ALPs @ GeV scale & their photoproduction

1st Workshop on New Light Physics and Photon-beam Experiments

DA, Yotam Soreq, Mike Williams, arXiv: 1811.03474, PRL 123
Cristiano Fanelli, same people, arXiv: 1903.03586, PRL 123

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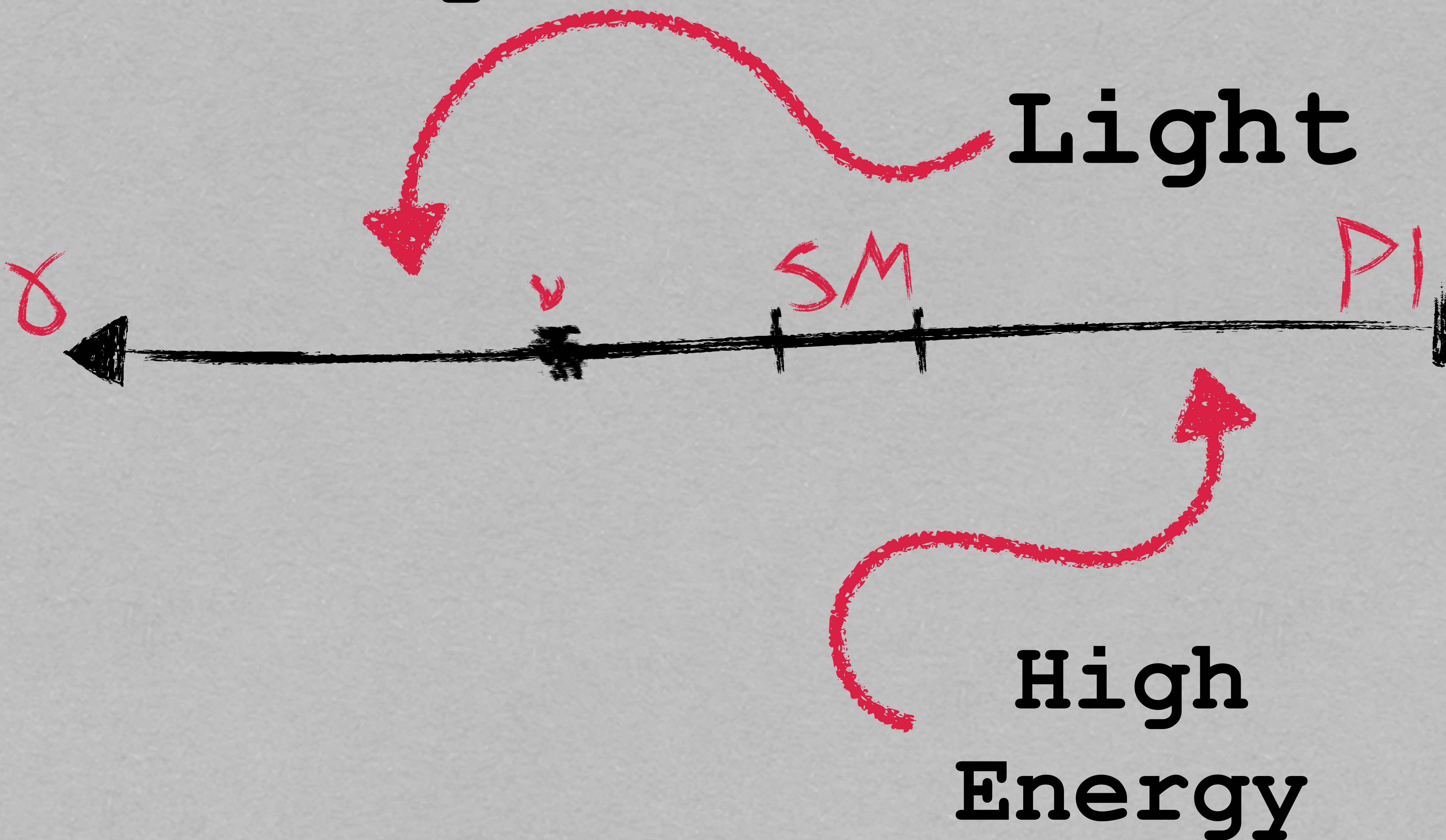
Why photon-beam experiments?



ALPs = axion like particles

- PNGB → All interactions are suppressed by some cutoff Λ >> m_a.

- We focused on

$$\mathcal{L}_{eff.} = -\frac{4\pi\alpha_s}{\Lambda} c_g a G\tilde{G} + \frac{1}{4\Lambda} c_\gamma a F\tilde{F}$$

with $c_g = 1, c_\gamma = 0$ or $c_g = 0, c_\gamma = 1$

& $0.1\,\mathrm{GeV} \lesssim m_a \lesssim 3\,\mathrm{GeV}$.

- Why are we interested in that?

