Status of the CONNIE experiment

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on behalf of the CONNIE Collaboration

November 16, 2020
Magnificent CEνNS workshop

the CONNIE collaboration

Argentina

Centro Atómico Bariloche
Universidad de Buenos Aires
Universidad del Sur / CONICET
ICAS / ICIFI / UNSAM

Brazil

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

Mexico

Universidad Nacional Autónoma de México

Paraguay

Universidad Nacional de Asunción

Switzerland

University of Zurich

USA

Fermilab National Laboratory

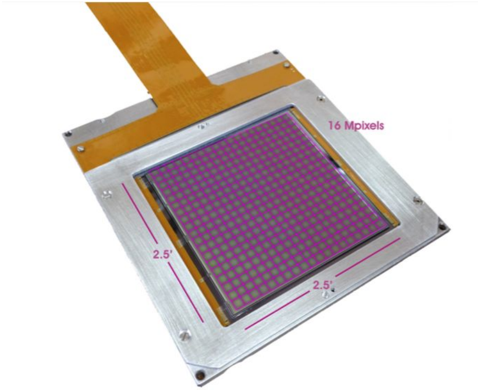
~30 members

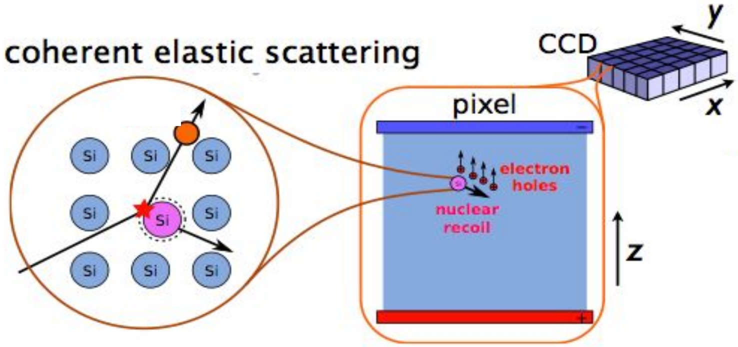
the CONNIE experiment

- the main goal of the COherent Neutrino–Nucleus Interaction Experiment is to detect CEνNS in Silicon Nuclei and probe physics beyond the Standard Model

- scientific CCDs with high resistivity and low noise with 675μm (5.25 g) created at LBNL and used in the DAMIC experiment

- threshold of ~40 eV for ionization energy of the nuclear recoil (quenching factor)





the CONNIE detector

30 m from the Angra 2 reactor core, Rio de Janeiro – Brazil

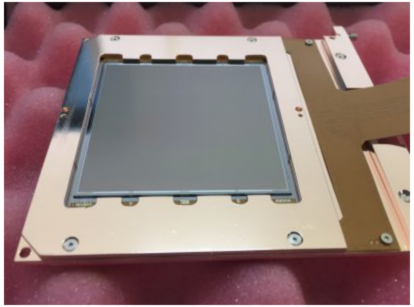
antineutrino source of 3.8 GW_{th}

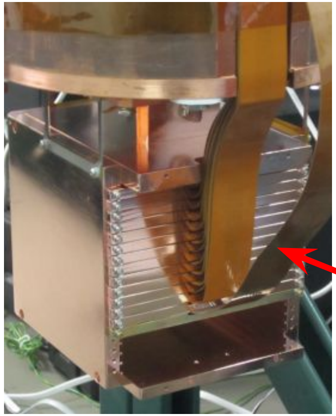
estimated flux of 7.8 x 10^{12} ν $s^{-1}cm^{-2}$ at the detector position.

