A SNEAK PEEK AT XENONnT IONIZATION-ONLY ANALYSIS

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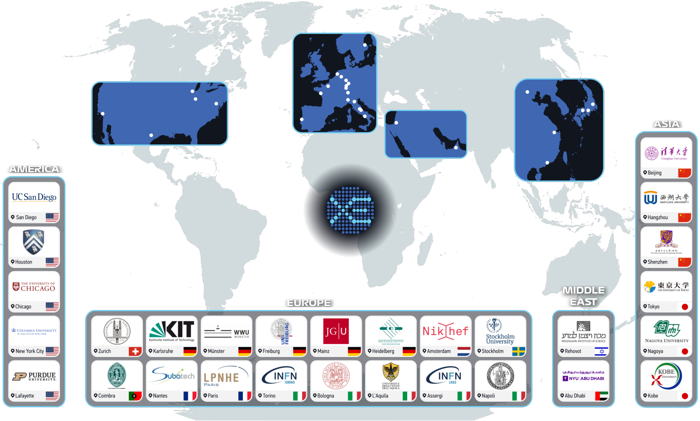
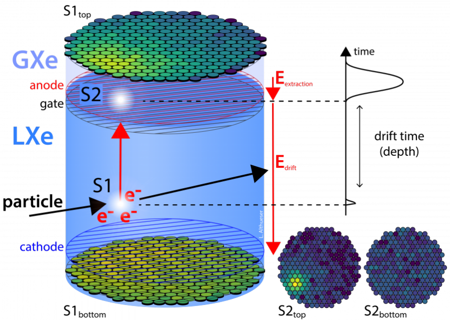


◇ 29 institutions worldwide

◇ ∼200 members

Liquid Xenon TPC Working Principle



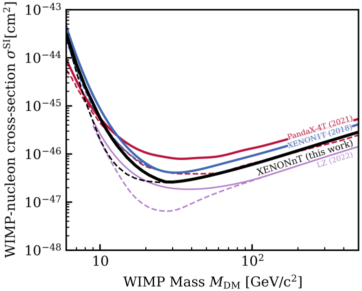
$w = 13.7\ eV/$quanta

g_1/g_2: Photoelectron (PE) per quanta (γ/e^-)

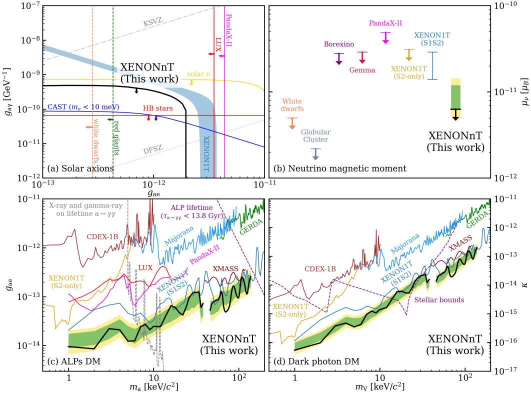
- ◇ Signals
  - ⋆ Primary scintillation signal (S1)
  - ⋆ Secondary scintillation signal (S2)
- ◇ Interaction Reconstruction
  - ⋆ S2 hit pattern → Interaction (x, y)
  - ⋆ S1-S2 arrival time difference → Interaction z
  - ⋆ Energy Reconstruction $E = w\left(\frac{cS1}{g_1} + \frac{cS2}{g_2}\right)$
- ◇ Particle Discrimination
  - ⋆ Electronic Recoil (β, γ, light DM, etc.)
  - ⋆ Nuclear Recoil (neutron, WIMP-like, CEνNS)

XENONnT Scientific Results

[Phys. Rev. Lett. 131, 041003 (2023)]



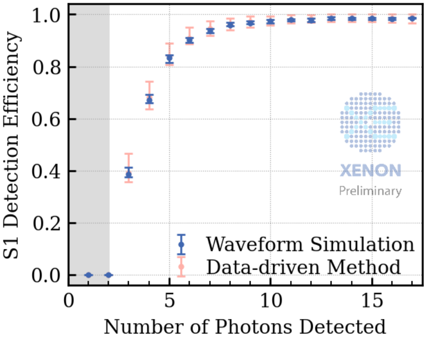
[Phys. Rev. Lett. 129, 161805 (2022)]

