Ultra-low Energy Calibration of the LUX detector with pulsed D-D neutrons and ^{127}Xe Electron Capture Events

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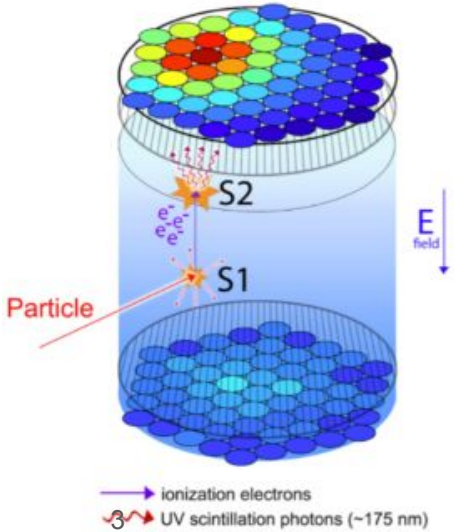
BROWN

Sec 1: LUX NR Energy Calibration using Pulsed D-D neutron

LUX Experiment

- LUX carried out two WIMP search runs from 2013 to 2016 (95 live days + 332 live days) arXiv:1608.07648
- LUX has also carried out a significant amount of calibrations for LXe NR and ER response
- LUX is leading the field of the NR calibration with DD neutron source arXiv:1608.05381
- I will present a way to further improve this technique

