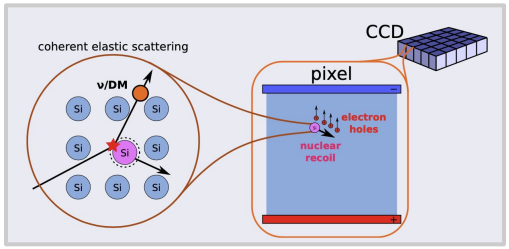
Installing a Skipper-CCD sensor in Atucha 2 power reactor: current status

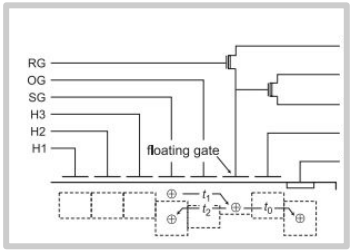
Magnificent CEvNS 2021

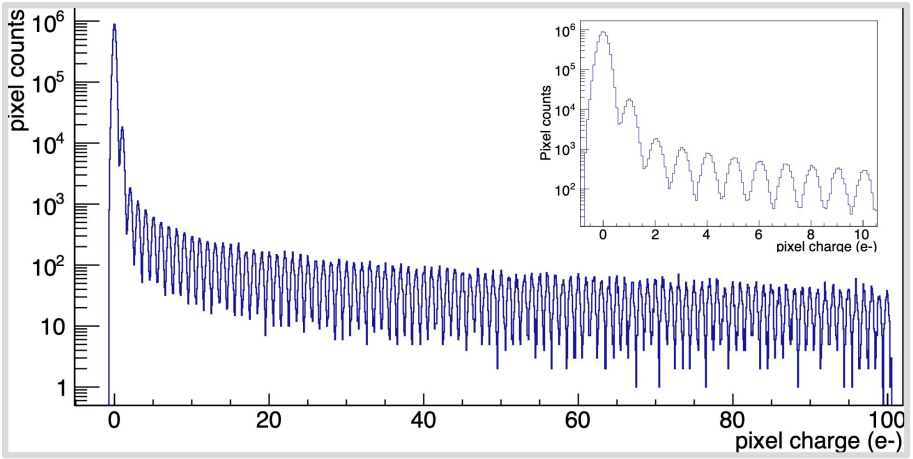
October 7, 2021

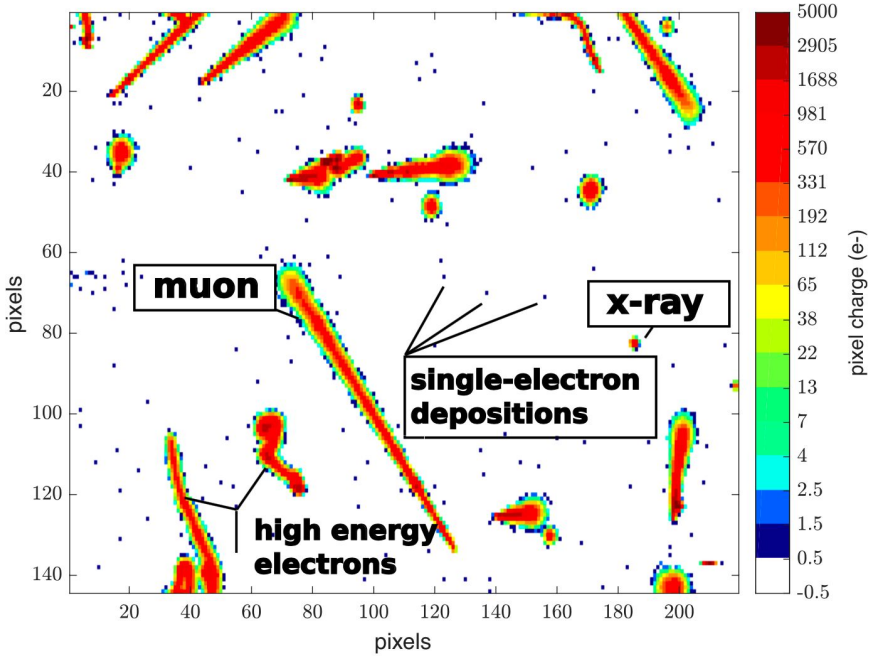
Speaker: Guillermo Fernández Moroni (Fermilab)

