

DarkSide-20k

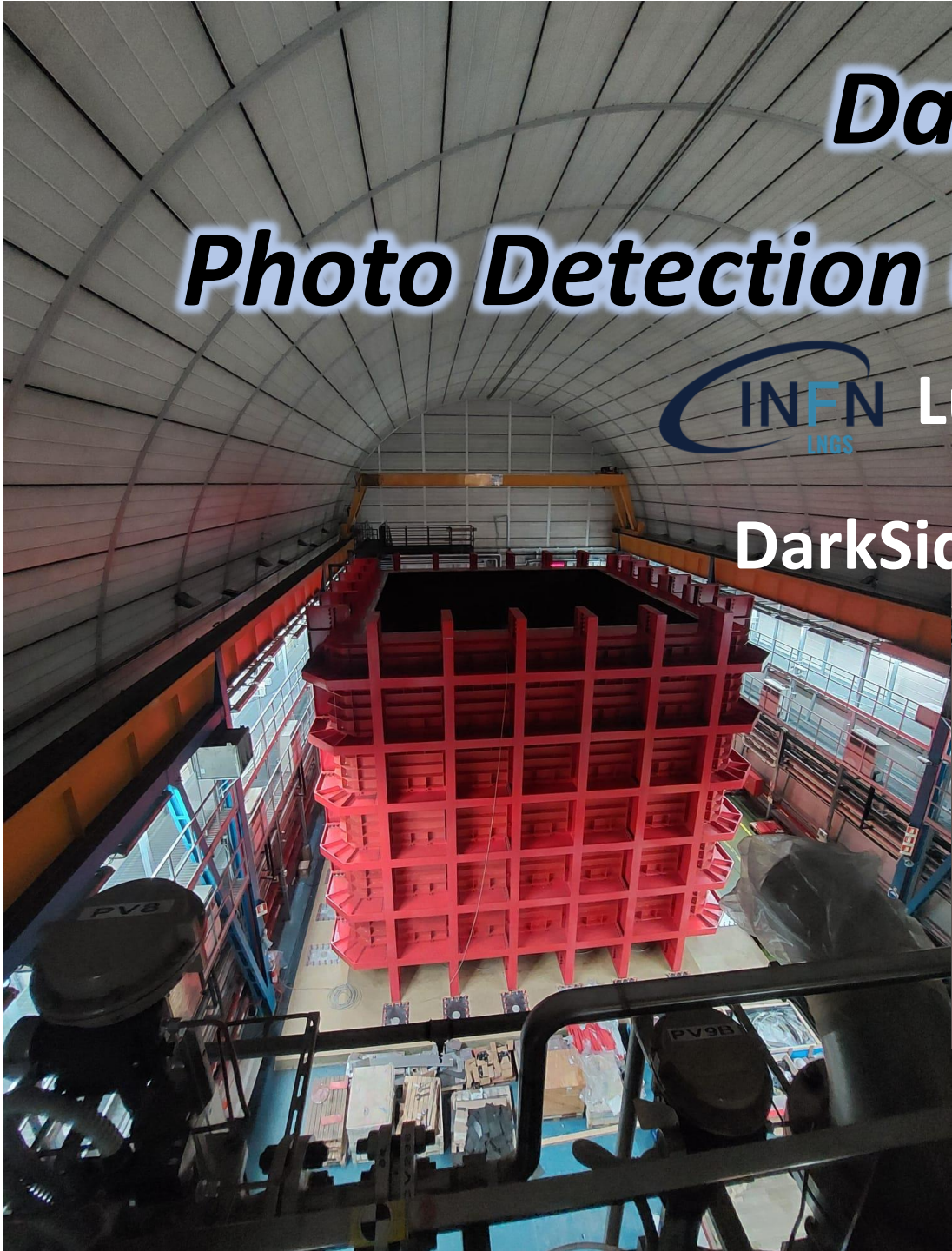
Photo Detection Unit production in NOA



Lucia Consiglio

On behalf of

DarkSide-20k collaboration



Outline



- ❖ DarkSide program
- ❖ DarkSide-20k detector overview
- ❖ SiPM photo-detection technology
- ❖ Photo Detection Unit (PDU) design
- ❖ NOA facility for the PDU assembly
- ❖ PDU production

Global Argon Dark Matter Collaboration

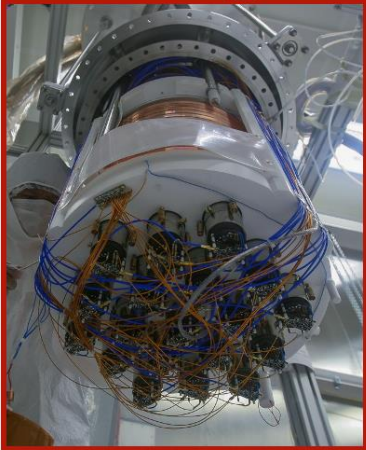


Over 400 researchers from > 100 institutions involving 14 countries searching dark matter down to neutrino floor and beyond with extremely low instrumental background with LAr technology

Current experiments

LAr mass: 46 kg

DarkSide-50 @LNGS



LAr mass 850 kg

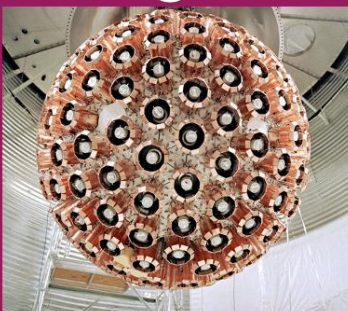
ArDM @Canfranc



MiniClean @Snolab



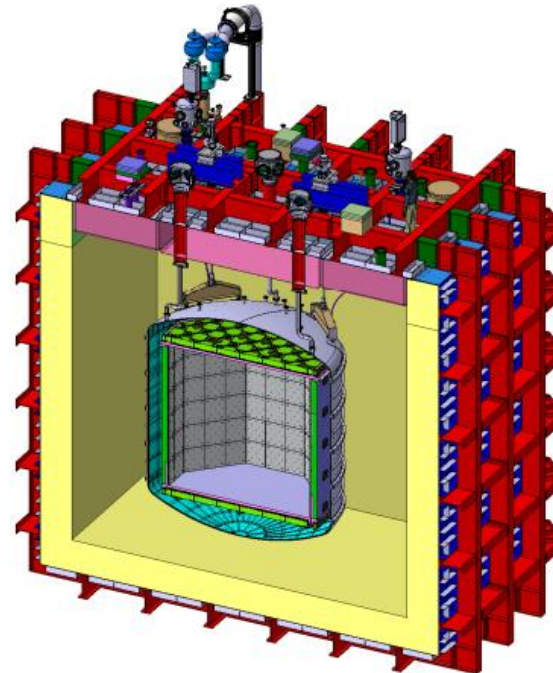
DEAP @Snolab



LAr mass 500 kg

LAr mass 3300 kg

Present and future experiments



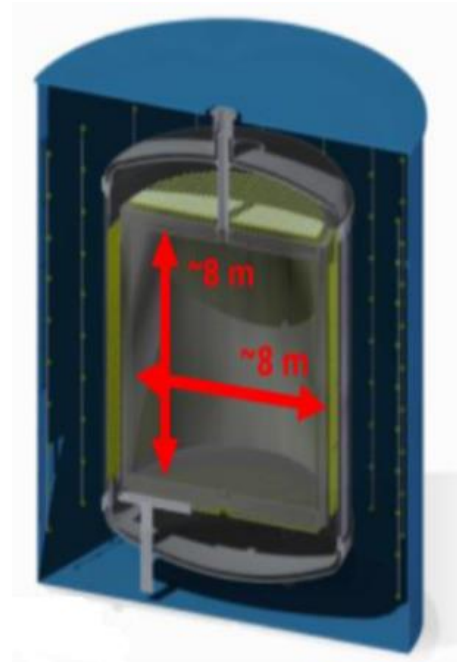
DARKSIDE-20k@LNGS

UAr mass 49.7 t (20 t fiducial)

200 t y total exposure

2026-2036

L.Consiglio, TREDI 2024, Torino 20-22 Feb.



ARGO@SNOLAB

UAr mass 400 t (300 t fiducial)

3000 t y total exposure

2030s -

DarkSide-20k detector concept



Dual-phase liquid argon Time Projection Chamber (TPC)

Light/Charge detection for Particle ID

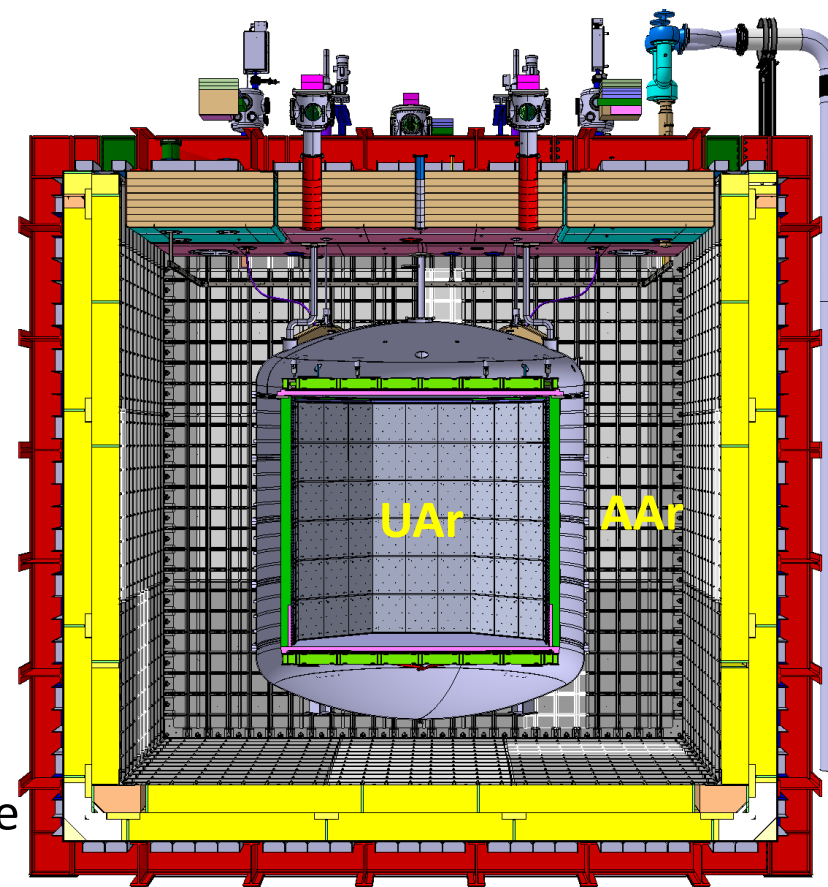
Target: < 0.1 instrumental background events in 200 t*yr exposure

Strategy:

- 1) low radioactive Underground Argon (UAr) depleted of ^{39}Ar
- 2) Large arrays of customized cryogenic photosensors (R&D since 2014)
- 3) Material screening for radiopurity qualification (sub mBq/kg)

Nested detector structure

- Octagonal TPC coupled with an Inner Veto (Inner Detector) within SS vessel filled with UAr
- Inner Detector panels Gd-loaded PMMA for n moderation and capture
- Plastic shielding around SS vessel (moderation of n from cryostat insulation)
- Outer muon veto
- DUNE-like membrane cryostat filled with AAr



Optical readout based on Silicon PhotoMultipliers (SiPMs)

DarkSide-20k apparatus installation



1400 m underground at the Gran Sasso National Laboratories (LNGS) ~ 3400 m.w.e.

