

# Analysis overview, plans and milestones

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Summer 2024 HPS Collab Meeting



# Ongoing & near future physics analysis

- We can break our searches into 3? categories:
  - just resonance
    - ***high-epsilon (i.e prompt) A's***
  - resonance+displaced vertex
    - ***high-ESum*** → ***low-epsilon A's***
    - low-ESum → SIMPs
  - just displaced vertex???
    - 3-body decays in extended dark sector – iDMs/SIMPs etc
      - not clear we can get interesting reach but need to investigate

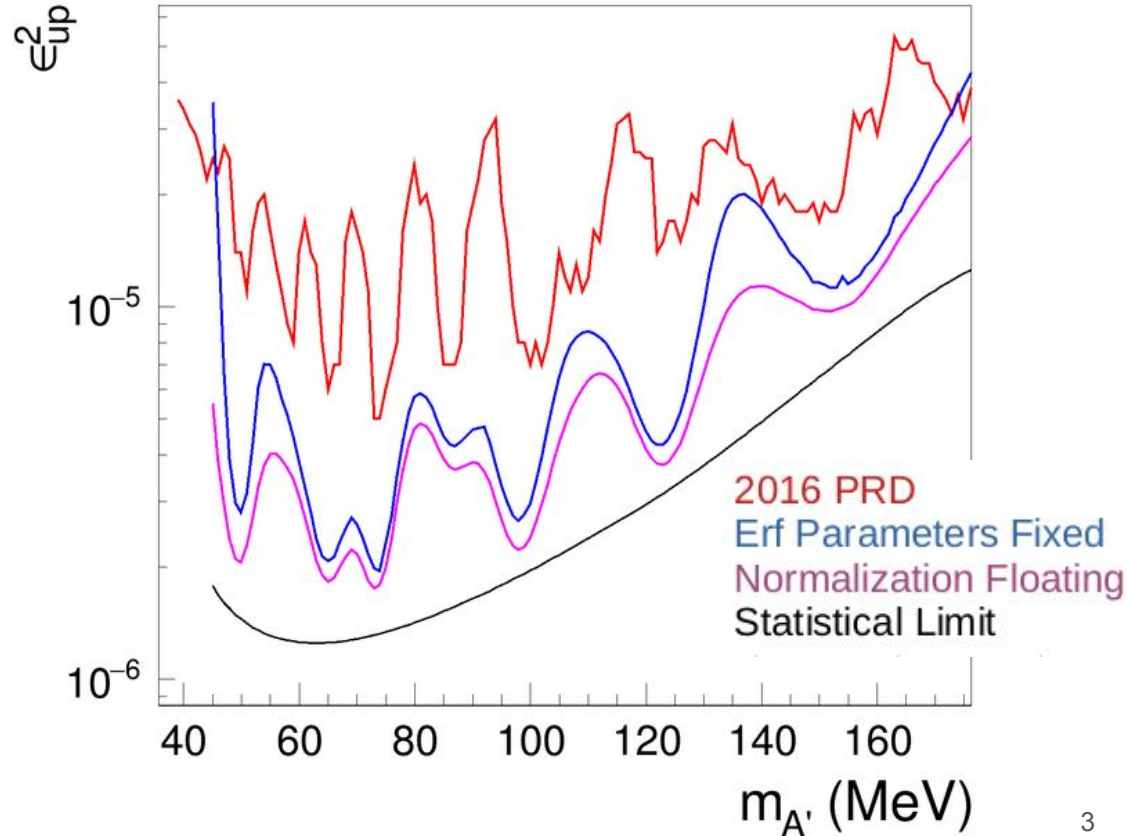
# Resonant Search: Bump-hunting and global mass fits

Emrys has made a lot of progress on global background fit, using 10% 2016 data as a test bed.

