

Composition Analysis of Commercial Tetrafluoroethane Available to Local RPC Laboratories

William W. R. A. da Silva^{1*}, Kevin Mota Amarilo², Mauricio Thiel², Helio Nogima², Tiago F. Silva¹

¹ Instituto de Física da Universidade de São Paulo, Rua do Matão, 1371, 05508-090, São Paulo, Brazil/ *willian.wallace@usp.br

² Instituto de Física da Universidade do Estado do Rio de Janeiro, Rua São Francisco Xavier, 524, 20559-900, Rio de Janeiro, Brazil

MOTIVATION

Resistive Plate Chambers (RPCs) are widely used in High Energy Physics due to their good time resolution, high-rate capability, and relatively simple construction.

The performance and long-term stability of gaseous detectors depend strongly on the composition and purity of the gas mixture. Impurities introduced through gas production, storage, or handling can modify the detector response and contribute to degradation processes.

Tetrafluoroethane ($C_2H_2F_4$) is commonly used as a working gas in RPCs. Therefore, characterizing its composition and identifying trace molecular species is important for assessing gas quality and establishing references for detector operation and aging studies.

RESEARCH QUESTION

- How does the molecular composition of commercially available $C_2H_2F_4$ vary between different gas sources?
- Which molecular species and characteristic fragmentation pathways can be identified by mass spectrometry, and how can they support the interpretation of gas-phase processes in RPC operation and aging?

Commercial Supplier Purity Mapping (N_2 vs. H_2O)

