Physics Modeling of Xenon and Argon detectors with the Noble Element Simulation Technique (NEST)

Kirsten McMichael
PhD Student, Rensselaer Polytechnic Institute
On behalf of the NEST Collaboration

September 15, 2021

What is NEST?

- C++ package with Python equivalent (nestpy)
- Optional GEANT4 and ROOT integration
- Simulates the scintillation, ionization, and electroluminescence processes in xenon and argon
- Github: https://github.com/NESTCollaboration
- Collaboration Website: http://nest.physics.ucdavis.edu/

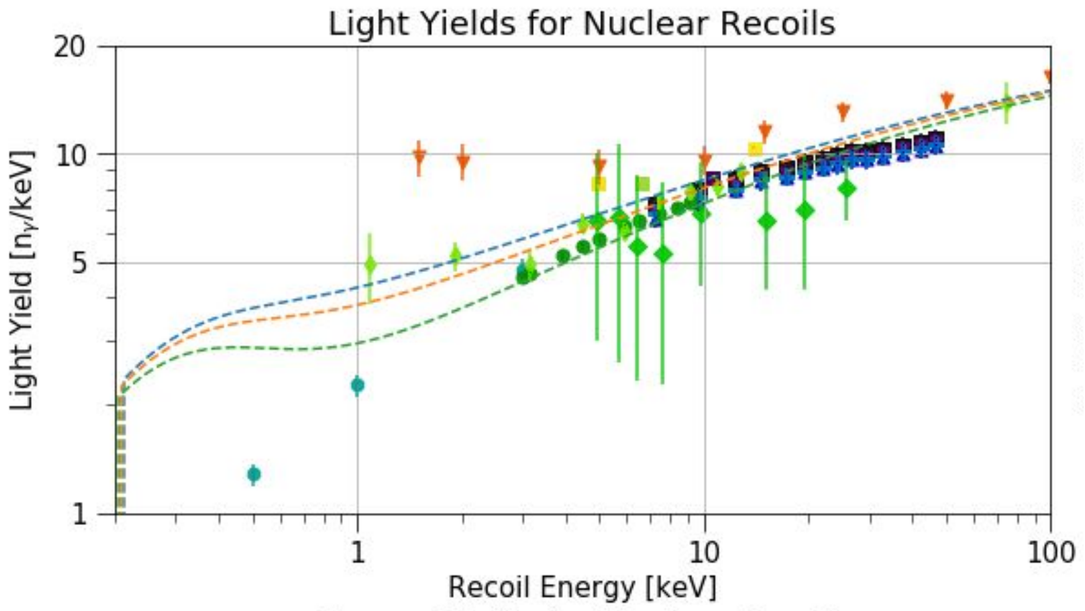
Who's Involved?

