The cryogenic electronics for Dark Side

SiPM readout

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on behalf of the
Dark Side Collaboration
The Dark Side overview

Proto 0
- 10 kg
- 38 PMTs

Proto 1 t
- 9000 SiPMs

DS 50
- 50Kg
- 50 SiPMs

DS 20 K
- 50 ton
- 50Kg
- 48 SiPMs

Towardss to the Global Argon Dark Matter Collaboration

Dark Side
- MiniClean
- Deap 3600
- ArDM

ARGO
- 300 ton

200000 SiPMs

50Kg

50 ton

50Kg

50Kg
DarkSide 20K

- A sealed acrylic vessel as TPC filled with 50 tons of Underground Argon (~ 8280 channels)
- Drift length 3.5 m
- nVeto with 2% Gd doped acrylic panels (~3000 channels)
- Membrane cryostat filled with Atmospheric Argon: based on the ProtoDUNE cryostat
- Silicon Photo Multipliers (SiPMs) instead of PMTs
DarkSide PhotoElectronics requirements

A sinergy between INFN PE groups & FBK started in 2014 for an R&D aimed to

- Increase PDE and reduce DCR and correlated noise
- High coverage area containing the number of channels (about 28 m² of single photon sensitive surface in LAr with 8280 readout channels)
- Fast and extremely low noise cryogenic electronics (SNR, timing)

For a single channel 5 x 5 cm²
- PDE > 40% at 420 nm
- Total Primary Noise Rate < 0.1 Hz/mm²
- SNR > 8
- Time resolution O(10ns)
- Power dissipation < 250mW
- Dynamic Range > 50 PE

All materials are screened for the radiopurity qualifications (sub mBq/kg)
Dark Side 20K Photo Detection Unit

The tile: Array of 6 x 4 NUV-HD Low Field SiPMs 12 x 8 mm² each

Single channel PhotoDetector Module (PDM) integrates a single tile and its FEB

LAr TPC top/bottom view: 8280 PDMs (200000 SiPMs)

The Front End Board inserted in an acrylic cage

The Motherboard: a matrix of 5 x 5 PDMs each with 24 cm² active surface

The Front End Board inserted in an acrylic cage

25 PDM
The Cryogenic Front End Board

Each 12 mm x 8 mm SiPM is a current generator+ high output capacitance (~50pF/mm²). High Bandwidth, Low Noise and low power dissipation cryogenic preamplifier.

TIA design to read a quadrant of the single tile (6 cm²)

BW >30 MHz @77 K

To combine 4 quadrants, 4 TIA pre-amplifiers each of them connected to 6 SiPMs are summed together by an adder with a differential output

FEB Power dissipation 250 mW
A voltage regulator and a microC to identify PDMs
Final PCB material: Pyralux
PDM performances

Gain: 52.68
σPED: 2.19
SNR = Gain/σPED : 24.1

DATA FROM A SINGLE TILE
24 cm² 30 µm 5 MΩ 7 VoV

Time Resolution
3.5 ns at 1PE
MB performances

July 2019: first successful demonstration test of MB1 in LAr
MB2 will be operated in LAr by the end of October 2019

Integrated acrylic TPC for S2 study with SiPMs as photosensors

DS-Proto0 2 MB

NUV-HD-LF cryo

Stable at 77 K up to 5 VoV DCR ~ 5 mcps/mm^2

SNR 20

Stable at 77 K over 9 VoV DCR ~ 5 mcps/mm^2
The Steering Module

The steering module provides the power lines and communicates by enabling/disabling the PDMs on the MB.

The first prototype produced in BNL and has been modified on the way to minimize the number of the conductors. Presently signals are routed across 13 pin of a Micro D connector to a custom cryogenic cable designed ad “hoc”.

Not radiopure materials at the moment. Successfully tested in September @ LNGS
Optical Transmitter

Optical fibers instead of copper for signal transmission to reduce the huge amount of the cabling, minimize the total radioactivity budget for the cables and get high noise immunity

- very good linearity, low noise, low power, high dynamic range
- The single channel prototype has been designed and tested @LNGS. The circuit is based on a differential receiver that generates the output single ended and a V-I converter with a high speed LED connected to an optical fiber which brings the signal outside the cryostat
- The Cagliari group has produced a 25 channels version
Optical Receiver

The optical receiver turns back the optical signal to differential (or single ended) for the DAQ digitizers.

- LNGS group designed and tested the one channel prototype.
  - Bologna has implemented a high-density module including a 3D printed LC connector that incremented the output signal of 50%.

The design is finalized, now is being built.
Mass production: the NOA facility

- 10000 PDM to be built
- The production procedures (electronics & packaging) will demand high reliability
- R&D on SiPM in collaboration with FBK (started in 2014) almost concluded
- FBK NUV-HD “Know how” transfer to LFoundry for massive production.
- Packaging in the new NOA facility @LNGS to be commissioned by next summer.
- Cleanroom installation by Sept 2020
Summary and perspectives

- The unique features of Dark Side 20K are the large volume TPC filled with UAr and the SIPM technology on a massive scale.
- INFN and FBK R&D came up with the choice of the NUV HD LF cryo SIPM.
- Huge work from all the PE groups to develop the full readout electronics
- PDM performance well above the DS-20k requirements
- Successful demonstration test in July 2019 of DS20k-Proto-0 of the first MotherBoard in a vessel filled with LAr.
- Proto-0 test: 2 MotherBoards and TPC (end of October 2019) and Proto 1-ton construction (2020)
- NOA packaging facility for massive production by September 2020
Thanks for Attention!
The MotherBoard architecture

First DS 20k MotherBoard installation: 25 PDMs assembled in September 2018. Signal extraction via analog optical transmission.

The copper mechanical structure of the MB that hosts all components and efficiently dissipates heat in LAr target, minimizing the bubble production.

Kapton finger strip
Provides electrical connections to the PDMs: LV to the FEBs Vbias to SiPMs, enable to TIAs and differential signals for the optical transmitter.

Back side: 2 connectors for the steering module and 3 for the optical module.

Front side: connectors for FEBs.
Packaging

PCB tile in Arlon. Materials and components are currently being selected and assayed to ensure radiopurity.

Presently: cryogenic conductive epoxy on the tile back side. DS-20k: bump-bonding with low-temperature solder.

Dual head manual die bonder in LNGS.

Now: wire bonding DS-20k: TSV.