After LUX: The LZ Experiment

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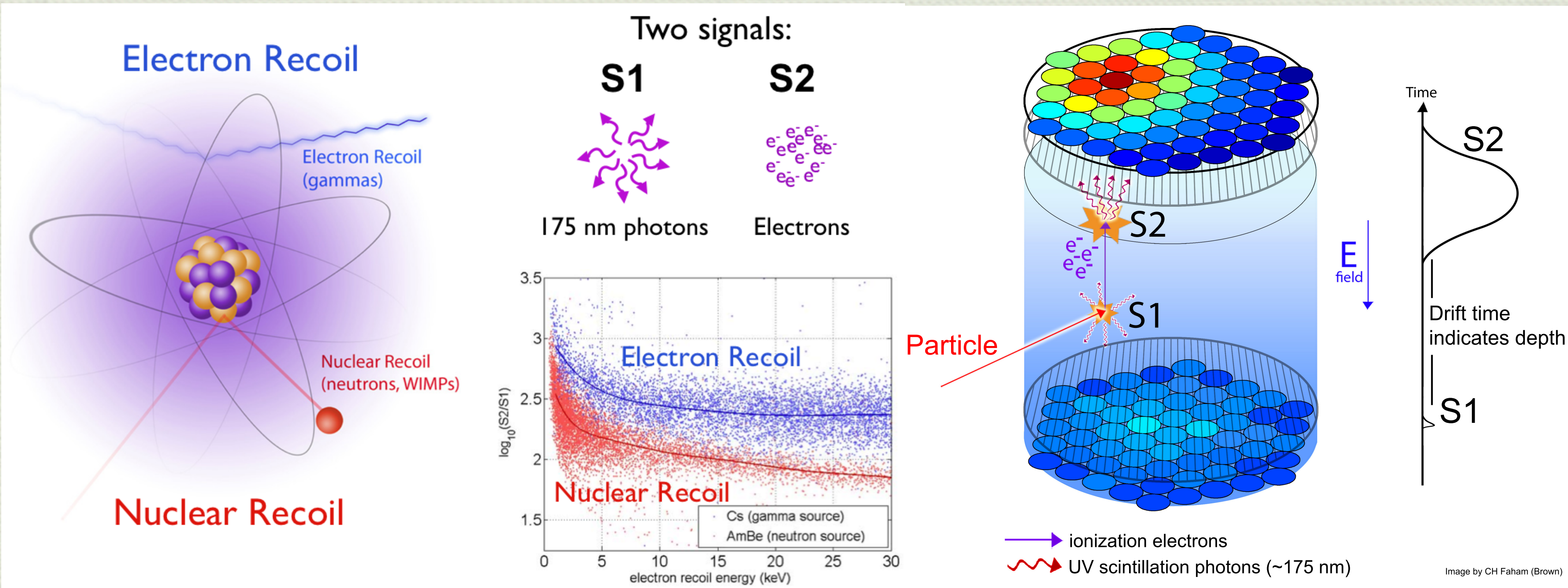
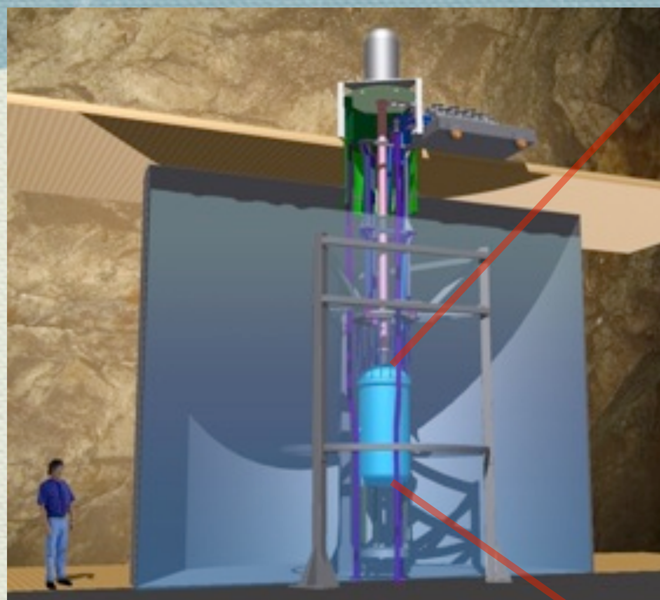
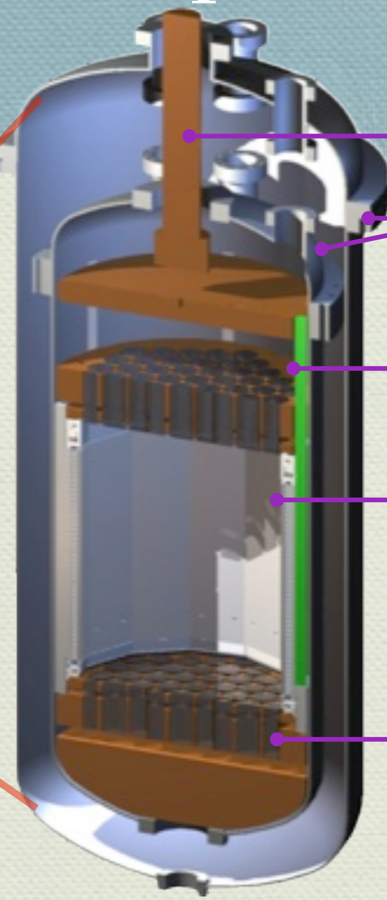
Liquid Xenon Time Projection Chambers (TPC)

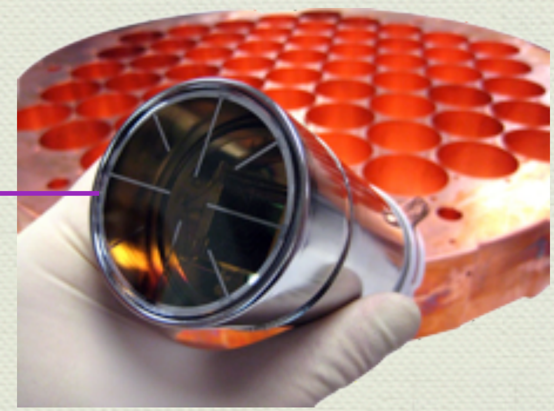


- Two-phase time projection chamber identifies interaction sites using 3-D position reconstruction and particles using primary and secondary scintillation signals
- Xenon has excellent scintillation and ionization sensitivity, is intrinsically radiopure, and easily scalable to higher masses with the advantage of increased self-shielding
- WIMP interactions in Xenon:
    - elastic scatter with Xe nucleus that is indistinguishable from neutrons
    - low interaction cross section -> single scatter in volume and low energy deposition

