Characterization and Mitigation of Radon and Cosmogenic Influence on Alpha Emissivity Measurements

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XIA
Instruments That Advance The Art

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Alpha Metrology: Current state

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- **2.0 cts·khr^{-1}·cm^{-2}**
  - **For 300 mm wafer:**
    - 1.4 α/hr or 34 α/day
  - **Brazil nuts: 47 cts·khr^{-1}·cm^{-2}**
  - **Challenging to measure even with improved instrumentation**
- **Small sources of variation can significantly impact results**
- **Considerable work over past several years to understand sources of variability**
- **Significant supply chain risk associated with measurement variability in results near specifications**
- **Everyone is either a supplier or purchaser, or both**

Ambient Radon Concerns

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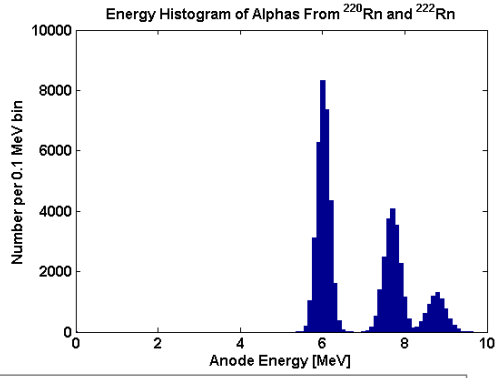
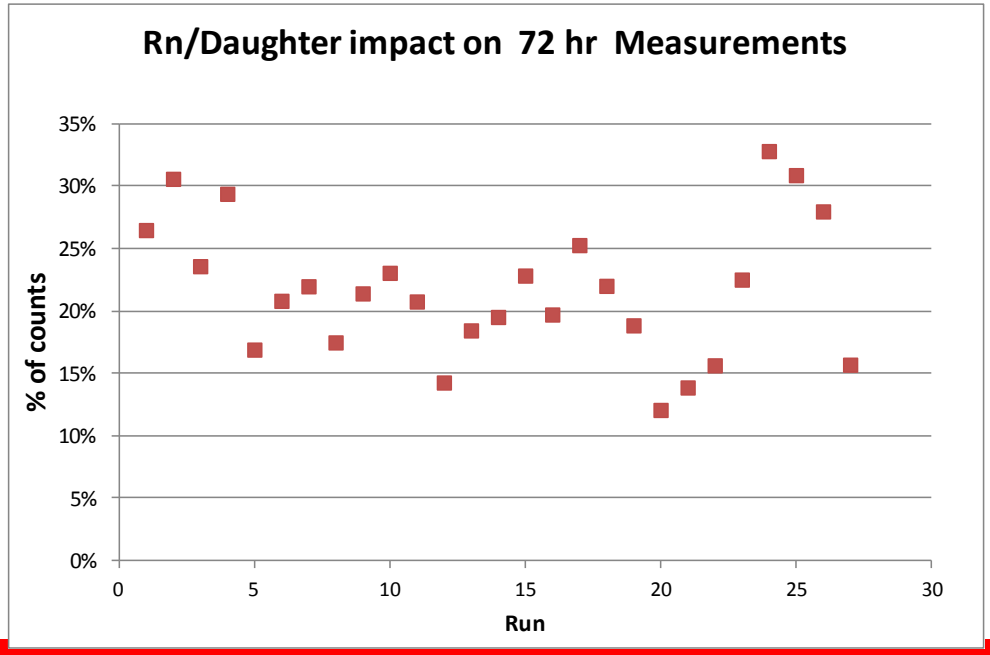
- **Previously reported**
  - Gordon et. al *IEEE TNS*, VOL. 59, NO. 6, DECEMBER 2012
  - Rn/Daughter alphas > 6 MeV
- **Location/Location variability significant**
  - Spokane 15-30 Bq·m^{-3} vs 3 Bq·m^{-3}
  - ~1x10^{5} Rn atoms/L
- **100 Rn atoms = 0.5 cts·khr^{-1}·cm^{-2} effect**
  - 0.1 % ambient Rn deposition



- ➢ < 2.0 cts·khr^{-1}·cm^{-2} samples
- ➢ Samples stored in N_2 purge chamber
- ➢ 1-2 minute exposure time
- ➢ Initial 5 hr rejection
- ➢ 12-33% impact



