

The logo for Universidad Autónoma de Madrid (UAM), featuring the letters 'UAM' in a green, stylized font with a blue triangle above the 'A'.The logo for HIDDe, featuring the text 'HIDDe' in white on a dark blue background with a galaxy pattern. Below it, the text 'Hunting Invisibles: Dark sectors, Dark matter and Neutrinos' is written in a smaller white font.The logo for Instituto de Física Teórica (IFT), featuring the letters 'ift' in a bold, black, lowercase font inside a yellow circle. To the right, the text 'Instituto de Física Teórica' and 'UAM-CSIC' is written in black.

in collaboration with L. Merlo (Madrid, IFT), Jean-Loup Tastet (Madrid, IFT)

based on **2212.11290**

Down to the Seesaw Line via the **JALZ ALP-HNL** Portal

by Arturo de Giorgi (Madrid, IFT)

Invisible23 - August 28, 2023

HNL

- **Neutrinos** need a **mass** \Rightarrow **right-handed** neutrinos, N_R ?

$$\mathcal{L}_{\text{HNL}} = i\overline{N}_R \not{D} N_R - \left(\overline{L}_L \tilde{H} Y_N N_R + \frac{1}{2} \overline{N}_R^c M_N N_R + \text{h.c.} \right)$$

“**Seesaw** mechanism”

$$m_\nu \sim v^2 Y^2 / M_N$$

- N_R interacts with **gauge bosons** via **mixing** with active neutrinos ν_α

$$\nu_\alpha \rightarrow \nu_\alpha + \Theta_\alpha N_R^c \quad \text{“mixing-angle”}$$

“**Seesaw Line**” $\|\Theta\|^2 \sim \frac{\|m_\nu\|}{\|M_N\|} \lesssim 10^{-12} \Rightarrow \text{hardly testable!}$

Another **portal**?

ALP

- **Pseudo-Goldstone boson**
- Generated by spontaneous **breaking** of a **global symmetry**, e.g. **U(1)**
- Part of many **BSM** scenarios, including **String Theory**
- Missing a UV? Mainly studied via **EFT**

$$\mathcal{L}_a = \frac{1}{2} \partial_\mu a \partial^\mu a - \frac{1}{2} m_a^2 a^2 - \frac{a}{f_a} \sum_X c_{aXX} X^{\mu\nu} \tilde{X}_{\mu\nu} - \frac{\partial_\mu a}{f_a} \sum_\psi \bar{\psi} c_\psi \gamma^\mu \psi$$

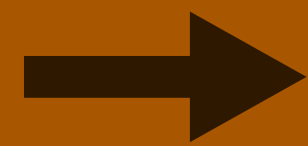
anomalous shift-symmetric

- **Coupling** proportional to **fermion mass**

$$\frac{\partial_\mu a}{f_a} \bar{\psi} \gamma^\mu \psi \sim \frac{a}{f_a} m_\psi \bar{\psi} \psi \quad \Rightarrow \quad \text{heavier} = \text{better!}$$

