Prototyping the SoLAr LArTPC Technology for Detecting MeV-Scale Neutrinos
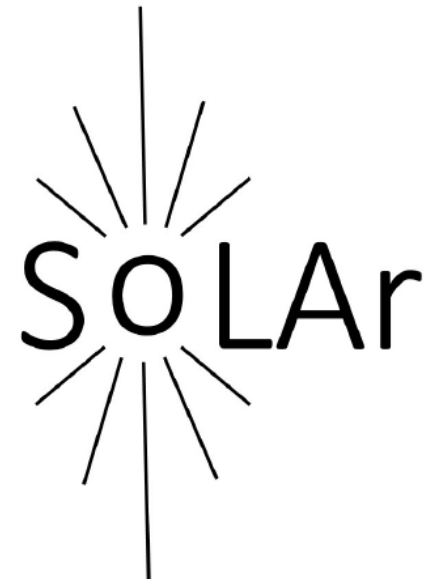
Richard Diurba (Bern) for the SoLAr Collaboration

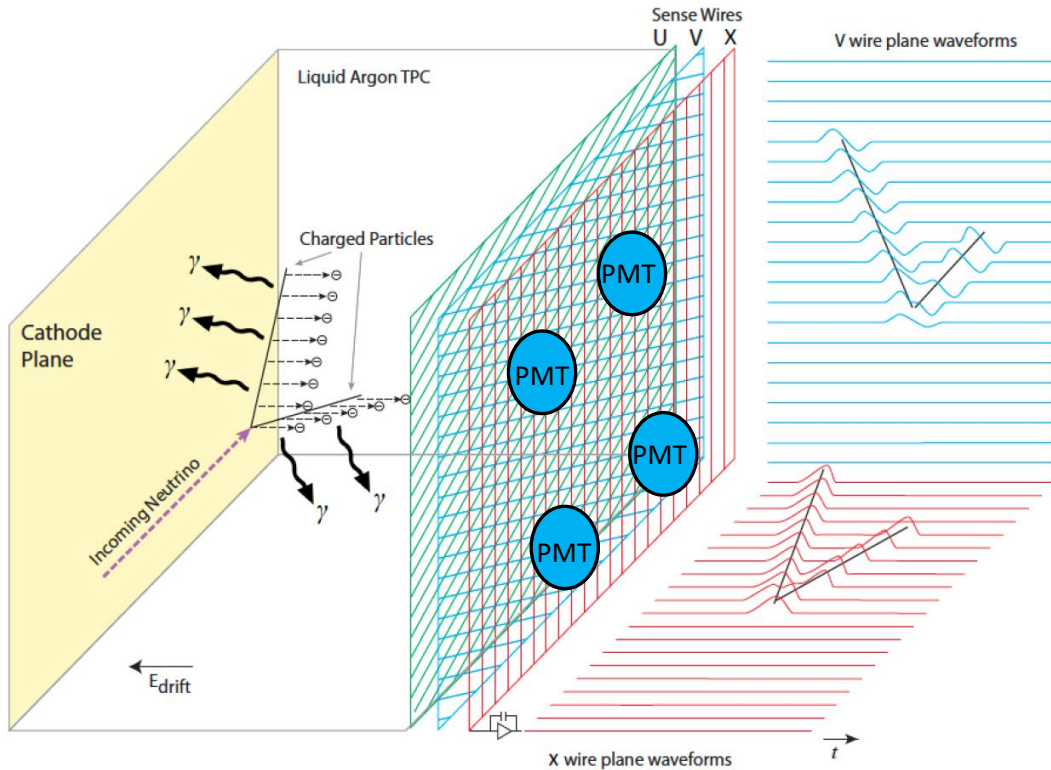u^b

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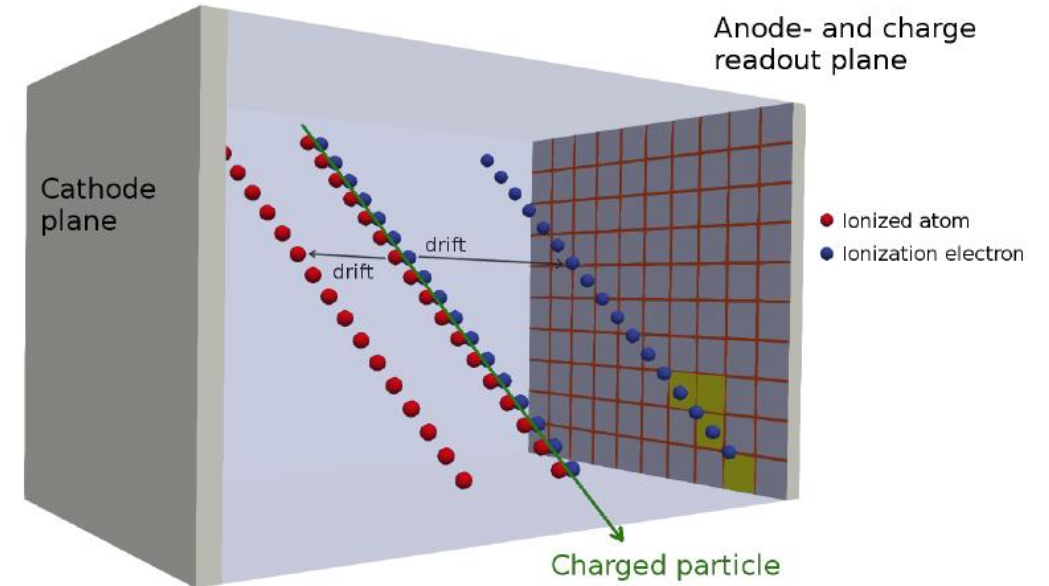BERN

First demonstration of detector concept: arXiv:2406.14121

Introduction

- Liquid argon time projection chambers have powerful imaging capabilities.
  - Chosen technology for GeV-scale neutrino experiments, such as SBN program and DUNE.
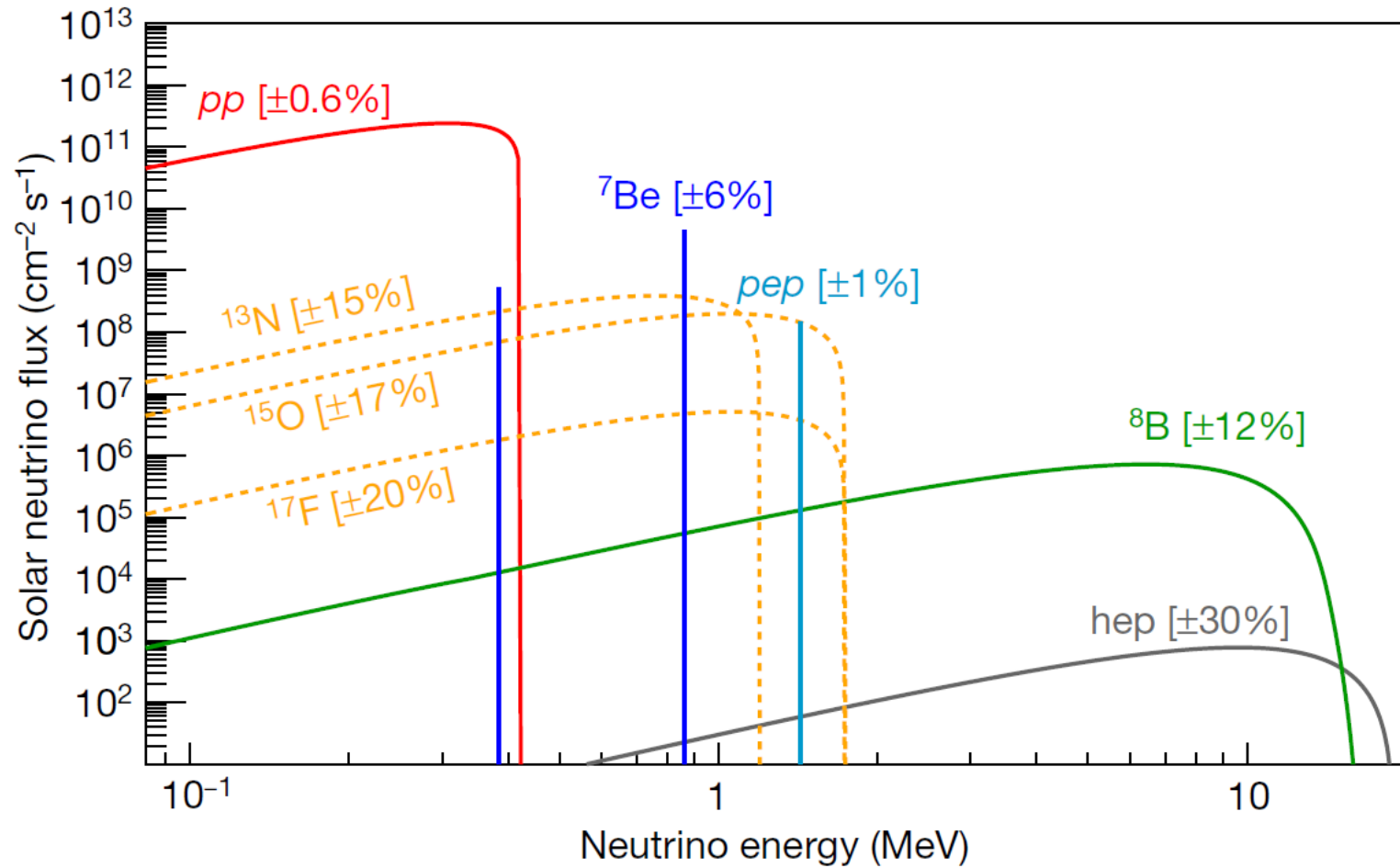

Example of a LArTPC with a wire-based readout with PMTs behind the wires (arXiv:2002.03005).

