

Production of 26 m² of SiPM Detectors for DarkSide-20k

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UNIVERSITY OF
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Edinburgh

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DarkSide-20k



Construction Progress of the DarkSide-20k Dark Matter Search Experiment

10 Apr 2026, 11:45

15m

Prestonfield

Parallel talk

Terrestrial Dark Mat...

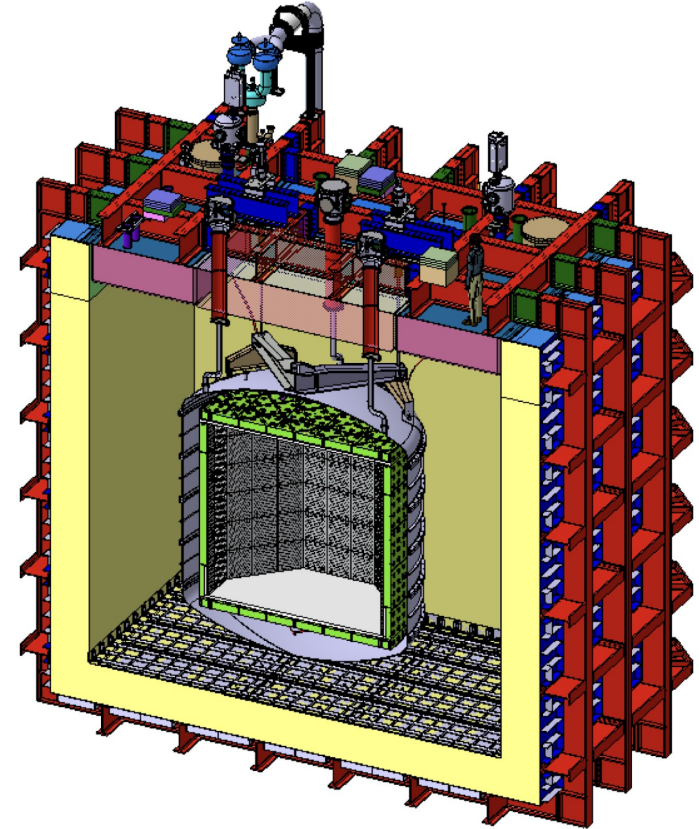
Parallel - dark matter

Speaker

Daria Santone

Description

DarkSide-20k is a global direct dark matter detection experiment in the construction phase at LNGS (in Italy). The core of the detector is a dual-phase Time Projection Chamber (TPC) filled with 50 tonnes of low-radioactivity liquid argon. The entire TPC wall is surrounded by a pure polymethylmethacrylate (PMMA) of 15 cm, which acts as a neutron veto, immersed in a second low-radioactivity liquid argon bath enclosed in a stainless steel vessel. The entire detector is enclosed in a protoDUNE-like cryostat filled with 600 tons of atmospheric argon. DarkSide-20k is designed to deploy several major novel technologies: (i) underground argon at the >100 tonne scale (integrated over the central time projection chamber and inner veto volumes); (ii) large-area cryogenic SiPM array detectors at the scale of 26 m²; and, (iii) a TPC fully formed in acrylic. This talk presents the progress of the overall experiment construction, and its flagship dark matter search sensitivity based on radioassay of the experiment component materials.



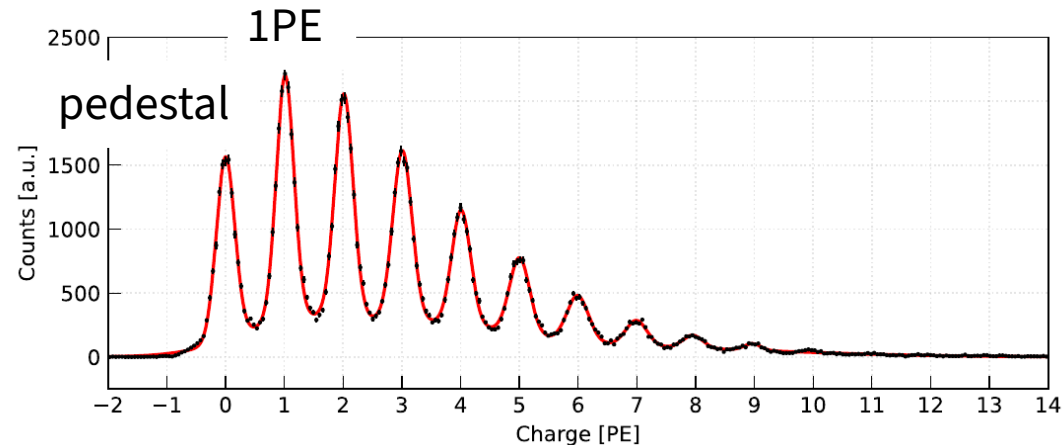
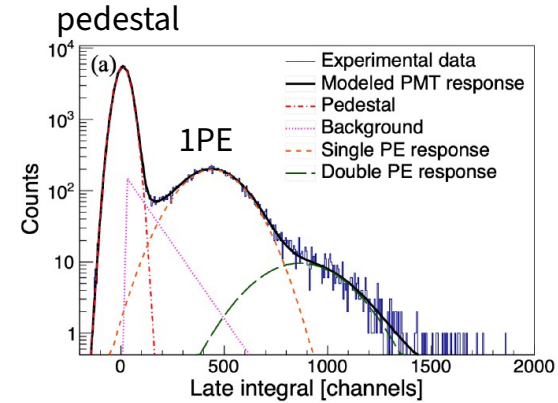
<https://indico.global/event/16271/contributions/147216/>

Silicon Photo Multipliers



- **Move from PMTs to SiPMs**
- **Advantages:**
 - Cryogenic temperature stability
 - *Better single photon resolution*
 - High photo-detection efficiency
 - High active surface area
 - Low voltage operation
 - Low dark count rate
 - Radiopurity
 - Low cost per area
- **Disadvantage:**
 - Small cells size

(e.g. 250,000 SiPMs to build DS-20k)



