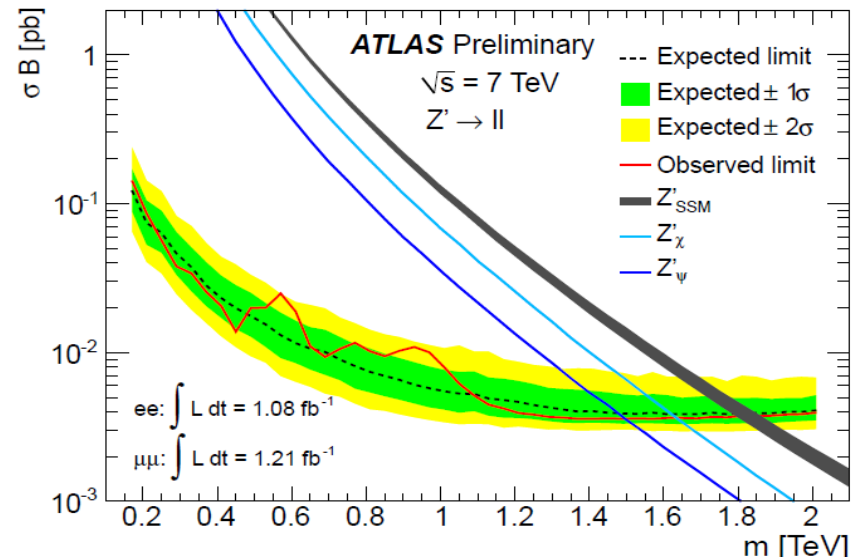
Search for New Heavy Neutral Gauge Boson

- Benchmark Signal: $Z' \rightarrow l^+l^-$



- Data consistent with DY predictions
- Limit: 1.83 TeV @ 95% CL for SSM Z'** (1.69 TeV ee and 1.60 TeV $\mu\mu$)
- Limits @ 95% CL on E_6 Model Z' (TeV)

Z'_ψ	Z'_N	Z'_η	Z'_I	Z'_S	Z'_χ
1.50	1.52	1.54	1.56	1.60	1.64

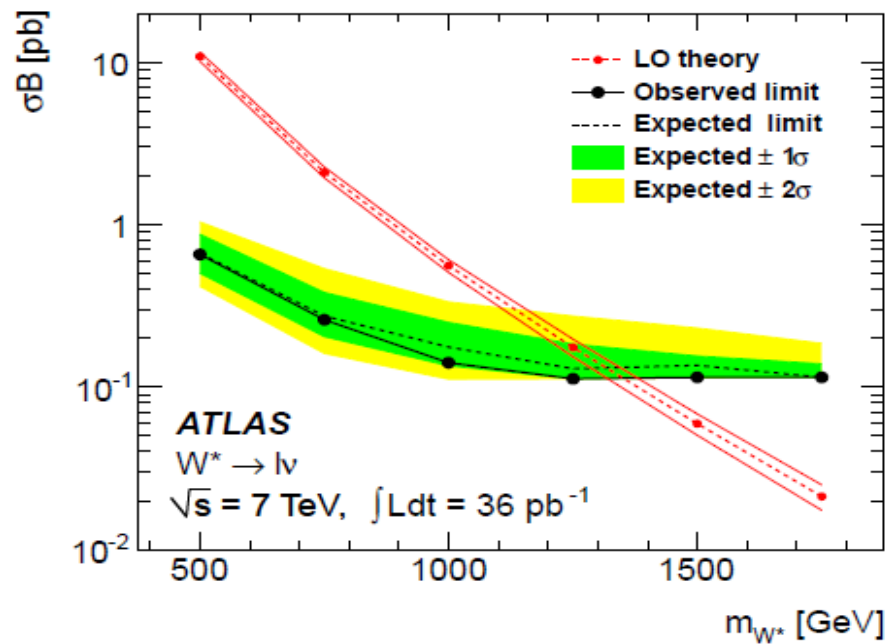
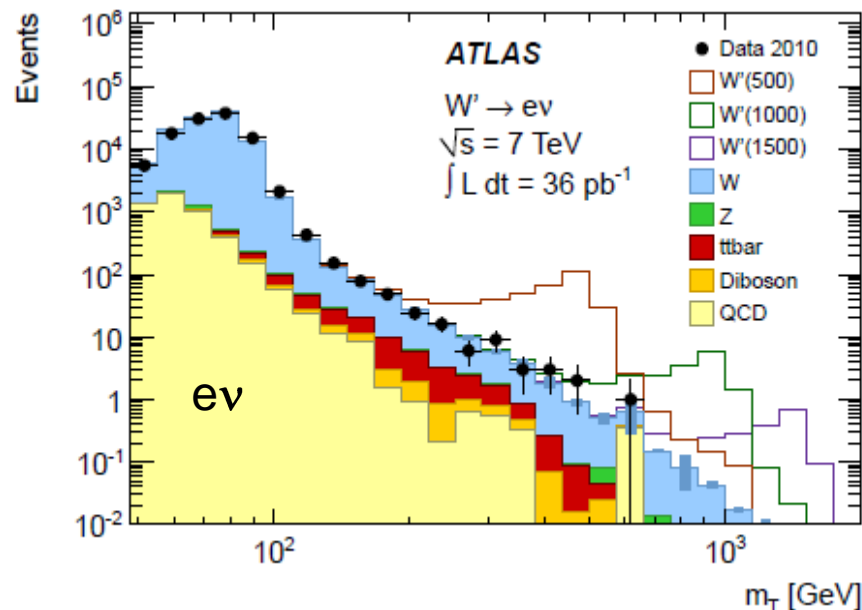


Search for New Heavy Boson with anomalous magnetic type couplings

- $W^* \rightarrow l\nu$ and $Z^* \rightarrow ll$ (same analysis as W'/Z')
- Assume quark-lepton universality gives similar Z^*/Z' width
- At LHC acceptances are also similar thus limits are closely related
- Only $\sim 40\text{pb}^{-1}$ of data used so far
- Data consistent with SM predictions
- Limits @ 95% CL with $36\text{pb}^{-1} M(W^*) > 1470 \text{ GeV}$ (1380 e, 1210 μ)

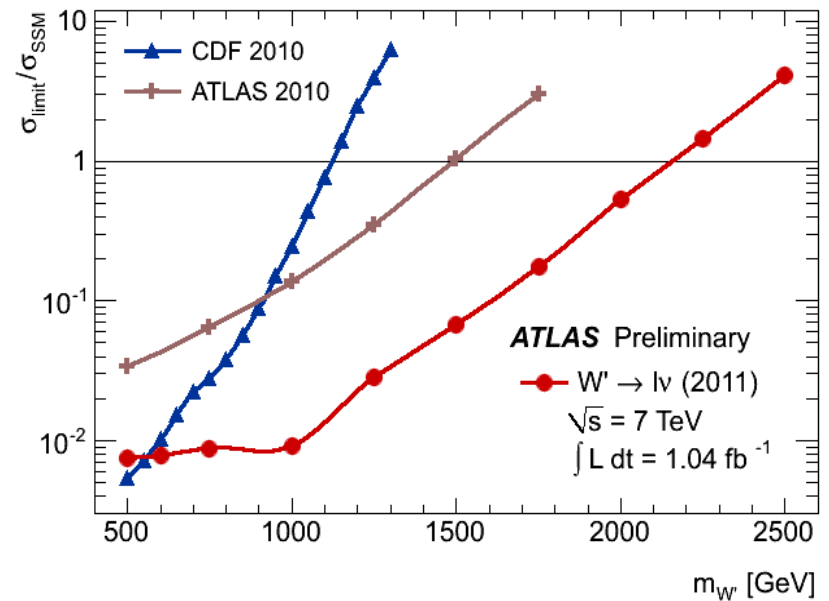
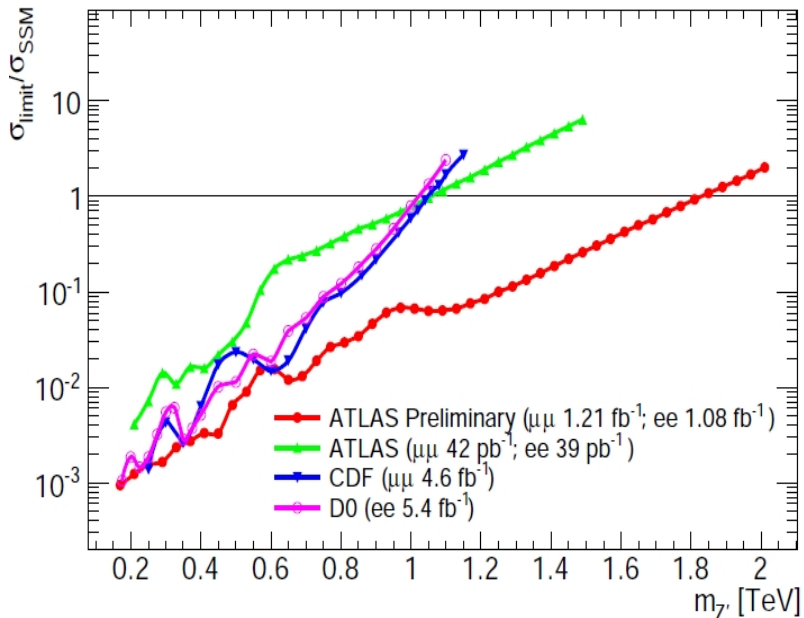
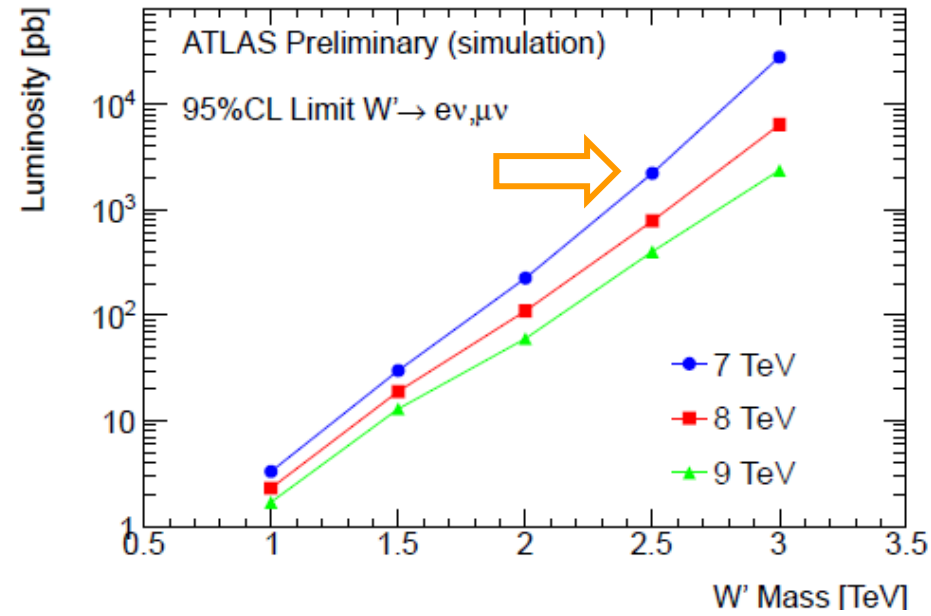
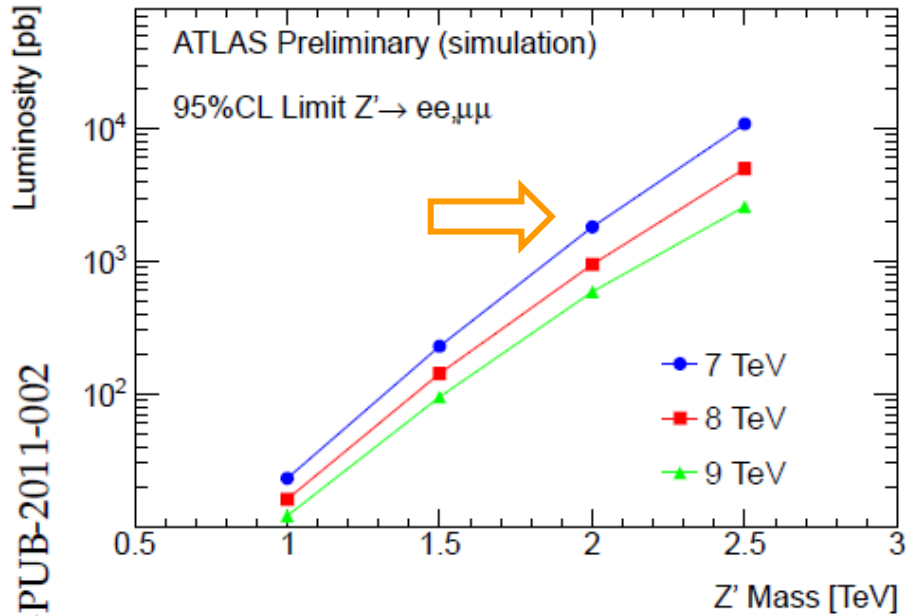
	Observed limit		Expected limit	
	mass [TeV]	σB [pb]	mass [TeV]	σB [pb]
$Z^* \rightarrow e^+e^-$	1.058	0.149	1.062	0.143
$Z^* \rightarrow \mu^+\mu^-$	0.946	0.265	0.995	0.199
$Z^* \rightarrow l^+l^-$	1.152	0.089	1.185	0.080

