SuperNEMO and the Radon Concentration Line

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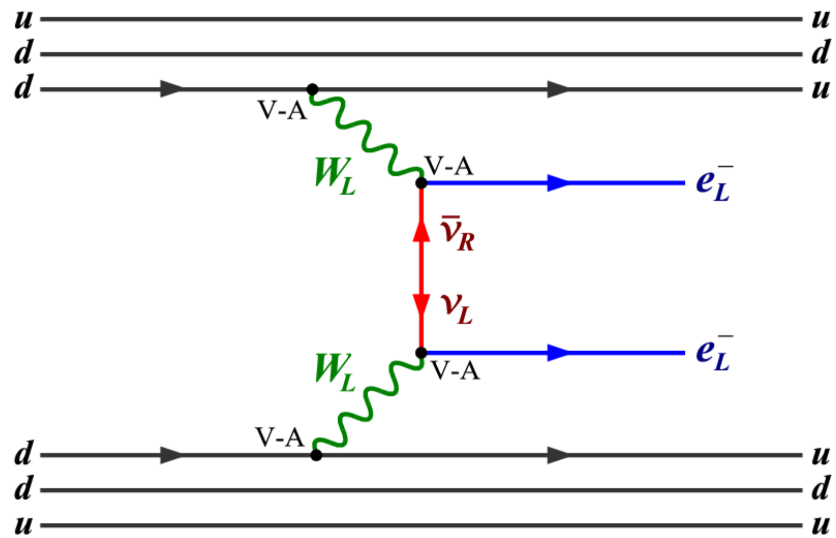
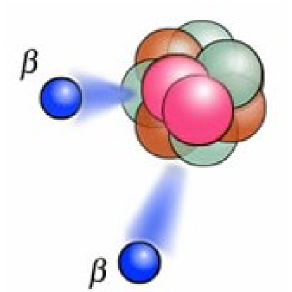
Neutrinoless Double Beta Decay (0νββ)

- 0νββ is a lepton-number violating transition:

$$2n \rightarrow 2p + 2e^-$$



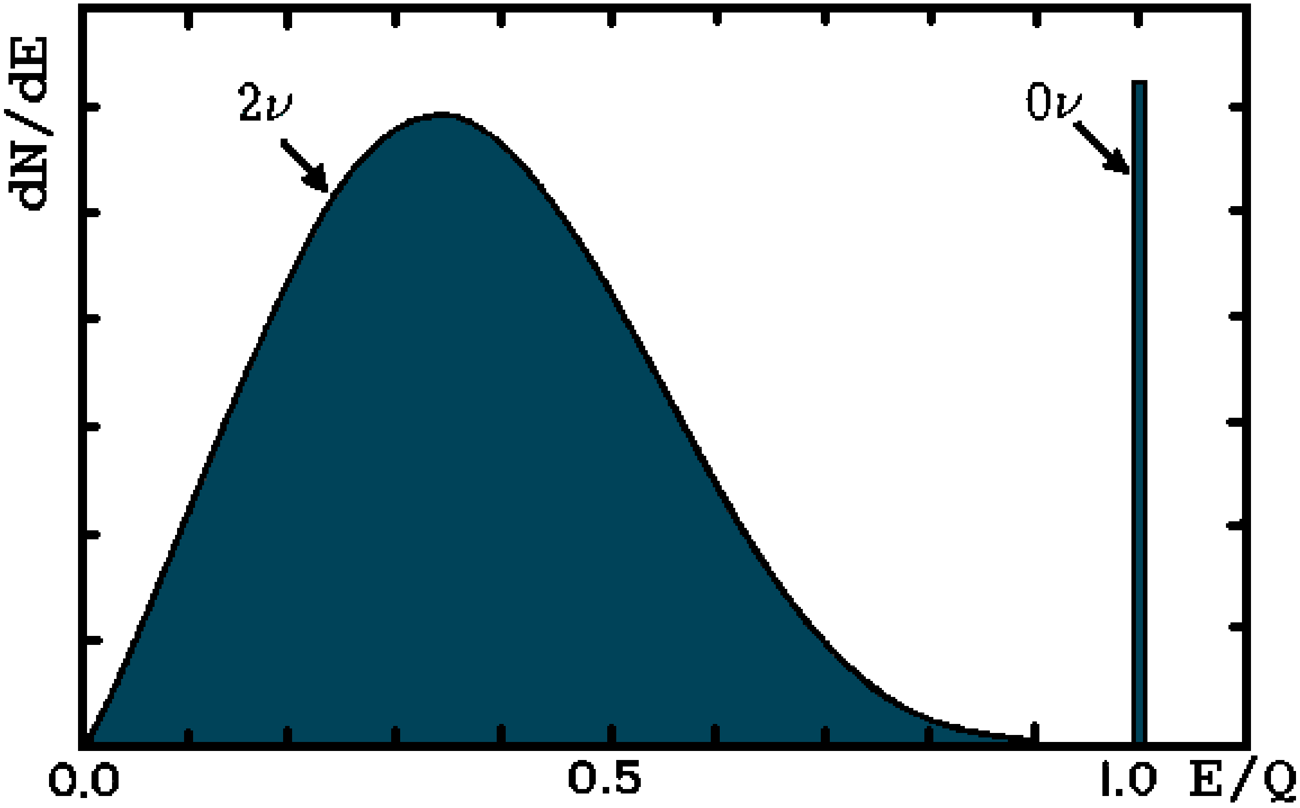
Light neutrino exchange mechanism



- Process requires that the neutrino must be its own antiparticle and must flip helicity.
- Implies that neutrinos must be **Majorana** and have **mass**

0vββ: Signal

- Measure the sum of the energy of the two electrons.
- The signal for 0vββ is a line at $Q_{\beta\beta}$ for the isotope:



0νββ: Extracting neutrino mass

- The half-life for 0νββ is related to neutrino mass by:

$$\left[T^{0\nu}_{1/2}\right]^{-1} = G^{0\nu}(Q_{\beta\beta}, Z)\left|M^{0\nu}\right|^2 \langle m_{\beta\beta}\rangle^2$$

where $G^{0\nu}$ is the (exactly calculable) phase space

$M^{0\nu}$ is the nuclear matrix element (NME)

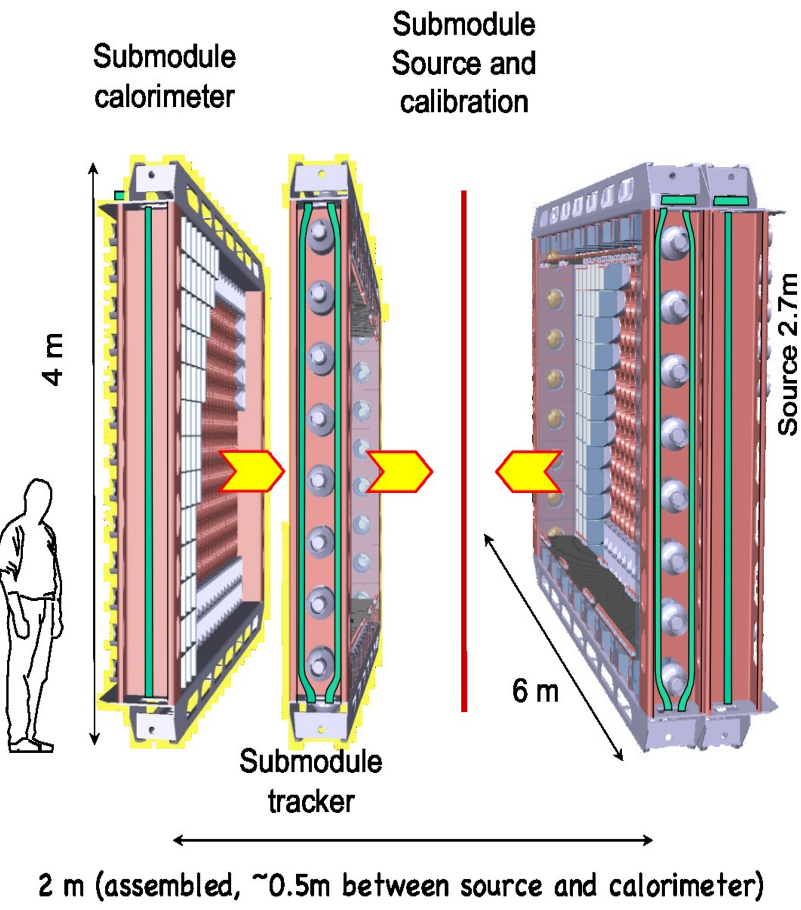
$<m_{\beta\beta}>$ is a lepton number violating parameter

