The cryogenic electronics for Dark Side SiPM readout

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on behalf of the
Dark Side Collaboration

Istituto Nazionale di Fisica Nucleare

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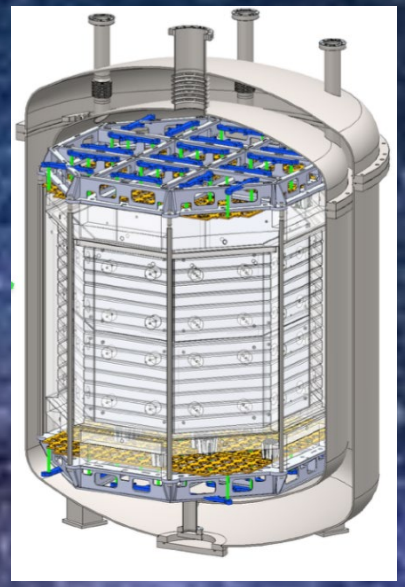
The Dark Side overview

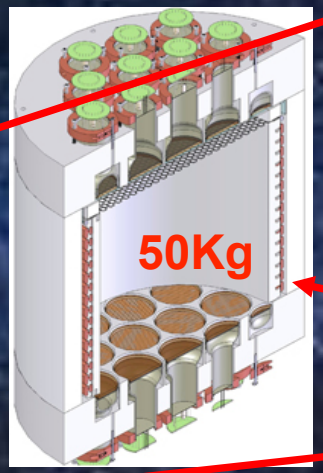


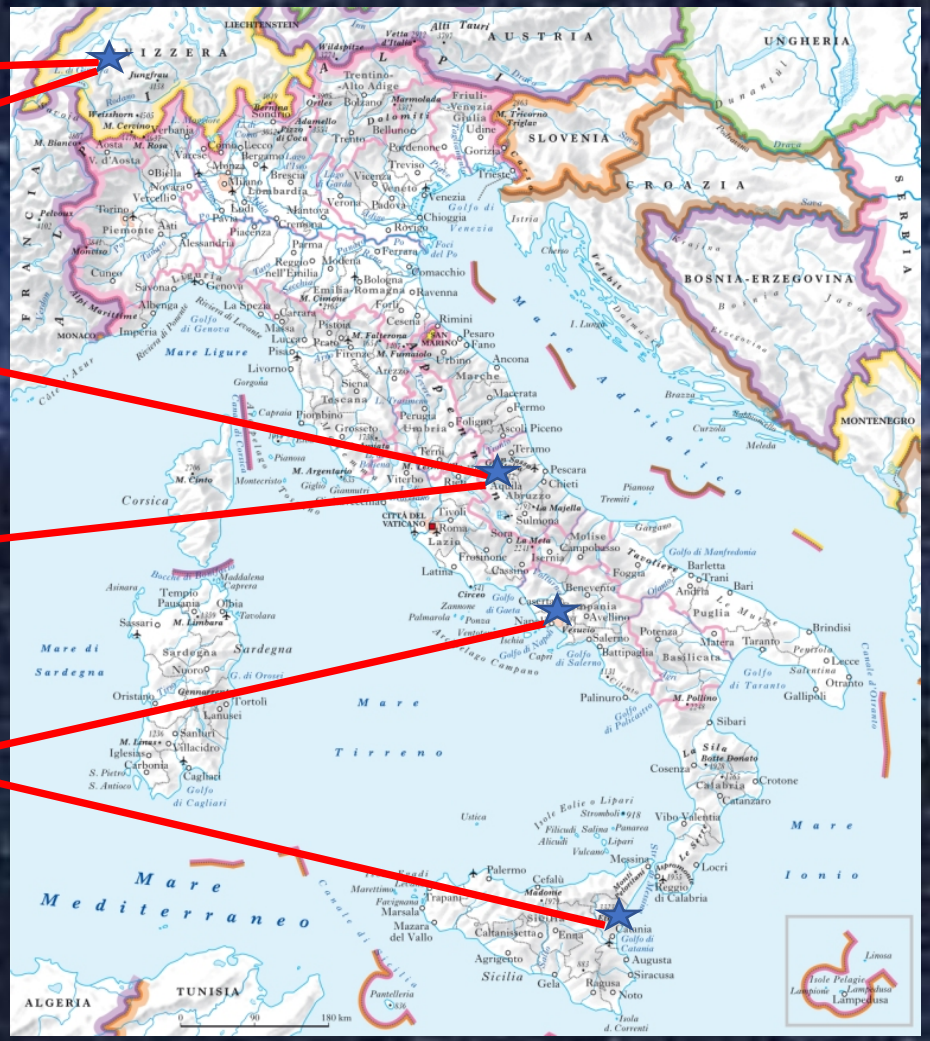
Proto 0
10 kg

Proto 1 t
9000 SiPMs

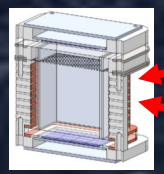
1200 SiPMs

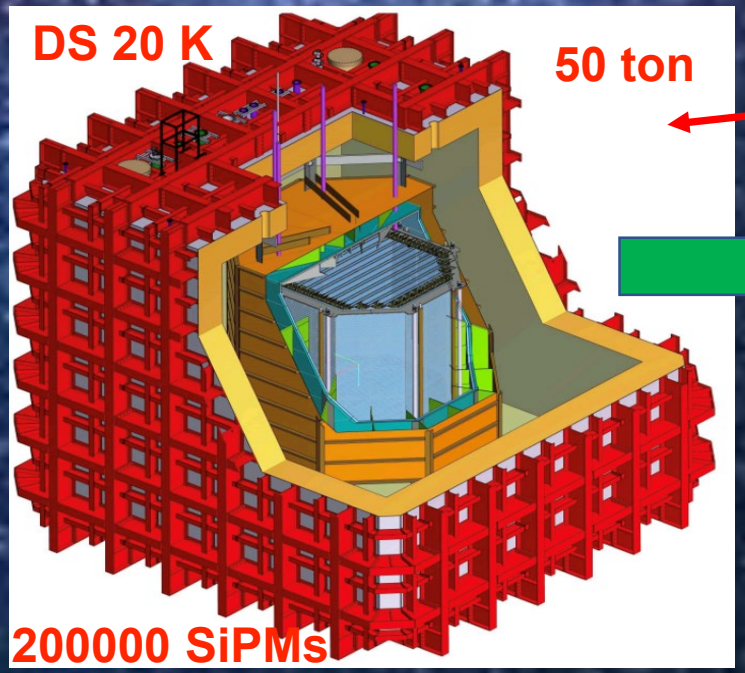
DS 50
38 PMTs





ReD
48 SiPMs





Towards to the
Global Argon Dark Matter
Collaboration

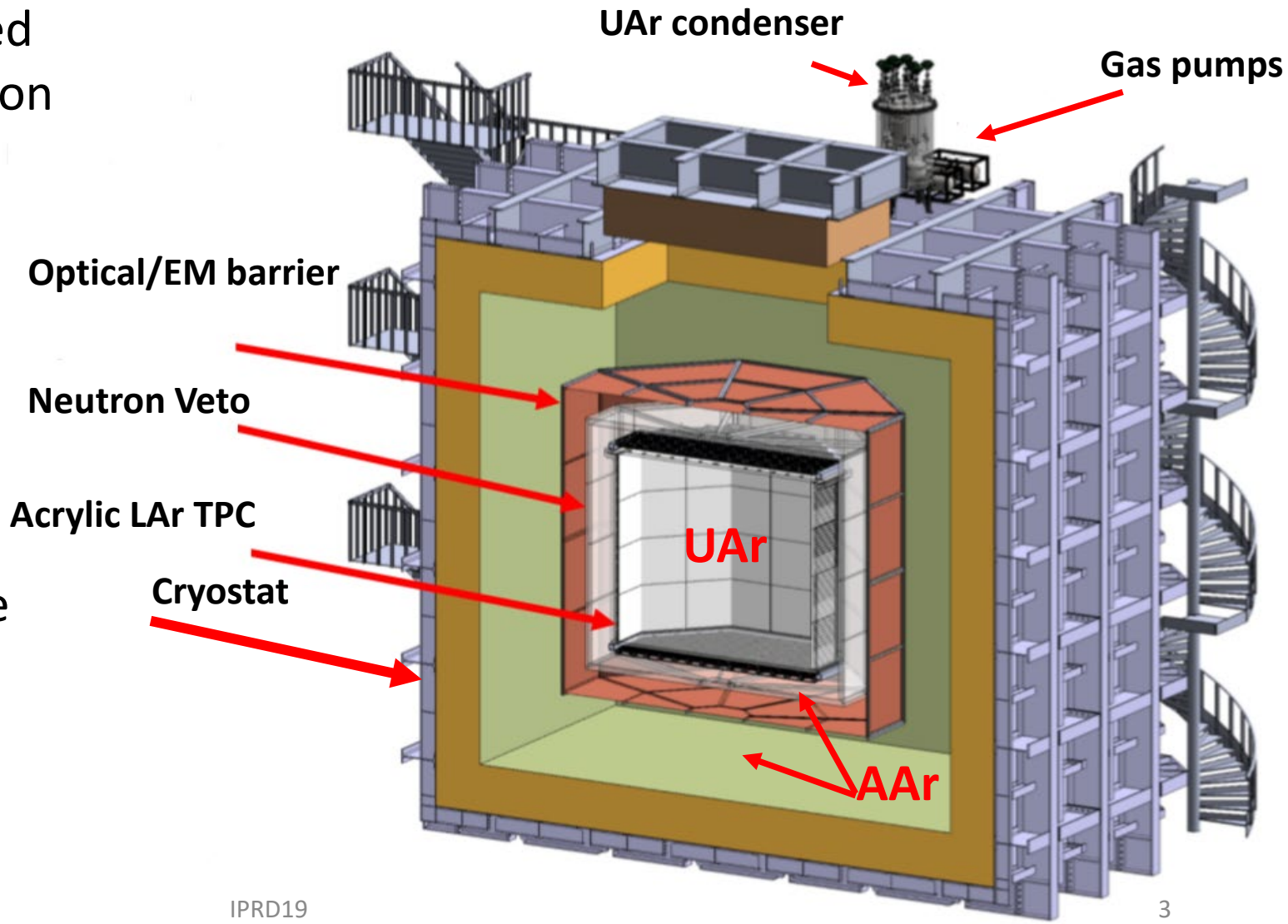
Dark Side
MiniClean
Deap 3600
ArDM

ARGO
300 ton

IPRD19

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

