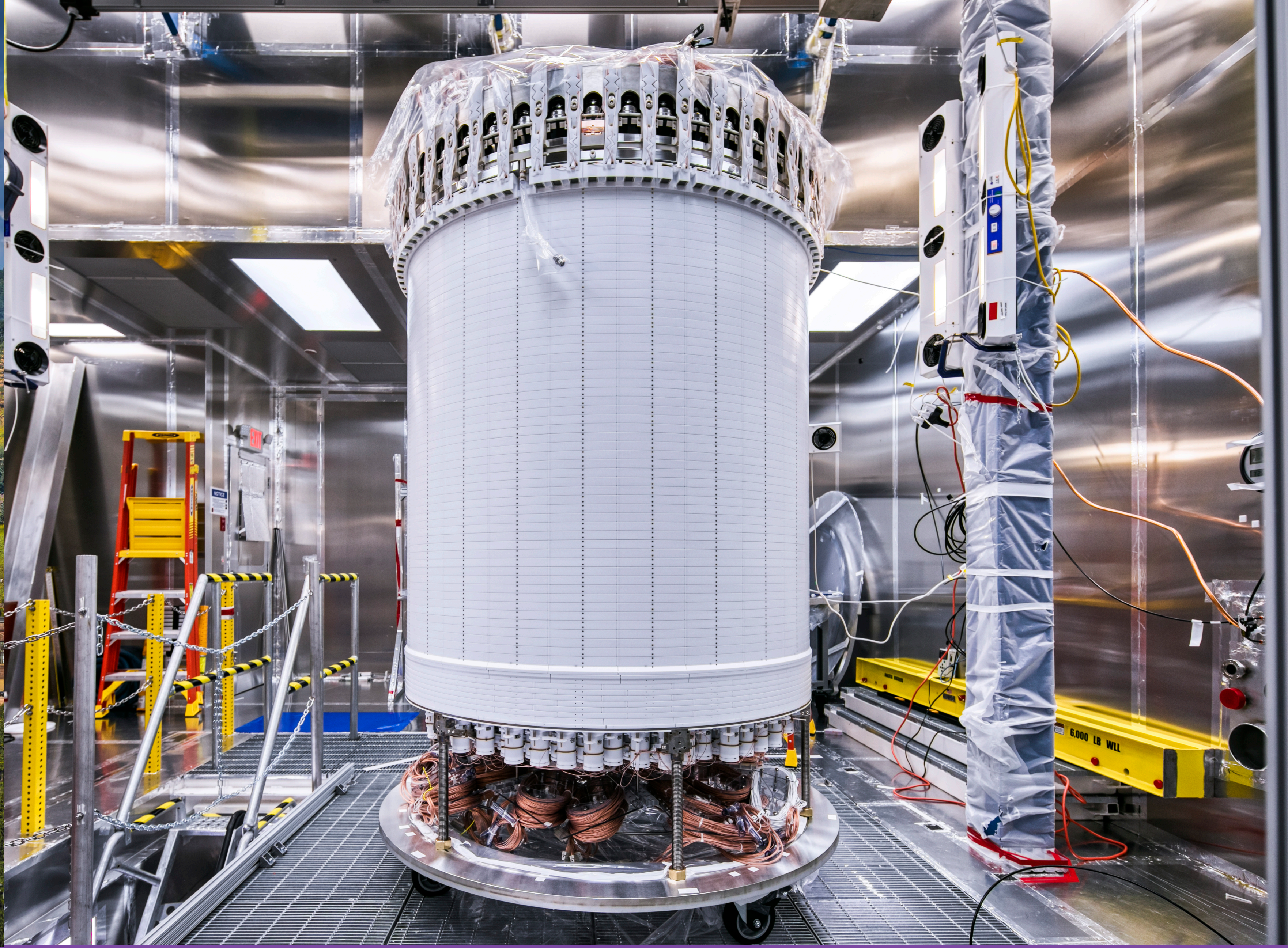
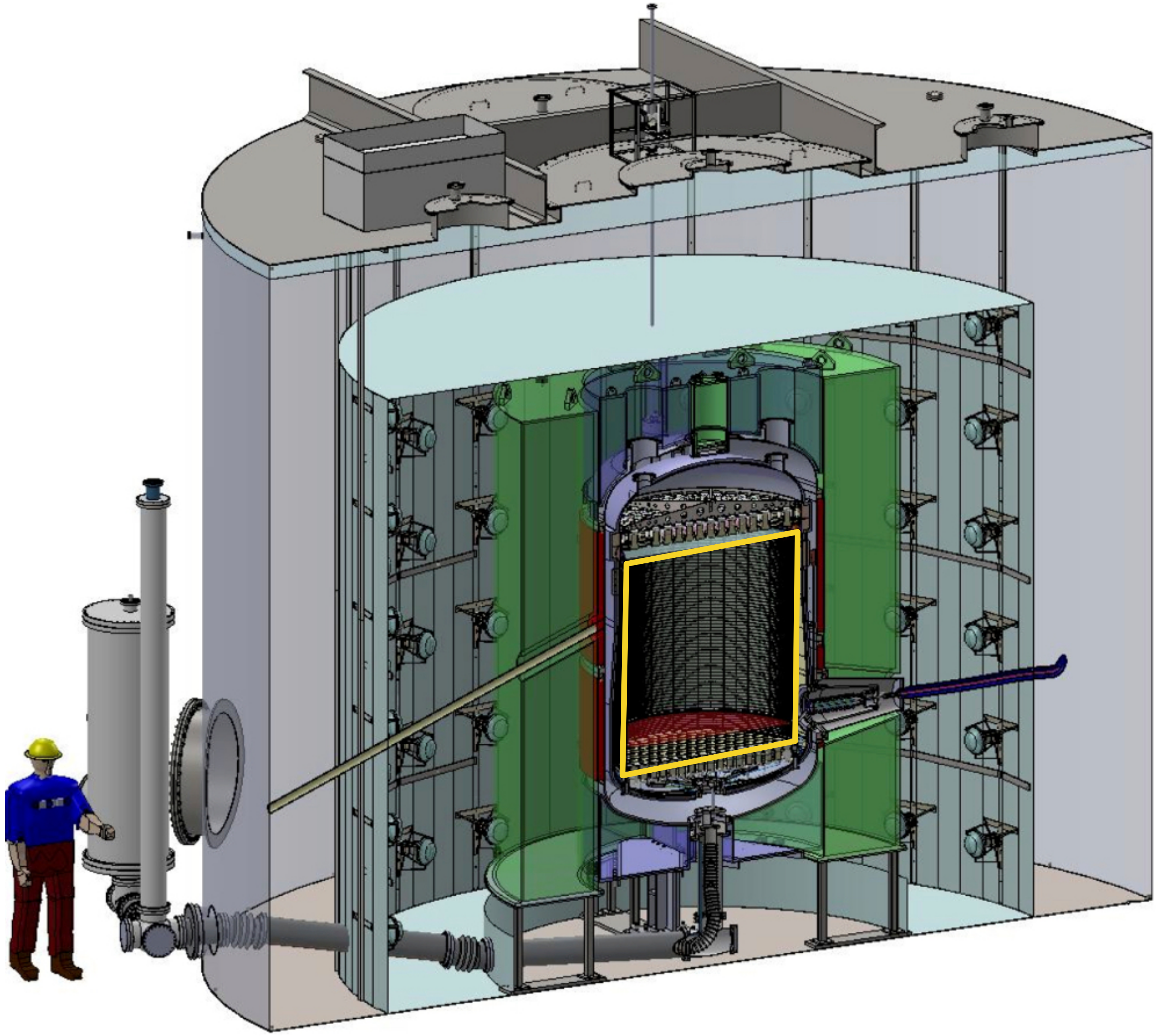


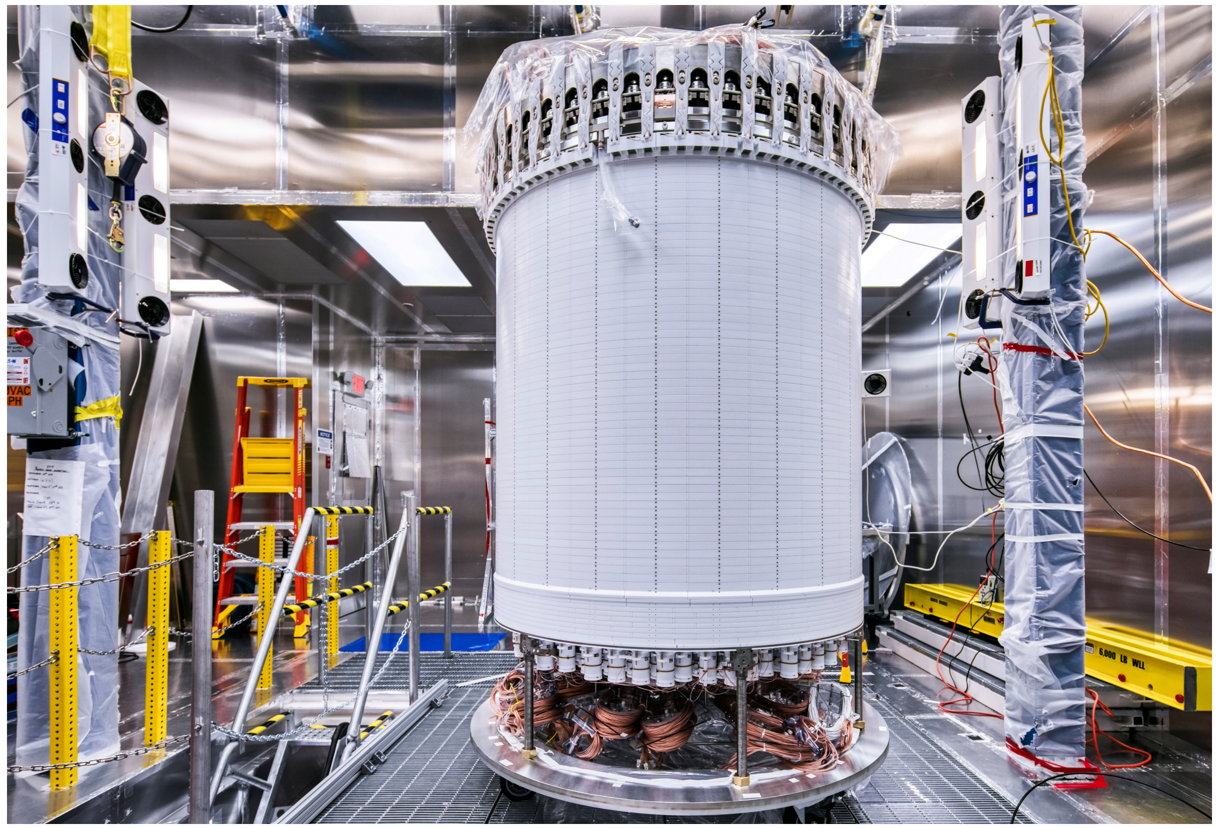
Research Opportunities in the LUX-ZEPLIN Experiment

Cláudio Silva,
on behalf of the LIP-Coimbra Dark Matter Group
7th Mini-school, Lisbon
isabel@coimbra.lip.pt, claudio@coimbra.lip.pt