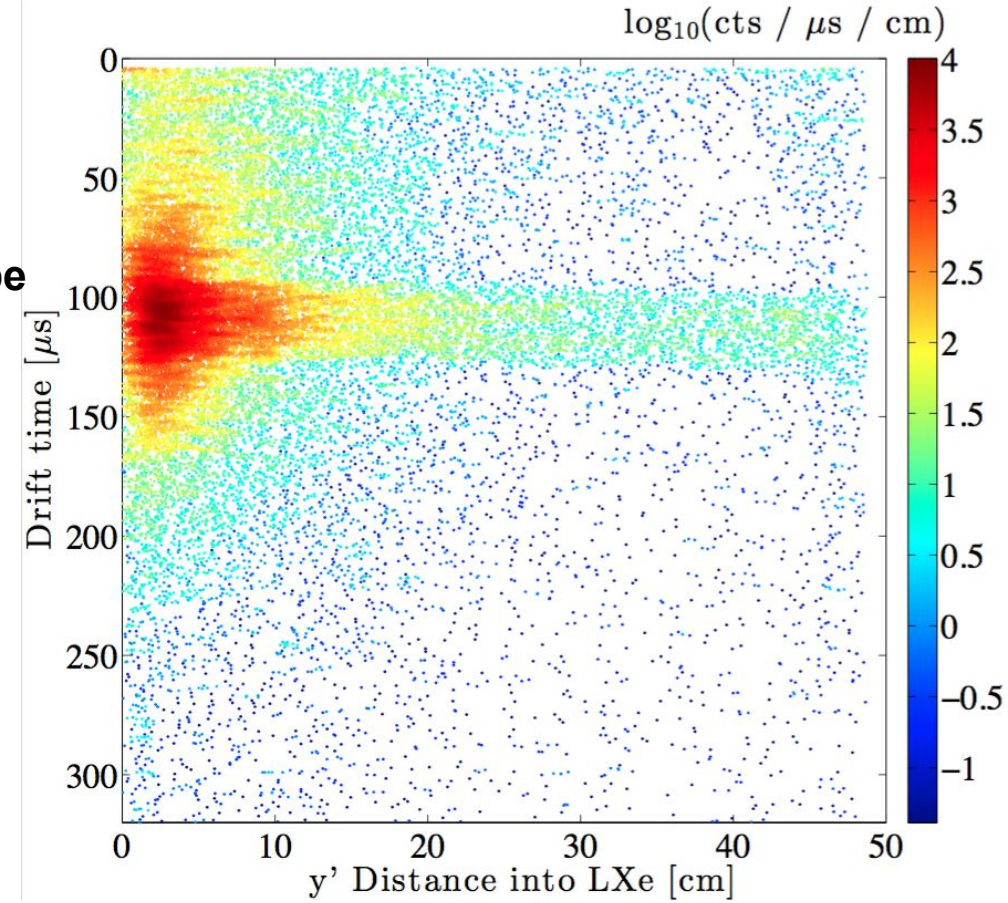
1492 m underground



LUX DD Neutron Calibration Review

DD Neutron Generator

Mono-energetic 2.45 MeV neutrons via 5 cm (ID) PVC tube

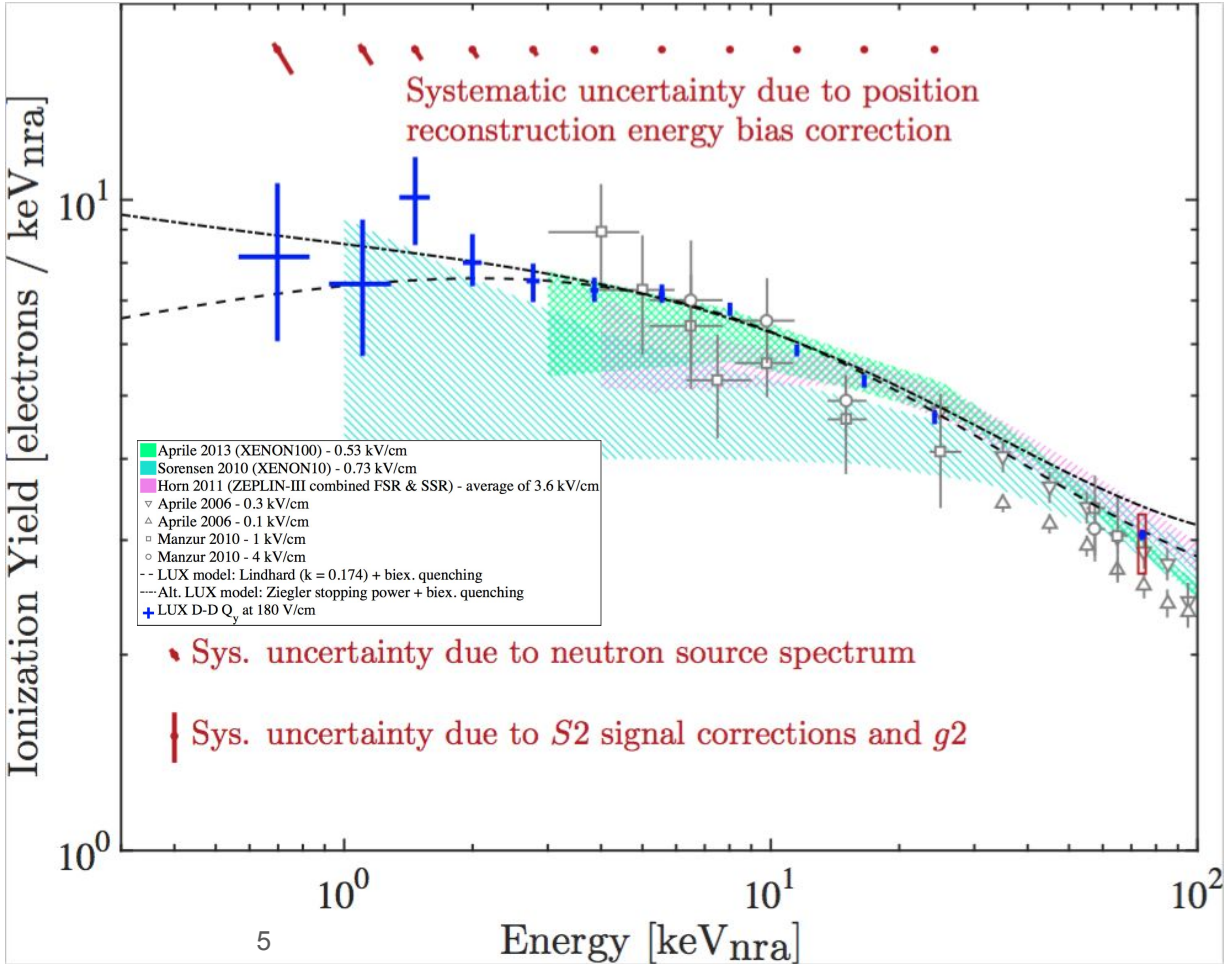


Previous LUX DD NR Calibration Results

- Blue crosses are LUX DD Qy measurements

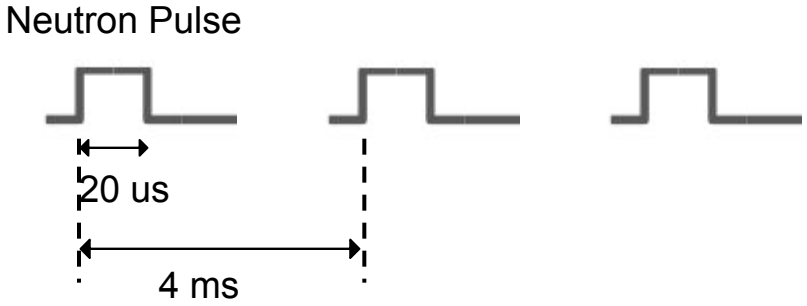
  (see backup slides for Ly)

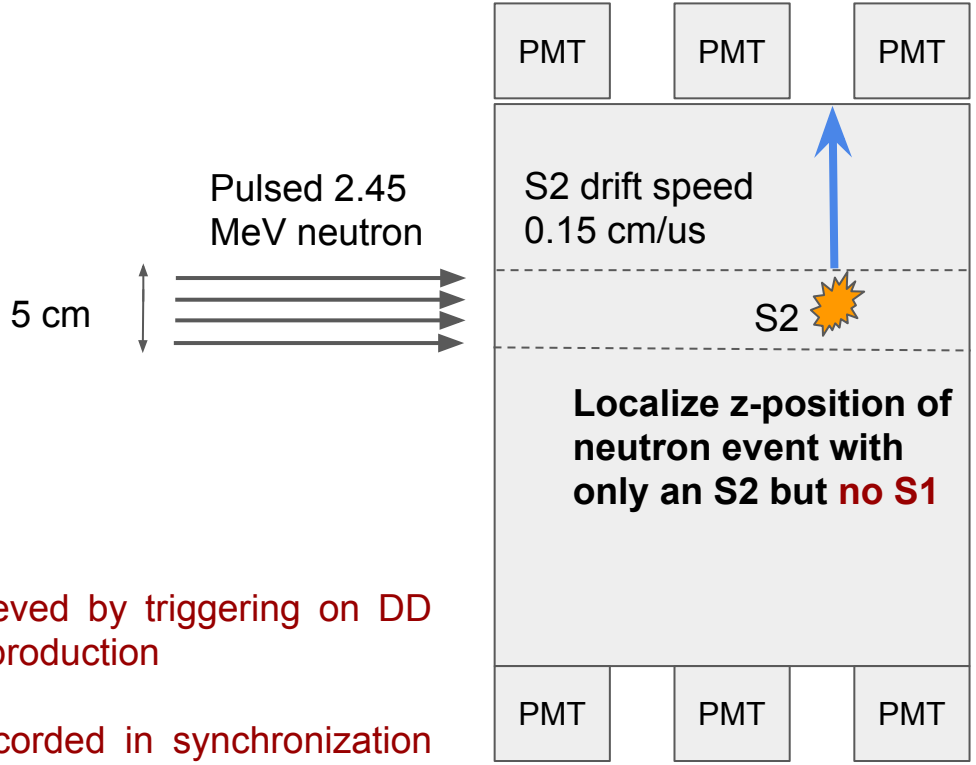
- Red bars (top and bottom) indicates the systematic uncertainties



D.S. Akerib *et al.* (LUX Collaboration), (2016), arXiv:1608.05381

LUX Pulsed DD Neutron Calibration





1. The neutron pulse is achieved by triggering on DD neutron generator neutron production
2. The DD trigger time is recorded in synchronization with LUX neutron event signals
3. Neutron time of flight is at an order of 100 ns, negligible given typical S2 width(10%-90%) at ~2 us.

LUX Pulsed DD Neutron Calibration

Event can be explored before DD trigger implemented:

1. Neutron event with one S1 and one S2

S1 define event t0 time

LUX Pulsed DD Neutron Calibration

Event can be explored after DD trigger implemented:

1. Neutron event with one S1 and one S2

2. Neutron event with no S1 and one S2

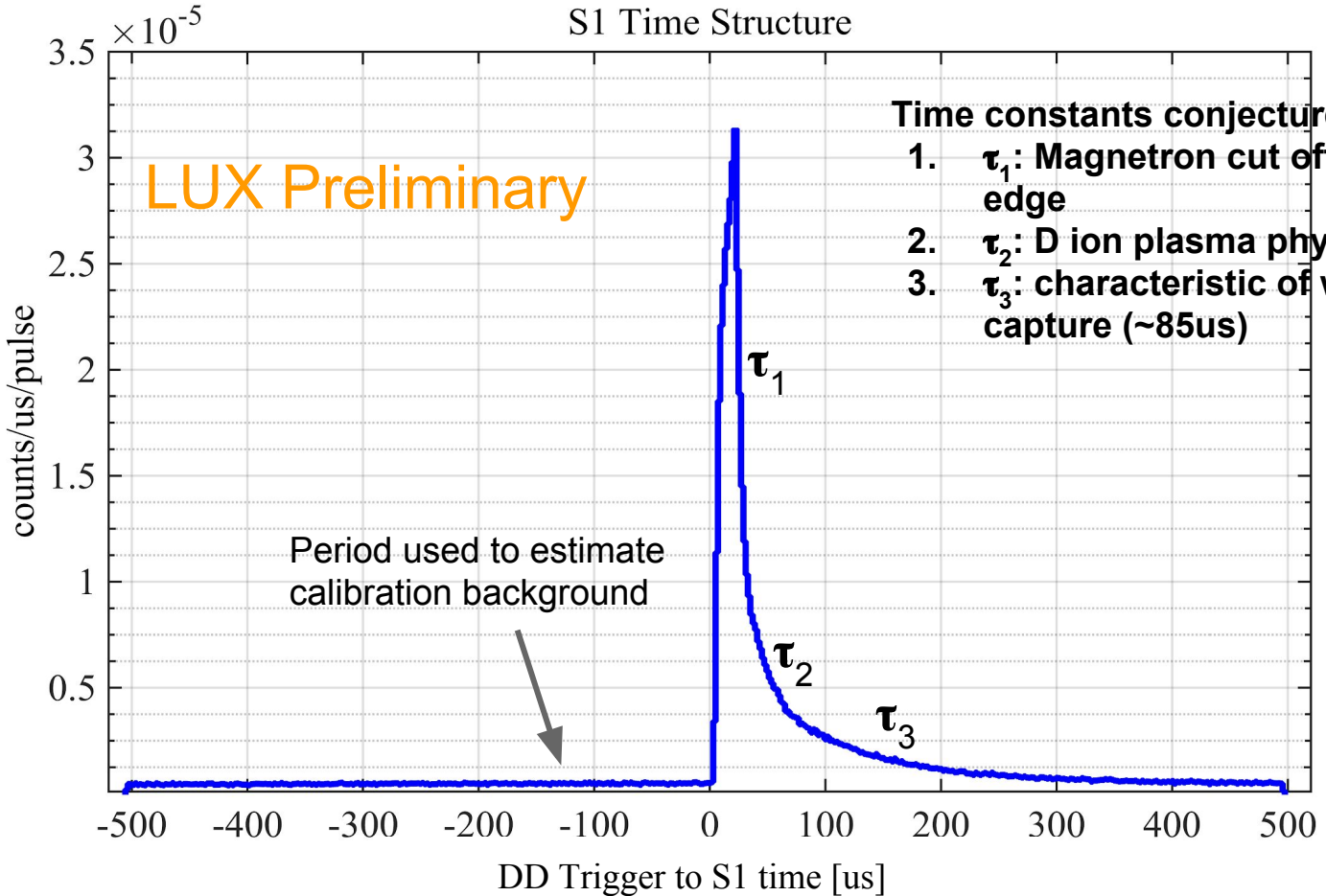
DD trigger can replace S1 to define event t0 time

LUX Pulsed DD Neutron Calibration

Advantages of Pulsed DD Neutron:

1. Probe no S1 one S2 neutron event
2. Reduce calibration background with increased instantaneous intensity but 0.5% duty cycle
3. Establish calibration background with events before neutron pulse to reduce systematics
4. Probe other physics associated with neutron (e.g. thermal component)

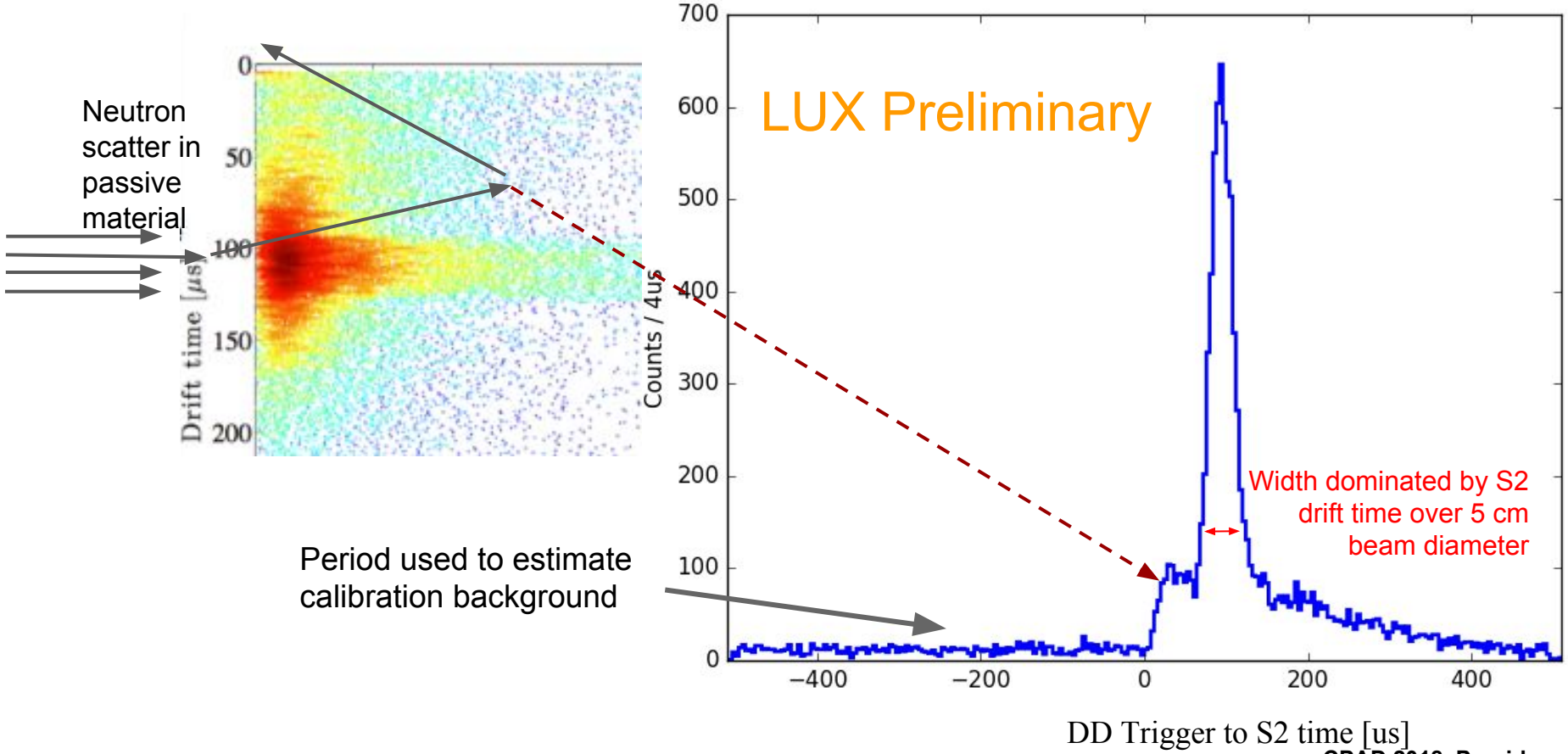
Neutron Event Time Structure (S1 wrt DD Trigger)