2010 data: Phys.Lett.B701:50-69,2011
 Phys.Lett.B700:163-180,2011



W' and Z' limits Expected Evolution

ATL-PHYS-PUB-2011-002

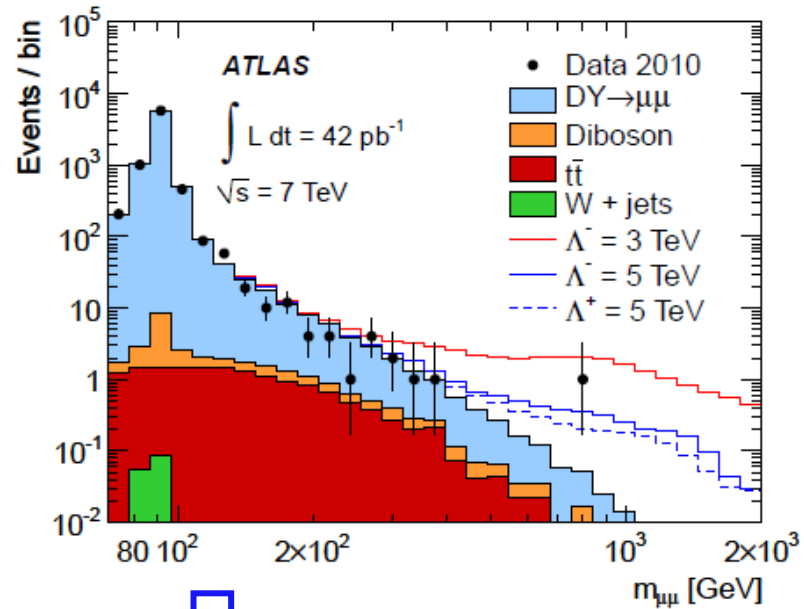


Other Models of New Interactions

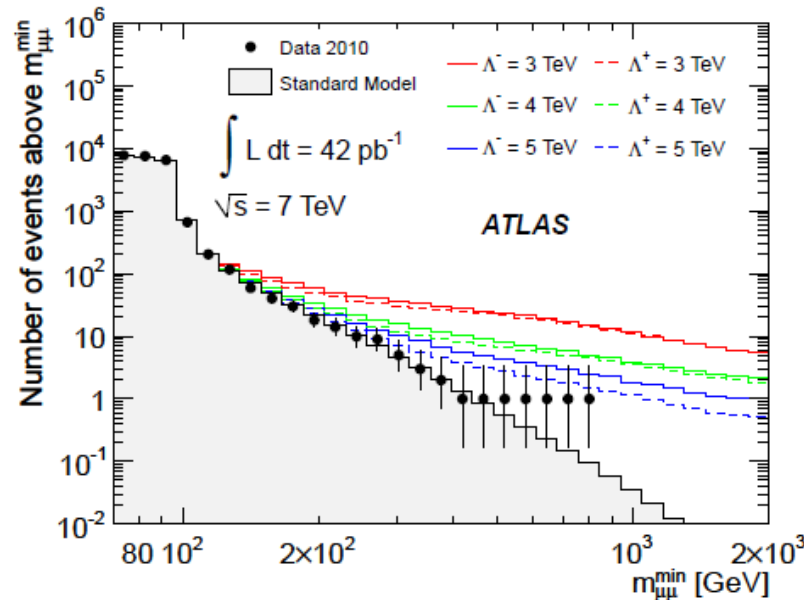
Compositeness

- Quark-lepton compositeness can be described as four-fermion contact interaction (CI) at low energy limit
- **Benchmark: left-left isoscalar model**

$$\frac{d\sigma}{dm_{\mu\mu}} = \frac{d\sigma_{DY}}{dm_{\mu\mu}} - \eta_{LL} \frac{F_I(m_{\mu\mu})}{\Lambda^2} + \frac{F_C(m_{\mu\mu})}{\Lambda^4}$$
 - $F_{I(C)}$ is interference (CI) term, $\eta_{LL} = \pm 1$
 - Λ is the energy scale below which fermion constituents are bound
- No excess, **limits at 95% CL:**
 - $\Lambda^- > 4.9 \text{ TeV}$ for constructive interference
 - $\Lambda^+ > 4.5 \text{ TeV}$ for destructive interference



Taking an integral...



