Cleaning LZ: how to get rid of unwanted backgrounds

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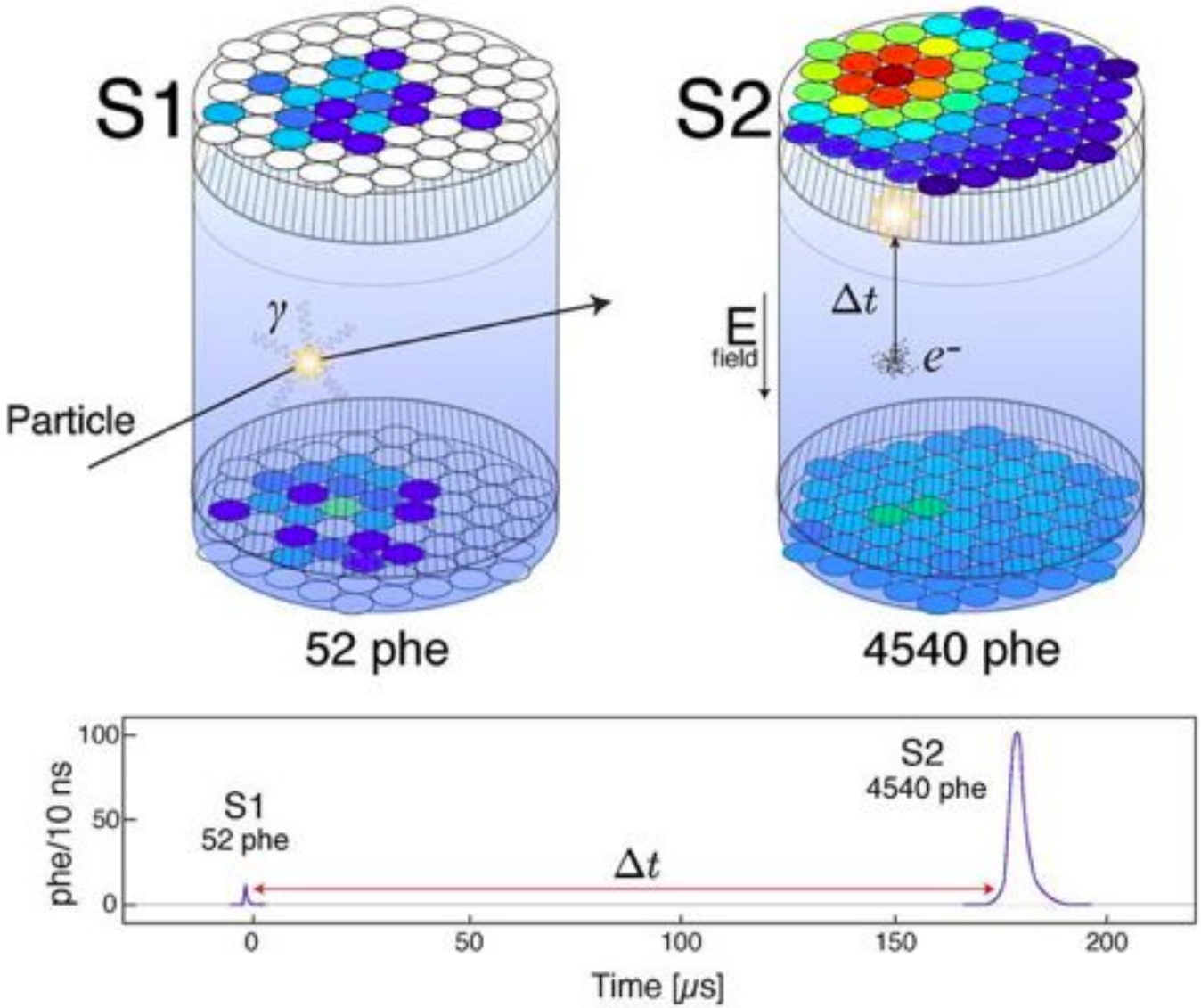
On behalf of the LZ collaboration
(with a lot of help from Dr. Alvine Kamaha)