5 hours rejection insufficient – but time is money

Glove Box Design

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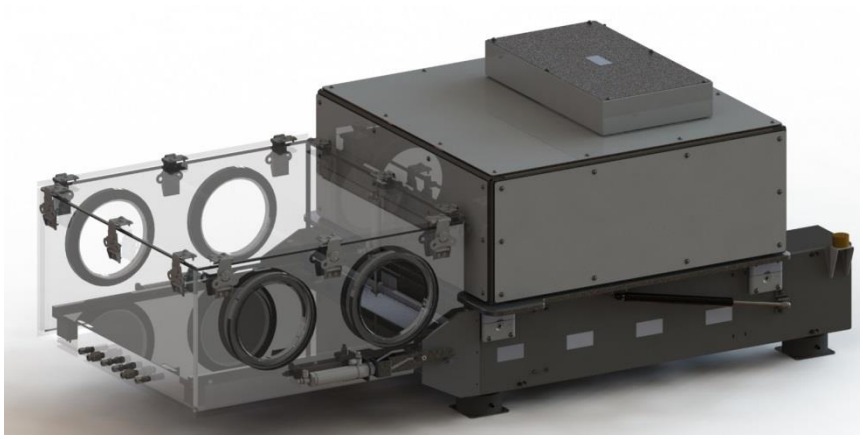
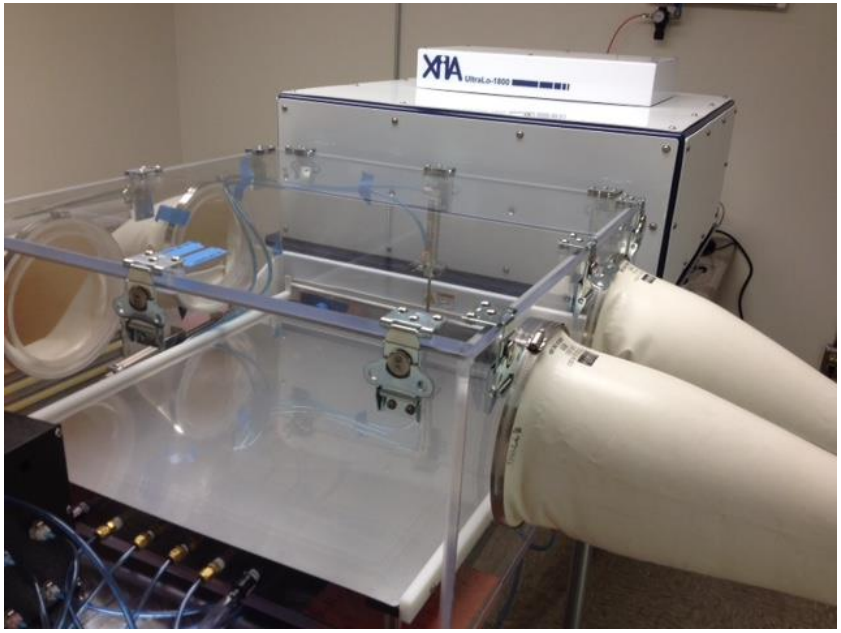
- **Goals for UltraLo Glove Box:**
  - **Radon mitigation**
    - Reduce exposure to ambient radon so no time cuts needed.
  - **Moisture mitigation**
    - Reduce 45-minute purge as much as possible
  - **Ease of Use**
    - Make mating to counter and introducing samples easy and convenient.





Field Testing Conditions

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- **Comparative reduction: Glove box vs Standard procedure**
  - **Ambient Rn 15-30 Bq/m^3**
  - **Ultra Low Activity samples (<2 cts·khr^{-1}·cm^{-2})**
  - **~ 2 minute exposure for standard procedure**
  - **Samples in glove box minimum of 48 hours prior to counting**
    - Sample exchange inside purge box utilized
  - **45 minute instrument Ar purge prior to measurement start**
- **Examine events >6 MeV over initial 5 hours to assess Rn reduction**
- **Data collected over 8 weeks**
- **Evaluate data vs baseline reference**
  - **Baseline 0.89 cts/hr on average in the 6-10 MeV range**

