Search for scalar dark energy in ATLAS

-- JC100

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Introduction

- Accelerated expansion of universe continues one of the biggest mysteries in cosmology and particle physics
- First evidence from High-Z Supernova Search and Supernova Cosmology Project
- Dark Energy (DE) as a new type of matter was added to explain the repulsive force in the context of general relativity.
- Corroborated by cosmic microwave background and large scale structure of the universe.

Models to describe Dark Energy

- Modifications of general relativity
- Addition of new particles beyond the SM
- Models with extra fields can have the same phenomenology as modified gravity models.
- Cosmological observations alone not able to distinguish the two scenarios
- Input from particle physics experiments is important for elucidating the microscopic nature of DE

Indirect and direct detection of DE

- Search for additional gravitational forces ("fifth forces") : deviation from $1/r^2$ law.
- Search for photons produced by the interaction of DE with intense magnetic fields.
- Direct detection of DE at colliders relies on the assumption of a non-zero coupling between the DE and SM fields.
- Essential ingredient for the screening of fifth forces mediated by scalar DE fields.

Direct DE production at collider

- Manifest itself in high energy particle collisions through:
  - Modifications of electroweak precision observables induced by virtual DE particles

    => found to yield very weak constraints on DE models
  - Through the **direct production** of DE particles.
- Direct DE production as an effective way of detecting or constraining DE models
  - Enhanced in final states with heavy quarks or high momentum transfers
  - Certain types of couplings (disformal) of DE to SM matter cannot be constrained by local tests of gravity since they do not generate fifth forces

Effective field theory for scaler DE

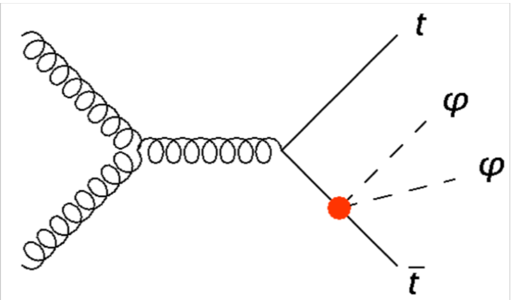
$$\mathcal{L} = \mathcal{L}_{\rm SM} + \sum_{i=1}^{9} c_i \mathcal{L}_i = \mathcal{L}_{\rm SM} + \sum_{i=1}^{9} \frac{c_i}{M_i^{(d-4)}} O_i^{(d)},$$

Leading terms:

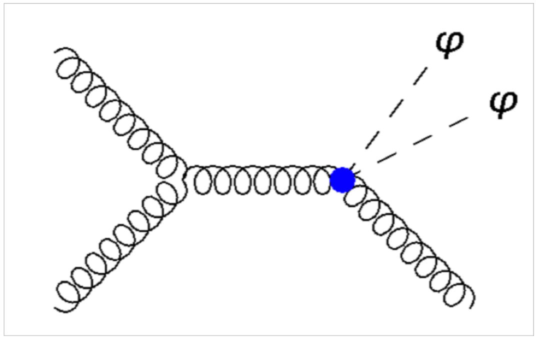
$$\mathcal{L}_1 = \frac{\partial_\mu \phi \partial^\mu \phi}{M_1^4} T^\nu_\nu$$