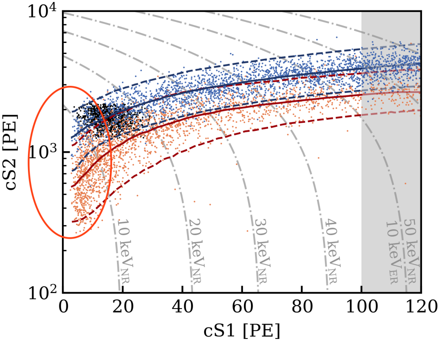


- ◇ Blind search
- ◇ Low energy threshold ($\sim 1\ keV$ ER and $\sim 3.3\ keV$ NR)
- ◇ Robust background model
- ◇ No significant signal-like excess

The S1 yield (~ 10 PE$/keV$, measured with 5.5 MeV α from ^{222}Rn) is much smaller than the S2 yield (~ 250 PE$/keV$)

$\rightarrow$ To probe lower energy, we are forced to rely on only S2s





Traditional S2-only Analysis

- ◇ Target S2 range: $5\ e^{-}$ to $\sim 100\ e^{-}$
- ◇ Sensitive to DM candidates interacting both via NR or ER

[Phys. Rev. Lett. 123, 251801 (2019)]

$\Downarrow$

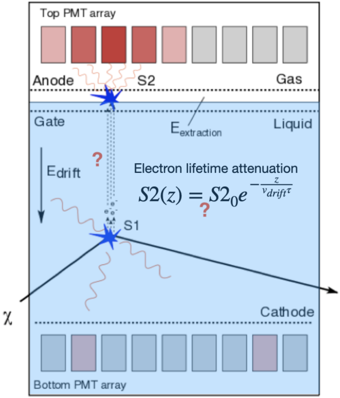
Few Electron Analysis

- ◇ Target S2 range: $1\ e^{-}$ to $5\ e^{-}$
- ◇ Sensitive to DM candidates interacting via ER (due to uncertainty in quenching factor at lowest energies for NR)

[Phys. Rev. D 106, 022001]

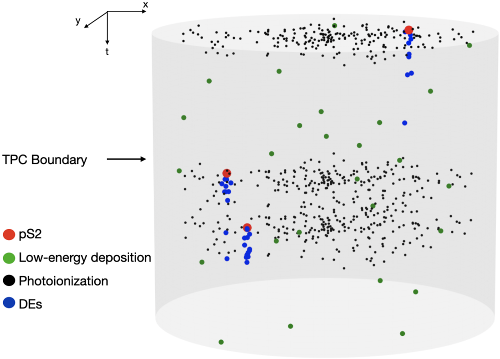
- ⋆ I will only introduce the methodology today, with some preliminary XENONnT results

- Energy depositions below S1 detection threshold (S2-only)
  1. Radioactive contaminants
  2. (Solar) Neutrino
  3. **Light DM/other BSM**
- Instrumental Backgrounds
  1. Spurious emission of single/few electrons from electrodes
  2. **Delayed electrons (DEs) following large (primary) S2s (pS2s)**

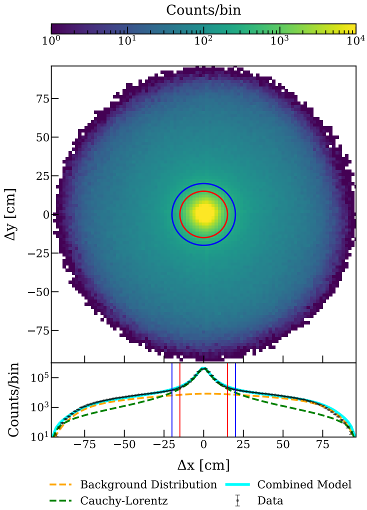


No S1→No z information

$z \rightarrow$ Delay Time (from preceding pS2s)



