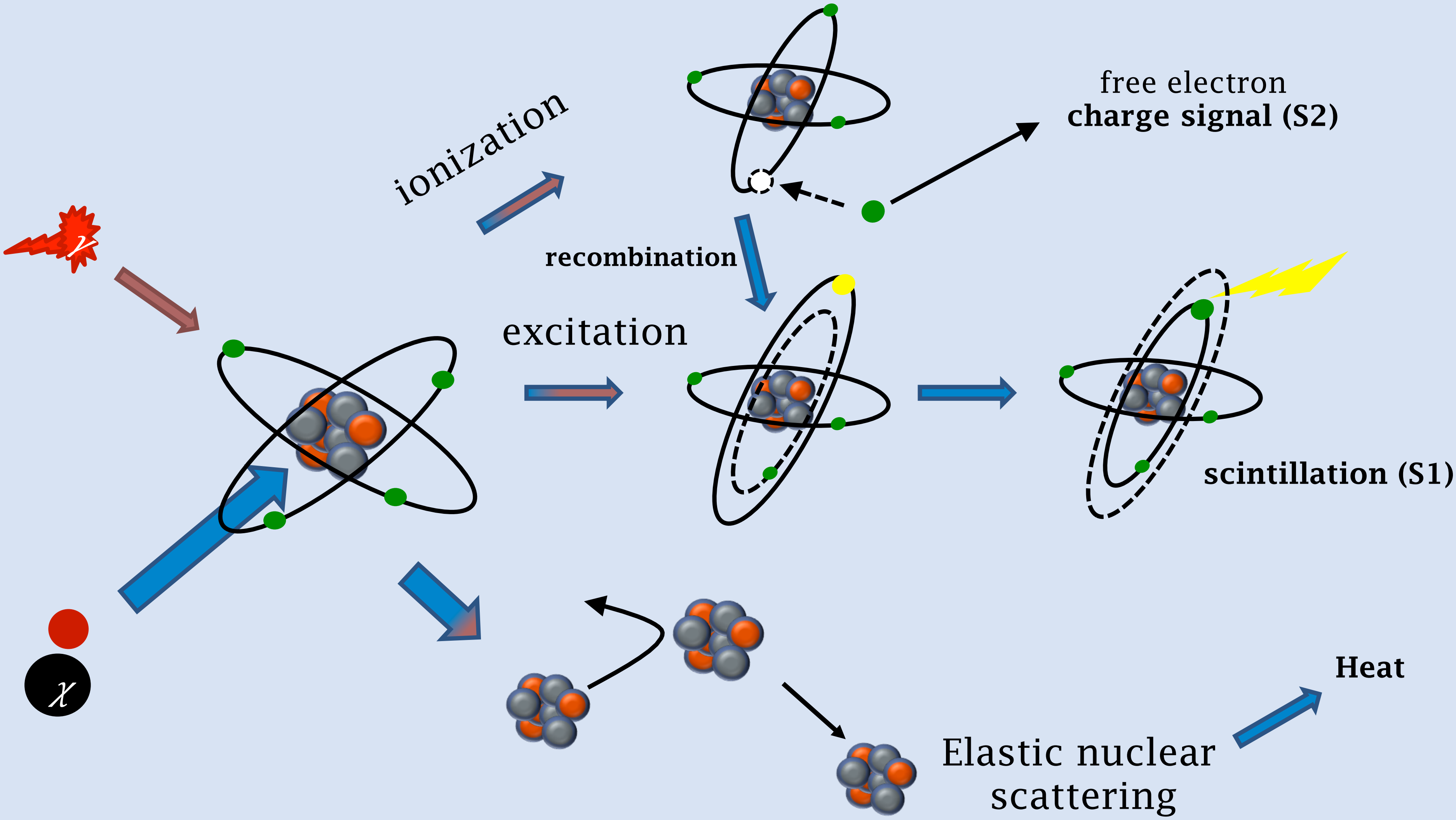
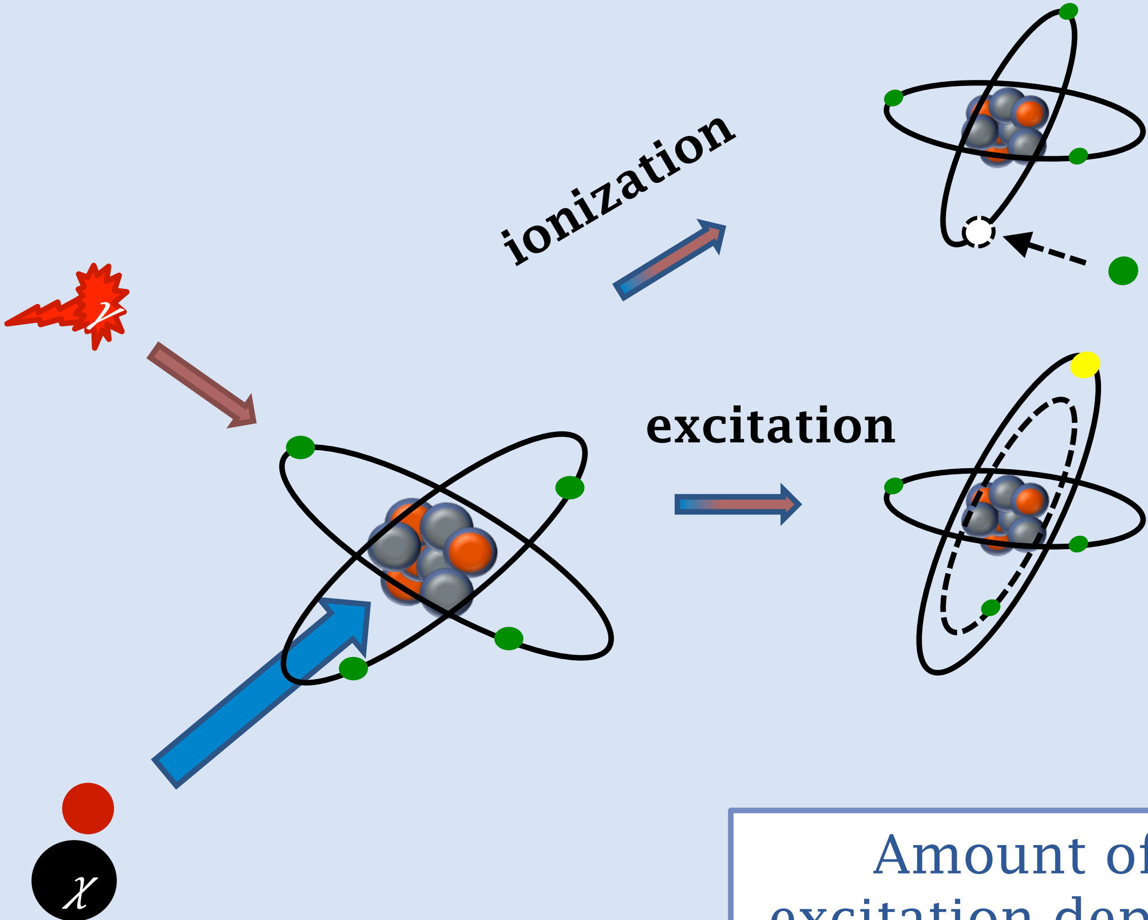
Observables in Dual-Phase LXe Detectors

