

PS Room Surface Contamination Estimate

A. Leveling

6/19/15

motivation

- ▶ predict the potential for tracking radioactive surface contamination from the PS room to the RHR
- ▶ Predict PS surface contamination levels due to beam operation
- ▶ Consider engineered controls to limit the creation and dispersal of surface contamination

technique

- ▶ Use MARS simulation airborne radioactivity production result mu2e doc 5569-v2
- ▶ Using ventilation parameters, determine steady state airborne radioactivity levels
- ▶ Assume fallout rate ranges from 0 to 100%
- ▶ Assume fallout is evenly distributed upon PS room surfaces
- ▶ Calculate the increase in surface contamination levels as a function of time and fallout rate

Consulted with G. Lauten on Be7 experience

0.45 nCi/100 cm² is FRCM action level for surface contamination

From RP note 146:

- Be7 produces ~ 1cpm/0.45 nCi with Frisker

- 100 X the action level is just detectable with the Frisker

- From 1x to 100 x the action level, Be7 is not observable with field instruments

- Results in implementation of ultra-conservative control measures

Beam power on miniboone target has been on the same order as that for mu2e (see beam doc.db 4769-v1)

Two main incidents at miniboone:

- 2003 - Be7 found in the pre-target beam line

 - continuous air flow to monitored exhaust stack in the Pre-target beam line

- 2015 - Be7 control issues in decay pipe region when blocks are removed from 25 m drop hatch

 - only recently implemented ventilation controls

 - air is not deliberately processed or released from the decay pipe region

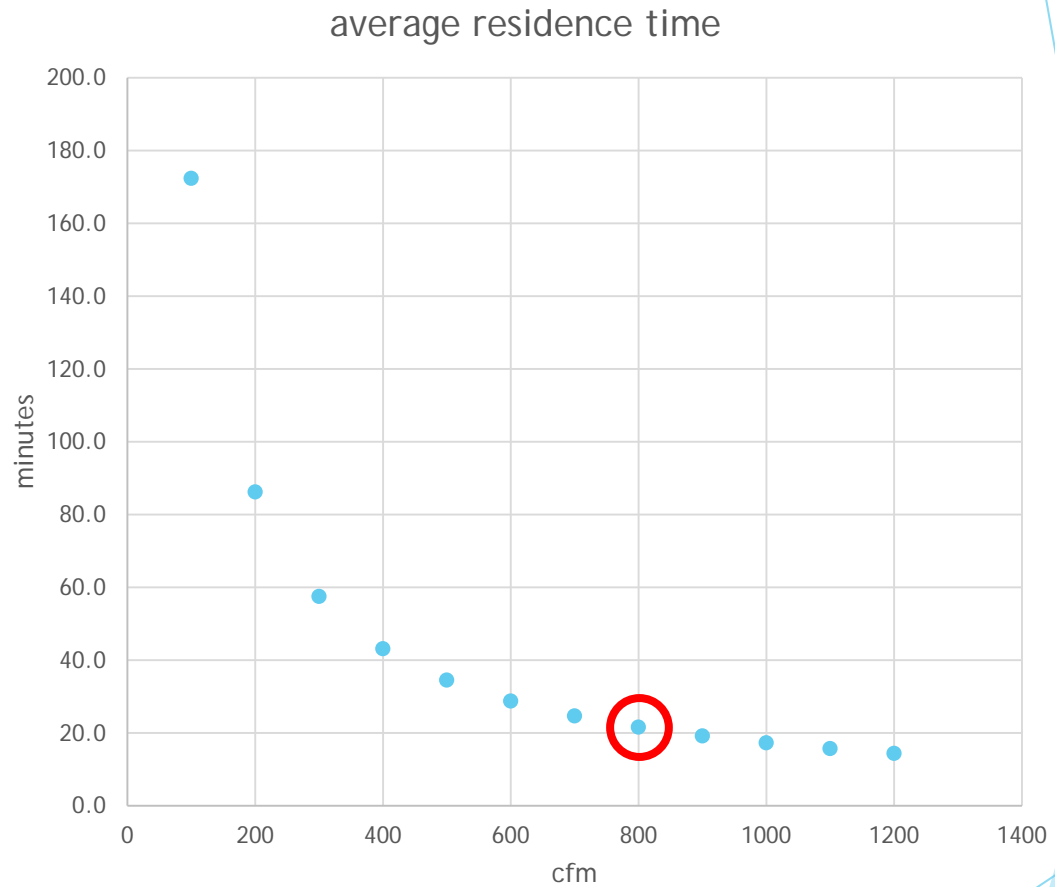
Atmospheric Production and Transport of Cosmogenic ^7Be and ^{10}Be

