LABORATÓRIO DE INSTRUMENTAÇÃO E FÍSICA EXPERIMENTAL DE PARTÍCULAS
partículas e tecnologia

Little Higgs Models Phenomenology

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Introduction and motivation – hierarchy problem

Electroweak hierarchy problem: quadratic sensitivity of Higgs boson to larger scales

- **Fermions**:
  when m→ 0, recover chiral symmetry.
- **Gauge bosons**:
  when m→ 0, recover gauge symmetry.

Contributions to their mass are proportional to the mass itself

Introduction and motivation – hierarchy problem

Electroweak hierarchy problem: quadratic sensitivity of Higgs boson to larger scales

- **Higgs boson:**
  no symmetry is recovered when m→ 0.

Contributions to its mass are quadratically proportional arbitrarily large scales

Introduction and motivation – hierarchy problem

- **SUSY:** introduce symmetry that ties fermions to bosons
  - Protection to fermions is extended to bosons.
- **Composite Higgs models (CHM)**: Higgs is a bound state and not sensitive to effects above compositeness scale.

↓

We will focus on Little Higgs models

Higgs as a pseudo-Goldstone boson

Goldstone theorem: NGB's arise when a continuous symmetry is spontaneously broken

NGB's *shift* under the broken symmetry:

$$\theta \to \theta + \alpha$$

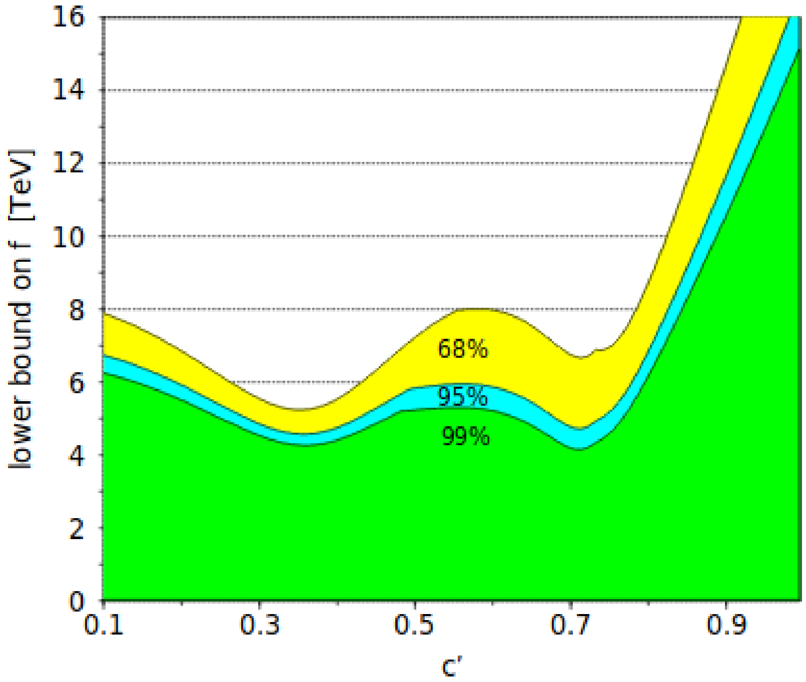
We need to explicitly break the symmetry

Littlest Higgs model:

$$\mathbf{SU(5)} \to \mathbf{SO(5)}$$

Unbroken	**Broken**	
$Q_1^a + Q_2^a$	$Q_1^a - Q_2^a$	$[SU(2) \times U(1)]^2 \to SU(2) \times U(1)$
$Y_1 + Y_2$	$Y_1 - Y_2$	
$SU(2)_W$ $U(1)_Y$	**Heavy gauge bosons**	**4 eaten goldstones**

Littlest Higgs model - constraints



Taken from: *hep-ph/0211124v2*

Scale of new physics severely constrained by EWPO

Littlest Higgs with T-parity – gauge sector

$$G_1 \overset{\mathrm{T}}{\longleftrightarrow} G_2 \qquad g_1 = g_2, g_1^{'} = g_2^{'}$$

