HPS Analysis Workshop

survey of plans and priorities for 2019/2021

Tim Nelson - SLAC

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U.S. DEPARTMENT OF ENERGY
Office of Science

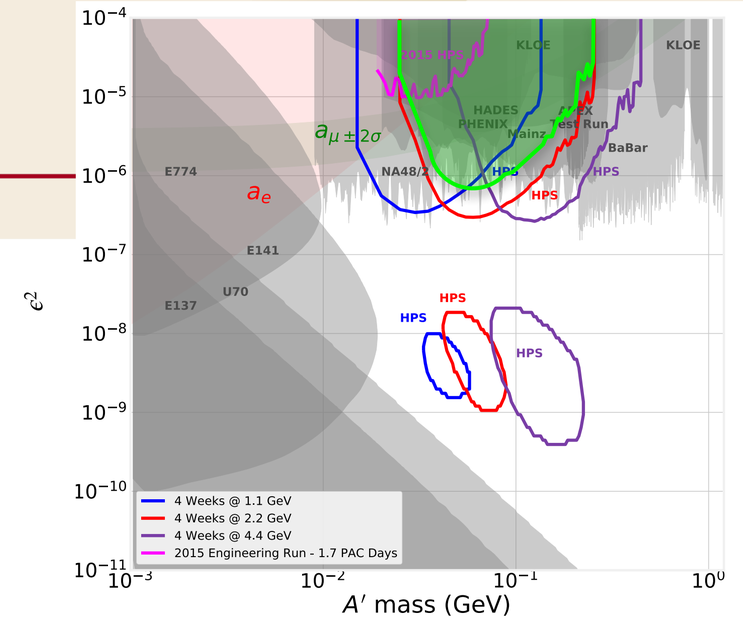
SLAC NATIONAL ACCELERATOR LABORATORY

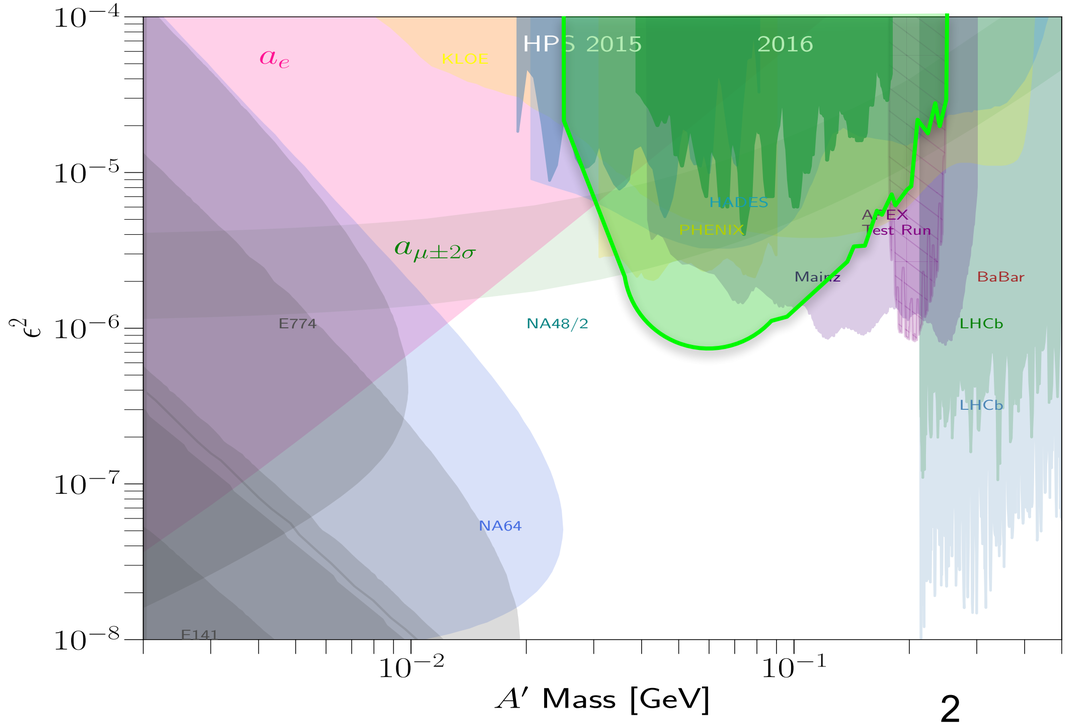
Resonance Search

The resonance search has fallen far short of sensitivity projections. There are a few key reasons.

