

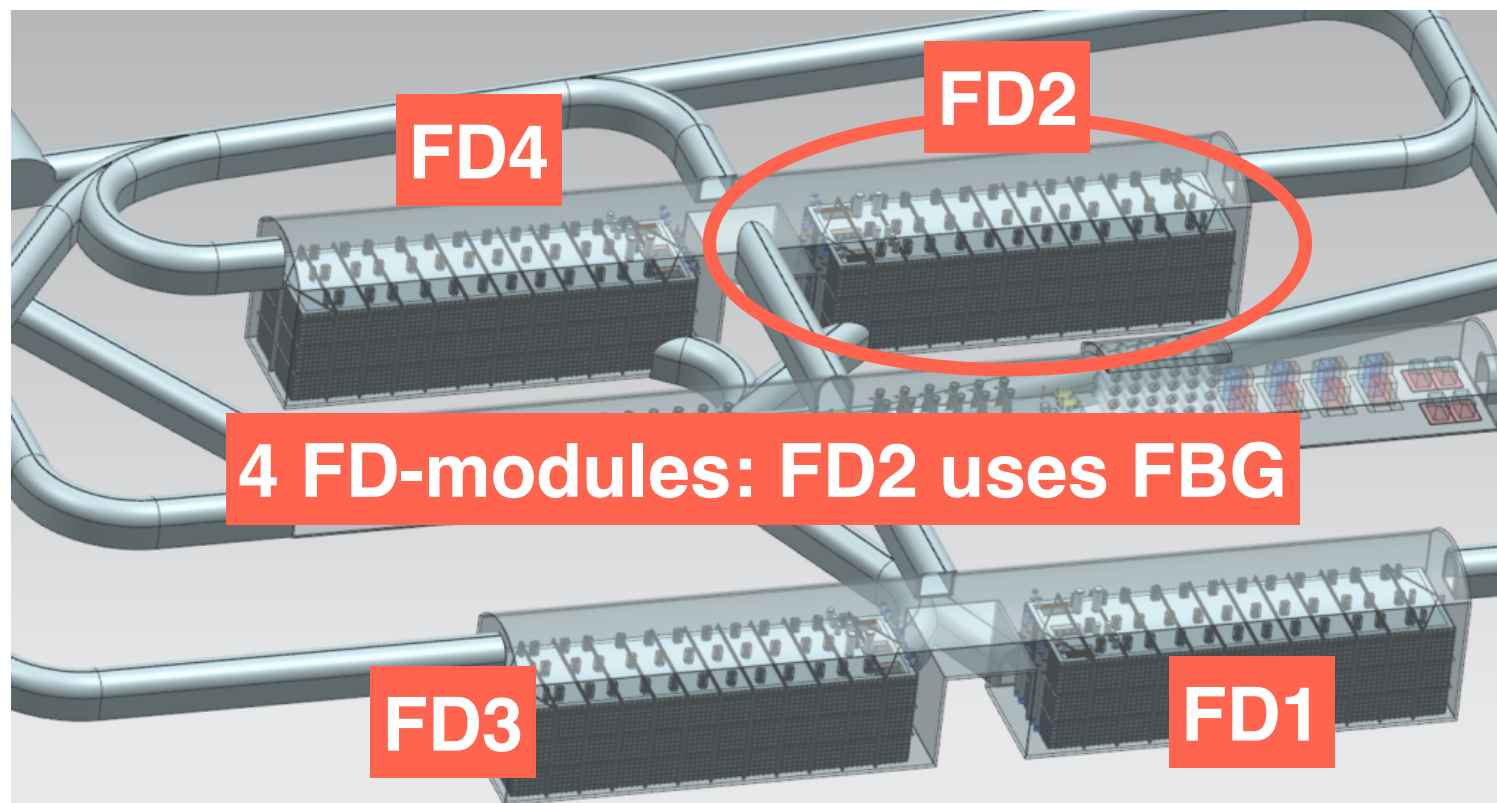
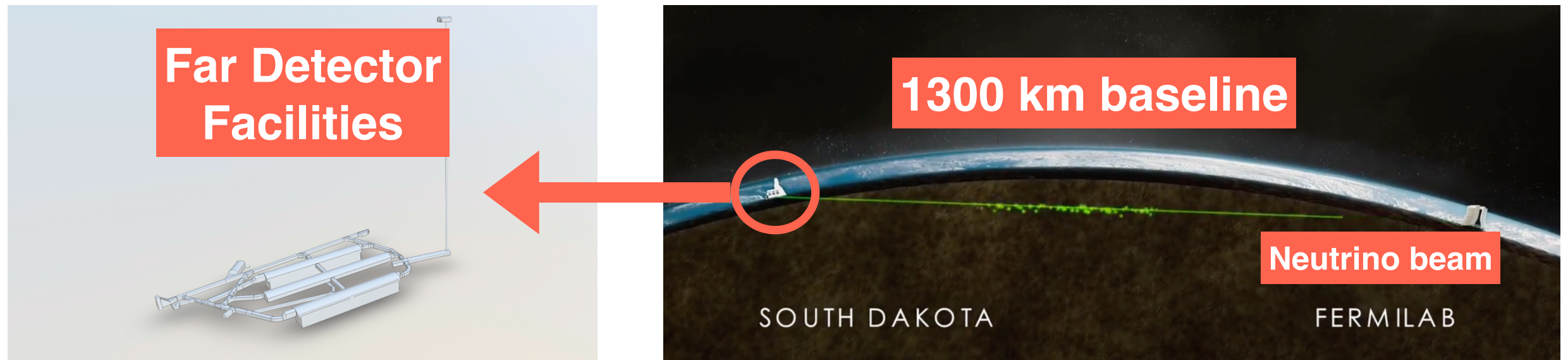
DUNE-Spain TMS for FD2

