University of Sheffield

# Charge Amplification in Sub-atmospheric $CF_4/SF_6$:He Mixtures

## 8th CYGNUS Workshop on Directional Recoil Detection

Slade Lecture Theatre, School of Physics, University of Sydney, NSW, Australia
11-15/Dec/2023

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14/Dec/2023

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4. Summary

# 1. Motivation for using Helium

# Addition of Helium to Low Pressure $CF_4/SF_6$

For a directional Dark Matter (DM) search, the pressure of $CF_4$ or $SF_6$ must be low in order to facilitate recoil tracks on the mm/sub-mm scale

Some studies suggest that this pressure should be lower than 100 Torr in order to improve both directionality and Nuclear Recoil (NR)/Electron Recoil (ER) discrimination

This low pressure requirement limits the target mass of your detector

Can not simply be addressed by increasing the pressure without sacrificing directionality…

Helium can be added to low pressure $CF_4$ and $SF_6$ without affecting the recoil length of C, F, and S nuclei due to its lower density

Although this will not significantly improve the target mass of your detector, it will improve the detectors sensitivity to lower WIMP masses

Also offers the possibility of operation at atmospheric pressure - potentially reducing the cost of a containment vessel

Stable charge amplification can not be easily predicted via simulations and so must be demonstrated experimentally

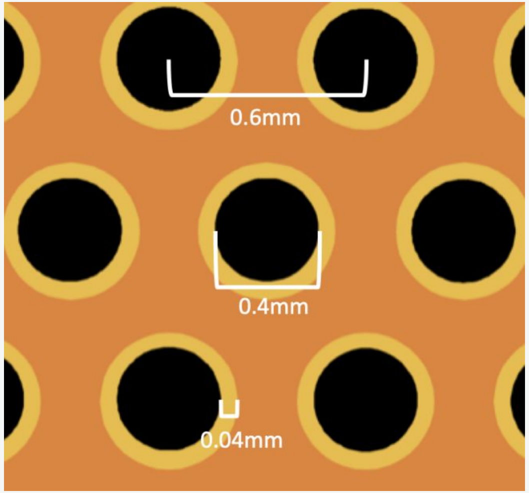
# 2. Charge Amplification with a Single ThGEM