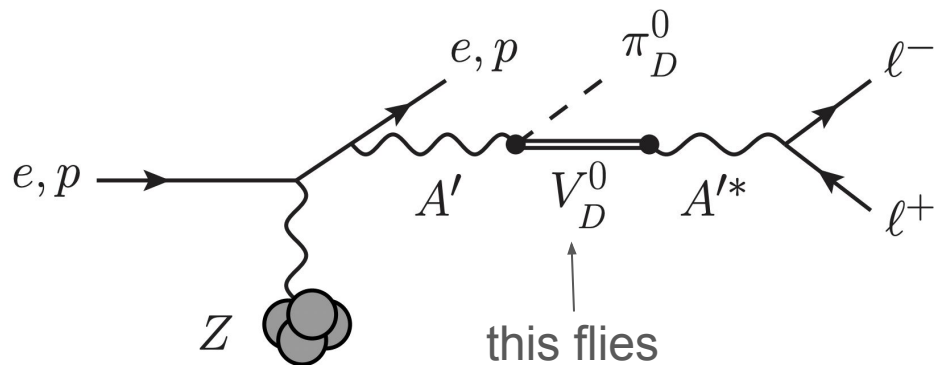
Currently investigating unblinding procedure ...  
10→100% can (but hopefully not) unveil new structures.

After this, start bump-hunt on new data.

[A document has been started](#)



# Resonance + Displaced Vertex: low-PSum



Alic and Tom are working on 2016 SIMPs, looking at this interaction...

Has a **resonance** at  $m(V_d^0)$  and **displaced vertex**.

Almost completely complementary to  $A'$  search in PSum.

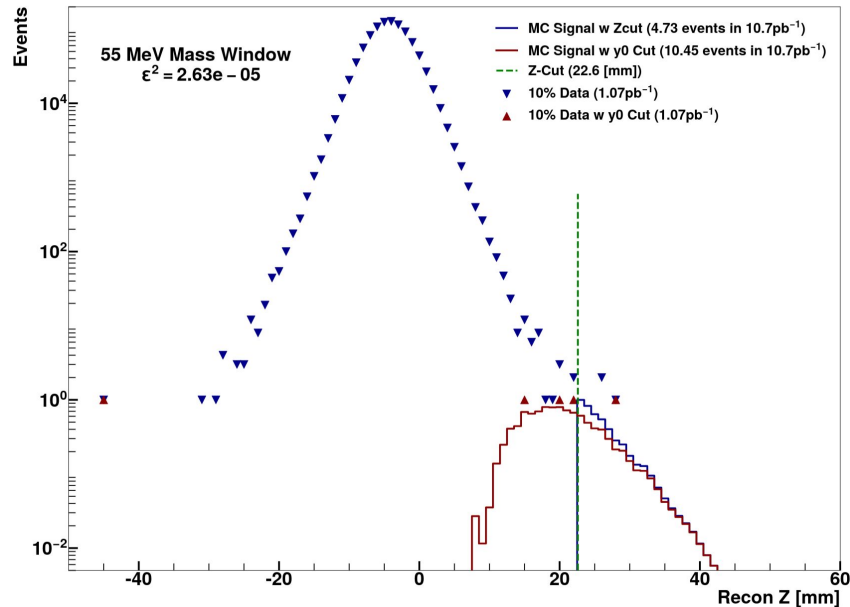
This analysis already [has a note started](#) and RC has approved selection.

Alic is focusing on L1L1 analysis...working on signal extraction procedure!

Tom will follow with L1L2 (and maybe L2L2?).