Photoelectronics in DarkSide-20k

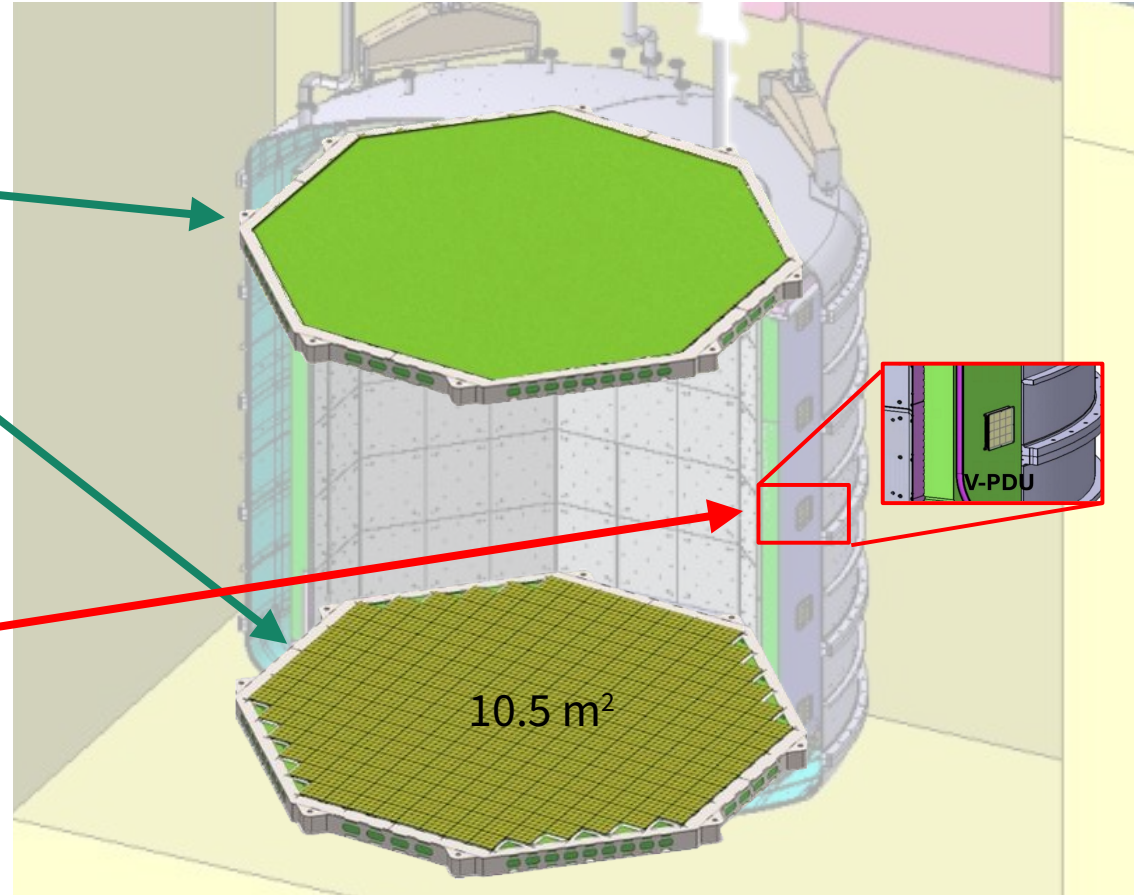


- **TPC (50t UAr)**

- two optical planes
- 21 m² in total
- full coverage of SiPMs
- 528 PDUs: 2112 channels

- **Veto (35t UAr + 650t AAr)**

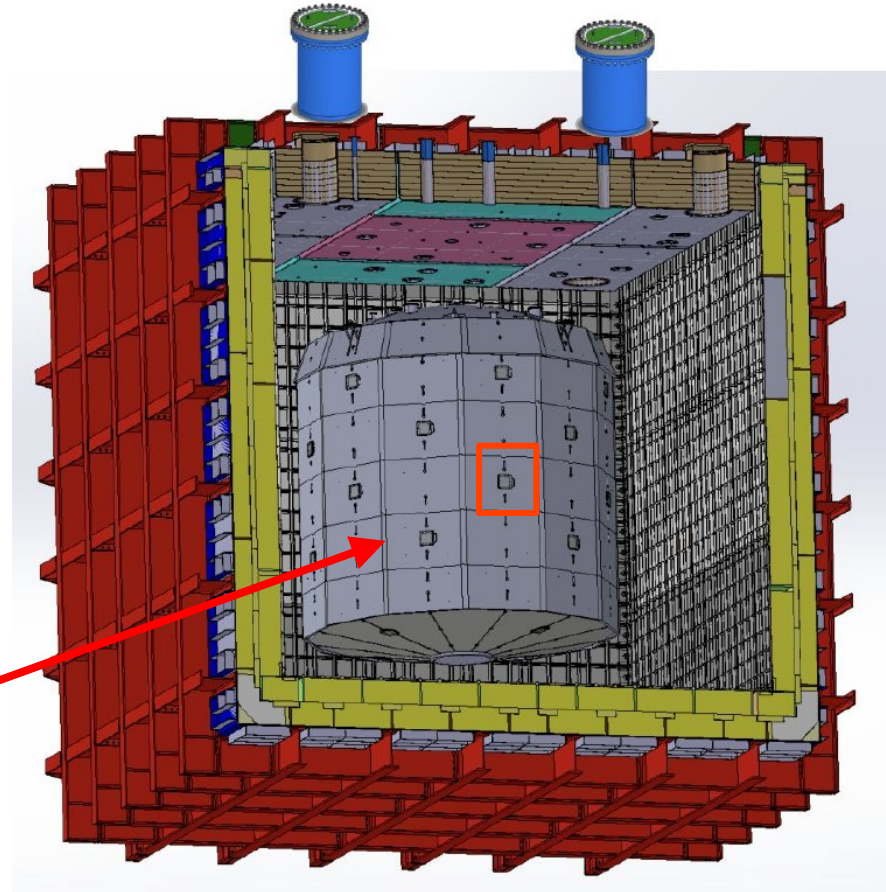
- inner veto: 120 vPDUs, 480 channels
- outer veto: 32 vPDUs, 128 channels