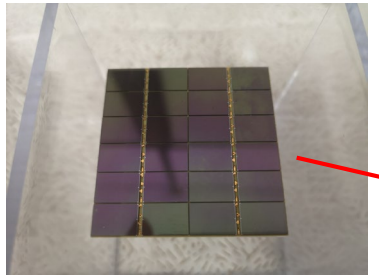
- Increase PDE and reduce DCR and correlated noise
- High coverage area containing the number of channels (about 28 m2 of single photon sensitive surface in LAr with 8280 readout channels)
- Fast and extremely low noise cryogenic electronics (SNR, timing)

For a single channel 5 x 5 cm2

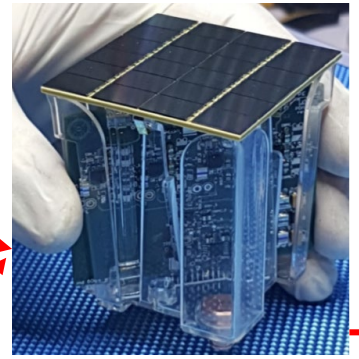
- PDE > 40% at 420 nm
- Total Primary Noise Rate < 0.1 Hz/mm2
- SNR > 8
- Time resolution O(10ns)
- Power dissipation < 250mW
- Dynamic Range > 50 PE

All materials are screened for the radiopurity qualifications (sub mBq/kg)

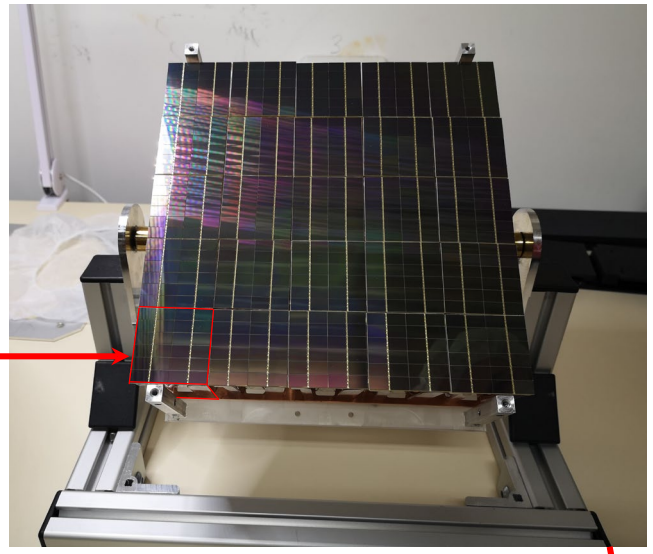
Dark Side 20K Photo Detection Unit



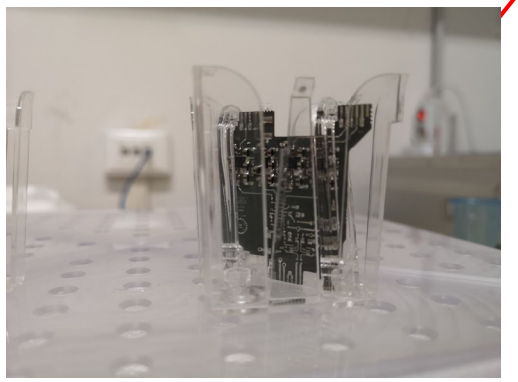
The tile: Array of 6 x 4 NUV-HD Low Field SiPMs 12 x 8 mm2 each