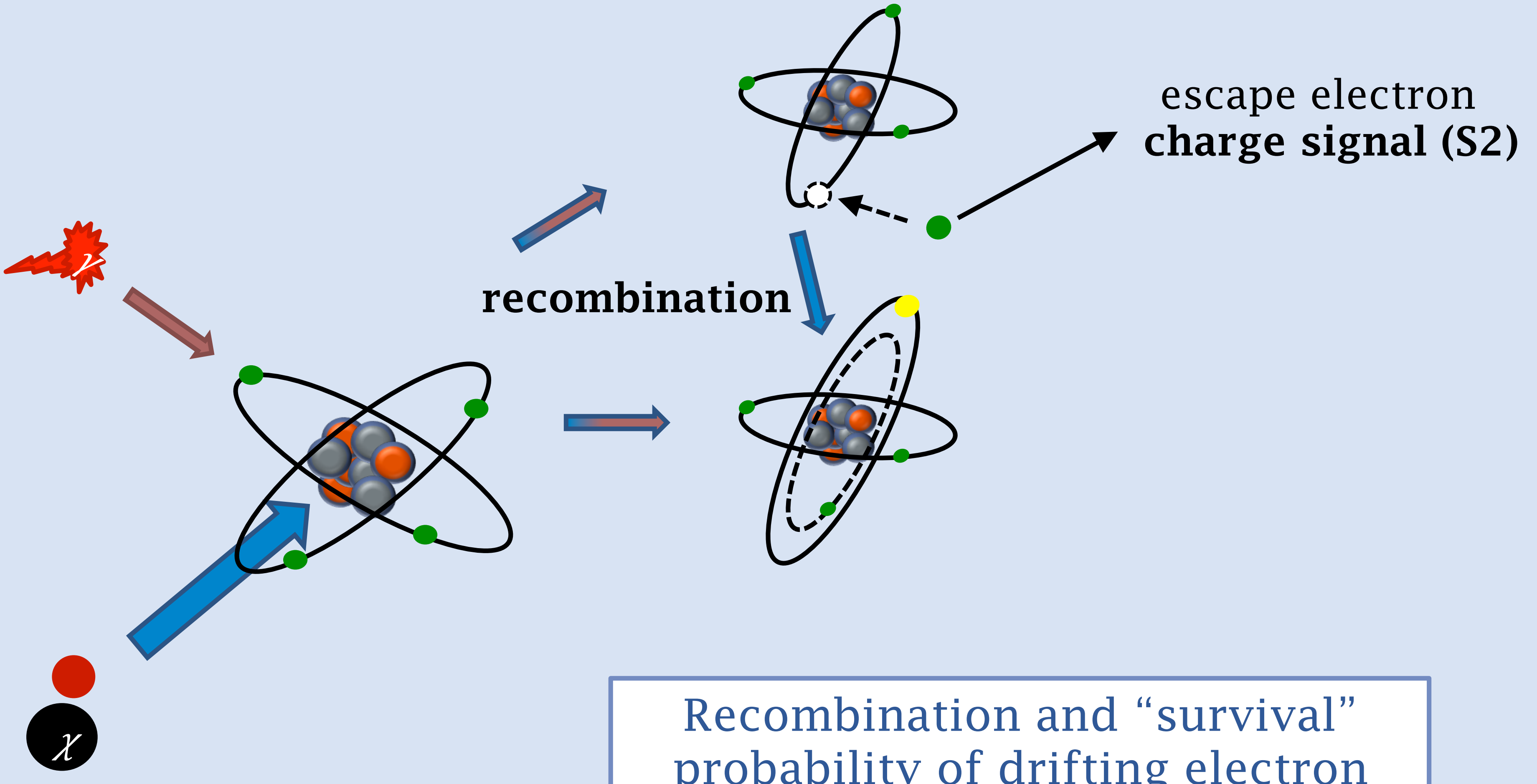


Observables in Dual-Phase LXe Detectors



Amount of ionization and excitation dependent upon **recoil energy** and **particle type**

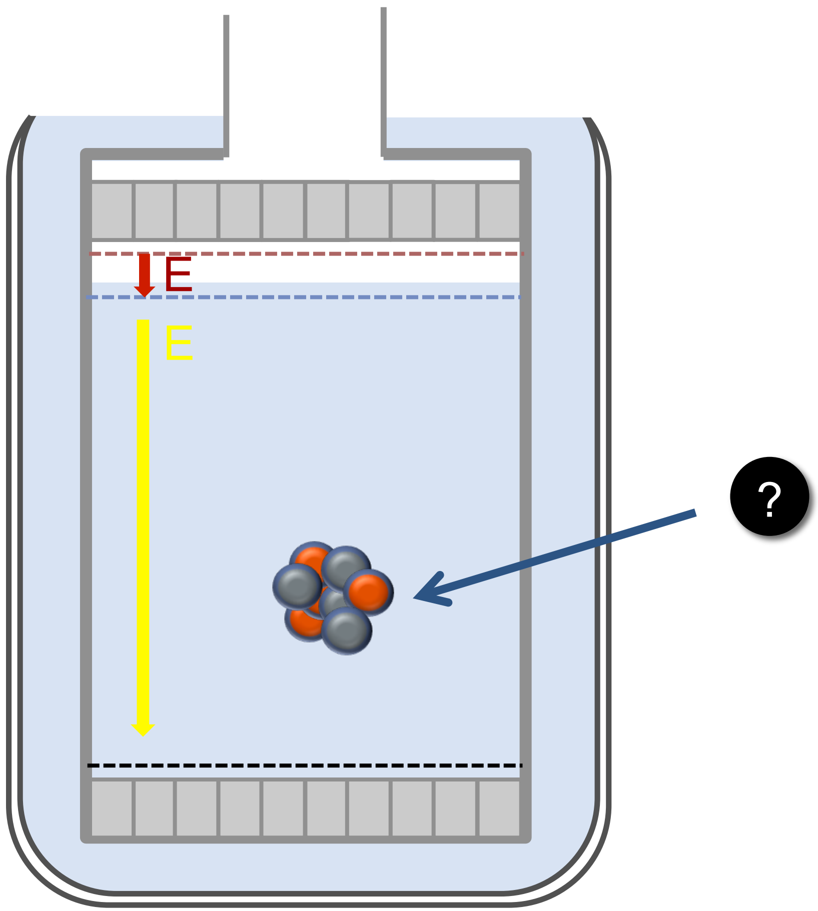
Observables in Dual-Phase LXe Detectors



Recombination and “survival” probability of drifting electron depend on **electric field**

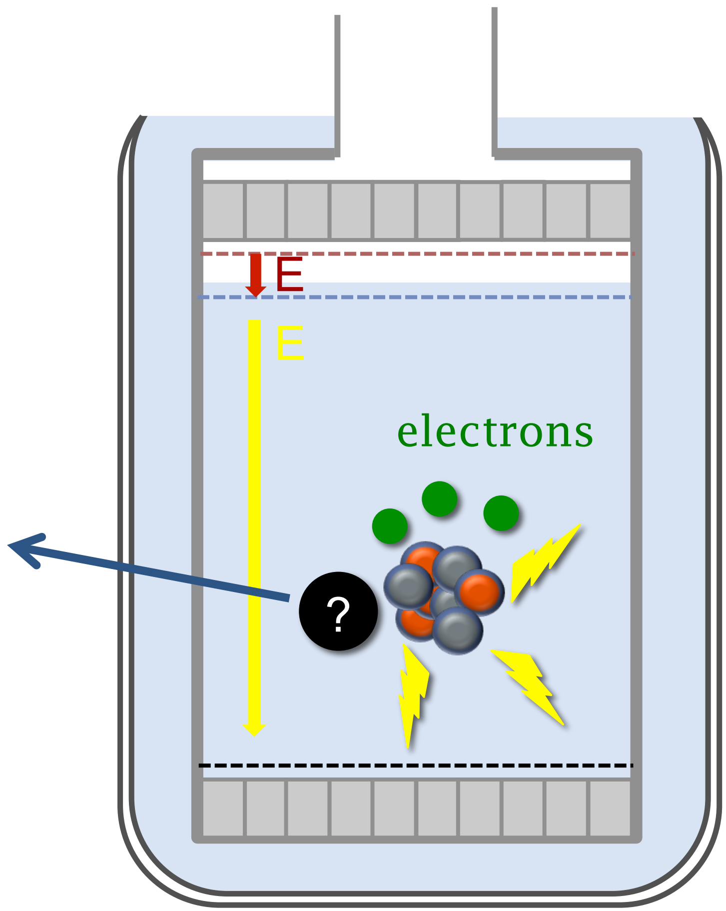
Observables in Dual-Phase LXe Detectors

A given particle enters the detector and interacts in the LXe



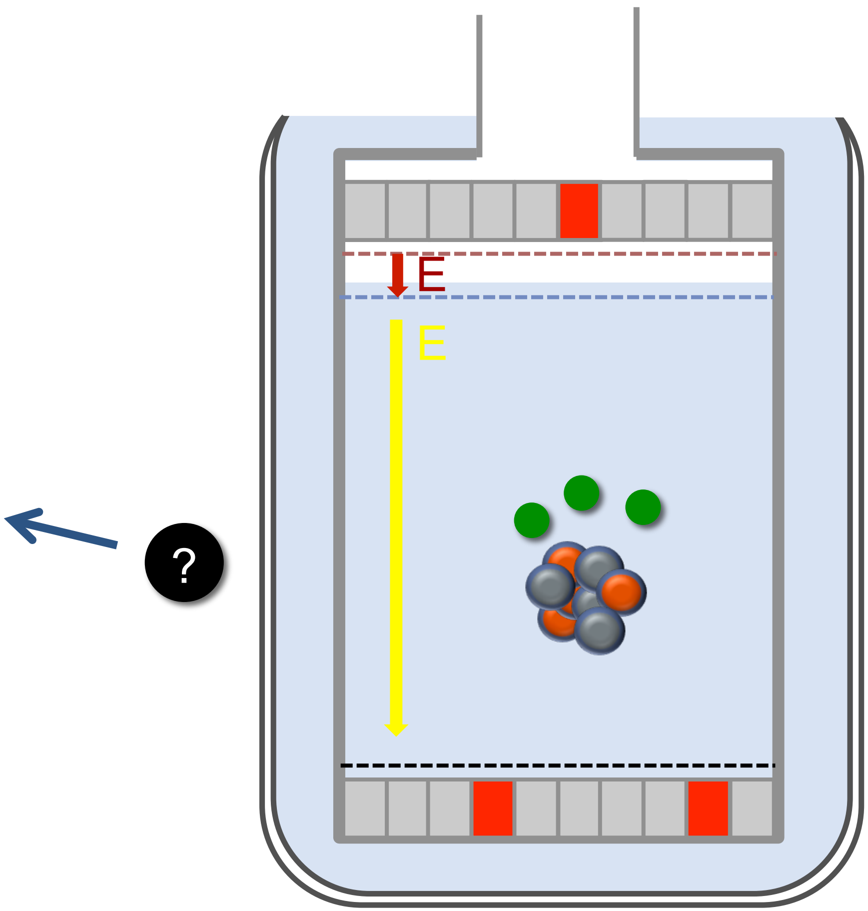
Observables in Dual-Phase LXe Detectors

Xenon atoms are simultaneously excited and ionized creating photons and free electrons

