



Science and
Technology
Facilities Council



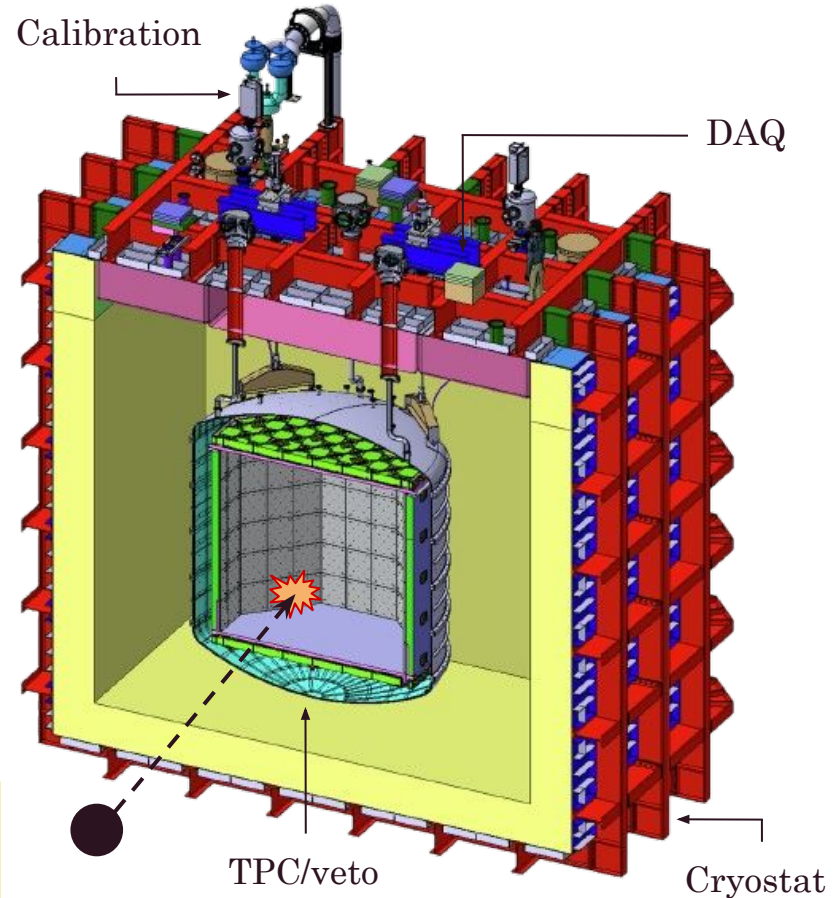
Preparing for DarkSide-20k veto photodetector installation

Isobel Sargeant
Science and Technology Facilities Council

What is DarkSide-20k?

- **Direct detection experiment** targeting keV to Planck-scale dark matter candidates
- **Dual-phase time projection chamber (TPC)**
 - 50-tonne liquid underground argon (UAr) active volume
- Underground at INFN Gran Sasso (LNGS) in Italy
- Using cryogenic **silicon photomultipliers**

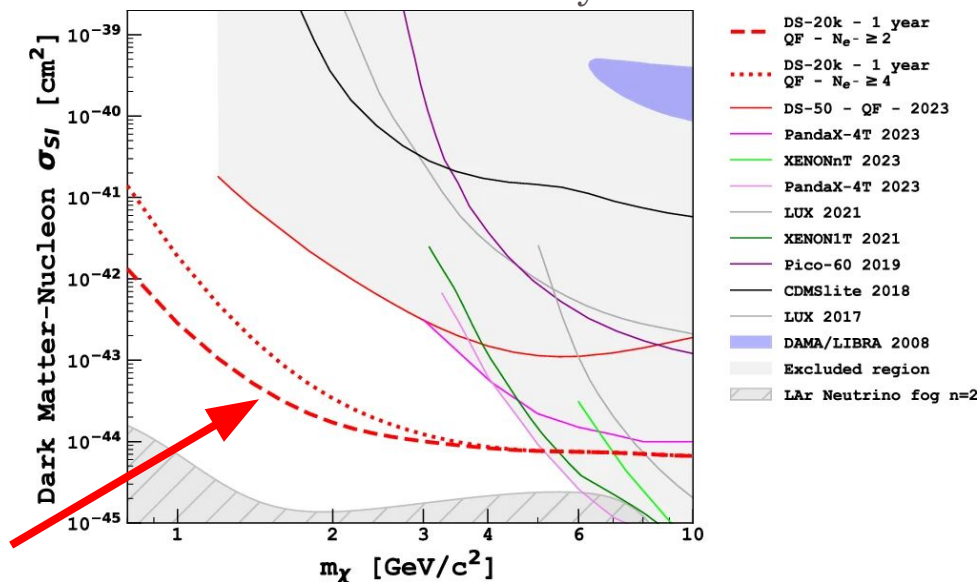
See Daria Santone's talk: "*Construction Progress of the DarkSide-20k Dark Matter Search Experiment*"
→ 11:45, 10/4, Dark Matter parallel session



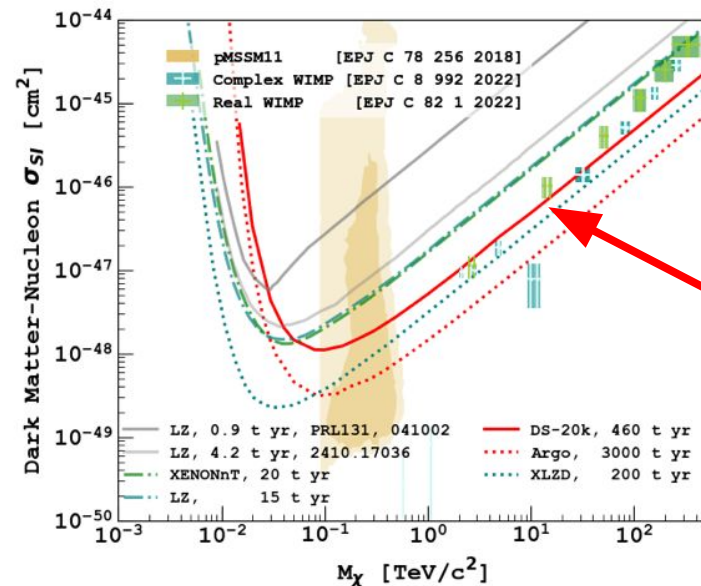
Zani, A. (2024) 'The DarkSide-20K Experiment', Journal of Instrumentation, 19(03).

DarkSide-20k Sensitivity

Low-mass sensitivity



High-mass sensitivity



- Projected to have world leading sensitivity to dark matter candidates in the GeV-TeV range
- Aims to be **background-free** (<1 background events with 200 t yr exposure)

Agnes, P. (2023) 'Direct detection of dark matter with DarkSide-20K', EPJ Web of Conferences, 280, p.06003.

The Darkside Collaboration (2024) 'DarkSide-20K sensitivity to light dark matter particles', Communications Physics, 7(1).

