

New Limits on Couplings of Reactor ALPs at the Kuo-Sheng Reactor Neutrino Laboratory

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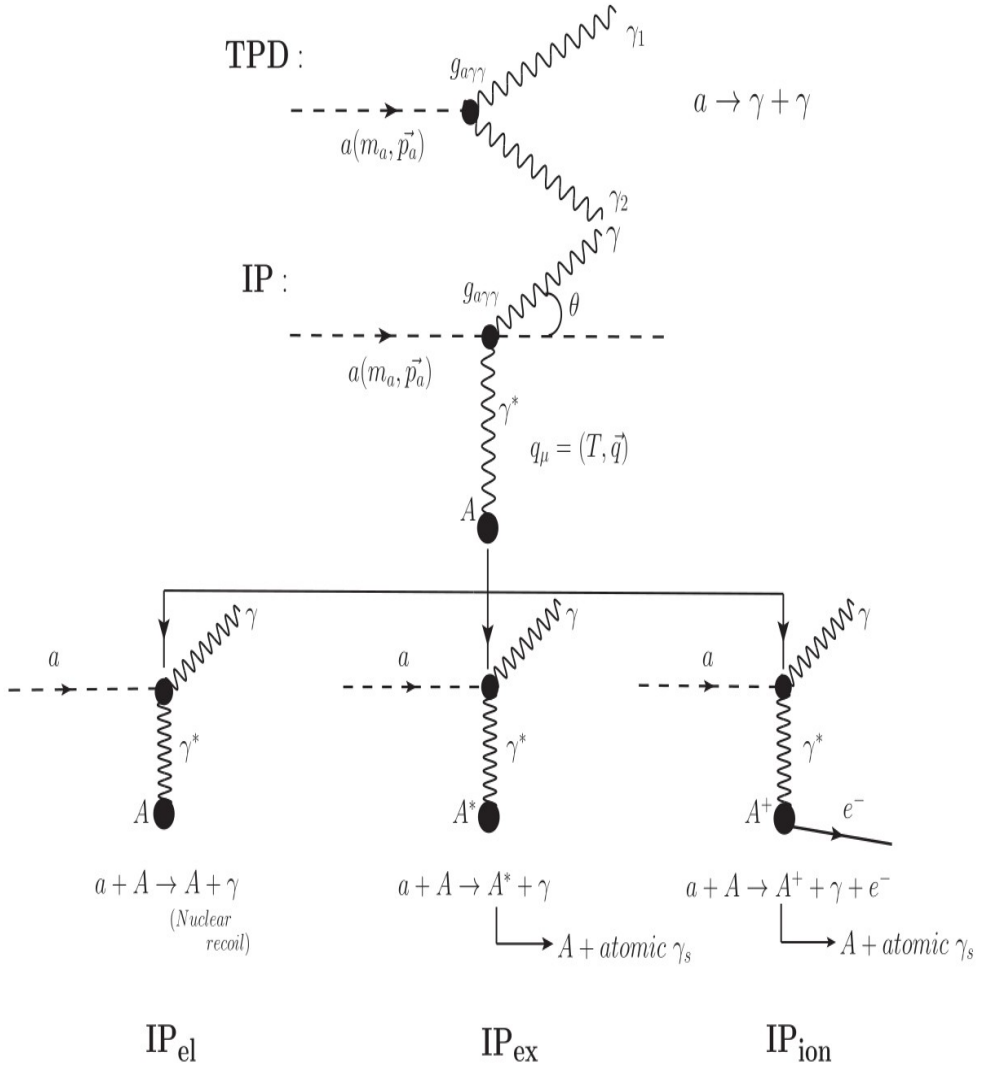
Axions and Axion-Like Particles