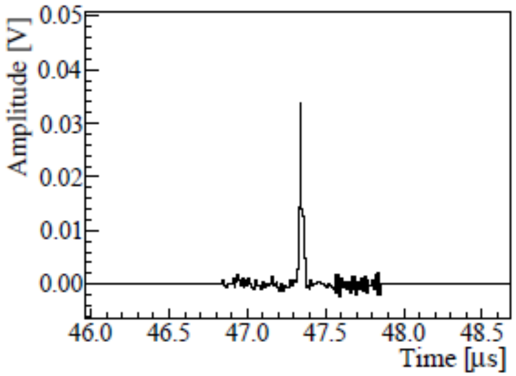


Observables in Dual-Phase LXe Detectors

Scintillation light from xenon excitation seen by PMTs almost immediately

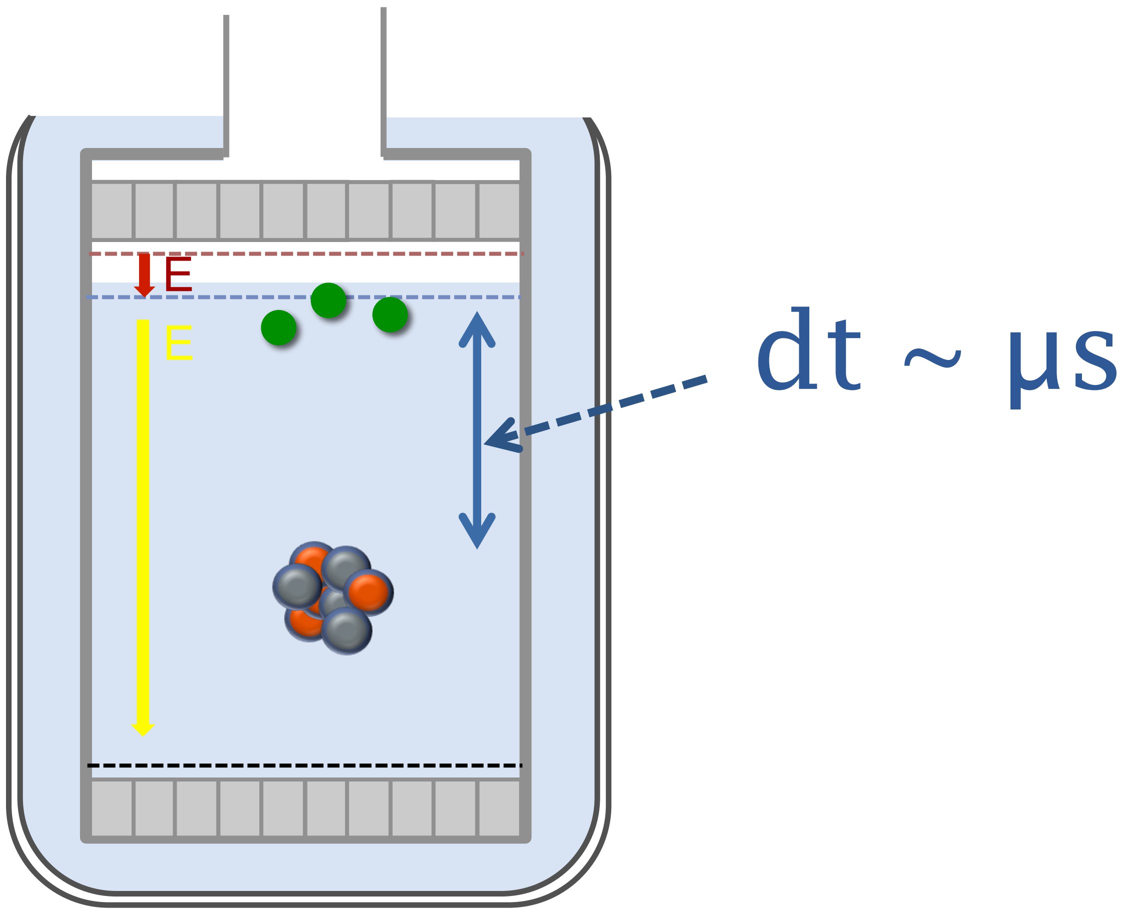


S1



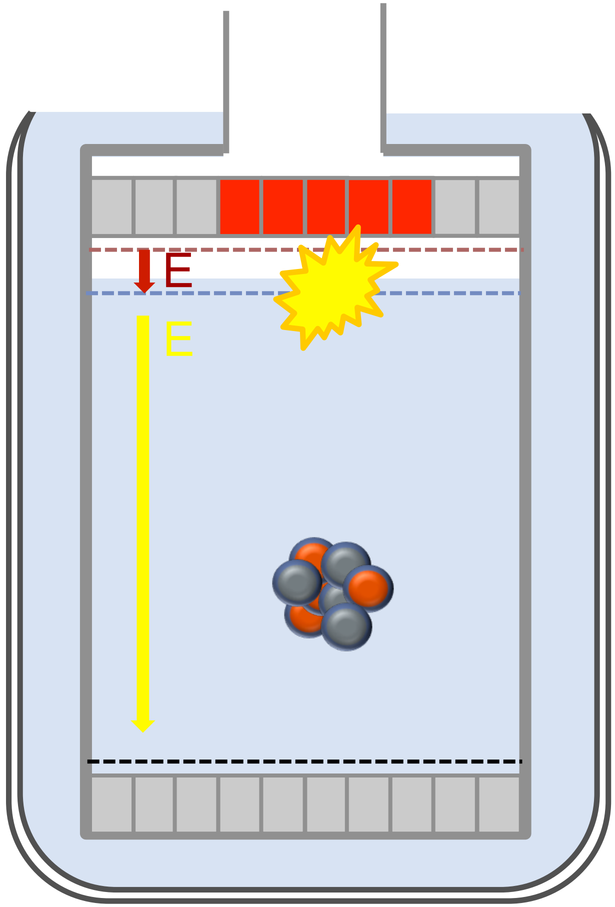
Observables in Dual-Phase LXe Detectors

After a time on the order of microseconds, electrons that remain free reach liquid gas interface

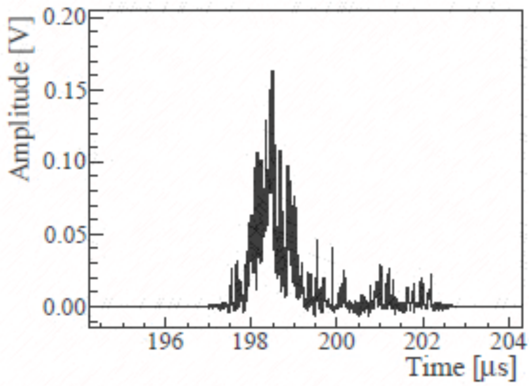


Observables in Dual-Phase LXe Detectors

Free electrons are extracted into the GXe and accelerated through creating light proportional to the number of electrons



