LZ Outer Detector

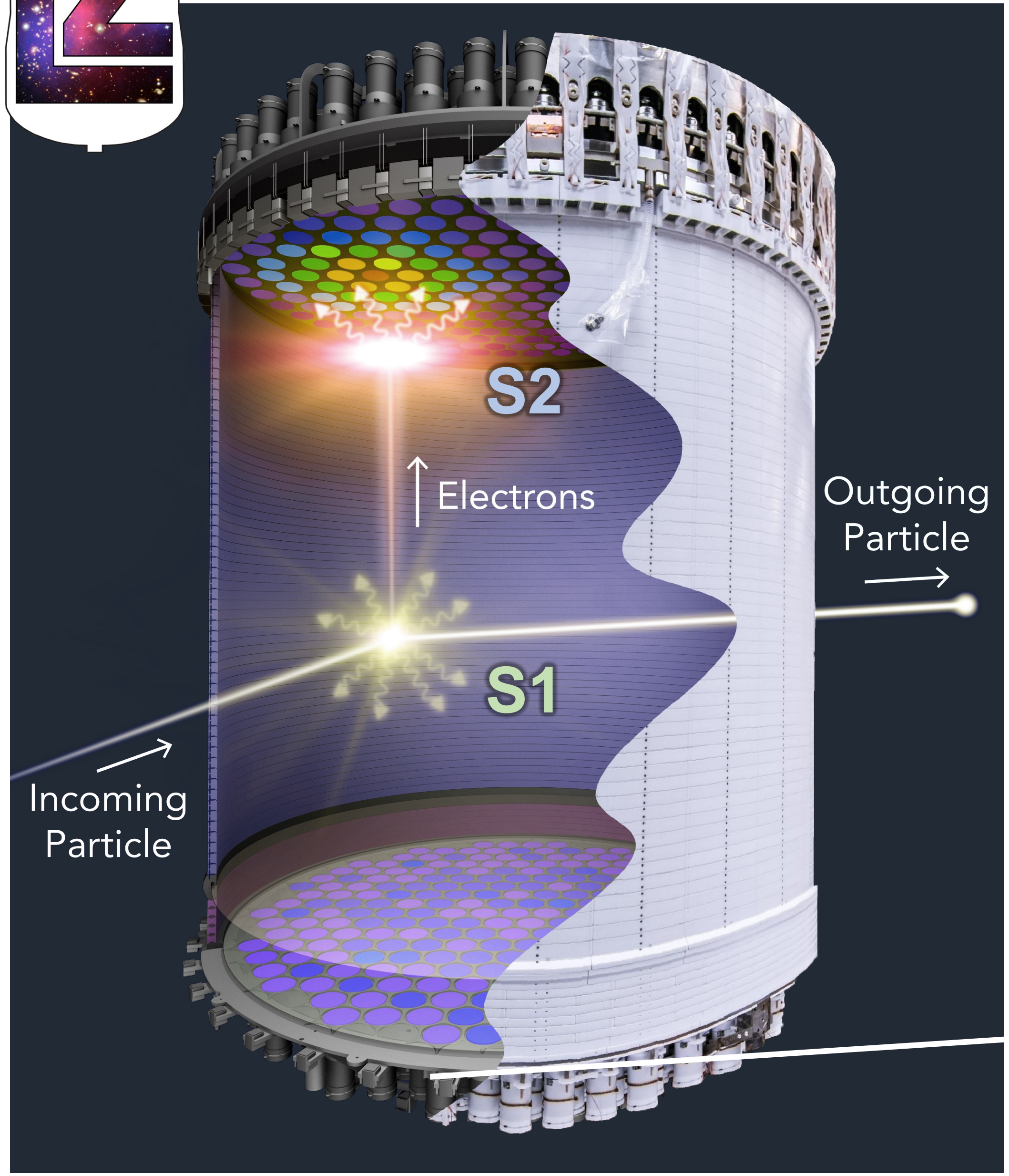
IDM Vienna 2022

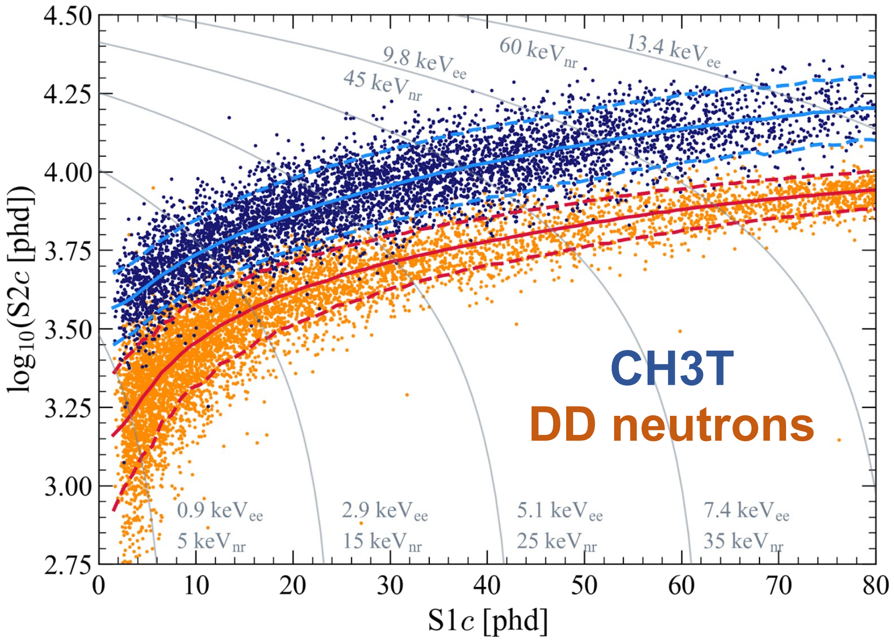
Dr. Alissa Monte

July 18th 2022

UCSB

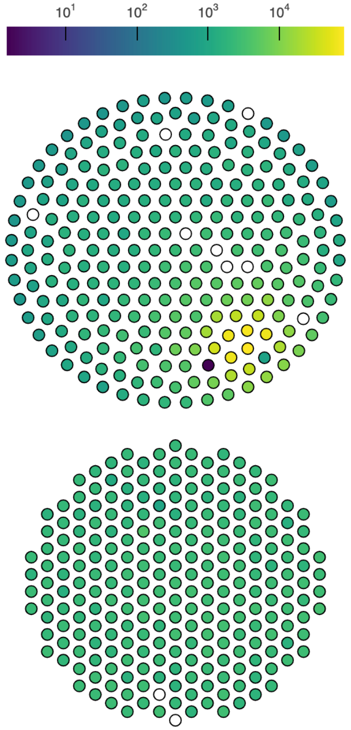
Direct detection with LXe TPCs



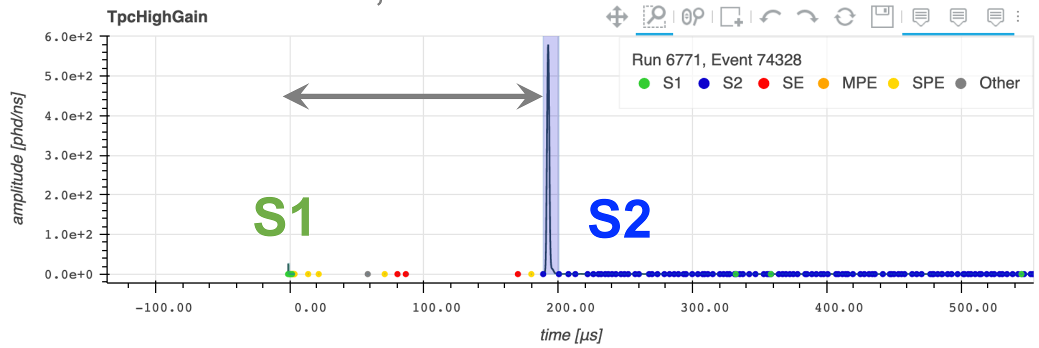


S2/S1 is different for electronic and nuclear recoil

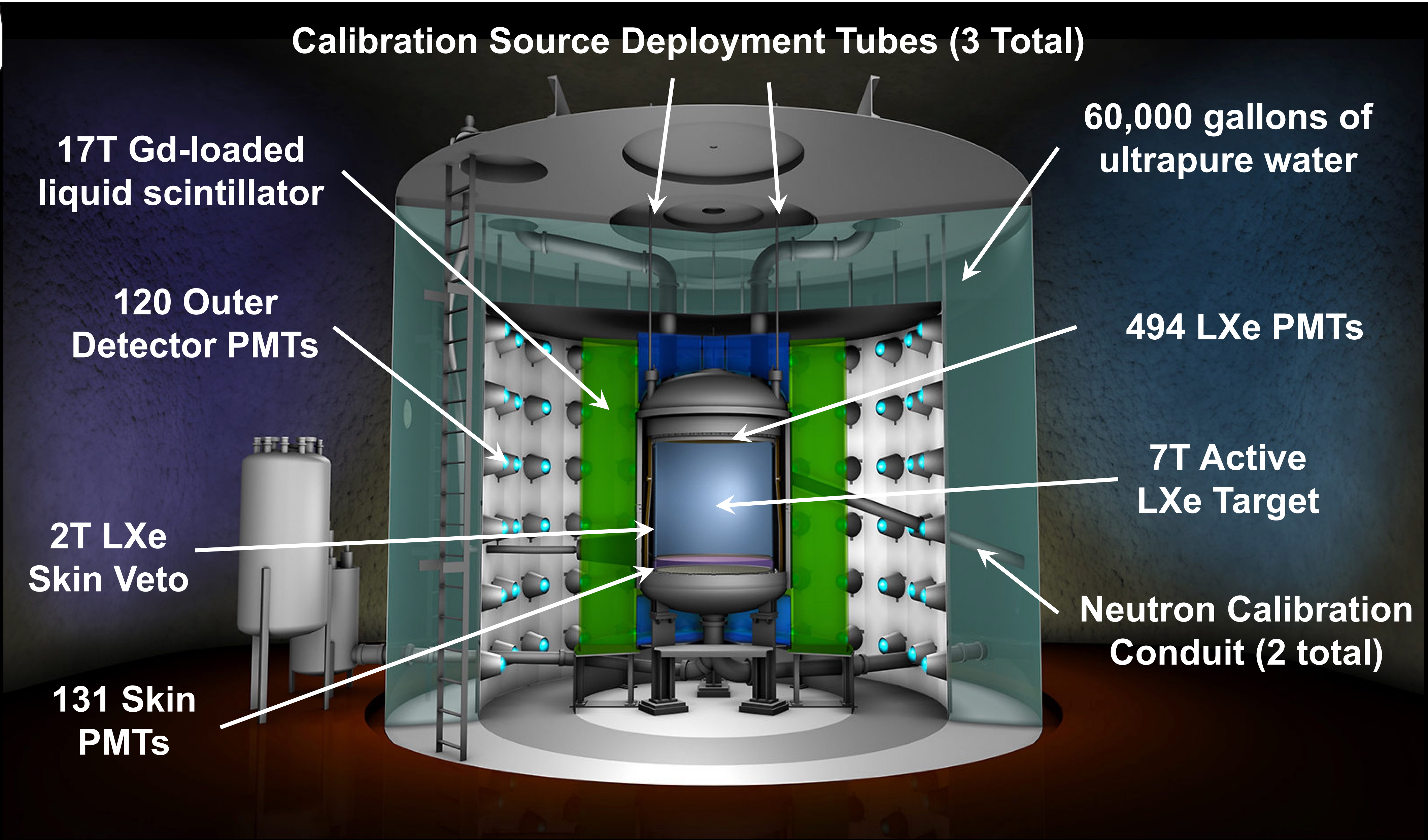
XY from PMT hit map



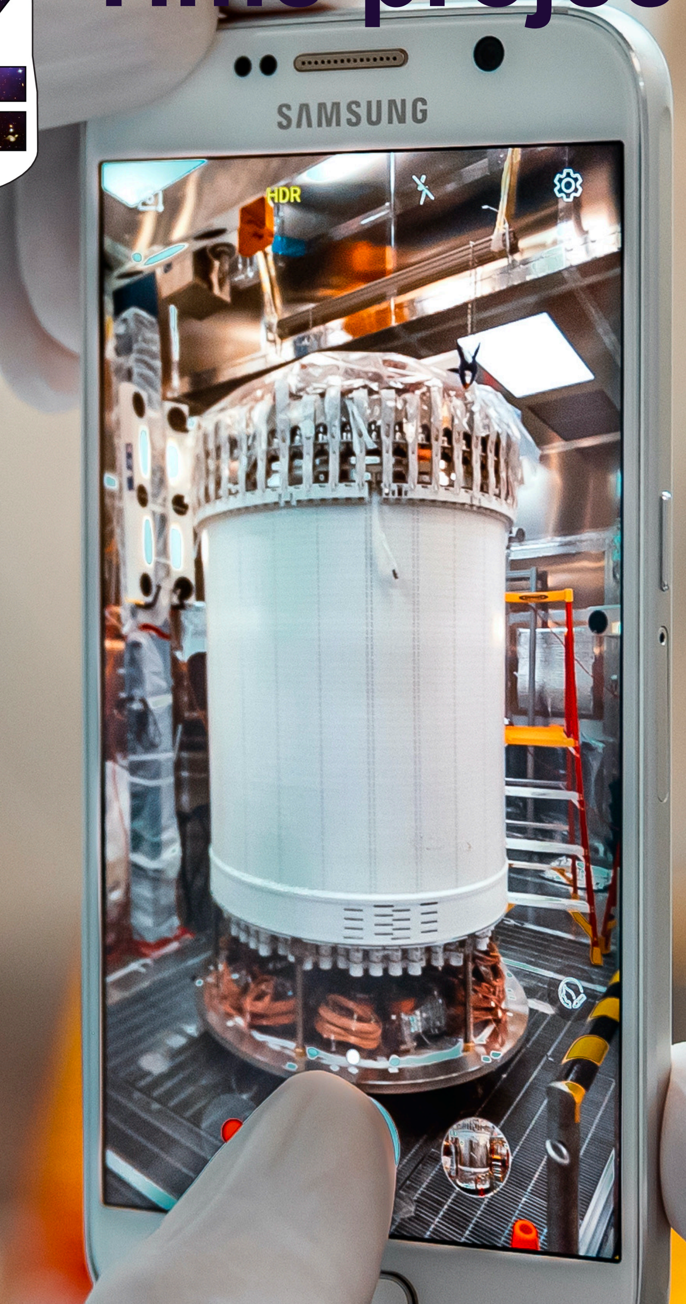
Z-position from time between S1, S2



LUX-ZEPLIN (LZ): nested detectors



Time projection chamber (TPC) & LXe skin



I will focus on the Outer Detector, if you want to hear more about the TPC and skin don't miss:

"LUX-ZEPLIN (LZ) Status" (our results talk) - A. Fan (tomorrow)

"Background Model and Statistical Analysis in the LUX-Zeplin Experiment" – I. Olcina (next talk)