Skipper CCD

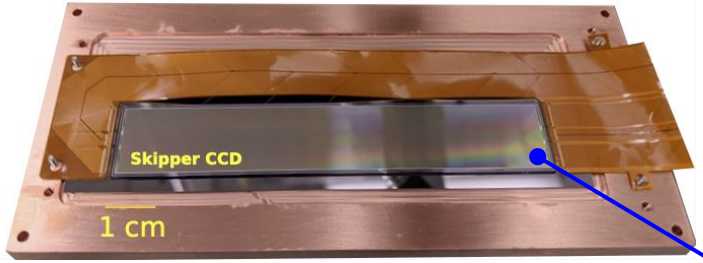

coherent elastic scattering
CCD
pixel
ν/DM
Si
electron holes
nuclear recoil


RG
OG
SG
H3
H2
H1
floating gate


pixel counts
pixel charge (e-)
Pixel counts
pixel charge (e-)

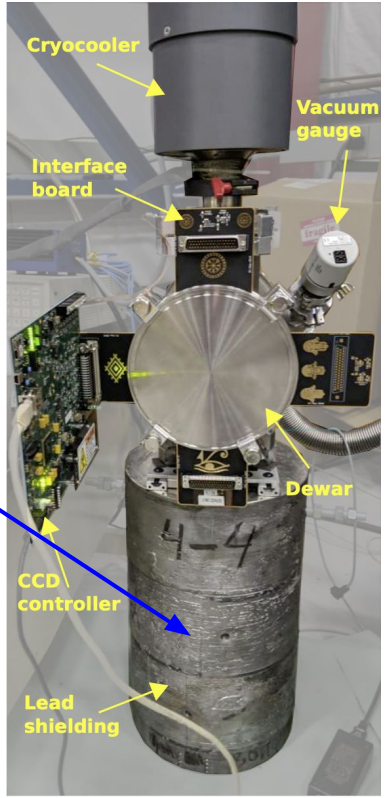

muon
x-ray
single-electron depositions
high energy electrons
pixels
pixels
pixel charge (e-)

