Constraining Radon Backgrounds in LZ

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On Behalf of the LZ Collaboration
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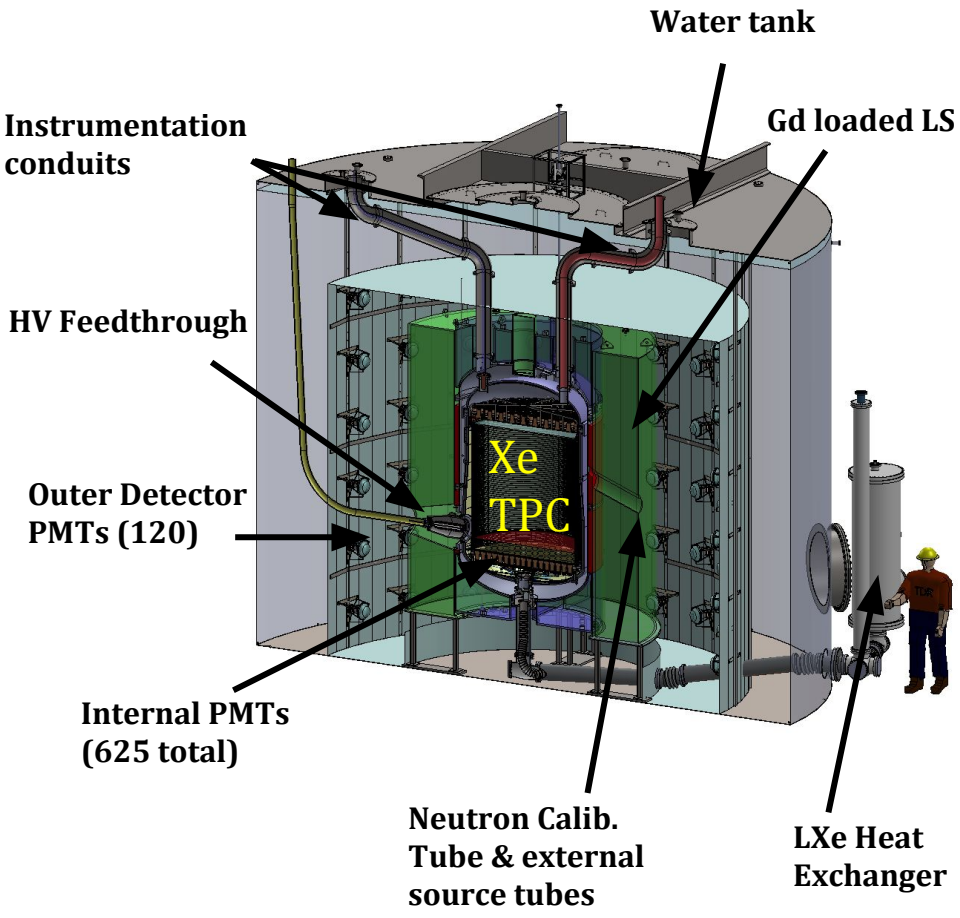
CoSSURF 2017

