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Xenoscope: a vertical demonstrator for the XLZD observatory

8th International Workshop on the Application of Noble Gas Xenon to Science and Technology (XeSAT2026) at TRIUMF, May 21, 2026

Jose Cuenca-García, on behalf of the Xenoscope team

European Research Council
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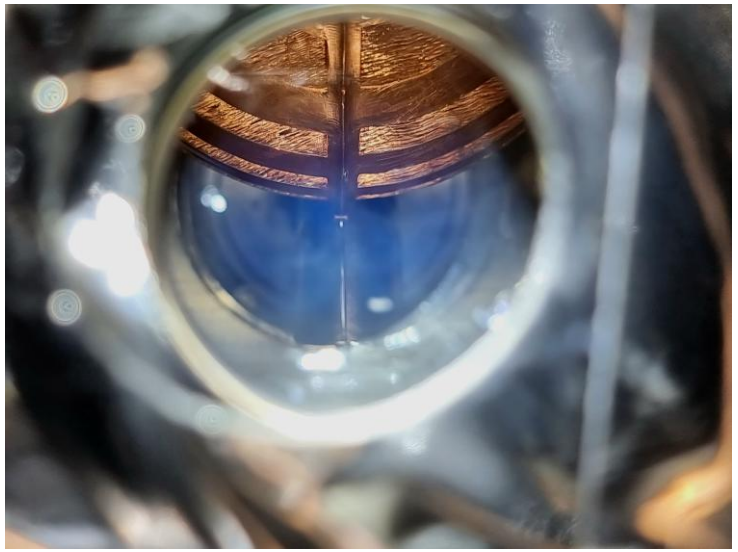


Xenoscope: a demonstrator for XLZD

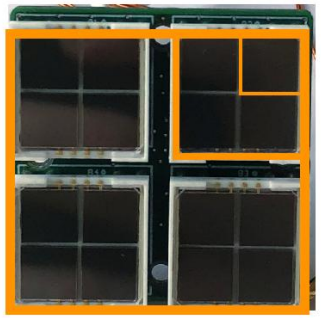
- Vertical demonstrator with goals:
  - Electron drift over 2.6 m
  - Electron cloud diffusion modelling
  - Custom high-voltage
  - Xenon optical properties
  - Application of radon mitigating surface coatings
- ~360 kg of xenon mass
- Phase I: purity monitor → COMPLETED
- Phase II: modular TPC → COMMISSIONED
- First Science run → COMPLETED
- Second Since run → ONGOING

L. Baudis et al, JINST 16 P08052 (2021)
M. Adrover et al, JINST 20 P04013 (2025)
L. Baudis et al, Eur. Phys. J. C 83, 717 (2023)

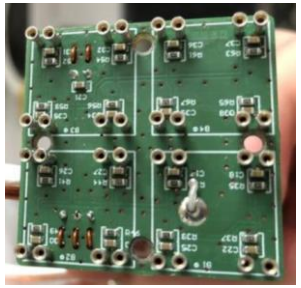
From a Purity Monitor to a 2.6-m Dual-Phase TPC

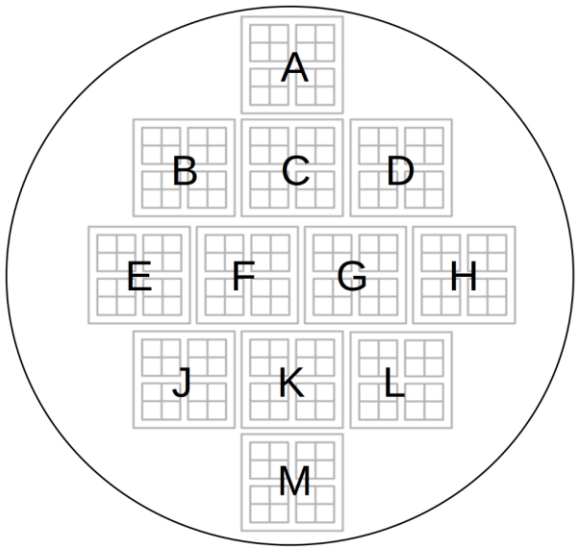
- 2.6-m tall TPC - 5 modules of 52 cm each
- Field cage with 173 OFHC copper rings ø160 mm
  - Two redundant resistor chains - 1 GΩ resistors
  - Six polyamide-imide (Torlon) pillars reinforced inside with PTFE
- Electrons extracted from photocathode at the bottom
- 3 electrodes for drift and extraction fields
  - Custom-made cathode HV delivery system rated up to 100 kV
- SiPM array at the top to detect light
- Levelmeters and weir for liquid level control

