Probing new physics with high-energy electronic recoil in XENONnT

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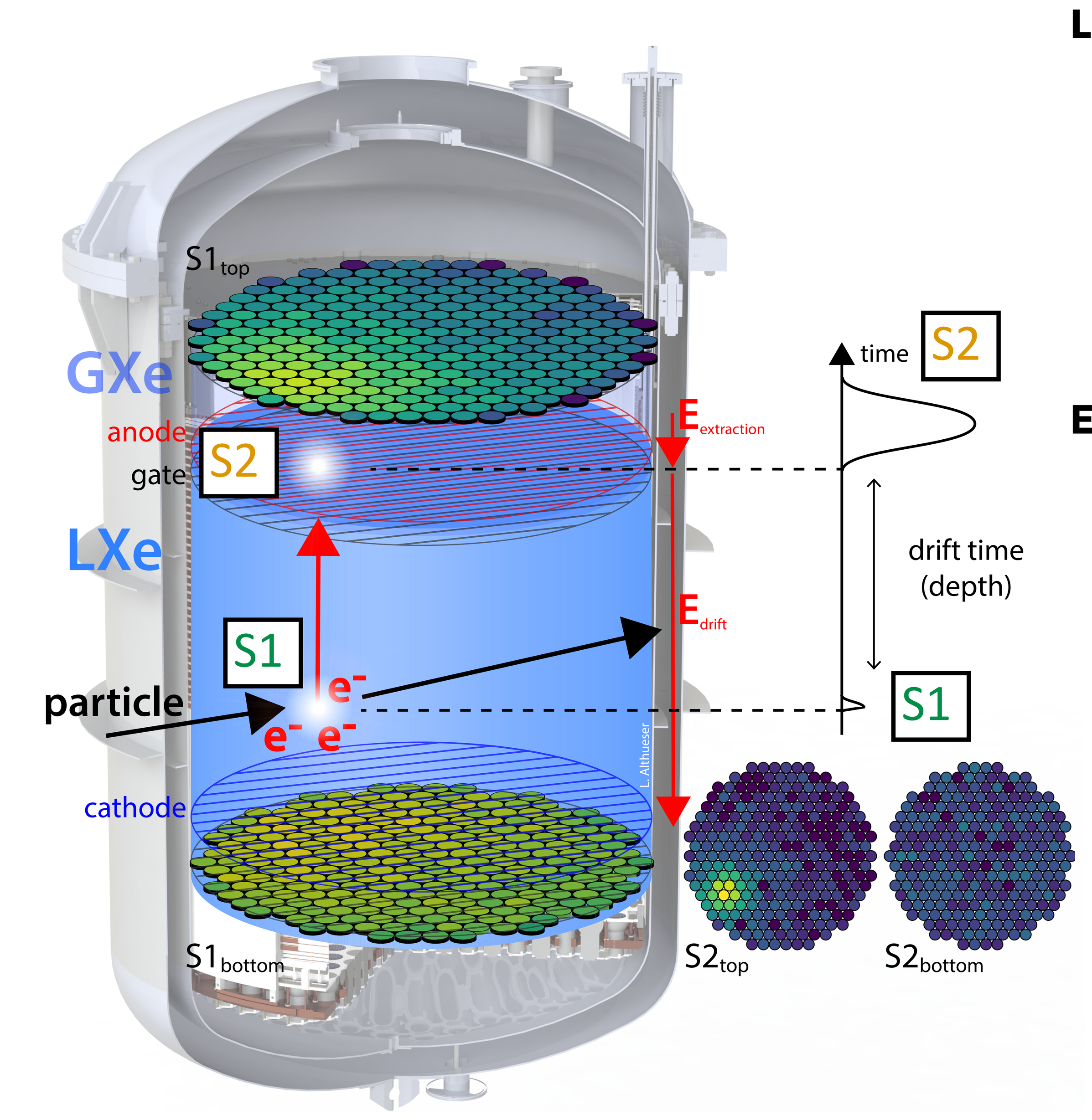
XENONnT's unprecedented background level reduction enables the investigation of rare processes beyond dark matter. Notably, the use of electronic recoils up to the MeV scale allows the study of ^{136}Xe double weak decay, both neutrino-full and neutrinoless, offering potential insights into new physics.

