Detector Cleanliness: Cleanliness Requirements

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Outdated CDR: “Clean Room at the Far Site Facility”

…

Single-phase Detector Installation

A temporary clean-area enclosure of class 10 000 (ISO 7 equivalent) will be constructed for the detector assembly near the entrance of the cryostat, covering the area around the open hatch. Enough HEPA and/or ULPA filters are installed (ideally on top of temporary clean tent if space allows) to ensure that the tent interior is constantly flushed with clean air and to create an overpressure that prevents dust and dirt from entering through small gaps in the tent structure. The tent will have an ante area for personal to gown with the appropriate clean-room clothing (Tyvek coveralls, powder-free latex gloves, head-covers) and safety shoes (covered by clean booties with slip-proof profile). A large closeable door will allow unloading of the detector components directly from the clean storage containers (located next to the door). Figure 1 shows the design of the clean area on top of the first cryostat.

The temporary clean room will be installed in the first cryostat and moved to the second cryostat once the assembly of the first one will be completed.

…

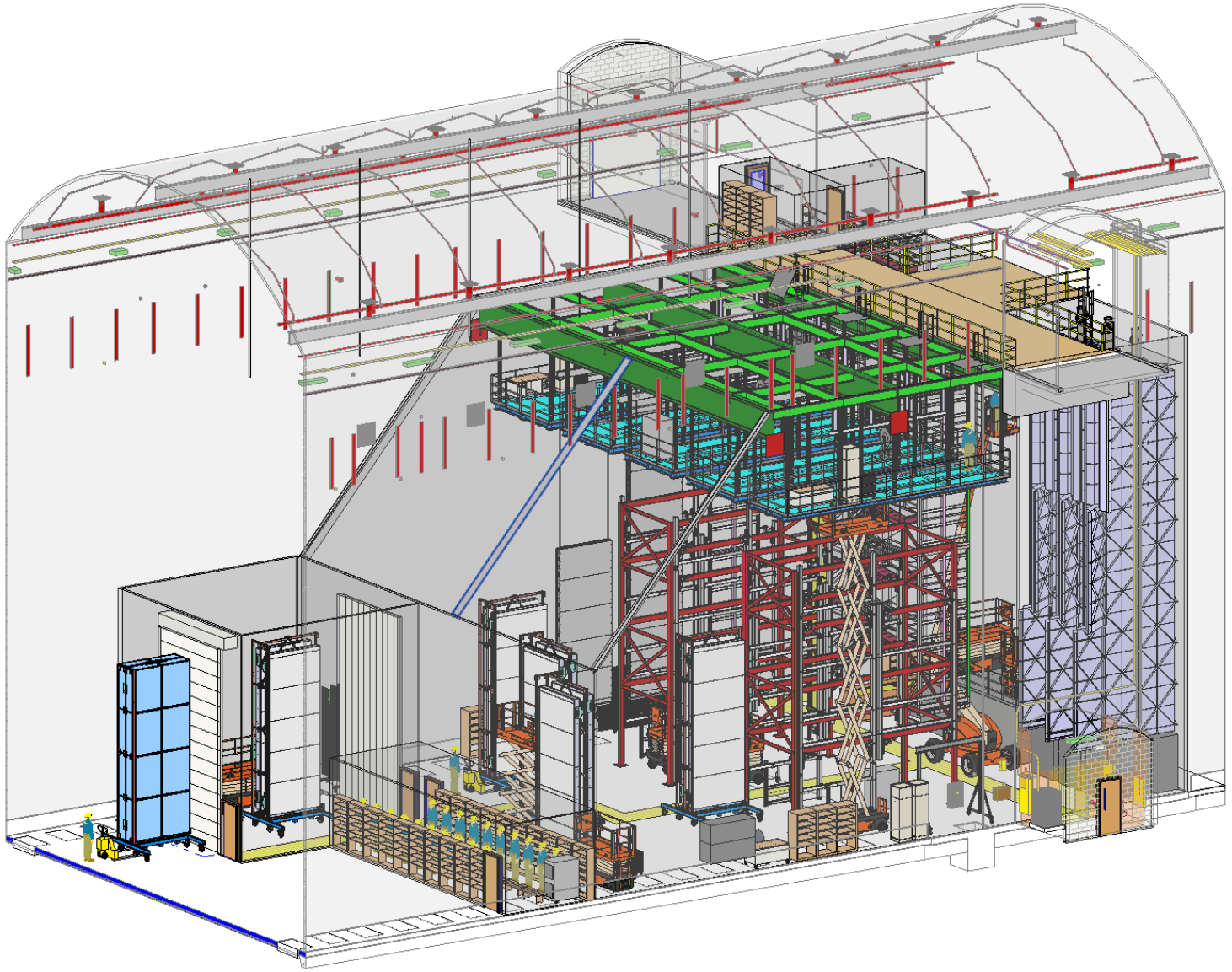
Do we really need Class 10,000 (ISO 7)?