the CONNIE detector

installed in 2014 and upgraded in 2016

4k x 4k pixel
675μm thick





CCDs in
copper box

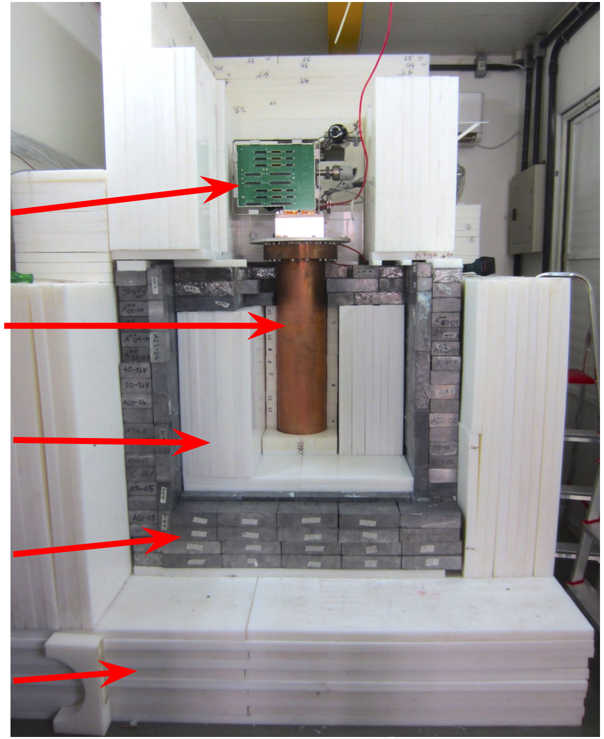
ViB readout board
(signal transport)

Dewar in vacuum

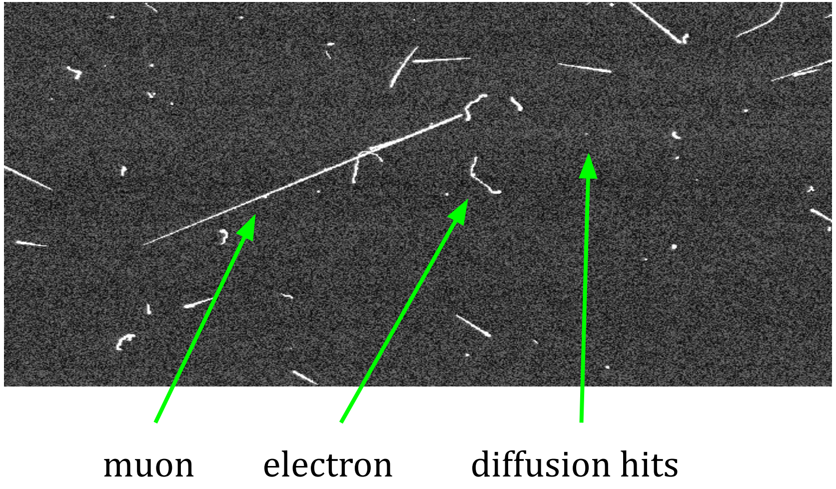
Inner Polyethylene
(neutrons) 30 cm

Lead (gamma) 15 cm

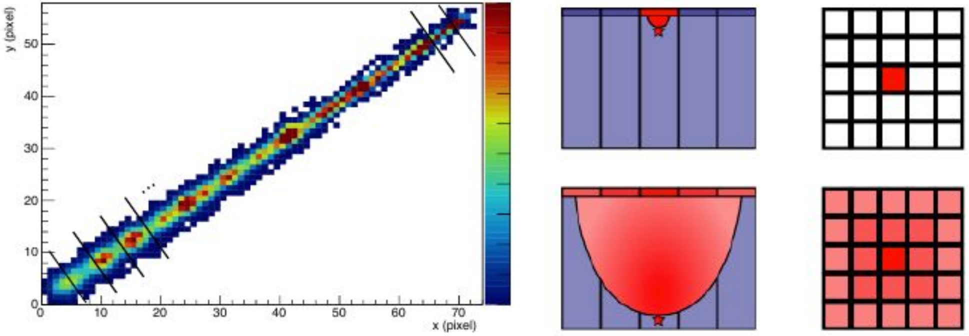
Outer Polyethylene
(neutrons) 30 cm



event reconstruction



- identify events from geometry
- calibrate energy with Si and Cu peaks in the spectrum
- calibrate depth with diffusion information over muon tracks