1. The XENONnT Dark Matter Experiment and its Physics Program

Dual-phase Xe Time Projection Chamber:



Light and Charge readout

- Prompt scintillation signal (**S1**)
- Secondary proportional scintillation signal in GXe from drifted electrons (**S2**)

Event reconstruction

- **3D Position:**
  - ➡ **Z** from drift time
  - ➡ (**X**, **Y**) from PMTs hit pattern
- **Energy:** combination of S1 & S2
- **Multiplicity:** number of S2s
- **Interaction type:**
  - ➡ Electronic (ER) vs Nuclear (NR) Recoil
  - ➡ **S2/S1** ratio

We can reconstruct different type of interaction → We can search for different physical proccesses.

Dark Matter interaction & much more!

Motivation to study double-weak processes in XENONnT

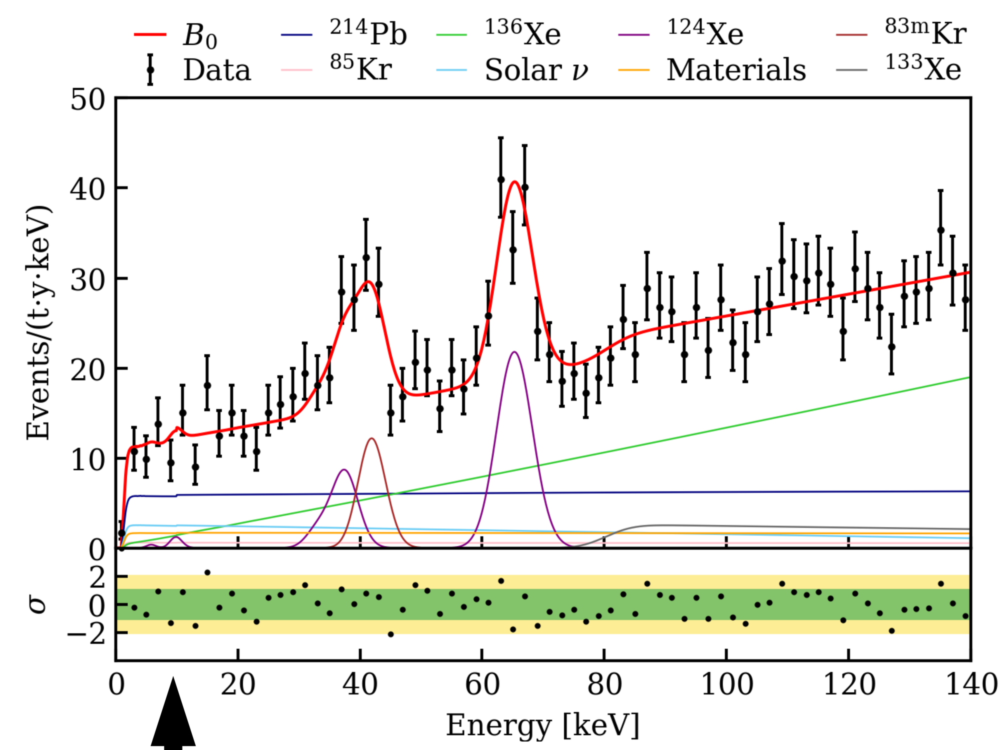
- Multiple isotope candidates with different decay mode are naturally present in the xenon target: ^{124}Xe, ^{134}Xe, ^{136}Xe.
- Help to test nuclear models.
- Probe Beyond Standard Model physics.

$0\nu\beta\beta:\ (A,Z) \rightarrow (A,Z+2) + 2e^-$
- ➡ Lepton number violation
- ➡ Majorana neutrino

$2\nu\beta\beta:\ (A,Z) \rightarrow (A,Z+2) + 2e^- + 2\bar{\nu}_e$
- ➡ BSM physics can induce spectral shape distortion [1, 2, 3]

