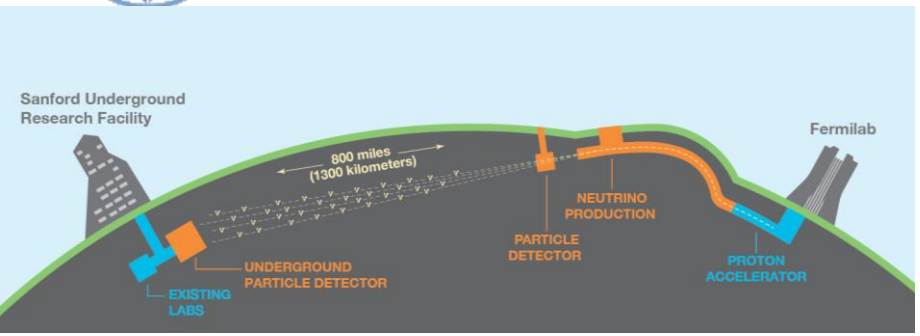
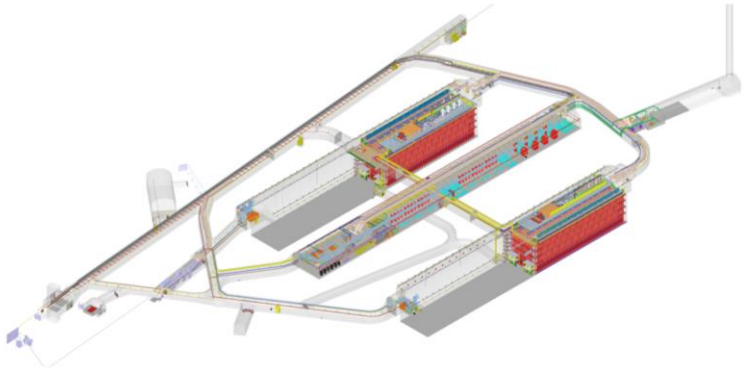
DUNE group
Technical development :
Vertical Drift Photo-Detection System

Séminaire projet du 24 mars 2022

Sylvie Blin

The DUNE experiment

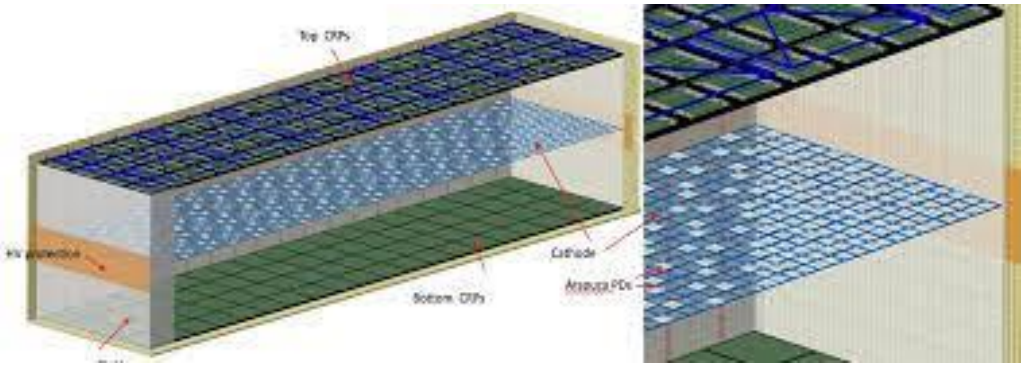




The Far Detector

Far Detector 1 (FD1): single-phase, horizontal drift TPC
Far Detector 2 (FD2): single-phase, vertical drift TPC

- Next generation long-baseline neutrino experiment
- LArTPC with electron drift along the vertical axis
- 2 volumes of 13.5 m x 6.5 m x 60 m dimensions separated by a cathode plane



DUNE Collaboration + France

> 1300 collaborators
> 200 institutions
33 countries + CERN

France contribution for Far Detector 2:

- Charge Readout Planes (anodes) + chimneys
- TPC top electronics
- Readout of Photon-Detection System -> APC

The APC team

2021

- Alessandra Tonazzo
- Thomas Patzak
- Jaime Dawson
- Sabrina Sacerdoti
- Joao Coelho