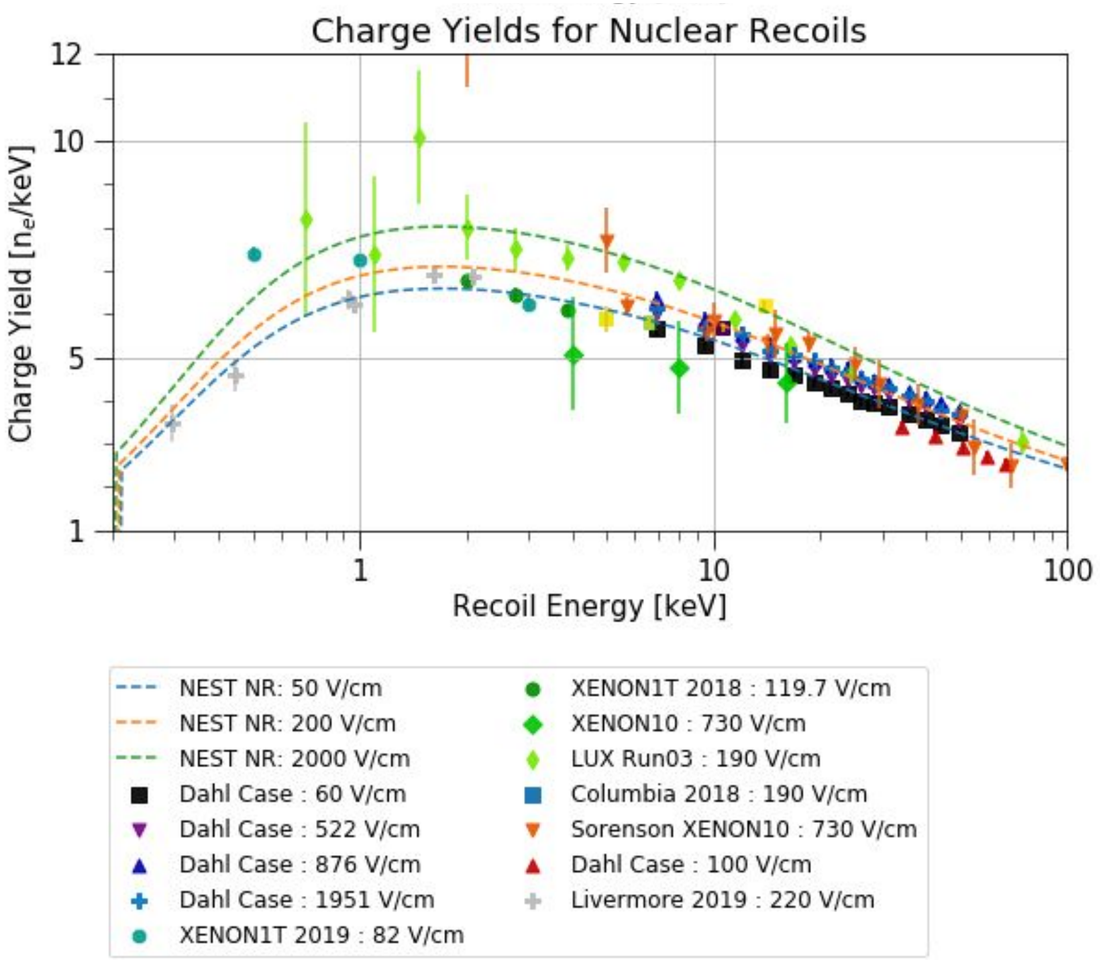
Features of NEST

- Models use a combination of empirical and first principle methods
- Customizable and fast
- Models for various types of energy deposits including: electronic recoils, nuclear recoils, alphas, etc.
- Calculates average light yield, charge yield, and recombination
- Simulates actual energy deposits in a detector

Nuclear Recoils - Xenon

Key Features: Models the light and charge signals, as well as the amount of energy lost to heat



