Noble Element Simulation Technique:
Reaching a Global Consensus on Noble Detector Response

Sophia Andaloro
Rice University
For the NEST Collaboration

July 27th, 2020
Snowmass Instrumentation Frontier: Noble Elements

Noble Element Simulation Technique:
Reaching a Global Consensus on Noble Detector Response

Ar

- Dark Matter
- Short & long baseline ν
- Neutrino monitoring
- Solar ν
- Supernovae

Xe

- Dark Matter
- 0νββ
- Double-electron capture
- Nonproliferation
- Medical imaging
- Supernovae
- Solar ν

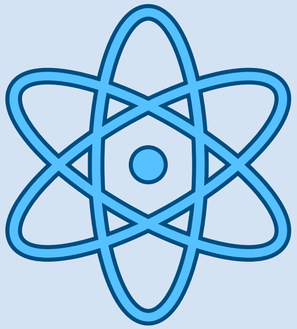
What is NEST?

Simulates response (yields) of n*oble elements* to various ***particle interactions***

Requires computation at the ***macroscopic + microscopic*** levels.

Electronic Recoils	***Nuclear Recoils***	***Other***
Photons (γ)	**Neutrons**	**Alphas (α)**
Leptons (β^- , μ^-)	**Heavy Nuclei**	**^{83m}Kr**
	WIMPs	**p, π**

Virtual Detector



The Macroscopic

- Nonuniformities
- Density, Temperature
- Drift field, mass

The Microscopic

- Particle types
- Recombination fluctuations
- Scintillation vs. ionization

What is NEST?

Simulates response (yields) of n*oble elements* to various ***particle interactions***

Requires computation at the ***macroscopic + microscopic*** levels.

Electronic Recoils

Photons (γ)

Leptons (β^- , μ^-)