Do we really need to gown up?

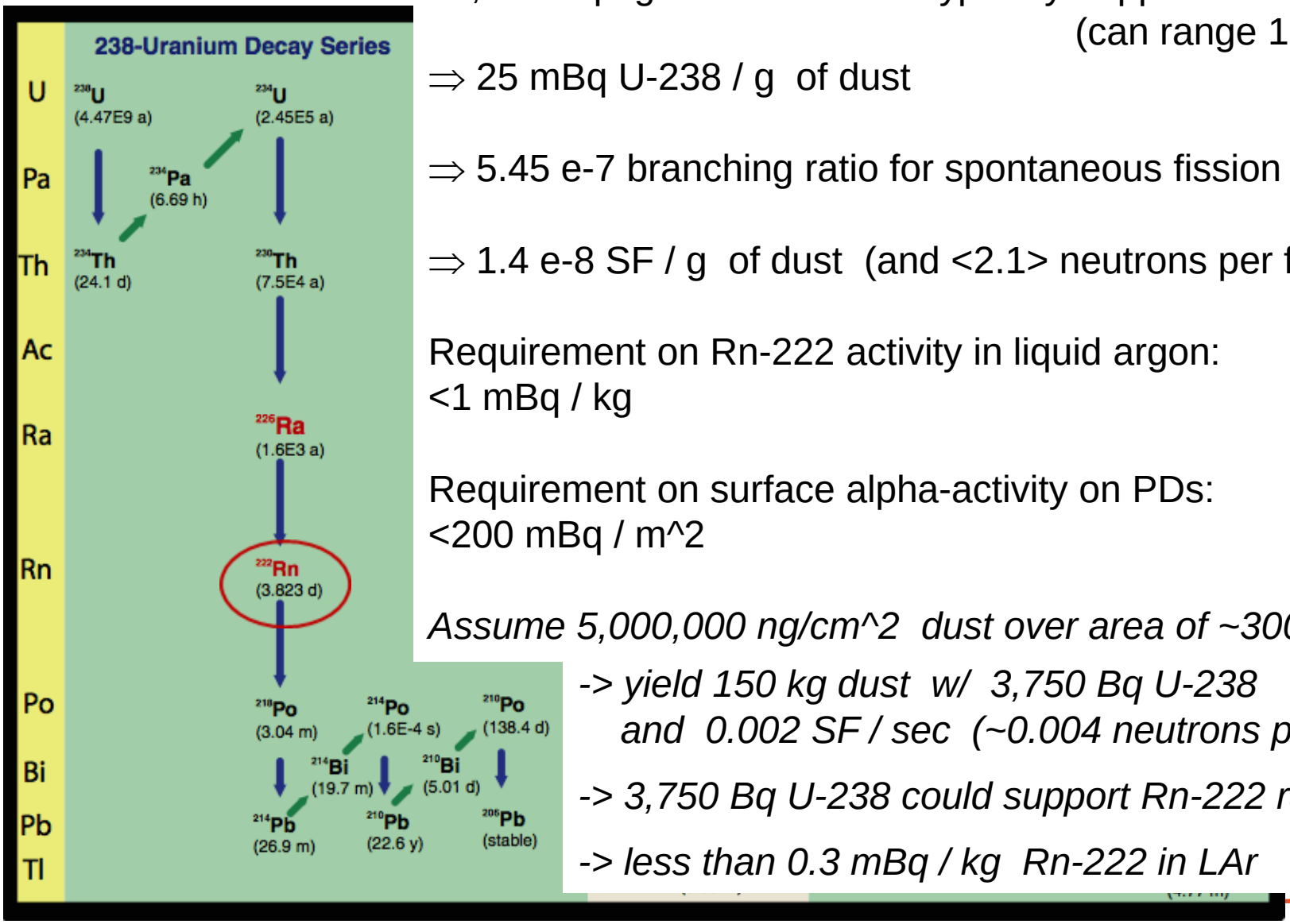
Do we need a clean room (and ante) at all?

