Workshop Summary: Timing for LLP Searches

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LLP Workshop @ LBNL

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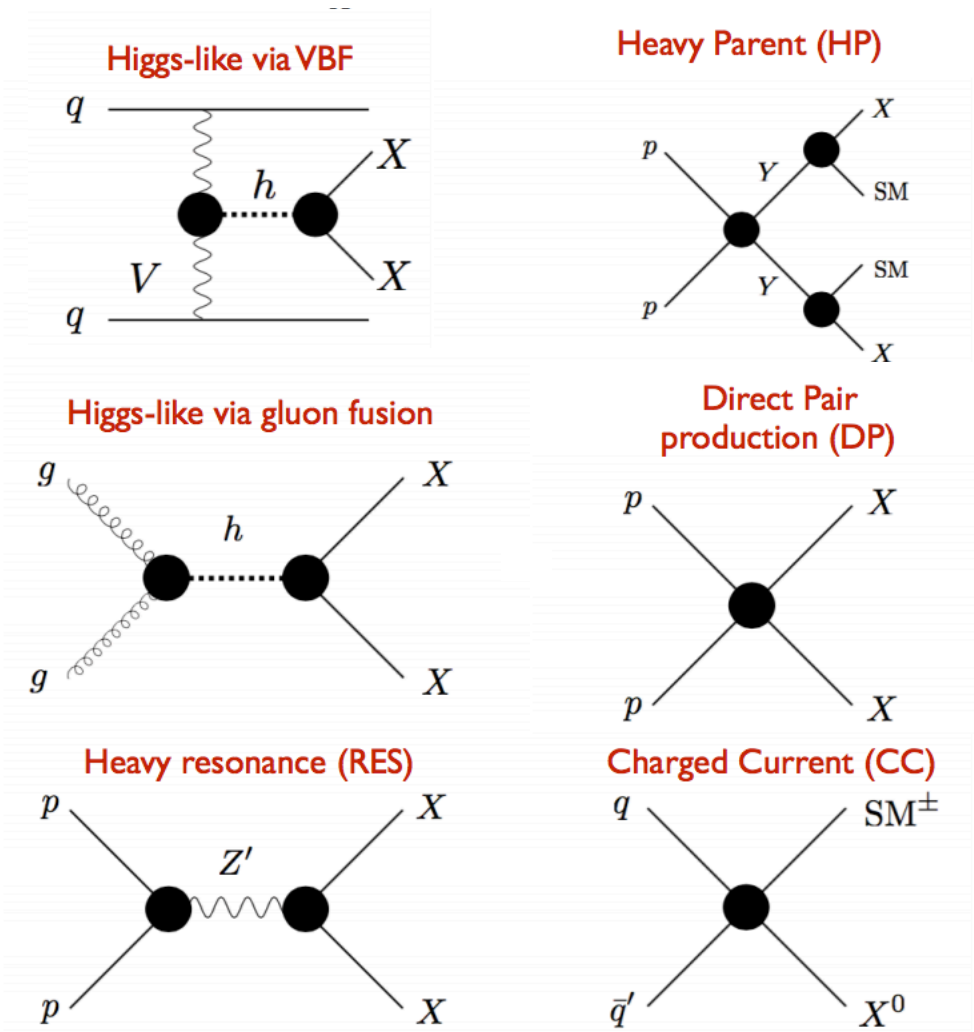
Objective 1: More Global Overview of Impact of Timing



Simplified Models (chapter 2 of LLP community report)

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- From Chapter 2 of LLP Community Report
- Factorizes production and decay;

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Big Signal selection enhancement
Big trigger efficiency enhancement

Mapping to UV Models

Neutral Long-lived particles

LLP decay modes

Production \ Decay	$\gamma\gamma(+\text{inv.})$	$\gamma + \text{inv.}$	$jj(+\text{inv.})$	$jj\ell$	$\ell^+\ell^-(+\text{inv.})$	$\ell^+_\alpha \ell^-_{\beta\neq\alpha}(+\text{inv.})$
DPP: sneutrino pair	†	SUSY	SUSY	SUSY	SUSY	SUSY
HP: squark pair, $\tilde{q} \to jX$ or gluino pair $\tilde{g} \to jjX$	†	SUSY	SUSY	SUSY	SUSY	SUSY
HP: slepton pair, $\tilde{\ell} \to \ell X$ or chargino pair, $\tilde{\chi} \to WX$	†	SUSY	SUSY	SUSY	SUSY	SUSY
HIG: $h \to XX$ or $\to XX + \text{inv.}$	Higgs, DM*	†	Higgs, DM*	RHν	Higgs, DM* RHν*	RHν*
HIG: $h \to X + \text{inv.}$	DM*, RHν	†	DM*	RHν	DM*	†
RES: $Z(Z') \to XX$ or $\to XX + \text{inv.}$	Z', DM*	†	Z', DM*	RHν	Z', DM*	†
RES: $Z(Z') \to X + \text{inv.}$	DM	†	DM	RHν	DM	†
CC: $W(W') \to \ell X$	†	†	RHν*	RHν	RHν*	RHν*