Neutron Veto

Radiogenic neutrons from contaminants

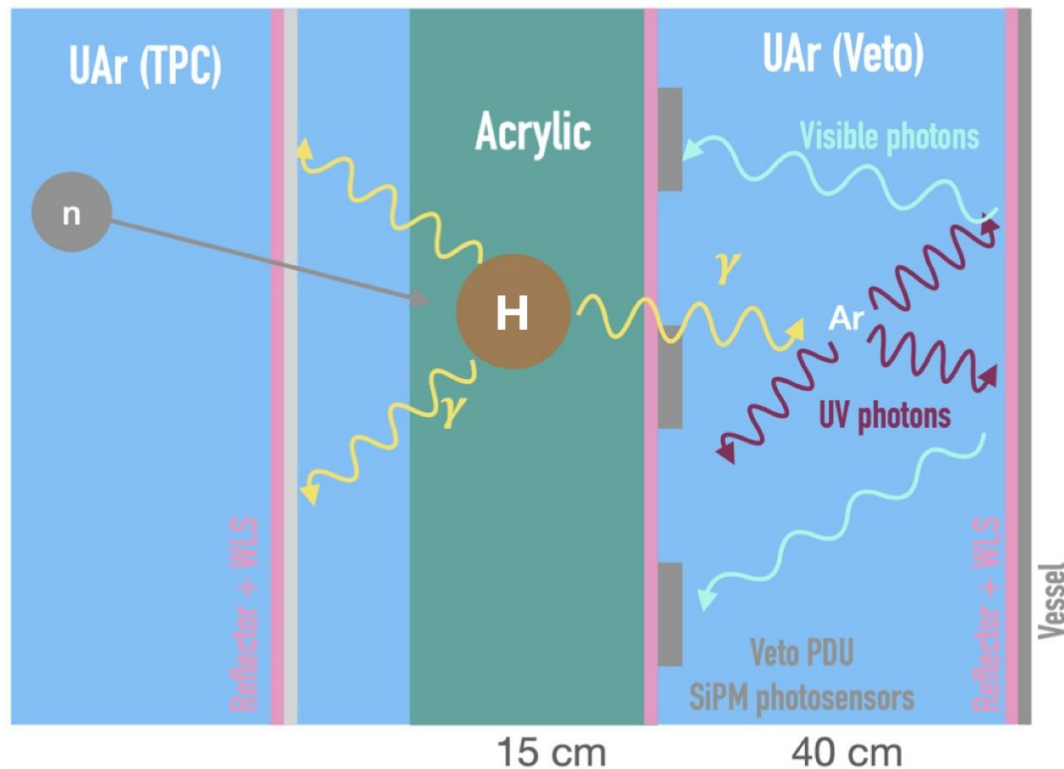
- irreducible
background
- nuclear recoils
mimic dark matter

Neutron Veto

Radiogenic neutrons from contaminants

- irreducible background
- nuclear recoils mimic dark matter

Also selecting materials with low intrinsic radioactivity

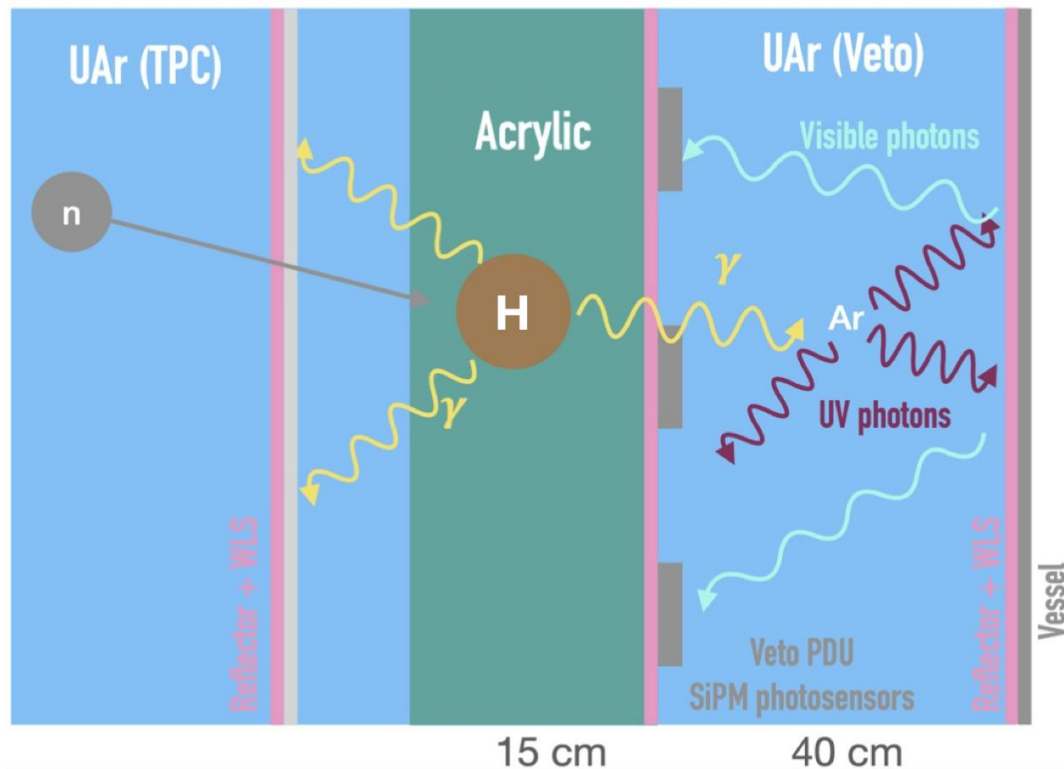


Neutron Veto

Radiogenic neutrons from contaminants

- irreducible background
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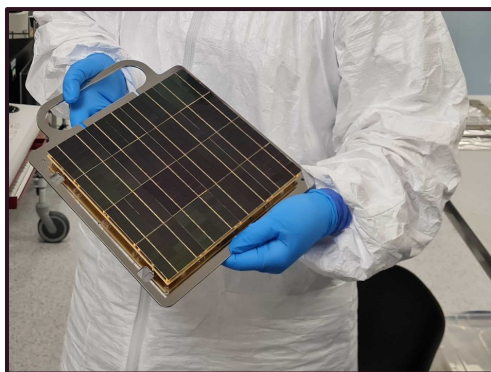
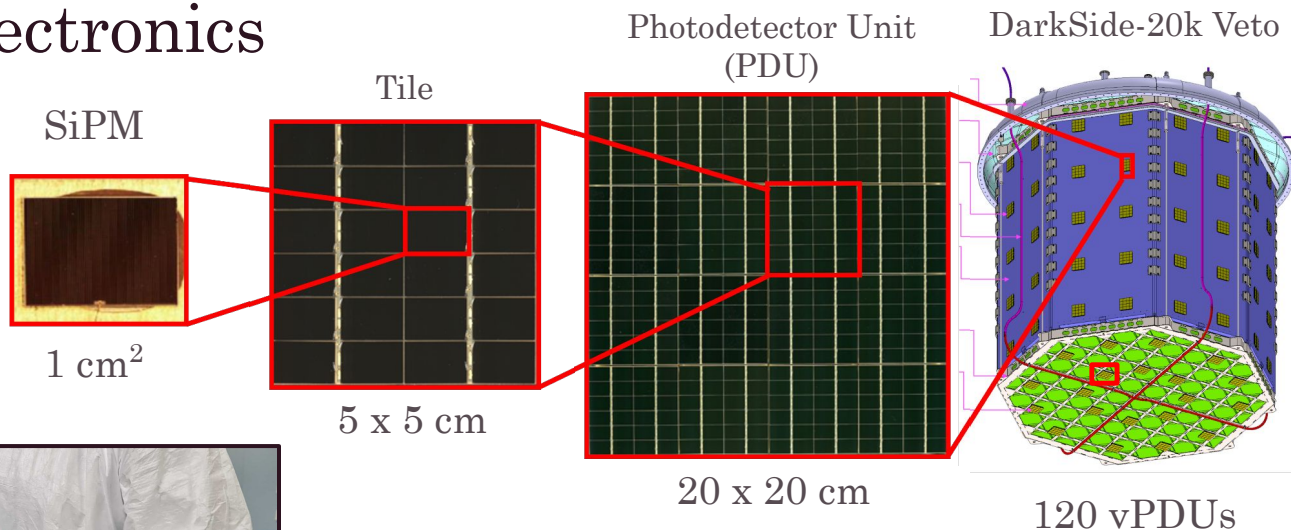
Also selecting materials with low intrinsic radioactivity



Looking for evidence of neutron capture with $\sim 800 \mu\text{s}$ coincidence window from candidate dark matter nuclear recoil event in TPC

Manthos, I. (2024) 'DarkSide-20K: Next generation direct dark matter searches with liquid argon', EPS-HEP 2023, p. 113.

