Exploring Track Trigger Parameters for SUEPs

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SUEP Track Triggers

LLP and exotic signatures are not currently well served by existing track triggers.

This study serves to determine the best parameters for a hardware level trigger suitable for a range of LLP models.

Four signatures are considered: SUEPs, stable charged particles, displaced leptons, and displaced verticies.

Here we will focus on SUEPs. (Other signatures will use SUSY and exotic higgs models.)

SUEP? That sounds like soup. I like soup.

Sorry, not that "soup"...

SUEPs = soft unclustered energy patterns

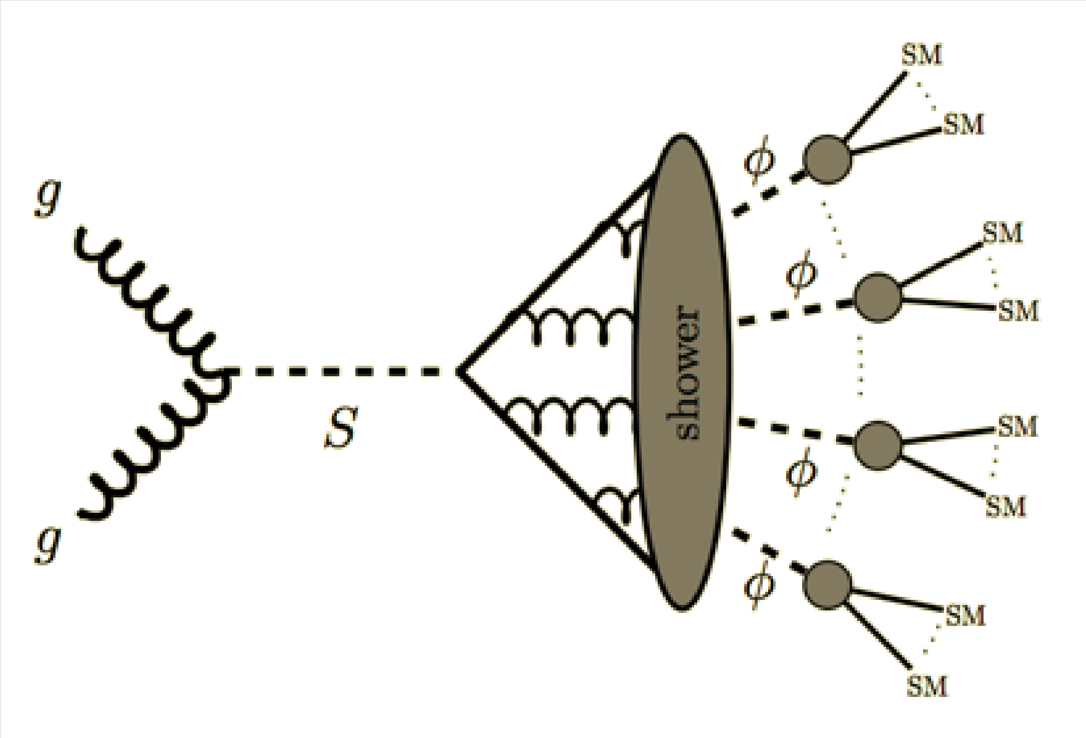
(Less tomato soup, more low momentum soft particle "soup")

SUEPs have a large collection of low transverse momentum tracks.

We start with SUEPs as it is the easiest model (no displacement).

SUEP 'Recipe'

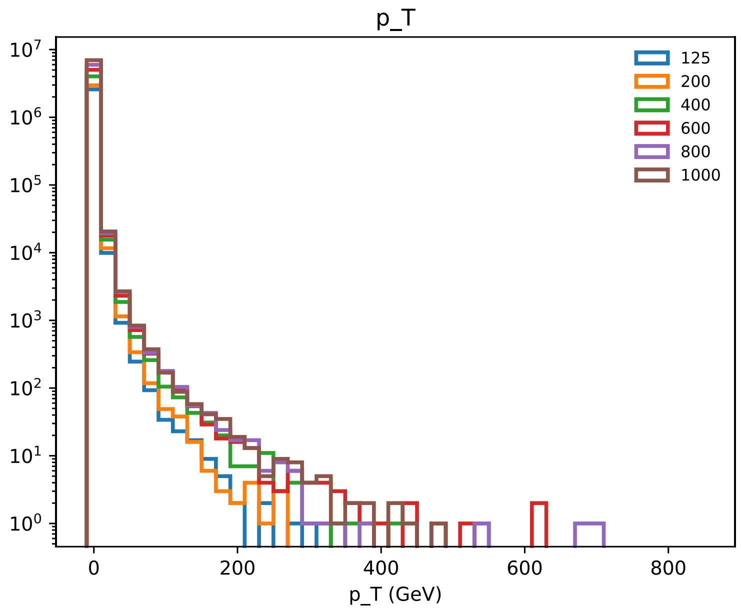
- Creating SUEPS:
  - Strongly coupled hidden valley.
  - Accessed via a heavy scalar mediator.
  - Large 't Hooft coupling, sub GeV hadronization scale --> spherically symmetric, soft spray of many dark mesons.
  - Dark mesons decay promptly back to the SM via a dark photon.
  - Momenta of the ϕ particles follow a thermal distribution. Number of particles roughly determind by the mass ratio mS/mϕ.



