Proposed EU contribution to the VD PDS

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DUNE FD-2 (VD) Photon Detector Workshop

26 July 2021

GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

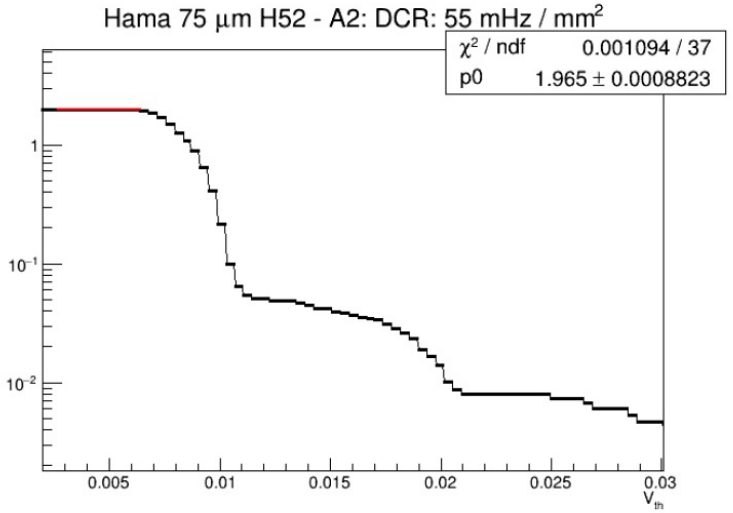
EU Institutions

- **Italy**: INFN Bologna, Ferrara, Genova, LNS, Milano, Milano-Bicocca, Napoli
  - Strongly involved in the design and construction of the HD-PDS especially on SiPMs and cold electronics
  - Significant expertise in most of the items (SiPMs, WLS bars, cold and warm electronics, dichroic filters); see the forthcoming talks by A. Montanari and C. Cattadori
  - Supported by several infrastructures for SiPM testing (Milano, Mi-Bicocca), development of cryogenic photosensors and electronics (Naples/Darkside), cold electronic (LNS, Milano, Mi-Bicocca), tests of supercell (Milano, Mi-Bicocca)
  - Additional groups interested to contribute specifically on the VD
- **Spain**: CIEMAT Madrid, IFIC Valencia, University of Granada
  - Leaders of ProtoDUNE-DP PDS
  - Strong technical and scientific teams involved in SiPMs, cold electronics, mechanics, light simulation, prototyping for HD PDS with infrastructures for LN2 and LAr setups
  - Additional groups interested (U. Santiago)
- **Czech Republic**: Institute of Physics of the Czech Academy of Science (FZU), Institute of Experimental and Applied Physics (IEAP), Czech Technical University (CTU) → see tomorrow's session
  - HD-PDS SiPMs and electronics involvement
- **France**: APC Paris
  - Optocoupler and readout electronics for the VD PDS
- In contact with **other EU institutions** that expressed interests

