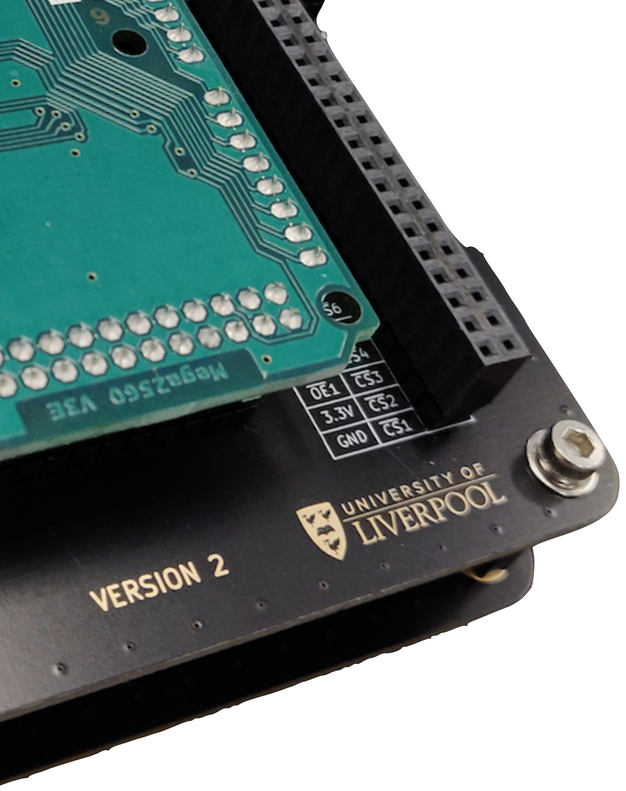


DarkSide-20k Update

Particle Physics Annual Meeting
Friday 24th May 2024

M. Queiroga Bazetto, L. Boynton, G. Casse, H. Frandini Gatti,
T. Jones, K. Mavrokoridis, S. Ravinthiran, A. Roberts, A.Taylor, J. Taylor, J. Vossebeld

Special thanks to:
K. Bridges, A. Bukowski, M. Brown, J. Carroll, D. Hollywood, A. Kumar, K. McCormick, M. Whitley

UNIVERSITY OF LIVERPOOL

DARKSIDE

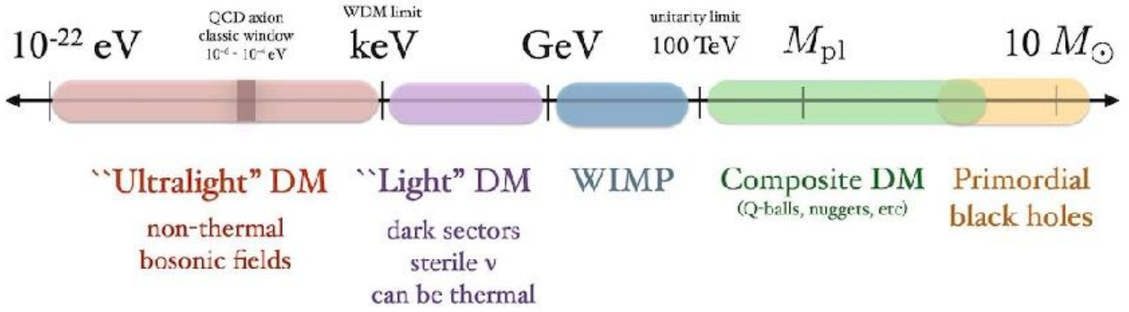
Outline

- Experiment overview
- Production status
- Production flow
    - vTile Assembly
    - vPDU Cold Testing
- Future

Experiment overview

- **Dark Matter (DM) direct detection experiment @ LNGS [1]**
- **Liquid argon, 20 tonne fiducial volume**
- **FBK Near-UV SiPMs with wavelength shifter: 128 nm to 420 nm**

- **Primary DM candidate:**
  - **Cold dark matter: Weakly Interacting Massive Particle (WIMP)**
  - **sensitivity 1.2×10^{-47} cm^2 for WIMP mass of ~1 TeV/c^2**



[2]

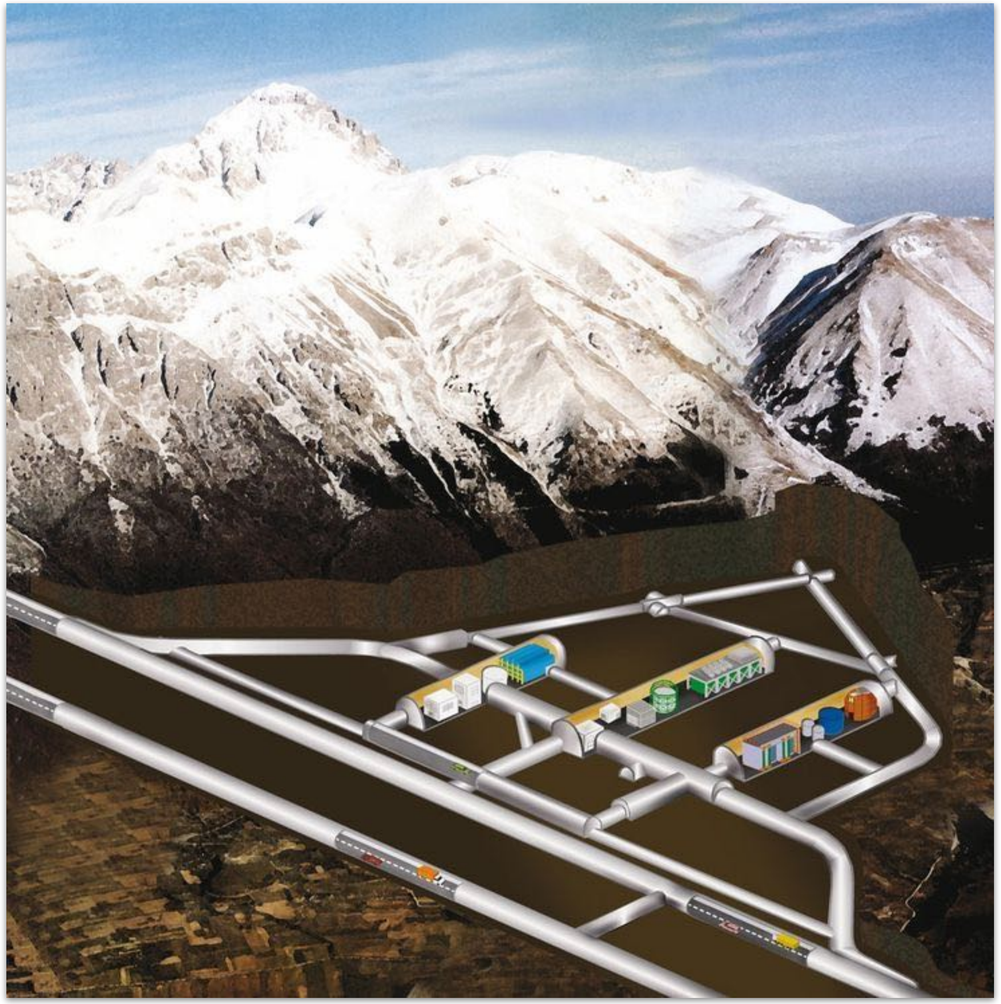
[1] Kish, A., 2021, *DarkSide-20k dual-phase argon TPC for particle dark matter detection,* https://indico.cern.ch/event/1041835/
[2] *The future of the DarkSide-20k Dark Matter Search*, Michela Lai, COSSURF2024,

