

The Photo Detection Units of the DarkSide-20k experiment for direct detection of WIMPs

13th of May 2024

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on the behalf of the DarkSide collaboration

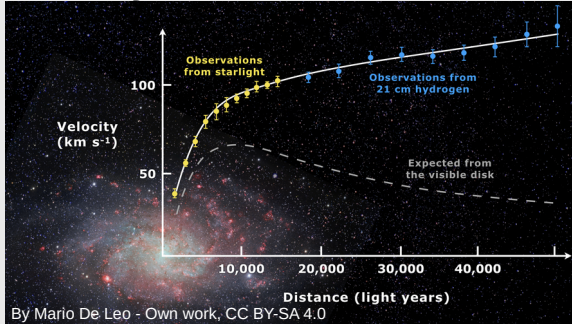
DPF-PHENO 2024



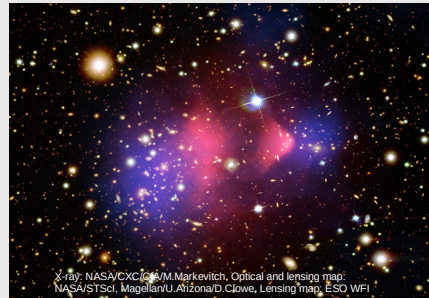
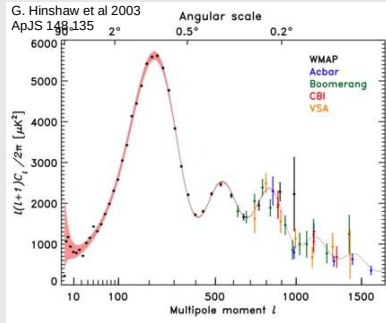
Dark matter summary

Evidence

- Galaxy rotation curve



- CMB anisotropy



- Bullet cluster
- Etc

Properties

- About 27% of the energy content of the Universe
- Interacts gravitationally
- Most likely “cold”

→ One possible candidate: WIMPs (Weakly Interacting Massive Particles)

DarkSide goal: probe WIMP-nucleus cross section and other exotic phenomena

DarkSide experiments

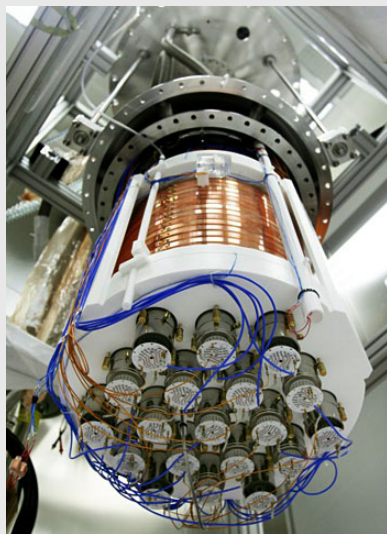
Liquid Argon Time Projection Chamber (LArTPC)

- Cryogenic temperature
- Signal through scintillation and ionization
- Transparent to own scintillation
- Low energy threshold
- Possibility to amplify ionization signal (Dual phase)
- Discrimination between electron recoil (ER) and nuclear recoil (NR) thanks to pulse shape discrimination

Detectors

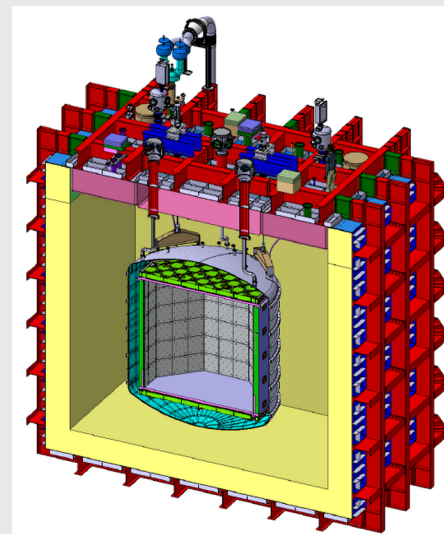


► Prototype
DarkSide-10
Light Yield in DarkSide-10
T. Alexander et al.

