SRC-CT ALP Bump Hunting Procedure

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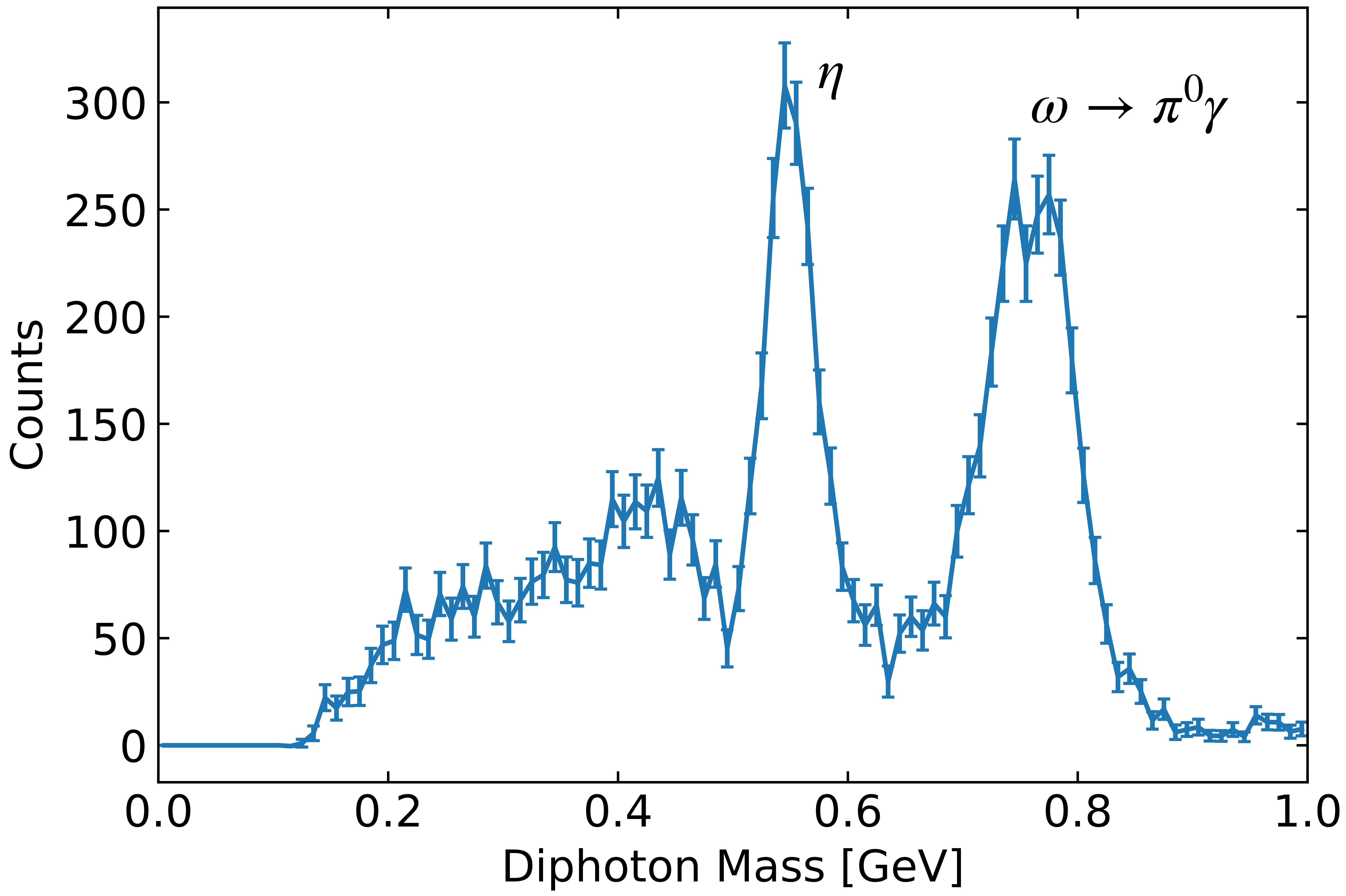
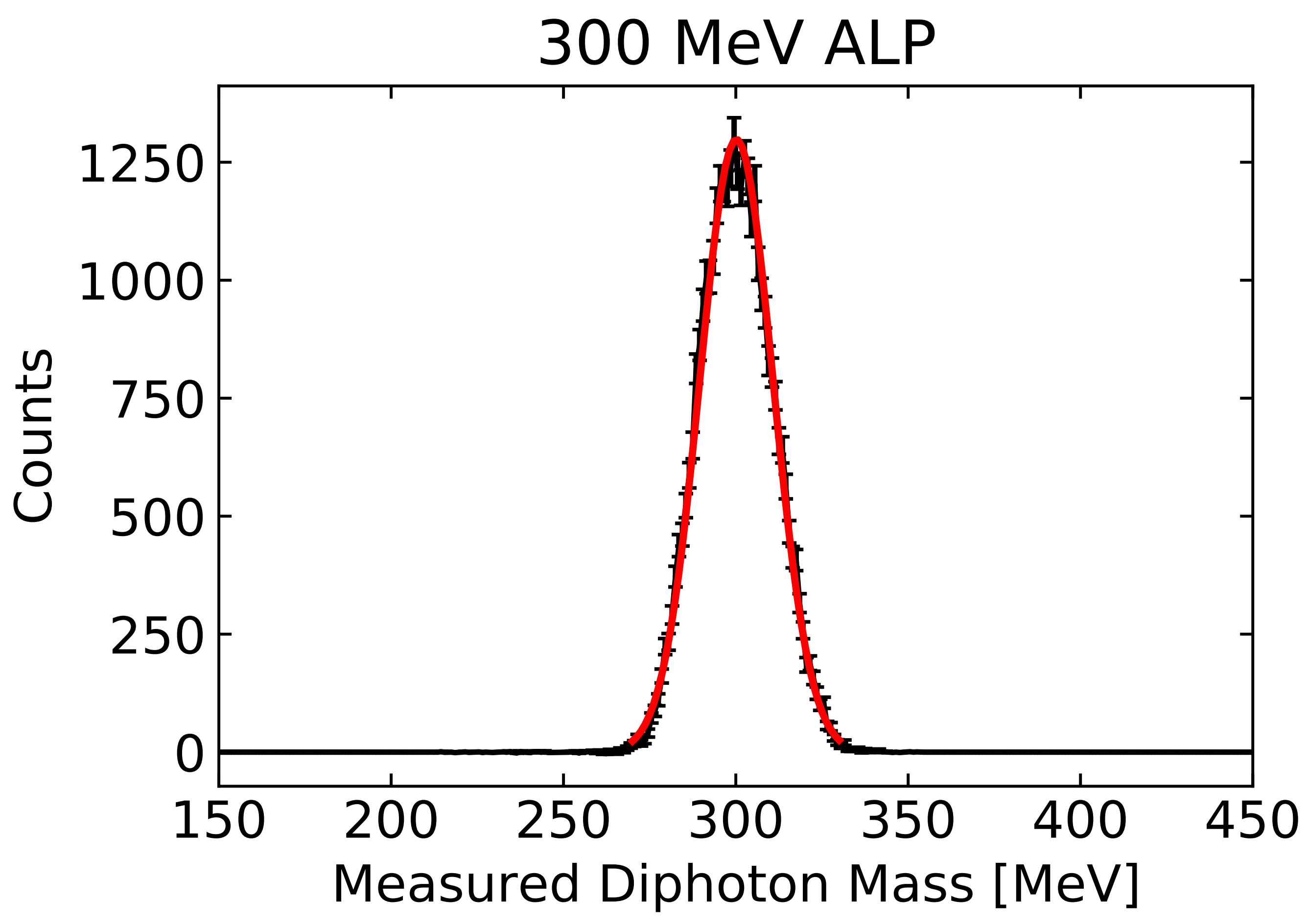
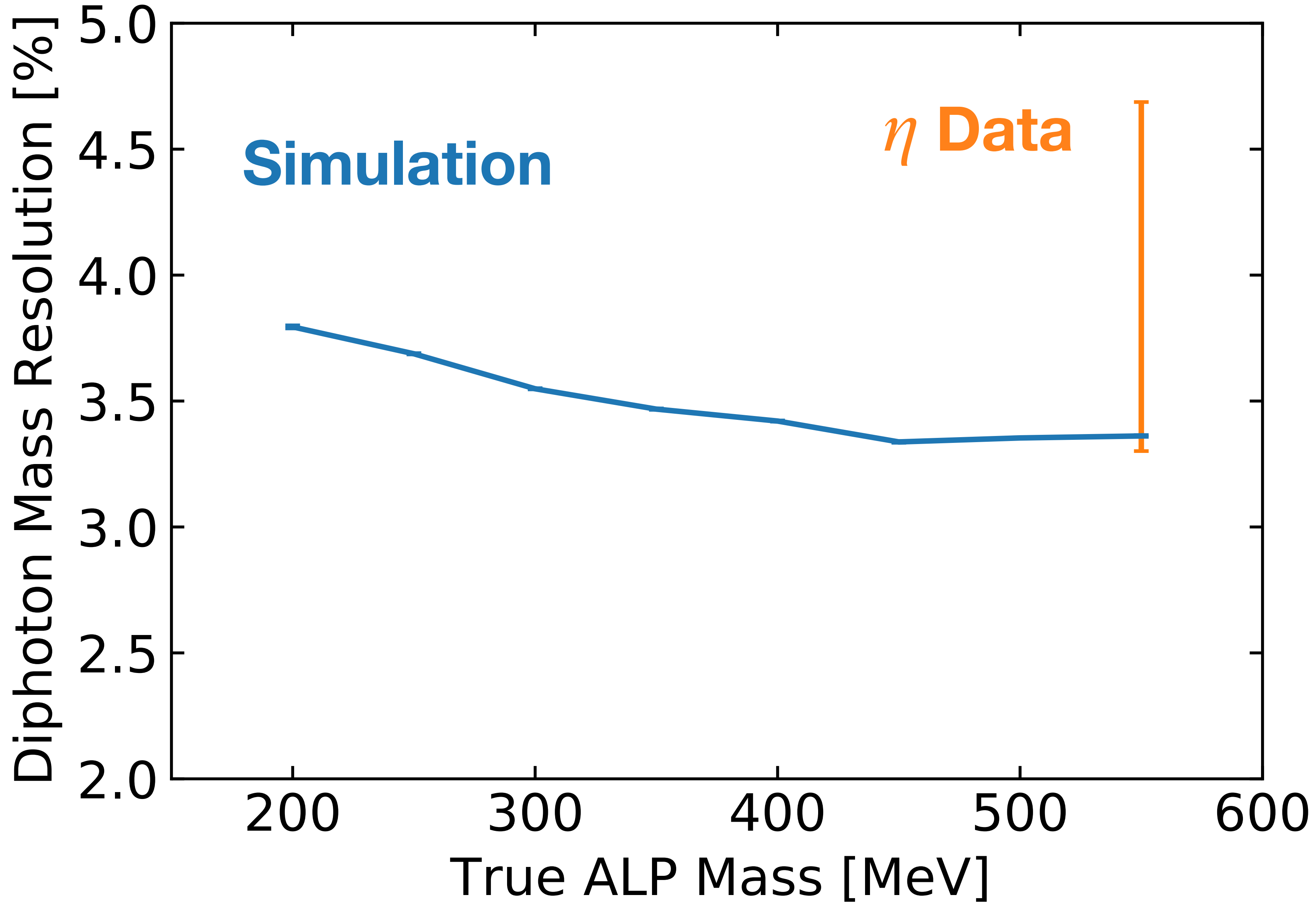
How do we tell where this spectrum has bumps?

