Summary WG 3: Triggering strategies and recommended studies for experiments for LLP searches

Conveners:
Henry Lubatti, Chris Hill, Xabier Vidal, David Curtin

Searches for long-lived particles at the LHC:
Workshop of the LHC LLP Community

CERN, Geneva

26 April 2017

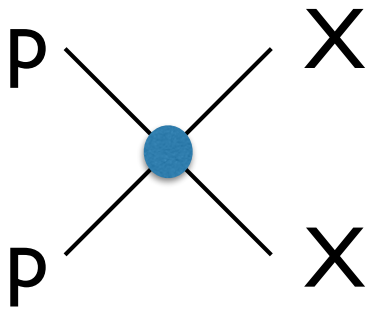
Objective:

Find current gaps in coverage of LLP signature space, and outline how (new) triggering strategies can help fill those gaps.

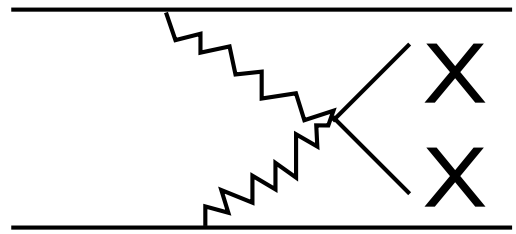
This requires some parameterization of the signature space, so we can look for holes in coverage systematically.

LLP Production Modes

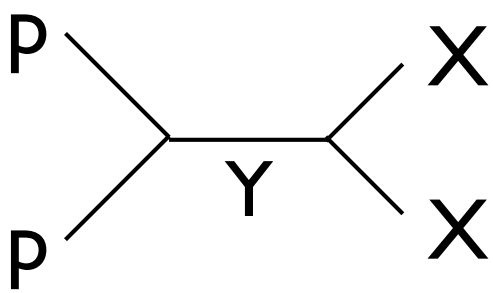
(See Simplified Models summary)



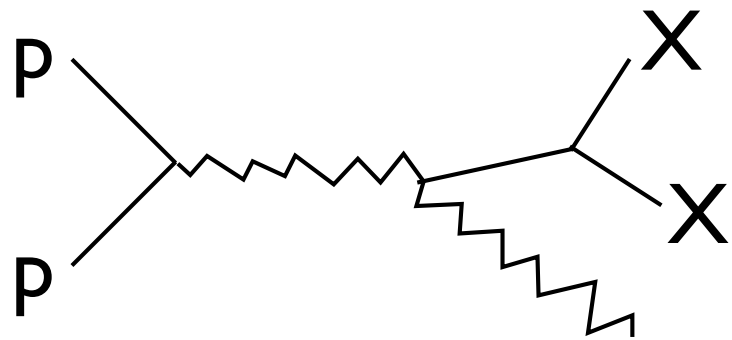
Pair Production



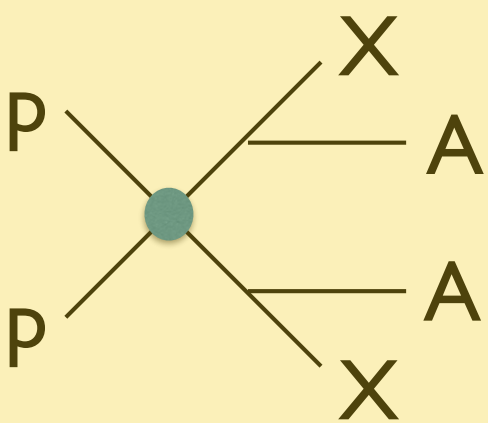
VBF



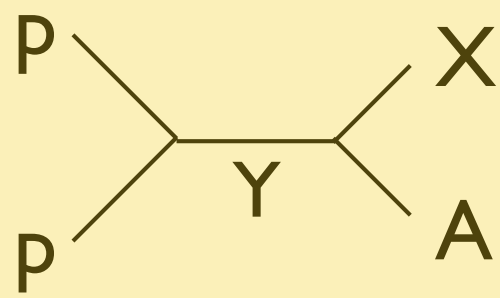
Resonance



Associated Production



Heavy Parent



Single Production

A = invis, j, top, W, Z, L, h (oof…) … maybe even γ?