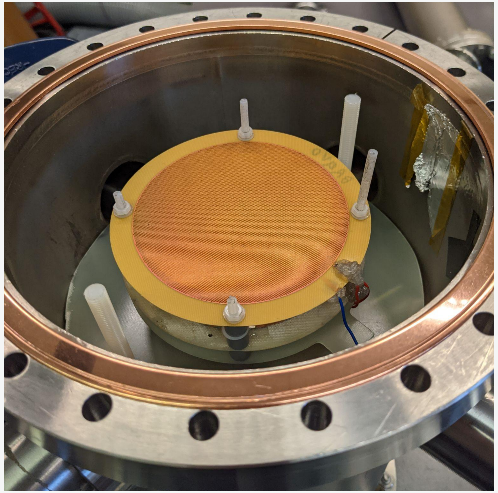
# Single ThGEM Experimental Setup

## Single ThGEM TPC

ThGEM: T:0.4 mm, P:0.6 mm, D:0.4 mm, R:0.04 mm

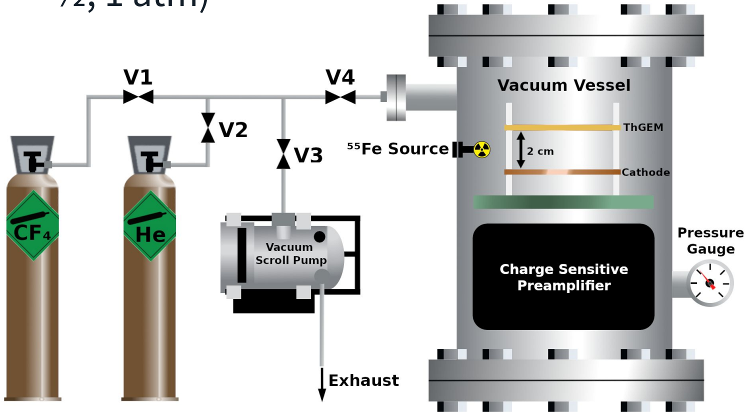
Drift gap: 2 cm



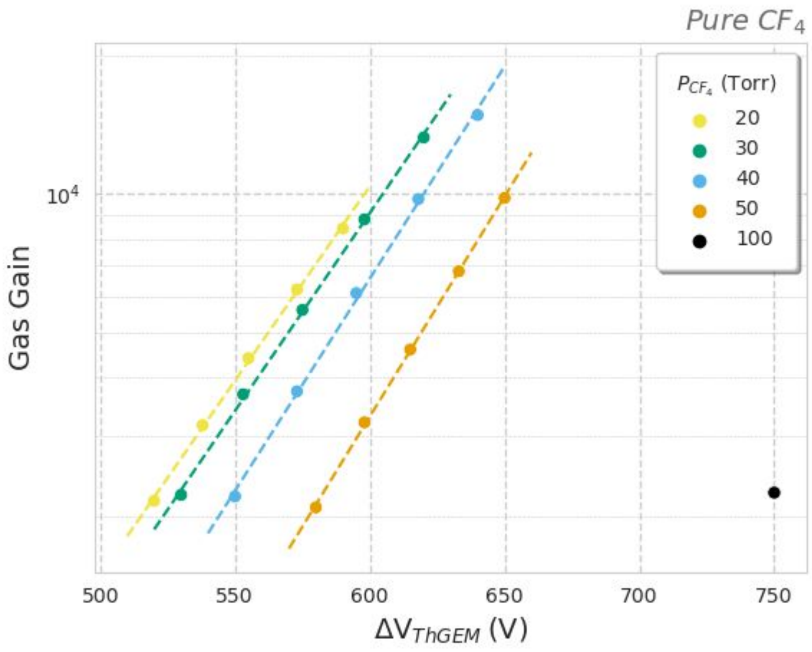



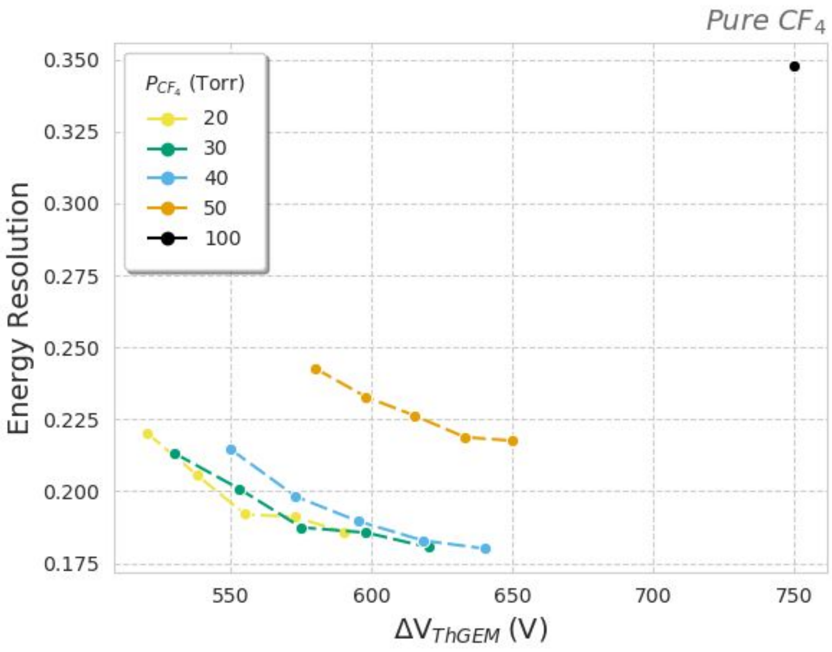
## Gas Mixing Procedure

- Vessel and gas line evacuated
- Vessel filled with low partial pressure of $CF_4$ (5, 10, 20, 30, 40, 50, and 100 Torr)
- Gas line evacuated
- Vessel filled with Helium up to total pressures of 95, 190, 380, 760 Torr (⅛, ¼, ½, 1 atm)



