Bump Hunt on 2016 Data

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Outline

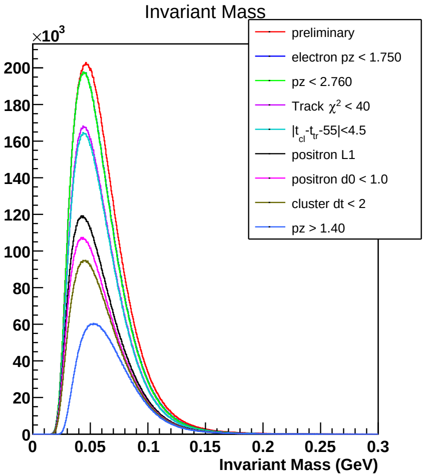
- Trident selection
  - Effects of cuts on dataset
  - Comparison with 2015 dataset
- Mass resolutions:
  - A' MC.
  - Mollers from data, MC
- Radiative fraction
- Bump hunting
  - Background models
  - Most significant "bump" found
  - Signal yields
  - Upper limits on coupling
    - Blinded
    - Unblinded (projection)
- Homework

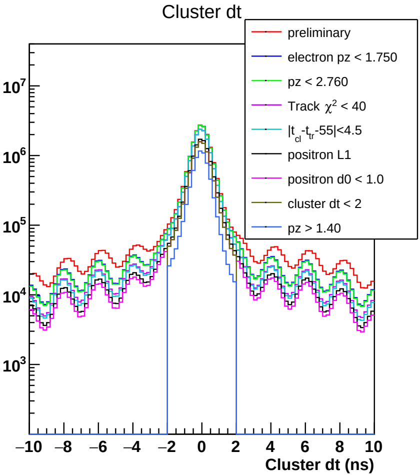
Trident Event Selection Criteria

- Preliminary cuts
  - GBL Tracks
  - If > 3 shared hits, use the track with the best fit χ^2.
  - Track-cluster match $\chi^2 < 10$
  - Clusters on opposite sides of Ecal.
  - Pair1 trigger
- Accidental background reduction
  - FEEs: $p_{e^-} < 1.75$ GeV. ($\approx 75\%\ E_{\mathrm{beam}}$)
  - $p_{\mathrm{sum}} < 2.76$ GeV. ($\approx 1.2\ E_{\mathrm{beam}}$)
  - Track fit $\chi^2 < 40$
  - $|t_{\mathrm{cluster}} - t_{\mathrm{track}} - 55\ \mathrm{ns}| < 4.5\ \mathrm{ns}.$
- WAB reduction cuts
  - Positron track has a hit in L1.
  - Positron $d_0 < 1.1$ mm
- Cluster time difference < 2 ns.
- Radiative cut: $p_{\mathrm{sum}} > 1.4$ GeV ($\approx 61\%\ E_{\mathrm{beam}}$)

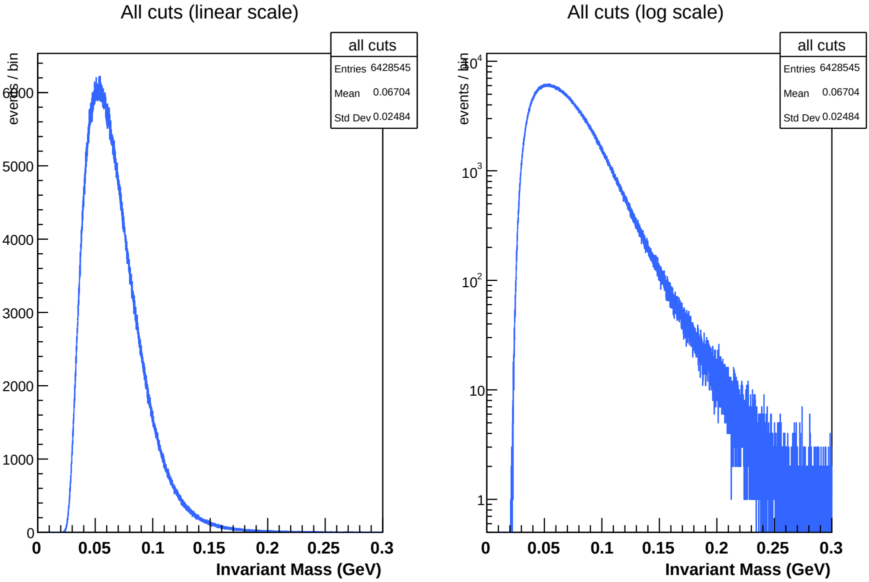
*(most of these cuts are based on Omar's trident event selection for 1.05 GeV, scaled up for 2.3 GeV)