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Your Inst Logo

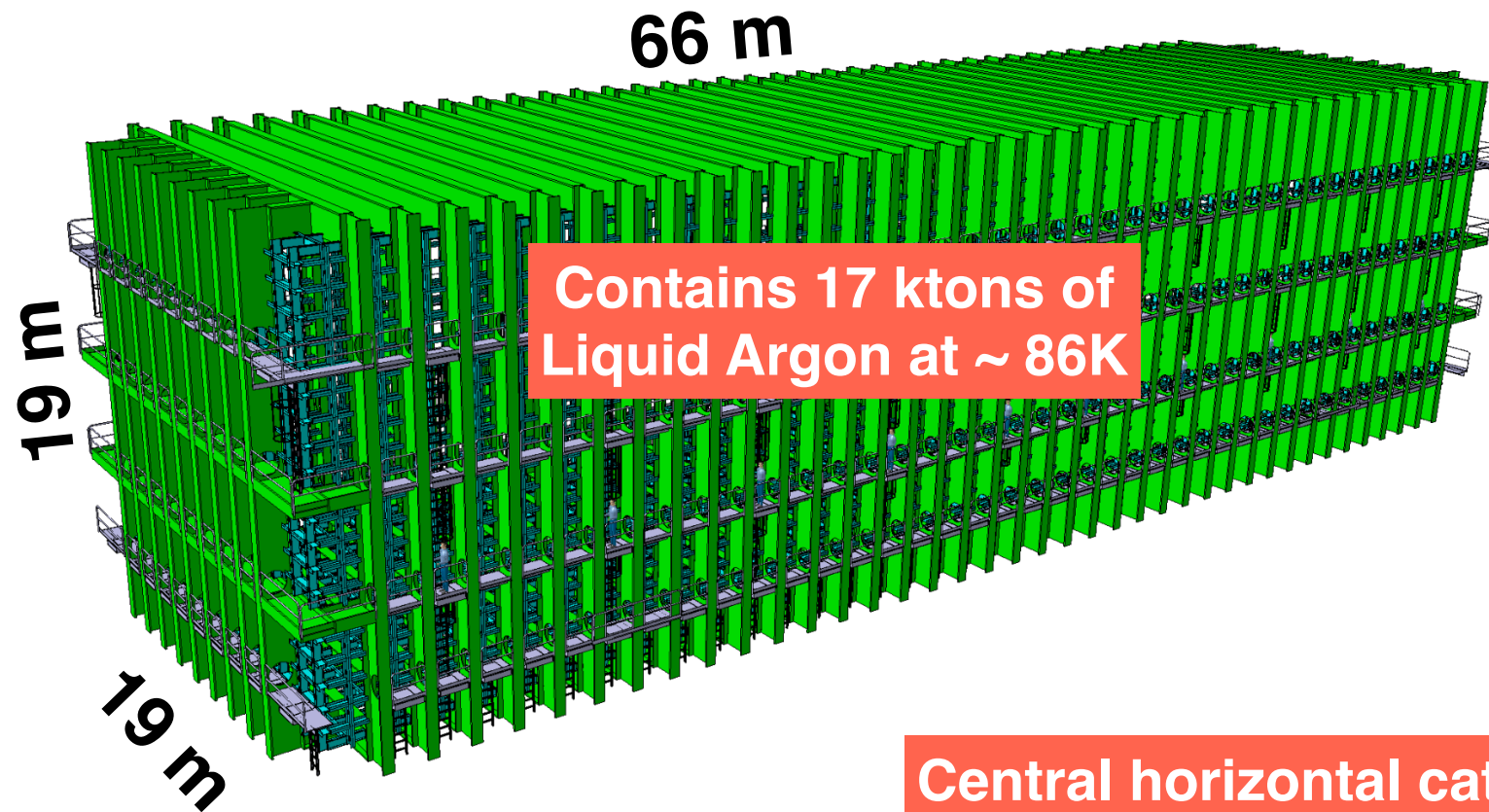


Project Overview



Module 1 will use standard RTDs for monitoring the temperature. Module 2 will use FBG instead. Modules 3 & 4 are not yet decided, there exists the possibility to use FBGs also there, depending on the technology.