ABDULHADI KULAN

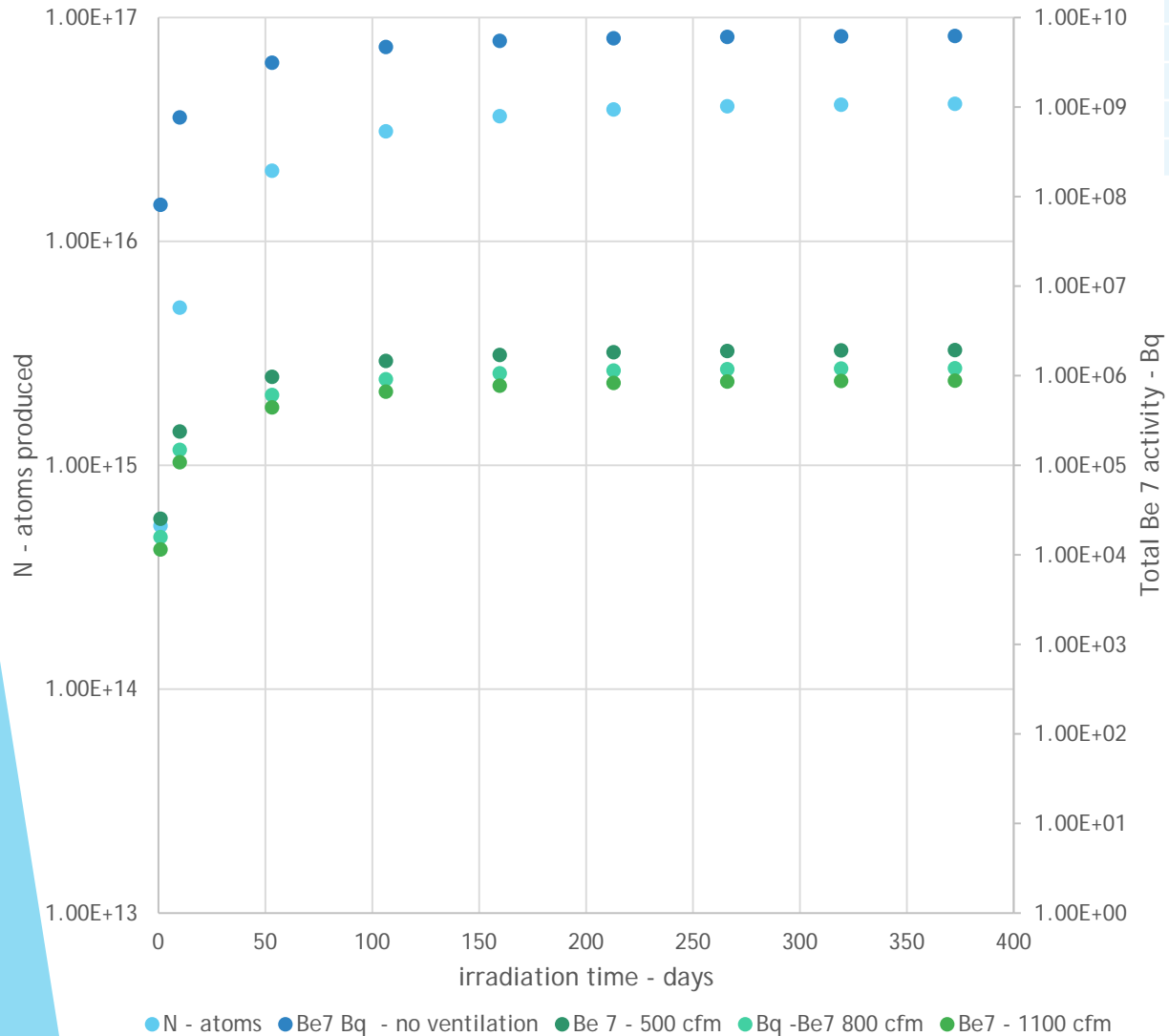
*Digital Comprehensive Summaries of Uppsala Dissertations
from the Faculty of Science and Technology 321*

The fate of a cosmogenic isotope in the atmosphere depends very much on its geochemical properties as an example; ^{14}C is oxidized to $^{14}\text{CO}_2$ and exchange between the Earth system reservoirs, while ^{36}Cl is largely present in gaseous form (Beer et al., 2002). As stated, ^7Be and ^{10}Be are adsorbed onto aerosol particles or may occur as a free aerosol of sub-micron order and thus follow the fate of aerosols in contrast to the gaseous compounds. Accordingly, that is one of the causes for the relatively short residence time of beryllium in the atmosphere and faster response to variability in production and climate change.

MARS room volume less RHR	4.88E+08	cc	
cfm	cc/min	average time in PS room (minutes)	average time in PS room (seconds)
100	2.83E+06	172.3	10340
200	5.66E+06	86.2	5170
300	8.50E+06	57.4	3447
400	1.13E+07	43.1	2585
500	1.42E+07	34.5	2068
600	1.70E+07	28.7	1723
700	1.98E+07	24.6	1477
800	2.27E+07	21.5	1292
900	2.55E+07	19.1	1149
1000	2.83E+07	17.2	1034
1100	3.12E+07	15.7	940
1200	3.40E+07	14.4	862



