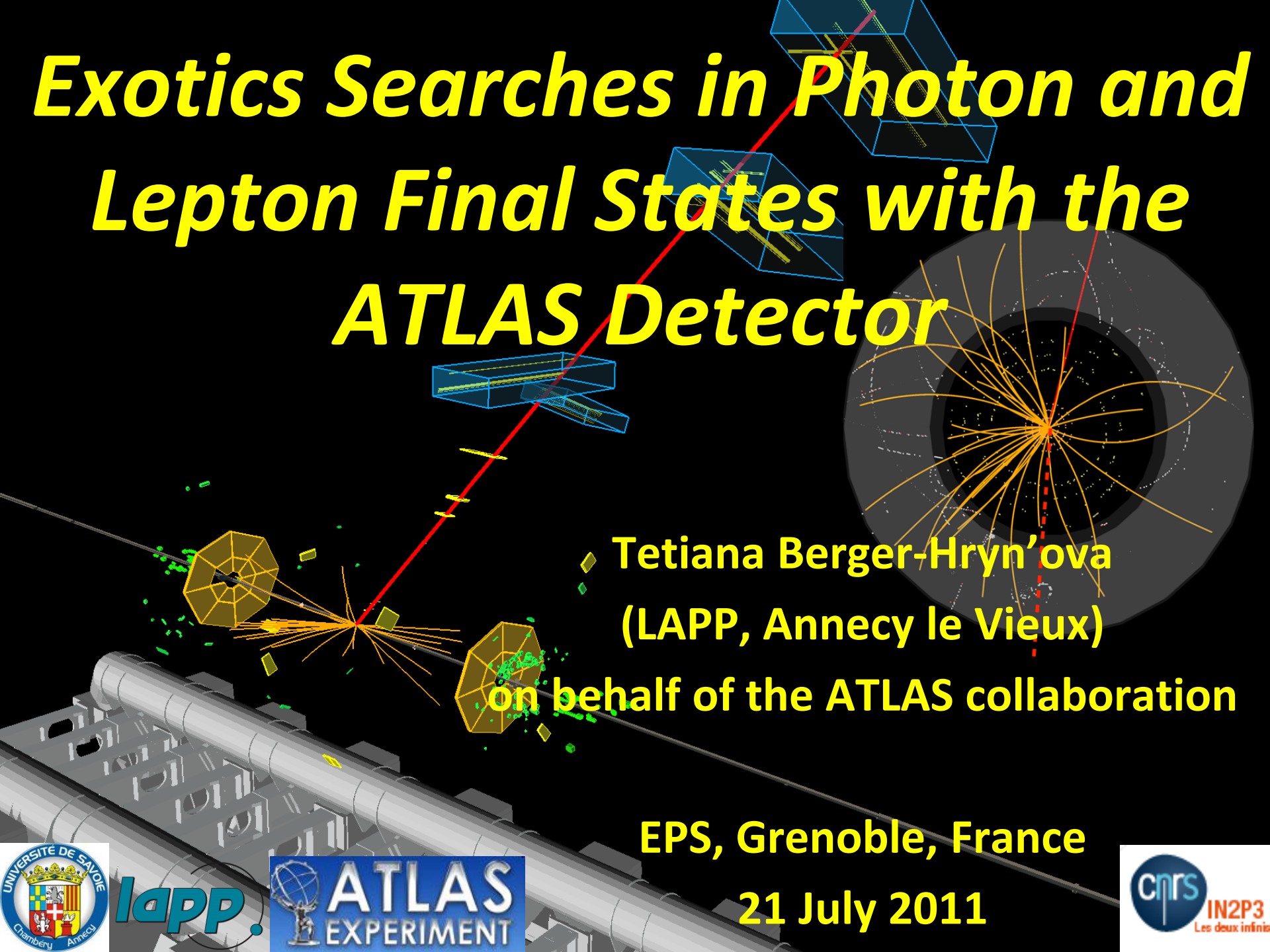
# Exotics Searches in Photon and Lepton Final States with the ATLAS Detector




Tetiana Berger-Hryn'ova

(LAPP, Annecy le Vieux)

on behalf of the ATLAS collaboration


EPS, Grenoble, France

21 July 2011

# Introduction

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

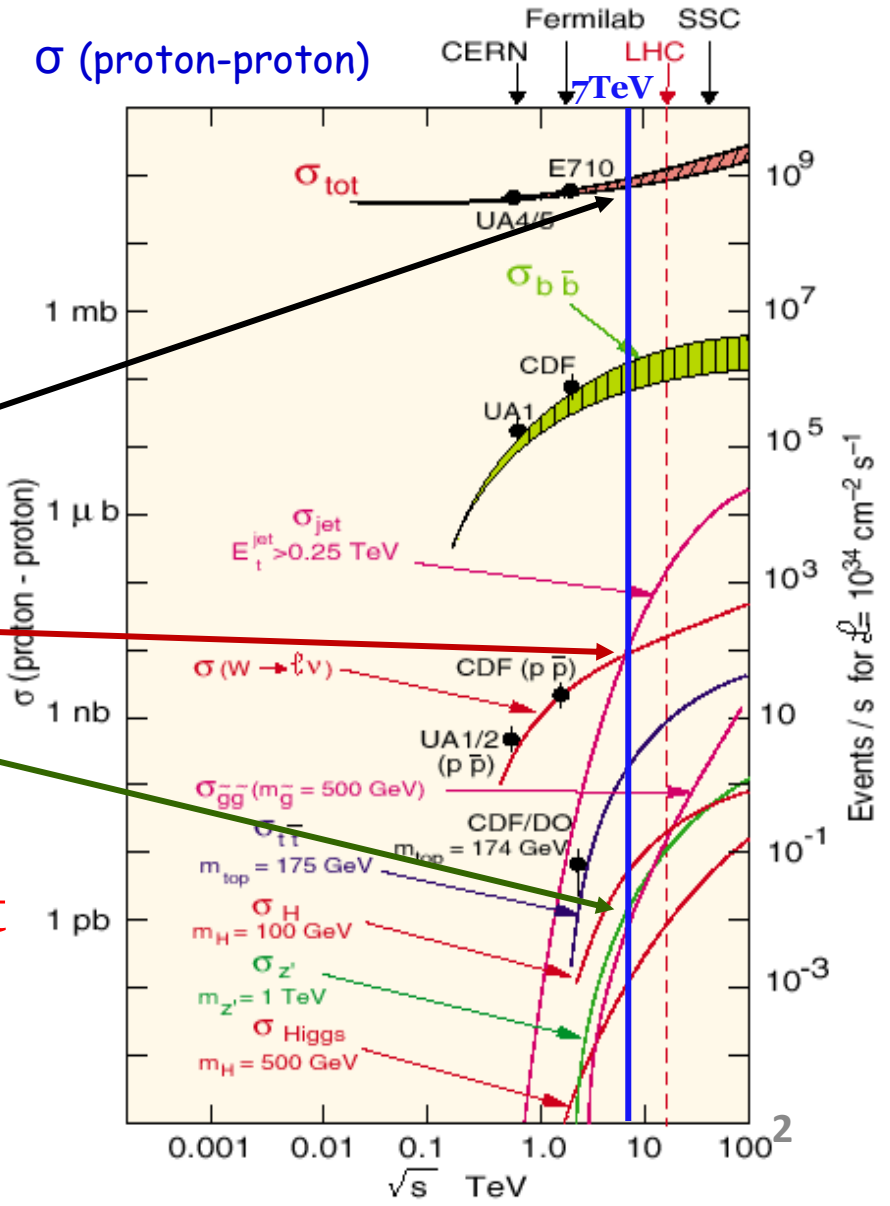
New Physics is needed at the weak scale ~1TeV

Physics Processes at LHC:

- Total cross-section
- SM Processes: W→eν
- New Physics: hard lepton, photon (Z'→ee, etc.)

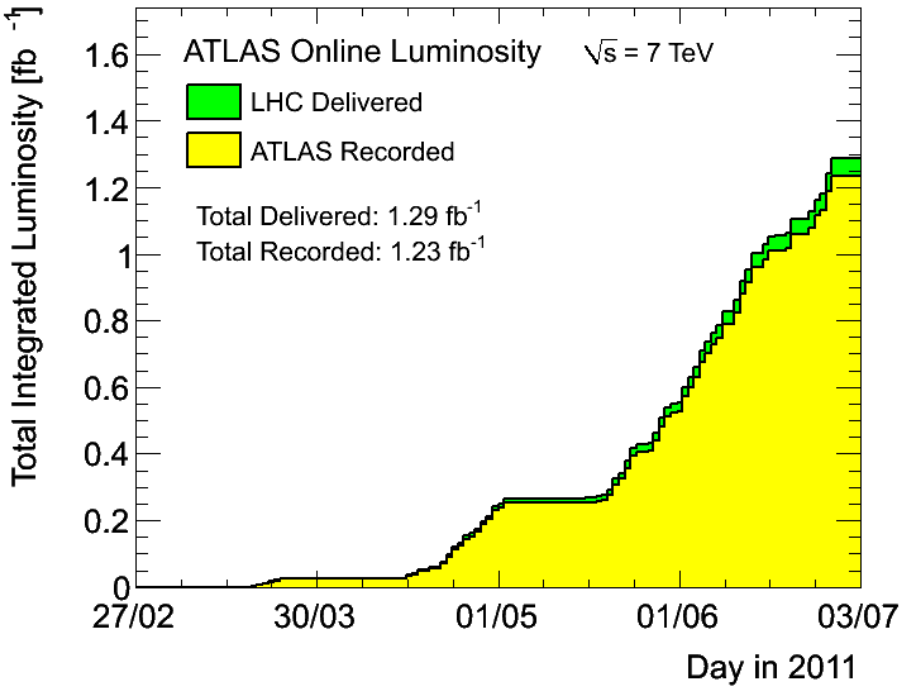
Need large luminosity and efficient background rejection to see interesting signal events:

lepton & photon identification helps!



