Reinterpreting Long-Lived Particle Searches

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Department of Physics

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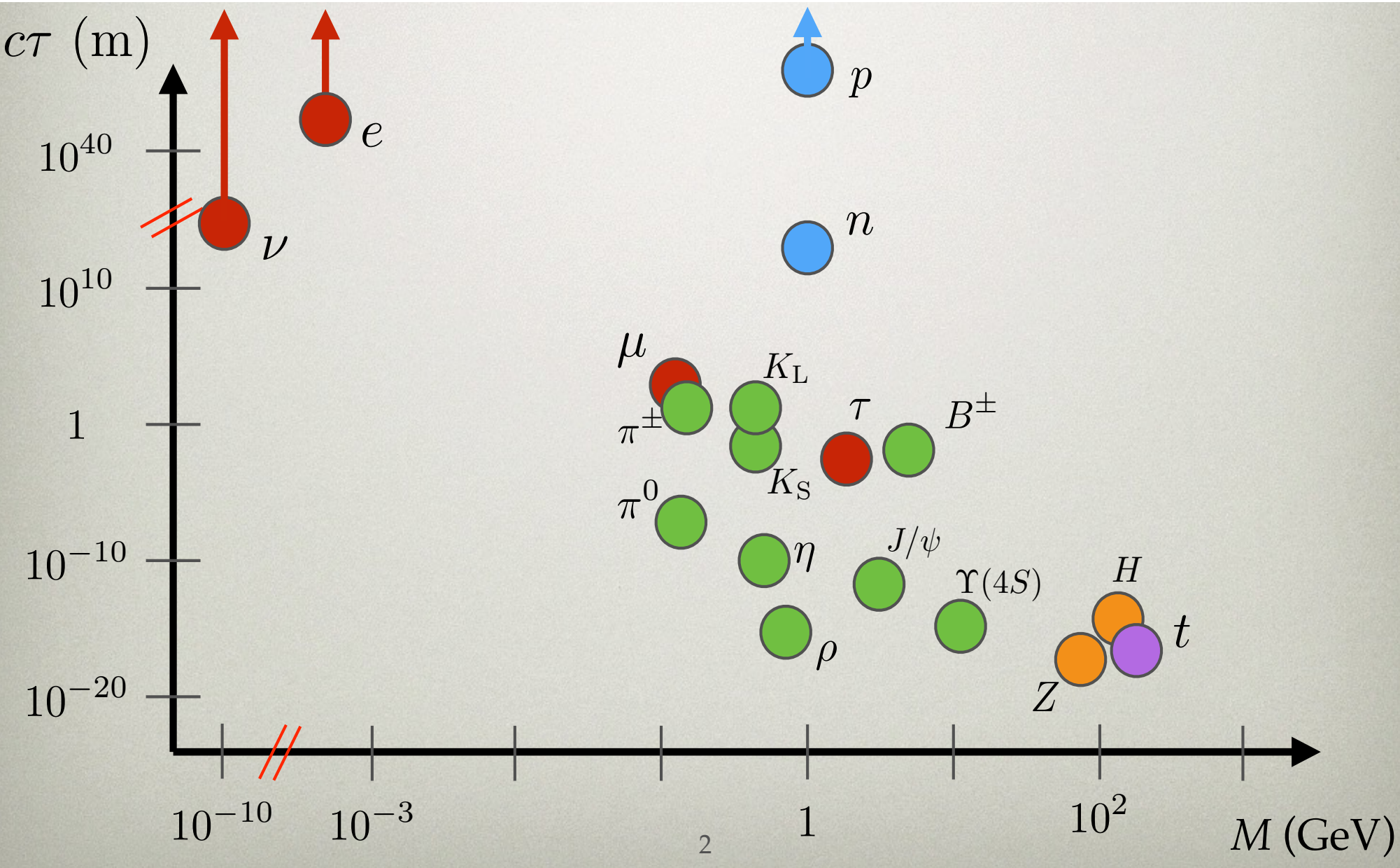
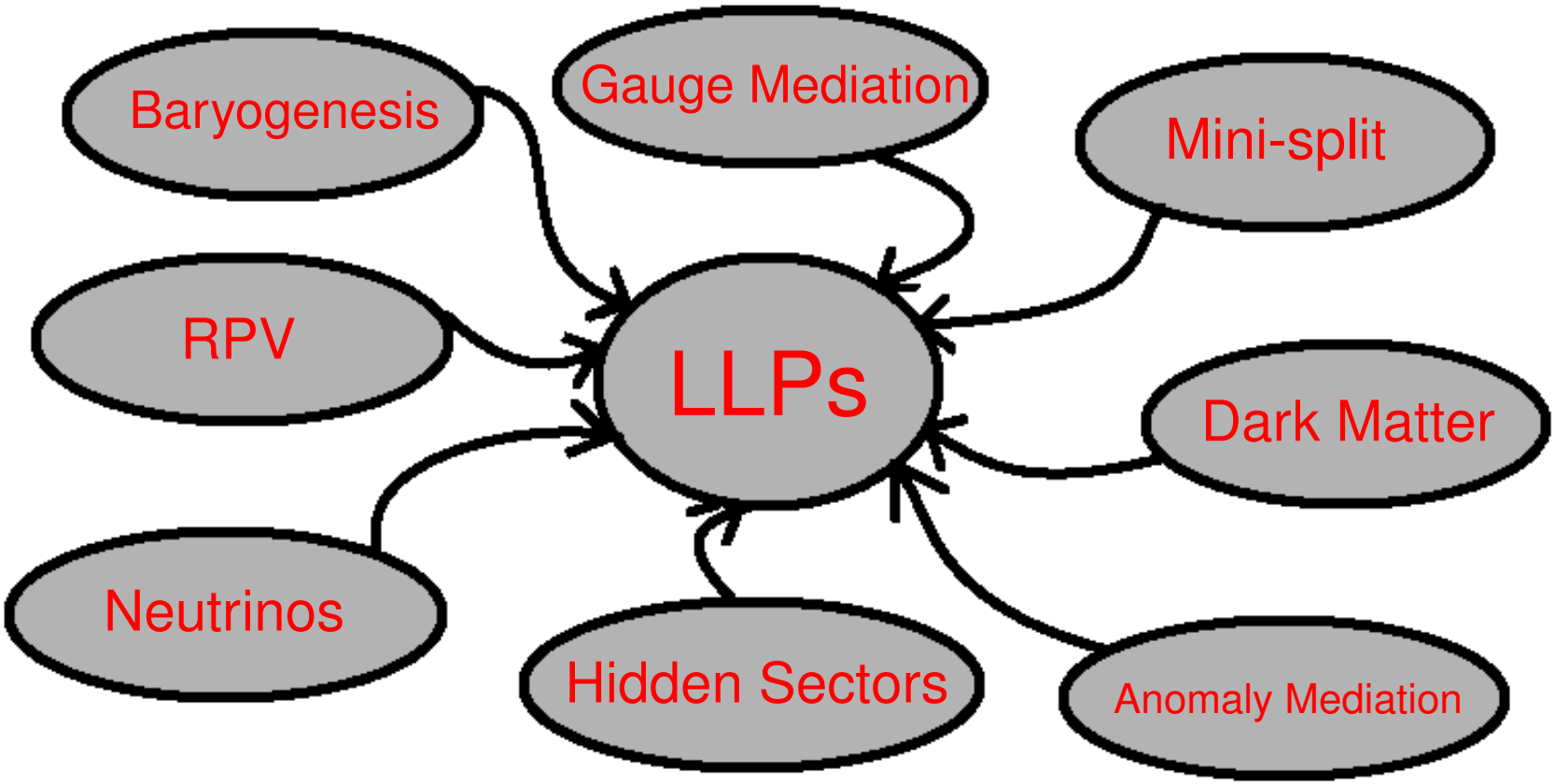
Long-lived Particles in the Standard Model

Slide by Brian Shuve



Long-lived Particles Beyond the Standard Model



Many, many, many BSM models have LLPs!!!

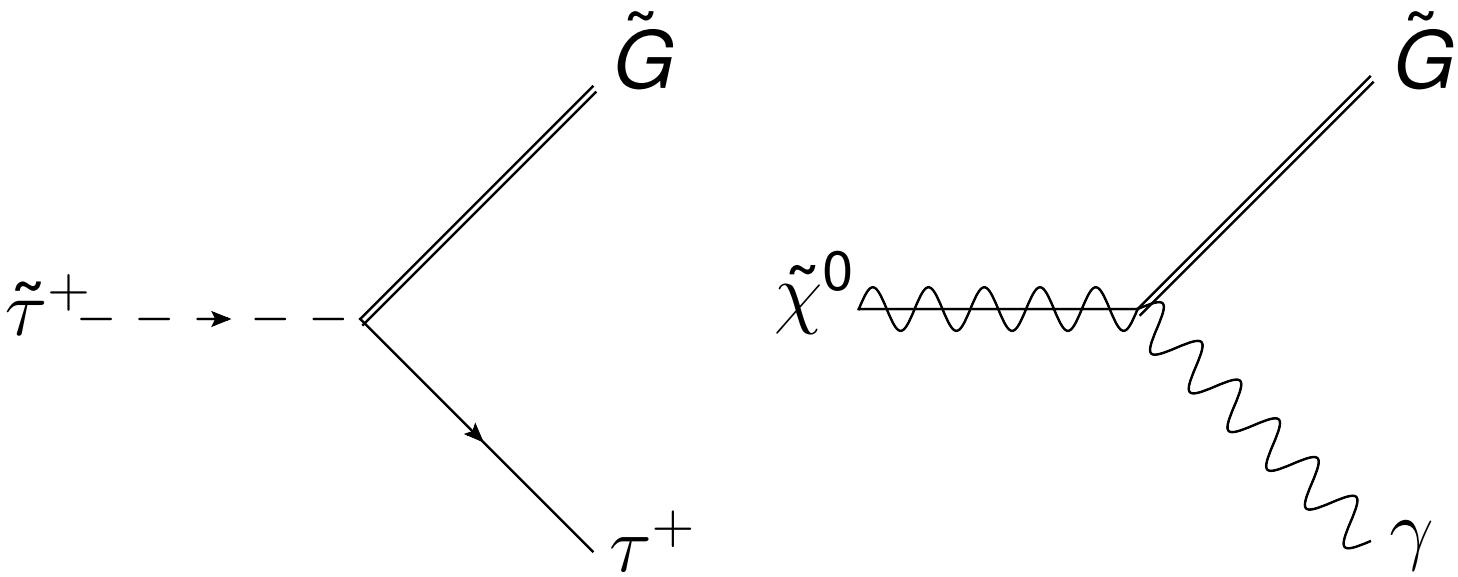
Lifetime comes from: high-dimension operators, very small couplings, heavy mass scales, or suppressed phase space