Example of a LArTPC with a pixel-based readout (https://argoncube.org/LArTPCs.html).

Solar Neutrino Flux

Nature **562**, 505–510 (2018)

Challenges for Solar Neutrinos in LAr

- Physics requirements for discovery *hep* branch solar neutrino physics with LAr:
  - 7% energy resolution at the MeV-scale (*PRL* **123**, 131803).
  - Low data rate for both background rejection and calibrations.
- Please see DUNE General talk (slide 7) from Thursday for more information.
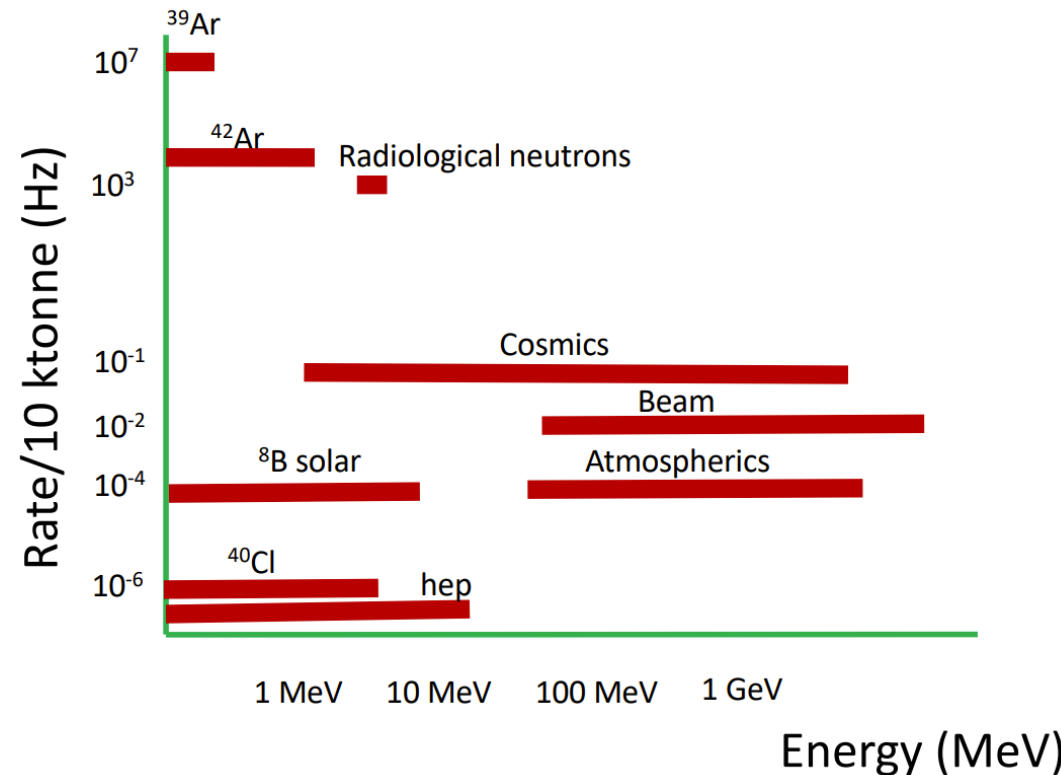
Predicted frequency of events for a DUNE Far Detector Module (*JINST* **15** T08008)
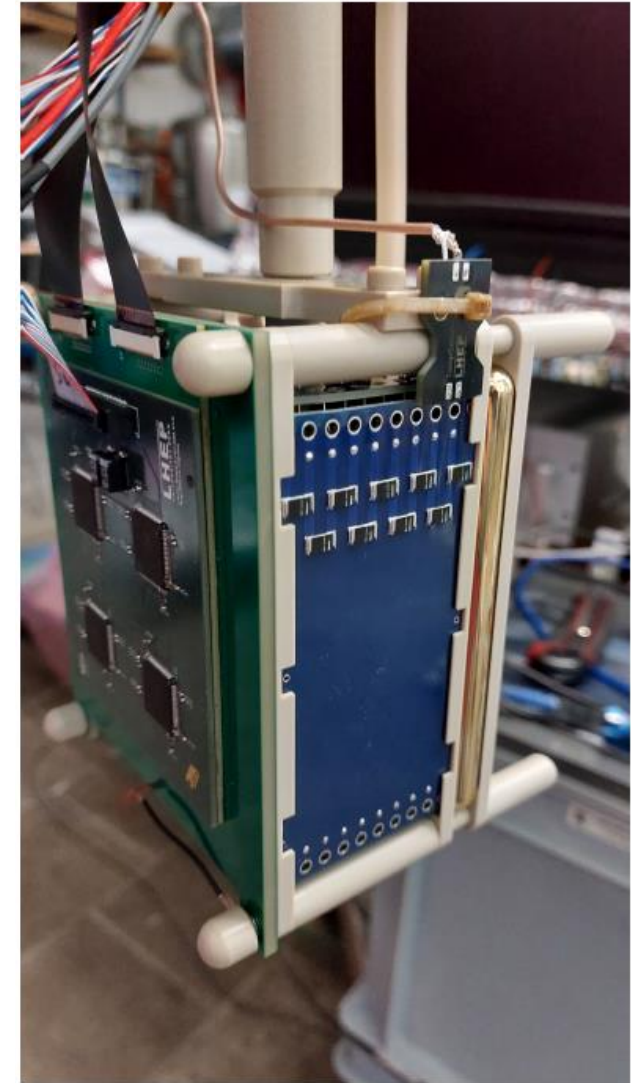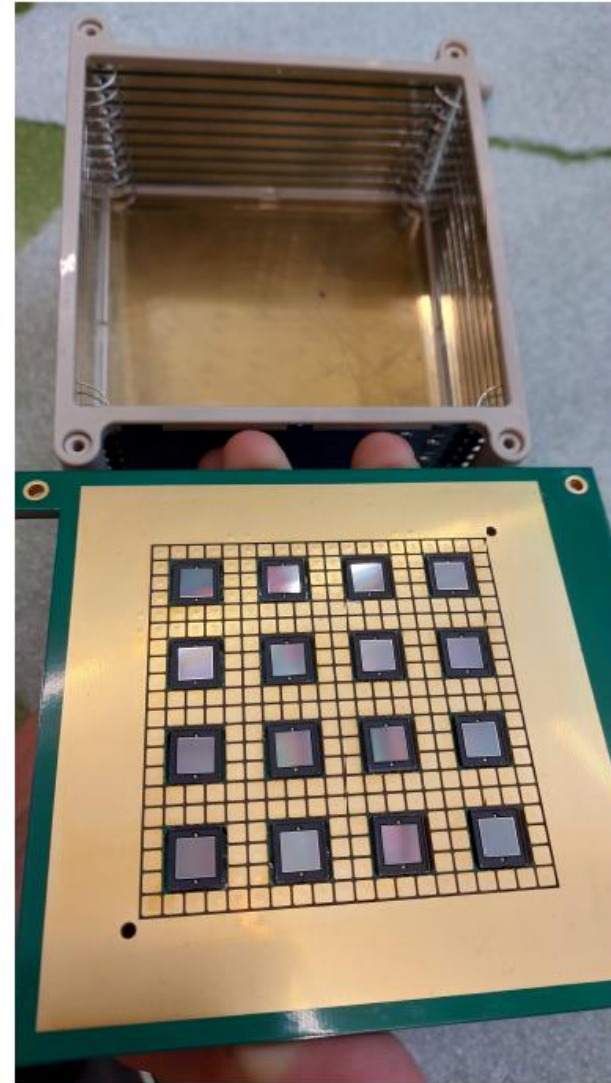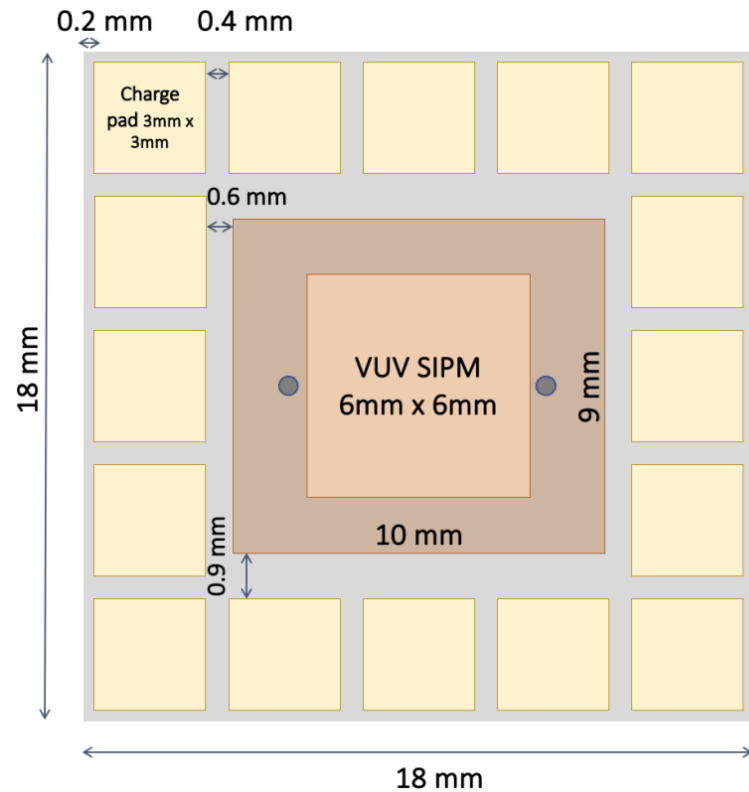
SoLAr Detector Concept