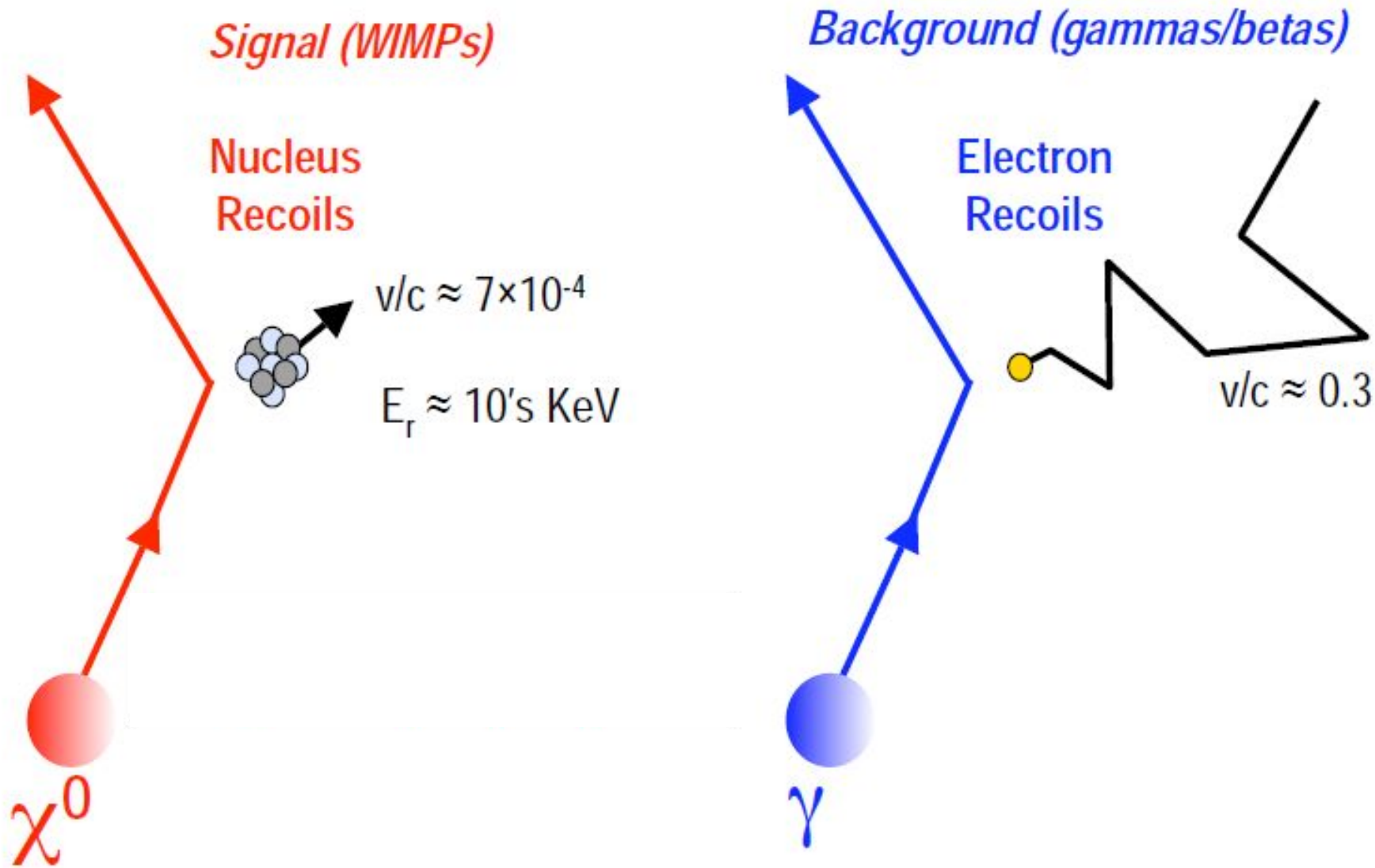
APS - DPF Boston, July 30th, 2019

UNIVERSITY AT ALBANY
State University of New York

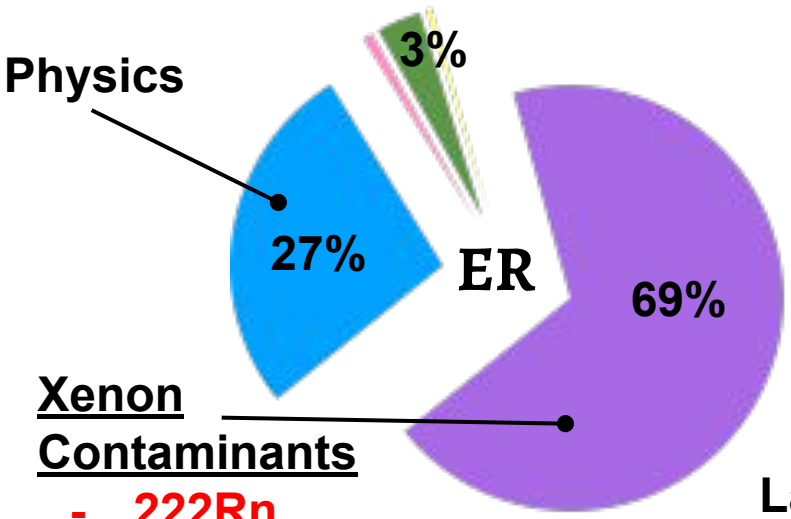
LZ Working Principle - Brief Recap

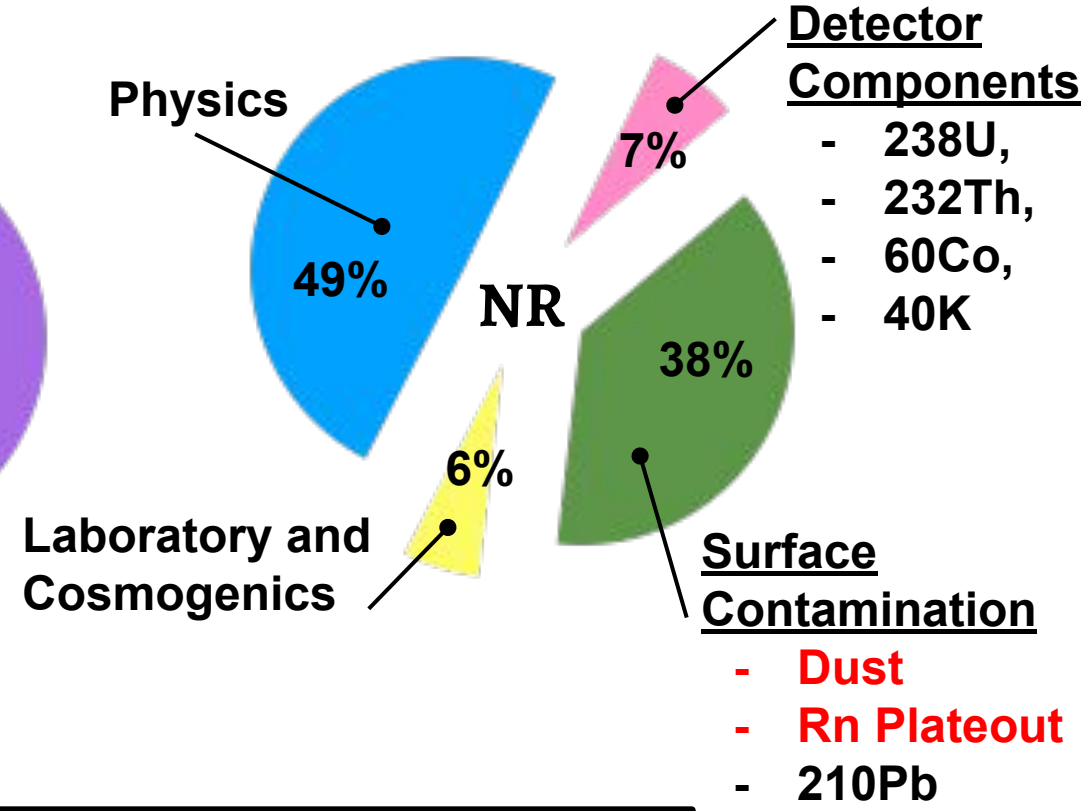


ER vs NR


Signal (WIMPs)
Nucleus
Recoils
v/c ≈ 7×10-4
Er ≈ 10's KeV
χ0
Background (gammas/betas)
Electron
Recoils
v/c ≈ 0.3
γ