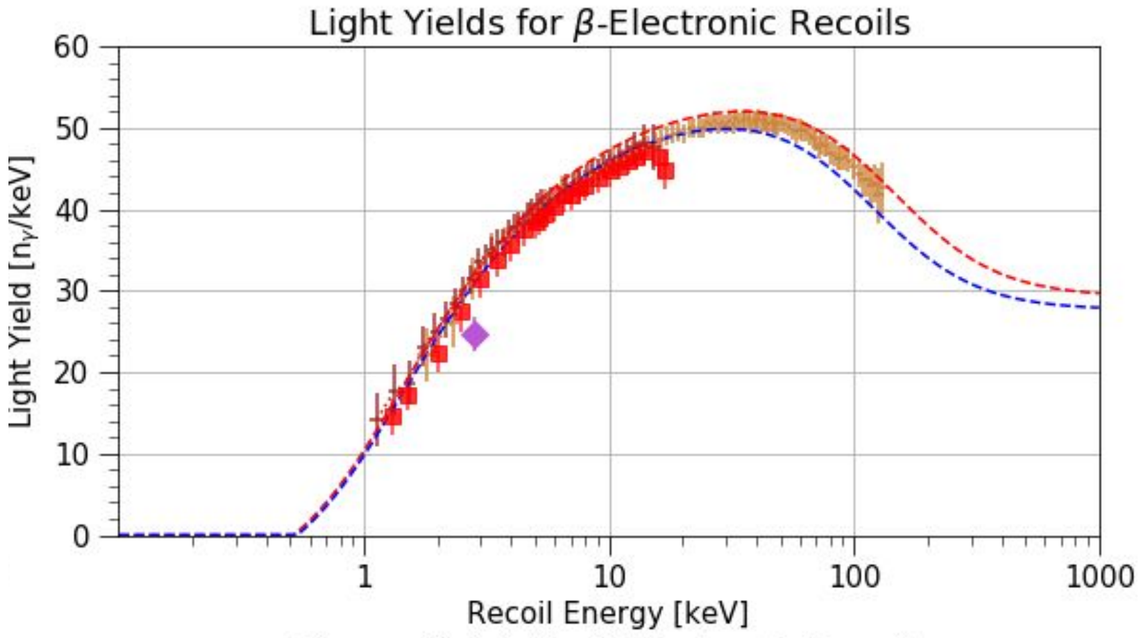


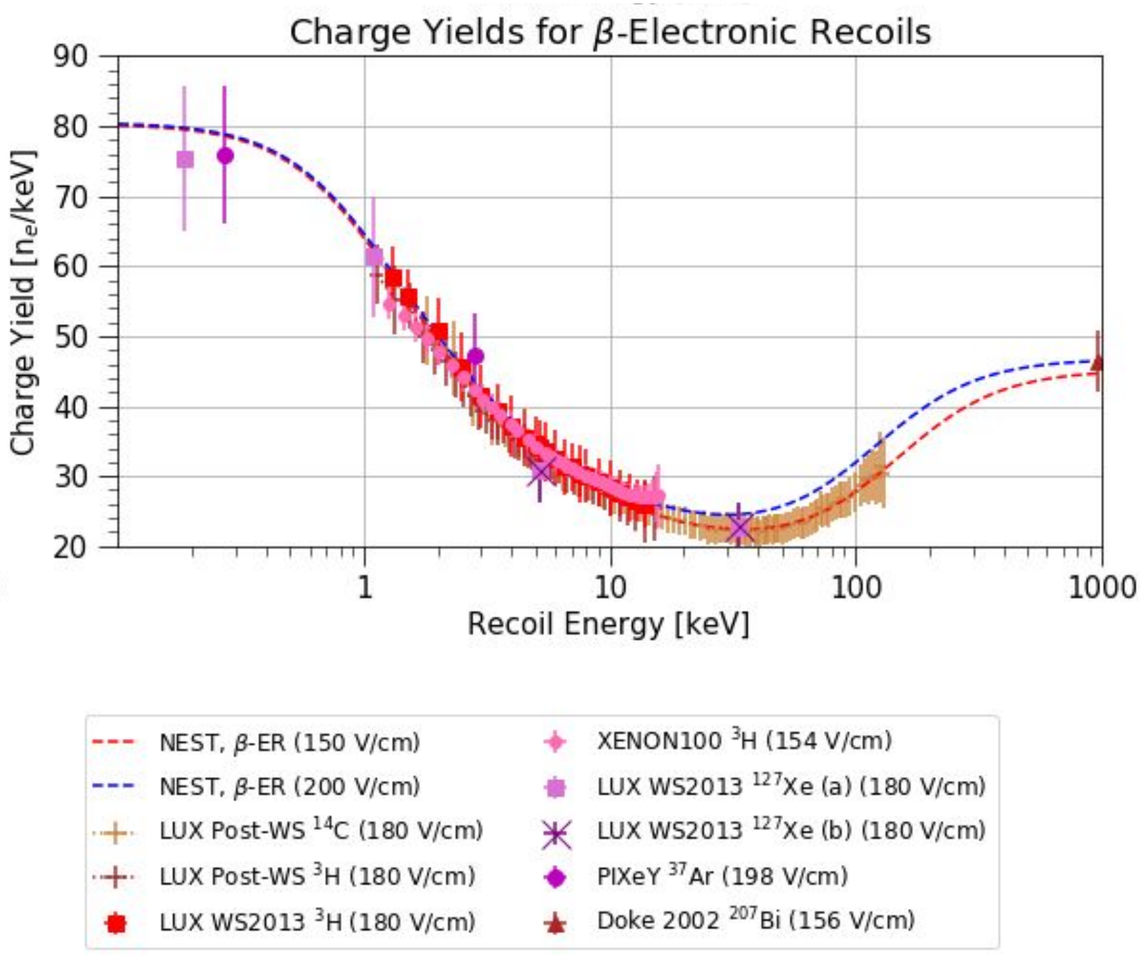
Electronic Recoils - Xenon

Key Features: NEST offers beta and gamma models that fit to data from sub-keV to MeV energies

The shape “wiggles” as it passes through Thomas-Imel box and Doke/Birks regimes

*Shown is beta model for (150 and 200 V/cm)

