Track-Based Triggers for Long-Lived Particles at Future Colliders

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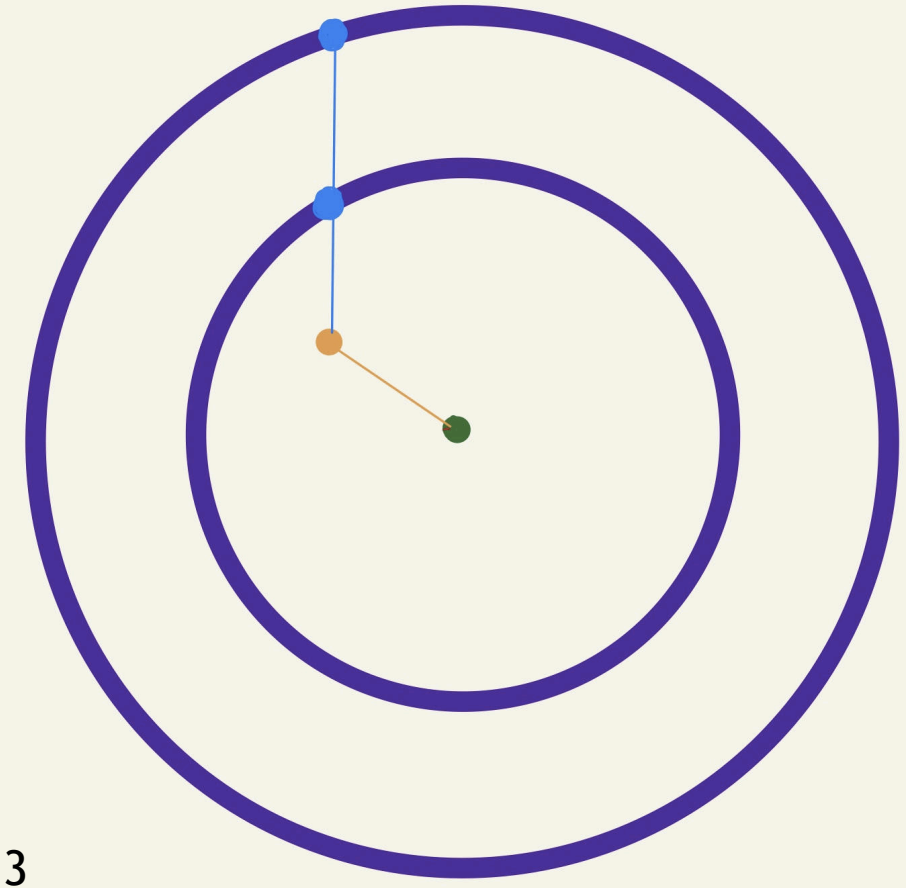
High Luminosity Upgrade at the Large Hadron Collider

- Plans to be online by 2027
- Increase luminosity by a factor of ~10
  - Luminosity is proportional to number of collisions in a given amount of time
  - Higher the luminosity -> more amount of data to be analyzed
- This allows for more sensitive searches of exciting physics such as BSM particles

