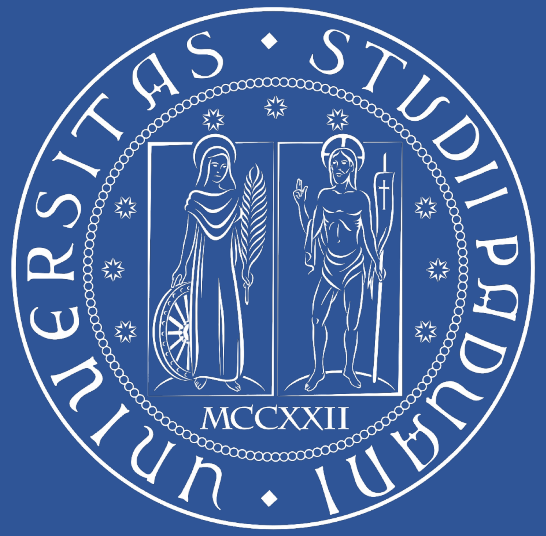


θ-dependence of α-decay half-lives

Claudio Toni

based on the work w/
Carlo Broggini, Giuseppe Di Carlo and Luca Di Luzio
arxiv: 2404. 18993, accepted by PLB

Bologna, Invisibles workshop , 2 July 2024

Signal of axion DM trough α-decays

- Axion potentially addresses the Strong CP problem and dark matter puzzle
- In a misalignment mechanism the DM axion field induces a time varying θ-term

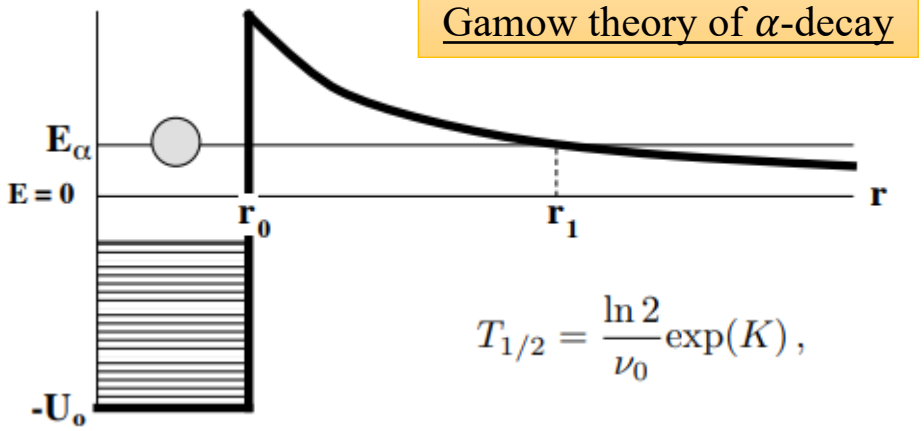
$$\mathcal{L}_\theta = \frac{g^2\theta}{32\pi^2} G_{\mu\nu}\tilde{G}^{\mu\nu}$$

$$\theta \simeq \sqrt{\frac{2\rho_{DM}}{m_a^2 f_a^2}}\cos(\omega t + \vec{p}\cdot\vec{x} + \phi)$$

For its impact on the halftimes of β-decays, see:
-Houston et al. arxiv:2303.09865
-Meissnier at al. arxiv:2006.12321

- We investigate the impact of such term on the halftimes of α-decay processes

Gamow theory of α-decay



$$T_{1/2} = \frac{\ln 2}{\nu_0}\exp(K)\,,$$

$$K = \frac{2}{\hbar}\int_{r_1}^{r_2} dr\,\sqrt{2\mu[V_{\rm tot}(r) - Q_\alpha]}$$

