Development of Internal Calibration Source Injection Hardware for LZ

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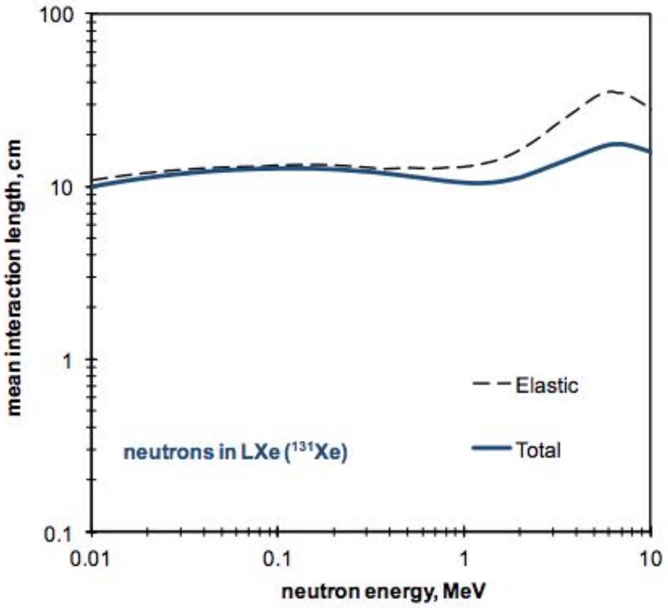
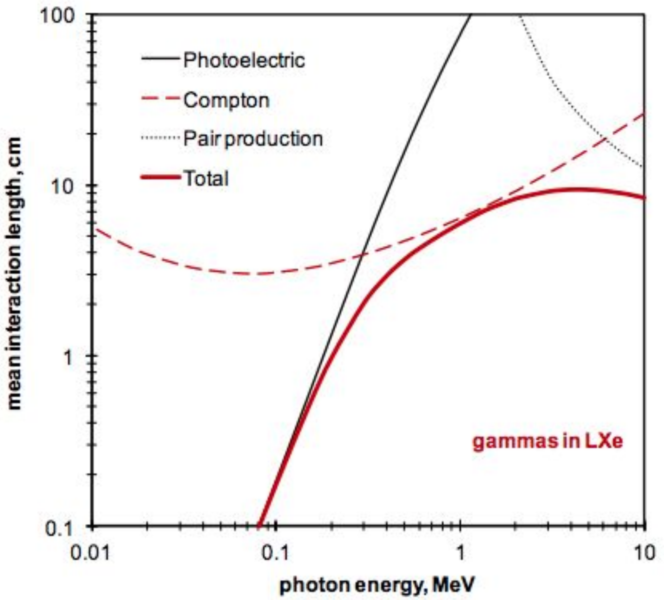
CPAD Instrumentation Frontier Workshop

Self-Shielding

- High density (and high Z) in LXe means particles and radiation don't travel very far
- Great for rejecting background events in large detectors
- Makes calibration with an external source difficult for large detectors



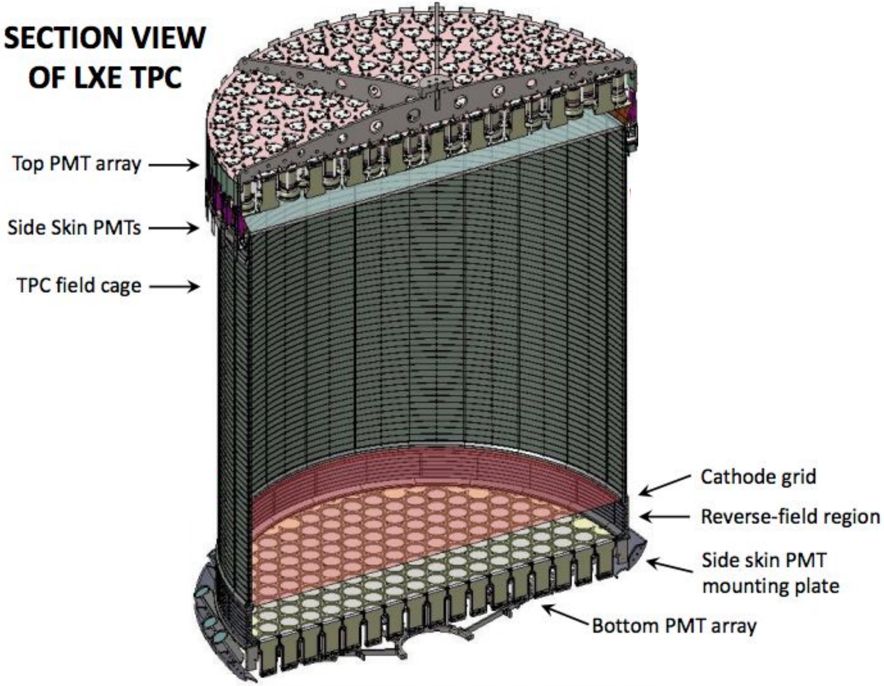
M. B. Chadwick et al., Nucl. Data Sheets 112, 2887 (2011), special issue on ENDF/B-VII.1 library.