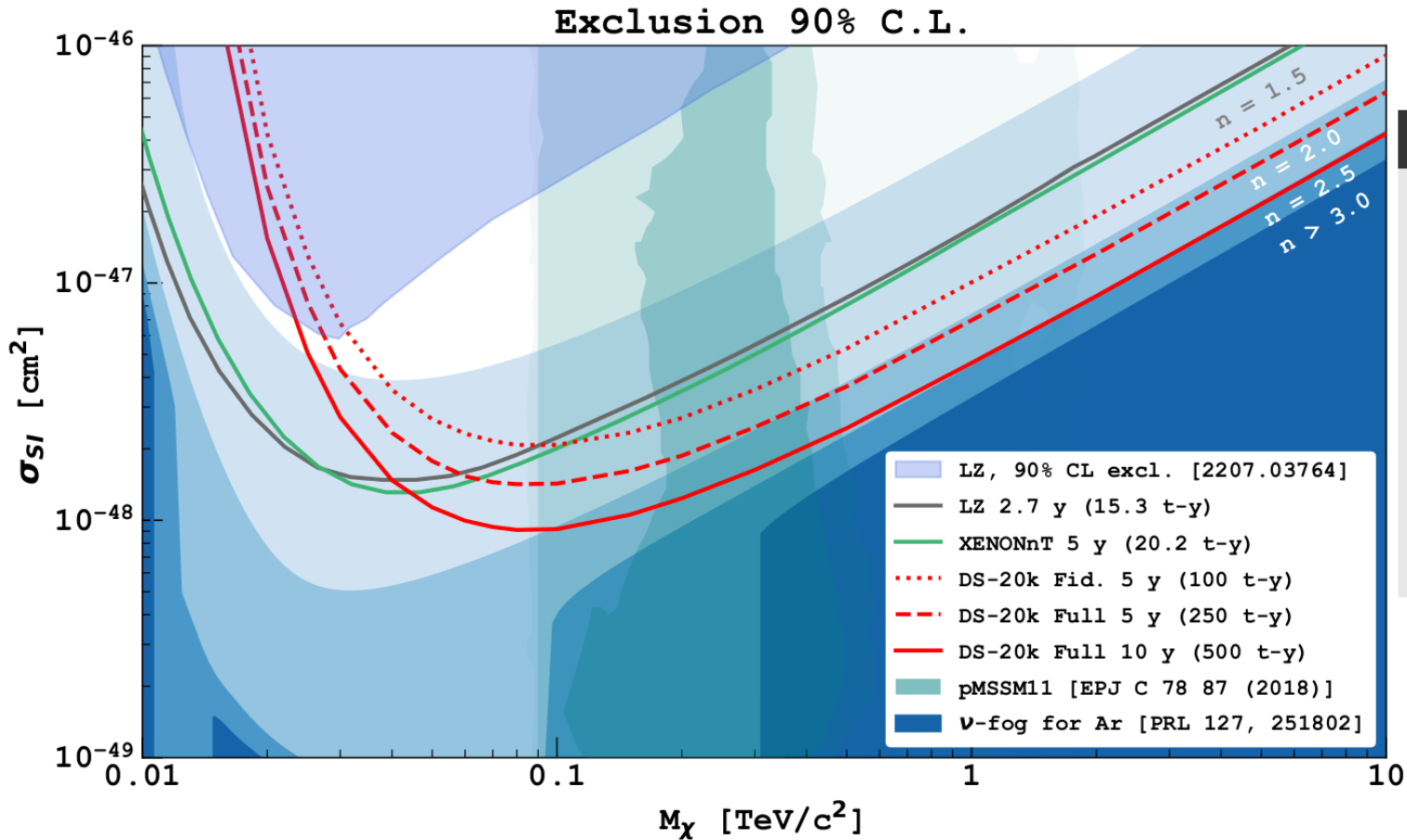


◀ DarkSide-50
2013-2020
Search for low-mass dark matter
WIMPs with 12 ton-day exposure
of DarkSide-50
P. Agnès et al. (DarkSide-50 Collaboration)

