Exploring Track Trigger Parameters for Exotic and Long-Lived Particle Searches

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Motivation and Goals

- Current ATLAS and CMS triggers are not sufficient for all long lived particle (LLP) and exotic searches.
  - No tracking information in hardware level (first stage of trigger).
  - For many LLPs, track signatures are the most conspicuous feature.

- Future hardware-based track triggers could be adapted to better accommodate these searches.

- Our study is looking at the best parameters for such a trigger in the context of a range of typical LLP and exotic model signatures.

Choice of Models / Signatures

- Difficult to trigger on:
  - Low pT:
    - Soft Unclustered Energy Patterns (SUEPs)
    - Higgs Portal
  - High d0:
    - Displaced leptons
  - Only signature is a track:
    - Stable charged particles

- As displaced vertices are a common part of many signatures - we wanted to include a model that has them.

Study Structure

For each model:

- 10,000 events for each model, mediator mass, and lifetime.
- Look at applicable parameters (pT, d0, number of tracks).

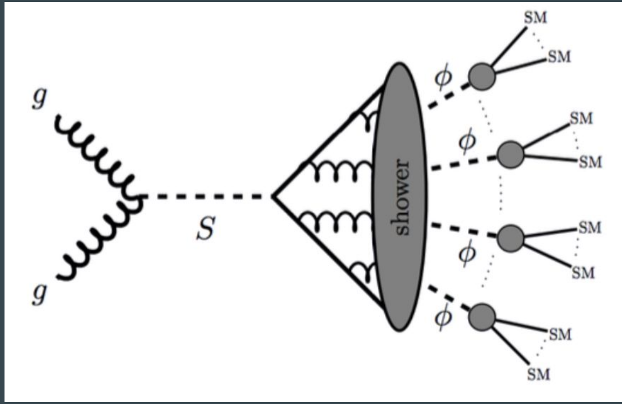
Apply cuts in three stages:

- Detector acceptance
- Cuts on track parameters of interest
- Number of remaining tracks

Check efficiency for each cut combination.

SUEPs

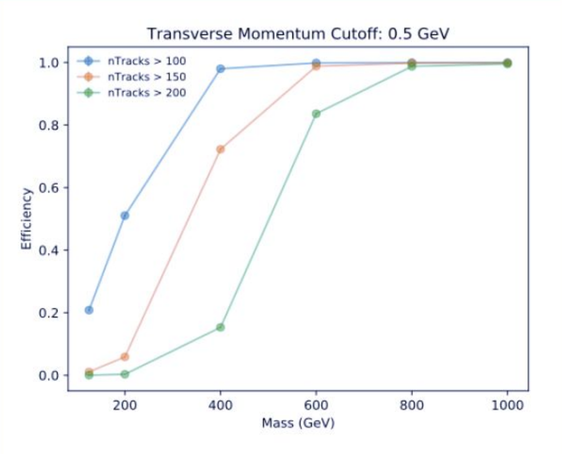
- SUEPs one of the easier to analyze thanks to prompt decay.
- However - a lot of low pT tracks.
- Looking at range of scalar masses between 125-1000 GeV.
- Cut stages:

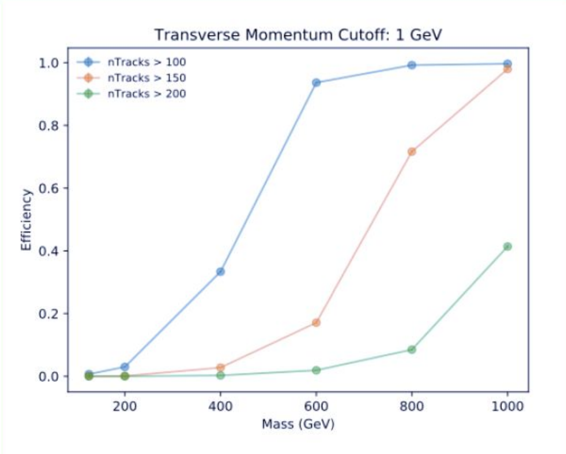


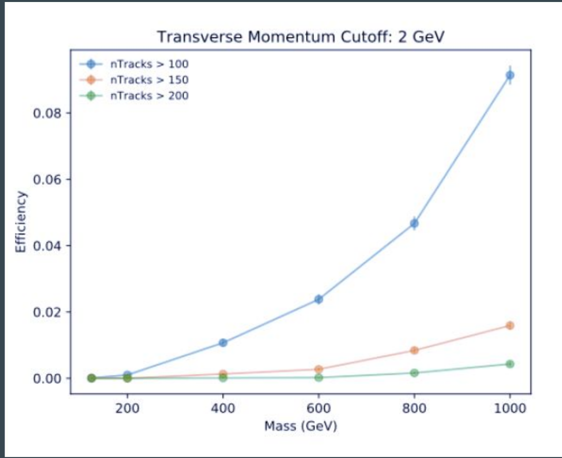
Knapen, S, et.al. “Triggering Soft Bombs at the LHC.” *Journal of High Energy Physics*, vol. 8, 2017.

Cut	Value	Stage
Charged	Yes	Stage 1
Stable	Yes	Stage 1
Eta	≤ 2.5	Stage 1
p_T	$> 0.5, 1, 2$ GeV	Stage 2
Number of tracks	$> 100, 150, 200$	Stage 3

SUEP Results



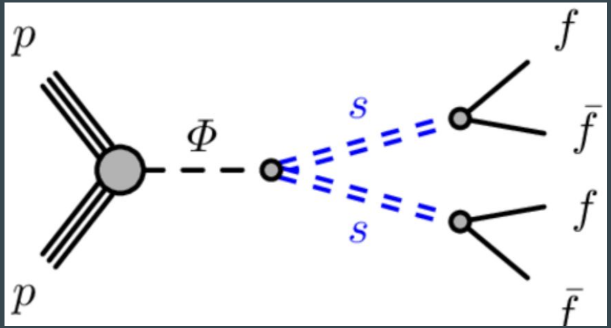




- Low mass - low efficiency.
- pT more impactful than number of tracks.
- Can use HT as additional measure due to low 2 GeV pT cut efficiencies.

Higgs Portal

- More difficult to analyze since displaced.
- 1, 0.1, 0.01 ns lifetimes.
- Range of scalar masses between 5 - 55 GeV.
- Cut stages:

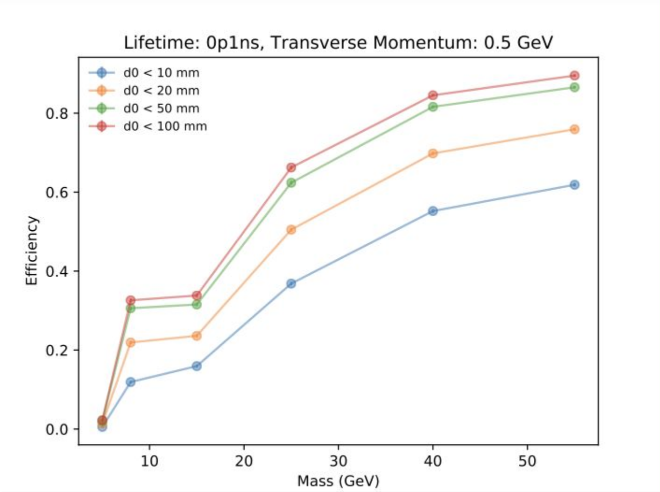


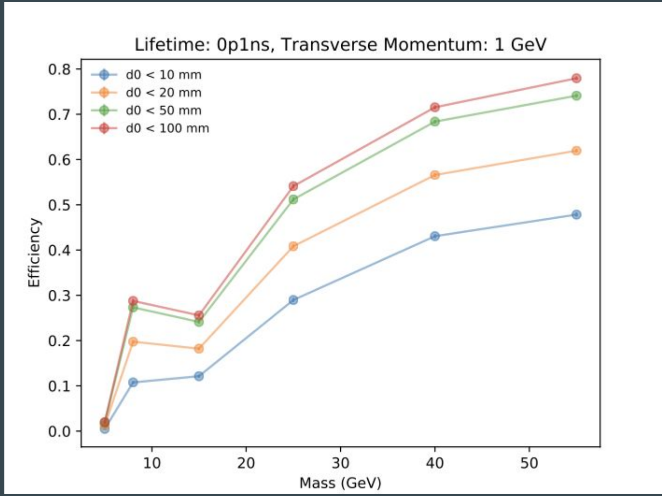
Aad, G, et al. "Search for Long-Lived Neutral Particles Produced in Pp Collisions at Sqrt(13 TeV) Decaying into Displaced Hadronic Jets in the ATLAS Inner Detector and Muon Spectrometer."

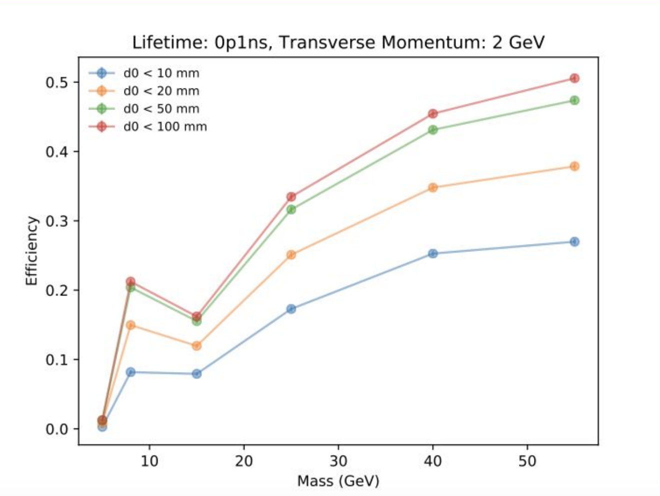
Cut	Value	Stage
Charged	Yes	Stage 1
Stable	Yes	Stage 1
Eta	≤ 2.5	Stage 1
Decay vertex	None or ≥ 200 mm from production vertex	Stage 1
Production vertex	< 300 mm from origin	Stage 1
p_T	$> 0.5, 1, 2, 5$ GeV	Stage 2
d_o	$< 10, 20, 50, 100$ mm	Stage 2
d_o	> 2 mm	Stage 2
Number of tracks	≥ 5	Stage 3

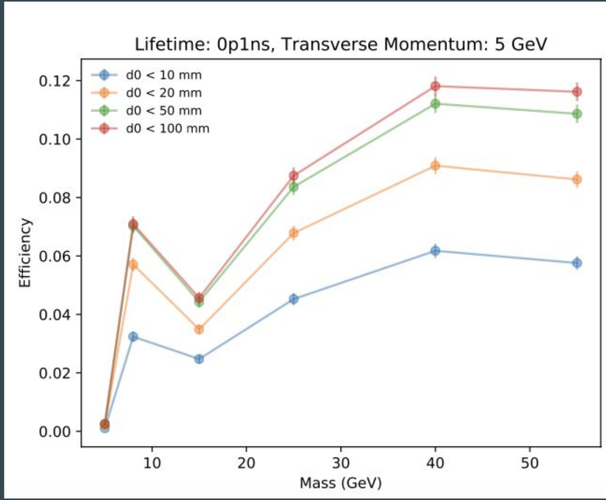
Higgs Portal Results

- Low mass - low efficiency.
- Minimal d0 impact at shorter lifetimes.
- pT more impactful than d0.



