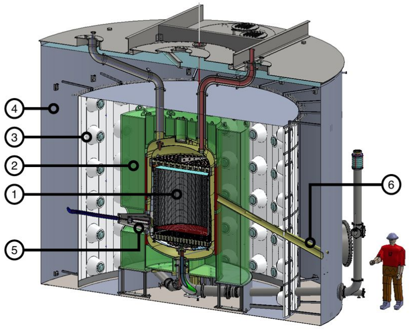
Direct Detection of Dark Matter With the LUX-ZEPLIN Experiment

Arthur Barreira and João Santos

Supervisors: Paulo Brás and Cláudio Silva

The LUX-ZEPLIN Experiment

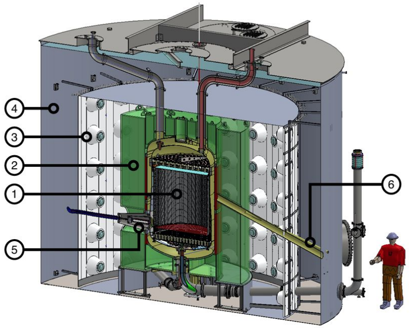
- Goals
  - Detect WIMPs which are one of the best candidates for cold Dark Matter.
  - Detect some other particles like neutrons and axions.
- Currently the most sensitive Dark Matter detector.



xenon TPC (1), Outer Detector (2), cathode high voltage connection (5), GdLS (3), water (4), pitched conduit (6)

The Detector

- 1478 m underground
- 7 tons of xenon
- photomultipliers at the top and bottom
- Several layers of shielding



xenon TPC (1), Outer Detector (2), cathode high voltage connection (5), GdLS (3), water (4), pitched conduit (6)

WIMPs

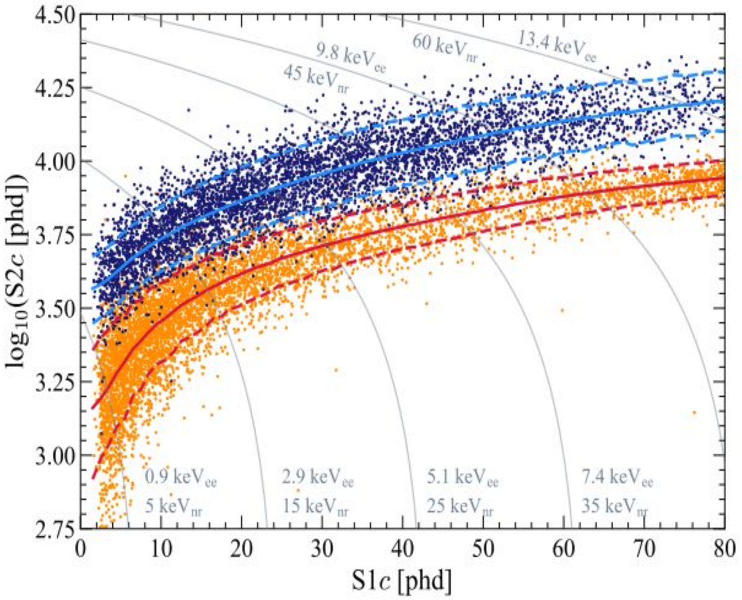
This is an abbreviation for Weakly Interactive Massive Particles. These are one of the best candidates now for the so called cold dark matter.

Their masses are expected to be between 1 and 10^5 GeV.

It is expected that some nuclear recoil events could produce signal from these particles.

Data Acquisition

- There are 2 kind of recoils happening inside the detector, nuclear recoil (in orange) and electron recoil (in blue).
- In this experiment we are interested in the nuclear recoils as they might be related to WIMPs.
- The recoils generate a characteristic signal depending on its type and that is why we need to discriminate each signal and analyse the ones we are interested in.

