Radon Compensation Challenges in the SabreBPM™ Beta Particulate Monitor

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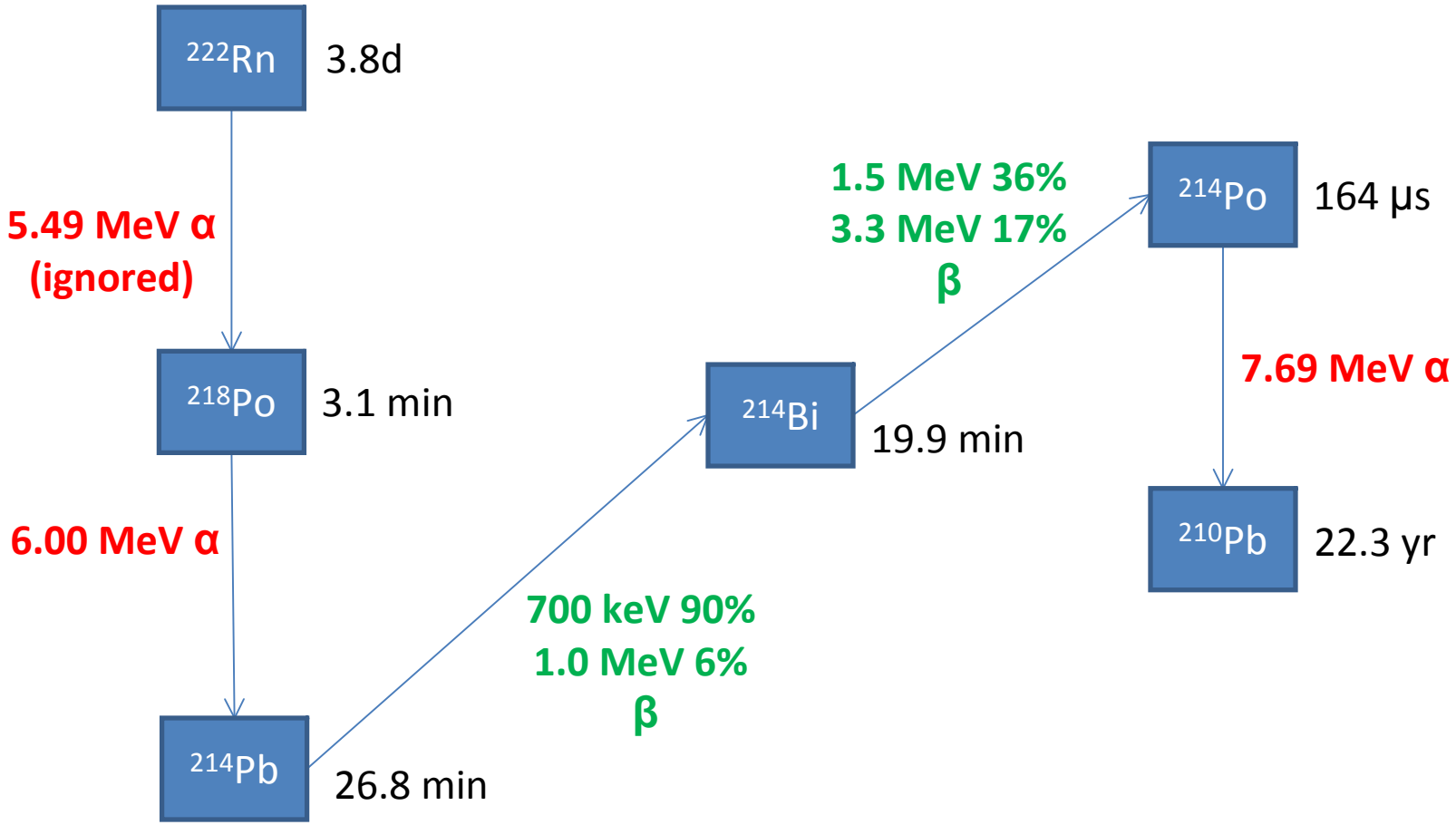
The Goal