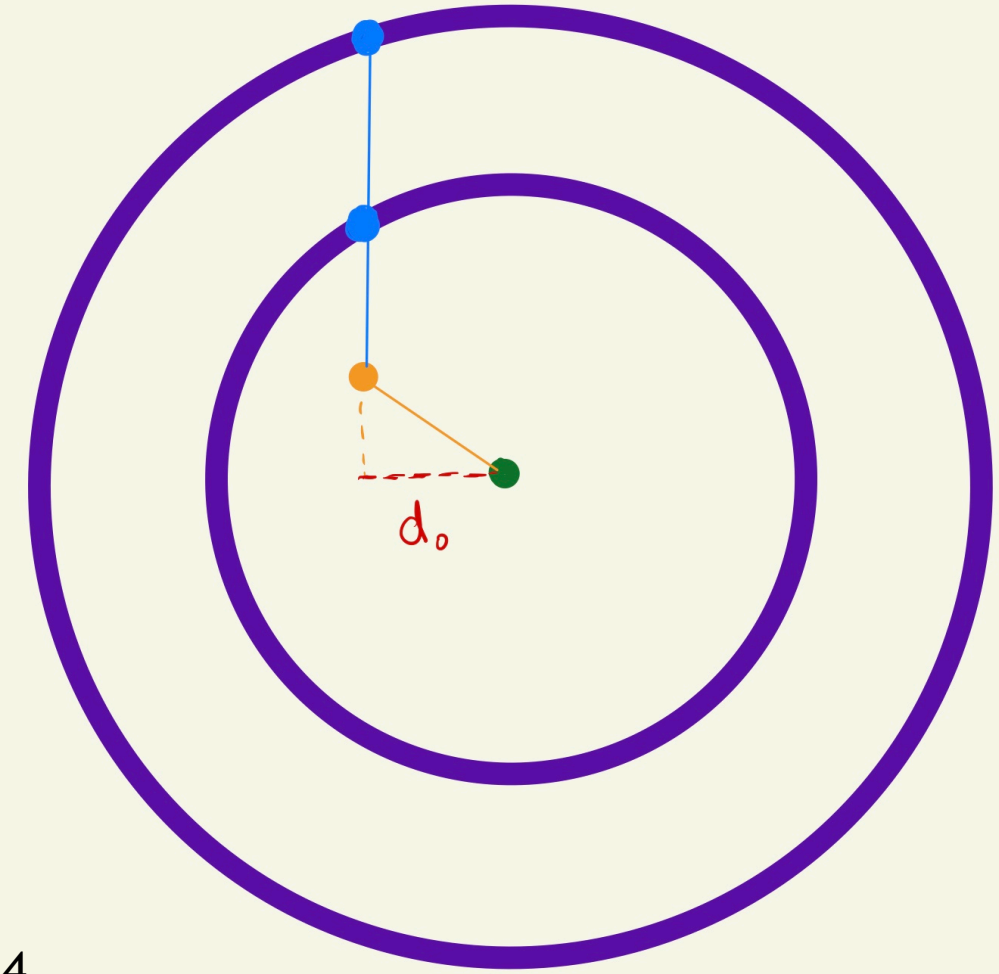
Pictured below: LHC

Long Lived Particles (LLPs) They're Exciting!



- LHC was built with two goals in mind
  - Measure mass of Higgs
  - Find BSM physics
- No new BSM physics found so far
  - Why haven't we seen it?
- LLPs are a feature of many BSM models
  - Searches have been done, but experiments are not optimized for LLPs

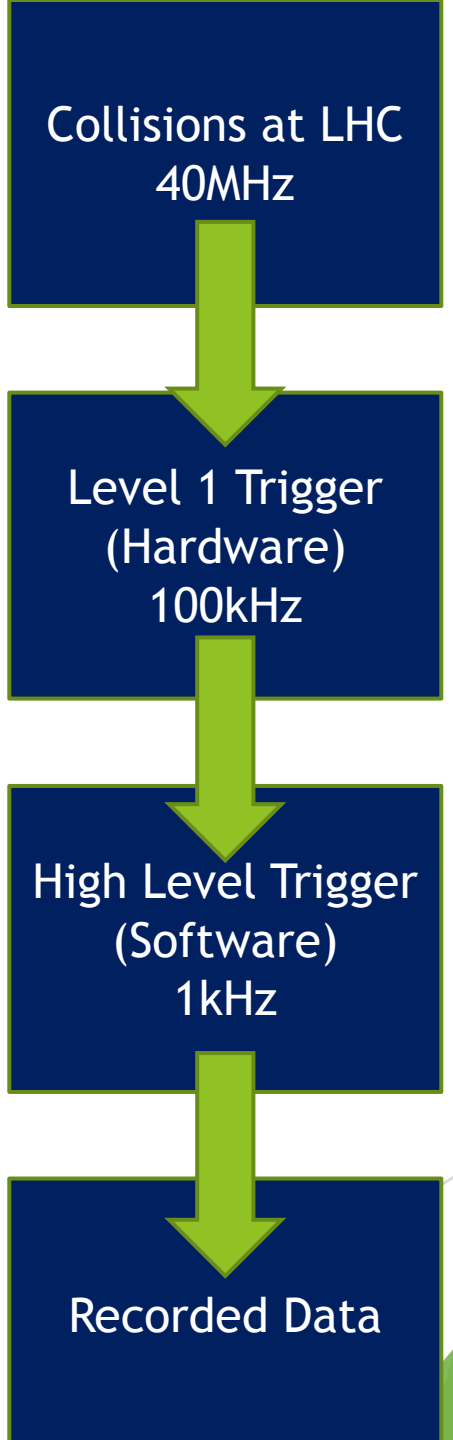
If they're so long lived, where are they?