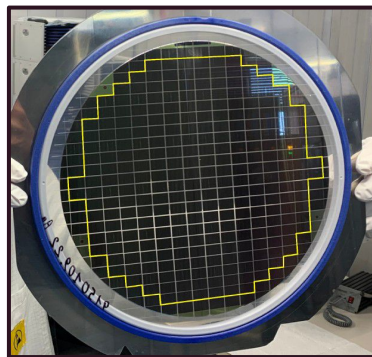
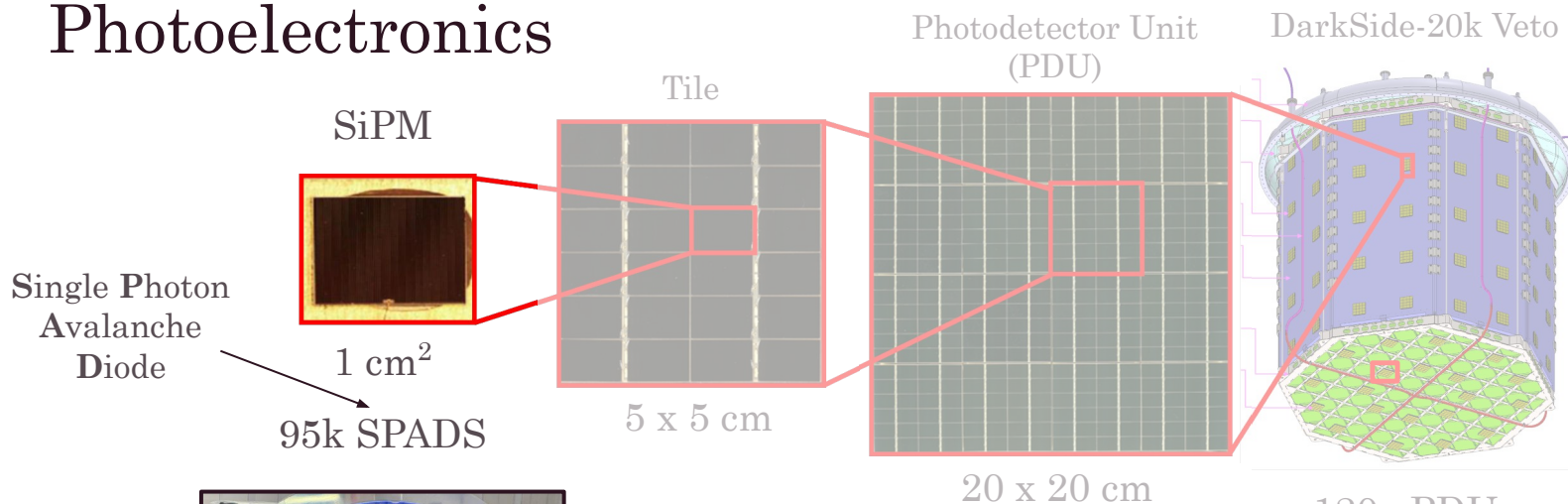
Photoelectronics



Person holding PDU for scale!

vTile and vPDU refer to veto components

Photoelectronics



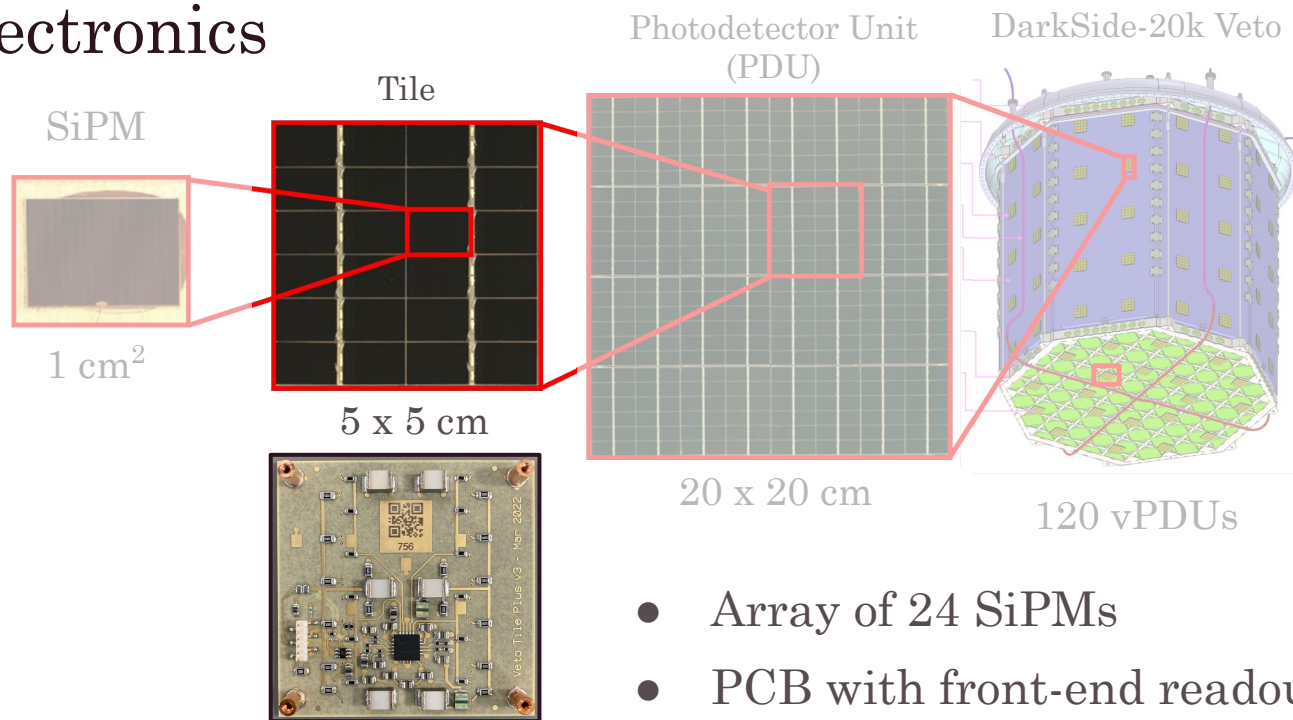
Chosen for their:

- low intrinsic noise
- high radiopurity
- single photon resolution

arXiv:2412.18867

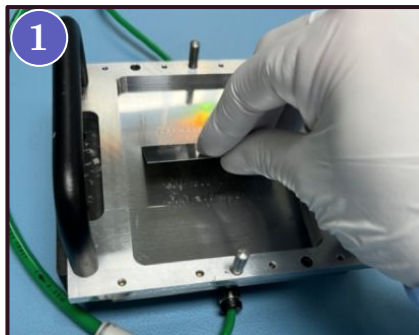
Aalseth, C.E. et al. (2017) 'Cryogenic characterization of FBK RGB-HD SiPMs, Journal of Instrumentation, 12(09).

Photoelectronics



- Array of 24 SiPMs
- PCB with front-end readout amplification

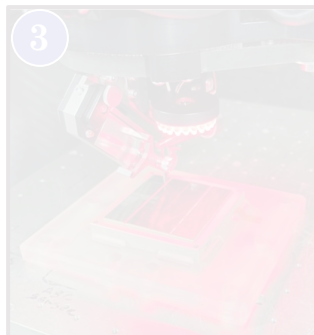
vTile Production



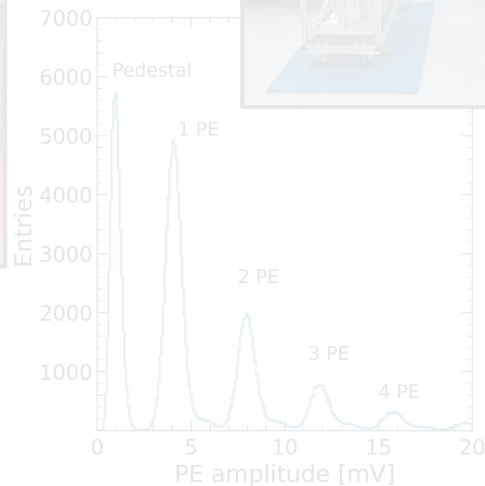
1 Deposit glue



2 Place SiPMs

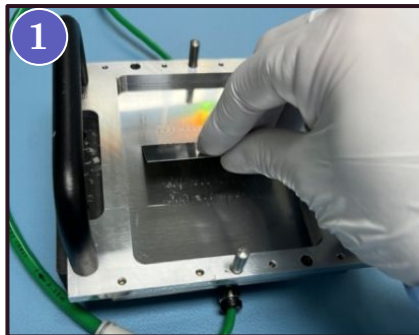


3 Wire bond

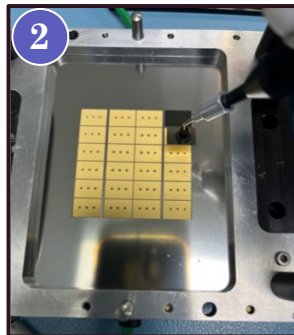


Electrical testing
at room
temperature
(warm) and in
liquid nitrogen at
77K (cold)

