

# Cryogenic characterization of the DarkSide-20k veto photo-detector units

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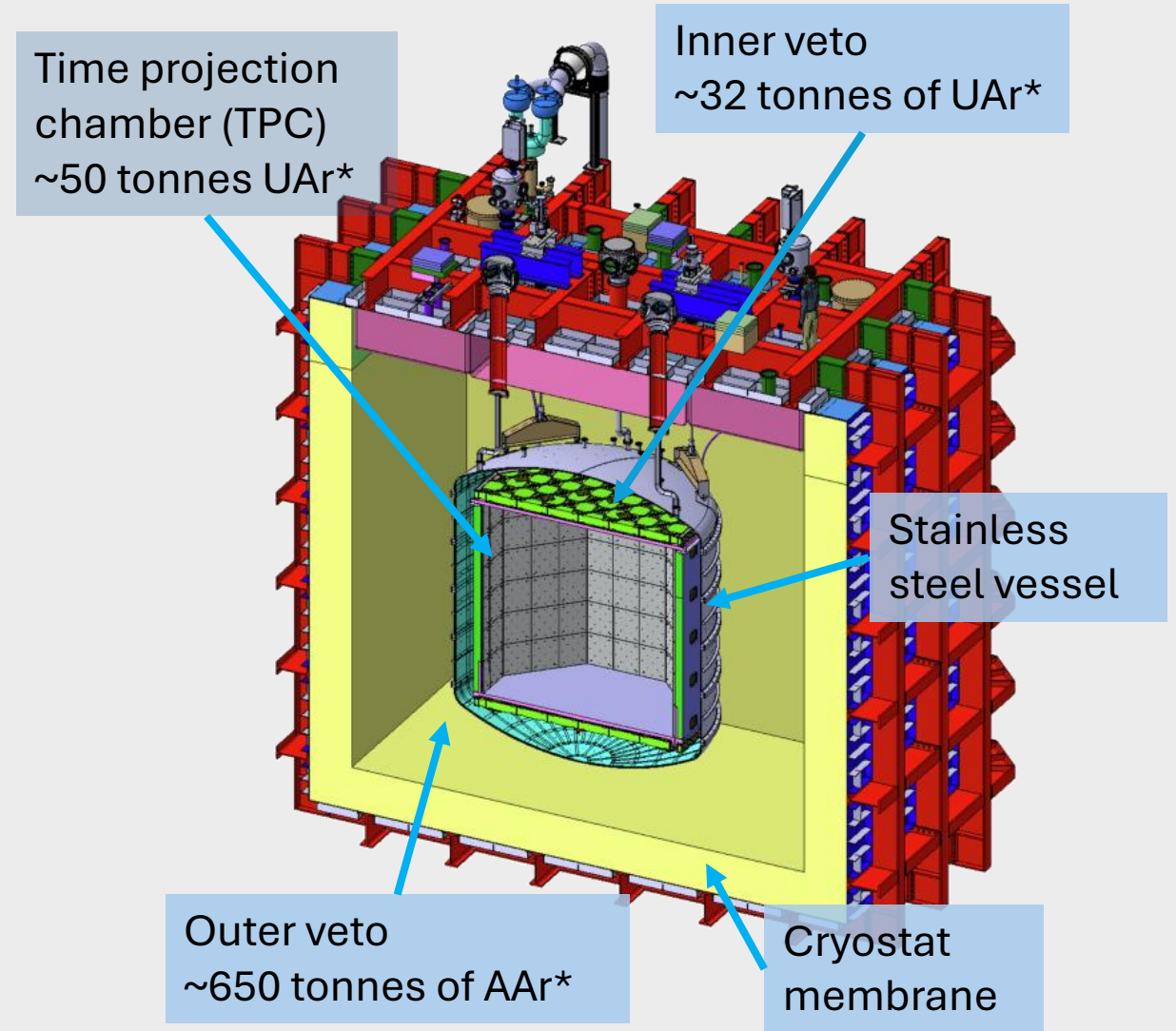
THE UNIVERSITY  
*of* EDINBURGH

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University of Edinburgh  
IOP APP/HEPP Annual Conference  
April 9, 2026



# DarkSide-20k

- **Direct detection dark matter experiment currently under construction** at the Gran Sasso National Laboratory (LNGS) in Italy.
- Goal to make direct detection of spin-independent dark matter with a sensitivity to the WIMP-nucleon cross section of  $10^{-48}$  cm<sup>2</sup> at 0.1 TeV
- Extremely strict radioassay and dust requirements in order to be **instrumental background free** (<0.1 background events) in 200 tonne-year exposure