Long-lived Particles

Candidate Particles

1) The NLSP in gauge mediated SUSY breaking (GMSB)

Particles couple to gravitino LSP via higher-dimension operators sensitive to SUSY breaking scale $\mathcal{O} \sim \Lambda^{-2} \tilde{X}_\alpha \gamma^\mu \gamma^\nu \partial_\nu X \partial_\mu \tilde{G}_\alpha$



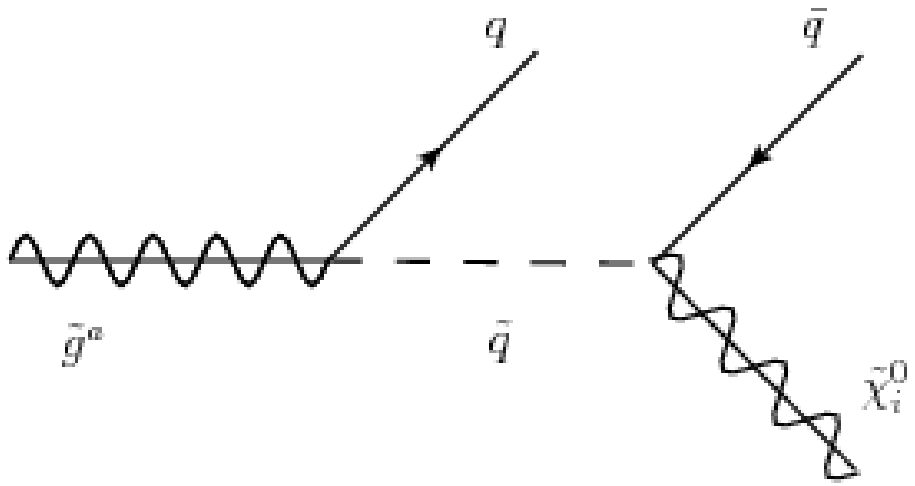
$$c\tau\left(\tilde{X} \to X\tilde{G}\right) \approx 100\,\mu\text{m}\left(\frac{100\text{ GeV}}{m_{\tilde{X}}}\right)^5\left(\frac{\Lambda}{100\text{ TeV}}\right)^4$$

2) The gluinos of mini-split SUSY

Mini-split: scalars heavy, gauginos light $\Rightarrow$ unification, but tuned

Integrating out heavy mass scale (squarks) gives dim-6 operator

$$\mathcal{O} \sim \frac{c}{m_{\tilde{q}}^2} \tilde{g}\tilde{\chi}\bar{q}q$$



$$c\tau\,(\tilde{g} \to \tilde{\chi} jj) \approx 100\,\mu\text{m} \left(\frac{m_{\tilde{q}}}{\text{PeV}}\right)^4 \left(\frac{\text{TeV}}{m_{\tilde{g}}}\right)^5$$

3) Scalars in exotic Higgs decays

Add a real scalar to the standard model, S gets vev, v_s

$$\mathcal{L} = \epsilon S^2 |H|^2 - \frac{\mu_S^2}{2} S^2 + \frac{\lambda_S}{4!} S^4$$

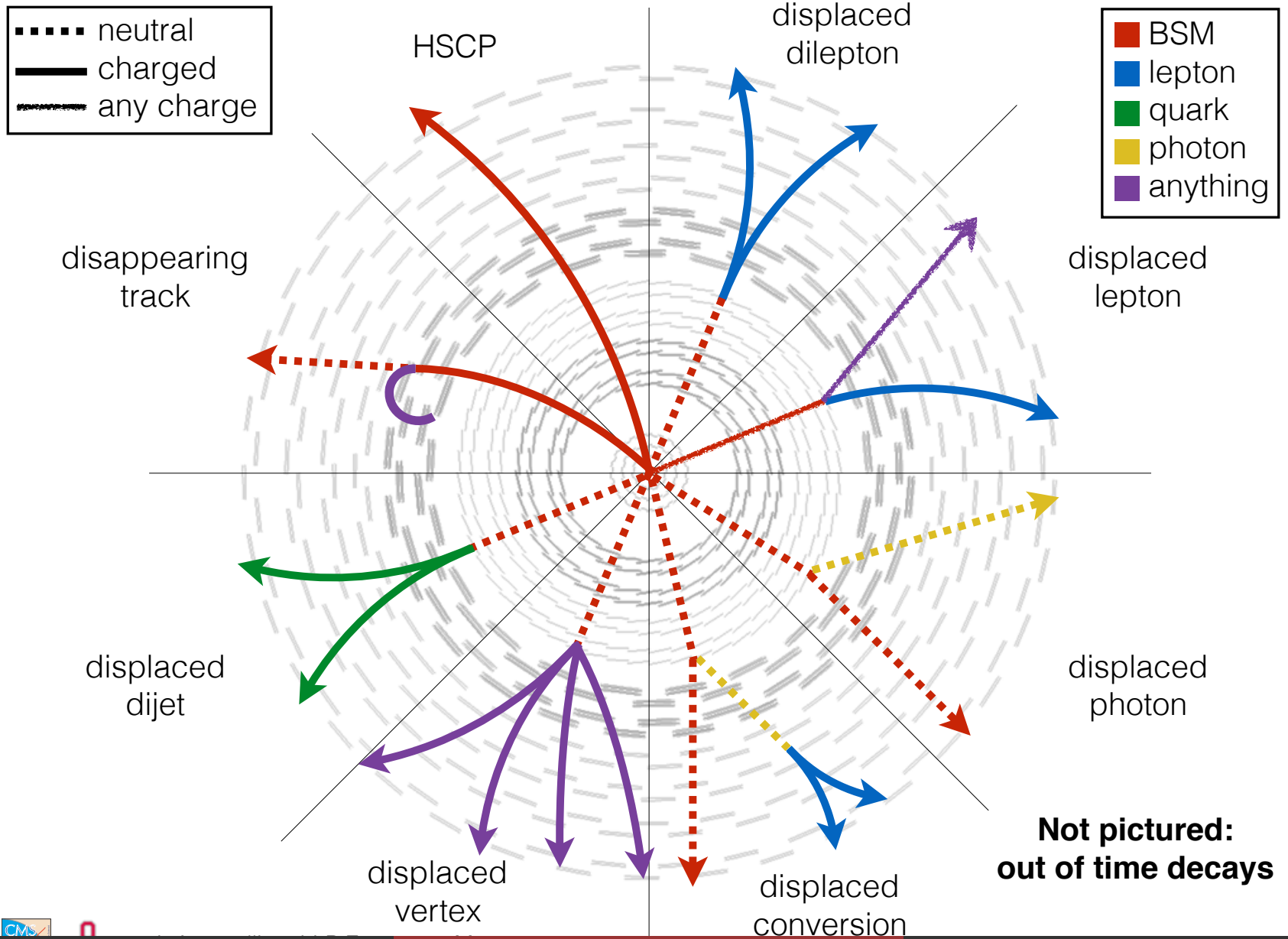
Mixes slightly with Higgs due to very small coupling, $\sin\theta \sim \frac{\epsilon v_s v_h}{m_h^2}$

$$c\tau\left(S \to b\bar{b}\right) \approx 2 \text{ mm} \left(\frac{10^{-5}}{\sin\theta}\right)^2 \left(\frac{40 \text{ GeV}}{m_{\tilde{S}}}\right)$$

$$c\tau\left(S \to \tau^+\tau^-\right) \approx 1 \text{ mm} \left(\frac{10^{-4}}{\sin\theta}\right)^2 \left(\frac{6 \text{ GeV}}{m_{\tilde{S}}}\right)$$

Searches for Long-lived Particles

Slide by Jamie Antonelli



Difficulties in Recasting

Prompt Searches

Signal Generation

Selection Cuts

Signal Region Cuts

ID Efficiencies

Trigger Efficiencies

Validation

(CR Contamination)

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All that and...