The LUX-ZEPLIN (LZ) Experiment



- The LUX aims to detect the interaction of dark matter particles with the atomic nuclei
- At the core:
  - 7 tonnes (active) of a Liquid Xenon TPC
    - 1.5 m heigh, 1.5 m ⌀



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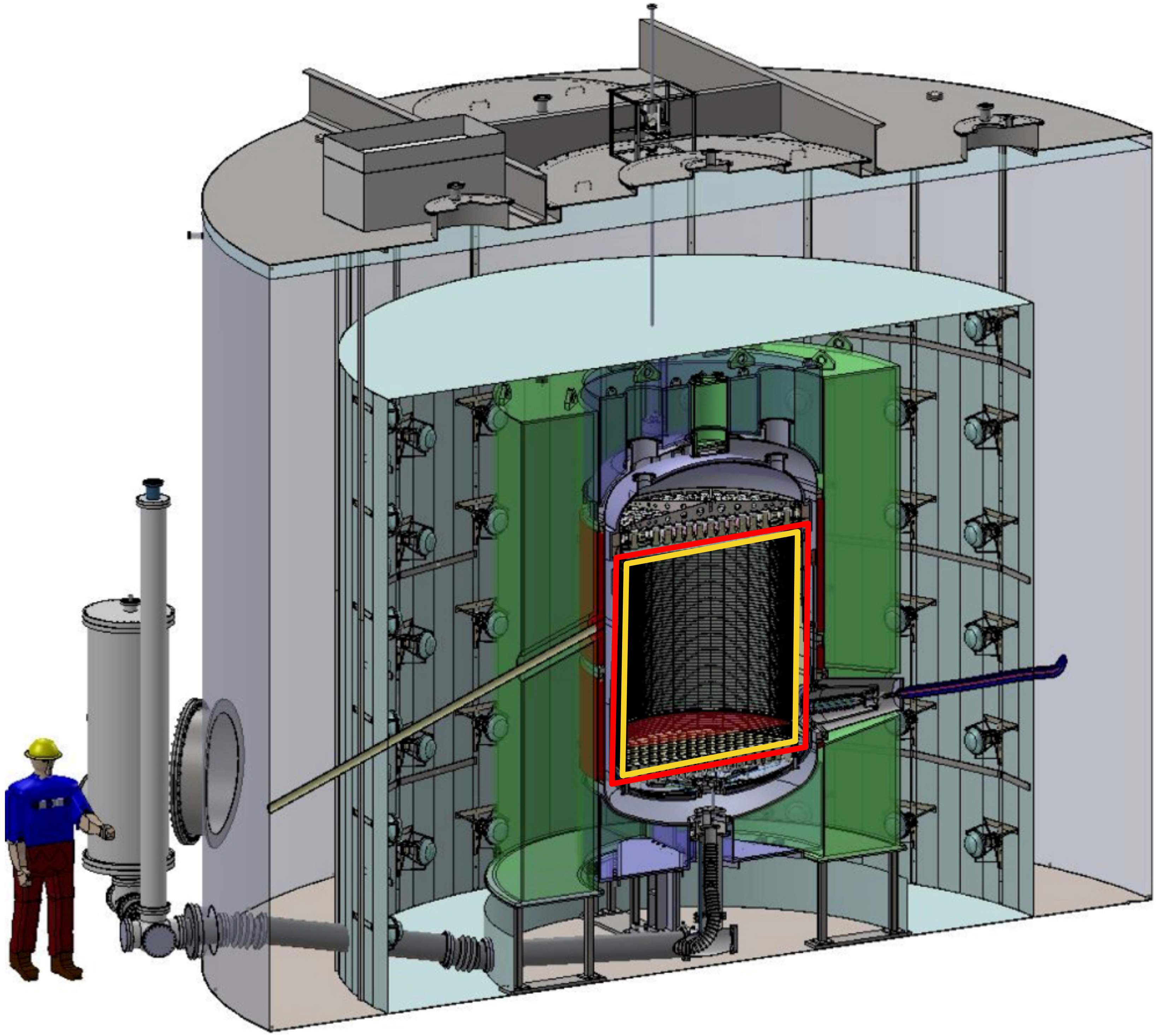

- The LUX aims to detect the interaction of dark matter particles with the atomic nuclei
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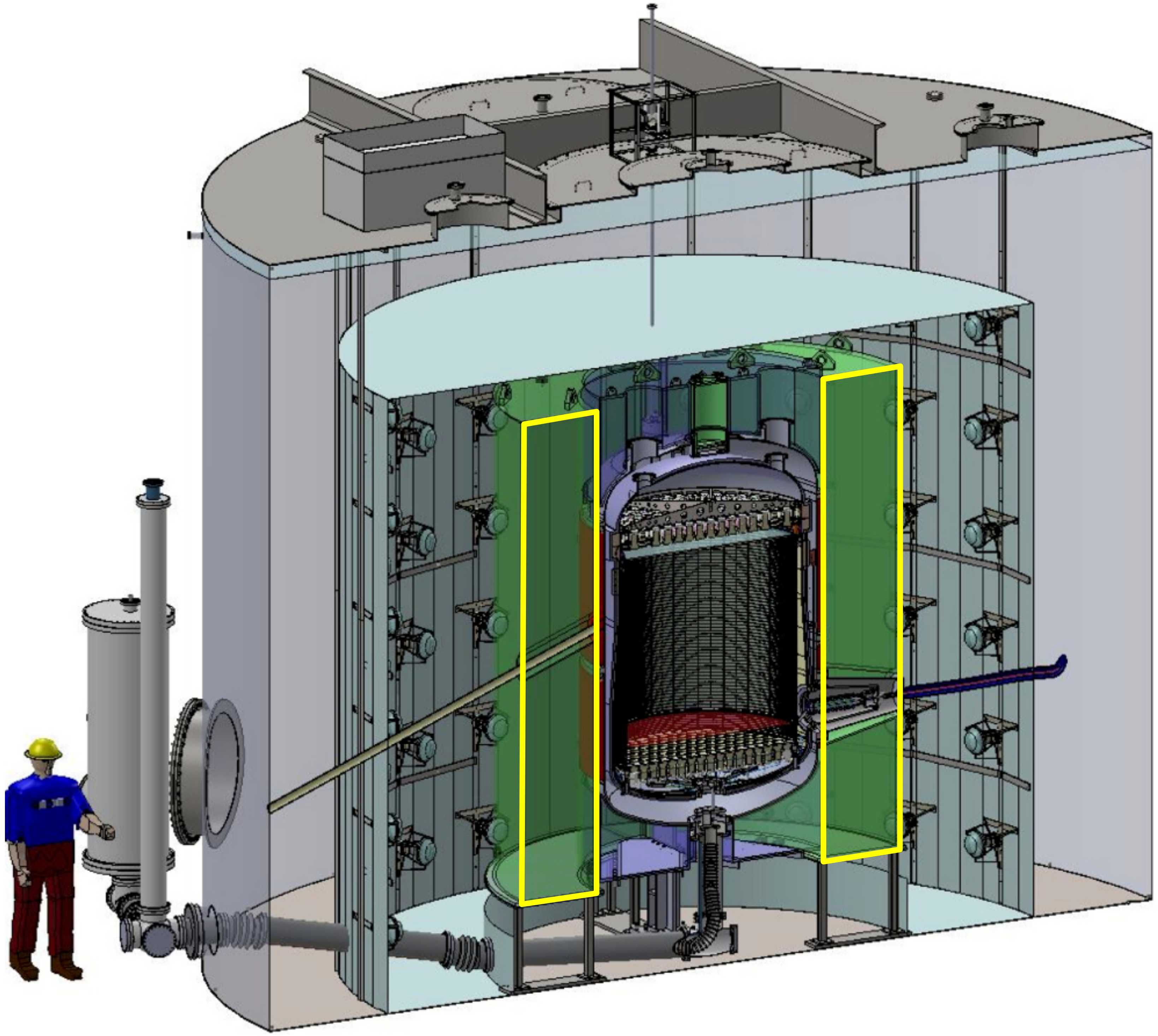
- 3-component veto system
  - Xenon layer around the the main TPC