LLP Decay Modes

Many possibilities, but keep it simple for now while ensuring coverage:

$X \rightarrow$ $\mu\mu$, ee, $\tau\tau$, jj, $\gamma\gamma$

for simplicity either
gauge- or
Yukawa-ordered

$X \rightarrow$ μ, e, τ, j, γ + invis

(GMSB-like)

Keep in mind: ideally want to examine three scopes:

1. current detector hardware (ATLAS, CMS, LHCb)
   focus on (new) algorithmic trigger strategies

2. Proposed HL-LHC hardware upgrades
   which upgrades are better?
   new uses? any upgrades particularly good for LLP?
   new ideas for upgrades?

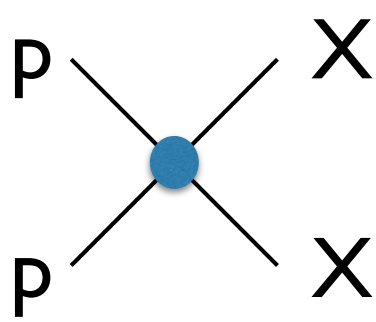
Experimentalists: get us up to speed! :)

3. Blue-Sky possibilities within HL-LHC timeframe
   new detectors, weird ideas, …

Identifying Gaps in Coverage

Examine X → μμ, ee, $\tau\tau$, jj, γγ to try and identify gaps in coverage of current triggers.

Crucial simplification: from a trigger point of view, the most difficult production mode is simple **Pair Production**, so let's only consider this right now:

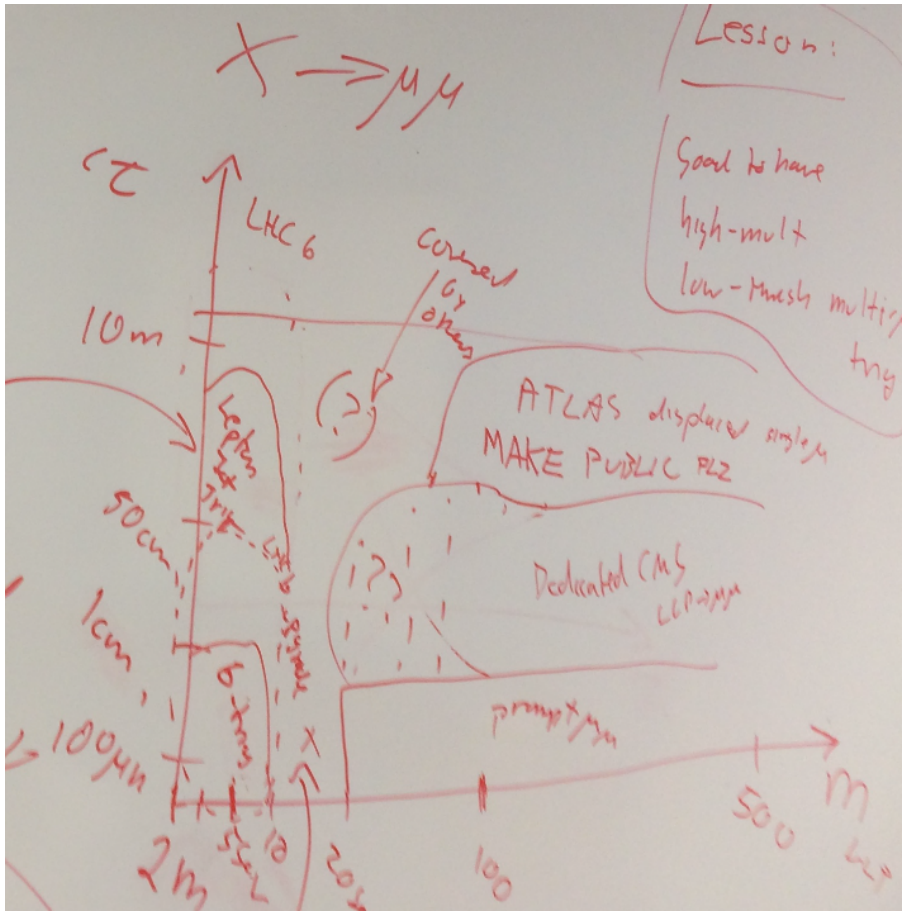


Pair Production

Identifying Gaps in Coverage

$X \to \mu\mu$

Look at LLP mass-lifetime plane.



