

Production and performance of first DarkSide-20k Photo Detector Units

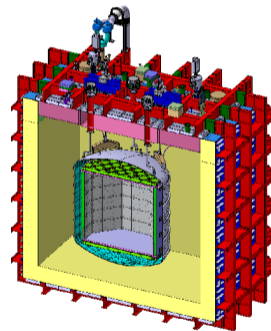
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DarkSide-20k

Direct dark matter search experiment under construction
in Laboratori Nazionali del Gran Sasso (LNGS), Assergi (AQ), Italy



DarkSide-20k (DS-20k) cryostat under construction in Hall C

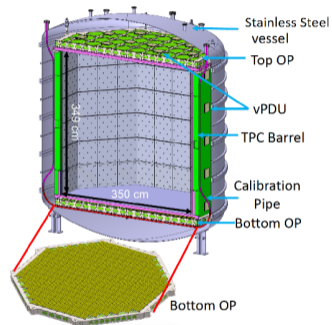
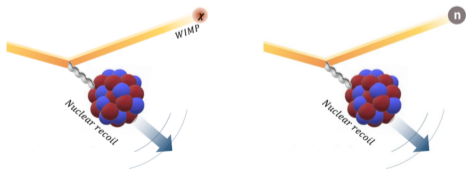
LNGS, view of the external laboratories (top)
and entrance of the underground ones (bottom)

DarkSide-20k backgrounds

Search for a WIMP-nucleus scattering inside the double phase DS-20k Time Projection Chamber (TPC)

Background sources:

- electron recoil (reducible)
 - electrons
 - gammas
 - alpha particles
- nuclear recoil (irreducible)
 - neutrons
 - coherent elastic neutrino-nucleus scattering (CE ν NS)



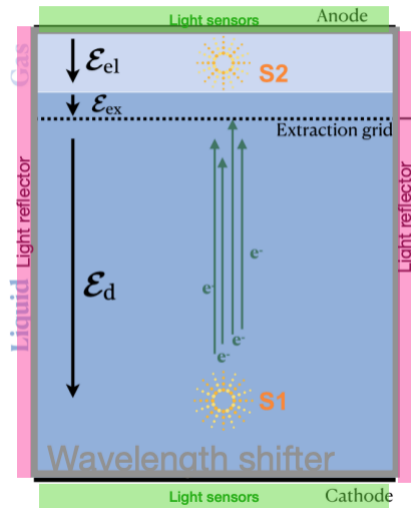
DS-20k veto:

- UAr with SiPM-based optical readout
- Gd-doped PMMA walls for efficient neutron background rejection

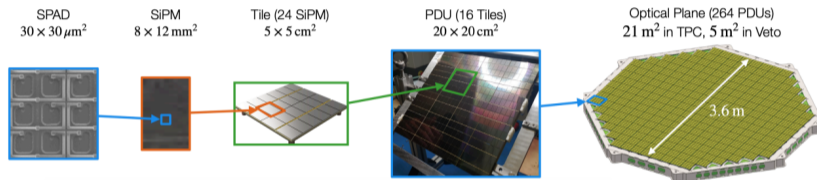
DarkSide-20k Time Projection Chamber (TPC)

DS-20k double phase TPC:

- prompt isotropic scintillation light (S1) from DM scattering off liquid UAr
- 200 V/cm drift electric field
- ionized electrons produce a localized light signal (S2) once arrived in the gas pocket
- SiPM-populated optical planes on TPC's top and bottom
- TPB wavelength shifter to convert 128 nm Ar emission to 420 nm
- 3D event localization (S1 drift time + S2 position)



Tessellation of two 10.5 m^2 optical planes with large-area SiPM matrices



NUV-HD-Cryo SiPM designed by FBK and produced by LFoundry, tested in liquid nitrogen ($T = 77 \text{ K}$)

- Photon Detection Efficiency (PDE) $> 40\%$ at $\lambda \sim 420 \text{ nm}$
- Breakdown Voltage $V_{BD} = 27.2 \pm 0.1 \text{ V}$
- Dark Count Rate (DCR) at 7 VoV: $0.44 \pm 0.01 \text{ Hz/SiPM}$
(preliminary, DS-20k requirement: $< 0.01 \text{ Hz/mm}^2 \implies 0.96 \text{ Hz/SiPM}$)

