



THE UNIVERSITY
of EDINBURGH



Cryogenic qualification of SiPM array detectors for the DarkSide-20k experiment

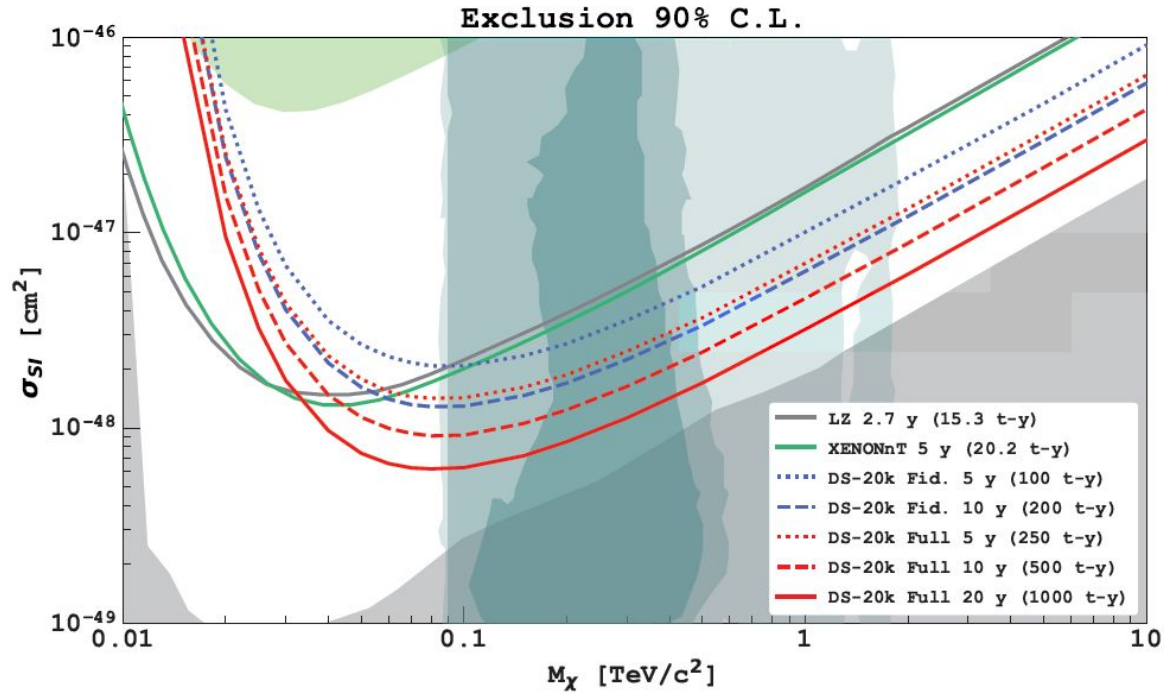
Alice Hamer
IOP APP, HEPP and NP Conference
10/04/2024

DarkSide-20k

DarkSide-20k aims to detect WIMPs using a dual-phase LAr TPC.