Signal: Measure energy deposit from the two emitted electrons ➜ ER

2. ER measurements from few keV to $Q_{\beta\beta}$

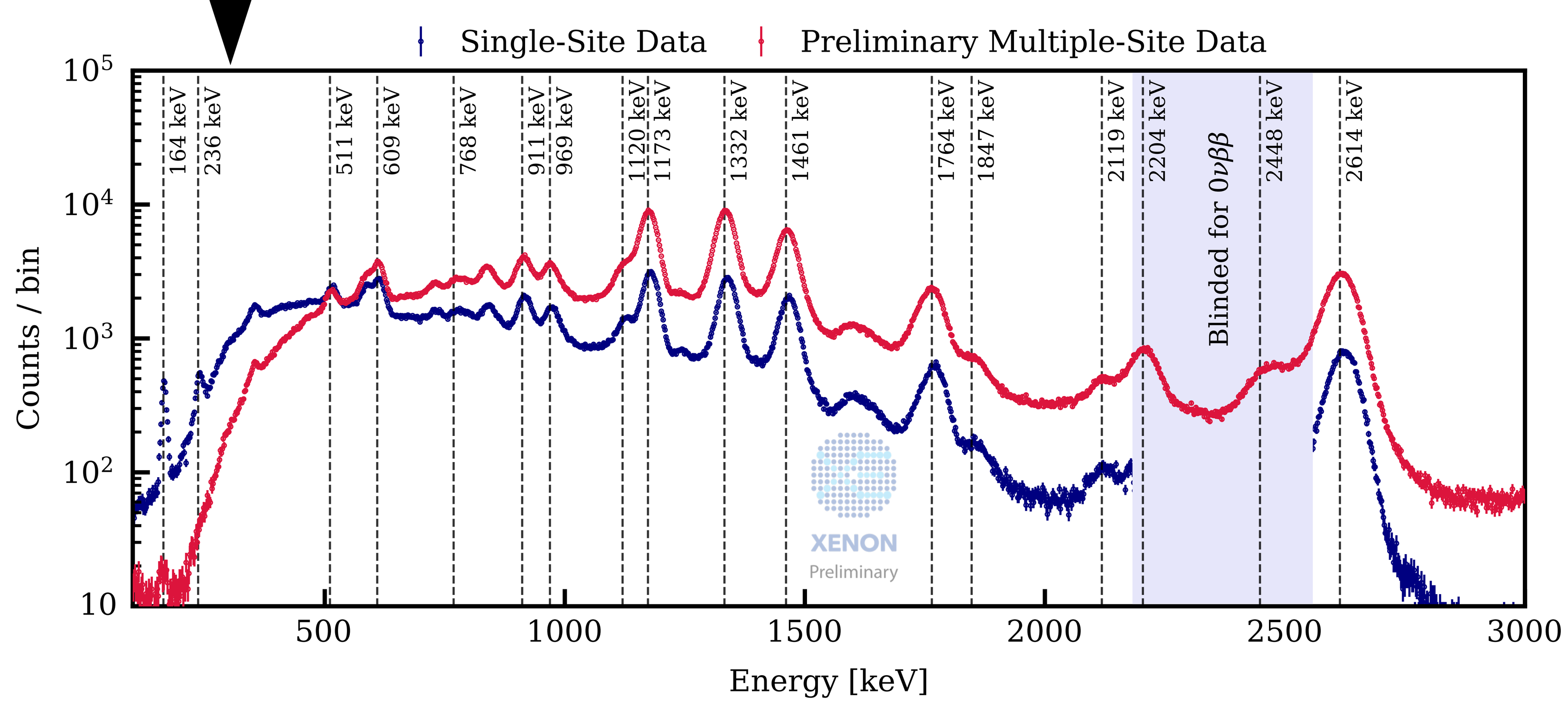


- First search for new physics in low-energy ER with XENONnT first science run [4].
- Lowest ER rate ever achieved with such detector.

Double Weak decays start to be a dominant contributor in the low-energy ER region of interest.

Ability to measure the 2νββ decay energy spectrum from few keV up to $Q_{\beta\beta}$ @ 2457 keV

