Radon Assay Facility at University of Windsor for nEXO Experiment

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University of Windsor
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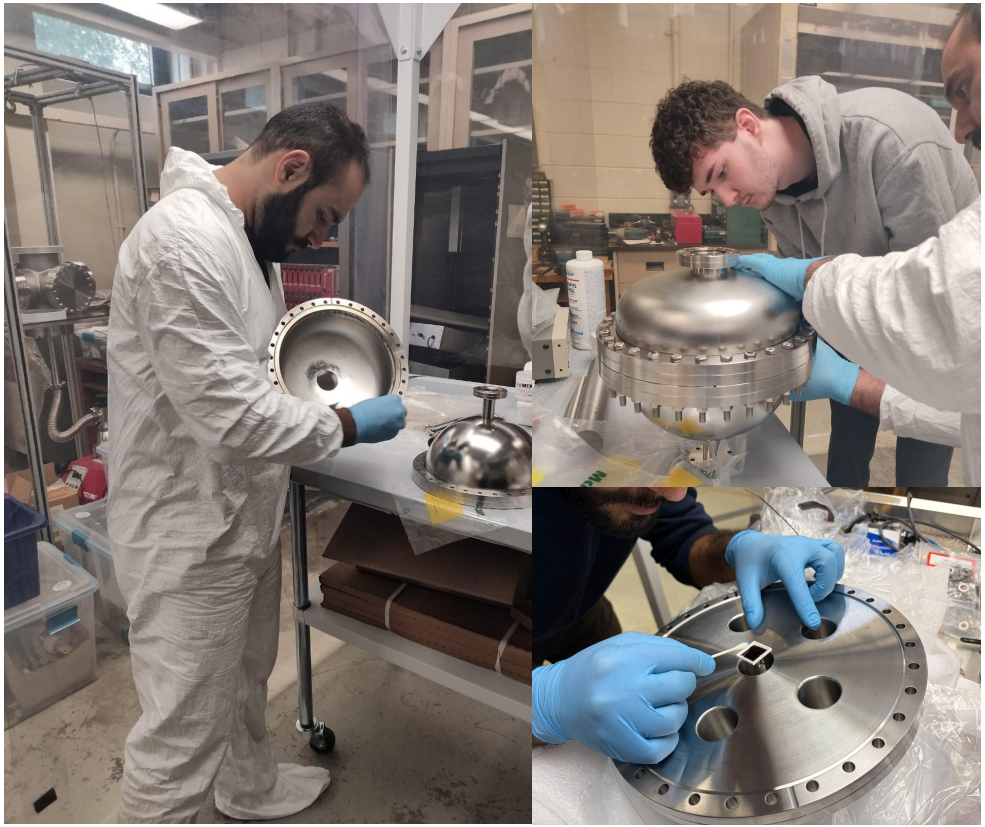
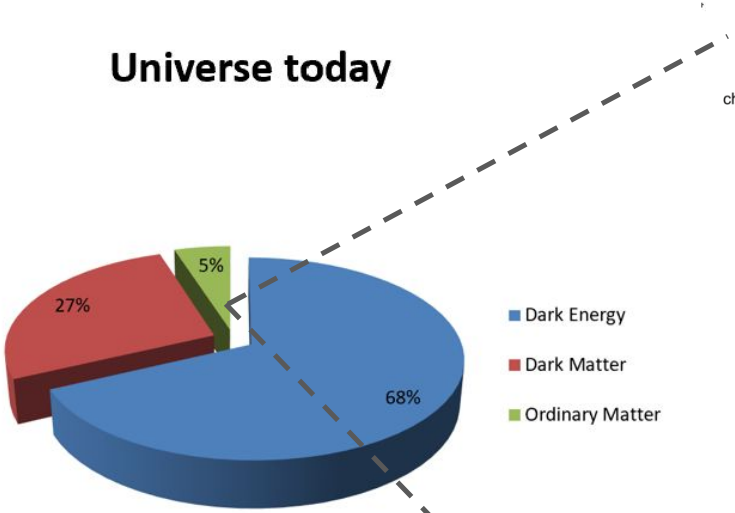
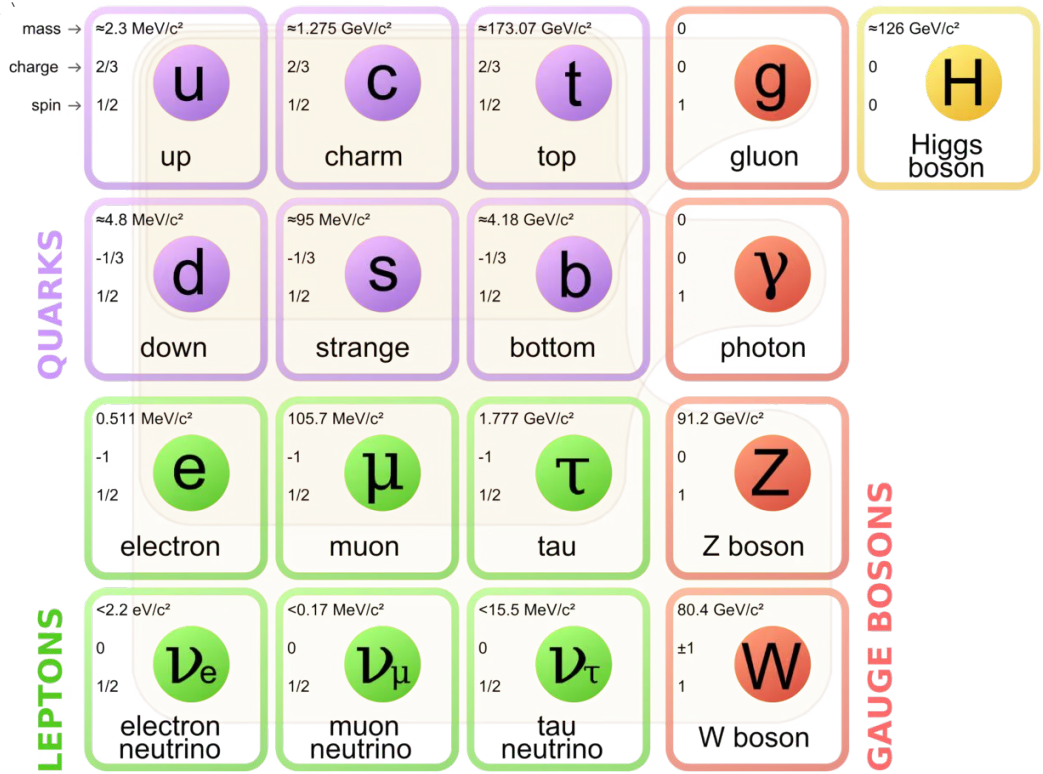
Outline