The LUX-ZEPLIN (LZ) Experiment



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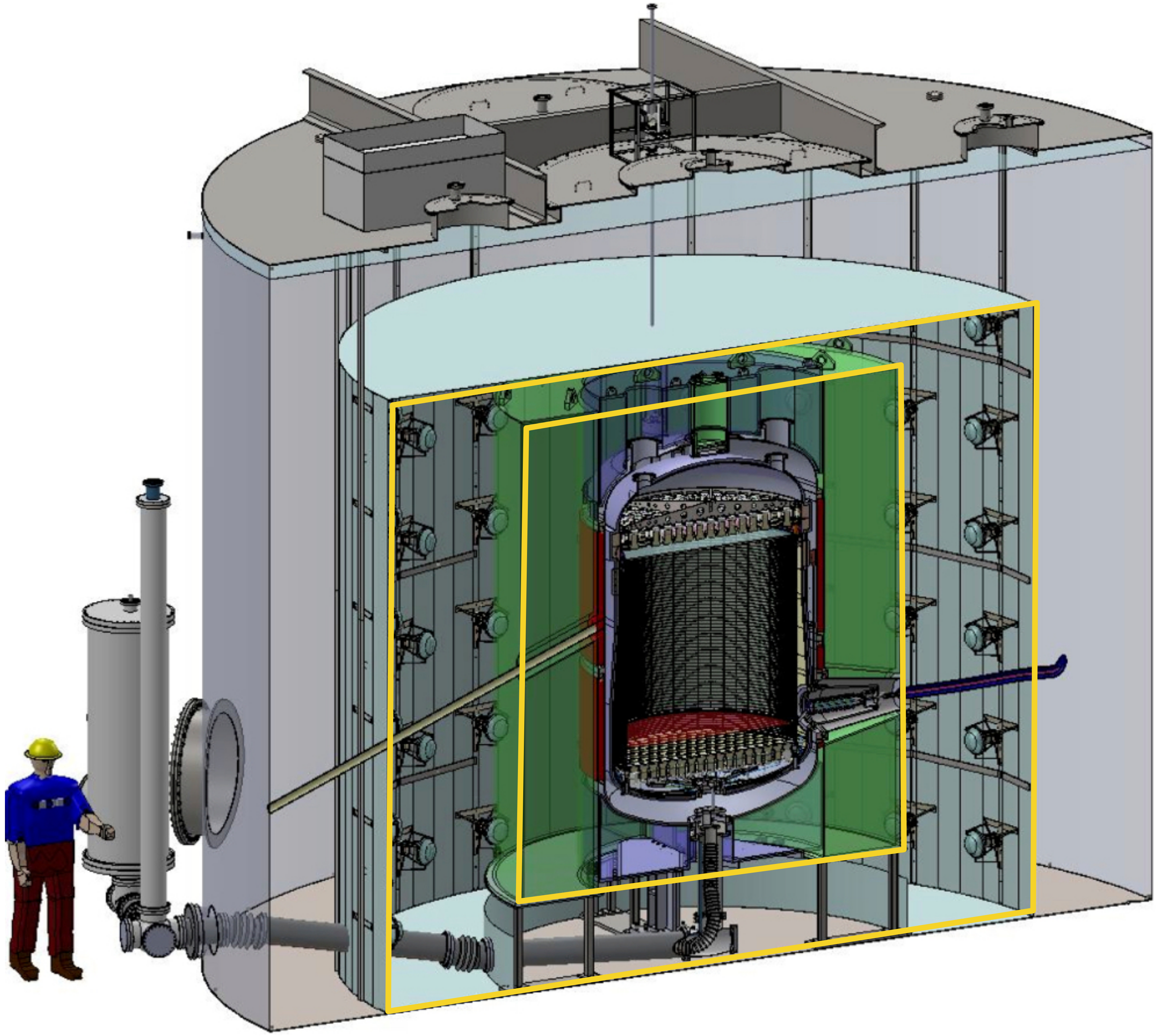
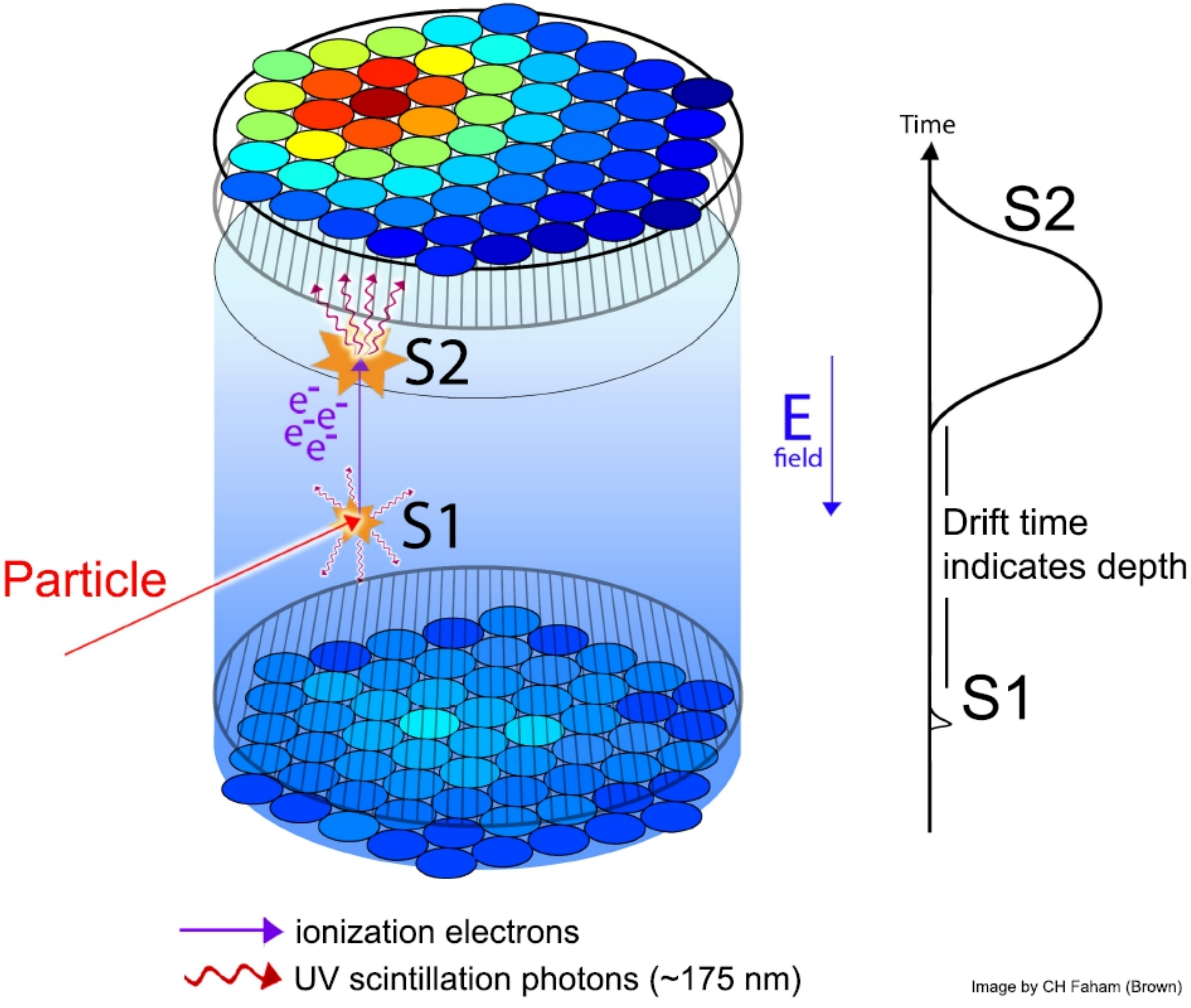


- The LUX aims to detect the interaction of dark matter particles with the atomic nuclei
- At the core:
  - 7 tonnes (active) of a Liquid Xenon TPC
    - 1.5 m heigh, 1.5 m ⌀
- 3-component veto system
  - Xenon layer around the the main TPC
  - Gadolinium-loaded scintillator
  - Water Cherenkov tank

- LZ collaboration formed in 2012
- LZ detectors have been commissioned and science data-taking is underway
- The primary scientific program lasts until 2026

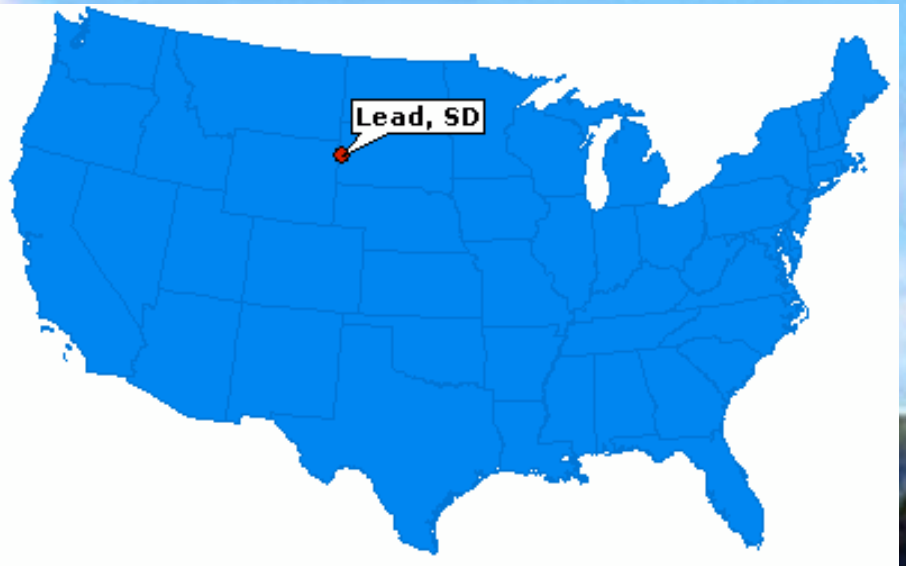
GO to ⟶ https://luxzeplin.org/

Liquid Xenon TPC Principle



- Dual Phase Liquid/gas detector
  - Two sets of PMT arrays, placed on the top and bottom of the detector
  - An electric field of ~200 V/cm across the liquid
- A particle interacts in the liquid producing
  - S1 - prompt scintillation
  - S2 - from the electroluminescence of the charge extracted into the gas phase
- Advantages:
  - Very low threshold (few keV)
  - Excellent reconstruction of the position of interaction
  - Possibility to distinguish charged from non-charged particles based on the ratio S2/S1.

LZ Experiment Location



- Sanford Underground Research Facility Lead, South Dakota, USA.
- At a depth of 1478 m
- Cosmic-rays reduced by a factor of 10^7

GO to → https://www.sanfordlab.org/

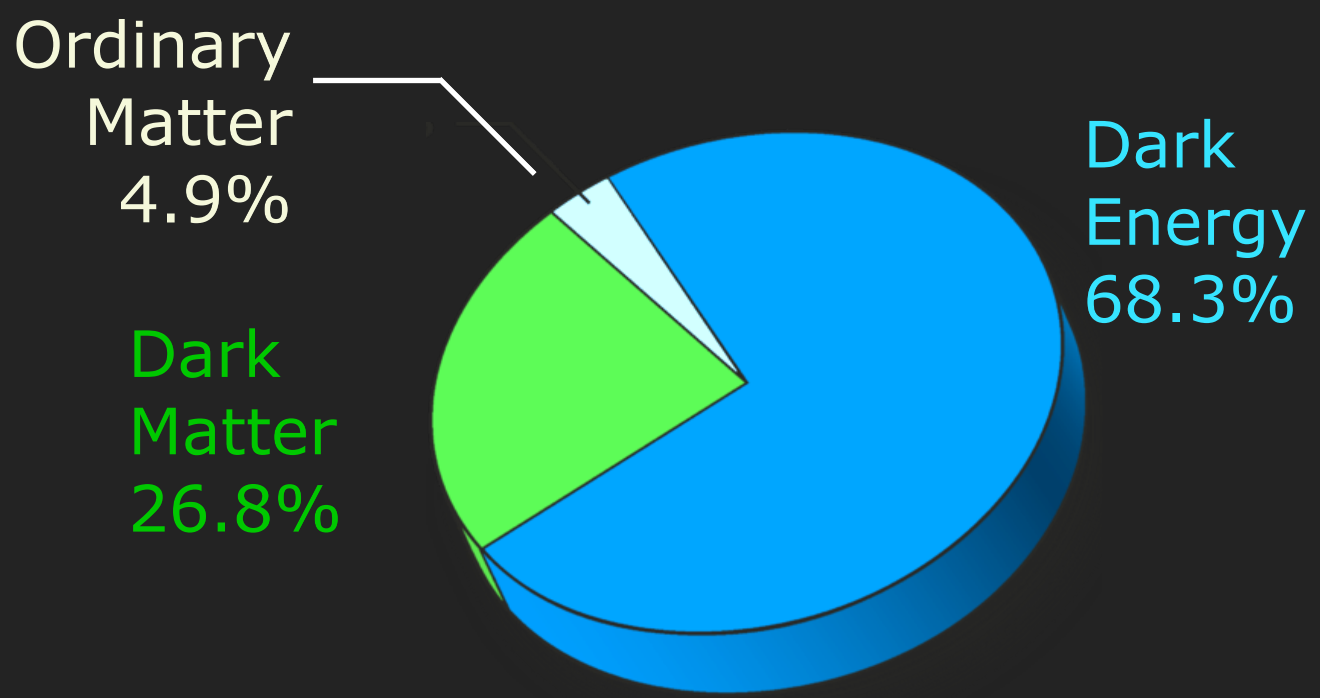
LZ Primary Scientific Objective - Dark Matter