DarkSide-20k ◀
under
construction

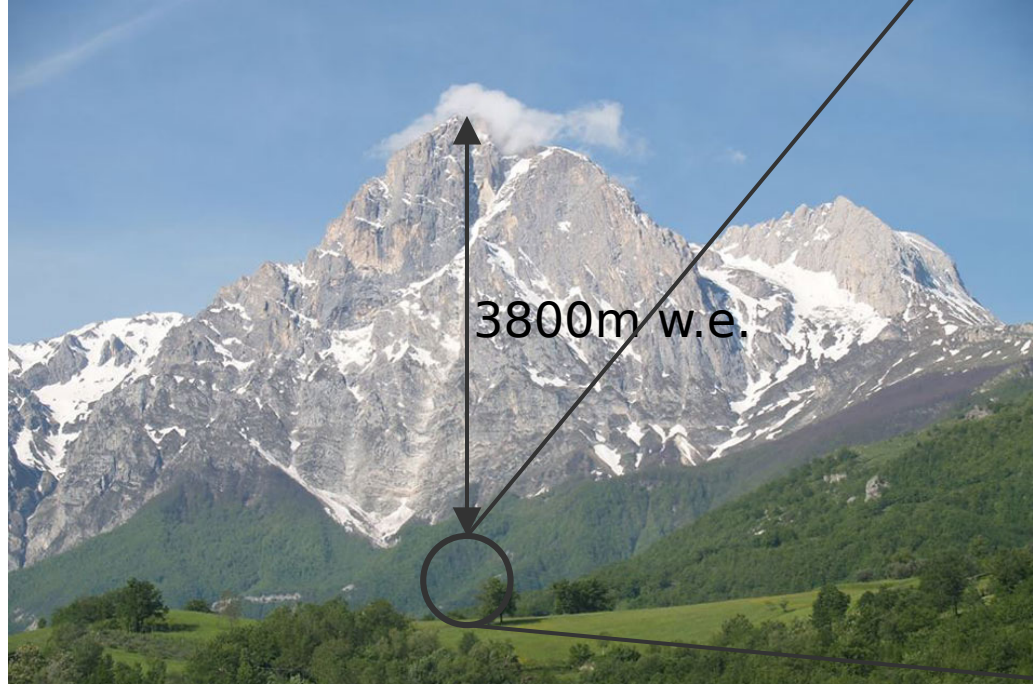


DarkSide-20k expected sensitivity



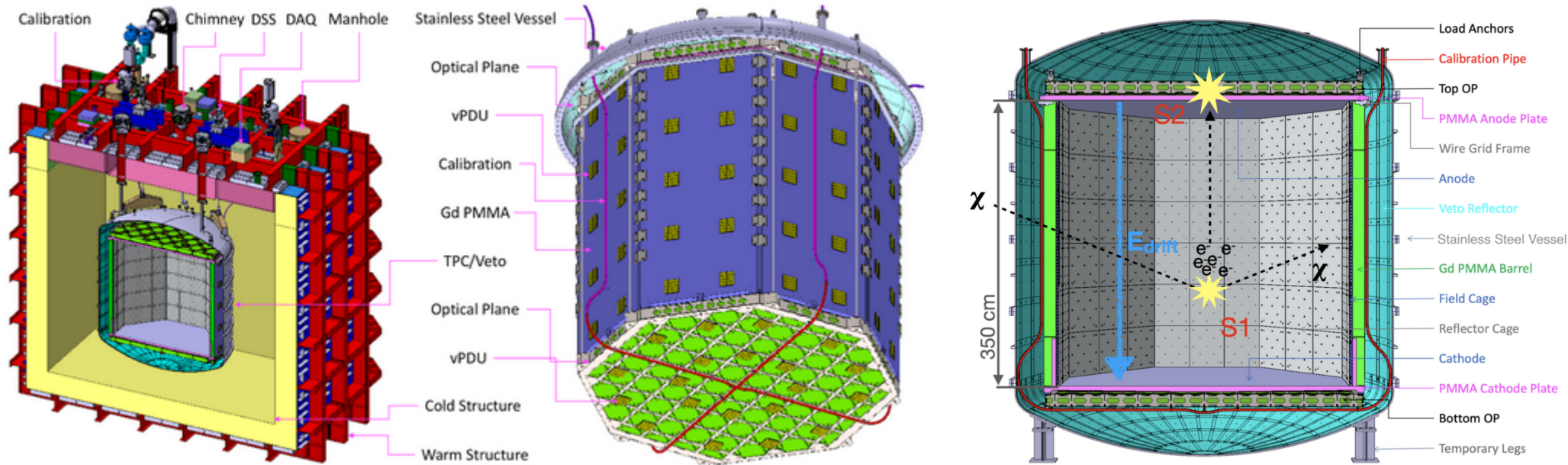
- Sensitivity to spin independent WIMPs
- Compared to LZ and XENONnT
- Five years (dotted and dashed)
Ten years (Solid)
- Fiducial (dotted)
- Full (dashed and solid)