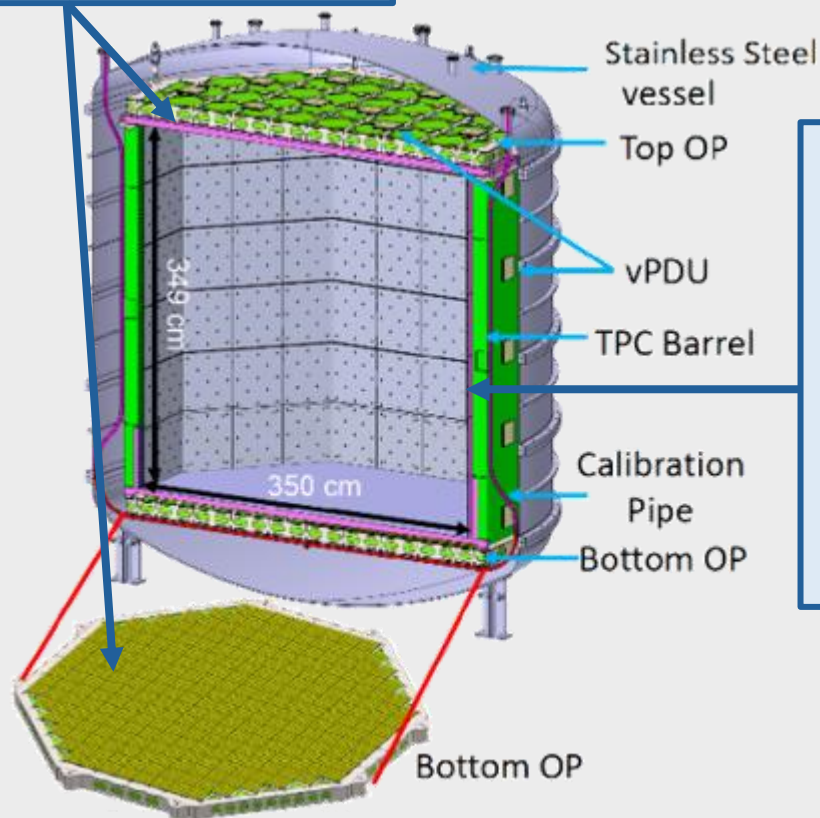
UAr = underground argon  
AAr = atmospheric argon

# DarkSide-20k

## TPC

528 PDUs mounted on the top and bottom optical planes monitoring 50 tonnes of argon

PDU = photo-detector unit  
vPDU = inner veto photo-detector unit

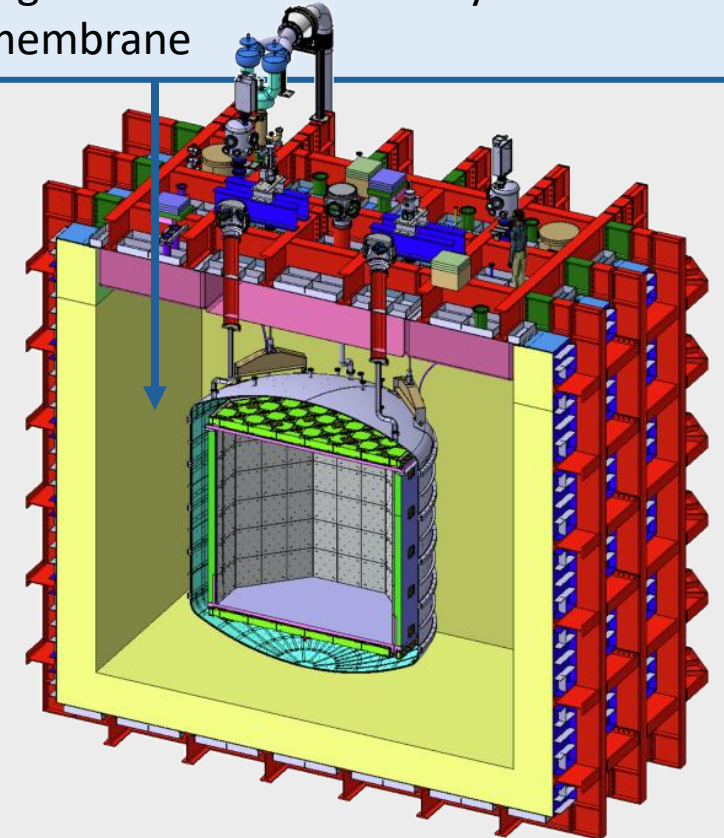


## Inner veto

120 vPDUs mounted on the outside of the TPC (top, bottom and sides) looking outwards towards 32 tonnes of argon