Production of TPC photoelectronics

Mass production and test of the TPC Tiles in NOA, an ISO 6 Rn-free clean room with an area of 420 m²

Production and test of about 10000 Tiles and 625 PDUs with automated procedures by NOA personnel and shifters from DS-20k collaboration

Storage capacity for all DS-20k TPC photodetectors



Information about the production process stored in the collaboration database

Complete track of Tile test results

Work in progress: daily monitoring of production parameters (die bonding, wire bonding, etc...)

Tile roadmap

SiPM Tiles assembled in Nuova Officina Assergi (NOA):

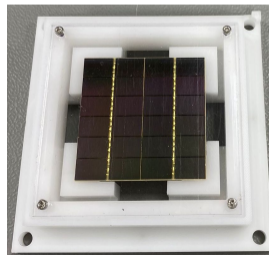
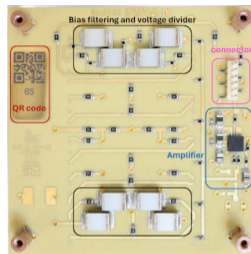
- 24 SiPMs bonded on the same substrate
- 1 output channel amplified by a low-noise cryogenic TIA
- Tile tracking by a unique QR code

Test of all produced Tiles

Tile quality control (under finalization)

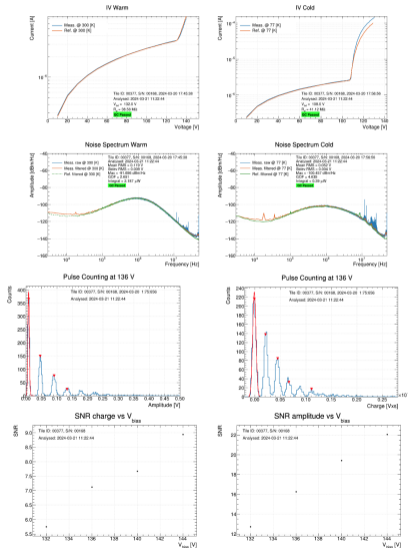
- numerical QC evaluation of measured parameters
- automatic classification uploaded on collaboration database

Only good Tiles will be mounted in DS-20k

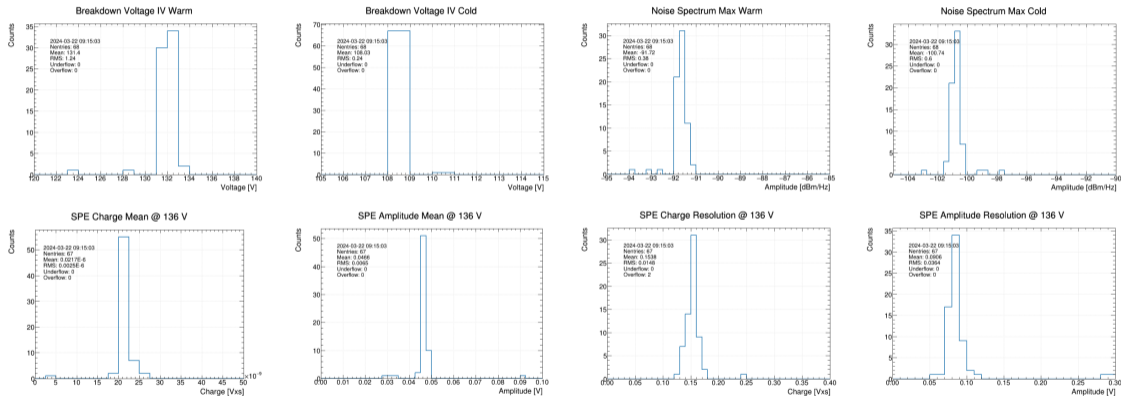


2 LabView-automated test setups for Tiles characterization at warm (room temperature) and at cold (liquid nitrogen)

- 1 current absorption
- 2 I-V curve
- 3 noise power spectrum
- 4 response to laser pulses (only at cold)
 - Signal to Noise Ratio (SNR)
 - Crosstalk probability
 - Single Photo Electron (SPE) resolution
 - Additional Prompt Avalanche (APA)
 - signal rise time and fall time
- 5 warming up in a dry dewar (after cold test)



