

# Hardware R&D Towards DARWIN: Construction of a Radon Emanation Chamber

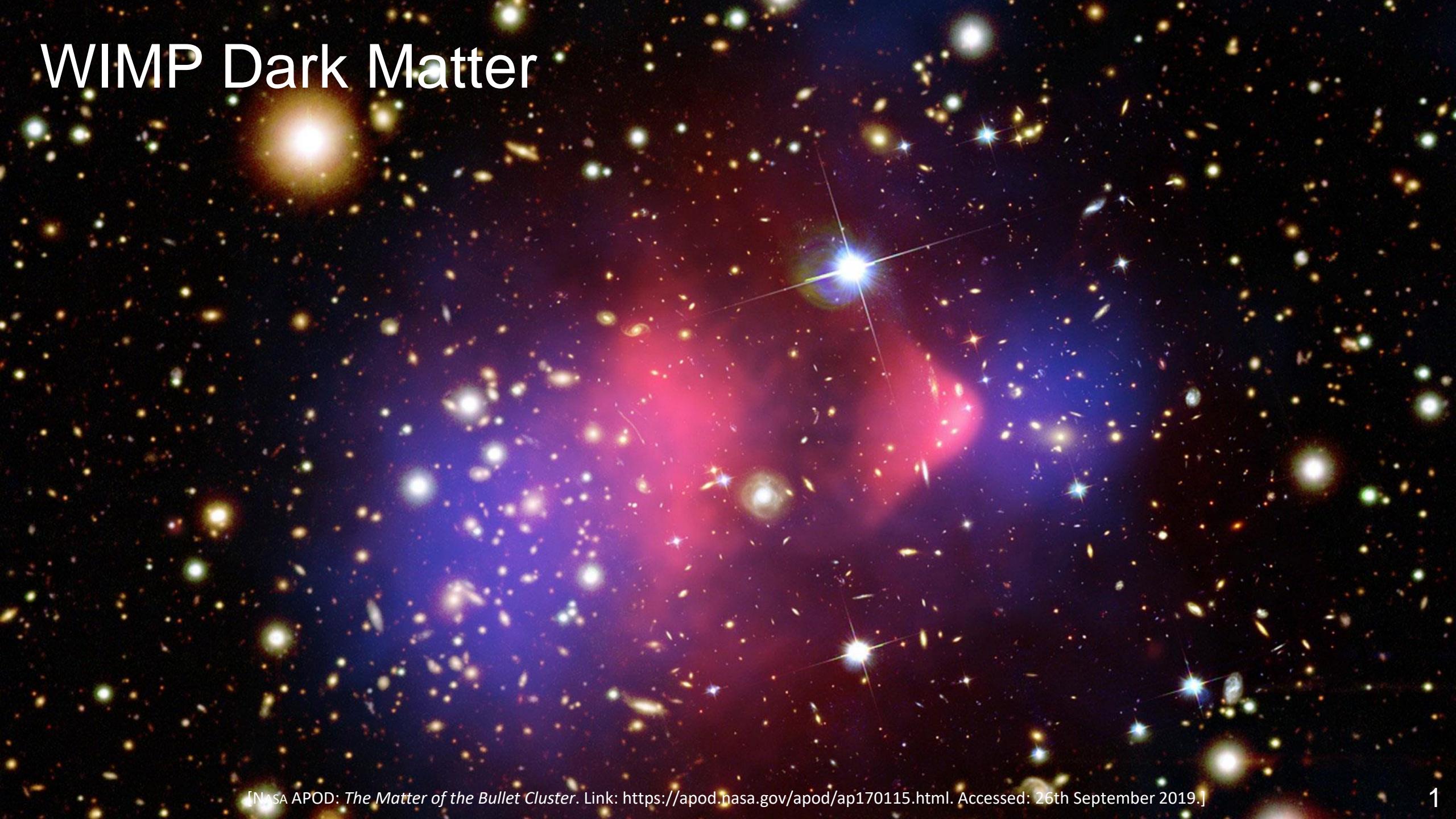
Daniel Baur

Astroparticle School 2019

5<sup>th</sup> October 2019, Obertrubach-Bärnfels



# WIMP Dark Matter



[NASA APOD: *The Matter of the Bullet Cluster*. Link: <https://apod.nasa.gov/apod/ap170115.html>. Accessed: 26th September 2019.]

# Radon Induced Background in DARWIN

# DARWIN the Ultimate WIMP Detector

- **collaboration:** ~150 members

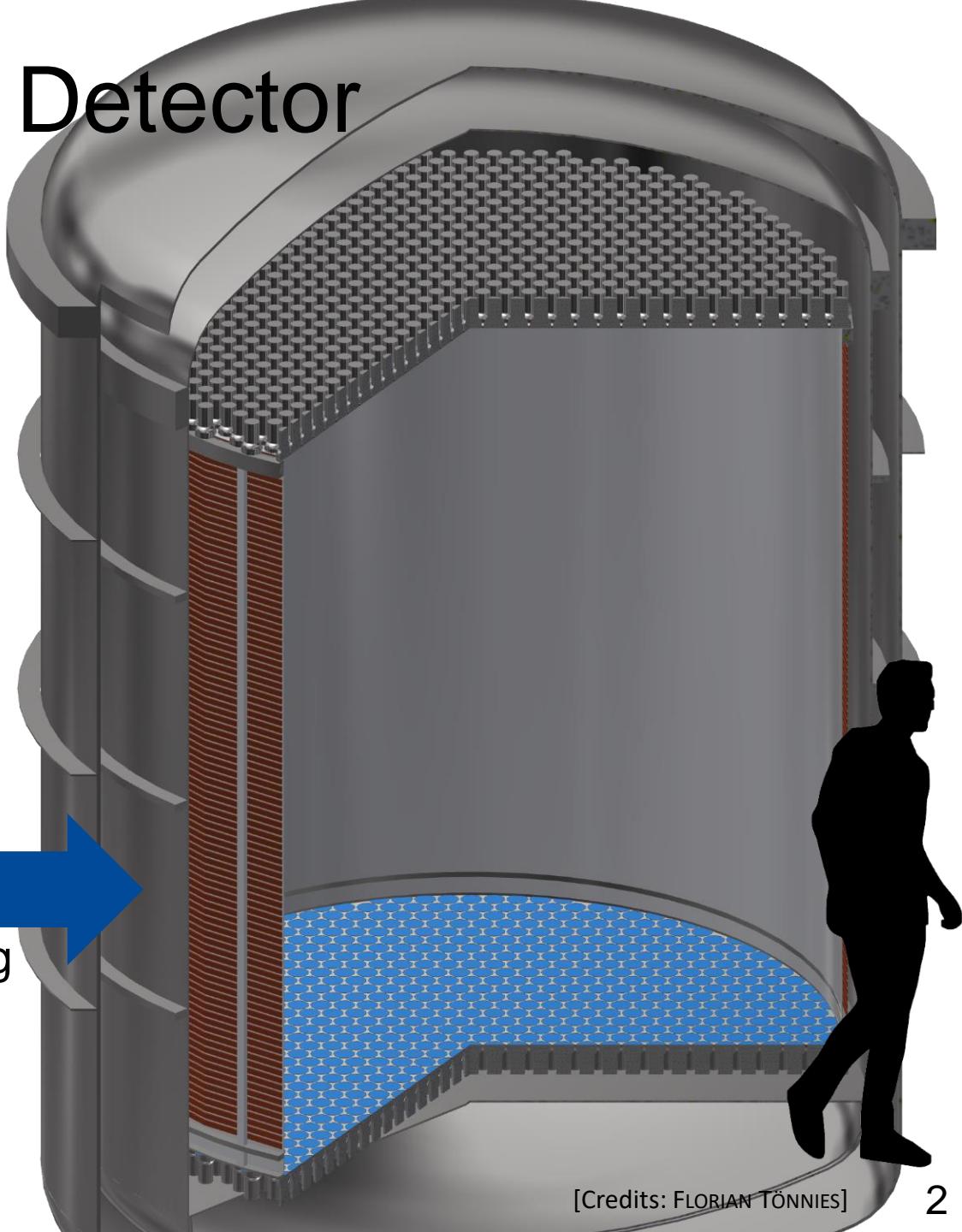
- **detector:** dual-phase LXe TPC

- **physics channels:**

- WIMPs
- neutrinoless double beta decay
- other rare interactions



- **challenges:** radon induced background



[Credits: FLORIAN TÖNNIES]

# DARWIN the Ultimate WIMP Detector

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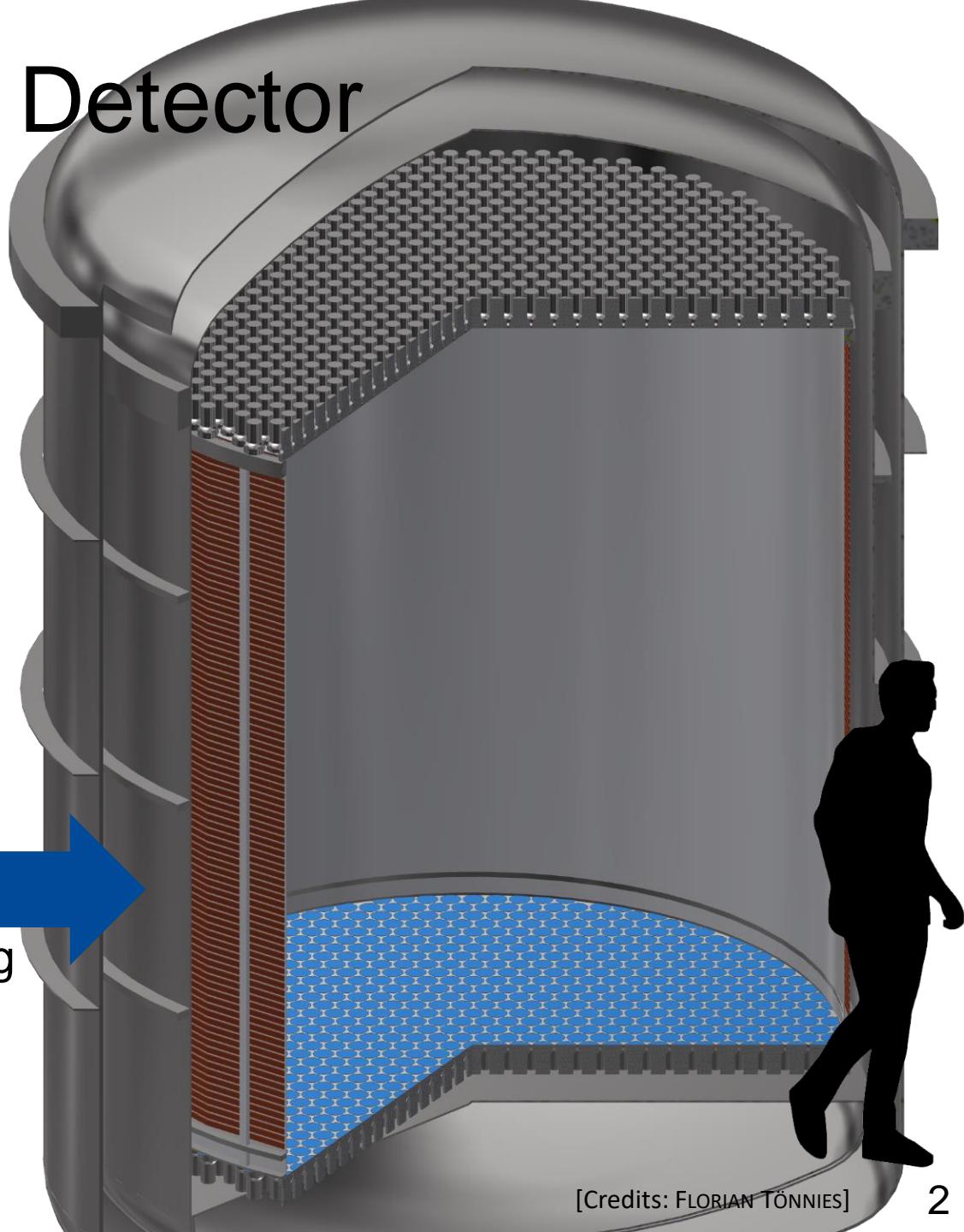
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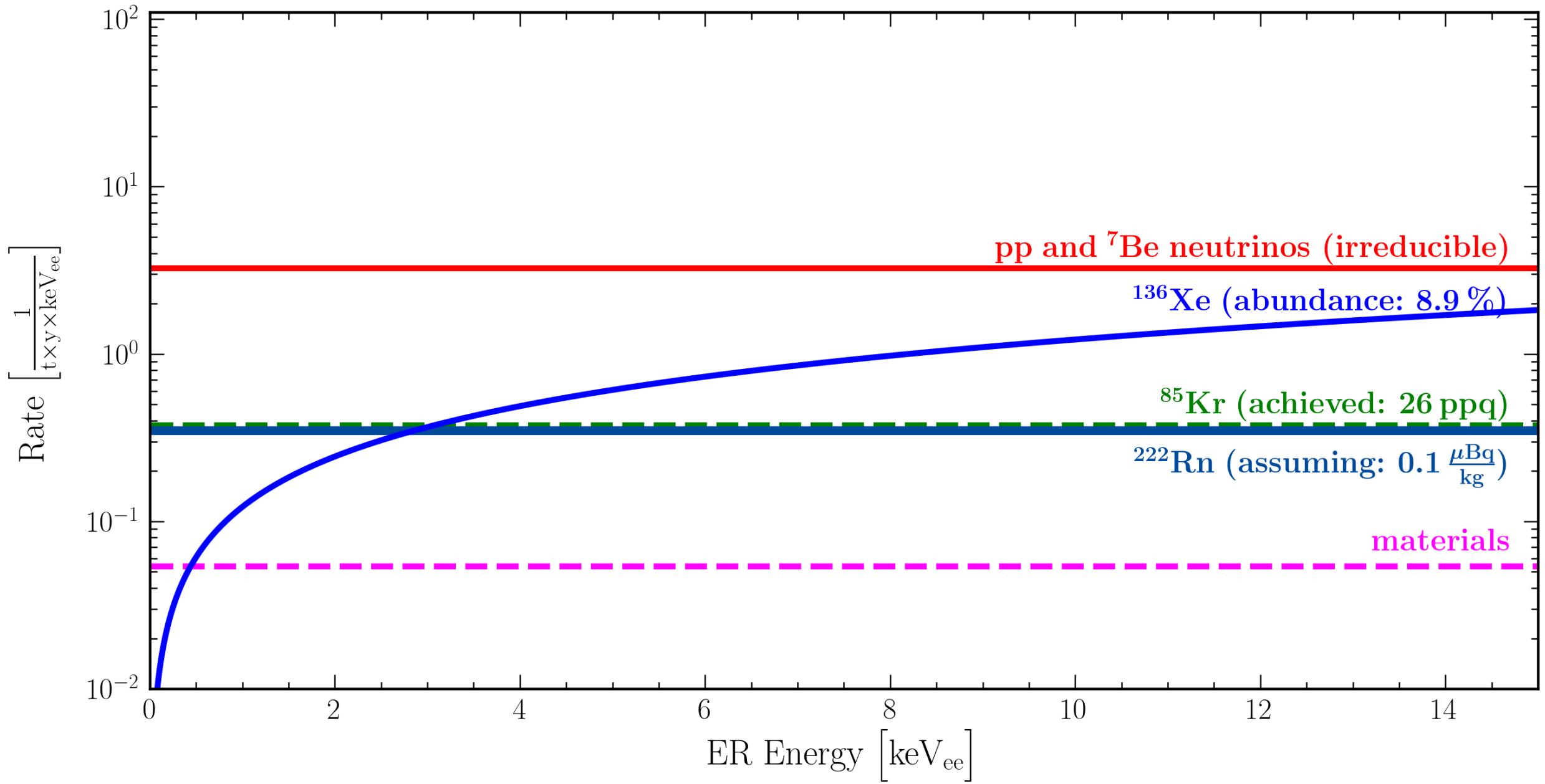
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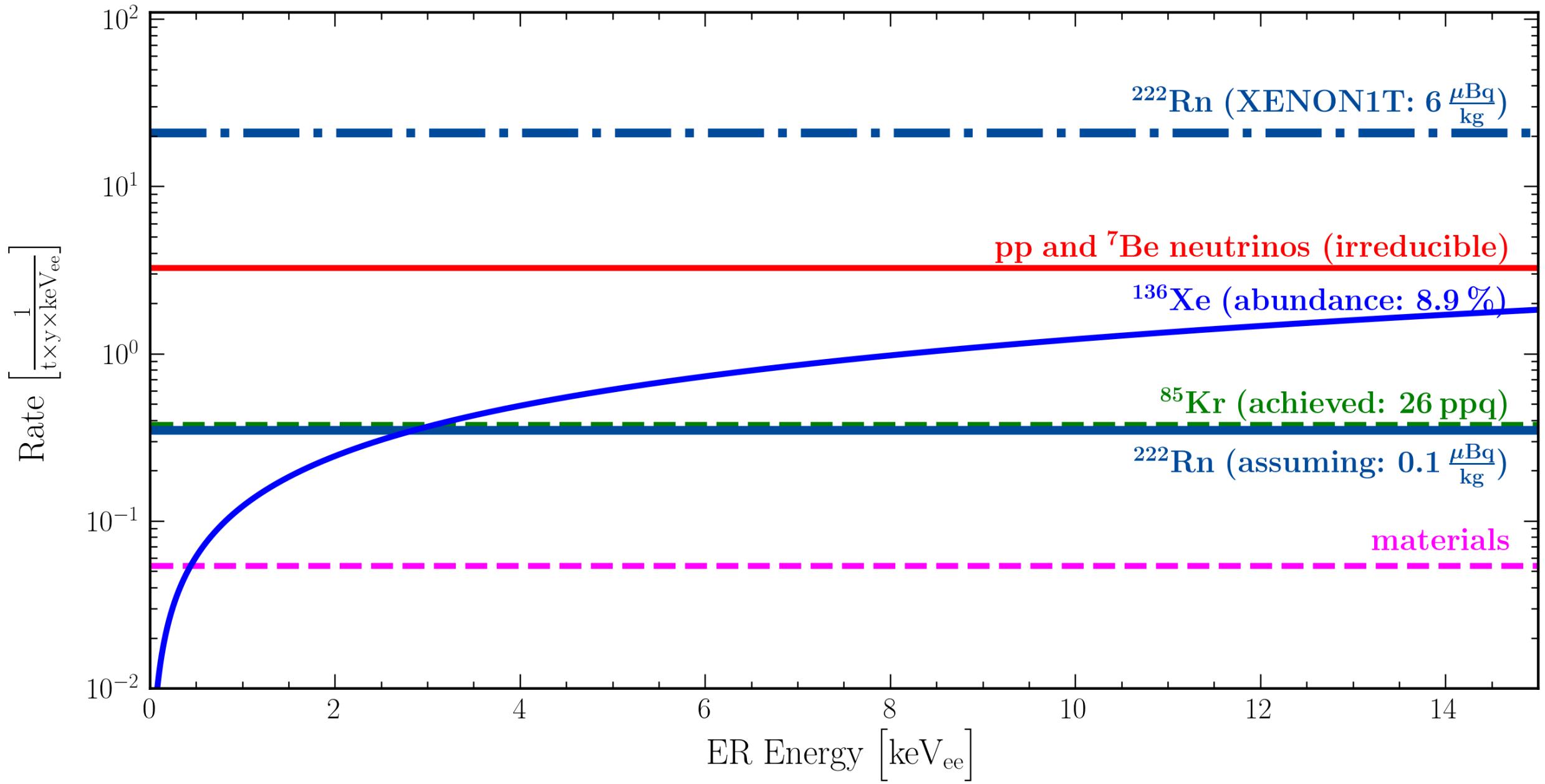
- **challenges:** radon induced background