- In the light-neutrino exchange mechanism, $<m_{\beta\beta}>$ is the effective Majorana neutrino mass, given by:

$$\langle m_{\beta\beta}\rangle = \left|\sum_i m_i U_{ei}^2\right|$$

The SuperNEMO Experiment

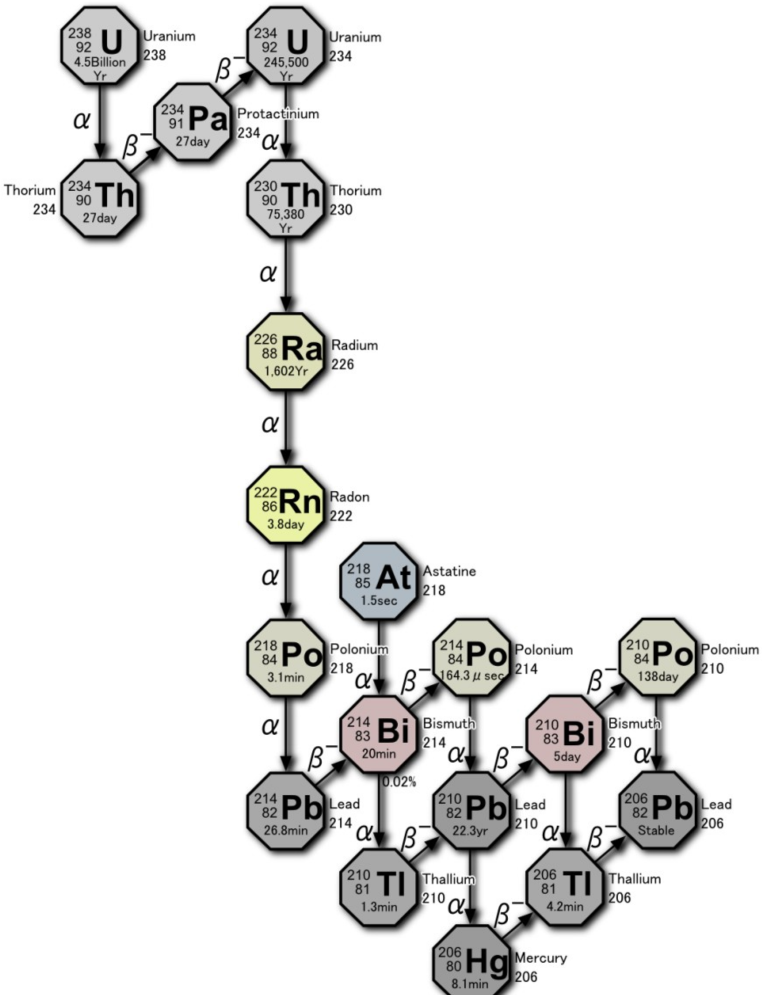
- Consists of 20 identical planar modules, each containing:



- **Source foil:** ~ 5 – 7 kg of ^{82}Se, ^{150}Nd or ^{48}Ca
- **Tracker:** Drift chamber with ~ 2000 cells in Geiger mode.
- **Calorimeter:** 500 PMTs & scintillator blocks
- Aims to study half-life up to 10^{26} yr **($\langle m_{\beta\beta} \rangle$ = 40 - 100 meV)**
- Employs a 'smoking-gun' approach:
  - Particle identification, event topology reconstruction & strong background rejection
  - But poorer energy resolution compared to experiments where detector is also source

Radon R & D: Background

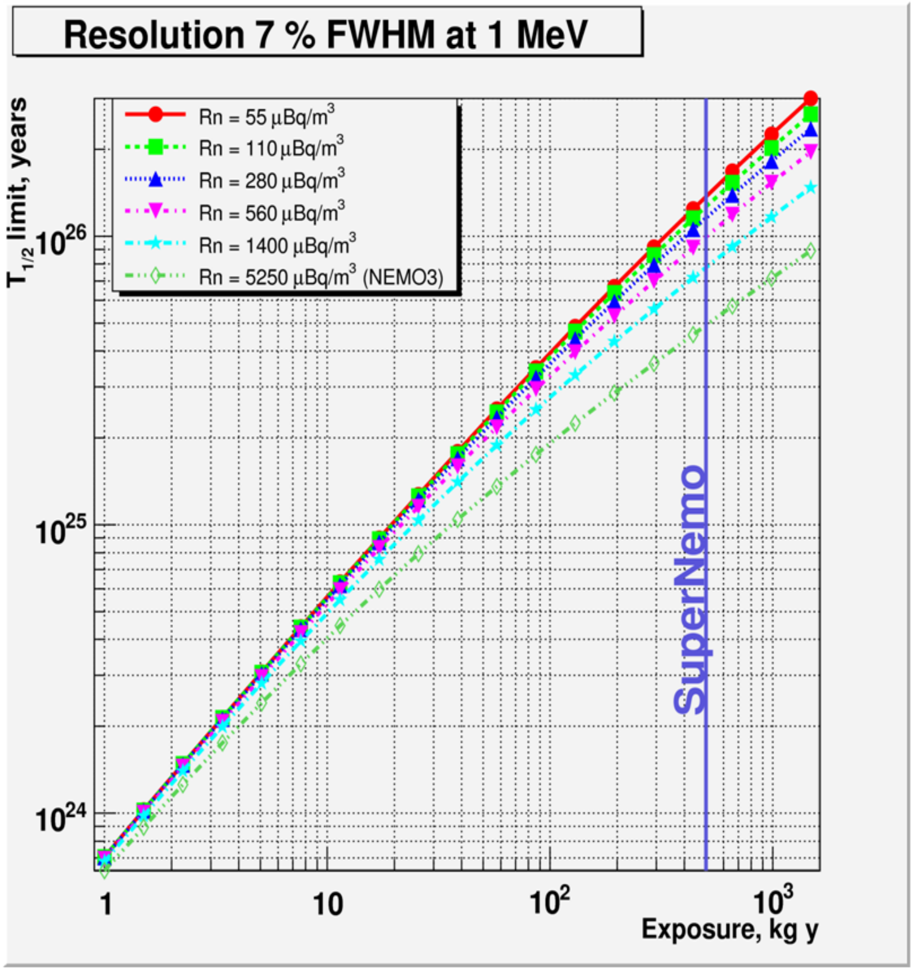
- All materials contain small traces of uranium and thorium and their decay products, one of which is radon.