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

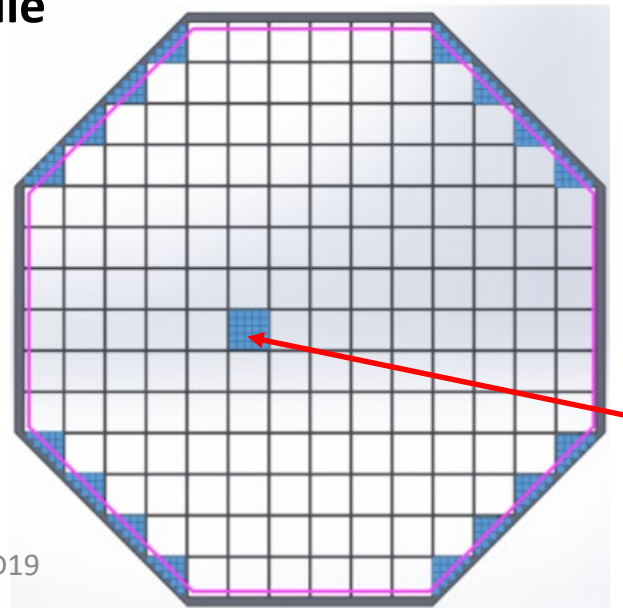


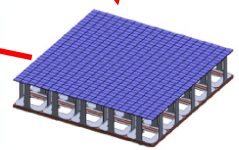
The Motherboard: a matrix of 5 x 5 PDMs each with 24 cm2 active surface



The Front End Board inserted in an acrylic cage

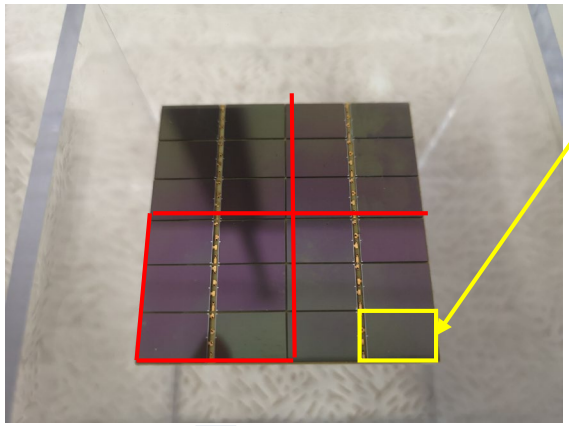
LAr TPC top/bottom view: 8280 PDMs (200000 SiPMs)





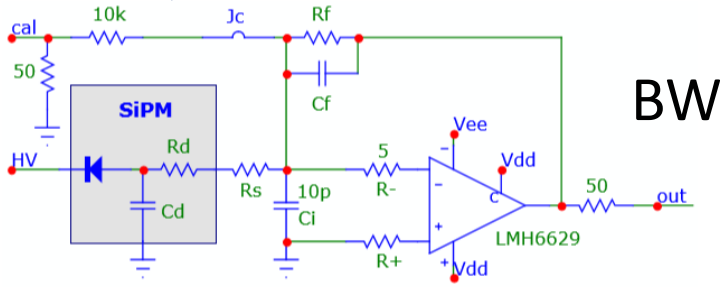
25 PDM

The Cryogenic Front End Board

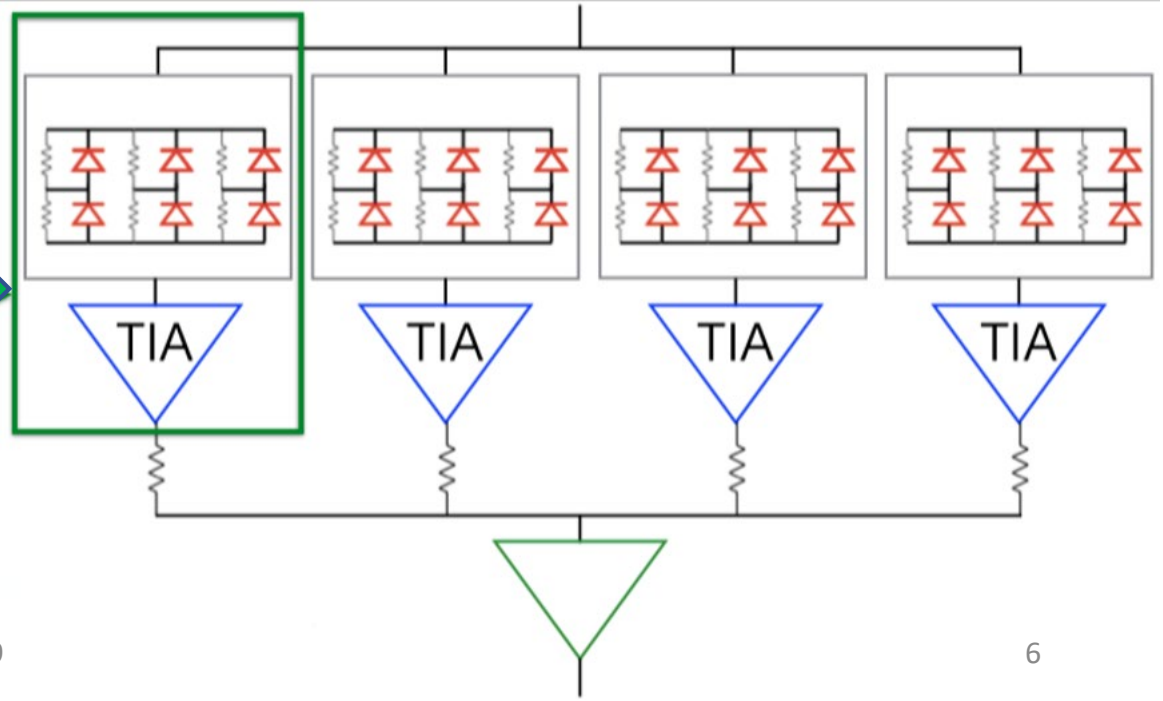


Each 12 mm x 8 mm SiPM is a current generator+ high output capacitance (~50pF/mm2).
High Bandwidth, Low Noise and low power dissipation cryogenic preamplifier.
TIA design to read a quadrant of the single tile(6 cm2)