Detector shipped to Atucha 2 power plant



Sensor package:
Skipper CCD + Kapton cable + Copper tray

Sensor stays inside the lead shield

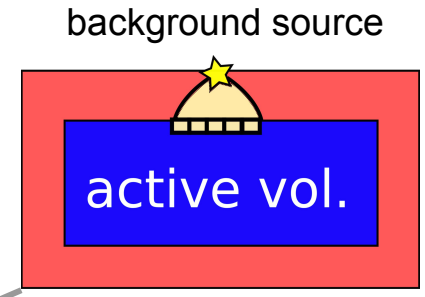


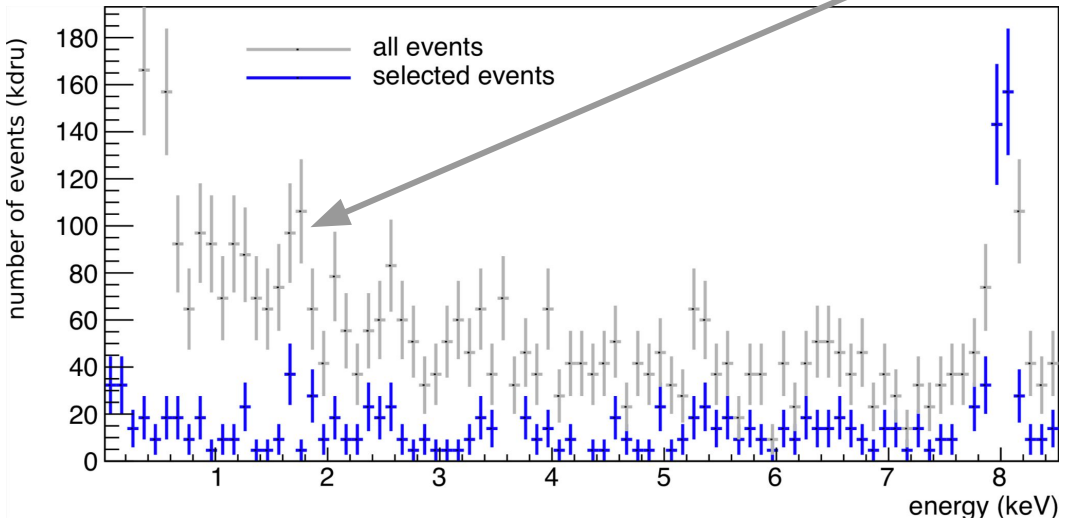
5 cm of lead around the sensor

- Skipper output stage designed at LBNL
- CCDs on high resistivity silicon developed at LBNL

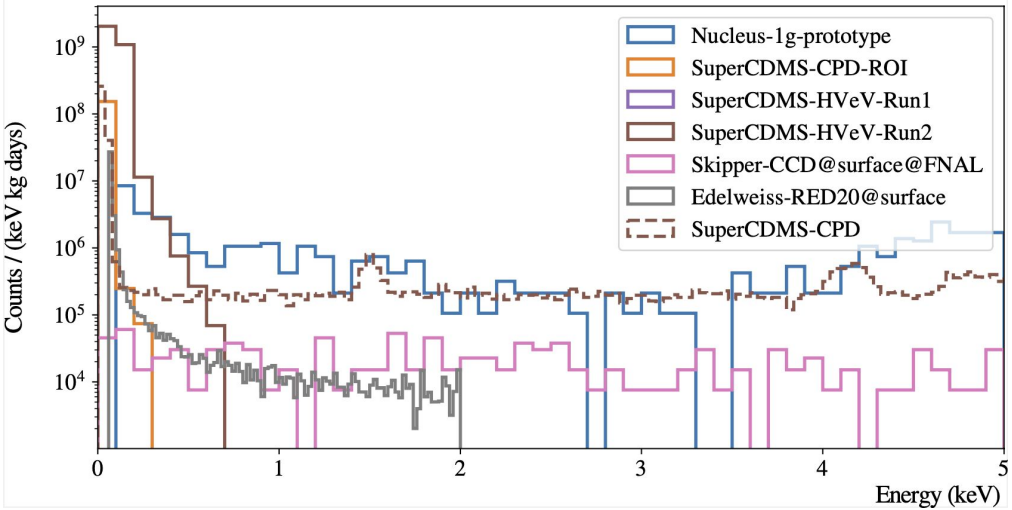
Study how to operate the Skipper for experiments above ground (arXiv:2107.00168)

- **Results run @ Fermilab before shipping**
- **0.675 grams of active silicon**
- **running for 3.21 days**
- **events with 5e- (18.75 eV) or more**
- spectrum not normalized by efficiency
- Best fit: efficiency(%) = 59 - 0.17xE (keV)





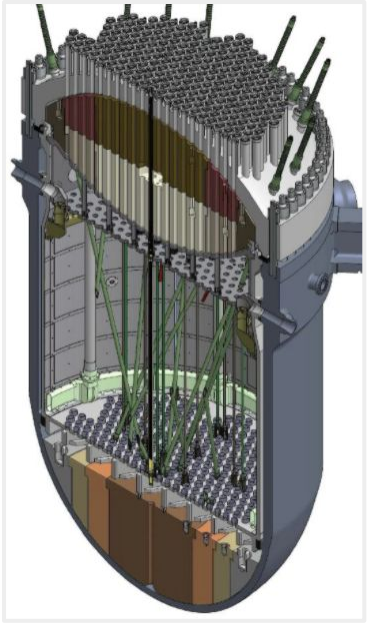
Comparison with other technologies @ surface