The SiPM array

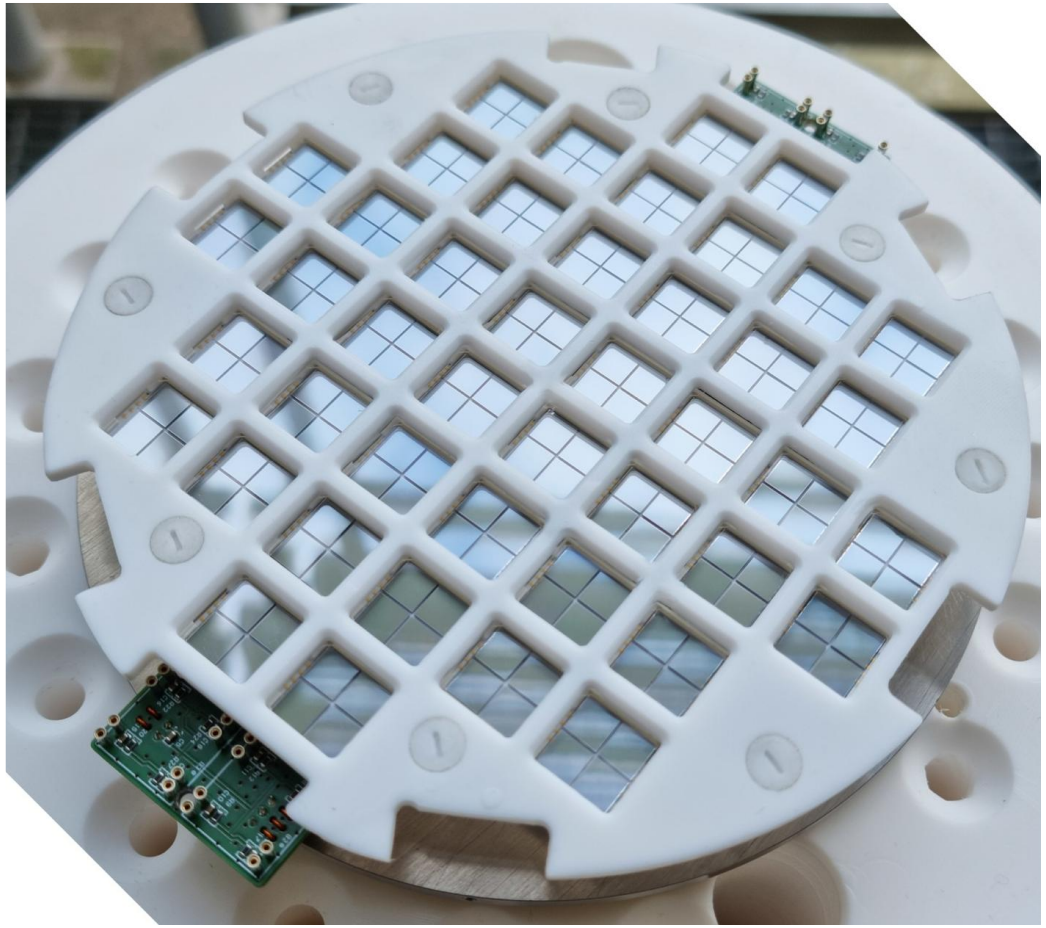


Cell = 6 x 6 mm^2
Quad = 4 cells
Tile = 4 quads





- Hamamatsu S13371-6050CQ-02 MPPC VUV SiPM
- Array = 12 tiles (or 192 SiPM cells) 12 mm x 12 mm each
- Readout is made in parallel, so we have 12 channels
- 20x amplification per tile



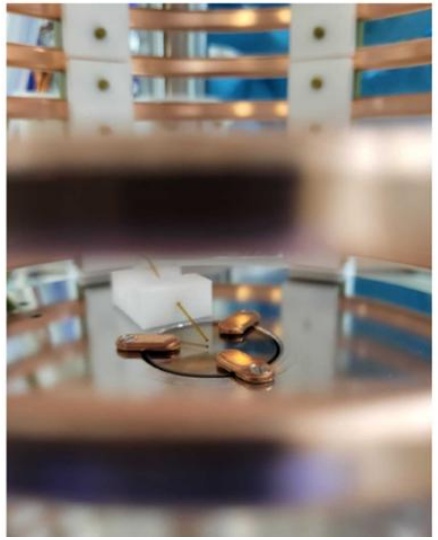
JINST 18 C03027 (2023)

Reading of the tiles can be modified to get better granularity → Future upgrade

Data taking

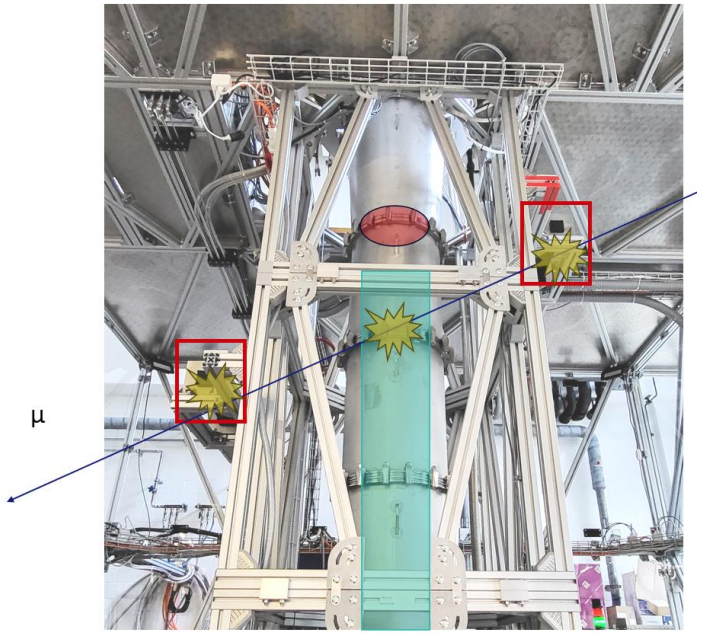
Xenon lamp

- Gold coated photocathode (50 nm thickness) on a quartz substrate (2 mm thick) at the bottom of the TPC
- Xe flash lamp pulse transmitted through optical fibre (~10^6 electrons/pulse are produced, frequency of 1-4 Hz)

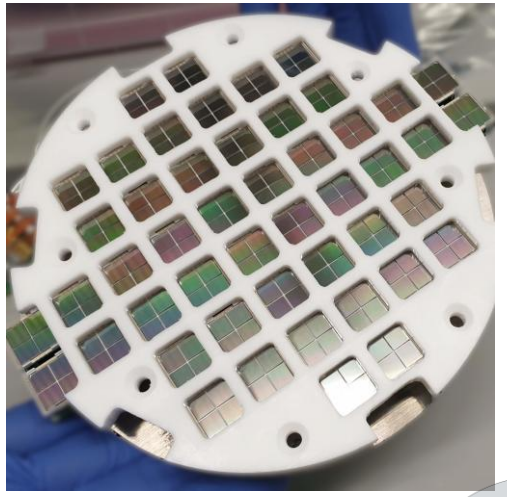


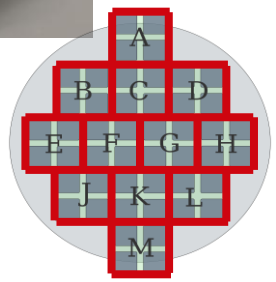
Cosmic muons

- Two plastic scintillators, one at each side of the TPC
- If there is a coincidence then the signals of the array are recorded within a 2.6 ms time window (~1 event every 3 minutes)



