GAS-RELATED STUDIES ON TRIPLE-GEM DETECTORS

EP-DT-FS
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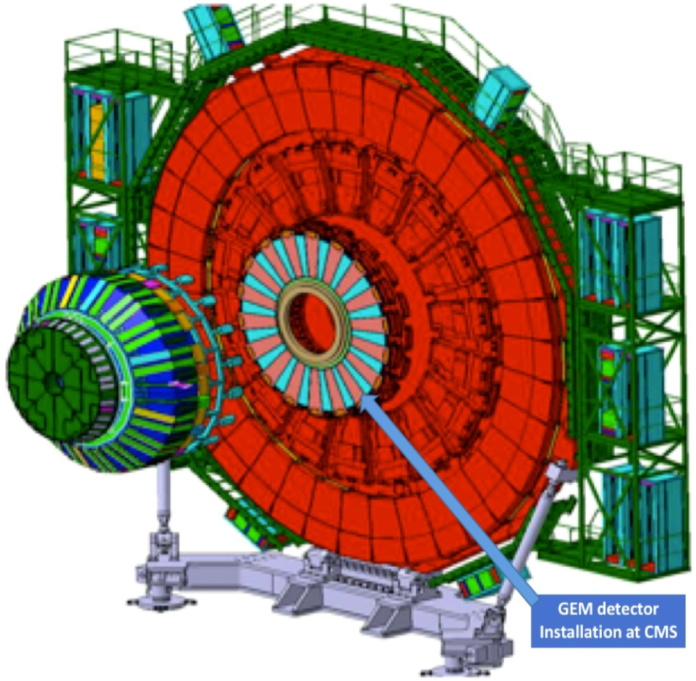
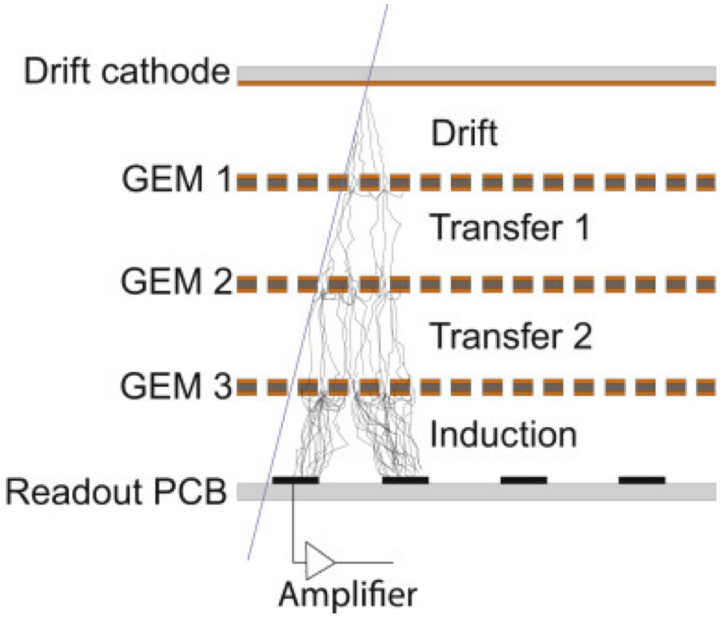
GEM DETECTORS AT LHC



- GEMs: Gaseous Electron Multiplier detectors used in the muon systems of CMS and LHCb as well as in ALICE TPC.
- LHCb GEM operated with Ar/CO2/CF4 45/15/40 in gas recirculation (now dismounted)
- CMS GEM operated with Ar/CO2 70/30 in open mode
- ALICE TPC is changing MWPC with GEM detectors and operation will be in gas recirculation
- It is important to provide a stable and correct gas mixture to all LHC gas detectors
- We want to test effects of gas mixture variation and creation of impurities in GEM gas systems



