Towards a gas filtration setup for ultra-sensitive SF_6 gas based rare-event Physics experiments

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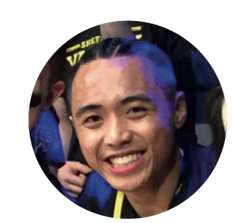


Introduction

- The gas **SF_6** has attracted attention for use in directional dark matter searches due to its **novel properties**
- Problems with signal detection can arise from **contaminants** such as **radon** and **impurities**.
- **Radon** decays can **mimic genuine events**, producing unwanted background events
- I**mpurities** can capture interaction-produced electrons, which **cause issues with signal detection**.
- Very **Important to use pure SF_6!**

SF_6 environmental impact

- **SF_6** is the **most potent greenhouse gas**, making its disposal problematic
- Work towards **gas filtration setup** minimising contamination and **reducing the amount of the total SF_6 used**

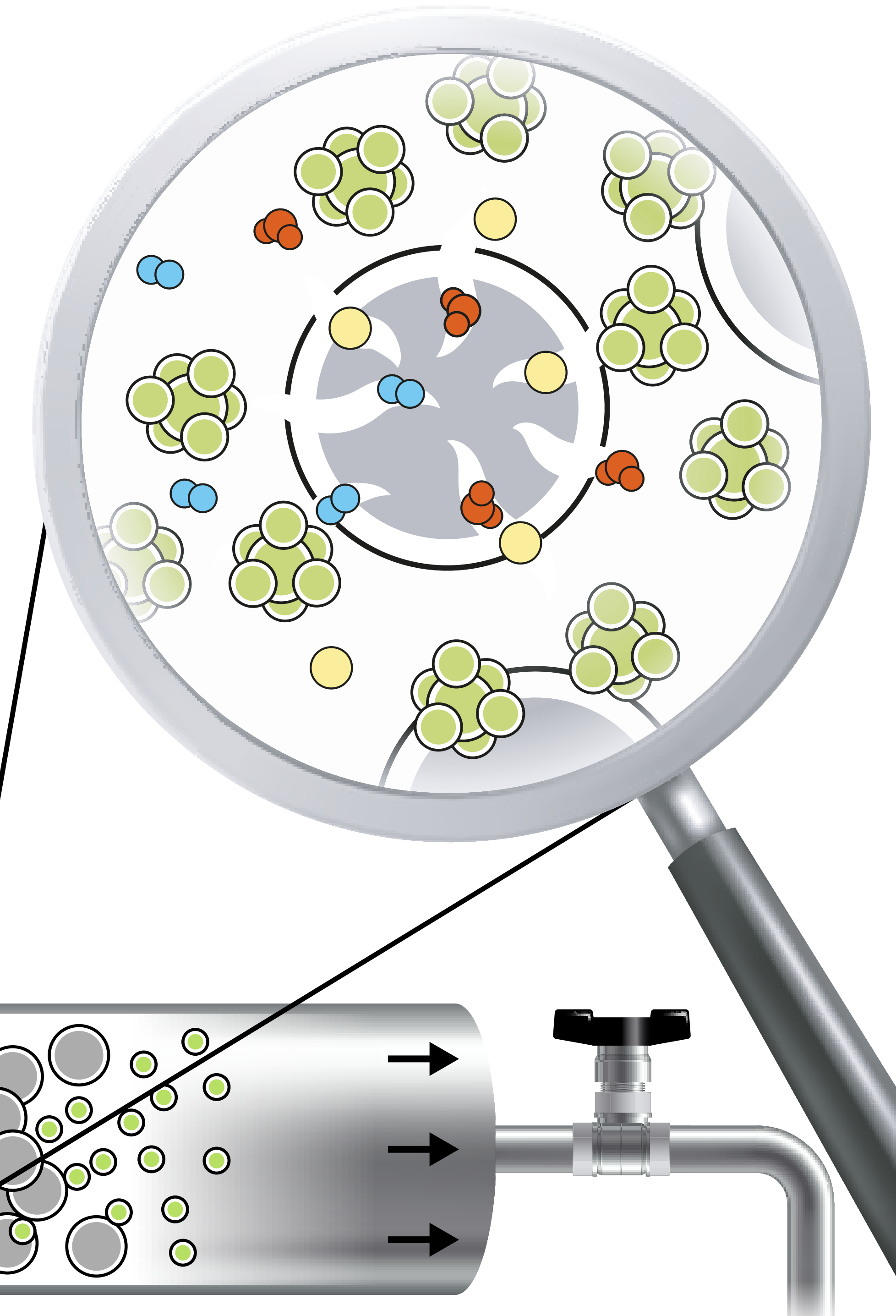
Greenhouse Gas	Formula	100-year GWP (AR4)
Carbon dioxide	CO_2	1
Methane	CH_4	25
Nitrous oxide	N_2O	298
Sulphur hexafluoride	SF_6	22,800
Hydrofluorocarbon-23	CHF_3	14,800
Hydrofluorocarbon-32	CH_2F_2	675
Perfluoromethane	CF_4	7,390

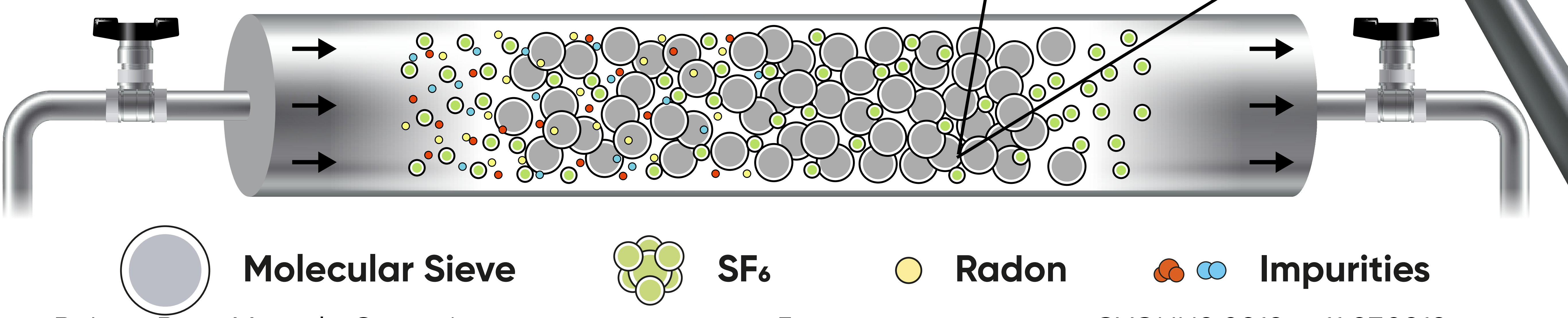
Outline

1. What are molecular sieves?
2. Removal of radon from SF_6
3. Removal of impurities (H_2O and N_2) from SF_6
4. Application to TPC Triple GEM
5. Further work

