Investigating Another SIMP Analysis Channel

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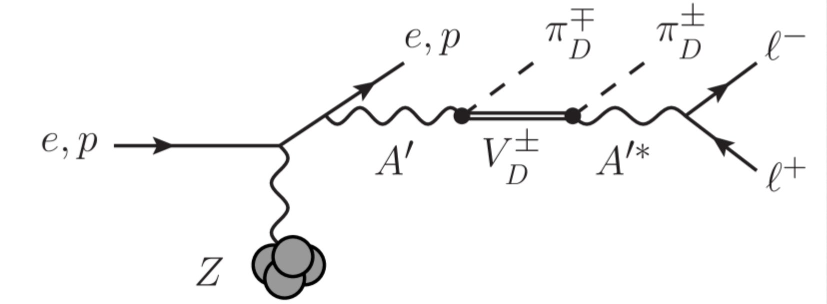
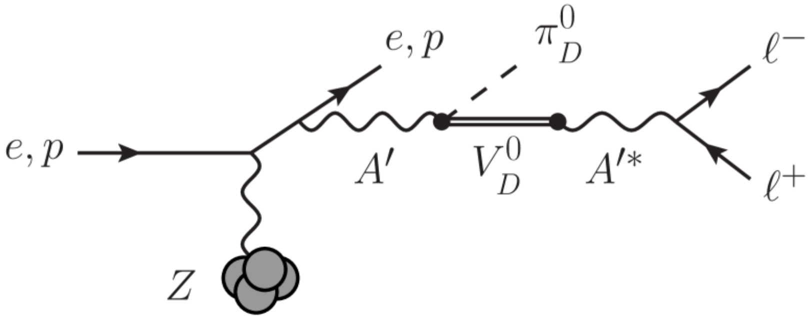
Non-Resonant SIMPs (▸ arXiv:1801.05805)

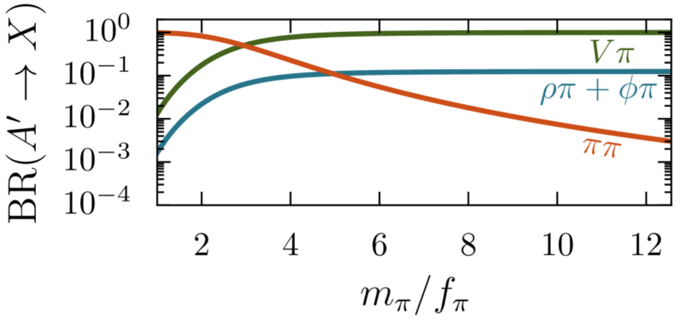


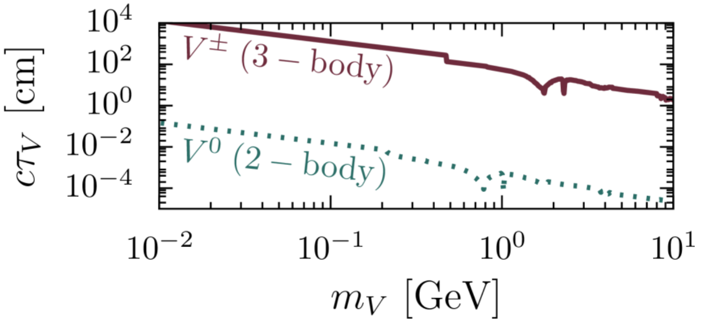
Current SIMPs (as being studied by Alic)



QCD-like Dark Sector ⇒ dark-charged mesons

Higher branching ratio but more complicated decay topology





How to Study?

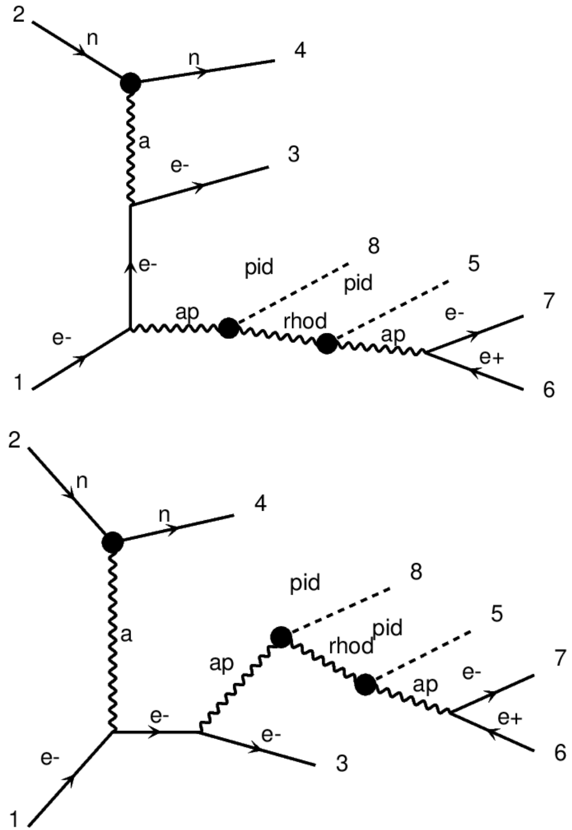
Emailed with authors of ▸ arXiv:1801.05805
(credit to Nikita Blinov)