S2



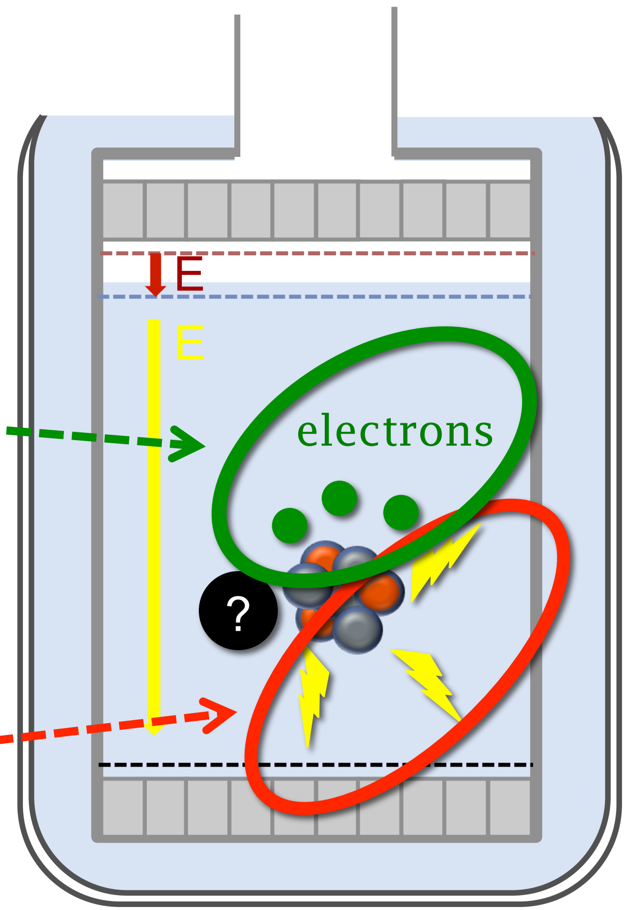
Reconstructing Energy

Goal: improve understanding of low energy interactions in LXe

Charge Yield = **Electrons** / Energy

Energy **Drift Field** **Particle**

Light Yield = **Photons** / Energy



Reconstructing Energy

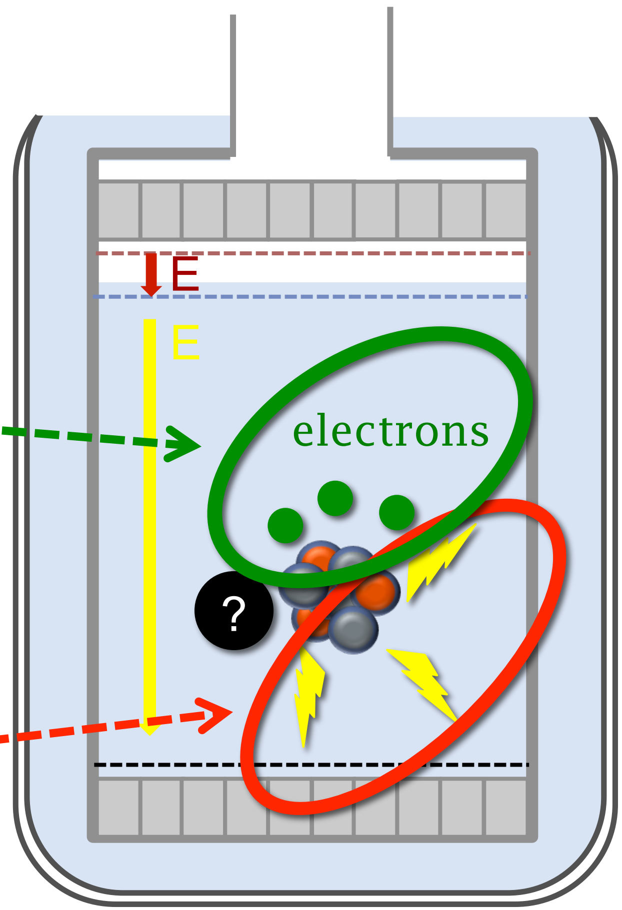
Goal: improve understanding of low energy interactions in LXe

- **Given an electronic or nuclear recoil at a certain energy in a drift field, how much light and charge do you expect to be produced?**

Charge Yield = Electrons / Energy

Energy Drift Field Particle

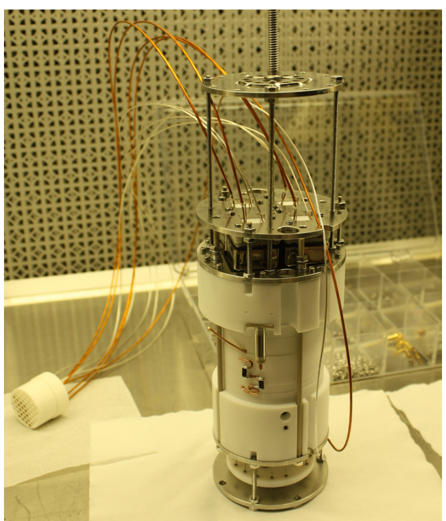
Light Yield = Photons / Energy

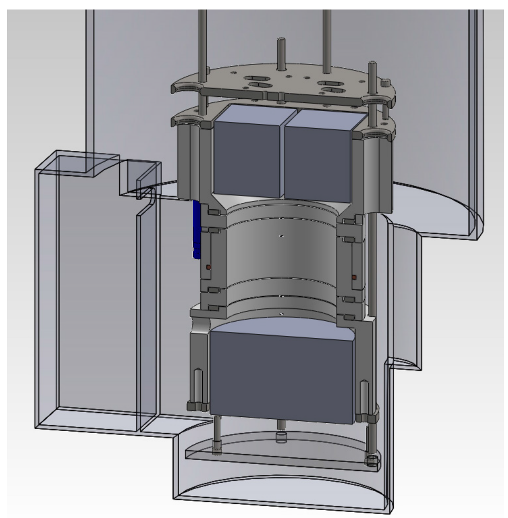


neriX Detector

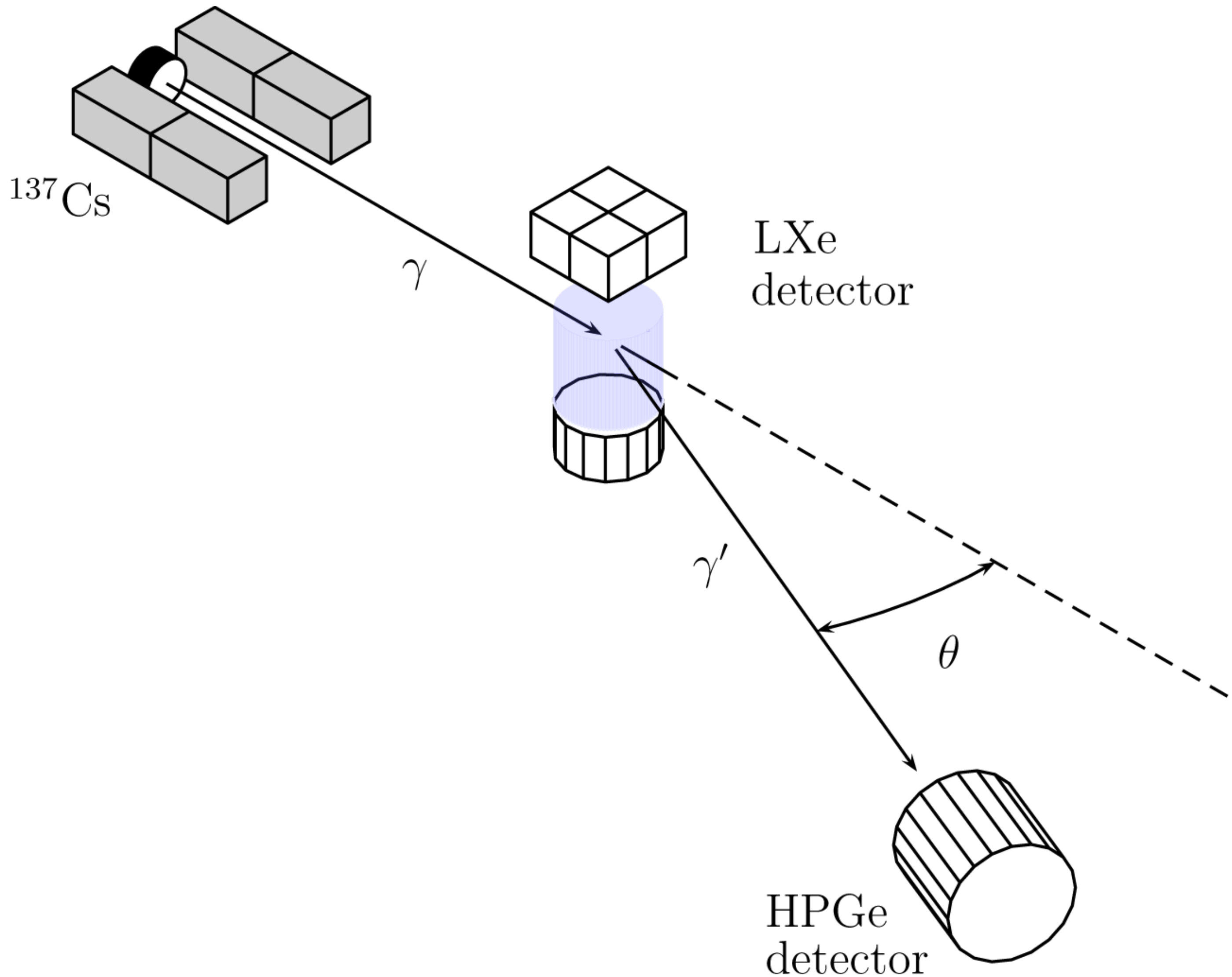
Dual-phase LXe Time Projection Chamber for measuring **n**uclear and **e**lectronic **r**ecoils **i**n **X**enon

- Small size and minimal materials surrounding fiducial volume make this detector well-suited for measurements of the light and charge yield
- Unlike most previous measurements, can measure the light and charge yield as a function of drift field applied
- Pursue light and charge yields as low as 1 keV

