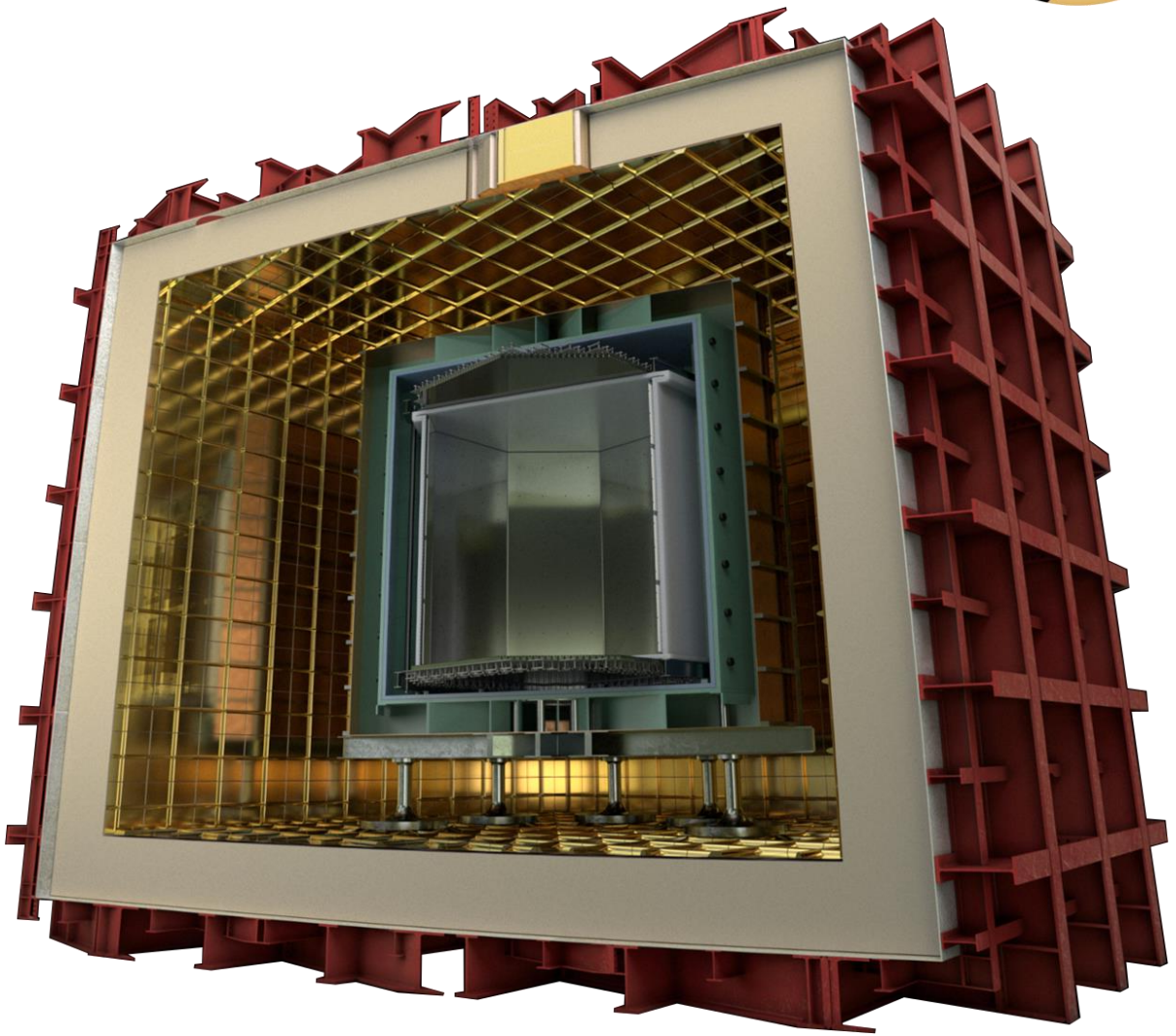
DarkSide-20k

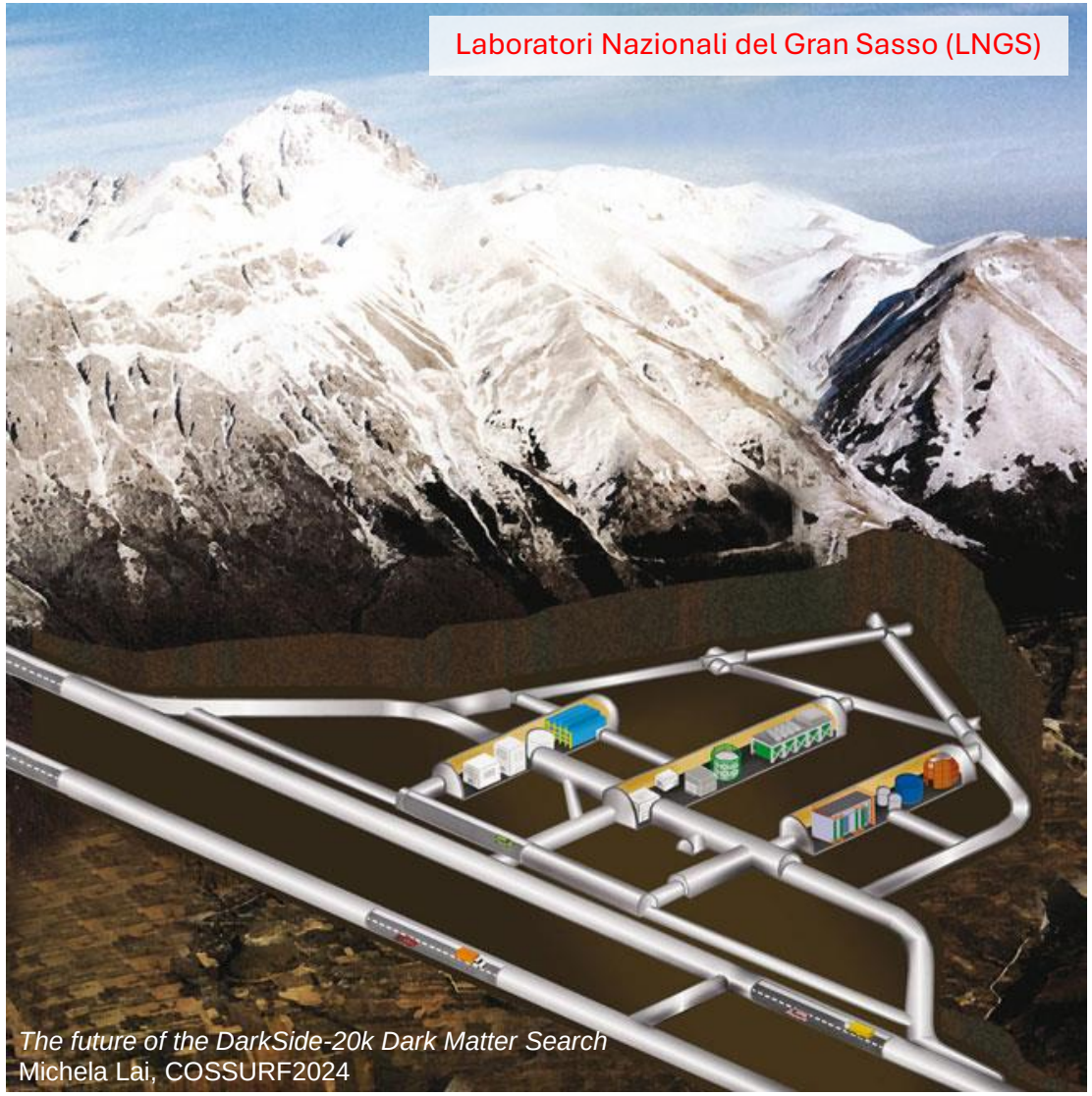
Maria Cecilia Queiroga Bazetto

HEP Annual Meeting
22-23 May 2025



DS-20k Overview

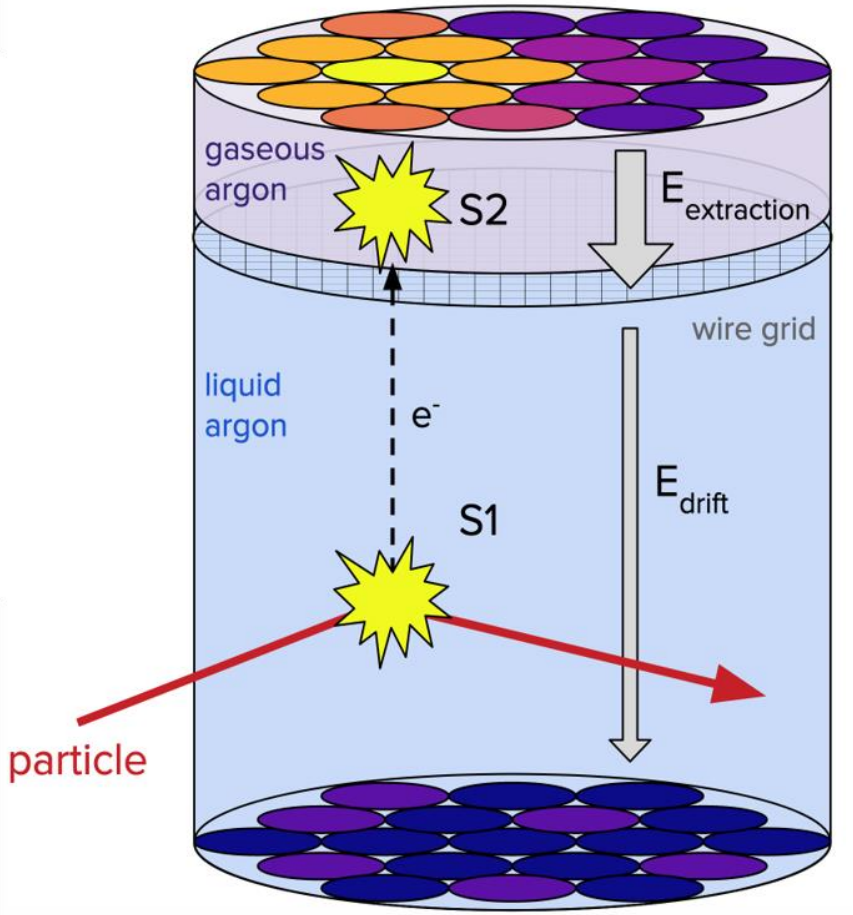
- Dark Matter direct detection experiment
- Search for WIMPs - promising DM candidate
- Hosted at LNGS, Italy
- 1400m natural shielding against cosmic rays (source of background noise)



