SEARCHING FOR NEW HIGH MASS PHENOMENA DECAYING TO MUON PAIRS USING PROTON-PROTON COLLISIONS AT $\sqrt{s}$ = 13 TEV WITH THE ATLAS DETECTOR AT THE LHC

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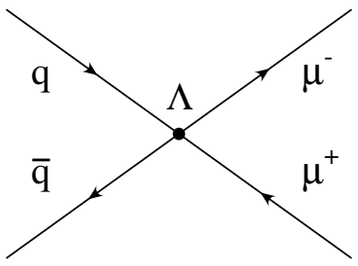
Motivation

Contact Interactions (CI)

- Probes quark and lepton compositeness, with binding energy scale Λ

$$\mathscr{L} = \frac{g^2}{\Lambda^2}\left[\eta_{LL}\,(\bar{q}_L\gamma_\mu q_L)\,(\bar{\ell}_L\gamma^\mu\ell_L) + \eta_{RR}(\bar{q}_R\gamma_\mu q_R)\,(\bar{\ell}_R\gamma^\mu\ell_R) + \eta_{LR}(\bar{q}_L\gamma_\mu q_L)\,(\bar{\ell}_R\gamma^\mu\ell_R) + \eta_{RL}(\bar{q}_R\gamma_\mu q_R)\,(\bar{\ell}_L\gamma^\mu\ell_L)\right]$$

- Observable as **broad excess** in dilepton invariant mass spectrum



Z Prime (Z')

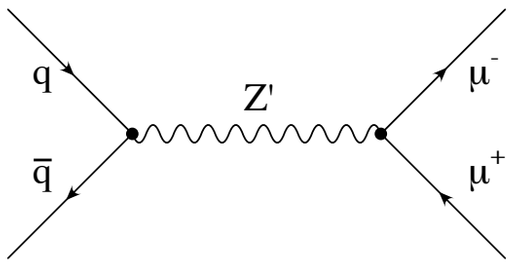
- Additional spin-1 neutral gauge boson
- Sequential SM (Benchmark): additional heavy boson with same couplings as SM Z
- Predicted by GUT models based on the E_6 gauge group

$$E_6 \rightarrow SO(10)\times U(1)_\psi \rightarrow SU(5)\times U(1)_\chi \times U(1)_\psi$$

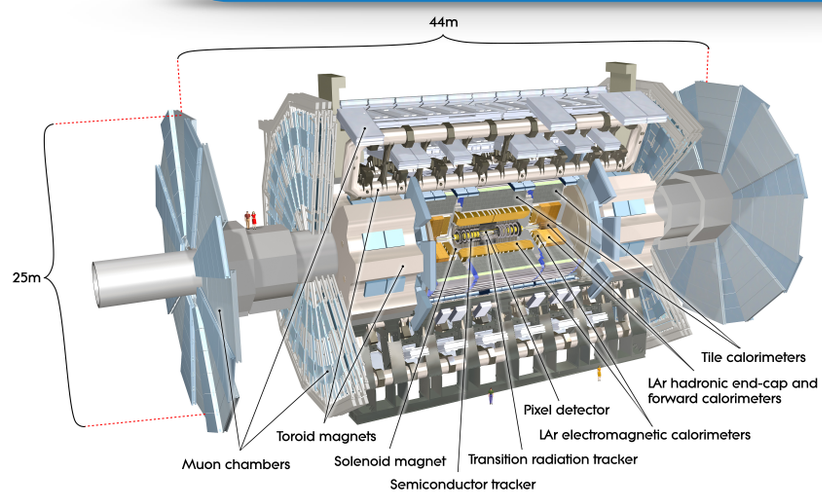
- Two additional U(1) gauge fields

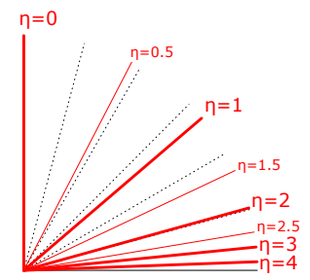
$$Z'(\theta_{E_6}) = Z'_\psi\cos\theta_{E_6} + Z'_\chi\sin\theta_{E_6}$$

