CONNIE: Coherent Neutrino-Nucleus Interaction Experiment

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on behalf of the CONNIE collaboration

II Latin American Strategy Forum for Research Infrastructure:
an Open Symposium for HECAP
7 July 2020

The CONNIE collaboration

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~30 members, since 2010

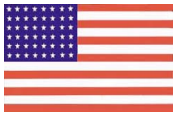
Argentina
Centro Atómico Bariloche
Universidad de Buenos Aires
Universidad del Sur / CONICET

Paraguay
Universidad Nacional de Asunción

Brazil
Centro Brasileiro de Pesquisas Físicas
Universidade Federal do Rio de Janeiro
CEFET-Angra

Switzerland
University of Zurich

Mexico
Universidad Nacional Autónoma de México



USA
Fermilab National Laboratory

The CONNIE experiment

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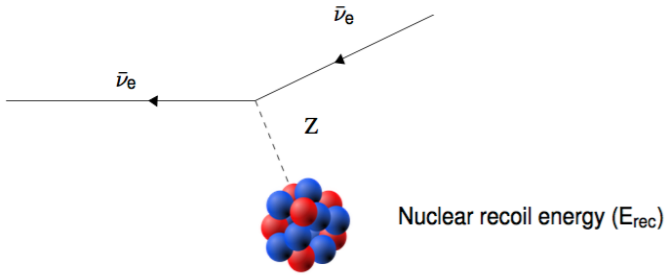
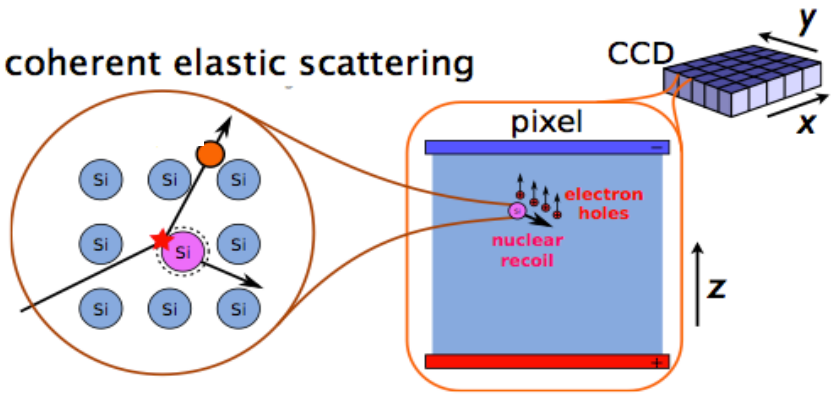
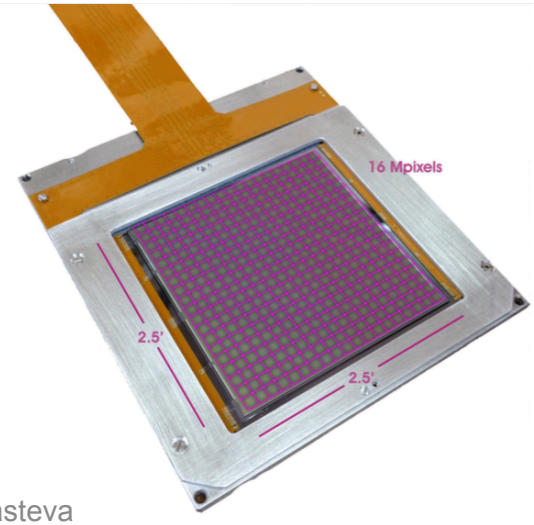
- The main goal is to detect Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) in silicon nuclei and put limits on physics Beyond the Standard Model.
  - CEνNS is the dominant interaction for E_ν<50 MeV.
  - But nuclear recoil energies are small (E_{rec} ~ keV).
  - And the ionisation signals are a fraction of E_{rec}.



- Scientific CCDs with high resistivity and large thickness (675 μm, 5.75 g mass), created at LBNL and used also by DES and DAMIC.
- Very low-energy detection threshold (~40 eV) and low noise.