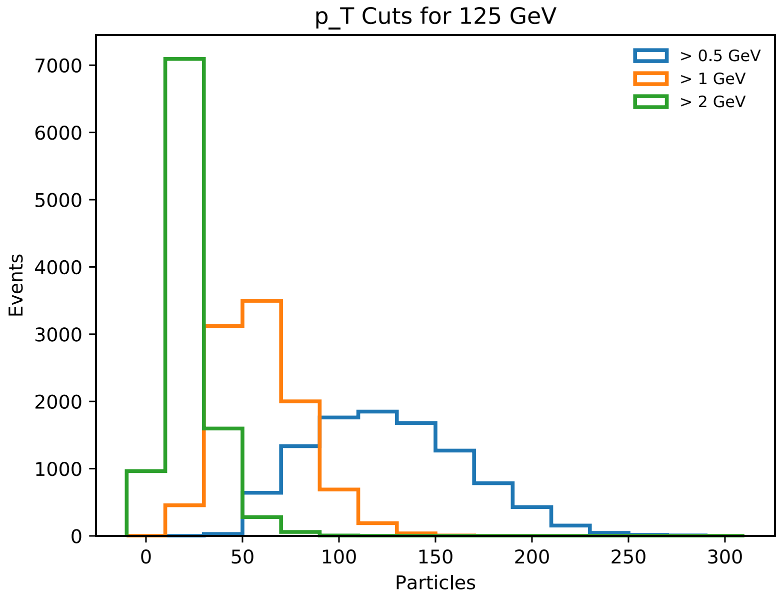
SUEP Plots

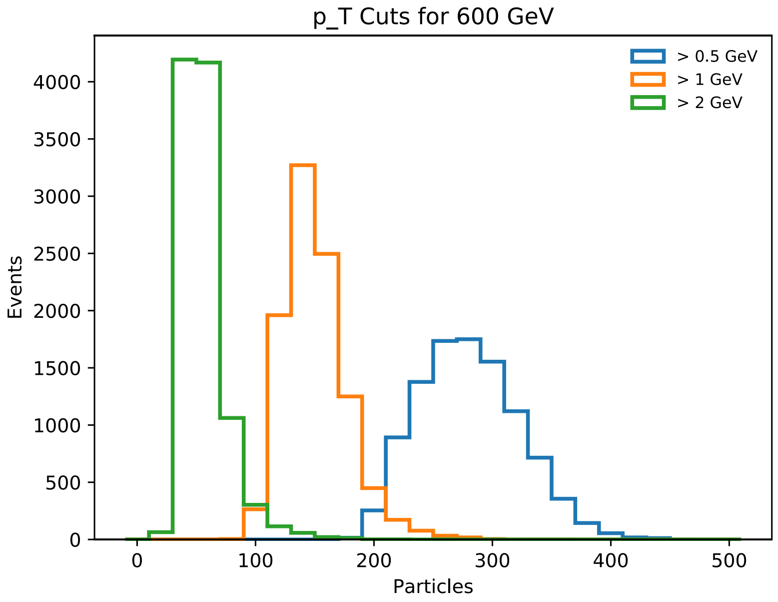
- Plots made at truth level from hepmc files generated with sqrt(s) = 14 TeV.
- Parent particles identified by first instance pid = 25 in decay chains.
- Stable particles identified by particle status of 1.
- Charged particles identified via Monte Carlo particle numbering sheet ids.
- Want to determine efficiency of possible track trigger for different track reconstruction pT thresholds and numbers of tracks.
- Events checked against conditions:
  - nTracks cutoffs of 100, 150, and 200
  - Transverse momentum cutoffs of 0.5, 1, and 2 GeV

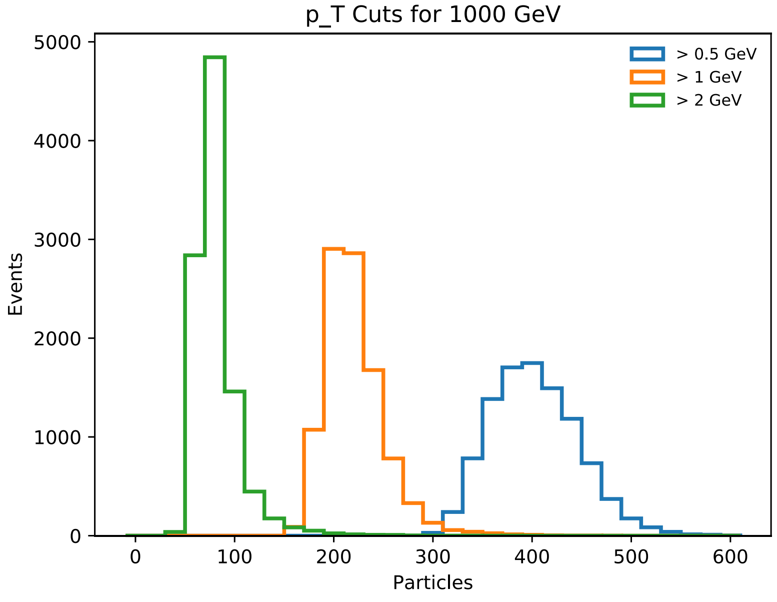
SUEP Transverse Momentum

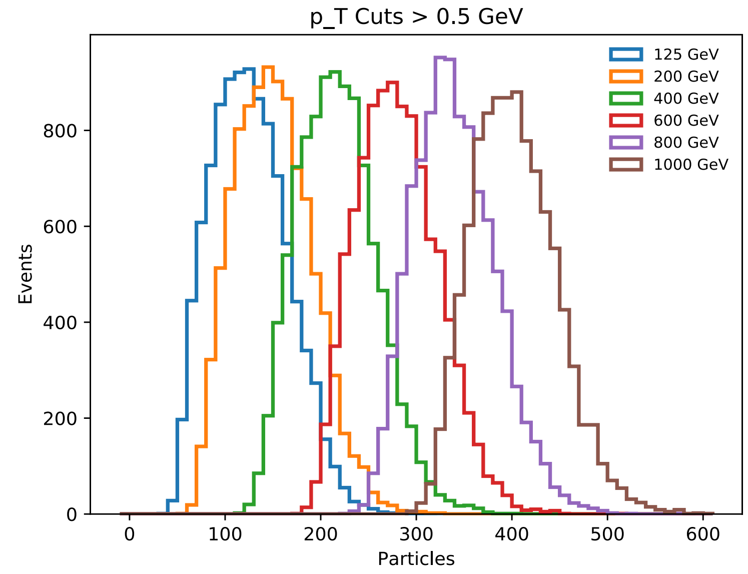


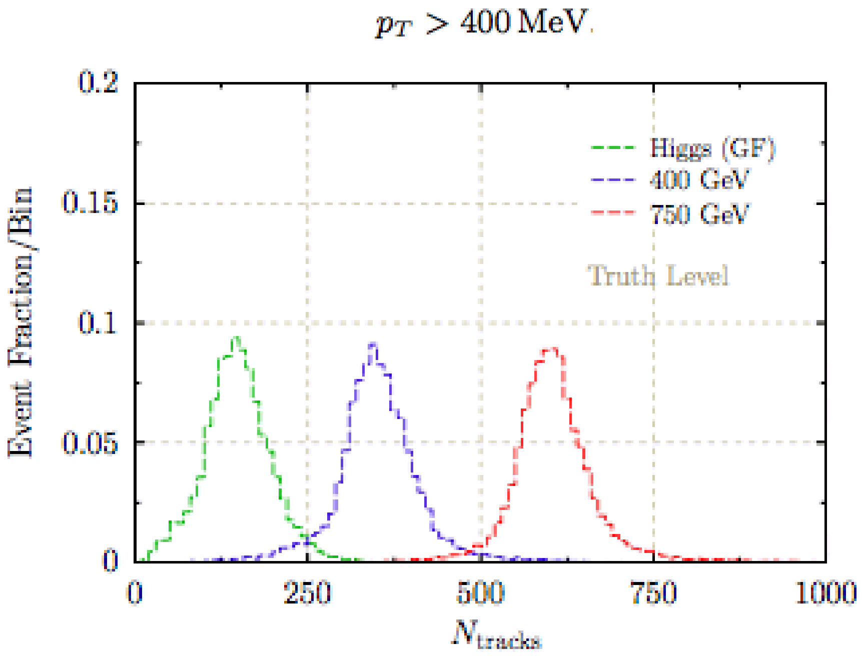
- **Left**: Eta inclusive plots for charged particle overall transverse momentum distribution.
- **Below**: Particle per event counts for fixed mass and variable transverse momentum cuts.
  - As mass increases, particle count likewise increases.
  - Transverse momentum cut at 2 GeV excessively limiting across all masses.

