COherent Neutrino-Nucleus Interaction Experiment (CONNIE): Status and Plans

CONNIE Collaboration

Alexis Aguilar-Arevalo,[a] Xavier Bertou,[b] Carla Bonifazi,[c] Gustavo Cancelo,[d] Brenda Aurea Cervantes-Vergara[a] Claudio Chavez,[e] Juan C. D'Olivo,[a] Juan M. De Egea,[e] João C. dos Anjos,[f] Juan Estrada,[d] Aldo R. Fernandes Neto,[g] Guillermo Fernandez-Moroni,[d,h] Ana Foguel,[c] Richard Ford,[d] Julián Gasanego,[i] Victor Gollo,[c] Federico Izraelevitch,[i] Ben Kilminster,[j] H. P. Lima Jr,[f] Martín Makler,[f] Larissa Helena Mendes,[c] Jorge Molina,[e] Philipe Mota,[f] Irina Nasteva,[c] Eduardo Paolini,[h] Youssef Sarkis,[a] Miguel Sofo Haro,[b] Diego Stalder,[e] Javier Tiffenberg,[d] and Christian Torres.[e]

[a] *Universidad Nacional Autónoma de México, Ciudad de México, México*

[b] *Centro Atómico Bariloche and Instituto Balseiro, Comisión Nacional de Energía Atómica (CNEA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Universidad Nacional de Cuyo (UNCUYO), San Carlos de Bariloche, Argentina.*

[c] *Universidade Federal do Rio de Janeiro, Instituto de Física, Rio de Janeiro, RJ, Brazil*

[d] *Fermi National Accelerator Laboratory, Batavia, IL, United States*

[e] *Facultad de Ingeniería - Universidad Nacional de Asunción, Asunción, Paraguay*

[f] *Centro Brasileiro de Pesquisas Físicas, Rio de Janeiro, RJ, Brazil*

[g] *Centro Federal de Educação Tecnológica Celso Suckow da Fonseca, Angra dos Reis, RJ, Brazil*

[h] *Instituto de Investigaciones en Ingeniería Eléctrica, Departamento de Ingeniería Eléctrica y Computadoras, Universidad Nacional del Sur (UNS) - CONICET, Bahía Blanca, Argentina*

[i] *Universidad Nacional de San Martín (UNSAM), Comisión Nacional de Energía Atómica (CNEA), Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina*

[j] *Universität Zürich Physik Institut, Zurich, Switzerland*

Abstract: **The CONNIE experiment is located at a distance of 30 m from the core of a commercial nuclear reactor, and is based on a CCD (charge-coupled device) detector array sensitive to an ∼1 keV threshold for the study of coherent neutrino-nucleus elastic scattering.This experiment has the physics goal of detecting the nuclear recoils produced by coherent scattering of neutrinos, and exploring new physics in the low energy neutrino sector. We discuss here the current status and plans for the experiment.**

1 Physics Goals

Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) is a Standard Model (SM) process predicted more than 40 years ago [1] through which a neutrino interacts coherently with all nucleons present in an atomic nucleus, resulting in an enhancement of the scattering cross section. The enhancement is approximately proportional to the square of the number of neutrons in the nucleus. However, despite its large cross section, this process took a long time to be observed due to the difficulty of measuring the low-energy nuclear recoils produced by the neutrino-nucleus scattering events. Recently, CEνNS was detected by the COHERENT collaboration [2] thanks to the development of novel detectors and the unique neutrino beam facility of the Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory.

The Coherent Neutrino-Nucleus Interaction Experiment (CONNIE) [3] uses low-noise fully depleted charge-coupled devices (CCDs) [4] with the goal of measuring low-energy recoils from CEνNS produced by reactor antineutrinos with silicon nuclei [5]. The CEνNS signal has not been detected yet for the low energy reactor neutrinos.

The potential for CEνNS as a tool to search for beyond the Standard Model physics has been extensively discussed in the literature [6–17]. CONNIE has the scientific goal of exploring low energy CEνNS to search for new physics, and its first results have been recently published [18].

2 Status

The CONNIE engineering run, carried out in 2014–2015, is discussed in [19]. The detector installed in 2016 has an active mass of 73.2 g (12 CCDs) and is located 30 m from the core of the Angra 2 nuclear reactor, which has a thermal power of 3.95 GW. The CONNIE detector is sensitive to recoil energies down to 1 keV. A search for neutrino events is performed by comparing data with the reactor on (2.1 kg-day) and the reactor off (1.6 kg-day), the results show no excess in the reactor-on data [20]. A model independent 95% Confidence Level (C.L.) upper limit for new physics was established at an event rate of $\sim$40 times the one expected from the SM at the lowest energies. These data were used to search for low mass mediators, establishing the best world limits from CEνNS for the benchmark scalar and vector simplified models [18]. This result shows the potential of experiments searching for CEνNS with low-energy reactor neutrinos to probe new physics in a way that is complementary to spallation neutrino experiments.

3 Plans

CONNIE has continued operations for two more years after the published results [20]. The new data have been collected with hardware binning in the CCD readout, a technique used to increase the signal to noise for low energy events. This gives an increased efficiency at low energies, and higher signal-to-background discrimination in the region of most interest for CEνNS and non-standard neutrino interactions. The results of this new run are expected by the end of 2020.

