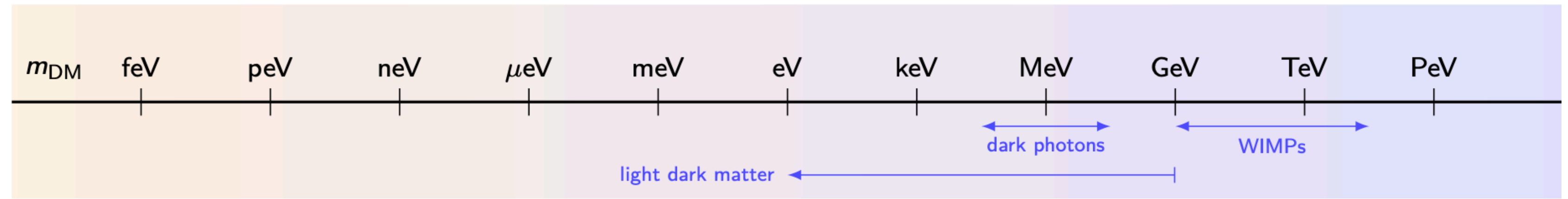


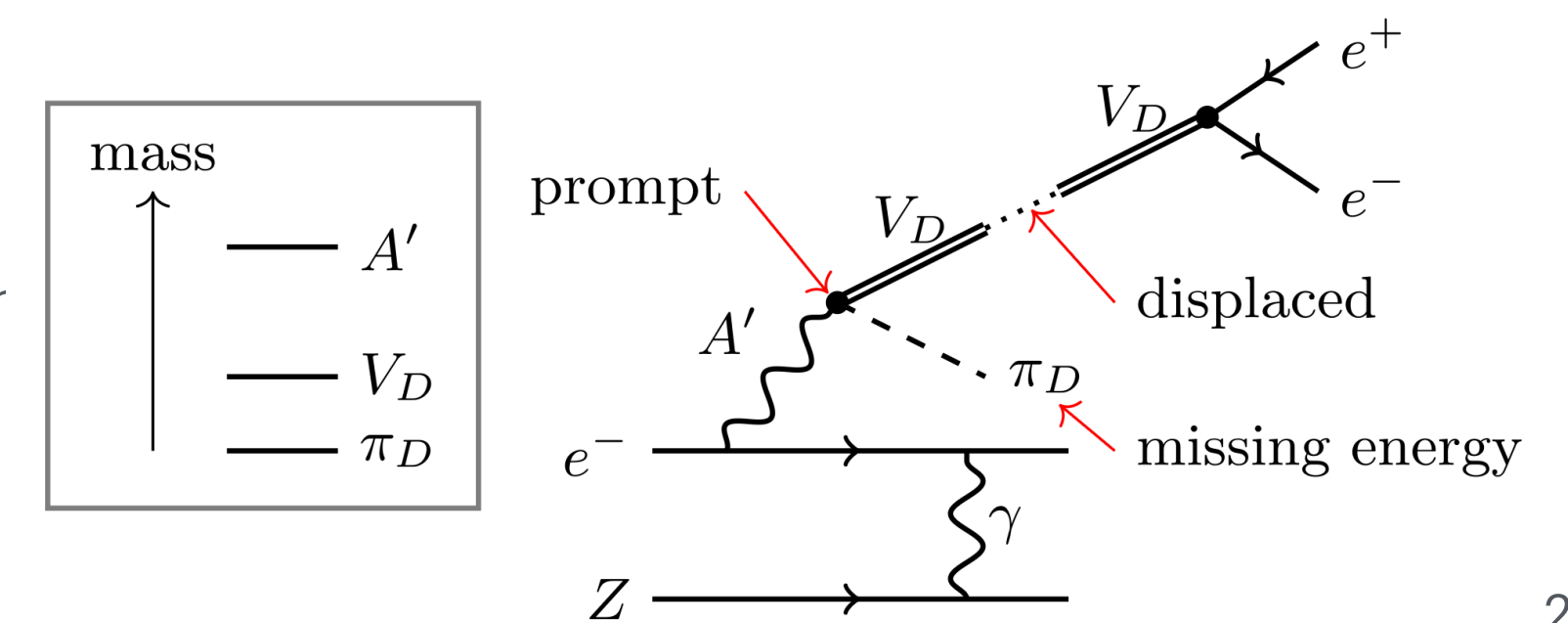
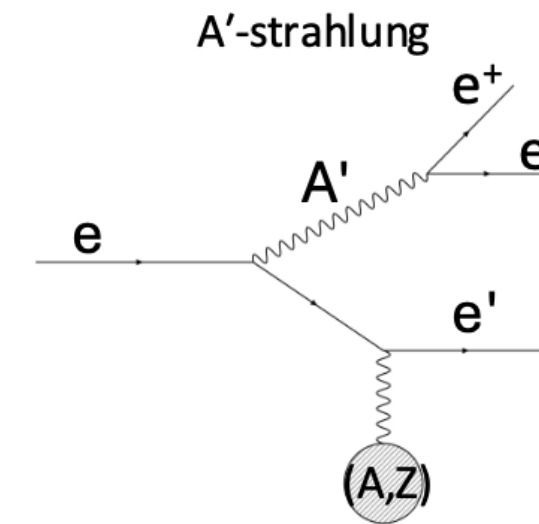
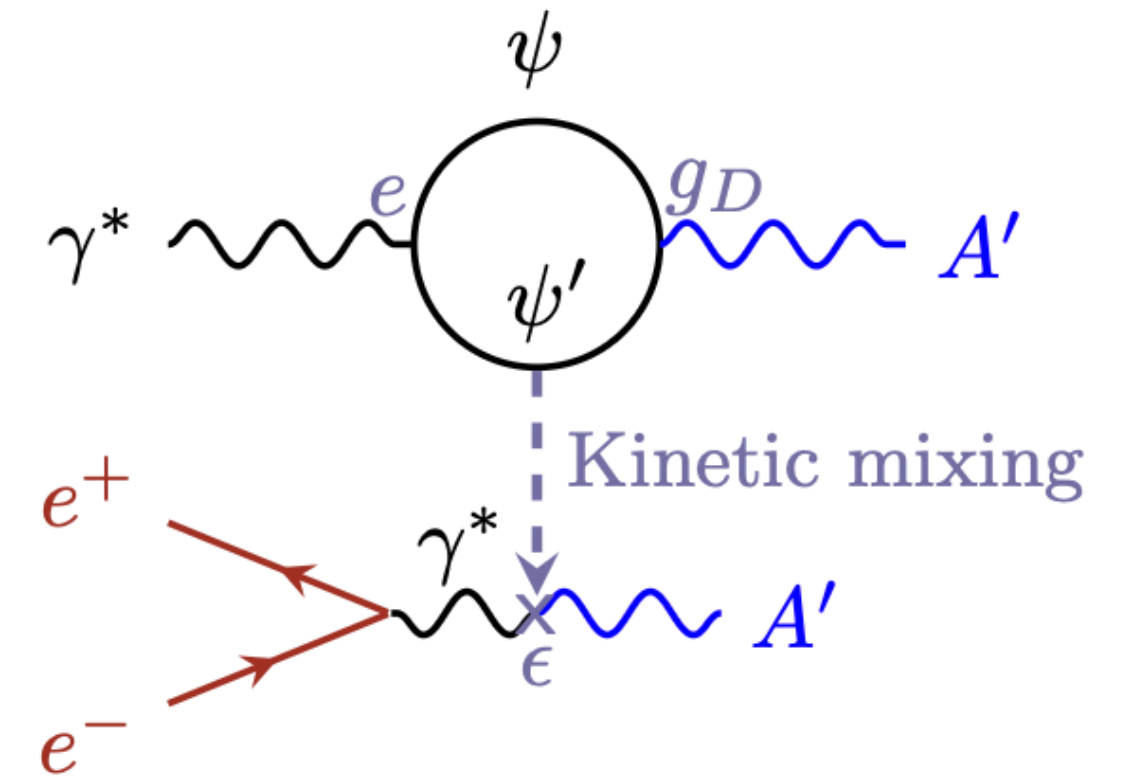
HPS SIMPs Search