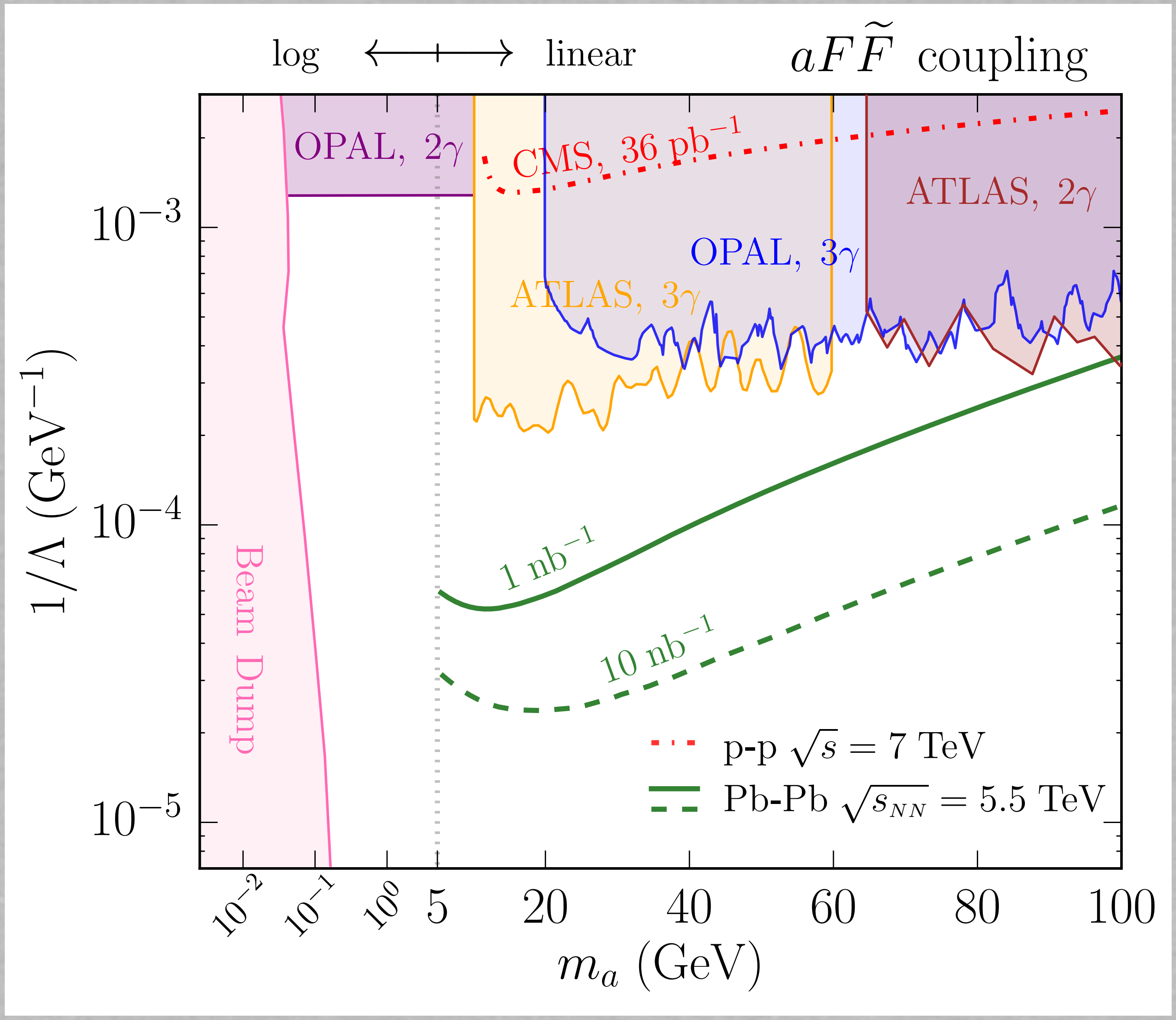
Motivation A:

- ALPs are generic in many BSM scenarios.
- We have great experiments which can look precisely for that.
- If we can → We should!

Motivation B:

$c_g = 0, c_\gamma = 1$

- This is a blind spot of experiments

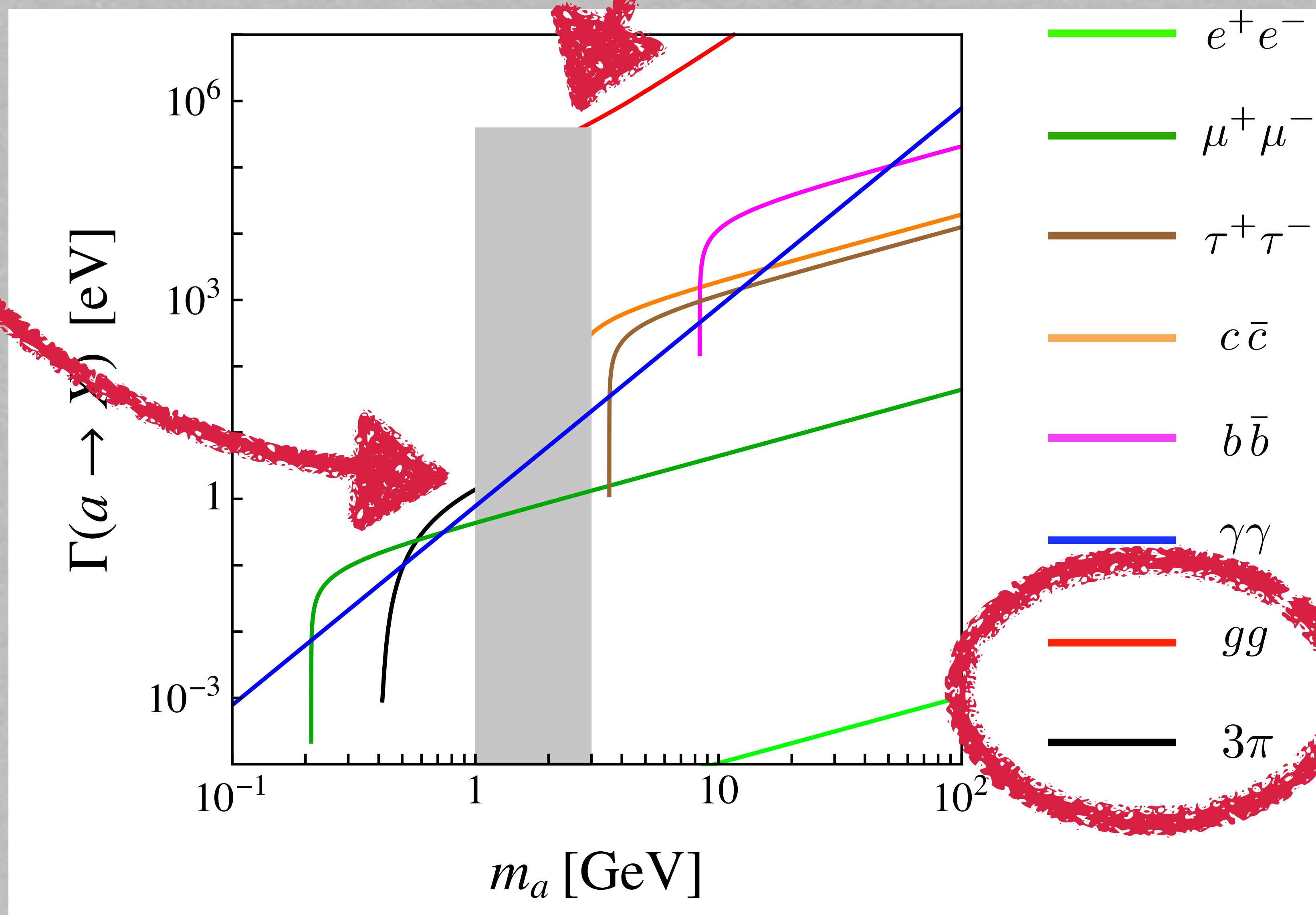


Knapen, Lin, Lou, Melia 1607.06083

Motivation C:

$c_g = 1,\ c_\gamma = 0$

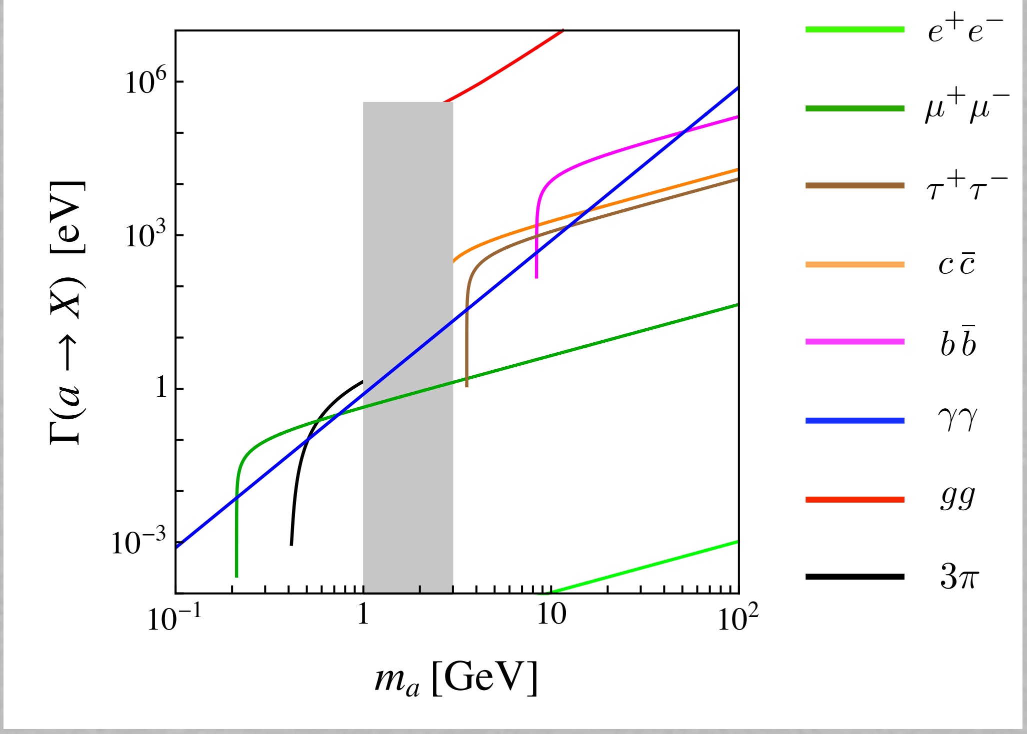
- This is a blind spot of theory



Bauer, Neubert, Thamm 1708.00443

Motivation C:

- $$\frac{\Gamma_{a\to gg}(m_a = 2\,\mathrm{GeV})}{\Gamma_{a\to 3\pi}(m_a = 0.5\,\mathrm{GeV})} = \mathcal{O}(10^5)$$



Bauer et.al, 1708.00443

- This is puzzling!

- Although $a\to gg$ is well known, what are the exclusive final states?

Coupling QCD-Scale ALPs to Gluons

1811.03474, PRL 123 (2019) 3, 031803

DA, Yotam Soreq, Mike Williams

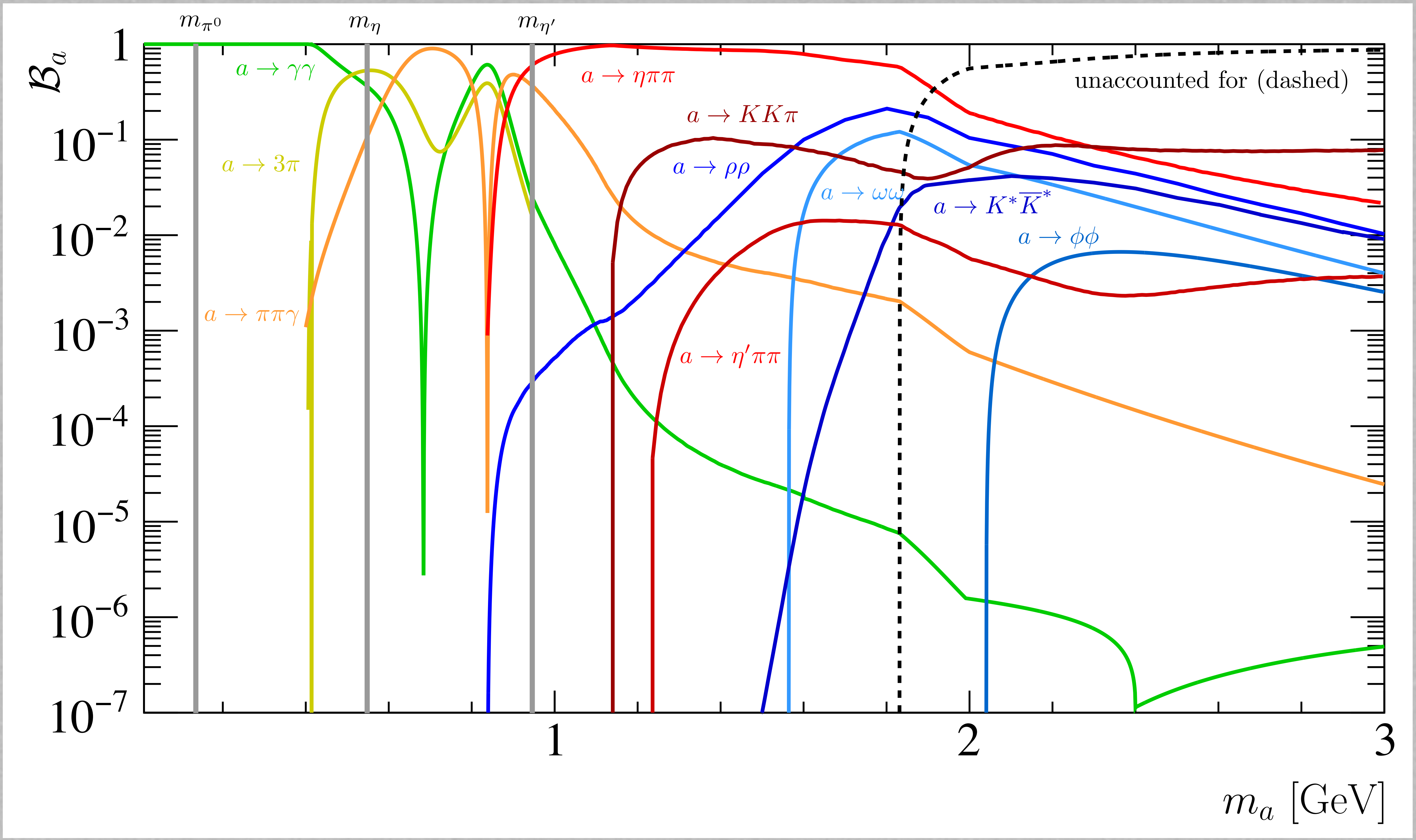
ALPs to hadrons

- Interaction eigenstate $\neq$ Mass eigenstate.
- Using U(3) flavor symmetry one can calculate the ALP-PS mixing

$$\langle a\pi \rangle\,,\ \langle a\eta \rangle\,,\ \langle a\eta' \rangle\ .$$

- Using crossing-symmetry and a data driven method we developed a machinery to calculate the ALP decay rates to hadrons.

