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GOBIERNO DE ESPAÑA · MINISTERIO DE CIENCIA, INNOVACIÓN Y UNIVERSIDADES

Plan de Recuperación, Transformación y Resiliencia

GENERALITAT VALENCIANA Conselleria de Educación, Universidades y Empleo

GVANEXT

ASFAE

ASTROFÍSICA Y FÍSICA DE ALTAS ENERGÍAS

NEXT & DUNE

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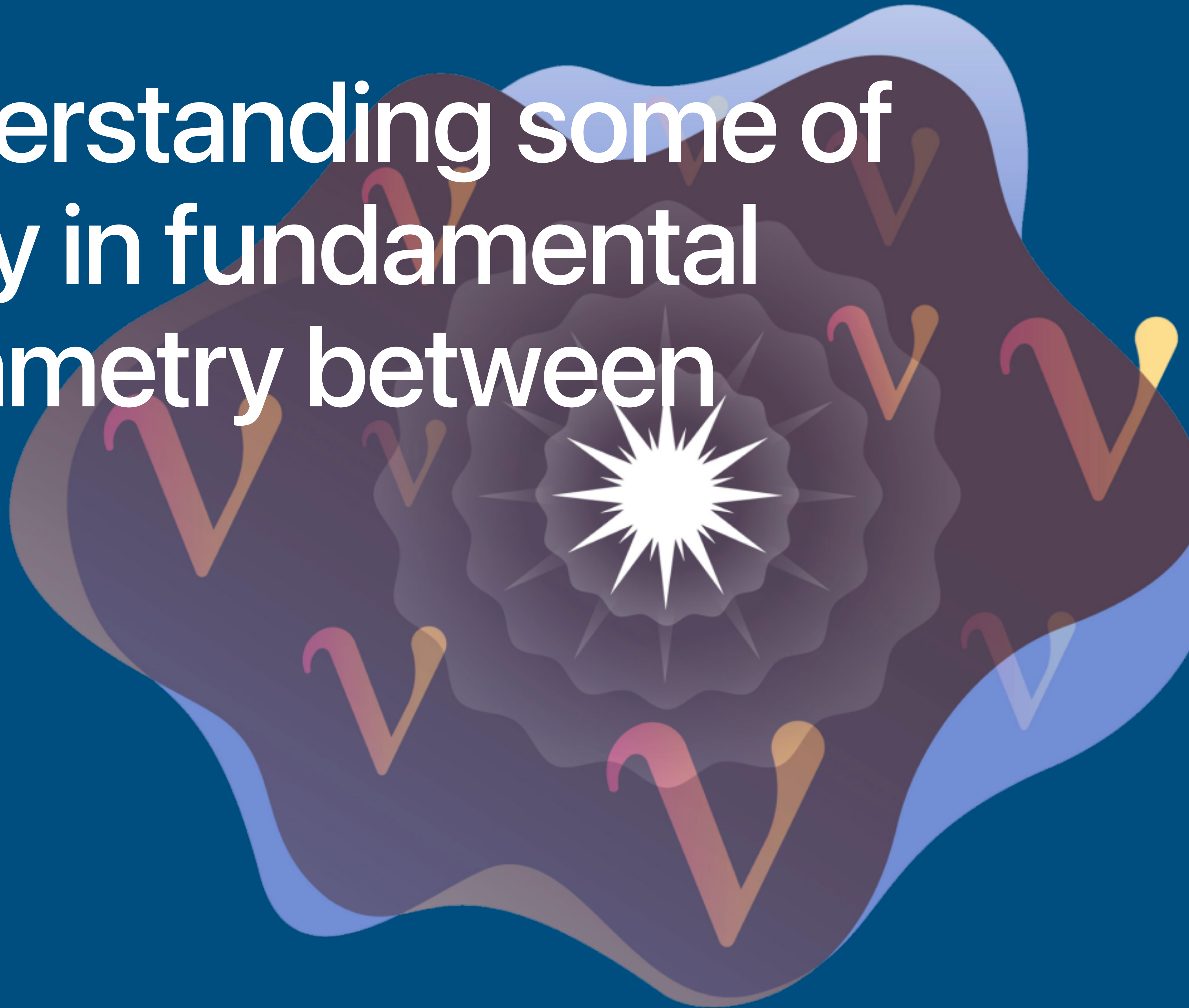
Instituto de Física Corpuscular (IFIC) – CSIC & Universitat de València

ASFAE 2024 Workshop ▪ Universidad de Alicante, 4-6 March 2024

Universitat de València · Universitat Politècnica de València · Universitas Miguel Hernández · Universitat d'Alacant Universidad de Alicante · CSIC Consejo Superior de Investigaciones Científicas

Neutrinos are the most abundant matter particles in the universe (about 300 cm^{-3}). And yet, they are the particles that we understand the least.

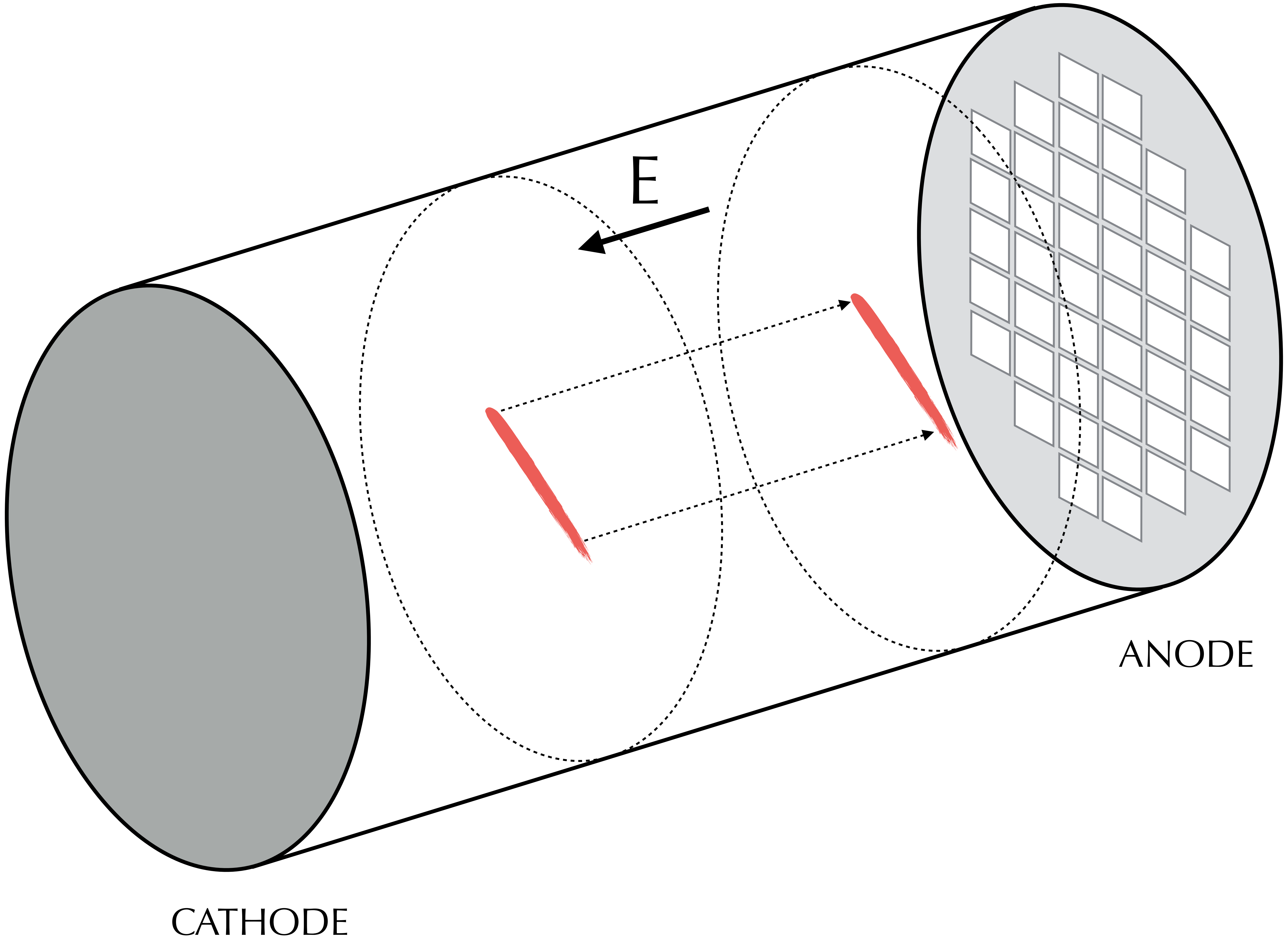
Neutrinos could be the key to understanding some of the most pressing questions today in fundamental physics, such as the cosmic asymmetry between matter and antimatter.