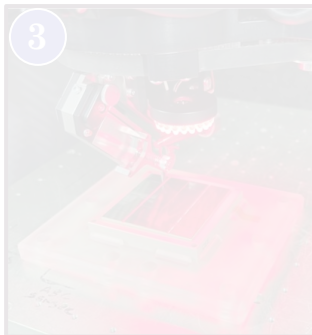
vTile Production



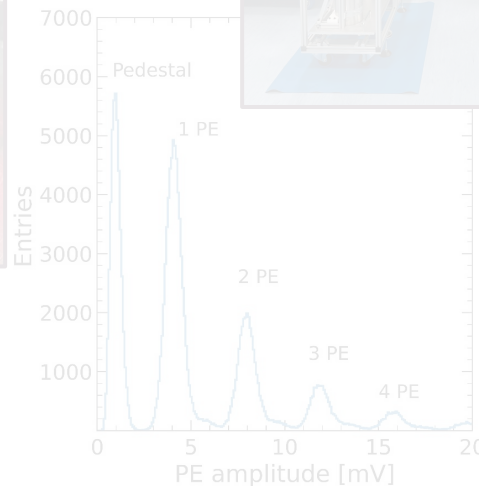
Deposit glue



Place SiPMs

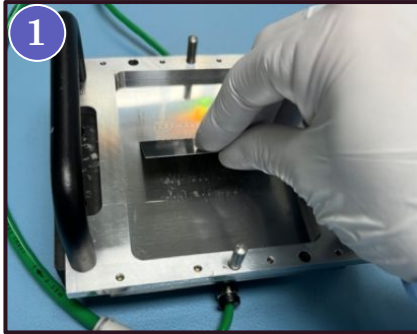


Wire bond

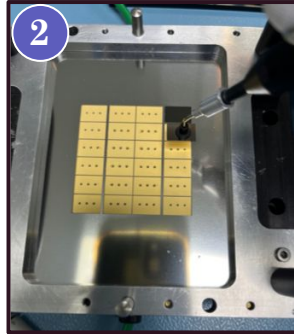


Electrical testing
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vTile Production



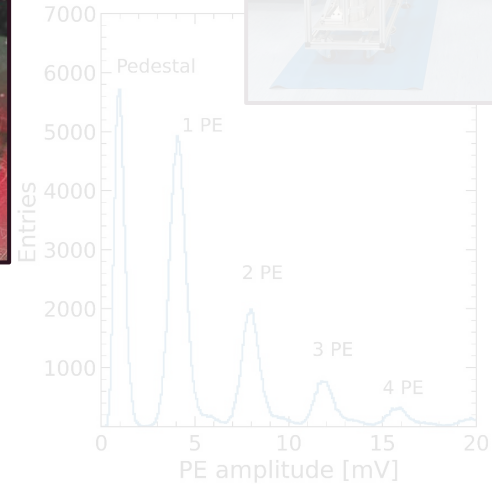
Deposit glue



Place SiPMs

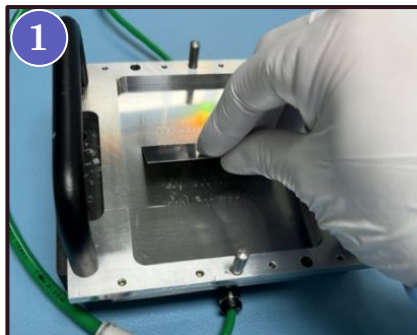


Wire bond

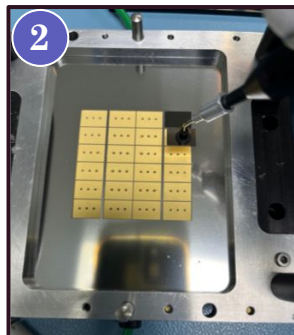


Electrical testing at room temperature (warm) and in liquid nitrogen at 77K (cold)

vTile Production



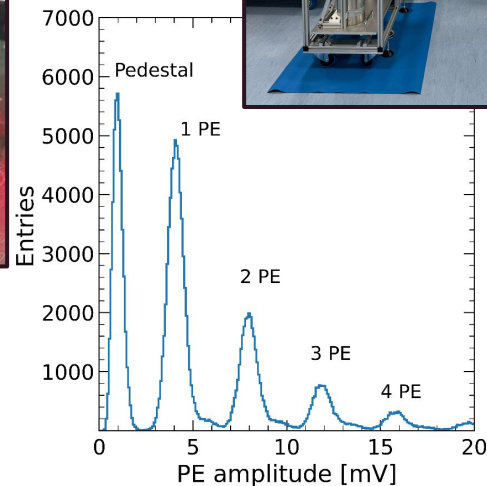
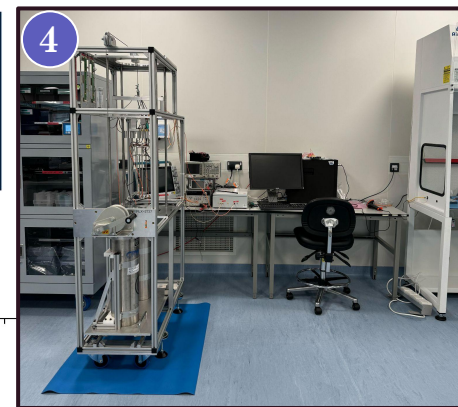
Deposit glue



Place SiPMs

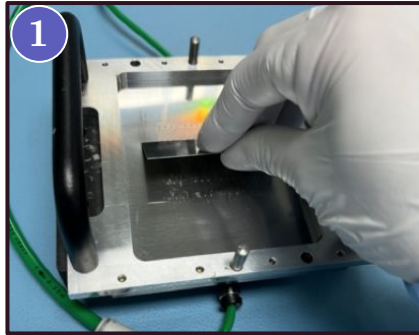


Wire bond

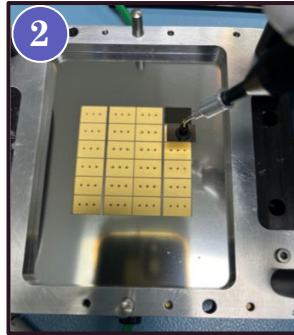


Electrical testing
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vTile Production



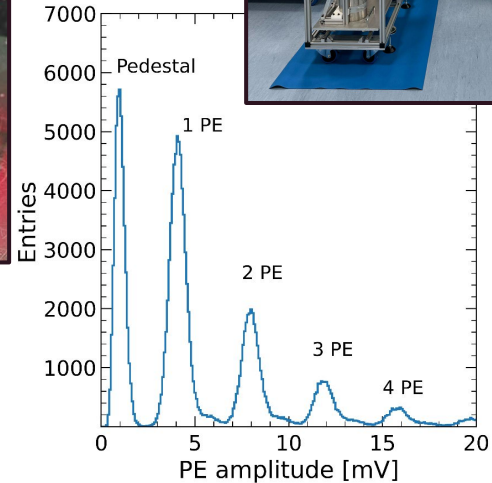
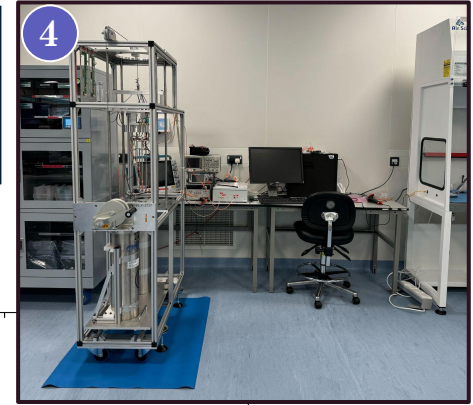
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2 Place SiPMs