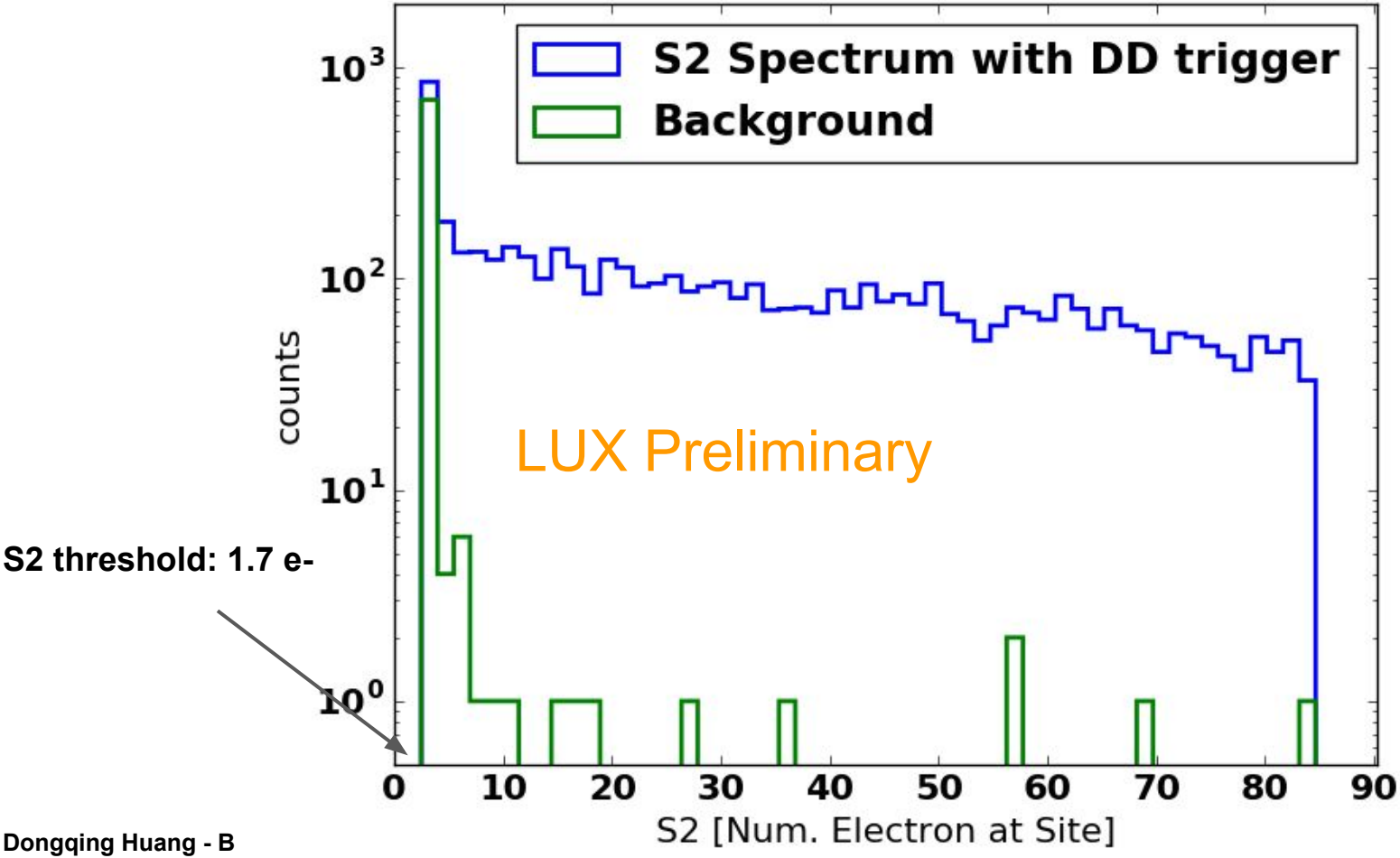
Time constants conjecture

1. **τ_1: Magnetron cut off / peak falling edge**
2. **τ_2: D ion plasma physics (~30us)**
3. **τ_3: characteristic of water thermal capture (~85us)**