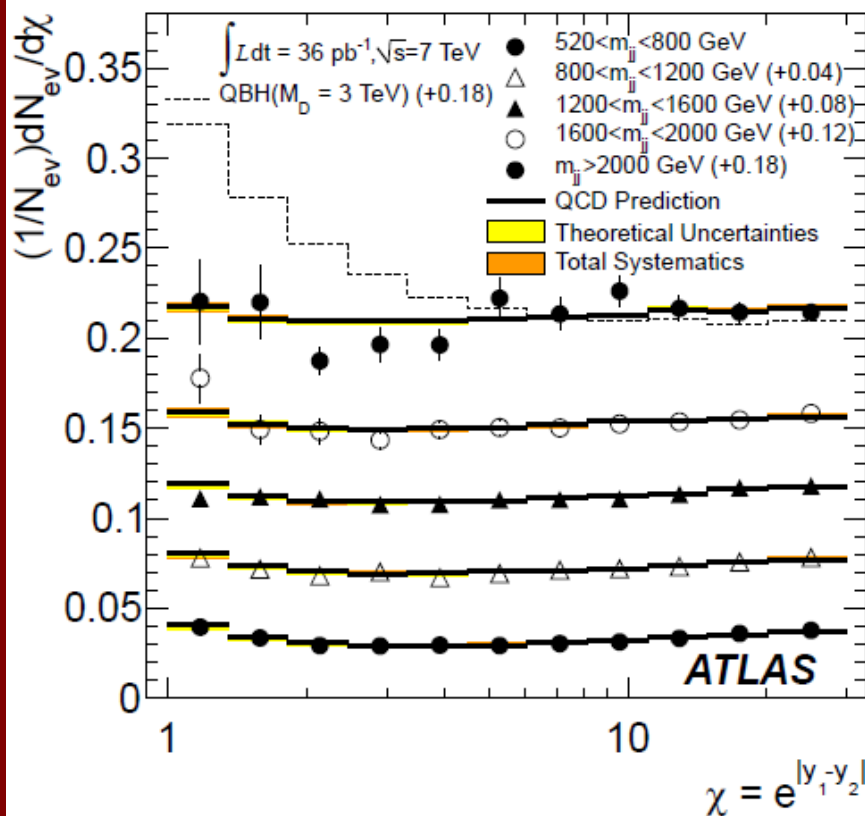
arxiv:1104.4398 accepted by PRD

If quarks have substructure which it will appear at compositeness scale Λ

$$\chi = \exp(|y_1 - y_2|) = \frac{1 + |\cos\theta^*|}{1 - |\cos\theta^*|}$$

$y_{(2)1}$ (sub)leading jet rapidity,
 θ^* angle between two jets

Flat distribution for SM processes, excess at low χ for signal

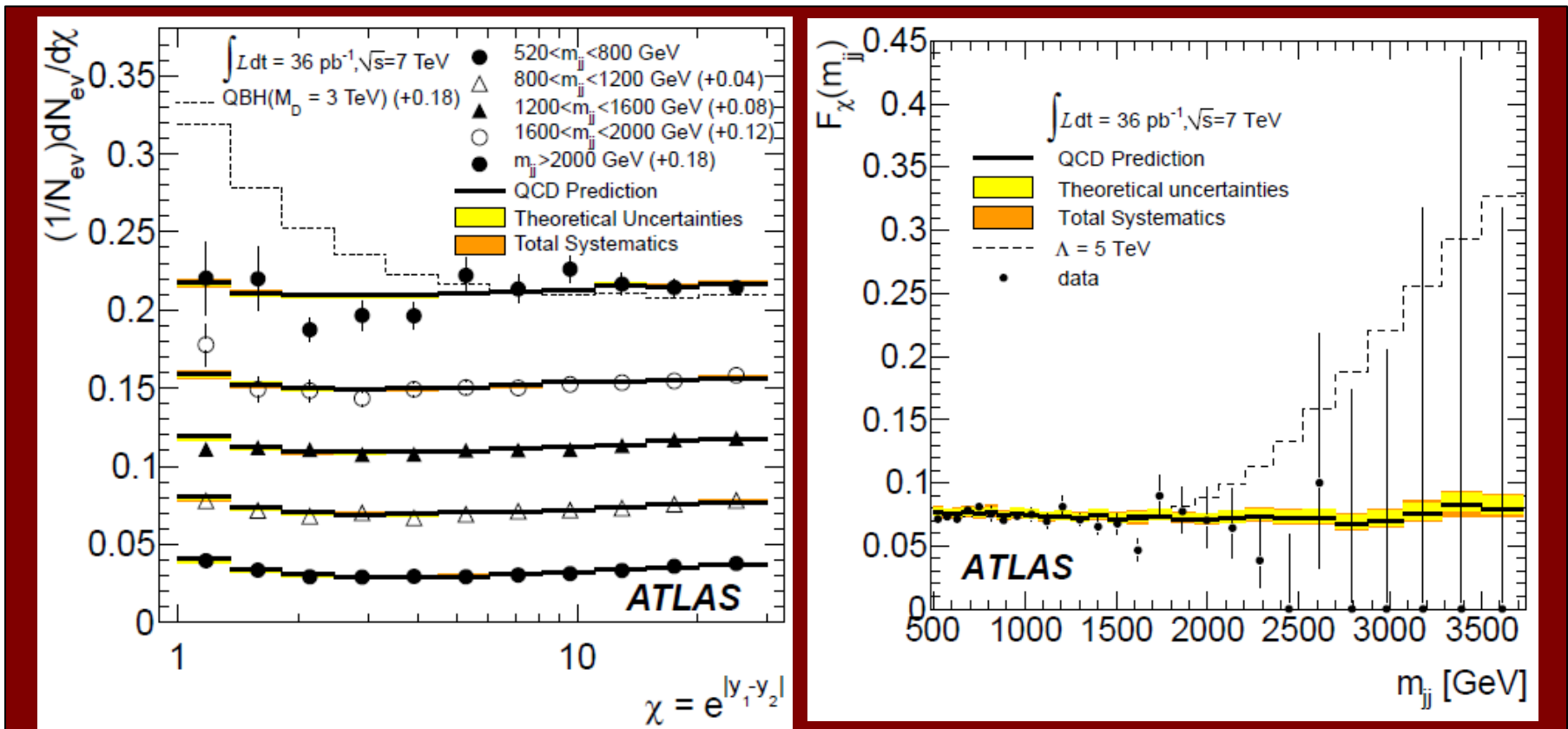


F_χ is ratio of events
in the first four χ bins to
full χ distribution

If quarks have substructure which it will appear at compositeness scale Λ

$$\chi = \exp(|y_1 - y_2|) = \frac{1 + |\cos\theta^*|}{1 - |\cos\theta^*|} \quad \begin{array}{l} y_{(2)1} \text{ (sub)leading jet rapidity,} \\ \theta^* \text{ angle between two jets} \end{array}$$

Flat distribution for SM processes, excess at low χ for signal

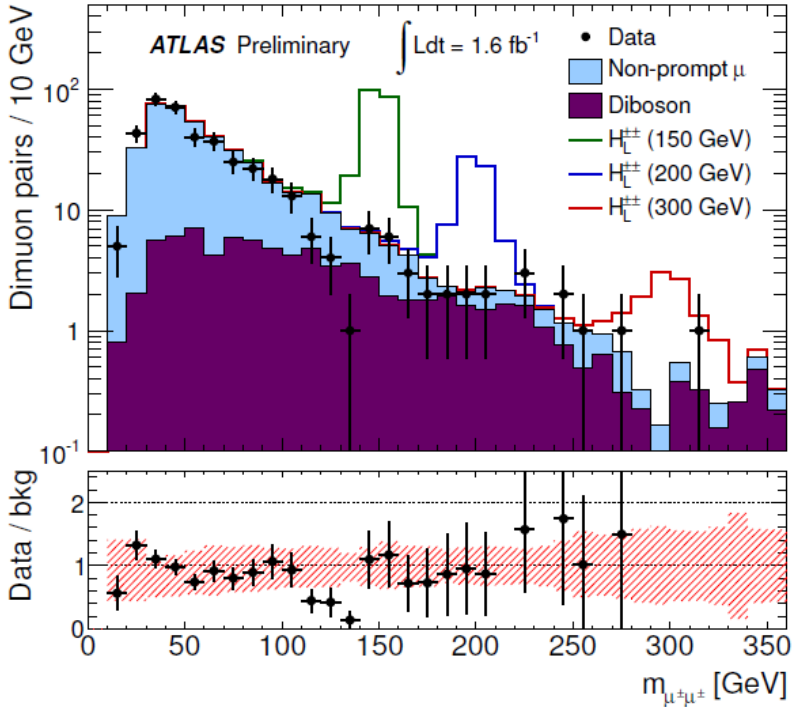
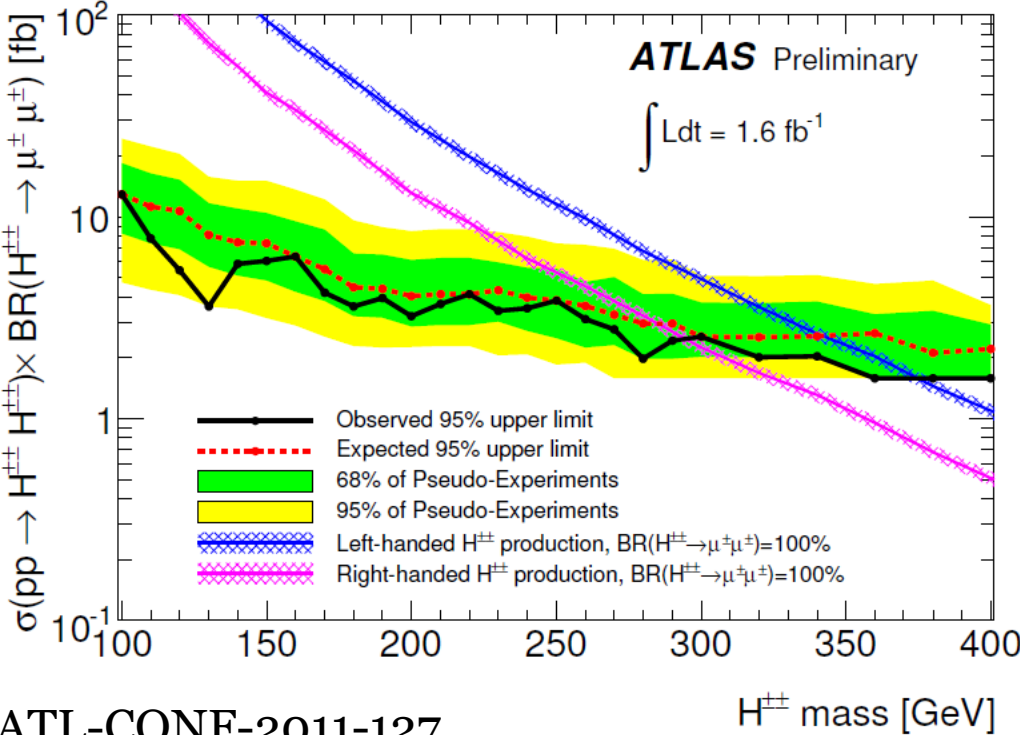


Data > 2 TeV below SM prediction. Exclude $\Lambda < 6.7$ TeV (bayesian method),
expected limit $\Lambda < 5.7$ TeV

New Particles Searches

Search for doubly charged Higgs $\rightarrow \mu\mu$

- Models: Left-Right Symmetric (LRSM), Higgs triplet, Little Higgs
- Pair production: $pp \rightarrow H^{++}H^{-}$
- $H/\mu\mu$ Coupling $\sim 10^{-5}-0.5$ considered to have lifetime $< 10\mu\text{m}$ and $\Gamma/M < 1\%$
- In LRSM $2\sigma(H^{++}_R) \sim \sigma(H^{++}_L)$