Some results



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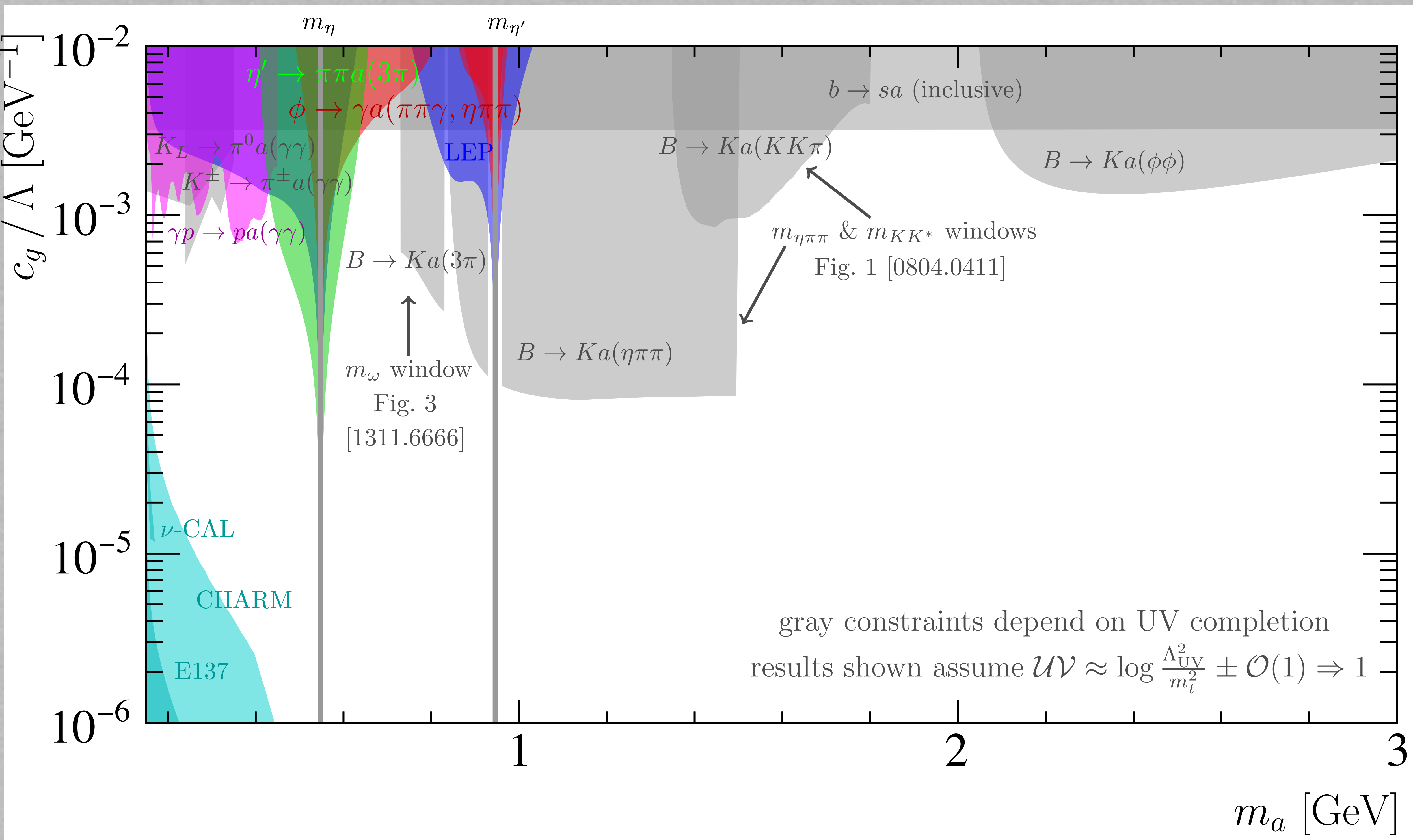
Results



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Photoproduction of Axion-like particles