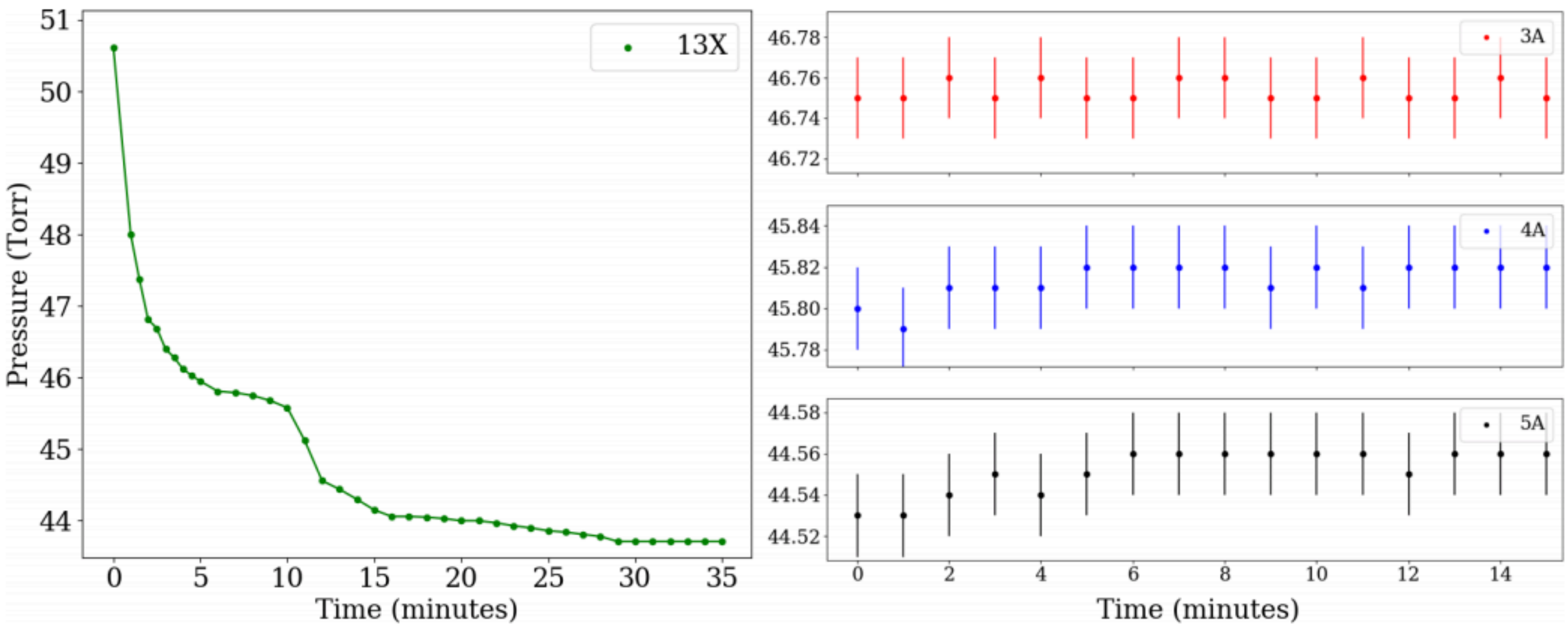
Molecular sieves

- Molecular sieves are crystalline metal aluminosilicate structures with specific pore sizes (**Commercially available 3A, 4A, 5A, 13X)**
- Pores allow molecules with the critical diameter equal or below to be adsorbed on to the structure
- Molecules with diameters larger than the critical diameters pass between the bead gaps.





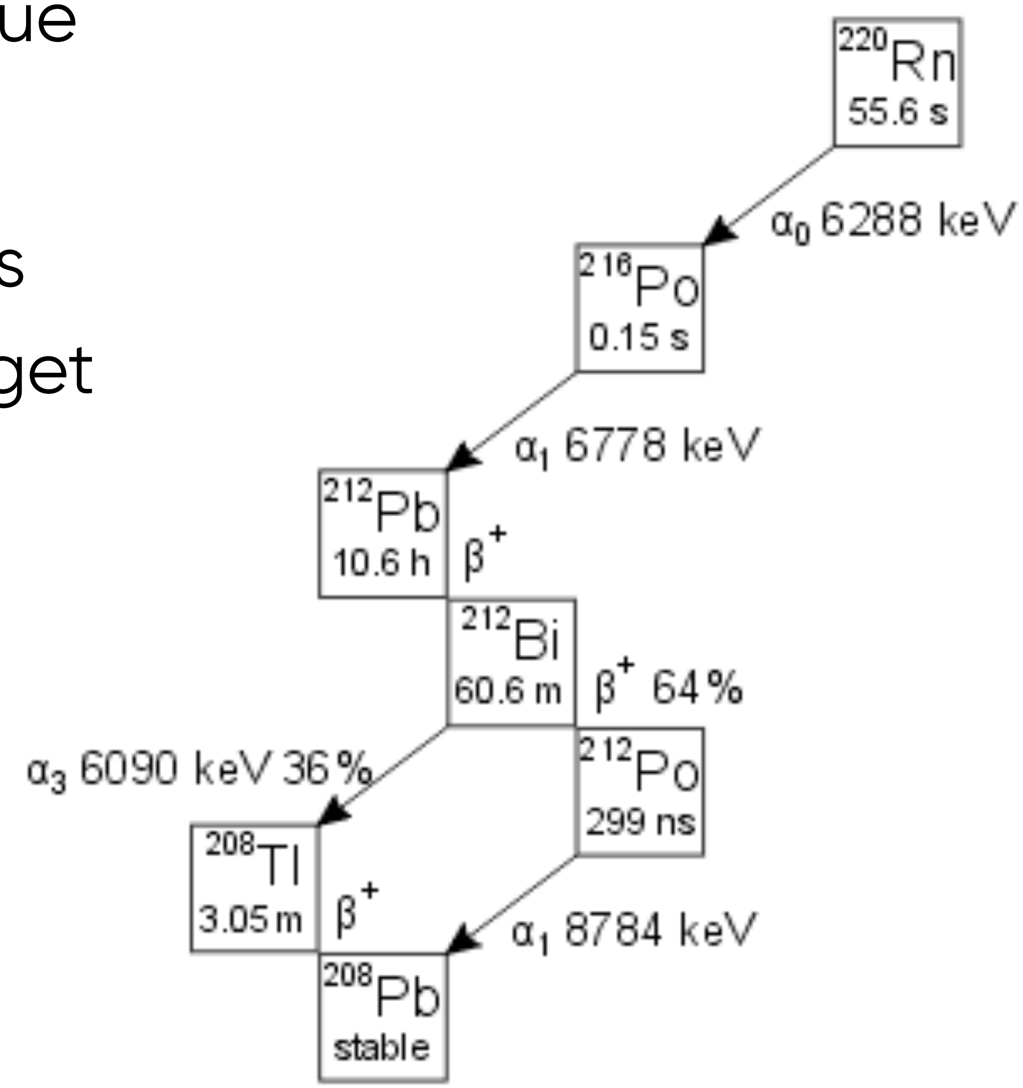
SF_6 absorption test



- SF_6 absorption test with commercially available molecular sieves (3A, 4A, 5A and 13X)
- **3A, 4A** and **5A** molecular sieves **do not absorb SF_6**
- **13X** molecular sieve **absorbs SF_6** so cannot be used for filtration