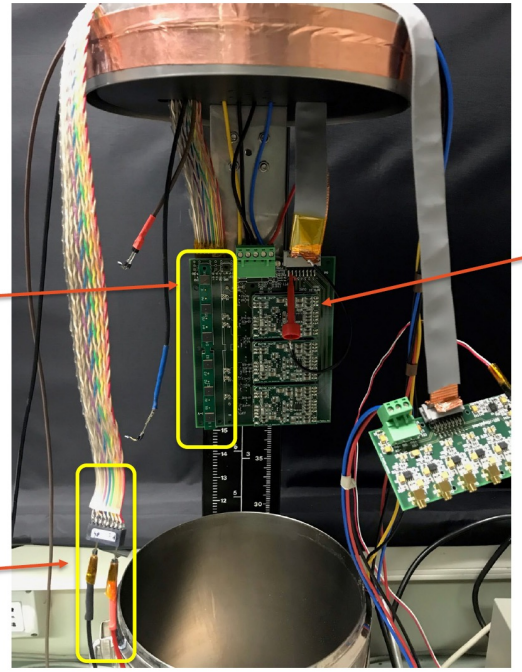
Expertise of the Italian groups in PDS

- **INFN Bologna**: SiPMs development at 87 K, cryogenic electronics, designer and production center of the mass test facility for HD-FD
- **INFN Ferrara**: decade long expertise on SiPMs and analog electronics, designer and production center of the mass test facility for HD-FD
- **INFN Genova**: involved in all items concerning cryogenic photosensors and cold integrated electronics (GRAIN in the DUNE-ND, HD-FD and DarkSide)
- **INFN LNS (Laboratori Nazionali del Sud):** decade long expertise in photosensors, cryogenic systems and electronics in extreme environment. Designer of the mass test facility for the cold electronics of HD-FD
- **INFN Napoli**: decade long expertise in cryogenic SiPMs, analog and digital electronics at 87K, mass characterization of large area cryogenic SiPMs (Darkside), light detection in liquid Argon (hardware, simulation and data analysis)
- **INFN Milano and Milano-Bicocca (+Univ. of Insubria, Milano, Milano-Bicocca):** development of cryogenic SiPMs and cold electronics (HD-FD, DarkSide), WLS bars, coating for light trapping and frequency shifting. Designer of the cold electronics for HD-FD and of the cold-warm interface. Integration of the HD PDS (grounding, APA interface), simulation of electronic components at 87 K, material screening. Simulation and analysis of the HD-FD

Bologna and Ferrara: cryogenic lab and mass test facility

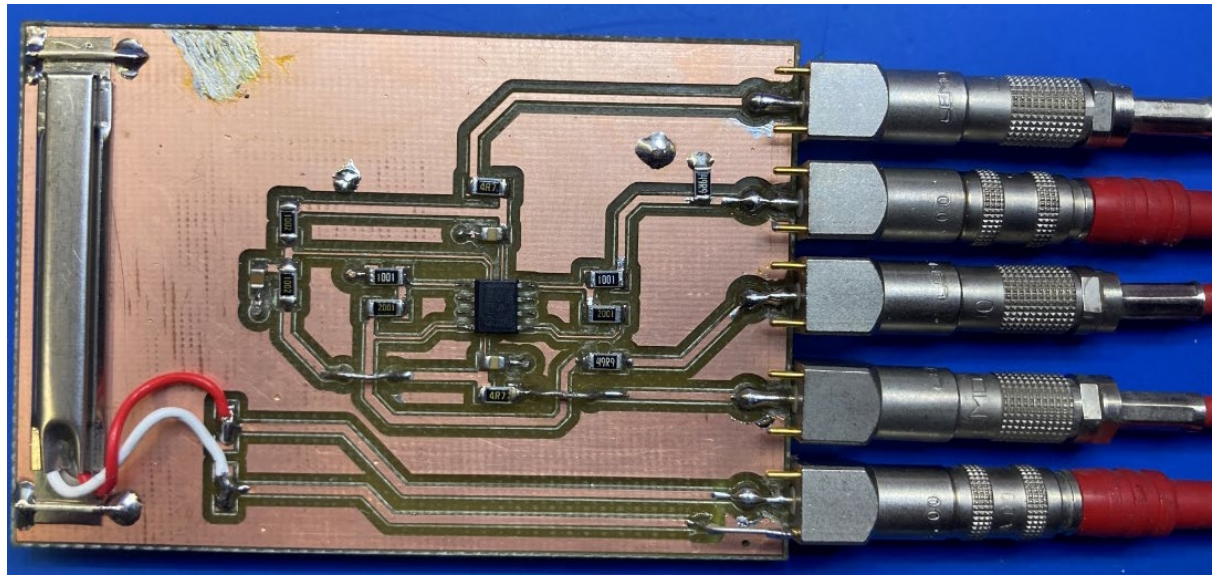


Setup:



- Strong synergies with the DarkSide group: DUNE-DarkSide task force for the design of the VD optocoupler (see S. Sacerdoti's talk)
- Investigation of bursts in cryogenic SiPMs and possible mitigation in the VD (see A. Montanari's talk)

