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Construction and Characterization of Gas Filters

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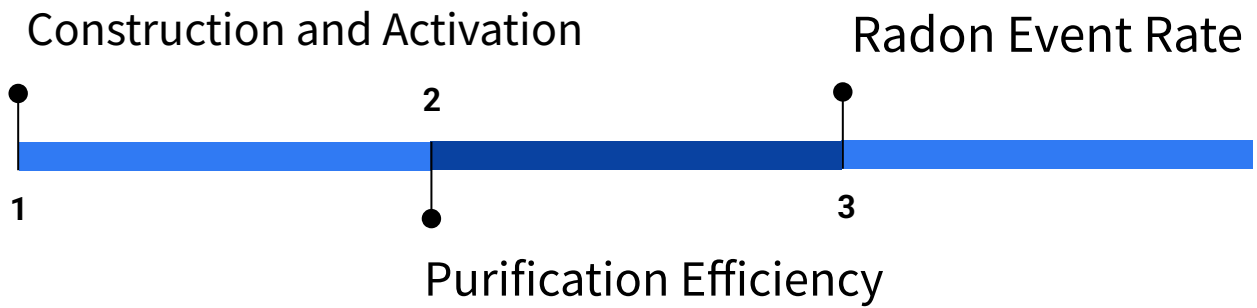
Motivation

- High gas purity is essential for stable detector operation
- High-purity gas is available (6N)
  - additional filtration may further reduce contaminants
- Goal: long term detector operation
  - requires gas circulation system
  - Filters remove contaminants accumulating during operation due to materials outgassing

Work Progression



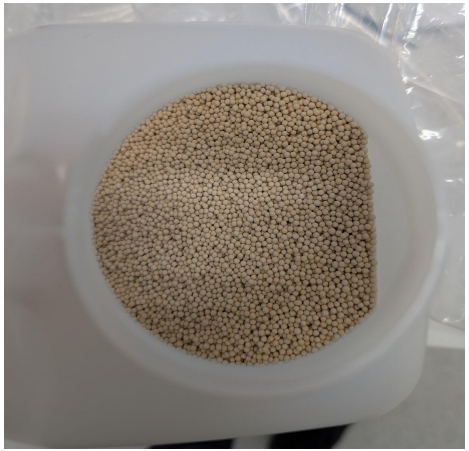
Material Selection

- Copper oxide (Q5) for oxygen removal
- Activation: **$CuO + H_2 \rightarrow Cu + H_2O$**
- Filtration: **$2Cu + O_2 \rightarrow 2CuO$**
- Molecular sieves for water removal

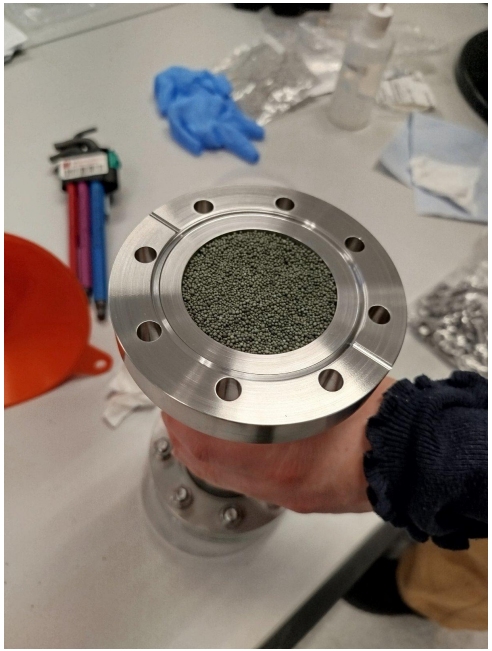
60 % Molecular sieve 3A - higher selectivity

+

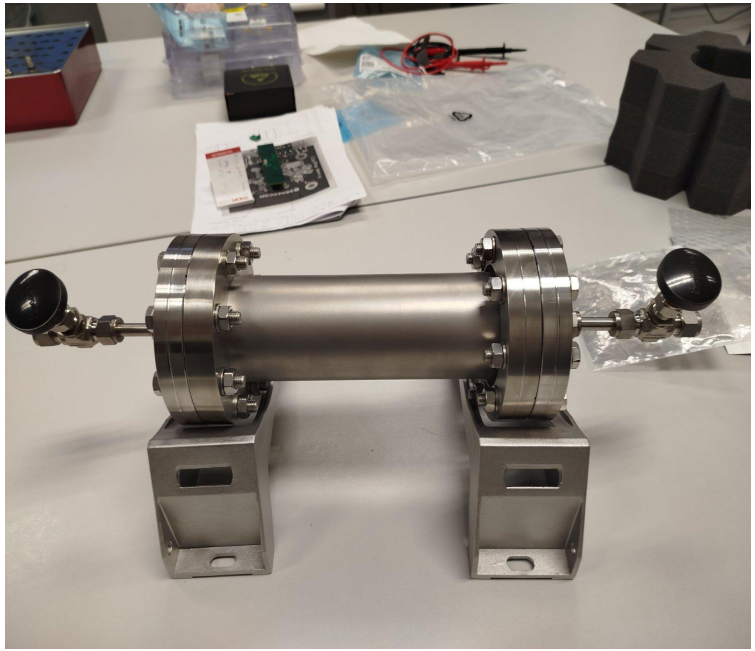
40 % Molecular sieve 4A - higher capacity



