

Long-Lived Particle Summary

LLPs are spectacular, with low SM fake rates.

But, we have to "hook" the detectors beyond usual expectation of particles coming from beam spot

→ more tailored analyses, non-standard objects

By now, we have an impressive array of searches by ATLAS/CMS/LHCb.

Group started with set of discussion questions. refined to:

- ★ plots.
 - gaps in current coverage. we made a list of simplified models that allow effective comparison
 - how to fill gaps? new searches required (some already started)
 - what if backgrounds worse in new signal regions?
↳ new methods or ideas
 - new (sub)-detectors, → longer term future.

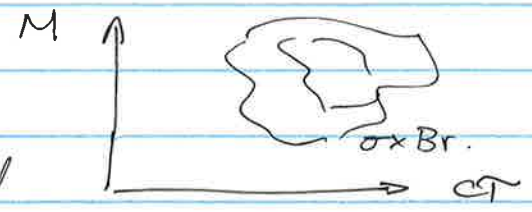
Simplified Models

Diverse motivations: SUSY, neutral naturalness, HV, RHN, dark sectors, ...

Important features

- typical mass scale & kinematics (\mathcal{P}/m , boost)
- lepton multiplicity
- 1 LLP vs. 2 LLPs vs. many. (LLP multiplicity).

For each model, make ONE plot



→ word of caution: sometimes find unexpected things!

(ex. DV could be better than longer lifetime searches)

List of models

$h \rightarrow XX$

- 1) $X = \text{Higgs-like scalar}$ ($b\bar{b}, \tau\bar{\tau}, \dots$)
- 2) $X = \text{dark photon}$ (democratic, so l^+l^- key)
- 3) X couples to pairs of gauge bosons ($g_s, \gamma\gamma$)
- 4) simple variations: \rightarrow above + E_T , $\gamma + E_T$
 \rightarrow 2 DV

≥ 2 DVs, may not wait \geq at short / long / inefficient tagging

$h \rightarrow XY$

X is same as above

$Y = E_T$, prompt objects (j, l, γ)

ex. $h \rightarrow \tilde{\chi}_2^0 \tilde{\chi}_1^0$, $\tilde{\chi}_2^0 \rightarrow \text{DV} + \tilde{\chi}_1^0$ (sum, DM, ...)

★ ONLY 1 DV! ★

→ soft

additionally
 → use
 VBF, VH, etc.
 (v. powerful)

but these
 are precise for
 models w/o
 it too!!

Direct neutralino production ($\tilde{\chi}^0 \tilde{\chi}^0$)

→ EW scale cross section or below.

(depends on nearby charged states, mixing)

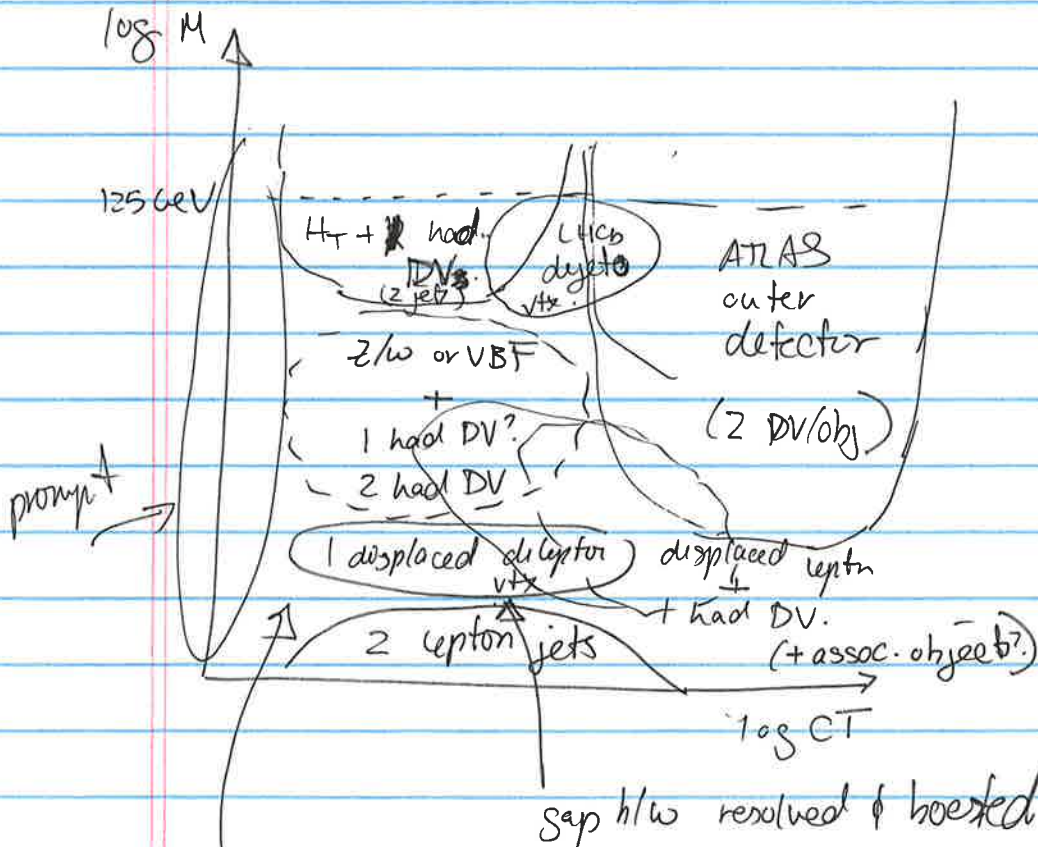
→ LEP puts strong constraints on $M \leq 100$ GeV.