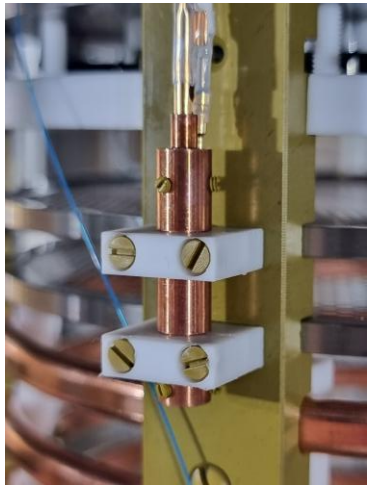
Commissioning run (23.04.2024 – 09.08.2024)





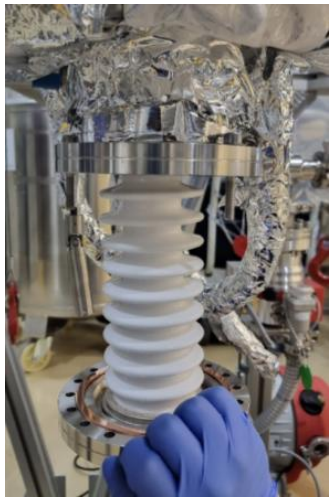
SiPM array:

- 192 VUV units
- Arranged in 12 tiles



Levelling system:

- Short and long level meters
- Weir to adjust the level

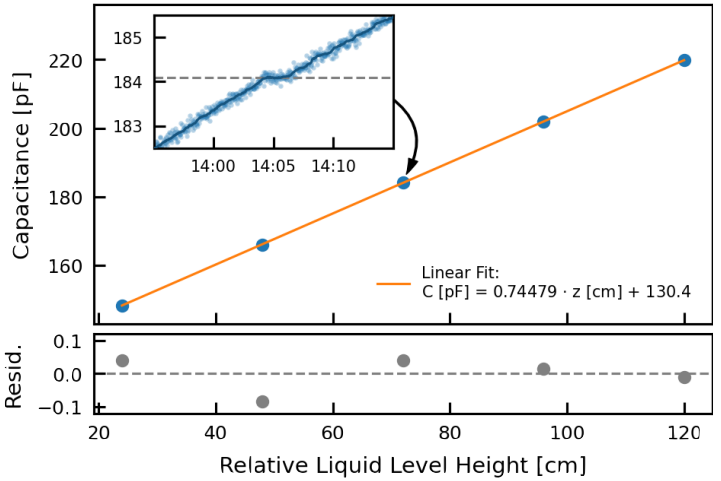


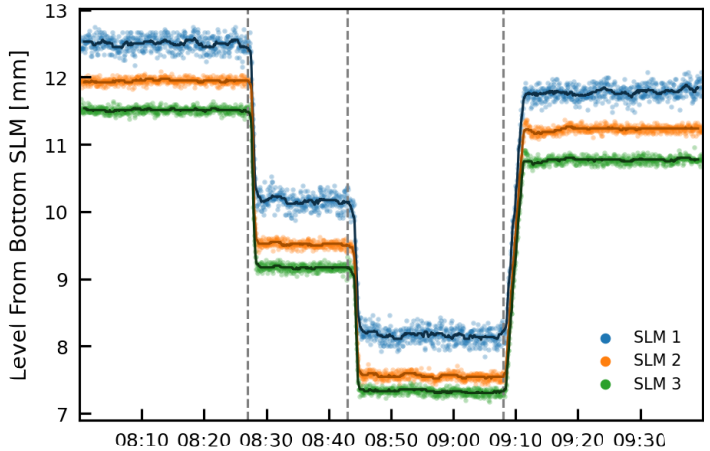
High-voltage:

- In-house cryofitted air-to-vacuum FT
- Heinzinger PNC 1000000 supply (maximum voltage of 100 kV)

Results of the commissioning run

- Tested recirculation and filling correlated with integrated xenon flow at ~50 slpm→ Filled ~360 kg of xenon
- Five spacer rings along each LLM used as calibration points
- Weir commissioned by varying the liquid level and monitoring it through the SLM
- Getter not operation during commissioning → no purity for science data
- HV ramp gradually up to monitor stability and set to:
  - Drift field: ~100 V/cm
  - Extraction field: 6 kV/cm