What is? Only 5% of the matter-energy is of a known-origin

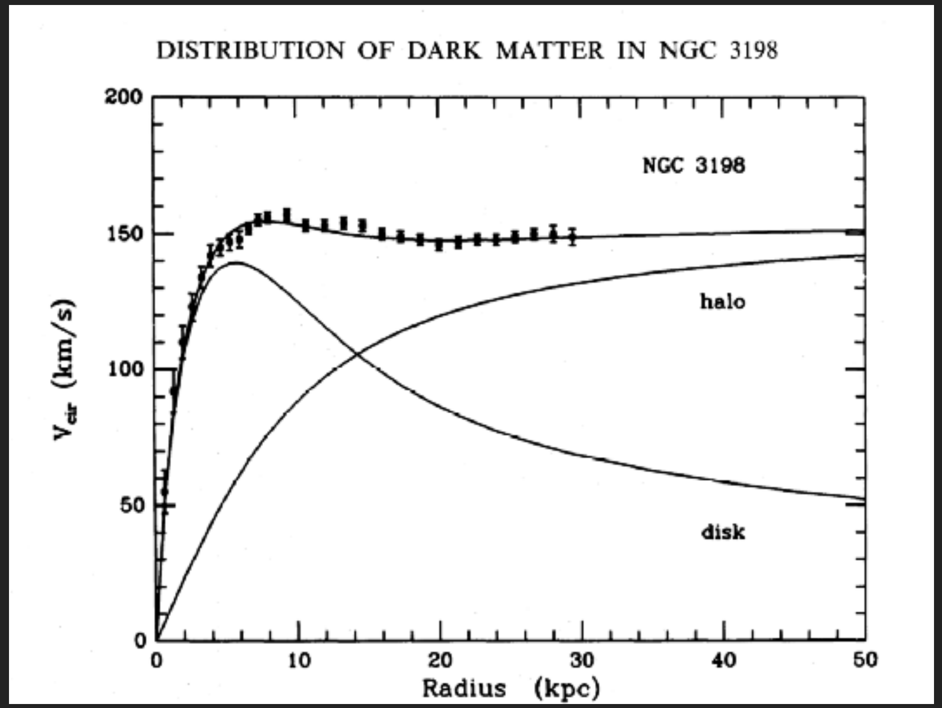
Plenty of astrophysical evidences

No particle in the Standard Model is able to explain the current dark matter fraction

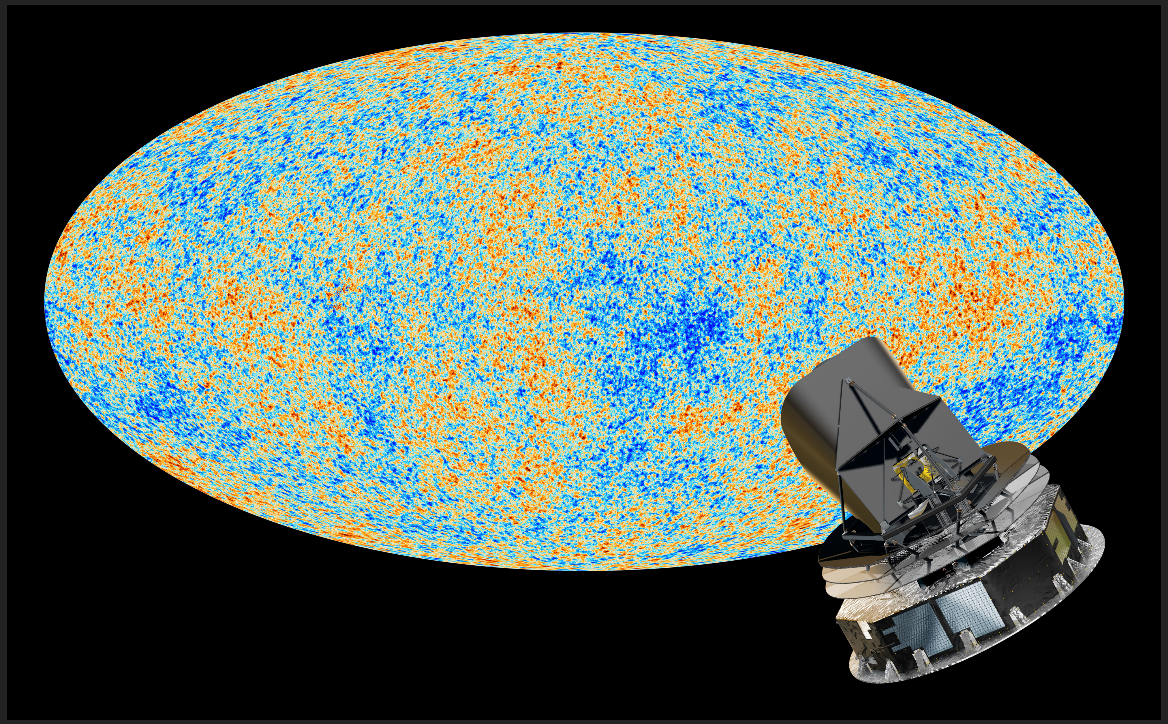
LZ is mainly designed to look for WIMPs but it can look into other possible Dark Matter particles such as Axions, Dark Photons, LIPs, etc…



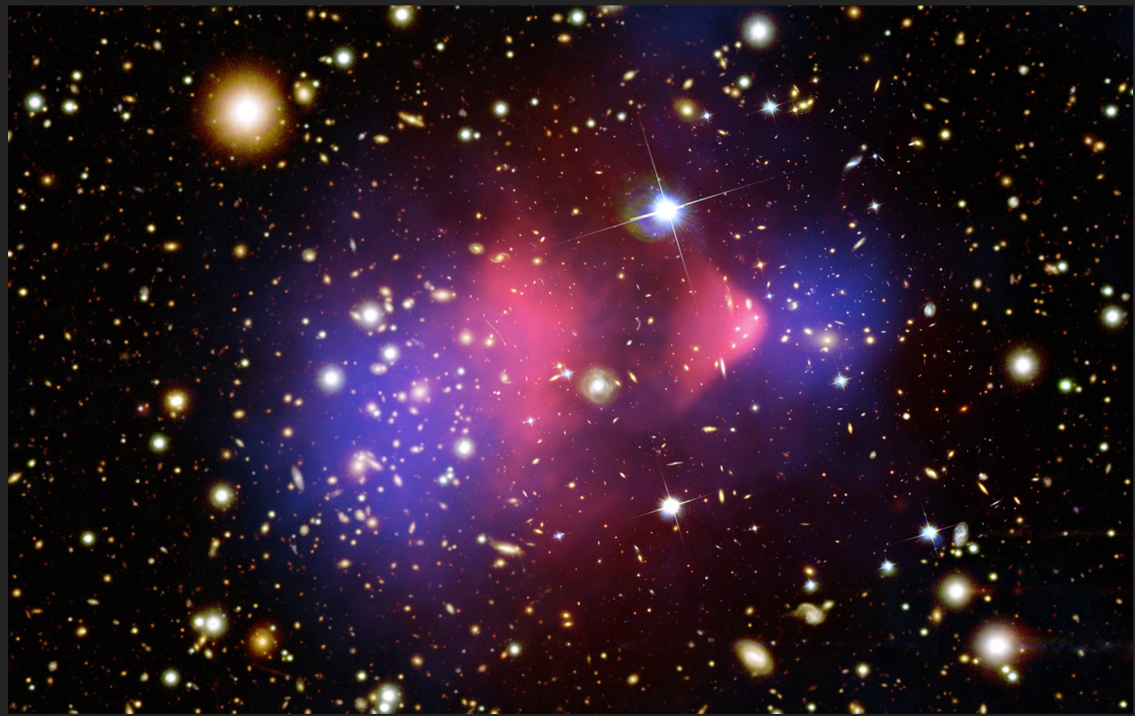
Galaxy Rotation Curves



Cosmic Microwave Background



Collision of Galaxy Clusters



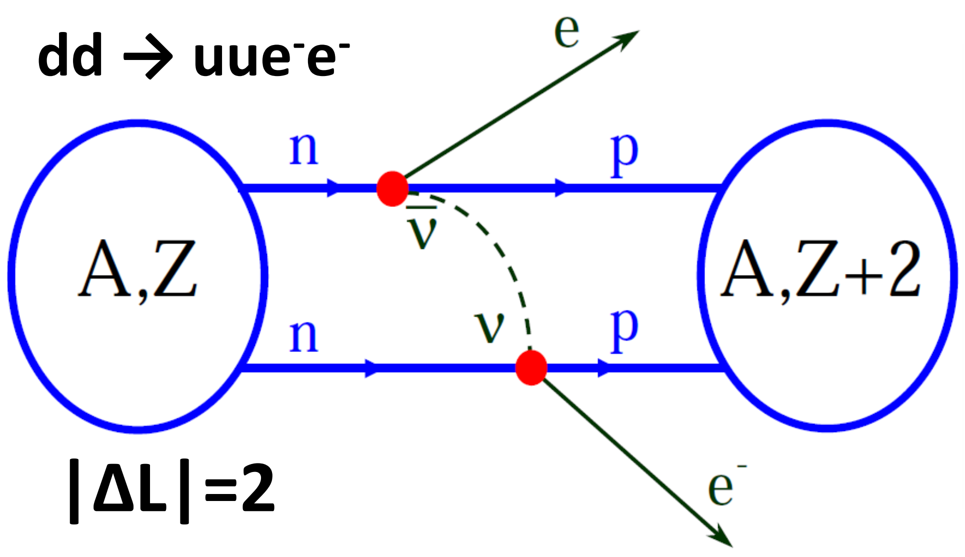
And many more…

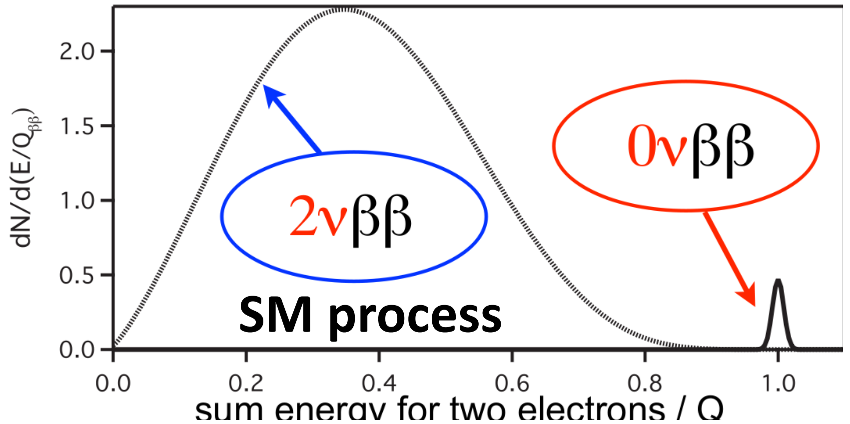
LZ Secondary Objective - Neutrino Physics and Rare Decays

- Neutrinoless double beta decay 0νββ:

$$^{136}_{54}\mathrm{Xe} \to ^{136}_{56}\mathrm{Ba} + 2e^-$$

- Not allowed in the standard model:
  - Neutrino is its own anti-particle (Majorana particle);
  - Lepton number violation (ΔL = 2), and B–L violation;
- Observation of a mono-energetic peak at the 2νββ Q-value;
  - Half-life above 10^{26} years - In LZ backgrounds have to be less than 10 events per year