Phase Space Generation

SIMP Model as-is is sufficient since the SM-DM interactions are the same without a full implementation of dark-QCD, **but cannot calculate decay rates**.

Decay Rates

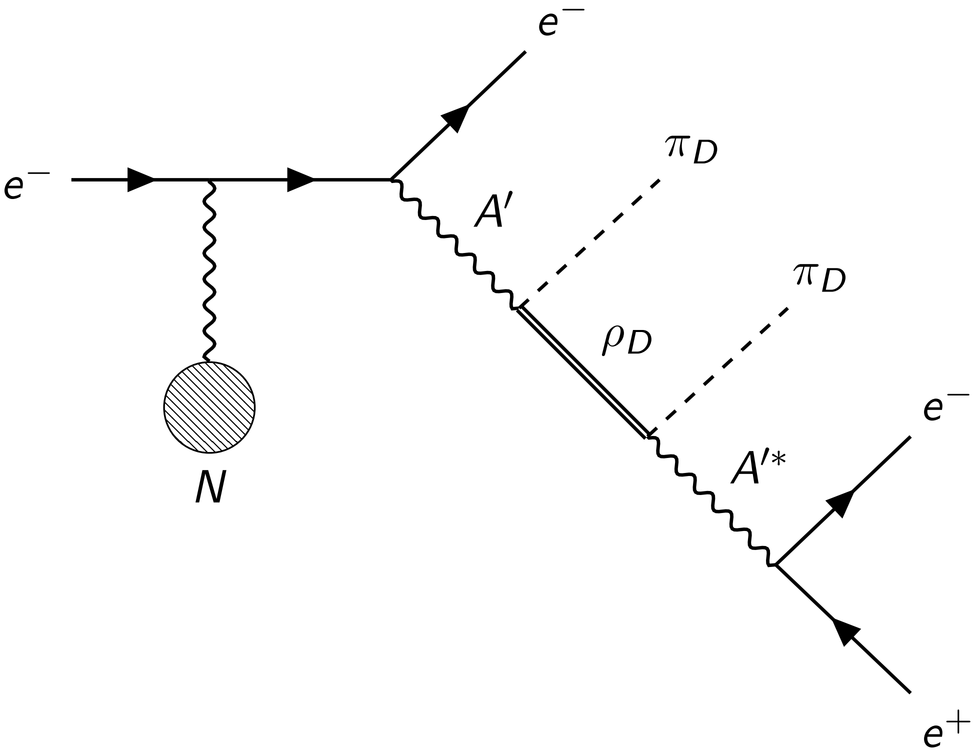
Paper has an equation relating SIMP parameters to decay rates ✓



How to Study?