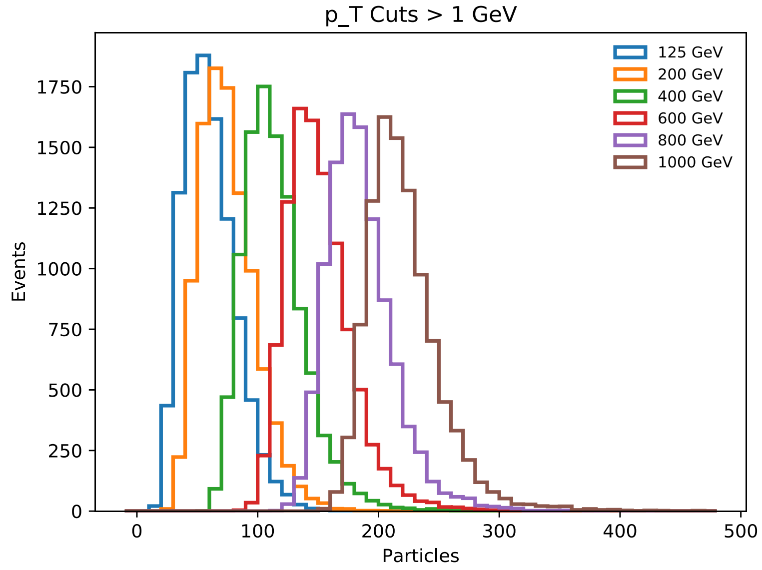


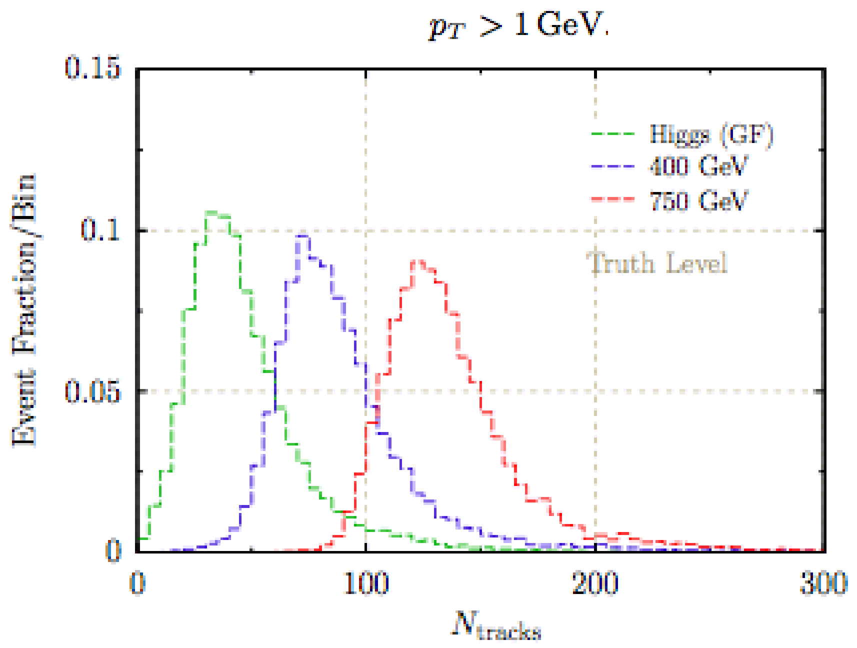












Transverse Momentum Cuts

Top:
Left: Our results for transverse momentum cutoff of 0.5 GeV.
Right: "Triggering soft bombs at the LHC" 0.4 GeV cutoff.

Bottom:
Left: Our results for transverse momentum cutoff of 1 GeV.
Right: "Triggering soft bombs a t the LHC" 1 GeV cutoff.

General shape of both plots consistent with expected.

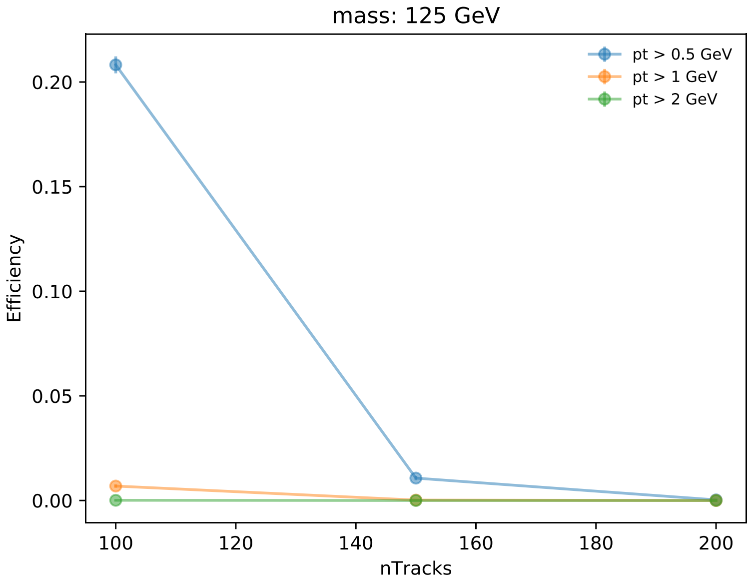
"Triggering soft bombs at the LHC": https://doi.org/10.1007/JHEP08(2017)076

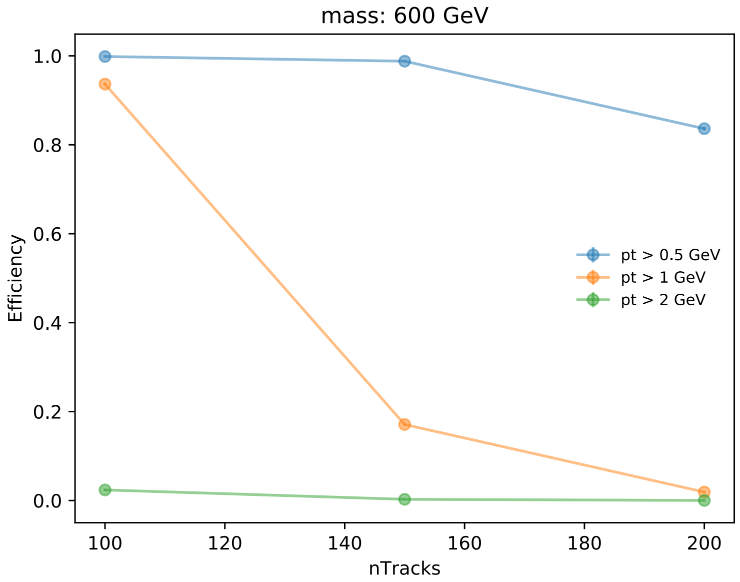
Efficiencies:

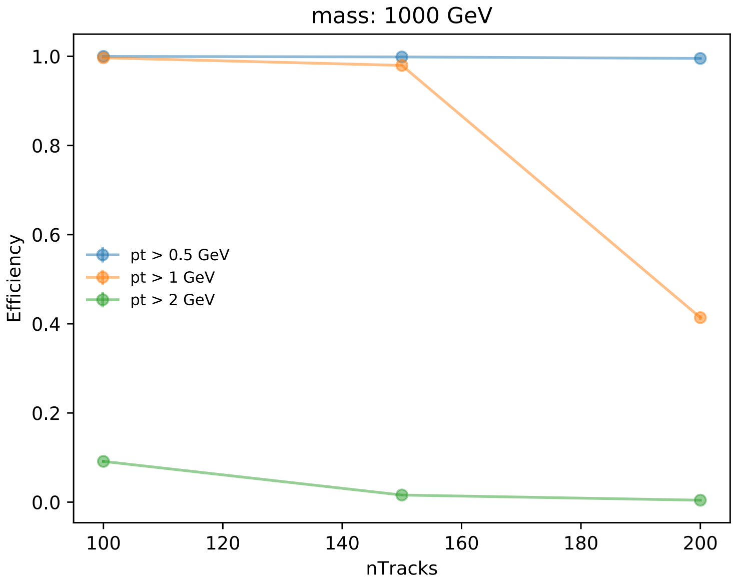
- When finding efficiencies, all particles of interest were required to have |eta| < 2.5.