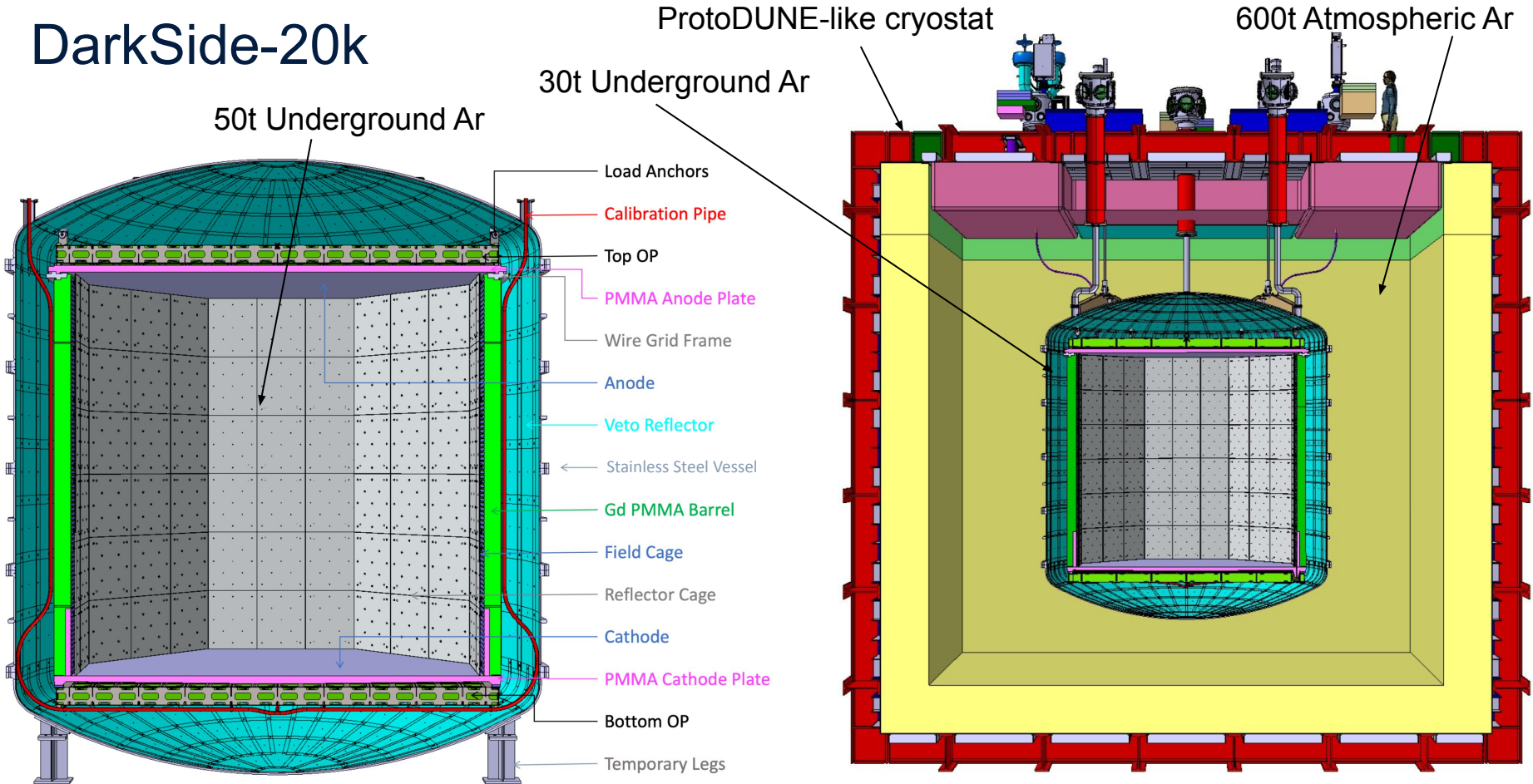
Under construction at Gran Sasso National Lab in Italy.

Expected to run 2026 - 2031.