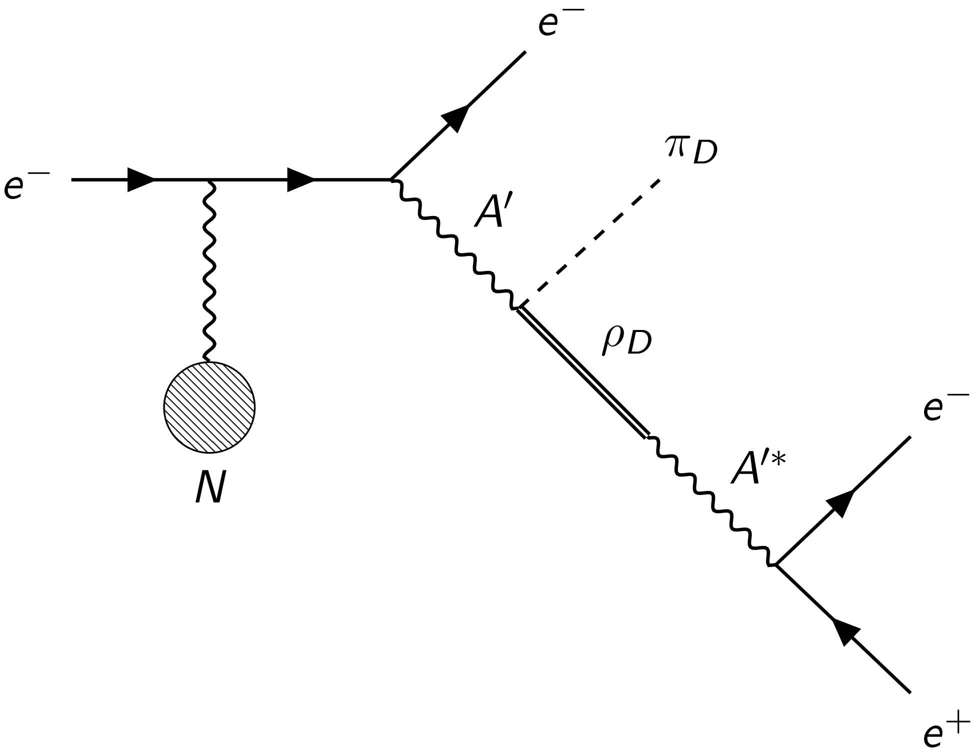
Signal Sample Generation

- ✓ Have MadGraph model that calculates this diagram.
- ✓ Model now integrated into and being run from hps-mc
- Events displaced randomly and simulated
- Readout and reconstructed with standard 2016 steering files

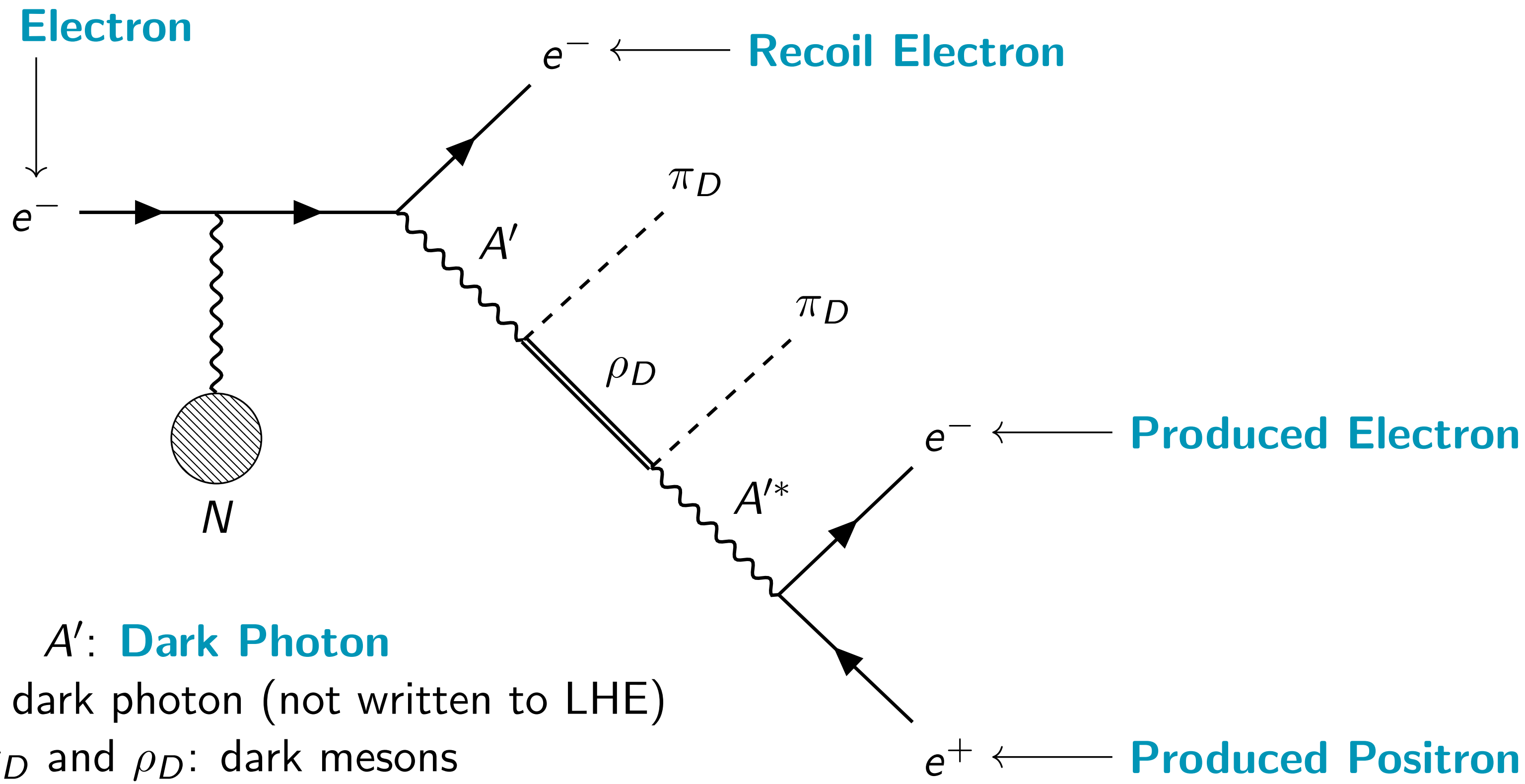


Comparison to 2-Body Decay

- Same except for number of π_D produced
- Allows for direct comparison of SM particles (same vocabulary)