- Efficiencies were then calculated for every mass, transverse momentum, nTrack combination.
  - Efficiency = events passed/total event count

- Errors propagated via binomial method.
  - Error = sqrt(efficiency (1 – efficiency) / total event count)

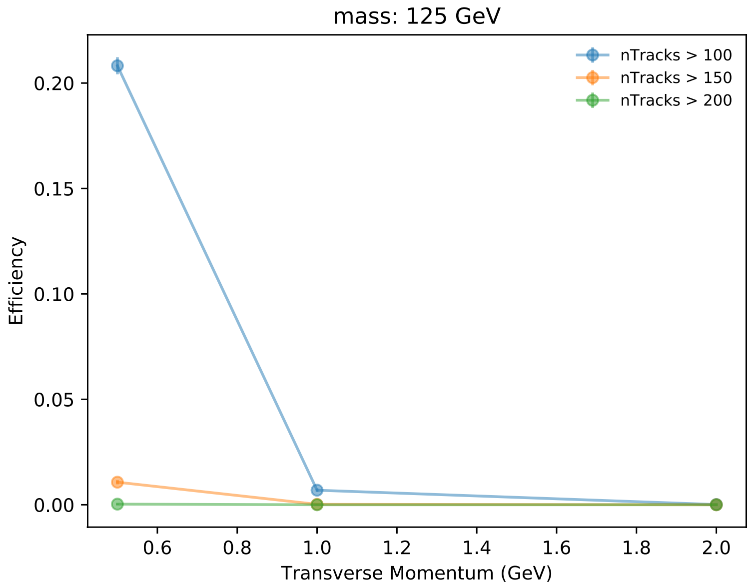


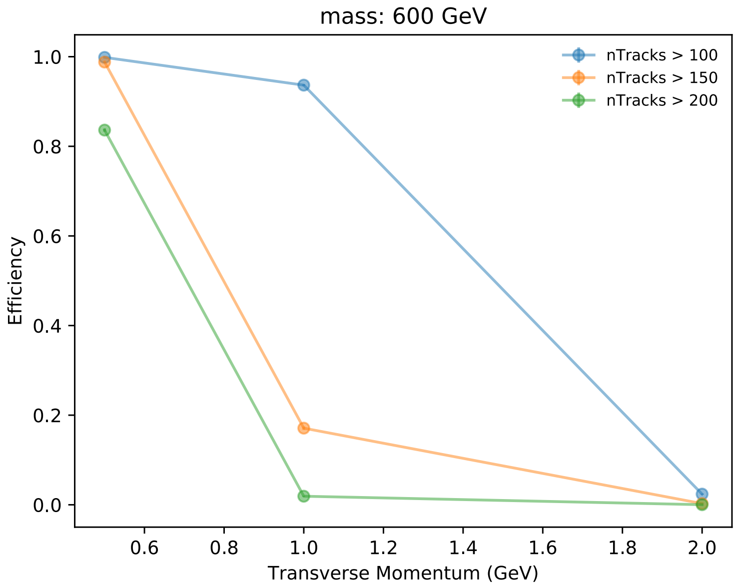


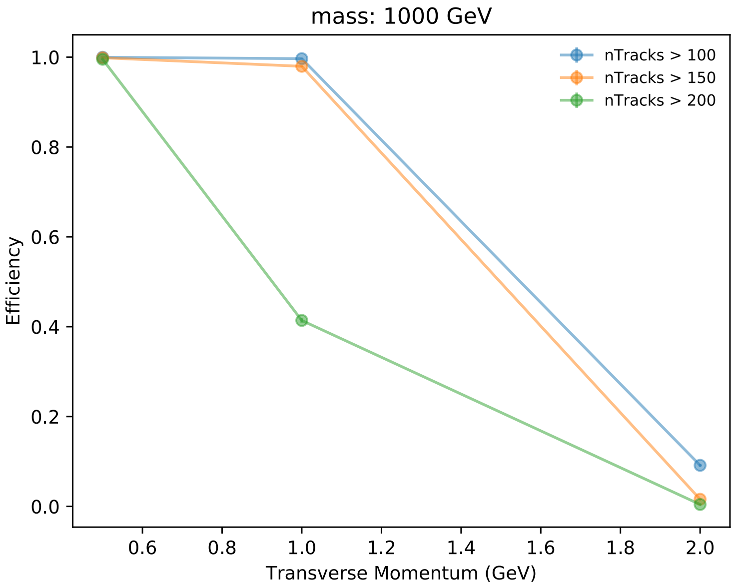


Efficiency vs. nTracks for Fixed Mass

- 125 GeV mass - efficiency low regardless of cutoffs.
- 600 GeV mass - some increases in efficiency.
- 1000 GeV mass – continued increases.
- Only mild efficiency changes with nTrack cutoff changes.