Detector overview & dimensions



The temperature inside the cryostat is expected to be very stable (within ~20 mK) according to CFD simulations.

Central horizontal cathode at 300k Volts

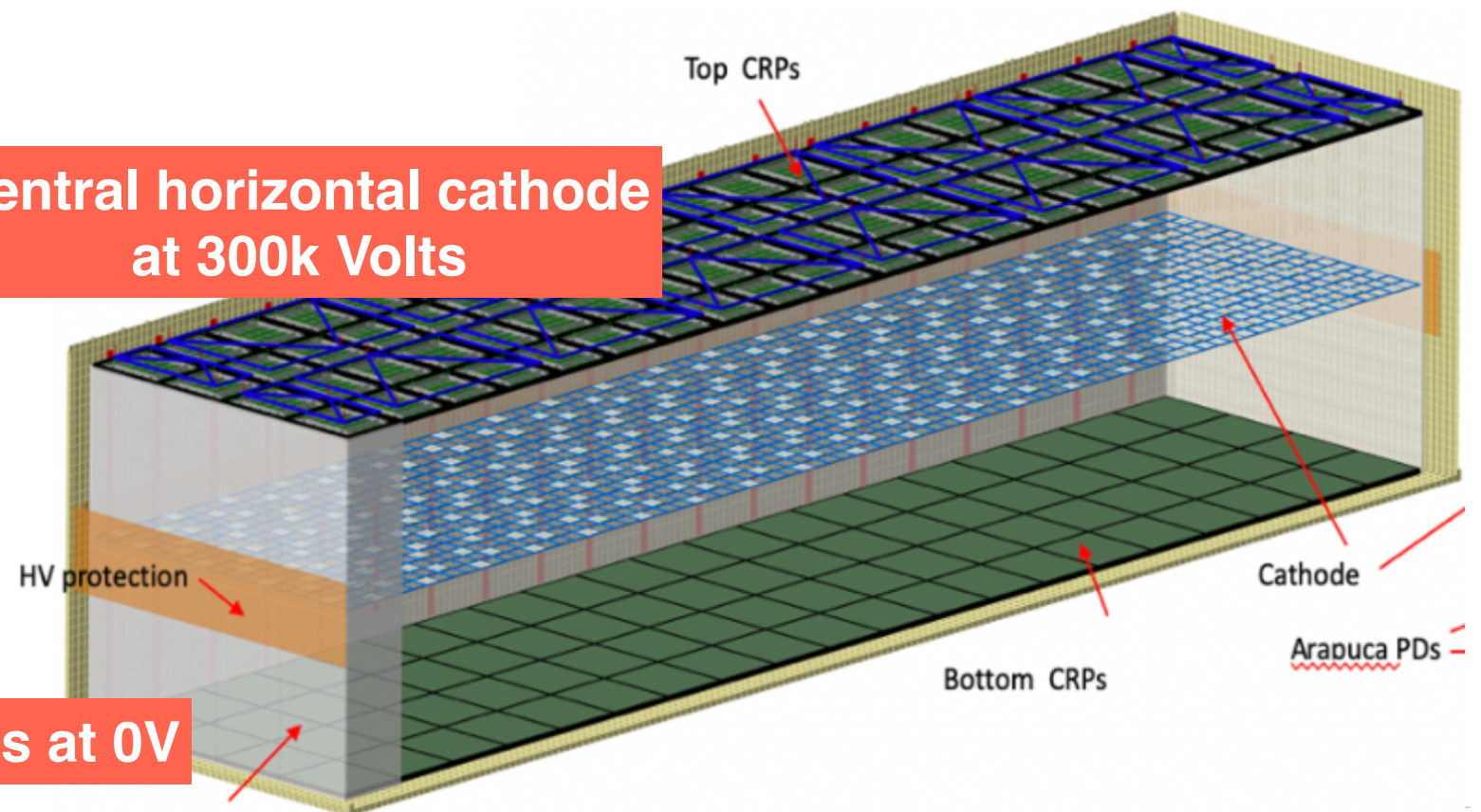
A red text box with white text indicating the central horizontal cathode is at 300k Volts.

