

The Physics Case and Benchmark Models for GAZELLE

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with

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The Physics Case for LLP

In case you didn't pay attention during the workshop...

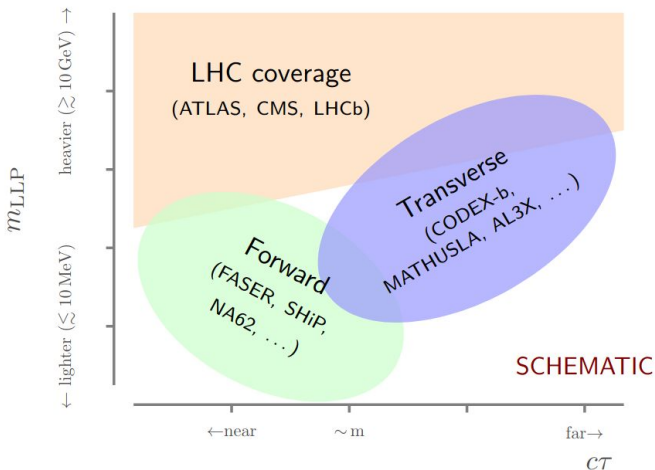
Wide variety of physical motivations:

- Mediators to a Dark Sector (ex: dark photons)
- New \sim GeV scalar and pseudoscalars (ex: ALPs)
- Flavor specific models (ex: Heavy Neutral Leptons)

Other ideas?

Extending the Lifetime Frontier

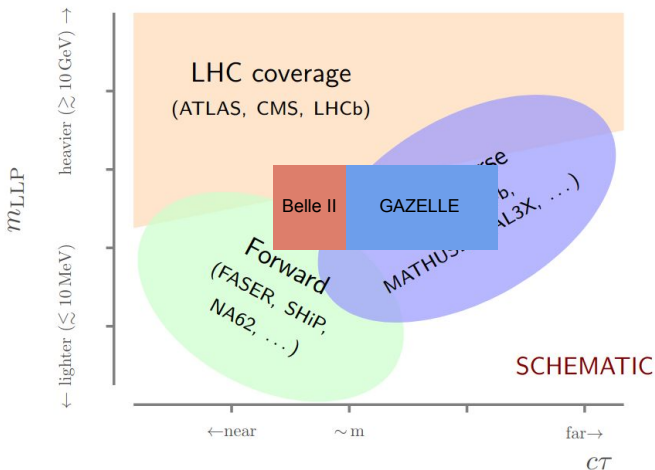
Exploit low background and high luminosity experiments to extend the reach in lifetime



[CODEX-b EOI:1911.00481]

Extending the Lifetime Frontier

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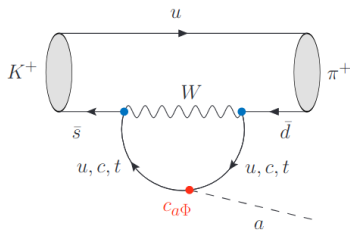
- Probe longer lifetimes from Belle II events;
- High statistics (in principle);
- Currently only e and μ as final states;

Preliminary Leading Order (PLO) studies

- Axion-Like Particles (ALPs) decaying in two fermions (PLO);
- Heavy Neutral Leptons (HNL), universal and tau specific (P²LO);
- Inelastic Dark Matter (IDM) with vector portals (P³LO);

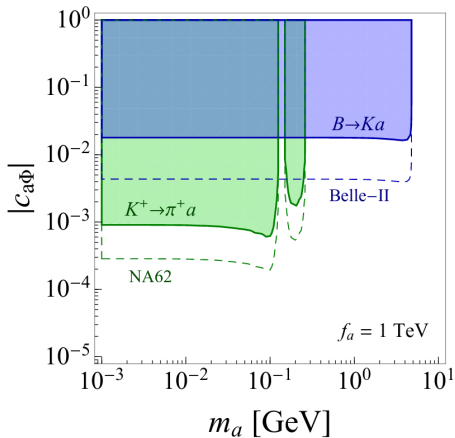
Production through $B^+ \rightarrow K^+ a$

$$\mathcal{L}_{prod} \supset -\frac{\partial_\mu a}{f_q} g_{ij} \bar{d}_i \gamma_\mu P_L d_j$$



$$g_{ij} = -g^2 \sum_{q=u,c,t} \frac{V_{qi}^* V_{qj}}{64\pi^2} \frac{m_q^2}{m_W^2} c_{a\Phi} \log\left(\frac{\Lambda_{UV}^2}{m_q^2}\right)$$

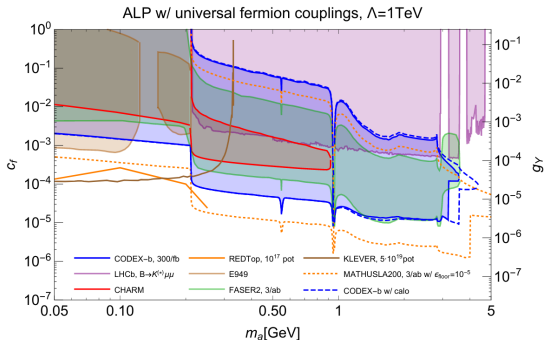
[Gavela et al:1901.02031]