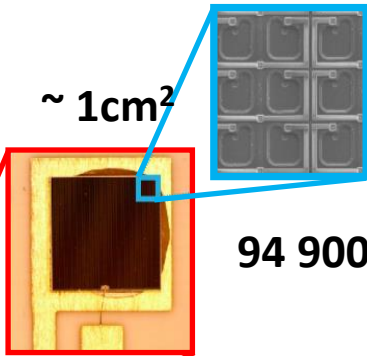
LNGS site



Light detection with SiPM technology



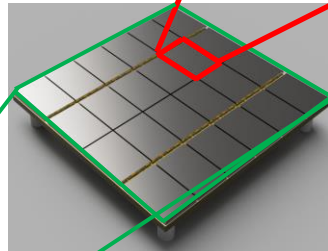
- Large area cryogenic SiPMs (NUV-HD-CRYO by FBK)
- Low noise cryogenic electronics
- Technological transfer for photosensor massive production (LFoundry)



SPAD: single photon avalanche diode 30 μm pitch

94 900 SPADs

Tile: 24 SiPM array integrated with signal preamplifier
Photo Detection Module (PDM)

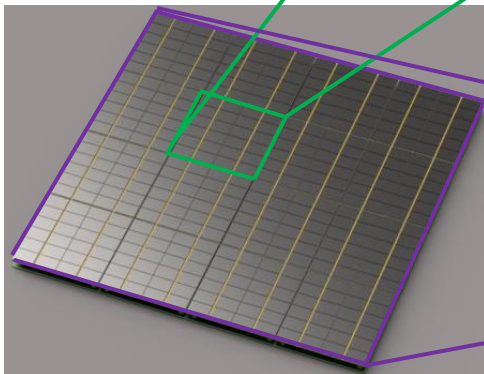


5 x 5 cm^2

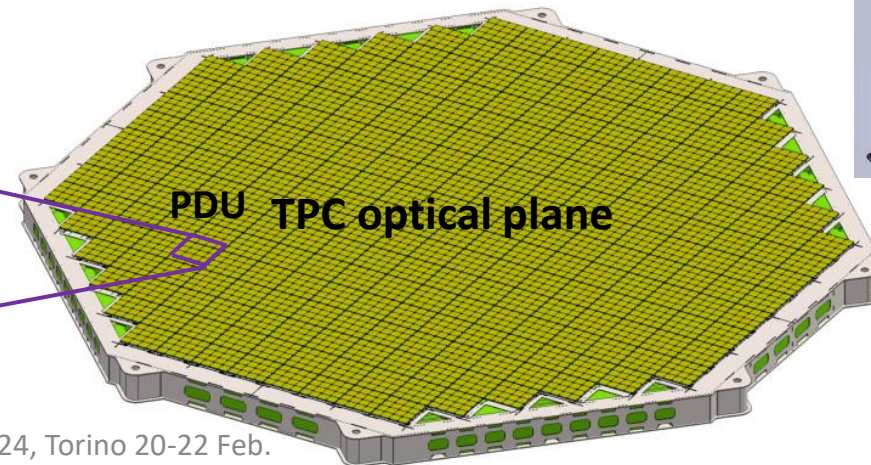
TPC Top and bottom optical planes: 528 PDUs
Inner Veto: 120 V-PDUs
Outer Veto: 32 V-PDUs
Total SiPM area 26 m^2

Photo Detection Unit (PDU)

16 tiles -> 4 readout channels
(10 x 10 cm^2)



20 x 20 cm^2



PDU TPC optical plane

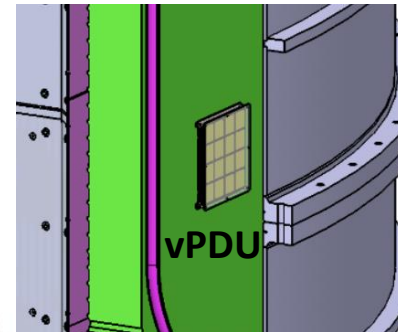
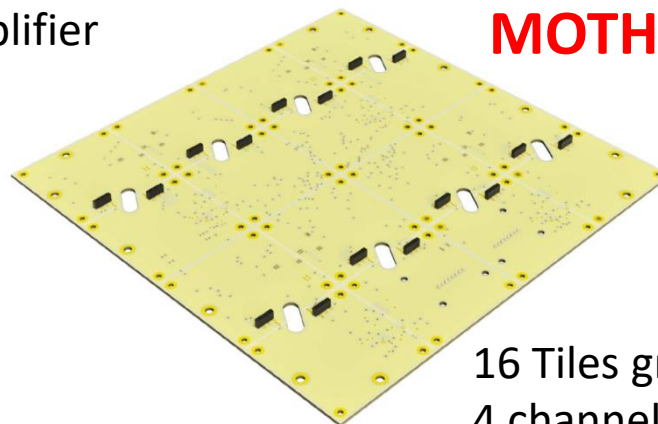
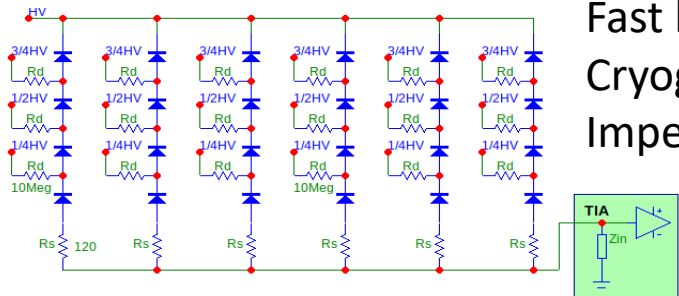


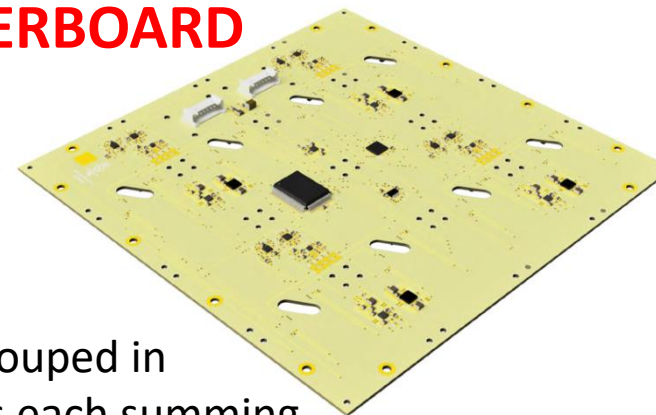
Photo Detection Unit



Fast low noise
Cryogenic Trans
Impedance Amplifier

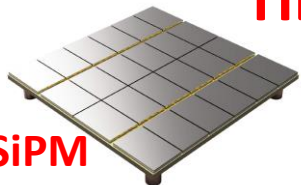


MOTHERBOARD

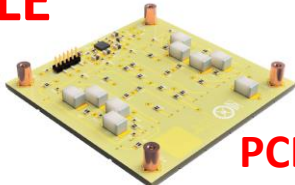


16 Tiles grouped in
4 channels each summing
4 tiles into a differential output
Power distribution HV and LV remotely controlled.