- Pixelated charge and light readout.
  - Light and charge tracking and calorimetry.
  - SiPM isolate charge pixel ROI.
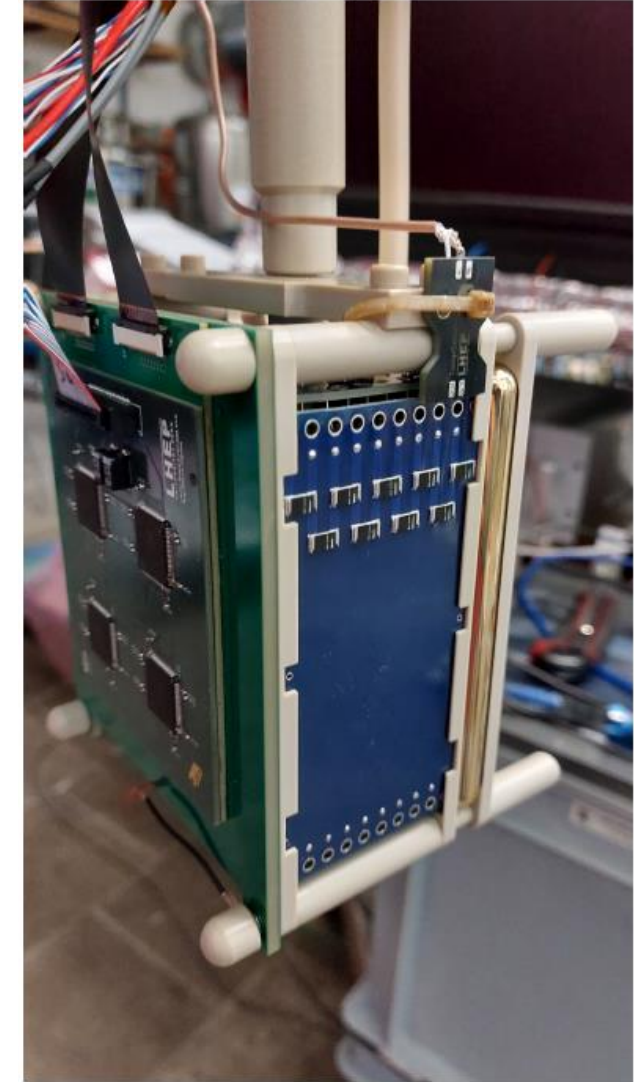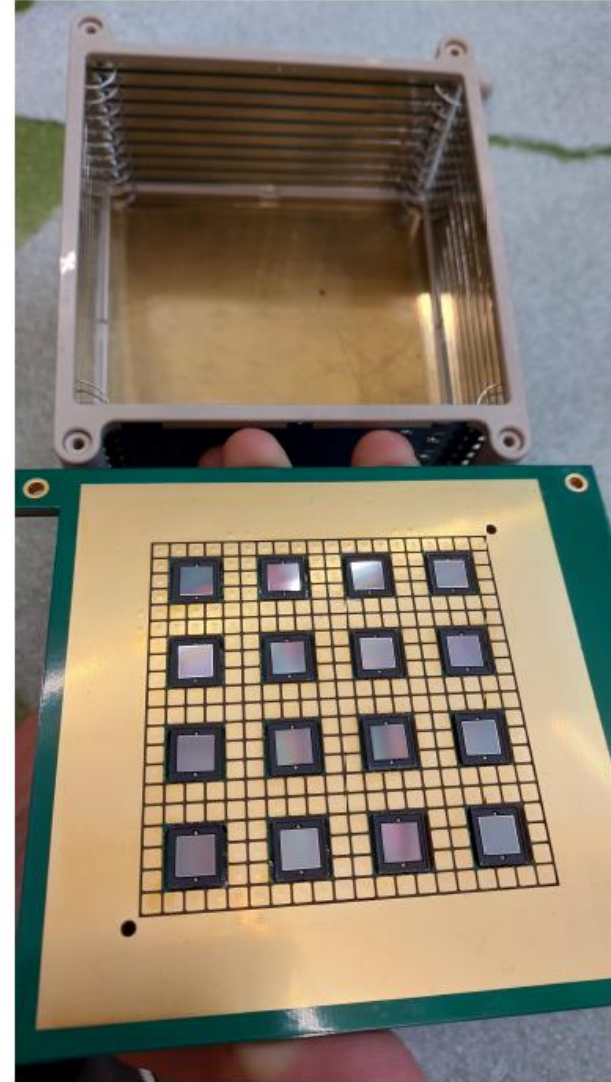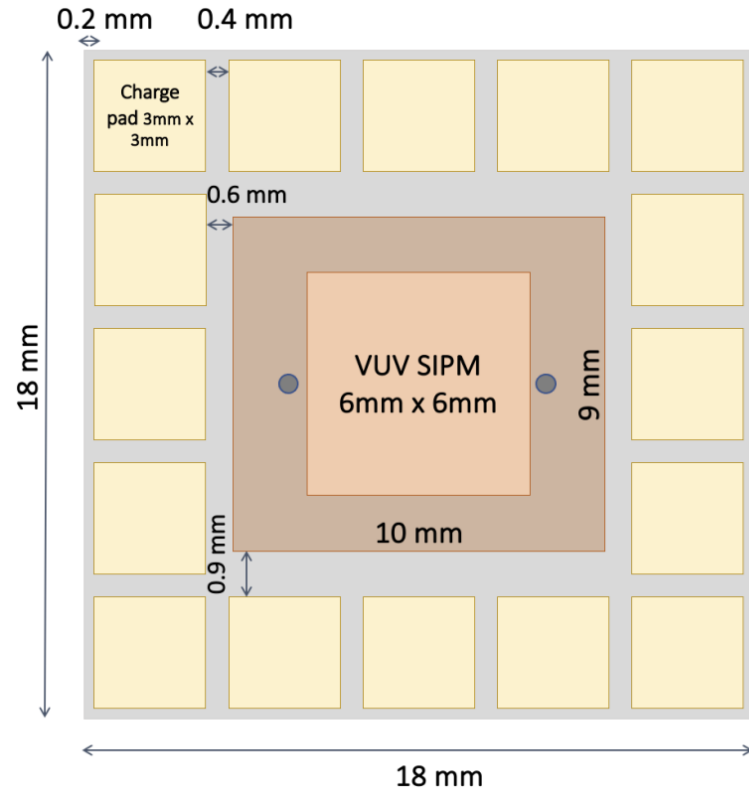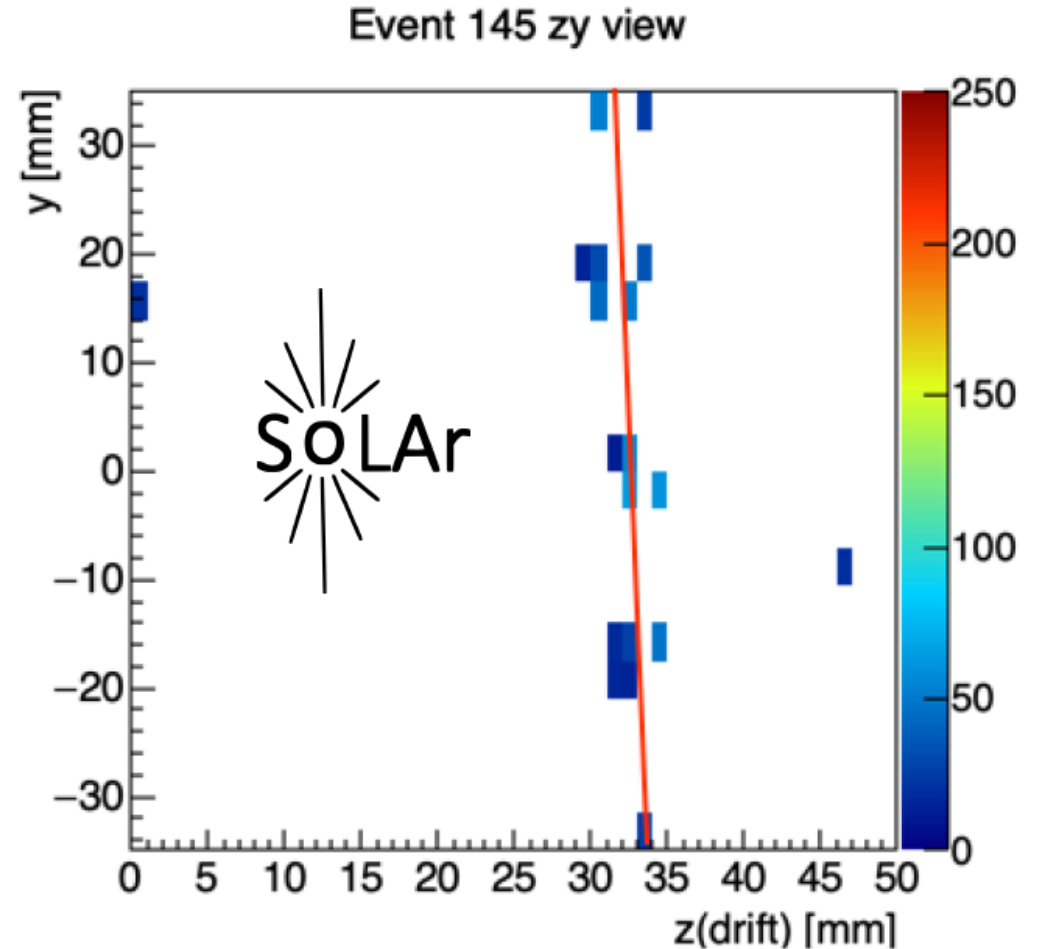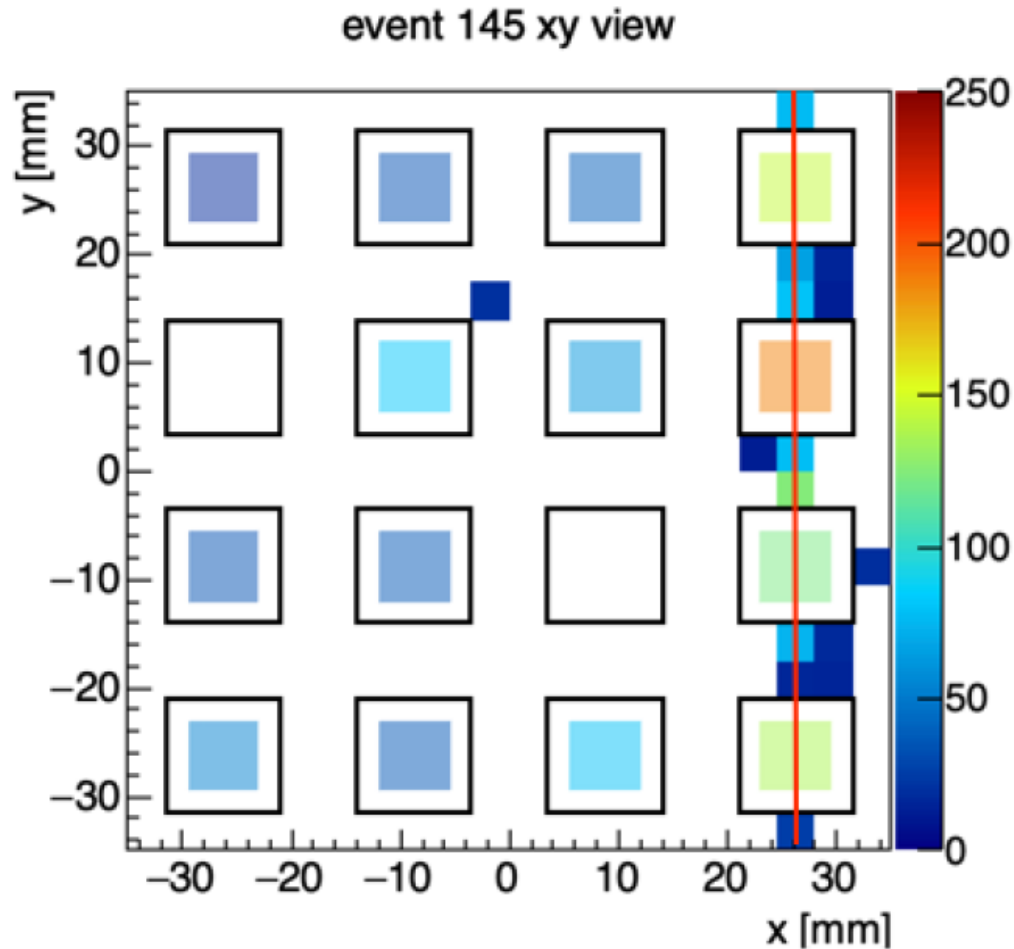
First Prototype of the SoLAr Detector Concept

