* Based on Arxiv:2204.03011 Pilar Coloma, Maria Concepcion Gonzalez-Garcia, Michele Maltoni,J.P.P., Salvador Urrea

Constraining New Physics with Borexino Phase-II spectral data

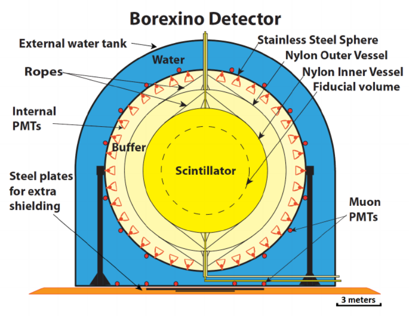
João Paulo Pinheiro*

Universitat de Barcelona

May 7, 2023

Summary

Experiment



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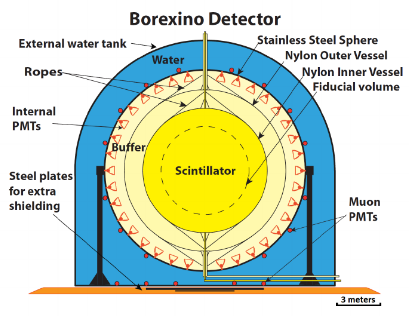
Experiment



Borexino Phase-II data was collected between December 14th, 2011 to May 21st, 2016 and the CNO flux was not detected yet.

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Analysis of Borexino Phase-II Spectrum

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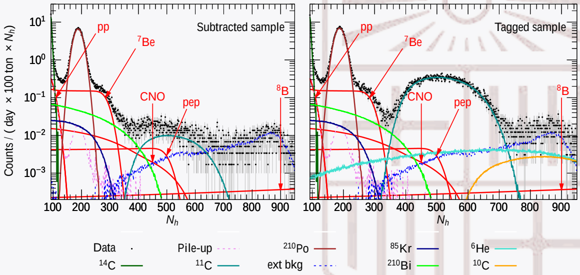

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⋆ With the constructed and verified χ^2 we studied BSM scenarios affecting the propagation and/or de interaction of the neutrinos.

SM interactions

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⋆ In the calculation of the $\nu_e \to \nu_\beta$ neutrino transition probabilities $P_{e\beta}(E_\nu)$, we included the propagation matter effects thought the Sun and Earth.

INTERPLAY OSCILLATIONS-INTERACTIONS IN LFV BSM SCENARIOS

⋆ In our analysis we made use of the full density matrix of neutrino's propagation, $\rho^{(e)}_{\alpha\beta} = S_{\alpha e} S^{\star}_{\beta e}$, where S is the neutrino evolution matrix, thus accounting also for its non-diagonal entries as compared to a formulation based solely on neutrino probabilities:

$$N_{\rm ev} \; / \; \sum_{\beta} P_{e\beta}\, \sigma_{\beta}^{\rm SM} \; ! \; N_{\rm ev} \; / \; Tr\left[\rho^{(e)}\, \sigma^{\rm SM}\right] \, ,$$

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$$N_{\rm ev} \propto \sum_{\beta} P_{e\beta}\, \sigma^{\rm SM}_{\beta} \;\to\; N_{\rm ev} \propto Tr\left[\rho^{(e)}\, \sigma^{\rm SM}\right],$$

⋆ In the SM, the generalized cross section matrix $\sigma^{\rm SM}$ is diagonal in the flavour basis: $\sigma^{\rm SM} = (\sigma^{\rm SM}_{\beta})$, hence recovering the usual probability-based formula.

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INTERPLAY OSCILLATIONS-INTERACTIONS IN LFV BSM SCENARIOS

$\star$ When the BSM is not lepton-flavour conserving, the CC-defined flavour basis may no longer correspond to the NC eigenstates, and extra care must be taken with the interplay of oscillations and scattering. In this case the corresponding generalized cross section matrix σ^{BSM} will not be diagonal.

NON-STANDARD INTERACTIONS

$$L_{\mathrm{NSI,NC}} = 2\sqrt{2}G_F \sum_{f,P,\alpha,\beta} \epsilon^{f,P}_{\alpha\beta}(\nu_\alpha\gamma^\mu P_L\nu_\beta)(f\gamma_\mu P f) ,$$

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⋆ We considered four Lorentz structures of NSI operators: Vector, Axial, Left and Right.

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⋆ We considered four Lorentz structures of NSI operators: Vector, Axial, Left and Right.

⋆ We included all 6 (real) NSI coefficients for each structure $\to$ quantify importance of correlations and cancellations.