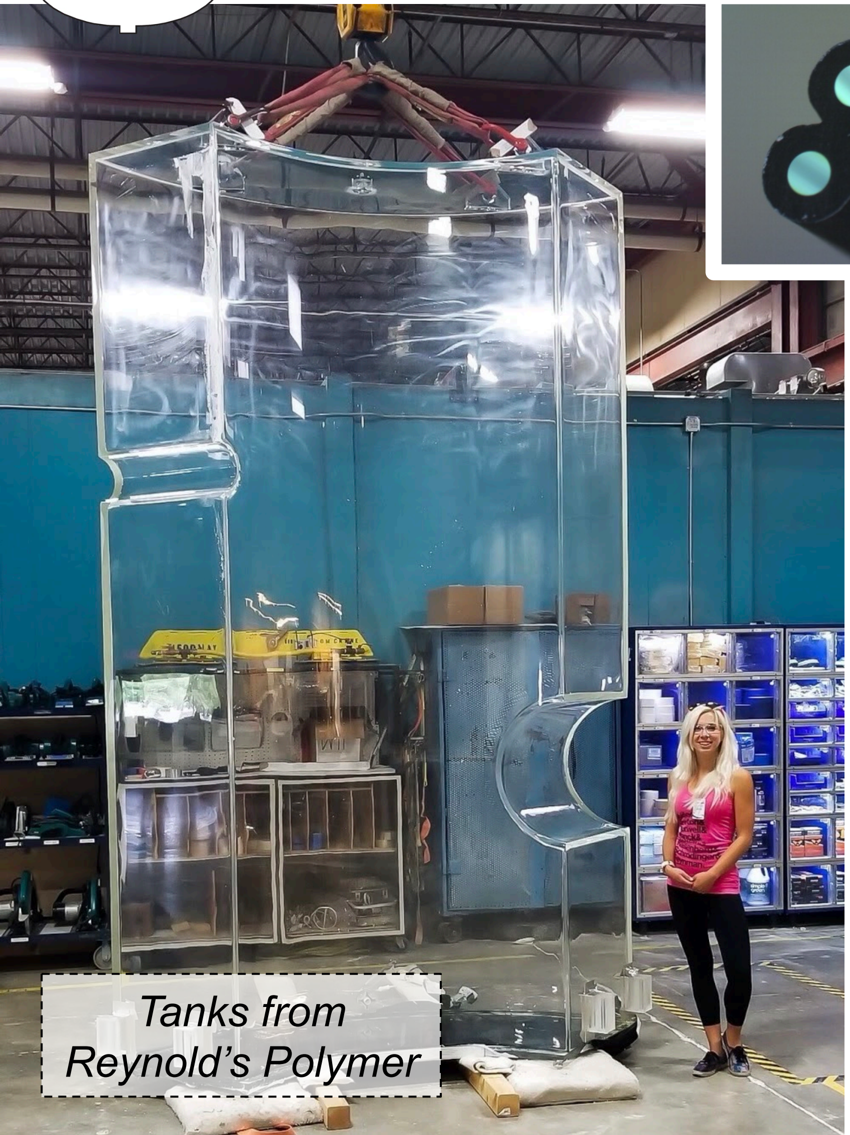
"Identification and removal of coincidence backgrounds in the LUX-ZEPLIN experiment" – D. Hunt (poster)

"Background model fitting in the LUX-ZEPLIN experiment" - A. Musalhi (poster)

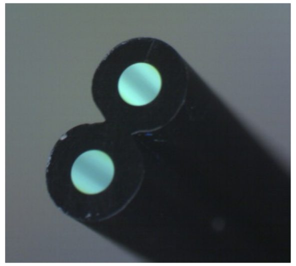
LZ's Outer Detector (OD)

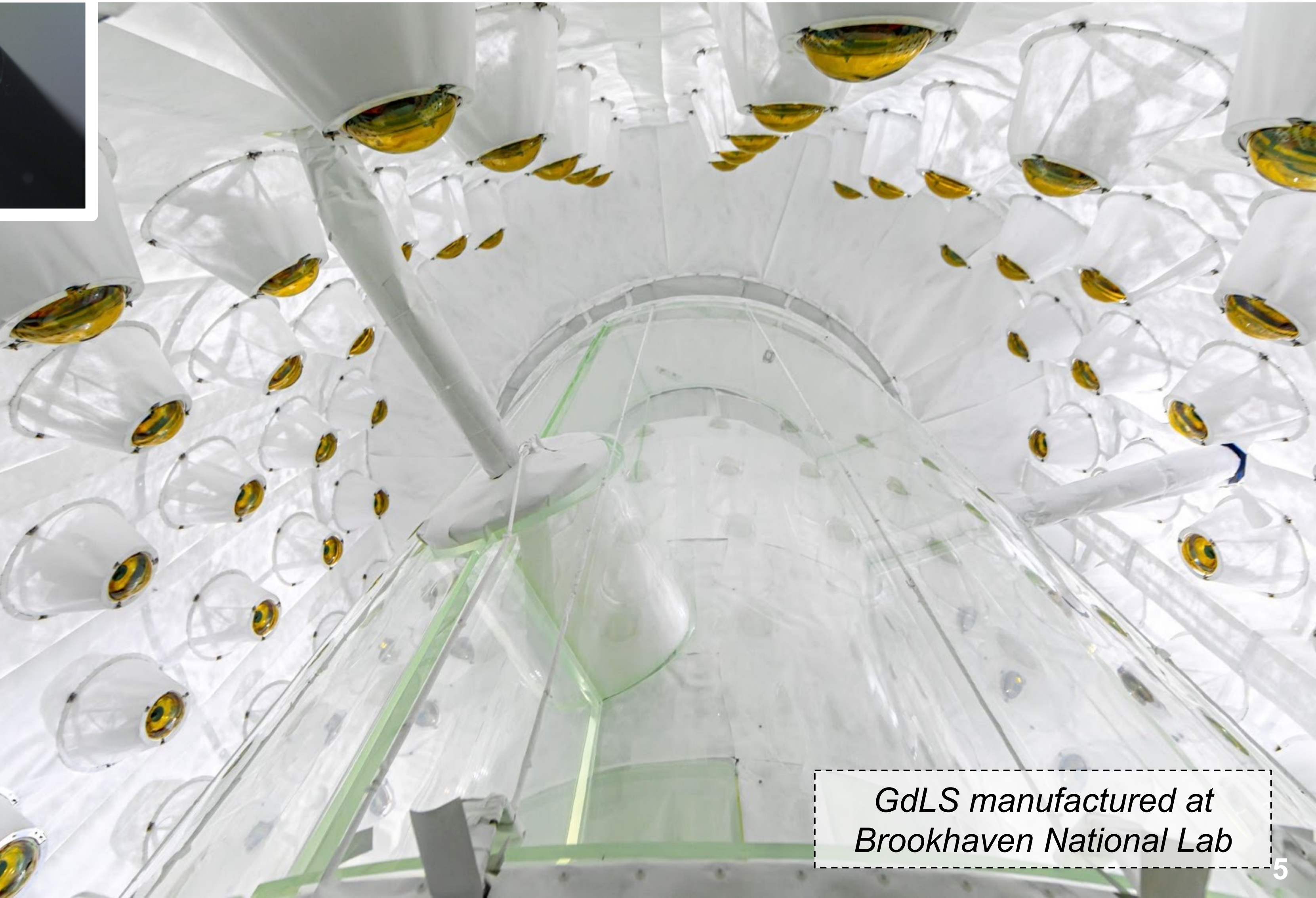
Neutron detector with 95% design efficiency
NIM A 937 (2019), NIM A 1010 (2021)

10 acrylic tanks filled with
17t Gadolinium-loaded liquid scintillator
Observed by 120 8" R5912 PMTs
40 optical fiber injection points for calibration



Tanks from Reynold's Polymer





GdLS manufactured at Brookhaven National Lab

Outer detector installation

Side acrylic vessel lowering into water tank

Post acrylic tank cleaning yoga

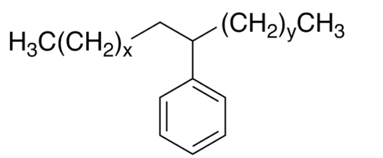
All acrylic vessels in place

PMT and Tyvek installation

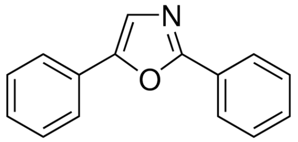
OD construction completed and tanks filled spring 2021

Neutron interactions with the OD

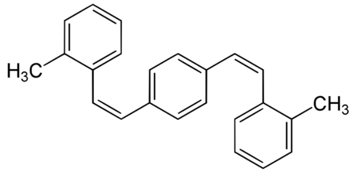
GdLS



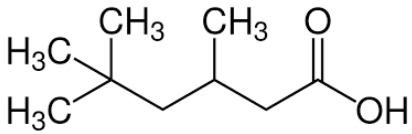
Linear Alkylbenzene (LAB)



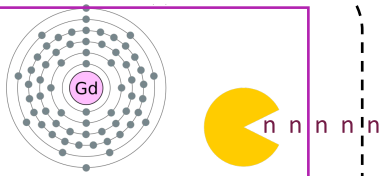
2,5-Diphenyloxazole (PPO)



1,4-bis(methylstyryl) benzene (Bis-MSB)

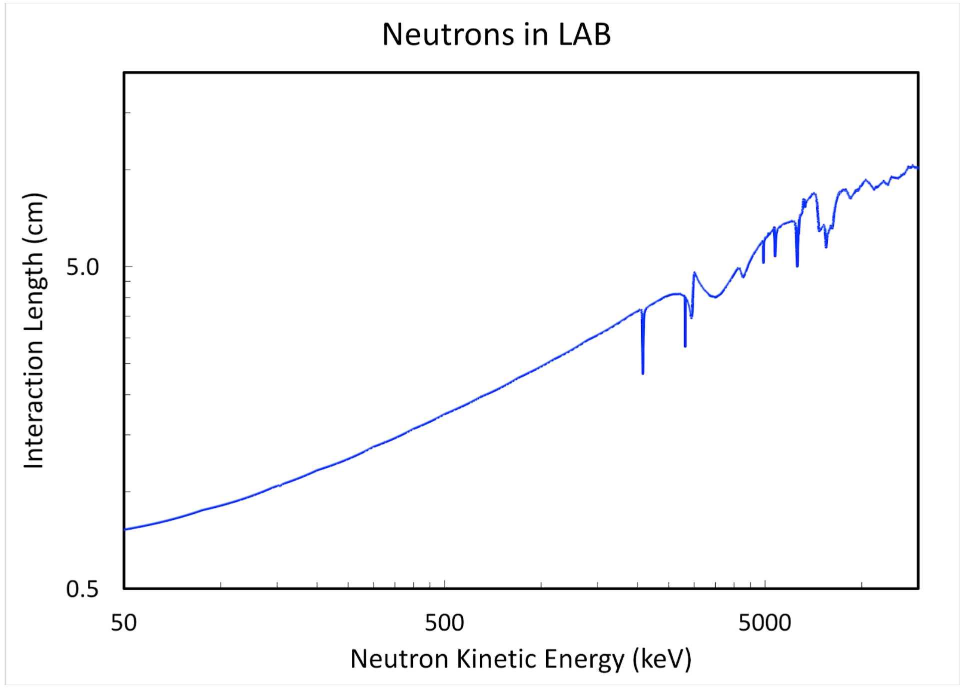


Trimethylhexanoic Acid (TMHA)