Glove Box Operation

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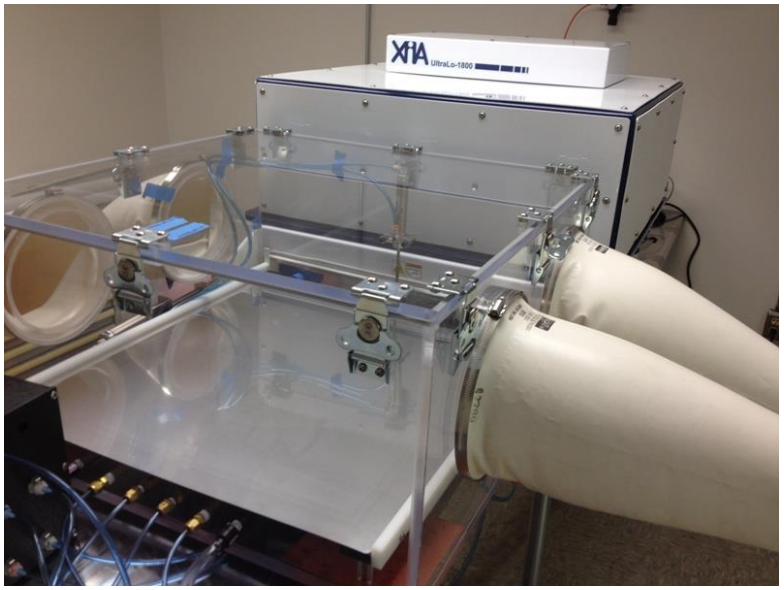