2026 JLUO Annual Meeting

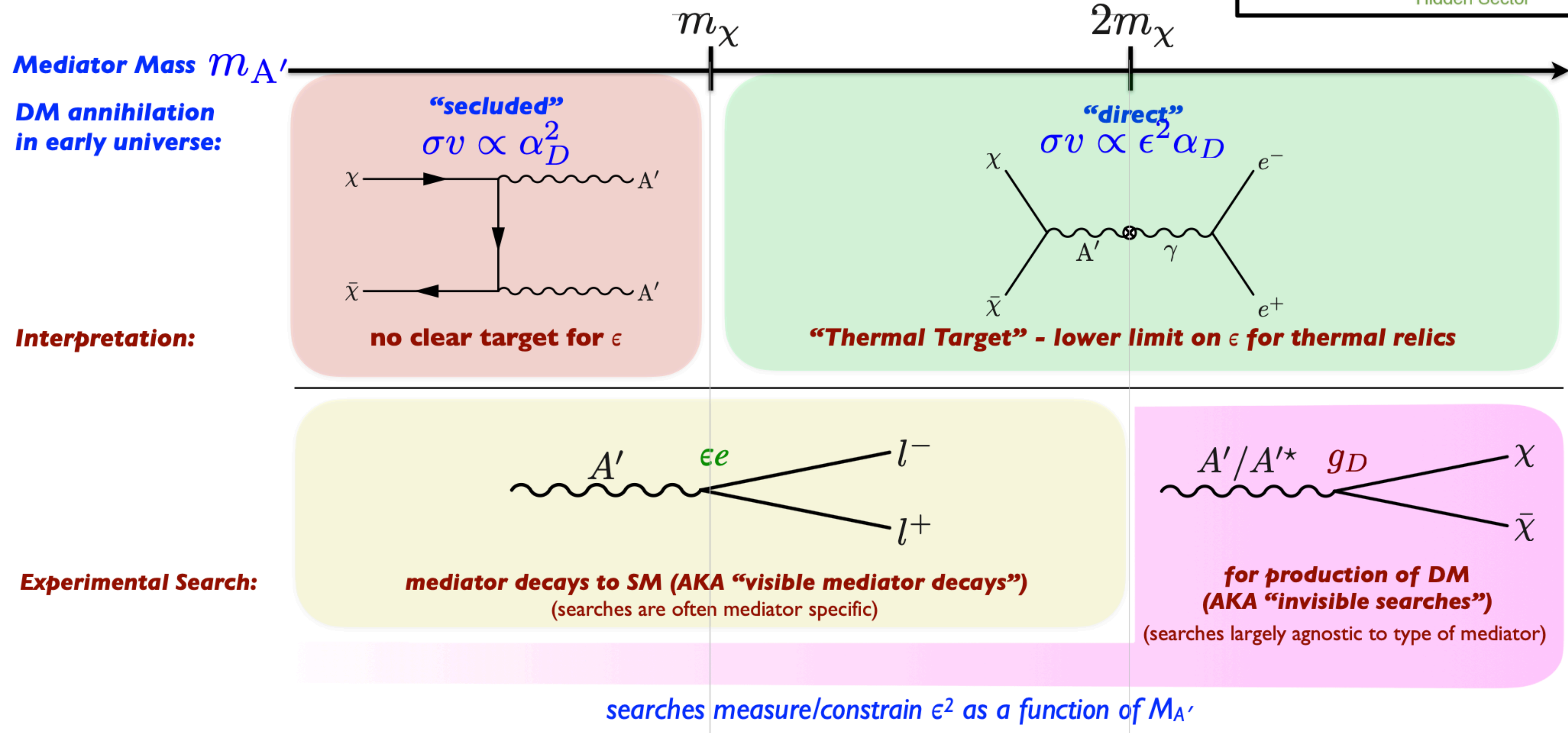
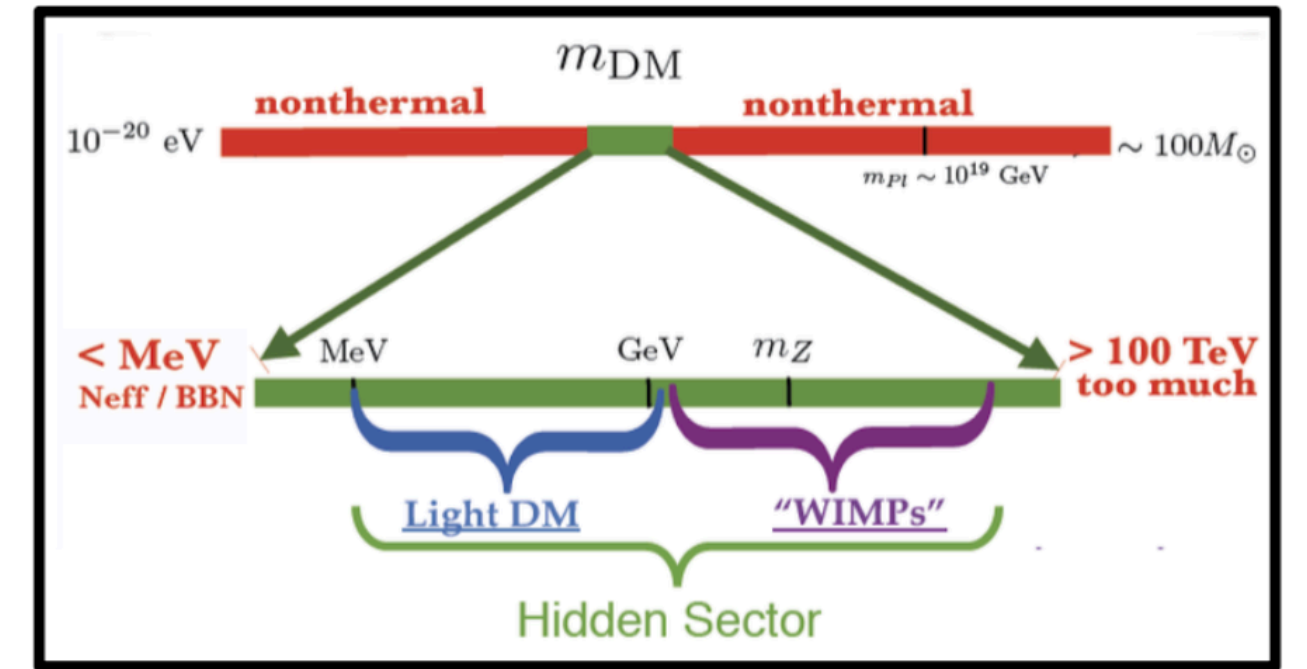
Landscape



- Extensions to the Standard Model propose to account for dark matter and thermal relic abundance with new gauge symmetries and dark sectors with indirect coupling to the SM
- The simplest is a $U(1)_D$ giving rise to a massive spin-1 vector gauge boson, the "dark photon", A'
- Kinematic mixing with the SM photon enables "bremsstrahlung" A' electro-production on nuclear targets
 - Through a massive charged fermion loop, often represented by a simplified coupling strength, ϵ
- Experimental signatures of the A' decay depend on the dark sector's structure
 - Assuming it's the lightest dark state, all A' decay back to SM leptons (the proposed HPS experiment)
 - Other models include Strongly Interacting Massive Particles (SIMPs) in the dark sector
 - Y. Hochberg, et.al, Phys. Rev. Lett. 113, 171301 (2014) and Phys. Rev. Lett. 115, 021301 (2015).



A' Parameter Space



The HPS Experiment

Proposed

- CEBAF electron beam on Tungsten target
- 6-layer Silicon Vertex Tracker in uniform dipole field, acceptance from 15 mrad
- Downstream PbWO₄ Electromagnetic Calorimeter for triggering and timing coincidence
- Symmetric top/bottom, with dipole sheet of flame in vacuum
- Bump Hunt and Displaced Vertex searches for visible $A' \rightarrow e^+e^-$ decays