The future of the DarkSide-20k Dark Matter Search
Michela Lai, COSSURF2024


Photo: Olly Macfadyen, 2024

• Dual-phase TPC

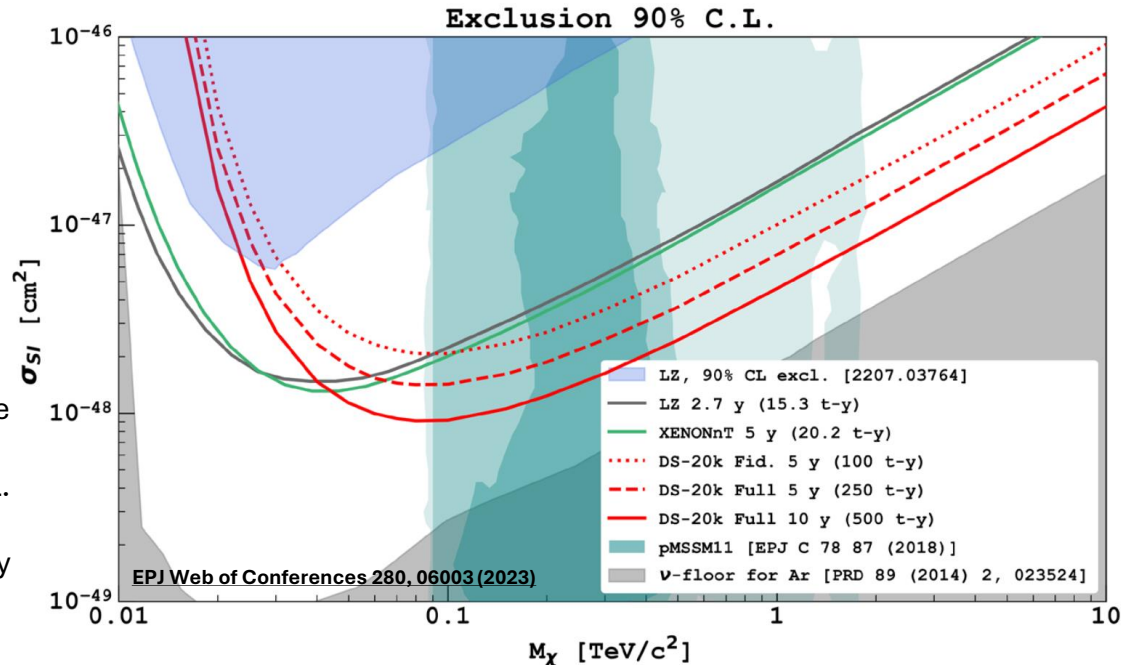


The detection mechanism is based on a dual-phase Argon TPC. WIMP candidate elastically scatters off an argon nucleus, it produces scintillation photons (S1, liquid phase) and ionization electrons (S2, gas phase). These signals are detected by two optical planes (~600 photodetectors manufactured at NOA/Italy) located at the top and bottom of the TPC giving information for the event reconstruction.

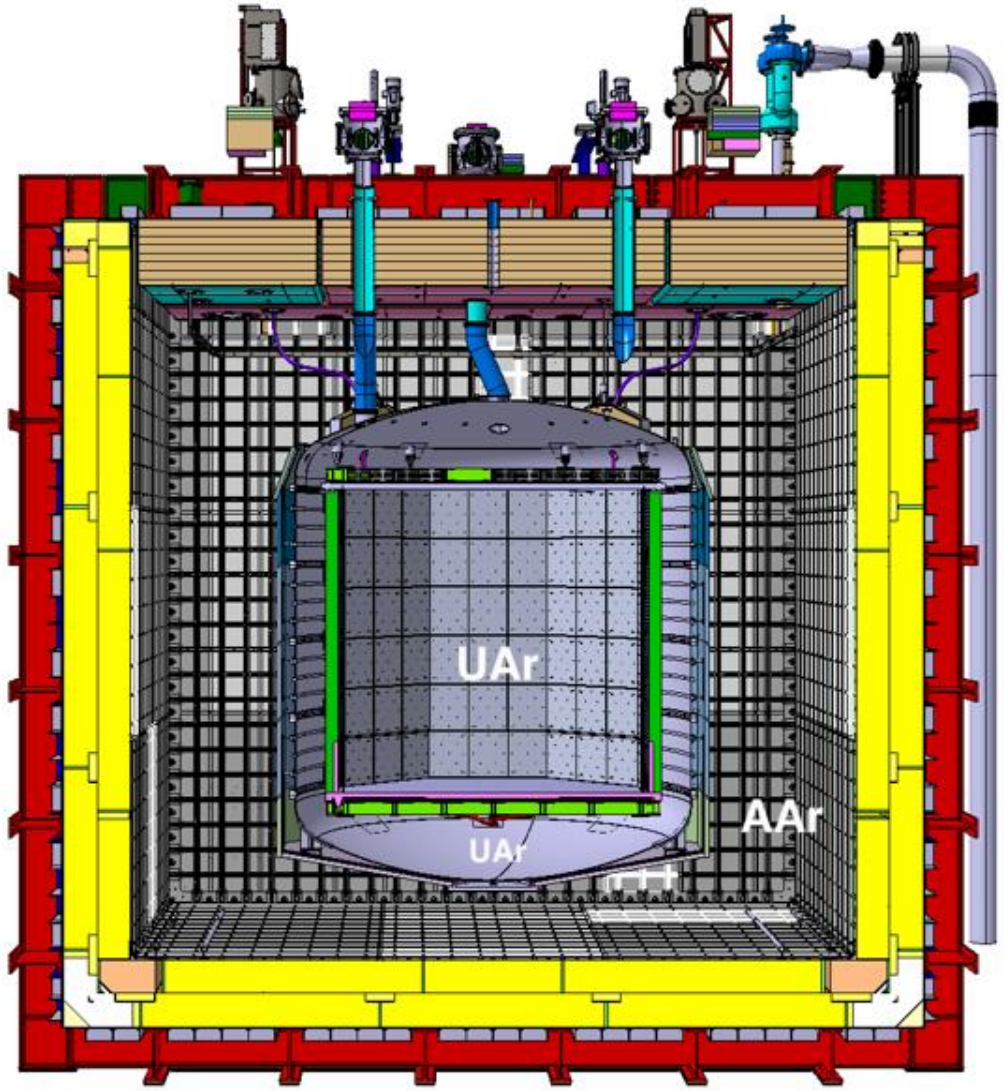
TPC: ~50 t of low-radioactivity UAr

The detector was design to operate in a negligible background level, (<0.1 neutron-WIMP-like events) to achieve significant sensitivity .

10 yr run, fiducial volume exposure of 200 t·yr
7.4×10^{-48} cm^2 for 90% C.L. level exclusion
2.1×10^{-47} for 5σ discovery for 1 TeV/c^2 WIMP



• DS-20k Veto



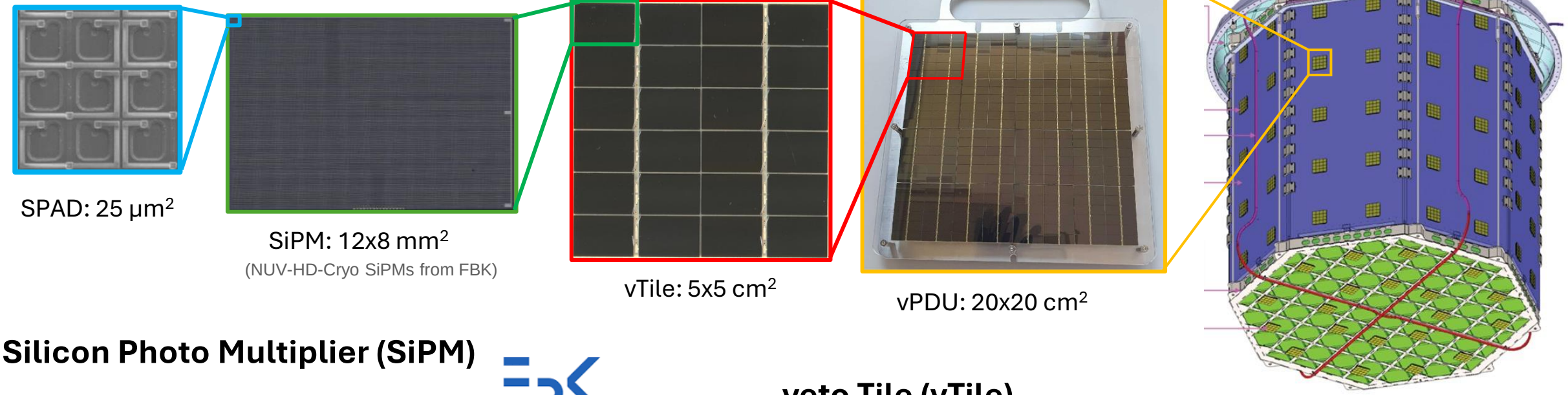
Crucial component is the active veto system, which acts as a shield against external and instrumental background sources.

