Characterization of Pb-206 Nuclear Recoils in Liquid Xenon

Daniel Naim, University of California, Davis

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with Mani Tripathi (PI), Aaron Manalaysay, Jacob Cutter, Ben Godfrey

Outline

- Detector Setup (DAX)
- Signal Measurements of waveforms and Co-57 Calibration sources
- Alpha Tagging on Pin Diode for Po-210
- Distribution of Pb-206 Signals (Results)

The **Da**vis **X**enon R&D Platform (DAX)

- The **Da**vis **X**enon R&D platform (DAX) is a testbed system for xenon detector studies at UC Davis, including operation of a **dual-phase time projection chamber (TPC)**

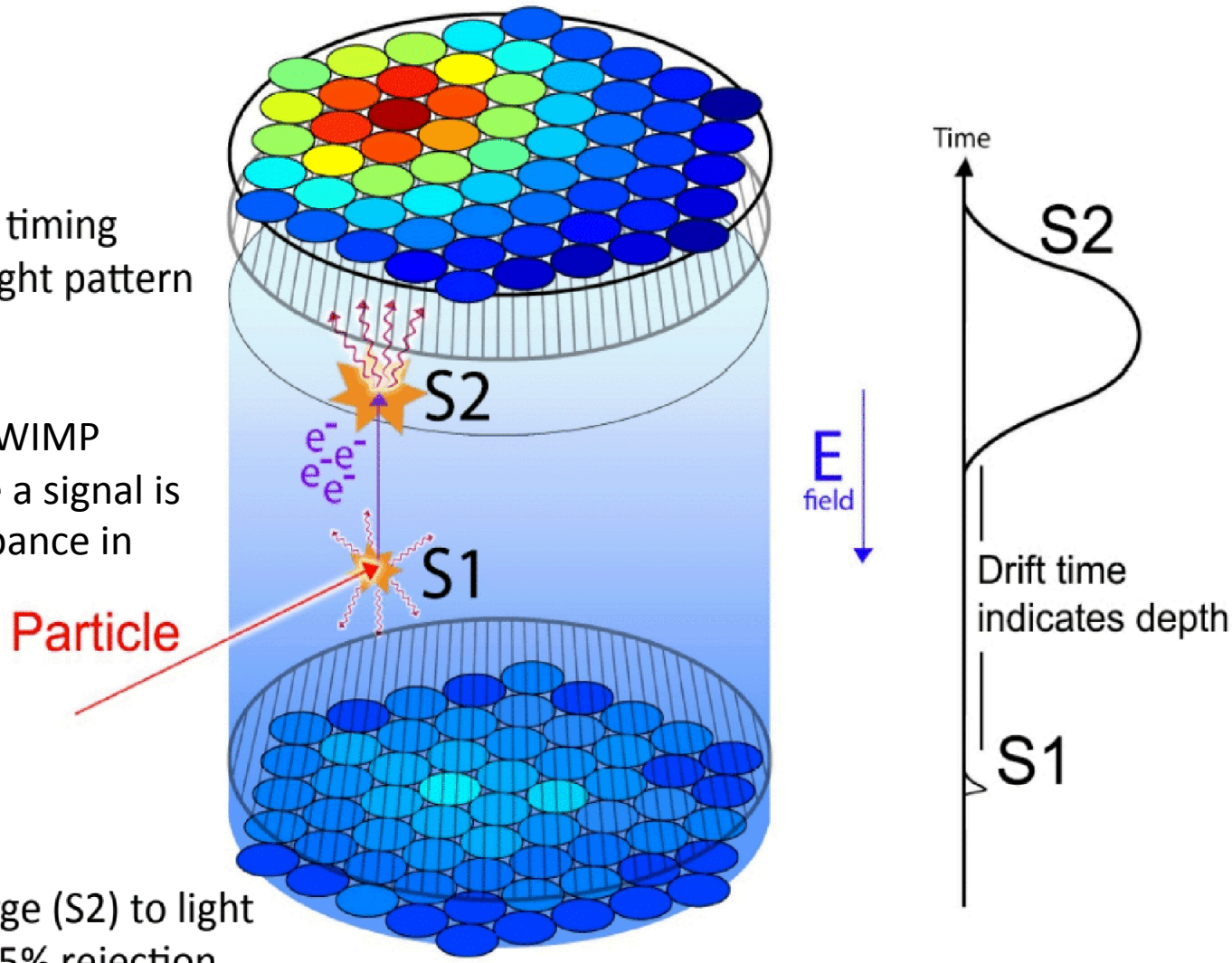
- One of the primary goals of DAX is to characterize a common class of backgrounds in noble element dark matter detectors — heavy nuclei emitted as decay daughters.

- Improving our understanding of low-energy nuclear recoils (NR) is important for informing background models of future experiments.

Liquid Xenon TPC Principle

Z position from S1 – S2 timing
X-Y positions from S2 light pattern

We can use xenon as a scintillation target for WIMP Nuclear Recoils, where a signal is generated via a disturbance in the detector.

