Constraints on models with light mediators from the latest CONNIE results

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The CONNIE detector

The Coherent Neutrino-Nucleus Interaction Experiment (CONNIE) [1], located 30 m from the core of the Angra 2 nuclear reactor in Rio de Janeiro, Brazil, uses low-noise fully depleted charge-coupled devices (CCDs) with the goal of measuring low-energy nuclear recoils from the coherent elastic scattering produced by reactor antineutrinos with silicon nuclei (CEνNS).

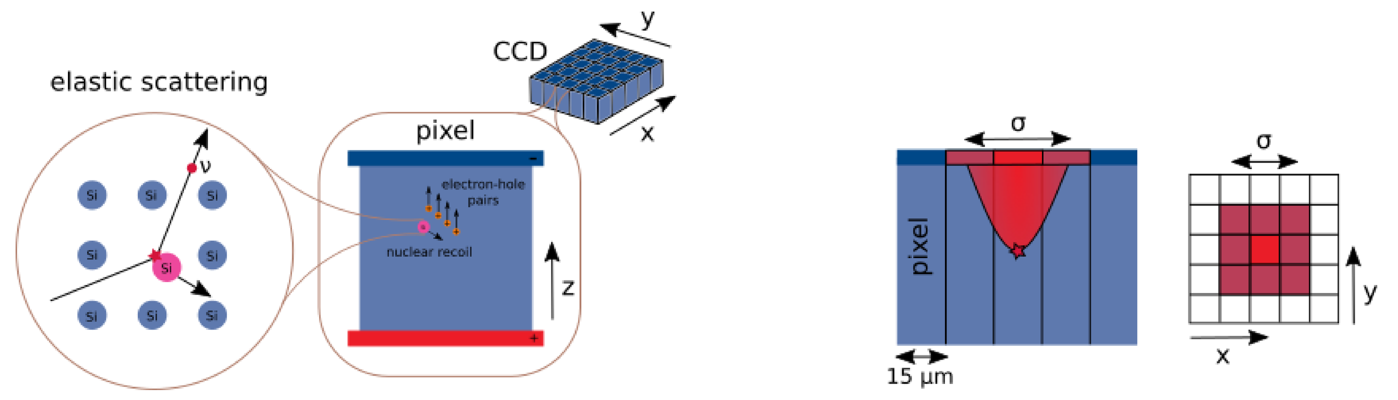

Figure 1. CCD mechanism of particle detection.

Information of interest

- The CONNIE engineering run was carried out in 2014–2015.
- Since August 2016, CONNIE has been taking data continuously.
- Its active mass is 73.2 g (12 CCDs).
- Energy calibration is stable within 0.2%.
- Energy resolution and size-depth calibration are well described by normal distributions with given variances.
- Low-energy background is stable during reactor on (RON) and reactor off (ROFF) periods.
- Typical ranges of readout noise and dark current are $\sigma \simeq 1.7 - 2.2$ e$^-$ and $\lambda \simeq 0.05 - 0.25$ e$^-$/pix/hr, respectively.