- Physics motivation
- The nEXO experiment
- Why do we care about Radon?
- Radon facility at UW
- Future work



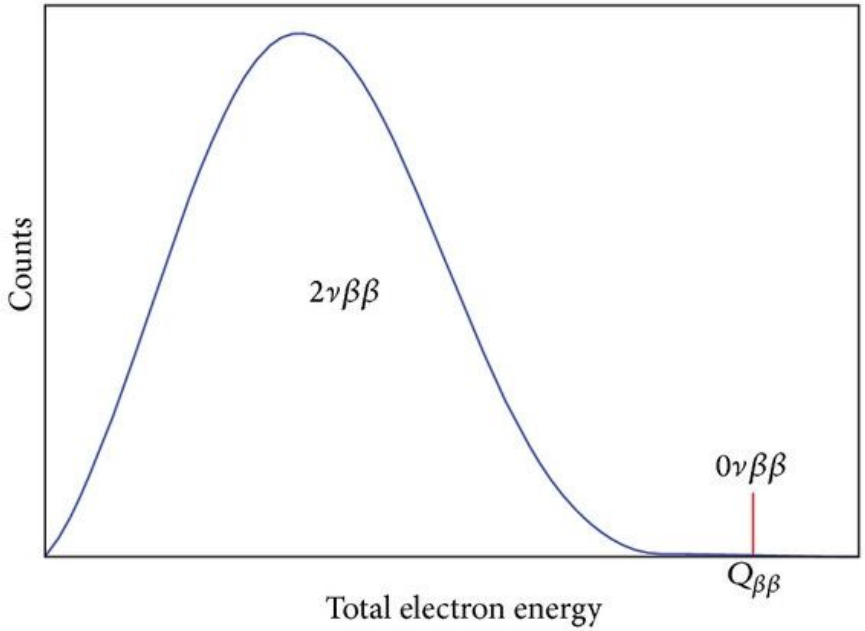
Physics motivation (Why neutrinos are interesting?)



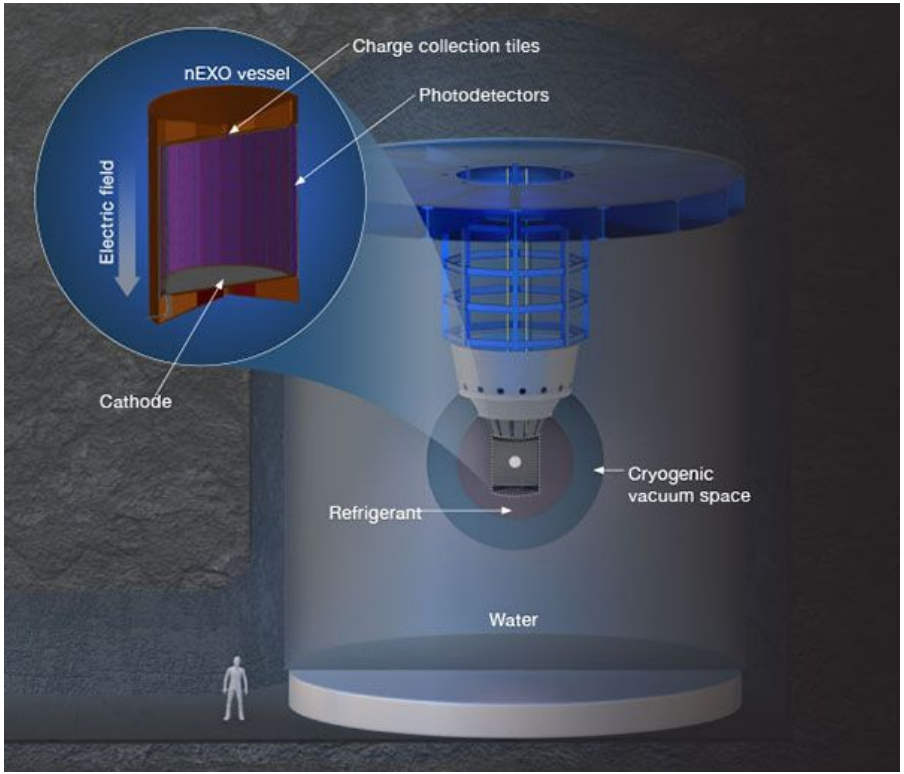


Neutrinoless double beta decay (0νββ)