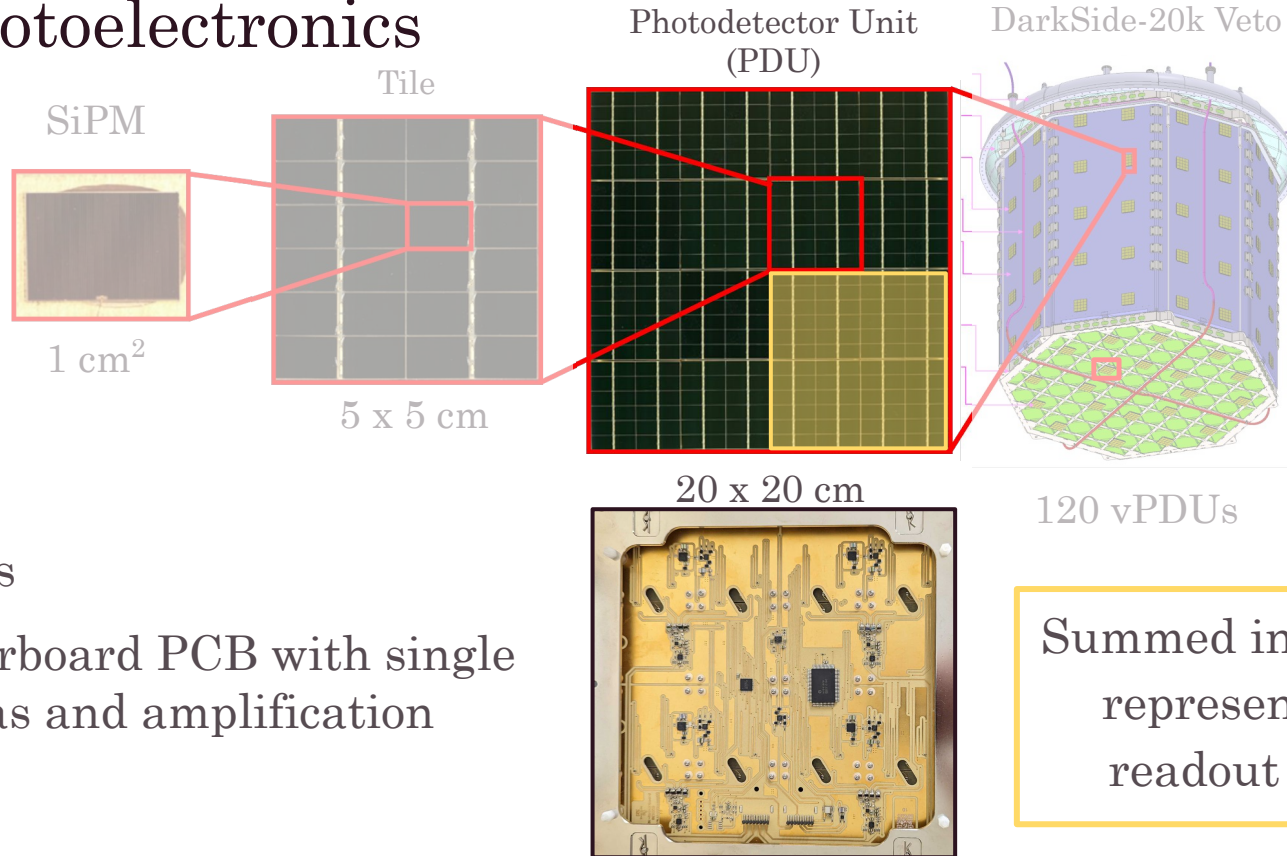
3 Wire bond



Electrical testing at room temperature (warm) and in liquid nitrogen at 77K (cold)

Produced over 2000 tiles in the UK, with an overall yield of 94%

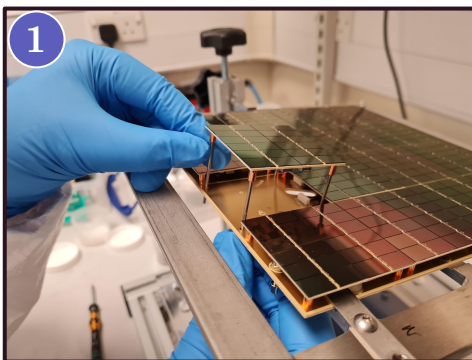
Veto Photoelectronics



- 16 tiles
- Motherboard PCB with single tile bias and amplification

Rogers, G. (2024) 'Production of the DarkSide-20K photo-detectors', NIM-A, 1068, p. 169723.

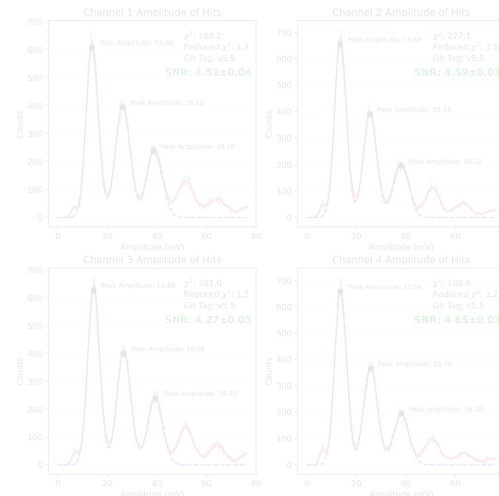
vPDU Production



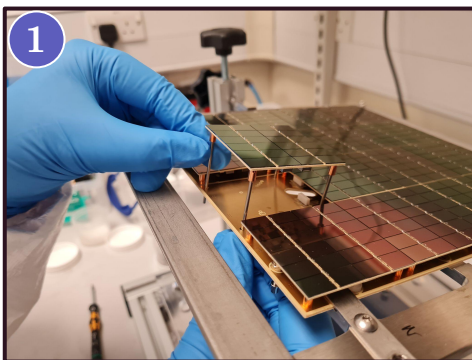
Assemble tiles on motherboards



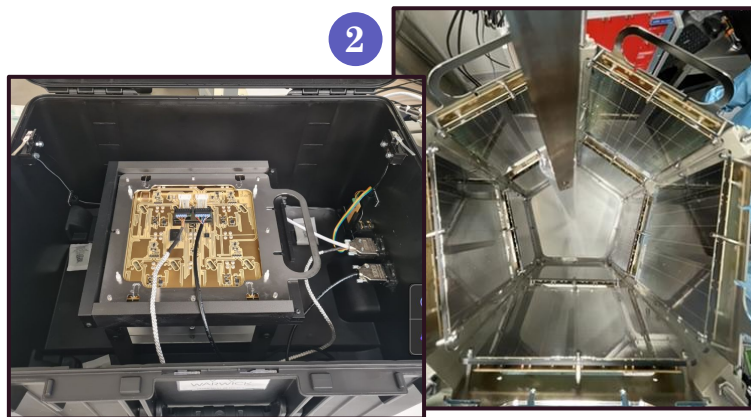
Further warm and cold electrical testing