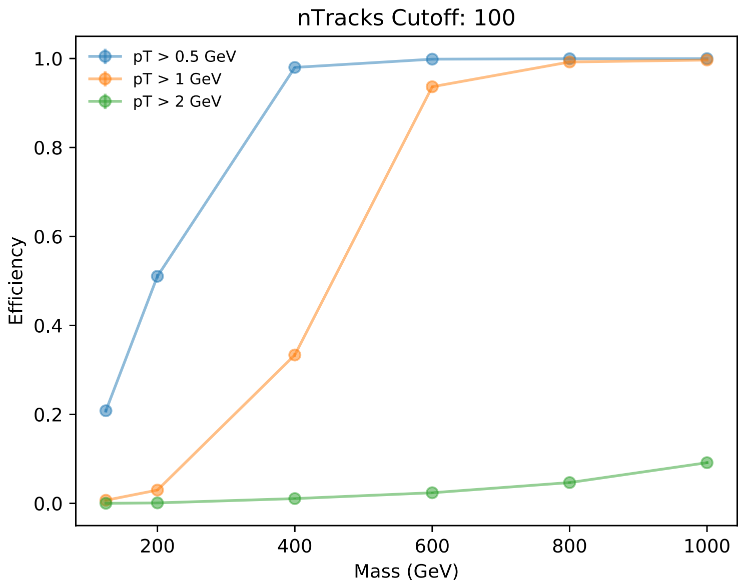


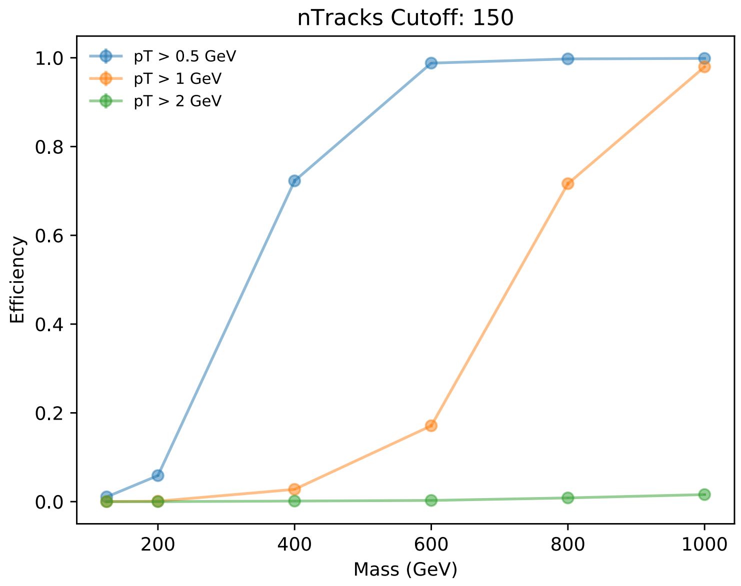


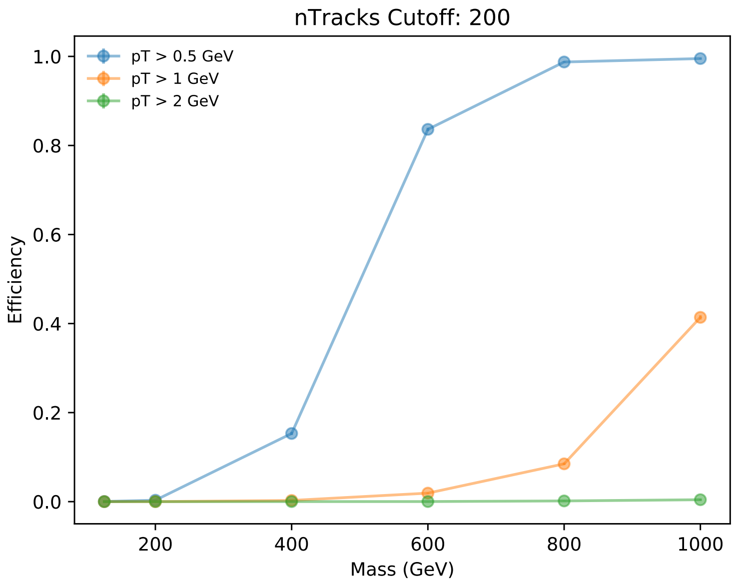


Efficiency vs. Transverse Momentum for Fixed Mass

- 125 GeV mass - efficiency low regardless of cutoffs.
- 600 GeV mass – notable increase in efficiency for low cutoffs.
- 1000 GeV mass – minor increases in efficiency.
- Choice of transverse momentum cut greatly impacts efficiency.

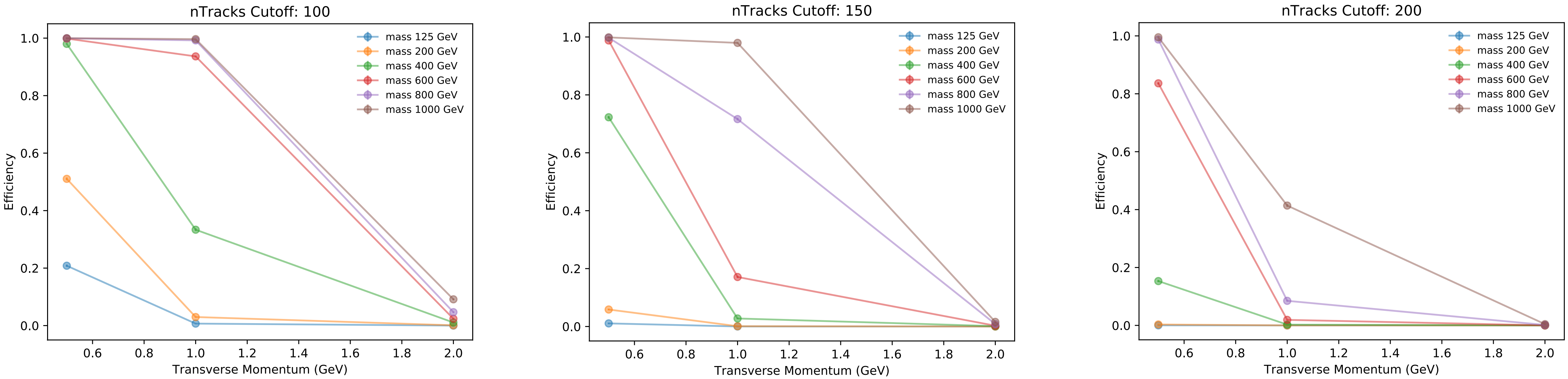






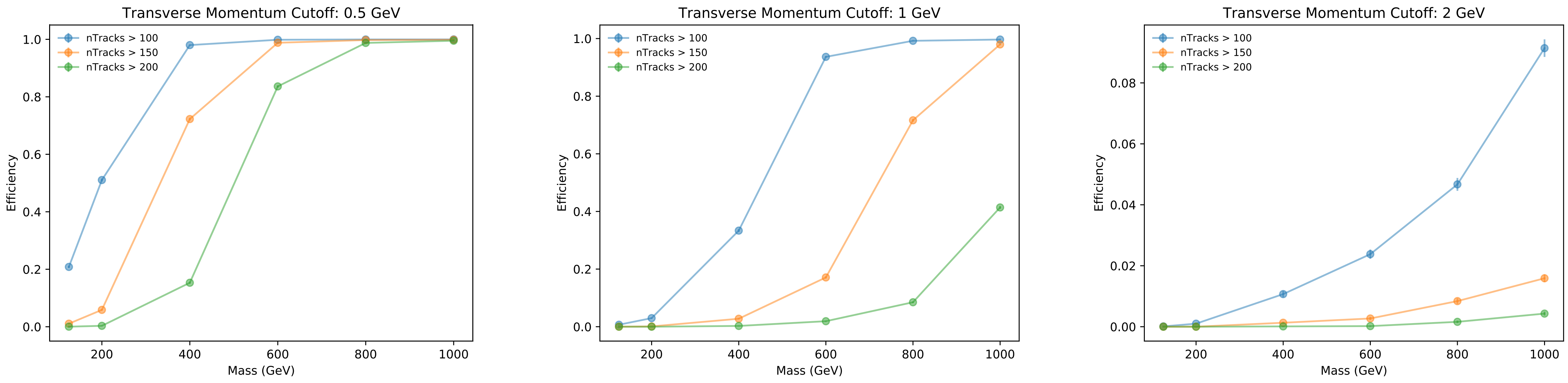
Efficiency vs. Mass for Fixed nTracks

- 100 nTracks – efficiency better with higher masses (> 400 GeV).
- 150 nTracks – minor loss in efficiency.
- 200 nTracks – loss greatest for mid transverse momentum cutoff.
- Efficiency changes greater for mass and transverse momentum.



