Axion-Like Particle Search Update

Jackson Pybus

Recent Updates

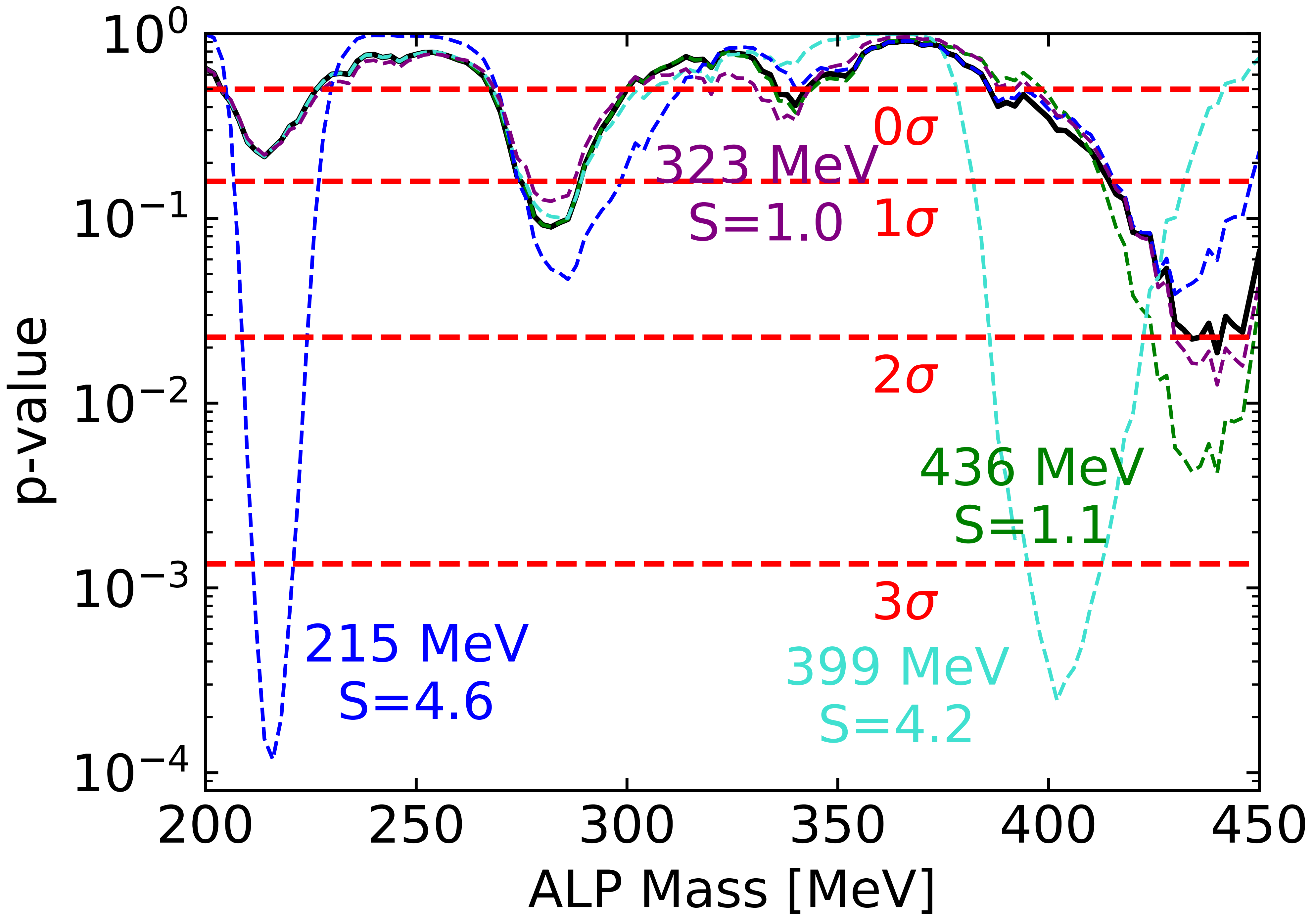
Signal Injection Test

- Randomly generated signals injected into the observed mass spectrum

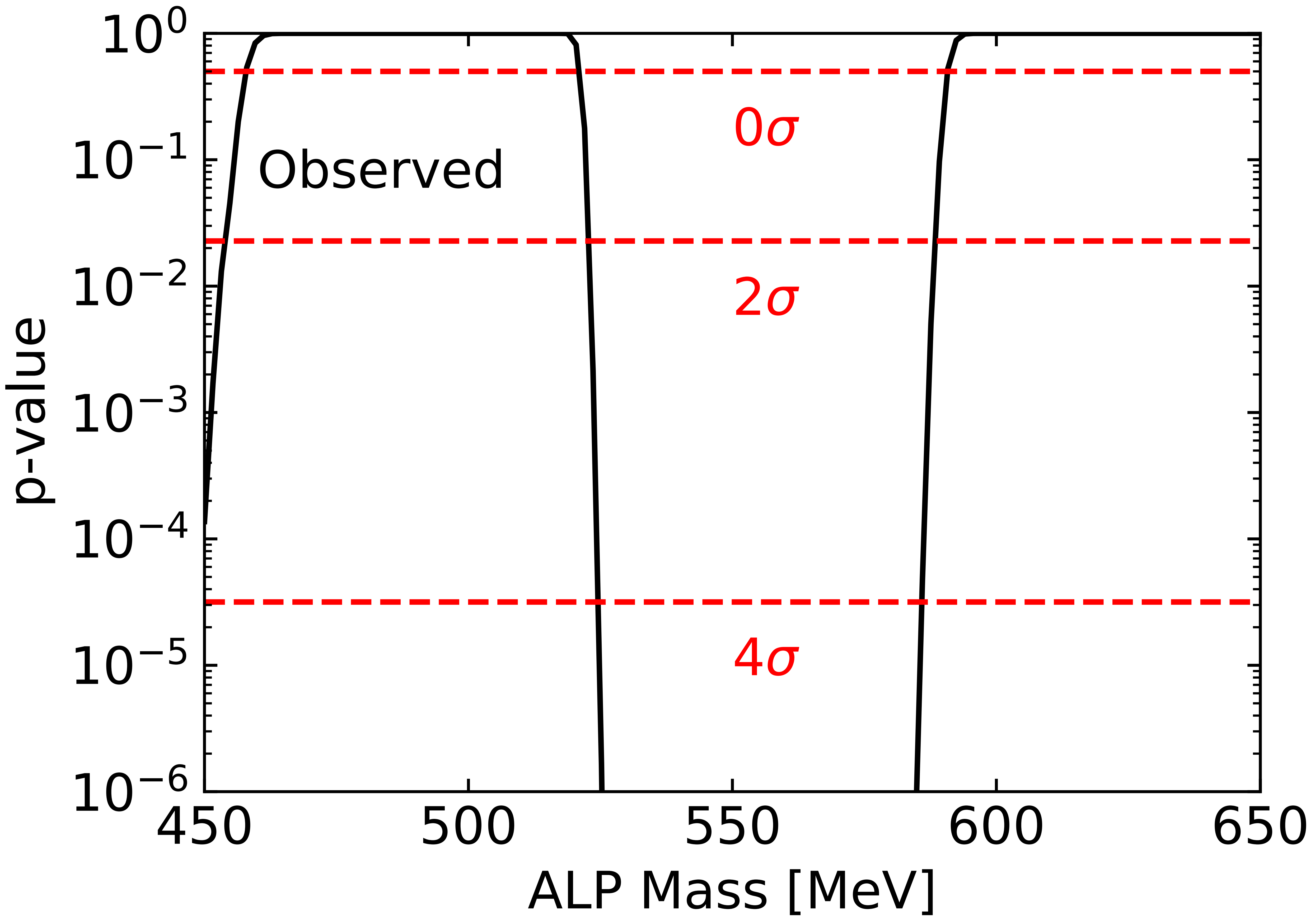
- Mass and significance randomly selected

- $$S = \frac{N_{injected}}{\sqrt{\int_{\pm\sigma} N_{data}(m)\ dm}}$$

- Plot of local p-values shows increases of significance near injected signal masses, with strength correlating to injected significance