The LUX Experiment







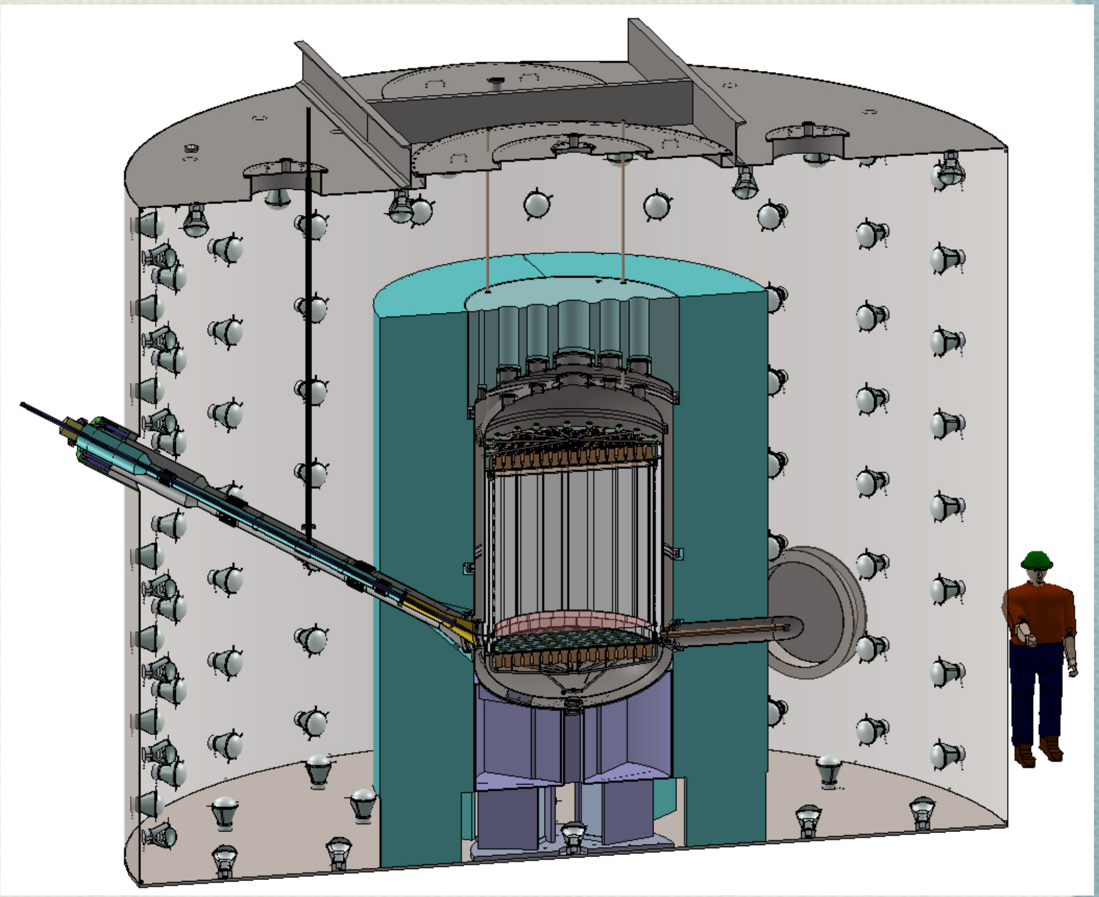
2" Hamamatsu R8778
Photomultiplier Tubes (PMTs)

- 370 kg liquid Xenon time projection chamber (TPC)
- detector in 8m x 6m water tank
- 4850 ft underground at Homestake mine in Lead, SD
- low radioactivity Ti
- 122 R8778 PMTs for detection
- PTFE reflector cage
- Thermosyphon for cooling Xe to ~170K

Stay tuned for results!

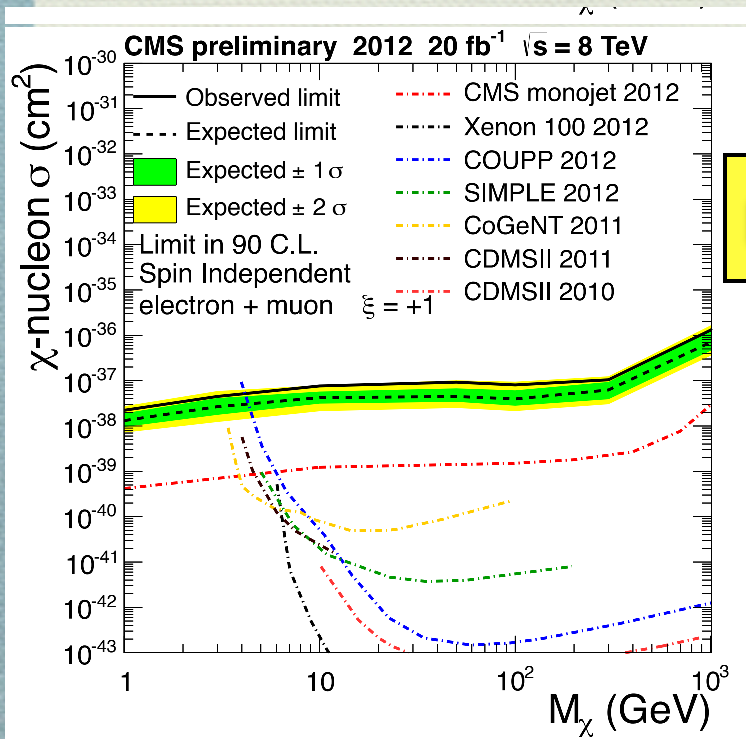
Scaling up: The LZ Experiment

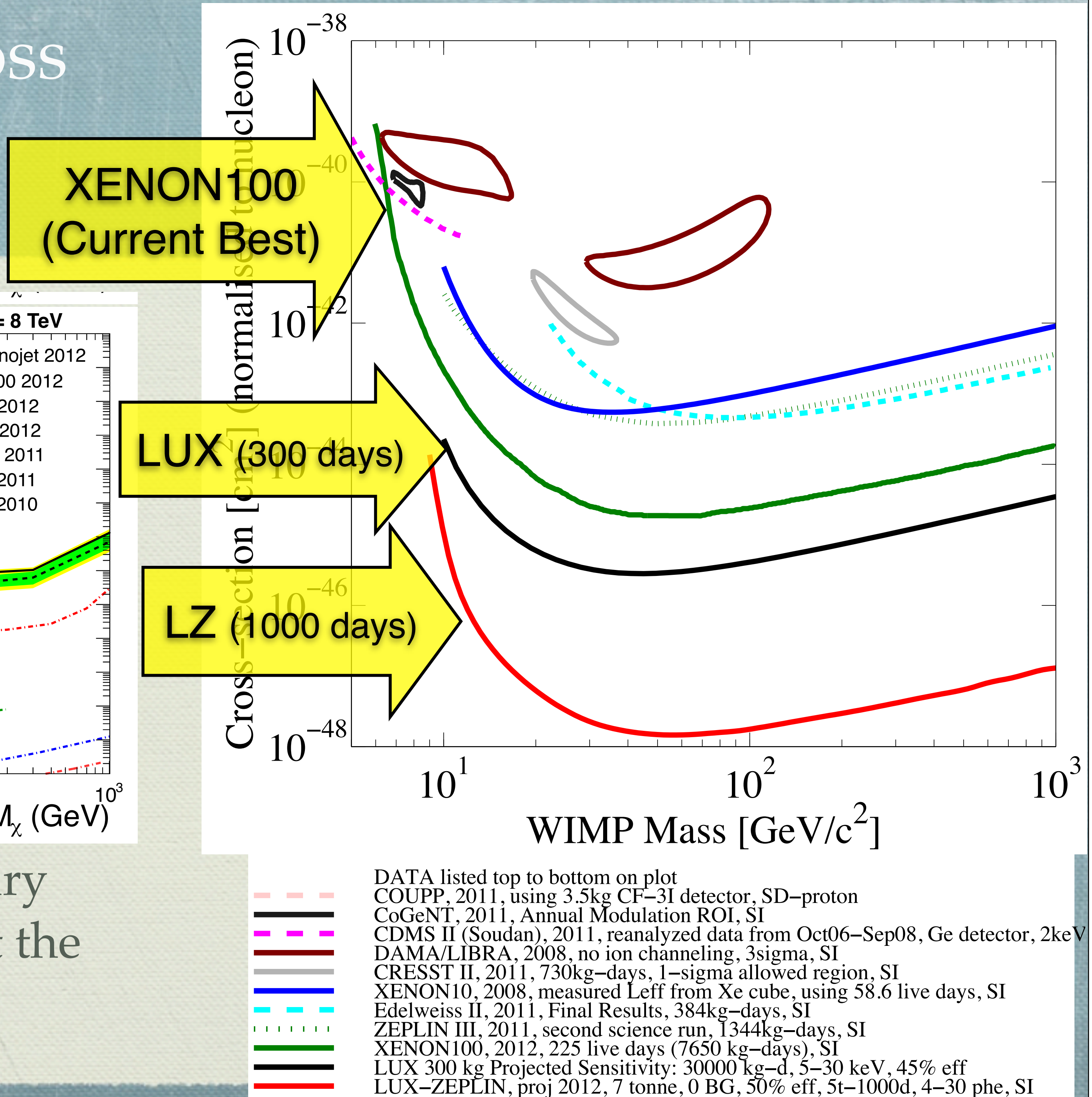
- LUX + ZEPLIN collaboration
- 7.2 tonnes ~~370 kg~~ liquid Xenon time projection chamber (TPC)
- detector in 8m x 6m water tank
- 4850 ft underground at Homestake mine in Lead, SD
- low radioactivity Ti
- ~500 R11410 ~~122 R8778~~ PMTs for detection
- PTFE reflector cage
- Thermosyphon for cooling Xe to ~170K



