Determination of Backgrounds for the LUX Experiment

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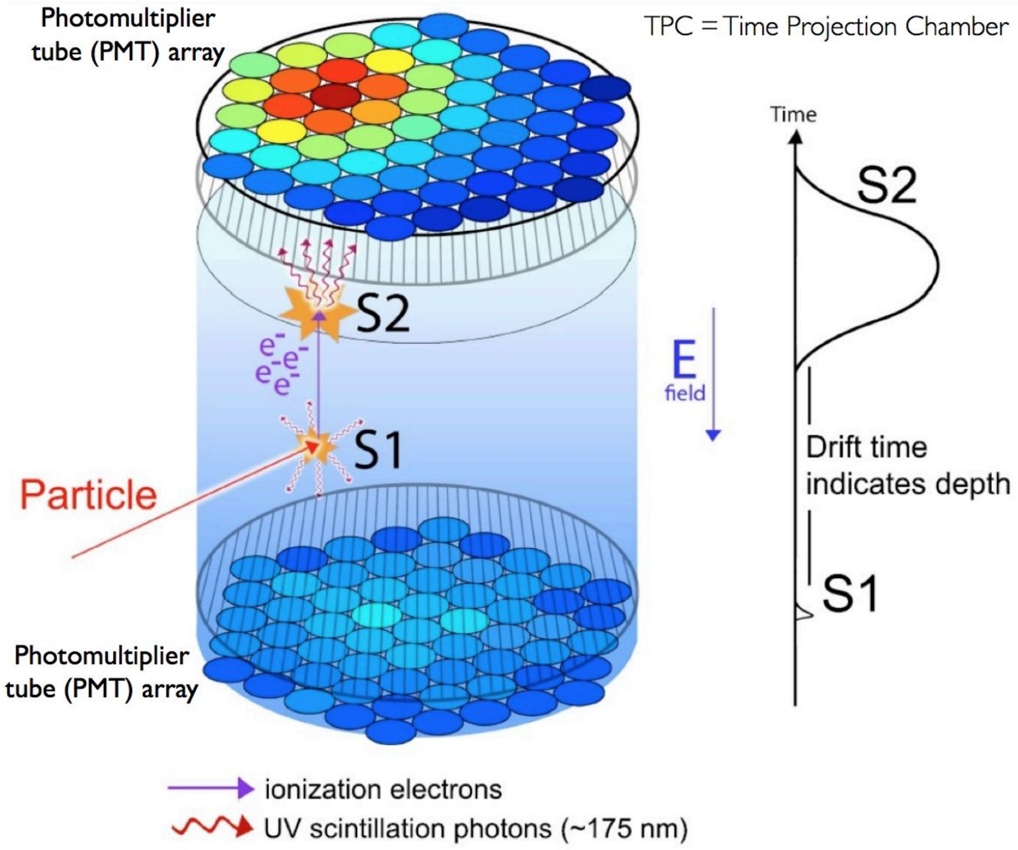
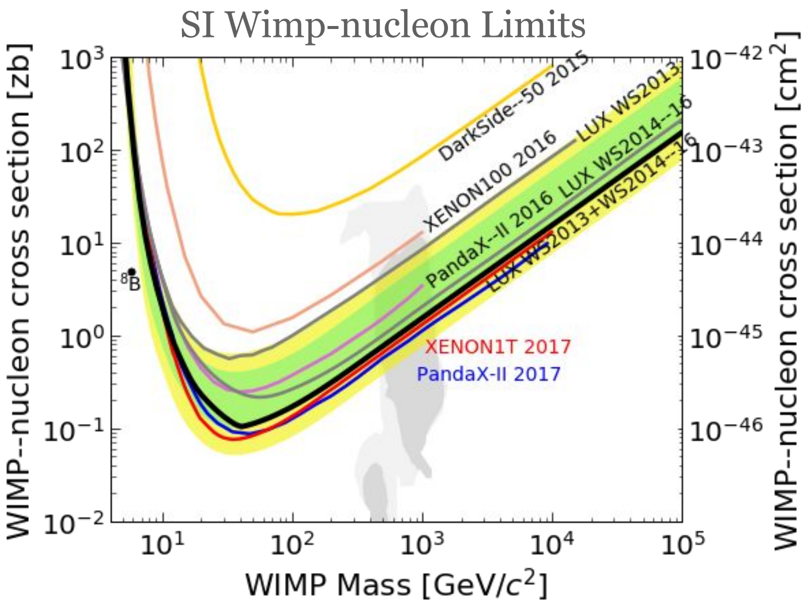
On behalf of the LUX collaboration