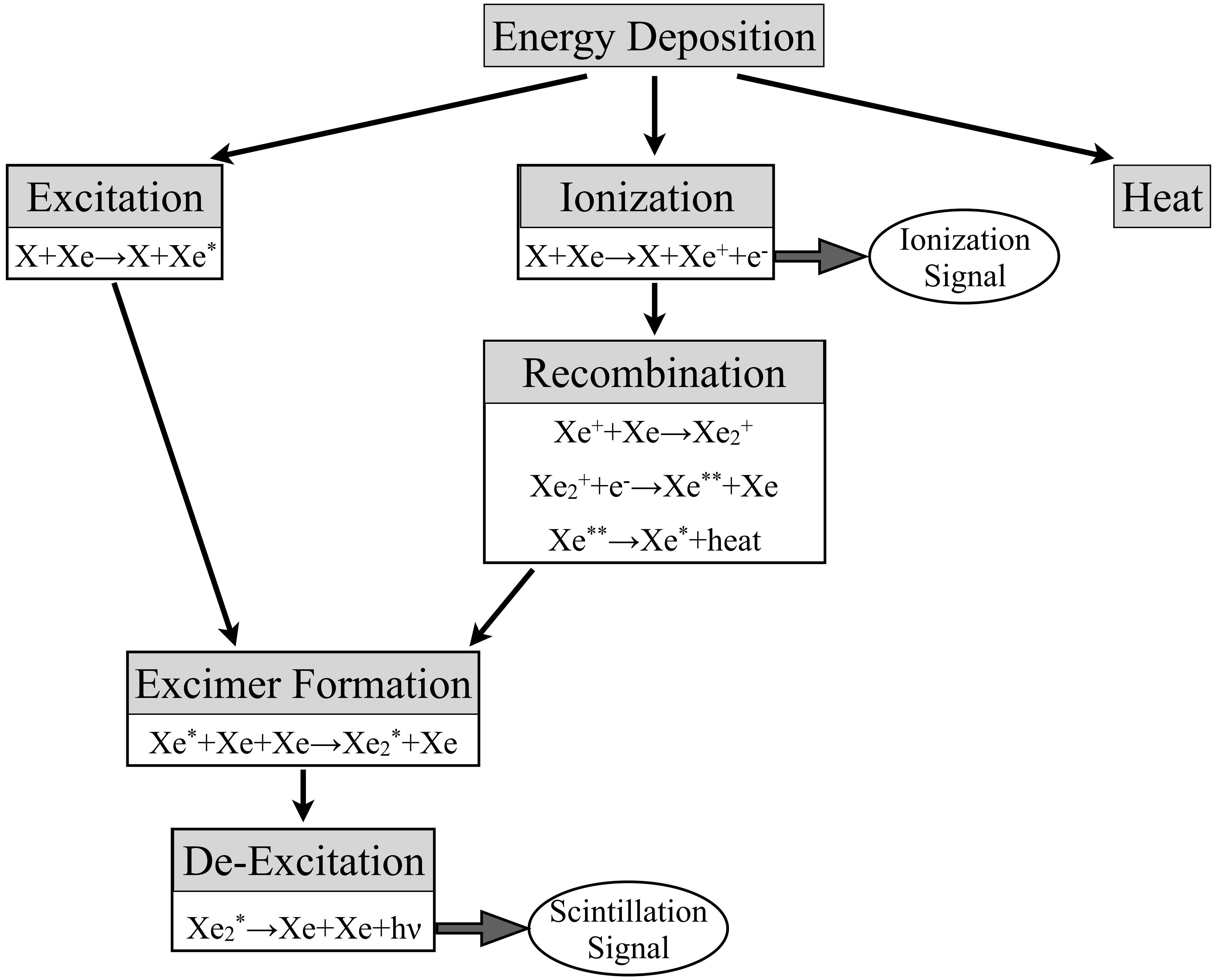
Long-baseline neutrino oscillations

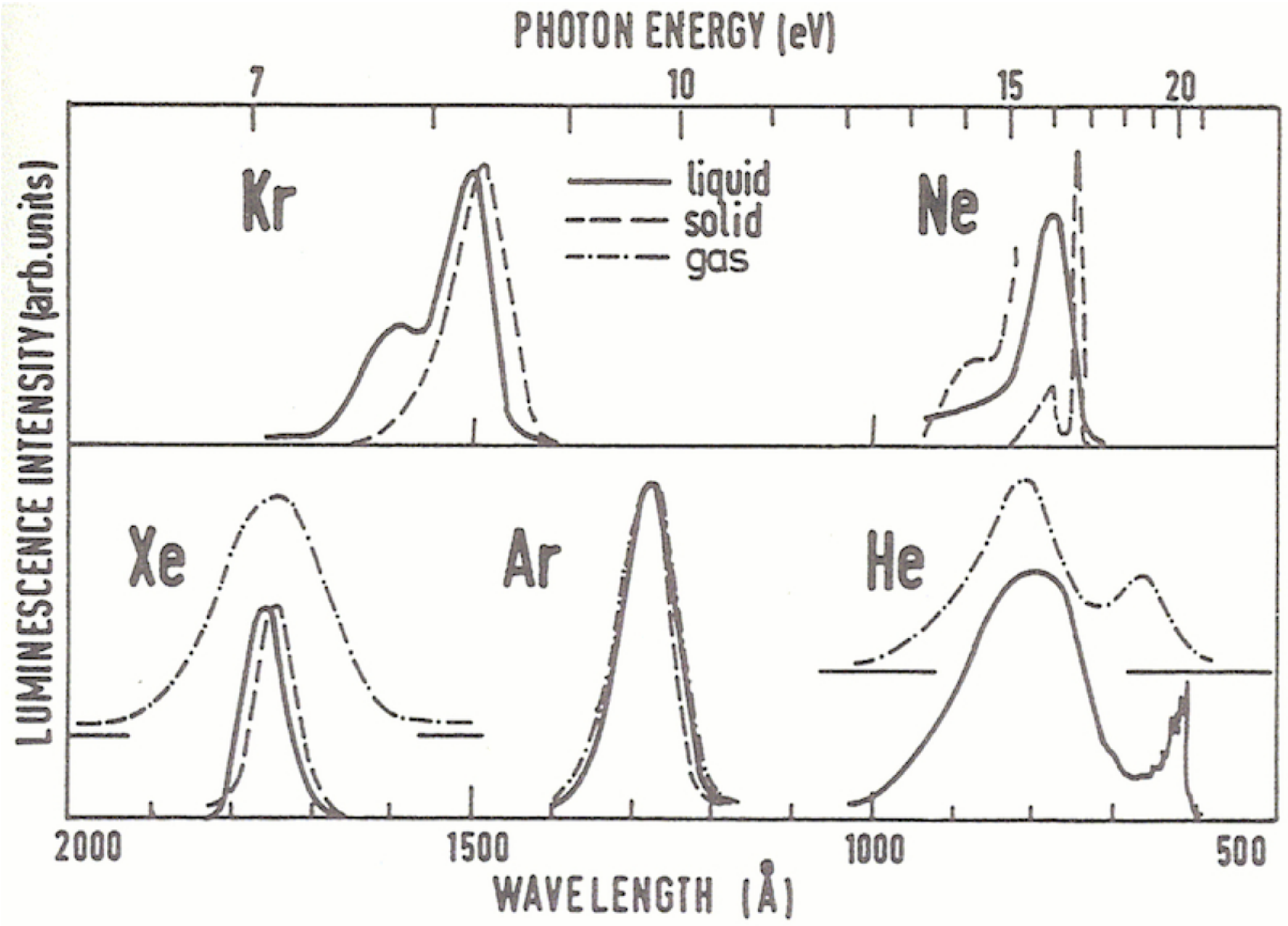
Neutrinoless double beta decay searches

The time projection chamber



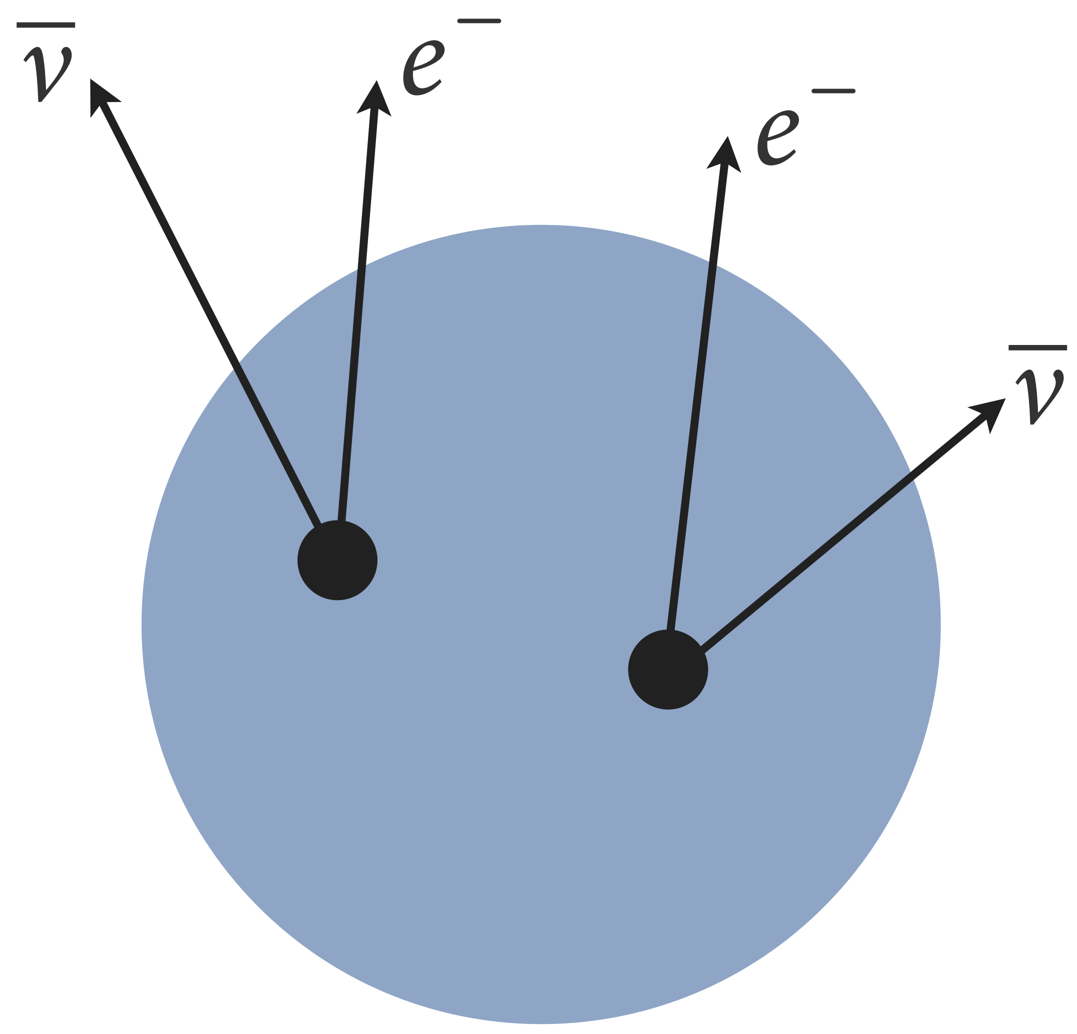
Noble elements as detection media



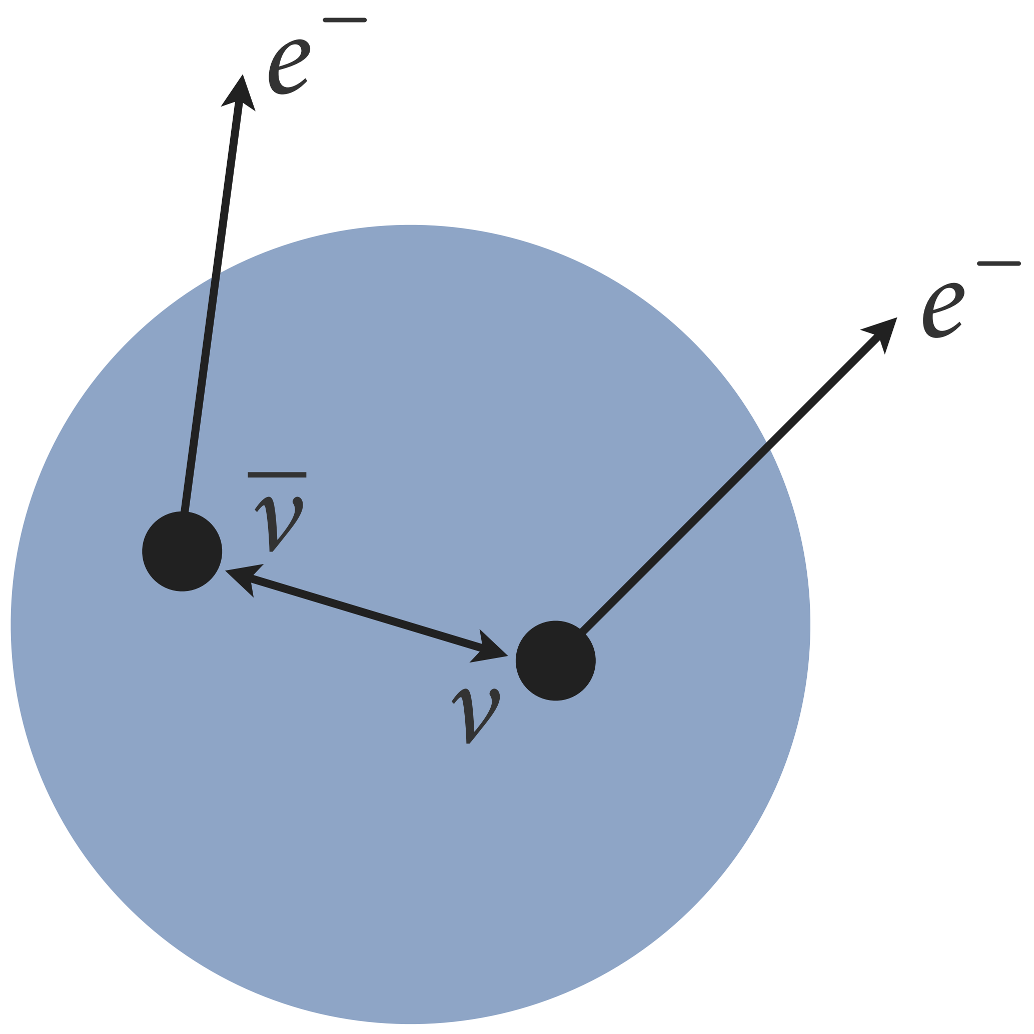



next
Laboratorio
Subterráneo
Canfranc
Nantes
Cholet
Bourges
Châteauroux
Poitiers
Montauban
Toulouse
Montpellier
Béziers
Perpignan
Gijón
Bilbao
Irun
Pau
Vitoria-Gasteiz
Pamplona
Logroño
León
Zaragoza
Lérida
Girona
ESPAÑA
Tarragona
Barcelona
Madrid
Toledo
Castelló de la Plana
Valencia
Palma de Mallorca
Alicante
0
100
200
300 km

Double beta decay



$2\nu\beta\beta$

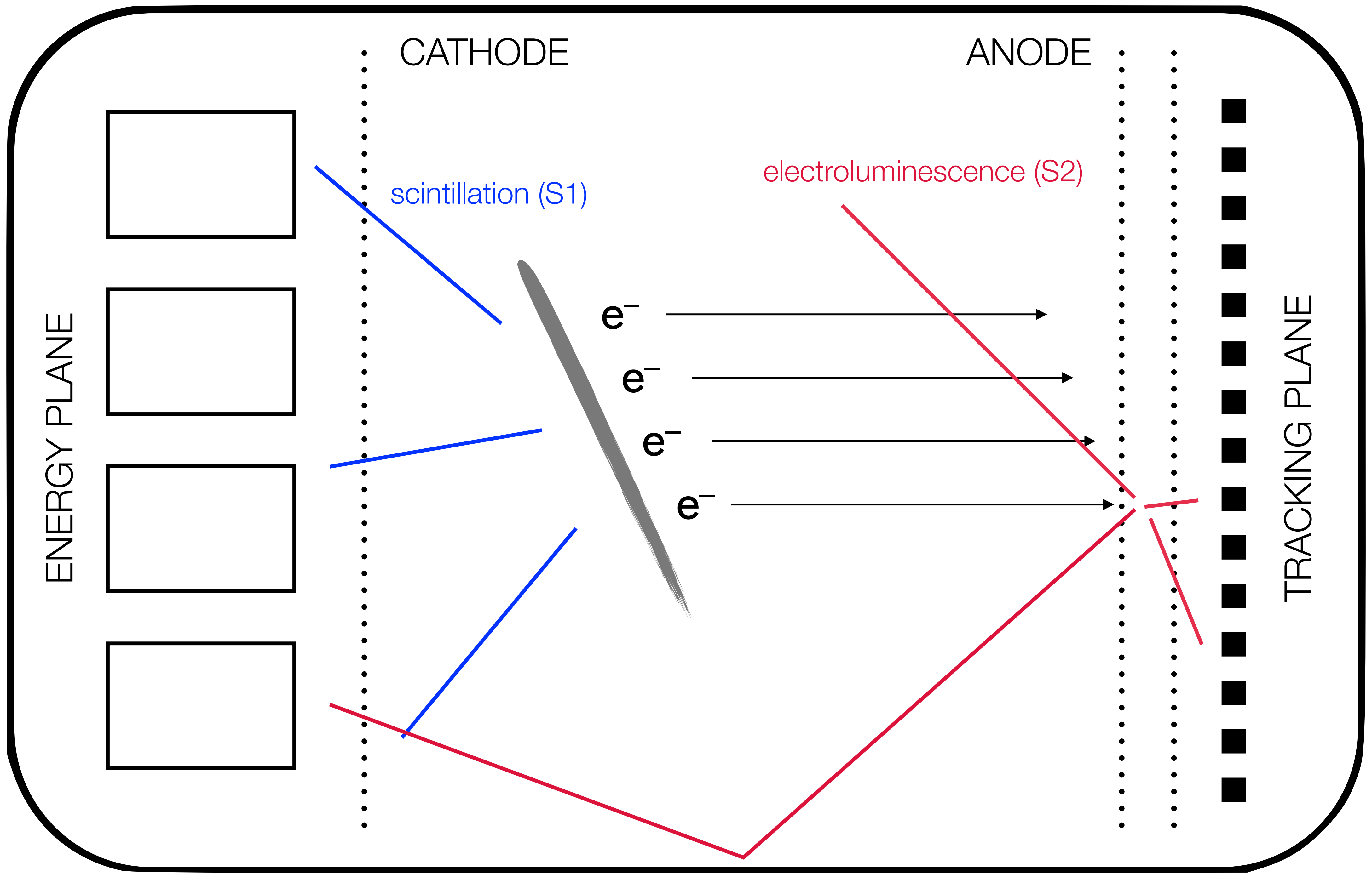


$0\nu\beta\beta$

SM-allowed process. Observed in several isotopes with half-lives of order 10^{18}–10^{22} years.

Forbidden in SM; only possible if neutrinos are **Majorana particles**. Half-life longer than 10^{26} years.

The NEXT detector concept

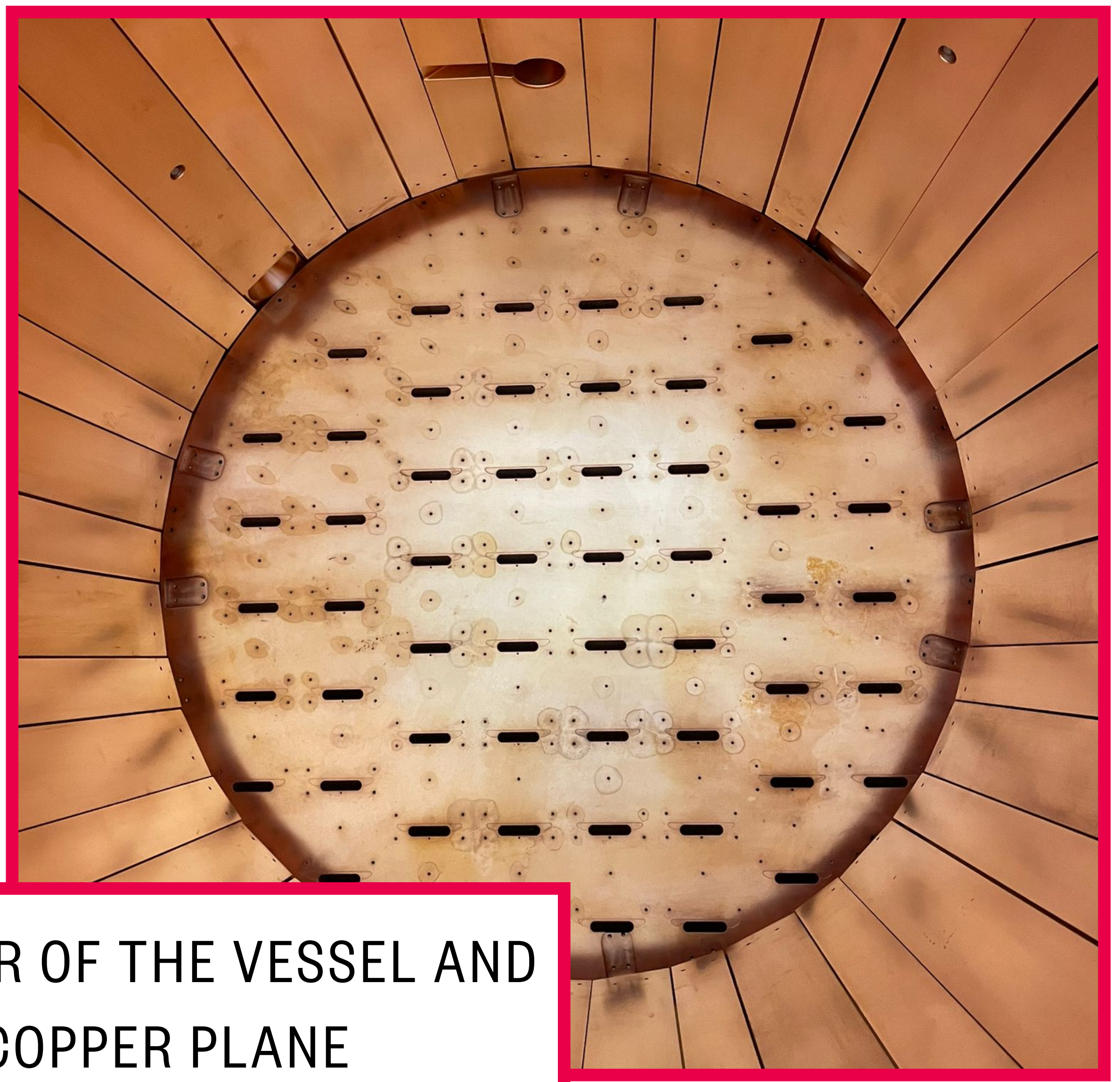


High-pressure xenon gas time projection chamber with electroluminescence-based amplification.