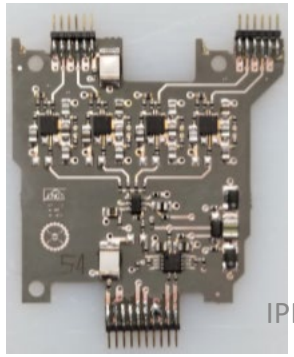
To combine 4 quadrants, 4 TIA pre-amplifiers each of them connected to 6 SiPMs are summed together by an adder with a differential output



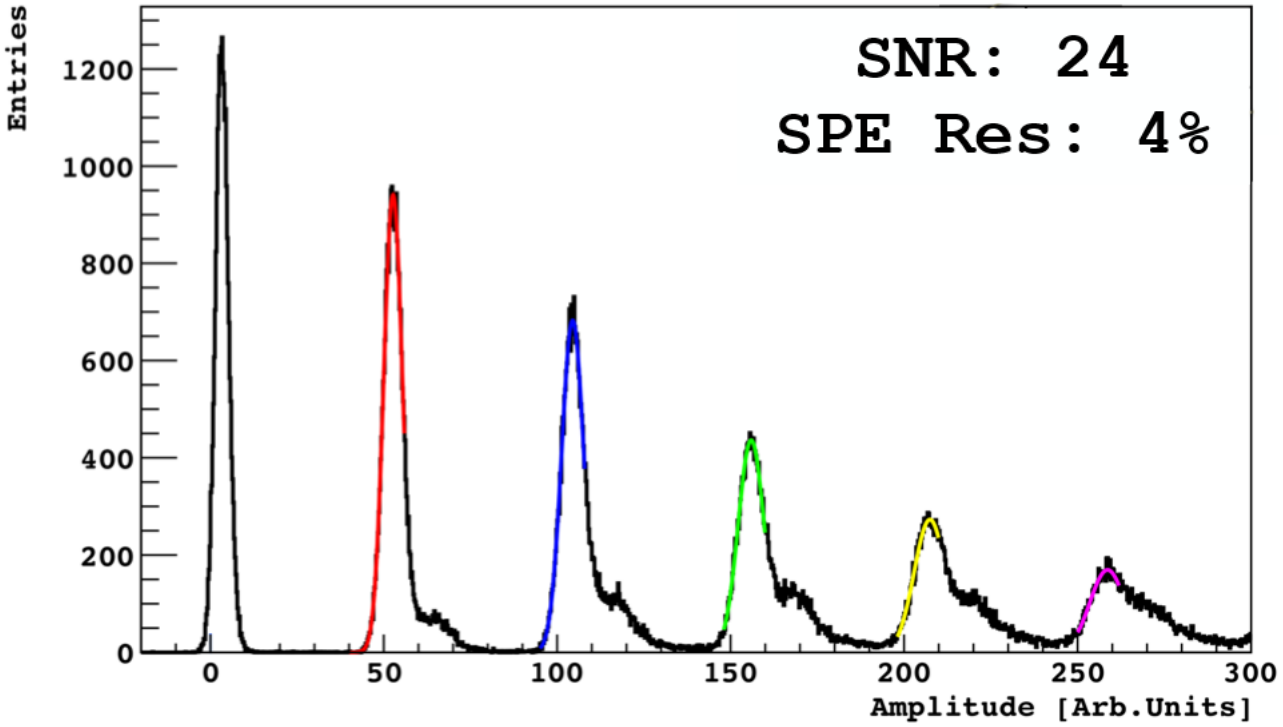
BW >30 MHz @77 K



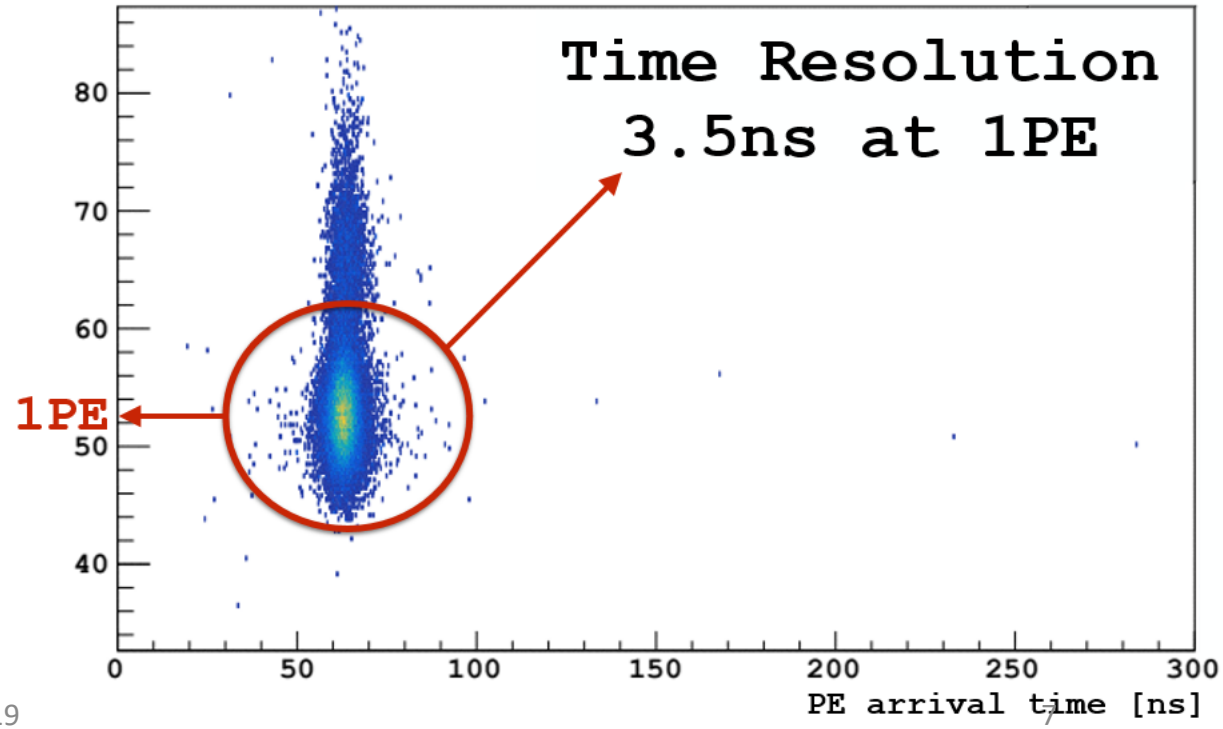
FEB Power dissipation 250 mW
A voltage regulator and a microC to identify PDMs
Final PCB material: Pyralux