https://edms.cern.ch/document/2113015/2

Clean Room Update (Justin Freitag Apr 2020)



Dominant U-238 Decay Chain



12,445 Bq / g of U-238 and typically 2 ppm U-238 in dust (can range 1 - 3 ppm)

⇒ 25 mBq U-238 / g of dust

⇒ 5.45 e-7 branching ratio for spontaneous fission

⇒ 1.4 e-8 SF / g of dust (and <2.1> neutrons per fission)

Requirement on Rn-222 activity in liquid argon:
<1 mBq / kg

Requirement on surface alpha-activity on PDs:
<200 mBq / m^2

Assume 5,000,000 ng/cm^2 dust over area of ~3000 m^2:

-> yield 150 kg dust w/ 3,750 Bq U-238 and 0.002 SF / sec (~0.004 neutrons per sec)

-> 3,750 Bq U-238 could support Rn-222 rate

-> less than 0.3 mBq / kg Rn-222 in LAr

How much dust to expect during 1 year installation: SNO Model

Assume ISO 8 for now (just cleaner than typical outside air):

Selected model is the SNO model

Maximum dust mass density (ng/cm^2) allowed	5000000

Defaults:

Fresh Air Input Class (N(D>0.5 microns)/cubic ft)	7500000
Inverse Particle Size Dependence Exponent (standard is 3.08)	3.08
Clean Room Area (square meters)	840
Clean Room Volume (cubic meters)	11760
Filter Transmission	0.0003
Air Exchange Rate (volumes/hr)	1
Fresh Air Fraction	0.1195228609
Particle Size Cutoff (microns)	100.0
Dust Carry-In Rate (g/day)	100
Average Dust Density (g/cc)	1.0

Quantity	Units	Value
Maximum exposure time	**days**	**503.281 (= 503d 6h 44m 34.5s)**
Fresh Air Class		7500000.0
Size Distribution Exponent		3.08
Clean Room Area	square meters	840.0
Clean Room Volume	cubic meters	11760.0
Input Filter Transmission		0.0003
Air Exchange Rate	clean room volumes/hr	1.0
Fresh Air Fraction		0.119522860933
Particle Size Cutoff	microns	100.0
Carry In Rate	g/day	100.0
Average Particle Mass Density	g/cc	1.0
Fresh Air Mass Loading	mg/cubic meter	5.09164280847
Equilibrium Inside Air Class	N(D>0.5 microns)/cubic ft	515400.294295
Mass Settling Rate	ng/sq cm/hr	413.95

⇒ ***Class 100,000 / ISO 8 appears to give us right ball-park number for allowable dust deposition using SNO model***

How much dust to expect during 1 year installation: ASML-Delft Model

Selected model is the ASML-Delft model

Maximum dust mass density (ng/cm^2) allowed: 5000000

Defaults:

Cleanroom Class (N(D>0.5 microns)/cubic ft): 100000

Particle Size Cutoff (microns): 100.0

Average Dust Density (g/cc): 1.0

Quantity	Units	Value
Maximum exposure time	**days**	**252.781 (= 252d 18h 44m 50.4s)**
Cleanroom Class	N(D>0.5 microns)/cubic ft	100000.0
Particle Size Cutoff	microns	100.0
Average Particle Mass Density	g/cc	1.0
Number Fallout Rate	number (D>5 microns)/sq cm/hr	42.2187821365
Number Fallout Rate Range	number (D>5 microns)/sq cm/hr	4.22187821365 - 422.187821365
Mass Fallout Rate	ng (D>5 microns)/sq cm/hr	824.164867134
Mass Fallout Rate Range	ng (D>5 microns)/sq cm/hr	82.4164867134 - 8241.64867134

The measurements for operational cleanrooms fall almost entirely between the lower limit of the range and the parameterized rate

⇒ ***2nd model confirms that class 100,000 / ISO 8 appears to give us right ball-park number for allowable dust deposition***

What happens with dust when liquid argon is filled in detector?