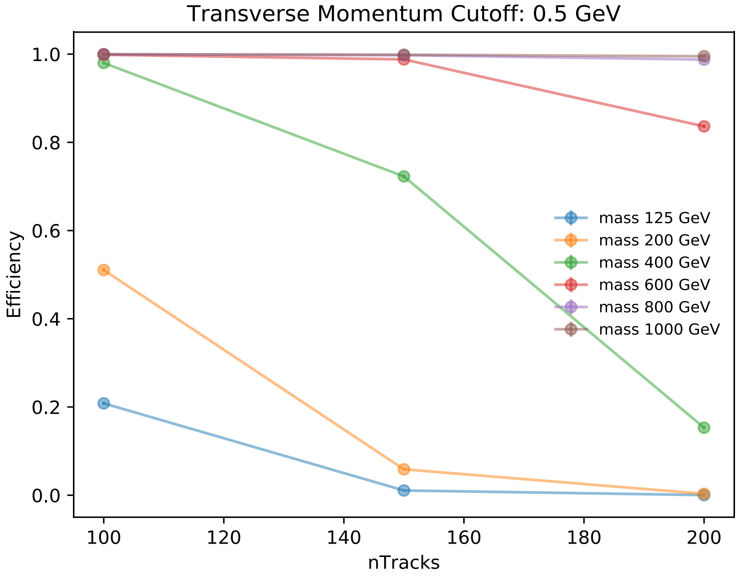
Efficiency vs. Transverse Momentum for Fixed nTracks

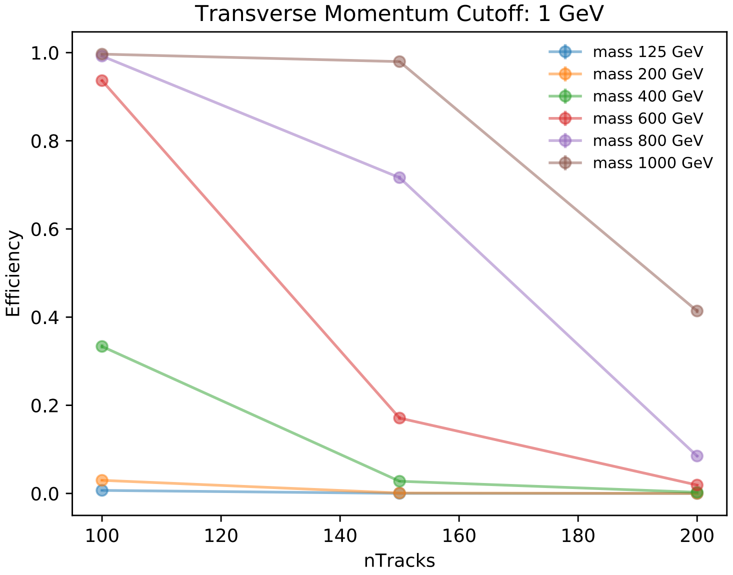
- 100 nTracks – efficiency best at low transverse momentum cutoffs.
- 150 nTracks – minor loss in efficiency.
- 200 nTracks – loss greatest for mid transverse momentum cutoff.
- Poor efficiency always with high transverse momentum cutoff.

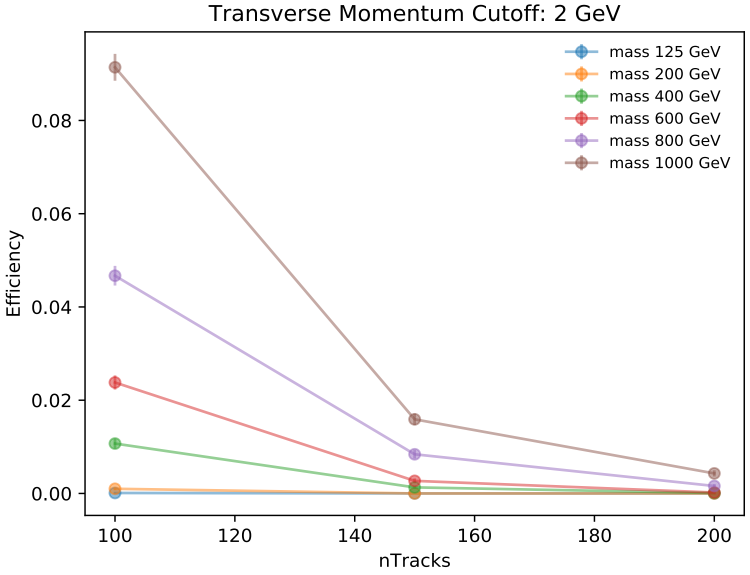


Efficiency vs. Mass for Fixed Transverse Momentum

- 0.5 GeV pT – very high efficiency at higher masses.
- 1 GeV pT– efficiencies start to decline.
  - More notable for higher ntrack cutoffs.
- 2 GeV pT– efficiency essentially zero for all cases.