Addition of liquid scintillator veto outside Ti cryostats and instrument liquid Xe skin outside of field cage

Projected Cross Section



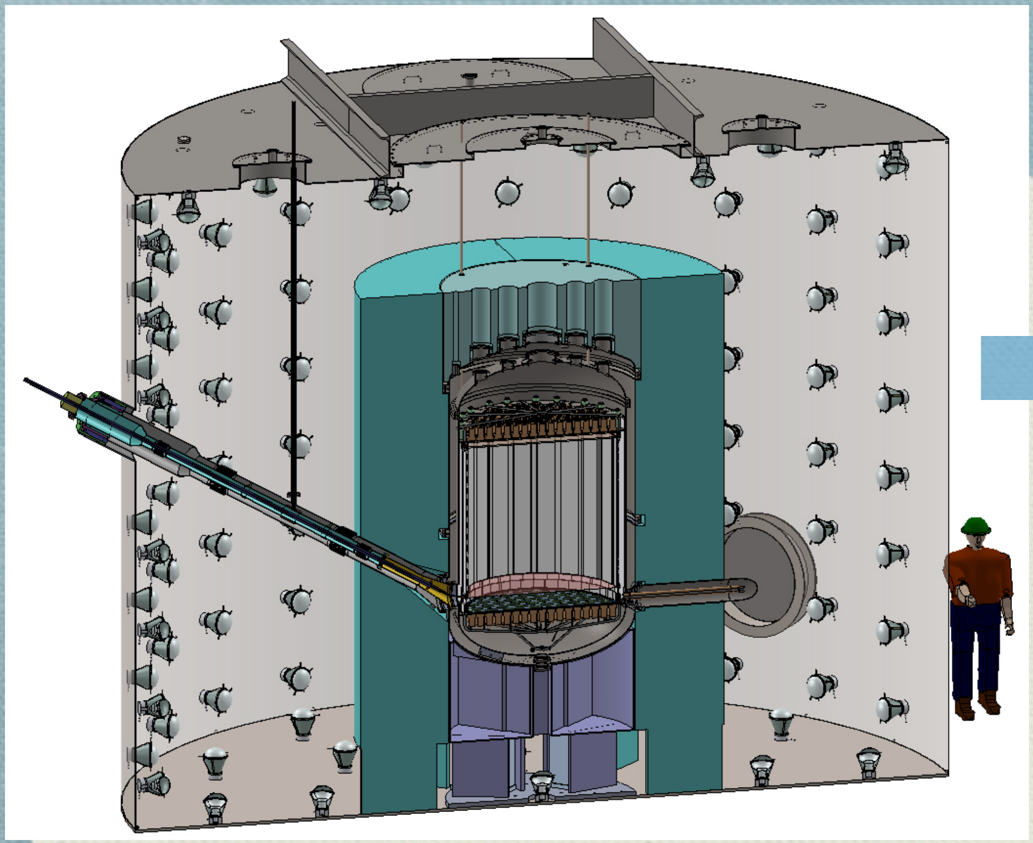


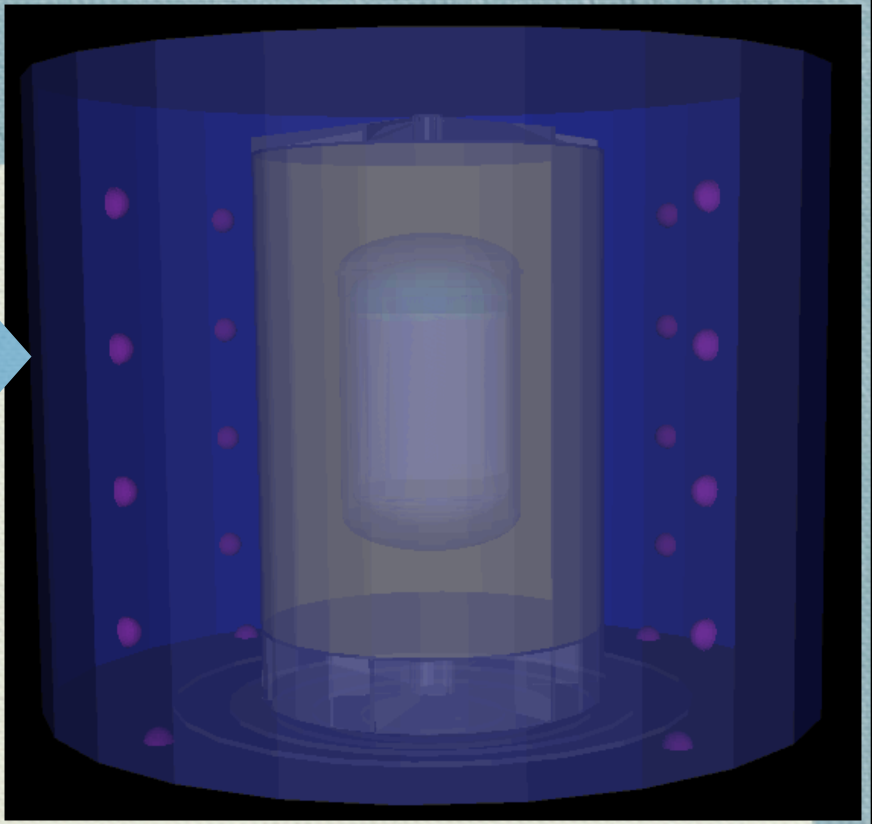
Complimentary searches also at the LHC

Major Challenges

- Can we accomplish a multi-tonne scale up of a liquid Xe TPC?
  - Xe purification, Kr removal, Rn contamination?
- Can we achieve good ER/NR discrimination?
  - HV? Light collection?
- Engineer and commission new active veto system
- Can we keep the backgrounds in the experiment low for a rare event search?