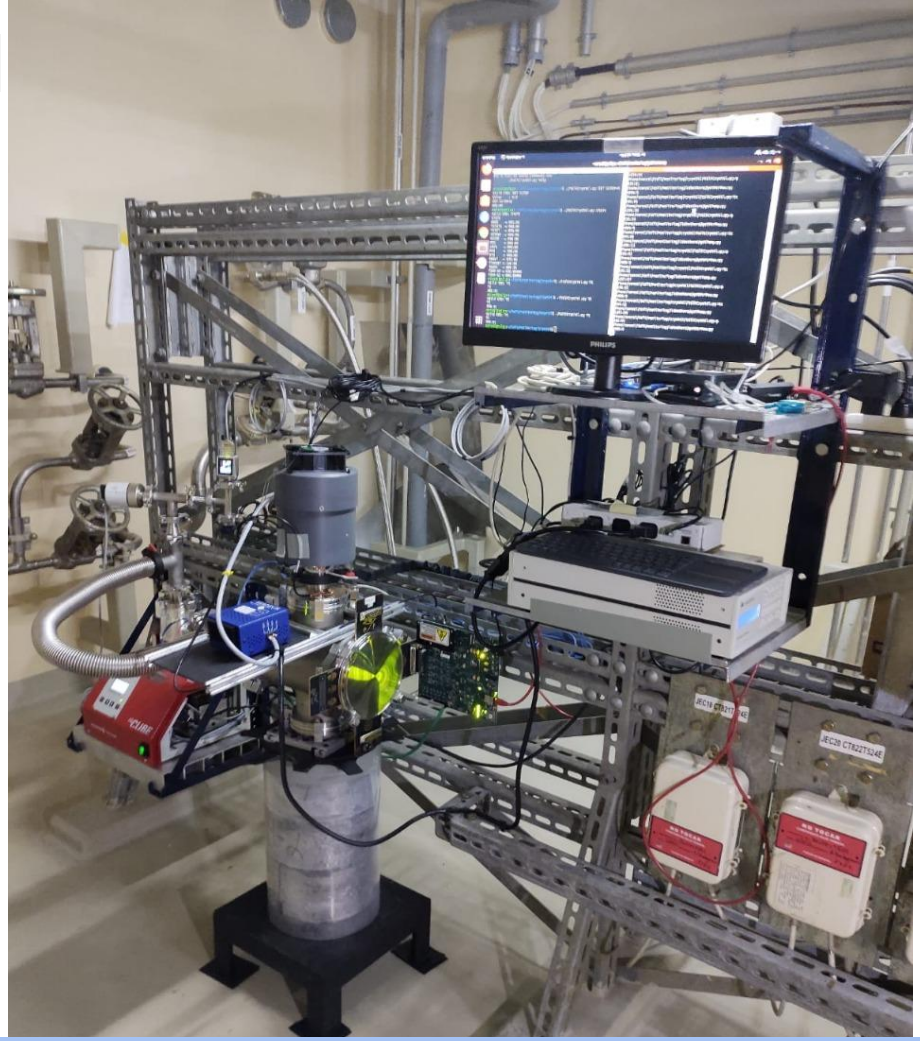
- **All spectra scaled by efficiency**
- **Only published results are shown here**

To generate spectrum: https://indico.cern.ch/event/1013203/attachments/2264385/3847018/how_to_plot_excess.pdf