Effects of the cuts on the Data

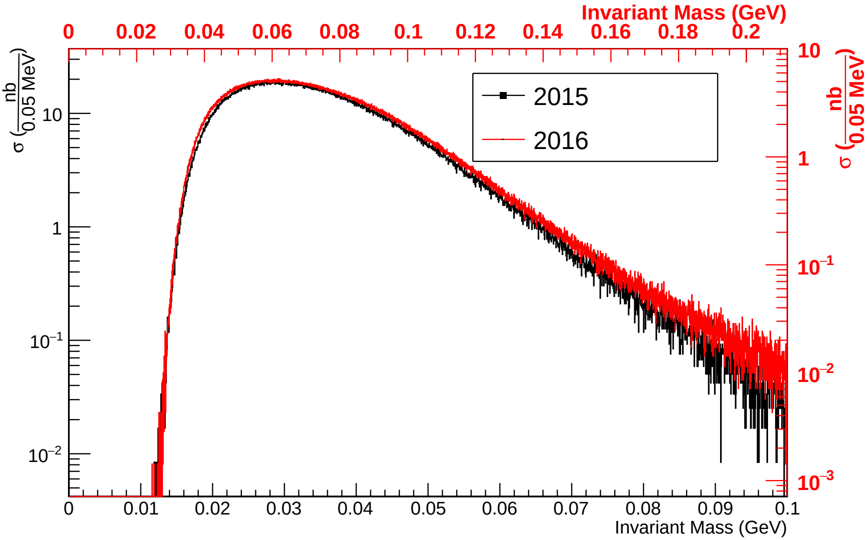




Invariant Mass Spectrum of Selected Events



Comparison between 2015 and 2016 datasets



Calculating Mass Resolution

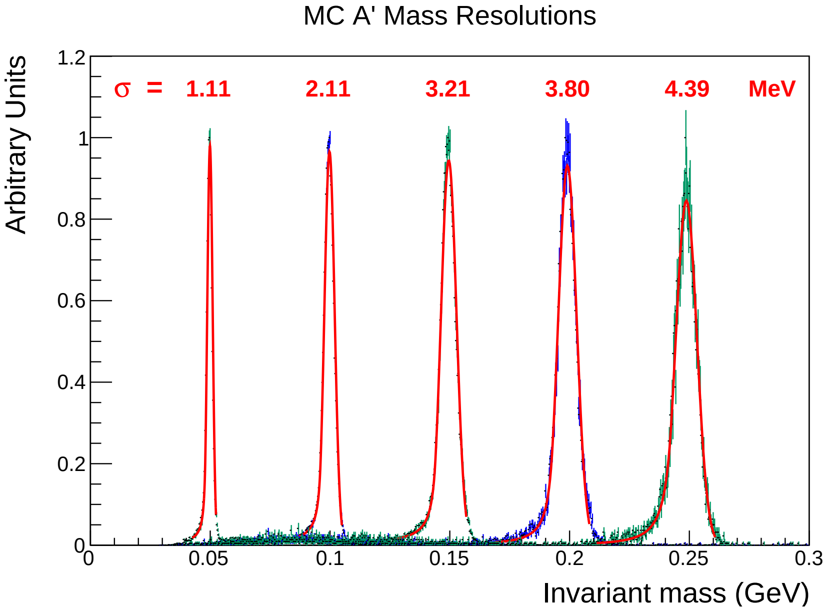
Tridents / A's

- Generated O(10k) A' events in MC with $m_{A'}$ at (50, 100, 150, 200, 250) MeV.
- Applied similar cuts to MC as were applied to data
- Fit each spectrum to crystal ball function
- mass resolutions fit to 3rd order poly of mass

Mollers (for corroboration):

- Data from upass0 single0 skim.
- Monte-Carlo events generated with s0 trigger.
- Cuts are mostly from SVT (two slides from now)
- Out-of-time background ($\Delta t_{\mathrm{track}} > 4$ ns) subtracted from signal.
- fit moller candidates to a signal gaussian plus a wider background gaussian.