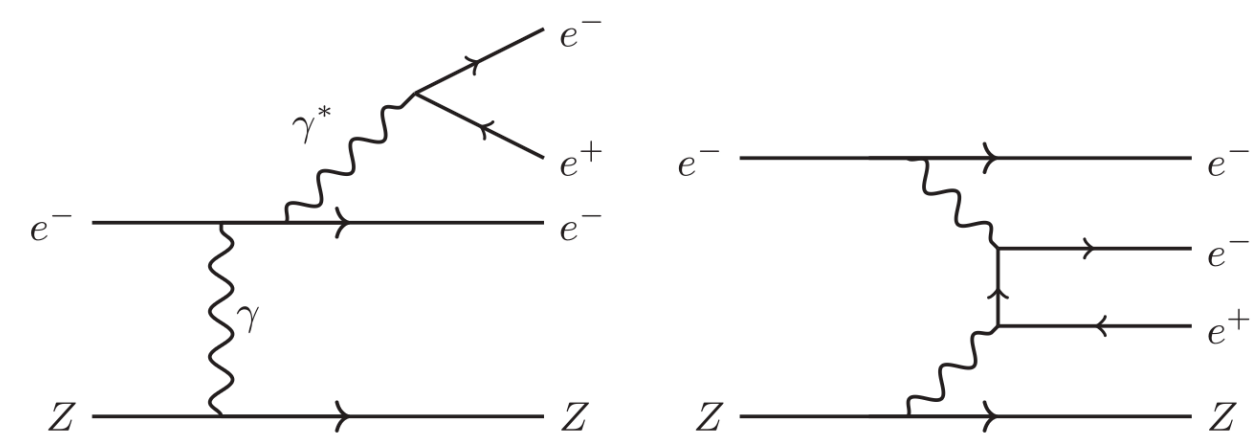
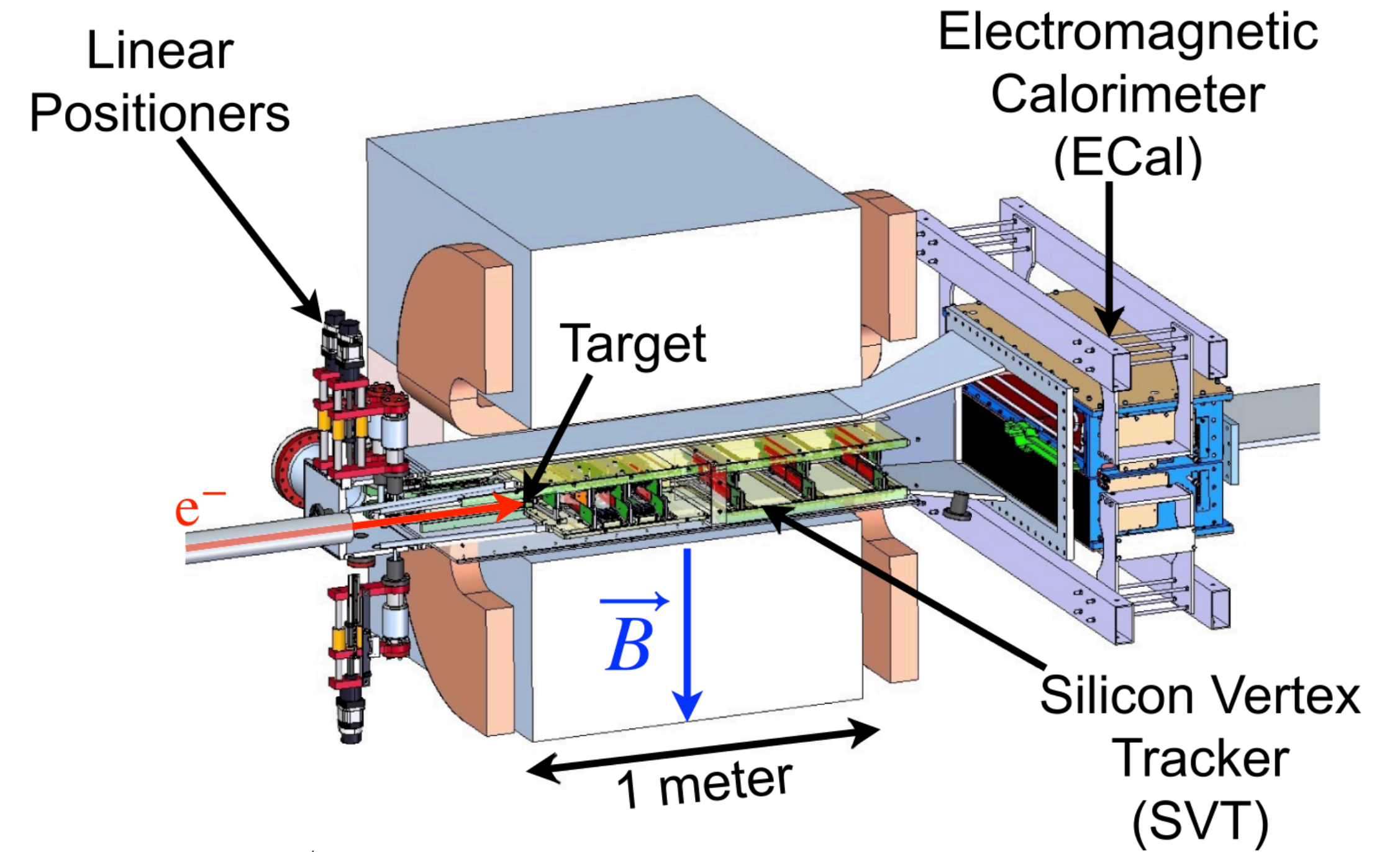
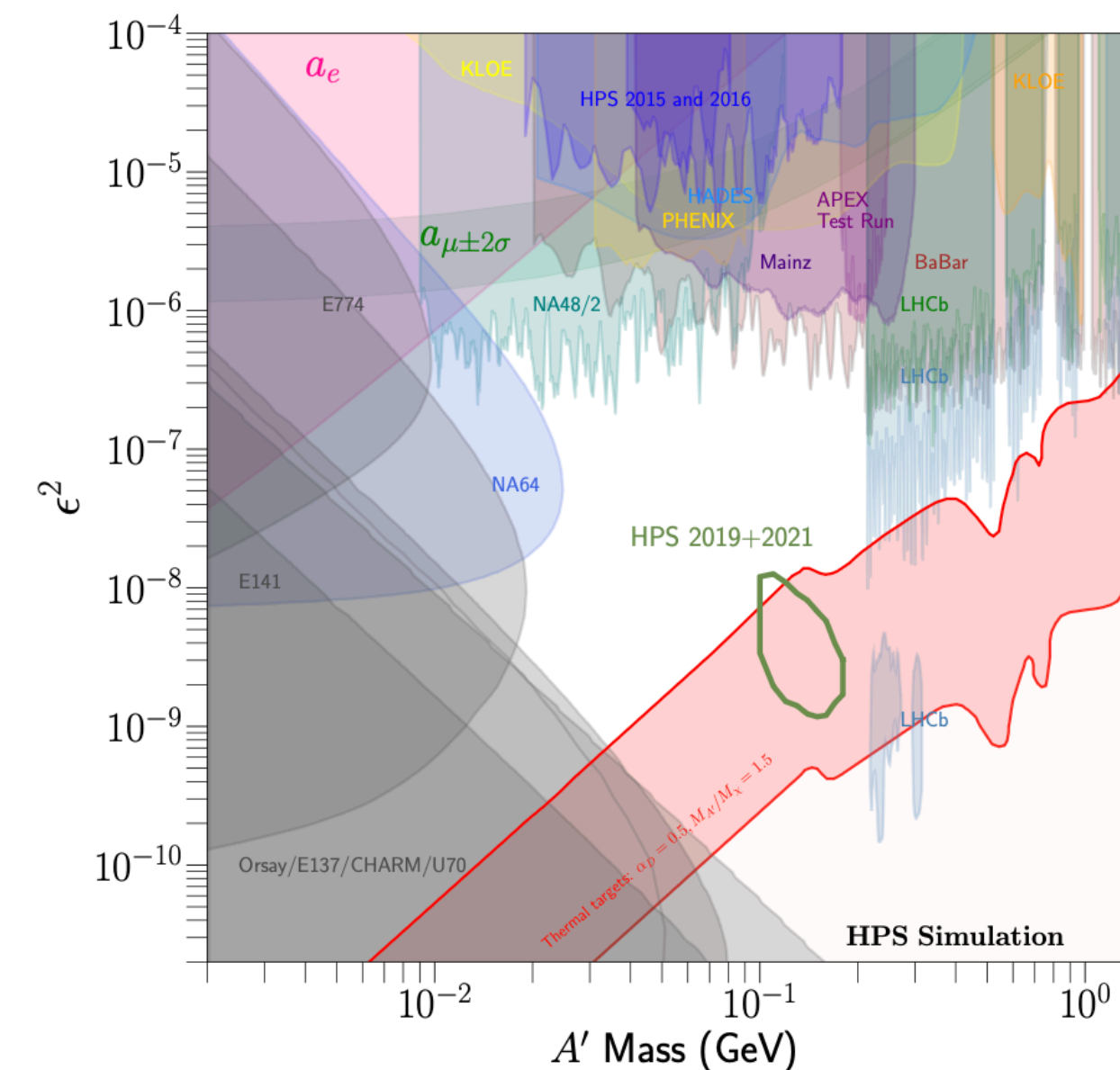