Vocabulary



A': **Dark Photon**

A'^* : virtual dark photon (not written to LHE)

π_D and ρ_D: dark mesons

ρ_D width is what causes the displacement

MadGraph-Level Comparison

Using the same SIMP parameters Alic has been using (and taken from the paper).

$$\frac{m_{A'}}{m_{\pi_D}} = 3 \qquad \frac{m_{\rho_D}}{m_{\pi_D}} = 1.8 \qquad m_{\rho_D} \in \{60, 90, 120, 150, 180, 210\} \text{ MeV}$$

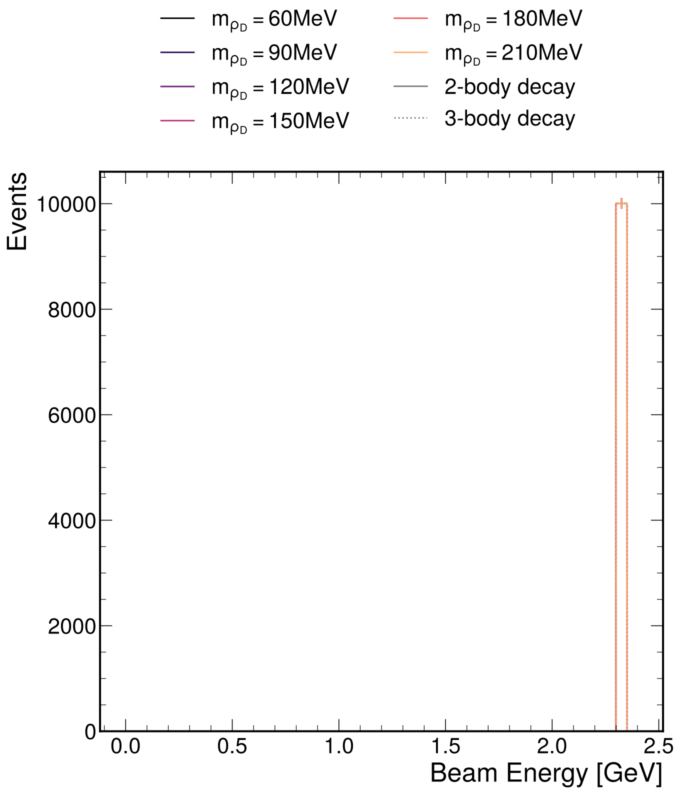
General Notes

- No displacement of decay vertex
- No relative-rate scaling applied
- Line color maps onto choice of m_{ρ_D}
- Line style maps onto decay topology

Relationship to iDM

- iDM has similar diagrammatic structure as 3-Body-Decay SIMPs
- Expect strong similarities in event topology
- SIMPs have more model specifics (including analytic calculation of decay rates) which will make the study more concrete