Nuclear Recoils

Neutrons

Heavy Nuclei

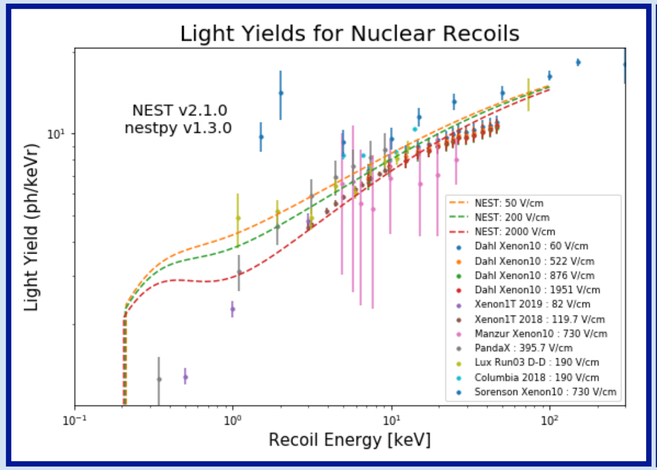
WIMPs

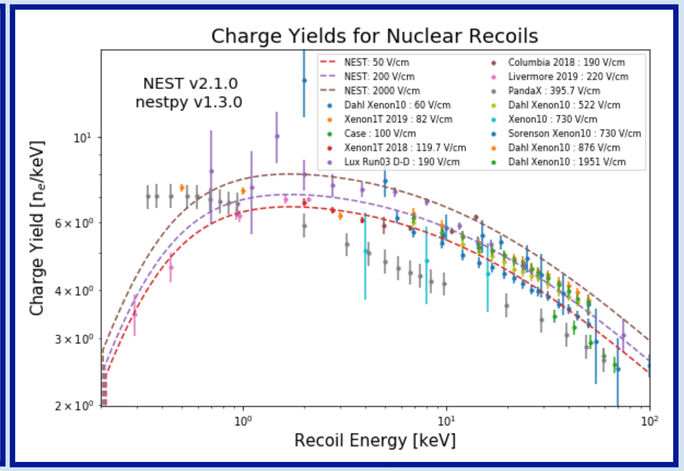
Other

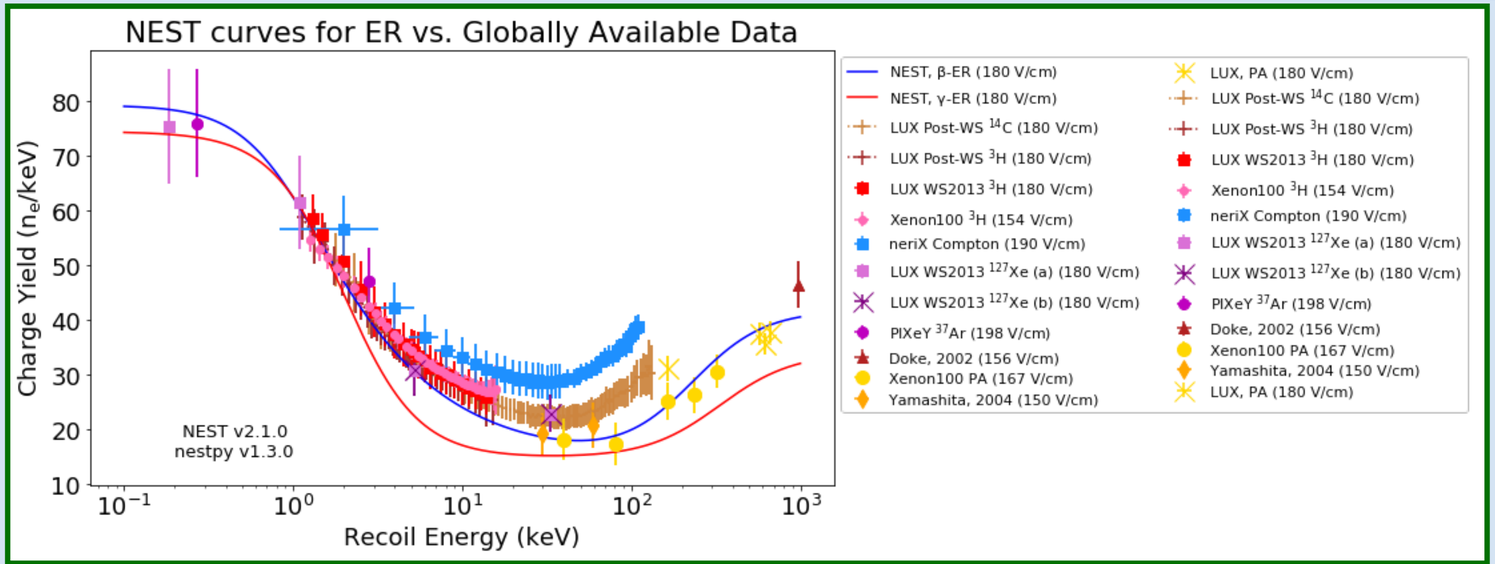
Alphas (α)