- Hypothetical decay only if neutrinos are Majorana (own antiparticle)
- 0νββ : $^{136}Xe \rightarrow {}^{136}Ba + 2e^-$
- Q-value: 2.458 MeV
- Different from 2νββ



The nEXO experiment

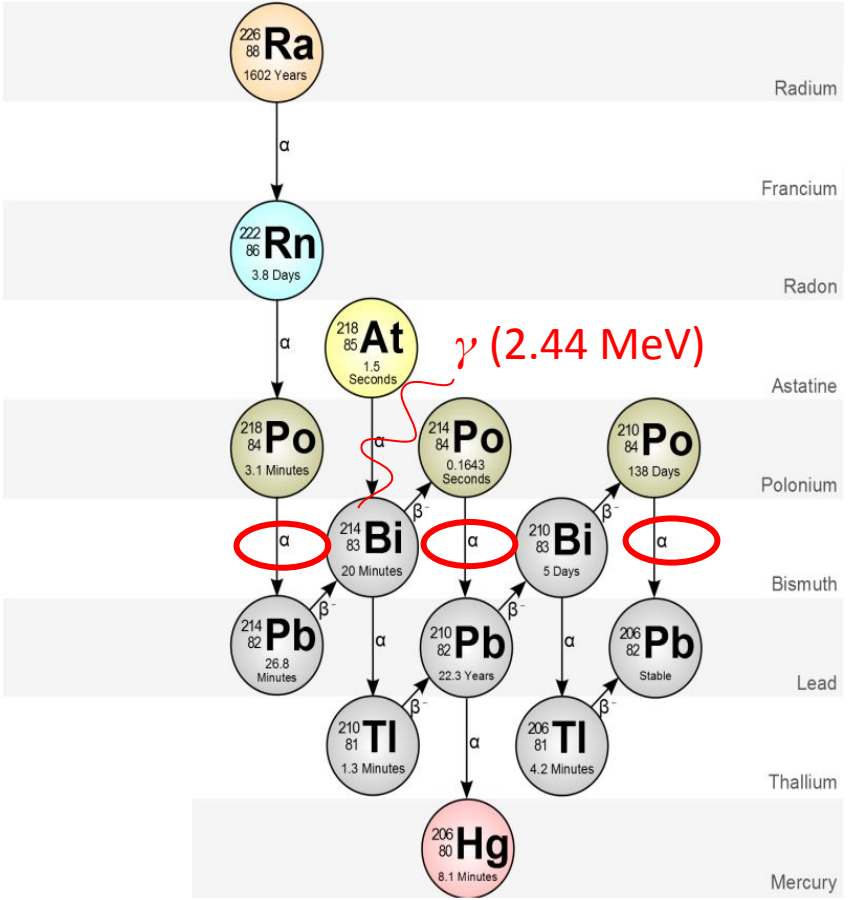


- Probe neutrino masses
- nEXO:proposed experiment, sensitivity of $T_{1/2} > 10^{28}$ years
  -age of universe is 10^{10} years-
- nEXO/XLZD: liquid xenon TPC technology

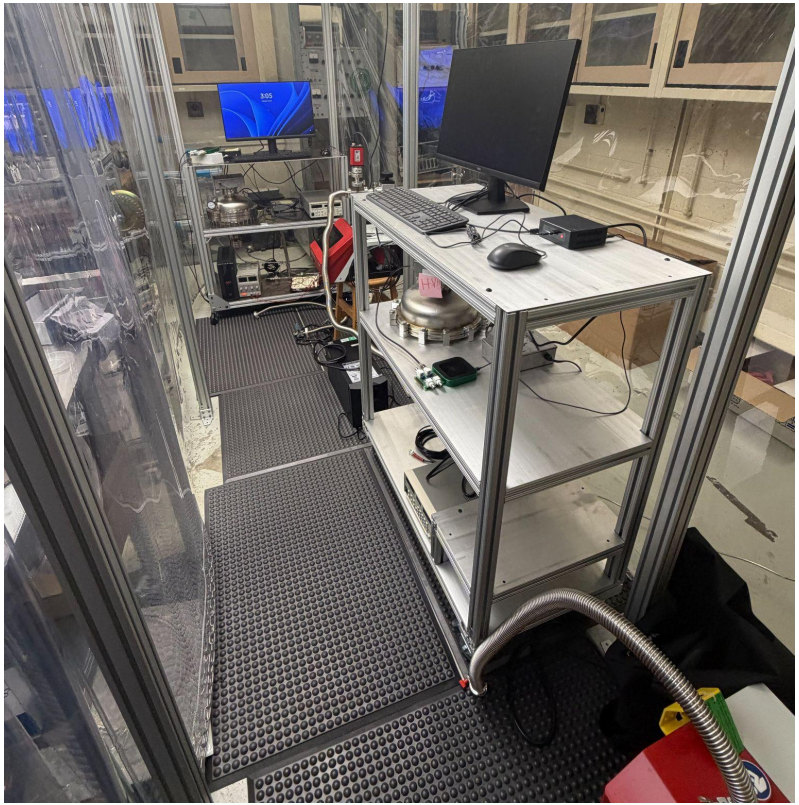
DOI: https://doi.org/10.1103/PhysRevC.97.065503

Why do we care about Radon?