DarkSide-20k



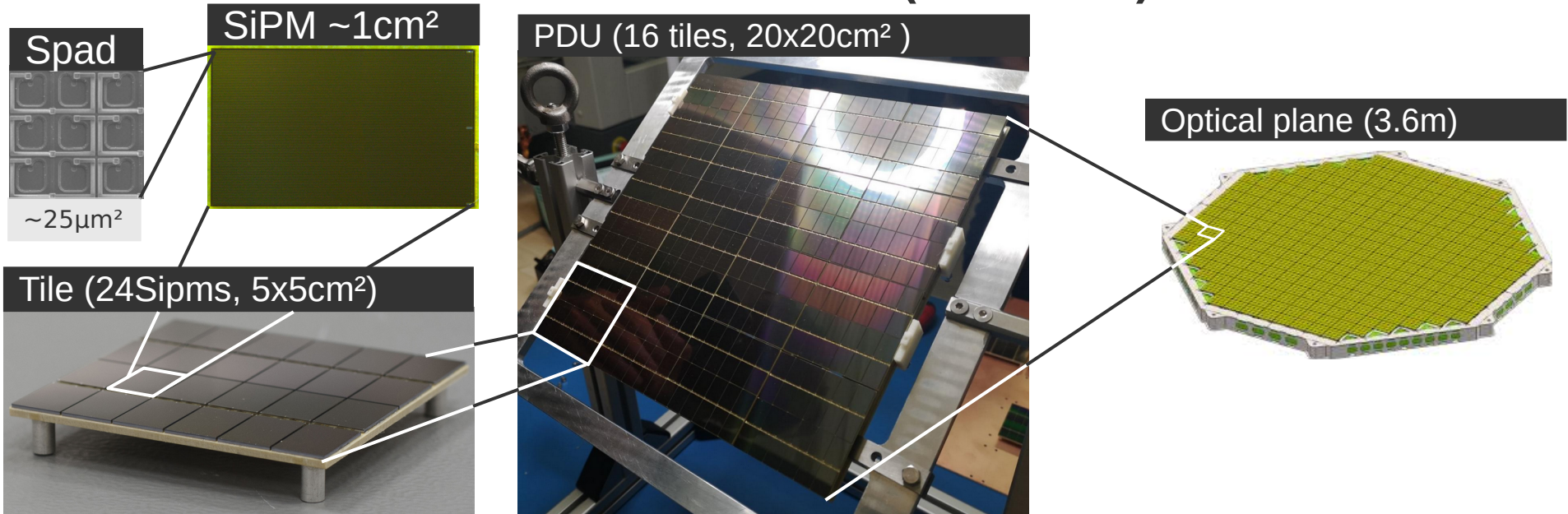
DarkSide-20k under construction at Gran Sasso's underground laboratory (Italy).

DarkSide-20k



Designed to maximize background suppression allowing to operate in nearly background-free condition. (β , γ and neutrons).

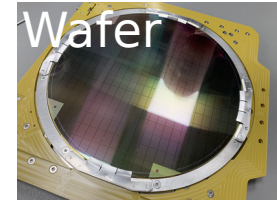
Photon Detection Units (PDUs)



SiPM properties

- Cryogenic SiPM designed by FBK (Italy)
- Low dark count at cryogenic temperature (0,01 Hz/mm²)
- Good photon detection efficiency (~45%)

Nuova Officina Assergi (NOA)