- 7 cm by 7 cm detector with 5 cm drift.
- Charge readout: LArPix (*JINST* **13** P10007)
- Light readout: Hamamatsu VUV SiPMs
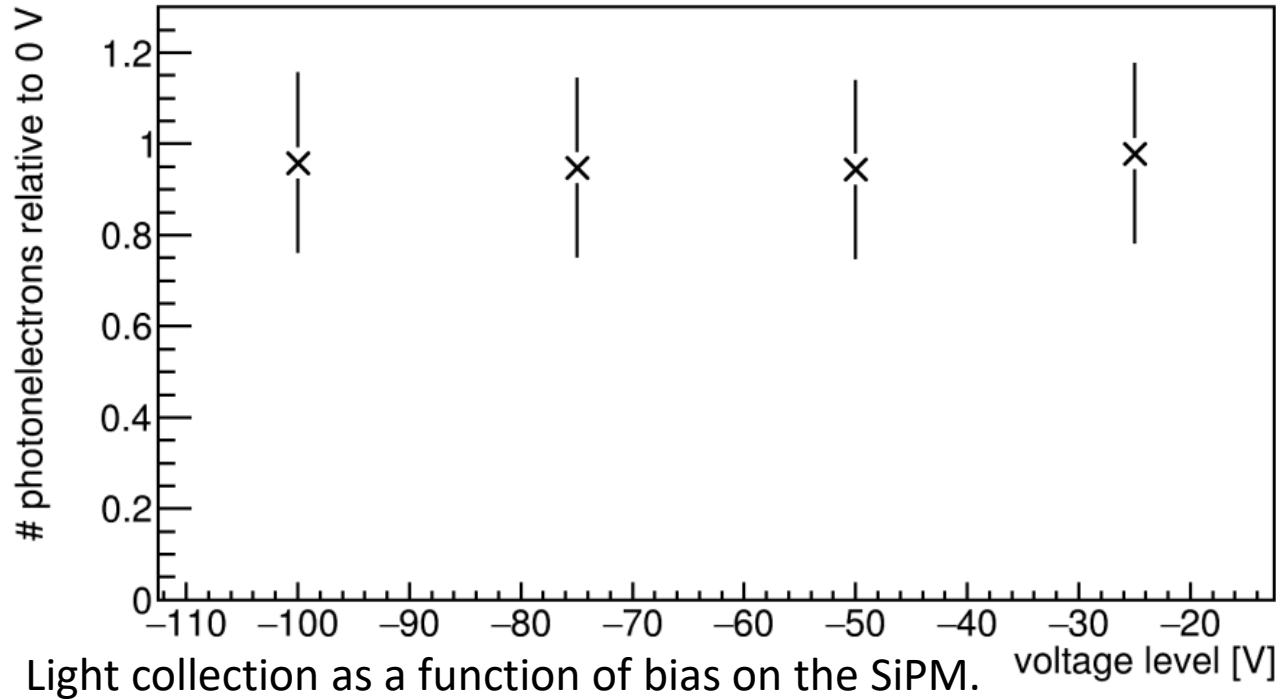