# Game changer? Hard z0 cut!

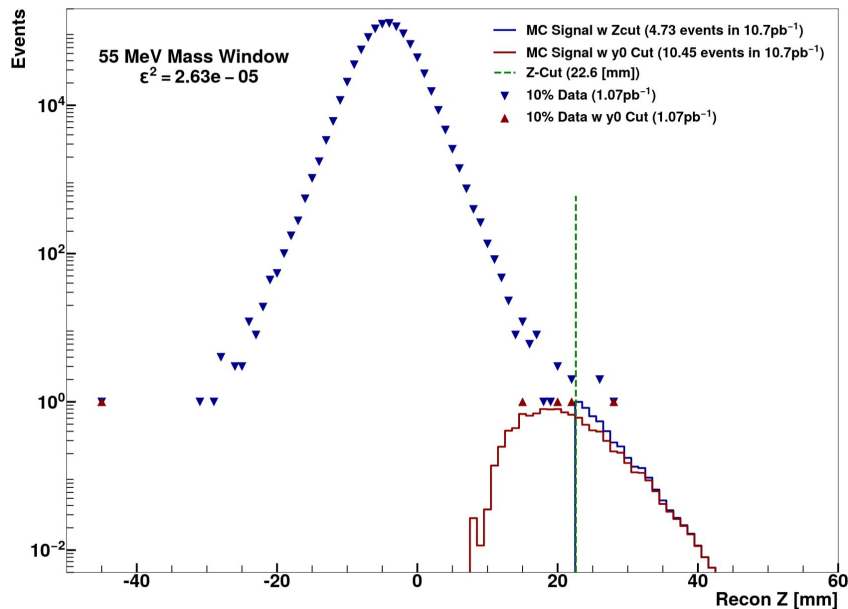
- [Back at the November CM](#), Alic showed a bunch of optimization and then snuck in this with a very hard, flat z0 cut...gets rid of almost high-z background (and prompt peak) with great signal efficiency



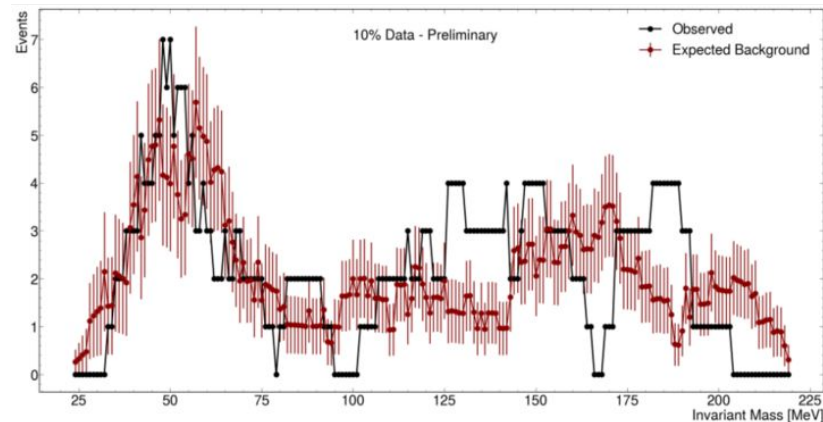
Too good to be true? Nope, looks legit...

# Game changer? Hard z0 cut!

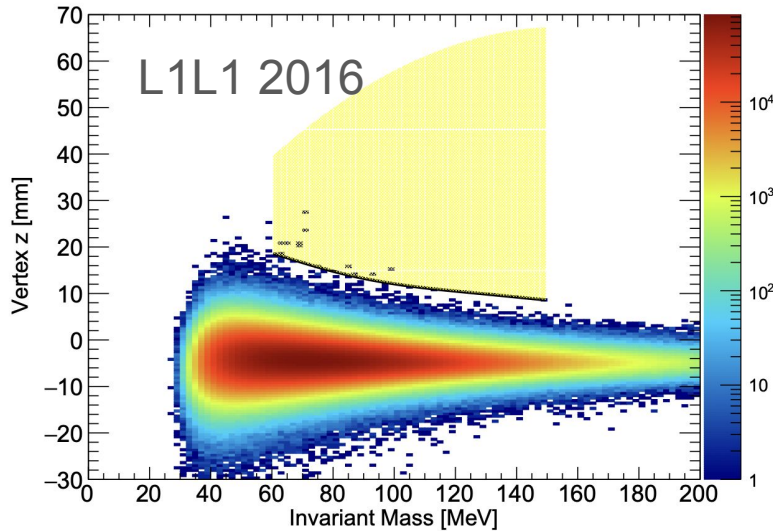
- This does leave a some high-z events (someone should look at these) but gives efficiency at much lower vertex-z.
- Should work for nominal  $A'$  search as well...though production rates are smaller (well, at least compared to the SIMP parameters we are looking at)
- See Tom's talk in this meeting for his high pSum studies with this cut



## Estimating the Expected Background



# Resonance + Displaced Vertex: high-P<sub>Sum</sub>



“For 2019/2021, we haven’t started in an organized way yet; what I would call “underlying” tasks are being finished up.”