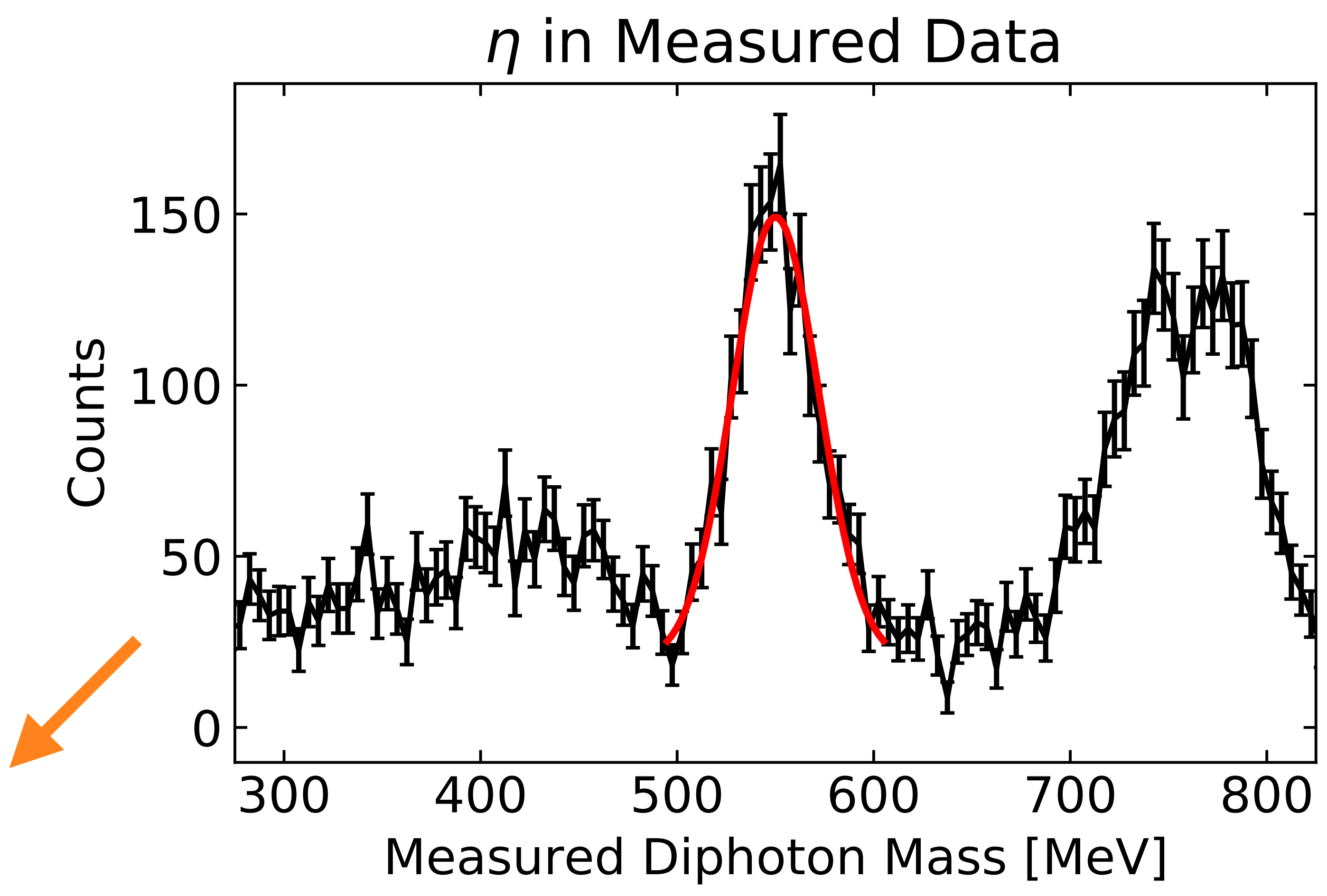


Signal model: Gaussian distribution



GEANT model + ALP signal used to calculate $\sigma(m_X)$

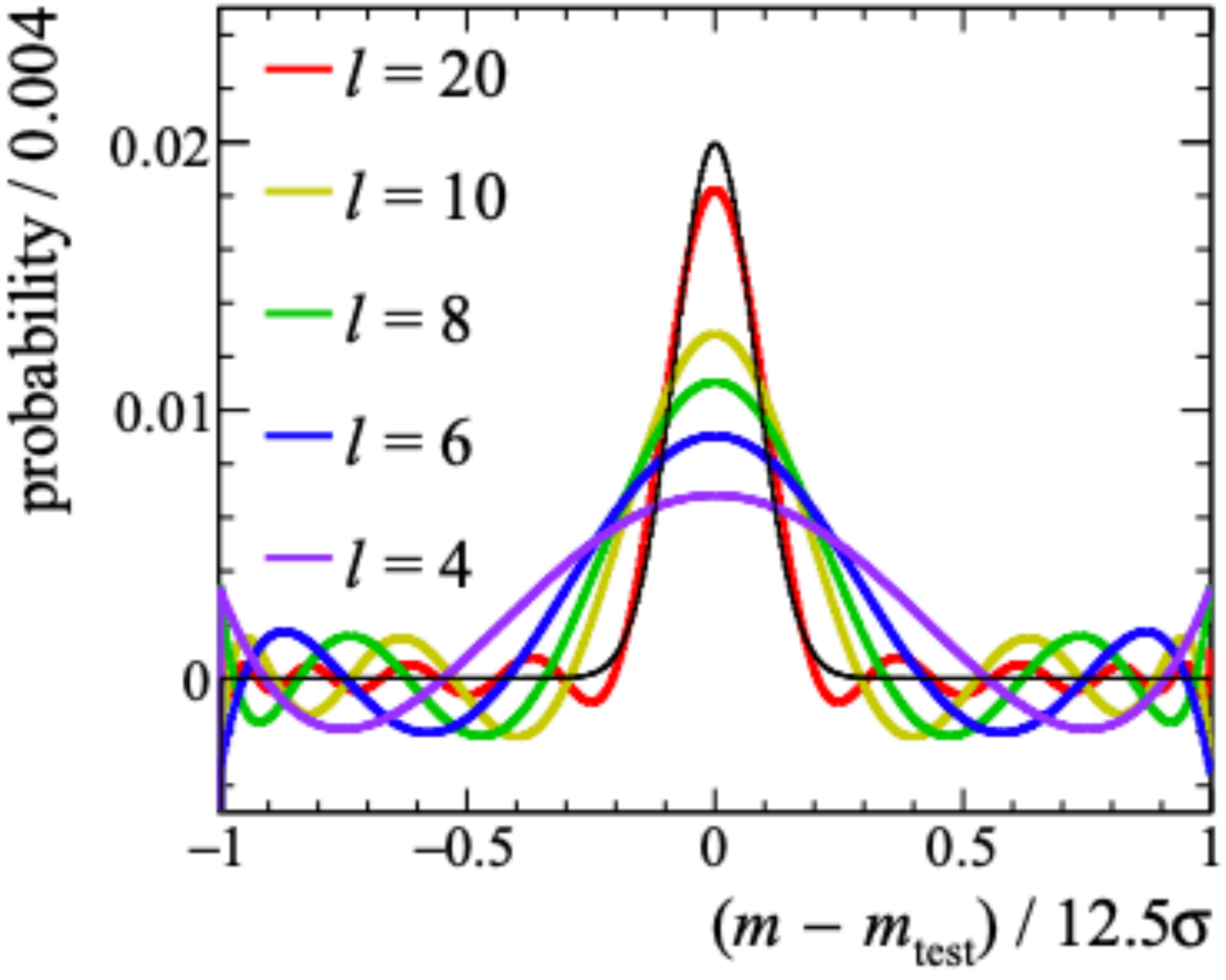




GEANT predictions within uncertainty for η in measured data

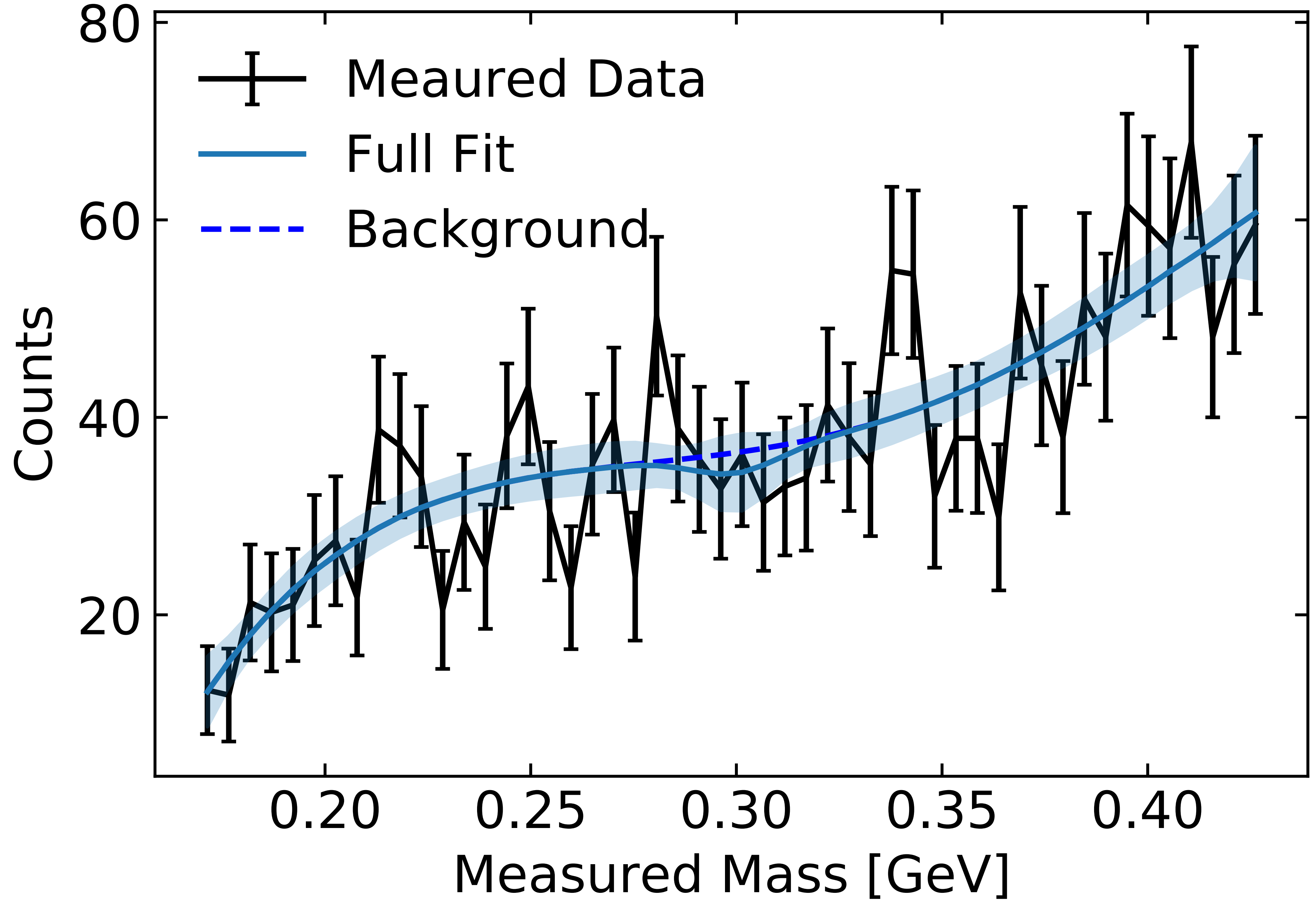
Background model: Polynomial fit

- Need a background model which **can't** compete with relatively sharp signal
- Also need to pick a fit window large enough to include background-only regions
- Good combination: $25\sigma_{mass}$ window, $l = 5$ polynomial background
- This enforces a smooth background that can't compete with signal peak