# ER Background in DARWIN



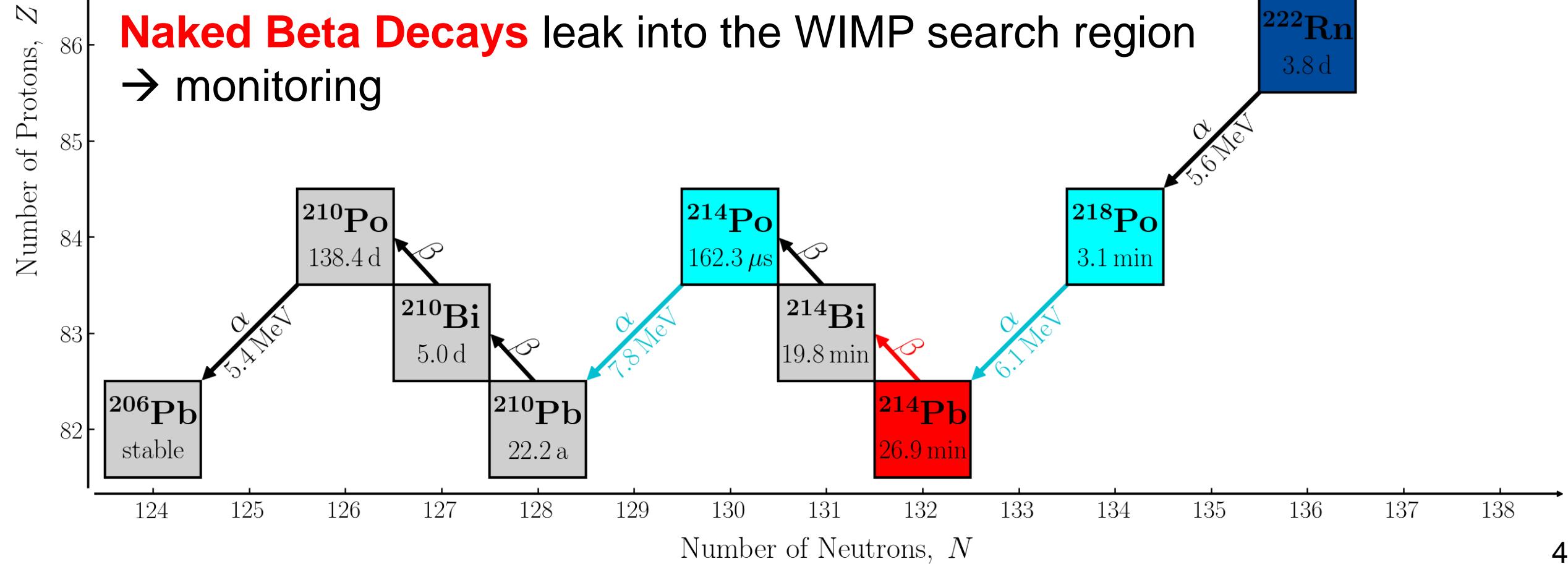
# ER Background in DARWIN



# Radon Emanation

**$^{222}\text{Rn}$  Emanation** from the surface of the detector components  
→ homogeneous distribution within the TPC

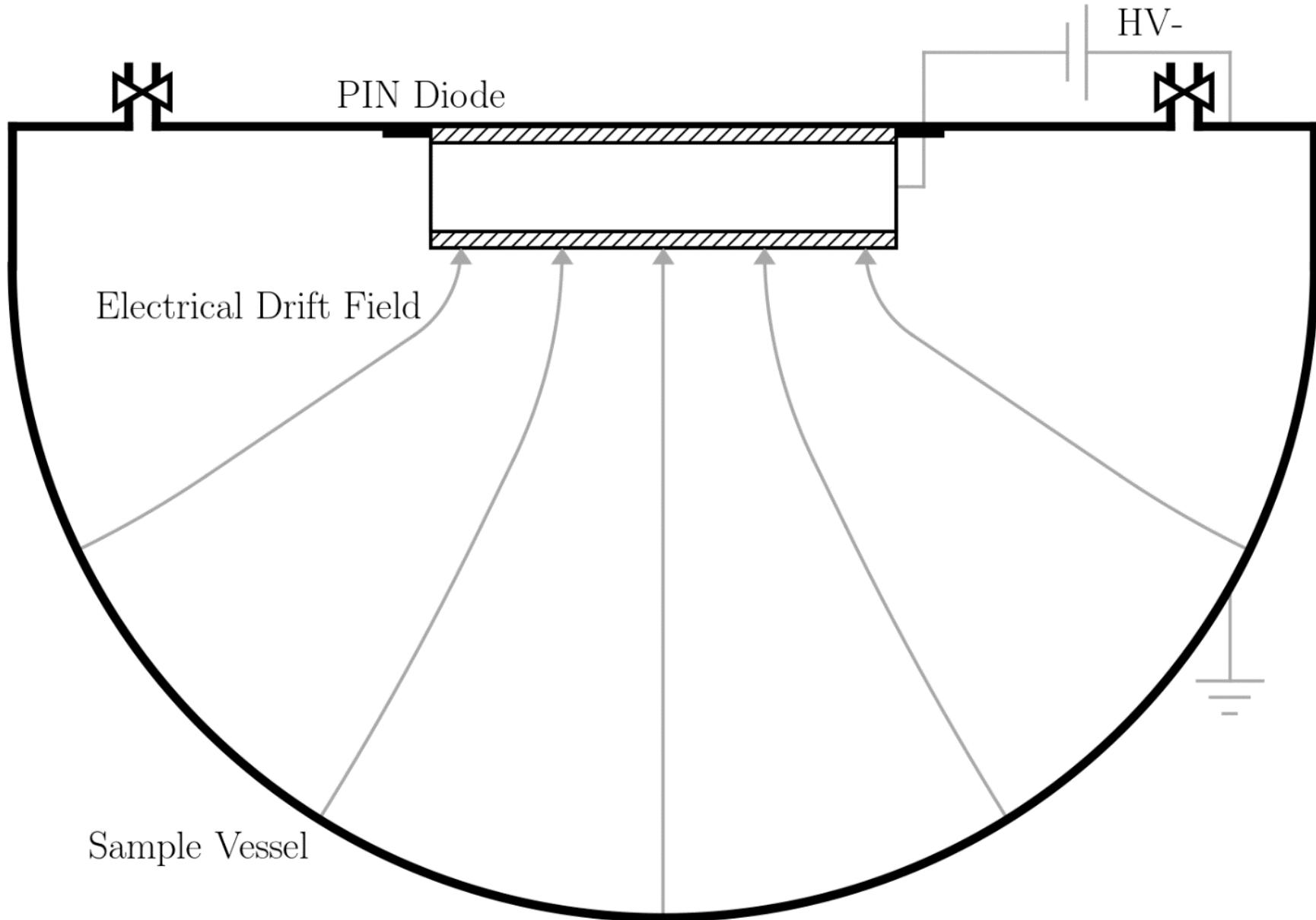
**Naked Beta Decays** leak into the WIMP search region  
→ monitoring



# The MonXe Radon Emanation Chamber

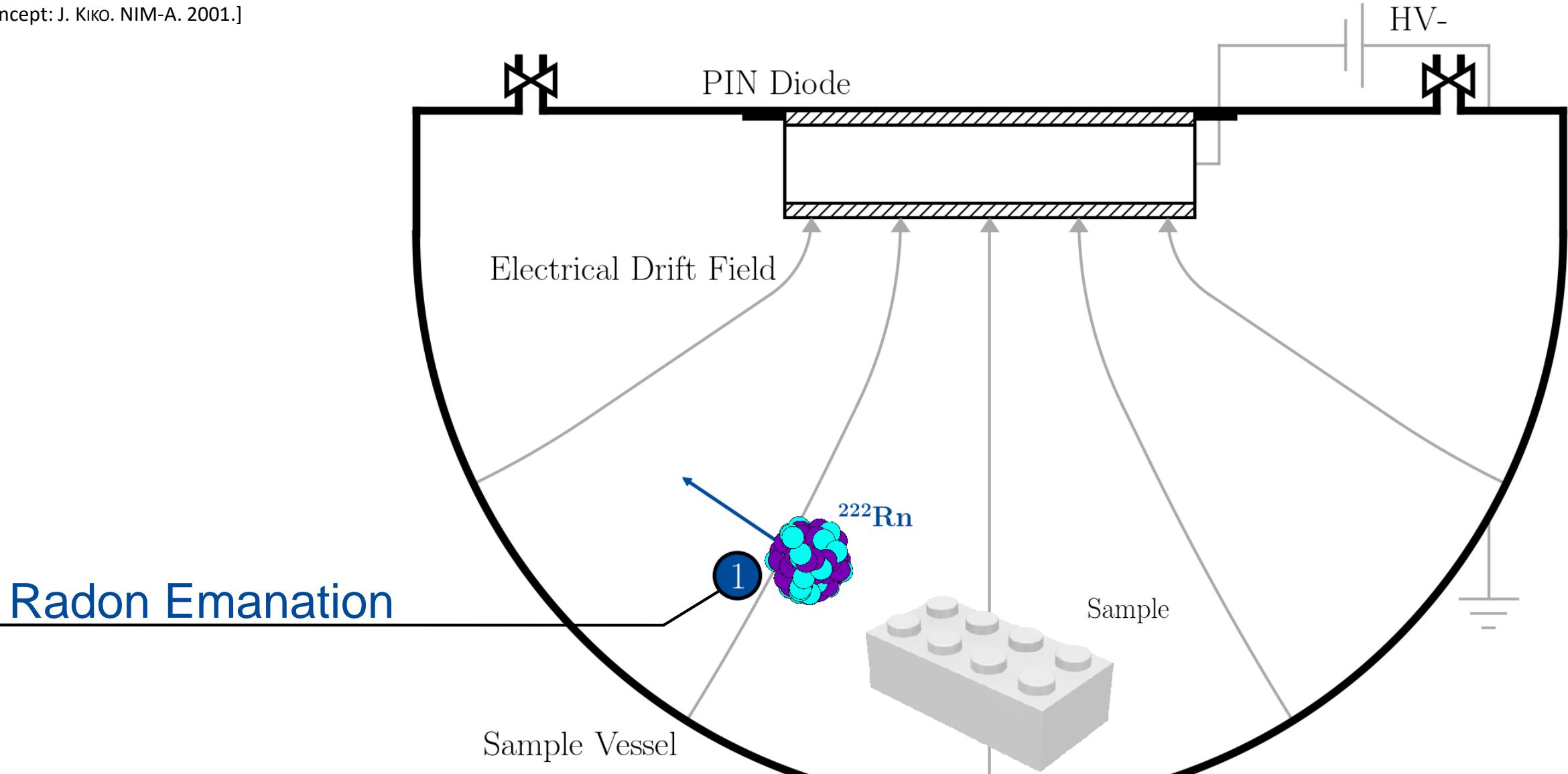
# Radon Emanation Chamber

[Concept: J. Kiko, NIM-A. 2001.]