PDM performances

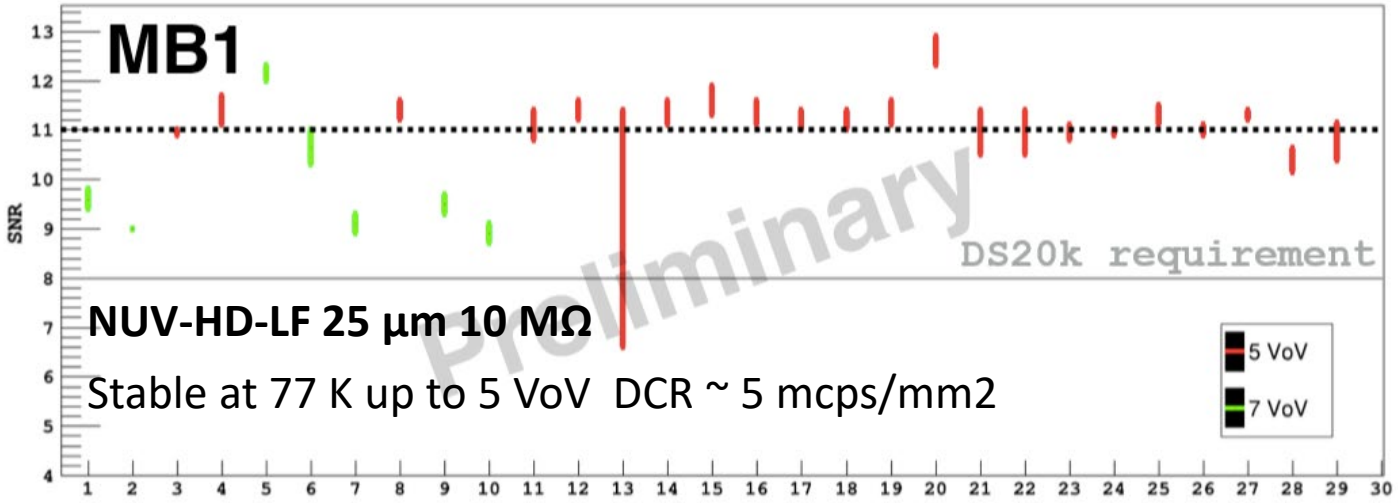


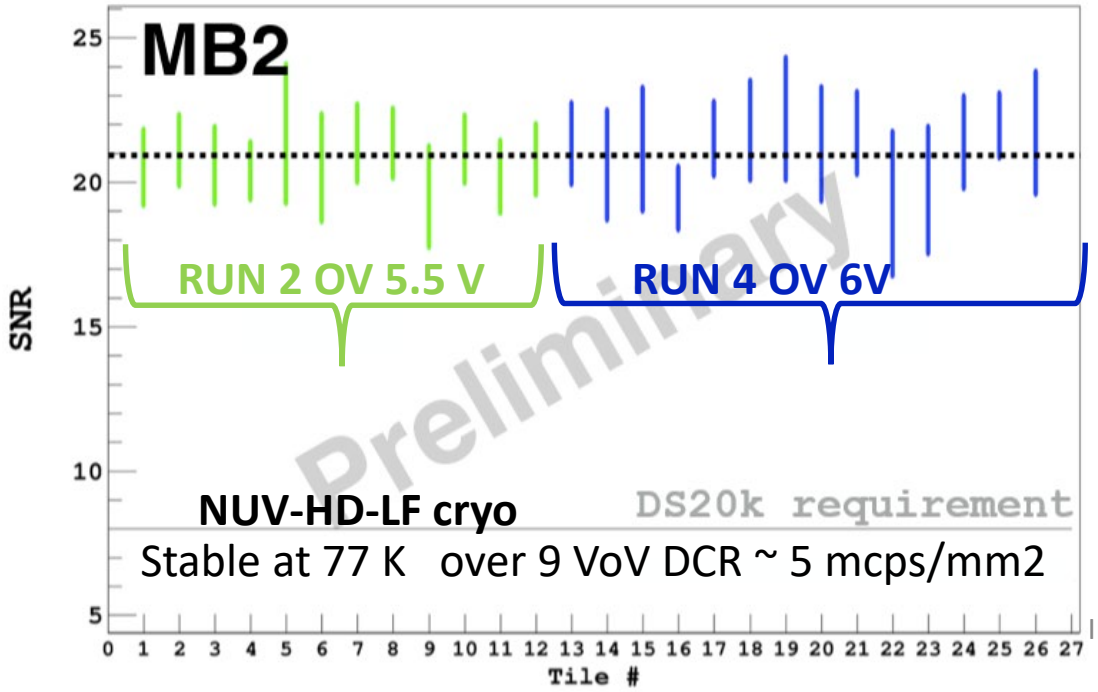
DATA FROM A SINGLE TILE
24 cm2 30 µm 5 MΩ 7 VoV