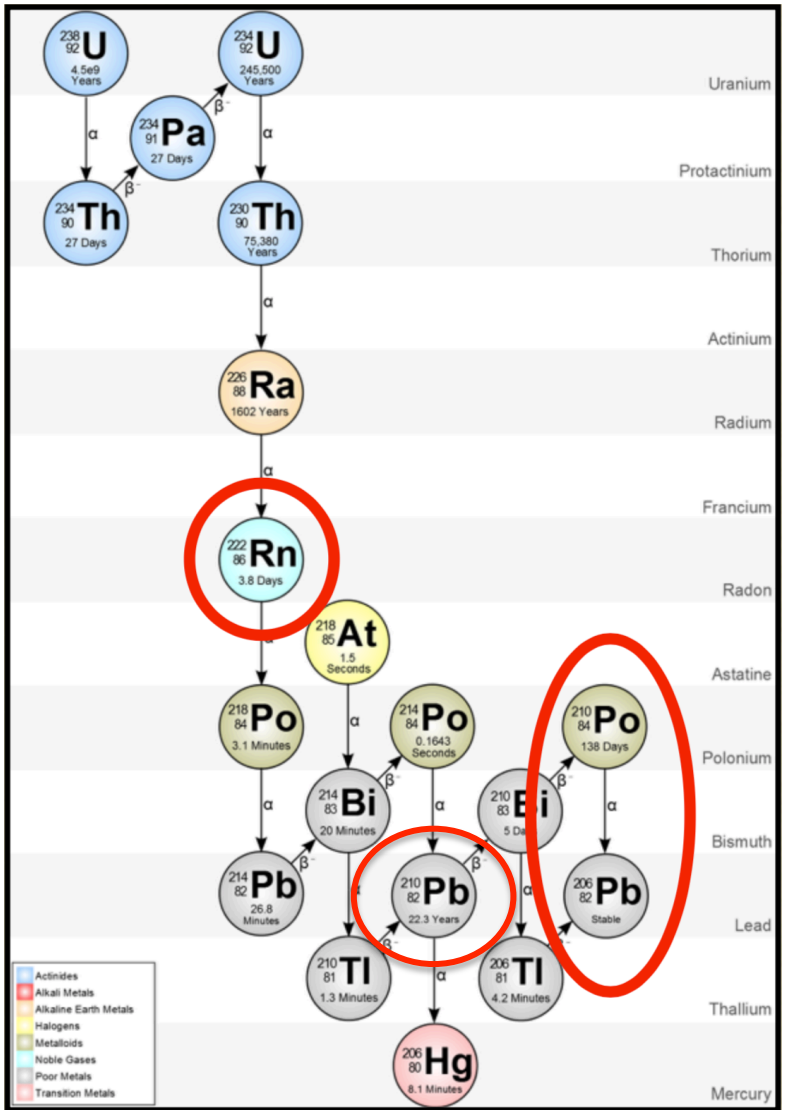


Reject gammas by charge (S2) to light (S1) ratio. Expect > 99.5% rejection.

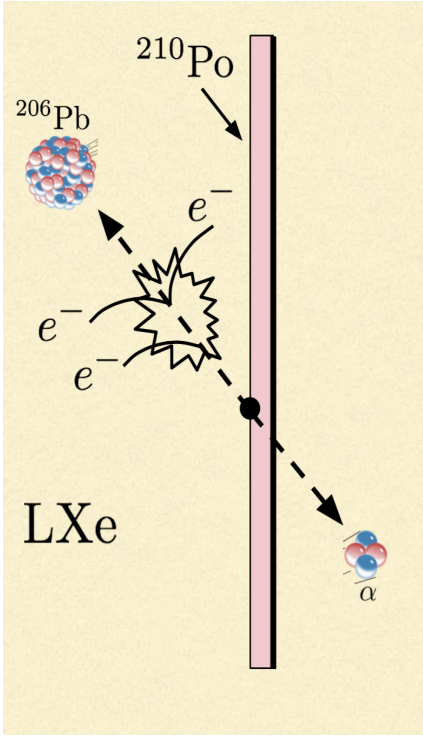
ionization electrons
UV scintillation photons (~175 nm)

Image by CH Faham (Brown)

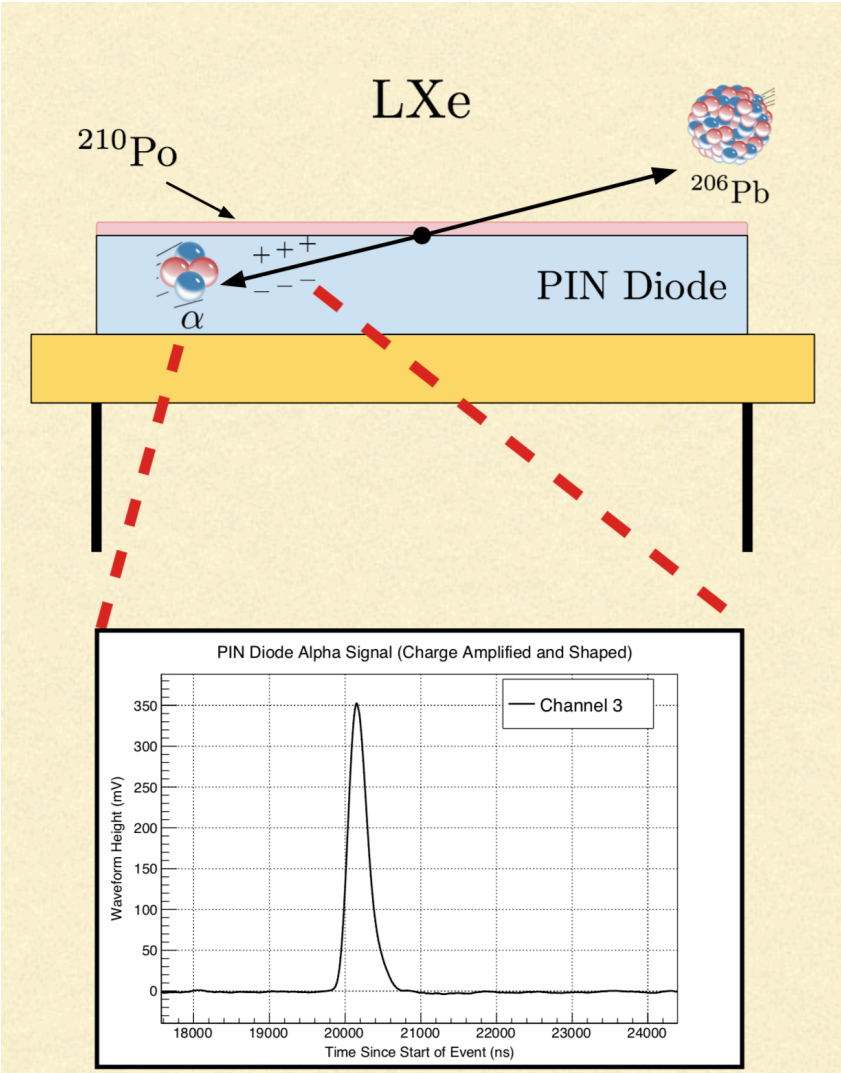
Identifying a Source for Pb-206



- ^{222}Rn which will diffuse through air and eventually place its decay products onto surrounding surfaces ("Radon Plate Out")
- Our interest is in characterizing the long lived ^{210}Pb decay, which is an unavoidable background in Dark Matter and Neutrino experiments
- $^{210}\text{Po} \rightarrow \alpha + {}^{206}\text{Pb}$