^{83m}Kr

p, π





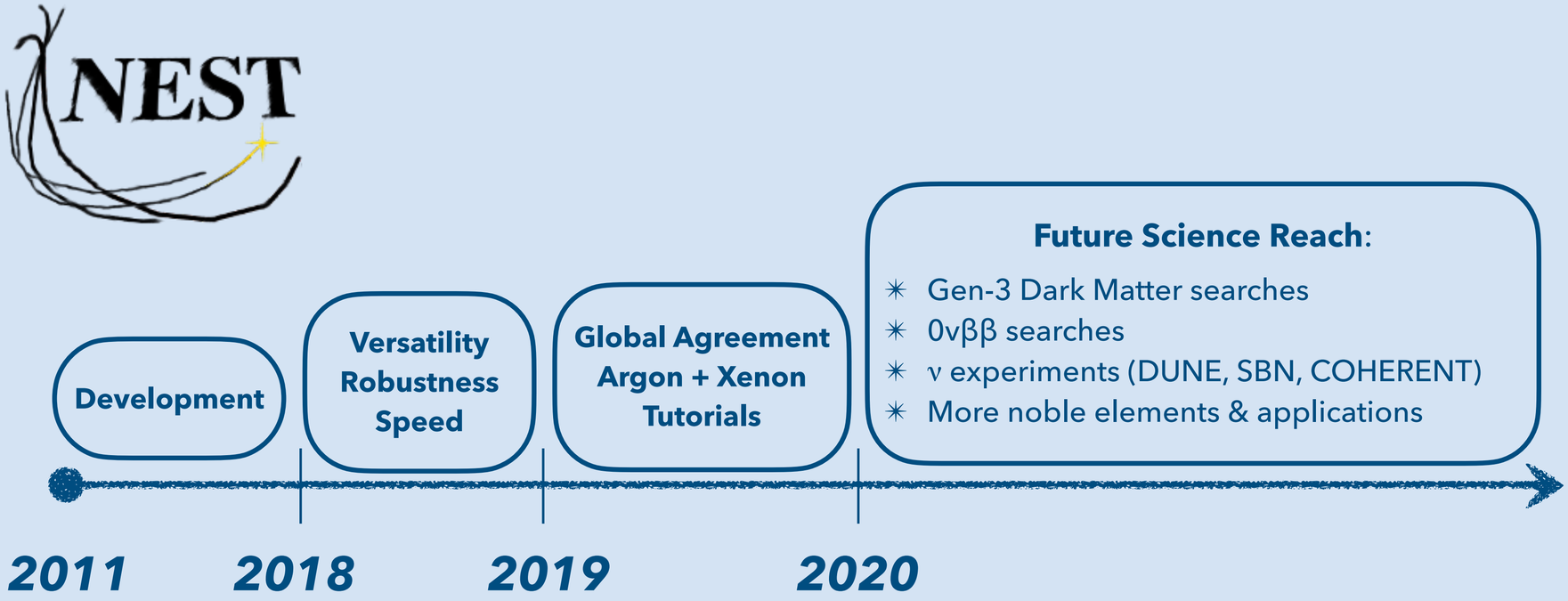


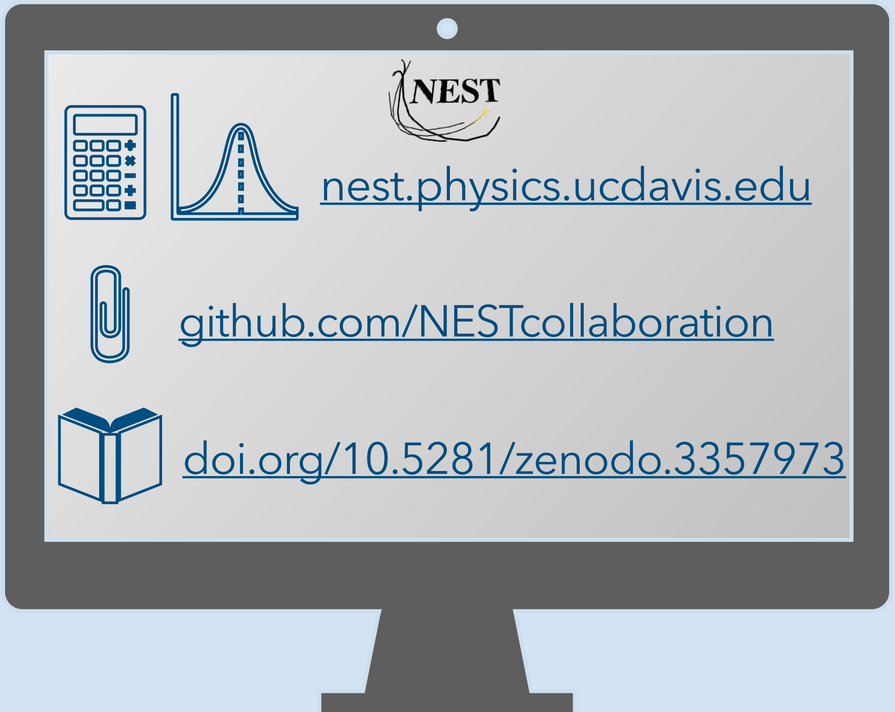
Where we stand

- C++, Python, G4, ROOT
- Open-source, actively maintained
- Calculate observables, fluctuations for LXe, LAr (with precision)

Where we're going

- Global constraints
- Expansion to more elements
- First-principle noble element atomic physics
- Broader applications





Backup

What is NEST?

Simulates the response of *Noble Elements* to various ***particle interactions*** →

Requires computation at the *macroscopic* + *microscopic* levels.

Used In:

- ✳ Setting limits
- ✳ Commissioning & monitoring
- ✳ Validation of findings

Electronic Recoils

Photons (γ)

β^- , μ^- (leptons)