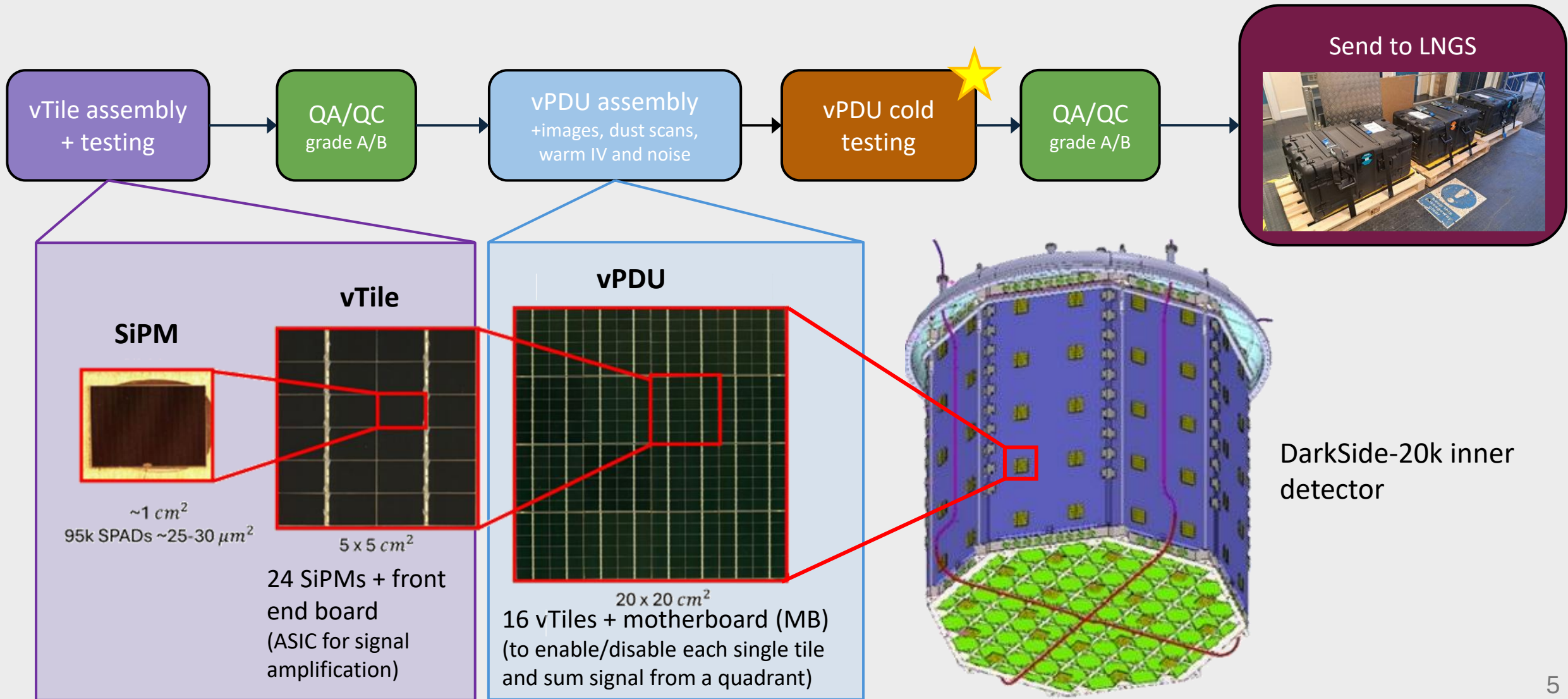
## Outer veto

32 PDUs mounted on the outside of the steel vessel monitoring 650 tonnes of argon contained in the cryostat membrane

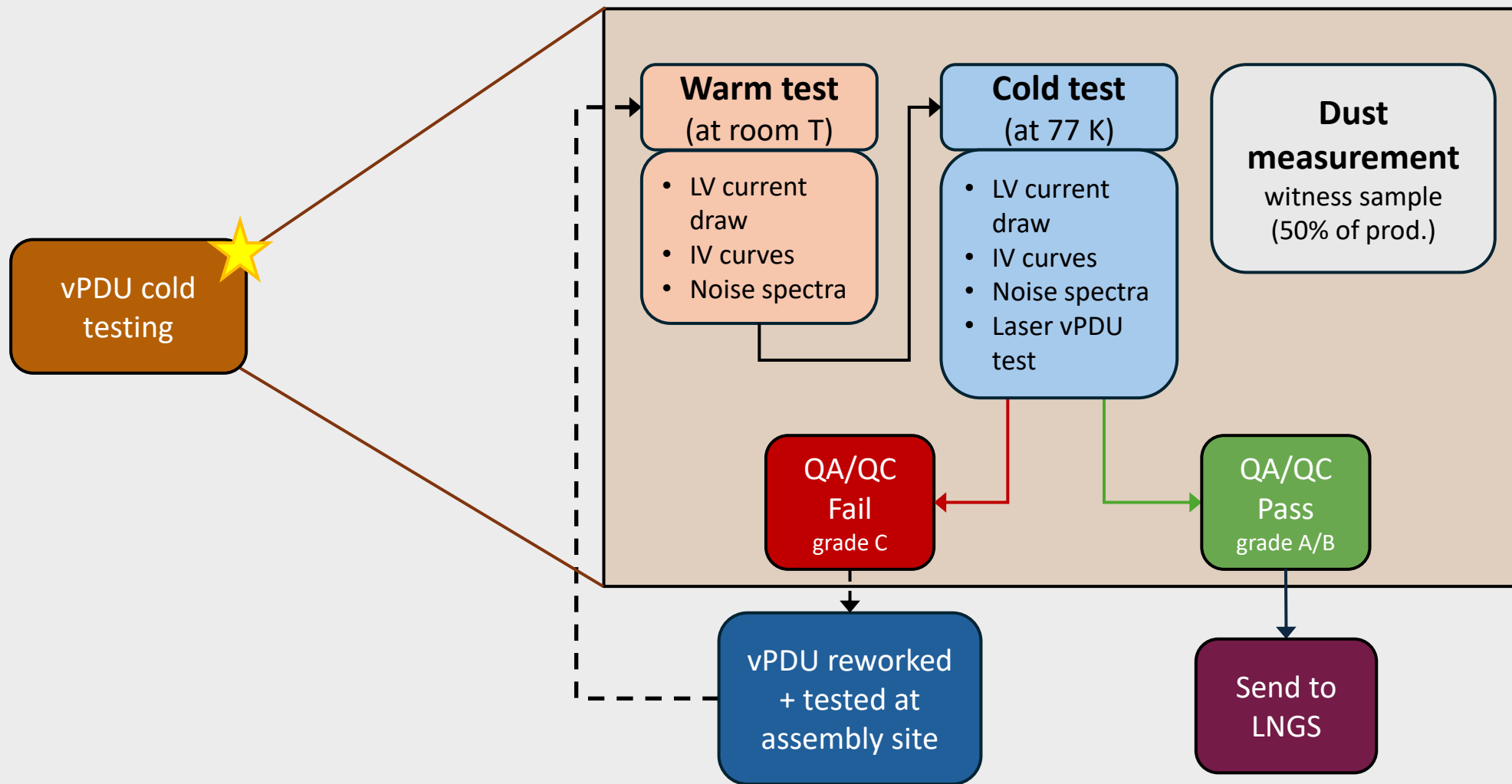




# vPDU Production



# Veto PDU Cryogenic Tests



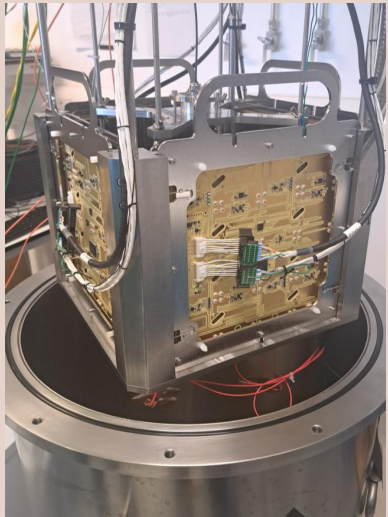
# Cold Test Stands

We have  
Tested  
(not including backup  
/replacement vTiles)

**131 vPDUs**  
**= 2,096 vTiles**  
Containing 50,304 SiPMs

