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Search for Long-Lived Heavy Neutrinos at the LHC with a VBF Trigger

J. Jones-Pérez, **J. Masias,** J.D. Ruiz-Álvarez

Type 1 Seesaw Lagrangian

$$\mathcal{L} = \mathcal{L}_{SM} - \bar{L}_a \left(Y_\nu\right)_{as} \nu_{R_s} \tilde{\phi}$$
$$- \frac{1}{2} \bar{\nu}^c_{R_s} \left(M_R\right)_{st} \nu_{R_t} + \text{h.c.}$$

Type 1 Seesaw Lagrangian

$$\mathcal{L} = \mathcal{L}_{SM} - \bar{L}_a \left(Y_\nu\right)_{as} \nu_{R_s} \tilde{\phi} - \frac{1}{2} \bar{\nu}^c_{R_s} \left(M_R\right)_{st} \nu_{R_t} + \text{h.c.}$$

Extended Model

$$\Delta\mathcal{L} = -\frac{\lambda_{st}}{\Lambda} \bar{\nu}^c_{R_s} \nu_{R_t} \phi^\dagger \phi + \text{h.c.}$$

$$\mathcal{L}_{h^0 \nu_h \nu_h} = -\left(\alpha_{NH}\right)_{st} \bar{\nu}^c_{R_s} \nu_{R_t} h^0 + \text{h.c.}$$

$$\left(\alpha_{NH}\right)_{st} \equiv \lambda_{st} \, v_{\text{SM}} / \Lambda$$

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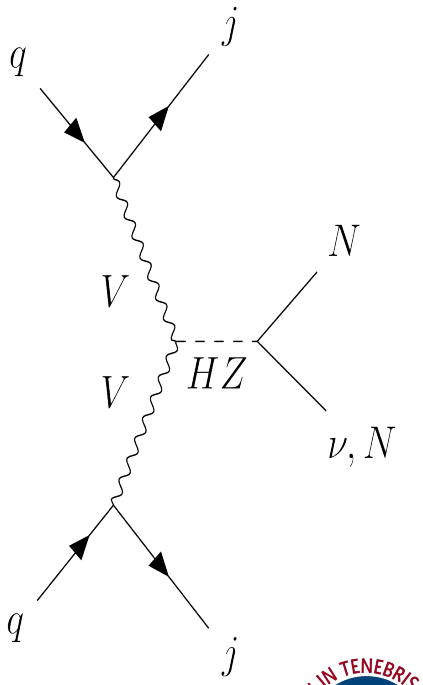
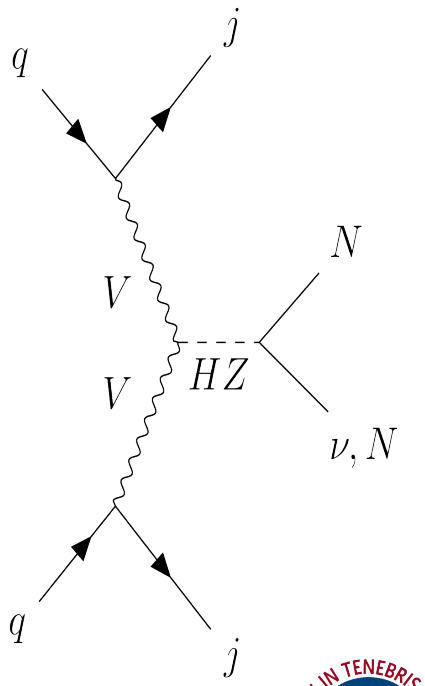
The VBF Trigger



The VBF Trigger

$p_T(j_1)$	> 30 GeV
$\lvert \eta(j_1) \rvert$	< 5.0
$p_T(j_2)$	> 30 GeV
$\lvert \eta(j_2) \rvert$	< 5.0
$\eta(j_1) \cdot \eta(j_2)$	< 0
$\lvert \Delta\eta(j_1, j_2) \rvert$	> 4.2
$m_{j_1 j_2}$	> 750 GeV
$\sum_j p_T$	> 200 GeV



Cuts used for displaced dileptons search

$p_T(e)$	> 10 GeV
$p_T(\mu)$	> 8 GeV
$\lvert\eta(\ell)\rvert$	< 2.4
$\Delta R(\mu, e)$	> 0.5
$\sqrt{L_x^2 + L_y^2}$	$< 40\,\text{mm}$
L_z	$< 300\,\text{mm}$

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$$d_0 = \frac{|p_x^\ell\, L_y - p_y^\ell\, L_x|}{p_T^\ell}$$

- **SR III**: $|d_0|_{e,\mu} > 1000\,\mu$m
- **SR II**: $|d_0|_{e,\mu} > 500\,\mu$m and at least one of the leptons outside of **SR III**.
- **SR I**: $|d_0|_{e,\mu} > 200\,\mu$m and at least one of the leptons outside of **SR II**.