Depending on the results from the 2020 run, CONNIE will decide to either continue operating the existing CCD array or upgrade the detector to include a small fraction of skipper-CCDs [21]. These new sensors reduce the threshold by approximately a factor of five, enhancing the scientific reach of the experiment for CEνNS and non-standard neutrino interactions. The CONNIE Collaboration is working closely with a larger group of researchers developing a multi-kilogram skipper-CCD reactor neutrino experiment with an active mass of several kilograms. We see the ongoing CONNIE effort as a pathfinder for this ultimate low energy skipper-CCD experiment at a nuclear reactor.

References

[1] D. Z. Freedman, *Coherent effects of a weak neutral current*, *Phys. Rev. D* **9** (1974) 1389.

[2] **COHERENT** Collaboration, D. Akimov et al., *Observation of Coherent Elastic Neutrino-Nucleus Scattering*, *Science* **357** (2017) 1123, [arXiv:1708.01294].

[3] **CONNIE** Collaboration, A. Aguilar-Arevalo et al., *The CONNIE experiment*, *J. Phys. Conf. Ser.* **761** (2016) 012057, [arXiv:1608.01565].

[4] S. E. Holland, D. E. Groom, N. P. Palaio, R. J. Stover, and M. Wei, *Fully depleted, back-illuminated charge-coupled devices fabricated on high-resistivity silicon*, *IEEE Transactions on Electron Devices* **50** (2003), no. 1 225.

[5] G. Fernandez Moroni, J. Estrada, E. E. Paolini, G. Cancelo, J. Tiffenberg, and J. Molina, *Charge Coupled Devices for detection of coherent neutrino-nucleus scattering*, *Phys. Rev. D* **91** (2015) 072001, [arXiv:1405.5761].

[6] R. Harnik, J. Kopp, and P. A. N. Machado, *Exploring ν signals in dark matter detectors*, *JCAP* **07** (2012) 026, [arXiv:1202.6073].

[7] J. Billard, J. Johnston, and B. J. Kavanagh, *Prospects for exploring New Physics in Coherent Elastic Neutrino-Nucleus Scattering*, *JCAP* **11** (2018) 016, [arXiv:1805.01798].

[8] J. Liao and D. Marfatia, *COHERENT constraints on nonstandard neutrino interactions*, *Phys. Lett. B* **775** (2017) 54, [arXiv:1708.04255].

[9] D. Aristizabal Sierra, V. De Romeri, and N. Rojas, *COHERENT analysis of neutrino generalized interactions*, *Phys. Rev. D* **98** (2018) 075018, [arXiv:1806.07424].

[10] A. N. Khan and W. Rodejohann, *New physics from COHERENT data with an improved quenching factor*, *Phys. Rev. D* **100** (2019) 113003, [arXiv:1907.12444].

[11] T. S. Kosmas, D. K. Papoulias, M. Tortola, and J. W. F. Valle, *Probing light sterile neutrino signatures at reactor and Spallation Neutron Source neutrino experiments*, *Phys. Rev. D* **96** (2017) 063013, [arXiv:1703.00054].

[12] C. Blanco, D. Hooper, and P. Machado, *Constraining Sterile Neutrino Interpretations of the LSND and MiniBooNE Anomalies with Coherent Neutrino Scattering Experiments*, arXiv:1901.08094.

[13] D. K. Papoulias and T. S. Kosmas, *COHERENT constraints to conventional and exotic neutrino physics*, *Phys. Rev. D* **97** (2018) 033003, [arXiv:1711.09773].

[14] P. B. Denton, Y. Farzan, and I. M. Shoemaker, *Testing large non-standard neutrino interactions with arbitrary mediator mass after COHERENT data*, *JHEP* **07** (2018) 37, [arXiv:1804.03660].

[15] B. Dutta, S. Liao, S. Sinha, and L. E. Strigari, *Searching for Beyond the Standard Model Physics with COHERENT Energy and Timing Data*, *Phys. Rev. Lett.* **123** (2019) 061801, [arXiv:1903.10666].

[16] O. G. Miranda, D. K. Papoulias, M. Tórtola, and J. W. F. Valle, *Probing neutrino transition magnetic moments with coherent elastic neutrino-nucleus scattering*, *JHEP* **07** (2019) 103, [arXiv:1905.03750].

[17] D. K. Papoulias, T. S. Kosmas, and Y. Kuno, *Recent Probes of Standard and Non-standard Neutrino Physics With Nuclei*, *Front. in Phys.* **7** (2019) 191, [arXiv:1911.00916].

[18] **CONNIE** Collaboration, A. Aguilar-Arevalo et al., *Search for light mediators in the low-energy data of the CONNIE reactor neutrino experiment*, *JHEP* **04** (2020) 054, [arXiv:1910.04951].

[19] **CONNIE** Collaboration, A. Aguilar-Arevalo et al., *Results of the Engineering Run of the Coherent Neutrino Nucleus Interaction Experiment (CONNIE)*, *JINST* **11** (2016) P07024, [arXiv:1604.01343].

[20] **CONNIE Collaboration** Collaboration, A. Aguilar-Arevalo et al., *Exploring low-energy neutrino physics with the coherent neutrino nucleus interaction experiment*, *Phys. Rev. D* **100** (2019) 092005, [arXiv:1906.02200].

[21] J. Tiffenberg, M. Sofo-Haro, A. Drlica-Wagner, R. Essig, Y. Guardincerri, S. Holland, T. Volansky, and T.-T. Yu, *Single-Electron and Single-Photon Sensitivity with a Silicon Skipper CCD*, **119** (Sept., 2017) 131802, [arXiv:1706.00028].