The High Voltage (HV) forbids the use of standard resistance temperature detectors

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Anodes at 0V

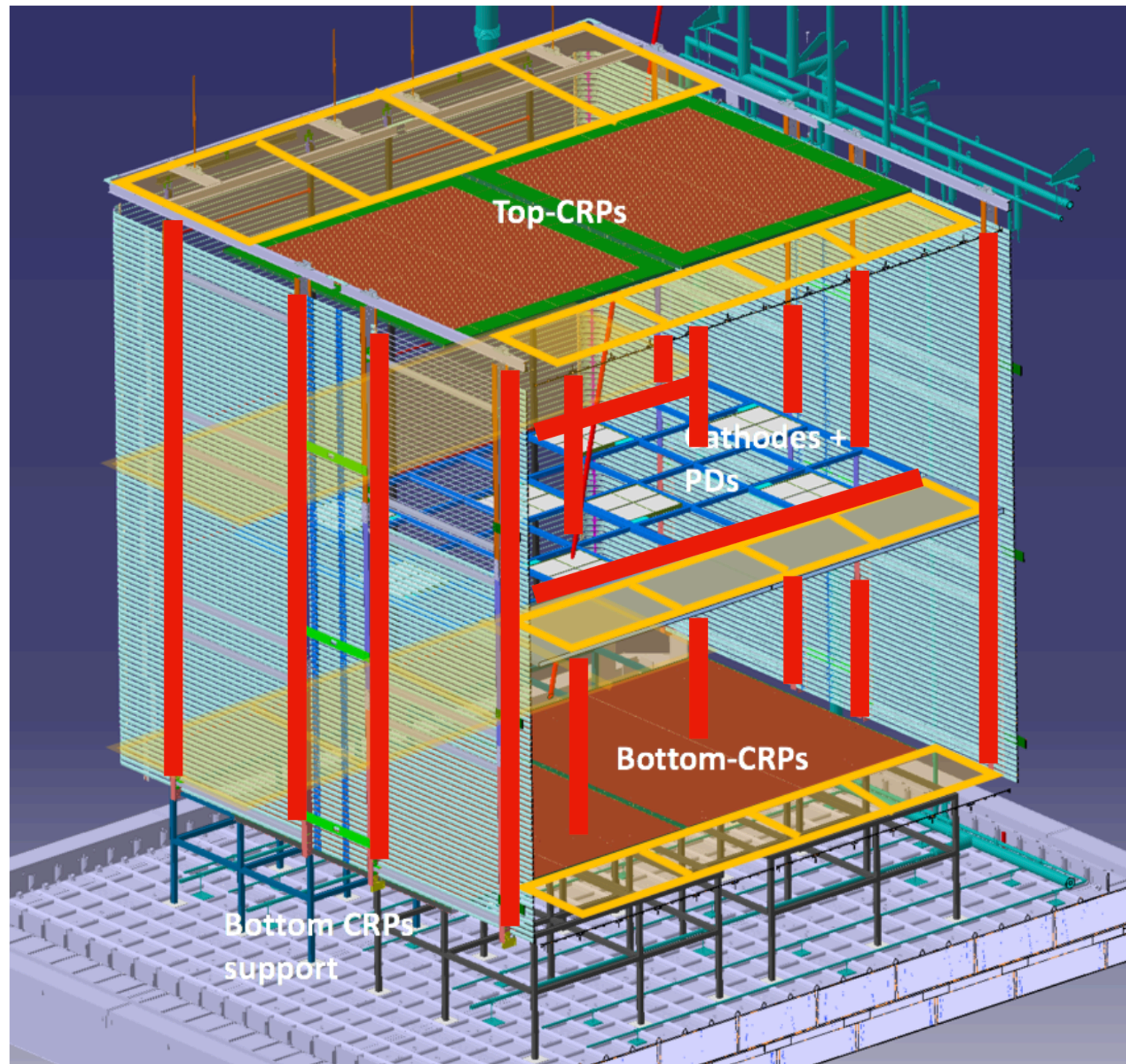
A red text box with white text indicating the anodes are at 0V.