Simulation Modeling





- LUXSim (arXiv:1111.2074) used for full detector response
  - Geant4 based
  - scintillation yield modeled by NEST (arXiv:1106.1613)

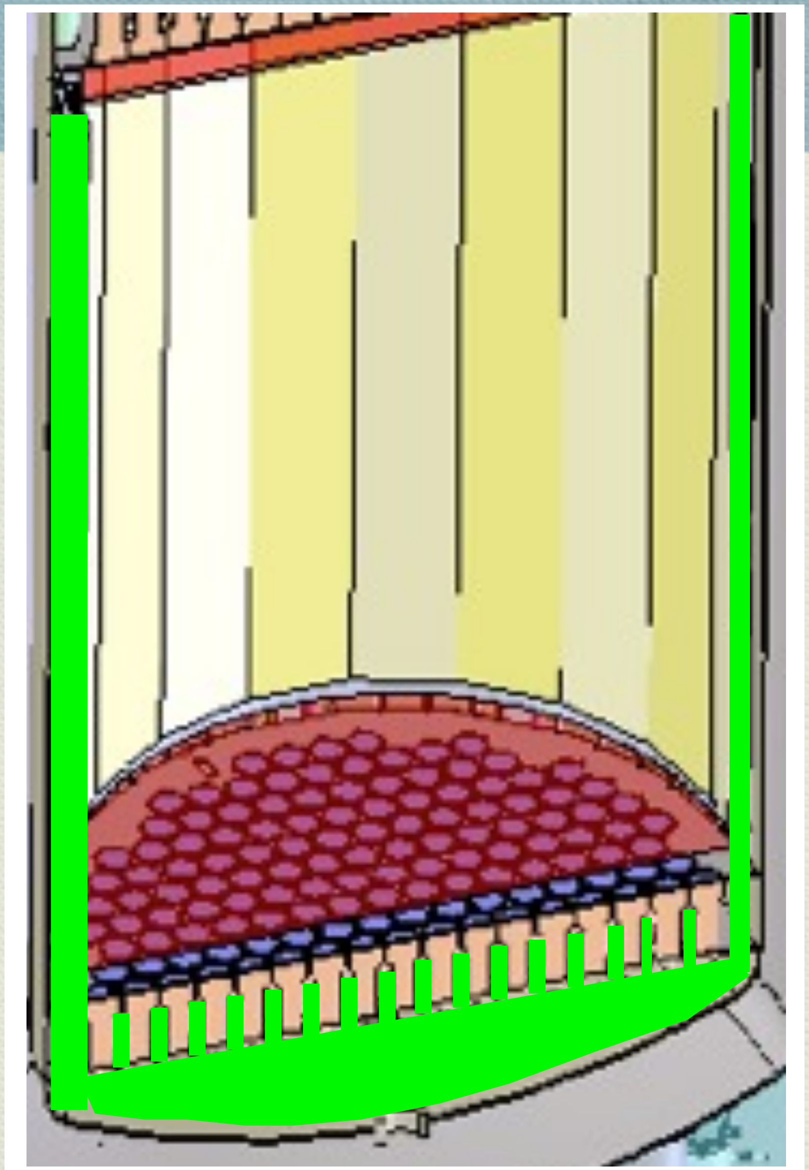
Active Veto Regions

Liquid Scintillator

- 23 tonnes of LAB with 0.2 % doped Gd
- 75 cm thick surrounding cryostat
- neutron capture produces 2.1 MeV gamma from H, gamma cascades of 7.9 MeV and 8.5 MeV from ^{157}Gd and ^{155}Gd

Liquid Xenon Skin

- enlarged space between PTFE walls and inner Ti cryostat
- 4 cm thick



Veto Efficiencies

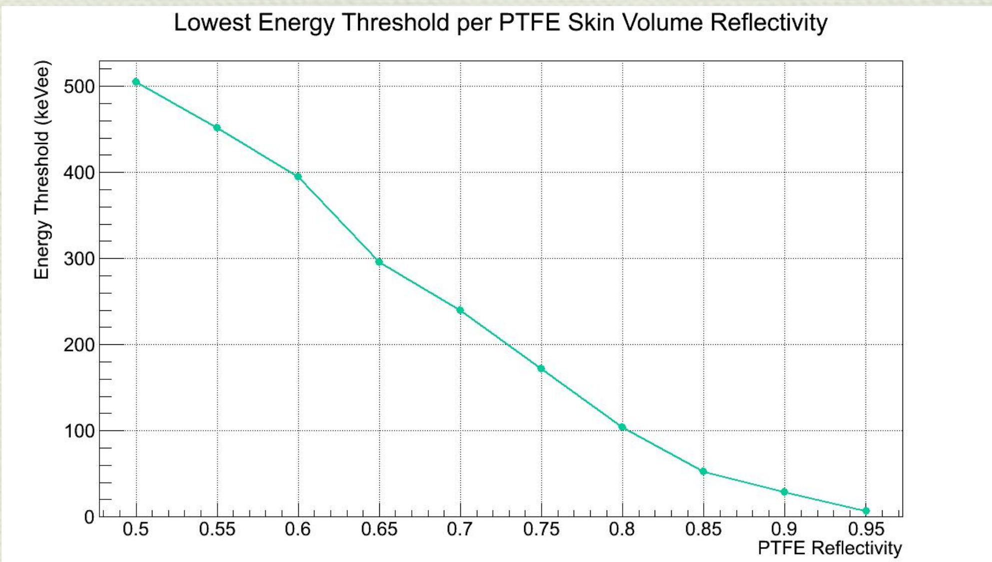
- gammas - scatter and capture in either liquid Xe skin or in the LS
- neutron - relies on thermal neutron capture resulting in gamma emission

100 keVee threshold	LS only	LXe Skin only	LS or LXe Skin
single scatter gamma events (1.2 MeV):	55%	55%	96%
single scatter neutron events (3 MeV)	92%	35%	~98%

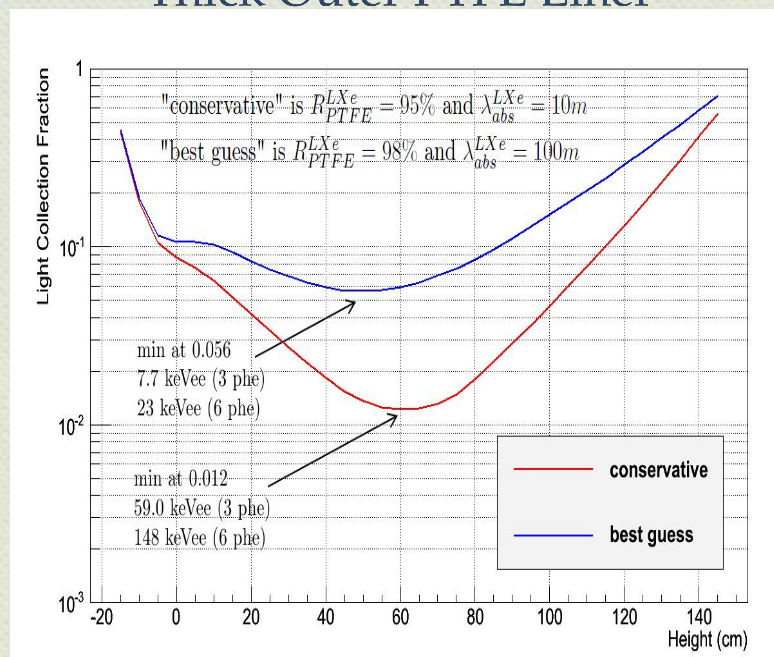
Light Collection: Liquid Xe skin

- liquid Xe skin - efficiency studied as function of PTFE reflectivity, skin thickness, purity, detector mass, radius and height
- 100 keVee threshold requires at least 1% light collection based on PMT QE and coverage and E field in skin

