CEvNS and physics Beyond the Standard Model with the CONNIE Experiment

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Introduction

CONNIE (Coherent Neutrino-Nucleus Interaction Experiment) aims to measure the coherent elastic scattering (CEvNS) of reactor antineutrinos with silicon nuclei in CCDs and to probe physics beyond the standard model [1,2].

Located 30 m from the 3.8 GW Angra2 reactor in Angra dos Reis, Brazil, CONNIE benefits from a high flux of approximately 7.8×10¹² $\bar{\nu}_e$ /s cm².

Fig 1. CONNIE site in the Almirante Álvaro Alberto nuclear power plant, in Angra dos Reis, Brazil.

Skipper-CCDs

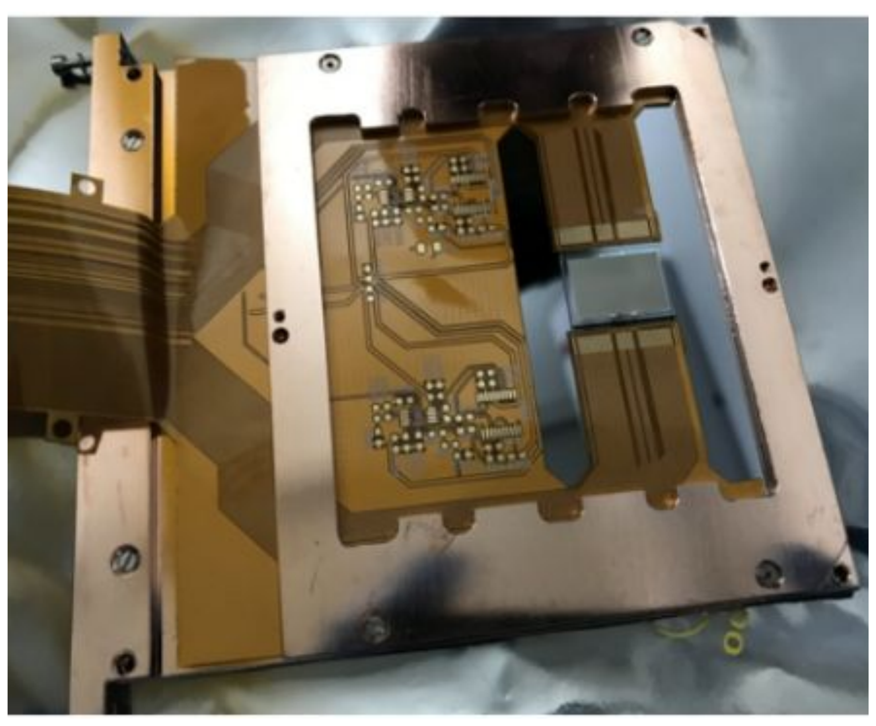

Fig 2. CONNIE Skipper CCD (15μm×15μm) (675μm×1022x682 pixels).

Skipper-CCDs are an array of metal oxide semiconductor capacitors organized in pixels. With a nondestructive output readout stage, they enable multiple charge samplings in each pixel, reducing readout noise to sub-electron levels [3].

This reduction in the noise is essential for lowering the detection energy threshold, optimizing their sensitivity to low energies required for detecting CEvNS.

In July 2021 two Skipper-CCDs were installed in the CONNIE detector [4].