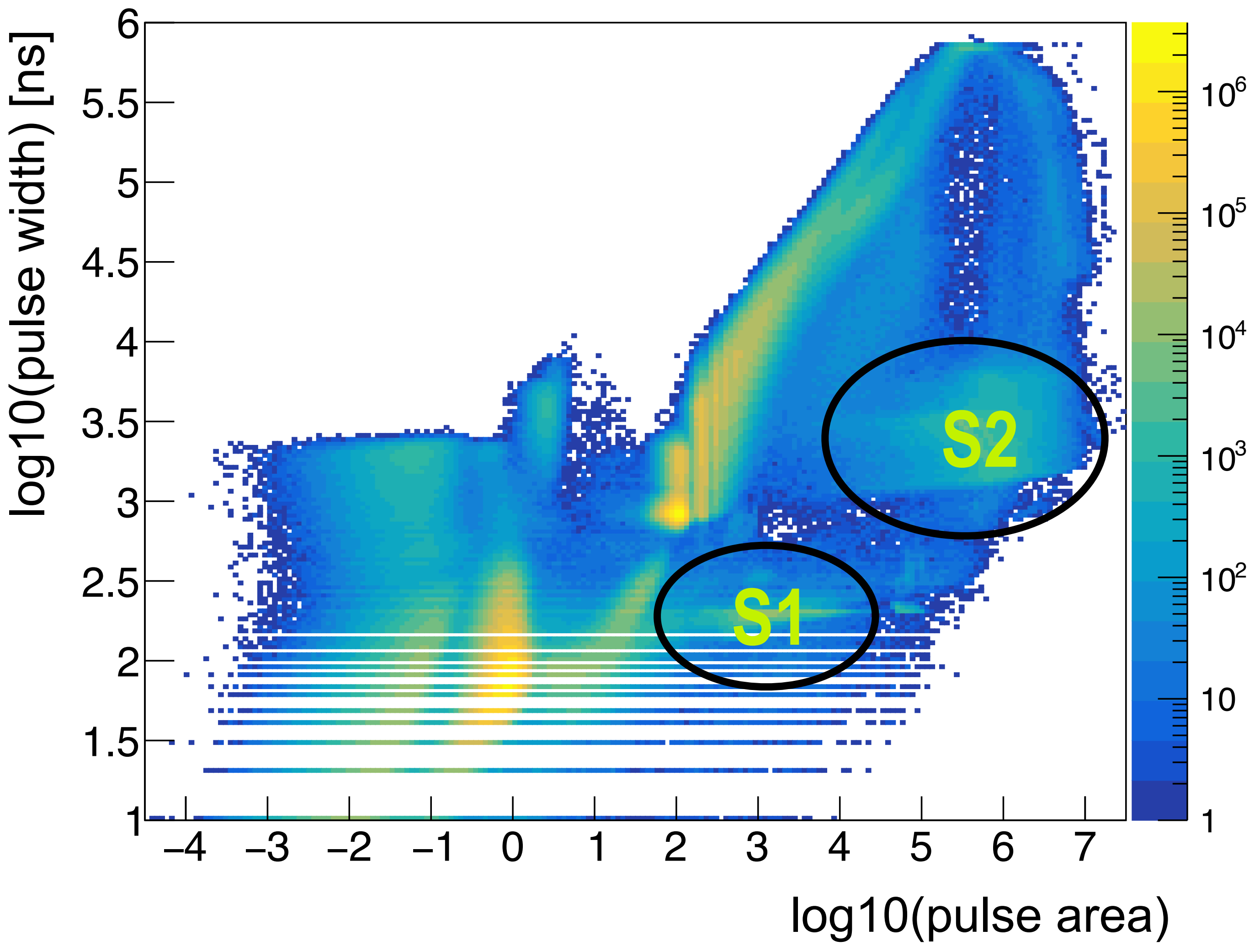




- Other Neutrino Physics:
  - CEνS;
  - Elastic Scattering of Solar Neutrinos
  - Neutrino Magnetic Moment;
  - Supernova neutrinos;
  - etc
- Rare decays:
  - $^{124}_{54}\mathrm{Xe} + 2e^- \to ^{124}_{52}\mathrm{Tl} + 2\nu_e$
  - $^{134}_{56}\mathrm{Xe} \to ^{134}_{56}\mathrm{Ba} + 2e^- + 2\nu_e$
  - etc

Thesis Proposals #1

- For all scientific activity - LZ activity focuses on the following 3 steps:
  - Control the detector and understand the detector signals (event characterization, energy deposition, the position of interaction, event topology (SS vs DS) etc…;
  - Removal or description of the backgrounds in the detector;
  - Development of signal models and sensitivity calculation



Pulse Finding and Pulse Classification

Improvement of the pulse finding and pulse classification algorithms using new methods based on machine learning algorithms such as conventional neural networks.

Contacts: neves@coimbra.lip.pt, paulo@coimbra.lip.pt

Thesis Proposals #2

- For all scientific activity - LZ activity focuses on the following 3 steps:
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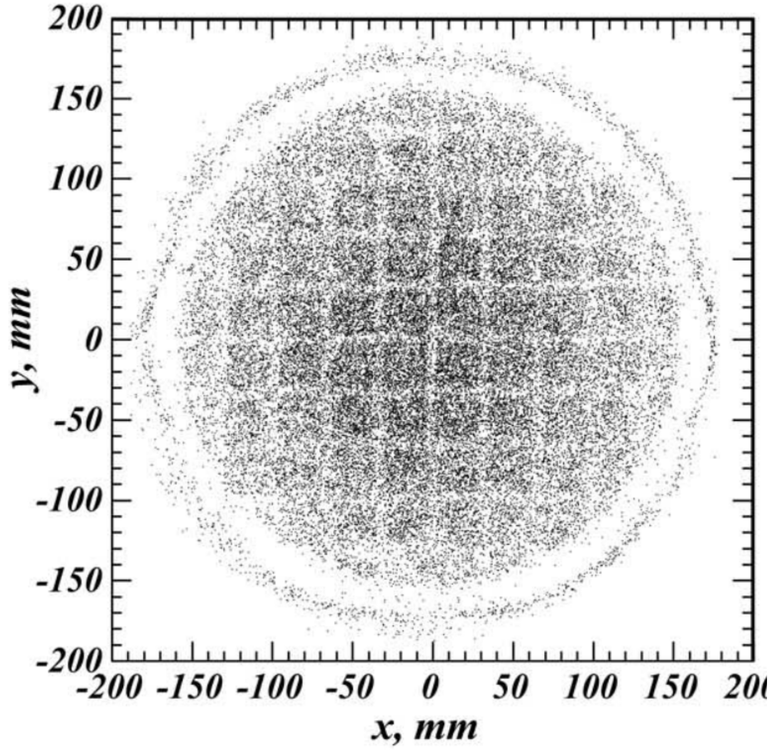
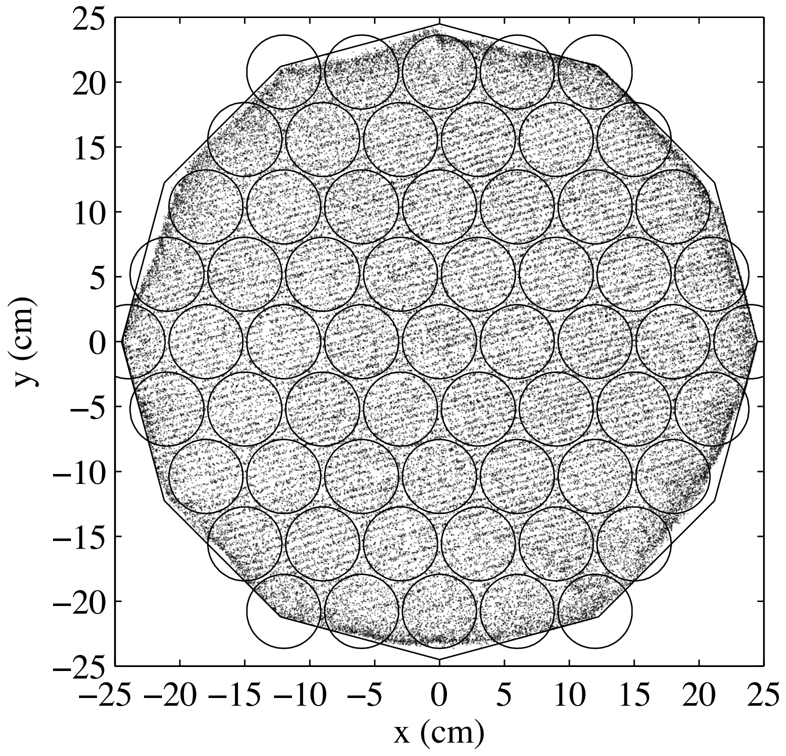
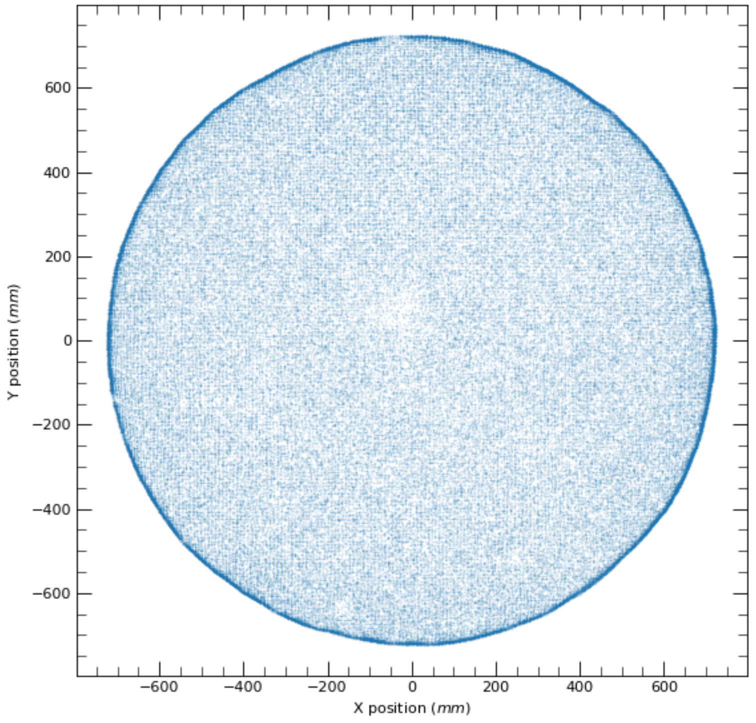
ZEPLIN-3 (2010)



LUX (2016)



LZ (2022)



Improvement Position Reconstruction in LZ and G3 detectors

Improvement of the pulse finding algorithm using new methods based on machine learning algorithms such as conventional neural networks.