Timing most significant because
No tracking & No displaced vertex

X represents the LLP
*model definitely include missing energy;
+signature not appeared in the minimal/simplest model setup;

Big Signal selection enhancement

Big trigger efficiency enhancement

Charged Long-lived particles

LLP decay modes

Production \ Decay	$\ell + \text{inv.}$	$jj(+\text{inv.})$	$jj\ell$	$\ell\gamma$
DPP: chargino pair or slepton pair	SUSY	SUSY	SUSY	
HP: $\tilde{q} \to jX$	SUSY	SUSY	SUSY	
ZP: $Z' \to XX$	Z', DM*	Z', DM*	Z'	
CC: $W' \to X + \text{inv.}$	DM*	DM*		

Canonical production modes

Mapping to UV Models

Colored Long-lived particles

LLP decay modes

Production \ Decay	$j + \text{inv.}$	$jj(+\text{inv.})$	$j\ell$	$j\gamma$
DPP: squark pair or gluino pair	SUSY	SUSY	SUSY	

Canonical production modes

Mapping to UV Models

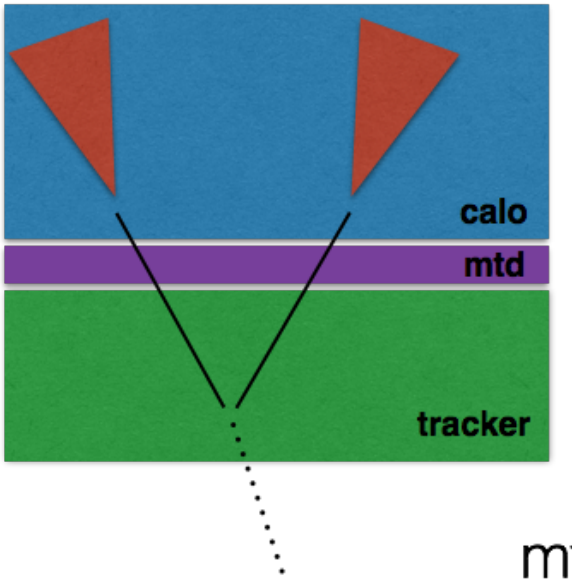
- Basic Summary of our understanding:
  - For all models, **timing helps** (reduce bkg / allow to loosen cuts)
  - For large fraction of models, **timing @ trigger level helps A-LOT** by enabling LLP-targeted triggers
  - For decays to photons, **timing is critical** because there are no other handles (no tracking, no displaced vertices)

Objective 2: Timing Trigger

- We explored a few timing trigger options:
  - On-chip filtering: only send out hits that have significant time delays
    - Here we need 20-100x reduction factor to get within readout bandwidth capability
  - Calo-based pre-trigger (or ROI) : trigger on delayed jets
    - Here we (estimate) need 10-100x reduction factor on top of jet rate to get to reasonable L1 accept rate

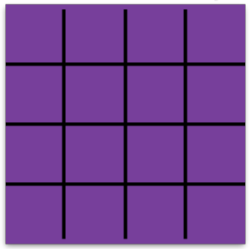
Timing Trigger

- We explored a few timing trigger options:

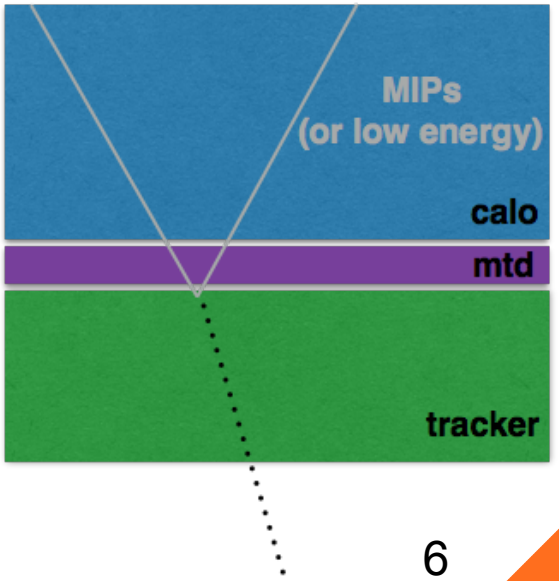


Use tracker/ECAL
to narrow to small regions
(max 1/20 of detector)

mtd chip



mtd cell (1cmx1cm)