Thin Outer PTFE Liner (assume inner PTFE liner is 100% reflective)

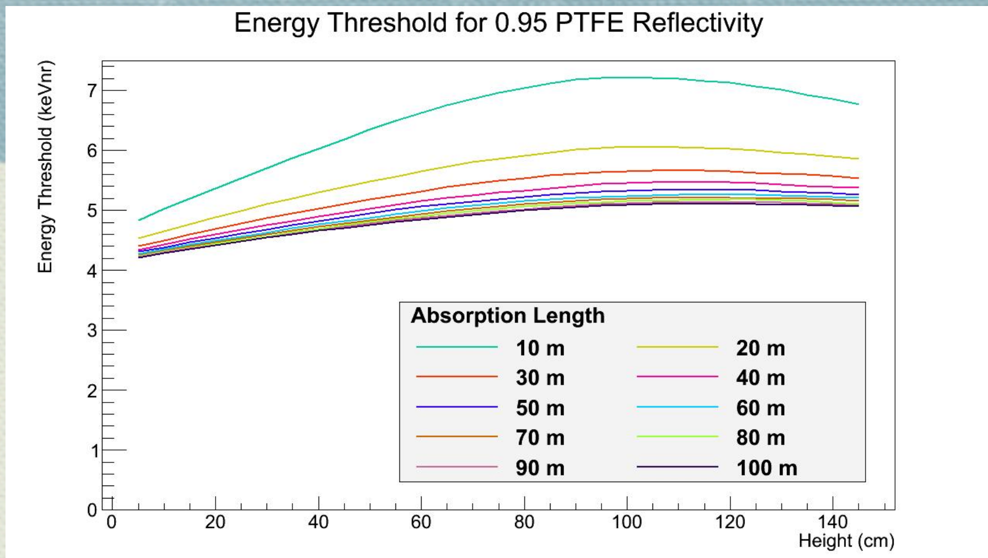


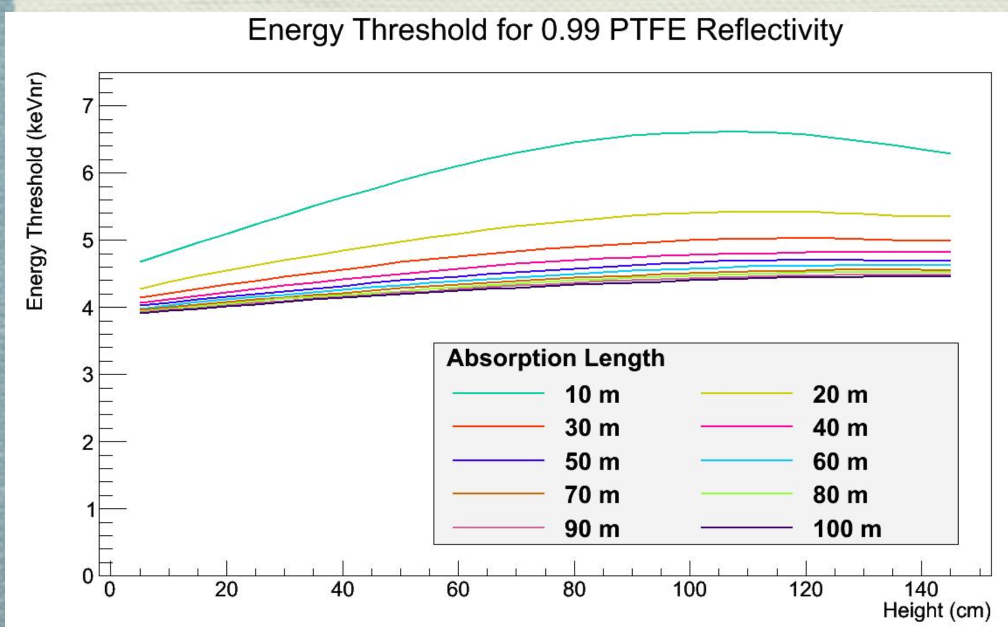
Thick Outer PTFE Liner



- Thick Outer PTFE liner reaches 100 keVee threshold easily
- Thin PTFE liner must have at least 80% reflectivity for 100 keVee threshold

Light Collection in Liquid Xenon Target



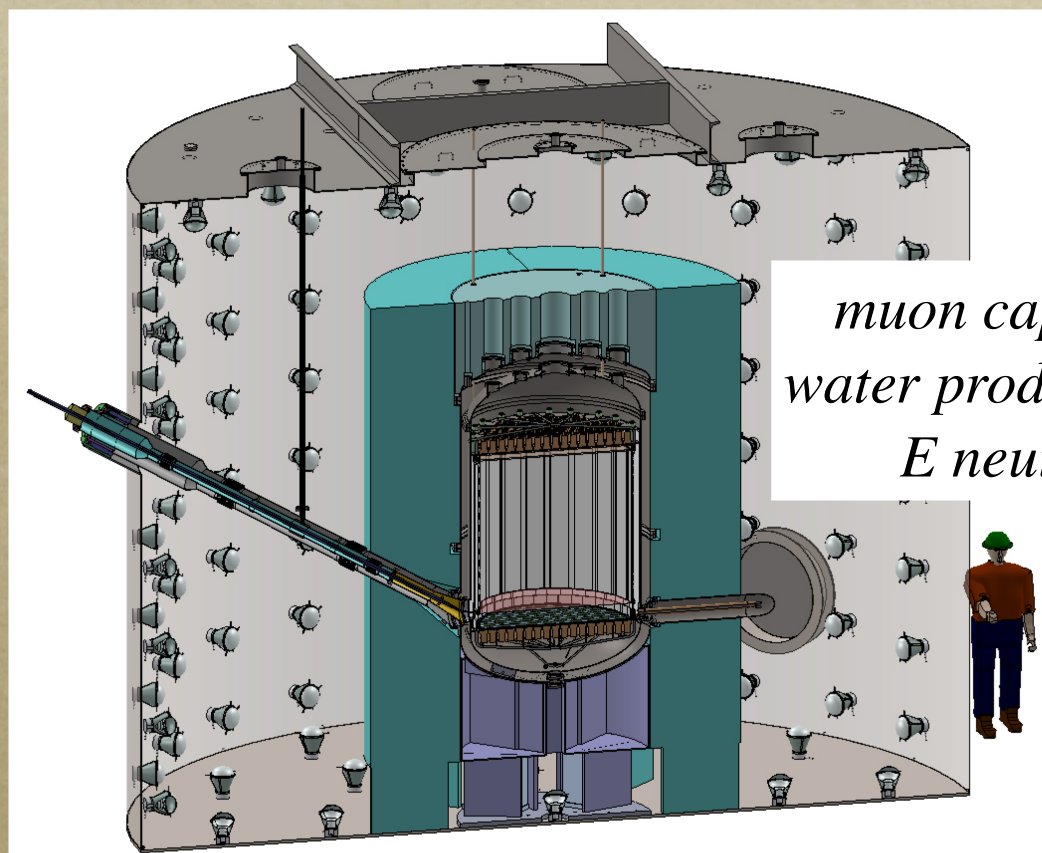


- Given the LZ detector size, light collection does not change monotonically, but has a minimum near the middle like in the skin
- not much change with PTFE reflectivity
- NR recoil threshold found between ~4-7 keVnr using conservative assumptions

