Latest search for dilepton resonances and new constraints on Dark Matter mediators[1]

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Motivation

$$\underbrace{SU(3)_c \times SU(2)_L \times U(1)_Y}_{\text{SM}} \times \overbrace{\cdots \times U(1)_X}^{\text{BSM}}$$

- **Superstring-inspired E6 GUT**

$$E_6 \rightarrow \underbrace{SO(10)}_{} \times U(1)_\psi \quad \rightarrow Z'_\psi$$

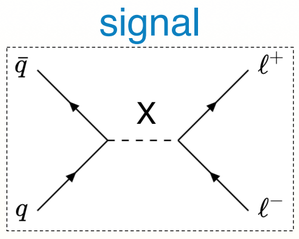
$$SO(10) \rightarrow SU(5) \times U(1)_\chi \quad \rightarrow Z'_\chi$$

- **Dark Matter mediator (vector or axial-vector)** $\rightarrow Z'_{A/V}$

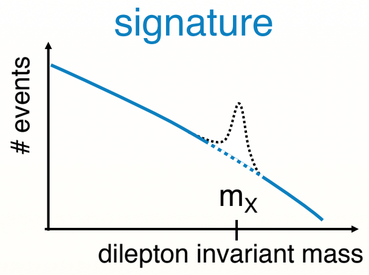
$$\mathscr{L}_V \supset \frac{1}{2} m_{Z'}^2 V_\mu V^\mu - g_q^{ij} V_\mu \bar{q}_i \gamma^\mu q_j - g_\ell^{ij} V_\mu \bar{\ell}_i \gamma^\mu \ell_j - g_\chi V_\mu \bar{\chi} \gamma^\mu \chi$$

- **Spin ≠ 1 models (signal efficiency within 4%)**
  - **spin-0**: MSSM extended scalar sector
  - **spin-2**: Excitations of Randall-Sundrum graviton

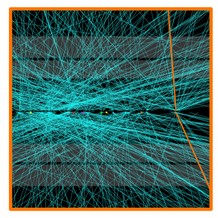
signal



signature

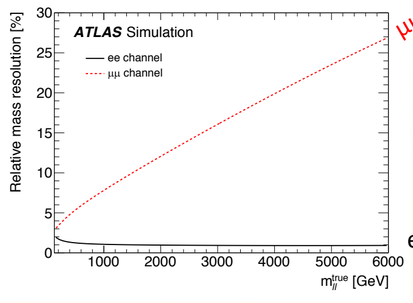


pileup



~ 34 interactions per crossing

mass resolution

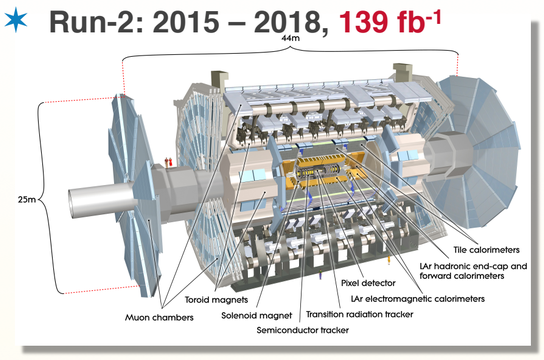


μμ channel

ee channel

Detector

- **L1+L2 triggers: ~1 MHz ⇒ 1 kHz**
- **B-field: 2T (solenoid), 4T (toroid)**
- **Run-2: 2015 – 2018, 139 fb^{-1}**



Background model

ee spectrum

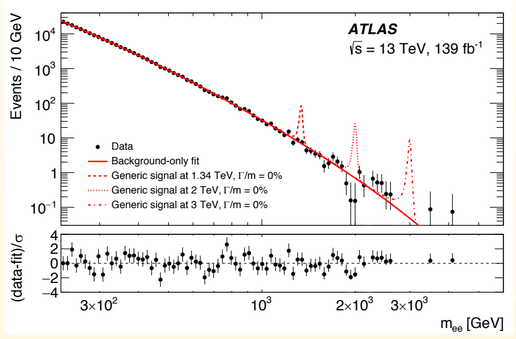
Trig: lowest-E_T unprescaled 2e

ID: "medium"