Backgrounds Origins and Expectations





Total:	1195 ER	1.03 NR
After cuts:	5.97 ER	0.52 NR

Based on 1000 live days, 5.6T FV https://arxiv.org/pdf/1802.06039.pdf

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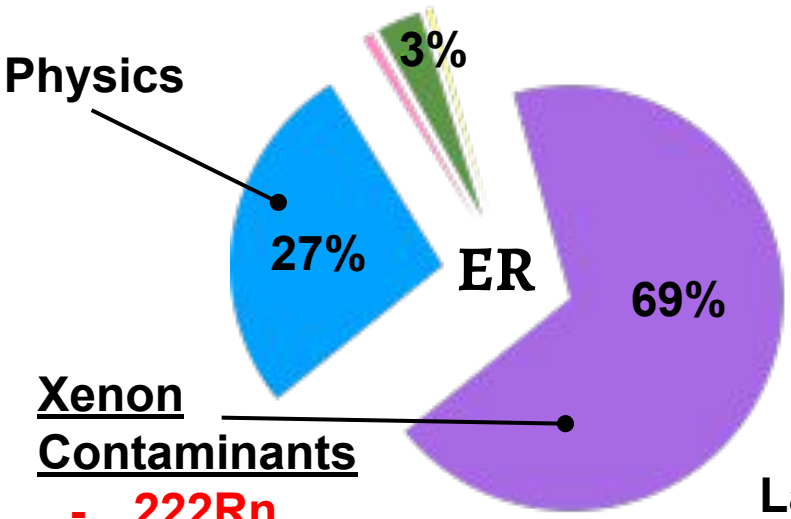
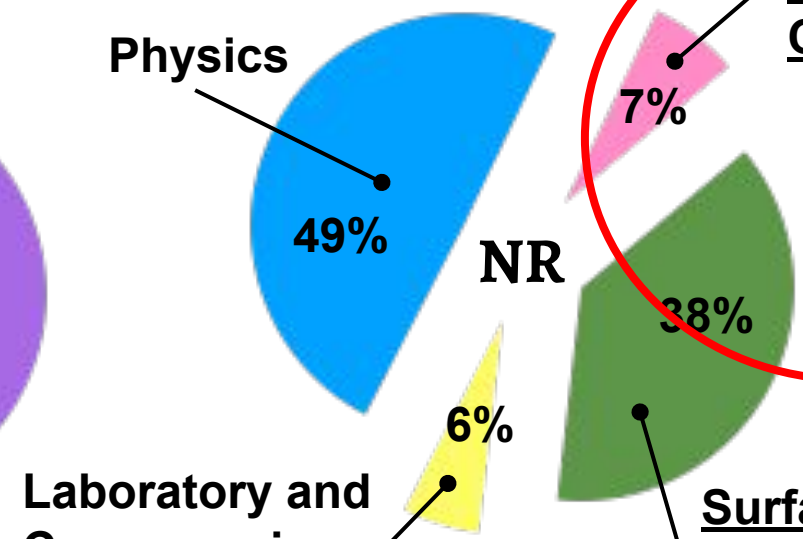


Xenon Contaminants
- 222Rn,
- 220Rn,
- natKr,
- natAr



Detector Components
- 238U,
- 232Th,
- 60Co,
- 40K

Laboratory and Cosmogenics

Surface Contamination
- Dust
- Rn Plateout
- 210Pb

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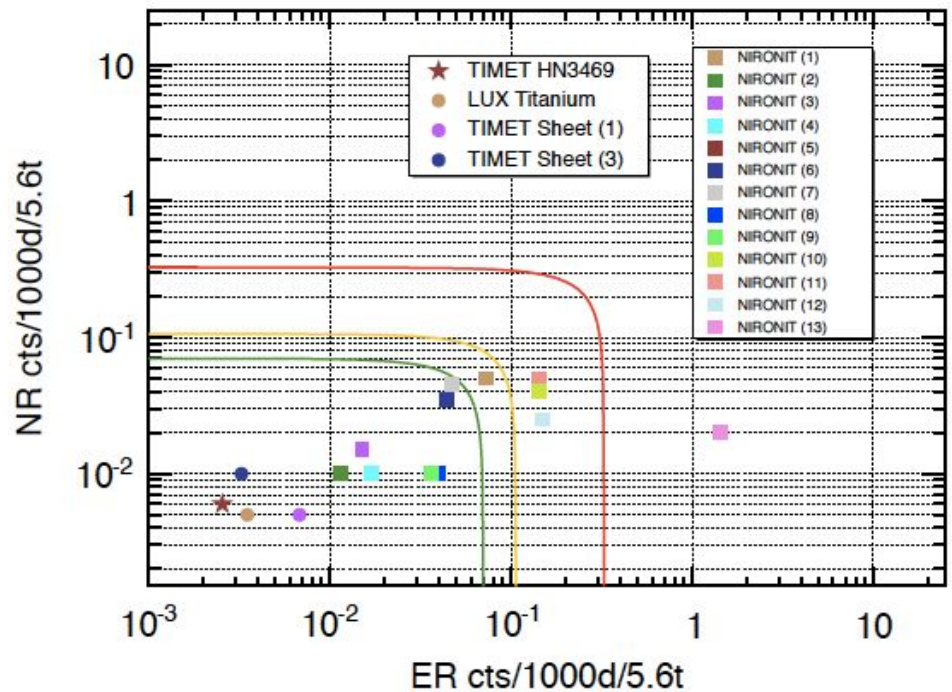
Screening

Materials are screened and selected to have the lowest possible **intrinsic radioactivity**

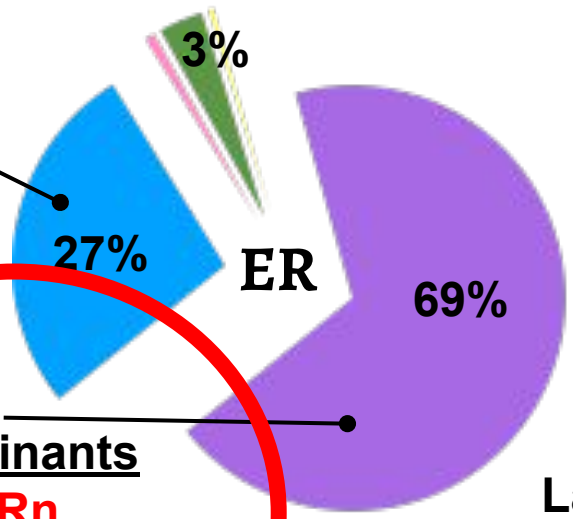
- High purity **germanium** detectors (14 detectors across 4 sites: SURF, UK, Berkeley, Alabama) for gamma rays spectrometry from 60Co and 40K
- **Mass Spectrometry** for abundance of 238U and 232Th (UCL)