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Cuts used for displaced multitrack jets search

$p_T(j_1)$	$> 25(70)$ GeV
$p_T(j_2)$	$> 25(-)$ GeV
$\lvert\eta(j_i)\rvert$	< 4.9
# of tracks	≥ 5
m_{DV}	> 10 GeV
$\lvert d_0\rvert$	> 2 mm
$\left(\sqrt{L_x^2 + L_y^2}\right)_{\text{min}}$	4 mm.
$\left(\sqrt{L_x^2 + L_y^2}\right)_{\text{max}}$	300 mm.
$\lvert L_z\rvert$	< 300 mm.

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Final number of events with displaced dilepton for $\alpha_{NH} = 10^{-3}(10^{-2})$

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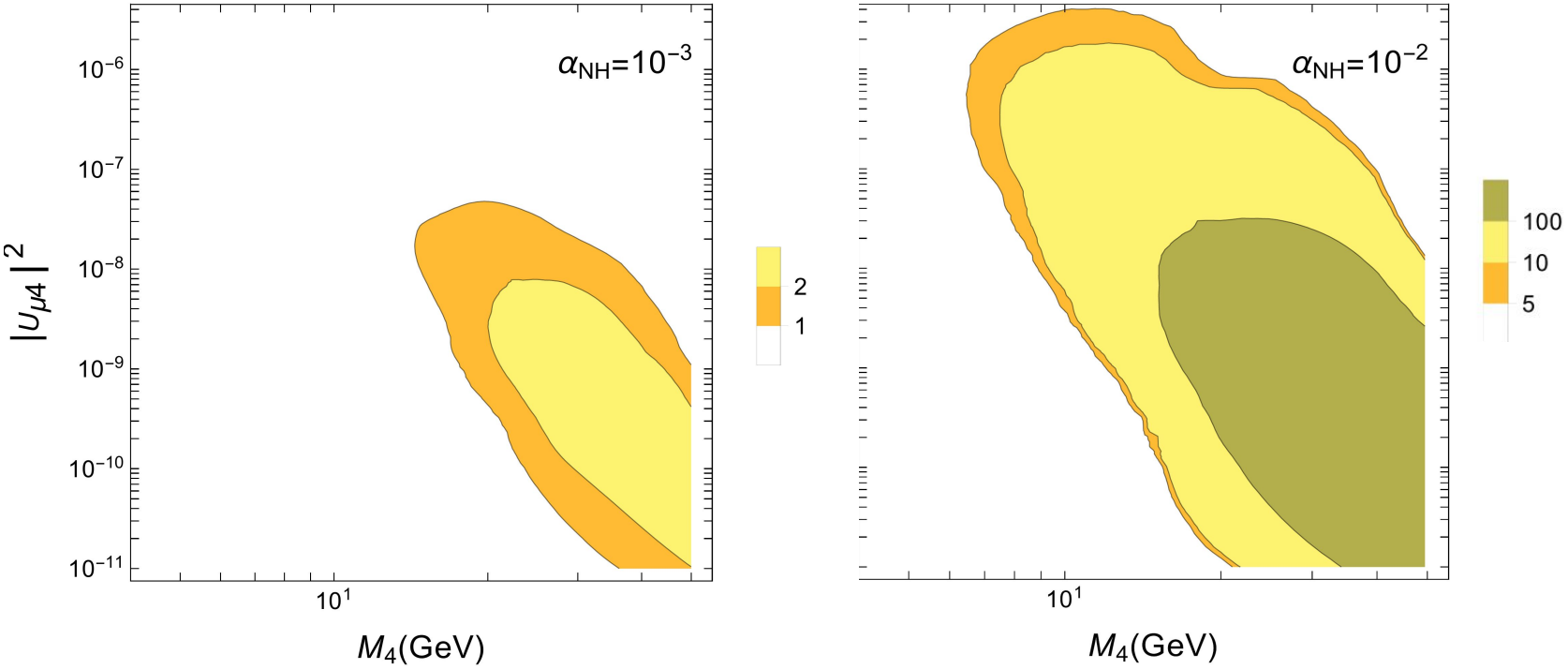