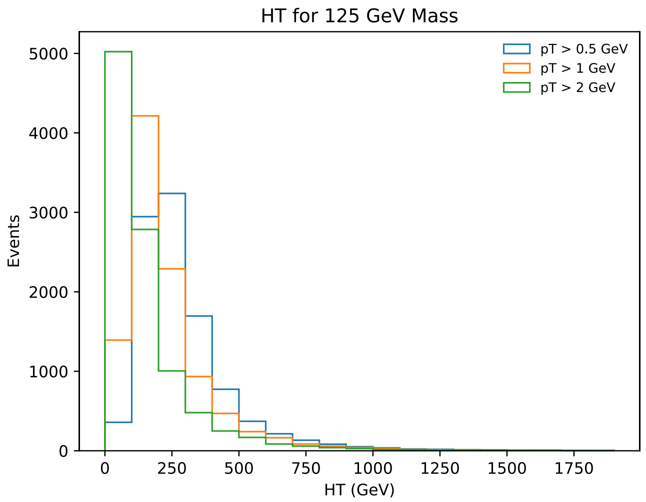


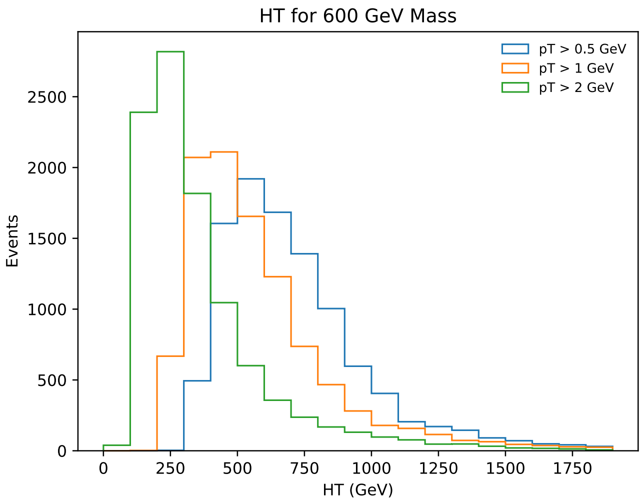


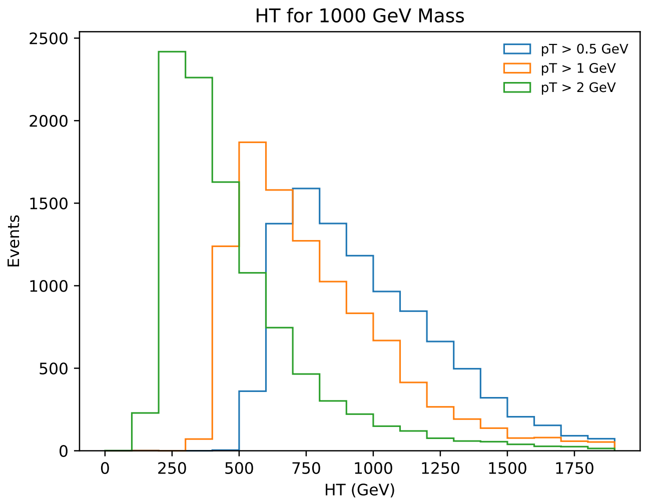


Efficiency vs. nTracks for Fixed Transverse Momentum

- 0.5 GeV pT – efficiency drops with nTrack cutoff increase.
- 1 GeV pT– efficiencies start to decline at all nTrack cutoffs.
  - Changes due more to mass not nTracks (for 0.5, 1 GeV pT).
- 2 GeV pT– efficiency essentially zero for all cases.







HT for Fixed Mass

- A CMS-style track multiplicity trigger for tracks with pT>2 GeV provides ~ no efficiency for SUEPs.
- We instead quickly considered a L1 HT trigger.
- CMS L1 HT computed from particle flow candidates with the same pT>2 GeV threshold.
- Assuming a threshold of ~450 GeV HT (from TDR), we can retain decent trigger efficiency at L1 for SUEPs.

Conclusions

- Tested possible trigger selections based on number of tracks, minimum track pT.
- Lower-mass parent particles lead to lower efficiencies in all cases.
- Minimum track pT cut had the strongest effect by far, with very low efficiency for the 2 GeV cut regardless of mass.
- Signals fairly robust to nTracks selections.
- Of use to both CMS and ATLAS

What's Next

- Complete process for three additional long-lived particle BSM models.
- Compare results of all four signature efficiencies.
- Determine best parameter set for all models.
- Provide rough estimate of background rates for trigger selections.

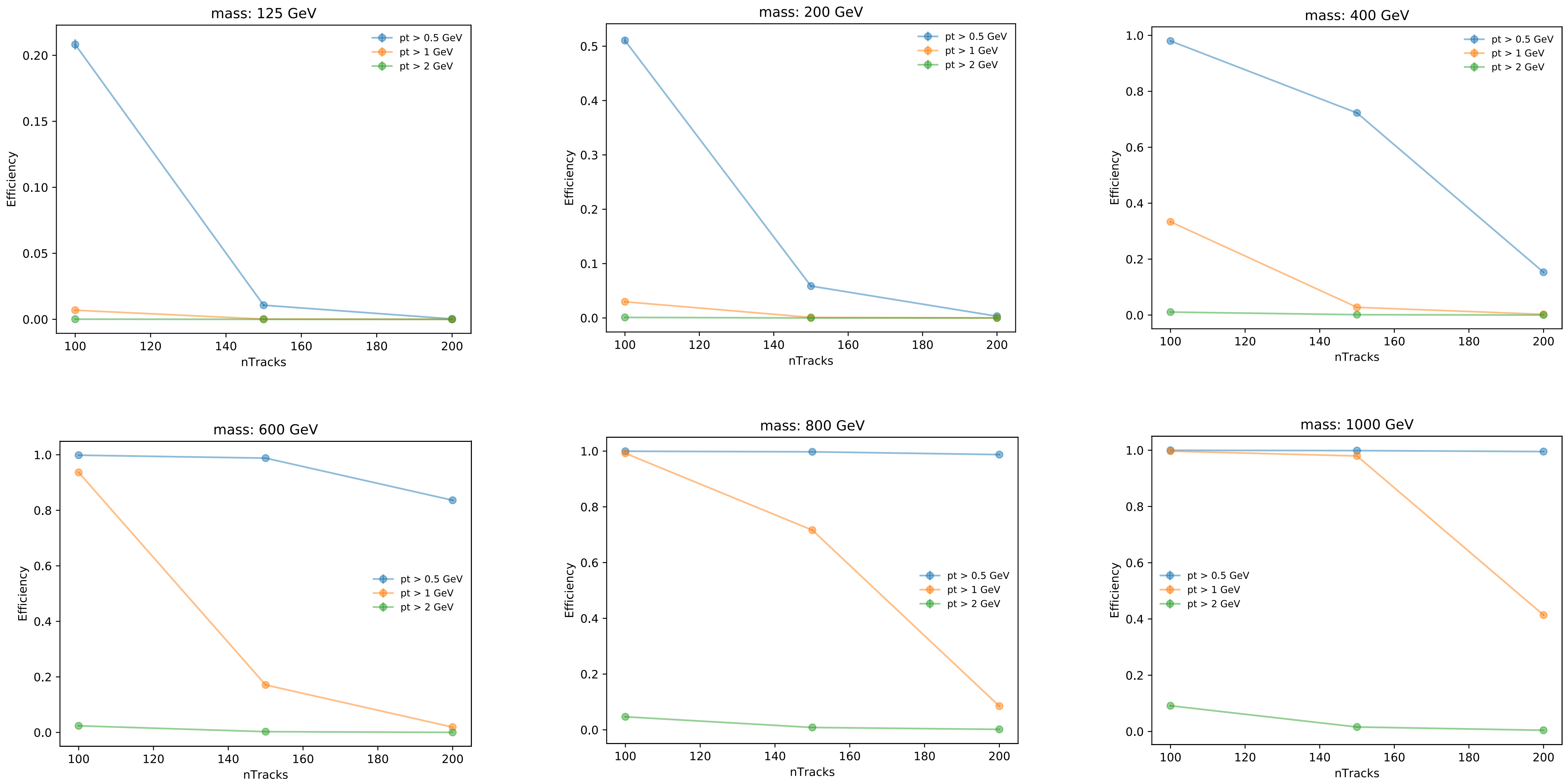
References

[1] Di Petrillo, K., Holmes, T., Pachal, K.,"Snowmass LOI", https://www.snowmass21.org/docs/files/summaries/EF/SNOWMASS21-EF9-IF4-008.pdf