Iso: "gradient"

Extra: exclude barrel-endcap transition ($1.37 < \eta < 1.52$)

Efficiency: 62% – 74%



μμ spectrum

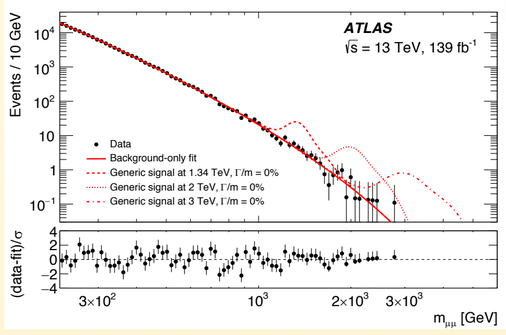
Trig: lowest-p_T unprescaled 1μ

ID: "high-p_T" + "good muon"

Iso: "fixed cut tight track only"

Extra: require opposite charge

Efficiency: 53% – 38%



- **Background modeled by functional fit to data:**

$$f_{\ell\ell}(m_{\ell\ell}) = f_{\mathrm{BW},Z}(m_{\ell\ell}) \cdot (1 - x^c)^b \cdot x^{\sum_{i=0}^{3} p_i \log(x)^i}$$

$$x = \frac{m_{\ell\ell}}{\sqrt{s}}$$

- Avoid effect of limited MC statistics, PDF uncertainties at high p_T
- Validated on smooth MC estimate
- *Spurious signal* uncertainty accounts for potential mismodeling

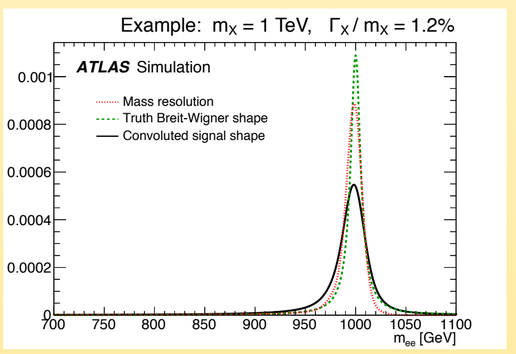
Signal model

- **Continuous function of mass, width**

Generic signal = Breit-Wigner ⊗ mass resolution

- **Cross section defined within fiducial cuts:**

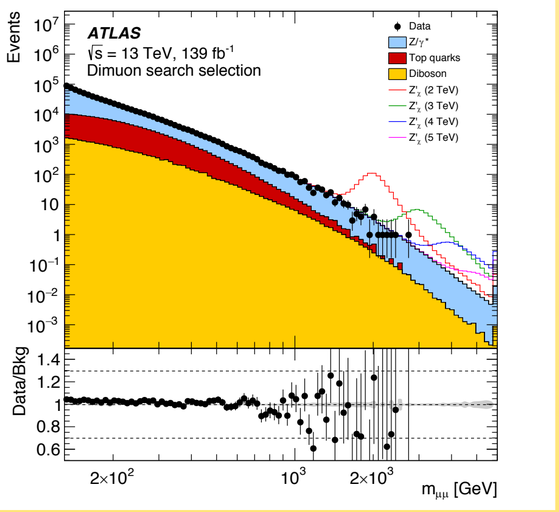
$$p_T^{\mathrm{lead}}, p_T^{\mathrm{sublead}} > 30\ \mathrm{GeV}$$
$$\left|\eta^{\mathrm{lead}}\right|, \left|\eta^{\mathrm{sublead}}\right| < 2.5$$
$$m_{\ell\ell} > m_X - 2\Gamma$$