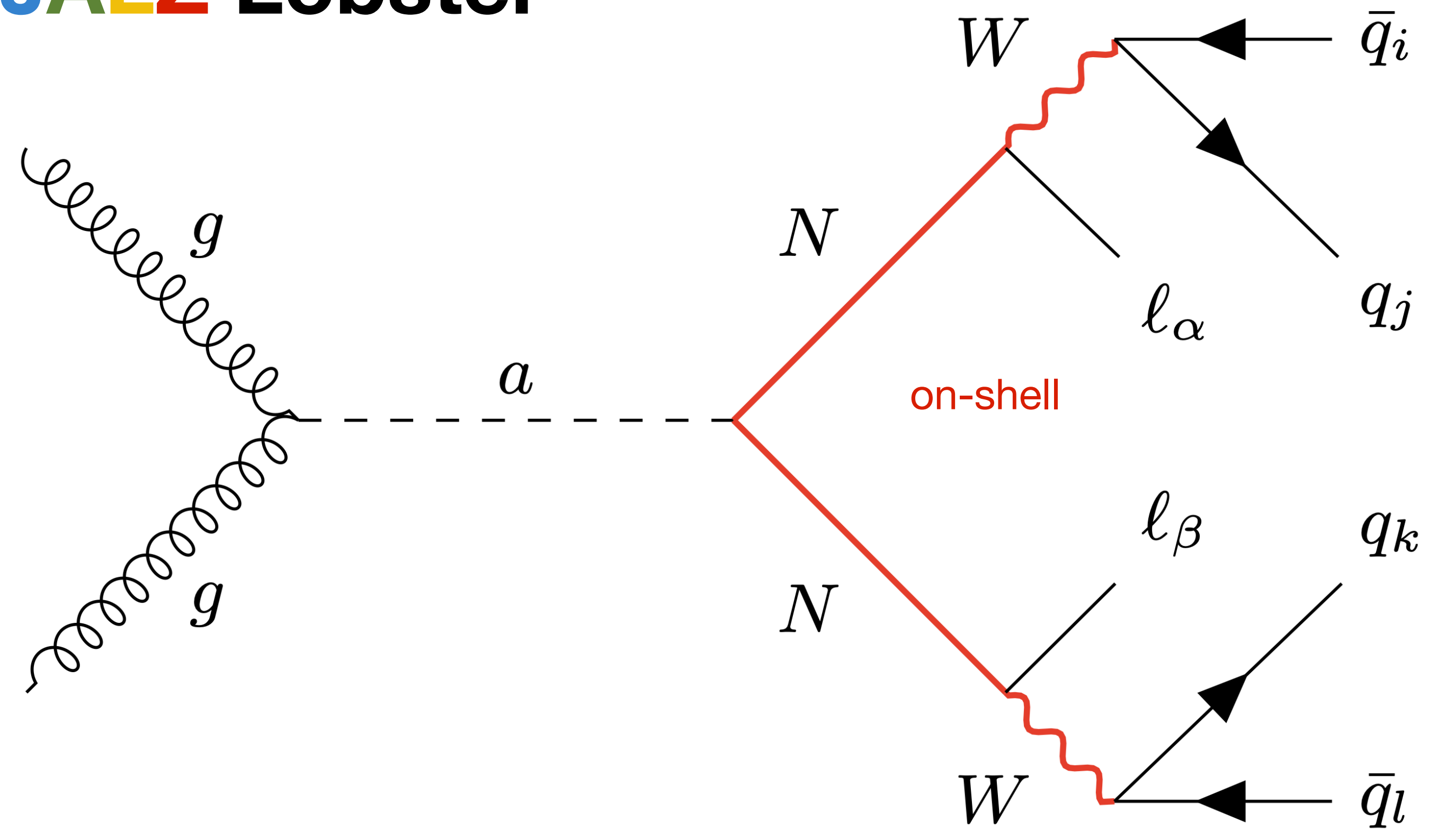
Can we take **advantage** of that?

$$\mathcal{L}^{\text{eff}} = \mathcal{L}_{\text{SM}} + \mathcal{L}_{\text{HNL}} + \mathcal{L}_a \quad \mathcal{L}_a \supset -\frac{\partial_\mu a}{f_a} \overline{N_R} \gamma^\mu \mathbf{c}_N N_R$$