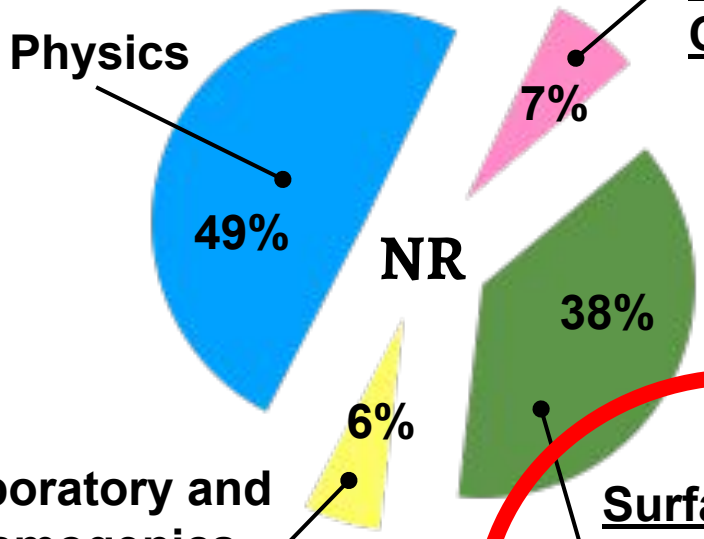


Success story: cryostat titanium well below requirement

https://arxiv.org/abs/1702.02646

Backgrounds Origins and Expectations





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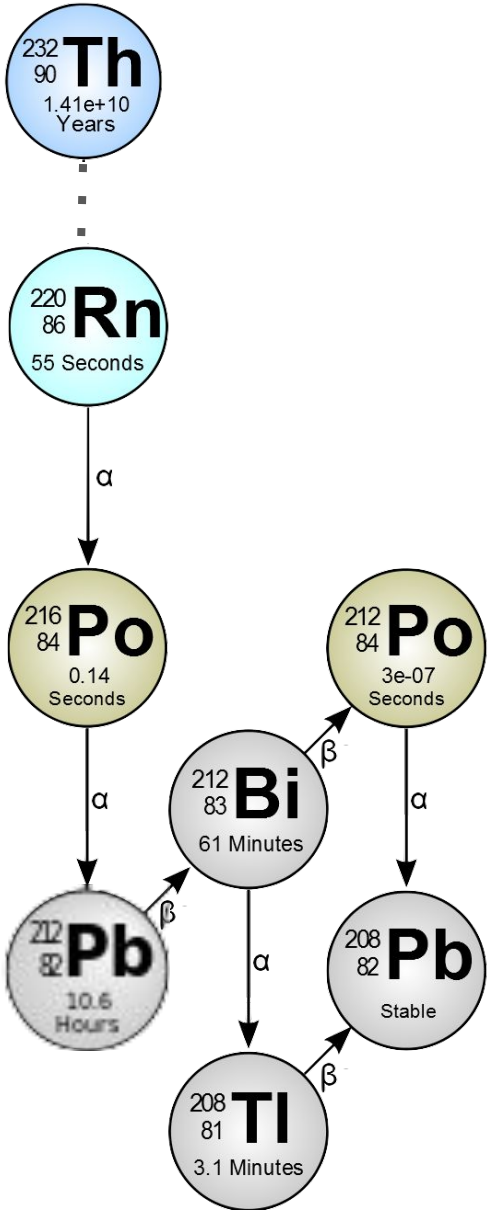
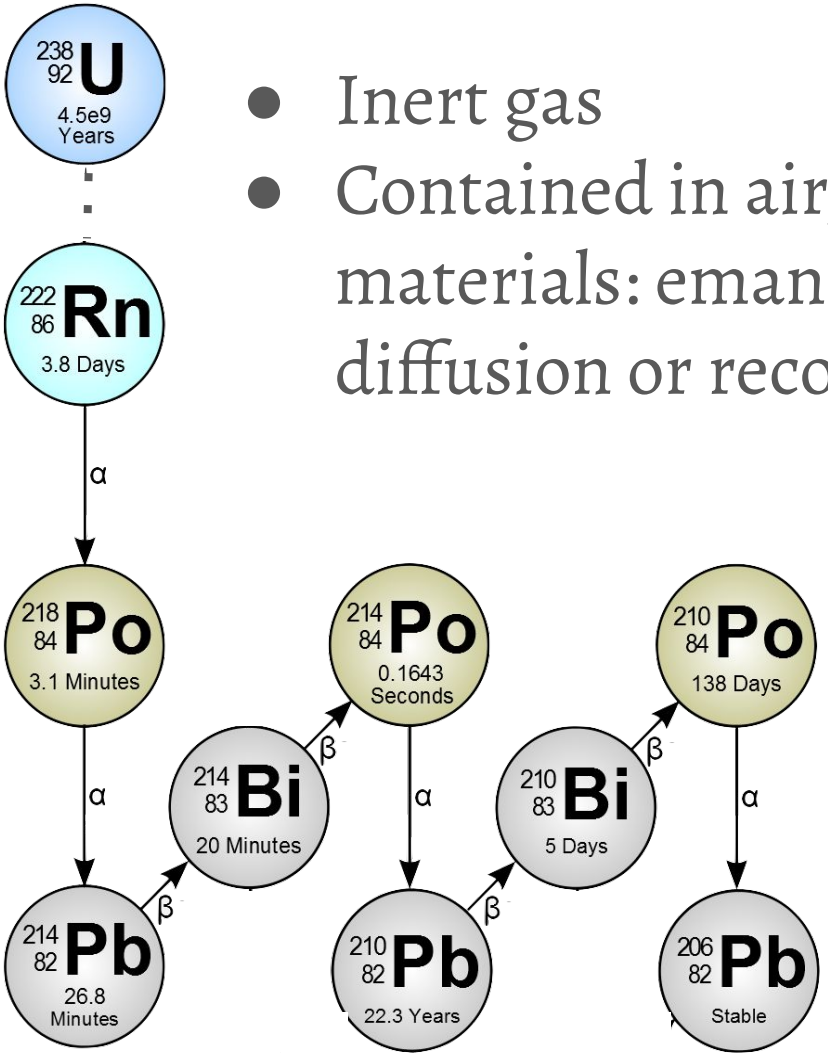
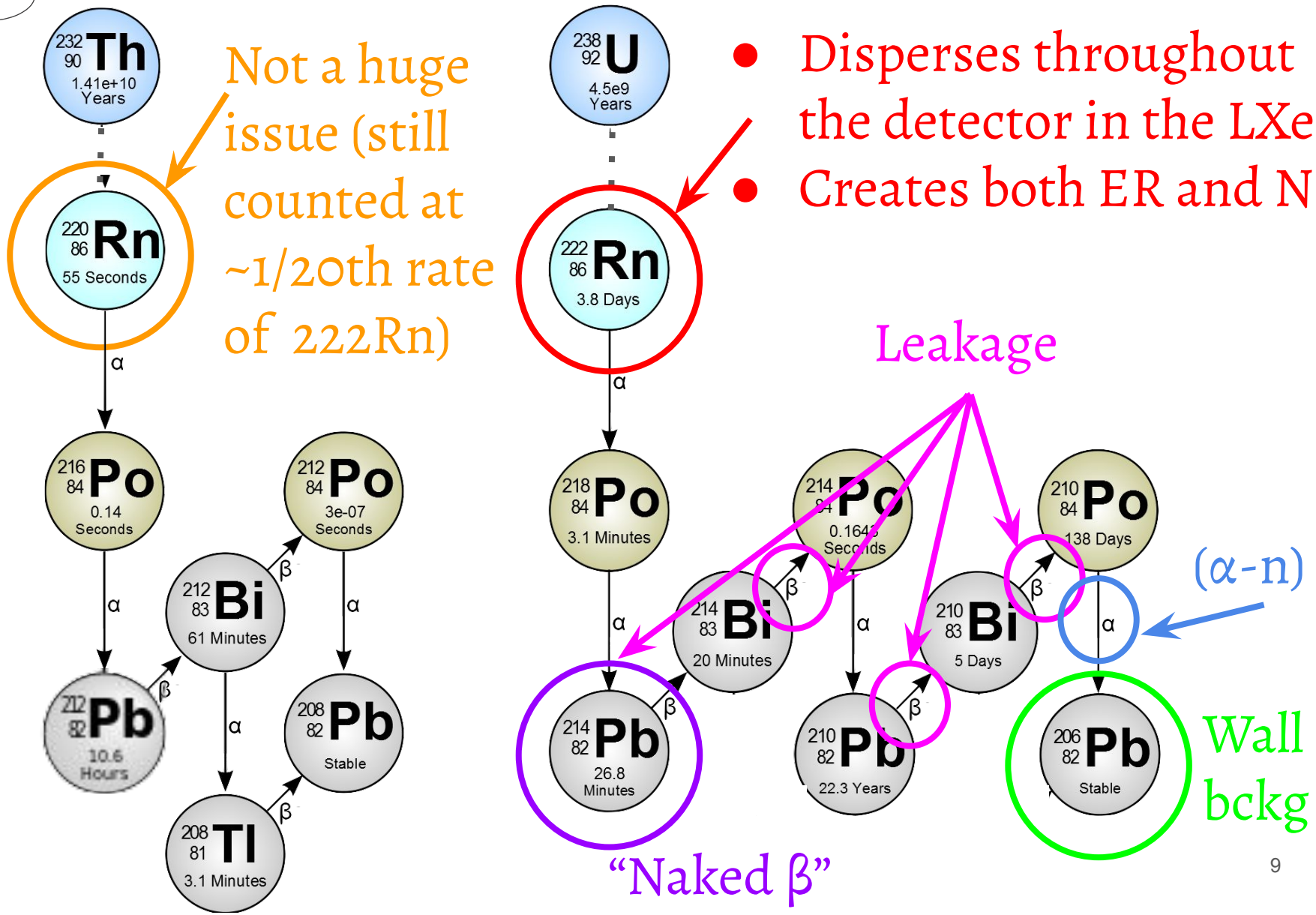
Radon, Radon, always Radon