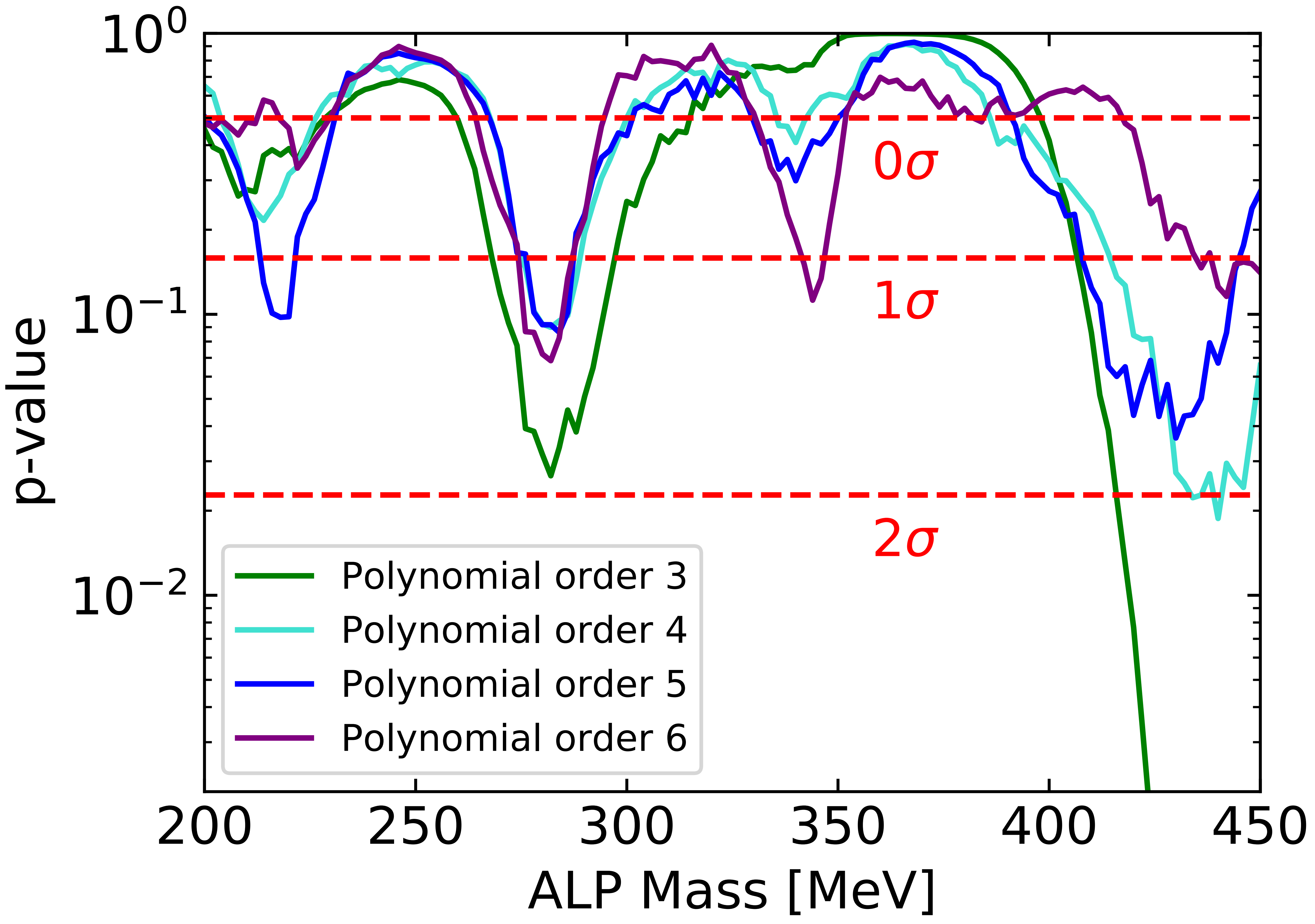


η Discovery Test



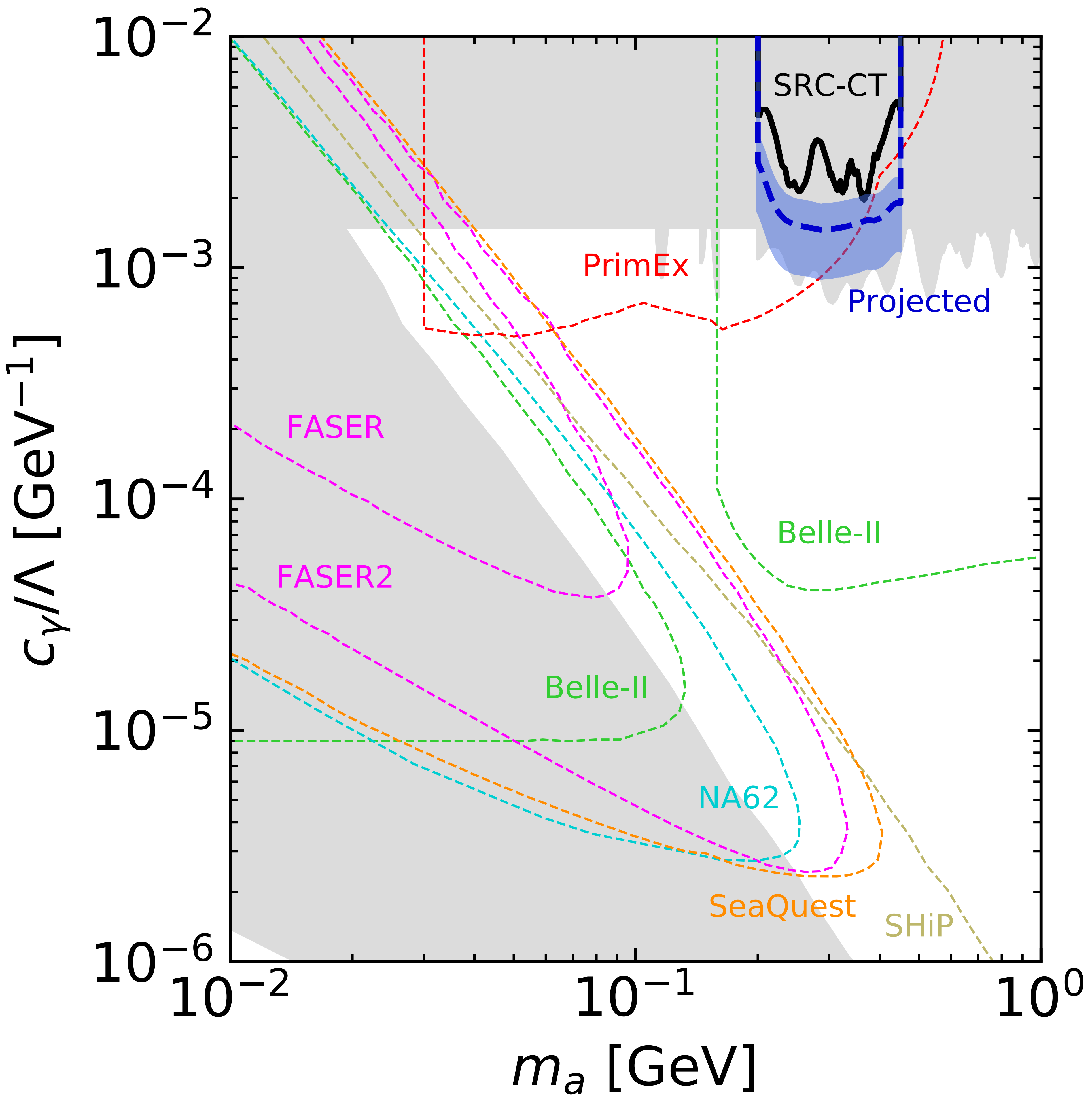
- Discovery test performed over known mass of η meson
- High significance found in the vicinity of the η peak

Polynomial Order Check



- Different order polynomials used to describe the mass background
- Qualitative features of local p-value are the same for different orders
- Only order-3 polynomial shows significance in any apparent signal
  - Order-3 polynomial too inflexible to describe high-mass shoulder

Final projected exclusion for data

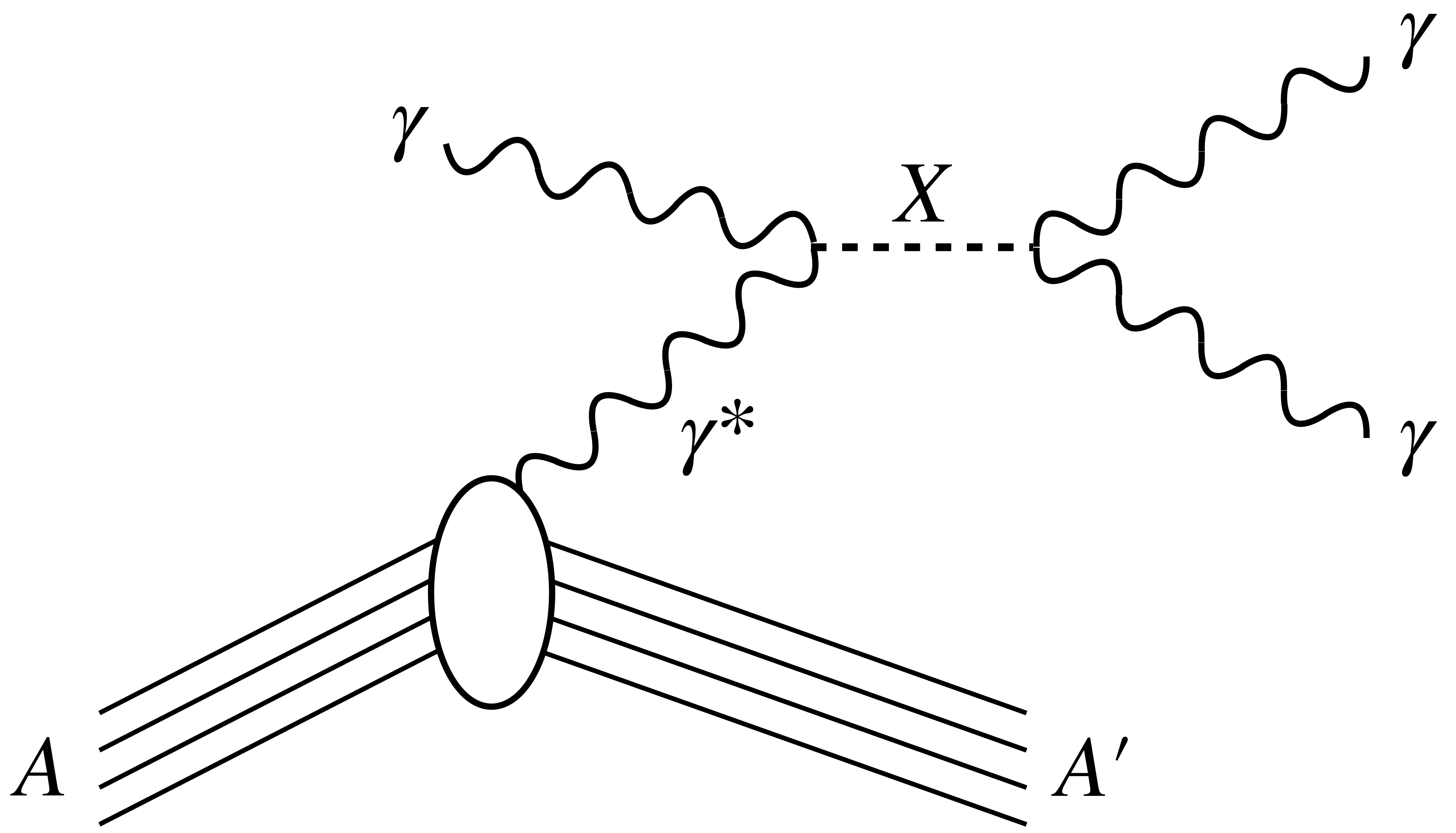


- 95% exclusion limits shown for current analyses (grey) and projections for other experiments (dashed)
- Black curve shows current 10% data exclusion
- Blue curve shows protection for full dataset
- Final unblinded data will likely not be world-leading

Analysis Overview

Introduction

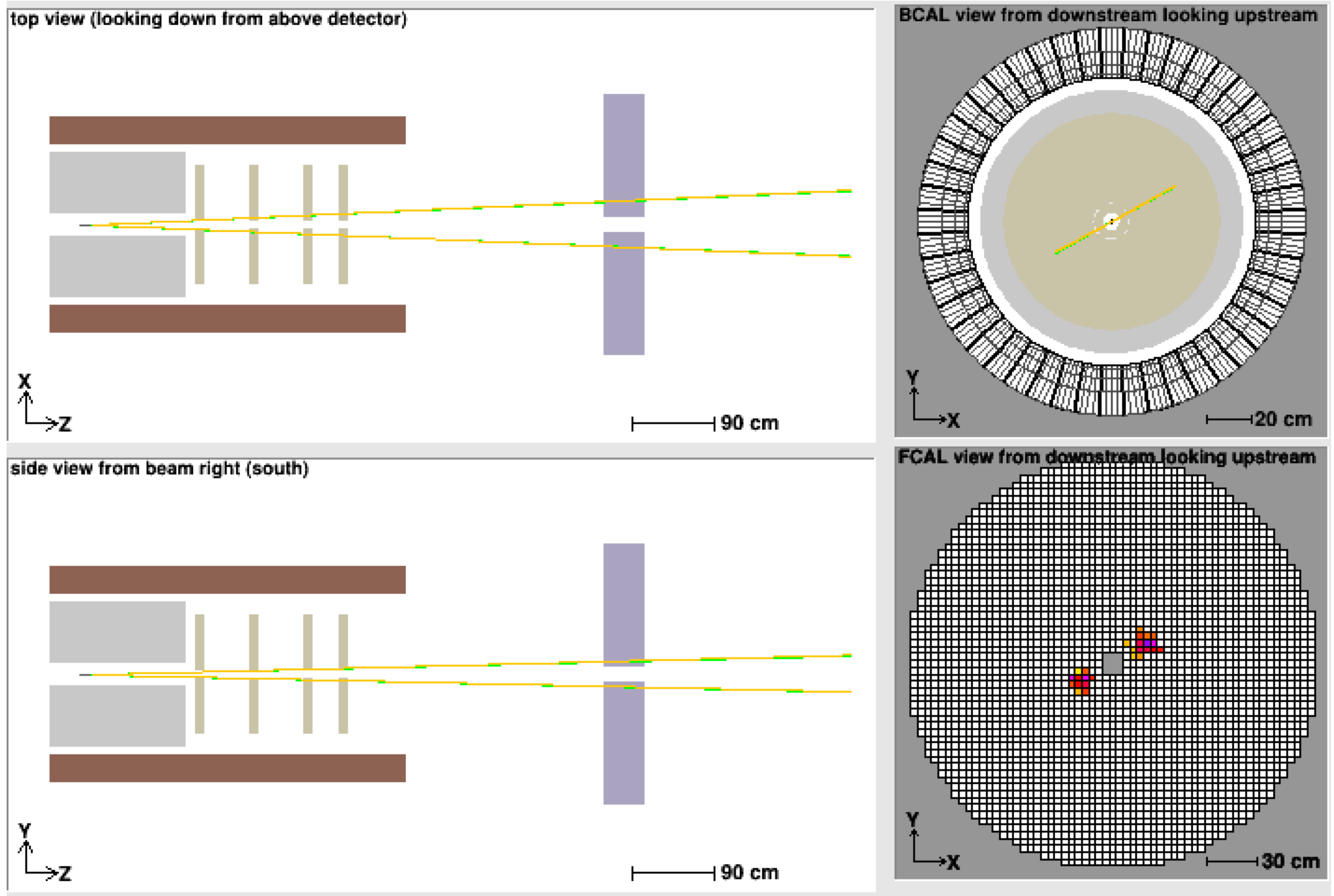
- Searching for Axion-Like Particles in $\gamma A \to \gamma\gamma A$ Primkaoff production