Experiment Overview

Laboratori Nazionali del Gran Sasso
Gran Sasso d'Italia

https://www.lngs.infn.it/en/lngs-overview

Experiment overview



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

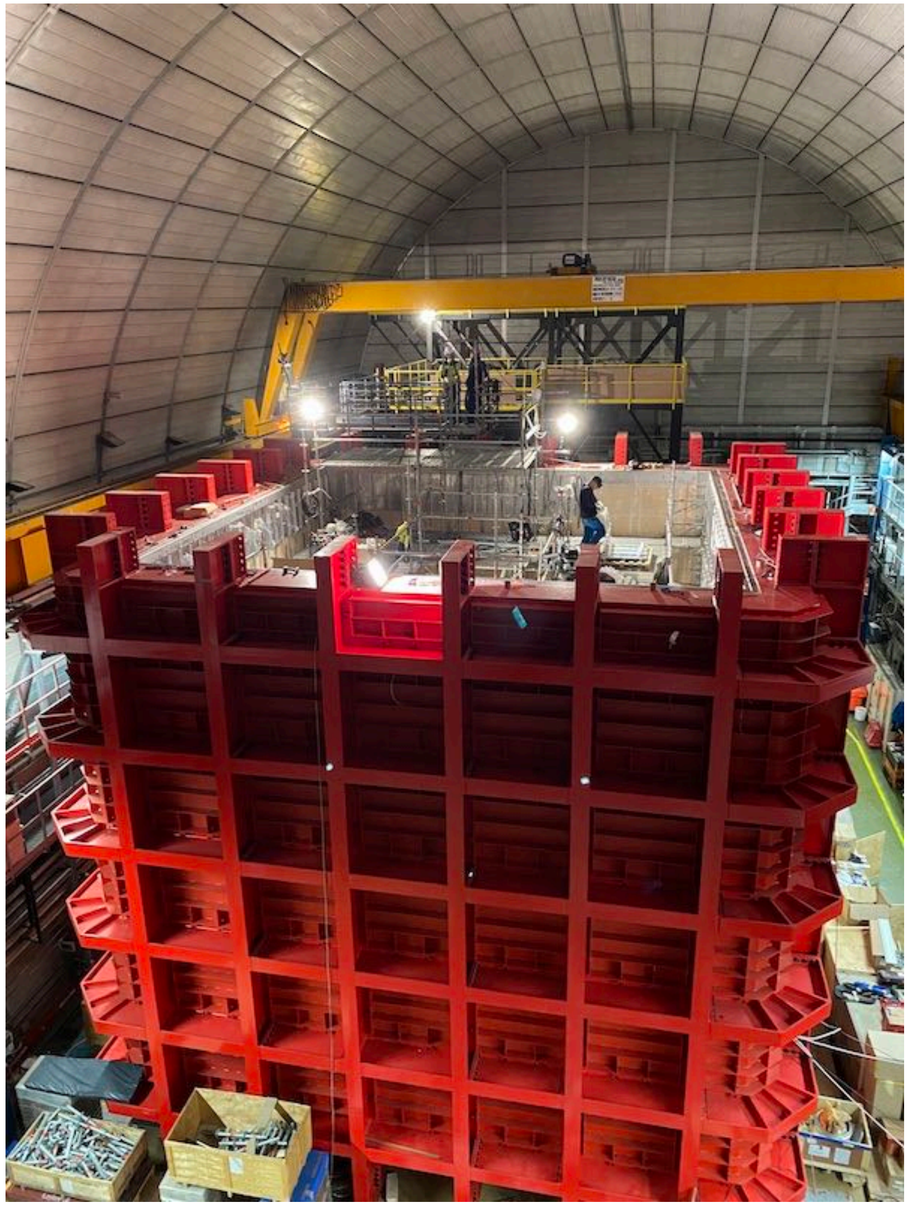
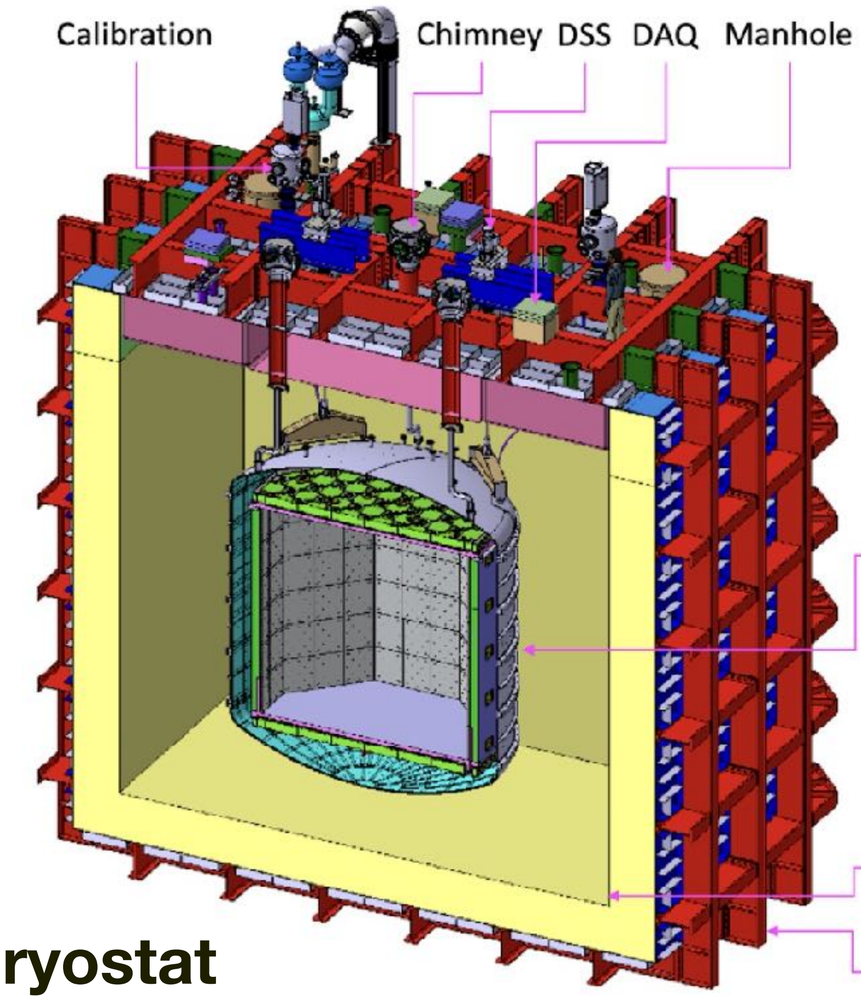


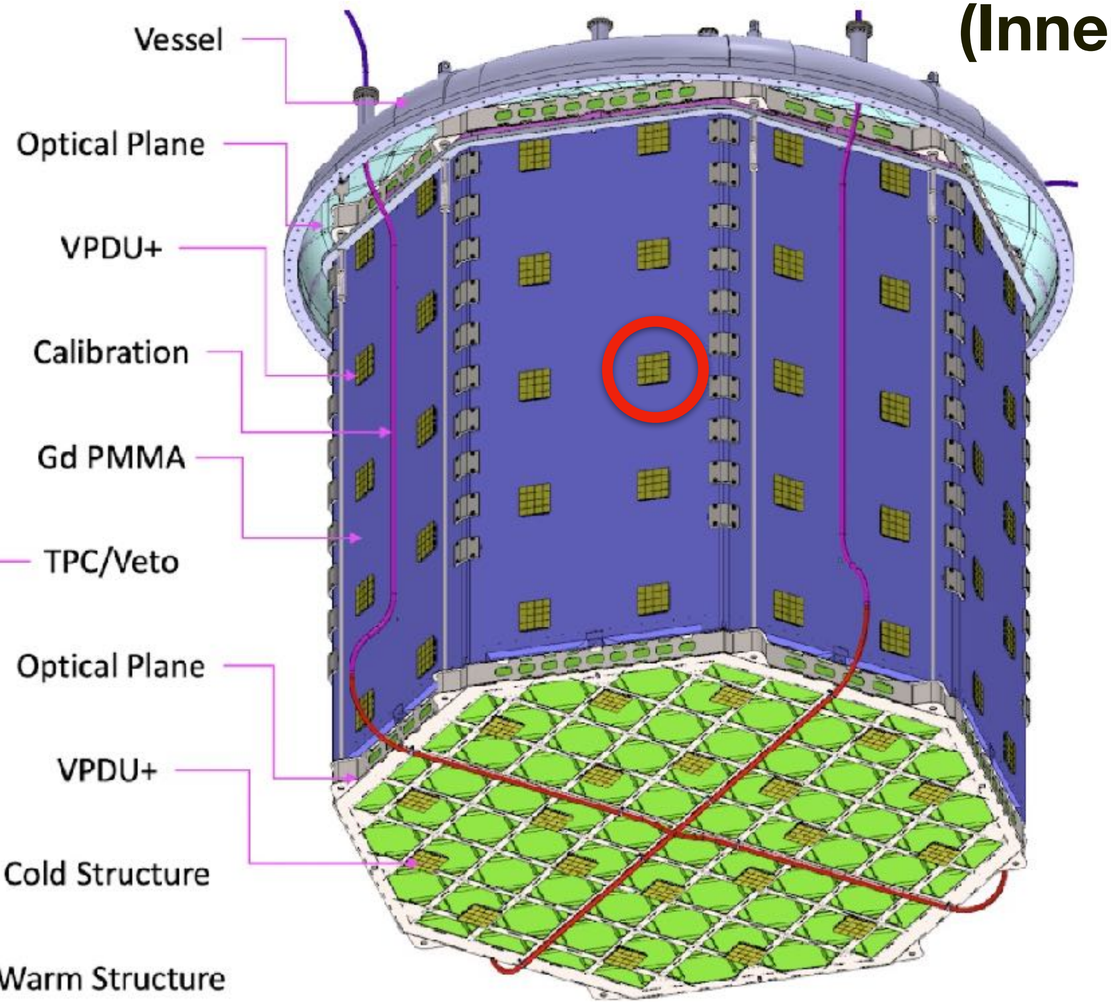
Photo: Olly Macfadyen, April 2024

Experiment Overview



Cryostat

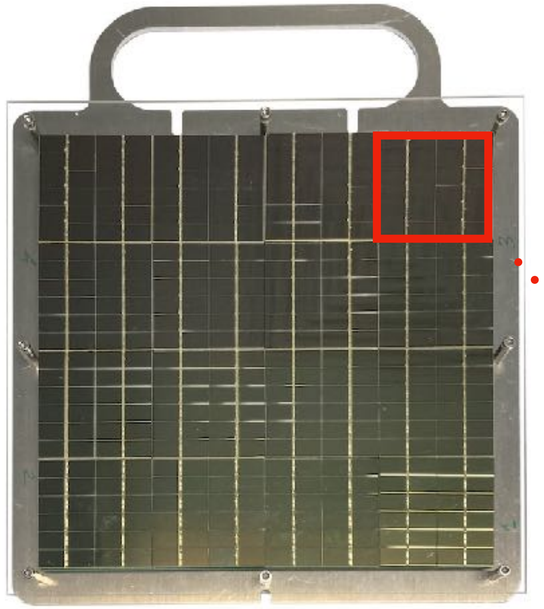
TPC vessel (Inner veto)