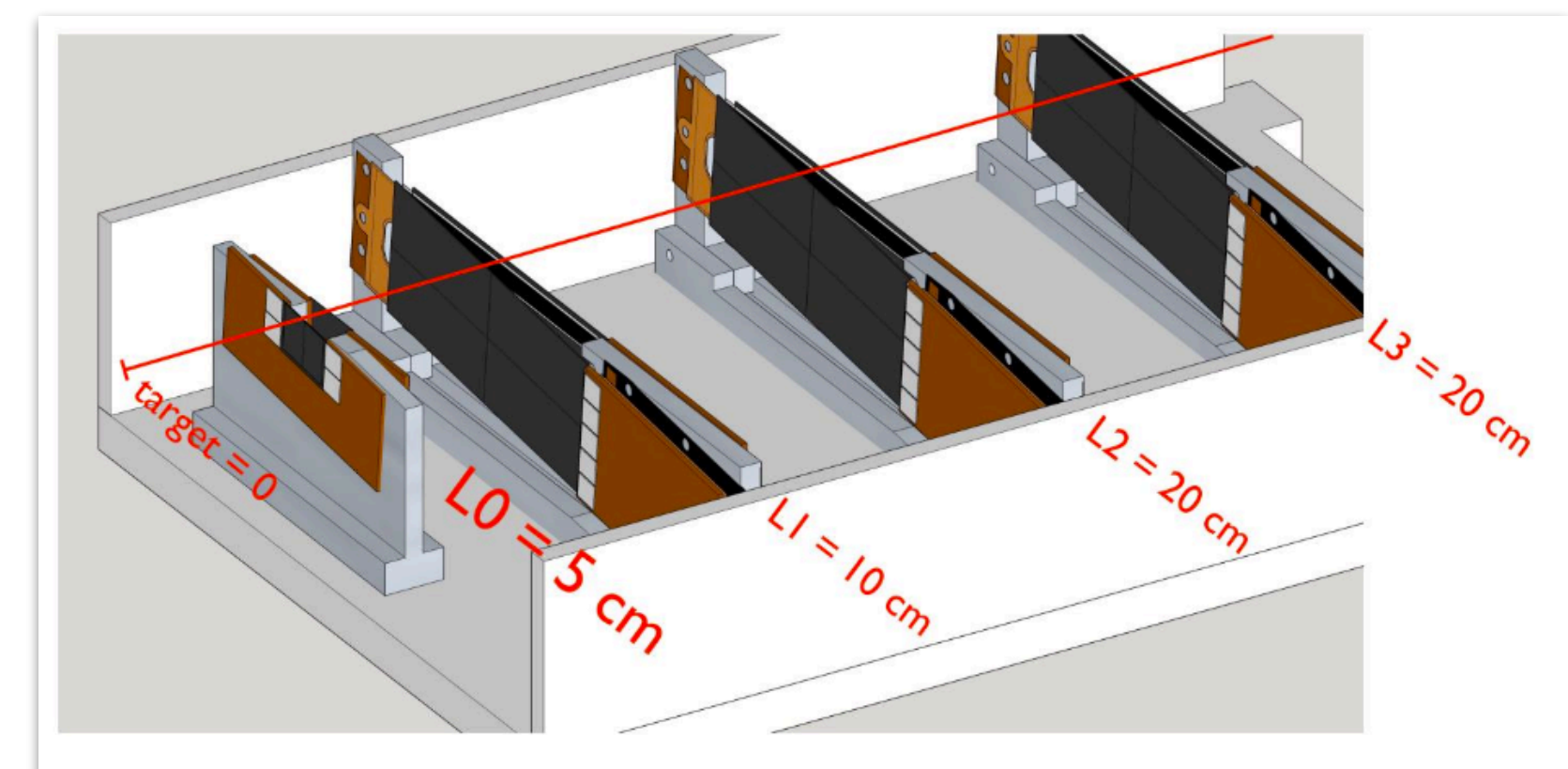
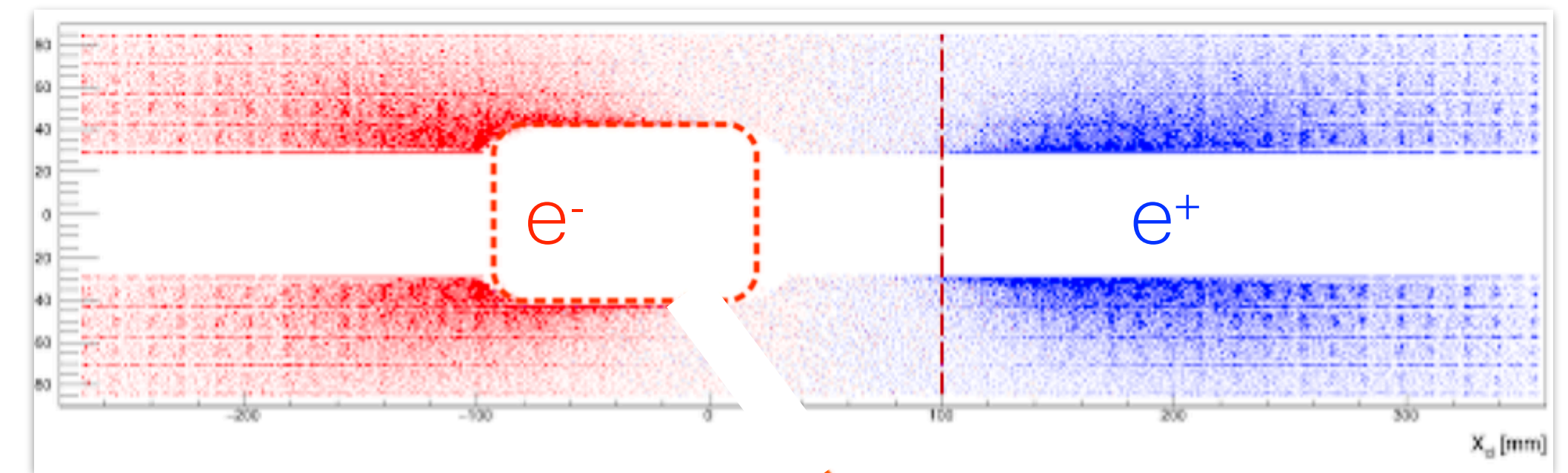
FIG. 3. Radiative (left) and Bethe-Heitler tridents (right) have the same final state particles as the e^+e^- production from a dark vector decay shown in Fig. 1.



The HPS Experiment

Status

- 180 PAC days approved, ~half remain
- Two engineering runs in 2015 and 2016 (1.1 and 2.3 GeV electrons)
 - Training ground for understanding background, detector, analysis techniques
- Physics runs in 2019 and 2021 (4.6 and 3.8 GeV), with upgrades!
 1. Additional L0 tracking layer nearest the target
 2. Single-arm "positron" trigger with new hodoscope
- HPS's proposed A' searches were published from the short engineering runs, with the later, larger data sets coming soon with combined analysis
- Meanwhile, HPS can do invisible searches too ...



Event Selection

- Data analysis is very similar to HPS's visible $A' \rightarrow l^+l^-$ decays
- All the same background sources and using everything we learned from previous analyses
- Except the missing energy pushes signal kinematics to lower e^+e^- energy-sum.