Coverage very good

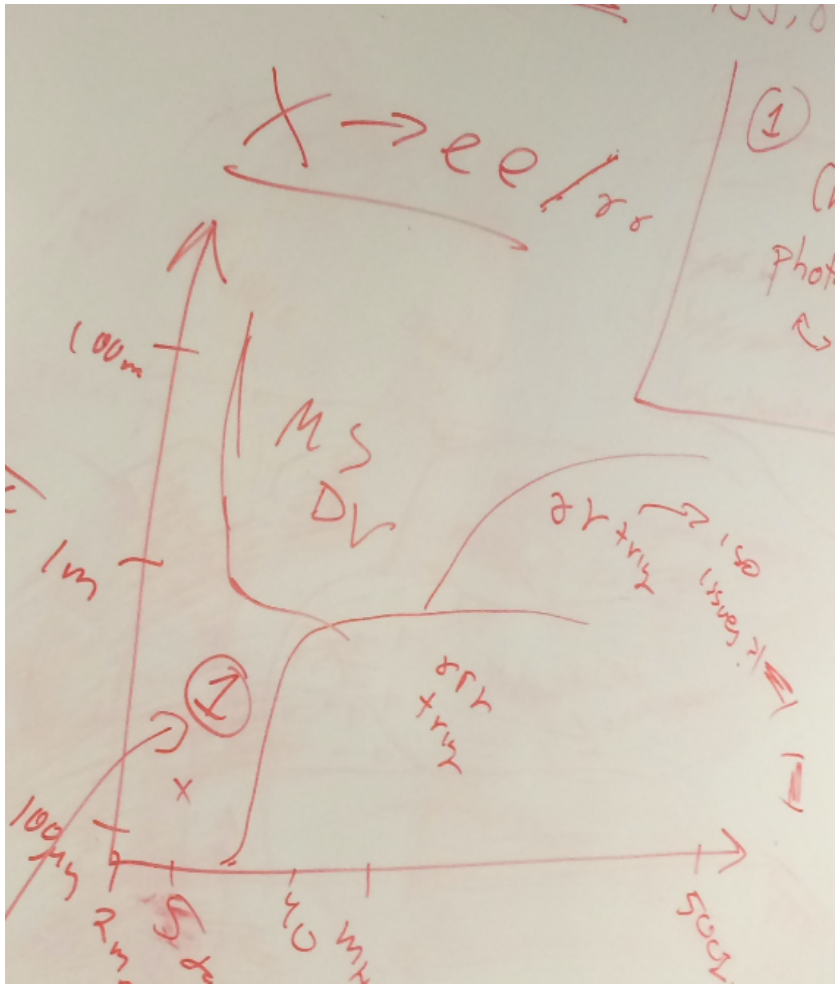
In some places, may have isolation issues.

Could be helpful (also for showers?):
trigger for soft high-multiplicity muons?

(All of these diagrams are very schematic!)