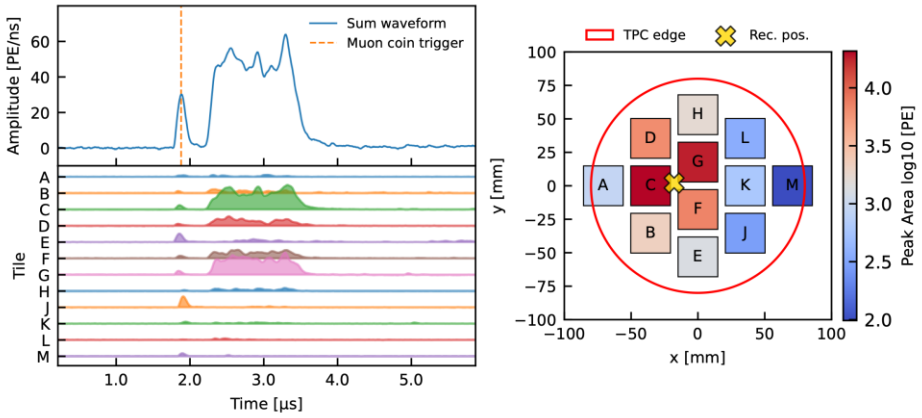




Results of the commissioning run

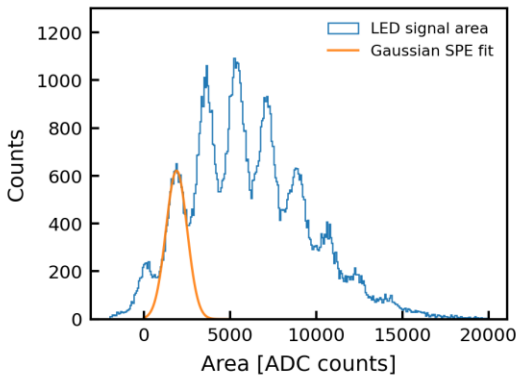
Muon data

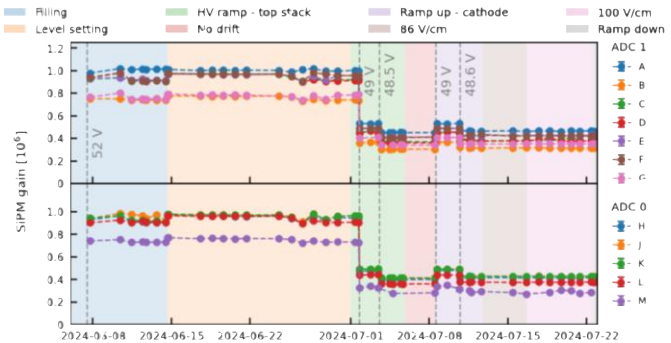
- Acquired cosmic muons crossing the top of the LXe (drift <10 µs - no purification)
- 2 scintillator panels with 3” PMTs in coincidence to trigger the event
- S1 in coincidence with the muon trigger system



LED calibration

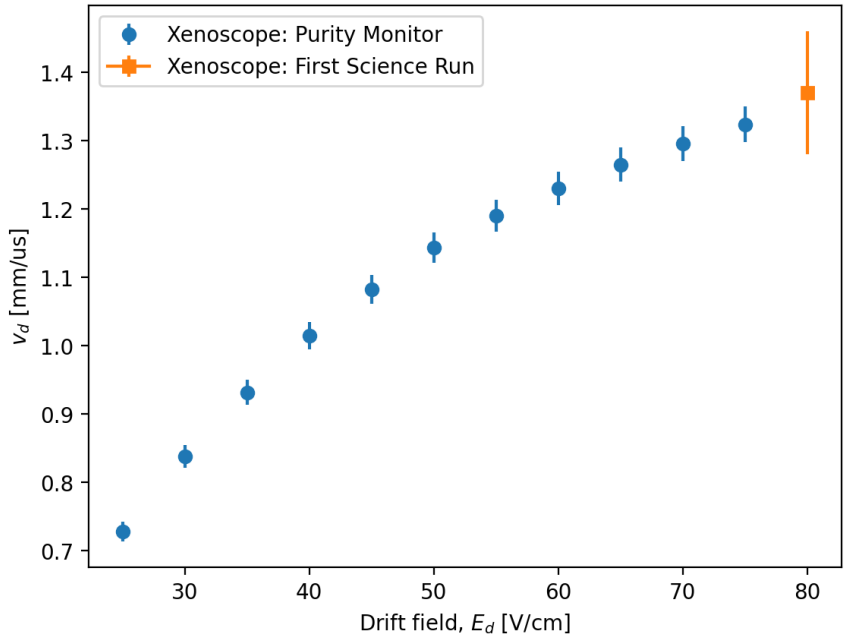
- SiPM array performance monitored with low intensity blue LED light $\lambda \approx 400$ nm routed by two fibres directed toward the array
- The mean value of the single photoelectron (SPE) peak fit is used to calculate the gain
- SiPM bias and gain adjusted to avoid saturation

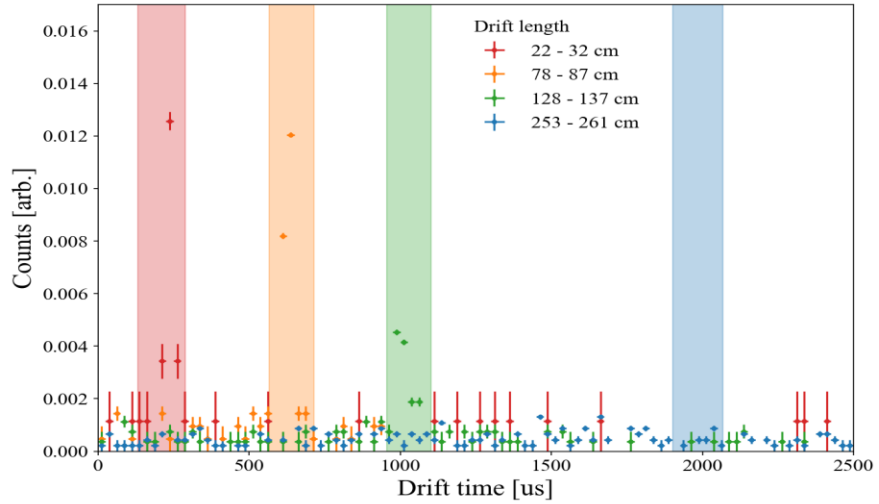




First science run (08.04.2025 – 19.06.2025)

- Upgrades to the gas system: getter, adjustable speed of the compressor
- Xenon management (circulation, purification, recovery) successful
- Field configuration
  - ✓ Drift field: 80 V/cm
  - ✓ Extraction field: 8 kV/cm
- Calibration of the SiPM array: stable gain during run but two channels showed excessive light collection
- Electrons from the photocathode: not visible. We observed a lot of light from the lamp
- Muon data gave good signals at 3 positions. The lowest position was not producing clear signals