External Backgrounds

Rock radioactivity

Muon-induced neutrons from spallation with rock

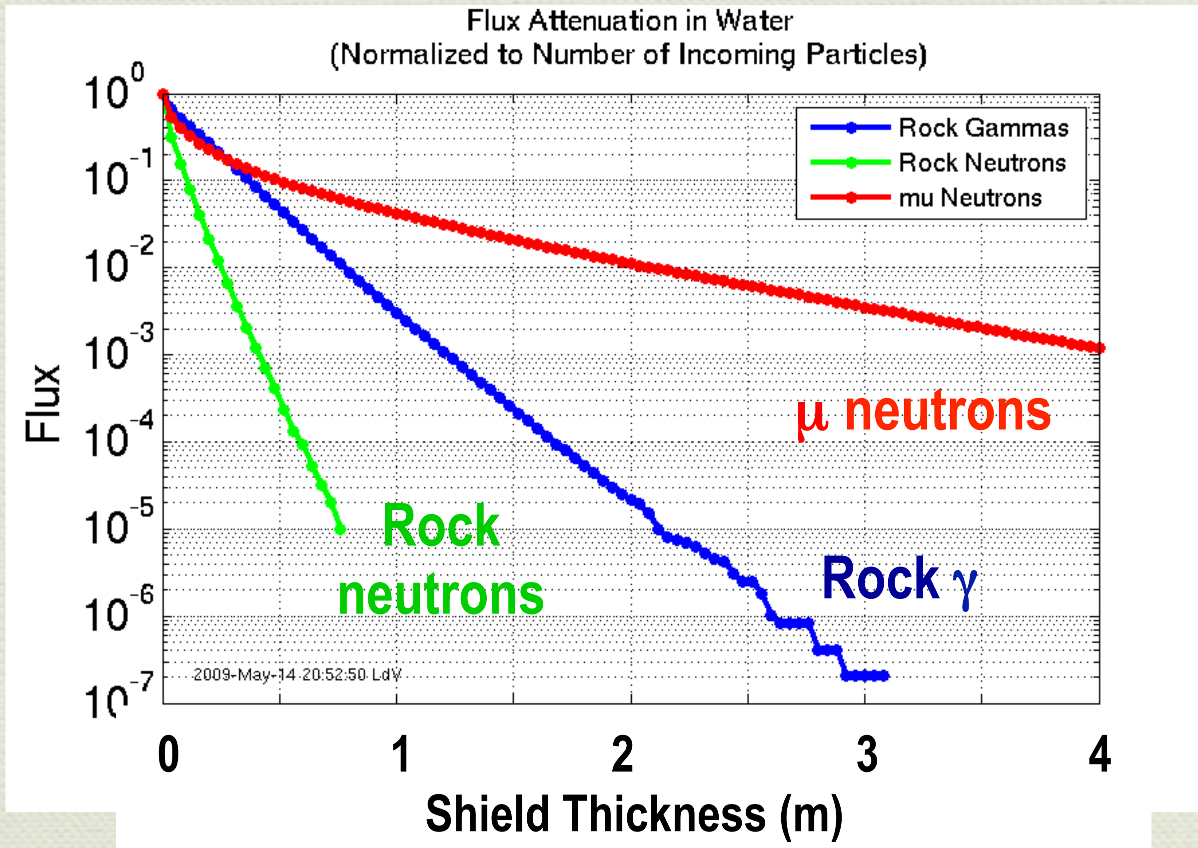


muon capture in water produces high E neutrons

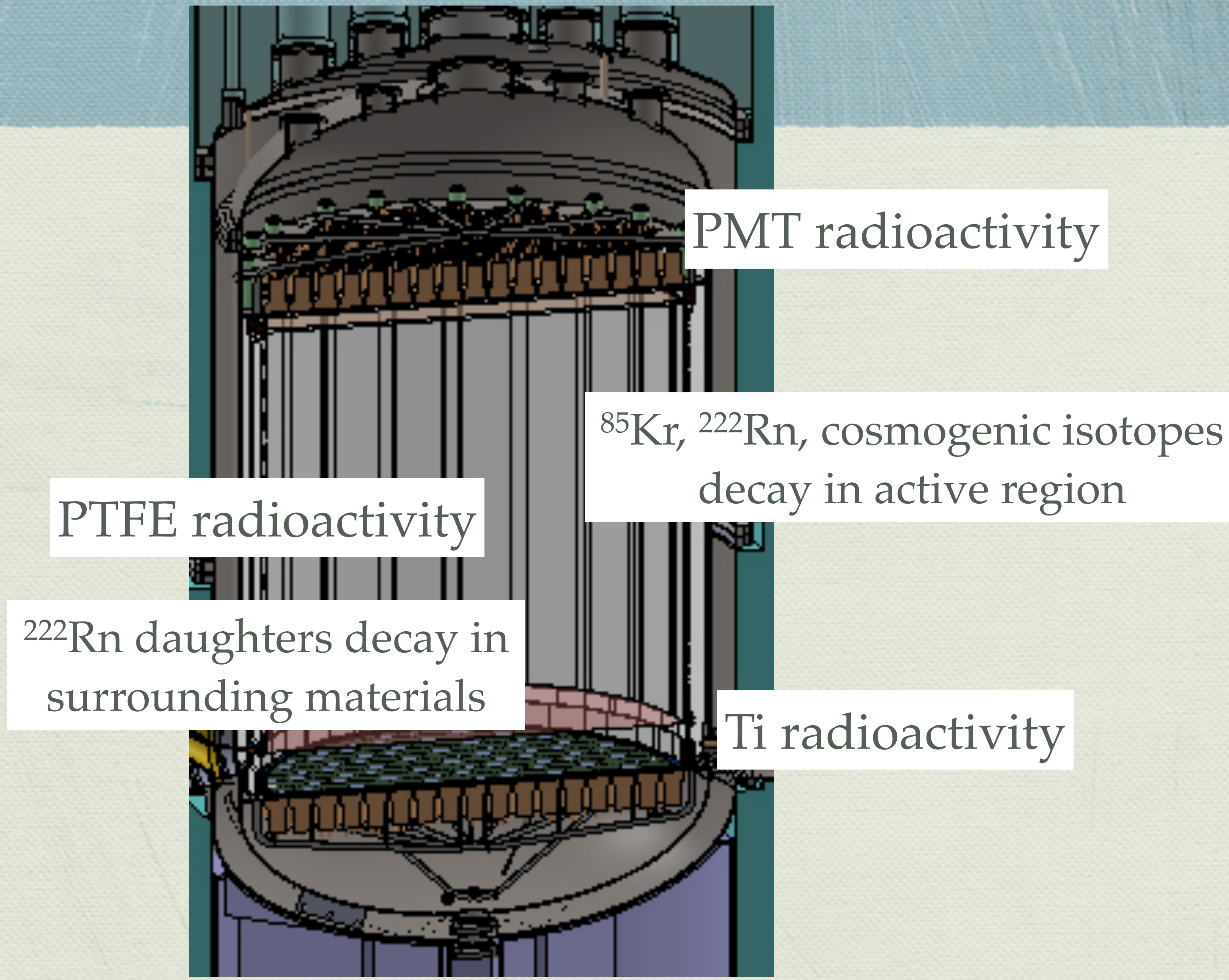
pp solar neutrino sets background floor for experiment at 10^{-5} dru_{ee} (cts/kg/keV_{ee}/day)