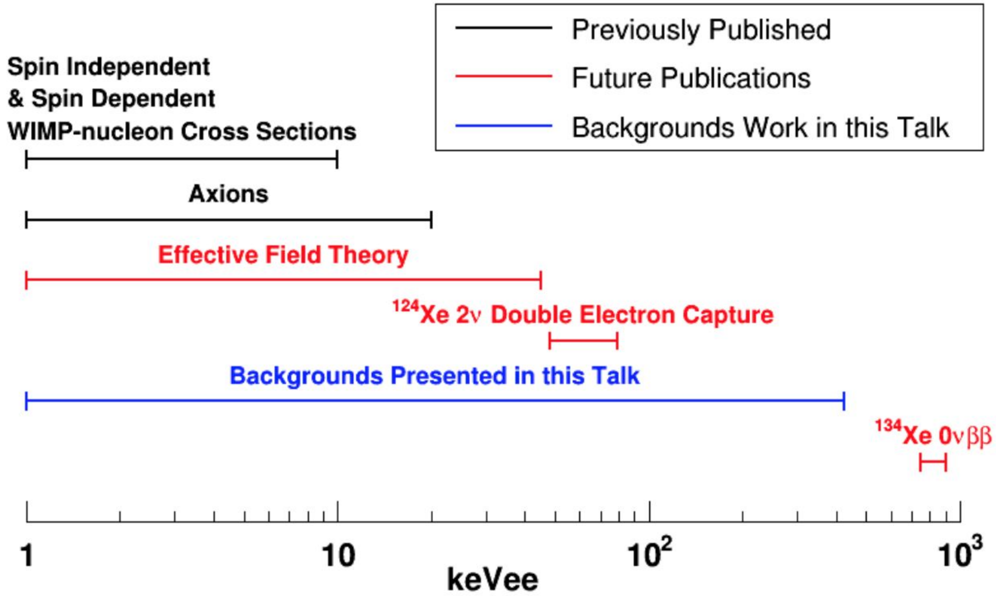
Large Underground Xenon (LUX) Detector

- Two-phase xenon time projection chamber
- An interacting particle deposits energy in two channels
  - Excitation
  - Ionization
- Prompt scintillation (S1 signal) is immediately detected by PMTs
- Electrons are drifted upward and extracted into the gas phase region creating secondary scintillation detected by the PMTs (S2 signal)



Extending Energy





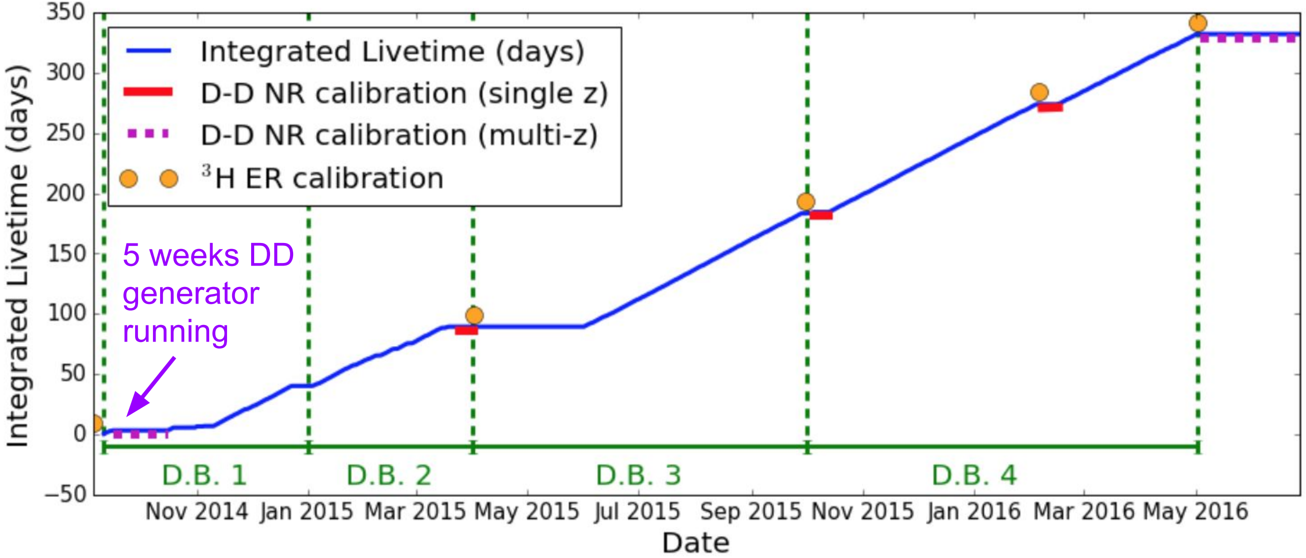
- In Jan 2017, LUX published final spin independent WIMP limit (~ 1-10 keVee)
- Data from two runs: WS-2013 (95 live days) and WS-2014/16 (332 live days)
- Now we're looking at high energy physics processes
- Additional backgrounds from **β**, **ε**, and isomeric transition decays in the xenon
- This talk will present background search results from WS-2014/16 in the energy range 0 - 425 keVee

Outline

1. Calibration of WS-2014/16 electron recoil energy scale
2. Four sources backgrounds:
   a. Short lived radioisotopes from activation of the xenon with a DD neutron generator calibrations
   b. ^{210}Pb from ^{222}Rn daughter plate-out on detector surfaces
   c. Detector effects, such as PMT afterpulsing, photoionization of grids and impurities, and electron trains
   d. Neutron backgrounds from PMTs and PTFE

WS-2014/16 Calibration Data

- Every three months we perform:
  - Calibrations of the electron recoil (ER) band, light and charge yields with tritium source
  - Calibrations of the nuclear recoil (NR) band, light and charge yields with 2.45 MeV neutrons from a DD generator
  - **Calibrations of the energy of electron recoils in the detector using ^{131m}Xe, ^{129m}Xe, ^{125}Xe xenon activation lines from the DD neutron generator**