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Not much information

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Recasting is trailblazing

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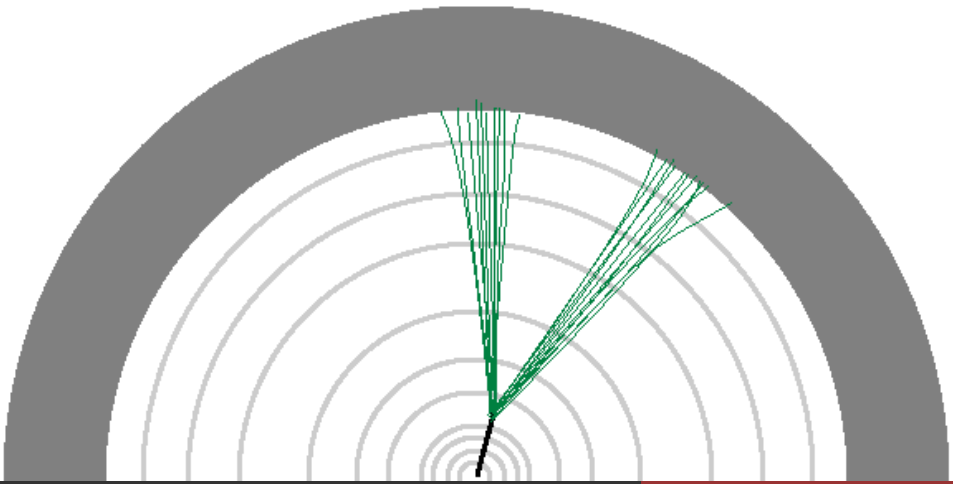
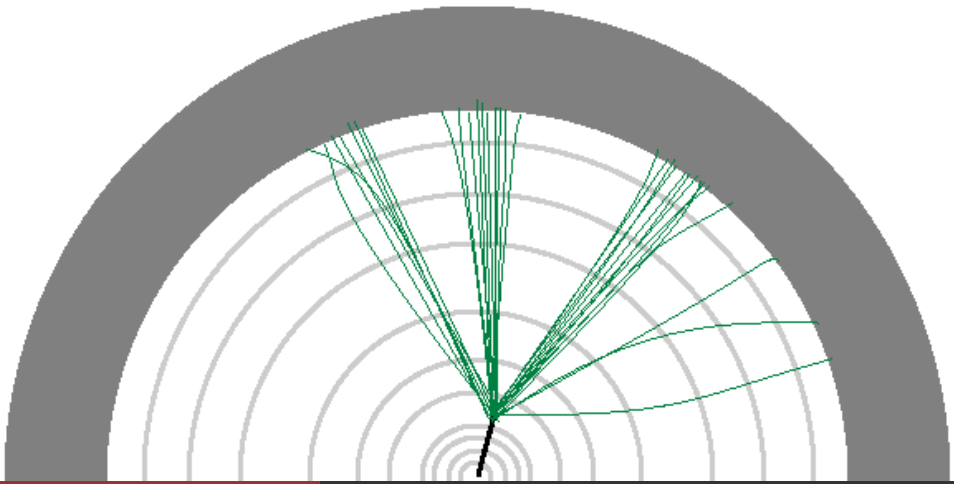
Risk of dangerously uncontrolled extrapolations

inF.A.Q.

Simple Situations, Tricky Questions

- My vertex has additional objects, how does that affect vertex reconstruction efficiency?





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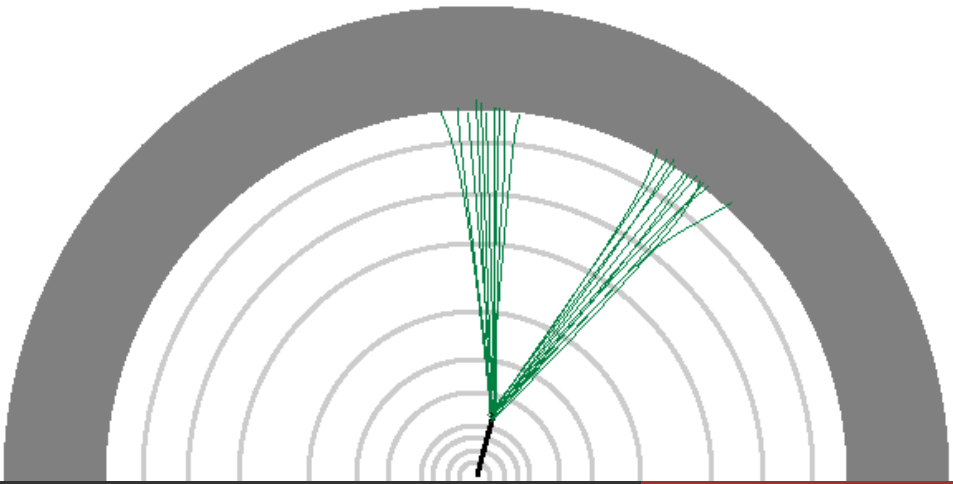

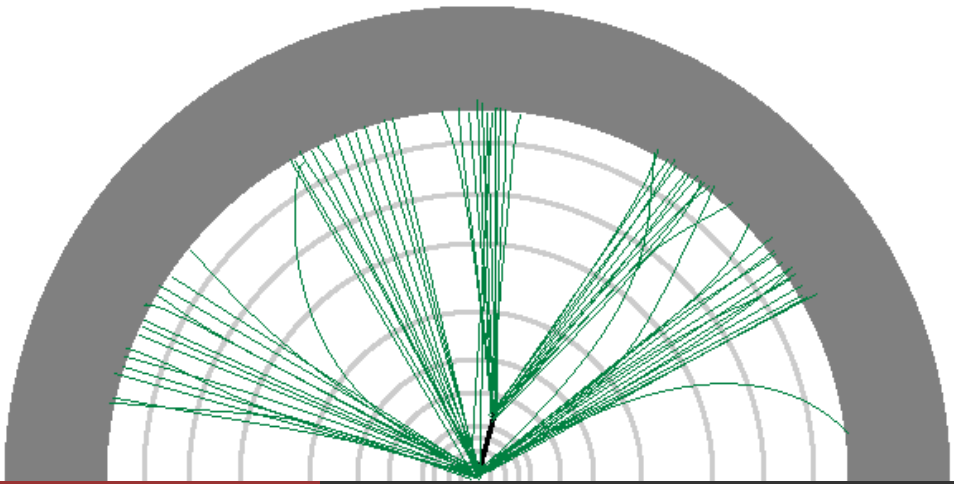

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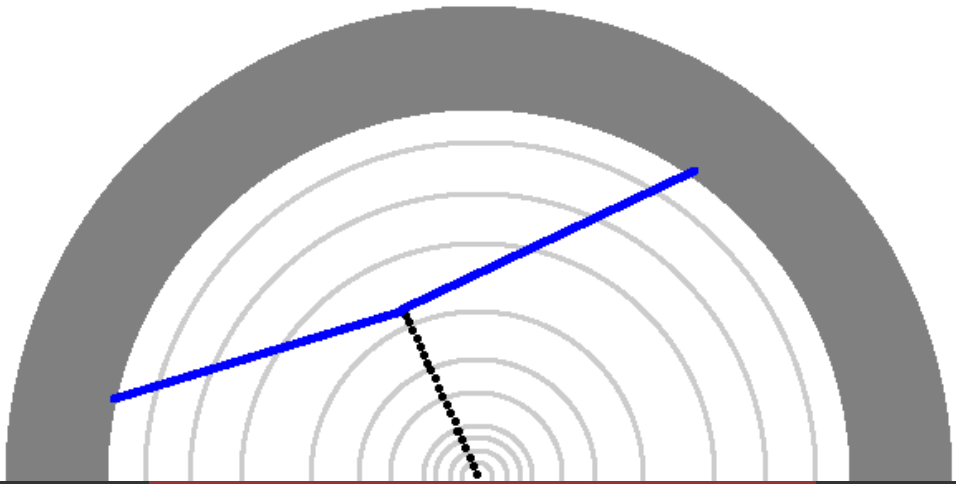

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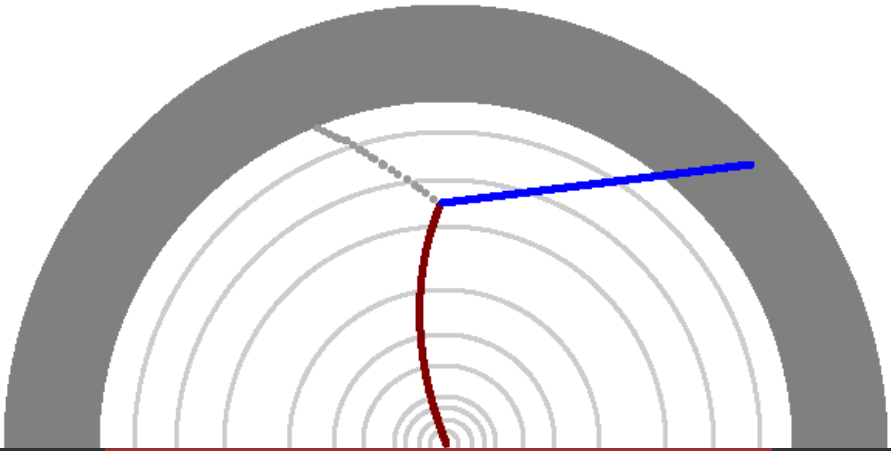

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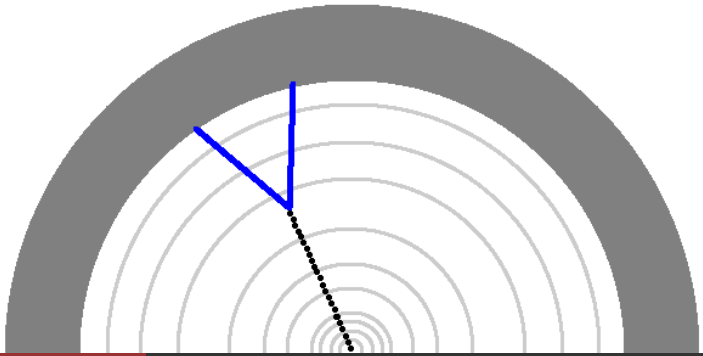

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- My particle is produced with very different kinematics than the benchmark in the search, how does this affect the selection?

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Along what axes could searches lose sensitivity?

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3. Long lifetime

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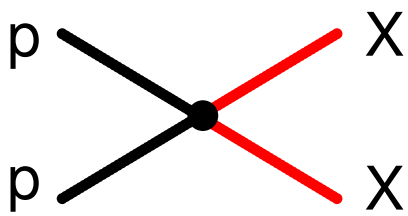
Judicious choice of Simplified Models can target these axes!