New Physics with neutrinos

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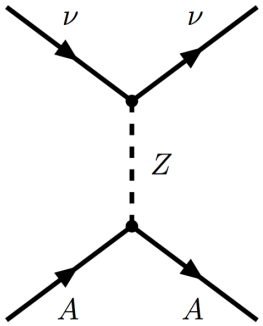
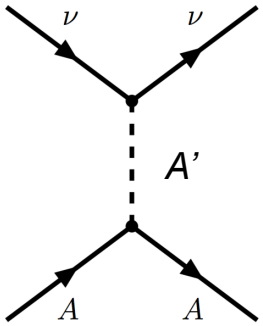
- The coherent scattering rates are calculated with precision in the SM.
- Any discrepancy can be a sign of contributions from “New Physics” interactions:
  - Non-standard interactions of neutrinos (e.g. dark photons).
  - Sterile neutrinos.
  - Neutrino magnetic moment.
  - Neutrino oscillations at low energies and very short baselines.

R. Harnik et al, JCAP 07 (2012) 026
J. Billard et al, JCAP 11 (2018) 016
T. Kosmas et al, PRD 96 (2017) 063013
J. Dent et al, PRD 96 (2017) 095007
D.K. Papoulias et al, Front. Phys. 7 (2019) 191
C. Blanco et al, PRD 101 (2020) 075051

Standard Model





Model with New Physics

- Also important for direct DM searches and supernova physics.
- Once the detection is established, it can be used to create compact detectors for reactor monitoring.

B. Cogswell, P. Huber, Science and Global Security 24, 2 (2016) 114

The CONNIE detector

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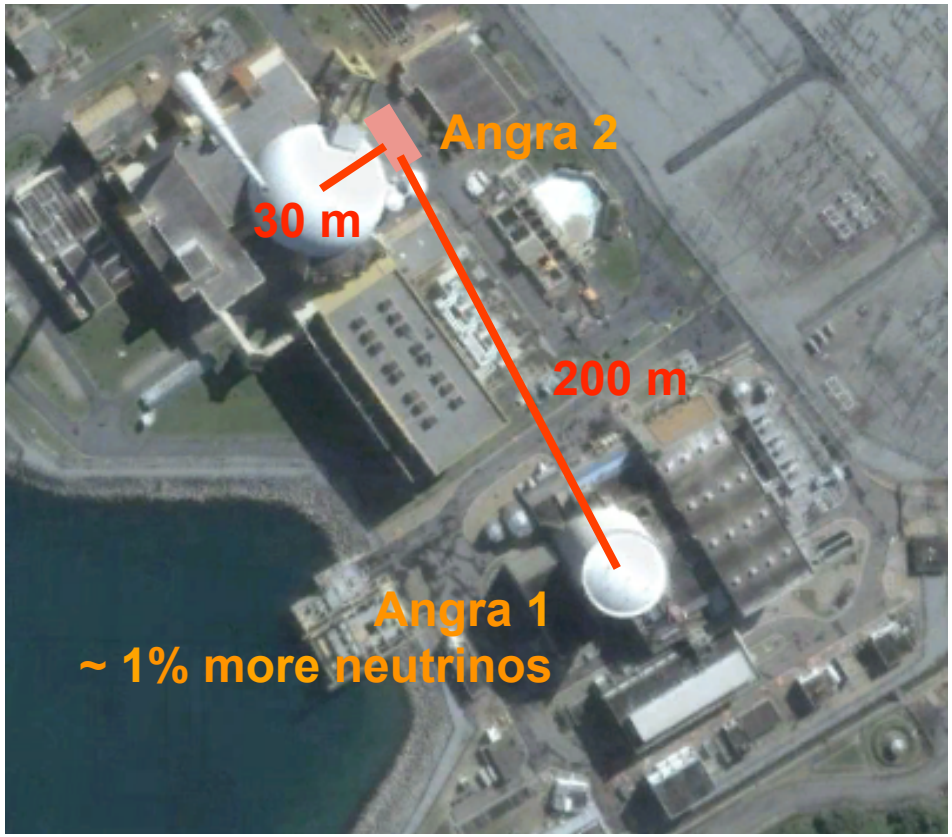
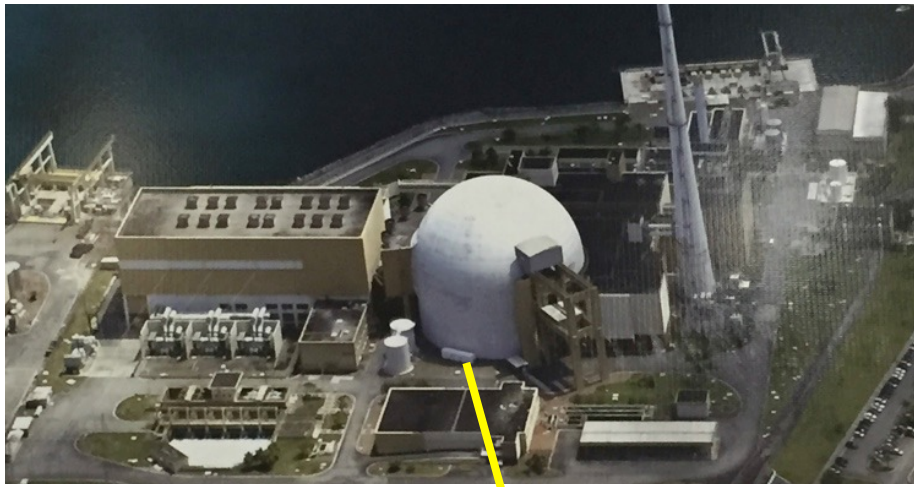
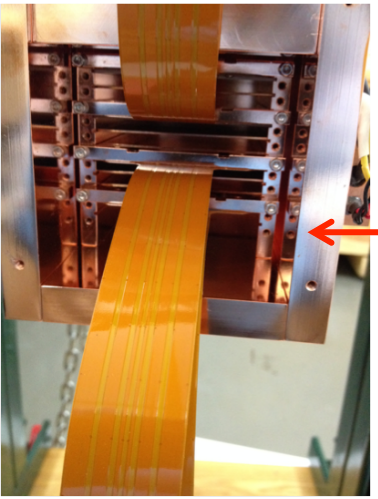
- Located 30 m from the nucleus of the Angra 2 reactor (Rio de Janeiro, Brazil).
- Shared lab with the Neutrinos Angra expriment.
- The reactor is an antineutrino source with 3.8 GW_{th}.
- Flux of 7.8 x 10^{12} $\overline{\nu}$ $s^{-1}cm^{-2}$ at the detector position.