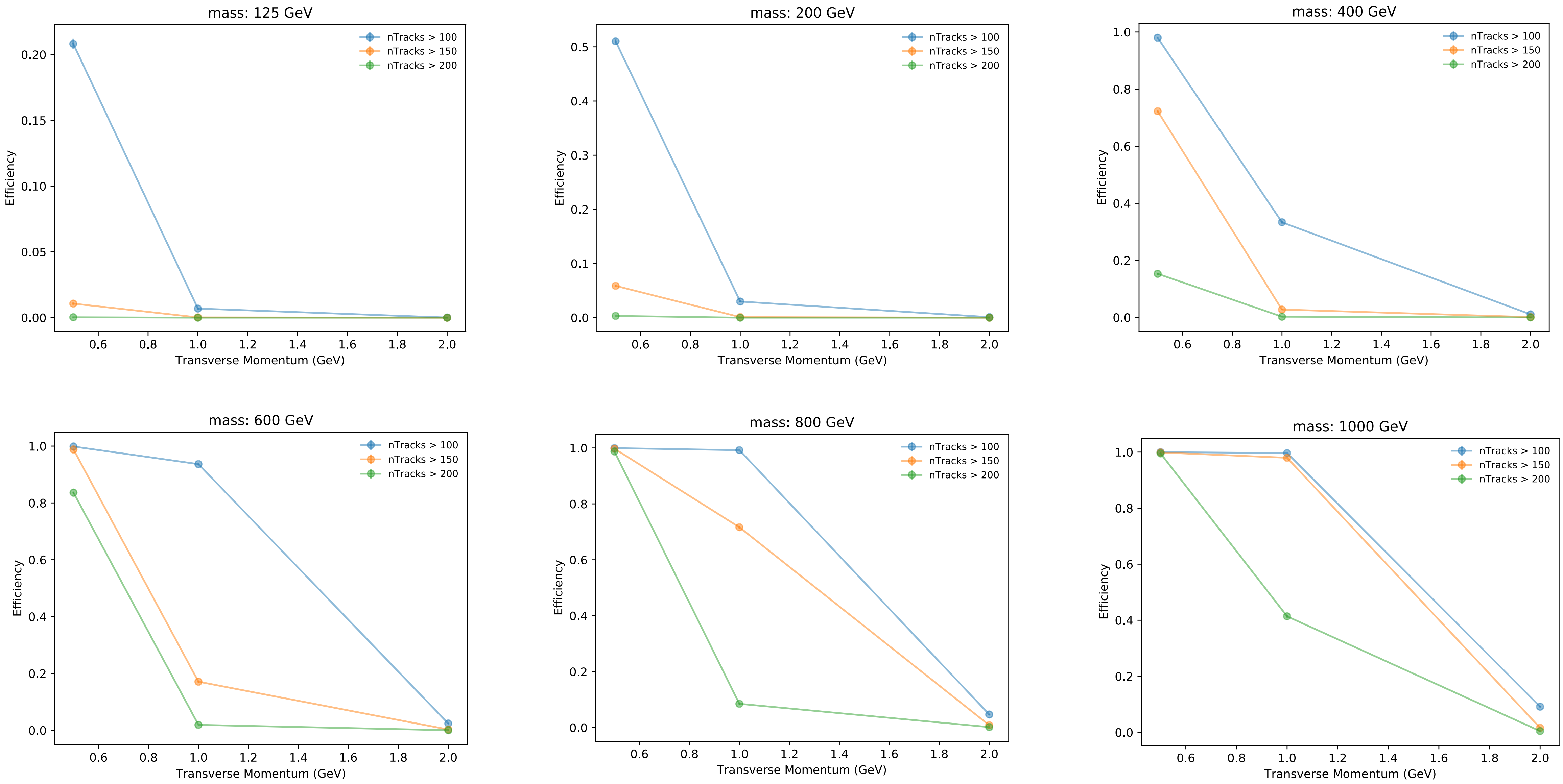
[2] Knapen, Simon et al. “Triggering Soft Bombs at the LHC.” Journal of High Energy Physics 2017.8 (2017): n. pag. Crossref. Web.

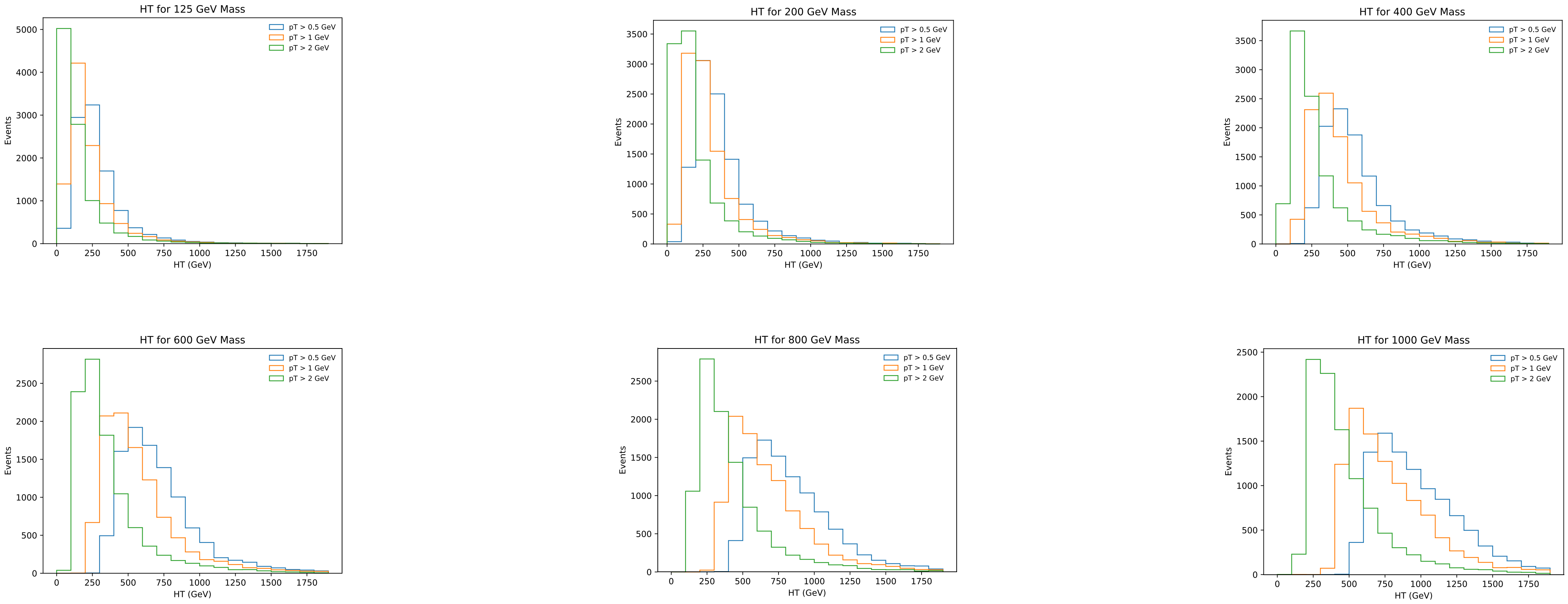
[3] Lee, Lawrence et al. “Collider Searches for Long-Lived Particles Beyond the Standard Model.” Progress in Particle and Nuclear Physics 106 (2019): 210–255. Crossref. Web.

Efficiency vs. nTracks for Fixed Mass (Complete)



Efficiency vs. Transverse Momentum for fixed Mass (Complete)





HT for Fixed Mass (Complete)