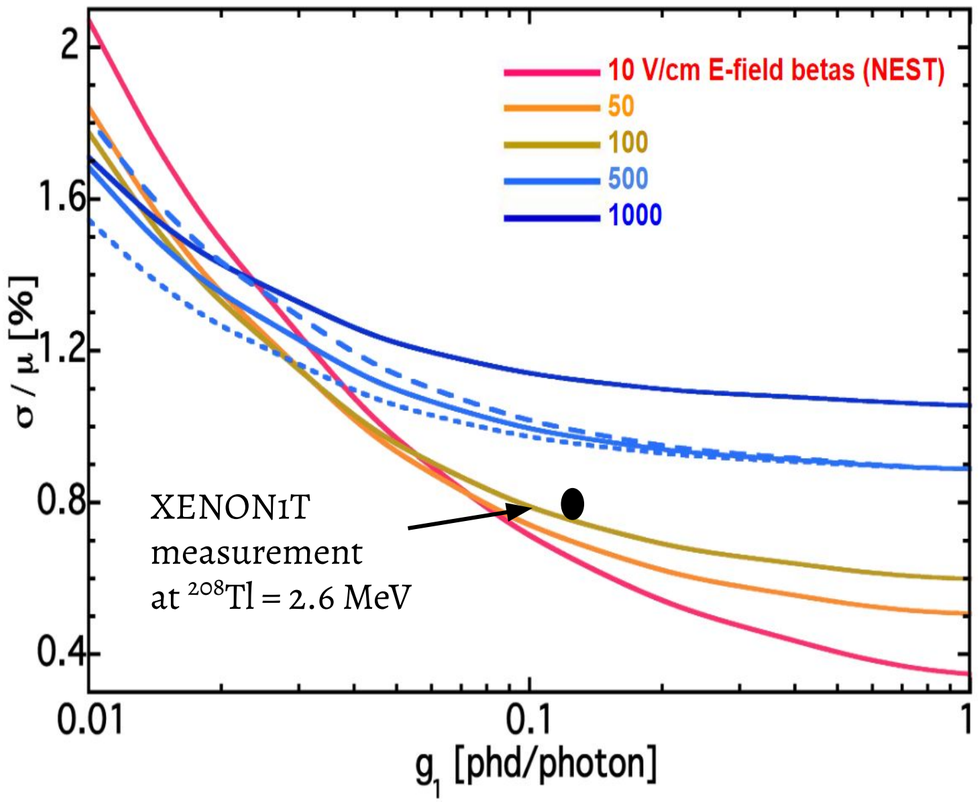




Energy Resolution - Xenon

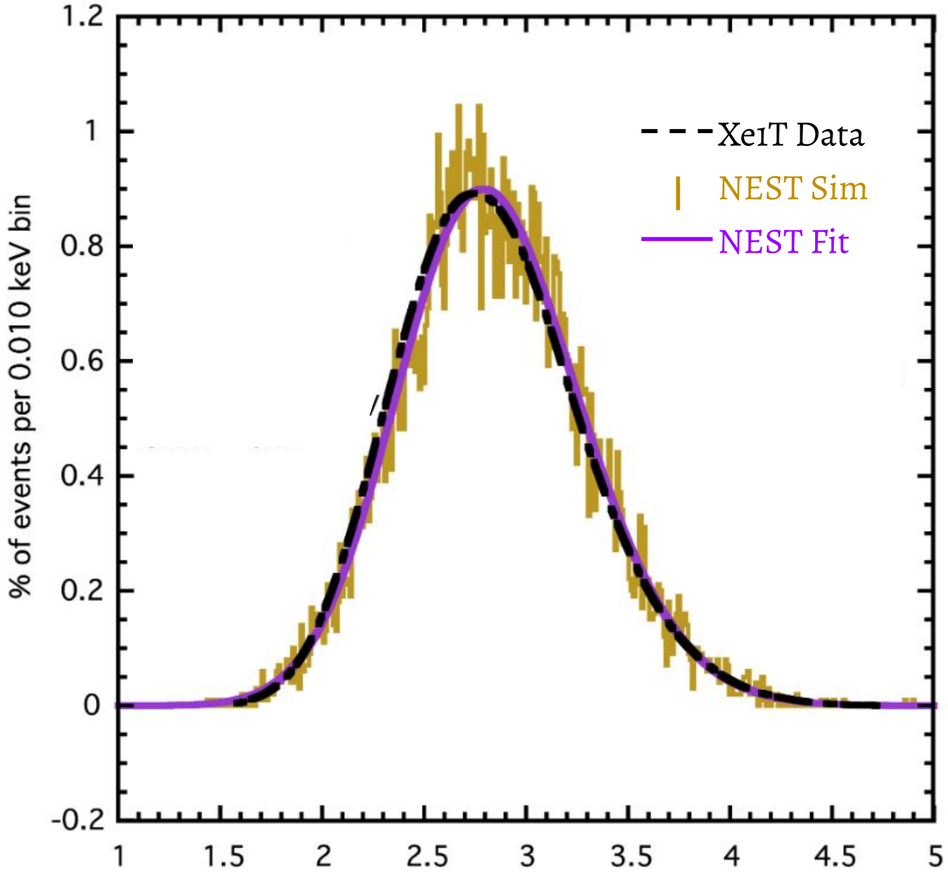
- Excellent agreement w/ Xe1T at high and low energies
- Skewness is also accounted for in NEST (PhysRevD.102.112002)

