

# Physics reach of a far detector at Belle II: GAZELLE

Ruth Schäfer

Heidelberg University

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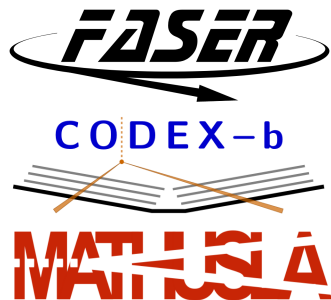
Based on the SnowMass2021 Contributed Paper [2105.XXXXX] with S. Dreyer, T. Ferber, A. Filimonova, C. Garcia-Cely, C. Hearty, S. Longo, K. Schmidt-Hoberg, M. Tamaro, K. Trabelsi, S. Westhoff and J. Zupan; RS supported by GRK 1940

# What is GAZELLE?



- ▶ GAZELLE is the Approximately Zero-background Experiment for Long-Lived Exotics

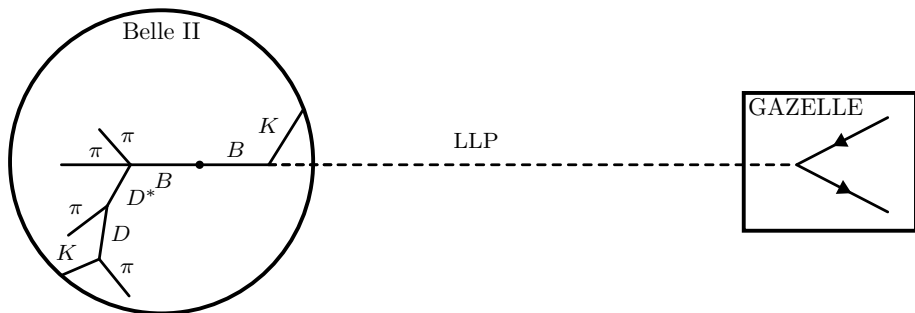
# What is GAZELLE?



- ▶ A far detector for long-lived particle searches at Belle II

[1811.12522], [1901.04040], [1911.00481]

# A far detector for Belle II



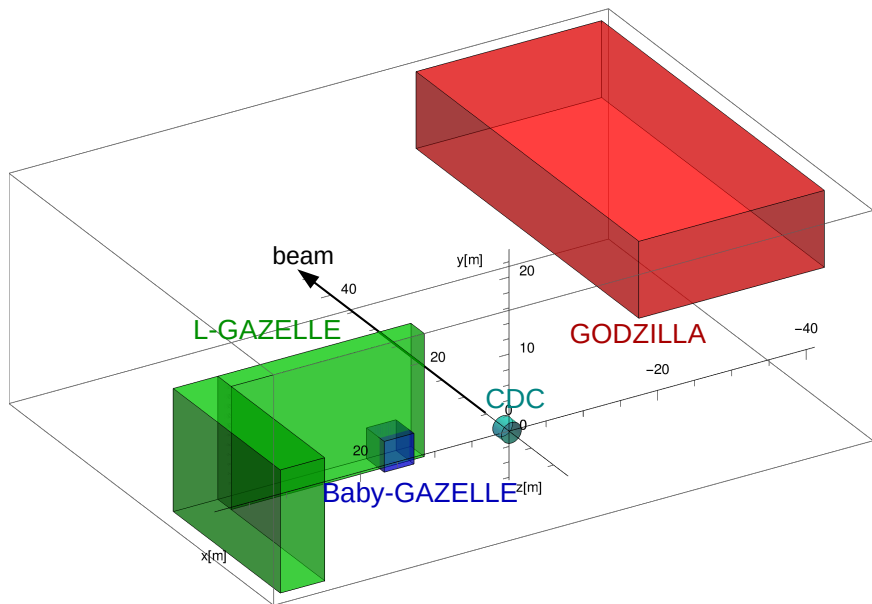
- ▶ Probes longer lifetimes
- ▶ Has lower background
- ▶ Let one trigger the other