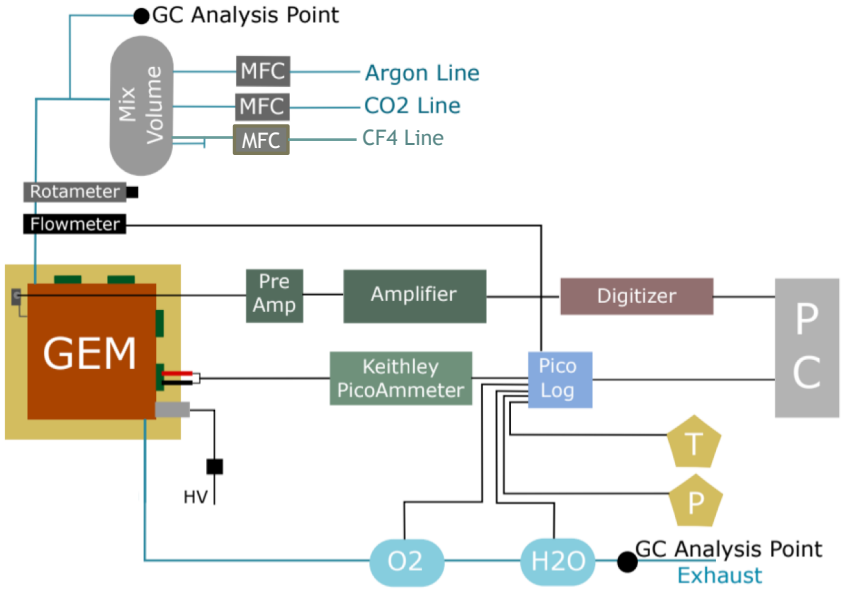
GEM working principle:

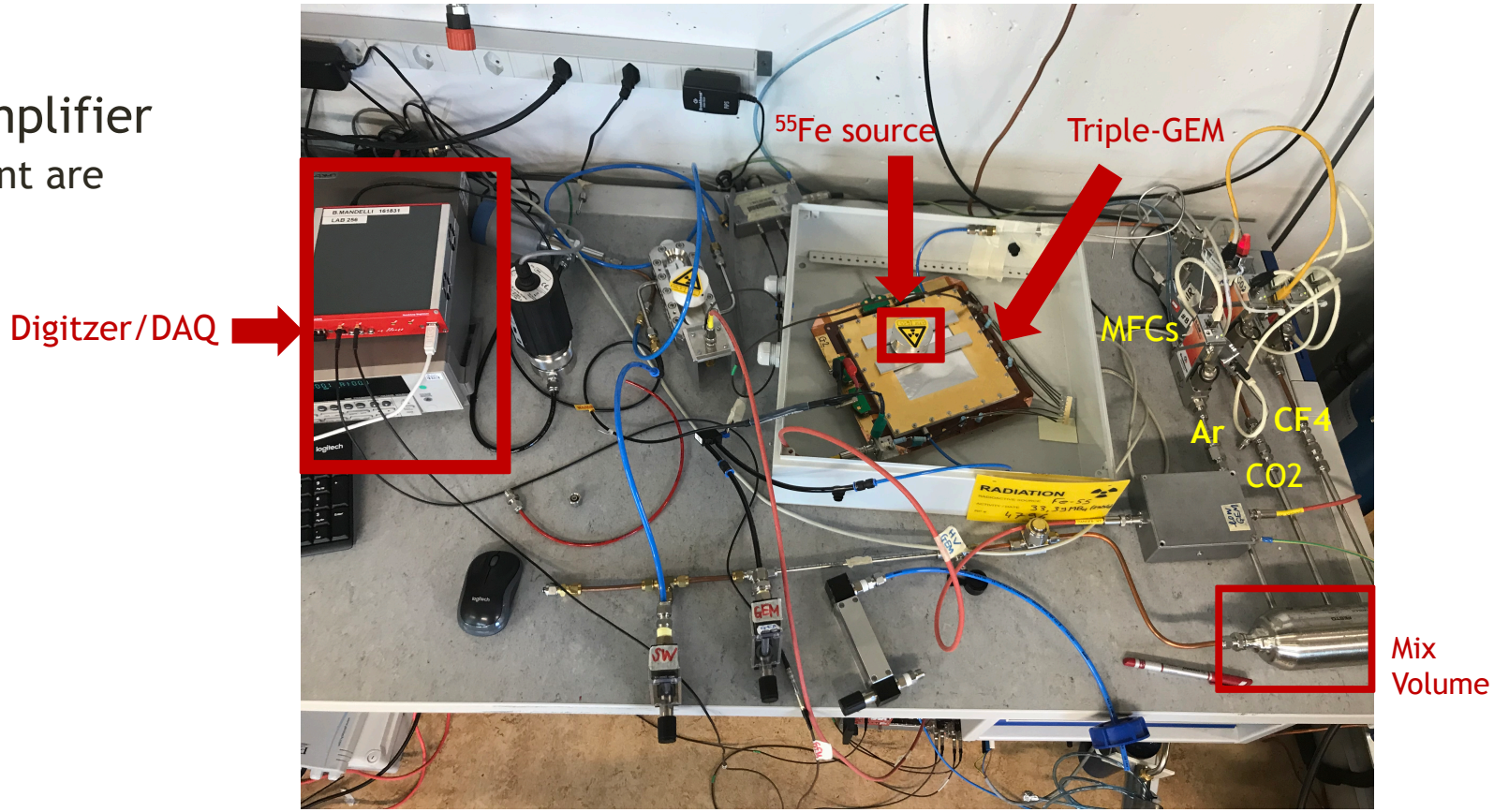
- Charged particle passes through → ionizes molecules along its path
- Free electron drifts down due to applied electric field and multiplies in areas of high field density (inside holes)
- With 3 foils & an applied voltage of ~400V to each foil → ~10^4 total gain

