Continuous Air Monitor Algorithm Development

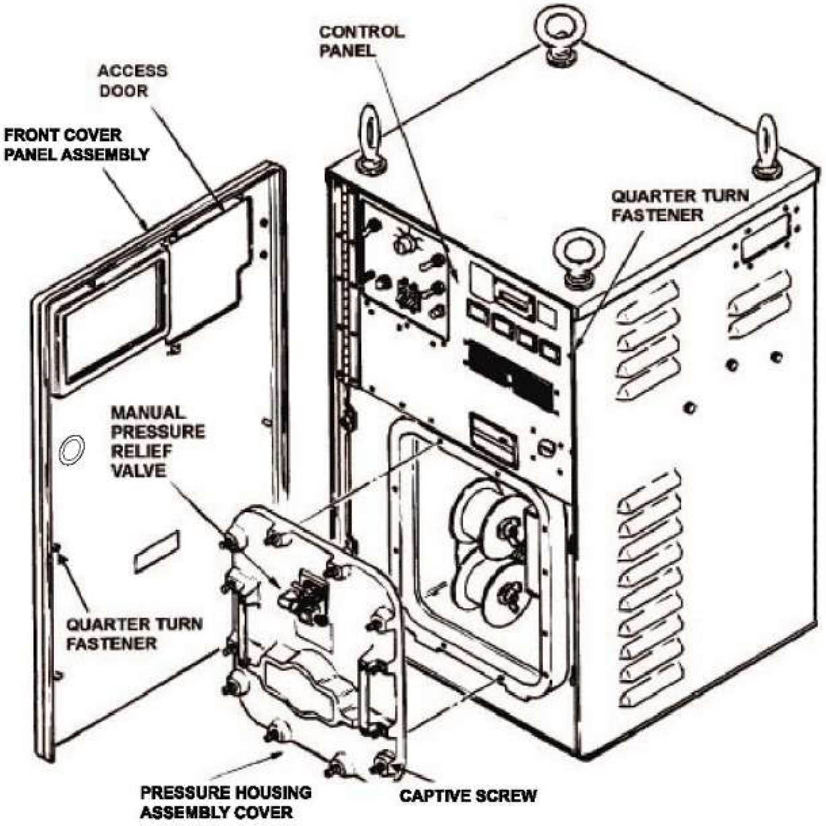
Robert B. Hayes, Ph.D., CHP, PE
Remote Sensing Laboratory
Las Vegas, NV 89193
702-794-8825 hayesrb@nv.doe.gov

ICRS-11 & RPSD-2008, April 13-18

REMOTE SENSING LABORATORY

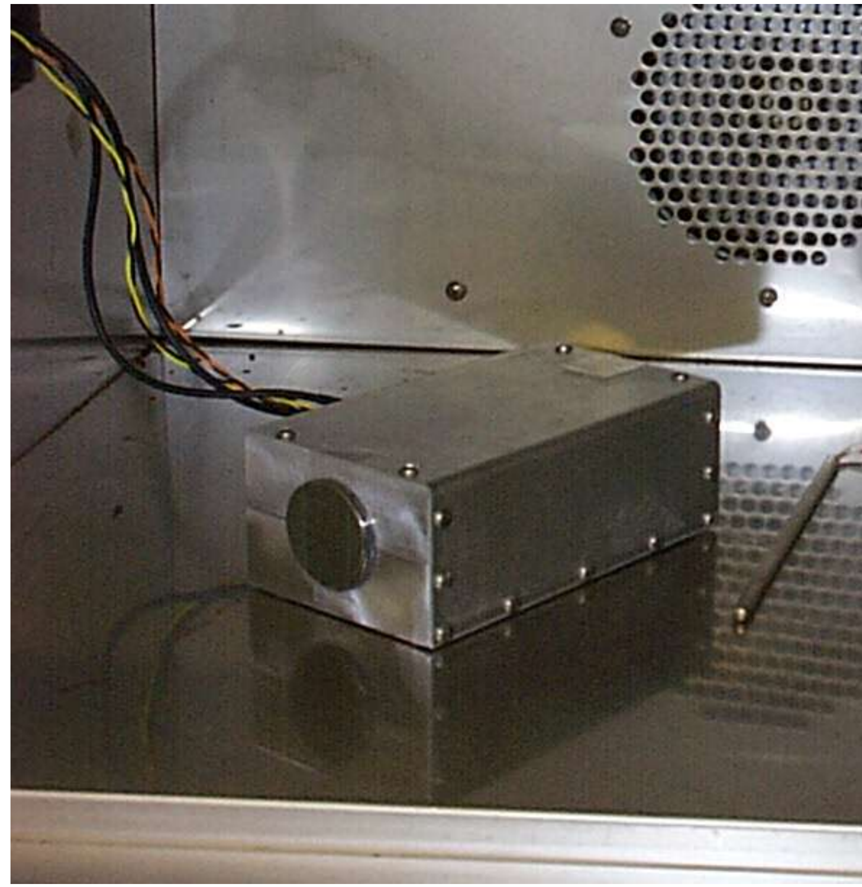
How does the present design work?

