Radon Emanation at SDSM&T

M. A. Bowles
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G. Gamow Series
Physics Dept Colloquium

presenting work done with or by
Megan Stark
Ray Bunker@ PNNL
Eric Miller
R. W. Schnee

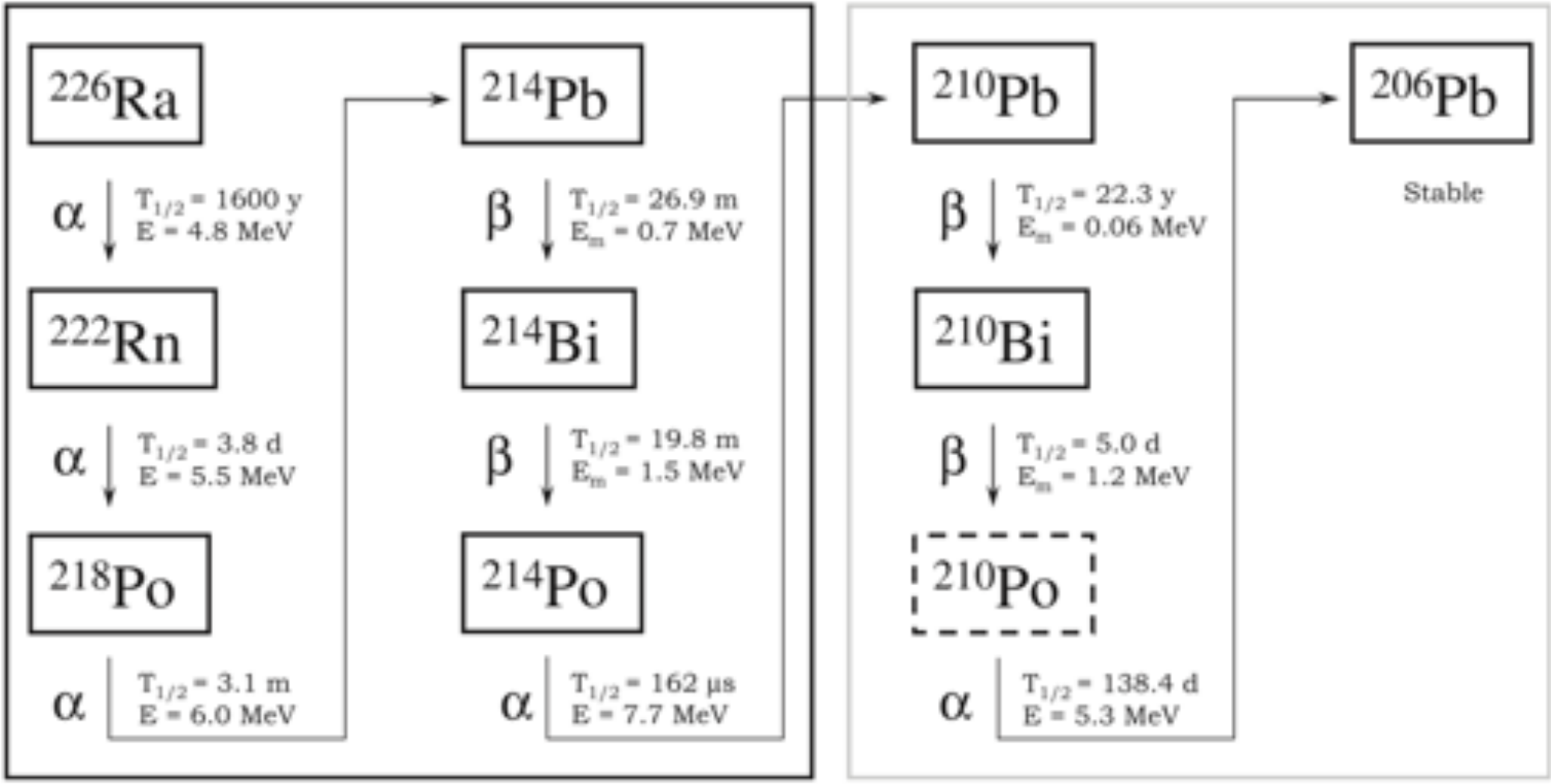
Outline

please stop me to ask questions

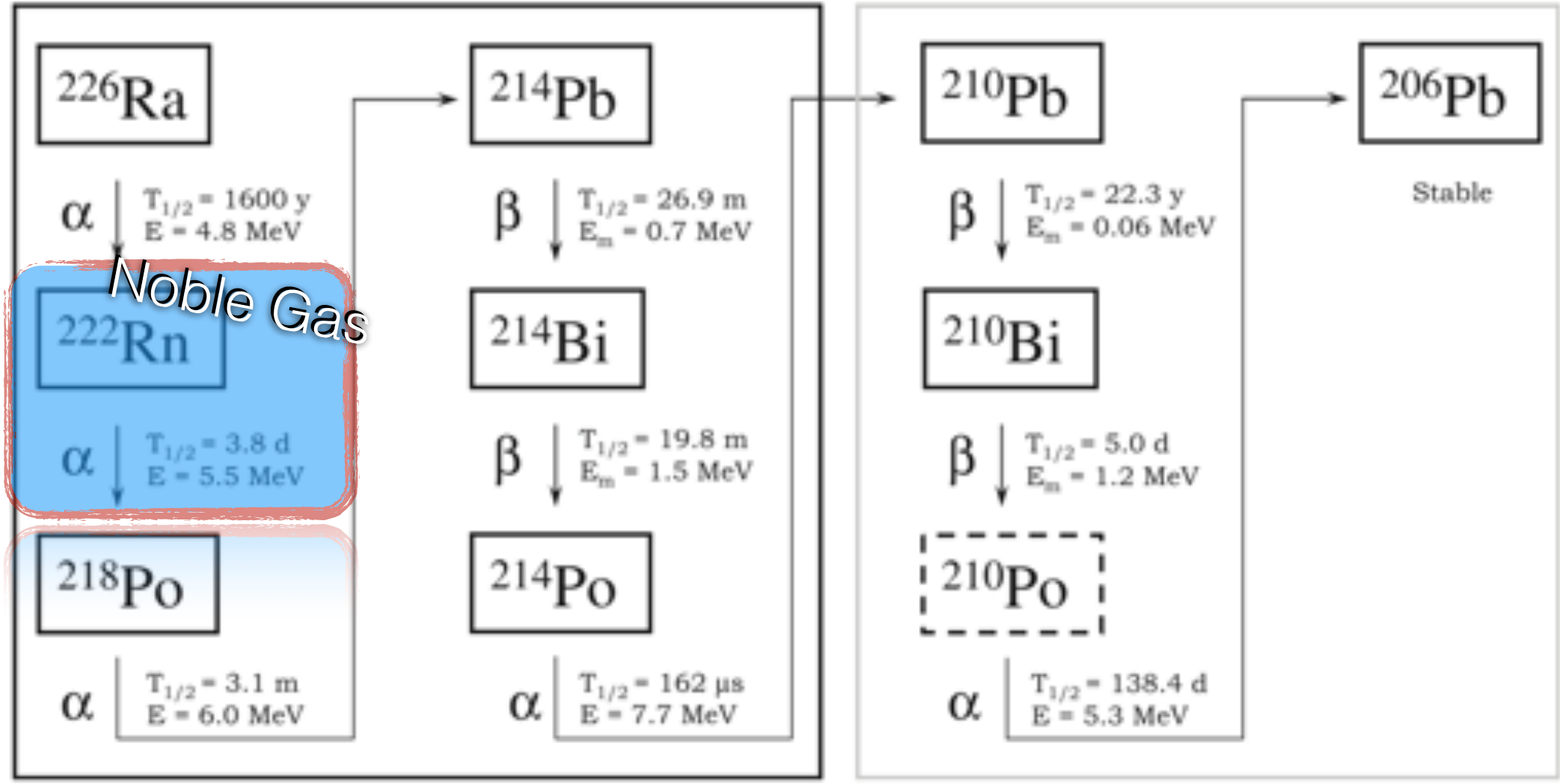
- Radon & Motivation: LZ & SuperCDMS
- Emanation System & Radon Detection
- Detector Performance & Data Taking
- Radon Background Studies
- Conclusions & Future Outlook