$$\mathcal{L}_2 = \frac{\partial_\mu \phi \partial_\nu \phi}{M_2^4} T^{\mu\nu}$$

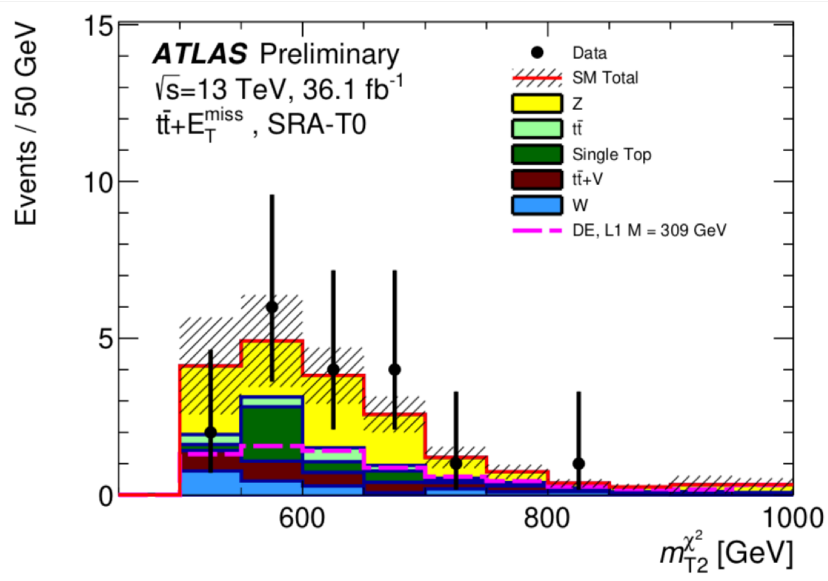
Kinetically dependent conformal

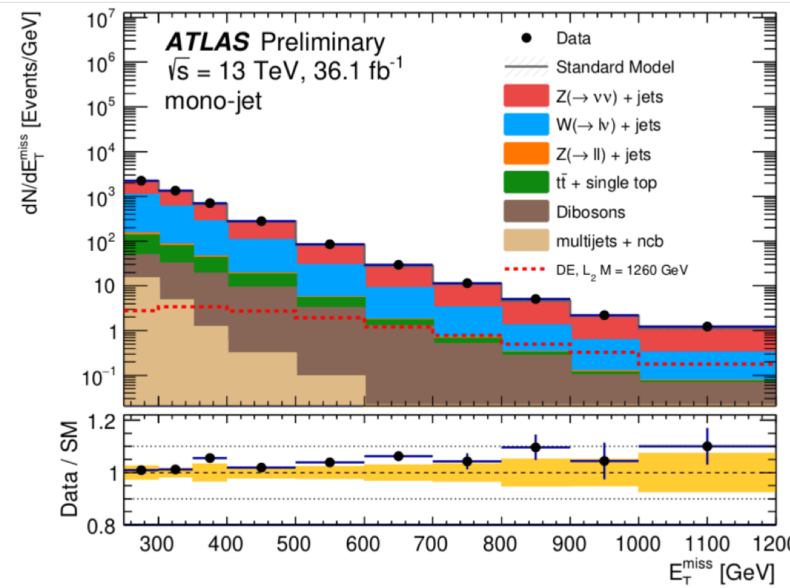


disformal



Results





Channel	Operator	Lower limits on M [GeV]					
		Observed	Expected	$+2\sigma$	$+1\sigma$	-1σ	-2σ
$t\bar{t} + E_{\mathrm{T}}^{\mathrm{miss}}$	$\mathcal{L}_1$	309^{+19}_{-24}	313	284	299	326	338
Mono-jet	$\mathcal{L}_2$	1260^{+50}_{-60}	1350	1200	1280	1400	1450

Exclusion plots

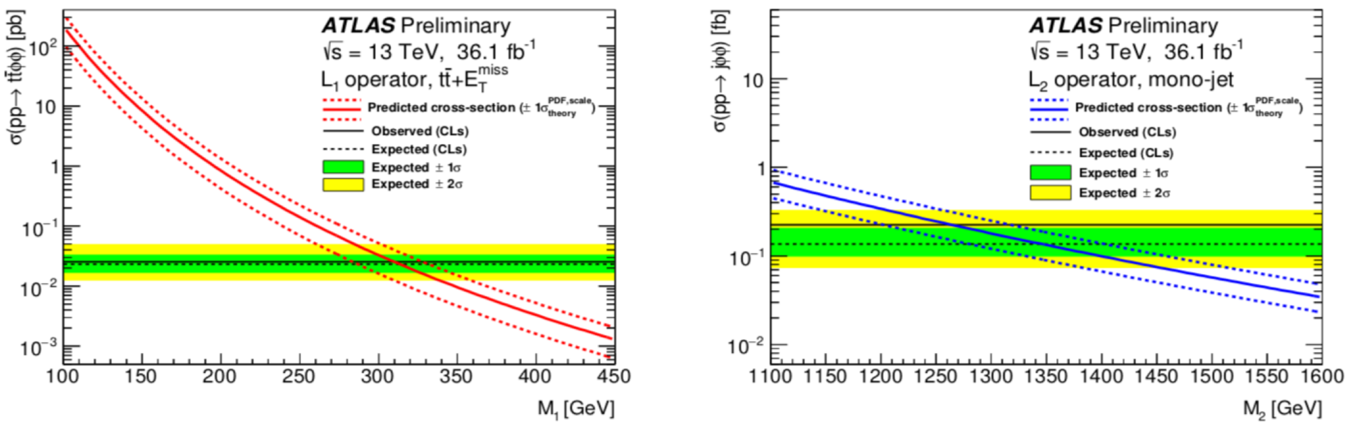


Figure 4: Exclusion plots for $\mathcal{L}_1$ (left) and $\mathcal{L}_2$ (right) from the $t\bar{t}+E_{\mathrm{T}}^{\mathrm{miss}}$ and mono-jet channels respectively, without taking into account the EFT validity criterion. The errors on the predicted cross-sections correspond to the scale and PDF uncertainties.