- In this work, I focused on the gas mixture: Ar/CO2/CF4 45/15/40

EXPERIMENTAL SETUP

- GEM pulse signal is shaped in Pre-Amplifier and amplified again in Amplifier
  - Height of pulse signal and detector current are both measures of gain





GEM GAS COMPOSITION STUDIES

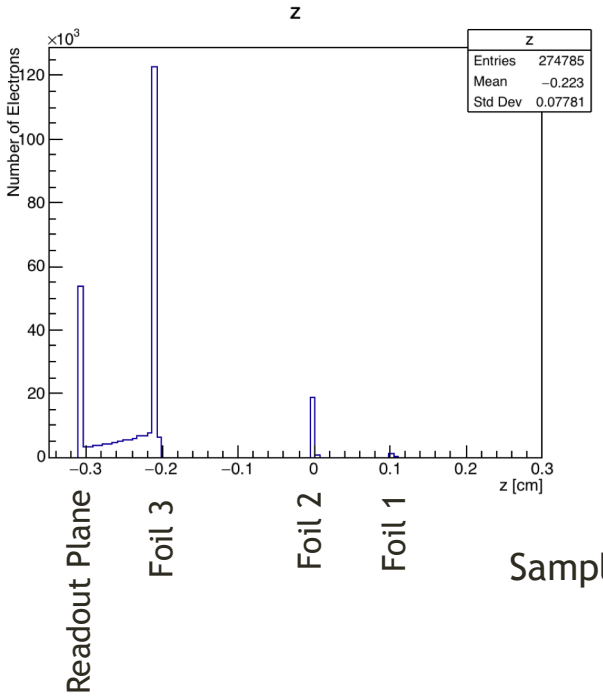
Component	Role
Ar	Primary ionization
CO2	Limits avalanche spread by absorbing photons
CF4	Improves time resolution

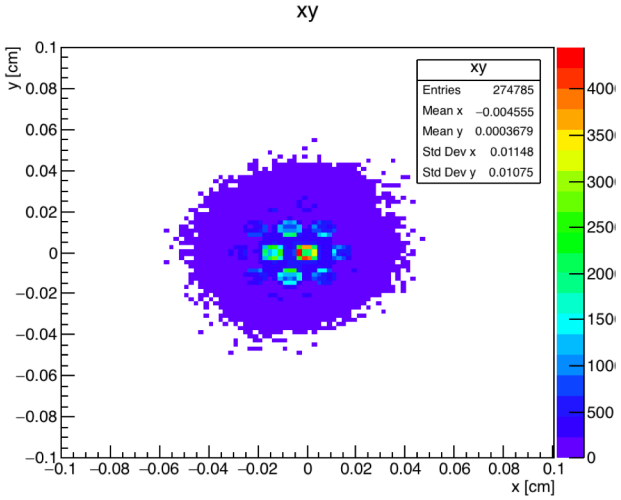
Experimental:

- Test GEM gain response to signal from ^{55}Fe source under varying gas compositions
- Tests: Constant CO2, Constant Ar, Constant Ar/CO2 ratio

Simulation:

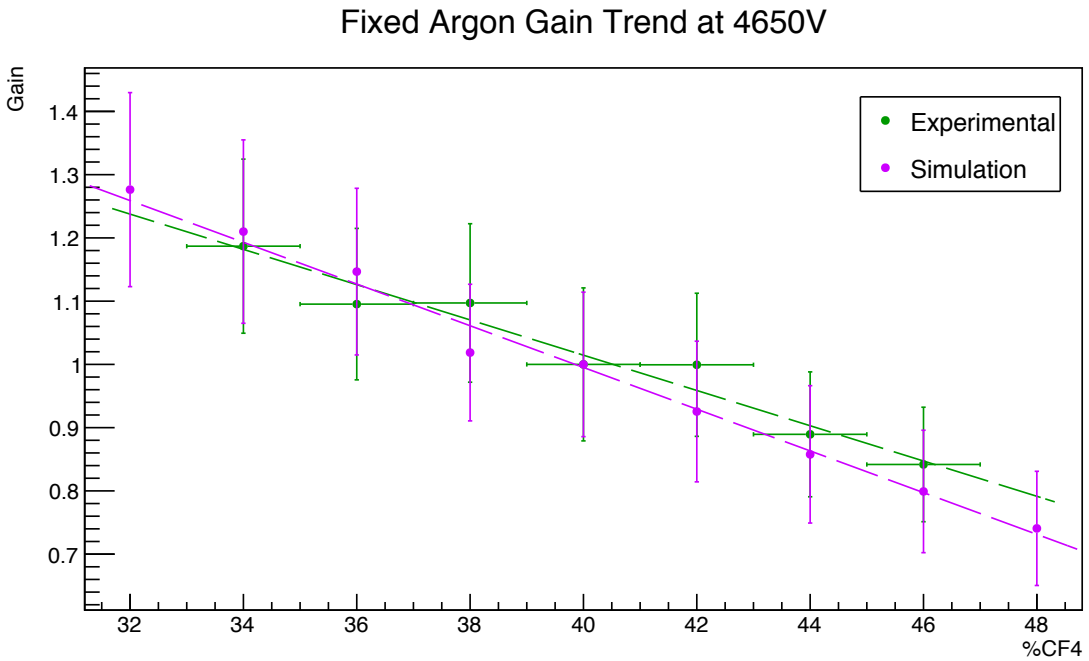
- ANSYS models field inside GEM and Garfield++ computes electron avalanche process
- Output is properties of electrons formed in avalanche