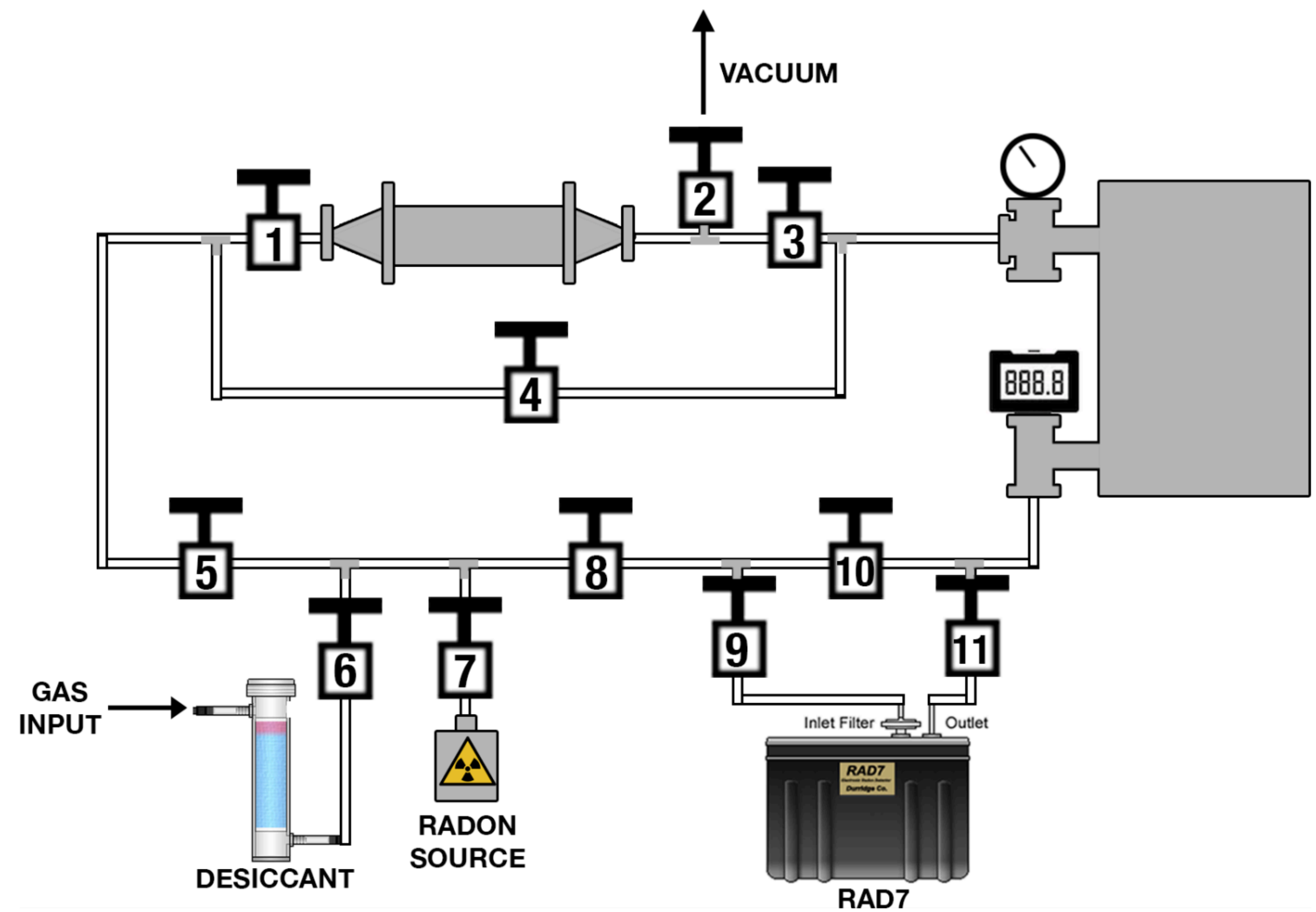
Radon

- **Radon is an inert radioactive gas** causing unique problems
- Radon can diffuse through materials even solids and emanate from the surface into the gas target
- Radon daughters can mix up with the bulk of a material during the production phase
- **Radon decays can mimic genuine events**, producing unwanted background events
- **Important to remove radon!**



Method: Radon removal from SF_6

- A DURRIDGE RAD7 continuous radon detector was used to measure a closed SF6 gas system
- The system was injected with radon using a passive radon-radium source
- Radon measurements were made with and without the molecular sieve filter engaged