Beam Energy

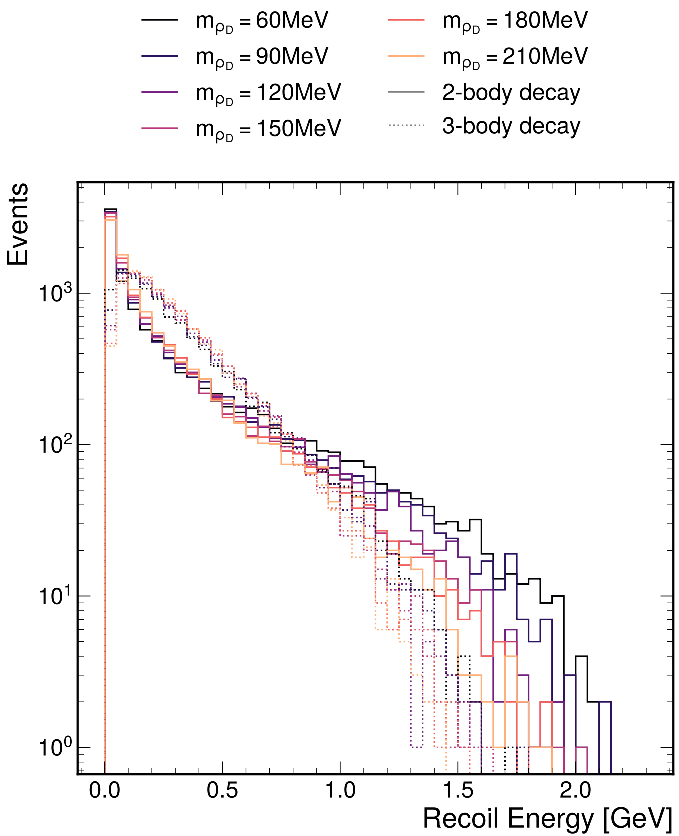


Boring plot, but helps highlight a few things

1. Each mass point for each decay has 10k events
2. Higher-mass DM is shown with brighter/lighter color shades
3. 2-body decay (resonant decay, what Alic is focusing on) is solid lines
4. 3-body decay (non-resonant decay, this new investigation) is dotted lines

Now let's go through the SM final-state particles.

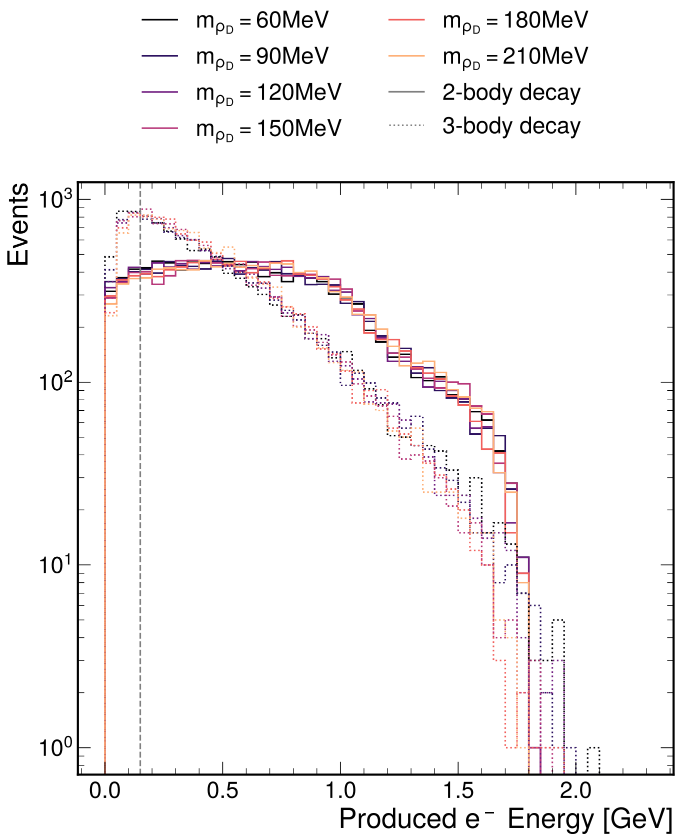
Recoil Energy



Total energy of recoiling electron

1. Decay path strongly groups distributions together
2. 3-body decay produces a much wider distribution (not even peaking in zero bin)
3. Both still have low tails at high energy

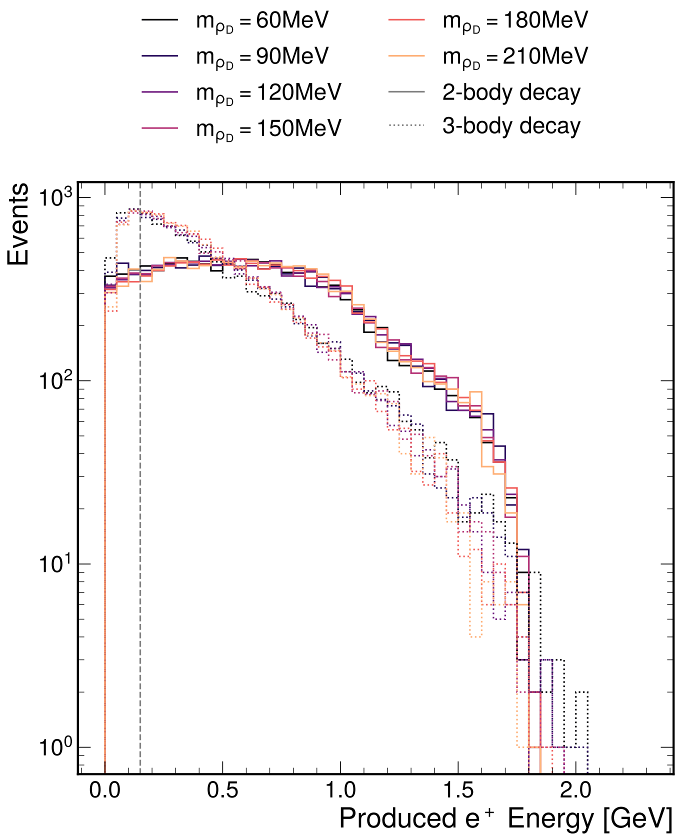
Produced e^- Energy



Total energy of produced electron

1. 3-body decay shifts distribution towards low-end peak
2. Observable decrease in events above minimum energy cut from trigger

