After LUX: The LZ Program

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APS DPF Conference
August 10, 2011

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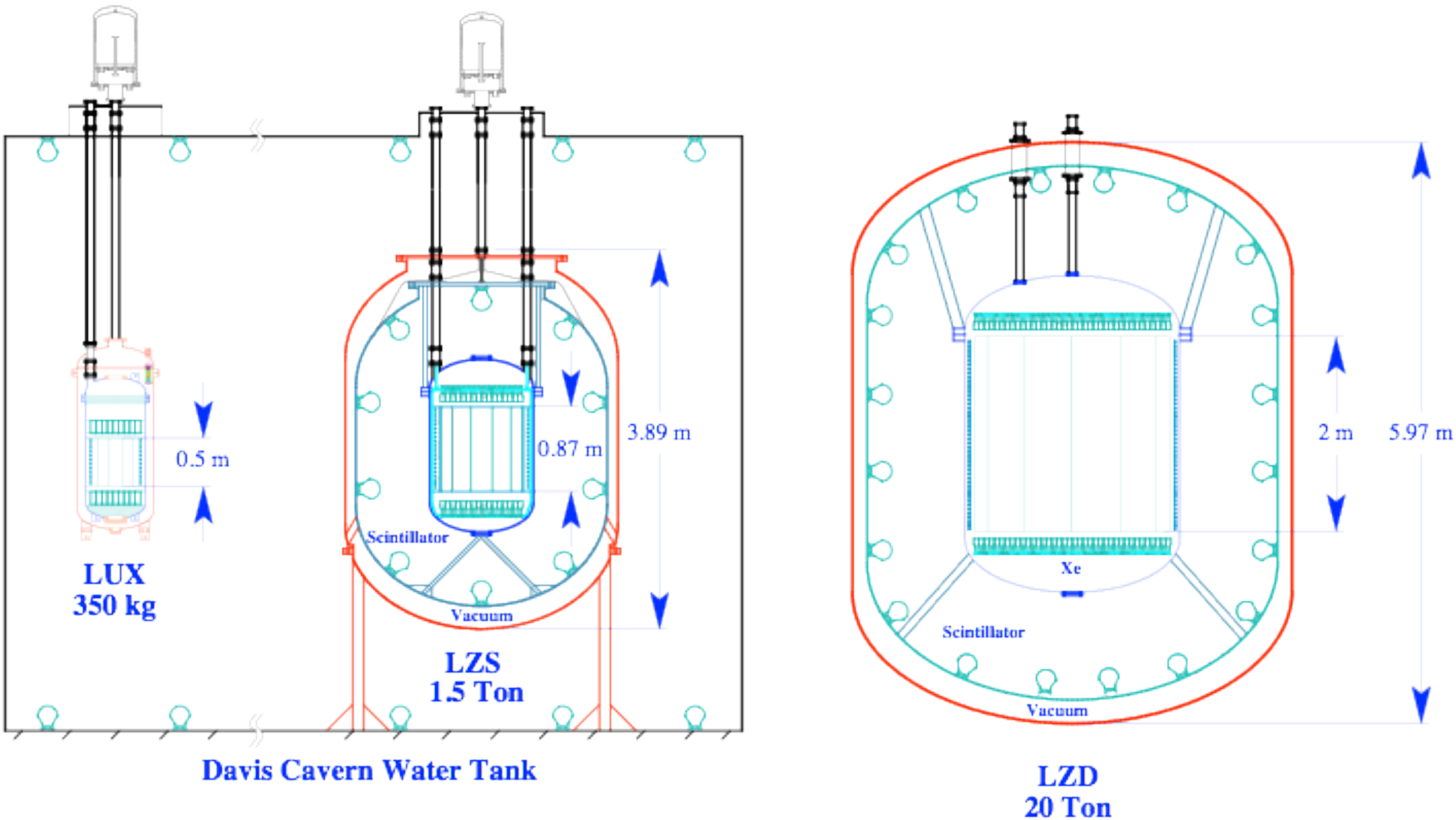
The LZ Program

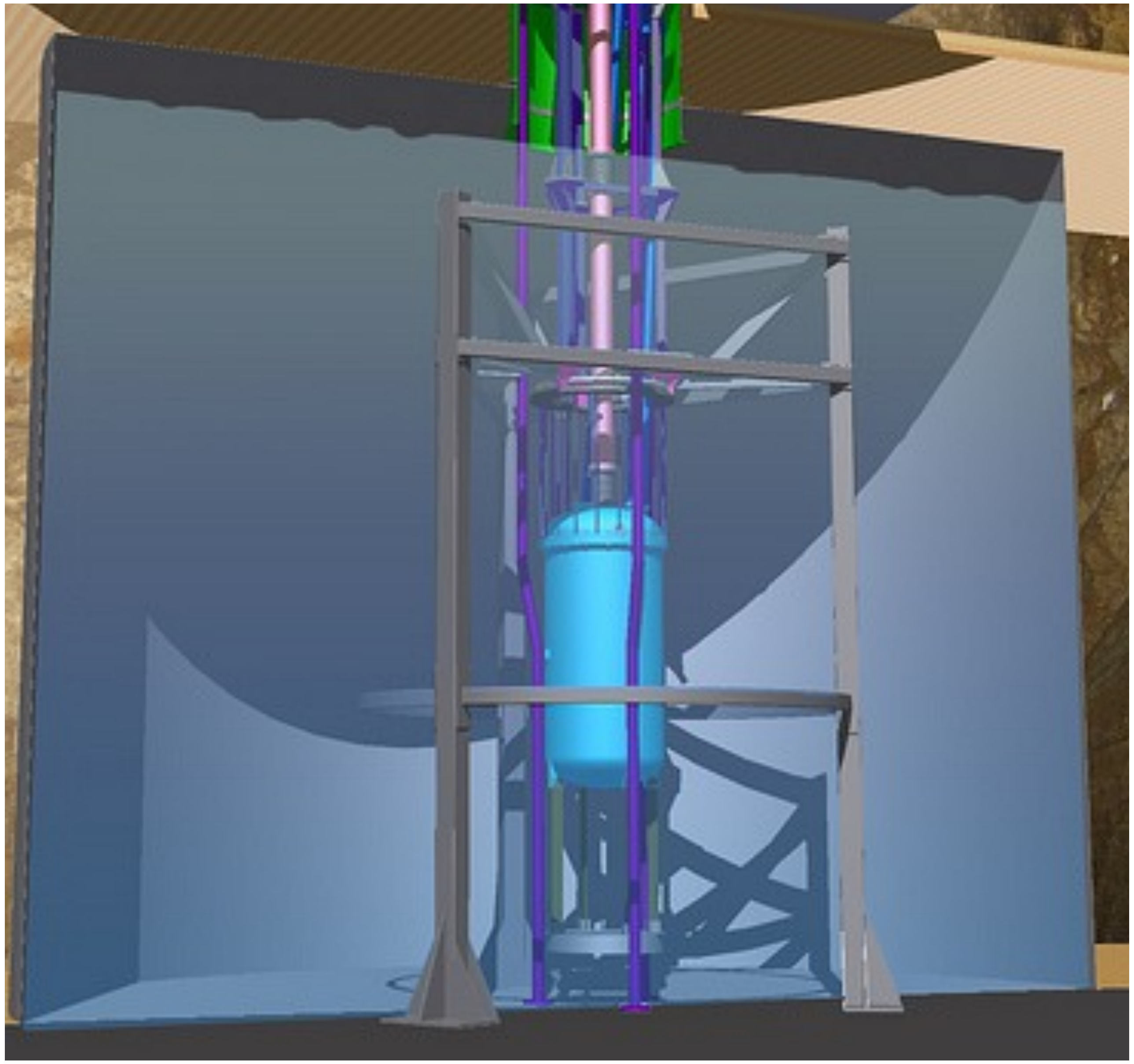
- LZ ≡ LUX-ZEPLIN
- LUX (14 U.S. institutions) + new collaborators from ZEPLIN, other U.S. institutions
- Two phases
  - LZ-S (1.5T or 3T)
    Construction late 2012; running 2014-2016
  - LZ-D (20T)
    Construction 2014; running 2018 onward