Radon removal from SF_6 using 5A molecular sieve

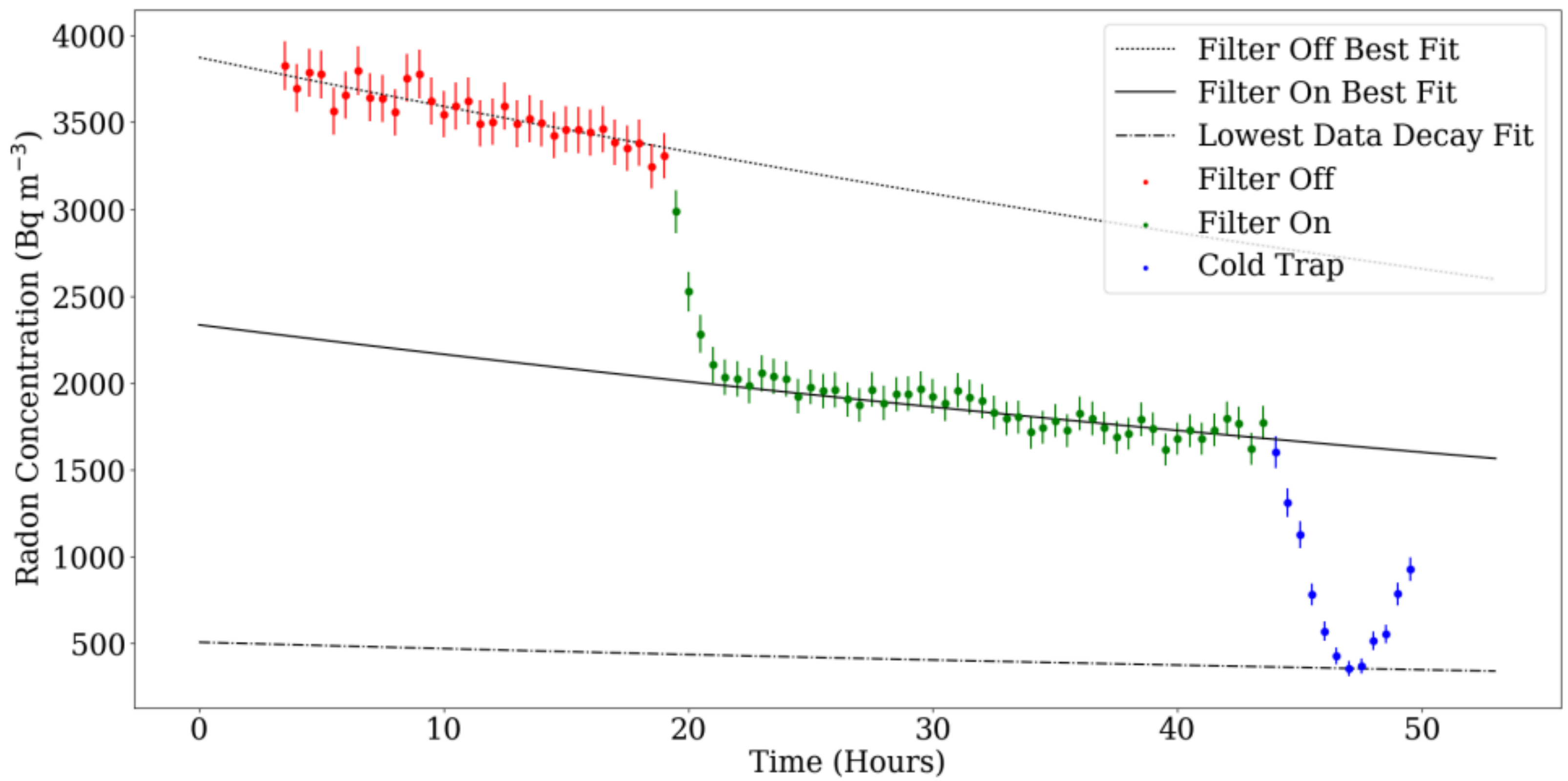


Figure 10. Radon concentration in SF_6 shown over time for the 5Å molecular sieve filter. The filter was engaged after 20 hours and the cold trap was engaged after 44 hours. The decay fit on the blue data set was determined using only one data point to extrapolate the lowest possible radon concentration achieved.

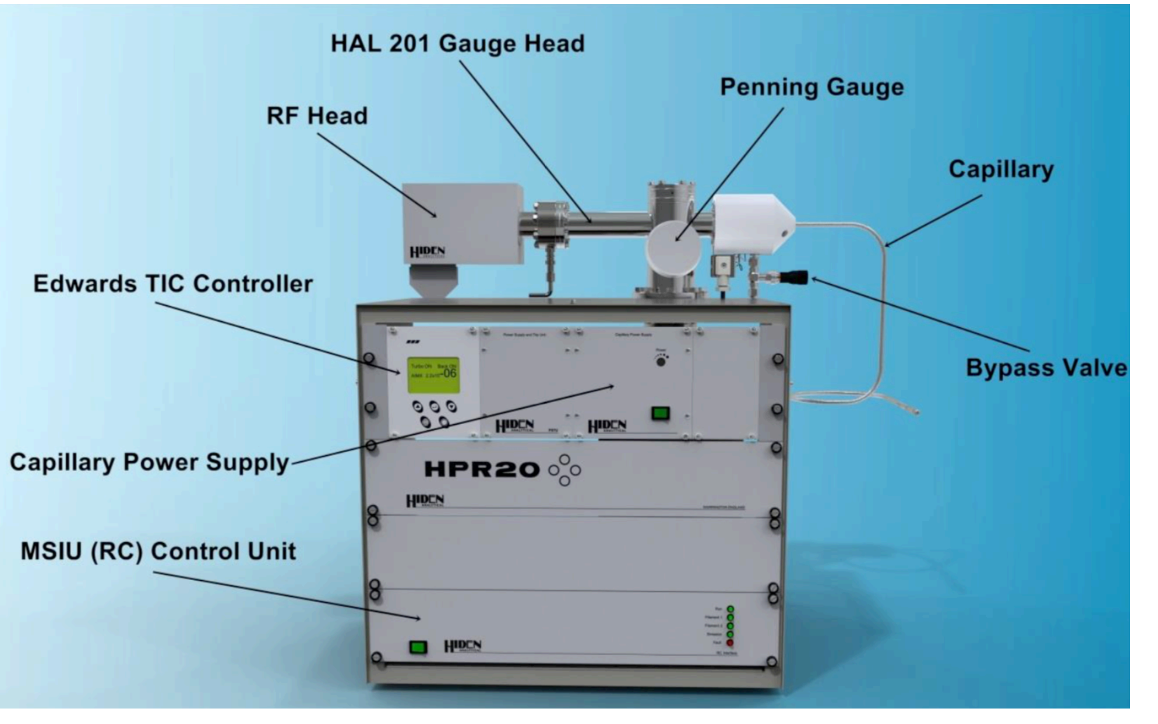
- Radon concentration was **reduced by 36%** with the **5A molecular sieve**
- Total reduction of radon was **improved to 87%** when **cooled with dry ice**
- 100g of molecular sieve used for 34L 1 atmosphere of SF_6

Impurities: H_2O and air

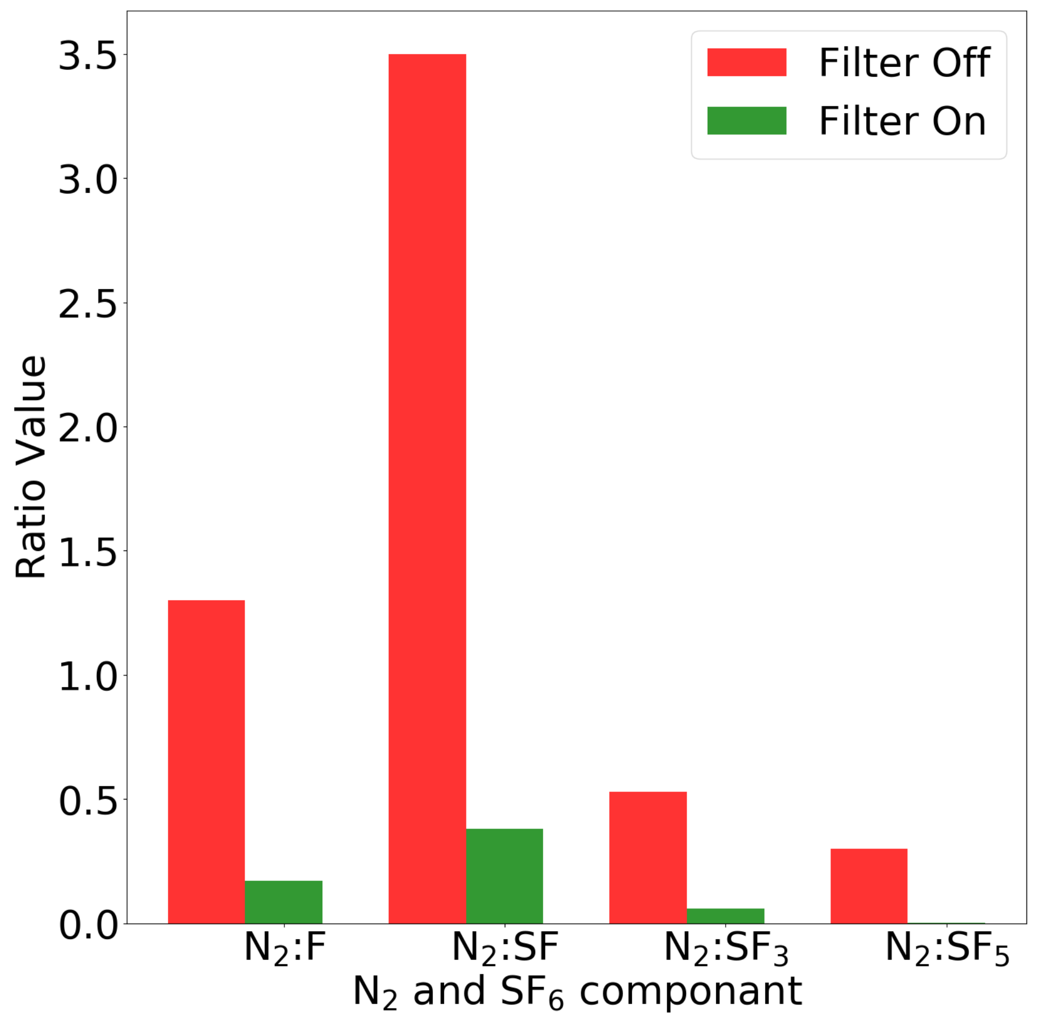
- Out gassing and leaking can introduce impurities such as water and air
- **Impurities** can capture interaction-produced electrons, which which **cause issues with signal detection**
- **H_2O** can change the shape of signal reducing the signal pulse height by reacting with the SF_6
- **Important to remove impurities!**