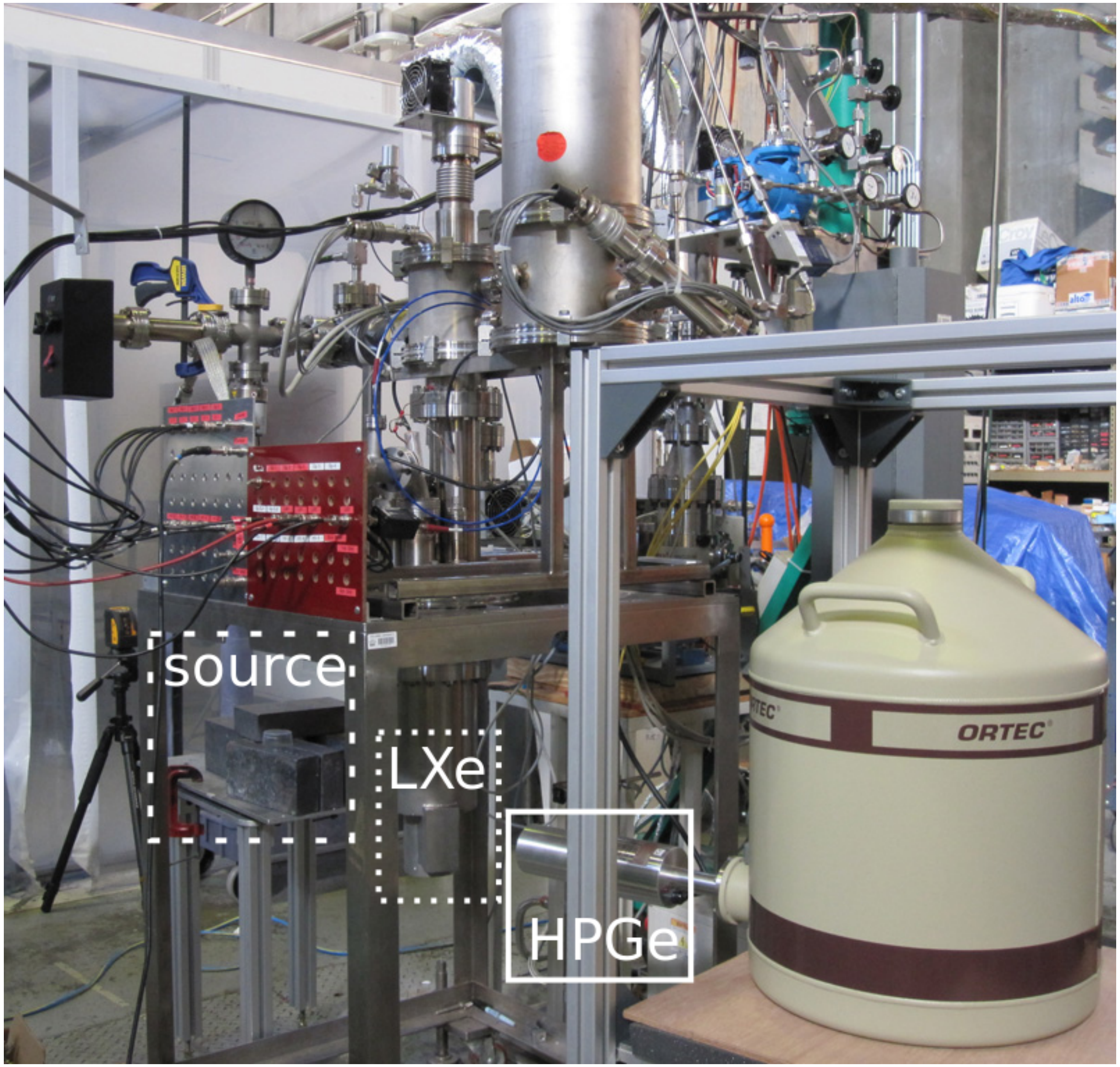




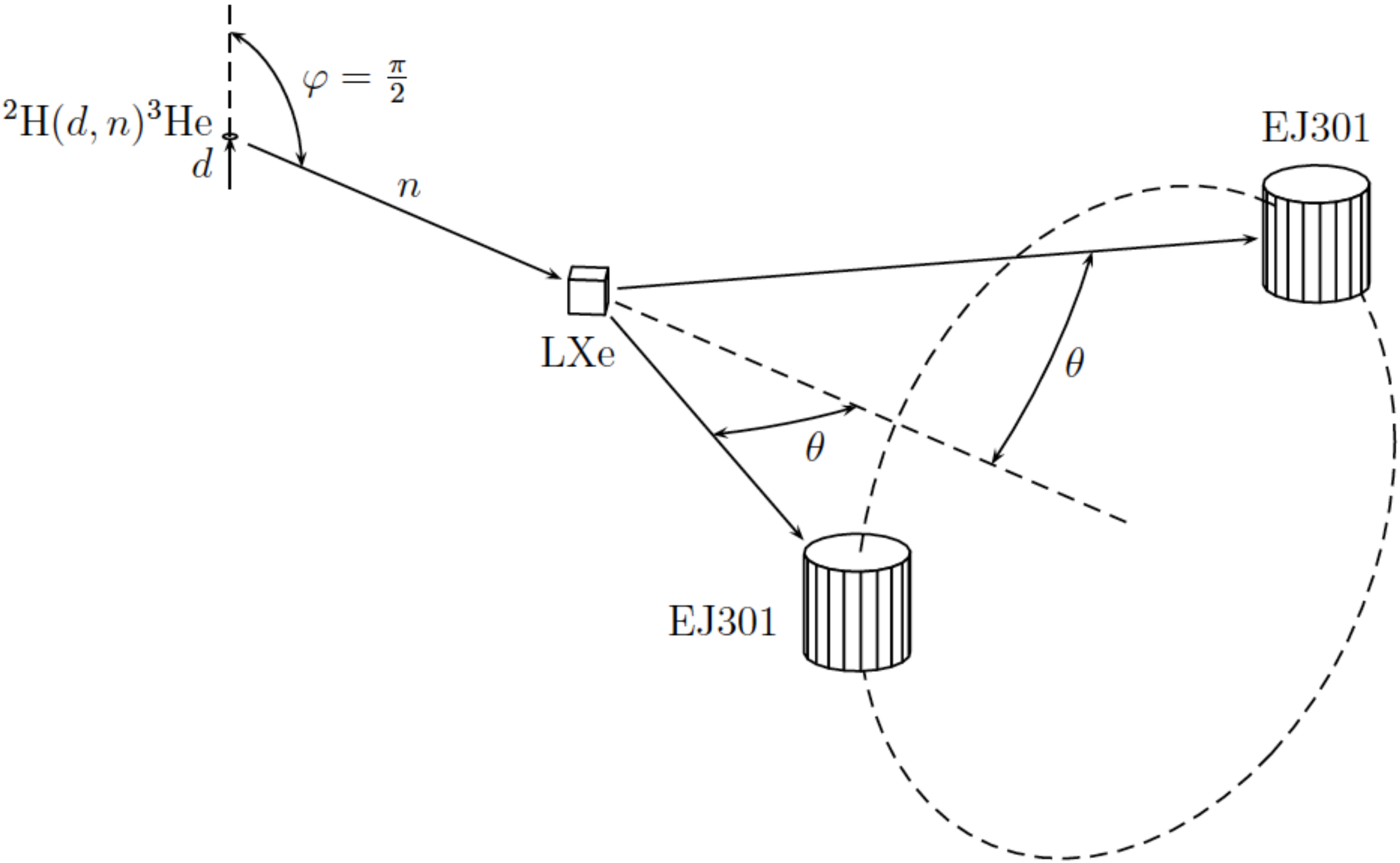
Coincidence Techniques



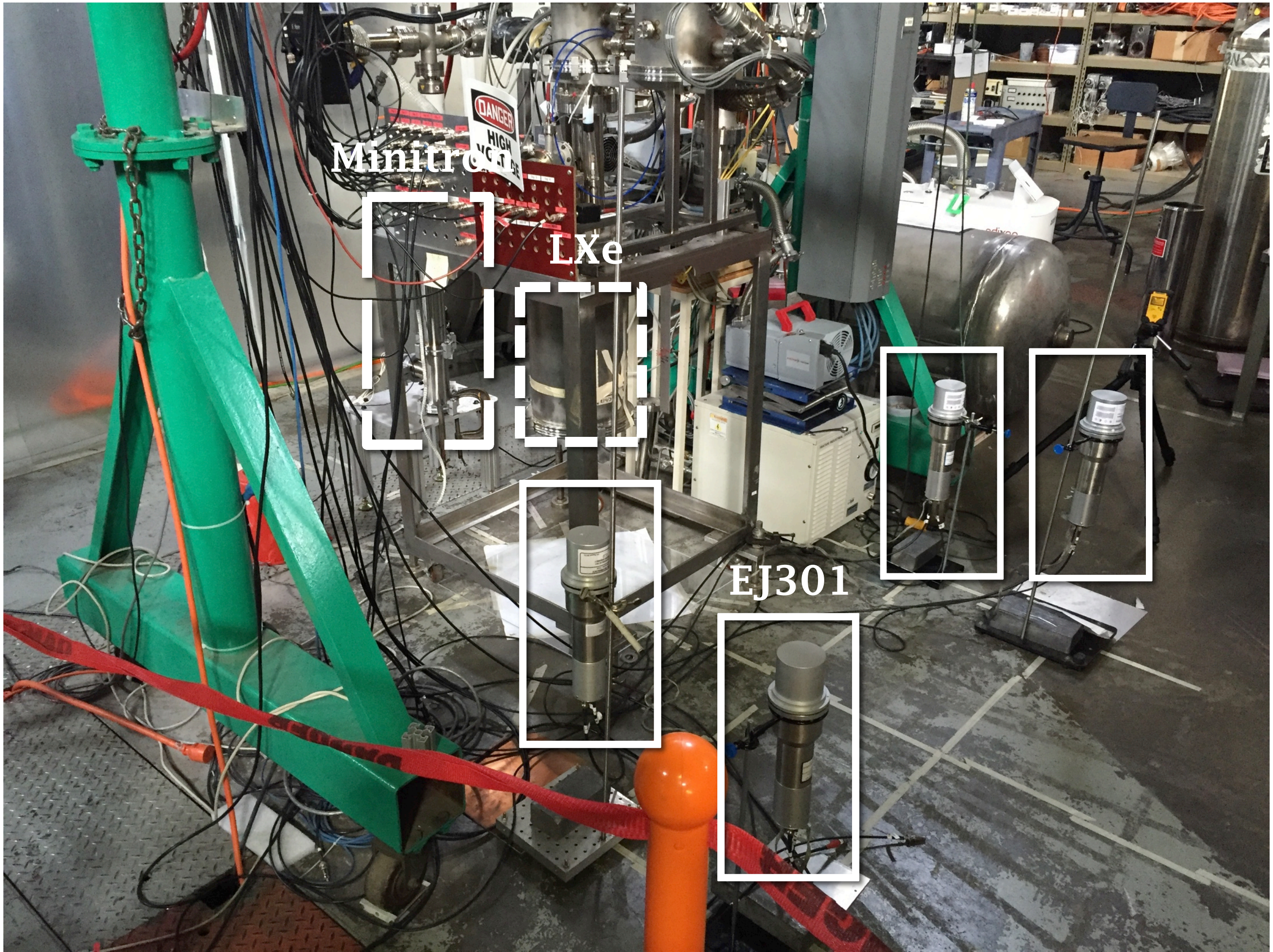
Coincidence Techniques



Coincidence Techniques



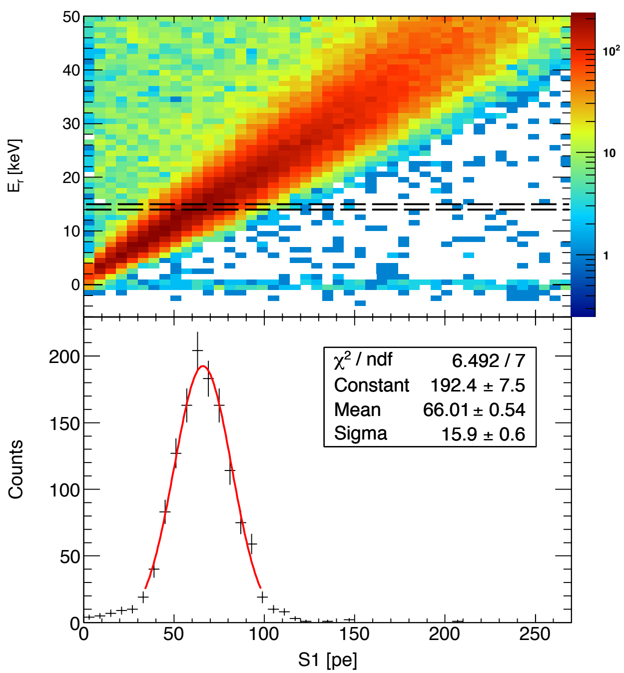
Coincidence Techniques



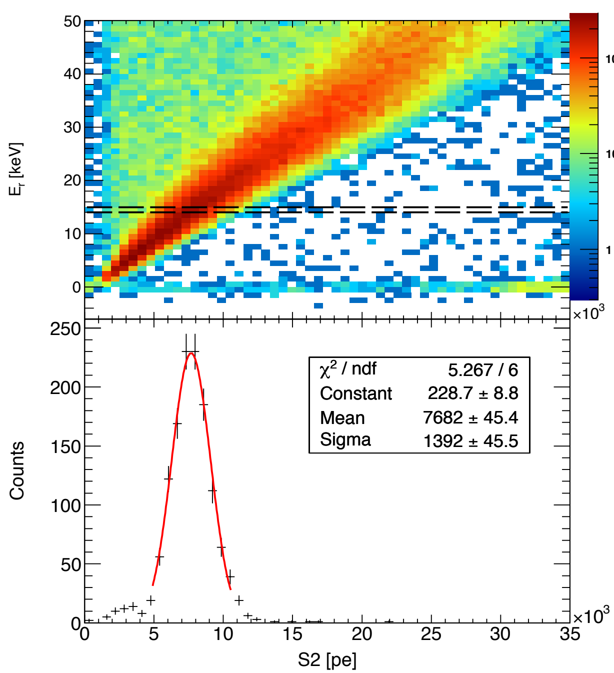
Coincidence Spectra

Below are two sample coincidence spectra that are used to determine the light and charge yield at a given energy