- Sylvie Blin
- Bernard Courty
- Pierre Prat

- Dariusz Nita (CDD)
- Etienne Chardonnet (PhD)

2022

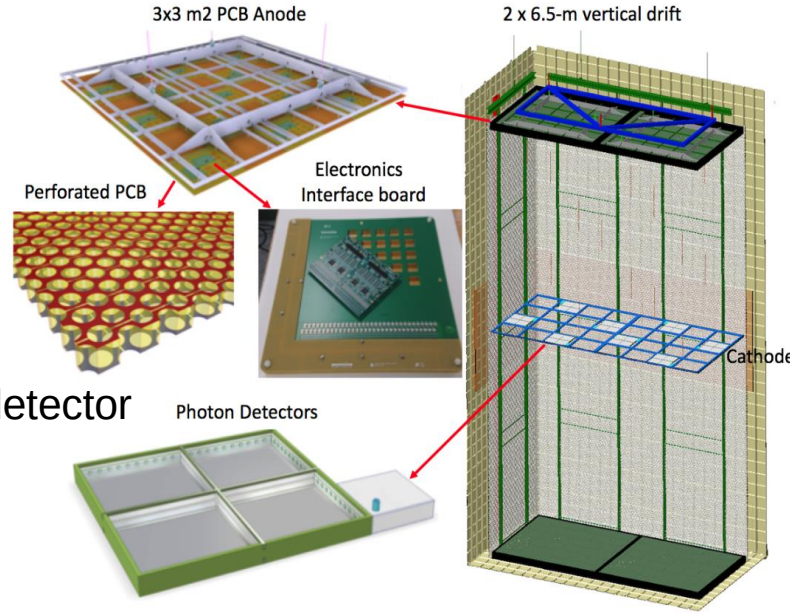
- Alessandra Tonazzo
- Thomas Patzak
- Jaime Dawson
- Sabrina Sacerdoti
- Camelia Mironov
- Joao Coelho

- Sylvie Blin
- Bernard Courty
- Pierre Prat
- Cédric Champion

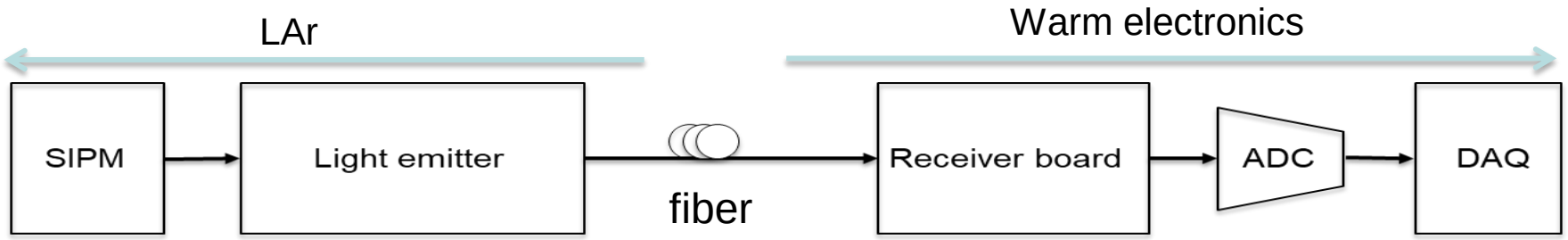
- Henrique Vieira de Souza (PostD)
- Ariel Cohen (PhD)
- Camille Sironneau (4 months/PhD ?)
- Davide Moretti (Erasmus 6 months)

LAr Vertical Drift TPC

- Cathode hanging at mid-height, bias voltage: -300kV
- Drift distance of 6.5m
- Field cage ensures field uniformity of 500V/cm
- Anodes: perforated PCBs on the top and bottom of the detector
- Photon sensors on cathode and behind field cage
  - provide timestamp & trigger for events in the TPC
  - power and signals transmitted via optical fibers