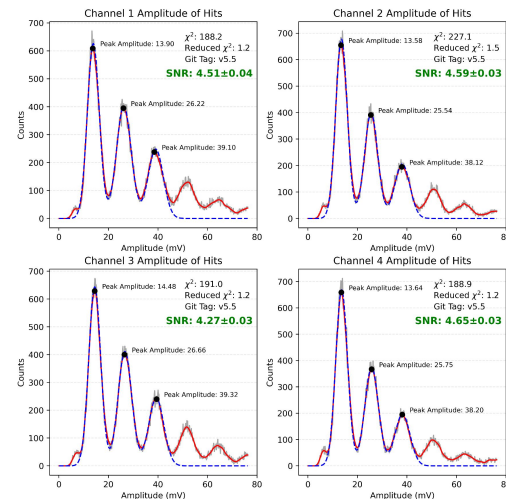
vPDU Production



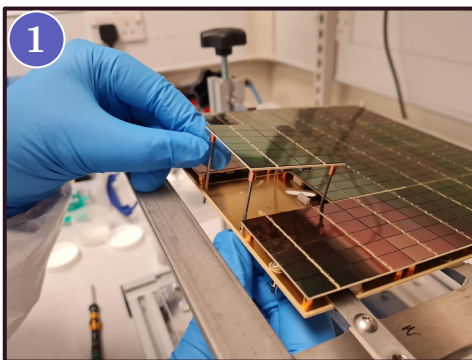
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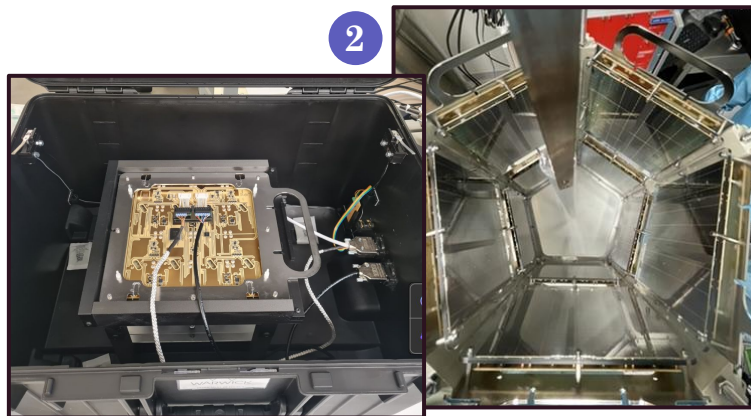
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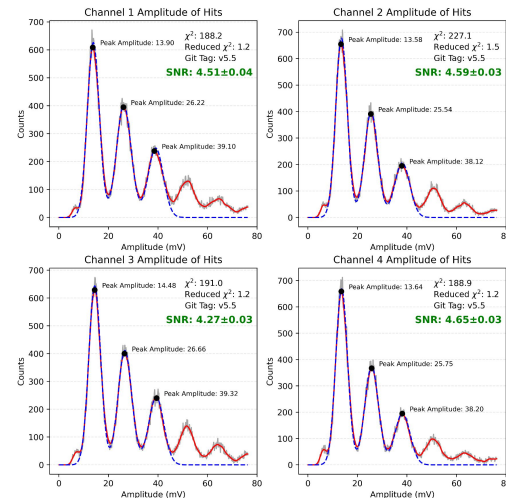
vPDU Production



Assemble tiles on motherboards

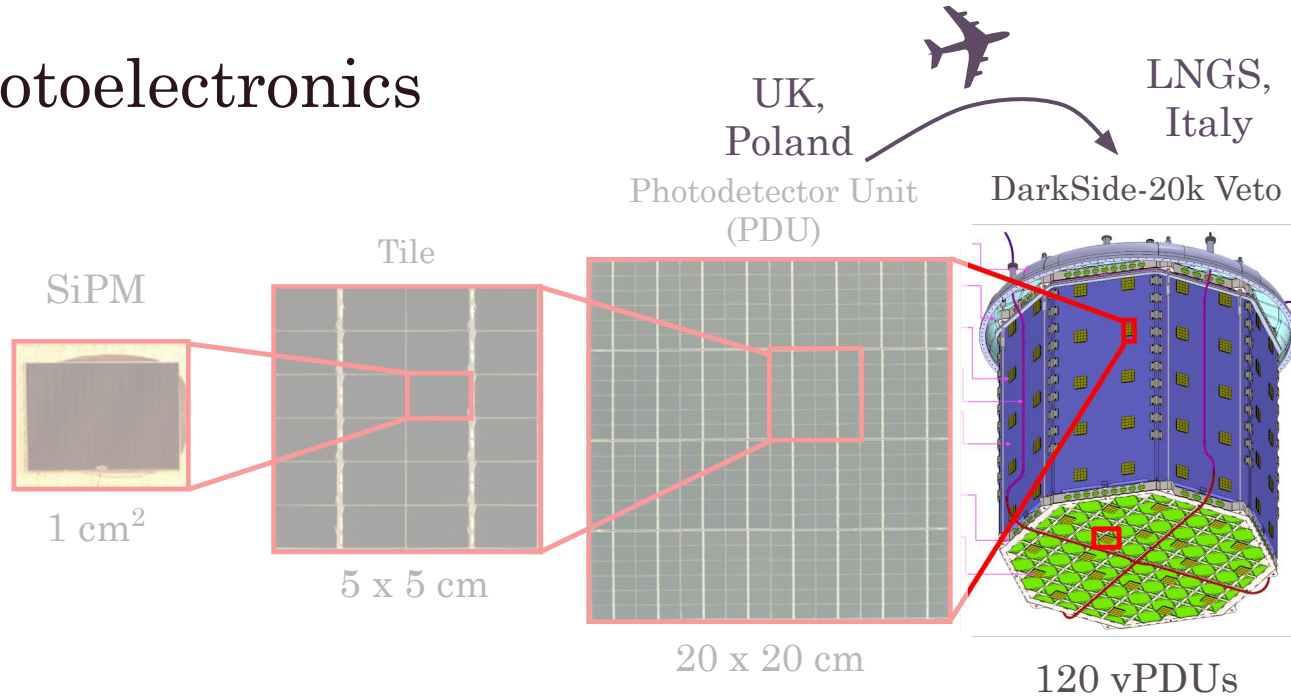


Further warm and cold electrical testing



Produced over 120 PDUs in the UK, with an overall yield of 95%

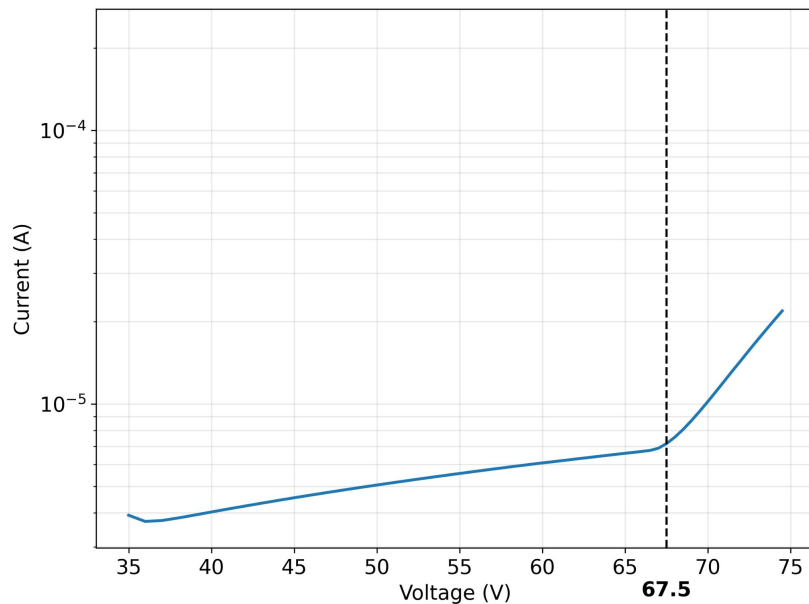
Veto Photoelectronics



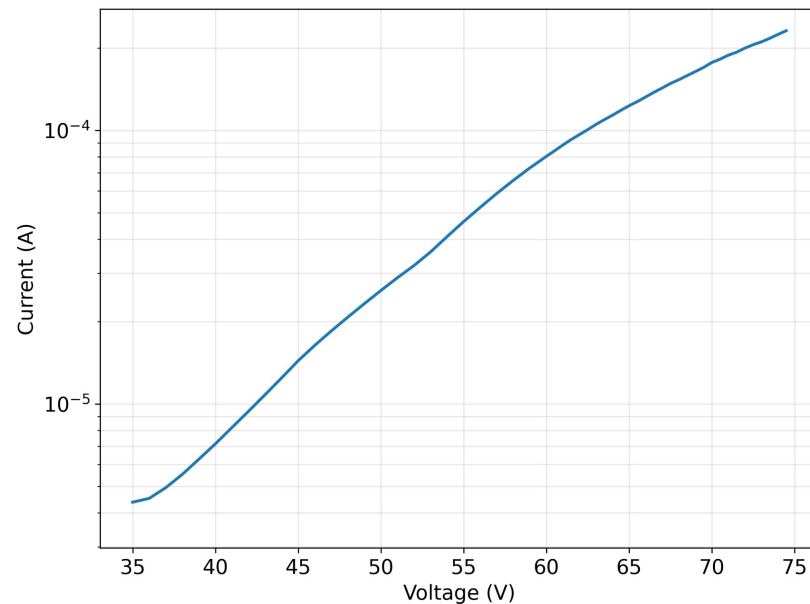
- vPDUs will be installed on the **optical plane** and **barrel** of the TPC
- A **warm electrical test** will be performed before installation to ensure no transport damage occurred