Contacts: solovov@coimbra.lip.pt, claudio@coimbra.lip.pt

Thesis Proposals #3

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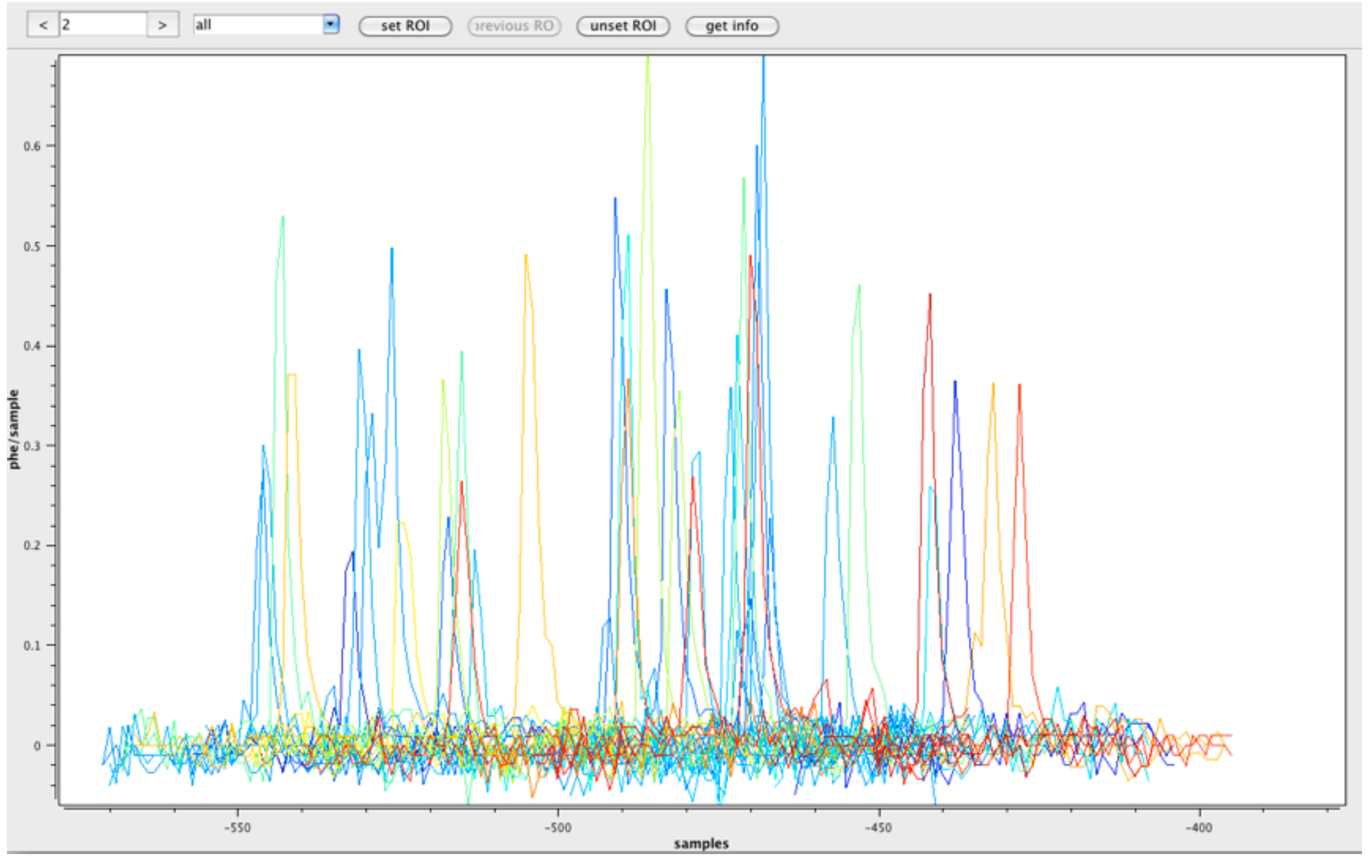

Photon Counting - Counting Light

Photon counting improves the detector energy and time resolutions by identifying individual photons detected by the photosensor. We propose an innovative approach based on compressed sensing to count photons and estimate their time of arrival.

Contacts: claudio@coimbra.lip.pt, solovov@coimbra.lip.pt

Thesis Proposals #4

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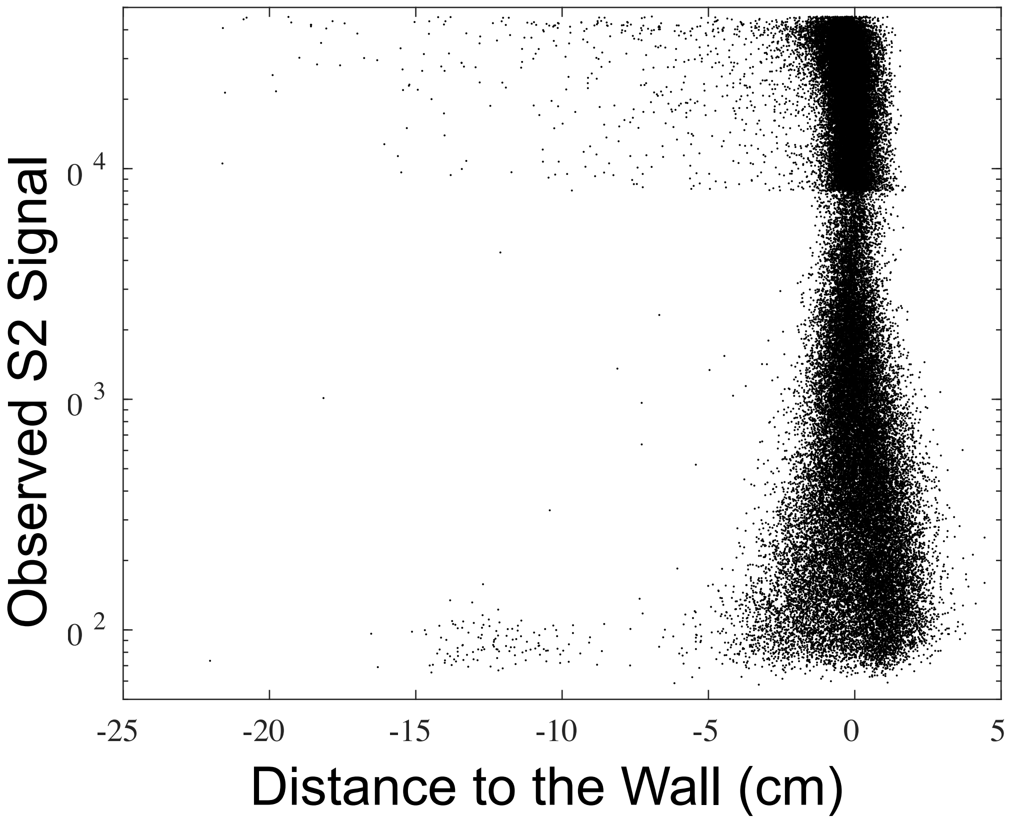

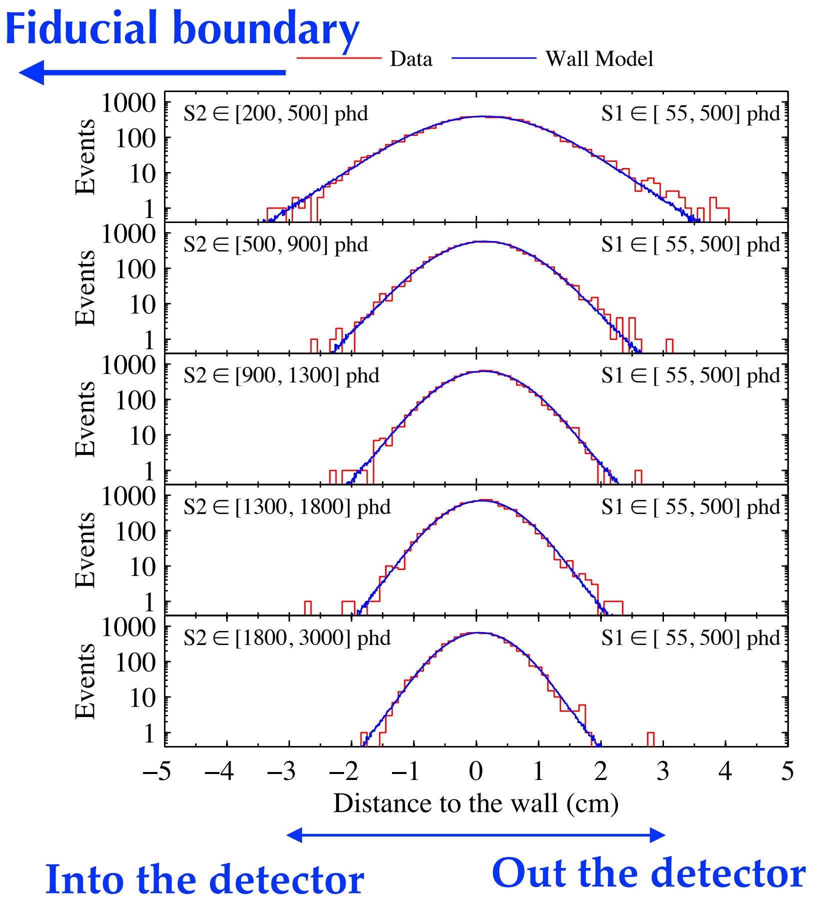

Description of the Background of the detector

- Modeling backgrounds in the detector are caused by recoils of ^{210}Pb platted in the walls.
-Remove background events using the time tagging of the decay ^{222}Rn-^{218}Po

Contacts: claudio@coimbra.lip.pt, Alex.lindote@coimbra.lip.pt

Thesis Proposals #5

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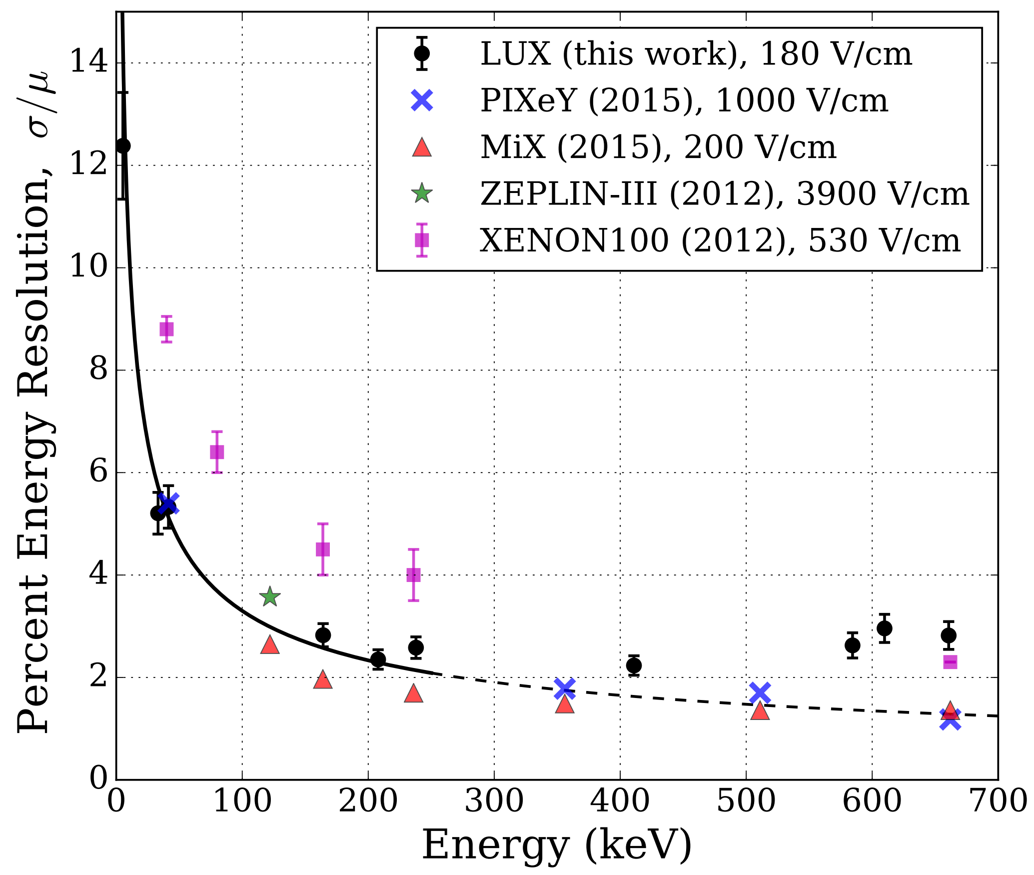

Energy Resolution for LUX

Energy Resolution

A good energy resolution is essential to the 0νββ searches and also to improve our background models.
We aim to improve the current energy resolution and create a model of the energy resolution based on first principles.