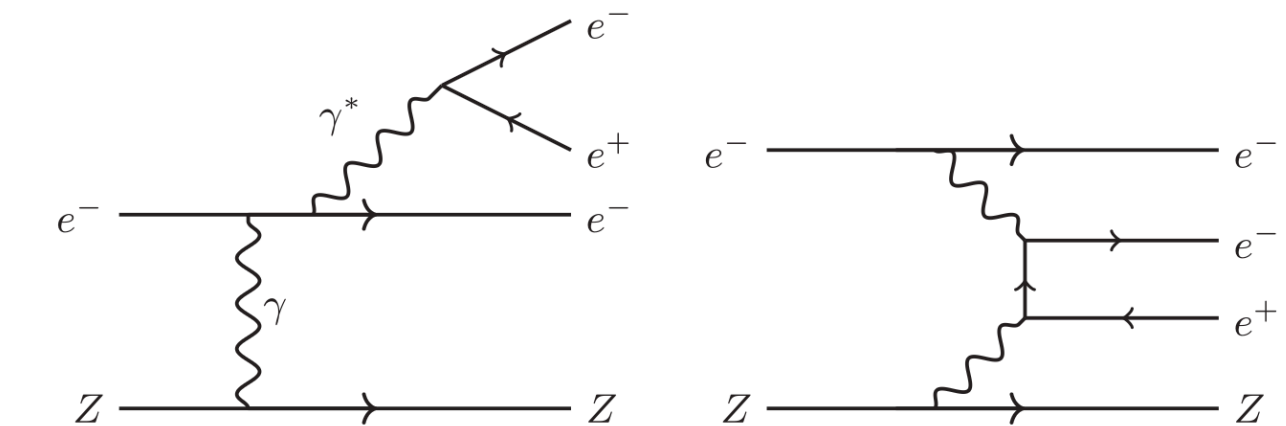
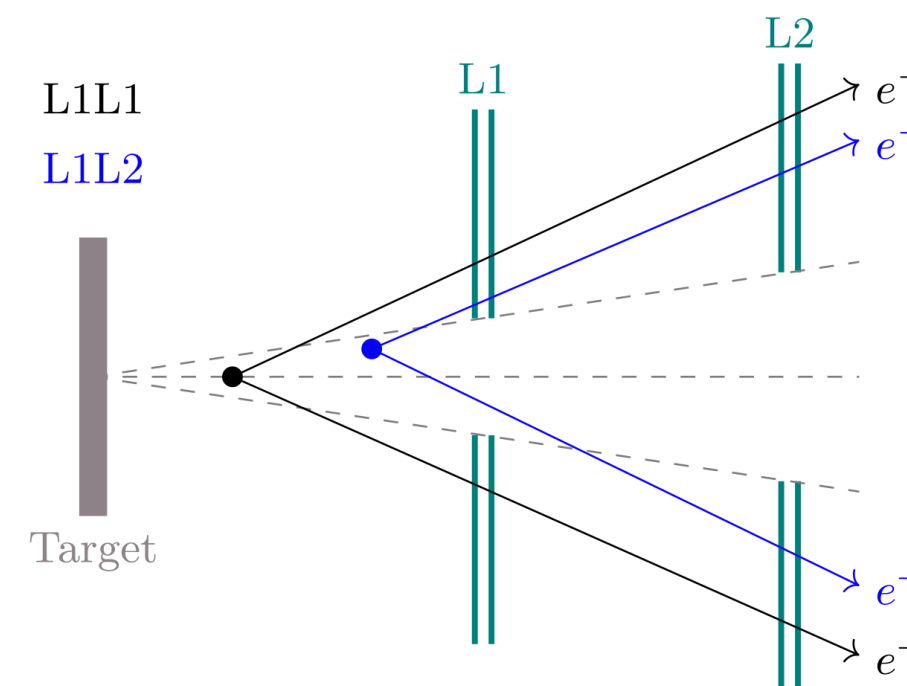
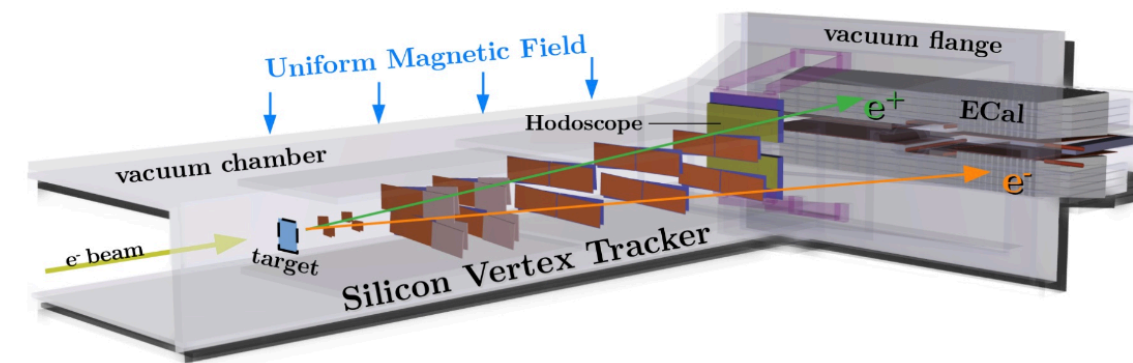
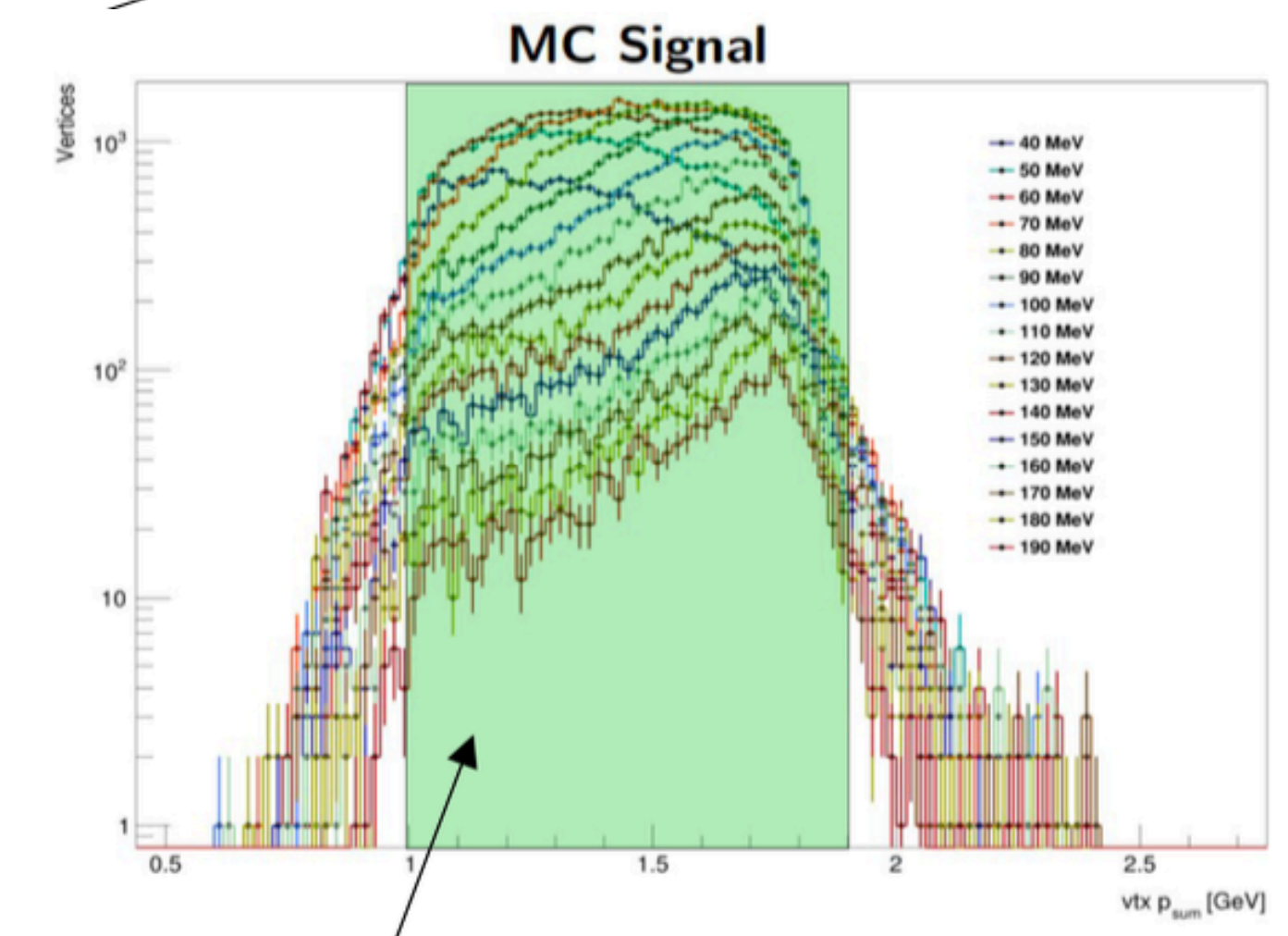
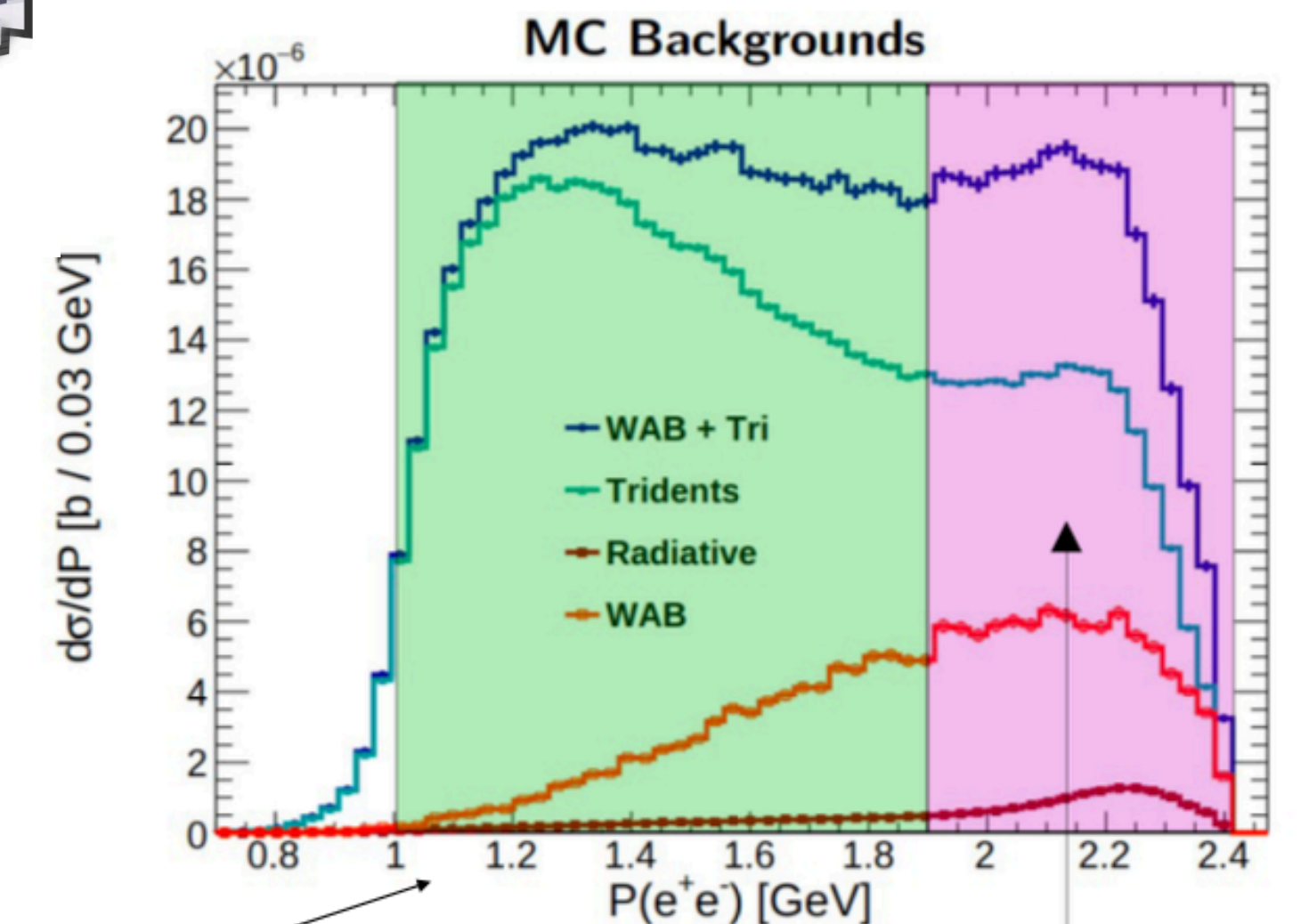