# Results in Pure $CF_4$




Gain curves could not be obtained for 5 and 10 Torr, only 1 data point could be obtained for 100 Torr due to narrow range of operating voltages

Energy resolution found to be similar for 20, 30, and 40 Torr but increases significantly at 50 and 100 Torr

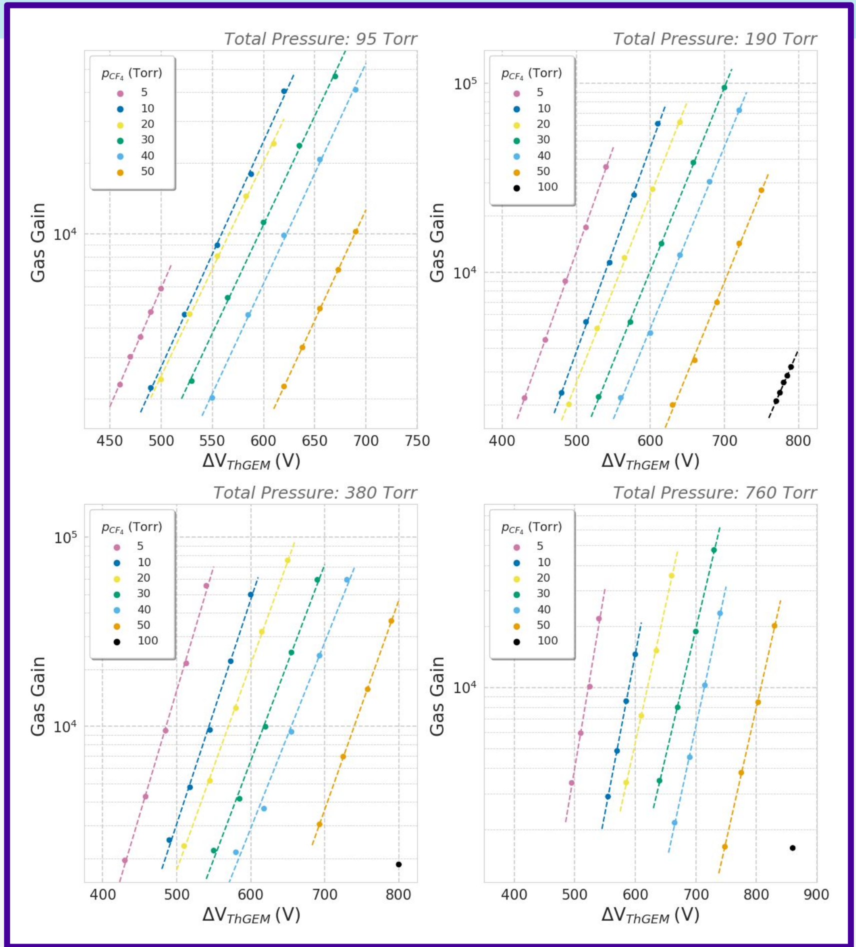
# Results in $CF_4$:He Mixtures - Gas Gain

Gain curves follow similar trend to pure $CF_4$

As total pressure increases the highest stable voltage increases

Addition of helium improves the gas gain compared to pure $CF_4$ counterpart - even at atmospheric pressure!