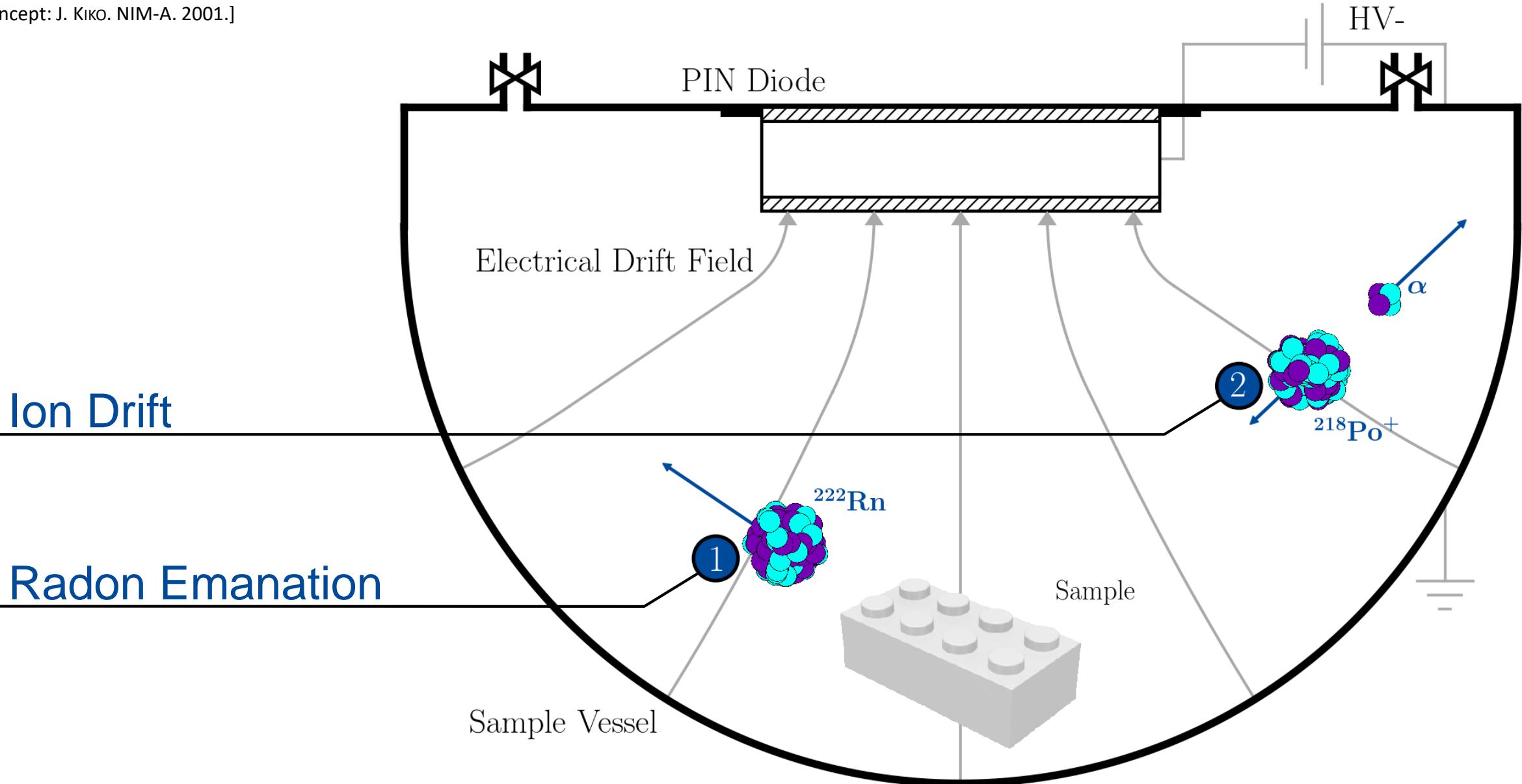
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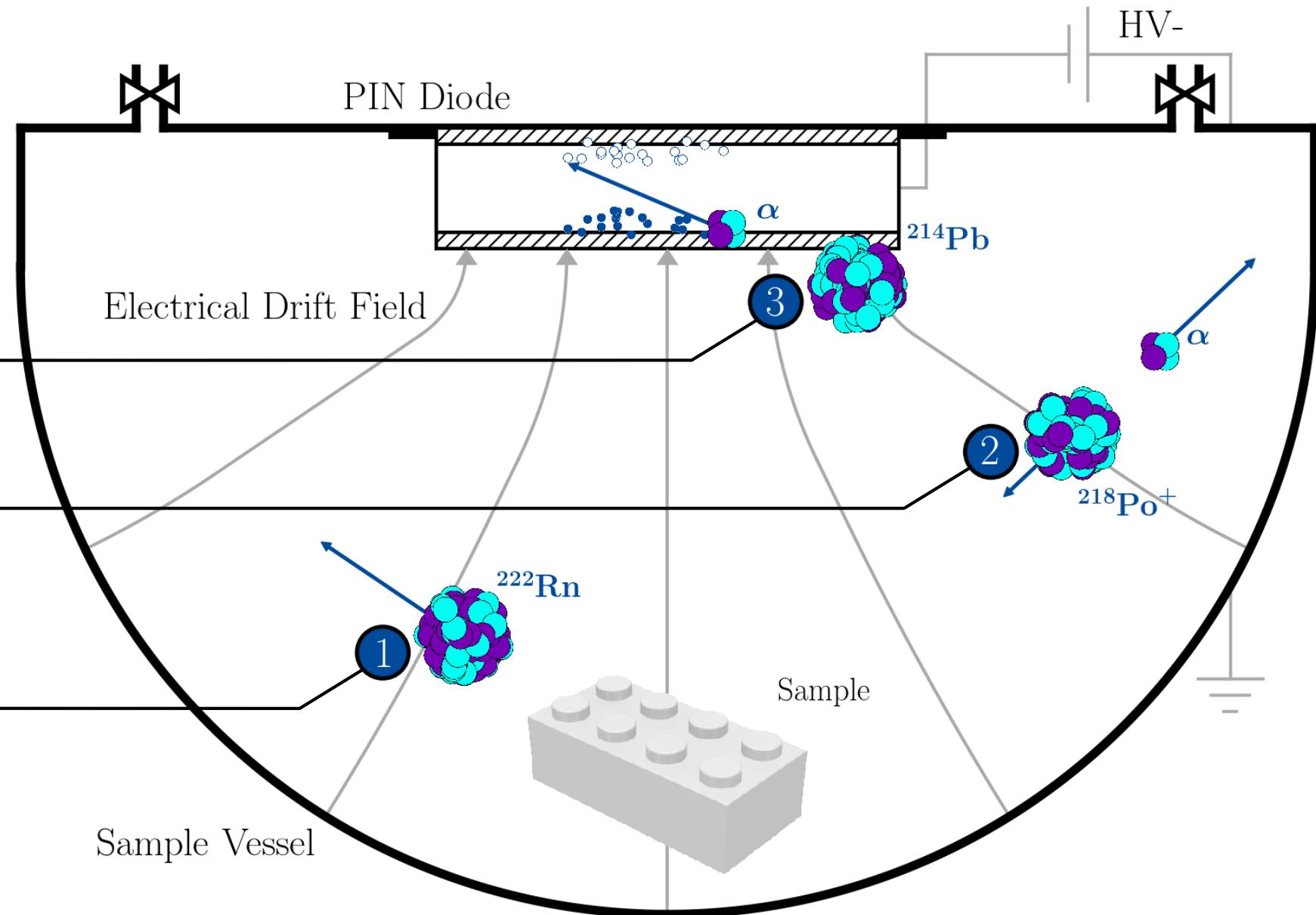
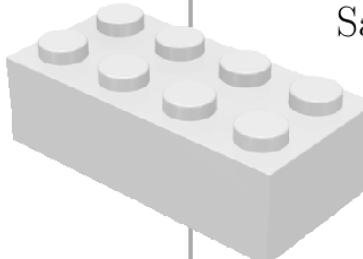
[Concept: J. Kiko, NIM-A. 2001.]

