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Towards a Gas Recirculation System for SF_6, CF_4 & He Ultra-Sensitive Gas Based Physics Experiments

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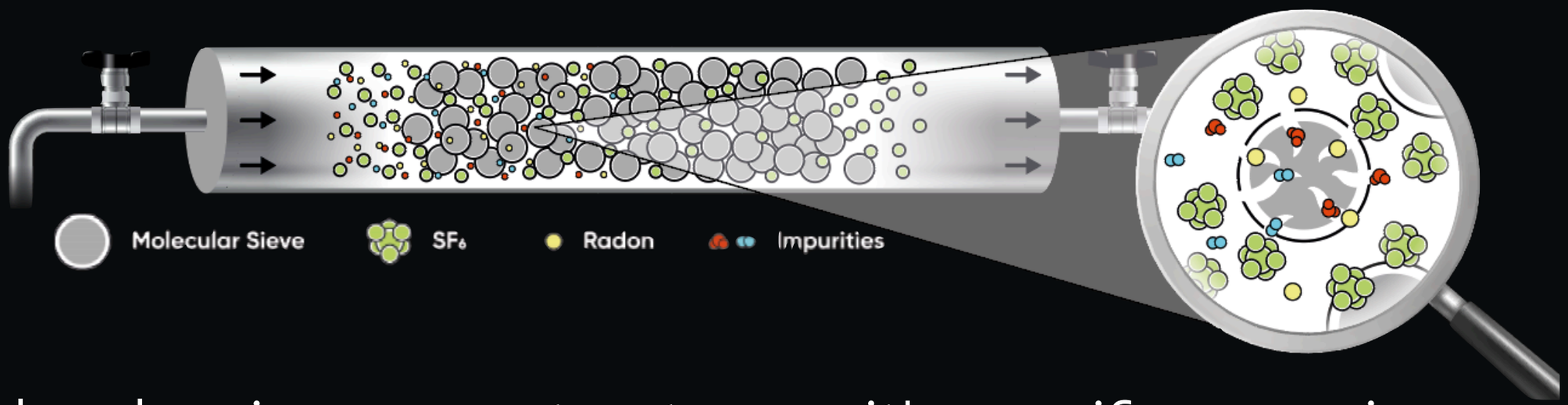
Introduction

- In ultra-sensitive gas-based experiments, it is important to use pure target gases (SF_6/CF_4/He)
- Contaminants such as water, nitrogen and oxygen can be gain harming. Radon contamination can produce unwanted backgrounds
- Continuously using ‘fresh’ gas is problematic due to strict regulations with the use F-gases
- Critical to have a gas recycling system for these experiment to reduce the F-gases used and to remove radon

Molecular Sieves



- Molecular sieves are structures with specific pore sizes.
- 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
- Molecules with diameters much smaller than the critical diameter can escape these pores

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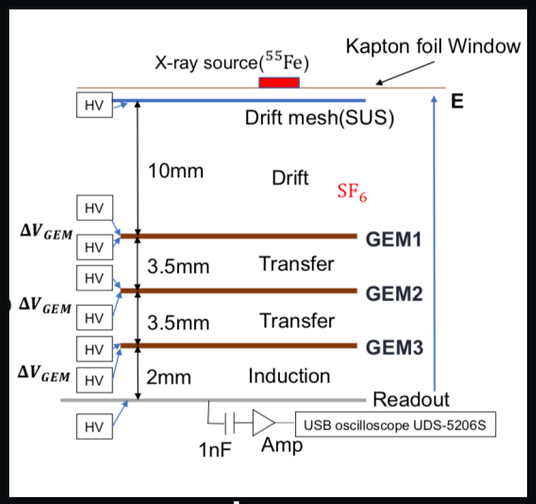
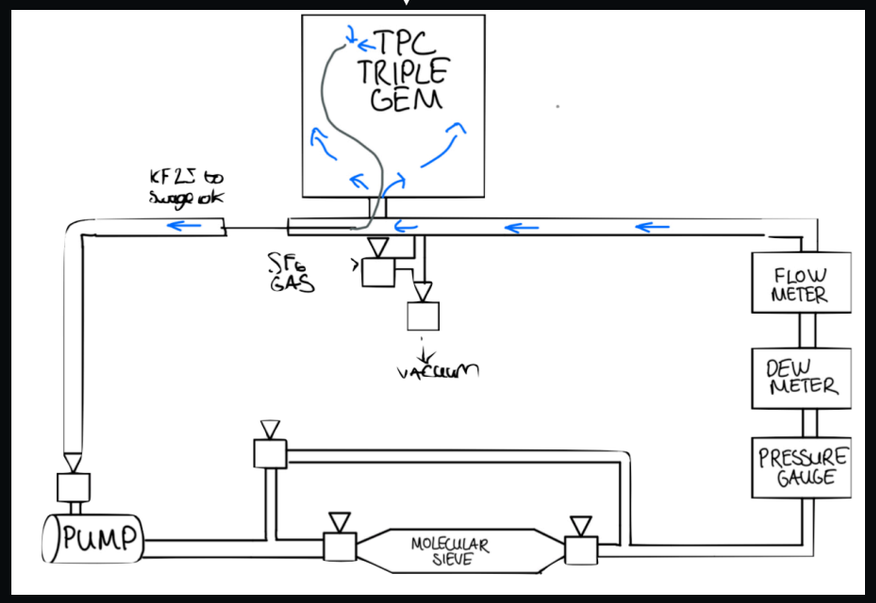
Molecular Sieve Testing Summary