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- ➔ Axions were proposed by Peccei and Quinn in 1977
 - To solve the strong CP problem in QCD
 - QCD Axions
 - Mass and coupling of QCD axions are strictly related to each other
- ➔ **Axion-Like Particles (ALPs)** are a broader class of pseudo-Nambu-Goldstone bosons
 - Appear in various extensions of the Standard Model
 - ALPs do not have to solve the strong-CP problem
 - Their mass and coupling are independent of each other
- ➔ ALPs are studied on various aspects
 - Candidates for dark matter
 - Solar ALPs
 - **ALPs produced at nuclear reactor sites – Reactor ALPs**

Inverse Primakoff (IP) interactions:

$a + A \rightarrow$	$\gamma + A$	IP_{el} : elastic scattering
	$\gamma + A^*$	IP_{ex} : atomic excitation
	$\gamma + A^+ + e^-$	IP_{ion} : atomic ionization



- Studied ALPs as DM candidates and of Solar ALPs
- Identified **new detection channel (IP_{ion})** to probe $g_{a\gamma\gamma}$ for laboratory-based experimental searches.
- IP_{ion} channel has **discovery potential** for the search of ALPs.
- Employed **sophisticated tool (FCA)** for calculating cross-section for many-body systems.

- Nuclear reactors can generate photons having energy up to 10 MeV

Interaction Lagrangian:

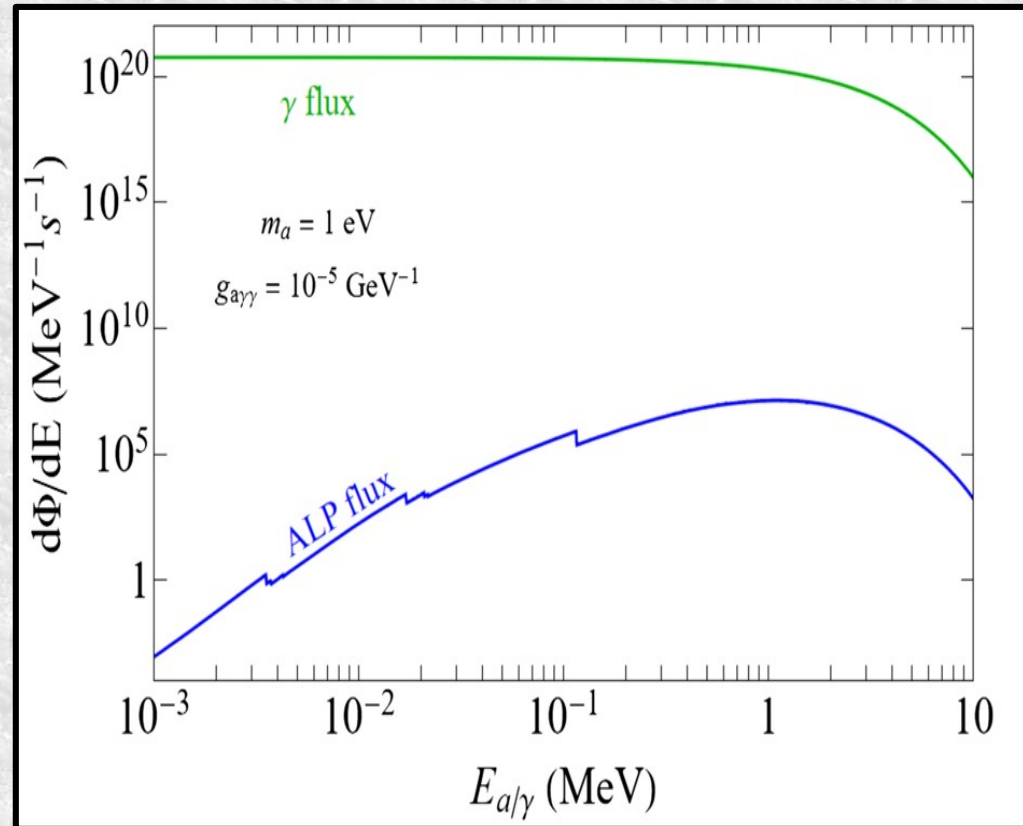
$$\mathcal{L}_I = -\frac{g_{a\gamma\gamma}}{4} a F_{\mu\nu} \tilde{F}^{\mu\nu} - \sum_f \frac{g_{aff}}{2m_f} (\partial_\mu a) \bar{\psi}_f \gamma^\mu \gamma_5 \psi_f$$