Nuclear Recoils

Neutrons

Heavy Nuclei

WIMPs

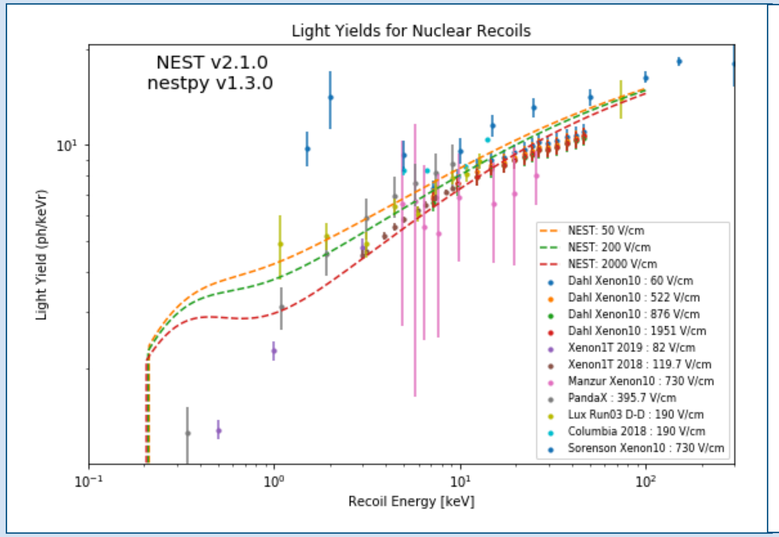
Other

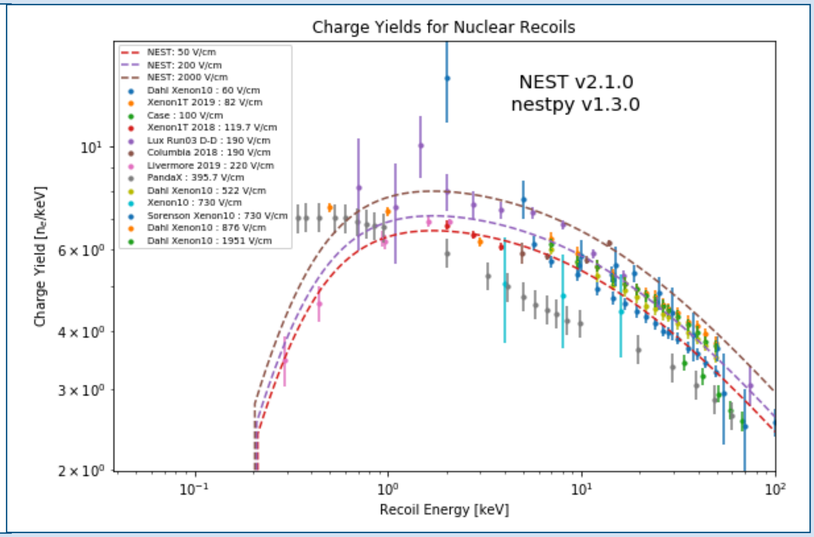
α (alphas)

^{83m}Kr

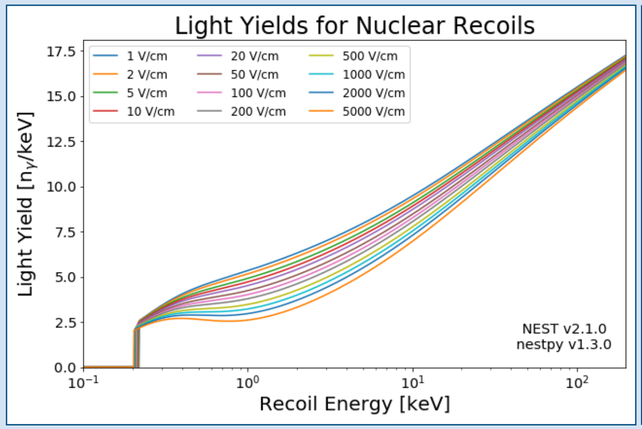
Protons

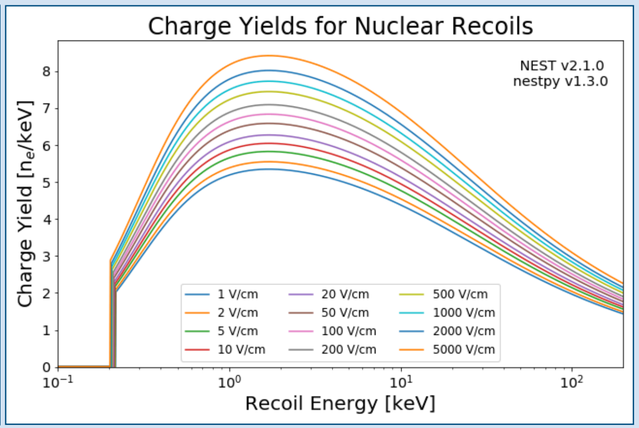
Fits





Extrapolations





What is NEST?