Experimentally demonstrated to be captured by MS type	
Experimentally demonstrated not to be captured by MS type	
Not yet tested	
Not captured (Technical Specification of SUPELCO MERCK)	*

	SF_6	CF_4	He	Rn	H_2O	N_2	O_2
Critical Diameter (A)	5-10	5-10	2.0	4-5	3.2	3.0	2.8
13X MS Type (10A)			*				
5A MS Type			*				
4A MS Type			*				
3A MS Type							
Ideal MS for All Gas Mixtures							
Ideal MS for SF_6/CF_4 Only			N/A				

Proof of Concept with SF_6 Triple GEM and MS(3A:5A) Mixture





Aims of experiment:

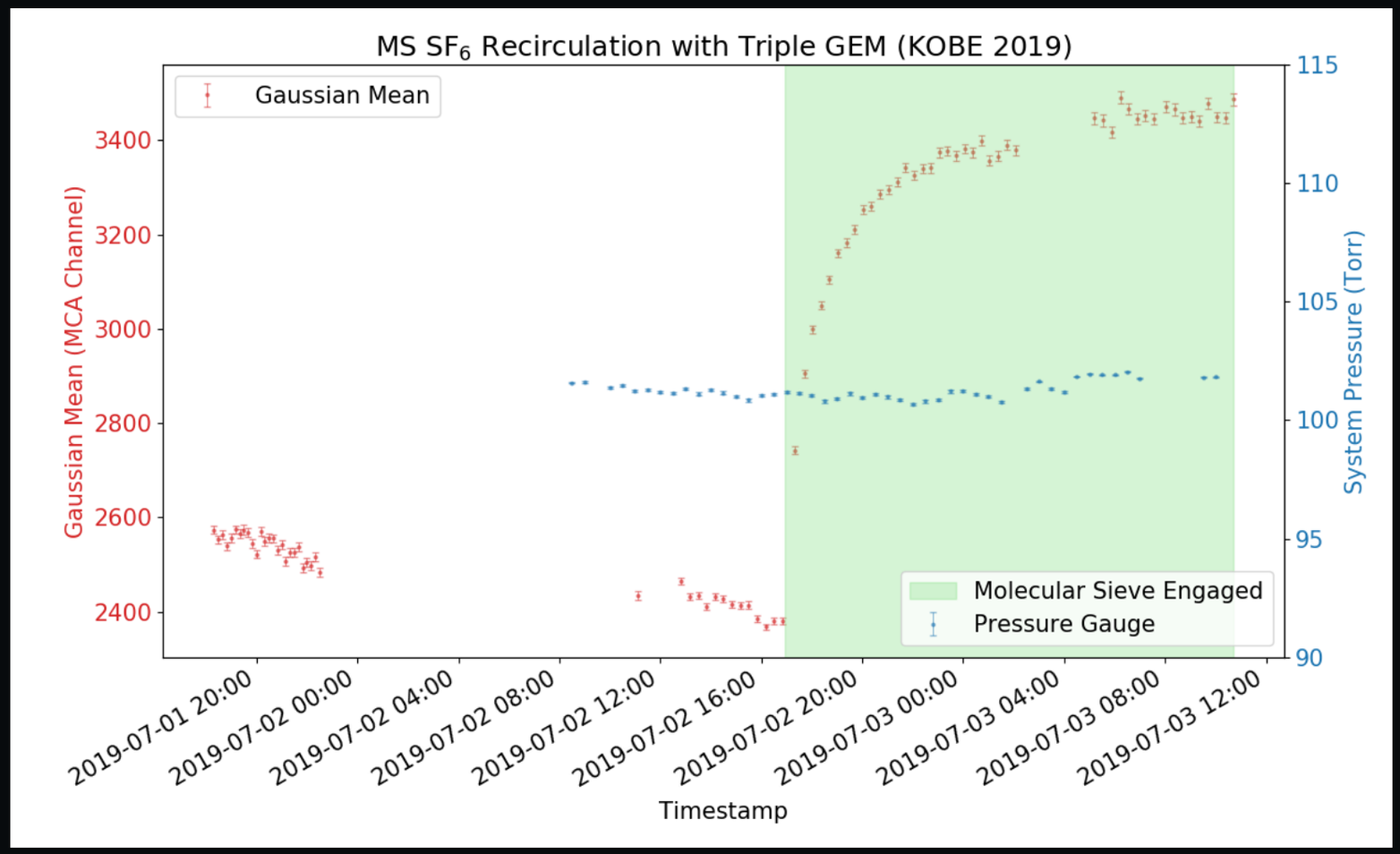
(1) Demonstrate gas gain deterioration over time due to gas contamination