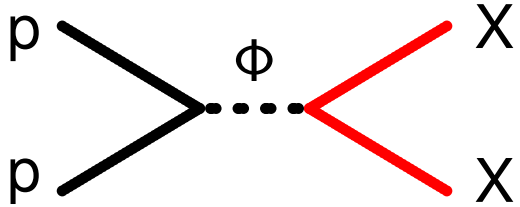
Simplified Models

Production Modes $\otimes$ Decay Modes

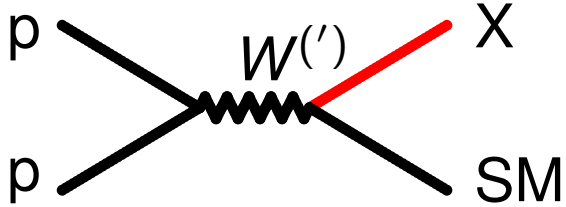
Direct Pair Production



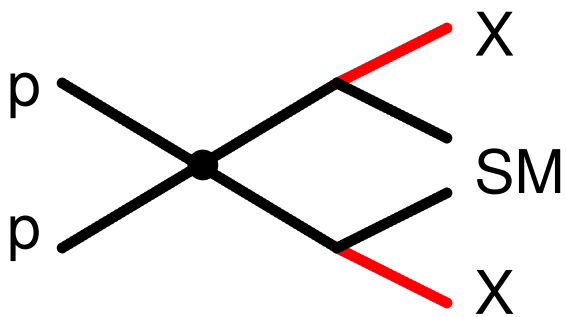
Heavy Resonance (Higgs)



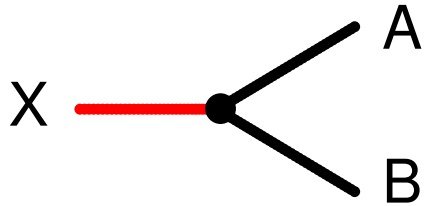
Charged Current



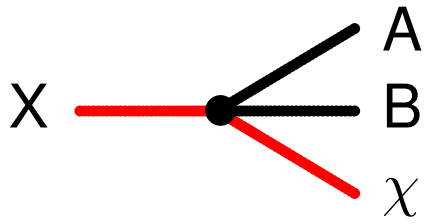
Heavy Parent



Direct Decay



Dark Decay



$$\text{AB} = \ell\ell,\ \ell\ell',\ \ell j,\ jj,\ \gamma\gamma$$
$$\ell\chi,\ j\chi,\ \gamma\chi,\ j\gamma,\ \ell\gamma$$

where χ = invisible particle

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Displaced Dilepton

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Complementarity with lepton-jets?

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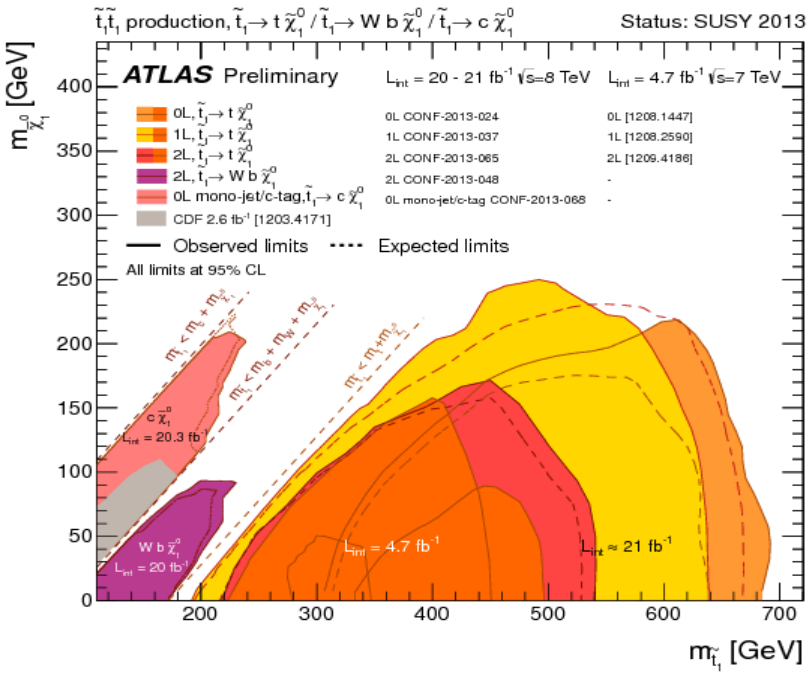
Highlighting Limitations Spur Innovation

The evolution of compressed stops...



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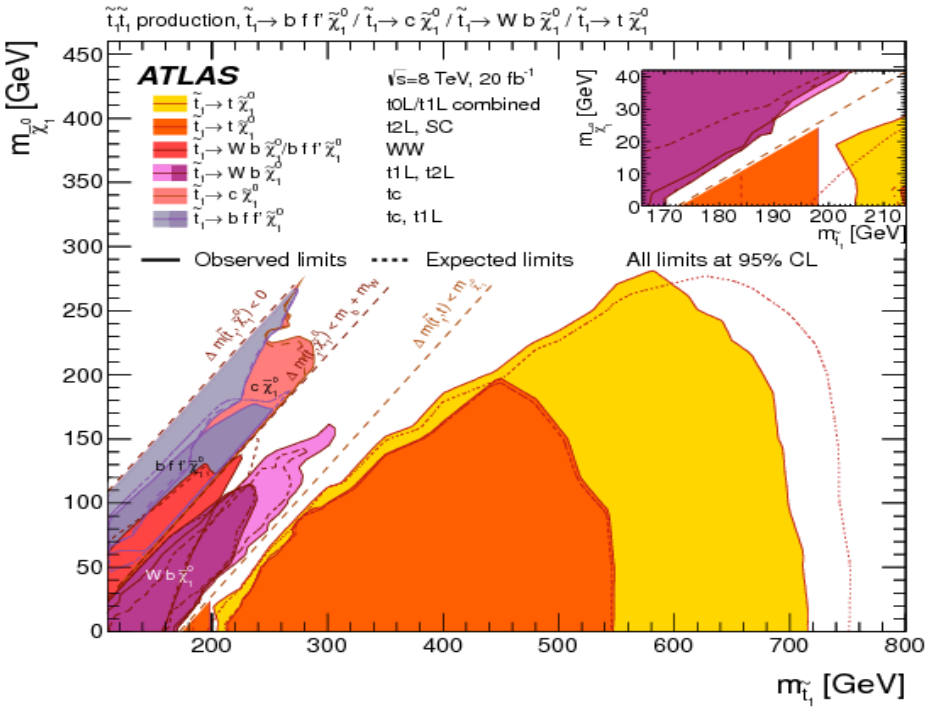

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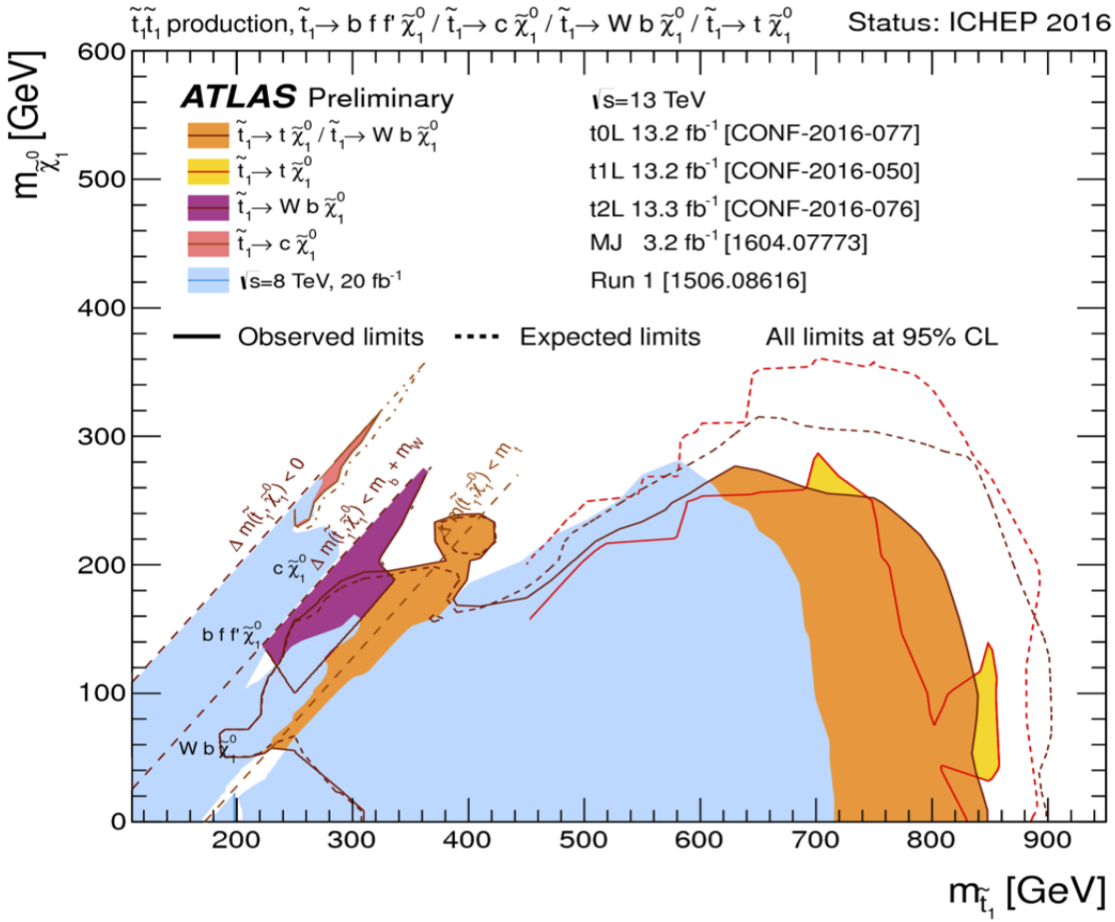