1. **Lower than expected radiative fraction with larger than expected uncertainties**
   - Bethe-Heitler tridents
   - converted wide-angle brems (cWAB)
2. **Larger than expected mass resolution**
   - worse than expected momentum resolution
3. **Poorly contstrained background shape**
   - background model uses independent polynomials in individual mass windows: signal yield and free parameters of background shape are highly correlated.
   - correlations, and errors on signal yield, increase rapidly with width of signal peak.

These are all potentially addressable



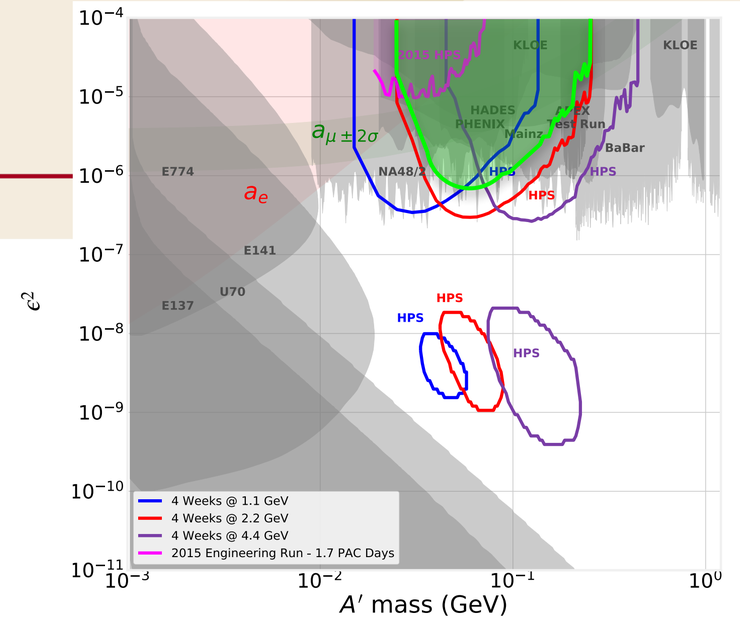


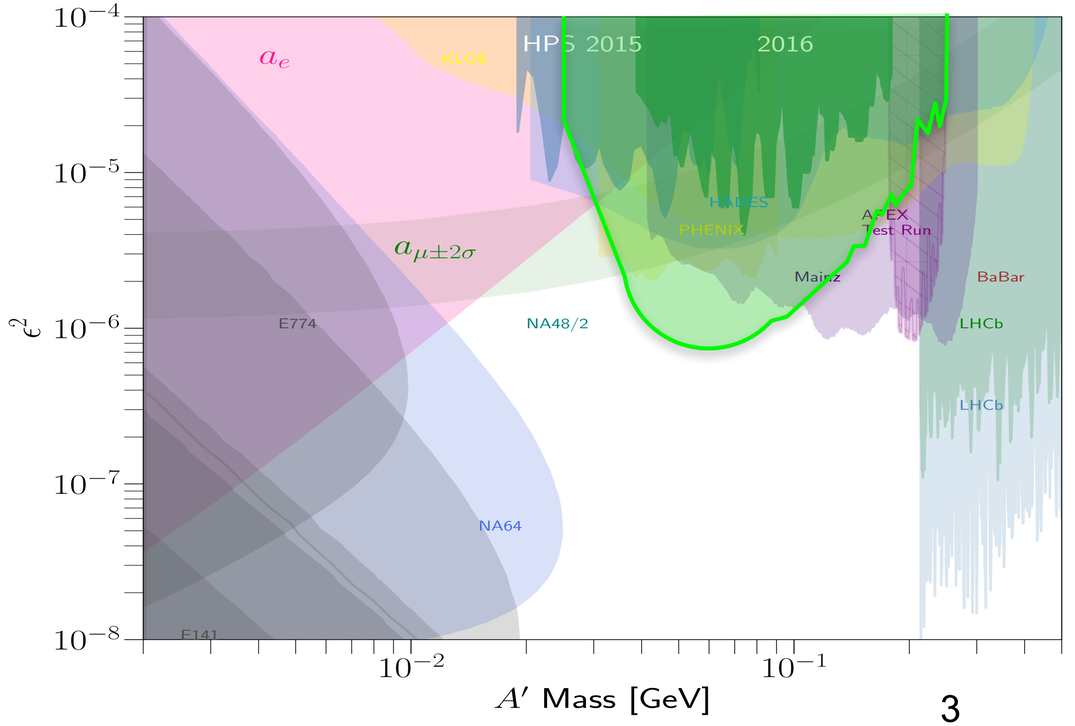
Improving the Resonance Search

1. Increase the radiative fraction / decrease relative uncertainty through improved event selection.

- use missing momentum and direction of cWAB positron to infer momentum/location of recoil/cWAB electron.
- utilize tracker to identify (and possibly but not necessarily reconstruct) tracks corresponding to the lost electron.
- For cWAB, lost electron must have same $\tan\lambda$ as positron – already a powerful variable.
- For BH events, the angular distribution of recoils much wider than radiative events. We've never looked at this, even at generator level.
- A number of variables have some power to reject these backgrounds, especially cWAB, but it's hard to make gains in S/sqrt(B) with square cuts. Suggests ML techniques.