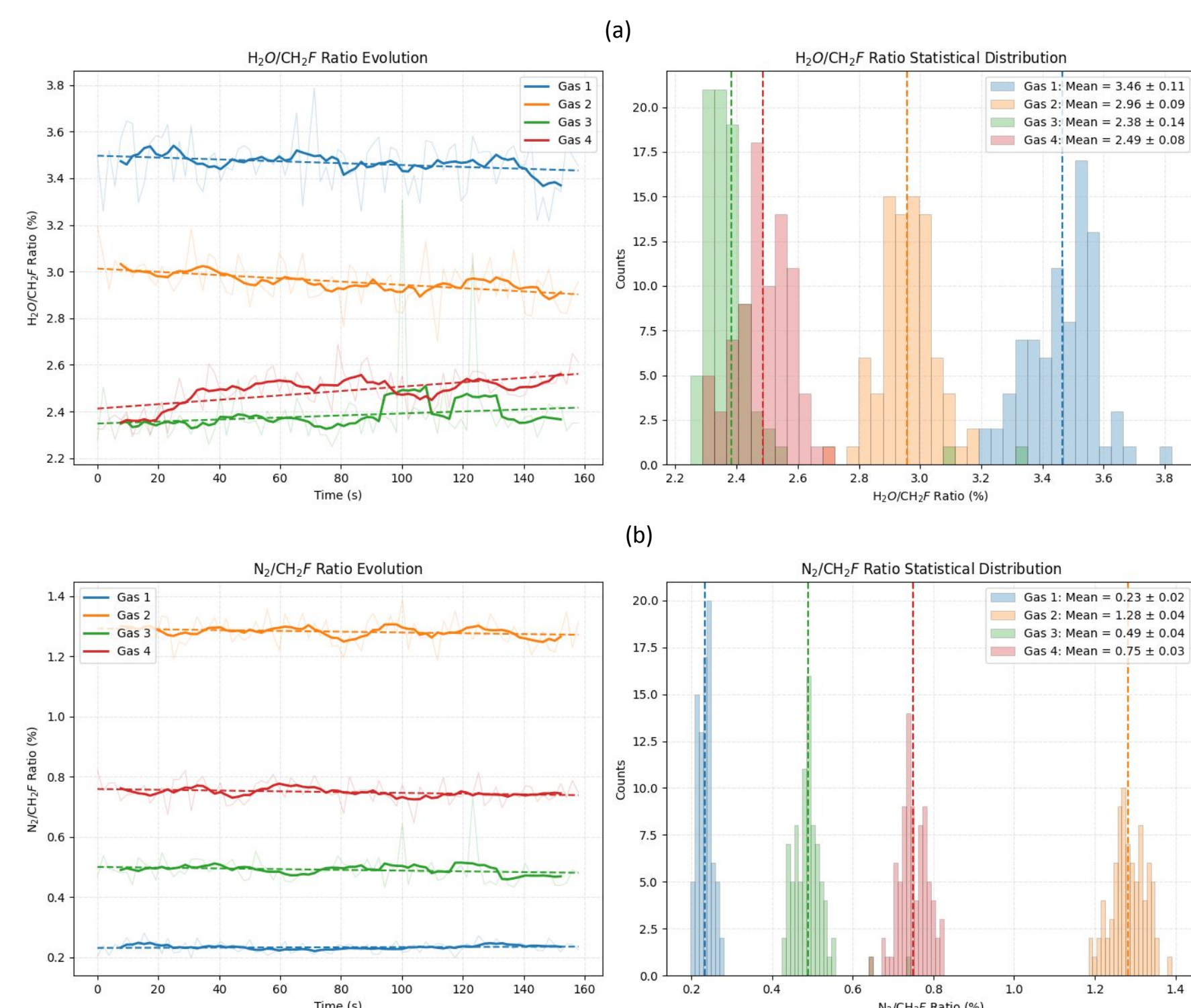


Figure 1: Supplier-dependent contamination profiles in commercial $C_2H_2F_4$ cylinders. (a) Time-series evolution and statistical distribution of the moisture contamination ratio (H_2O/CH_2F , $m/z = 18/33$), identifying Gas 3 as the driest sample (2.38 ± 0.14 %). (b) Atmospheric nitrogen contamination ratio (N_2/CH_2F , $m/z = 28/33$), demonstrating a 5 times variance between Gas 1 (0.23 ± 0.02 %) and Gas 2 (1.28 ± 0.04 %). Dashed lines indicate mean values ($\mu \pm \sigma$).