Milano and LNS: LASA and the infrastructure of LNS



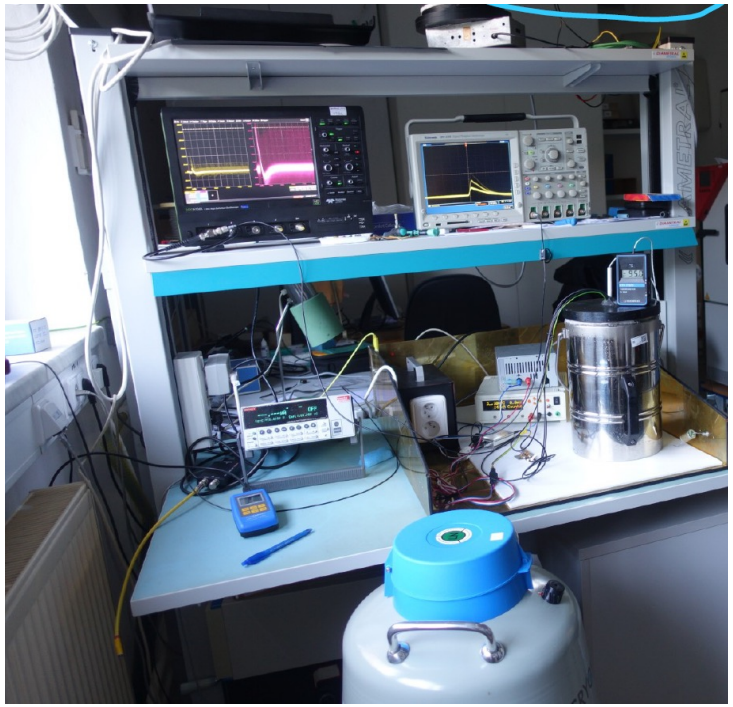
- Already involved in the VD simulation (P. Sala) and design
- Significant expertise in optoelectronics thanks to the collaboration with Univ. of Parma (new group interested in the VD developments)

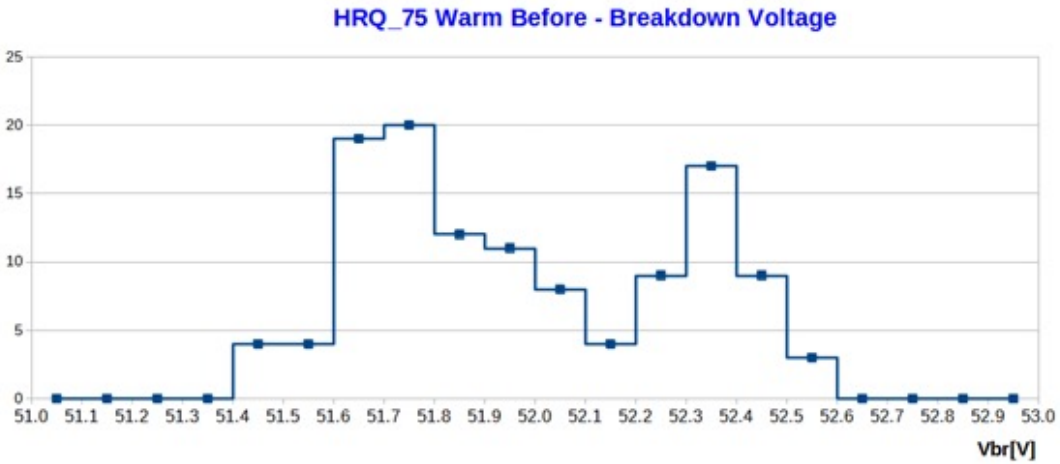
Milano-Bicocca and Univ. of Insubria

- Already involved in the design of the VD: WLS bars, flexi board- SiPM- bar coupling, simulation of electronics (E. Cristaldo), SiPM development and investigation of new dichroic filters (see A. Montanari and C.Cattadori's talk)

Czech Republic

- One of the leading groups in the HD-FD PDS with major expertise in cryogenic photosensors and cold electronics.
- New Czech groups are already active in the VD design and simulation