# Searching for New Physics …

- New Heavy Gauge Bosons:
  - Lepton+$E_T^{Miss}$
  - Dileptons
- Compositeness: dimuons
- Extra Dimensions
  - Same-sign dimuons (ADD)
  - Dileptons (RS)
  - Diphotons (RS)
  - Diphotons+$E_T^{Miss}$ (UED)
- Leptoquarks
- Highly Ionising Particles




- 2010: 45pb$^{-1}$ recorded
- 2011 (till 1/07): 1.23fb$^{-1}$ recorded
- Peak Lumi of 1.26x10$^{33}$ cm$^{-2}$s$^{-1}$
- 6 interactions per BC on average

# New Heavy Gauge Bosons

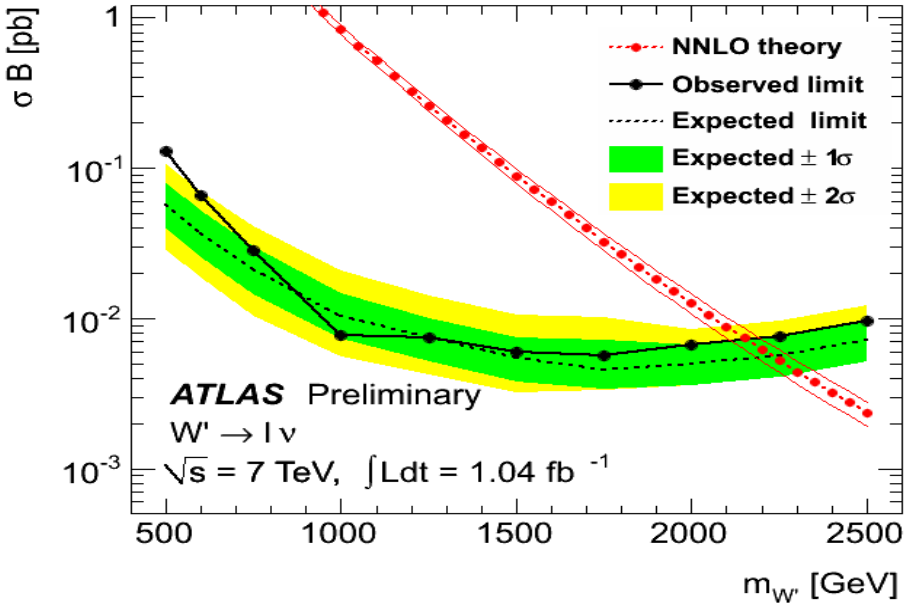
# Search for New Physics in Lepton + $E_T^{Miss}$

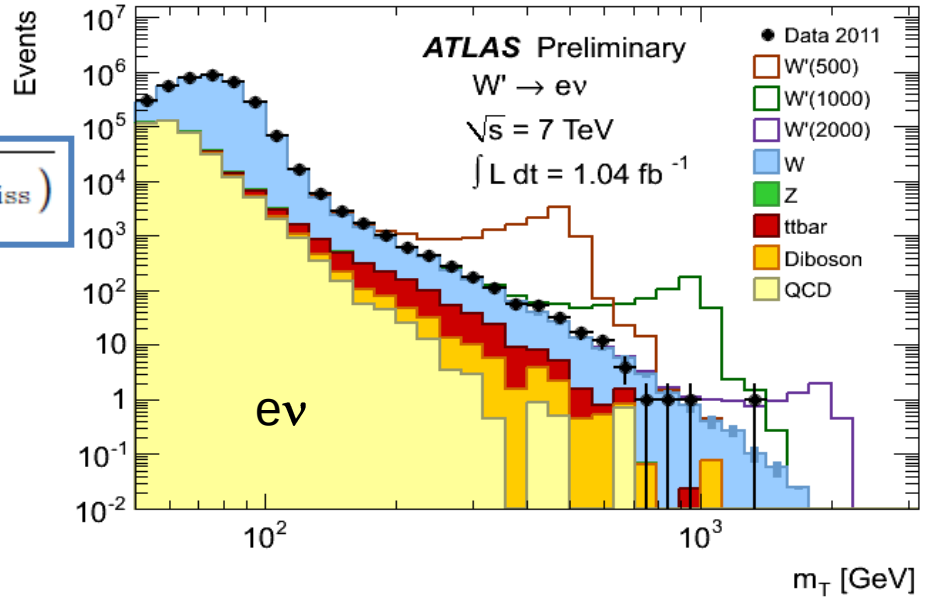
New!

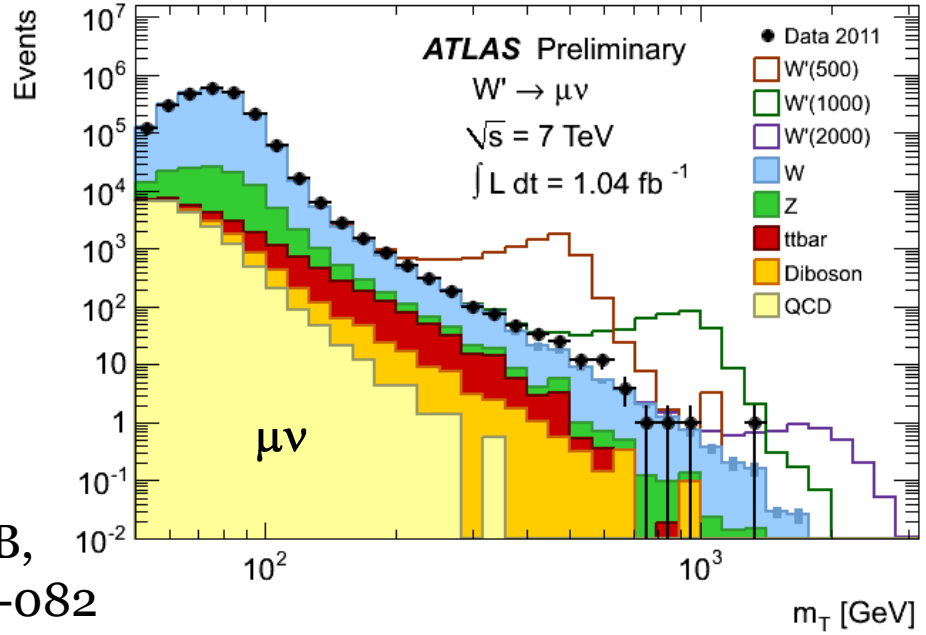
- Benchmark Signal: W'→lν
- Observable

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

- Data consistent with SM prediction
- Limit @ 95% CL mass of SSM W'
  >2.15TeV (2.08TeV e & 1.98TeV μ)



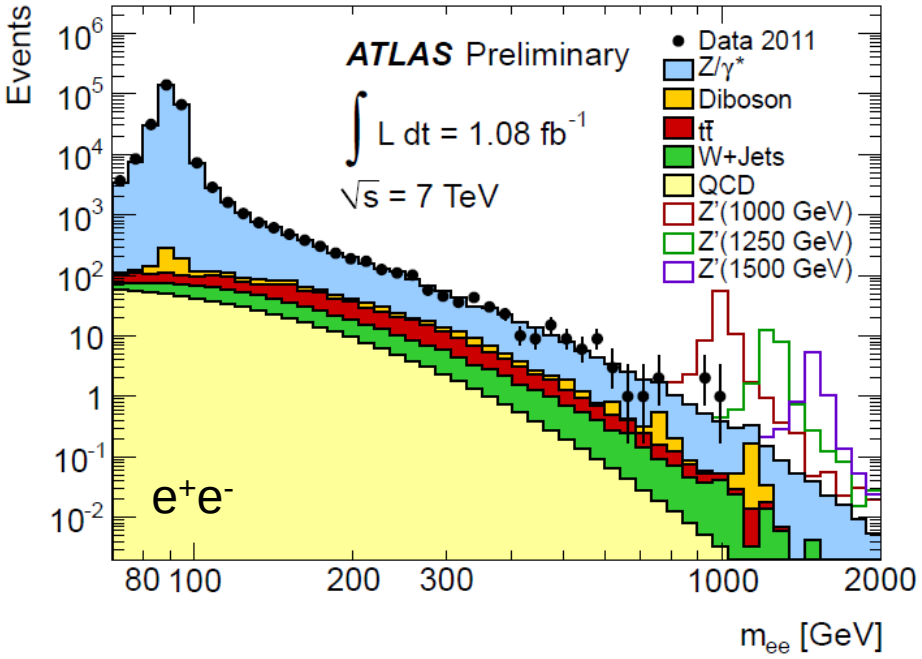

2010 data: arXiv:1103.1391, accepted by PLB,
2011 data 200pb$^{-1}$ update: ATL-CONF-2011-082

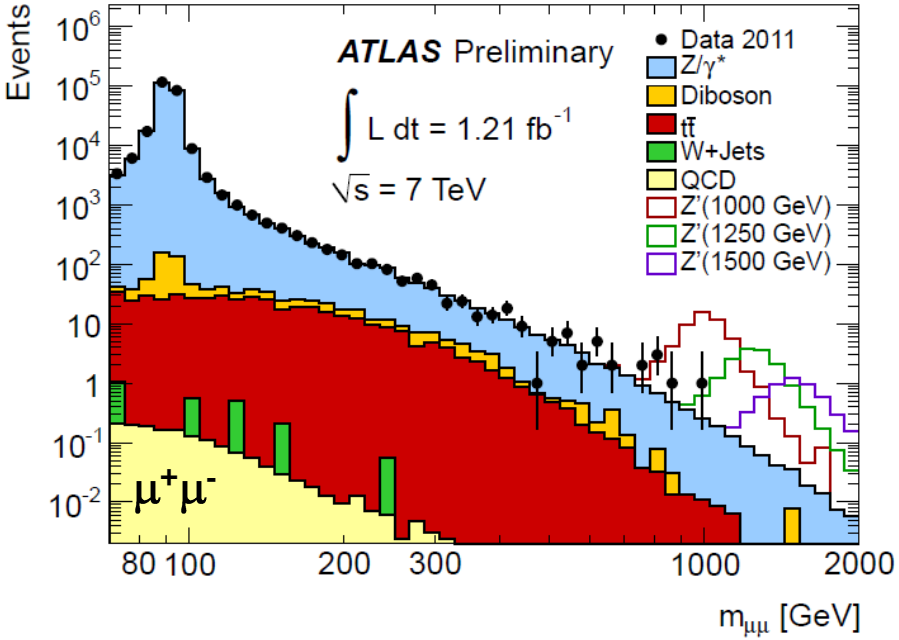
# Search for New Physics in Dileptons

New!