- Observable as **narrow resonances** in dimuon invariant mass spectrum



The ATLAS Detector

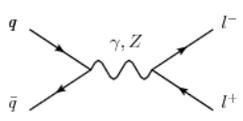




- **Muon Spectrometer (MS):**
  - Barrel region: |η| < 1.1
  - Endcap region: 1.1 < |η| < 2.7.
  - Toroidal magnetic field allows for transverse momentum (p_T) measurements by measuring the curvature of the muon tracks
  - p_T resolution up to 10% for muons with p_T ~ 1TeV
- **Inner Detector (ID):**
  - Contained in a 2T magnetic field
  - Used for the tracking of charged particles
  - ID track combined with MS track to form "combined" muon

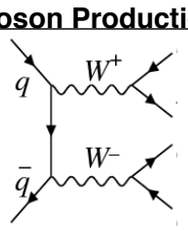
Backgrounds

Drell-Yan Production



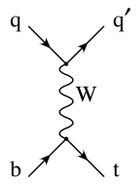
Generator	Powheg v2
Order	NLO
Shower	Pythia 8.186
PDF	CT10
Samples	Mass-Binned

Diboson Production

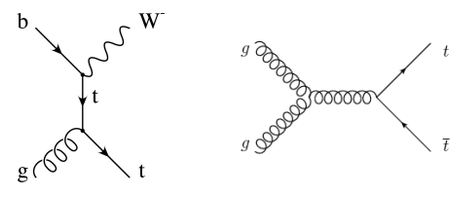


Generator	Sherpa 2.1.1
Order	NLO
Shower	Sherpa 2.1.1
PDF	CT10
Samples	Mass-Binned

Top Production



Generator	Powheg v2
Order	NLO
Shower	Pythia 6.428
PDF	CT10
Samples	Unbinned



* Fake muon background is negligible

Event Selection

Event Level Criteria

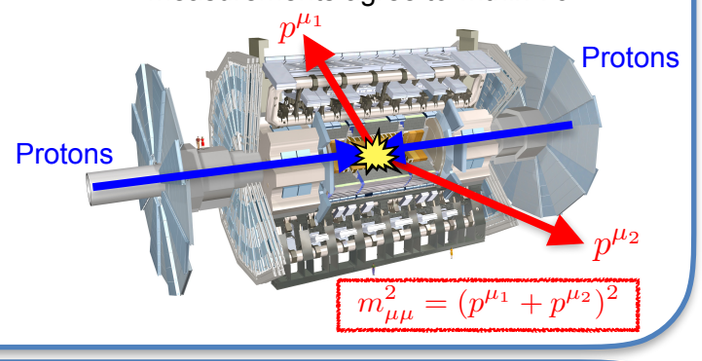
- Good Run List (GRL)
- Single-muon trigger: 1 isolated μ with p_T > 26 GeV OR 1 μ with p_T > 50 GeV
- At least 2 combined muons
- Require Opposite Charge
- Select highest p_T pair: $m_{\mu\mu}$ > 80 GeV

Muon Selection

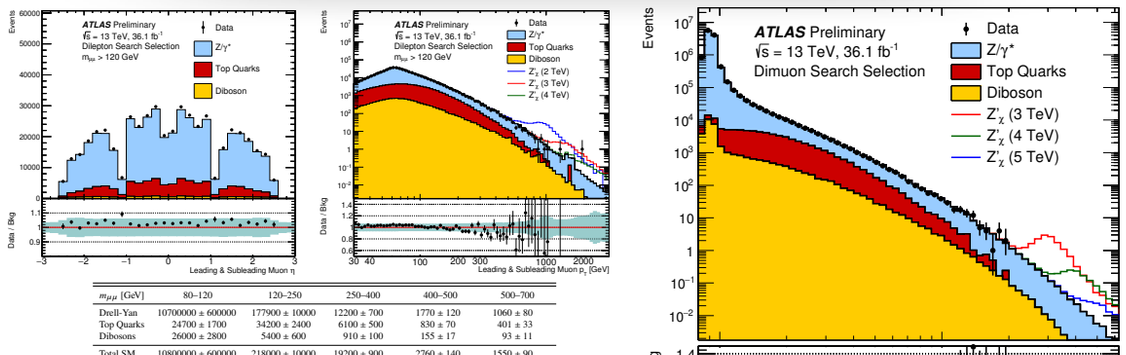
- Muon p_T > 30 GeV
- High-p_T Muon Working Point
- Bad Muon Veto
- Track quality requirements:
  - d_0 significance < 3
  - $|z_0 * \sin\theta|$ < 0.5 mm
- Loose isolation on tracks