Introduction

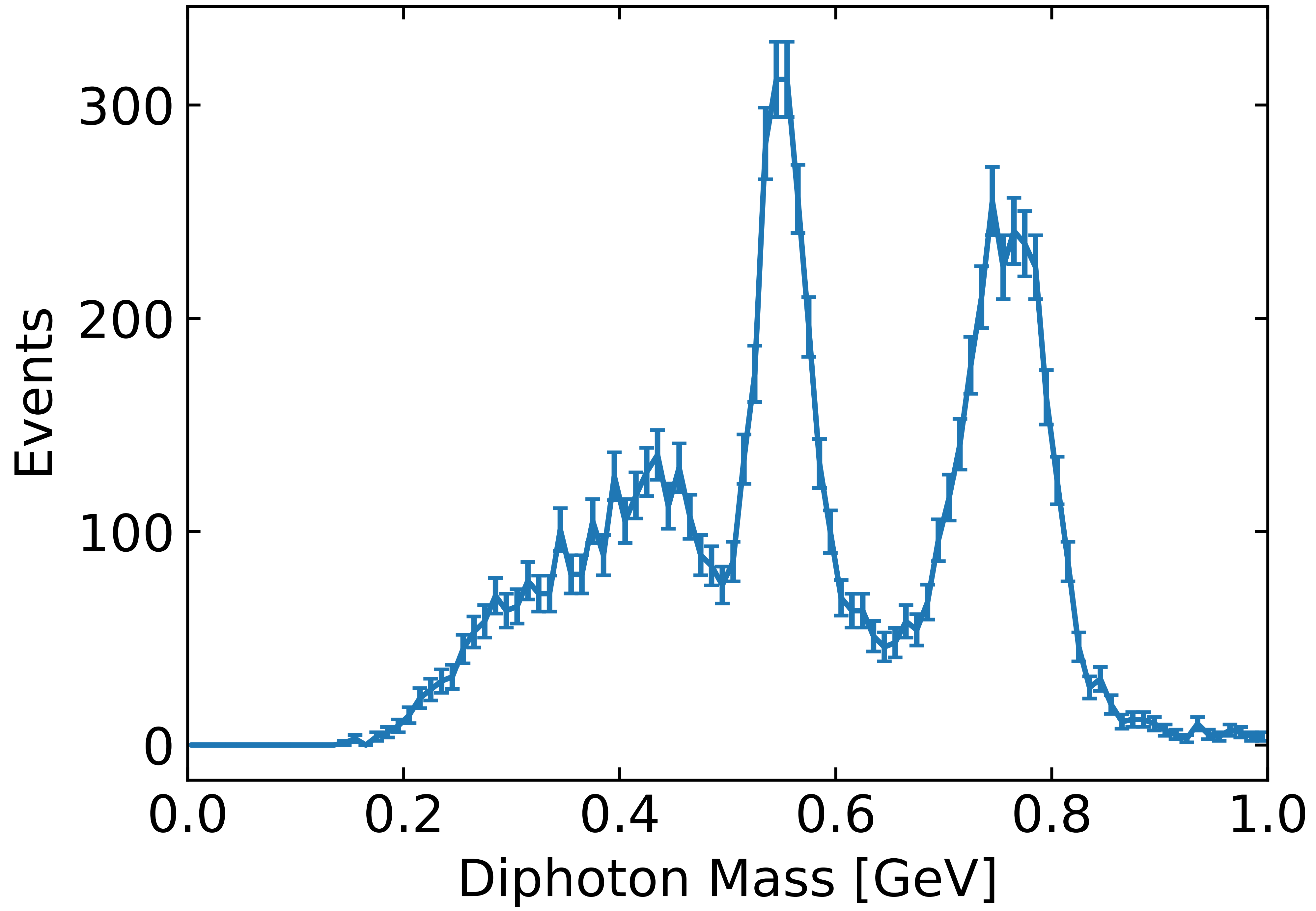
- Searching for Axion-Like Particles in $\gamma A \to \gamma\gamma A$ Primkaoff production

- Diphoton final-states detected via two final-state shows in FCAL; target-centered vertex assumed for momentum reconstruction



Introduction

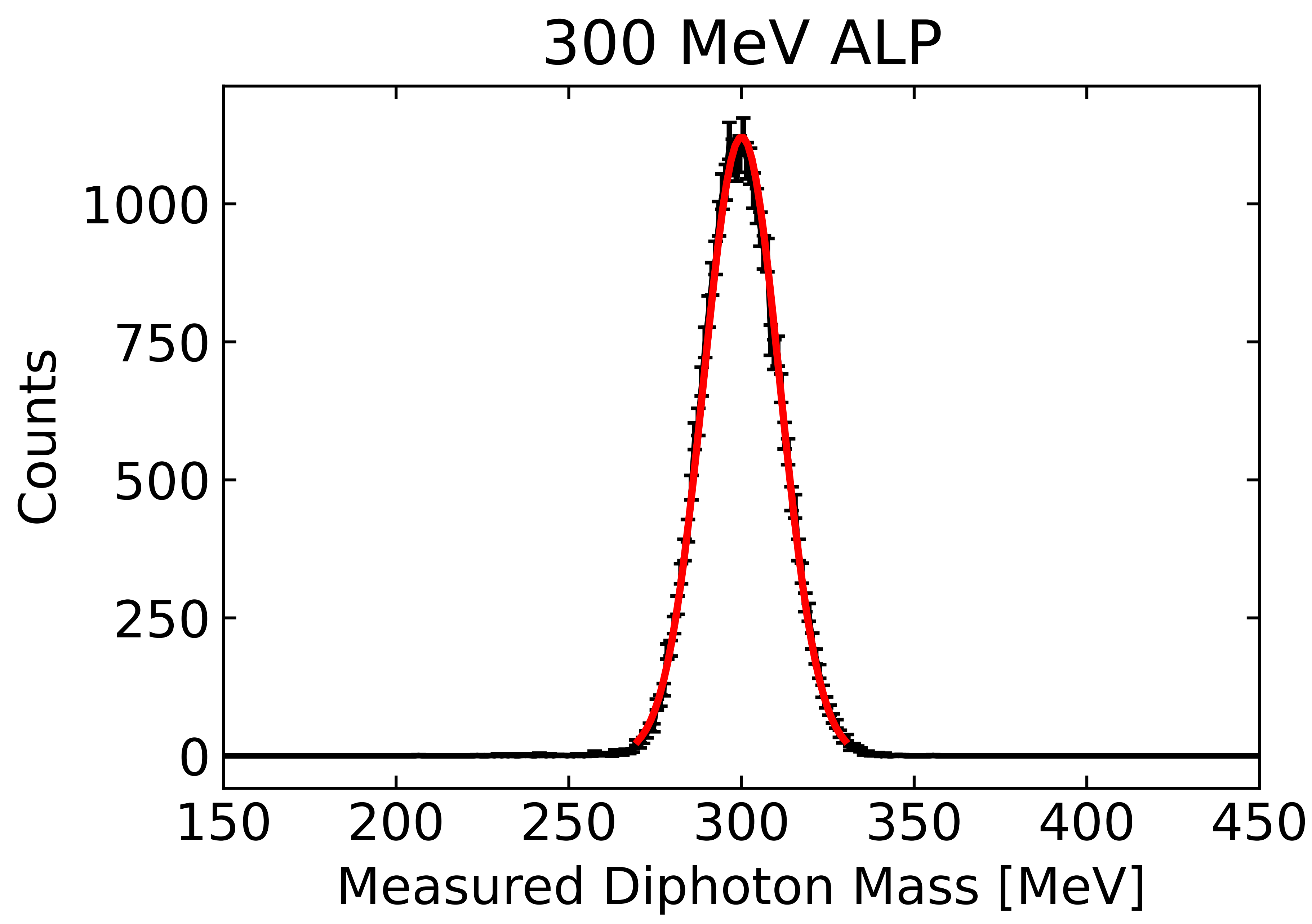
- Searching for Axion-Like Particles in $\gamma A \rightarrow \gamma\gamma A$ Primkaoff production
- Diphoton final-states detected via two final-state shows in FCAL; target-centered vertex assumed for momentum reconstruction
- Bump hunt performed over mass spectrum, searching for statistically significant resonances

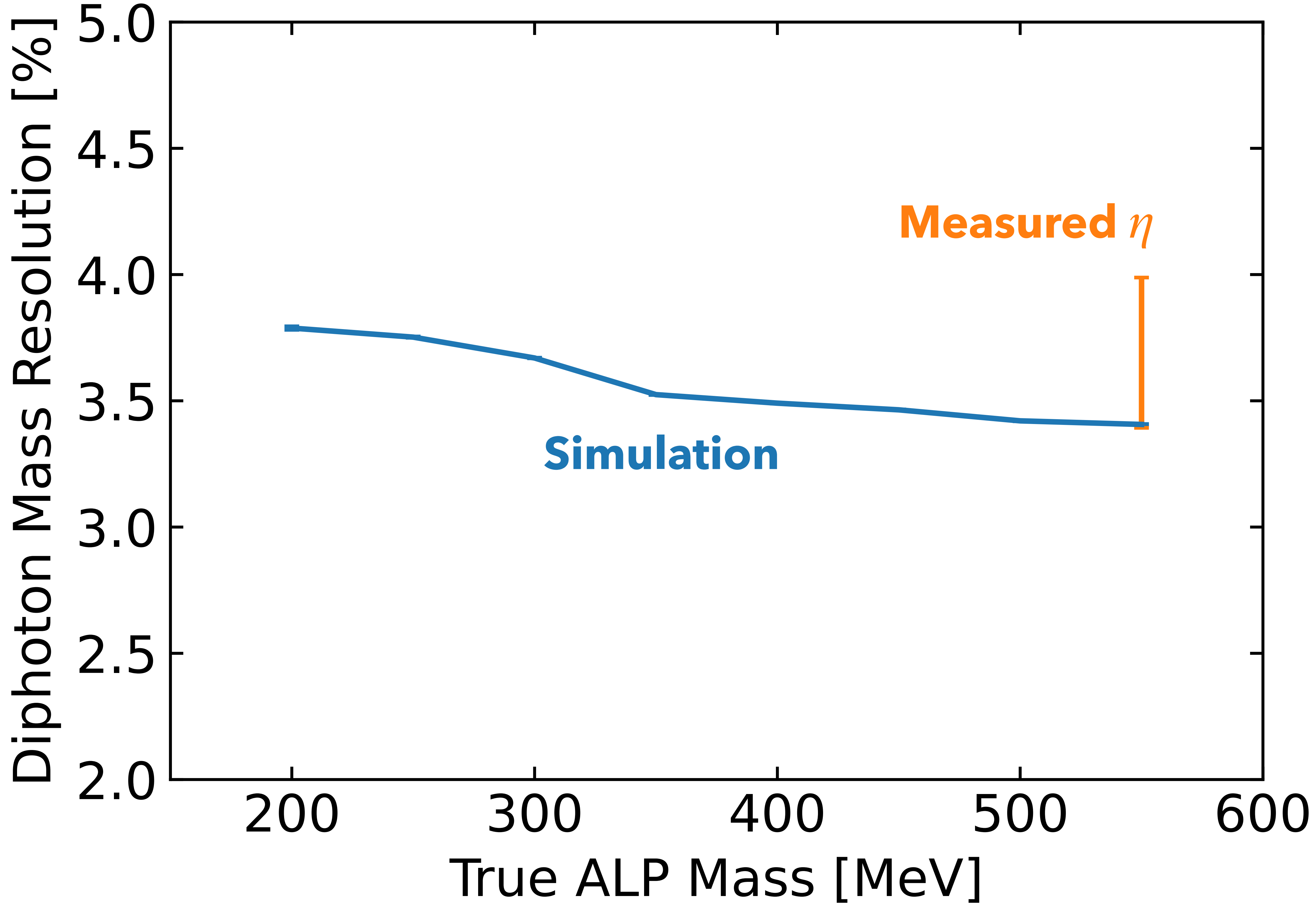


Selection Criteria

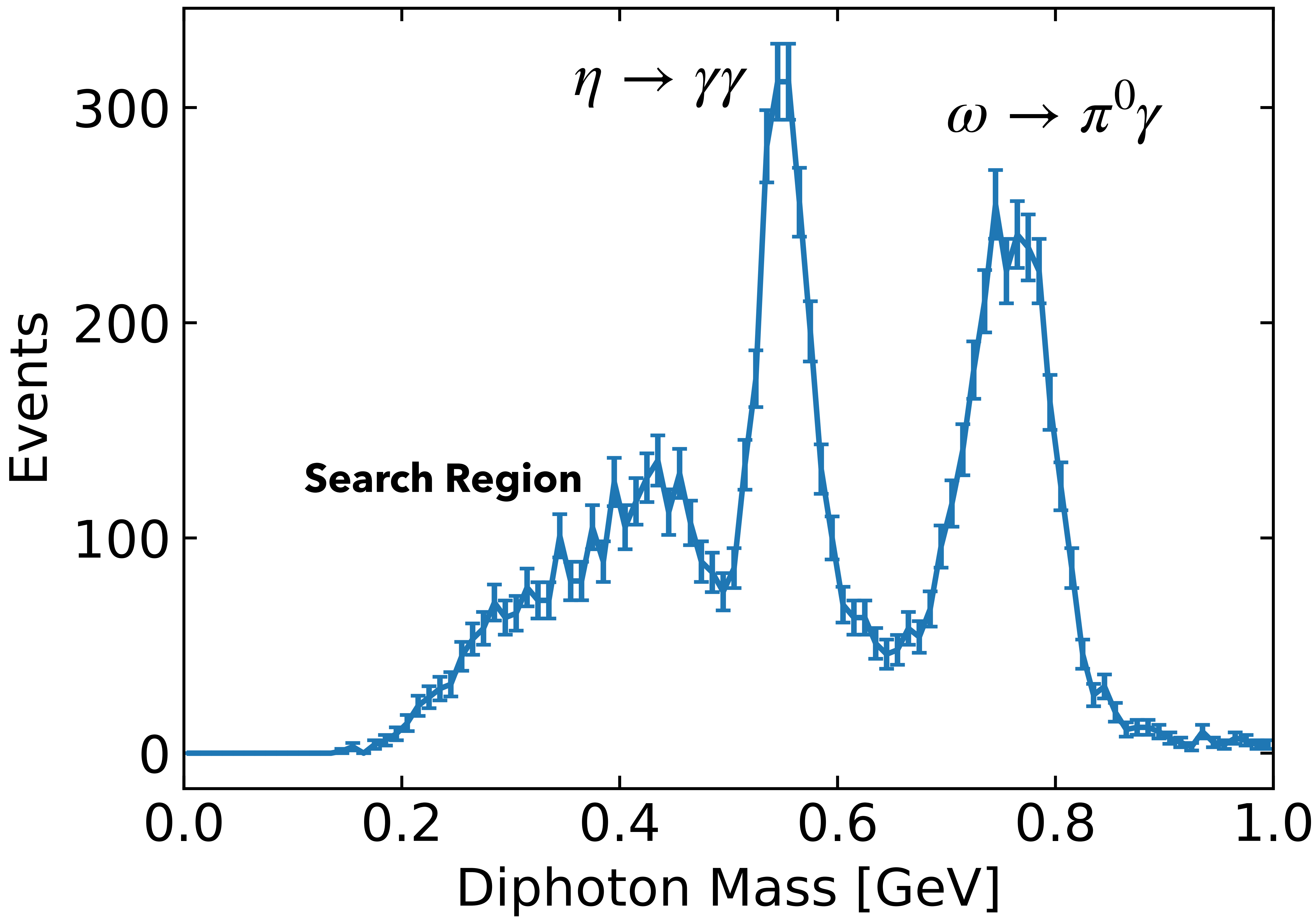
- Two showers required close to RF time, within FCAL fiducial region, above 100 MeV energy
- Vetos applied on:
    - FTOF hits within 6 cm and 6.5 ns of FCAL showers
    - SC hits within 8 ns after RF times
    - Additional Shower within 4 ns of RF time
- Physics cuts applied:
    - "Elasticity" of events: $0.95 < E_X/E_\gamma < 1.05$
    - Forward Primakoff Region $\theta_X < 0.5^\circ$
- Vetos and Cuts optimized using data-simulation comparisons