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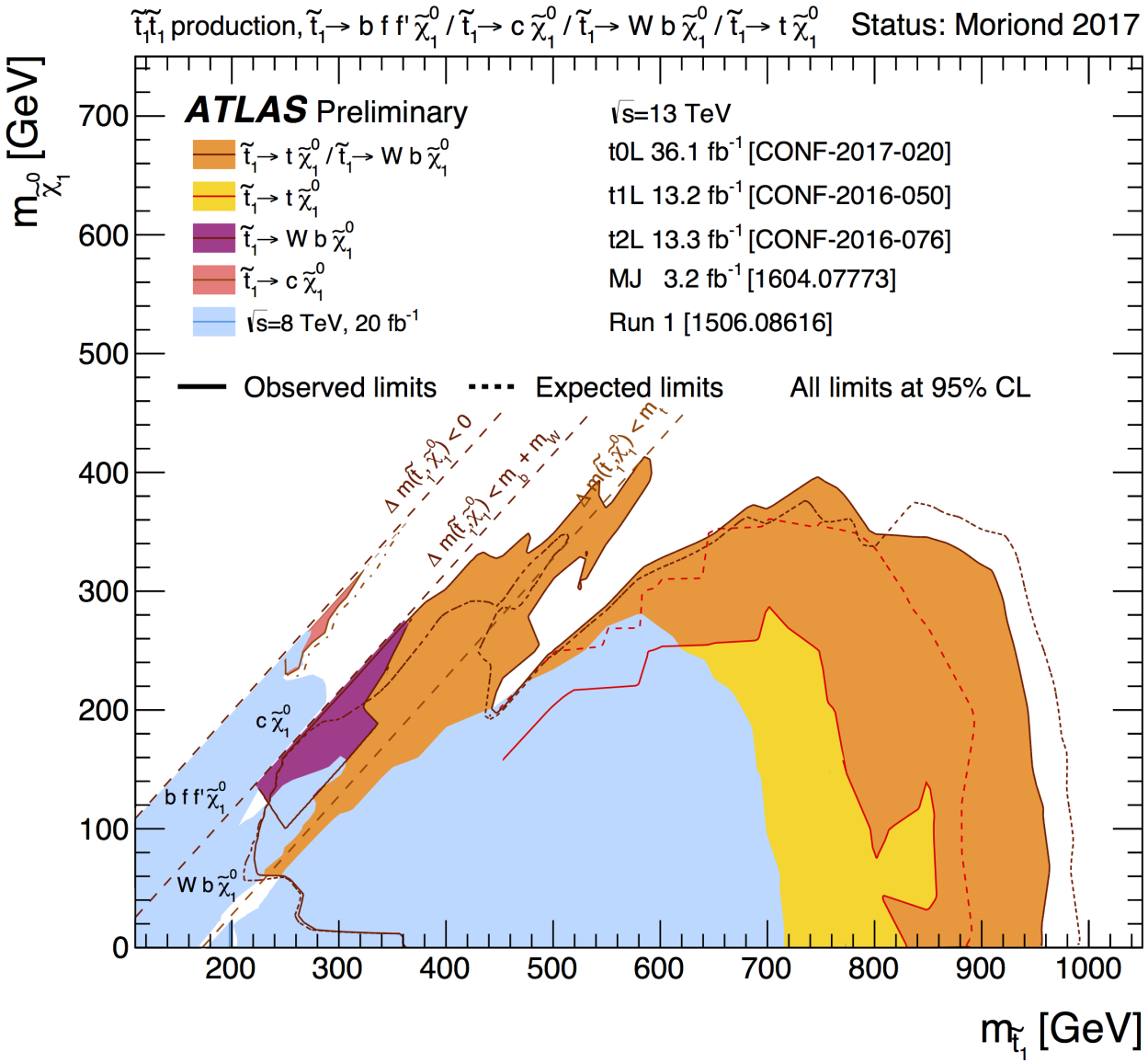

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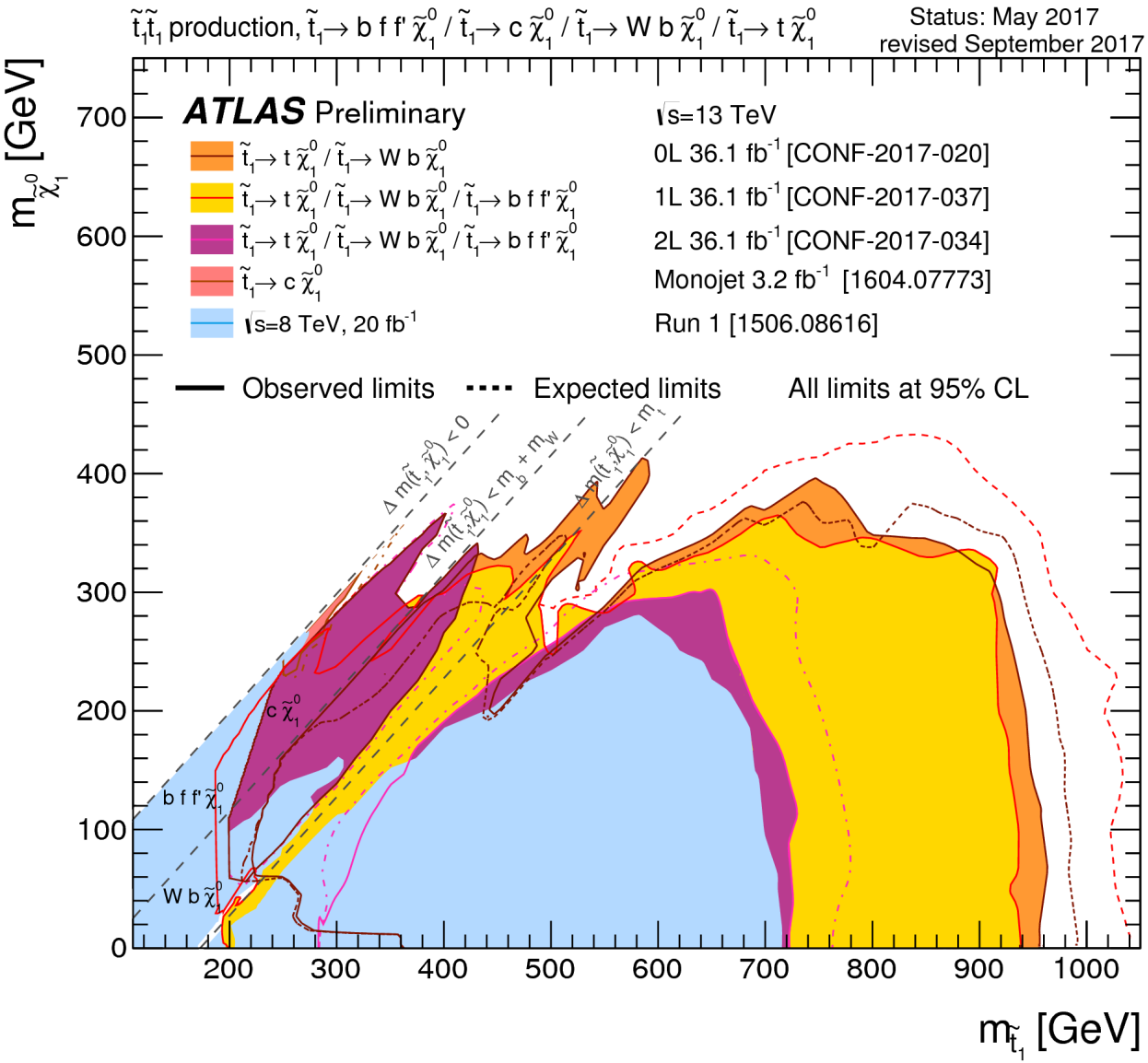
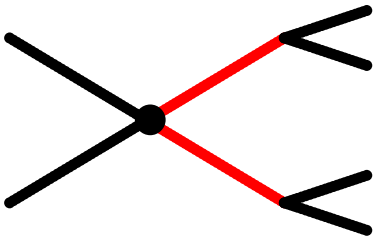


What Information Should Experiments Provide?

A Simplified Model



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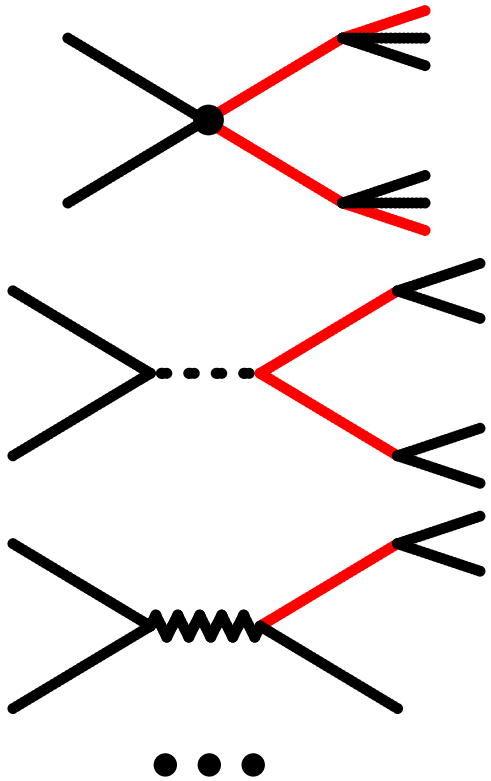

Parameterized Efficiencies

$\epsilon_{object}(p_T, \eta, d_{xy}, d_z, n_{tr}, ...)$

(Now in several studies!)