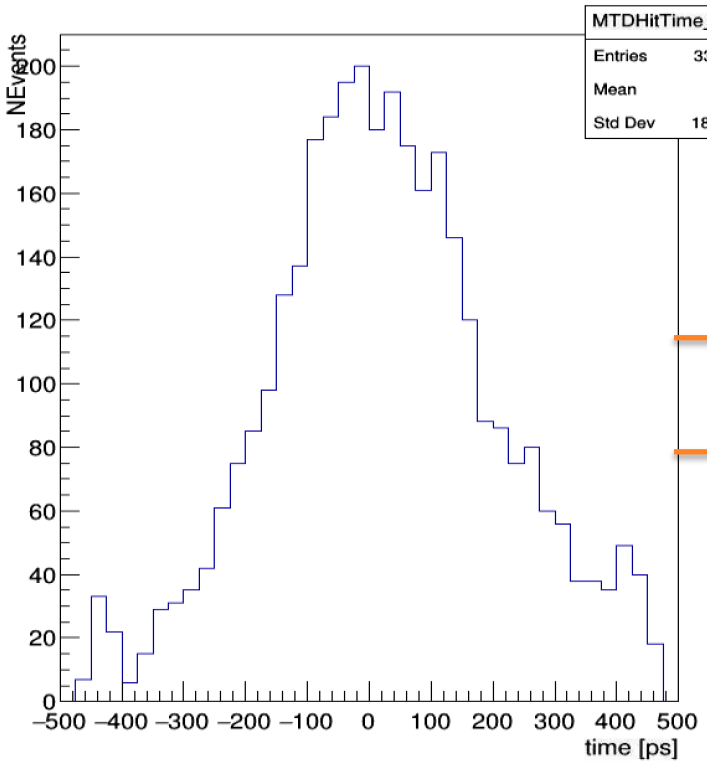


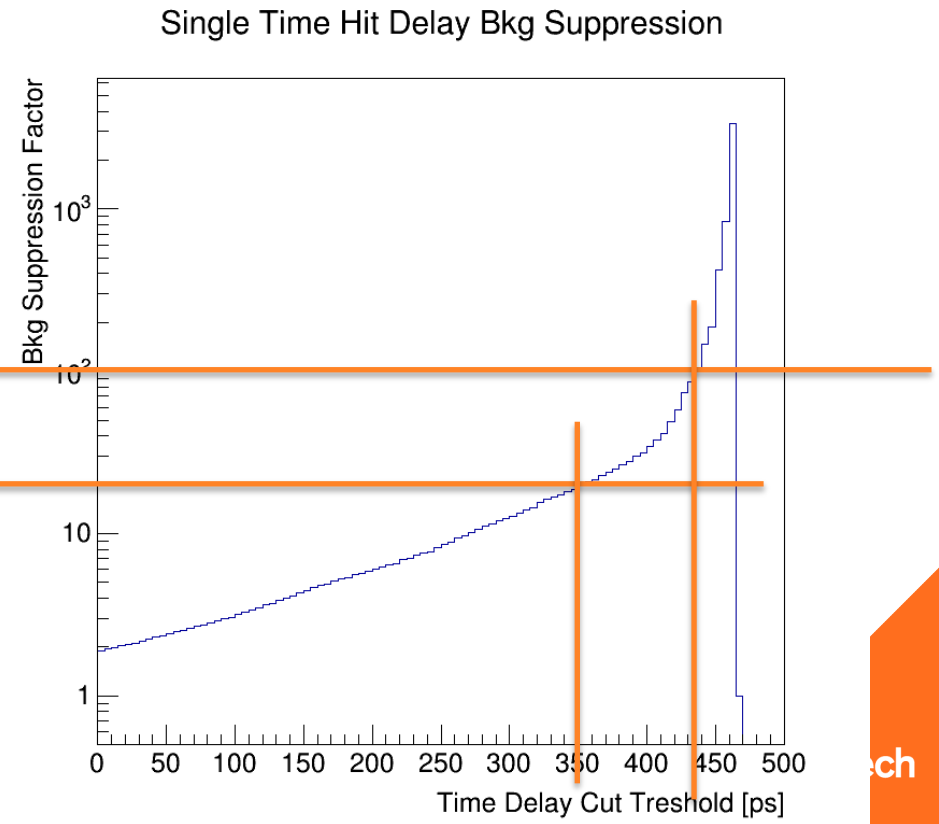
Use only timing layer to trigger
- need chip level data (4cmx4cm)

Timing Trigger

- How much (readout) rate reduction can I get by reading out delayed hits only?

- QCD Multijet MC, simulated with Delphes + customized Delphes timing module





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Timing Trigger

- How much (readout) rate reduction can I get by reading out delayed hits only?

