Hardware Development for the Radio Neutrino Observatory in Greenland (RNO-G)

Daniel Smith, on behalf of the RNO-G Collaboration, University of Chicago, danielsmith@uchicago.edu

Introduction

The Radio Neutrino Observatory in Greenland (RNO-G) is designed to make the first observations of ultra-high energy neutrinos at energies above 10 PeV and will be the world's largest in-ice Askaryan radio detection array. The experiment will be composed of 35 autonomous stations deployed over a 5x6 km grid near NSF Summit Station on top of the Greenland ice sheet. The first deployment is ongoing, with the first team arriving in May 2021.

Station Design

Each station is centered around the environmental enclosure, which contains the data acquisition system (DAQ), power controls, batteries, and single-board computer-based station controller. The primary sensing component are the antennas that are deployed down three, 100 m boreholes. The surface array of high-gain antennas is used for noise rejection, cosmic ray tagging and improved reconstruction. Station power is composed of a battery bank and solar panels. Wireless communications is performed over a LoRaWAN and LTE network.

Digitizer and Triggering

Signal digitizing is performed on a custom, 24 channel board based on the LAB4D, a custom ASIC that is a single channel, switched-capacitor array with 12-bit sampling [2]. The board is optimized for low power and runs at approximately 12.5 W. Surface triggering is performed using a Schottky diode detector circuit (a threshold trigger on an enveloped signal) that is deployed alongside each channel on the digitizing board. Deep triggering is performed using a four channel, 100-250 MHz phased array trigger implemented on a dedicated FPGA [3].

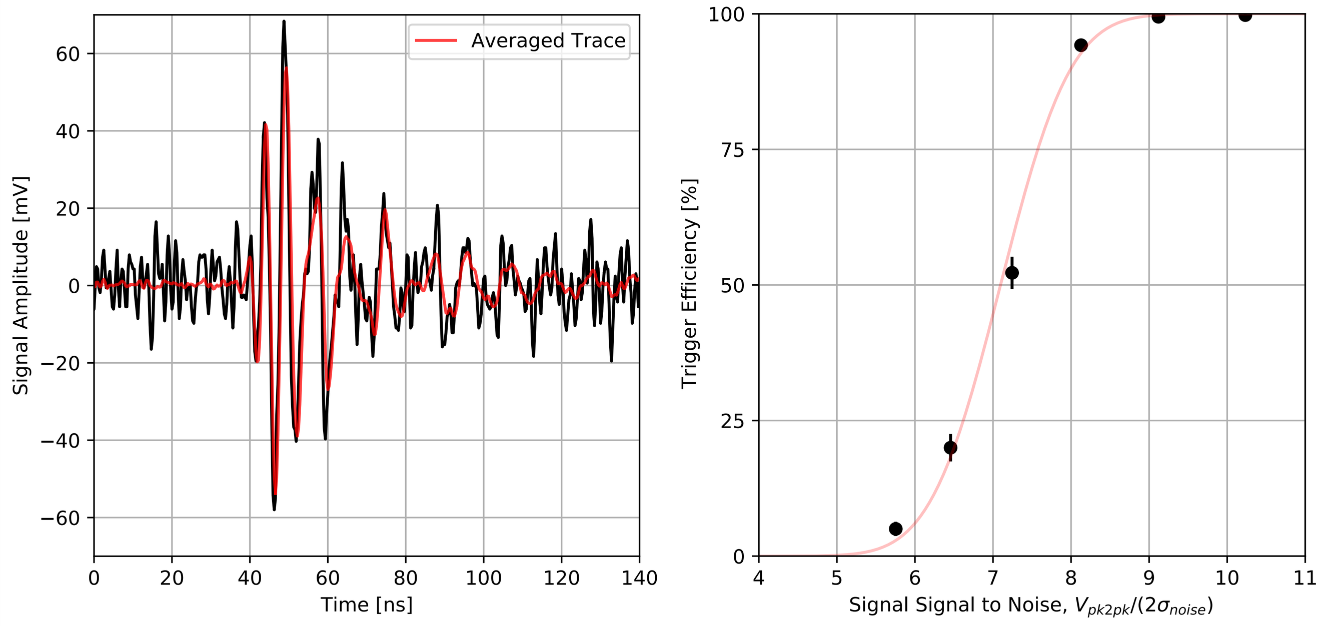


Fig 1: **Left**: 100-225 MHz pulse through signal chain and digitized by LAB4Ds.
Right: Preliminary trigger efficiency of surface antennas on 100-225 MHz pulse.