Direct Detection of Dark Matter with DarkSide-20k, Paolo Agnes, 2023
https://doi.org/10.1051/epjconf/202328006003

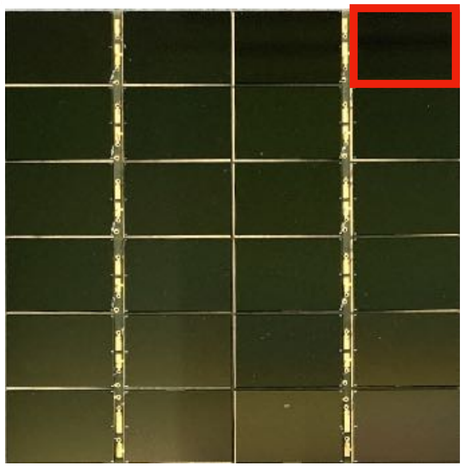
Experiment overview

vPDU
(16x vTile)



20 x 20 cm
(Liverpool: Cold test)

vTile
(24x SiPM)



5 x 5 cm
(Liverpool: Assembly)

SiPM*
(~94900 SPADS)

11.7 x 7.9 mm

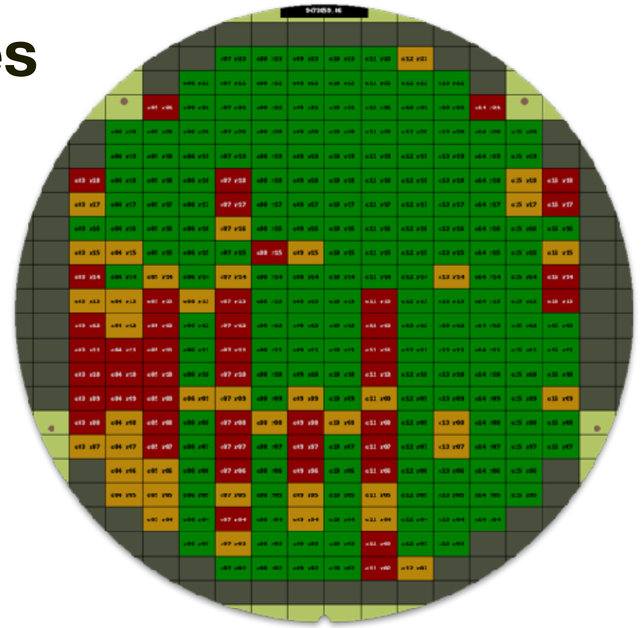
* FBK NUV-HD-Cryo triple dose SiPMs

Experiment overview

- The 150 veto PDUs (120 inner, 30 outer) are comprised of 2400 vTiles
- Liverpool’s contribution
    - Cold testing of vPDU assemblies
    - Production of 50% of the vTiles, n=1200
- STFC Interconnect will assemble the remaining 1200 vTiles

Experiment overview (software infrastructure)

- PostgreSQL production database
  - Full traceability of ASICs and SiPMs and assemblies
- Common Python API [1]
  - Interface to the database
  - Wafer drawing
  - Cross-platform (Windows/macOS/Linux)
- Numerous automation command line scripts and GUIs
- Analysis tools



- Some performance sensitive code written in Rust

[1] https://zenodo.org/records/10817039

Production status (UK)

- **vPDU Cold Testing**
  - **Core capability in place, awaiting production volume**
- **vPDU Assembly**
  - **11 complete: several others in assembly**
  - **Some electronic changes to vMotherboards in progress**
- **vTile Assembly**
  - **Production commenced, volume ramp-up in progress**
  - **Goal: 65 per week**

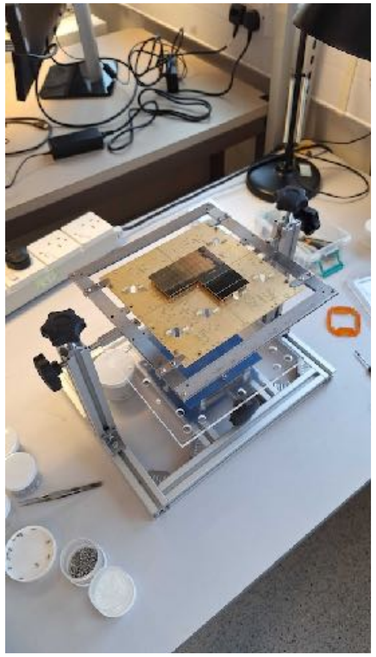
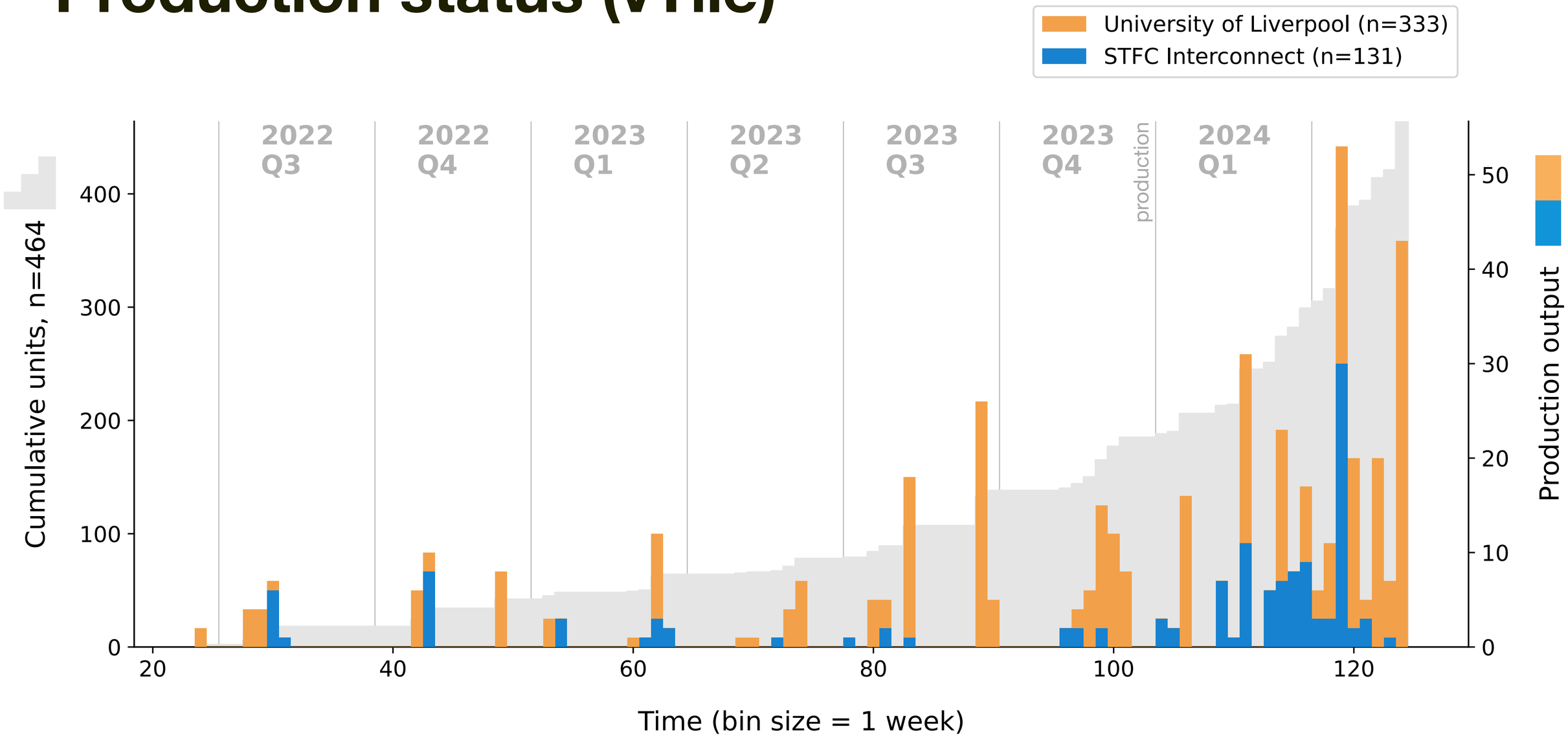


Photo: *DarkSide-20k: vPDU testing*, Alice Hamer, 2024, https://indico.cern.ch/event/1361633/contributions/5919338/

Production status (UK, vTiles)

- Yield loss is observed to occur from:
    - Mechanical failures (during production, test, or vPDU integration)
    - Double breakdown (I-V)
    - High dark current rate exceeding acceptance criteria in cold test
    - Bad SPE shape in cold test (but without double breakdown or high dark current rate)
- vTile yield target > 80%, Liverpool: 82%
    - Last 6 vPDUs 86%