(2) Recover the drop in gas gain by applying MS

Setup:

- Fe-55 and Triple GEM with 100 torr SF_6 setup
- ThGEM voltage was maintained at a constant value
- Periodic measurements with MCA spectrum to calculate effective gain
- After ~24 hours MS(3A:5A mixture) filter was applied

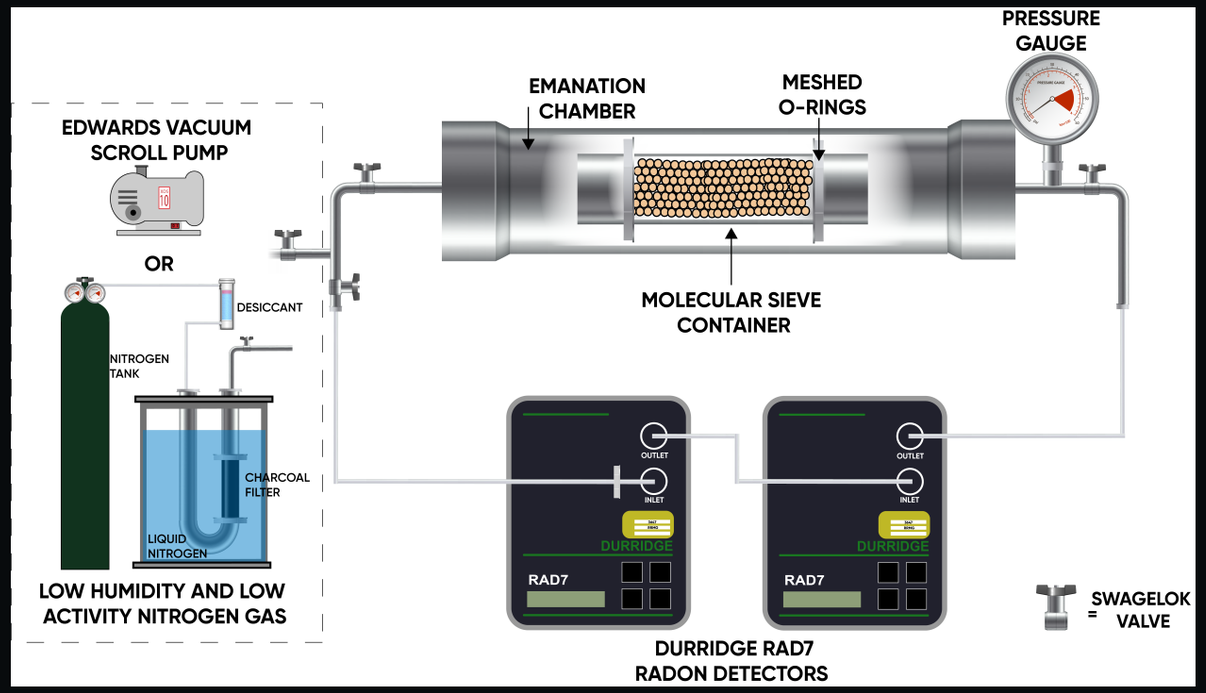
Proof of Concept with SF_6 Triple GEM and MS(3A:5A) Mixture