Still true, and that needs to happen quickly. We are a lot closer...need to make decisions on alignment. When is good enough good enough?

*“To a large extent, we know how to do this...having layer 0 and KF tracking mixes things up a bit but if we just wanted to do L1L1 following the 2016 analysis, we could get this out quickly.”*

Also still true, but we plan on using hard z<sub>0</sub> cut ... no more plots like the above one!

# Near term analysis results (in time-order)

- 2016 data: SIMPs – Alic, Tom
  - [There is a note started](#)
  - [We have an RC](#): Lauren (chair), Alessandra, Natalia
  - ~~Preselection has been signed off...working on “tight” cuts~~
  - Background estimate on 10% and projected reach
  - Documentation and unblinding
- 2021 data: Nominal A' Displaced Vertex – Everyone
  - get a quick analysis published on 2021 data using 2016 L1L1 analysis flow + (probably) hard z0 cuts
  - then follow up with full 2019/2021 paper with improvements like 2d fitting to get signal & upper limits, L1L2, L2L2, MVA etc...
- 2019/2021 (+ 2016?+2015?) Resonance Searches
  - Emrys has made a ton of progress...need to make sure we can do this blinded
  - I think we should include 2015 & 2016 re-analysis using global background fit
- Down the line...2019/21 SIMPs, non-resonant displaced vertex studies



# Tasks & Milestones (for quickie 2021 displaced vertex)

#1A+ is to settle on 2021 alignments for entire run period

→ including top vs bottom & global

After that, with 1% (or whatever) data:

- MC, RECO: beam X,Y angle vs run
- MC, RECO: target Z
- MC: hit-on-track efficiencies
- momentum/mass smearing (Mollers as x-check)
- semi-optimize cuts

Then, while running 100%:

- generate *final* MC samples
- finalize cuts

***To be continued....***



# Tasks & Milestones (for quickie 2021 displaced vertex)

...continued...

- calculate radiative fraction
- relative signal efficiency vs. vertex Z
- projected result from X% data
- documentation, documentation, documentation....
- unblind
- get final signal significance/limits
- submit PRL

...might have skipped a few steps...

This list is the minimal path...also should look at: track efficiency, rates, shapes vs run + probably other stuff I'm missing.

We will have surprises.