Fig 2: Station Antenna Layout

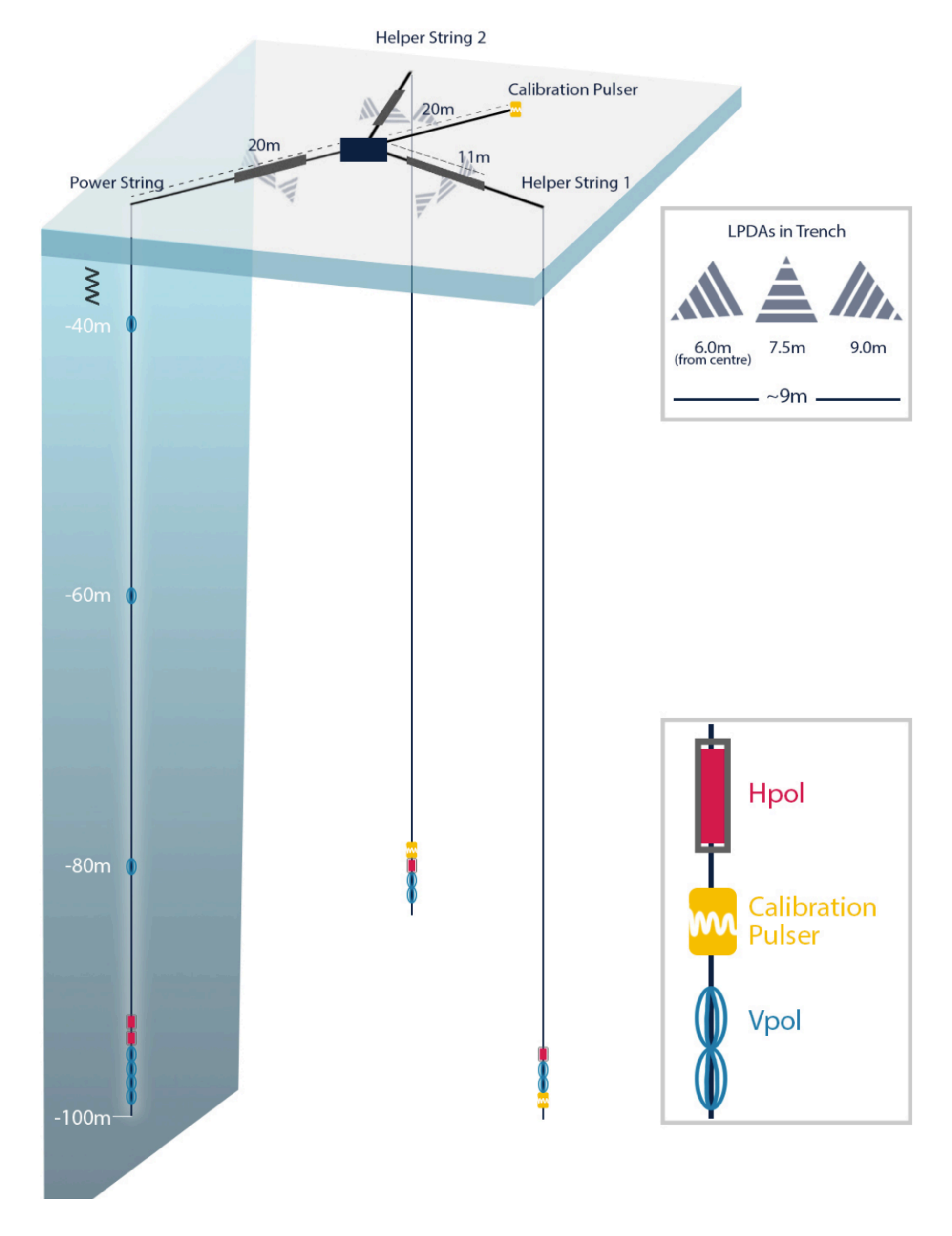