Be7 activity loading in PS hall air for various beam dump cooling air flow steady state operation at 8 kW



irradiation time (days)	N	Bq - no ventilation	lambda decay (sec ⁻¹)	lambda ventilation 800 cfm	λ'	Bq - with ventilation
1.00	5.36E+14	8.07E+07	1.51E-07	7.74E-04	7.74E-04	1.57E+04
10.00	5.06E+15	7.62E+08	1.51E-07	7.74E-04	7.74E-04	1.48E+05
53.22	2.06E+16	3.11E+09	1.51E-07	7.74E-04	7.74E-04	6.06E+05
106.44	3.10E+16	4.67E+09	1.51E-07	7.74E-04	7.74E-04	9.10E+05
159.66	3.62E+16	5.45E+09	1.51E-07	7.74E-04	7.74E-04	1.06E+06
212.88	3.88E+16	5.85E+09	1.51E-07	7.74E-04	7.74E-04	1.14E+06
266.10	4.01E+16	6.04E+09	1.51E-07	7.74E-04	7.74E-04	1.18E+06
319.32	4.07E+16	6.14E+09	1.51E-07	7.74E-04	7.74E-04	1.20E+06
372.54	4.11E+16	6.19E+09	1.51E-07	7.74E-04	7.74E-04	1.21E+06

Radioactive decay constant λ
 Ventilation removal constant - r

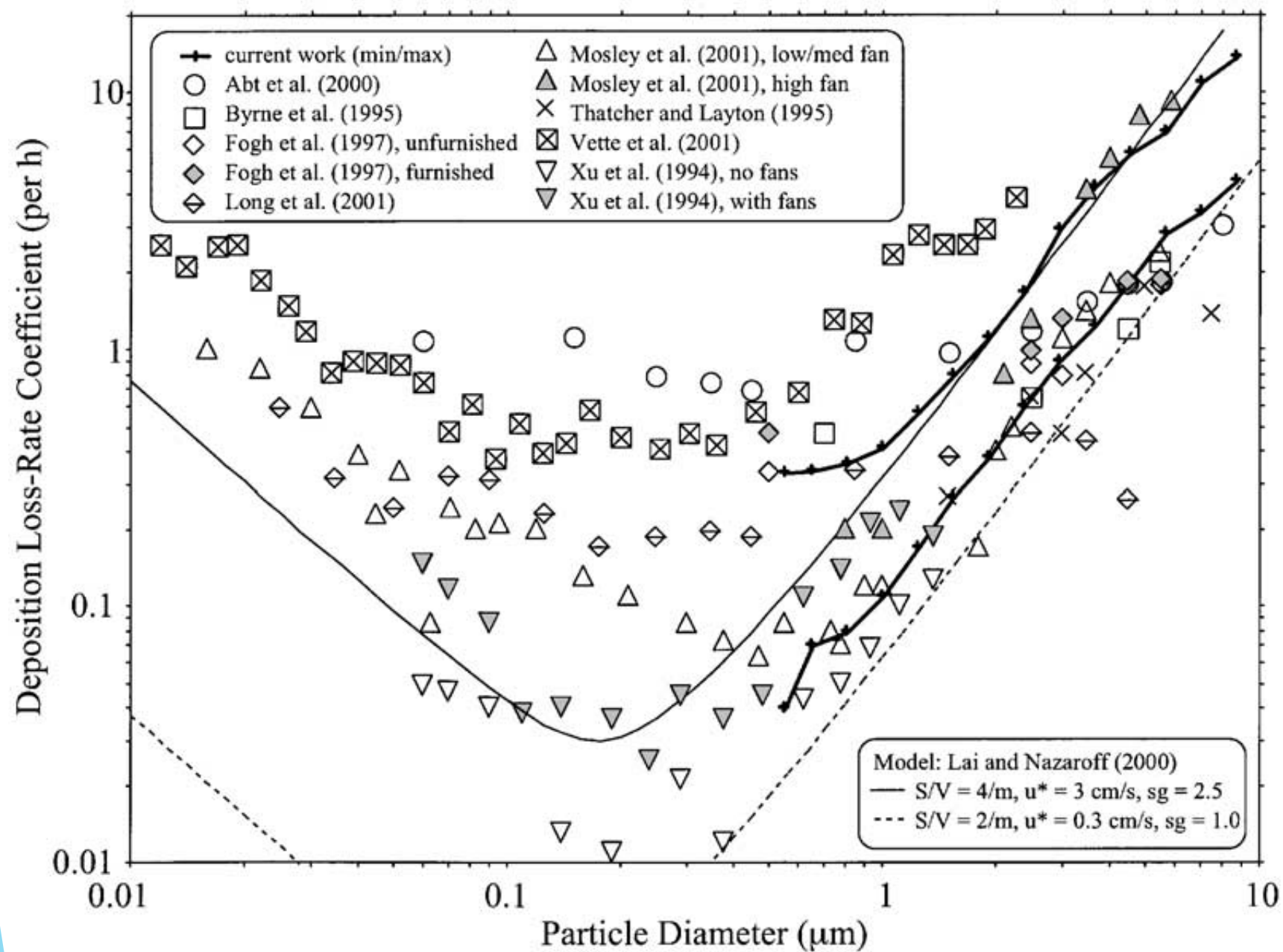
Activity is calculated as a function of irradiation time in DETRA

To account for activity dilution by ventilation, Multiply by:

$$\lambda' = \lambda / (\lambda + r)$$

Floor contamination estimate

- ▶ 1.2E6 Bq is steady state Be7 air loading - 800 cfm ventilation rate
- ▶ 1092 ft² is area of PS room or ~1E6 cm² (Emil)
- ▶ Next step is to determine residence time of Be7 in air and the corresponding buildup rate
 - ▶ **Estimating the Resuspension Rate and Residence Time of Indoor Particles**, *Journal of the Air & Waste Management Association*, Jing Qian ^a, Andrea R. Ferro ^a & Kathleen R. Fowler, Department of Civil and Environmental Engineering , Clarkson University , Potsdam , NY , USA, Department of Mathematics and Computer Science , Clarkson University , Potsdam , NY , USA, Published online: 24 Jan 2012.