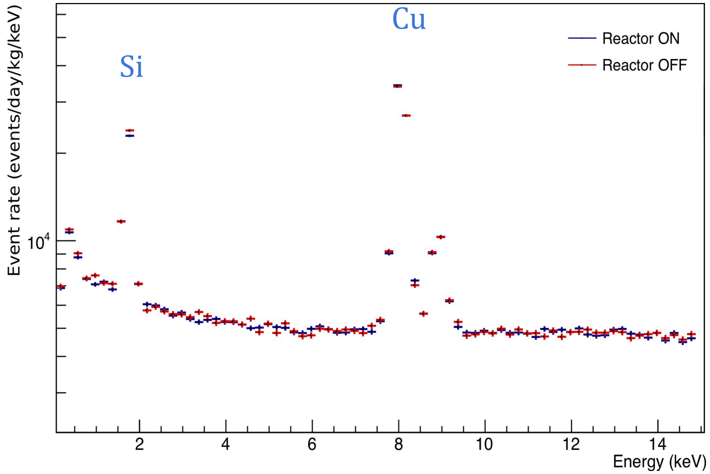


Phys. Rev. D 100 (2019) 092005

results 2016–2018

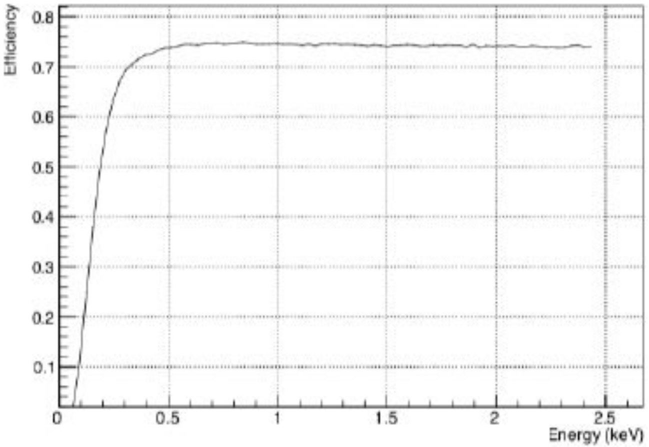
data stability is controlled through

- read-out noise and dark current
- calibration of Cu and Si peaks
- high-energy event rates



efficiency computation

- **simulate** low-energy neutrino events in each image and process the full event reconstruction analysis



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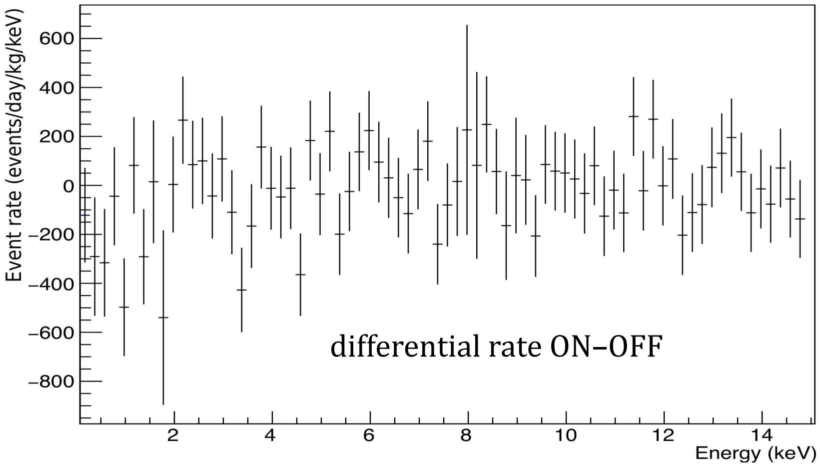
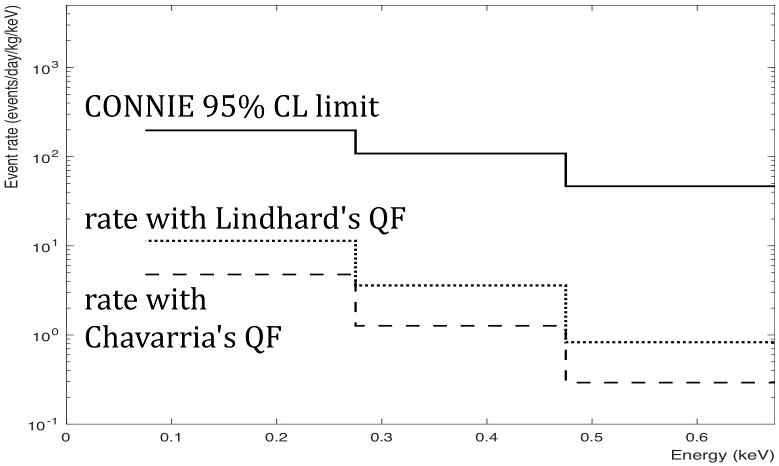
results 2016–2018