- Air is brought through a paper filter via a pump mechanism.
- The filter is continuously moving from a roll paper feed source.
- The detector is a scintillator/PMT combination placed approximately 1 inch offset from the active sampling location.
- The paper takes approximately 30 minutes to move from the sampling location to the counting position.
- Alarms are based on gross counting thresholds.
- Only local alarm capability.



Preliminary Prototype Design and Testing Completed

- All RSL testing indicates final prototype will meet Navy specifications.
- Initial prototype passed all critical tests.
- Initial prototype did not fail any tests performed.
  - Tests not conducted include drip-proof test.



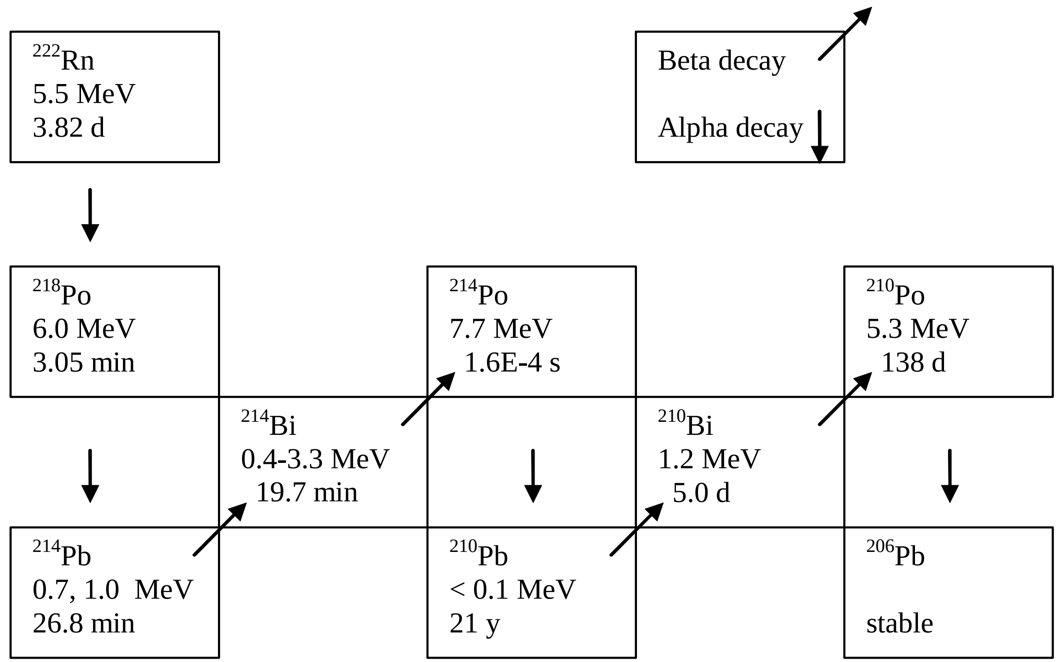
Excellence
RSL
REMOTE SENSING LABORATORY

Why Spectrometry?

- Alarms are attributed to radon progeny causing high beta activity during a temperature inversion on shore.
- By measuring the alpha simultaneously with the beta, the beta, due to radon, can be accurately predicted allowing it to be subtracted from the total beta being monitored.
  - The NGAPD is primarily a beta air monitor.
- By compensating for the radon progeny under all credible source term distributions (including interaction on the air filter), a robust algorithm can be developed to prevent false alarms.
  - Too many false alarms will cause sailors to not respond, they will assume any alarm is a false alarm.
  - If the alarm threshold is raised, the sensitivity of the instrument is compromised.