SiPM part number: Hamamatsu S13370-6050CN

SoLAr Prototype v1 Event Displays

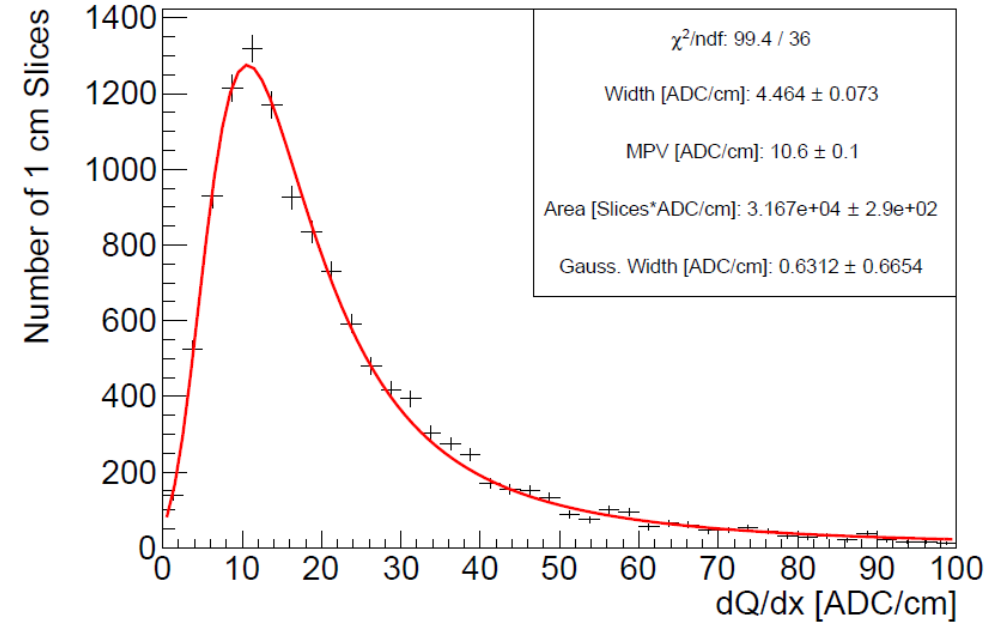- Collected data from October 24-26 2022.

SoLAr Prototype-v1 Performance

- Measured performance parameters such as:
  - Charge collected per unit length (right).
    - Ensure preliminary clustering operational.
  - Photon detection as a function of SiPM bias (bottom).

χ^2/ndf: 99.4 / 36

Width [ADC/cm]: 4.464 ± 0.073

MPV [ADC/cm]: 10.6 ± 0.1

Area [Slices*ADC/cm]: 3.167e+04 ± 2.9e+02

Gauss. Width [ADC/cm]: 0.6312 ± 0.6654

Charge collected per unit length with slices of 1 cm across a cosmic-ray muon.

Uses a rudimentary tracking algorithm using linear fits in two-dimensional planes.

Light collection as a function of bias on the SiPM.

The SiPM bias forces ionization electron on the pixels, not the SiPMs.
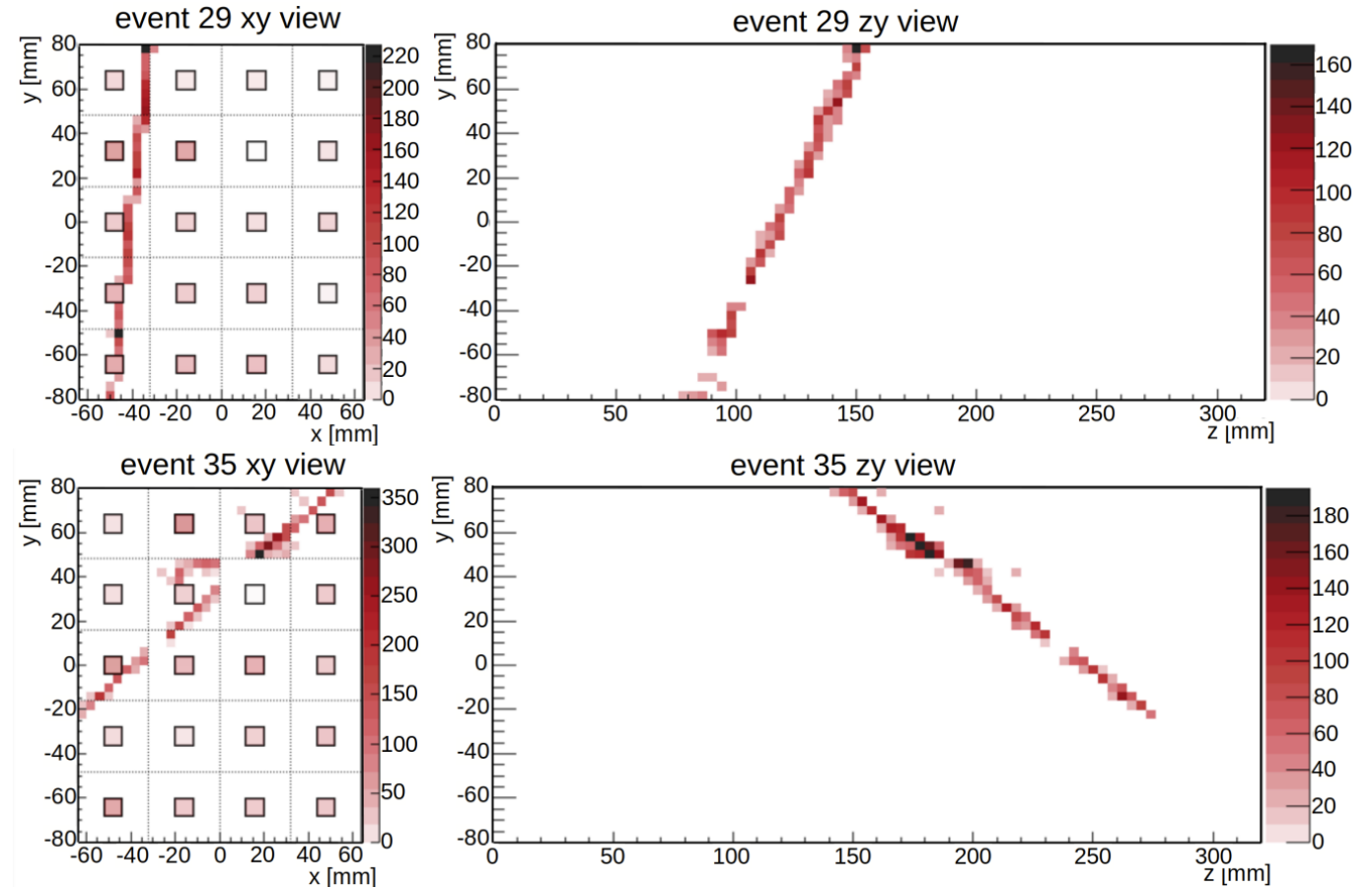
SoLAr Prototype-v2