Photoelectronics in DarkSide-20k

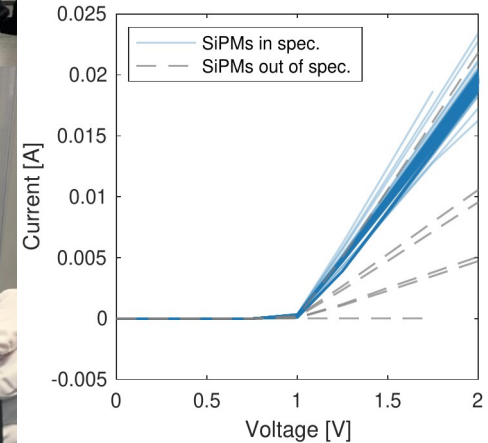
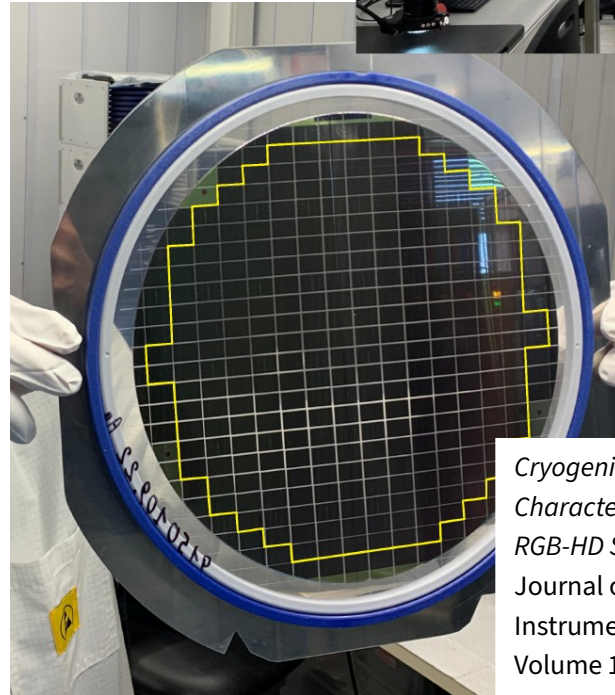


- TPC (50t UAr)
 - two optical planes
 - 21 m² in total
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SiPMs

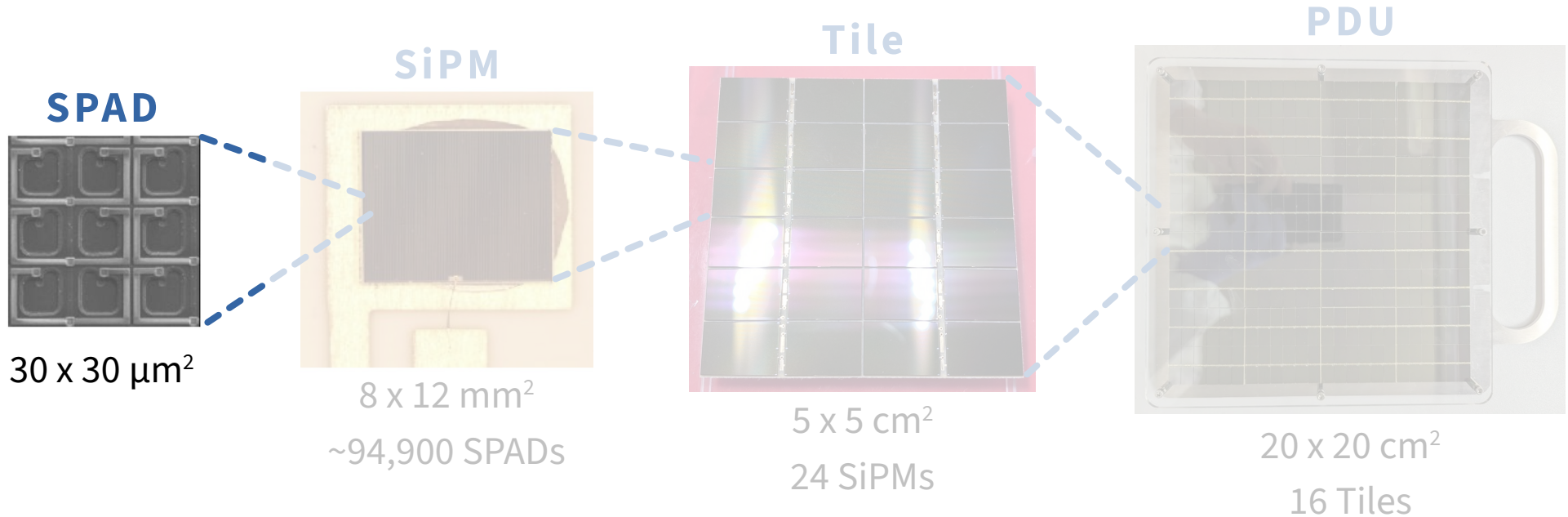
- All **1400 wafers** cryoprobed and fully characterised in NOA (Assergi, Italy)
- 264 accessible SiPMs/wafer
- Common criteria to ensure low variability of the SiPMs populating the vTiles
- ~10% rejected → create a map for future integration



*Cryogenic
Characterization of FBK
RGB-HD SiPMs
Journal of
Instrumentation,
Volume 12, September
2017*

*Quality assurance and
quality control of the
SiPM production
for the DarkSide-20k
dark matter experiment
Eur. Phys. J. C 85, 534,
2025*

Photo Detector Units



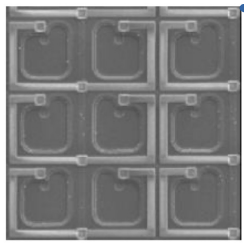
Single Photon Avalanche Diode

- Semiconductor devices based on a p-n junction
- Reverse biased well above breakdown voltage
- Minimal “pixel” operating in Geiger mode