Radon (^{222}Rn) Progeny

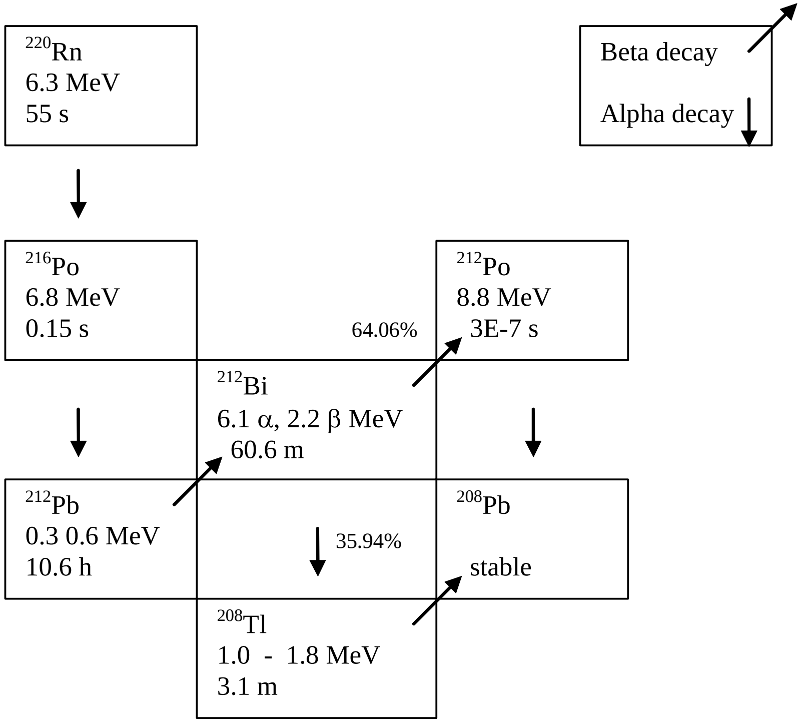
- Characteristic half hour decay constant
- Typical environmental activity ratios for first 4 progeny isotopes 1/0.9/0.6/0.4
- Continual equilibrium of ^{214}Po with ^{214}Bi
- Negligible ^{210}Pb in ambient aerosols



REMOTE SENSING LABORATORY

Thoron (^{220}Rn) progeny

- Negligible ^{216}Po
- Continual equilibrium of ^{212}Bi and ^{212}Po
  - ^{212}Po will have 64.06% the activity of ^{212}Bi
- Branching ratio for ^{212}Bi is approximately 2/3 beta and 1/3 alpha



Basic Relationships

- Radon will have approximately equal alpha and beta contributions:

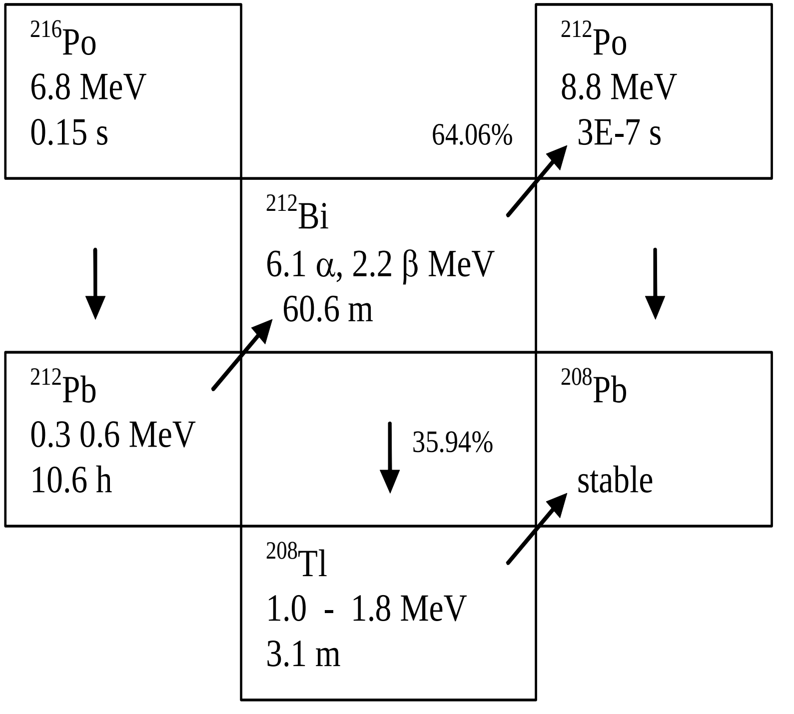
$$Ac_{Rn}(\beta)=Ac_{Rn}(\alpha)$$

- Thoron can utilize the 8.8 MeV decay of ^{212}Po as a metric.
  - Some attention to detail is required here