Possible penning ionisation ($He^*/CF_4$) could be responsible…



# Results in $CF_4$:He Mixtures - Energy Resolution

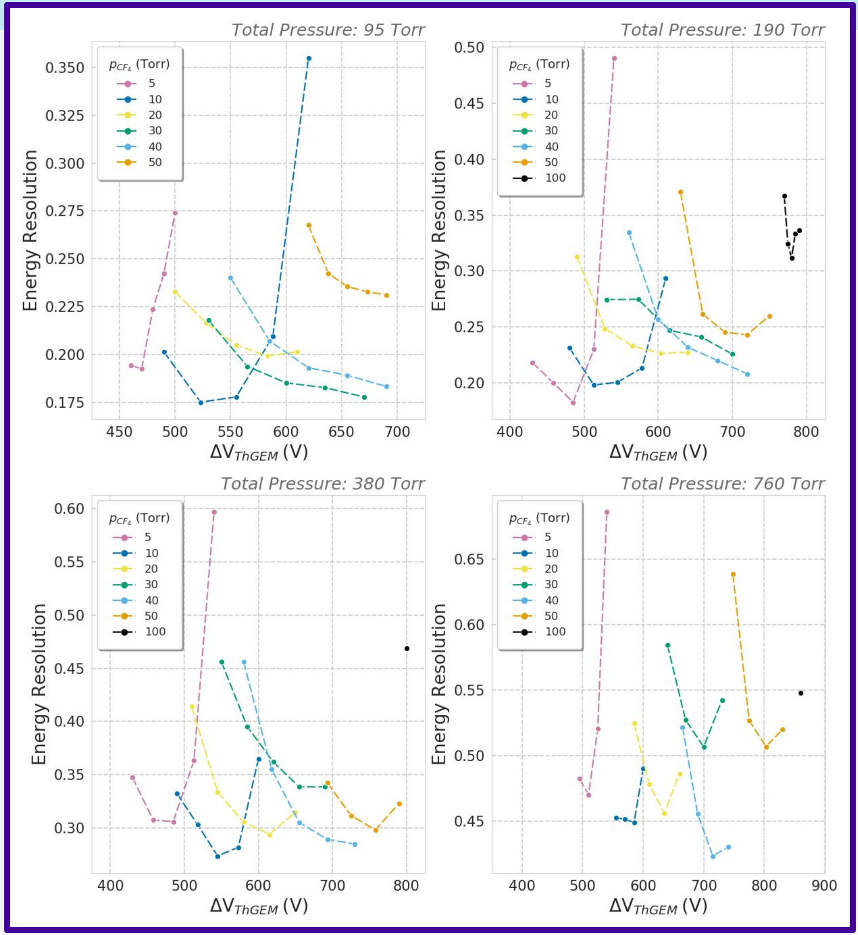
For lower total pressures (95 and 190 Torr) with $CF_4$ partial pressures of 20-50 Torr the energy resolution generally decreases with increasing voltage

At higher total pressures local minima can be observed to occur at the higher end of the operating voltages - coinciding with a relatively high gas gain

Similar minima can be seen in 5 and 10 Torr mixtures but these occur at lower end of operating voltages - not good for optimising both gain and energy resolution simultaneously

As total pressure increases the lowest observed energy resolution increases - energy resolution worsens as more He is added to the vessel

Results can be used to optimise a mixture at atmospheric pressure - $CF_4$:He 40:720 Torr recommend based on these results



# Pure Helium (and NID gas mixtures)

Pure helium was tested at pressures of 5, 10, 20, 30, 40, 50, 95, 195, 380, 760 Torr

Sparking occurred before an observable $^{55}Fe$ absorption peak could be observed in the energy spectrum…

$SF_6$ and $SF_6$:He and $CF_4$:$SF_6$:He mixtures were also tested with this setup

Again, sparking occurred before a peak could be observed in the energy spectrum…

Likely require multistage amplification device!