Veto system consists:
-Inner Veto: ~35 t of UAr between the TPC and the SSV to mitigate critical background that comes from neutron scattering;

-Outer Veto: ~700 t of AAr within an 8x8x8 m^3 membrane cryostat surrounding the SSV to detect and tag external neutrons and muons.

TPC + Veto System
instrumented 26m^2 of silicon photomultipliers (SiPMs)

• PhotoDetector



Silicon Photo Multiplier (SiPM)

- Custom SiPMs developed by FONDAZIONE BRUNO KESSLER
- Consists of ~95,000 SPADs (Single Photon Avalanche Diode)

<u>Benefits compare to PMTs</u>

- Lower voltage operation
- Lower intrinsic radioactivity
- Higher photon detection efficiency
- Lower noise (@cryo temp)
- Higher coverage surface area

veto Tile (vTile)

- Module of 24 SiPMs assembled with front end electronic board (vPCB)

veto Photon Detection Unit (vPDU)

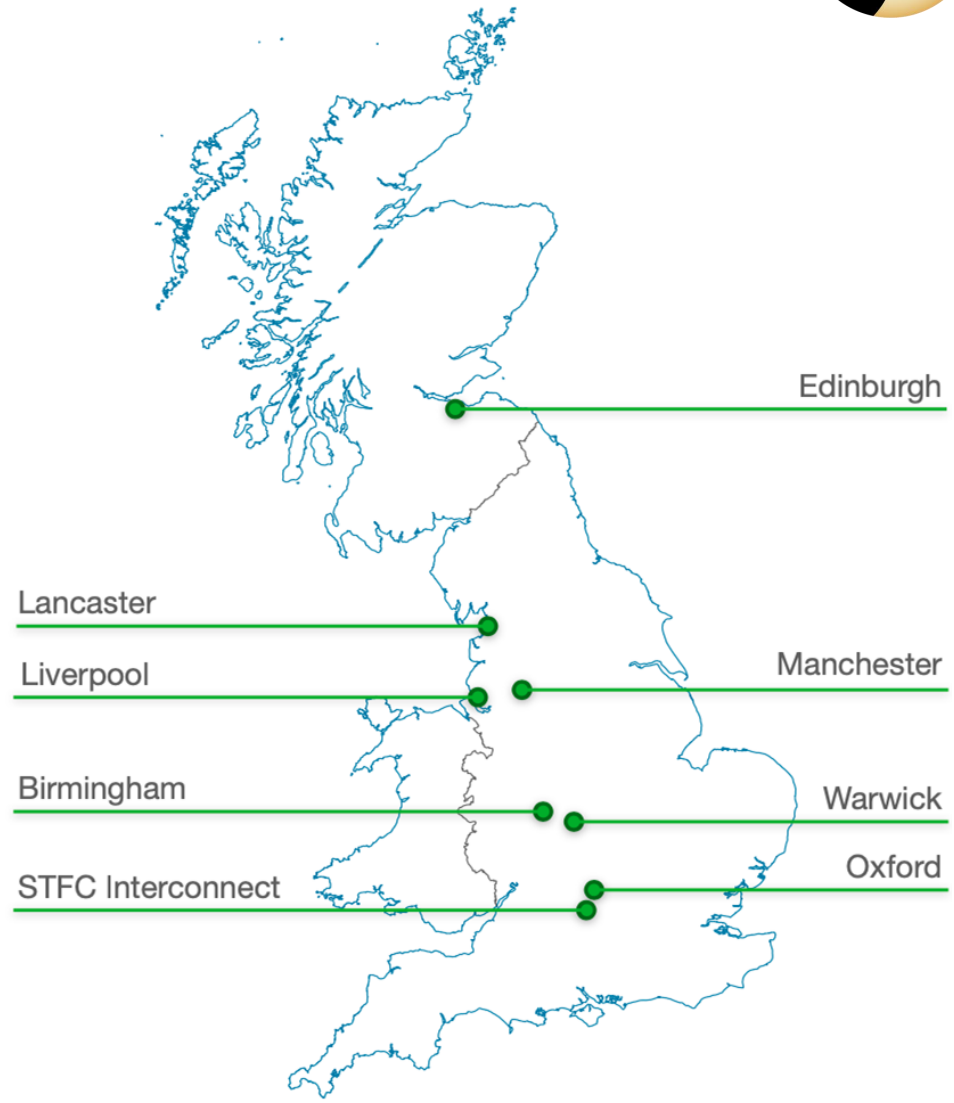
- 16 vTiles integrated onto a motherboard (MB)
- Provides signal and power to the vTiles

UK tasks

- Production, testing, QA/QC and delivery of ~130 vPDUs (~2400 vTiles incl. spares) to instrument the inner and outer veto
- Radiopurity control of vTiles and vPDUs
- Characterization facilities to qualify vTiles and vPDUs at both warm and cold temperatures

Liverpool's contribution

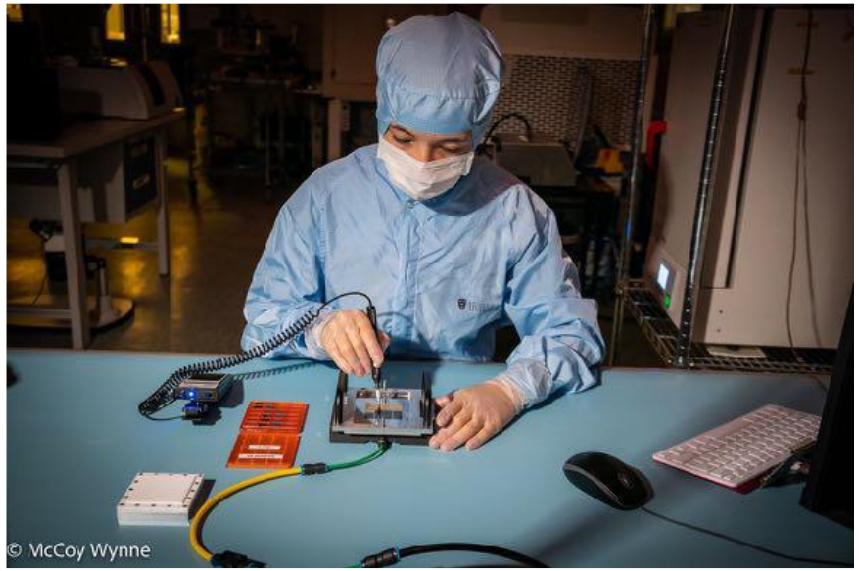
- Originally 50% of the vTiles production (n=1200)
- Cold testing of vPDU assemblies



Liverpool team

- Maria Bazetto
- Liam Boynton
- Gianluigi Casse
- Heriques Gatti
- Tim Jones
- Adam Lowe
- Kostas Mavrokoridis
- Sudi Ravinthiran
- Adam Roberts
- Alan Taylor
- Jon Taylor
- Joost Vossebeld

Collaborative effort by Liverpool team!!!



Special thanks to:
- Mike Lockwood
- Mark Whitley, Dan Hollywood and DDMF team
- Rob Fay, Mark Wong
- Julie Clark, Angie Reid, Hannah Melia

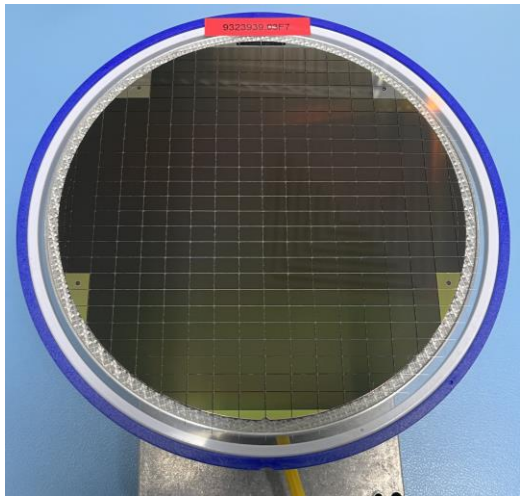
• Liverpool vTile Production (Clean Room at LSDC)

The radioactive contamination can be introduced during the assembly and characterisation processes. All the production phases are performed in ISO-5/ISO-7 clean room/nitrogen cabinet storage/limit exposure to Radom to control the presence of airborne particles and prevent recontamination.