TILE

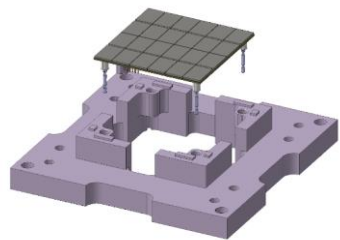


24 SiPM

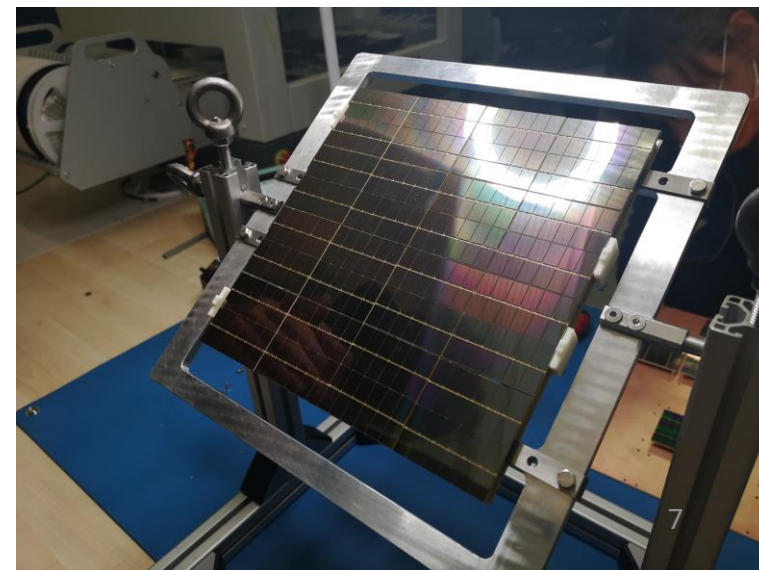


PCB + FE

PDU



20 cm x 20 cm
Power consumption@77K: 2W



NOA: Nuova Officina Assergi

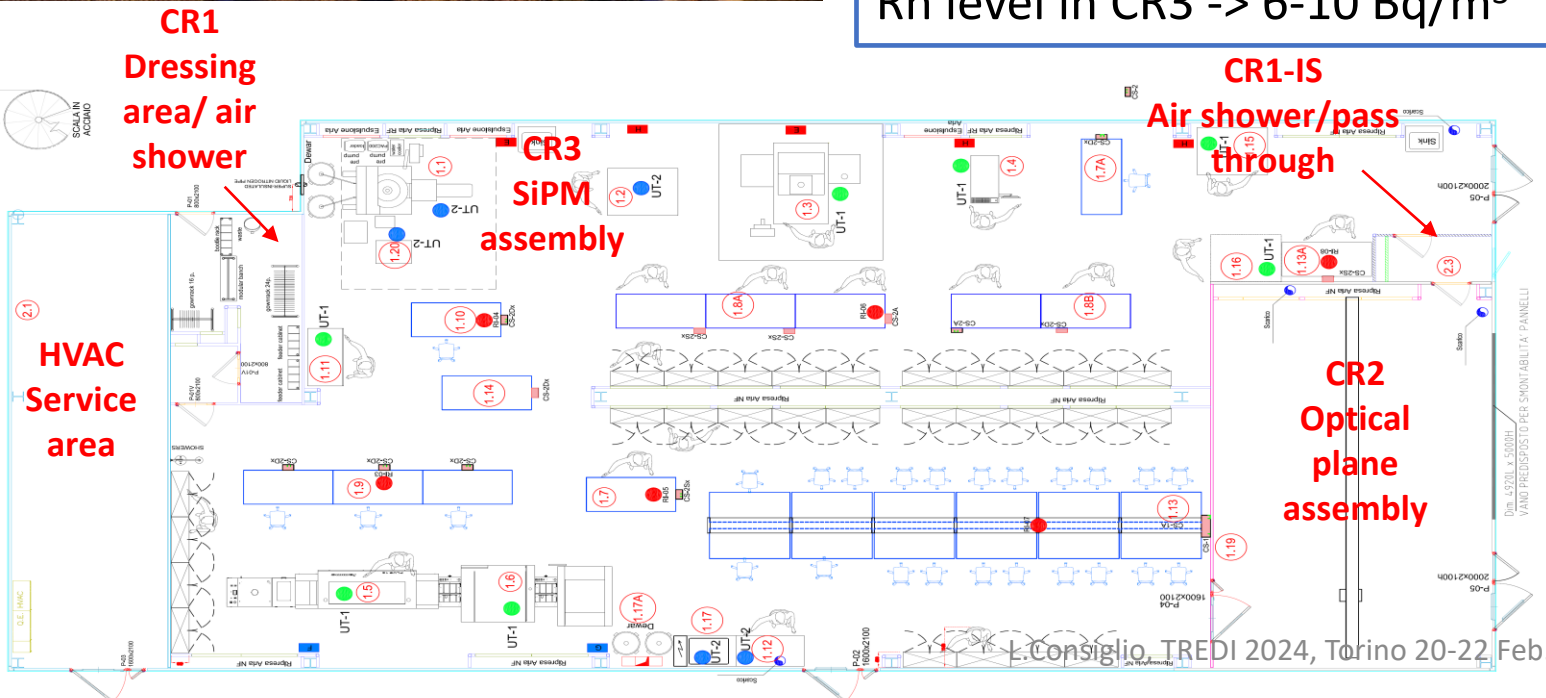


NOA site: LNGS HALL di MONTAGGIO



- Class ISO 6 clean room with an overall area -> 420 m²
- CR3 : 3.0 m high and an area of 353 m² devoted to the silicon device packaging, test and integration
- CR2: 5.8 m high and an area of 68 m² devoted to large volume detector assembly

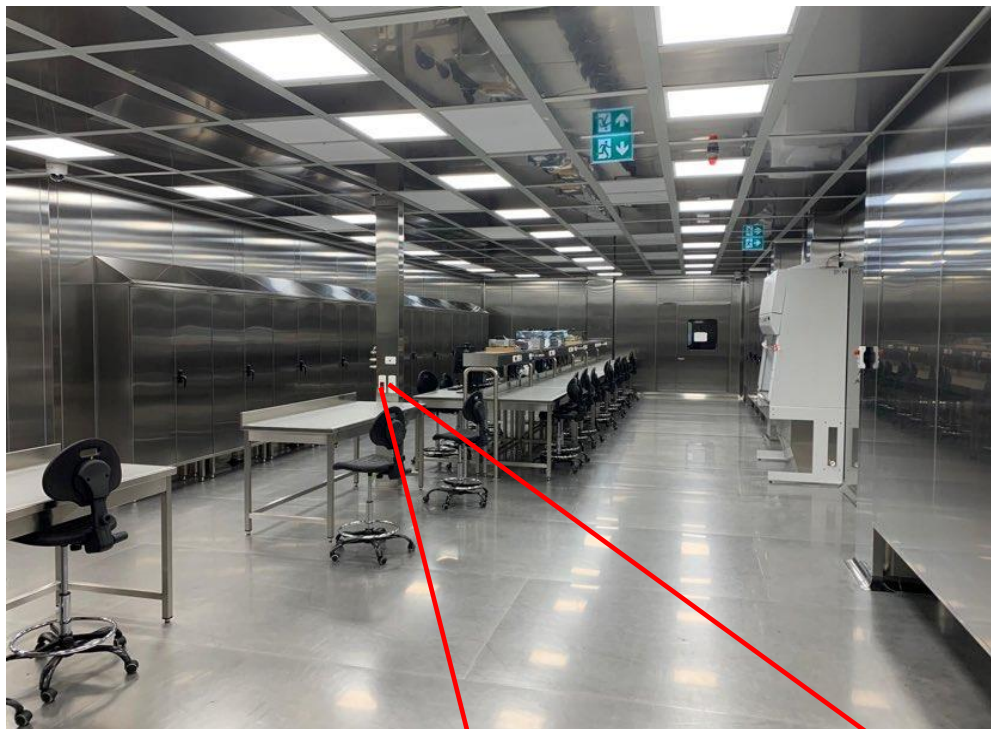
Continuous monitoring of the Rn concentration in 3 samples points: 2 in CR3 and 1 in CR2. Rn level in CR3 -> 6-10 Bq/m³



NOA utilities



CR3 test & assembly area : 25 workstations



CR3 utilities



- Liquid nitrogen charging station
- High pressure gas nitrogen
- Industrial water
- Refrigerated water (delivery@ 7°C)
- Dionized water
- Two dionized water sinks
- Two chemical hoods

Workstation utilities



- Electricity (220V, 50Hz) from normal and UPS power supply
- Compressed air
- Low pressure gas nitrogen
- Vacuum
- LAN and telephone lines



CR2
Floor resistance
2000 kg/m²

NOA packaging area



FORM FACTOR PAC200
CRYOPROBE



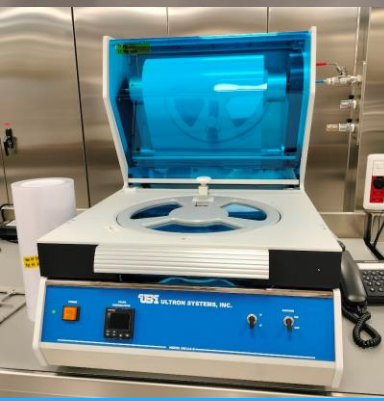
ADT 7122 DICER



AMICRA NOVA PLUS
FLIP CHIP BONDER



HESSE
WIRE BONDER



FRAME MOUNTER



DIE EXPANDER



UV CURING



TWO MICROSCOPES



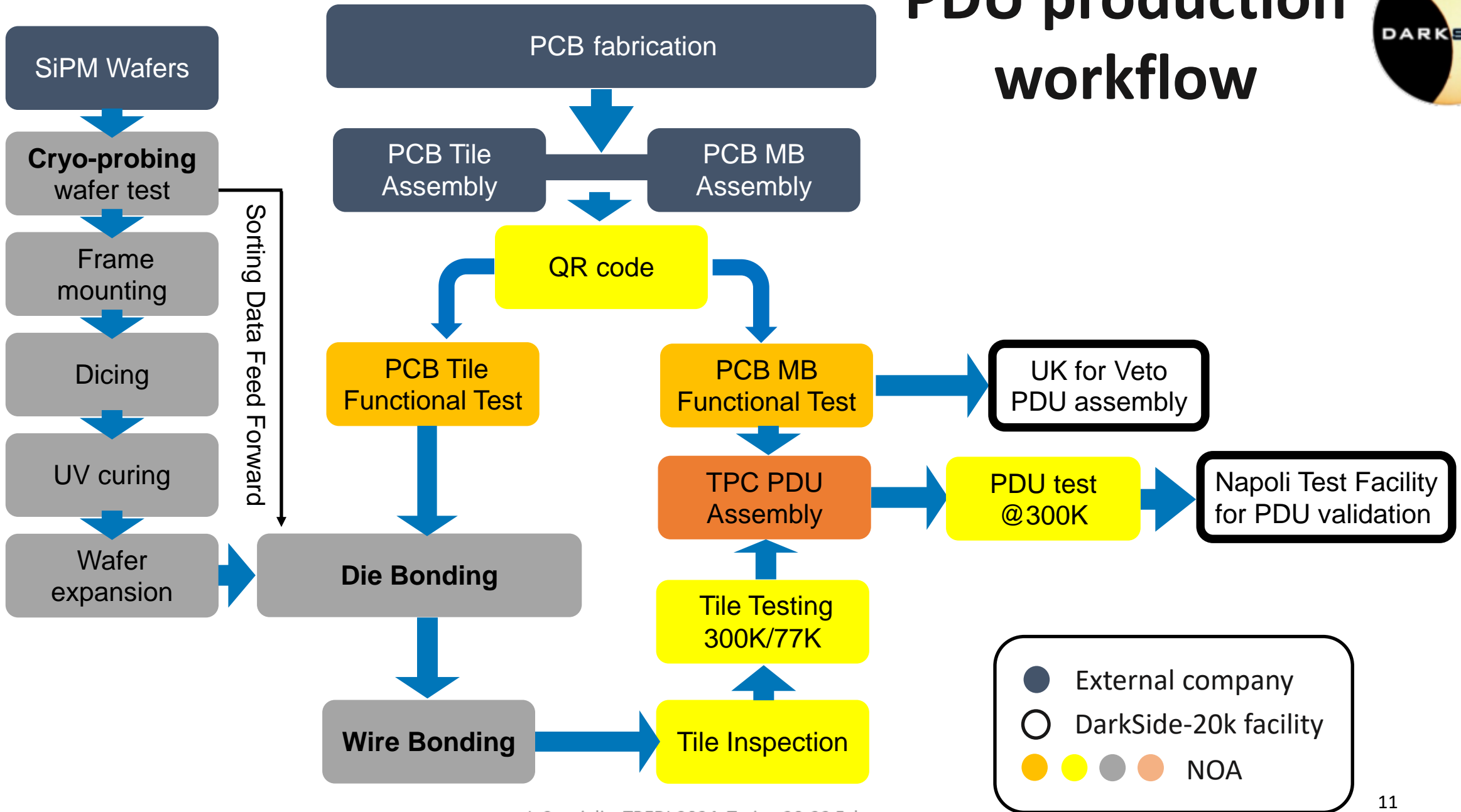
LASER ENGRAVER



PULL TESTER

TREDI 2024, Torino 20-22 Feb.