- Radium is long lived ($T_{1/2}$=1602 y)
- Radon is noble gas, xenon purification via noble gas
- Q-value of 0νββ for ^{136}Xe coincide with ^{214}Bi gamma
- Alpha-n (**α**-n) reaction may produce n-capture ^{137}Xe (β)

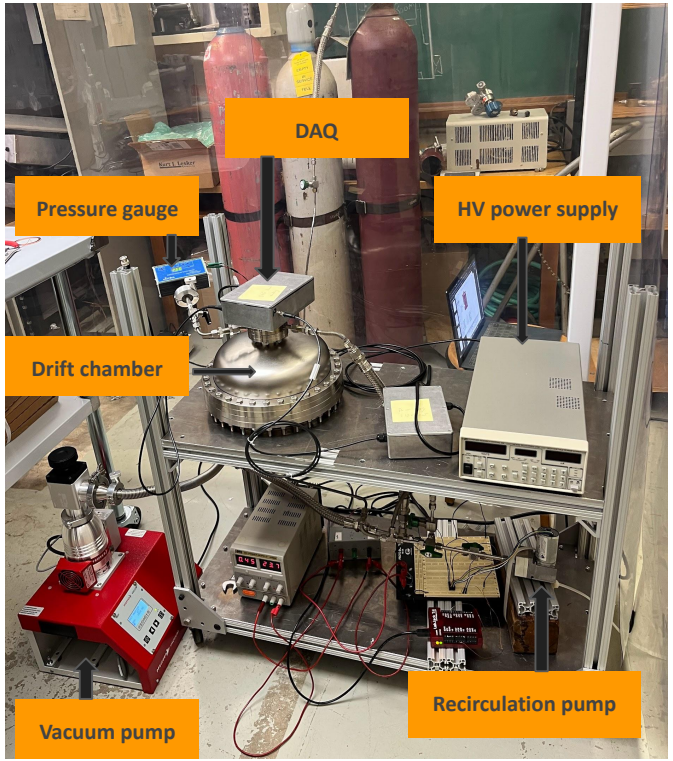


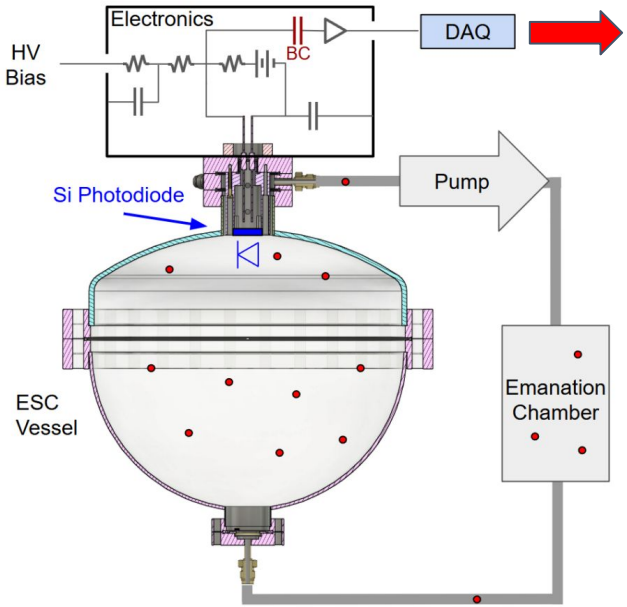
Radon assay facility at University of Windsor

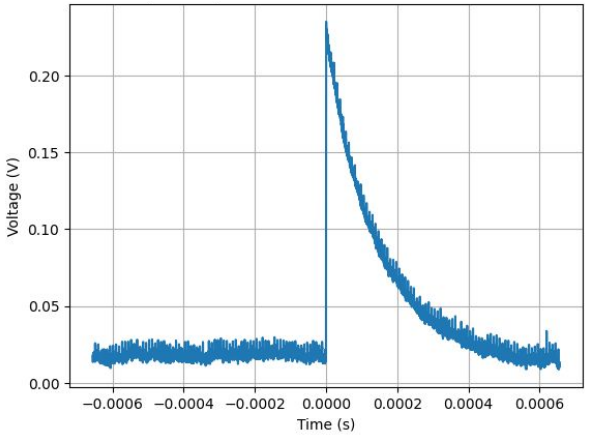


- Building three electrostatic counter for radon assay
- ESC is alpha spectrometry of radon progeny
- ESC is state of the art technology, sensitive to 10s of μBq, recirculation system

How does an electrostatic counter work?