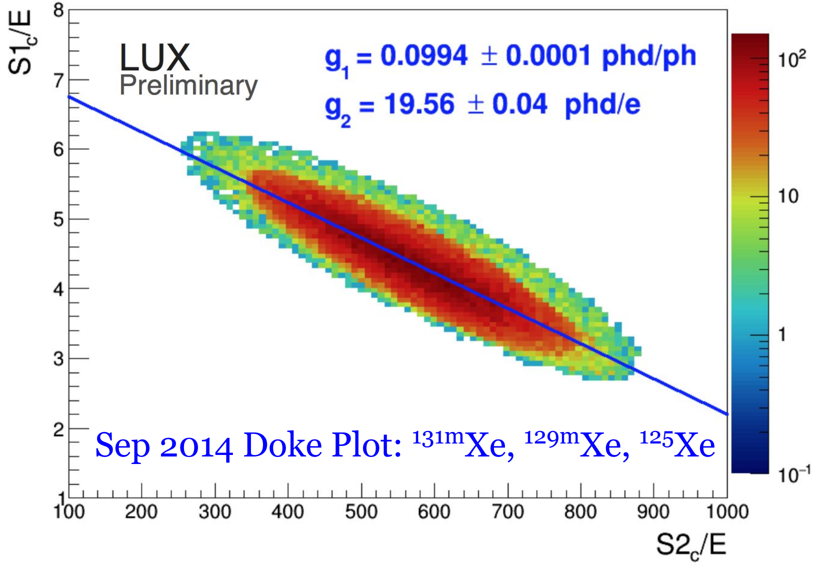


- The **data is divided into four date bins** and specific energy reconstruction parameters are applied to each bin

LUX ER Energy Calibration

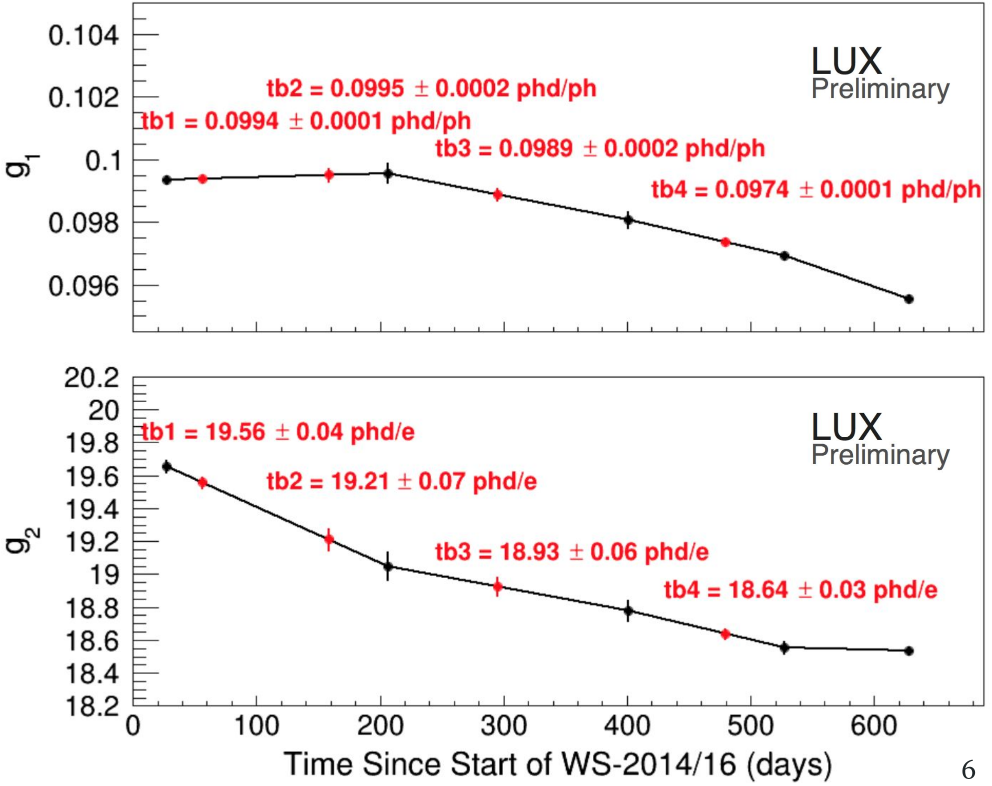
$$E = W\,(S1/g1 + S2/g2)$$

g1 = efficiency for detection of a prompt scintillation photons
g2 = efficiency/gain for detection of electron signal
W = average energy to produce a single excited or ionized atom