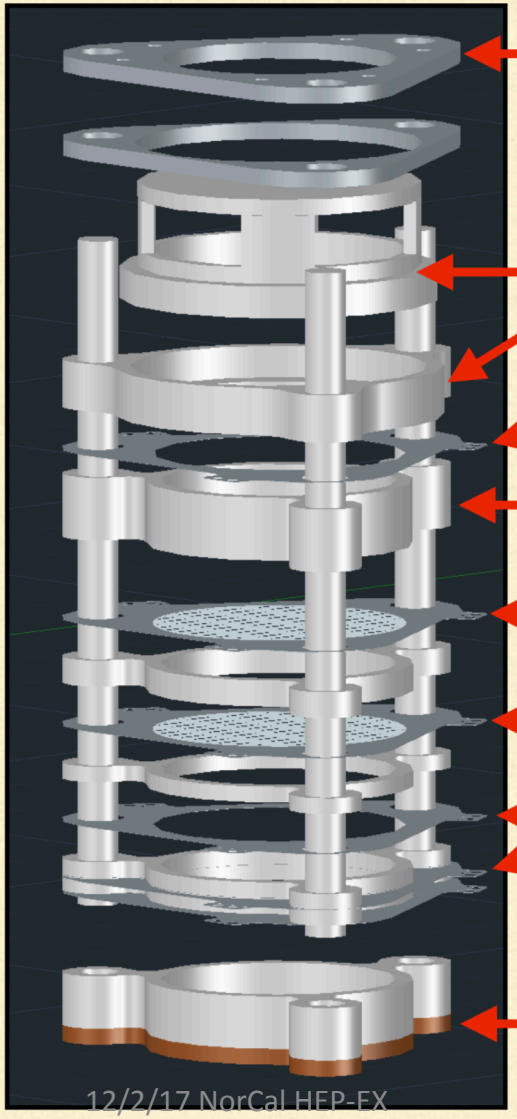


Using Pin Diodes to Detect Alpha

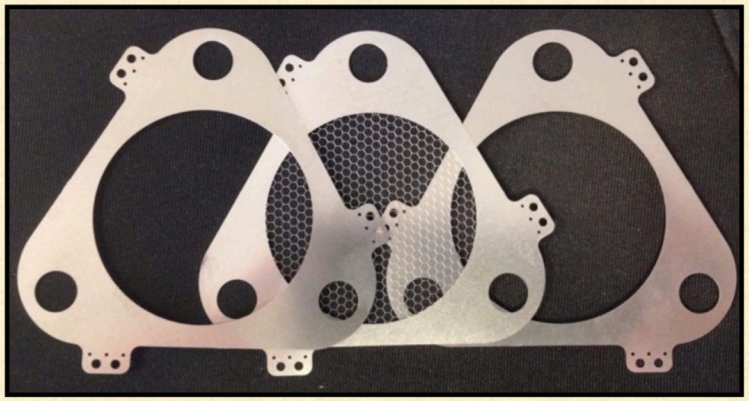


- **PIN diodes** are silicon devices that can be operated as charged particle detectors under reverse bias.
- ^{210}Po is deposited on the surface of a bare PIN diode, and undergoes alpha decay.
- When a ^{206}Pb nucleus recoils through LXe, the event can be tagged via the alpha signal in the PIN.
- In this way, we can directly measure light and charge yields from ^{206}Pb nuclear recoils in a Xe TPC.