Background preliminary results

- We ran different background runs for both custom-spherical and hemispherical ESCs
- In first runs there were leaks due to bad weldings
- Once fixed, backgrounds reduced from 1000 µBq (20,000 uBq) to <400µBq (800µBq) for the hemispherical ESC (custom-spherical ESC)
- Comparable to literature 197µBq (DOI:2504.15464)

ESC detection efficiency

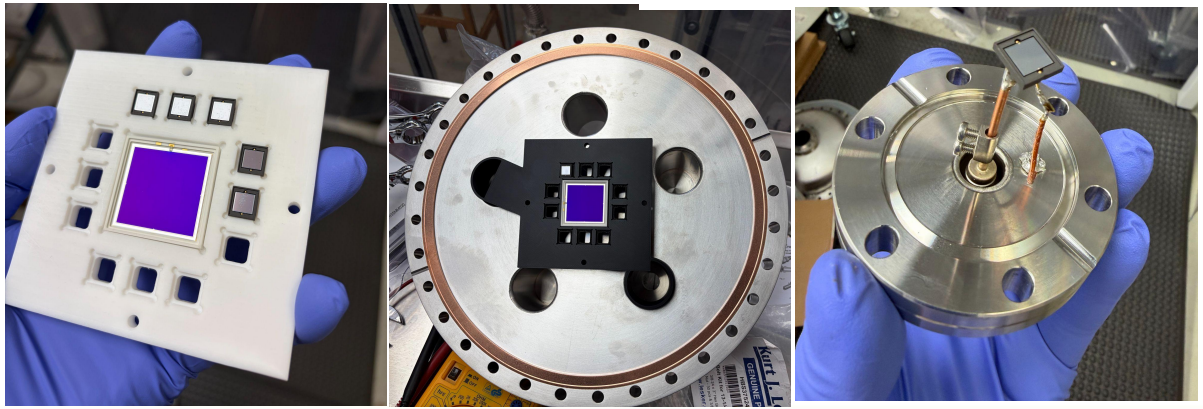
$$\varepsilon_{Detection} = f_{\alpha} \times f_{S} \times f_{E} \times f_{V}$$

Due to volume sharing

88% ion in air
From Rn decay

Isotopic decay
solid angle 50%

Ion collection eff.
Due to electric field
intensity and uniformity



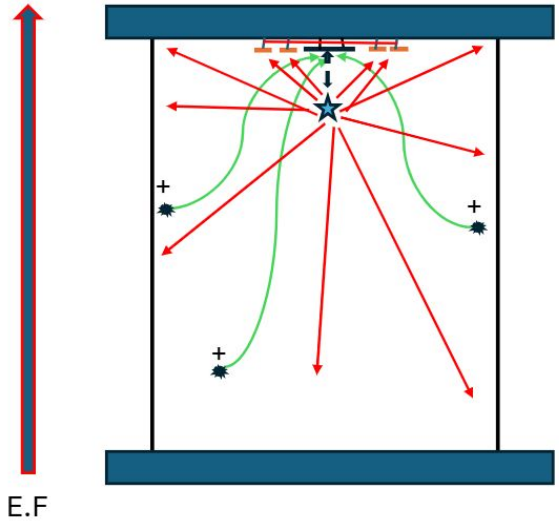
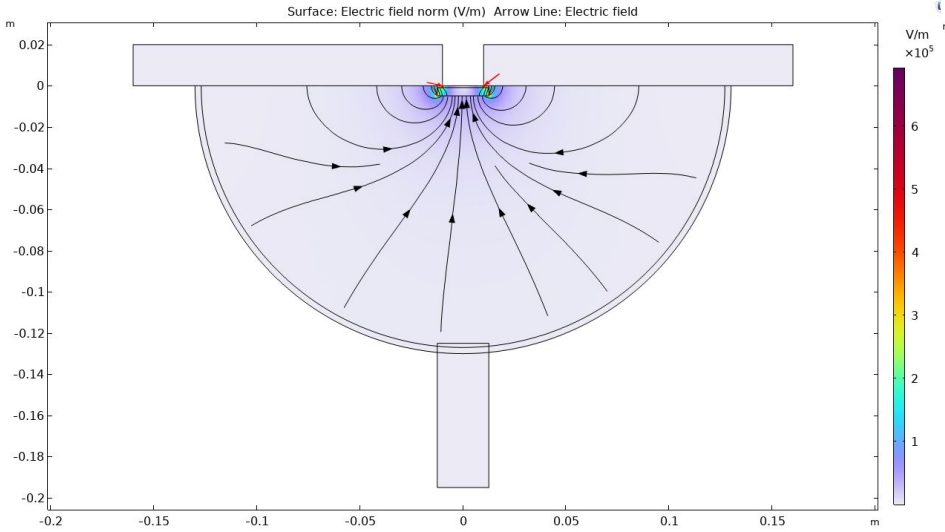
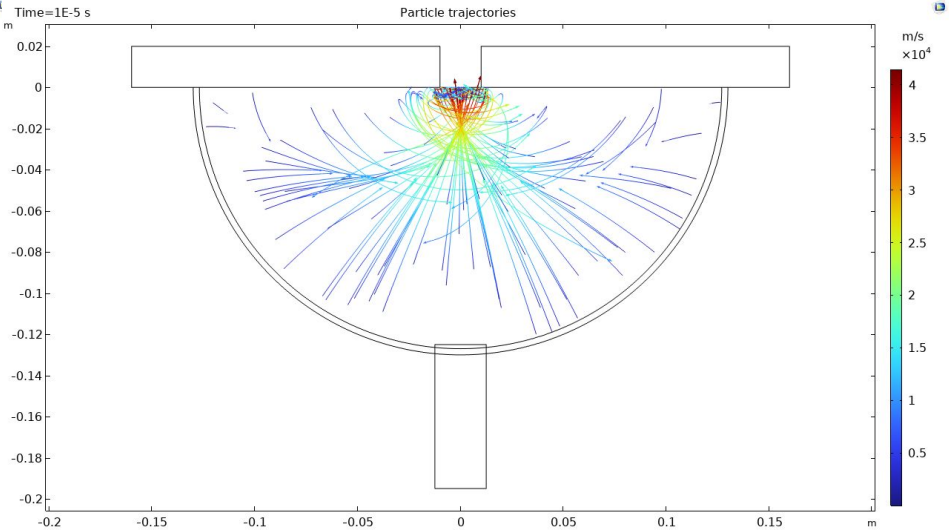