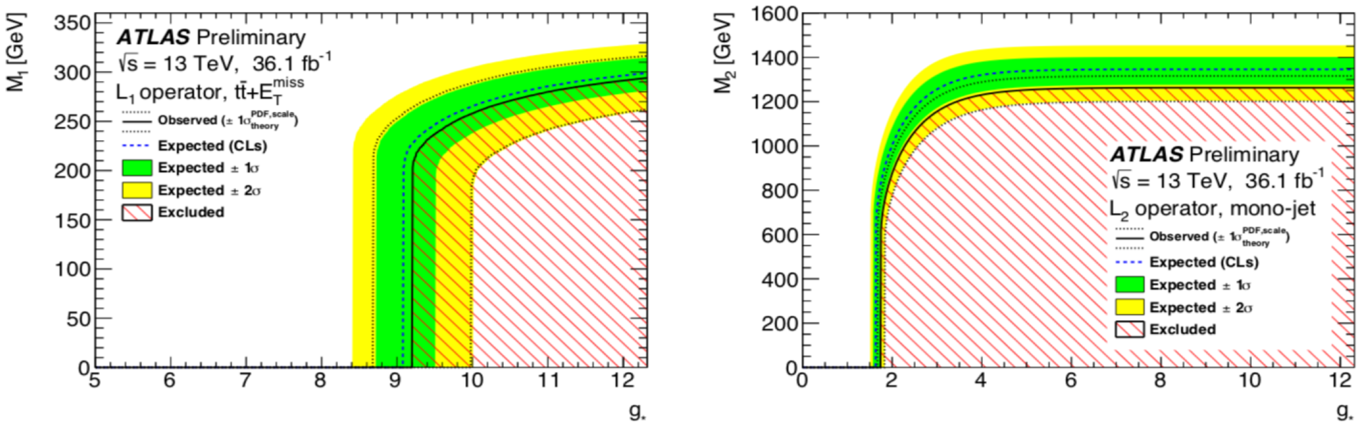


Figure 5: Exclusion plots for $\mathcal{L}_1$ (left) and $\mathcal{L}_2$ (right) on the $\{g_*, M\}$ plane, after rescaling to take into account the EFT validity criterion.

Questions

Shan

- "What's the commonly used methods for searching for the dark energy?"

Yuhang

- In table.3, how to get the value of +1σ,-1σ?

Channel	Operator	Lower limits on M [GeV]					
		Observed	Expected	$+2\sigma$	$+1\sigma$	-1σ	-2σ
$t\bar{t} + E_{\mathrm{T}}^{\mathrm{miss}}$	$\mathcal{L}_1$	309^{+19}_{-24}	313	284	299	326	338
Mono-jet	$\mathcal{L}_2$	1260^{+50}_{-60}	1350	1200	1280	1400	1450

Table 3: Lower limits on the suppression scale M (in GeV) for the $\mathcal{L}_1$ operator from the 0-lepton $t\bar{t} + E_{\mathrm{T}}^{\mathrm{miss}}$ search and for the $\mathcal{L}_2$ operator from the mono-jet search. The errors on the observed limit correspond to the uncertainty on the signal production cross-section. The limits quoted here are not rescaled to take into account the EFT validity criterion.

Kai

The dark energy effect is observed at very large scale on the galaxies very far away, i,e, the galaxies are getting further with accelerated speed.

But is there any evidence observed that our milk way galaxy, or even our solar system being expanded by dark energy?

The motivation of this question is: If only the distances between galaxies are expanding, but galaxies themselves are not expanded at all, the density of dark energy in solar system/our Galaxy may be very very small. And considering that the amount of particles with similar or even higher energy in the sun/ center of the Galaxy is far more than that produced in collider, I personally doubt the worth of searching dark matter in collider.

Ryuta

- Are there any indications on fifth force, or more specificly, on quintessence ?

Suyu

- How could dark energy be produced in collider? We use conservation of energy to constrain target particle.