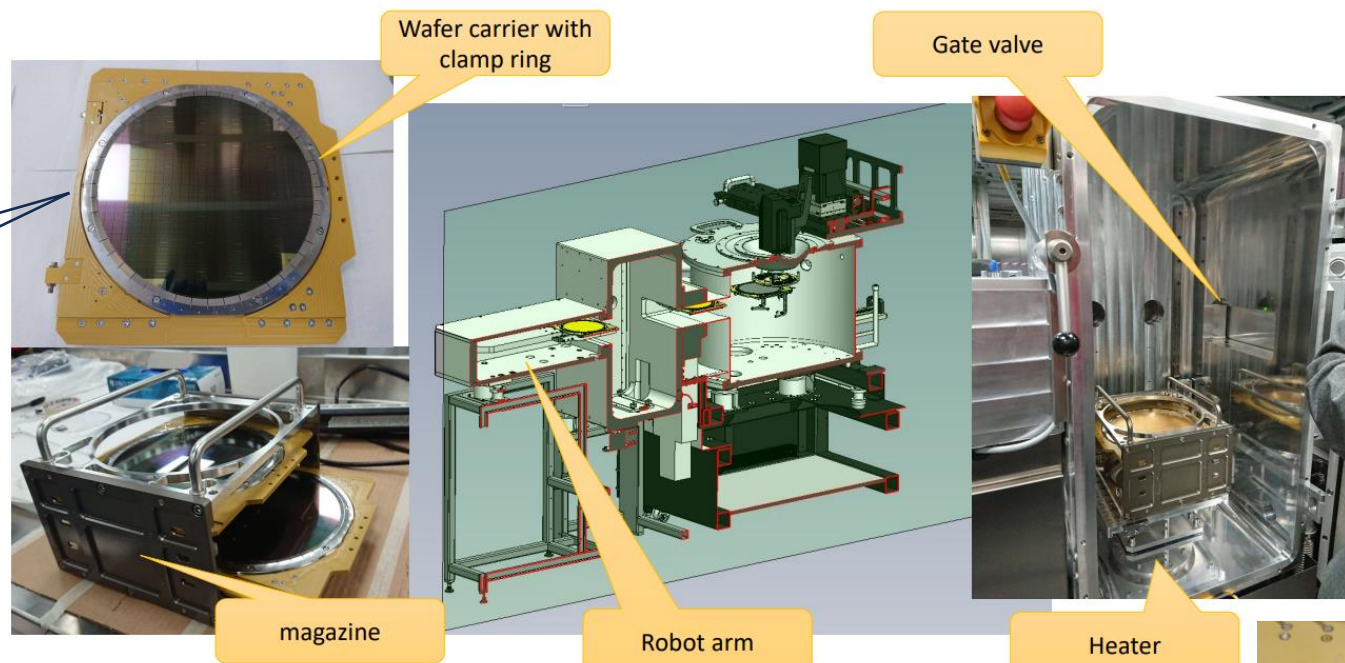
PDU production workflow



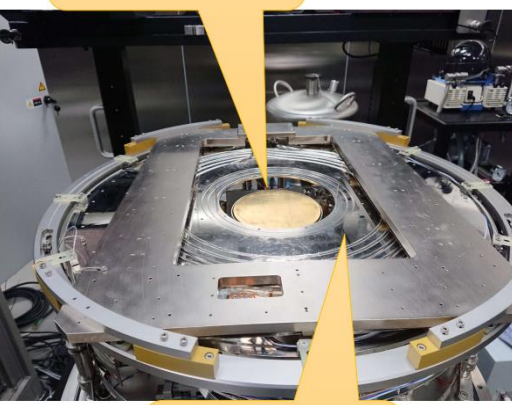
- External company
- DarkSide-20k facility
- ● ● ● NOA

Cryoprobe wafer test

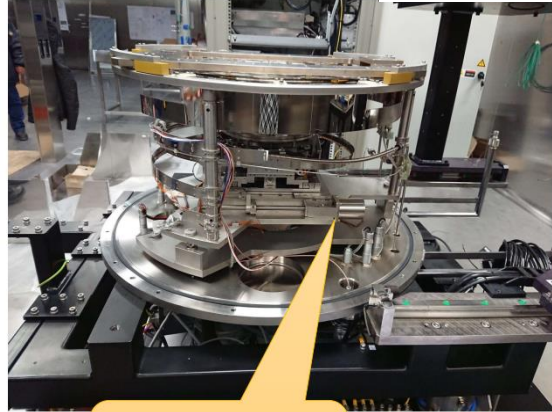
DarkSide-20k Silicon wafer (LFoundry)
200 mm diameter, 550 μm thick ; 264 SiPMs to be characterized at cryogenic temperature



Chuck



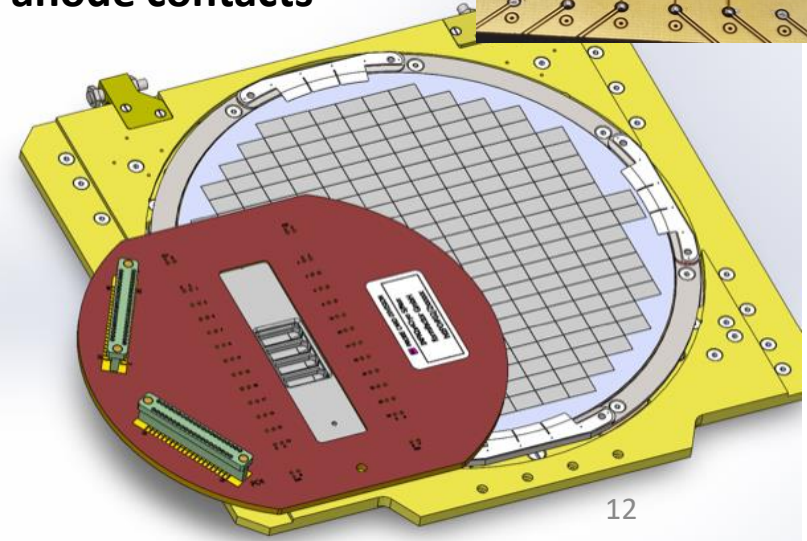
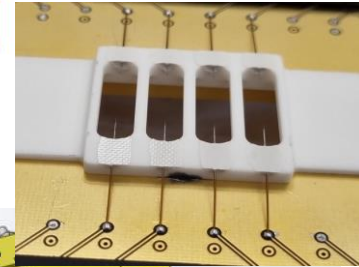
ColdShield



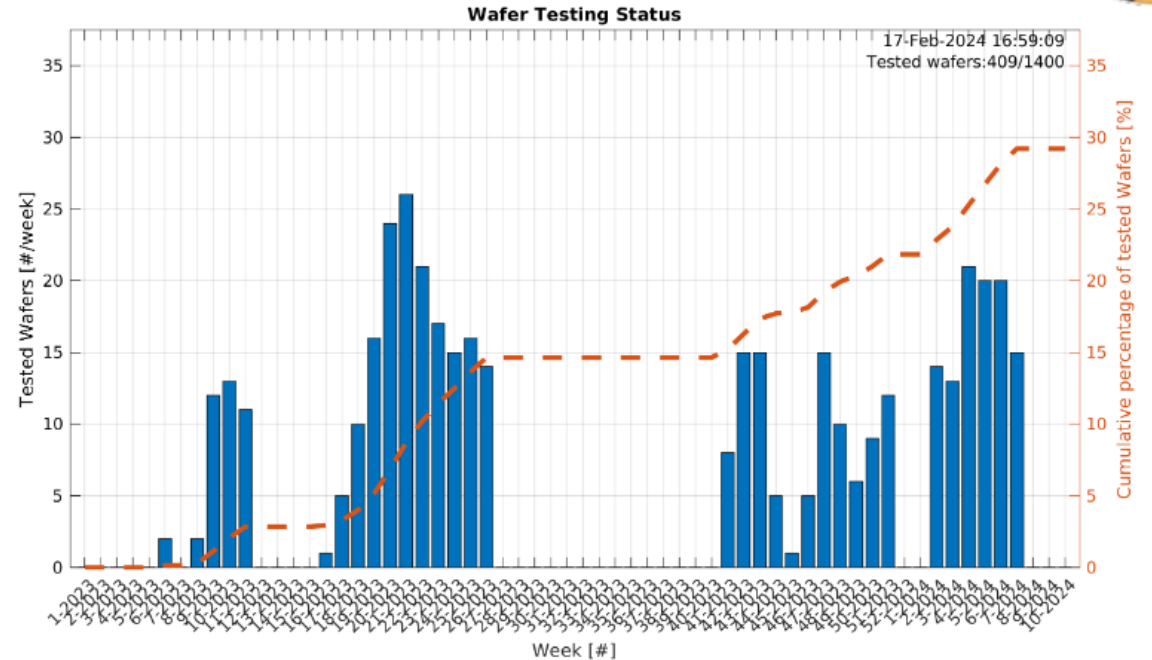
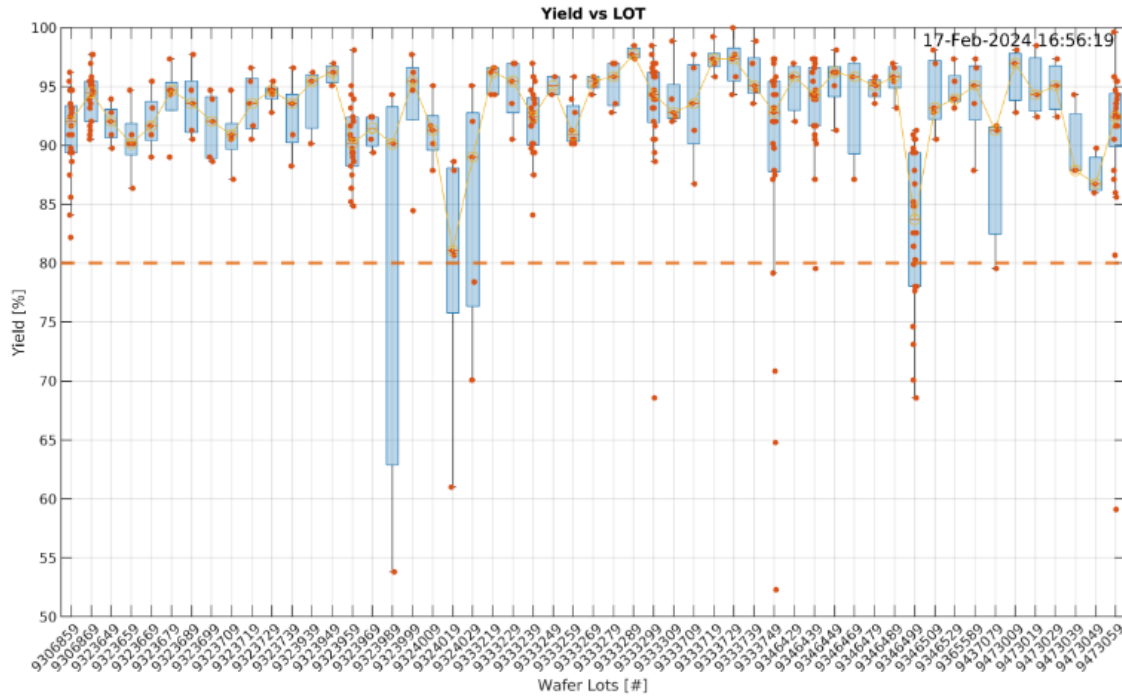
X, Y, Z, theta stepping motors to control the movement of the chuck



