Exotics at ATLAS

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On behalf of the ATLAS collaboration

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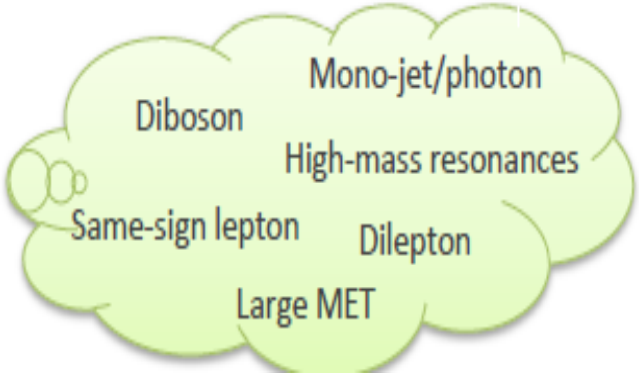
New Physics motivation...

- Higgs-like discovery particle is the Great achievement of 21th century science
  - Fits even better with the Standard Model (SM)
    - All SM particles observed !!
- However several open questions still unsolved by SM:
  - Hierarchy problem, higher symmetries, dark matter/energy, ……
  - There could be either SUSY, reviewed by Evgeniy Khramov (JINR Dubna) or Exotics phenomena, target of this talk

Numerous Beyond the SM theories predict New phenomena at the TeV scale that are accessible at the LHC

Compositeness
Leptoquarks
Extra-dimension
No Higgs
Little Higgs
Technicolors
Hidden Valley
GUT
LRSM, heavy neutrino
4^{th} generation t'
4^{th} generation b'
etc.



- Try to cover all possible signatures
- Setup model-independent analyses
- Interpret results using benchmarks

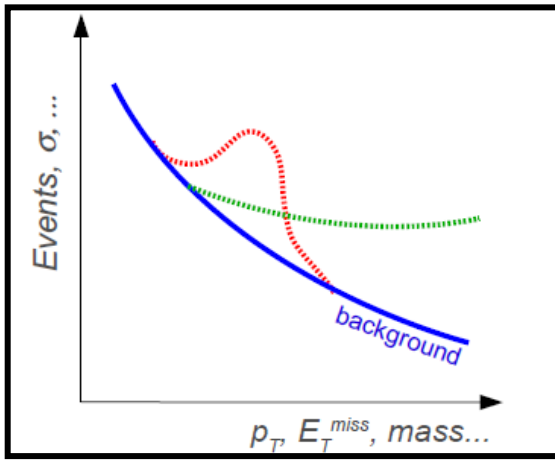
New Physics motivation...

- Investigating whether the answers may come from exotic models
- Search for Beyond-SM resonances on smooth SM backgrounds

- **Exotics on ATLAS:**
  - 60 papers published on 7 TeV data
  - 13 papers published/submitted on 8TeV data
- **Focus on selected recent ATLAS results**
- Search for heavy resonances in:
  - **Dilepton events**
  - **ttbar events**
  - **Heavy quarks events (W´(Z´)→tb)**
  - **Diboson events**
- **All limits are quoted at the 95% CL**

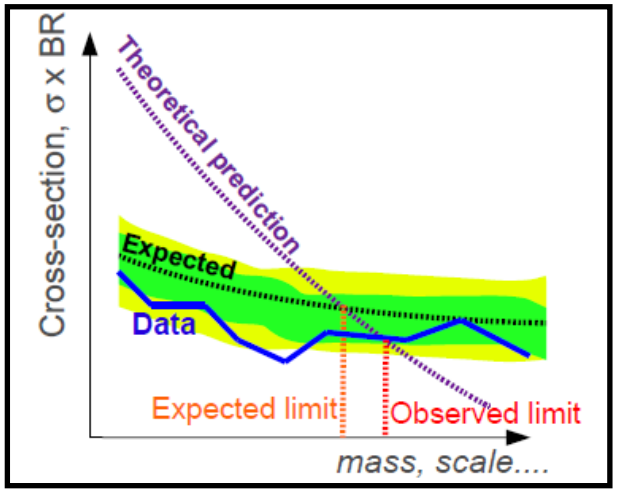
Typical Search strategy

- Focus on observables such as invariant mass, p_T or E_T
- Search for deviations from known background (BG)
  - Search for bump (**resonant phenomena**)
  - Search for excess in tail (**non-resonant phenomena**)



Main steps for Limit setting:

- Compute **theoretical prediction**
- Estimate acceptance, efficiency
- and luminosity and their uncertainties
- **Pseudo-experiments**
  - generate BG only pseudo experiments (PE)
  - for each PE estimate the consistency between
  - pseudo-data and signal+background hypothesis and get 95%CL limit on signal cross-section
  - for all PE calculate the **median**, the **1 sigma RMS** and the **2 sigma RMS**
- **plot the σ (Data)**
- compute **observed limits**
- compute **expected limits**