Where to look?
Promising signal with **4-jets** and **2-leptons**

The **JALZ** Lobster

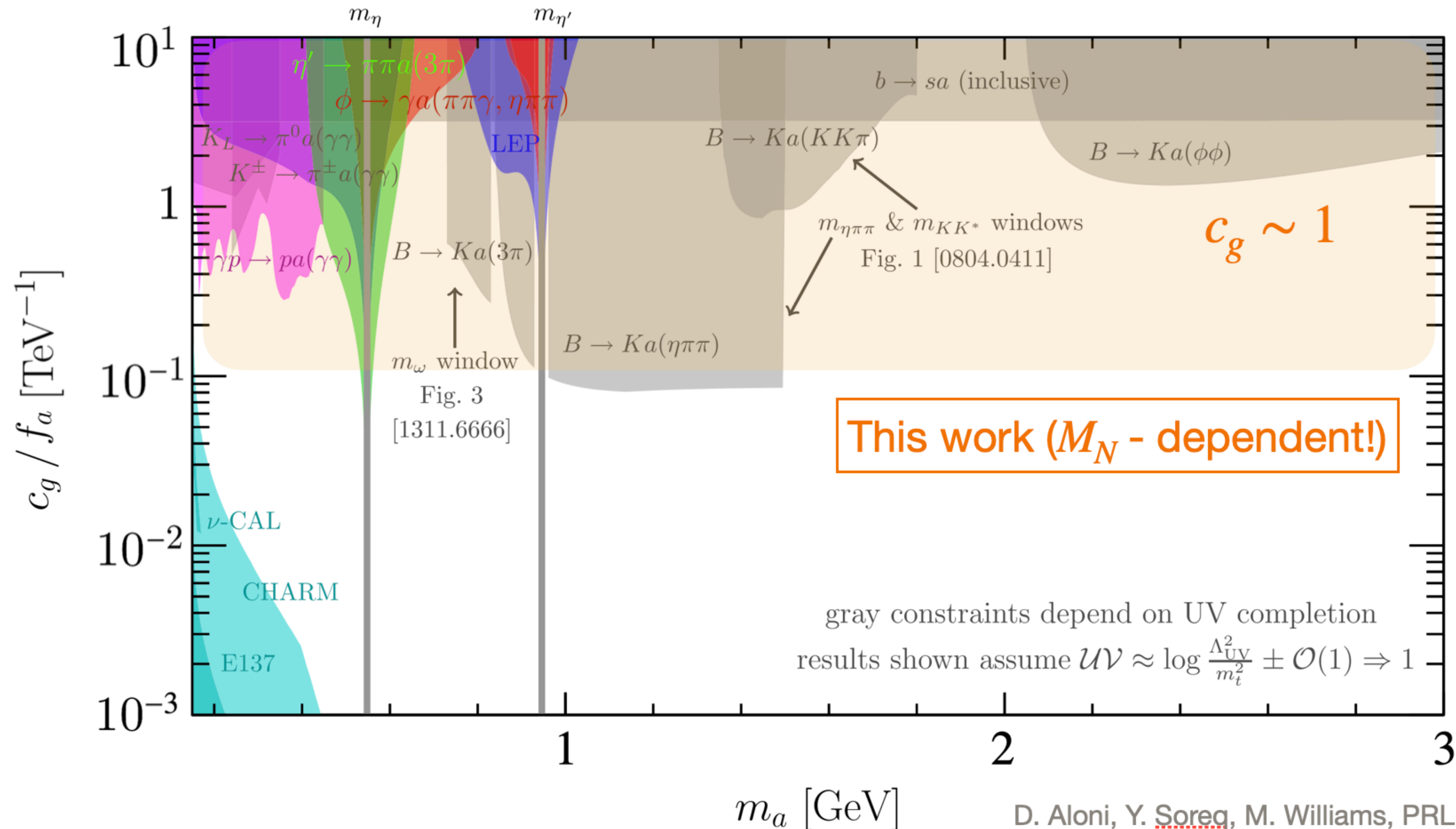


Astonishing bounds

- Dynamical origin of $M_N \Rightarrow \bar{N}_R^c M_N N_R \rightarrow \phi \bar{N}_R^c Y_N N_R \Rightarrow c_N = 1$


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Do you want to discuss and know more?


Come visit me!



UAM



HIDDe
Hunting Invisibles: Dark sectors, Dark matter and Neutrinos



ift
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- Smallness of m_ν ? Majorana mass is a free parameter \Rightarrow Seesaw mechanisms

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- N_R interacts with gauge bosons via mixing with active neutrinos ν_α

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- "Seesaw Line" $|\Theta|^2 \sim \frac{|m_\nu|^2}{|M_N|^2} \lesssim 10^{-12} \Rightarrow$ hardly testable!