- Inert gas
- Contained in air, and materials: emanates via diffusion or recoils

Radon, Radon, always Radon



- Disperses throughout the detector in the LXe
- Creates both ER and NR

Fighting Rn

- Need to know exactly how much Rn is being emanated by all the different materials that are in contact with the xenon

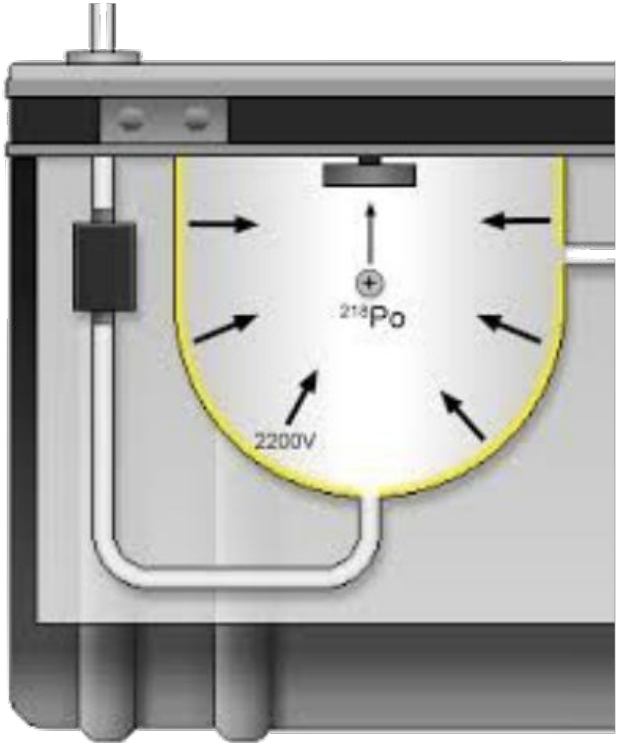
- Need to know exactly how much Rn is being **deposited** on the **surface** of materials **during assembly**

Rn Emanation

2 methods:

- Dissolve Rn into **liquid scintillator** and identifies radon by the 214Bi-214Po timing coincidence (UAlabama)

- UCL, Maryland, SDSM&T : **silicon-pin diode** which measures the alpha decays from 214Po and 218Po