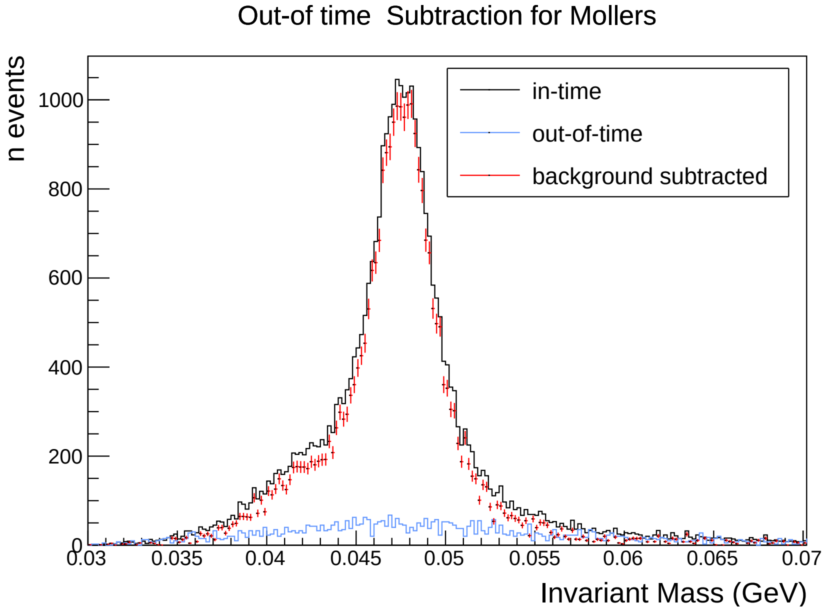
Mass Resolution: A' Monte Carlo



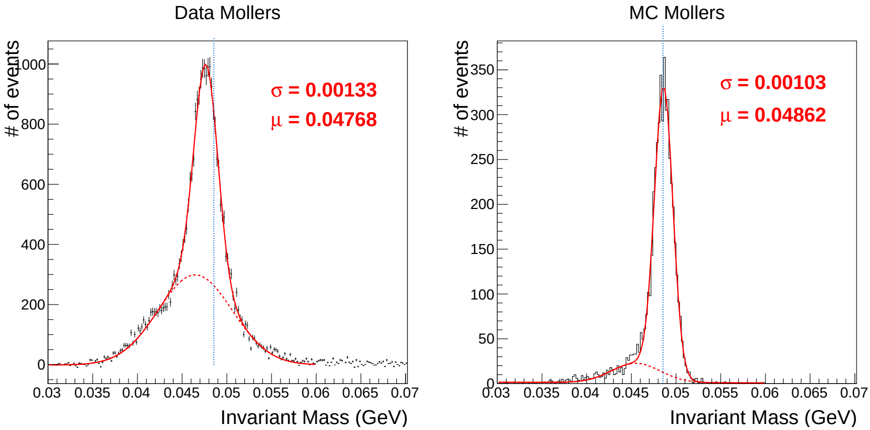
Moller Cuts

- single0 trigger
- both track fit $\chi^2/\mathrm{d.o.f.} < 5$
- both tracks $|d_0| < 1.5$ mm
- both tracks $p < 1.75$ GeV
- track time difference < 2 ns $(\approx 2\sigma_{t\_track})$
- p_{sum} between 1.75 GeV and 2.6 GeV
- only one cluster:
  - $x_{\mathrm{cluster}} < -80$ mm
- no positrons