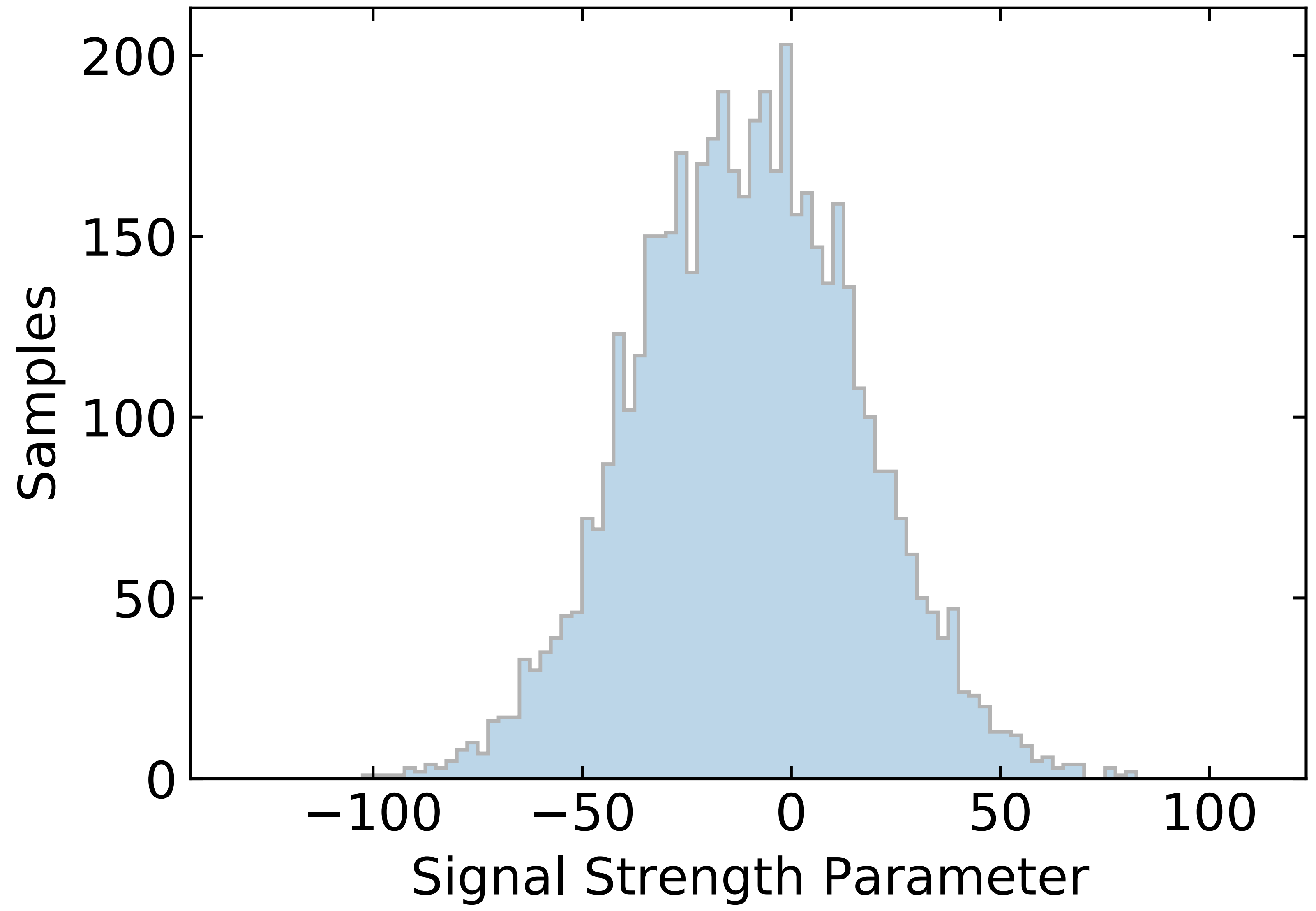


Bump hunting procedure

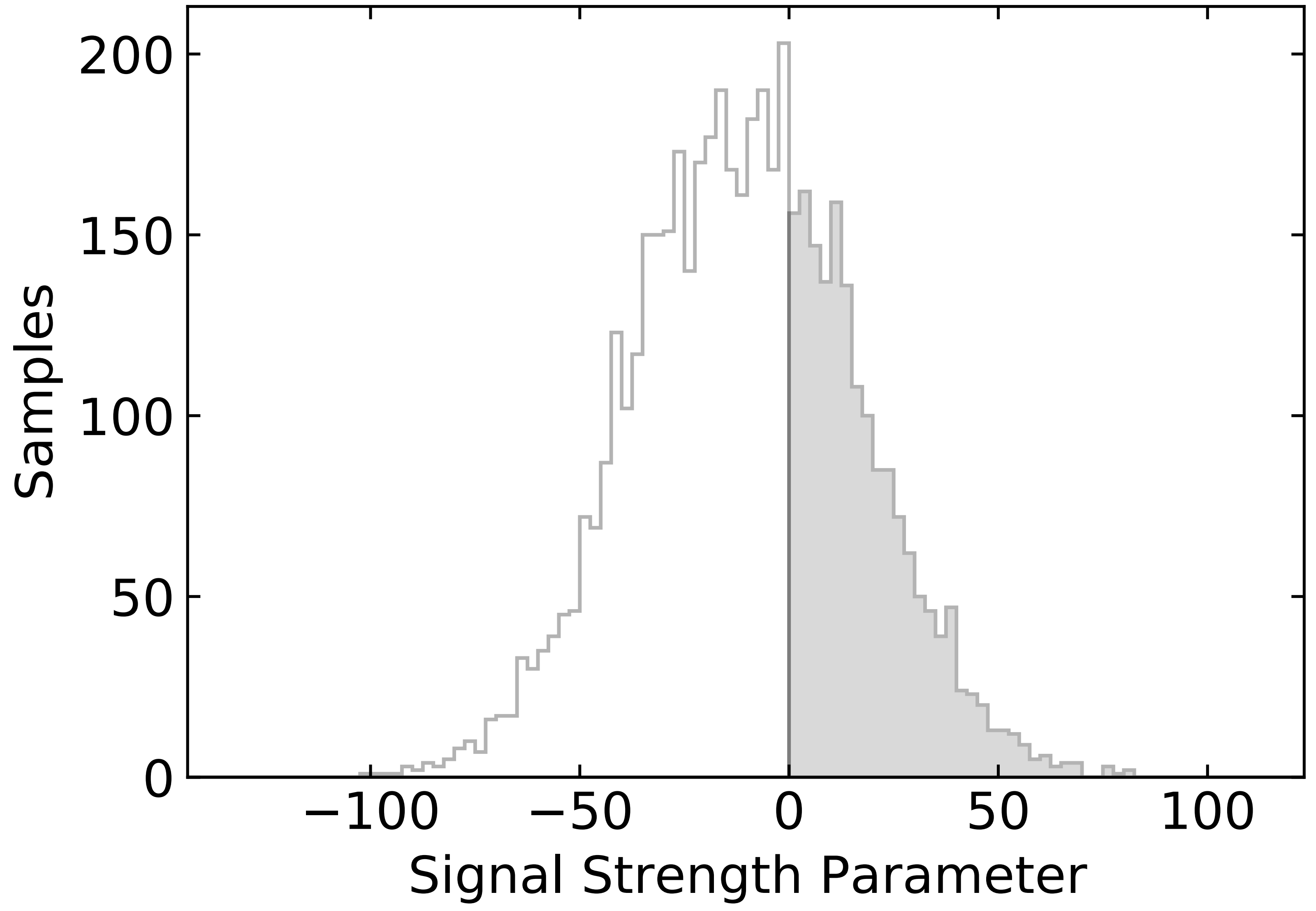
- Pick a **fixed** m_{ALP} hypothesis with known resolution
- Pick fit window $25\sigma_{mass}$ wide around the hypothesis mass