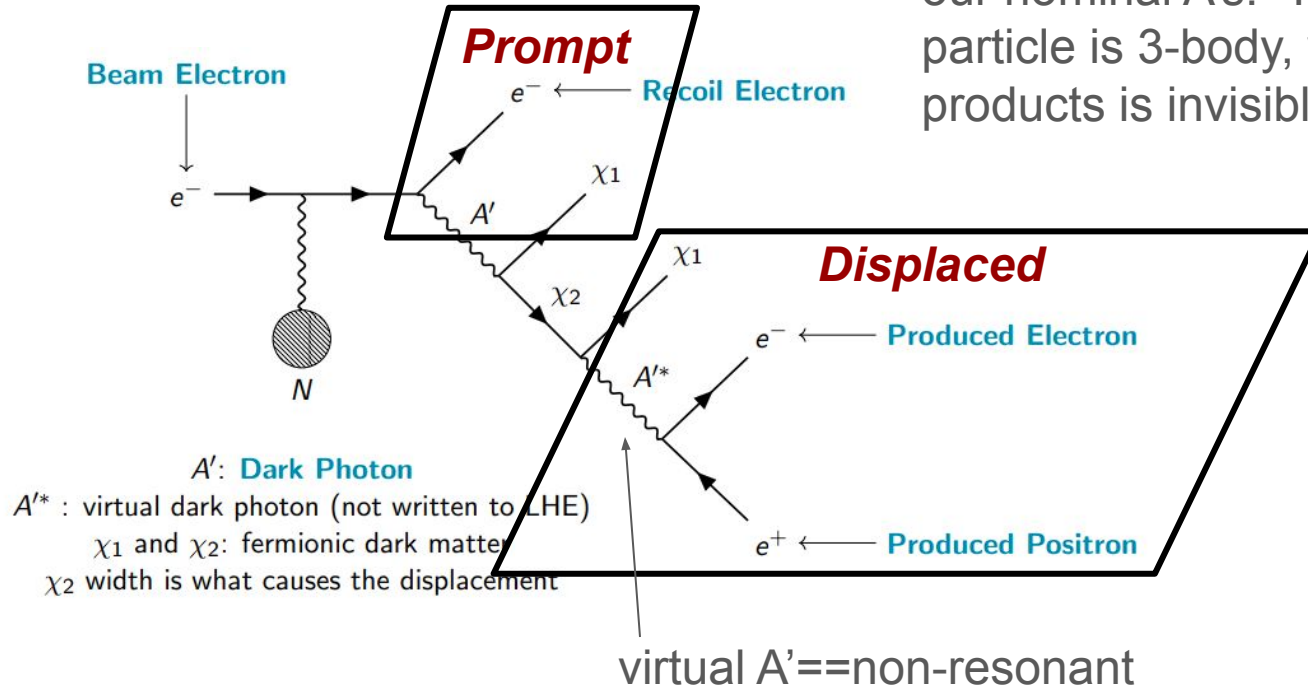
# Summary and other stuff

- What about 2019?
  - With PF's passing, I'd put this on the backburner for now. The alignment there is pretty close too, but if we need to get a result out soon we need to focus.
- We have a lot to do for the quick 2021 analysis, but we have the tools and experience to do it
  - hopefully can leverage improvements from SIMPs on this, namely selection and signal extraction
- Longer term, we really should start investigating ML (machine learning) for selection and ML (maximum likelihood) for signal extraction
  - .....I know, we've been saying this for a decade....

We have a mini-analysis workshop Wednesday ~3pm→????.

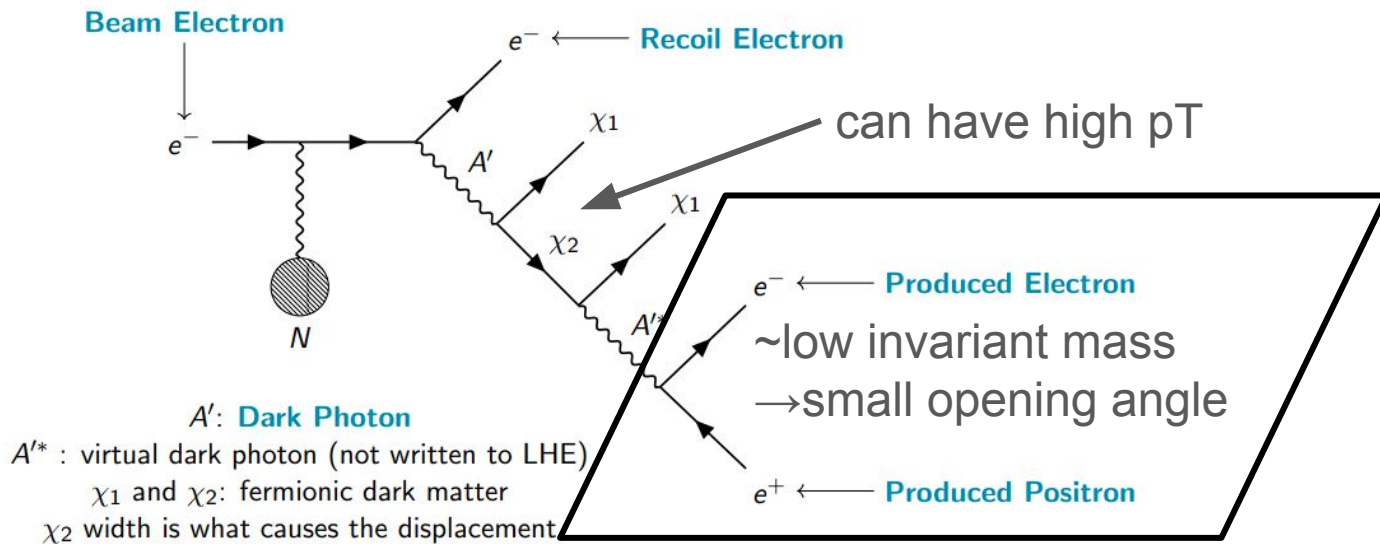
# Low PSum, non-resonant displaced vertex: iDM

Tom's iDM study showed that the signatures are quite a bit different than our nominal A's. The decay of displaced particle is 3-body, where one of the products is invisible.