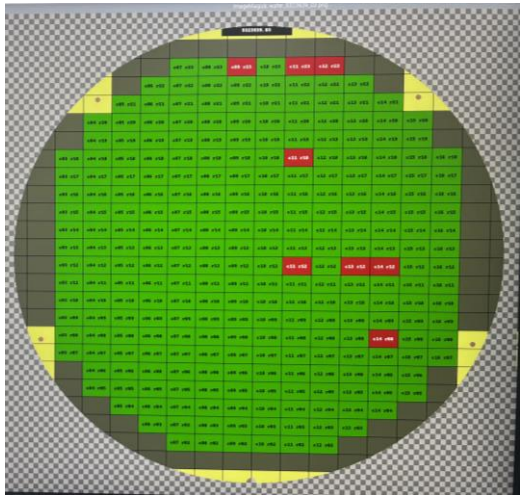

Items to assemble a vTile

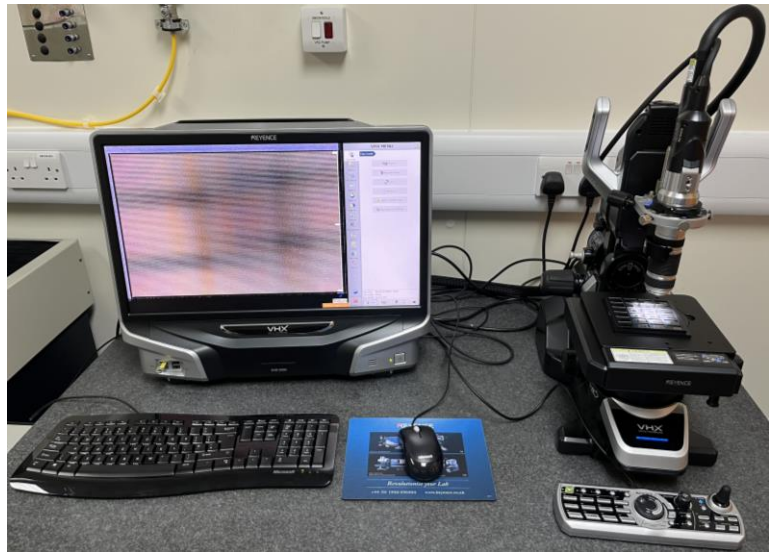

Clean Room at LSDC

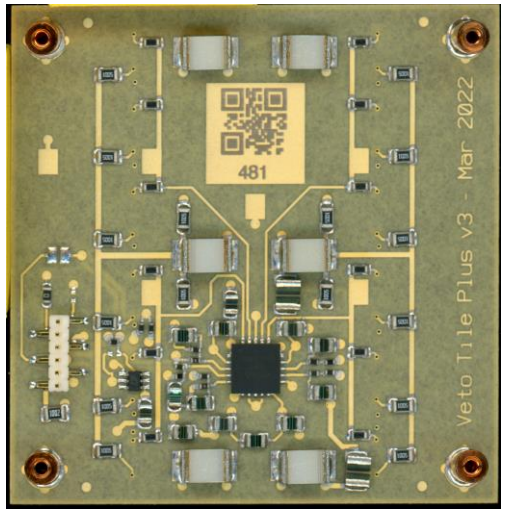
• Initial visual inspection

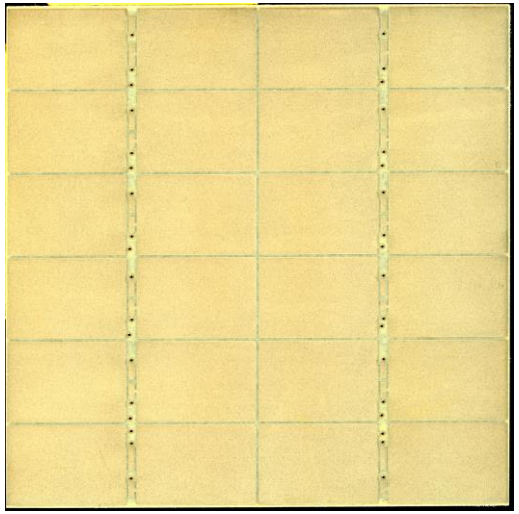


The production process starts with SiPMs being picked from the wafer (following the DB map) and arranged into trays of 24 spaces, replicating the vTile positions.
A visual inspection of individual SiPMs is performed using an optical microscope to identify and replace any defective units and scans are taken of both the populated backside and unpopulated front side of the vPCB.



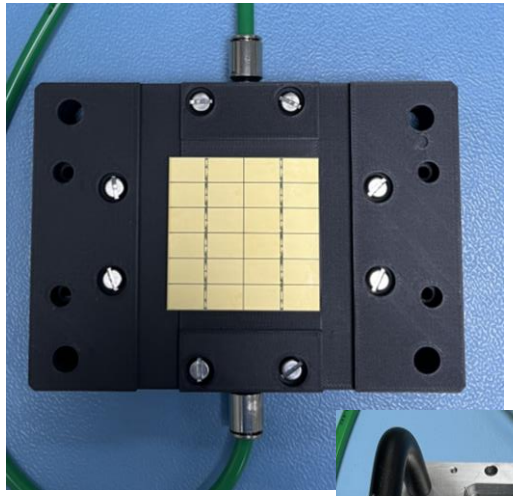


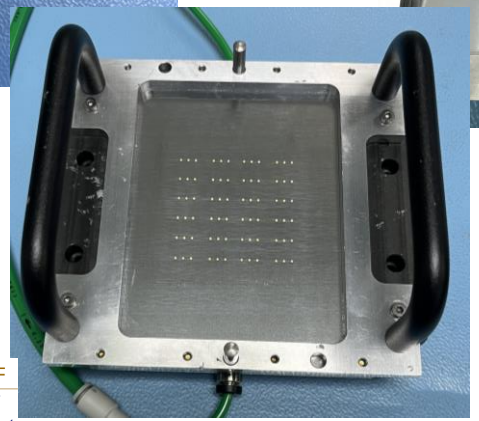


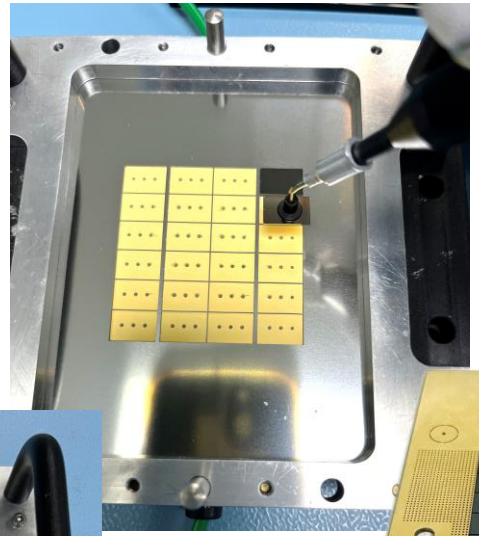


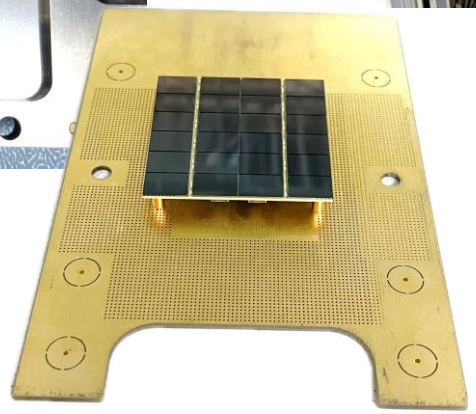
• Die attach

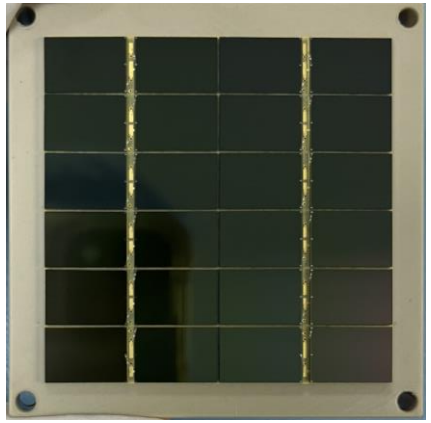
The vPCB is positioned into a 3D-printed vacuum jig, and conductive indium solder paste is applied using a laser-cut stencil. With a vacuum pen, the SiPMs are placed using an alignment stencil. Baking is performed in an ARGOLABTCN30 Plus convection oven with temperature monitored by 3 thermocouples. After the baking, the vTile is transferred to a process carrier and stored in nitrogen cabinet till the next step.