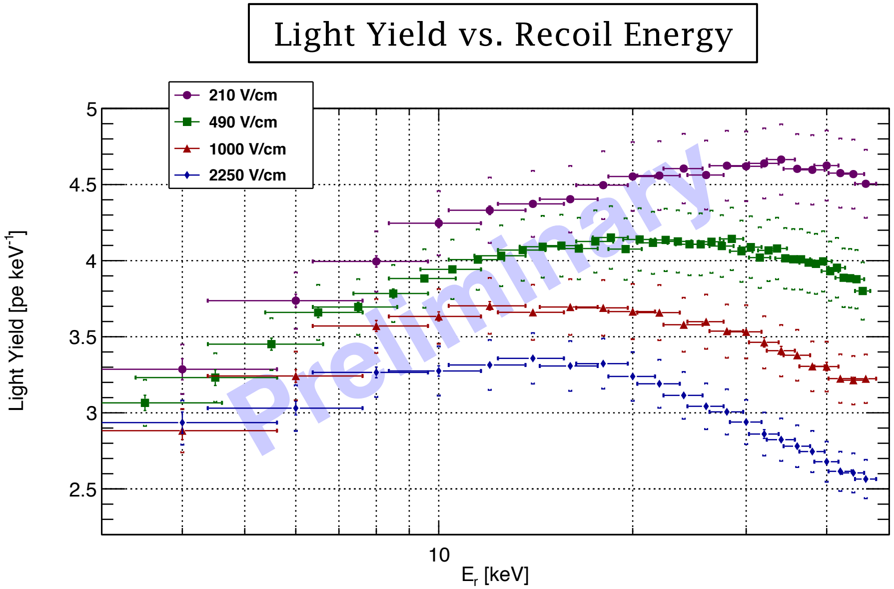
Prompt Scintillation Light (S1) vs. Energy Deposited in LXe

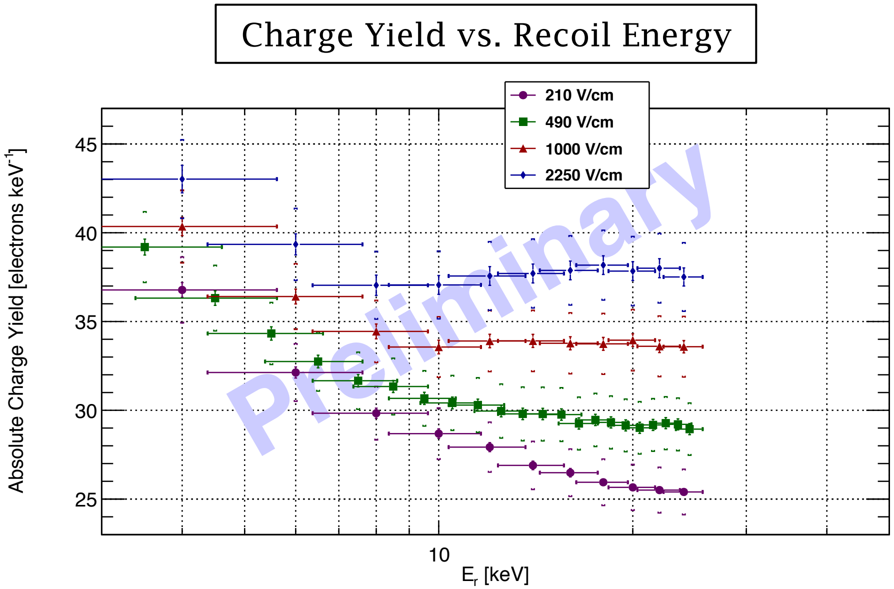


Proportional Scintillation Light (S2) vs. Energy Deposited in LXe



Electronic Recoils: Light and Charge Yields



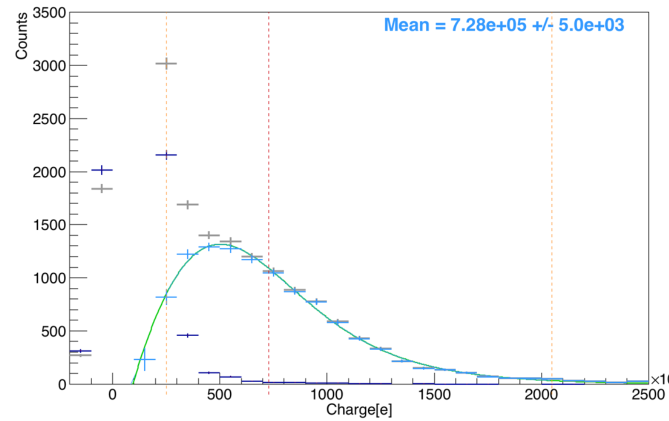


Backup

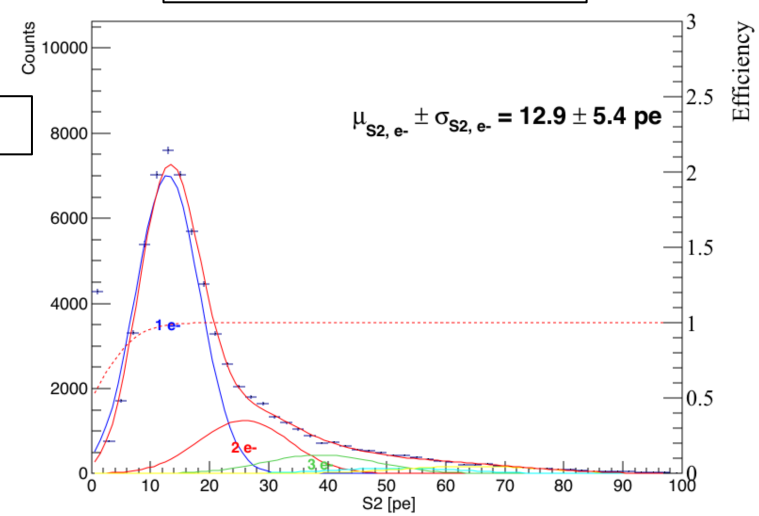
Single Photoelectron and Electron Detection