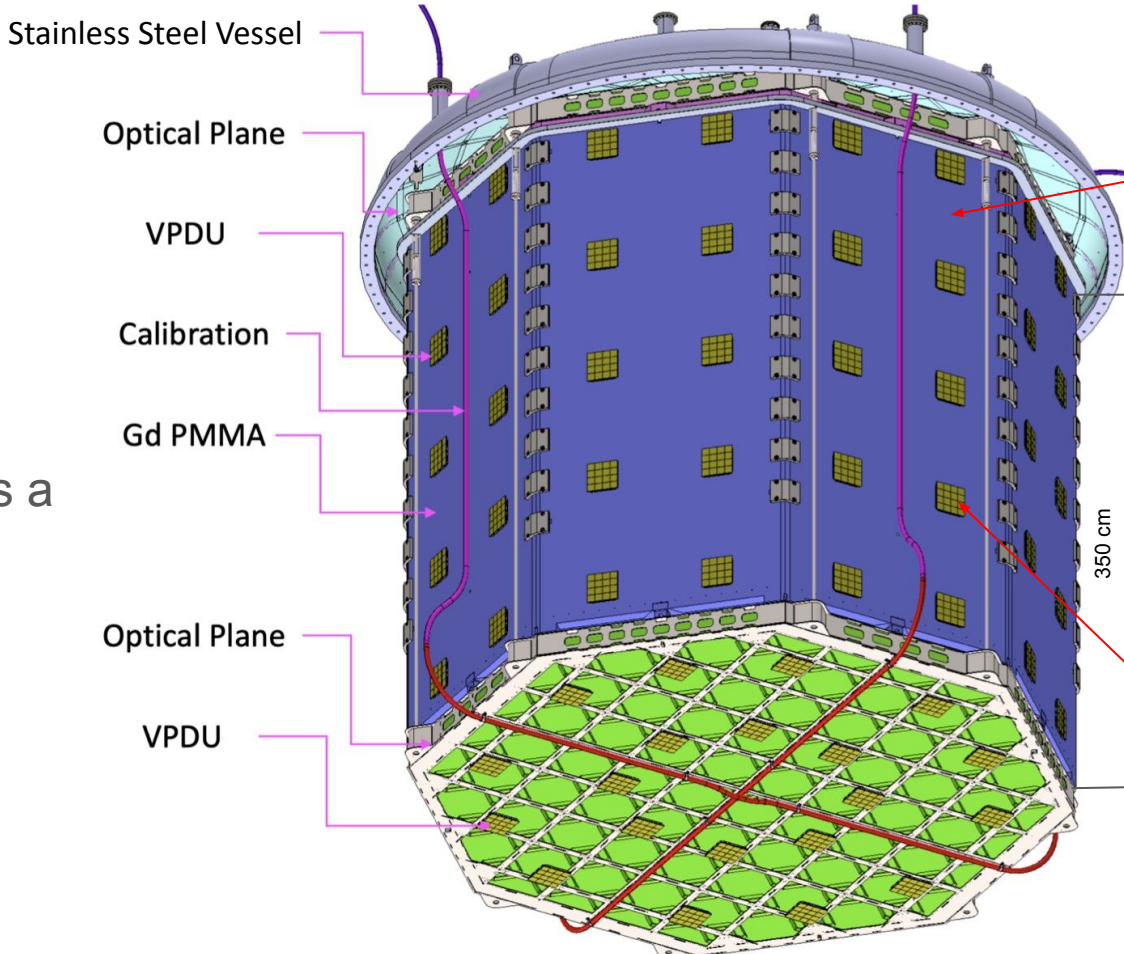
P. Agnes, 2023, EPJ Web of Conferences **280**, 06003

DarkSide-20k



DS-20k Neutron Veto

LAr is used as a
scintillation
medium.

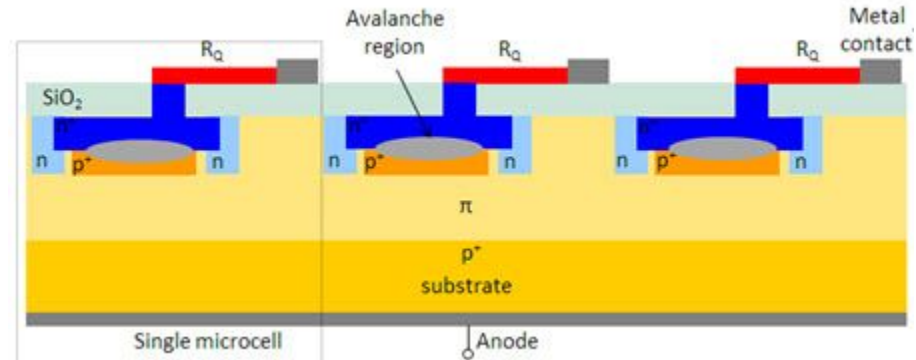


Gd-loaded
acrylic walls
which capture
neutrons as
they leave the
TPC.

SiPMs used to
detect
scintillation
light.

Why SiPMs?

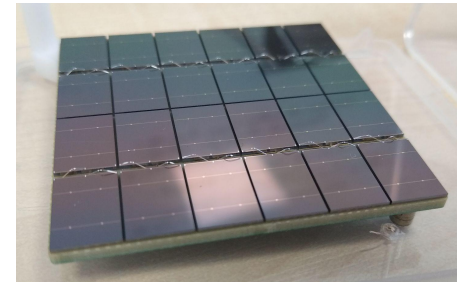
Silicon photomultipliers (SiPMs) are pixelated solid state photo sensors.



<https://hub.hamamatsu.com/us/en/technical-notes/mppc-sipms/what-is-an-SiPM-and-how-does-it-work.html>

Advantages over PMTs:

- Better photon detection efficiency
- Better single photon resolution.
- Lower operating voltages.
- Smaller -> less material -> less background contamination.



Photon Detection Units

Each SiPM measures
11.7 x 7.9 mm.