Simulation used to determine mass resolution for bump hunt





Mass spectrum obtained after all selection vetos and cuts

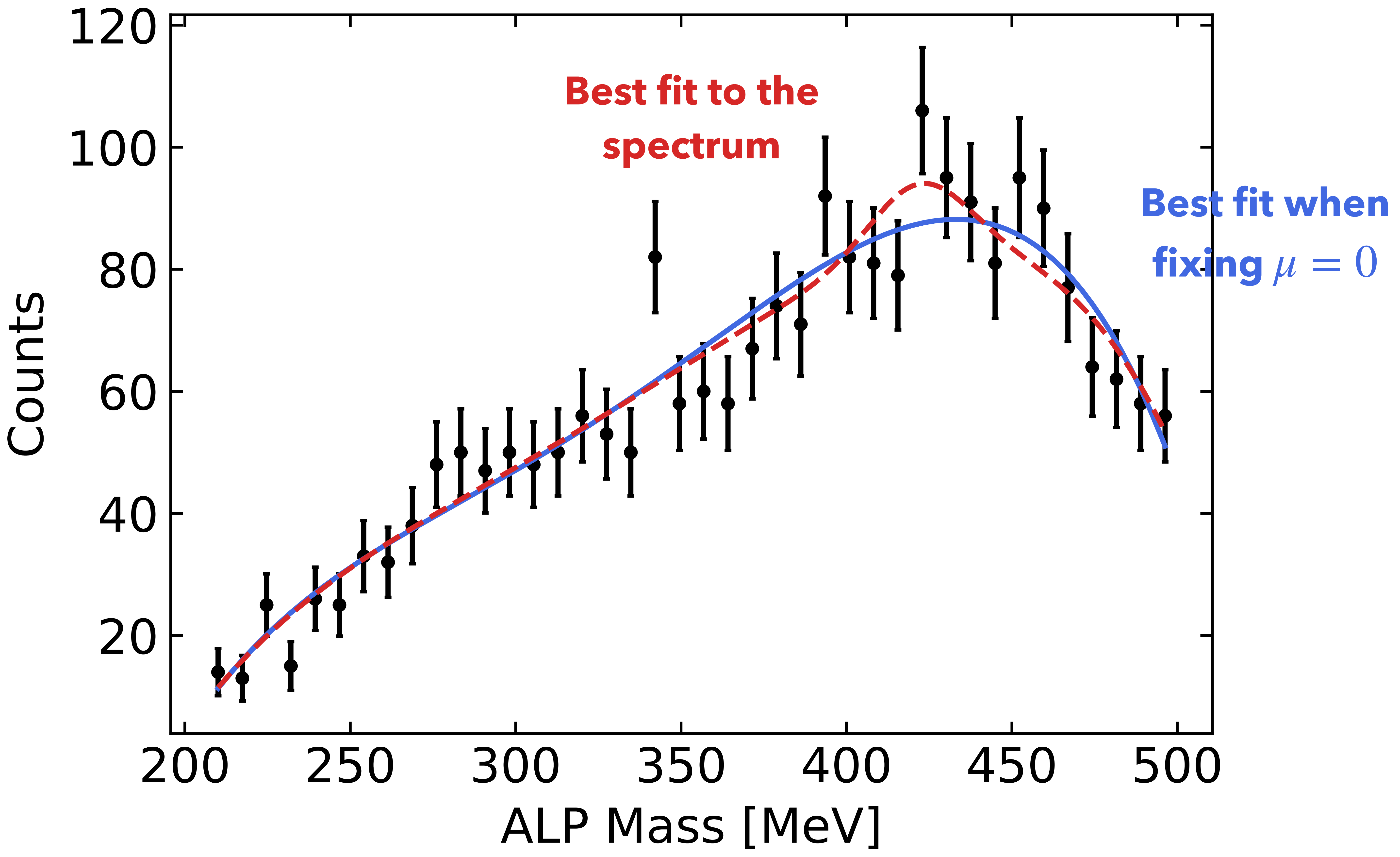


Bump Hunt Statistics

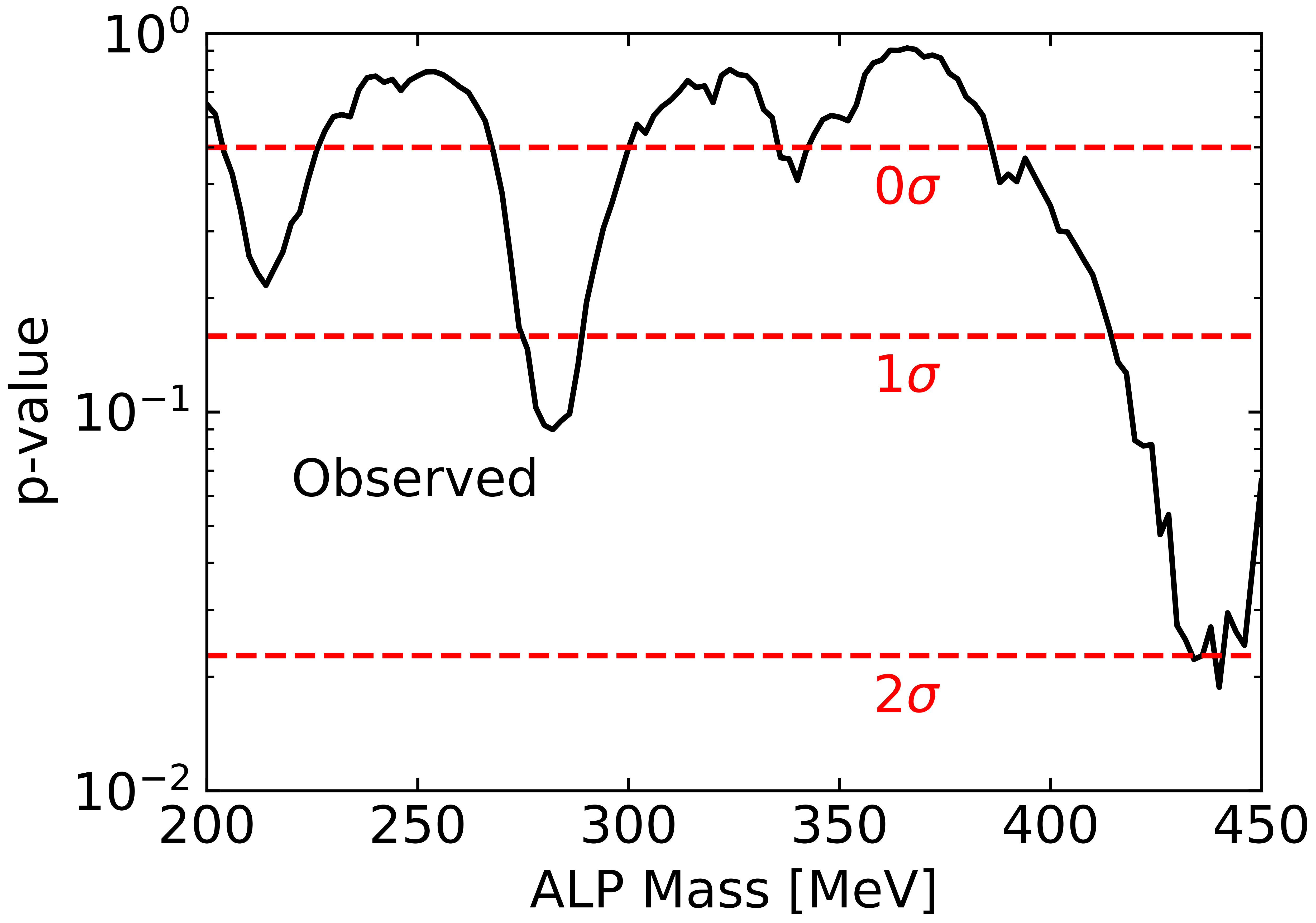
- Signal taken as gaussian with known resolution
- Background taken as 4th-order polynomial
- Data examined in 20σ region surrounding mass peak hypothesis
  - 500 MeV cut on search region due to η background
- Statistics calculated using Frequentist "profile likelihood ratio":

$$\lambda(\mu) = \frac{L\left(\mu, \tilde{\theta}(\mu)\right)}{L\left(\hat{\mu}, \hat{\theta}\right)}$$

Example fits to spectrum



Test of Discovery – how good is 0-signal fit?



- Local p-value for different masses examined
- No excess signals of high significance found
- Accounting for look-elsewhere effect even the largest excess is less than 1σ signal