- Improve the beta background compensation of a state-of-the-art alpha/beta CAM
- Improve the accuracy of PAEC and Working Level measurements in a real-time radon working level CAM

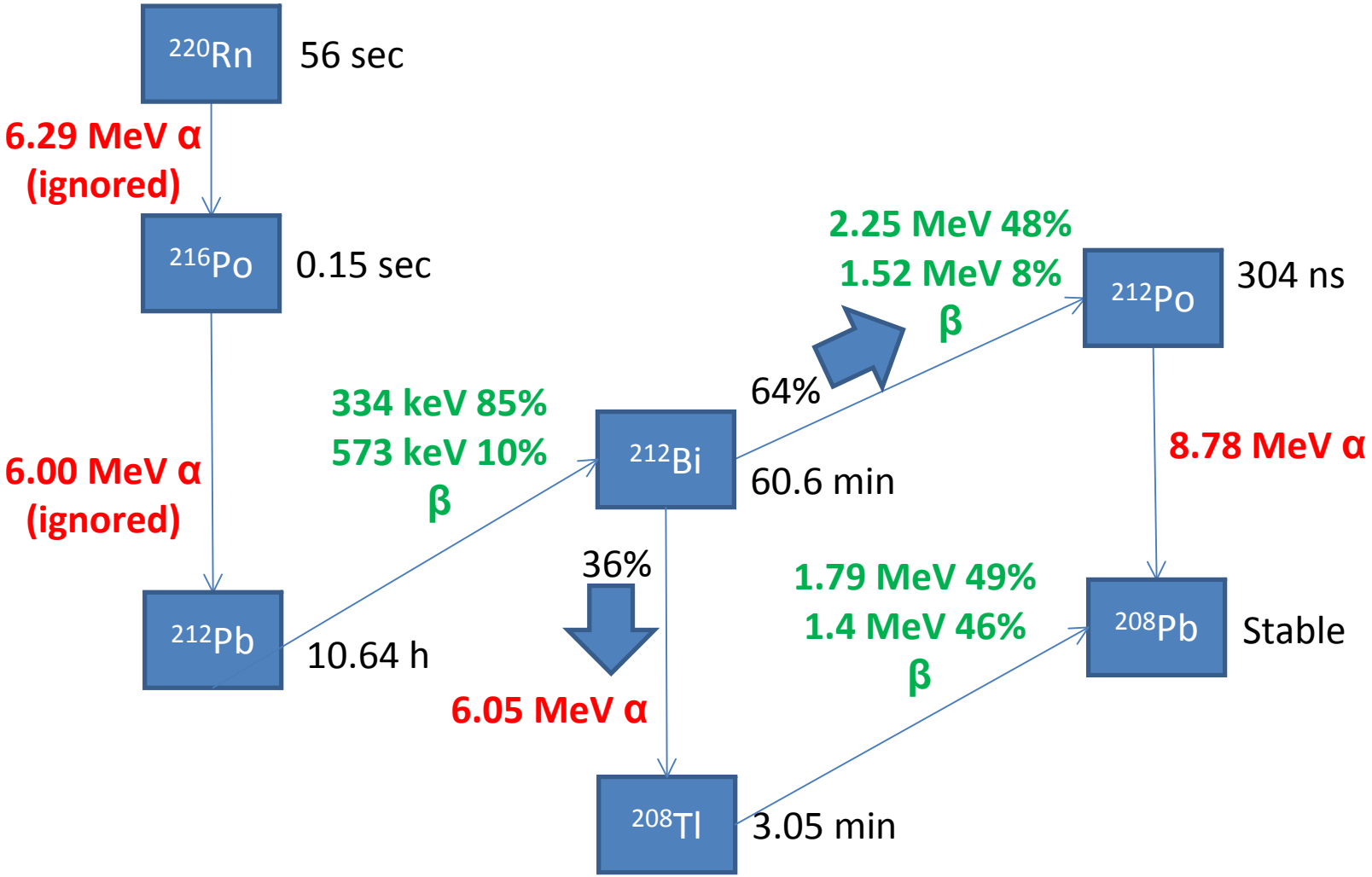
SabreBPM Basics

- 1024-Channel alpha spectroscopy
- Alpha peak shape fitting capability providing
  - Individual filter activities for ^{218}Po, ^{214}Po, and ^{212}Po
- Gross gamma guard channel
- Gross beta channel
  - Net beta rate derived from gross minus fixed and gamma background.
  - Separate RDP rate from net beta