24 SiPMs are combined
to make a 5 x 5 cm tile.

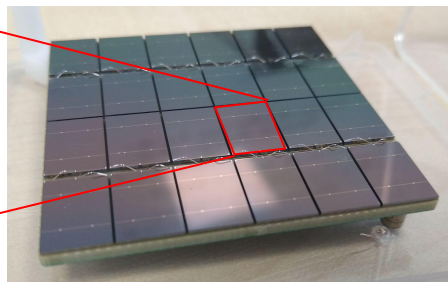
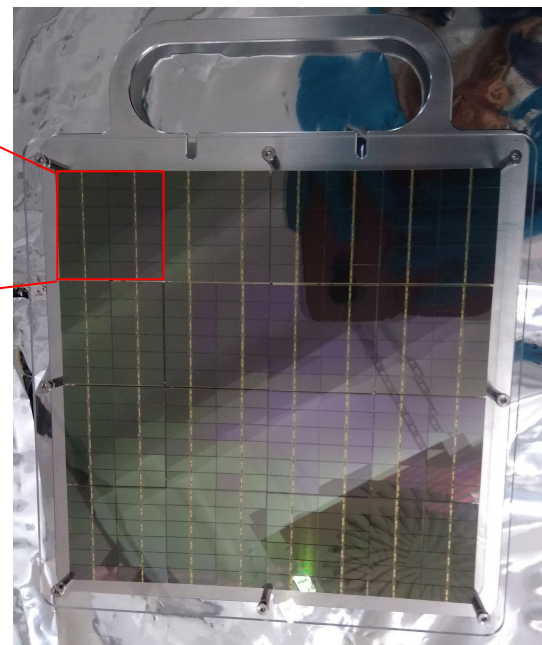


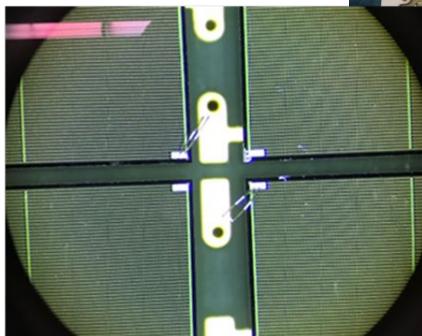
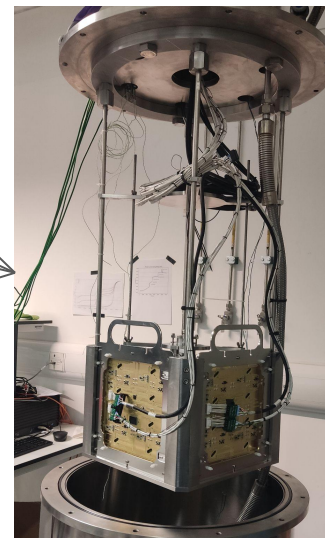
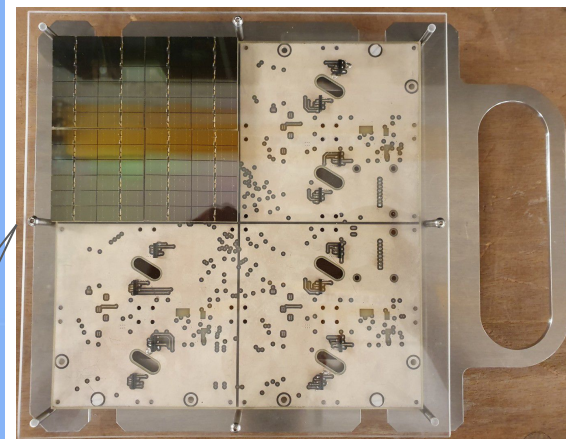
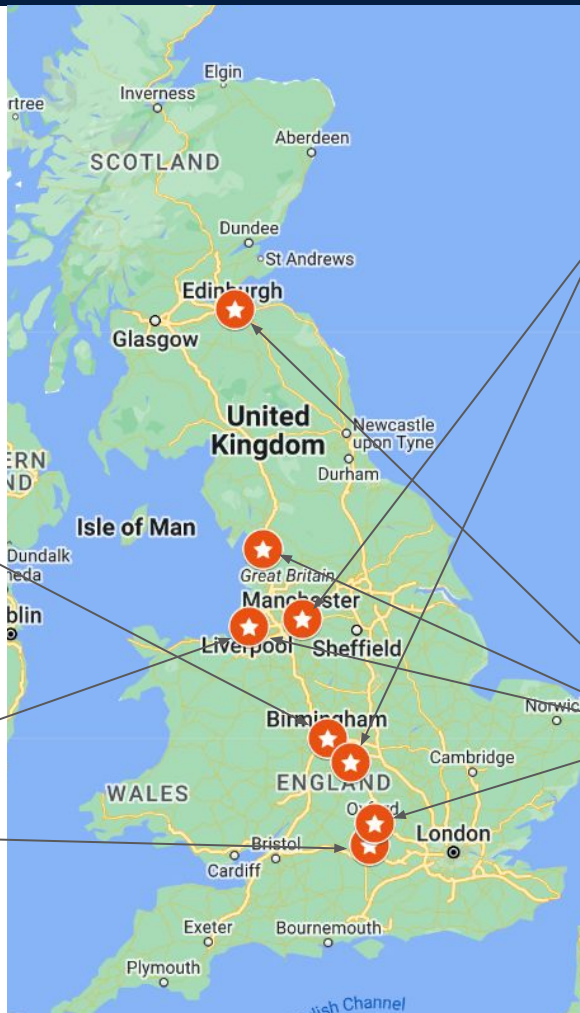
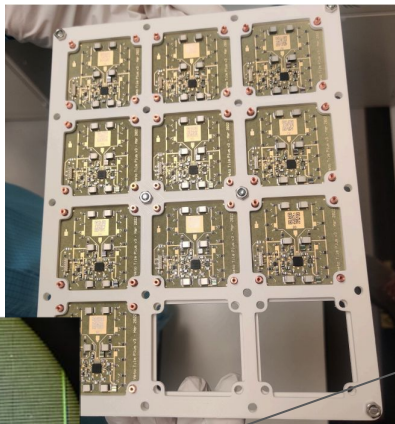
Photo Detection Units (PDUs)
are 20 x 20 cm SiPM arrays
consisting of 16 tiles.



