Search for the dark scalar S in $\eta(') \to S\pi^0$ at GlueX/JEF

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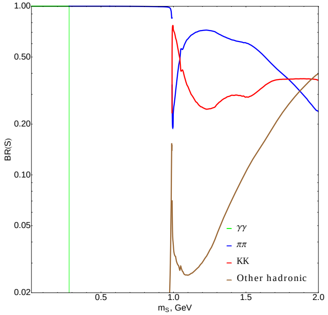
Introduction

Search for a MeV-GeV dark Higgs boson, S, that couples to quarks and gluons. Initially proposed by B. Batell et al. (arxiv:1812.05103) and refreshed by L. Gan et al. (arxiv:2007.00664)

- B. Batell et al.:
  - For, $m_S < 2m_\pi$, $S \to \gamma\gamma$
  - For, $m_S \geq 2m_\pi$, $S \to$hadrons and in particular $\pi\pi$
- L. Gan et al.:
  - For, $m_S < 2m_\pi$, $S \to \gamma\gamma$
  - For, $m_S \geq 2m_e$, $S \to e^+e^-$
  - For, $m_S \geq 2m_\mu$, $S \to \mu^+\mu^-$
  - For, $m_S \geq 2m_\pi$, $S \to$hadrons and in particular $\pi\pi$



Numbers of expected events and UL on observed events

Relation between number of expected events, ${\rm N_{th}}^S$, and of UL on observed events, ${\rm N_{obs}^{UL}}$

- ${\rm N_{th}}^S = {\rm N}_\eta \cdot \mathcal{B}(\eta \to S\pi^0)$
  - ${\rm N}_\eta$: number of η; ${\rm N}_\eta = \sigma \cdot \mathcal{L}$
    - σ: cross-section
    - $\mathcal{L}$: integrated luminosity
  - $\mathcal{B}$: branching ratio
- ${\rm N_{obs}^{UL}} = {\rm N_{th}}^S \cdot \epsilon$
  - ϵ: detection efficiency

Then,

- $\mathcal{B}(\eta \to S\pi^0) = \frac{{\rm N_{obs}^{UL}}}{\epsilon \cdot {\rm N}_\eta}$

So, for $S \to \gamma\gamma$

- $\mathcal{B}(\eta \to S\pi^0) = \frac{{\rm N_{obs}^{UL}}}{\epsilon \cdot \mathcal{B}(\eta \to \gamma\gamma) \cdot {\rm N}_\eta}$
- $\mathcal{B}(\eta \to S\pi^0) \simeq 0.056 \left(\frac{g_u}{7 \times 10^{-4}}\right)^2$
- $\alpha_S = g_u^2/(4\pi)$
- $\alpha_s^{\rm UL} = \frac{1}{4\pi} \frac{\left(7 \times 10^{-4}\right)^2}{0.056} \frac{{\rm N_{obs}^{UL}}}{\epsilon \cdot \mathcal{B}(\eta \to \gamma\gamma) \cdot {\rm N}_\eta}$

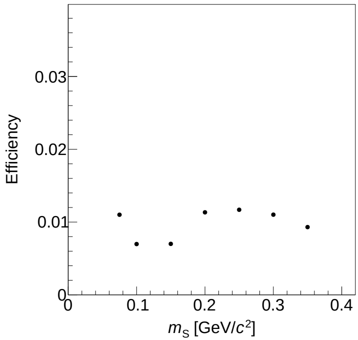
Sensitivity

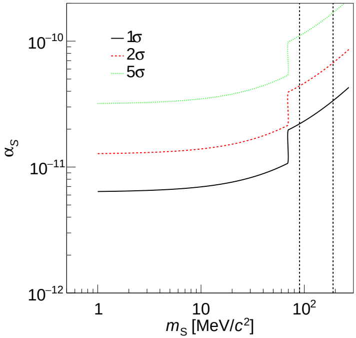
Is defined as $\mathrm{N_{sig}} = x\sqrt{\mathrm{N_{bkg}}}$ where:

- $\mathrm{N_{sig}}$, number of signal for a given m_S and window corresponding to $\Delta m_S = 3\sigma$ (σ is the signal resolution)
- $\mathrm{N_{bkg}}$, number of background for the same m_S and window
- x is the significance in "sigma" unit

Then by replacing $\mathrm{N_{obs}^{UL}}$ by $\mathrm{N_{sig}}$

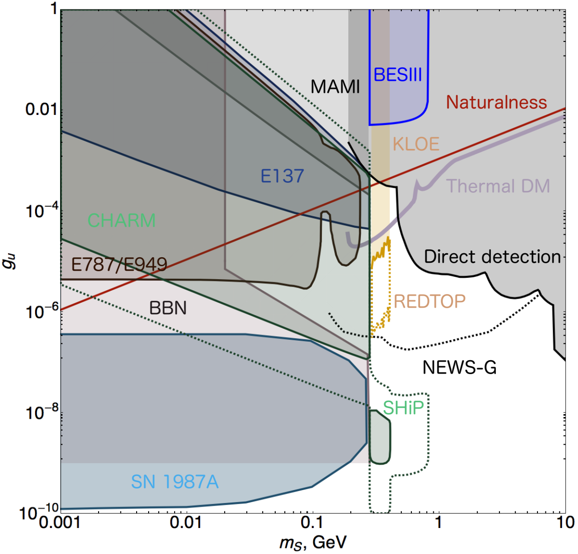
- $\alpha_s^{\mathrm{Sensitivity}} = \frac{1}{4\pi}\frac{(7\times10^{-4})^2}{0.056}\frac{x\sqrt{\mathrm{N_{bkg}}}}{\epsilon\cdot\mathcal{B}(\eta\to\gamma\gamma)\cdot\mathrm{N}_\eta}$
- $\mathrm{N}_\eta = 5\times10^7\ \eta$





Comparison to existing bound and future experiments

For 100 days, $g_u \sim 7 \times 10^{-5}$



Conclusion

To be continued