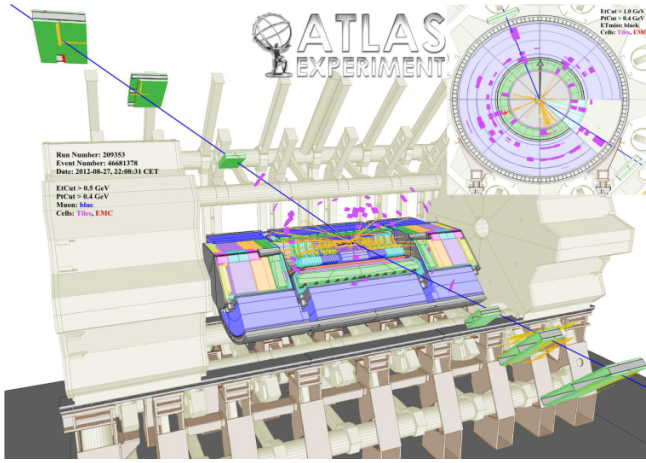


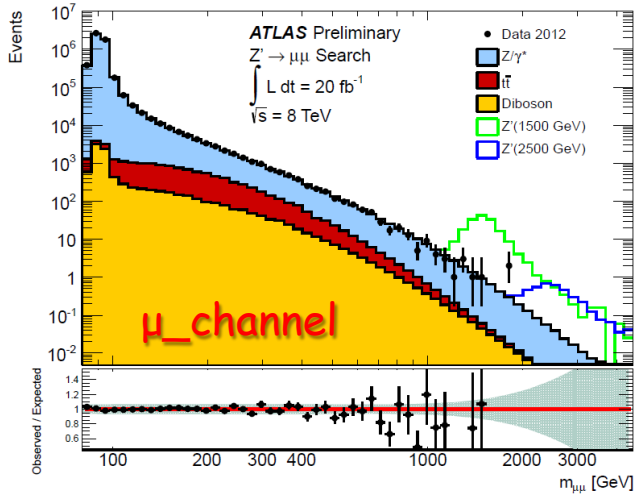
Dilepton resonances

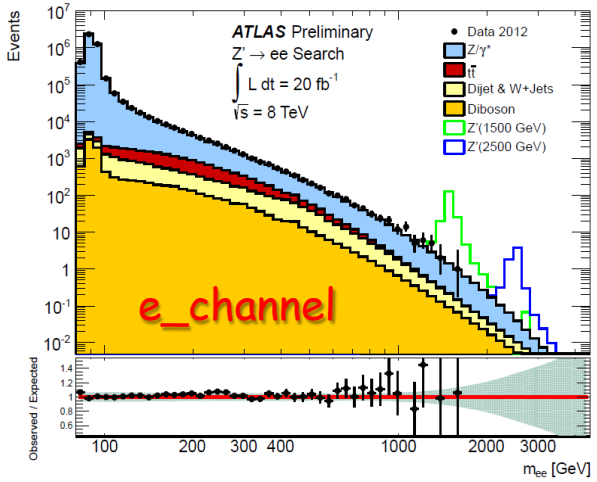
ATLAS-CONF-2013-017

- Select events with two isolated leptons:
  - Clean signature: e+e- or $\mu^+\mu^-$
  - But present significant experimental challenges
    - understand detector Performance
    - confidence in alignment, simulation
- Dominant Background: Drell-Yan
  - require high mll
- MC estimation: Z/γ*, ttbar , diboson
  - data-driven estimation: multijet, W+jets