- These radon atoms can diffuse out of the detector materials into the tracking volume.
- The alpha decay of radon is not easily confused with beta decay
- But the decay of ^{214}Bi is more problematic (Q_β = 3.27 MeV)

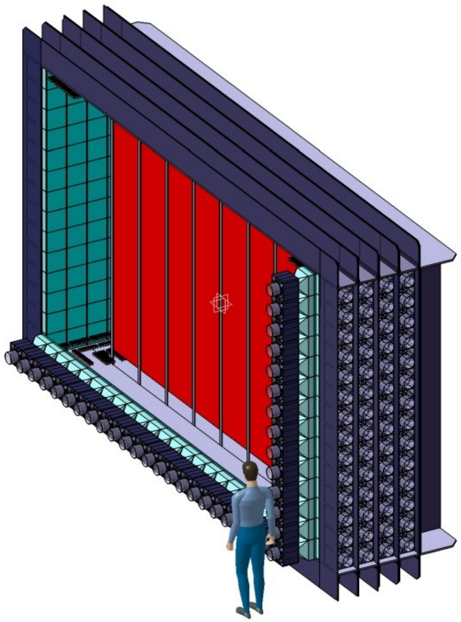
Radon R & D: Target Level

- Studies suggest that we need the radon background in the tracker to be < 0.15 mBq/m^3 to achieve the target sensitivity.



- Good radon detectors (electrostatic collection) are typically sensitive to 1 mBq/m^3.
- We need to measure down to 0.15 mBq/m^3 so we need to use a different technique.

Radon Concentration Line: Concept



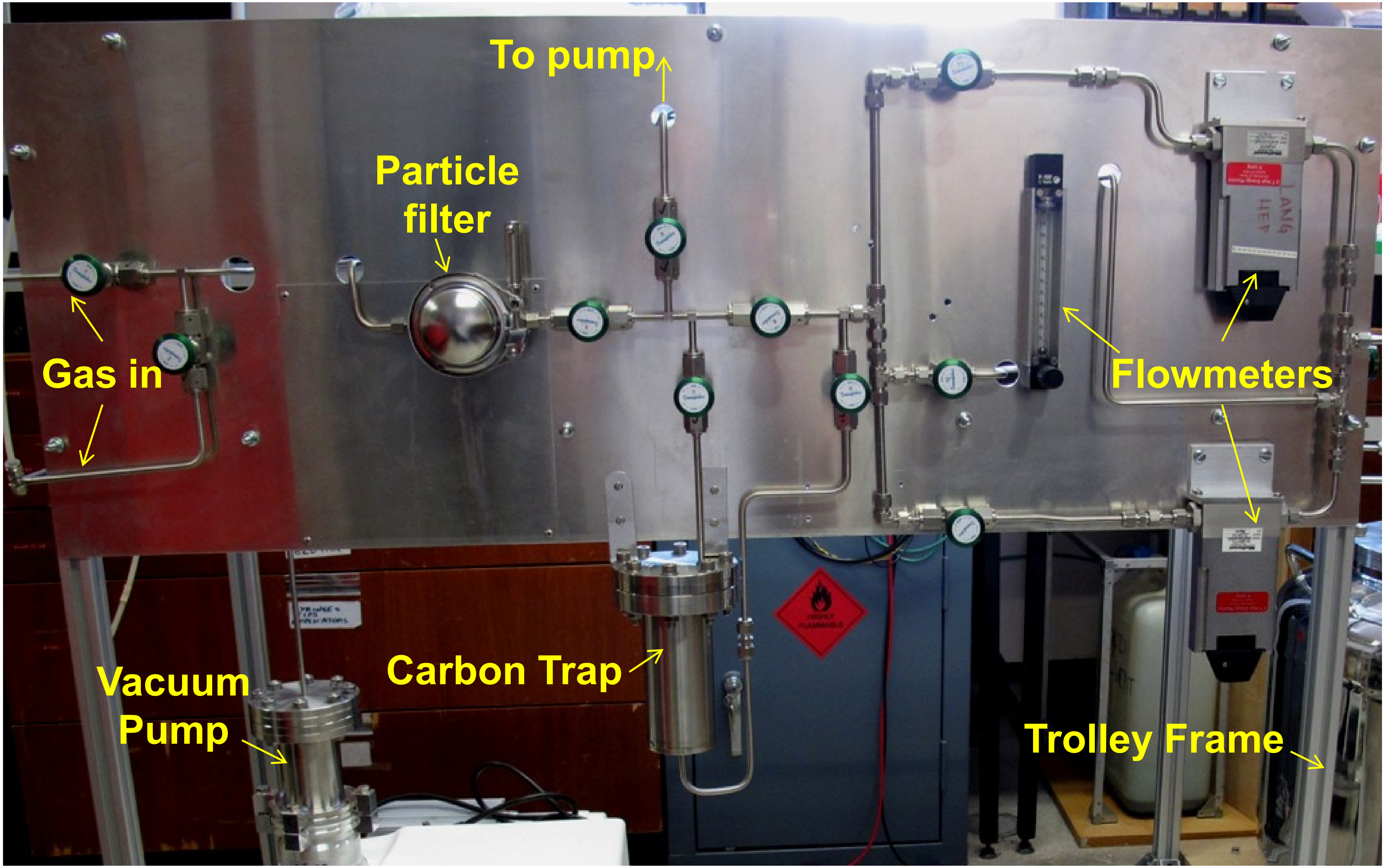
SuperNEMO tracker sub-module (~ 4m^3)