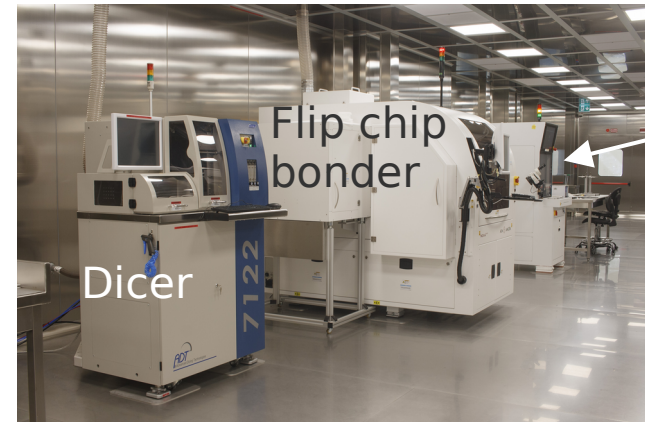


NOA

- ISO6 Clean room at LNGS completed in 2023
- Made for large-area silicon photodetectors production and part of the detector assembly

Process flow

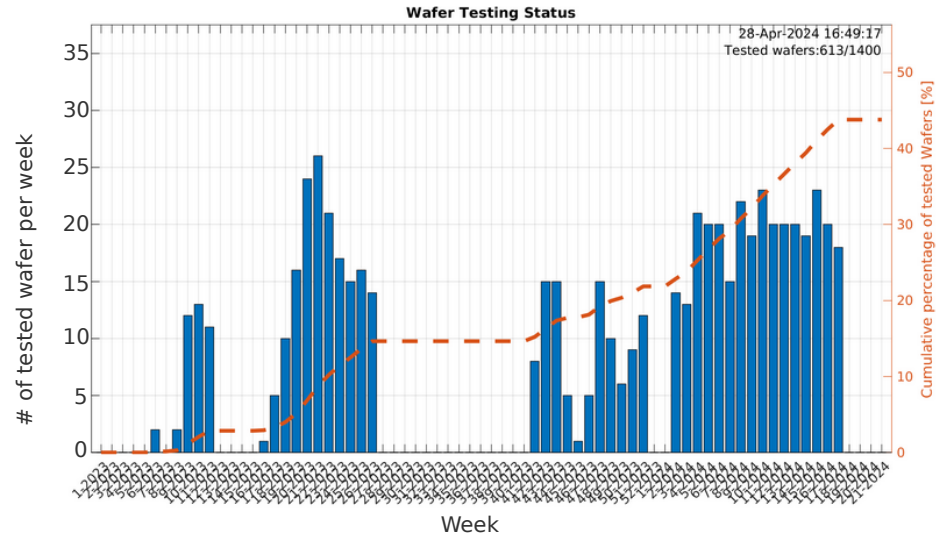
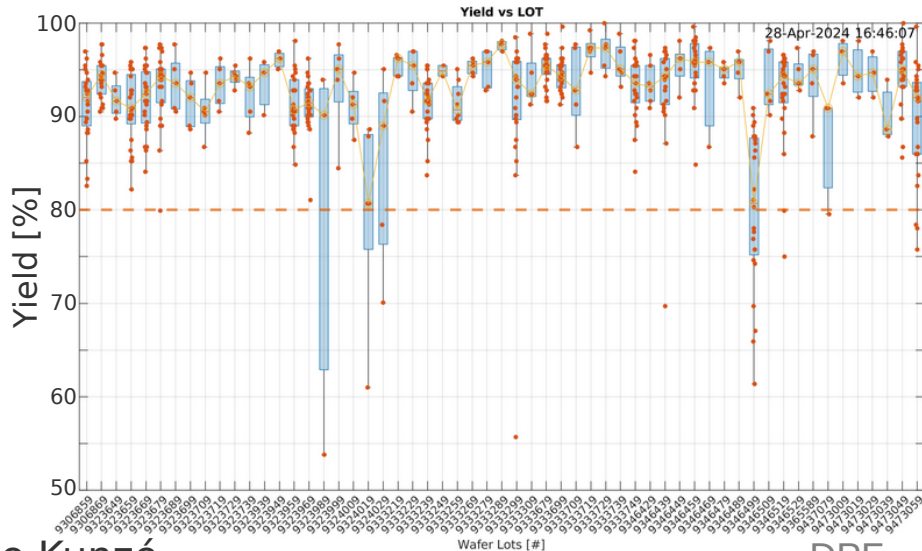
- Test wafers (SiPMs) with cryoprobe
- Dicing single SiPM from tested wafer
- Mounting SiPMs on board with Flip chip bonder
- Wire connection of SiPMs on board to create the Tile with wire bonder



Production database

- Database to store information on production
- Software developed to update database during production
- Online webpage to visualize database:
 - Status of different objects
 - Different test results