less work for experimenters more

less usefulness to theorists more

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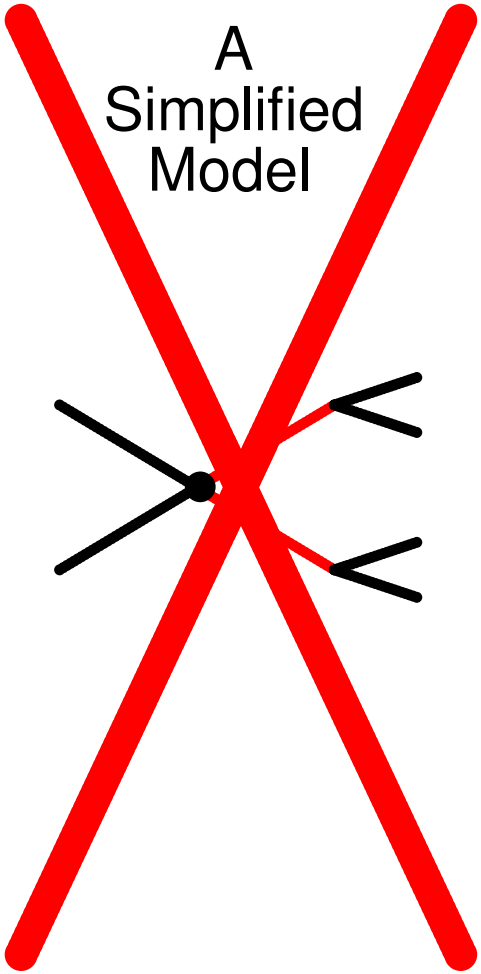

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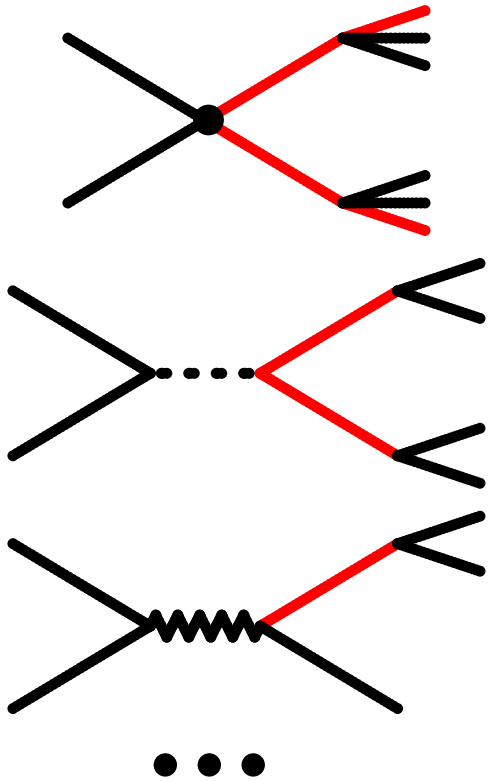

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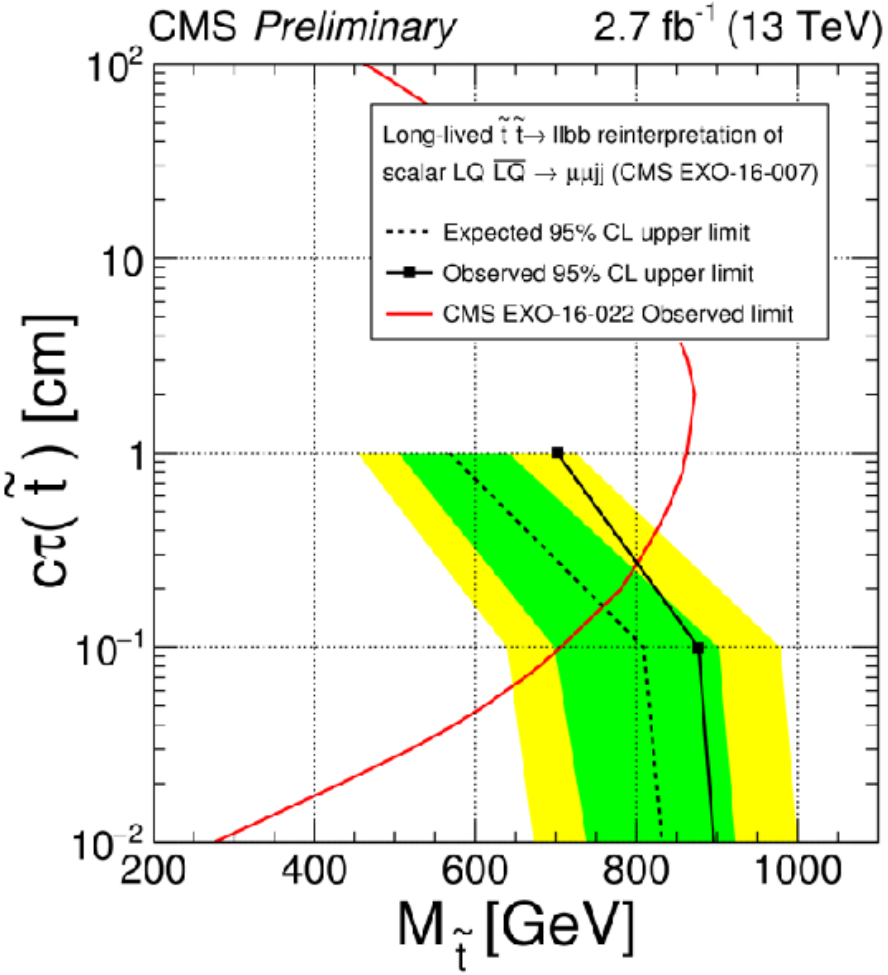

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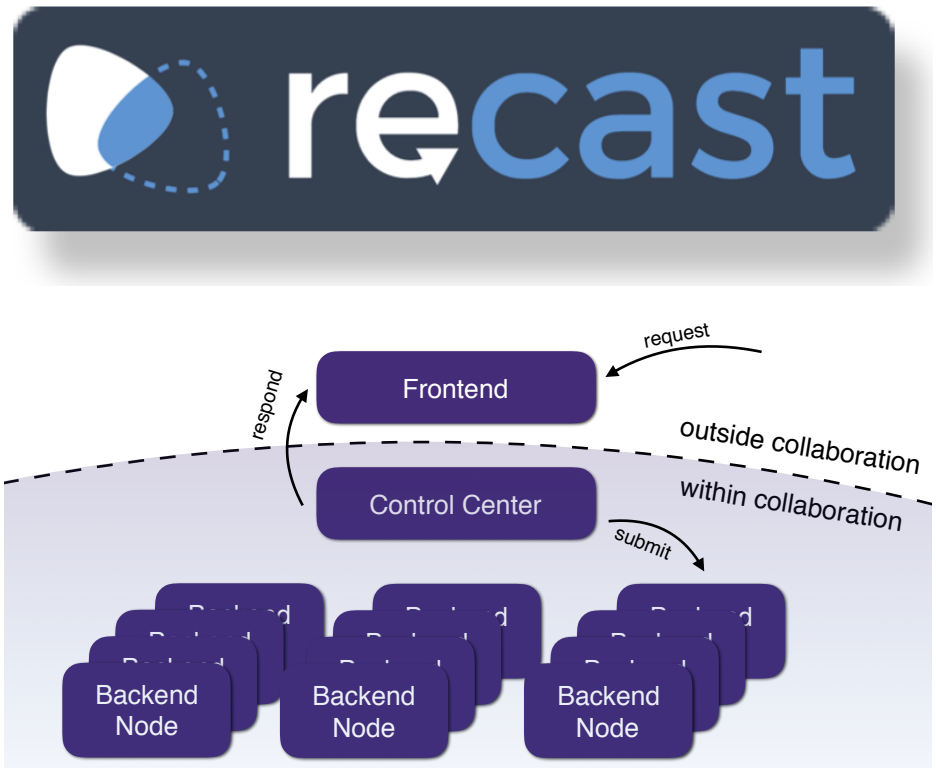
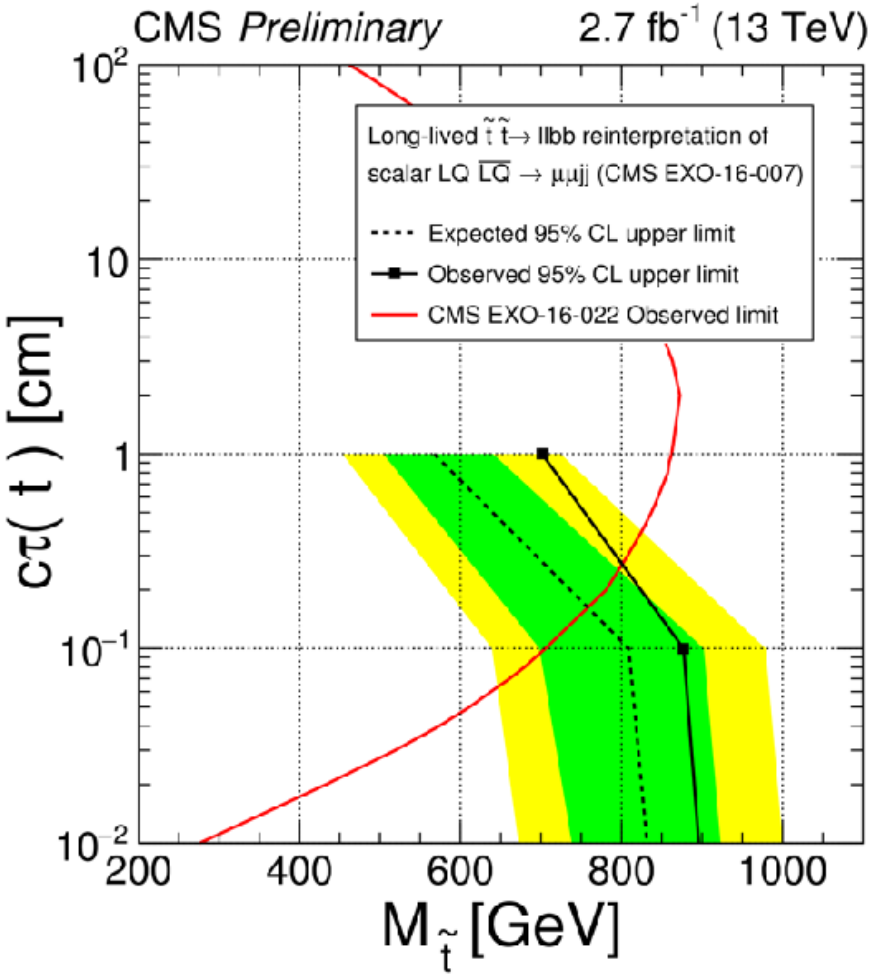
Perfect opportunity for RECAST!