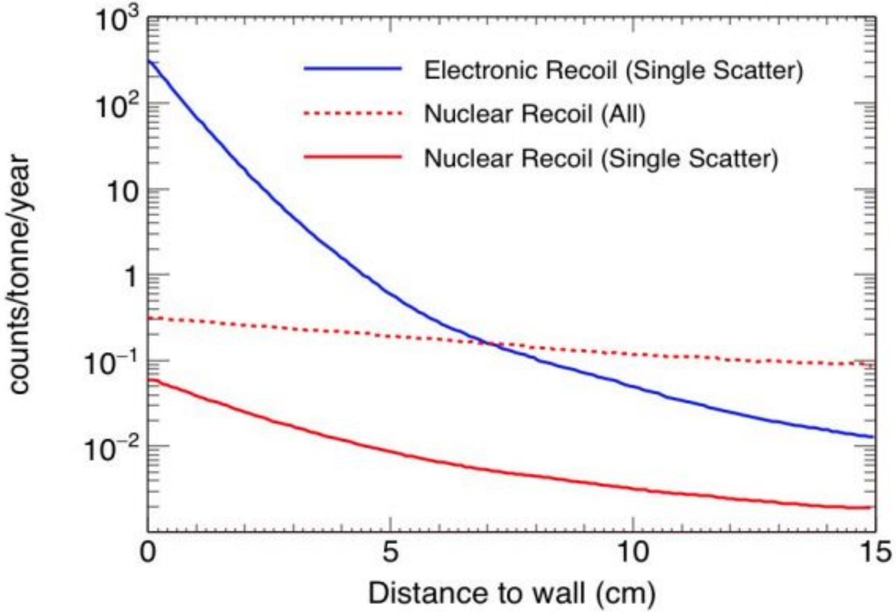
M. J. Berger et al., XCOM: Photon Cross Section Database (version 1.5) (2010), National Institute of Standards and Technology, 100 Bureau Drive, Stop 1070, Gaithersburg, MD 20899-1070.

Self-Shielding in LZ

- LZ TPC ~1.5 meters in diameter and height
- Calibration sources must be injected directly into the liquid volume



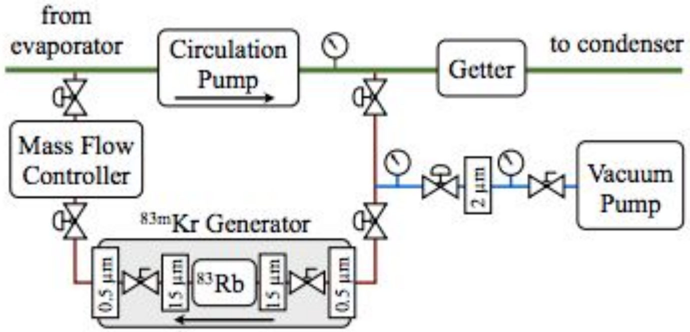
NRs 6 - 30 keV
ERs 1.5 - 6.5 keV



arxiv:1703.09144

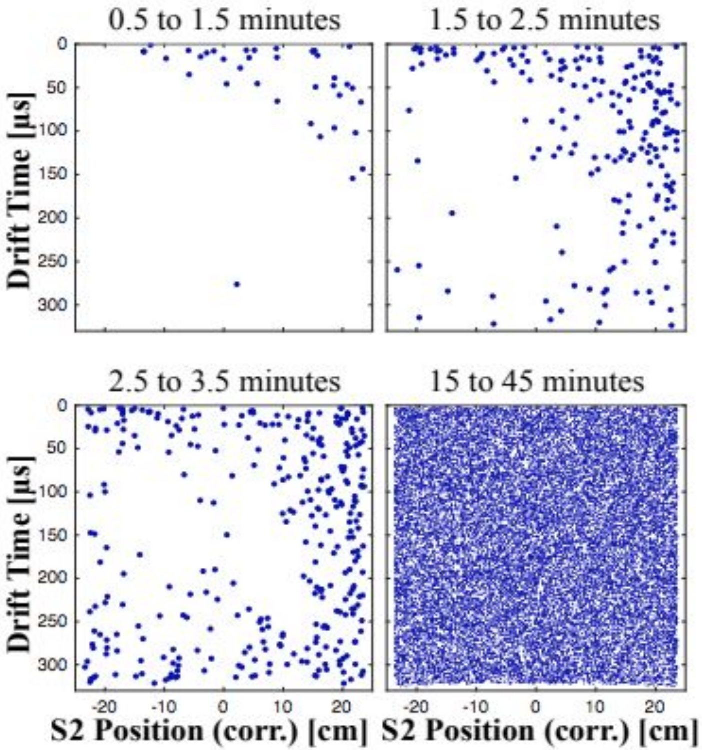
Source Injection Example in LUX: ^{83m}Kr