Signal Formation

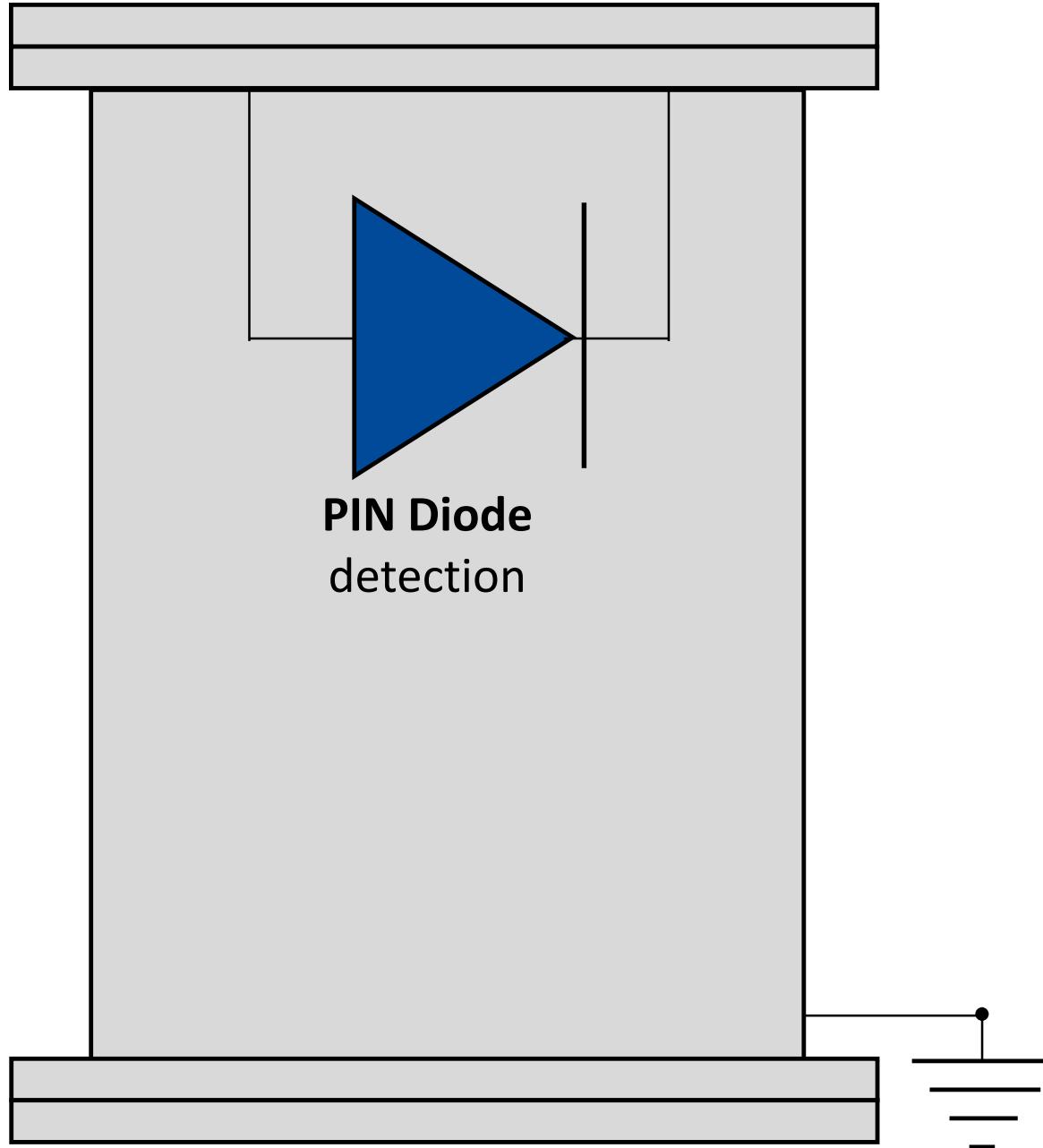
Ion Drift

Radon Emanation

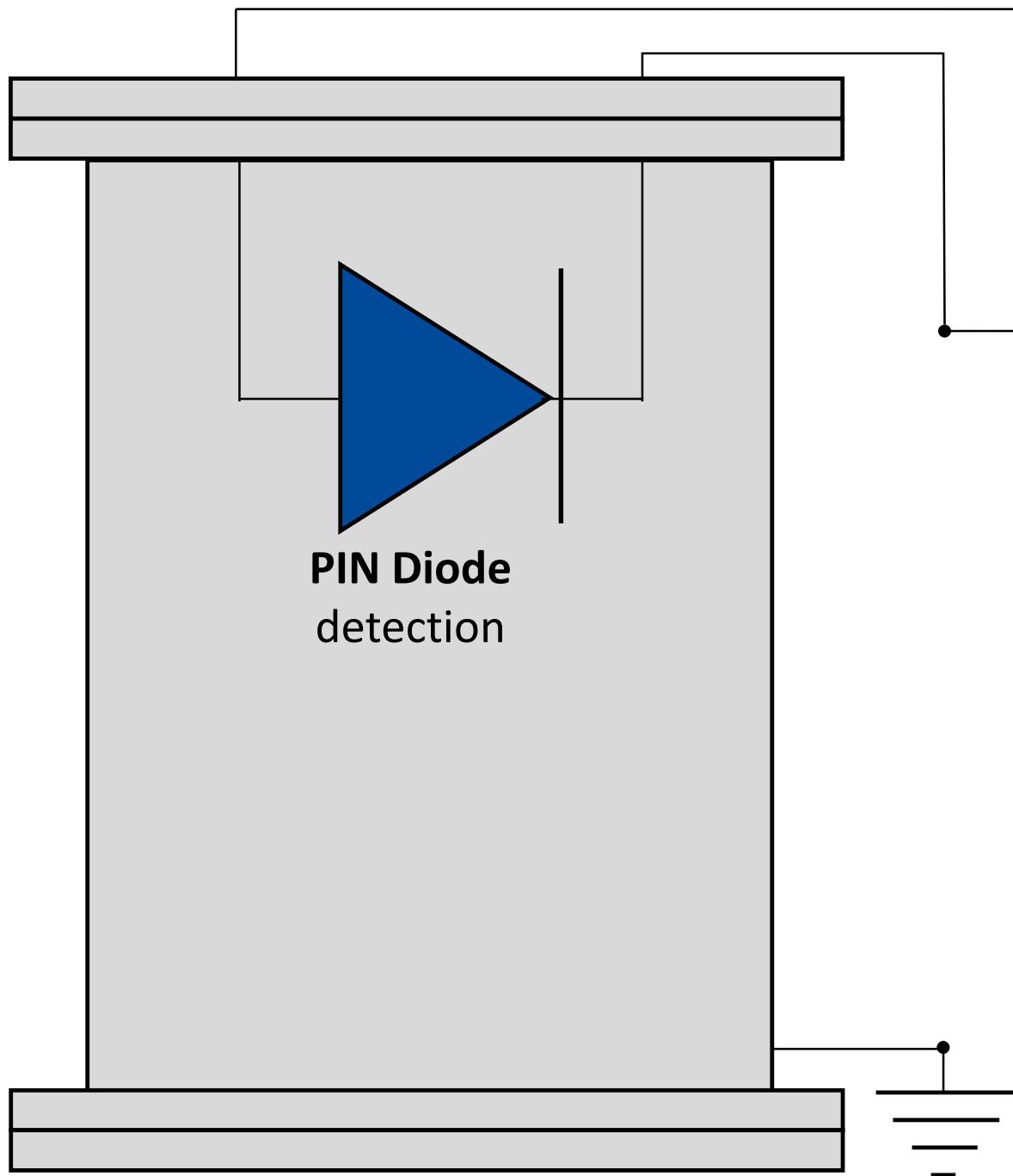
Sample Vessel



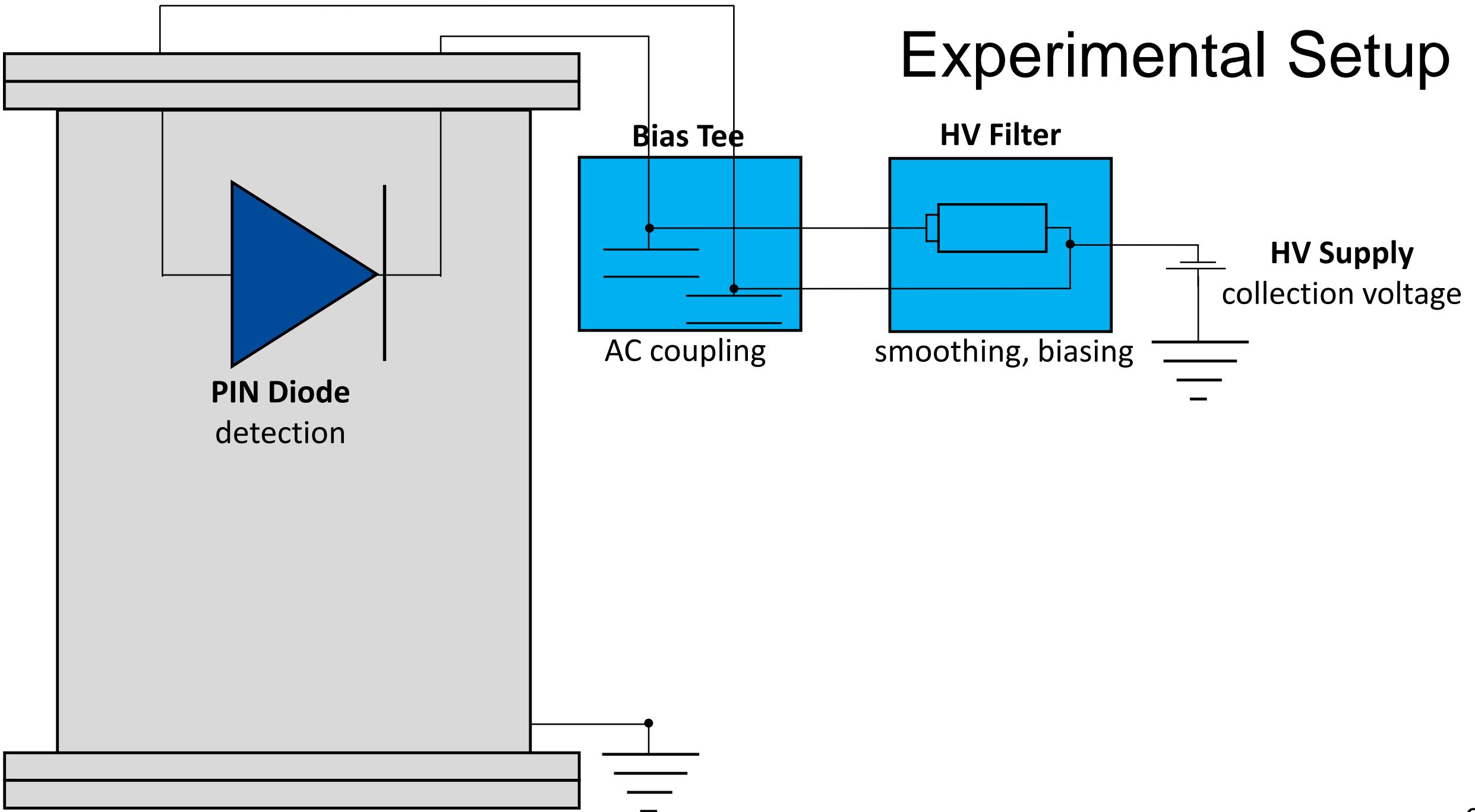
# Experimental Setup



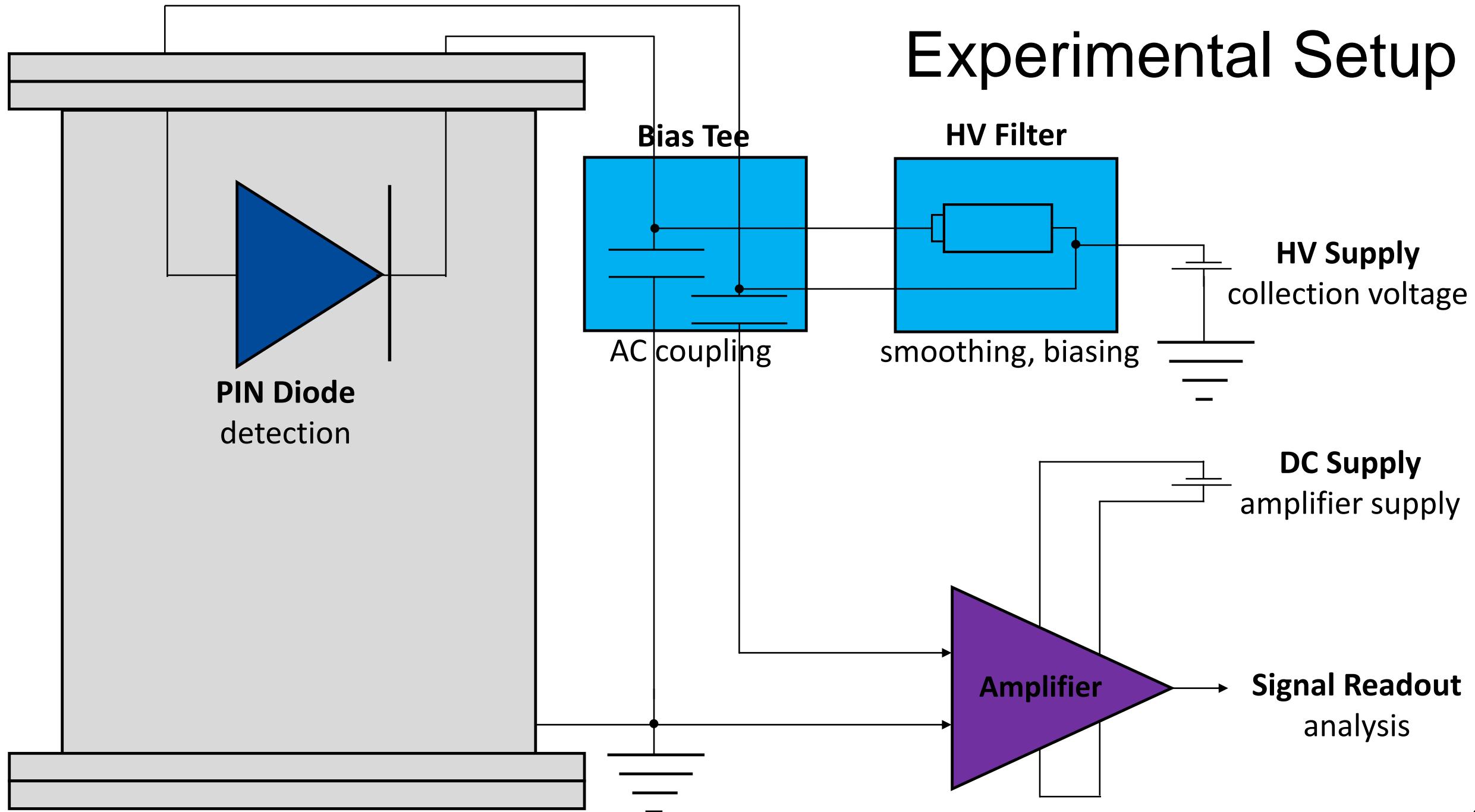
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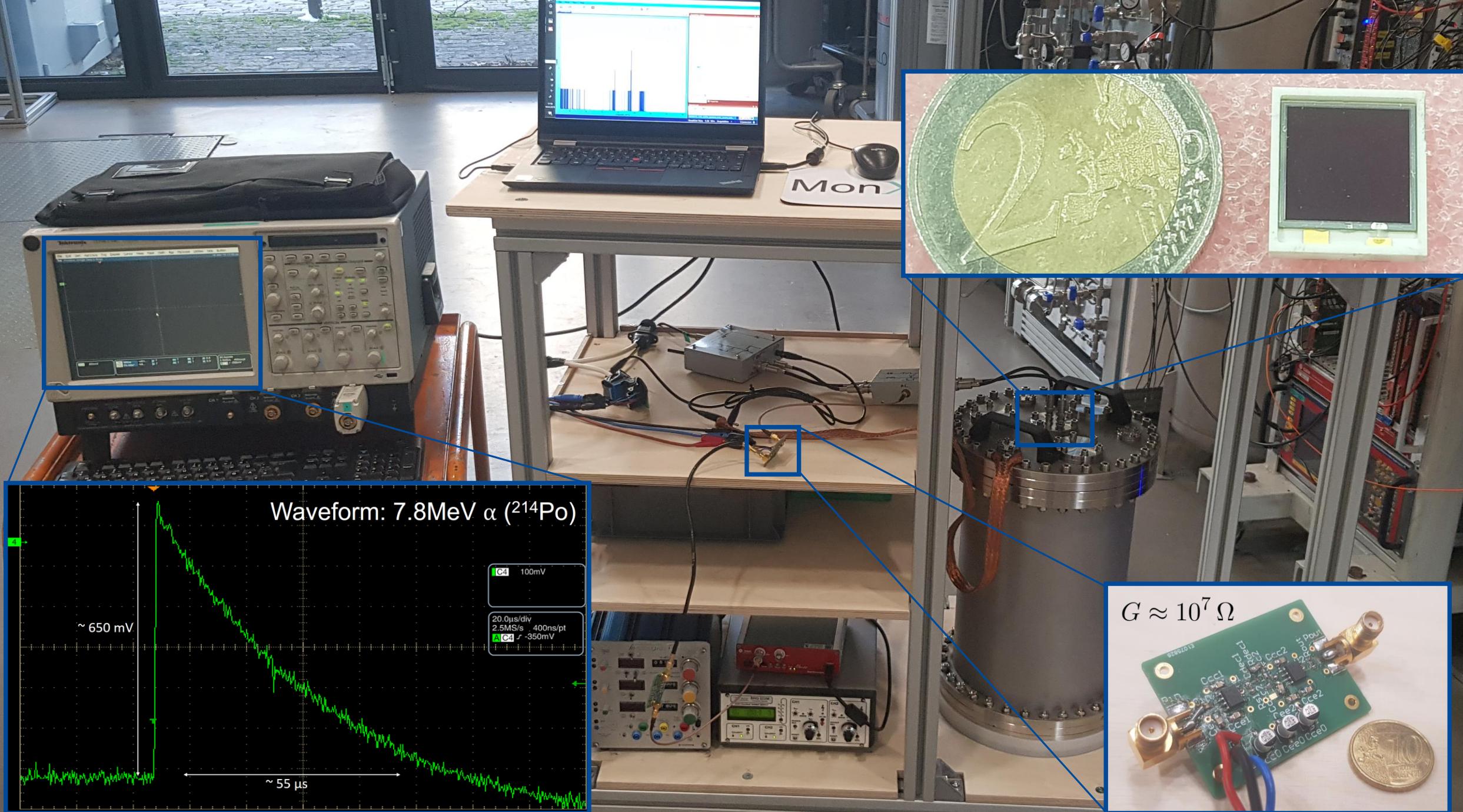


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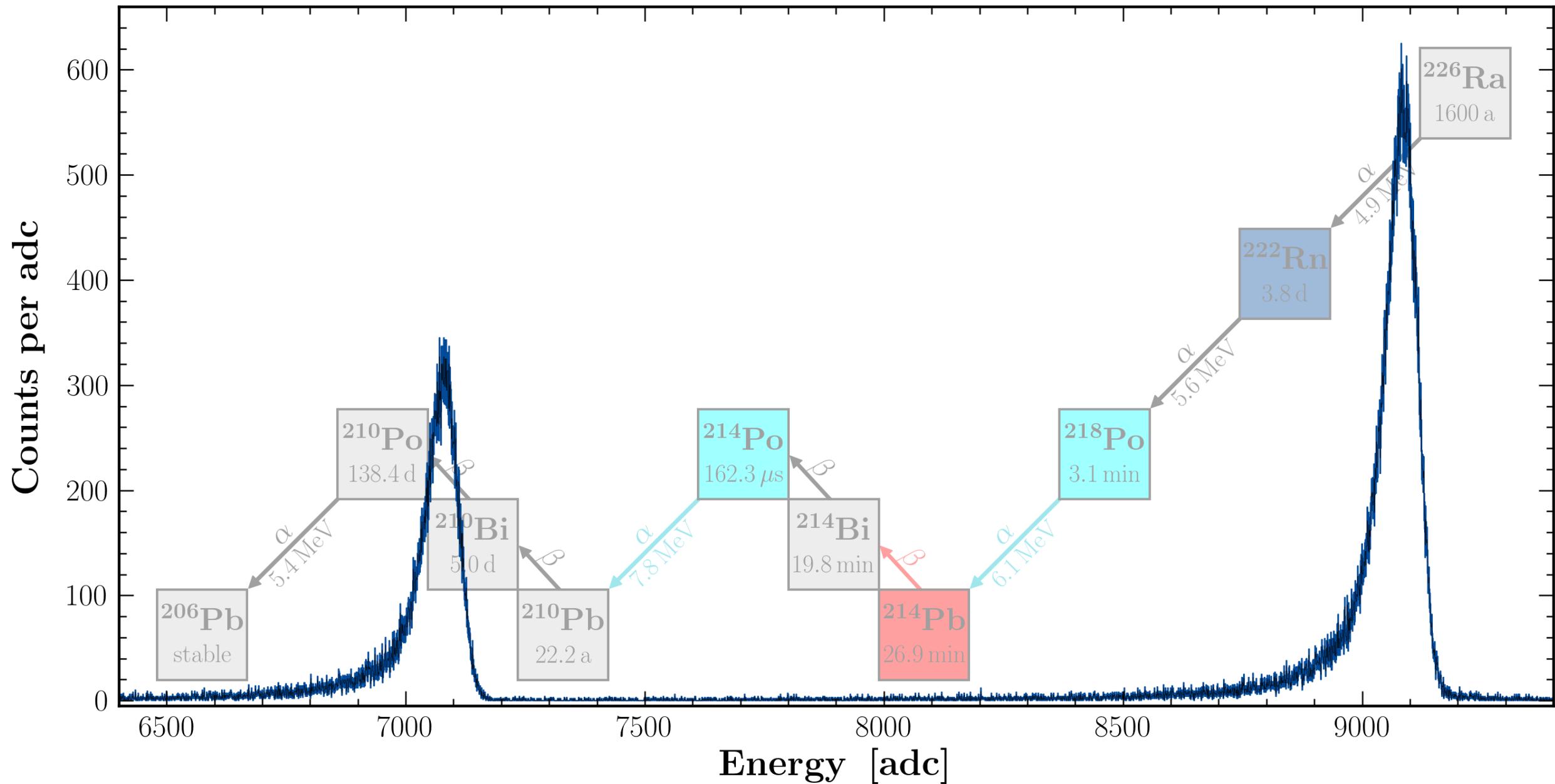