The CONNIE detector



Installed in 2014
Upgraded in 2016

CCDs in copper box

ViB readout board (signal transport)

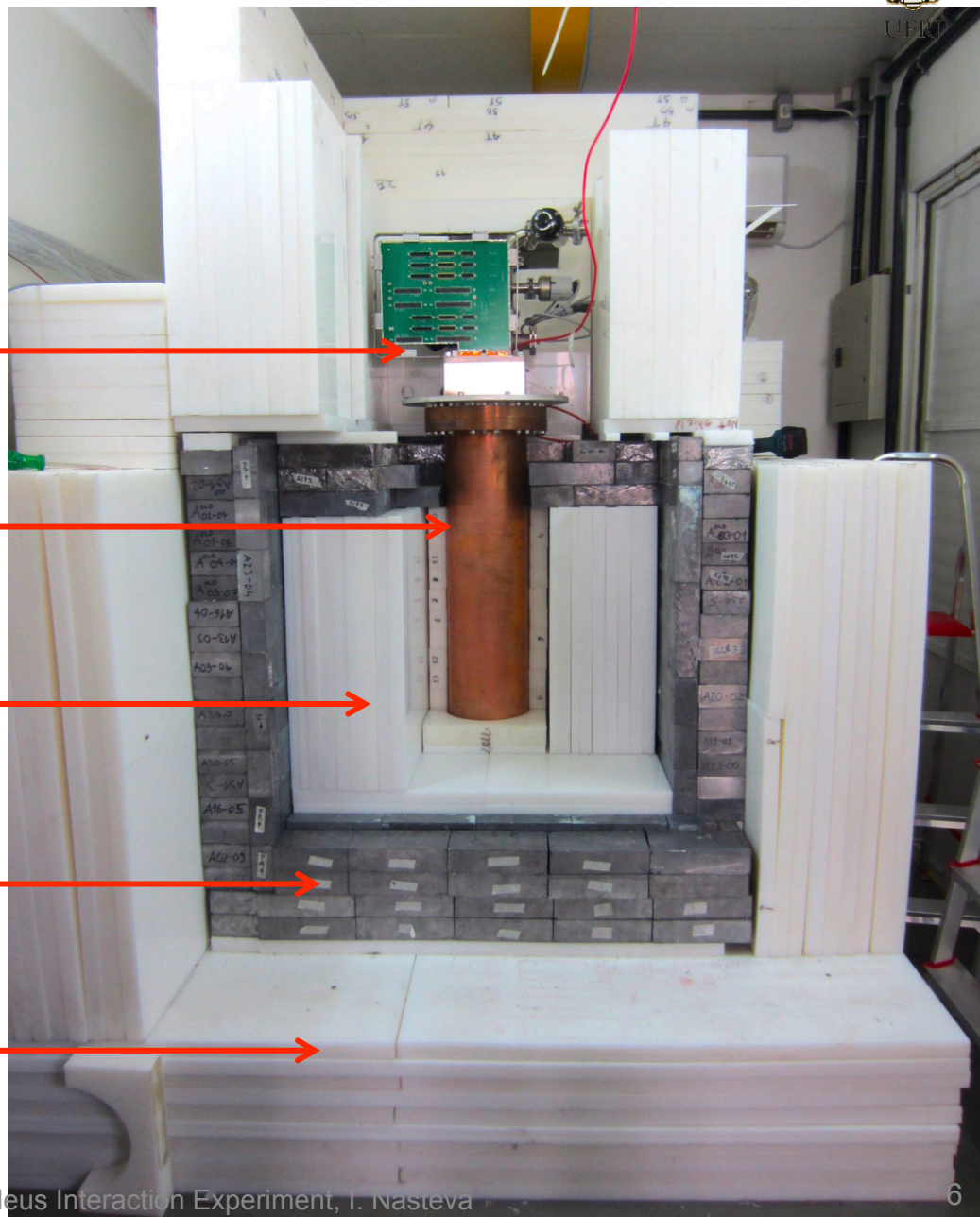
Dewar (vacuum)