Atucha 2 reactor (2 GW of thermal power), Lima, Buenos Aires, Argentina

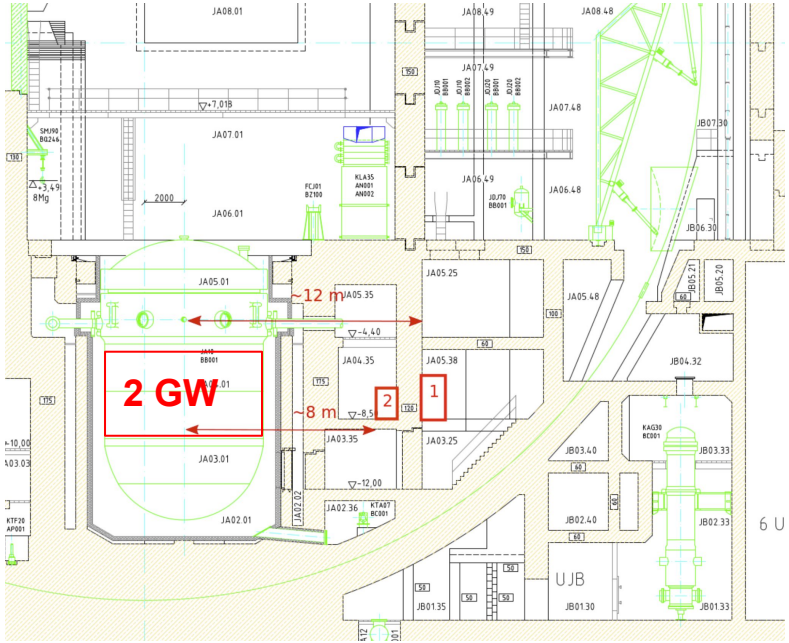


Installation in Atucha 2 (September, 2021)

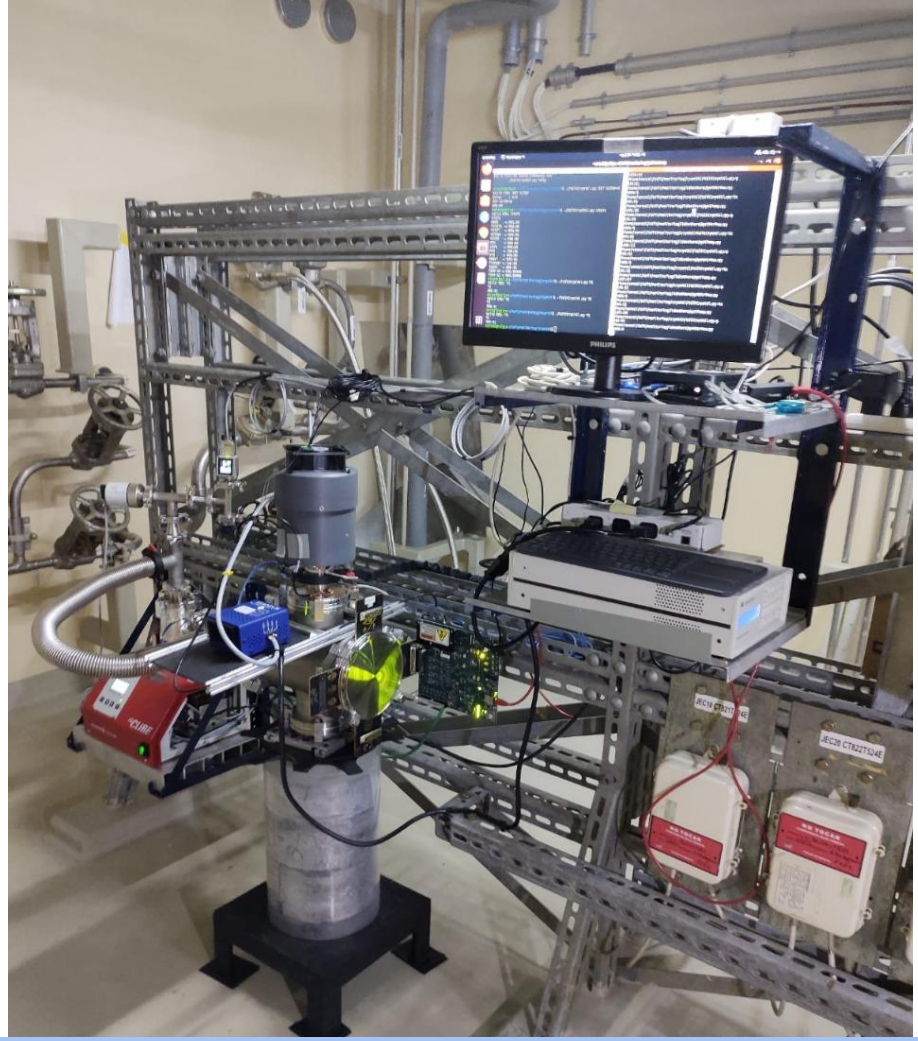


- A team of scientist from Buenos Aires and Bariloche and engineers from the nuclear plant installed the detector.
- The group conducted a background measurement campaign using a HPGe detector to find the best spot.