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

MB performances

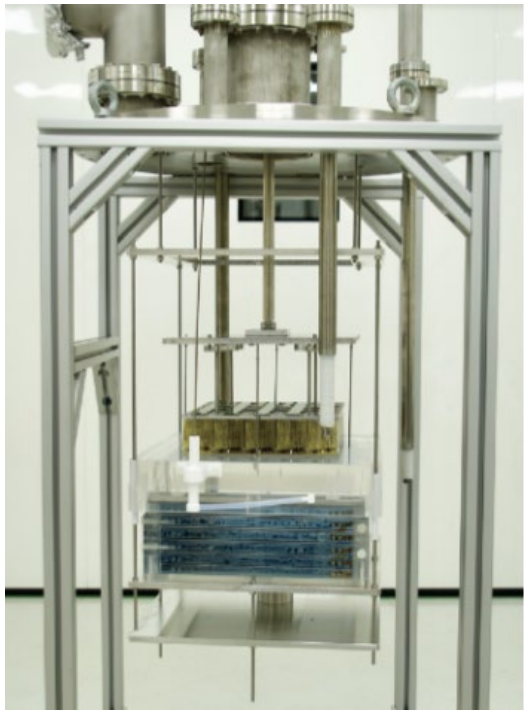




SNR 20

DS-Proto0 2 MB

Integrated acrylic TPC for S2 study with SiPMs as photosensors



July 2019: first successful demostration test of MB1 in LAr

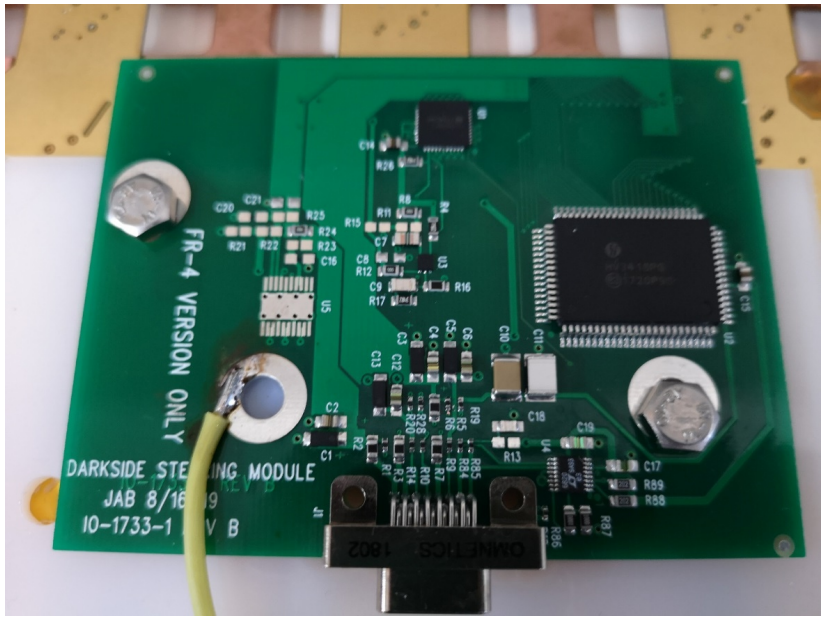
MB2 will be operated in LAr by the end of October 2019

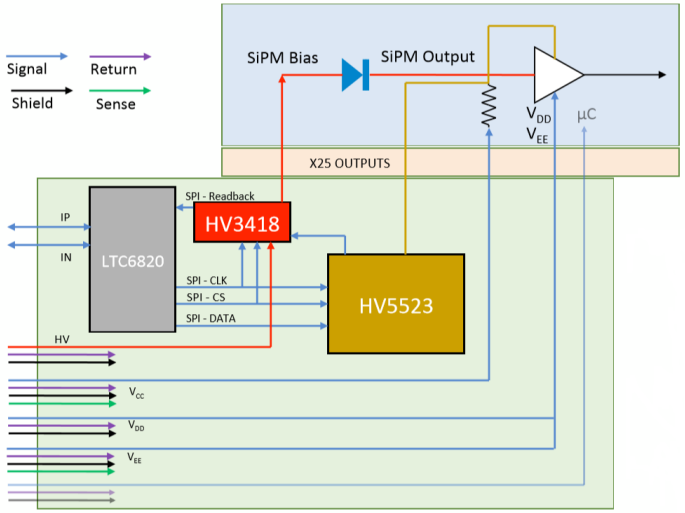
The Steering Module

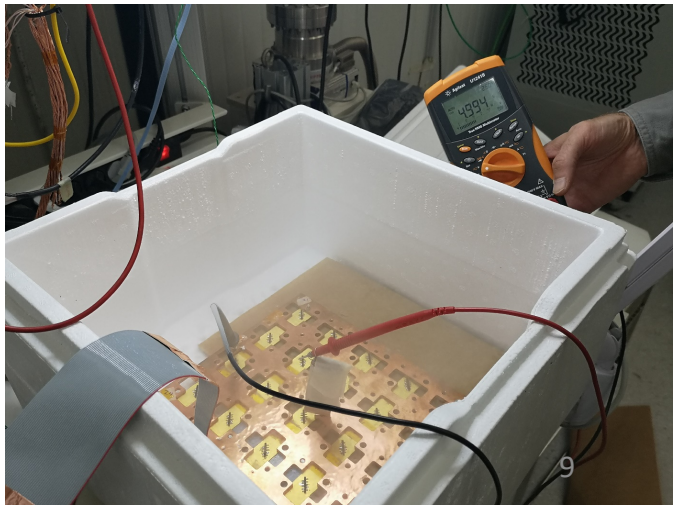
The steering module provides the power lines and communicates by enabling/disabling the PDMs on the MB.

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”.

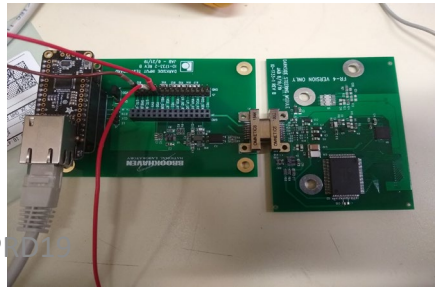
Not radiopure materials at the moment. Successfully tested in September @ LNGS