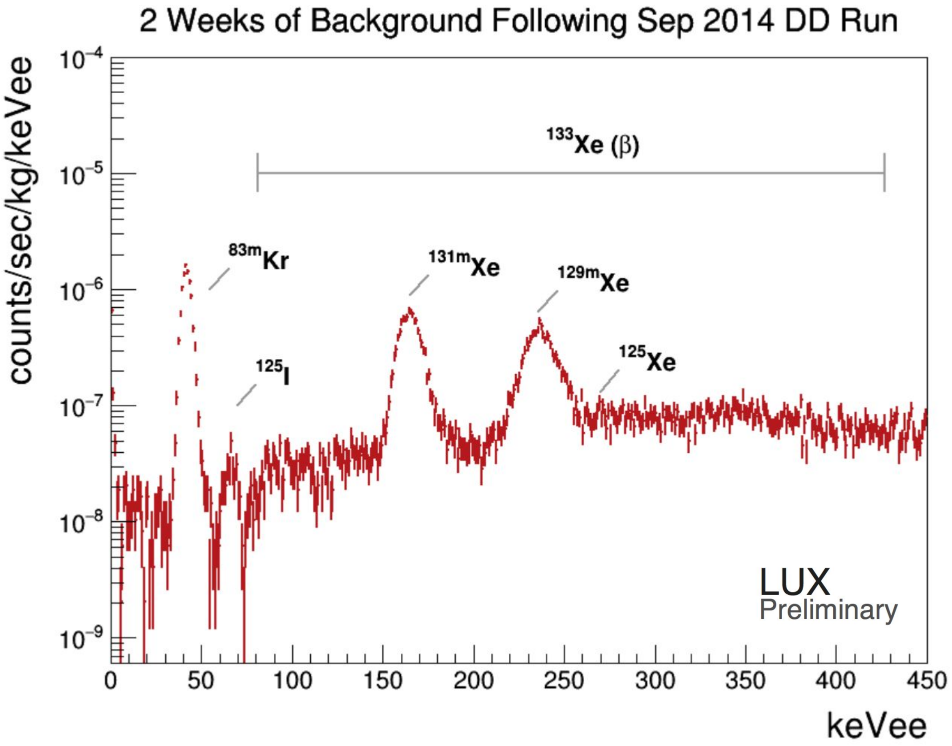


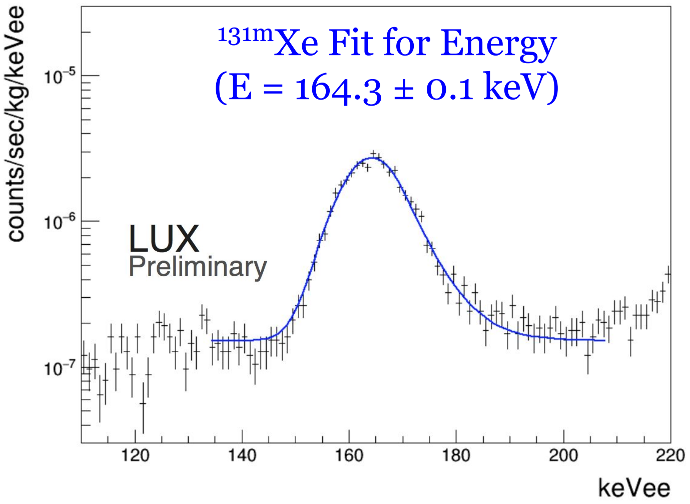
Error on g1 and g2 includes both statistical and systematic components. The systematic component comes from the elliptical cuts used to select the calibration sources.

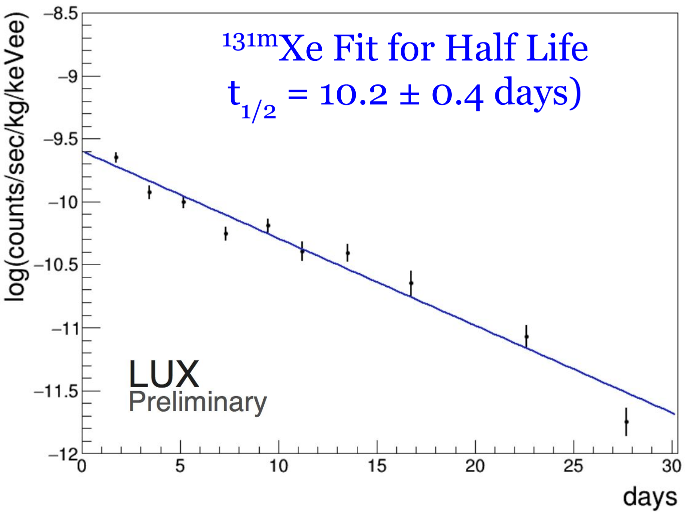
- g1 and g2 calculated at each DD calibration time
- g1 and g2 interpolated to the midpoint of each date bin



Short Lived DD-n Activation of Xe







- In addition to activation peaks, ^{83m}Kr (continuously being injected for calibration) is visible
- **Data on this slide follows the multiple neutron calibration runs over 5 weeks at different z-depths that occured in Sep 2014**

Determination of Short Lived Xe Activation Isotopes

	Decay Mode	Energy *	Measured Energy	Half Life *	Measured Decay Constant
^{125}I	ε	67.3 keV **	67.1 ± 0.4 keV	59.4 d	5.4 ±0.4 d ***
^{133}Xe	β+IT	Q_{max} = 346.4 + IT 81 keV		5.2475 d	5.0 ± 0.3 d
^{131m}Xe	IT	163.9 keV	163.6 ± 0.1 keV	11.84 d	10.7 ± 0.4 d
^{129m}Xe	IT	236.1 keV	235.3 ± 0.1 keV	8.88 d	9.1 ± 0.3 d
^{125}Xe	ε	275 keV **	275.5 ± 0.6 keV	16.9 h	

LUX Preliminary

Uncertainties in table are statistical uncertainty in the fit for energy or half life