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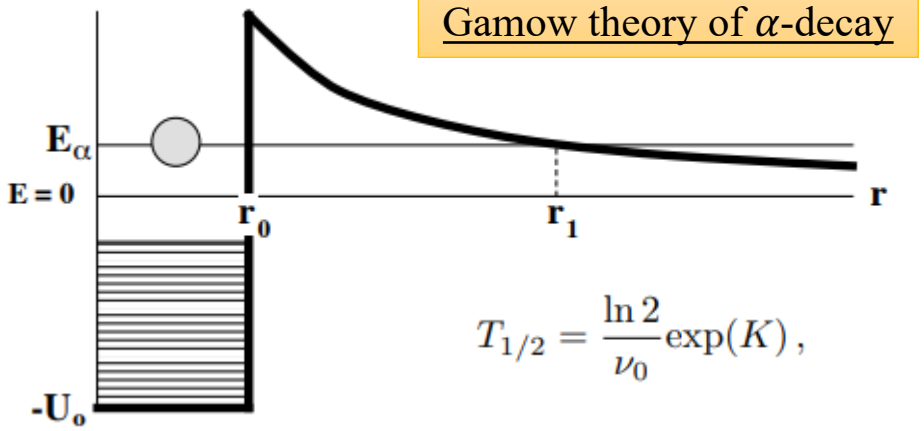

$$T_{1/2} = \frac{\ln 2}{\nu_0}\exp(K)\,,$$

$$K = Z_\alpha Z_d \alpha_{\mathrm{QED}}\left(\frac{8\mu}{Q_\alpha}\right)^{1/2} F\left(\frac{Q_\alpha R_{\mathrm{well}}}{Z_\alpha Z_d \alpha_{\mathrm{QED}}}\right),$$

with

$$F(x) = \arccos\sqrt{x} - \sqrt{x}\sqrt{(1-x)} \approx \frac{\pi}{2} - 2\sqrt{x} + \ldots\,,$$

Signal estimate

- The halftime are highly sensible to small variation of the energy released in the decay, thus the θ-dependence of Q is the most relevant and impacting

Question: how the θ-term impacts the Q?

$$Q_\alpha = \mathrm{BE}(A-4, Z-2) + \mathrm{BE}(4,2) - \mathrm{BE}(A,Z),$$

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$$Q_\alpha = \mathrm{BE}(A-4, Z-2) + \mathrm{BE}(4,2) - \mathrm{BE}(A,Z),$$

- The θ-term changes the size of the scalar (attractive) and vector (repulsive) nuclear interaction that contributes to the BEs

$$H = G_S(\bar{N}N)(\bar{N}N) + G_V(\bar{N}\gamma_\mu N)(\bar{N}\gamma^\mu N)\,,$$

$$\eta_S = \frac{G_S(\theta)}{G_S(\theta=0)}\,, \quad \eta_V = \frac{G_V(\theta)}{G_V(\theta=0)}\,.$$

$$Q_\alpha(\theta) = Q_\alpha(\theta=0) - 97\ \mathrm{MeV}\ (\eta_S(\theta)-1) \times ((A-4)^{2/3} + 4^{2/3} - A^{2/3})\,.$$