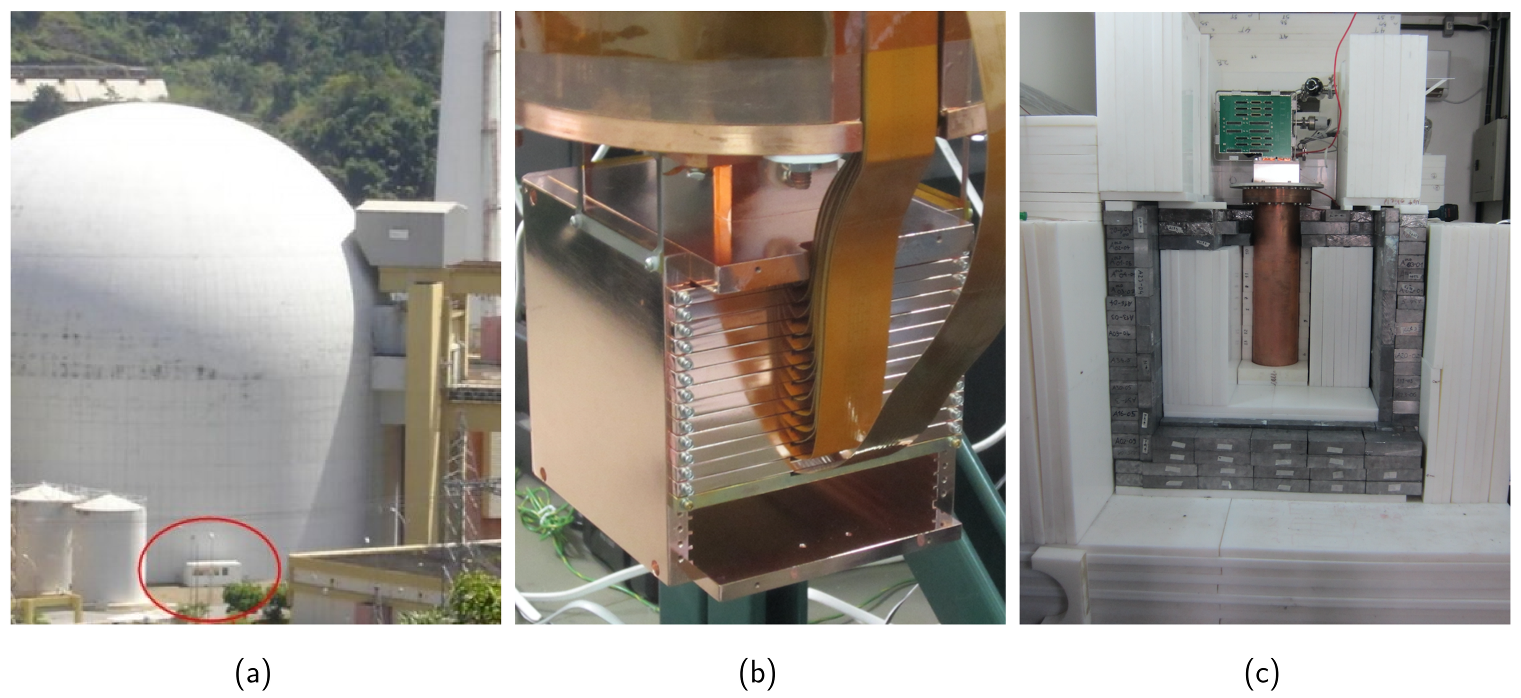

Figure 2. (a) CONNIE location next to Angra 2 reactor, (b) Cold box with 14 CCD packages and (c) Shielding partially disassembled.

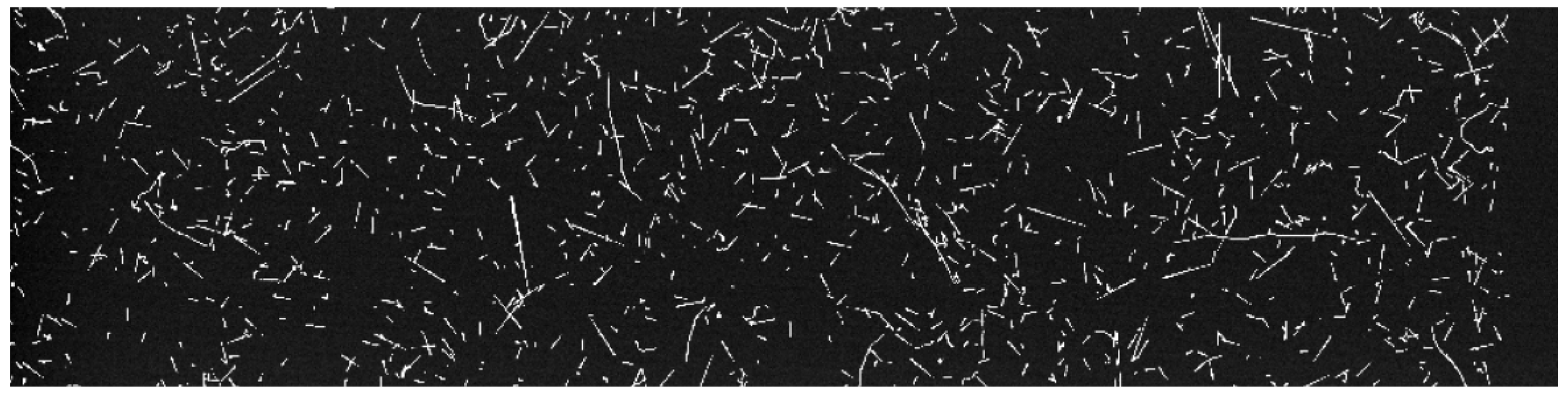

Figure 3. Part of a 3 hours exposure CONNIE image.