- A 30 cm by 30 cm prototype produced and operated in 2023.
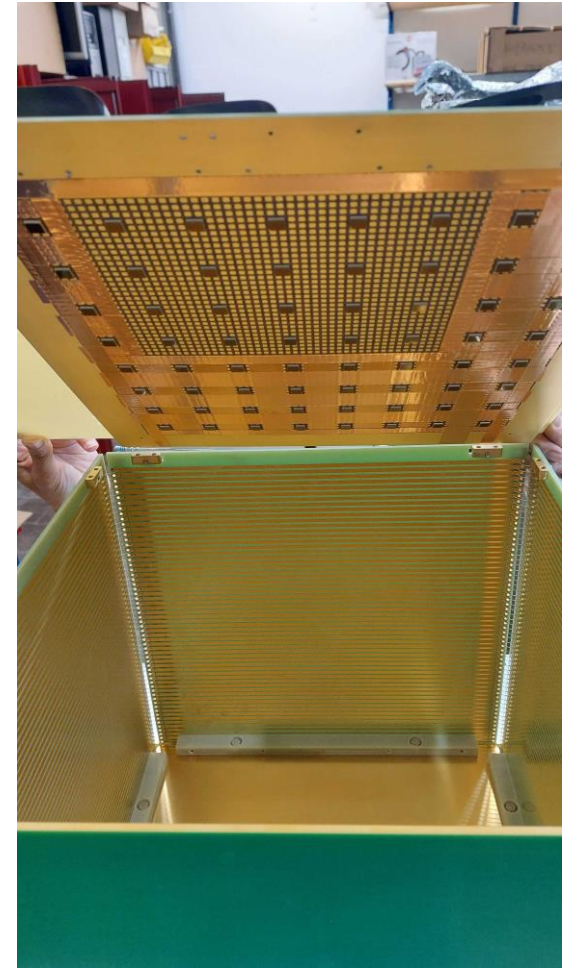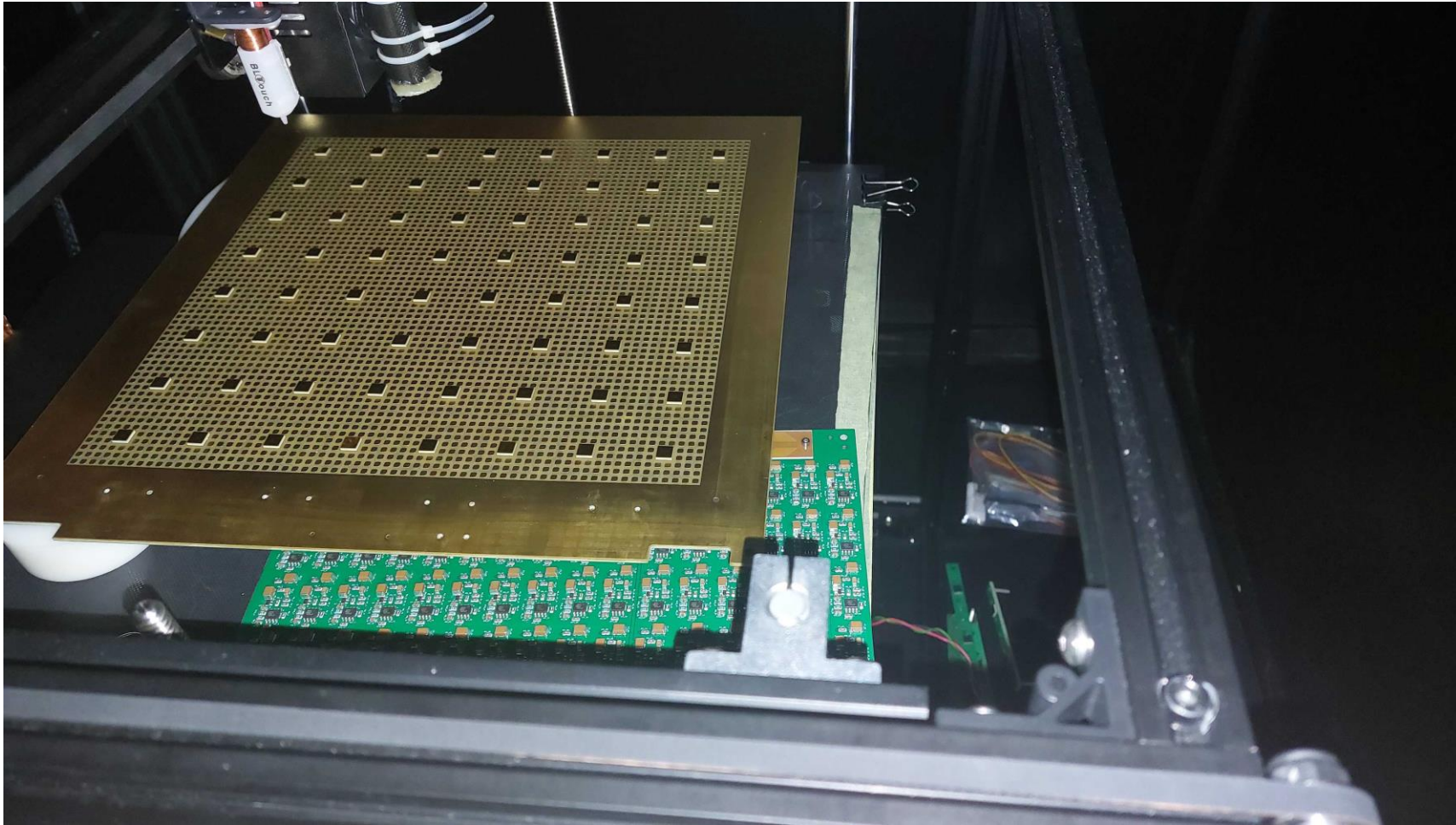
- SiPM was changed to a Hamamatsu (S13370-2221) surface-mounted on a single surface.

SoLAr Prototype-v2

- Operated over a week in July 2023.
- Collected thousands and thousands of cosmic-ray muons.
 - Included dedicated data-taking period with cobalt source.
- Analysis ongoing.

Event display of a cosmic-ray muon from SoLAr Prototype-v2 (*JINST* **19** C02075)

Conclusion

- SoLAr is an exciting new design for a dual-readout liquid argon time projection chamber.
  - Targets high energy solar neutrinos with a target for finding *hep* process solar neutrinos.
- Has developed two prototypes, one with public results and the other with analysis ongoing.
- Short term larger-scale prototype being proposed for the Boulby Underground Laboratory.
- Long term development to scale technology for a kiloton-scale module.