- LUX has demonstrated internal calibration source injection with a variety of radioisotopes
- GXe flow carries calibration isotopes from generator into circulation, from circulation to TPC
- Noble elements like ^{83m}Kr pass freely through the getter



arxiv:1708.02566

Demonstration of mixing with Kr83m



arxiv:1708.02566

UMass Hardware Contribution to LZ

A prototype of the LZ source injection system has been constructed and is currently being tested at UMass Amherst

Goals:

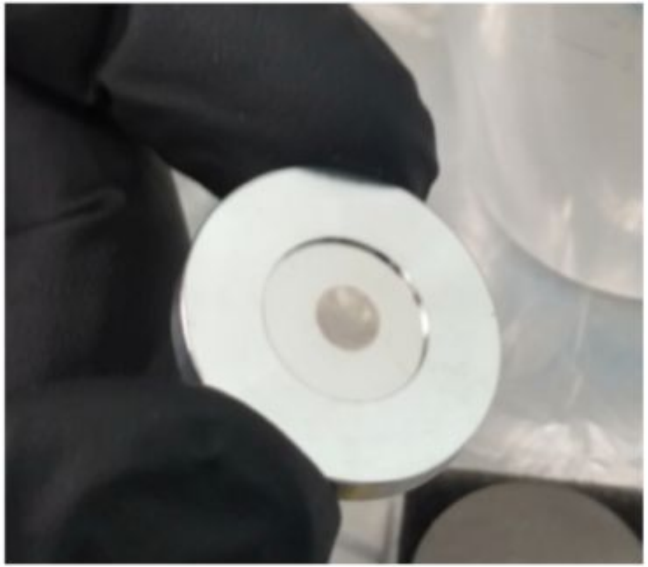
- Refine injection system and generator design, and fabrication techniques
- Develop new injection procedures for better precision and accuracy
- Practice performing injections with the prototype before construction of the LZ source injection system is scheduled to begin

Internal Calibration Sources

Source	Type	Energy	Half Life	Purpose
^{131m}Xe	Internal conversion	164 keV	11.8 d	3D efficiencies and gains & 3D position correction
^{83m}Kr	Internal conversion	41.5 keV	1.8 h	
^{220}Rn & (Rn Daughters)	Alpha(s) & (Betas and Gammas)	several high energy alphas (~7000 keV) and betas	10.6 h	Skin calibration & Material surface physics
^{3}H	Beta	18.6 keV endpoint	~days long purification timescale (12.3 y)	ER energy scale & discrimination
^{14}C	Beta	156 keV endpoint	~days long purification timescale (5,780 y)	

Generator Materials for Injected Calibration Sources

Electroplated ^{228}Th on platinum (commercial source)

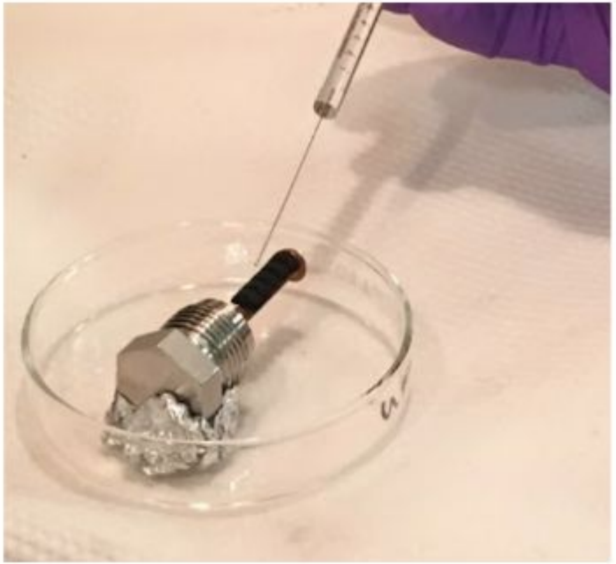


$^{228}Th \rightarrow {}^{224}Ra \rightarrow$ $\mathbf{^{220}Rn}$

Passive matrix of anhydrous sodium phosphate dosed with ^{131}I solution within gelatin capsule