The ^{222}Rn decay chain



The ^{220}Rn (Thoron) decay chain



The real-time problem: Two behaviors combined

- RDP growth on the filter from airborne sampling
  - The growth on a filter of individual radon decay products is a known behavior based on the Bateman equations.
- RDP growth on the filter from parent contribution
  - The additional growth of RDPs on a filter from the on-filter decay of the parent nuclide is also a known behavior.
- Real-time monitoring requires accounting for ***both behaviors simultaneously***!

Consider the simplest case

- ^{222}Rn is in equilibrium and unchanging
- No Thoron present
- 100% collection efficiency
- Activity measurements are instantaneous

^{218}Po buildup on a filter

$$I_{218Po} = QC * 4.39 * (1 - e^{\frac{-t}{4.39}})$$

^{214}Pb buildup on a filter

$$I_{214Pb} = QC * 38.6 * (1 - e^{\frac{-t}{38.6}})$$

Plus…

^{214}Pb buildup from decay of ^{218}Po on the filter:

$$QC * 4.39 * (1 + 0.128\, e^{\frac{-t}{4.39}} - 1.128\, e^{\frac{-t}{38.6}})$$

^{214}Po buildup on a filter

$$I_{214Po} = QC * 28.4 * (1 - e^{\frac{-t}{28.4}})$$

Plus…

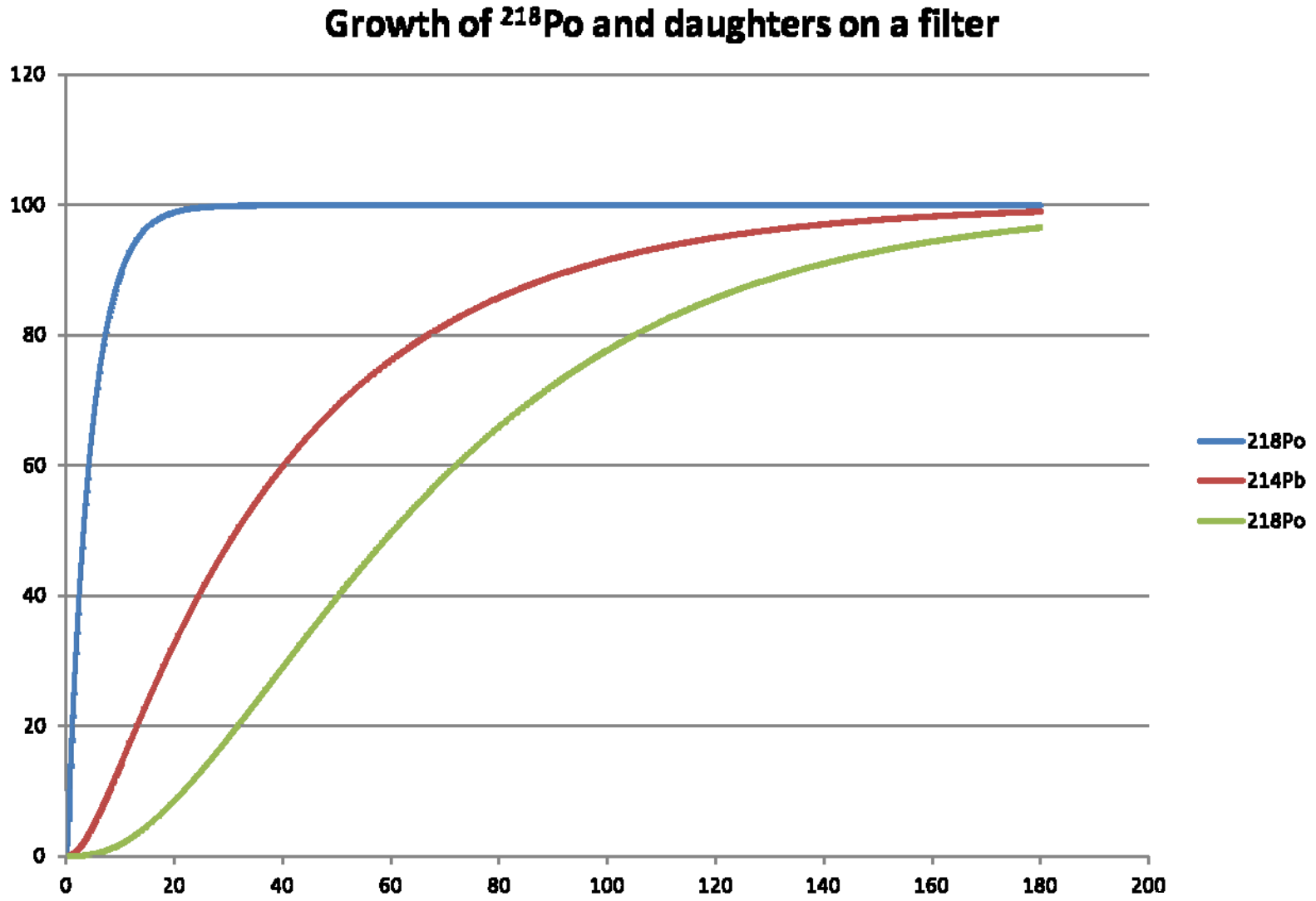
^{214}Po buildup from decay of ^{214}Pb on the filter:

$$QC * 38.6 * (1 - 3.784\, e^{\frac{-t}{38.6}} + 2.784\, e^{\frac{-t}{28.4}})$$

Plus…

^{214}Po buildup from the decay of ^{218}Po on the filter:

$$QC * 4.39 * (1 - 0.0235\, e^{\frac{-t}{4.39}} - 4.2594\, e^{\frac{-t}{38.6}} + 3.2829\, e^{\frac{-t}{28.4}})$$


Growth of 218Po and daughters on a filter
120
100
80
60
40
20
0
0
20
40
60
80
100
120
140
160
180
200
218Po
214Pb
218Po

Real-World Considerations

- In the “real-world”:
  - RDPs are not in equilibrium
  - ^{222}Rn concentration is not constant
  - ^{220}Rn is present
  - Collection efficiencies of RDPs are not equal
  - Activity measurements are not ‘instantaneous’

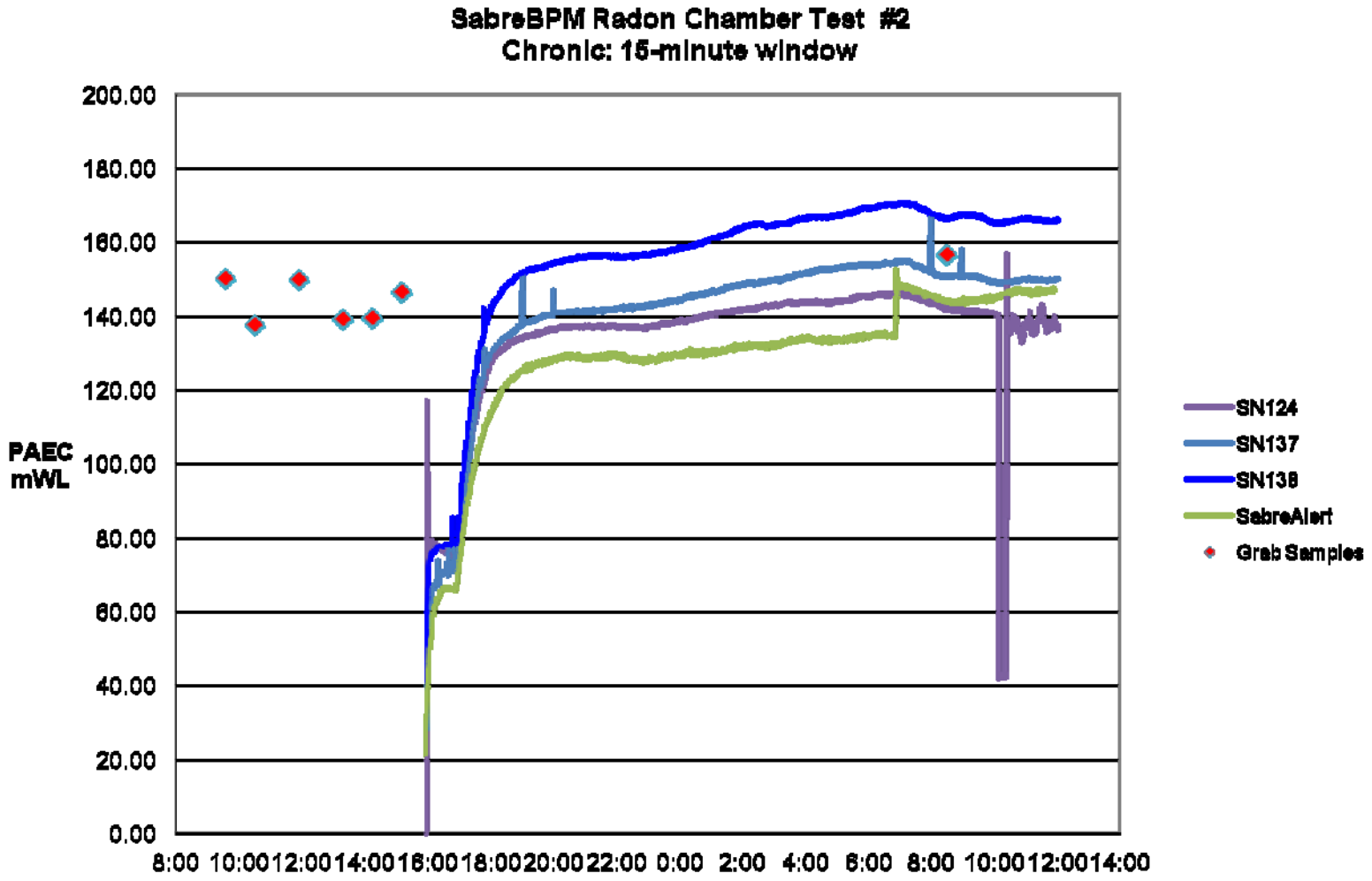
SabreBPM Approach

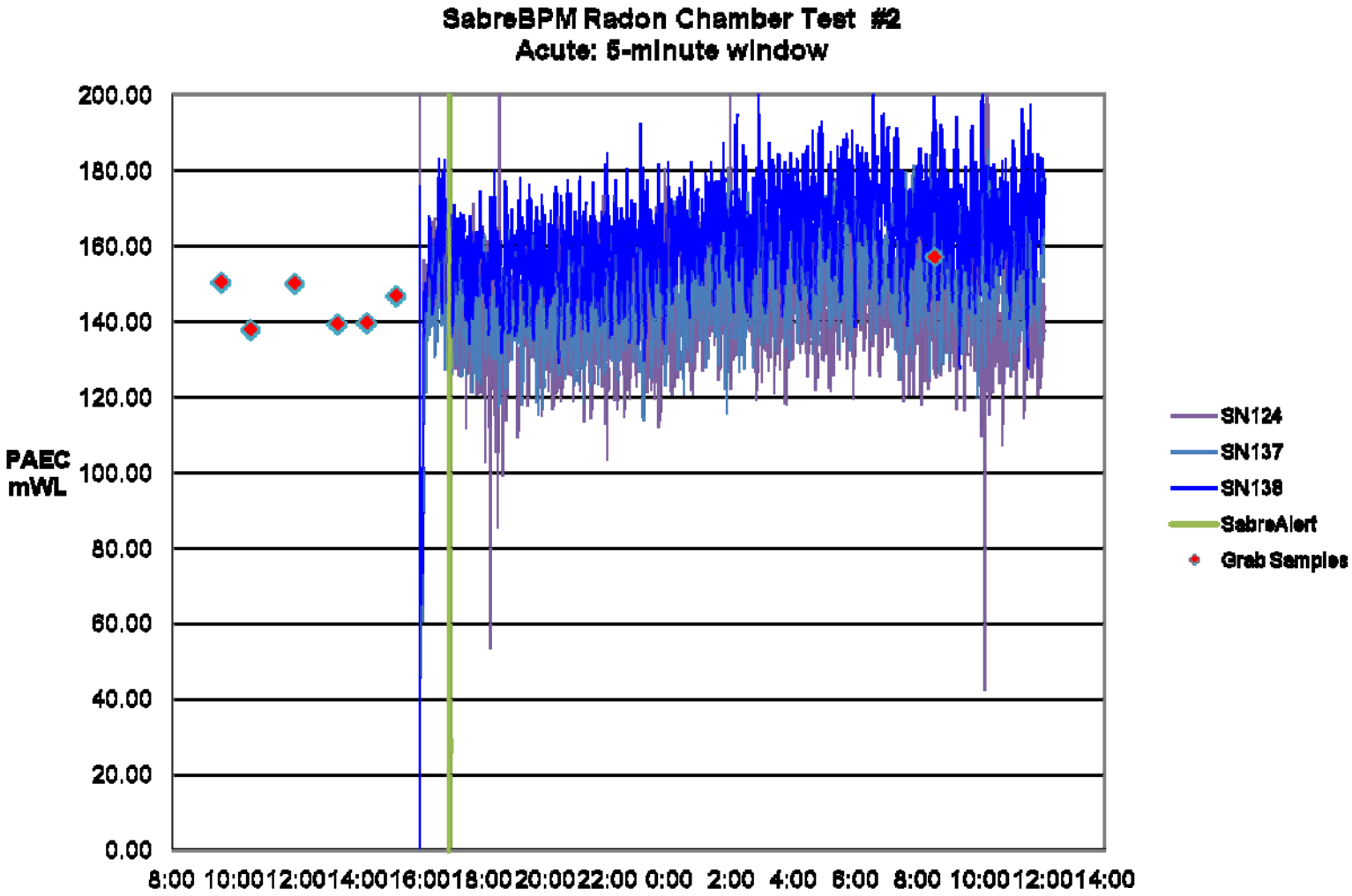
- Measure beta, ^{218}Po, ^{214}Po and ^{212}Po activities
- Adjust ^{218}Po activity for ‘uncollected fraction’ and ^{212}Bi contribution to 6 MeV activity
- Estimate ^{214}Pb activity
  - Radon Mode: assume all betas are due to RDPs
  - Non-radon mode: all RDP betas subtracted
- Correct ^{214}Po activity for known ^{212}Bi and estimated ^{214}Pb daughter accumulation