High Energy: $Q_{\beta\beta}$ = 2.5 MeV



arXiv:2102.10209
(Comprehensive analysis on energy reconstruction)

Low Energy: ^{37}Ar Peak



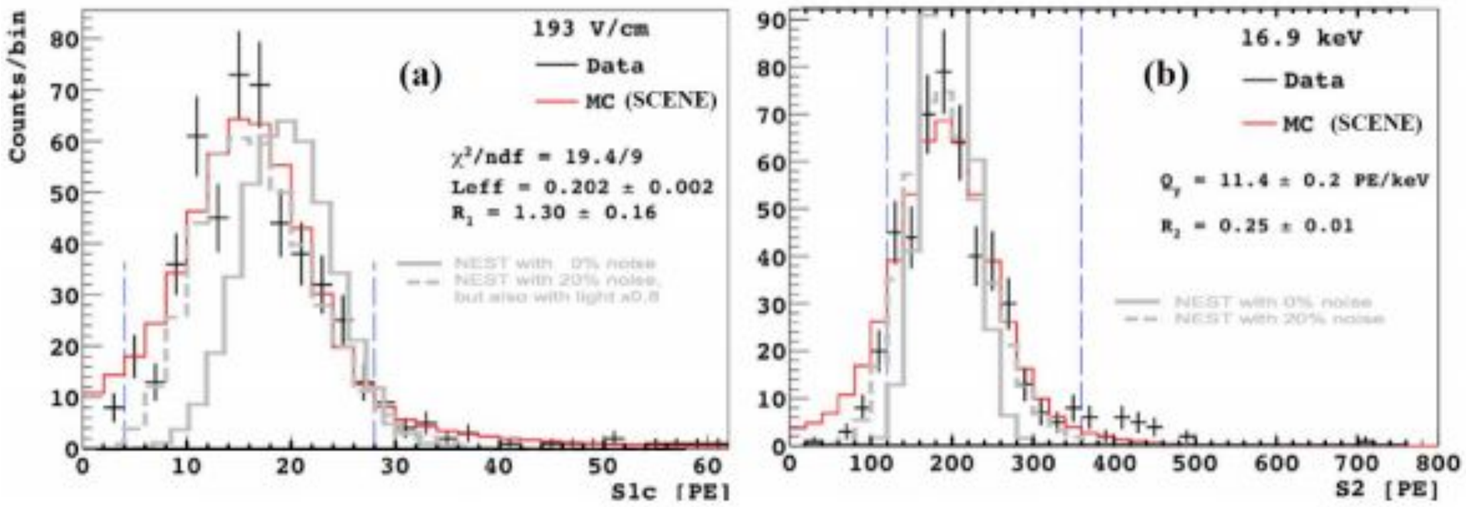
arxiv:2007.00528

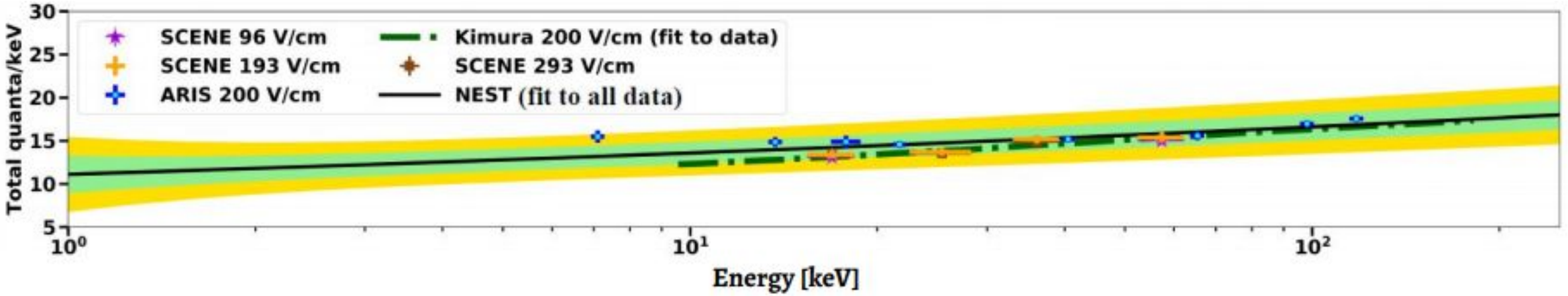
Nuclear Recoils - Argon

arXiv:2102.10209

Now fully implemented in main NEST code

Built using data from SCENE, ARIS, DS-50, Joshi, Aprile, Lippincott, Kimura, Doke, etc.