Signal Injection Test

- Randomly generated signals injected into the observed mass spectrum

- Mass and significance randomly selected

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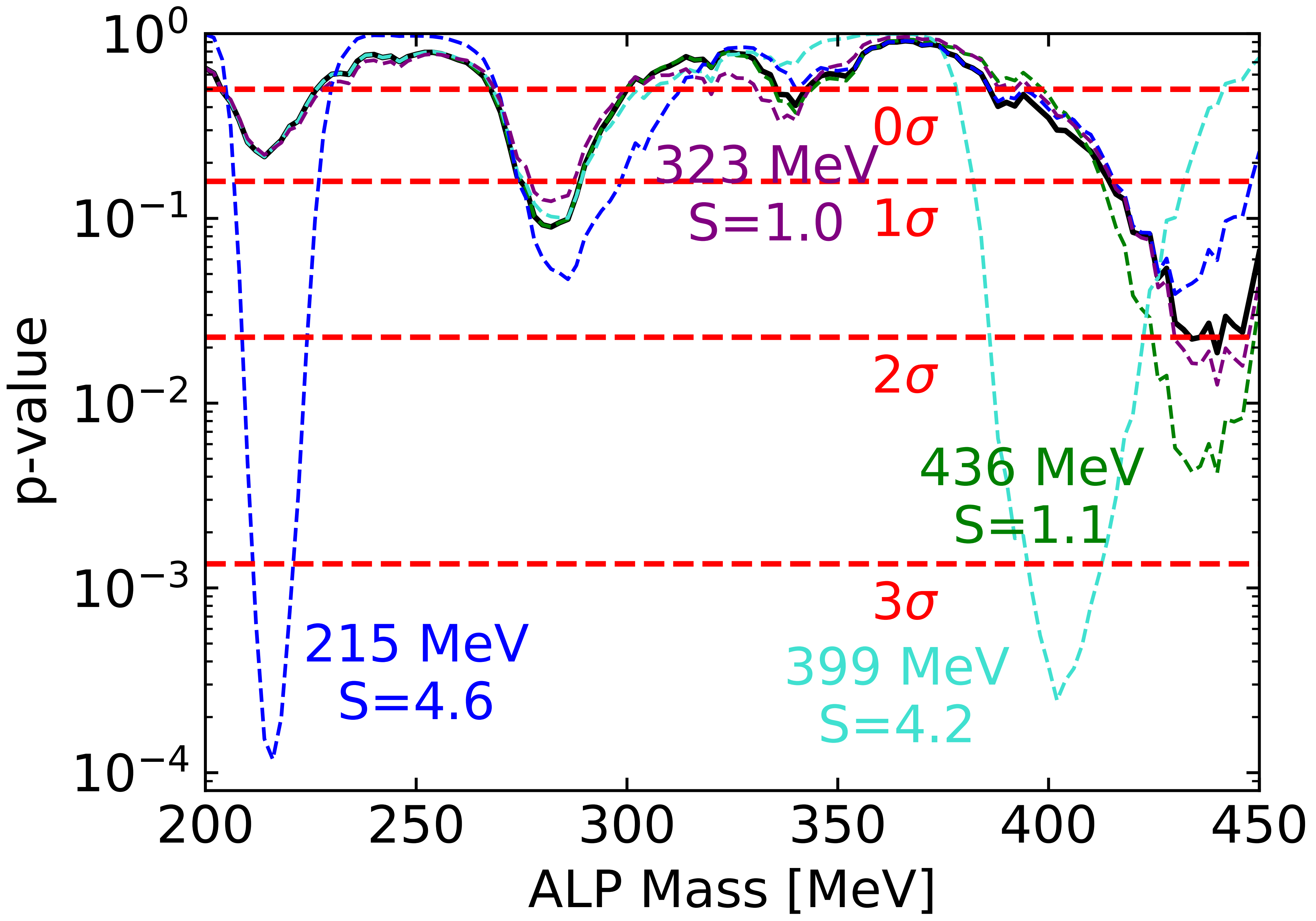
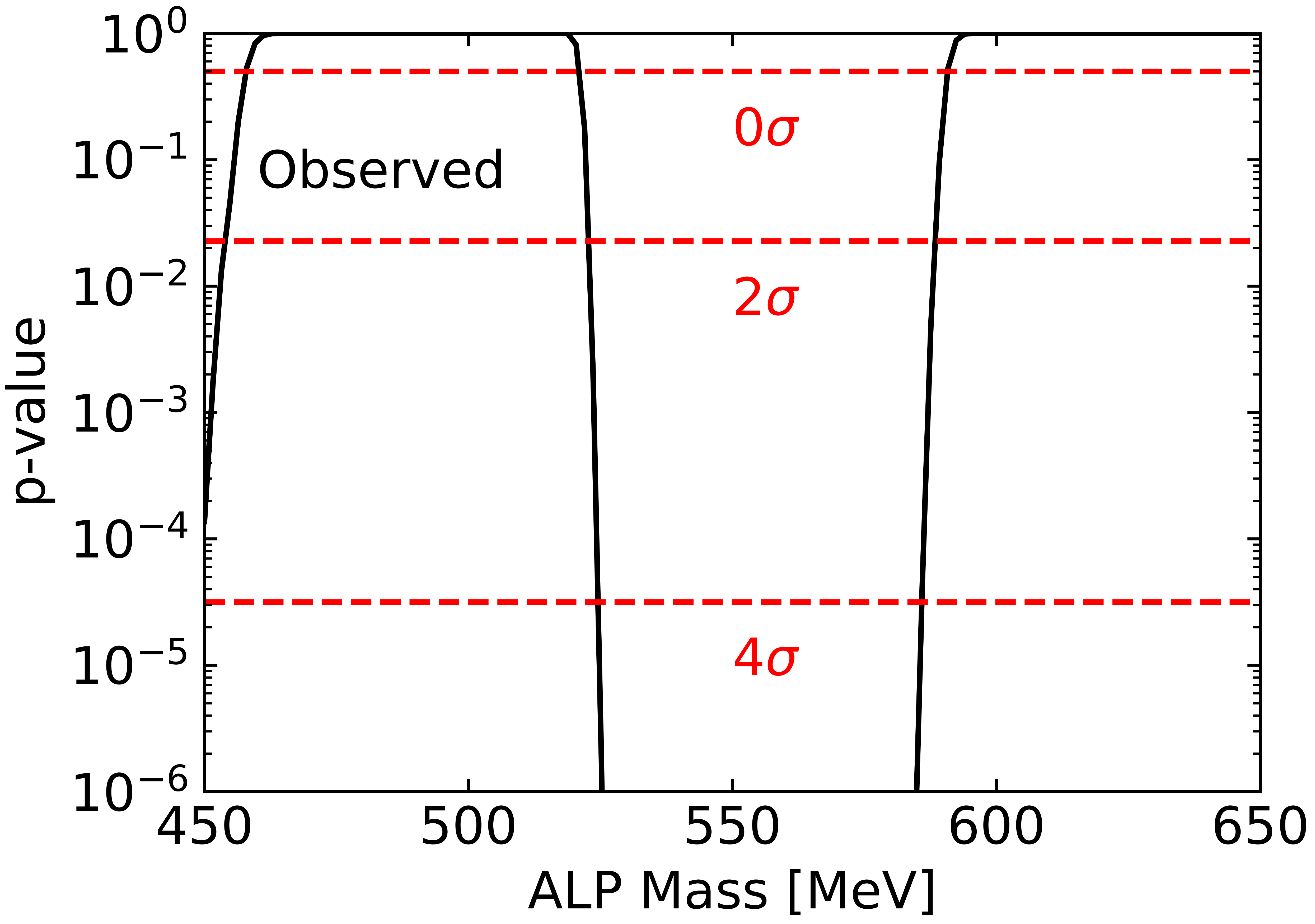
- Plot of local p-values shows increases of significance near injected signal masses, with strength correlating to injected significance



η Discovery Test



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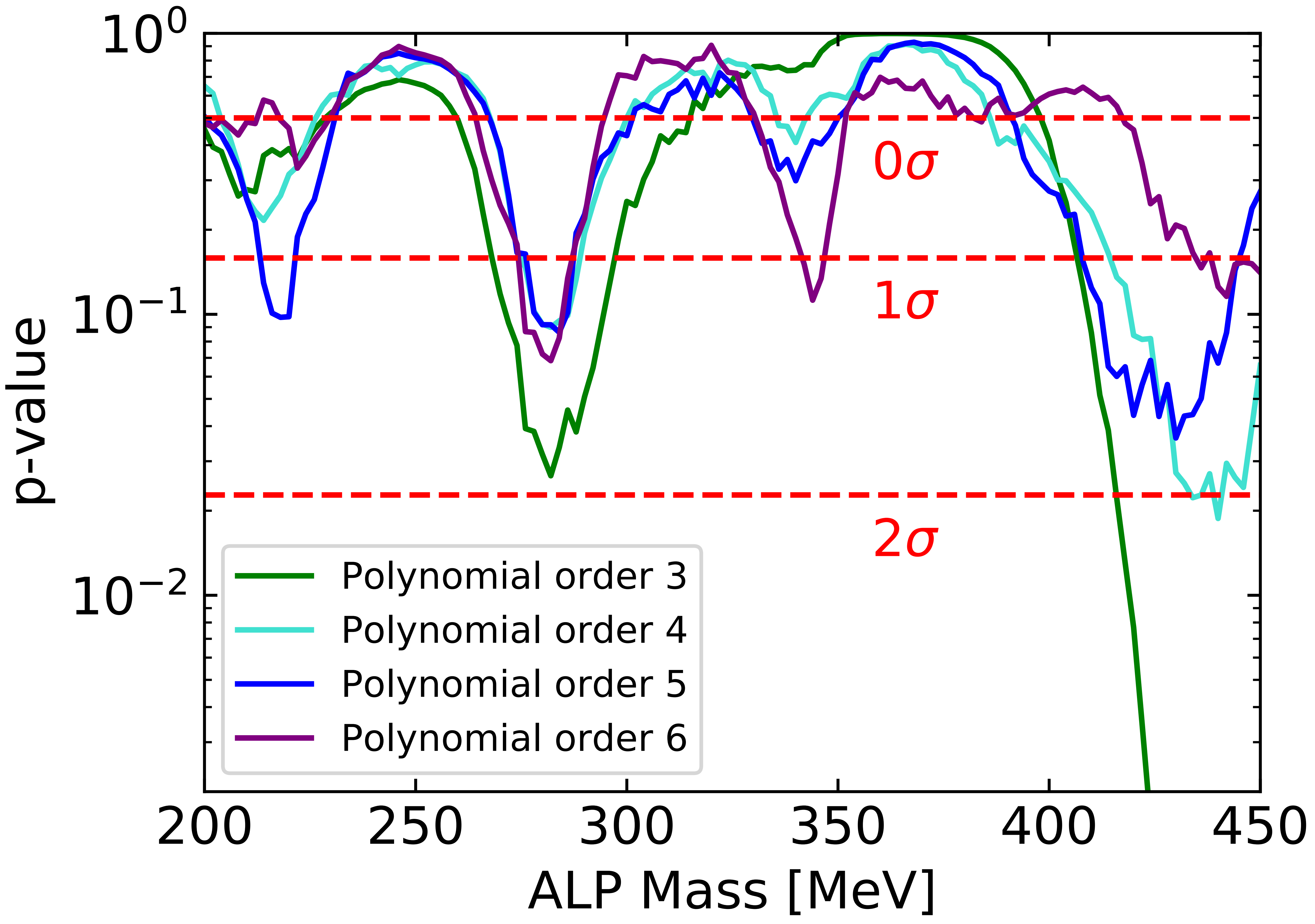
Polynomial Order Check