Probe-card
2 x 4 needles for anode contacts



Wafer production quality



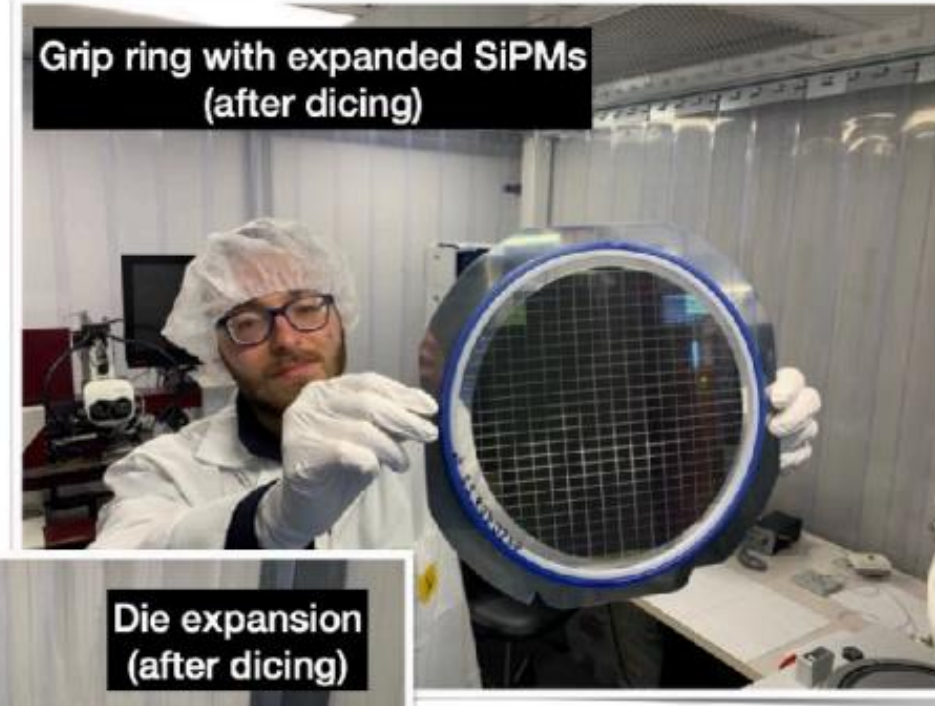
1400 production wafer to be tested (in progress): 29% done

Average Yield 90%

Measurement rate: 4 wafers/day + 3 wafers/day (weekends)

Shift plan : LNGS local people + DS-20k collaborators + 2 operators

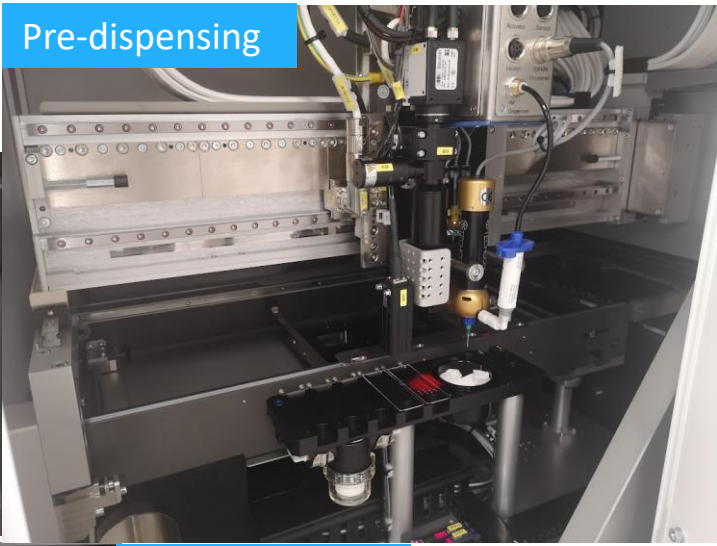
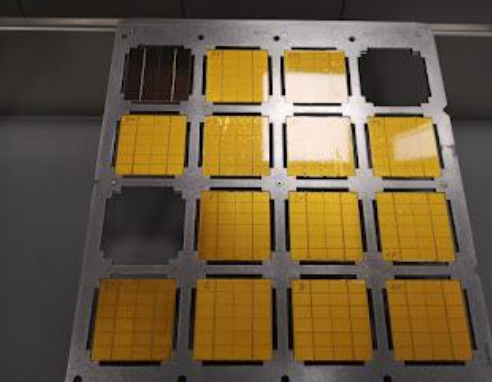
Manual packaging operations



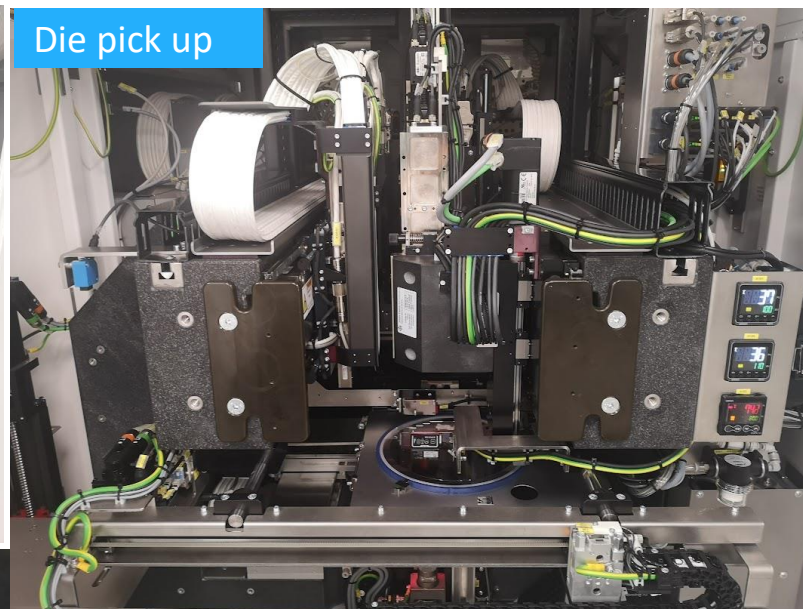
Die bonding



Input frame with 16 slots

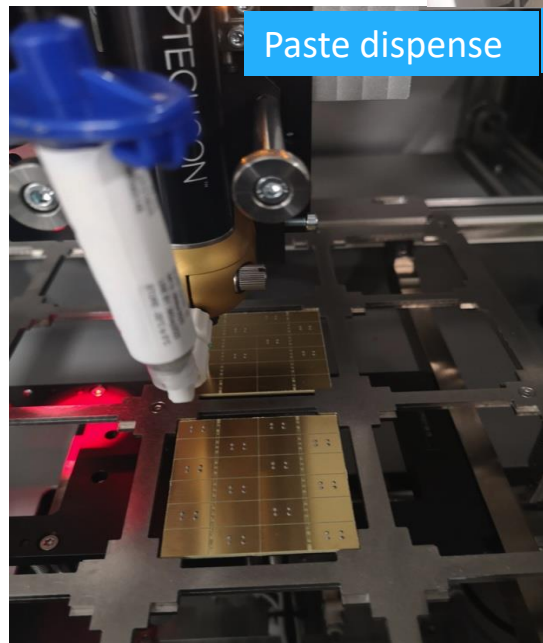


Pre-dispensing

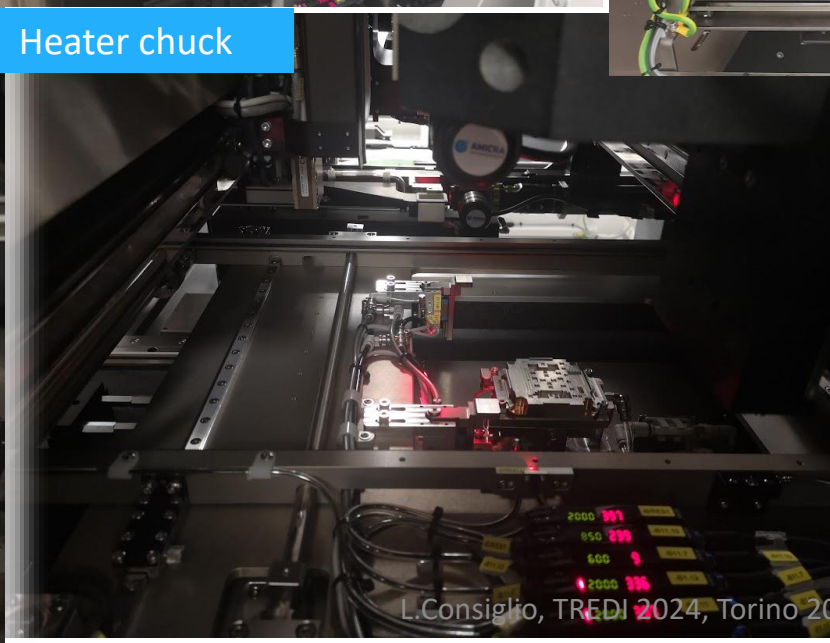


Die pick up

Thermo Compression Bonding:
Two bond heads work in temperature over 350°C
Chuck max temp 350°C



