

SEARCH FOR HIGH-MASS DIMUON RESONANCES USING PROTON-PROTON COLLISIONS AT $\sqrt{s} = 13$ TEV WITH THE ATLAS DETECTOR

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Motivation

Z Prime (Z')

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

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

- Two additional $U(1)$ gauge fields

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

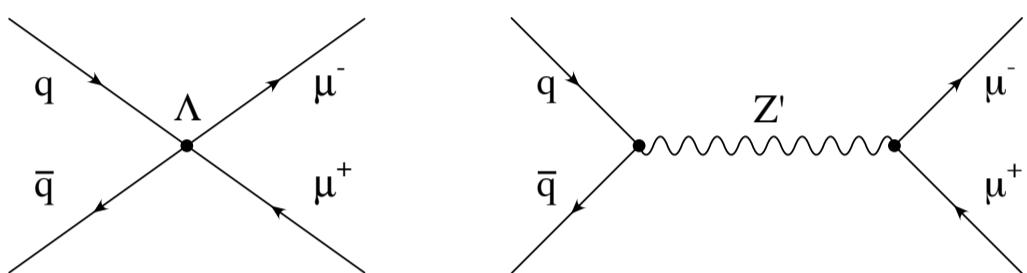
- Observable as **broad excess** in dilepton invariant mass spectrum

Contact Interactions (CI)

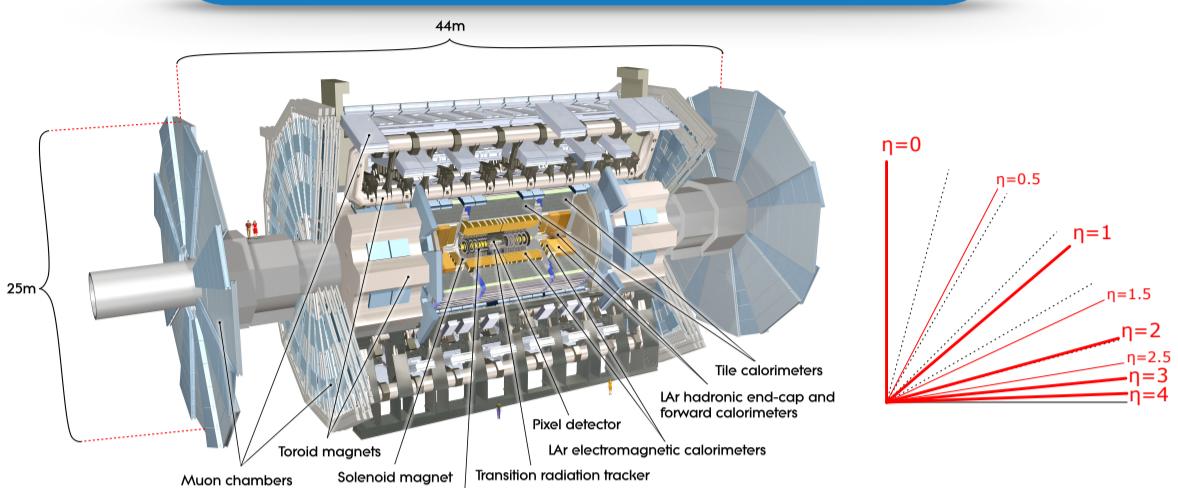
- Probes quark and lepton compositeness, with binding energy scale Λ

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

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



The ATLAS Detector



Muon Spectrometer (MS):

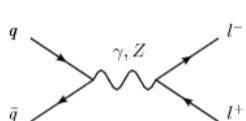
- Barrel region: $|\eta| < 1.1$
- Endcap region: $1.1 < |\eta| < 2.7$.
- Toroidal magnetic field allows for transverse momentum (p_T) measurements by measuring the curvature of the muon tracks
- p_T resolution up to 10% for muons with $p_T \sim 1$ TeV