LZ at a Glance



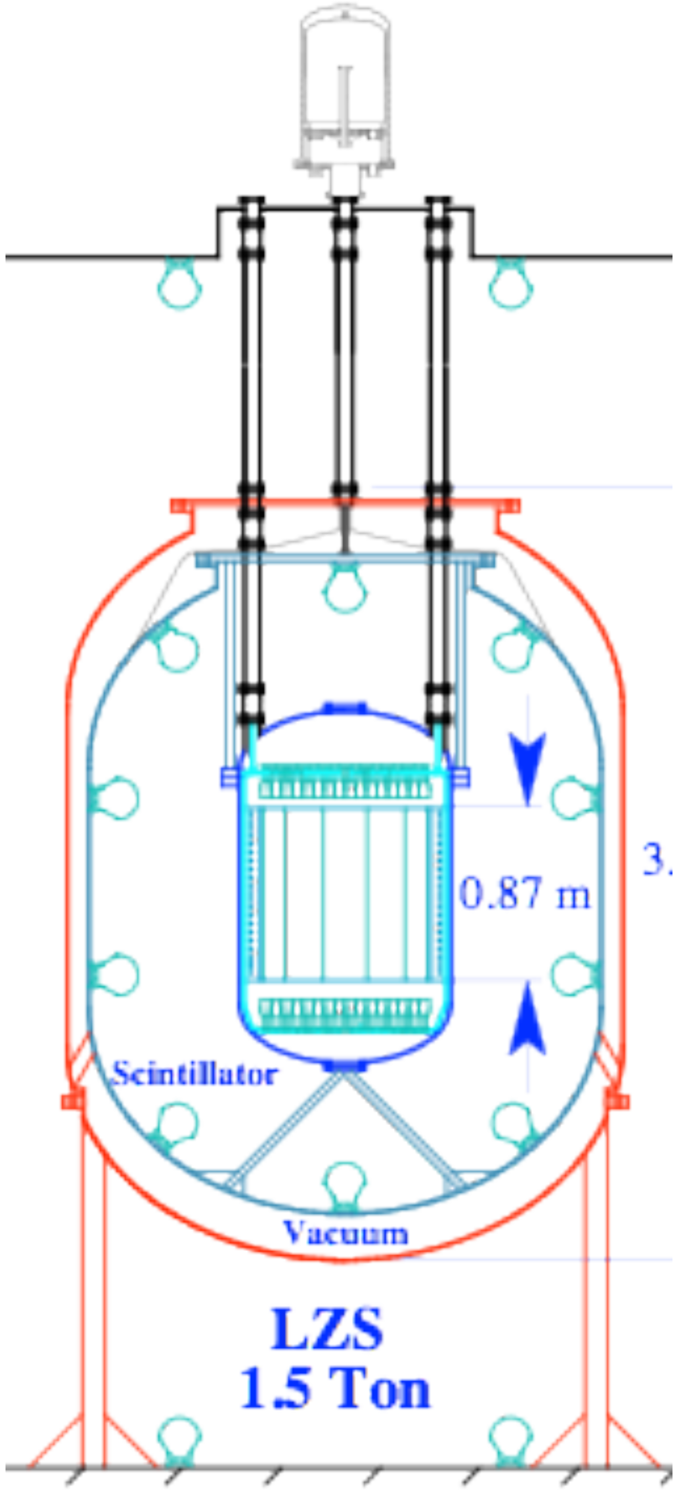
LUX Innovations for LZ

- Davis Cavern infrastructure, water shield: ready for up to 3 ton instrument
- Heat exchanger, high flow rate Xe purification system
- Remote feedthroughs and cryogenics
- Low-background titanium cryostat
- Scalable internals construction
- Scalable trigger and DAQ (DDC-8)
- ^{83m}Kr, ^{3}H calibration sources
- Automated Control and Emergency Recovery systems
- Safety review process