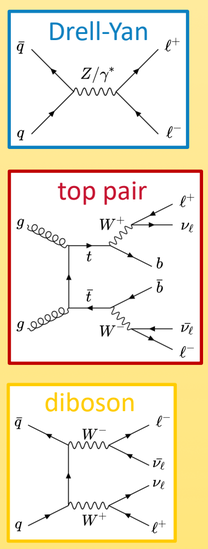
- Removes model-dependent PDF tail, interference effects

Data composition

μμ spectrum with MC

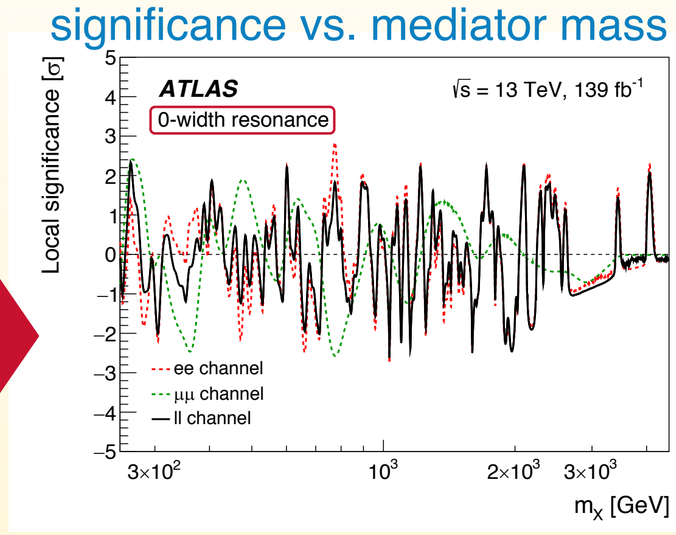


data = Drell-Yan + top pair + diboson (+ signal?)



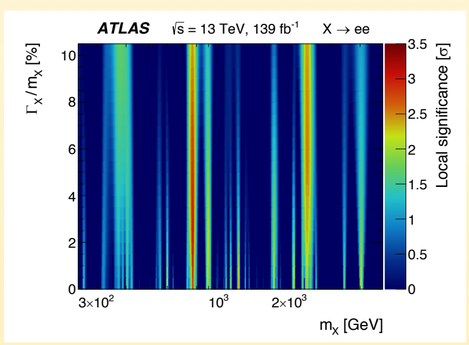
Search

significance vs. mediator mass

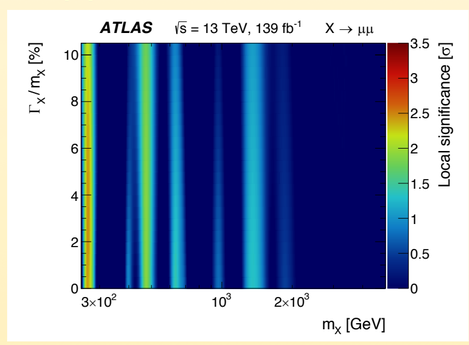


- **LLR test statistic:** $z_0^2 = q_0 = \ln\left[\frac{\mathcal{L}(\mathrm{data}|H_{\mathrm{bkg+sig}})}{\mathcal{L}(\mathrm{data}|H_{\mathrm{bkg}})}\right]^2$
  - Discriminate between null, alternate hypotheses (asymptotic approximation)