Data summary from Thatcher, et. al.

Observations for a WAG at contamination buildup

- ▶ Experience at Fermilab AD ES&H
 - ▶ Be7 is captured by High Efficiency Particle Absolute filters
 - ▶ No Be7 has been detected downstream of these filters
- ▶ Typical spec for High Efficiency Particle Absolute filters
 - ▶ 99.9999% efficiency for $\geq 0.3 \mu\text{m}$ particles
- ▶ The efficiency of High Efficiency Particle Absolute filters is unknown for particles $< 0.3 \mu\text{m}$
- ▶ On this basis, assume that colloidal forms of Be7 are of the order of $0.3 \mu\text{m}$
- ▶ Fallout rate can be estimated at about 15% per hour
 - ▶ see following curve from Thatcher, et. al.

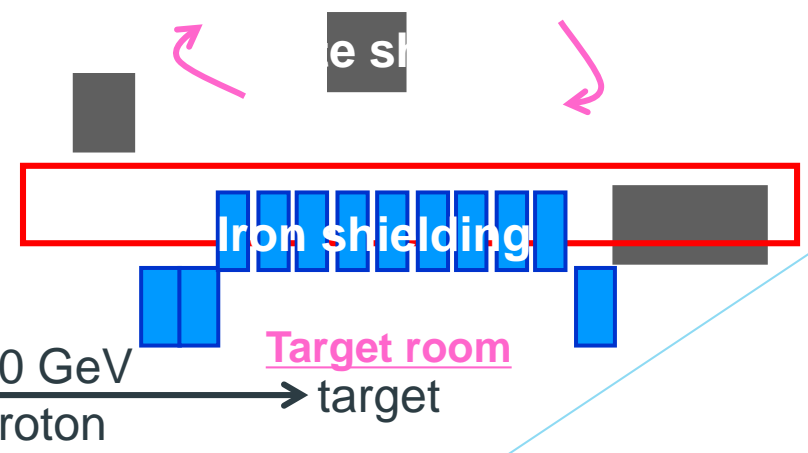
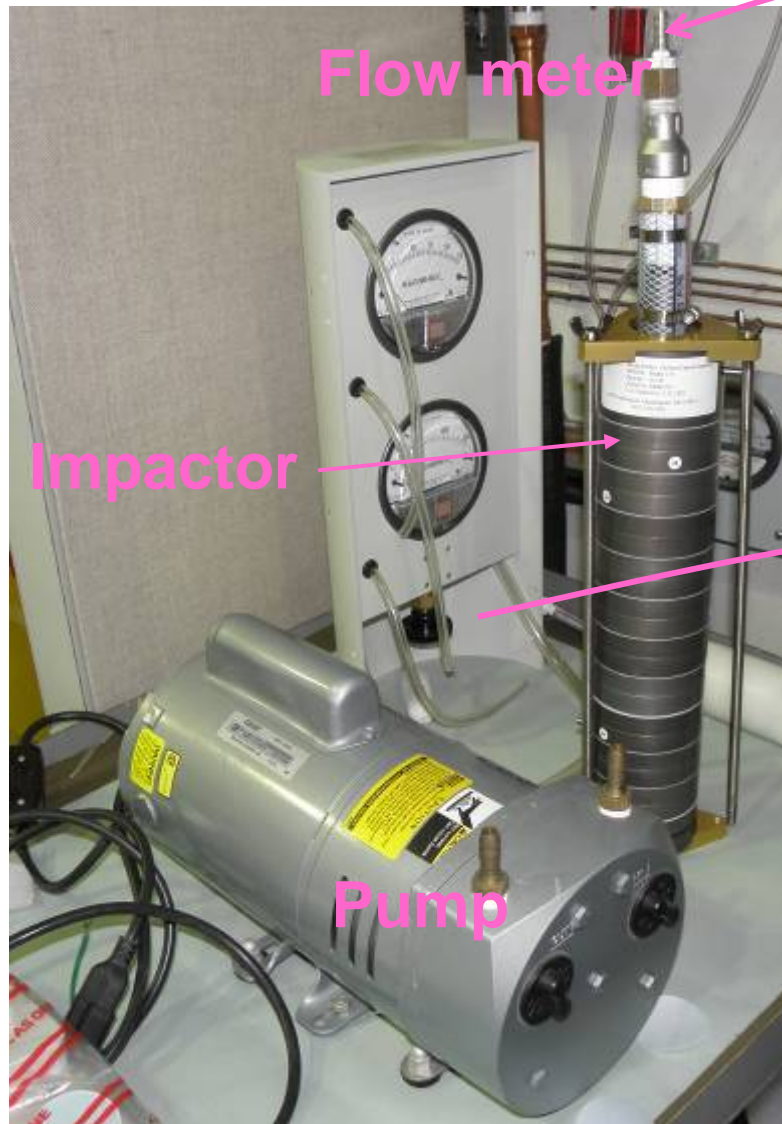
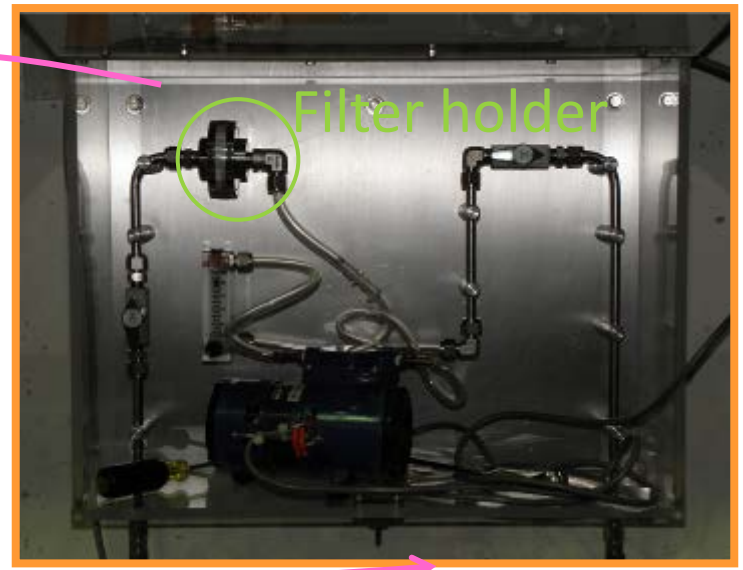
Be7 particle size determination