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



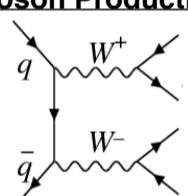
Generator: Powheg Box

Order: NLO & NNLO

Shower: Pythia 8.186

PDF: CT10

Diboson Production



Generator: Sherpa 2.1.1

Order: NLO

Shower: Sherpa 2.1.1

PDF: CT10

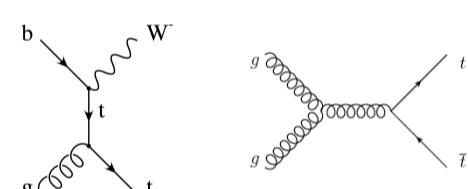
Top Production

Generator: Powheg Box

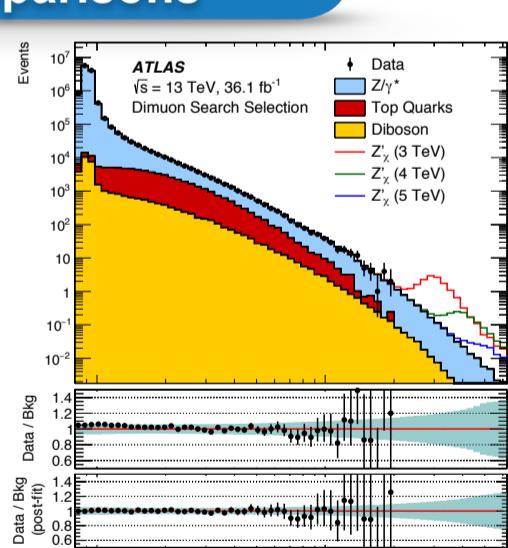
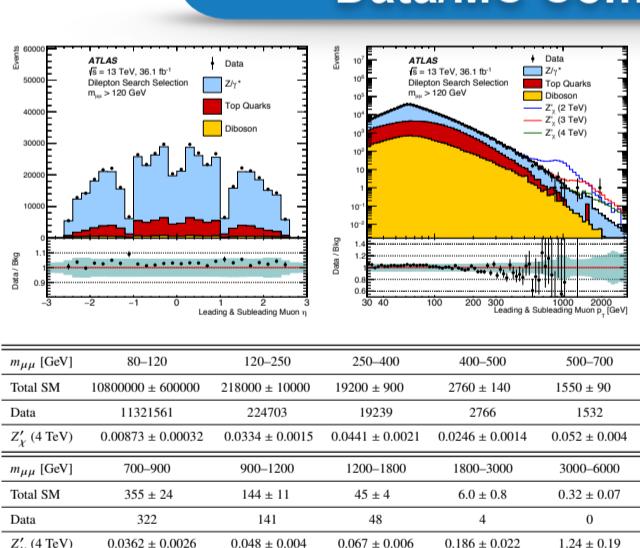
Order: NLO & NNLO

Shower: Pythia 6.428

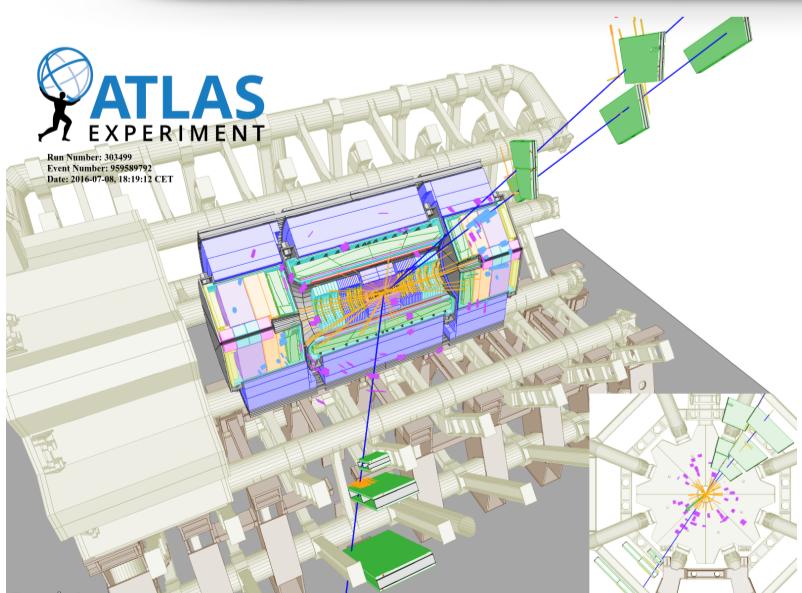
PDF: CT10



Data/MC Comparisons



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:
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Event Selection