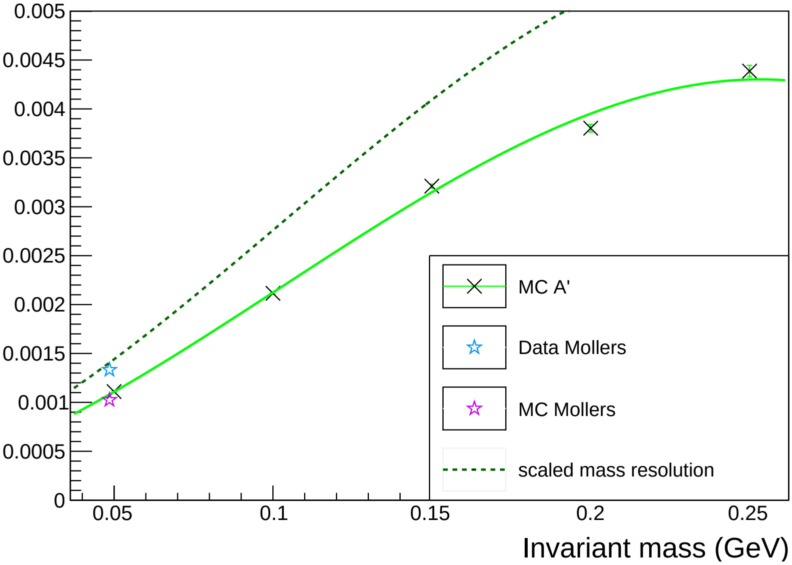
Out-of-time Moller background subtraction



Mass Resolution: Mollers



Mass Resolution



Radiative Fraction

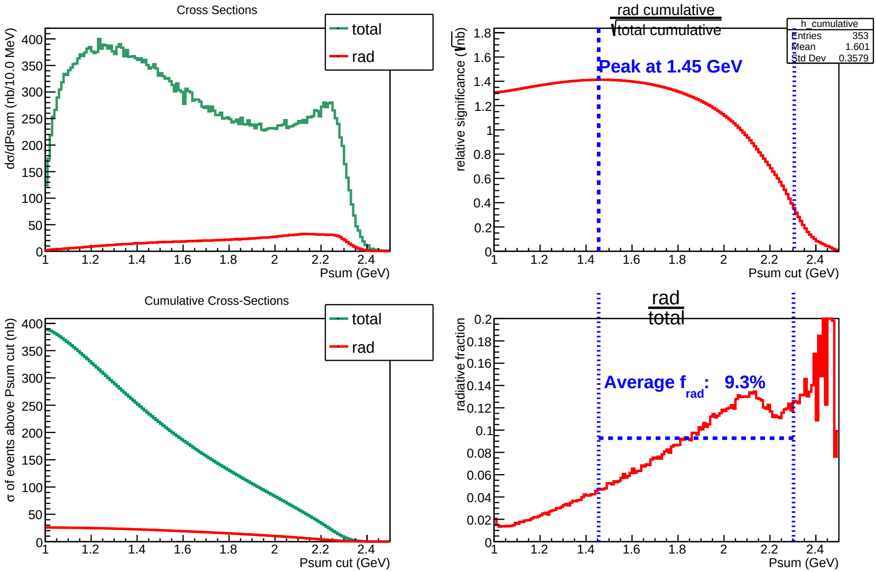
Purpose

- A' cross-section is proportional to radiative cross section
- Necessary for calculating upper limit on A' coupling ϵ^2

Procedure

- Monte-Carlo:
  - tri-trig (total) and RAD (radiative)
  - Both from MadGraph 5.
  - Applied similar kinematic cuts to those used on data
- Found lower cut on p_{sum} such that $\frac{\sigma_{\mathrm{rad}}}{\sqrt{\sigma_{\mathrm{total}}}}$ is maximized for events above the cuts.
- Calculated ratio of cross sections $\frac{\sigma_{\mathrm{rad}}}{\sigma_{\mathrm{total}}}$ for events passing the cut.