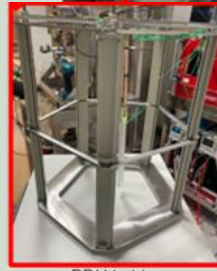
## Edinburgh

- 4 vPDU capacity per run
- 34 vPDUs tested



## AstroCeNT

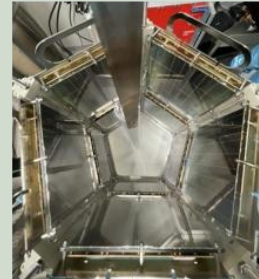
- 10 vPDU capacity per run
- 78 vPDUs tested



vPDU holder



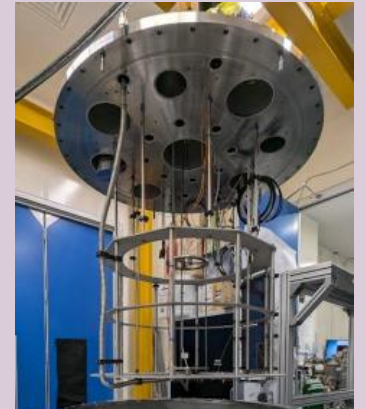
Diffuser: PMMA rod



10 vPDUs capacity holder

## Liverpool

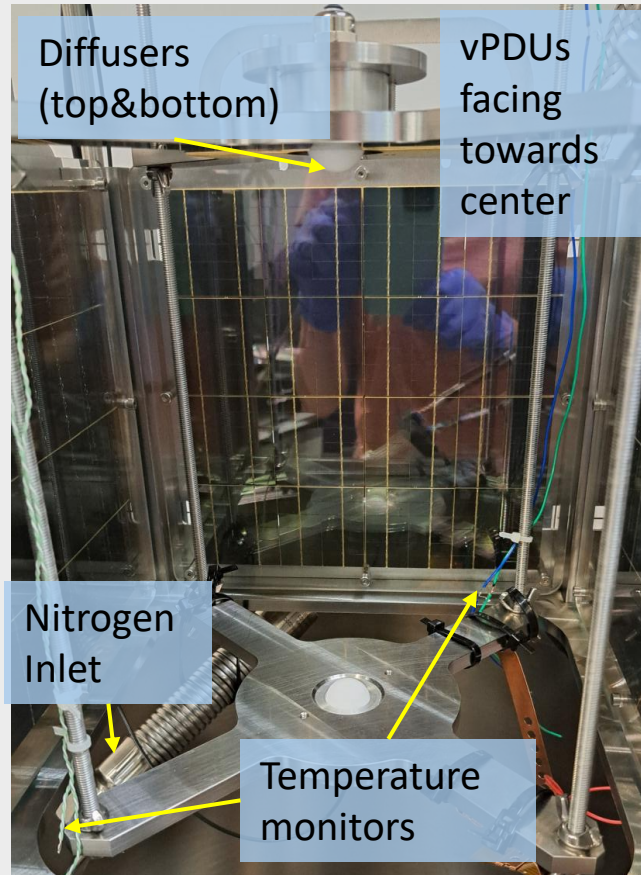
- 16 vPDU capacity per run
- 19 vPDUs tested
- 16 also tested in LAr