2010 data: PLB700:163-180,2011
2011 data 200pb$^{-1}$ update: ATL-CONF-2011-083

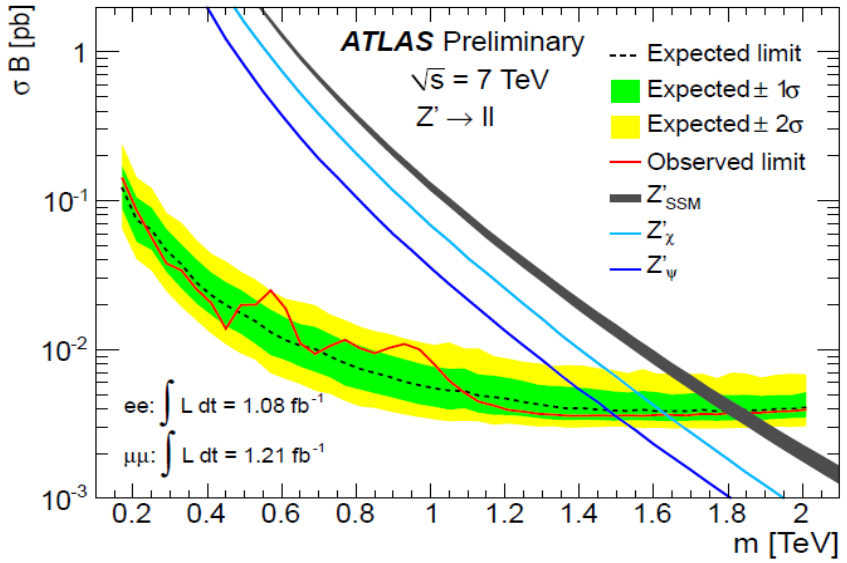
- Benchmark Signal: Z'→$l^+l^-$




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

| $Z'_\psi$ | $Z'_N$ | $Z'_\eta$ | $Z'_I$ | $Z'_S$ | $Z'_\chi$ |
|---|---|---|---|---|---|
| 1.50 | 1.52 | 1.54 | 1.56 | 1.60 | 1.64 |



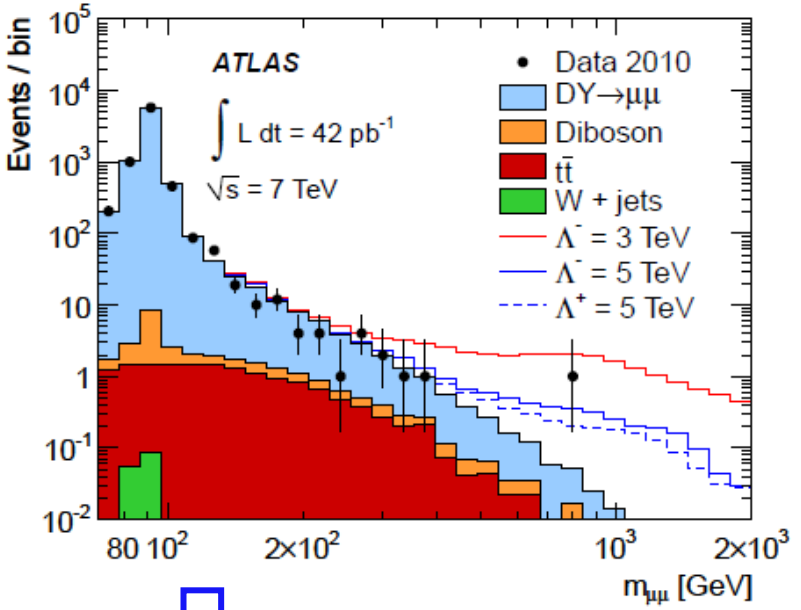

See posters by S. Heim & S. Viel for details

# Contact Interactions

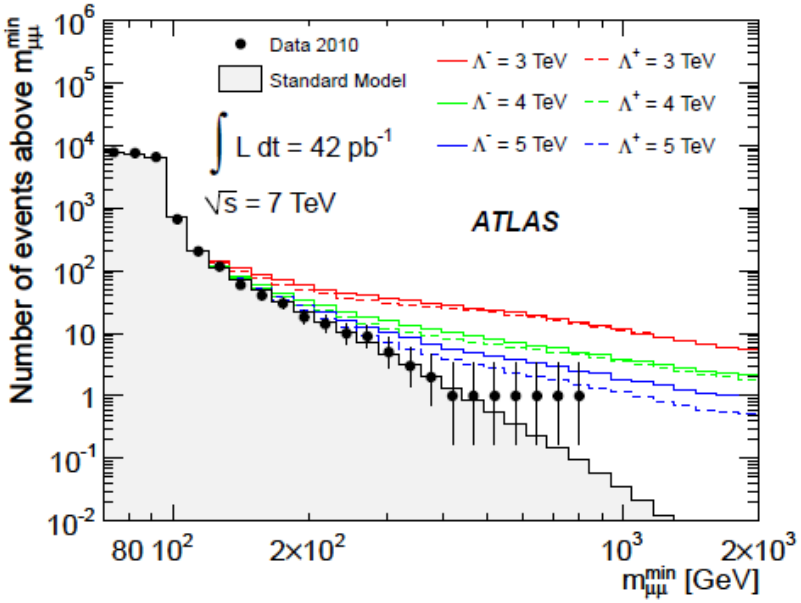
- Four-fermion contact interactions (CI) at low energy limit describe phenomena as:
  - Large Extra Dimension ADD Model
  - Quark-lepton compositeness
- Benchmark: left-left isoscalar model

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

  - $F_{I(C)}$ is interference (CI) term, $\eta_{LL}=\pm 1$
  - $\Lambda$ is the energy scale (below which fermion constituences are bound)
- No excess, limits at 95% CL:
  - $\Lambda^{-}>4.9$TeV for constructive interference
  - $\Lambda^{+}>4.5$TeV for destructive interference




**Taking an integral…**

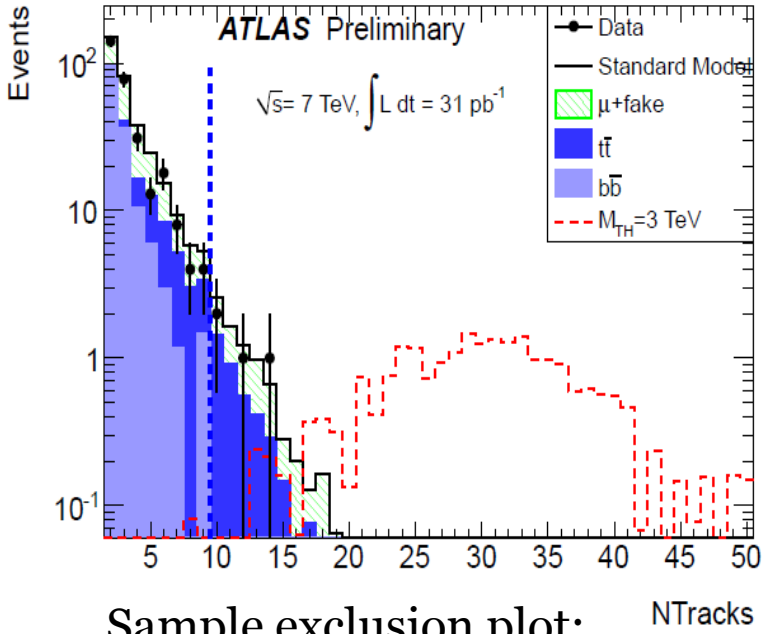



arxiv:1104.4398 accepted by PRD

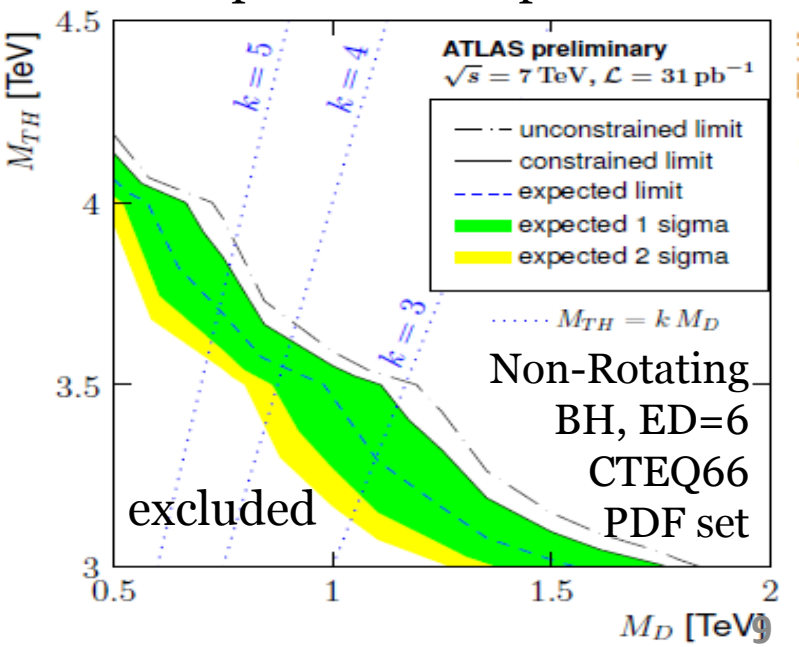
# Searches for Extra Dimensions

# Search for New Physics in Same-sign dimuons

- Benchmark Model: Large ED ADD Model
- $M_D$ is the Planck scale in n+4 D ($M_D << M_{Pl}$)
- If there are ED and $M_D$~1TeV, microscopic black holes (BH) can be produced at LHC
- Assume continuous BH production from $M_D$ to LHC $\sqrt{s}$=7TeV, but remove mass region ($M_{TH}$) close to $M_D$ where classical BH production and semi-classical BH decay approximations are not valid
- Strategy:
  - Select events with same sign di muons, with at least one being isolated, to minimize SM bkgs
  - Look at track multiplicity distribution
- No excess over SM expectations seen
- 95% CL limit on σ×A×BF of new physics in this final state is 0.184pb
- Exclusion plots in low scale gravity model