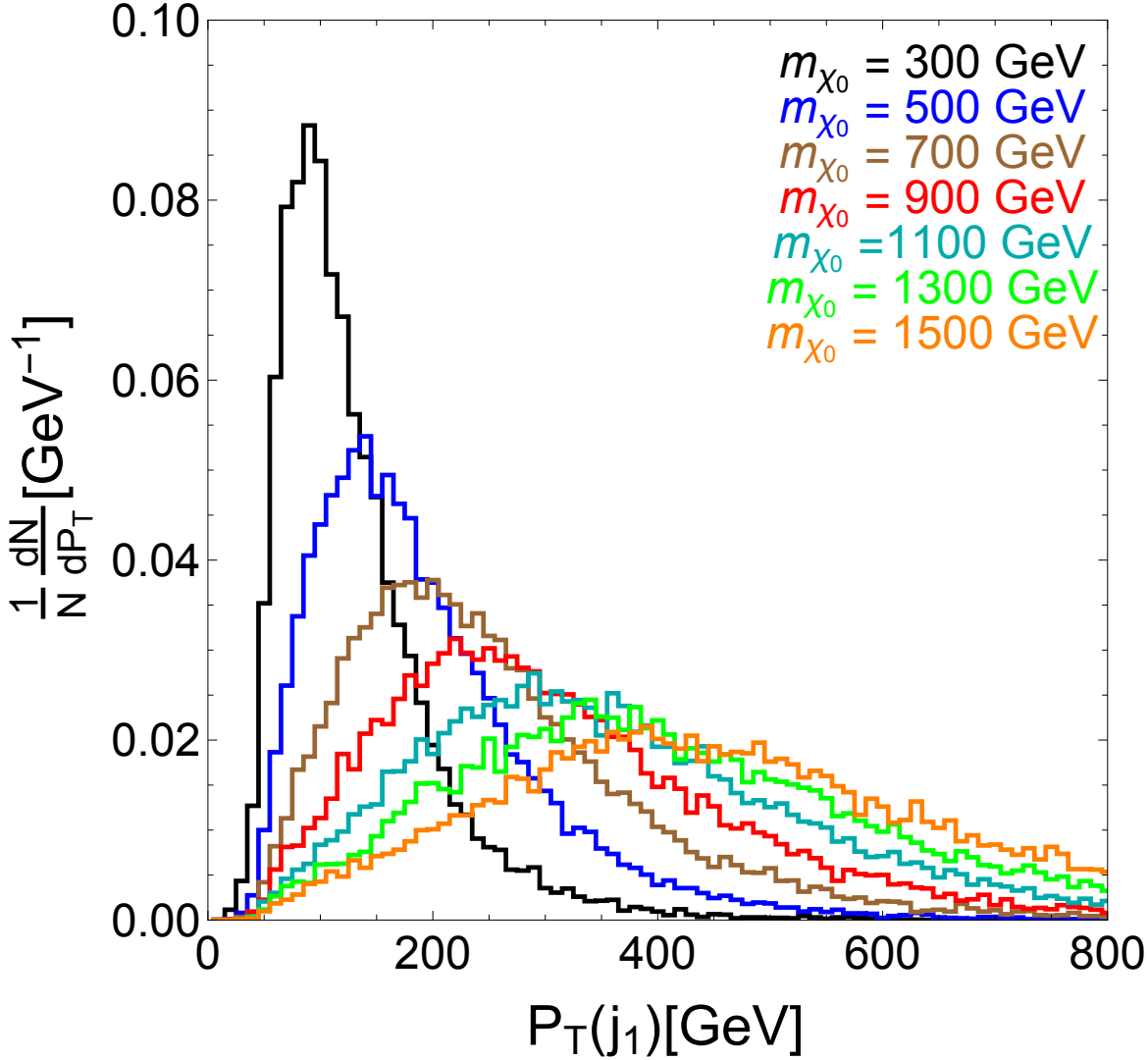
- QCD Multijet MC, simulated with Delphes + customized Delphes timing module

# of Coincidences	Threshold for 20x suppression	Threshold for 100x suppression
1	350ps	440ps
2	185ps	290ps
3	115ps	200ps

- **With 2-3 coincidences on the same readout chip (4cmx4cm sensor area), looks like we can have reasonable performance**

Timing Trigger with Jets

- To retain large signal efficiency down to low masses, need relatively low jet threshold, eg. 70GeV for 90% efficiency at m = 300 GeV