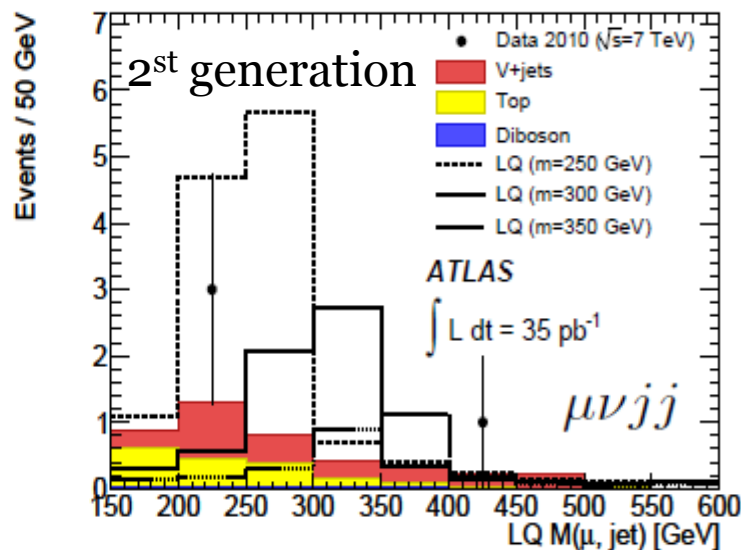
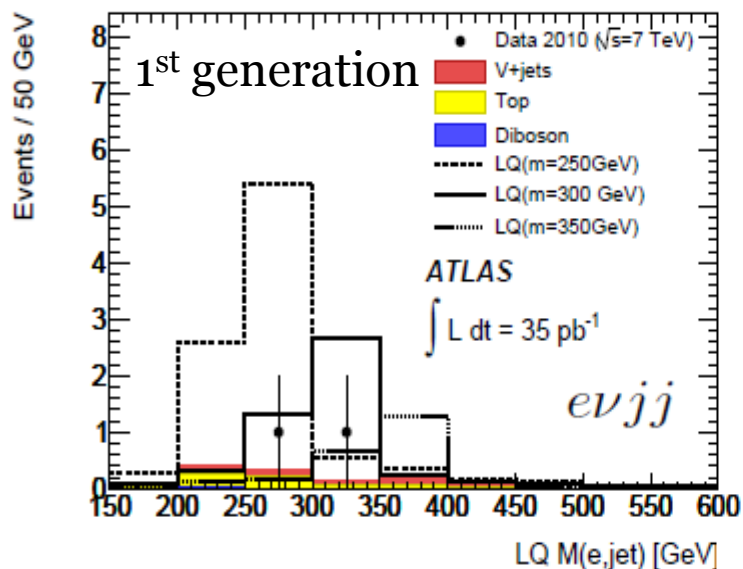


In LRSM with 1.6 fb^{-1} &
 $BR(H^{++} \rightarrow \mu\mu) = 100\%$
 $M(H^{++}_{R/L}) < 295/375 \text{ GeV} @ 95\% \text{ CL}$
 $BR(H^{++} \rightarrow \mu\mu) = 33\%$
 $M(H^{++}_{R/L}) < 210/268 \text{ GeV} @ 95\% \text{ CL}$

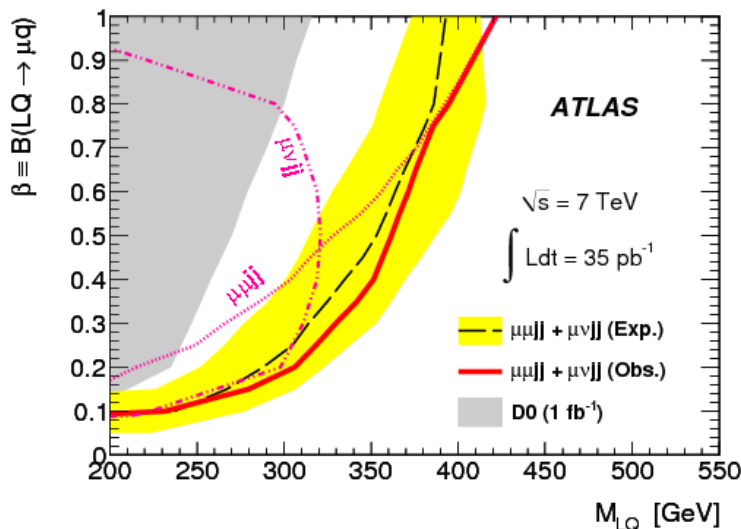
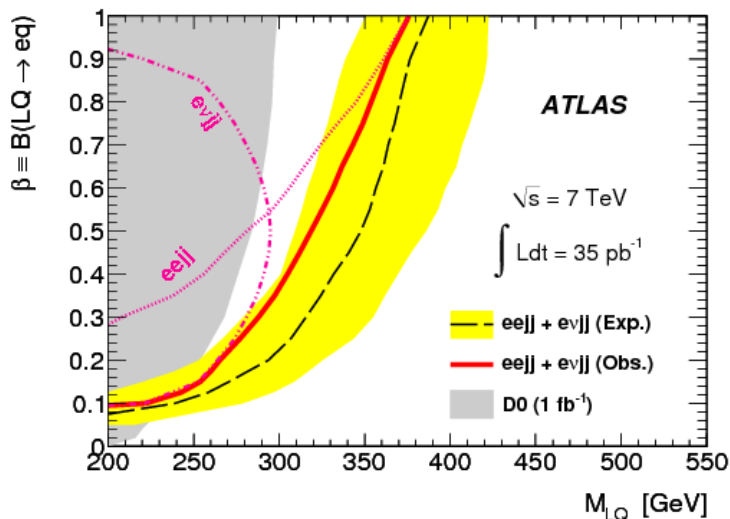
World best limits on H^{++}

Search for Leptoquarks

- Benchmark model: pair production of leptoquarks (LQ)
- Particles with both lepton and baryon quantum numbers
- Consider 2 lepton + 2 jets and lepton + 2 jets + E_T^{Miss} final states



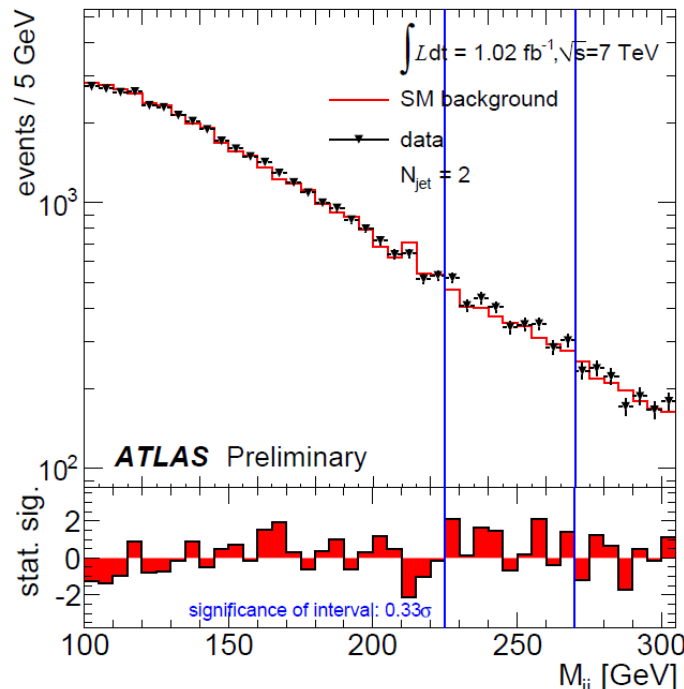
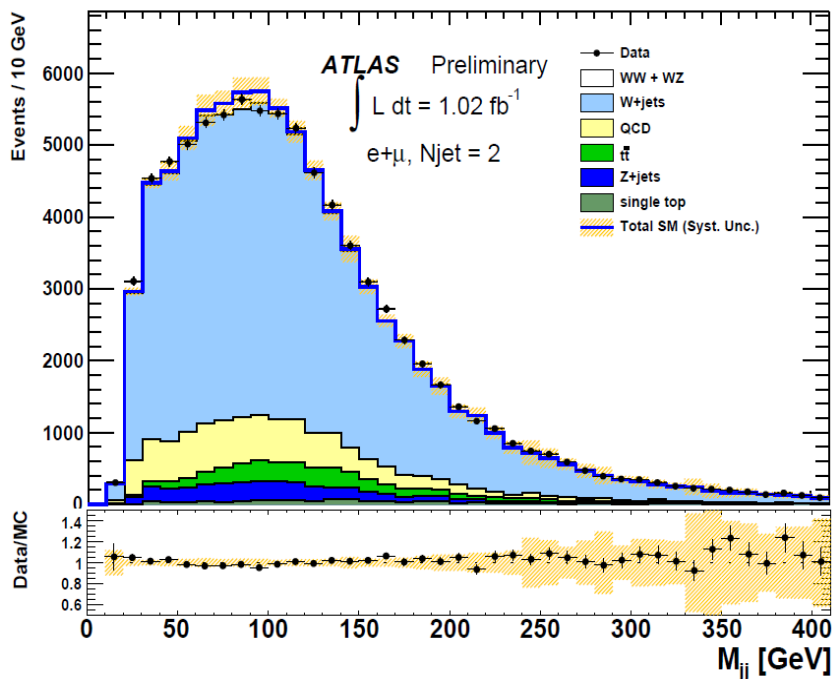
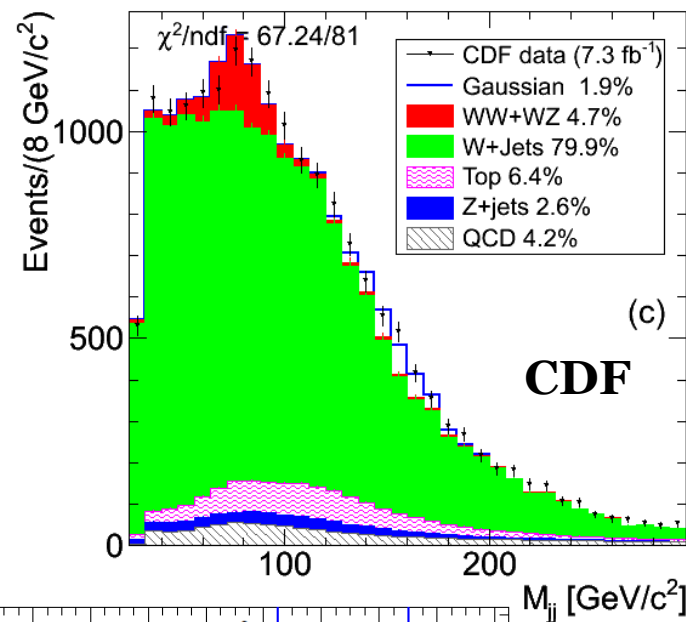
Average
 lj invariant
 mass