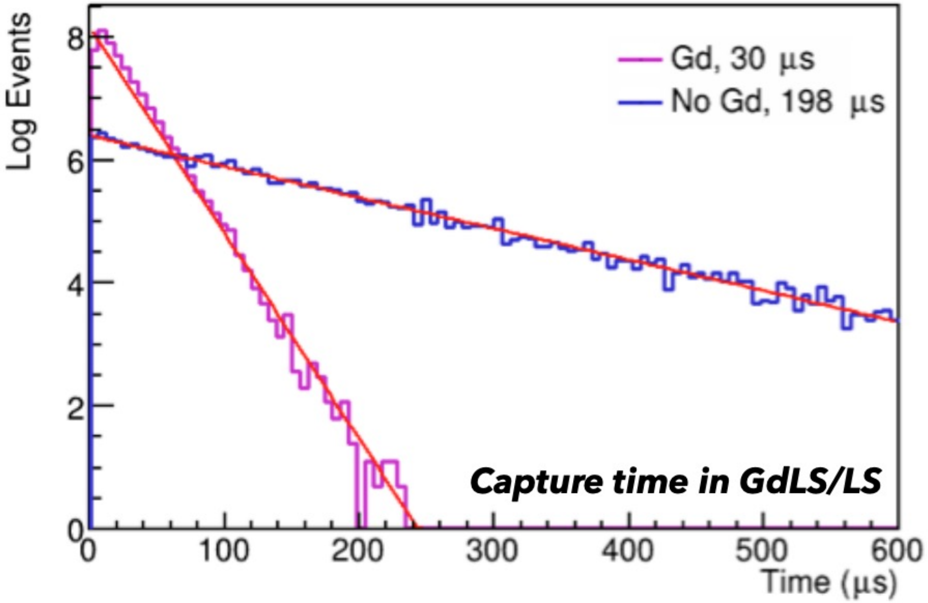


Gadolinium (Gd), neutron eater

Neutron loses energy scattering on protons in scintillator/acrylic



Neutron captures on Gd or H

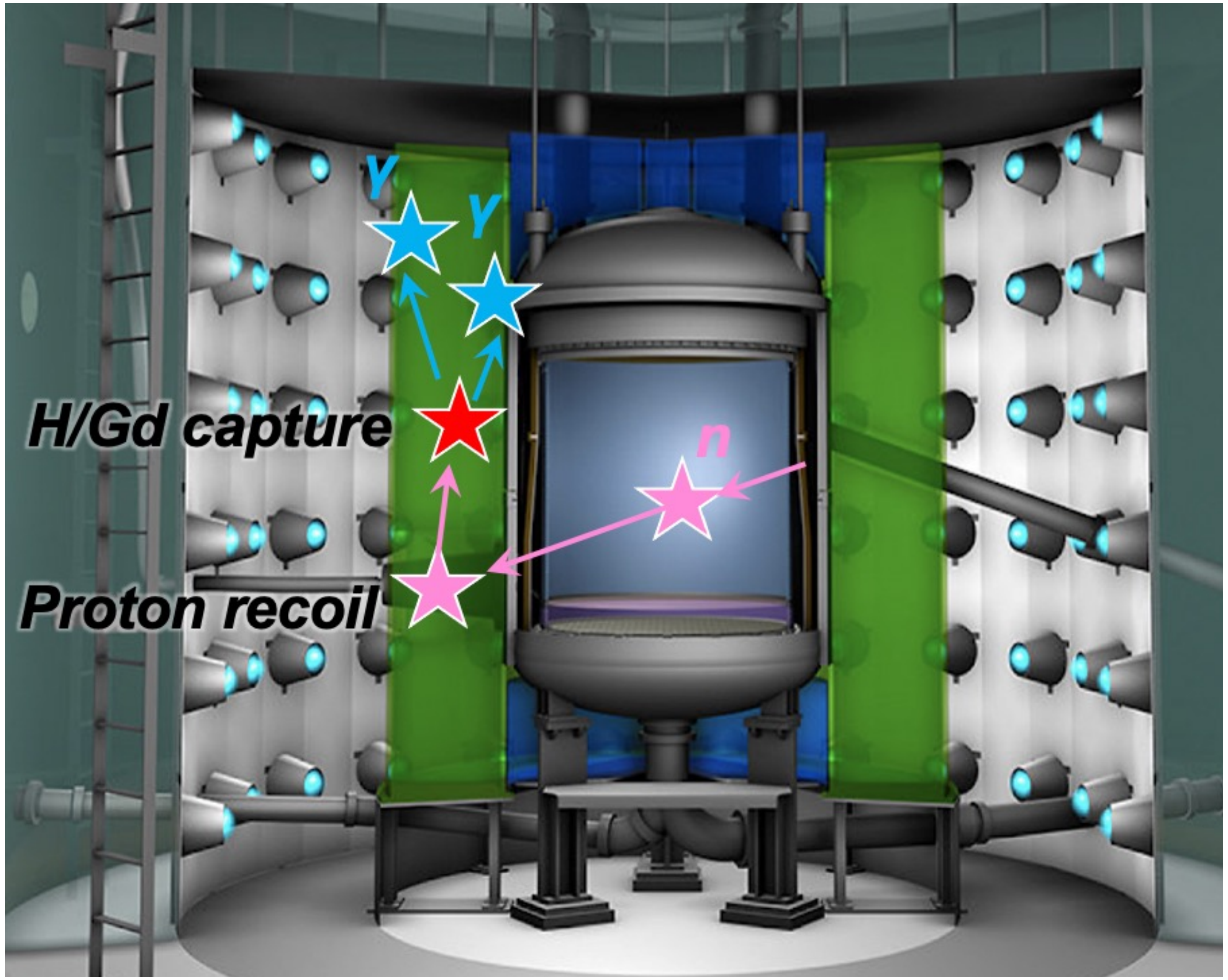


H produces a 2.2 MeV γ, Gd produces 4-5 γs totaling ~8 MeV

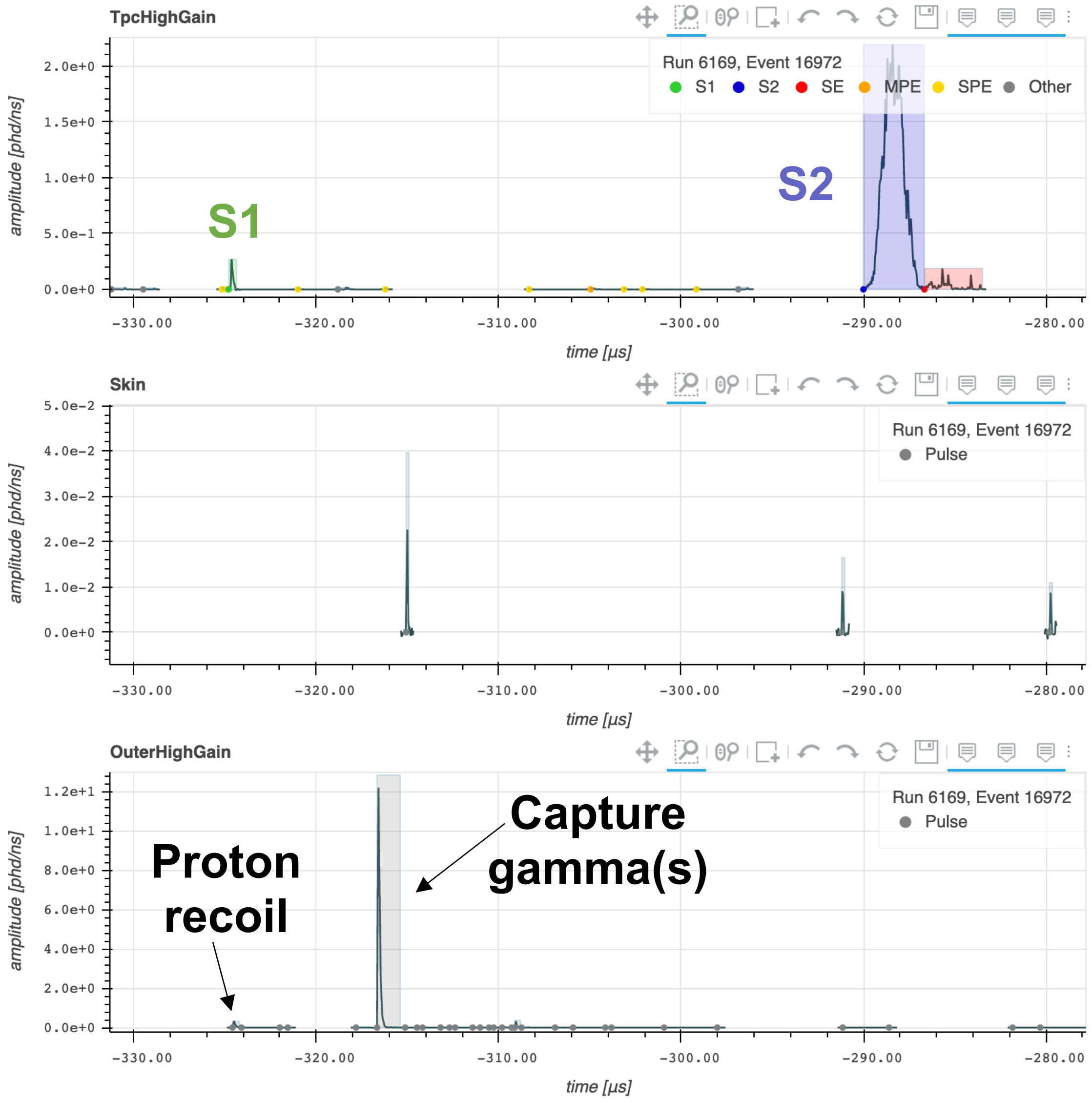
^{155}Gd: 8.5 MeV

^{157}Gd: 7.9 MeV

Tagging neutrons in the OD

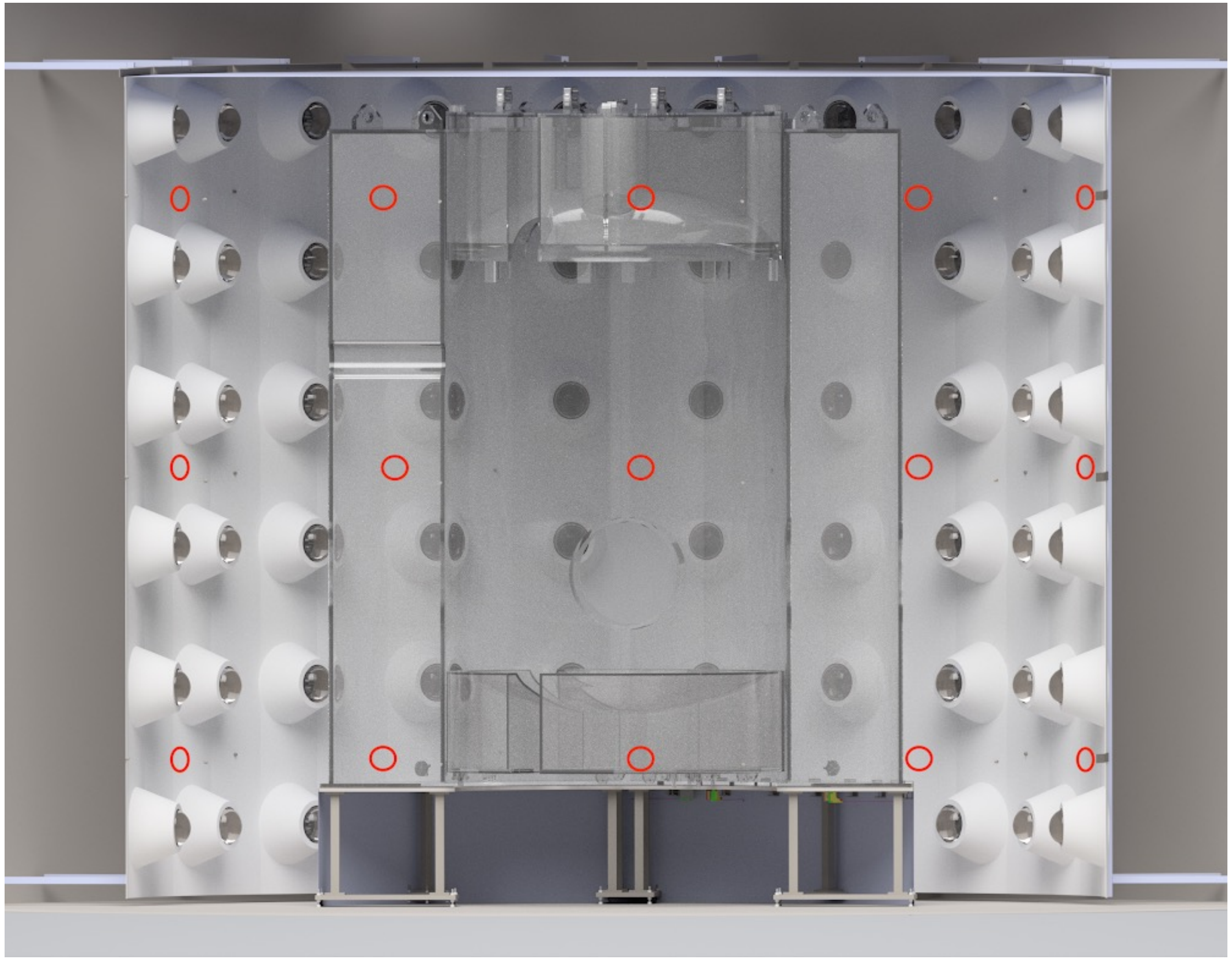


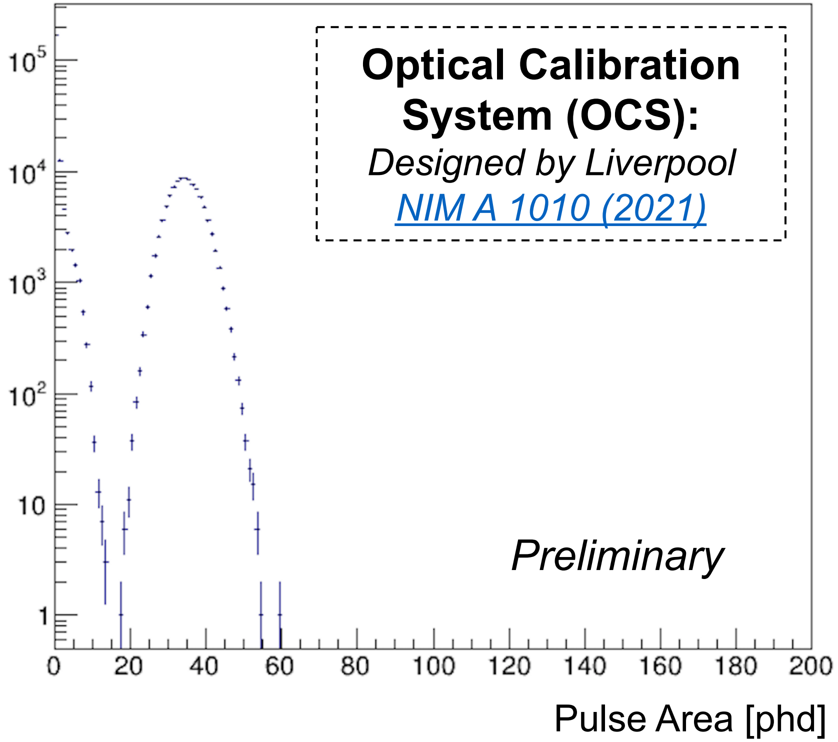
Real LZ AmLi calibration neutron event



Calibration of the OD: OCS

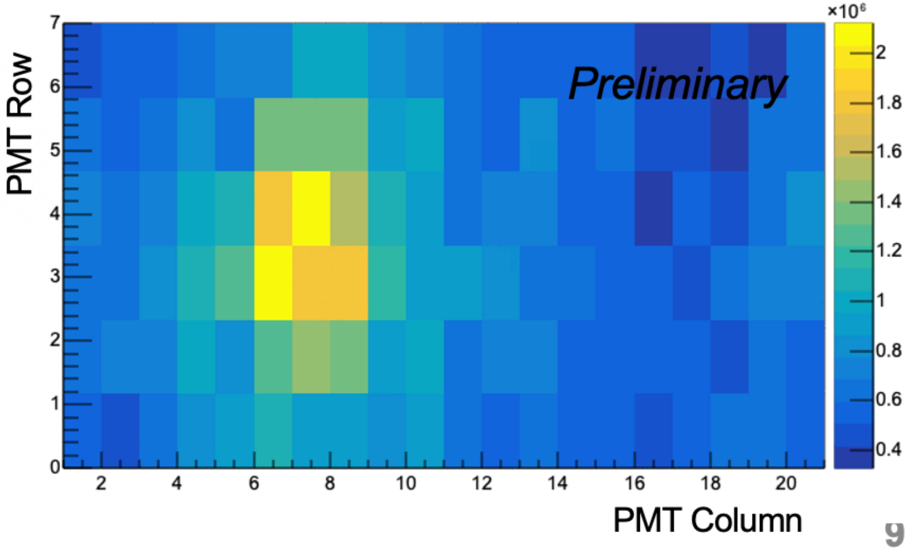
40 injection points used to calibrate PMT single photon response, measure afterpulsing, study light collection efficiency