- Fit the data in this window with model of background + signal; **strength** of signal can vary
- Look at probability distribution on signal strength parameter
  - Bayesian approach; nuisance parameters are *marginalized* (integrated over)

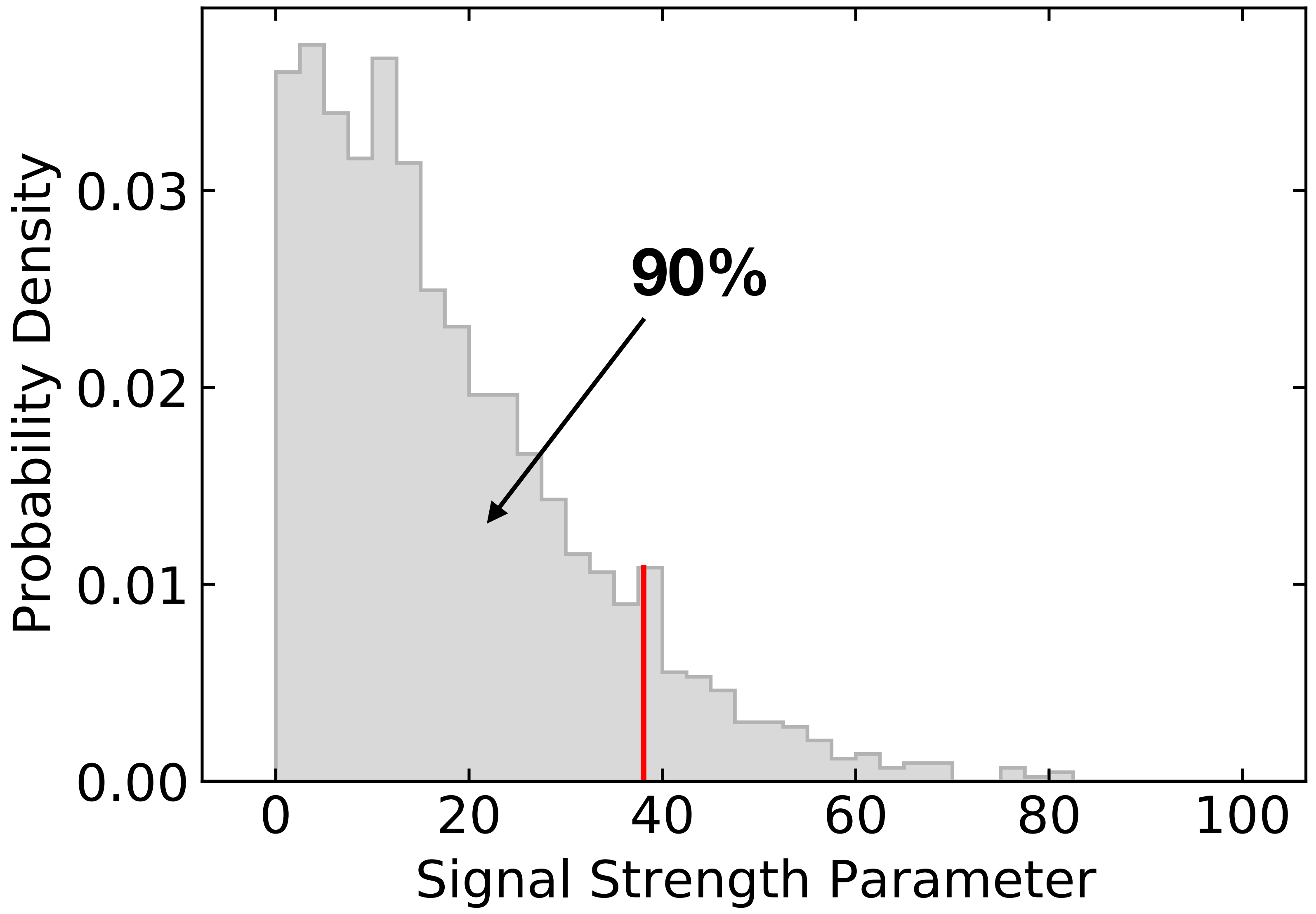


Limit extraction (Bayesian)