95% CL
 exclusion
 region

Search for $lvjj$ resonance

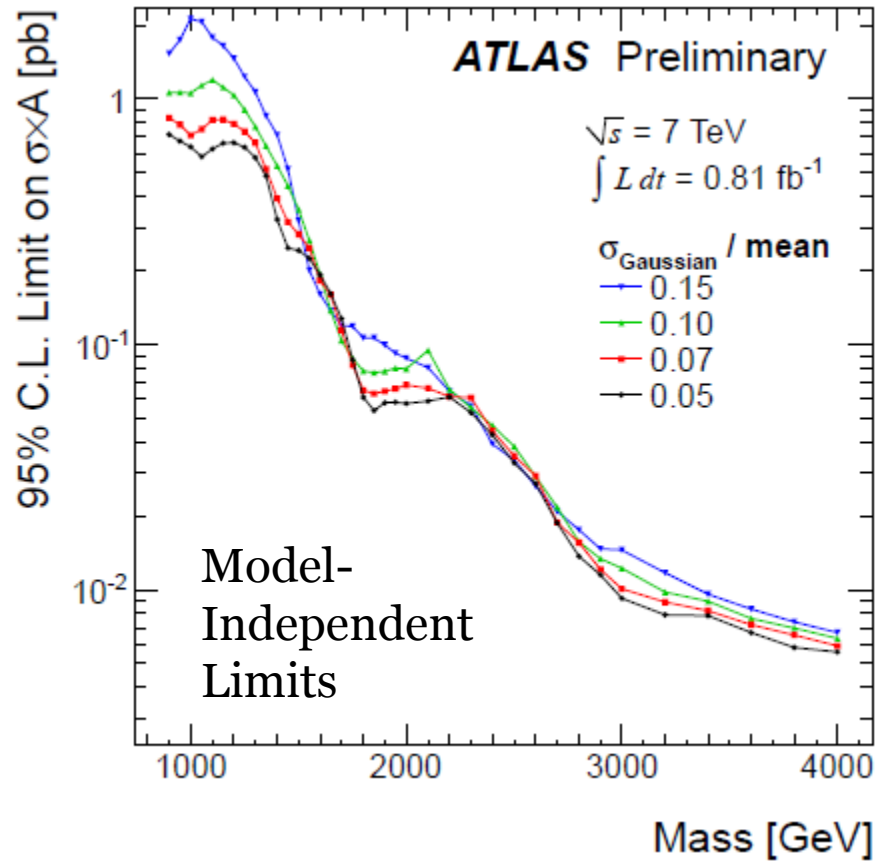
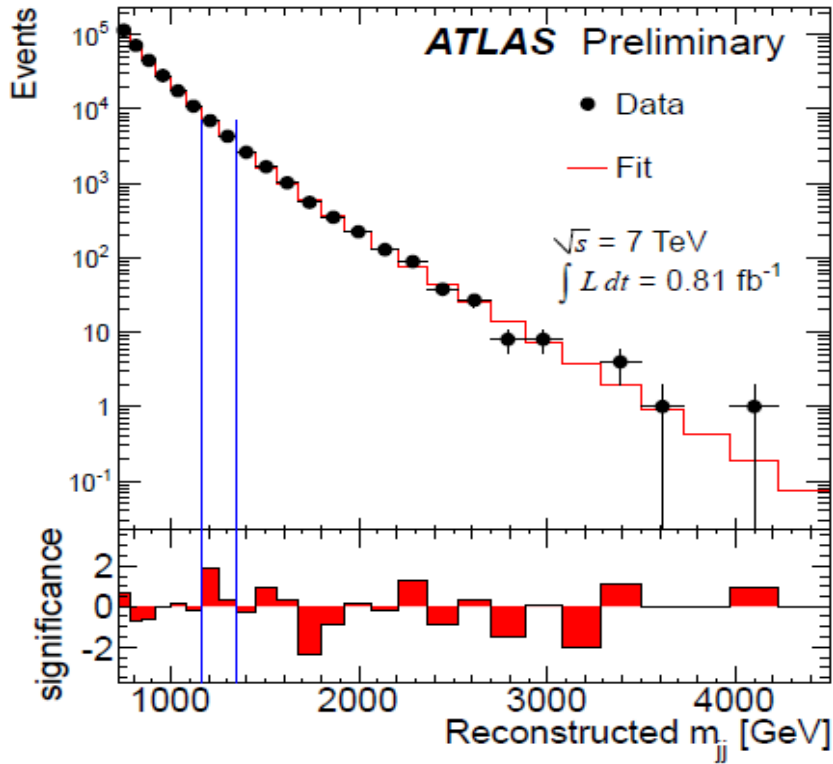
- CDF has reported an excess of 4.1σ at $\sim 145\text{GeV}$ in jj mass distribution in $lvjj$ channel with 7.3fb^{-1} of data
- This channel is not optimal at LHC with $W+\text{jet}$ bkg 20 times higher, but this can be model dependent
- Selection: $p_T^j > 30\text{GeV}$, $p_T^e > 25\text{GeV}$, $p_T^\mu > 20\text{GeV}$, $p_T^{jj} > 40\text{GeV}$, $E_T^{\text{Miss}} > 25\text{GeV}$, $M_T^W > 40\text{GeV}$, $|\Delta\eta| < 2.5$, $|\Delta\phi^{j1,ET^{\text{Miss}}}| > 0.4\text{GeV}$
- Looked at $N_j=2$ (shown) and $N_j \geq 2$ (in backup)



No significant excess over Standard Model processes seen in 1.02fb^{-1} of data

Searches for a di-jet resonance

Looked for di-jet resonance in the measured M_{jj} distribution
 → spectrum compatible with a smooth monotonic function → no bumps



Model	95% CL Limits (TeV)	
	Expected	Observed
Excited Quark q^*	2.77	2.91
Axigluon	3.02	3.21
Color Octet Scalar	1.71	1.91

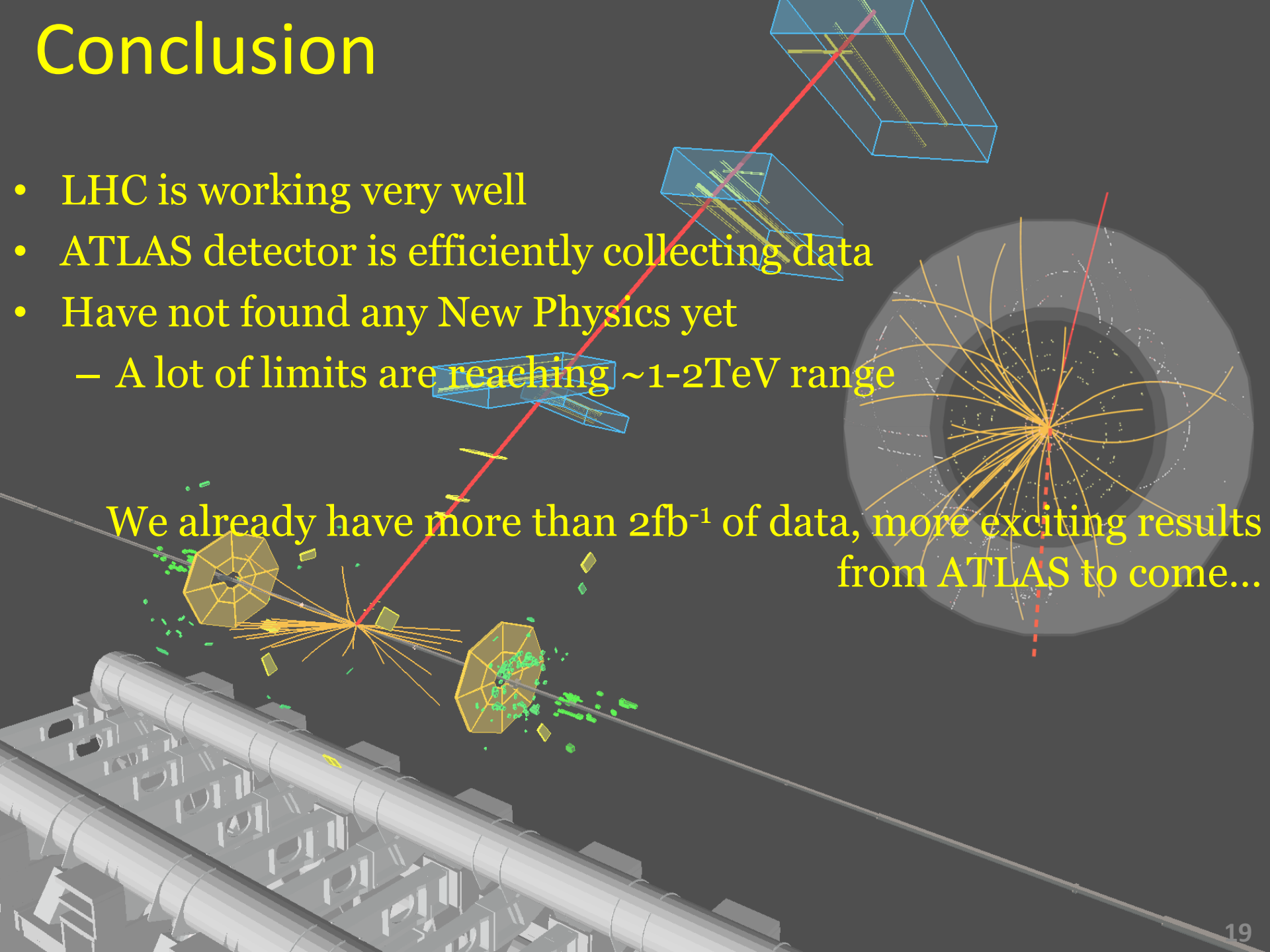
More ATLAS exotics results to be shown...