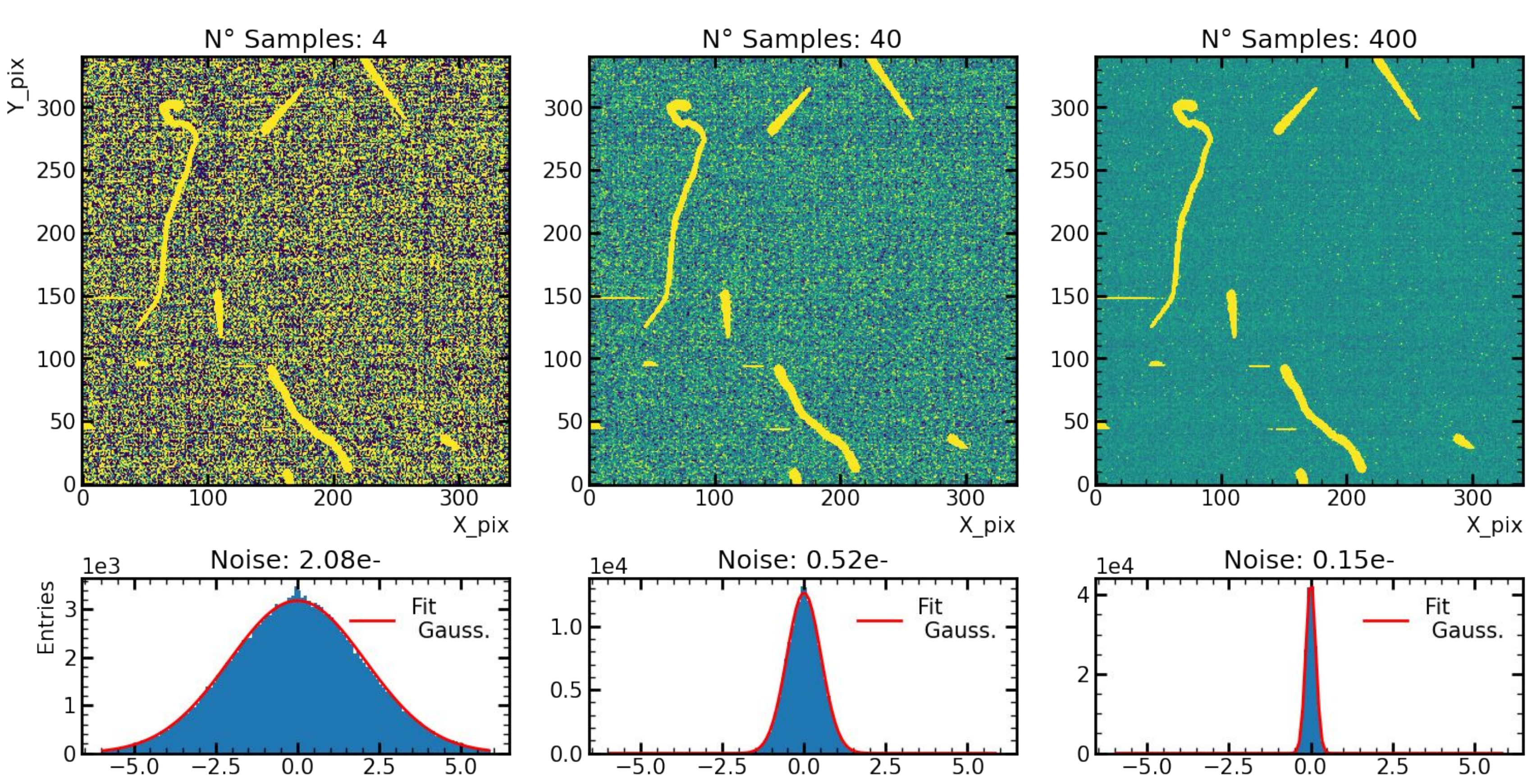

Fig 3. Impact of the Nº of samples in the sharpness of the image and in the Readout Noise.

Detector Setup

The CONNIE detector is surrounded by a passive shielding consisting of outer and inner 30 cm layers of polyethylene to block neutrons and an inner 15 cm layer of lead. The CCDs are kept in a vessel cooled to ~100 K in a vacuum. A Low Threshold Acquisition readout board is utilized for data acquisition [5].

To achieve the detection goals, background measurements are done in reactor shutdown periods and compared with data obtained when the reactor is operational.

Fig 4. A view of the CONNIE detector and its shielding.