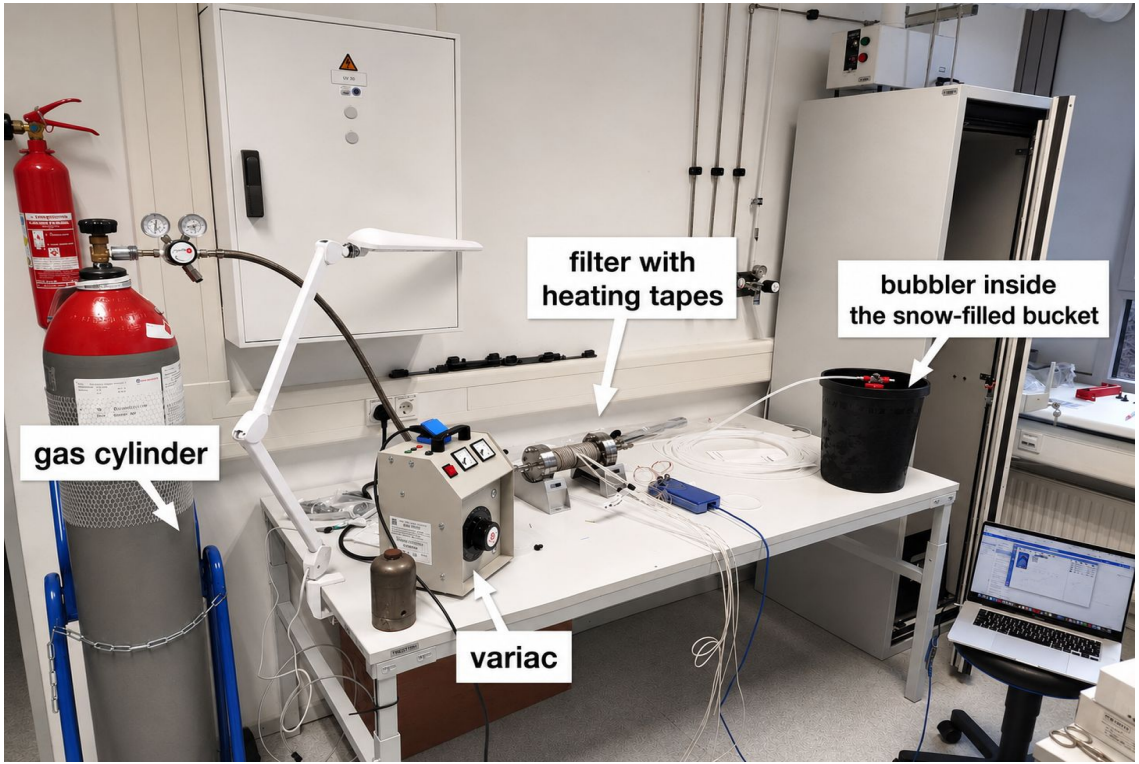
Filter Construction







Activation


filter with
heating tapes
bubbler inside
the snow-filled bucket
gas cylinder
variac



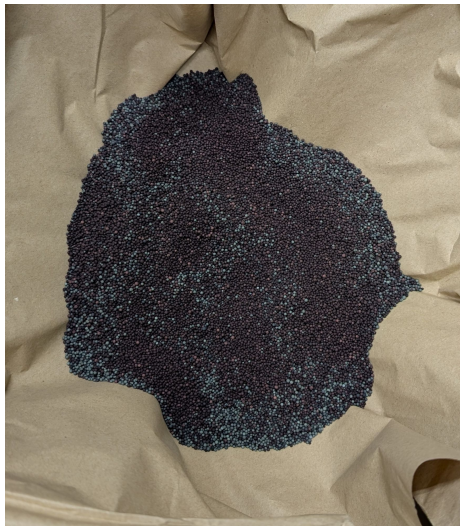
Activation

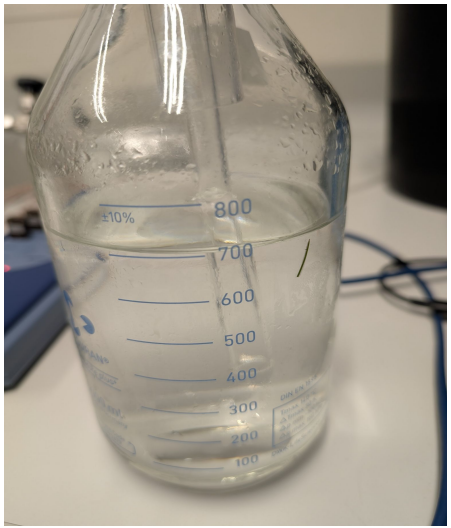
Oxygen-removing filter:

- Reddish copper color
- Increase in temperature during refilling

Water-removing filter:

- Bubbles released in water
- Rise in water level after increasing path length





Activation

Oxygen-removing filter:

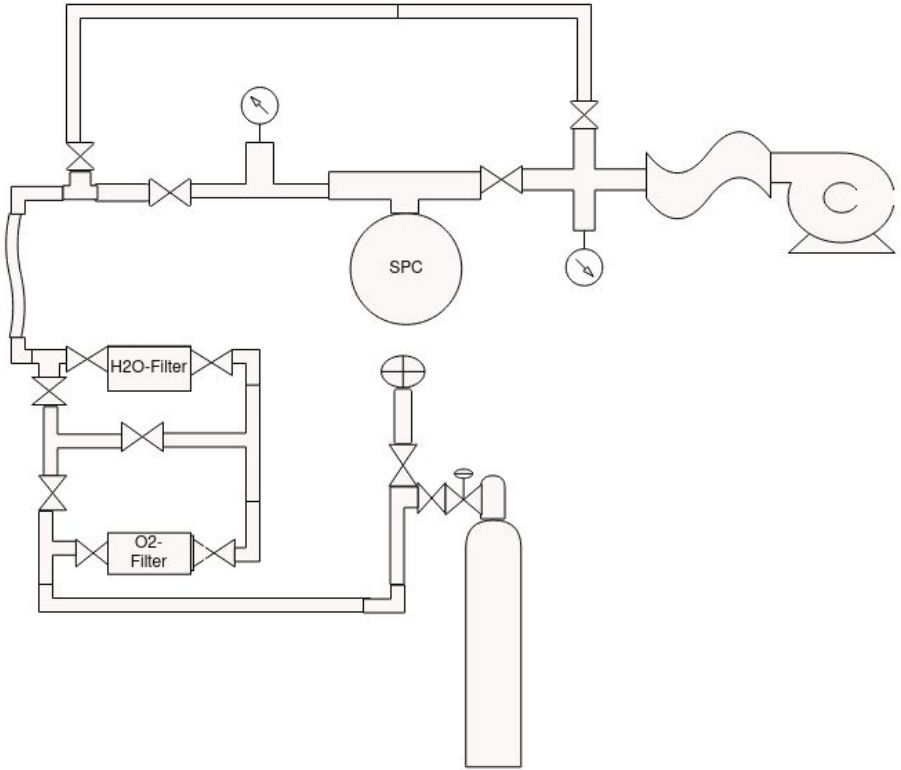
- Reddish copper color
- Increase in temperature during refilling

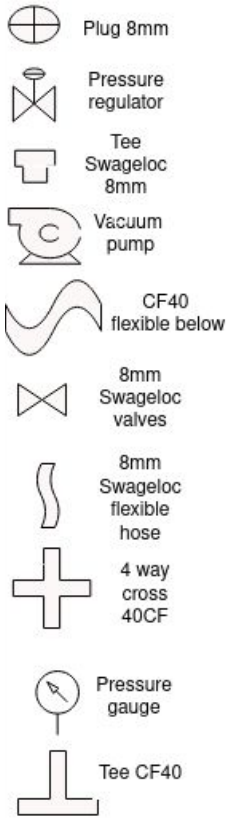
Water-removing filter:

- Bubbles released in water
- Rise in water level after increasing path length

Increase in path length required

Experimental Setup





Experimental Setup

Setup chosen to enable flexible operation:

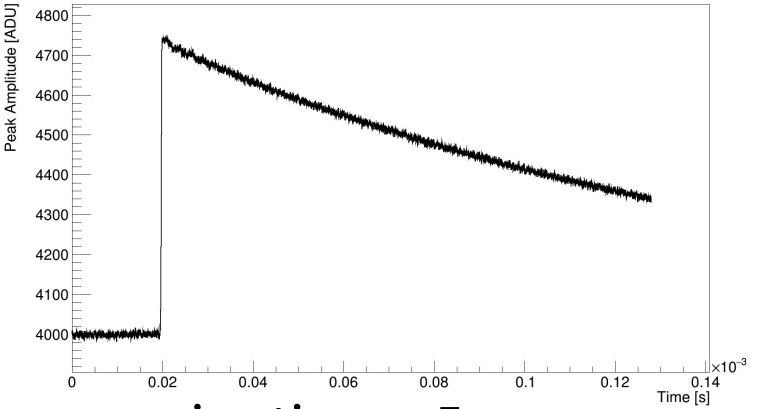
1. use none of the filters
2. use both filters
3. use each filter separately