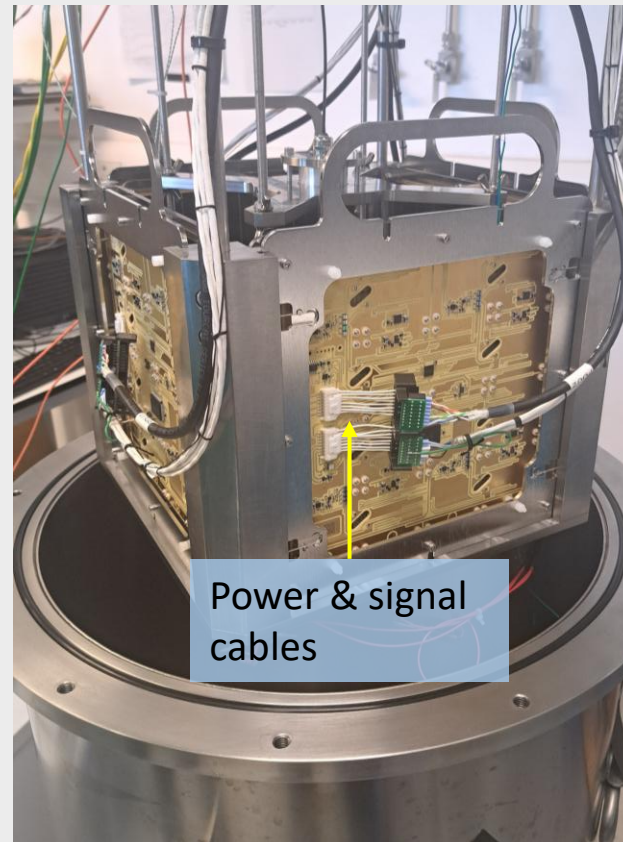
# Cold Test Stand Setup Example

(Edinburgh test stand shown in images)

## vPDUs in support structure



## Outer view of support structure



## Outside of the test stand

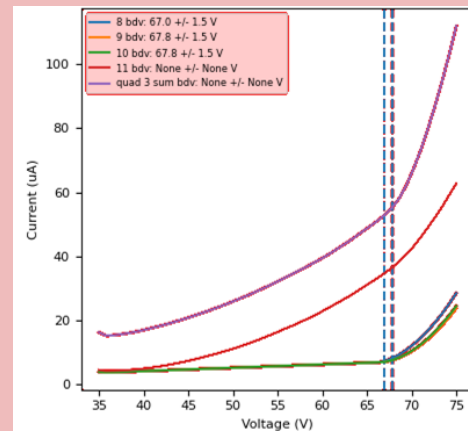


# Cold Tests – IV Curves

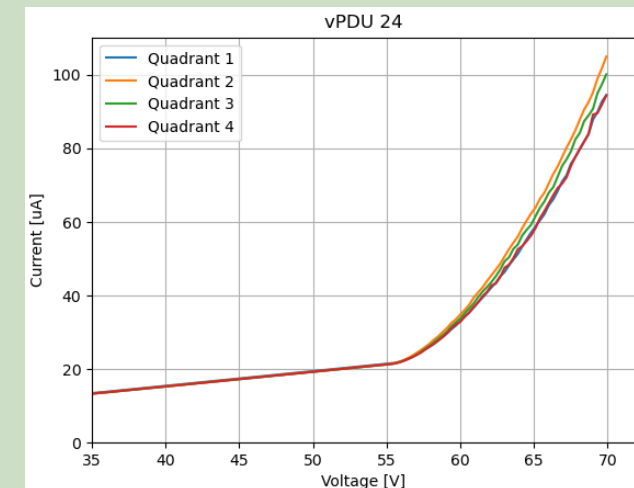
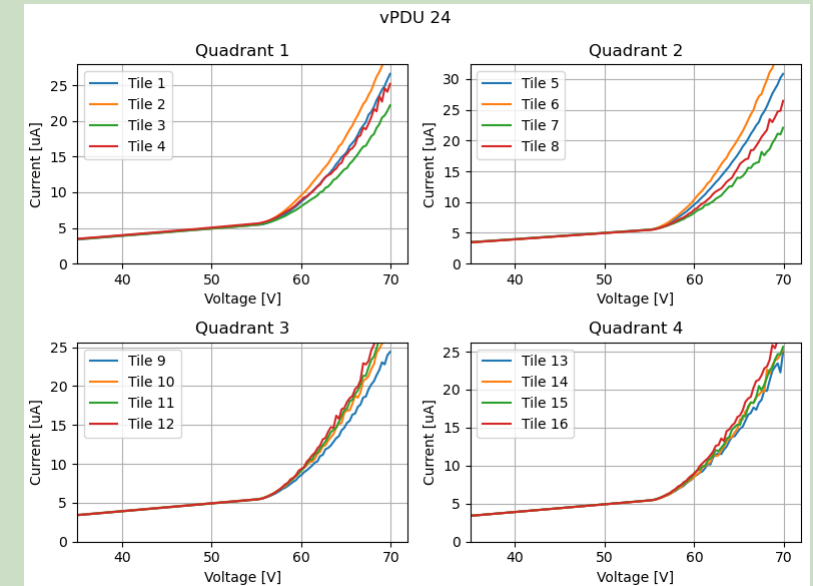
- Measured individually for each tile and quadrant.
- Also done for warm tests
- QA/QC
  - Breakdown voltage within acceptable range
  - IV curve has typical shape, no double breakdown