Inner Polyethylene – 30 cm (neutrons)

Lead – 15 cm (gamma)

Outer Polyethylene – 30 cm (neutrons)

Engineering run:
JINST 11 (2016) P07024



CONNIE Results

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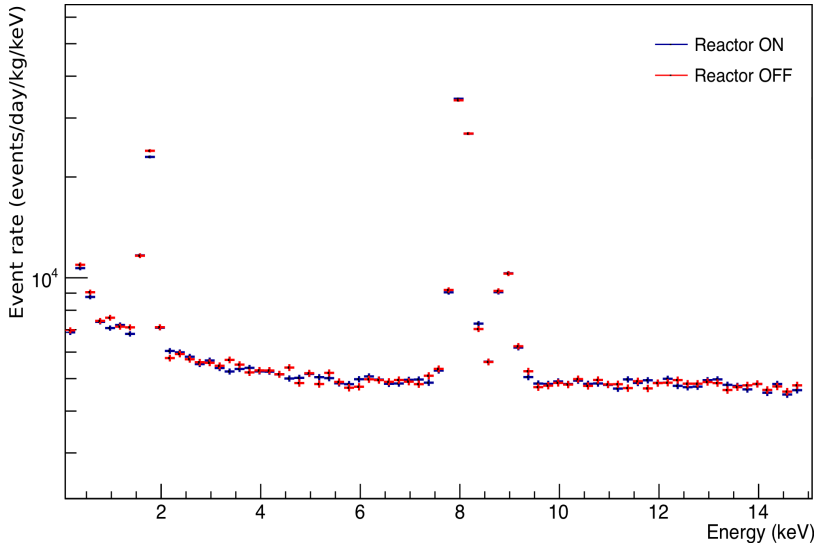
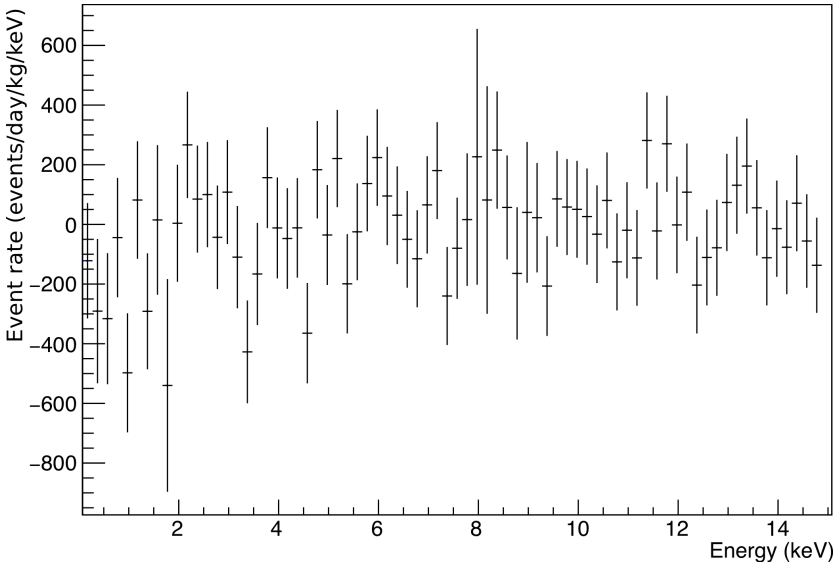
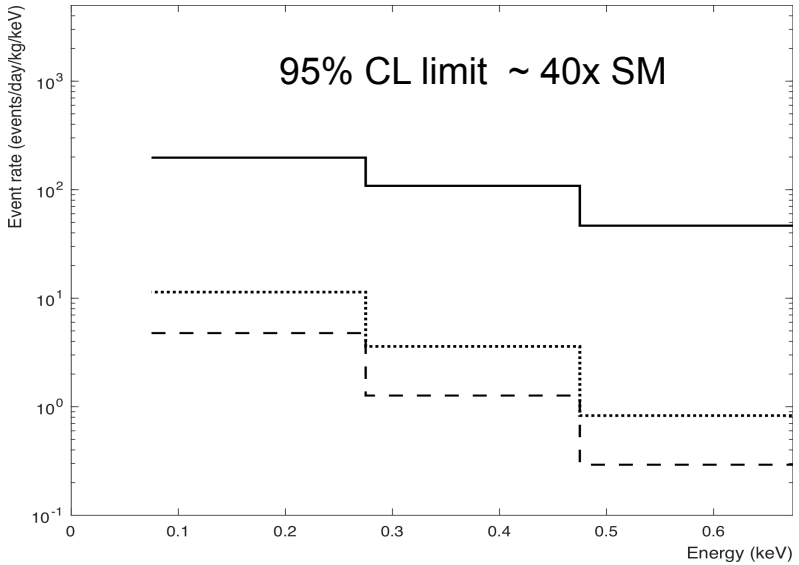