$^{131}I \rightarrow$ $\mathbf{^{131m}Xe}$

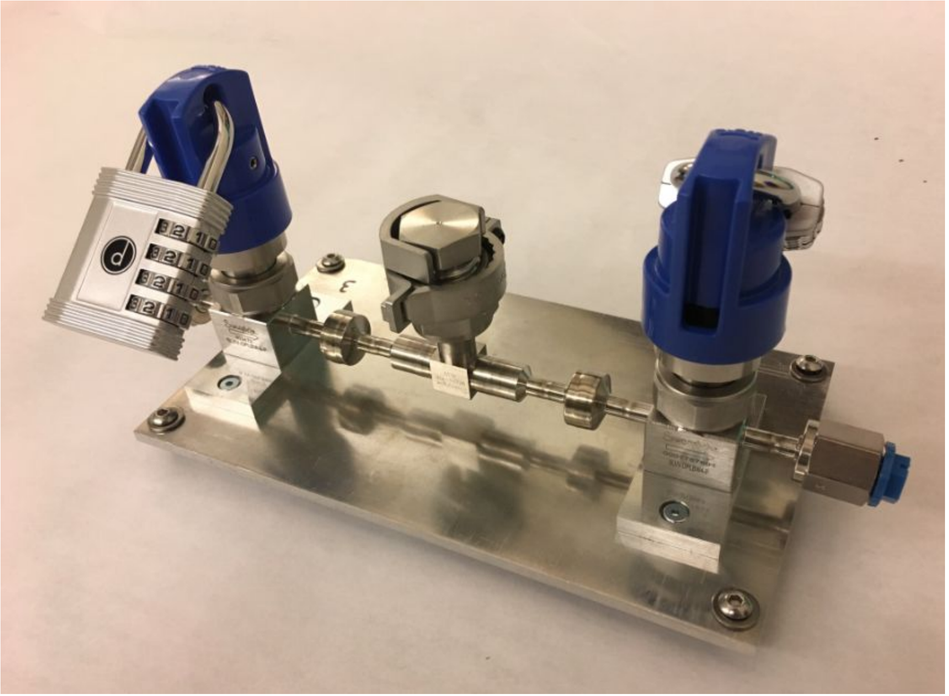
Activated charcoal dosed with ^{83}Rb aqueous solution



$^{83}Rb \rightarrow$ $\mathbf{^{83m}Kr}$

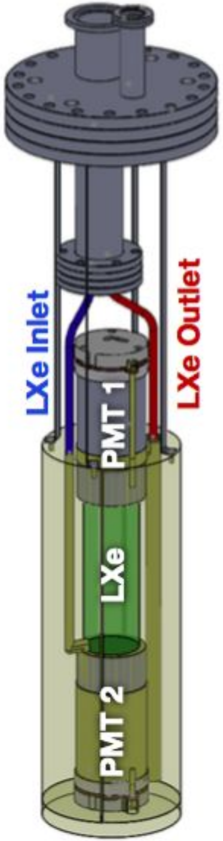
Flow-through Generator Design

- Source volume enclosed by sintered-nickel filters, valves
- Generators all have same overall length and panel fittings - interchangeable on panel
- Source is attached to VCR cap for easy installation and removal in ^{83}Kr and ^{131m}Xe generators



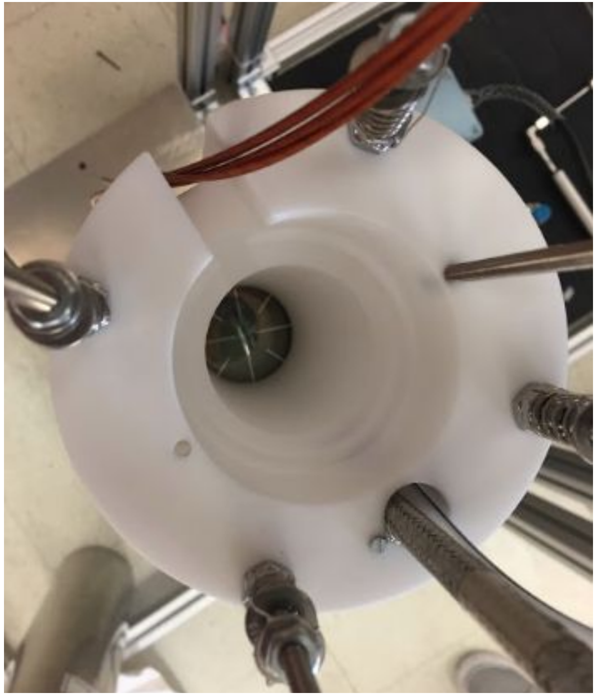
UMass LXe Detector

- Single phase (‘S1 only’) LXe detector
- ~1 kg LXe between PMT faces
- Constant GXe recirculation and purification with getter as in LZ



UMass LXe Detector Features

- Monolithic VUV-reflective PTFE walled LXe volume
- Temperature monitoring and capacitive liquid level sensing inside cryostat