Detection efficiency

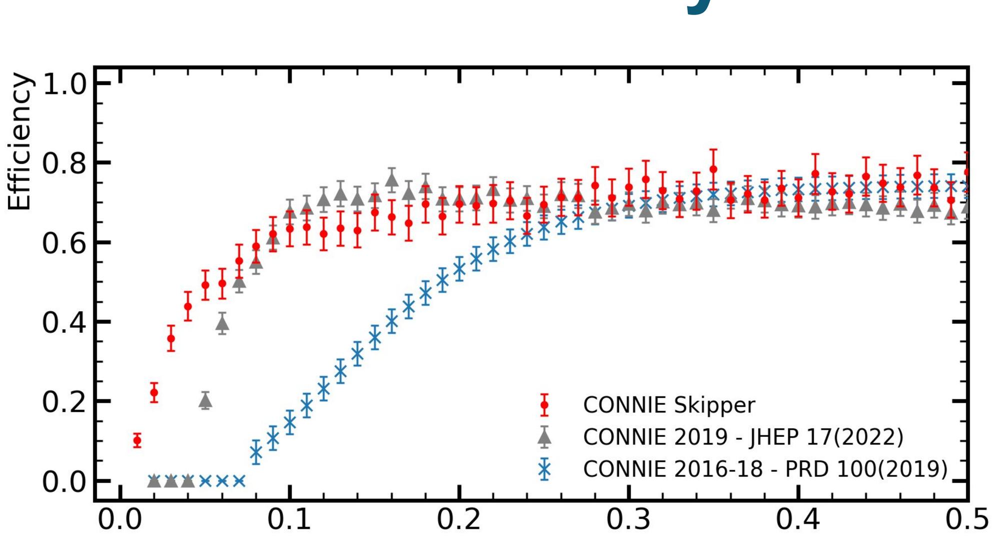

Fig 5. CONNIE detection efficiency comparison [4].

The overall detection efficiency accounts for the event extraction acceptance and the selection cuts.

Based on the extended efficient operation to lower energies, the energy detection threshold was reduced to 15 eV.

Energy spectrum

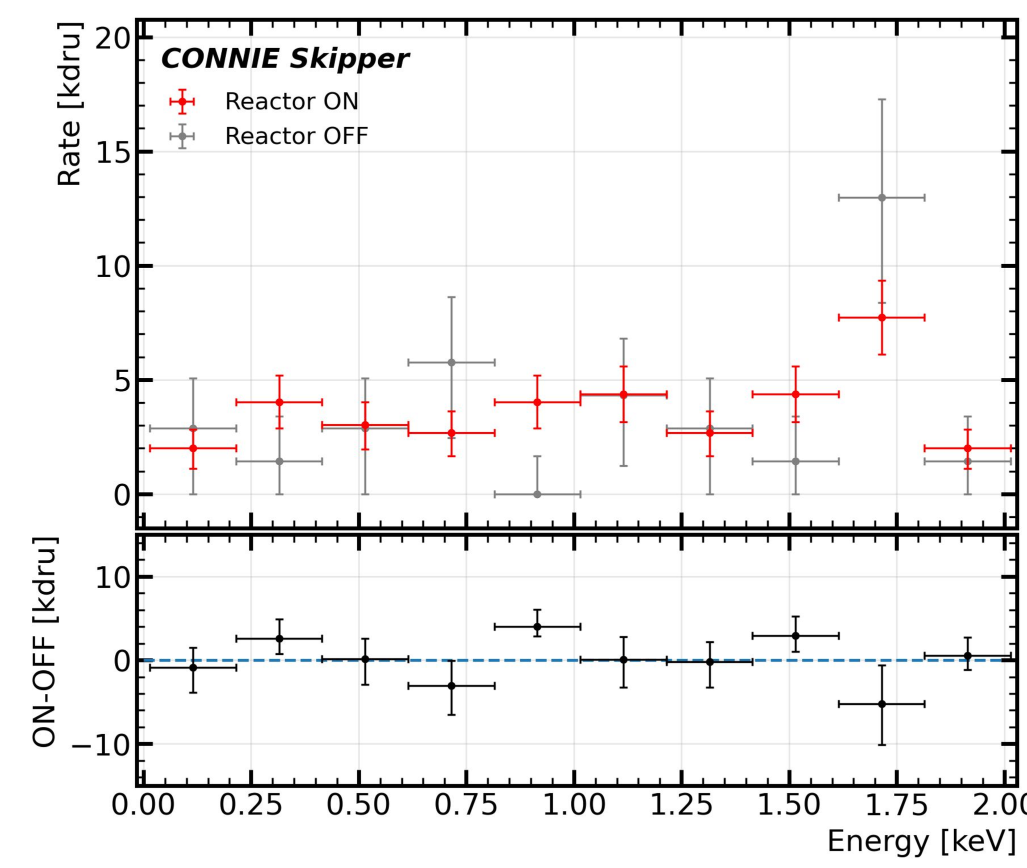

Fig 6. CONNIE Skipper reactor-on and off spectra and their difference [4].