- Different order polynomials used to describe the mass background
- Qualitative features of local p-value are the same for different orders
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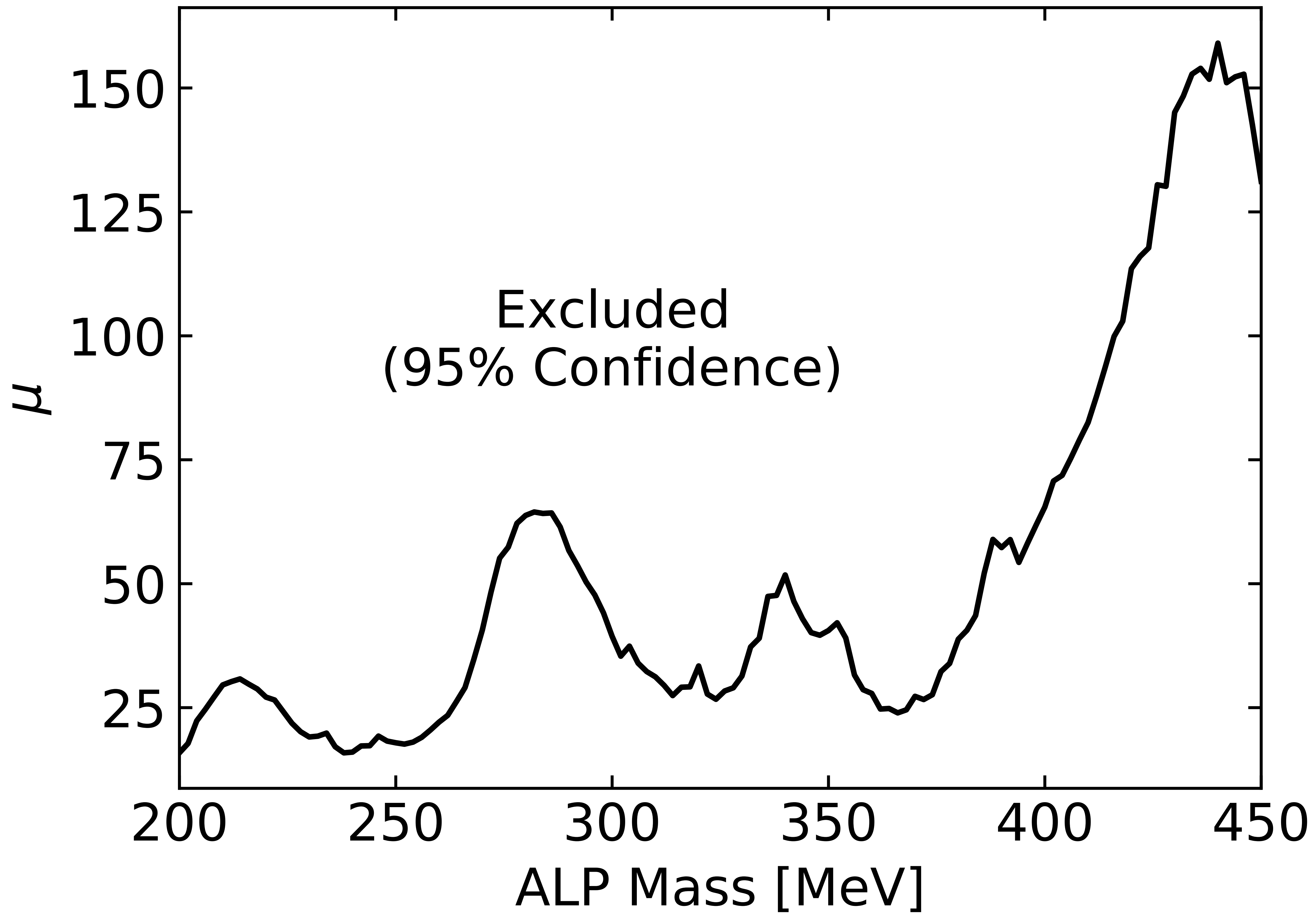
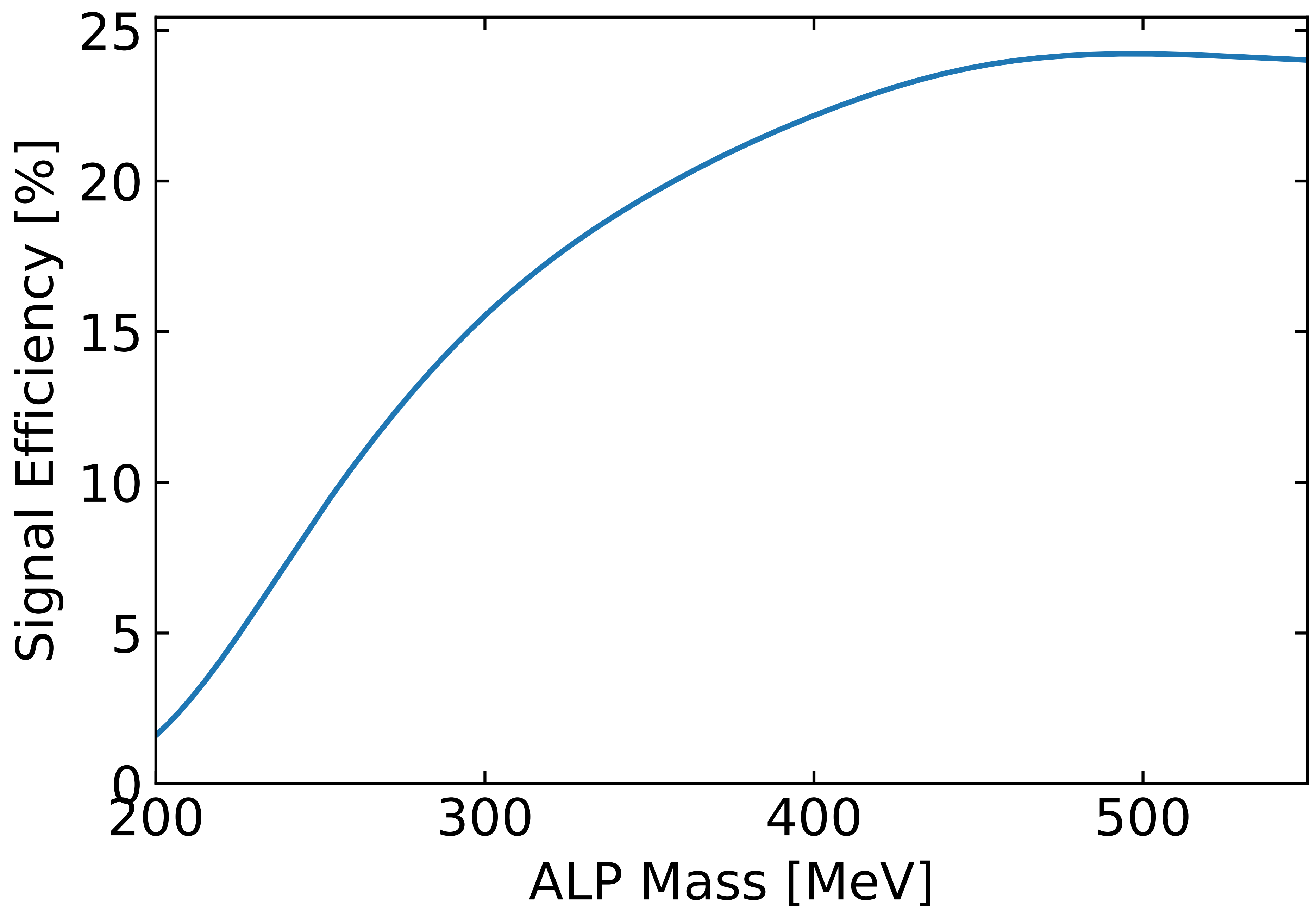
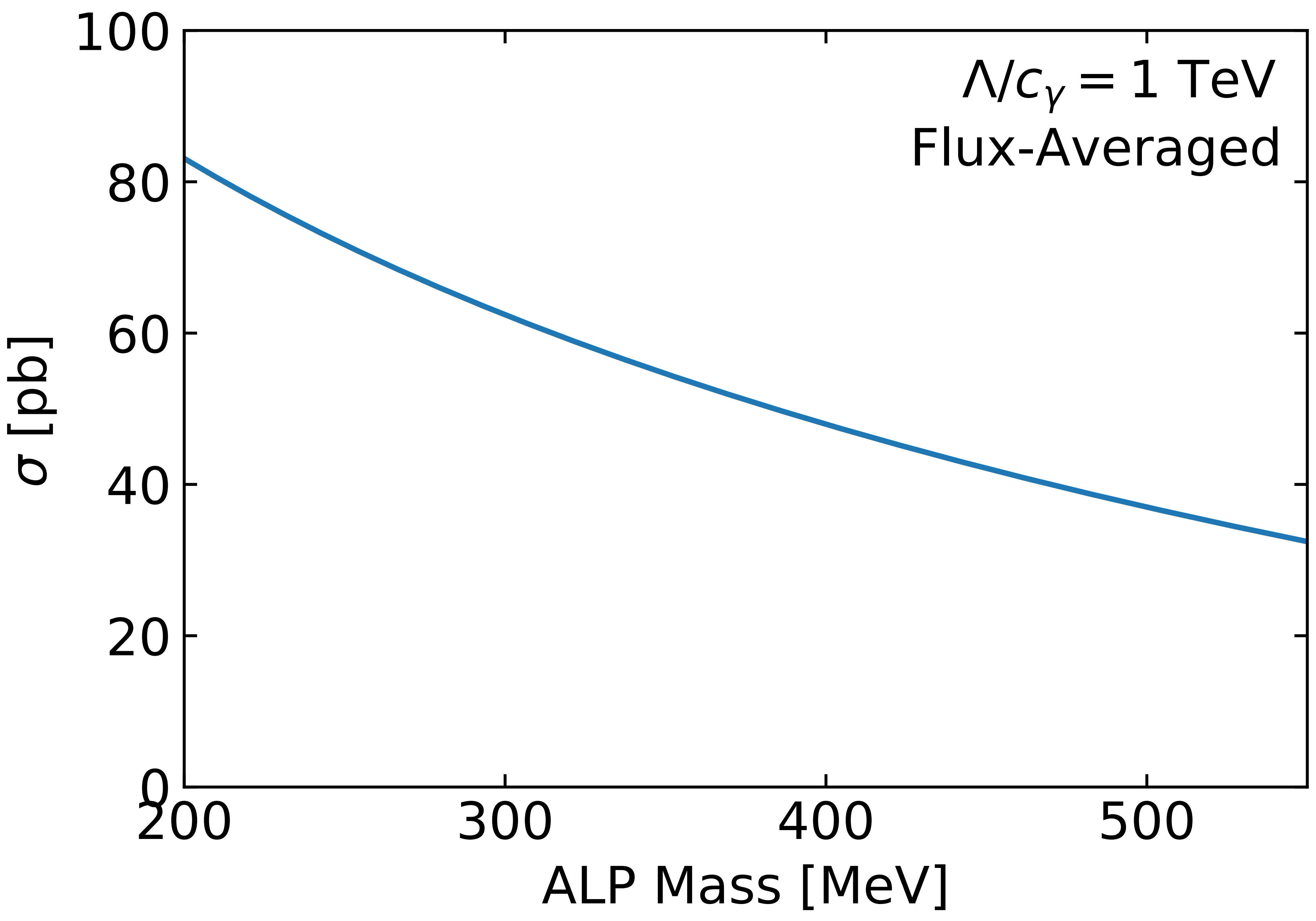
Test of Exclusion — how much signal can we allow with the data?



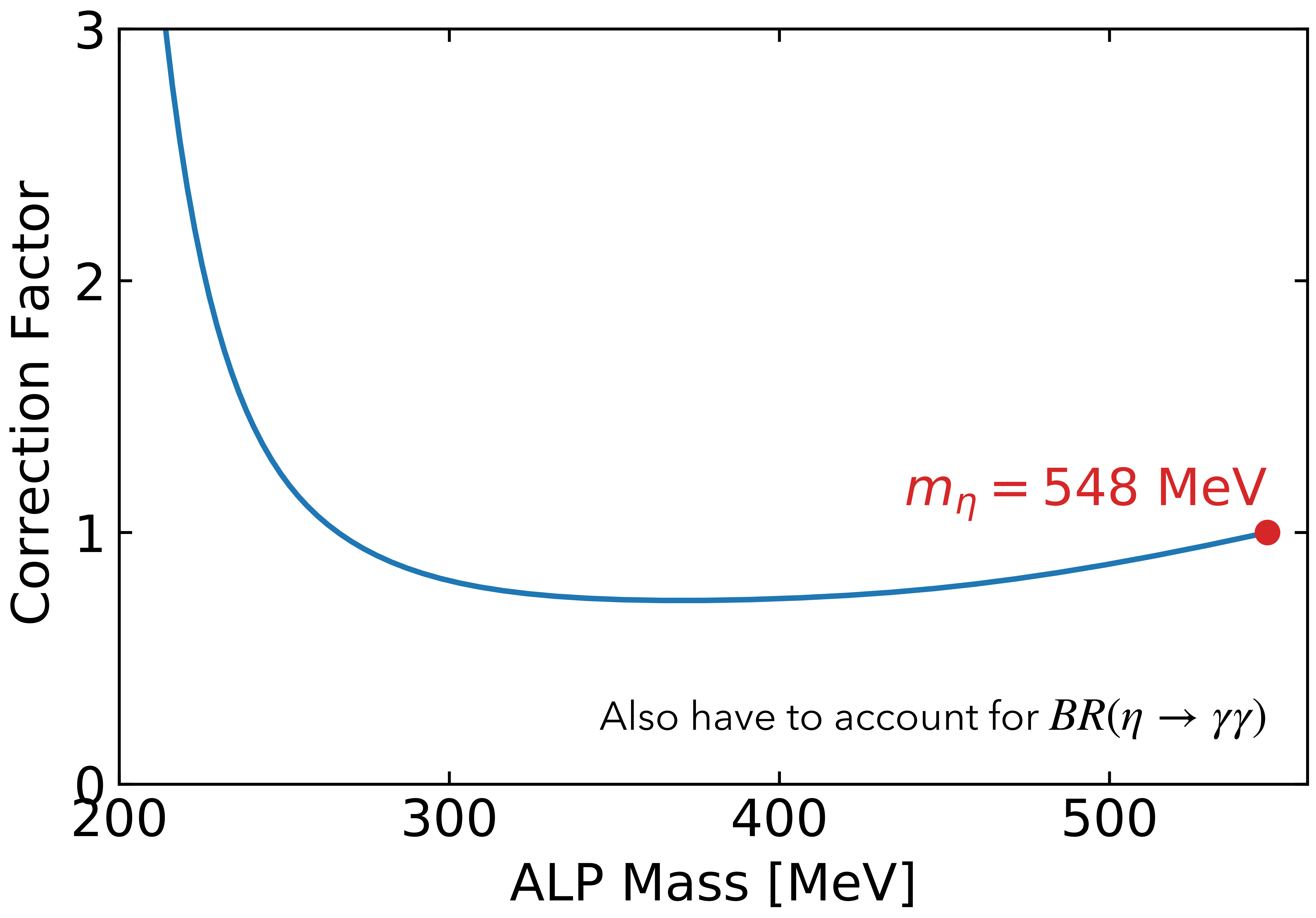
- 95% limits on signal strength calculated for different masses
- Must be further normalized to correspond with coupling strength