- **Top, Top-like BSM & Boosted Objects**
 - Talk by **J. Ferrando**, Wed pm
 - Includes: $Z' \rightarrow t\bar{t}$, Heavy top partner in $t\bar{t} + E_T^{\text{Miss}}$ channel, 4th generation light quark searches (u_4 & d_4)
- **Extra dimension signatures**
 - Talk by **F. Ruehr**, Thu am
- **Long-Lived particles and other weird things**
 - Talk by **D. Milstead**, Thu am
- **ATLAS Review of BSM signatures w/o E_T^{Miss}**
 - Talk by **E. Etzion**, Wed am
- **ATLAS overview of E_T^{Miss} signatures**
 - Talk by **R. Bruneliere**, Tue am

Conclusion

- LHC is working very well
- ATLAS detector is efficiently collecting data
- Have not found any New Physics yet
 - A lot of limits are reaching $\sim 1\text{-}2\text{TeV}$ range

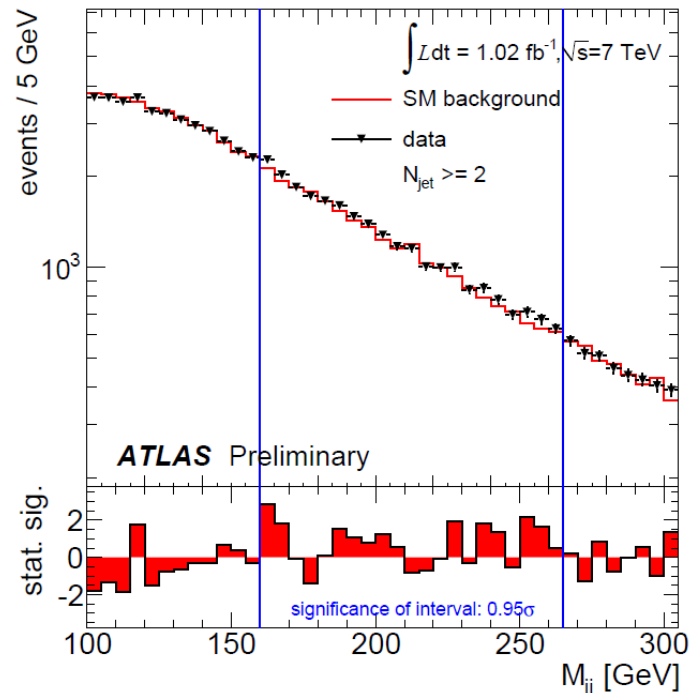
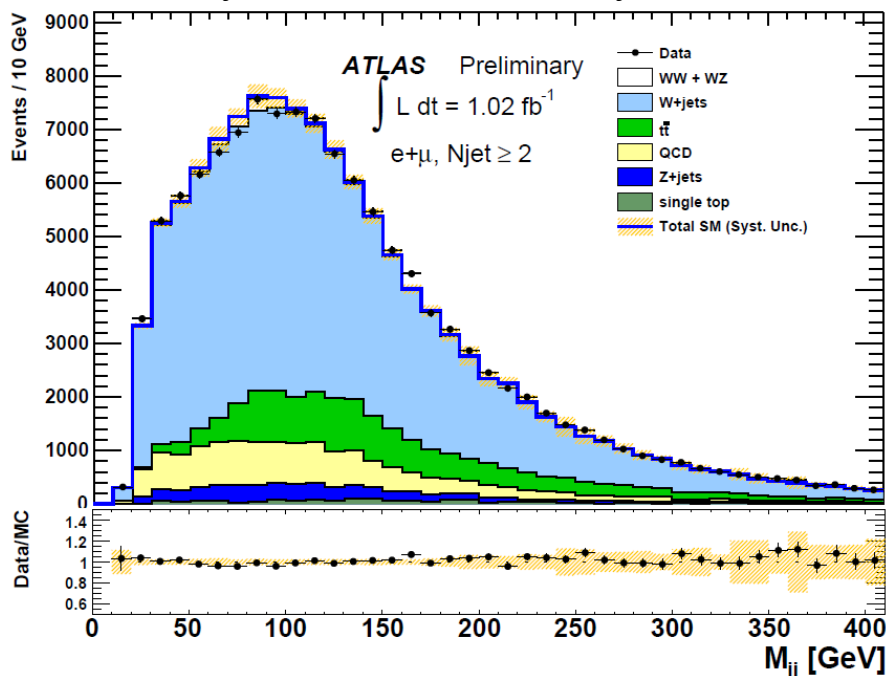
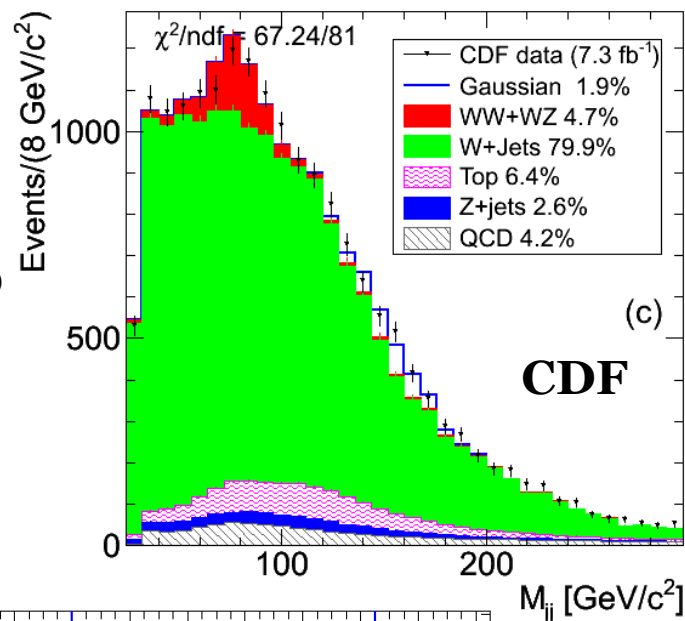
We already have more than 2fb^{-1} of data, more exciting results from ATLAS to come...



Backup Slides

More on $lvjj$ channel (backup)

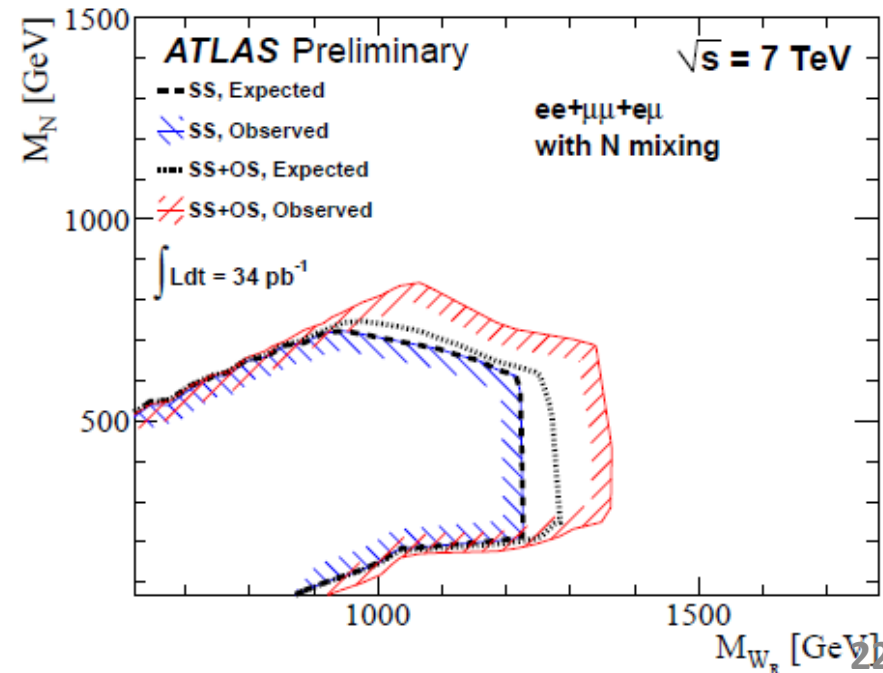
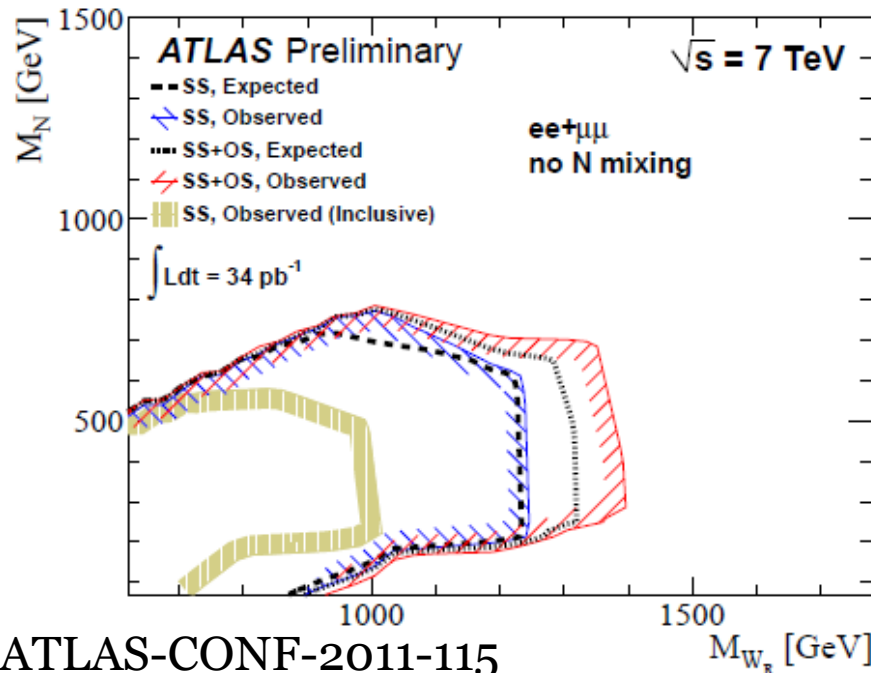
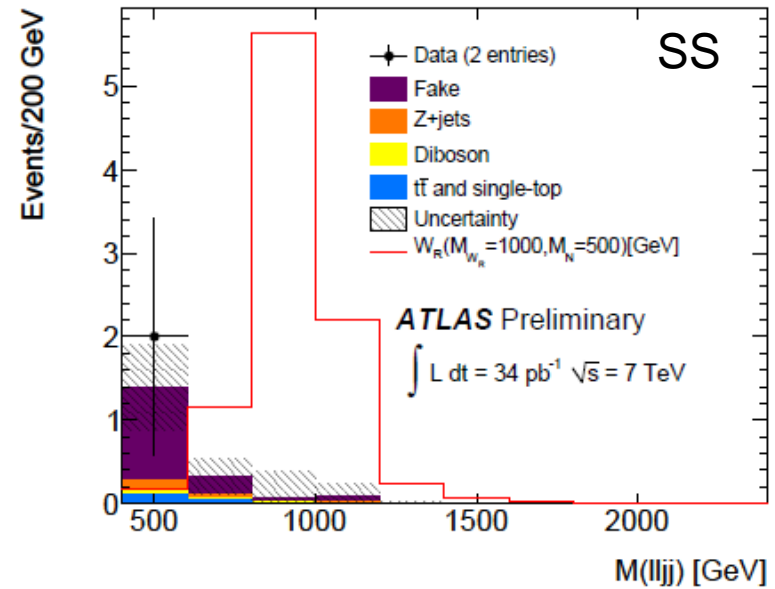
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No significant excess over Standard Model processes seen in 1.02fb^{-1} of data