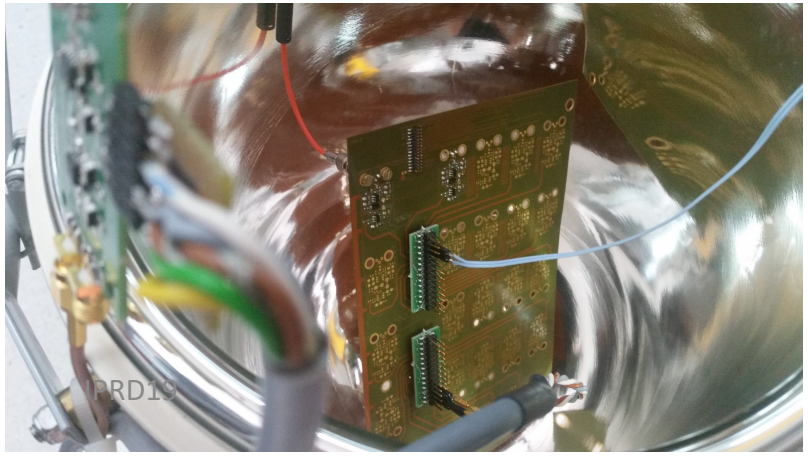
LTC communication board

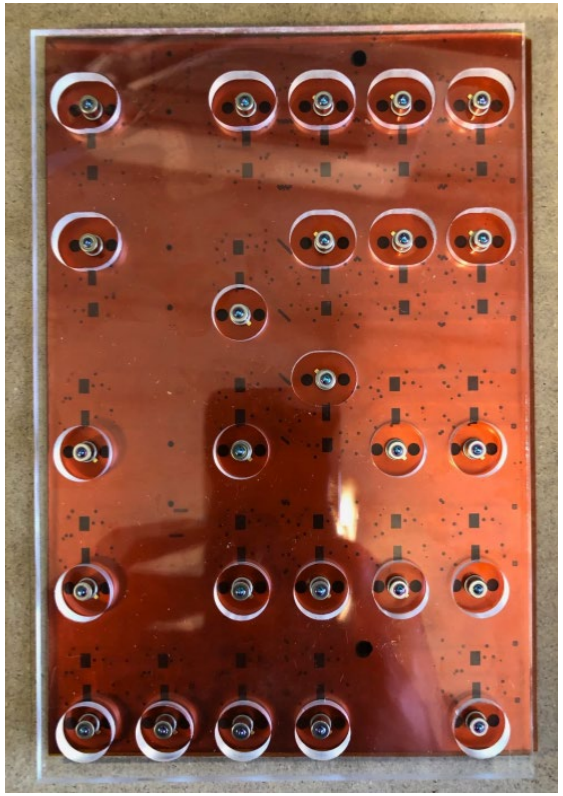


Optical Transmitter

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

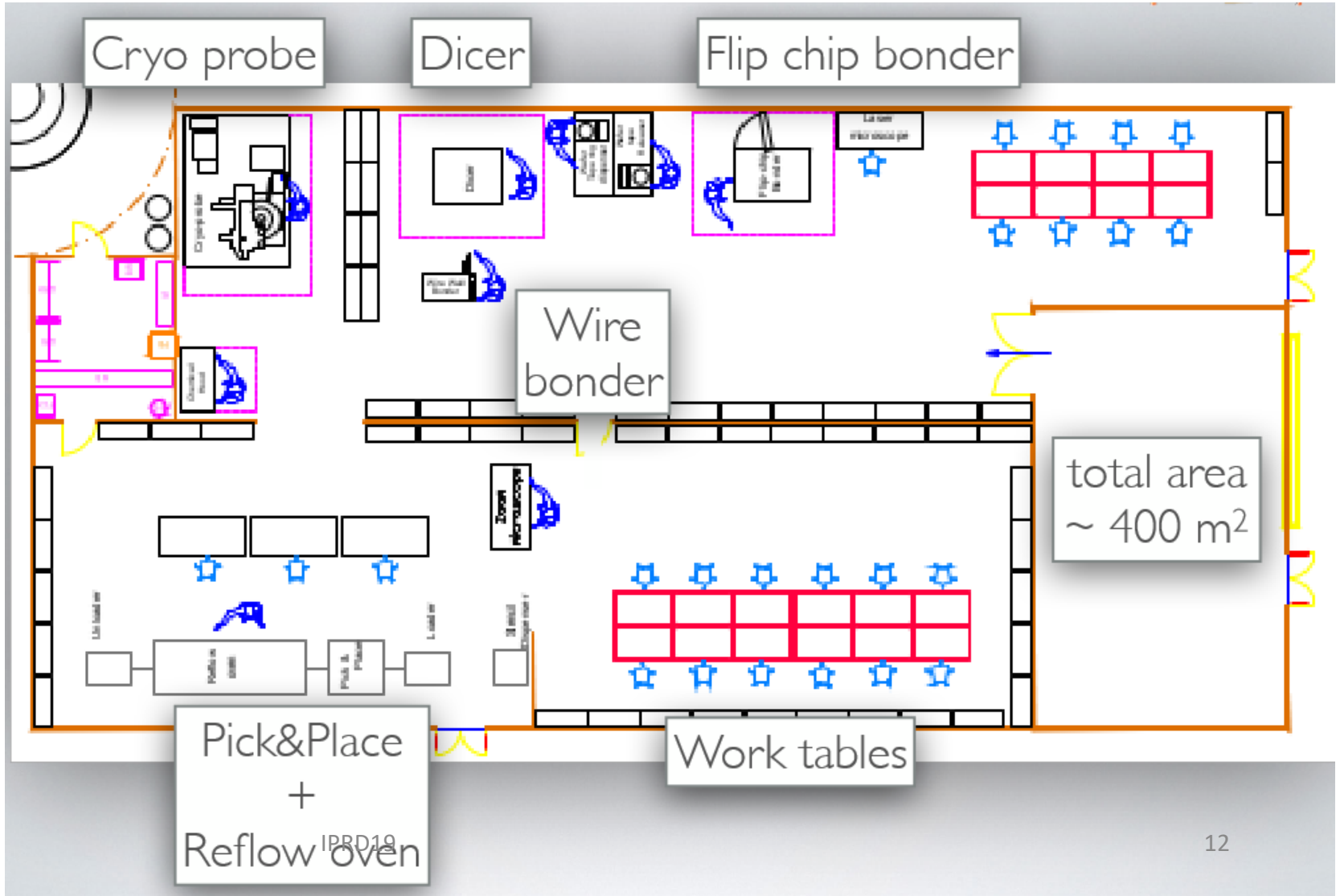
- LNGS group designed and tested
  the one channel prototype

- 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

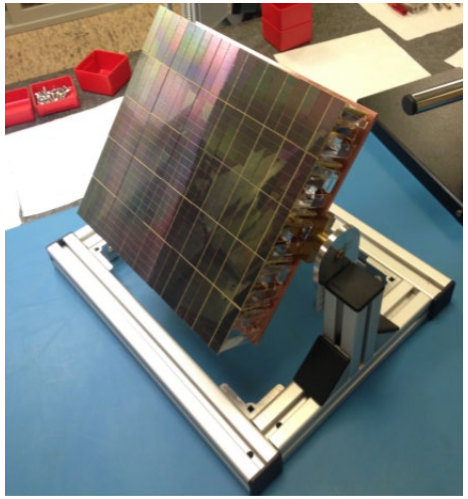
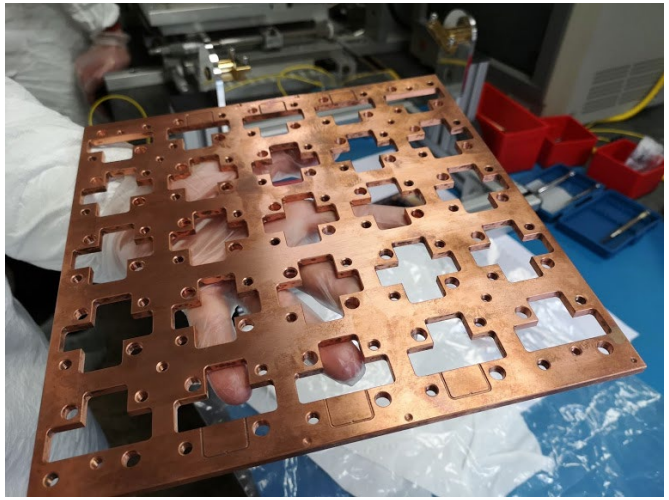
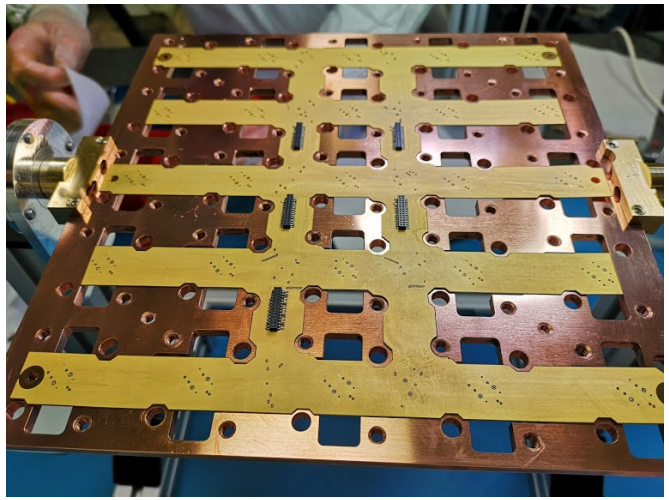
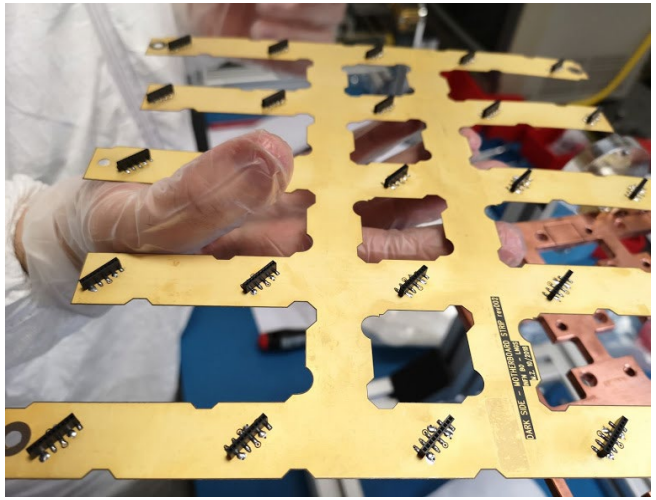