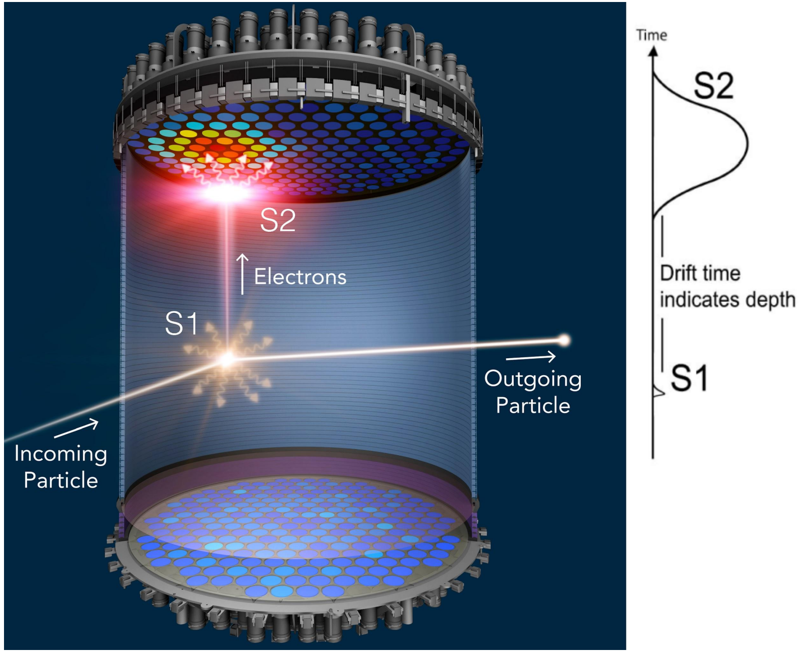


Data Acquisition

- Inside the detector there is an electric field that is responsible to extract the electrons from the interaction by conducting them to the top of the detector.
- At the bottom and the top of the detector the PMTs are responsible to detect the scintillation.
- These 2 components of the detector provide us with the S2 (second scintillation),
- S1(first scintillation) and drift time. These 3 data are the most important for our analysis.

Data Analysis - Corrections in position and energy

- Two signals are generated when a particle reaches the detector (S1 and S2).
- The drift time enables us to know the coordinate Z (depth) of the event.
- X and Y are determined directly by the pattern in the top PMT array