- discard images with high read-out noise and dark current
- remove CCD edge effect and dead pixels
- total exposure Reactor ON (2.1kg·day) and OFF (1.6kg·day)
- uncertain quenching factor (QF)
- place limit at x40 the SM expected rate





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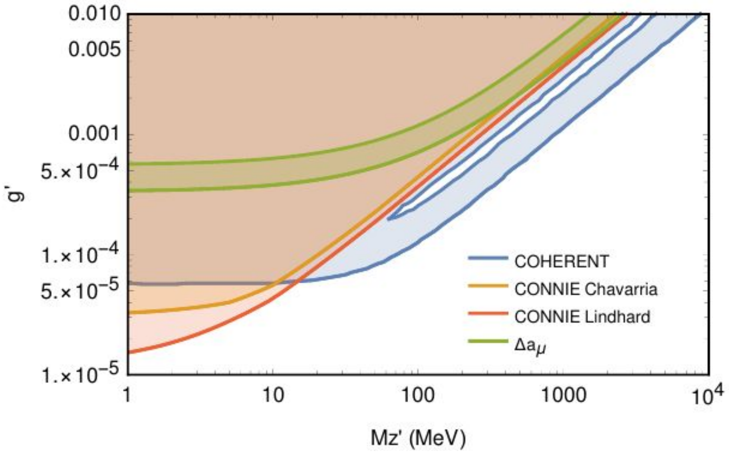
constraining BSM physics

- event rates in the lowest-energy bin yield limits on non-standard neutrino interactions:
  - light vector (Z') mediator
- we obtain the most stringent limits for low mediator masses $M_{z'} < 10$ MeV.
- first competitive BSM constraint from CEvNS in reactors!

- light vector mediator Z'

$$\frac{d\sigma_{SM+Z'}}{dE_R}(E_{\bar{\nu}_e}) = \left(1 - \frac{Q_{Z'}}{Q_W}\right)^2 \frac{d\sigma_{SM}}{dE_R}(E_{\bar{\nu}_e})$$

$$Q_{Z'} = \frac{3(N+Z)g'^2}{\sqrt{2}G_F(2ME_R + M_{Z'}^2)} .$$



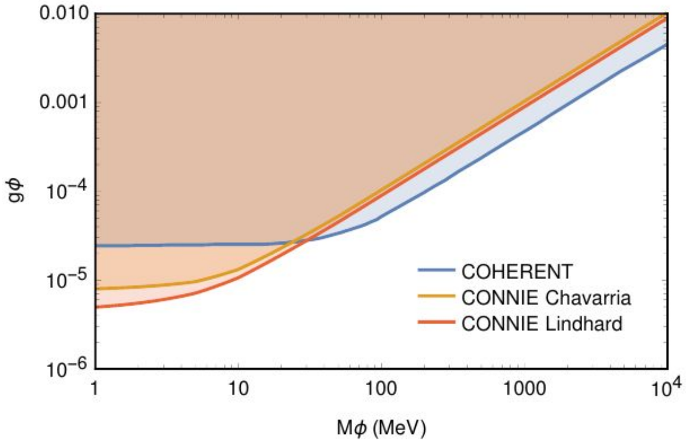
constraining BSM physics

- event rates in the lowest-energy bin yield limits on non-standard neutrino interactions:
  - Light scalar (ϕ) mediator.
- we obtain the most stringent limits for low mediator masses $M_\phi < 30$ MeV
- first competitive BSM constraint from CEvNS in reactors!