Dust densities range from 0.5 g / cm^3 for ultra-fine dust to almost 1.4 g / cm^3 for coarse dust

LAr density is 1.4 g / cm^3

⇒ ***Will all dust float on LAr?***

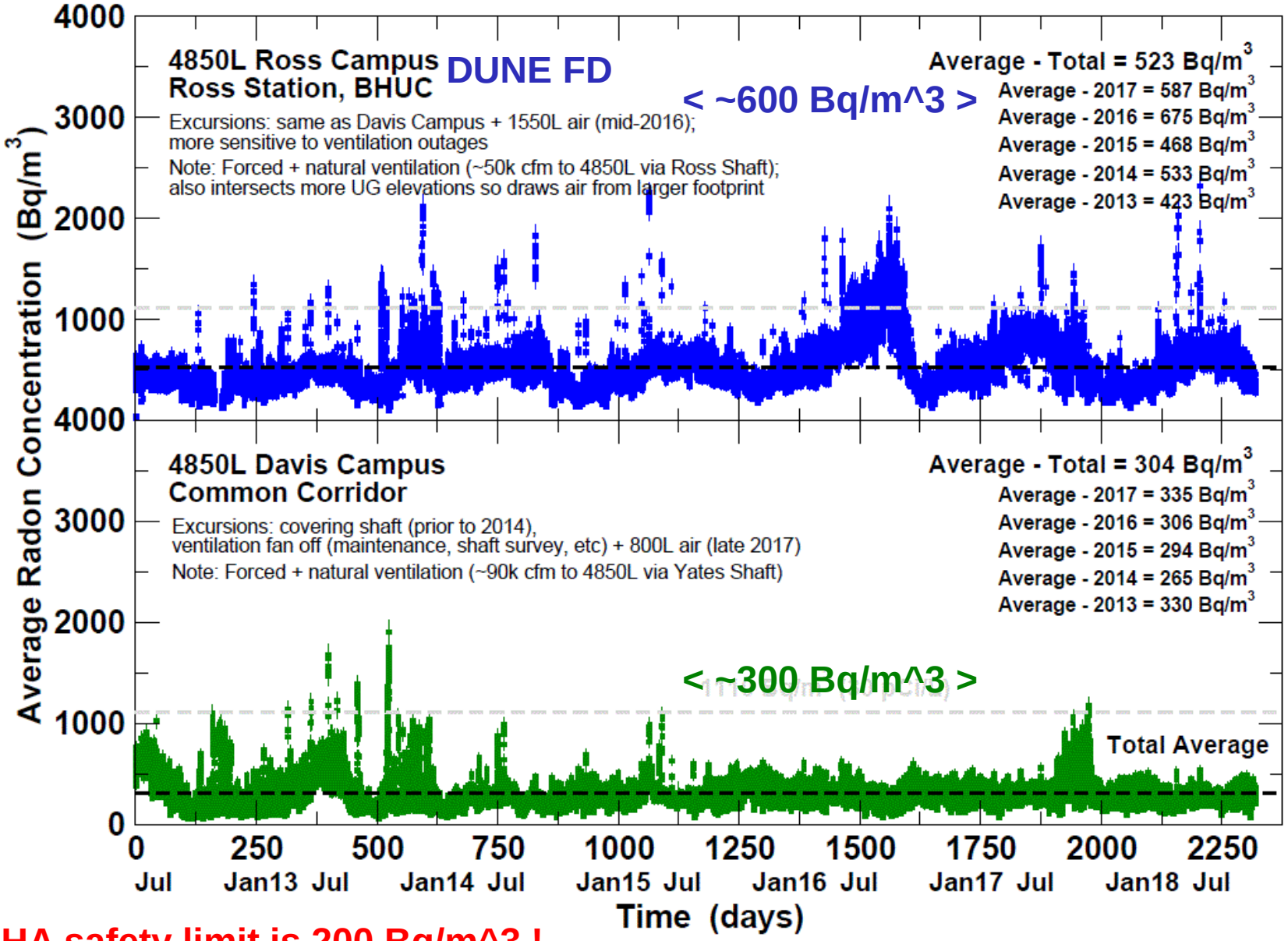
⇒ ***Make tests with material slides exposed to mine dust and assess mass deposition before and after submerging in LAr dewar***

Mine dust should be also collected for gamma-assay

⇒ ***Are ~150 kg of dust filtered out? Do they cause a filter issue?***

SURF Underground Radon Concentration

Using Saphymo Alphaguard detectors since July 2012



OSHA safety limit is 200 Bq/m^3 !