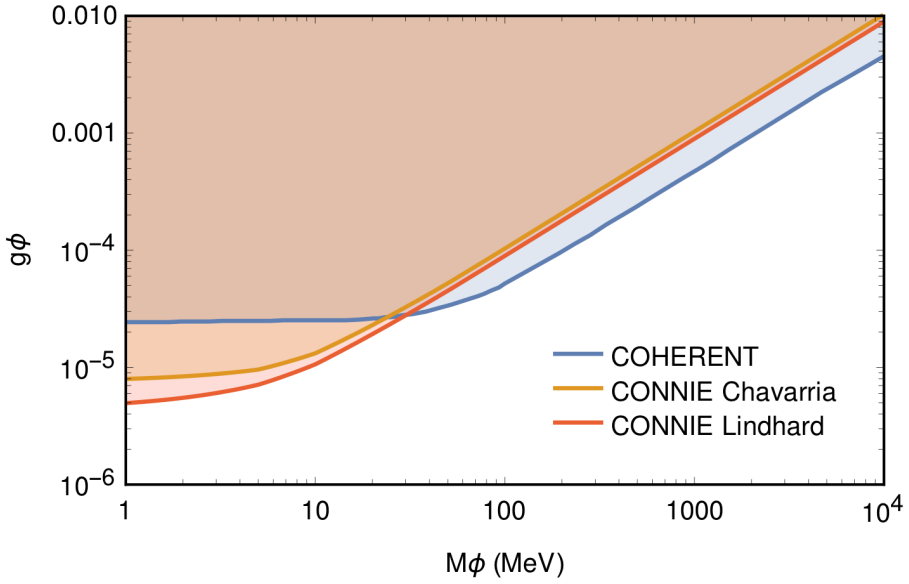
Phys. Rev. D 100 (2019) 092005

- Taking data with active mass 47.6 g.
- First results from 2016-2018 run.
- Energy spectrum in Reactor On (2.1 kg-day) vs Reactor Off (1.6 kg-day).
- Limit on CEνNS event rate.