SOUTH DAKOTA SCHOOL OF MINES & TECHNOLOGY

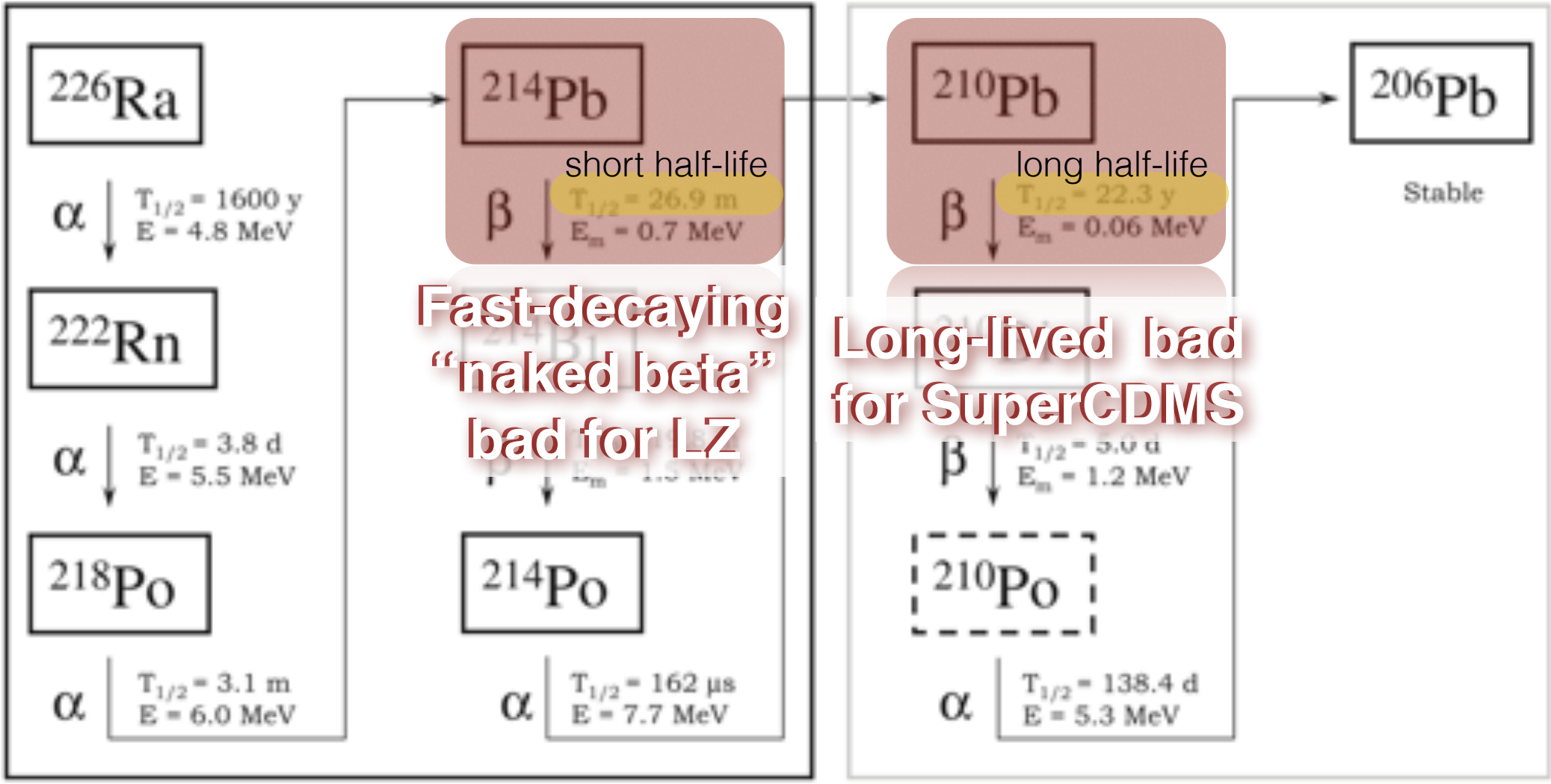
Radon and its Daughters



Unique Radon Problem