Radon concentration line

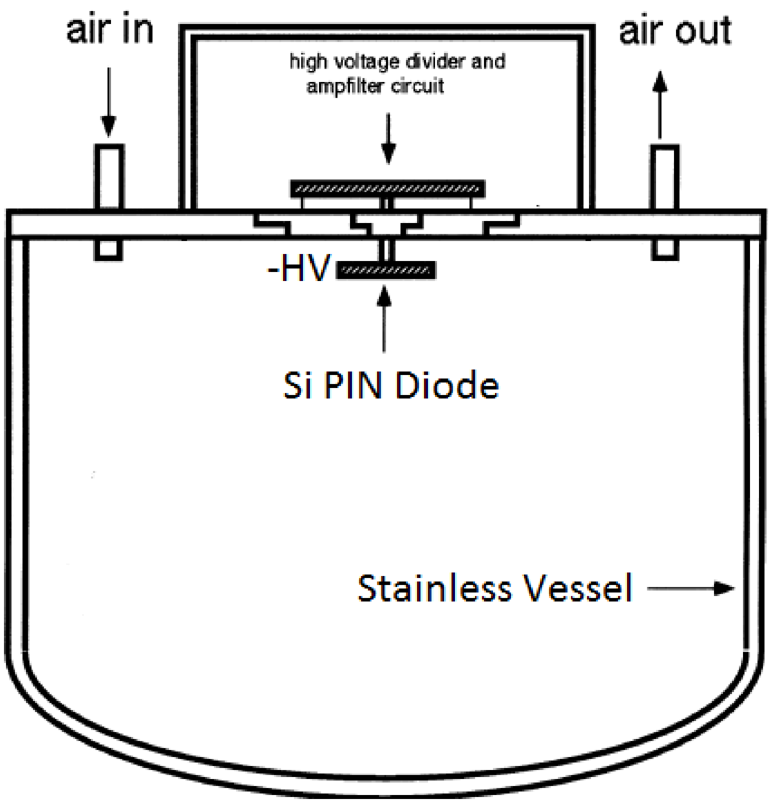
Electrostatic detector

- Gas from the tracker is pumped through a cooled ultra-pure carbon trap and the ^{222}Rn in the gas is adsorbed.
- The concentrated sample is then heated and transferred to an electrostatic detector via helium purge.