# Experimental Setup

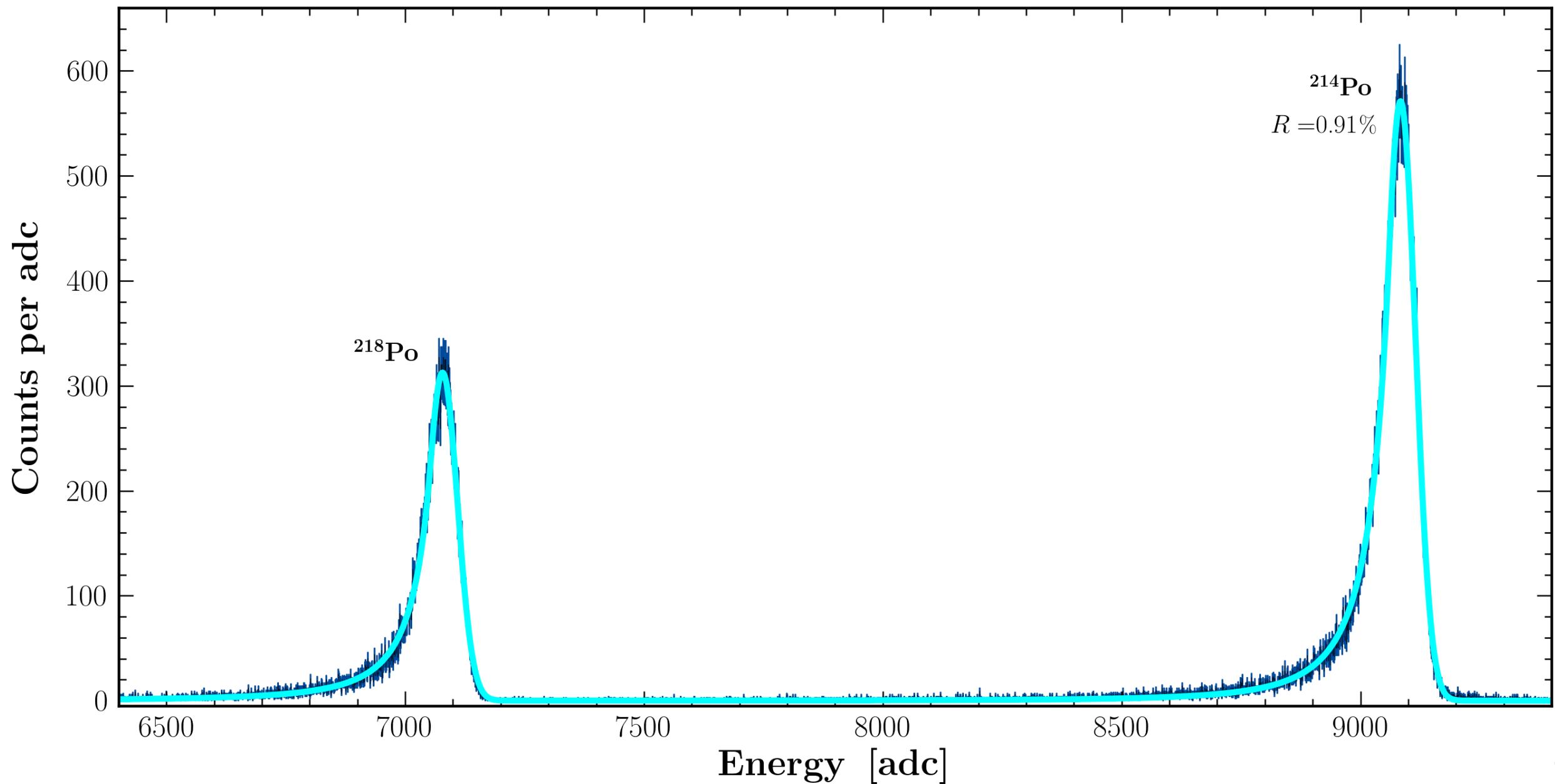




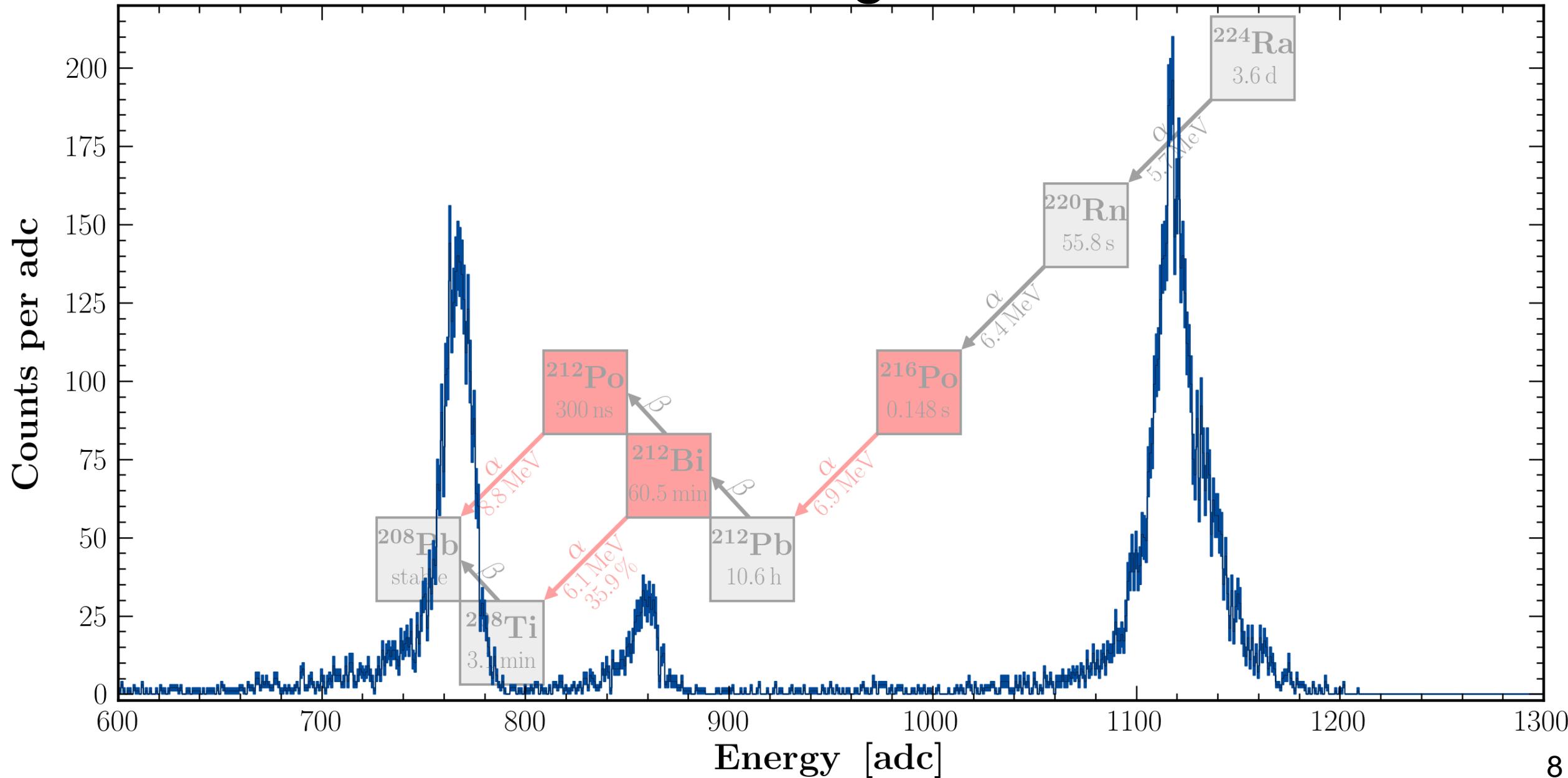
# $^{222}\text{Rn}$ in Ambient Air



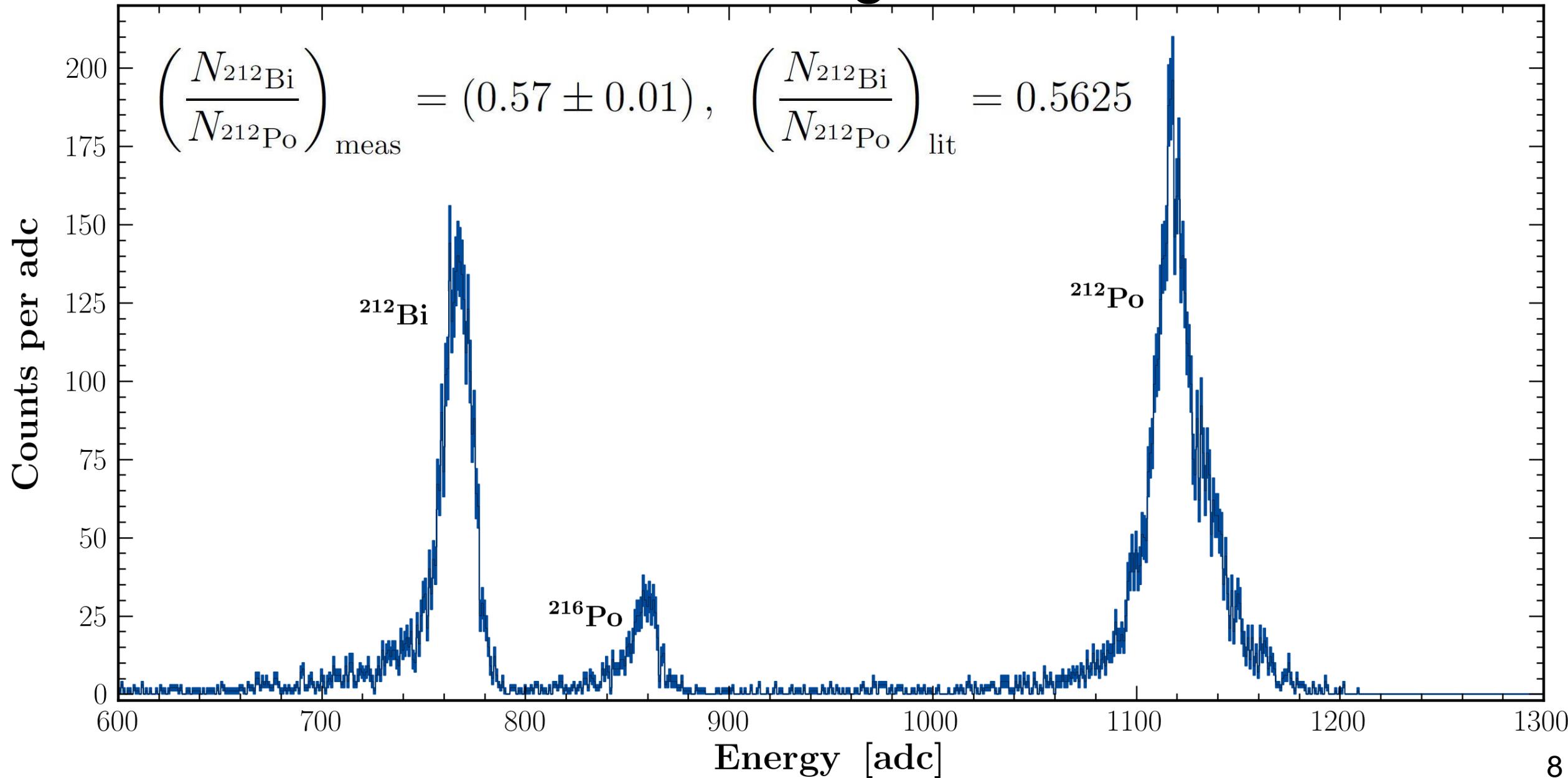
# $^{222}\text{Rn}$ in Ambient Air



# $^{220}\text{Rn}$ from Thoriated Welding Rods in Helium



# $^{220}\text{Rn}$ from Thoriated Welding Rods in Helium

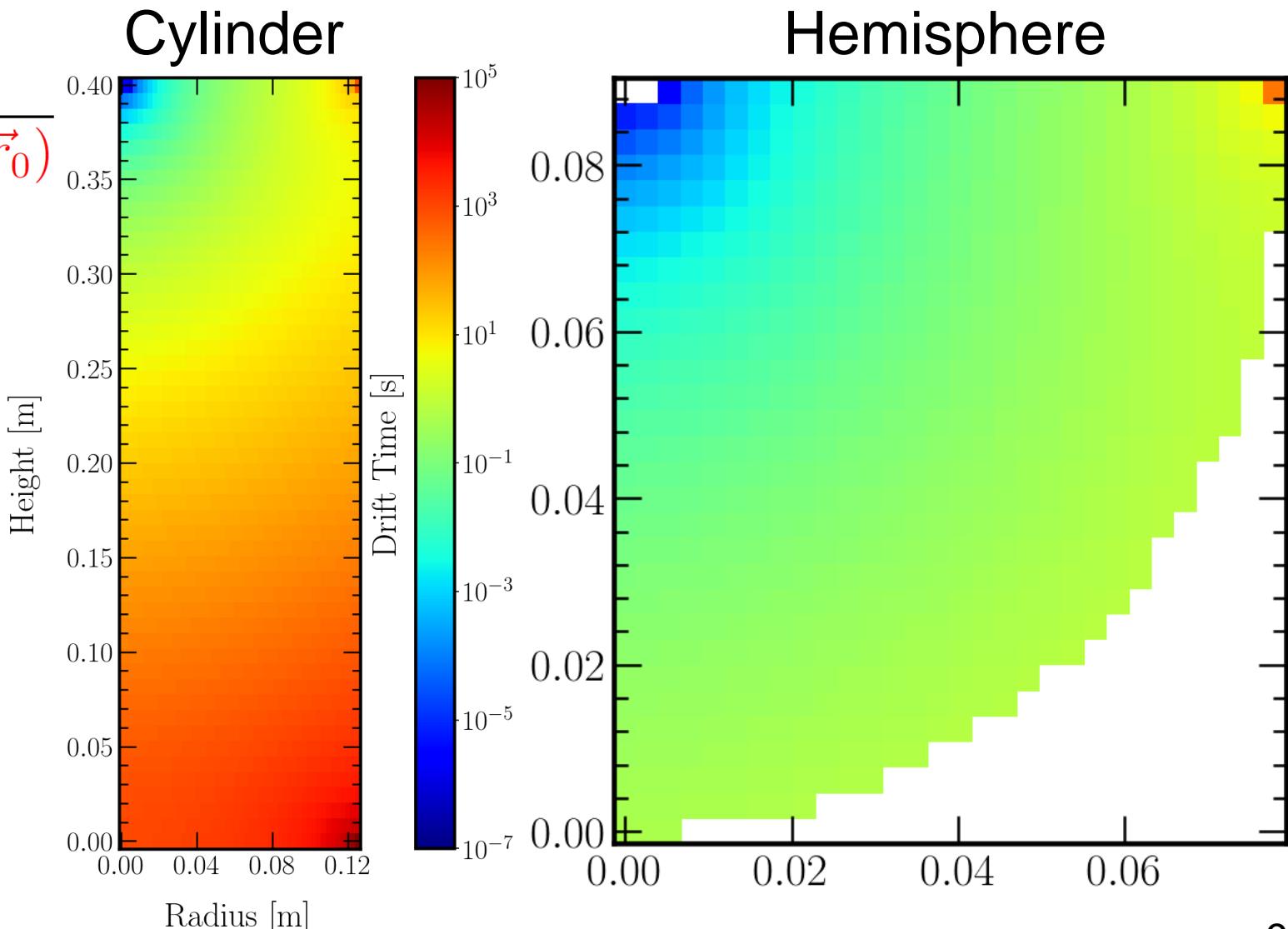


# Drift Time Estimation

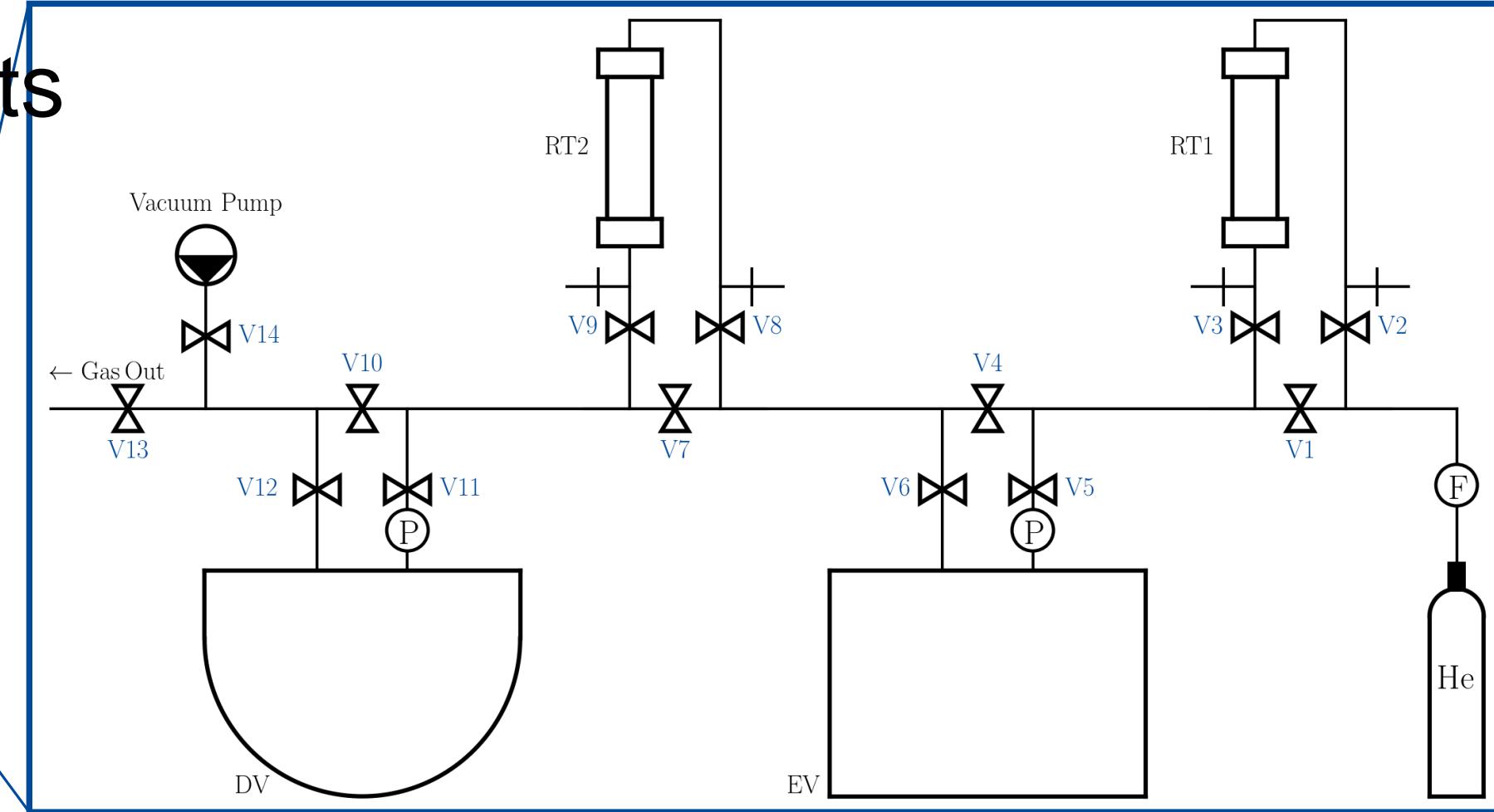
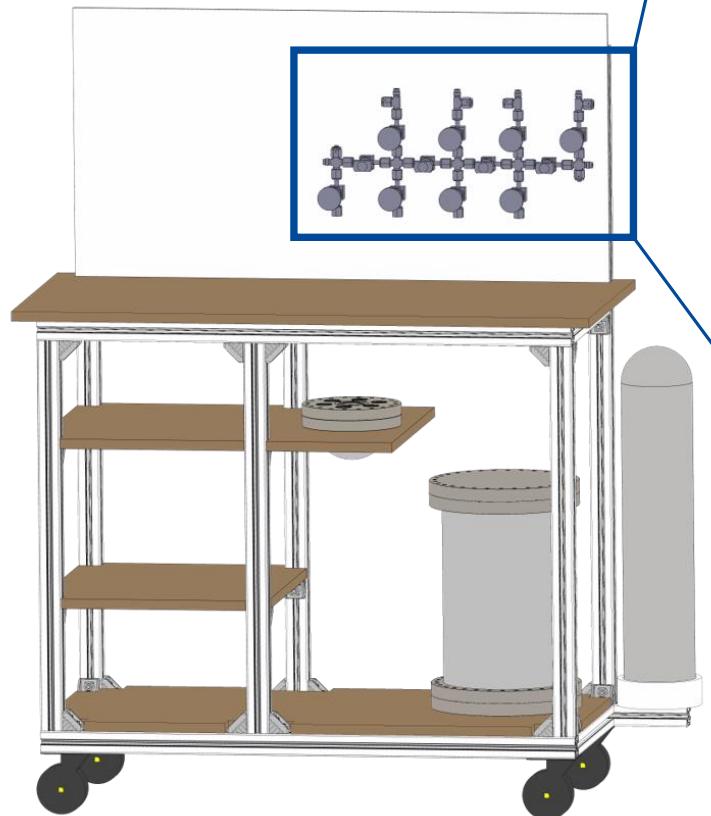
[L. GOD: *Efficiency Studies for the MonXe Radon Emanation Chamber*. B.Sc. Thesis. Aug 2019. Freiburg.]

$$\tilde{t}_{\text{drift}} = \frac{\tilde{d}}{\tilde{v}_{\text{drift}}} = \frac{h(\vec{r}_0) + r(\vec{r}_0)}{\mu(E_{\text{eff}}, p, T) \cdot E_{\text{eff}}(\vec{r}_0)}$$

- **drift path**  
geometric approximation
- **ion mobility**  
LXcat database
- **electrical drift field**  
Comsol simulation