With 2 Skipper-CCDs (~0.25 g total) and the exposure parameters in Table 1, a difference between the spectra is constructed.

Table 1. Exposure parameters.

Reactor Periods	Readout Time	Exposure Time	Total Exposure
OFF	1,1 months	17 days	3.5 g.day
ON	5 months	75 days	14.9 g.day

Flat Reactor-ON and OFF spectra are observed. As expected, due to the small mass of the detector, the Reactor ON-OFF rate is consistent with zero.

Search for CEvNS

A 95% C.L. upper limit was established for the observed and expected event rates, and the predicted SM rates were calculated using Sarkis' new quenching factor model [6].

Measured Energy [keV_{ee}]	Sarkis (2023) rate [$kg^{-1}d^{-1}keV_{ee}^{-1}$]	Chavarria rate [$kg^{-1}d^{-1}keV_{ee}^{-1}$]	Observed 95% C.L. [$kg^{-1}d^{-1}keV_{ee}^{-1}$]	Expected 95% C.L. [$kg^{-1}d^{-1}keV_{ee}^{-1}$]
0.015 − 0.215	$29.3^{+4.6}_{-4.7}$	17.7 ± 3.3	2.24 × 10³	3.18 × 10³
0.215 − 0.415	$2.70^{+1.3}_{-1.2}$	2.20 ± 0.21	7.36 × 10³	4.77 × 10³
0.415 − 0.615	$0.43^{+0.41}_{-0.39}$	0.36 ± 0.04	3.41 × 10³	3.31 × 10³

Table 2. CEvNS event rates [4].

New light vector mediator

For a simplified model with a new light vector mediator *Z'* the limit in the phase space represents an improvement to our previous result [2] with much larger exposure.

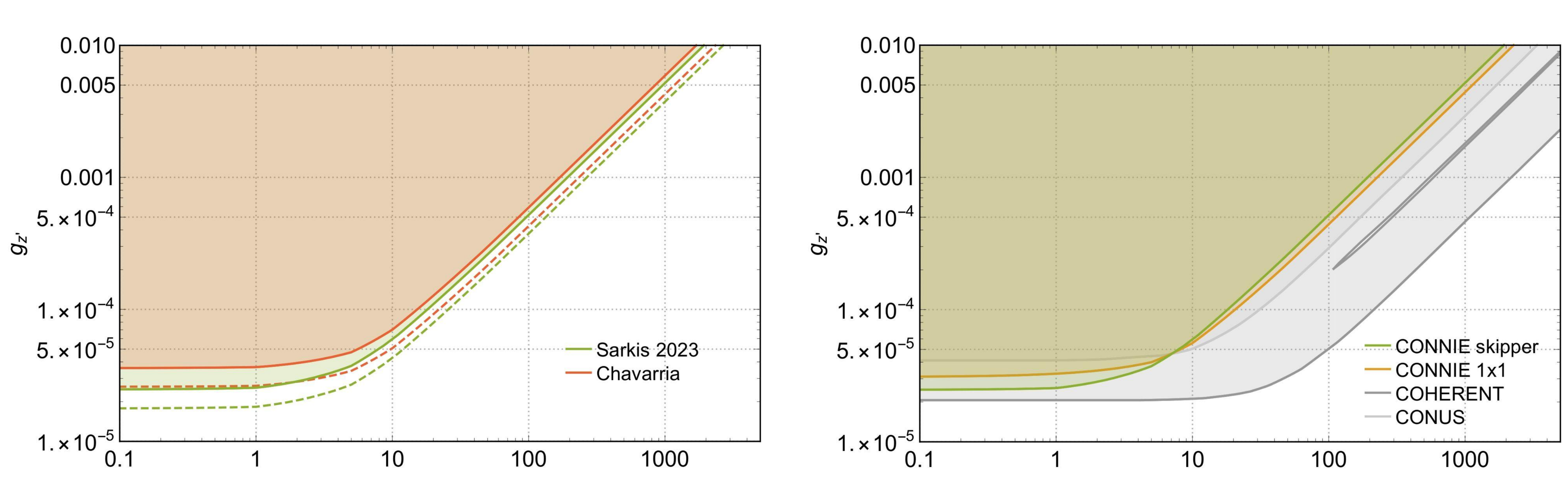

Fig 7. Exclusion limits at 95% C.L. from the CEvNS detection channel for a light vector mediator and it comparison with a previous result and other experiments [4].