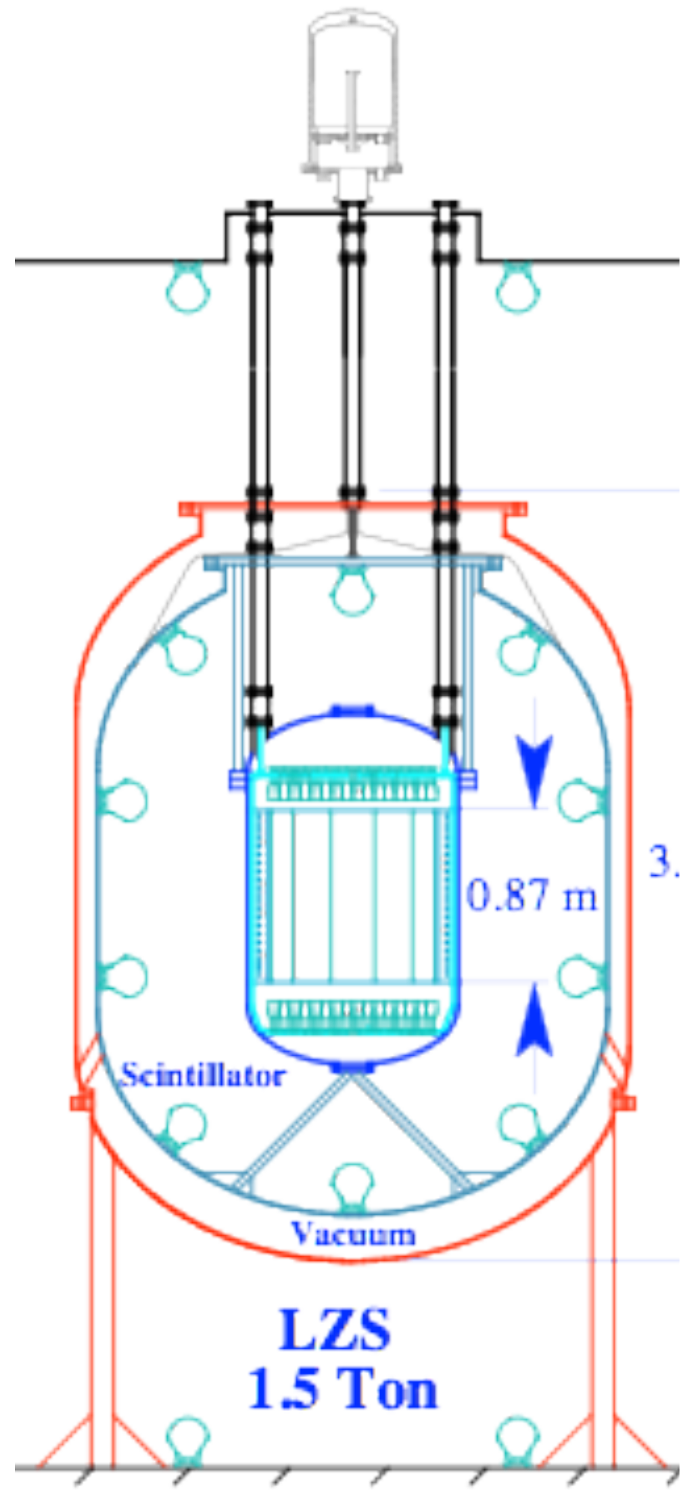
LZ Innovations

- 3" PMTs at <1 mBq $^{238}U+^{232}Th$
- Liquid scintillator shield/veto
- Internal active plastic veto
- Internal imaging system



Scintillator Shield/Veto

- Scintillator housed as close as possible to LXe
  - Ti cryostat especially helpful, want ~1 cm thickness
- Cold (175 K) placement, immediately outside LXe
  - Highest efficiency
  - Likely choice: iso-hexane + flour. Expect factor 2-3 less light than pseudocumene; less flammable
- Warm: better cryo safety, reduction in efficiency
- Program of low temperature scintillator study, combined with MC studies
- Goal: <x1/10 reduction of gamma, neutron rates in LXe
- Final decision on scintillator veto option based on performance, safety



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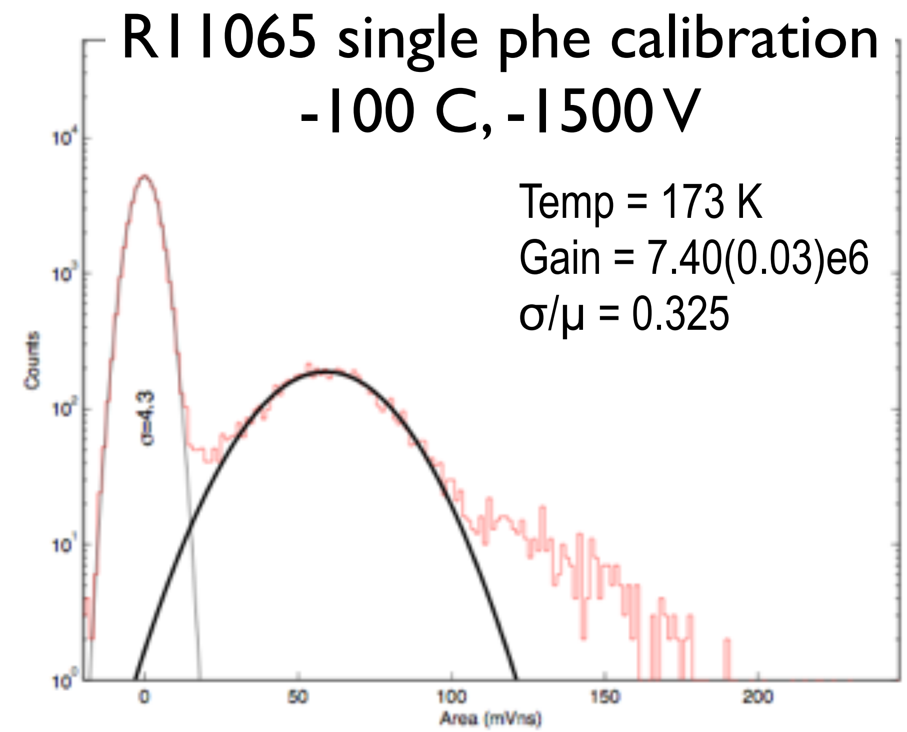
PMTs

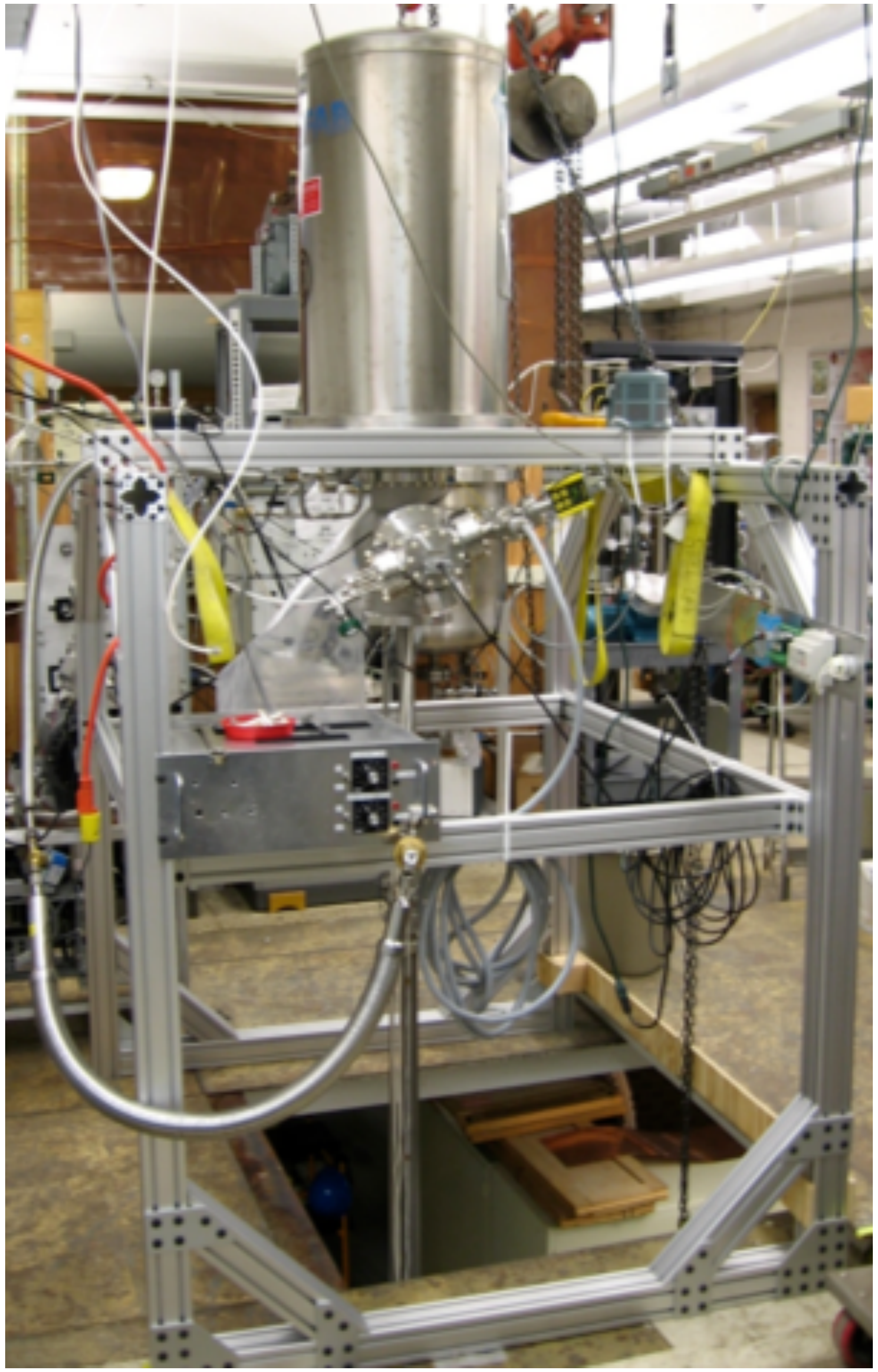
- LZ PMTs will have 3” diameter
  - 2x photocathode surface area compared to LUX R8778s
- Initial 3” testing: comparable performance to R8778s in LXe (QE, gain, single phe resolution)
  - QE to be improved with super bialkali photocathodes
- R11410 MOD: Measured <0.4 ^{238}U / <0.3 ^{232}Th mBq/PMT
  - <x1/15 EM, <x1/18 neutron emission from R8778
  - Potentially used in LUX (2x 31-PMT arrays)