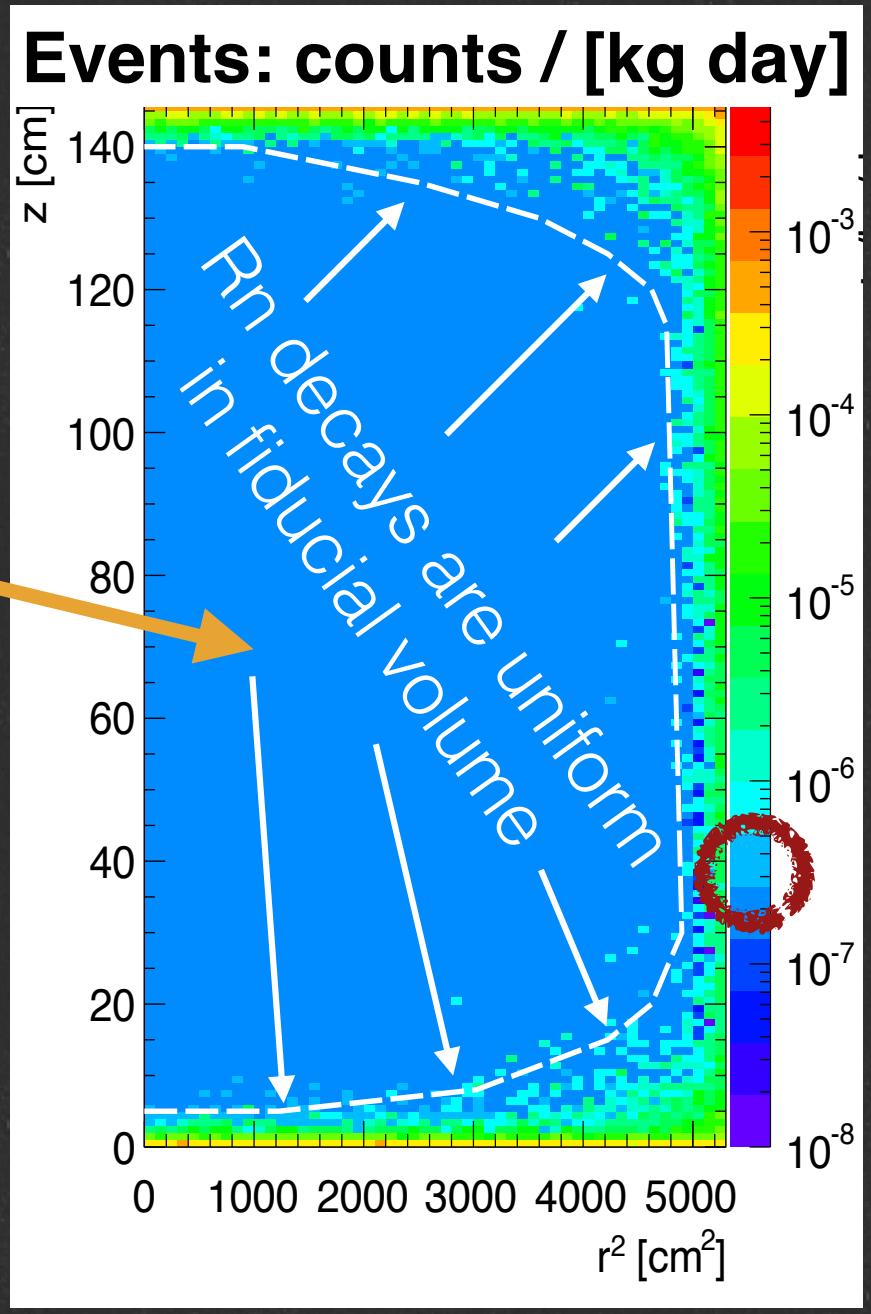


Radon Plate-out Contaminants



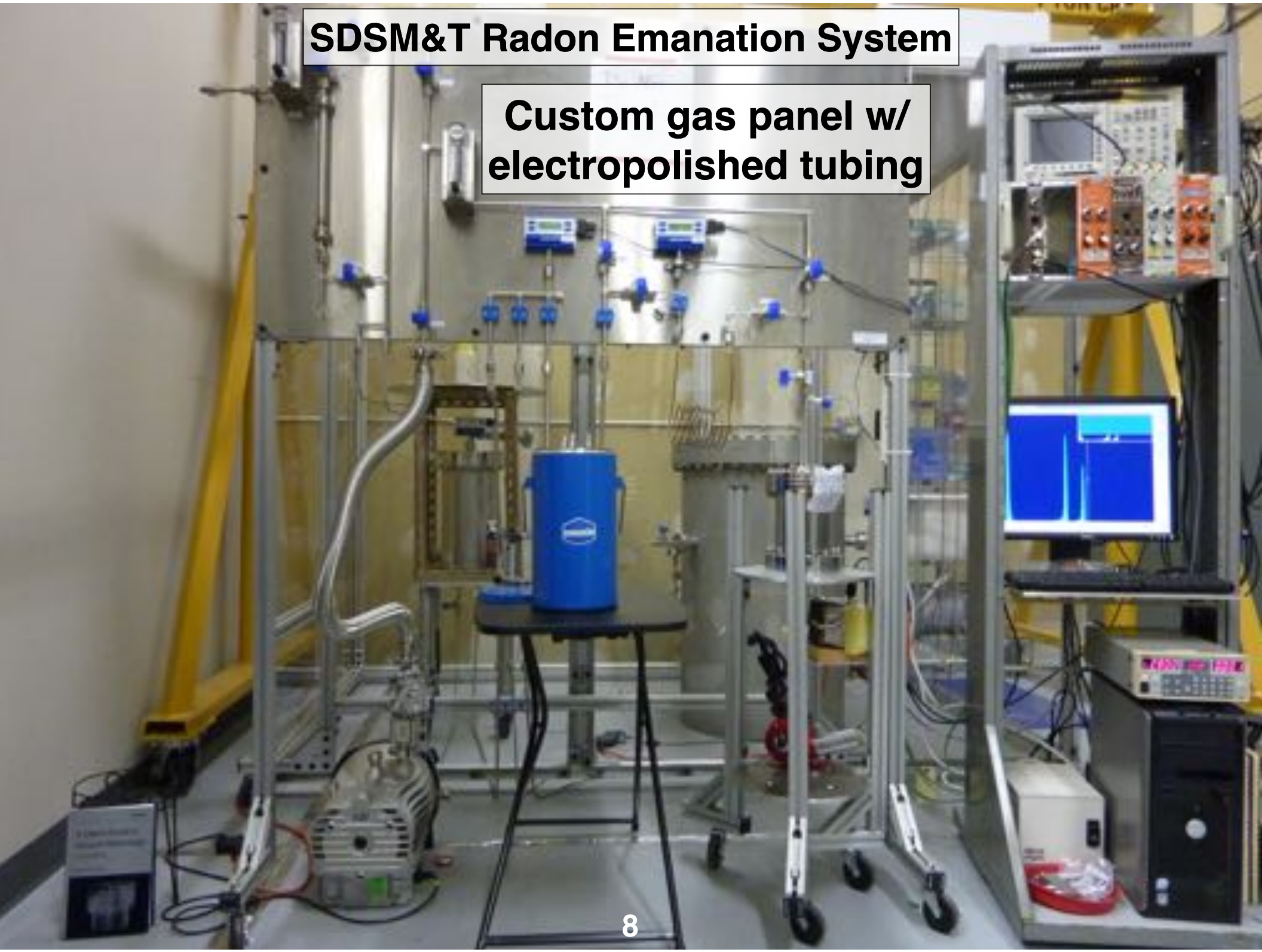
LUX Zeplin (LZ)