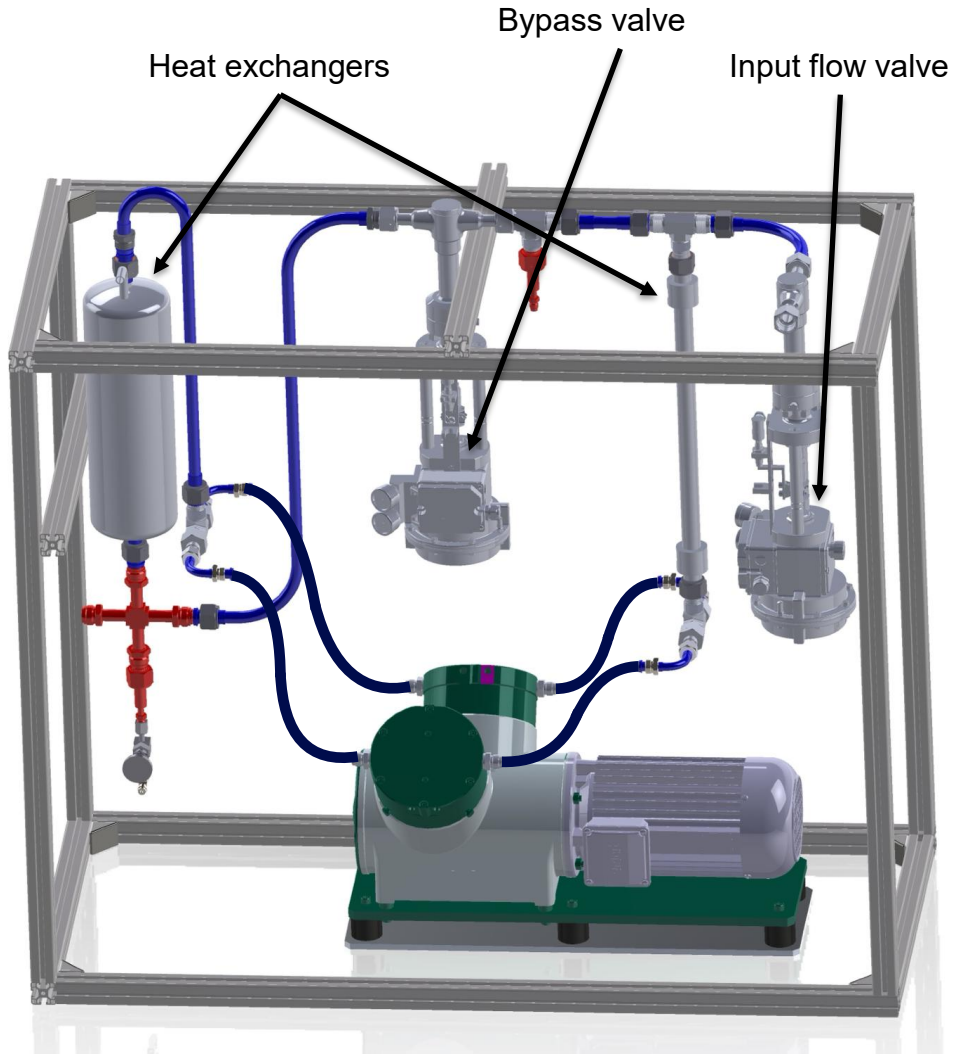
More upgrades after the run: a safer gas system

We have also improved the gas system to add more protection to the xenon compressor. This will allow us to have:

- Xenon circulation up to 70 slpm
- Protection of the membranes against overheating (i.e., longer runs)
- Lower impedance in the line

New chiller line to circulate 5 ºC water:

- Cooling the pump heads
- Xenon gas cooling with input and output heat exchanger
- Bypass line between inlet and outlet to bring cooled xenon gas to the input and reduce pressure



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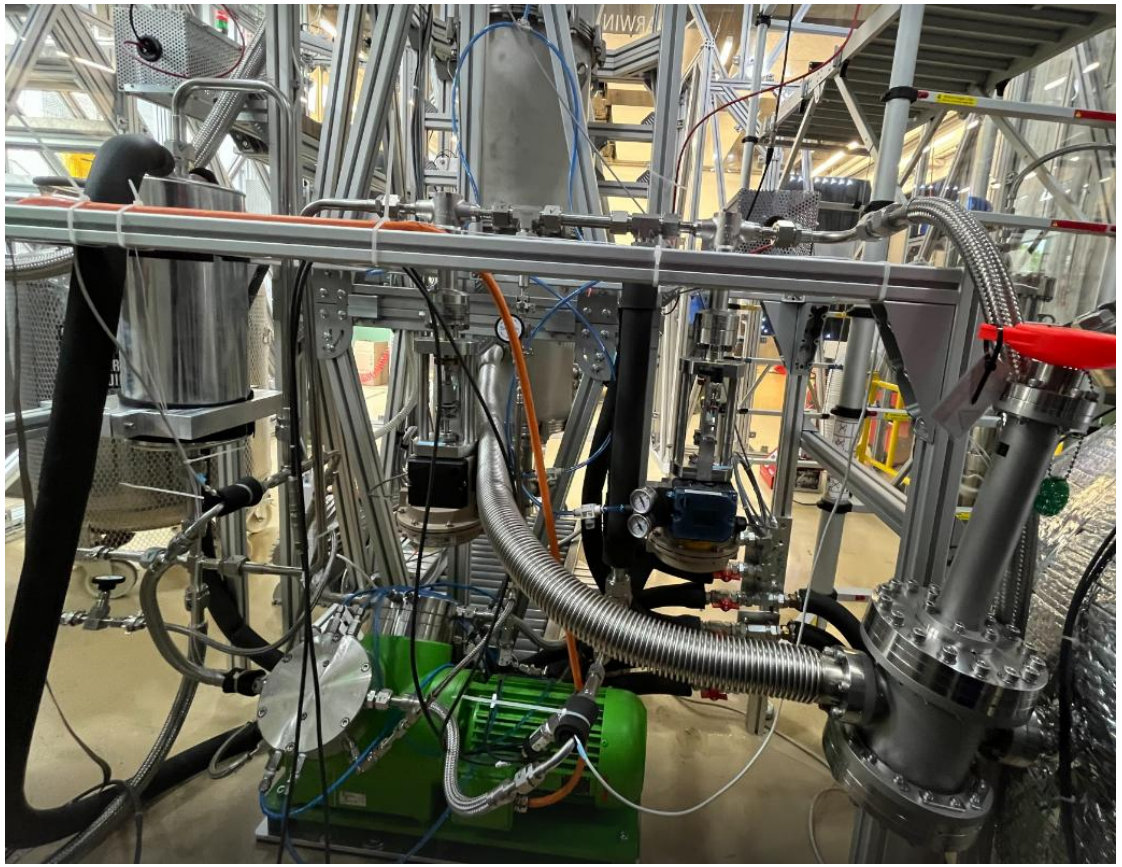