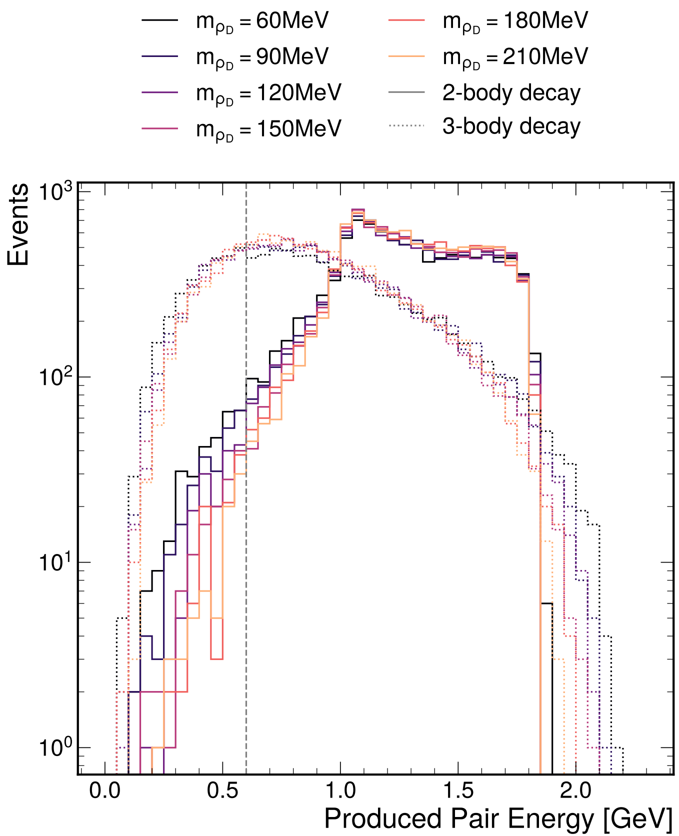
Produced e^+ Energy



Total energy of produced positron

1. Same distribution as produced electron in both decays

Produced Pair Energy

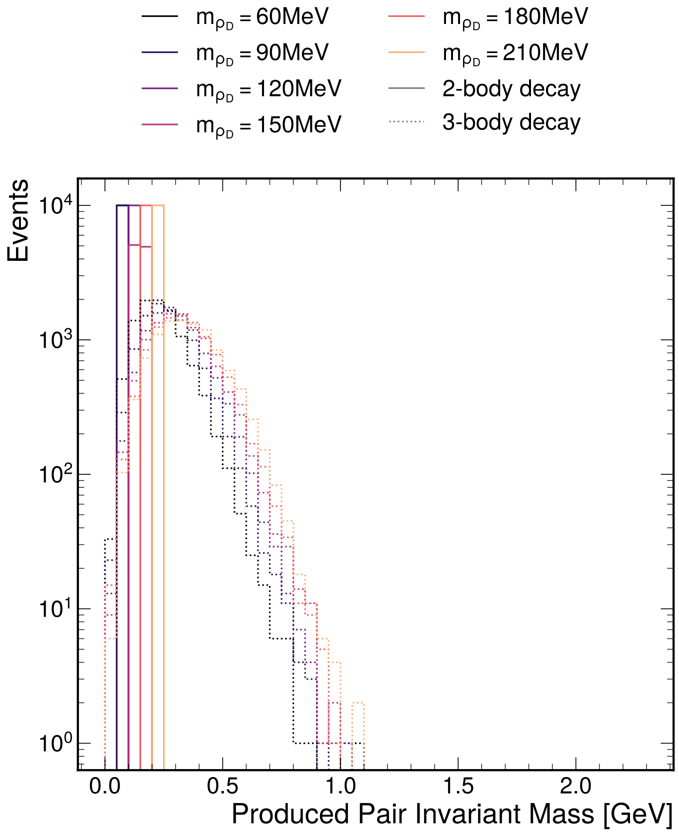


Total energy of produced pair: $E_{e^+} + E_{e^-}$

i.e. Mimicking a cluster-wise energy sum

1. The lowering of both energy distributions has a large effect on the total energy distribution
2. Just barely peaking above the trigger energy threshold of 600MeV
3. Much more significant loss of events to below the trigger threshold