- Primakoff process --- via $g_{a\gamma\gamma}$

$$\gamma + N \rightarrow a + N$$

- Compton-like scattering --- via g_{aee}

$$\gamma + e^- \rightarrow a + e^-$$



Detection of Reactor ALPs

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- Inverse Primakoff (IP): $a + \gamma \rightarrow \gamma + a$
 - Two Photon Decay (TPD): $a \rightarrow \gamma + \gamma$
- } $g_{a\gamma\gamma}$

- Inverse Compton-like scattering (IC): $a + e^- \rightarrow \gamma + e^-$
 - Axio-electric Absorption (AE): $a + e^- + Z \rightarrow e^- + Z$
 - Electron-Positron Decay (EPD): $a \rightarrow e^- + e^+$;
Opens only for $m_a > 2m_e$
- } g_{aee}

Total diff. Rate for IP and TPD:

$$\frac{dN_{a\gamma}}{dE_a} = \frac{N_{target}}{4\pi L^2} \sigma_D^P \frac{d\Phi_a^P}{dE_a} + \frac{A}{4\pi L^2} \frac{d\Phi_a^P}{dE_a} P_{decay}$$

A -- Transverse Area of Detector, L -- Reactor to detector distance,
 P_{decay} -- Decay Probability

Experimental Data

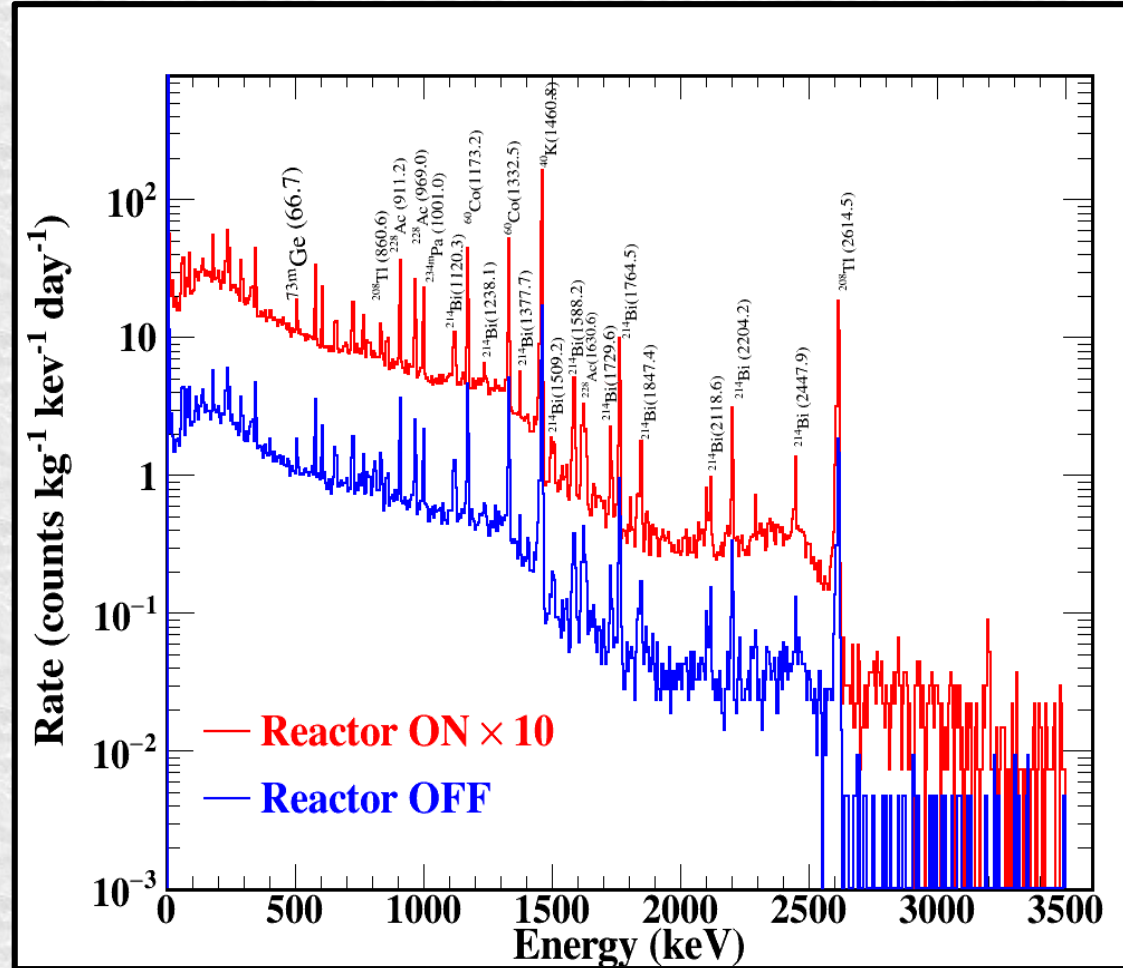
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- ❑ TEXONO collaboration utilizes Ge detectors of different generations
- ❑ Data from a HPGe detector of mass 1.06 kg
- ❑ Reactor to Detector distance = 28 m
- ❑ Reactor Power = 2.9 GW_{th}
- ❑ 278.9/43.6 days of reactor ON/OFF data
- ❑ No significant signal excess observed
- ❑ 90% CL upper limits are derived in:

✓ (m_a , $g_{a\gamma\gamma}$)

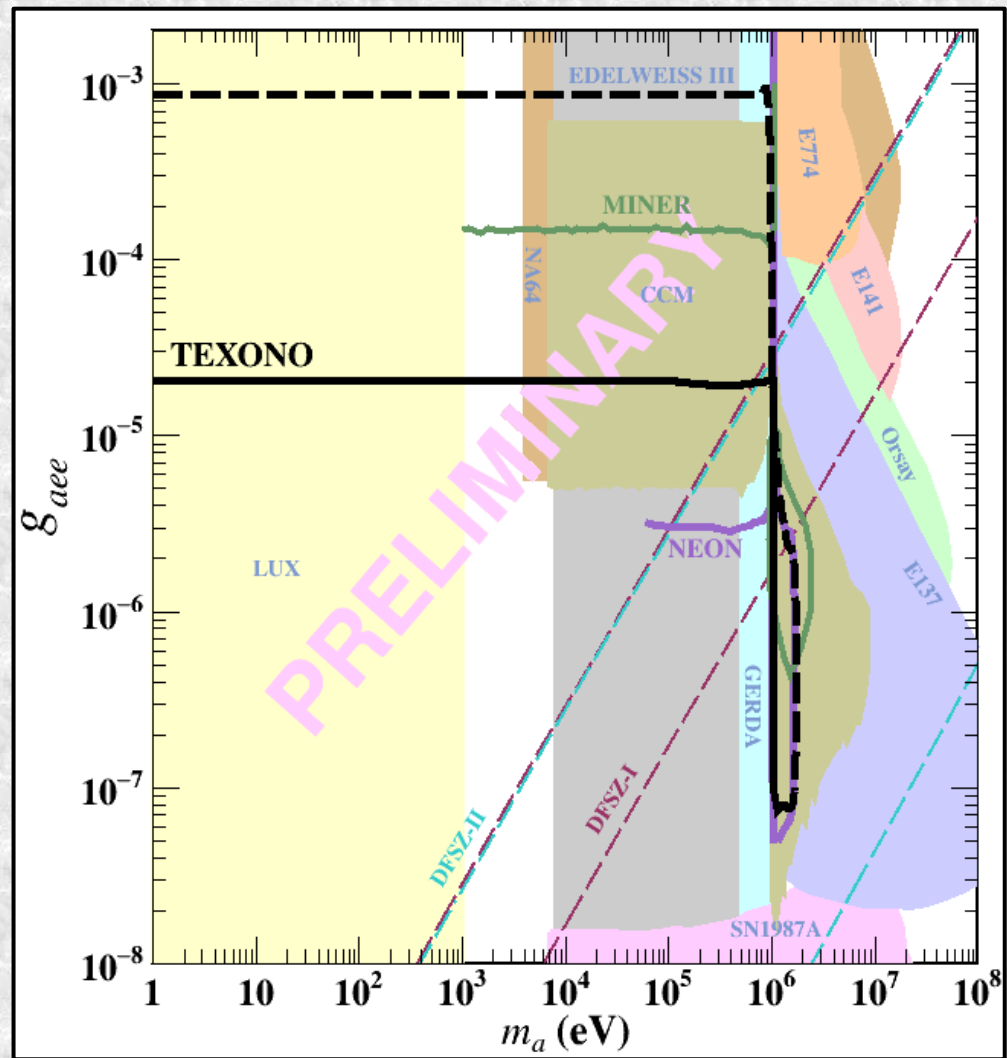