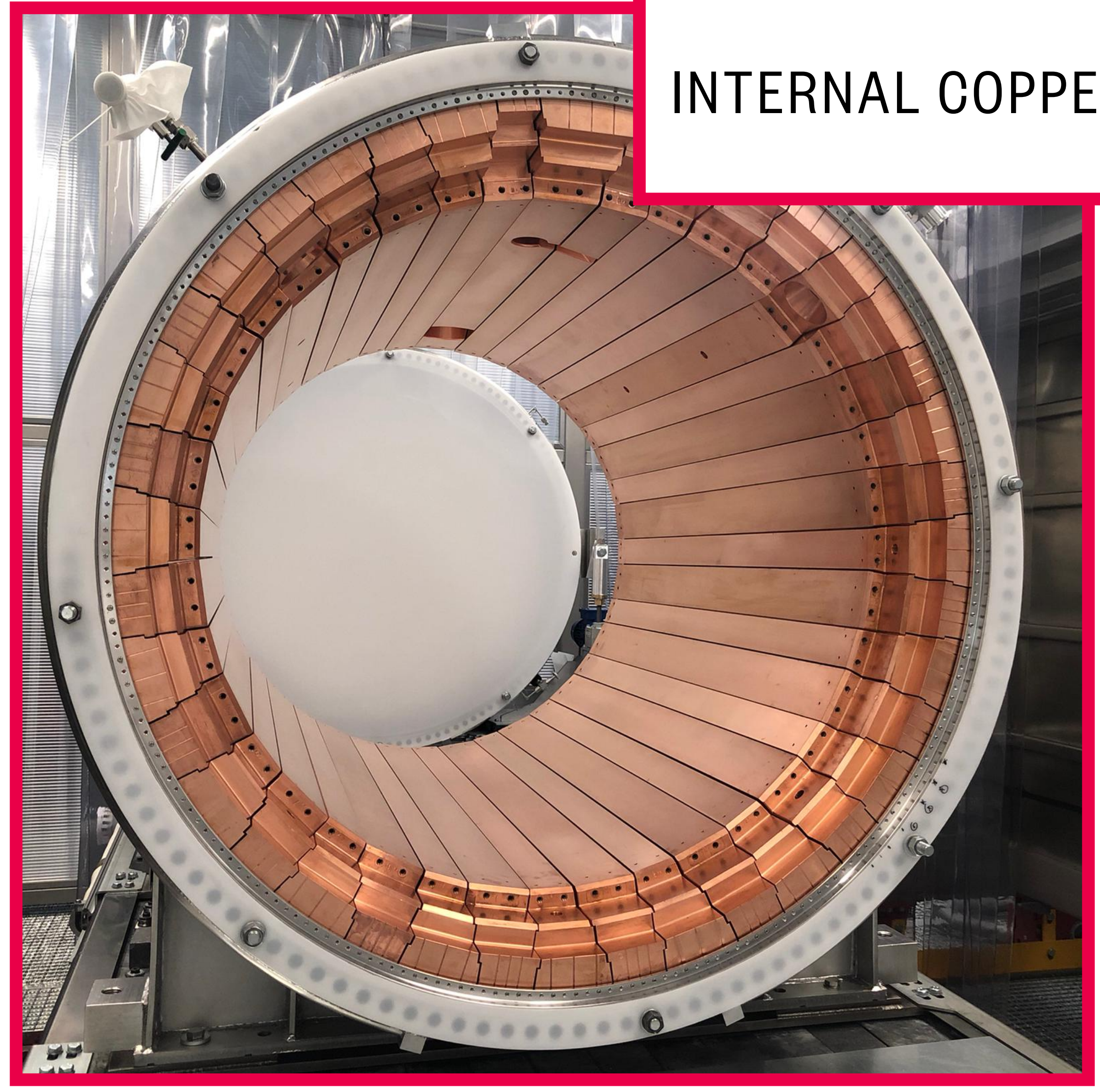
- Excellent energy resolution: better than 1.0% FWHM at 2.5 MeV.
- Track reconstruction for the discrimination of signal and background.

NEXT-100

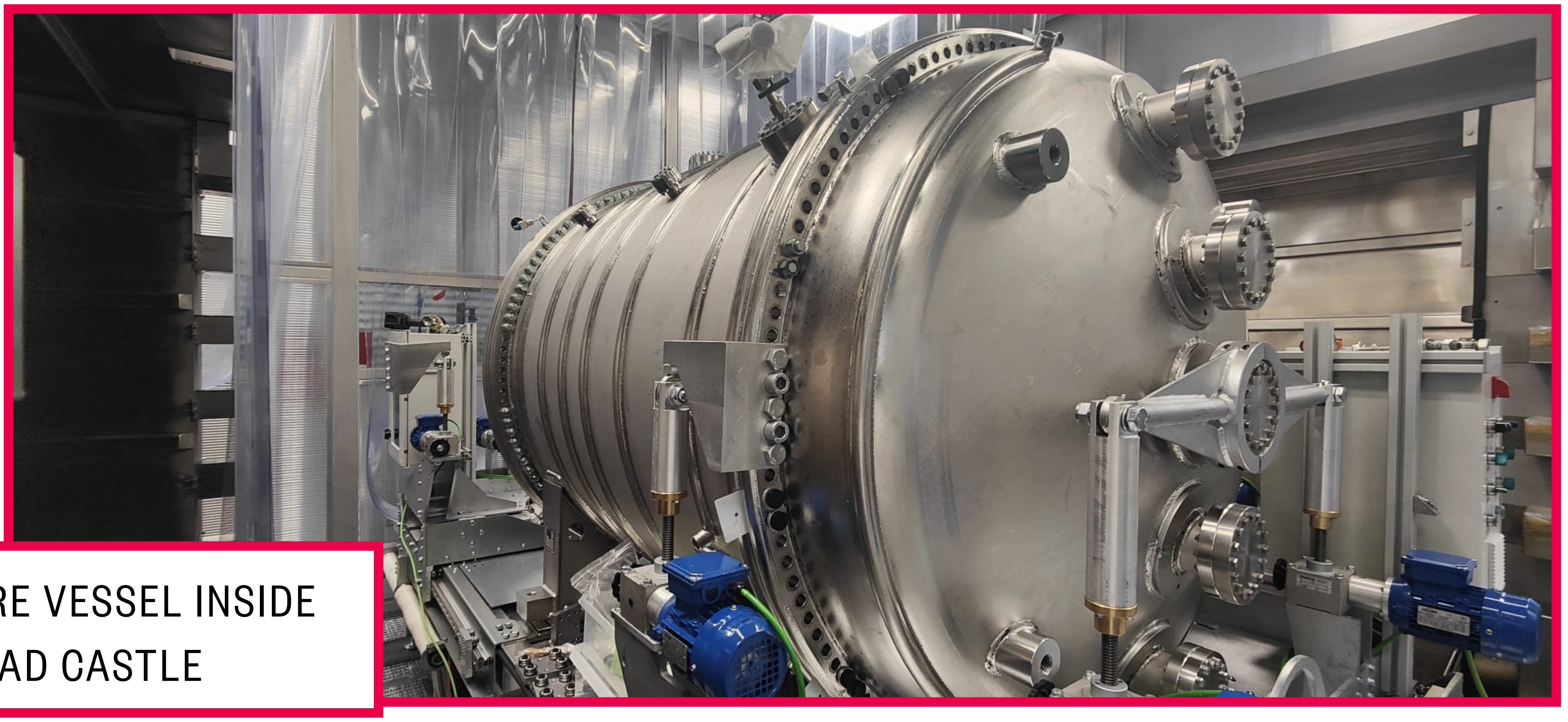
NEXT-100



INTERIOR OF THE VESSEL AND COPPER PLANE

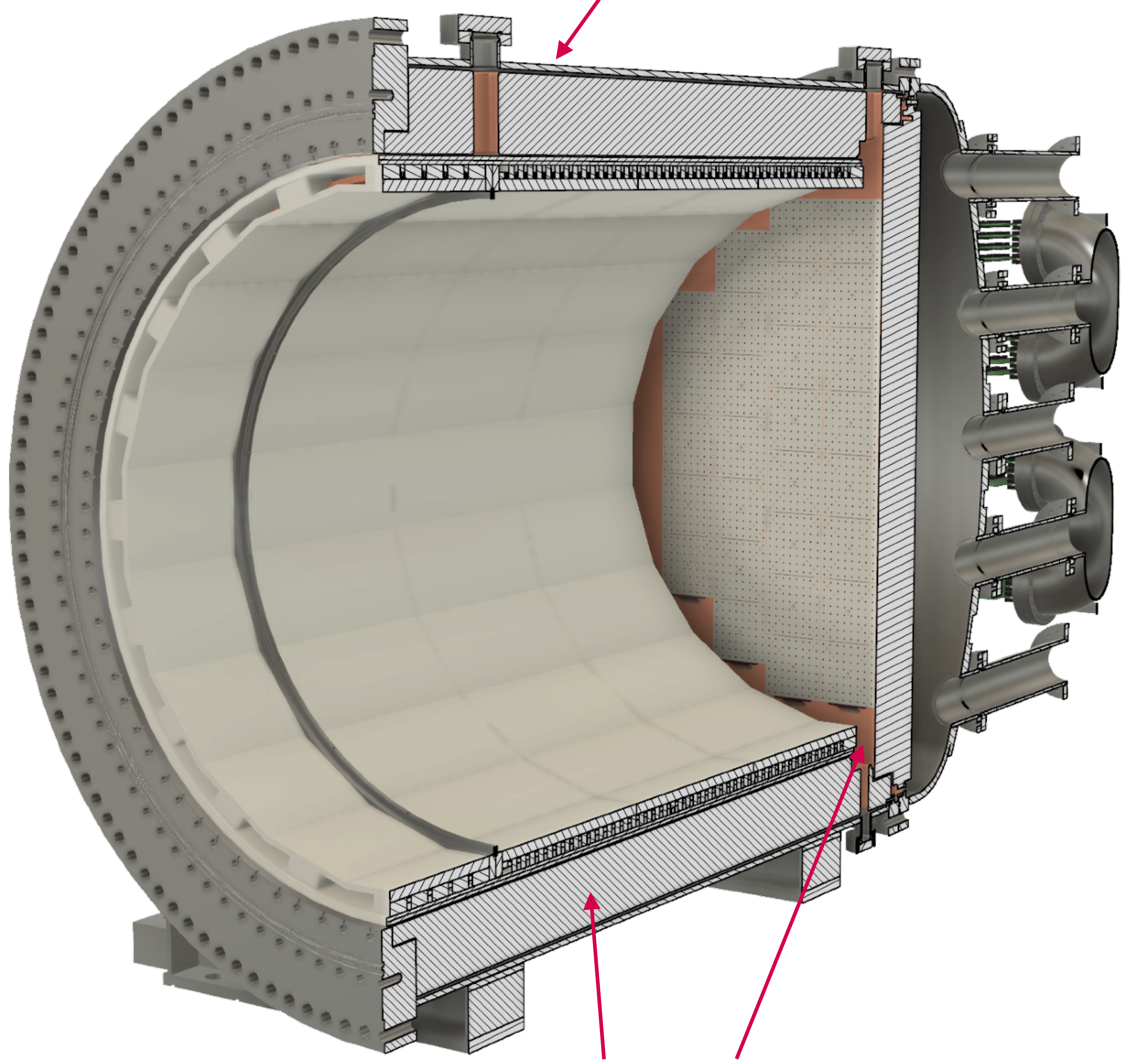


INTERNAL COPPER SHIELDING



PRESSURE VESSEL INSIDE LEAD CASTLE

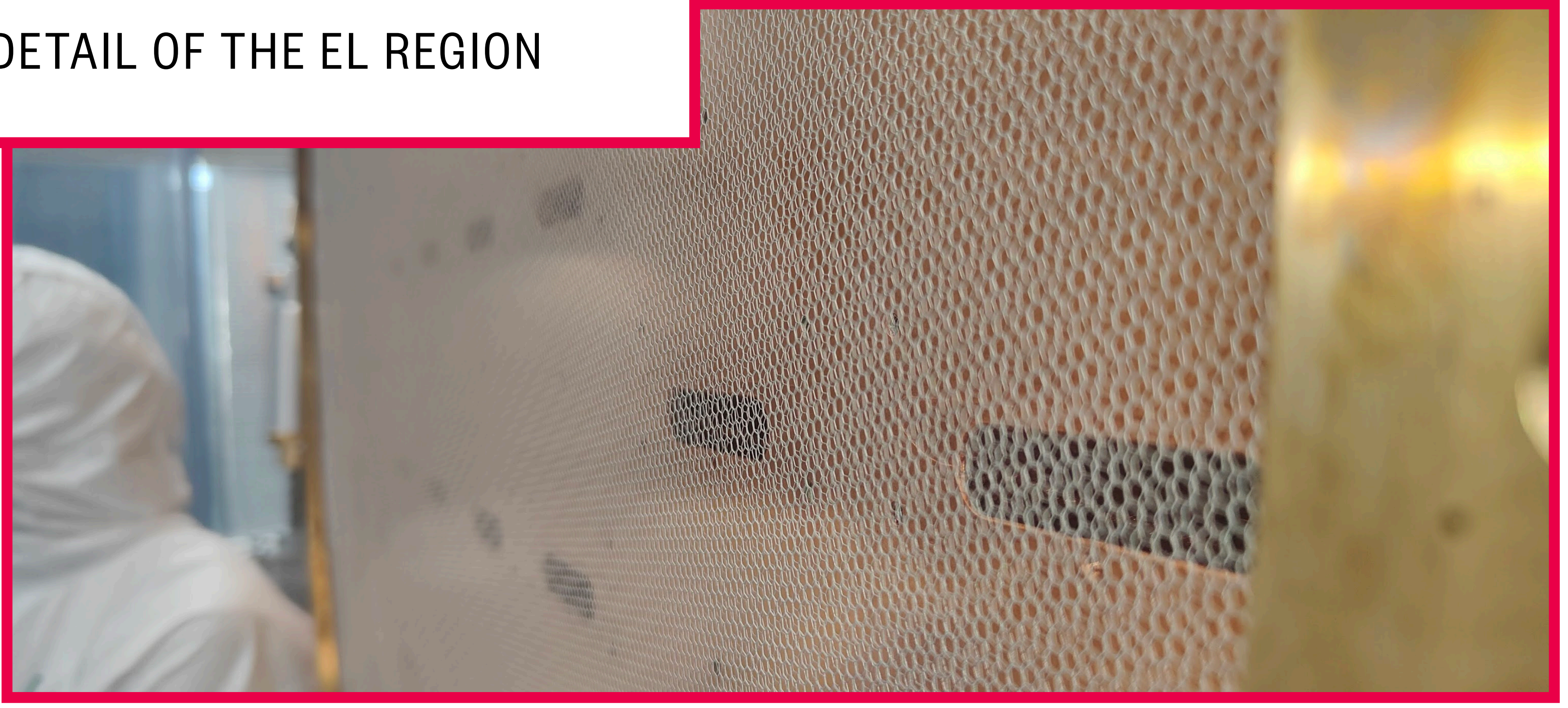
Pressure Vessel
100kg fiducial mass @ ~15bar



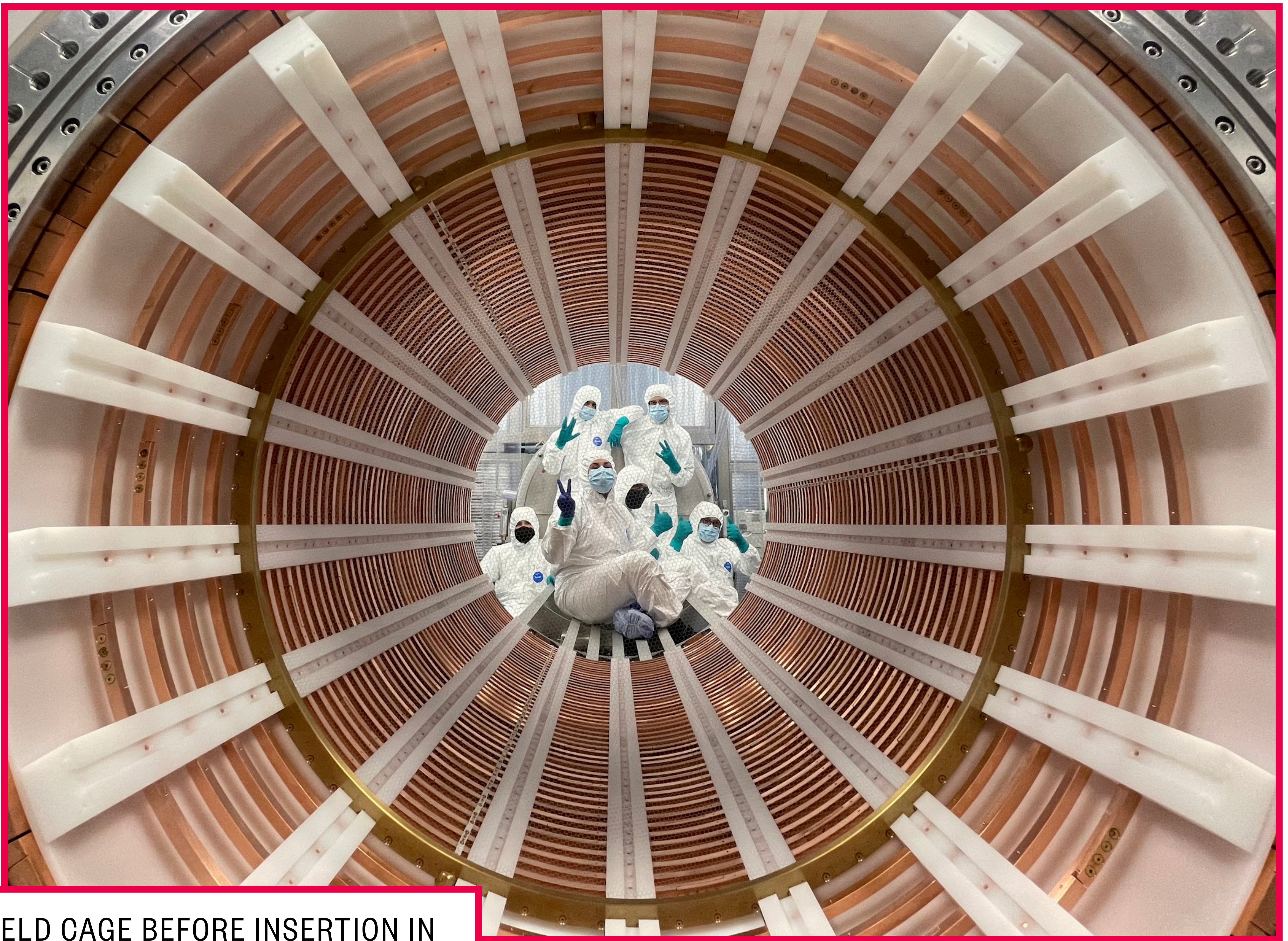
Copper Shielding
Thicker (12cm) ultra-pure copper shielding
Big machinery for production