TPC Design and Assembly

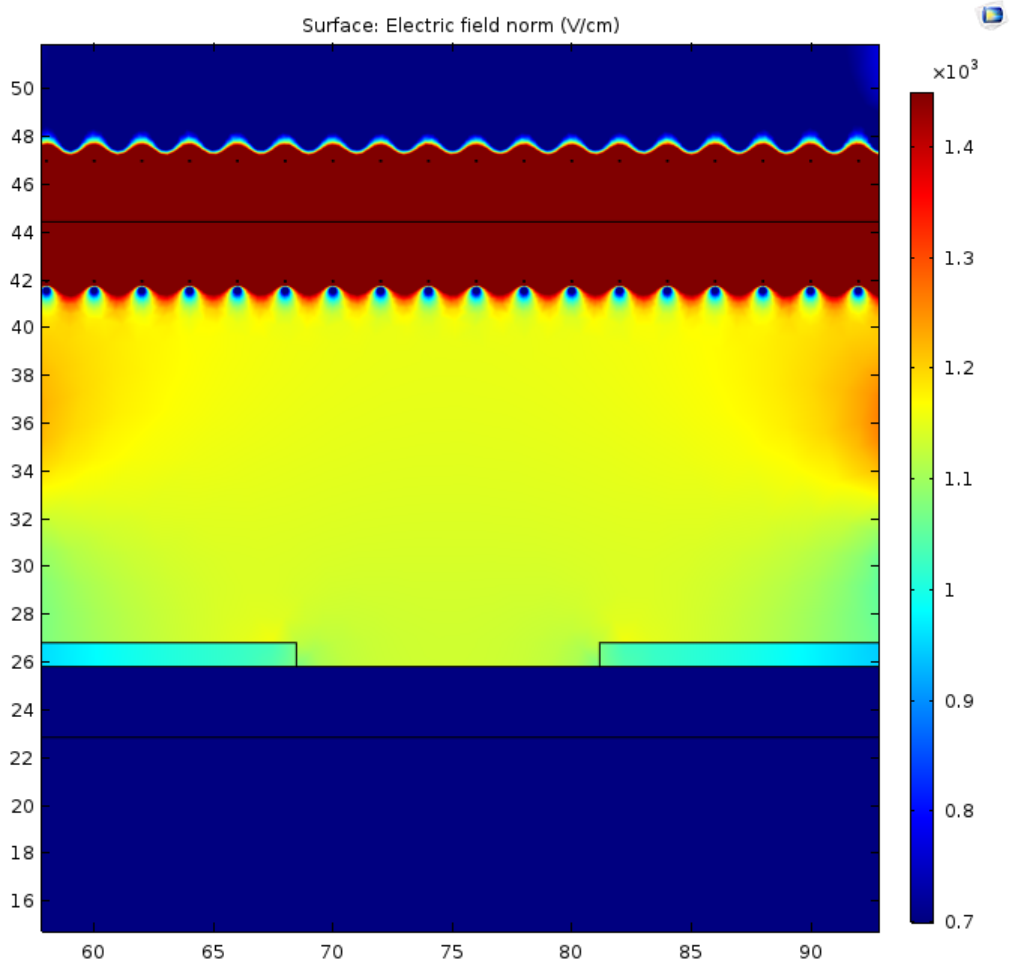


50 um stainless steel etched grids

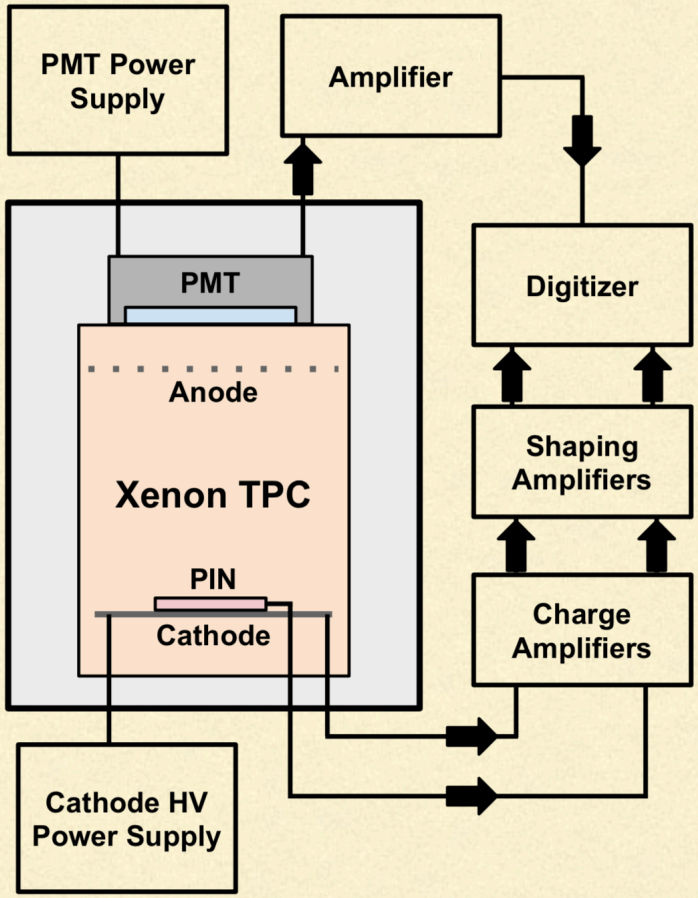


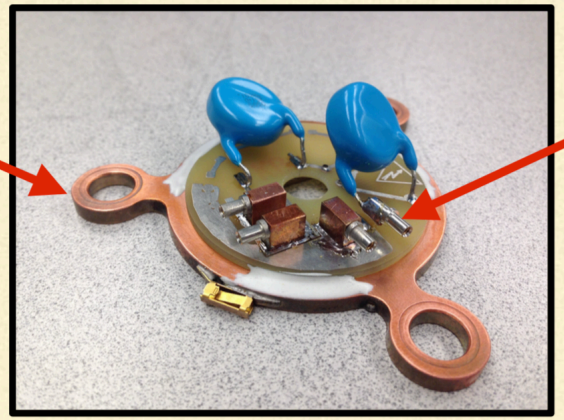
PTFE spacers and mounting plate

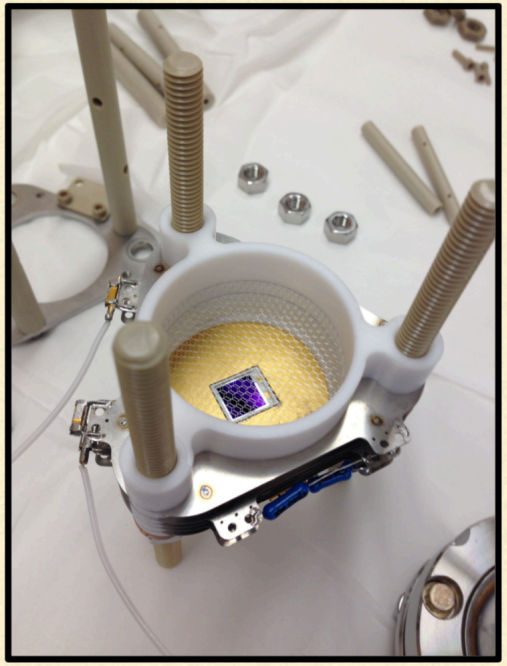
Example of Electric Field Simulation inside DAX