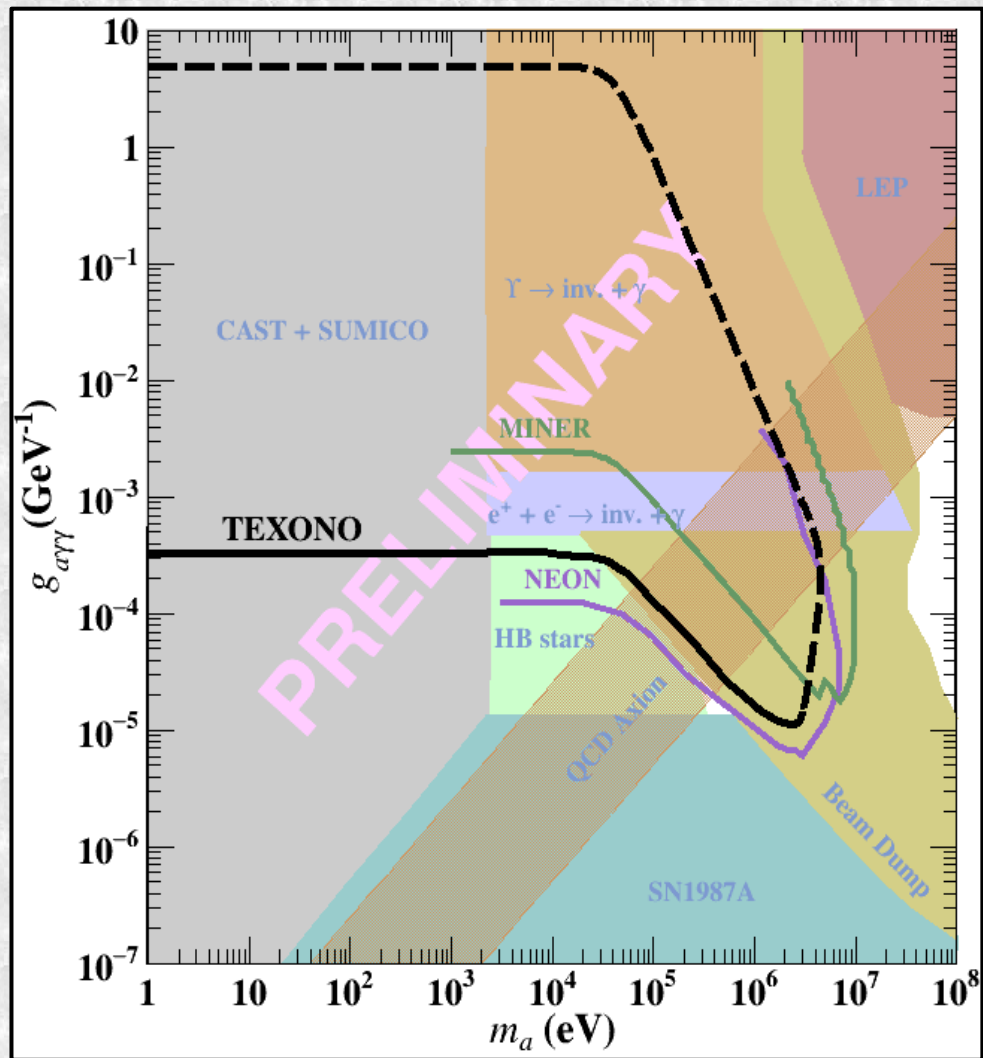
✓ (m_a , g_{aee})