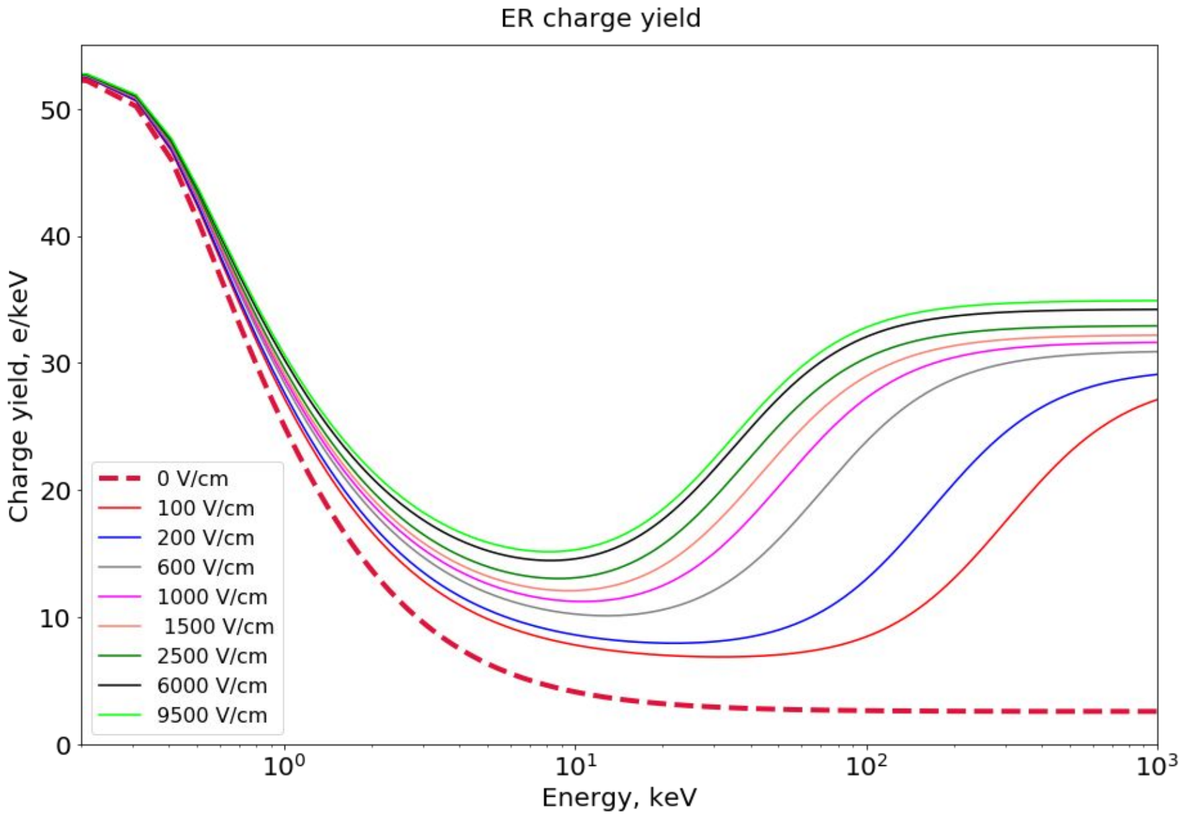


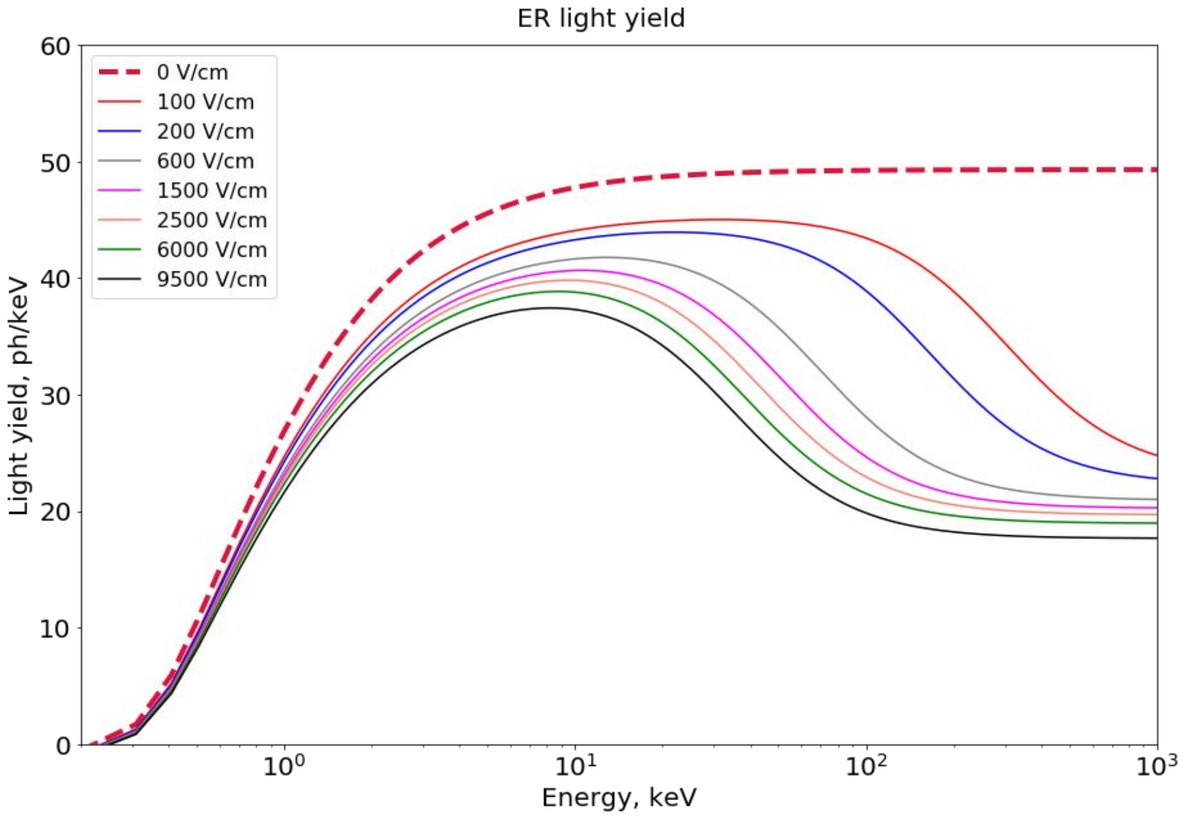


Electronic Recoils - Argon

ER-Ar now published in NEST code based on world data

Model is still being finalized with hopes of a final, stable, “Birks-like” model for both high and low energies





W-Value Discrepancy w/ EXO-200

- In 2020, EXO-200 reported a discrepancy between their W-value and the NEST value (arXiv:1908.04128v2).
- EXO-200 W-value: 11.5eV
- NEST W-value in 2020: 13.7eV
- We are currently looking into IR photons as a potential culprit
- The initial fix - Introducing the RmQuanta flag
- Current status - Determining field dependence to match EXO-200 LY

Conclusion and Future Work

- NEST models the intrinsic physics of noble detectors while maintaining a format that is accessible and customizable for users
- Recent and upcoming changes
  - Improvements to LAr ER model
  - Improvements to LXe ER model
  - Gamma calibrations
  - W-value agreement with EXO-200 results
  - Noise

Backup Slides

^{83m}Kr in Xenon

- Two-step conversion electron process, depositing 32.1 and 9.4 keV. The second deposition depends on the time between the decays, exponentially distributed with $t_{1/2}$ = 150 ns.
- Common calibration source in xenon detectors
- Model compares well to data from PIXeY, Xurich, LUX, PANDA-X