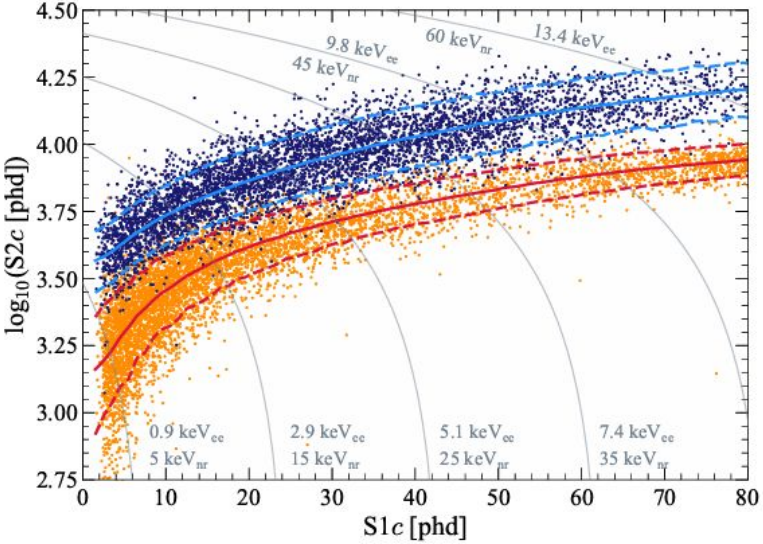


A simple depiction of S1 and S2 generation by an incoming particle

Data Analysis - Corrections in position and energy

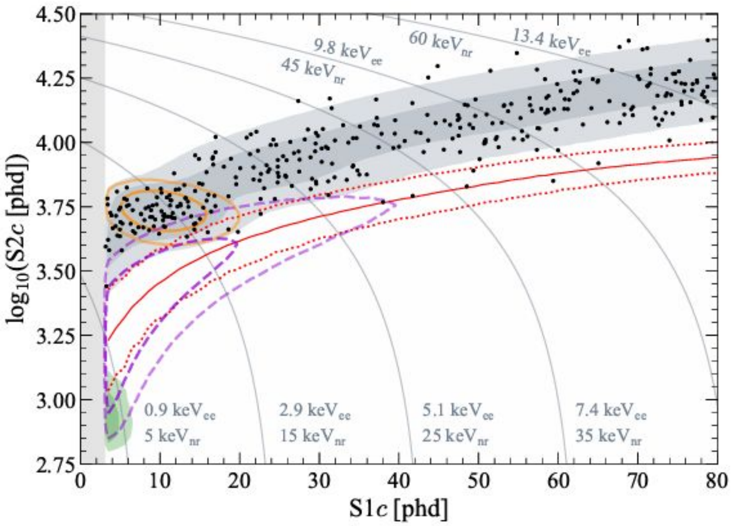
$$E = w \cdot \left(\frac{S1}{g1} + \frac{S2}{g2}\right)$$

- w=13.5 eV
- g1 and g2 must be calibrated



Data Analysis - Corrections in position and energy

- Most of the work is cutting what does not matter
- Objective:
  - select the data based on the drift time and radius
  - study S1 and S2 and make corrections to the signals
  - evaluate the energy of the events

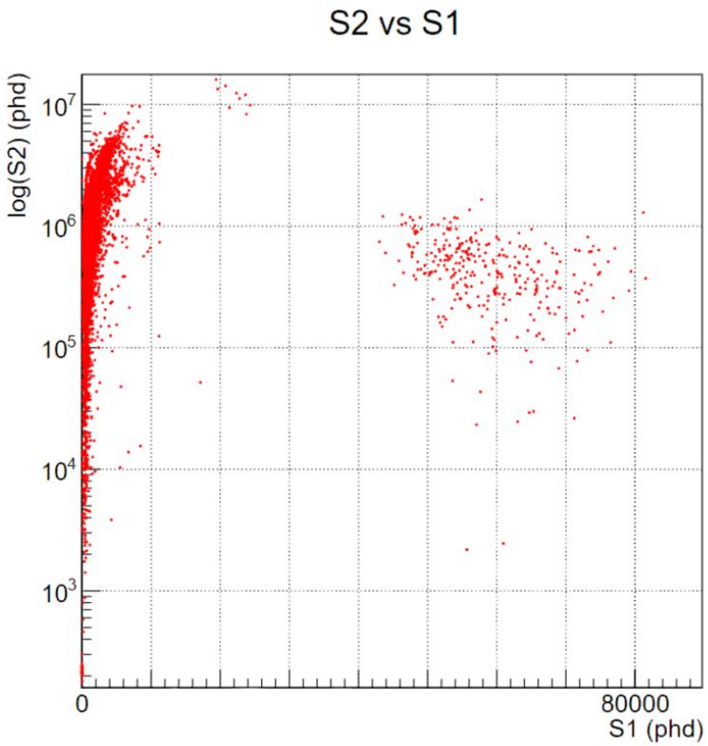


Data after all the cuts. Purple dashed lines is where WIMPs of a few GeV should be