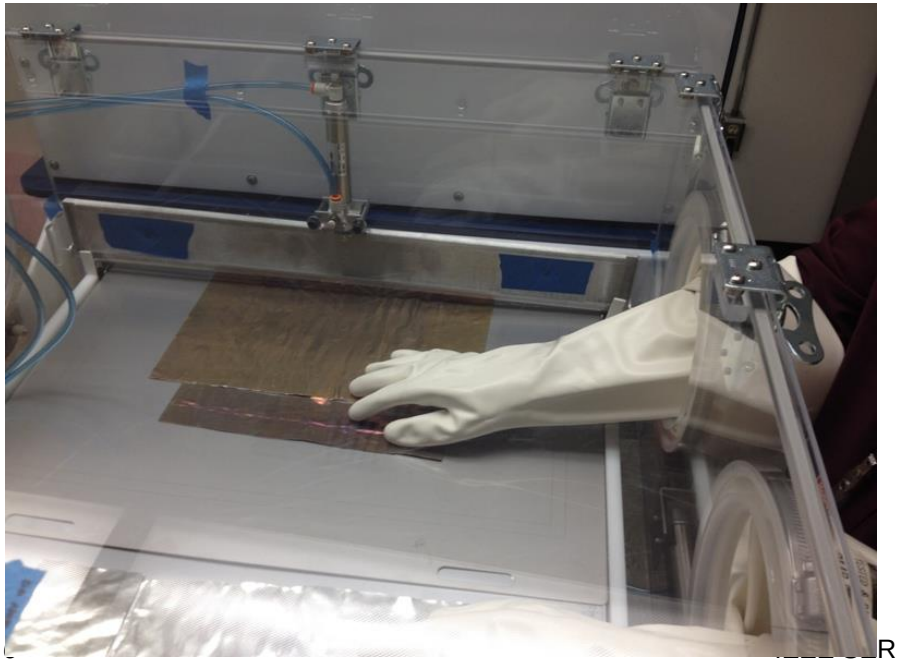

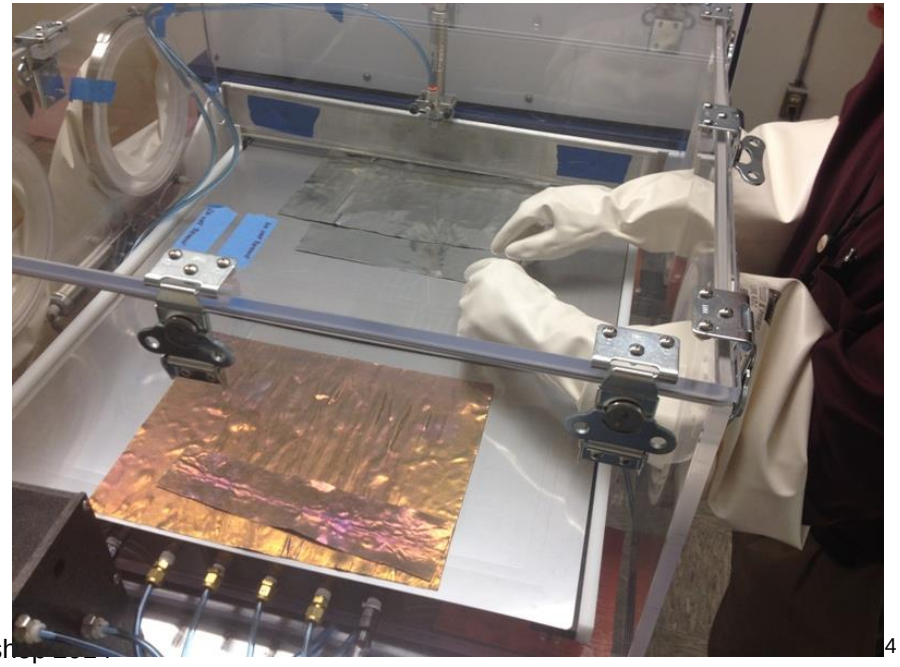

Field Testing Results

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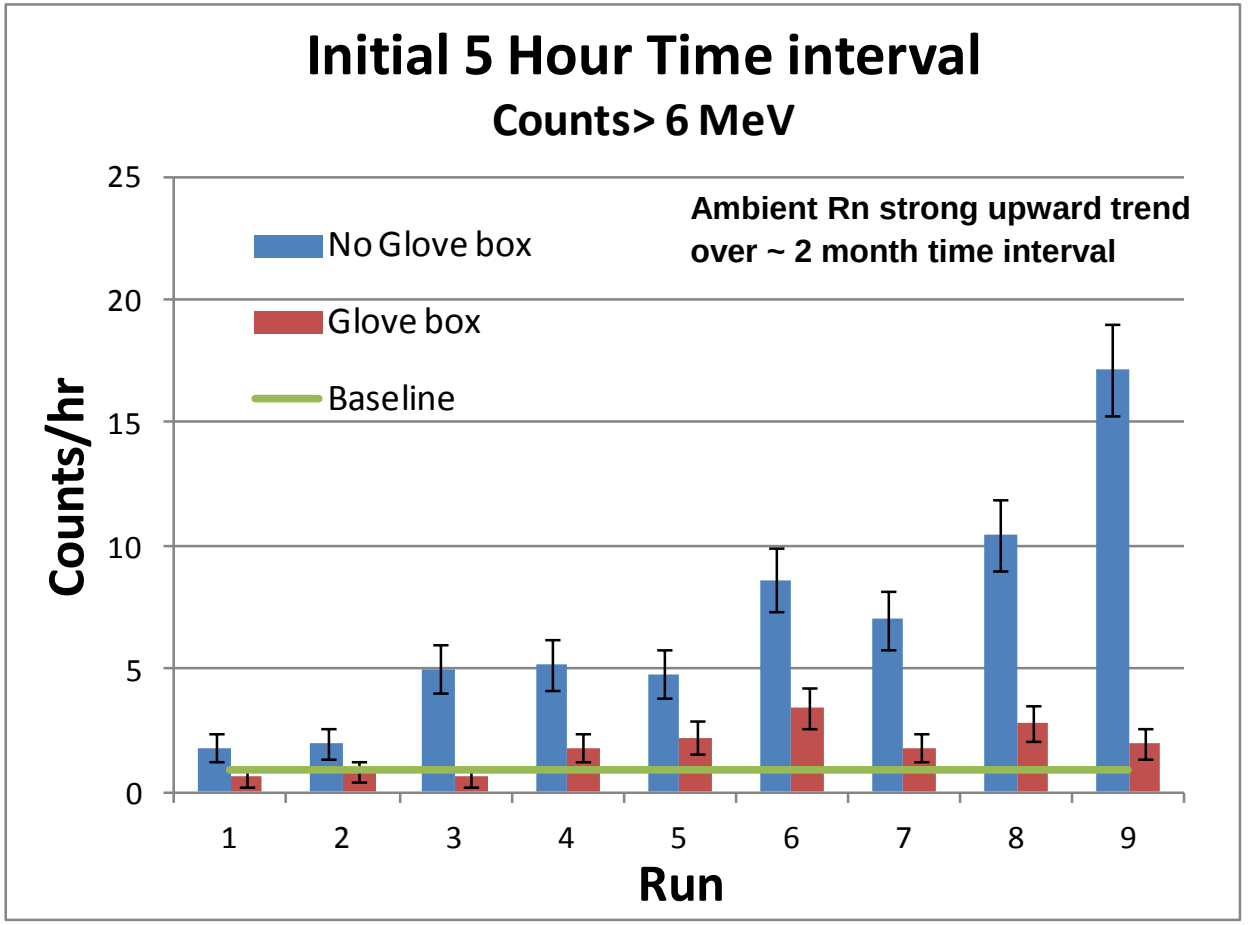

- **Rn reduction factor 2-9x depending on ambient**
- **Residual effect from air gap most likely contributor**