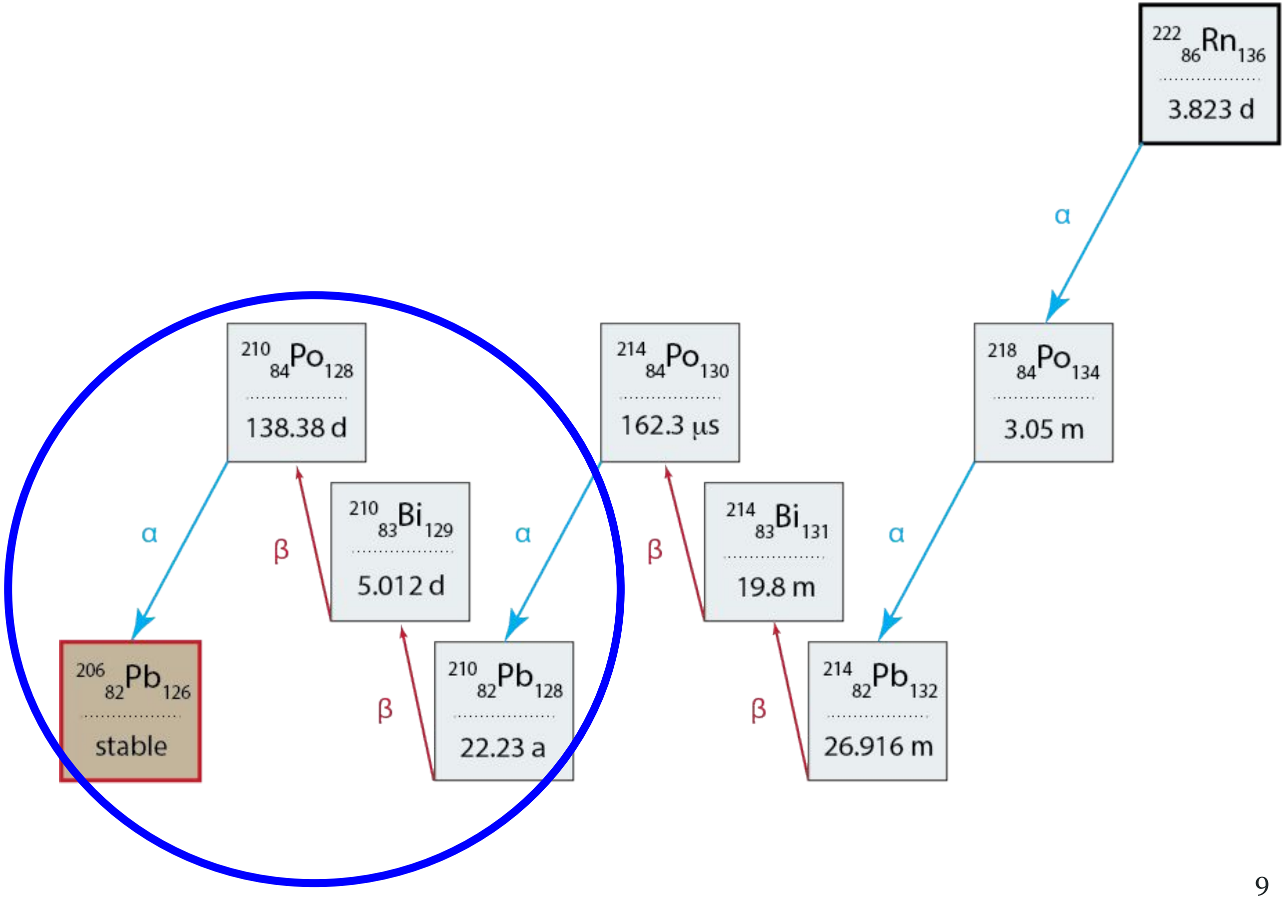
*Energy and half life measurements from National Nuclear Data Center website (http://www.nndc.bnl.gov/chart/chartNuc.jsp)

**An estimate of energy deposited in electron recoils in LUX from a K-shell electron capture

***Effective half life. Represents rate at which ^{125}I is removed from the xenon by the getter. Energy is the close the two neutrino Double Electron Capture ^{124}Xe Energy (63.6 keV)