- Currently limited access to these particles
- Have distinct, yet challenging experimental signatures
  - LLPs travel a large distance before decaying
  - Their decay products have a macroscopic d_0

Triggers

- Only can record 1 in 40000 events
- Triggers are necessary to determine which events are notable before going to further analysis
- Trigger system composed of hardware and software [1]
- With the HL-LHC, upgrades will allow us to utilize the tracker in the first stage of acquisition [1]
  - New opportunities to set parameters for LLP discoveries



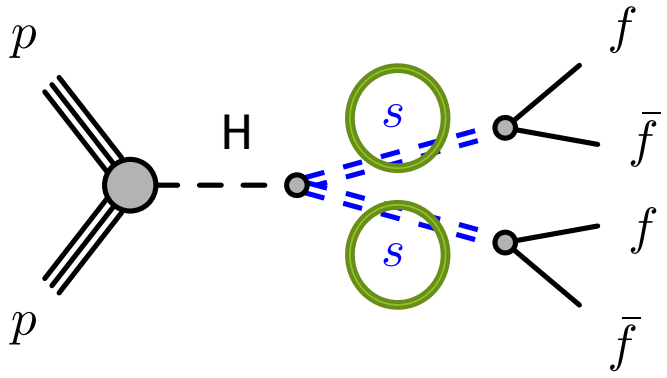
Pictured left: Flow chart describing trigger system

Why so soon?

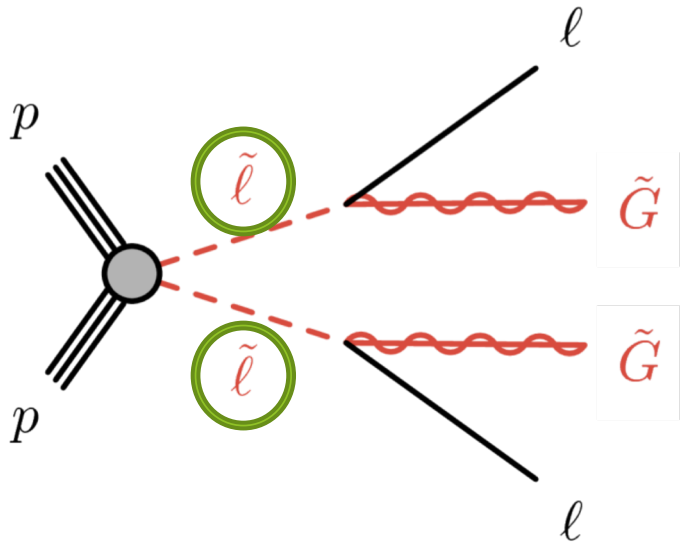
- Must build hardware systems far in advance with LLPs in mind
- Detector designers are not the ones searching for the exotic signatures of LLPs
- We are creating a broad overview that can be used as a reference for many different experiments
  - To be contributed to Snowmass studies [2]

2 Different LLP Models

- Interested in studying LLPs sensitivity to a range of various BSM models



Feynman diagram of LLP that couples to a Higgs and decays



Feynman diagram of SUSY scenario with long-lived sleptons

What kind of tracker do we need?

- How do variations in p_T and d_0 acceptance impact sensitivity to LLP signals
- Examining decay products of LLPs
  - Using simulated events
  - Place different cuts and look at event level efficiency