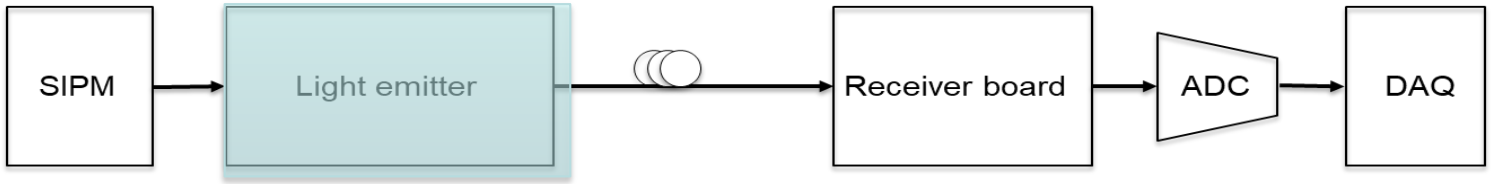


analog light readout=
SiPM photodetector + Analog Signal out by fiber + digitalisation in warm



Very intense R&D campaign on-going to prove the feasability and validate the design

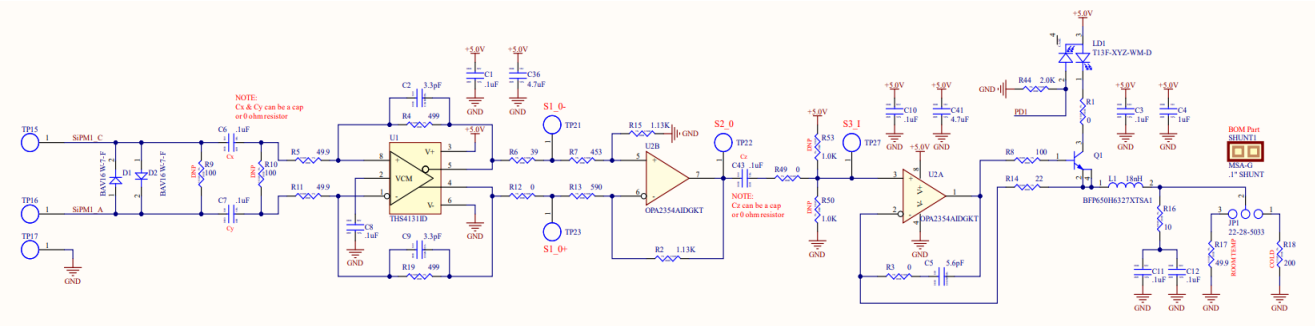
ARGONx_ch2 : light emitter



- Key component : cryogenic analog optical transmitter
- Started development at APC in ~January 2021
  - a preliminary choice of components that work in LN2 (LAr)
  - design of a linear laser diode driver
  - PSpice simulations done to optimize components combination

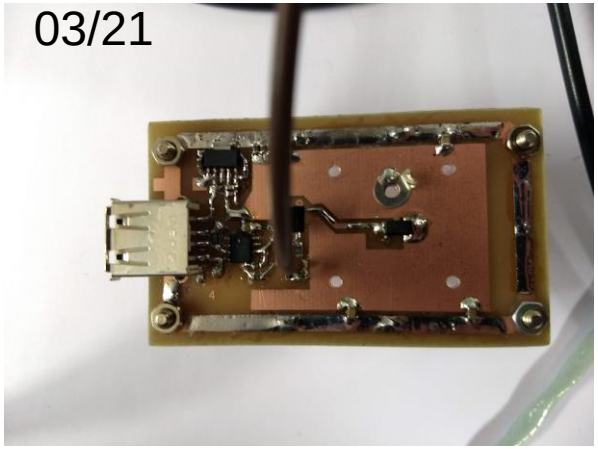
Requirements

Low power consumption
Bandwidth ~50 MHz
Single Photo-Electron SNR> 4
Dynamic Range ~1 PE - 2 kPE



Prototype evolution

First laser driver 03/21



First ARGON2 full transmitter (06/21)