# Where to put GAZELLE?



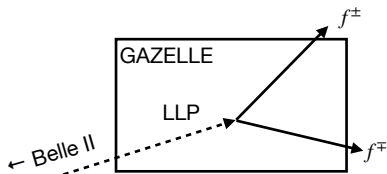
Tsukuba hall, where Belle II lives

# Where to put GAZELLE?

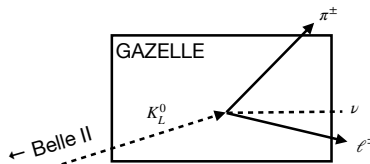


# What can GAZELLE do?

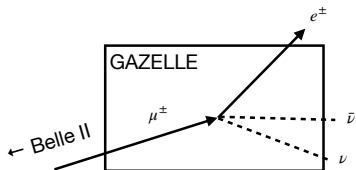
## ▶ Signal



## ▶ Background

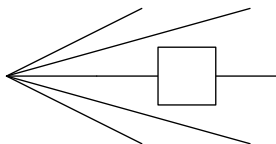


- ▶ Displaced vertices
- ▶ Direction
- ▶ Timing
- ▶ Mass

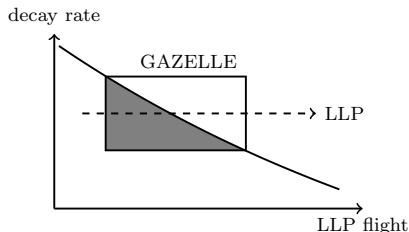


# GAZELLE's LLP sensitivity

- ▶ How many LLPs fly through GAZELLE?



- ▶ How many decay in its volume?



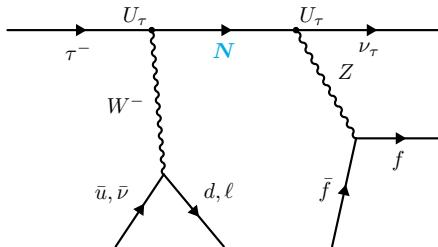
$$\langle \mathbb{P} \rangle = \frac{1}{N} \sum_i e^{-\frac{d_{in}^i}{\gamma\beta c\tau_i}} - e^{-\frac{d_{out}^i}{\gamma\beta c\tau_i}} \approx \frac{\Omega}{4\pi} \frac{D}{\langle \gamma\beta \rangle c\tau} \quad \text{for } \gamma\beta c\tau \gg d_{in}, D$$

Detector	Belle II	Baby-GAZELLE	L-GAZELLE	GODZILLA
$\Omega \times D$	7 sr m	0.2 sr m	3 sr m	3.4 sr m

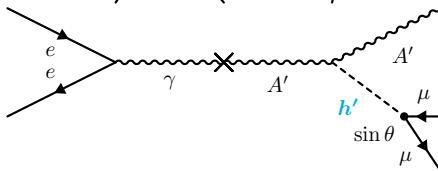


# LLP Benchmark models

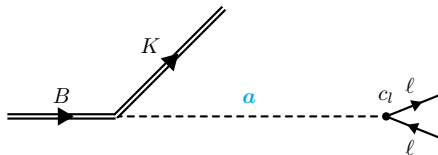
- ▶ Clean  $\tau$  production  
 $\Rightarrow$  HNLs:  $N$



- ▶ Displaced vertices  
 $\Rightarrow$  iDM:  $h'$



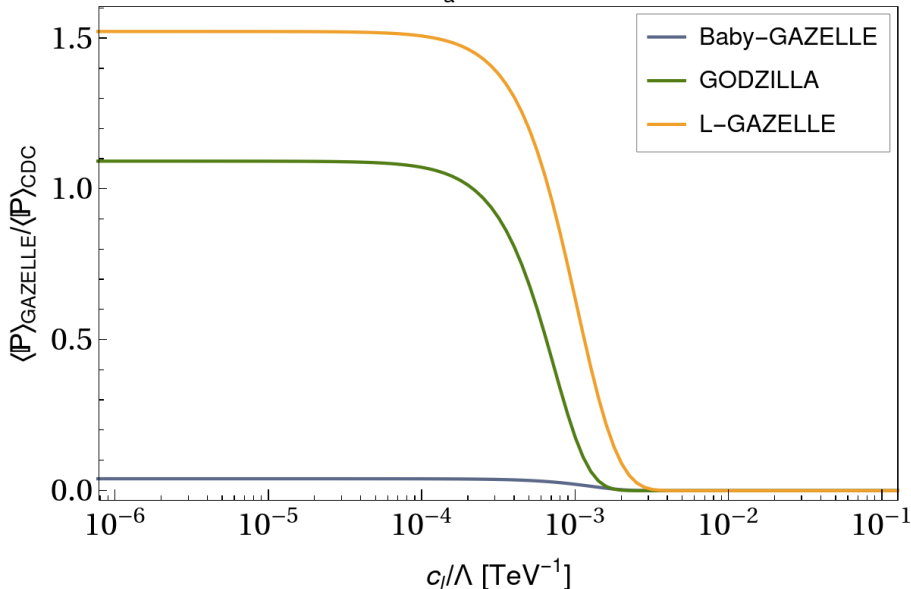
- ▶ Rare  $B$  decays  
 $\Rightarrow$  ALPs:  $a$