Glove box effectively removes Rn to near baseline

Cosmogenic Effects on Alpha Counters

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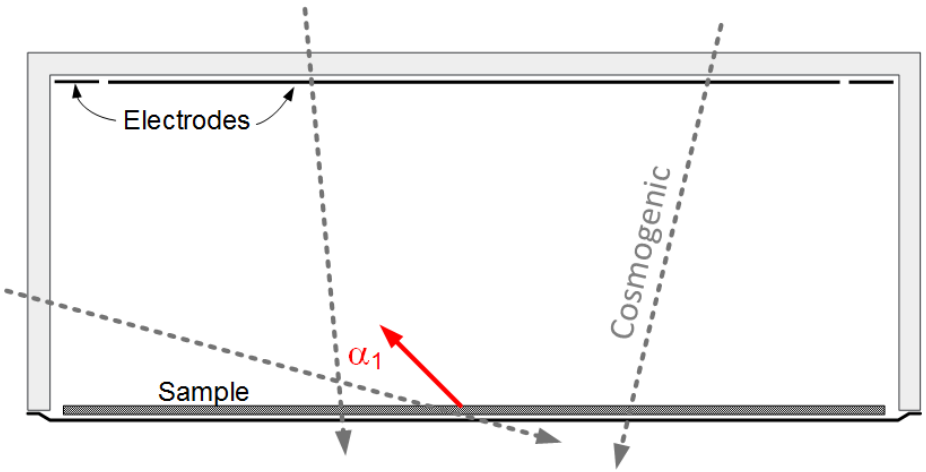
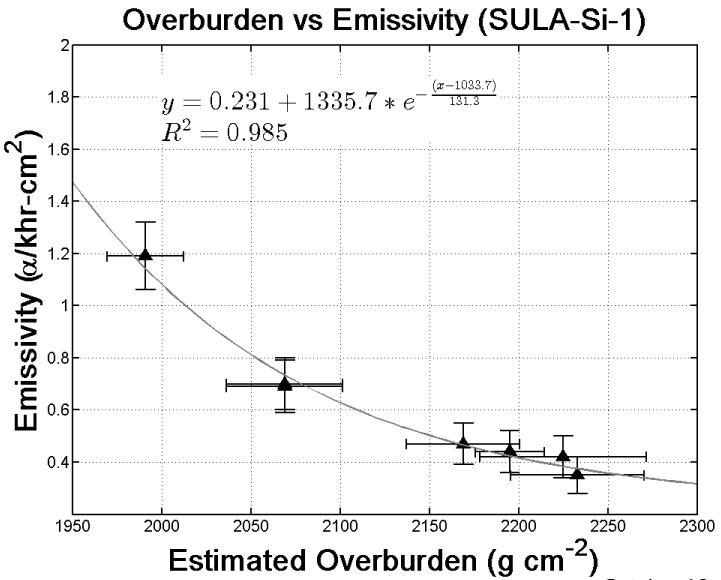
- Historically, gas-filled detectors were most commonly used for measuring fluxes of cosmic radiation
- Proportional counters make two measurements and subtract, hoping to sufficiently account for this effect
- Detailed studies recently conducted with UltraLo-1800 which has some cosmogenic discrimination built in





McNally et al, doi:10.1016/j.nima.2014.02.052

Cosmogenic Differentiation Challenge

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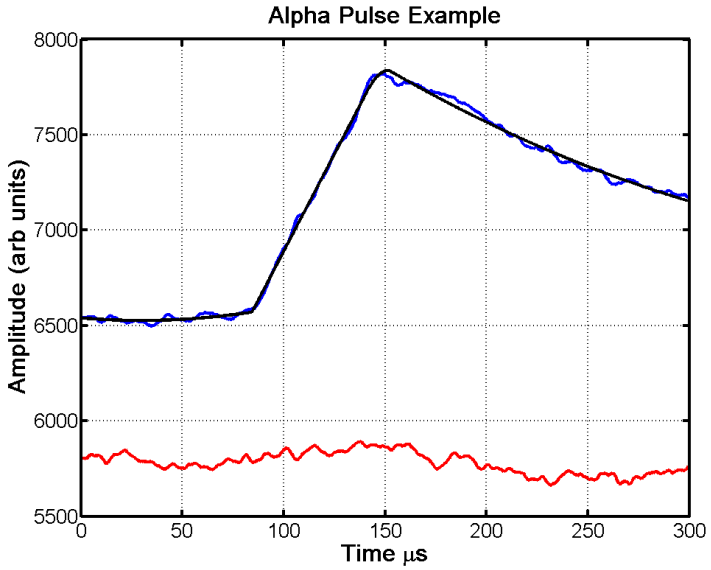
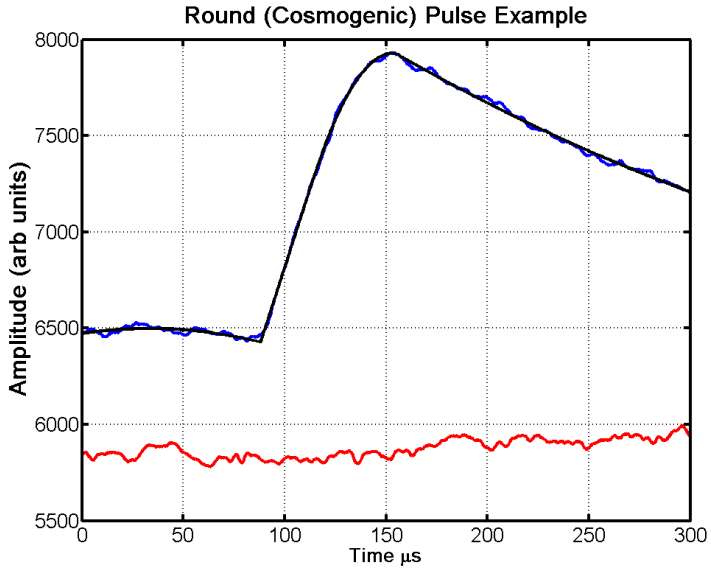
- **Examples of alpha & round pulses @ ~ 2 MeV**