T-even

$$W^{\pm} = \frac{1}{2}\left[\left(W_1^1 + W_2^1\right) \mp i\left(W_1^2 + W_2^2\right)\right], \quad W^3 = \frac{W_1^3 + W_2^3}{\sqrt{2}}, \quad B = \frac{B_1 + B_2}{\sqrt{2}}$$

T-odd

$$W_H^{\pm} = \frac{1}{2}\left[\left(W_1^1 - W_2^1\right) \mp i\left(W_1^2 - W_2^2\right)\right], \quad W_H^3 = \frac{W_1^3 - W_2^3}{\sqrt{2}}, \quad B_H = \frac{B_1 - B_2}{\sqrt{2}}$$

$$A, Z, Z_H, A_H$$

Littlest Higgs with T-parity – fermionic sector

To construct a T-parity preserving fermionic sector we need to double the fermionic content

$$\Psi_1 = \begin{pmatrix} -i\sigma^2 l_{1L} \\ 0 \\ 0 \end{pmatrix} \qquad \Psi_2 = \begin{pmatrix} 0 \\ 0 \\ -i\sigma^2 l_{2L} \end{pmatrix}$$

$$l_L = \frac{l_{1L} - l_{2L}}{2} \qquad l_{HL} = \frac{l_{1L} + l_{2L}}{2}$$

Looking for vector like leptons
– SM or MET

SM decays

- 50% $W\nu$
- 25% $Z\ell$
- 25% $H\ell$

Decay to missing energy

- Littlest Higgs with T-parity
- Recast of slepton searches

$$BR(E \to A_H \ell)$$

0% ⟷ 100%

Looking for vector like leptons – SM or MET

SM decays

Search for heavy lepton resonances decaying to a Z boson and a lepton in pp collisions at $\sqrt{s}$ = 8 TeV with the ATLAS detector

The ATLAS Collaboration

1506.01291

Decay to missing energy

Search for electroweak production of supersymmetric particles in final states with two or three leptons at $\sqrt{s} = 13$ TeV with the ATLAS detector