Fig 3: Station Schematic

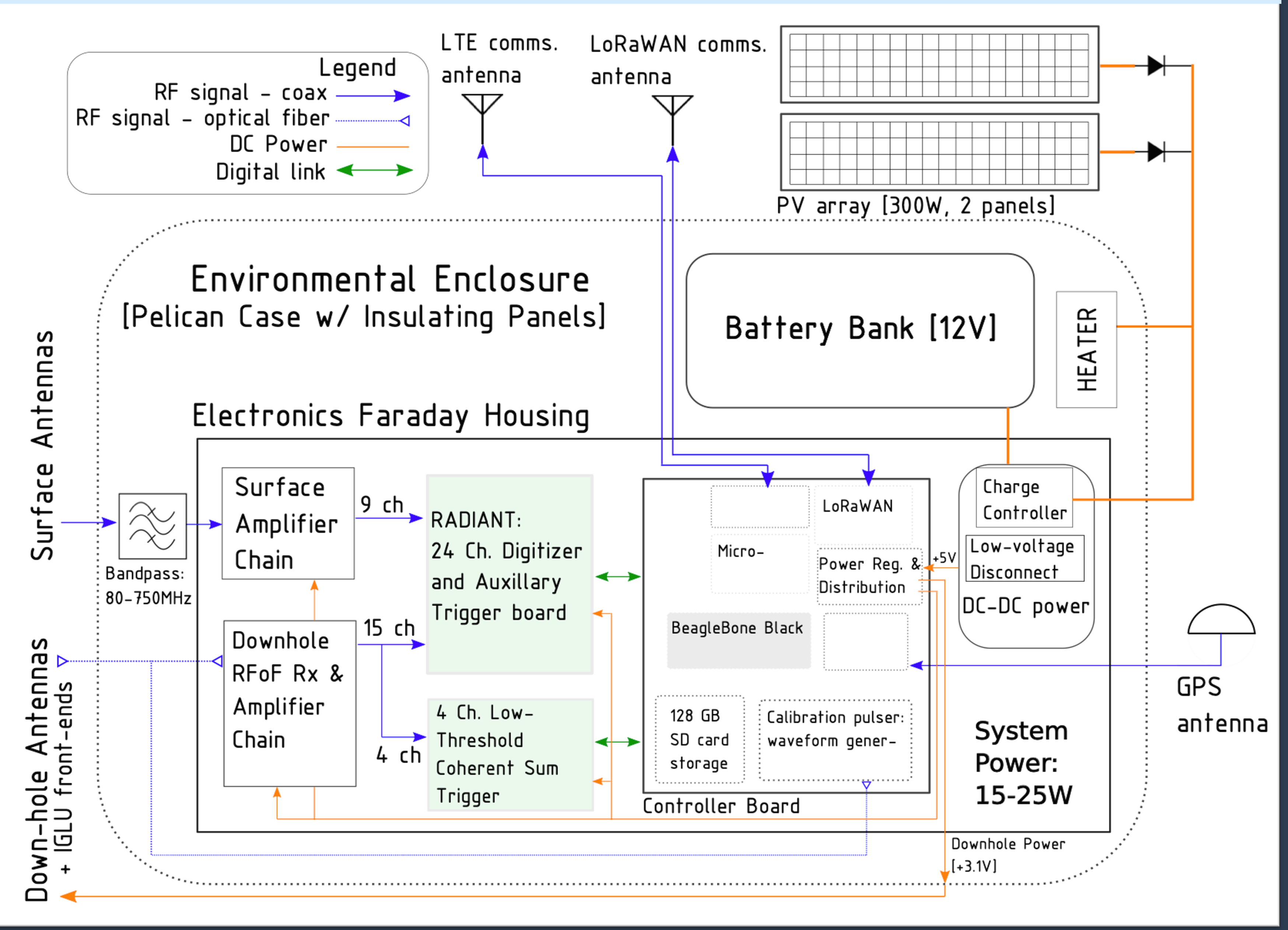


Fig 4: Antennas & Simulations