Paste dispense

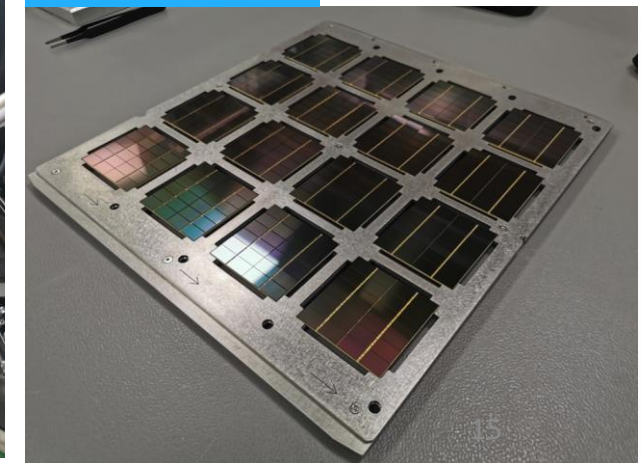


Heater chuck

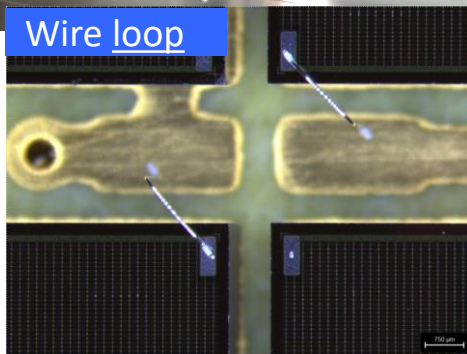
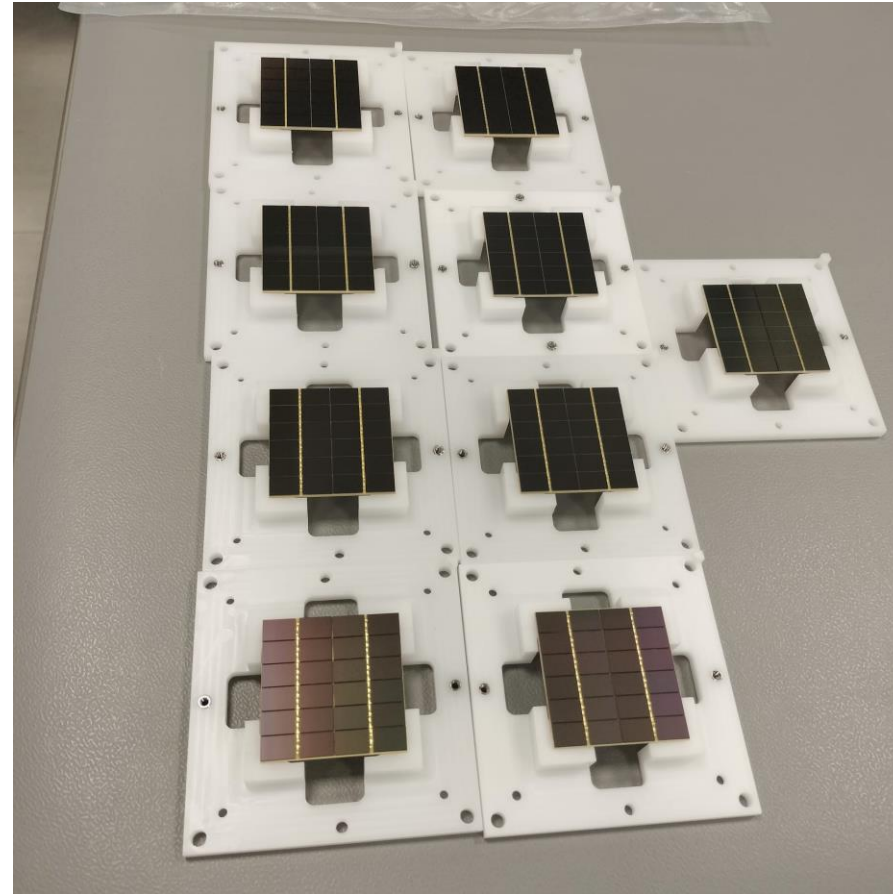
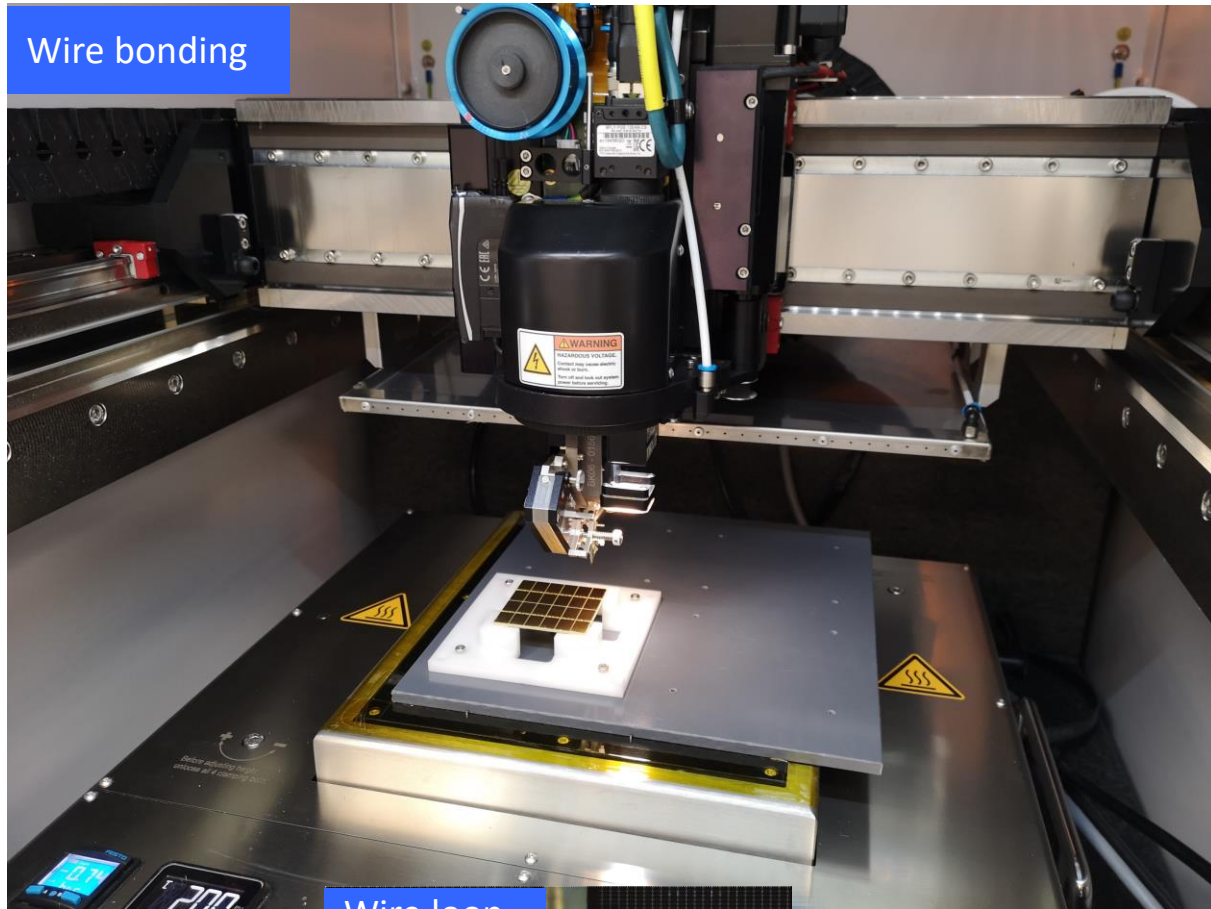