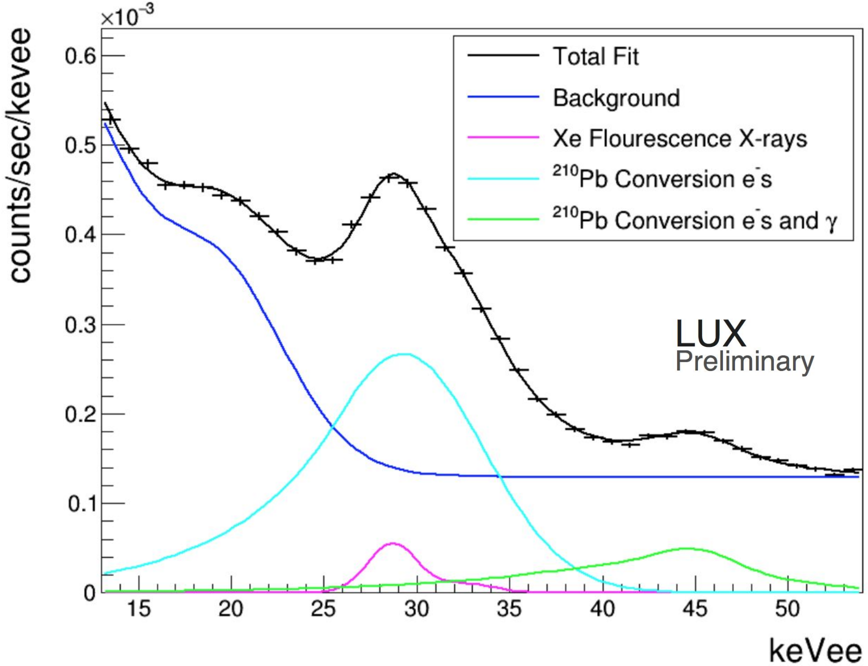
^{210}Pb on Detector surfaces

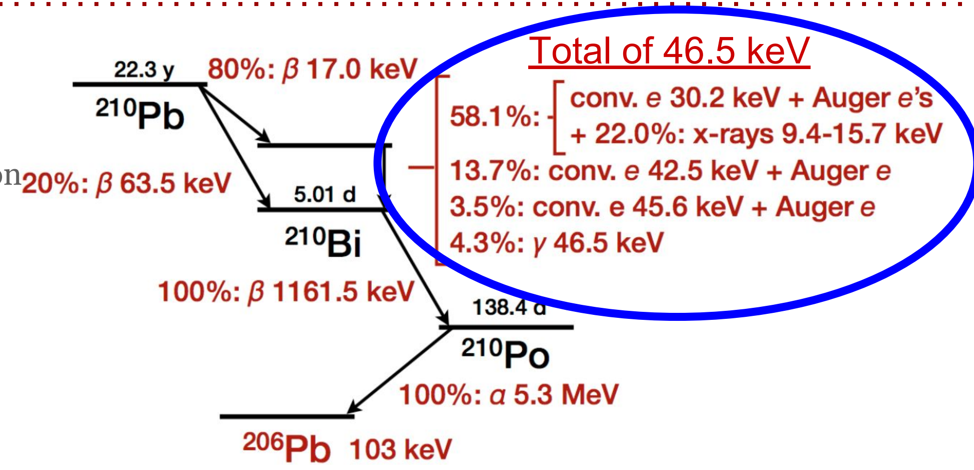
- During construction ^{222}Rn progeny plate out on the inner PTFE walls of the detector
- All short lived isotopes decay away leaving ^{210}Pb, ^{210}Bi, and ^{210}Po
- These isotopes can be absorbed off of the walls into the xenon



^{210}Pb on Walls

Fit requires contributions from ^{210}Pb conversion electrons in the range 30.1-33.1 keV, ^{210}Pb conversion electrons and gamma ray in range 42.6-46.5 keV, and xenon fluorescence in range 29.5-34.5 keV. Lower limit is set assuming LUX is capable of seeing a fraction of the ^{210}Pb decay products on the wall.





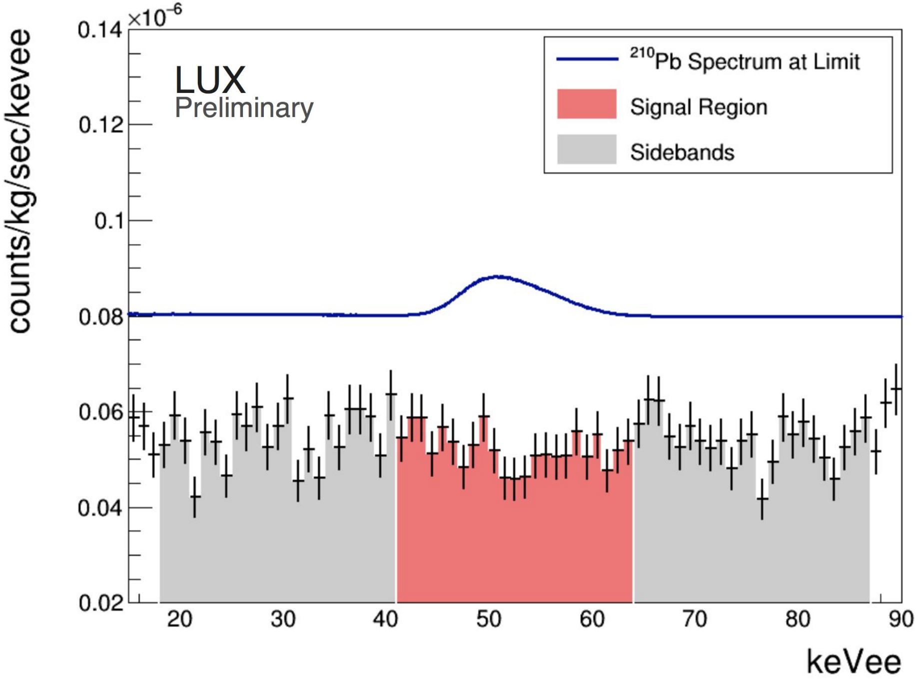
J.Low Temp.Phys. 176 (2014) no.5-6, 959-965

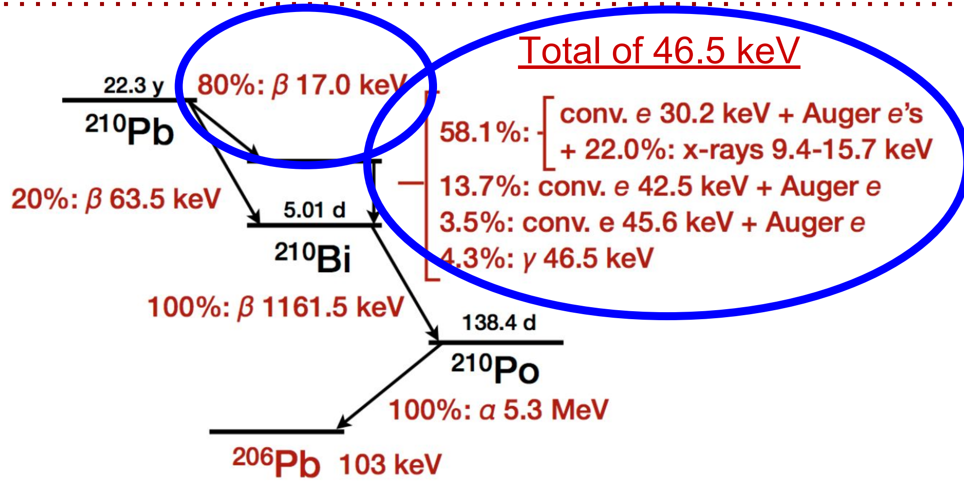
Activity of ^{210}Pb on wall in the fiducial volume drift range for WS-2014/16 > 9.6 ± 0.6 mBq

LUX
Preliminary

^{210}Pb in the Fiducial Volume

Background rate is estimated in 17 keV beta region using sidebands. Limit is set at 90% confidence interval as defined in: Applied Radiation and Isotopes Vol 53, Issues 1–2, 15 July 2000, P 45-50.