- **Alpha vs round event discrimination 'efficiency' decreases with energy (i.e. lower S/N)**
  - **Pulse Noise + curve fitting error = misclassification**
  - **On the order of 3-4% Round pulses misclassified**
- **Spokane Hourly Round rate = 15.4/hr (1800 cm^2)**
  - **Hayward 7.5 (1800 cm^2)**

Lab/Lab Characterization and correction necessary

Cosmogenic Effect: 600 M Elevation

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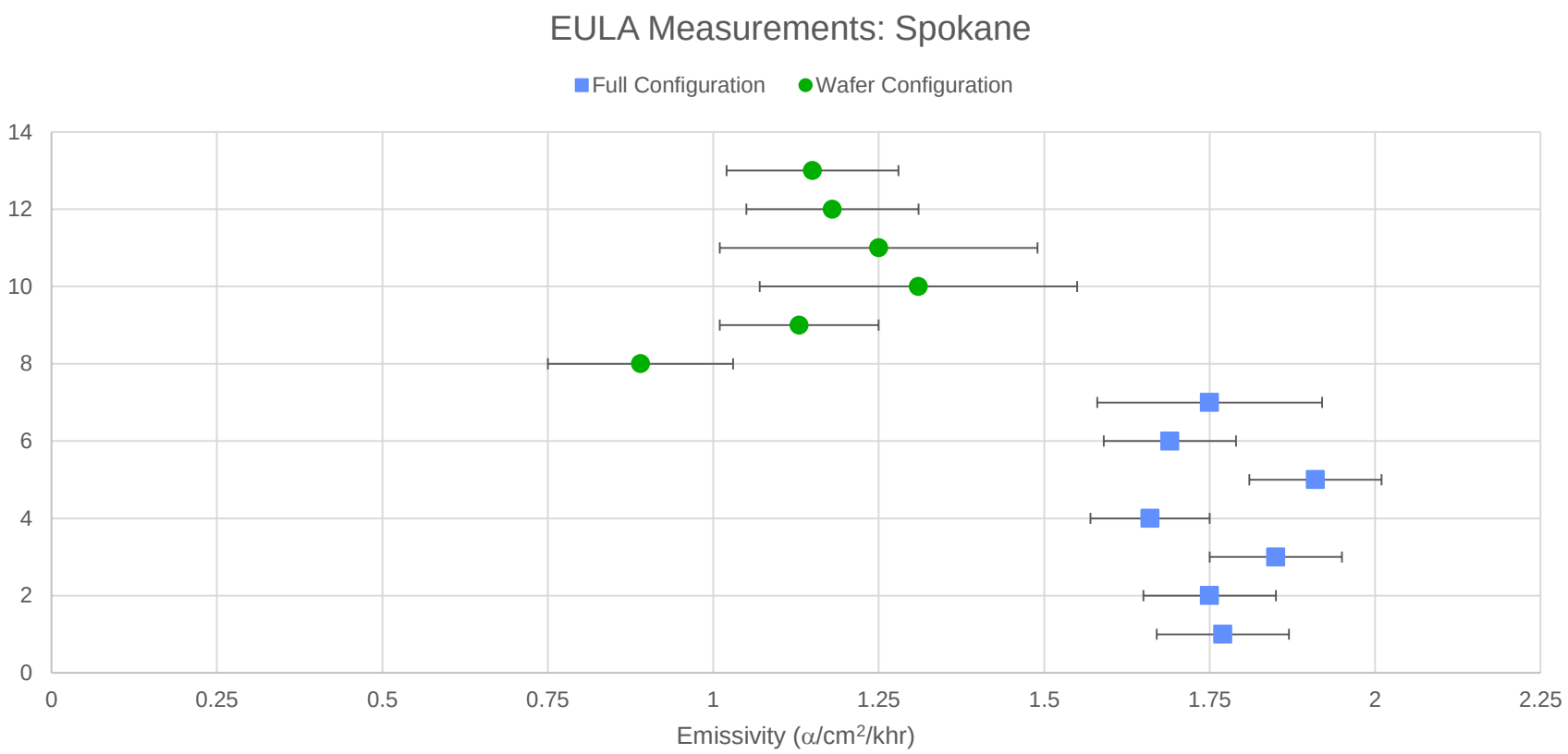