These are significant tasks, but some studies have already been done and the tools are generally in hand





Improving the Resonance Search

2. Reduce the mass resolution

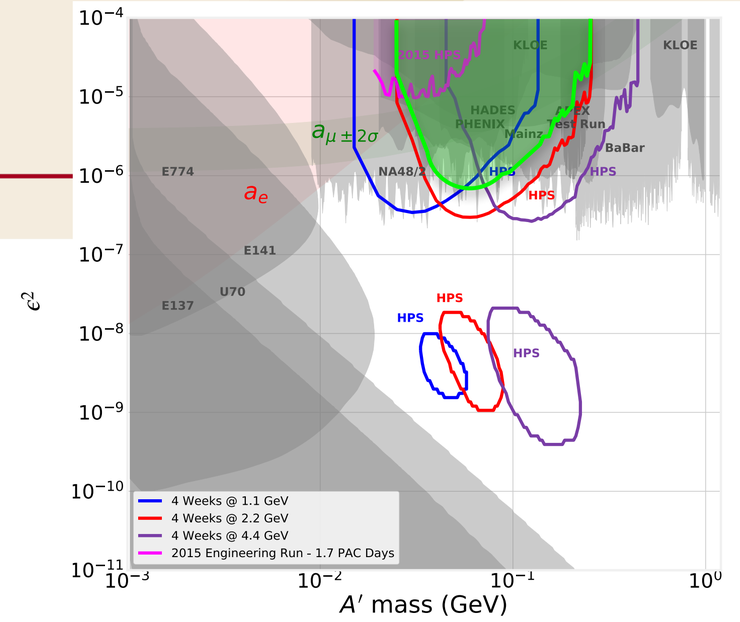
- improve alignment
- use ECal energy measurement as a constraint in the track fit

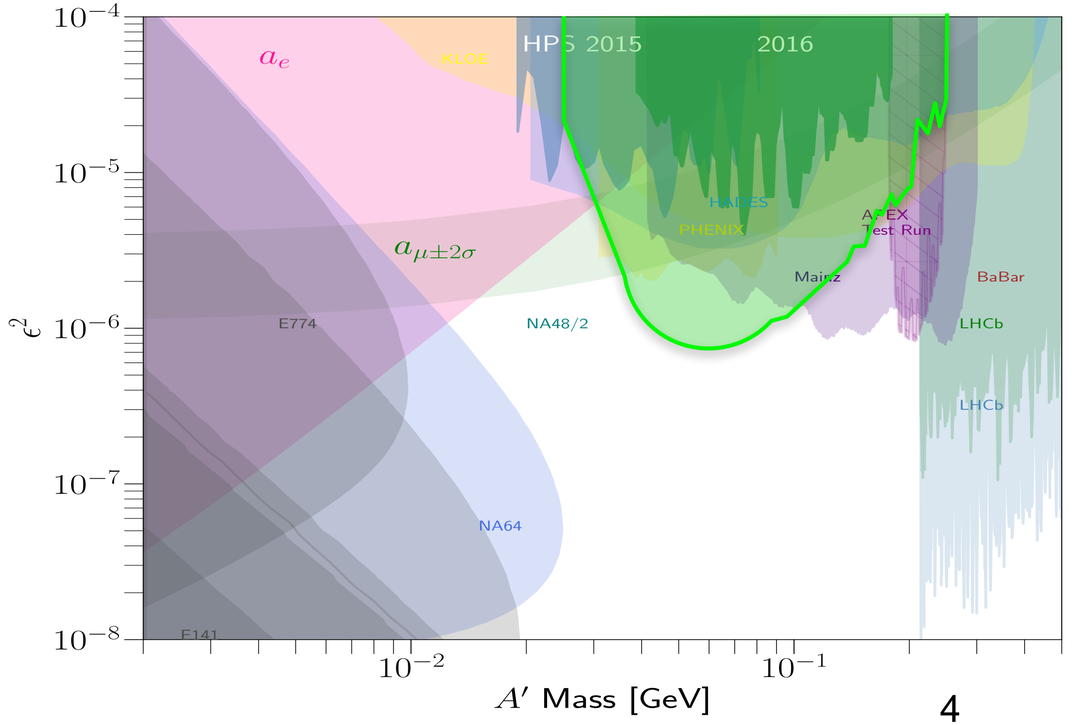
  a.refine matching criteria

  b.develop calibration map for ECal face using FEE and cross-check with three-prongs

  c.adding energy contstraint to track fit should be relatively straightforward.