Production status (vTile)



Data from 2024 05 22; “live” data updated every 24 hours: https://hep.lancs.ac.uk/~pfranchini/DarkSide/production.html

Production flow (two-stage vTile assembly)

Indium Corp.
52In48Sn, 118°C

2

130°C for 4 min

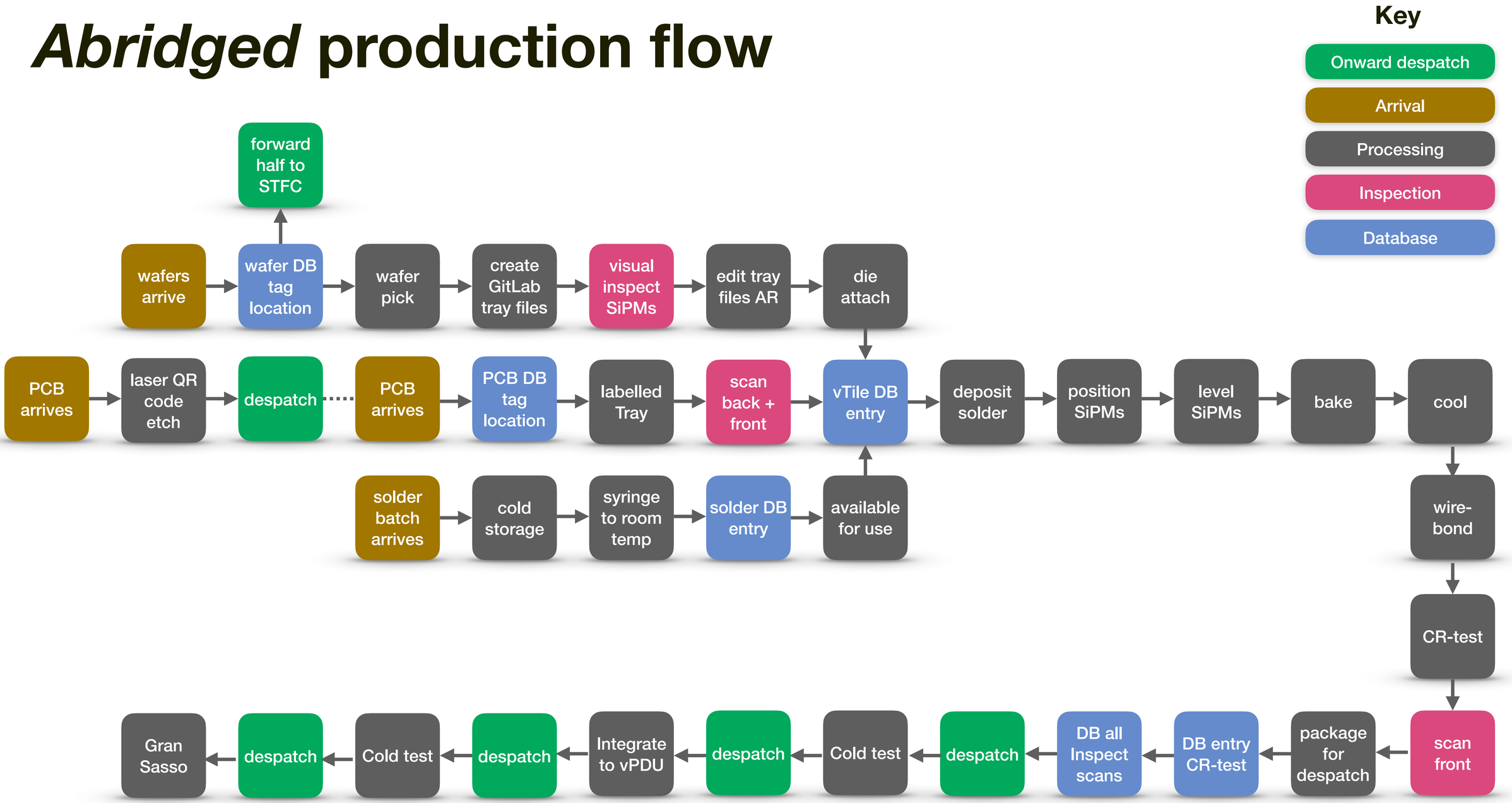
Arlon NT55 PCB

CHIPQUIK
42Sn57.6Bi0.4Ag, 138°C

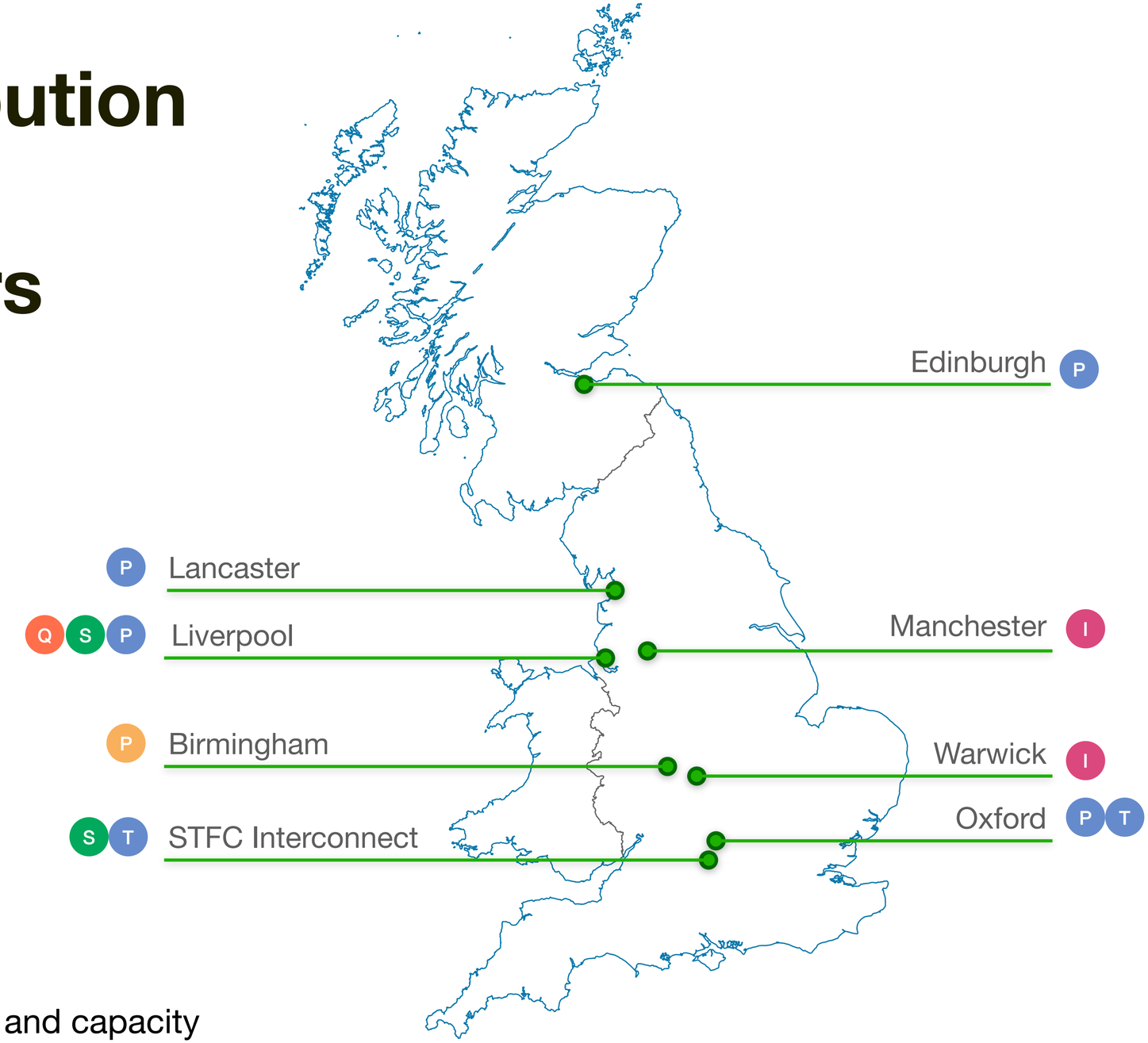
1

150°C for 5 min
200°C for 1 min

Abridged production flow



Geographical distribution of DarkSide-20k UK consortium members

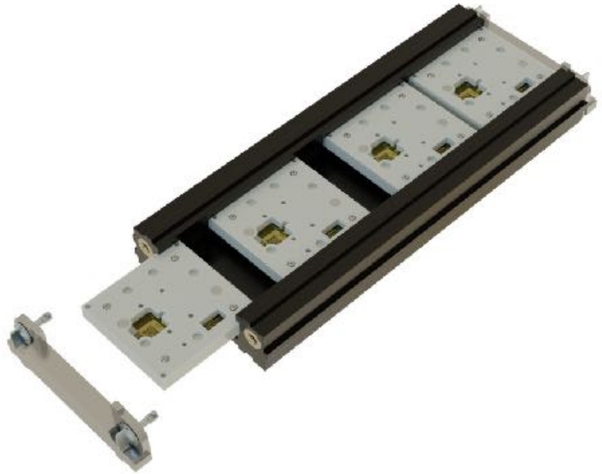


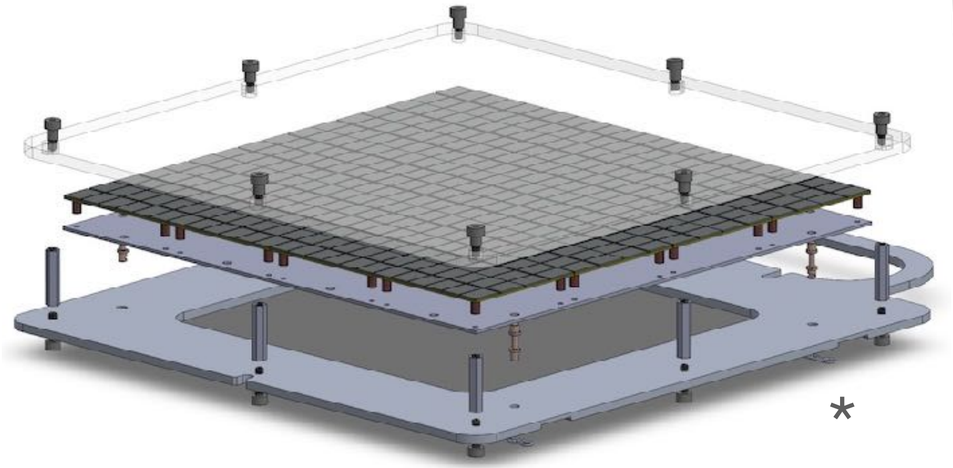
Key

- Q — QR code etching
- P — PCB population
- S — SiPM die attach + wire bonding
- T — vTile cold test
- I — Integration (vPDU) and warm test
- P — vPDU cold test

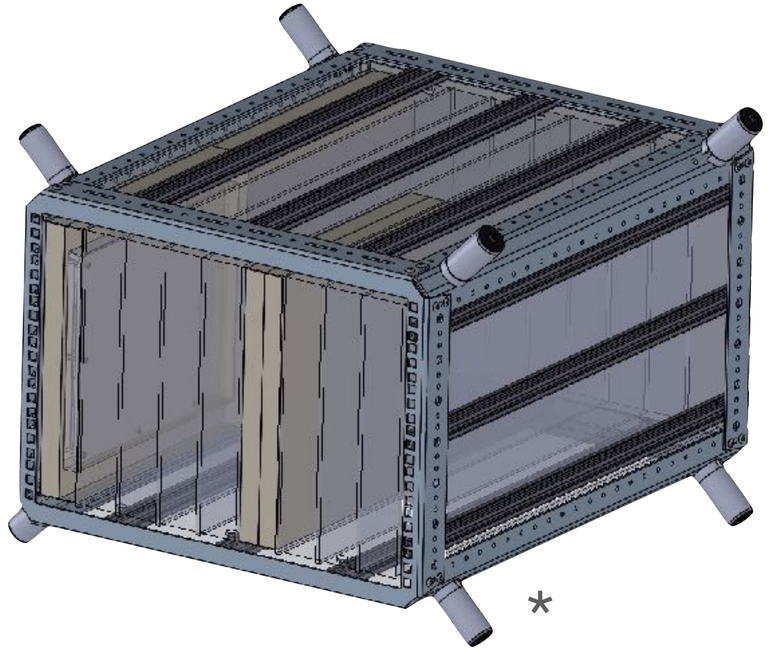
Duplicated capability at various sites: redundancy and capacity

Production flow: shipping





*



*

* https://indico.cern.ch/event/1178135/timetable/#59-shipping-transport, Rob Chapple

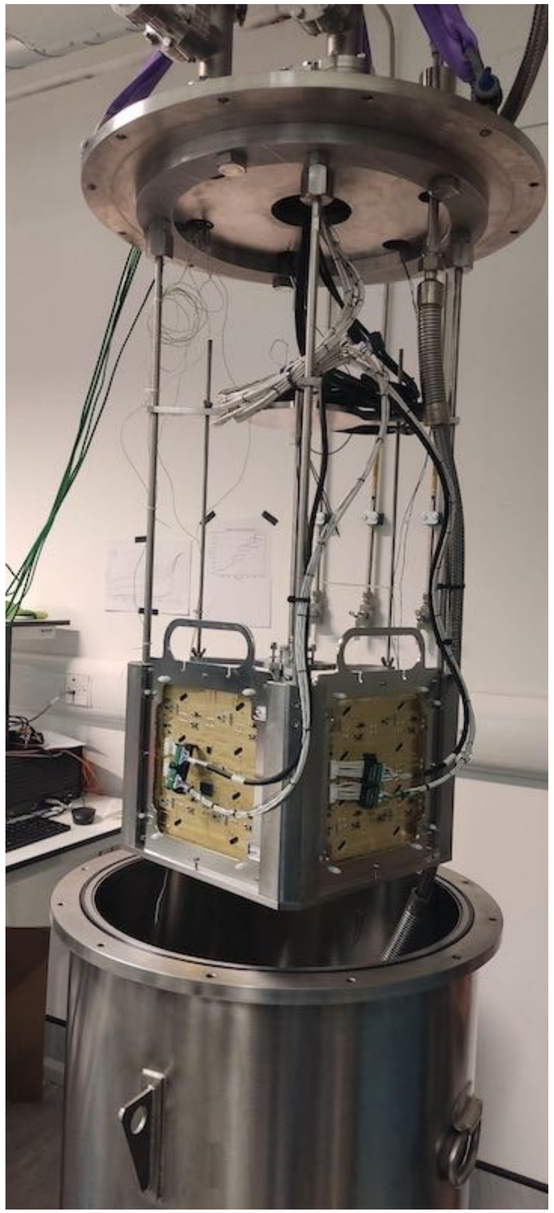
vPDU cold testing sites

- **Duplicated capability for capacity and redundancy (150 vPDUs)**

Site	Capacity
Edinburgh	4
Lancaster	4
Liverpool	16
Oxford	4
Warsaw (AstroCeNT)	5

vPDU cold testing (UK)

- **Existing vPDU tests in LAr performed at Edinburgh [1]**
- **Test time**
  - **1 vPDU : ~2 days**
    - **1 day cool-down, confidence checks**
    - **1 day data taking**
- **Core test racks, electronics, laser light source and data acquisition system and is common across all consortium test sites for reproducibility**