Event Level Criteria

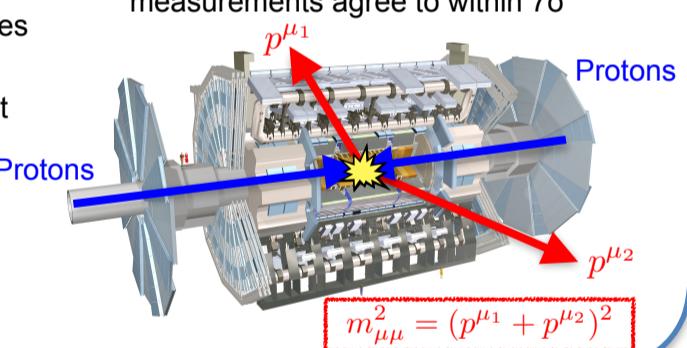
- Good Run List (GRL)
- Single-muon trigger: 1 isolated μ with $p_T > 26$ GeV OR 1 μ with $p_T > 50$ GeV
- At least 2 combined muons
- Require Opposite Charge
- Select highest p_T pair: $m_{\mu\mu} > 80$ GeV

Muon Selection

- Muon $p_T > 30$ GeV
- High- p_T muon working point improves momentum resolution at high p_T
- Require track origin to be consistent with primary vertex:
 - d_0 significance < 3
 - $|z_0 * \sin\theta| < 0.5$ mm
- Loose isolation on tracks

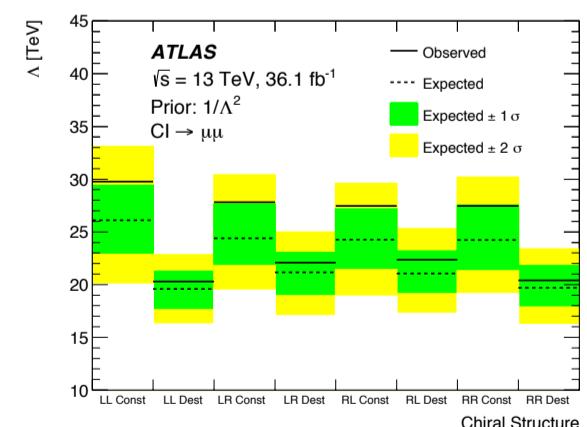
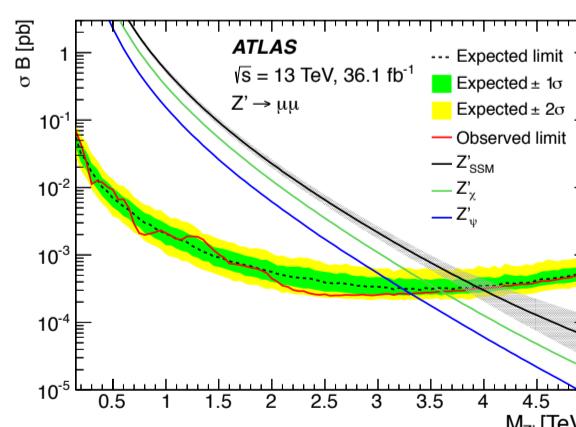
High- p_T Muon Working Point

- 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



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	Obs	Exp	Obs
Z'_{SSM}	3.0	-	4.3	4.3	4.0	3.9	4.5	4.5
Z'_χ	1.2	0.50π	3.9	3.9	3.6	3.6	4.1	4.0
Z'_S	1.2	0.63π	3.9	3.8	3.6	3.5	4.0	4.0
Z'_I	1.1	0.71π	3.8	3.8	3.5	3.4	4.0	3.9
Z'_η	0.6	0.21π	3.7	3.7	3.4	3.3	3.9	3.8
Z'_N	0.6	-0.08π	3.6	3.6	3.4	3.3	3.8	3.8
Z'_ψ	0.5	0π	3.6	3.6	3.3	3.2	3.8	3.7