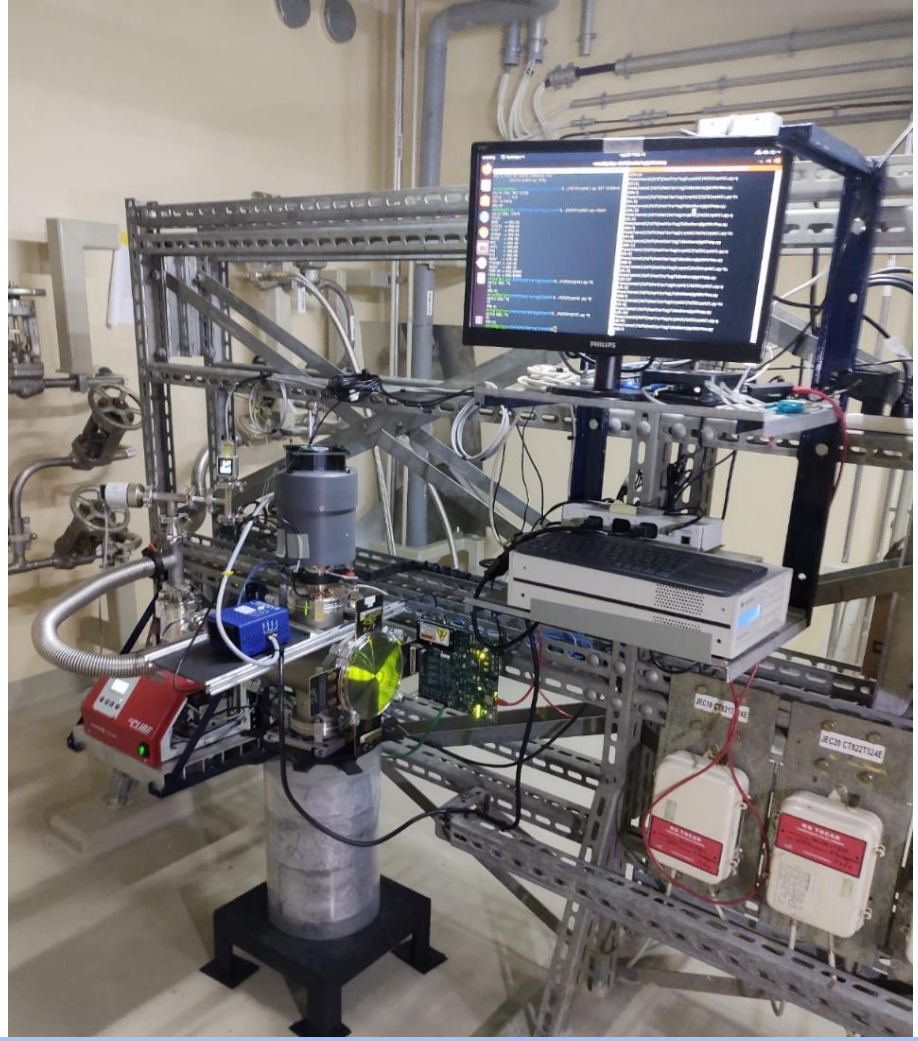
Installation in Atucha 2



from Poster 523 Neutrino 2020.
https://nusoft.fnal.gov/nova/nu2020postersession/pdf/posterPDF-523.pdf



Installation in atucha: first light



Conclusions and future work

- The Skipper CCD is a promising technology for neutrino interaction and other searches at very low deposited energy.
- The technology has shown a good background control for events of 5 ionized electrons or more.
- The installation is still in progress. We are optimizing optimizing noise sources of the system.
- One Skipper CCD (2.5 grams of instrumented silicon) running at 12 m of a 2 GW reactor.
- First step is to measure the background rate below 500 eV using single electron counting.