Wafer Production Quality



darkside
two-phase argon TPC for Dark Matter Direct Detection

DarkSide-20K Database

Available apps



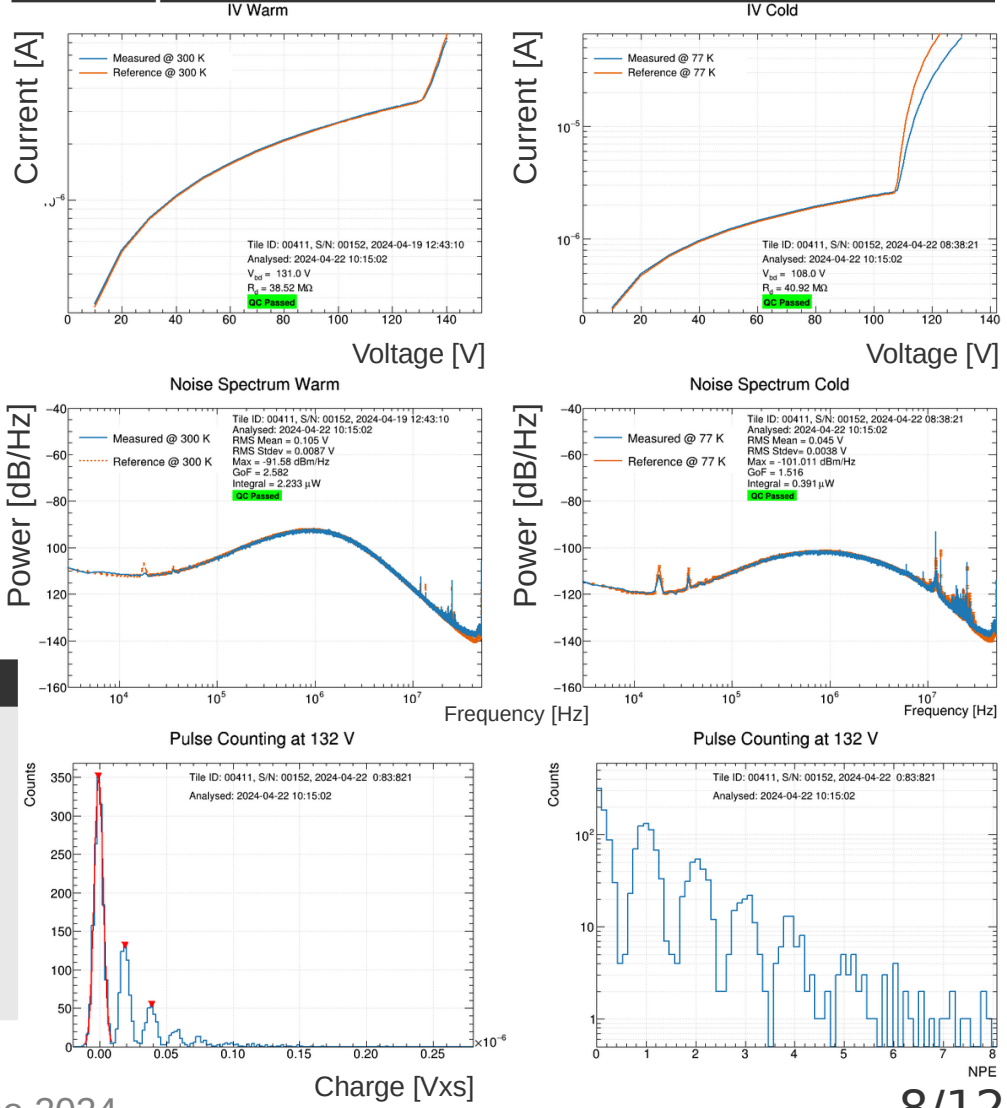
Tile testing

Testing setup in NOA



- Test at warm and cold temperature
- Automated with LabView software and linked to database
- I-V curve, noise power spectrum and response to laser pulses
- QA/QC criteria