- **EULA Reference Sample <0.3 cts·khr^{-1}·cm^{-2}**
- **Average emissivities:**
  - **1800 cm^2 = 1.8 cts·khr^{-1}·cm^{-2}**
  - **707 cm^2 = 1.2 cts·khr^{-1}·cm^{-2}**

Cosmogenic Effect: 50 M Elevation

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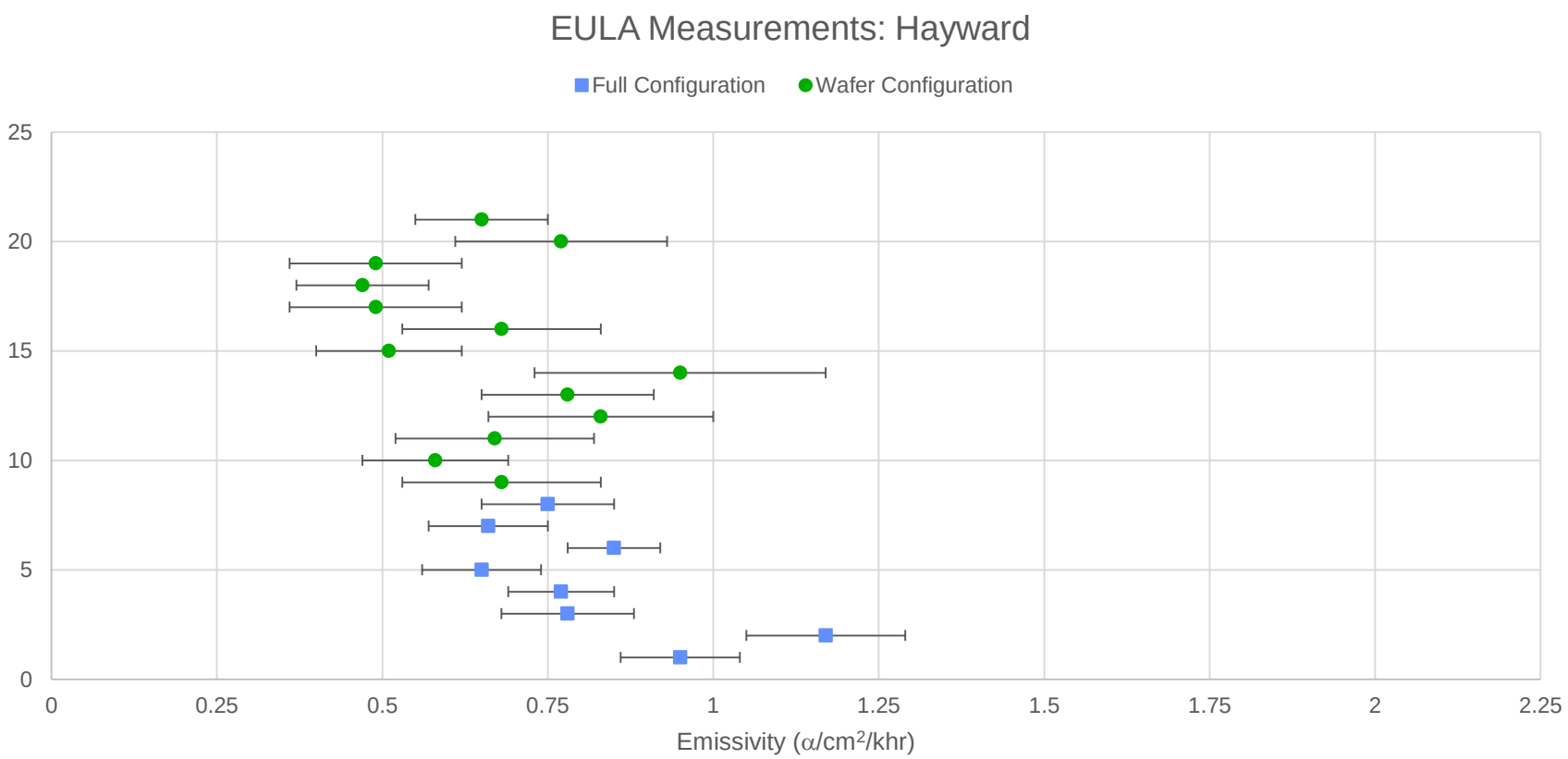