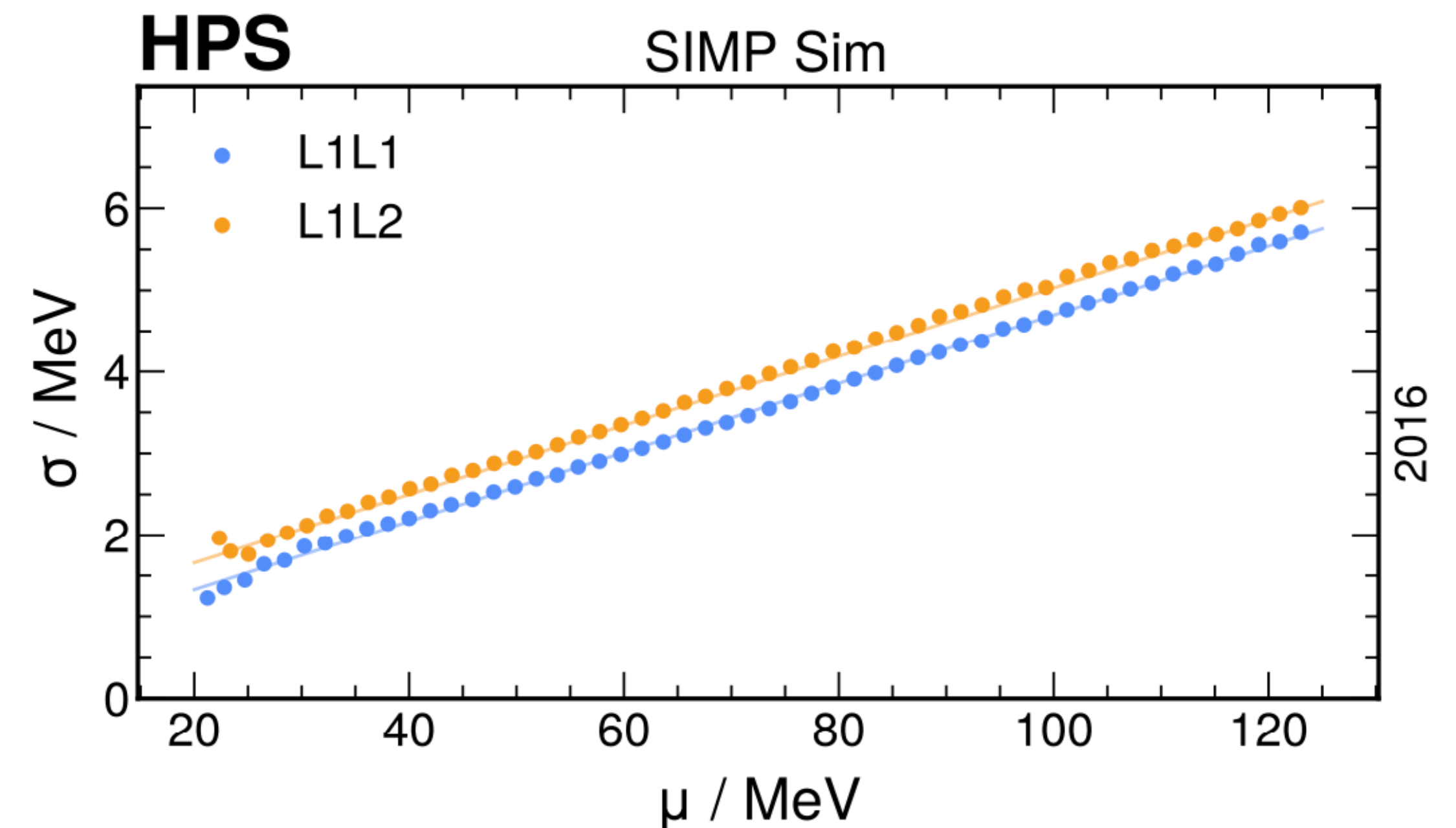
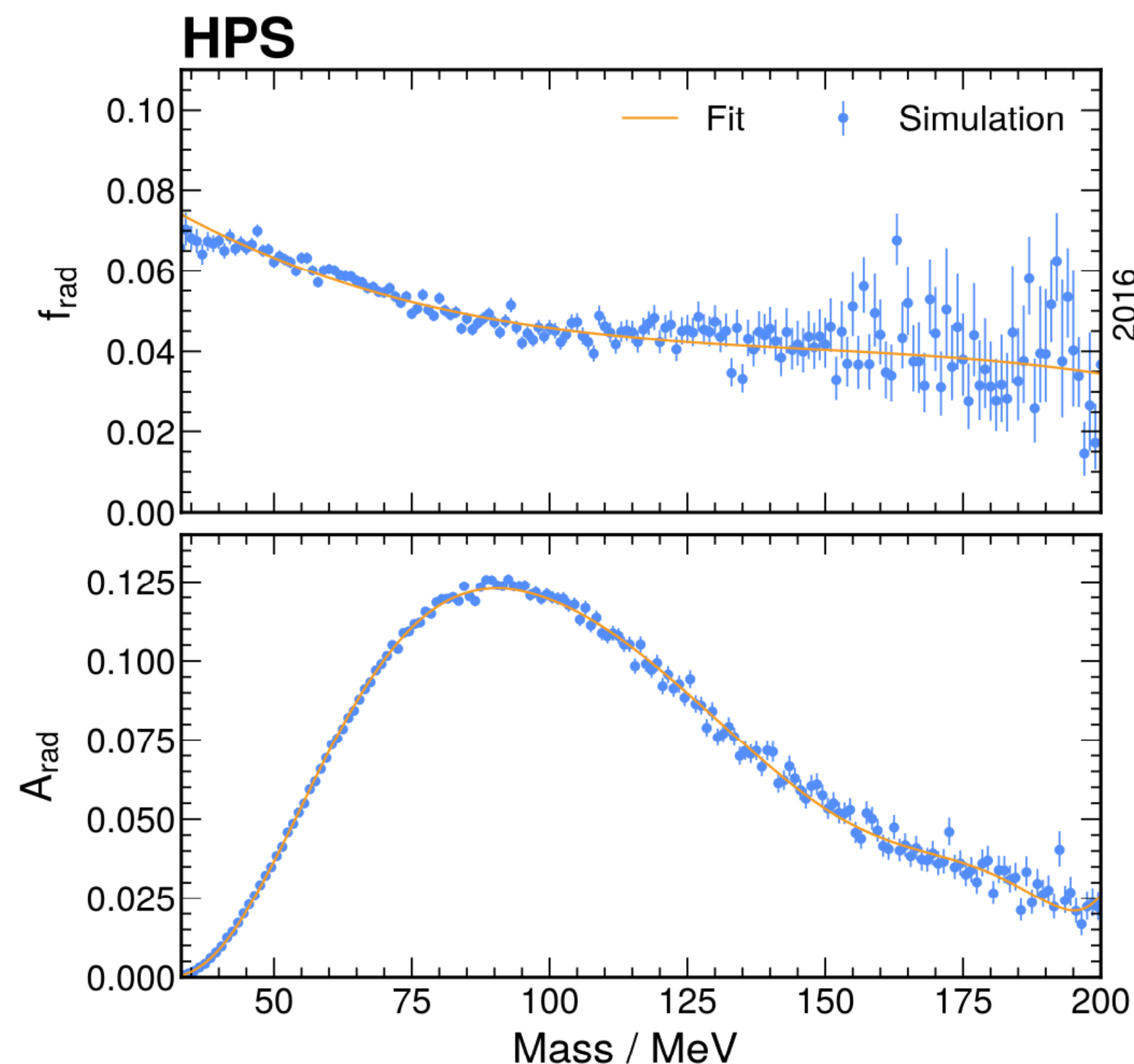
FIG. 3. Radiative (left) and Bethe-Heitler tridents (right) have the same final state particles as the e^+e^- production from a dark vector decay shown in Fig. 1.



Cut description	Requirement
Trigger	Pair1
Track time relative to trigger	$ t_{\text{trk}} \leq 6 \text{ ns}$
Cluster time difference	$\Delta(t_{\text{clu},e^-}, t_{\text{clu},e^+}) \leq 1.45 \text{ ns}$
Track-cluster time difference	$\Delta(t_{\text{trk}}, t_{\text{clu}}) \leq 4.0 \text{ ns}$
Track quality	$\chi^2_{\text{trk}} / \text{n.d.f.} \leq 20.0$
Beam electron cut	$p_{e^-} \leq 1.75 \text{ GeV}$
Minimum hits on track	$N_{\text{hits}} \geq 7$
Unconstrained vertex quality	$\chi^2_{\text{vtx}} \leq 20.0$
e^+e^- momentum sum	$p_{\text{sum}} \leq 2.4 \text{ GeV}$