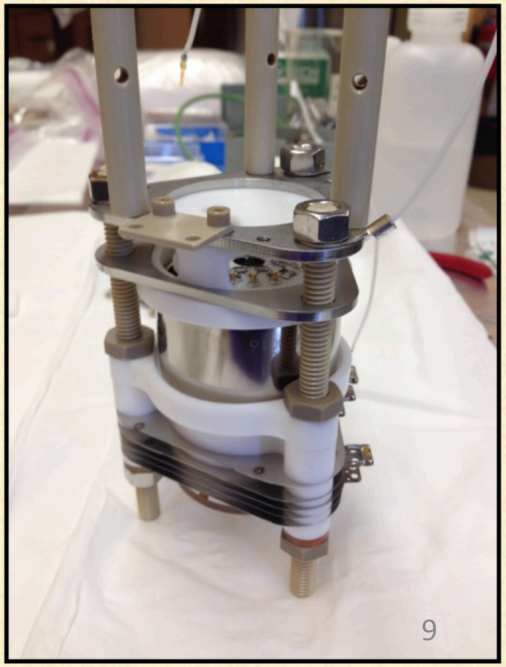


PIN Diode Implementation







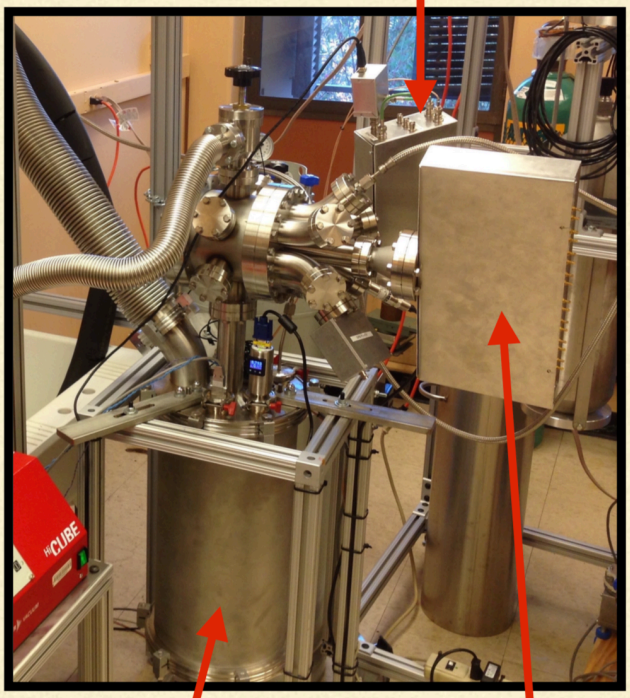


DAX External Setup

Thermosiphon LN dewar

Nitrogen loop

Charge Amplifiers



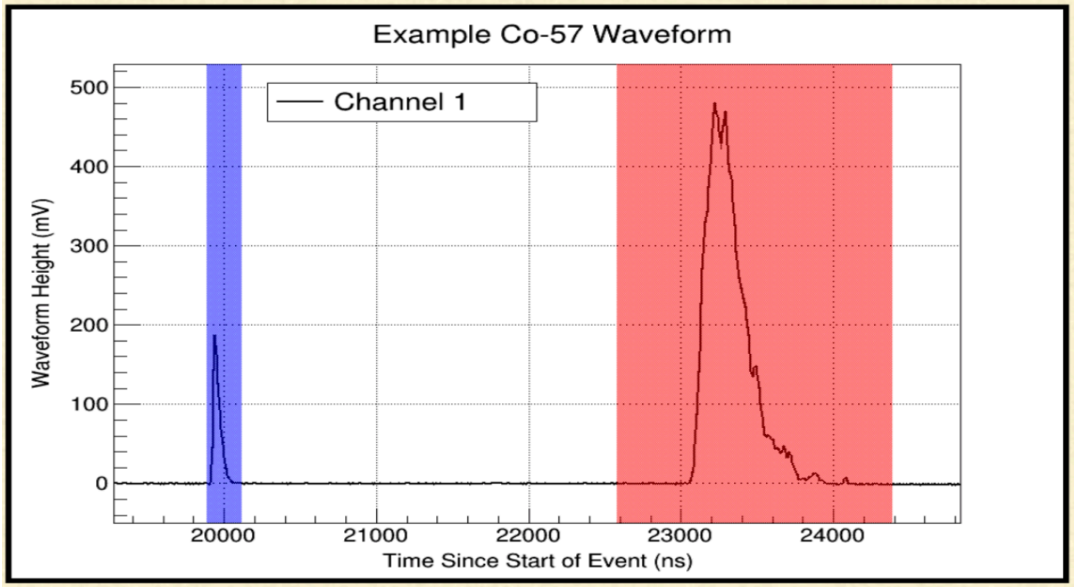
Outer vacuum cryostat

PMT Amplifier

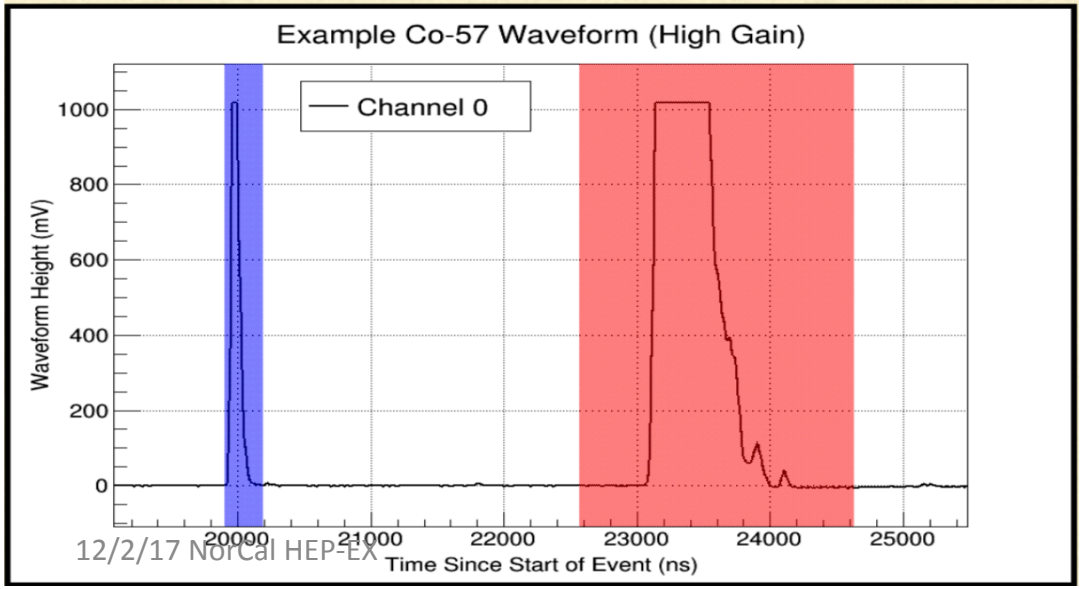
Xe circulation rack

Getter for purification

Co-57 Calibrations

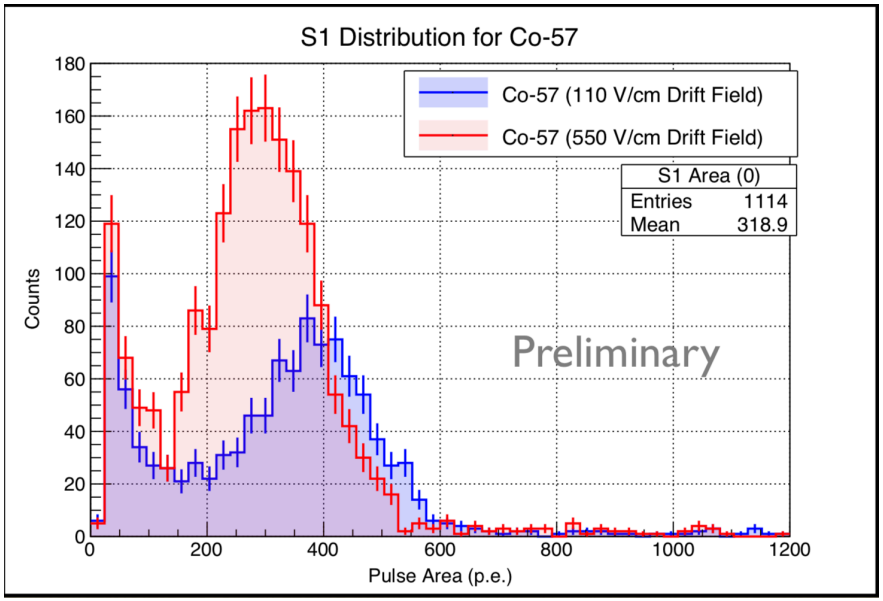


Calibrate using Co-57 source, which produces a 122 keV gamma likely to undergo full photo-absorption in the LXe.



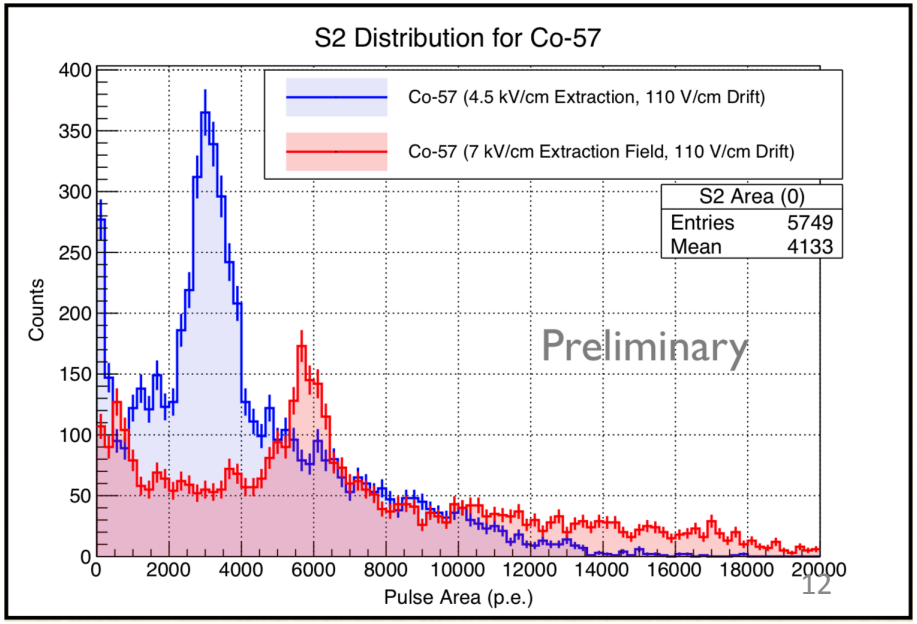
Shown is an example Co-57 event in both gain channels.