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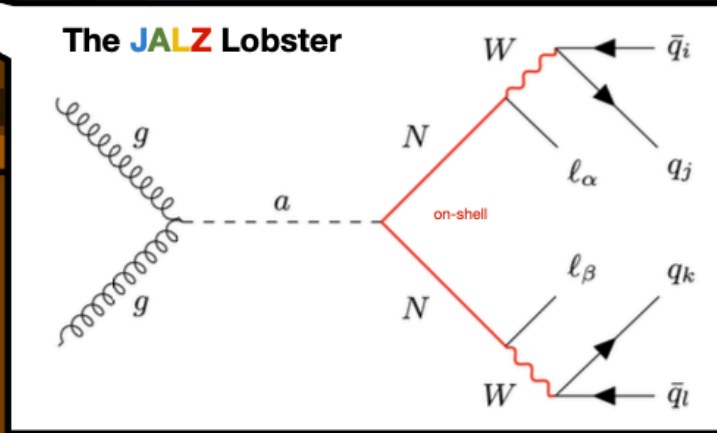
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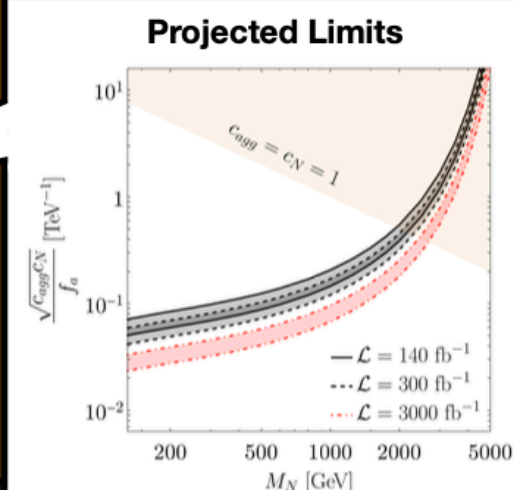
Why JALZ?

Advantages:

1. $\mathcal{M} \propto M_N / f_a \rightarrow$ enhancement!
2. $\mathcal{M} \propto \Theta_\alpha$
3. $\mathcal{M}(m_\nu)$
4. 2 HNLs \rightarrow 2 peaks
5. $\ell_\alpha^\pm \ell_\beta^\pm \rightarrow$ SM background suppressed!

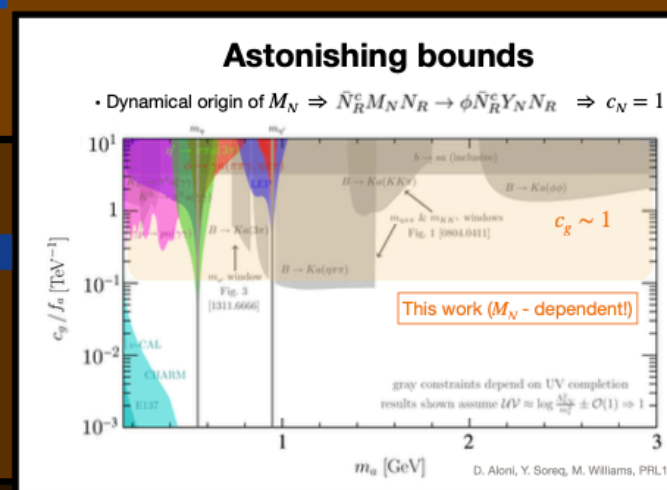
$$\sigma_{\alpha\beta} \propto \frac{c_{\alpha\beta}^2 c_N^2}{f_a^2} |\Theta_\alpha|^2 |\Theta_\beta|^2 \propto \frac{c_{\alpha\beta}^2 c_N^2}{f_a^2} |\Theta_\alpha|^2 |\Theta_\beta|^2$$

Projected Limits



Astonishing bounds

• Dynamical origin of $M_N \Rightarrow \bar{N}_R^c M_N N_R \rightarrow \phi \bar{N}_R^c Y_N N_R \Rightarrow c_N = 1$



This work (M_N -dependent)

Take Home Messages

- ALP? Still, neutrinos need masses!
- HNLs ~ simplest and most motivated candidates to explain ν -masses
- ALP-Portal allows for new channels (e.g. JALZ) and stronger bounds!

Interesting phenomenology ahead of us!