Sample exclusion plot:

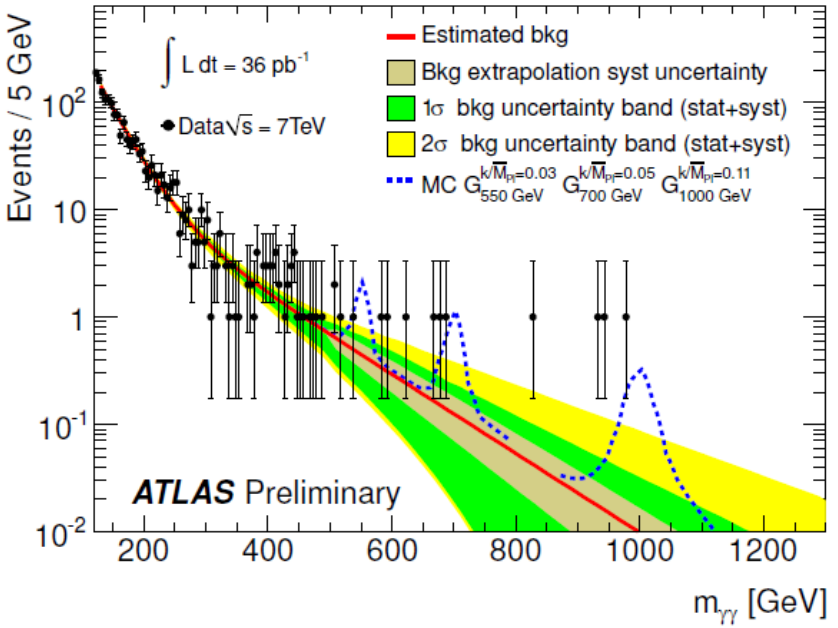


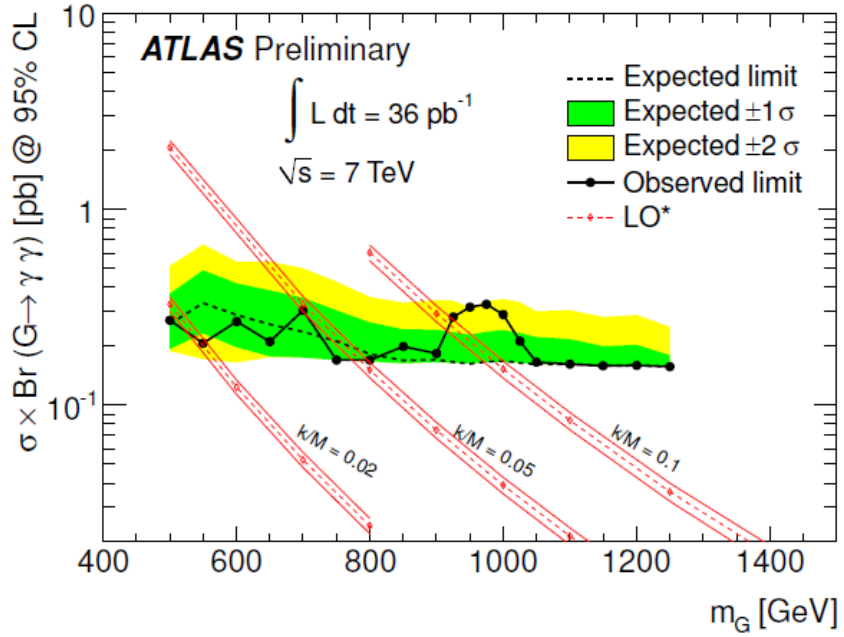

ATLAS-CONF-2011-065

# 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 $k/M_{Pl}<0.1$ (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 $k/M_{Pl}=0.1(0.02)$

See poster by X. Anduaga for more details




ATLAS-CONF-2011-044

# Search for New Physics in Dileptons

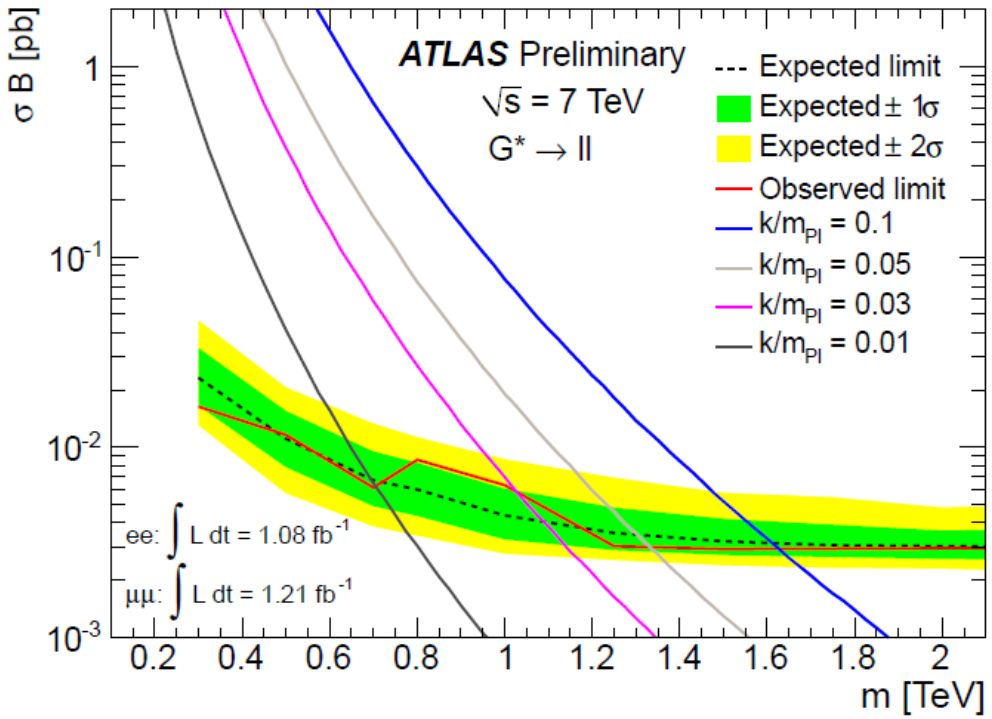
New!

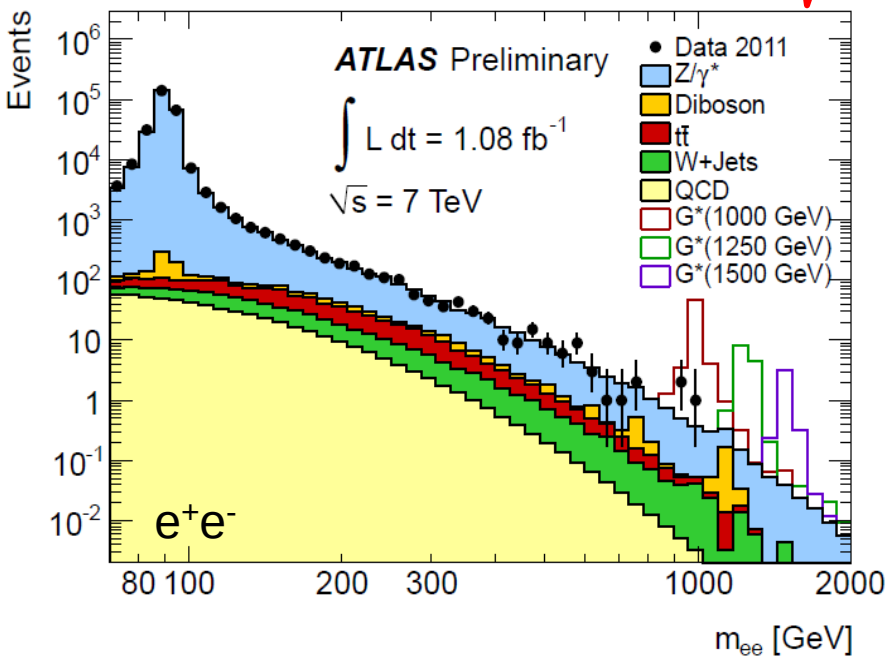
Benchmark signal: RS $G^* \rightarrow l^+l^-$