FIPs'20: [2102.12143]

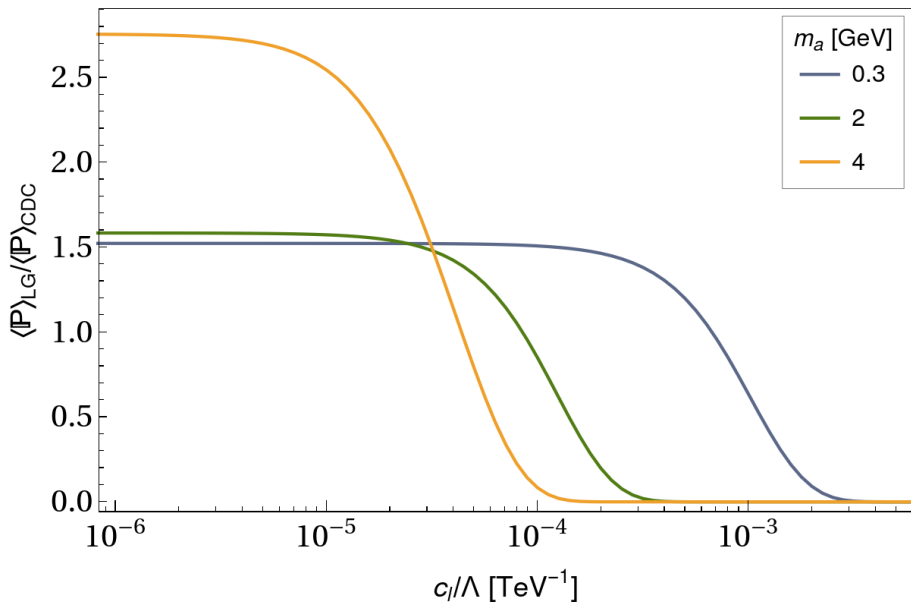
# Compare Decay Probability by detector (ALPs)

$m_a=0.3$  GeV

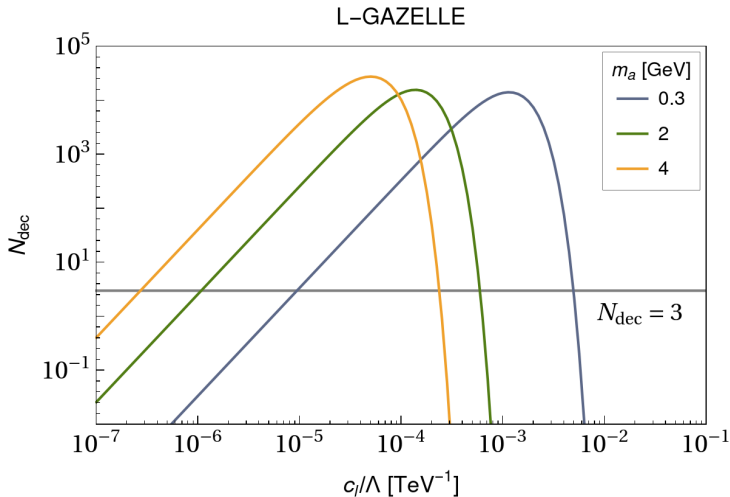


# Compare Decay Probability by mass (ALPs)

L-GAZELLE



# Numbers of events in GAZELLE (ALPs)



$$N_{\text{events}} = N_{BB} \times Br(B^+ \rightarrow K^+ a) \times Br(a \rightarrow \ell\ell) \times \langle \mathbf{P} \rangle$$