Warm Test: IV Curve

Pass



Fail



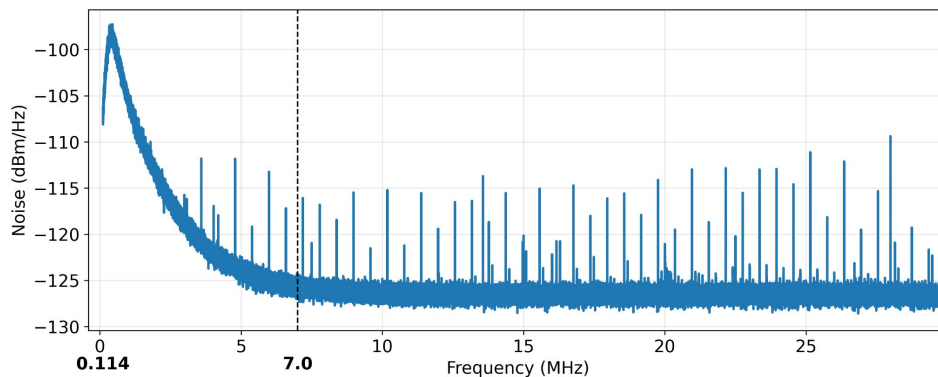
- The **SiPM breakdown voltage** is the voltage at which the device enters Geiger mode
 - Calculated using a **log single-derivative peak fit**
- Early breakdown usually from mechanical damage on the SiPM

Matteucci, G. (2025) 'Cryogenic SiPMs for the optical readout of DarkSide-20K', JINST, 20(06).

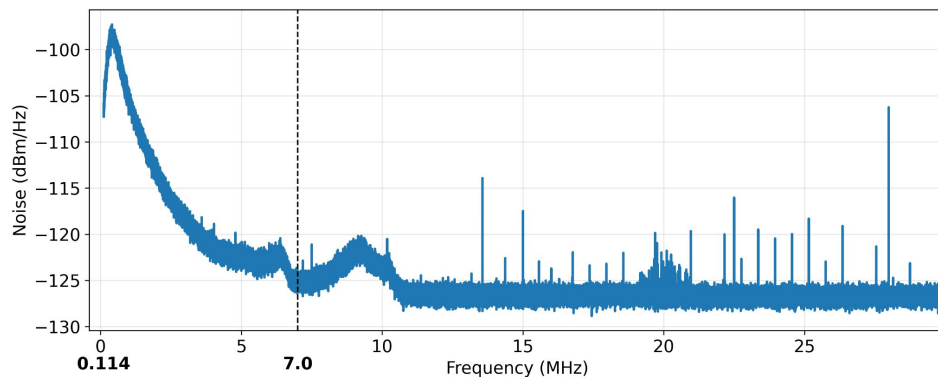
Warm Test: Noise FFT

Acquired at 40 V bias and averaged

Pass



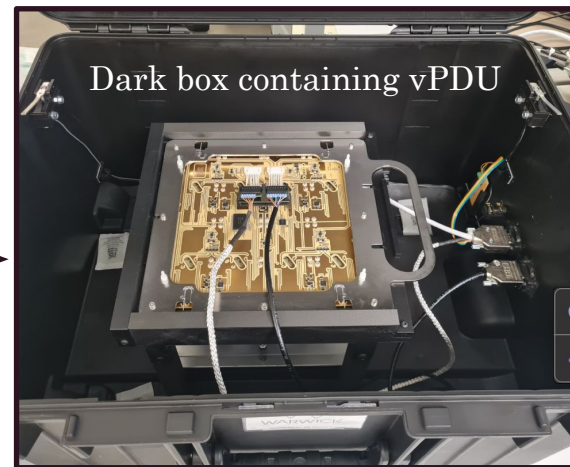
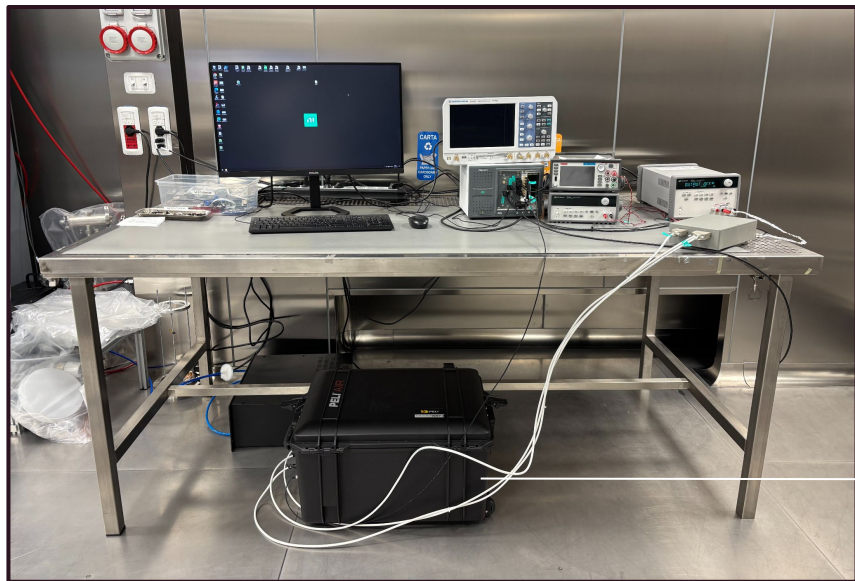
Fail



- Expect low-frequency peak with flat electronic noise floor
- **Reduced χ^2** comparison with nominal spectra
- Unusual noise spectra usually due to **damaged vTile**

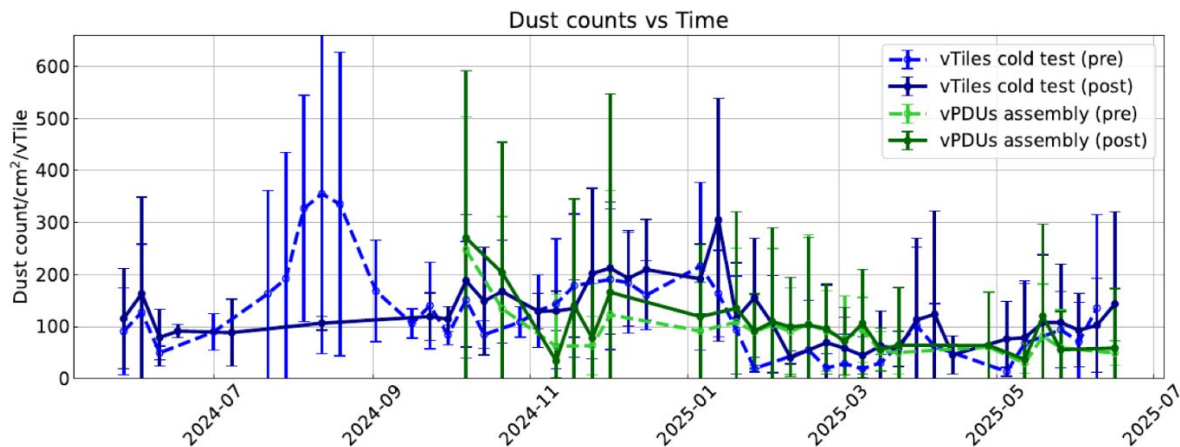
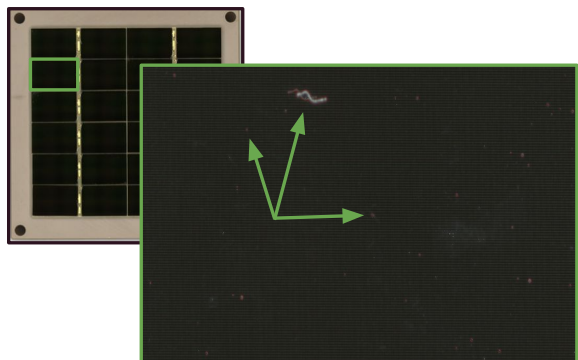
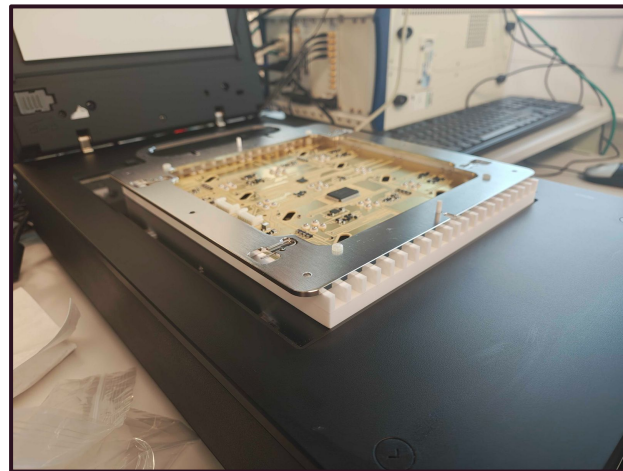
Pre-installation Warm Testing at LNGS