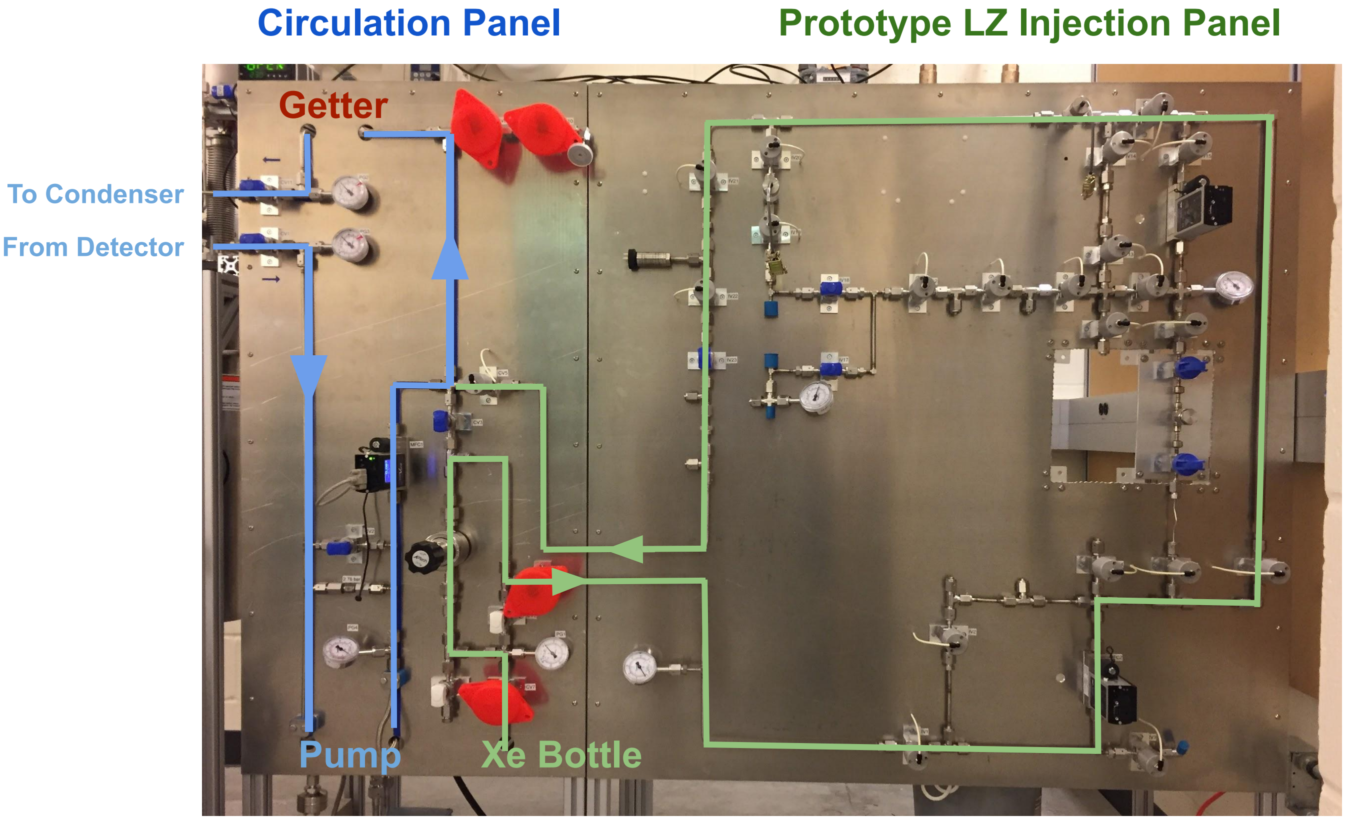


Complete UMass System

Circulation and Injection System

- Injection outlet meets circulation upstream of heated getter as in LZ

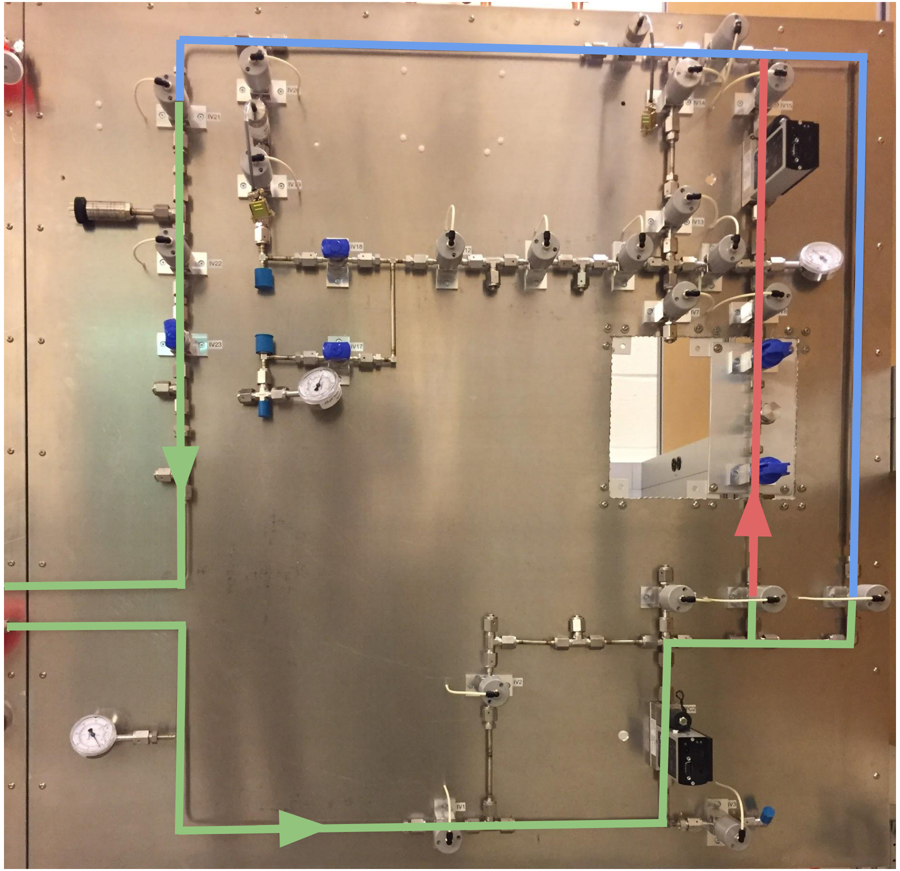
- As simple as possible circulation path