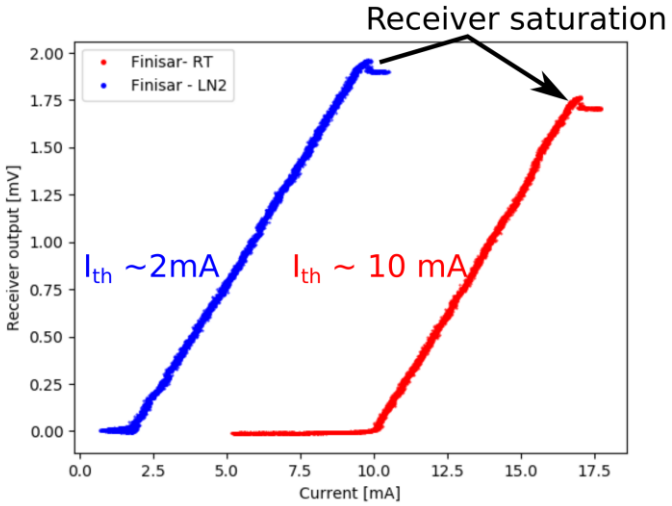
ARGON2x2 transmitter (collab w/Fermilab), installed in Coldbox1

- Starting team :
  - CR : Sabrina, Jaime
  - Ing : Bernard, Dariusz (CDD 2019-2021)

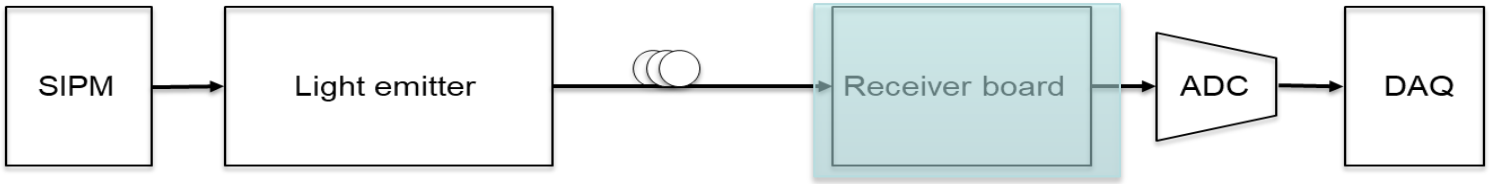
- Laser characterization :

lower threshold current in cold, linear behaviour

- Evaluation of components behaviour in cold
- Design validated

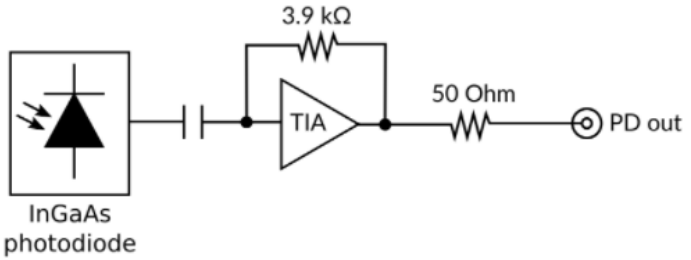


Optical receiver board



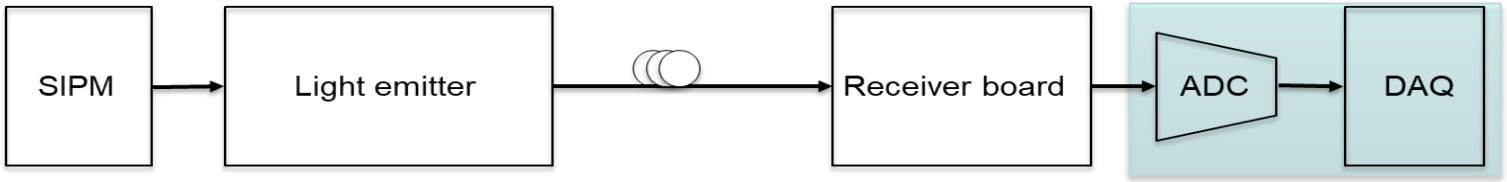
Commercial board Koheron PD100

- inconvenients :
  - Saturation at 600 uW input
    - Gain too large
    - One modification attempt not successful
  - Only one channel
  - External power/channel



- Proposition from APC:
  - New receiver board
    - Multichannel
    - Enhanced dynamic range to remove the saturation problem
    - External power per board
  - Planning : before May to be ready for coldbox3 milestone