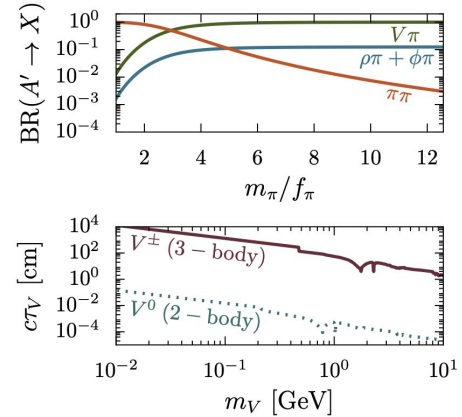
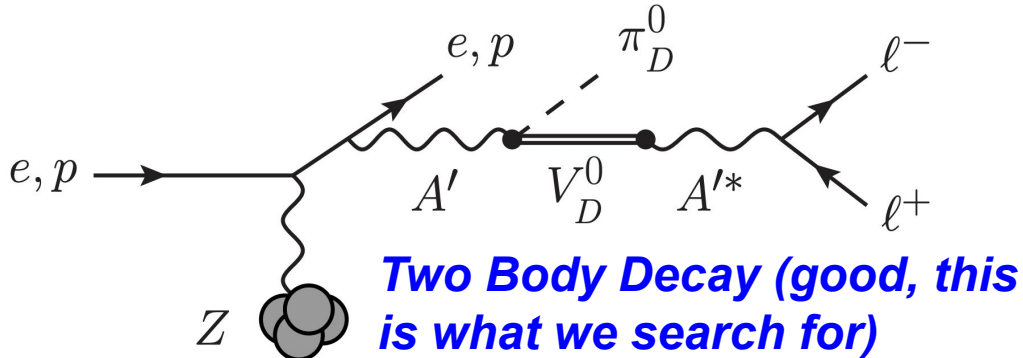


# Low PSum, non-resonant displaced vertex: iDM

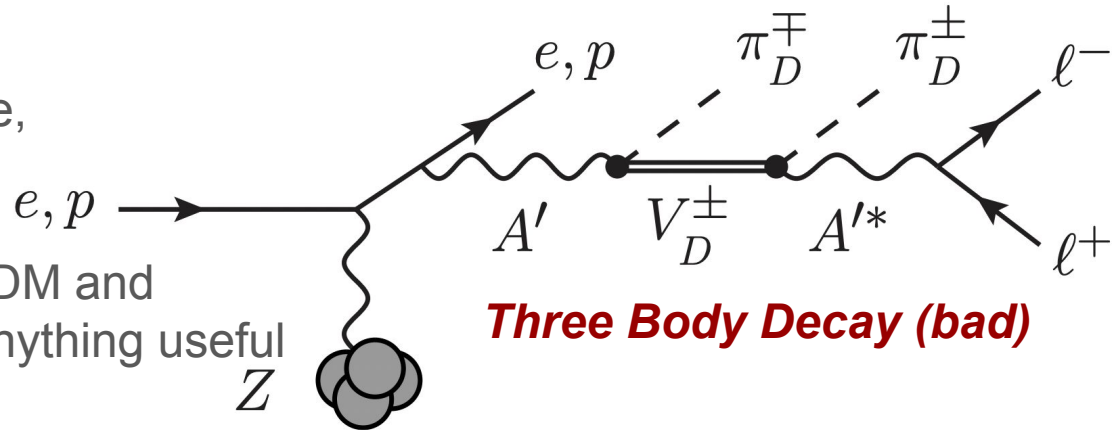
Decays will mostly have pairs in same half of detector (top or bottom) so positron-only trigger accepts a lot more events compared to pairs trigger. Also,  $e^+e^-$  may not point back to target?



# Significant 3-body decays in SIMPs too....



$A'$  decays to charged  $V\pi$   
 7x more often than neutral  
 and have much longer lifetime,  
 maybe too long.



At any rate, similar signal to iDM and  
 we should see if we can do anything useful