Co-57 Calibrations

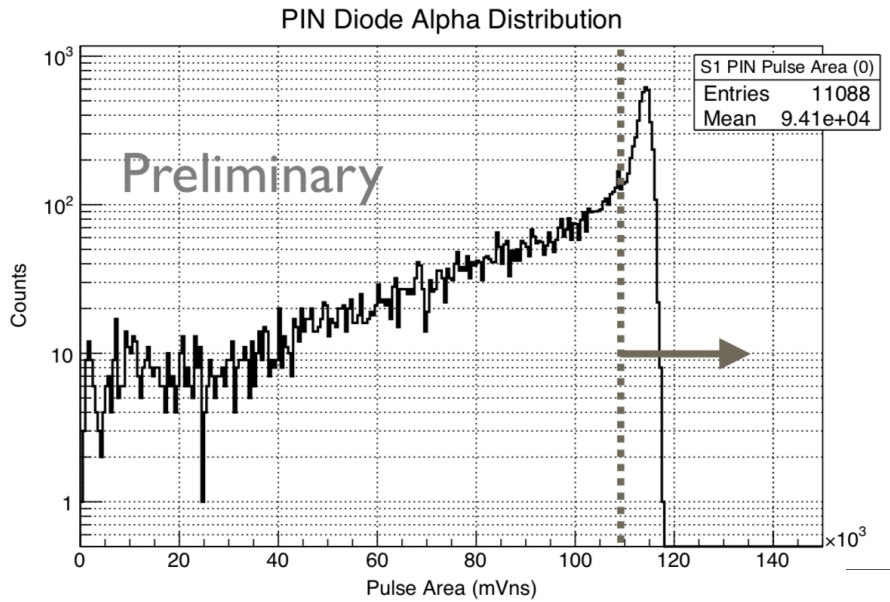


Higher Electric fields inside our TPC yield decreased S1 signals

Raising the extraction field at the liquid surface (via the anode voltage) gives an expected increase in the S2 size.

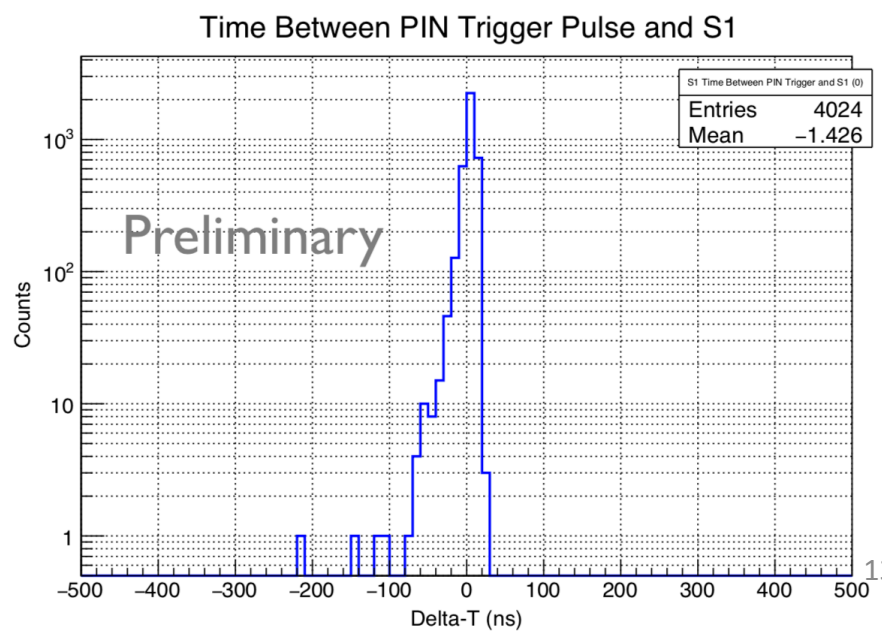


Alpha Tagging in DAX DATA



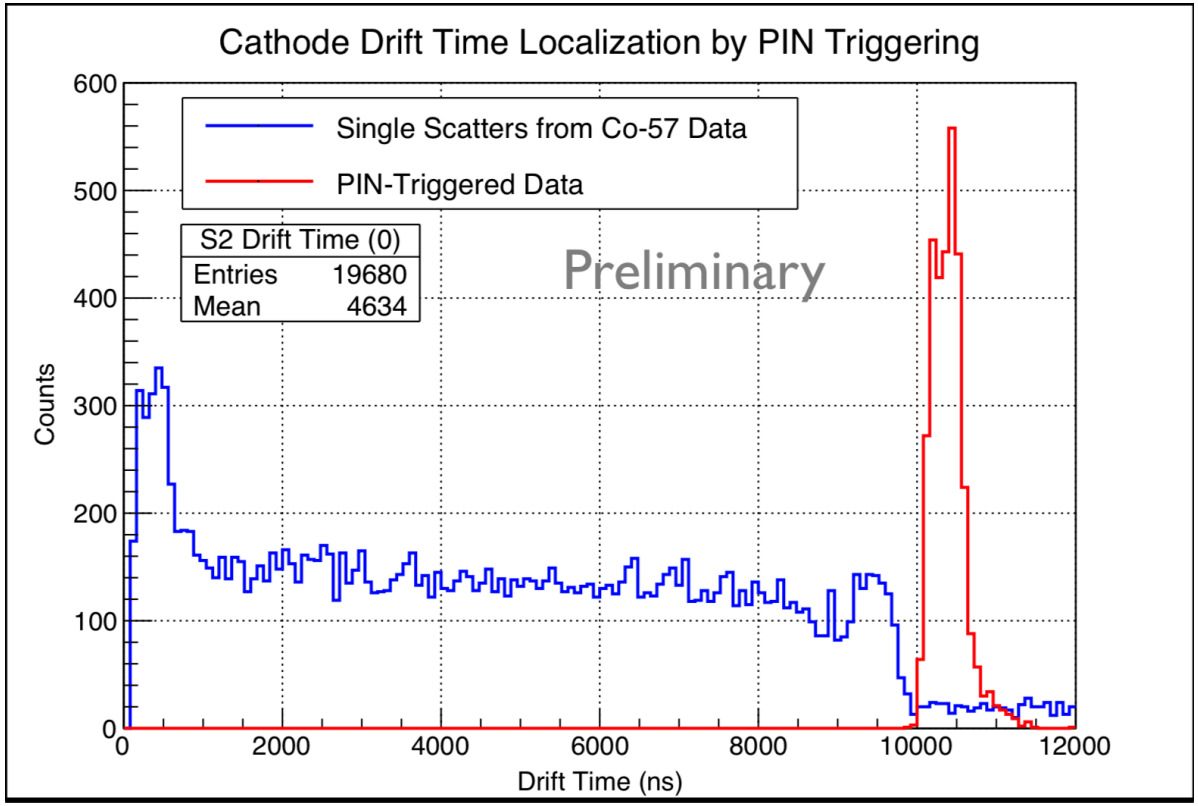
We cut on the sharp area peak, where alphas are emitted straight down into the PIN with full energy deposition.