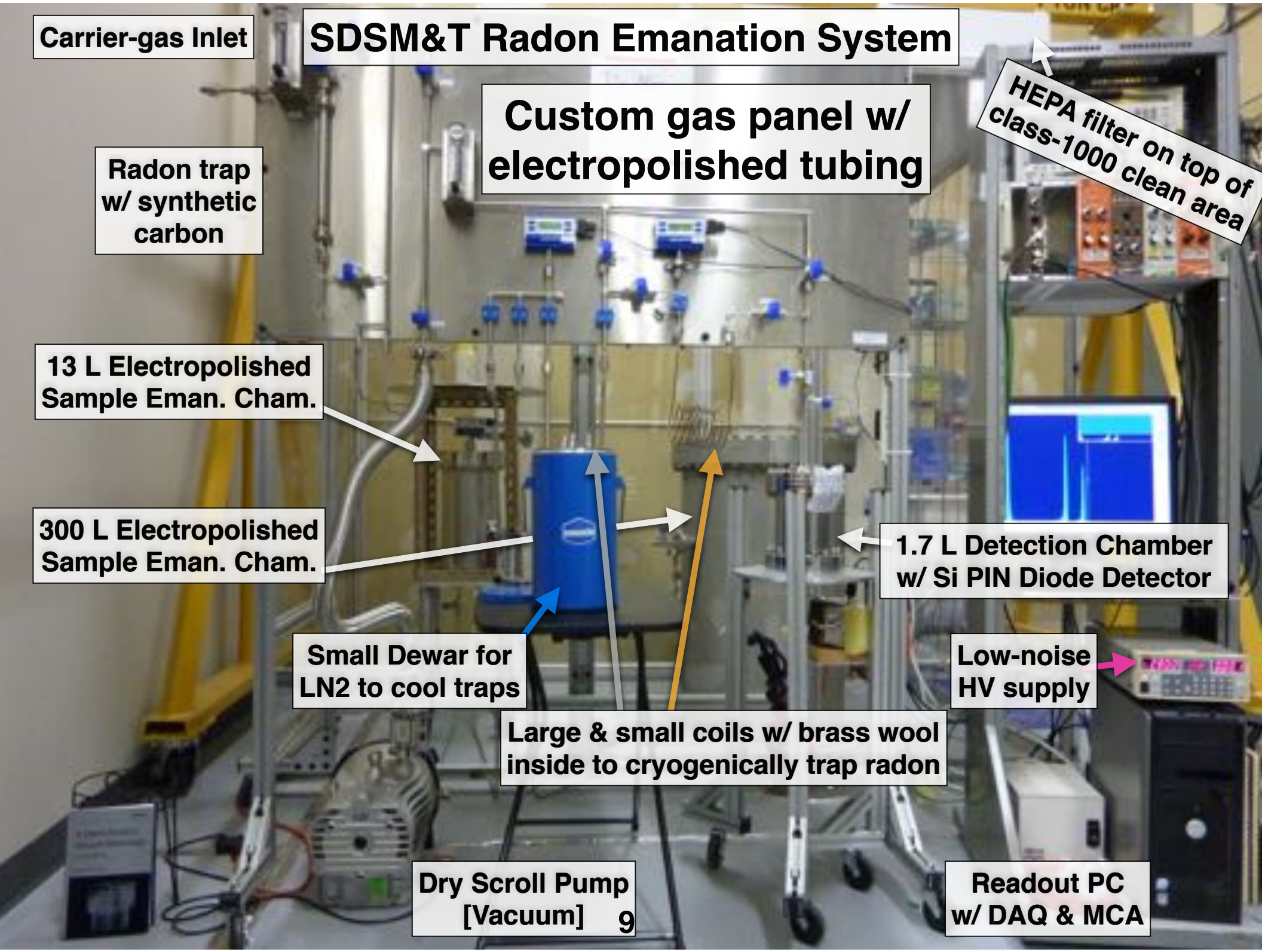
- Expect few bkgds external to Xenon volume
- Rn-222 leads to fast-decaying isotopes uniformly in the detection volume
  - Radon decay background *can't be removed* by fiducial volume cuts
  - Larger risk from ^{214}Pb "**naked**" β decay to ^{214}Bi with 20 min. half-life: *mimic DM signal*
    - No quick decay to use for timing cut
- LZ Rn Emanation goal for *all materials*: ~1 mBq
  - This room's emanation rate: ~100 Bq/m^3
- Radon emanation prevention is **crucial!**



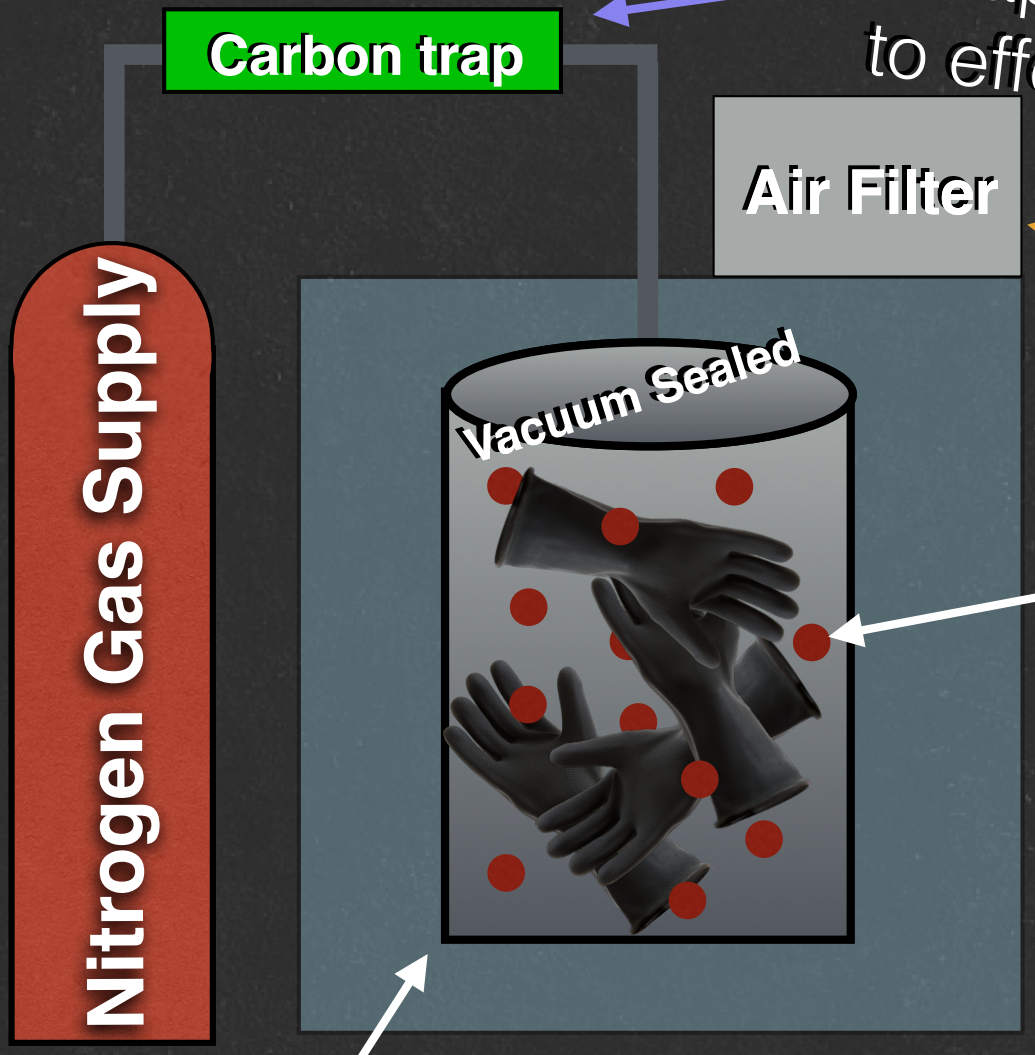
SuperCDMS SNOLAB

- HV detectors don't have ER discrimination
- Rn-222 plate-out leads to Pb-210 betas
  - Very low probability during data-taking
- Plate-out **during fabrication & transfer** is the real potential problem
  - Quarantine detectors in Radon-free box
  - O-rings may emanate radon into volume