Simulation used to determine cross sections and cut efficiency for signal

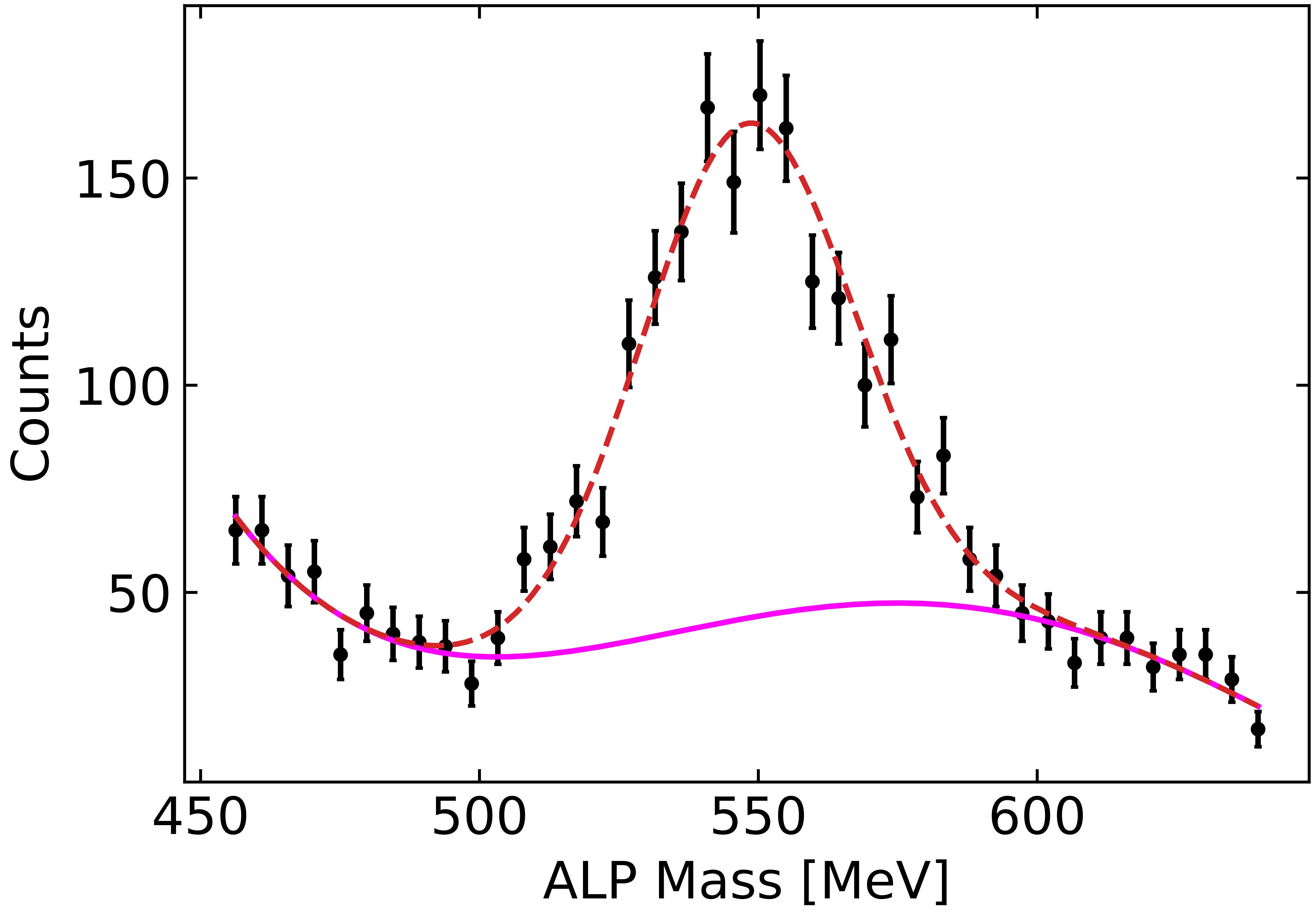




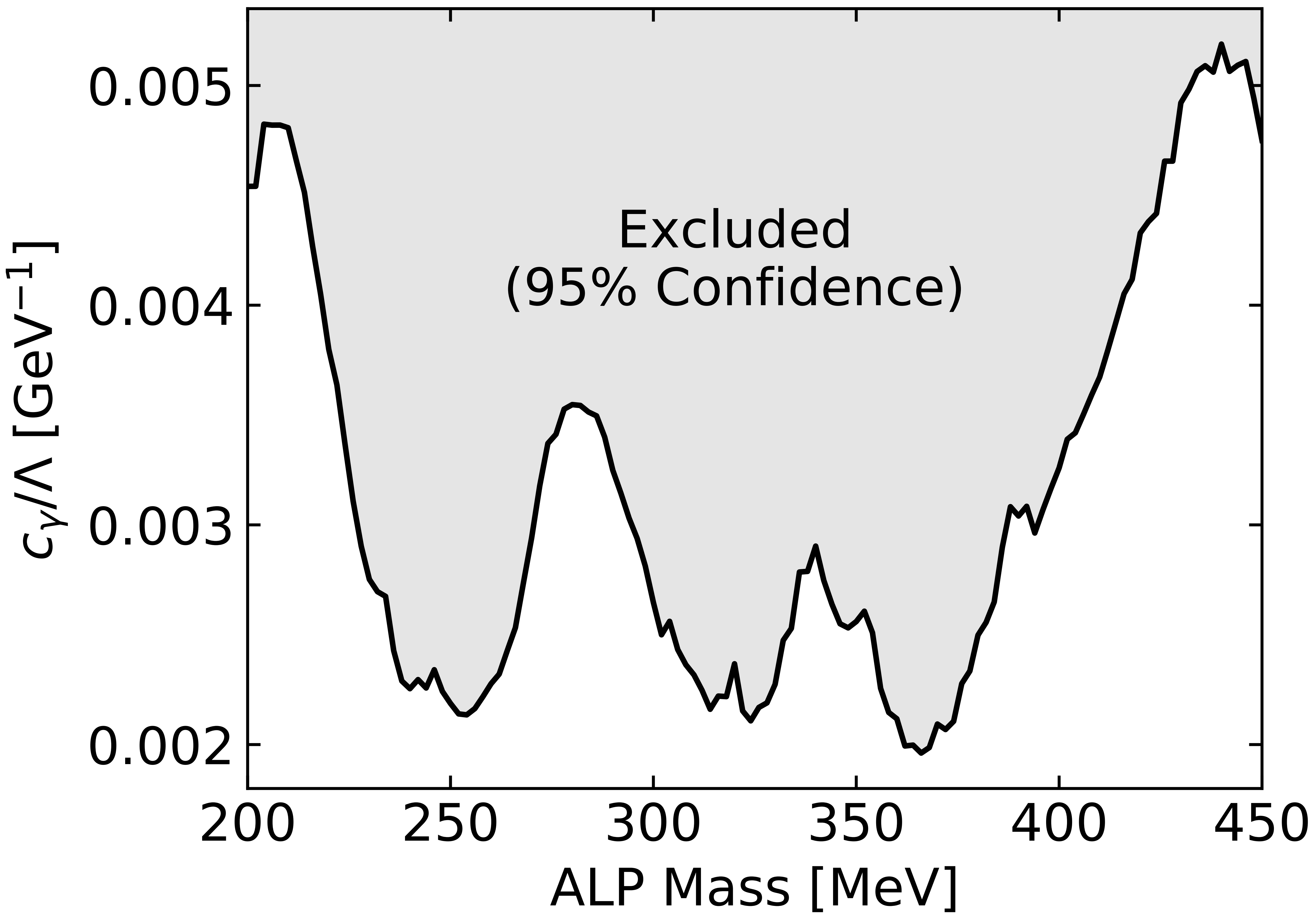
Mass-dependent cross section and efficiency corrections allows us to normalized to η signal observed



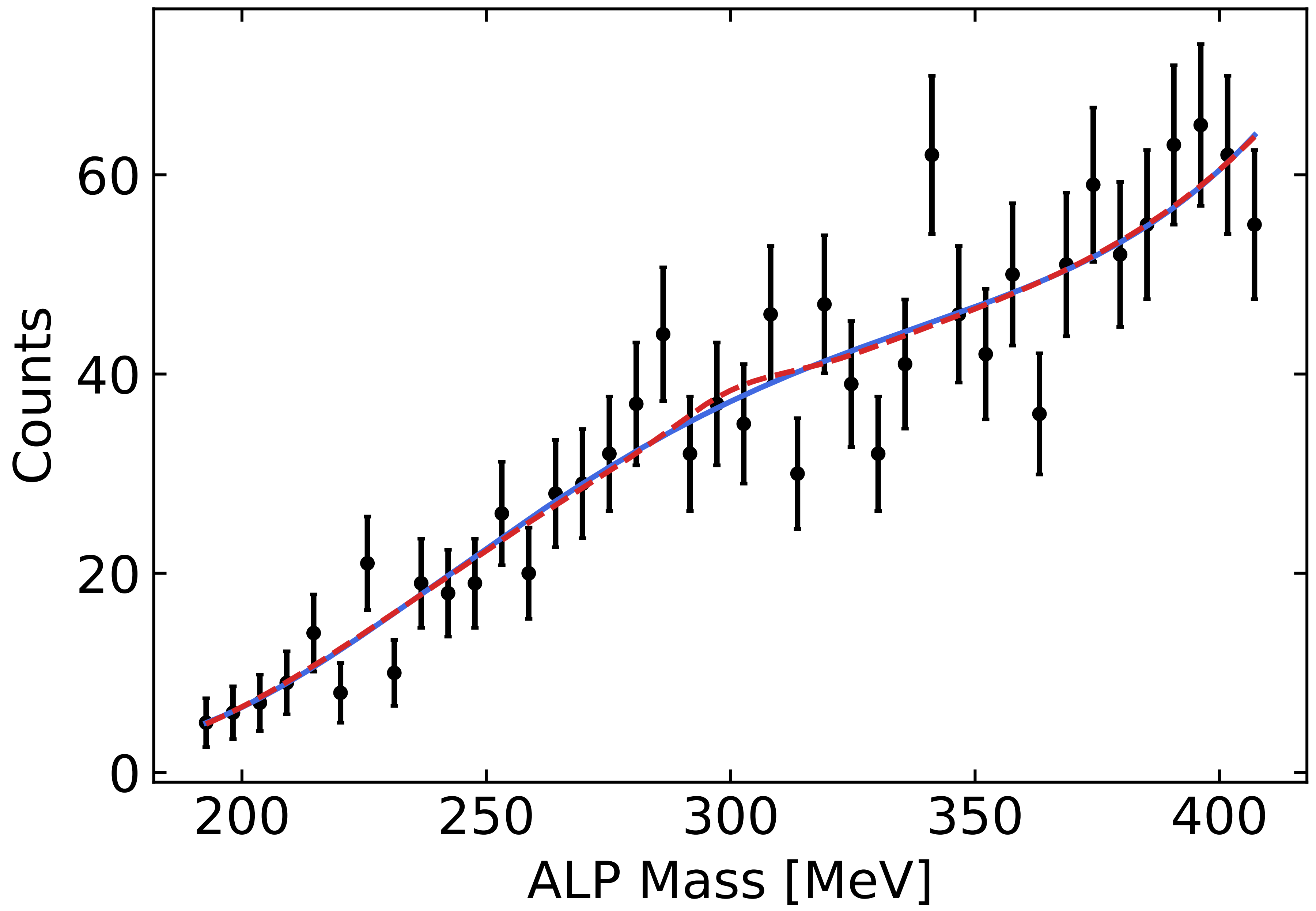
Signal for $\eta \to \gamma\gamma$ measured

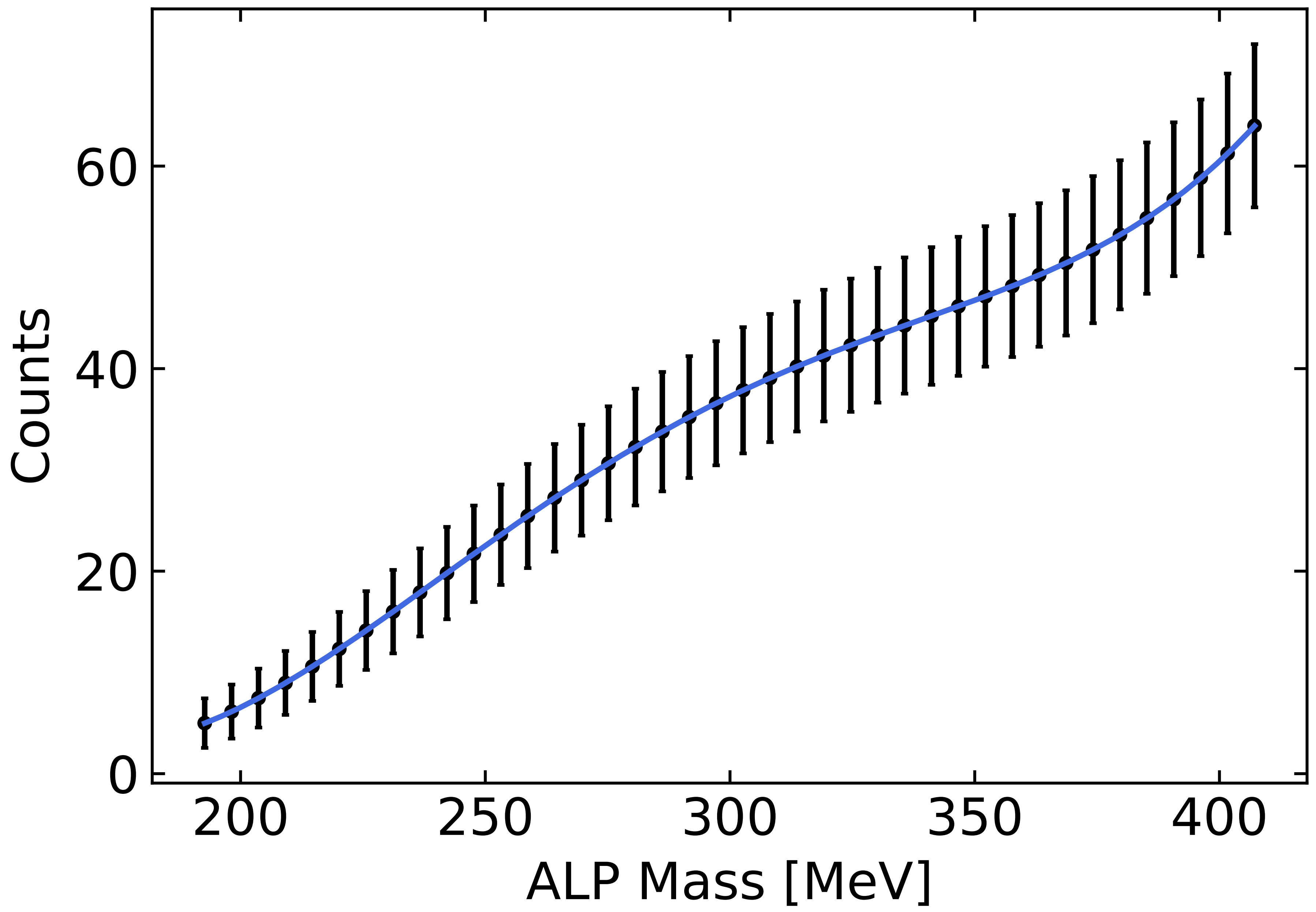


Correcting for mass effects, we can related excluded signal strength to excluded coupling by normalizing to η