Signal readout is 1 channel per 4 tiles -> 4 channels per PDU.

UK vPDU production and testing

DarkSide-20k veto PDUs (vPDUs) are being produced in the UK.



Cryogenic test stands

Liverpool - 20 vPDU capacity

Warsaw - 5 vPDU capacity

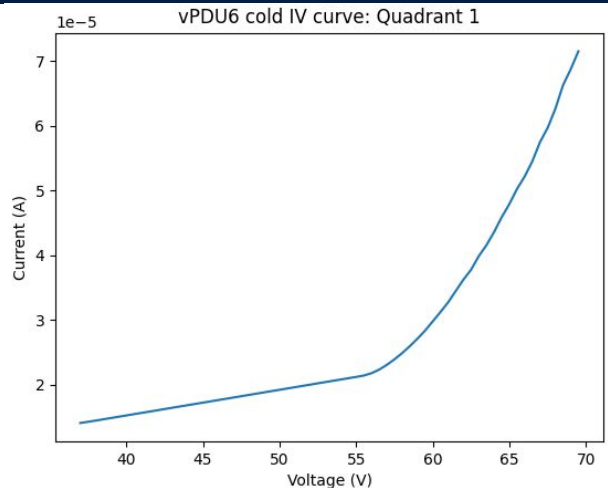
Edinburgh - 4 vPDU capacity

Lancaster - 4 vPDU capacity

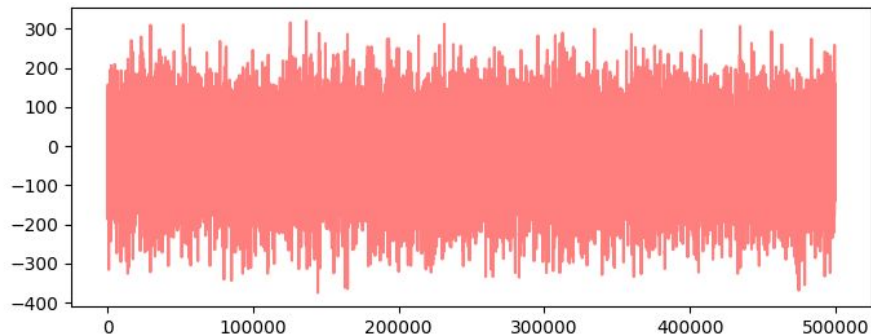


Tests to be performed

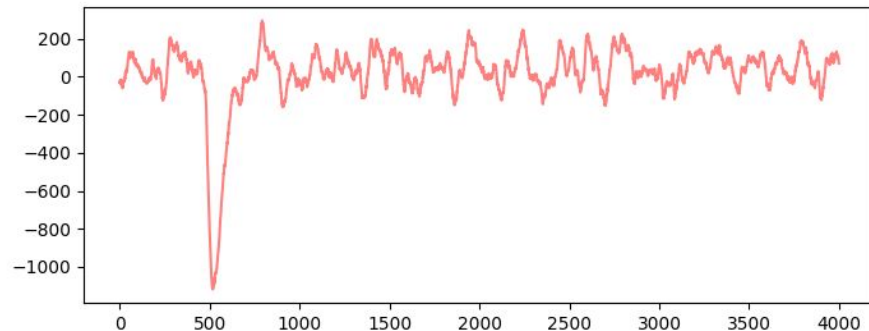
IV curves - measure current draw at increasing bias voltages with some light source present.



Noise analysis - Record long waveforms at 40V bias and look at fourier transforms.



SPE analysis (laser data) - Send small light pulses

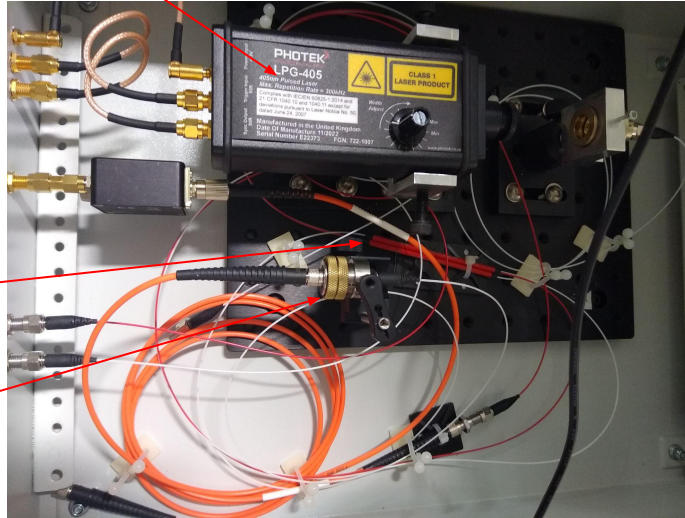


Test stand design

The light pulses are produced by a 405 nm laser

vPDUs are positioned in a ring, facing inwards, with a light source at the centre.

The amount of light is reduced using a 99:1 splitter and a variable attenuator.



