# Collider searches for electroweak states suggested by the Fermi line

Brian Shuve

J. Liu, BS, N. Weiner, I. Yavin, arXiv:1303.4404

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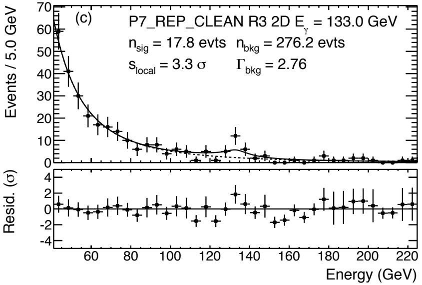
# Fermi gamma-ray line

- Fermi sees evidence for a gamma-ray line at 130-135 GeV in observations of the galactic centre (Bringmann *et al.*; Weniger; Tempel *et al.*; Finkbeiner and Su;...)
  - Most recent line analysis [arXiv:1305.5597]




- The origin of the excess is still unclear
- Assuming DM origin of the line, this implies $\sigma(\bar{\chi}\chi \to \gamma\gamma)v \sim 10^{-28} - 10^{-27}\ \mathrm{cm}^3/s$
  - What are the implications for physics at the weak scale?

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**Gamma-ray lines with weak-scale cross sections naturally imply new charged states at the weak scale accessible at LHC**

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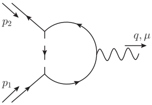


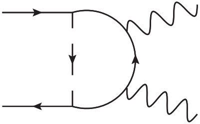

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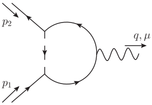


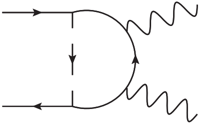

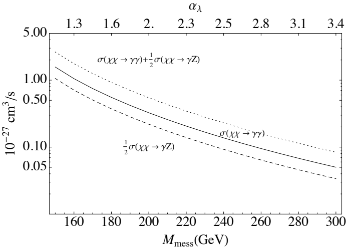

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- We focus on colour-singlet charged states

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- Some of these are reminiscent of SUSY, 2HDM, etc., but different gauge charges and decay modes allowed in some cases
  - Motivate more general electroweak searches

# Gauge charges and decay modes

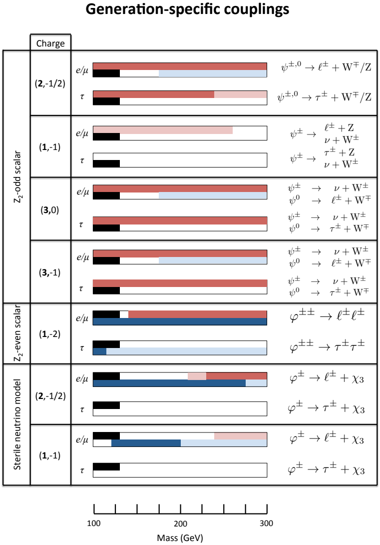
- Consider "reasonable" gauge charges
  - Triplet and lower because higher multiplets have large cross sections
  - Similar hypercharge to SM to allow renormalizable decays in minimal model

| $\mathrm{SU}(2)\times\mathrm{U}(1)$ charge | $Z_2$-odd $\varphi$ | $Z_2$-odd $\psi$ |
|---|---|---|
| $(\mathbf{1},-1)$ | $\ell H^*\psi^{\mathrm{c}}$ | $\varphi(\epsilon\ell_i)\ell_j$ |
| $(\mathbf{2},-\frac{1}{2})$ | $\psi H^* e^{\mathrm{c}}$ | $\mathcal{L}_{\mathrm{2HDM}}(\varphi,h)$ |
| $(\mathbf{3},0)$ | $(\epsilon H)\,\psi^a\sigma^a\ell$ | $H^*\varphi H$ |
| $(\mathbf{3},-1)$ | $\ell(\psi^{\mathrm{c}})^a\sigma^a H^*$ | $(\epsilon H)\varphi^a\sigma^a H$<br>$(\epsilon\ell)\varphi^*\ell$ |

# Qualitative results

- What kinds of models do we expect to be ruled out? To be accessible at LHC14? To be challenging and study more intensively?
- Dilepton/multilepton searches strongly constrain particles decaying to **leptons + gauge bosons or leptons + MET**
- **Large** $\mathrm{SU}(2)$ **multiplets** are mostly ruled out, while **singlets** are much less constrained
- **Tau final states and decays with large QCD backgrounds** are among the least constrained from electroweak production
- **Scalars** are generally less constrained than fermions because of lower cross section

# Results summary

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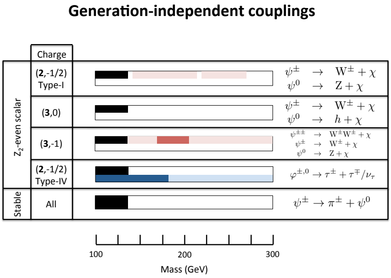


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# Conclusions and Outlook

- The potential observation of a gamma-ray line around 130 GeV provides an independent motivation for new charged states at the weak scale
- Classify models by the allowed couplings to SM consistent with gauge and discrete symmetries; paramterization applies across UV theories
- Many models are ruled out by dilepton + MET and multilepton searches
- Models with $\mathrm{SU}(2)$ singlets and tau-rich final states are less constrained but can be probed at LHC14
- A few examples ($\tau\tau$ + MET or disappearing charged tracks) are challenging at the LHC
- A linear collider would be an ideal environment for studying all scenarios!

# Back-up slides

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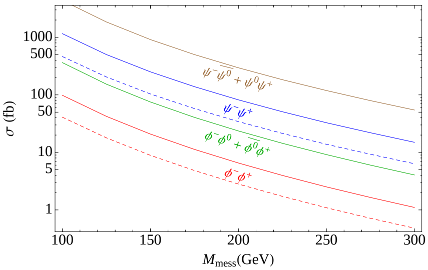
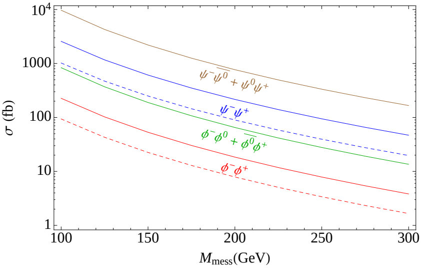
# Messenger production cross sections

**8 TeV:**

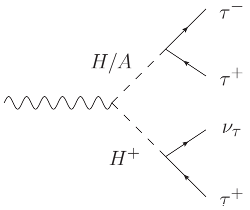


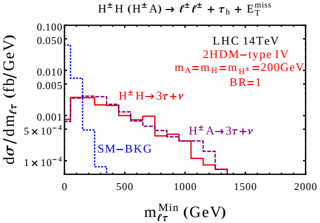

**14 TeV:**




- Dashed: $\mathrm{SU}(2)$ singlet, $Y = 1$
- Solid: $\mathrm{SU}(2)$ doublet, $Y = 1/2$

# Example: Type-IV 2HDM




- $3\tau \to \ell^{\pm}\ell^{\pm} + \tau_{\rm h} + \not{E}_{\rm T}$
- Exploit kinematics ($m_{\ell\tau}$)