First Step: Filter what does not matter

- We start by making a cut in radius and drift time

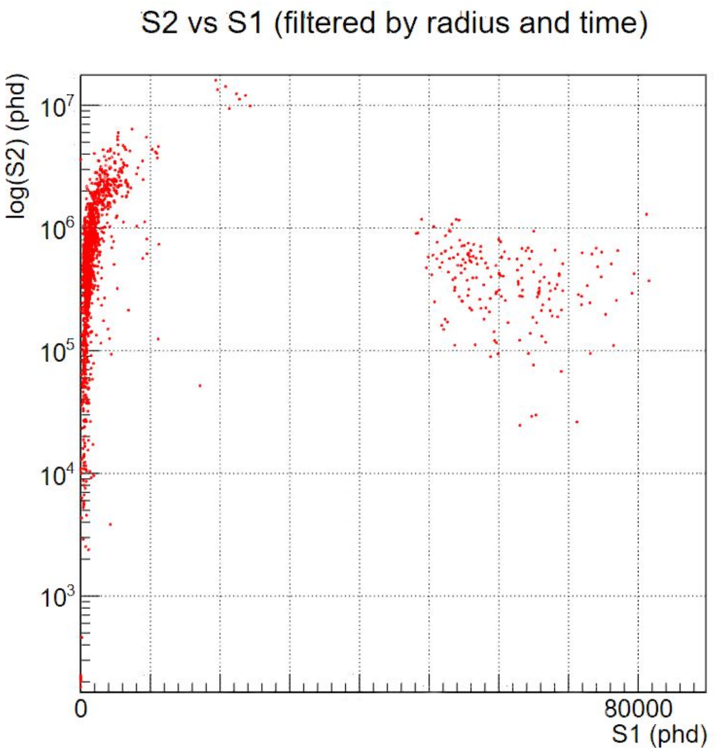
- Events too close to the edge of the detector outside the fiducial volume (FV) are considered background noise.
- Events of large drift time may be too polluted because of lower efficiency.



First Step: Cut out what does not matter

- We start by making a cut in radius and drift time

- Events too close to the edge of the detector outside the fiducial volume (FV) are considered background noise
- Events of large drift time may be too polluted because of lower efficiency