New chiller line to circulate 5 ºC water:

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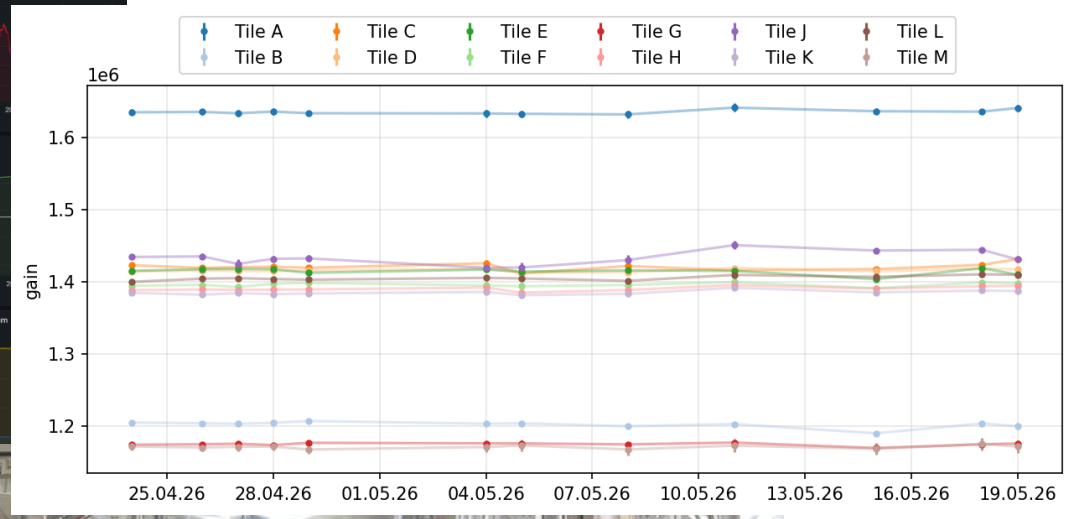
Second science run (25.03.2026 - ??)

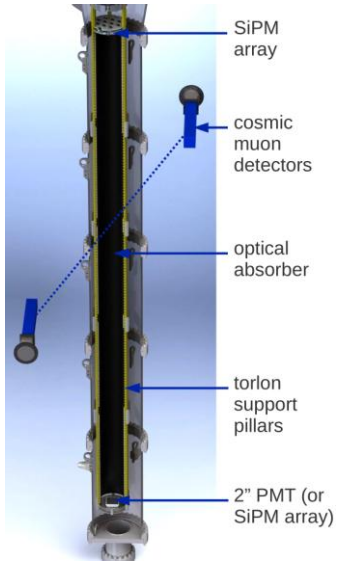


- So far, stable run
- Muon and xenon lamp data taking
- HALO monitor has been tested (H_2O concentration below 300 ppt)
- SiPM array working
- 100 V/cm drift field, 8 kV/cm extraction field. Very stable

Future plans for Xenoscope

Optical measurements

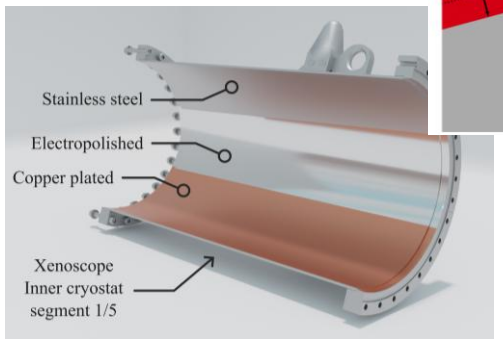
- Light attenuations in LXe with large setup
- Disentangle absorption and Rayleigh scattering

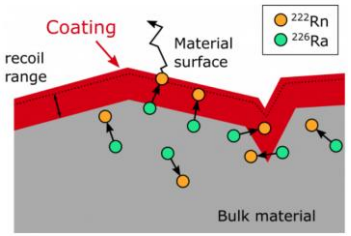


- Hodoscope with muon scintillators
- Measure refractive index from group velocity

Radon mitigation

- In collaboration with MPIK Heidelberg
- ~5 μm electrodeposited copper surface coating on the inner cryostat
- Verify cryogenic and xenon purity demands

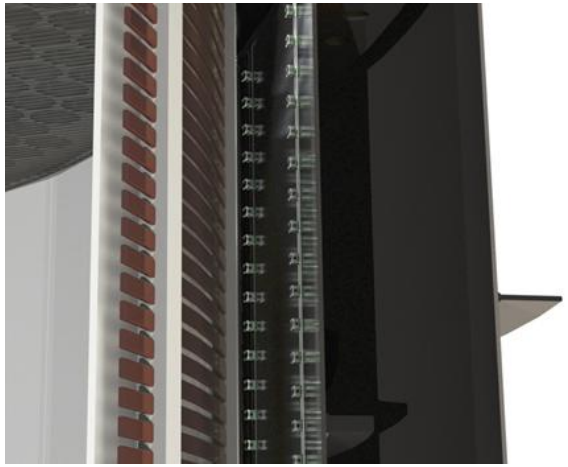




MAX-PLANCK-INSTITUT FÜR KERNPHYSIK

LXe skin tagging

- Joint UZH-Imperial R&D for the LXe skin
- Chains of SiPMs to improve light collection