Downselected sensors from Hamamatsu for HD-FD (Prague, March 2021)

Expertise of the Spanish groups in PDS

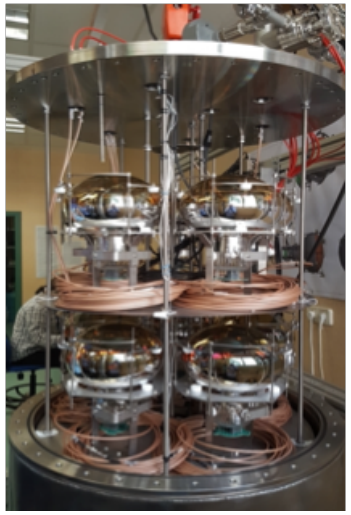
- Dual-Phase Photon Detection System:
  - Responsible for the whole ProtoDUNE-DP PDS system; Consortium Leader (I. Gil-Botella)
- Long experience in light detection with SiPMs from the NEXT experiment
- Current PDS involvement:
  - Light simulation → co-convenor of DUNE PDS Simulation and Physics WG (M. Sorel), convenor of SBND PDS Simulation and Reconstruction WG (D. García-Gámez)
    - Preparation of the VD CDR
  - Photon Collectors → co-convenor of VD PD PhCollector WG (C. Palomares)
  - Photosensors → co-convenor of Photosensor WG (I. Gil-Botella)
    - SiPM characterization, downselection and purchase for ProtoDUNE-II and DUNE 1st FD
    - Development of an automated system for SiPM mass characterization
    - SiPM ganging
    - X-ARAPUCA supercell mounting and testing in LN2 and LAr (production & testing center for ProtoDUNE-II)
  - Anode reflectance: Measurements of reflectance of several materials

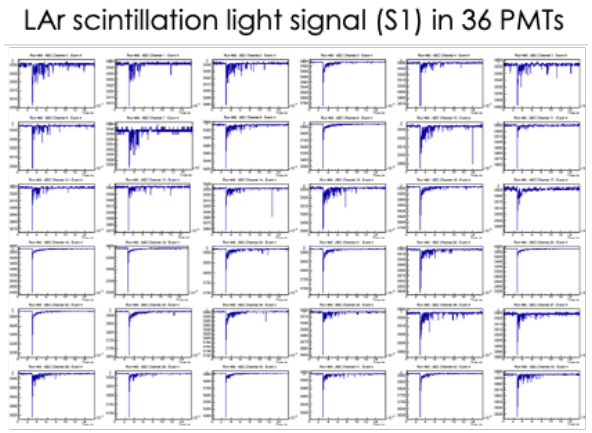
Dual Phase Photon Detection System

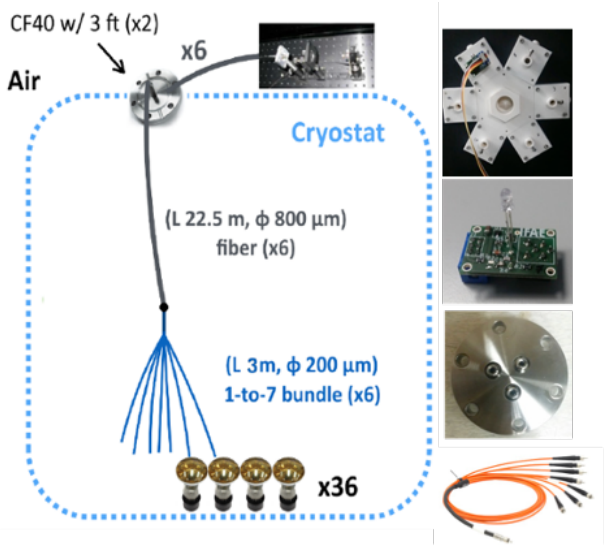
DUNE-DP FD simulation and low-E physics studies (TDR)