Latest results

The total exposure of good-quality data considered is 2.1 kg-days with RON and 1.6 kg-days with ROFF. **The data show no significant excess of events in the RON and ROFF subtraction, yielding a 95% C.L. limit on the neutrino interaction rate [1].**

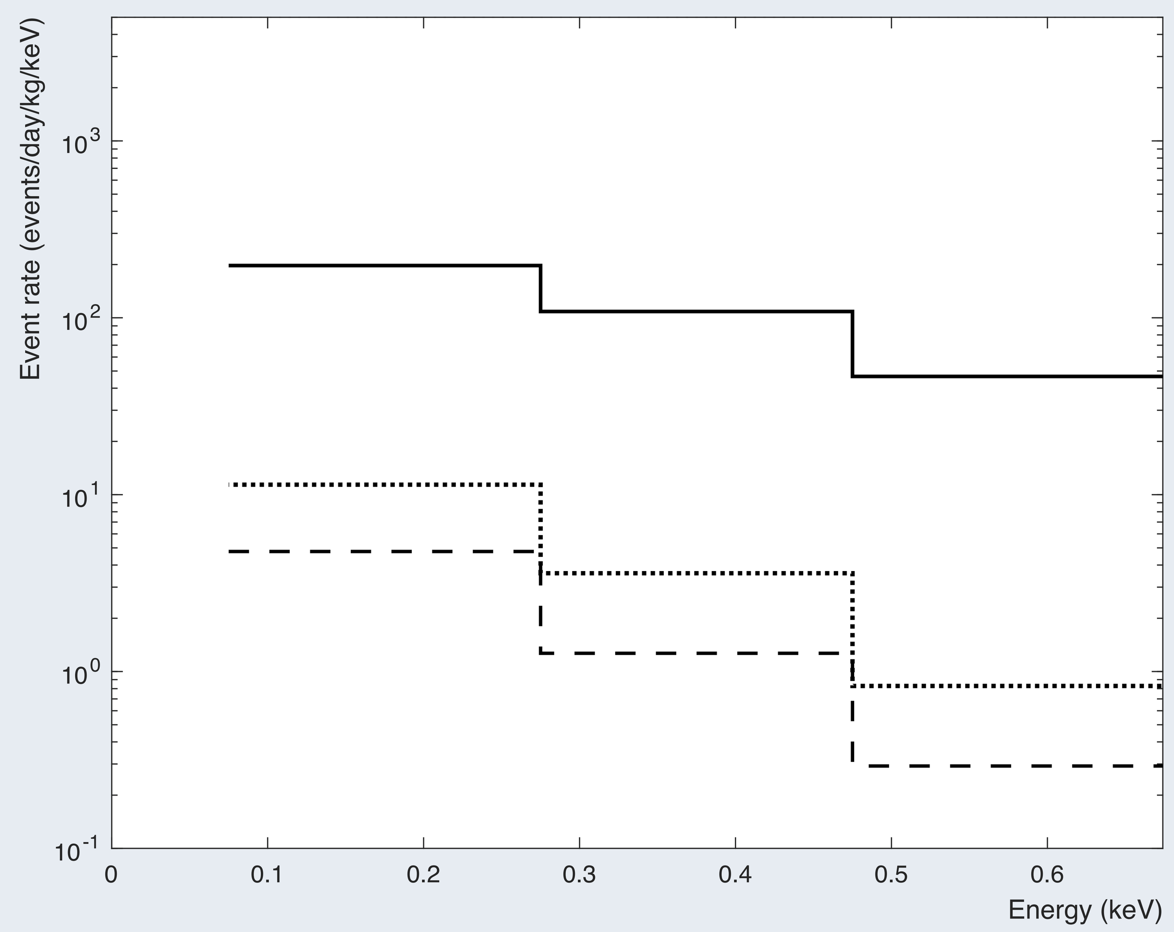

Figure 4. CEνNS event rate: 95% C.L. limit from the RON−ROFF measurement (solid) and neutrino signal expected from the Standard Model using the Chavarria [2] (dashed) and Lindhard [3] (dotted) quenching factors.