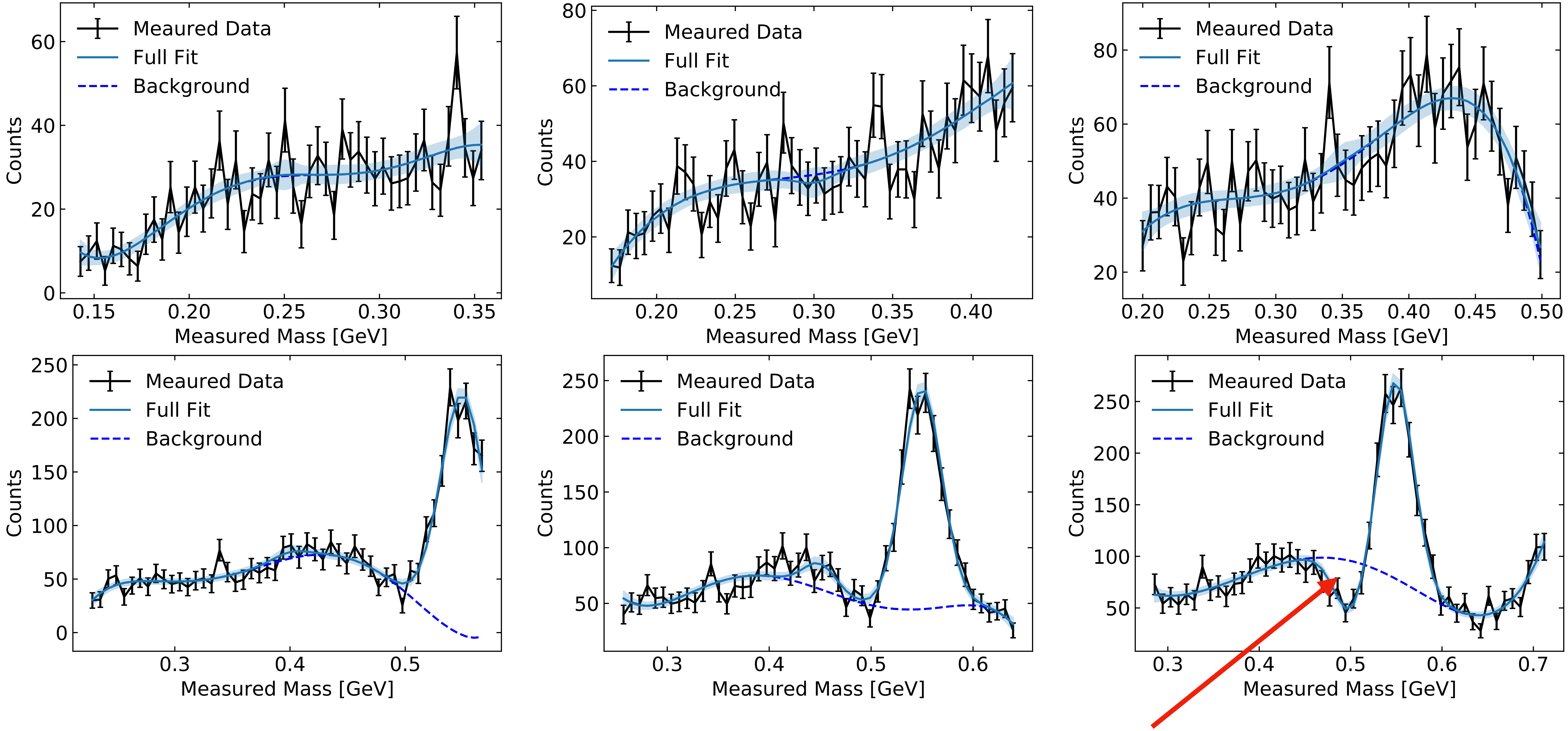
Truncate probability distribution at $\mu > 0$; Negative signal is unphysical