- ▶ The JASMIN experiment (Shun Sekimoto, et. al) provides us with an analysis of Be7 particle size
 - ▶ Air sampling at the pbar target station



Experimental (Aerosol-sampling) (3h sampling)

Gas/ aerosol-sampling device ↓



Experimental (Aerosol-sampling)



← Impactor

10 stages for particles with 0.056 to 10 μm diameter

Collected on Aluminum foil

30 L of air /min of flow rate

3 h-sampling ($\approx 5.4 \text{ m}^3$ of air in total)

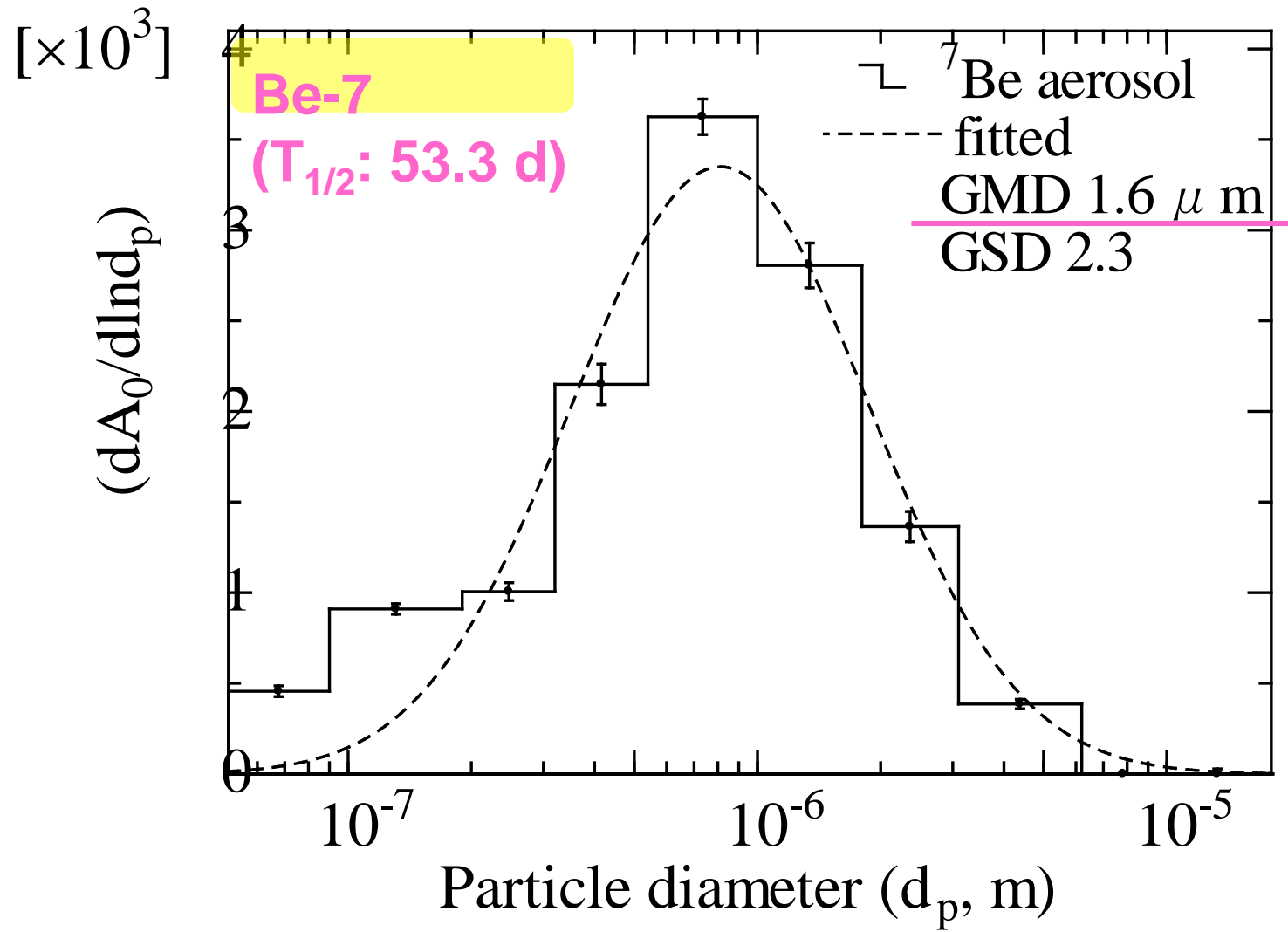
gamma-ray spectrometry

Separation of **radioactive aerosols** into several samples with different particle size

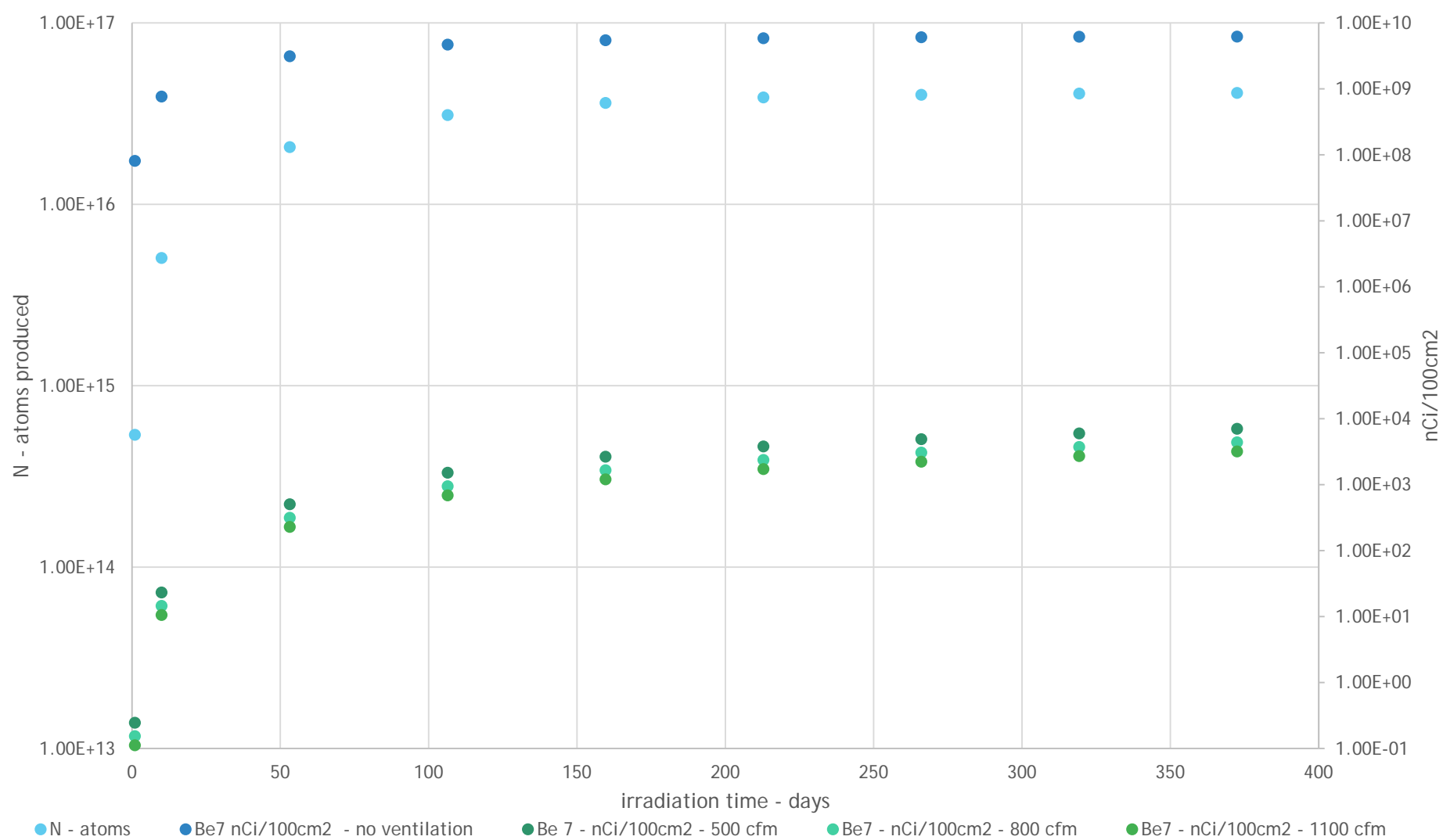
Results: 14 nuclides

→ **Be-7, Na-22, Na-24, Sc-46, Sc-47, V-48, Cr-51, Mn-54, Co-56, Co-57, Co-58, Co-60, Au-196, Au-198**