Photo Detector Units

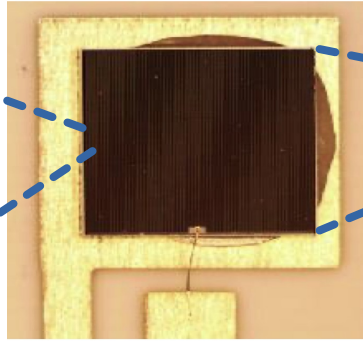


SPAD



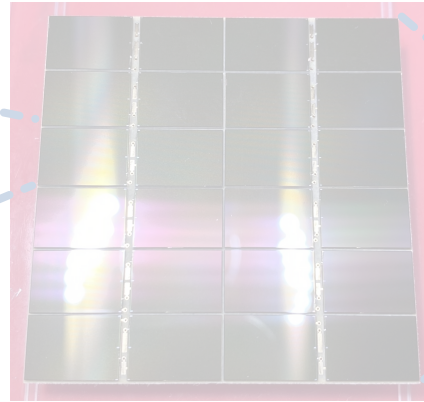
$30 \times 30 \mu\text{m}^2$

SiPM



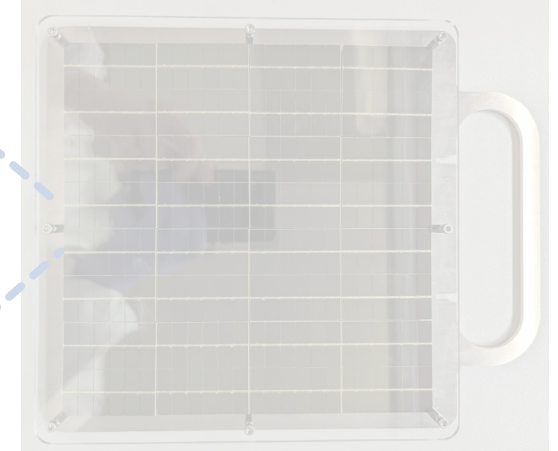
$8 \times 12 \text{ mm}^2$
~94,900 SPADs

Tile



$5 \times 5 \text{ cm}^2$
24 SiPMs

PDU

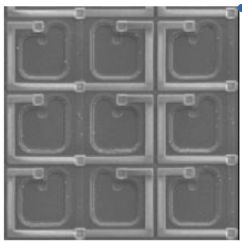


$20 \times 20 \text{ cm}^2$
16 Tiles

Photo Detector Units

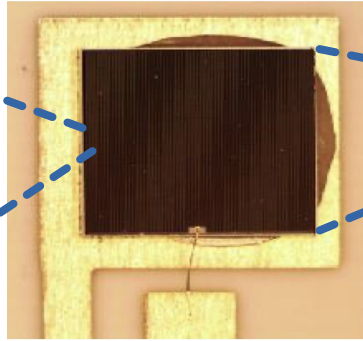


SPAD



$30 \times 30 \mu\text{m}^2$

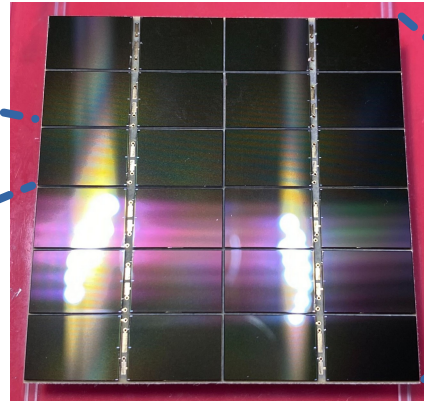
SiPM



$8 \times 12 \text{ mm}^2$

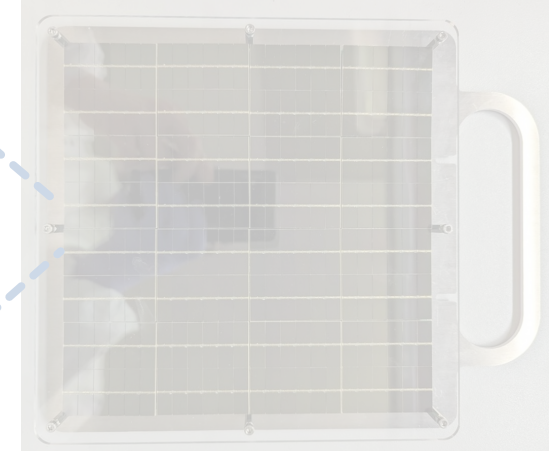
~94,900 SPADs

Tile



$5 \times 5 \text{ cm}^2$

PDU



$20 \times 20 \text{ cm}^2$

16 Tiles

Tile

- 24 SiPM signals summed
- Backside: front end readout amplification developed by the DS-20k collaboration

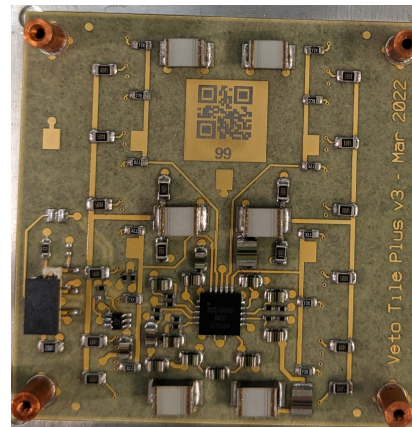


Photo Detector Units

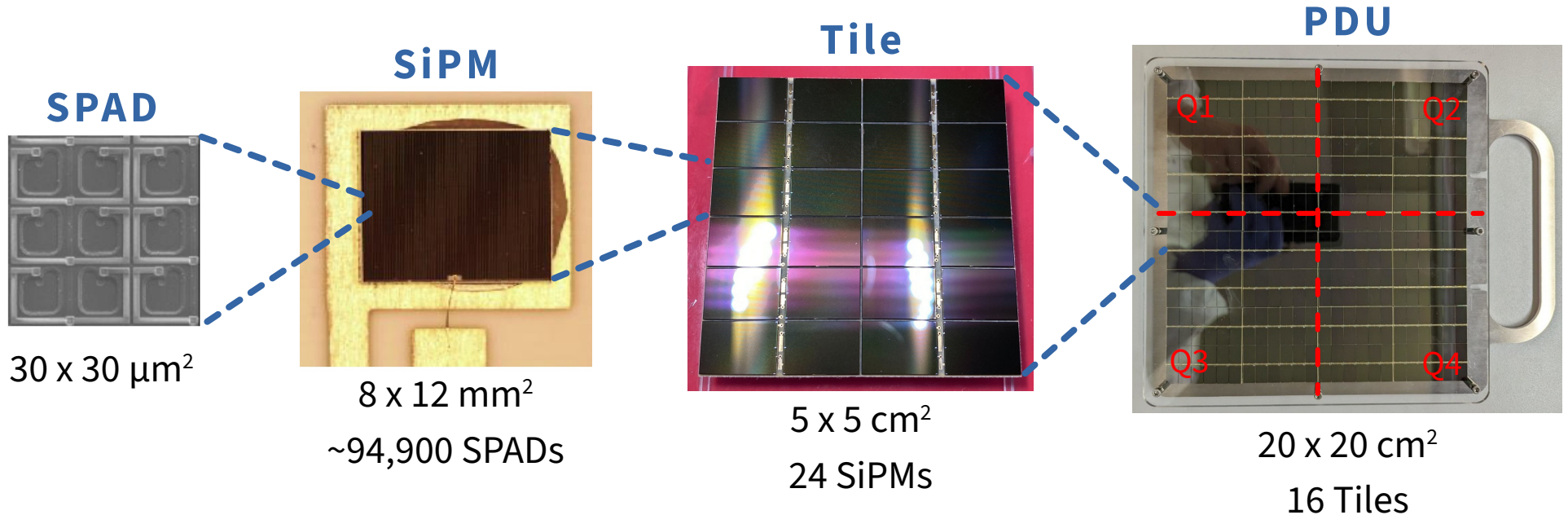
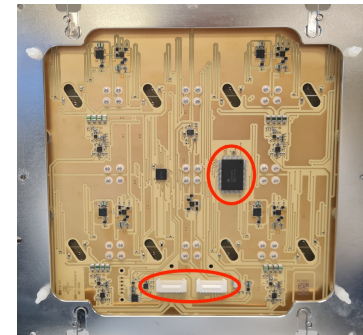