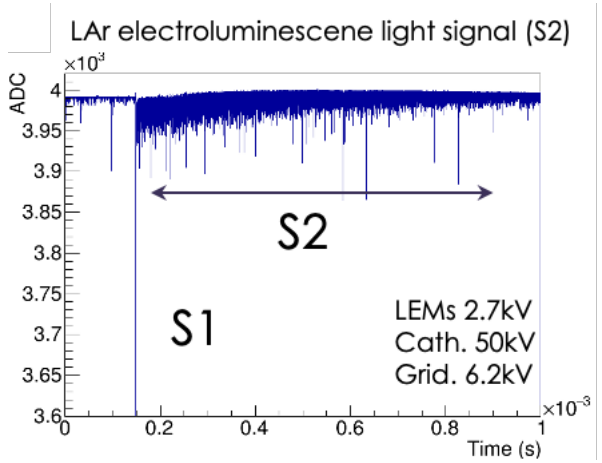
ProtoDUNE-DP PDS → Full responsibility from Spain

- Full system design and implementation
- Large photomultipliers (testing in LN2) and associated electronics
- Characterization of WLS (TPB coating vs PEN)
- Design and implementation of light calibration systems (LED and fibers)
- Installation, commissioning, DAQ and controls, data taking and analysis
- LAr scintillation and electroluminescence light detection and characterization (ProtoDUNE-Dual Phase)