- **37% of vPDUs tested** so far (equivalent to $\sim 1.8 \text{ m}^2$ of SiPMs)
- Next step: investigate any failures



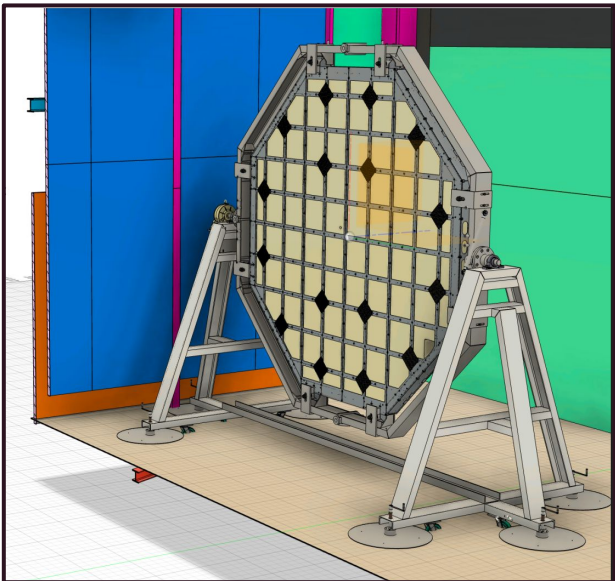
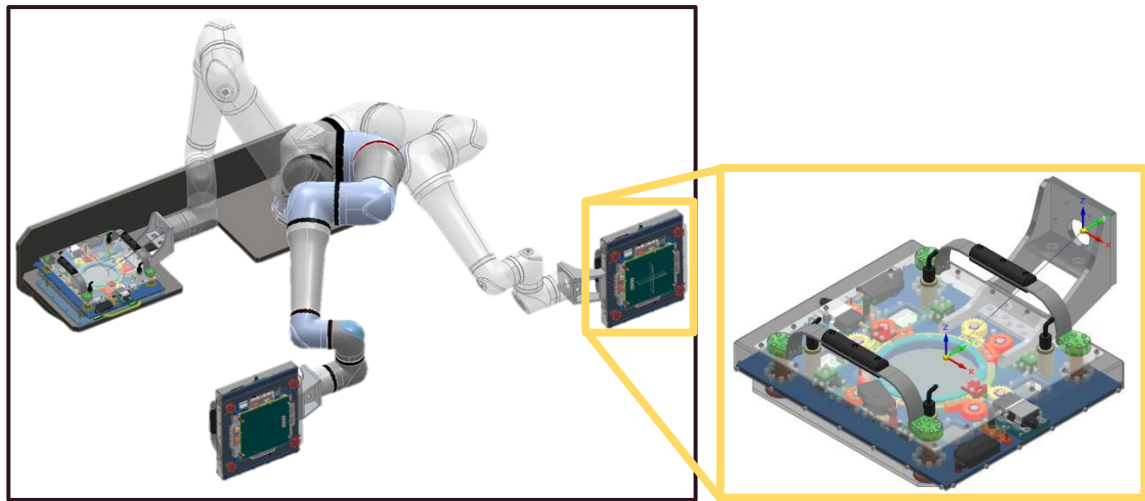
Dust Metrology

- **Dust on the SiPM surface** monitored during production to track contamination
- **Flatbed scanner** and image analysis software used to count and measure particles
- Consistent dust levels observed since June 2024



Installation Next Steps

In autumn 2026, vPDUs that have passed the reception testing will be installed on the **Optical Plane** (right), then a **final electrical test** using the DAQ



Using **cooperative robot arm** and custom pickup tool

Conclusions

- **Background-free dark matter detector** with neutron veto
- **vPDU SiPM photoelectronics** undergoing final testing before installation
- **37%** of vPDUs tested so far
- **Dust contamination** being monitored
- **Installation on Optical Plane** using robotic arm



STFC DarkSide-20k team in the cleanroom.

Thank you

Back-up

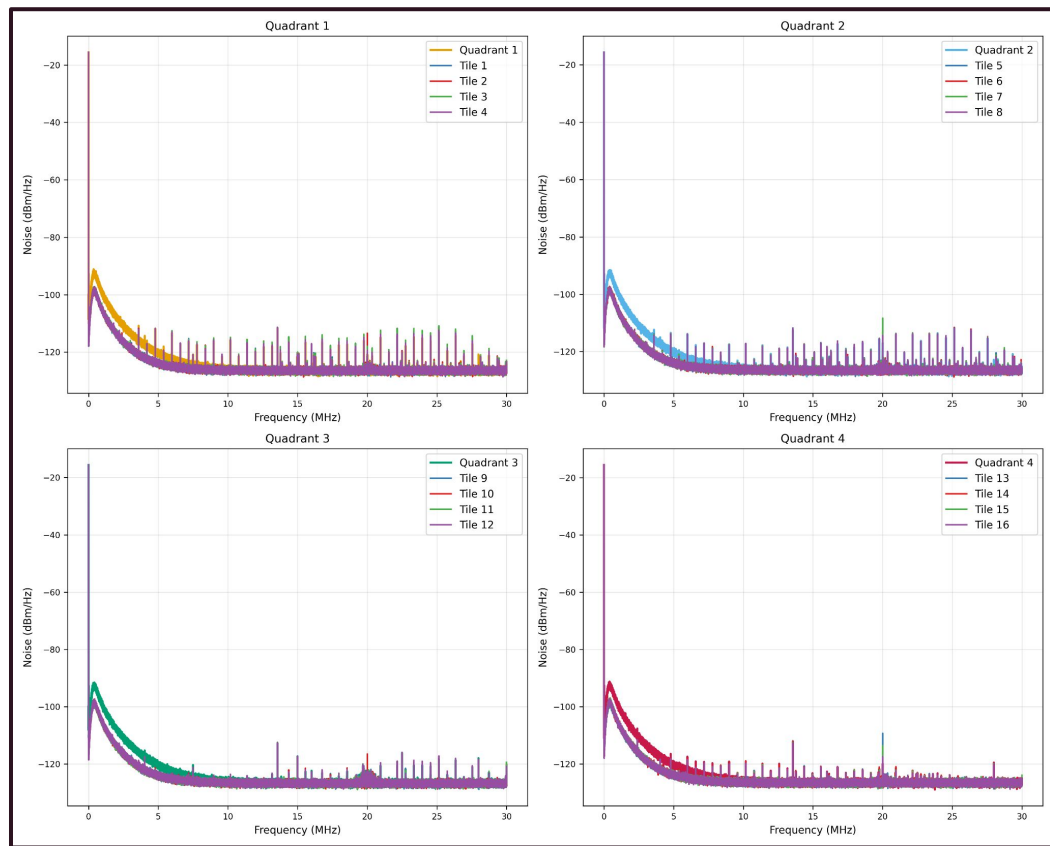
Transporting vPDUs

- vPDUs are **triple-bagged** to protect against moisture and radioactive contamination
- **Shock loggers**
- Transport Peli case holds up to 16 vPDUs in **inner frame with shock dampeners**
- Each vPDU sits in **foam insert**.
- Ship **strapped to a pallet** to prevent manual handling by courier



Noise FFT Details

- Noise samples collected with these parameters:
 - 60 MHz sampling rate
 - 240000 samples (4 ms)
 - Result: ~130000 noise bins in 30 MHz interval
 - 100 averages
 - 40 V HV bias
- Dark volume is a Peli case, i.e. no Faraday cage
 - Some environmental noise peaks



Post-installation Testing

- The vPDUs are very fragile and could be damaged during installation, so we need to **perform another electrical test** using the detector DAQ
- Normally the PDU is tested in a dark box, so we are studying the **effect of increased ambient light** on the IV curves