$P(\mu 1)_T$ =653 GeV, = $P(\mu 2)_T$ 646 GeV, mμμ =1844 GeV







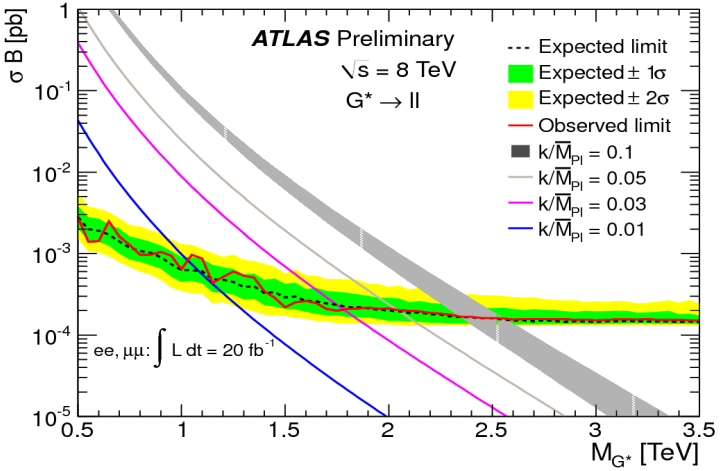
- Focus on invariant mass spectrum

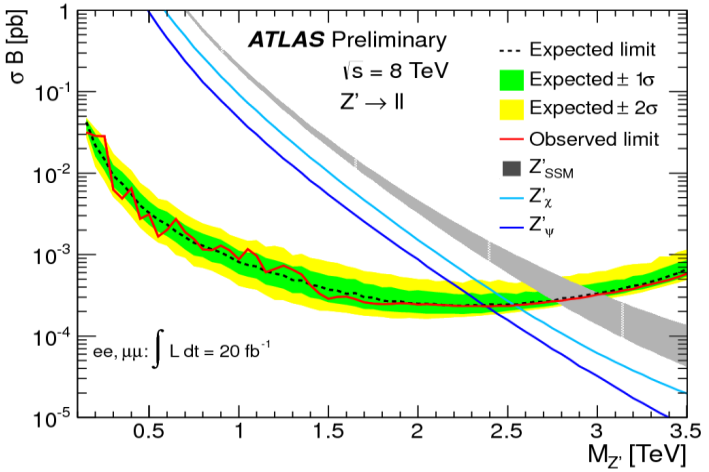
The pair with the highest p_T scalar sum is selected; Sum of backgrounds is normalized to data in 80-110 GeV region

Dilepton resonances: Results

ATLAS-CONF-2013-017

- Results are interpreted using the following Benchmark models:
  - Sequential SM: assume Z' with same couplings as SM Z
  - Randall-Sundrum KK graviton
- Bayesian approach used to set upper limits on σ times BR





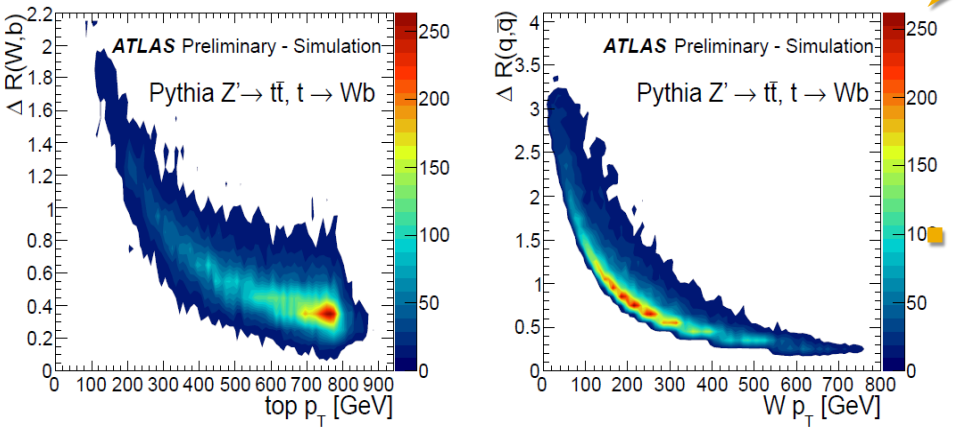
- 95 % C.L Expected and observed mass limits with 20 fb^{-1} at 8 TeV

model	Z'_{SSM}	Z'_{ψ}	Z'_{N}	Z'_{η}	Z'_{I}	Z'_{S}	Z'_{χ}	G^* $(k/M_{Pl}=0.1)$
Observed mass limit [TeV]	2.86	2.38	2.39	2.44	2.42	2.47	2.54	2.47
Expected mass limit [TeV]	2.85	2.37	2.38	2.43	2.40	2.46	2.53	2.47

ttbar resonances

ATLAS-CONF-2013-052

- With the increase of energy and luminosity at the LHC, decay of heavy resonances associated with new physics is in the multi-TeV mass range
- Result in highly boosted very massive objects such as Top
  - Decay products of Boosted Tops collimated in direction of pT
  - Separation can be described according to $\Delta R \sim m/pT$



(a) $t \to Wb$ ATLAS-CONF-2012-065 (b) $W \to q\bar{q}$

- Standard reconstruction methods are no longer sufficient for boosted top quarks
- Many new techniques are developed to reconstruct and identify boosted tops
  - Jet substructure →**fatjet**
  - Less-isolated leptons

ttbar resonances

ATLAS-CONF-2013-052

Benchmark models to quantify sensitivity:

- Topcolour assisted technicolour leptophobic Z'
  - Narrow resonance (width ~1% of the mass, Spin 1)