SDSM&T Radon Emanation System
Custom gas panel w/
electropolished tubing


Carrier-gas Inlet
SDSM&T Radon Emanation System
Custom gas panel w/ electropolished tubing
HEPA filter on top of class-1000 clean area
Radon trap w/ synthetic carbon
13 L Electropolished Sample Eman. Cham.
300 L Electropolished Sample Eman. Cham.
1.7 L Detection Chamber w/ Si PIN Diode Detector
Small Dewar for LN2 to cool traps
Low-noise HV supply
Large & small coils w/ brass wool inside to cryogenically trap radon
Dry Scroll Pump [Vacuum]
Readout PC w/ DAQ & MCA

Sample Emanates Radon

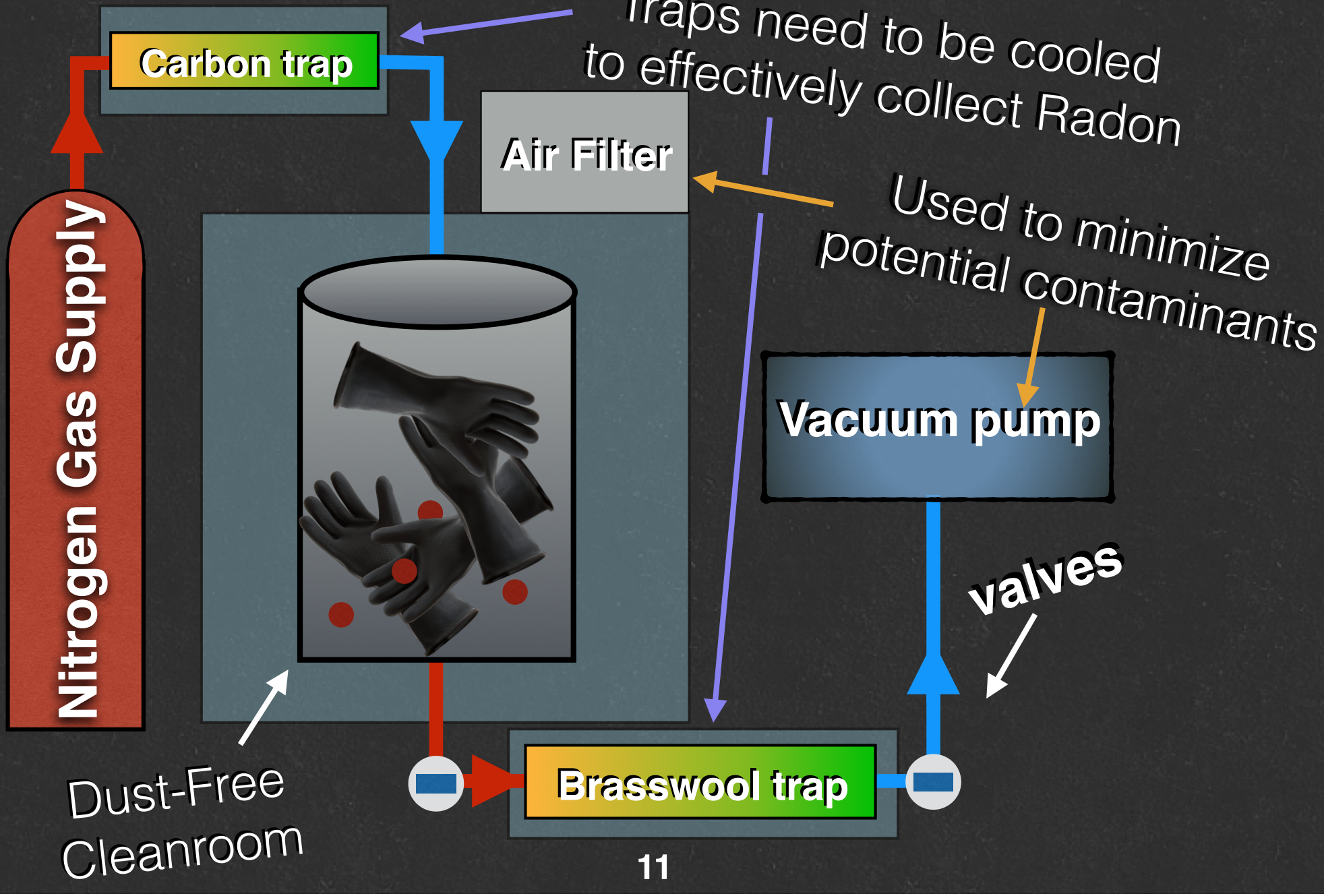


Traps need to be cooled to effectively collect Radon

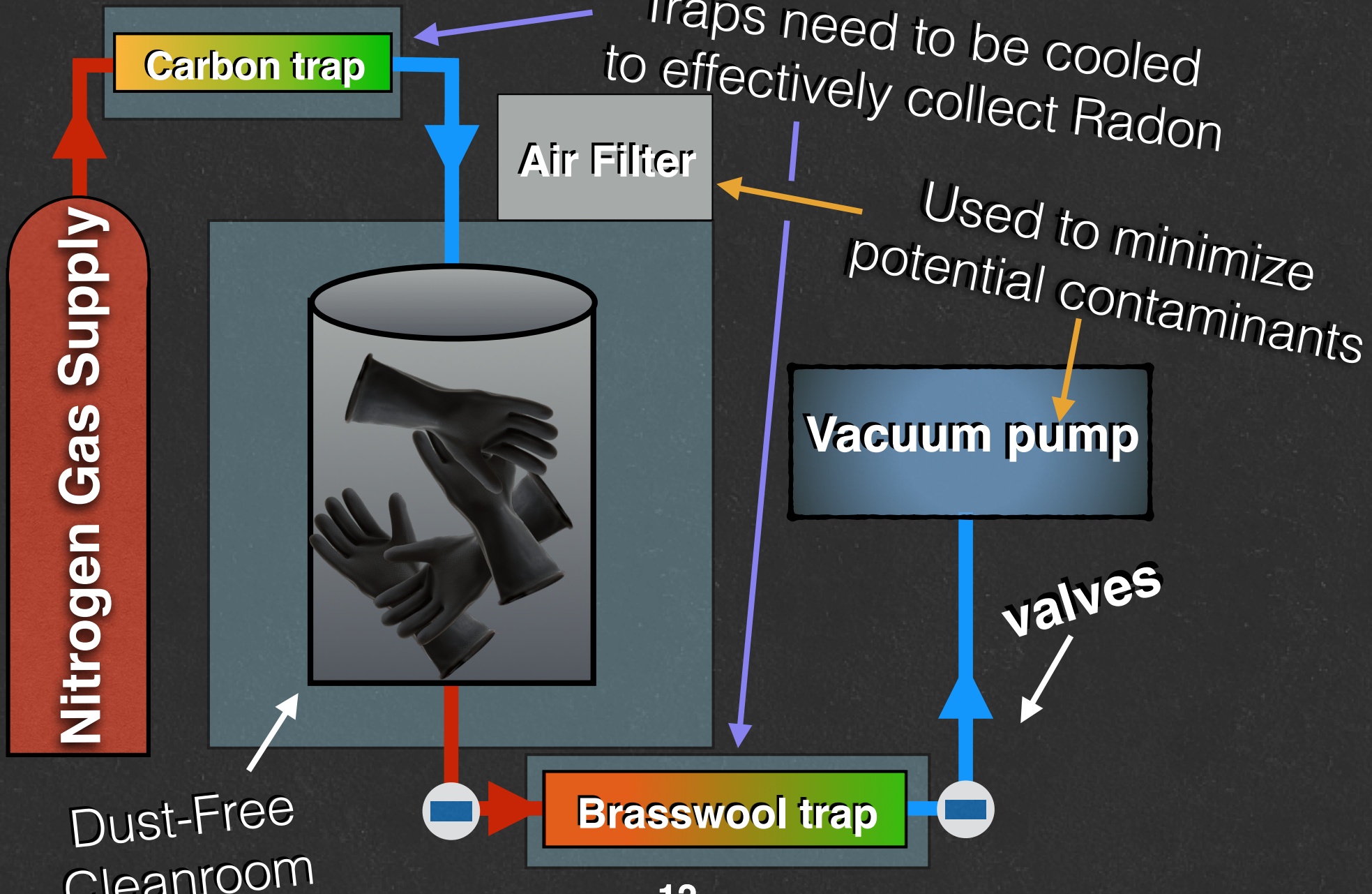
Used to minimize potential contaminants

1. Emanate sample for ~1 week
   - Radon half-life $t_{1/2} \approx 3.8$ days
2. Displace w/ low-radon carrier gas
3. Flow Rn-222 sample into low temperature brasswool trap
4. Free-expand to detection volume