Produced Pair Mass

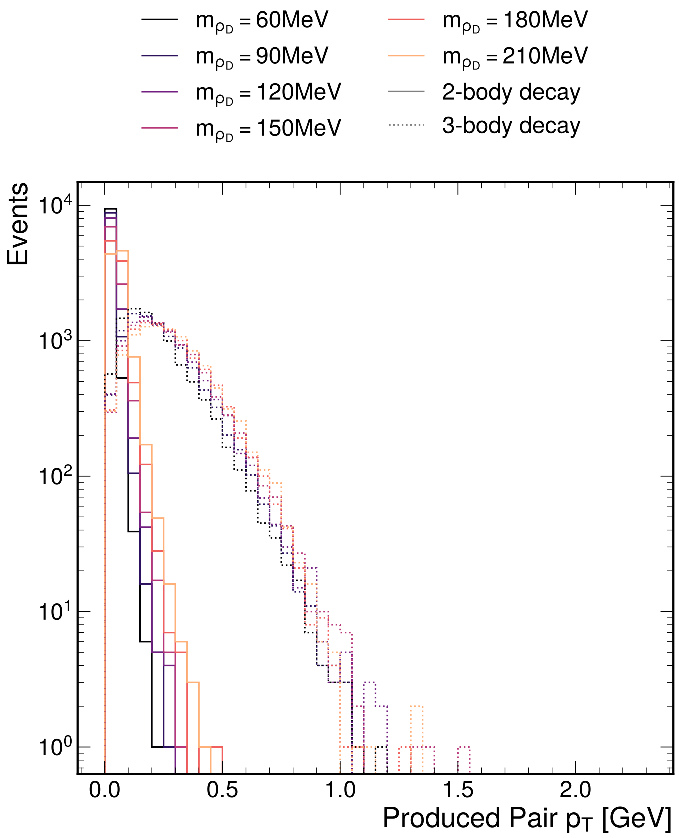


Invariant Mass of produced pair: $M(p_{e^+} + p_{e^-})$

i.e. Mimicking a particle-wise momentum sum

1. 2-body decay gives the mass of the real ρ_D (whose width is smaller than the bin width)
2. 3-body decay smears the invariant mass distribution, making the distinction between different mass points much more difficult

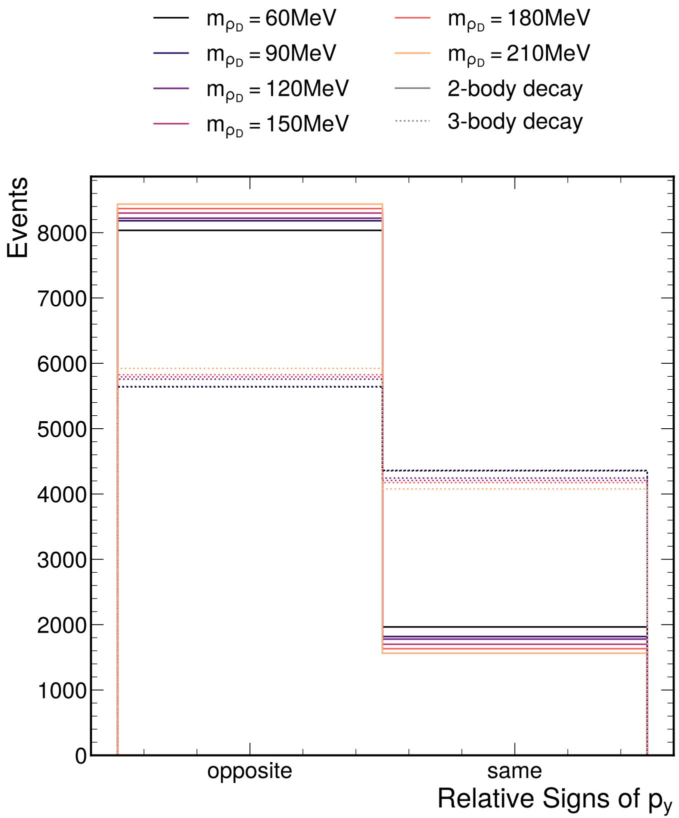
Produced Pair p_T



Transverse Momentum of produced pair: $(p_{e^+} + p_{e^-})_T$

1. 2-body decay keeps the pair centered on the beam axis
2. 3-body decay pushes the pair off-axis

Produced Pair sign(p_y)