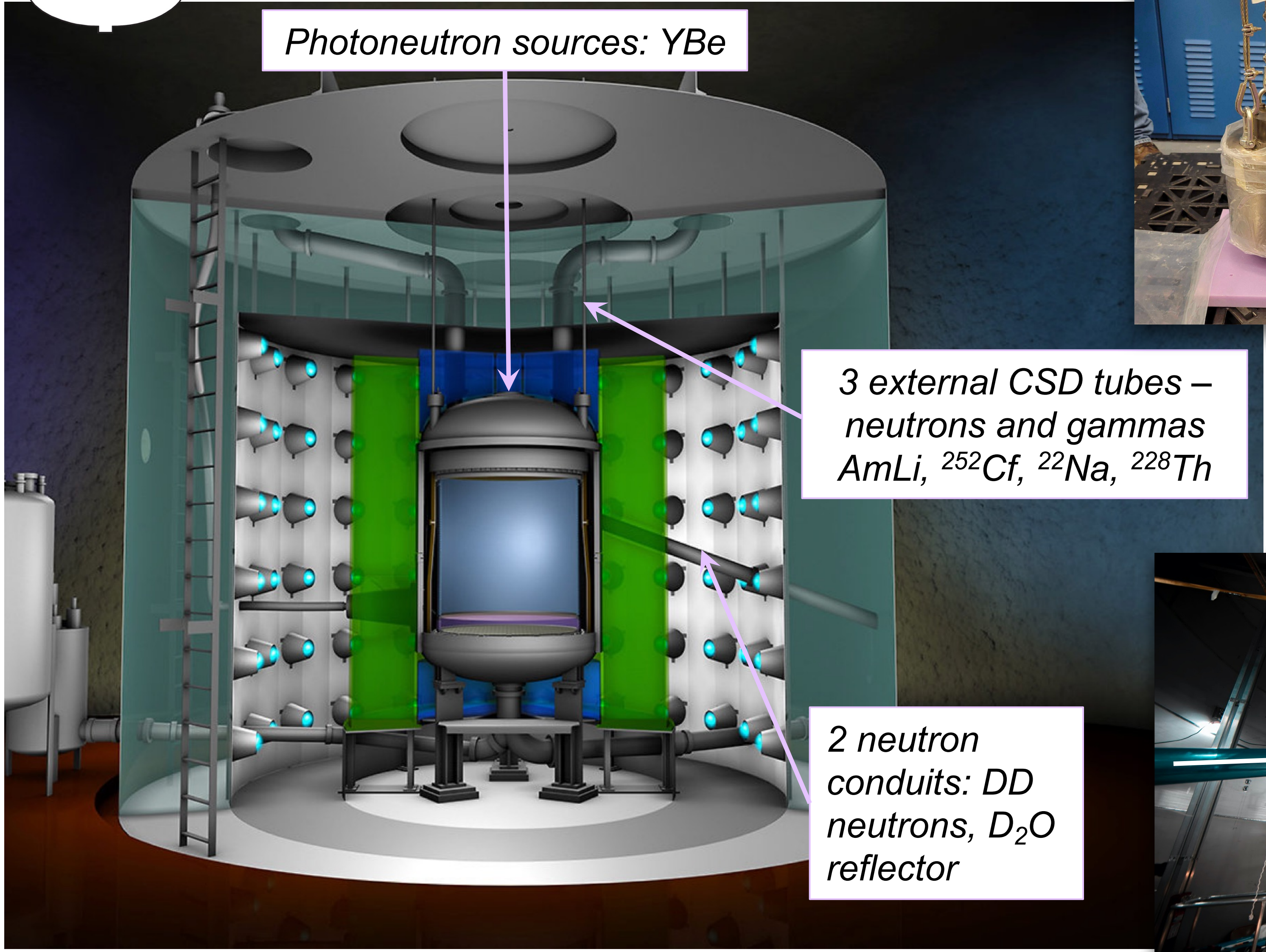


Optical Calibration System (OCS):
Designed by Liverpool
NIM A 1010 (2021)

OCS injections moving through fibers



Calibration of the OD

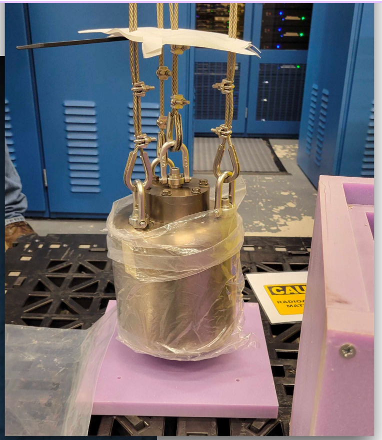


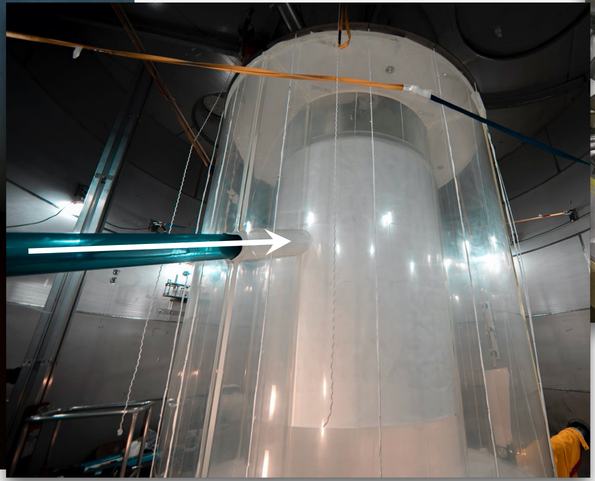
Photoneutron sources: YBe

3 external CSD tubes – neutrons and gammas AmLi, ^{252}Cf, ^{22}Na, ^{228}Th

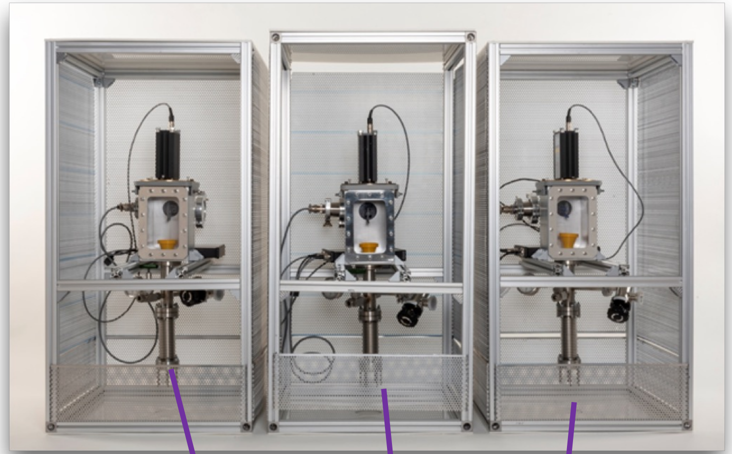
2 neutron conduits: DD neutrons, D_2O reflector

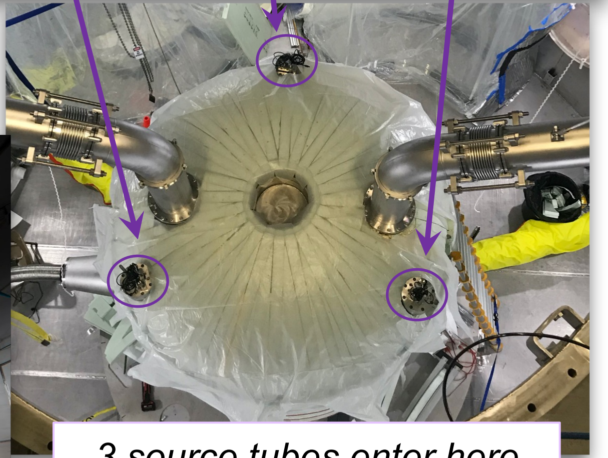
Source in tungsten shield lowered to top of OCV (low energy neutrons)





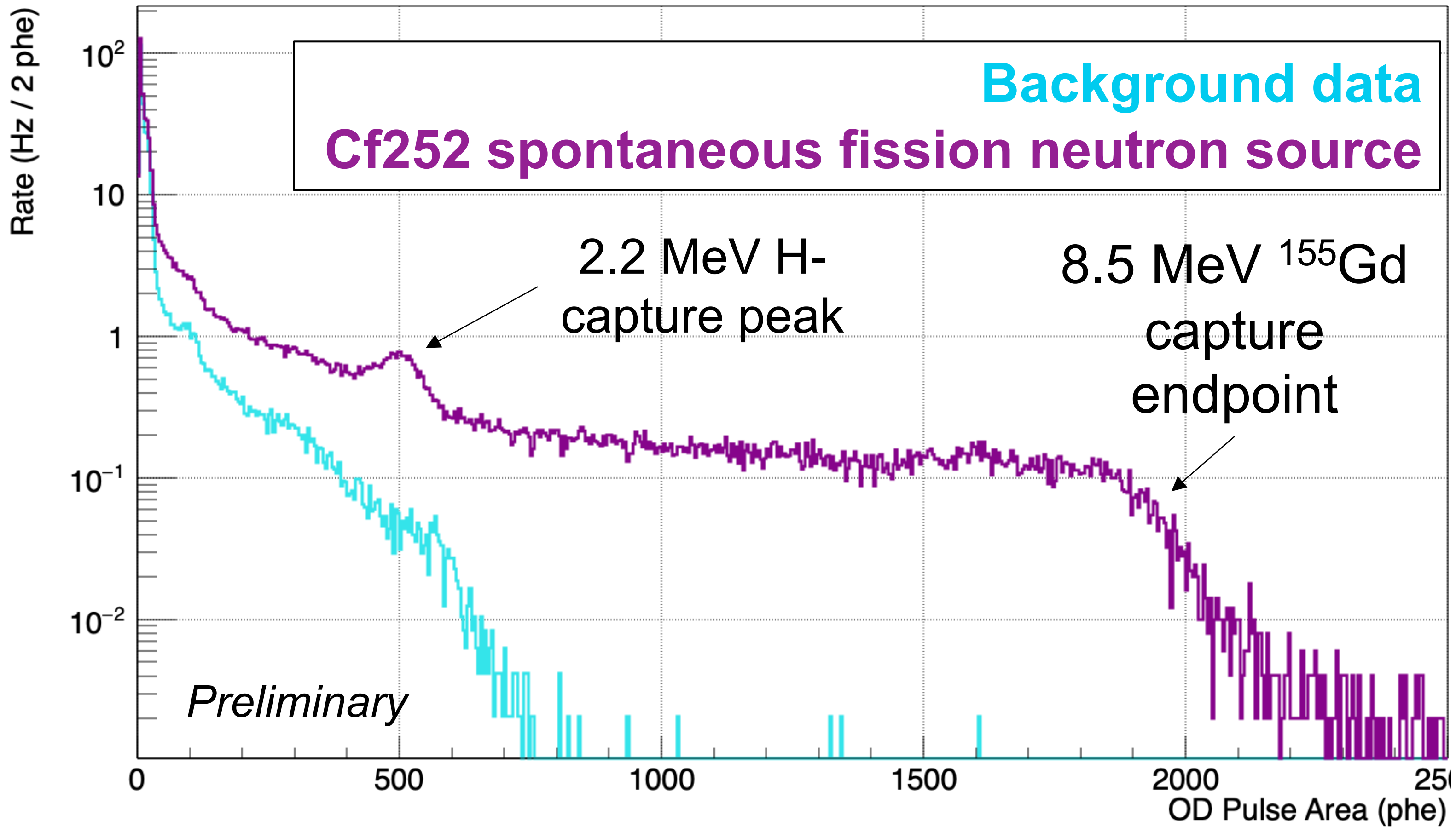
Gamma and neutron sources loaded on upper deck and lowered to specific Z position via computer-controlled motors





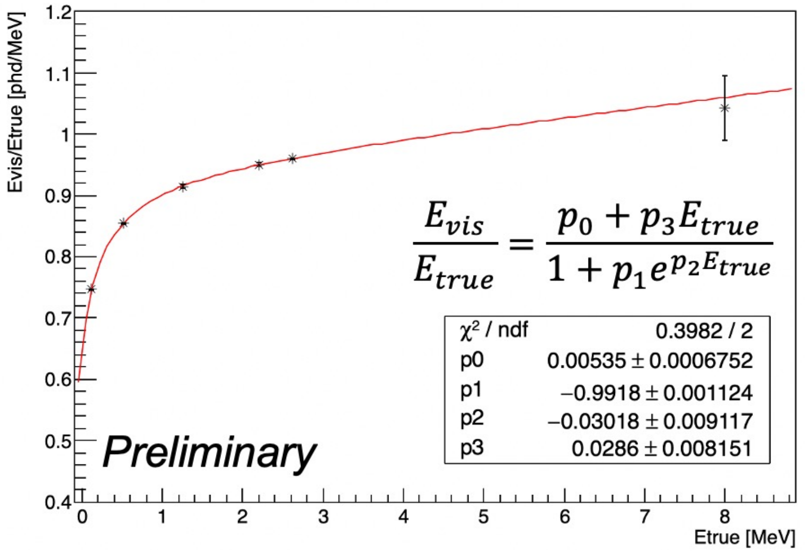
3 source tubes enter here and sit in vacuum between inner and outer vessels

OD background and neutron calibration spectra



Experiment	phe/MeV
RENO	150
Borexino	438
Daya Bay	162
Kamland	200
SNO+	300
LZ OD	230

GdLS response measured with ^{208}Tl, ^{22}Na, ^{57}Co, H/Gd-captures

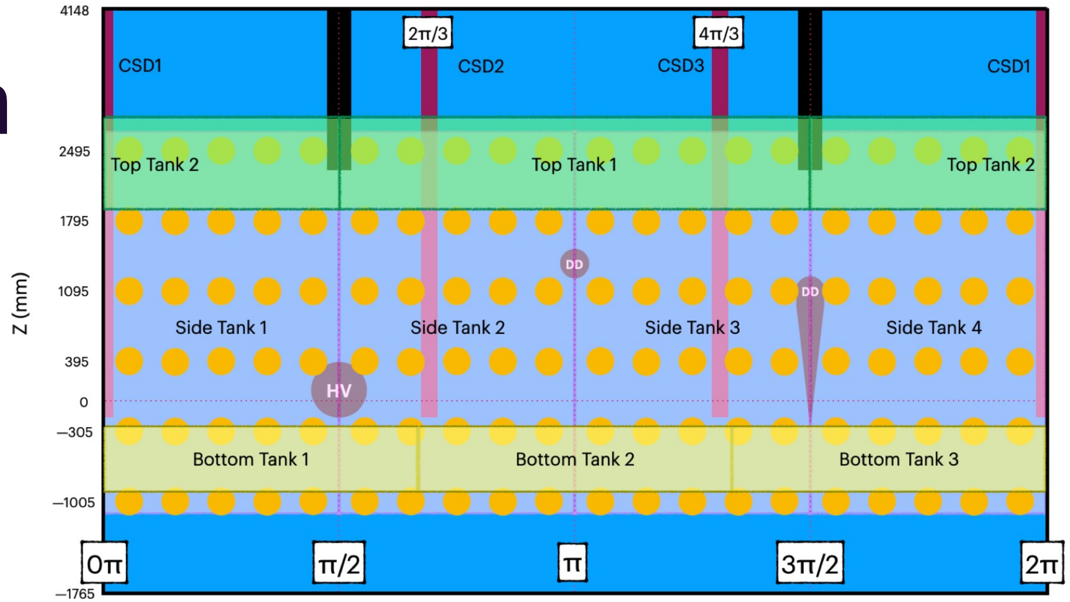


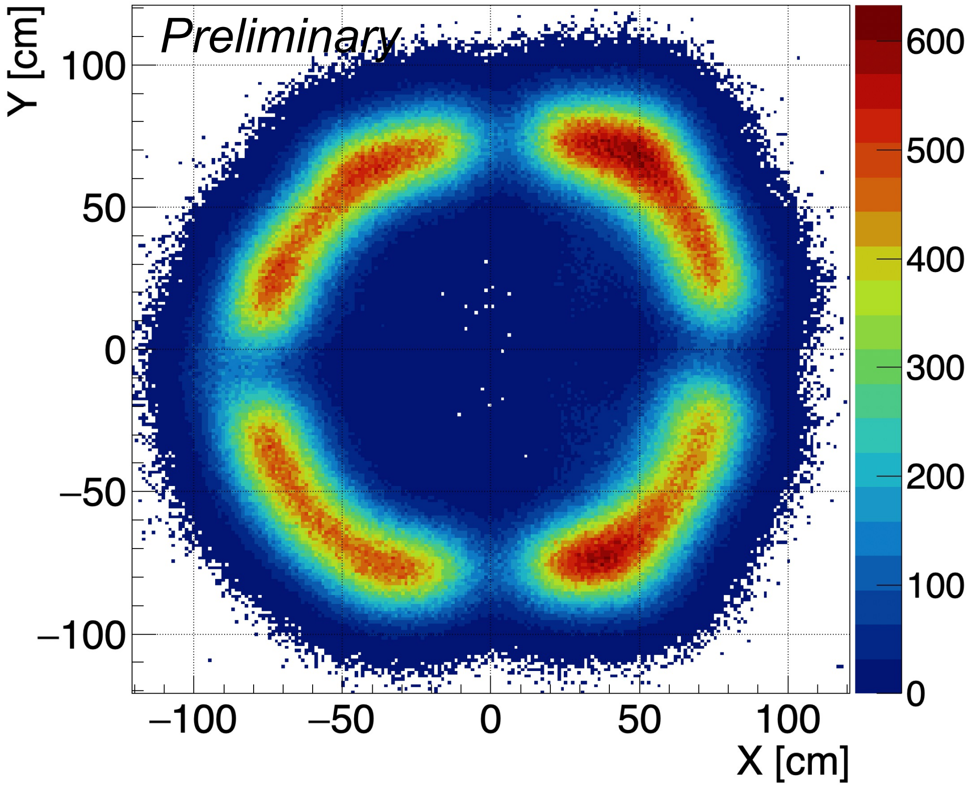
E_{true} is the true energy deposited in the GdLS
E_{vis} is the visible energy accounting for nonlinear GdLS response

