Background Study in S2-only Analysis in XENON Experiments

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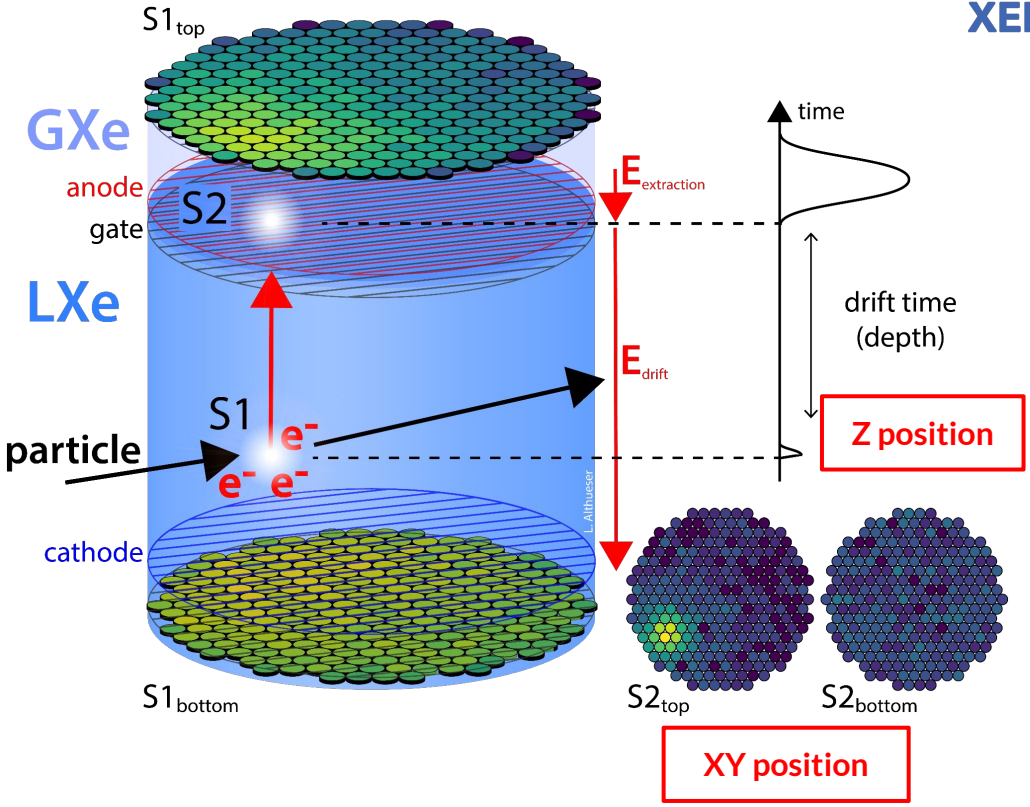
Dual phase Xe Time projection chamber (TPC)

- S1: Prompt scintillation light
- S2: Secondary scintillation light induced by ionionized electrons
- Position reconstruction: drift time + PMT pattern
- ratio of S2/S1

⇒ electronic recoil (ER) induced by β, γ

⇒ nuclear recoil (NR) induced by Neutrons, WIMPs

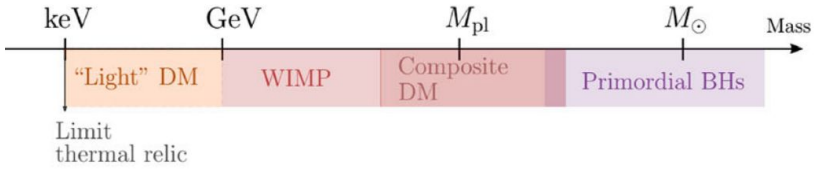


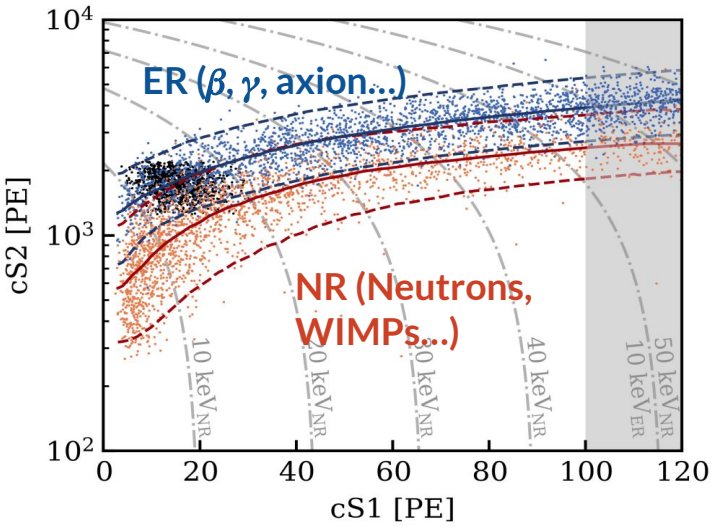
Why S2-only?