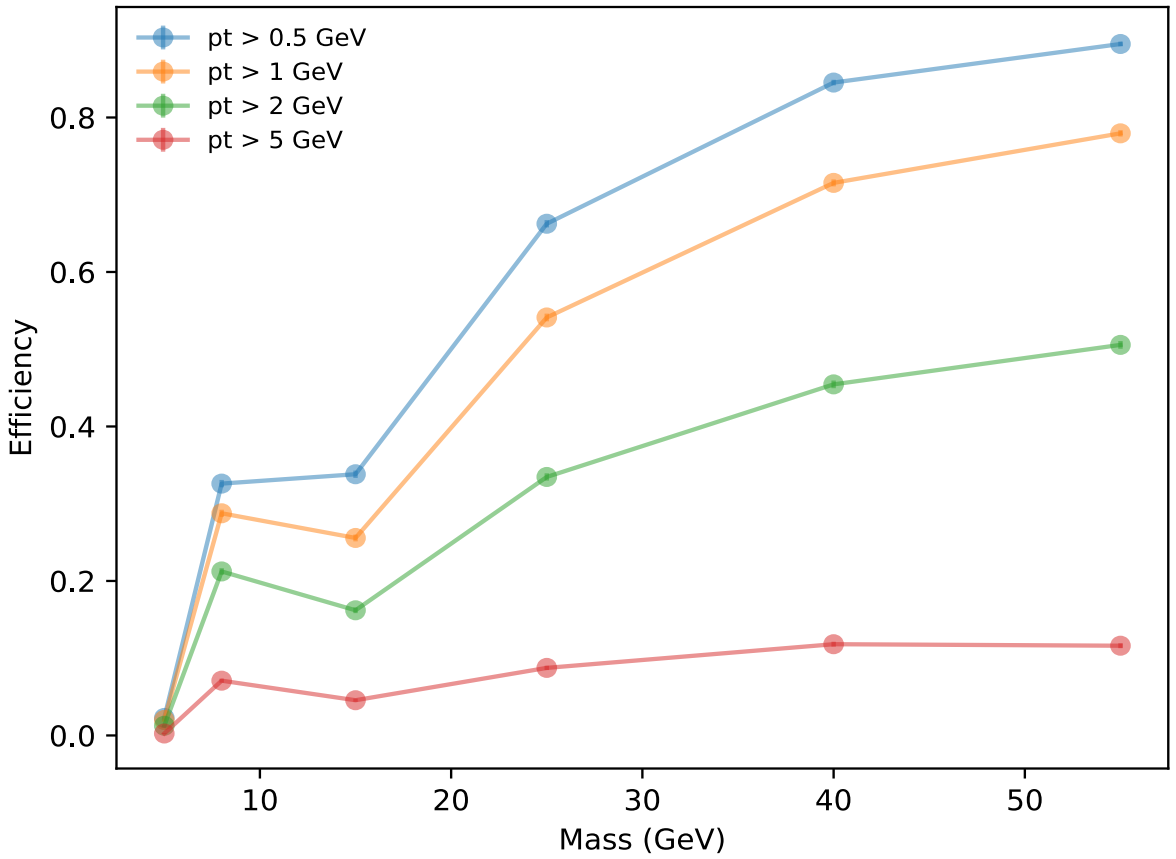
Cut	Value	Stage
Charged	Yes	Stage 1
Stable	Yes	Stage 1
Eta	≤ 2.5	Stage 1
Decay vertex	None or ≥ 200 mm from production vertex	Stage 1
Production vertex	< 300 mm from origin	Stage 1
p_T	$> 0.5, 1, 2, 5$ GeV	Stage 2
d_o	$< 10, 20, 50, 100$ mm	Stage 2
d_o	> 2 mm	Stage 2

Pictured above: Analysis cuts [3]