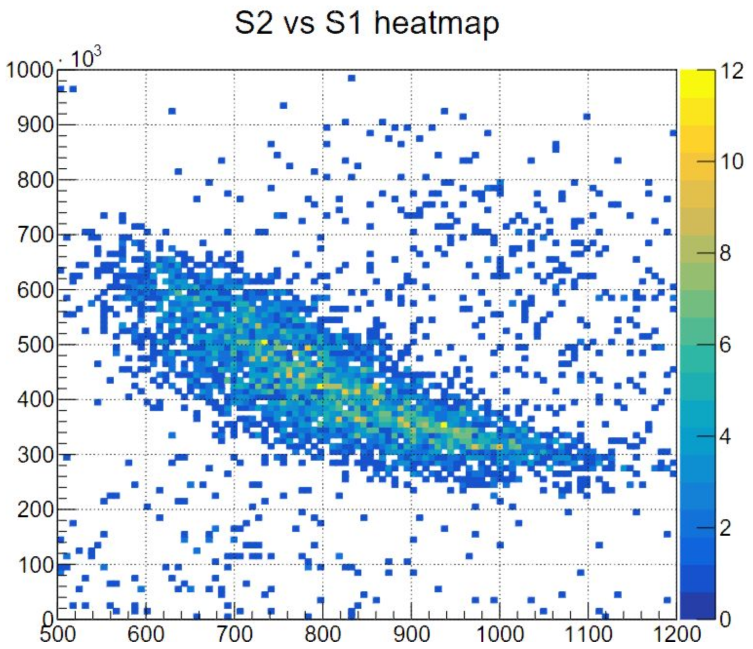
Exploring the region of interest

500<S1<1200 phd

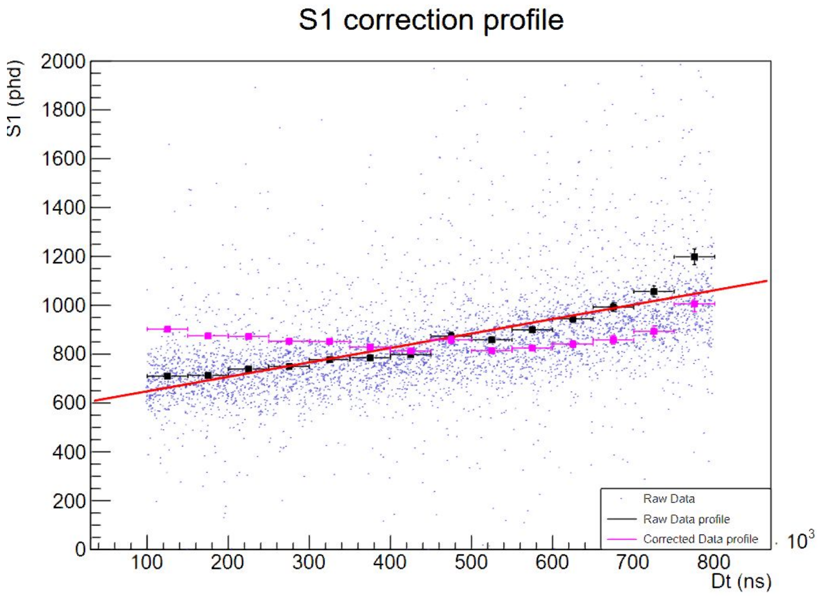
S2<10e6 phd

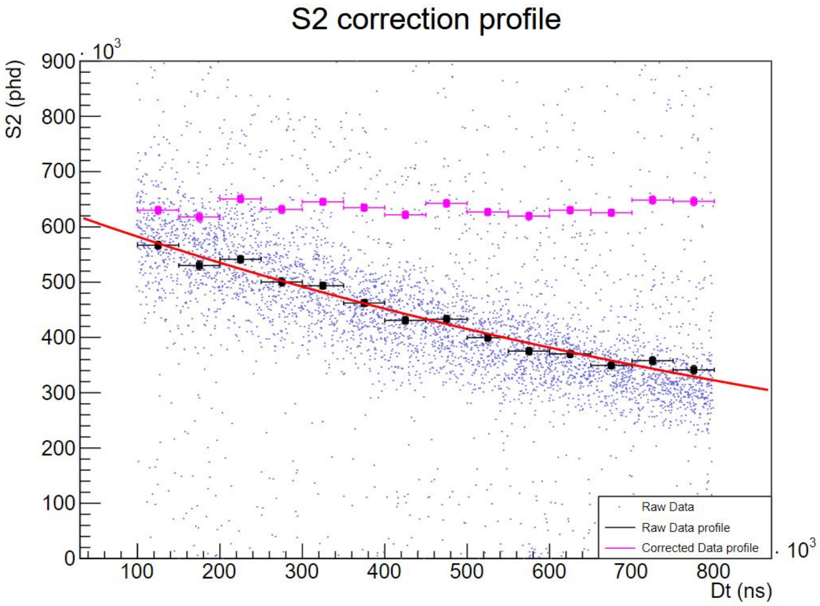
We can clearly see an activity spot (Xe131m)