- light vector mediator ϕ

$$\frac{d\sigma_{SM+\phi}}{dE_R}(E_{\bar{\nu}_e}) = \frac{d\sigma_{SM}}{dE_R}(E_{\bar{\nu}_e}) + \frac{G_F^2}{4\pi}Q_\phi^2\left(\frac{2ME_R}{E_{\bar{\nu}_e}^2}\right)MF^2(q)$$

$$Q_\phi = \frac{(14N+15.1Z)g_\phi^2}{\sqrt{2}G_F\left(2ME_R+M_\phi^2\right)}$$



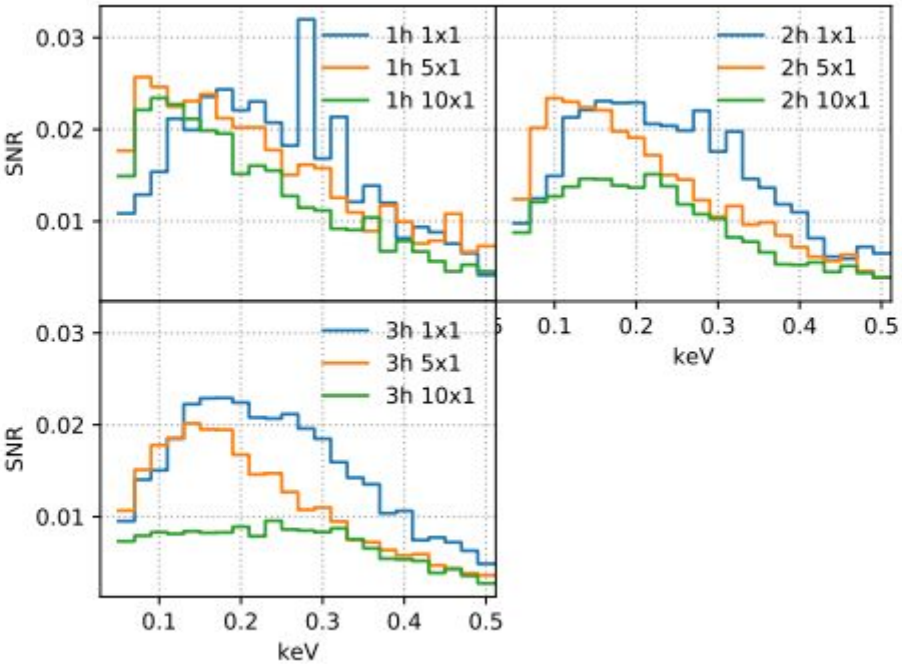
JHEP 04 (2020) 054

CONNIE 2019–2020 data

1x5 rebinning of the data acquisition

- reduce the impact of the readout noise relative to the collected charge in each pixel

simulated signal to noise ratio
with several rebinning scenarios



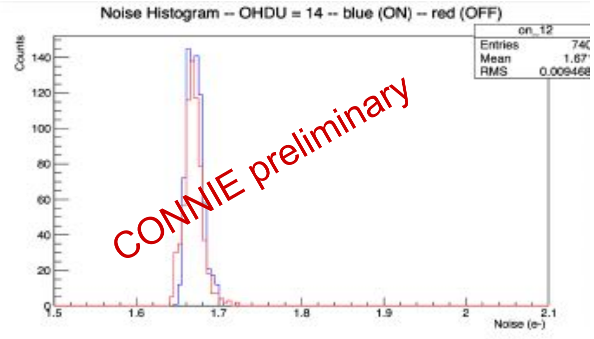
CONNIE 2019–2020 data

1x5 rebinning of the data acquisition

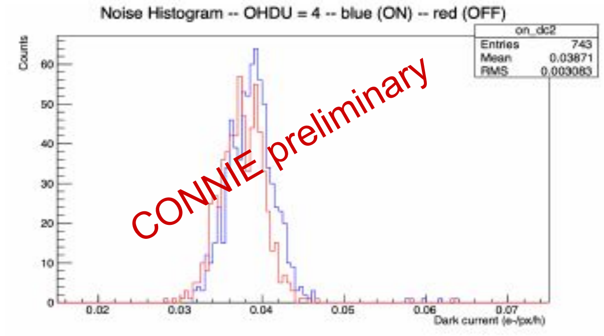
- recalibration of the depth diffusion
- improved techniques for depth determination
- multiple cross-checks