Radiative Fraction



Background Models and Fitting Parameters

I am currently testing 3 types of background models. (x = mass of A')

Name	Formula	Parameters
poly	$\sum_{i=0}^{n} a_i x^i$	$a_0 ... a_n$
exp (poly)	$\exp\left[\sum_{i=0}^{N} a_i x^i\right]$	$a_0 ... a_n$
exp $\times$ poly	$e^{-kx}\left[\sum_{i=0}^{N} a_i x^i\right]$	$k,\ a_0 ... a_n$

Also varying window-size to mass-resolution ratio f, and polynomial orders n.

Background Models

Several pieces of information will go into my decision of which model/window-size to use:

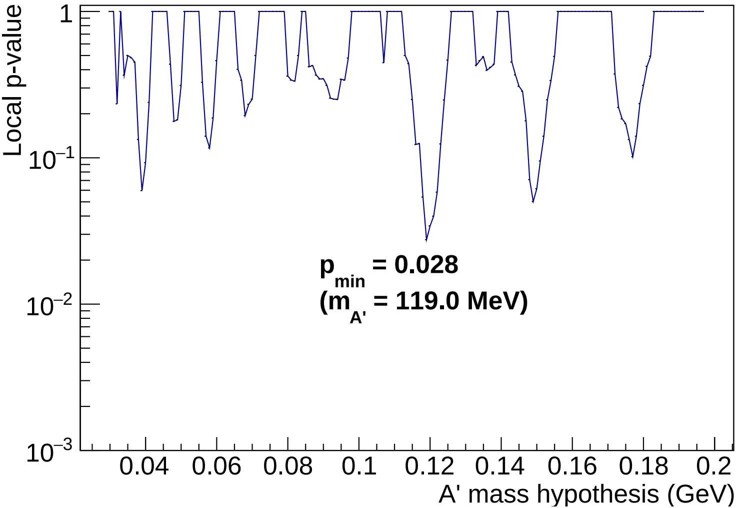
- pull $:= \frac{\text{(mean yield) - (injected signal)}}{\text{(sigma yield)}}$ for toy signals
- p-value calculated for data fits
- minimize median upper limit for toy distributions (while keeping all other things reasonable)

*For the slides in this presentation I use:

- model: poly
- order: $n = 5$
- window size $= 19\sigma_M$

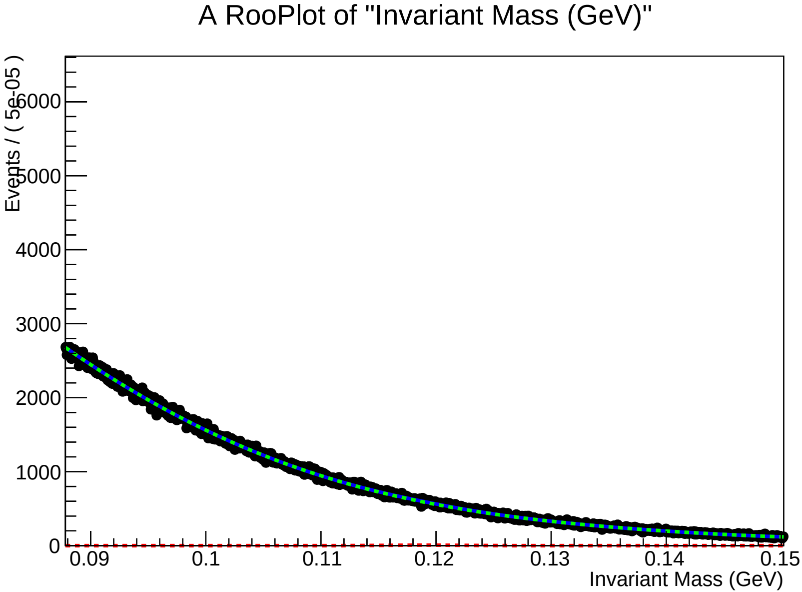
* This is NOT a finalized decision.