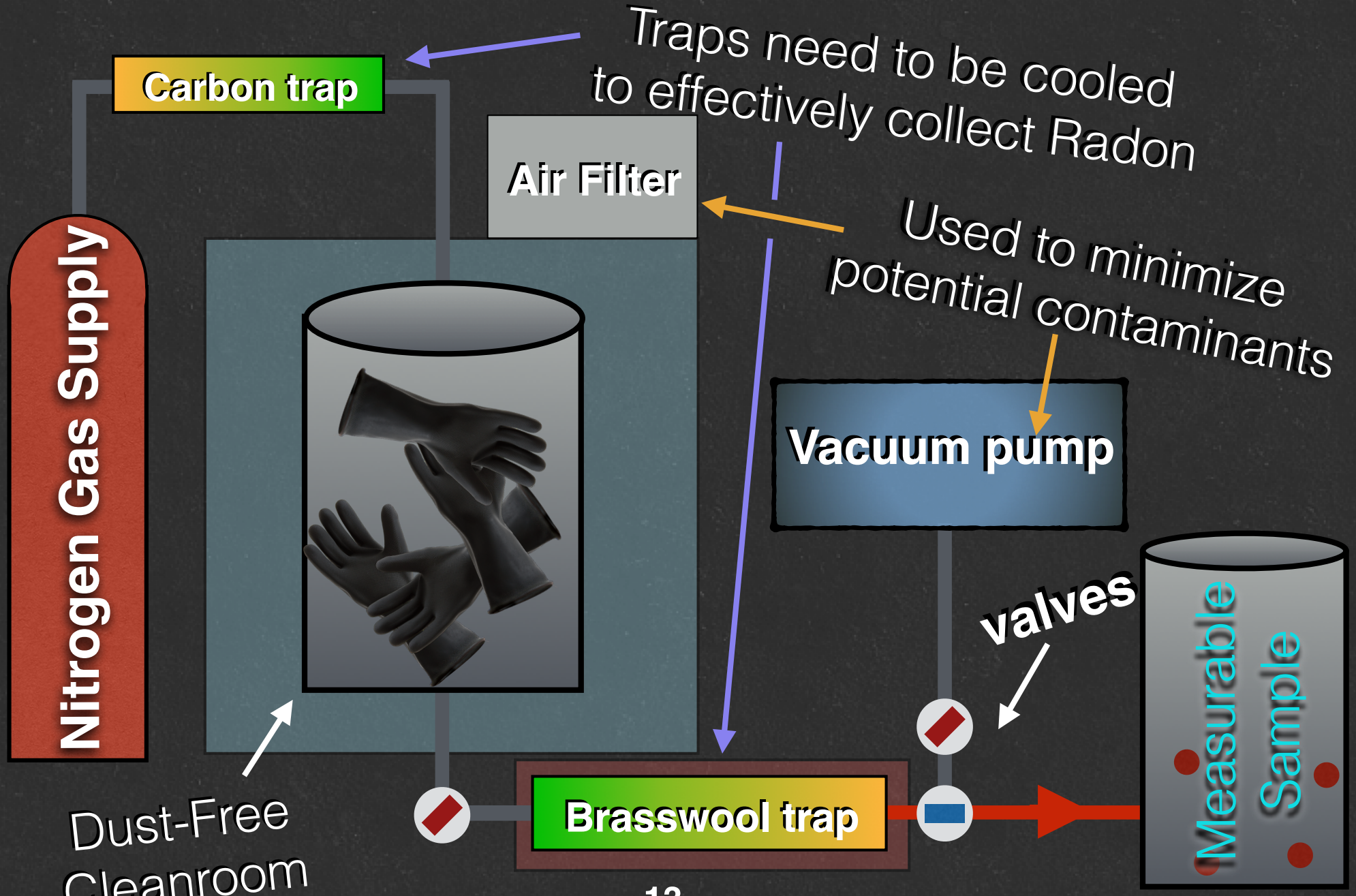
Cryogenically Trap Sample



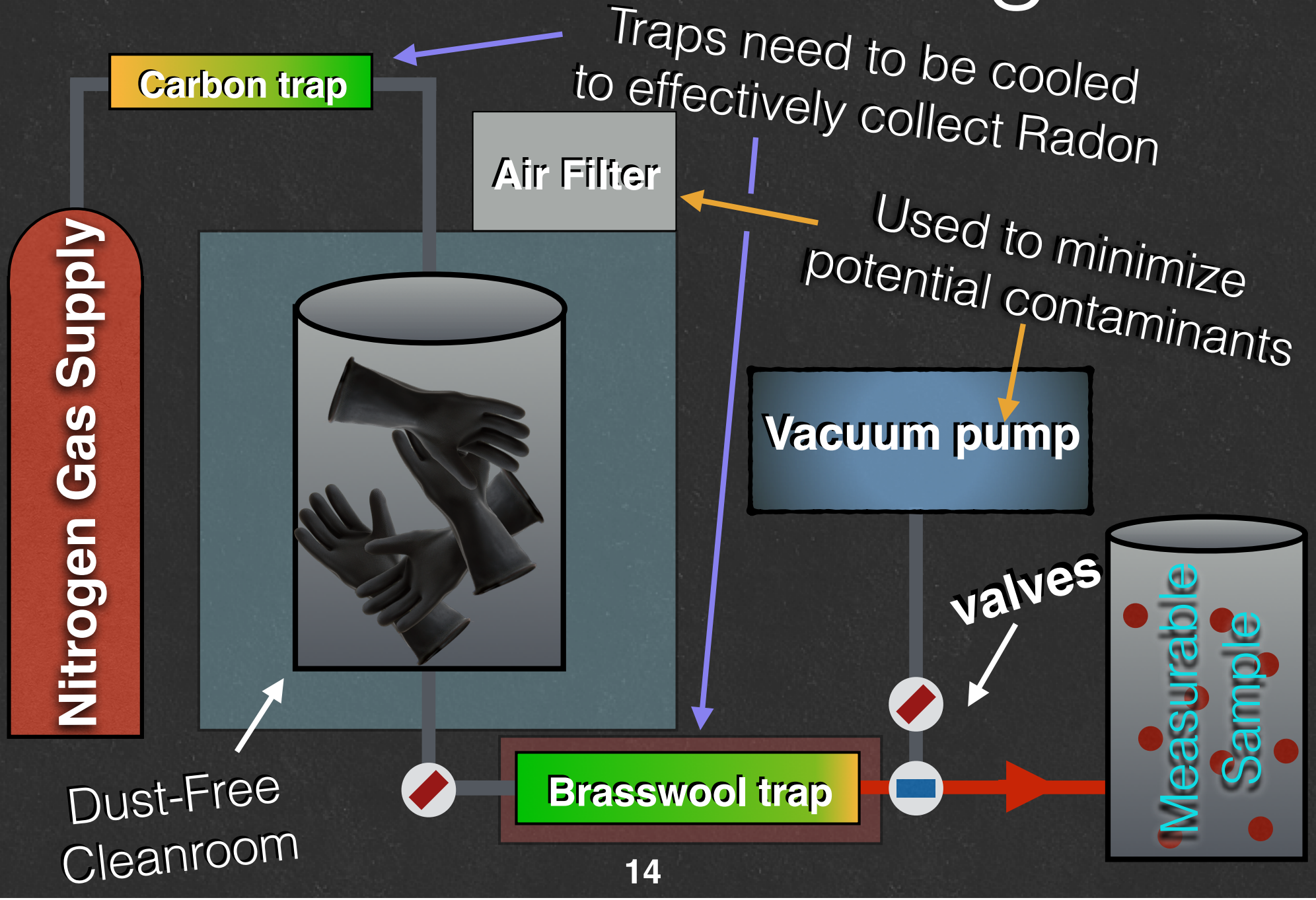
Cryogenically Trap Sample



Gas Expands into Detection Cham.