Search for New Physics in $lljj$ channel

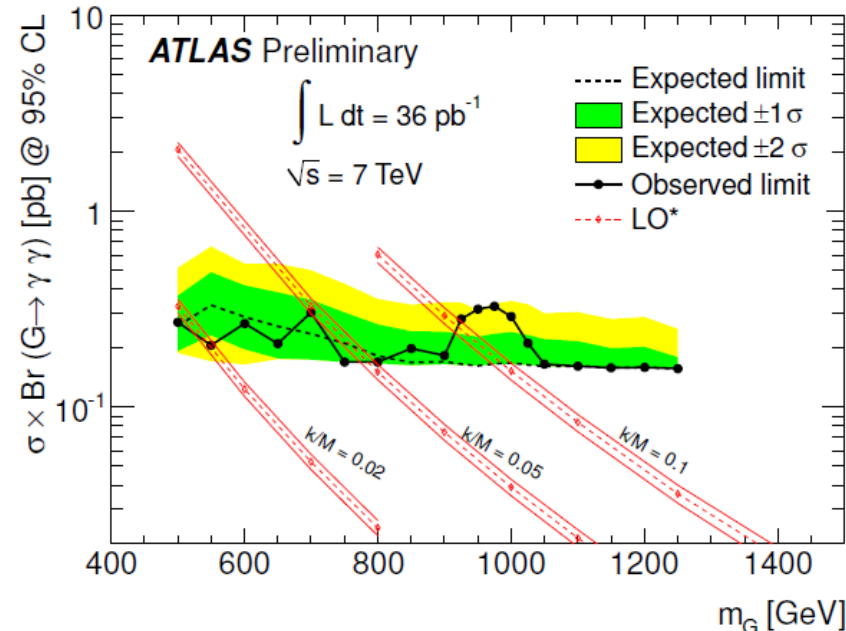
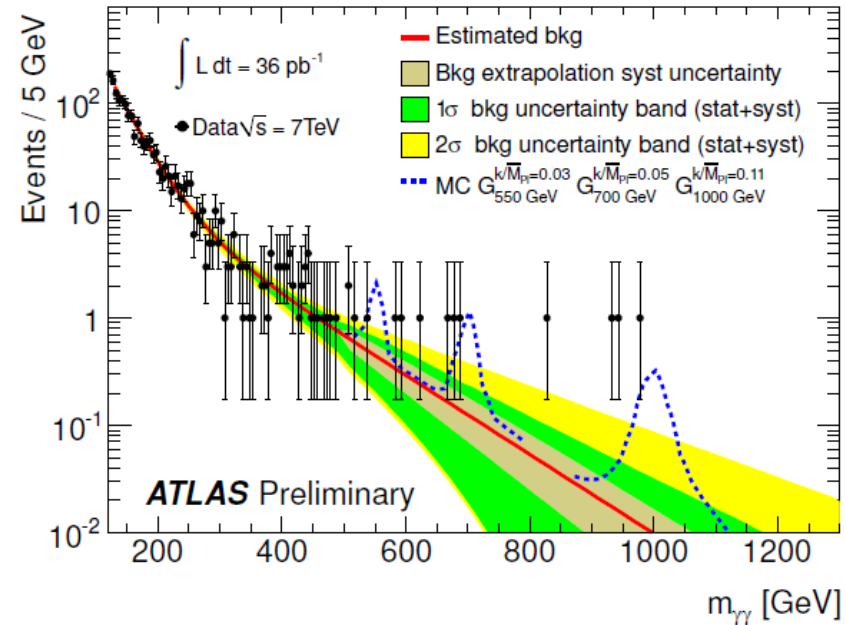
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- Heavy neutrinos (N):
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 - Non-Majorana N : only l^+l^- (OS)
 - Majorana N: both $l^\pm l^\pm$ (SS) and l^+l^- (OS)
 - N can mix if masses are different both no-mixing and 100% mixing cases considered
- Data consistent with SM predictions



Search for New Physics in Diphotons

- **Benchmark Signal RS Gravitons (G)**
- 5-D space-time bound by two 3+1D branes with SM particles localized on one and gravity on the other
- Only G propagate in bulk resulting in massive spin-2 Kaluza-Klein (KK) excitations
- Narrow intrinsic width if $k/M_{\text{Pl}} < 0.1$ (k is space-time curvature in ED)
- Graviton decays to SM fermions or bosons: Diphoton branching fraction is twice higher than dilepton one
- Data consistent with SM predictions
- **Limit @ 95% CL $> 920(545)$ GeV for $k/M_{\text{Pl}} = 0.1(0.02)$**

See poster by X. Anduaga for more details



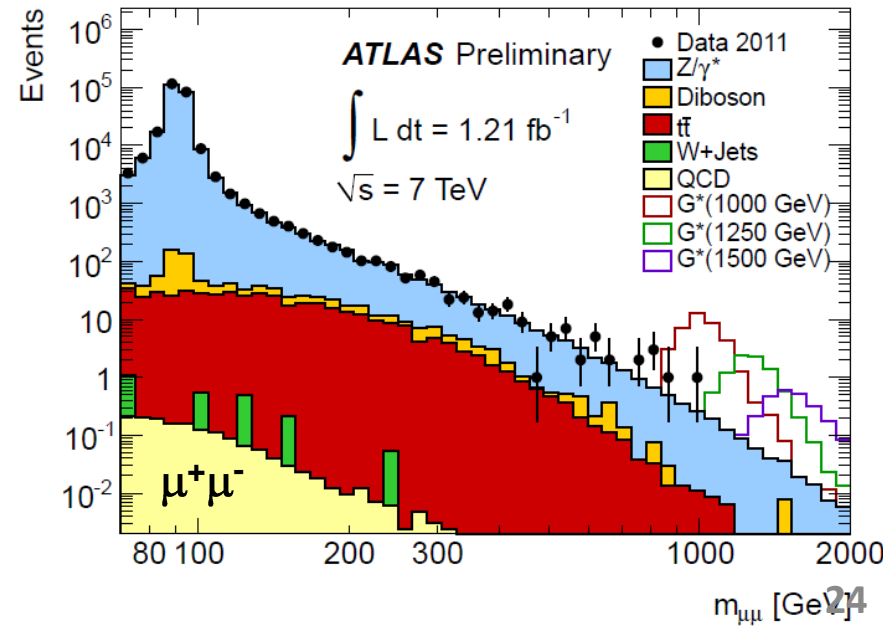
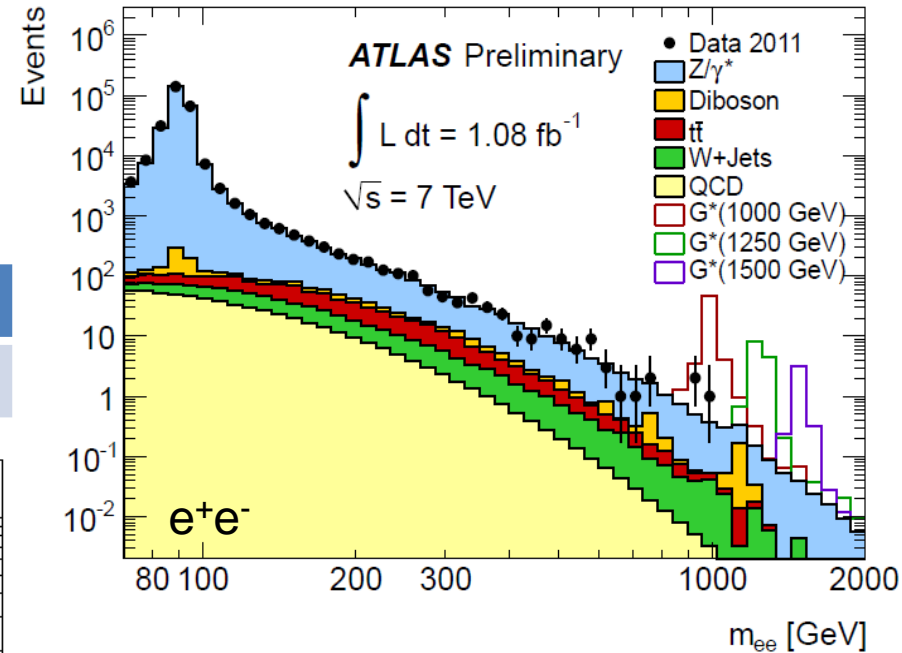
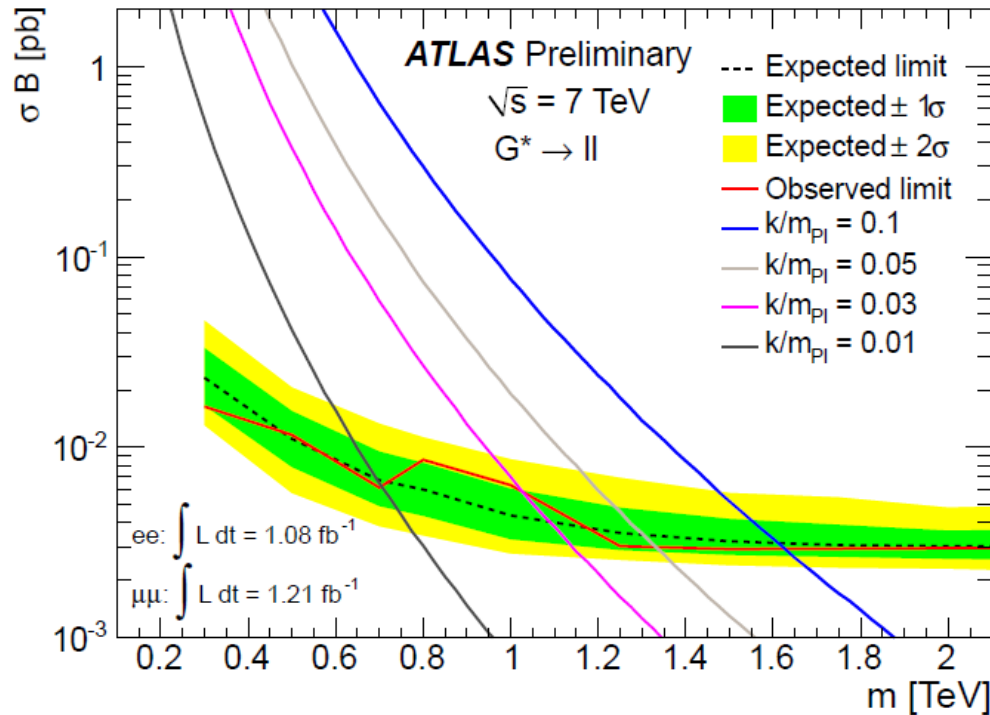
Search for New Physics in Dileptons