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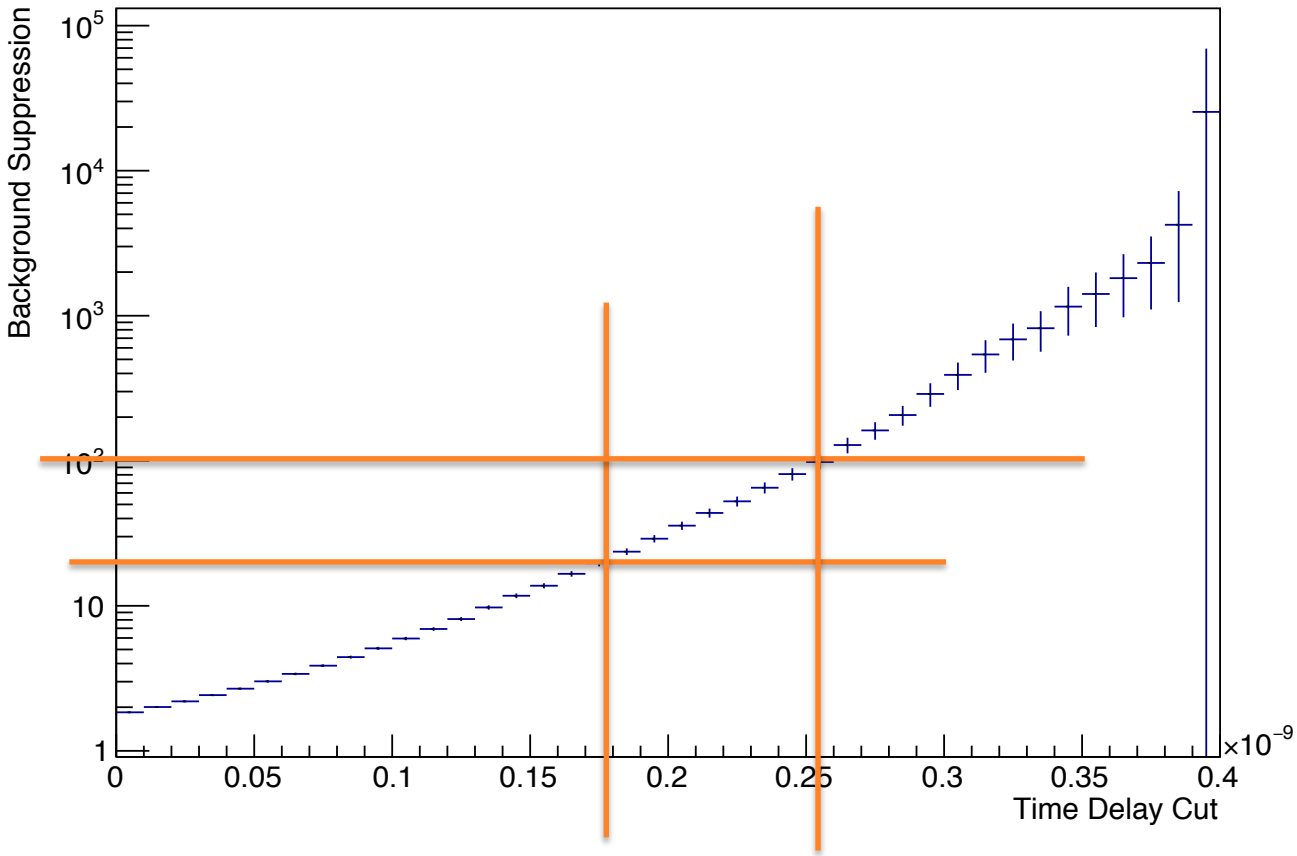
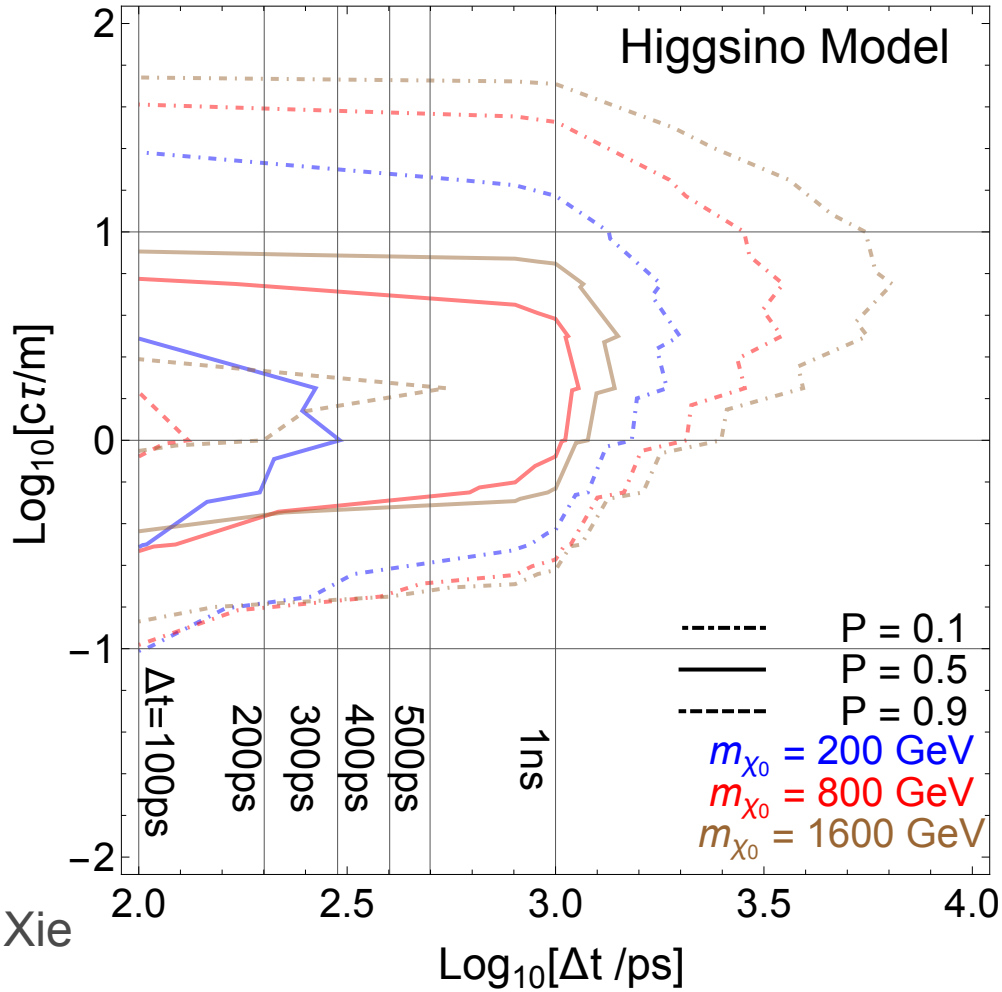
Timing Trigger with Jets