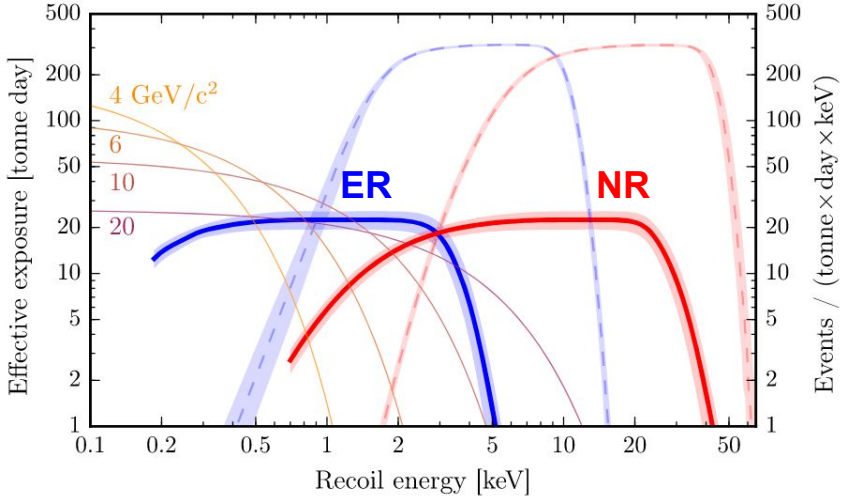
Xe TPCs most sensitive to mass of dark matter $m_\chi \geq 6$ GeV/c^2

Typical S1 (>3 PE):
recoil energy > 3.5 keV
Typical S2 (>150 PE) :
recoil energy > 0.7 keV (NR)
> 0.186 keV (ER)

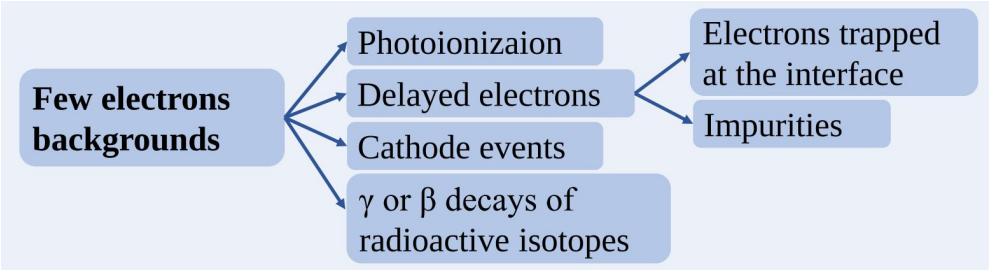
⇒ S2-only lowers the detectable energy threshold for 'light' dark matter