- An exponential + Gaussian fit was applied to each MCA spectrum measurement. The gaussian mean was used to indicated the effective gain
- The effective gain appeared to decrease due to gas contamination
- When the MS(5A:3A) filter was applied, the effective gain was recovered and improved - implicating gas gain harming impurities were initially present

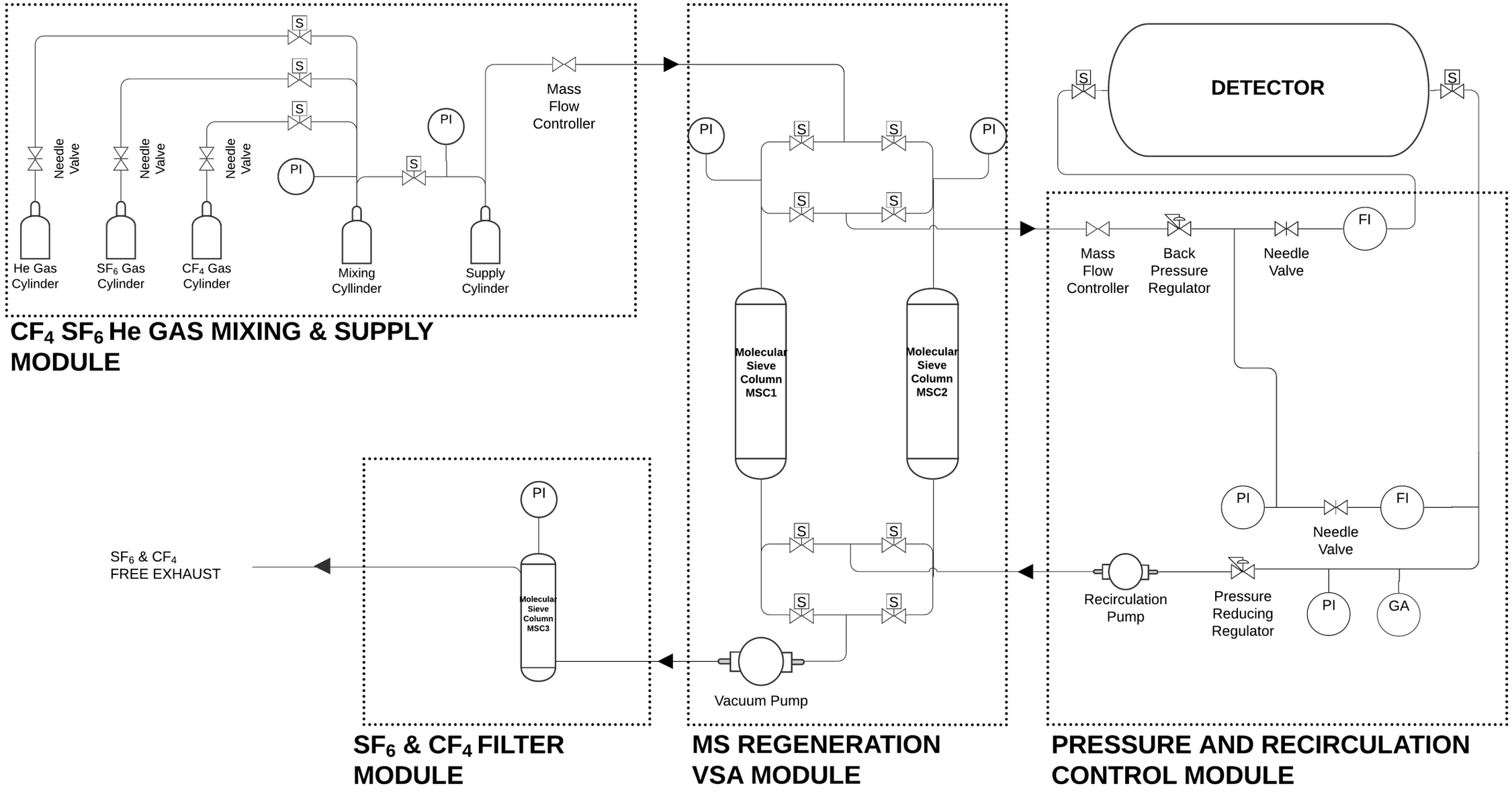
Measuring Intrinsic MS Background

- All MS testing completed has used commercial sieves
- Radon emanation from commercial sieves was measured to be 490±120 mBq/kg