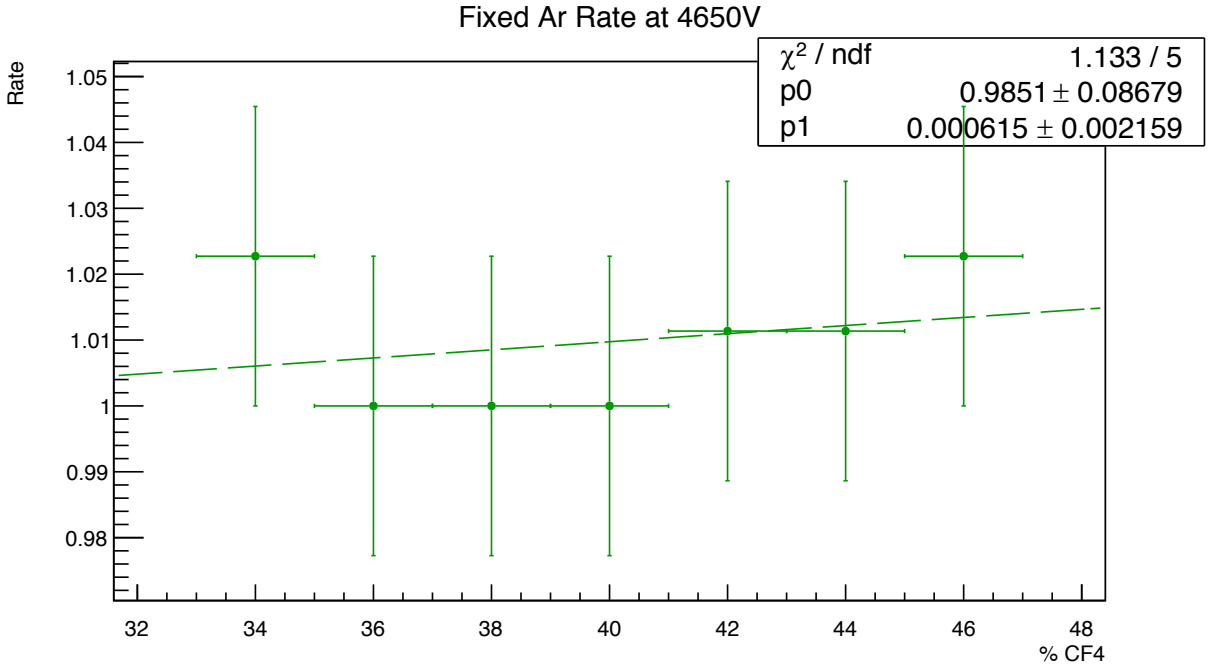




Sample statistics from avalanche

CONSTANT AR TEST



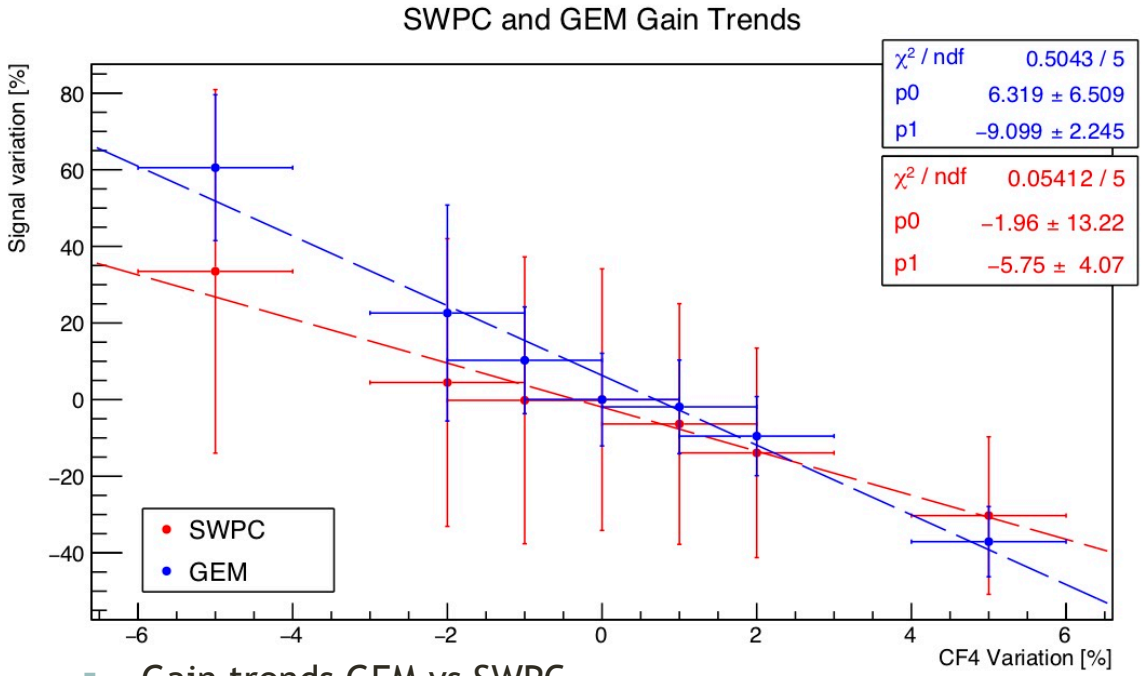


- Gain trends experimental vs simulation
- Decreasing CO2 → smaller gain suggests CF4 effect dominates over CO2 effect