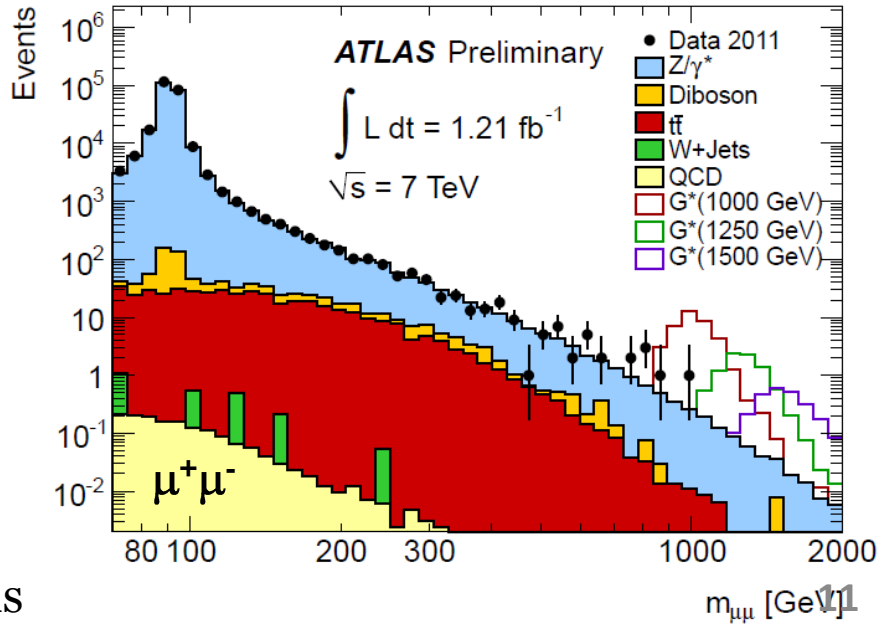
Same spectrum at for Z', no excess

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 |



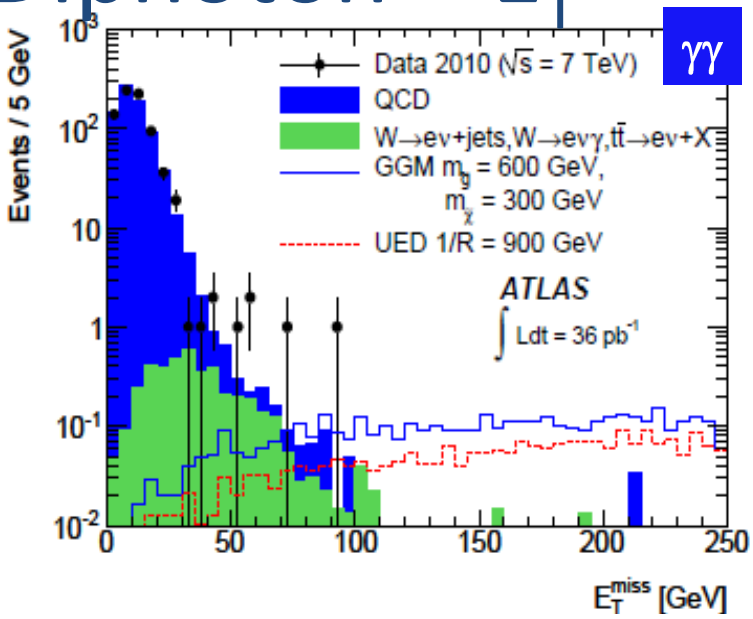



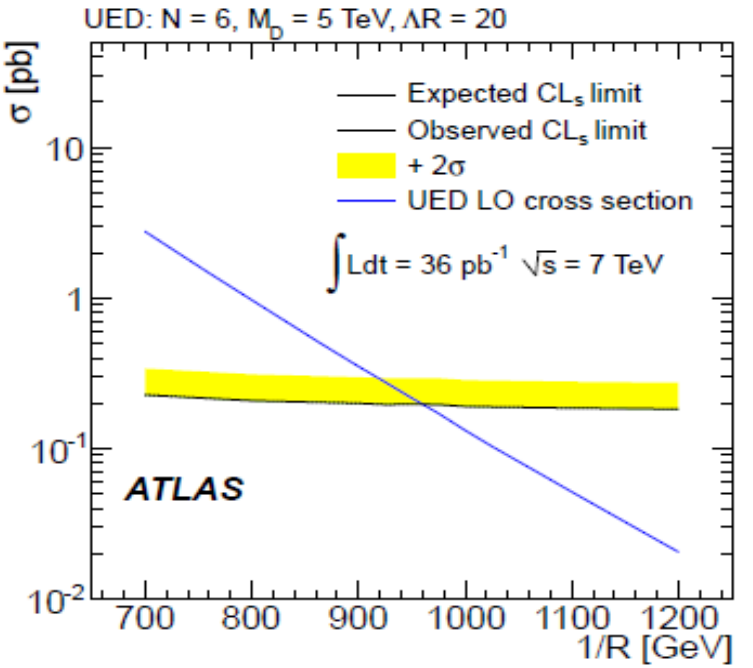




See posters by S. Heim & S. Viel for more details

# Search for New Physics in Diphoton + $E_T^{Miss}$

- Benchmark: effective theory of one $TeV^{-1}$ size UED valid at $\Lambda > 1/R$ (R = ED size)
  - SM particles in bulk $\Rightarrow$ KK excitations
  - Mass degeneracy of KK excitations broken by radiative corrections
  - Lowest KK particle $\gamma^*$ decays to $\gamma$+Graviton
- Expect excess of UED events at high $E_T^{Miss}$:
  - No events observed in $E_T^{Miss} > 125$GeV
  - Background events expected $0.10 \pm 0.04(stat) \pm 0.05(syst)$
- UL @ 95% CL on $\sigma < 0.18$-$0.23$pb for 1/R=700-1200GeV in UED model
- At $36pb^{-1}$ exclude @95% CL 1/R<961GeV




arXiv:1107.05661, submitted to EPJC

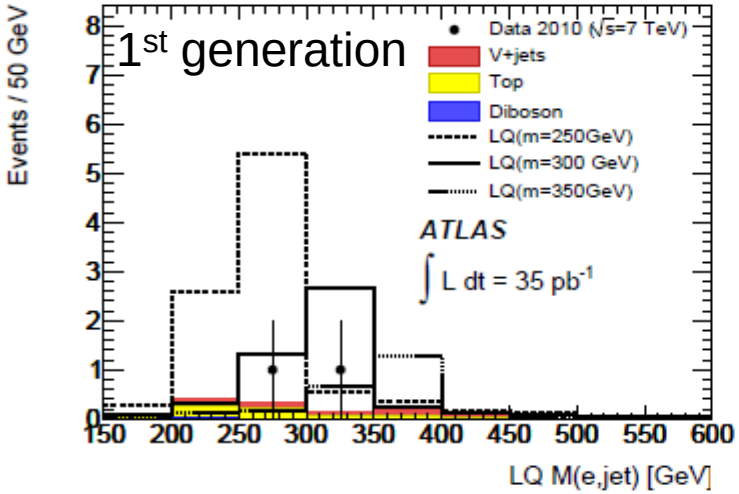
# Other Searches

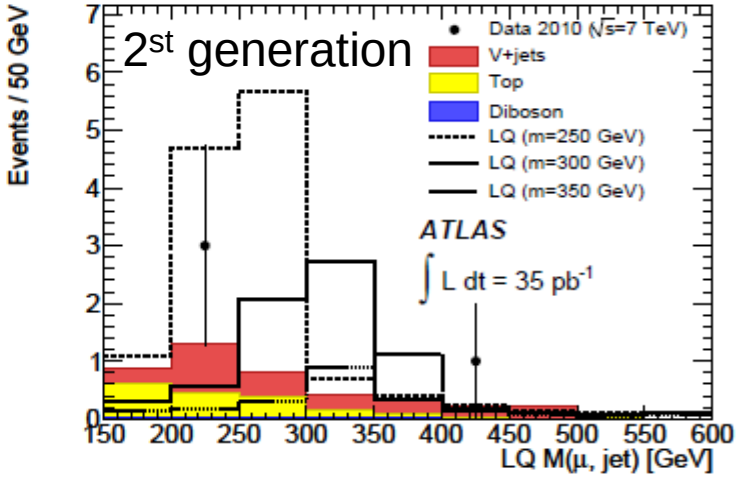
# Search for Leptoquarks

arxiv:1104.4481, accepted by PRD

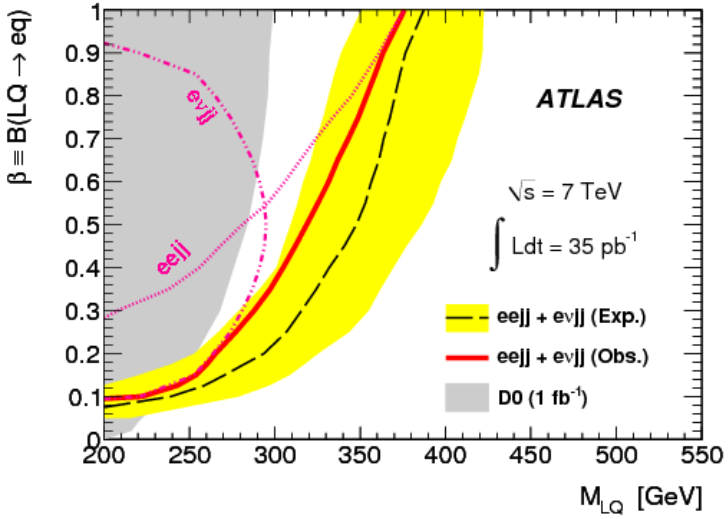
- Benchmark model: leptoquarks (LQ)
- Look for pair production of particles with both lepton and baryon quantum numbers
- Consider 2 lepton + 2 jets and lepton + 2 jets + $E_T^{Miss}$ final states