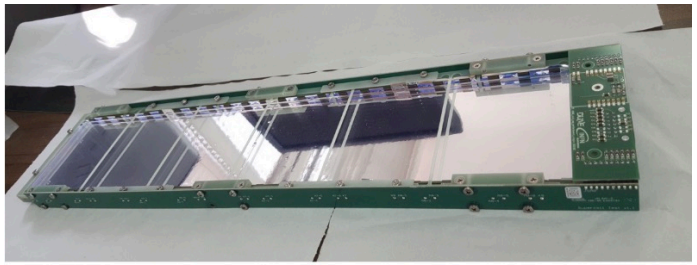




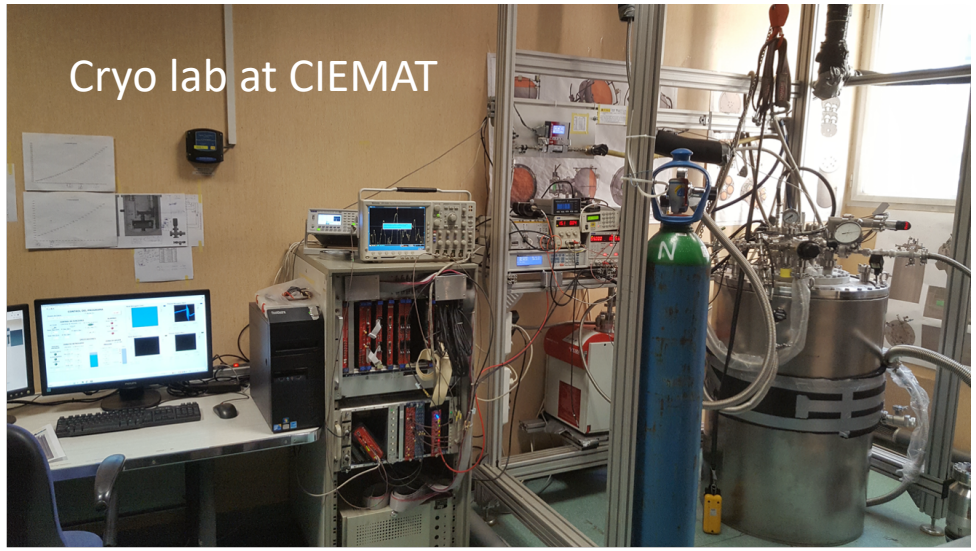


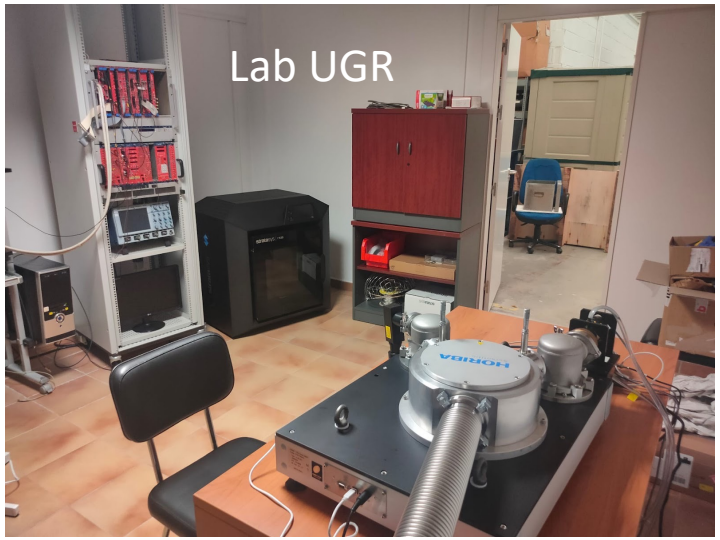
Infrastructures in Spain

- Electronics and mechanical workshops in all three labs
  - PCB prototypes
- Cryogenic and vacuum installations with radioactive sources
- Test facilities for prototype testing in LN2 and LAr



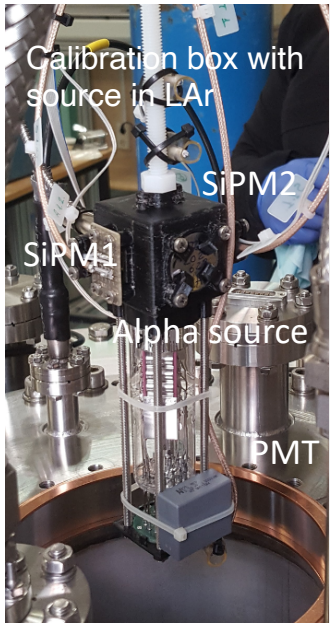
2 fully assembled supercells at CIEMAT
(different SiPM models and WLS bars)



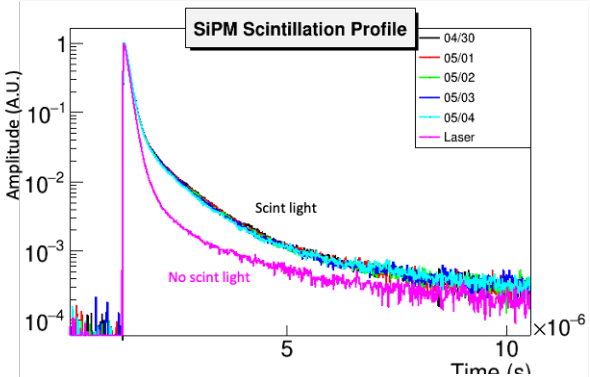


Test benches and prototypes in Spain

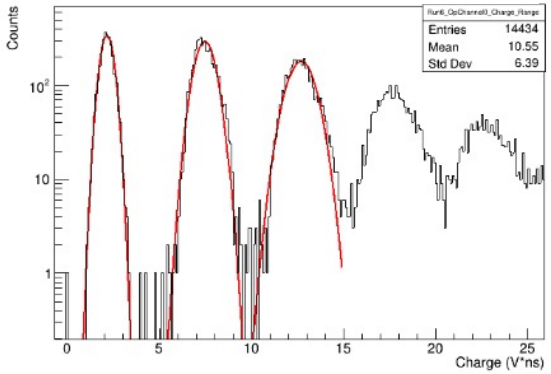
- HPK and FBK SiPM characterization (I-V curves, gain, correlated noise) in warm and cold + SiPM ganging tests
- Setup for X-ARAPUCA efficiency in LAr
- Setup for ProtoDUNE-II supercell testing and validation in LN2
- Setups for photon collector characterization
- Vacuum monochromator for studying material properties (reflectance, transmission) and system components performance (dichroic filters, WLS, etc) at well defined wavelengths, down to 100 nm
- Integrating sphere and associated equipment for studying reflectance of materials