NEXT-100

FIELD CAGE ASSEMBLED

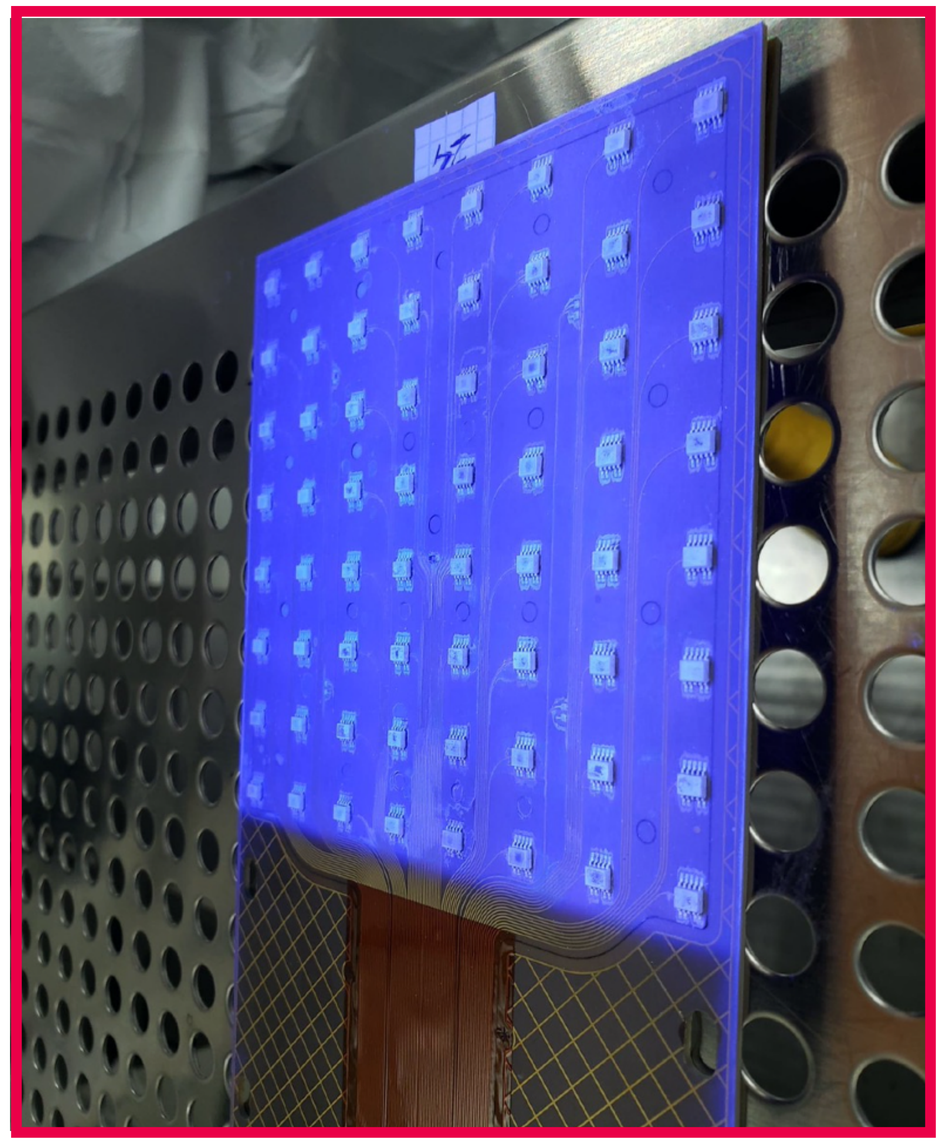


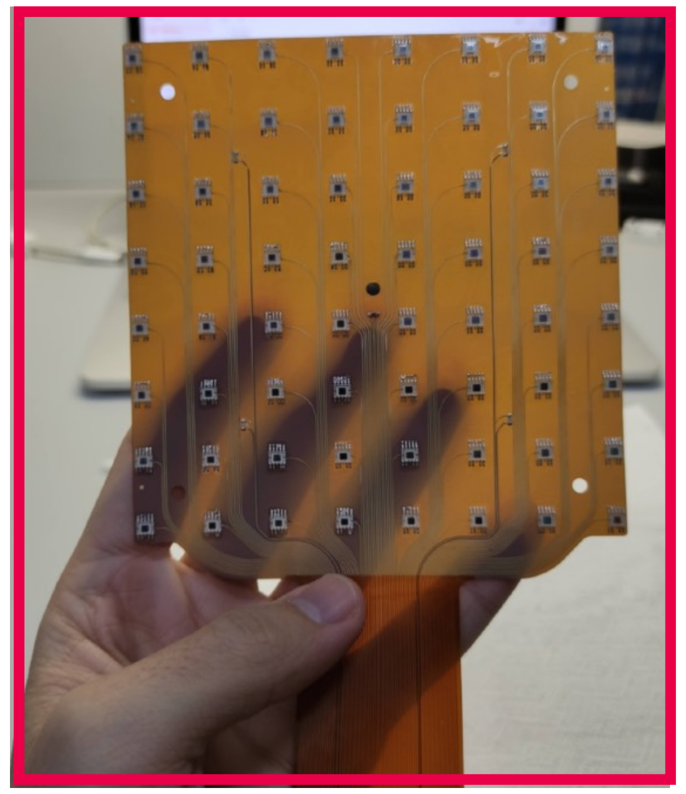
DETAIL OF THE EL REGION



FIELD CAGE BEFORE INSERTION IN PRESSURE VESSEL

NEXT-100

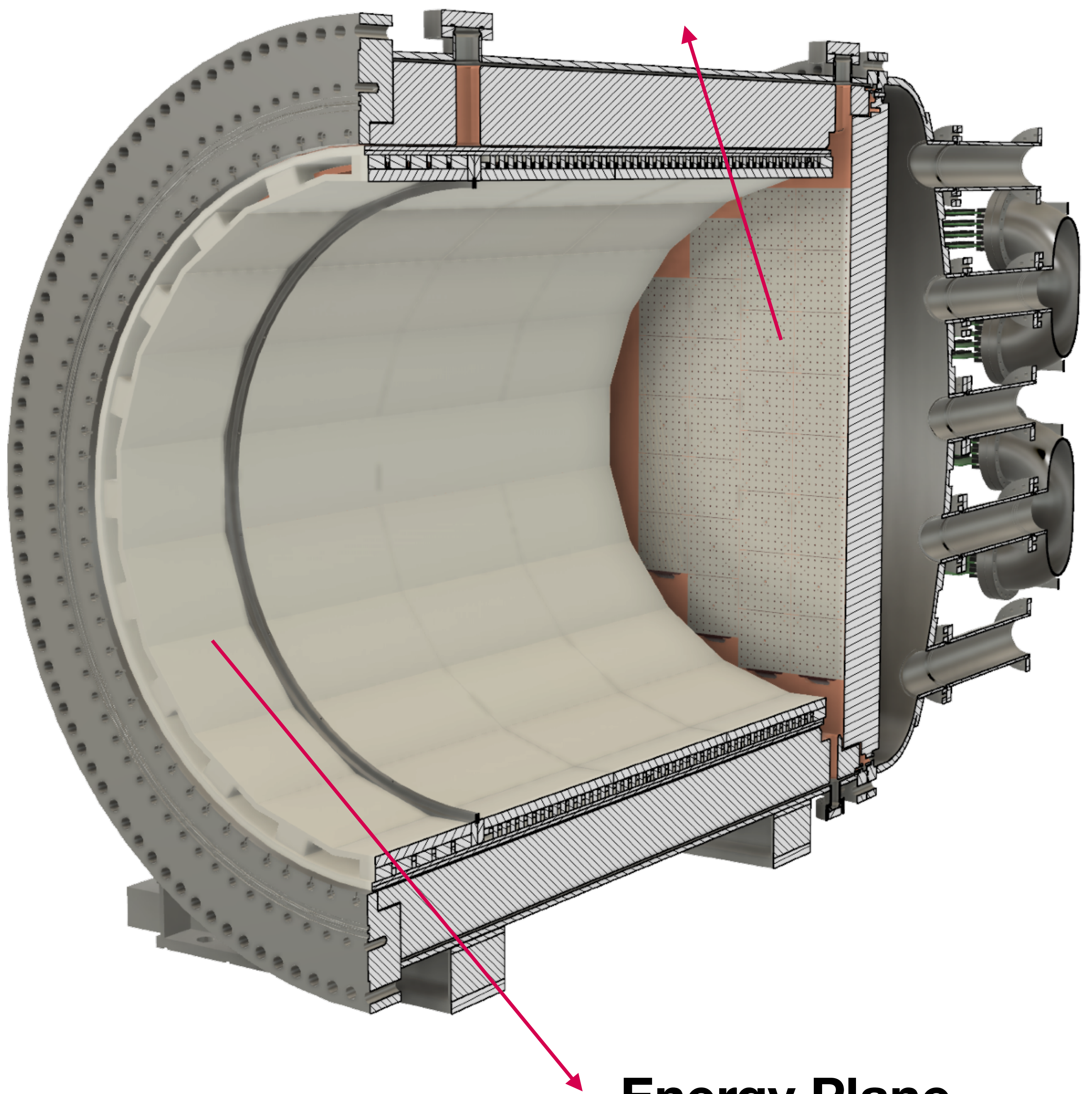




Hamamatsu SiPMs:
easier to mount,
more robust,
larger area.
Better for
dynamic range

Coated with TPB
for better light
detection

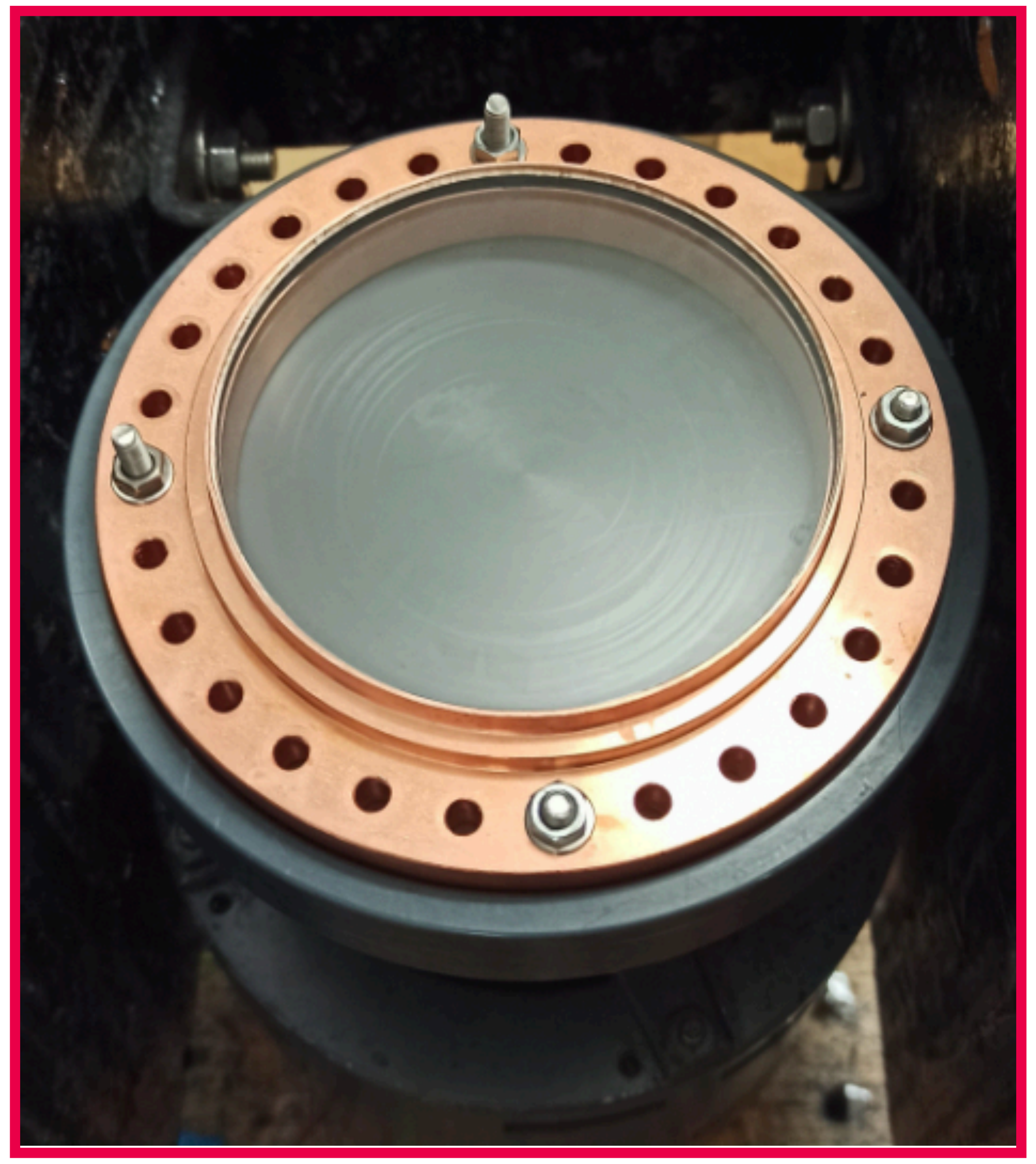
Tracking Plane
3584 Hamamatsu SiPMs
1.3x1.3 mm2 - 15.55 mm pitch
(60% more photons)



Energy Plane
60 Hamamatsu PMTs
R11410-10 - Same NEW
(30% coverage)

PMTs coupled
to xenon gas
through
sapphire
windows
welded to a
radio pure
copper frame

WINDOWS ARE COATED
WITH PEDOT



The **Deep Underground Neutrino Experiment** (DUNE) is an upcoming long-baseline neutrino oscillation experiment under construction in the United States. It will consist of three new systems:

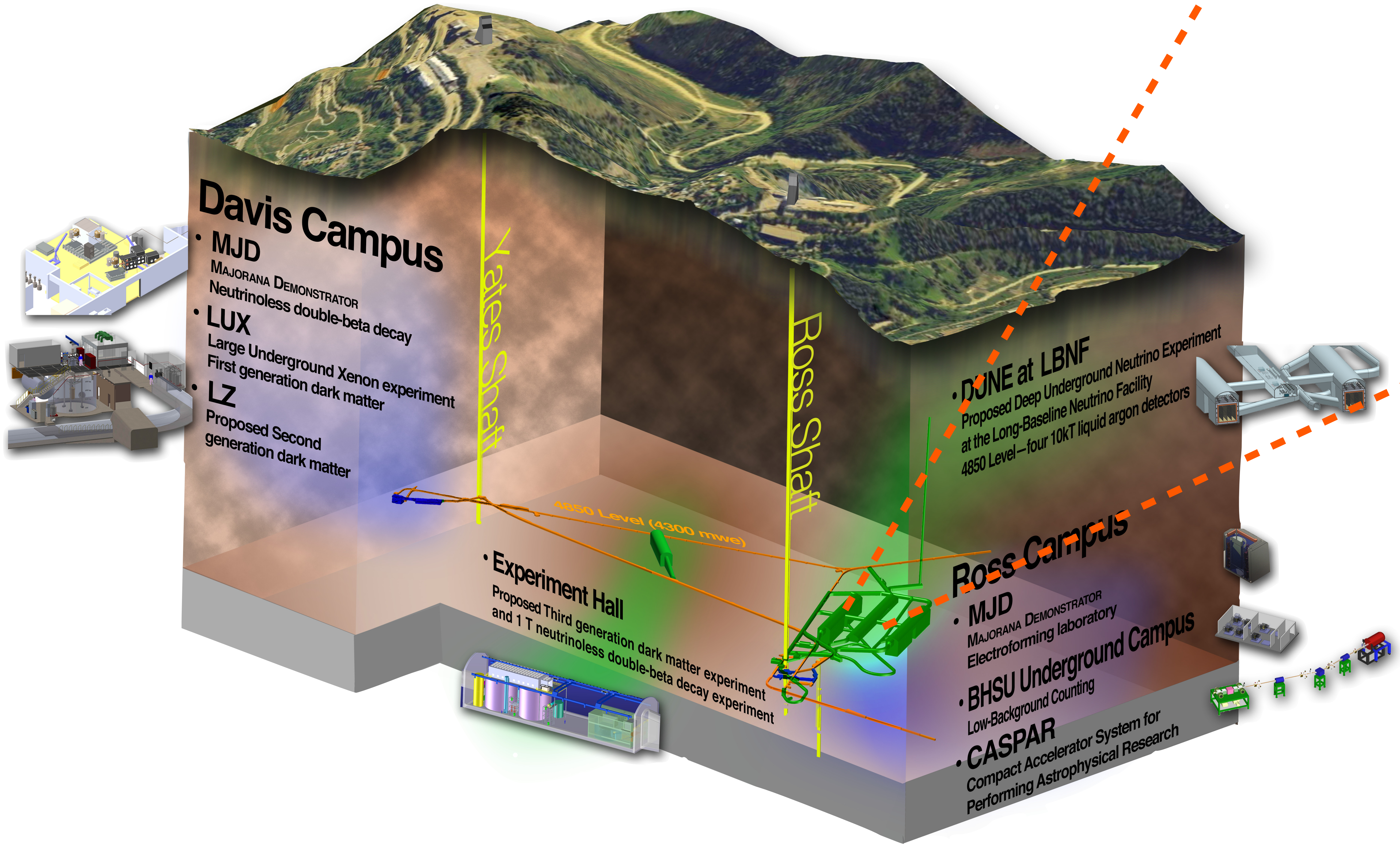
- a new MW-scale neutrino beamline (LBNF);
- a high-resolution, high-rate near detector (ND);
- a far detector (FD) comprising four 17-kiloton liquid argon TPC modules.

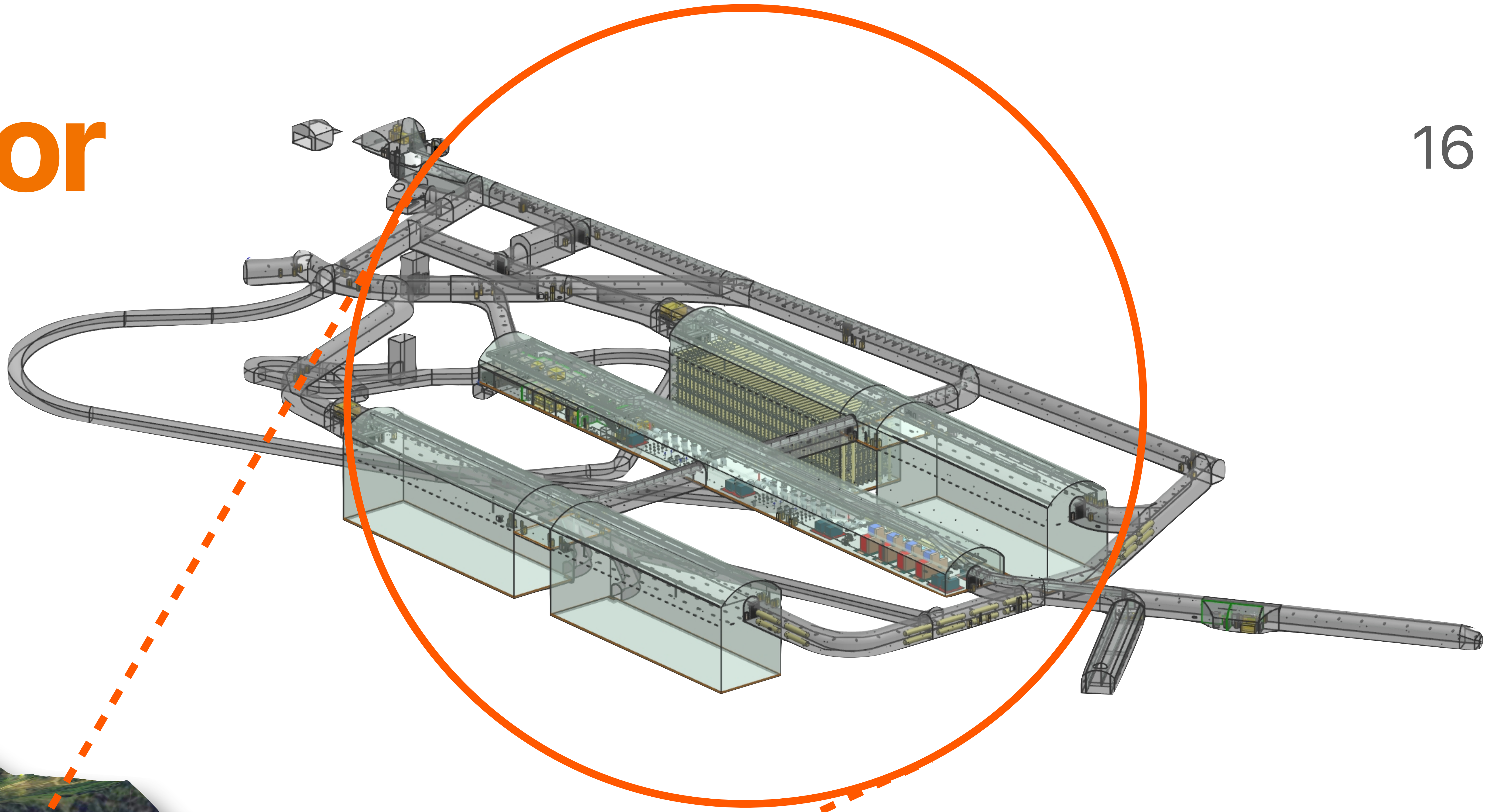
The **science program** of DUNE covers three major areas:

- Long-baseline neutrino oscillations.
- Neutrino astrophysics.
- Searches for phenomena beyond the Standard Model (BSM).

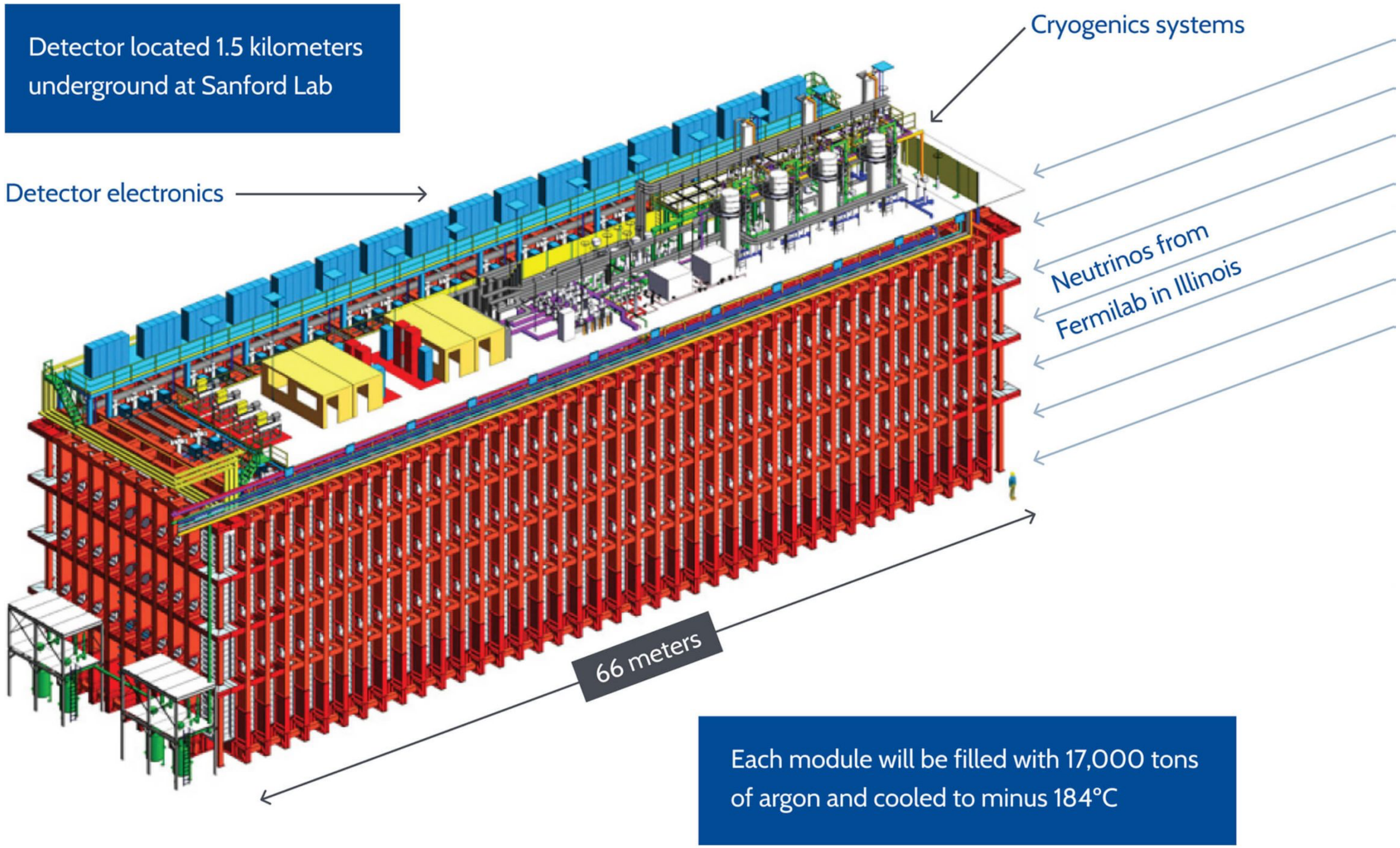

DUNE
1.284,59 km
1.000,00 km
500,00 km
0
Estados Unidos
Sanford Underground Research Facility
(Lead, South Dakota)
Fermi National Accelerator Laboratory
(Batavia, Illinois)
Medir distancia
Haz clic en el mapa para ampliar la ruta
Distancia total: 1.284,59 km (798,21 mi)
Capas
Datos del mapa ©2023 Google, INEGI
España
Términos
Privacidad
Enviar comentarios
200 km

The DUNE far detector





The DUNE far detector



ProtoDUNE at CERN

Two large-scale prototypes of the DUNE far detector built at CERN to test different technologies.

IFIC-NuLight and -NuCryo

NuLight & NuCryo

- **ASFAE 2022/029 (IFIC-NuLight):** *"Development of state-of-the-art light detection systems for the DUNE and NEXT experiments".*
  - Nadia Yahlali (IP1), Justo Martín-Albo (IP2), Michel Sorel.
- **ASFAE 2022/028 (IFIC-NuCryo):** *"Creation of a multipurpose laboratory at IFIC for the development of cryogenically-cooled gas and liquid noble element detectors".*
  - Anselmo Cervera (IP1), Neus López (IP2), Pau Novella.
- Goals:
  - R&D on VUV photon collection for NEXT and DUNE aimed at enhancing their physics reach.
  - R&D on mK-precision temperature monitoring system of cryogenic liquids for DUNE.
  - Expansion of the NEXT and DUNE laboratories at IFIC to general-purpose facilities for photon detection and for cryogenically-cooled gaseous and liquid noble elements.
  - The IFIC Neutrino Group aims at becoming a worldwide reference in these detection technologies, with broad impact in science and high transfer potential.

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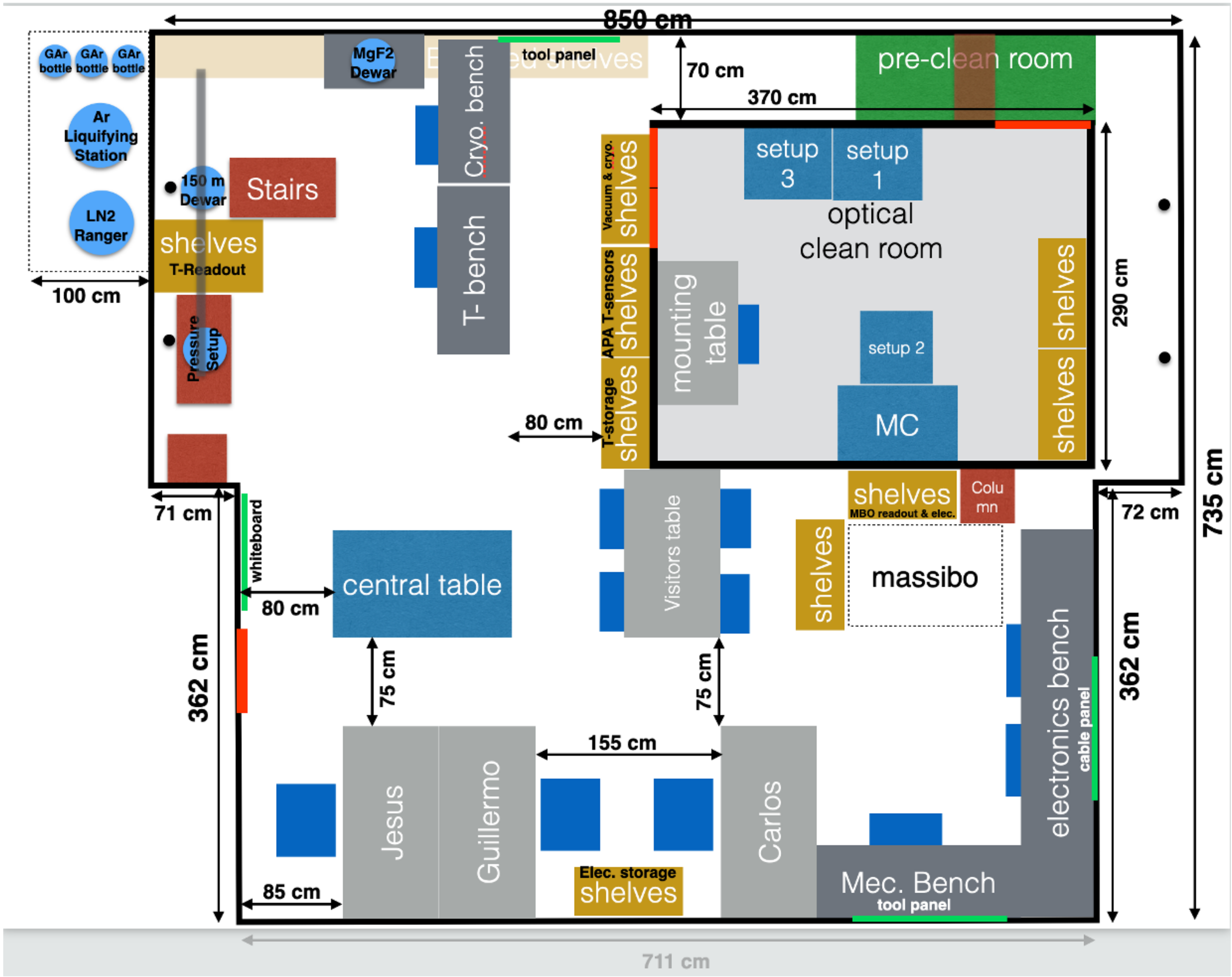
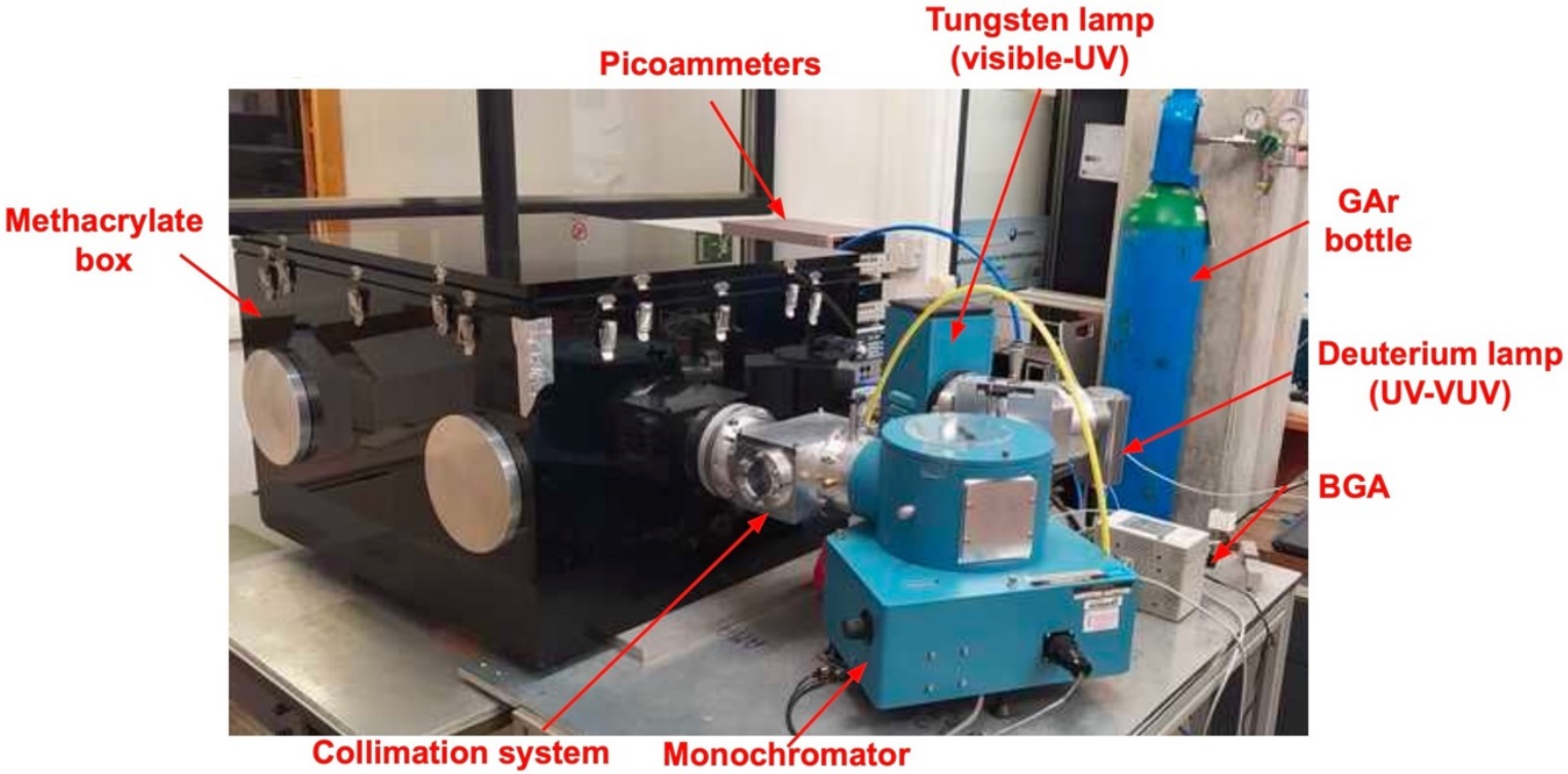
Specific objectives