**Example of double breakdown in a warm test**  
Can be due to damaged vTile(s)



**Example of a vPDU with all good IV curves at 77 K**

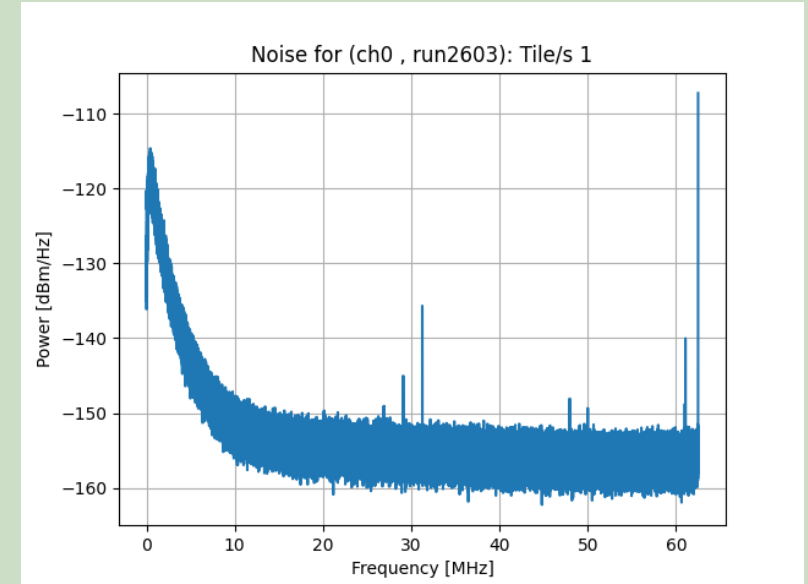


# Cold Tests - Noise Spectra

- Taken at both warm and cold
- No specific noise spectrum criteria for cold test QA/QC
- Useful to diagnose issues with vPDUs or test stands



Example of a vPDU tile with a good noise spectrum

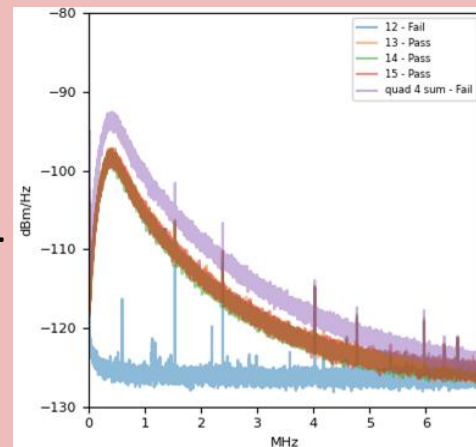


(this spectrum and the two below have different x scales)



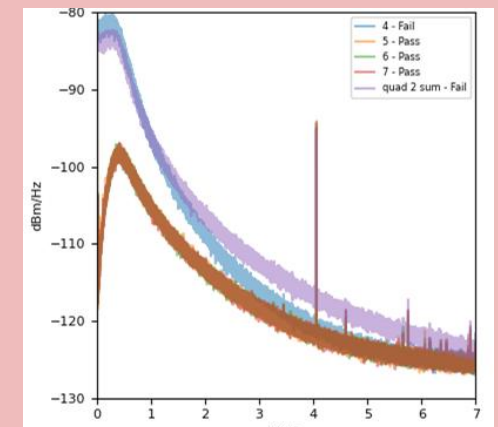
## No response from 1 vTile

Normal response from other 3 vTiles.  
Solution : vMB replacement



## Absormal noise spectrum

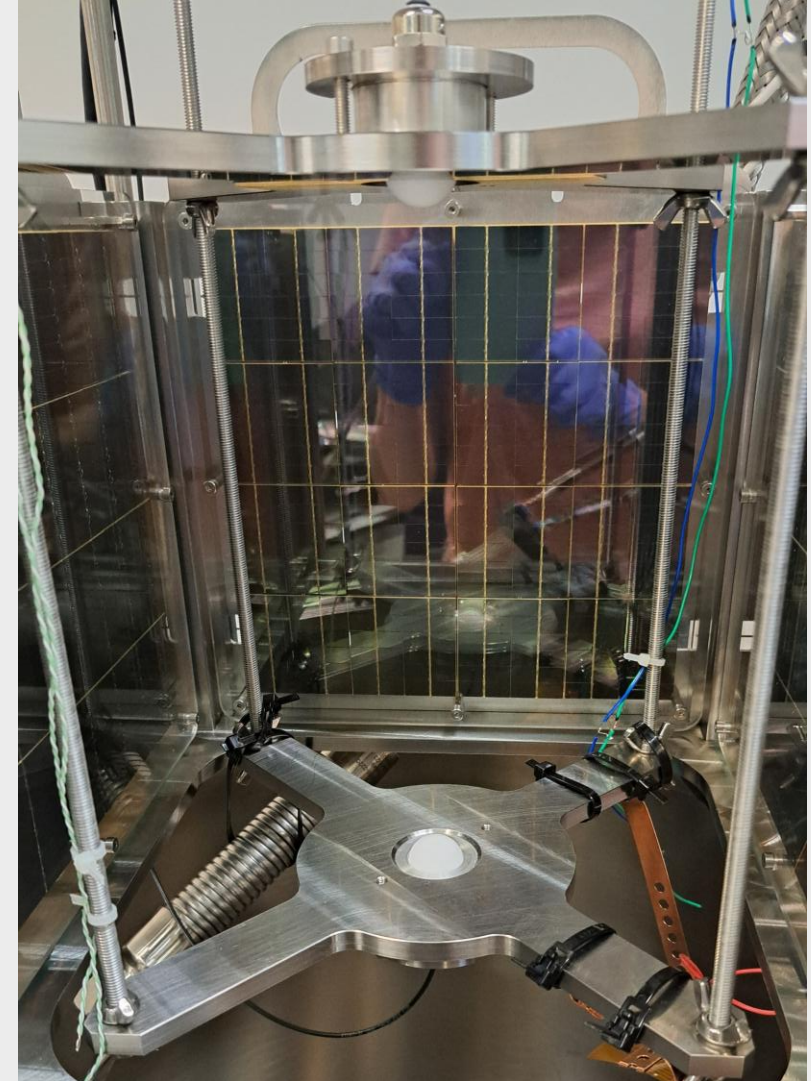
Normal response from other 3 vTiles.  
Solution : vTile replacement