Contacts: claudio@coimbra.lip.pt, solovov@coimbra.lip.pt

Thesis Proposals #6

- For all scientific activity - LZ activity focuses on the following 3 steps:
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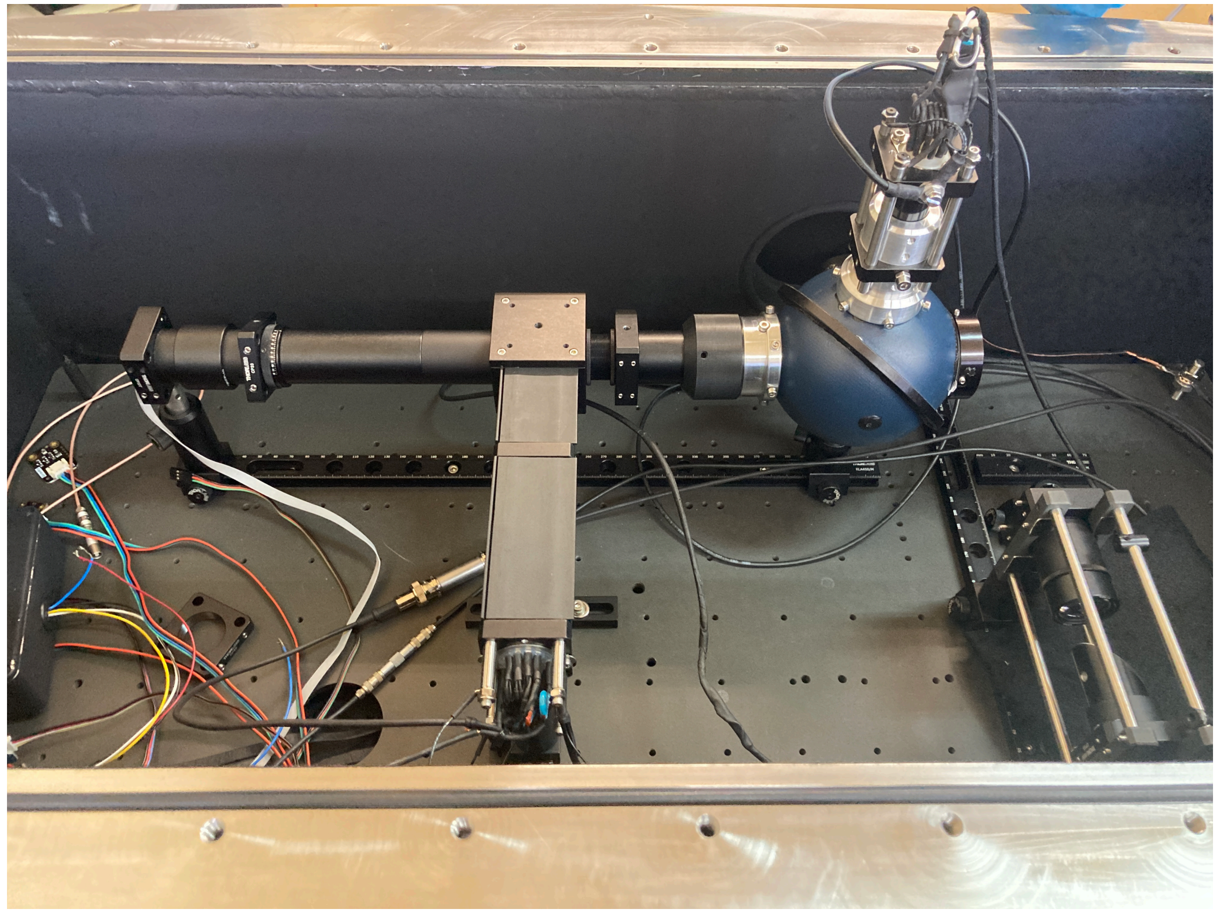

Measurement of Optical Properties in Liquid Xenon detectors

This activity focus on the measurement of optical properties with relevance to liquid xenon detectors. These properties are the reflectance, the fluorescence, etc

Contacts: claudio@coimbra.lip.pt, solovov@coimbra.lip.pt

Thesis Proposals #7

- For all scientific activity - LZ activity focuses on the following 3 steps:
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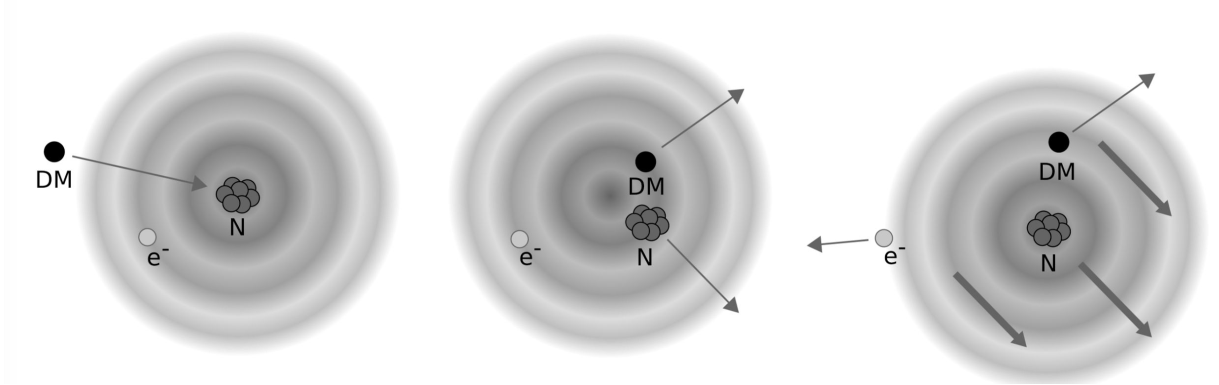
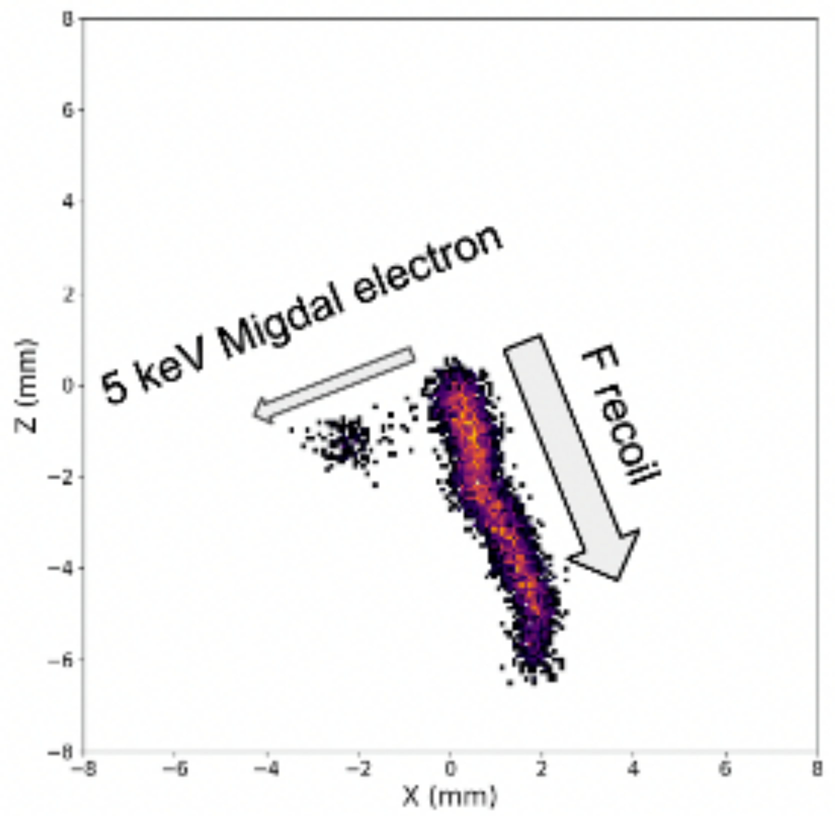
Participation on the data analysis of the confirmation of the Migdal Effect

Migdal effect corresponds to the expected emission of an atomic electron when the atomic nucleus is perturbed.
LIP participates in an experiment aiming to detect for the first time the signal from the Migdal electrons.



Migdal Effect - nucleus moves relative to the electron cloud. An individual electron might be left behind leading to ionisation.



Example image of tracks produced due to Migd

Contacts: isabel@coimbra.lip.pt, neves@coimbra.lip.pt

Thesis Proposals #8

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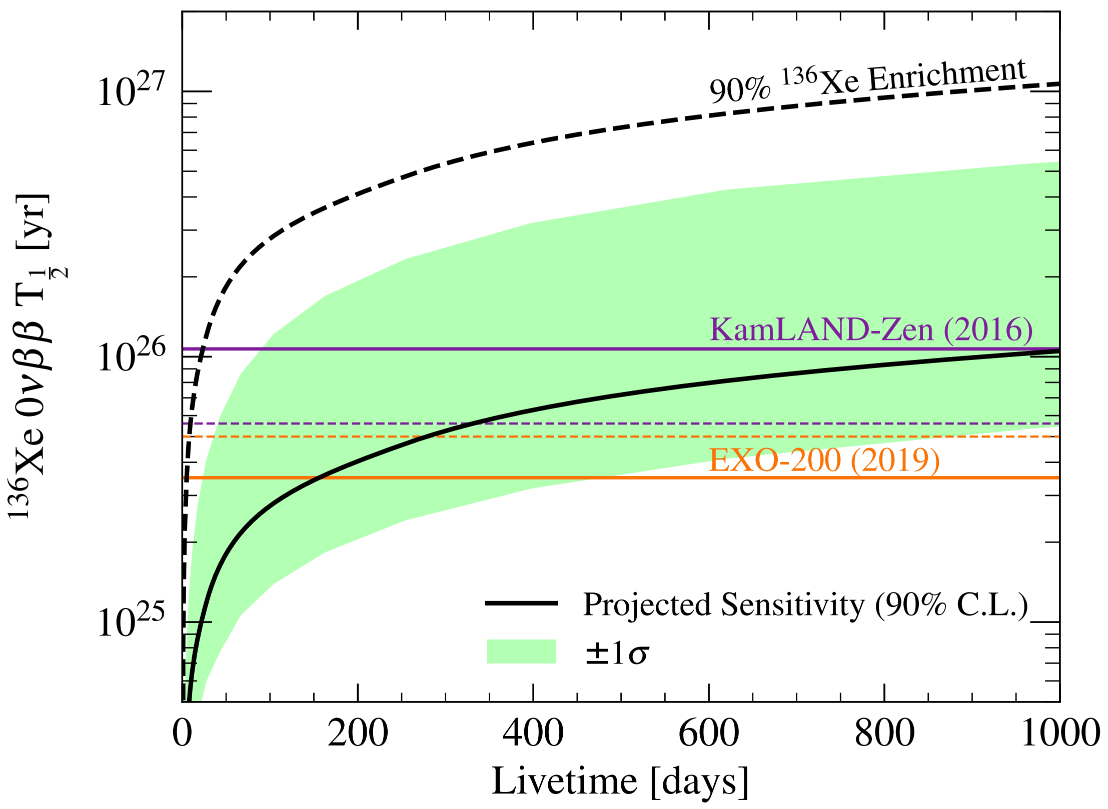