Updated November 9, 2018

How much Radon Daughter Plate-Out to expect: Jacobi Model

High radon levels underground!

Selected model is the Jacobi model

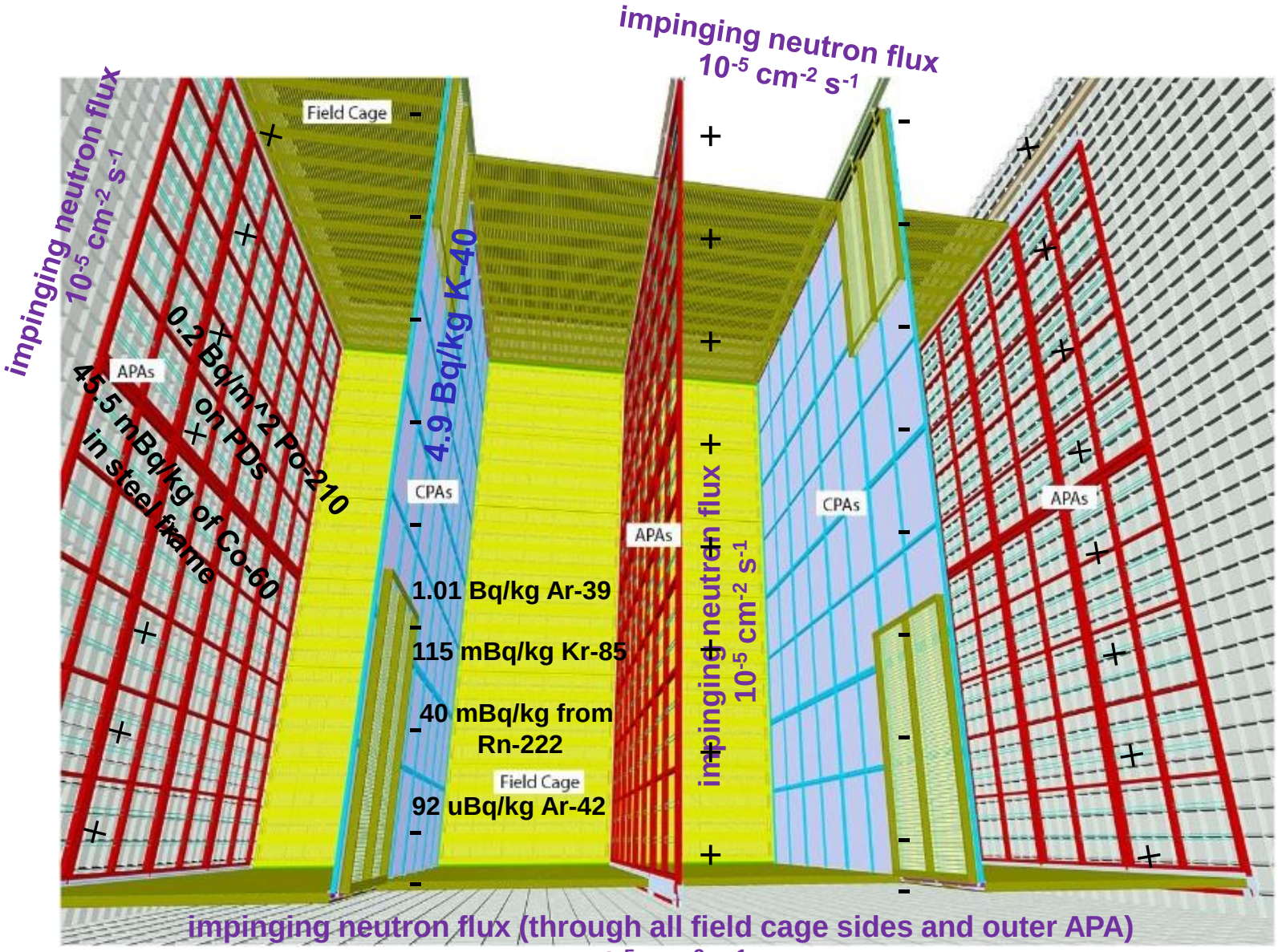
Total Pb-210 activity allowed on component (mBq/m^2)	200.0
Radon Concentration (Bq/m^3)	300.0
Clean Room Volume (m^3)	11760.0
Clean Room Surface Area (m^2)	3360.0
Radon Daughter Diffusion Velocity (m/hr)	10.0
Air Recirculation Rate (cfm)	10000.0