ALPs

Decay in two fermions

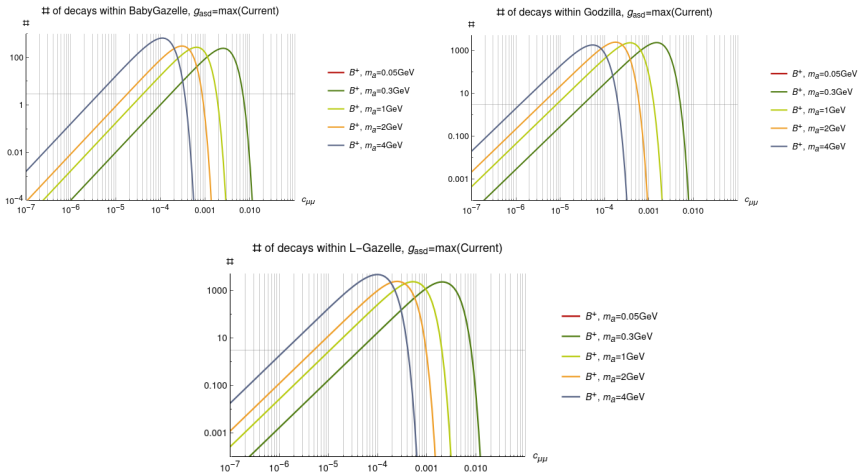
$$\mathcal{L}_{decay} \supset \frac{c_f}{f_f} \partial^\mu a (\bar{f} \gamma_\mu \gamma_5 f) \quad \Gamma(a \rightarrow f^+ f^-) = \frac{c_f^2}{f_f^2} \frac{m_f^2 m_a}{8\pi} \sqrt{1 - 4 \frac{m_f^2}{m_a^2}}$$



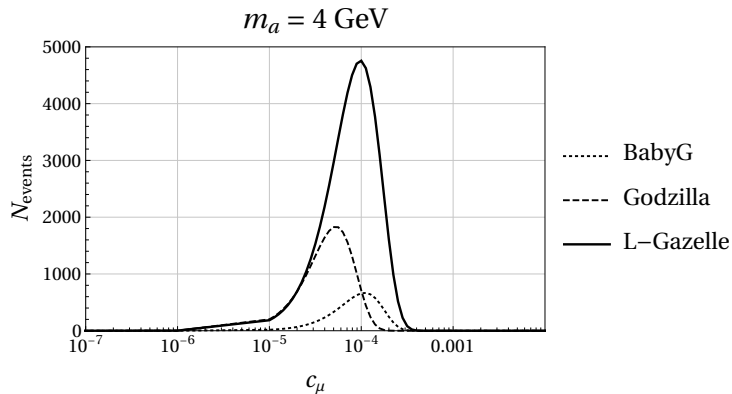
[CODEX-b EOI:1911.00481]

$m_a = 1 \text{ GeV}$, $c\tau(a \rightarrow ee) \simeq 50\text{m} \rightarrow c_f \sim 10^{-2}$, $c\tau(a \rightarrow \mu\mu) \simeq 50\text{m} \rightarrow c_f \sim 4 \cdot 10^{-5}$

Expected events in GAZELLE with $f_f = 1$ TeV (credits to A. Filiminova and R. Scäfer)



Expected events at GAZELLE (credits to A. Filiminova and R. Scäfer)



Angular coverage vs size

Heavy Neutral Leptons

$$\mathcal{L}_{int} = \sum_{\alpha, I} c_{\alpha, I} (\bar{L}_{\alpha} H) N_I$$

After EWSB the HNL mixes with ν_{α} with mixing angle U_{α} .

Production:

Flavor universal: produced by $B^{\pm} \rightarrow N_{\ell} \ell^{\pm}$ and $B \rightarrow N_{\ell} D \ell$

Tau flavored: production dominated by τ decays, e.g. $\tau^{-} \rightarrow N \pi^{-}$

Decay:

Decays in $\nu \ell^{+} \ell^{-}$ via off-shell W and Z

[K. Bondarenko et al:1805.08567]

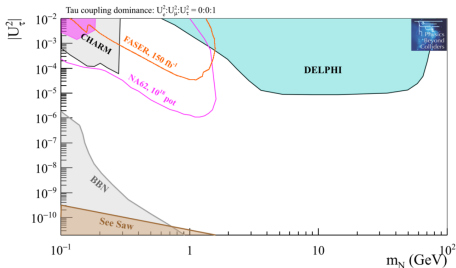
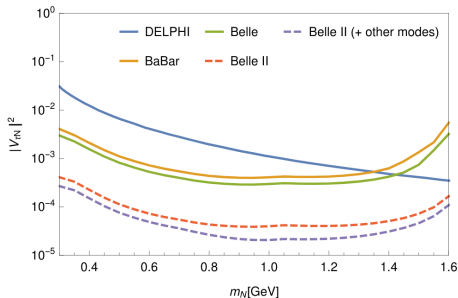
At Belle II [C. O. Dib et al:1908.09719].

Decay chain $\tau \rightarrow \pi(\pi)N, N \rightarrow ee, \mu\mu$

Projected bounds [PBC report:1901.09966]

$c\tau(N \rightarrow \nu_\tau \ell^+ \ell^-) \sim 50 \text{ m}$

with $m_N = 1\text{GeV}$, $|U_\tau|^2 \sim 10^{-4}$



Conclusions

Going forward:

- Fully explore the reach of Belle II;
- Have solid simulations of events (and backgrounds) for the three benchmarks;

Remarks:

- GAZELLE can be complementary to proposed LLP searches at LHC;
- Could (potentially) include γ s in the final states or particle ID ;