[1] *DarkSide-20k: vPDU testing*, Alice Hamer, 2024
https://indico.cern.ch/event/1361633/contributions/5919338/

vPDU cold testing (UK)

- **RHS: Liverpool PHAIDRA setup: awaiting production volume of vPDUs**
- **Complex flange with numerous feedthroughs**

- **Estimated test time for 16 vPDUs**
  - **~2 week cycle time**
    - **vPDU installation, cool down, test, warm up**
    - **Actual test time once cool: ~2 days**

Photo: Sudikshan Ravinthiran

vPDU cold testing (DAQ)

- VX2745 digitiser board, VME80D4X rack
- 64 channels (3 LV, 1 HV per vPDU)
  - 3x CAEN A2551A (LV)
  - 1x CAEN A1541LP (HV)
- MIDAS-based data acquisition
- A common MIDAS setup is used for final integration tests and the experiment itself

- Acquired data stored in the Grid for analysis

Photo: Sudikshan Ravinthiran

vPDU cold testing (DAQ)

- Liverpool made steering control module for signal routing
  - SPI selection of vPDU functions
  - Multiplexes to multiple vPDUs

- Used across all test sites, and for the final experiment for > 600 TPC PDUs

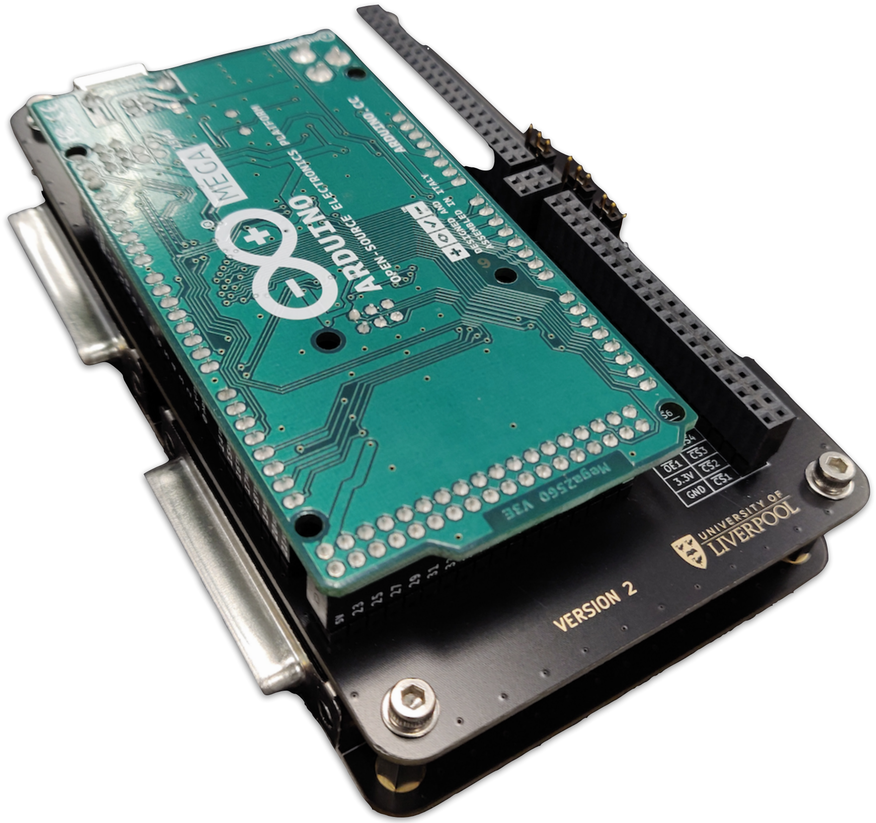


Photo: Sudikshan Ravinthiran

Future

- All of the core parts of the pipeline are in place: tested, operational
- Integration of the Nordson glue robot into the production pipeline
- Production ramp-up about to commence
- Veto production paper being readied for review
- Experiment operational startup estimated for Q4 2026