(See Lukas's Talk)





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Simplified model basis covers many possibilities – nearly complete

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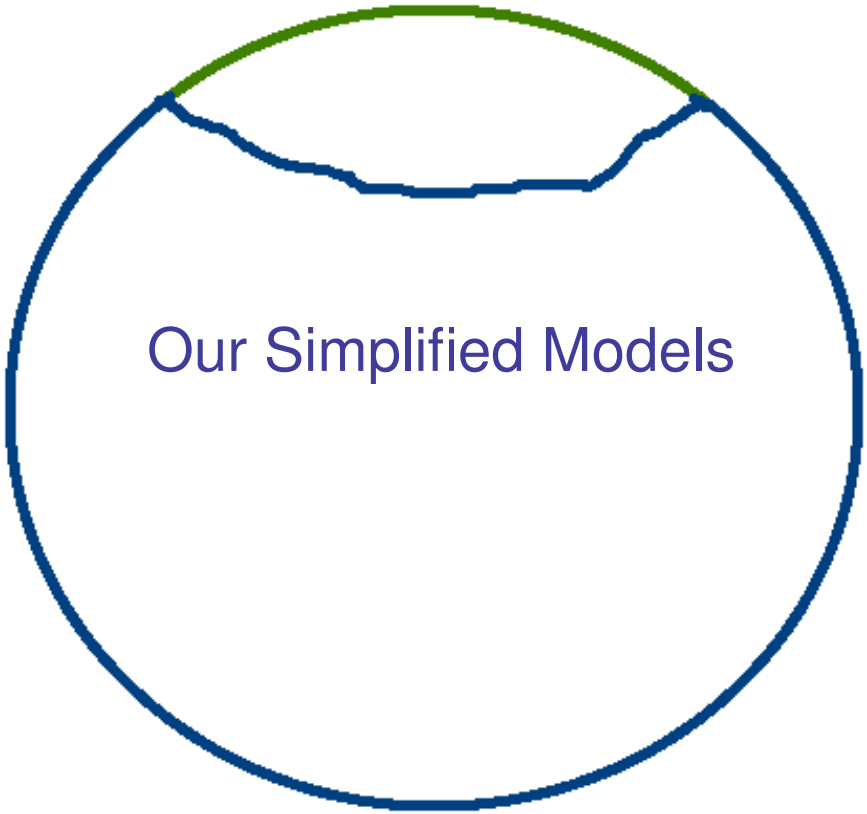

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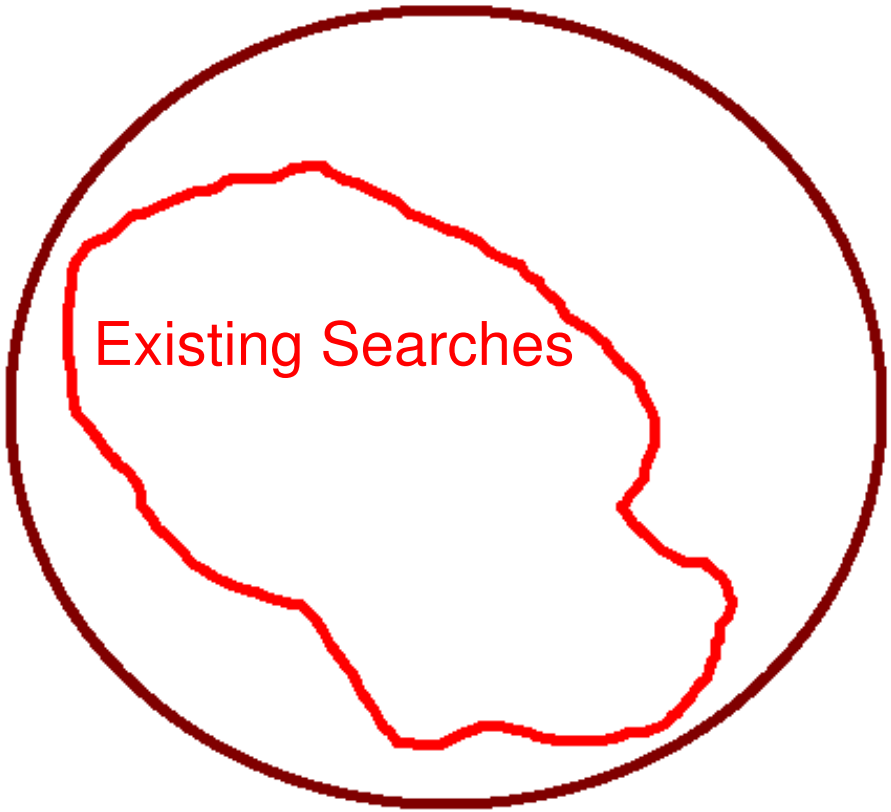

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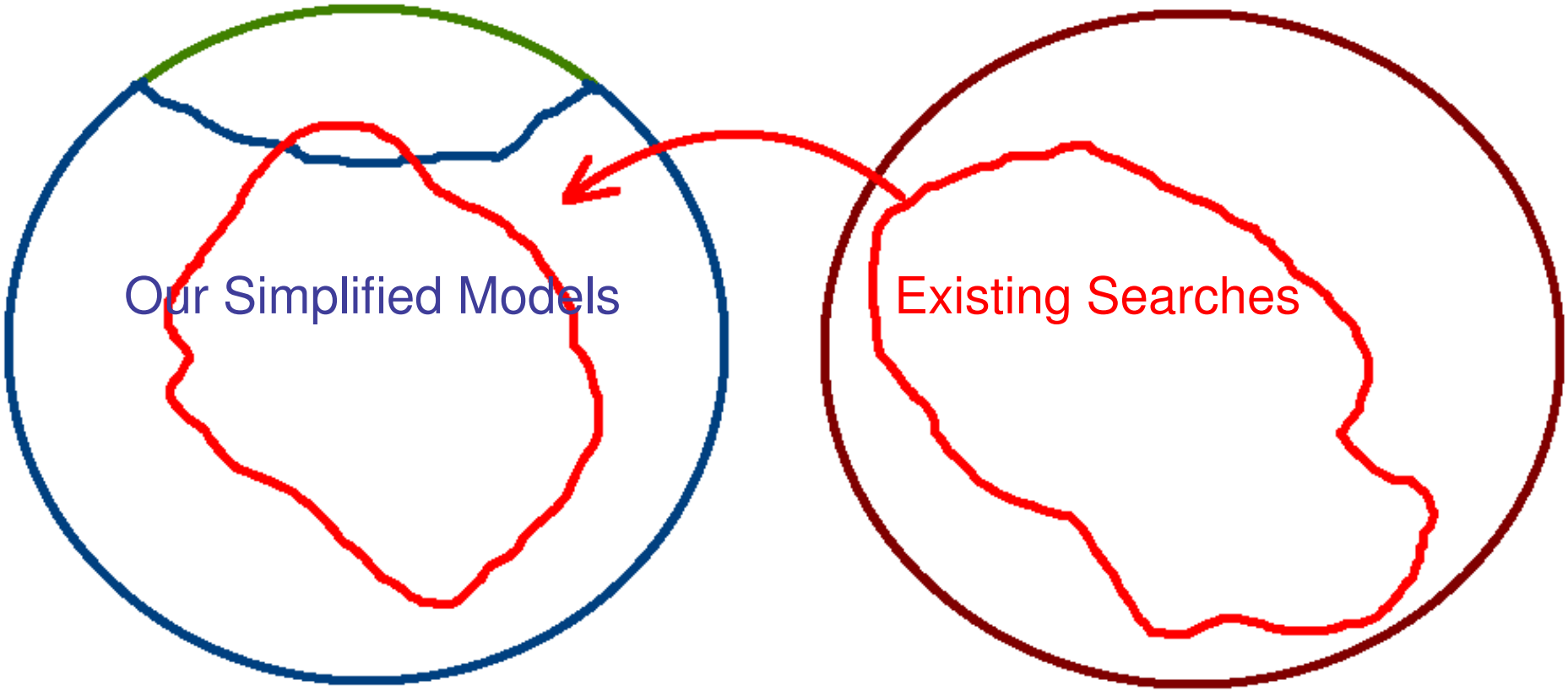