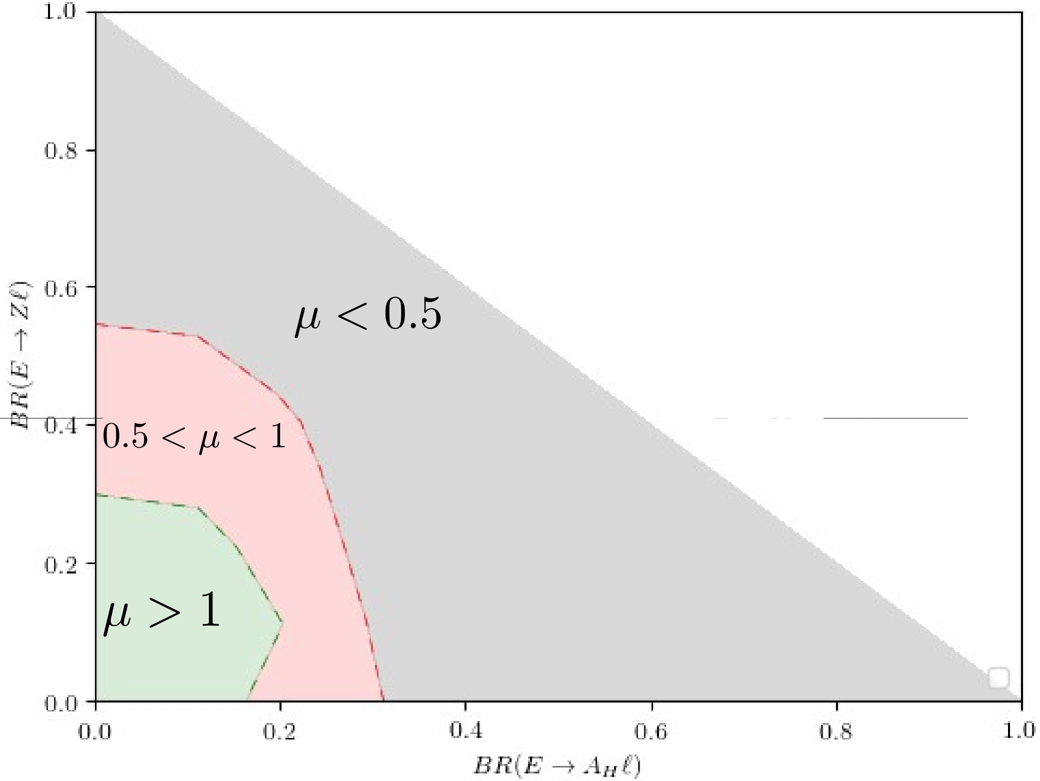
ATLAS Collaboration*

1803.02762

$$BR(E \to A_H \ell)$$

0% ⟵⟶ 100%

| Looking for vector like leptons – SM and MET



$$M_E = 400 \text{ GeV}$$

$$M_{A_H} = 98 \text{ GeV}$$

$$\sqrt{s} = 13 \text{ TeV}$$

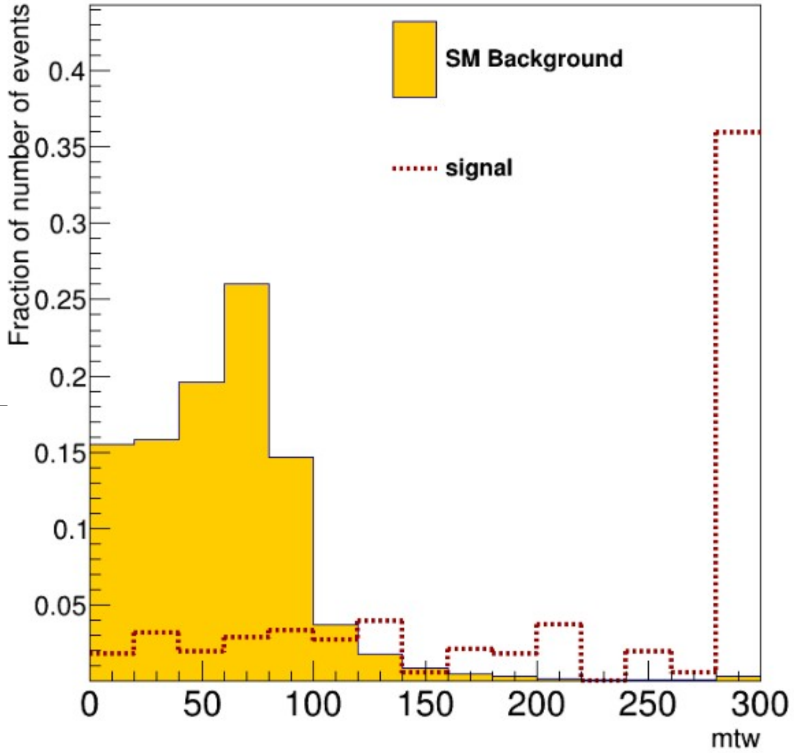
Looking for vector like leptons
– improving the analysis

Main background:

$$WZ \to \nu\ell\ell\ell$$

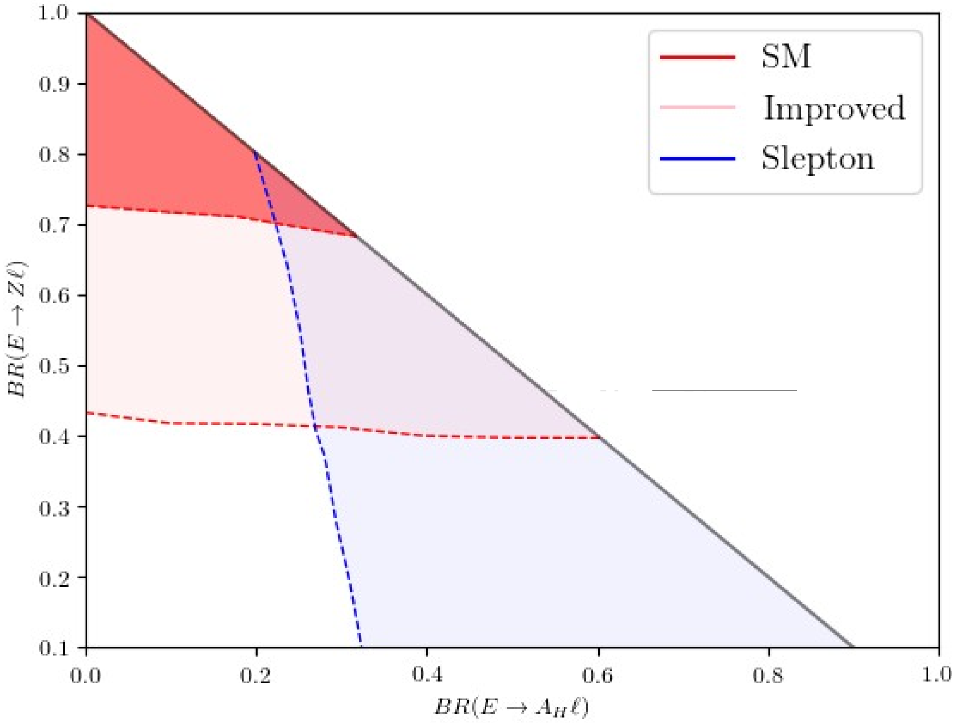
New cut:

$$m_{TW}^2 = 2(\not{E}_T p_{T_\ell} - \not{E}_x p_{x_\ell} - \not{E}_y p_{y_\ell})$$



Looking for vector like leptons
– improving the analysis

w/ new analysis



$$M_E = 500 \text{ GeV}$$

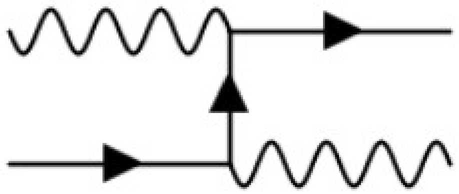
$$M_{A_H} = 98 \text{ GeV}$$

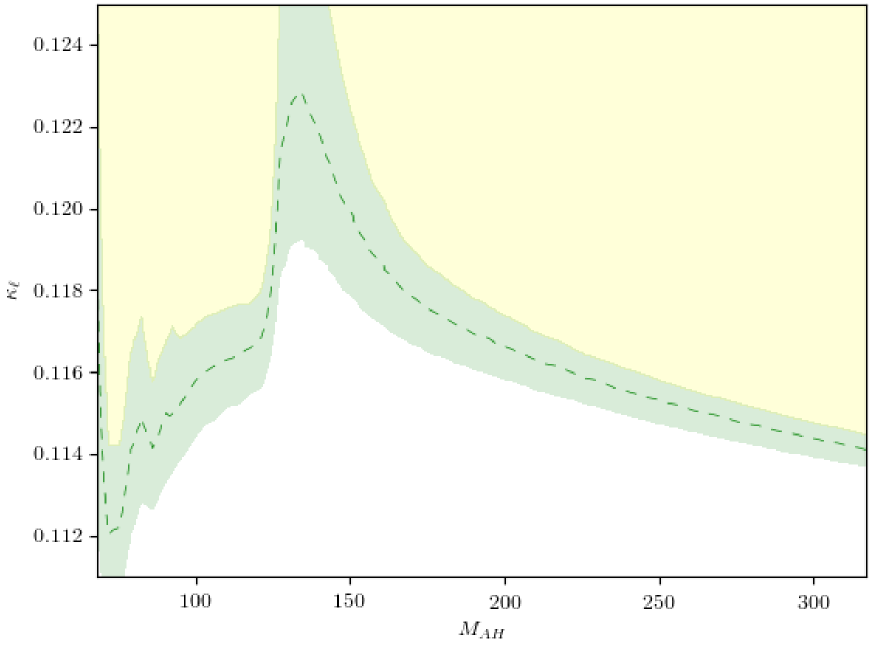
$$\sqrt{s} = 13 \text{ TeV}$$

Looking for vector like leptons
– dark matter

$$M_{VLL} - M_{A_H} \propto \kappa_l$$

Co-annihilation





Masses must be very close

Future work

VLL analysis:

- Improve sensitivity of slepton analysis to other decay channels

- Higher energies and luminosities

Other projects:

- Recast of Monotop searches in light of CHMs

- 1-loop matching of SMEFT + pseudoscalar

Thanks

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