Light mediators simplified models

The CEνNS Standard Model differential cross-section $d\sigma_{SM}/dE_R$ is modified by the presence of new light mediators (LM) [4]:

- **Light vector mediator Z'**

$$\frac{d\sigma_{SM+Z'}}{dE_R}(E_{\bar{\nu}_e}) = \left(1 - \frac{Q_{Z'}}{Q_W}\right)^2 \frac{d\sigma_{SM}}{dE_R}(E_{\bar{\nu}_e}) \quad \text{where} \quad Q_{Z'} = \frac{3(N+Z)g'^2}{\sqrt{2}G_F\left(2ME_R+M_{Z'}^2\right)}.$$

- **Light scalar mediator ϕ**

$$\frac{d\sigma_{SM+\phi}}{dE_R}(E_{\bar{\nu}_e}) = \frac{d\sigma_{SM}}{dE_R}(E_{\bar{\nu}_e}) + \frac{G_F^2}{4\pi}Q_\phi^2\left(\frac{2ME_R}{E_{\bar{\nu}_e}^2}\right)MF^2(q) \quad \text{where} \quad Q_\phi = \frac{(14N+15.1Z)g_\phi^2}{\sqrt{2}G_F\left(2ME_R+M_\phi^2\right)}.$$

Here, Z' (ϕ) has a purely vector (scalar) interaction with a universal flavor-conserving coupling g' (g_ϕ) to the first generation of quarks and leptons. M, N and Z are the mass, neutron and proton numbers of the recoiling nucleus. $E_{\bar{\nu}_e}$ and E_R are the incident antineutrino and recoiling nucleus energies, respectively.

Constraints on light mediators models

The CONNIE expected event rates including the LM interactions were calculated for the lowest-energy bin of Fig. 4. The limits on the LM models' parameters are set when this rate equals the 95% C.L. limit established by the latest CONNIE results [5].

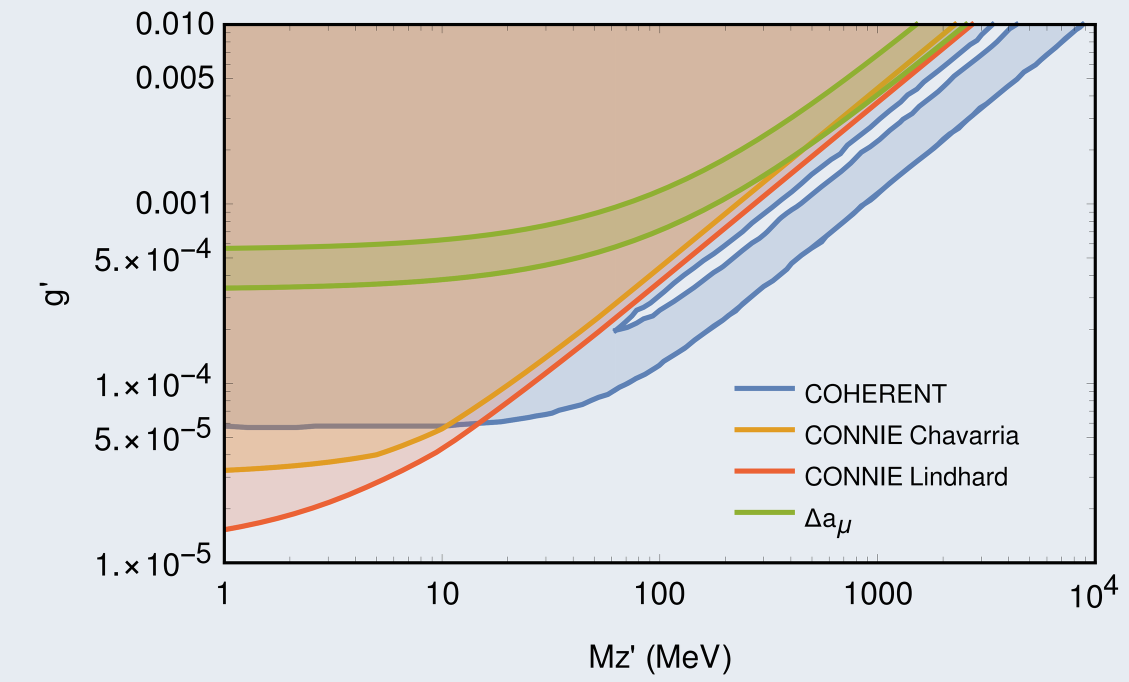

Figure 5. Exclusion region for a vector mediator in the $(M_{Z'}, g')$ plane assuming quenching factors from Chavarria [2] (orange) and Lindhard [3] (red). The COHERENT limit curve [6] (blue) and the 2σ allowed region to explain the anomalous magnetic moment of the muon ($\Delta a_\mu = 268 \pm 63 \times 10^{-11}$) (green) are shown for reference.