Identifying Gaps in Coverage

X → ee/γγ



Coverage good, except for m < 10s of GeV and dominant decay in tracker

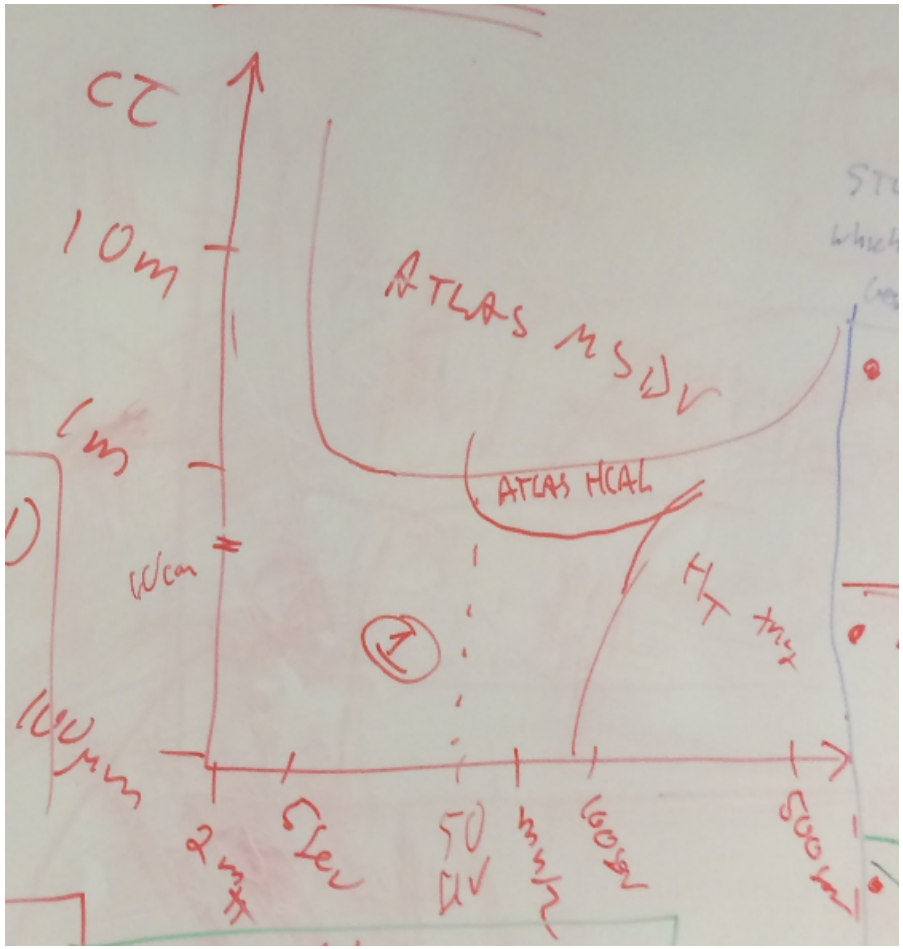
In that region, you're stuck with mono-jet etc searches

For ee, maybe no problem since usually such LLPs also decay to muons.

For γγ, genuine gap in coverage. No obvious fix.

Identifying Gaps in Coverage

$X \rightarrow jj$



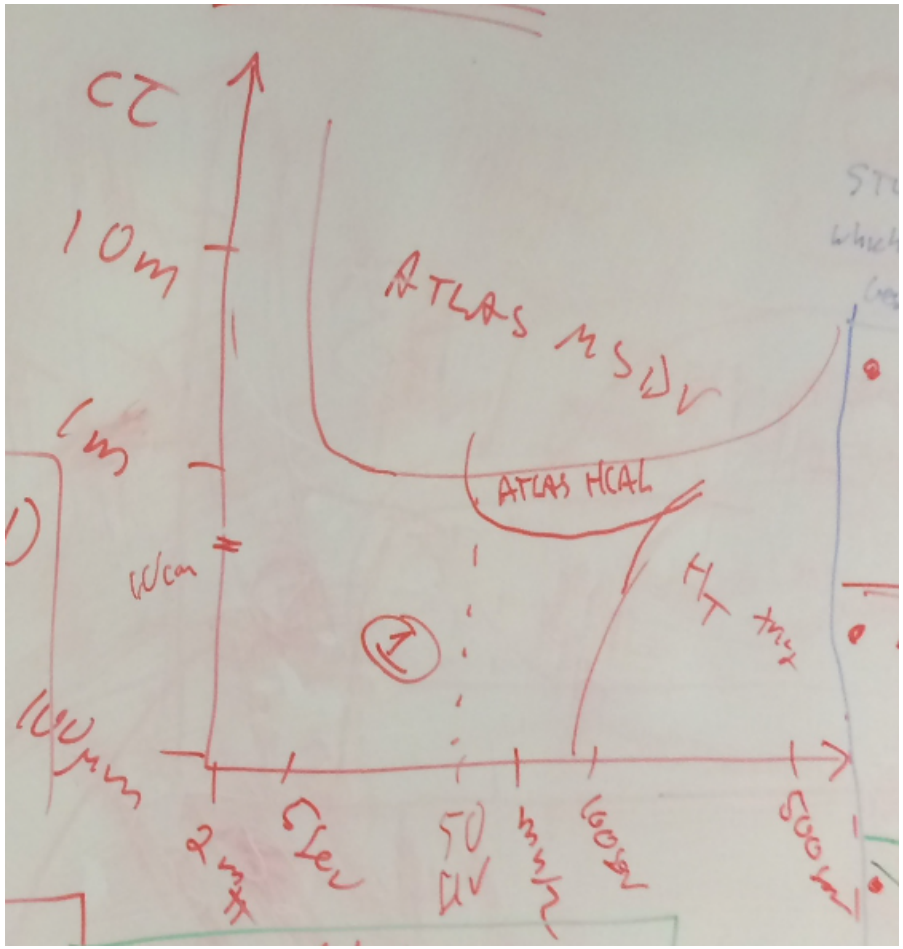
No coverage of pure pair production for decays in tracker and m < ~ 100 GeV