Photo Detector Unit

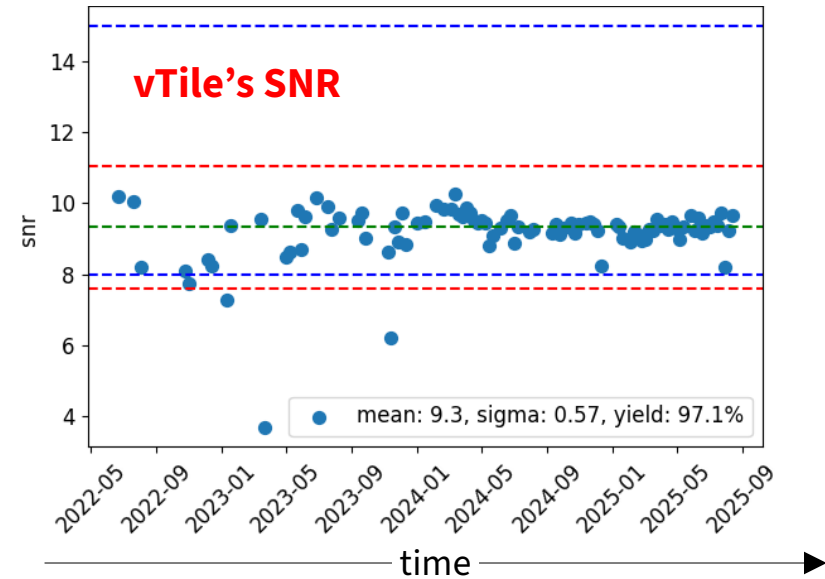
- Backside: Single Motherboard PCB
- Single Tile bias and amplification
- **4 Quadrants**: 4 channels summing 4 Tiles



Quality Assessment and Control



- Baseline analysis from all the test stands, e.g.
 - Breakdown, Signal-to-noise Ratio (SNR), RMS, Dark Counts
- Assess the full production chain over time
 - maintain good production yield
 - spot production problems at an early stage
 - keep radioactivity contamination low
- Assign quality grades
 - uniform detector
 - single photo-electron resolution
- Identify tiles replacements and reworking of components



Veto PDU production: UK

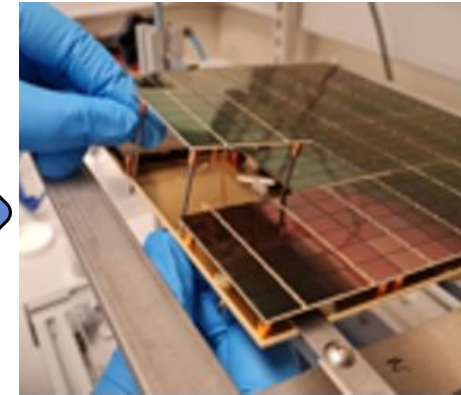
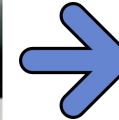
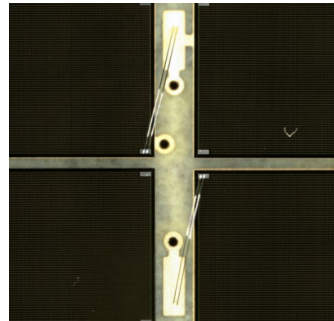
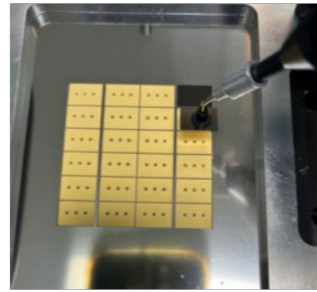
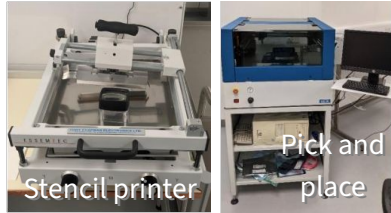
“Construction and characterisation of the DarkSide-20k veto silicon photo-multiplier tiles”
Submitted to EPJ-C
[arXiv:2604.02551](https://arxiv.org/abs/2604.02551)