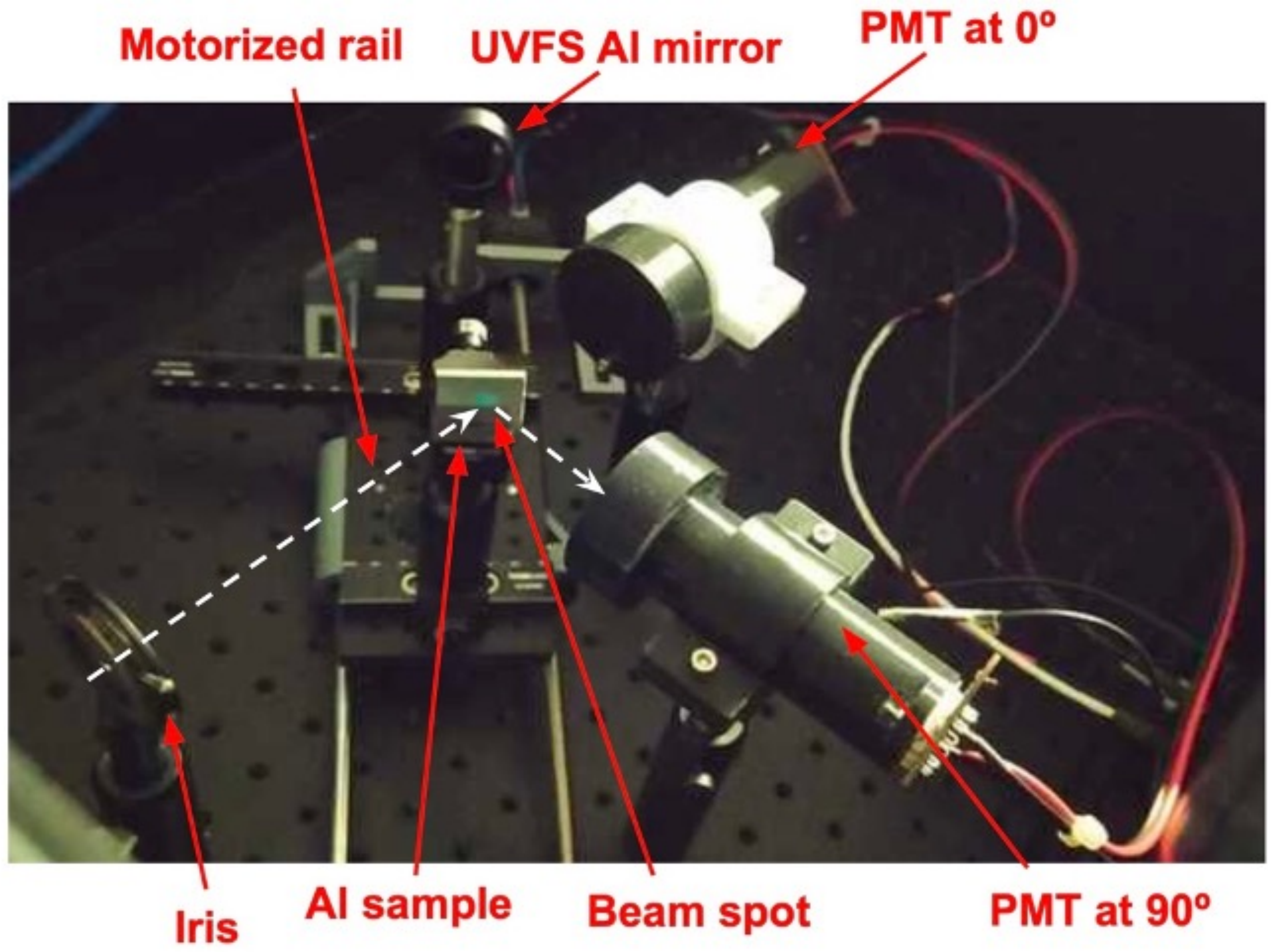
- IFIC-NuLight:
  - Upgrade our laboratory, equipped already with a vacuum monochromator and lamps, to a general-purpose facility for fast spectral analysis of materials and photosensors used in NEXT and DUNE.
  - Design and build infrastructures for testing large photon collectors of NEXT and DUNE in the VUV range using the photospectrometer system.
  - Development of large-area photon detector system prototypes for future upgrades of the NEXT and DUNE experiments.
- IFIC-NuCryo:
  - Acquisition of a large multipurpose cryostat able to operate with cryogenically-cooled gases and liquid noble elements for testing large-area photon collectors for DUNE and NEXT.
  - Upgrade the existing gas system with the necessary equipment to improve the noble element purity.
  - Design and build cryogenic infrastructures for temperature monitoring for DUNE far detector.
  - Contribute to the operation of cryogenics infrastructures at CERN for testing full scale photon collectors and cryogenics instrumentation systems.