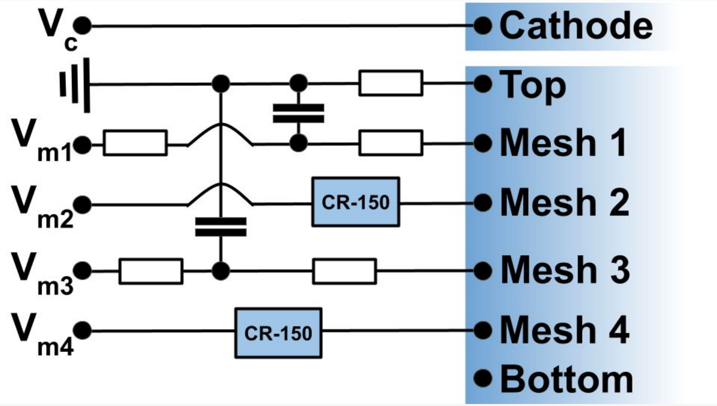
# 3. Charge Amplification with the Two Stage MMThGEM

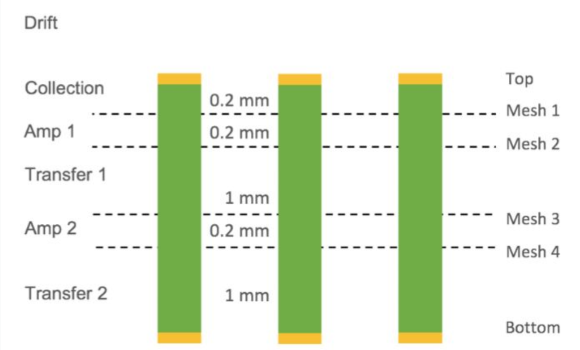
# Two Stage MMThGEM Experimental Setup

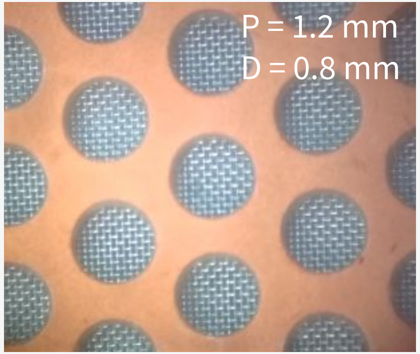
## Two Stage MMThGEM TPC

Same experimental setup as used in earlier talk…

Gas mixing procedure is identical to that used in section 1 of this talk (with additional $SF_6$ gas cylinder)