- Knowledge exchange with our colleagues at LNGS
  - Outreach, UK/Italy collaboration

https://x.com/EdLLewellynFCDO/status/1731740993605554218

Backup slides

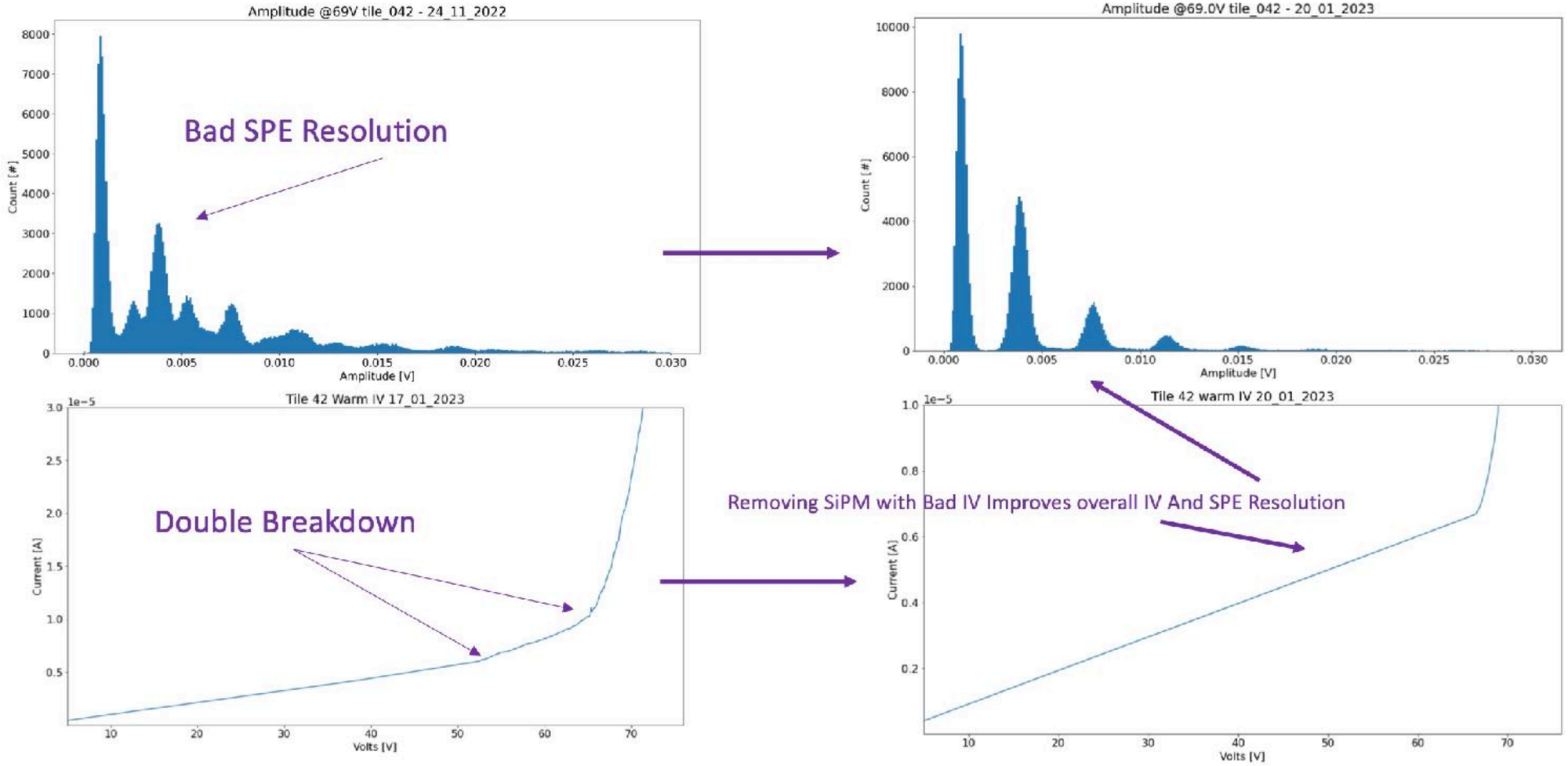
People: Liverpool

- **Research staff/academics:**
- Gianluigi Casse, Tim Jones, Kostas Mavrokoridis, Adam Roberts, Jon Taylor, Joost Vossebeld

- **Technical staff:**
- Maria Cecilia Queiroga Bazetto, Liam Boynton, Heriques Frandini Gatti

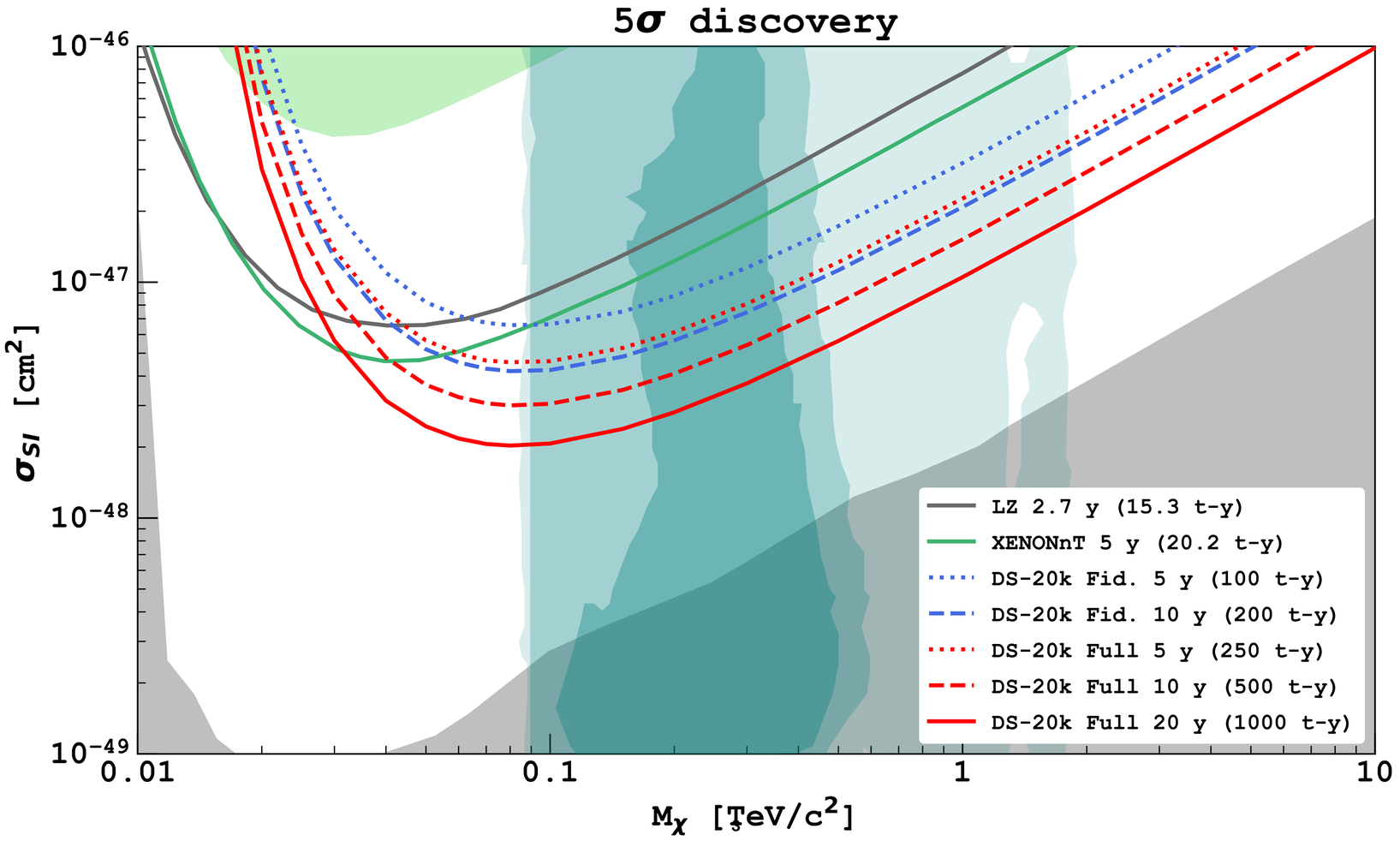
- **PhD students:**
- Sudikshan Ravinthiran, Alan Taylor

vTile double breakdown



Single Tile Cold Testing – Root Cause Analysis, Daria Santone, et. Al. DarkSide-UK collaboration meeting - Birmingham (28-29 March 2023)
https://indico.cern.ch/event/1178135/contributions/5327162/attachments/2620509/4530546/Single%20tile%20Cold%20Testing%20-%20BHAM%20-%2028_03_2023.pdf