https://arxiv.org/pdf/1708.08533.pdf

Emanation chamber where sample outgases

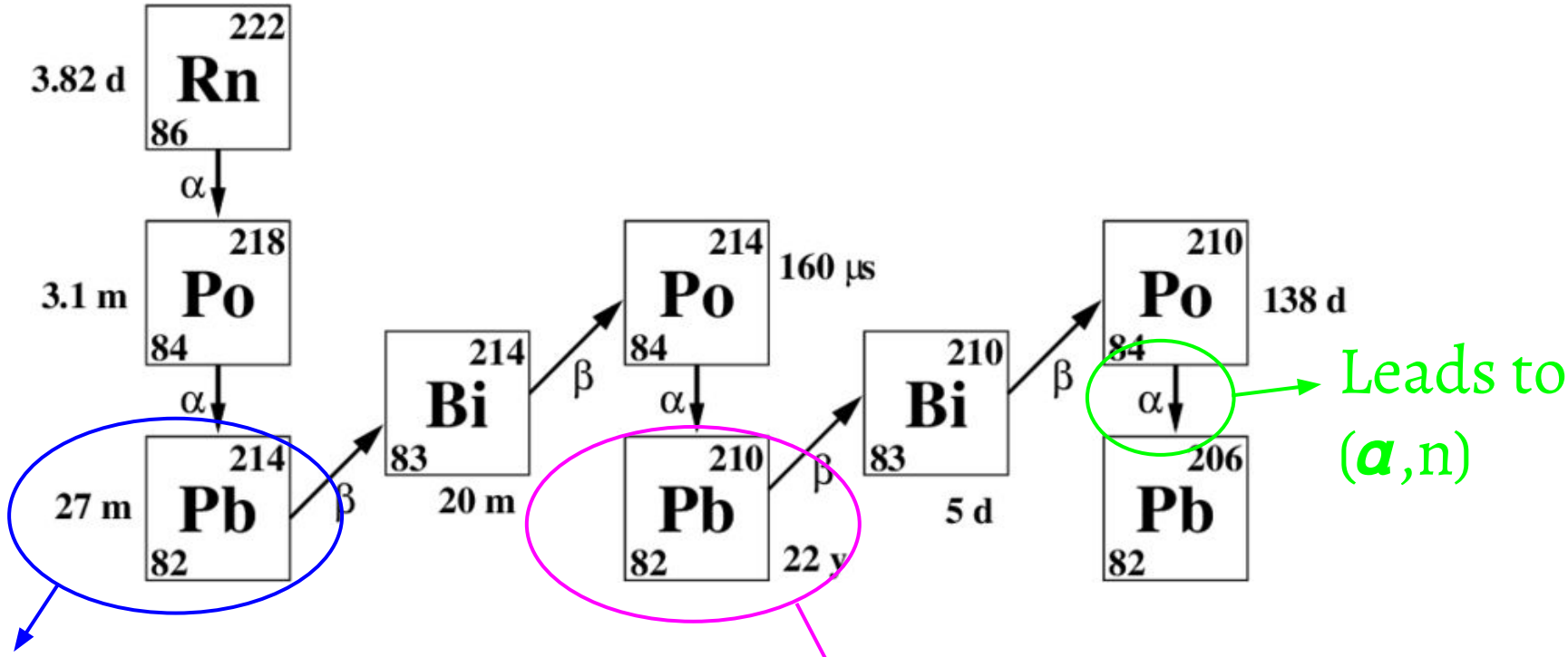
Evacuation: Rn freezes in cold trap

N flowing with Rn into Detection chamber

222Rn decays, 218Po is positively charged and collect to the diode

218Po and 214Po alpha and are readout by the diode

Surface Deposition



During data taking

Comes from Rn emanated from dust

Slowly dispersed in TPC

During LZ construction

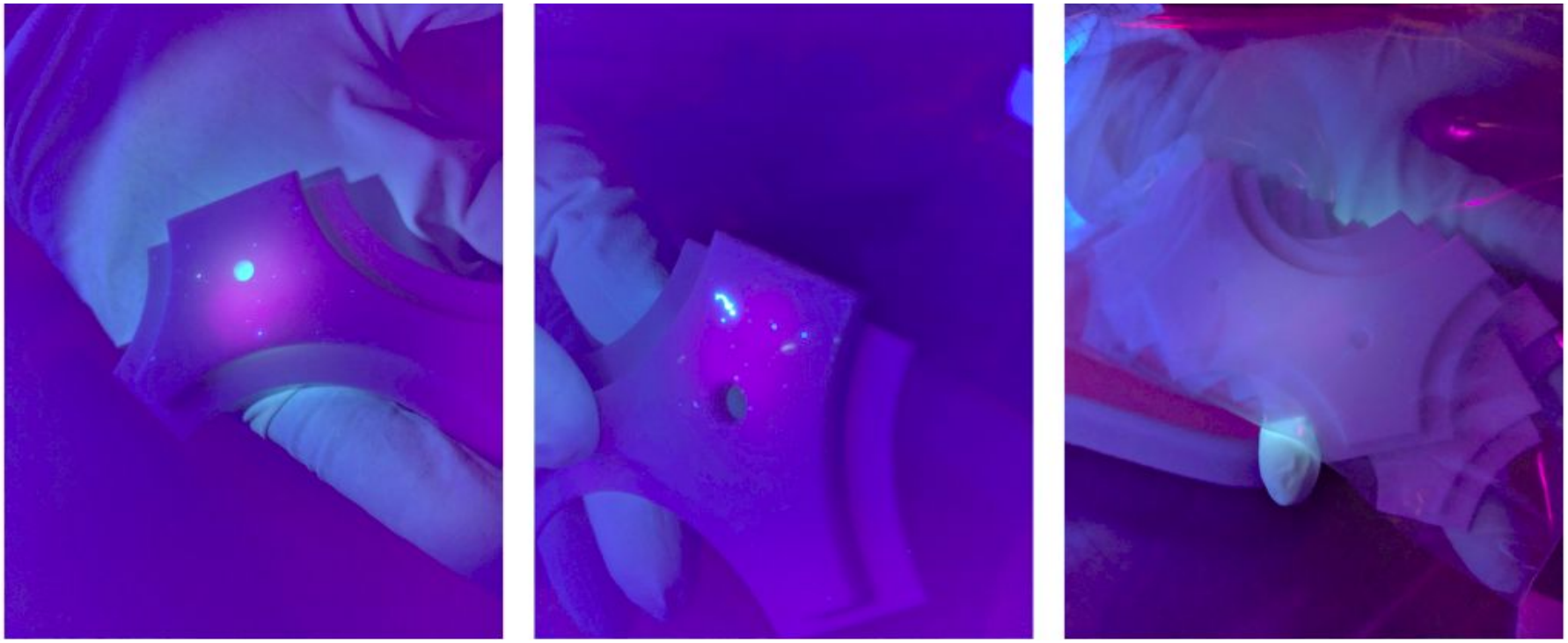
Comes from ambient Rn in air

Plateout on surfaces

How to minimize surface deposition

- Reduced Rn Cleanroom (RCR)
- Rn and dust constantly monitored
- Develop cleanliness protocols
  - Reduce personnel to a strict minimum within cleanroom
  - Do not lean/No paper allowed
  - Garb and gloves changed everyday
  - Everything must be cleaned (IPA wiped) prior and after assembly
  - Everything must be cleaned under de-ionizing (DI) fans
  - If not in use, everything must be double bagged
  - No circular motion when wiping
  - Etc etc etc…