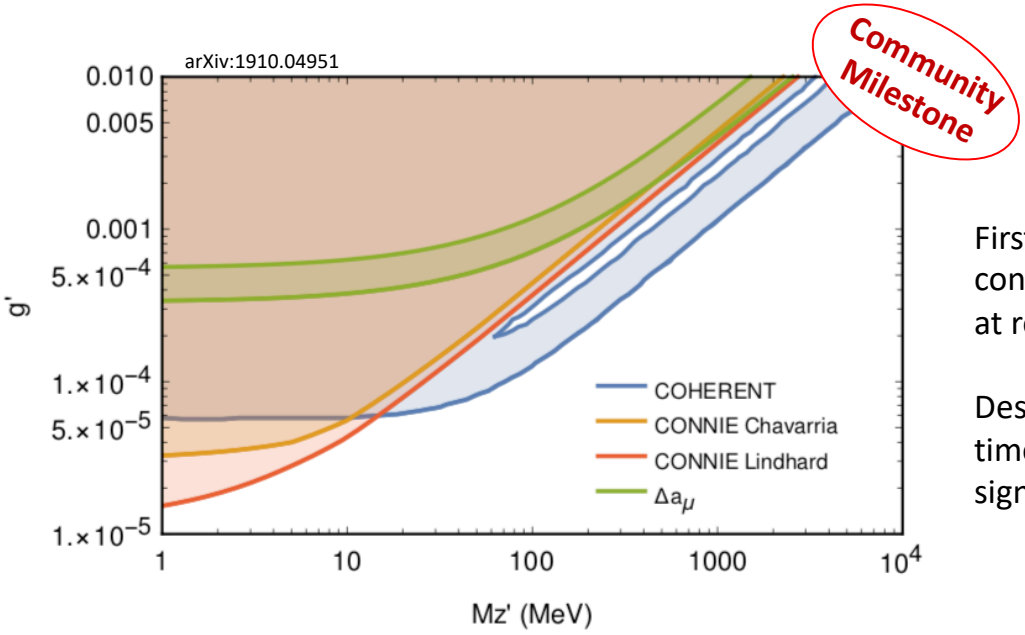


CONNIE Results



JHEP 04 (2020) 054

- Event rates in the lowest-energy bin yield limits on non-standard neutrino interactions:
  - Light vector (Z') mediator.
  - Light scalar (ϕ) mediator.
- We obtain the most stringent limits for low mediator masses $M_{Z'}$ (M_ϕ)< 10 MeV.



CONNIE

First competitive BSM constraint from CEvNS at reactors!

Despite background ~40 times above CEvNS signal.

Raimund Strauss, Neutrino 2020

Current status

- A hardware binning of data reduces the effect of readout noise at low energies.
- Improved analysis techniques increase the efficiency:
  - New calibrations of event size vs depth and energy.
  - Revised neutrino signal selection.
- Improved control of backgrounds:
  - Low-energy background is understood and reduced.
  - Stable muon rates monitored using a new tool.
- An analysis of 2019-2020 data will be published this year.

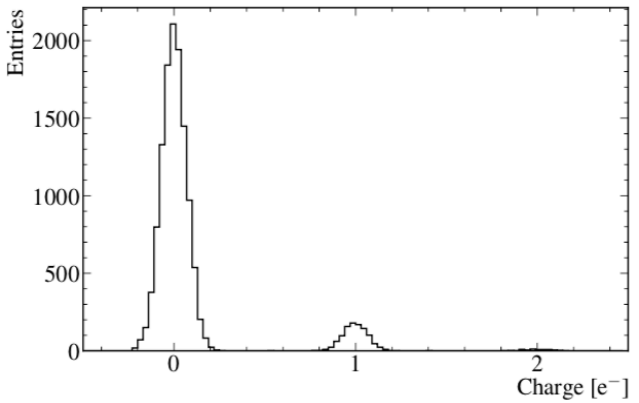
New since White Paper submission

- CONNIE has developed greatly the Latin American expertise in reactor neutrino experiments.
  - Instrumentation and data analysis.
  - 14 postgraduate theses and 9 undergraduate student projects (past and current).