Project Description

- The DUNE experiment is divided in two phases: the P1 comprises the installation and commissioning of the first two modules (ends by 2026), while the P2 will account for the fabrication, installation and commissioning of the other 2 modules, the near detector and the neutrino beam (ends by ~2035).
- By the moment we are interested in the P1. Important to notice that if we are successful this technology can be used in other modules also. For the P1 we will need around 2 km of fibres and several interrogators or optical multiplexers to read-out the sensors.
- Before the installation of the FD2 several prototypes were (2018-2019) and will be (2022-2024) constructed. They are opportunities to test the technologies to be installed in the FDs.
- The next prototype is ProtoDUNE-VD, which needs to be installed before March 2023. Our plan is to perform a mechanical integration with “dummy” sensors, as we are not in time to install real properly-designed sensors.

ProtoDUNE-VD description



- ProtoDUNE-VD is a 6x6x6 m prototype of the FD2 module. It uses the same technology that will be used and the HV is already present in this prototype.
- Our plan is to install 200 m of fibres with sensors spaced every ~50 cm. This would mean something like ~ 25 8-meter long fibres (considering the length to route them to the output ports) with 16 sensors each.
- The plan is to use the subjection rods on the cathode to guide the fibres in such a way that they do not suffer any additional strength. We can also try with some floating fibres.

Interrogator Device



- We will acquire in the coming days the **I4-G 16-channel** device for the interrogation.
- It offers a **wavelength precision < 0.1 pm**, which is the best we have found so far during the market study.
- The **wavelength range** is within the common used range for most applications.

Performance

Wavelengths Range	39.2nm	1529nm to 1568.2nm
Number of Channels	16	
Number of Sensors per Channel (see Note 1)	1 to 30	16ch * 30 = 480 sensors (assuming 1.2nm spacing of FBG sensors)
Wavelength Sample Size / Resolution	1 pm	
Wavelength Absolute Accuracy	< 1 pm	Gas Cell and MZI referenced with PM circuit to guarantee long-term performance
Wavelength Precision	< 0.1 pm	Standard deviation of a tracked HCN P10 Gas Cell line measured > 8 -hours
Wavelength Repeatability (see Note 2)	< 0.1 pm	
Laser Line-Width	20 MHz	Self-heterodyne measured line-width at static wavelength
Laser Output Power per Channel (see Note 3)	+0 to +3dBm	Performance is maintained even with 20dB optical power loss
Scan Frequency / FBG Processing	250Hz	
Scan Frequency (Full Spectrum @ 1pm)	1 Hz	1Hz for 16 channels with 1pm resolution
Polarization Switching States	2 States	Switches polarization state every sweep when user enabled
Sensor Range / Distance	0 to 10 km	Lead-in cable (0 to 7.5km), FBG section (0 to 3.25km)

Physical

Dimensions (W x D x H)	324x276x116mm	Colour is white
Max. weight	4.9 kg	
Housing material	Stainless steel	
Input Voltage and Power Consumption	12V and 25W	Auto-detect 100V to 240V AC with 12V supply block included
Fiber port	LC/APC	We offer hybrid optical jumpers and adapters to FC/APC, SC/APC, and other sensor connectors
Certifications and Test Reports	YES	
Communications Interface	YES	100Mbps Ethernet, REST control interface and multiple data output formats/ports
Supplied Software	YES	FEMTOSENSE configuration tool, LABVIEW interface examples, API Support Document

Temperature Measurements

- We are aiming to achieve < 5 mK precision when comparing the temperature measurement between two given sensors, let's call it OFFSET.
- We are not very interested into the absolute temperature measurement, but for the OFFSET to be reproducible within ~ 1 -5 mK over multiple measurements.
- We will calibrated at the IFIC laboratory the sensors in the fibre by keeping them under very stable conditions, take measurements and compute the OFFSET of all sensors with respect to one of them (the reference, arbitrary).
- Then, we will measure the gradient inside the cryostat by applying the calibration obtained at IFIC, for this reason we don't care that much about the absolute measurement.

Fibres' Requirements

- By following a very simplistic calculations, assuming the perfect performance of the sensors and the interrogator, assuming the worst-case scenario of 0.1 pm wavelength resolution, it would be needed for the sensors to have a sensitivity vs temperature as big as $100 \text{ pm/K} = 0.1 \text{ pm/mK}$.
- Far from the cryogenic temperature, there are some fibres offering 10 pm/K, which would lead to a resolution around 10 mK.
- There must exist some improvement on the interrogator side, as 0.1 pm resolution is a top bound for a relatively high sampling rate, by sampling slower it should increase the resolution.
- We need to find room of improvement also on the fibre side, but it needs to be studied as for the LAr temperature ($\sim 86\text{K}$) the sensitivity is not as high as 10 pm/K.