RDP Betas

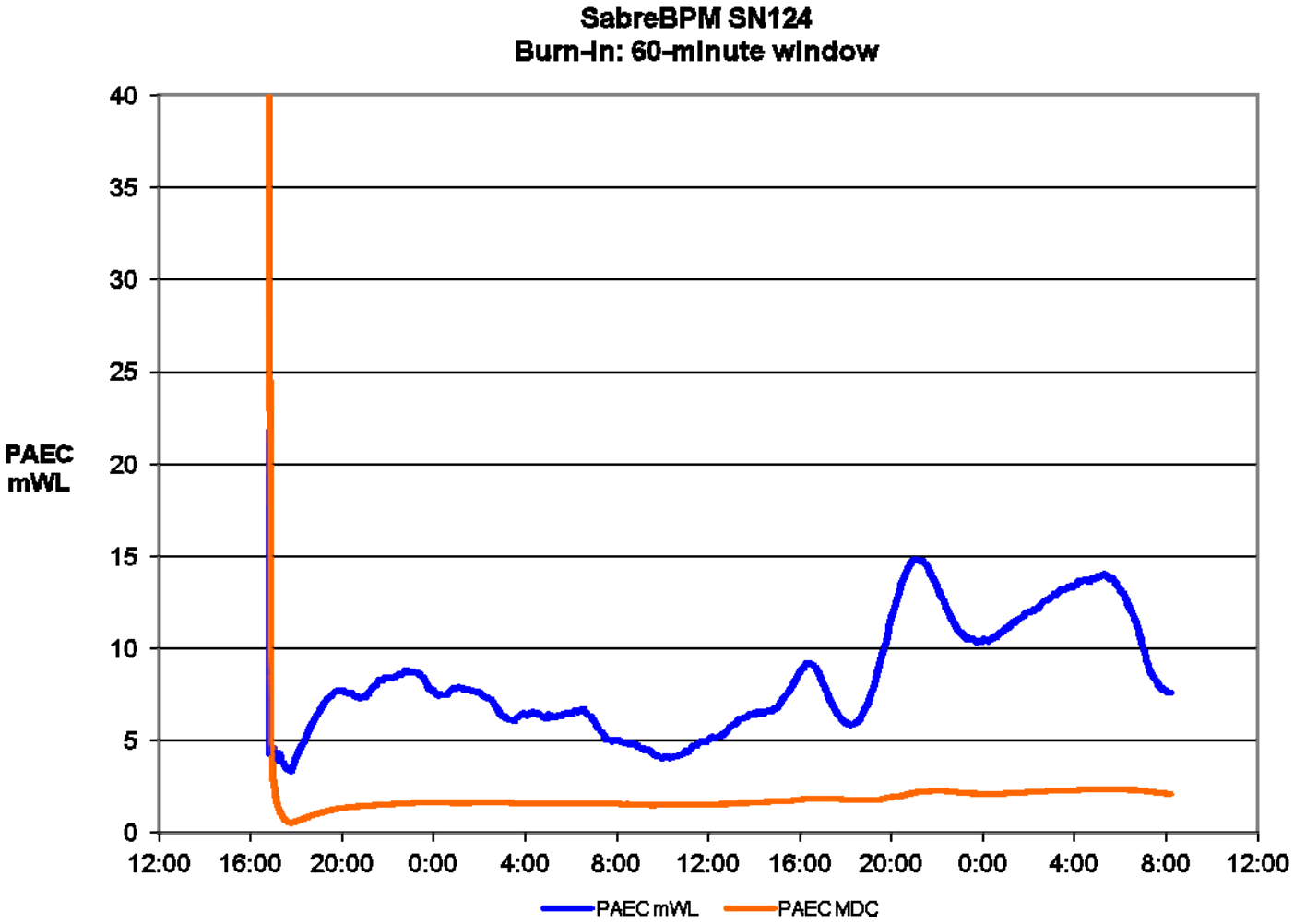
Isotope	Energy	Total Yield	Notes
^{214}Pb	700 keV (90%)	100%	
^{214}Bi	1.5 – 3.3 MeV	100%	Precedes ^{214}Po by 164us
^{212}Pb	330 – 570 keV	100%	Estimated from ^{212}Bi
^{212}Bi	1.5 – 2.2 MeV	64%	(1/0.64) of ^{212}Po
^{208}Tl	1.4 – 1.8 MeV	36% of ^{212}Bi	(0.36/0.64) of ^{212}Po