PCB population
in Birmingham

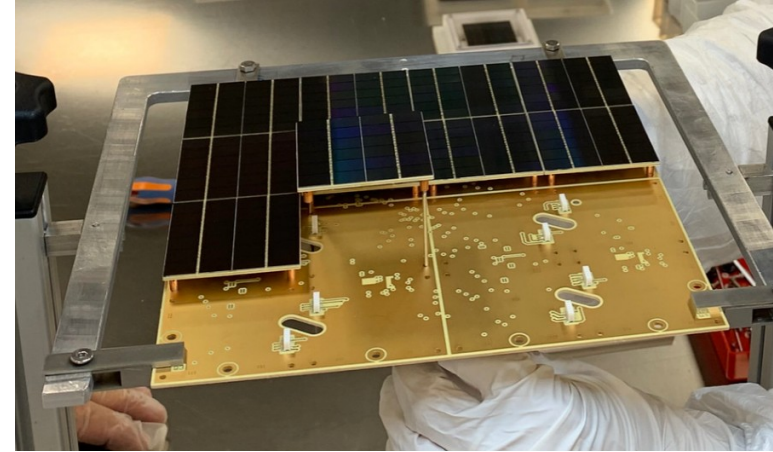
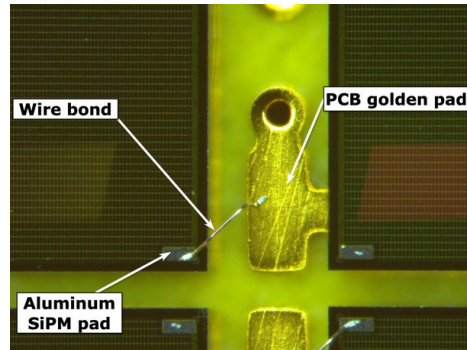
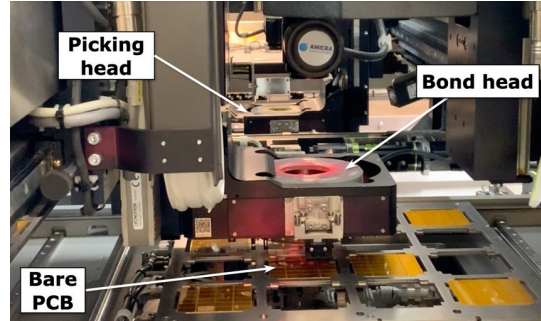
SiPM die attach and wire
bonding in Liverpool
and STFC Interconnect

vTile testing in RHUL,
Oxford and STFC
Interconnect

vPDU assembly in
Manchester and Warwick



TPC PDU production: NOA

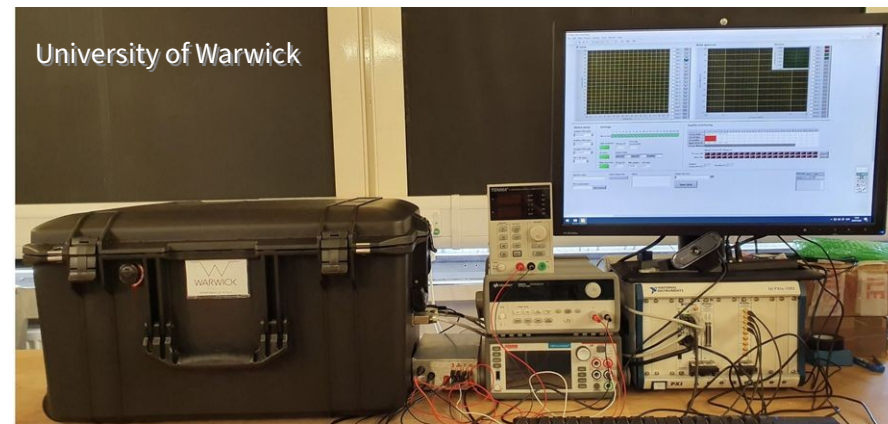
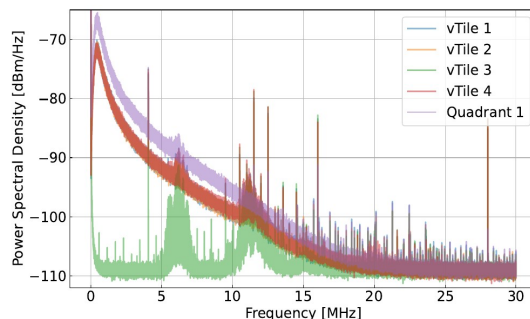
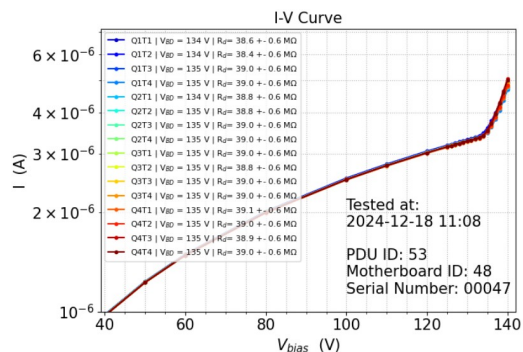
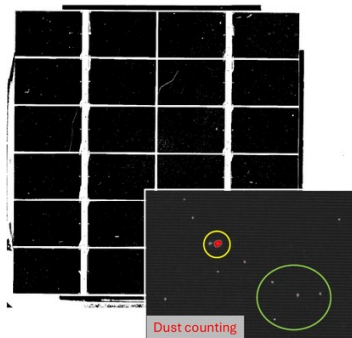


*“Production, Quality Assurance and Quality Control of the SiPM Tiles for the DarkSide-20k Time Projection Chamber”
Eur. Phys. J. C 85, 1334 (2025)*

Preliminary tests “at warm”



- Performed on each (v)PDU quadrant/tile
- Visual inspection and dust count
- IV curves
- Noise FFTs