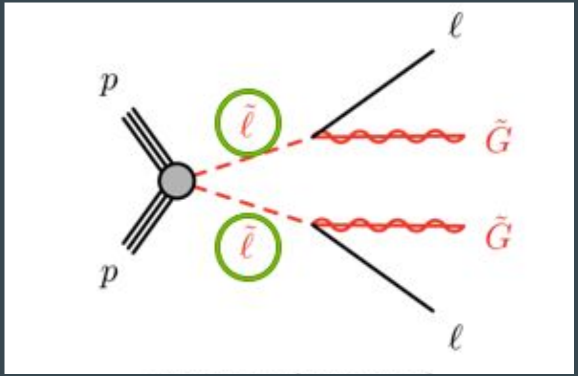






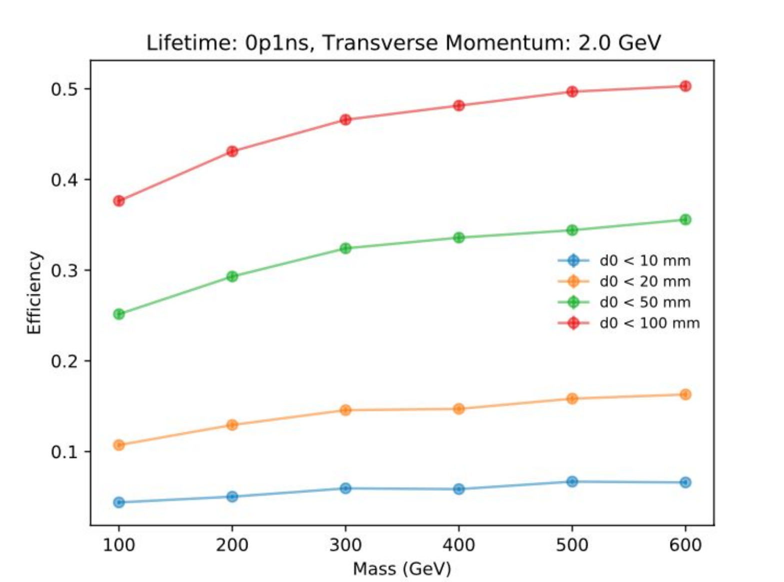
Staus

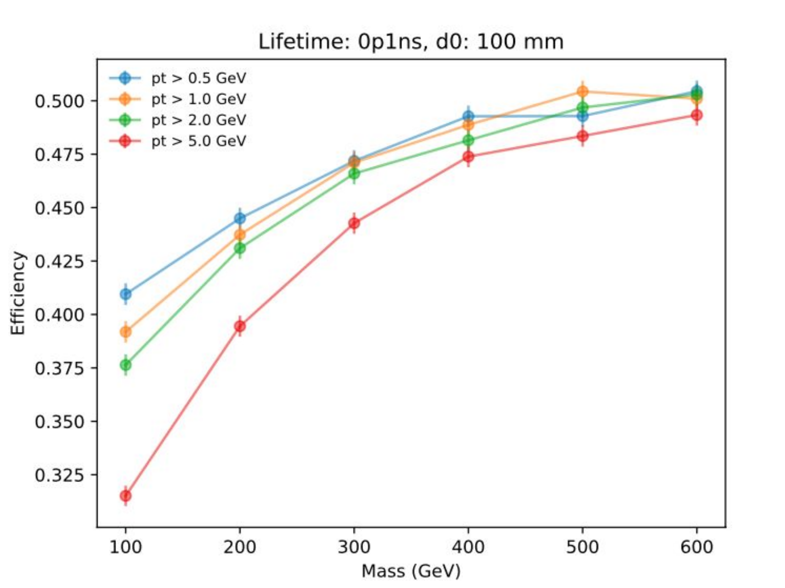
- Similar to Higgs Portal except:
  - leptonic not hadronic decay - higher pT
  - Stage 3 only requires 2 or more tracks.