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Activity of ^{210}Pb in fiducial volume < 0.099 μBq/kg

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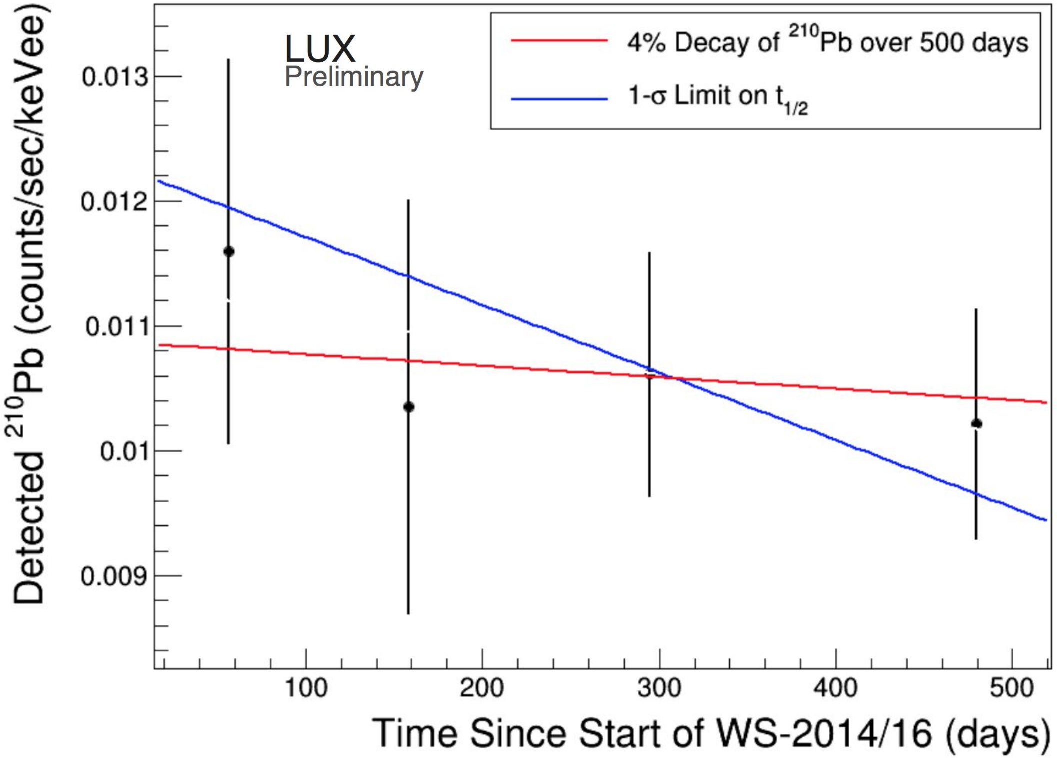
Limit on Leaching of ^{210}Pb into Xenon



- Activity of ^{210}Pb was measured for each date bin
- If there is no leaching, ^{210}Pb activity will decay by 4% over length of WS-2014/16
- Limit on decay constant for leaching of ^{210}Pb from detector walls is given as the fit value less 1-**σ**, correcting for 4% ^{210}Pb decay

$t_{1/2}$ of ^{210}Pb leaching off wall > 1.6 x 10^3 days

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Detector Effects: High Energy Event Classification

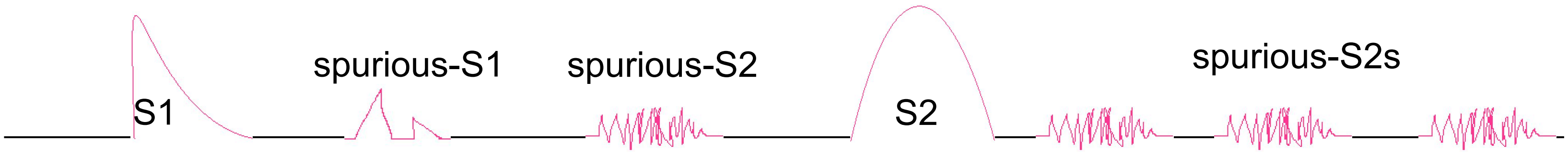
Following Large S1s:

- PMT afterpulsing
  - During PMT calibrations the probability of afterpulsing was measured
  - The results of this calibration were not folded into the pulse/event classification algorithm for high energy data
- Photo-ionization of the grids and impurities in the xenon