The DUNE laboratory at IFIC

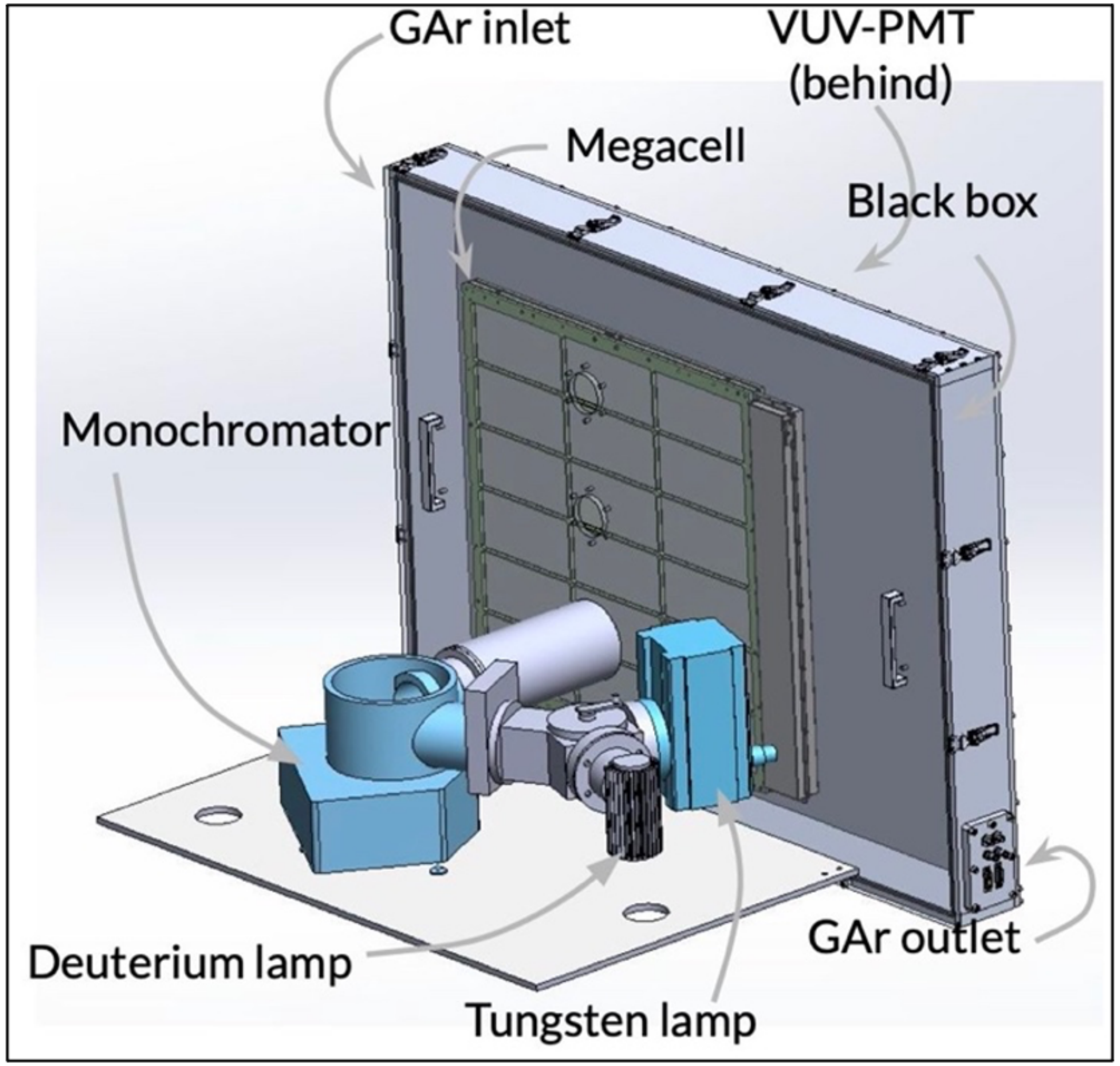


NuLight: VUV-Vis photospectrometer

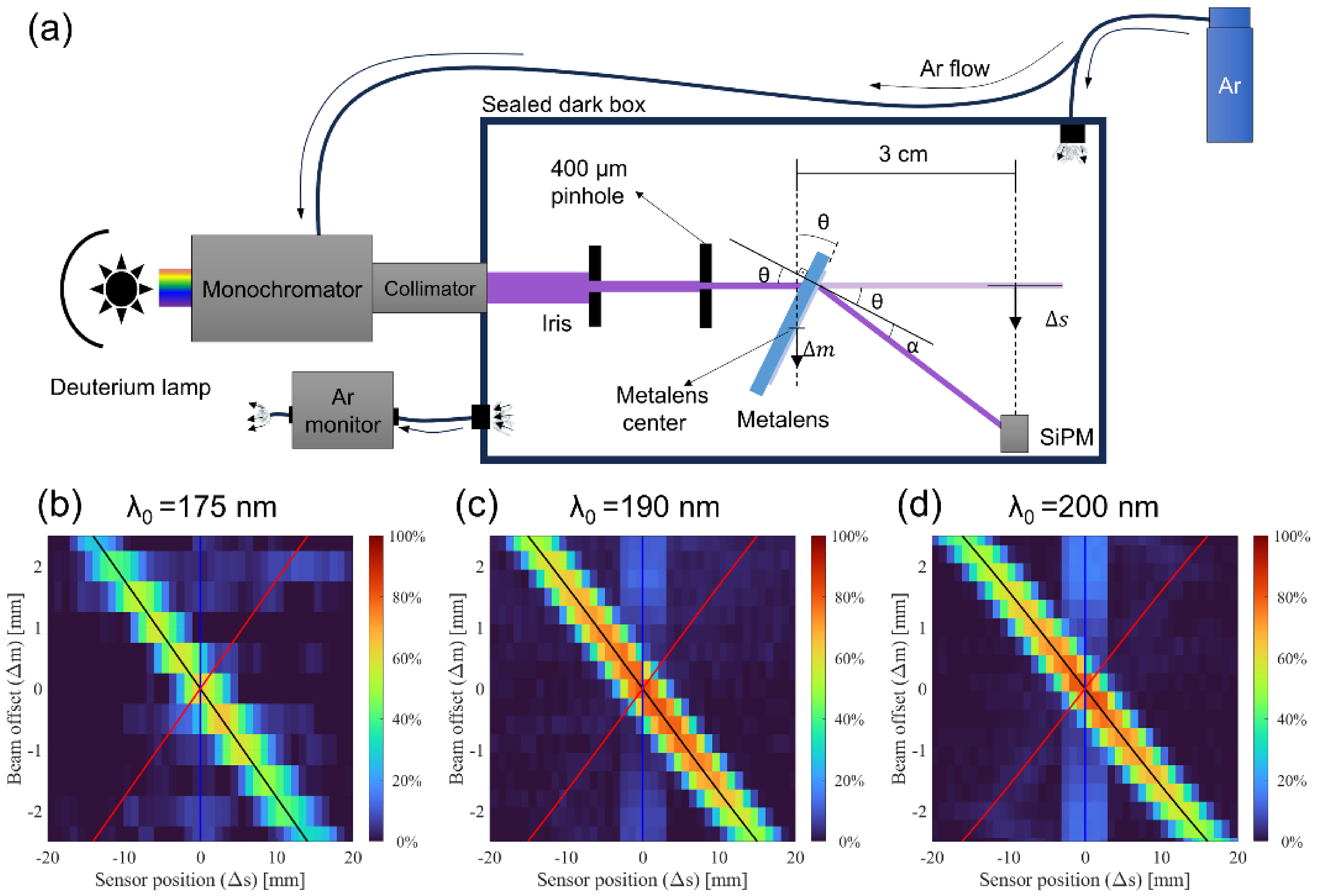


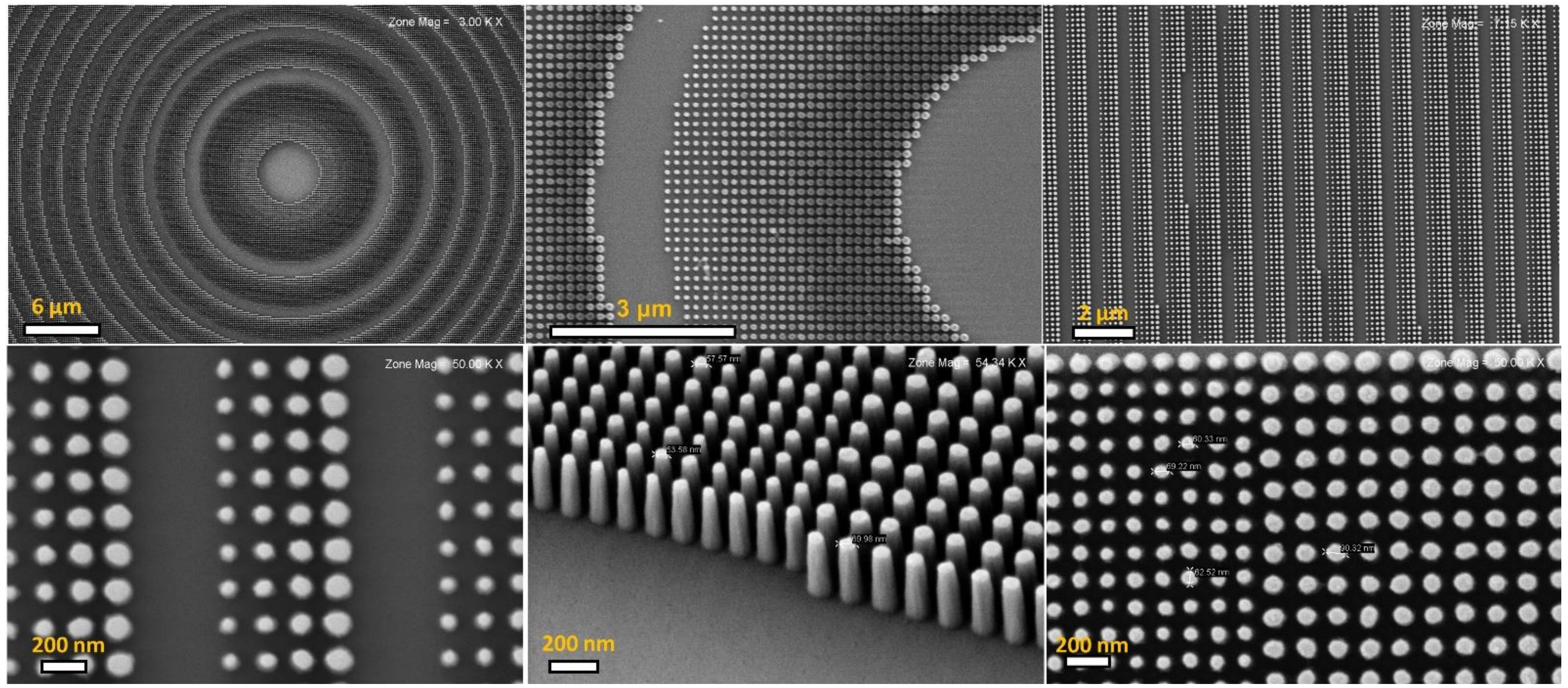


NuLight: Photon collector characterisation



NuLight: VUV metalenses

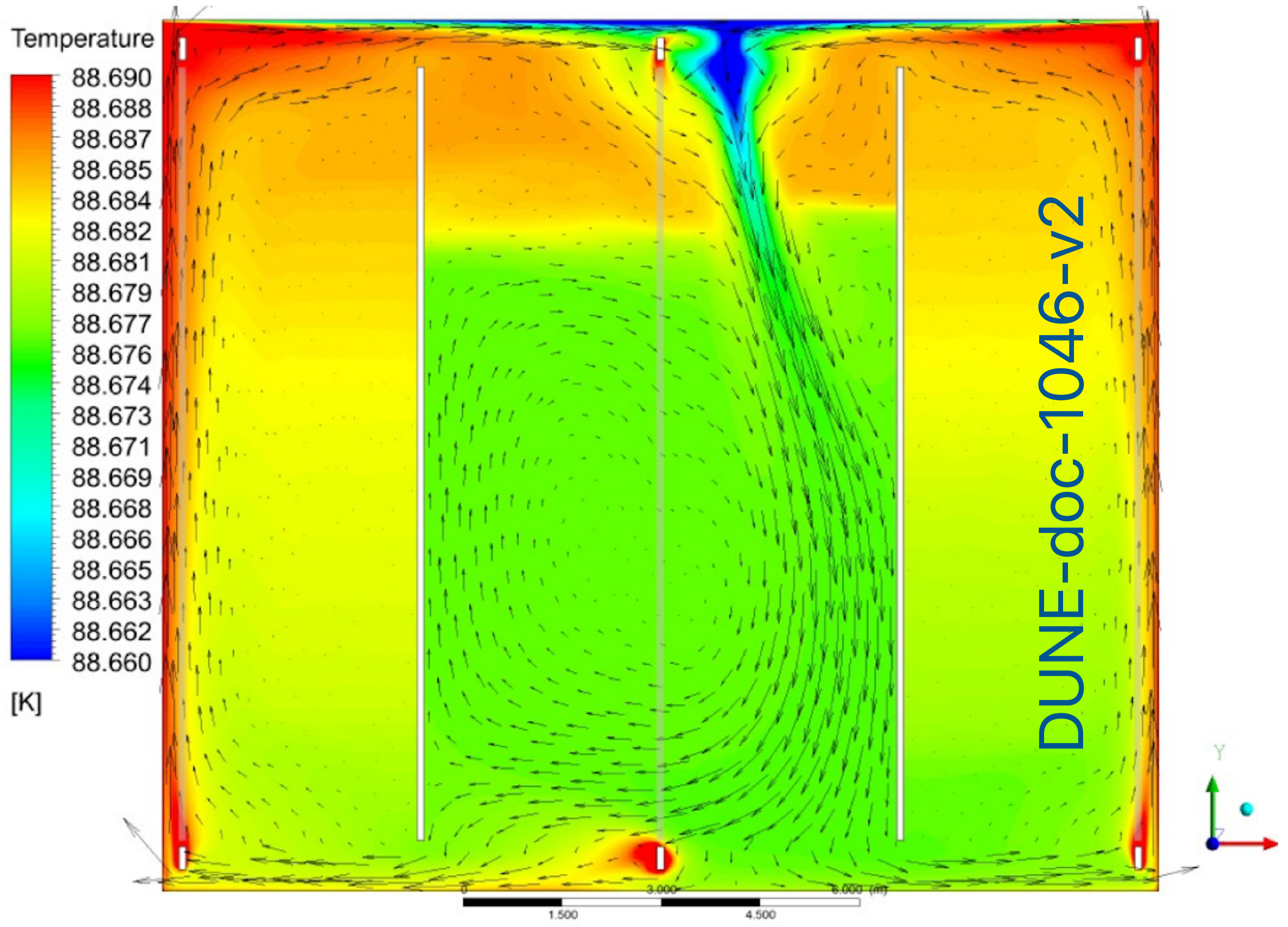


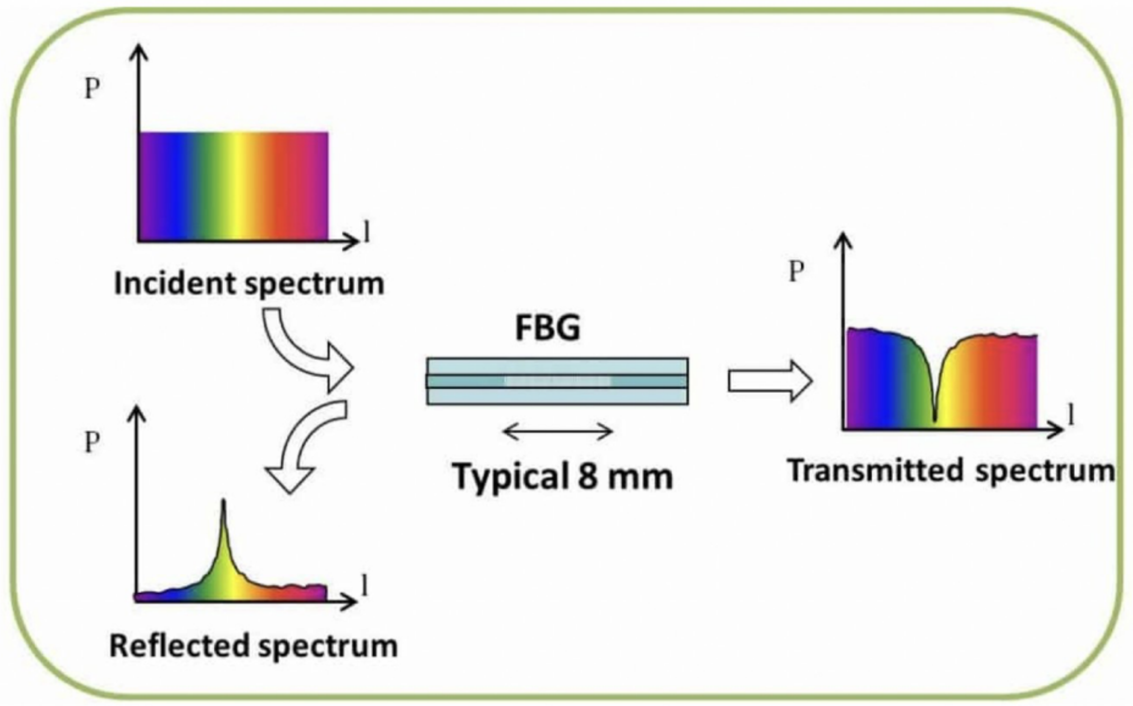


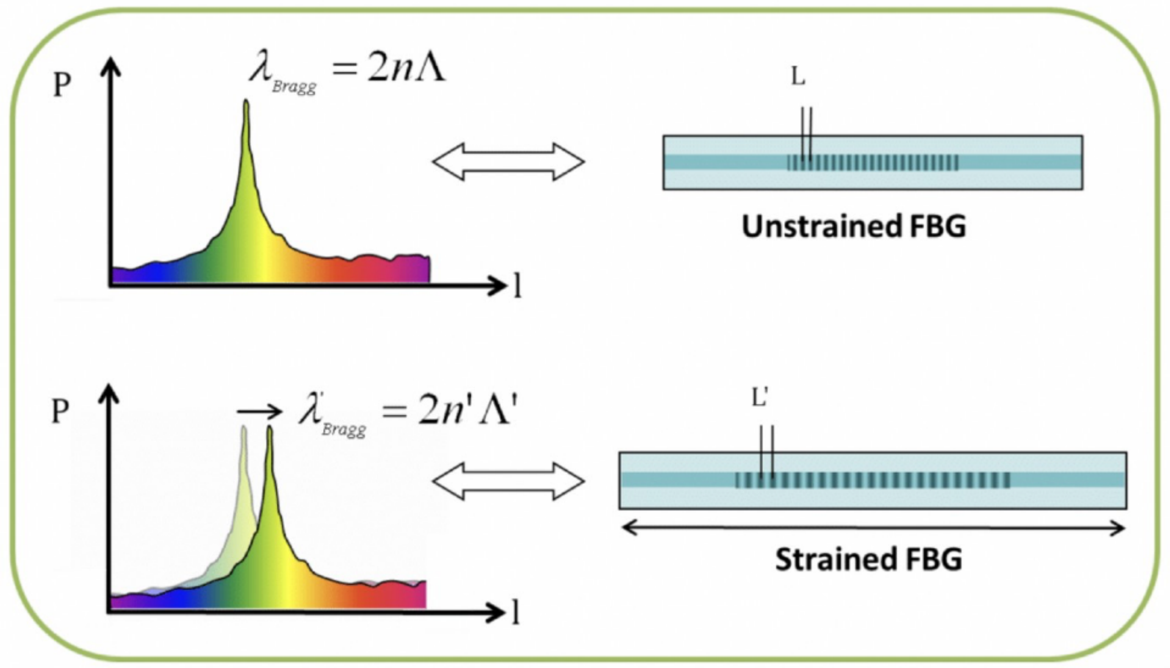
arXiv:2401.11315

NuCryo: LAr thermometry

- Precise 3D LAr temperature maps constrain the fluid dynamic simulations (top figure) that predict important parameters for detector performance such as impurity levels (which have an effect on the intensity of the scintillation signal).
- We are developing temperature sensors for the DUNE LAr TPCs based on the fibre Bragg grating (FBG) technology, which uses the changes in the reflected/transmitted spectral response of an optical fibre to measure strain and temperature.
- Our application has requirements (e.g. relative precision of 2 mK) beyond the typical commercial specs of FBG.







Summary

- Our group is carrying out a focused, interdisciplinary R&D to optimise and enhance photon collection in the DUNE and NEXT experiments; namely:
  - Improving light propagation via highly reflective detector materials.
  - Improving the detection efficiency existing large-area collectors beyond the few-percent level using optimised components (dichroic filters, light guides…) or new technologies (e.g. metasurfaces).
- While this R&D has neutrino experiments at its center, other applications (in particle physics or medical imaging, for example) may be explored as well.

(Backup material)

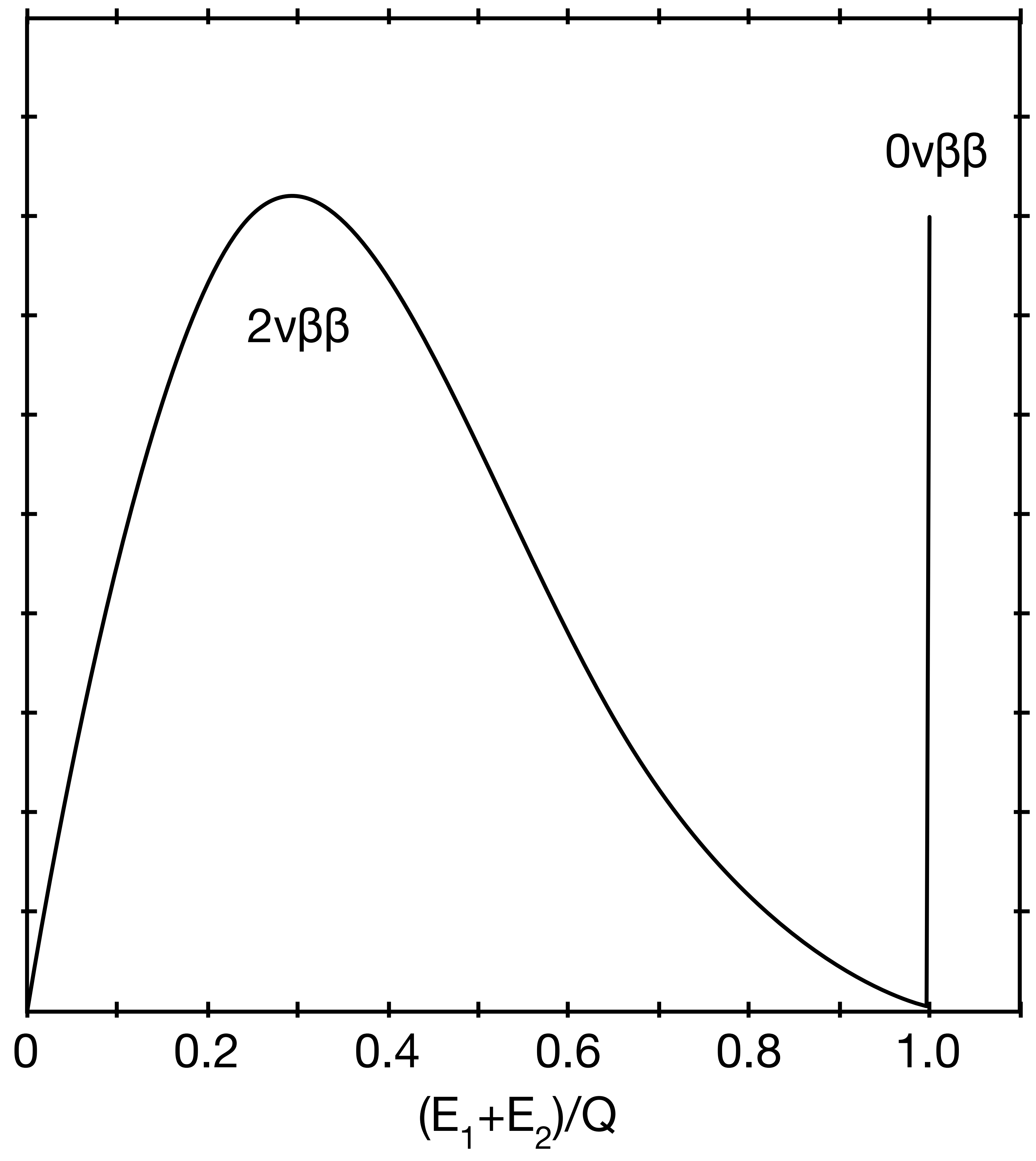
We know neutrinos oscillate… but what is the origin of neutrino mixing? Is there an underlying flavour symmetry?