R8778 R11410 MOD



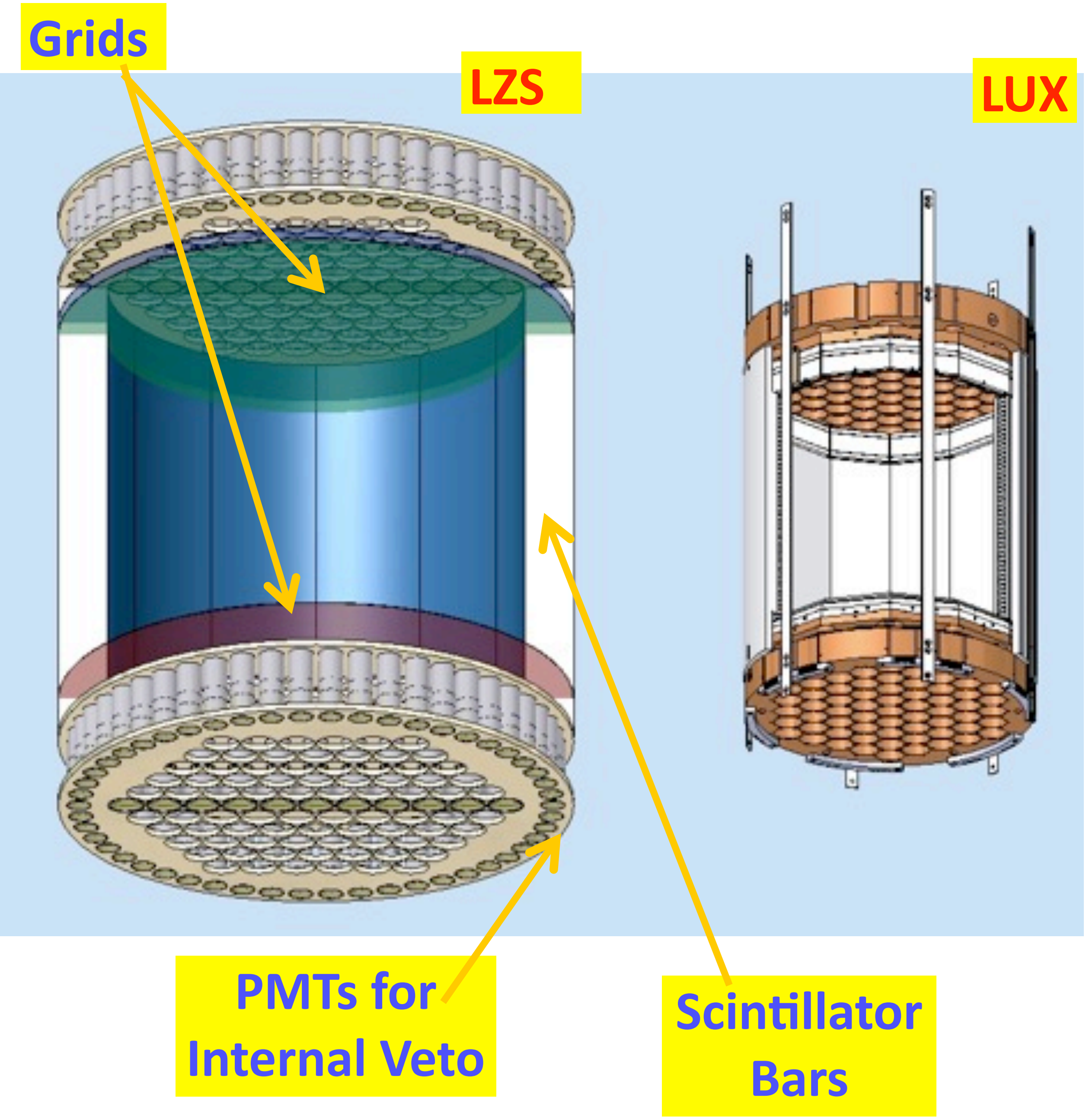
Cryogenics

- Architecture developed for LUX
  - 2 years operational experience on full-size prototype (LUX 0.1).
  - ~70 thermometers, 5 PID control points.
- Liquid nitrogen (LN) thermosyphon backbone
  - Extremely high capacity, remotely deployed, multiple cold heads, tunable to low power for fine control
  - Intrinsically safe: passive, insensitive to power loss
- Probable LN generation on site to avoid LN transport
- "Conventional" system for pre-cooling scintillator



Internals

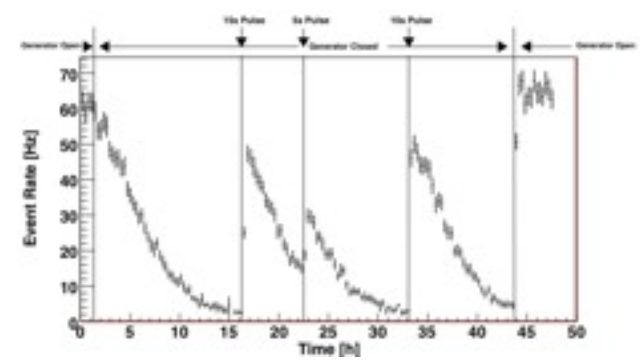
- Large area grid prototyping
  - Scale will increase from 0.5 m to 2m and maintain acceptable deflection
- Low mass field ring development
  - Minimize mass for veto
- Investigation of active plastic to enhance veto capability
  - LXe compatibility
  - Maximize light collection
- Development of internal imaging system for enhanced monitoring
  - Internal fiberscope to view liquid surface and components