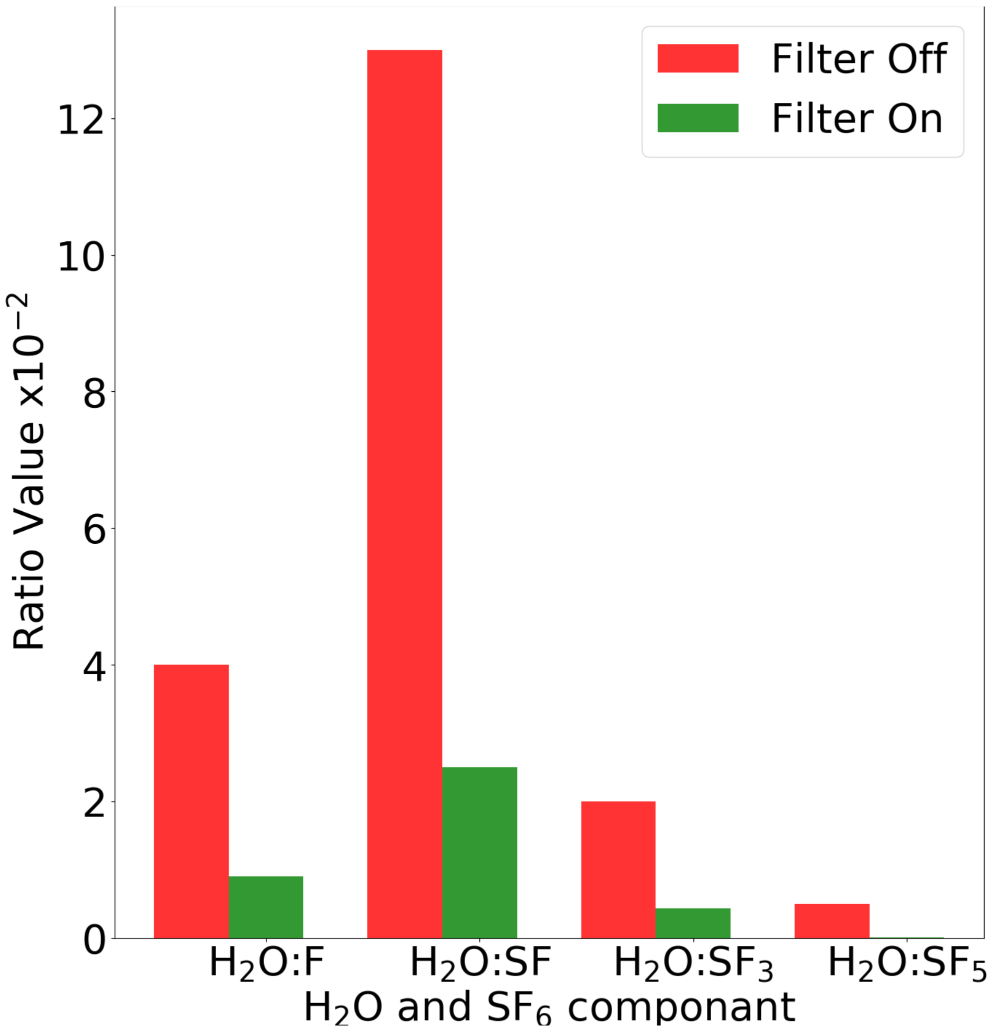
Method: H_2O and N_2 removal from SF_6 using 3A molecular sieve

- A Hiden Analytical residual gas analyser was used to monitor the gas composition over time of a closed SF_6 gas system
- Fresh' high purity SF_6 gas was introduced to the gas system and was left to 'age' over time
- RGA measurement were made with and without the molecular sieves



H_2O and N_2 removal from SF_6 using 3A molecular sieve





- **Nitrogen decreased by 89%**
- **Water decreased by 79%**
  - 100g of molecular sieve in 96L of 200 torr of SF_6

Summary so far

3A Molecular Sieve

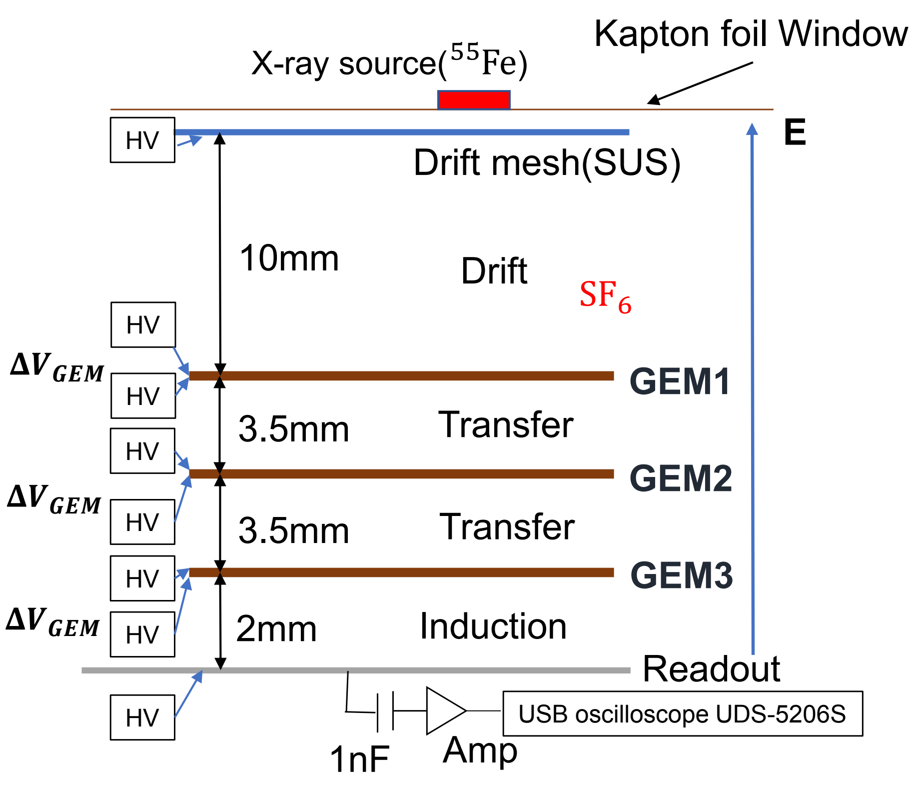
- **Nitrogen decreased by 89%** from SF_6
- **Water decreased by 79%** from SF_6
- 100g of molecular sieve in 96L of 200 torr of SF_6