1903.03586, PRL 123 (2019) 7, 071801

DA, Cristiano Fanelli, Yotam Soreq, Mike Williams

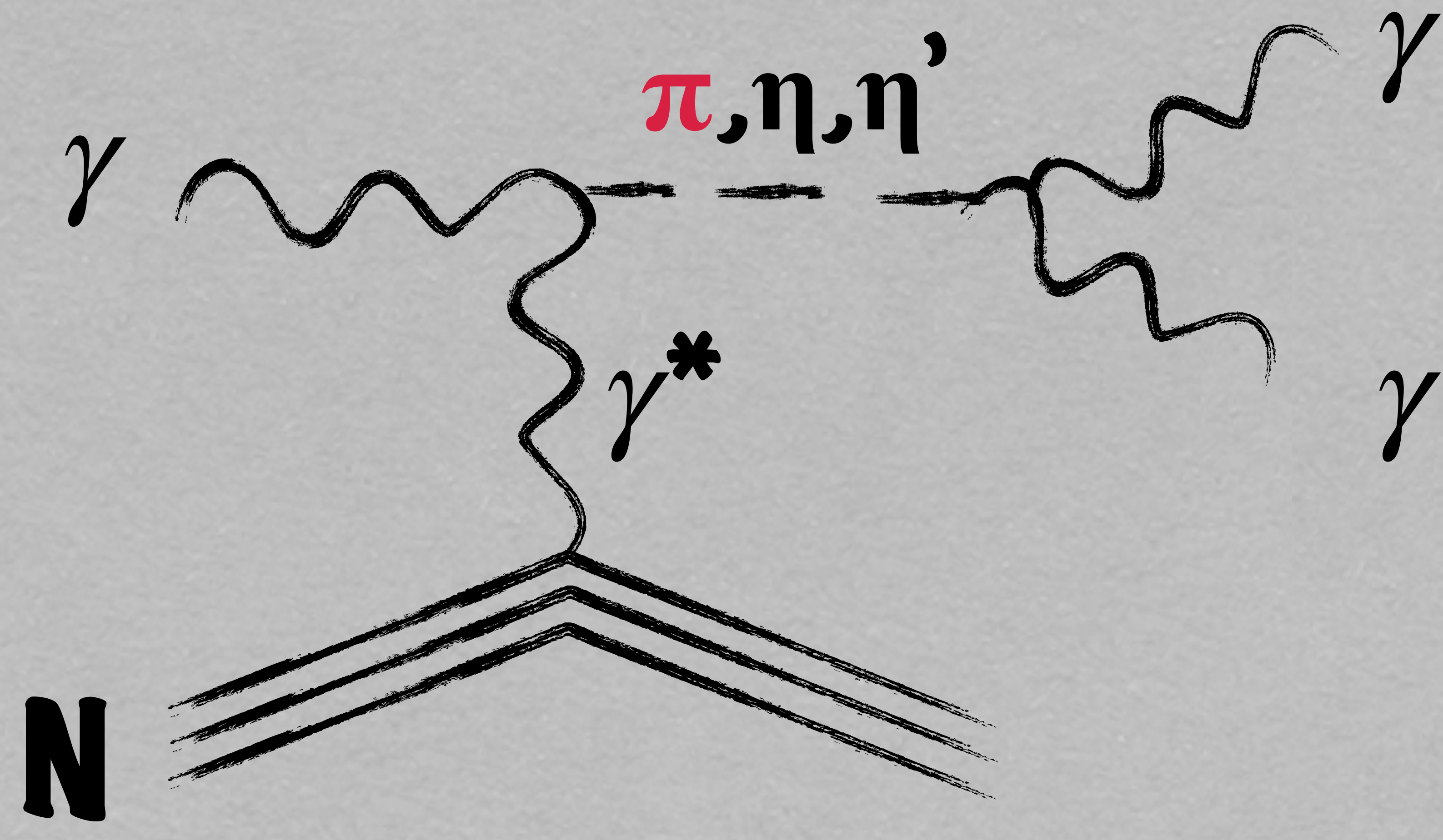
Photoproduction of ALPs

JLAB photon-beam on fixed target experiments:

- (old ~ 2004) PrimEx — 5.2 GeV γ @ Lab frame.
- (currently) GlueX — 8.5-11.1 GeV γ @ Lab frame.

PrimEx

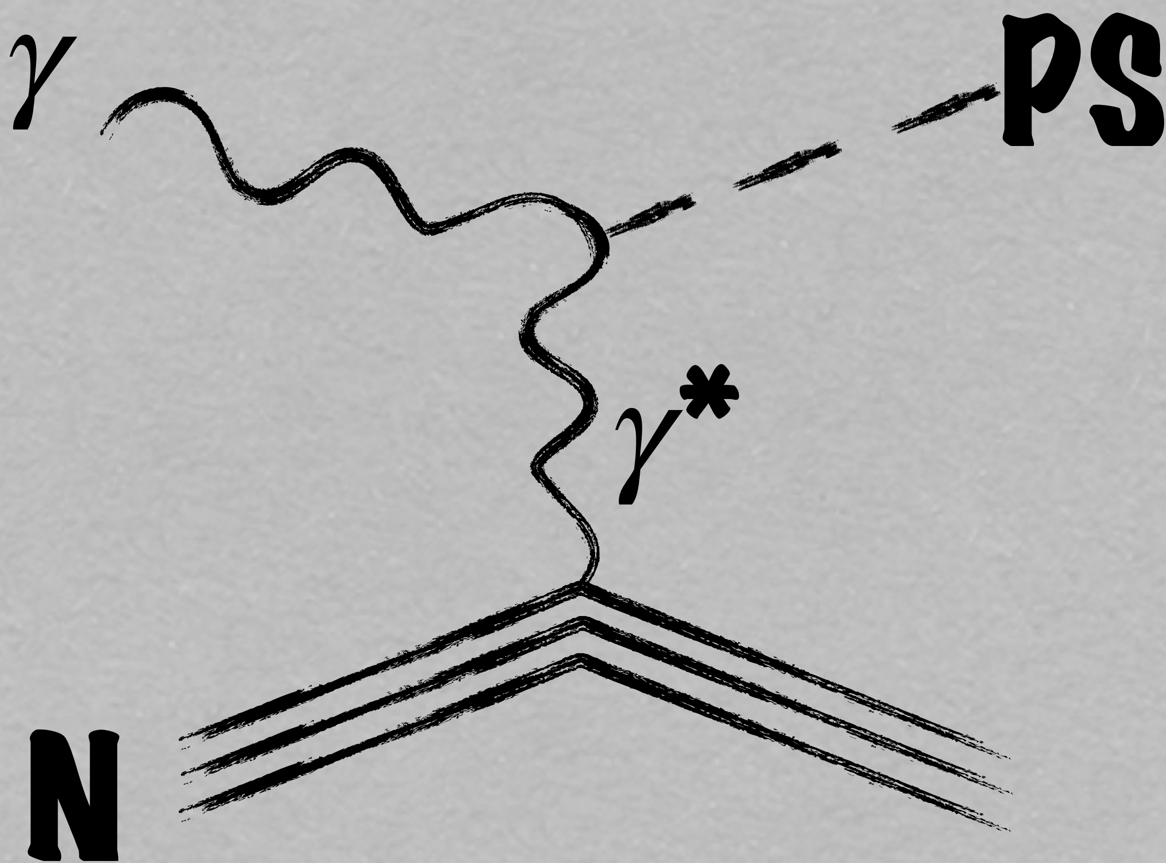
- Measurement of f_π via Primakoff production