Quantity	Units	Value
Exposure Limit for 200.0 mBq/m^2	**day**	**3.36990643221**
Radon Activity	Bq/m^3	300.0
Room Volume	m^3	11760.0
Room Surface Area	m^2	3360.0
Deposition Rate	hr^{-1}	2.85714285714
Ventilation Rate	hr^{-1}	1.44474489796
Plate-out Activity Deposition Rate	$mBq/m^2/day$	59.3488288246
Exposure Limit for 1 mBq/m^2	day	0.0168495321611

⇒ ***Recommend to protect PDs / APAs with foil (and ideally fill bags with nitrogen) to limit exposure during a one year long installation***

⇒ ***Surface alpha-activity on PDs from dust deposition in one year: 10 Bq / m^2 (>> 0.2 Bq / m^2 requirement from earlier slide) -> limit dust exposure on PDs***

Model Migration of Radon Daughter Ions in LAr



Conclusion and Outlook

- Need cleanliness level equivalent to Class 100,000 / ISO 8
  (this level seems also ok regarding HV stability as 35 ton assay showed)

=> Should we better go to ISO 7 ?

- Need to additionally protect PDs / APAs during installation due to radon daughter plate-out and dust deposition

- Suggest to make exposure tests with mine dust and submerging of dust deposition samples in LAr to see how much dust stays on sample

- Collect mine dust and gamma-assay for specific activity of isotopes

- During installation continuously monitor dust and radon levels

- During installation regularly assay dust deposition in detector

- During installation collect deposited dust from sweepings, cleanings and HEPA filters and gamma-assay

DUNE Cleanliness Requirements for FD

- ISO 7 or 8 might be sufficient (-> check with samples from 35 t prototype)

- Dust/dirt can trigger HV break down?

-> Bo Yu took tape-lifts of interior of 35 t prototype before its decommissioning in mid June

Picture and
Description of 35 t Cleanliness Procedures
from Bob Kubinski (FNAL):

Nitrile gloves,
change shoes, sticky pad,
AC hose for ventilation because of body heat built up inside cryostat (air intake from outside PC4),
daily vacuuming of exterior plates,
few interior wipe downs with DI water.

Exposure through manhole: 15-20 days at 6 hours

Inputs for SNO Model of Dust Deposition Customized for 35t Calculation (Used LZ Calculator from Jerry Busenitz/UA)

Quantity	Units	Value
Maximum exposure time	**days**	**2.627 (= 2d 15h 2m 54.0s)**
Surface area of component	sq cm	1.0
Total dust accum. component	ng	47500.0
Fracion of total (5.0 mg) dust		0.0095
Fresh Air Class		7500000.0
Size Distribution Exponent		3.08
Clean Room Area	square meters	10.8
Clean Room Volume	cubic meters	38.0
Input Filter Transmission		0.1
Air Exchange Rate	clean room volumes/hr	0.1
Fresh Air Fraction		0.1
Particle Size Cutoff	microns	100.0
Carry In Rate	g/day	2.0
Average Particle Mass Density	g/cc	1.0
Fresh Air Mass Loading	mg/cubic meter	5.09164280847
Equilibrium Inside Air Class	N(D>0.5 microns)/cubic ft	25221766.0669
Mass Settling Rate	ng/sq cm/hr	753.39

Prediction with exposure of 20 days at 6 hours: 90.4 micrograms/cm^2

DUNE Cleanliness Requirements for FD

- No stringent cleanliness requirements indicated, ISO 8 seems ok, no HV break-down observed

- See note for more details on planned cleanliness requirements for FD and protoDUNE, and HV test stand