# Towards the First Results of XENONnT: $^{37}$Ar Calibration


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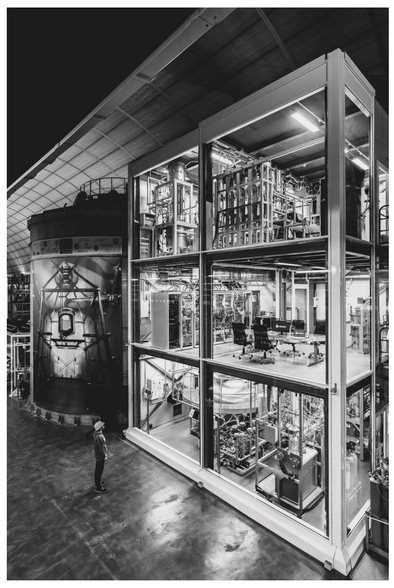
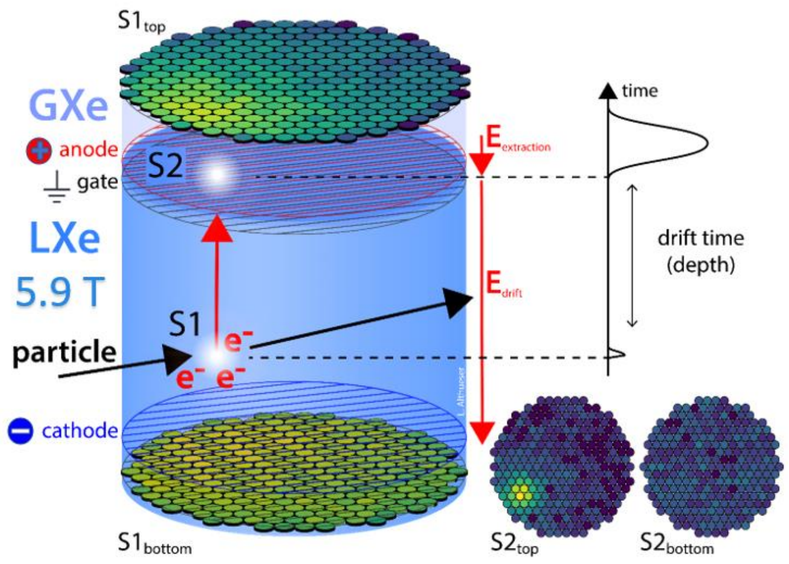
XENON

ASTROPARTICLE PHYSICS

## XENON Detection Principle

The XENONnT detector is a dual-phase time projection chamber (TPC) filled with liquid xenon (LXe) as a target medium.
It is located in the underground INFN Laboratori Nazionali del Gran Sasso (LNGS) in Italy using the mountain as a natural shield to suppress external background.
The primary, but not single, scientific goal is the direct detection of *weakly interacting massive particles* (WIMPs), a well motivated class of particle dark matter candidates.

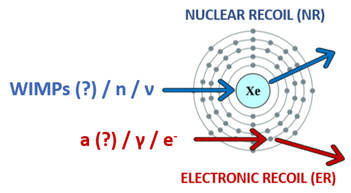





- Particle interactions in the liquid phase generate *prompt scintillation signal* (**S1**) and free *ionization electrons*.
- Electrons are drifted towards the gas phase where they are extracted and generate secondary scintillation signal (**S2**).
- Two arrays of photomultiplier tubes (PMTs) at top and bottom detect scintillation light.
- **3D** position reconstruction :
  - **X,Y**: from S2 hit pattern in the top PMT array
  - **Z**: from drift time t(S2) - t(S1).
- Particle identification : **S1/S2** ratio depends on dE/dx.