Can you construct hybrid trigger that looks for "jet activity @ L1" + "displaced stuff in tracker"?

CMS already does this! Bandwidth limited!

Identifying Gaps in Coverage

X → jj



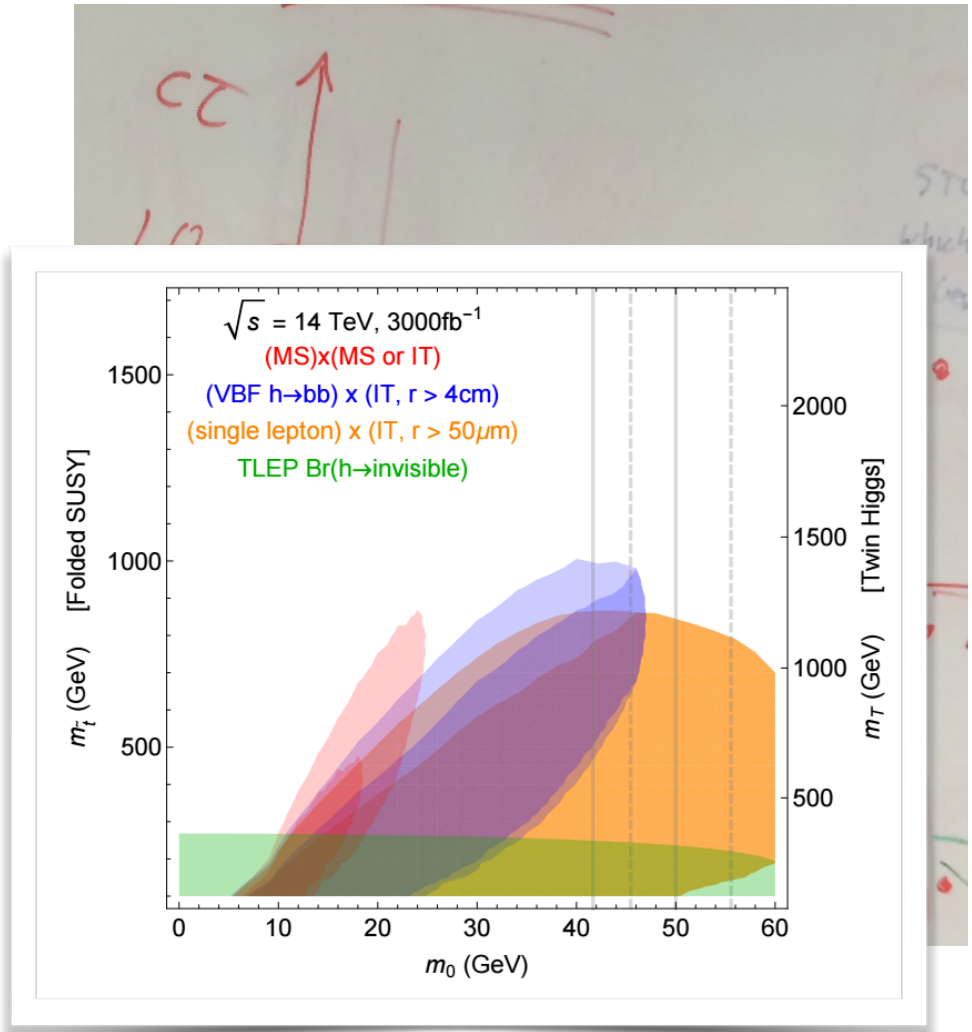
No coverage of pure pair production for decays in tracker and m < ~ 100 GeV

So any jetty hybrid DV trigger won't catch e.g.