S2 Arrival Time wrt DD Trigger

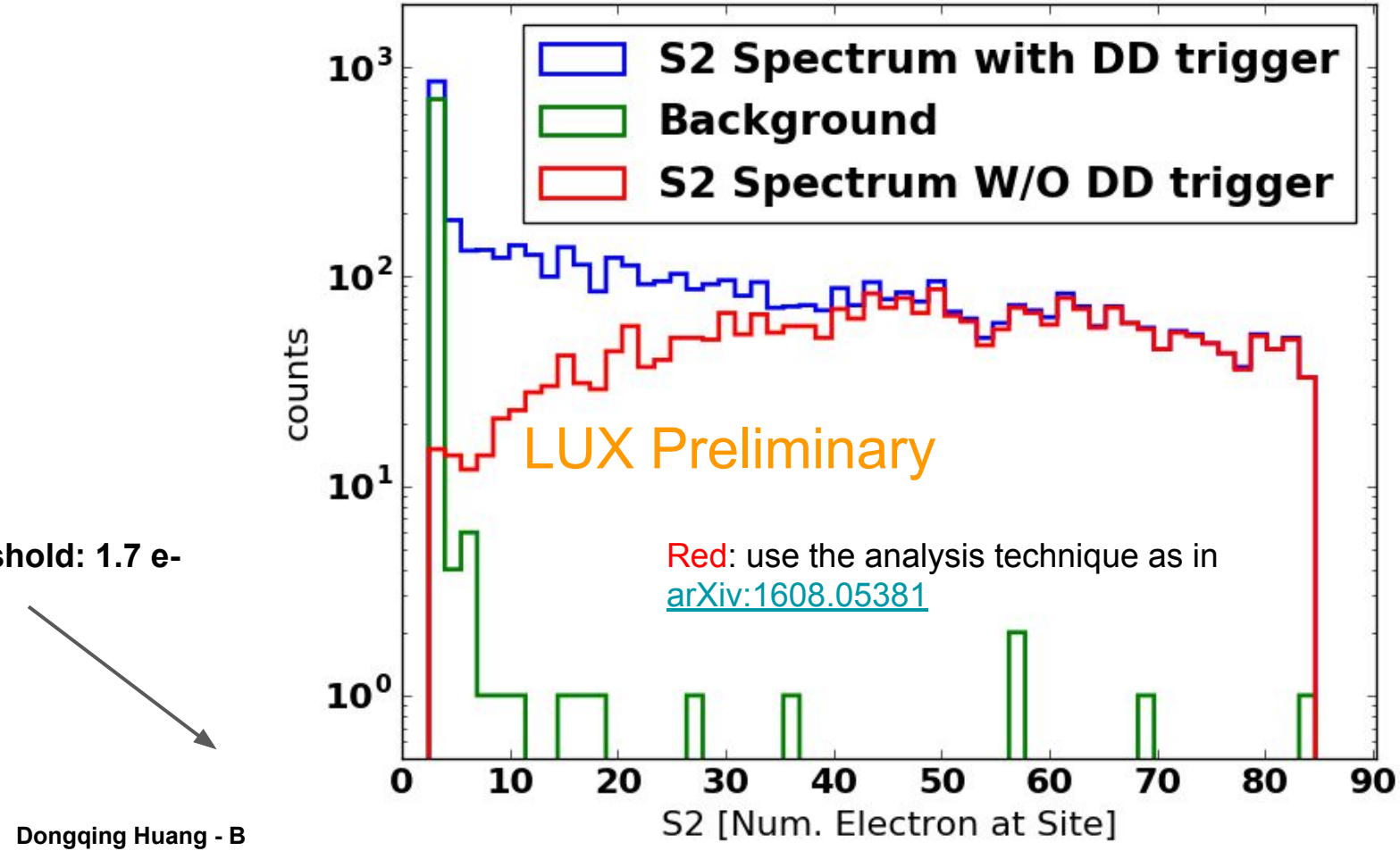


S2 Spectrum of Events With Pulsed Neutron

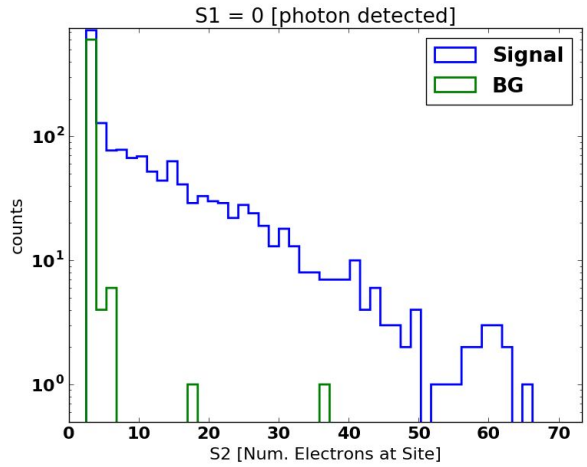


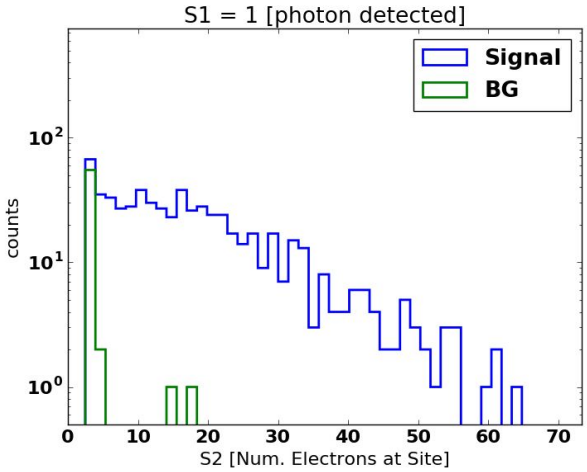
S2 Spectrum of Events With Pulsed Neutron

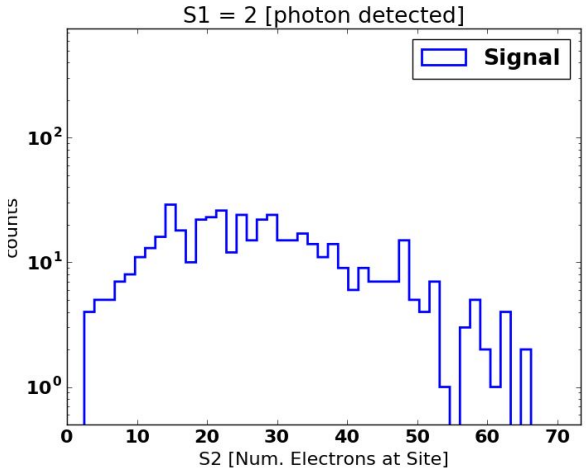
shold: 1.7 e-

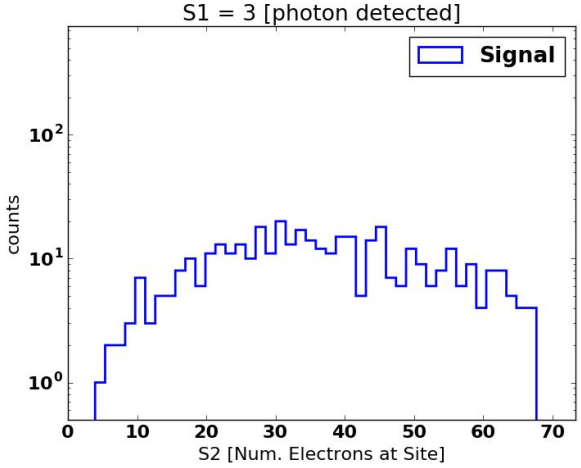


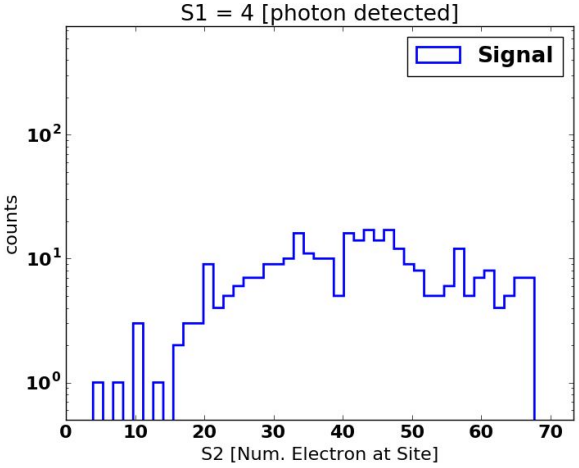
S2 Spectrum @ S1=0,1,2,3,4 phd











(see backup slides for LUX S1 resolution)

All figures in this slide LUX Preliminary

Discussion and Conclusion For DD NR Calibration

1. Compare data and sim of relative counts among S1=0, 1, 2, 3, and 4 phd to measure NR light yields
2. Compare data and sim of S2 spectra at S1=0 and 1 phd to measure NR charge yields
3. Additional work (not presented at this talk) has shown good agreement between LUX pulsed DD neutron data and Sim modeling
4. Additional work (not presented at this talk) has demonstrated LUX pulsed DD neutron data has an sensitivity to 0.2 keVnr, a significant step beyond the most accurate low energy calibrations by LUX Run3 DD calibration
5. Final Result will be available to public early of 2019