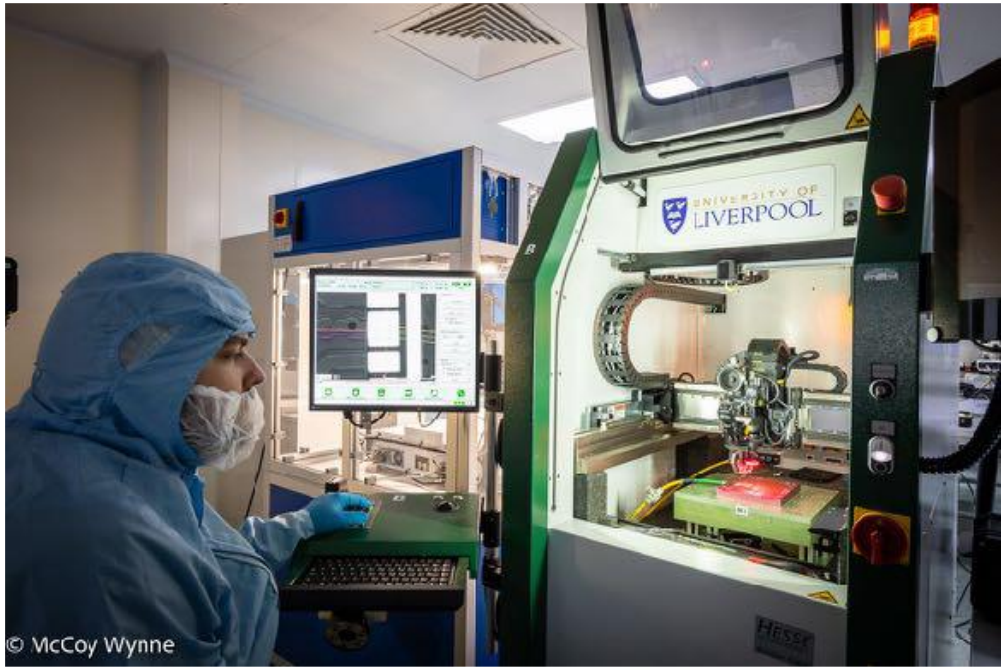


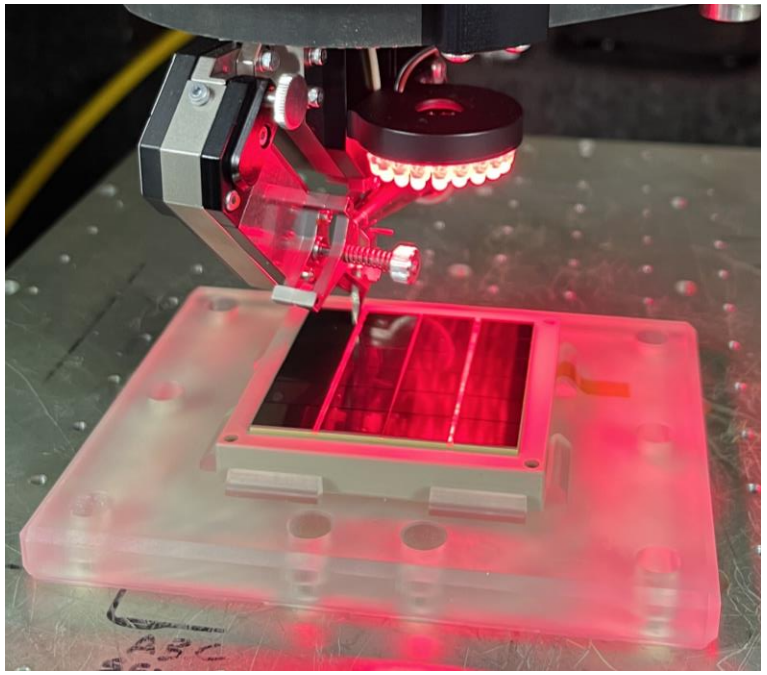


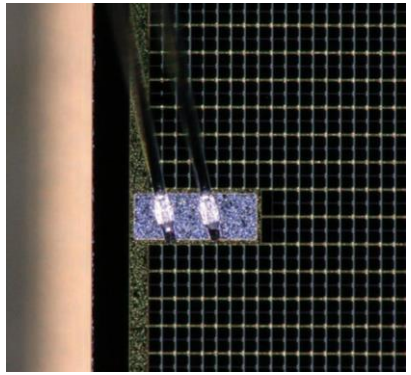


• Wire-bonding

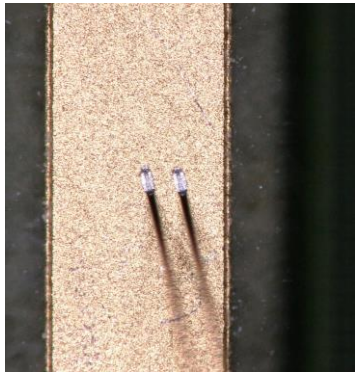
Performed on a HESSE BJ820 wire bonder. This process involves precisely calibrated parameters as mechanical pressure, temperature and ultrasonic energy to create the electrical connection between the SiPMs and the vPCB components.

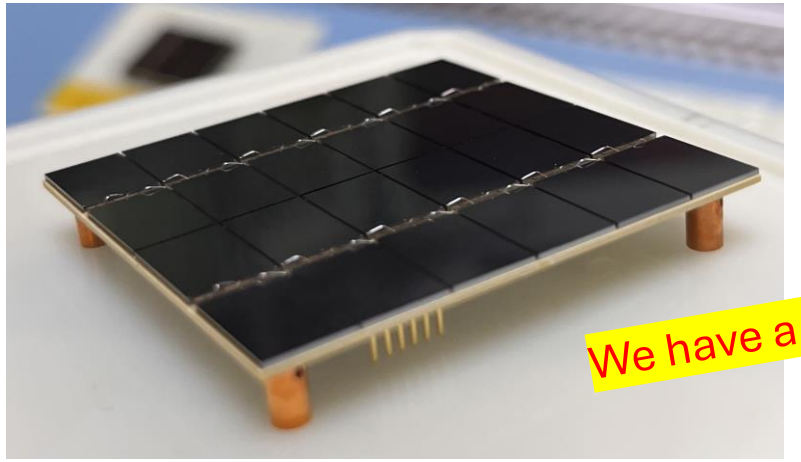






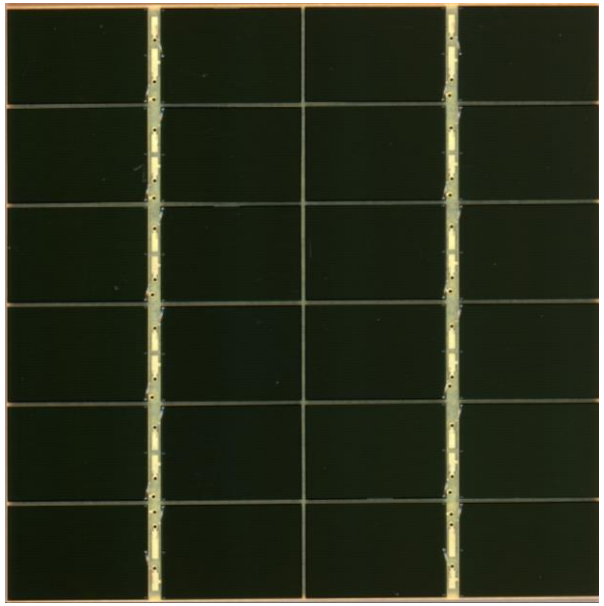
2 wires (25 μm thick) each SiPM pad

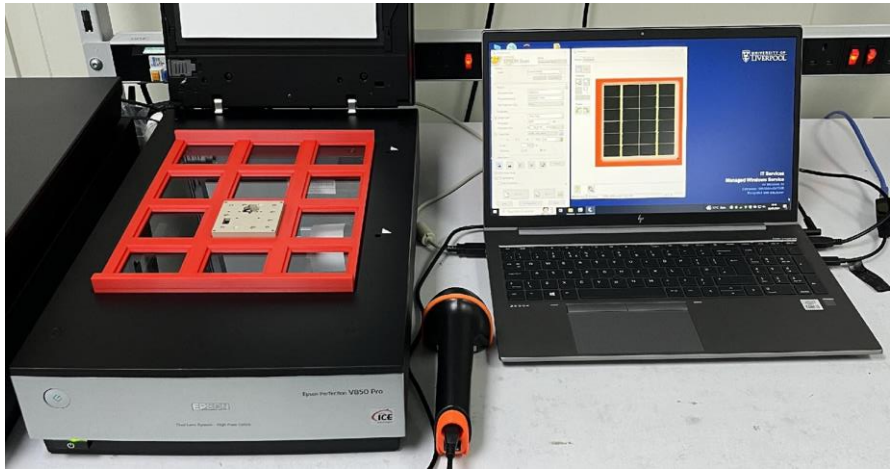




• CR-test and final inspection

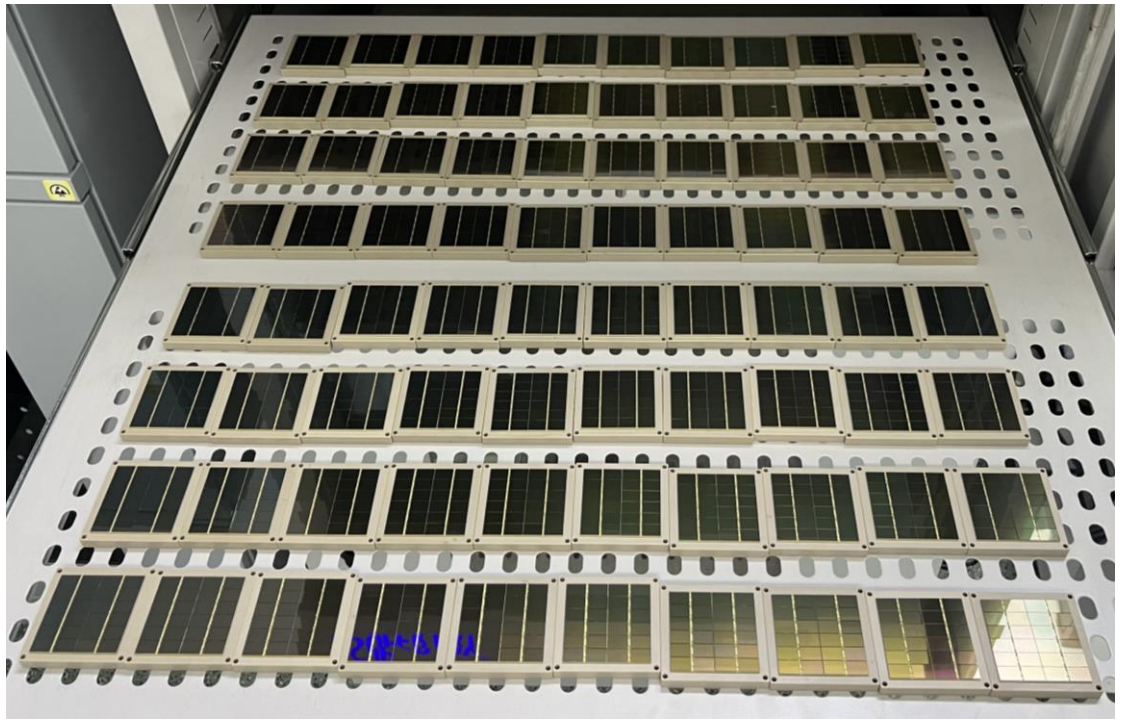
To qualify the electrical connections (wire bonds, solder joints) the vTiles are submitted to a CR-test. The setup consists of a Keysight E4980A Precision LCR meter for measuring the Cs-Rs properties. Results are checked against reference values and a high-resolution flatbed scanner captures images of the SiPMs surface with visible wire-bonds for a final inspection.