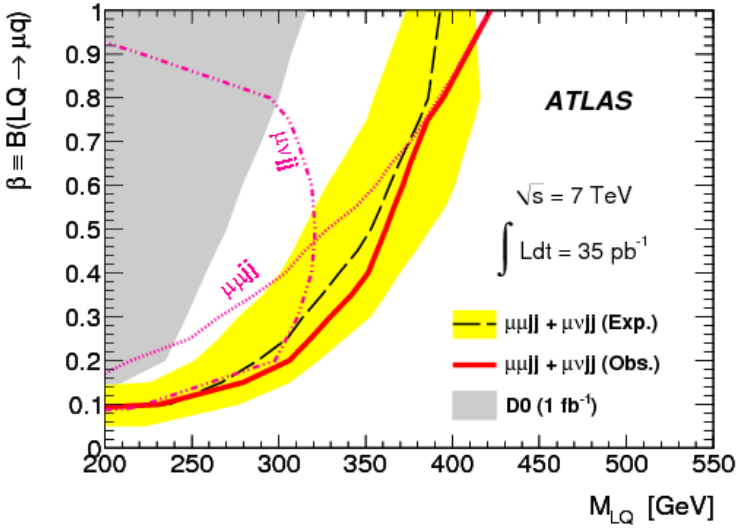
Average lj invariant mass




95% CL exclusion region



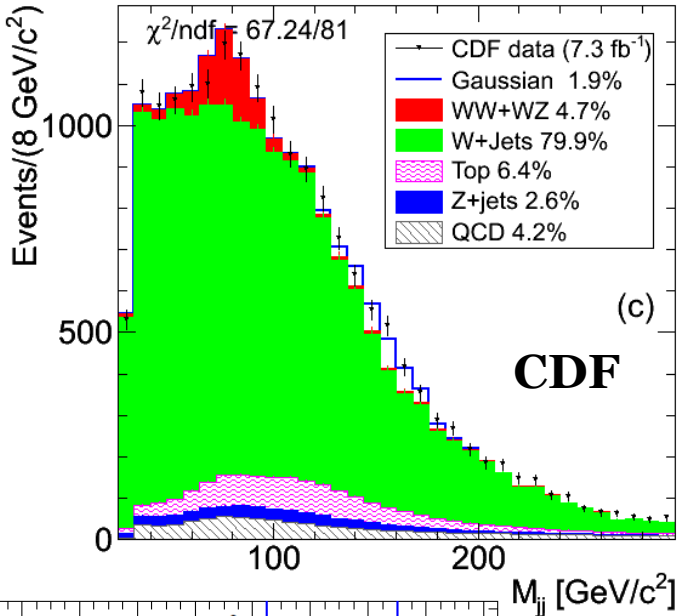



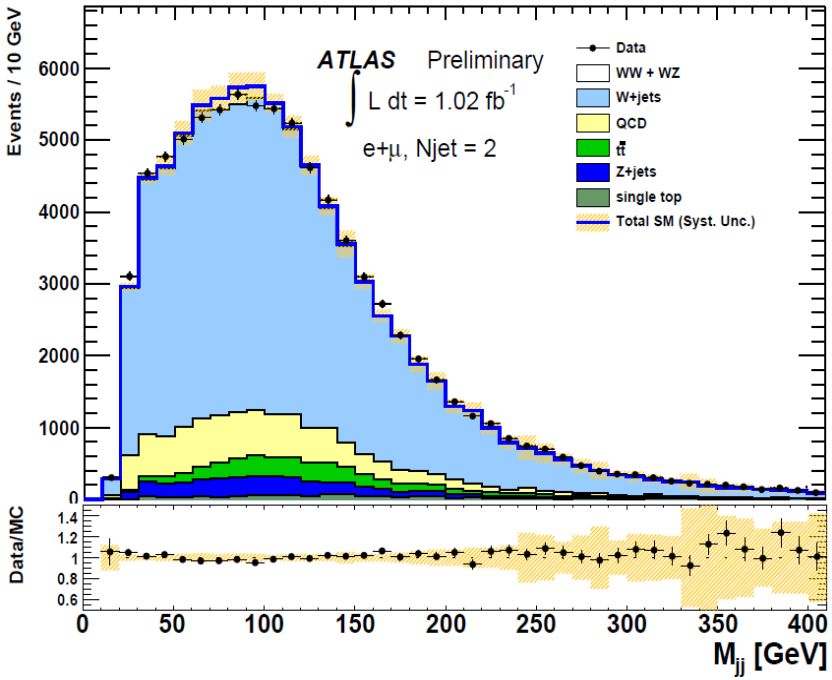

See poster by C. Deluca Silberberg for more details

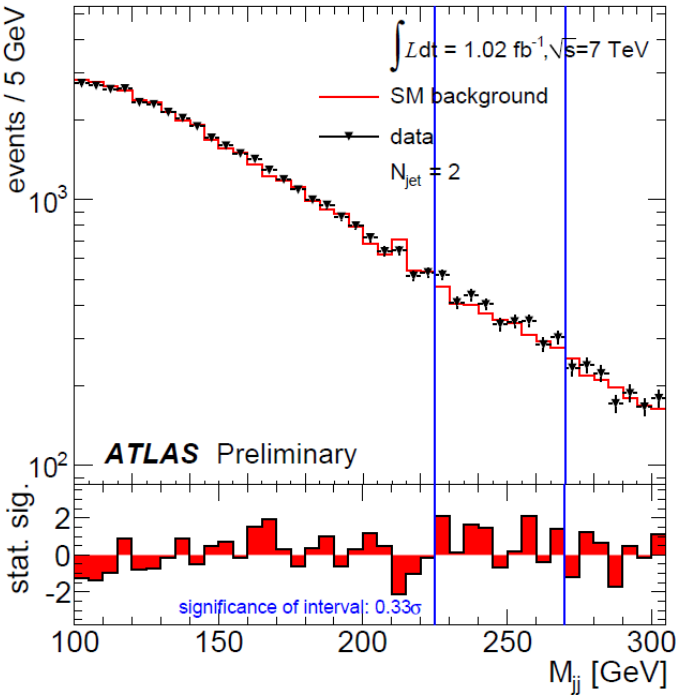
# More on lνjj channel

New!

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



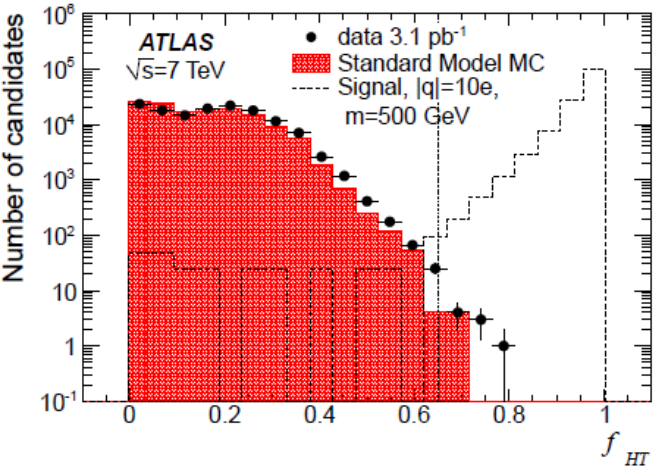



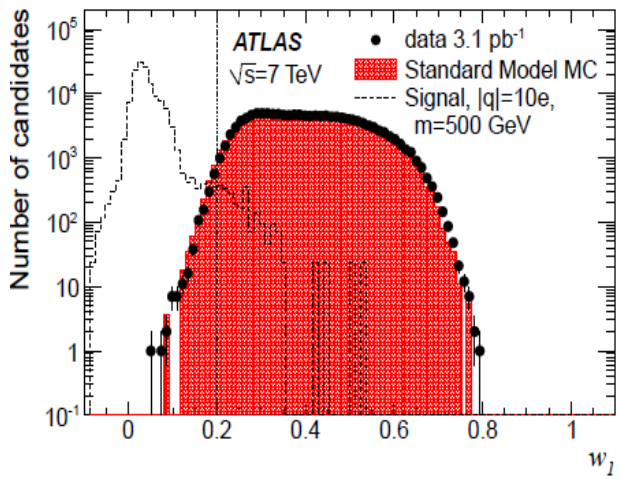



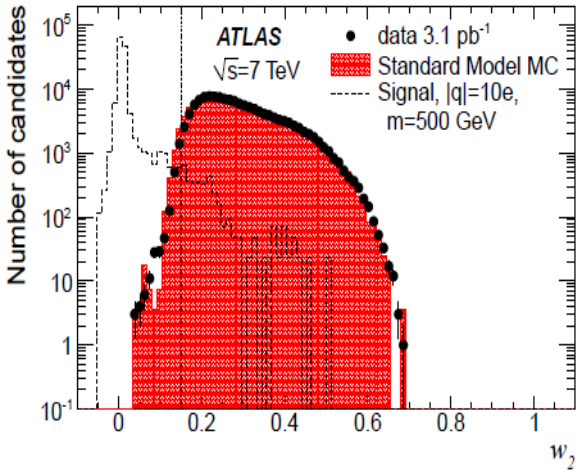

No significant excess over Standard Model processes seen in 1.02fb$^{-1}$ of data

ATL-CONF-2011-097

# Search for Massive Long-Lived Highly Ionising Particles




- Search for massive long-lived HIP: concentrate on large mass (>100GeV), non-relativistic speed, charges 6-17e (Q-balls, stable micro black holes)
- Signal has high ionization in tracker, narrow calorimeter deposits
- No events pass selection shown above (96% efficient for signal)

Cross-section limits @ 95% CL in pb for any model

| $m$ [GeV] | $\|q\| = 6e$ | $\|q\| = 10e$ | $\|q\| = 17e$ |
|---|---|---|---|
| 200 | 1.4 | 1.2 | 2.1 |
| 500 | 1.2 | 1.2 | 1.6 |
| 1000 | 2.2 | 1.2 | 1.5 |