Summary and perspectives

- 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


darkside
two-phase argon TPC for Dark Matter Direct Detection
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

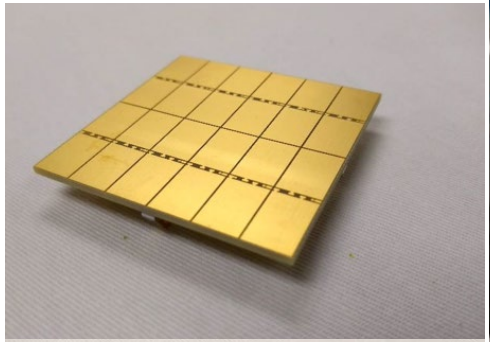
Kapton finger strip

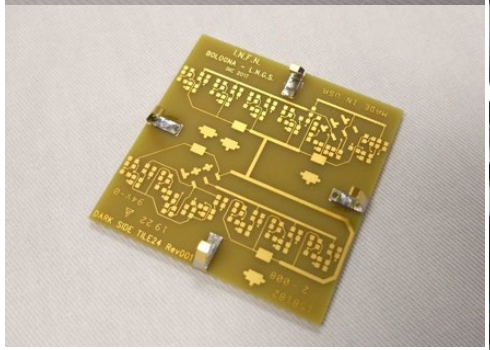
Provides electrical connections to the PDMs: LV to the FEBs Vbias to SiPMs, enable to TIAs and differential signals for the optical transmitter

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

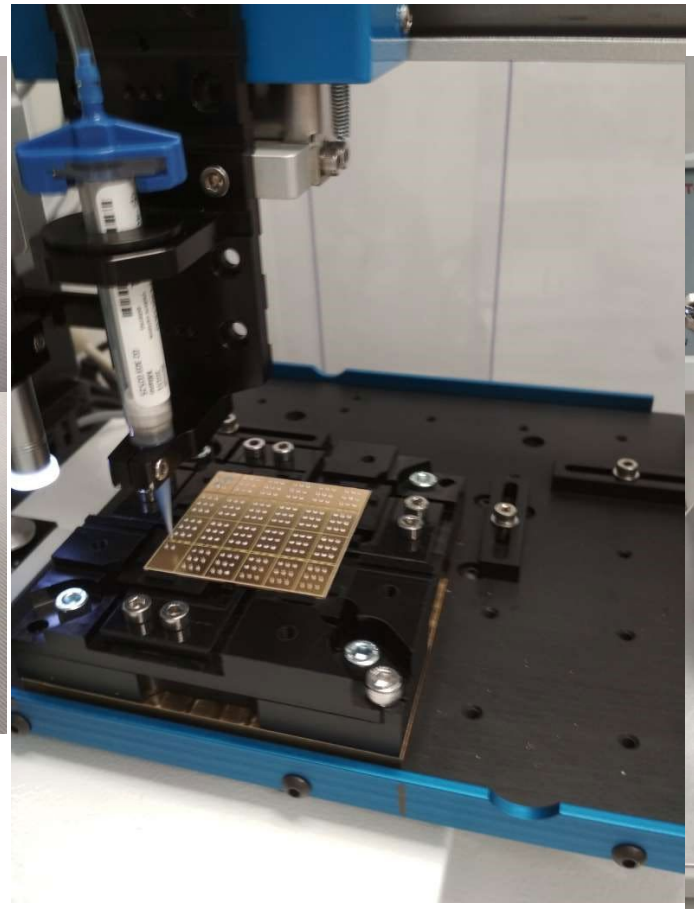
Front side: connectors for FEBs

Packaging



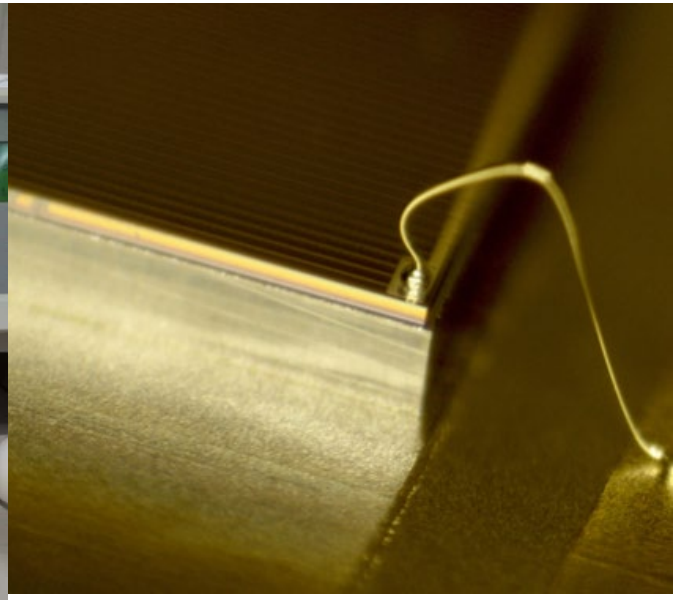


PCB tile in Arlon. Materials and components are currently being selected and assayed to ensure radiopurity



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