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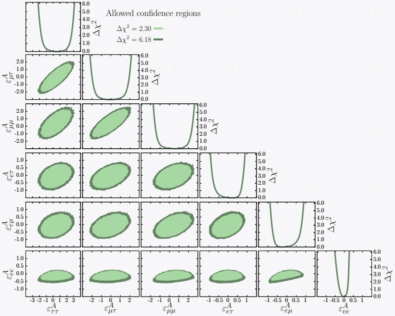
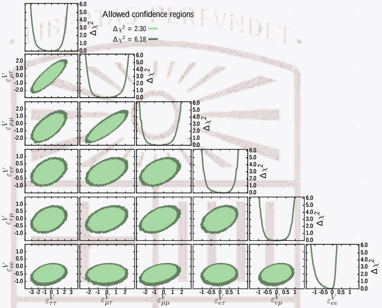
NON-STANDARD INTERACTIONS-Vector and Axial



Axial



Vector

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NEUTRINO MAGNETIC MOMENT

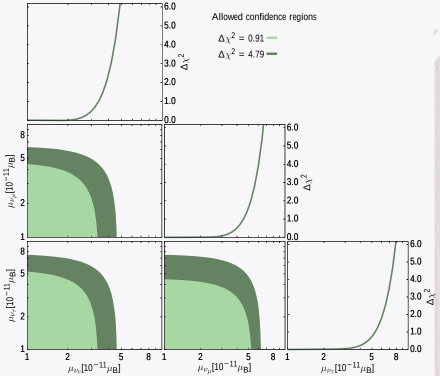
$$L_{MM} = \sum_{\alpha} \frac{\mu_{\nu_\alpha}}{m_e \mu_B} \nu_{\alpha,L} \sigma^{\mu\nu} \nu_{\alpha,R} F_{\mu\nu},$$

NEUTRINO MAGNETIC MOMENT

$$L_{\rm MM} = \sum_{\alpha} \frac{\mu_{\nu_\alpha}}{m_e \mu_B} \nu_{\alpha,L} \sigma^{\mu\nu} \nu_{\alpha,R} F_{\mu\nu},$$

⋆ We allowed different magnetic moments for the different neutrino flavours - albeit still imposing that they are flavour-diagonal.

NEUTRINO MAGNETIC MOMENT



Obtained the bound (with 90% CL for 1 d.o.f., one-sided)

$$\mu_\nu < 2.8 \times 10^{-11} \mu_B,$$

and for one-dimensional projections (with 90% CL for 1 d.o.f., one-sided)

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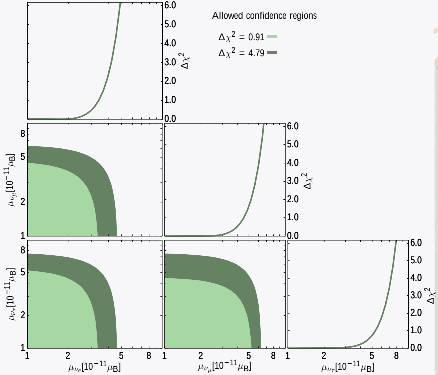
NEUTRINO MAGNETIC MOMENT



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$$\mu_\nu < 2.8 \quad 10 \quad ^{11}\mu_B,$$

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$\mu_{\nu e} < 3.7 \quad 10 \quad ^{11}\mu_B$,
$\mu_{\nu\mu} < 5.0 \quad 10 \quad ^{11}\mu_B$ and
$\mu_{\nu\tau} < 5.9 \quad 10 \quad ^{11}\mu_B$.

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LIGHT SCALAR, PSEUDO-SCALAR AND VECTOR MEDIATORS

$$L_{\phi} = g_{\phi}\,\phi\left(q_{\phi}^{e}\,ee + \sum_{\alpha} q_{\phi}^{\nu_\alpha}\,\nu_{\alpha,R}\,\nu_{\alpha,L} + \text{h.c.}\right) \quad \frac{1}{2}M_{\phi}^{2}\,\phi^{2}\,,$$

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$$L_{\varphi} = i\,g_{\varphi}\,\varphi\left(q_{\varphi}^{e}\,e\gamma^{5}e + \sum_{\alpha} q_{\varphi}^{\nu_\alpha}\,\nu_{\alpha,R}\,\gamma^{5}\nu_{\alpha,L} + \text{h.c.}\right) \quad \frac{1}{2} M_{\varphi}^{2}\,\varphi^{2}\,,$$