These are significant tasks, but some studies have already been done and the tools are generally in hand



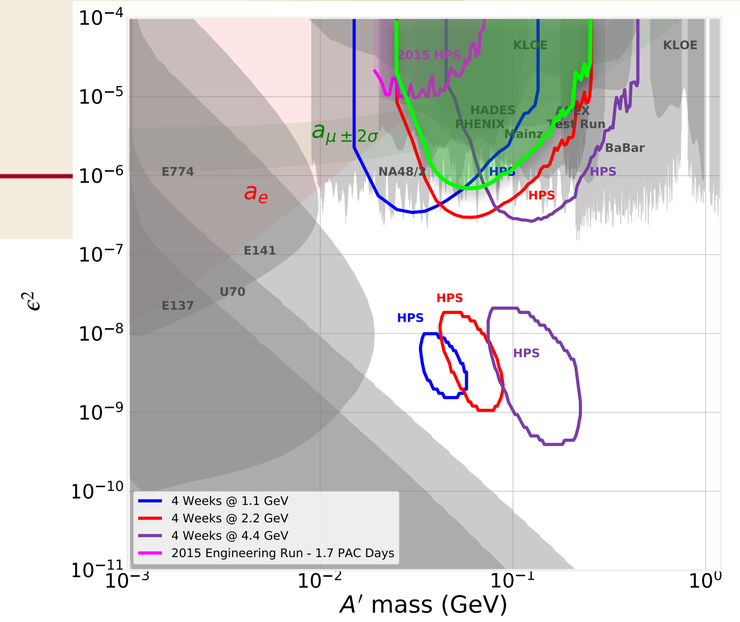


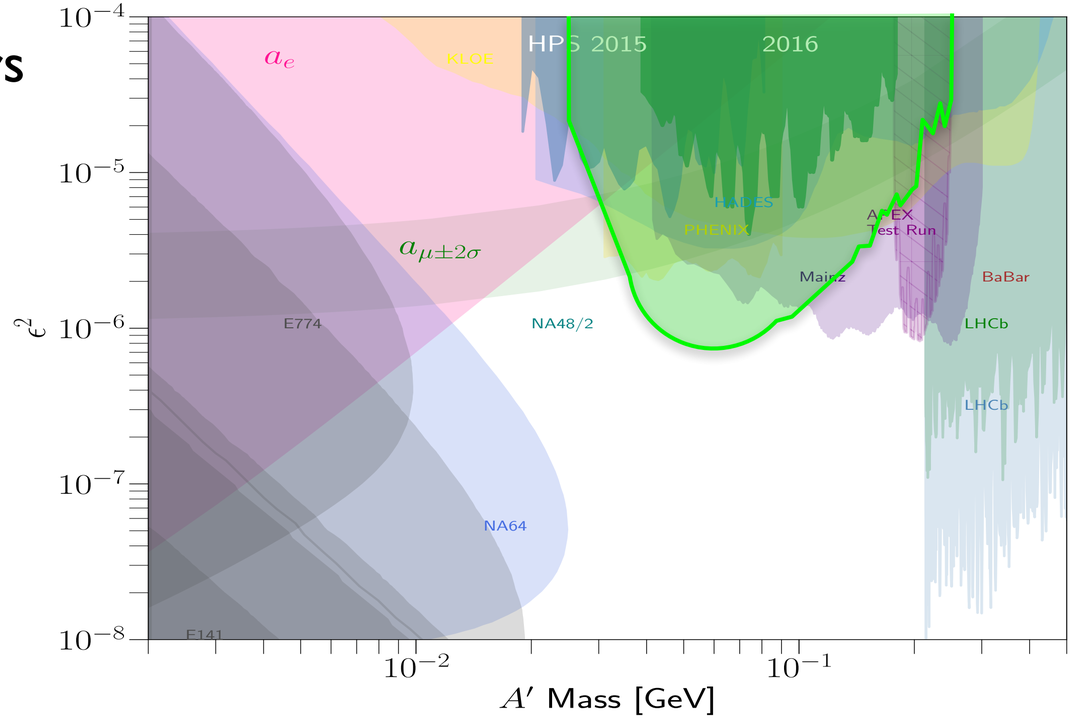
Improving the Resonance Search

3. Reduce impact of background shape uncertainties on signal yield

- A more sharply peaked signal lineshape (best mass resolution possible for each event) pays back much more rapidly than simple reduction in background under the peak via S/sqrt(B)
- investigate alternate background models: those that are global (as Rafo used at lower stats) or have free parameters that are less correlated with signal yield.
- investigate development of background models on Monte Carlo in attempt to understand and model undulations in the background shape that are only somewhat wider than signal lineshape.
- Investigate development of background model that can be frozen on subset of data, or on sidebands, before fitting

These are significant tasks, but some studies have already been done and there are some reasonable ideas on how to proceed.