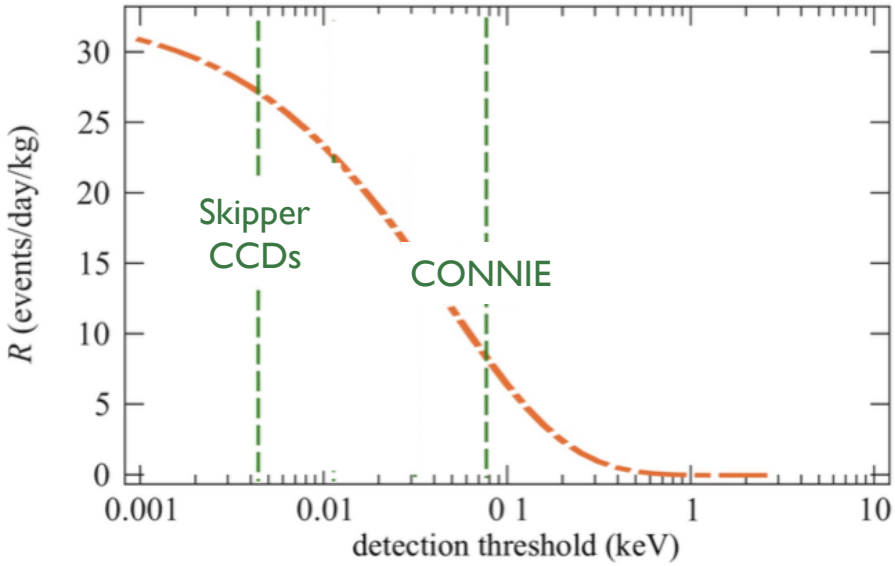
Perspectives

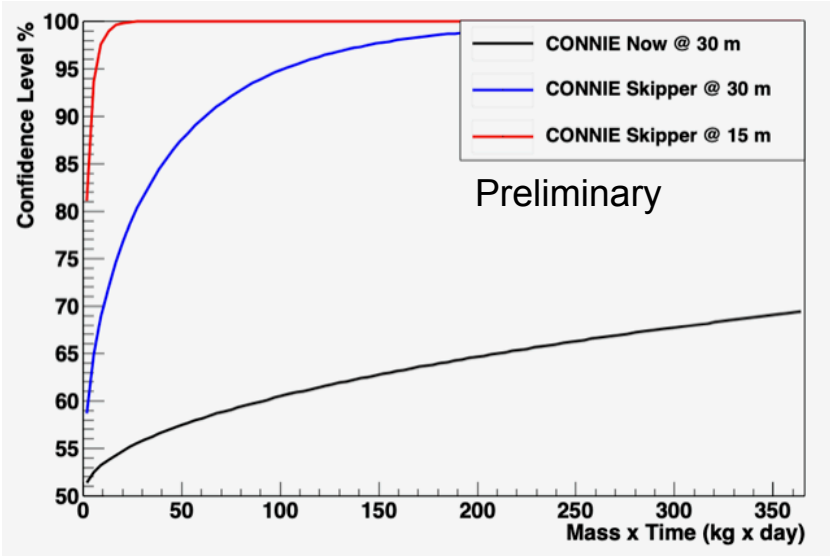
- Plans to upgrade CONNIE with new Skipper CCDs:
  - Reduction in electronic noise.
  - Individual electron detection.
  - Promissing for neutrino and dark matter detection.
  - Extensive research on Skipper CCDs – Fermilab.
- Reduce CONNIE energy threshold to 7 eV.
- Preliminary projections show improved sensitivity.

J. Tiffenberg et al, PRL 119 (2017)



JHEP 04 (2020) 054, Skipper from vIOLETA





Perspectives

- Plans to upgrade CONNIE with new Skipper CCDs next year.
  - Expected increase of up to 6x in neutrino rate.
  - Lower threshold requires improved quenching factor measurement, ongoing efforts.
- In the long-term, it is fundamental to have a larger-mass (kg) reactor neutrino experiment with Skipper CCDs.
  - Would require new infrastructure at Angra 2.
  - Understanding reactor background is a challenge.
  - We also participate in a wider effort for the next large Skipper CCD experiment (see talk by G. Moroni).
- An upgraded CONNIE with Skipper CCDs can act as a pathfinder for future larger-scale experiments.
  - Very well known background environment.
- CONNIE is in a unique position now as the most significant particle physics experiment in Latin America.
  - Expertise in reactor neutrino experiments and training new specialists.