- Single Photoelectron Gain
  - Use LED at low light level to measure SPE gain
  - Relatively low gain (~4-7 x 10^5 e^-) to avoid saturation
  - Use background subtraction and coincidence cut to clean distribution
- Single Electron Gain
  - Use photoionization of cathode by S2 to find small numbers of electrons

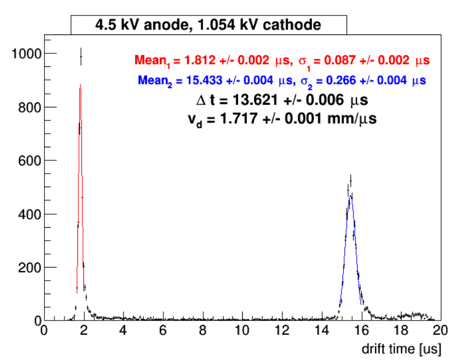
SPE Gain Calibration



Single Electron Gain



Photoionization of Gate and Cathode



More details on single electron gain: J. Phys. G: Nucl. Part. Phys. 41 (2014) 035201

Position Reconstruction

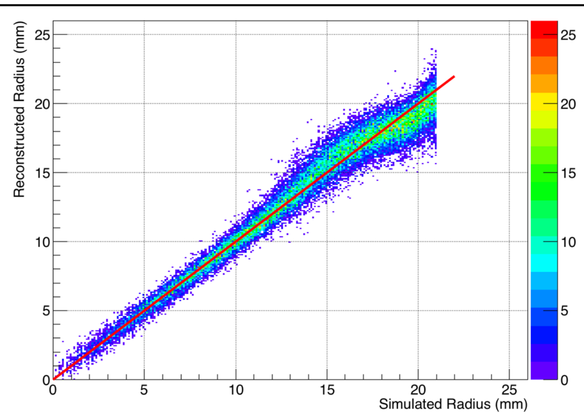
Similar to larger LXe detectors, neriX is able to reconstruct the 3D position of an event

- More difficult given small size of the detector
- Used Geant4 construction of the detector to simulate S2 patterns at given positions
- Train neural network on the simulation using FANN open source library
- Average error of simulated data inside radius of 18 mm ≅ 0.5 mm

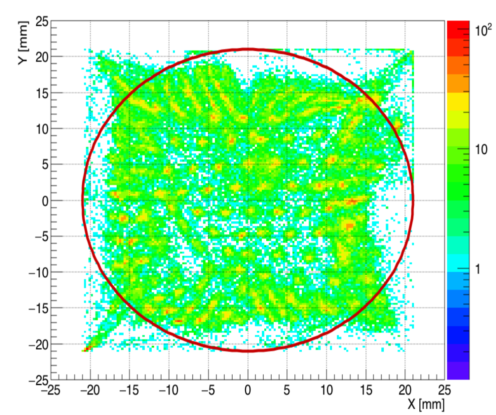
$$\{S2_1,\ \ldots,\ S2_{16}\} \Rightarrow$$