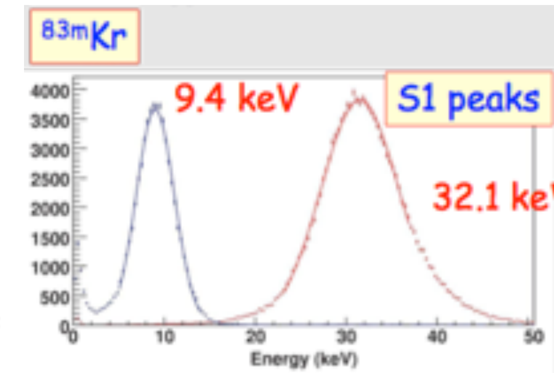
Calibrations

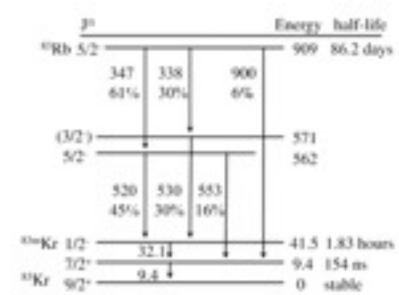
- External gamma sources unable to penetrate tonne-scale detectors -- require internal sources
- Two methods developed for LUX to be used in LZ:
  - Energy calibration: ^{83m}Kr
  - Electron recoil discrimination: ^{3}H

arXiv:0905:1766

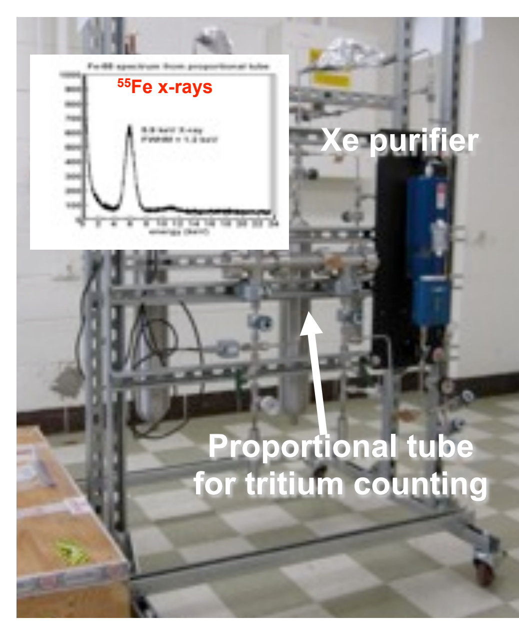


^{83m}Kr: 1.8 hr half-life

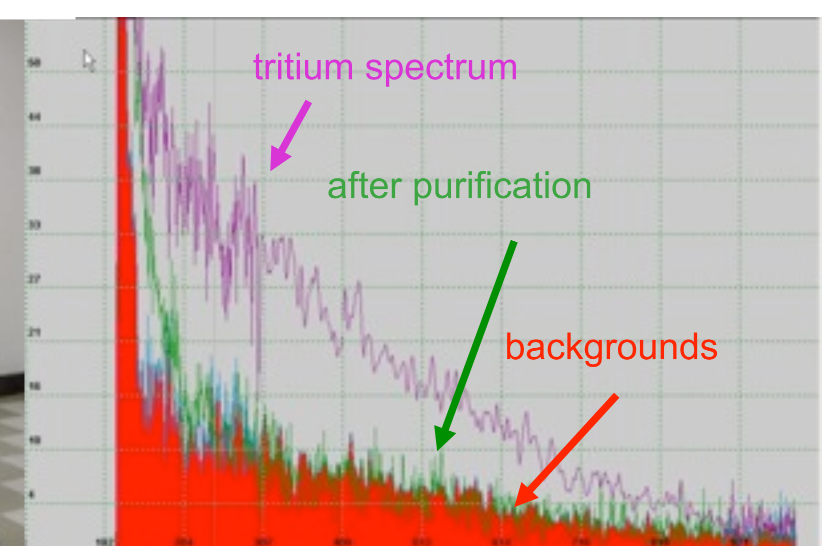




Tritiated methane (CH_3T)