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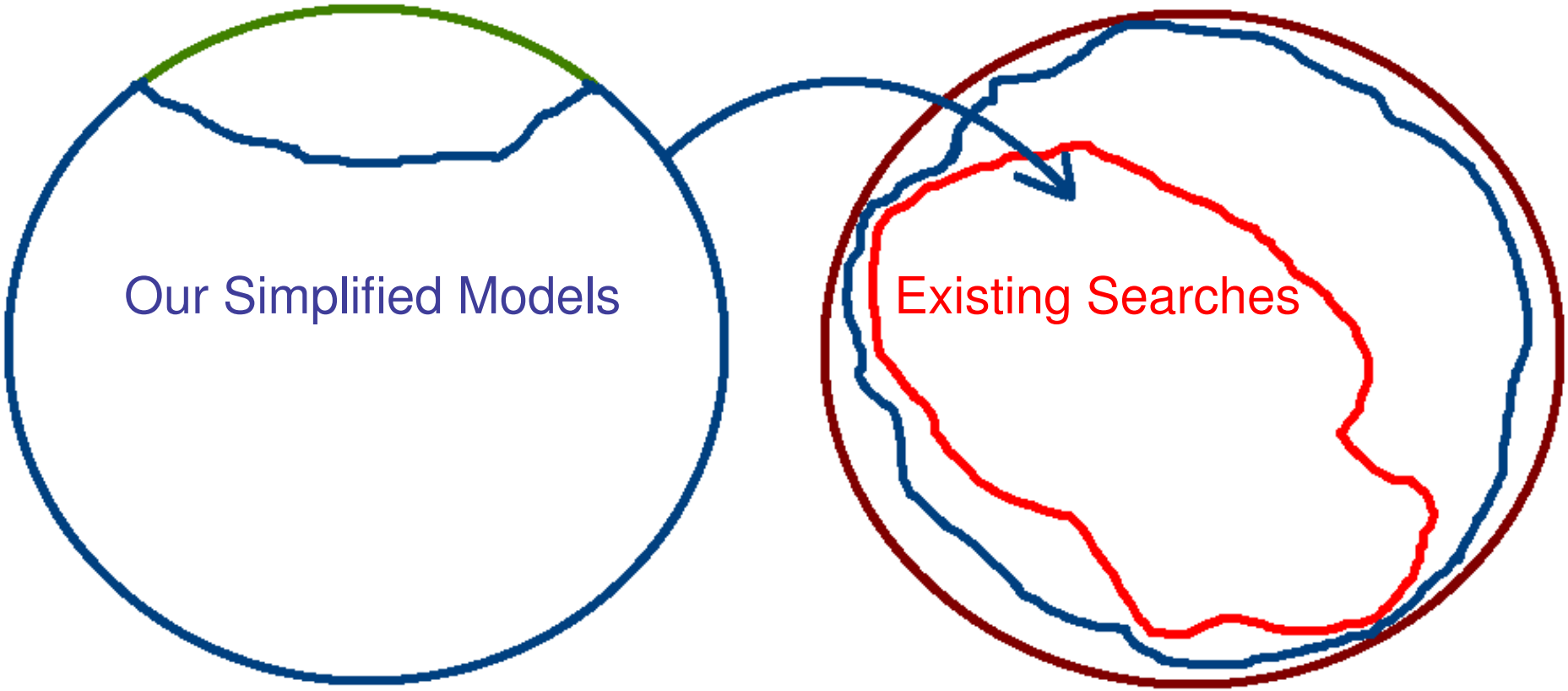

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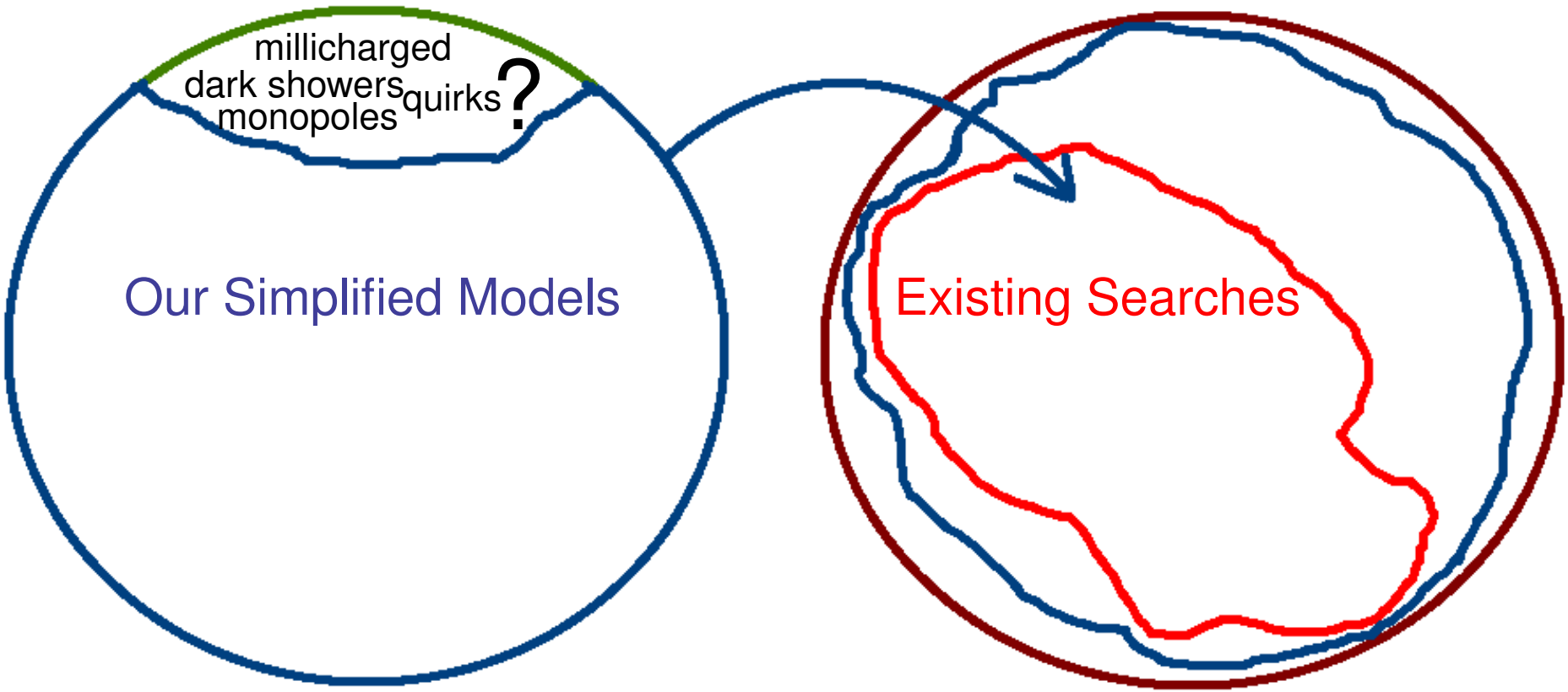

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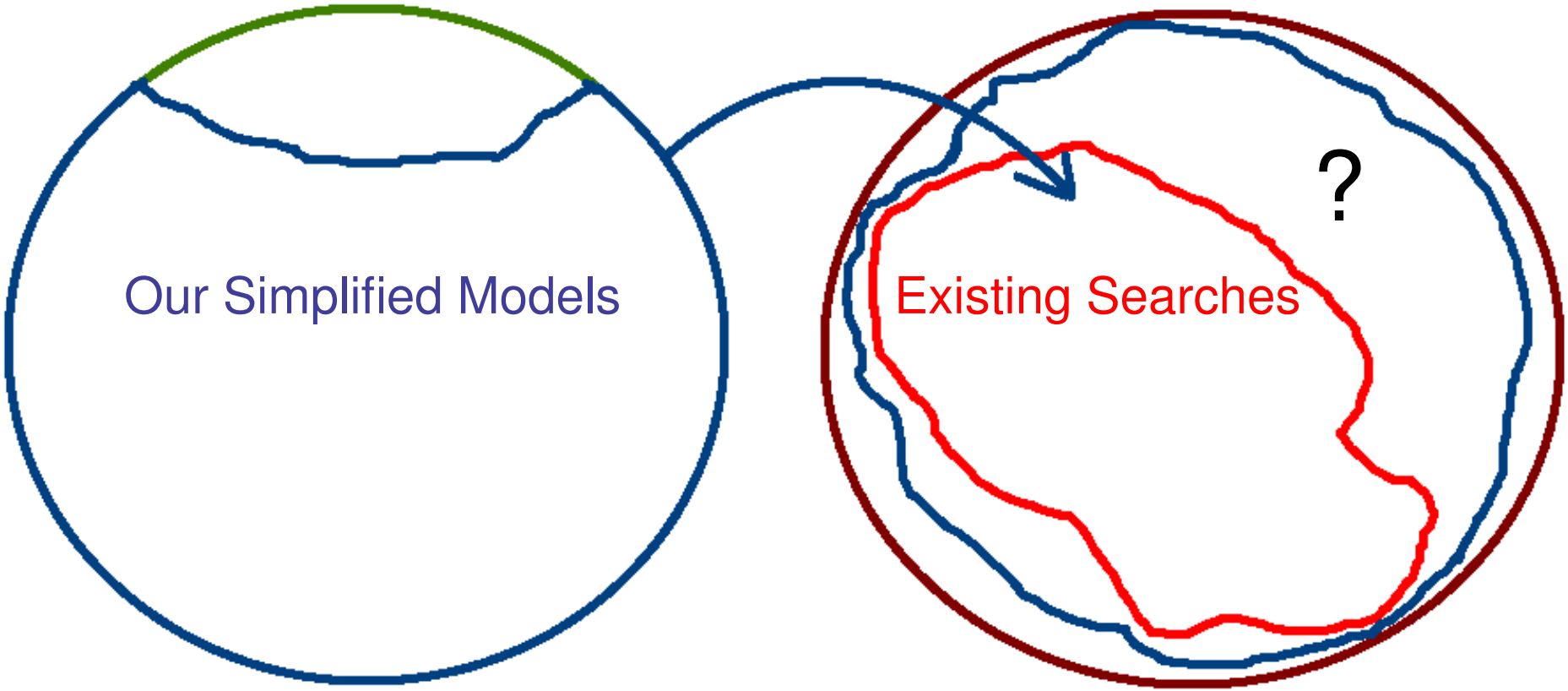

Conclusions

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- Prompt search sensitivity to LLPs should be illustrated (RECAST)
- The program must expand – iterative incremental improvements are good, but novel ideas may bring optimal coverage sooner