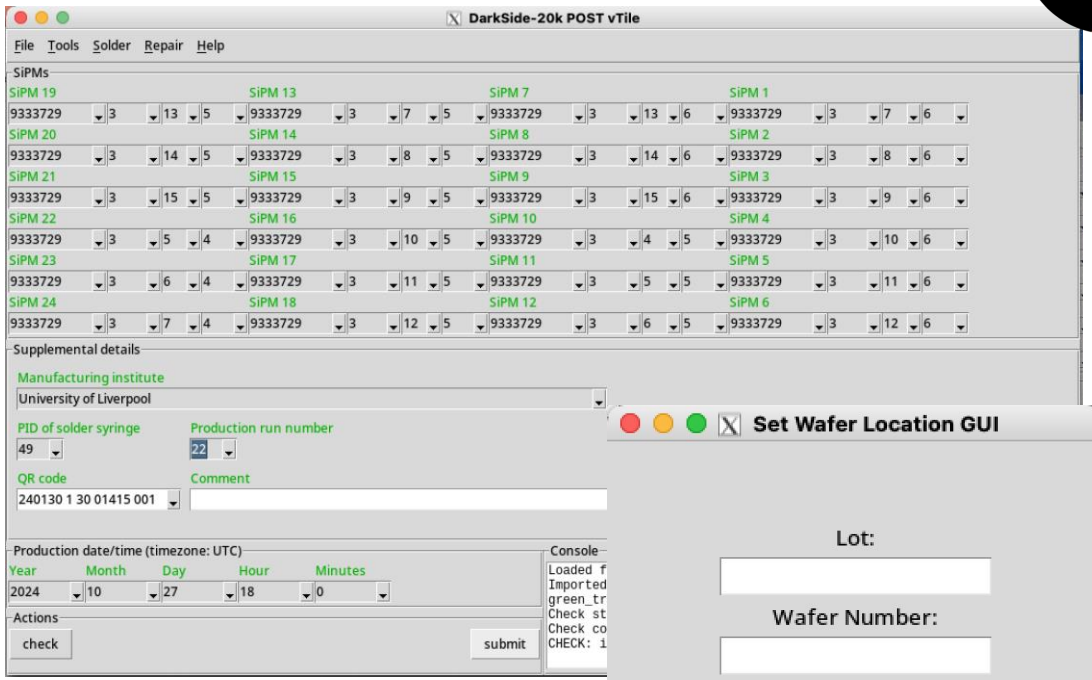
• Packaging

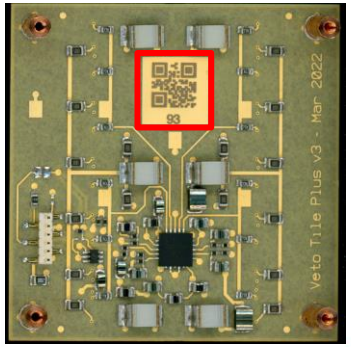
Once the vTiles have been scanned, they are carefully placed into shipping fixtures that protect the wire bonds and SiPM surfaces. They are packaged in partial-vacuumed bags and dispatched to other sites for individual cold testing and subsequent integration into vPDUs

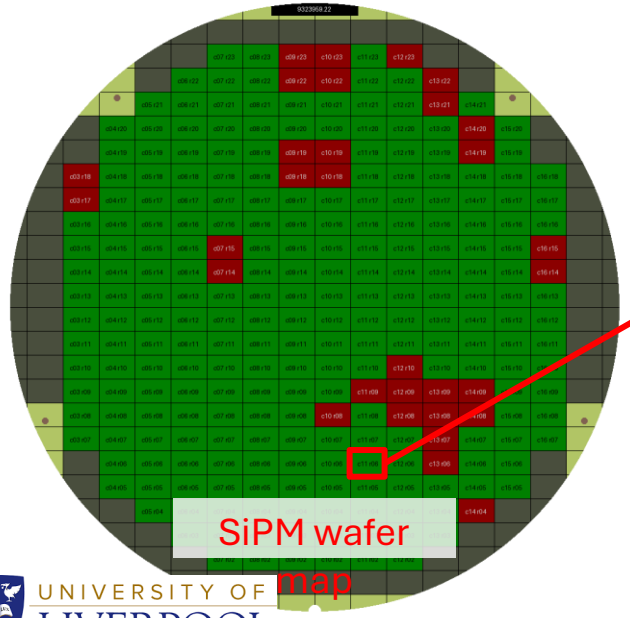


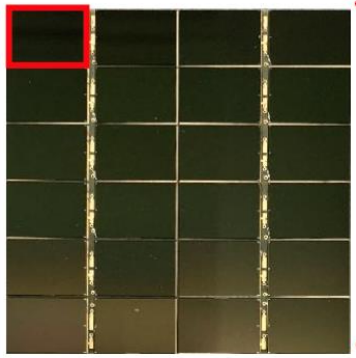
• vTile Production and Database

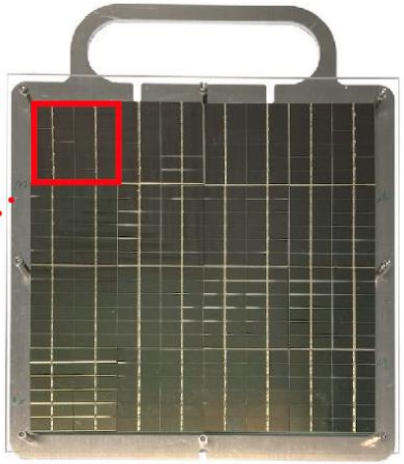
The production DB stores test results collected during the assembly phase, providing data for QA/QC assessment and inventory purposes. The DB also tracks the progress and location of each component to assist the future integration phase of the experiment. Liverpool wrote the database interface software used across the collaboration.