Published 1T result

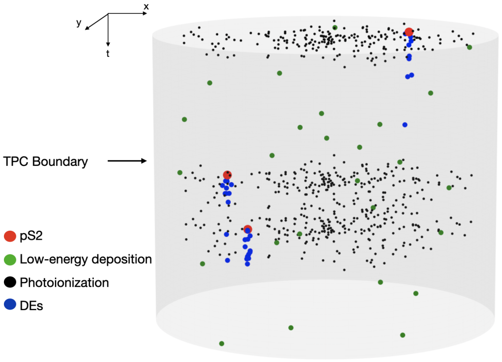


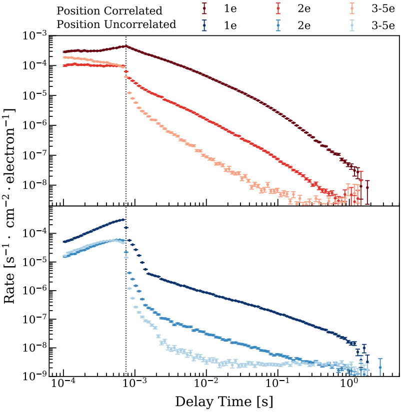
[Phys. Rev. D 106, 022001(2022)]

DEs: Time Correlation with pS2

Published 1T result

$z \to$ Delay Time (from preceding pS2s)

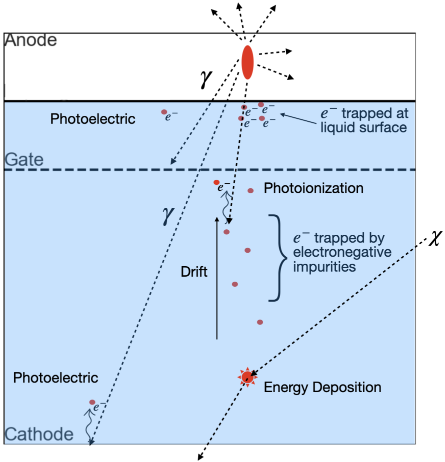




[Phys. Rev. D 106, 022001(2022)]

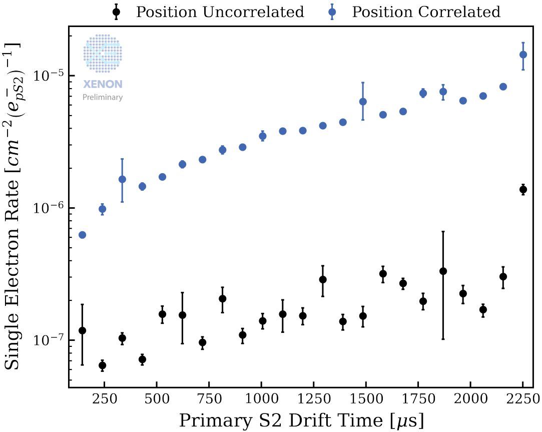
Hypotheses of the Delayed Electrons

1. Photoionization from pS2 photons
   - ⋆ Short time gap with their preceding pS2s (< 1 full drift time, $\sim 23\ \mu s$)
   - ⋆ Large photoionization can cause further photoionization iteratively
   - ⋆ Weak spatial and temporal correlation with their preceding pS2s
2. Slow extraction at the interface
   - ⋆ Long time gap with their preceding pS2s (up to seconds)
   - ⋆ Strong spatial and temporal correlation
3. (?) Trapped by electronegative impurities in liquid



Evidence of Trapping by Impurities

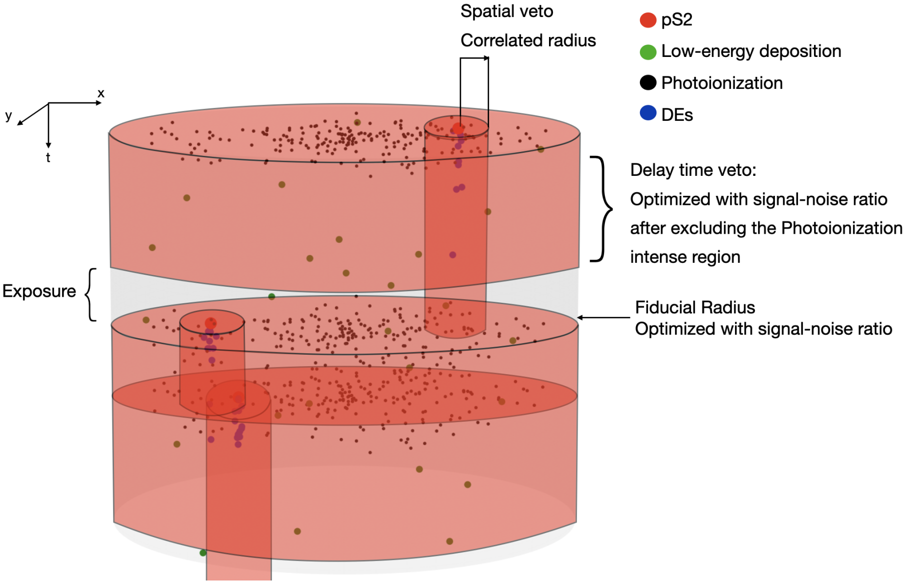
- A strong correlation between the rate of position-correlated single electron (SE) and the pS2 drift time was observed
- The rate of the position-uncorrelated SE is relatively constant with respect to the drift time of the preceding pS2s