- These levels of radioactivity in Commercial MS is not suitable for ultra low background physics experiments
- Dr. H. Ogawa (Nihon University) has developed a method to produce low radioactive MS [1]
- Nihon University MS was measured to emanate radon 90±20 mBq/kg

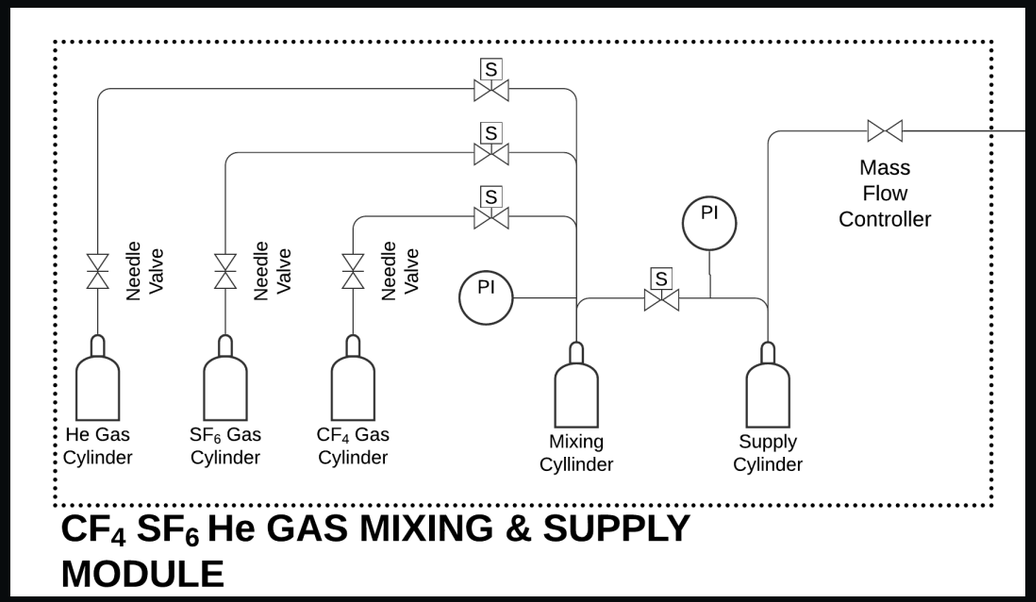


[1] Ogawa, H., Abe, K., Matsukura, M., & Mimura, H. (2020). Development of low radioactive molecular sieves for ultra-low background particle physics experiment. *Journal Of Instrumentation*, *15*(01), P01039-P01039. doi: 10.1088/1748-0221/15/01/p01039