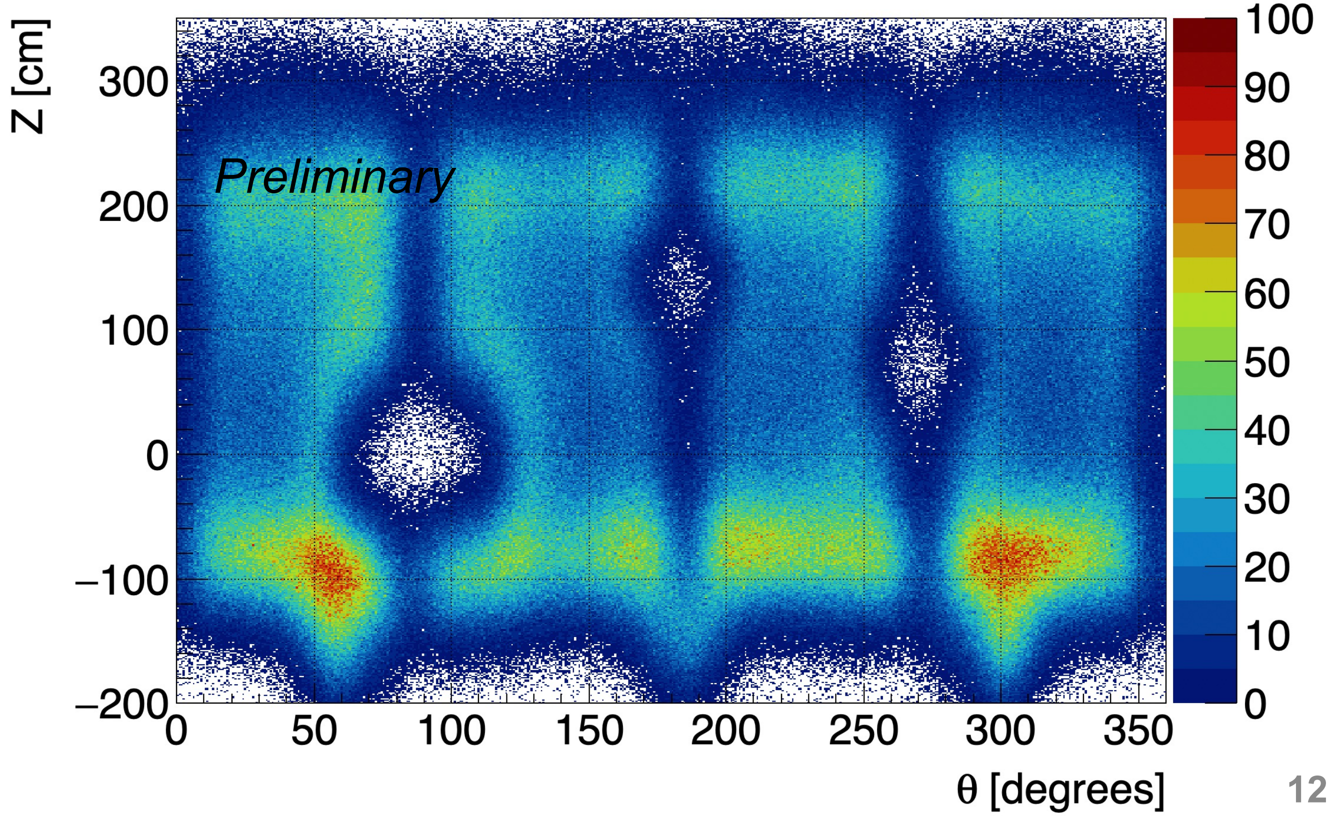
Position reconstruction

We resolve individual tanks through a simple centroid position reconstruction!
(Z-position is corrected based on CSD gamma calibration)

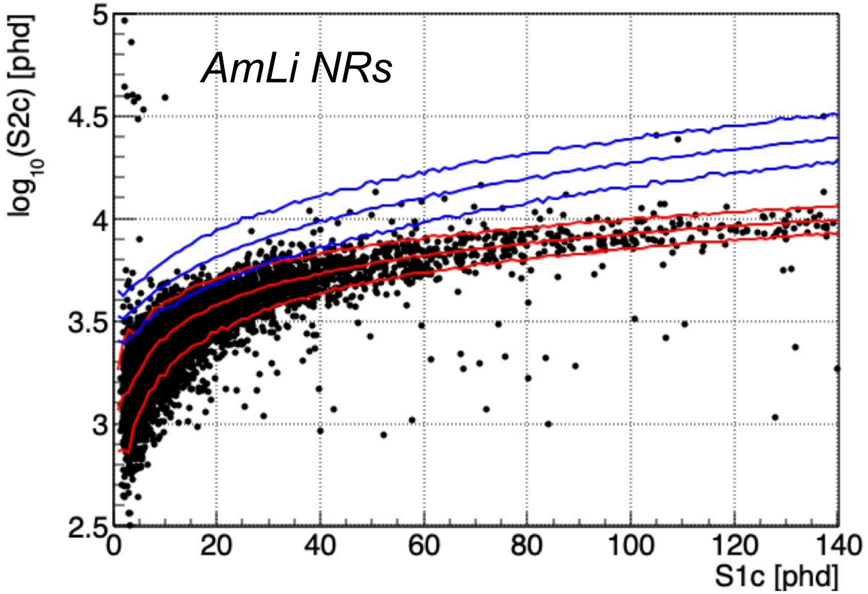
Can correlate angle between TPC, skin, OD