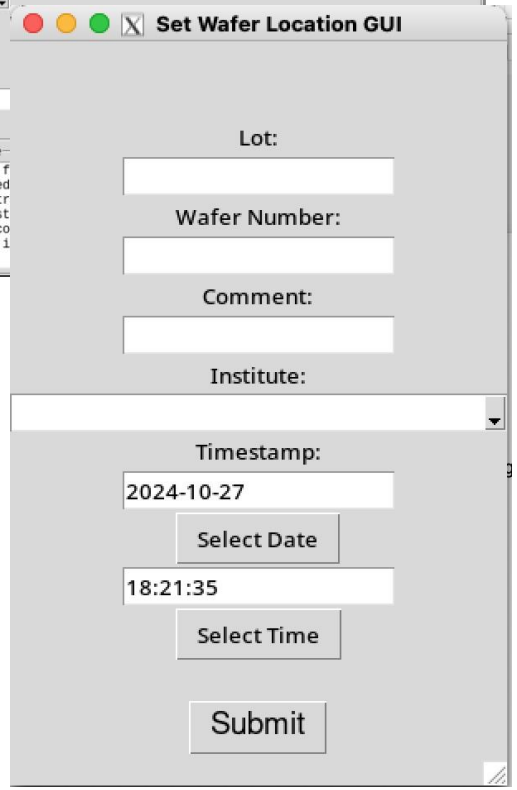






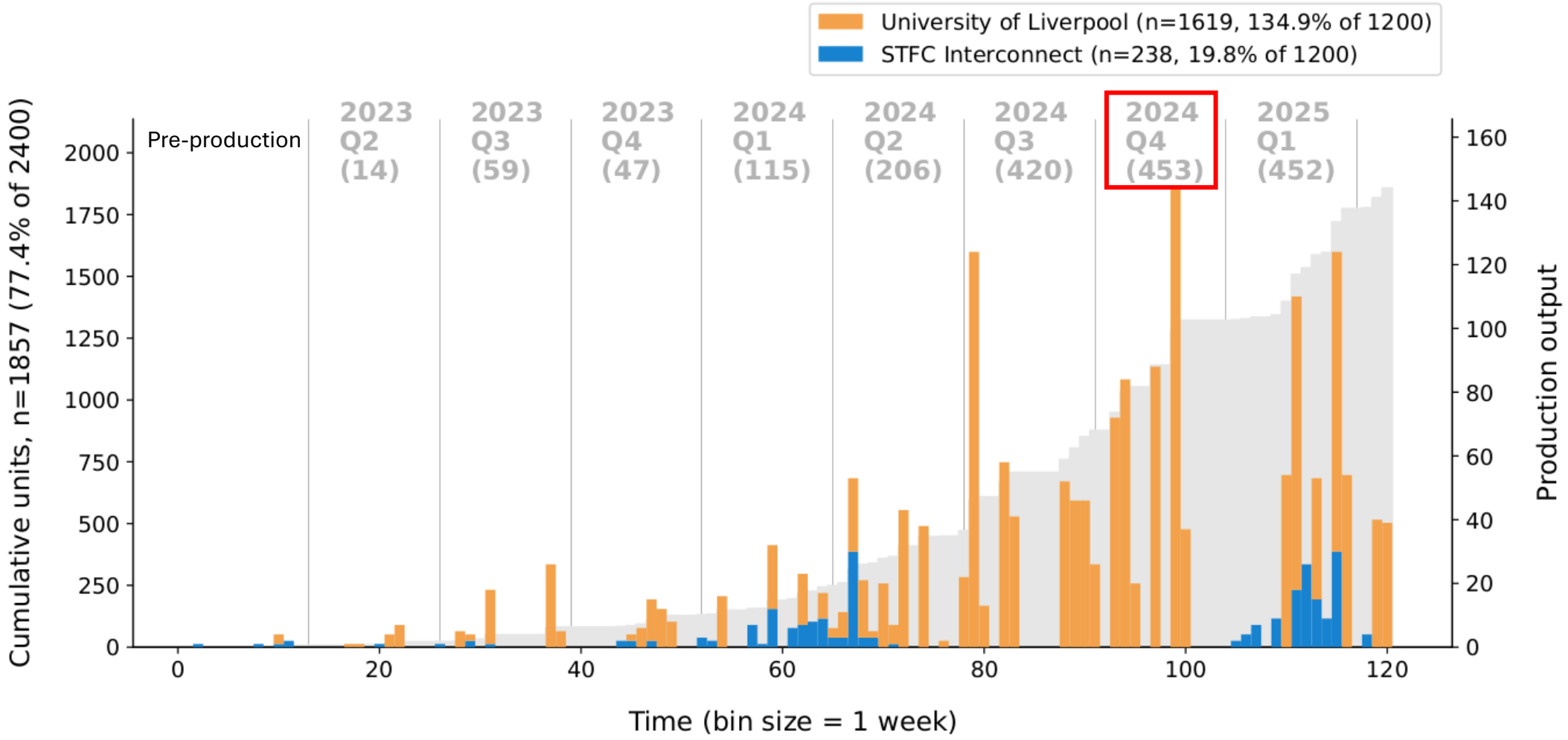






vTile Production Status

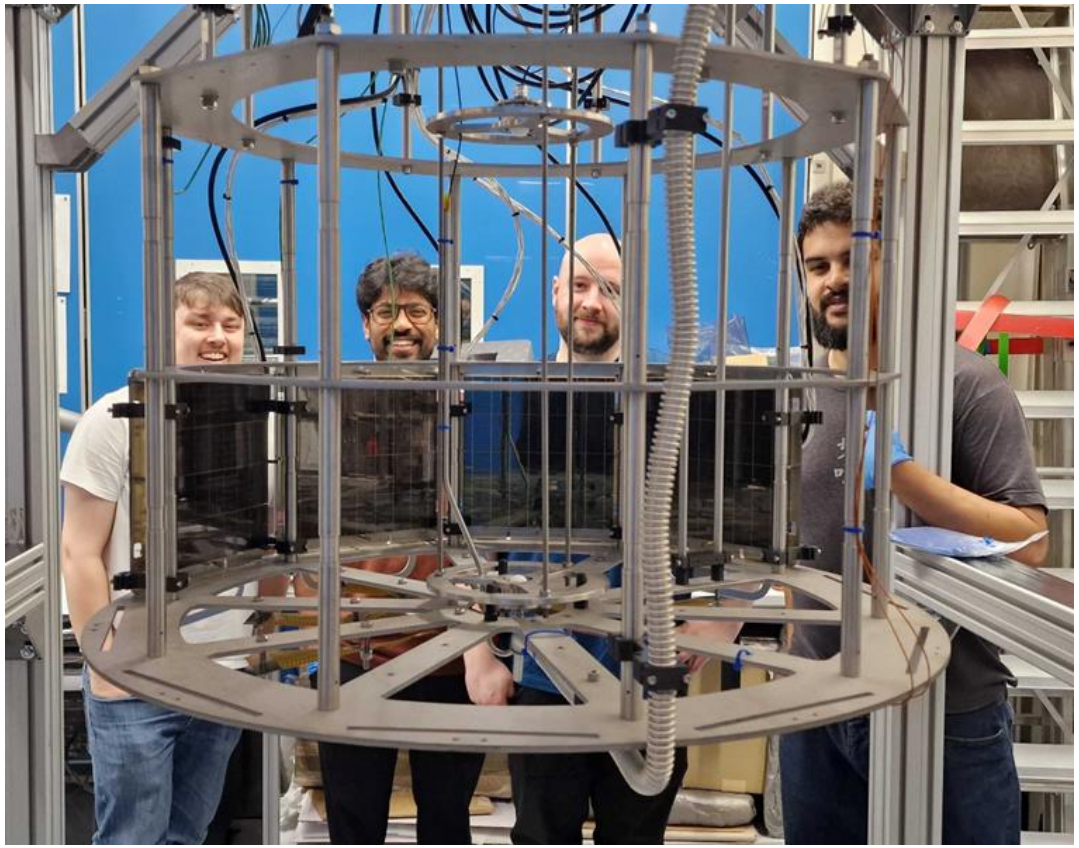
Liverpool went over the expectations, concluding our target in Dec/2024, continuing and to date completing 1619 units produced
Production in UK is nearing completion; the primary production already finished, now producing spares
The cumulative vTile yield passing cryogenic QA/QC is greater than 90% (requirement 80%)

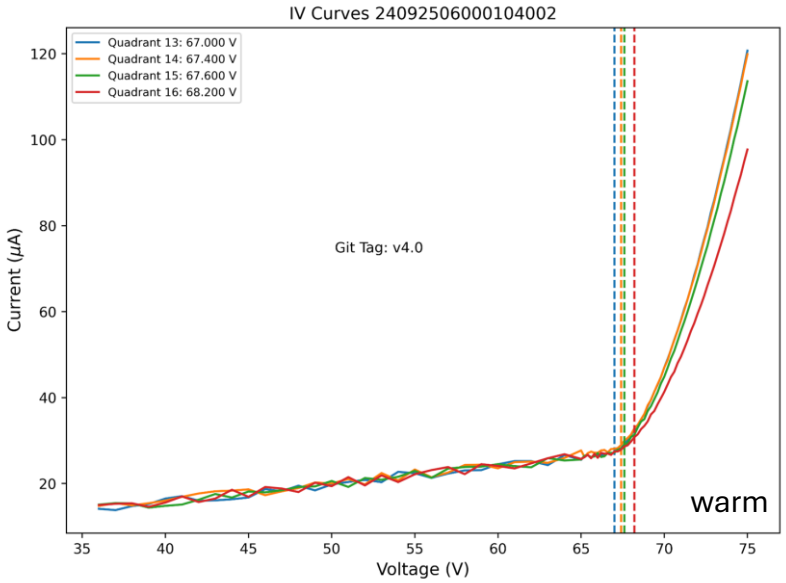


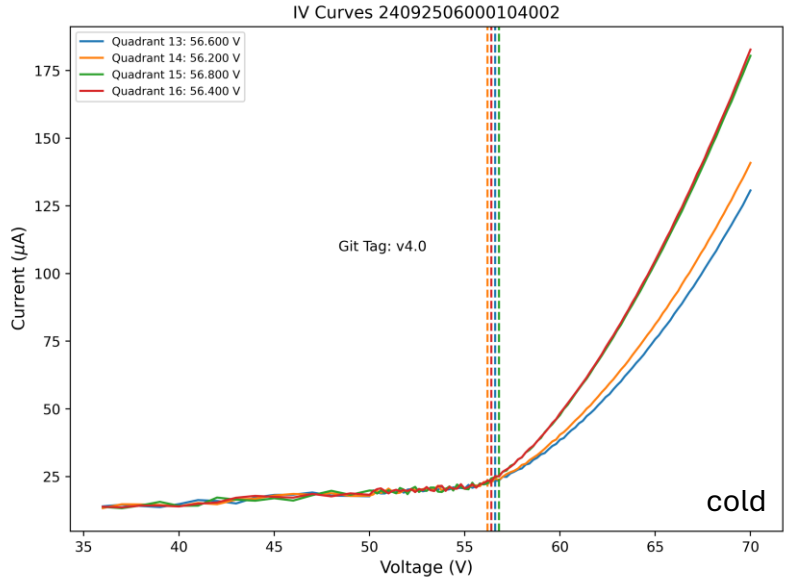
• Liverpool Cold Tests

vPDUs assembled in a fixture cage ready to be placed withing the cryostat.