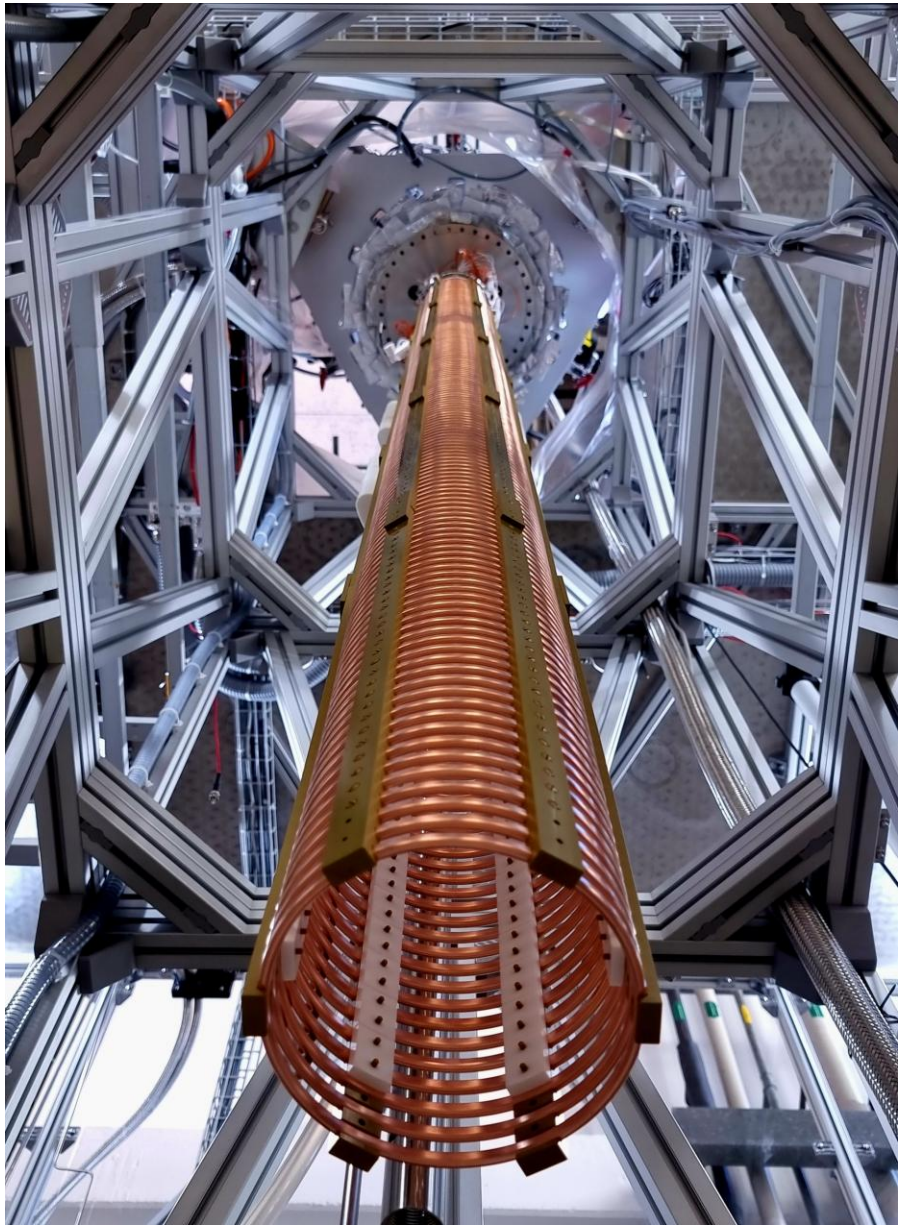


Summary

- We have built Xenoscope with a 2.6-m TPC (successfully commissioned)
- First science run completed
- Several upgrades were performed to improve safety and stability of the runs
- A second science run is currently ongoing
- More upgrades are being developed in paralell

The Xenoscope team:

Nicolas Angelides, Marta Babicz, Erin Barillier, Laura Baudis, Harvey Birch, Chiara Capelli, Paloma Cimental, Jose Cuenca García, Sebastian George, Rebecca Hampp, Miguel Hernandez, Luisa Hötzsch, Florian Jörg, Knut Morå, Margherita Noia, Sana Ouahada, Björn Penning, Francesco Piastra.



XLZD: the next xenon experiment

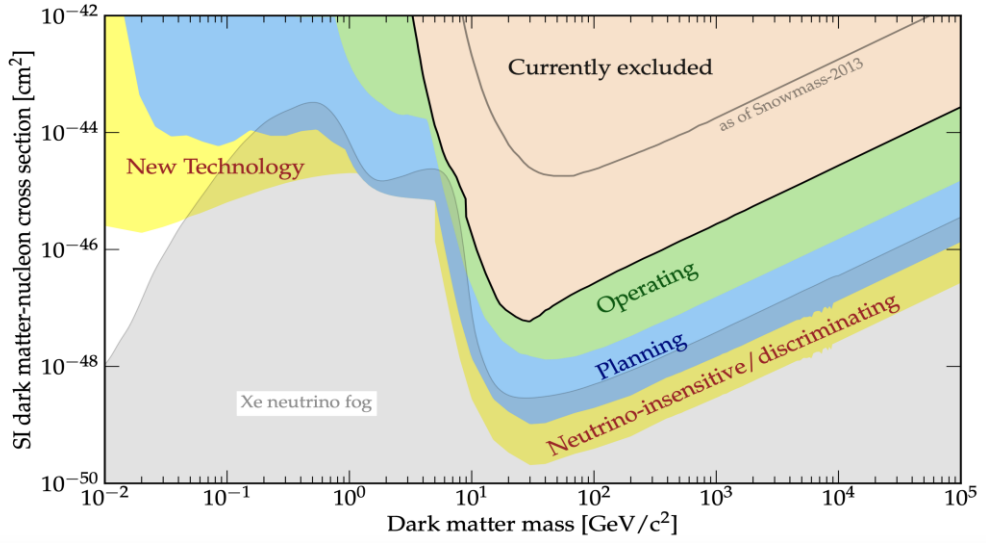
The leading xenon experiments merged into a new collaboration to build the ultimate WIMP detector