Measure Radon Signal



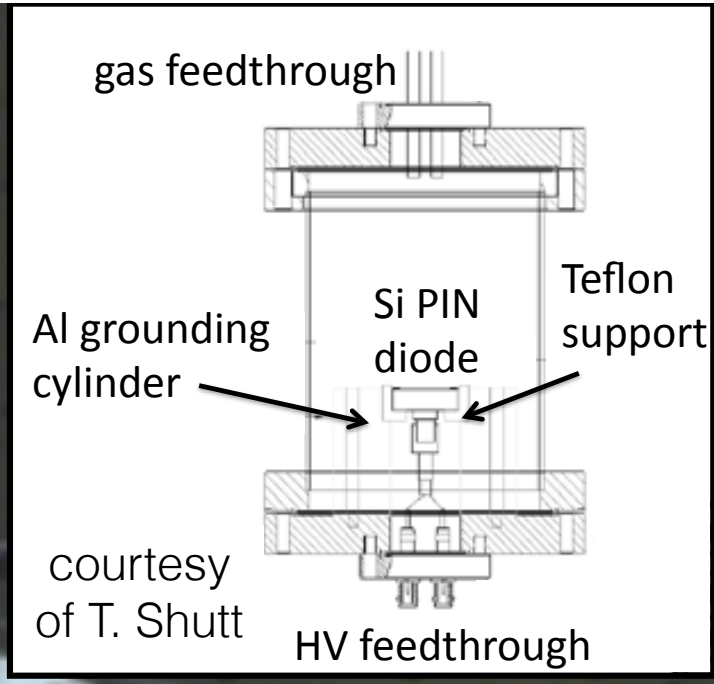
Chamber Top

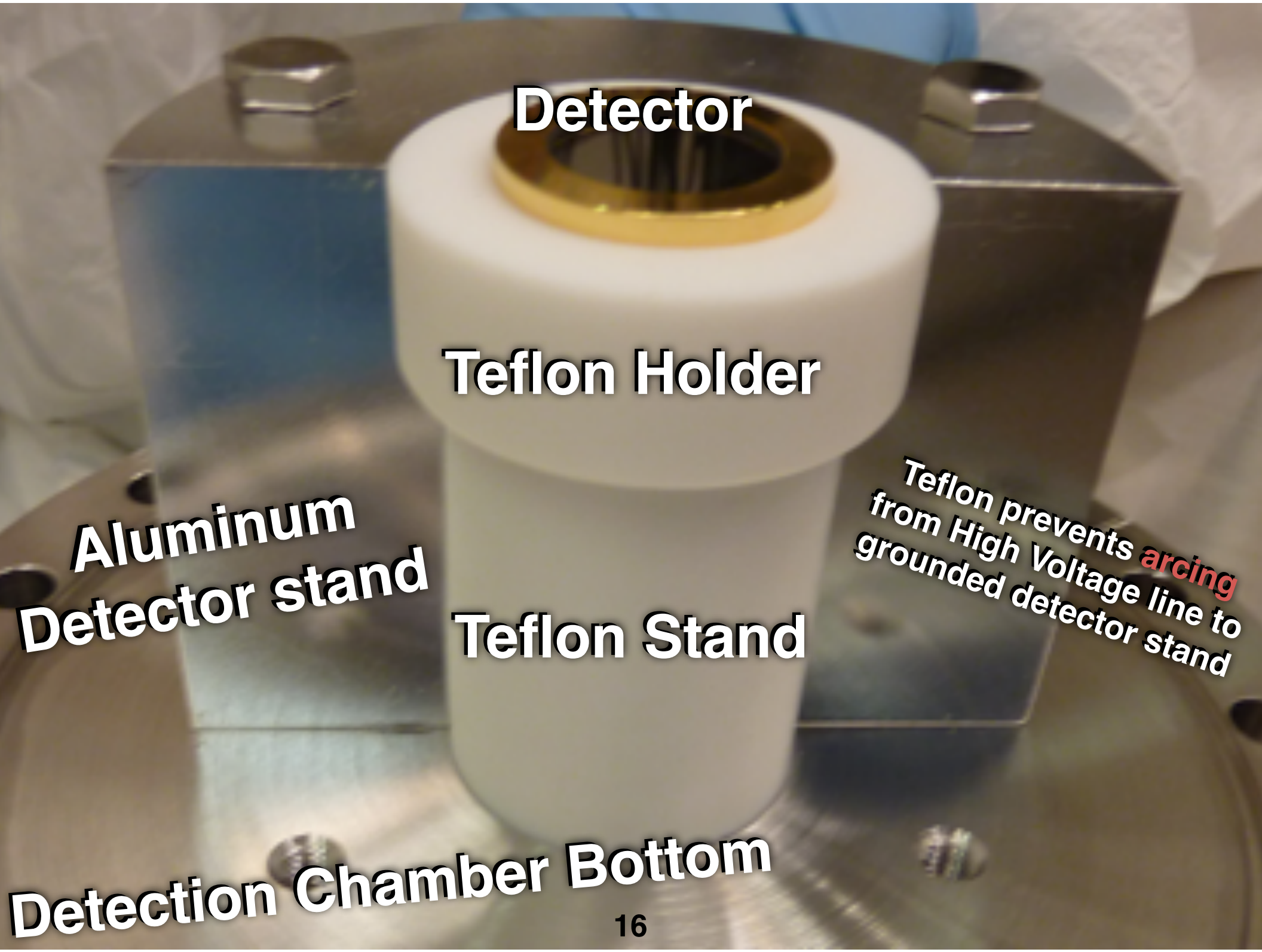
Vacuum Sealed
with Gas Inlet/Outlet
and HV Feedthrus