Activity outside the ROI is mainly Alfa particles



Corrections to S1 and S2

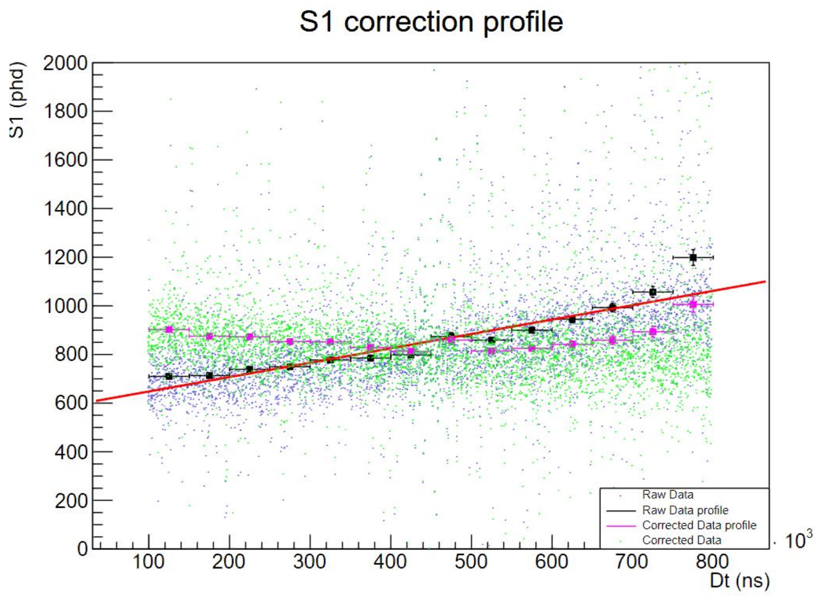




$$S1 = m \cdot d_t + b$$

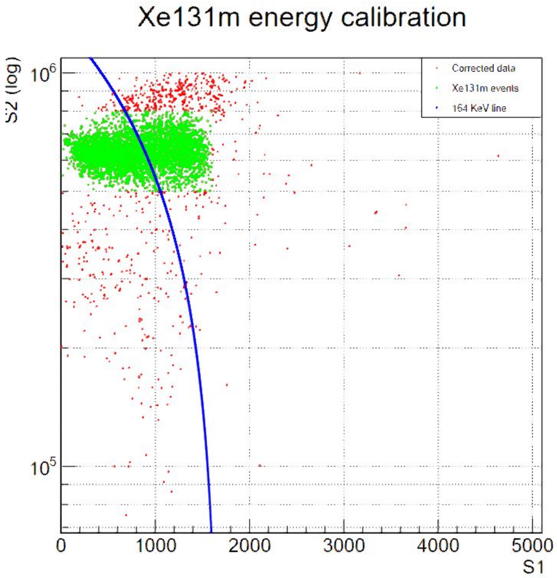
$$S2 = Ae^{-d_t/E_l}$$

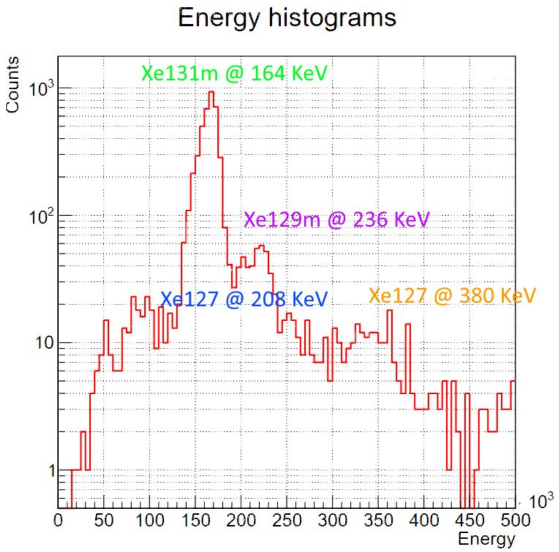
Corrections to S1 and S2



$$E_l = 1.45\, ms$$

Energy of events

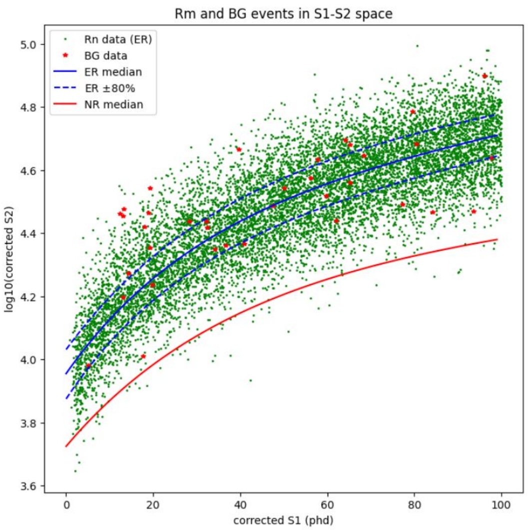


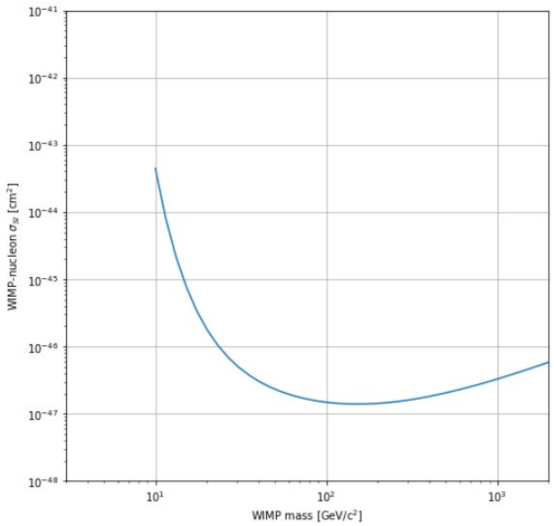


$g1 = 0.1383 \qquad g2 = 110.48$

$$E = w \cdot \left(\frac{S1}{g1} + \frac{S2}{g2} \right)$$

What could be done next





- Rn calibration of ER events
- Detector sensitivity

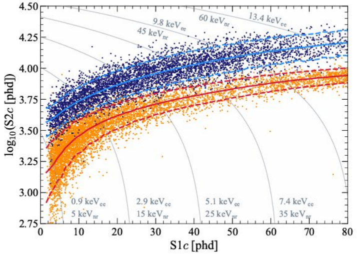
Conclusions

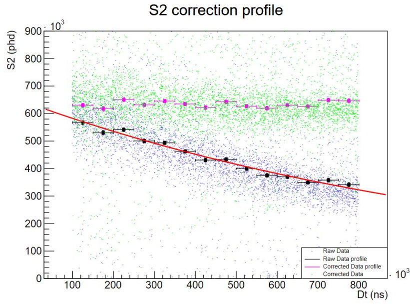
- The lux-zeplyn experiment aims to detect dark matter as WIMPs