REMOTE SENSING LABORATORY

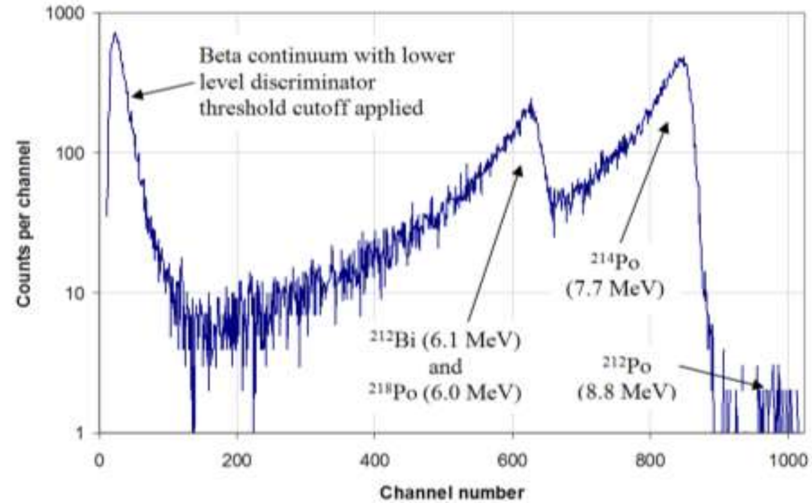
Thoron beta activity

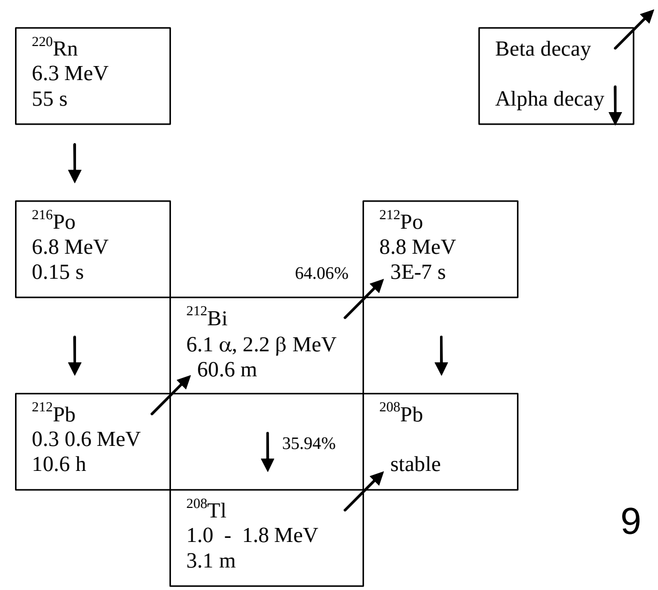
- For each ^{212}Po α, there is a ^{212}Bi β.
- For each ^{212}Be β, there are 0.6406^{-1} or 1.56 ^{212}Pb β's.
- For each ^{212}Pb β, there are 0.3094 ^{212}Bi α's.
- $A_{Tn}(\beta) =$ $A_{Po}\,[1 + 1.56(1+0.3594)]$.



Prior to Combining Rn and Tn

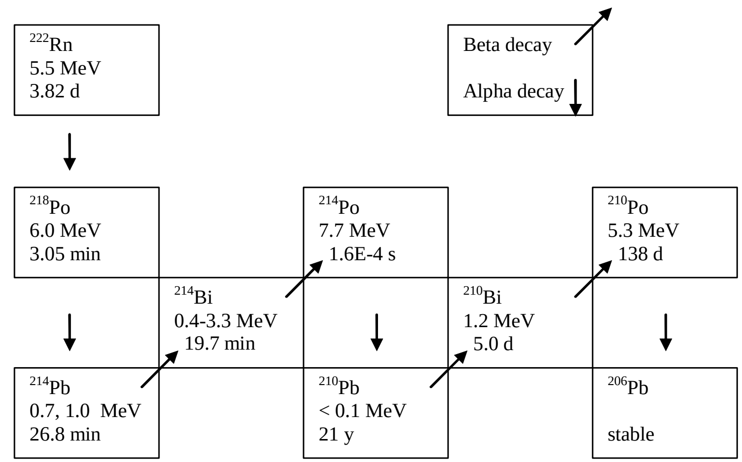
- The 6 MeV peak has contributions from radon and thoron.
- The 8.8 MeV peak assay can be used to determine the thoron contribution to the largely radon 6 MeV peak.