References from slide 5

Legend label	References
Skipper-CCD@surface@FNAL	this talk
Nucleus-1g-prototype	[33–36]
SuperCDMS-CPD-ROI	[37]
SuperCDMS-HVeV-Run1	[38]
SuperCDMS-HVeV-Run2	[39]
Edelweiss-RED20@surface	[40, 41]
SuperCDMS-CPD	[42]

[33] R. Strauss, J. Rothe, G. Angloher, A. Bento, A. Gütlein, D. Hauff, H. Kluck, M. Mancuso, L. Oberauer, F. Petricca, et al., *"Gram-scale cryogenic calorimeters for rare-event searches,"* Physical Review D **96** (2017), 10.1103/physrevd.96.022009.

[34] G. Angloher, P. Bauer, A. Bento, C. Bucci, L. Canonica, X. Defay, A. Erb, F. v. Feilitzsch, N. F. Iachellini, P. Gorla, et al., *"Results on mev-scale dark matter from a gram-scale cryogenic calorimeter operated above ground,"* The European Physical Journal C **77**, 637 (2017).

[35] B. Flebus, G. E. W. Bauer, R. A. Duine, and Y. Tserkovnyak, *"Theory of the magnon-mediated tunnel magneto-seebeck effect,"* Physical Review B **96** (2017), 10.1103/physrevb.96.094429.

[36] J. Rothe, G. Angloher, F. Ardellier-Desages, A. Bento, L. Canonica, A. Erhart, N. Ferreiro, M. Friedl, V. M. Ghete, D. Hauff, et al., *"Nucleus: Exploring coherent neutrino-nucleus scattering with cryogenic detectors,"* Journal of Low Temperature Physics **199**, 433 (2020).

[37] C. W. Fink, S. L. Watkins, T. Aramaki, P. L. Brink, J. Camilleri, X. Defay, S. Ganjam, Y. G. Kolomensky, R. Mahapatra, N. Mirabolfathi, et al., *"Performance of a large area photon detector for rare event search applications,"* Applied Physics Letters **118**, 022601 (2021).

[38] R. Agnese, T. Aralis, T. Aramaki, I. J. Arnquist, E. Azadbakht, W. Baker, S. Banik, D. Barker, D. A. Bauer, T. Binder, et al., *"First dark matter constraints from a supercdms single-charge sensitive detector,"* Phys. Rev. Lett. **121**, 051301 (2018).

[39] D. W. Amaral, T. Aralis, T. Aramaki, I. J. Arnquist, E. Azadbakht, S. Banik, D. Barker, C. Bathurst, D. A. Bauer, L. V. S. Bezerra, et al., *"Constraints on low-mass, relic dark matter candidates from a surface-operated supercdms single-charge sensitive detector,"* Phys. Rev. D **102**, 091101 (2020).

[40] E. Armengaud, C. Augier, A. Benoît, A. Benoit, L. Bergé, J. Billard, A. Broniatowski, P. Camus, A. Cazes, M. Chapellier, et al. (EDELWEISS Collaboration), *"Searching for low-mass dark matter particles with a massive ge bolometer operated above ground,"* Phys. Rev. D **99**, 082003 (2019).

[41] E. Armengaud, C. Augier, A. Benoît, A. Benoit, L. Bergé, J. Billard, A. Broniatowski, P. Camus, A. Cazes, M. Chapellier, et al., *"Searching for low-mass dark matter particles with a massive ge bolometer operated above ground,"* Physical Review D **99** (2019), 10.1103/physrevd.99.082003.

[42] I. Alkhatib, D. W. P. Amaral, T. Aralis, T. Aramaki, I. J. Arnquist, I. A. Langroudy, E. Azadbakht, S. Banik, D. Barker, C. Bathurst, et al., "Light dark matter search with a high-resolution athermal phonon detector operated above ground," (2021), arXiv:2007.14289 [hep-ex].

Back-up slides