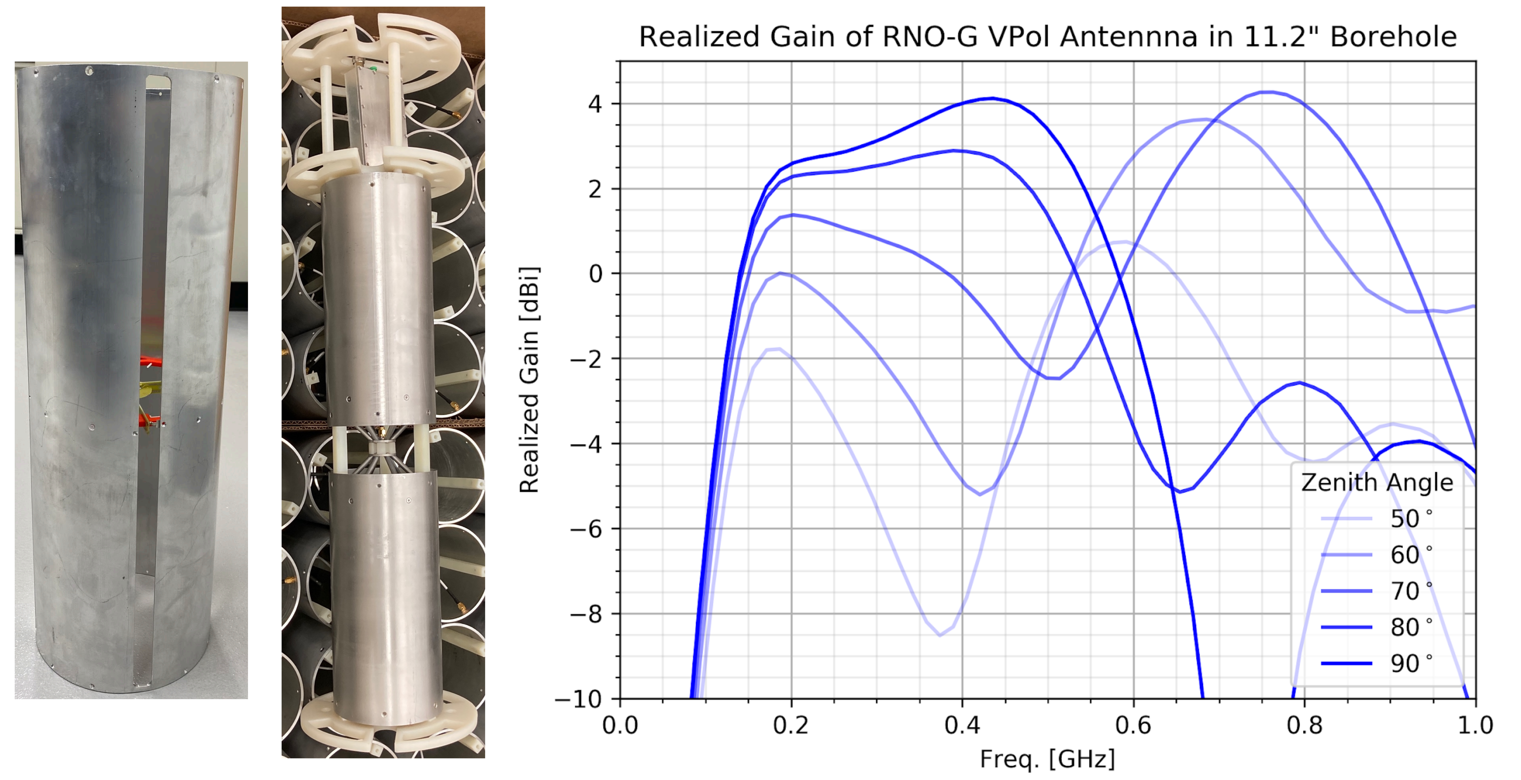
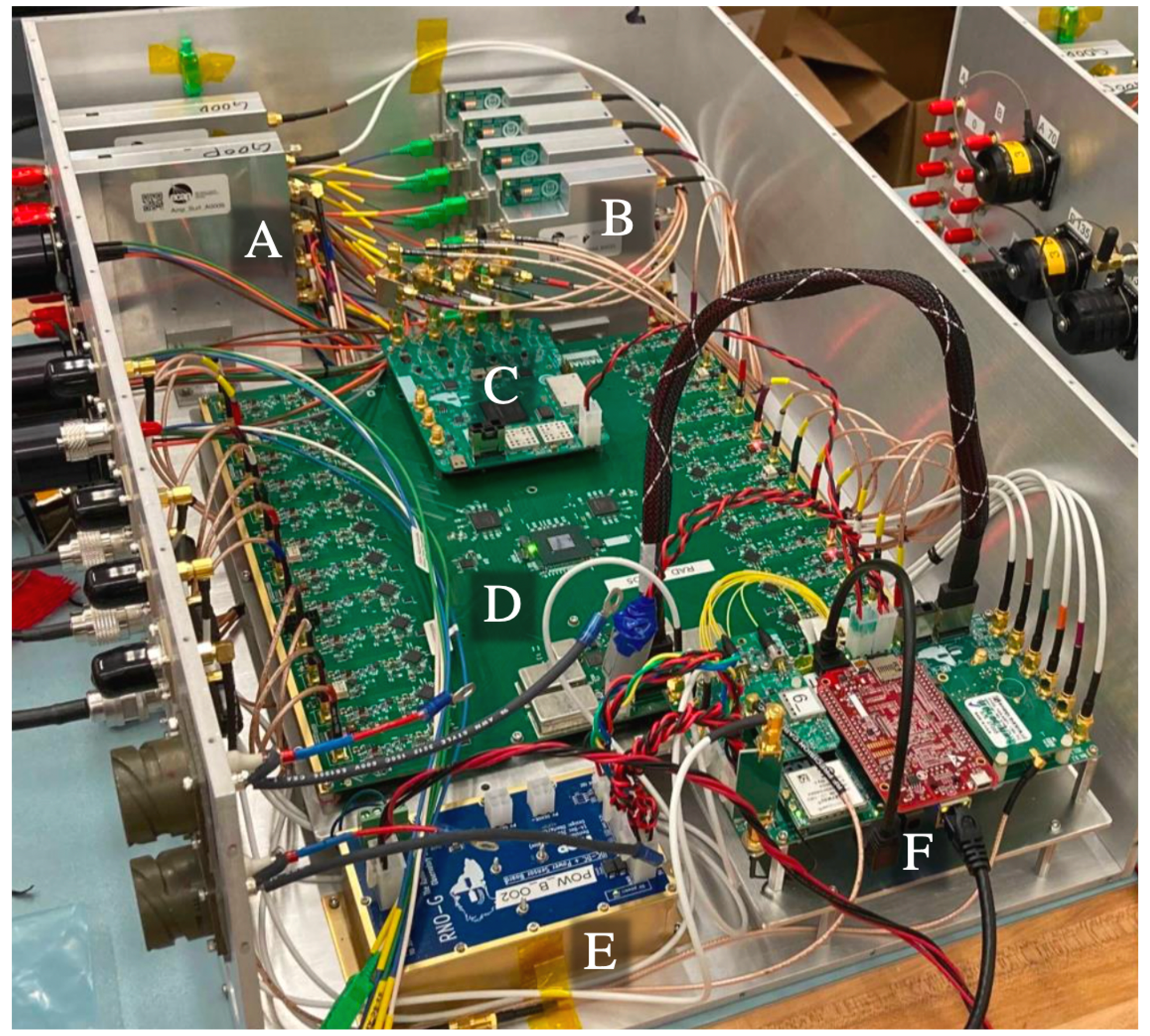