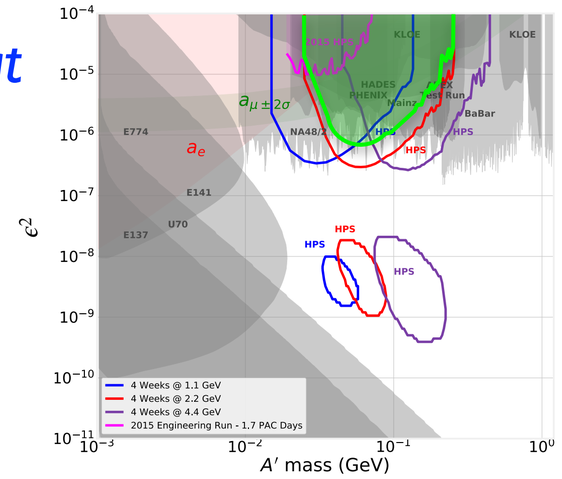


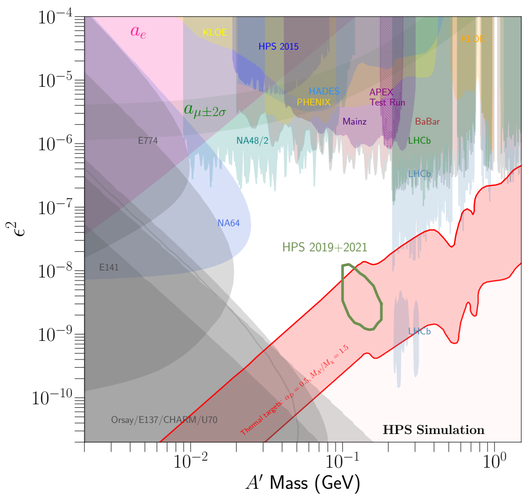
Displaced Vertex Search

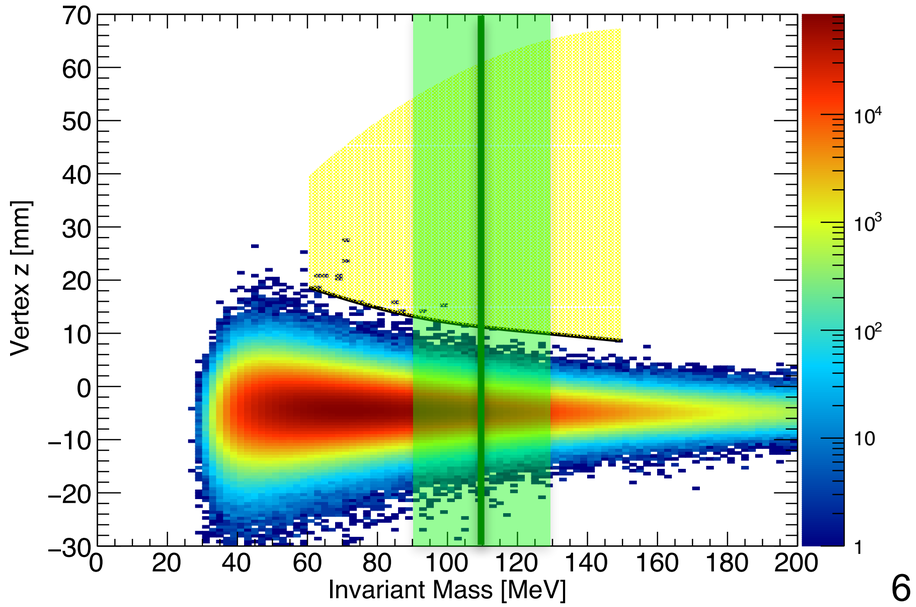
The displaced vertex search has come close to projections at high masses, but has proven more difficult at lower masses

1. Increased statistics and occupancies will mean confronting more new backgrounds in 2019/2021
2. z_{min} for cut & count analysis is difficult to optimally determine. For 2016 analysis…
   - at low mass, more background than expected
   - at high mass, z_{min} could have been even lower
3. larger than expected mass resolution raises effective z cut not only by increasing background normalization but by accepting lower masses where prompt events have longer z-tails.