Sensitivity with displaced multitrack jets for $\alpha_{NH} = 10^{-3}(10^{-2})$

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Sensitivity with displaced multitrack jets for $\alpha_{NH} = 10^{-3}(10^{-2})$

$$Z_A = \sqrt{2\left((\mathrm{s}+\mathrm{b})\ln\left(1+\frac{\mathrm{s}}{\mathrm{b}}\right)-\mathrm{s}\right)}$$

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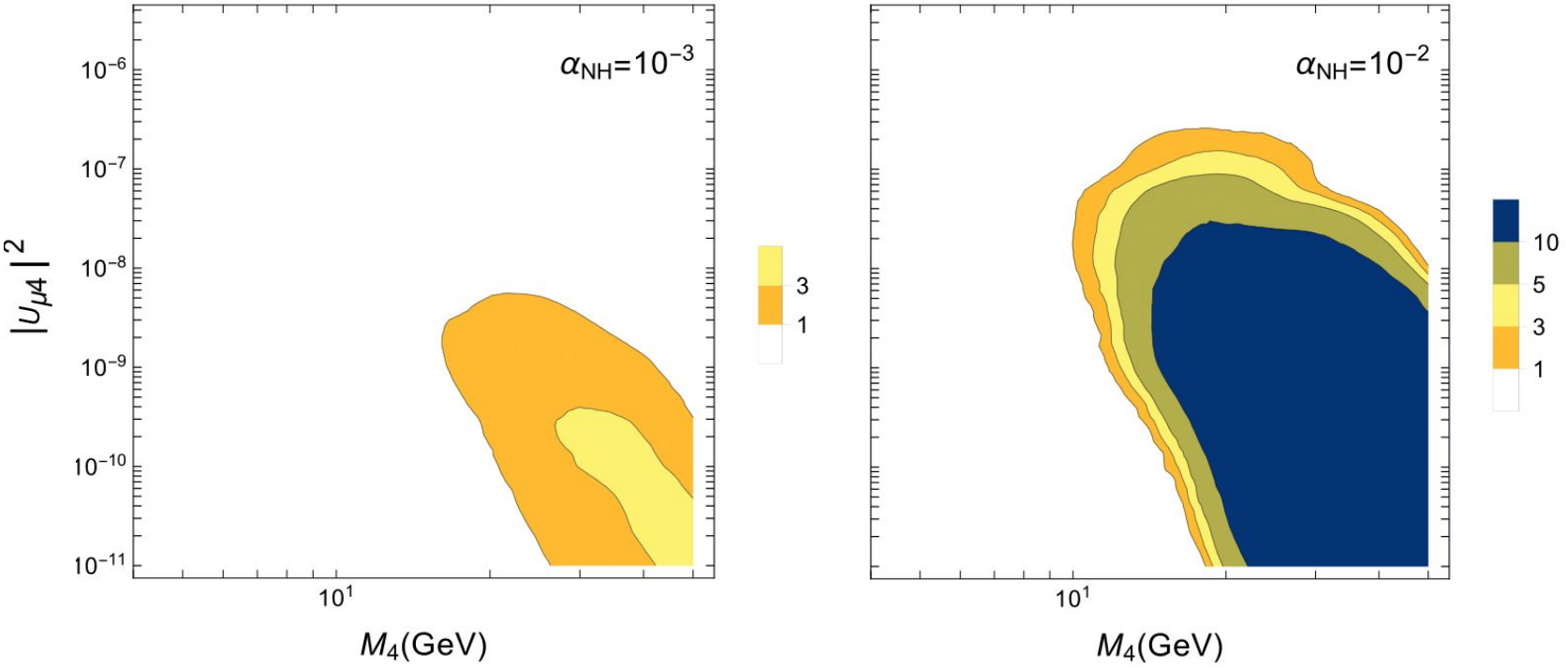
Sensitivity with displaced multitrack jets for $\alpha_{NH} = 10^{-3}(10^{-2})$



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