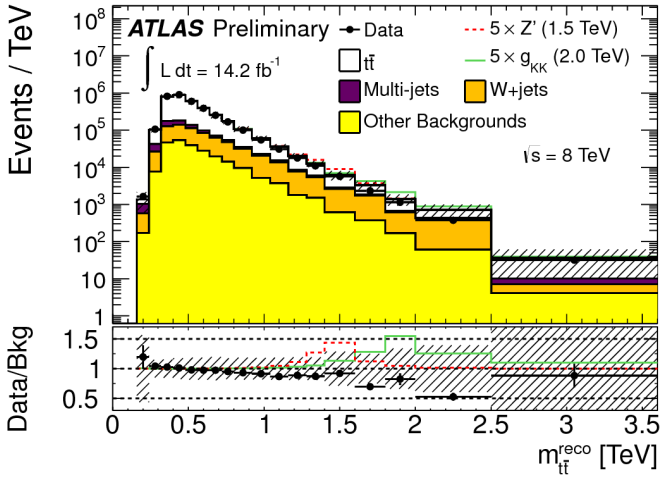
- Randall-Sundrum Kaluza-Klein gluons, g_{KK}
  - Broad resonances (width ~10-15% of the mass, Spin 1)
  - Present a challenge for detector resolution

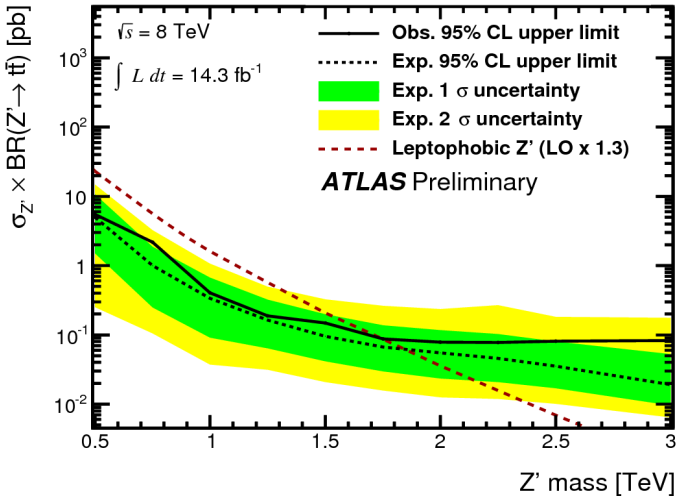
- **Analysis strategy**
- Top quark signature is difficult to reconstruct efficiently → Many objects
  - Adapt the event selection and reconstruction to the final configuration
    - **Event selections:**
      - **Resolved**: standard top reconstruction with narrow jets
      - **Boosted**: using large-cone "fatjet to reconstruct the hadronic top
    - **Event reconstruction:**
      - Combined limit of boosted and resolved selection:
        - Resolved selection mainly relevant at low mtt
        - Boosted selection relevant at high mtt

ttbar resonances: Results

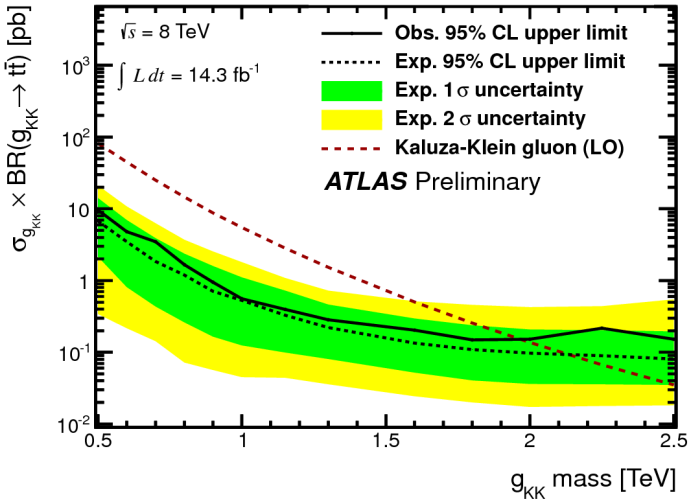
ATLAS-CONF-2013-052

- Focus on invariant mass spectrum, m_{tt}
  - **No significant deviations from the Standard Model**





- Expected and observed upper cross section limits times ttbar branching ratio (95 % C.L.)



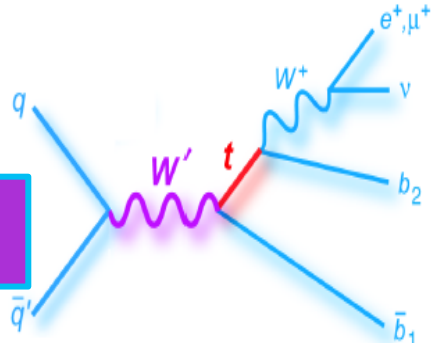
- **Exlusion @95% CL limit (Bayesian)**
  - **0.5 TeV < $m_{Z'}$ <1.74 TeV**
  - **0.5 TeV < mg_{KK}< 2.07 TeV**