Light enters the setup via two hemispherical diffusers

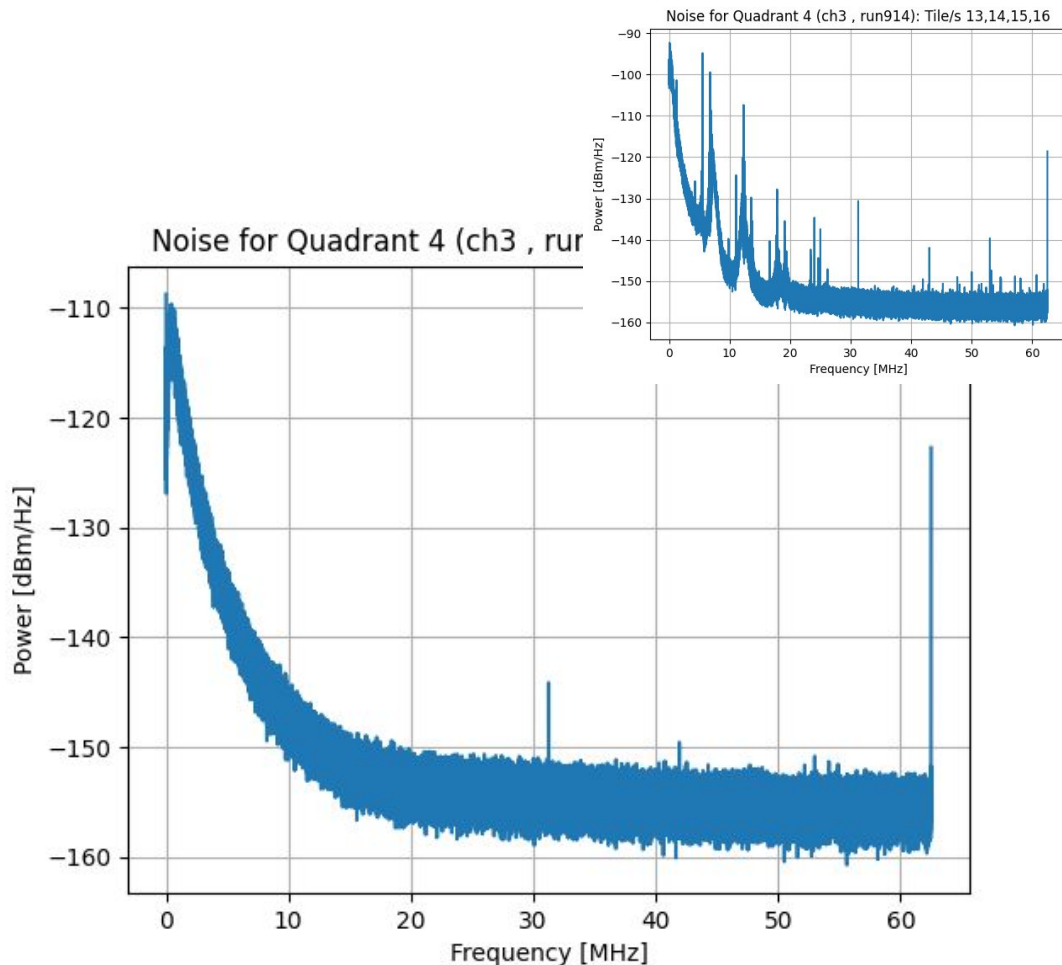


Noise analysis

Need to ensure the baseline fluctuations are reasonably low.

Noise data is taken at 40V bias (below breakdown) and with the light source switched off.

Noise characterised using Fourier transforms.



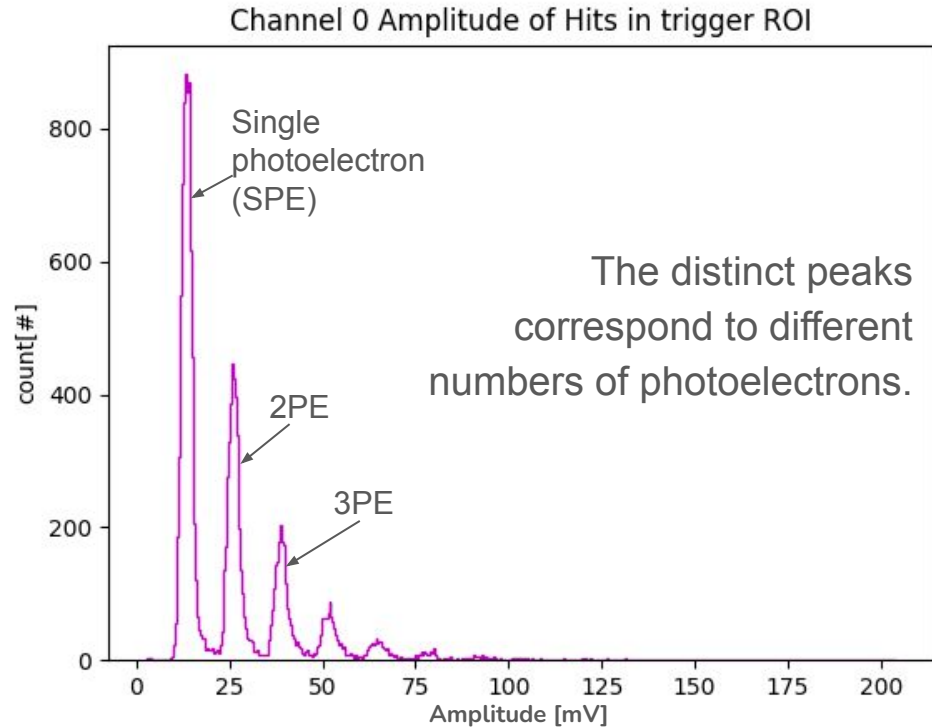
Light source data

Pulses are identified and characterised by height and area.

Plotting pulse height as a histogram produces a “finger plot”.

Use the positions of these peaks to calculate signal-to-noise ratios.

6 vPDUs have been produced and tested so far.



Summary

DarkSide-20k will start taking data in 2026 and will be the largest and most sensitive dark matter experiment to date.

SiPMs will be used to detect scintillation light produced by interacting particles.

The UK is producing and testing the SiPM arrays for the DarkSide-20k veto.

Tests so far have shown low noise levels and clear signals which meet the requirements of the experiment.