Benchmark signal: RS $G^* \rightarrow l^+l^-$

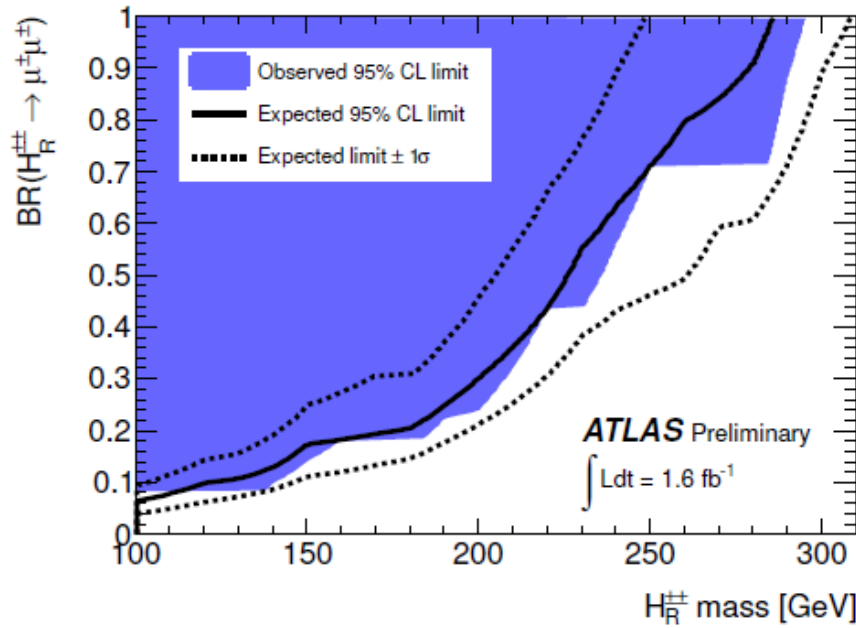
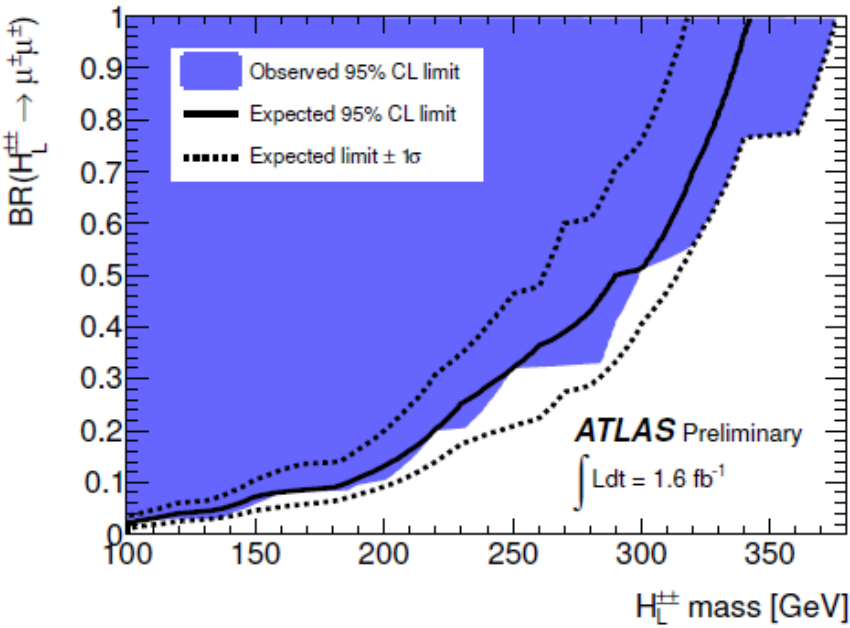
Same spectrum as for Z' , no excess

UL @95% CL on $M(G^*)$

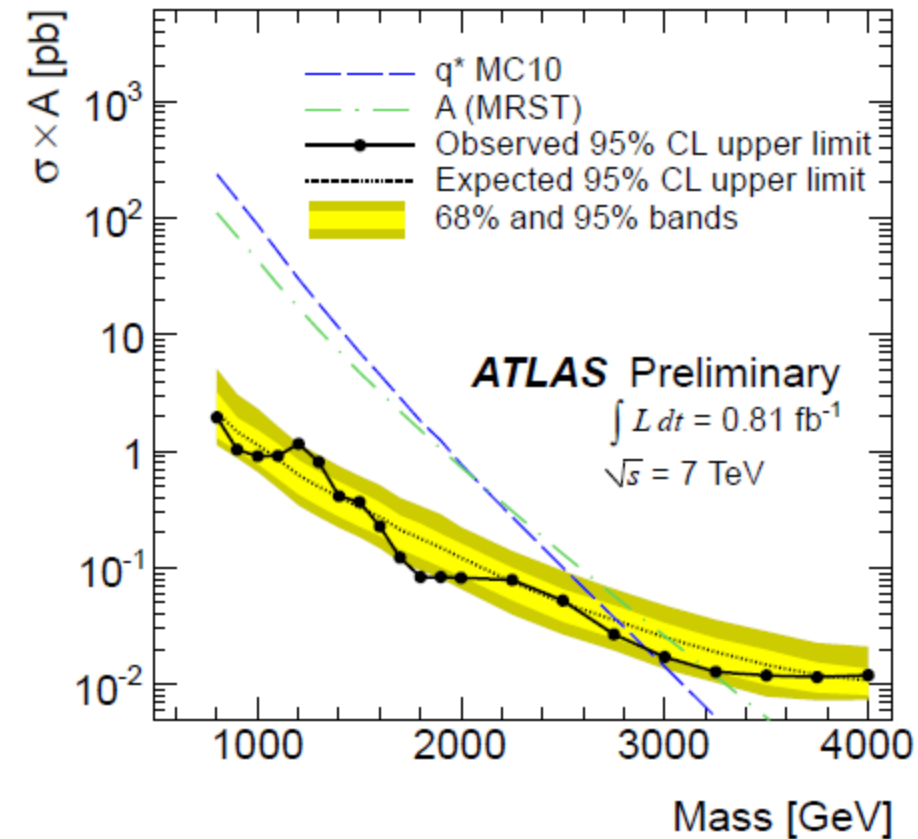
Coupling(k/M_{Pl})	0.01	0.03	0.05	0.1
UL@95%CL(TeV)	0.70	1.03	1.33	1.63



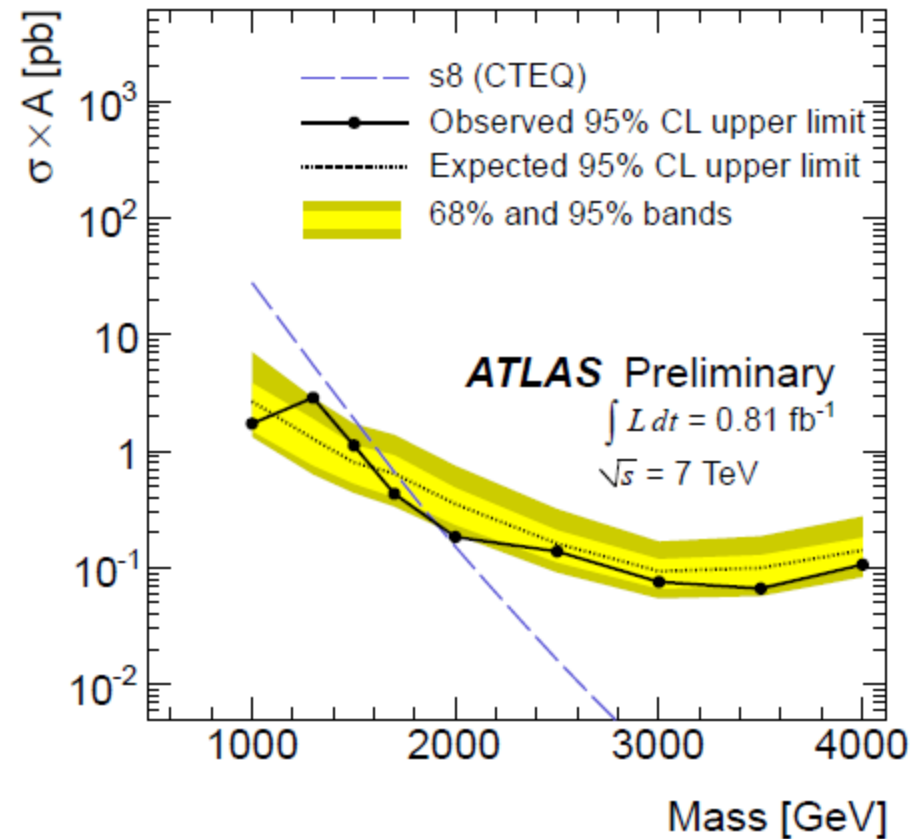
Search for doubly charged Higgs $\rightarrow \mu\mu$



Searches for New Physics in Dijets



(a) Excited-quark and axigluon models.



(b) Color octet scalar model.