- With calo trigger seed, study how much time delay of jets we need to get us sufficient bkg rate suppression
- Use mean timestamp of hits within the jet (dR<0.4 cone)
  - 20x suppression @ 180ps
  - 100x suppression @ 250ps



Timing Trigger with Jets

- What's the impact of a 200-250ps cut on signal?
  - Seems to be not so bad…

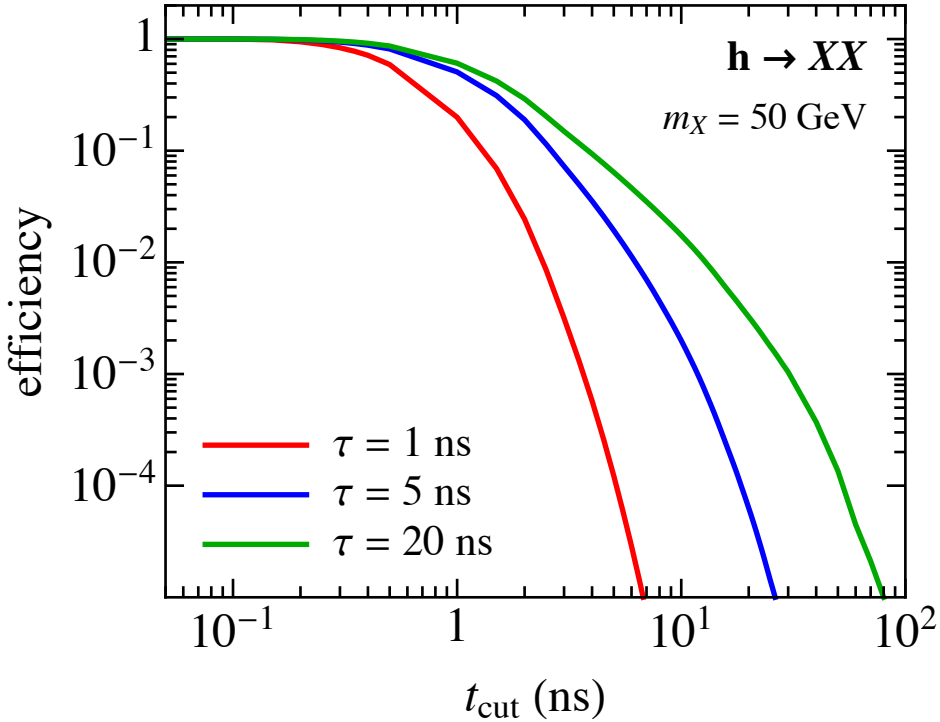


- With 200ps cut:
  - 50% signal efficiency contour covers cτ up to 3-8m depending on mass
  - 10% signal efficiency contour covers cτ up to 25-50m