5A Molecular Sieve

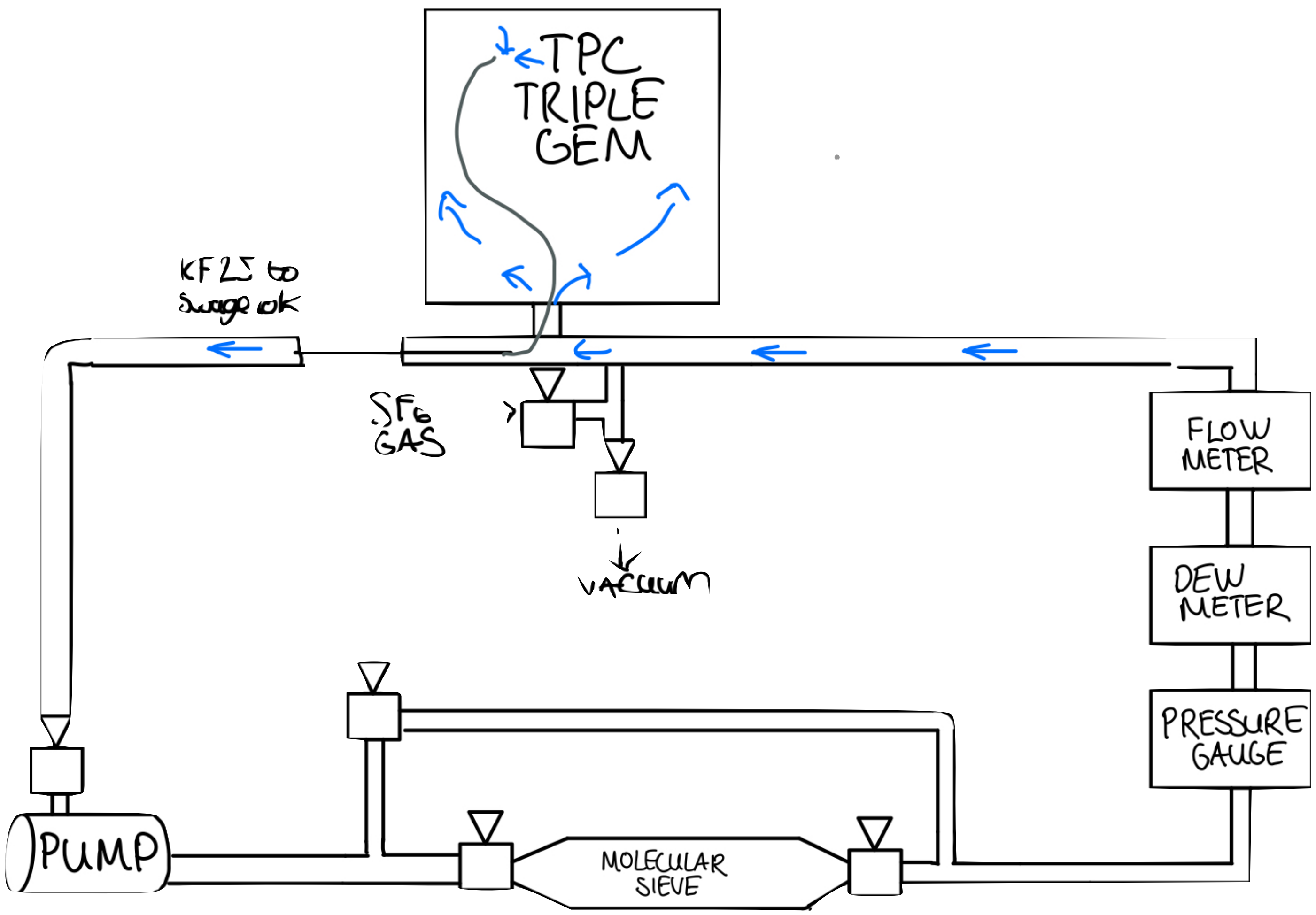
- **Radon** concentration was **reduced by 36%** from SF_6
- **Total reduction of radon** was **improved to 87%** when **cooled with dry ice**
- 100g of molecular sieve used for 34L 1 atmosphere of SF_6

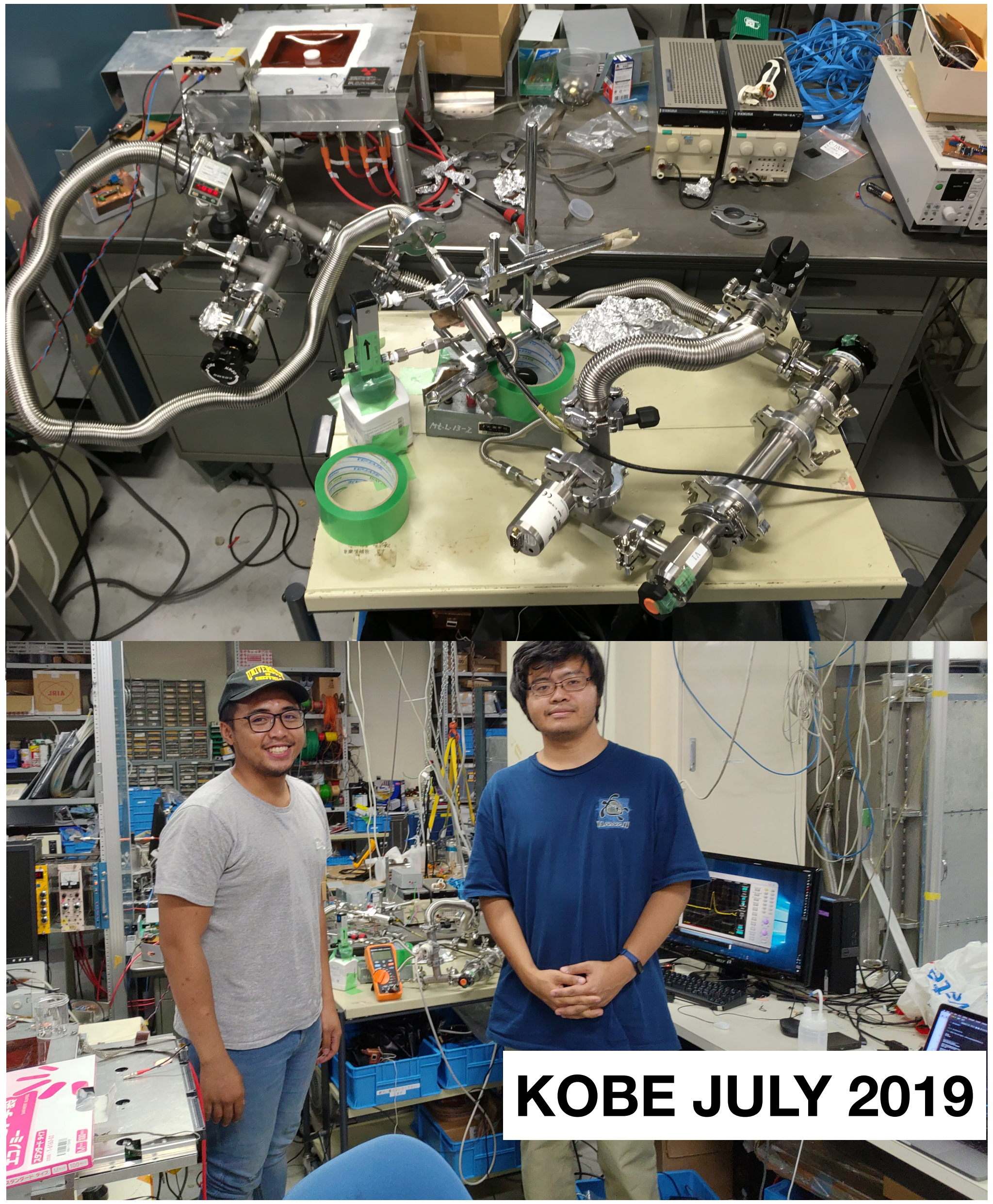
Application to a TPC Triple GEM

- A Thick Gaseous Electron multiplier (ThGEM) is used as the electron avalanche and readout device in a closed SF_6 system
- Investigate **signal deterioration** over time due to old SF_6
- **Signal recovery** with 5A and 3A molecular sieve