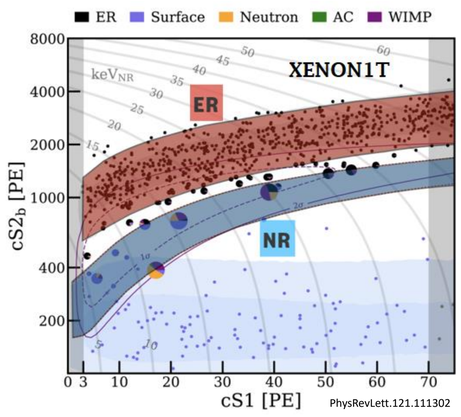
## Low Energy Electronic and Nuclear Recoils: Science Objectives

- Detected signals come from either nuclear or electronic recoils.
- Background events are well understood in the ER/NR bands so *excesses* can be searched.




| ER Band | NR Band |
|---|---|
| Axion-like particles<br>Dark photons<br>ν magnetic moment<br>& more | Spin-independent WIMPs<br>Spin-dependent WIMPs<br>Sub-GeV DM<br>& more |

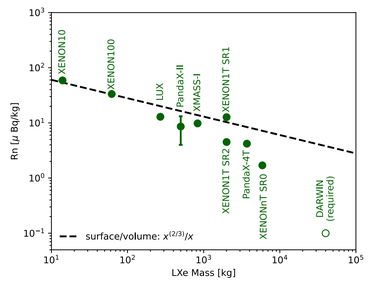
$$\left(\frac{S2}{S1}\right)_{ER} \gg \left(\frac{S2}{S1}\right)_{NR}$$



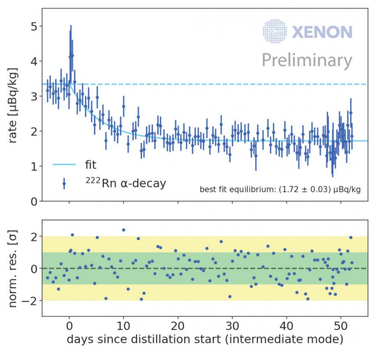

- In NR about 80 % of the energy deposit is lost as *heat*, while for ER that is negligible (PhysRevD.83.063501).

## Background Suppression

- Reduction of external and internal background is crucial to improve the sensitivity to new physics and it is one of the main experimental challenges.
- $^{222}$Rn main source of ERs background, internal background emanating from detector building materials.




- In addition to the selection and the screening of the materials (arXiv:2112.05629, largely at MPIK), a novel radon distillation system is introduced (arXiv:2205.11492).
- ***Lowest*** background rate ever achieved at O(keV) energy.
- ***Lowest*** $^{222}$Rn intrinsic background level ever reached in LXe TPC, $(1.72 \pm 0.03\ \mu Bq/kg)$.



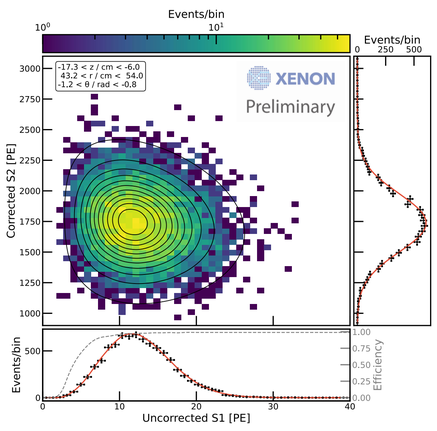

## Calibration of Low Energy ER Response with $^{37}$Ar

- **$^{37}$Ar** is a **low-energy ER internal calibration** source which provides monoenergetic lines

| | Energy | Probability |
|---|---|---|
| K-shell | **2.8224 keV** | 90.21% |
| L-shell | 0.2702 keV | 8.72% |
| M-shell | 0.0175 keV | 1.06% |

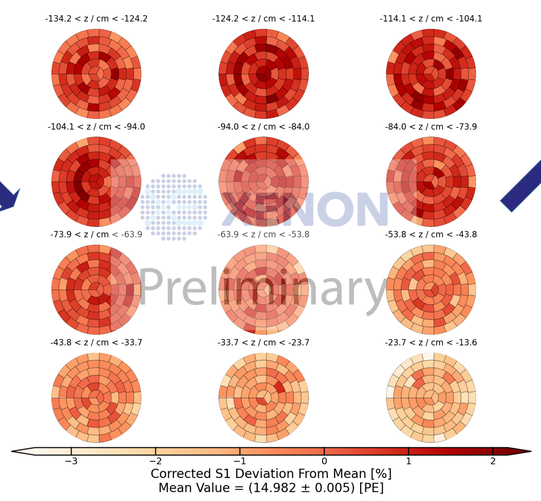
from 100% electron capture decays.