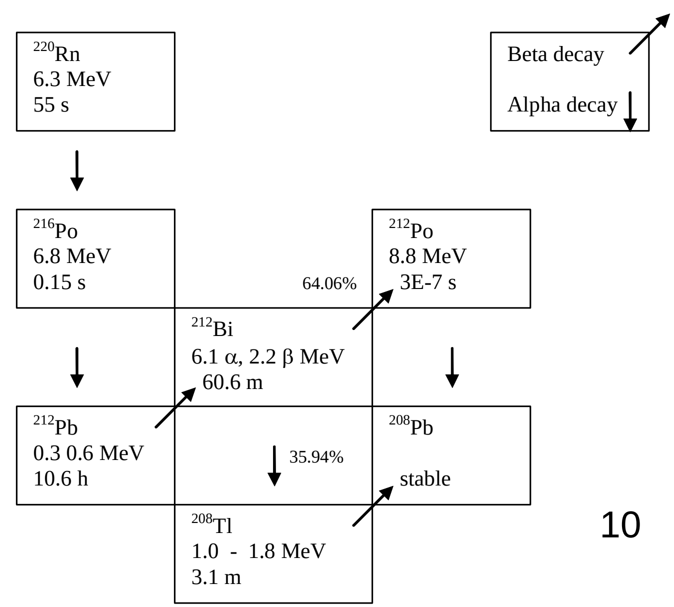




??Combing the Equations

- Correcting for the 6 MeV peak requires subtracting 0.6404/0.3594=1.78 as many alphas as assayed for the 8.8 MeV peak.
- Utilize calibrated regions of interest (ROI).





Utilize Equilibrium Distributions

- Aerosol plate out is effectively a decay term modeled here using equilibrium estimates.
- Thoron values used 1/0.8/0.8 and radon 1/0.9/0.6/0.4 (NCRP 94)

$$Ac(\beta) = Ac_{212Po}(8.8\ \text{MeV}\ \alpha)\cdot[1 + 1.561\cdot(1+0.3594)/0.8] +$$

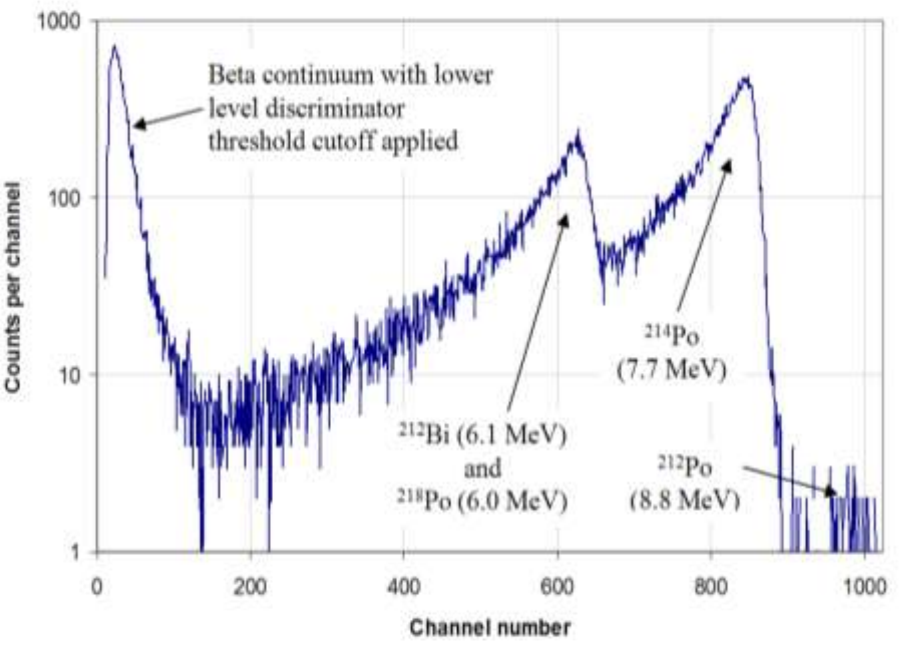
$$Ac_{214Po}(7.7\ \text{MeV}\ \alpha) + Ac_{218Po}(6.0\ \text{MeV}\ \alpha)\cdot 0.6/0.4 -$$

$$1.78\cdot Ac_{212Po}(8.8\ \text{MeV}\ \alpha)\cdot 0.4/0.6$$

Excellence RSL REMOTE SENSING LABORATORY

Using ROI's

- The beta ROI = channel 30 to 199 = ROI1
- ROI2 = channel 200 to 670
- ROI3 = channel 671 to 890
- ROI4 = channel 891 to 1024