Dark matter search by diurnal modulation

A study of diurnal DM modulation was performed for the first time by CONNIE and the results denote the best limits on the DM-electron scattering cross-section, obtained by a surface-level experiment.

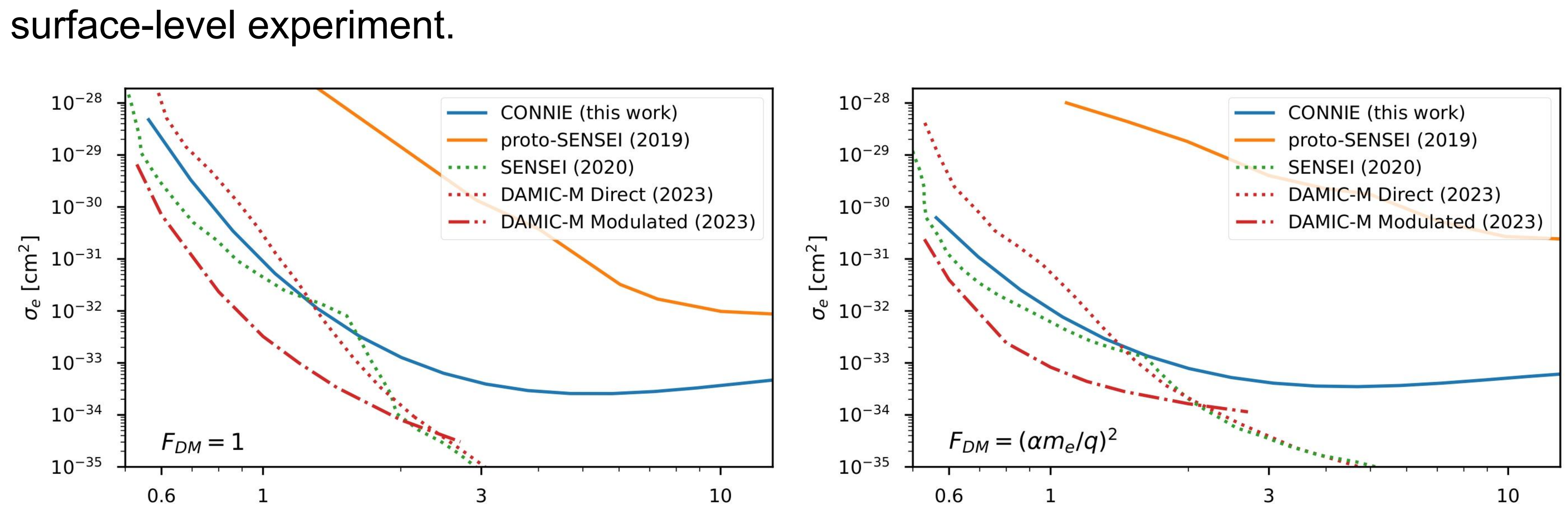

Fig 8. 90% C.L. upper bounds on DM-electron interactions mediated by a heavy (left) and an ultralight dark photon (right) with solid lines for experiments running on the surface and dotted/dashed obtained underground [4].

Future Perspectives

- Installation of 16 new sensors in a compact arrangement on a Multi-Chip-Module (MCM) designed by Oscura is planned for 2024 and will lead to a 32-fold increase in sensor mass;
- A future 1-kg detector with current parameters could detect CEvNS at 90% C.L. in around a month.

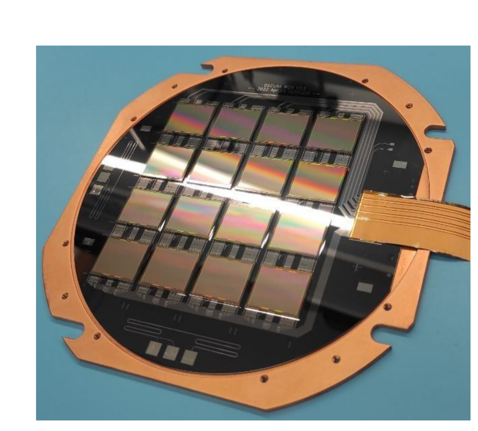

Fig 9. Oscura Design of (MCM) [7].

Acknowledgments

References

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