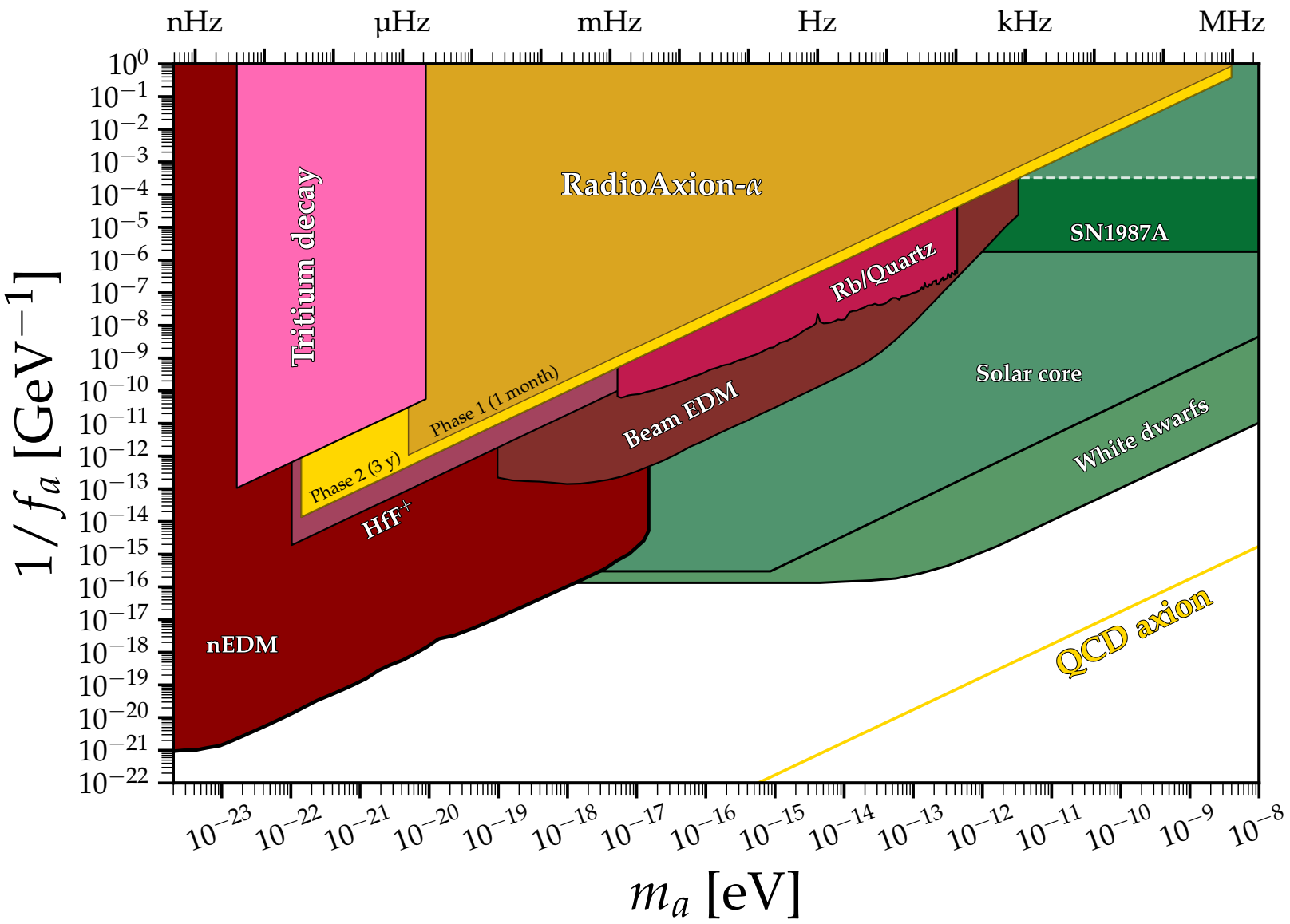
Damour, Donoghue arxiv:0712.2968

Experimental prospects

Prospect limits from measurements of Americium-241 α-decay

- Our experiment, based under Gran Sasso, is starting data taking now!
- We aim to take data for at least 3 years

$$I_{\rm exp}(t) \equiv (N(t) - \langle N\rangle)/\langle N\rangle$$
$$= -4.3\times 10^{-6}\cos(2m_a t)\left(\frac{\rho_{\rm DM}}{0.45\,{\rm GeV/cm^3}}\right)$$
$$\times\left(\frac{10^{-16}\,{\rm eV}}{m_a}\right)^2\left(\frac{10^{8}\,{\rm GeV}}{f_a}\right)^2,$$



The End

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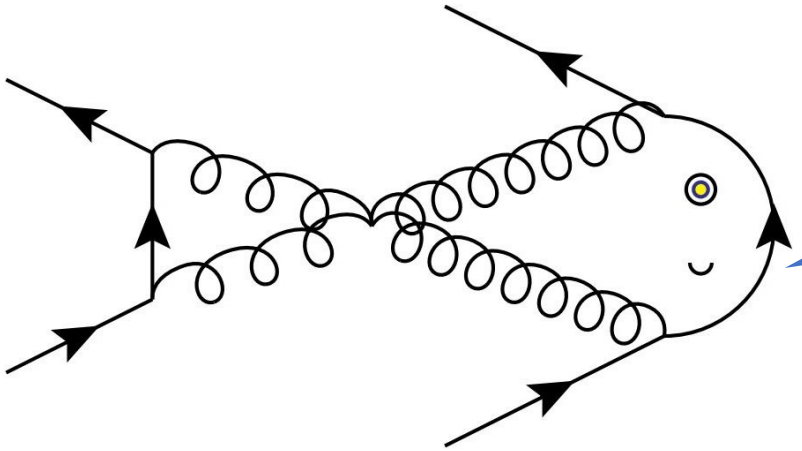

THANK YOU FOR THE ATTENTION!