# Other models

- ▶ Forward LLP production
  - ▶  $e^+e^- \rightarrow \gamma A', e^+e^- \rightarrow \gamma a$
  - ▶ Forward GAZELLE
- ▶ Emerging jets, quirks, soft bombs
  - ▶ Many emissions at different distances
  - ▶ Additional volume for detection

## ▶ GAZELLE

- ▶  $\mathcal{O}(1)$  improvement over Belle II in LLP sensitivity
- ▶ Forward physics, confining sectors
- ▶ LLP characterisation if discovered

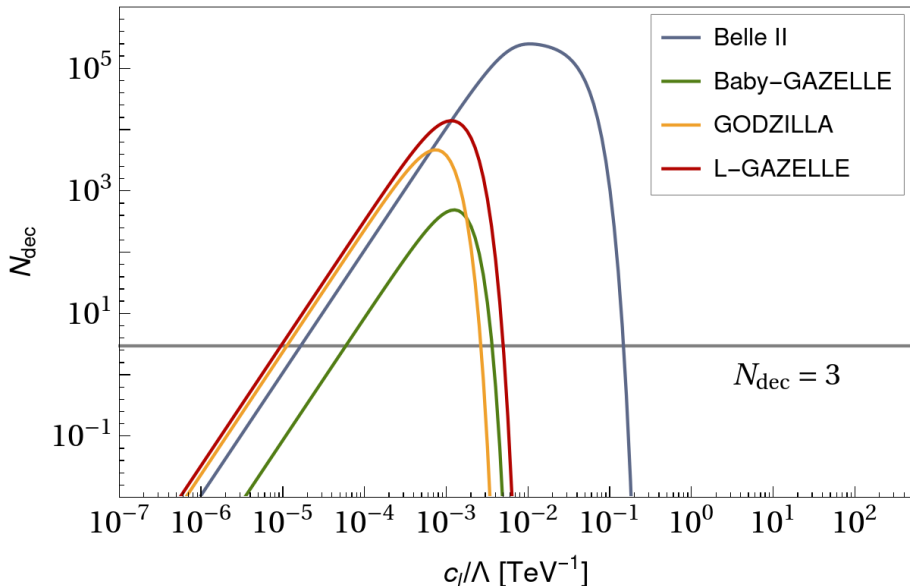
- ▶ Belle II and GAZELLE can cover the sensitivity gap at intermediate lifetimes between prompt and far detectors

## ▶ Belle II

- ▶ Is itself sensitive to LLPs
- ▶ Displaced vertices and missing energy complementary

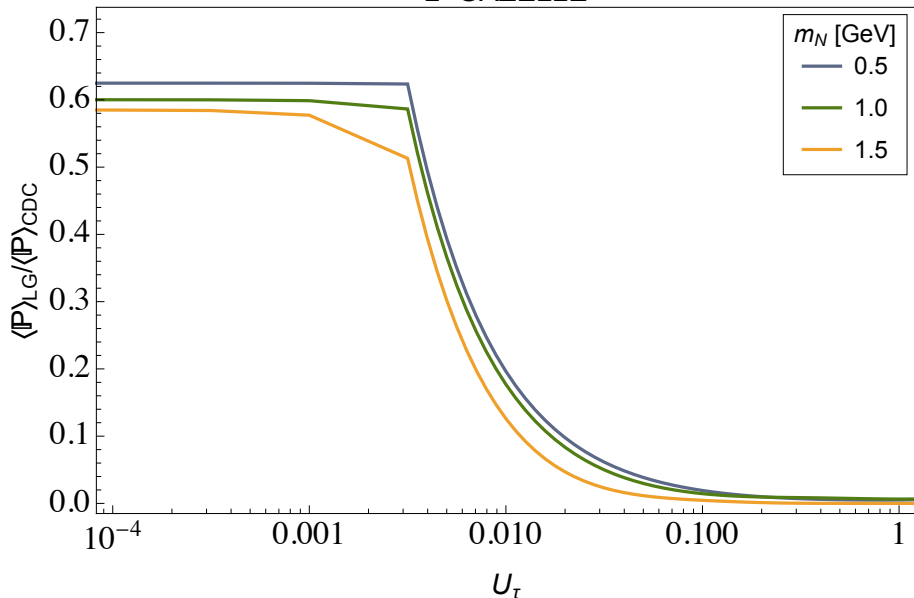
# Number of events by detector (ALPs)