The LZ Experiment

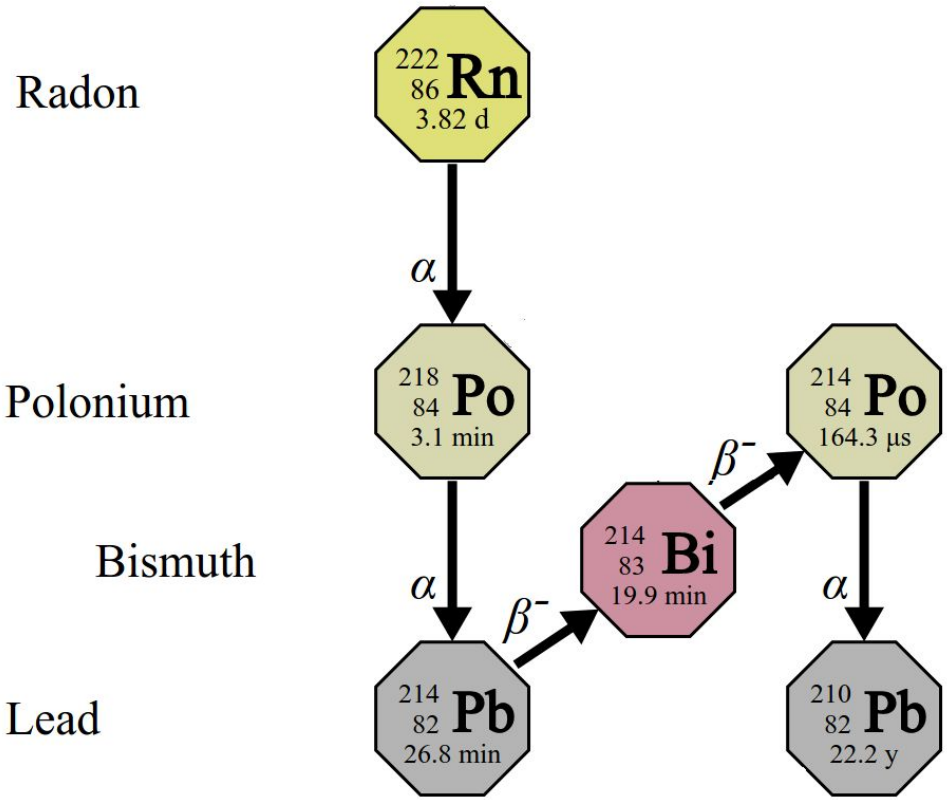


Successor of LUX and ZEPLIN Dark Matter experiments

Fiducial mass: 5.6 tonne liquid Xe

WIMP sensitivity better than 2.3×10^{-48} cm^2 at 40 GeV

Backgrounds in LZ



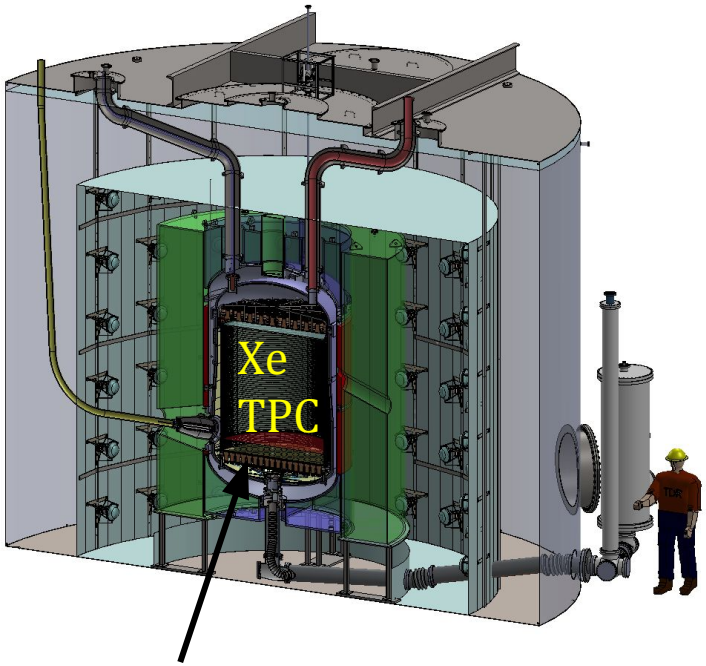
Most Probable (> 99.9%) decays from Radon

Background estimate for 1,000 livetime-days including discrimination and efficiencies:

Environmental	0.05
Argon + Krypton	0.14
^{210}Bi Migration	0.20
Material Contamination	0.28
^{136}Xe	0.34
Neutrinos	1.64
Radon & Daughters	3.81
Total	**6.44**

Radon migrates to fiducial volume; ^{214}Pb decays by untagged beta

Backgrounds in LZ



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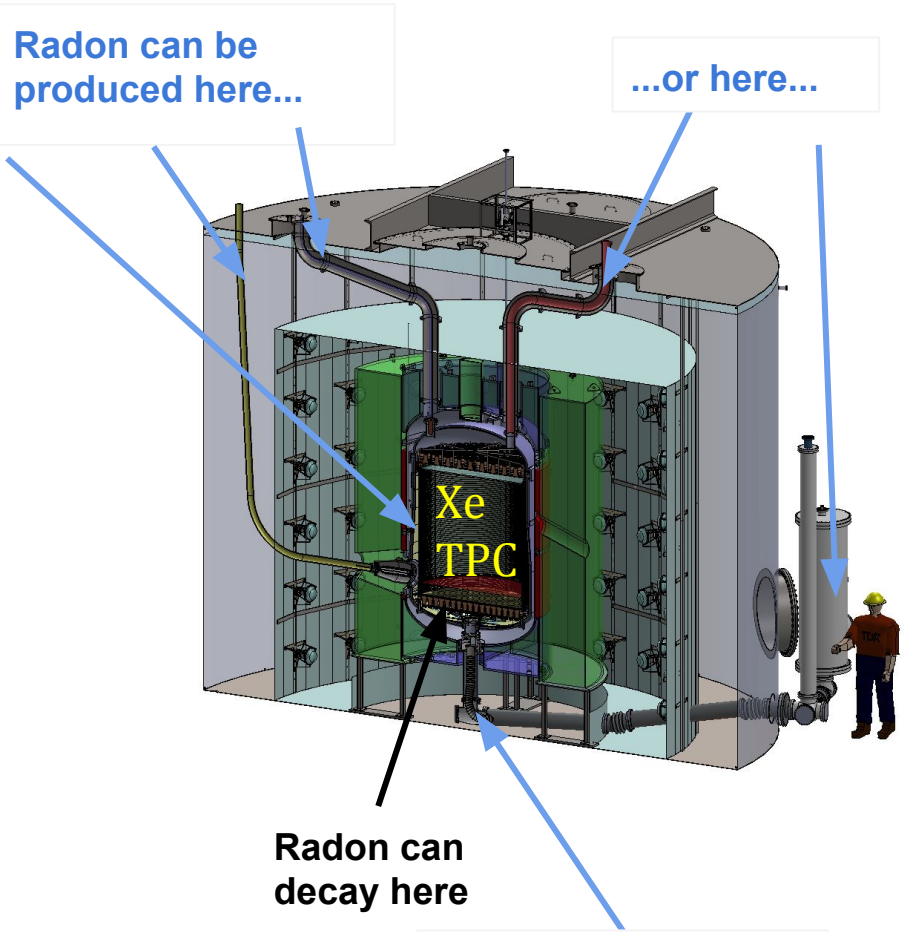