P-values

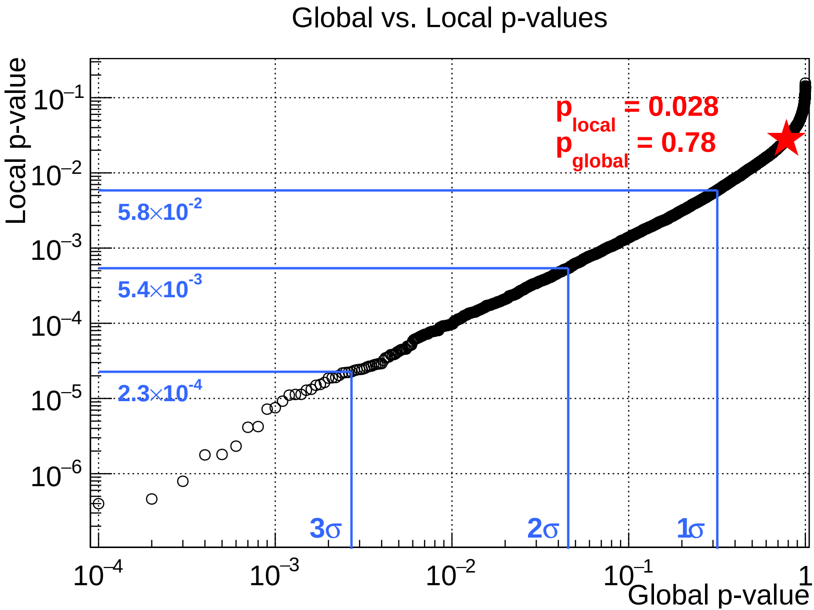


*Look Elsewhere Effect not accounted for yet (wait for it...).

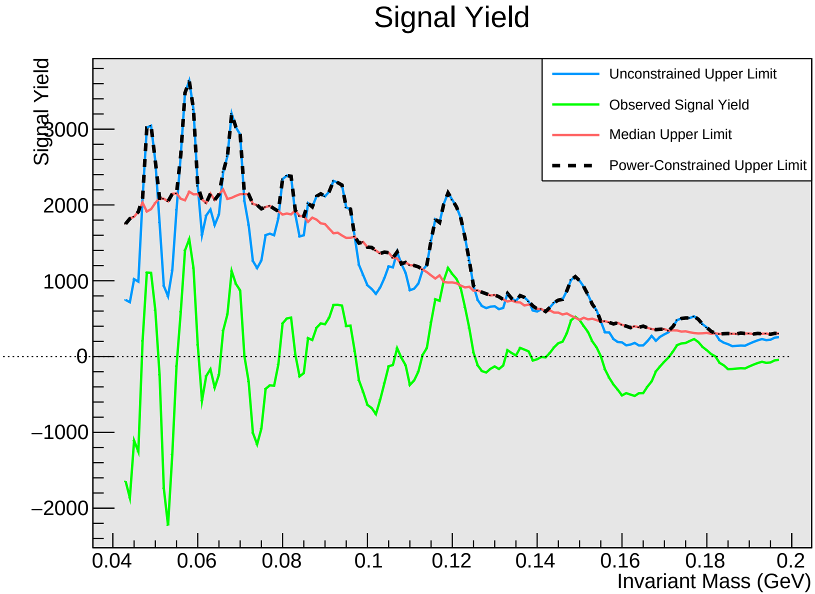
Most significant bump (.119 GeV)