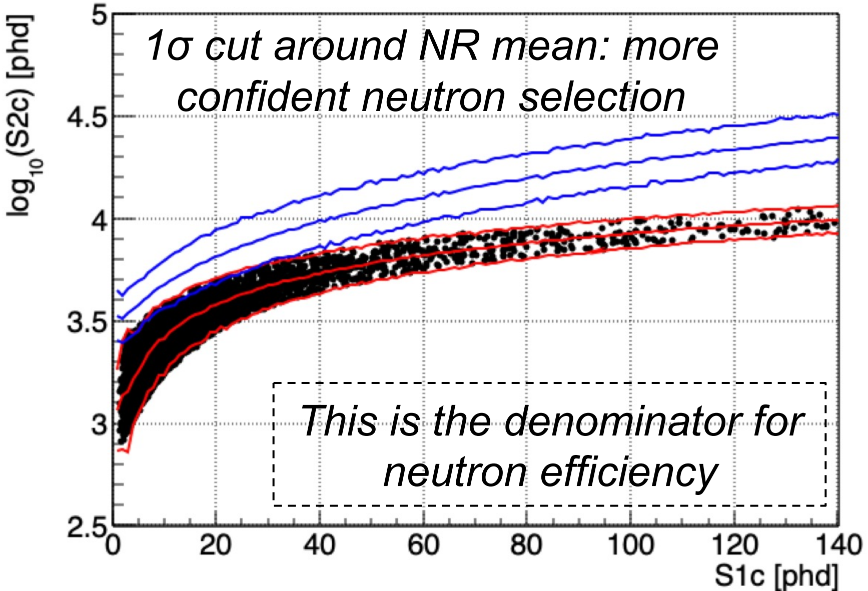




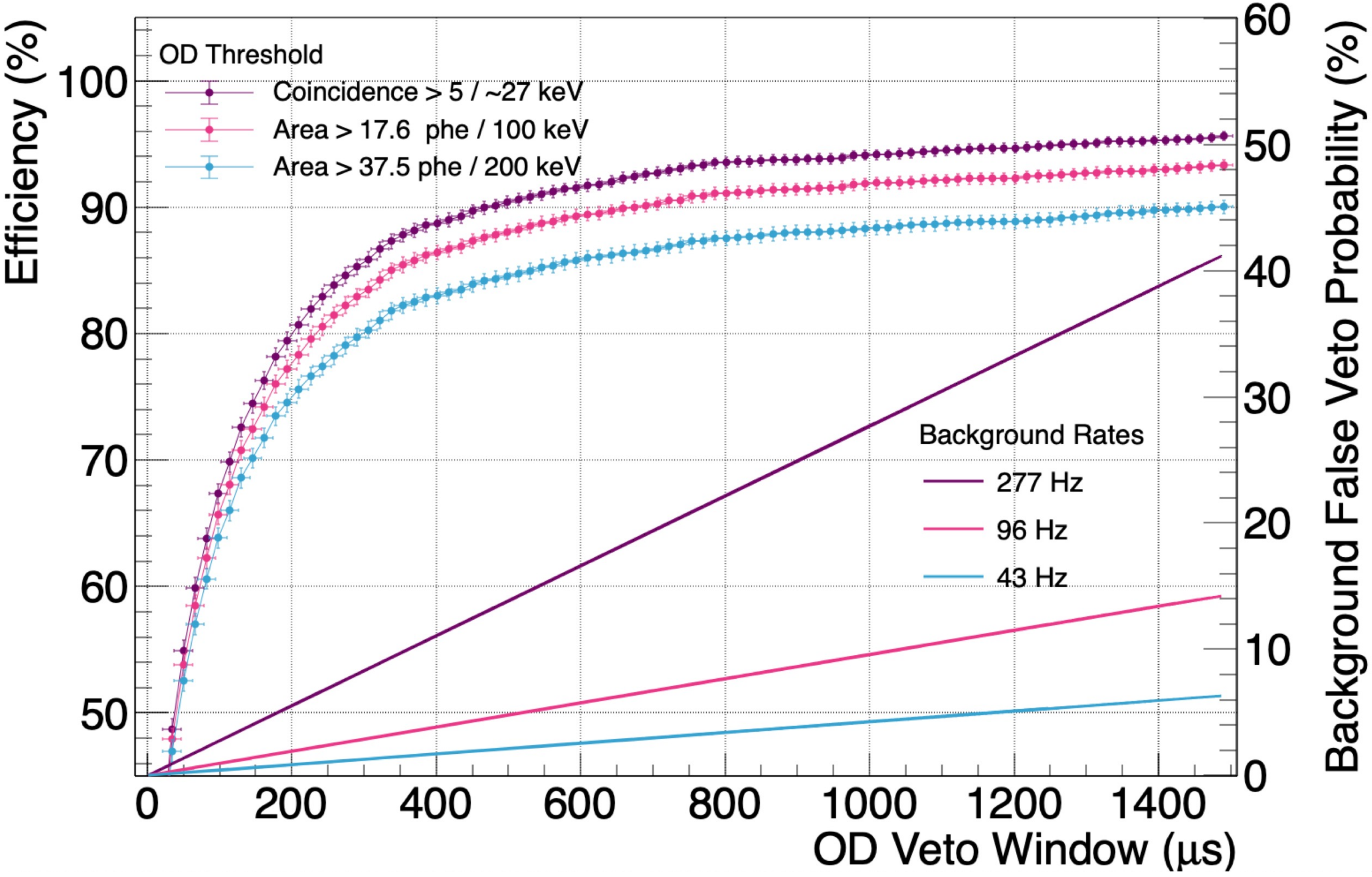


Neutron tagging efficiency measured with AmLi

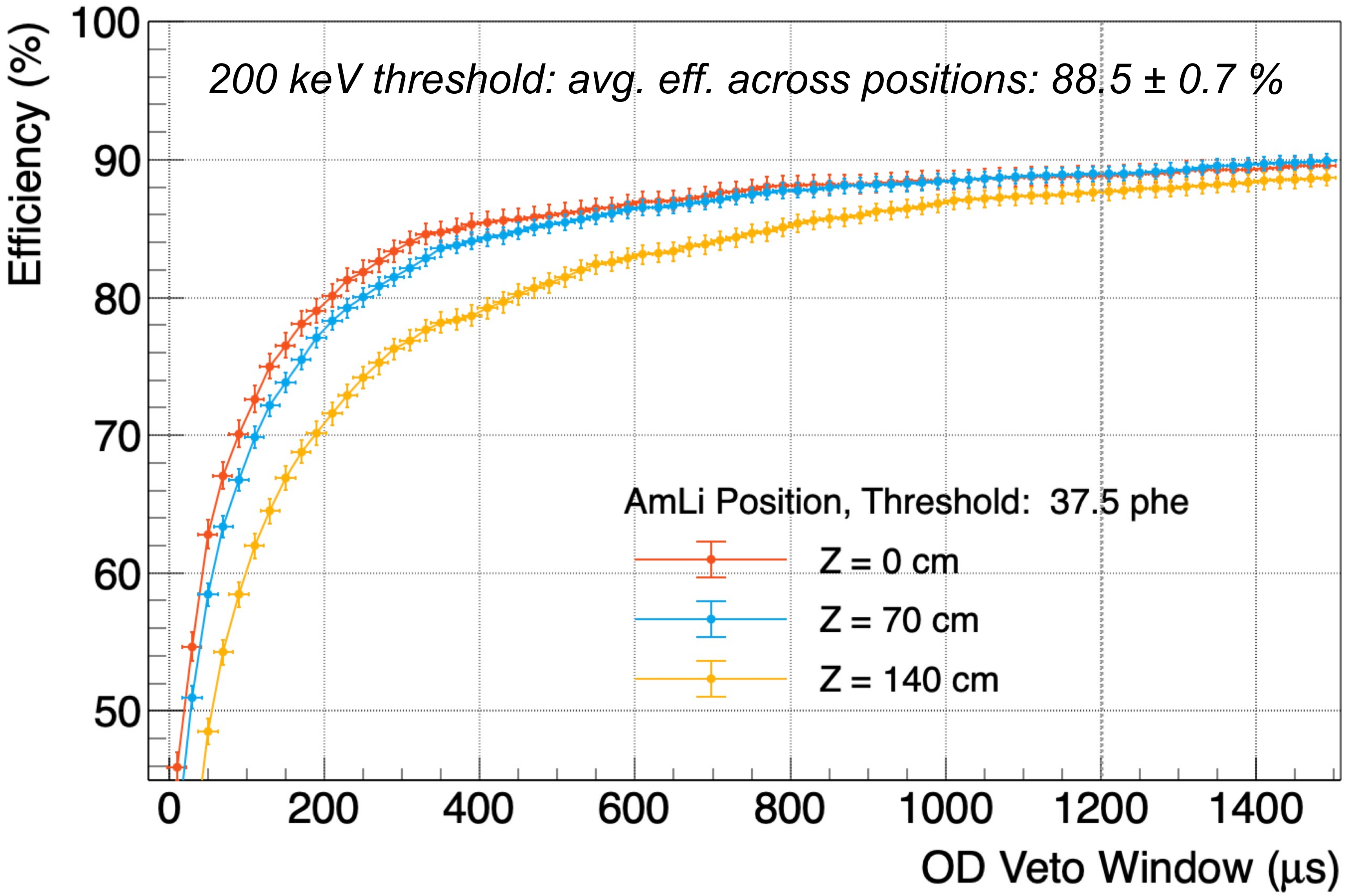




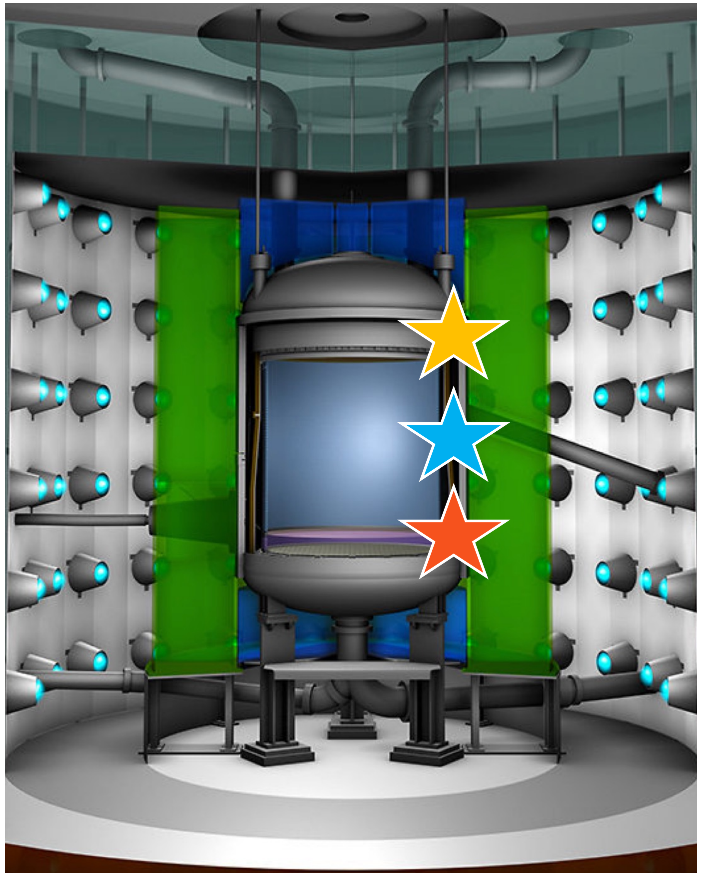
Assess efficiency and false veto fraction for different windows and thresholds



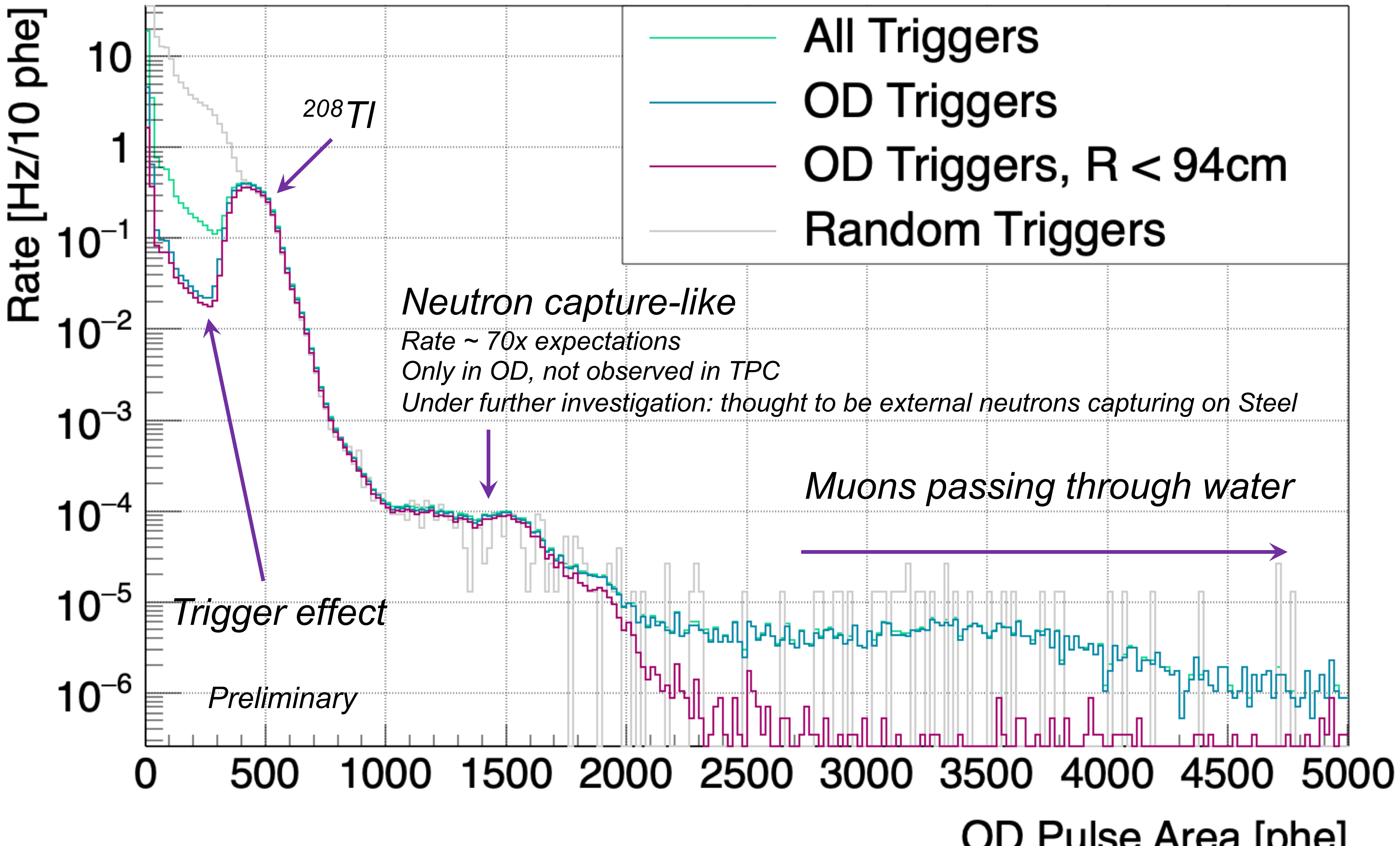
Neutron tagging efficiency versus position



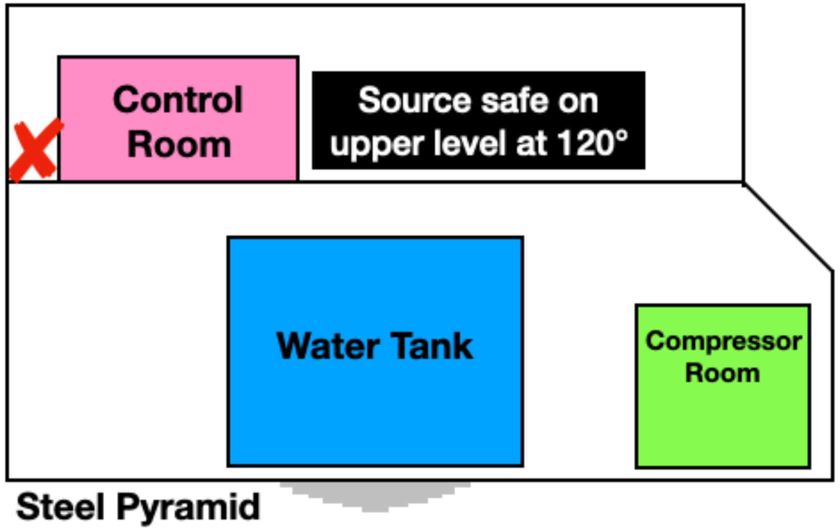
Source locations

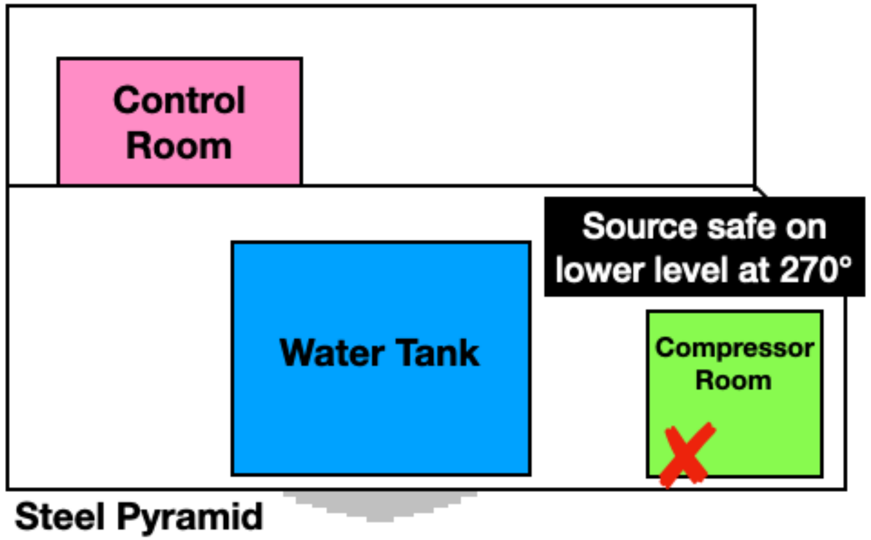


The OD in Science Run 1 (SR1)



The OD saw neutrons from inside our source safe

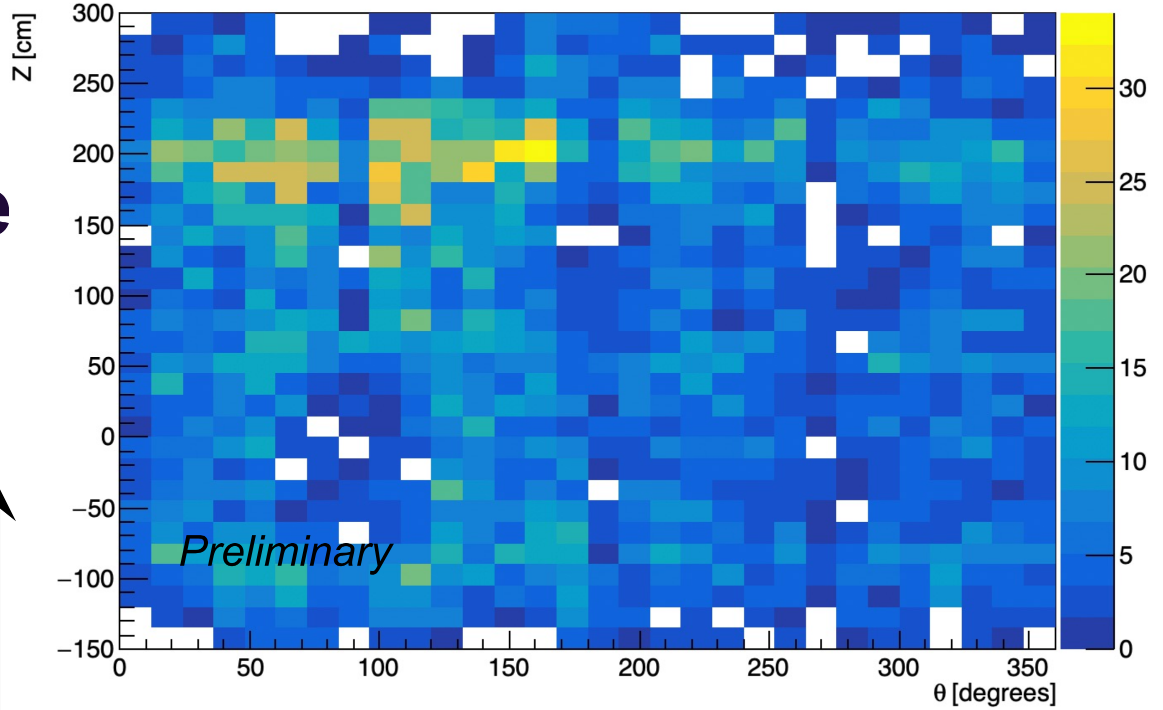


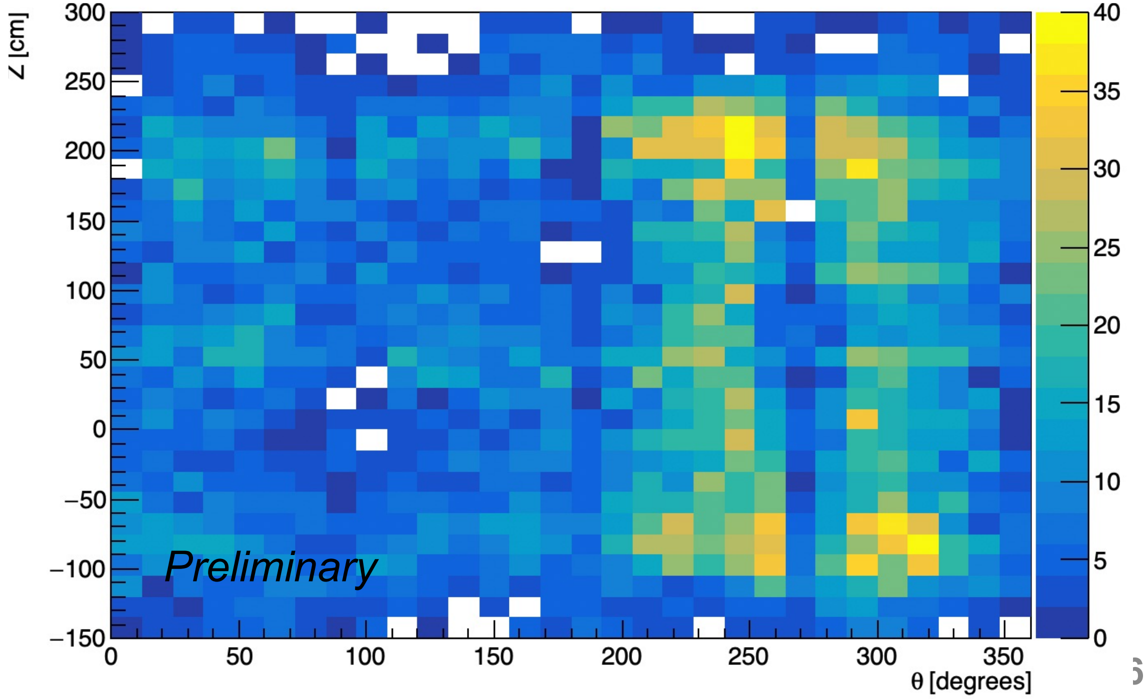


Source safe moved from lower Davis to upper deck

Consistent with neutron captures on Steel:

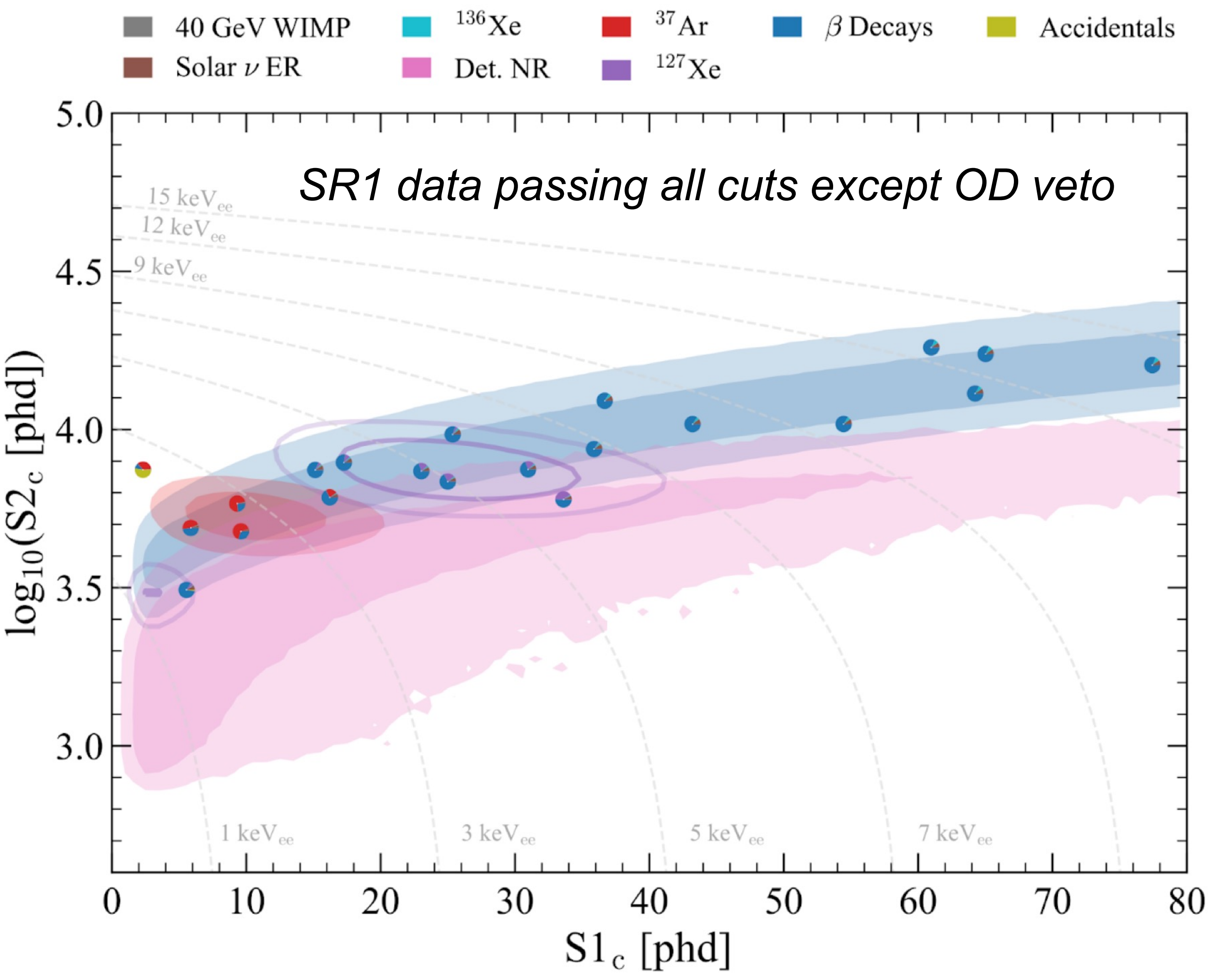
^{56}Fe (7.65 MeV), ^{58}Ni (9 MeV), ^{50}Cr (9.26 MeV), ^{52}Cr (7.54 MeV), ^{53}Cr (9.72 MeV)





OD constraints for the WIMP search

- Neutron backgrounds, “Det. NR”, with OD tag are 7.7 times larger than without (tagging efficiency is 88.5%)
- 5% of non-neutron backgrounds have an accidental OD tag by design
- We use OD-tagged data to set data-driven constraint on the rate of Det. NR: < 0.2 events (2-sided constraint)
- Consistent with simulation estimate of 0.06 events in 60 live-days
- OD is performing very well and has helped us get to our first science result!



Thank you!

@lzdarkmatter
https://lz.lbl.gov/

And thanks to our sponsors and participating institutions!

>35 institutions in USA, UK, Portugal, and Korea | ~250 scientists, engineers, and technical staff

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Sanford Underground Research Facility
South Dakota Science and Technology Authority

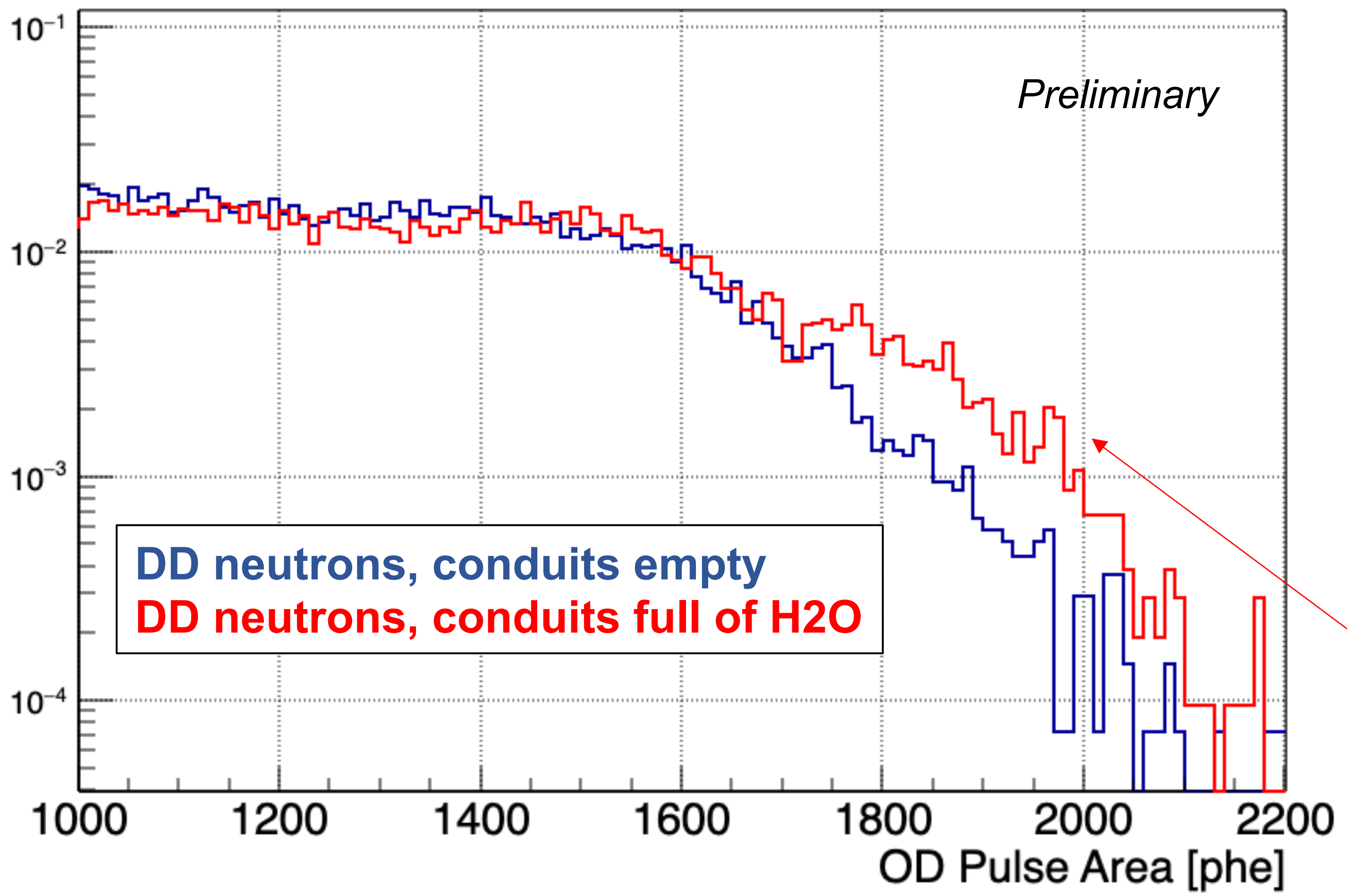
FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

UKRI Science and Technology Facilities Council

ibs Institute for Basic Science

Extras

Why we think external neutrons capture on steel

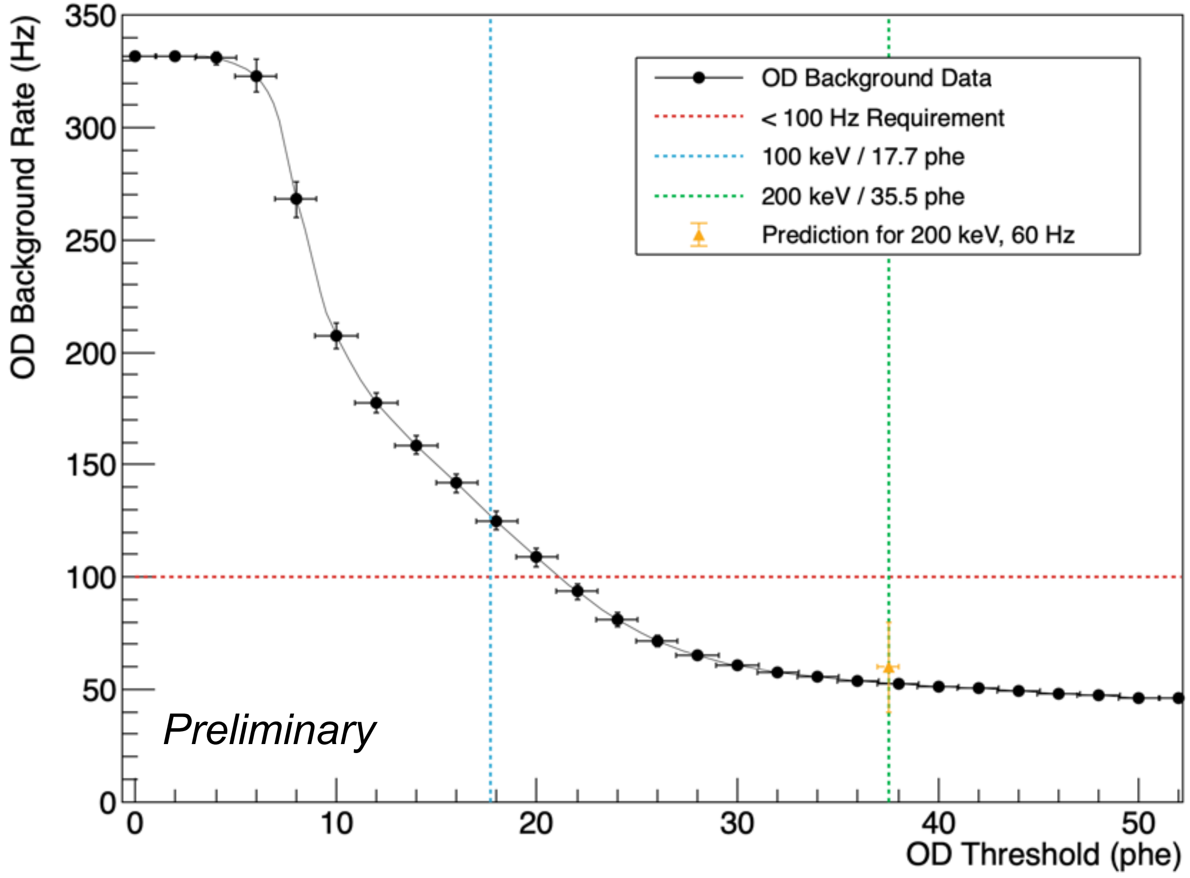


GdLS capture energies:
^{155}Gd (8.5 MeV)
^{157}Gd (7.9 MeV)

Steel element capture energies:
^{56}Fe (7.65 MeV),
^{58}Ni (9 MeV),
^{50}Cr (9.26 MeV),
^{52}Cr (7.54 MeV),
^{53}Cr (9.72 MeV)

Higher bump in conduit full data consistent with >9 MeV captures

OD background rate

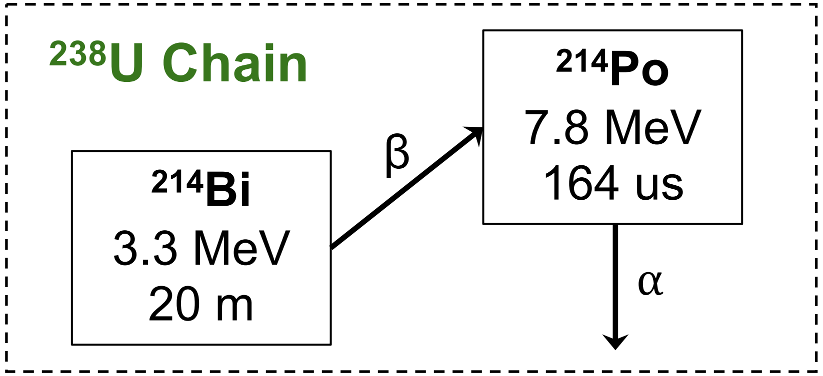


Background rate consistent with prediction!