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Measuring Radon from Materials

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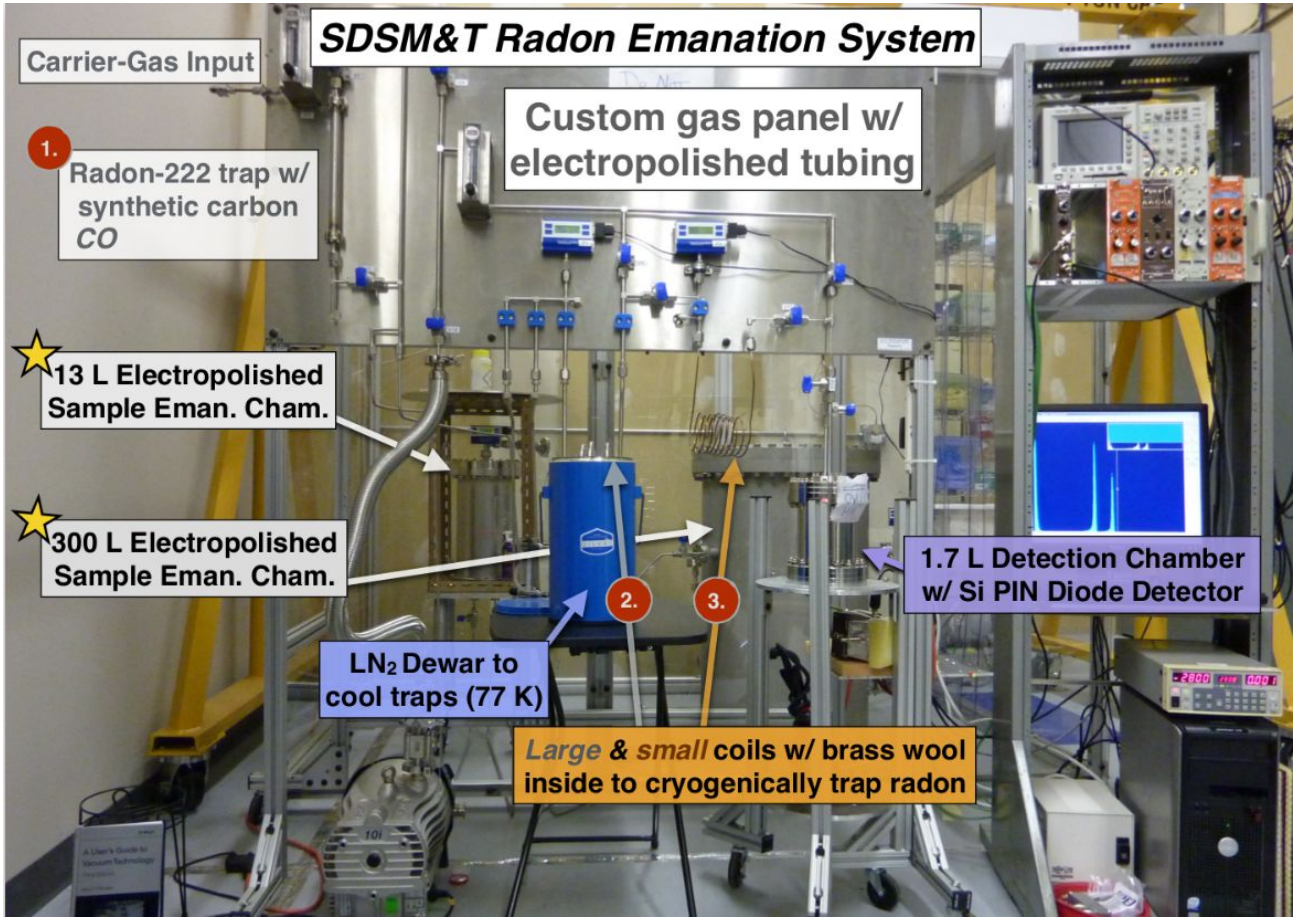
See poster by Rashyll Leonard!



The Radon emanation system at SDSM&T. Image by M. Bowles.