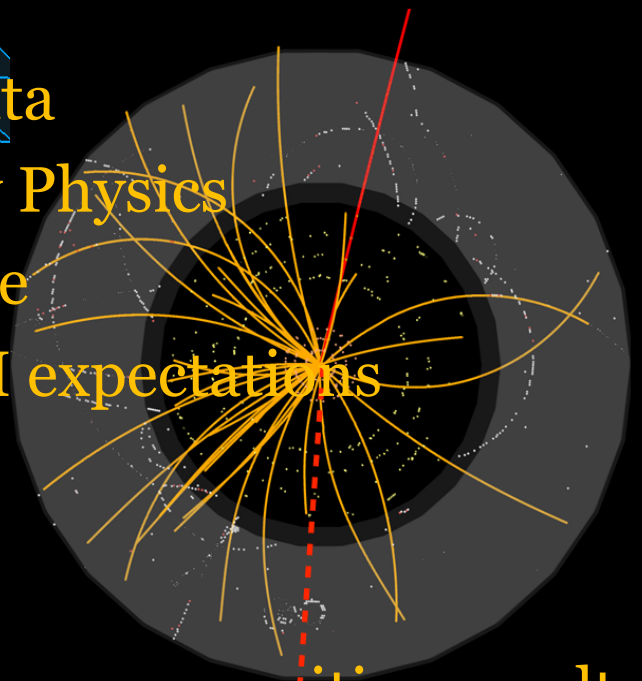
Cross-section limits at 95% CL in pb assuming Drell-Yan-like production mechanism

| $m$ [GeV] | $\|q\| = 6e$ | $\|q\| = 10e$ | $\|q\| = 17e$ |
|---|---|---|---|
| 200 | 11.5 | 5.9 | 9.1 |
| 500 | 7.2 | 4.3 | 5.3 |
| 1000 | 9.3 | 3.4 | 4.3 |

arXiv: 1102.0459, PLB698:353-370,2011

# Conclusion

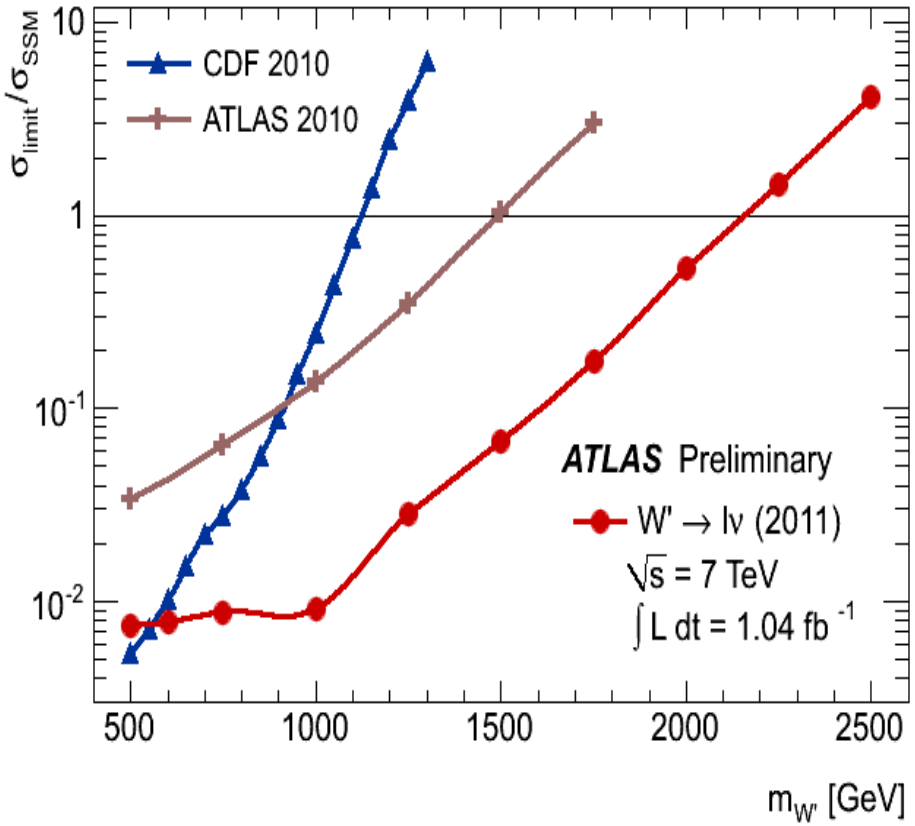
- LHC is working very well
- ATLAS detector is efficiently collecting data
- We are well on the way searching for New Physics
  - A lot of limits are reaching ~1TeV range
  - Distributions so far consistent with SM expectations
  - Previous limits substantially improved

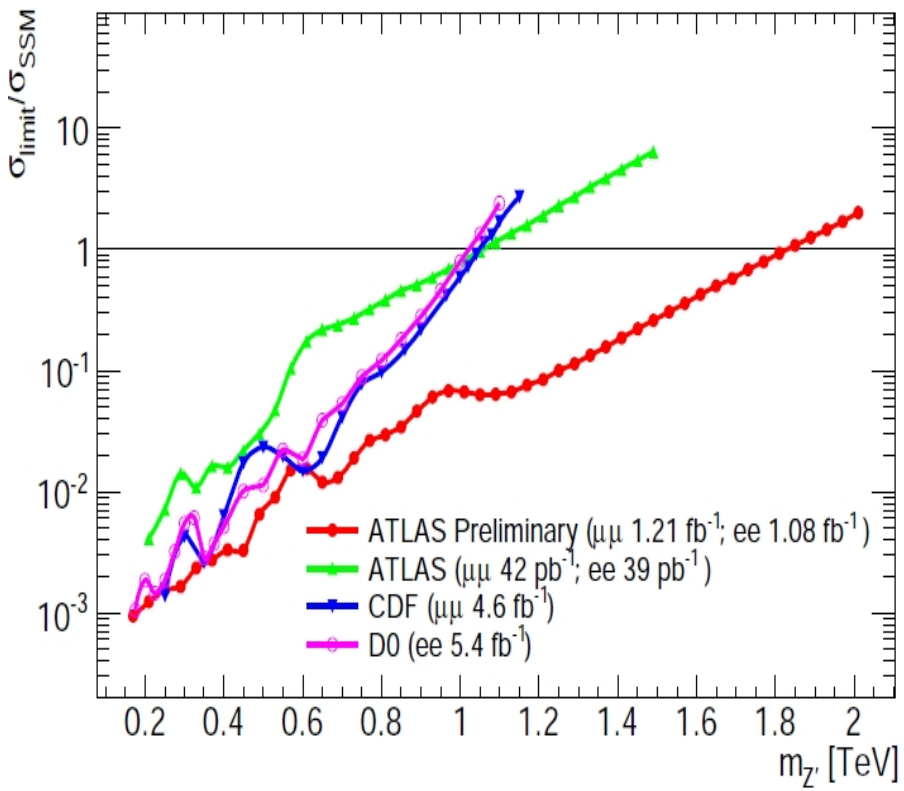


- We already have more than $1fb^{-1}$ of data, more exciting results from ATLAS to come…

# Backup Slides

# W’ and Z’ limits vs other expriments



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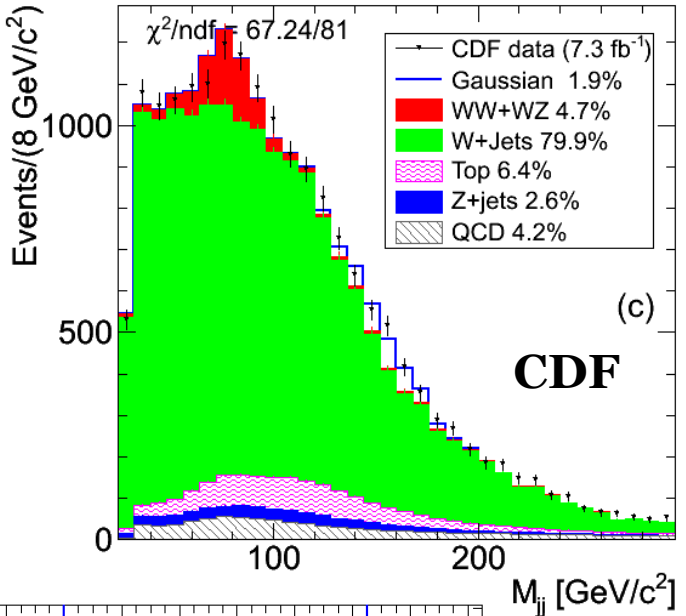
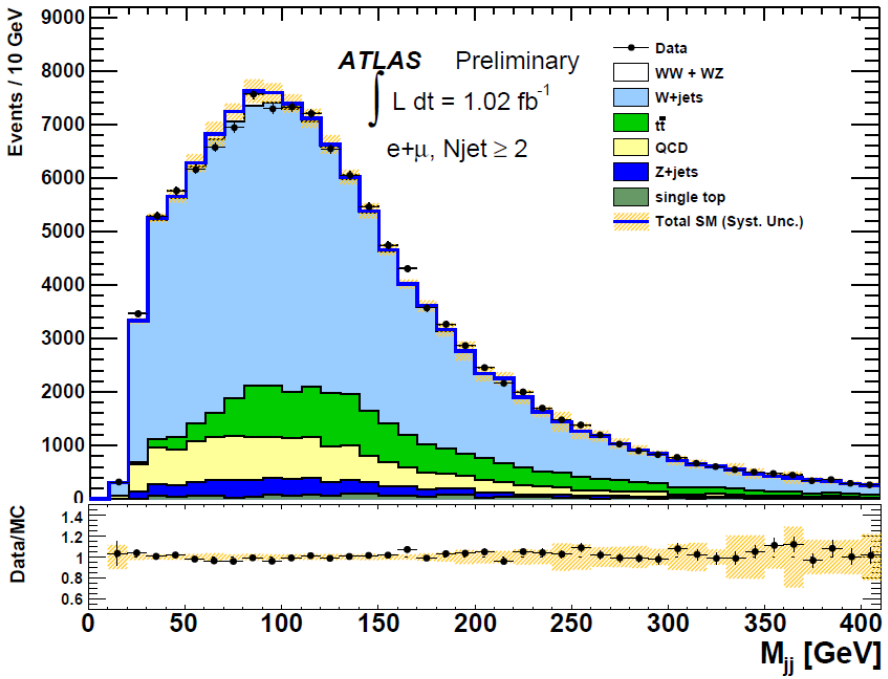
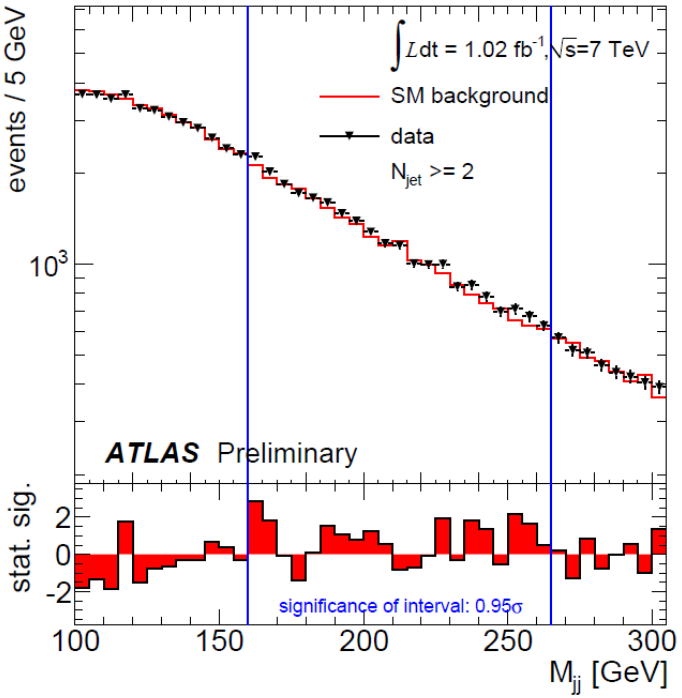