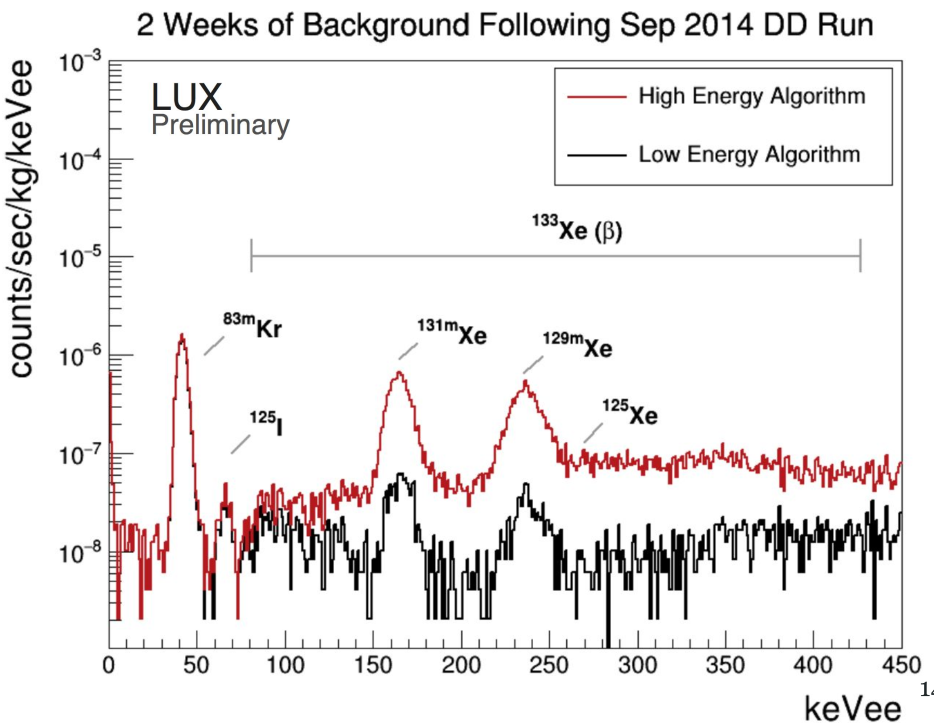
Following Large S2s:

- Electron trains
  - Trails of electrons caused by:
    - Photo-ionization of impurities
    - Emission of thermalized electrons not emitted in the primary S2 signal
    - Etc.

Spurious Pulse Classification Algorithm



- Above ~45 keVee, the detector effects described on previous slide can introduce spurious pulses that have the topology of an S1 or an S2
- A new algorithm was developed to identify and classify spurious pulses in high energy events
- In the ^{131m}Xe data, the resulting acceptance of single S1, S2 events increases by a factor of 10 (efficiency of ~100%)
- **Does not affect existing publications**



Simulation of Neutron Backgrounds

- PMTs
  - Neutrons from (α,n) from ^{238}U-chain α's
  - Neutrons from (α,n) from ^{232}Th-chain α's
  - Neutrons from ^{235}U-chain fission
- PTFE
  - Neutrons from (α,n) from ^{210}Po (^{238}U late) chain α's
- LUXSim was used to simulate energy depositions and libNEST was used to simulate the detector response
- Applied relevant data quality cuts
- Results (WIMP search ROI during WS-2014/16, 332 live days)
  - 0.16 events from PMTs
  - 0.016 events from PTFE

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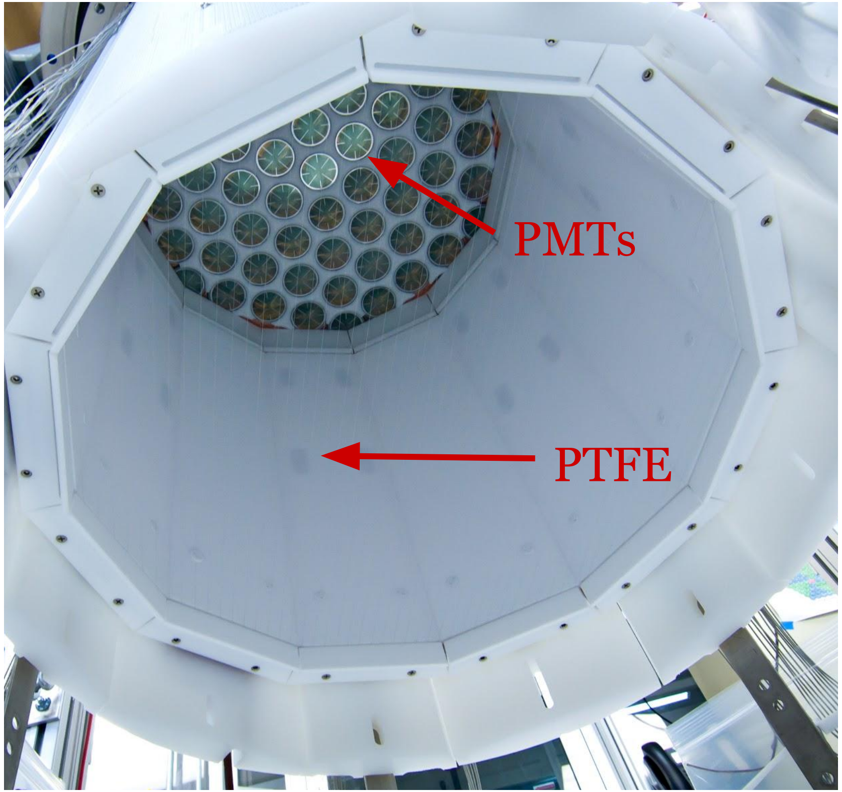

View of LUX TPC from below

Conclusion

- Short lived activation products from DD neutron generator **(including ^{125}I with effective decay constant 5.4 ± 0.4 days)**
- ^{210}Pb on the detector wall and in the fiducial volume **(1600 day $t_{1/2}$ for leaching from the walls into the fiducial volume)**
- Detector effects, such as PMT afterpulsing, photoionization of grids and impurities, and electron trains **(10x acceptance increase for ^{131m}Xe)**
- Neutron background from PMTs **(0.16 events during WS-2014/16)** and PTFE **(0.016 events during WS-2014/16)**

Thanks go to: the LUX Collaboration

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