Prototype LZ Source Injection System

Injection procedure:

- GXe carrier moves calibration isotopes from generator to isolated dose volume
- Dose volume is opened and flushed into circulation with GXe carrier
- Precise dosing achieved with combination of mass flow and pressure measurements
- Injections will be fully automated



Flush

Dose Volume

Generator Dose Path

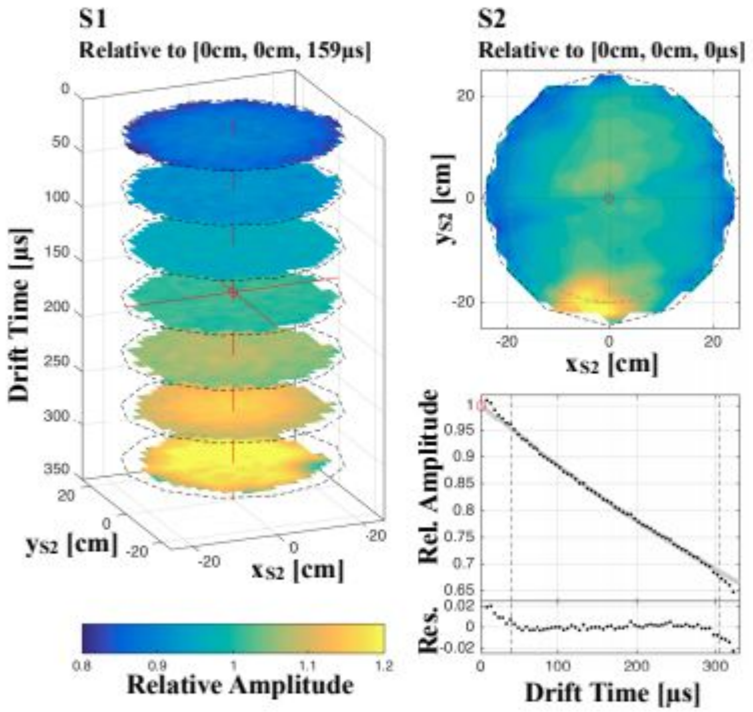
Summary and Future

- Self shielding in large liquid noble detectors requires injection of calibration isotopes directly into the liquid volume
- Internal source injection has been employed successfully in LUX and other similar experiments
- At UMass Amherst, we are drawing from past experience to refine the injection system design and the procedures for internal source injection in preparation for LZ
- Thorough testing of the LZ injection system prototype will be completed before the first injections in LZ are required

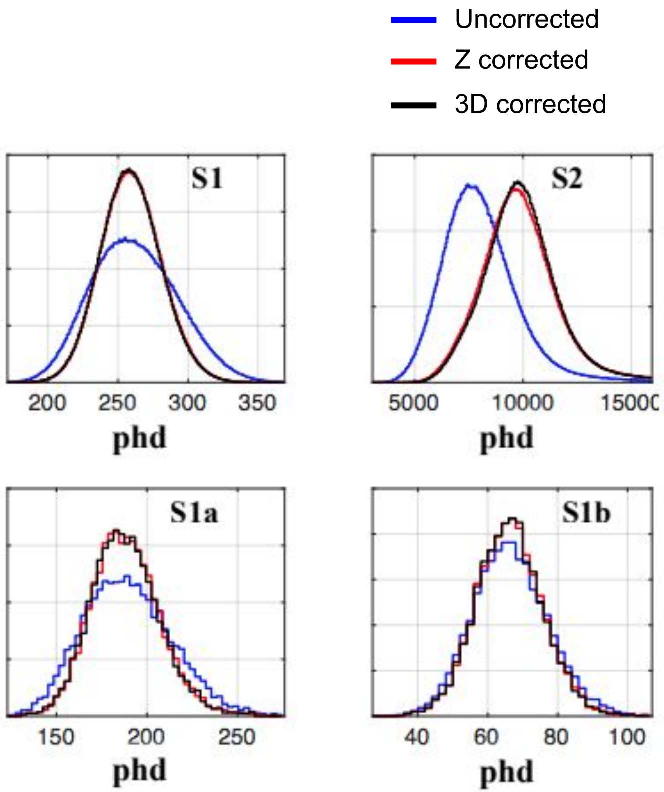
Extra Slides

Energy corrections with ^{83m}Kr in LUX

^{83m}Kr Events Selected in Analysis:



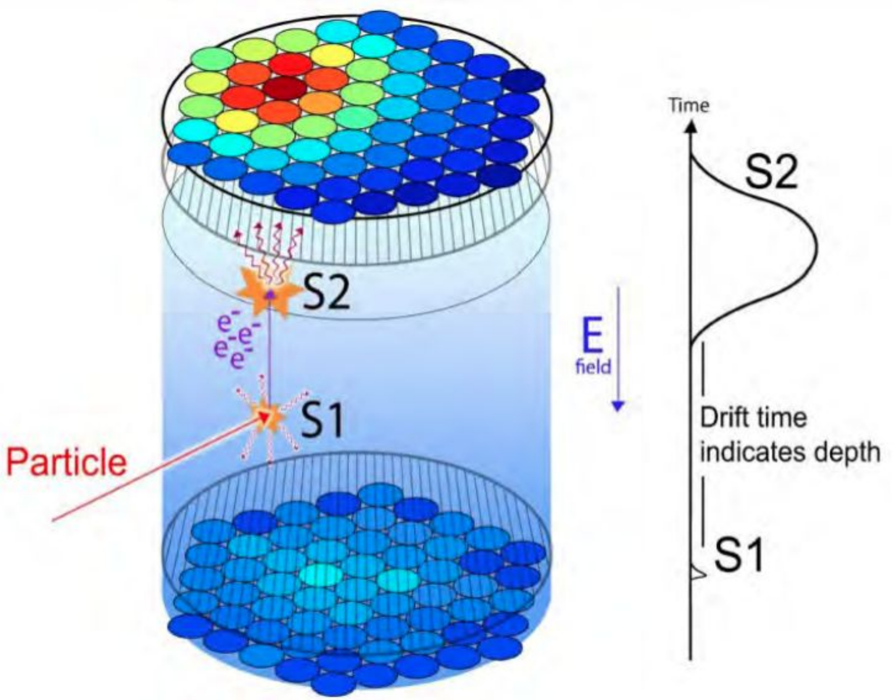
arxiv:1708.02566



arxiv:1708.02566

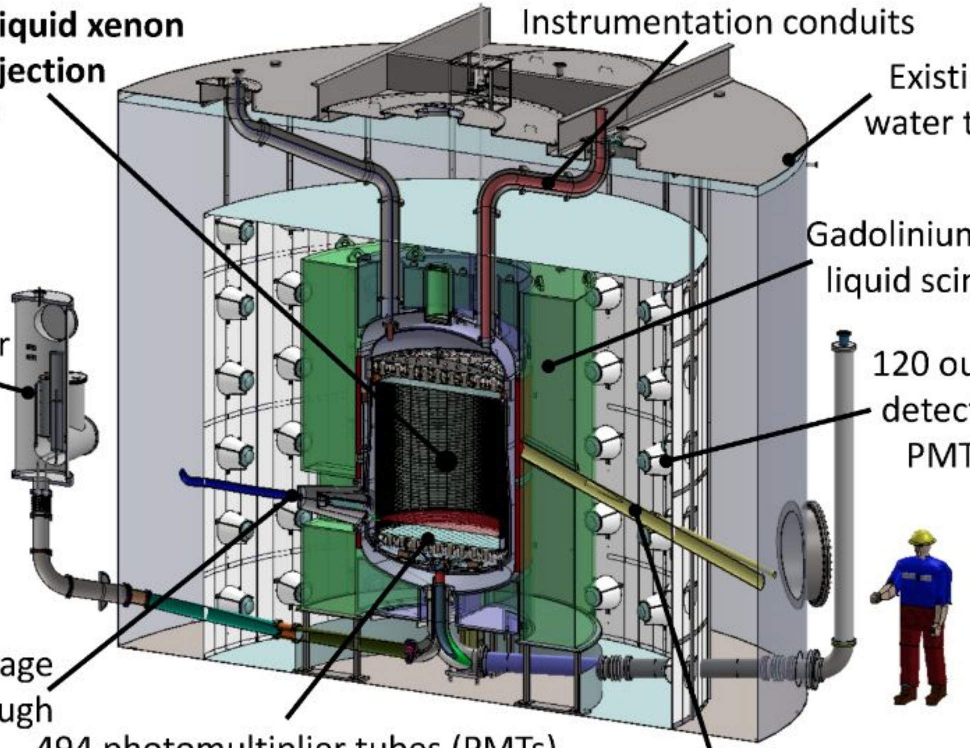
LXe TPC Operating Principle

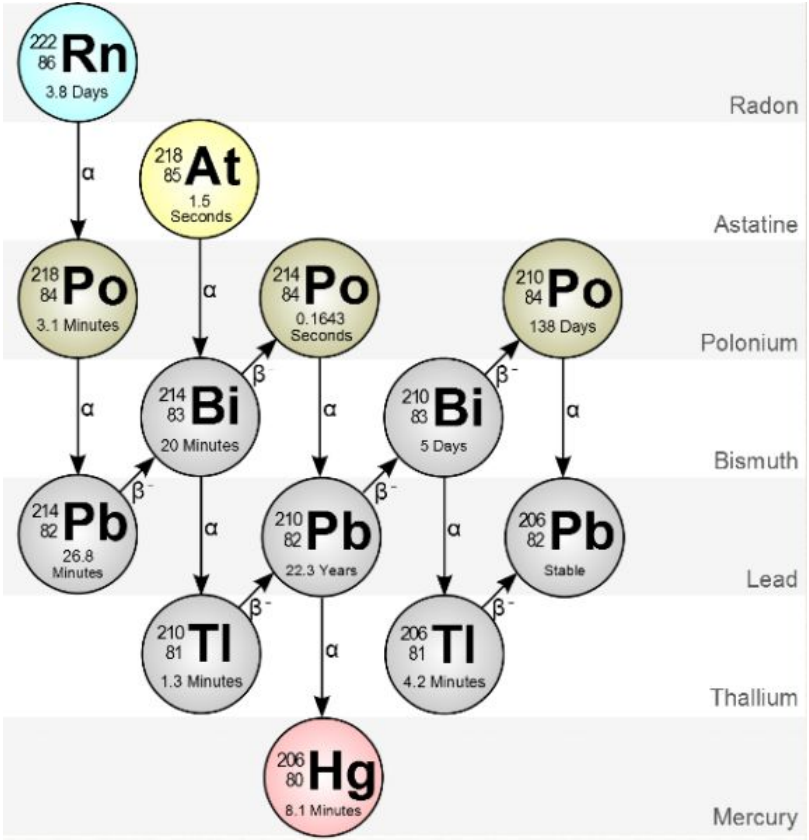
- Interaction in LXe produces:
    - Prompt scintillation photons (S1) from de-excitation of molecular dimer Xe^*_2.
    - Free electrons
- Electrons drifted out of liquid, produce electroluminescence photons in GXe (S2)
- Allows precise vertex location
- Discrimination between nuclear and electron recoils by relative S1 S2 size.



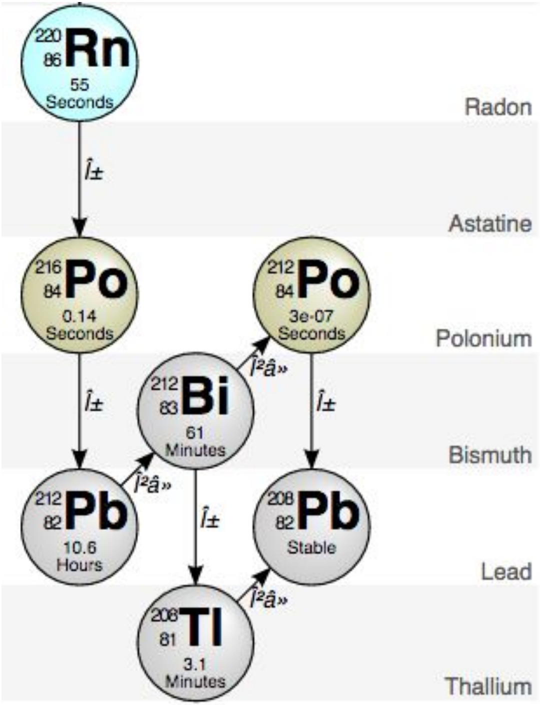
arxiv:1509.02910

The LZ Experiment





222 86 Rn
3.8 Days
α
218 85 At
1.5 Seconds
α
218 84 Po
3.1 Minutes
214 84 Po
0.1643 Seconds
210 84 Po
138 Days
α
214 83 Bi
20 Minutes
β-
α
210 83 Bi
5 Days
β-
α
214 82 Pb
26.8 Minutes
β-
α
210 82 Pb
22.3 Years
β-
α
206 82 Pb
Stable
210 81 Tl
1.3 Minutes
β-
α
206 81 Tl
4.2 Minutes
β-
206 80 Hg
8.1 Minutes
Radon
Astatine
Polonium
Bismuth
Lead
Thallium
Mercury



220 86 Rn
55 Seconds
Î±
216 84 Po
0.14 Seconds
212 84 Po
3e-07 Seconds
Î²â»
Î±
212 83 Bi
61 Minutes
Î±
212 82 Pb
10.6 Hours
Î²â»
Î±
208 82 Pb
Stable
Î²â»
208 81 Tl
3.1 Minutes
Radon
Astatine
Polonium
Bismuth
Lead
Thallium