blind analysis

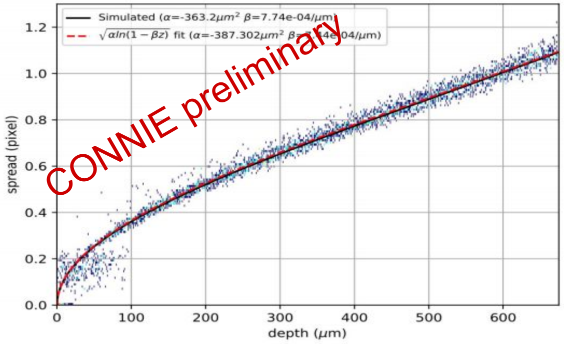
- adjust all analyses using only the reactor OFF data
- unblind the mid to high energy reactor ON data for stability check-ups
- **we are now ready** to unblind the reactor ON 2019 data



- stability of readout noise per each image



- stability of dark current per each image

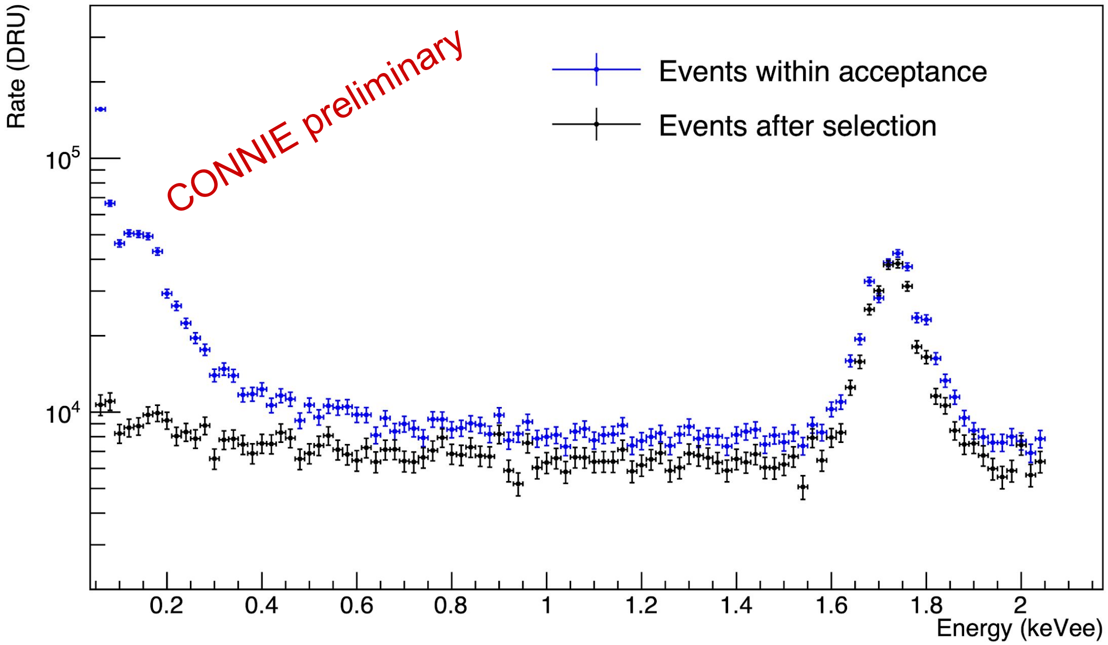


- depth calibration stability using muons

CONNIE 2019–2020 data

rate of events corrected by efficiency for reactor OFF

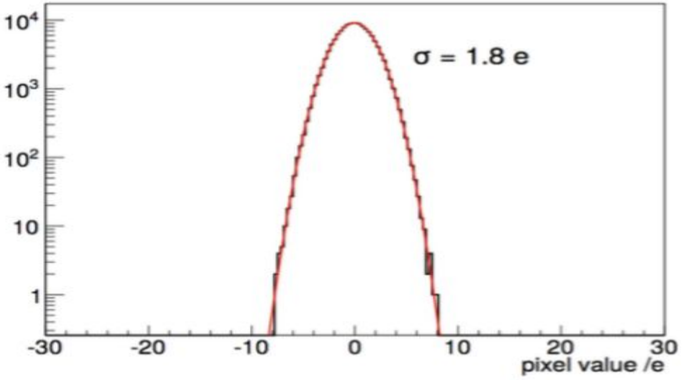
- understanding and controlling the low energy background
- improvement in event selection and
- revised neutrino signal selection with blinded analysis (only reactor OFF)
- exposures:
  reactor OFF 1.35 kg·day
  reactor ON 1.52 kg·day



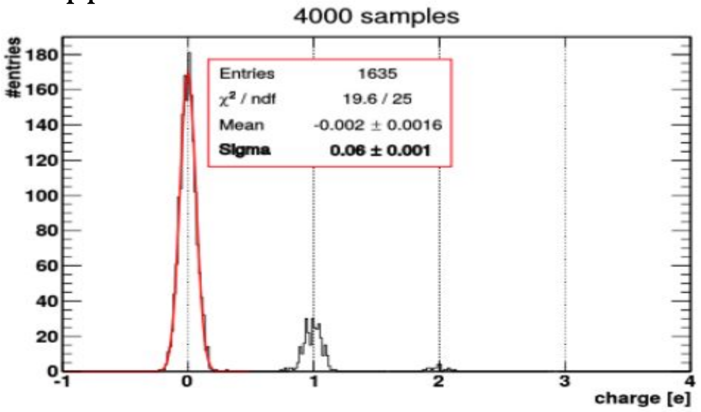
skipper CCD

- allows multiple sampling of each pixel during data acquisition
- reduces readout noise with number of samplings $\sigma \propto 1/\sqrt{N}$