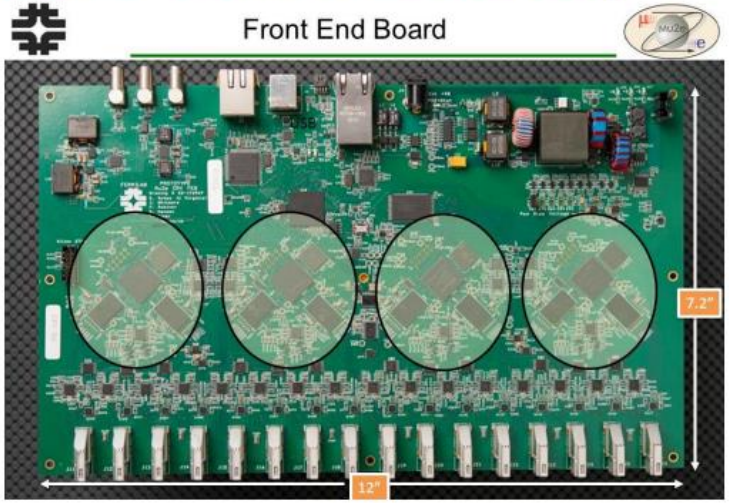
Digitalisation and DAQ



DAPHNE (Detector electronics for Acquiring PHotons from NEutrinos)

REQUIREMENTS:

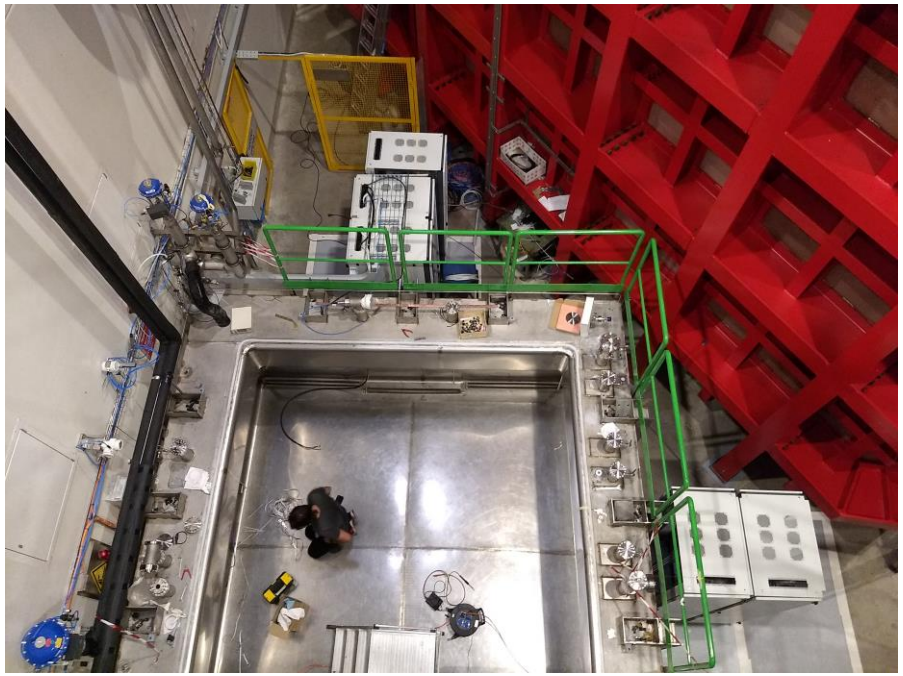
- Signal-to-noise > 4 (SP-PDS-14
- Time resolution < 1us (SP-FD-4
- Dark noise rate < 1kHz (SP-PDS-15)
- Dynamic range < 20% (SP-PDS-16)



- DAPHNE hardware: Fermilab-LA Collaboration
- DAPHNE firmware and software: LA responsability

Initially conceived as a Mu2e board upgrade
Same AFE device (ADC+signal conditioning)
Same basic power supply scheme