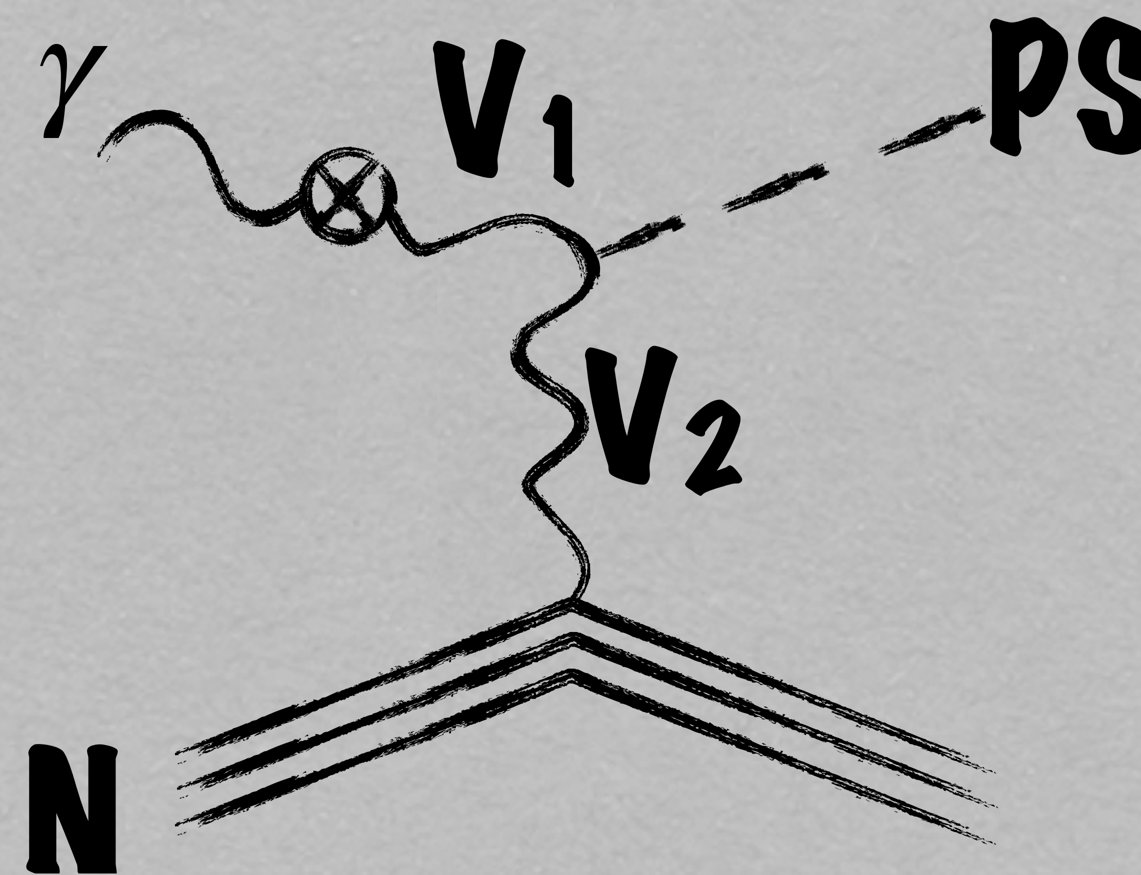


- Our proposal => Bump hunter $a \to \gamma\gamma$.

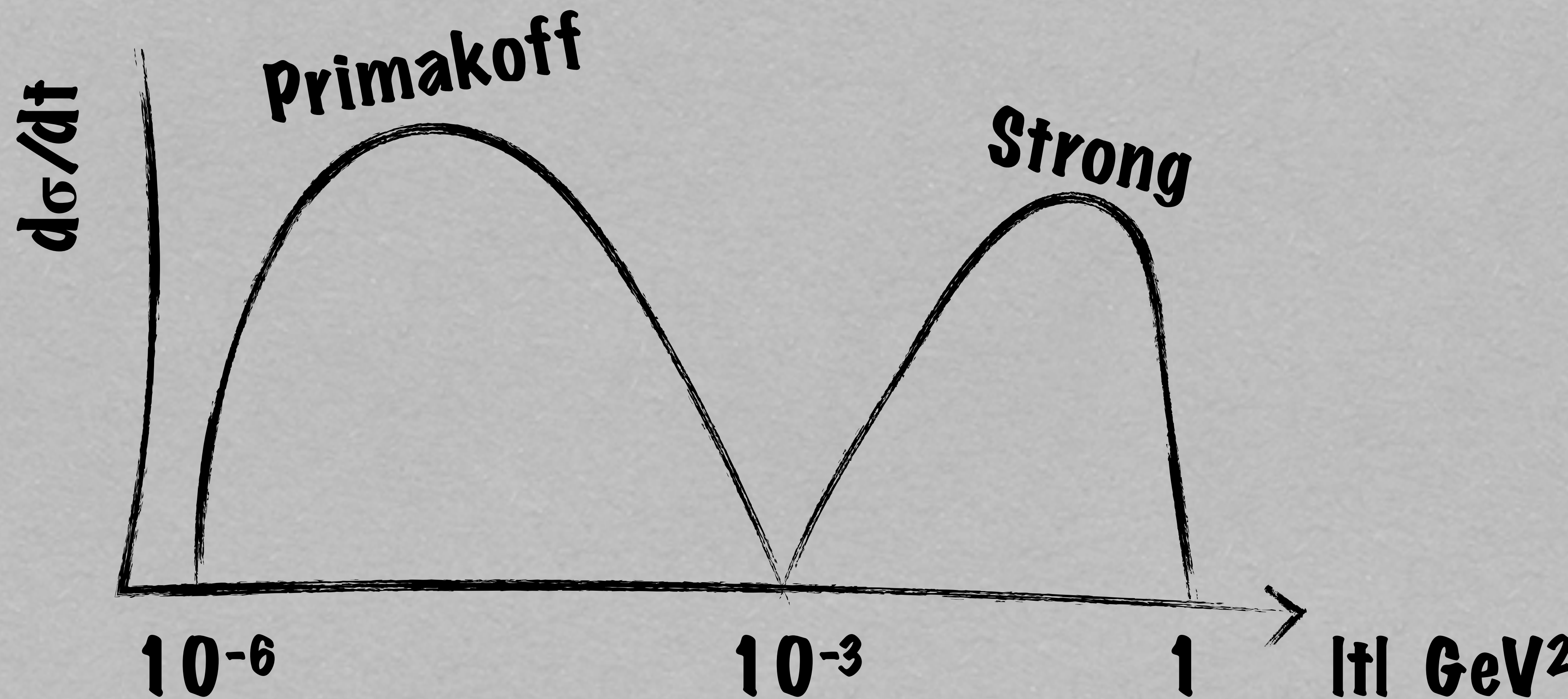
Production

Primakoff vs. Strong





Production
Primakoff vs. Strong



- Can be distinguished using differential cross-section.

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Case I: $c_\gamma=1$, $c_g=0$

- Theoretically the Nuclear Form-Factor (FF) is messy.

- To make long story short: The larger m_N the better - coherent scattering.