ee mass-width scan



μμ mass-width scan



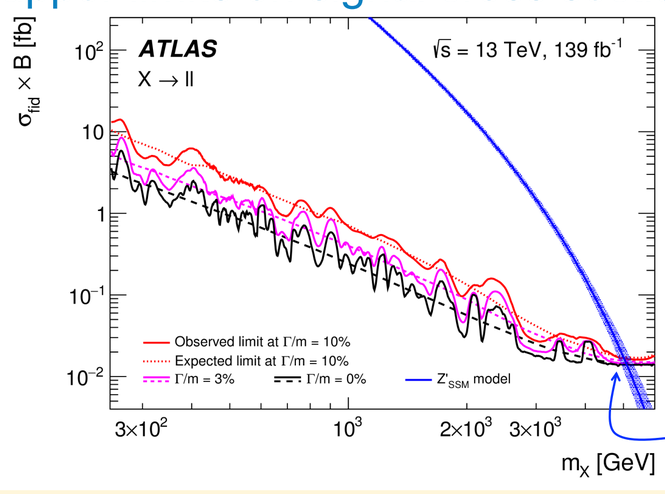
largest deviations

- Local significance (ignoring trials factor)

Channel	Excess			Deficit		
	p_0 [σ]	m_X [GeV]	Γ_X/m_X [%]	p_0 [σ]	m_X [GeV]	Γ_X/m_X [%]
ee	3.0	773	2.5	−3.2	1957	4.0
$\mu\mu$	2.5	268	2.5	−2.8	349	8.5
$\ell\ell$	2.3	264	0	−2.9	1958	3.0

Cross section limits

upper limits on signal cross section



SSM mass limit (Γ /M = 3%)

- **narrow, medium , and wide resonances shapes**

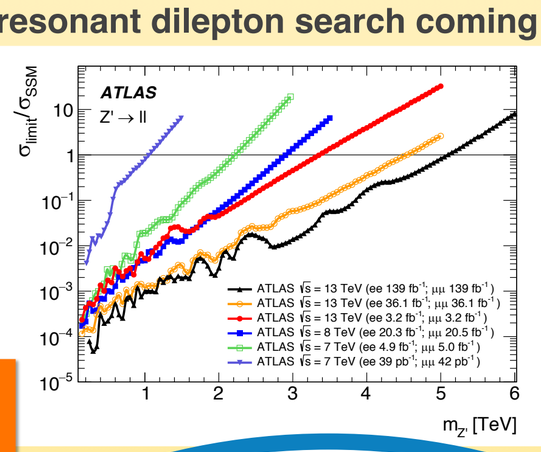
benchmark mass limits

Model	Lower limits on $m_{Z'}$ [TeV]					
	ee		$\mu\mu$		$\ell\ell$	
	obs	exp	obs	exp	obs	exp
Z'_ψ	4.1	4.3	4.0	4.0	4.5	4.5
Z'_χ	4.6	4.6	4.2	4.2	4.8	4.8
Z'_{SSM}	4.9	4.9	4.5	4.5	5.1	5.1