Heavy quarks resonances

ATLAS-CONF-2013-050

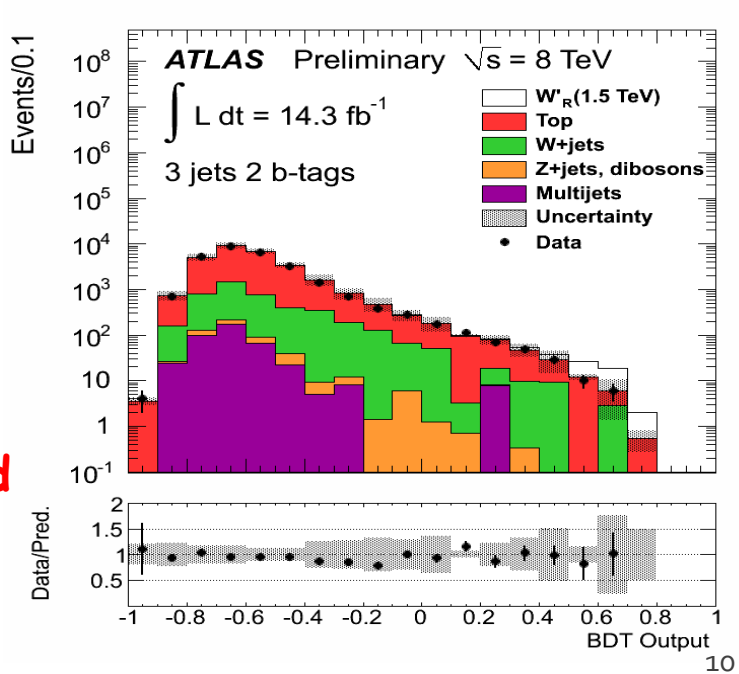
- Many beyond-SM predict heavy gauge bosons W′ (Z′)
  - GUT-inspired theories,
  - Kaluza-Klein excitations of gauge bosons

New heavy bosons W′ has strong coupling to third generation



- Search for heavy resonances decaying to tb
  - Select events with 2 b-jets, high invariant mass of tb system
- Boosted Decision Tree (BDT) for discrimination of signal to background
  - Main discriminants: m_{tb}, p_T(top)
    - separation between lepton and b-jet

BDT output for data, signal and background in signal region with 2 b-jets



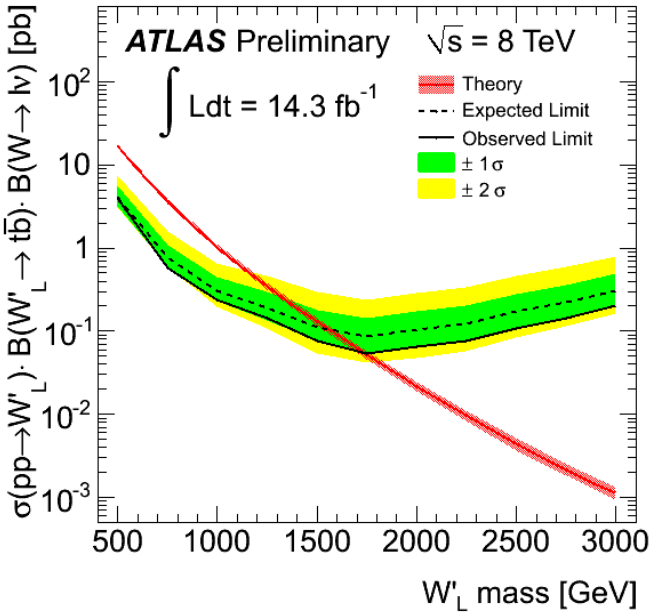
Heavy quarks resonances: Results

ATLAS-CONF-2013-050

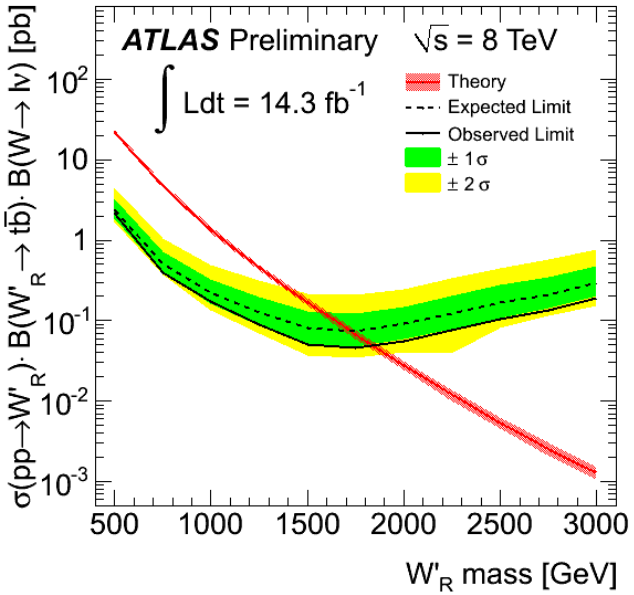
- No data excess over the expected SM background is observed in BDT output
- Set limits on W' with SM couplings (effective model)