Detector fits here

Detector Stand

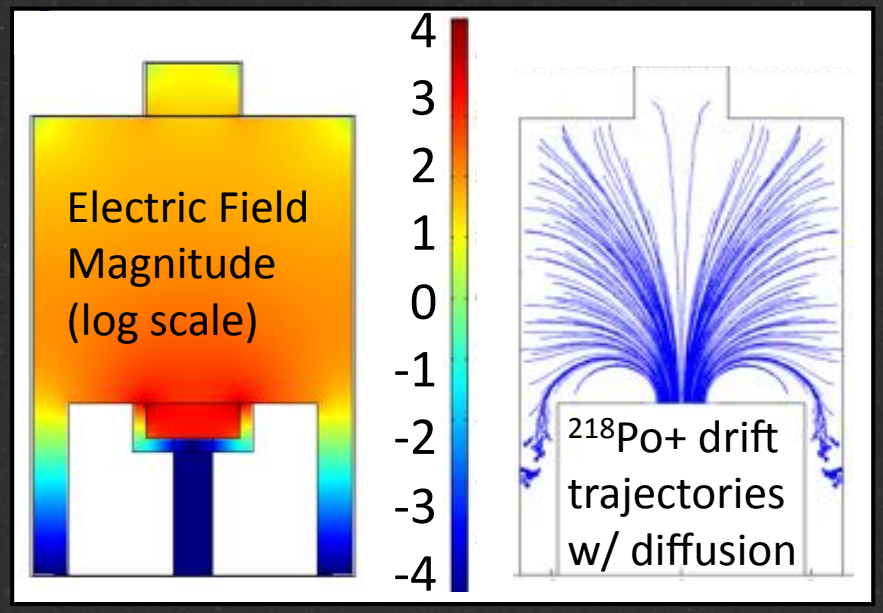
Chamber Bottom




Detector
Teflon Holder
Aluminum
Detector stand
Teflon Stand
Teflon prevents arcing
from High Voltage line to
grounded detector stand
Detection Chamber Bottom

Radon Progeny Collection

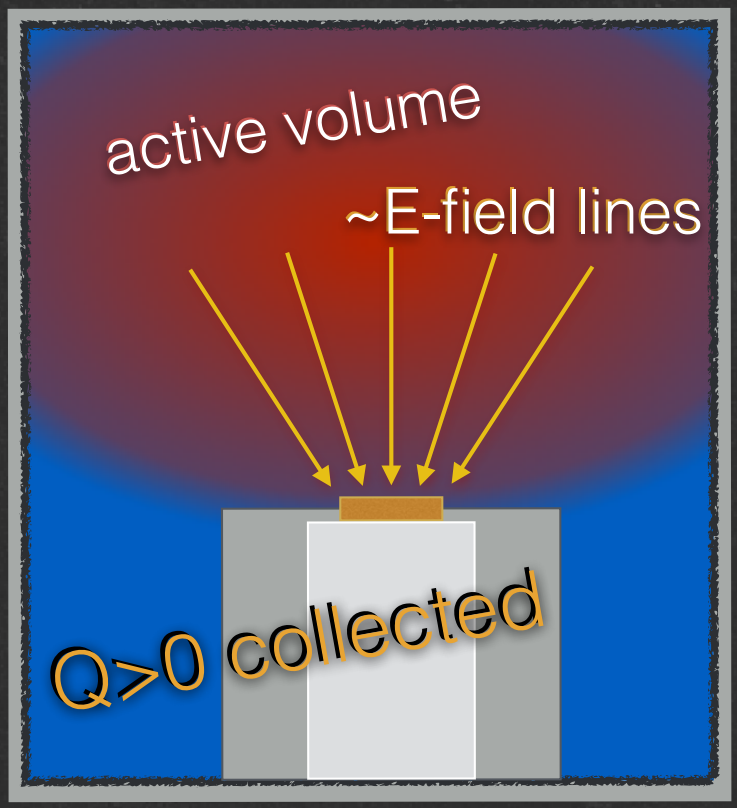
- Rn-222 alpha decays to Po-218
  - ~88% of Po-218 have $Q_{Po} > 0$
  - N_2 carrier gas slows Po ions
  - Po-218 is collected by E-field

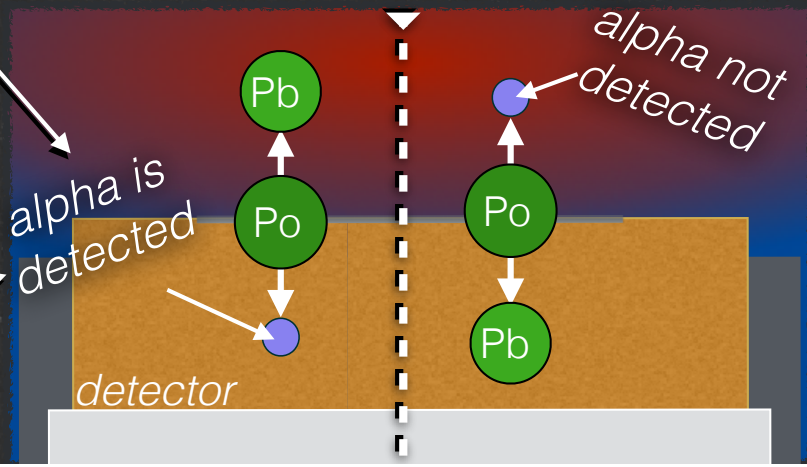


E-field calculation & Po-218 simulation by Devon Seymour (UMD)

Radon Progeny Collection

- Rn-222 alpha decays to Po-218
  - ~88% of Po-218 have $Q_{Po} > 0$
  - Po-218 is collected by E-field
- Po-218 alpha decays to Pb-214
  - Alpha is detected w/ 50% eff
- Pb & Bi-214 beta decay to Po-214
- Po-214 alpha decays to Pb-210
  - Alpha is detected w/ 50% eff





Emanation Characteristics

- Collection Efficiency Measurements
  - Resolution improvement, early background estimates
  - Maintaining good collection efficiency for long runs
  - Transfer efficiency: *% of emanated sample measured*
- Measuring/Simulating Backgrounds
  - Blank Rates: measure emanation chamber backgrounds
  - Diffusion Simulation: simulate diffusion into (& out of) teflon
  - Radon Adsorption: trap radon in gas using carbon column

Po Resolution & Sensitivity

- Energy resolution FWHM improved from ~5% to ~1.3% (1.6-2%)
- Early detector backgrounds ≈ 5 per day / 23% detection efficiency
  - 25 decays/day ≈ **250 μBq =** Minimum Detectable Activity < 100 μBq