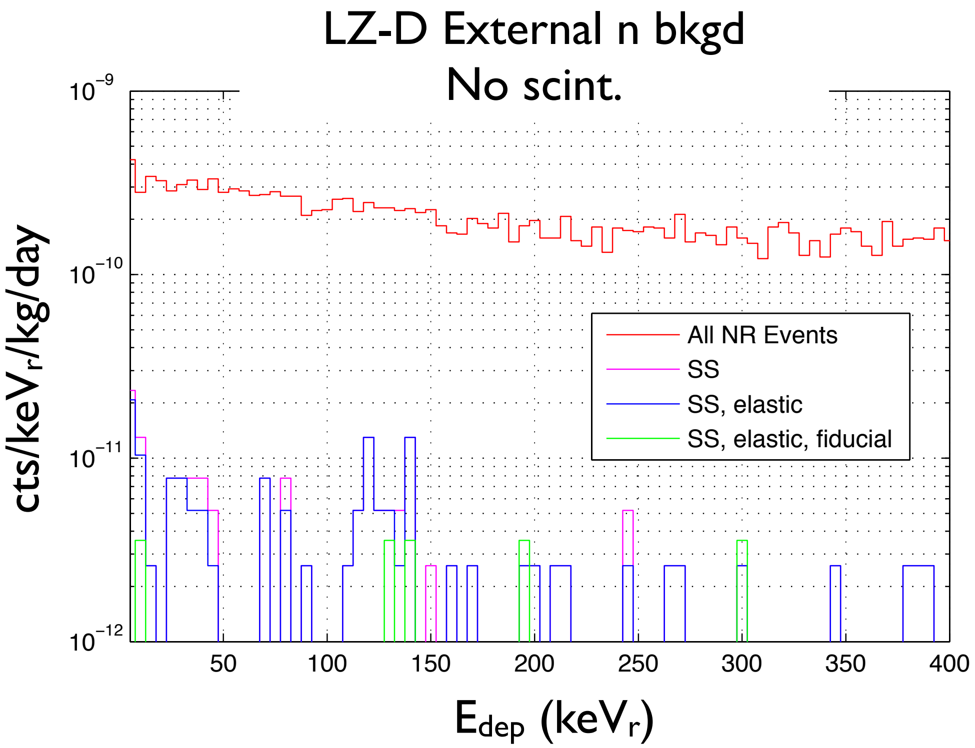
First test of removal from LXe: >90%

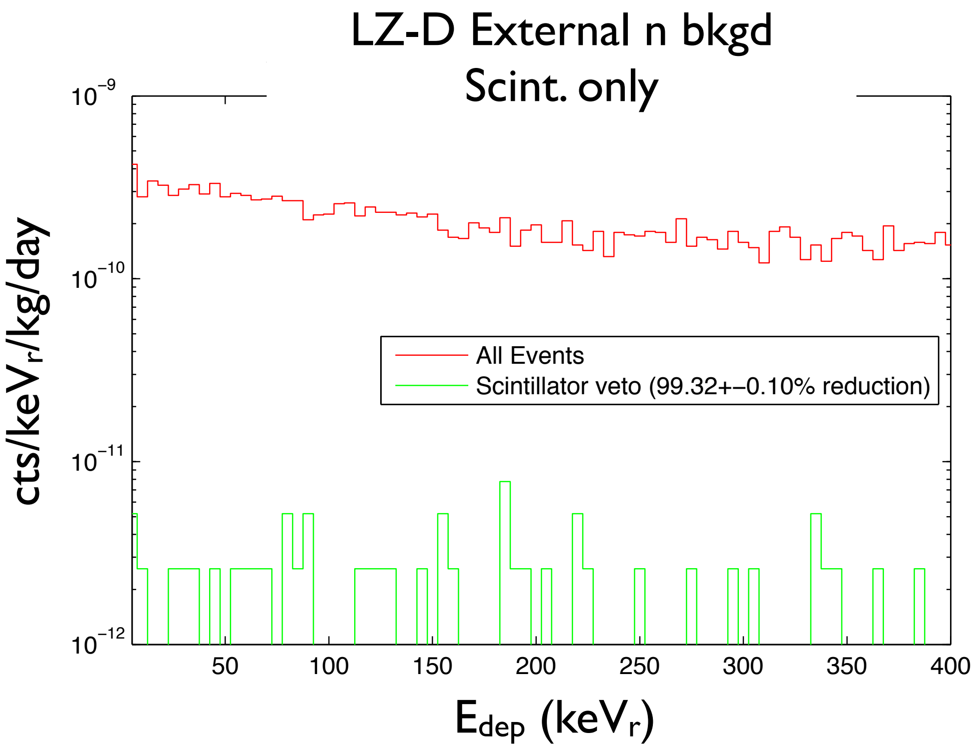


- 99.99% removal from gas (arXiv:1002:2791)

External Backgrounds

- LZ-D uses 12m x 12m water shield
- Water shield alone reduces fast neutron BG <1 WIMP-like evt / 1000 days
- Addition of scintillator veto: <x1/100 further suppression
- Further factor of x1/100 reduction from standard analysis cuts
- Comparable reductions in neutrons produced in water shield itself





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Internal Backgrounds

- Low-energy, single-scatter requirement: backgrounds dramatically suppressed in detector center

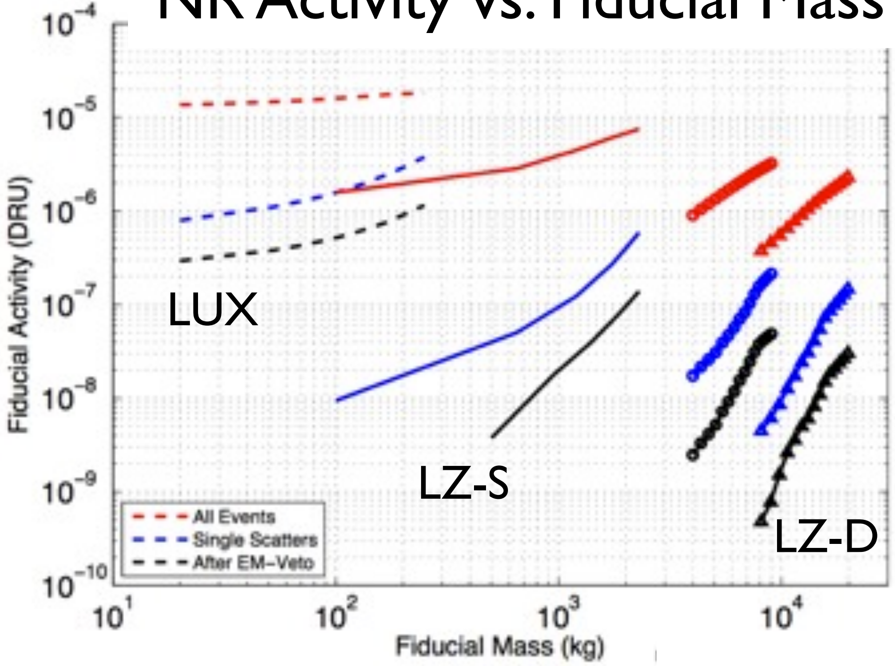
- With increase in total detector mass, dR_{BG}/dM_{fid} steepens substantially

- 13.5T fiducial set by requirement of <1 WIMP-like ER event / 1000 days from R8778-style tubes

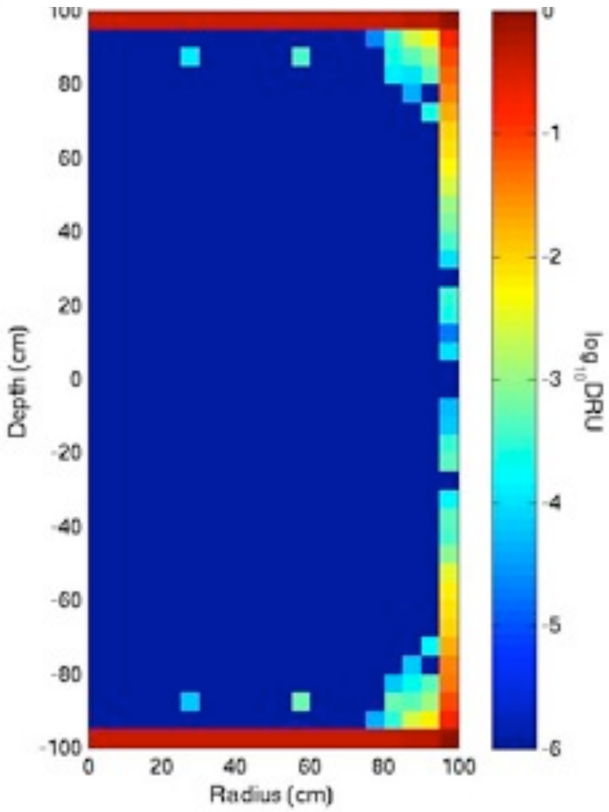
  - <1 mBq $^{238}U/^{232}Th$ tubes allow ~17T fiducial

- External scintillator provides additional rejection for escaping gammas and neutrons