Cumulative histograms show good uniformity of the relevant parameters across pre-production Tiles



About 70 final-design Tiles tested up to now

PDU assembly

QC compliant Tiles are mounted on a Motherboard

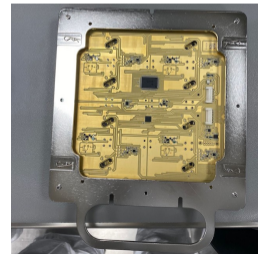
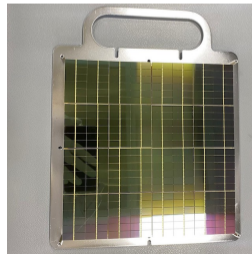
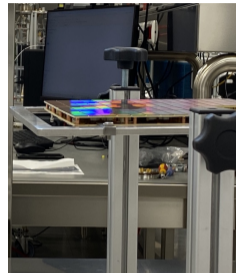
16 Tiles + 1 Motherboard \Rightarrow 1 PDU

Radiopure handlers designed by DS collaboration

PDU specifications:

- common HV & LV bias voltage
- 4 readout channels (quadrants)
- differential output
- enable channel for each Tile
- microcontroller for remote ID query
- complete status tracking via QR code

Dedicated protecting boxes to ship assembled PDUs to the test facility in Naples (see next slides)



PDU shipping test

Assembled PDUs are tested at warm to verify their integrity before to be shipped to Naples

Check of quadrant and Tile functionality:

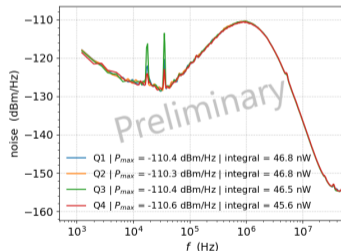
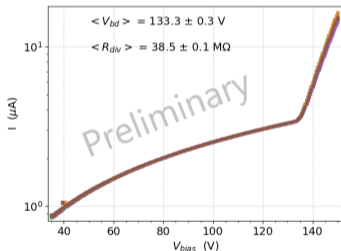
- 1 current absorption
- 2 I-V curve
- 3 noise power spectrum

Manual test up to now, automation with LabView in progress

A twin receipt test is foreseen when they will come back to NOA

QC compliant PDUs will be sealed in vacuum until their mounting on DS-20k optical planes

Latest data (PDU 21)

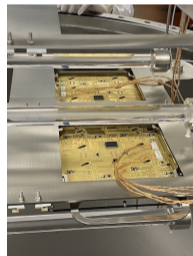
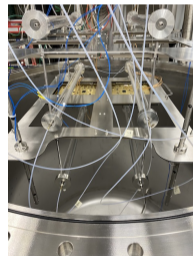


PDU performance

The PDUs produced in NOA will be tested within the Cryogenic Test Facility (CTF)

- ISO 6 clean room in the University of Naples
- mechanical structure to host up to 16 PDUs
- expected test time with 16 PDU loaded: 1 week

Warm and cold tests will be carried out with cabling length and instrumentation similar to DS-20k



Preliminary operations before the start of CTF:

- 1 filter for liquid nitrogen
- 2 remote control of multiple PDUs

Summary and conclusions

Joint effort for DS-20k TPC detectors production and test

NOA production facility (INFN-LNGS)

- possibility to produce thousands of large-area SiPM matrices
- tracking of production parameters
- quality assessment and tracking of SiPM tiles
- ready for safe detector shippings to the PDU test facility

CTF (Federico II University - INFN Naples)

- cryogenic setup for PDU performance study
- long-term operation PDU test
- testbench for DarkSide-20k cabling

The NOA team



Thank you for the attention!