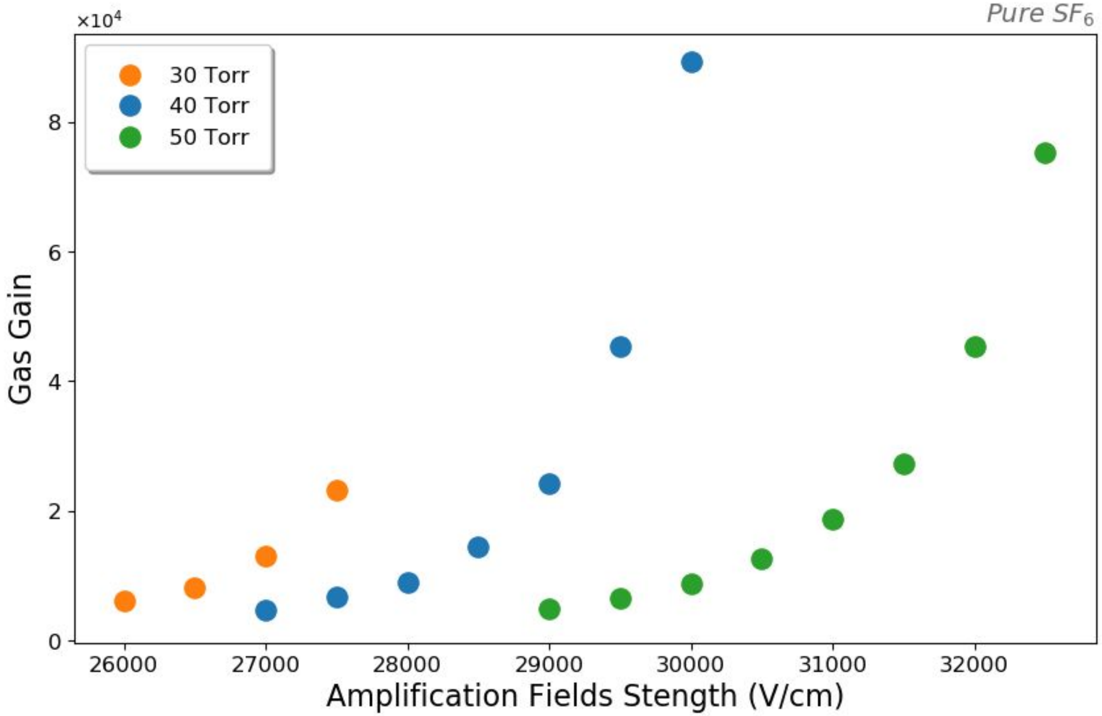

# Results in Pure $SF_6$

Utilising the optimised voltages found in 40 Torr of $SF_6$

Gas gain curve also measured in 30, 40, and 50 Torr of $SF_6$

Found that 40 Torr produced highest gas gain

Helium added to 40 Torr as this performed the best…



# Results in $SF_6$:He Mixtures

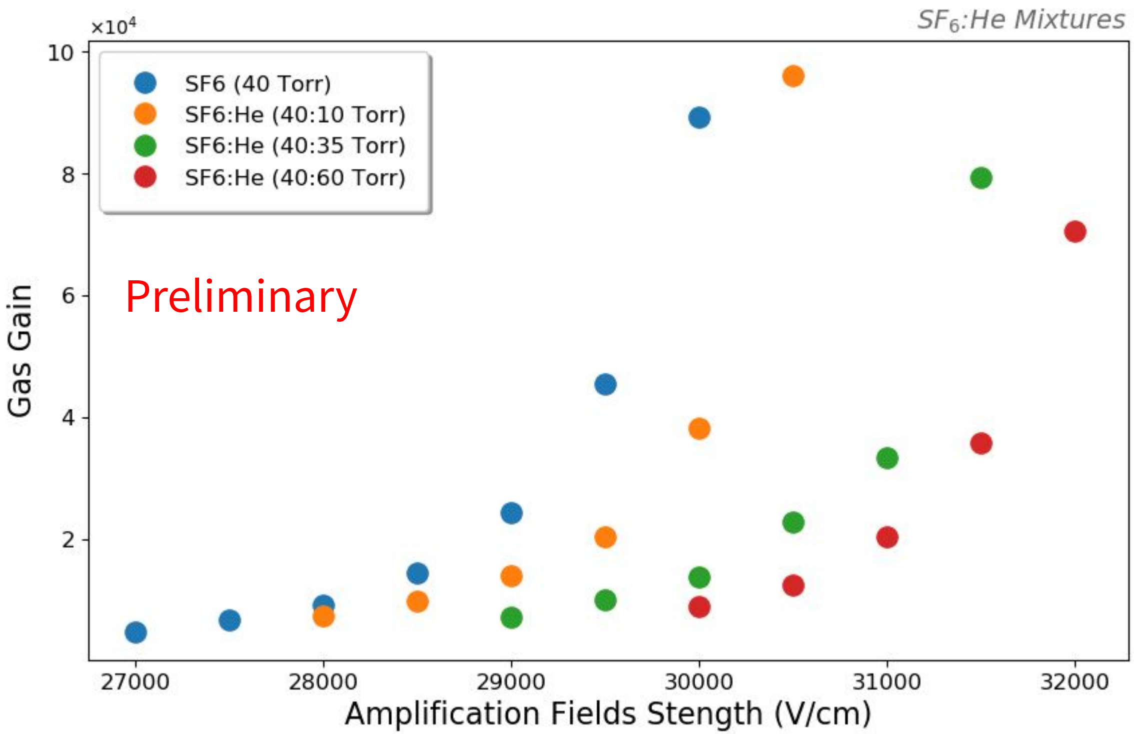
Helium was added to 40 Torr of $SF_6$ up to pressures of 50, 75, 100, 380 and 760