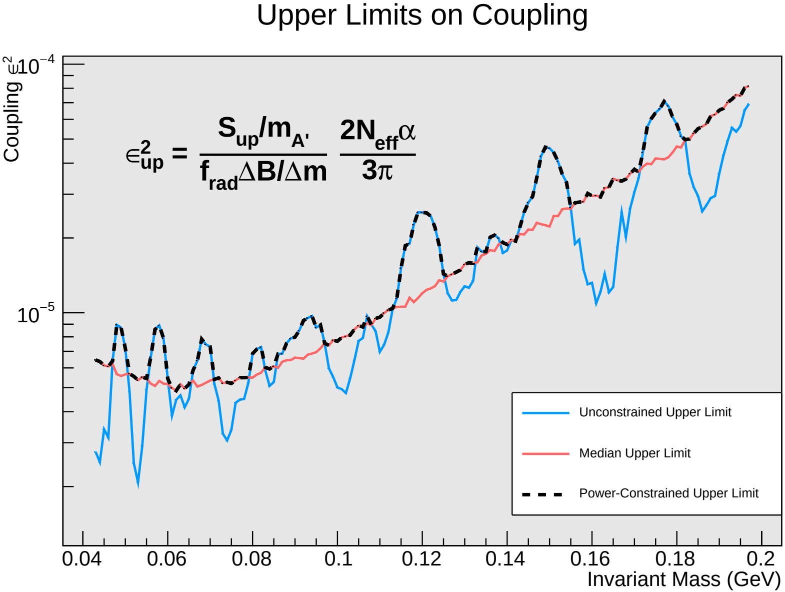
Look Elsewhere Effect



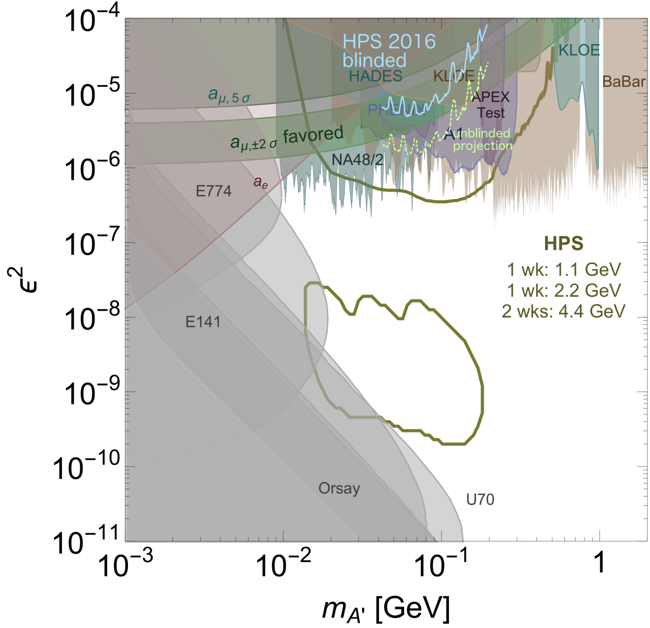
Signal Yields (using 10% of dataset)



Upper limit on coupling (blinded dataset)



Projected Upper Limit on Coupling (full dataset)



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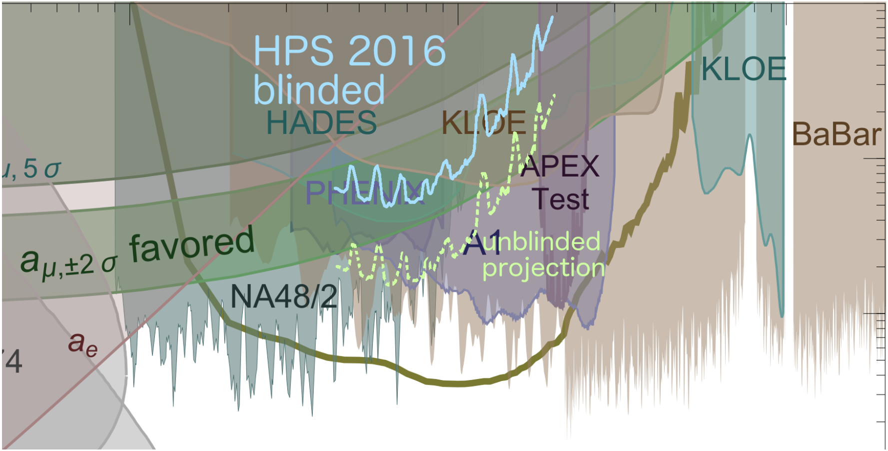

Homework:

- Figure out why the discrepency in moller resolutions between data and monte-carlo is so large:
  - Alignment problems in data?
  - underestimation of multiple scattering in Monte-Carlo?
- Improve efficiency:
  - L1 efficiency for e^- in data is $\approx 84\%$
  - Is problem from track fitting or SVT pulse fitting?
- Improvements on fitting invariant mass spectrum:
  - Does exp $\times$ poly perform better than poly?
  - Which order polynomial?
  - Window size?
- After pass1, ask ourselves: are we ready to unblind yet? if yes...
  - We unblind
  - We publish
  - I graduate.