Simulates the response of *Noble Elements* to various *particle interactions*

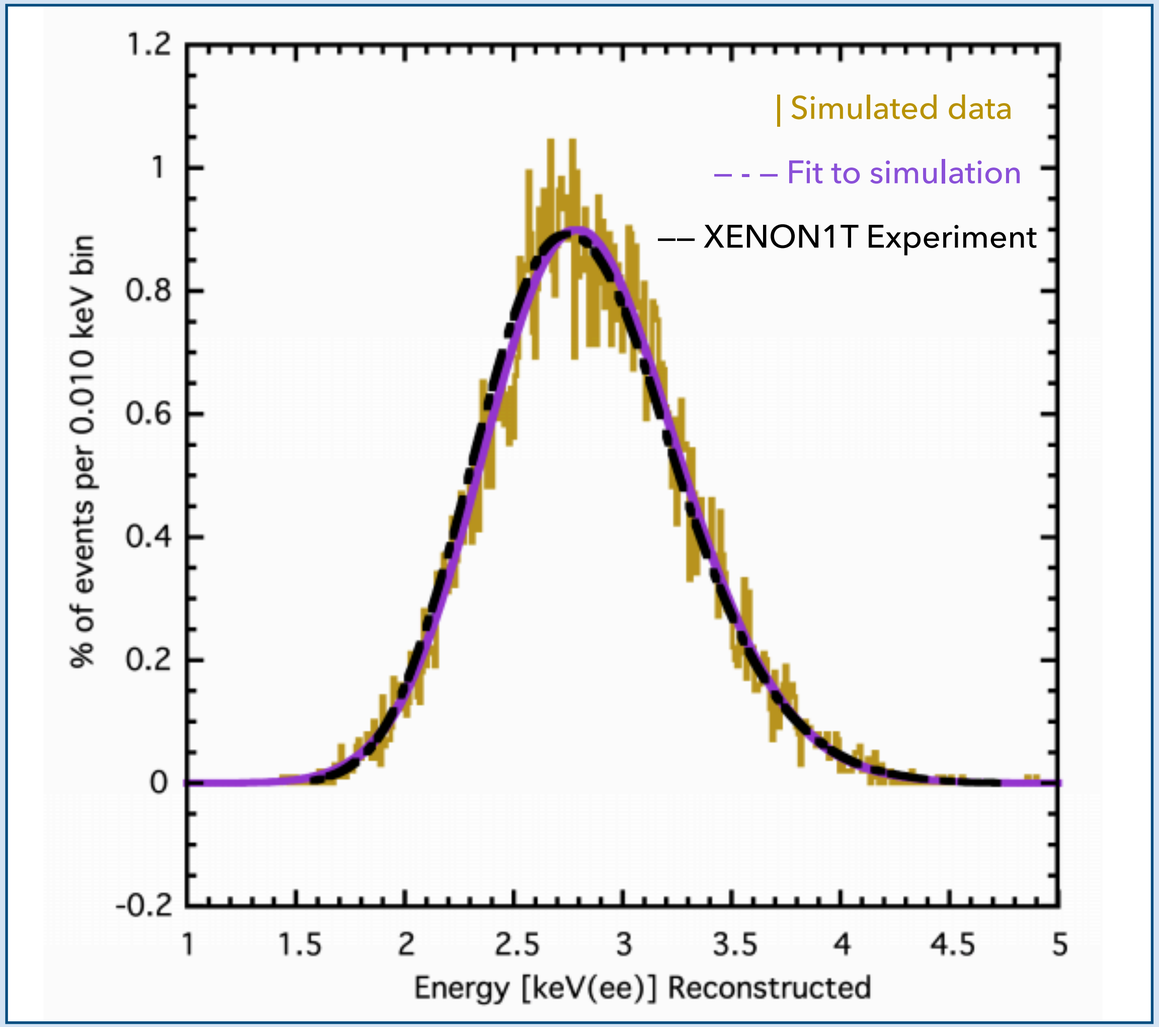
Requires computation at the *macroscopic* + *microscopic* levels.