Diagram of the new ESC design with SiPM

Comsol multiphysics simulations



Electric field shape for hemispherical ESC



Positive Po218 ions trajectory inside the ESC

Future work (Licciardi group)

- ➔ Dr. Rahman (RA): measurement of vessel backgrounds and building recirculation pumps
- ➔ Dr. Shetty (postdoc): calibration procedure with ^{222}Rn source, to precisely determine the detection efficiency
- ➔ Bakr (PhD), Matthew and Akira (undergrad): R&D to increase detection efficiency

Summary

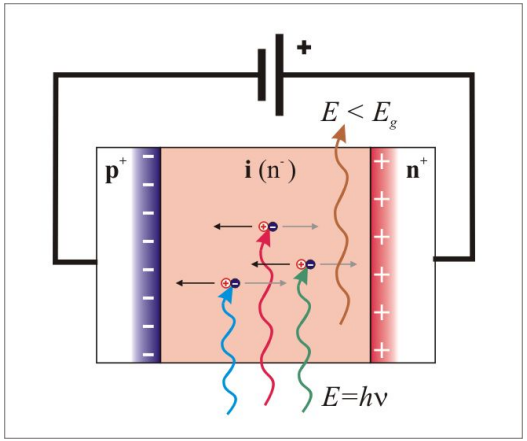
- ➔ It is important to understand radon contamination in low-background searches
- ➔ We are commissioning ultra-sensitive radon detectors at the University of Windsor, promising initial results of background levels
- ➔ On going work on calibration procedures and R&D for increase detection efficiency

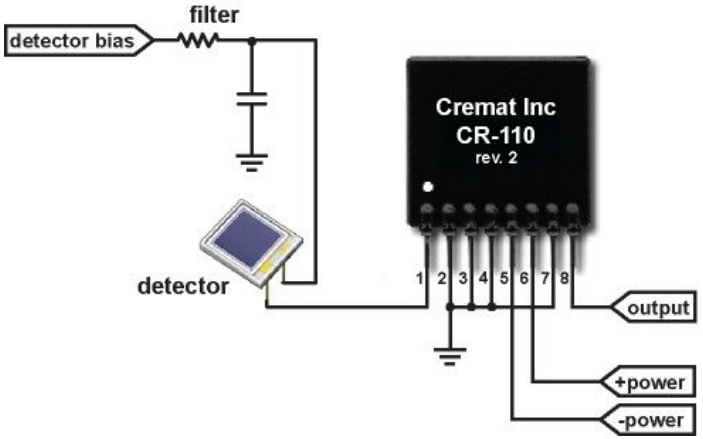
- ➔ **The radon assay facility at the University of Windsor is intended to serve as a central radon assay hub in Canada**

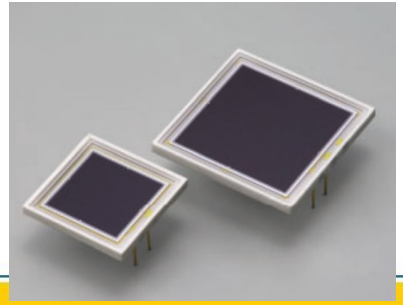
Extra slides

PIN Diode

- A PIN diode has a P-type region, a thick intrinsic (I) layer , and an N-type region
- When charged particles create electron-hole pairs, causing a current pulse
- This pulse is fed into a charge-sensitive preamplifier for energy measurement