Example of test result

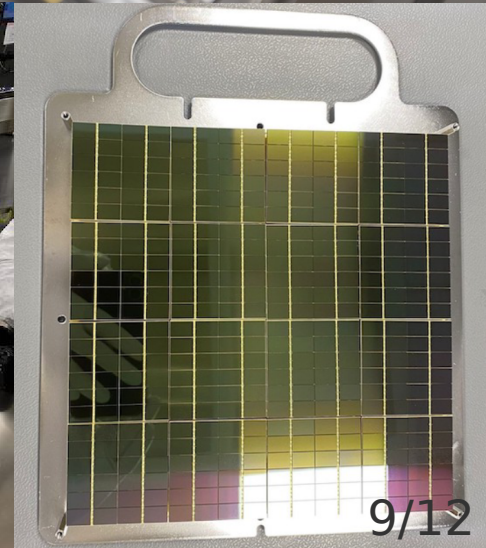
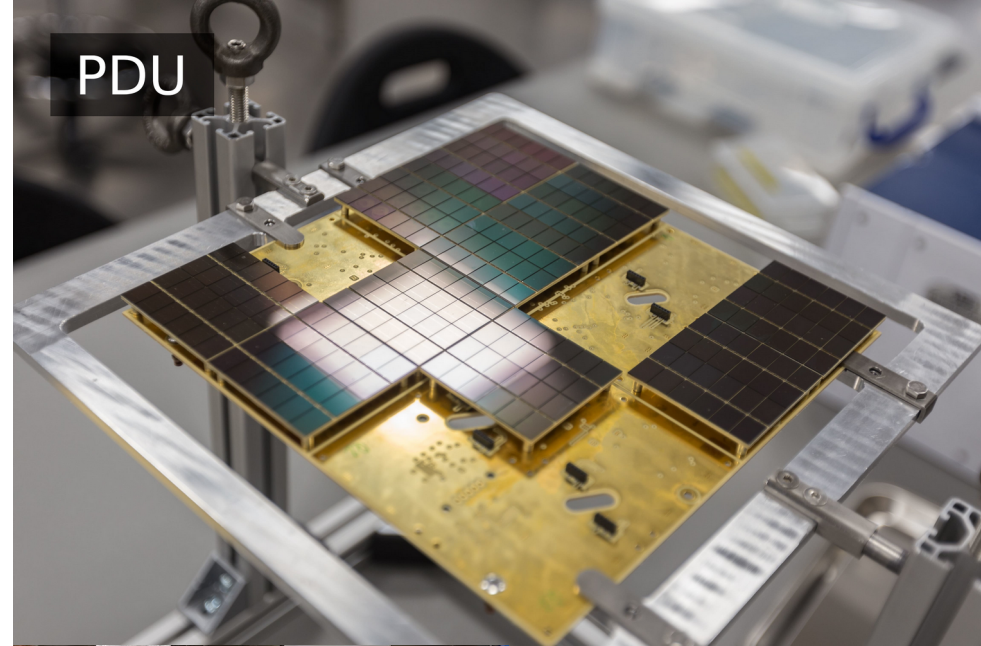


PDU assembly

PDU assembly in NOA

- Tiles passing the tests go to PDU assembly
- 16 tiles mounted on a motherboard to create a PDU
- Specific handler and safe transport box designed by the collaboration