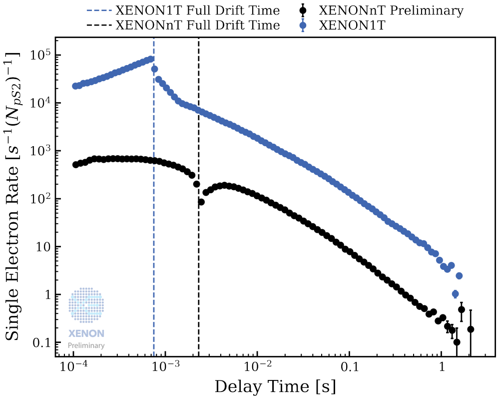
Longer drift time → higher chances to attach → higher DE rates observed

⇒**There is a significant in-liquid component, likely due to trapping**

S2-Only Analysis Veto Strategy



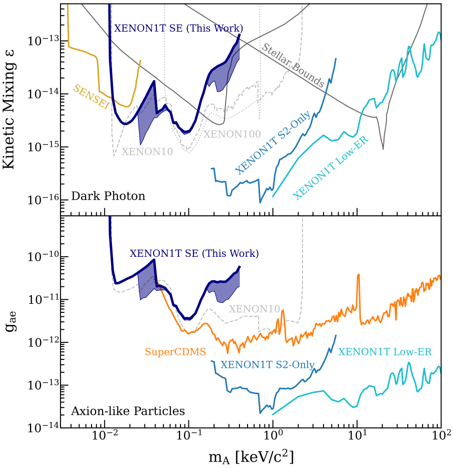
Single Electron Rate Comparison – nT vs 1T

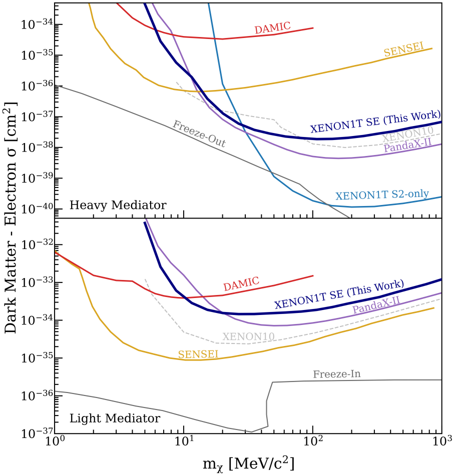


- ◇ Better purity (electron lifetime $> 15\ ms$)
  - → Less electronegative impurities
- ◇ less radioactive contaminants
  - → Lower pS2s rate
  - → Less low-energy physical depositions

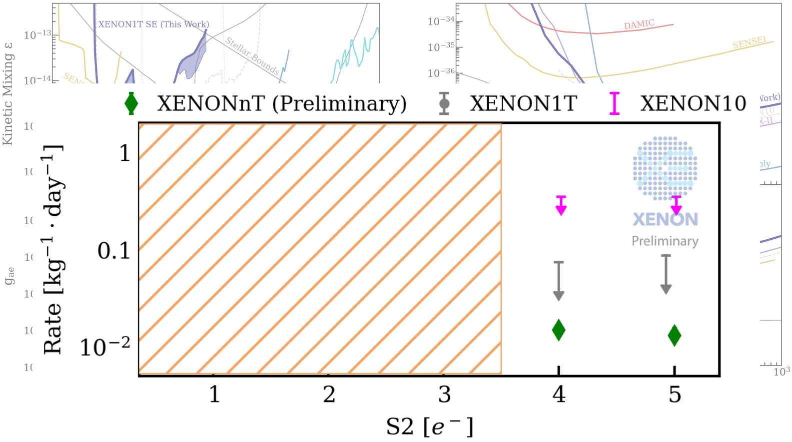
- ◇ ∼3× larger active target mass than 1T
- ◇ ∼10× overall lower DE rate compared to 1T
- ◇ ∼30× more calibration data and ∼20× larger exposure compared to 1T