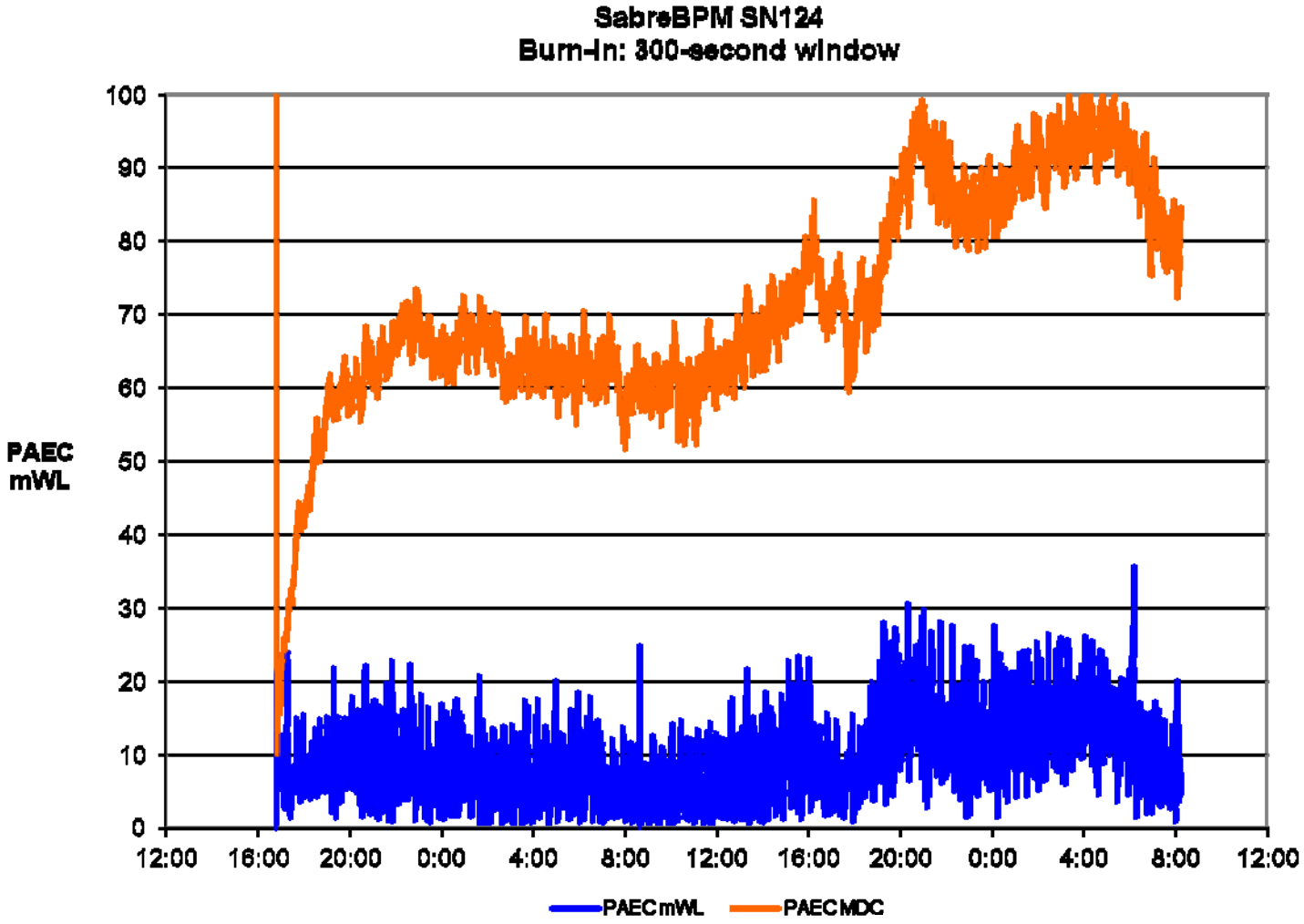
Testing at Bowser-Morner




SabreBPM Radon Chamber Test #2
Acute: 5-minute window
PAEC mWL
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
8:00 10:00 12:00 14:00 16:00 18:00 20:00 22:00 0:00 2:00 4:00 6:00 8:00 10:00 12:00 14:00
SN124
SN137
SN138
SabreAlert
Grab Samples

48-hour Residential Run




SabreBPM SN124
Burn-In: 300-second window
PAEC mWL
100
90
80
70
60
50
40
30
20
10
0
12:00
16:00
20:00
0:00
4:00
8:00
12:00
16:00
20:00
0:00
4:00
8:00
12:00
PAEC mWL
PAEC MDC

Conclusions

- Algorithm worked acceptably in test chamber and performed well in changing concentrations during residential test.
- Short averaging times can be used.
- Additional testing is needed in Thoron chamber.

Questions?

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