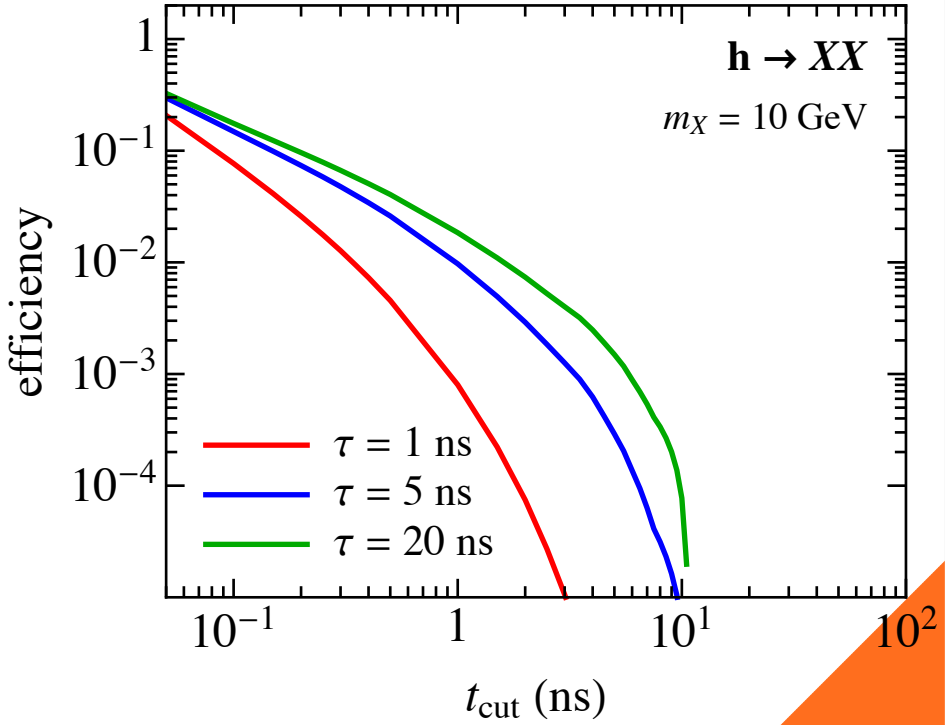
When do we need timing PRECISION?

- When LLP is heavy, retain very high efficiency for large range of cτ
- When LLP is lighter, efficiency suffers more.
  - Here we need **precision** timing (threshold below 50-100ps)

Heavy LLP



Light LLP



Objective 3: New Ideas

- Use timing for particle ID (pion/kaon discrimination possible up to 2-3 GeV) & combine with dE/dx to help improve HSCP searches

- Look for mismatch between time-based and momentum-based mass reconstruction → may indicate presence of missing decay product

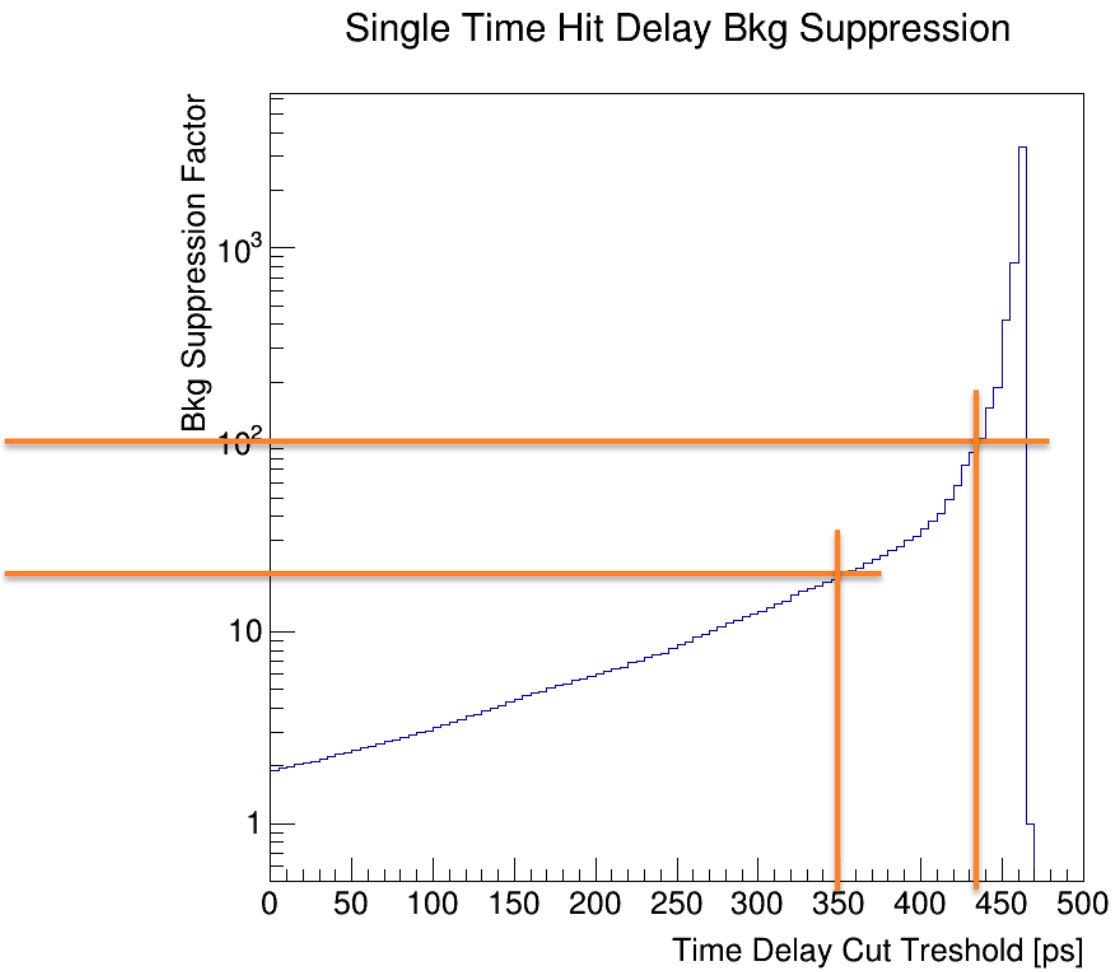
- Lorentz-violation tests for particles accessible only at LHC, eg. Top quark, Higgs
  - How much time precision is relevant?
  - Other existing constraints?