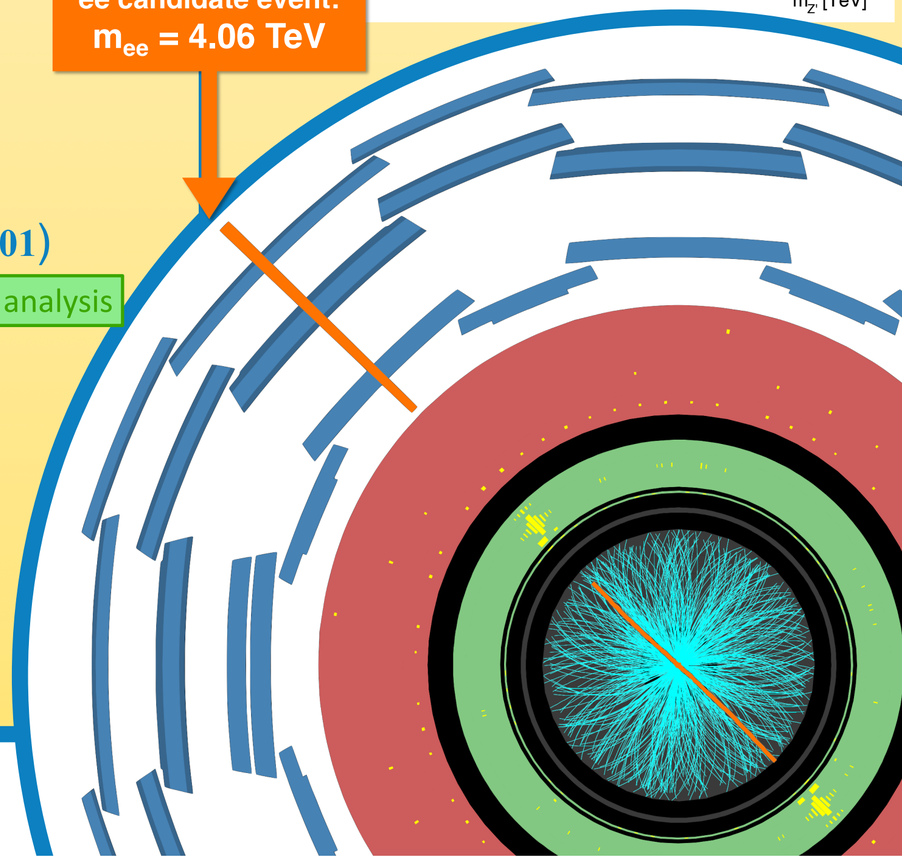
Take-home

- **No significant deviation from SM**
  - Final word from Run-2!
- **Limits set on generic signal x-section**
  - They can be easily reinterpreted via HEPData!
  - Applied to set new constraints on DM mediators
- **Non-resonant dilepton search coming**

historical reach

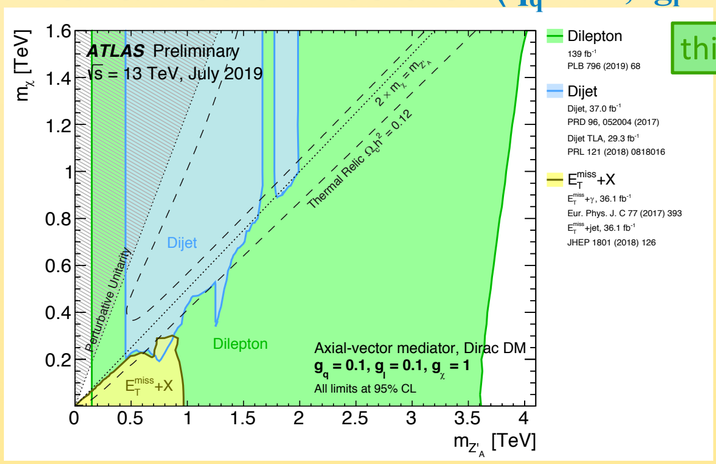


Highest mass ee candidate event: m_{ee} = 4.06 TeV



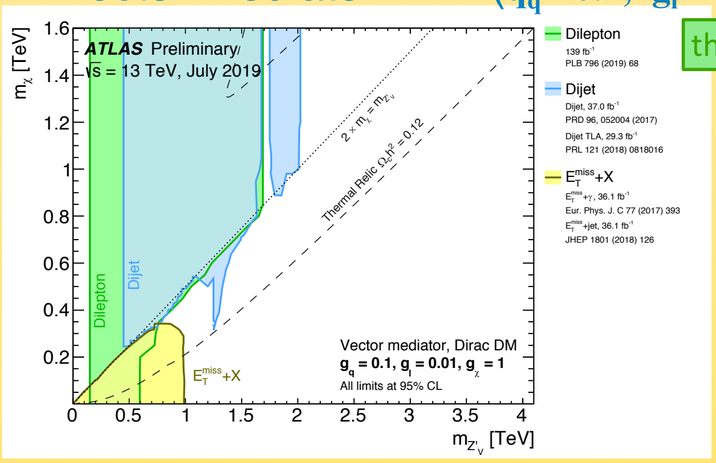
Constraints on DM mediators

axial-vector mediator ($q_q = 0.1$, $g_l = 0.1$)



this analysis

vector mediator ($q_q = 0.1$, $g_l = 0.01$)



this analysis

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