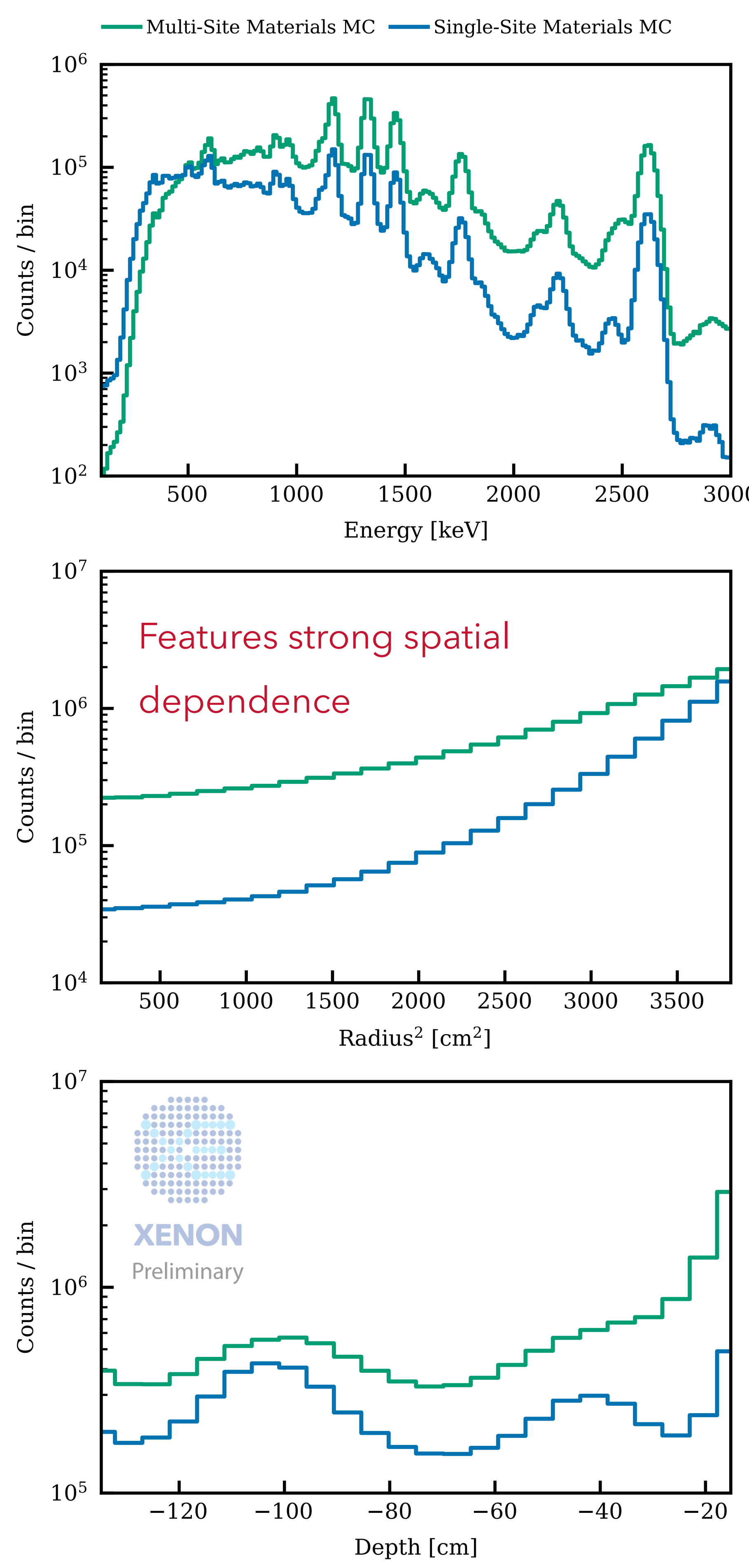
Reconstruct both Single-Site (SS) and Multi-Site (MS) events.



3. Background Model for 2νββ Decay

We use energy, position, and multiplicity information to constrain our background models. This enables precision measurement of the ^{136}Xe 2νββ decay spectral shape.

External Background Model



Internal Background Models

- Homogeneously distributed.

Source	Energy [keV]	Constrain source
^{212}Pb	0 - 600	MS fit
^{214}Pb	0 - 1000	MS fit
^{85}Kr	0 - 687	RGMS meas.
solar ν	0 - 210	Borexino flux
^{124}Xe 2νECEC	64.3	Half-life/ abundance
^{133}Xe	75 - 400	n-activation study
^{131m}Xe	163.9	n-activation study
^{129m}Xe	236.2	n-activation study

Exploit the different features of the new physics signal and detector background in the inference.

➜ Use MS high-energy gamma spectra to constrain the level of radiogenic contaminants in detector materials.

4. 2νββ Spectral Shape Measurement

3D binned likelihood fit of SS events where each energy bin is fitted independently:

$$-\ln \mathscr{L} = \Sigma_i \left[\mu_i^{SS} - k_{obs,i}^{SS} \ln \mu_i^{SS} + G_{constraints,i}\right]$$

Observed number of events per bin i

Expected number of events per bin i, with:

$$\mu_i^{SS} = N \sum_j n_j f_j^{SS}$$

Relative number of events for source j

PDF of source j

Open path to precision measurement of the 2νββ decay of ^{136}Xe full energy spectrum…Stay tuned!

REFERENCES

[1] Phys. Rev. D 103, 055019
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[3] Phys. Rev. Lett. 125, 171801
[4] Phys. Rev. Lett. 129, 161805

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