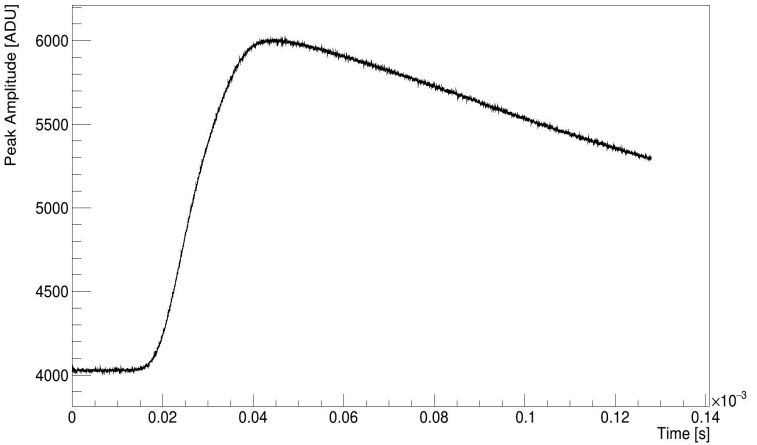
Analysis

- 4000 V & 1 bar N_2
- ^{241}Am source (alpha 5.49 MeV)
- readout channel 0 (F0)
- rise time > 5 µs
- positive pulse on channel 0 and negative pulses on remaining channels
- ppm(O_2) = 338 ± 36