- Exlusion @95% CL limit
  - $m(W'_L) > 1.74$ TeV
  - $m(W'_R) > 1.84$ TeV

left handed

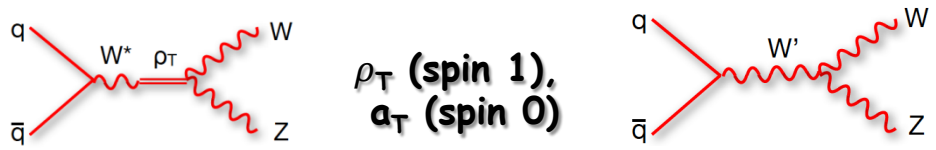


Right handed



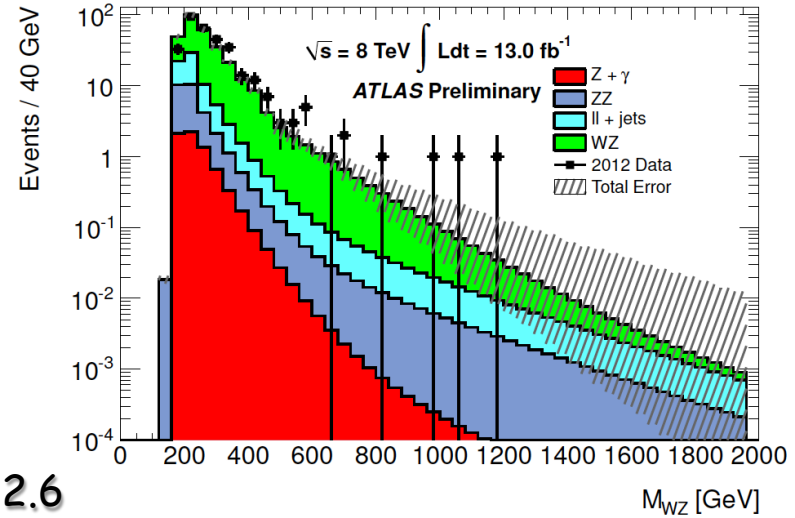
Diboson resonances

- Benchmark model of heavy resonances decaying to pairs of electroweak gauge bosons
  - W' in the Extended Gauge Model (EGM)
  - Technimesons (LSTC)



- Charged (WZ/γ)
- W´ (spin 1)
  - Triple gauge coupling W'WZ
  - Fermionic coupling like W

- WZ-> lνll signal selection (l=e,m)
  - exactly three leptons to reconstruct
  - a pair of W(ℓ±ν) and Z(ℓ+ℓ−)
  - W mass constraint for solving the pν
- Backgrounds: WZ, ZZ, Z+jets, ttbar, Zγ
  - data-driven estimation for Z+jets and ttbar
- Non-resonant WZ background suppression
  - WZ control region: $\Delta y(W,Z) < 1.8$ and $\Delta\phi(W,Z) > 2.6$
  - Z+jet control region: ETmiss < 25 GeV, mTW < 25 GeV