NR Activity vs. Fiducial Mass



LZ 20T 3" PMT ER Backgrounds
5-25 keV_{ee}, single-scatter, scint. veto



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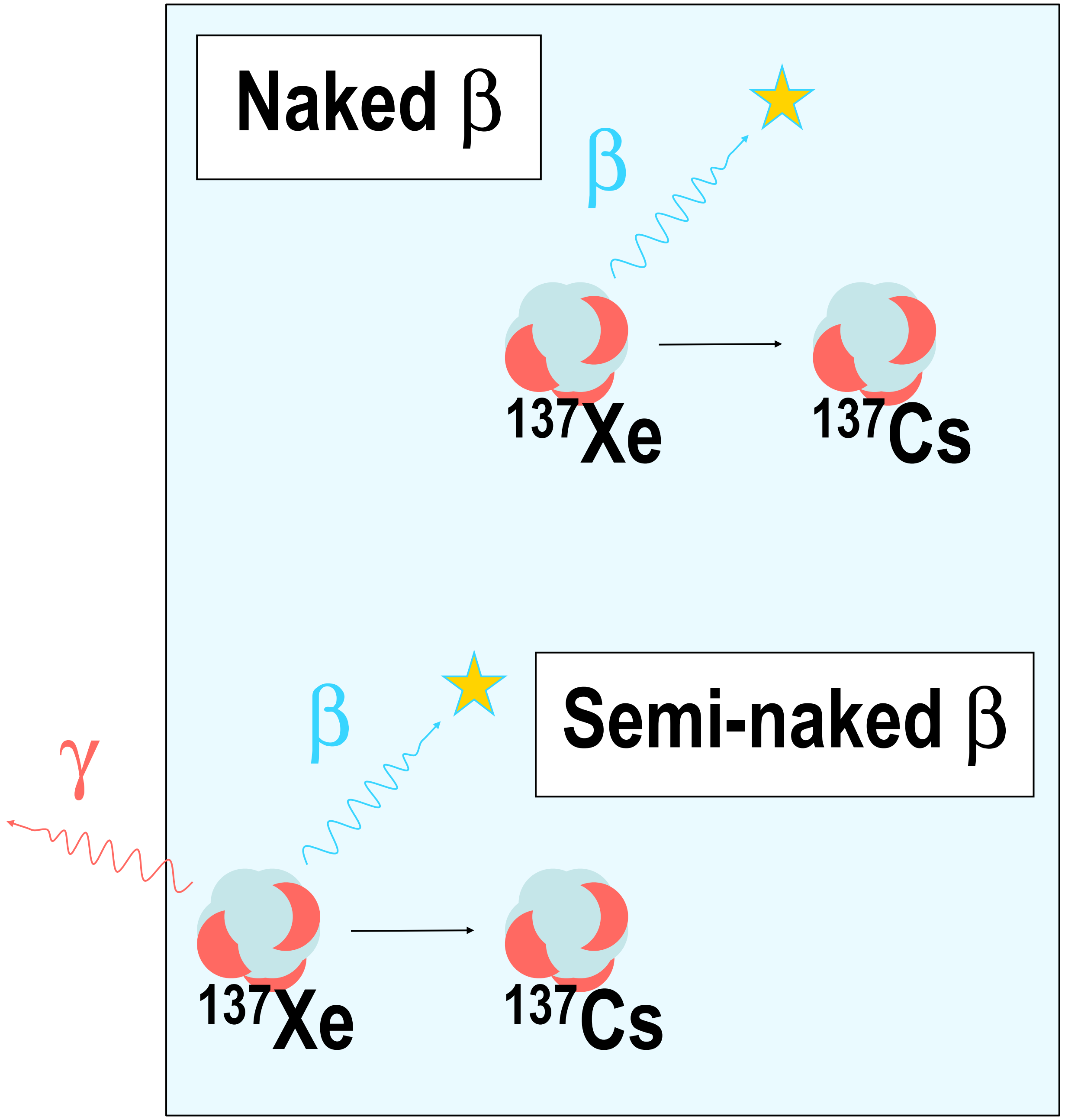
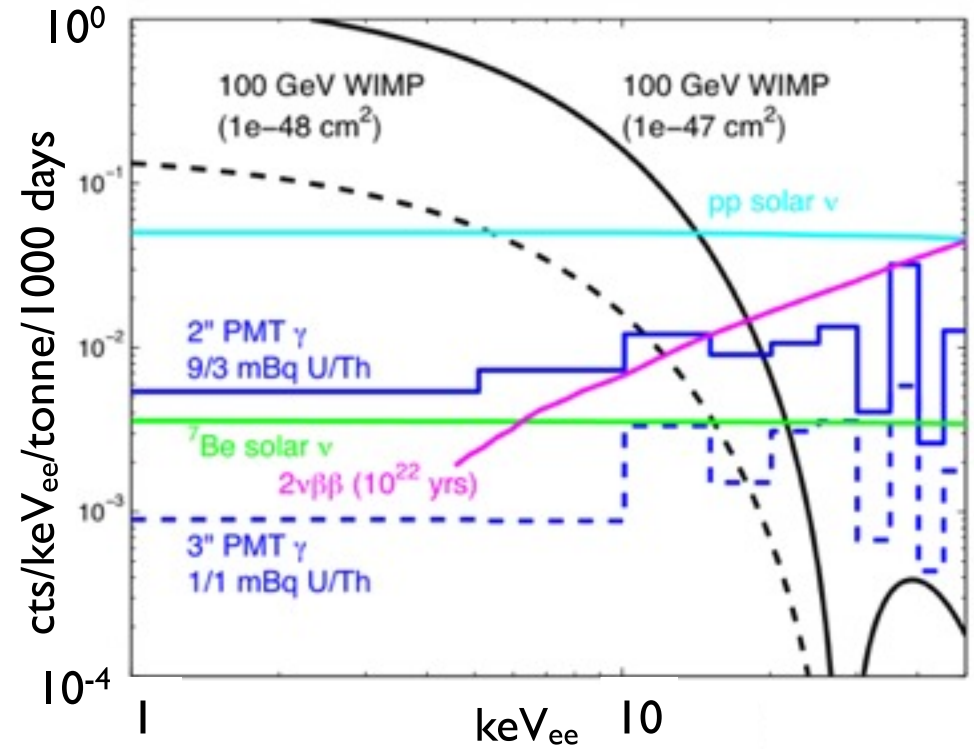
Cosmogenic Backgrounds