Cut	Value	Stage
Charged	Yes	Stage 1
Stable	Yes	Stage 1
Eta	≤ 2.5	Stage 1
Decay vertex	None or $\geq$ 200 mm from production vertex	Stage 1
Production vertex	$<$ 300 mm from origin	Stage 1
p_T	$>$ 0.5, 1, 2, 5 GeV	Stage 2
d_o	$<$ 10, 20, 50, 100 mm	Stage 2
d_o	$>$ 2 mm	Stage 2
Number of tracks	$\geq$ 2	Stage 3

Stau Results





- Low mass results in less extreme drop in efficiency than in other models.
- d0 more impactful than pT.

Conclusions

SUEPs:

- Benefit from less restrictive pT, more restrictive #tracks.
- However - can't reduce pT due to CMS limitations - add HT as parameter.

Higgs Portal:

- Benefit from less restrictive pT, more restrictive d0.

Staus:

- Benefit from less restrictive d0, more restrictive pT.
- However - efficiency decrease due to higher d0 cut less substantial than with pT for Higgs Portal and SUEPs.

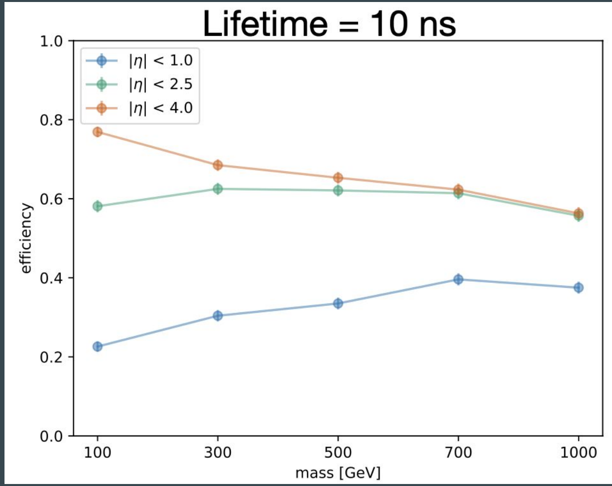
Some Additional Considerations

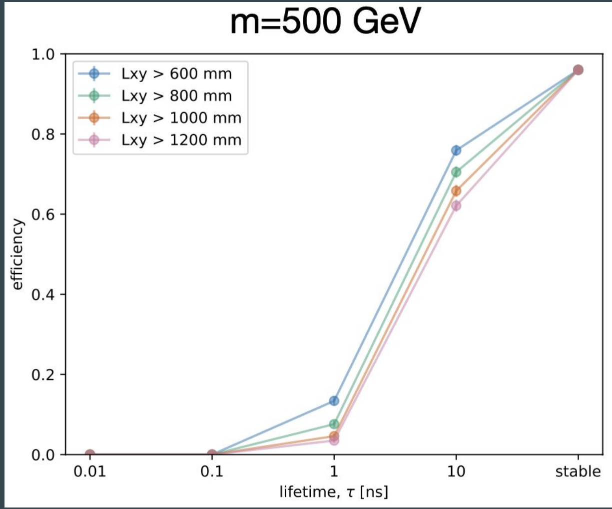
Top: Effect of different maximum eta
(Minimum Lxy = 1200 mm, minimum z=3000 mm, no pT cut)

- Important to maintain full eta range.
- Increase to highest range helpful for only 100 GeV.

Bottom: Effect of different Lxy
(|eta|<2.5, minimum z=3000 mm, no pT cut)

- Greatest improvement for 1ns.
- Still more effective to prioritize displaced leptons for 1ns.





Some Additional Considerations

Time of flight distribution:

- Currently assuming CMS L1 track information.
- Hit resolution=50ps, BS time spread and Z0 unknown.

- Mass computed with optimistic pT resolution.
  - pT=1% @ 100 GeV, above 100 GeV linear increase w/pT to 10% @ 1 TeV
- Bkg considered any non-stau tracks in event with >10 GeV.