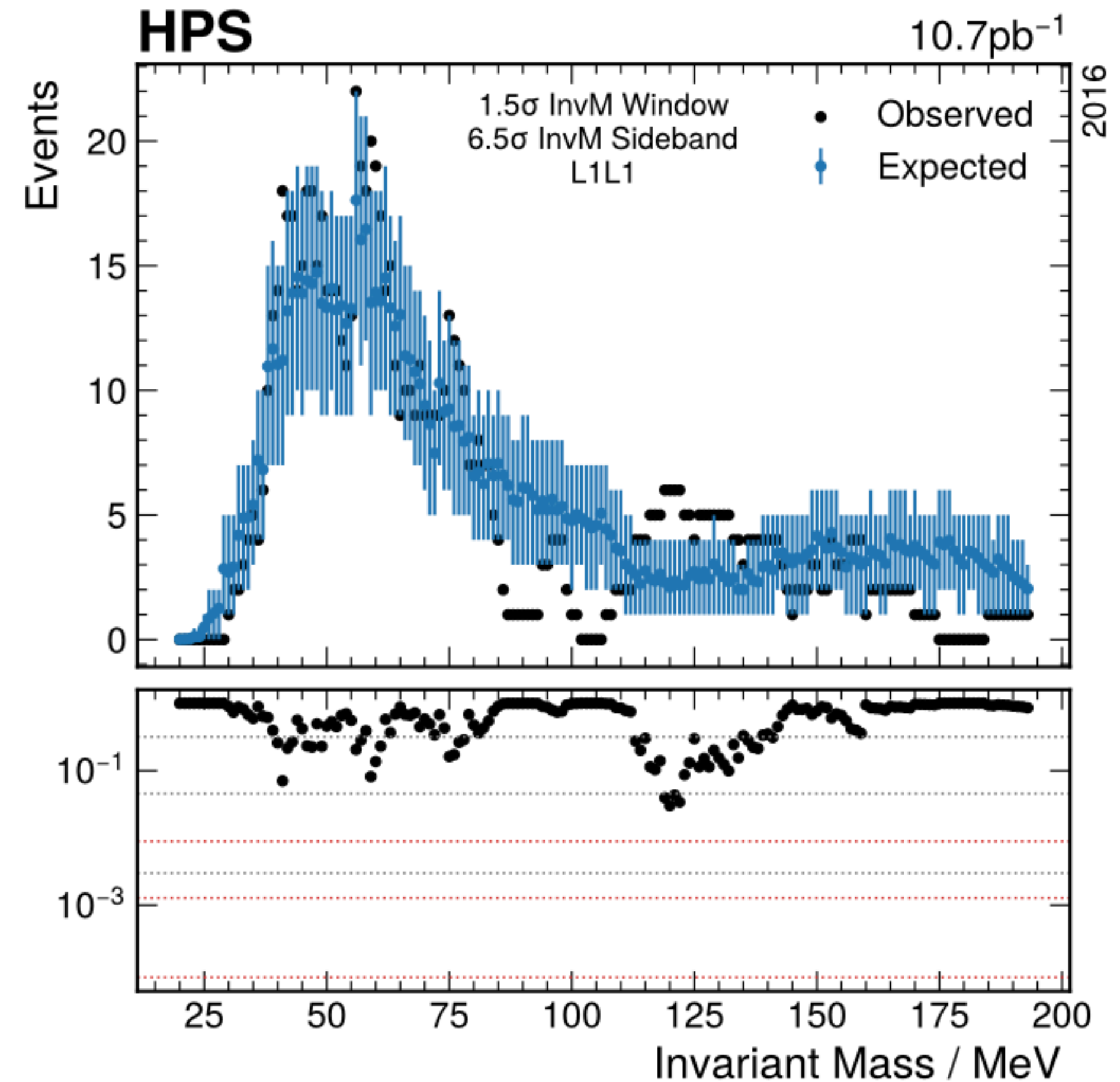
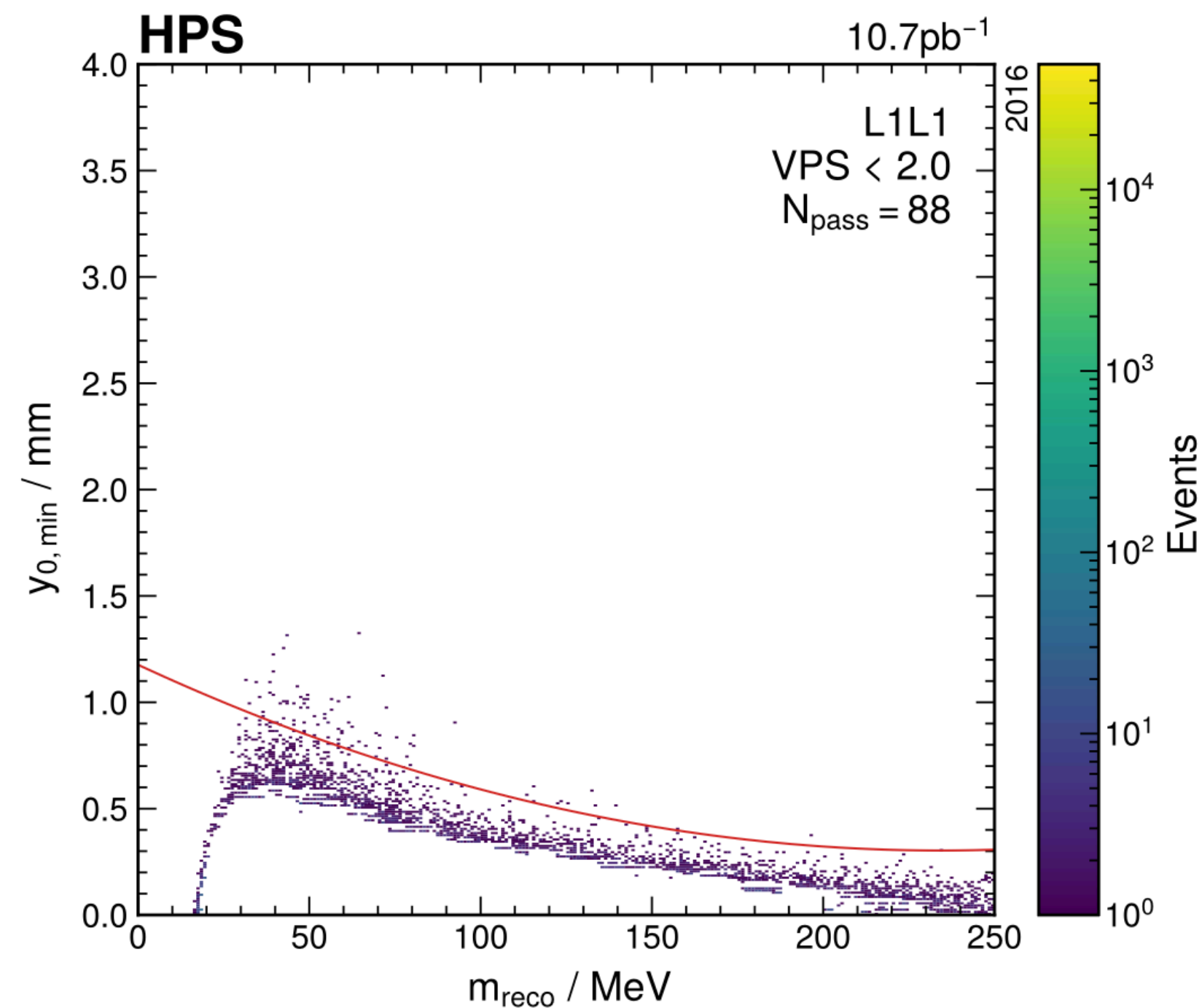
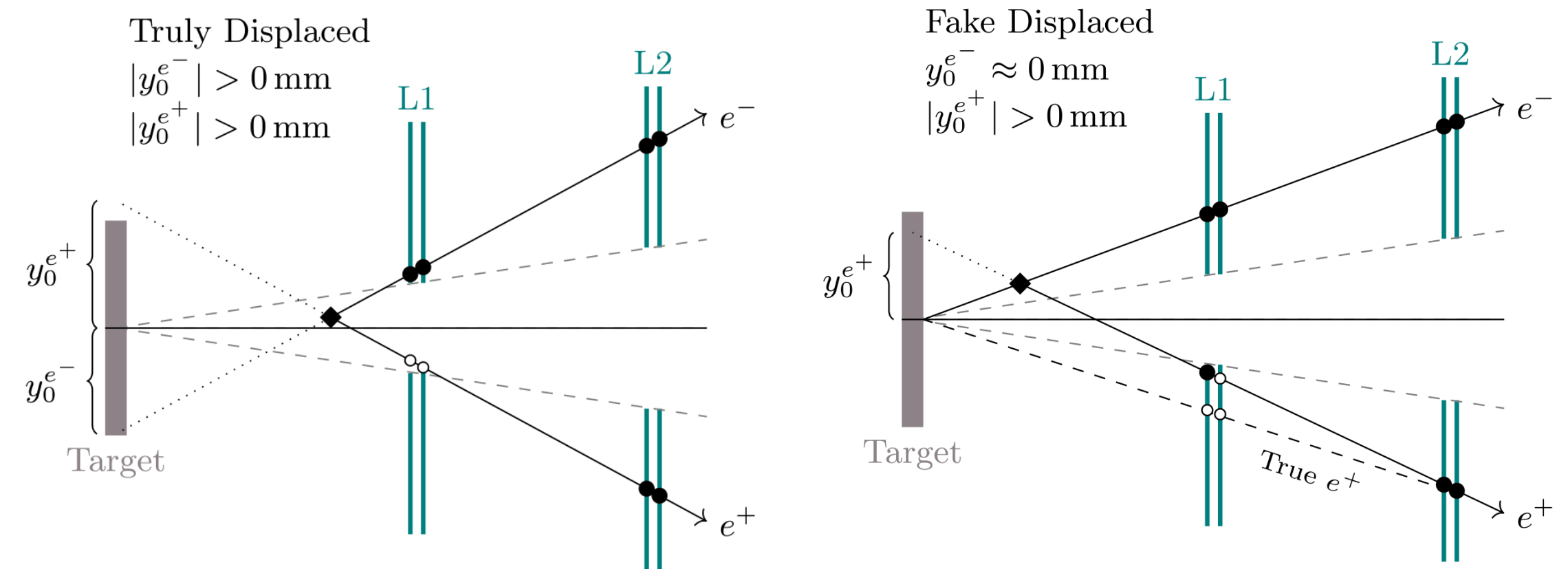
Radiative Fraction and Mass Resolution