Die bonding

1 tray -> 1 PDU



Wire bonding



Ultrasonic wedge-wedge
Aluminum wire 25 μ m

**Ready for wire
bonding**

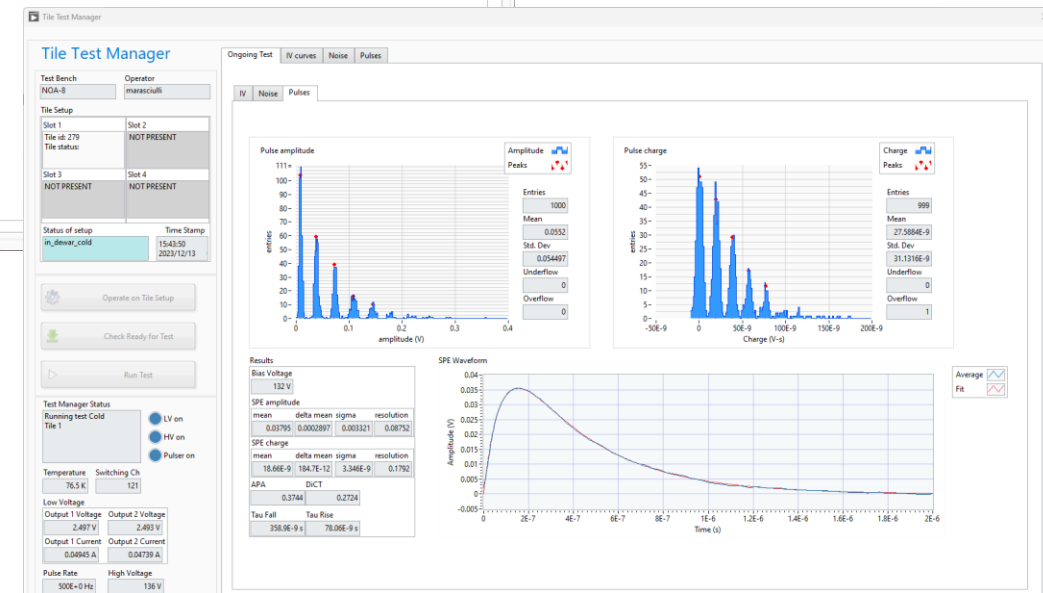
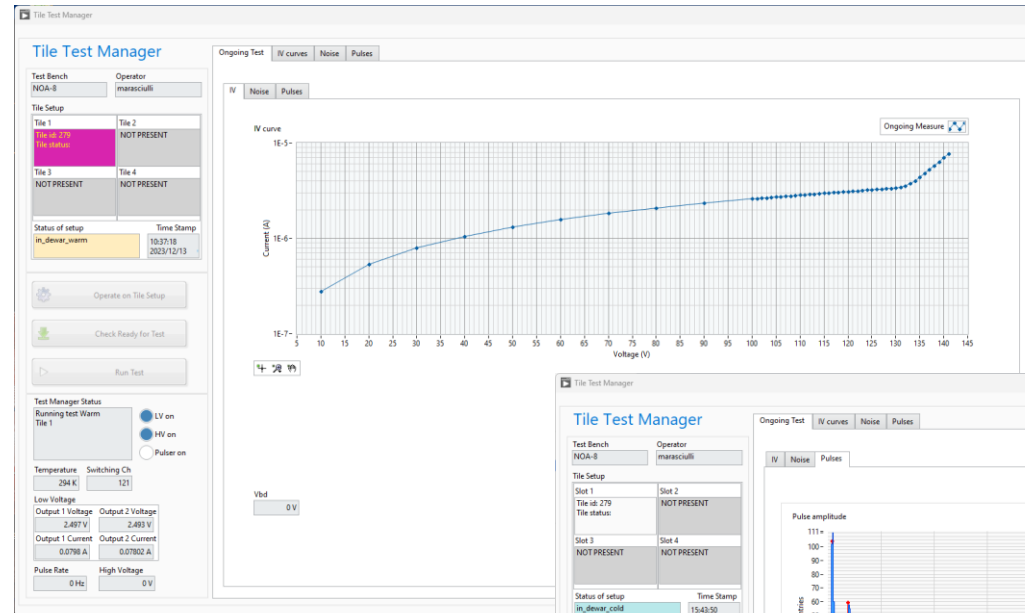
Tile testing: set up and analysis



- semi-automatic test procedure
- 1:10 h to test 4 Tiles

2 Tile testing set up:

- 4 Tiles each set up
- warm test
 - electronics characterization
- cold test
 - electronics characterization
 - laser light response
- thermalization cylinder for dry warming with GN₂ flux



Tile testing: database



Test data are saved in the collaboration database

- Tile tracking by means of QRcode
- summary tables with values of QA-QC parameters and Tile classification (good, bad...)
- webpage with the plots of a single Tile test
- Work in progress to add cumulative histograms with QA-QC parameters starting from the production



DarkSide-20K Database - TPC

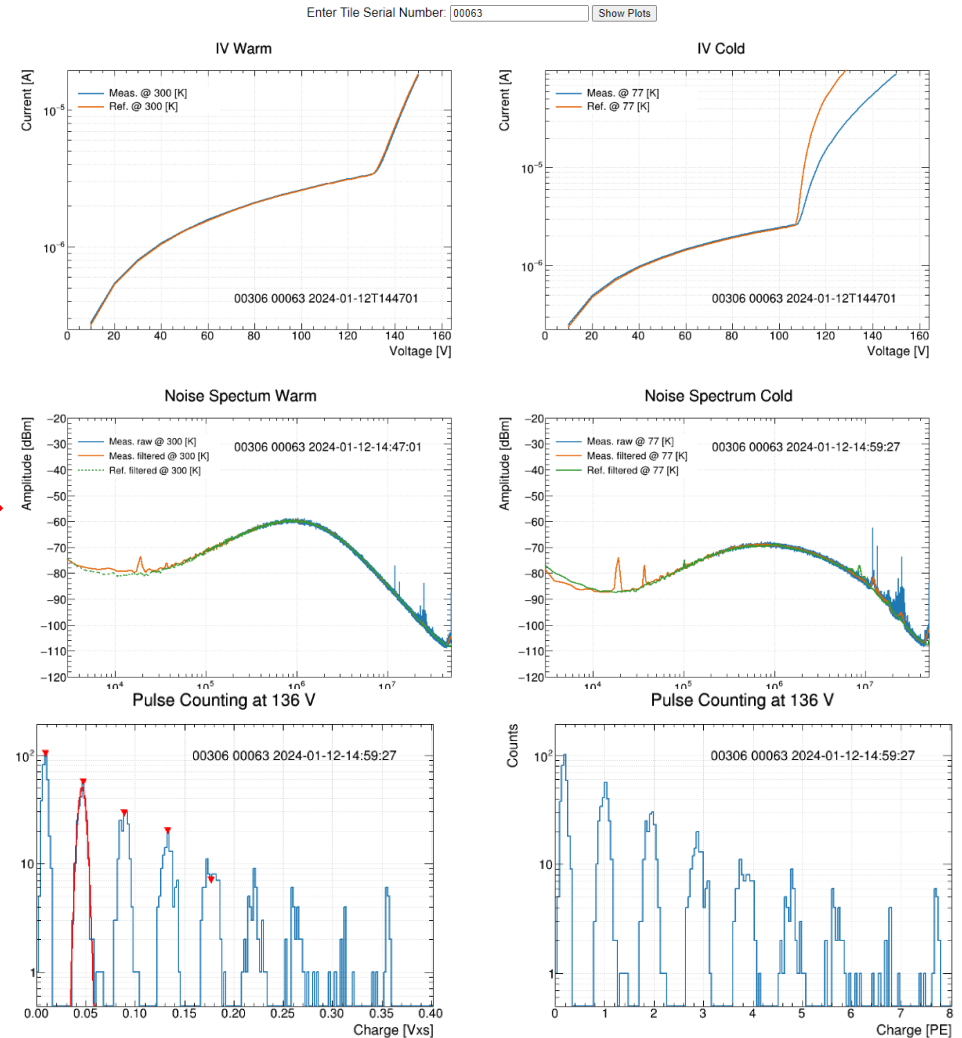
<https://ds20kdbi.cloud.cnaf.infn.it/preprod/html/TPCproduction.html>

TPC Production Control Plots

TPC Search QR **TPC Tile Testing Search**

PCB & Tile Production Control Tables

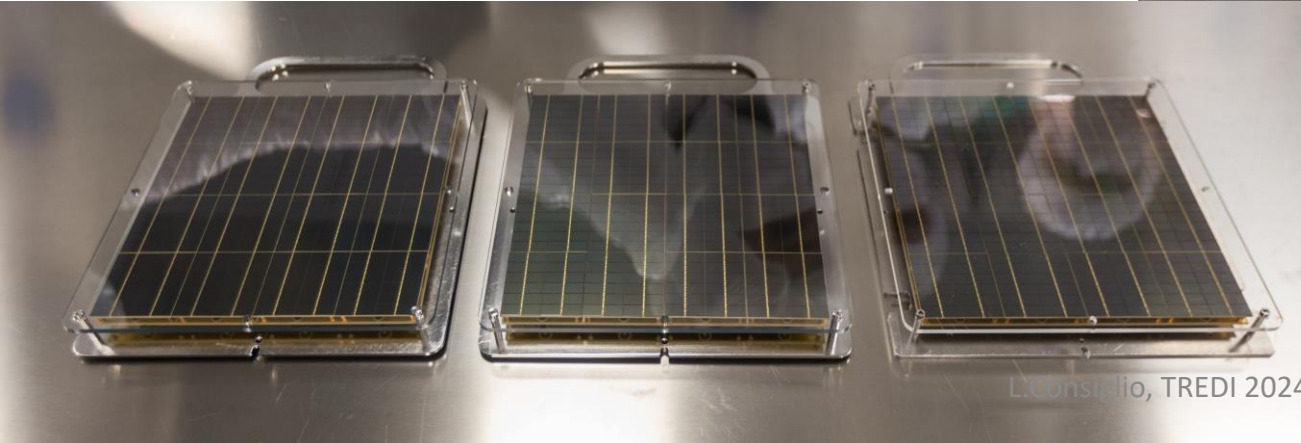
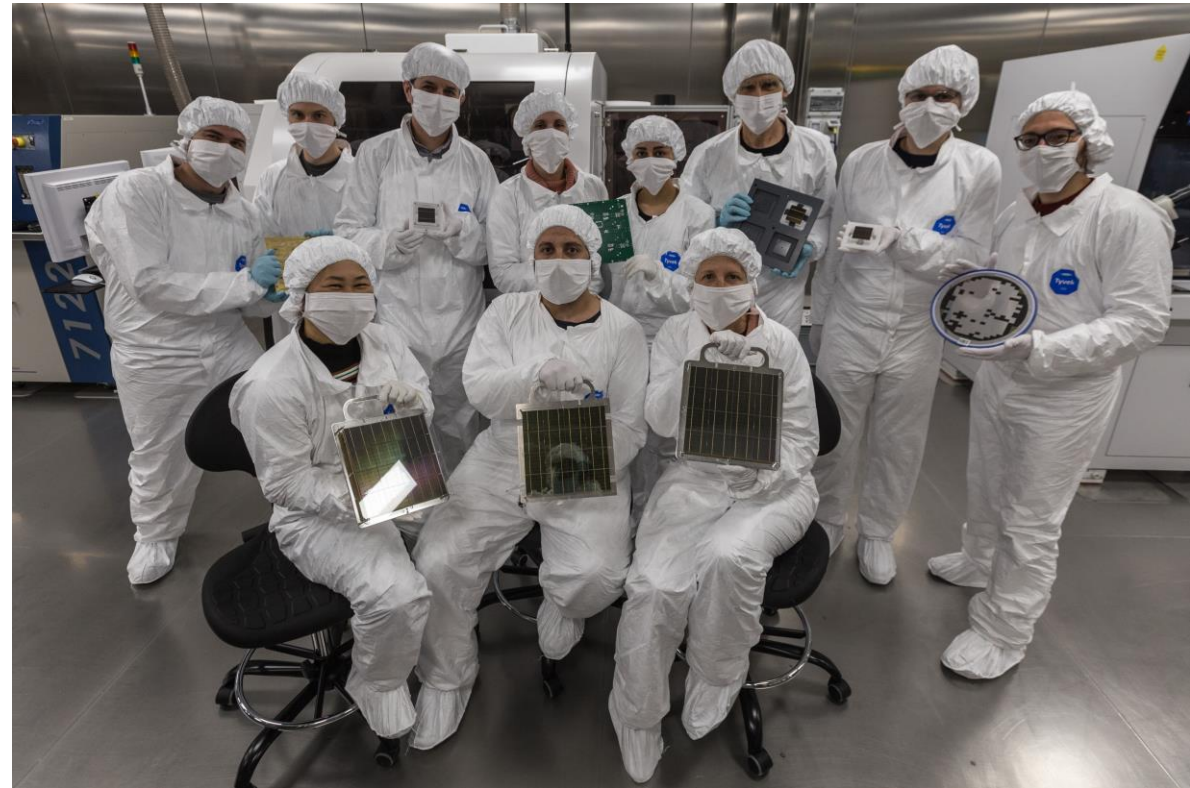
PCB Production Status Tile Production Status PCB & Tile History