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$$L_{V} = g_{Z^0}\,Z^0_{\mu}\left(q^{e}_{Z^0}\,e\gamma^{\mu}e + \sum_{\alpha} q^{\nu_\alpha}_{Z^0}\,\nu_{\alpha,L}\gamma^{\mu}\nu_{\alpha,L}\right) + \frac{1}{2}M^2_{Z^0}Z^{0\mu}Z^0_{\mu}.$$

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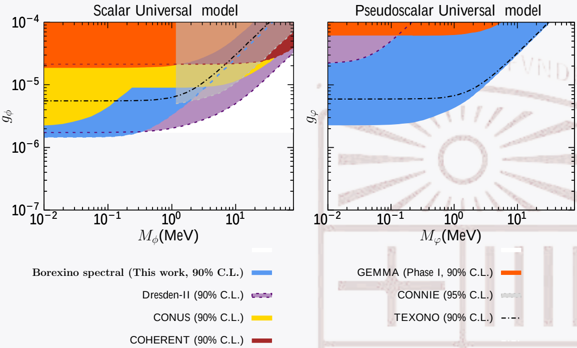
$$L_{V} = g_{Z^0}\, Z_{\mu}^{0} \left(q_{Z^0}^{e}\, e\gamma^{\mu} e + \sum_{\alpha} q_{Z^0}^{\nu_\alpha}\, \nu_{\alpha,L} \gamma^{\mu} \nu_{\alpha,L} \right) + \frac{1}{2} M_{Z^0}^{2} Z^{0\mu} Z_{\mu}^{0} .$$

⋆ We considered three anomaly-free vector mediators that can contribute for the electron neutrino ES.

SCALAR AND PSEUDO-SCALAR



⋆ In the scalar scenario ! very light mediator masses M_ϕ 0.5 MeV.

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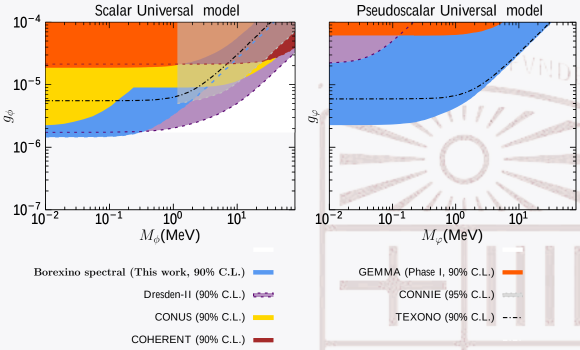

- ⋆ In the scalar scenario ! very light mediator masses M_ϕ 0.5 MeV.
- ⋆ In the pseudoscalar scenario ! mediator masses M_φ . 5 MeV.

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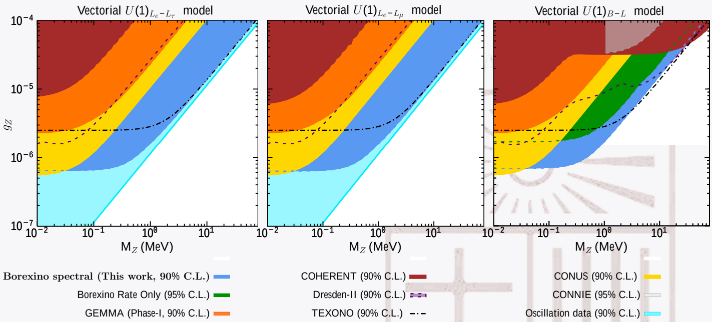
VECTOR MEDIATOR



⋆ Improved by a factor 60% on the upper bound for very light mediators (and by about 30% on g_{Z^0}/M_{Z^0} in the contact-interaction regime).

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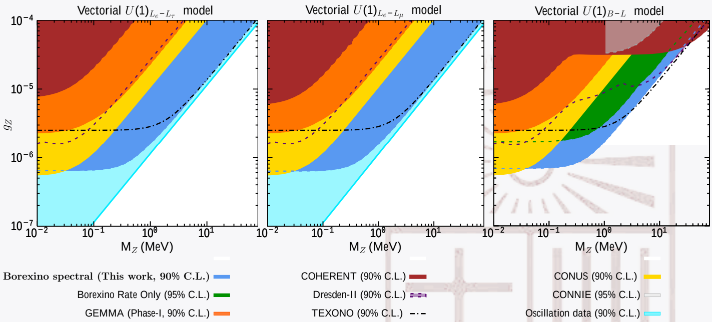

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⋆ Improvements on the bounds from scattering experiments.

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Thank you!

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