Radon Concentration Line: Real Life

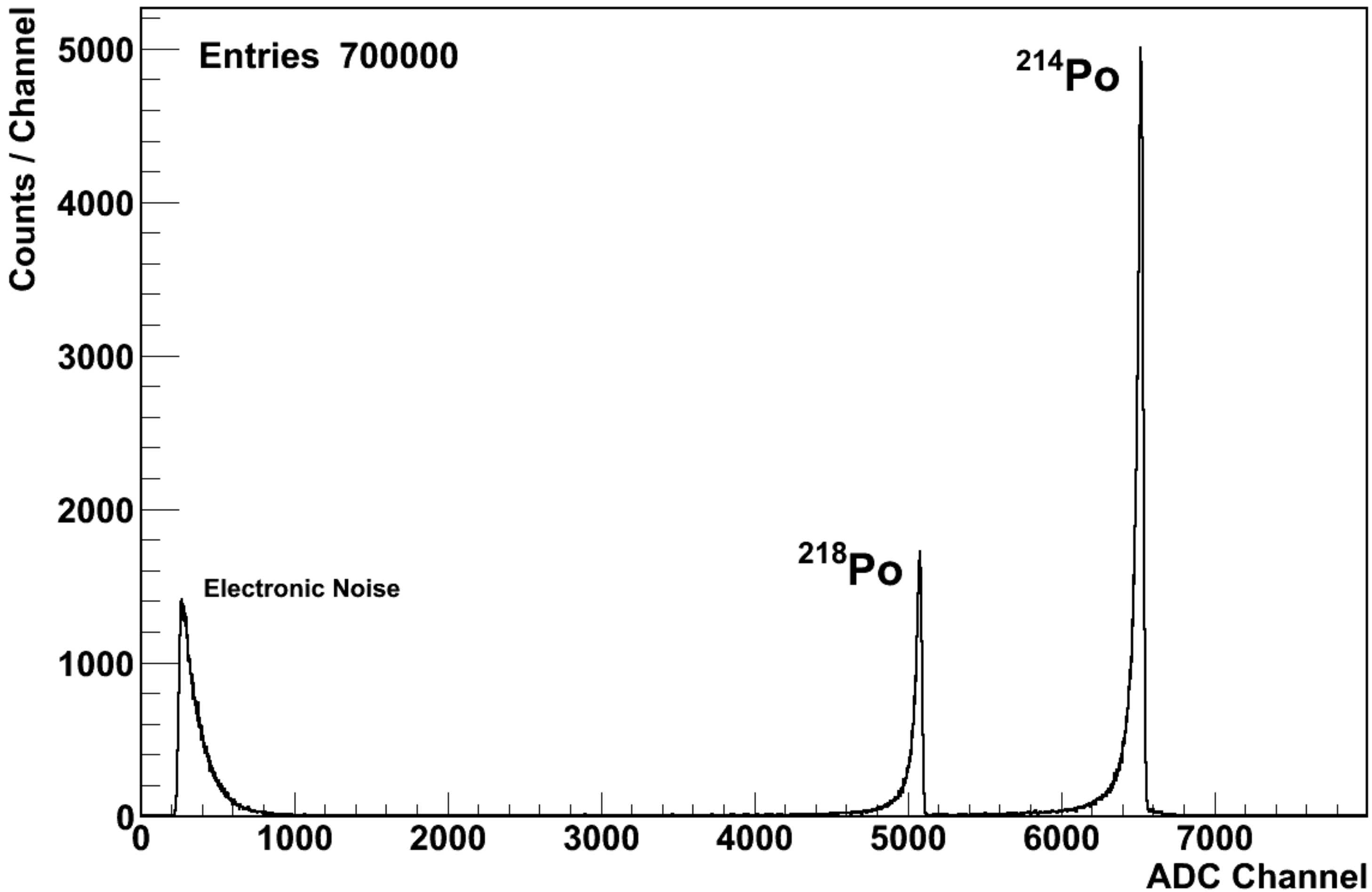


Electrostatic Detector: Principle of Operation



- ^{222}Rn is pumped into the vessel where it decays.
- Daughters of ^{222}Rn decay are mostly positive ions.
- These ions collect on the PIN diode due to the applied negative HV.
- Once on the photodiode, they decay and their alphas can be identified by the energy deposited.
- ^{214}Po is the most commonly used isotope for measuring ^{222}Rn.

Electrostatic Detector: Radon Spectrum



- Peaks from ^{218}Po (6.1 MeV) and ^{214}Po (7.9 MeV) are visible and have excellent resolution

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