Case I: $c_\gamma=1$, $c_g=0$

- Main result - Forward direction:

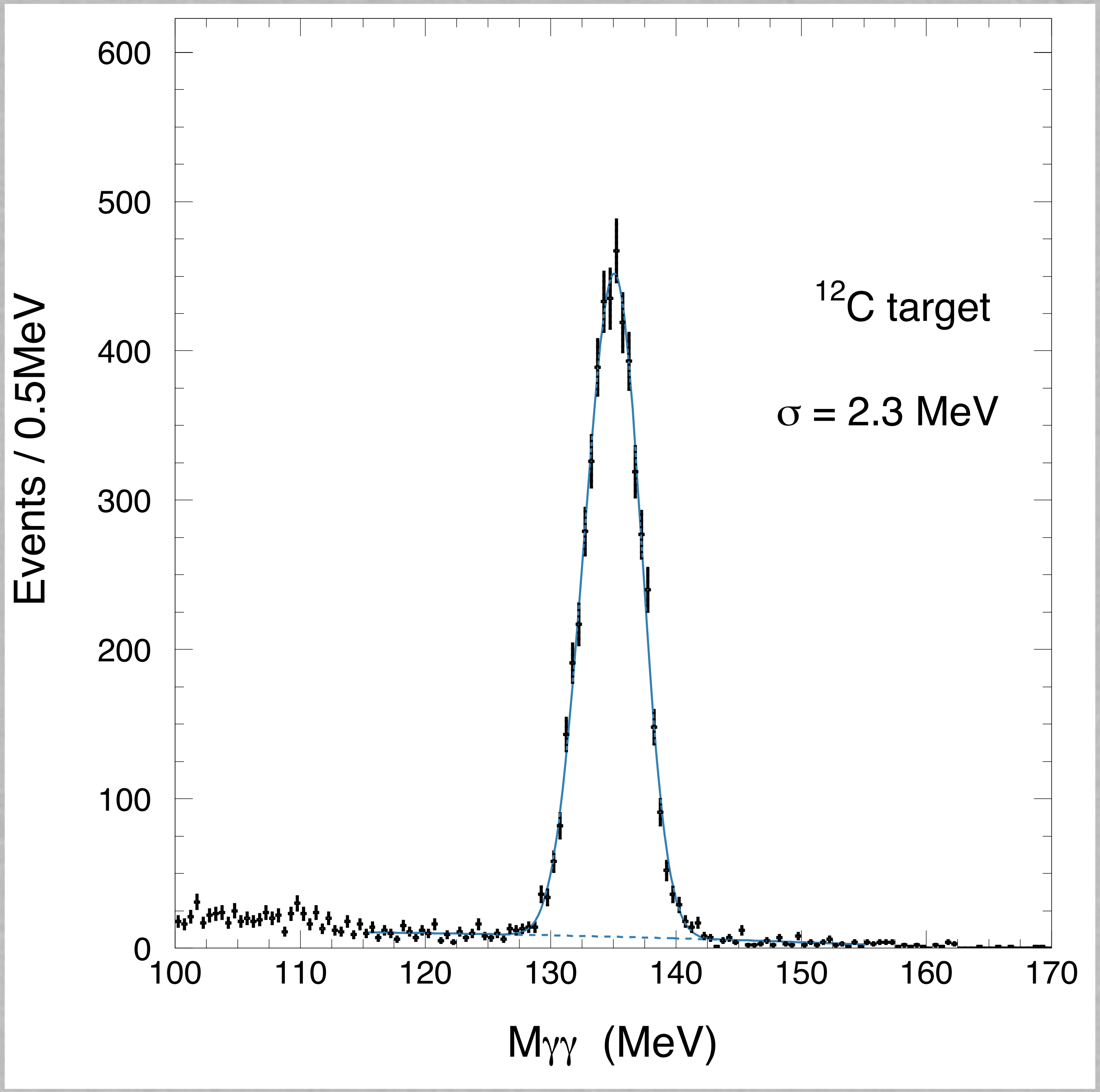
$$\frac{d\sigma^{Elastic}_{\gamma N\to aN}}{dt} = \frac{\Gamma_{a\to\gamma\gamma}}{\Gamma_{P\to\gamma\gamma}} \cdot \frac{H_N(m_a, m_N, s, t)}{H_N(m_P, m_N, s, t)} \cdot \frac{d\sigma^{Elastic}_{\gamma N\to PN}}{dt}$$

with **P** = π, η.

- Nuclear FF cancels in the ratio.

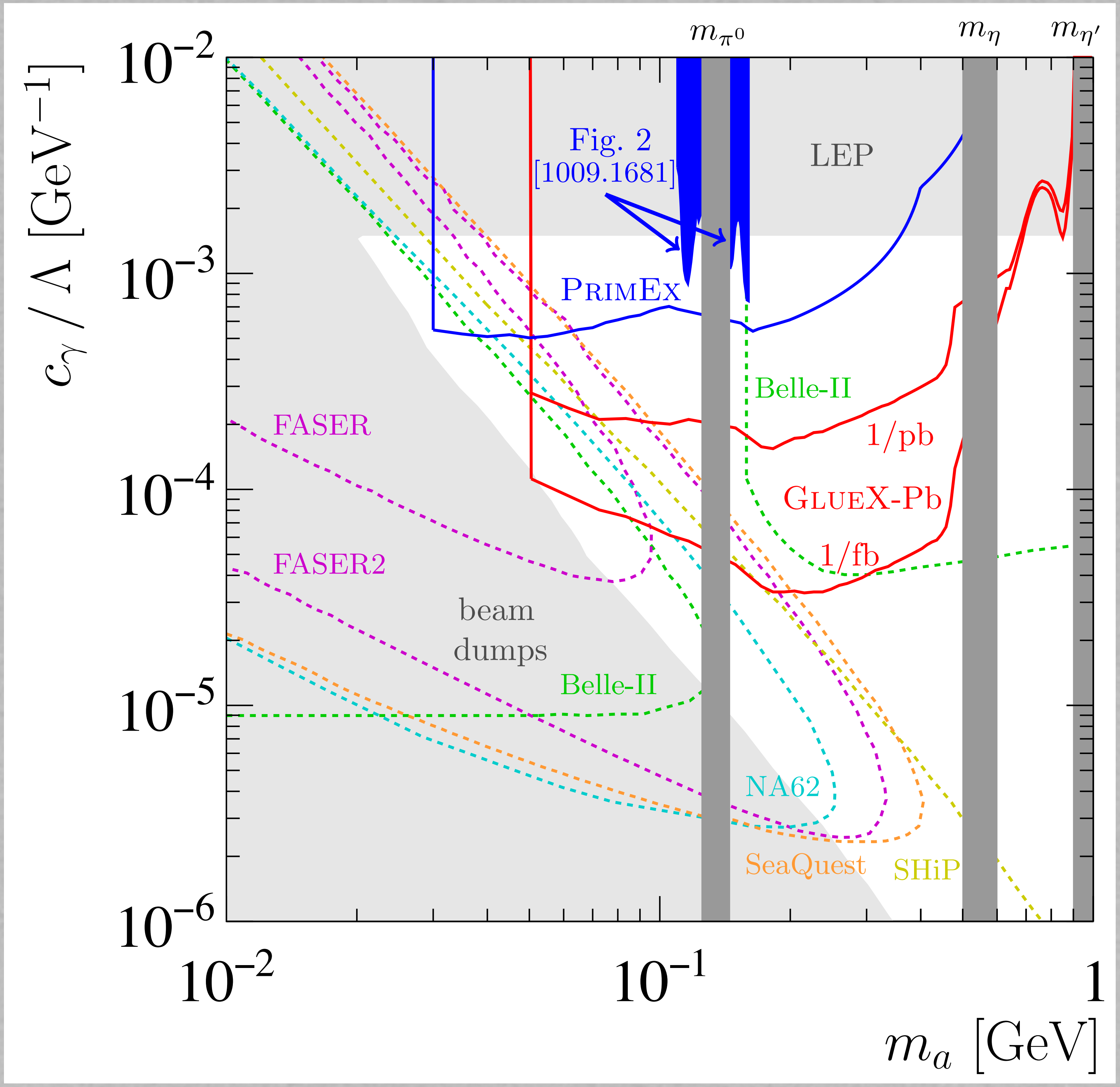
- Photon beam flux, yields, BG - are all data driven.