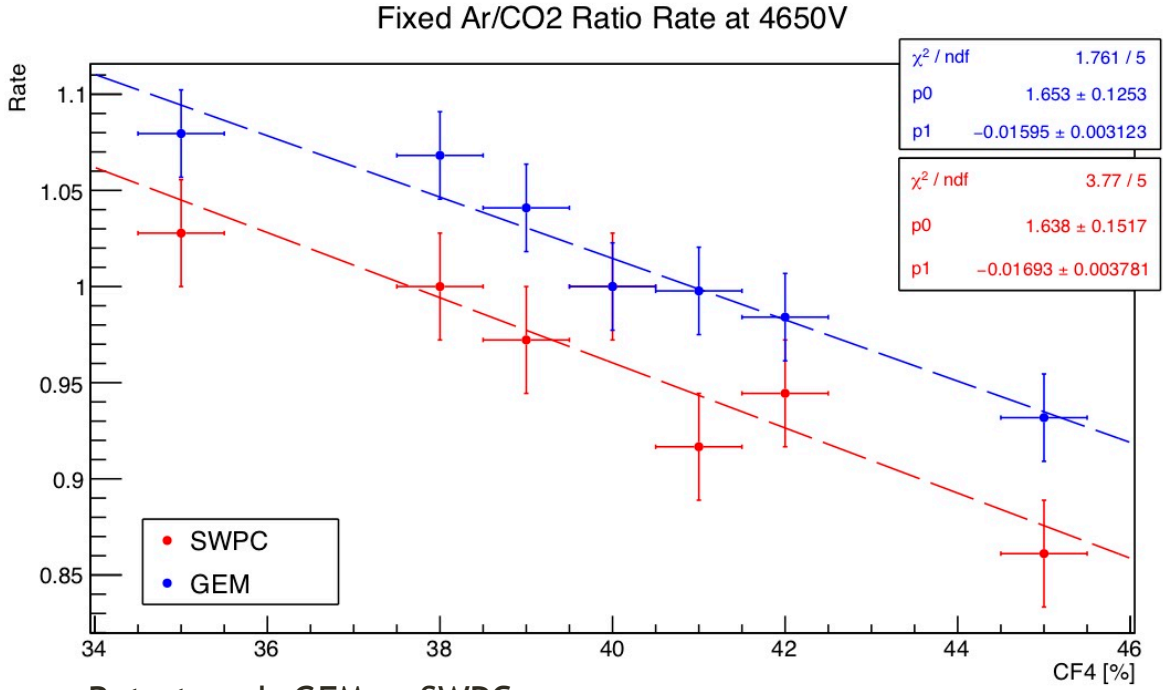
- Rate trend experimental only
- Decreasing gain does not imply a change in rate
- Argon being held constant so rate is approximately constant as well

CONSTANT AR/CO2 RATIO TEST

- Two objectives: to test gas mixture variation effects on gain/rate and to compare detector sensitivities to changes in CF4