JASMIN Result: Be7 Particle size distribution



GMD: Geometric mean diameter



Assuming 15% fallout rate and uniform distribution within the PS room

Miniboone contamination survey results from decay pipe at the 25 meter absorber

- Sample activity determination is activity sensitive
- Counting times range from a couple of hours up to 1 day
- Turn around time from sample collection to report >10 days

Radionuclide Analysis Facility
Gamma Analysis Report
 Issued by Meka E. Francis

Report Date: December 2, 2014
 Work Request #: 14-315
 Submitted by: Paul Sedory on 11/21/14
 Workbook: HPGe #1-15, page(s) 108
 HPGe #2-10, page(s) 71

MI-12 25M Absorber

The Accelerator Division/ES&H Group submitted 4 Tyvek coverall samples on Work Request# 14-315 for analysis of accelerator produced radionuclides. The following table lists the radionuclides detected in the samples along with the corresponding specific activities. If a sample activity was reported, it has been corrected to the time of sampling.

SampleID#	Sample Time	Location/Description	Count Info	Detector	Count Date	Radionuclide	Activity (pCi/Sample)
141121PS03	14:35	Tyvek Boot Sole	7,200sec @ 10cm	HPGe#2	11/22/14 @ 14:30	Be-7 Na-22	800,000 ± 100,000 50 ± 20
141121PS04	14:35	Tyvek Boot Sole	7,200sec @ 10cm	HPGe#2	11/22/14 @ 16:25	Be-7 Na-22	300,000 ± 40,000 40 ± 20
141121PS05	14:35	Tyvek Coverall Knee	7,380sec @ 20cm	HPGe#1	11/22/14 @ 17:27	Be-7	120,000 ± 20,000
141121PS06	14:35	Tyvek Coverall Knee	7,200sec @ 10cm	HPGe#2	12/2/14 @ 12:40	Be-7	49,000 ± 6,000

Accelerator Shutdown September 5, 2014
 No beam to miniboone starting this date
 77 days decay time

cc: Accelerator Division Distribution List D. Cossairt
 M. Francis I. Hoppie M. Quinn RAF Folder

Radionuclide Analysis Facility
Gamma Analysis Report
Issued by Meka E. Francis

Report Date: December 3, 2014
Work Request #: 14-314
Submitted by: Paul Sedory on 11/21/14
Workbook: HPGe #1-15, page(s) 113
HPGe #2-10, page(s) 78

MI-12 25M Absorber

The Accelerator Division/ES&H Group submitted 2 wipe samples on Work Request# 14-314 for analysis of accelerator produced radionuclides. The following table lists the radionuclides detected in the samples along with the corresponding specific activities. If a sample activity was reported, it has been corrected to the time of sampling.

SampleID#	Sample Time	Location	Count Info	Detector	Count Date	Radionuclide	Activity (pCi/Wipe)
141121PS01	10:15	25M Absorber - Steel Plate (Bottom)	75,144sec @ 10cm	HPGe#1	12/2/14 @ 14:47	Be-7	< 42
141121PS02	10:15	25M Absorber - Steel Plate (Top)	4,275sec @ 10cm	HPGe#2	12/2/14 @ 14:48	Be-7	38,000 ± 5,000

Accelerator Shutdown September 5, 2014
No beam to miniboone starting this date
77 days decay time

cc: Accelerator Division Distribution List D. Cossairt
M. Francis I. Hoppie M. Quinn RAF Folder

Radionuclide Analysis Facility
Gamma Analysis Report
 Issued by Meka E. Francis

Report Date: December 1, 2014
 Work Request #: 14-311
 Submitted by: Paul Sedory on 11/20/14
 Workbook: HPGe#1-15, page(s) 107
 HPGe#2-10, page(s) 70

MI-12 25M Absorber

The Accelerator Division/ES&H Group submitted 5 samples on Work Request# 14-311 for analysis of accelerator produced radionuclides. The following table lists the radionuclides detected in the sample along with the corresponding specific activity. If a sample activity was reported, it has been corrected to the time of sampling.

SampleID#	Sample Time	Location	Unit	Count Info	Detector	Count Date	Radionuclide	Activity (pCi/Sample)
141120PS01	10:15	25M Absorber Blocks Layer 1/2	Tyvek Boot Sole	70,089sec @ 10cm	HPGe#1	11/20/14 @ 13:31	Be-7 Co-57	1200 ± 200 23 ± 5
141120PS02	10:15	25M Absorber Blocks Layer 1/2	Tyvek Boot Sole	69,945sec @ 10cm	HPGe#2	11/20/14 @ 13:34	Be-7	1400 ± 200
141120PS03	10:15	25M Absorber Blocks Layer 1	Wipe	86,400sec @ 10cm	HPGe#1	11/21/14 @ 16:36	Be-7	150 ± 30
141120PS04	10:15	25M Absorber Blocks Layer 1	Wipe	74,189sec @ 10cm	HPGe#2	11/21/14 @ 16:37	Be-7 Co-57	170 ± 30 < 2.1
141120PS05	10:15	25M Absorber Blocks Layer 1	Wipe	86,400sec @ 10cm	HPGe#1	11/25/14 @ 11:33	Be-7	80 ± 30