XENON1T Results





XENONnT Results Preliminary



- ◇ Rates were calculated from a getter-bypassed calibration period after the SR0 scientific run ($\sim 1/7$ exposure)
- ◇ The physics runs are still blinded

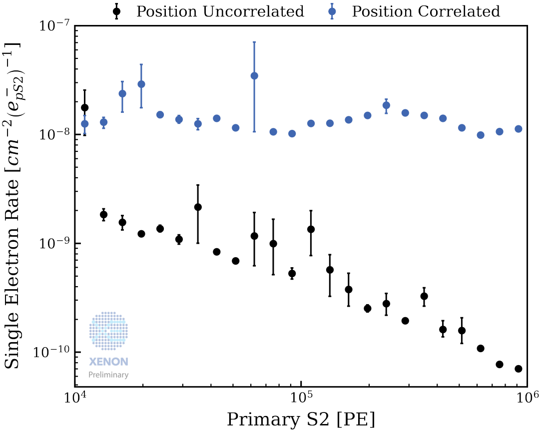
Thanks!

Backup Slides

Single Electron Rate Dependences in XENONnT

◇ pS2 size

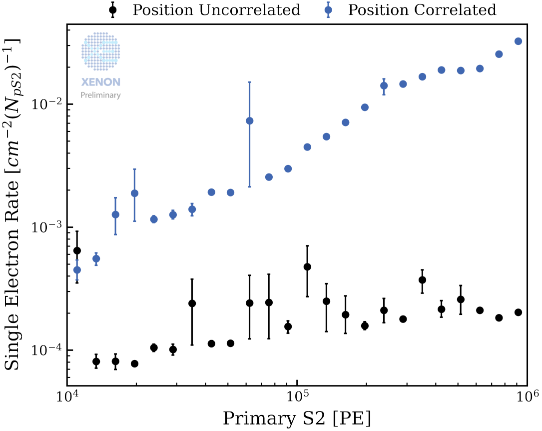
1. On average, a constant fraction of electrons from the pS2 electron cloud is trapped in liquid throughout the drift region ($\sim 10^{-8} cm^{-2}$).
2. On the contrary, the position-uncorrelated SE rate is independent of pS2s and thus has a dropping trend as the size of pS2s increases



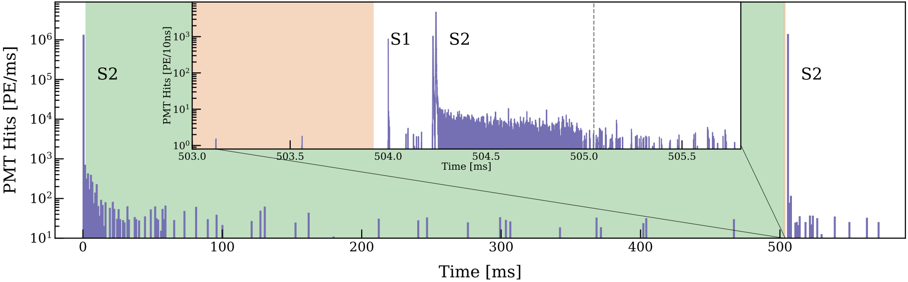
Only $1e^{-}$ DEs plotted

◇ pS2 size

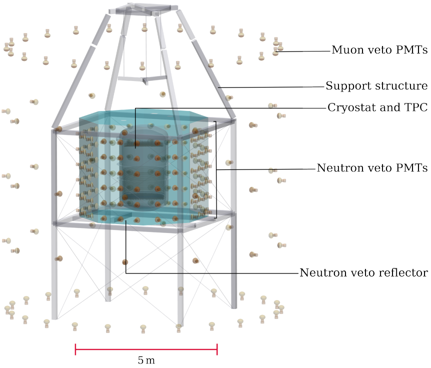
1. On average, each e^- in the pS2 deposits a constant amount of position-correlated DE SEs ($\sim 10^{-8} cm^{-2}$). Such a rate is independent of the size of the pS2
2. On the contrary, the position-uncorrelated DE SEs are constant per pS2, disregarding the size of the preceding pS2s