# Cold Tests

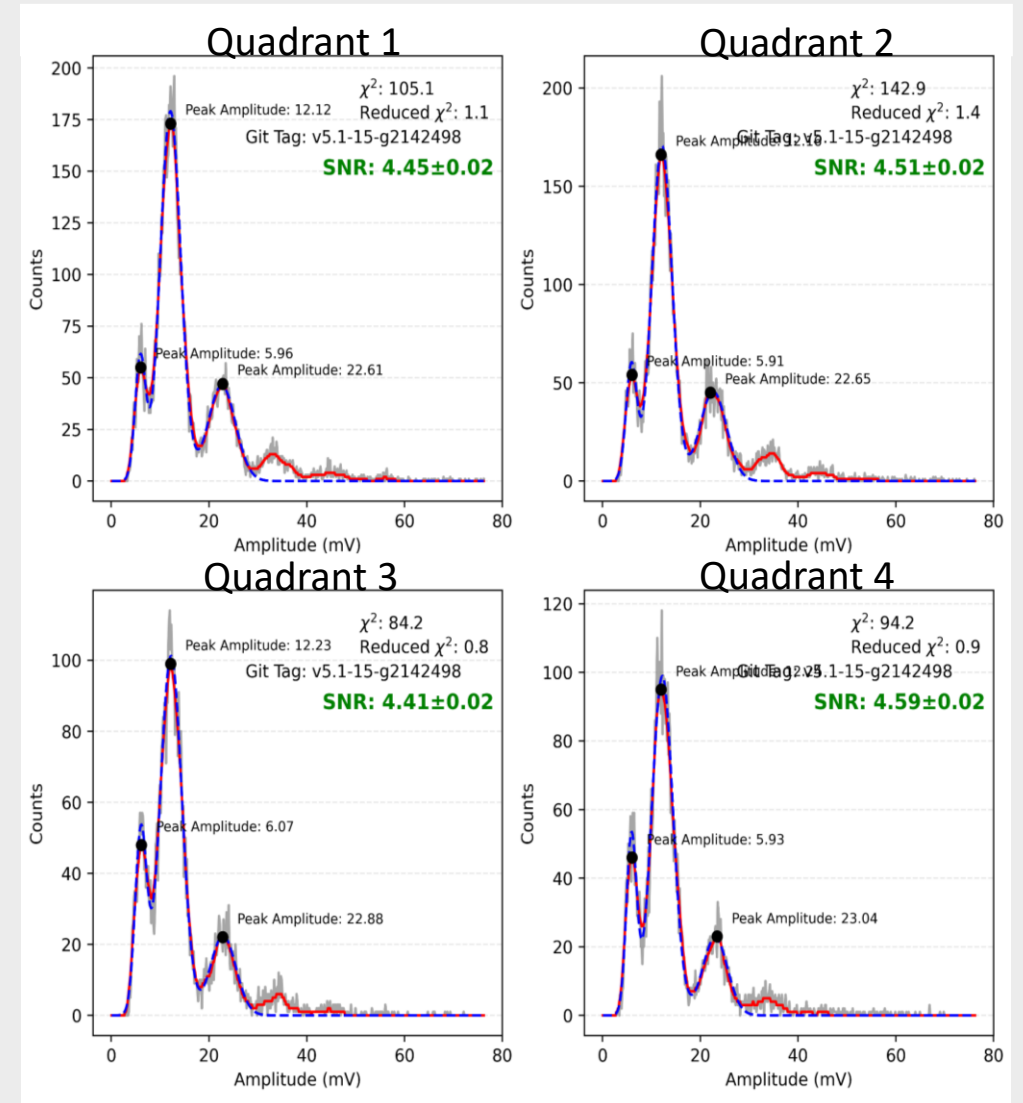
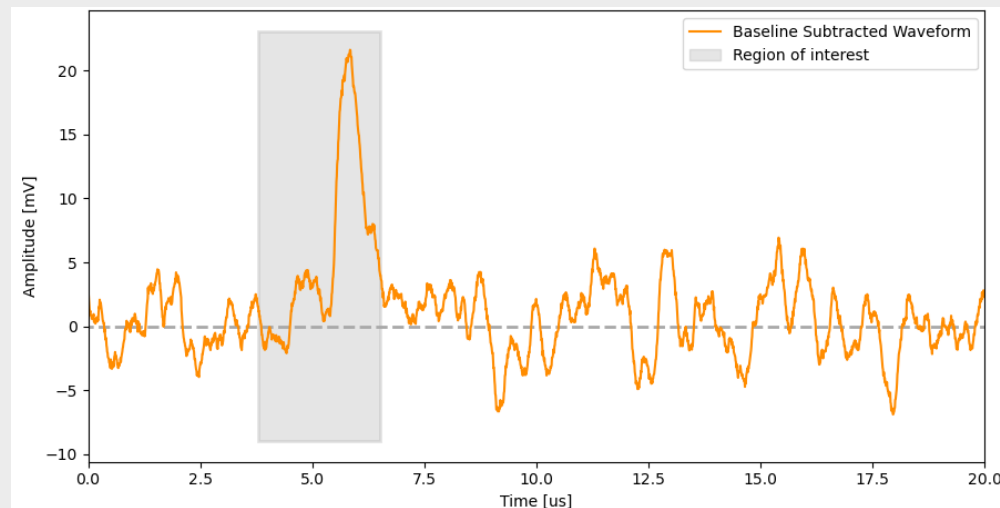
## – Laser vPDU Tests