Accelerator Shutdown September 5, 2014
 No beam to miniboone starting this date
 76 days decay time

cc: Accelerator Division Distribution List D. Cossairt
 M. Francis I. Hoppie M. Quinn RAF Folder

Radionuclide Analysis Facility
Gamma Analysis Report
Issued by Meka E. Francis

Report Date: December 1, 2014
Work Request #: 14-316
Submitted by: Paul Sedory on 11/21/14
Workbook: HPG#2-10, page(s) 75

MI-12 25M Absorber

The Accelerator Division/ES&H Group submitted 1 air filter sample on Work Request# 14-316 for analysis of accelerator produced radionuclides. Each sample was counted on detector HPG#2. The following table lists the radionuclides detected in the sample along with the corresponding specific activity. If a sample activity was reported, it has been corrected to the time of sampling.

SampleID#	Sample Time	Location	Container	Count Info	Unit	Count Date	Radionuclide	Activity (pCi/Filter)
141121PS07	9:15	MI-12 25M Absorber (Lowest Level)	Glassine Envelope	86,400sec @ 10cm	Filter	11/25/14 @ 11:33	Be-7	600 ± 100

Accelerator Shutdown September 5, 2014
No beam to miniboone starting this date
77 days decay time

cc: Accelerator Division Distribution List D. Cossairt
M. Francis I. Hoppie M. Quinn RAF Folder

Radionuclide Analysis Facility
Gamma Analysis Report
 Issued by Meka E. Francis

Report Date: June 23, 2015
 Work Request #: 15-160
 Submitted by: Joel Fulgham on 6/5/15
 Workbook: HPGe#1-16, page(s) 126

Booster-Neutrino Line

The Accelerator Division/ES&H Group submitted 1 wipe sample on Work Request# 15-160 for analysis of accelerator produced radionuclides. The sample was counted on detector HPGe#1. The following table lists the radionuclides detected in the sample along with the corresponding specific activity. If a sample activity was reported, it has been corrected to the time of sampling.

SampleID#	Sample Time	Location	Container	Count Info	Unit	Count Date	Radionuclide	Activity (pCi/Sample)
150605JF01	10:13	MI-12B Enclosure Robot Tread	Glassine Envelope	8,111sec @ 10cm	Wipe	6/18/15 @ 14:24	Be-7	3,100 ± 500
							Co-57	80 ± 10
							Co-60	150 ± 20
							Mn-54	210 ± 40
							Na-22	400 ± 60
							Zn-65	4,500 ± 600

New wipe result from a robot walk through the
 miniboone decay pipe
 Accelerator Shutdown September 5, 2014
 No beam to miniboone starting this date
 273 days decay time
 Note the present of other isotopes related to zinc
 coated steel decay pipe

cc: Accelerator Division Distribution List D. Cossairt E. Korzeniowski
 M. Francis I. Hoppie M. Quinn RAF Folder

Miniboone 25 meter absorber contamination measurement summary

sample ID	description	sample date	result (nCi)	decay (days)	corrected activity to beginning of shutdown
141121PS03	tyvek boot sole	11/21/2014	800	77	2182
141121PS04	tyvek boot sole	11/21/2014	300	77	818
141121PS05	tyvek coverall knee	11/21/2014	120	77	327
141121PS06	tyvek coverall knee	11/21/2014	49	77	134
141121PS01	25M Absorber - steel plate(bottom)	11/21/2014	<0.042	77	<0.1
141121PS02	25M Absorber - steel plate(top)	11/21/2014	38	77	104
141120PS01	25M absorber blocks - boot sole	11/20/2014	1.2	76	3
141120PS02	25M absorber blocks - boot sole	11/20/2014	1.4	76	4
141120PS03	25M absorber blocks - layer 1 wipe	11/20/2014	0.15	76	0.4
141120PS04	25M absorber blocks - layer 1 wipe	11/20/2014	0.17	76	0.5
141120PS05	25M absorber blocks - layer 1 wipe	11/20/2014	0.08	76	0.2
141121PS07	MI-12 25M absorber (lowest level)	11/21/2014	0.6	77	2
150605JF01	Robot track tread wipe	6/5/2015	3100	273	108673

Two strategies for Be7 contamination control

- ▶ Engineered controls
 - ▶ Minimize spread of Be7
 - ▶ Aggressively filter PS room air
 - ▶ Placement of a collection mat prior to operation
 - ▶ Remove mat before beginning permitting traffic flow in/out of room
- ▶ No engineered controls (ala miniboone)
 - ▶ Severe oversight constraints imposed by AD ES&H
 - ▶ Collection of all protective clothing, tooling, materials
 - ▶ Hold for decay, typically five $\frac{1}{2}$ lives, i.e., 270 days

Remote handling room Be7 contamination issues are self-healing

- ▶ If targets last 1 year
 - ▶ Remote handling room and robot equipment resets Be7 contamination to 0
- ▶ Presumes absolute control of contamination related to target change outs
 - ▶ Contamination due to target detritus from activated targets will remain for years