After requiring a PIN trigger pulse with sufficient area, we cut on single scatter events (1 S1, 1 S2) and plot the time separation between the S1 and PIN trigger.

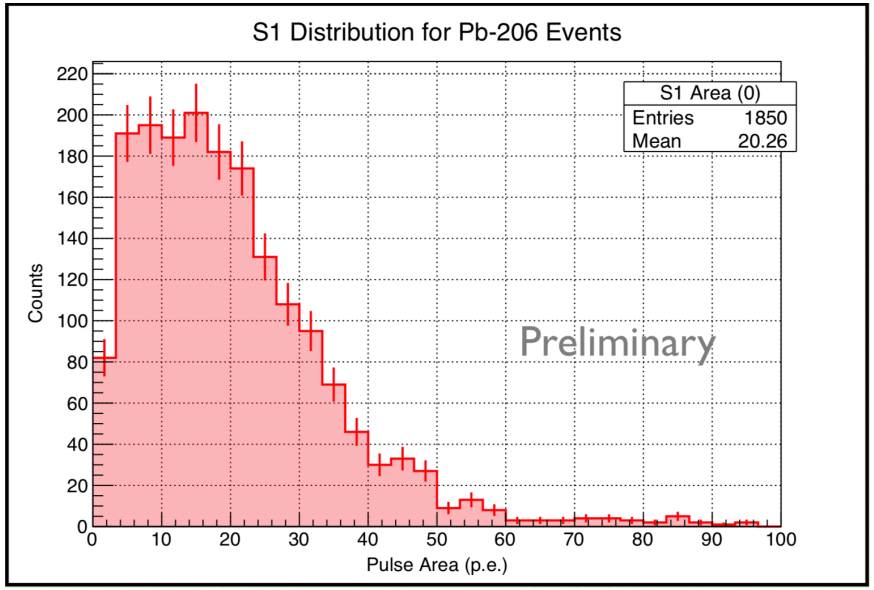


Drift Times for Candidate Pb-206 Events

The PIN pulse area and coincidence cuts give events exclusively at high S2 drift, localized to the cathode.



Distributions for ^{206}Pb Candidates

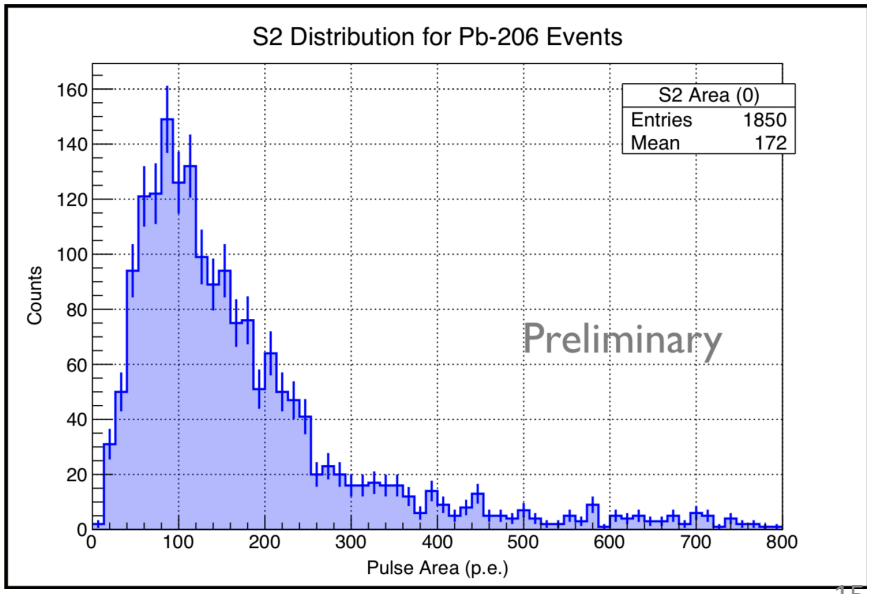


The S1 distribution for these events is peaked at ~15 photoelectrons.

Given that the light yield is very small, the distribution runs into our pulse-finding threshold at around 2 PE.