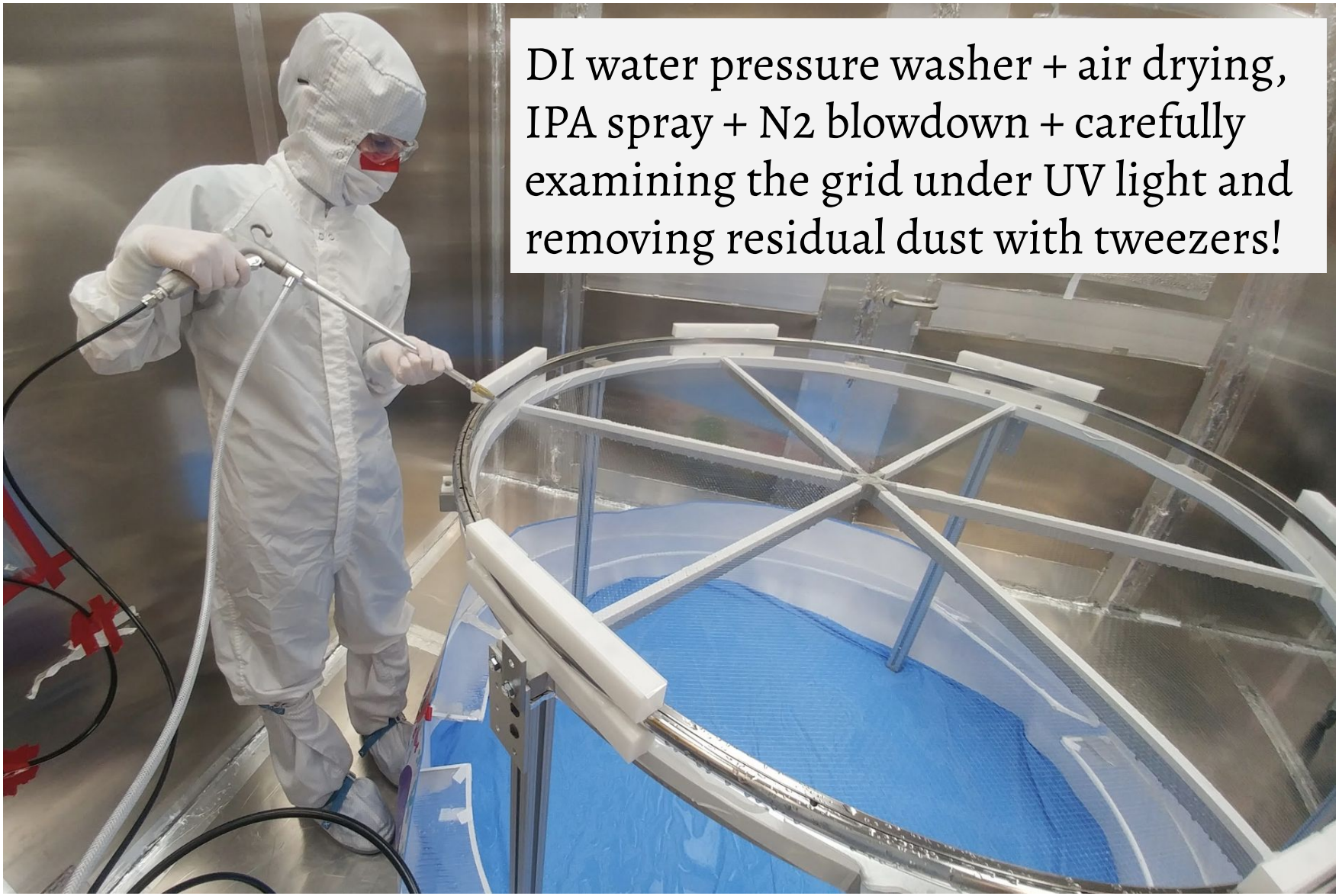
How to minimize surface deposition



Before and After IPA cleaning using saturated non-shedding mono-filament wipes (Teflon parts for the PMT arrays) under UV light

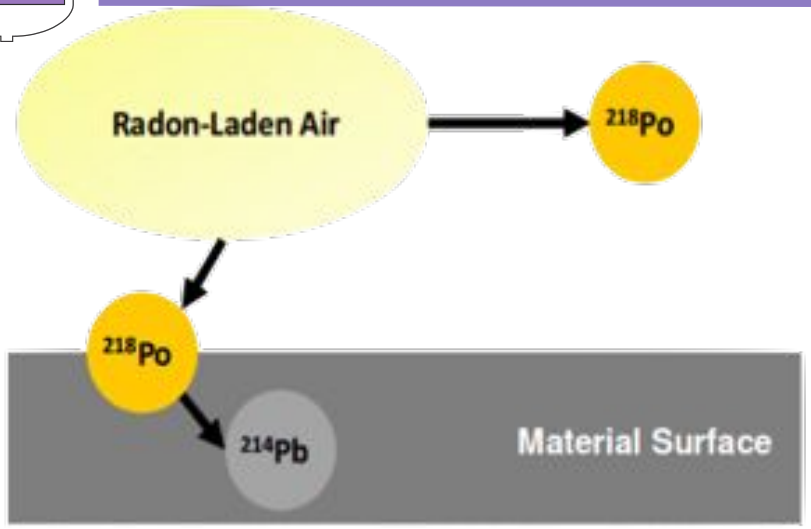
How to minimize surface deposition

How to minimize surface deposition



DI water pressure washer + air drying, IPA spray + N2 blowdown + carefully examining the grid under UV light and removing residual dust with tweezers!

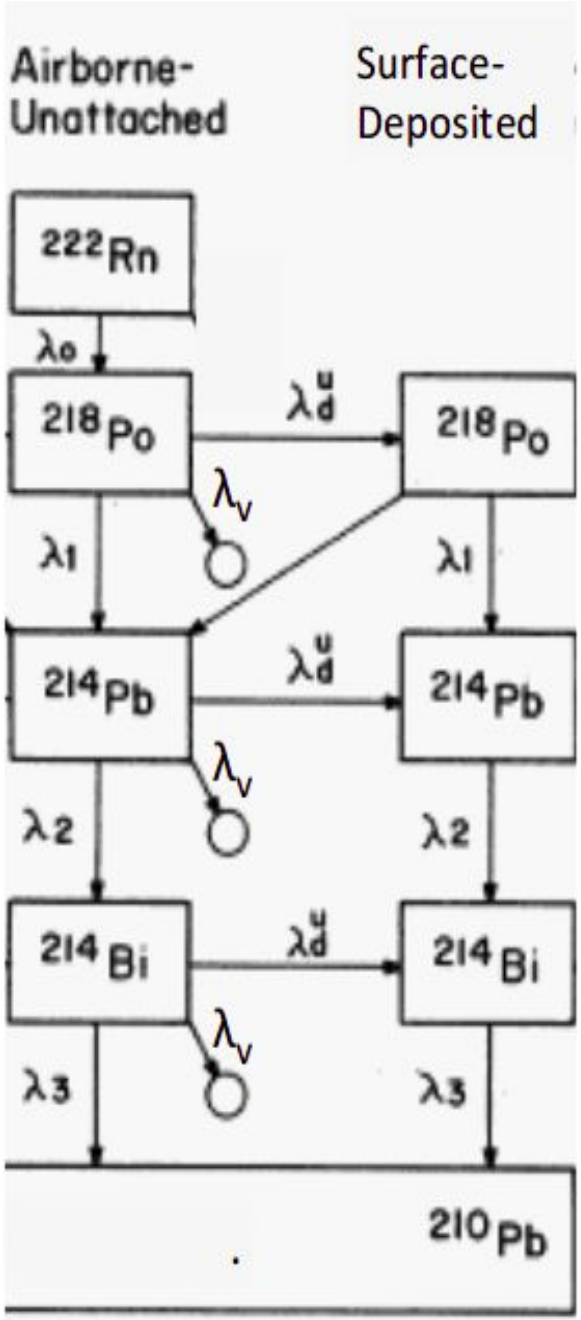
Rn Plateout calculations



Jacobi Model
https://pdfs.semanticscholar.org/64c9/72f4f2af5be3035168f48b1416780f05bc59.pdf

$$R_p = C_{Rn}\lambda_{Pb_{210}}\frac{\Lambda_d}{(\Lambda_d+\Lambda_v)}\frac{V}{A}$$

- Rn concentration within the clean room
- Pb-210 decay rate
- Ventilation rate (depending on clean room air circulation rate and size)
- Plateout deposition rate (depending on V, A and diffusion velocity of radon daughters)



Dust: Witness coupons and Tapelifts

Witness coupons deployment and tapelifts gives us two ways of estimating dust deposition