External Backgrounds

- Neutrons from rock radioactivity (< 10 MeV) ~3 order suppression for 1/2 m water
- Gamma rate from rock radioactivity 1/400 less than PMT rate in liquid Xe
- Muon-induced neutrons from rock and water were found to be two orders of magnitude below PMT rate in liquid Xe



Internal Backgrounds



Internal Backgrounds: The importance of screening

Background	Radioactivity Values	Units used for Radioactivity Calculations	Source	# neutrons emitted / day
PMT radioactivity	1 mBq/PMT U 1 mBq/PMT Th 1.4 mBq/PMT Co 18 mBq/PMT K	500 PMTs	LZ Measurement (arXiv: 1205.2272)	0.14 (U) + 0.11 (Th) = 0.25
Ti radioactivity	0.25 mBq/kg U 0.2 mBq/kg Th 1.2 mBq/kg K	1441 kg	LUX Ti Measurement (arXiv: 1112.1376)	0.14 (U) + 0.16 (Th) = 0.30
PTFE radioactivity	0.06 mBq/kg U 0.1 mBq/kg Th 0.75 mBq/kg K 0.03 mBq/kg Co	347 kg	Xenon100 (arXiv: 1103.5831)	0.13 (U) + 0.26 (Th) = 0.39

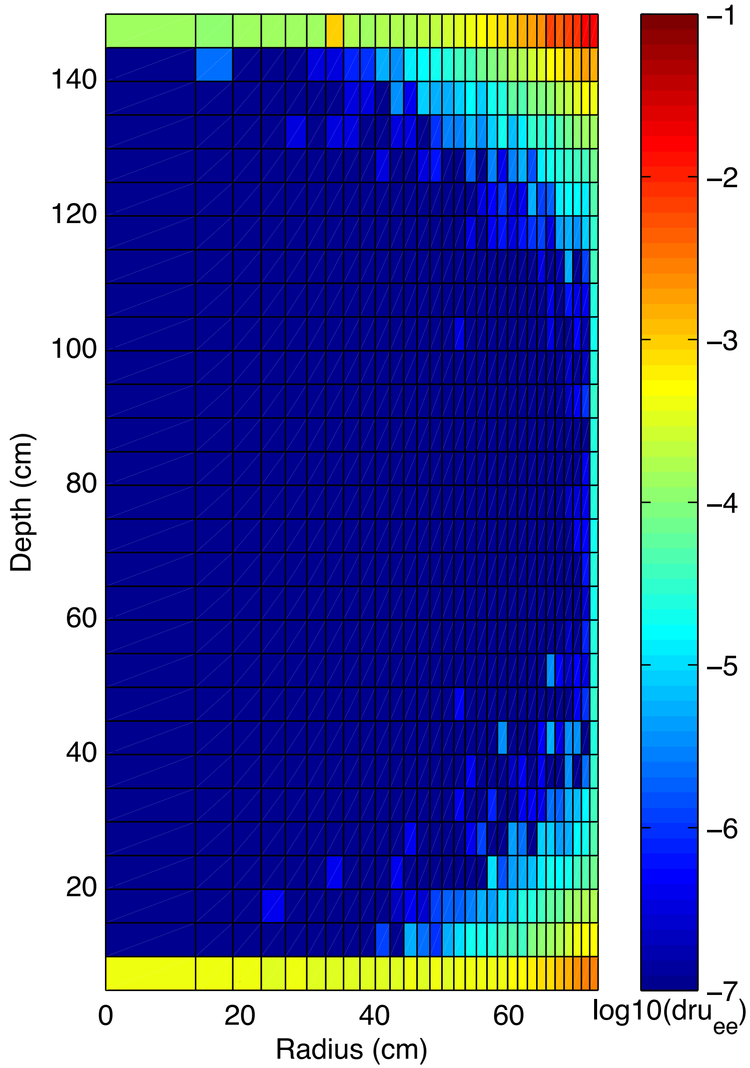
Internal Background Improvement: PMTs

- development program with Hamamatsu
- 2″ to 3″ diameter with lower background goal of < 1 mBq/PMT
- tests of the R11410 show same gain, sphe resolution, and QE at ~178 nm as the R8778
- Background measurements yield <1/20 ^{238}U and <1/2 ^{232}Th than R8778

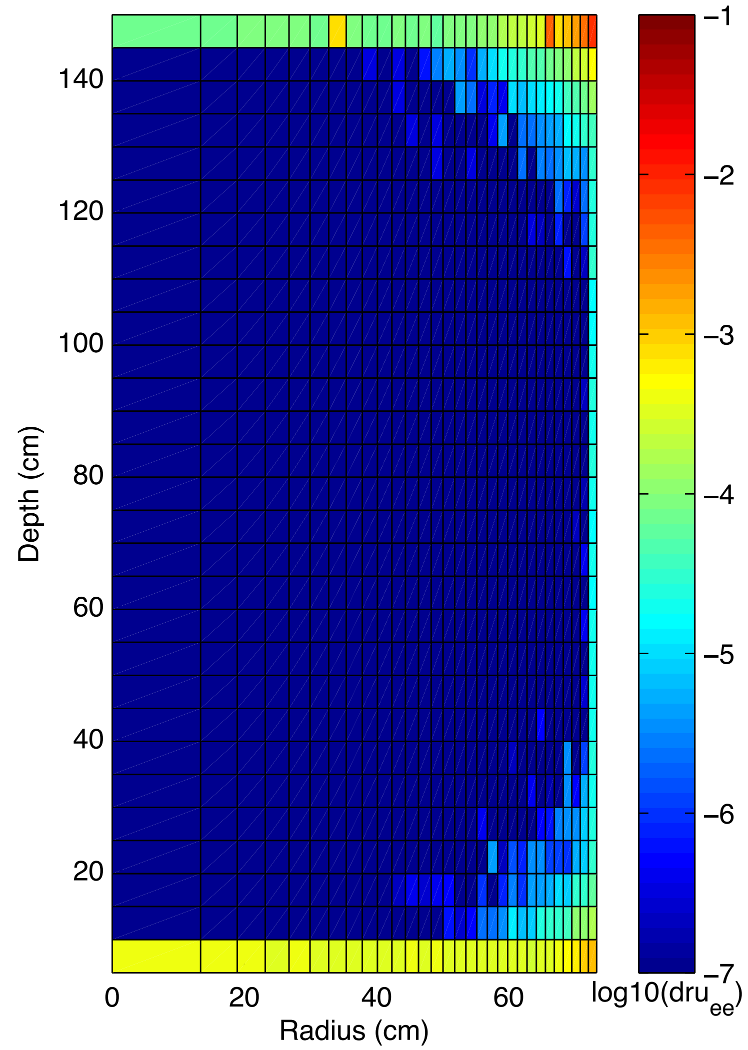
PMT	^{238}U (mBq/PMT)	^{232}Th (mBq/PMT)	^{60}Co (mBq/PMT)	^{40}K (mBq/PMT)
R8778	9.5 +/- 0.6	2.7 +/- 0.3	66 +/- 2	2.6 +/- 0.1
R11410-20	< 0.46	< 1.3 1.0 +/- 0.4	17 +/- 2	1.2 +/- 0.2

Major Internal Gamma Backgrounds (PMT, Ti, PTFE)