Simulated transverse momentum (p_T) w/set d_0 & lifetime

Higgs Decay

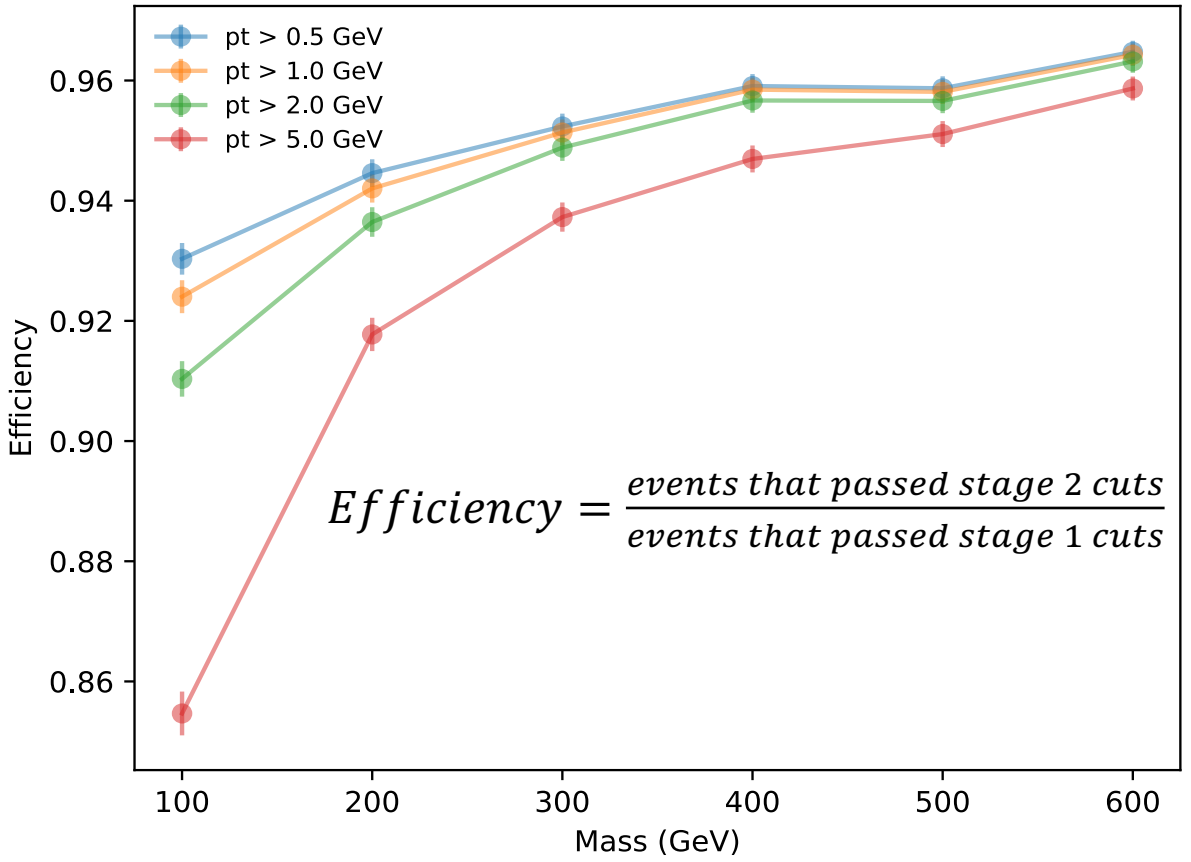
Preliminary Plot Lifetime: 0p1ns, d0: 100 mm