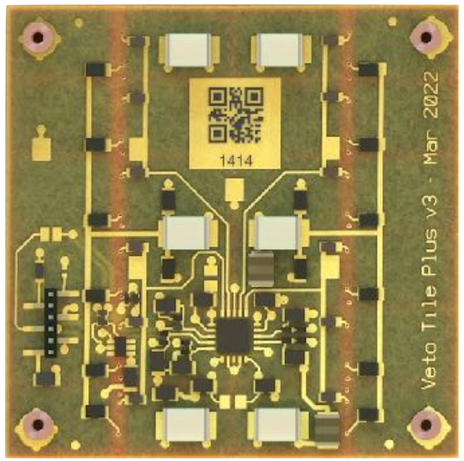
DarkSide-20k sensitivity [1]



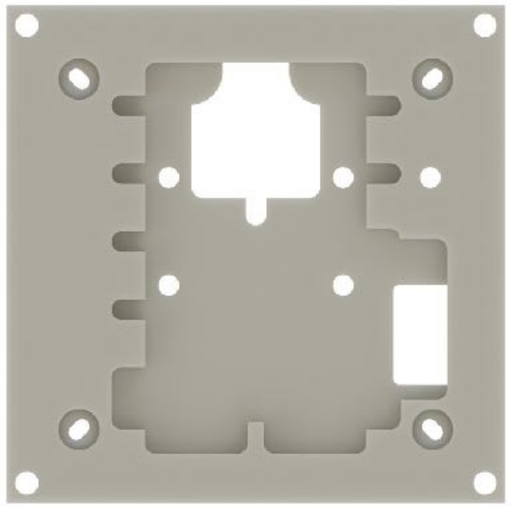
[1] Cristiano Galbiati. Overview of DS-20K: High level overview of DS-20K structure: technical, budget, schedule, management. Darkside TDR Re- view: Forti Committee Meeting. June 27, 2022. url: https://agenda.infn.it/event/31679/contributions/173234/attachments/92596/126642/Galbiati%20LNGS%20Forti%20Committee%20Meeting%20Jun%2026%202022.pdf (requires login)