These are all potentially addressable



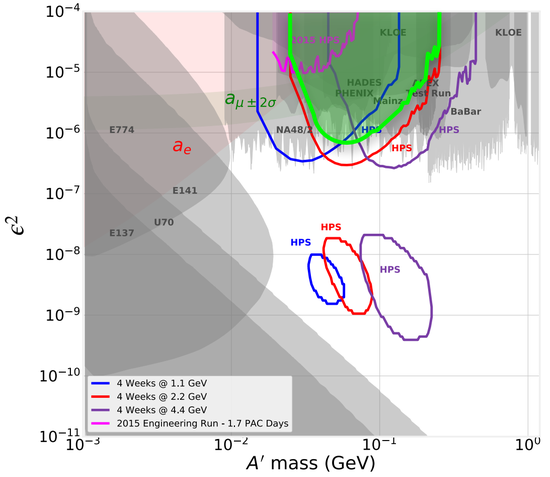


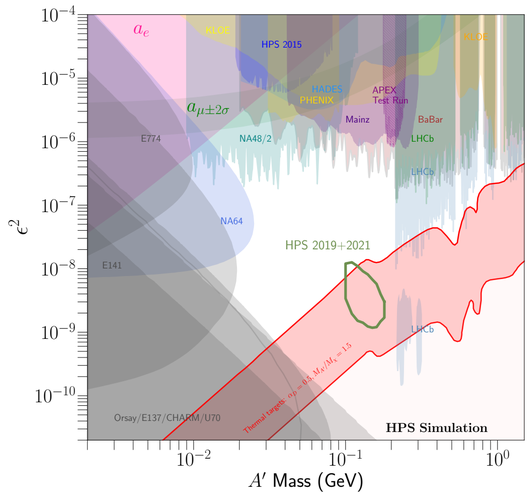


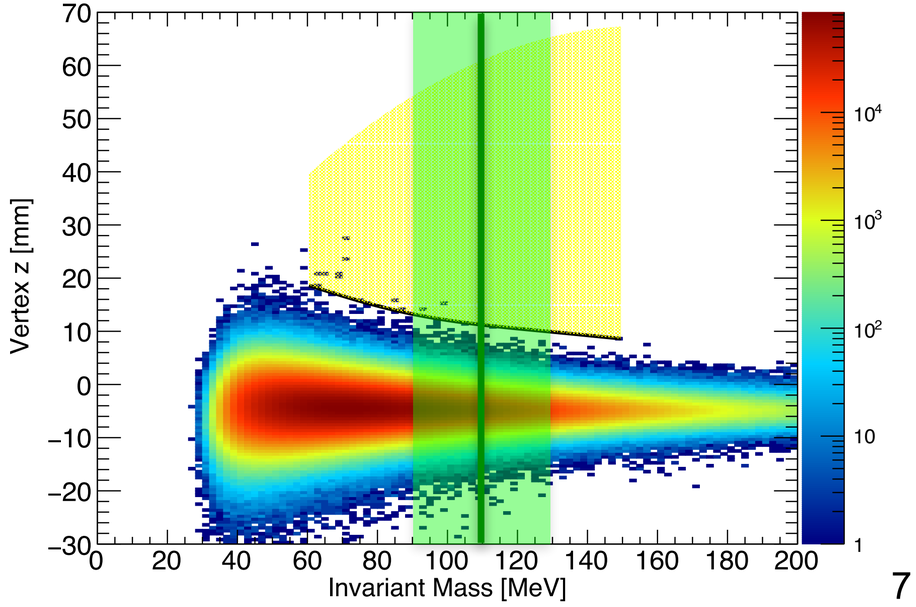
Displaced Vertex Search

1. **Reduce high-z backgrounds**
   - Reduce effective occupancy with better hit/track time calibration and reconstruction and use of time information in tracking
   - Improve in-time hit efficiency at high occupancies to maximize the effectiveness of isolation cut
   - Develop additional discriminators (e.g. decay length significance, improved isolation cut) and ML/MVA to make use of large number of variables with correlated discriminating power

These are significant tasks, but some studies have already been done and there are some reasonable ideas on how to proceed.