# Upgrade Efforts



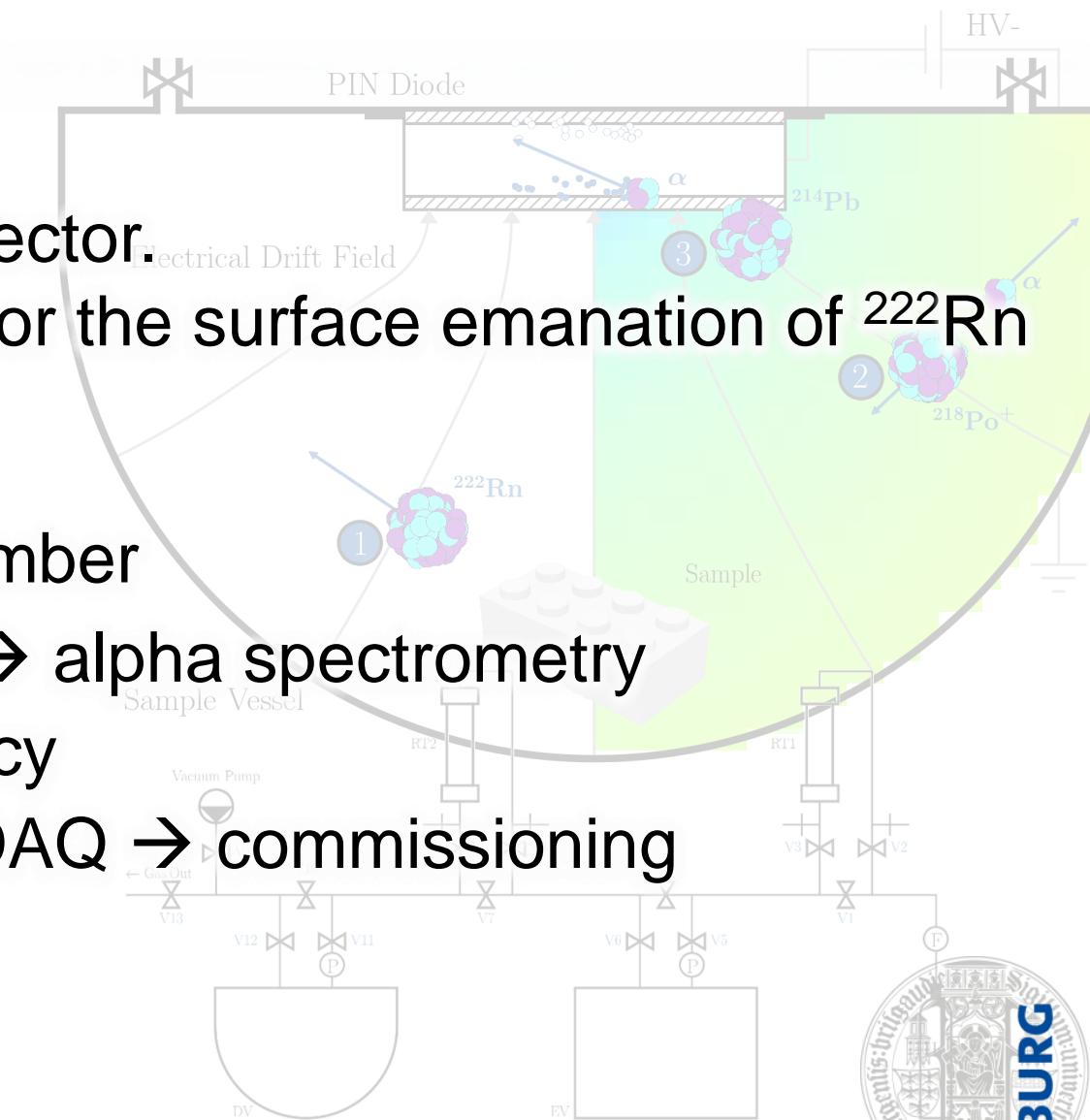
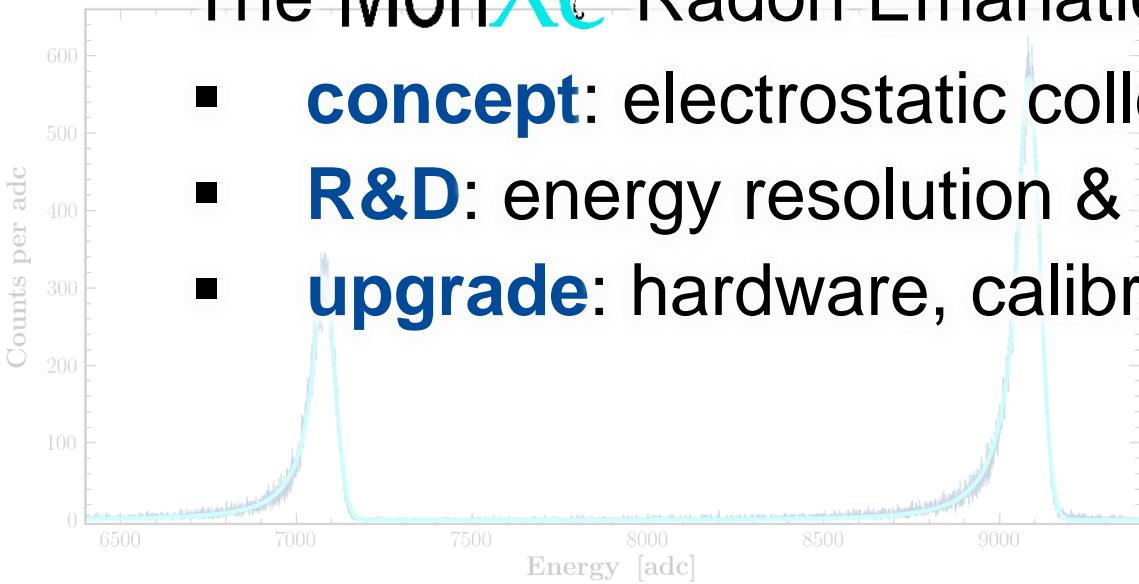
- **vessels:** decoupled emanation and detection vessels
- **gas system:** helium as carrier gas
- **DAQ:** database storage and slow control

# Summary

DARWIN will be the ultimate WIMP detector.  
→ **background mitigation**: monitor the surface emanation of  $^{222}\text{Rn}$

## The MonXe Radon Emanation Chamber

- **concept**: electrostatic collection → alpha spectrometry
- **R&D**: energy resolution & efficiency
- **upgrade**: hardware, calibration, DAQ → commissioning

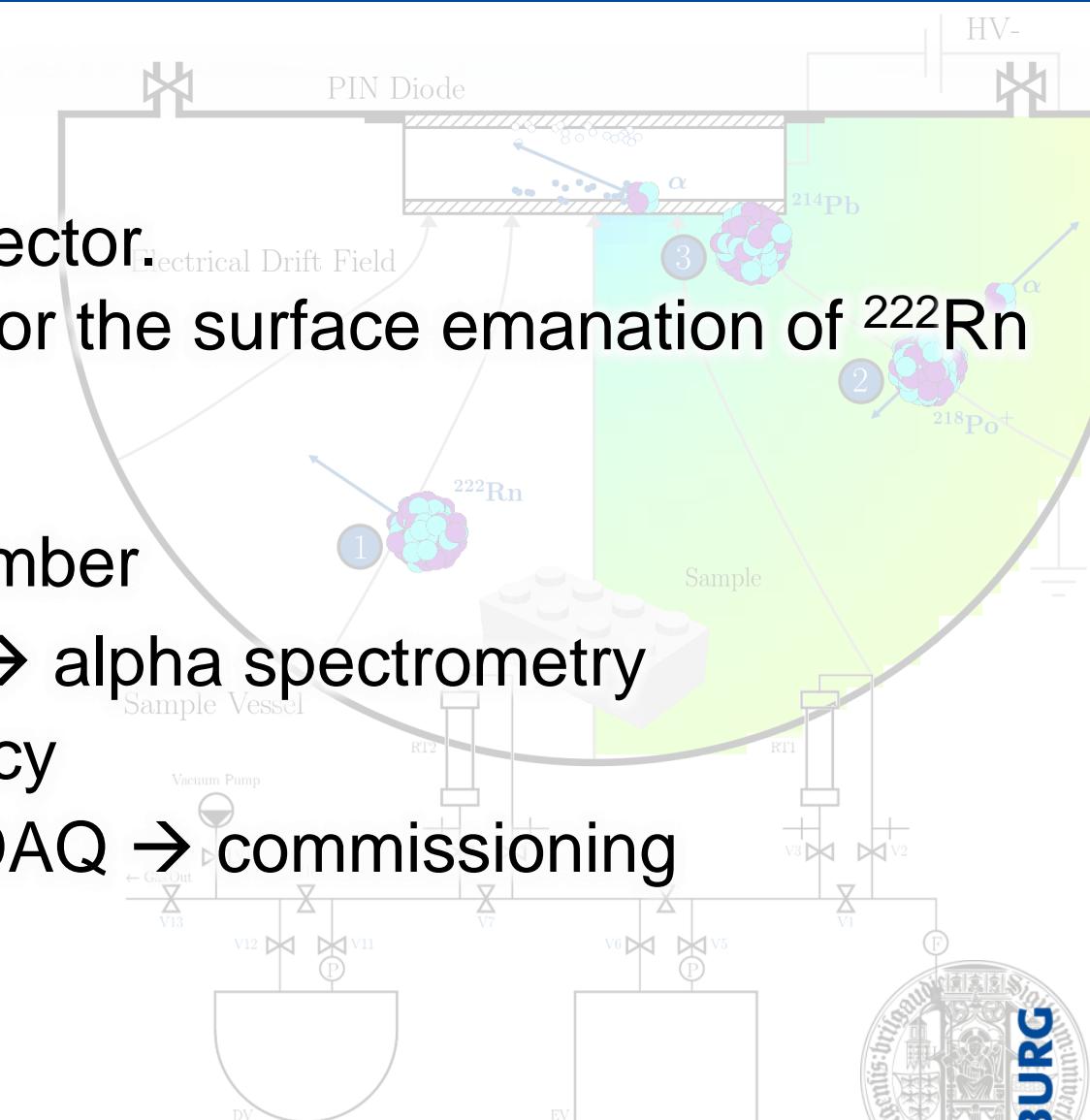
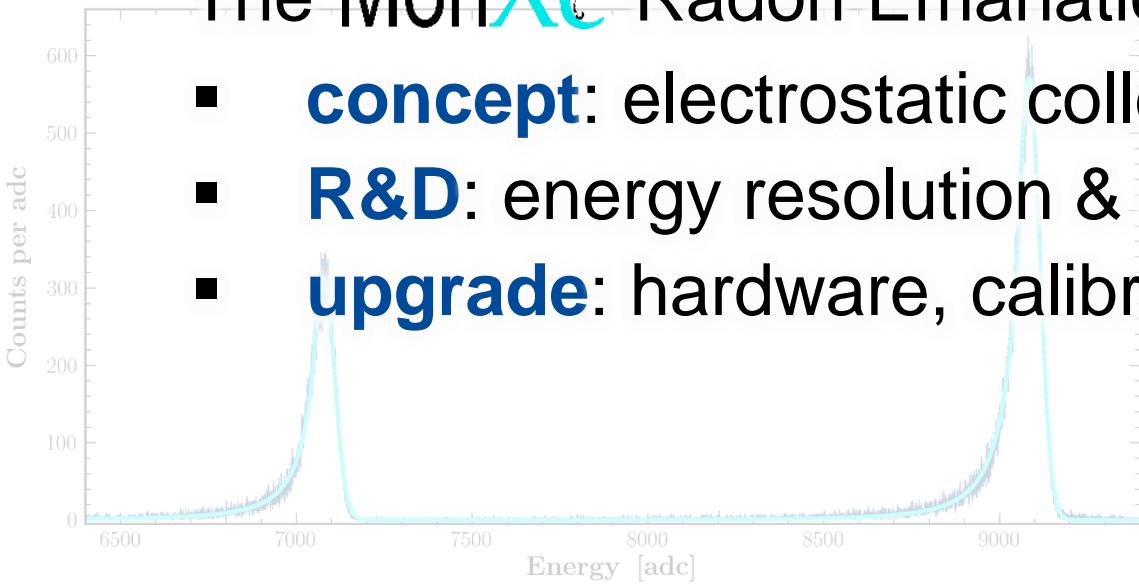


# Thank You for your Attention

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→ **background mitigation**: monitor the surface emanation of  $^{222}\text{Rn}$

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- **concept**: electrostatic collection → alpha spectrometry
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# Backup

# The DARWIN Collaboration



# Dual-Phase Time Projection Chamber

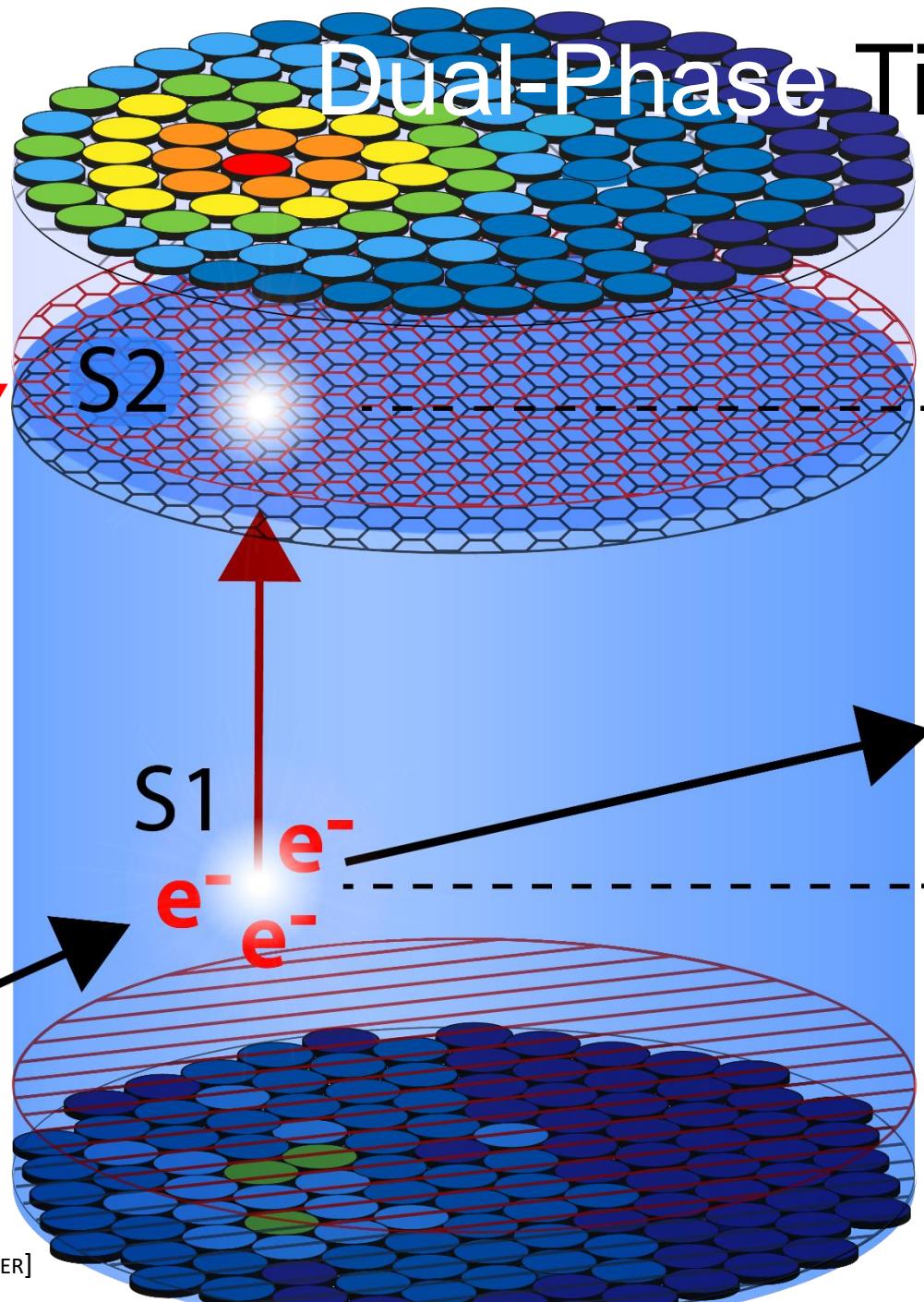
G<sub>Xe</sub>

E<sub>extraction</sub>

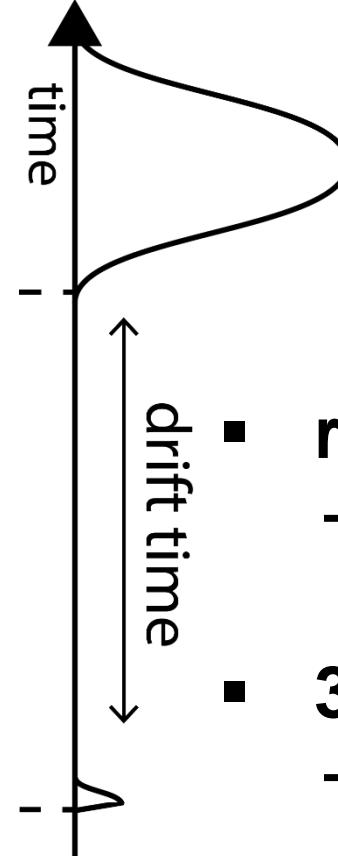
L<sub>Xe</sub>

E<sub>drift</sub>

particle



[Credits: LUTZ ALTHÜSER]



- **recoil: nuclei/electrons**  
→ discrimination
- **3D vertex reconstruction**  
→ fiducialization
- **design**  
→ scalability