Design Overview of Gas System



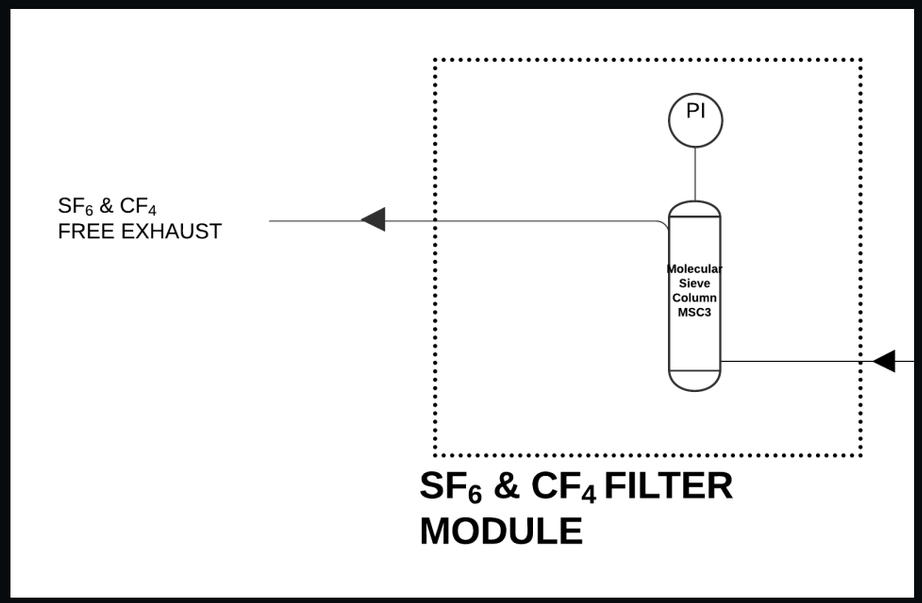
Supply & Disposal Modules



CF_4 SF_6 He GAS MIXING & SUPPLY MODULE

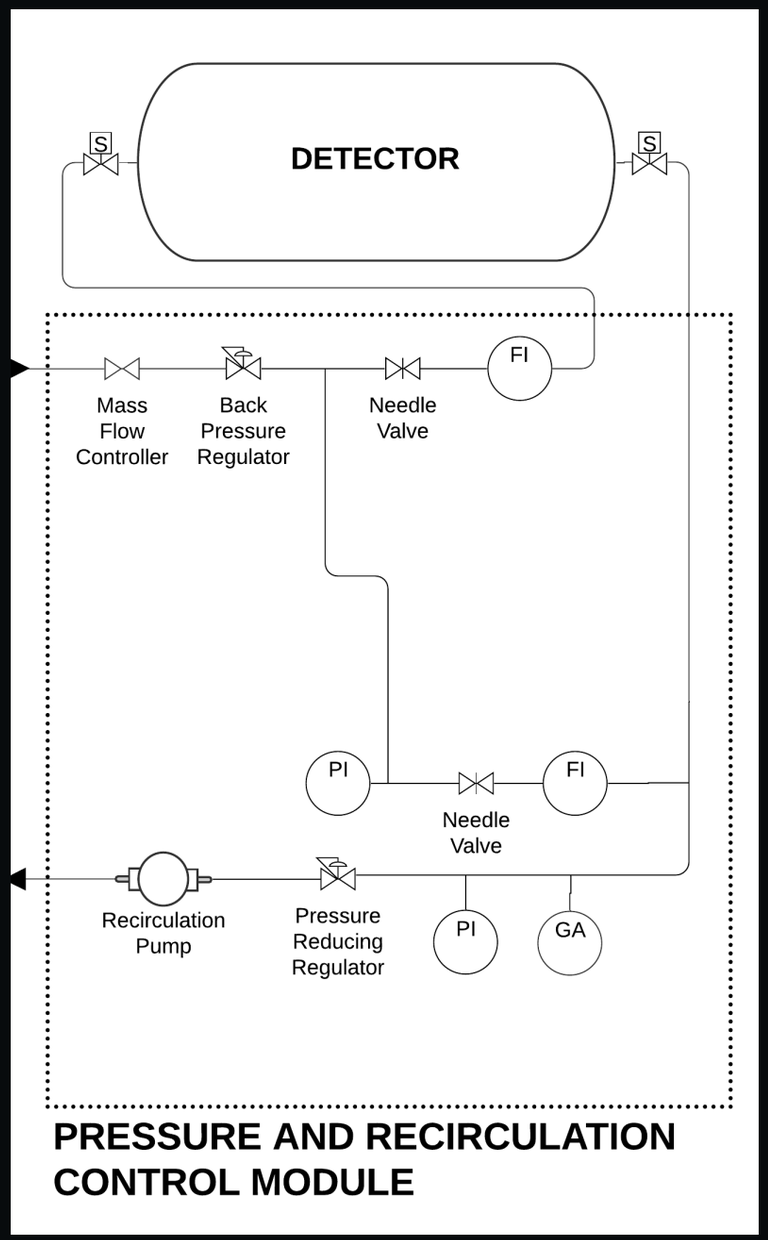
- A gas mixing module pioneered in DRIFT experiment
- Controls desired mixture of gases entering the experiment

- It is important not to release any SF_6 & CF_4 into the environment
- 13X molecular sieves filters are used to capture these greenhouse gases during evacuation