Production flow: shipping

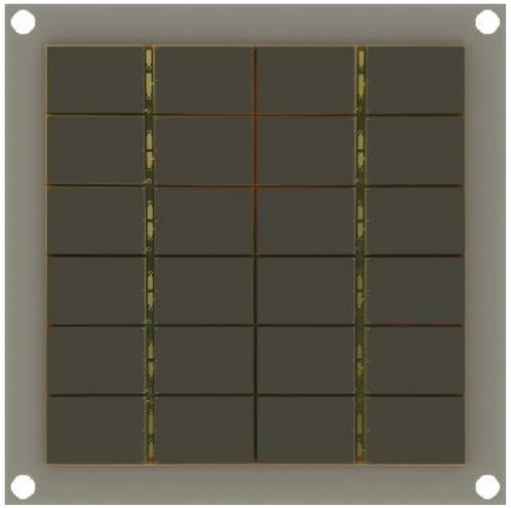
vTile



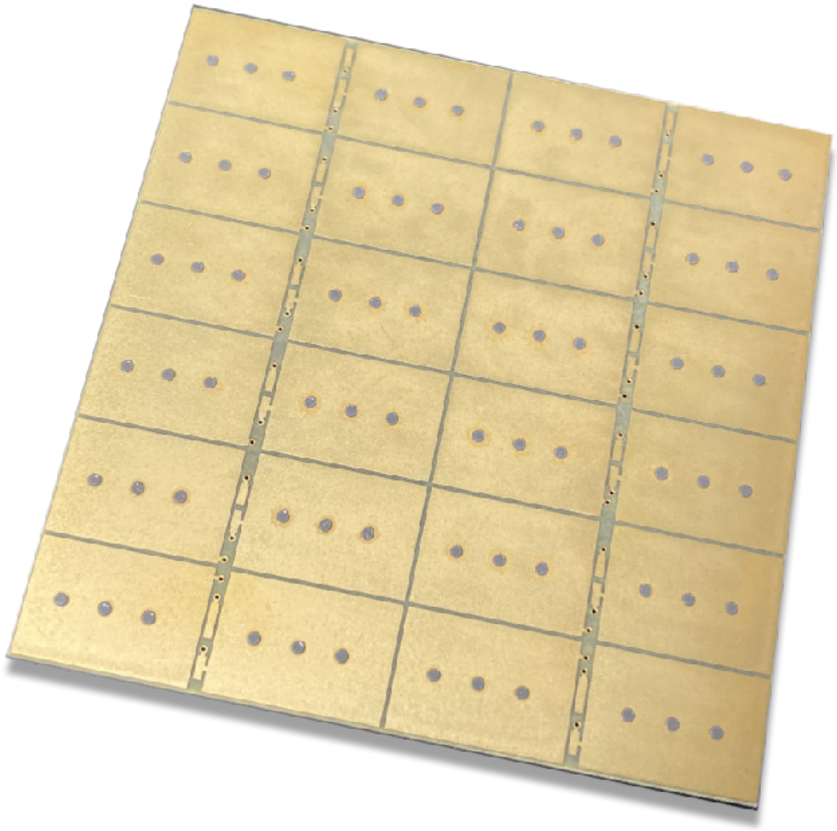
STFC
Process carrier



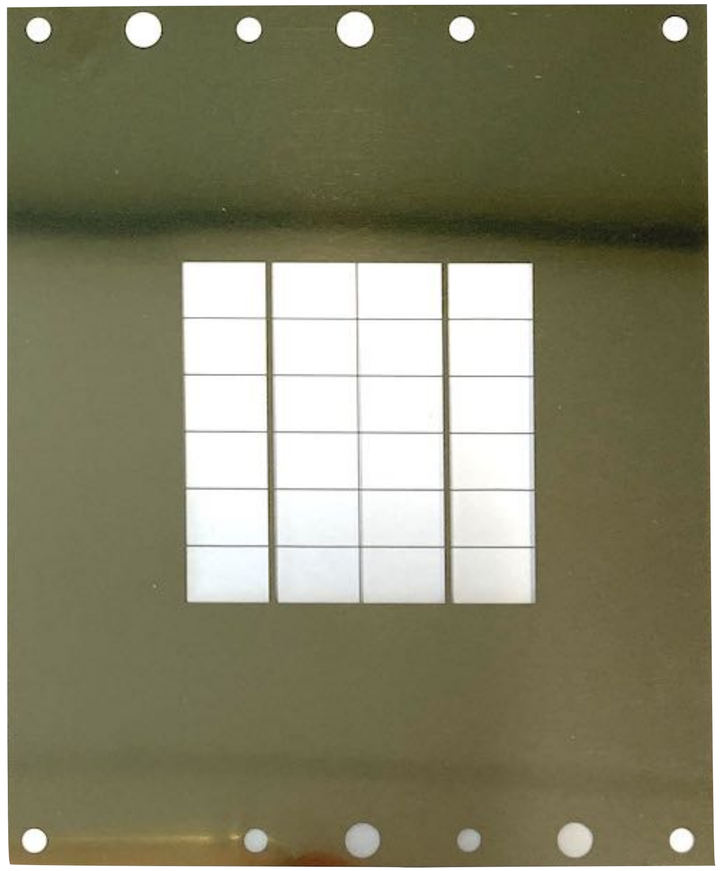
Assembly



vTile PCB

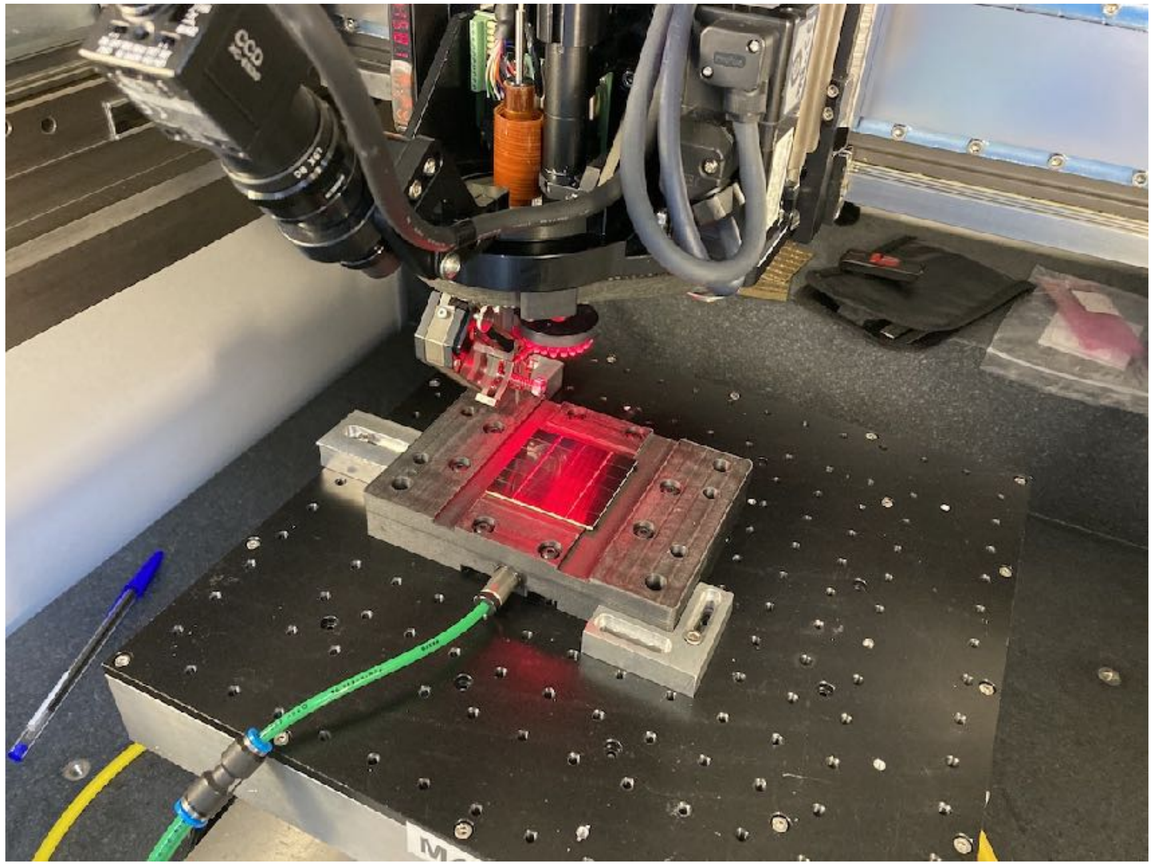


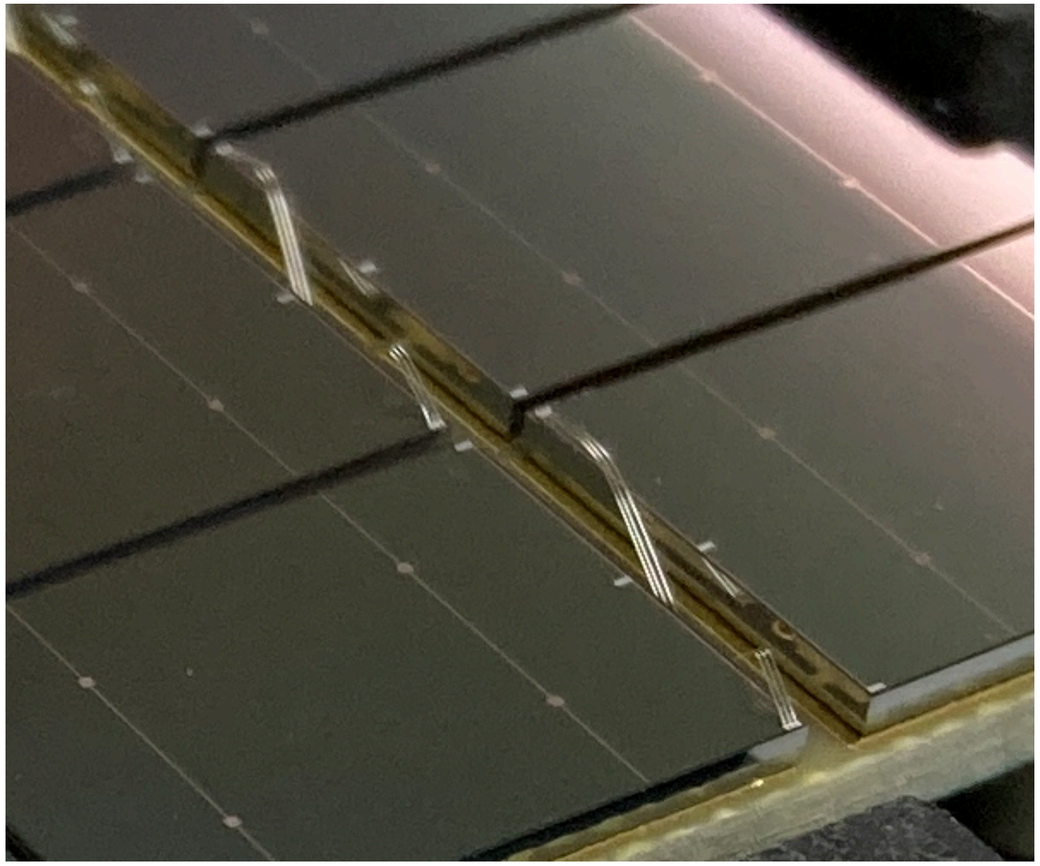
Indium solder paste deposition
(front-side)



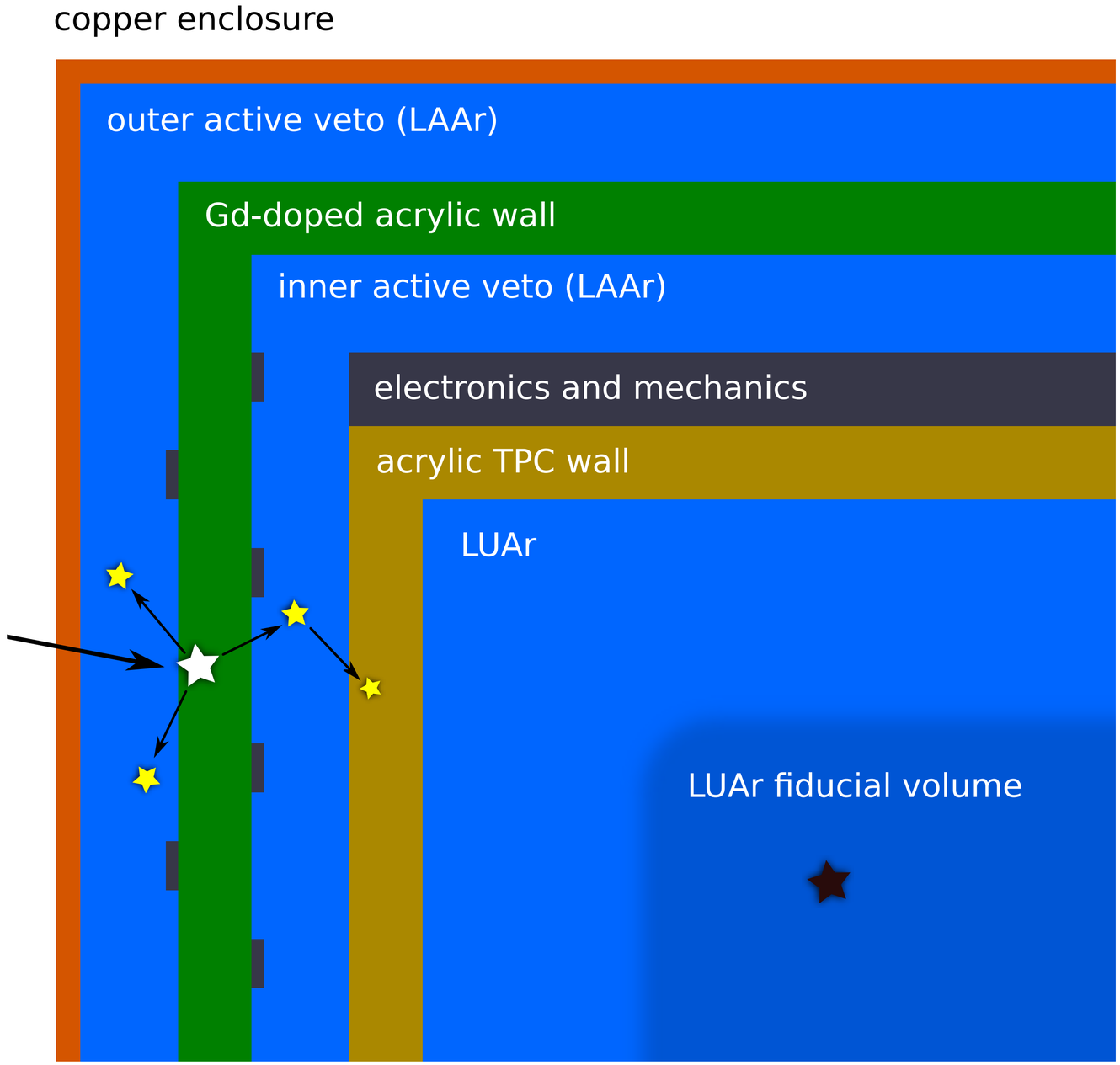
SiPM alignment stencil
(chemically etched)

Wirebonding





Veto schematic



Adapted from Santone, D., https://indico.cern.ch/event/797094/contributions/3367967/attachments/1827415/2991228/ds20k_santone.pdf