h → XX,
X → hadrons

Identifying Gaps in Coverage

X → jj



No coverage of pure pair production for decays in tracker and m < ~ 100 GeV

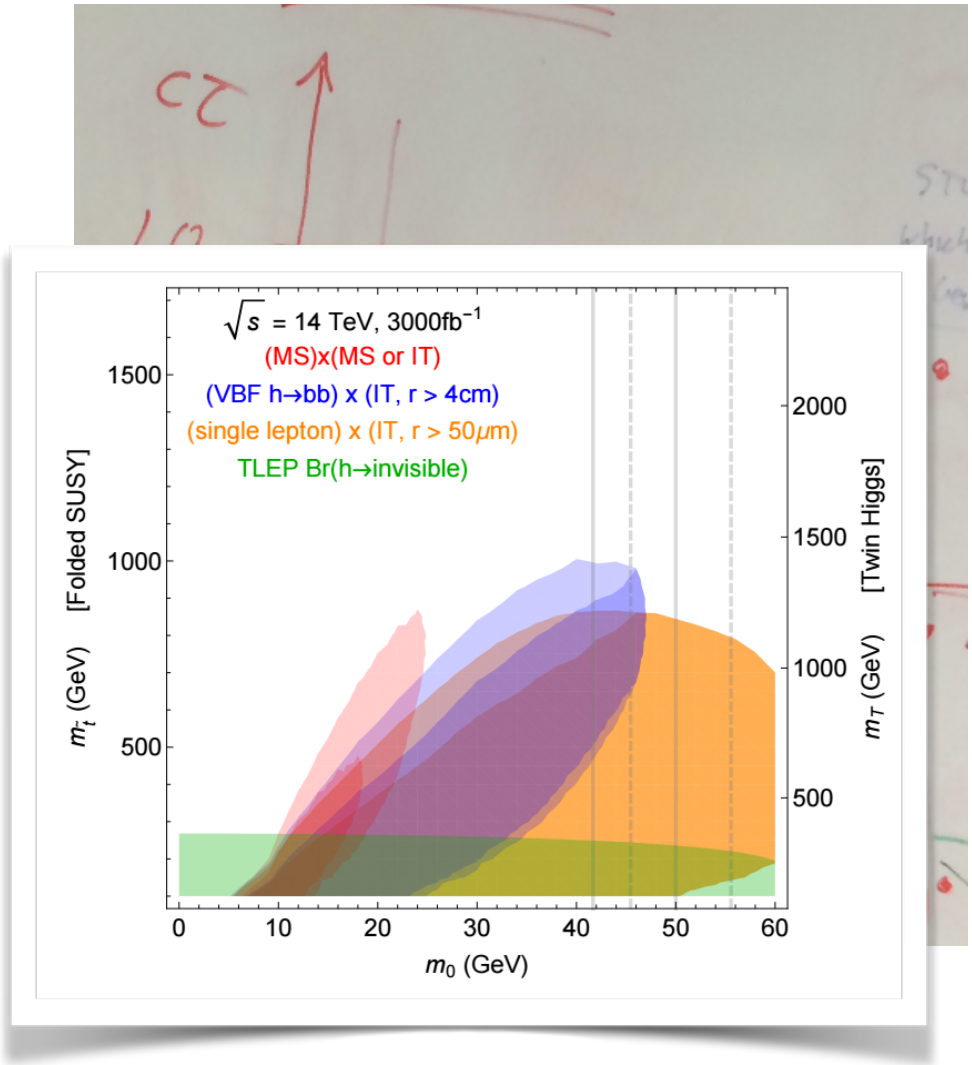
Can you play with VBF + displaced hybrid triggers?

No, VBF is going to be as difficult as just HT or jet pT, and ultimately not much better than VH.

in theory space, VH and VBF production simplified models are obviously highly correlated…

Identifying Gaps in Coverage

X → jj



No coverage of pure pair production for decays in tracker and m < ~ 100 GeV

No trigger solution here for ATLAS/CMS!

Just use prompt triggers to inclusively record VH (already on tape, no need for hybrid triggers) and do off-line search for DV in trackers!

Some Observations

At long lifetimes, the ATLAS MS DV triggers reign supreme. Use them for all searches!

Hadronic decays in tracker are difficult. CMS displaced jet triggers are as good as we'll ever get (probably) due to bandwidth limitations.