Thank you!
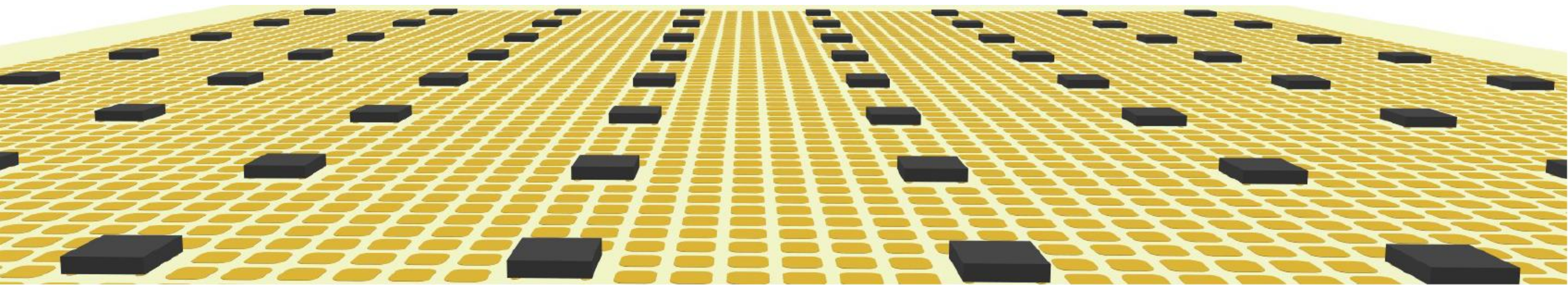
Conclusion

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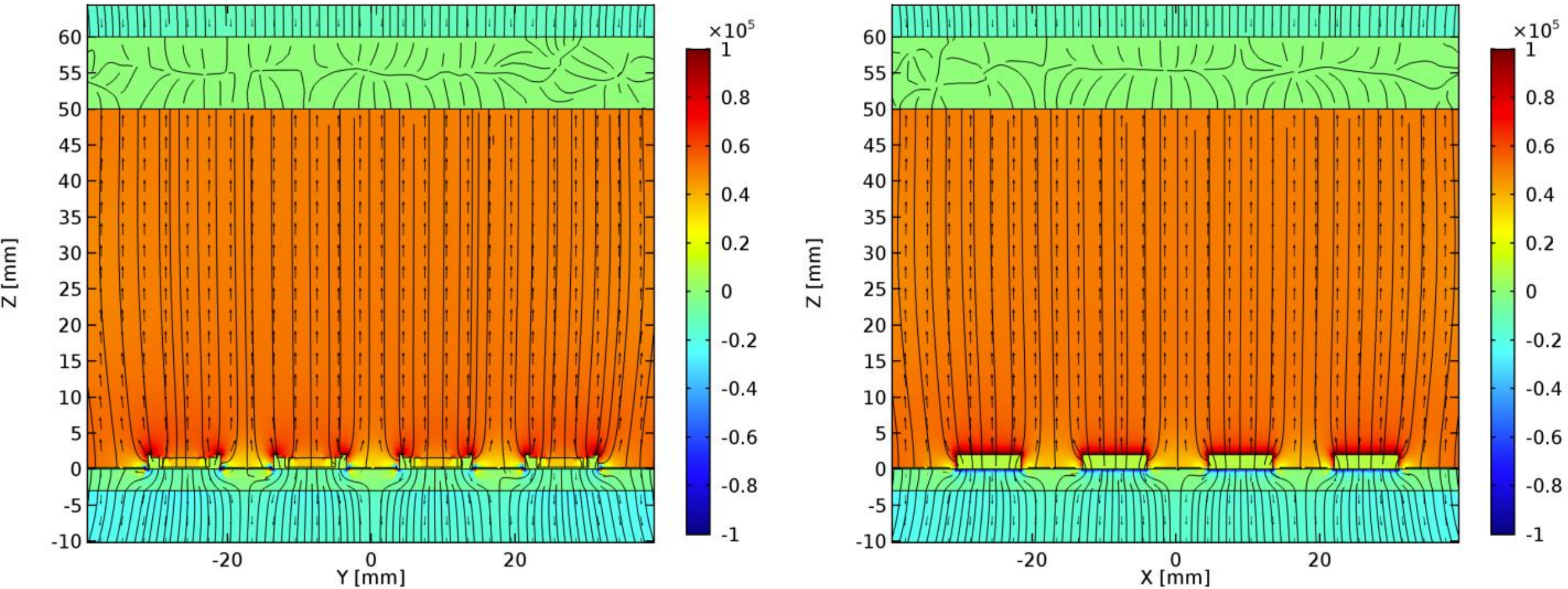
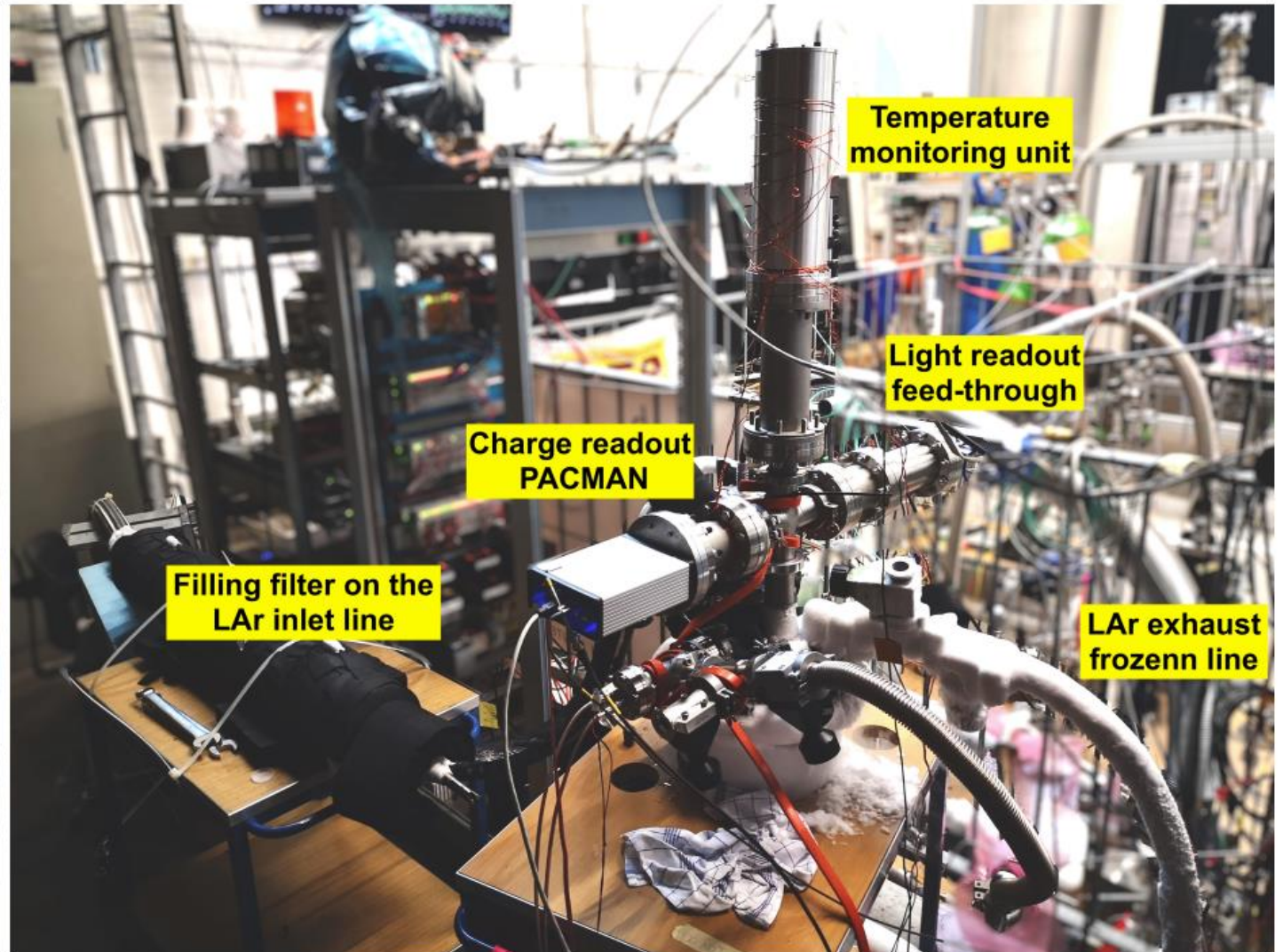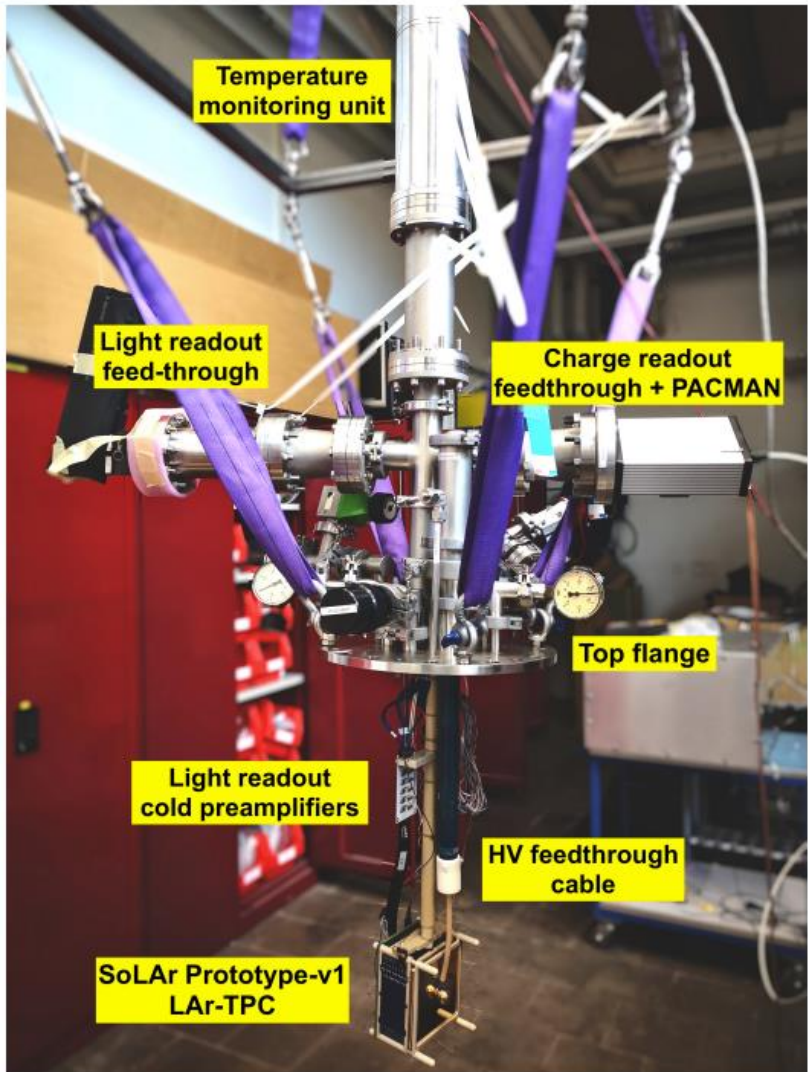Thank you!
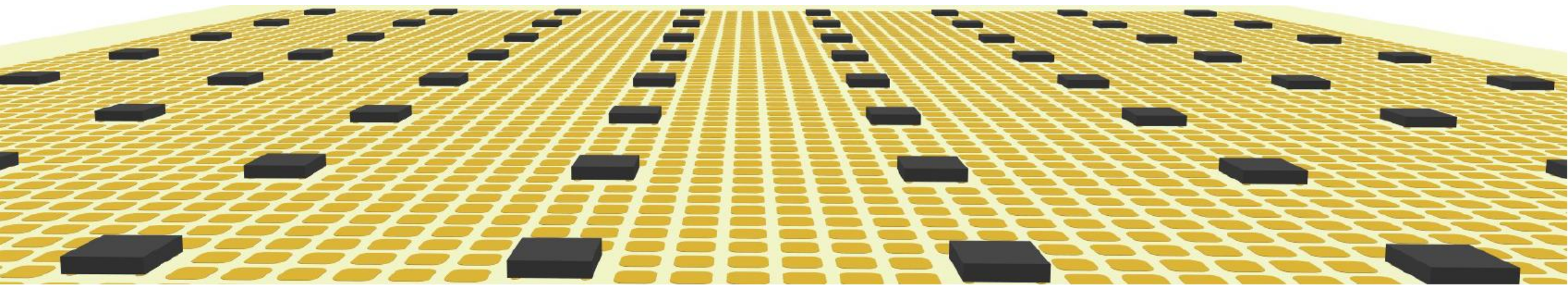
Backup Slides