No significant excess over Standard Model processes seen in 1.02fb$^{-1}$ of data

ATL-CONF-2011-097

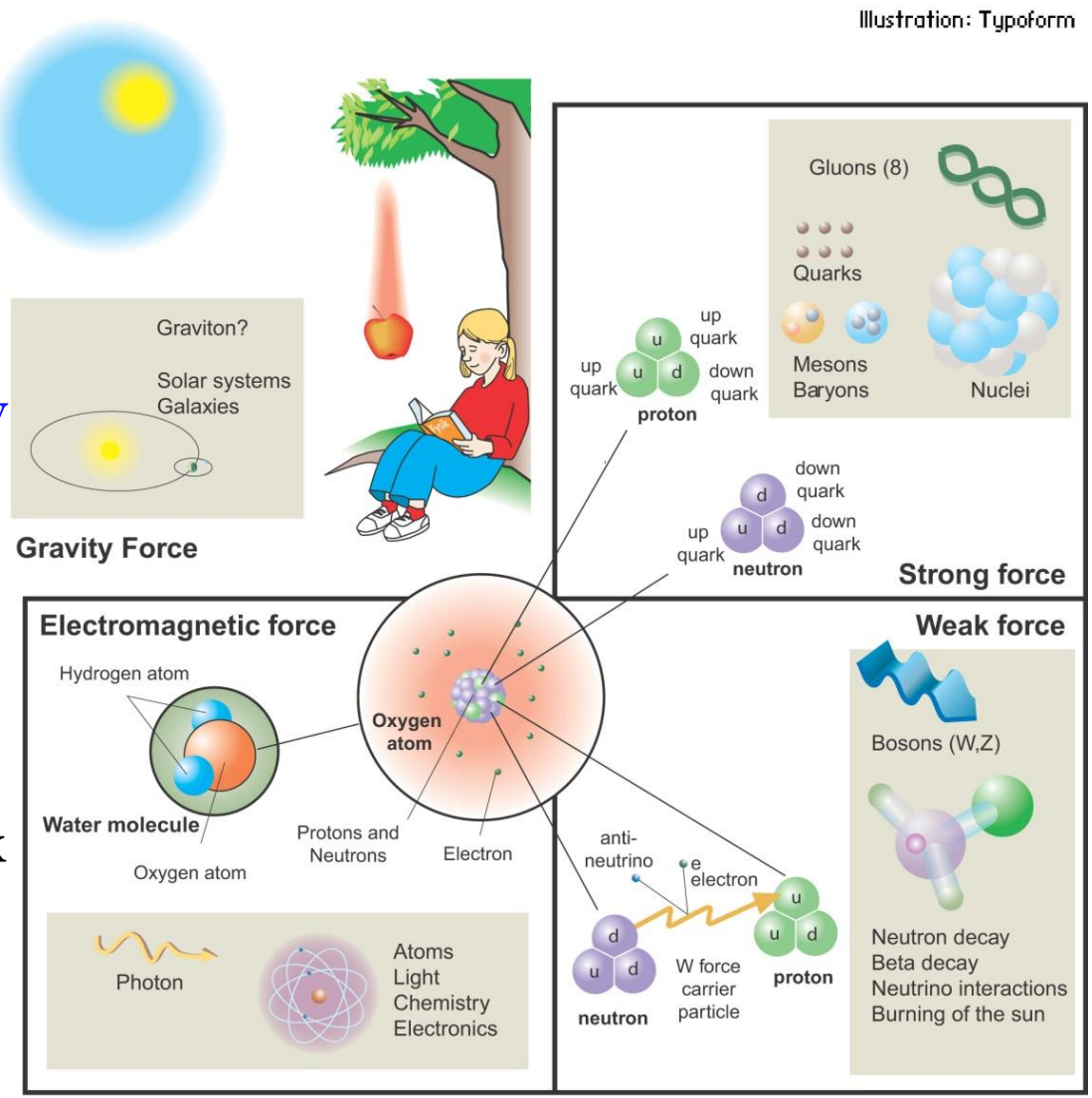
# Why go beyond the Standard Model?

Standard Model combines electroweak and strong theory describes data very well but

Does not include gravity

Higgs boson is not found yet

SM is low energy effective theory




- Why three families of quarks and leptons? Are they elementary?
- Too many free parameters
- Symmetry between EM & weak forces is broken
- Strong and EW forces are not unified
- Hierarchy problem

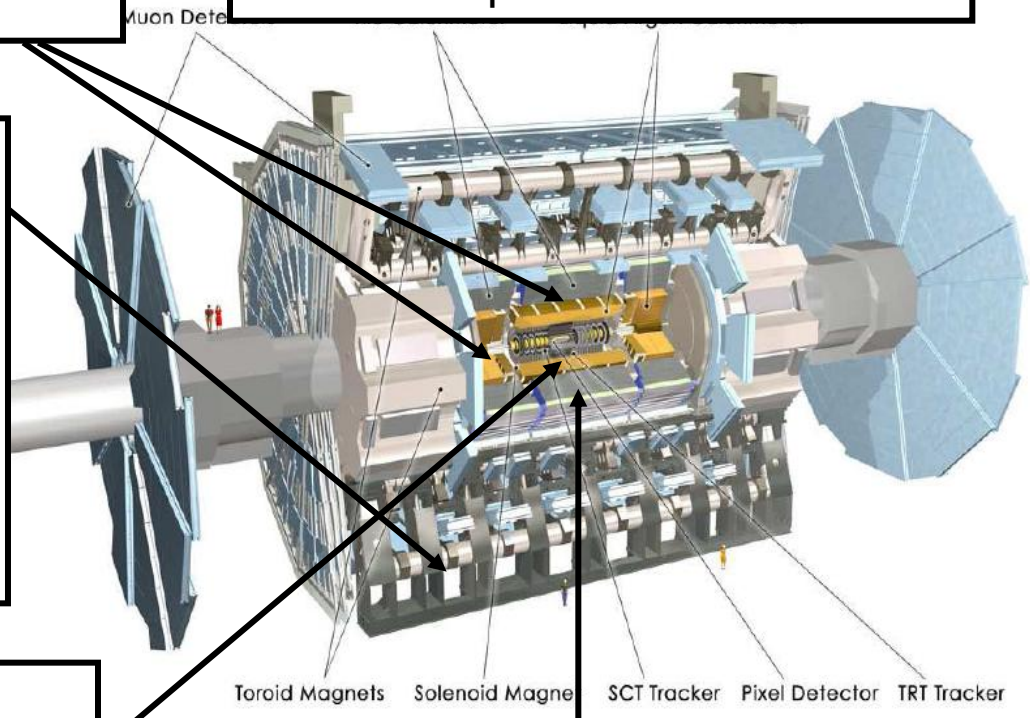
New physics is needed at the weak scale ~ 1TeV

# ATLAS Detector

**EM Calorimeter**: $|\eta| < 4.9$
- Barrel/Endcap: accordion-shaped Pb/LAr
- 3 longitudinal layers at $|\eta|<2.5$
- $\sigma_E/E = 10\%/\sqrt{E} \oplus 24.5\%/E \oplus 0.7\%$

**Trigger/DAQ:**
- Input rate ~1 GHz
- Rate to tape ~400 Hz

**Muon Spectrometer** : $|\eta| < 2.7$
- In air-core toroid with gas detectors
- Barrel: Resistive Plate Chambers & Cathode Strip Chambers
- Endcap: Thin Gap Chambers and Monitored Drift Tubes
- Standalone: $\sigma(p)/p = 3\%(0.1\text{TeV})\text{-}10\%(1\text{TeV})$




**Inner Detector:** $|\eta| < 2.5$
- 3 layers of Pixel Detector
- 4 layers of Semi-Conductor Tracker
- 73-layer Transition Radiation Detector (TRT) [only within $|\eta|<2.0$]
- In 2T solenoidal magnetic field
- $\sigma(p_T)/p_T = (0.034 p_T/\text{GeV} \oplus 1.5)\%$

**Hadronic Calorimeters**:
- 3 layers of scintillating tile/steel to $|\eta|<1.7$
- 4 layers copper/LAr for $1.5<|\eta|<3.2$