SF_6 & CF_4 FILTER MODULE

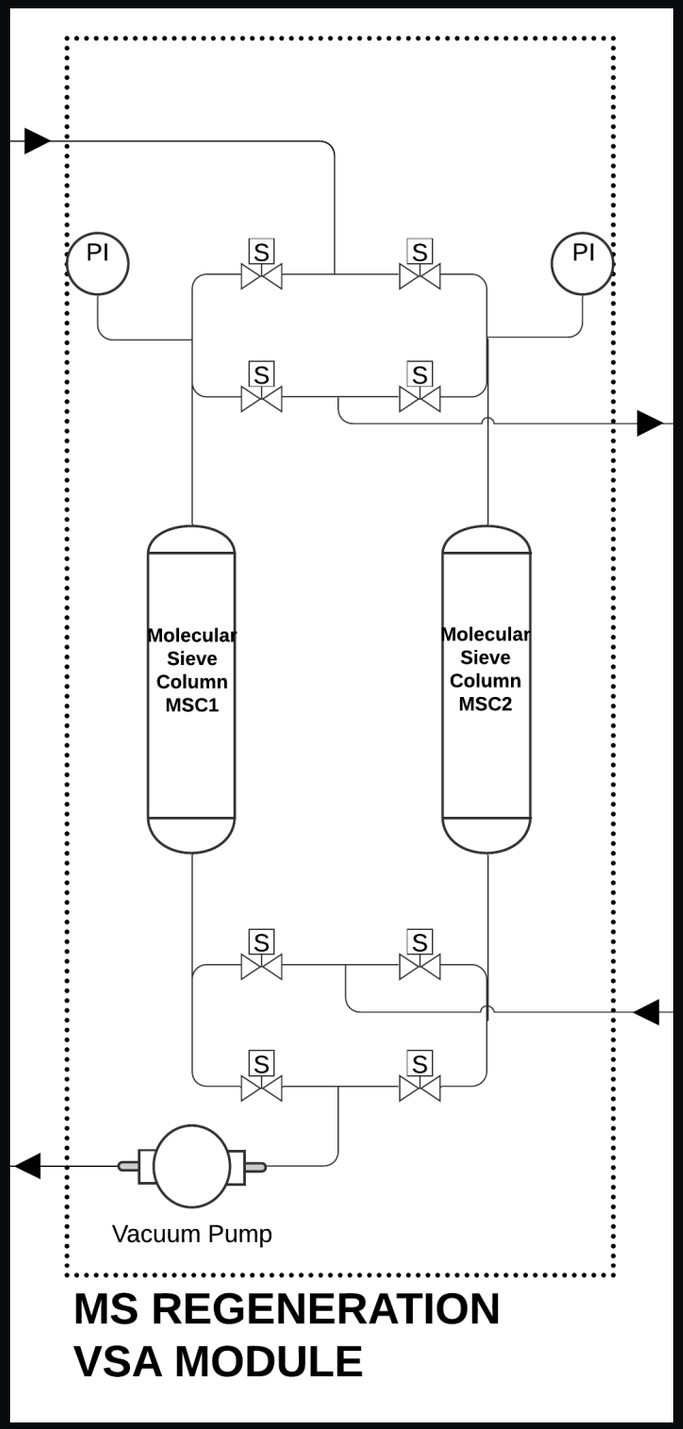
Pressure and Recirculation Control Module



PRESSURE AND RECIRCULATION CONTROL MODULE

- Pressure inside the detector is maintained by two regulators while allowing constant flow
- Recirculation pump drives a constant flow around the detector and molecular sieve filter
- A simple gas analyser will detect if a known contaminant like water, reaches a threshold concentration and prompt the use of fresh MS filter

On-site MS Regeneration Module



- Vacuum swing adsorption module allows one filter to be regenerating whilst the other is in use
- Regeneration is achieve by evacuating MS filter to sub-torr pressures
- VSA Module allows gas system to run fully autonomously for long periods depending on the size of the MS filters

Planned work

Gas System work

- Development and Construction of a Small Scale Gas System
- Field Testing with CF_4 ThGEM Set-up in Sheffield

Molecular Sieve Work

- Molecular sieve geometry type and mixture optimisation
- Radon emanation testing of different geometries
- Verifying Helium MS Filtration Manufacturers Specification