rise time < 5 µs



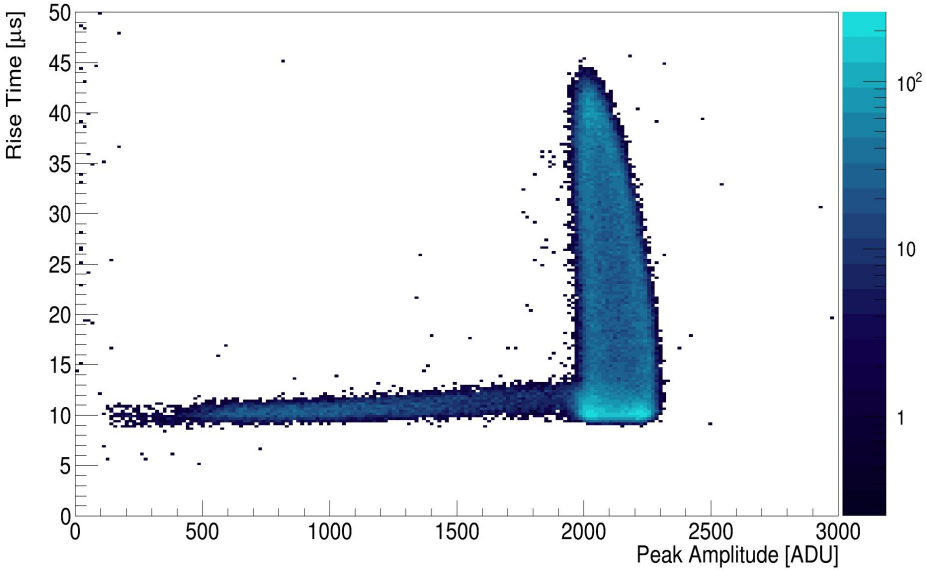
rise time > 5 µs



Purification Efficiency Measurements

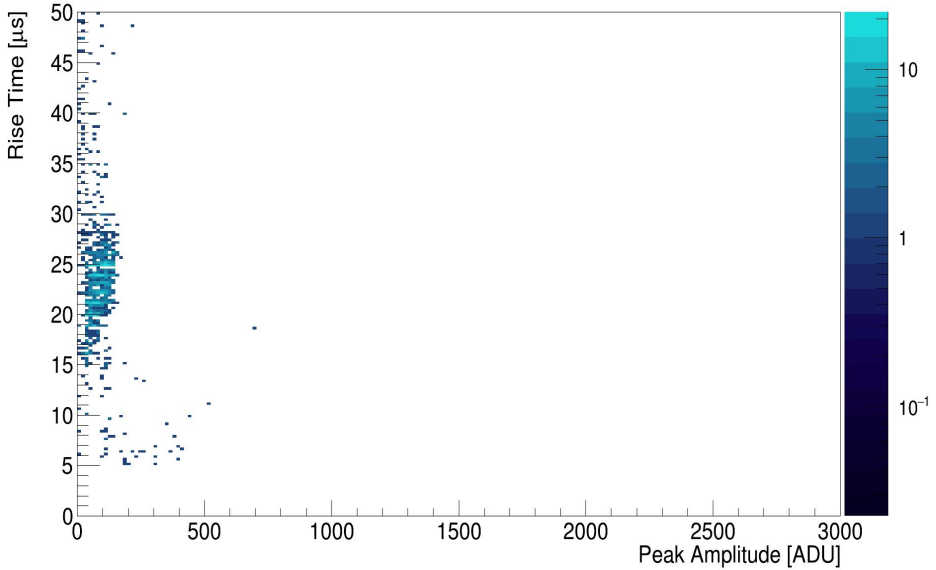
Without filters

Before contamination



9 µs < rise < 45 µs

After contamination

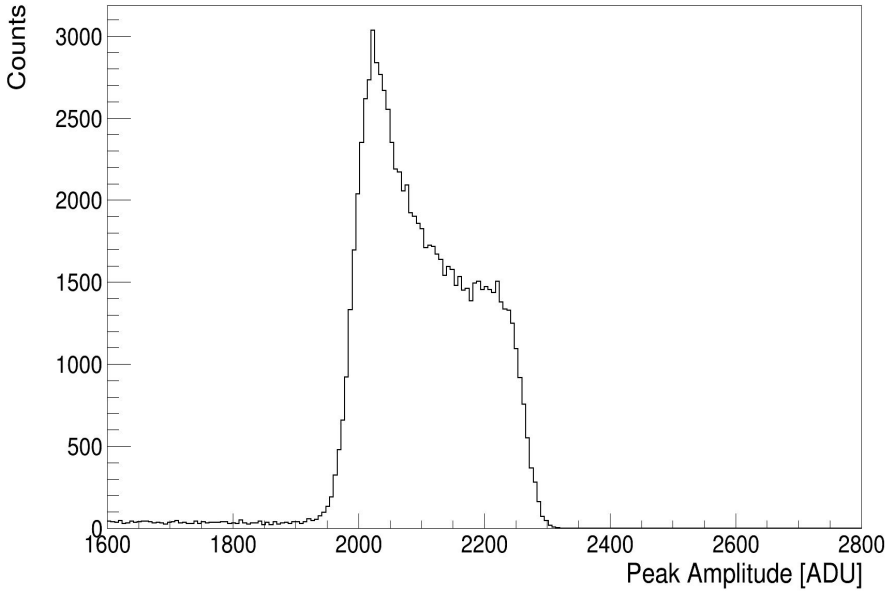


15 µs < rise < 30 µs

Purification Efficiency Measurements

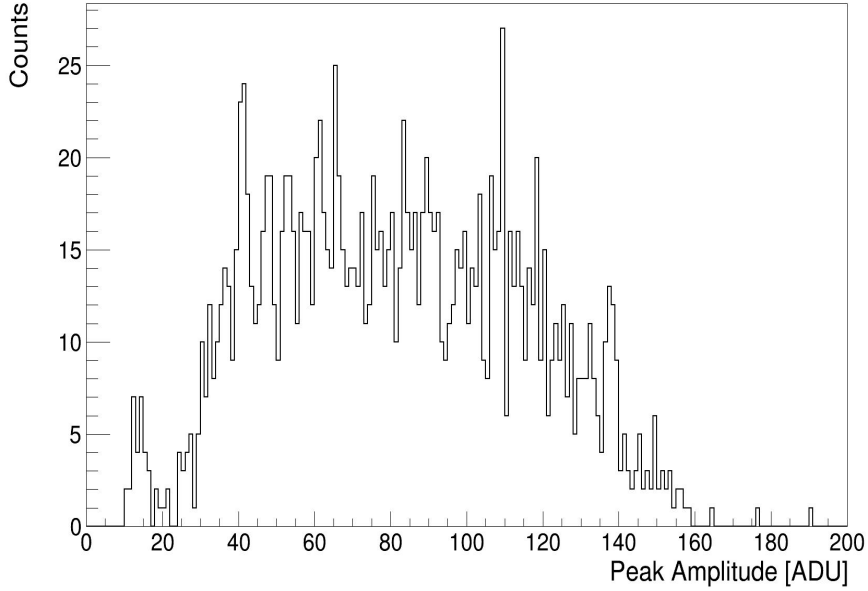
Without filters

Before contamination



Median peak amplitude = 2092 ADU

After contamination

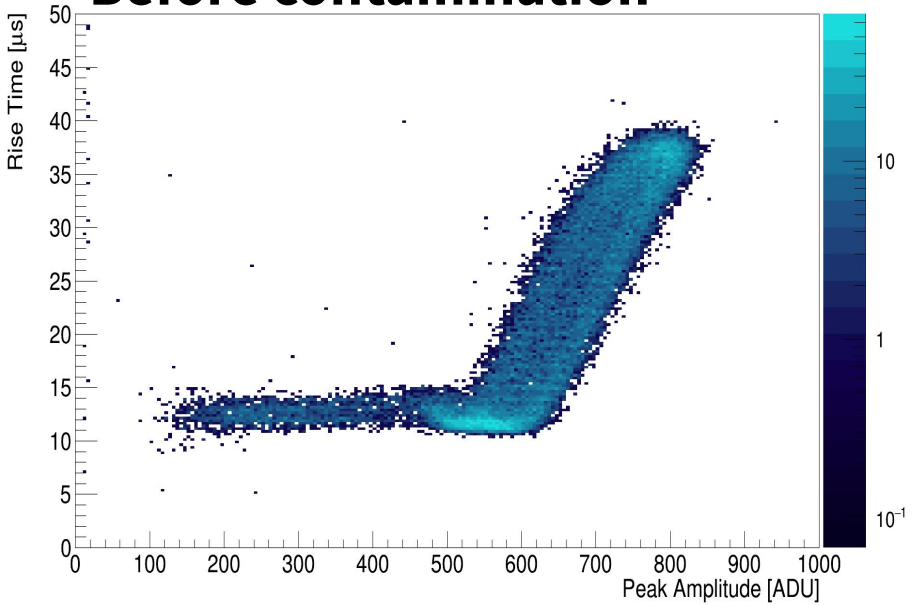


Median peak amplitude = 100 ADU

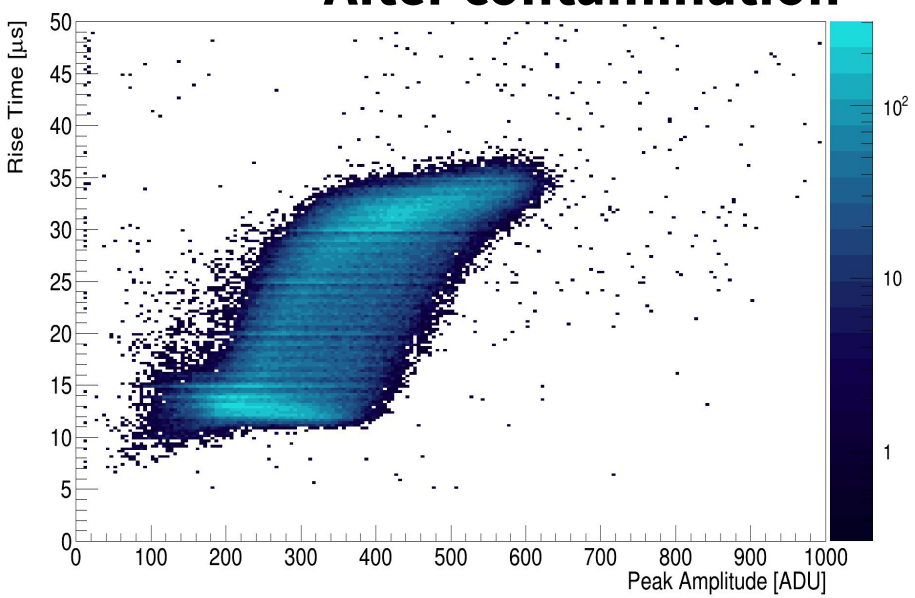