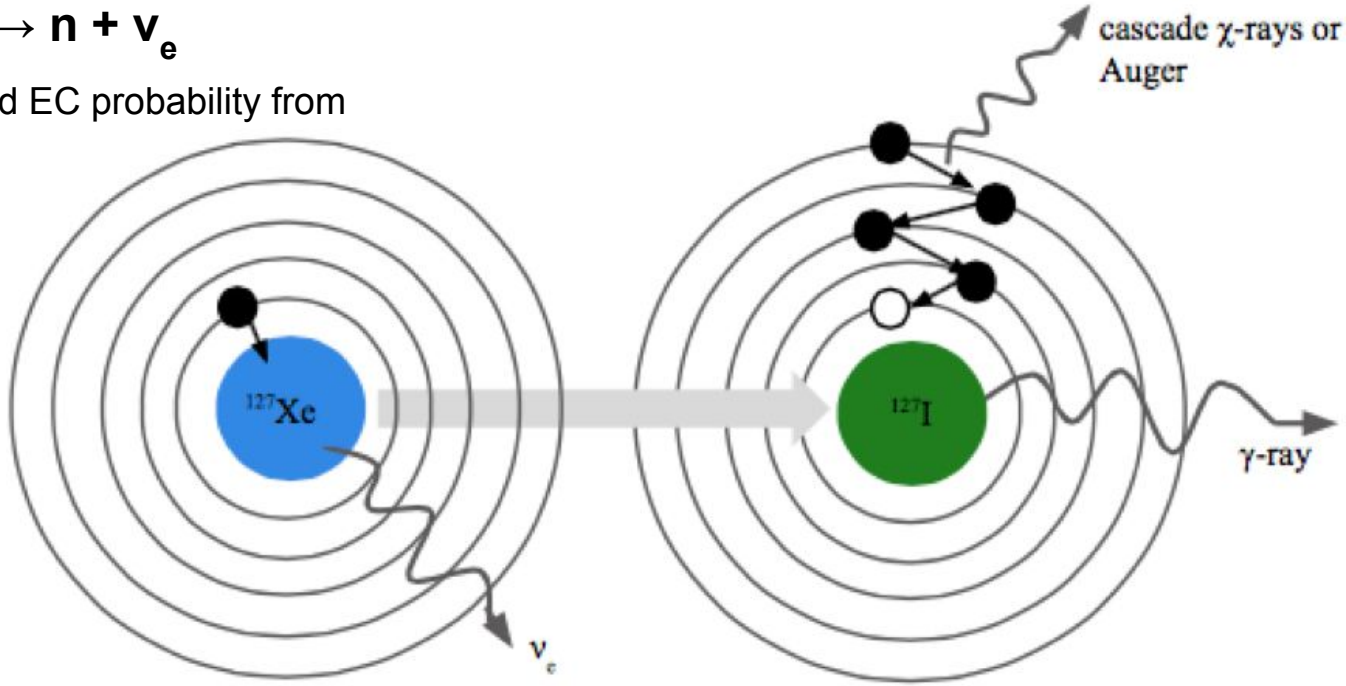
Sec 2: LUX ER Energy Calibration using ^{127}Xe Electron Capture Events

Xenon-127 Decay Toy Model

Electron Capture: $p + e^- \rightarrow n + \nu_e$

The binding energy and expected EC probability from that shell

- K: 33.2 keV 83.4%
- L: 5.2 keV 13.1%
- M: 1.1 keV 2.9%
- N: 186 eV 0.6%



- Cosmogenic activation
- Half life: 36 days
- Based on the measurement of Apr22 2013 data, there are ~0.8million ^{127}Xe atoms in LUX Xenon volume

Xenon-127 EC Decay Event in LUX Detector

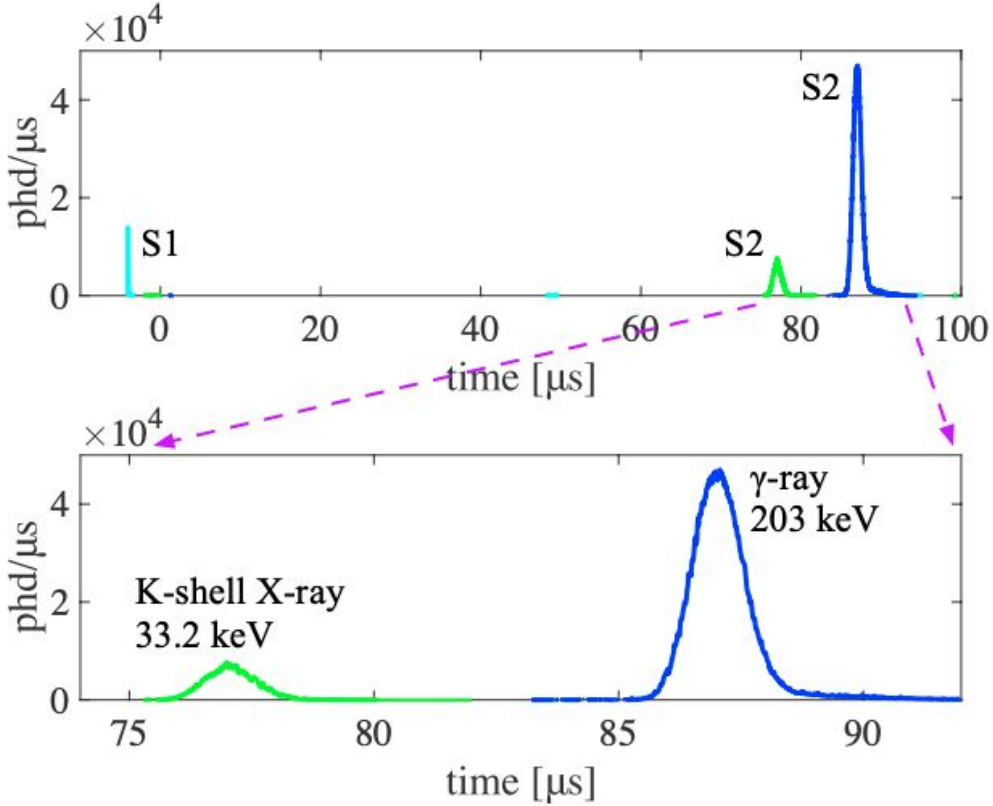


Fig. - A real 127Xe decay event with K shell electron capture. The event waveform appears as one S1 followed by two well-operated S2s