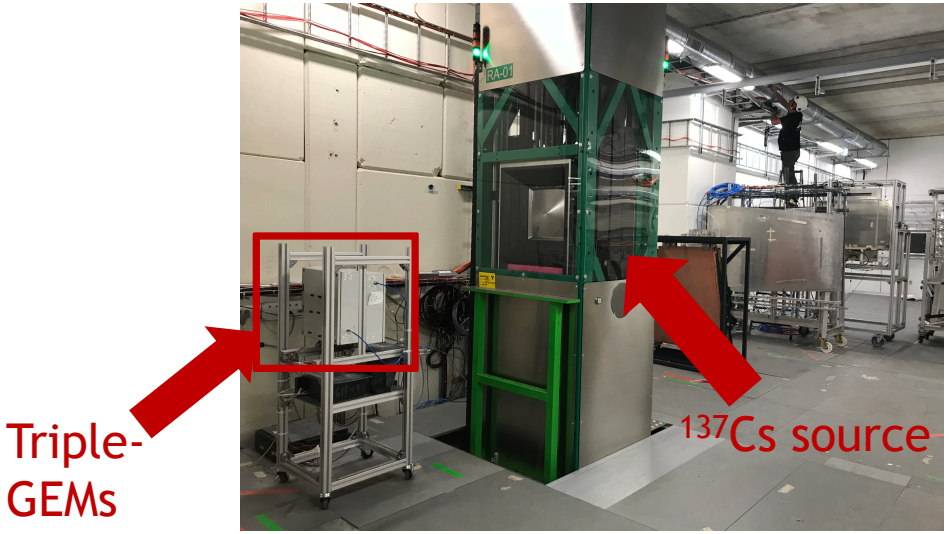
- Gain trends GEM vs SWPC
- GEM trend has steeper slope suggesting a higher sensitivity to changes in CF4 – possibly due to 3 stages of multiplication vs 1 stage in SWPC



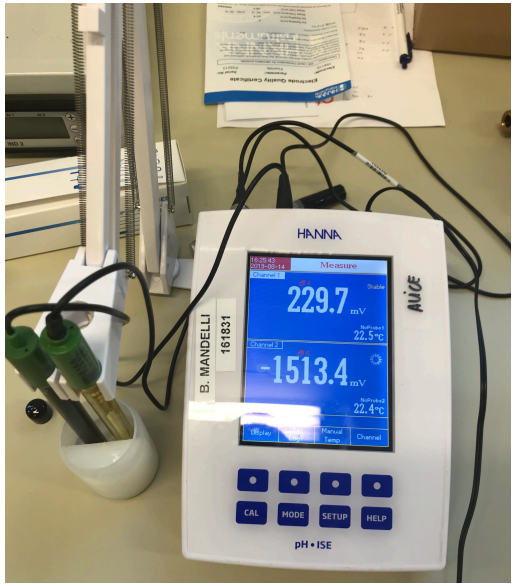
- Rate trends GEM vs SWPC
- Nearly identical slopes suggesting comparable sensitivity but SWPC is slightly steeper – maybe due to higher chance of primary electron absorption in drift volume

F^- ACCUMULATION

- CF4 can break down during irradiated GEM operation into CF3 and F^-
- F^- can react with H2O in detector to form HF which damages detector foils
- Objective: Expose triple-GEM detectors to radiation at GIF++ facility to test (using Ion Selective Electrodes) for production of F-
- ISE electrode: sensor that converts activity of an ion dissolved in a solution into an electric potential
  - 2 different electrodes used: Separated (Hanna) and Combined (ThermoFisher Scientific)