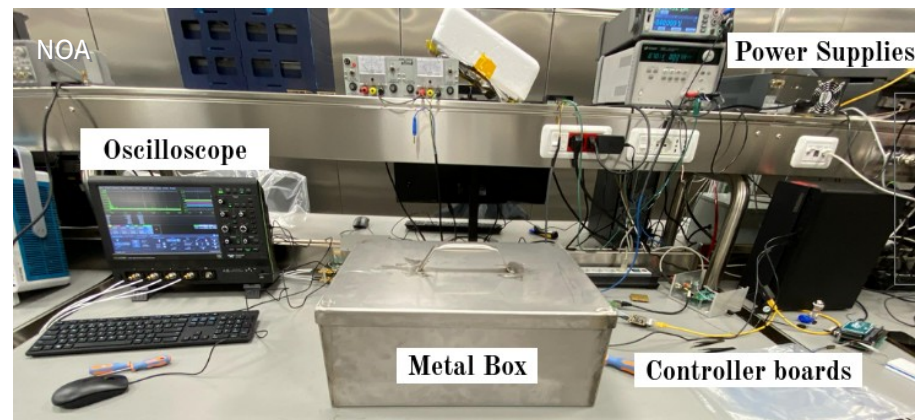
University of Warwick

Dark enclosure

Adapter box

Power supplies

PXI crate / Digitiser



NOA

Power Supplies

Oscilloscope

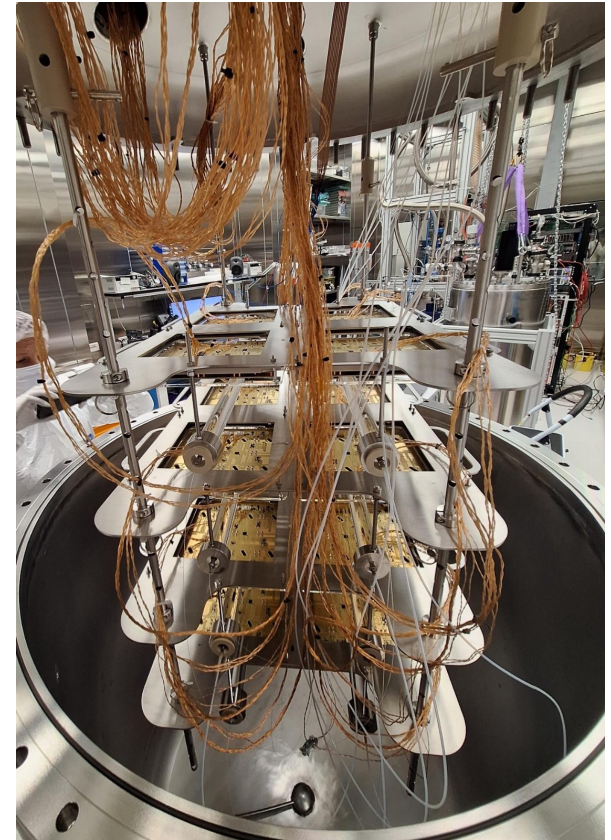
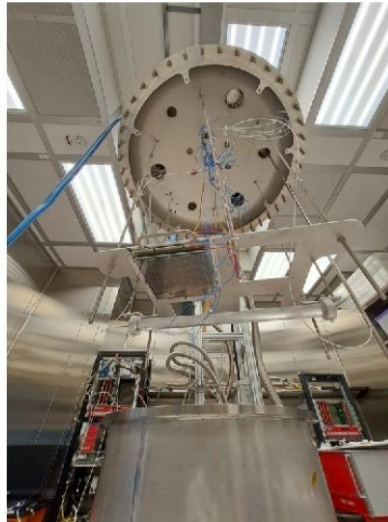
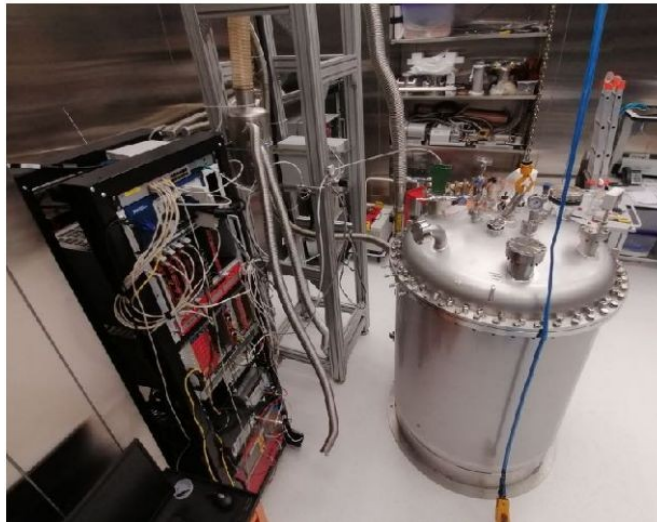
Metal Box

Controller boards

Cryogenic testing for PDUs



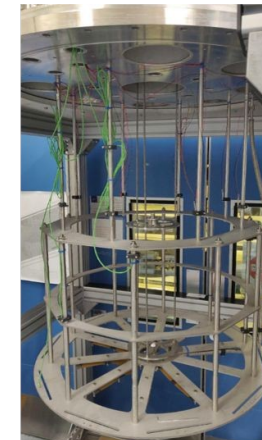
- PDU Testing Facility in INFN-Napoli (Italy)
- 16 PDUs capacity
- 2 CAEN VX2740 digitisers



Cryogenic testing for vPDUs



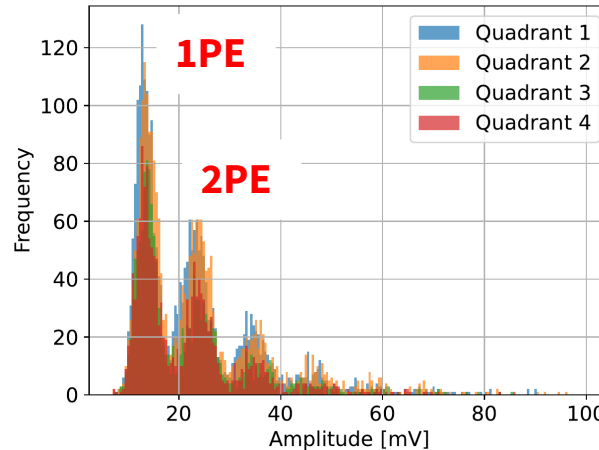
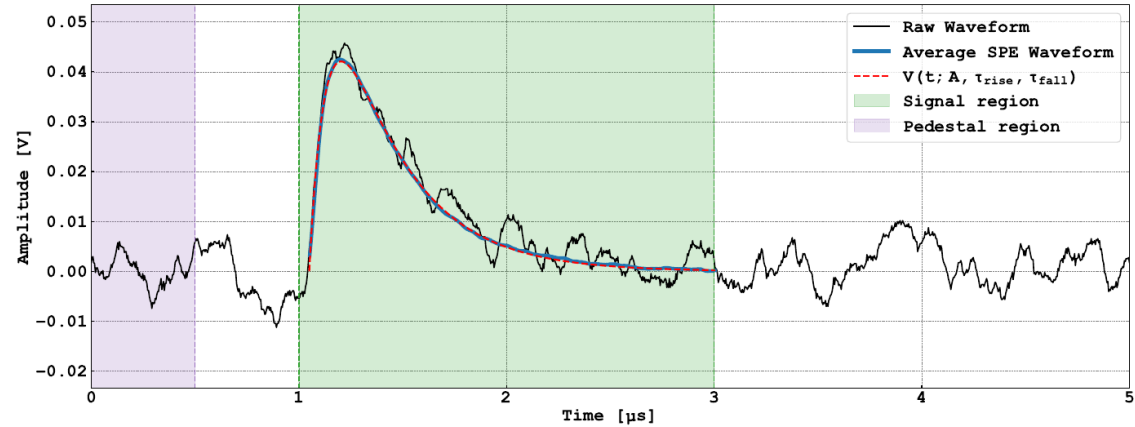
- Test facilities: Edinburgh, Liverpool and AstroCeNT (Poland)
- 30 vPDUs capacity in total
- Equivalent testing setups (PSUs, digitisers, DAQ)
- Tests in liquid nitrogen and argon