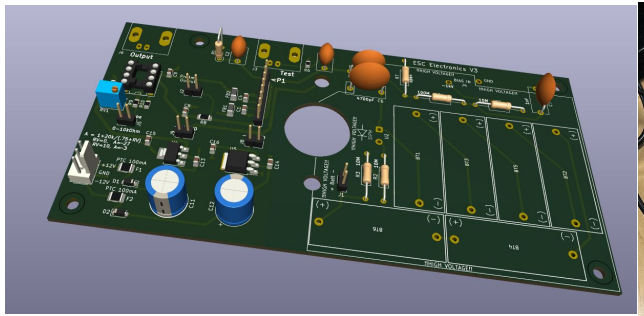


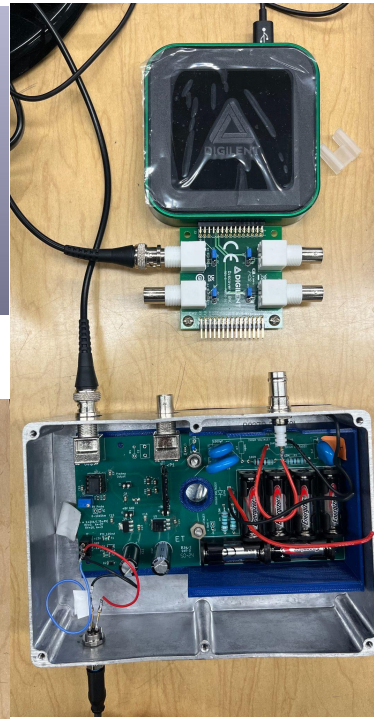


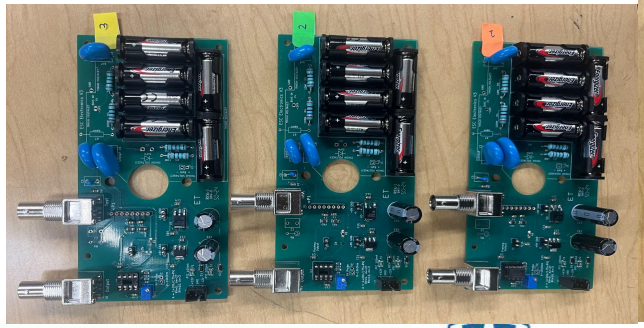


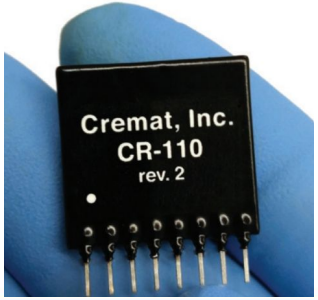
Data acquisition system (DAQ)

- Custom charge electronics board amplifies signal to ~0.3 V/MeV
- Signal is digitized using Digilent Analog Discovery 3: 125 MS/s USB Oscilloscope
- High voltage power supply for ion drifting inside the chamber









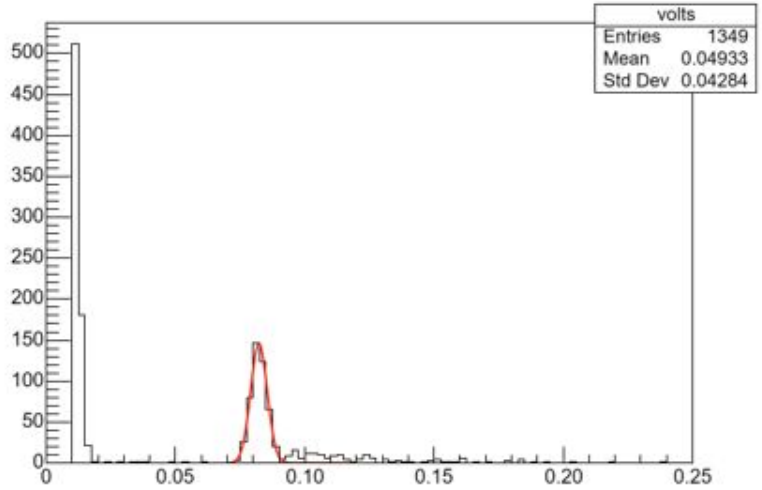
Using Cr-113 at –22C with cooled electronics the 1pe is visible

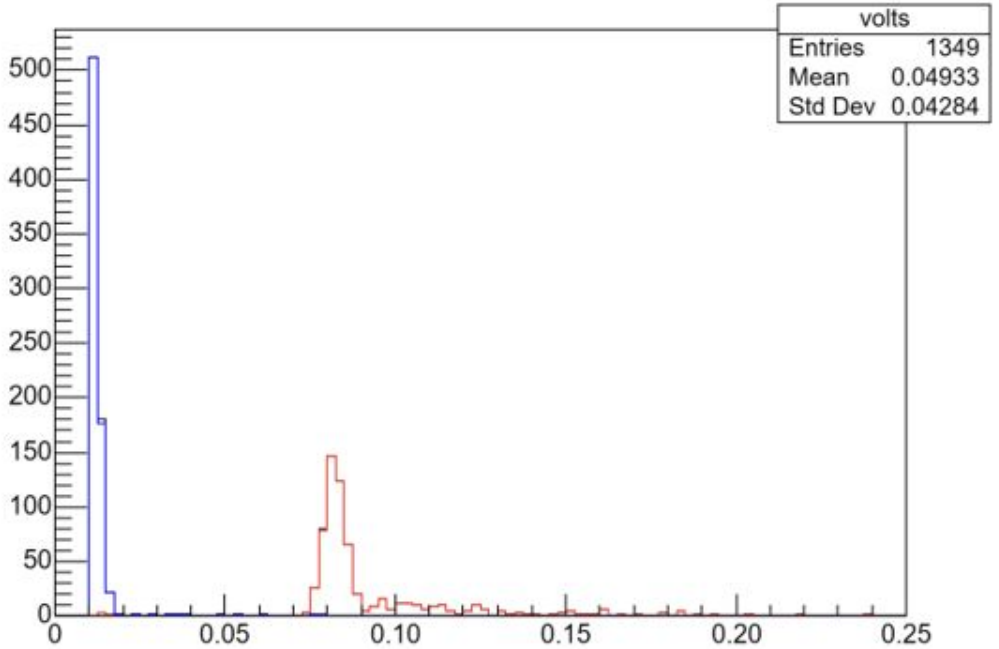
EDM=4.29953e-09 STRATEGY= 1 ERROR MATRIX ACCURATE

EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	5.82968e+02	7.90233e+01	3.19396e-02	-3.41302e-06
2	Mean	1.00067e-02	6.79470e-04	1.33930e-07	-8.77337e-01
3	Sigma	2.44090e-03	2.64435e-04	9.82731e-06	-1.16086e-02

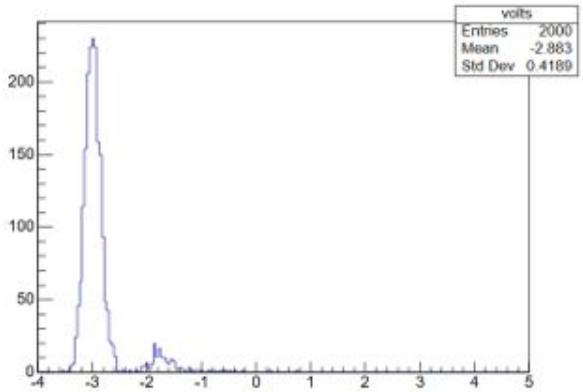
FCN=94.4262 FROM MIGRAD STATUS=CONVERGED 119 CALLS 120 TOTAL
EDM=5.87134e-07 STRATEGY= 1 ERROR MATRIX ACCURATE

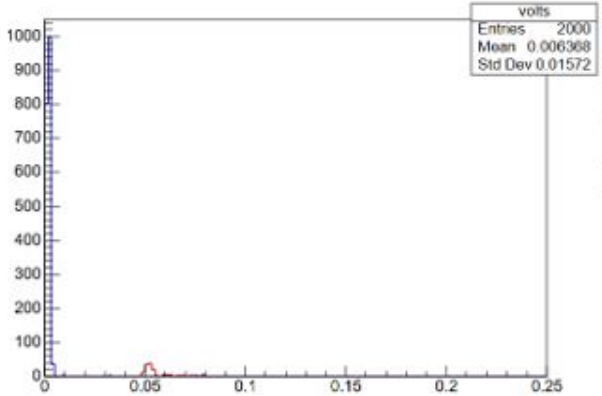
EXT PARAMETER NO.	NAME	VALUE	ERROR	STEP SIZE	FIRST DERIVATIVE
1	Constant	1.45217e+02	8.42473e+00	3.20576e-02	-9.44484e-05
2	Mean	8.22701e-02	1.51402e-04	7.11473e-07	2.81271e+00
3	Sigma	3.20726e-03	1.13097e-04	2.54360e-05	3.24012e-02

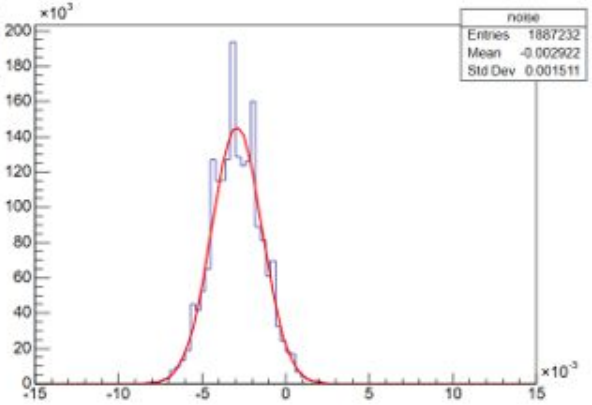




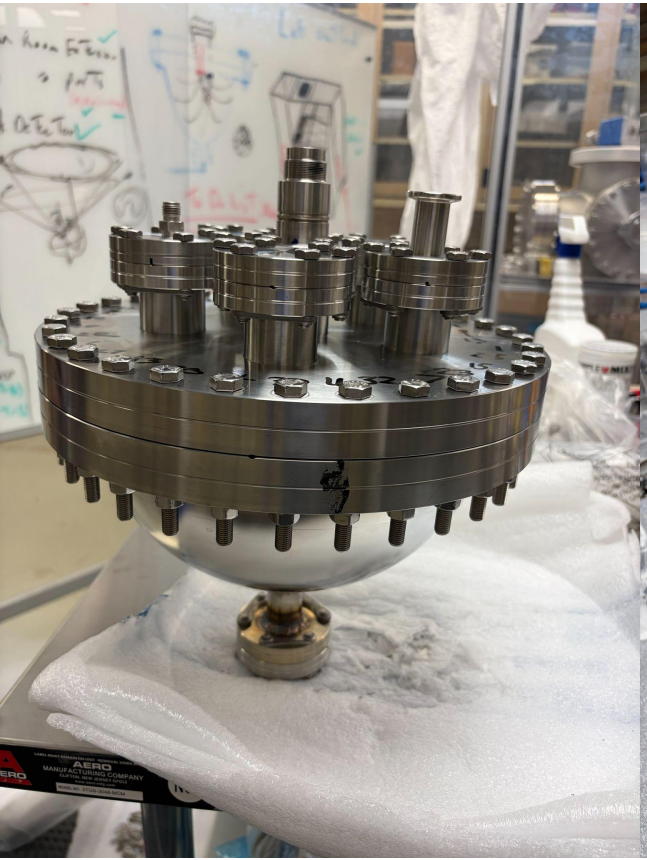
One MPPC, CR-112, 50 ns shaper, max fine gain, 55.71 V, -38 C, trigger 1 mV








Experiments
Assembly
Clean-Room


AERO
MANUFACTURING COMPANY