A few gain curves were successfully obtained

Significant gain still observed at 100 Torr ~ 70000

Either gain drops significantly or energy resolution worsens between 100 Torr and 380 Torr

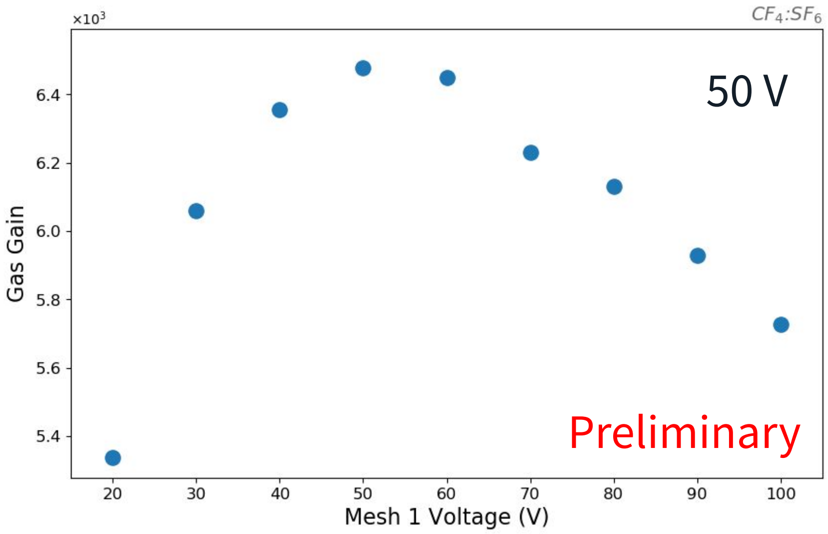
Clear $^{55}$Fe photo-peak could not be resolved on the energy spectrum before sparking occurred at 380 and 760 Torr

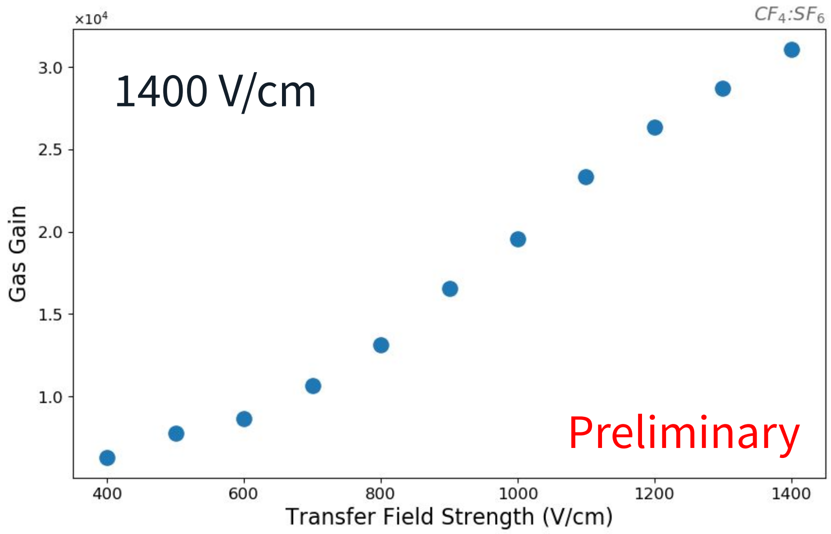


# $CF_4:SF_6$ Low Pressure Field Optimisation

$CF_4$ was mixed with a small amount of $SF_6$ in an attempt to improve gas gain while maintaining a mixture with a NID component

An optimisation procedure (previously used in 40 Torr pure $SF_6$) was used to optimise the collection and transfer fields in this base mixture of $CF_4:SF_6$ (38:2 Torr)