The goal: to build a 3 m height, 3 m diameter TPC operating 80 tonnes of xenon

For more info, please take a look to our design book and visit our web page

The XLZD observatory

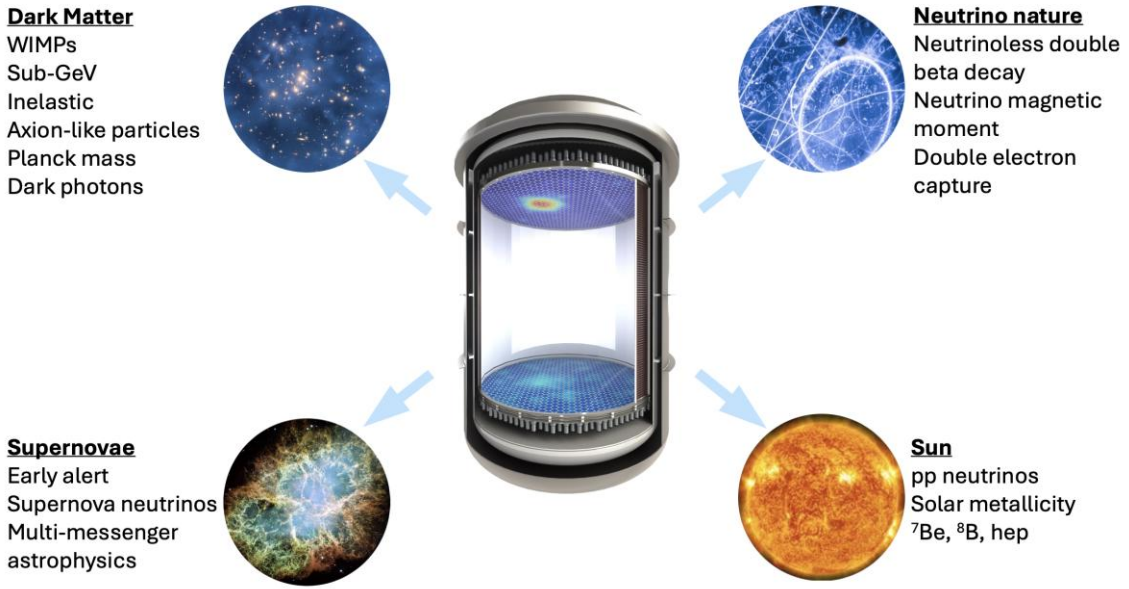
Snowmass Cosmic Frontier Report, arXiv:2211.09978



XLZD: XENON-LZ-DARWIN

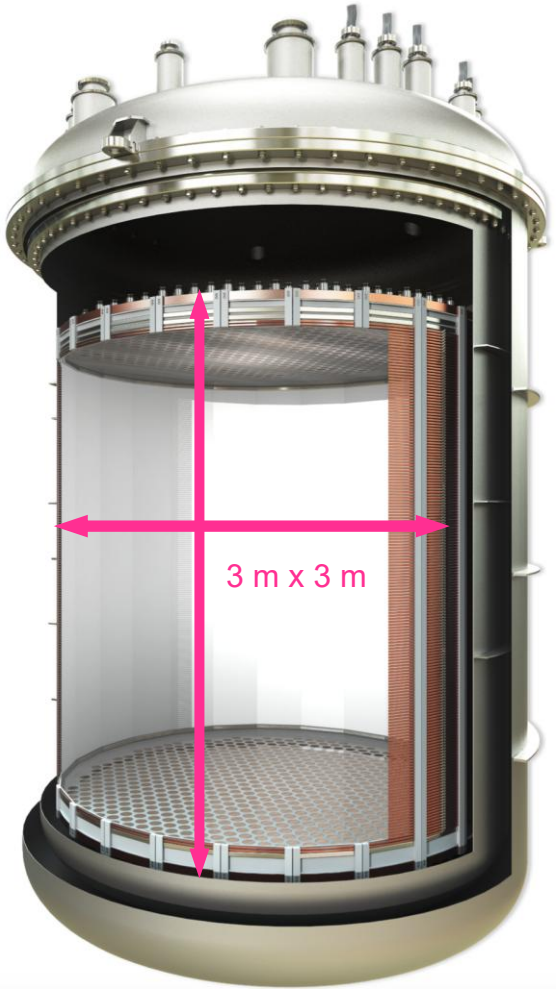
- WIMP search down to the neutrino floor
- Neutrino Physics
- Multi-channel observatory

- Current experiments $\mathcal{O}$(10 t) LXe and 1.5 m dimensions, 1:1 ratio
- The projected SI-WIMP sensitivity improves one order of magnitude ~10^{-48} cm^2 → ~10^{-49} cm^2



The XLZD TPC

- ~3 m diameter x ~3 m height
- 78 t/60 t LXe mass/active target → up to 80 t active mass depending on xenon supply market
- Two arrays of photosensors → baseline design with ~2400 3” PMTs
- Double-walled low-background Ti cryostat + LXe “skin” around the TPC
- Drift field of 240-290 V/cm and extraction field of 6-8 kV/cm for optimal discrimination between ER and NR
- Passive and active muon and neutron shielding
- Gadolinium loaded water tank to enhance neutron capture cross-section



Xenoscope is the vertical demonstrator of the next XLZD detector