Solar Neutrino Generation
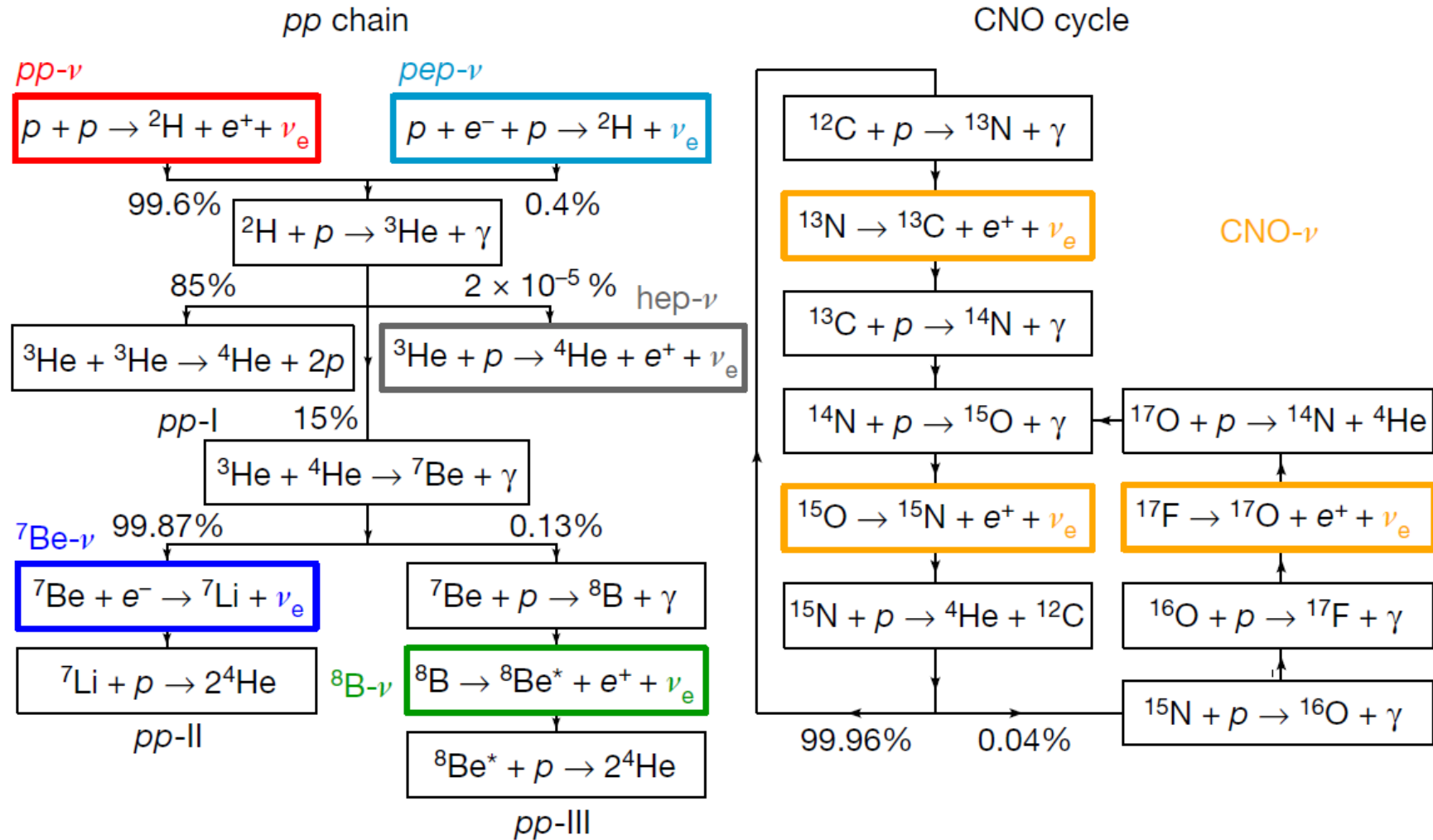
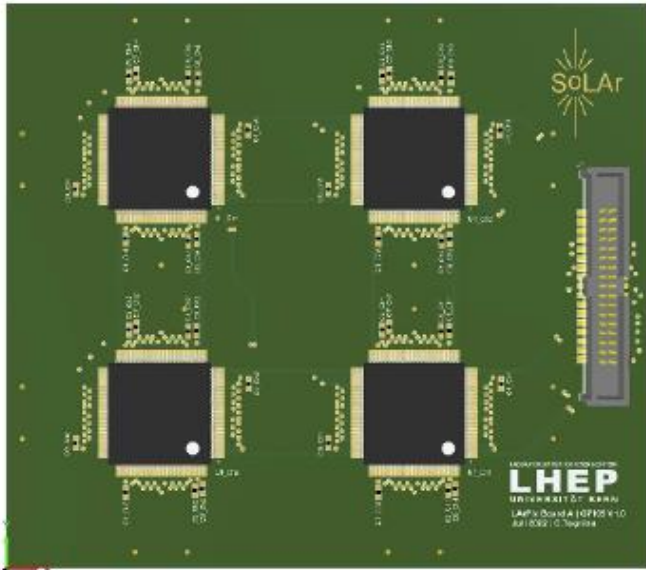Nature **562**, 505–510 (2018)

Electric field simulations

Electric field lines within a 500 V/cm electric field, showing how the a biased, raised SiPM will push charge to the nearby pixels.
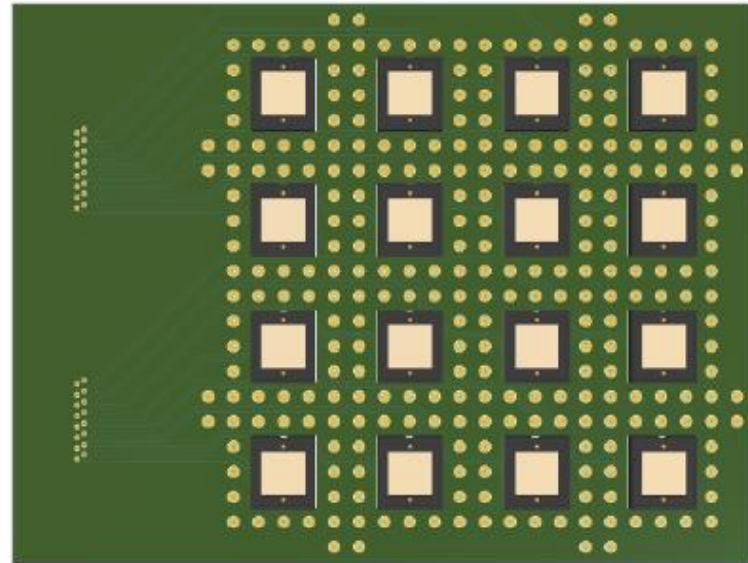
SoLAr Prototype-v1 Operating Setup
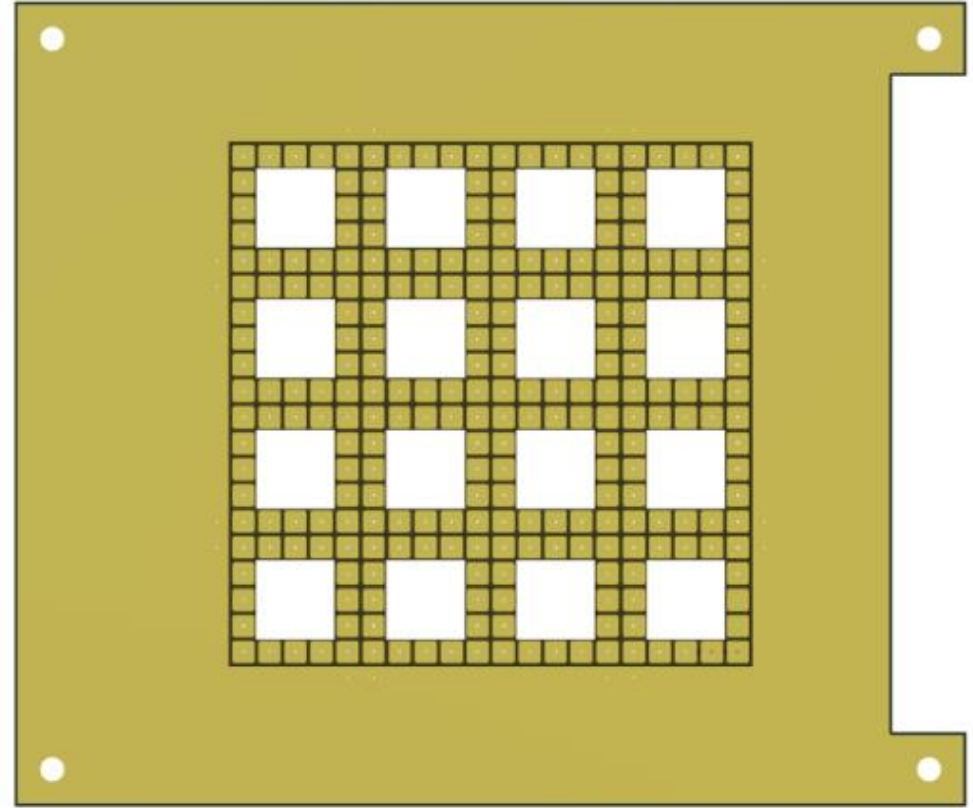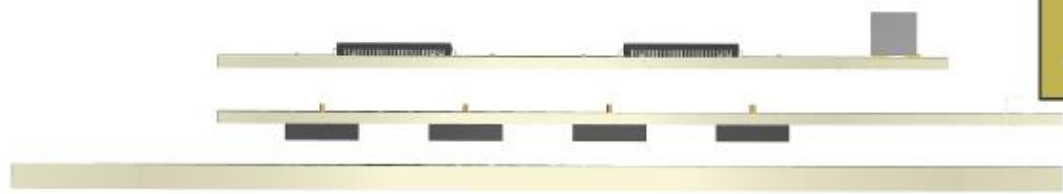
SoLAr Prototype-v1 Printed Circuit Board

A – charge readout
B – SiPM readout
C – pixel elevation

SoLAr Prototype v1 Event Displays

event 1932 xy view

Event 1932 zy view