Laser calibration “at cold”

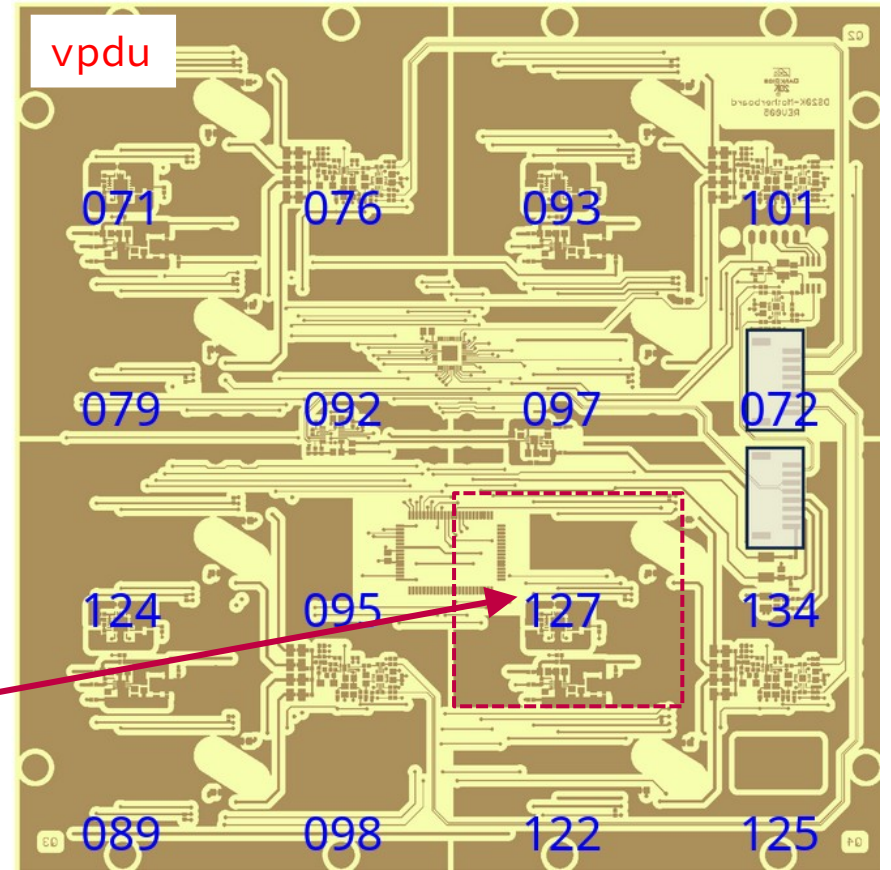
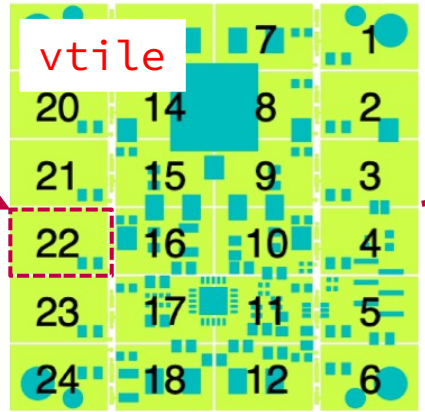
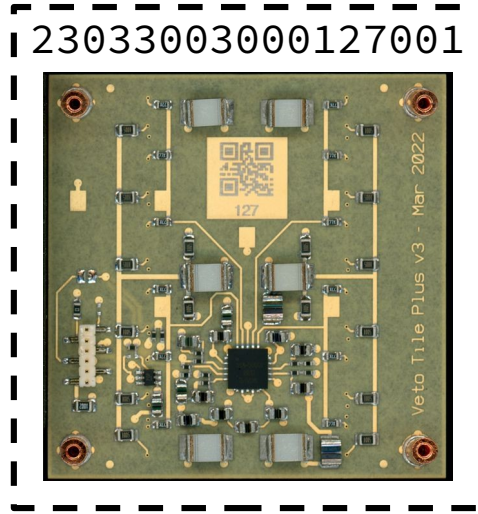
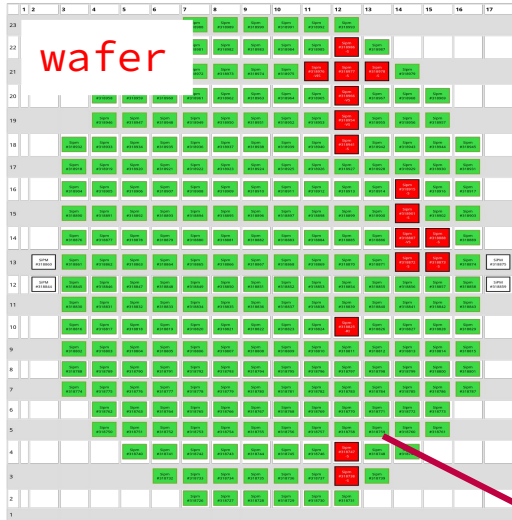


- Liquid nitrogen characterisations on
 - single tiles
 - integrated tiles
 - full quadrants
- Injected laser light
- Waveforms → peakfinder
- Baseline RMS
- Finger plots



1 PE ~ 14 mV
TPC: SNR > 6
Veto: SNR > 4

Production Database



Conclusions and Outlook



- **Veto PDU production:** 100% completed ✓ - 100% tested ✓ - **vPDU Yield 95%**
- **TPC PDU production:** 50% completed 🚀 - 30% tested 🚀 - **vTile Yield 88%**
- **Photoelectronics to be completed in 2026 and integrated in Q1 of 2027**

Thanks! Questions?