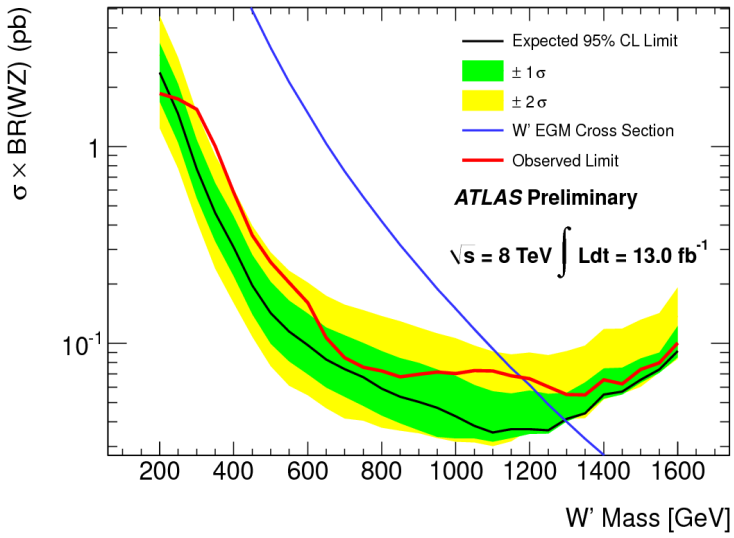


Diboson resonances: Results

ATLAS-CONF-2013-015

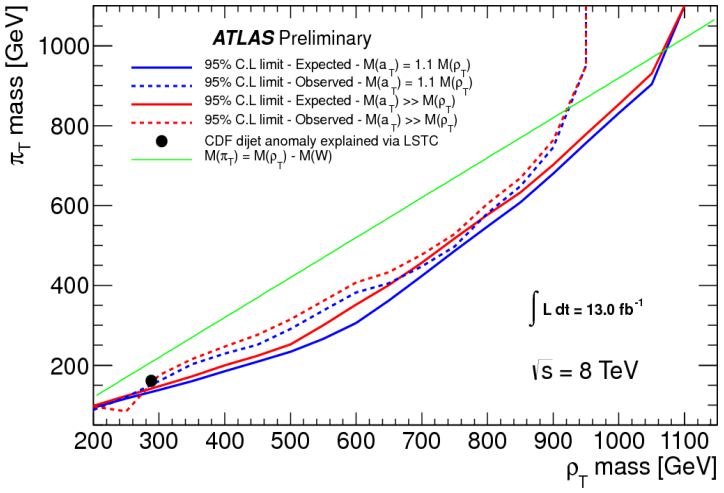
- **no significant excess observed**
  - 95% C.L. limits on σ × B(W' → WZ), and exclusion limits on (π_T, ρ_T) mass plane

➢W' in EGM



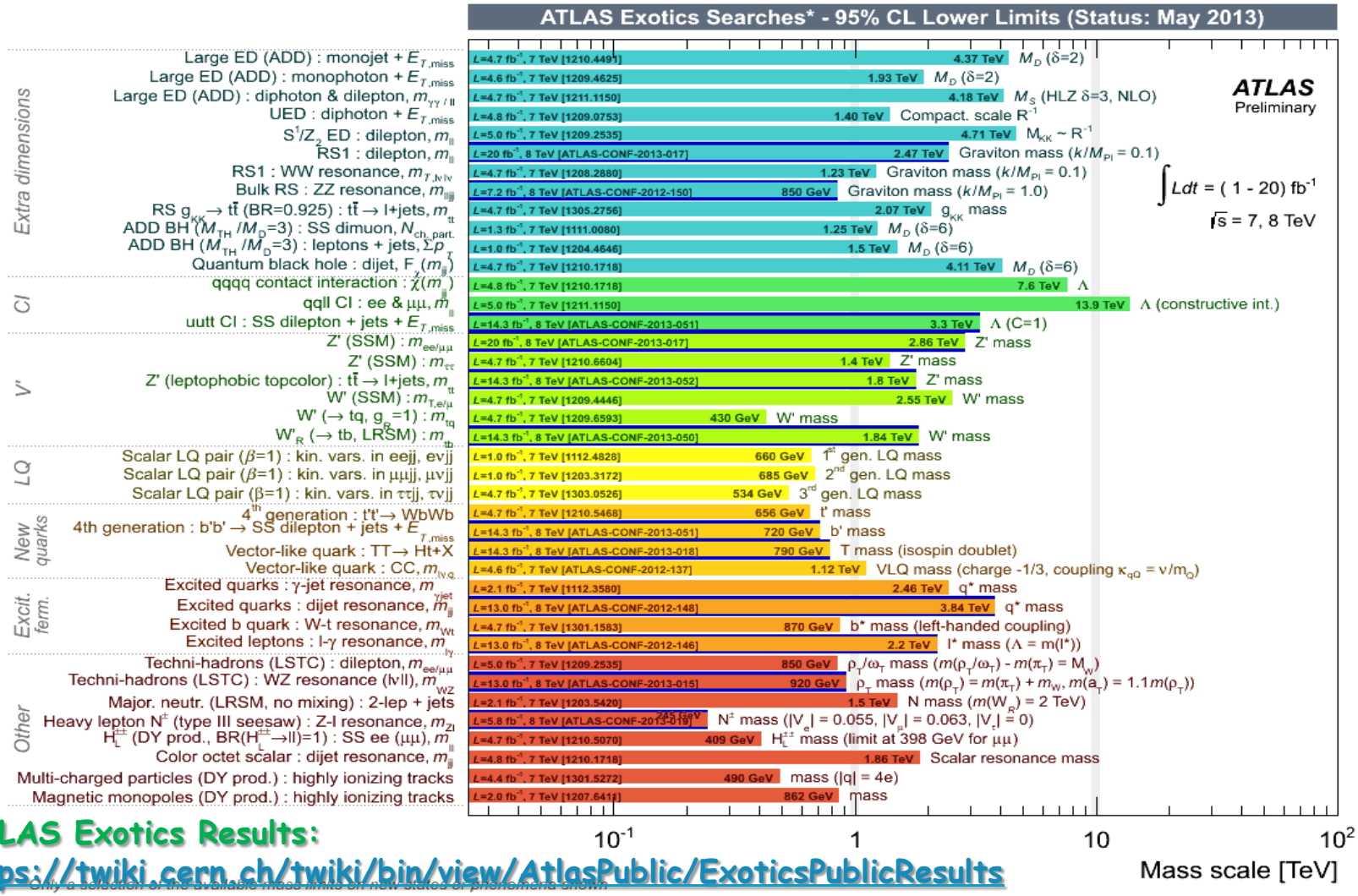
- Exlusion @95% CL limit
  - m(EGM W´) > 1.30 TeV