# The XENON Dark Matter Project



**XENON10**  
14 kg target mass



**XENON100**  
62 kg target mass

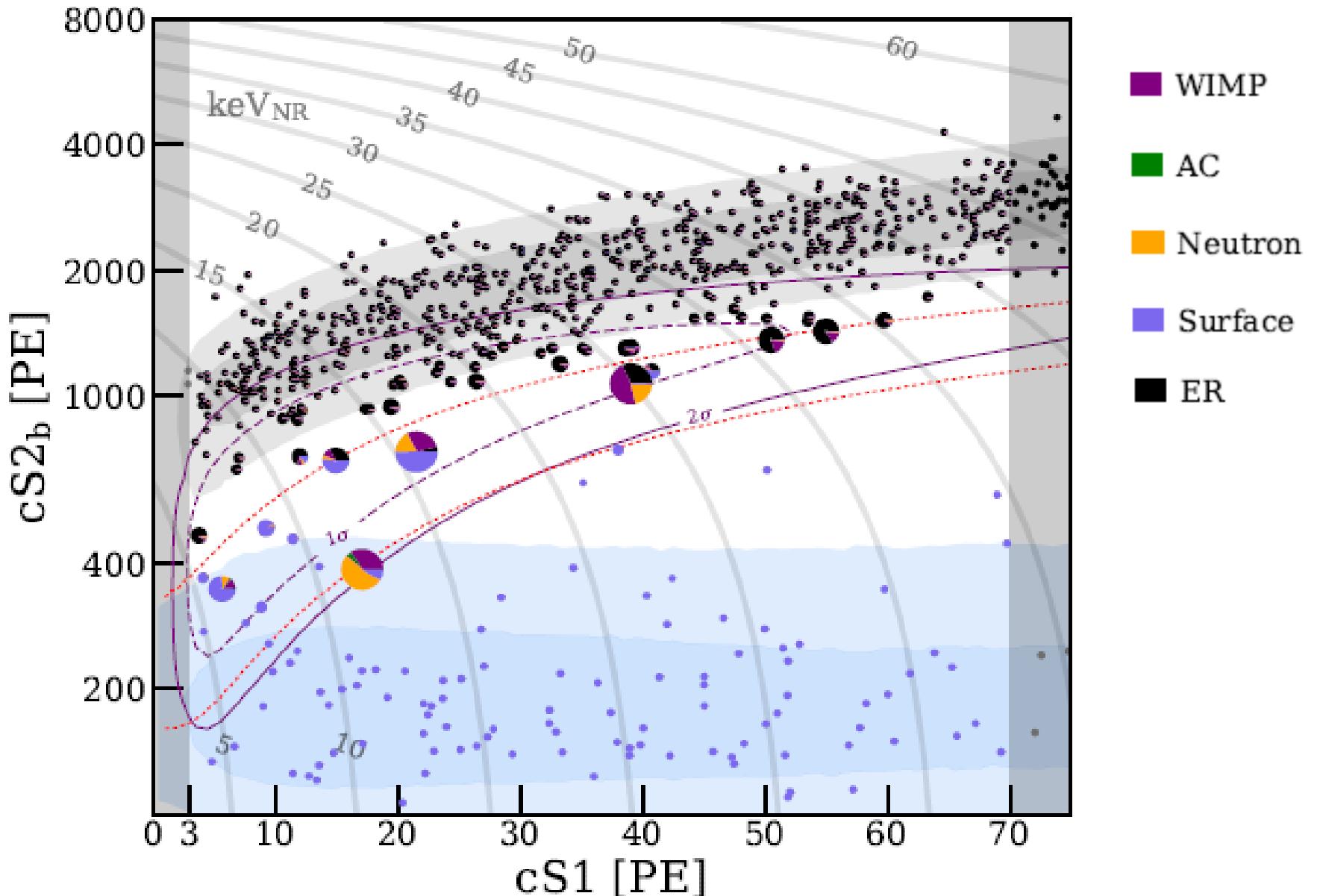


**XENON1T**  
2 t target mass

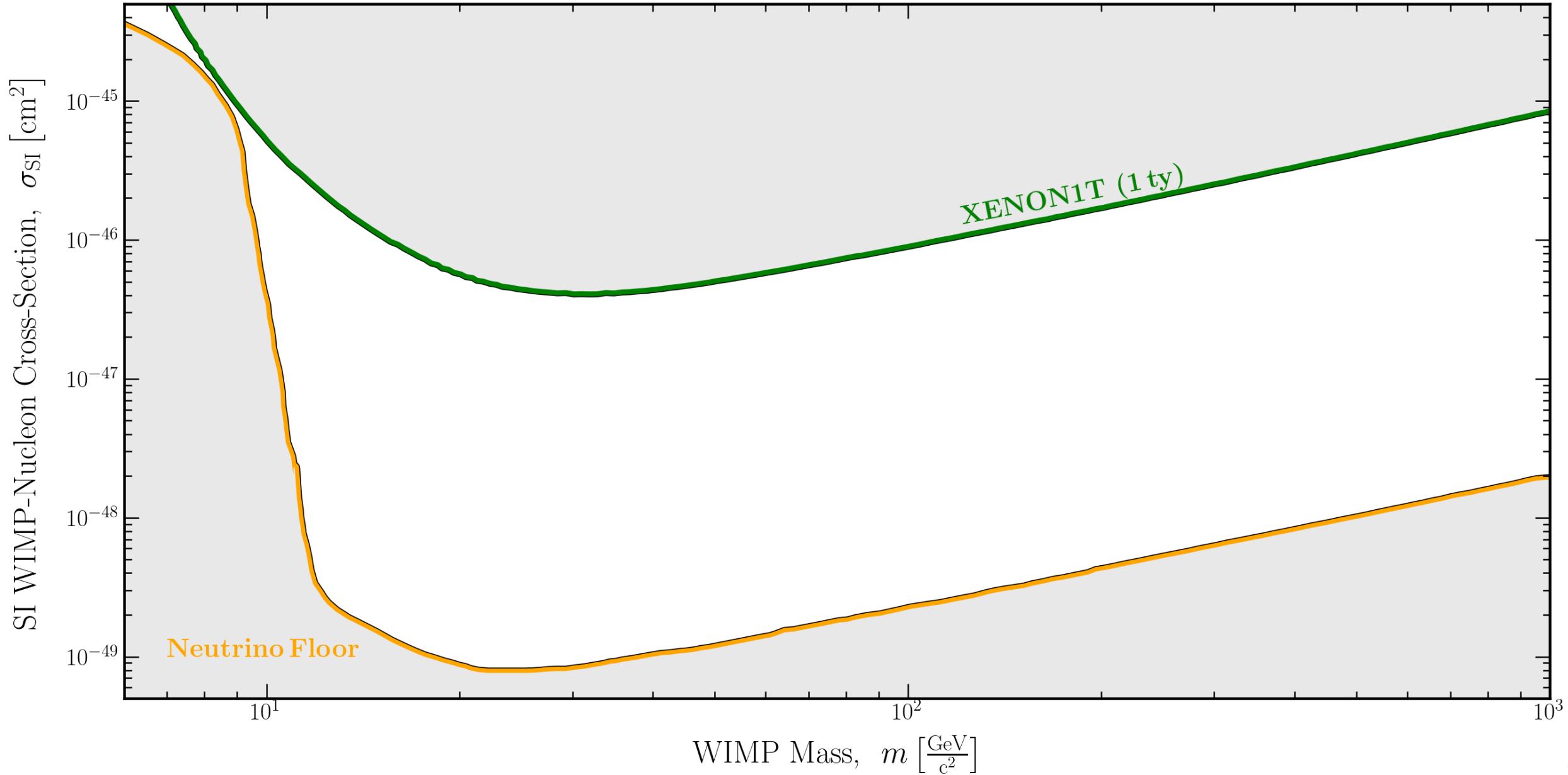


**XENONnT**  
5.9 t target mass

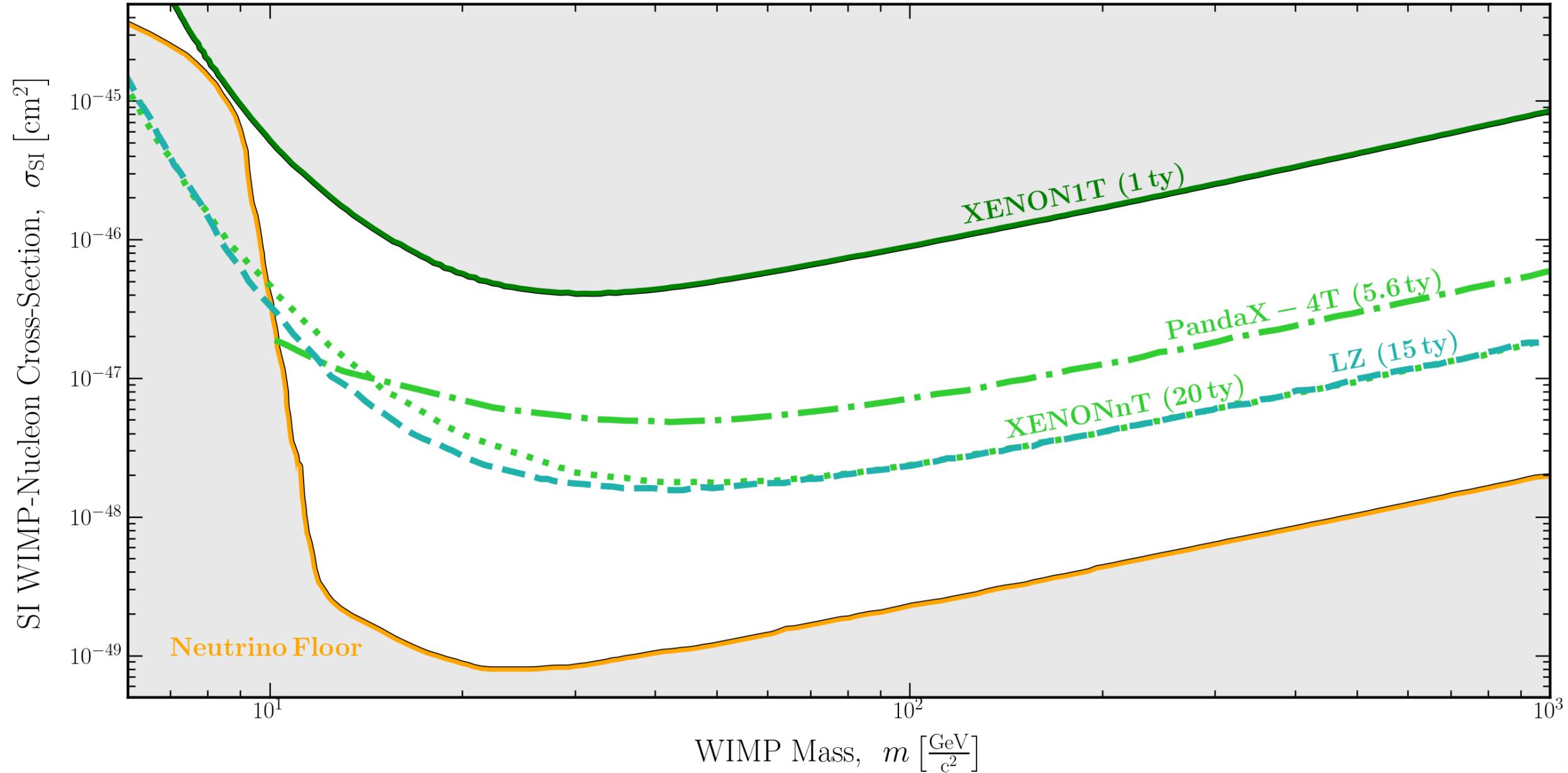
# Relevance of Radon Induced Background



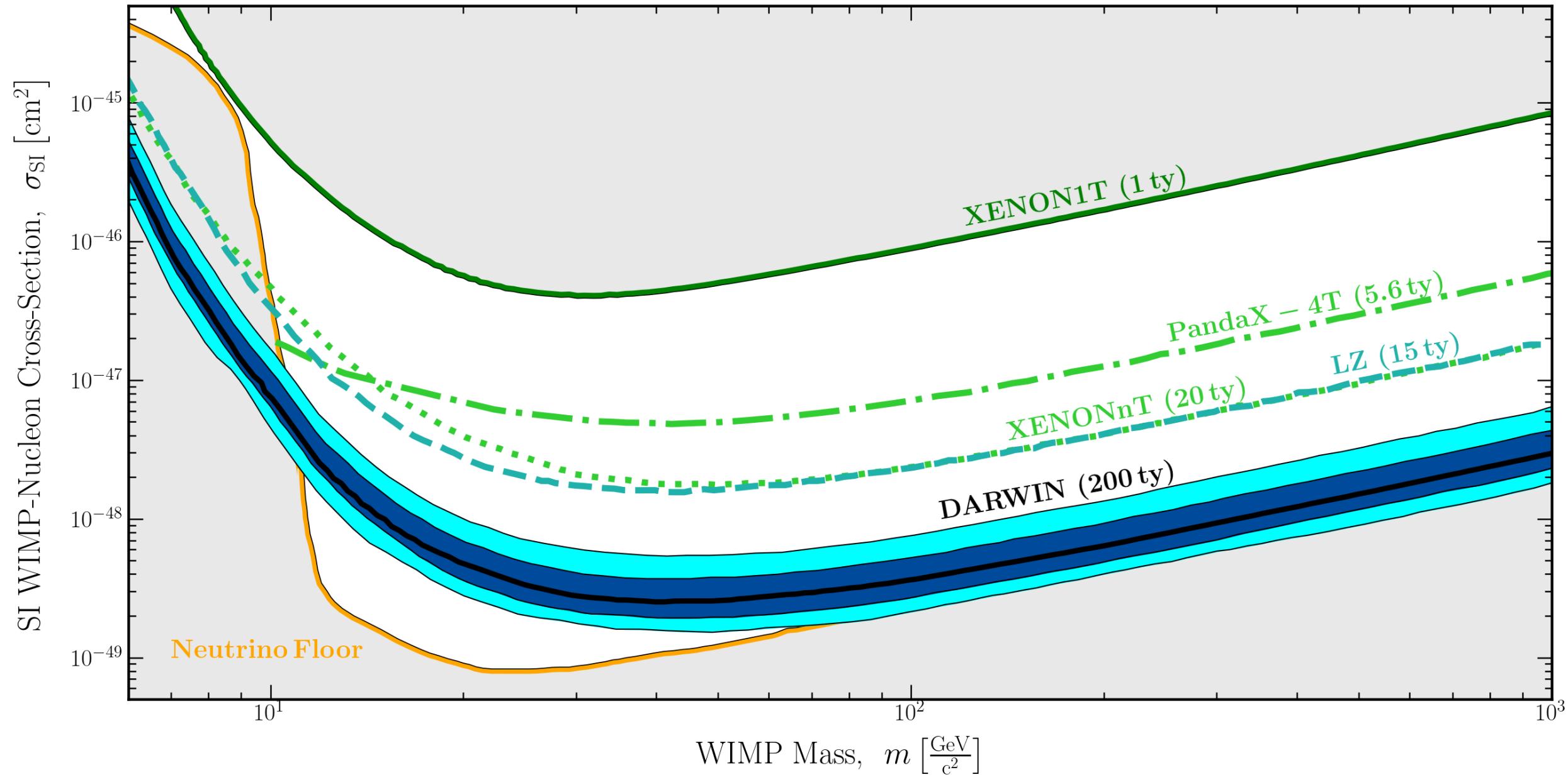
# The WIMP Parameter Space



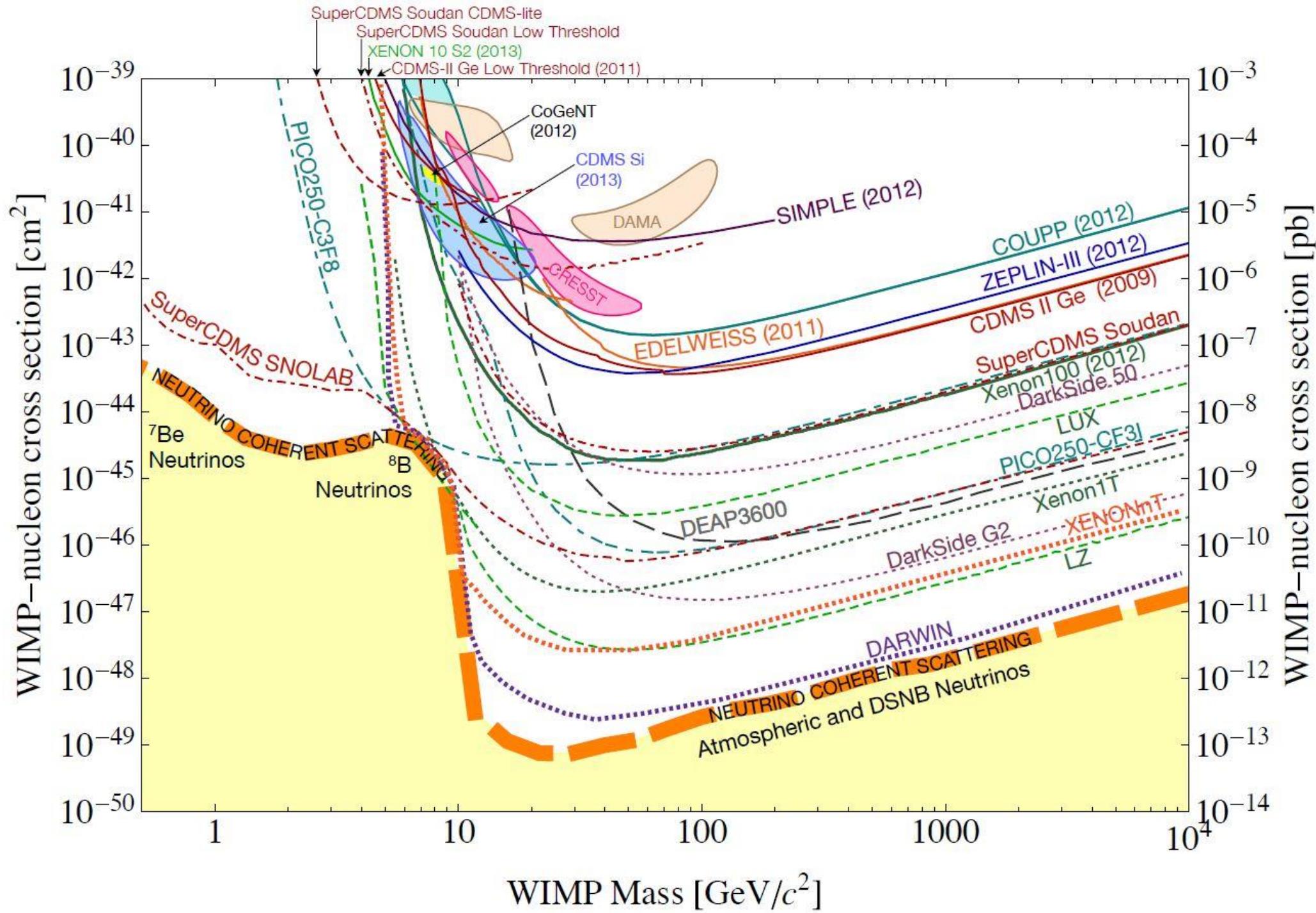
# The WIMP Parameter Space



# The WIMP Parameter Space



# WIMP Sensitivity

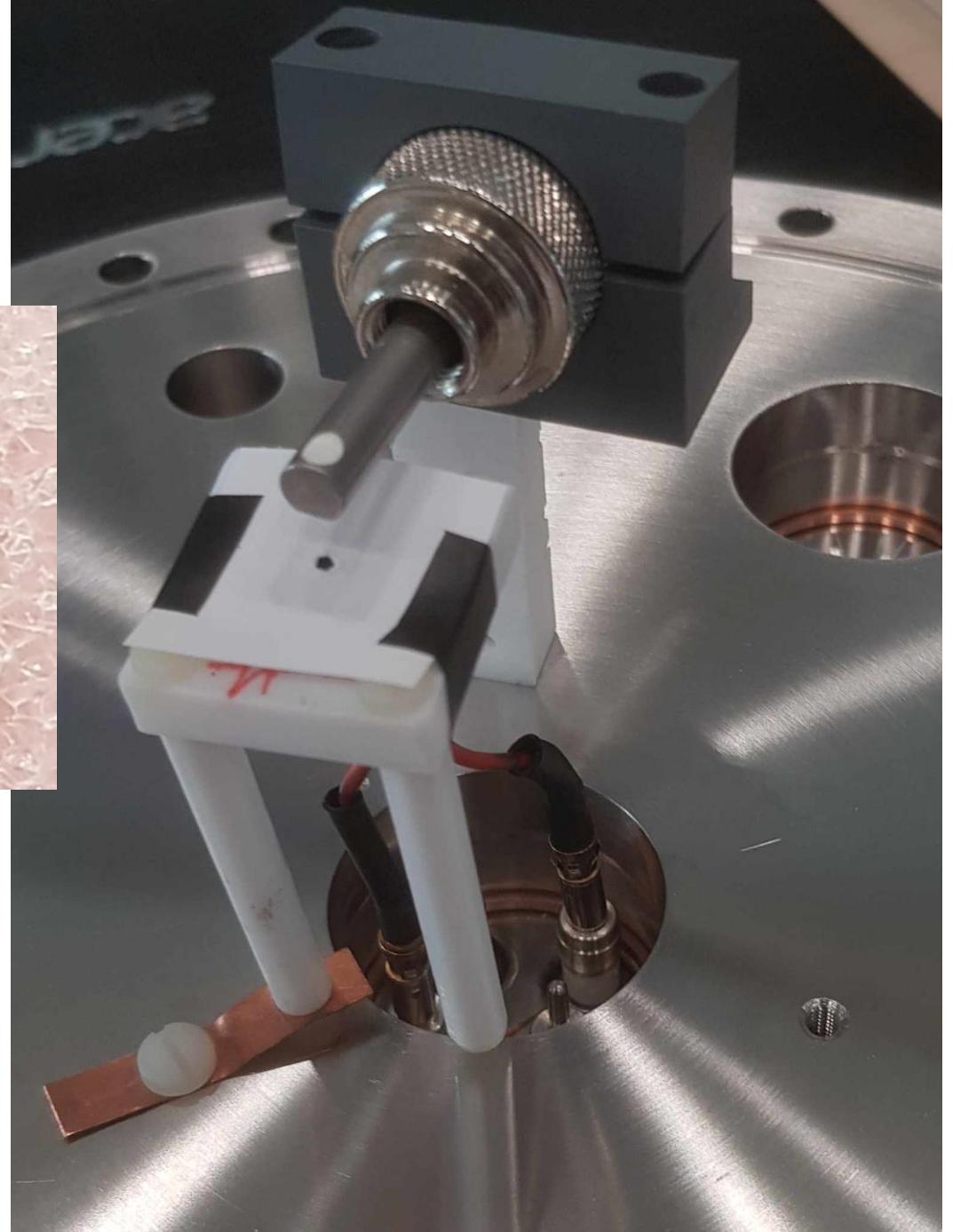