Radon Screening Program for LZ

Planned screening for all materials in contact with Xe

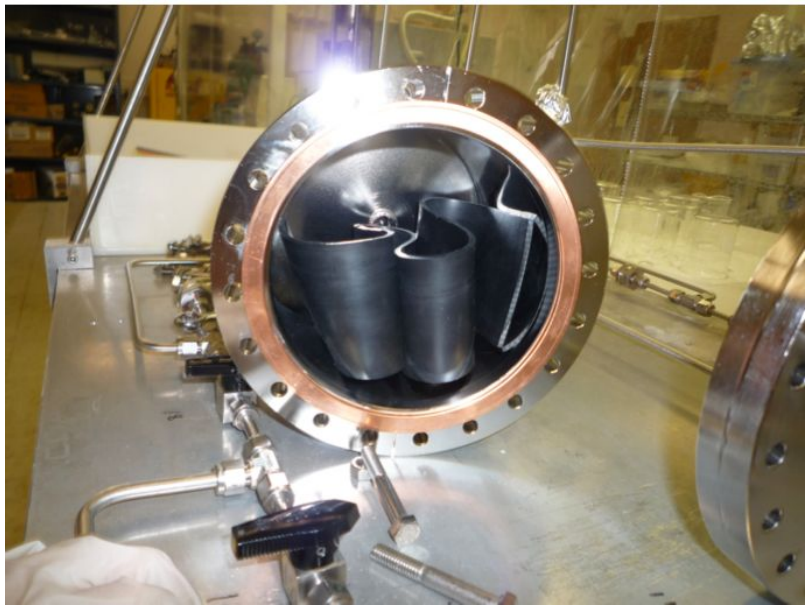
Screening devices at 4 LZ institutions

63 measurements completed so far

System	Technology	Emanation Chamber Volume	Blank Rate	Status
UCL	Electrostatic PIN-diode	2.6 liters 2.6 liters	0.2 mBq 0.4 mBq	Online (~6 LZ /year)
CWRU/ UMD	Electrostatic PIN-diode	4.7 liters	0.2 mBq	Online (~12 /year)
SDSM&T	Electrostatic PIN-diode	13 liters & 300 liters	<0.3 mBq ~0.3 mBq	Both Online (~18 LZ /year)
Alabama	Liquid Scintillator Coincidence	2x 2.6 liters	0.2 mBq	Both Online (~24 /year)

Instrument Cross-Calibration

- Each system already calibrated with radon source
- Plans to cross-calibrate all systems with at least two samples (blind)
  - One higher rate to calibrate efficiency w/o interference from backgrounds (rubber)
  - One lower rate to check understanding of backgrounds (thoriated rods)
- EXO Canadian collaborator J. Farine shared a rubber sample with UA to cross-calibrate systems.
- Measurements with 6/7 vessels agree on source strength within uncertainties
- Will begin sending around thoriated rods soon



The rubber sample in a chamber at UA

Preliminary Screening: PMT Cable

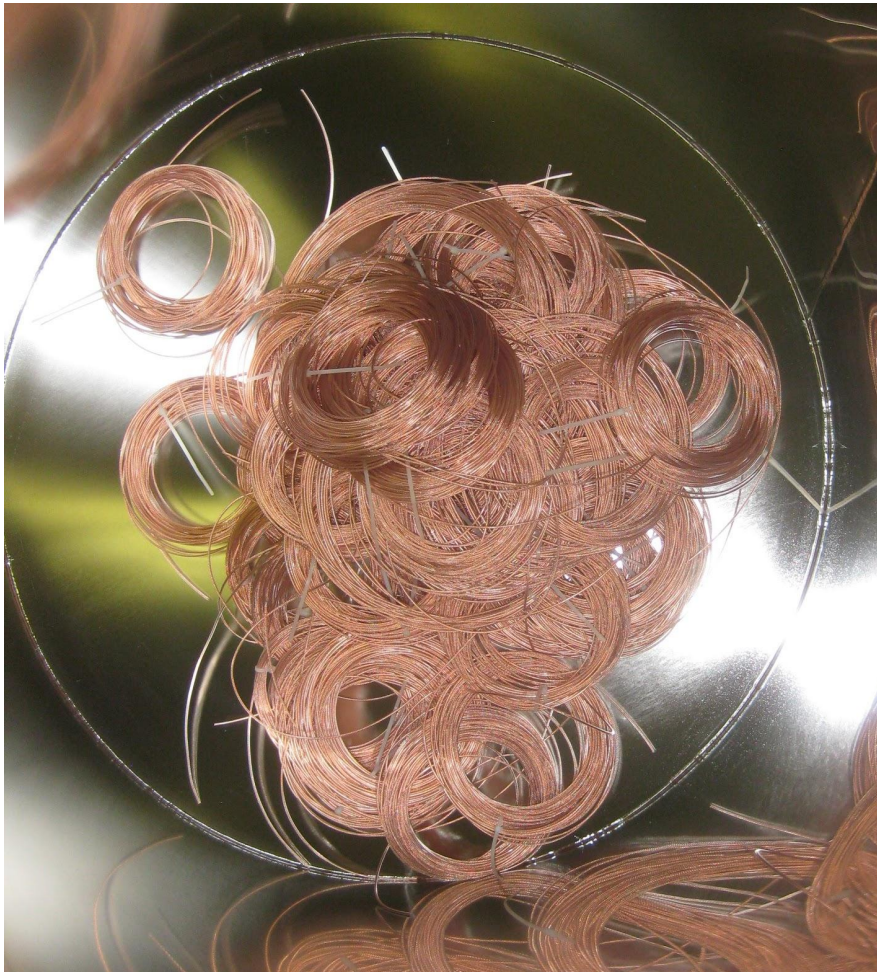
LZ to use over 17 km of PMT cabling

Screened 750 m sample of Axon cable

Measurement Results:

1.4 ± 0.1 mBq / km

1.4 ± 0.2 mBq / km



Preliminary Screening: HV Feedthrus

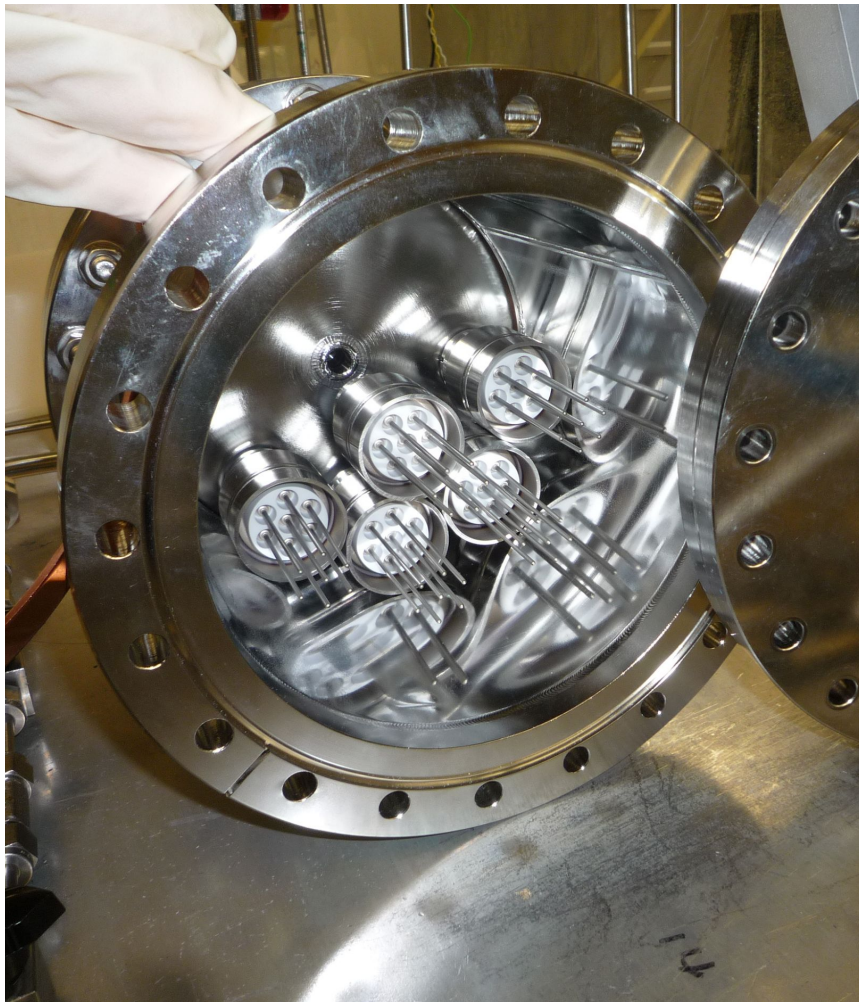
LZ Will have 116 HV feedthroughs, each with 7 pins

Screened 5 samples from manufacturer

Measurement Results:

0.1 ± 0.05 mBq / feedthrough

0.08 ± 0.06 mBq / feedthrough



Preliminary Screening: PMT Bases

LZ Will have 625 PMTs in Xe space; therefore 625 PMT bases

Screened 100 bases post-production

Measurement Results:

0.28 ± 0.17 mBq / 100 bases

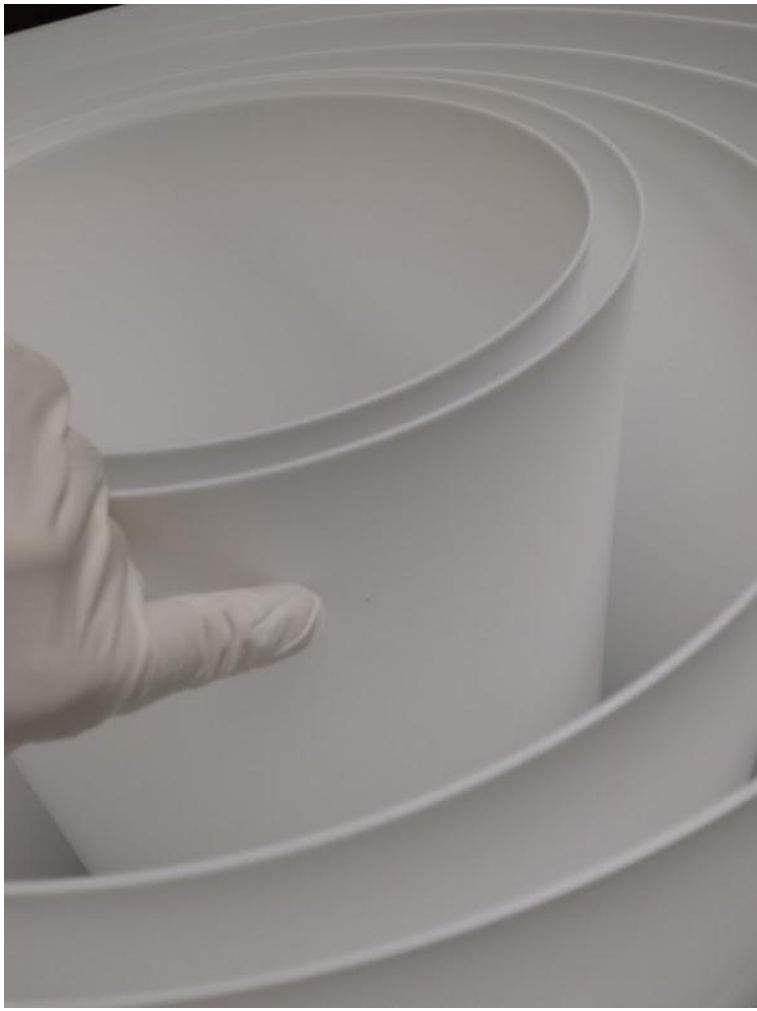
Preliminary Screening: PTFE

Approx 84 m^2 of PTFE in LZ

Screened 18 m^2 sample of skived material

Measurement Results:

< 0.015 mBq / m^2



Preliminary Screening: Cathode HV Cable

LZ will have about 8 m of (very) high-voltage cable to provide power to cathode.

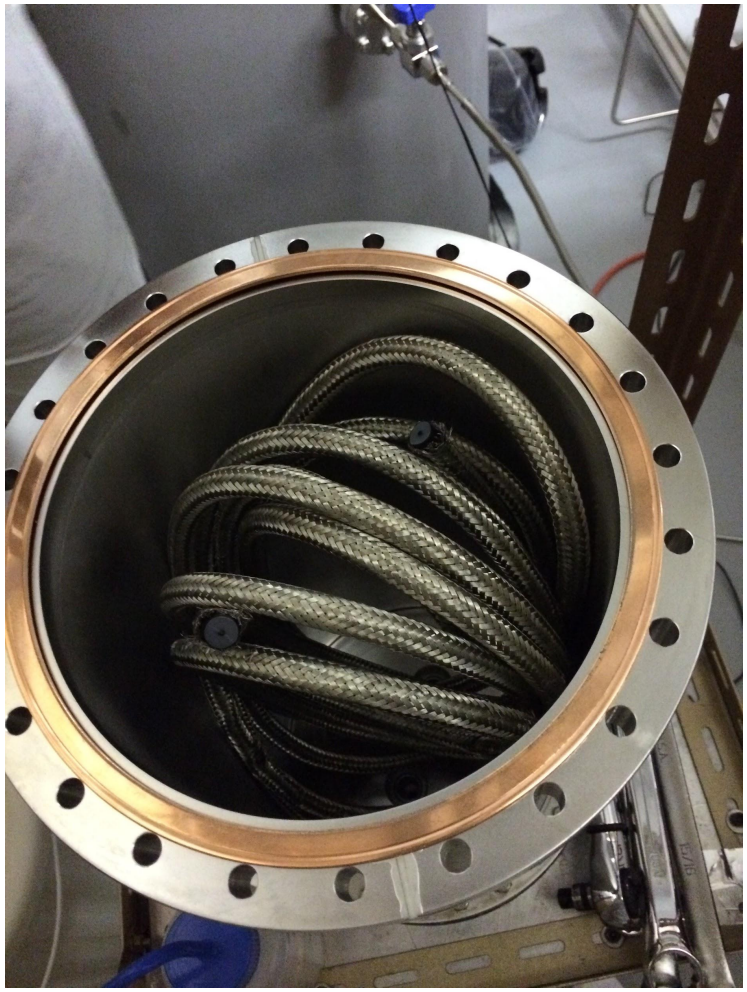
Screened 8 m sample of cable material

Measurement Results:

0.73 ± 0.33 mBq / m

0.26 ± 0.06 mBq / m

This cable has been rejected, for a variety of reasons.



Significant Preliminary Screening Results

Material	Result	Units	Contribution
PMT Cable - Axon	1.4 ± 0.1 1.4 ± 0.2	mBq / km	24 mBq
PMT HV Feedthroughs	0.1 ± 0.05 0.08 ± 0.06	mBq / unit	12.2 mBq 9.8 mBq
PMT Bases	0.28 ± 0.17	mBq / 100	1.8 mBq
PTFE	< 0.015	mBq / m^2	< 1.29 mBq
Umbilical Cable (rejected)	0.73 ± 0.33 0.26 ± 0.06	mBq / m	5.6 mBq 2.1 mBq

Sum of Rn production from all materials should be less than 10 mBq.