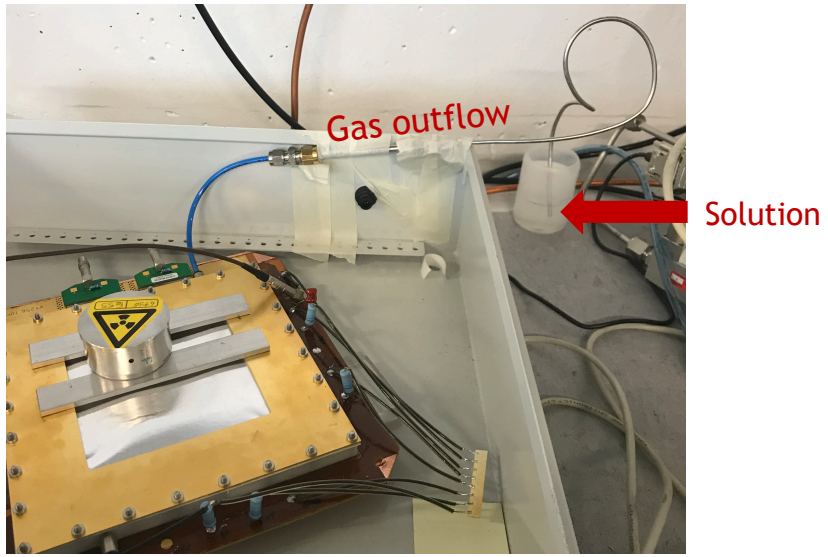
Setup of GIF++ bunker

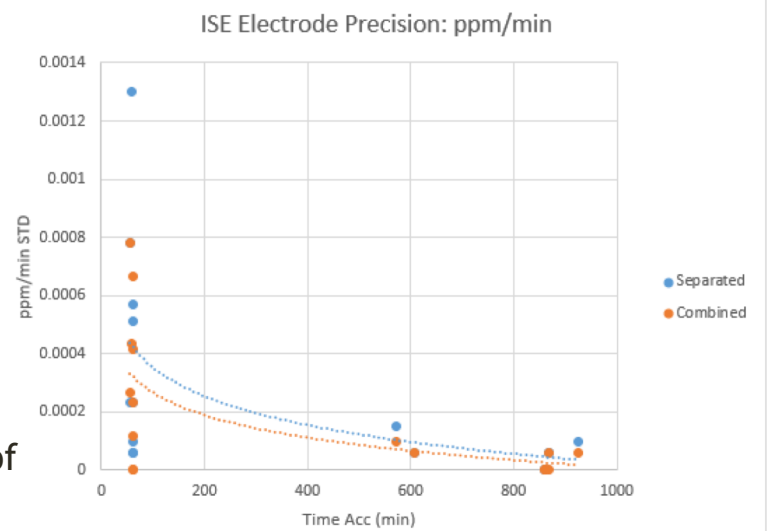


Hanna Instruments ISE electrodes and ISE station

ISE ELECTRODE MEASUREMENT CHARACTERIZATION

- Triple-GEM output gas bubbles into a solution in jar outside detector
- Electrodes tested solution for concentrations of F-
- Measurements performed first in lab with small Fe^{55} sources and then at GIF++ for time periods of one hour
- Switched to overnight measurements so GEM & source left on for 10-15 hours

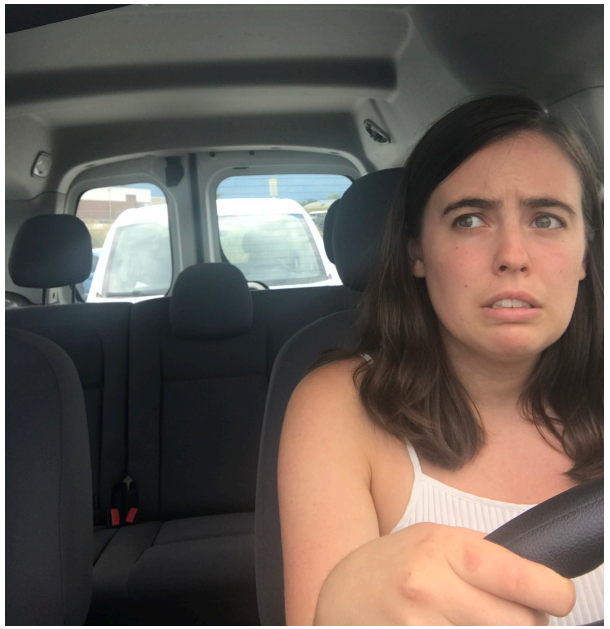




Standard deviation in measurements of ppm/min vs time accumulating

NEXT STEPS

- More ISE measurements using procedure characterized this summer
- Effect of applied voltage to the GEM on rate of CF4 breakage
- Effect of gas flow
- Effect of irradiation level



WHAT I LEARNED

- Working principles of gaseous detectors
- How to operate GEM detectors
  - Characterization and high voltage scans
- Software: ROOT
- How to operate ISE Electrodes
- A little bit of Italian
- How to drive manual (poorly)

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- Thanks to the rest of the EP-DT-FS team also