Purification Efficiency Measurements

With both filters

Before contamination

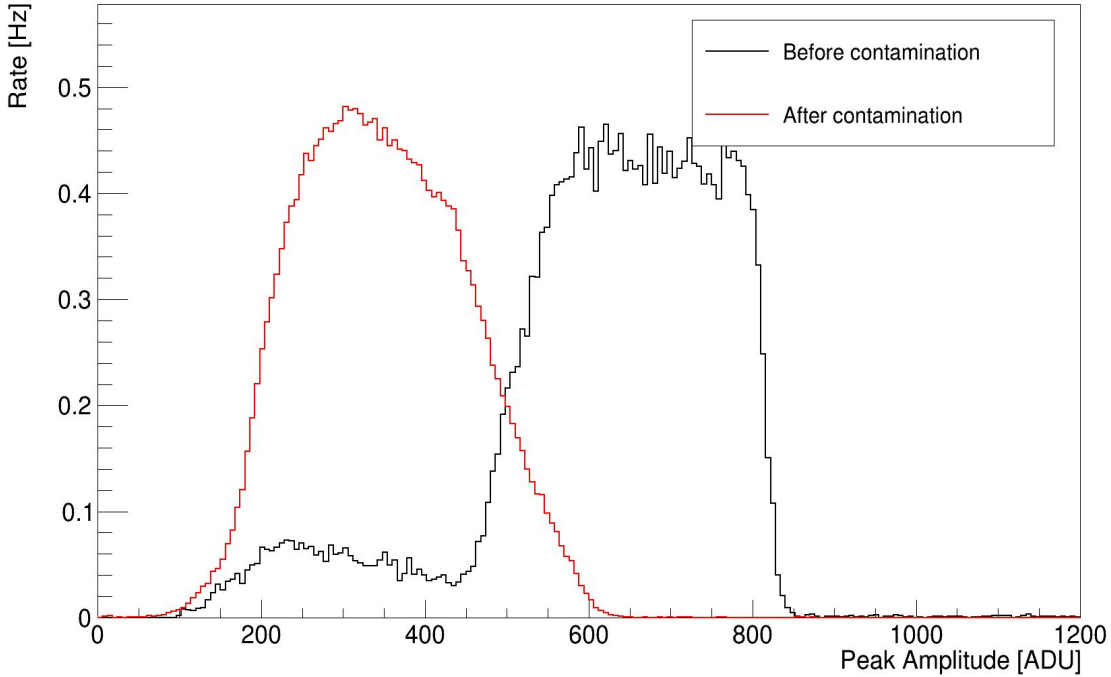


After contamination



All events selected

Purification Efficiency Measurements



With both filters

Median peak amplitude

before: 659 ADU
after: 288 ADU

Purification Efficiency Measurements

Without filters

- Peak amplitude ↓ 95 %
- Event rate 22 → 0.007 Hz

With both filters

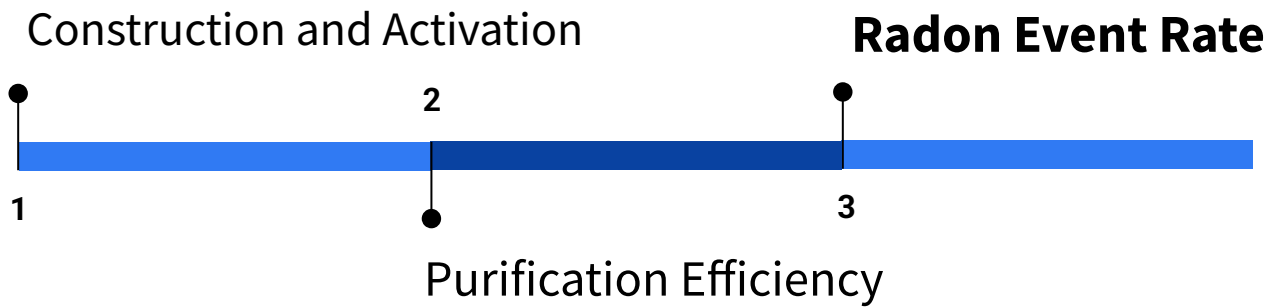
- Peak amplitude ↓ 56%
- Event rate 26 → 22 Hz

➡ Event-rate reduction mainly due to detector instability

➡ Significant improvement of the detector response

Filters significantly mitigate oxygen contamination!