10 mBq expected from dust as well. **See poster by Chris Hjelmfelt!**

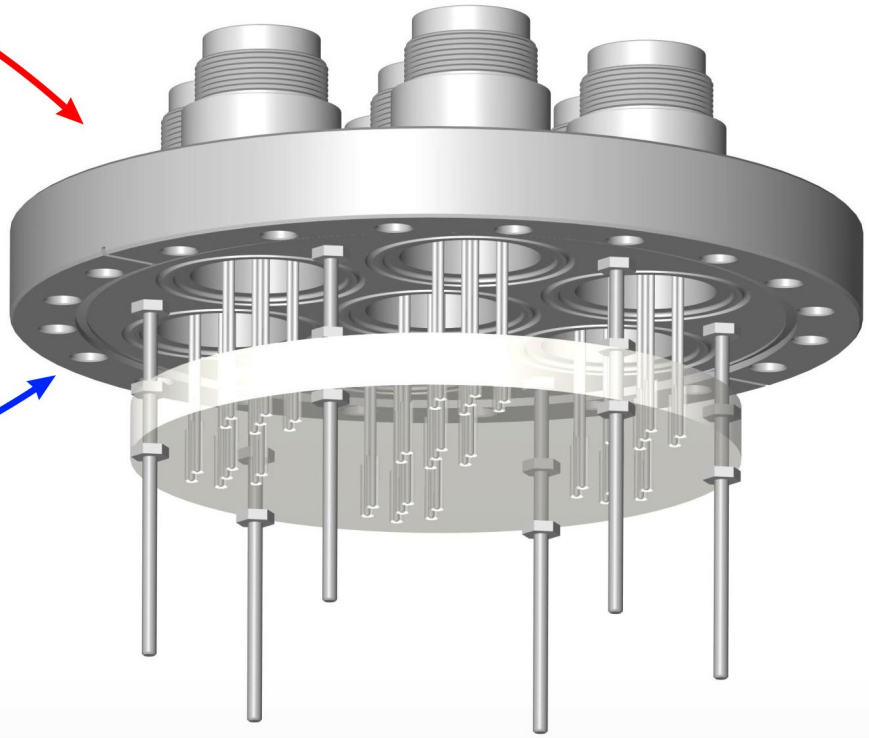
Radon Mitigation: Epoxy on Feedthrough

Coat wetted side of ceramic feedthrough with epoxy to prevent migration of radon.

Mine Air

Artist's representation of the wetted side of the HV feedthroughs with a Rn plug. Just add epoxy!

Gaseous Xe



Radon Mitigation: Carbon Trap

Radon can be removed from Xe with cooled carbon trap

Purification of full recirculation impractical, but can clean select regions:

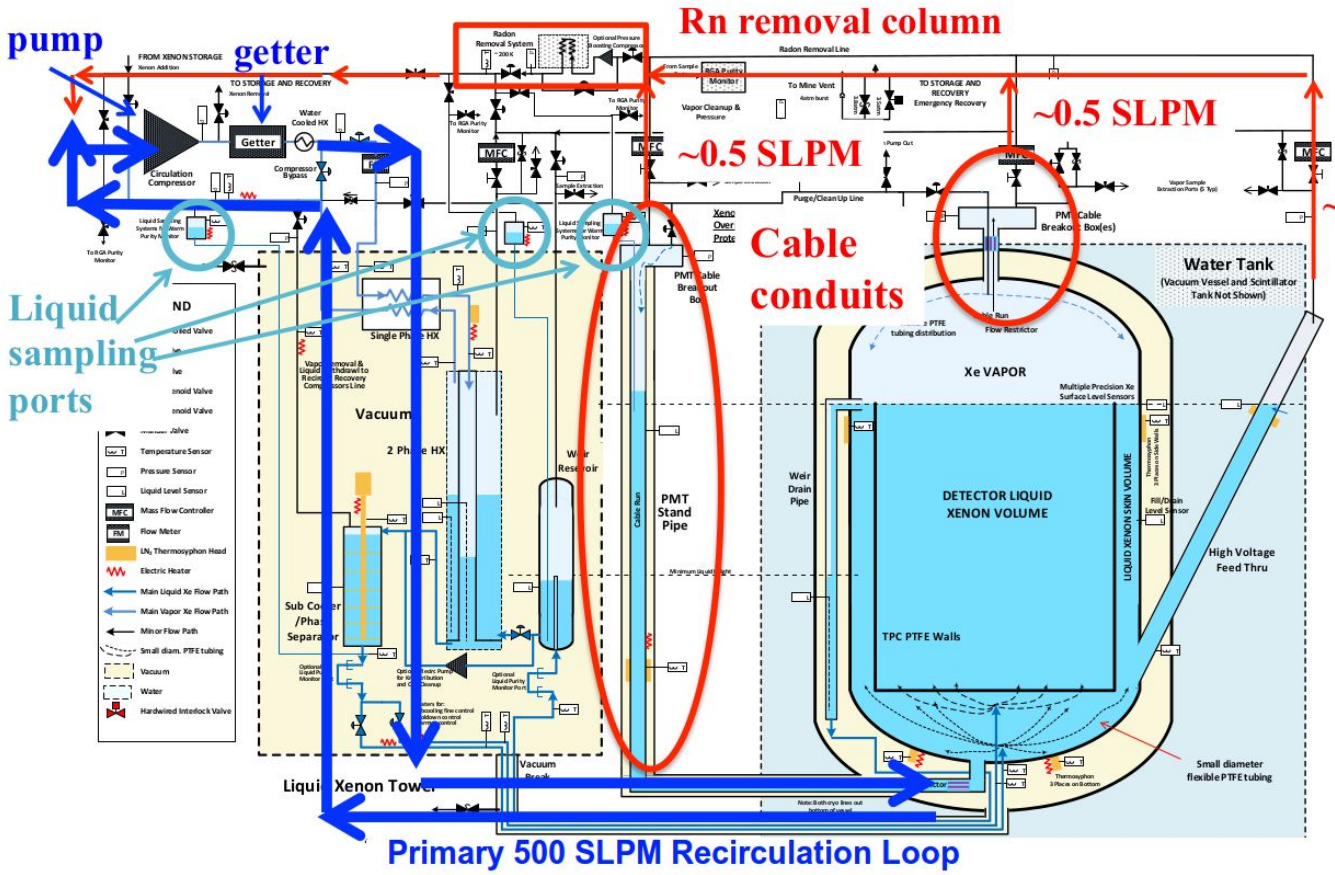


Image by
K. Pushkin, UM

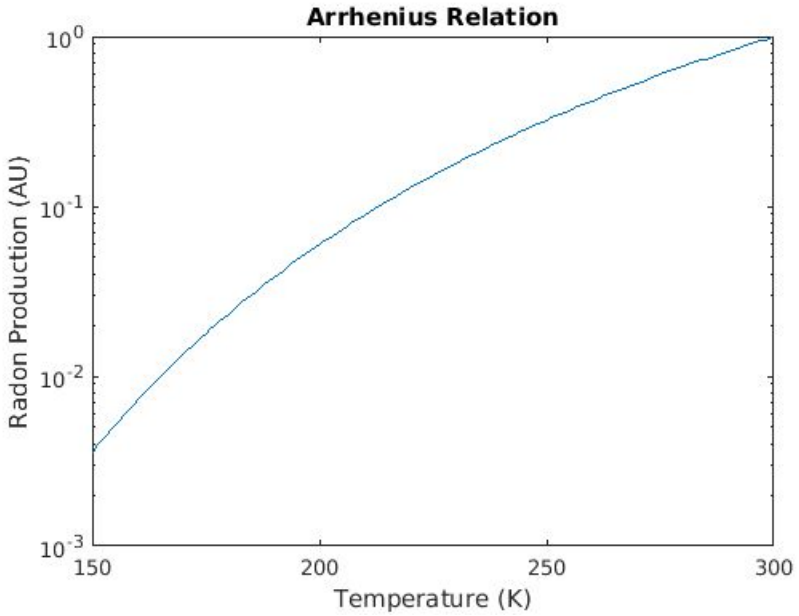
Radon Mitigation: Temperature

Diffusion of radon slows at low temperature, following Arrhenius relation:

$$D = A \exp(-T/T_0)$$

This implies ~100x reduction of radon **diffusing** out of typical materials and into LZ (170K) relative to screenings (300K)

Surface effects, like emanation from recoils or dust, are unaffected by temperature



Preliminary Screening Results After Mitigation

Sum of Rn production from all materials should be less than 10 mBq.

10 mBq expected from dust as well. **See poster by Chris Hjelmfelt!**

Material	Result	Units	Contribution	After Mitigation
PMT Cable - Axon	1.4 ± 0.1 1.4 ± 0.2	mBq / km	24 mBq	1.2 mBq
PMT HV Feedthroughs	0.05 ± 0.02 0.04 ± 0.03	mBq / unit	6.1 mBq 4.9 mBq	0.6 mBq 0.5 mBq
PMT Bases	0.28 ± 0.17	mBq / 100	1.8 mBq	< 1.8 mBq
PTFE	< 0.015	mBq / m^2	< 1.29 mBq	< 1.29 mBq
Umbilical Cable (rejected)	0.73 ± 0.33 0.26 ± 0.06	mBq / m	5.6 mBq 2.1 mBq	

Preliminary Radon Estimate for LZ

Item	Component Breakdown		Radon Emanat
	Component	*Material*	*Best*
R11410 3" PMTs	Total		1.26E+00
Cryostat & Flanges	Cryostat	Ti	1.50E-01
Cryostat Seals	Helicoflex Seals	Al	1.60E-02
PTFE Internals	Internals	Teflon	7.56E-01
R11410 PMT Bases	Circuitboard	Cirlex	9.66E-01
PMT Mounts		Ti	4.40E-02
PMT Structure LED (Upper + Lower)		Acrylic	5.60E-06
R8520 1" PMT	PMT		1.52E-01
R8778 2" PMT	PMT		9.00E-02
R8520 PMT Bases	Max Total		2.50E-01
PMT HV Cables	Cabling, cladding,	removal (UL)	1.30E+00
PMT Cable Feedthru	Feedthrough & Mitigation		7.80E-01
Field Rings		Ti	6.00E-02
Grid Supports	Grid Supports	Ti	1.80E-02
HV Umbilical	Feed-Through	Epoxy	1.11E-01
Heat Ex. Conduit			
Xe Recirculation Pump			
Xe Purification Getter	Est Total		1.34E+00
Recirculation transducers			
Recirculation valves			1.65E-01
Recirculation stainless steel			5.40E-02
Recirculation welds			1.09E-01
Cabling Conduit	Conduit + Rn Removal		5.50E-02
Umd Carbon Trap	Carbon	Carbon	4.00E-01
Dust	Dust	Dust	1.00E+01
Total			18.1

Summary

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Most significant backgrounds in LZ likely to be from Rn daughters

Radon screening program underway for LZ, employing sensitive screeners at 4 institutions

We have identified some mitigation strategies for problematic materials

Satisfactory expectation of 8.1 mBq from materials, and 18.1 mBq total

Questions?