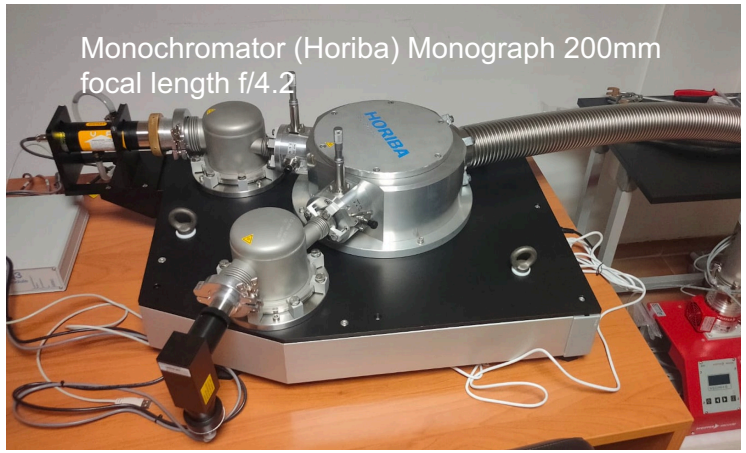


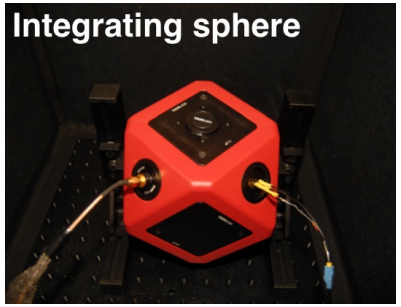
Alpha's detected in LAr by SiPMs

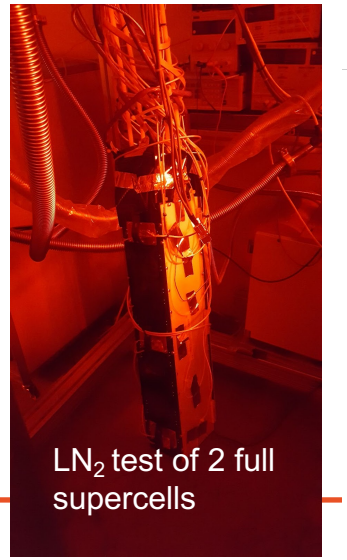


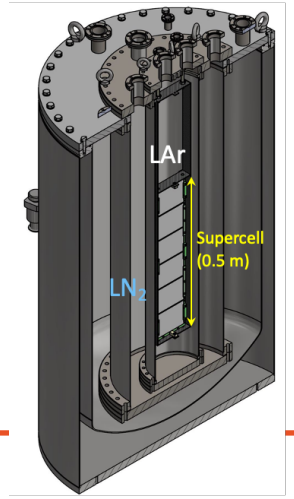
Ganging of 48 SiPMs (8 boards)