One bin of PrimEx



PrimEx collaboration 1009.1681

Results



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Case II: $c_\gamma=0$, $c_g=1$

- For $m_\pi \lesssim m_a \lesssim m_\eta$:

$$\frac{d\sigma^{Strong}_{\gamma N\to aN}}{dt} \simeq \left(\frac{f_\pi}{f_a}\right)^2 \left[\left|\langle a\pi\rangle\right|^2 \frac{d\sigma^{Strong}_{\gamma N\to \pi N}}{dt} + \left|\langle a\eta\rangle\right|^2 \frac{d\sigma^{Strong}_{\gamma N\to \eta N}}{dt}\right]$$

- For strong production we need two measurements(roughly speaking **ω** & **ρ** exchange) for a data driven study.

- Those are strong **π** & **η** production.

Case II: $c_\gamma=0$, $c_g=1$

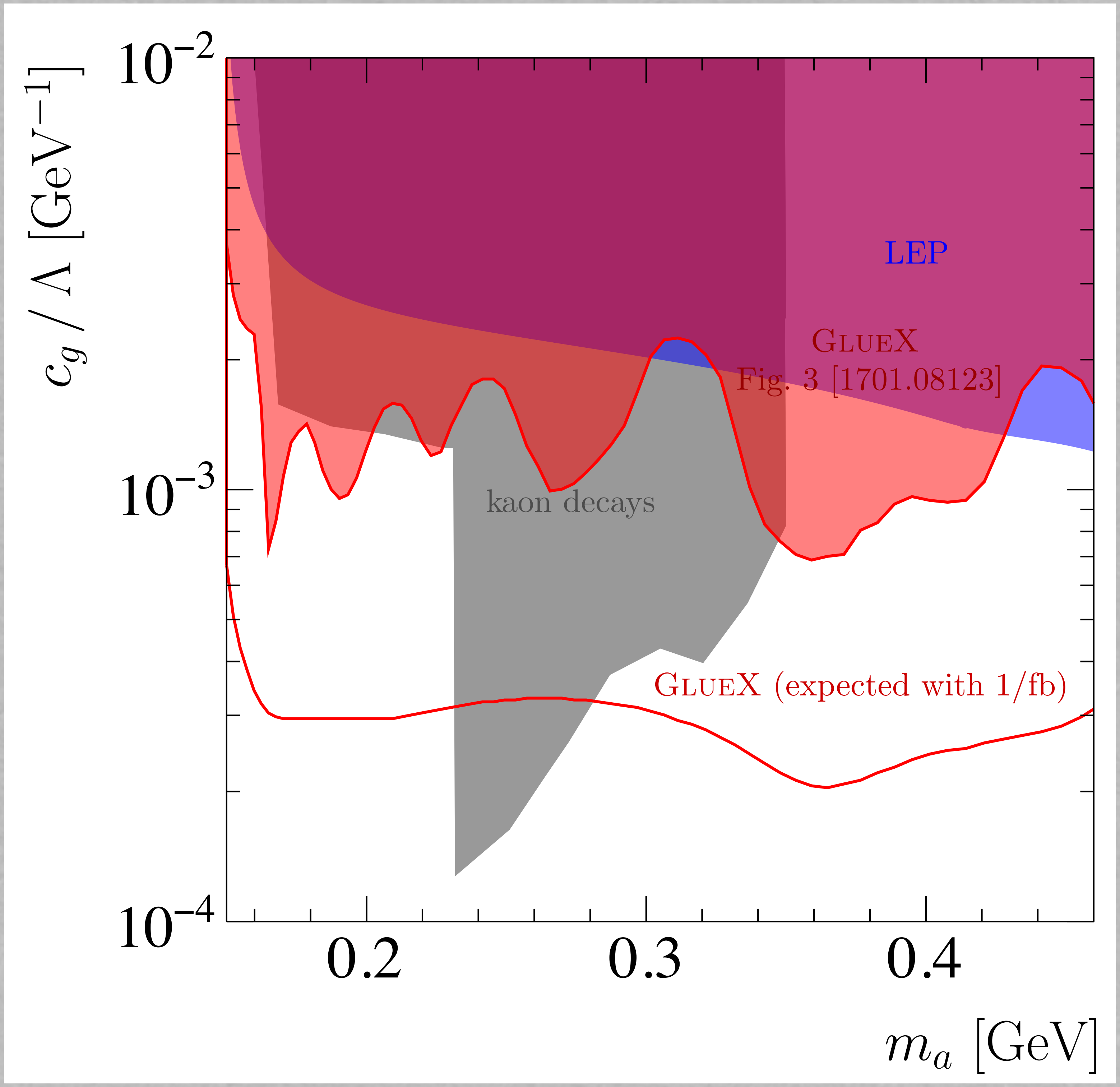
- For $m_\pi \lesssim m_a \lesssim m_\eta$:

$$\frac{d\sigma^{Strong}_{\gamma N\to aN}}{dt} \simeq \left(\frac{f_\pi}{f_a}\right)^2 \left[\left|\langle a\pi\rangle\right|^2 \frac{d\sigma^{Strong}_{\gamma N\to \pi N}}{dt} + \left|\langle a\eta\rangle\right|^2 \frac{d\sigma^{Strong}_{\gamma N\to \eta N}}{dt}\right]$$

- We neglect interference. We gain more in the experimental error than lose in the theoretical error.

- For strong production BG &signal scale the same (incoherent). Proton target is preferred.

Results



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Summary - QCD scale ALPS

- A new method to determine hadronic interaction strength with ALPs.
- Data-driven method for ALP photoproduction search at photon-beam experiments.
- World leading limits for ALP-gloun and ALP-photon couplings.
- Huge improvement with full data and dedicated searches.

Thank you!