- Diffused laser light pulses used to study vPDU light response
- Standardised vPDU analysis passport to evaluate vPDU performance across different institutions.
- QA/QC Criteria:
  - 1PE Amplitude
  - RMS
  - Signal-to-Noise Ratio (SNR)
  - Dark Count Rate (Pulse Count Rate)



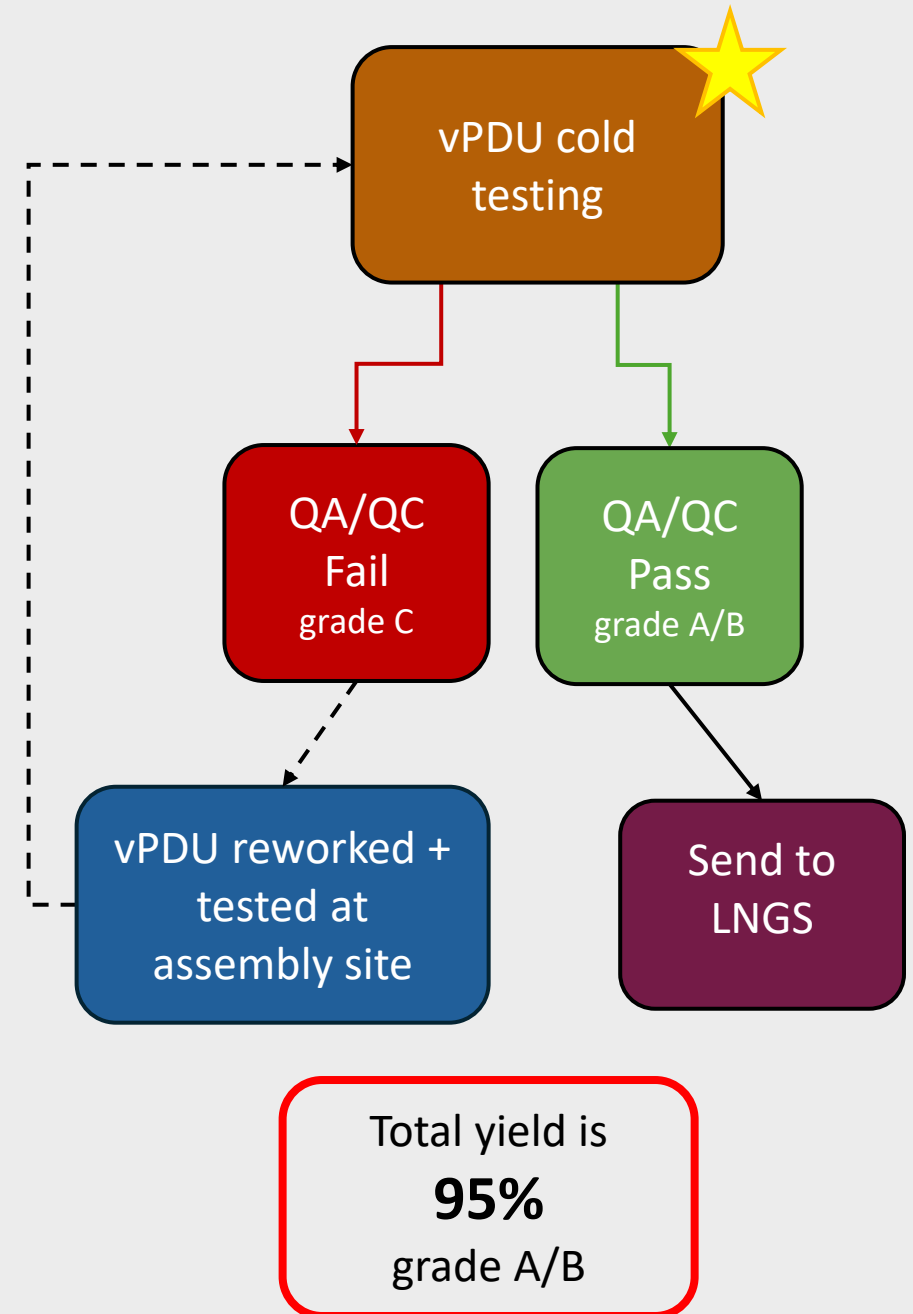
# Laser vPDU Tests - Data Acquisition

- Laser tests completed for each tile and quadrant on a vPDU
- Summed signal waveform from all SiPMs in a tile or quadrant is used for analysis
- The peak amplitude from each waveform is collected in a finger plot histogram.
- This finger plot is fit and it used to calculate QA/QC properties like the pulse count rate, RMS, SNR.



# vPDU Grading

- vPDUs are **classified as grade A, B or C** after analysis according to their **cold test performance**.
- Those that fail a test and are graded C are sent back for rework and warm tested. If it passes warm tests it is sent to be cold tested again.



# Summary

- The DarkSide-20k UK group is responsible for producing, testing and installing the inner veto photodetectors.
- Currently all **131 vPDUs produced** have been cold tested and after rework of some vPDUs we currently have **125 grade A/B vPDUs**.
- All vPDUs that have passed cold tests have been/are being shipped to LNGS where they will be warm tested as a reception test prior to installation.