➢Low scale TC
(assuming W'-like kinematics)



- Exlusion @95% CL limit
  - $ma_T = 1.1 m\rho_T$ > 0.92 TeV
  - $ma_T >> m\rho_T$ > 0.92 TeV

Exotics searches at a glance….



ATLAS Exotics Results:
https://twiki.cern.ch/twiki/bin/view/AtlasPublic/ExoticsPublicResults

Summary & outlook

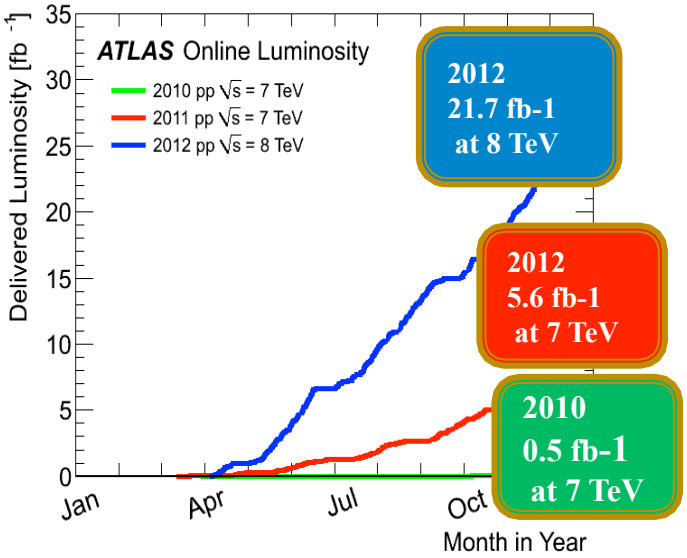
- **No hints of new physics yet!!**
- Results using the **full Run 1 dataset** are Starting to appear
- **Surprise can be around the corner !!**

- **Exiting perspective**
- LHC physics reach at TeV mass scale will be greatly extended by the **increased beam energy and intensity expected in Run 2**

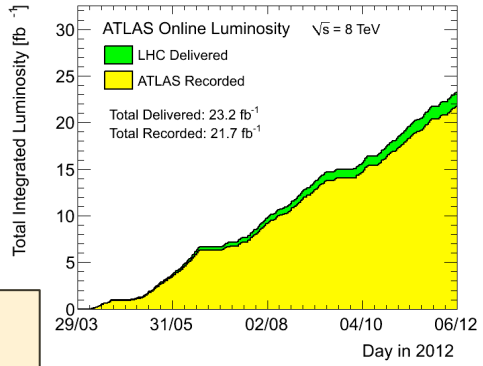
- **ATLAS has been doing great…**
  - Very competitive analyses in Exotica searches

BACKUP

Data Taking and Data Quality



LHC "Run I":2010-2013



Overall data-taking efficiency over 3 years: ~ 93.5%

Excellent performance of LHC
Excellent performance of ATLAS

ATLAS Detector Status

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	80 M	95.0%
SCT Silicon Strips	6.3 M	99.3%
TRT Transition Radiation Tracker	350 k	97.5%
LAr EM Calorimeter	170 k	99.9%
Tile calorimeter	9800	98.3%
Hadronic endcap LAr calorimeter	5600	99.6%
Forward LAr calorimeter	3500	99.8%
LVL1 Calo trigger	7160	100%
LVL1 Muon RPC trigger	370 k	100%
LVL1 Muon TGC trigger	320 k	100%
MDT Muon Drift Tubes	350 k	99.7%
CSC Cathode Strip Chambers	31 k	96.0%
RPC Barrel Muon Chambers	370 k	97.1%
TGC Endcap Muon Chambers	320 k	98.2%

ATLAS p-p run: April-December 2012

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
99.9	99.4	99.8	99.1	99.6	99.6	99.8	100.	99.6	99.8	99.5

All good for physics: 95.8%

Luminosity weighted relative detector uptime and good quality data delivery during 2012 stable beams in pp collisions at √s=8 TeV between April 4th and December 6th (in %) – corresponding to 21.6 fb⁻¹ of recorded data.

2012 data quality after reprocessing