$0\nu\beta\beta$ searches in ^{136}Xe

Verification and optimization of the assumptions used in the sensitivity study;
Conduct sensitivity studies for the next generation detectors;

Contacts:alex.lindote@coimbra.lip.pt, pbras@coimbra.lip.pt

Thesis Proposals #9

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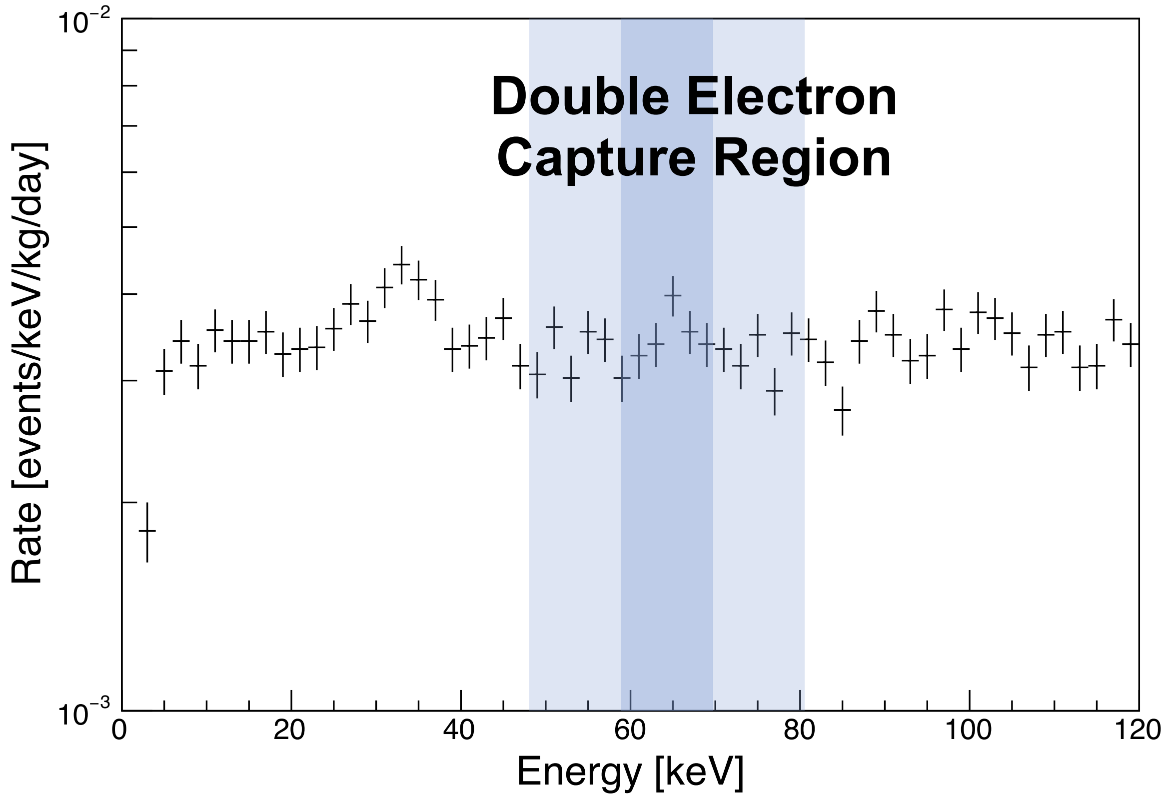
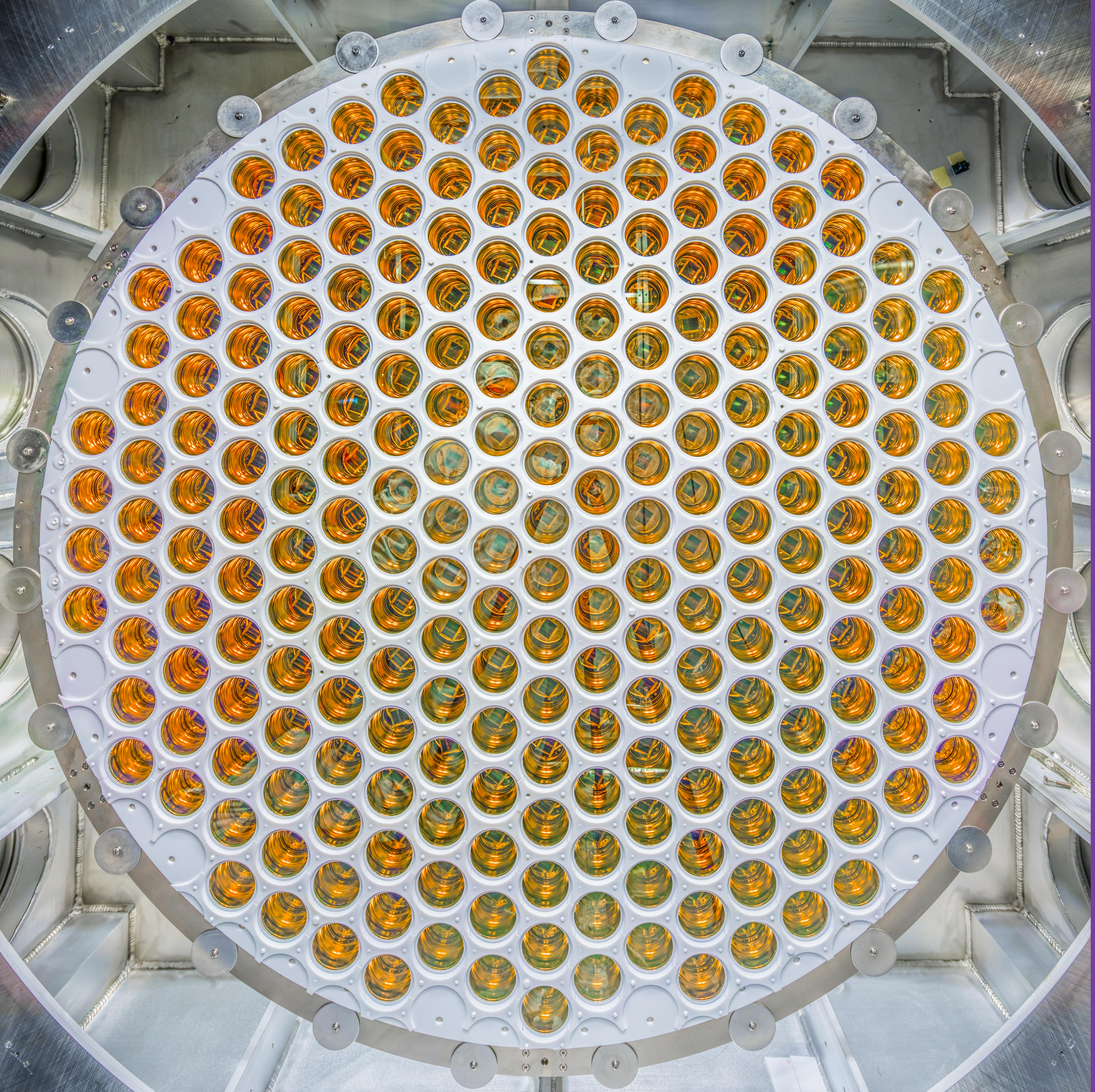


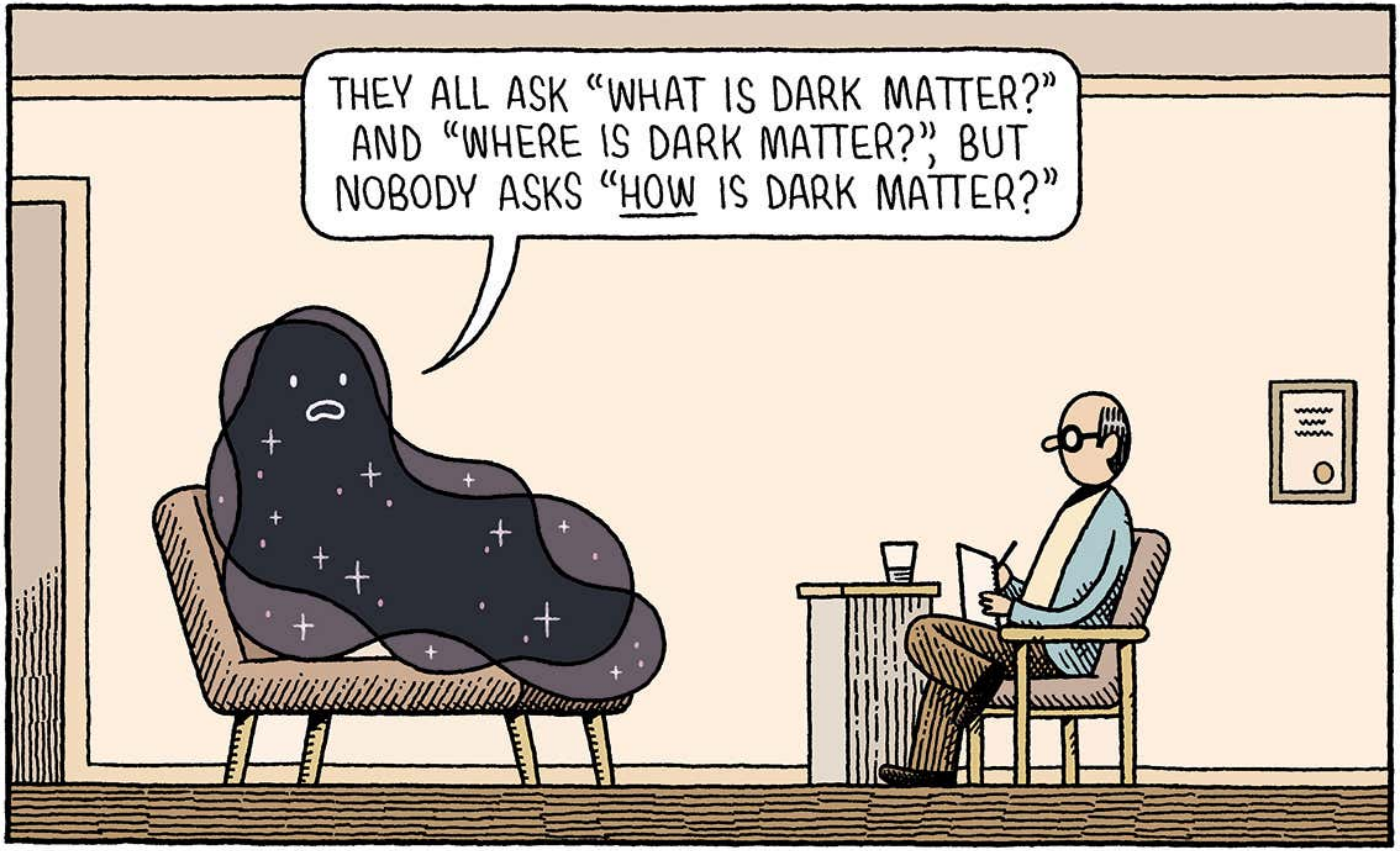
Double Electron Capture in ^{124}Xe

The double electron capture (2ν2EC) decay in Xe-124 is the rarest decay ever observed directly, surpassing the age of the Universe by 12 orders of magnitude. We plan to look into even rarer decays such as $2\nu EC\beta+$

Contacts:alex.lindote@coimbra.lip.pt, neves@coimbra.lip.pt



Obrigado!



TOM GAULD for NEW SCIENTIST