High-p_T Muon Working Point

- Require combined muons
- Require **3 separate muon stations** to have hits for a given muon (3 stations in the MS)
- **Remove** muon chambers with **poor alignment**; apply chamber vetoes based on η-φ track coordinates
- Require that the **track curvature be well measured**; ensure that the muon's ID and extrapolated MS momentum measurements agree to within 7σ



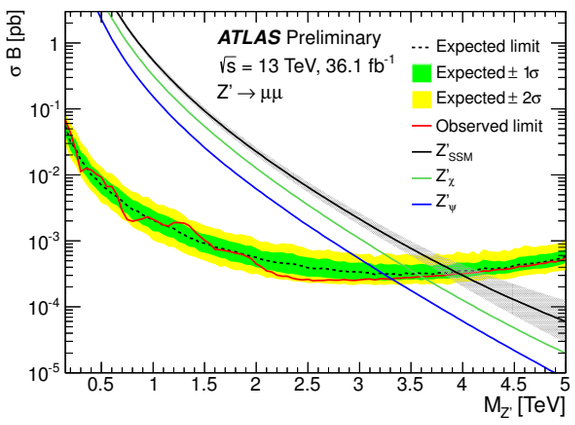
Data/MC Comparisons

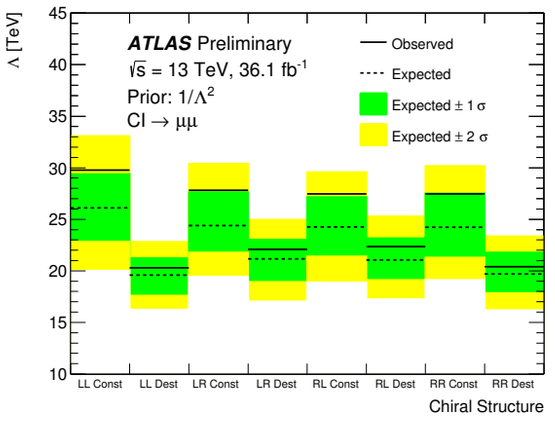


$m_{\mu\mu}$ [GeV]	80–120	120–250	250–400	400–500	500–700
Drell-Yan	10700000 ± 600000	177900 ± 10000	12200 ± 700	1770 ± 120	1060 ± 80
Top Quarks	24700 ± 1700	34200 ± 2400	6100 ± 500	830 ± 70	401 ± 33
Dibosons	26000 ± 2800	5400 ± 600	910 ± 100	155 ± 17	93 ± 11
Total SM	10800000 ± 600000	218000 ± 10000	19200 ± 900	2760 ± 140	1550 ± 90
Data	11321561	224703	19239	2766	1532
Z'_χ (4 TeV)	0.00873 ± 0.00032	0.0334 ± 0.0015	0.0441 ± 0.0021	0.0246 ± 0.0014	0.052 ± 0.004
Z'_χ (5 TeV)	0.00347 ± 0.00014	0.0137 ± 0.0006	0.0151 ± 0.0007	0.0105 ± 0.0006	0.0176 ± 0.0012
$m_{\mu\mu}$ [GeV]	700–900	900–1200	1200–1800	1800–3000	3000–6000
Drell-Yan	263 ± 23	110 ± 11	37 ± 4	5.4 ± 0.8	0.30 ± 0.07
Top Quarks	68 ± 6	24.5 ± 3.0	5.3 ± 0.9	0.11 ± 0.08	< 0.001
Dibosons	24.3 ± 2.9	9.8 ± 1.2	3.2 ± 0.4	0.45 ± 0.07	0.0184 ± 0.0035
Total SM	355 ± 24	144 ± 11	45 ± 4	6.0 ± 0.8	0.32 ± 0.07
Data	322	141	48	4	0
Z'_χ (4 TeV)	0.0362 ± 0.0026	0.048 ± 0.004	0.067 ± 0.006	0.186 ± 0.022	1.24 ± 0.19
Z'_χ (5 TeV)	0.0153 ± 0.0011	0.0185 ± 0.0015	0.0233 ± 0.0021	0.0258 ± 0.0029	0.118 ± 0.020