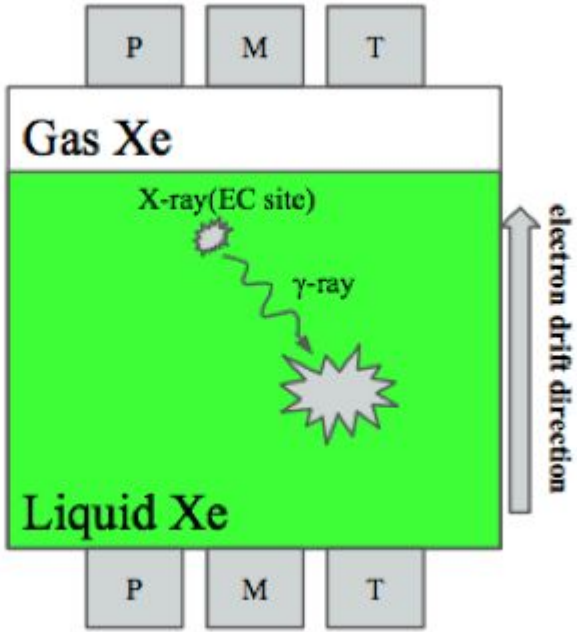


Fig. - Event Schematics in Detector

Xenon-127 EC Events in Data

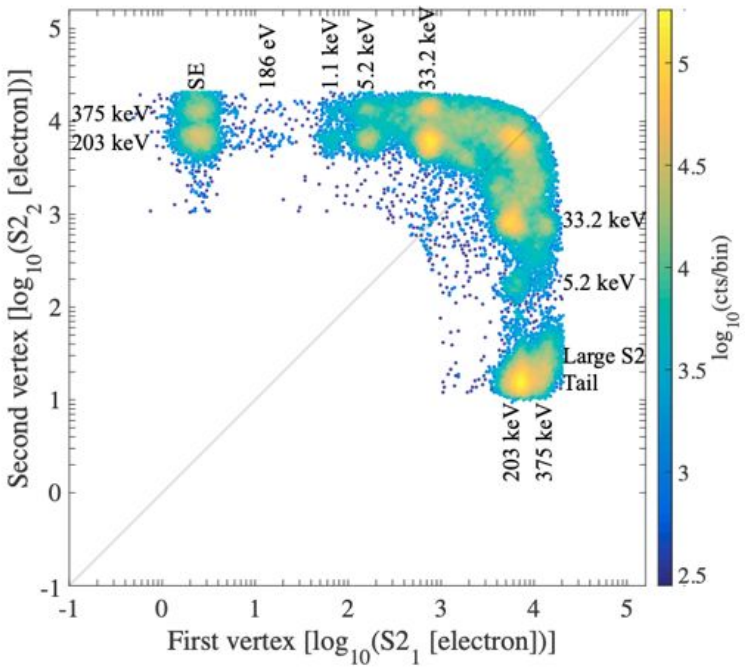


Fig. - Scatter plot of 127Xe events with area of first vertex S2 versus are of second vertex S2; “First Vertex” is the first S2 ordered by drift time

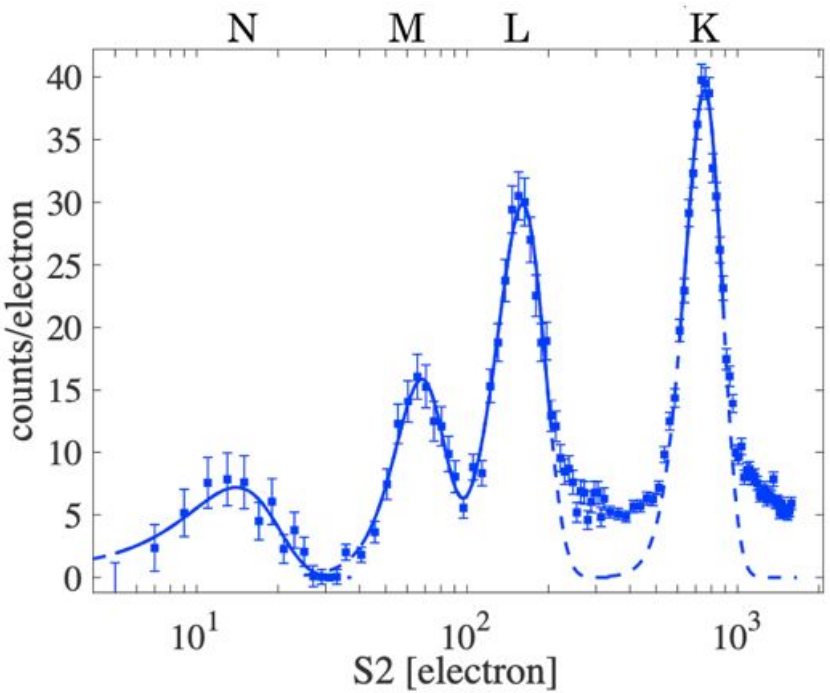
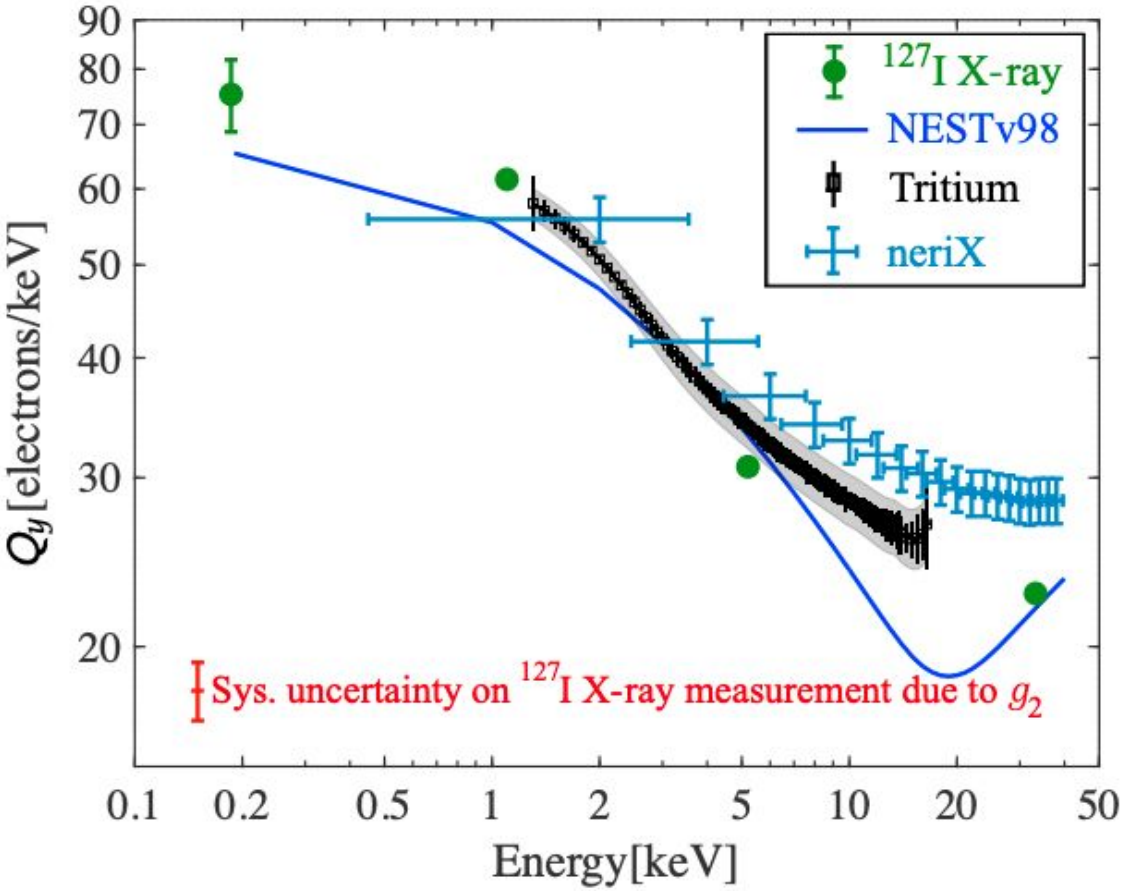