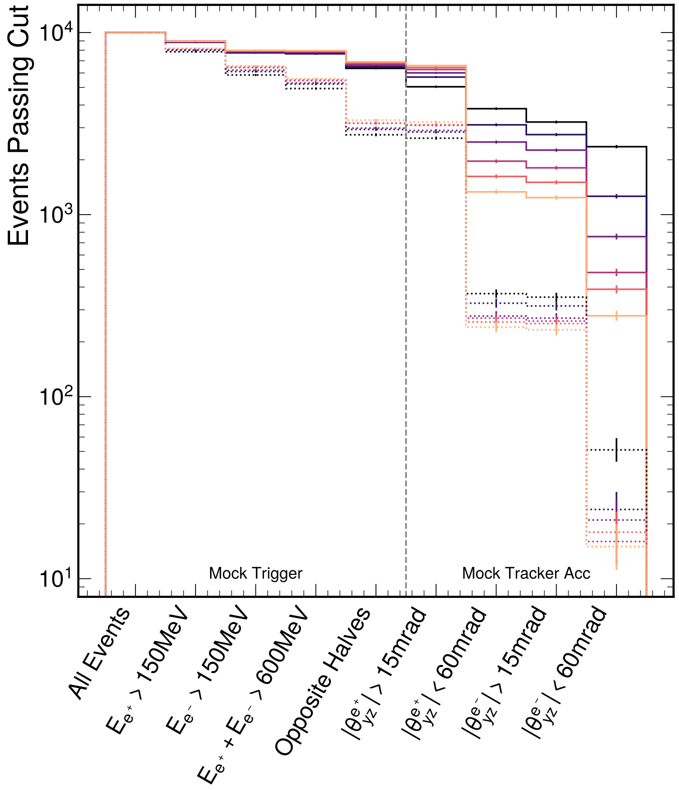


Relative signs of p_y in Pair: $\text{sign}(p_y^{e^+} \times p_y^{e^-})$

Roughly maps onto the style of vertex needed during reconstruction *and* the opposite-side nature of the pairs trigger in 2016

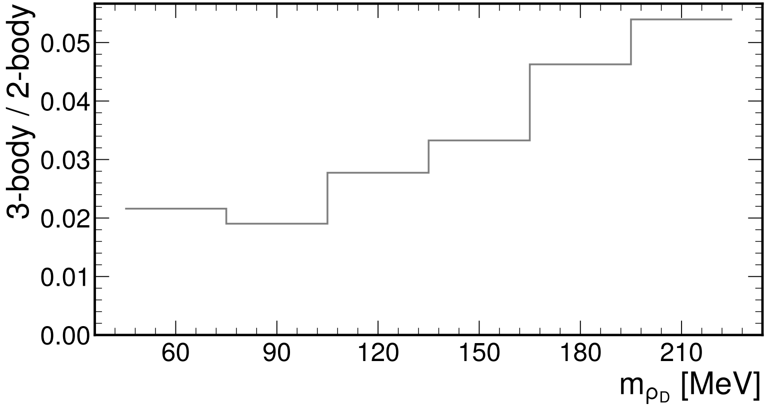
1. 2-body decay much more often has pairs with opposite signs in p_y, enabling opposite-half vertices as well as maintaining a higher trigger efficiency
2. 3-body decay makes the signs of p_y closer to a coin-flip relative to one another

Mock Cutflow



Using generator-level information, apply some basic cuts to mimic the 2016 pair-wise trigger (left) and rough tracker acceptance (right).

- Lose a factor of ~ 3 at the trigger and ~ 20 at tracker acceptance
- Similar to what was seen with iDM



Summary and Plans

Summary

- Using generator information, first comparison of two different SIMP decay channels at an HPS beam energy
- Similar to iDM, observing trigger and tracker acceptance difficulties for 3-body decay
- Loss in acceptance as estimated using generator-level information *for both* is between $1/20$ and $1/100$

Next

- Replicate current readout/reco pipeline for 2-body and apply the same pipeline to 3-body events like these
- More accurate acceptance *fraction* using reco information
- Estimate acceptance *rate* folding in ϵ, f_π and decay rate

Questions

Sample Detail

TriTrig and WAB

Produced by Cam and available at SLAC.
/sdf/group/hps/mc/2pt3GeV/HPS-PhysicsRun2016-Pass2/{tritrig,wab}/ecal_trig_res

Signal

Used ▸ tomeichlersmith/hps-prod container release ▸ 2023-12-06

- Chose same SIMP parameters as Alic (taken from pheno paper) $m_{A'}/m_{\pi_D} = 3$, $m_{\pi_D}/m_{\rho_D} = 1/1.8$