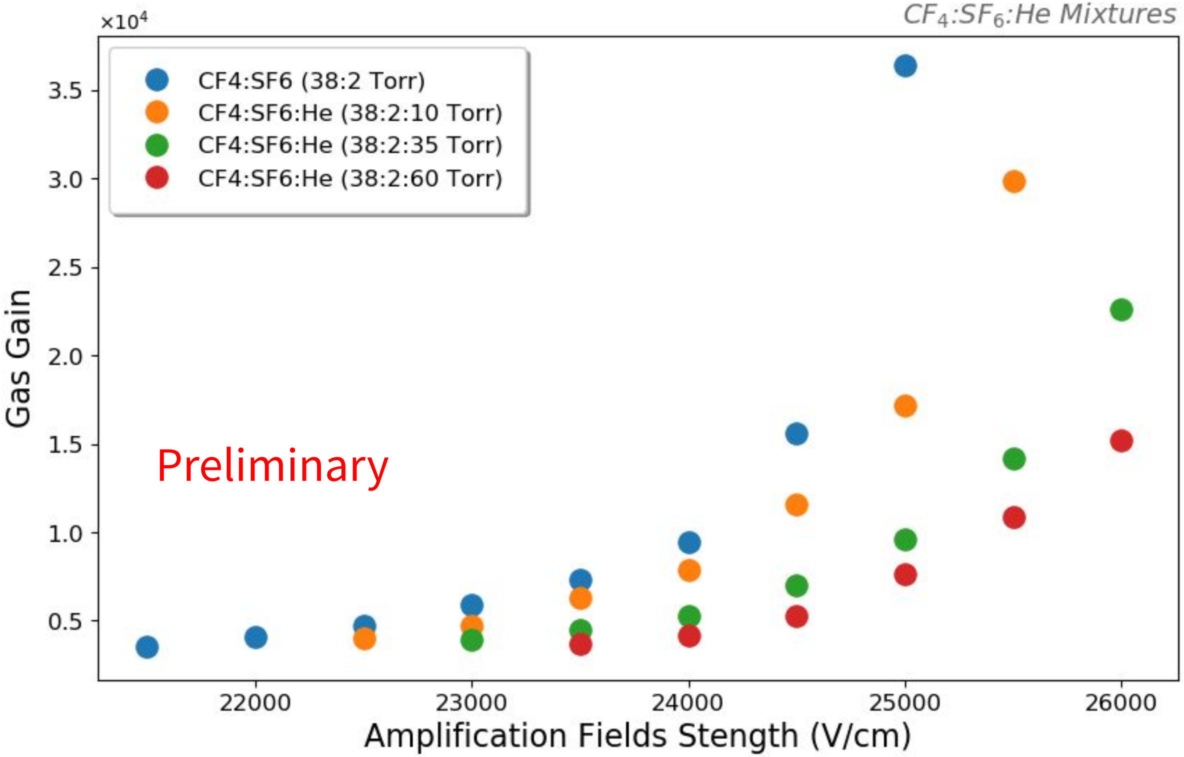



# Results in $CF_4$:$SF_6$:He Mixtures

As Helium is added to the vessel the maximum stable gas gain decreases as observed with the $SF_6$:He mixtures

The addition of $CF_4$ has significantly reduced the voltage required to achieve gas gains on the order of $10^4$

However the maximum stable gas gain is smaller than the $SF_6$:Helium mixtures



# Summary of Charge Amplification in He Mixtures

- A single ThGEM was capable of producing significant gas gains with reasonable energy resolution in $CF_4$:He mixtures with a low partial pressure of $CF_4$ up to atmospheric pressure

- This single ThGEM was not capable of sufficient charge amplification in sub-atmospheric mixtures containing a NID component ($SF_6$)

- The two stage MMThGEM was used to amplify charge in these ($CF_4$:)$SF_6$:He mixtures

- It was found that mixtures containing $SF_6$ were only able to produce measurable gas gains at relatively low pressures because they are likely limited by poor energy resolution at higher sub-atmospheric/atmospheric pressures

- More work is required for $SF_6$:He mixtures!

# Thank you for listening!

**Any questions?**