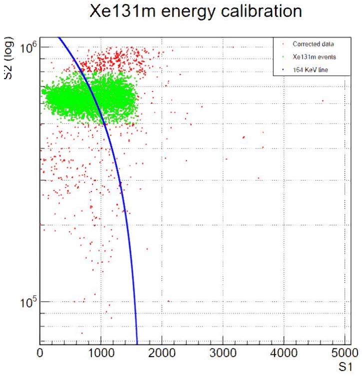
- The data is collected in the form of two signals S1 and S2. The analysis is done wit an exclusion process and the events are separated in ER and NR

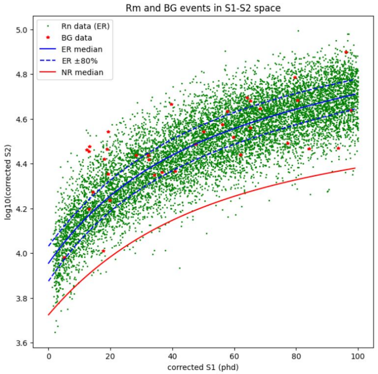
- We managed to apply filters in radius and drift time and focus on the ROI of the Xe131m activity

- Corrections to the signals were made and the energy model was reconstructed









References

- Neutron Activation Backgrounds in LUX-ZEPLIN (IOP 2023) by Tom Rushton on behalf of the LZ Collaboration
- 4850 Feet below: The hunt for dark matter
- The LUX-ZEPLIN (LZ) Experiment
- First Dark Matter Search Results from the LUX-ZEPLIN (LZ) Experiment
- Projected WIMP sensitivity of the LUX-ZEPLIN (LZ) dark matter experiment