Fig 2: Station antenna layout, including surface & deep antennas and calibration pulsers
Fig 3: Station schematic, outlining all subsystems of a single station.
Fig 4: HPol (left) and VPol (middle) antennas with Vpol simulated antenna gain (right)
Fig 5: Assembled DAQ box, including (a) Surface amplifiers, (b) Deep amplifiers, (c) low threshold trigger board, (d) digitizer board, (e) power regulator, and (f) controller board.

Fig 5: Assembled DAQ



Antenna Design

Surface antennas, unconstrained by geometry, are commercially available, high-gain log-periodic dipole antennas. Deep antennas must operate within the 11.2" diameter ice borehole. The custom vertically-polarized (Vpol) antennas are fat-dipoles and the custom horizontally-polarized (Hpol) antennas are quadslot antennas. Simulations are non-trivial due to the ice far-field and an ice / air interface from the borehole that is in the antenna near field. In-situ calibrations are forthcoming.

Deployment

Deployment is ongoing, with the first drilling and science team arriving at Summit Station in May 2021. To date, on-base infrastructure has been constructed (including the LTE network, LoRAWAN network, station data server and off-station telemetry), borehole drilling continues, and the first station has been deployed. Further station deployments will continue over the season and extensive in-situ calibration will be performed in August 2021. Deployments in Summer 2022 and 2023 are scheduled to complete the 35 station array.

Fig 6: **Top**: DAQ box assembly line **Left**: Completed borehole.
Middle: Ice drill ejecting chips **Right**: All assembled vertically polarized antennas

References and Acknowledgements

[1] RNO-G Collab., J. A. Aguilar *et al.* JINST 16 no. 03, (2021) P03025.
[2] M. Roberts *et al.* Nucl. Instrum. Meth. A 925 (2019) 92–100.
[3] P. Allison *et al.* Nucl. Instrum. Meth. A 930 (2019) 112–125.

Kavli Institute for Cosmological Physics at The University of Chicago