After assembly, PDU can be sent for PDU testing



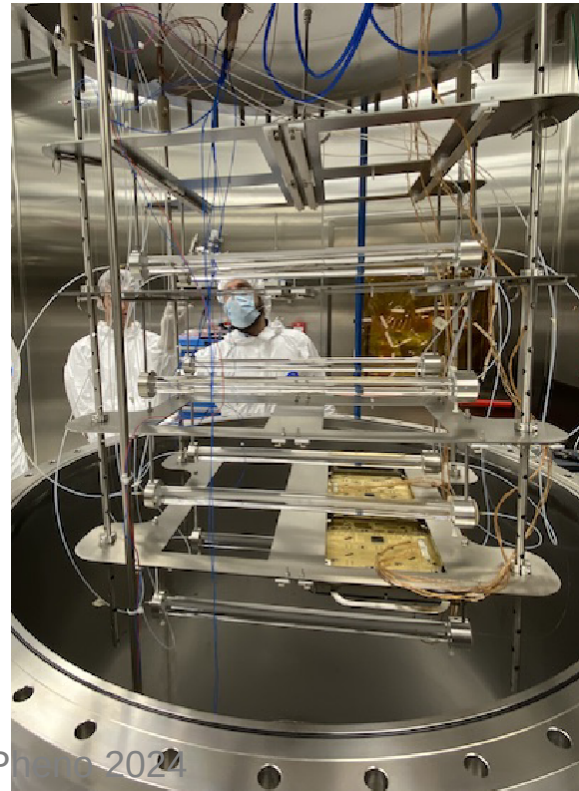
PDU testing

Cryogenic test facility in Naples

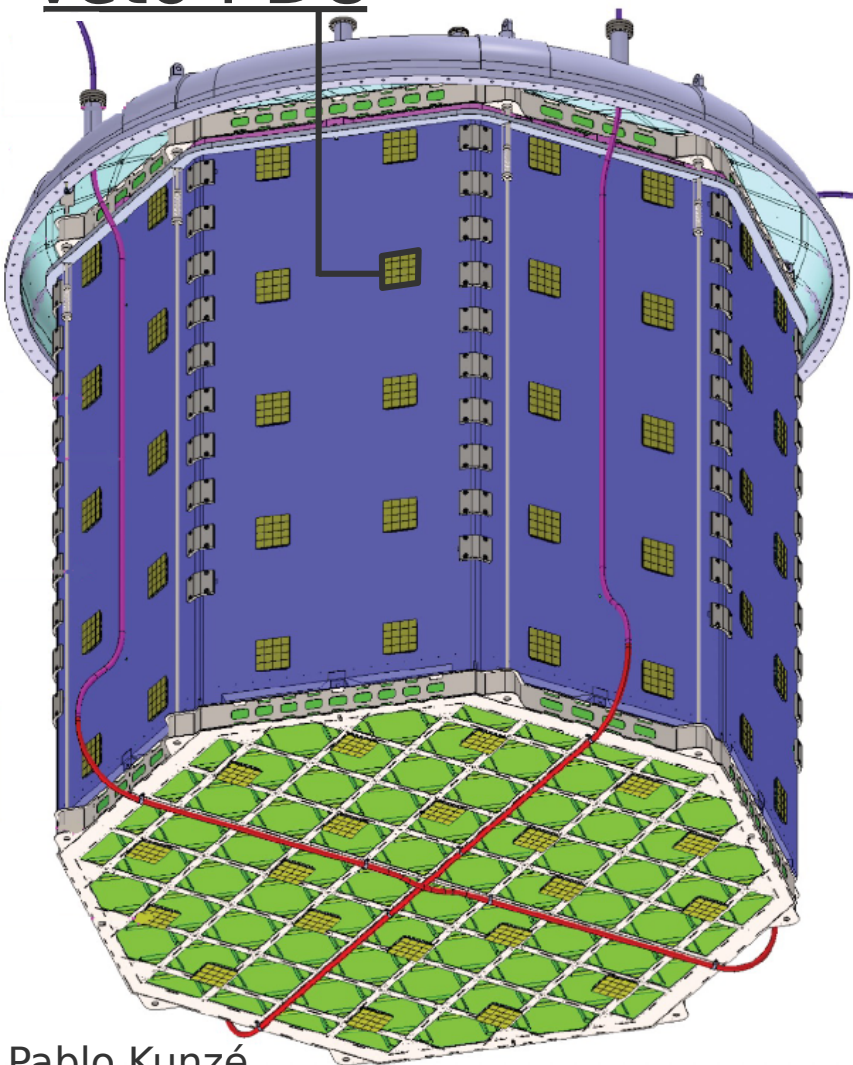
- ISO6 clean room
- Setup to test 16 PDUs at once

Once cold tested, PDU are sent back to NOA for a last warm test.

Sealed and stored until mounting in the optical plane, which will take place near NOA.



Veto PDU



- More than 500 TPC PDUs
- 120 Veto PDUs
- Similar technology
- SiPM from NOA but PDU produced in the UK (Birmingham, STFC interconnect, Manchester, and Liverpool)
- Tested at 3 sites: AstroCeNT, Edinburgh, and Liverpool

Conclusions

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- DarkSide-20k photosensors represent a real technical challenge and are a key point for the search of WIMPs.
- The PDU will be produced at NOA. Right now still on pre-production phase.
- Veto PDU will be produced in the UK
- Procedures for production and test of PDUs are in place.
- A joint effort from all the collaboration.

Thanks for your attention