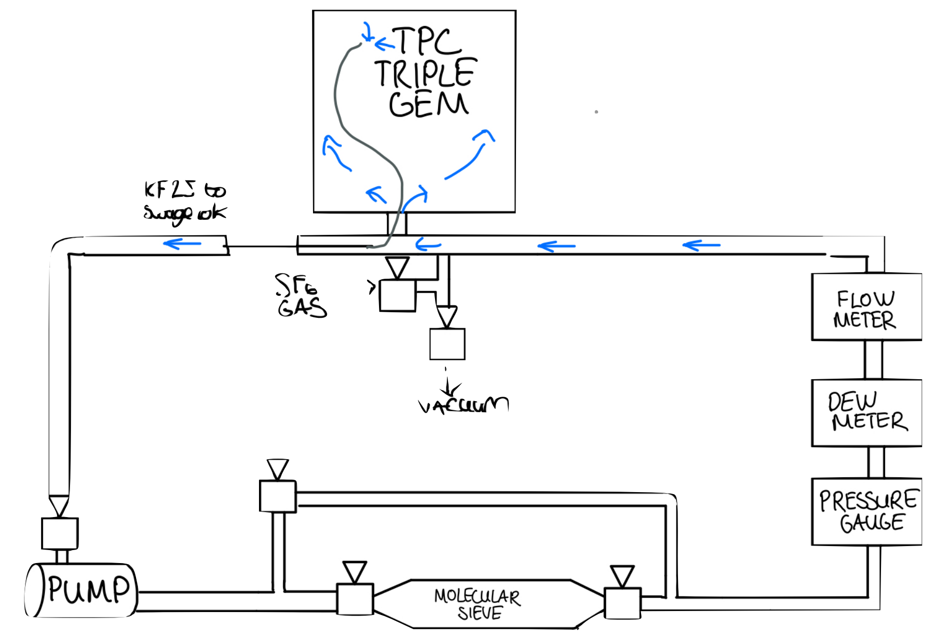
Molecular sieve recirculation with Triple GEM set up





Method: Molecular Sieve with Triple GEM (1)

- Fe-55 source was pointed into the TPC electric field cage to provide events
- 'Fresh' SF_6 was introduced into the TPC and signal was monitored over time as the gas 'ages'
- The molecular sieve was engaged after ~one day
- MCA, waveform, pressure and dew point was measured throughout the experiment
- Note that recirculating pump was on throughout the experiment



Method: Molecular Sieve with Triple GEM (2)

Experimental parameters that can affect signal

- Pressure in vessel
- HV between GEMs
- Contamination

Important to keep pressure and high voltage constant throughout the measurement!

Preliminary analysis

Pressure over time

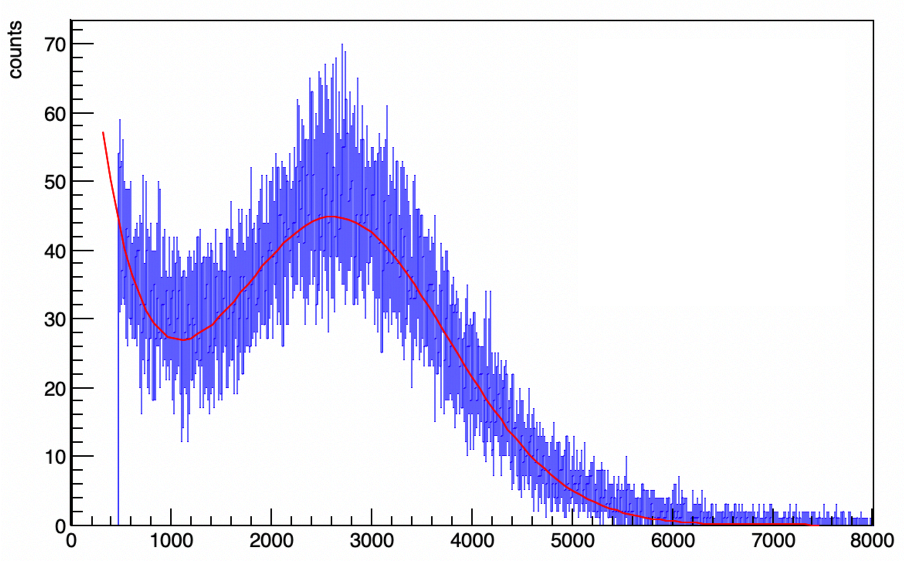
- Pressure was monitored and remained at 100 torr