Work Progression



Radon Measurements

Nuklid	Zerfall	HWZ	α-Energie	PAE/Atom	Atome/ Bq	PAE/Bq
Rn-222	α	3,825 d	5,49 MeV	0	0	0
Po-218	**α**	3,05 min	**6,00 MeV**	**13,68 MeV**	264	**3612 MeV**
Pb-214	β	26,8 min		**7,68 MeV**	2320	**17820 MeV**
Bi-214	β	19,9 min		**7,68 MeV**	1710	**13130 MeV**
Po-214	**α**	0,164 ms	**7,69 MeV**	7,68 MeV	0,000231	1,77 keV
Pb-210	β	22,3 a		0		
Bi-210	β	5.01 d		0		
Po-210	α	138,4 d	5,30 MeV	0		
Pb-206		stabil		0		

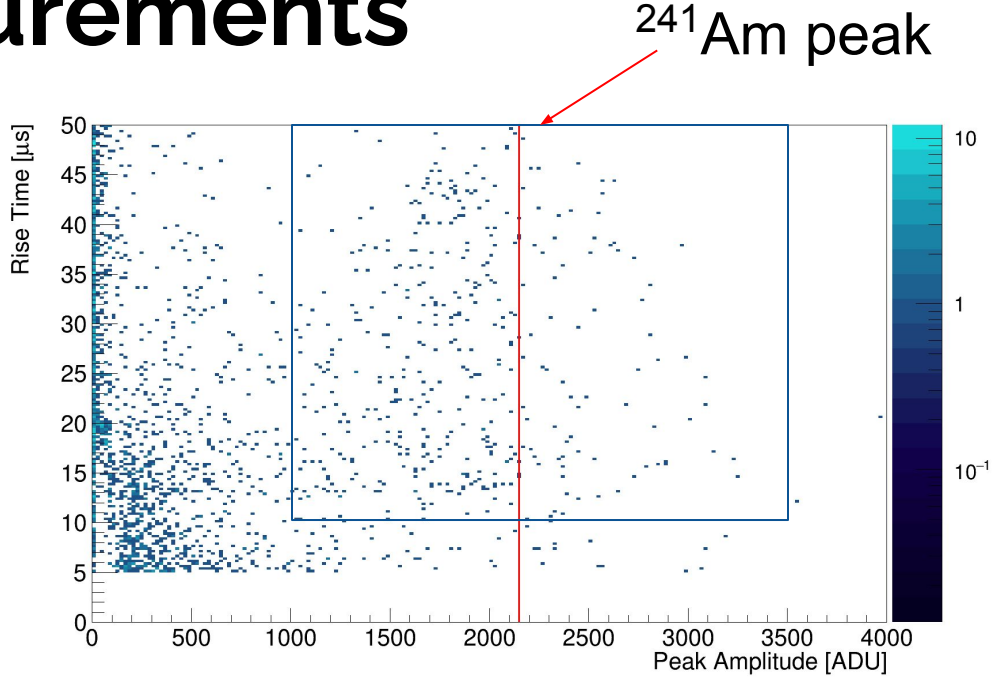
- Radon represents a particularly critical background source
- Gas purifiers may themselves emit radon