PDU assembly



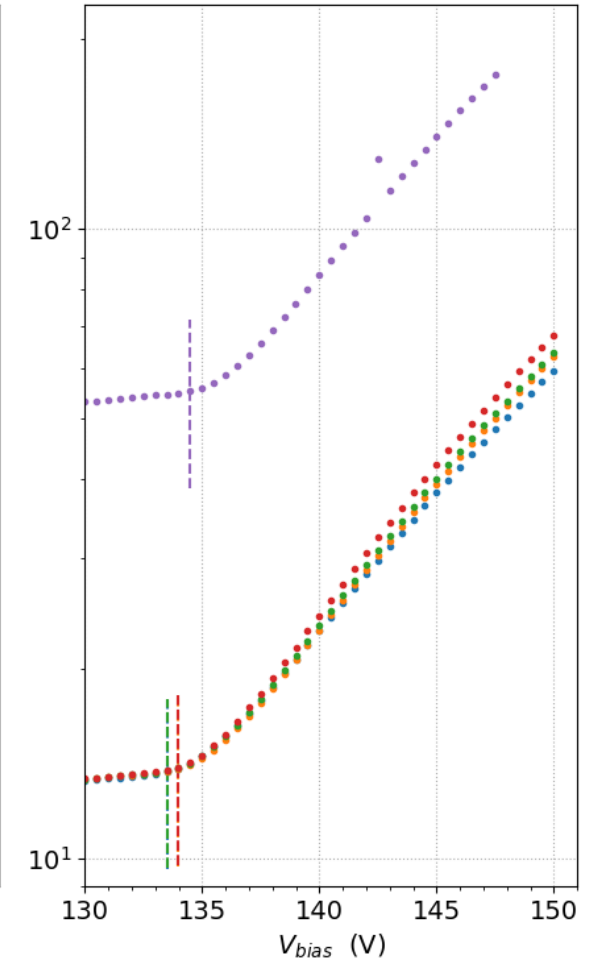
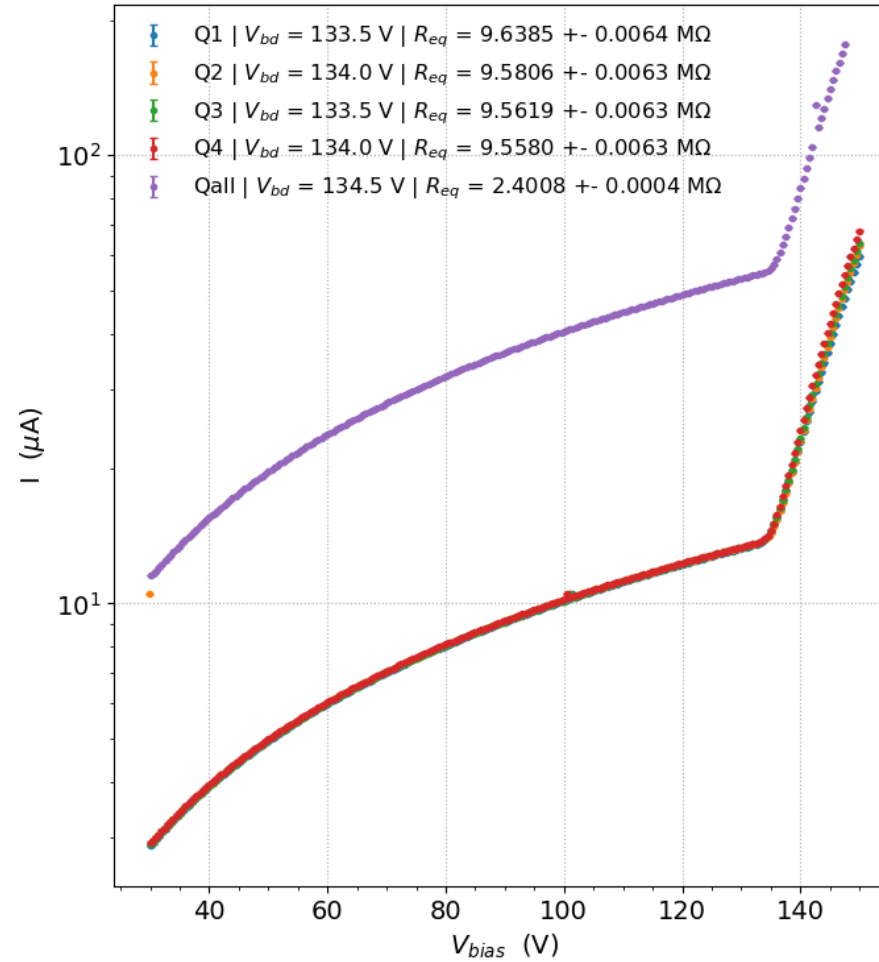
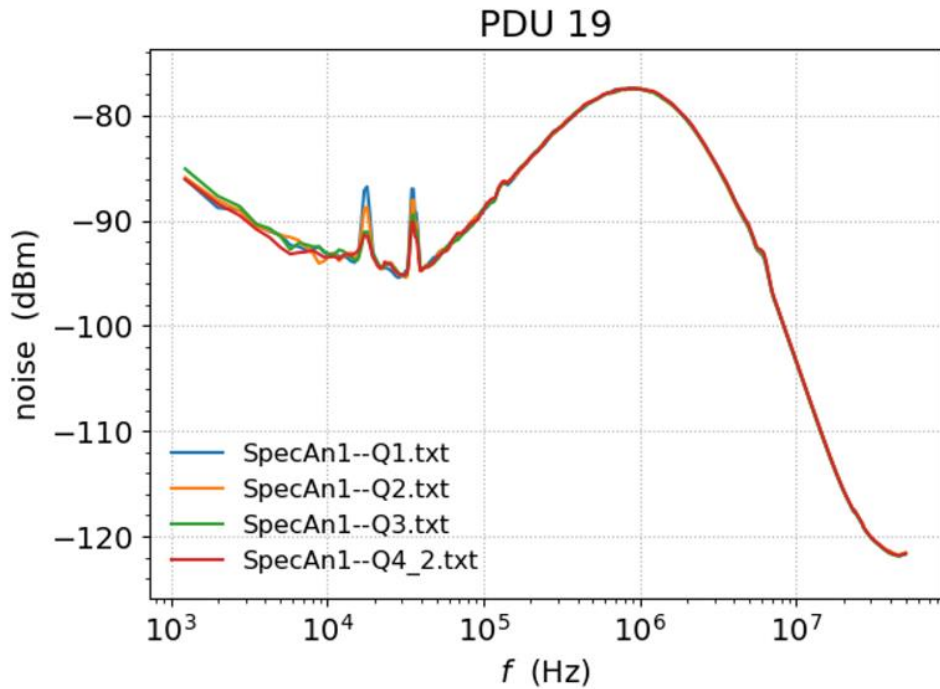
- mechanical support
- threaded rods
- screwdriver with controllable torque
- stainless steel handhandler
- acrylic protection



PDU mounted on the transportation handler to be tested in Naples facility

NOA Team

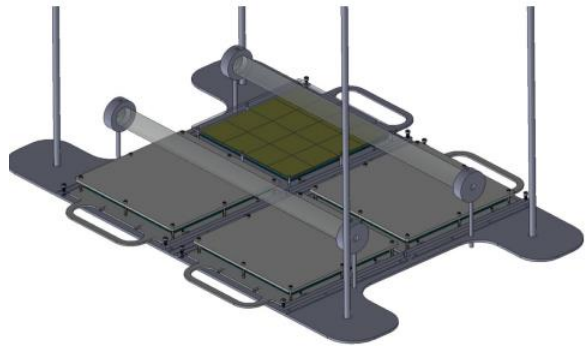
PDU Room temperature test



Napoli Test Facility



PDU characterization in liquid nitrogen in an ISO-6 clean room (50 m²)



Mechanical structure composed 4 levels each hosting 4 PDUs. Full integration with light distribution system.



Electronic rack with Caen mainframe for the Power Supplies board, VME crate for VX2740 ADCs, NIM crate with trigger logic formation unit and laser unit

Future Perspectives



- DarkSide-20k cryostat construction in Hall C to be completed in 2024
- NOA clean room commissioned in beginning of 2023 fully operational
- Silicon wafers characterization started in February 2023 -> 29% tested -> completion by spring 2025
- Process set up and training on the machine done completed
- Pre-production of 10 TPC PDU started in Jan 2024 (until April 2024)
- Full production of TPC PDUs in NOA planned to start in May 2024

Full commissioning foreseen by end of 2026