We know there are at least three neutrino states… but are there exactly three? Is the mixing matrix unitary?

We know neutrinos have mass… but what is the origin of neutrino mass? Why are the neutrinos so light? What is the absolute neutrino mass scale?

Build your own 0νββ-decay experiment

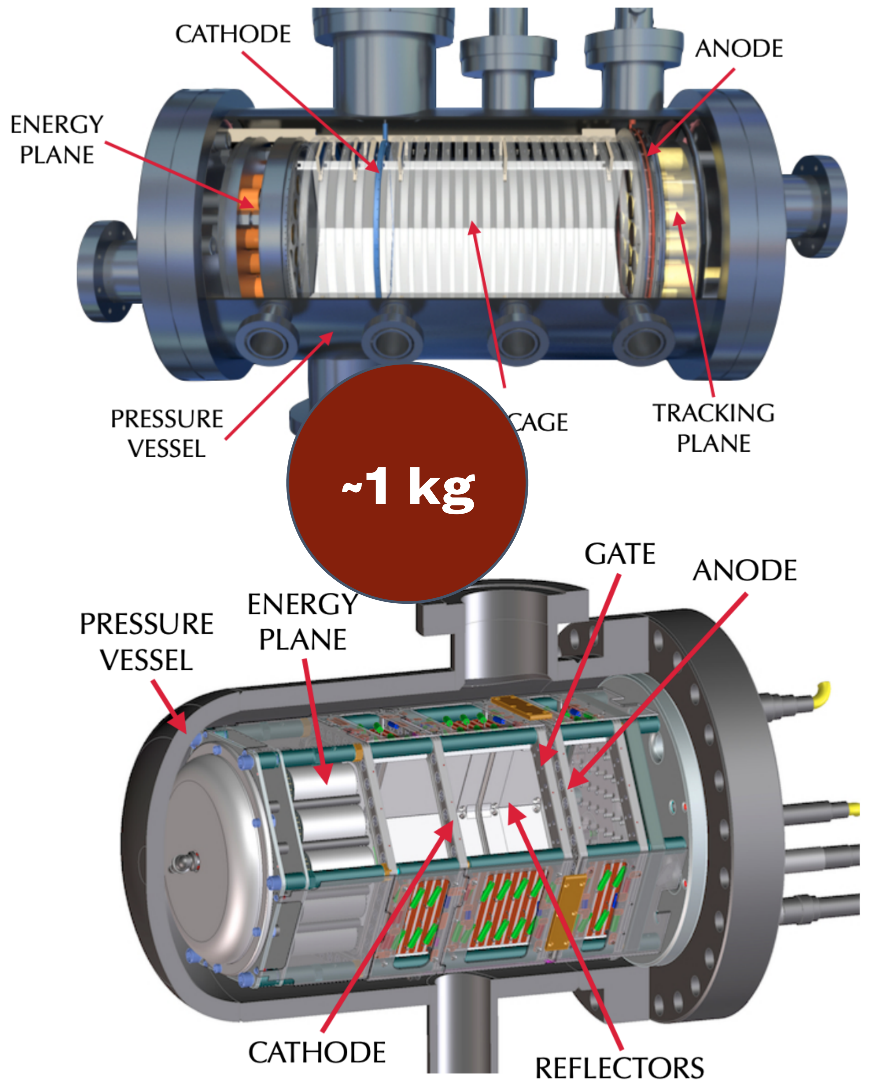
1. Acquire a large mass (*M*) of a double-beta emitter and a calorimeter with perfect resolution and efficiency.
2. Measure the energy of the radiation emitted by the source to separate the two double beta decay modes.
3. Count the number of neutrinoless decays (*N*) that have occurred in a given time (*t*) and calculate the corresponding half-life.



The NEXT project

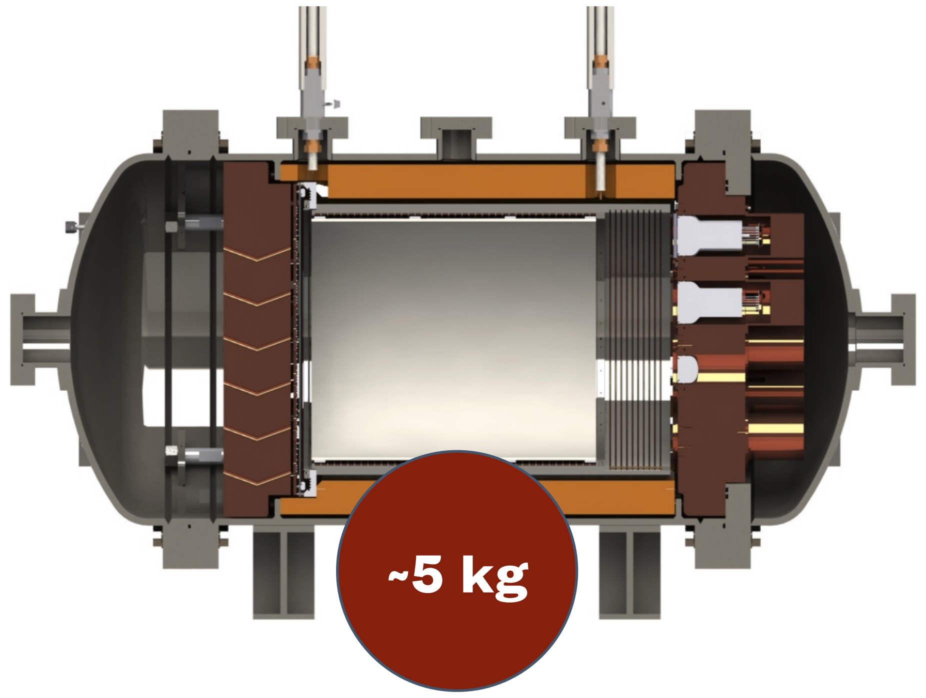
Prototypes
2010-2014

Demonstration of detector concept



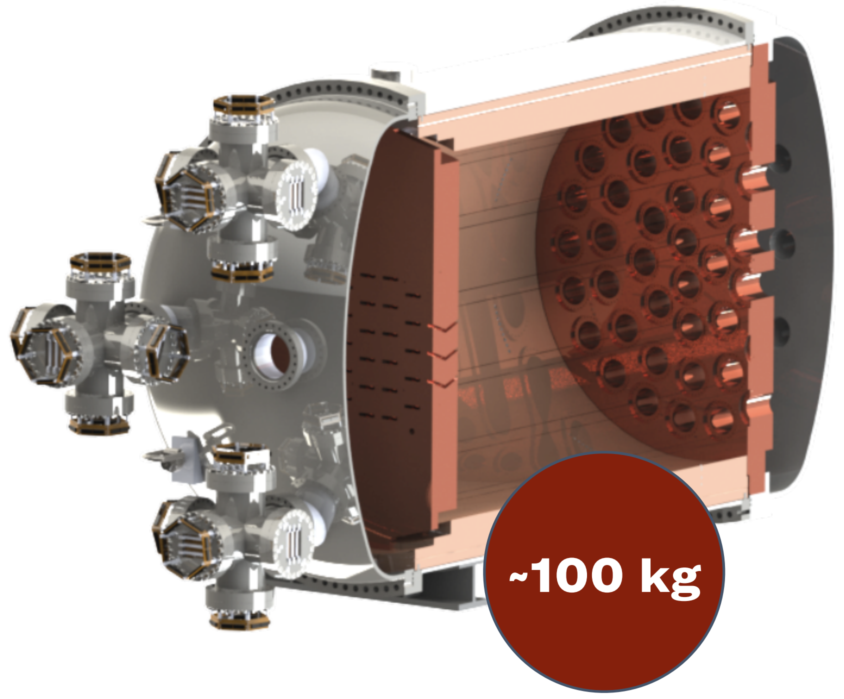
NEXT-White
2015-2021

Background model assessment
$2\nu\beta\beta$ measurement for ^{136}Xe



NEXT-100
2022-2026

Neutrinoless double beta decay search in ^{136}Xe (10^{27} y)

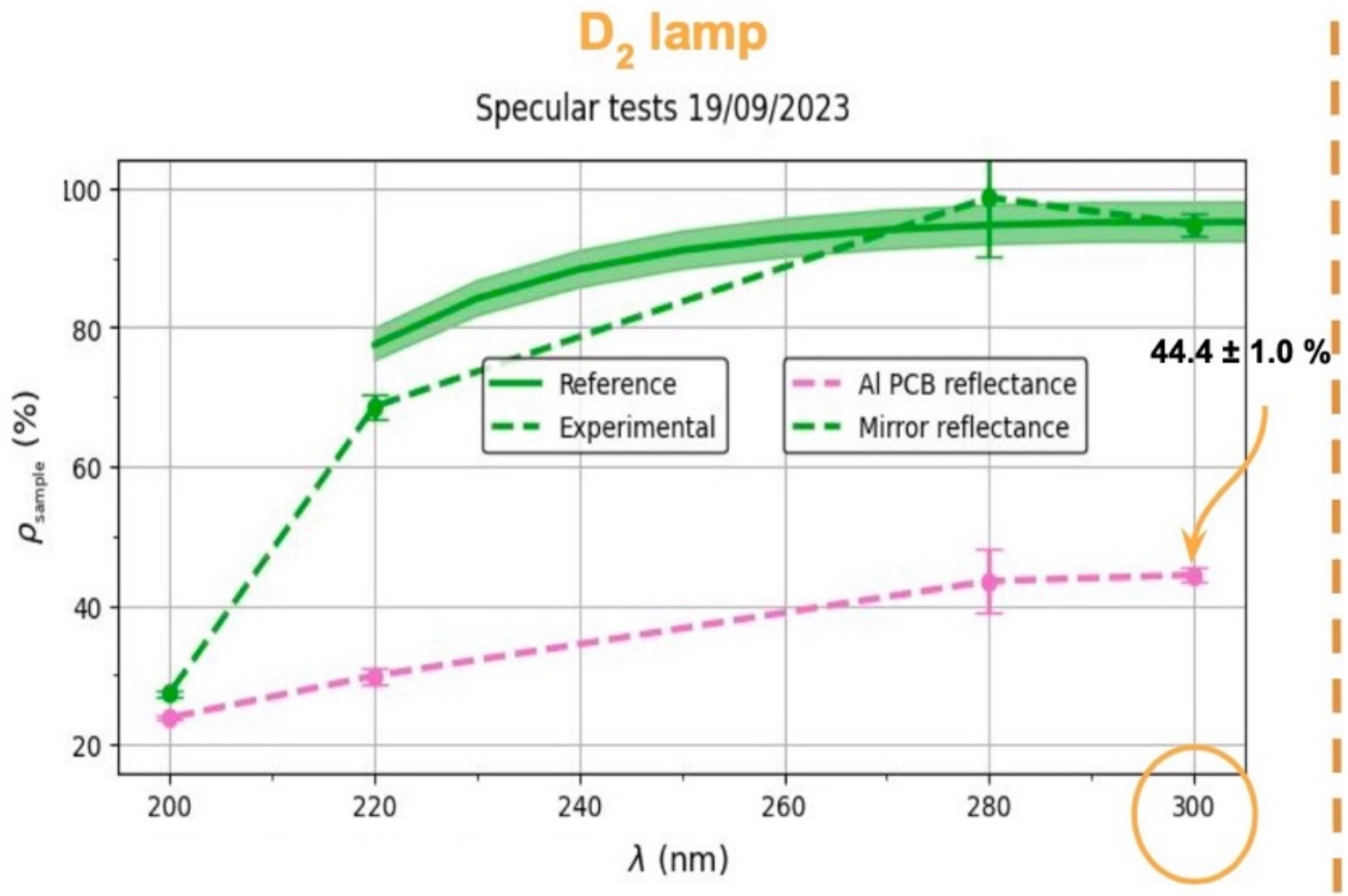


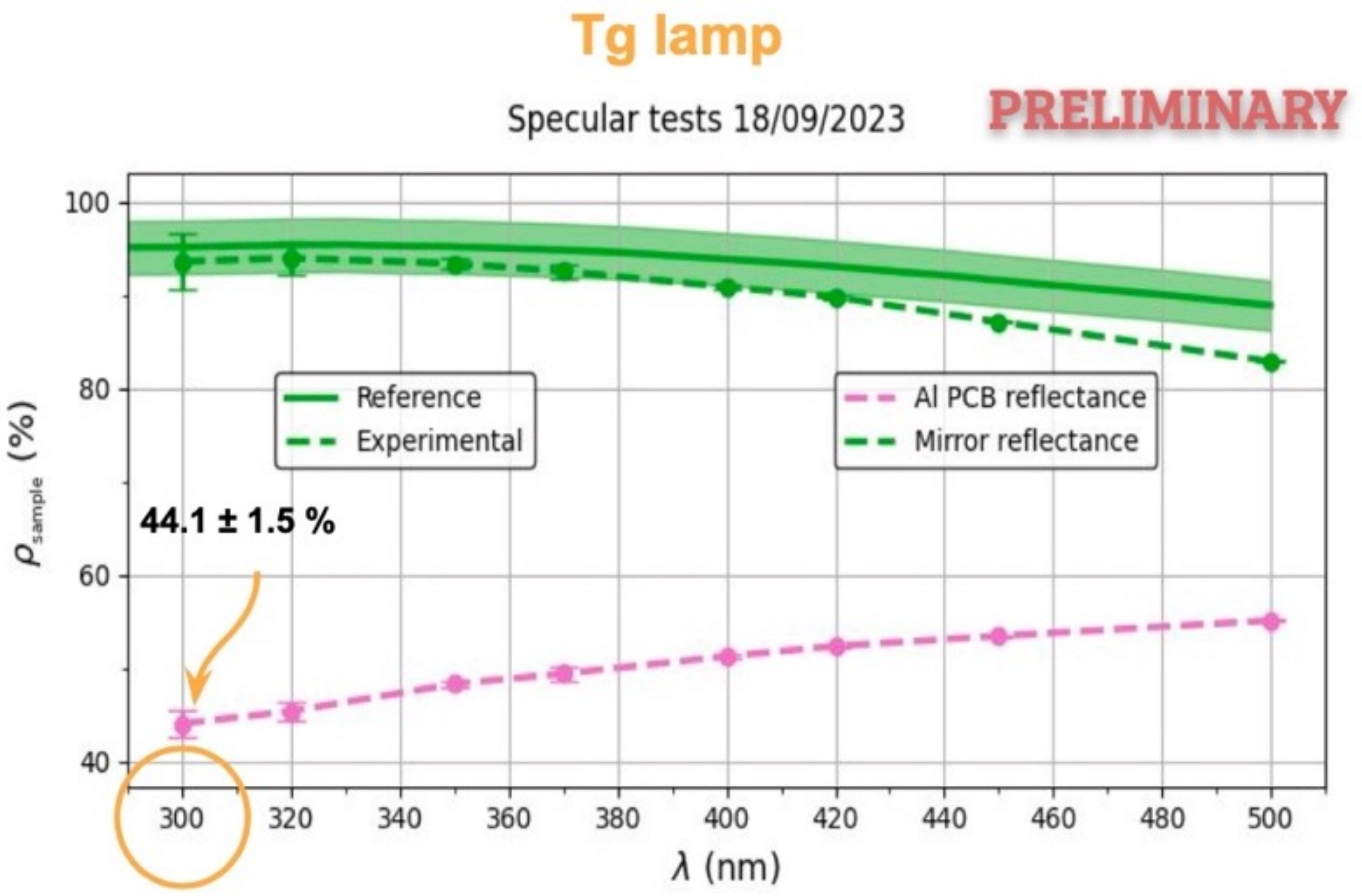
NEXT-HD
NEXT-BOLD

Ton-scale and barium tagging for background-free experiment in ^{136}Xe (10^{28} y)

2009 **2014** **2015** **2021** **2022** **2026** **2027**

NuLight: reflectance measurements





REFLECTANCE MEASUREMENTS in the VUV

An Aluminum sample reflectance as a function of wavelength measured at IFIC optical laboratory in the VUV (left picture) and in the visible (right picture) spectra. These commissioning results have been presented for the first time by Hamza Amar, PhD student, at the DUNE collaboration meeting of September 2023.