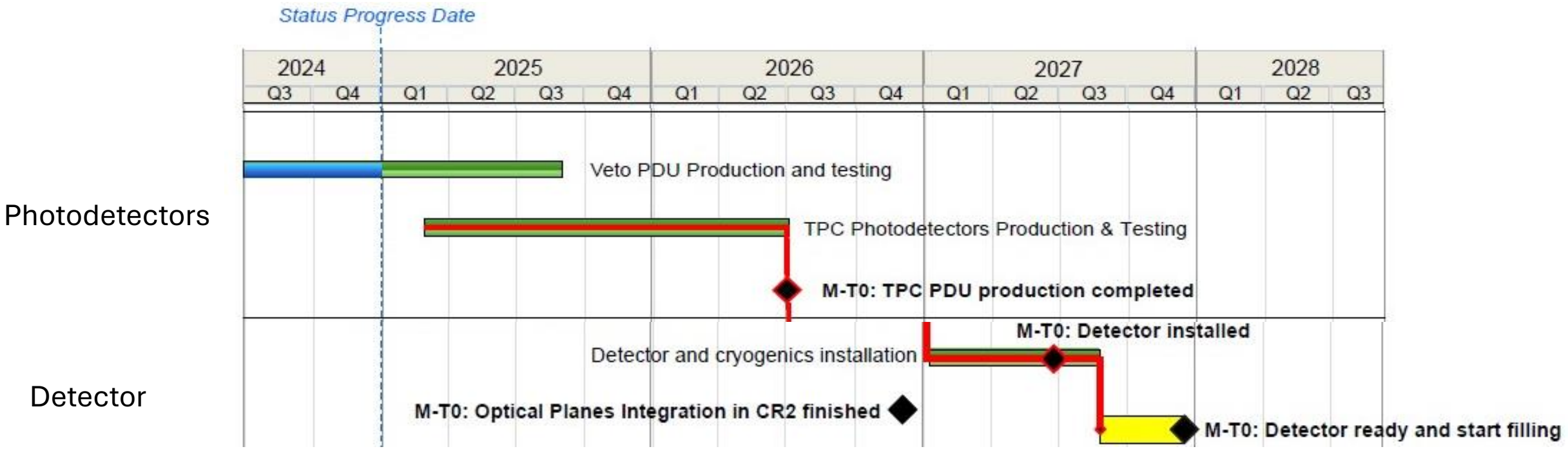
Example of the analysis IV characterization plot in warm and cold, determining the breakdown voltage.







• Current Schedule



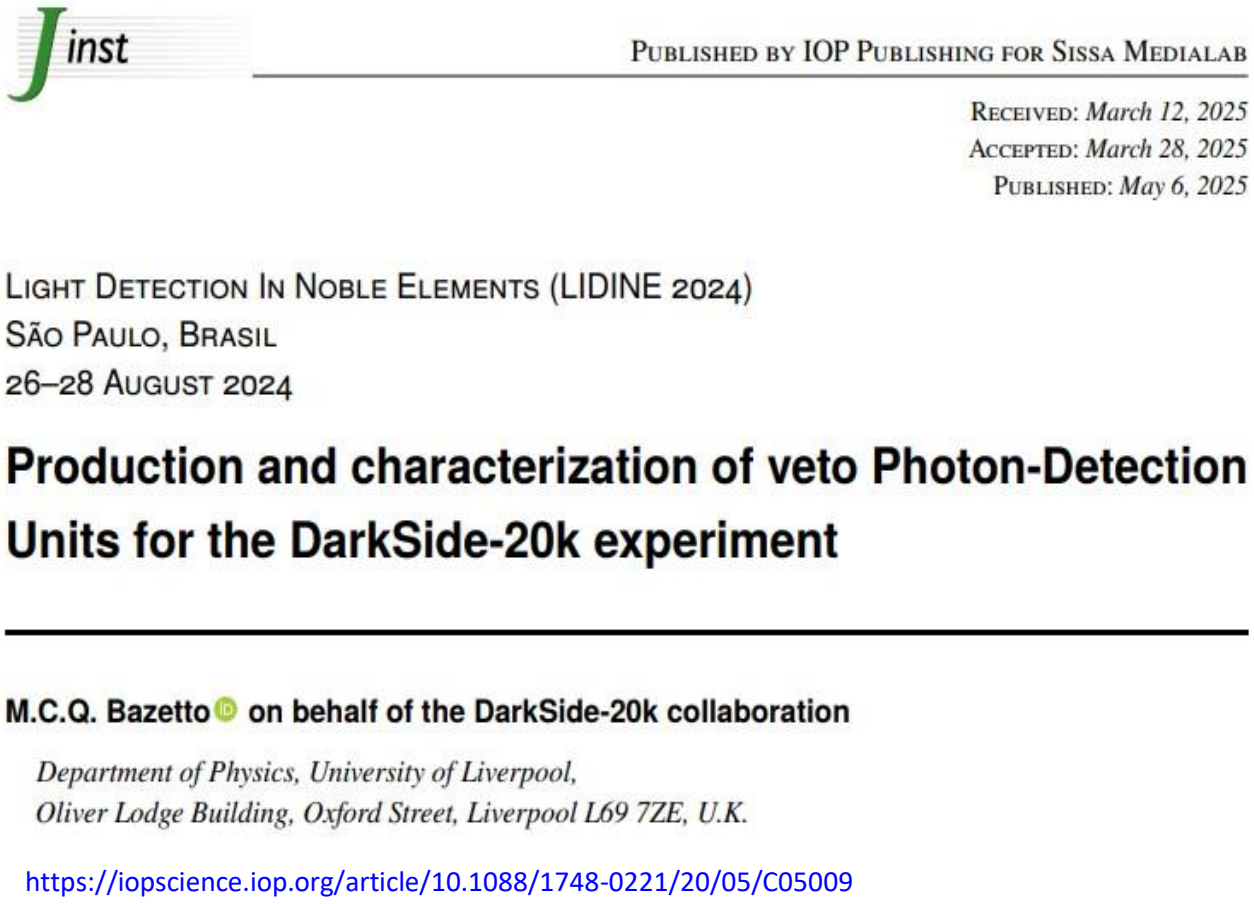
Documentation submitted 17 March 2025 to INFN DarkSide Review Committee, for April 9-11, 2025 meeting

- vPDU production is targeted to be completed in 2025
- Photodetectors installation on 2026/2027
- LAr fill expected to commence in Q4 2027

Expected to start taking data in 2028

• Publishing Contribution

Attend international conferences and contributed for 2 publications



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LIGHT DETECTION IN NOBLE ELEMENTS (LIDINE 2024)
SÃO PAULO, BRASIL
26–28 AUGUST 2024

Production and characterization of veto Photon-Detection Units for the DarkSide-20k experiment

M.C.Q. Bazetto on behalf of the DarkSide-20k collaboration

Department of Physics, University of Liverpool,
Oliver Lodge Building, Oxford Street, Liverpool L69 7ZE, U.K.

https://iopscience.iop.org/article/10.1088/1748-0221/20/05/C05009

2nd paper currently under internal review, which will be submitted soon…

• Summary/Outlook

DS-20k in UK

-Expected to complete the entire vTile production by August 2025;
-Perform cold characterization of integrated vPDUs;
-Finally shipping to LNGS for the detector integration.

DS-20k

-Utilises state-of-the-art technologies
-Cryogenic large-area SiPMs arrays
-Underground Ar
-Has innovated in production and testing methods for SiPM technologies

DarkSide-20k is set to be competitive with existing and future experiments across a search for Dark Matter

LNGS

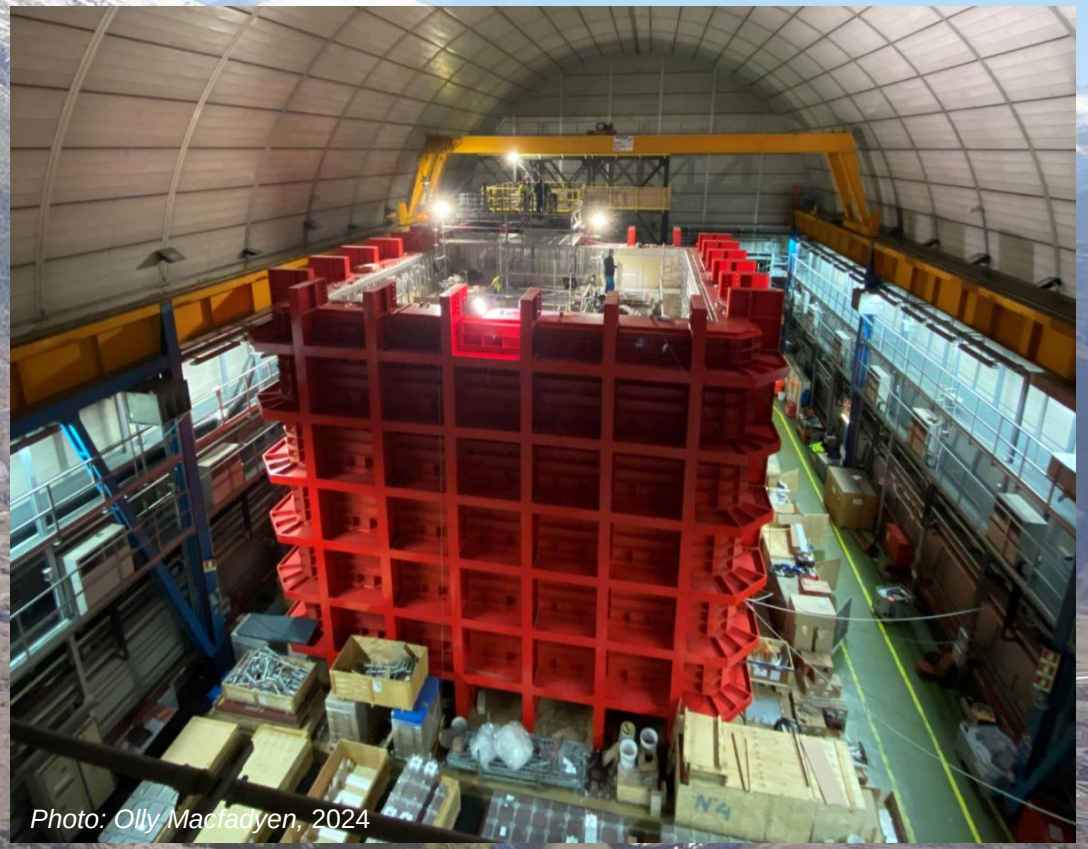

Photo: Olly Macfadyen, 2024

Thank you all here in Liverpool contributing to DS-20k!!!