The S2 distribution for these events is peaked at ~100 PE

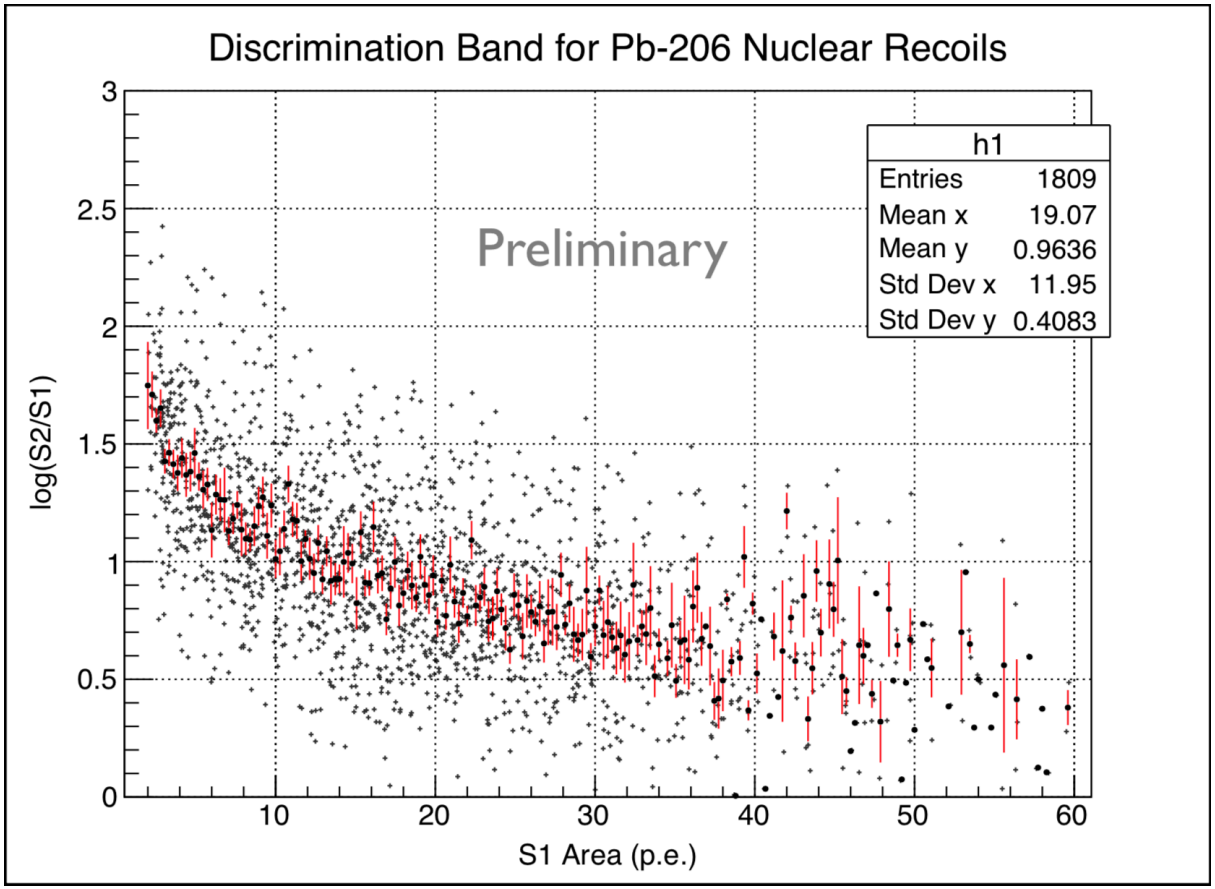
Charge loss and field effects near the cathode will need to be further studied.



Nuclear Recoil Band for ^{206}Pb

Shown is the charge-to-light ratio as a function of S1, which is used a discrimination tool in Xe detectors.

Means for the NR band are given with red error bars.



Summary

- A floating PIN diode doped with Po-210 has been utilized in the DAX Xe TPC, and is serving as an effective trigger for Pb-206 nuclear recoils.
- Further detector calibrations and characterizations are forthcoming, along with higher statistics datasets.
- More work remains to be done in order to precisely compare with current NEST models, and hopefully inform the model for Pb-206 nuclear recoils.

Special Thanks to

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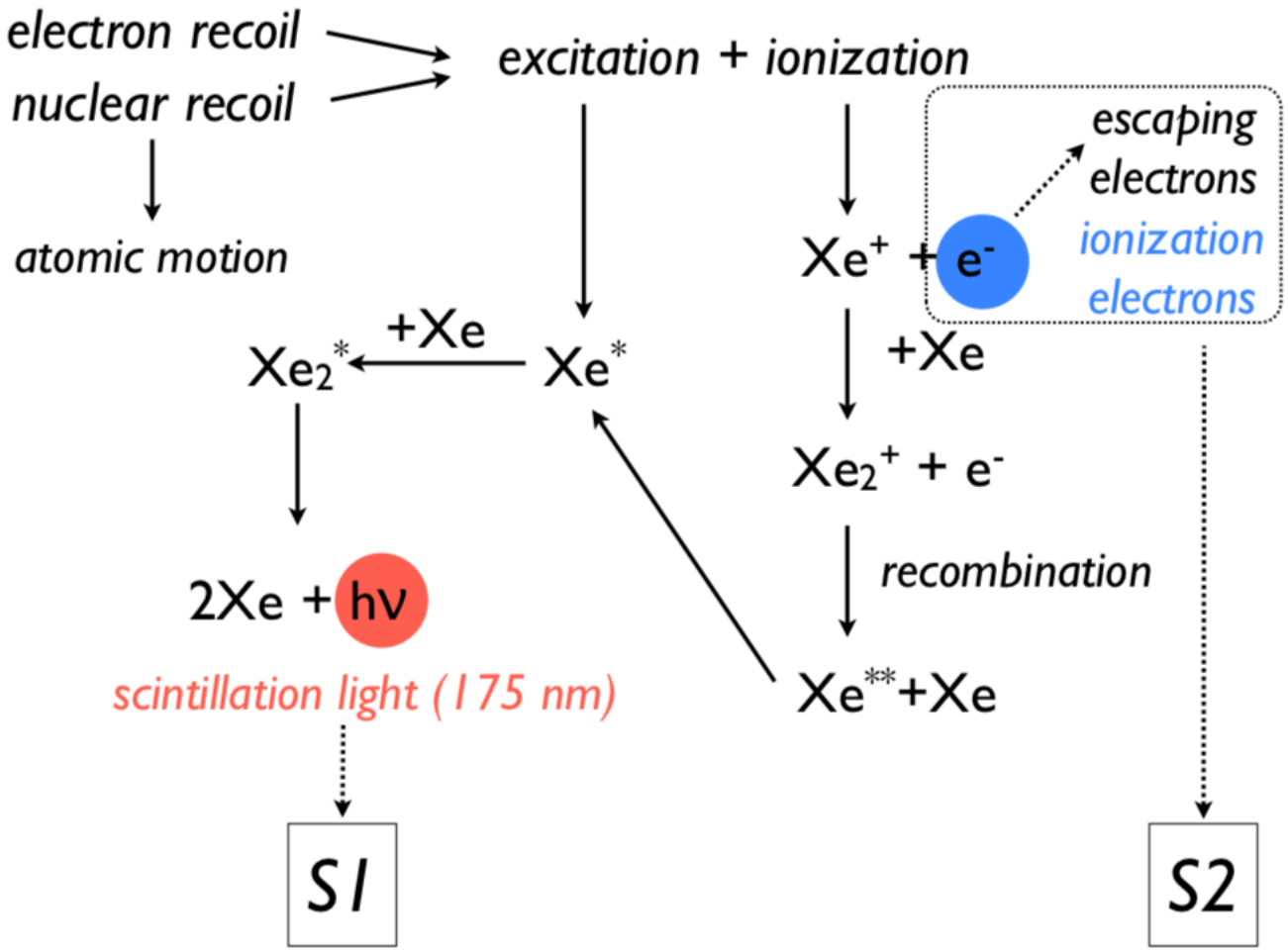
Extra Slides

Signal Production & Collection