➡ Three characteristic alpha lines expected

Radon Measurements

Only oxygen-removing filter

- Due to instability of ACHINOS, no identification of three distinct alpha lines possible
- Candidate region defined empirically



1000 ADU < peak amplitude < 3500 ADU
rise time > 10 µs

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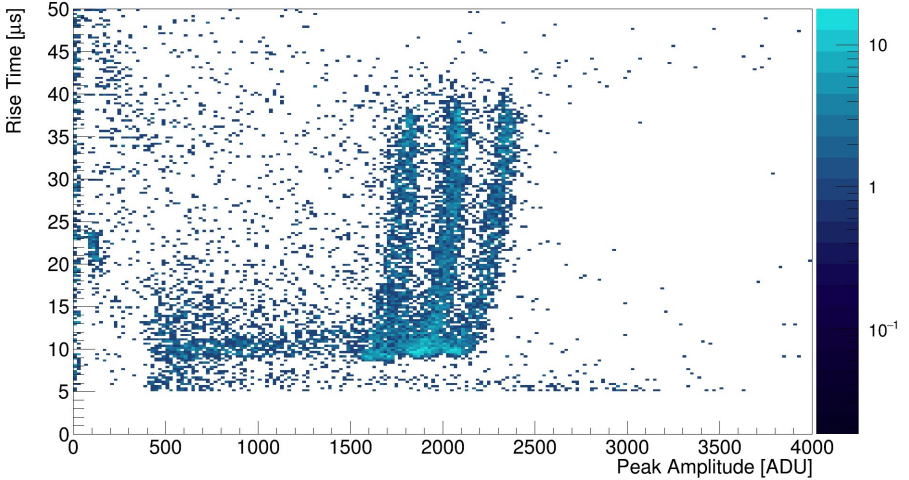
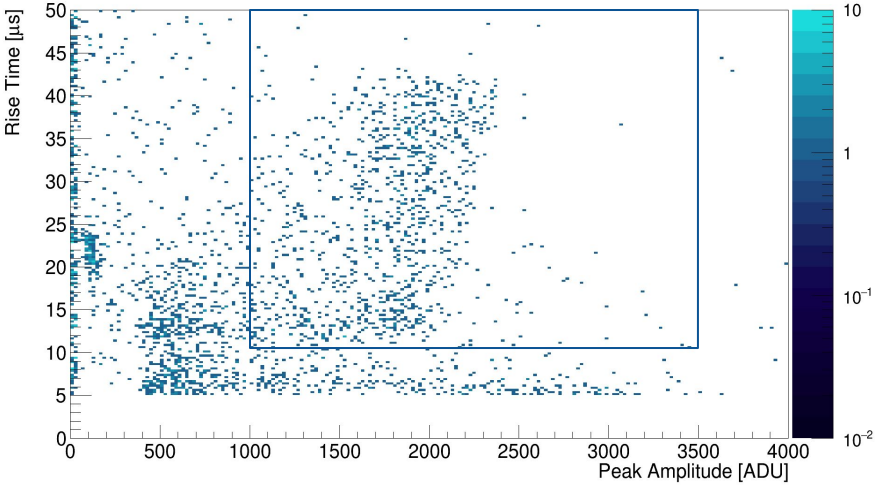
Radon Measurements

Only water-removing filter





same event selection criteria were applied

Radon Measurements - Results

- Radon event rates are overestimated
- More stringent event selection would likely have yielded lower radon event rates

Filter	Rate
Oxygen Filter	0.068 Hz
Water Filter	0.103 Hz
Entegris Filter	1.2 Hz
UOB-F1	0.086 Hz

Conclusion

- Both filters successfully constructed and activated
- Introduction of 338 ppm of O_2 led to a complete loss of efficiency
- Peak amplitude decreased by 95 % without filters and by 56% using both filters

➡ significant improvement through filters

- Significantly lower radon emanation rates than the Entegris filter
- First estimation of the radon event rate of the separate components

Thank you!

Questions?