✓ (g_{aee} , $g_{a\gamma\gamma}$)

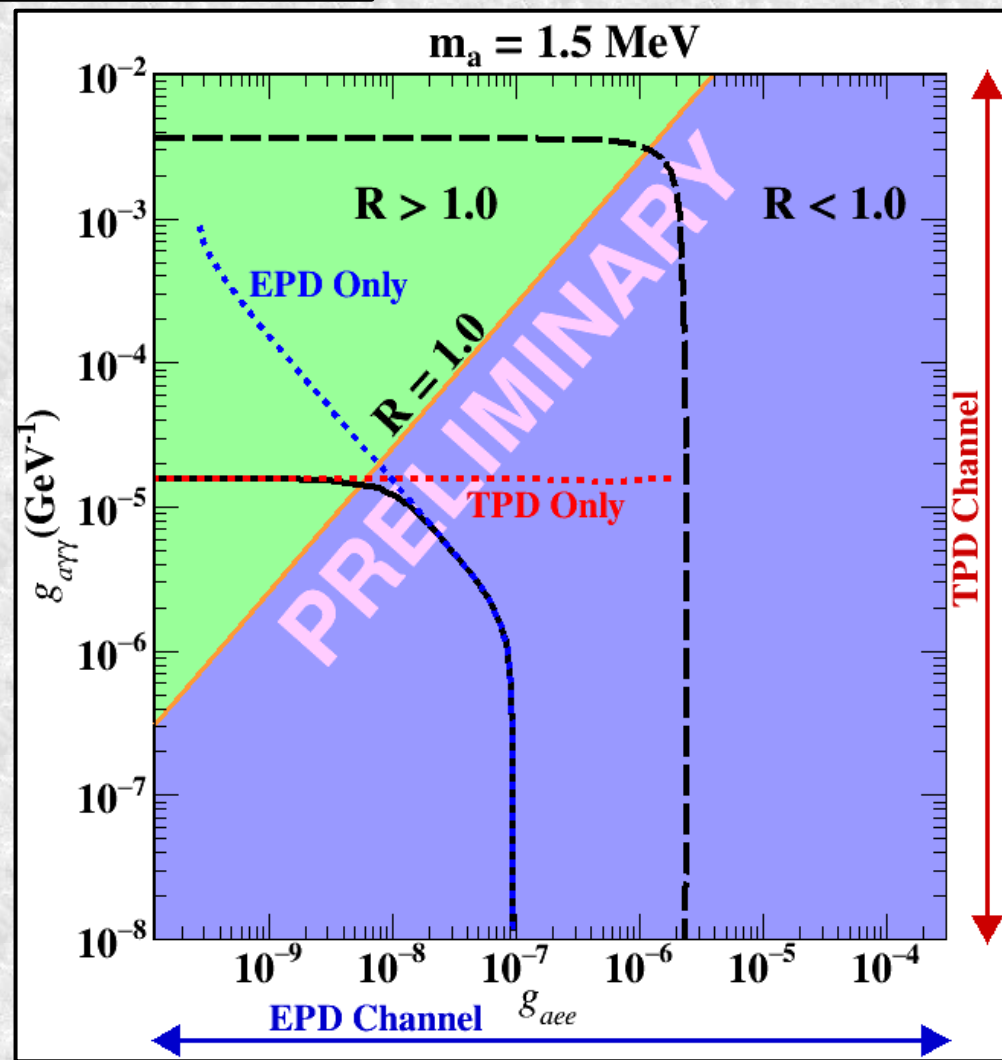
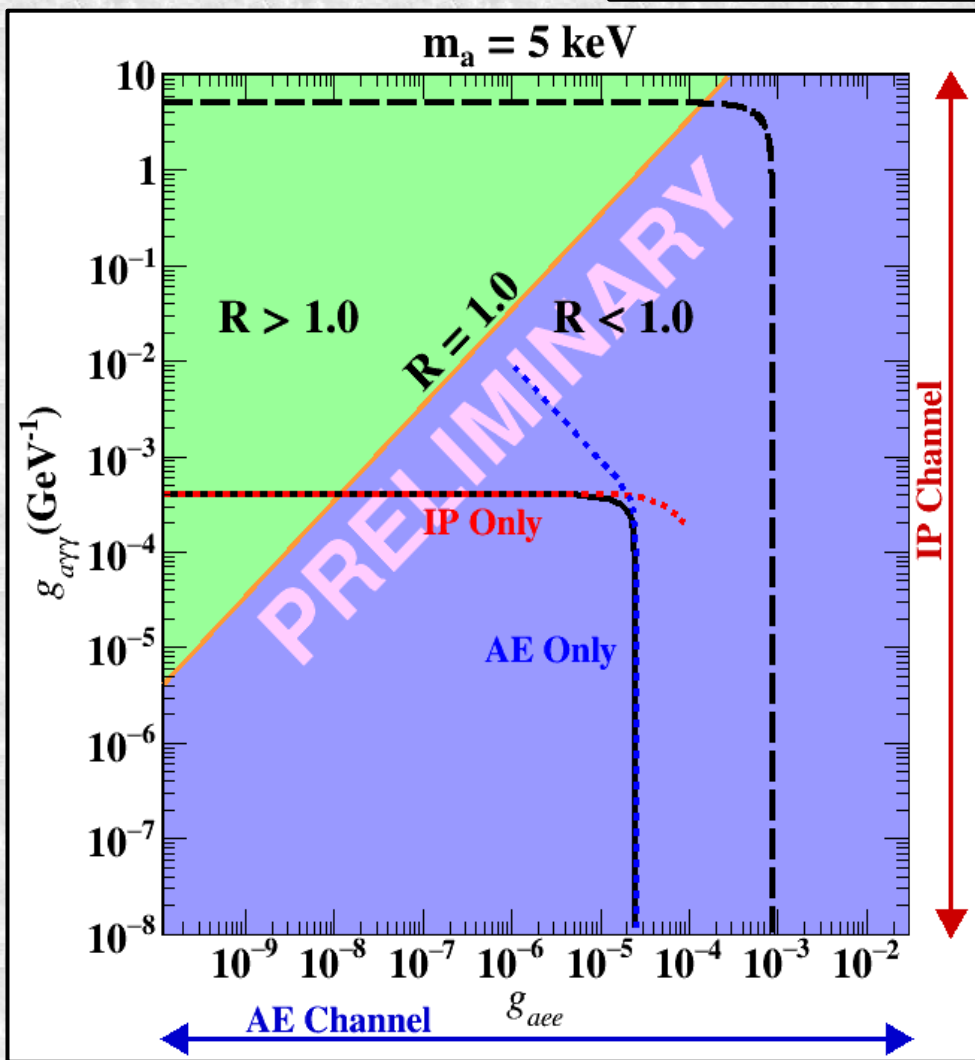


Exclusion Plots

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Global Exclusion Plots



Conclusion

- ✓ We present a comprehensive analysis of the data of TEXONO program acquired with 1.06 kg HPGe for both $g_{a\gamma\gamma}$ and g_{aee} couplings from 1 eV to 3 MeV mass range.
- ✓ A combined analysis is performed taking both couplings active simultaneously
- ✓ The findings demonstrate the power of compact, low-background reactor-based experiments to complement the sensitivity of much larger-scale facilities in the search for light ALPs.

Thank You!