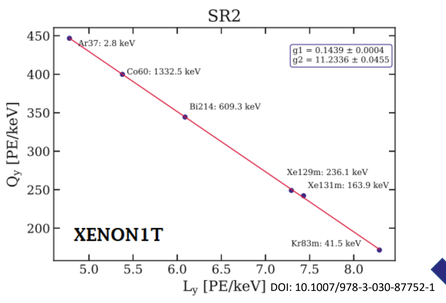
- Firstly used in 2018 for the XENON1T detector.
- *Why*: to study detector response at low energy, detection efficiency, energy threshold and to fully validate energy reconstruction down to a few keV.
- *How*: to extract the charge yield and light yield related to $^{37}$Ar K-shell peak the TPC volume is divided in equivolume bins (*voxels*) to properly take into account S1 detection efficiency.



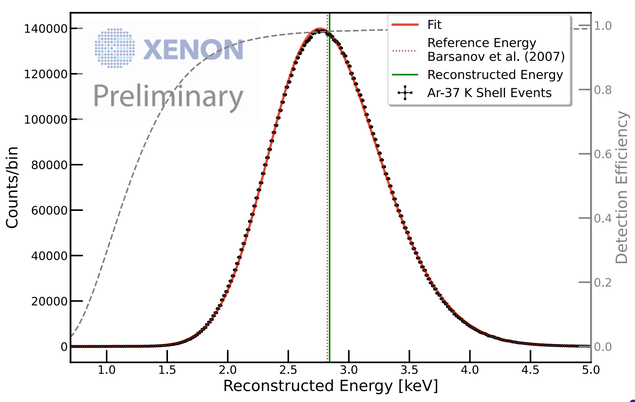

- Example of a fit in (uncorrected S1, corrected S2) space in one among the 936 voxels.
- Partition in voxels allows to correctly take into account *S1 detection efficiency* and *spatial dependent corrections*.

- ***Suitable signals spatial stability*** over the volume considered in the science analysis.



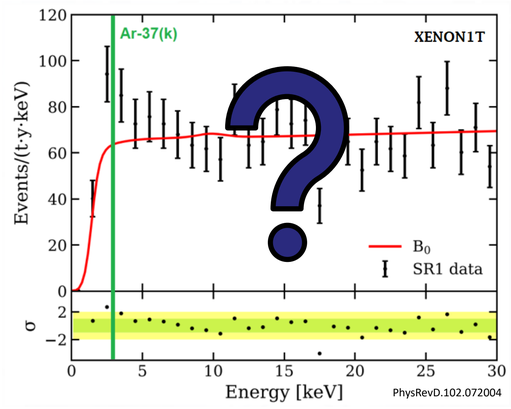




- To reconstruct the energy of each ER event corrected S1 $\propto n_{ph}$ and corrected S2 $\propto n_e$ are combined.
- Check anti-correlation (due to recombination) between primary scintillation and ionization with different calibration data.
- Powerful check to exclude an energy dependent response of the detector.




- ***Noteworthy energy reconstruction*** of the $^{37}$Ar K-shell peak with energy resolution ~ 17% .

- XENON1T found an unexpected 3.3σ Poissonian excess between (1-7) keV.
- Origin not clear:
  - new background component
  - statistical fluctuation
  - new physics signature.
- $^{37}$Ar from a constant air leak or initial amount in the xenon gas is excluded as possible explanation.
- One of the main goal of the first science run is to confirm or reject the excess.





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