Used In:

- ✳ Setting limits
- ✳ Commissioning & Monitoring
- ✳ **Validation of findings** →

Energy reconstruction: 37Ar calibration, XENON1T

– Accurate mean, skew, width –



2.8 keV ^{37}Ar peak reconstructed with NEST

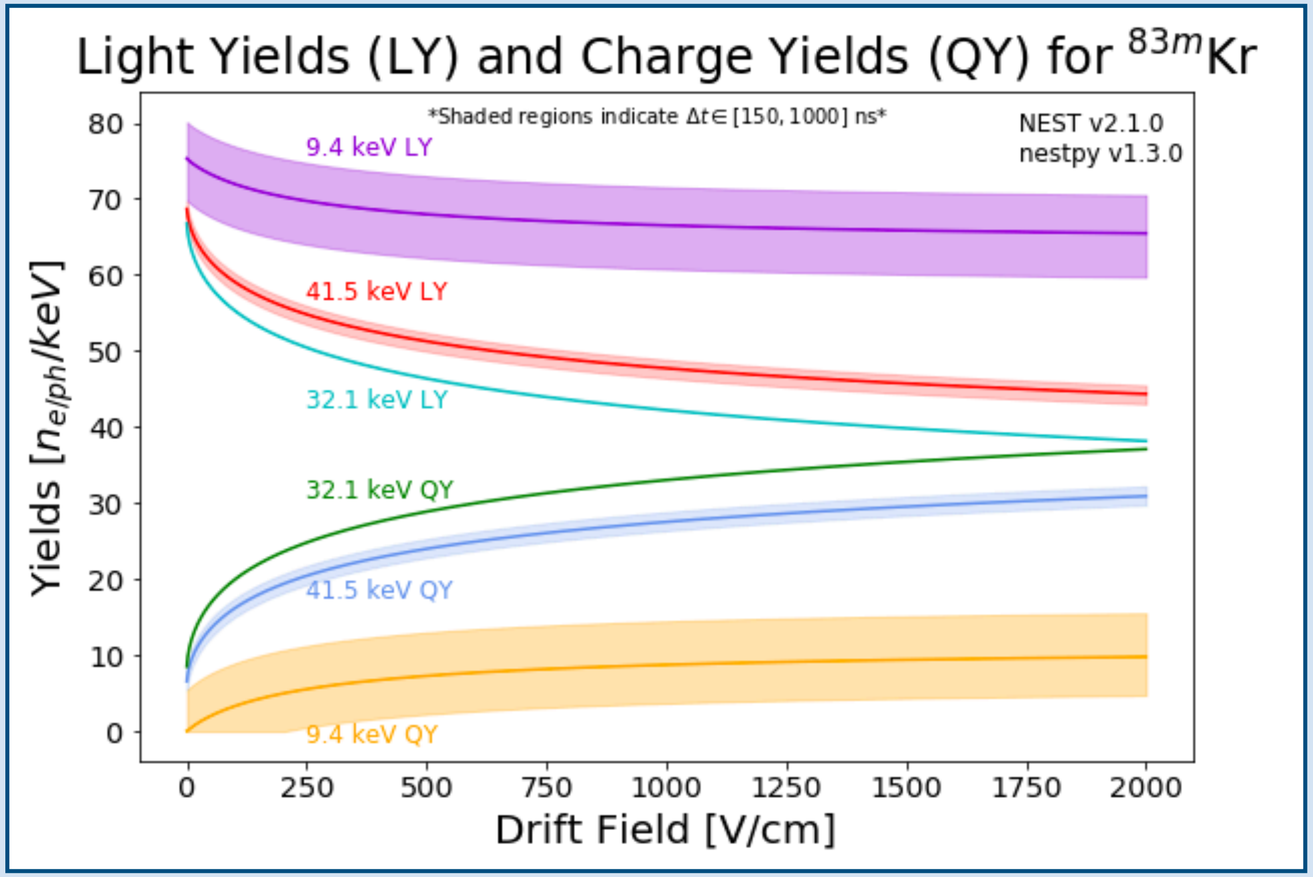
2006.09721 (XENON1T Ref.)

2007.00528 (Figure 8)

NEST v2.1.0

Some New Features:

- ✳ ^{83m}Kr model overhaul →
- ✳ **Time-dependent** variable options
- ✳ Macroscopic dependencies improved with nEXO data
- ✳ Heavy-ion interactions more theoretically robust
- ✳ ArNEST improved fits (**α** model)



ArNEST Model

PRELIMINARY

- Ultimately inferred via data for now, with priors on LXe
- Limited data, but we know scintillation (vs. ionization) grows with energy
- Quenching factors of light at ~1 kV/cm
- Theoretical justifications:
  - (ionization track density, fields in Ar can extract additional quanta, medium-high field "peak" in scintillation

Ekaterina Kozlova, Justin Mueller