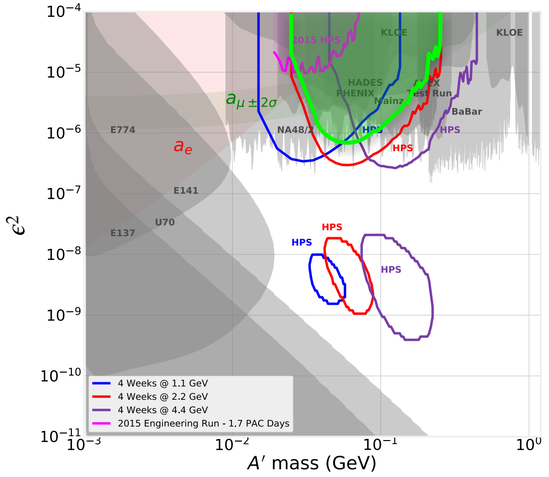


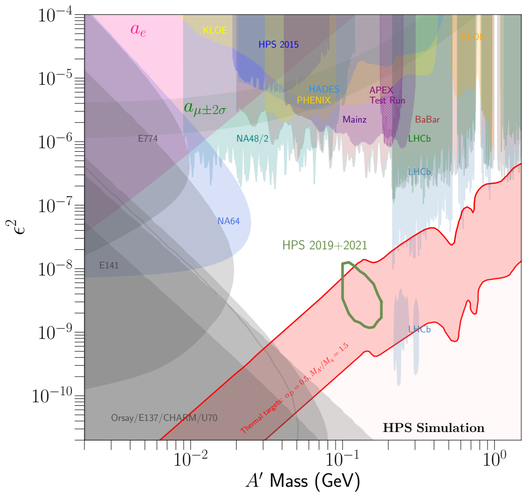


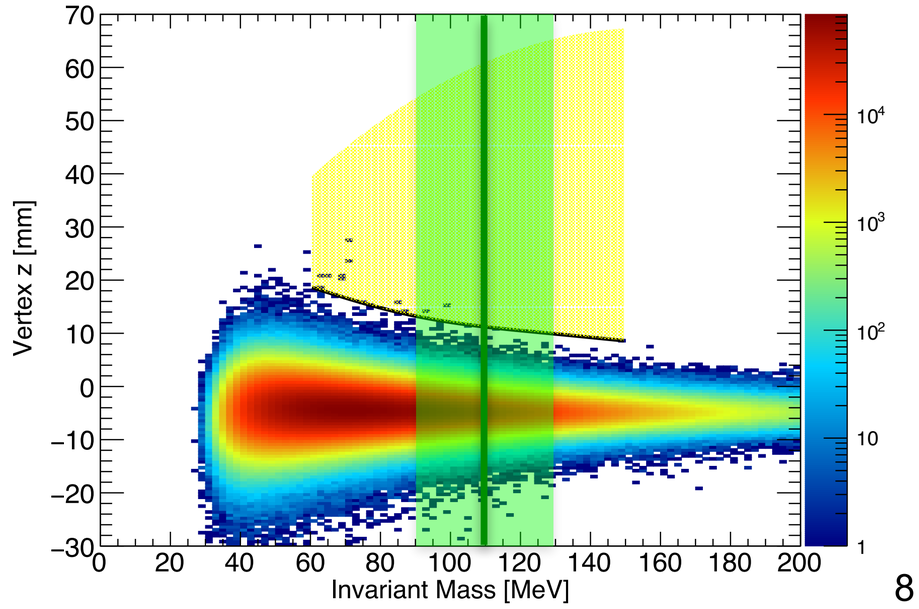
Displaced Vertex Search

2. Improve signal efficiency

- Improve in-time hit efficiency at high occupancies through better hit reconstruction, with focus on pileup and hit time estimation
- Develop additional layer combination analyses – more flexibility and complication with KF tracking