High voltage over time

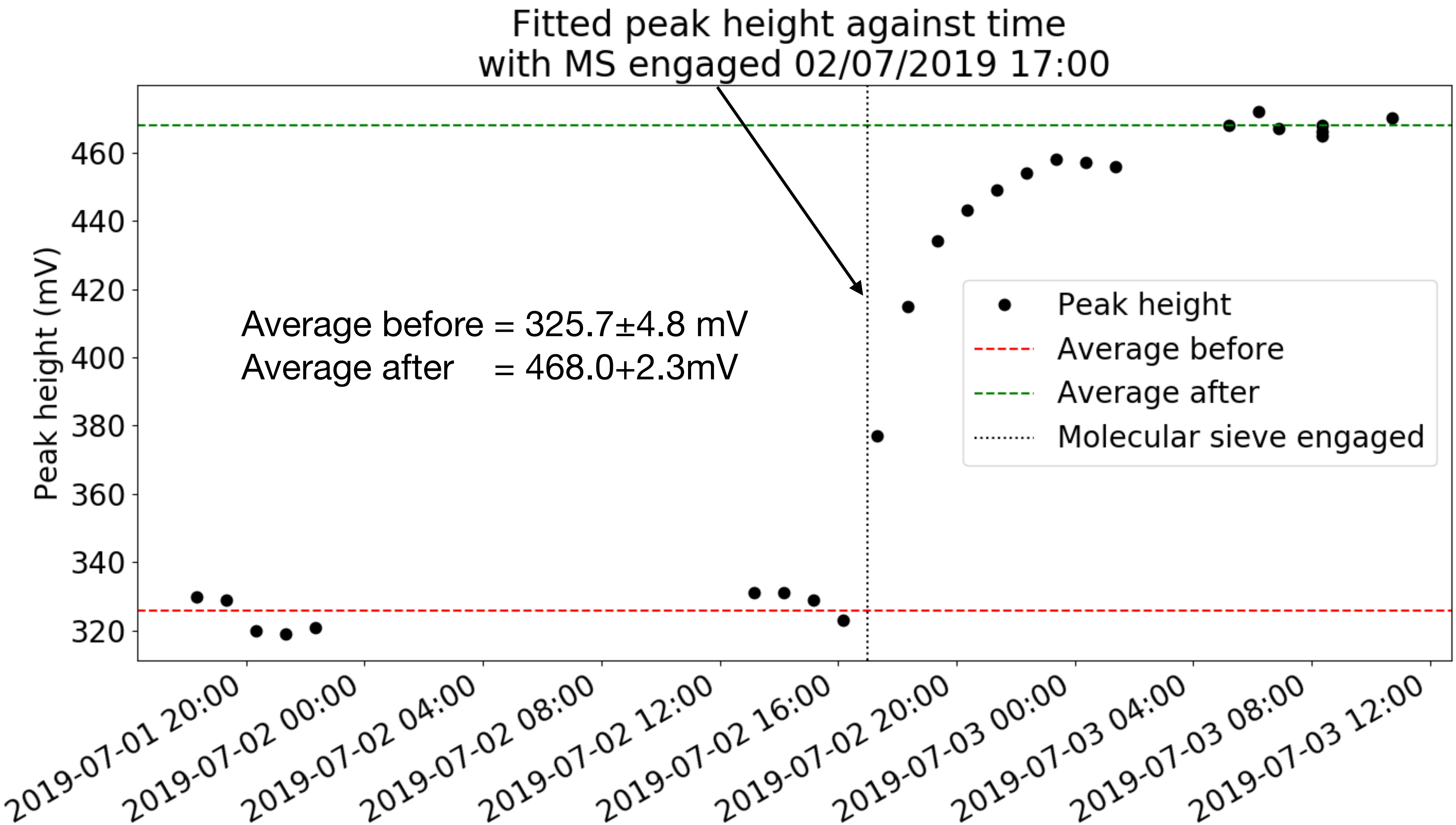
- High voltage remained constant throughout the measurement $\Delta V_{GEM} = 520V$

MCA over time

- MCA was fitted with a gaussian + exponential decay function
- Parameter of gaussian peak position used as pulse height value

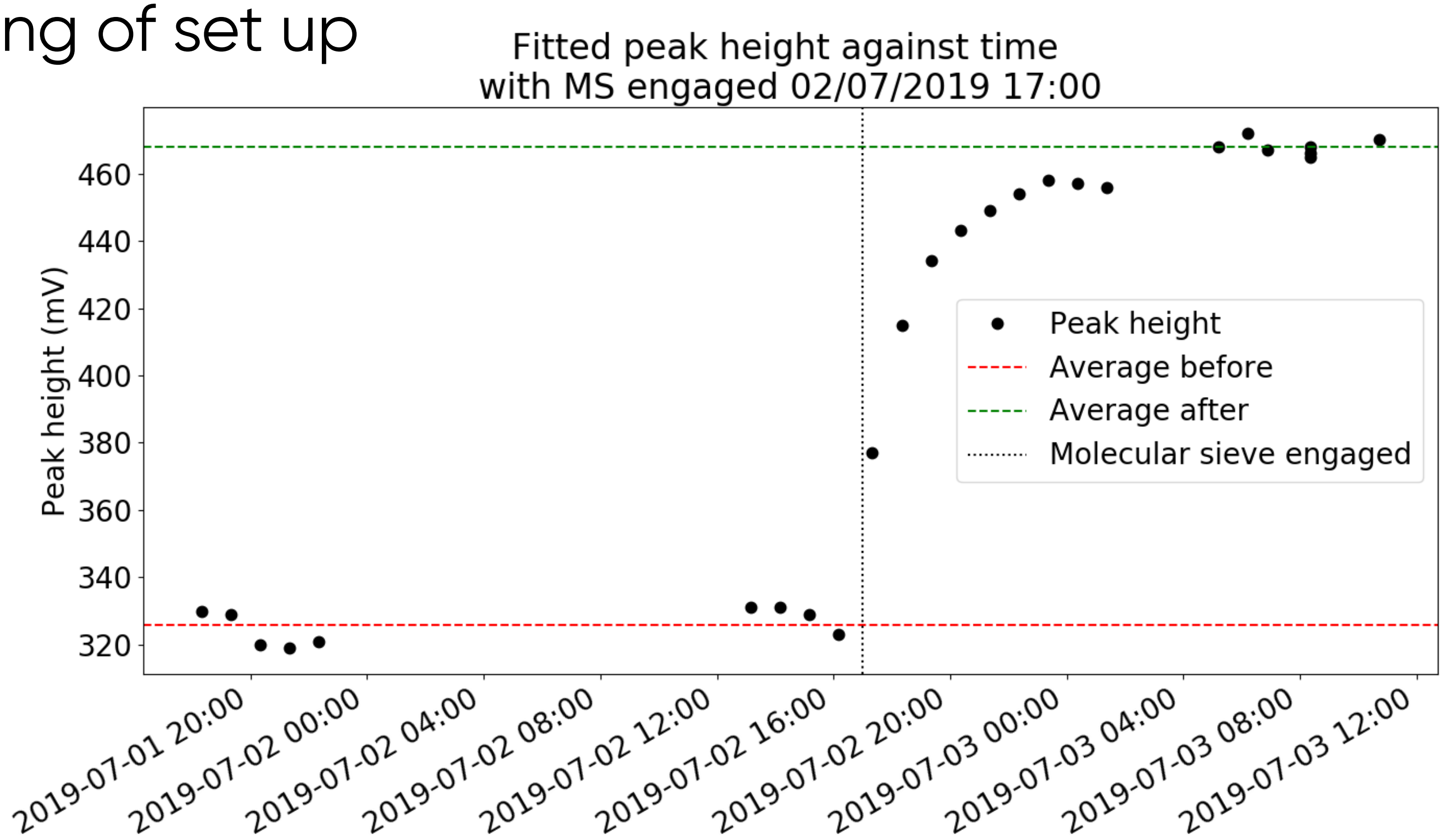


Preliminary Results



Discussion of results

- ~25 hours not long enough to observe deterioration
- Average signal peak increased from 325.7±4.8 mV to 468.0+2.3mV
- **~40% increase of signal** height with application of MS **for ~18h**
- It appears as the **gas** was **already contaminated**
- Outgassing of set up



Conclusion

- 5A and 3A molecular sieves have demonstrated the removal of radon, nitrogen and water from SF_6 by up to 87%, 89% and 79% respectively
- ~40% increase of signal pulse height in a TPC triple GEM SF_6 set up with application of molecular sieve for ~18 hour
- The TPC SF_6 gas appears to initially be contaminated

Further work

Further Analysis

- Pulse shape, total charge and dew point over time

Towards low emanating molecular sieves

- Collaboration with Hiroshi Ogawa in Nihon University who is working on the low RI MS development and Kobe University

Application to different gas mixtures

- Helium + SF_6 +CF_4 mixture
- Maintaining gas ratio