- Steep p_T turn on

Stau Decay

Preliminary Plot Lifetime: 0p1ns, d0: 100 mm



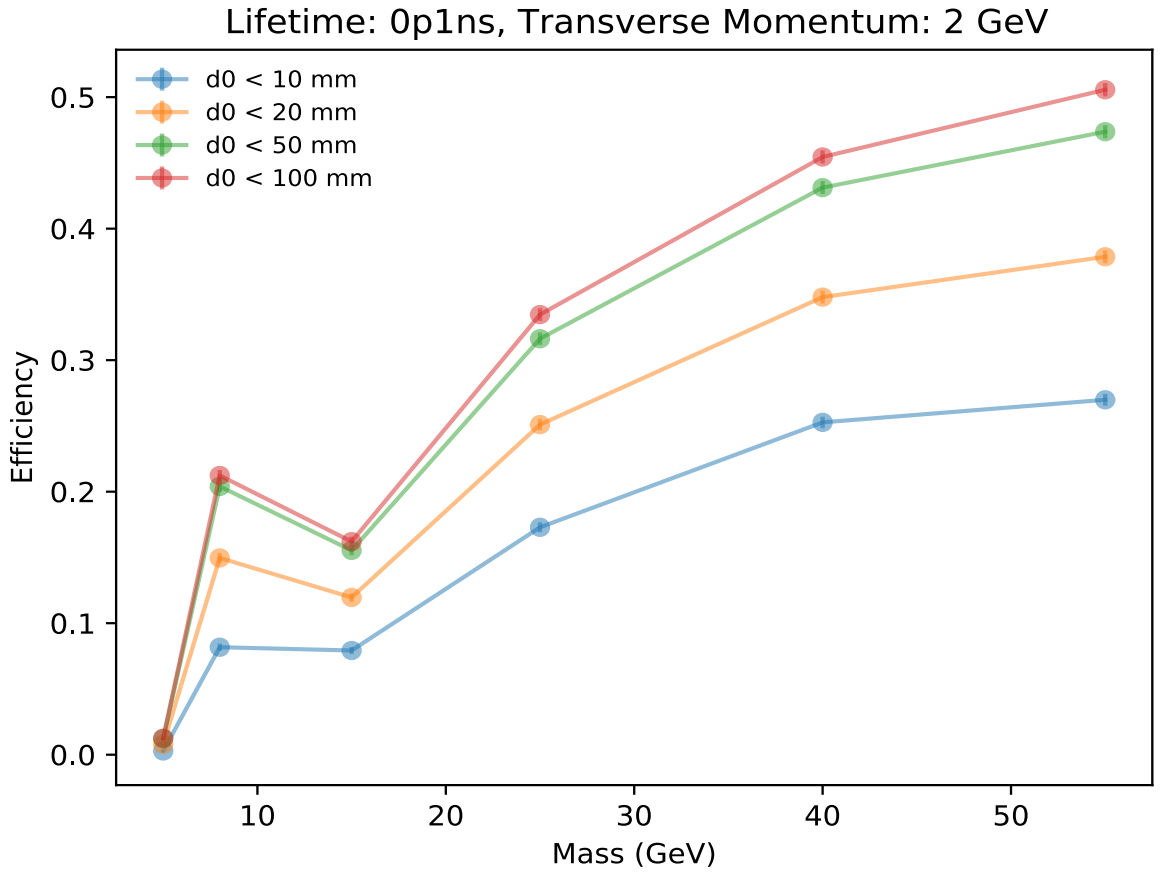
- No steep p_T turn on for 0.5-2.0 GeV (realistic detector range)