$m_a = 0.3 \text{ GeV}$



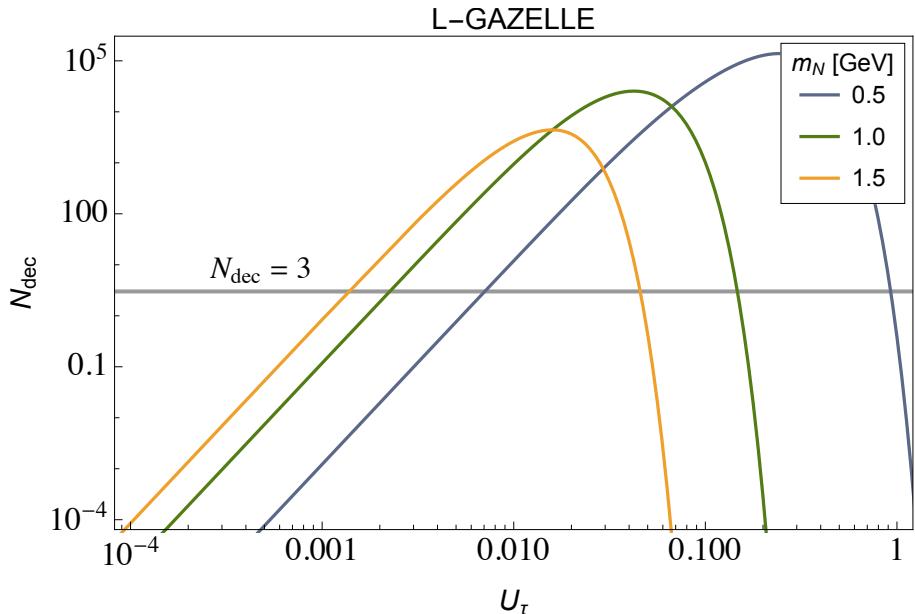
# Compare Decay Probability by mass (HNLs)

L-GAZELLE



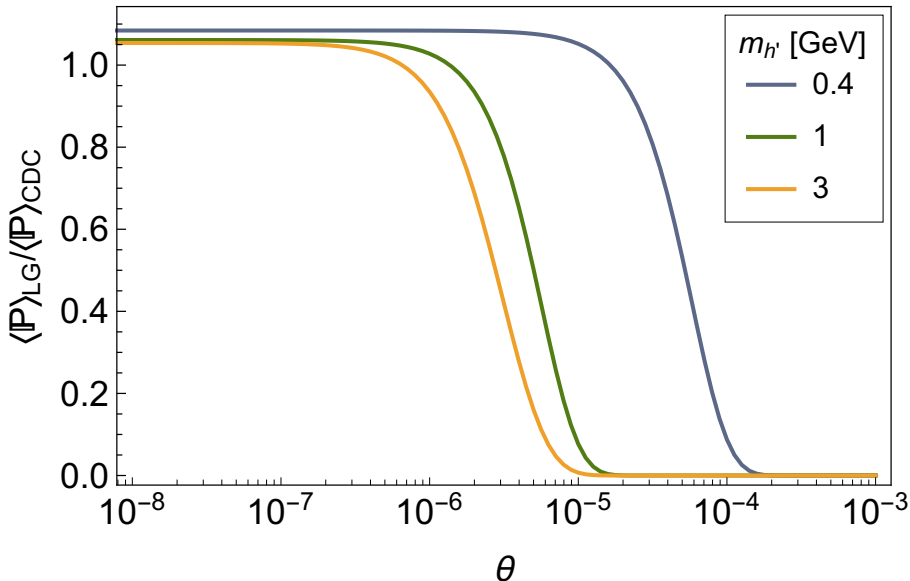


# Numbers of events in GAZELLE (HNLs)



# Compare Decay Probability by mass (iDM)

## L-GAZELLE



# Numbers of events in GAZELLE (iDM)

## L-GAZELLE