- **Let's continue to think about these….**

Backup

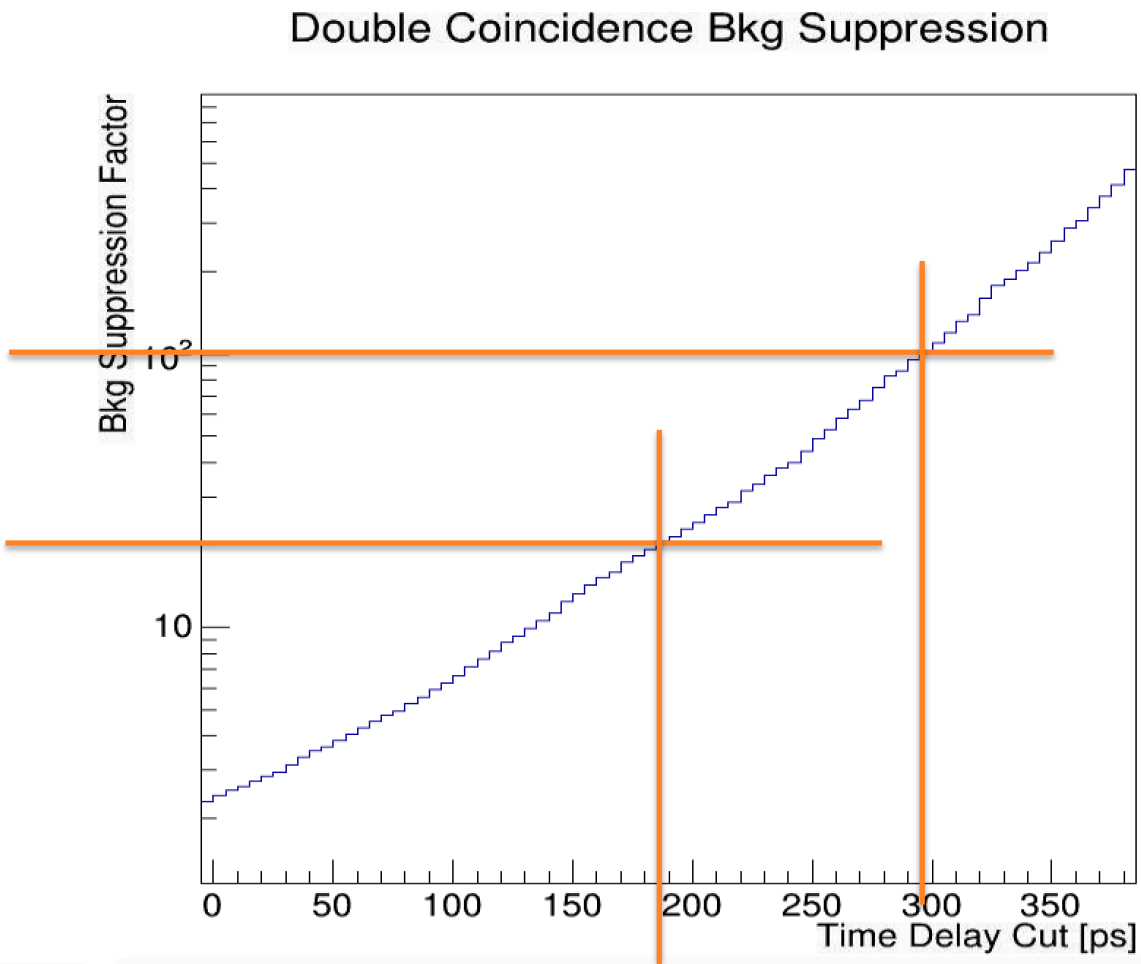
Timing Trigger

- Get 20x suppression, if we cut at 350ps
- Get 100x suppression if we cut at 440ps



Timing Trigger

- If I require 2 hits in the same readout chip:
  - 20x suppression @ 185ps
  - 100x suppression @ 290ps



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Timing Trigger

- If I require 3 hits in the same readout chip:
  - 20x suppression @ 115ps
  - 100x suppression @ 200ps