“Asimov” dataset used to calculate probabilistic exclusion limits for background-only hypothesis





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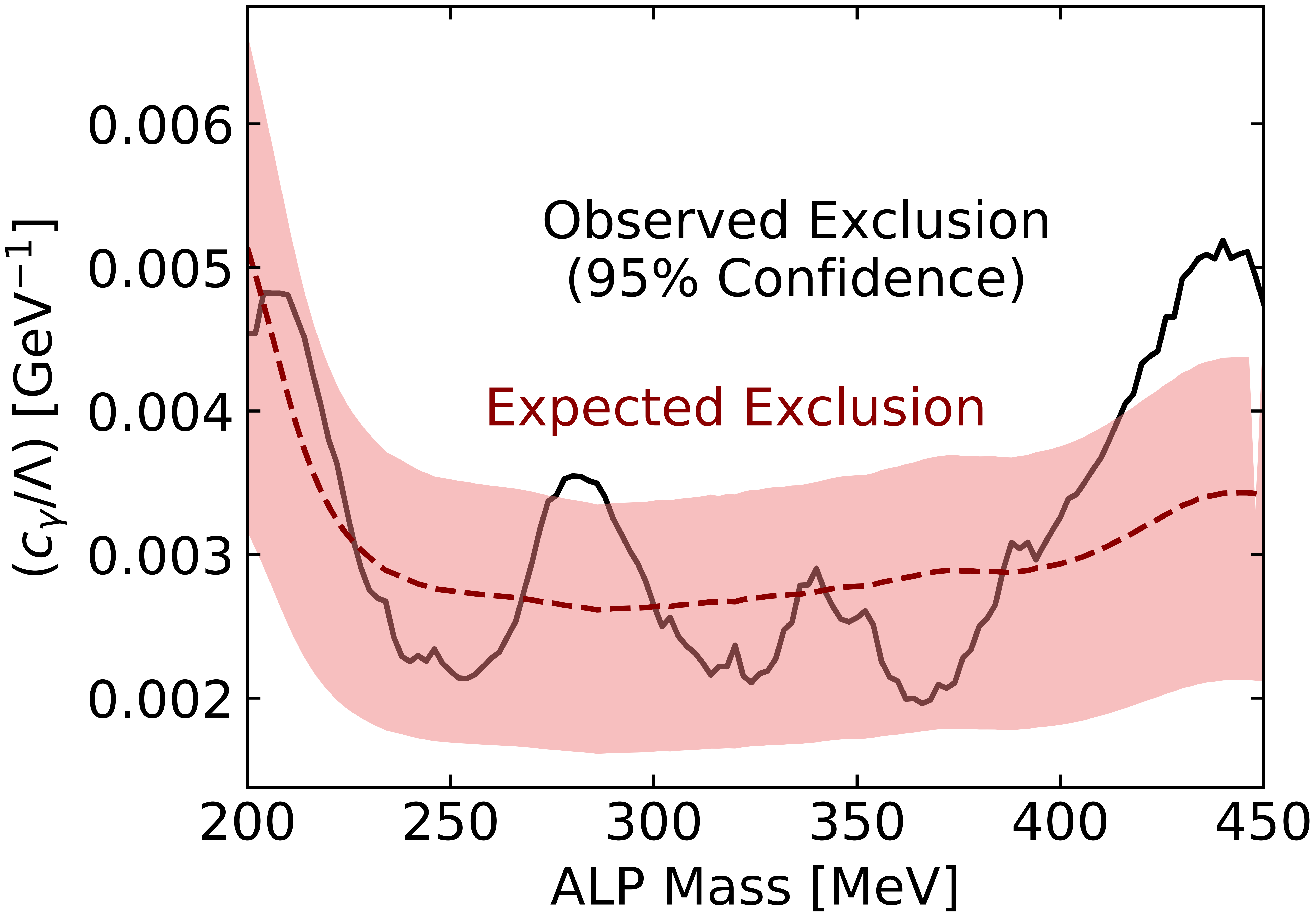
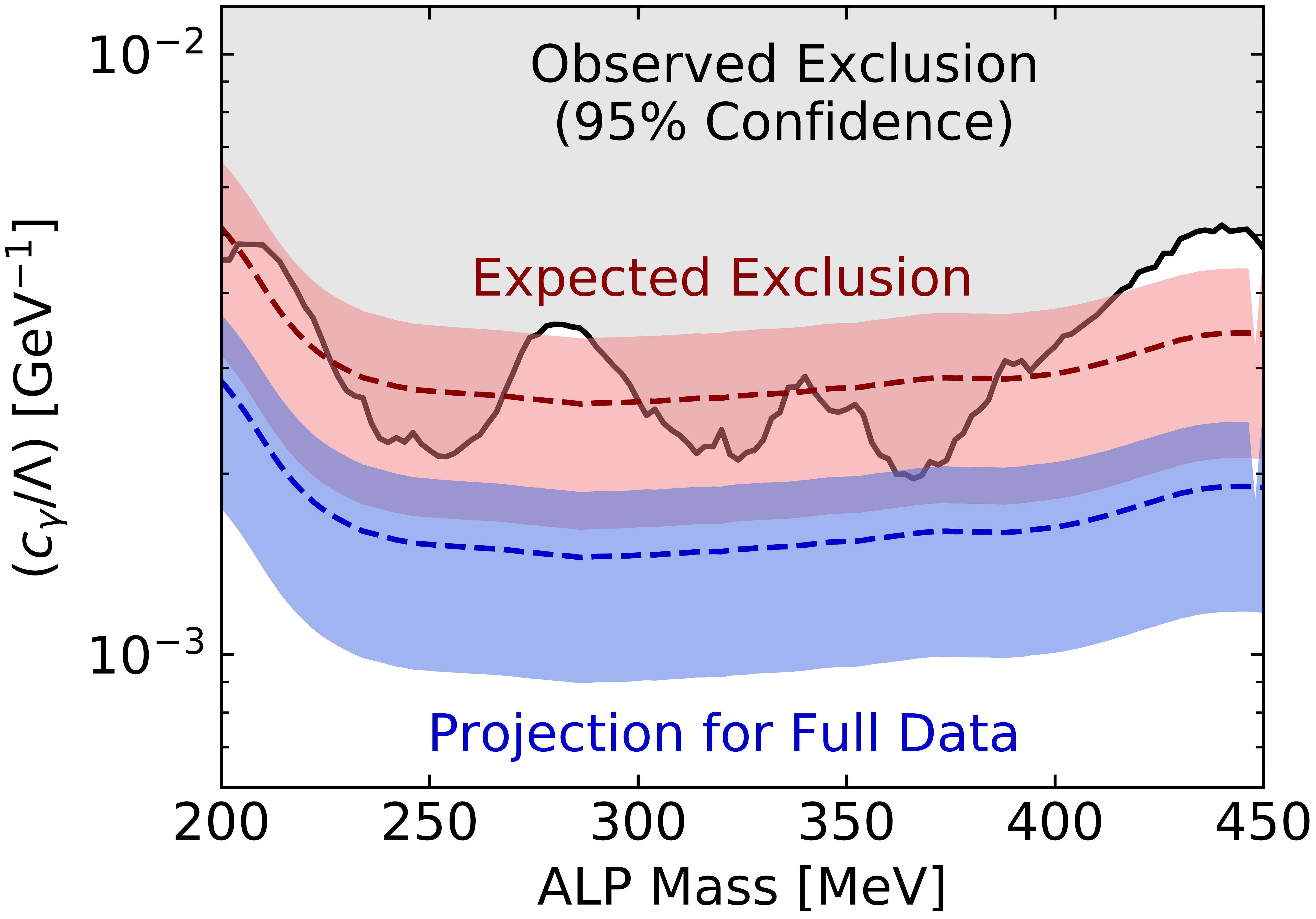
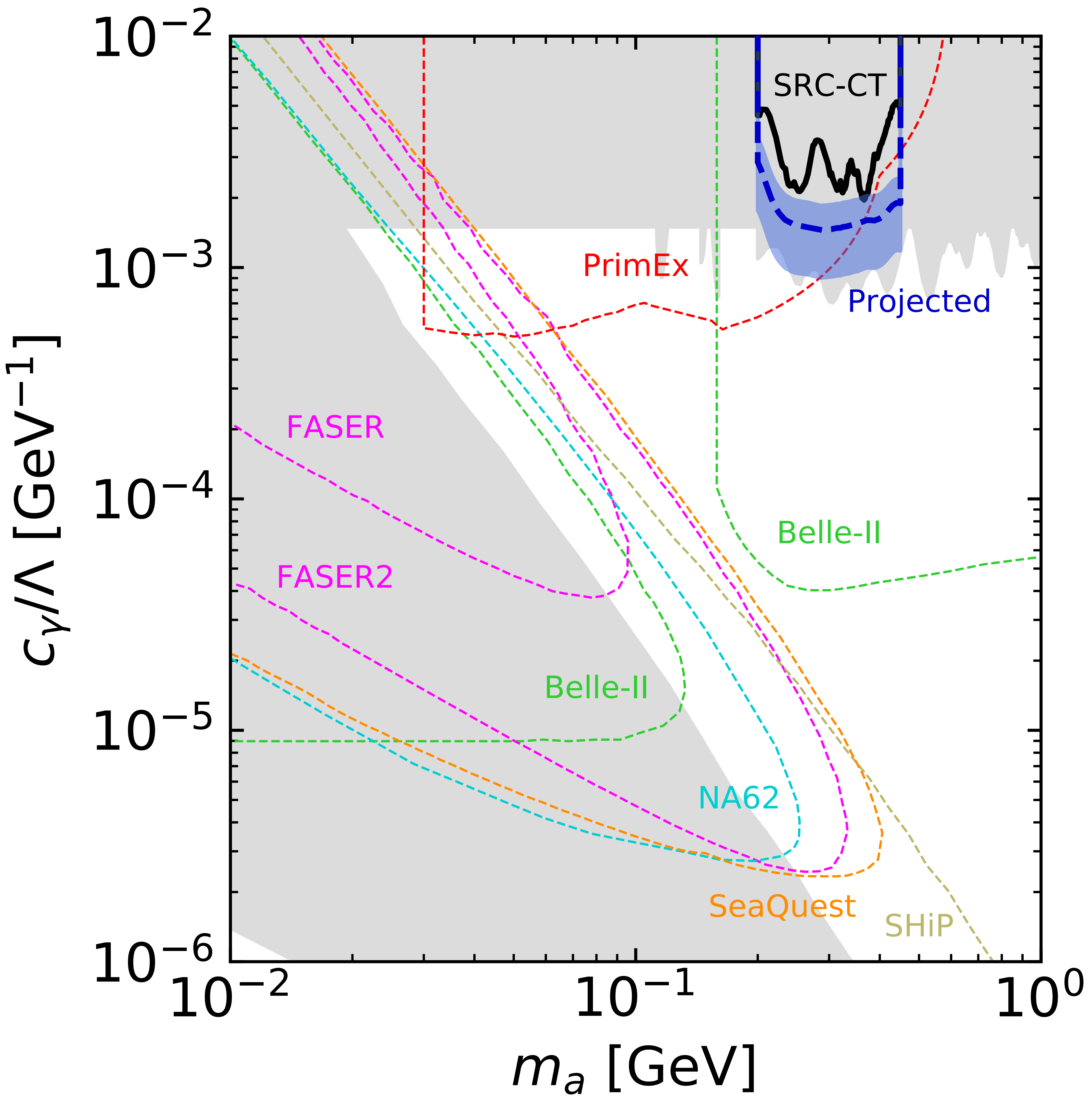


Can be scaled to full dataset to project unblinded results



Final projected exclusion for data



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