- With the irreducible Bethe-Heitler background, radiative fraction is always a key A' ingredient, and larger for a SIMP analysis
- And mass resolution, which we model with simulation and benchmark with Moller scattering

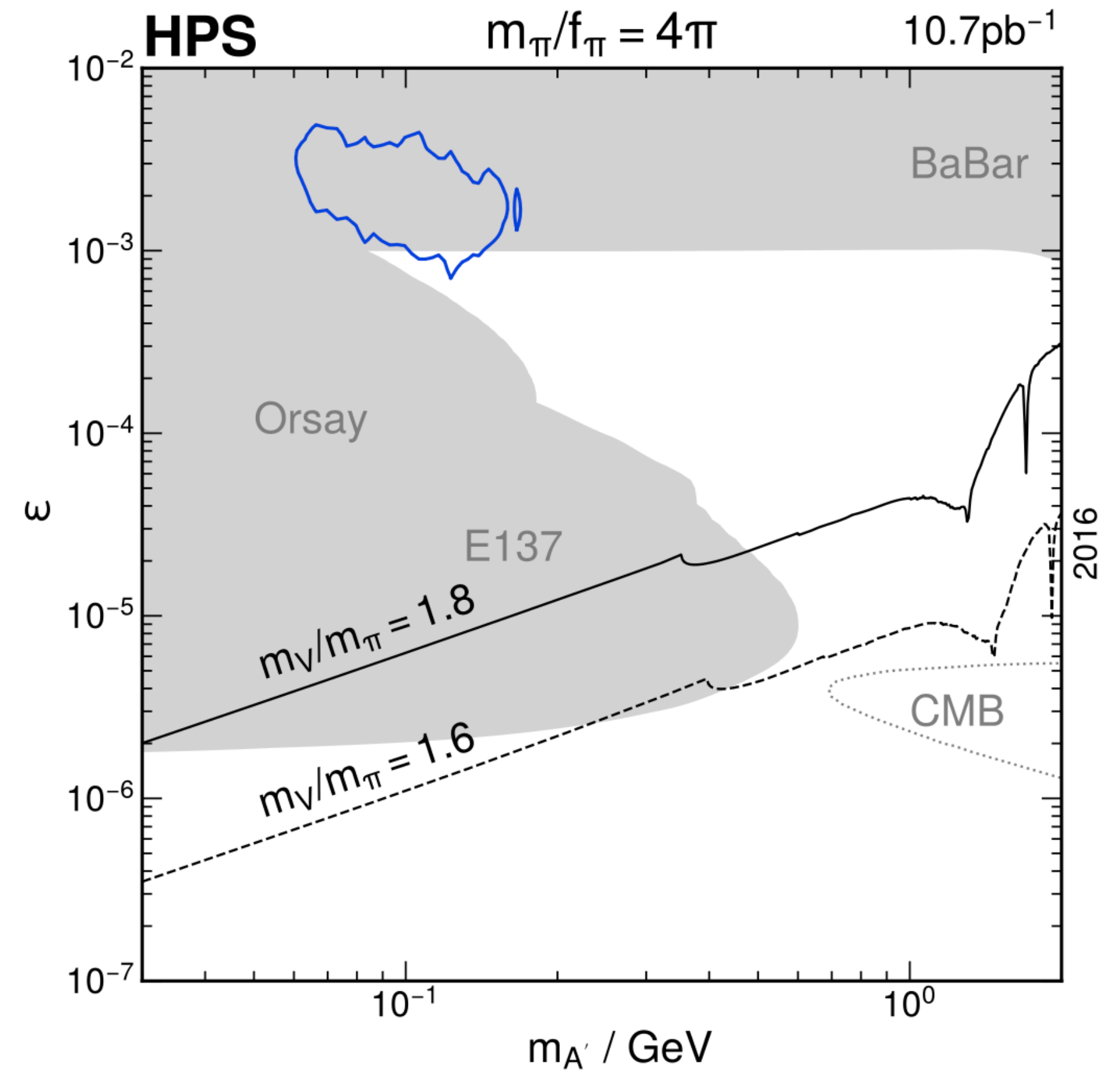
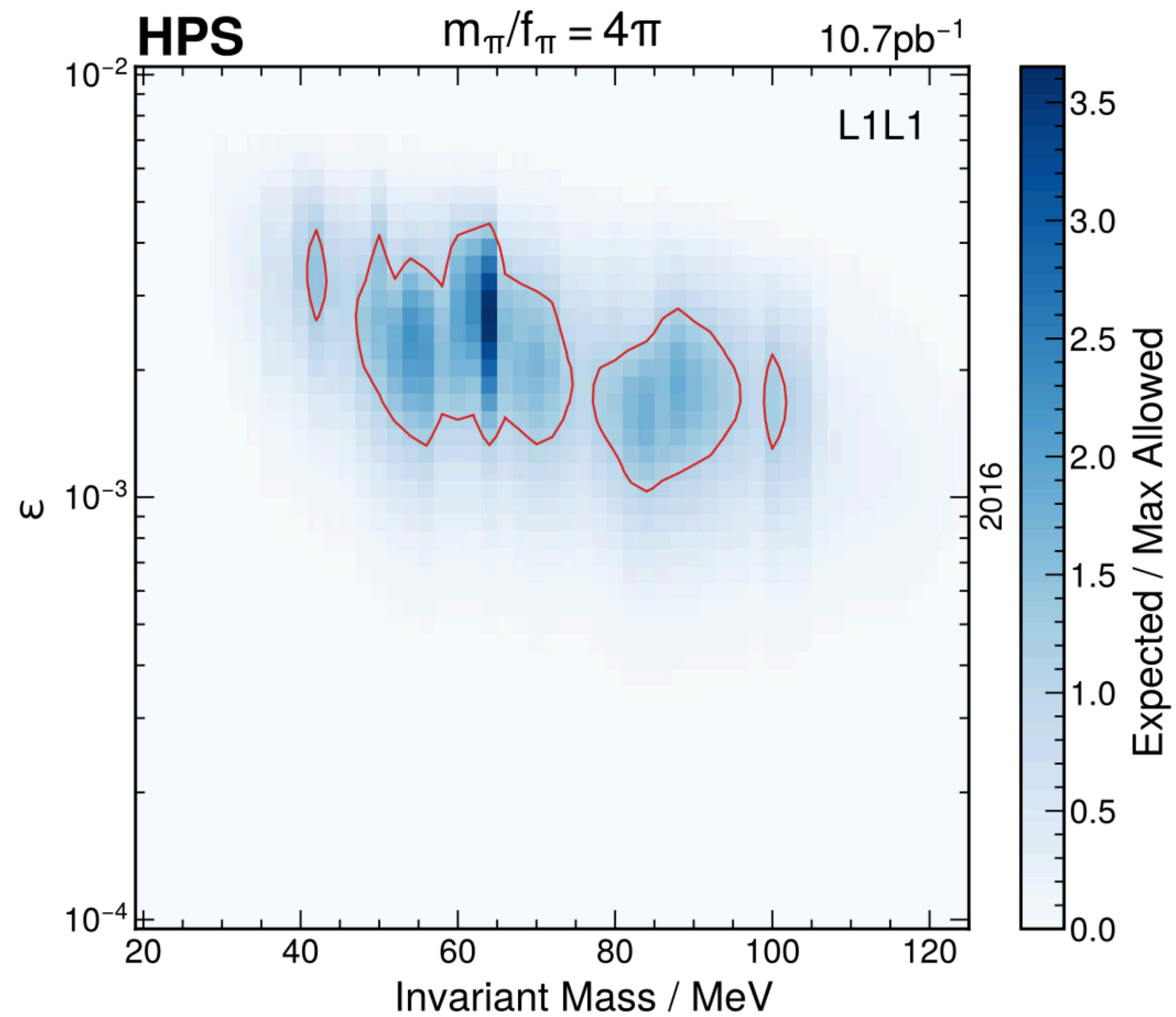


Signal Extraction

- Proxy variable for quantifying vertex detachment and separating fake displaced backgrounds



Exclusion Result



Summary

- HPS's first SIMPs search was published early this year, with our 2016 engineering run data set, extending beyond HPS's proposed measurements.
- This work to be extended to later data sets
- Also, visible A' searches for HPS's larger data sets are coming soon, in a combined analysis.

PHYSICAL REVIEW D **113**, 032019 (2026)

First displaced vertex search for electroproduced dark-sector strongly interacting massive particles by the HPS experiment

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Systematic	Value
Radiative fraction	7%
Preselection cuts	Neglected
Final selection cuts	Neglected
Radiative acceptance	
From preselection	Neglected
From target uncertainty	~5%
Signal yield	
From target uncertainty	2%
From mass resolution	0.5%
Beamspot	Neglected
p_{sum} shape	~3%
Total	~10%