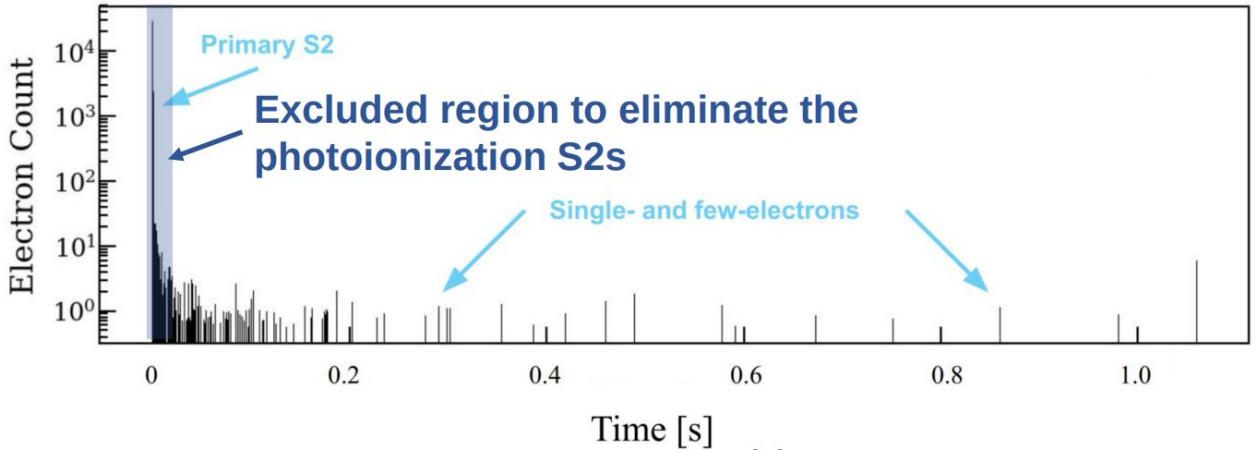


Background analysis of XENON1T



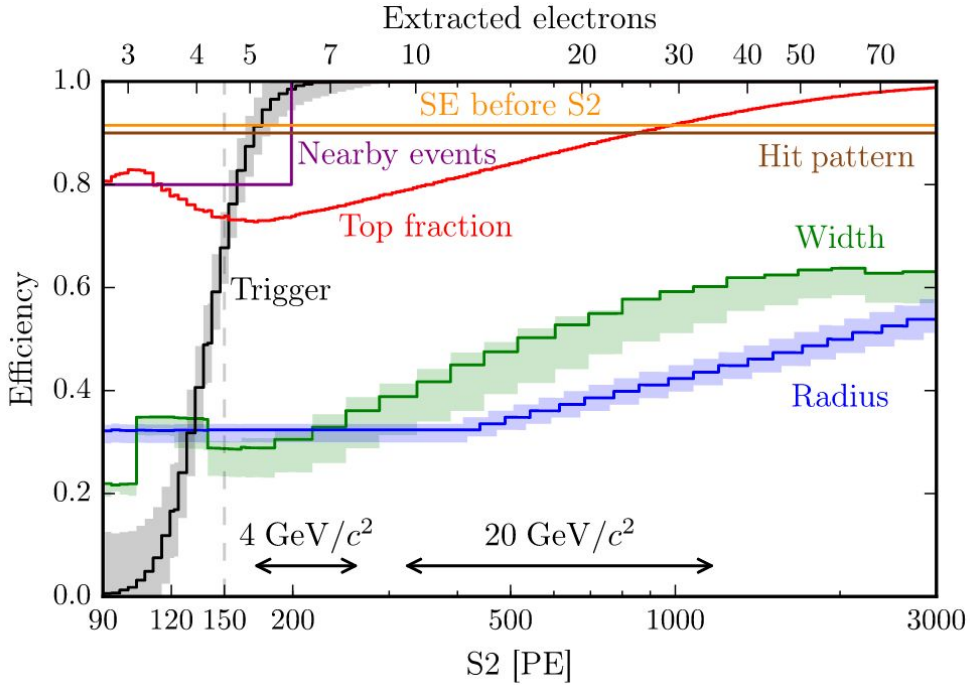
Photoionization electrons:

- induced by photons of S1 ou S2
- within maximum drift time



Background analysis of XENON1T

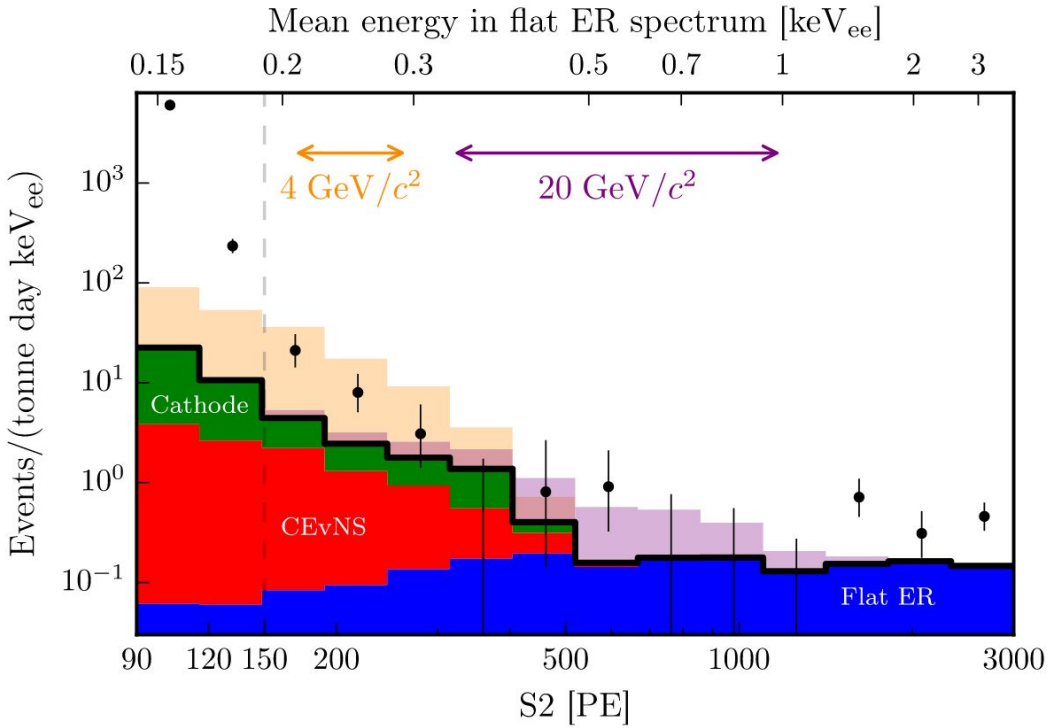
1. **Data selection:**
   - Eliminate unphysical events such as gas events, surface events, pileup of single electrons…