Exclusion Limits

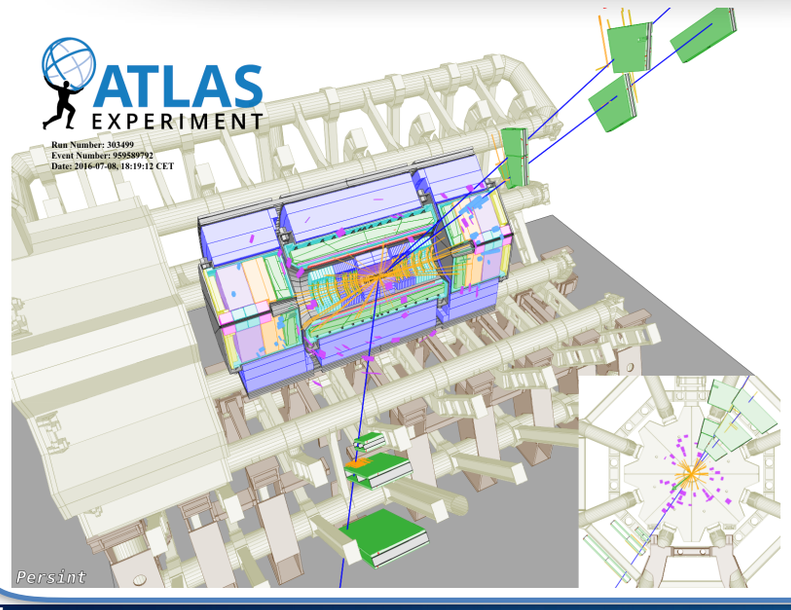
- No significant deviation from the Standard Model prediction was observed, so various theoretical models are constrained by setting limits on their parameters, e.g. the Z' boson masses or the contact interaction binding energy scale Λ





Model	Width [%]	θ_{E_6} [Rad]	Lower limits on $m_{Z'}$ [TeV]					
			ee		$\mu\mu$		$\ell\ell$	
			Obs	Exp	Obs	Exp	Obs	Exp
Z'_{SSM}	3.0	-	4.3	4.3	4.0	3.9	4.5	4.5
Z'_χ	1.2	0.50 π	3.9	3.9	3.6	3.6	4.1	4.0
Z'_S	1.2	0.63 π	3.9	3.8	3.6	3.5	4.0	4.0
Z'_I	1.1	0.71 π	3.8	3.8	3.5	3.4	4.0	3.9
Z'_η	0.6	0.21 π	3.7	3.7	3.4	3.3	3.9	3.8
Z'_N	0.6	-0.08 π	3.6	3.6	3.4	3.3	3.8	3.8
Z'_ψ	0.5	0 π	3.6	3.6	3.3	3.2	3.8	3.7

Highest $m_{\mu\mu}$ Event (1.99 TeV)



Leading μ (p_T, η, φ): (637 GeV, -0.43, -2.16)

Subleading μ (p_T, η, φ): (546 GeV, 1.81, 0.90)

Missing E_T: 109 GeV

Reference: ATLAS-CONF-2017-027

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