Simulated d_0 w/set p_T and lifetime

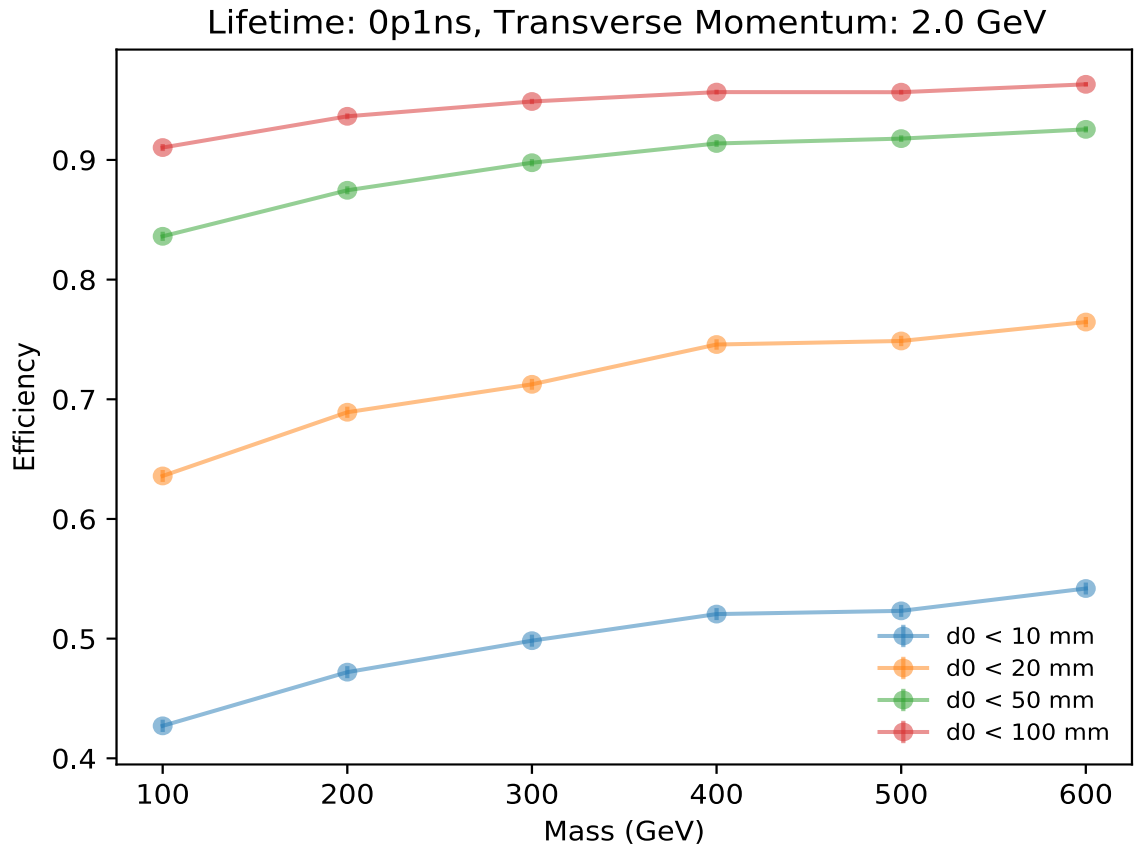
Higgs Decay

Stau Decay

Preliminary Plot



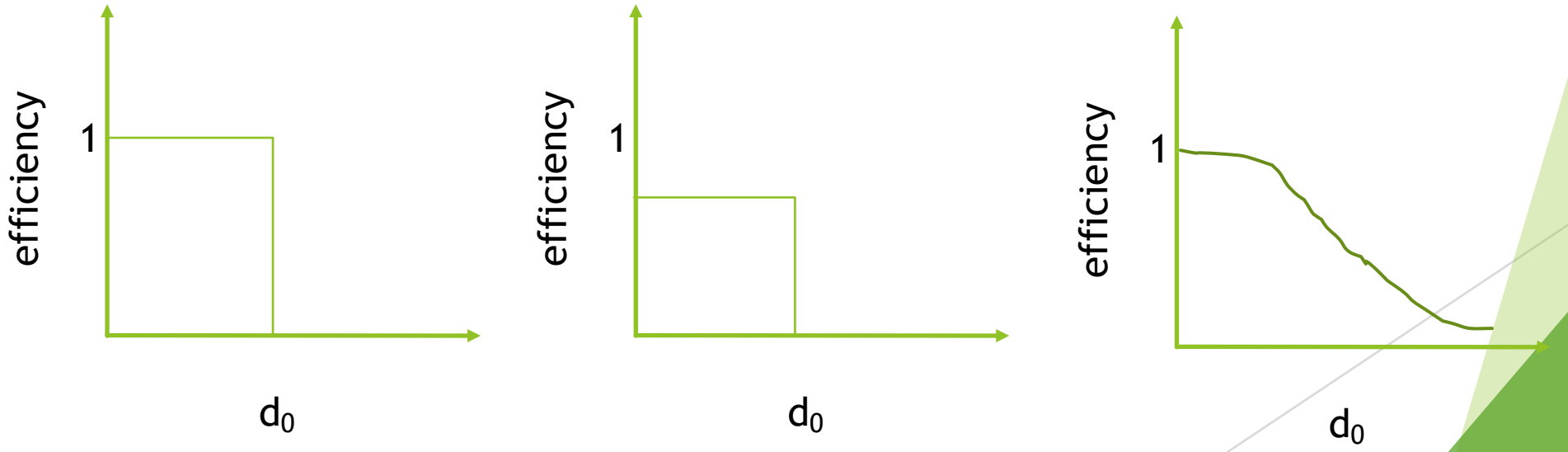
Preliminary Plot



- Larger d_0 yields a larger efficiency for both models
  - Stronger d_0 dependence for staus vs. Higgs

Next Steps

- Previous slides are preliminary results
- Currently only using binary definition of what a tracker would identify
- Use a random number generator to simulate different detector efficiencies
- Introduce concept of p_T and d_0 dependent efficiencies
- Tune track efficiencies vs. d_0 range for each model to understand the trade off



Conclusions

- The HL-LHC will utilize track triggering in order to study BSM physics
- We want to design the hardware so that it can detect LLPs
- Compare various parameters and how different combinations of those affect our results
- Create an outline that others can reference to determine when designing the next generation of LHC experiments

Acknowledgments

- Thank you to the Department of Energy for funding
- Thank you all for listening!
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