Fig. - X-rays’ ER charge spectrum

Xenon-127 Charge Yields



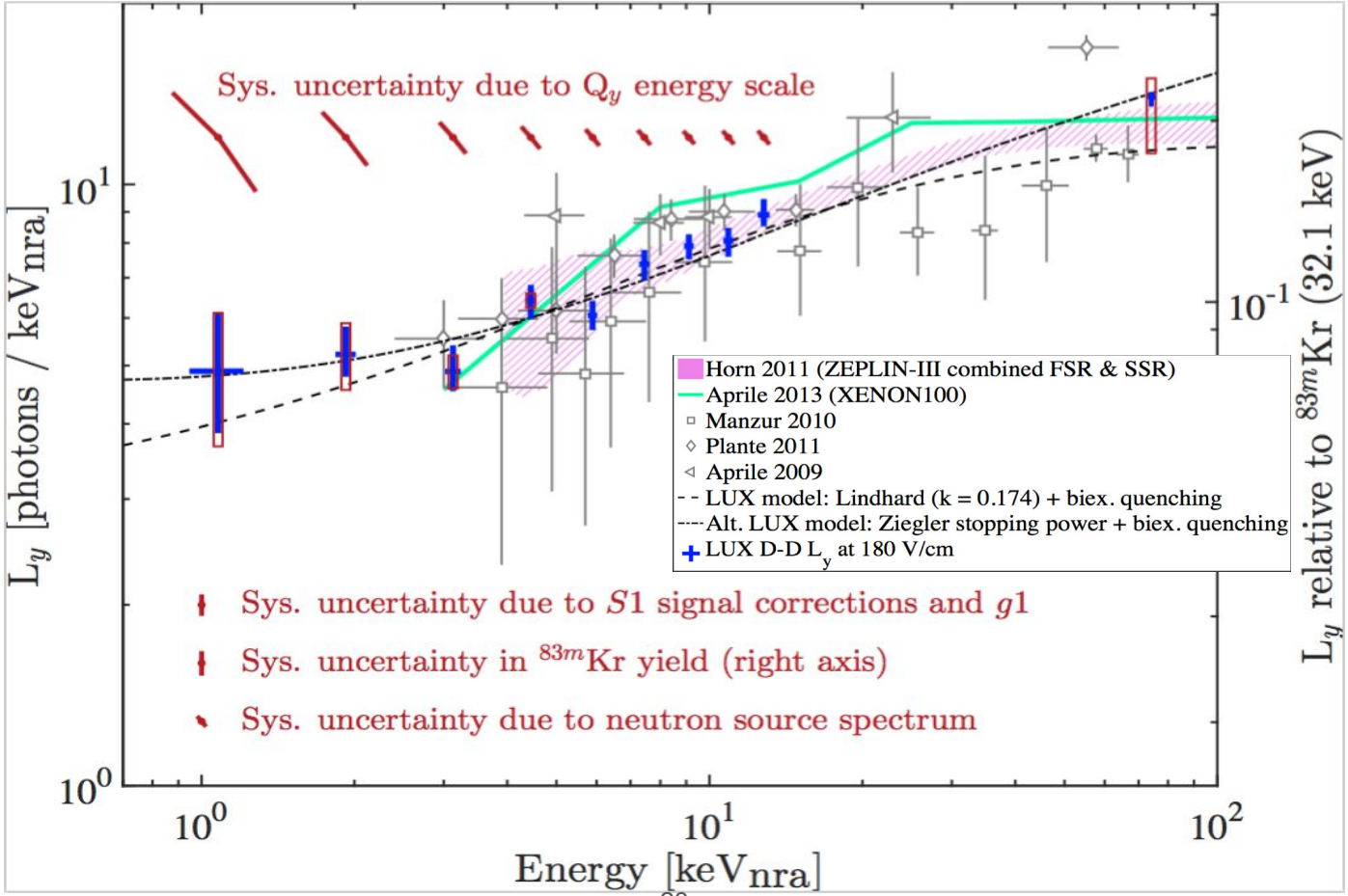
https://arxiv.org/pdf/1709.00800.pdf

Conclusion

- LUX has achieved a better understanding of Xe NR and ER response than any other dark matter search experiment
- In-situ calibration
- These results further improves LXe TPC to low mass WIMPs and Neutrino Scattering

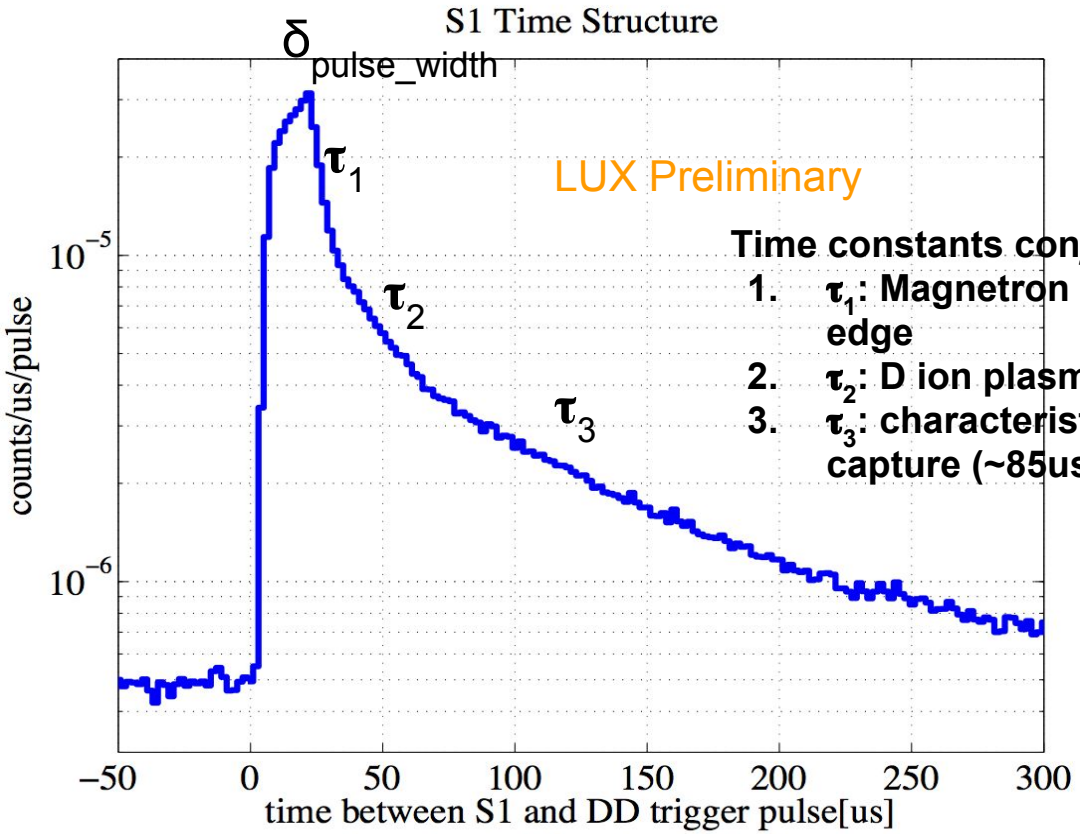
Backup

Previous LUX DD NR Calibration Results - Ly



Neutron Event Time Structure WRT DD Trigger

Log scale:



Time constants conjecture

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S1 Resolution

NR band taken from arXiv:1608.05381 for S1 resolution demonstration