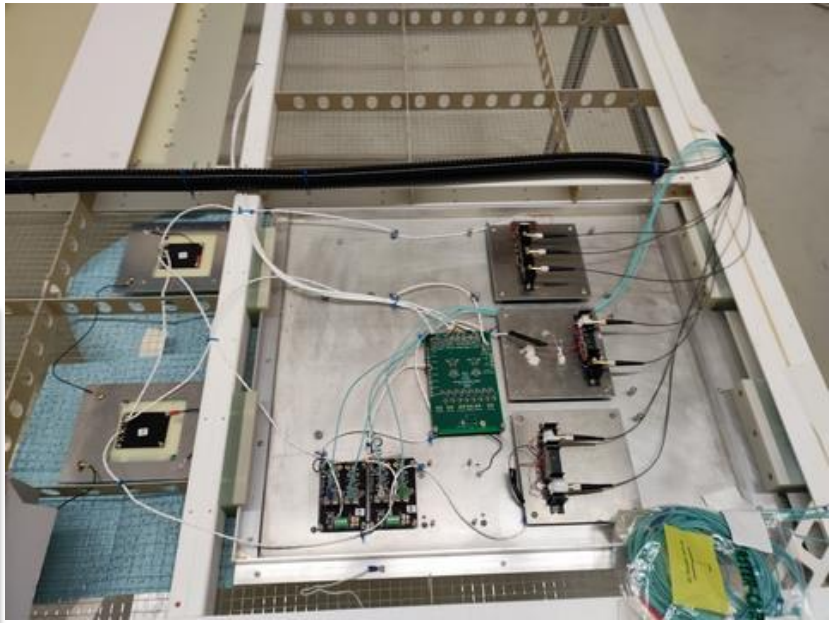
Coldbox Installation at CERN



- 3x3x1 m^3 cryostat
- Installation of first coldbox test in Sept 21
- Performed test and configuration of boards
- Participated in installation

(2 weeks at CERN, Sabrina/Ariel)

- Analysis of the data (Henrique)



Very good results, with only a few hours of data taking, we could see :

- small signals of few photo-electrons
- large signals from crossing muons
- system linearity up to ~1000 PE

-> targets largely accomplished

Summary APC technical contribution

(since December 2020)

- First tests of cryogenic laser drivers (Jaime,Sabrina,Dariusz,Bernard)
  - Component selection, including types of lasers and fibers
- Circuit design and simulation (Bernard, Dariusz, Pierre)
  - First prototypes (sent to Fermilab), proof of principle, characterisation in LN_2
  - The new version is on test at APC

- On-going assesment of circuit performance and design optimization

(Sabrina, Henrique, Ariel)

  - Large dewar borrowed from IJCLab now in the Hall thanks to J.P. Thermeau

  -> will start setup soon

  - LAr tests (LN_2 is not completely equivalent), now at CERN

- Coldbox
  - Participation in the installation (Sabrina/Ariel, 2 weeks)
  - Data analysis : PDS data needs to be analyzed for performance estimation and debugging (Sabrina/Henrique)

2022-2023 timeline

- **March 2022:**
  - PDS tests at coldbox -> data taking for benchmark measurements (SPE detection, noise characterisation...) and DAPHNE test
  - Test Setup in the APC Hall : low frequency noise measurement and resin to test the laser/fibre connection.

- **April 2022** : Review
  - Finalize performance characterization (lab and coldbox)

- **June 2022**: target coldbox3 : key benchmark test
  - Test of upgraded analog readout + receiver + digital (DAPHNE)
  - We should provide all installed prototypes, transmitter and receiver

- **December 2022** : installation ProtoDUNE-VD Module 0
  - Provide 16 transmitter boards + 32 channels warm receiver
  - Digitalisation system (?)

- **First months 2023**: start data taking ProtoDUNE-VD
  - Installation/calibration
  - Data analysis

Next steps

	engagement	ressource
APC Testbench	New Dewar setup	Sabrina, Jaime, Henrique
	ARGON3_2ch measurements	Sylvie, Ariel, Sabrina
Coldbox 3 (June 2022)	New APC board ARGON4_2ch	Bernard, Pierre, Guy (cabling)
	Optical receiver FE board	Bernard + CDD?
	DAPHNE	Cedric, Davide, Sabrina
ProtoDUNE (January 2023)	Production boards for 32 channels + (?) digitalisation	Bernard, ….

Conclusions

- Important changes in the APC-DUNE team in 2021 :
  - Members (arrivals/departures/leaves)
  - Activities (technical and analysis)

- Development of Photo-Detection readout :
  - Successful delivery of an analog optical transmitter : current baseline solution for PDS-VD
  - A lot of work has to be done for the warm part of the readout
  - Challenging to provide board layout design/population/mechanical design for June 2022

- On-going effort in data analysis and reconstruction algorithm improvements

Caveats:

The planning is continuously shifting

As is the distribution of tasks in the collaboration