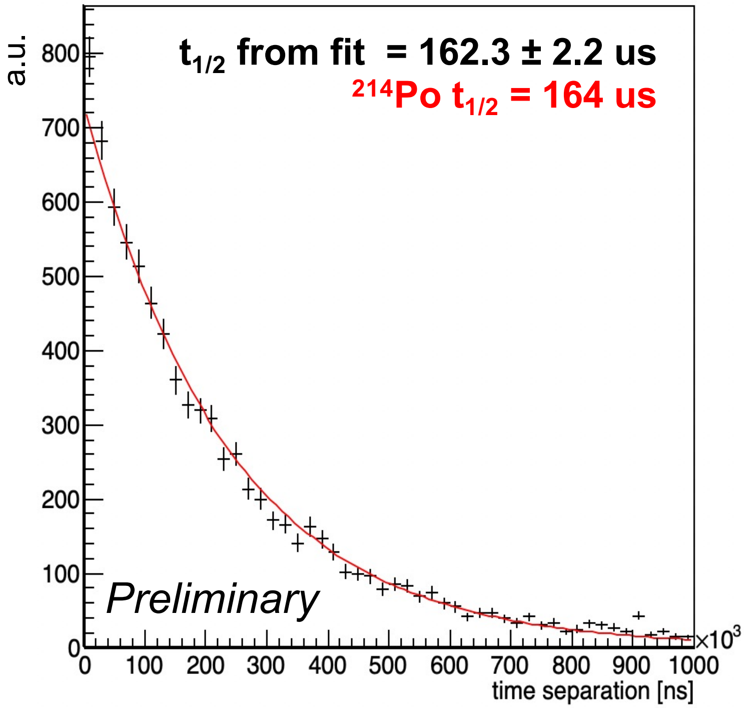
System	Component	OD Rate (Hz)
PMTs	PMTs	0.31
	PMT Bases	0.11
	Skin PMTs	0.11
	Skin PMT Bases	0.01
	PMT Supports	0.16
	PMT Cabling	0.14
	Total	**0.85**
TPC	PTFE	0.00
	Grid Holders & Wires	0.23
	Field Rings	0.03
	Sensors & Thermometers	0.03
	Conduits Cables, Tubing	0.22
	Total	**0.52**
Cryostat	Vessels	1.43
	Seals	0.63
	Insulation	0.45
	Total	**2.51**
Outer Detector	Acrylic Tanks & Support	5.42
	OD PMTs	2.48
	PMT Supports	0.09
	Externals Total	**7.99**
	Internal - LS	**5.88**
Davis Cavern		**42.0**
Grand Total		**60 Hz**

Simulation prediction: 60 Hz above 200 keV

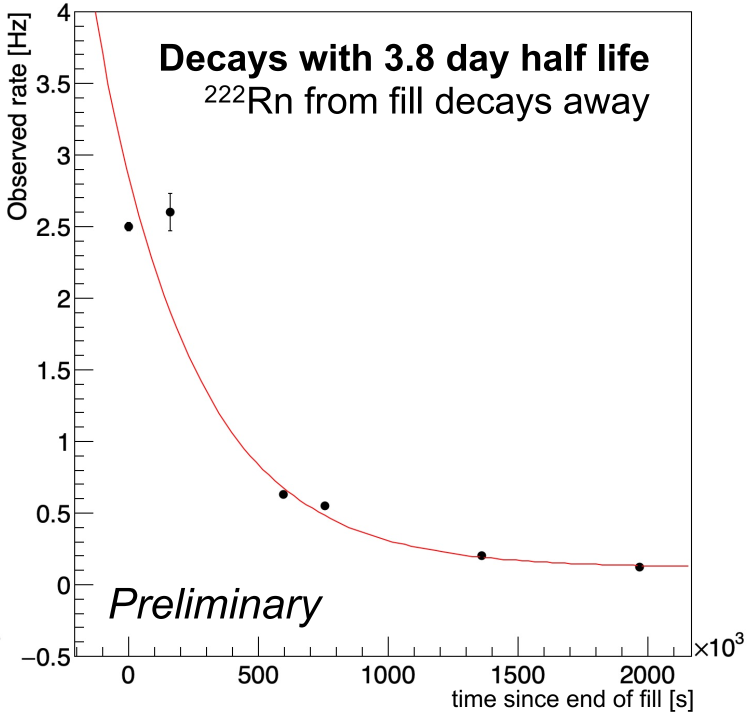
OD calibration with in-situ BiPos



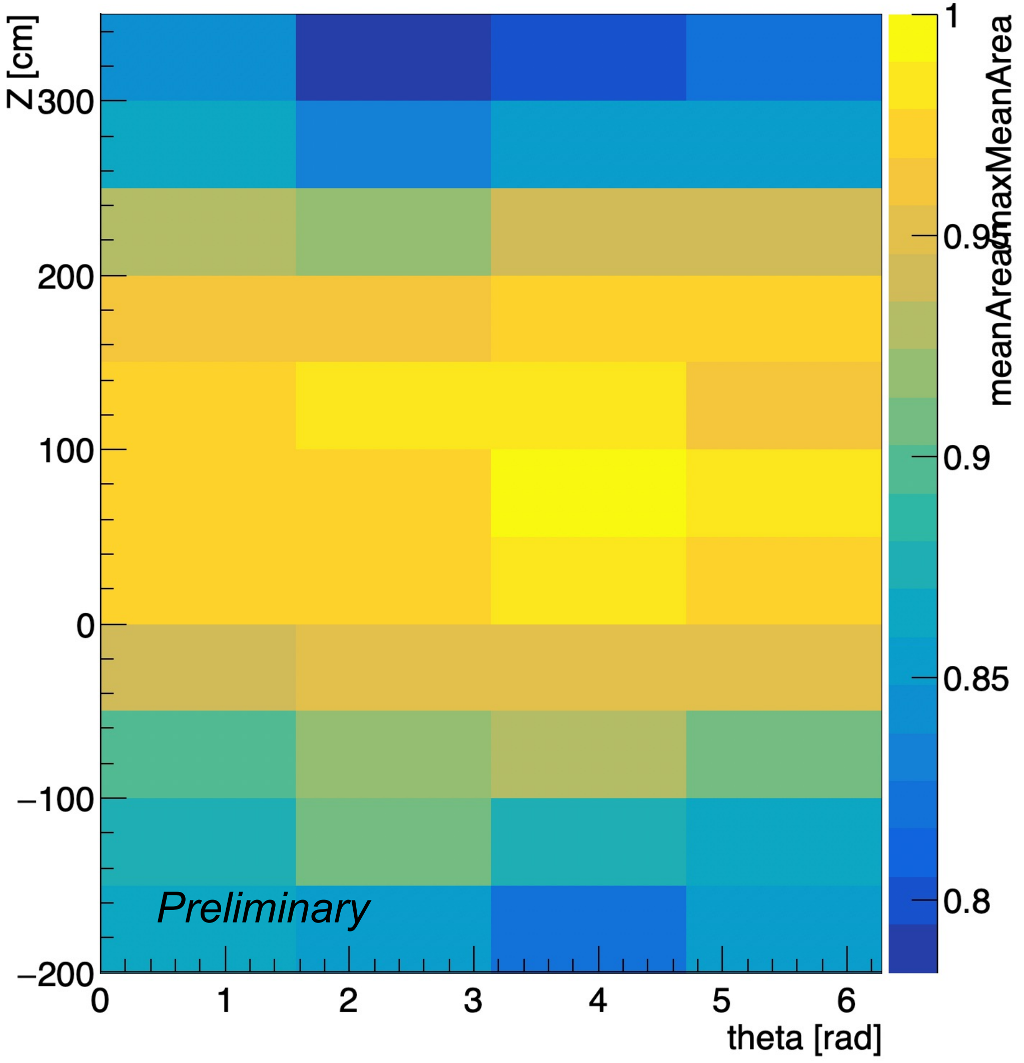
Measured BiPo time separation



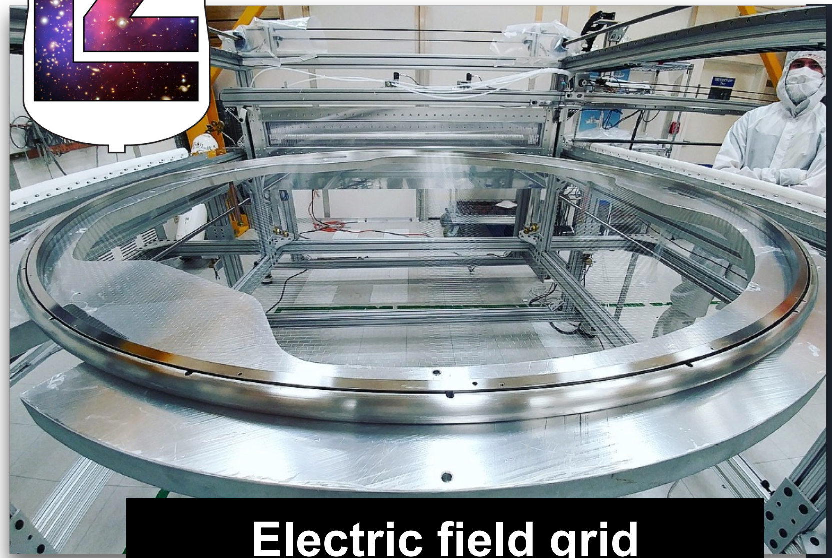
BiPo rate over time



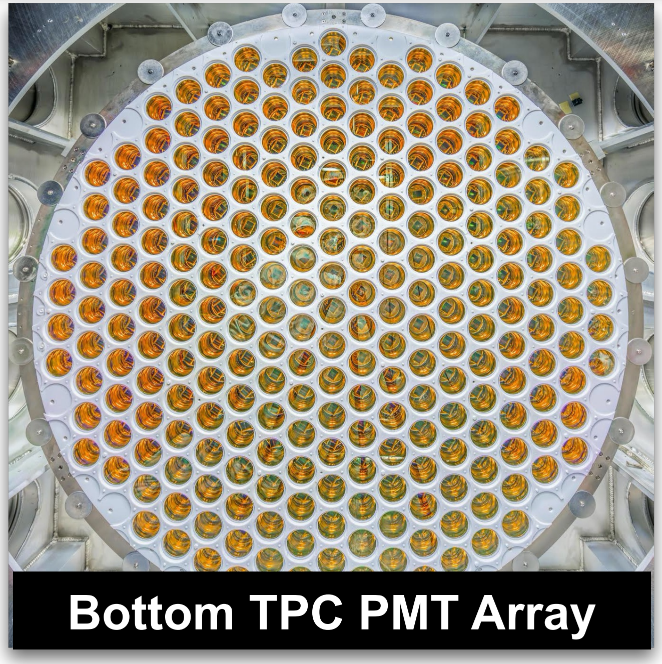
OD light map built from ^{214}Po α's: ~20% variation



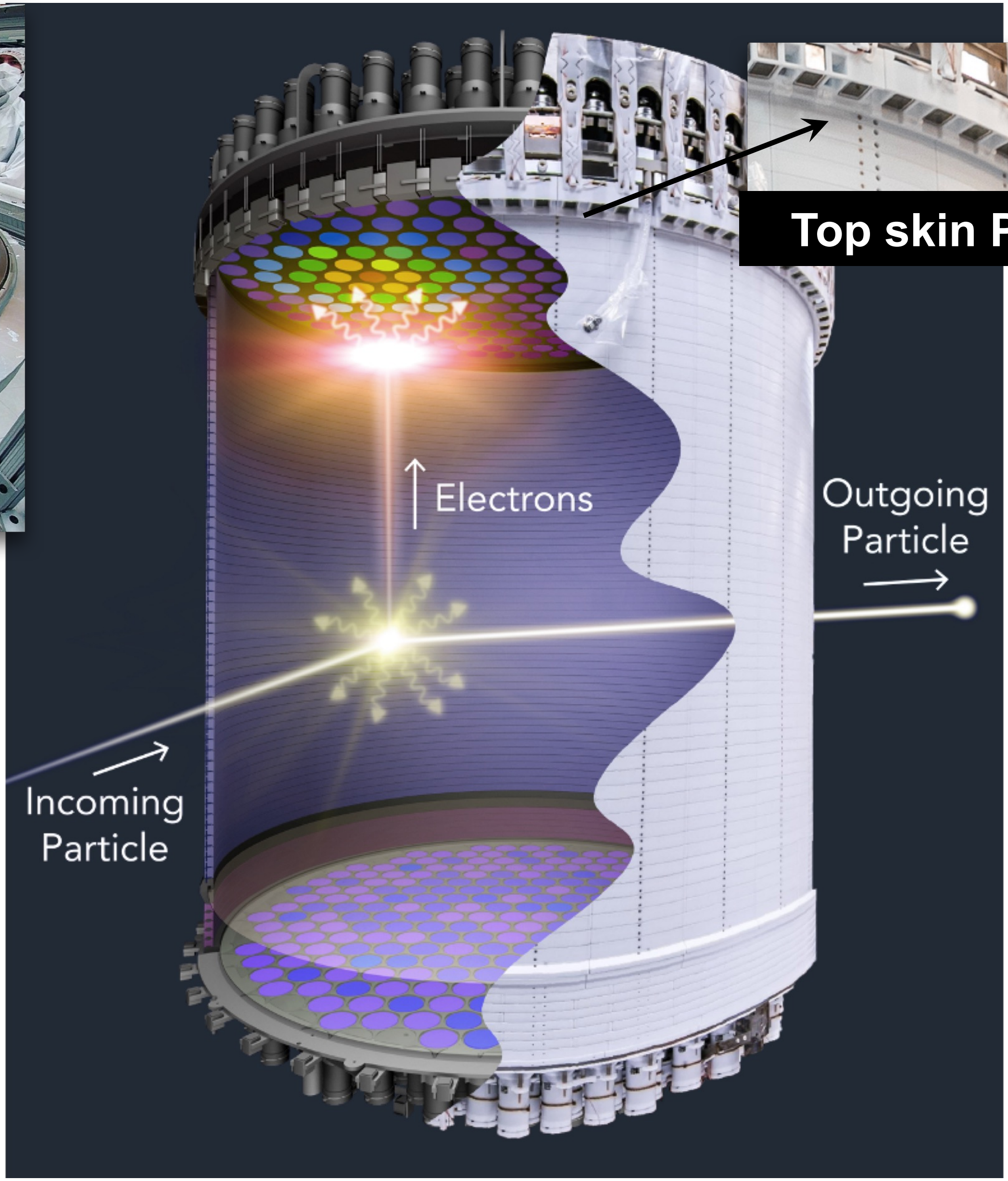
Time projection chamber (TPC) & LXe skin



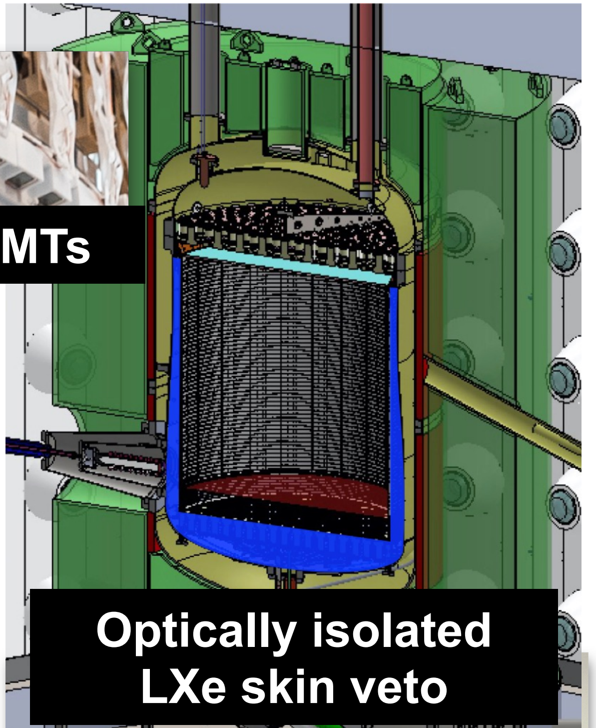
Electric field grid



Bottom TPC PMT Array



Top skin PMTs



Optically isolated LXe skin veto