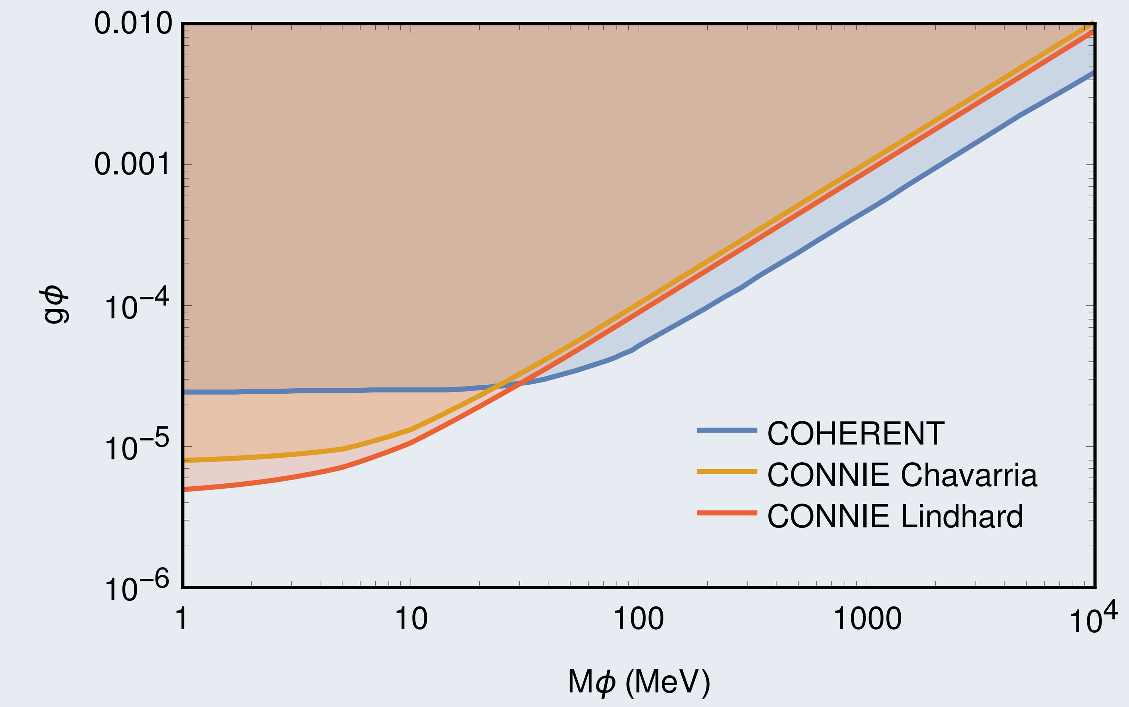

Figure 6. Exclusion region for a scalar mediator in the (M_ϕ, g_ϕ) plane assuming quenching factors from Chavarria [2] (orange) and Lindhard [3] (red). The 90% COHERENT limit curve [7] (blue) is shown for reference.

The current CONNIE data yields the most stringent limits, at low mediator masses (1-10 MeV), among the experiments searching for CEνNS. Reactor experiments provide a powerful probe for new physics at low energies [5].

References

[1] A. Aguilar-Arevalo et al. Exploring low-energy neutrino physics with the coherent neutrino nucleus interaction experiment. *Phys. Rev. D*, 100:092005, 2019.

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[4] D. G. Cerdeño et al. Physics from solar neutrinos in dark matter direct detection experiments. *JHEP*, 05:118, 2016. Erratum: JHEP 09 (2016) 048.

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[6] J. Liao and D. Marfatia. COHERENT constraints on nonstandard neutrino interactions. *Phys. Lett. B*, 775:54, 2017.

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Future perspectives

CONNIE has continued taking data with a new operation mode, improving the efficiency at low energies. New results are coming soon. Stay tuned!