$$X^0 \rightarrow \left. \begin{array}{l} 3g. \\ 2g + l/\cancel{g} \\ 2l + \nu \end{array} \right\} \text{RPV SUSY-like}$$

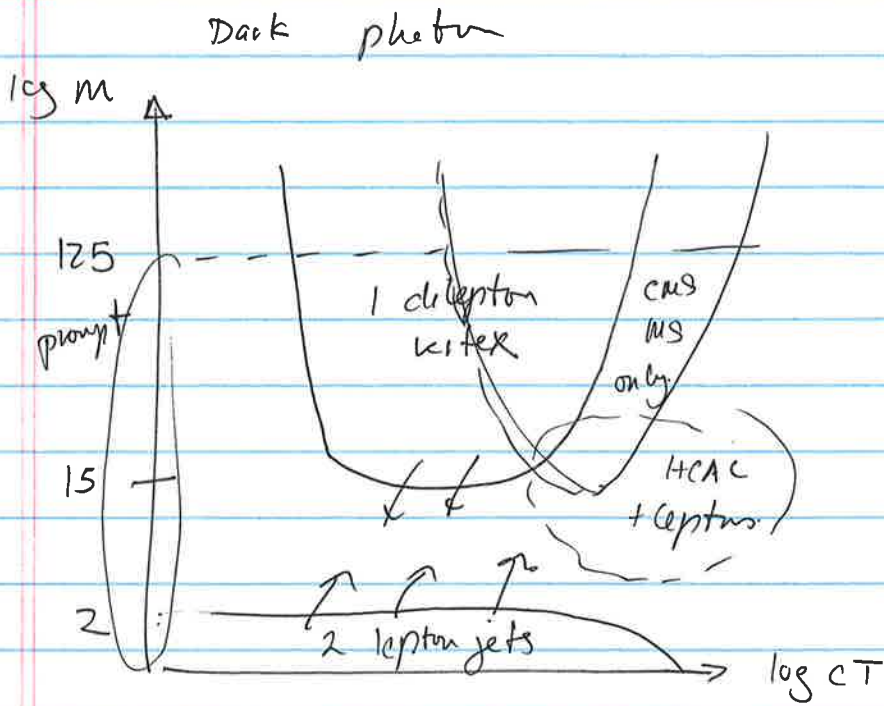
$$\left. \begin{array}{l} \gamma + \cancel{H}(G) \\ z + \cancel{H}(G) \\ h + \cancel{H} \\ s/2 \cancel{H} \end{array} \right\} \text{gauge mediation-like.} \\ (\mu_G = 0).$$

Looks like a lot (and it is!!), but many searches apply to multiple models. We focus on $h \rightarrow X\bar{X}$, $X \rightarrow (\bar{b}b, \tau\tau)$
 ϕ (X is dark photon), rest inferred or ran out of time.

Scalar



prompt \leftrightarrow displaced
 (where is this gap?)



leptons \rightarrow how low can you go?

\rightarrow could have

prompt $l/\bar{l}/VBF +$
all of these too!

(ex. $X \rightarrow DV +$ partially visible)

$H \rightarrow X \gamma$, same as above but only 1 DV work!

\hookrightarrow definitely need associated $l/\bar{l}/VBF$ in some cases.

\hookrightarrow challenges in moving to $X \gamma$, lose associated prod.

New searches / phase space \Rightarrow new bnds??

Background suppression (when necessary)

- isolation of vertex from prompt tracks/activity (nakes?)
- "di-jetiness", or multi-pronginess of tracks out of vertex
- max \bar{w} $N-1$ tracks (to remove led from random crossings)
- tighter selections on hit patterns of associated tracks.
- $p_{T, vtx} / p_{T, jet}$ (higher for signal than hadronic ind?)
- start requiring 1 or more leptons in vertex
(from $b = s/\bar{t}$, get π bcd... isolated, angles/ x_i ?)
- lots of other high-tdal things in event???

New (sub)-detector

other searches not mentioned

- non-pointing or delayed photons (\cancel{E}_T, \dots)
 - heavy near "stable" charged particles
 - stopped
 - disappearing tracks
 - other ideas??
- } our benchmarks
neutral

New (sub)-detectors / Upgrades

- Displaced L1 track trigger? should be able to do tracks to \sim mm. How big is IP?
- ~~Look for large IP tracks~~ FTK requires $|\Delta z| \lesssim$ few mm, but can look for large IP tracks in HLT around lepton w missing FTK track. other trackless objects
- improvement in timing could help w photons/HSCP
Timing for ECAL deposits from DV objects?
- CMS HGCAL \rightarrow do vertexing IN the FEAL?!
 \hookrightarrow like ATLAS HCAL searches
- other detectors to look for LLPs?
TORM or other forward detectors (tracking/timing/eta)