Simplified ROI Equation

A(b) = ROI1 =

$3.65 \cdot ROI4 + ROI3 + 1.5 \cdot ROI2 - 1.19 \cdot ROI4$

Note we have not corrected for the lower level threshold cutoff

Excellence RSL REMOTE SENSING LABORATORY

Lower Level Threshold

- Beta spectra are continuous to zero energy
- At zero energy, PIPS are very noisy
- Typical lower levels range up to many 10’s of keV
- Current design not calibrated to know exact cutoff limit
- Calibration expected in next few months

Ongoing Activities

- Considerations of some circuit redesign for reducing low energy threshold
  - It can be done, but is it just a “nice to have” or can it provide a meaningful improvement to sensitivity ?….maybe, or else this thought needs to be finished
- Manufacturer specifications for sensitivity
  - ^{90}Sr 24% ($E_{\beta max}$ for ^{90}Y 2.28 MeV)
  - ^{60}Co 15% ($E_{\beta max}$ for dominant mode 318 keV)
  - We know we can do better but should we?

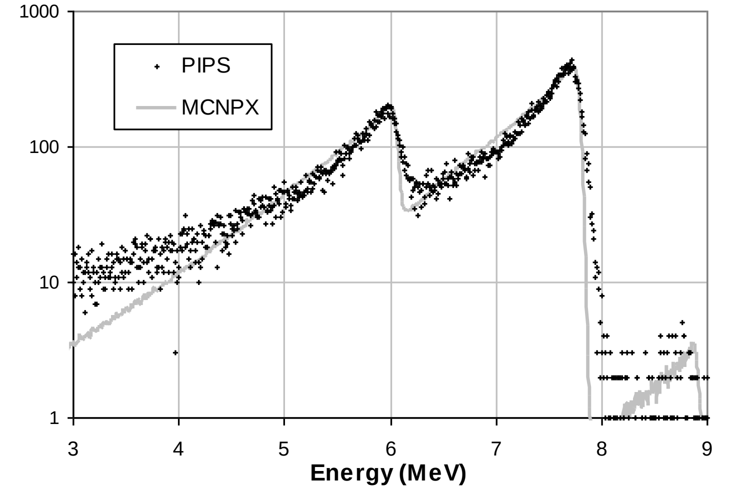
Algorithm Test Proof of Concept

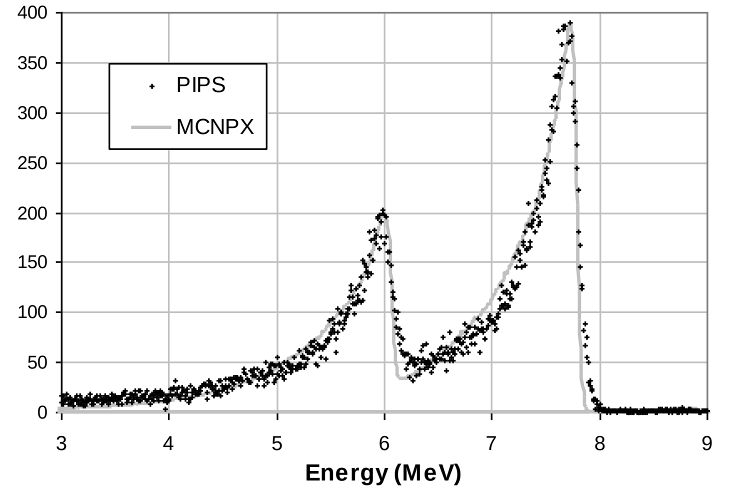
Excellent agreement was obtained using literature values for air deposition on filter substrate (R. Pollanen, T Siiskonen. *Health Phys*. **90**, 167-175, 2006).

Attenuated deposition into the filter was modeled.

Credible radon, thoron and actinon distributions were modeled (100:10:1 source term ratios).

Hayes R. B., Marianno C. M. Use of MCNPX for alpha spectrometry simulations of a continuous air monitor. *Trans. Amer. Nucl. Soc.* **96**, 631-633, 2007.





Conclusions

- The algorithm is designed to accurately correct for NORM contributions to beta activity.
- The algorithm is based on base principles of radionuclide decay, aerosol physics, and spectrometry analysis.
- The algorithm will be tested with MCNPX for expected operating environments.

Acknowledgements

- The United States Navy
- NAVSEA
- RSL
- NSTec
- DOE

Excellence
REMOTE SENSING LABORATORY