Tapelift under microscope

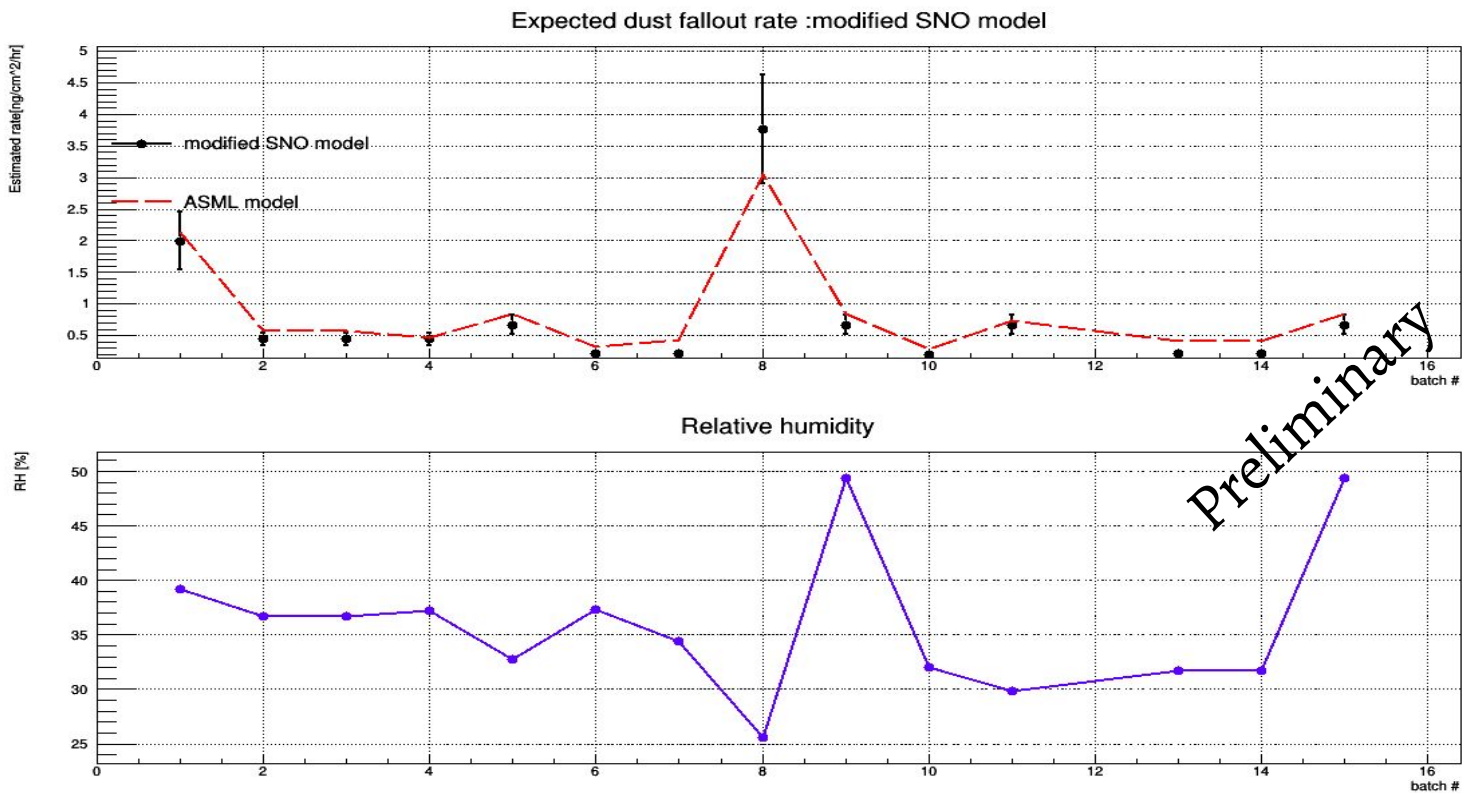
Witness plate under microscope: dust particulate and fiber (probably from personnel clothing) is visible.

Dust calculations: modified SNO model

$$\frac{dm}{dt} = \int_{D \geq 0.5\mu m} \frac{\pi}{6} n(D) \rho^3 \eta \; dD$$

https://sno.phy.queensu.ca/sno/str/SNO-STR-91-009.pdf

- D: particle diameter (assume sphere)
- n(D): dust particle density
- ρ: mass density in g/cc
- η: empirical correction factor that takes into account humidity, temperature and extra air flow



Information Repository

Database is keeping track of everything that will be in contact with the LXe:

- Parts (including surface area, material, mass, assembly, drawings, exposure eras, QA)
- Radioactivity contents,
- Screening protocols and assays,
- Cleaning protocols

Master ID	Brief Description	Quantity	WBS ID	Detector Region	Component ID	Assembly ID	Status	Location(City,State)	Drawing ID	Edited By(Name, yymmdd)	QR Code	Comment
2200	PLATE MOUNTING SECT1-LOWER SHIELD-4	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0766	Alvine Kamaha, 180814	Generate QR	Technetics
2201	PLATE MOUNTING SECT1-UPPER SHIELD-1	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0792	Alvine Kamaha, 180814	Generate QR	Technetics
2202	PLATE MOUNTING SECT1-UPPER SHIELD-2	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0781	Alvine Kamaha, 180814	Generate QR	Technetics
2203	PLATE MOUNTING SECT1-UPPER SHIELD-3	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0789	Alvine Kamaha, 180814	Generate QR	Technetics
2204	PLATE MOUNTING SECT1-UPPER SHIELD-4	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0797	Alvine Kamaha, 180814	Generate QR	Technetics
2205	LOWER PMT ARRAY SEGMENT-2	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0745	Alvine Kamaha, 180814	Generate QR	-
2206	PLATE, PMT MOUNTING, SECT2	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0768	Alvine Kamaha, 180814	Generate QR	UA
2207	PLATE MOUNTING SECT2-LOWER SHIELD-1	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0790	Alvine Kamaha, 180814	Generate QR	Technetics
2208	PLATE MOUNTING SECT2-LOWER SHIELD-2	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0793	Alvine Kamaha, 180814	Generate QR	Technetics
2209	PLATE MOUNTING SECT2-LOWER SHIELD-3	1	-	Bottom Skin array	list component	list assembly	In process	-	-	Alvine Kamaha, 180814	Generate QR	Technetics
2210	PLATE MOUNTING SECT2-UPPER SHIELD-1	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0791	Alvine Kamaha, 180814	Generate QR	Technetics
2211	PLATE MOUNTING SECT2-UPPER SHIELD-2	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0783	Alvine Kamaha, 180814	Generate QR	Technetics
2212	PLATE MOUNTING SECT2-UPPER SHIELD-3	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0798	Alvine Kamaha, 180814	Generate QR	Technetics
2213	LOWER PMT ARRAY SEGMENT-3	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0743	Alvine Kamaha, 180814	Generate QR	-
2214	PLATE, PMT MOUNTING, SECT3	1	-	Bottom Skin array	list component	list assembly	In process	-	LZ-0000-0802	Alvine Kamaha, 180814	Generate QR	UA

LZ cleanliness campaign in numbers

- 2988 parts,
- 1174 screening and Rn emanation assays,
- >1000 cleaning protocols, applications and references
- ~4000h of cleaning since the assembly started

	LZ Requirement	**Current Best Estimate**
Rn plateout (entire TPC)	0.5 mBq/m^2	**0.194 +/- 0.057 mBq/m^2**
Dust Deposition (entire TPC)	500 ng/cm^2	**210 +/- 16 ng/cm^2**
Total Rn emanation	20 mBq	**Underway...**

Conclusion

- Probably the most elaborate cleaning campaign ever to happen in this field
- Incredibly intense and required a lot of manpower and coordination
- Well worthwhile: LZ is on a trajectory to beat its cleanliness requirements
- Assay and Cleanliness paper to be posted *soon*

THANK YOU!

Back-up Slides