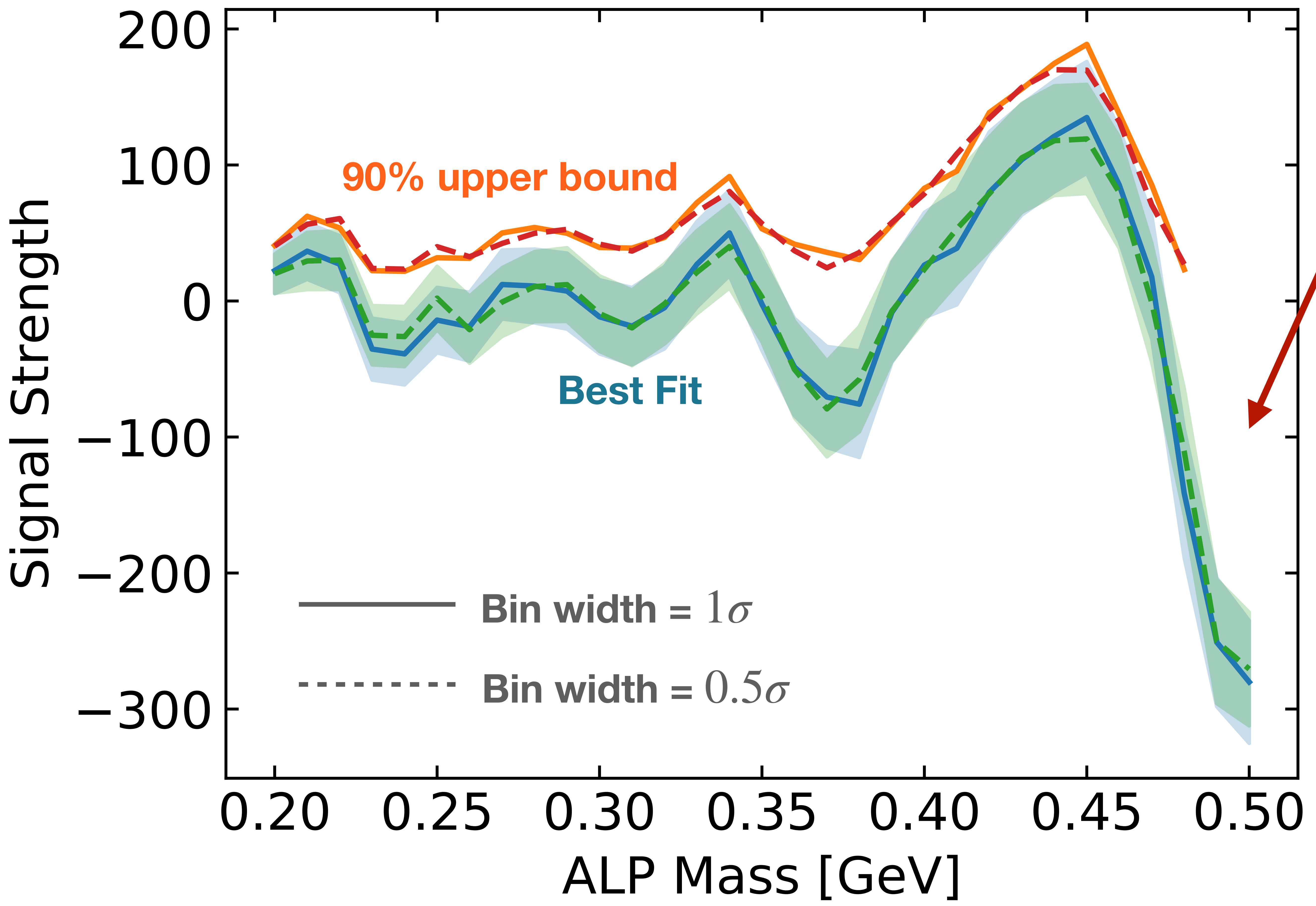
Take 90th-percentile value for μ

Repeat procedure for all mass hypotheses



Nonphysical; fitting peak as a dip

Unnormalized signal strength



Proximity to $m_\eta = 0.55$ GeV peak causes nonphysical fits

Conversion to coupling bound

- Signal strength μ is equal to the fit number of signal events at a given mass m_{ALP}
- Number of signal events is given by the product of the tagged luminosity, the total cross section, and the final event efficiency

$$\mu = L_{int}\sigma_{ALP}\epsilon$$

- The cross section scales as the square of the coupling/cutoff ratio:

$$\sigma_{tot} \propto \left(\frac{c_\gamma}{\Lambda}\right)^2$$

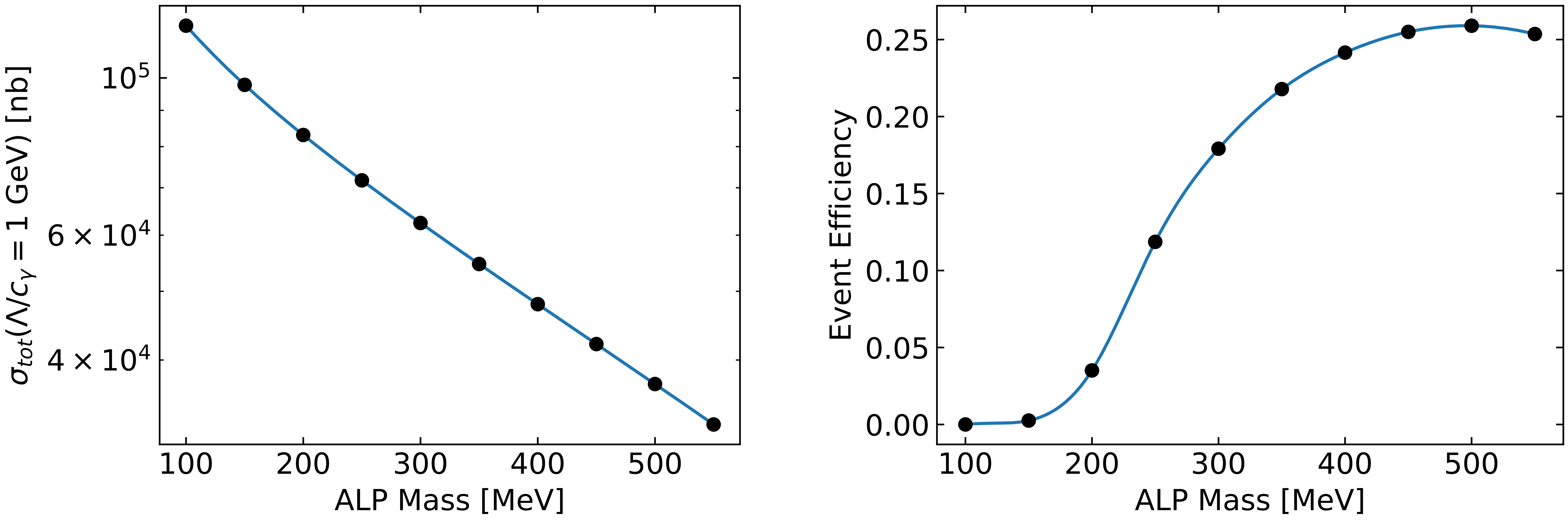
- By taking the cross section at a fixed ratio we can convert the upper limit on the signal strength to the upper limit on the coupling:

$$\left(\frac{c_\gamma}{\Lambda}\right)^2 [\text{GeV}^2] = \frac{\mu}{L_{int}\sigma_{tot,ref}\epsilon}$$

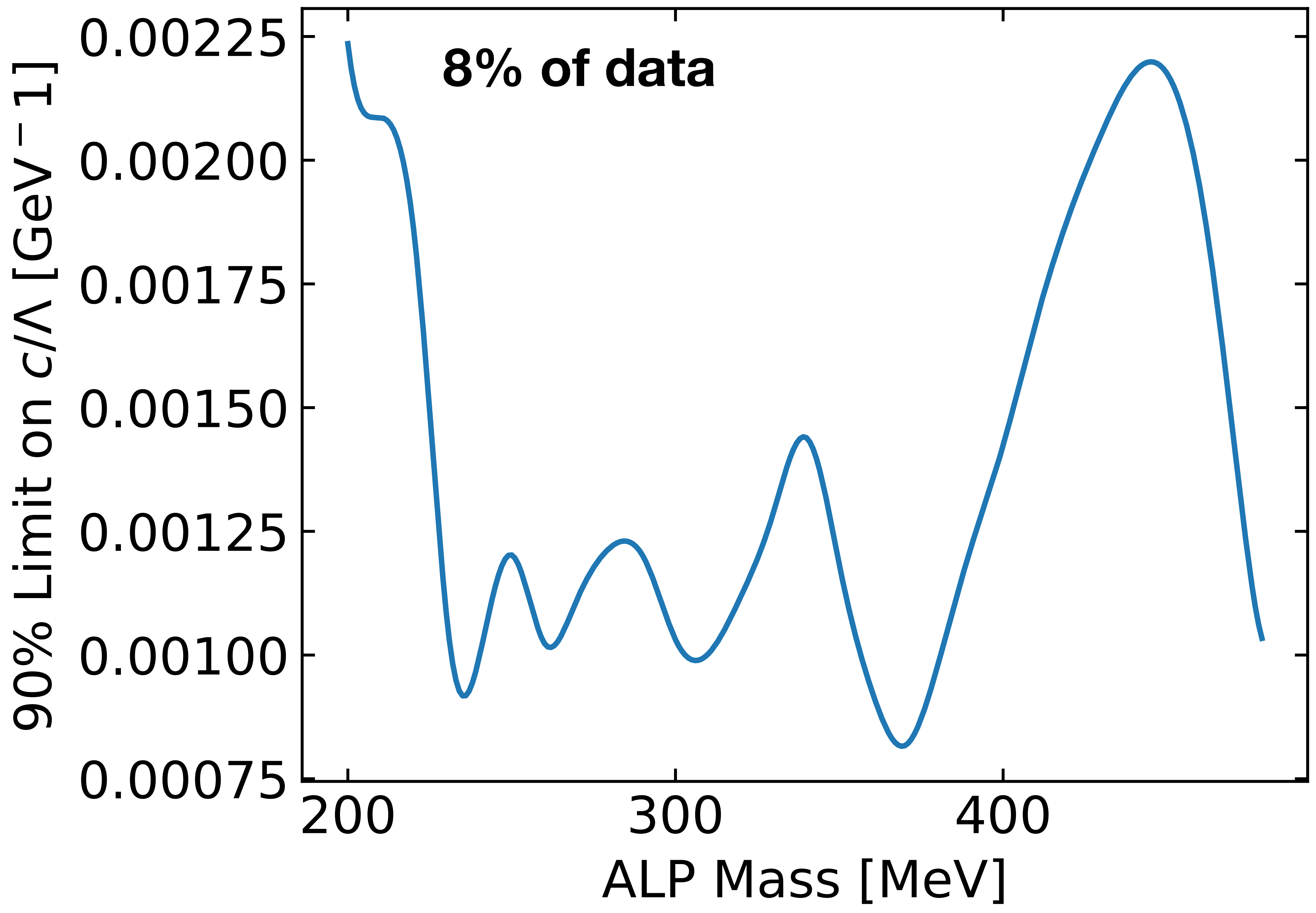
- Luminosity ($E_\gamma > 6$ GeV) scaled from run 90626 to blinded dataset:

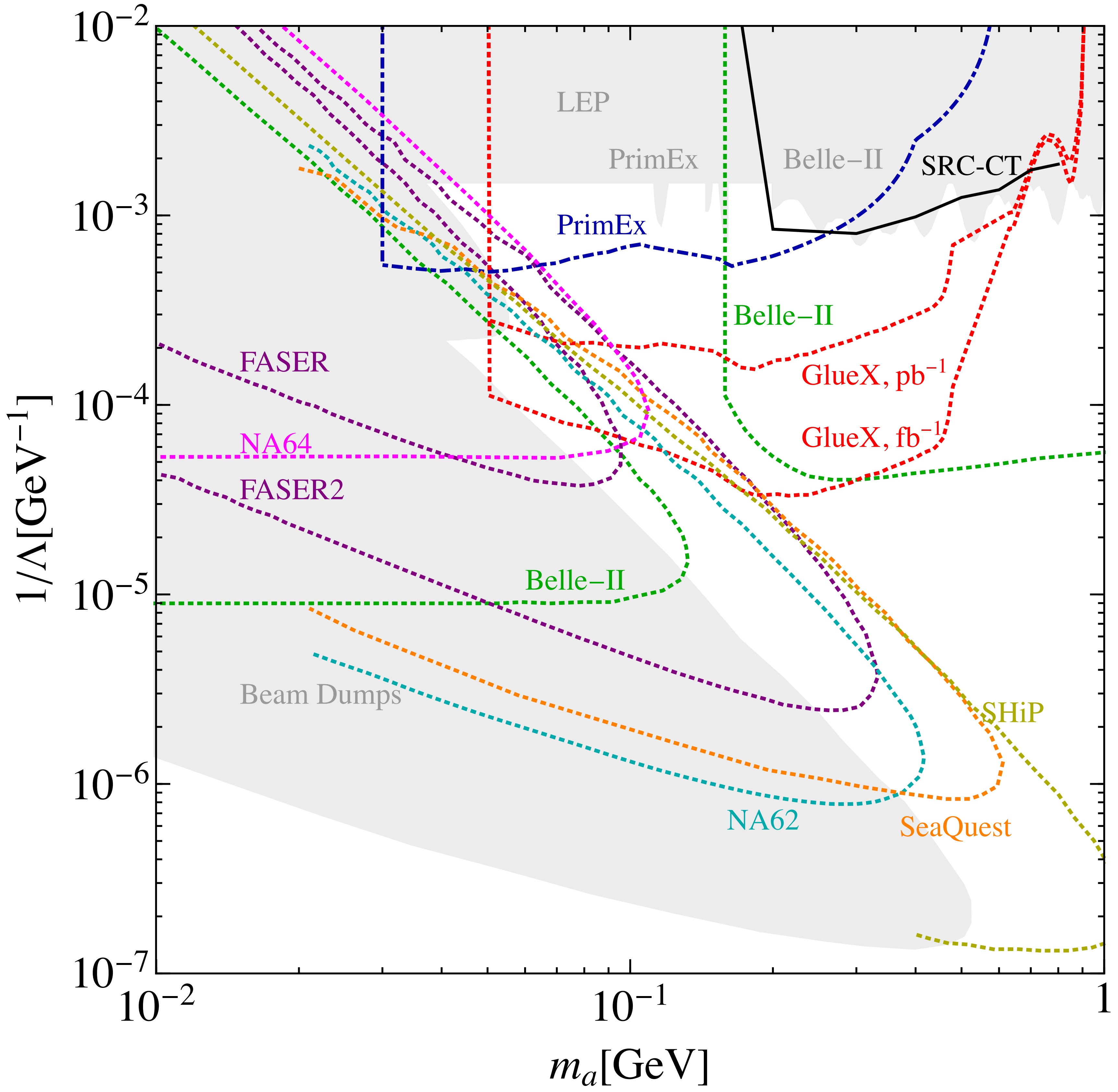
$$L_{int} = \frac{3.2 \times 10^9}{2.7 \times 10^8} \times 291\ \text{nb}^{-1} = 3500\ \text{nb}^{-1}$$

Cross section and efficiency from theory and simulation:



90% CL Limit


8% of data
90% Limit on c/Λ [GeV−1]
0.00225
0.00200
0.00175
0.00150
0.00125
0.00100
0.00075
200
300
400
ALP Mass [MeV]


LEP
PrimEx
Belle−II
SRC-CT
PrimEx
Belle−II
GlueX, pb−1
GlueX, fb−1
FASER
NA64
FASER2
Belle−II
Beam Dumps
SHiP
NA62
SeaQuest
1/Λ[GeV−1]
m_a[GeV]

Cross-check: η normalization

- Extract signal strength of $\mu \approx 1000$
- Corresponds to coupling of $\left(\frac{c_\gamma}{\Lambda}\right)^2 = 3.5 \times 10^{-5}$
- This gives a decay width to photons of $\Gamma_{\eta\to\gamma\gamma} = 0.03$ keV
- **But the known value is $\Gamma_{\eta\to\gamma\gamma} = 1.31$ keV**

Normalizing to η gives a different 90% bound