- **Average Emissivities:**
  - **1800 cm^2 = 0.83 $cts \cdot khr^{-1} \cdot cm^{-2}$**
  - **707 cm^2 = 0.66 $cts \cdot khr^{-1} \cdot cm^{-2}$**
  - **Consistent with previously reported wafer mode data**

Overburden Model revision

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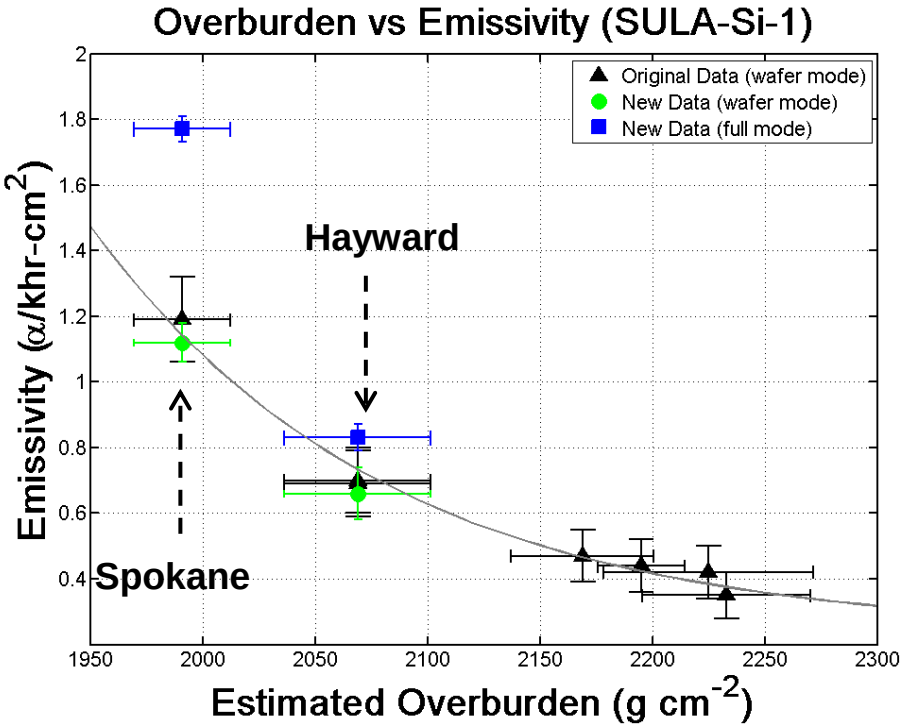
- Additional data consistent with previous observations
- 1800 and 707 different response vs overburden
  - Discrepancy due to different solid angle effects
  - Effect amplified with altitude
- Error in model warrants site specific cosmogenic factor determination



Conclusions

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- **Improvements in 2 key areas identified to enable timely, accurate data**
- **Radon mitigation**
  - **Increasingly important in elevated Rn environments**
  - **Glove box effective at reduction**
  - **Eliminate necessity to count longer**
- **Cosmogenic bias**
  - **Estimated 3-4% of cosmic events registered as alpha events**
  - **Extensive characterization at multiple sites completed**
  - **Overburden model updated**
  - **Site specific correction factor required to normalize results between laboratories**

Acknowledgements

- IBM – Use of the EULA activity large area sample
- Honeywell: Taylor Johnston, Sam Weber

Questions?

Glove Box Testing at XIA

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- **XIA's ambient Rn levels are low, ~10 Bq/m^3.**
  - **Tests run comparing standard desiccator box to mating glove box showed improvement: 2.08 vs. 1.48 α/kh/cm^2, respectively.**
  - **Difference is noticeable but acceleration would help.**
- **Accelerate testing with Uranium ore.**
  - **Put ore in sealed container, use that to introduce high-activity (~1kBq/m^3) air into gap between counter and glove box.**
  - **Test with no purge and with a purge of that volume.**
  - **Results: 31.7 vs 2.11 α/kh/cm^2.**
- **Moisture results good.**
  - **Reduces purge time from 45 to 7 minutes.**