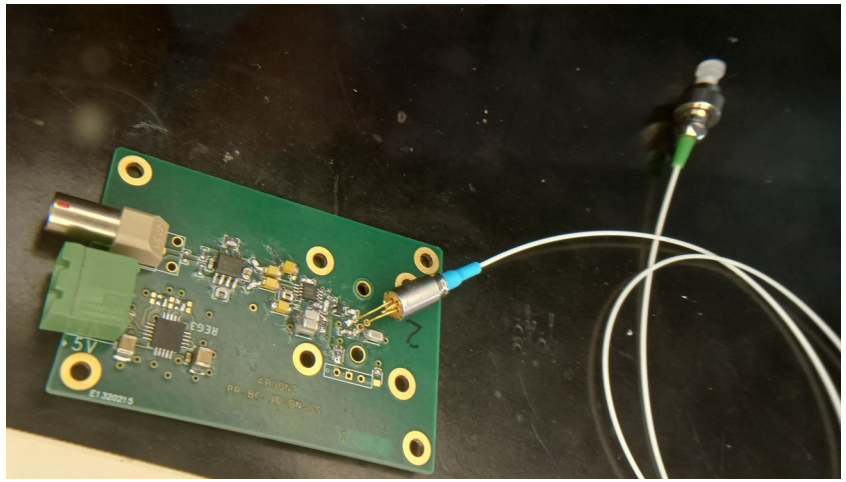


APC Paris

Transmitter

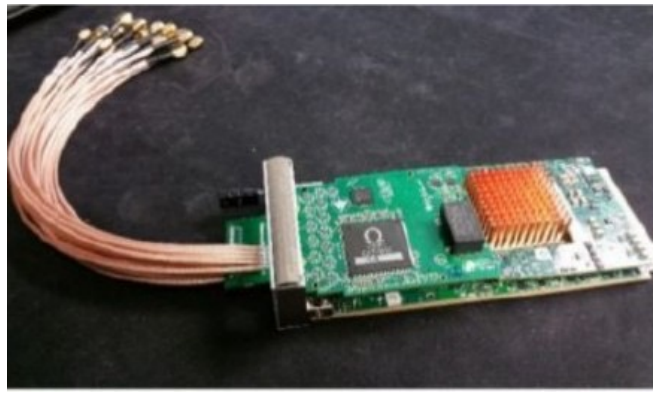
- Analog Optical Transmitter under development
  - Differential input from SiPM ganging
  - Amplification (x10)
  - Laser driver
  - 1310 nm laser
  - Works in cold
  - Bandwidth >50 MHz

  → see S. Sacerdoti's talk Tuesday



Receiver

- In-house receiver with InGaAs photodiode under development
- Digitization can be made (recycling effort for Dual-Phase Light Read Out)
  - µTCA standard
  - Design based on Charge Read Out (top electronics), integrates with White Rabbit timing and trigger distribution
  - DP Prototype with Commercial motherboard (Stratix IV FPGA) and 14 bit 65 MHz ADC
  - Considering new daughterboard – 14 bit >100 MHz ADC (AD LTC2155-14)



Interests (I)

Aligned with our expertise, the groups are interested in leading efforts for the VD PDS in SiPMs, WLS and dichroic filters, and related R&D (mechanics, optics…)

- SiPM R&D for VD
  - SiPM mounting and optical coupling
  - Development of low capacitance, low cross talk SiPMs
  - Burst-less cryogenic SiPMs
- WLS R&D for VD
  - Increase of conversion efficiency and cryo reliability in collaboration with the Dep. of Material Science of Milano-Bicocca
  - Dye composition, substrate and light attenuation optimized for the VD tile
- Optimization of dichroic filters for Xe light (in collaboration with Brazil)
  - Collaboration with vendors in North Italy specialized in optics for astronomy and space applications
  - Thicker dichroic filters
  - Filters optimized for Xe light (Xe-doping in VD)

Interests (II)

- Optimization of the X-ARAPUCA single-sided tiles
  - Physics-driven optimizations based on different geometry, location, electronics, etc.
  - Mechanics and prototypes
- Focus on the analog readout for the single and double-sided tiles
  - Analog optocoupler
  - Warm electronics
- Possibility to contribute to the VD-PDS construction (about 50% of the system), in particular, having PDS production centers in EU
- Other interests: SiPM ganging for single-sided tiles, calibration, ...

Summary

- Funding opportunity from EU to contribute with the construction of 50% of the full VD-PDS, including a PDS production center in EU
- Qualified personnel (technical and scientific) with expertise in PDS
  - New positions to be filled
- Interested in leading R&D efforts related to SiPMs, WLS, dichroic filters, analog readout electronics
- Interested in optimization of single-sided tiles PDS

THANKS

Other Spanish activities in DUNE

- Calibration and cryogenics instrumentation: A. Cervera technical lead
  - Spain is responsible for the temperature monitoring system of PD-SP and FD1/FD2
- Low-Energy Neutrino Physics: co-convenor C. Cuesta
- BSM Physics: co-convenor J. Martín-Albo
- Previous involvement in Nucleon Decay WG: co-convener M. Sorel
- Development of the HighLAND analysis framework for ProtoDUNE-SP
- Deep involvement in the data analysis of ProtoDUNE SP and DP