$$\Rightarrow \{X,\ Y\}$$

Simulated vs. Reconstructed Position

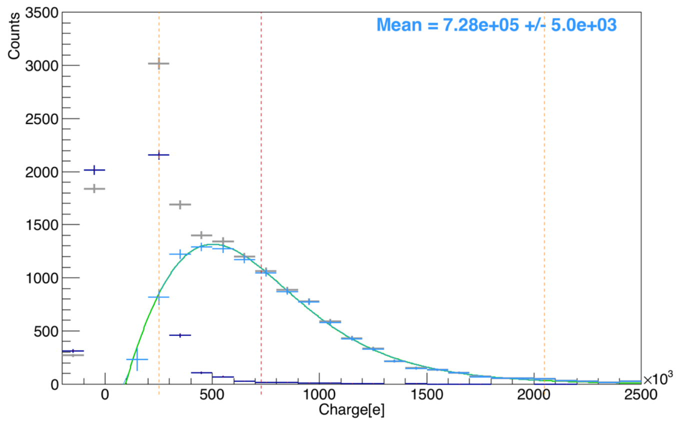


Co-57 Position Reconstruction

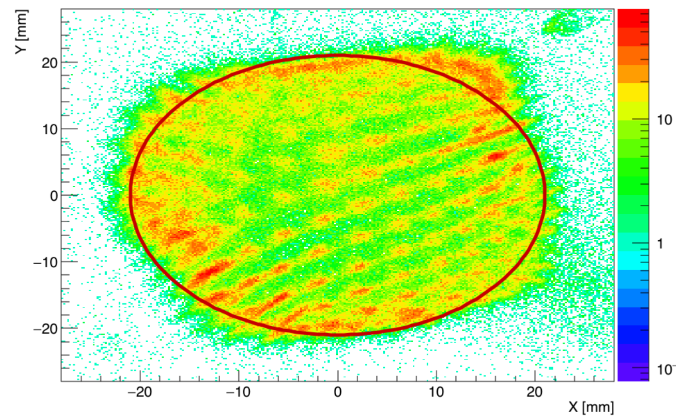


neriX Operation

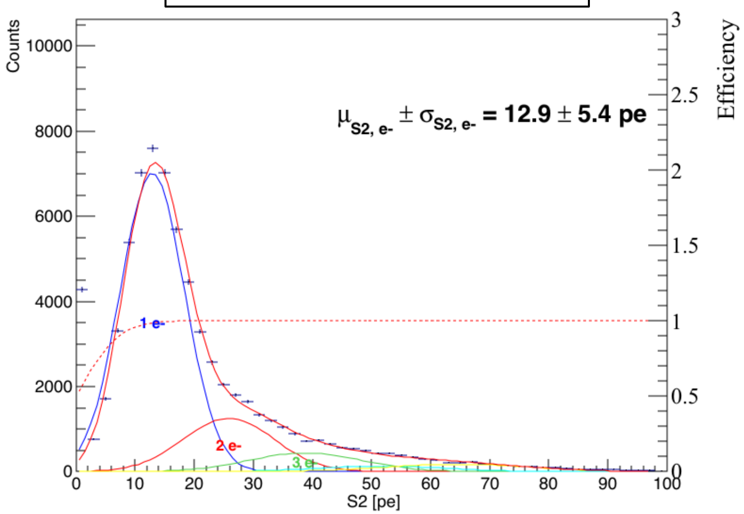
SPE Gain Calibration



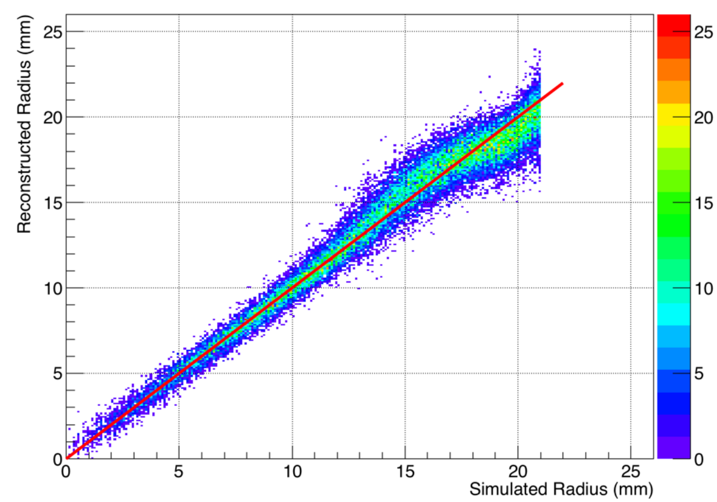
Position Reconstruction



Single Electron Gain



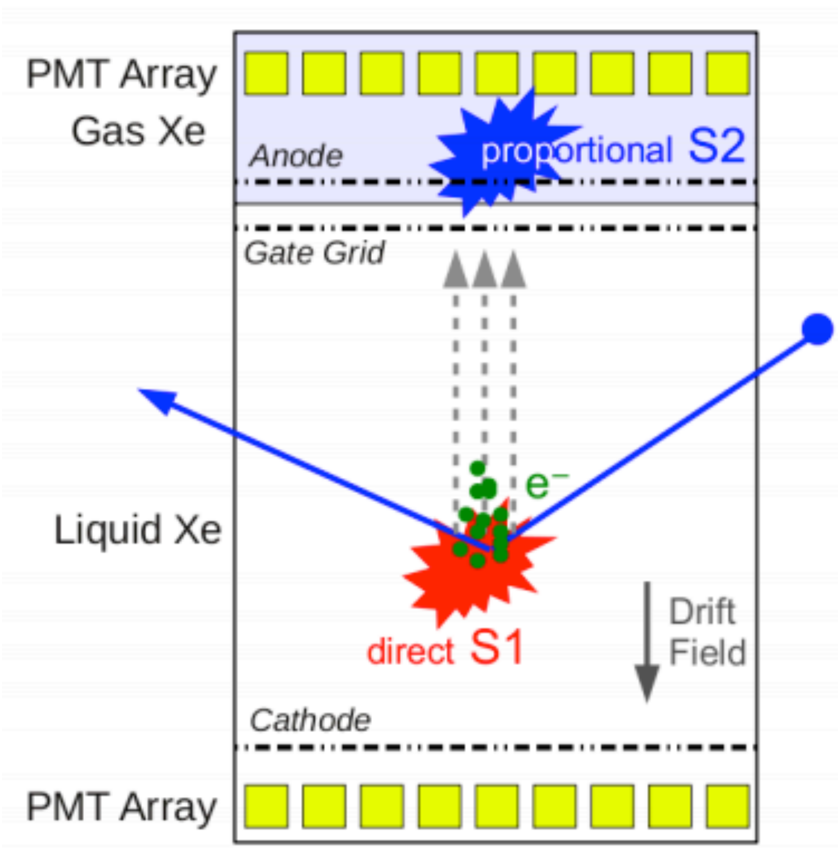
Simulated vs. Reconstructed Position

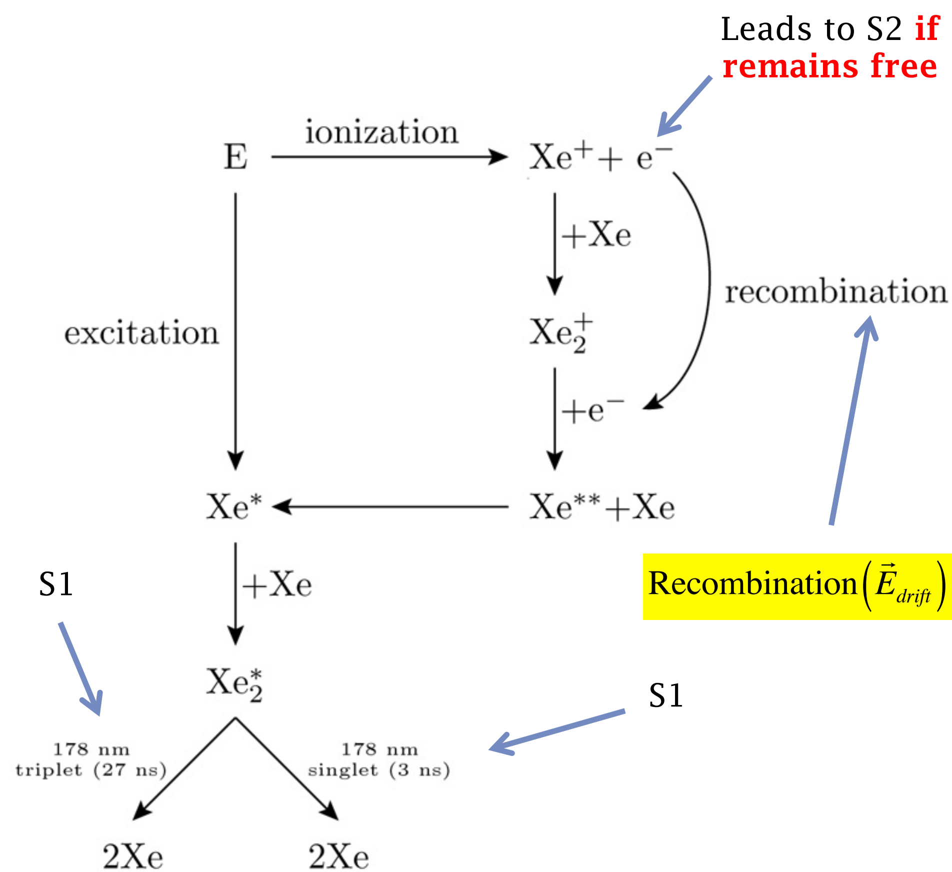


Motivation

LXe experiments lead direct dark matter scattering search

- Xenon100, LUX, Xenon1T





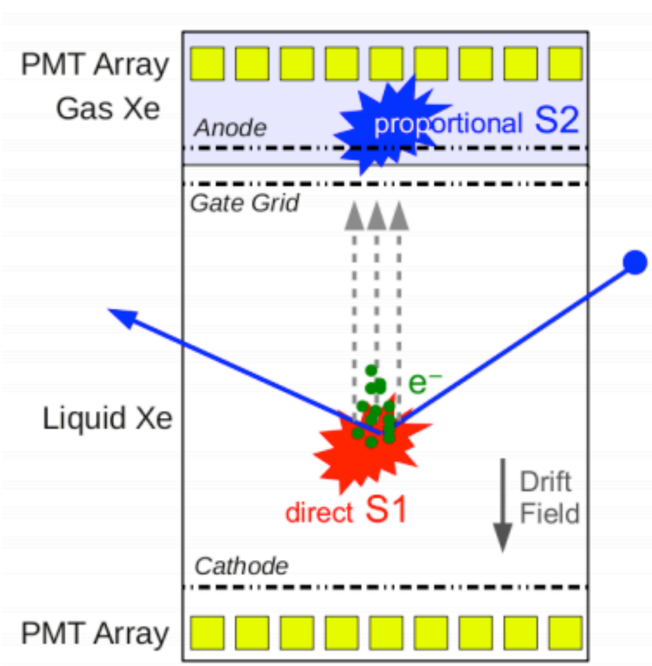
Motivation

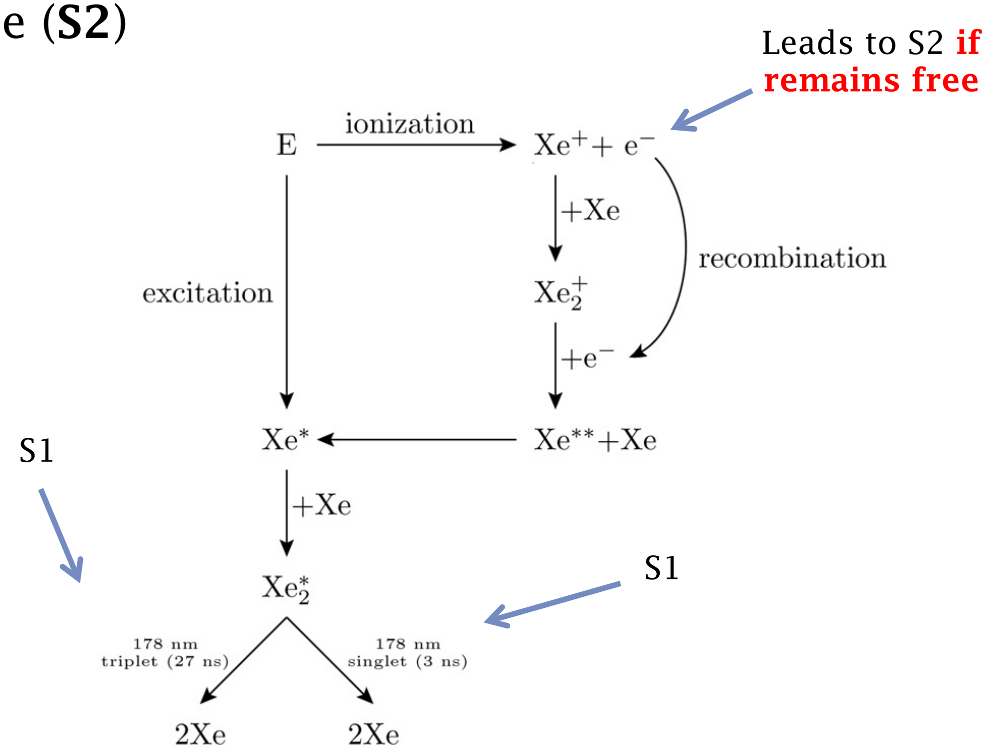
LXe experiments lead direct dark matter scattering search

- Xenon100, LUX, Xenon1T

Dual-phase detectors ➔ simultaneously detect light and charge

- Prompt light emission from interaction in LXe (**S1**)
- Complementary signal from acceleration of electrons through GXe after electrons drift through LXe (**S2**)





Motivation

Goal: improve understanding of low energy interactions in LXe

- **Given an electronic or nuclear recoil at a certain energy in a drift field, how much light and charge do you expect to be produced?**
- Light and charge yield **non-linear** in energy and drift field
  - Light Yield = Photoelectrons / Energy
  - Charge Yield = Free Electrons / Energy