Background analysis of XENON1T

2. Indentifying background:

- Due to lack of S1 information, we can not identify all backgrounds but set an upper limit

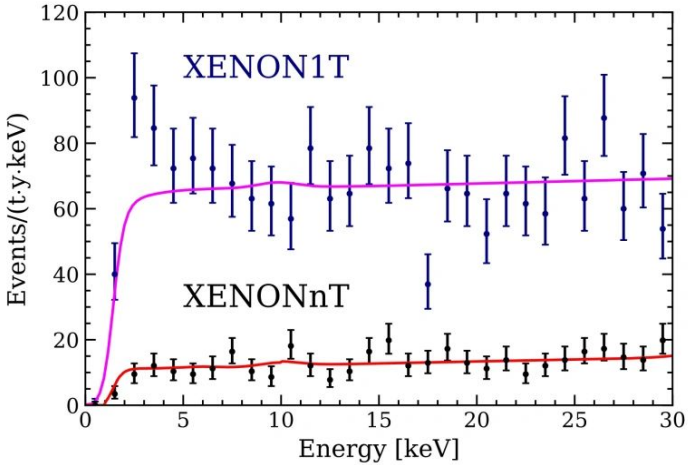


Improvement of XENONnT

1. Reduction of ER background:

Major background: β emitter ^{214}Pb, a daughter of ^{222}Rn

Rn distillation column
+ Liquid Xe purification system
⇒Reduction of ER background by a factor of ~6



2. Increasing xenon target:

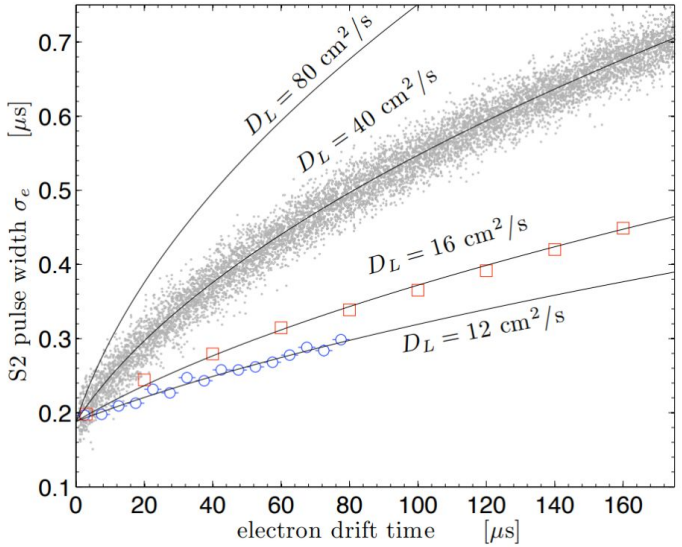
	XENON1T	XENONnT
Period	2012-2019	2020-2026
Xe mass	2 t Xe target	5.9 t active Xe
Electron lifetime	~0.5 ms	~10 ms
Sensitivity	4.1×10^{-47} cm^2	2.6×10^{-48} cm^2

Ongoing analysis of XENONnT

1. S2 width cut:

⇒ reject the events with nonphysical drift time

- General: diffusion model
- S2-only scale: first principles



2. Peak classification algorithm

XENON1T: “Primary S2s” and “delayed electrons”

⇒ identify more categories such as “multiple scatters”, “photoionization”

⇒ correctly pair primary S2s with their delayed electrons peaks and to register other peaks

Conclusions & perspectives

XENON

In conclusion:

- S2-only analysis opens up the possibility of exploring 'light' dark matter particles
- Reduction of ER background and greater active xenon mass in XENONnT

⇒ more stringent limits on 'light' dark matter set by S2-only analysis

Future works:

- Further study on S2 width cut in low energy region
- Characterization of different populations classified by new peak classification algorithm

Thank you for your attention!

References:

[1] XENON Collaboration, Emission of single and few electrons in XENON1T and limits on light dark matter. Physical Review D, 2022, 106(2): 022001.

[2] XENON Collaboration, Light Dark Matter Search with Ionization Signals in XENON1T. Physical Review Letters, 2019, 123(25): 251801.

[3] XENON Collaboration, Search for New Physics in Electronic Recoil Data from XENONnT. arXiv, 2022[2022-10-18].

[4] SORENSEN P. Anisotropic diffusion of electrons in liquid xenon with application to improving the sensitivity of direct dark matter searches. Nucl. Instrum. Methods Phys. Res. A: Accel. Spectrom. Detect. Assoc. Equip., 2011, 635(1): 41-43.