Only $1e^-$ DEs plotted



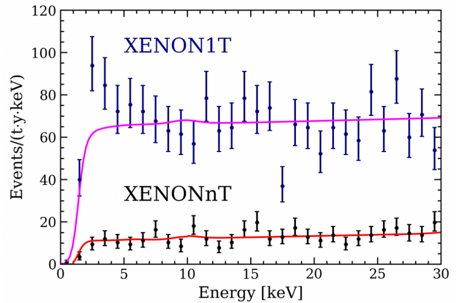
A sample of DE train after a large S2. The photoionization-cluster within 1 full drift time of the large S2 is shown in the zoomed-in picture.



- Muon veto (nT updates)
  - Water Cherenkov neutron veto
- Neutron veto (inherited from 1T)
  - Gadolinium-doped water detector

$\sim 7\times$ lower background rate than 1T

- Material Screening
- Radon and Krypton distillation columns
- Gas and liquid xenon Recirculation Systems
- Muon/Neutron Veto tagging
- Xenon self-shielding

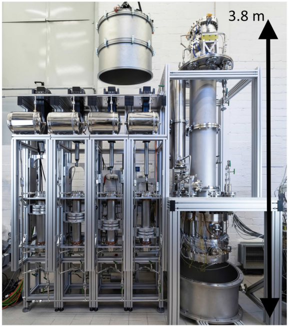


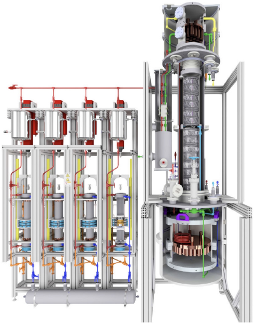
[Eur. Phys. J. C 77, 275 (2017)]
[Eur. Phys. J. C 82, 599 (2022)]
[Eur. Phys. J. C 82, 860 (2022)]
[Eur. Phys. J. C 82, 1104 (2022)]

[Phys. Rev. Lett. 129, 161805]
[Phys. Rev. D 102, 072004]

XENON Purification System - Radon Column

[Eur. Phys. J. C (2022) 82:1104(2022)]





^{222}Rn is trapped in LXe at the bottom of the column and decays away while LXe is reboiled and circulated through the rest of the purification system – lossless

- Targeting ^{222}Rn (daughter isotope ^{214}Pb is a dominant background)
- Lowest ^{222}Rn background ever: $< 1\mu Bq/kg$ (SR1, liquid+gas mode), $1.8\mu Bq/kg$ (SR0, gas mode)

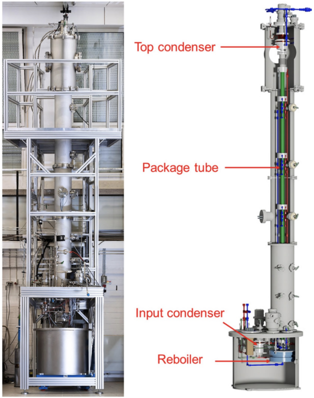
XENON Purification System - LXe Purification

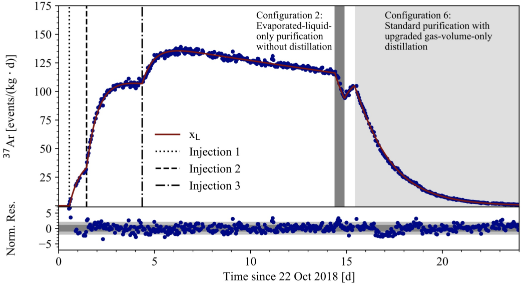
[Eur. Phys. J. C 82, 860 (2022)]

- Targeting electronegative impurities
- Boosted electron lifetime to greater than $10ms$ for XENONnT (8.6 ton)

XENON Purification System - Kryton Column

[Eur. Phys. J. C 77, 275 (2017)]
[Prog. Theor. Exp. Phys. 2022 053H01]





- ◇ Removes successfully Kryton (down to $360ppb$) and Argon impurities
- ◇ Allows ^{37}Ar as a calibration source