- 100% efficiency – detect single electrons
- promising for neutrino and dark matter detection

standard CCD readout noise



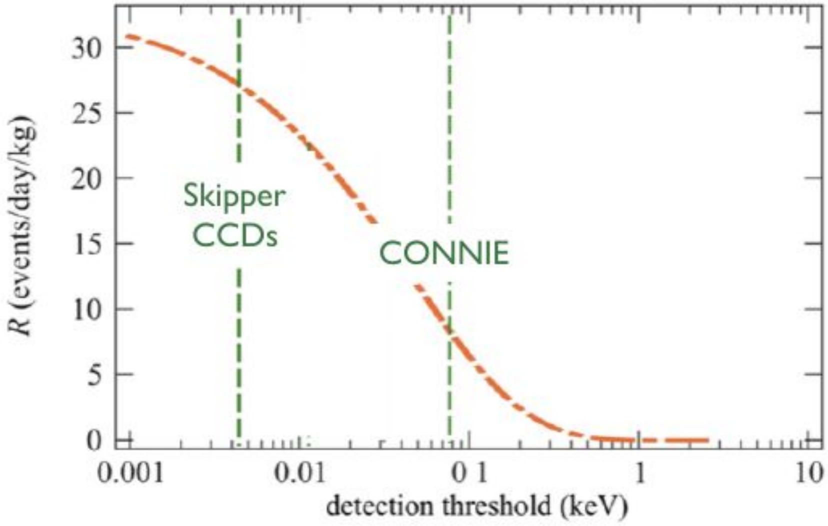
skipper CCD readout noise



perspectives

- upgrade CONNIE with new Skipper CCDs early 2021
  - expected increase of up to 6x in neutrino rate
  - threshold of 7 eV
  - understand skipper performance at sea-level within CONNIE environment
  - better control the background
- this is also part of the R&D for νIOLETA (G. Moroni's talk on Thursday)

expected rate



summary

- CCD are promising technologies to observer CEvNS at low energies
- the 2016–2018 data allowed us to place most restrictive for BSM low mediator masses $M < 10\text{MeV}$
- **new** 2019–2020 data is expected to improve our sensitivity significantly
- explore other beyond SM scenarios
- skipper CCDs perspective to greatly reduce the noise and control the background rate
- stay tuned for novel results!