LXe skin Veto

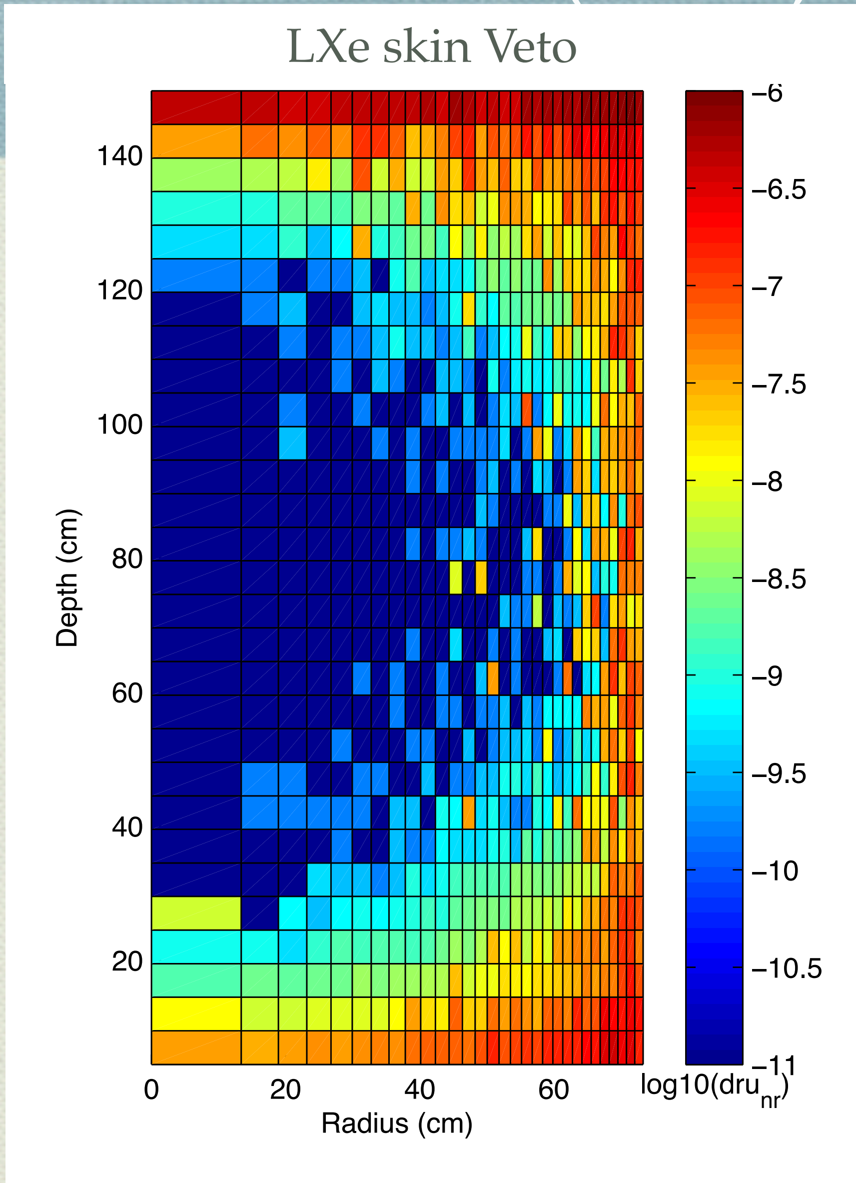


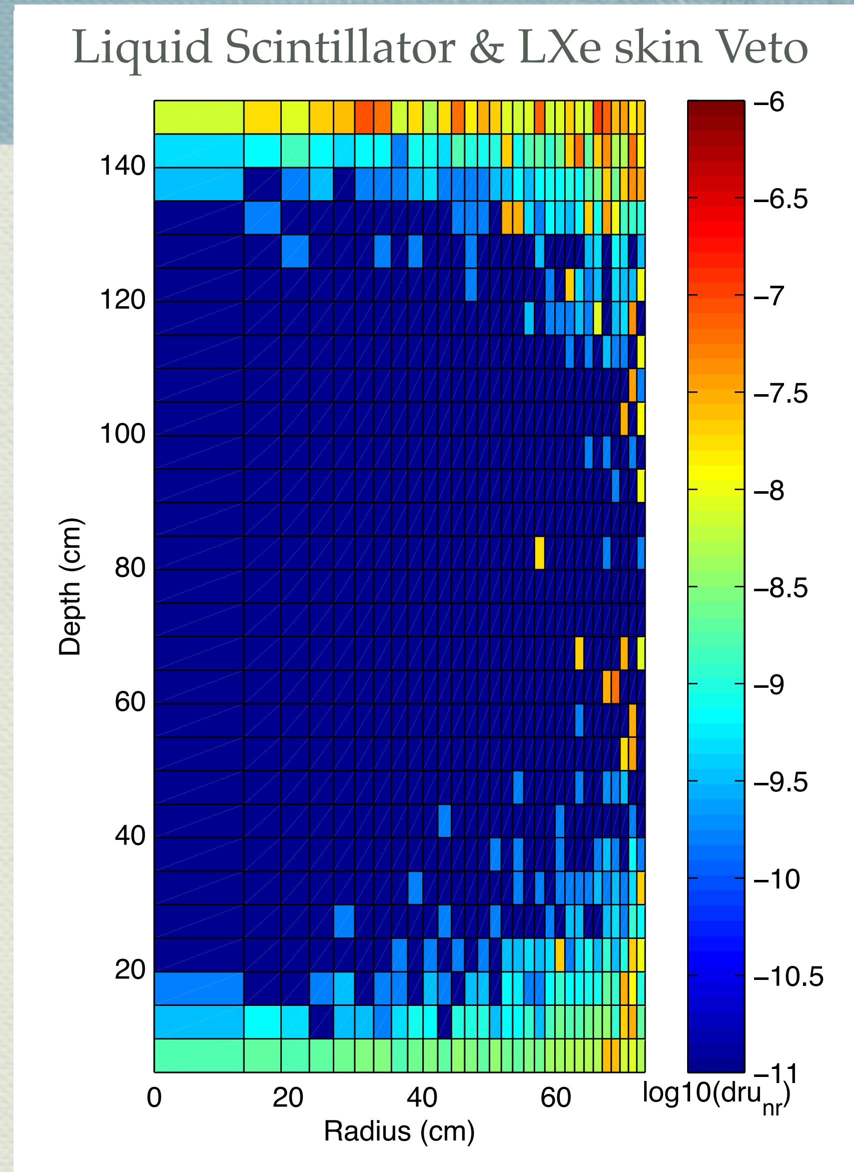
Liquid Scintillator & LXe skin Veto



$dru_{ee} = cts/kg/keV_{ee}/day$

Major Internal Neutron Backgrounds (PMT, Ti, PTFE)





$dru_{nr} = cts/kg/keV_{nr}/day$

Isotopes in the bulk

- ^{85}Kr to be removed from commercial Xe with goal of < 1 ppt and current R&D to study outgassing from plastics
- Xe activation examined for > 200 isotopes to look for naked beta or semi-naked beta decays
- Rn R&D to understand implantation, diffusion, and emanation in the detector and a program to actively mitigate Rn plateout in detector materials

Summary

- LZ will be a 7 T liquid Xenon TPC that will use existing infrastructure at Homestake and build on LUX design with improvements such as the active vetoes
- can reach WIMP cross sections as low as $\sim 10^{-48}$ cm^2
- careful understanding of potential backgrounds and developing programs to mitigate them results in virtually no background in the center of the detector
- Hopefully start in construction in 2016! Stay tuned for LUX results expected at end of 2013