# Experimental Setup: Diode

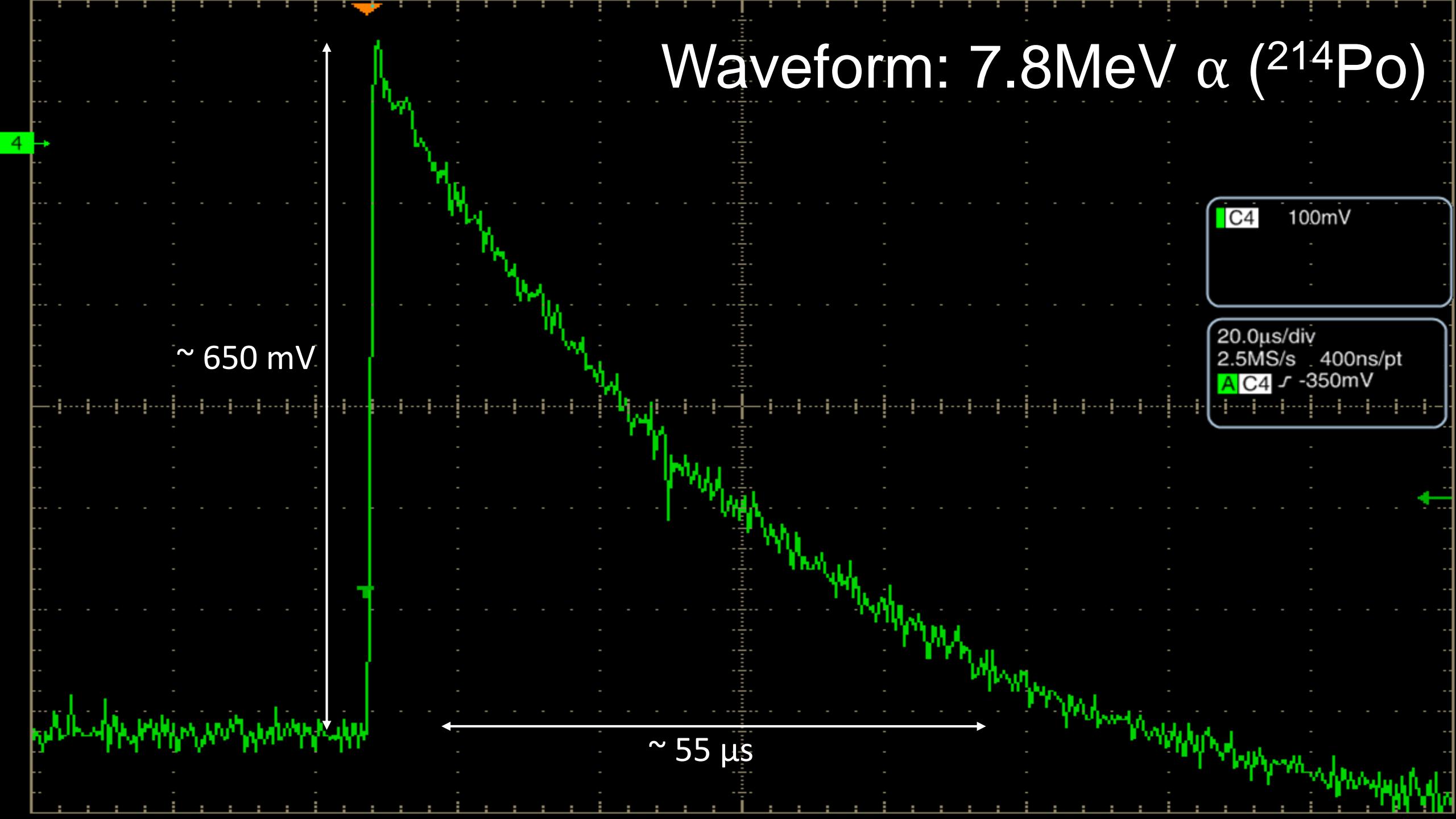
model: **Hamamatsu S3590-09**



- intrinsic layer:  $d_i = 300 \mu\text{m}$
- collection voltage:  $U_{\text{coll}} = -1000 \text{ V}$
- bias voltage:  $U_{\text{bias}} = 9 \text{ V}$

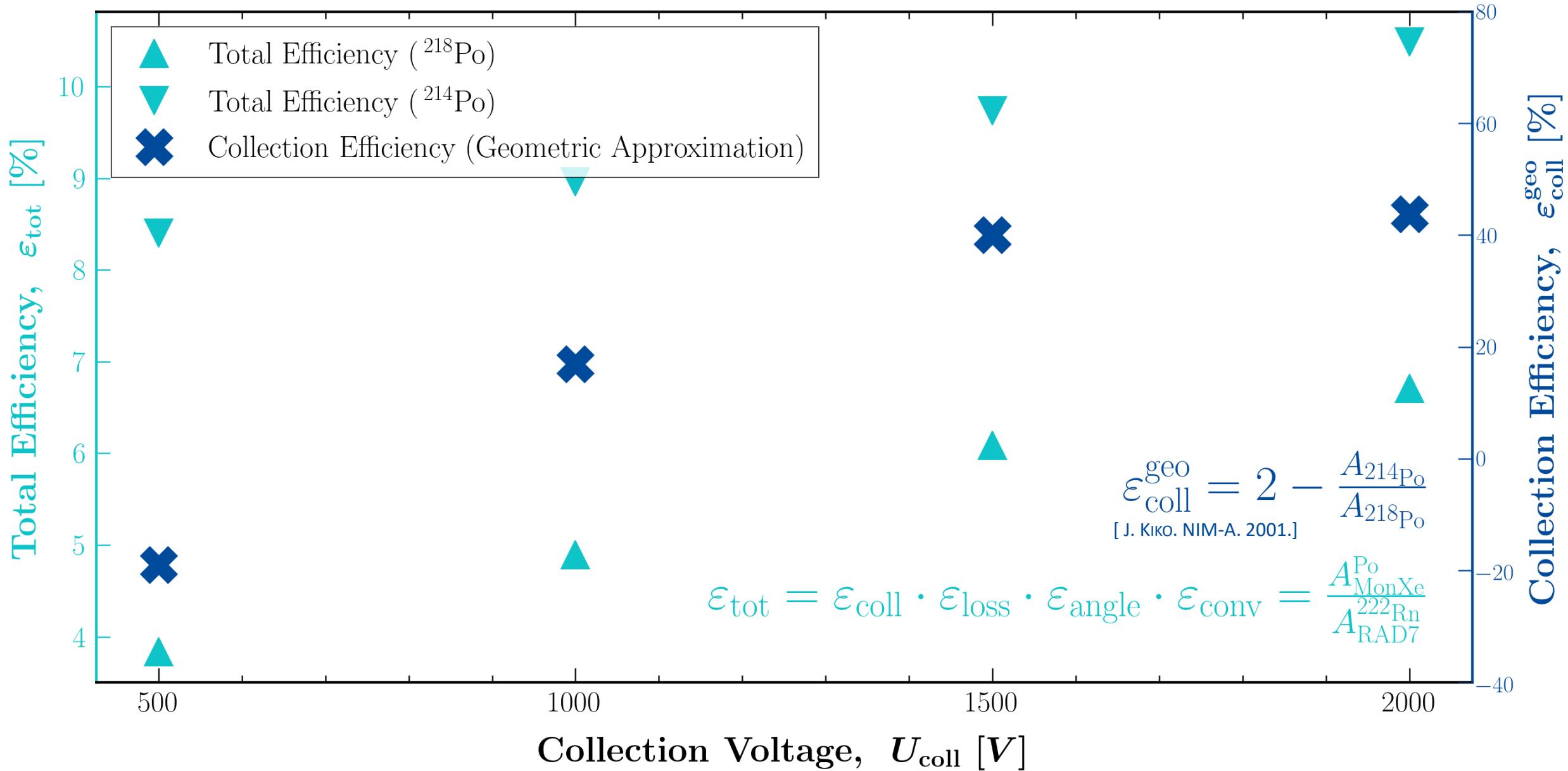


# Waveform: 7.8MeV $\alpha$ ( $^{214}\text{Po}$ )

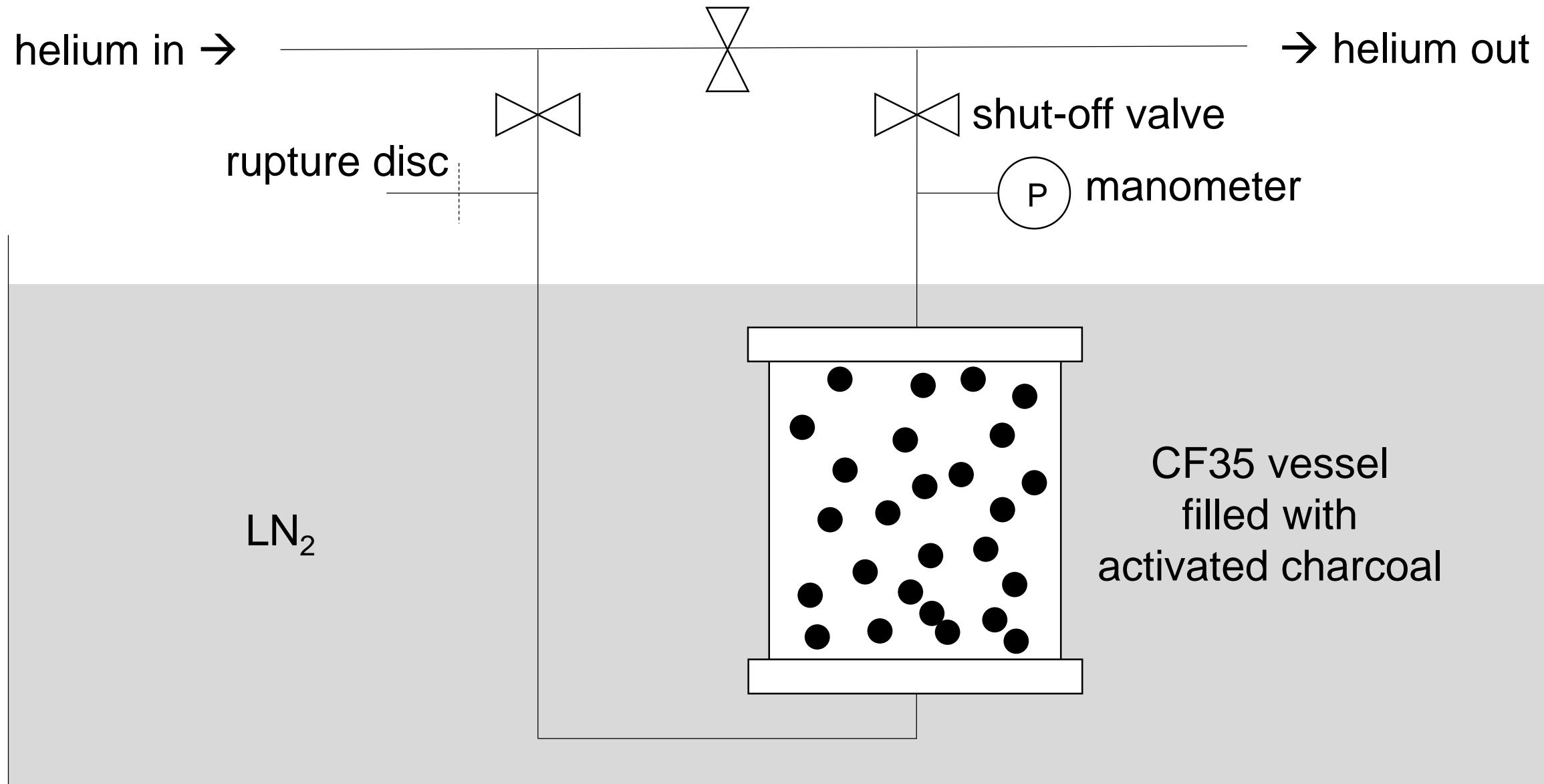


# Efficiency Studies

[L. GOD: *Efficiency Studies for the MonXe Radon Emanation Chamber*. B.Sc. Thesis. Aug 2019. Freiburg.]



# Activated Charcoal Filter



MonXe