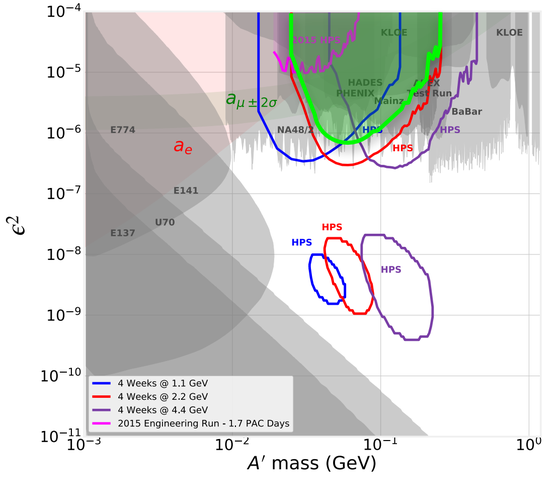


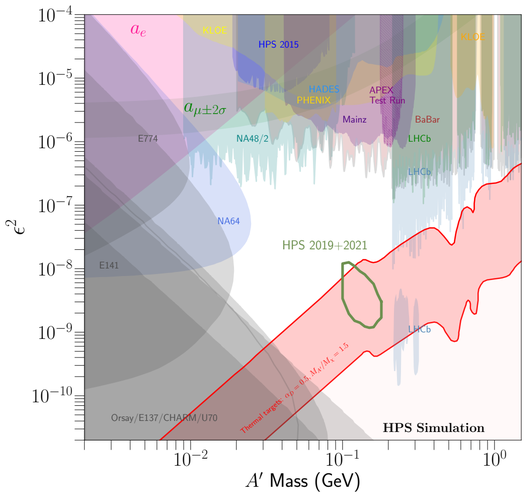


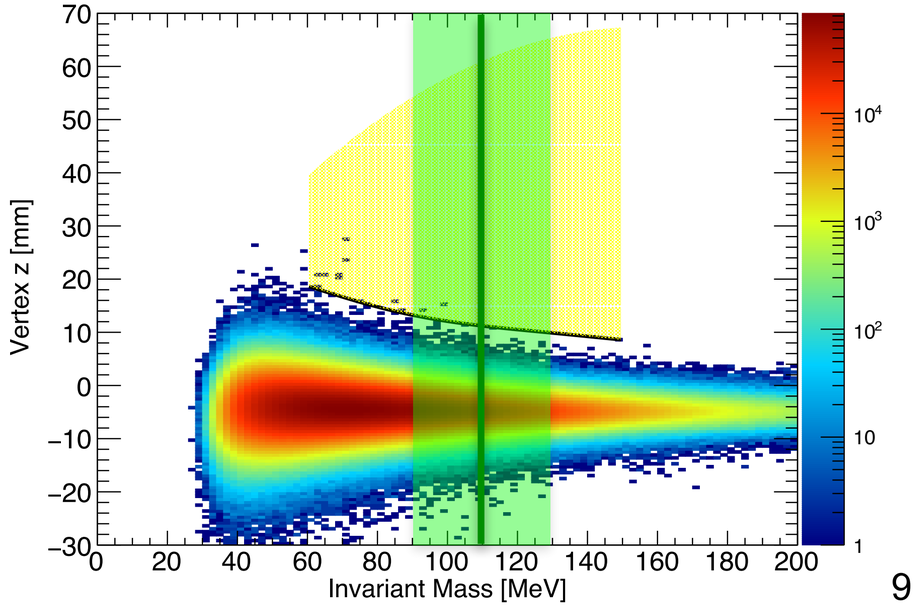


Displaced Vertex Search

3. **Reduce impact of high-z backgrounds on signal sensitivity**
   - perform 2-d fit to mass and decay length
   - better mass resolution helps a lot.







Draft Plan for Student Effort

1. Alic - Thesis: SIMP search of 2016 data, Service focus: 2019, 2021 track-cluster matching calibration, SVT calibration, tracking improvements
   - Track-ECal Cluster matching (completed)
   - SVT pulse fitting improvements and calibrations (completed)
   - Help with checking KF tracking on 2016 data by comparing to ST/GBL
   - Study Møllers with KF tracks
   - Reach estimates for SIMPs (underway)
   - 2016 SIMP search result
2. Tom - Thesis: iDM search of 2016 data, Service focus: alignment and tracking improvements
   - Debug KF alignment code and add some monitoring plots
   - Help with checking KF tracking on 2016 data by comparing to ST/GBL
   - Help get KF alignment working on 2019/2021 data
   - Fix phase space cut out in tritrig MC
   - Get iDM MC generation going and make reach estimate for at least 2016
   - iDM search strategy and reach
   - 2016 iDM search result
3. Rory - Thesis: displaced searches with 2019/2021 data, Service focus: svt hit formation
   - SVT pulse fitting analysis and improvements
   - SVT clustering algorithm analysis and improvements
   - SVT time calibration and integration of time into track finding and fitting
   - Help with validation of reconstruction of 2019/2020 data
   - 2019/2021 SIMP and iDM search results?
4. Emrys - Thesis: prompt A’ search on 2019/2021 data? Service focus: combining track and ECal/hodo information
   - Develop track-cluster and track-hodoscope matching selections
   - Develop improved event selection (improve/understand rad fraction)
   - Study Mollers in 2021 data (improve/understand global alignment and mass resolution)
   - Incorporate ECal energy measurement into e+/e- momentum estimate (improve mass resolution)
   - 2019/2021 A’ search result - prompt
5. Sarah - Thesis: displaced searches with 2019/2021 data, Service focus: Monte Carlo improvements
   - Alignment studies with MC
   - Characterization of SVT performance, including Data/MC comparison
   - Improvements to how we take into account efficiency issues
   - Development of search strategy (thinking in the direction of more generic search over full available phase space with model specific interpretations of that result)
   - 2019/2021 A’ search result - displaced