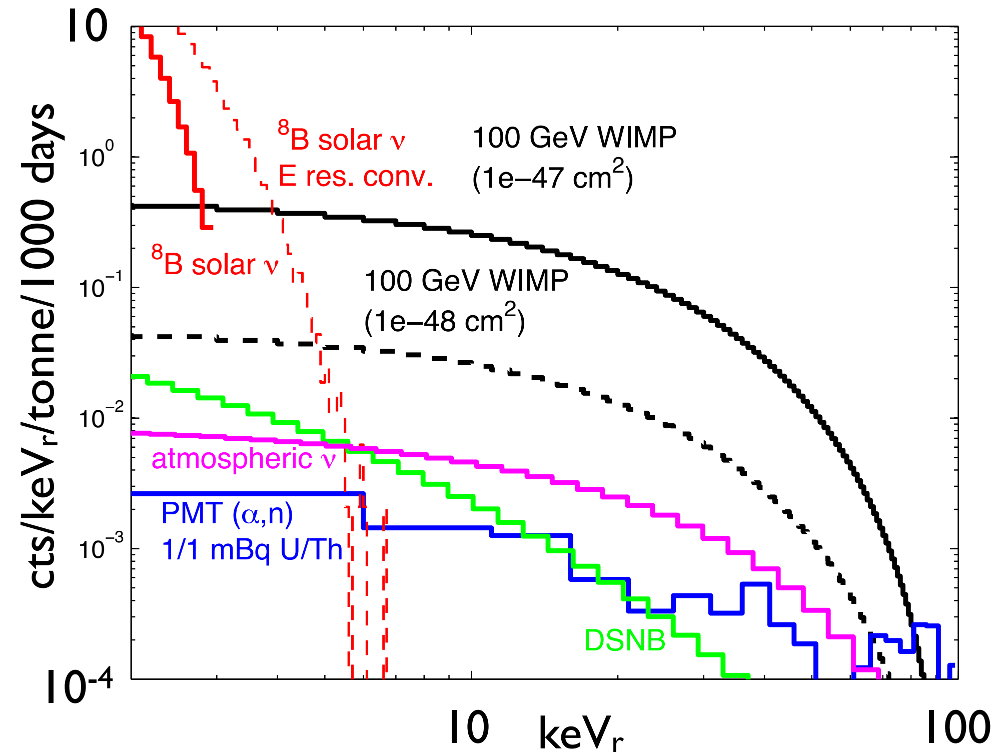
- LZ-D Xe mass x67 above LUX -- must search for cosmogenic products previously overlooked
- Xe activation by muon capture, neutron capture, fast neutron activation, etc.: >200 isotopes produced
- Only worry about naked or semi-naked beta emitters
- ~10^{-7} /keV/kg/day event rate, primarily from fast neutron activation (^{137}Xe)



Neutrino Backgrounds

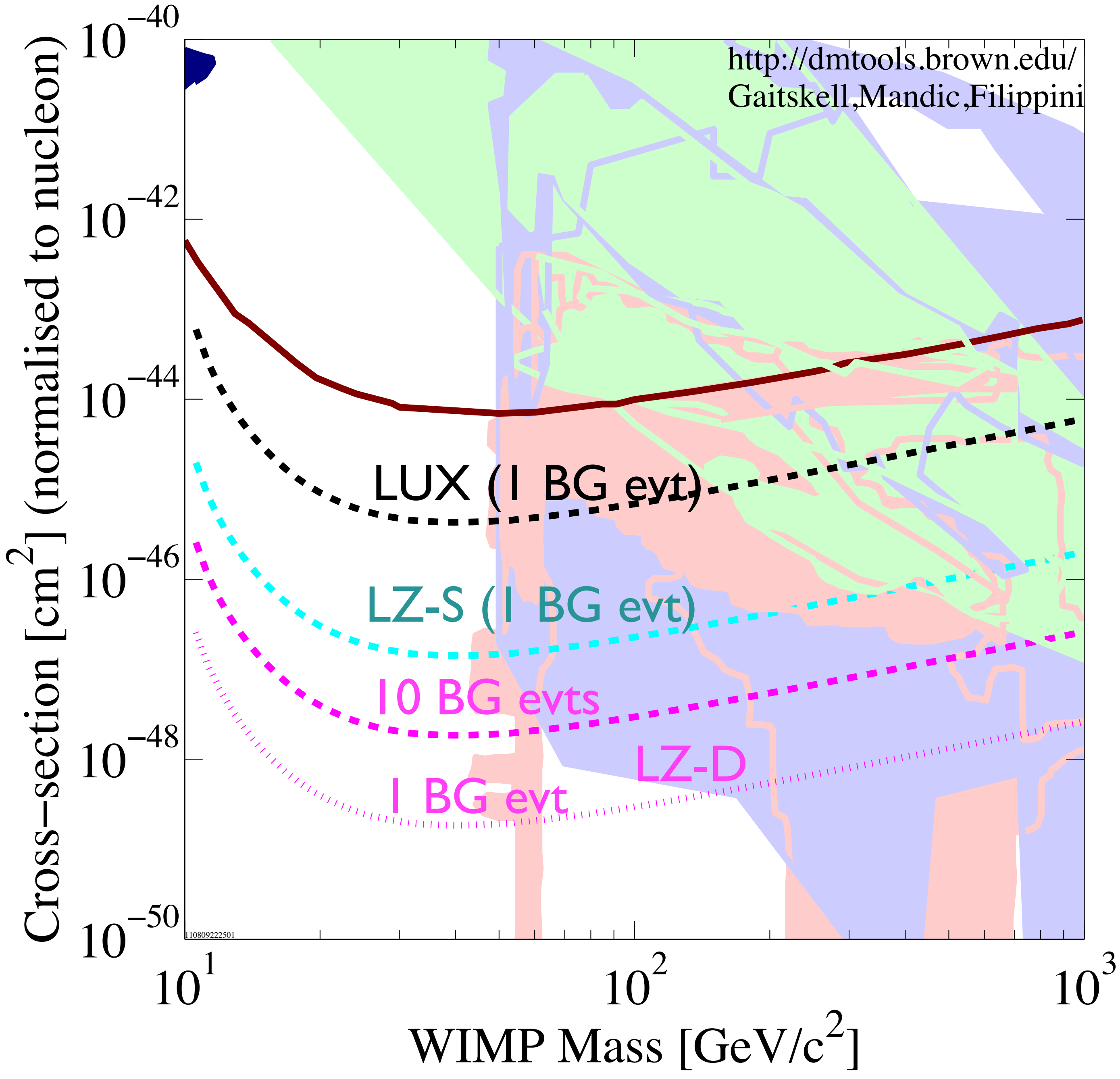
- Dark matter signal search fundamentally limited by neutrinos
- Electron recoil signal limited by p-p solar neutrinos
  - LZ-D: 5 evts (1-10 keV_{ee}) / 1000 days before ER rejection
- Neutron recoil signal limited by coherent neutrino scattering
  - ^{8}B
  - DSNB
  - Atmospheric
  - LZ-D: ~1 evt (5-25 keV_r) / 1000 days





SI WIMP Sensitivity

- Projections based on background studies, previously attained e- attenuation lengths and discrimination factors
- Fiducial volumes selected to match <1 NR event in experiment lifetime
- LUX (black): 100 kg x 300 days
- LZ-S (cyan): 1200 kg x 600 days
- LZ-D (purple): 13500 kg x 1000 days



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Summary

- LZ tonne-scale Xe detectors will use technology tested in LUX
    - Cryogenics, purification, low-background construction materials, internal calibration sources, etc.
- Combination of external scintillator and water shield reduces external backgrounds to levels subdominant to internal backgrounds for both LZ-S and LZ-D
- LZ-D will push LXe dark matter detection to its final limit from neutrino signals