Can ATLAS & CMS adopt each other's strategies? (should they?)

Holes in Coverage

XX pair production,

$X \rightarrow ee, \gamma\gamma, jj, \tau\tau$

for "light" m and decays in tracker

LHCb should be very competitive in this region once their software trigger goes online in 2019

New triggers?

There is one new CMS high-level trigger that could be very useful:

Consider $X \rightarrow \tau\tau$

τ L1 thresholds are much lower than jets due to calo shape

two τ pT thresholds
20,12 GeV @ L1,
35,25 GeV @ HLT

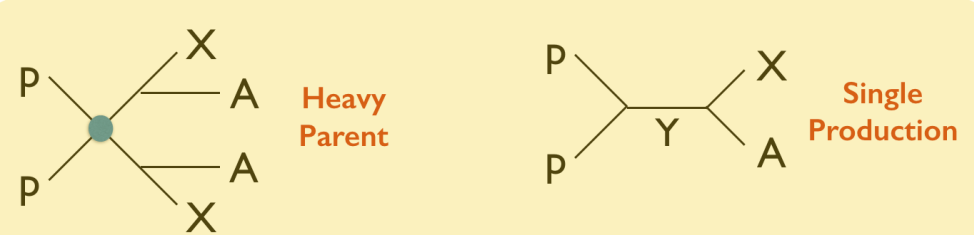
optimized for $h \rightarrow \tau\tau$
but inefficient for
$h \rightarrow XX$, $X \rightarrow \tau\tau$

New CMS trigger suggestion:
run displaced jet reconstruction on L1 τ seeds

Would be very sensitive to e.g. $h \rightarrow (X \rightarrow \tau\tau)(X \rightarrow bb)$ and many other models (light boosted X decaying hadronically, not just $\tau\tau$)… very physically motivated.

New triggers?

Don't the other production modes suggest new hybrid prompt + displaced triggers?



Not really…

The prompt triggers for t (t), V(V), l(l), h(h), tau(tau), gamma mostly are efficient for the cases we'd consider. (pending further checks..)

New triggers?

Two concrete suggestions:

1. **a new CMS displaced tau trigger**
2. possibly a high-multiplicity soft muon trigger

Apart from this, it seems that the current trigger menu is fairly optimal (given hardware limitations) for LLP searches.

(not considering shower production models for LLPs)

(obviously pending further checks & discussions…)

Implement (especially) that displaced tau trigger, move on to think about the required prompt searches!

Looking to the Future

Could we have a high-level trigger for general BSM LLPs decaying in tracker? ("generalized b-tagger")

CMS displaced dijet kinda does that now, but is not run on every L1 stream.

will CPU improvements help?

Could template tracking methods (FTK etc) reduce CPU load to run displaced reconstruction on all the rest?

Could template library be expanded to include some LLP signatures that the SM can fake, and then use the template tracking as a VETO and find LLP candidates quickly?

Blue-Sky HL-LHC Upgrades

Could extra tracking layers very close to beam pipe qualitatively increase sensitivity to e.g. short-lived LLPs?

POSSIBLE

but depends on character of b-quark background to LLP searches in that regime, which has not been studied

THIS STUDY NEEDS TO BE DONE (also just for the sake of offline searches)

can be done (at first pass) entirely with software, unlike many other LLP studies!

Blue-Sky HL-LHC Upgrades

One possible upgrade is sort of 'simplified' tracking at L1 (stups and tracklets)
This could lead to identification of DVs at L1!

Another is a timing layer at r ~ 1.2m with 30ps resolution, would be sensitive to LLPs with displacement > ~ cm

(both of these are originally for PU reduction and e.g. h->gaga measurement, but could be very useful for LLP trigger & searches)

What are the backgrounds?

Theorists should study these for LLP utility!

To Do's:

Existing triggers for LLPs:

Already very good coverage. **Can we get a full list?**

New trigger studies:

CMS displaced jets on tau L1 seed
high multiplicity soft muons

Offline study:

b-quark backgrounds for LLPs with d < mm.
Modified b-tagger? Backgrounds?
(both for future trigger possibilities and offline searches)

Offline Searches:

Point of white paper. Can mostly be done with existing triggers!
Most important currently uncovered signal is inclusive VH, H->LLPs decaying in tracker