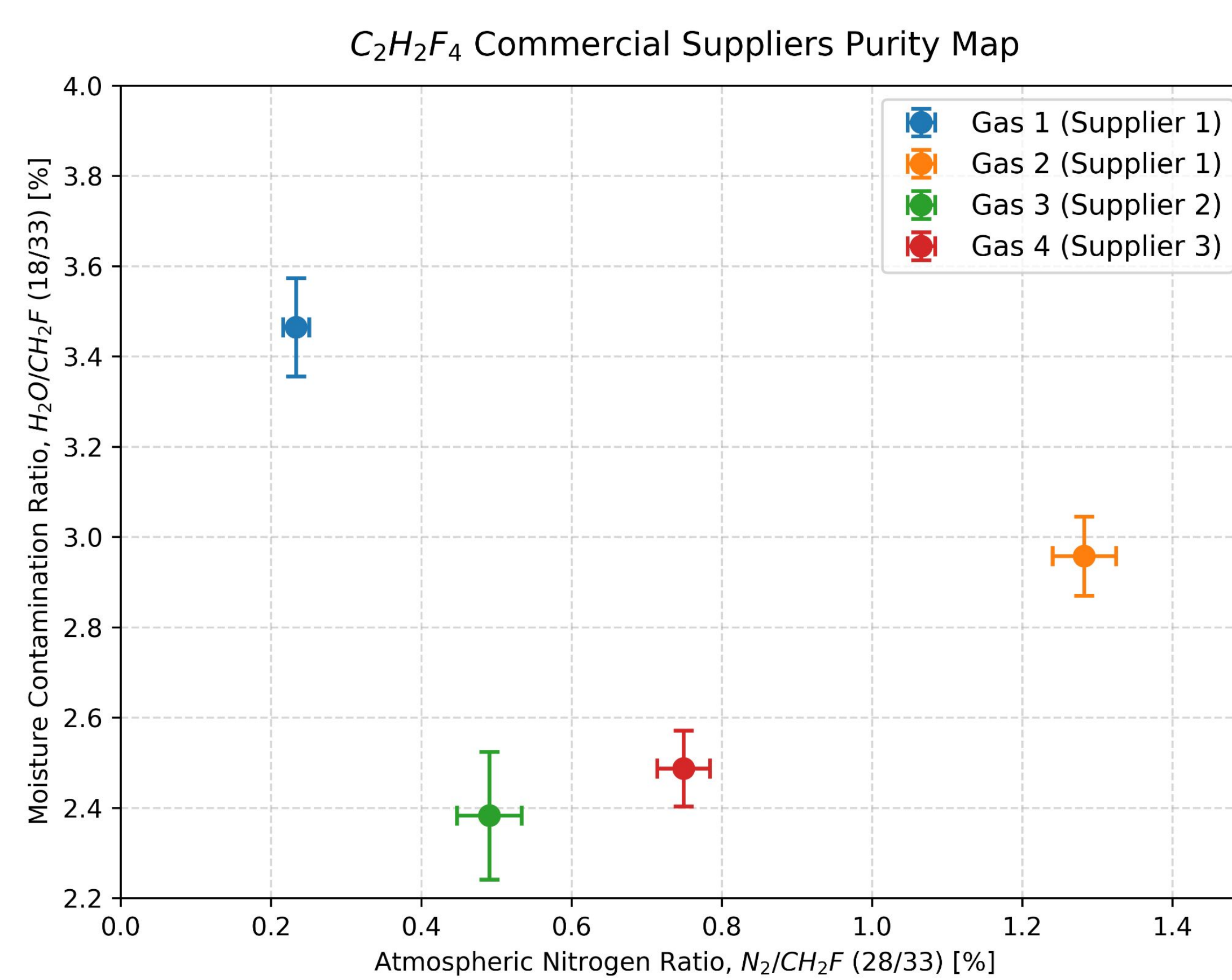


Figure 2: Supplier gas purity map highlighting moisture and nitrogen variations across four commercial $C_2H_2F_4$ cylinders.

EXPERIMENTAL APPROACH

Gas samples

Four commercial $C_2H_2F_4$ cylinders from three different suppliers were analyzed.

- Supplier A:** two cylinders — one previously in use and one sealed until analysis
- Supplier B:** one sealed cylinder
- Supplier C:** one sealed cylinder

Gas analysis

The gas samples were directly introduced into an ambient-pressure quadrupole mass spectrometer through a controlled-flow system.

- Gas-flow control system
- Pfeiffer Vacuum OmniStar GSD 350
- Mass range: **1–200 amu**
- Direct analysis without sample preparation
- Controlled and reproducible gas-flow conditions



- Significant Supplier Discrepancy:** Bi-dimensional purity analysis (N_2/CH_2F vs. H_2O/CH_2F) demonstrates distinct chemical profiles among commercial gas cylinders, confirming that gas purity varies significantly depending on the manufacturer.
- Moisture Variance ($m/z = 18$) and impact on RPC aging:** Gas 1 carries the highest water content (3.46 ± 0.11 %), whereas Gas 3 is the driest (2.38 ± 0.14 %). Under high-electric-field avalanches, excess H_2O reacts with fluorine radicals released by $C_2H_2F_4$ fragmentation, forming hydrofluoric acid (HF). HF corrodes inner electrode surfaces, accelerating dark current growth, degrading surface resistivity, and permanently shortening detector lifespan.
- Nitrogen Contamination ($m/z = 28$):** Gas 2 presents a severe nitrogen level (1.28 ± 0.04 %), over 5 times higher than Gas 1 (0.23 ± 0.02 %), establishing N_2 as the primary discriminator between manufacturers.

$C_2H_2F_4$ Fragmentation & Ionization Fingerprint

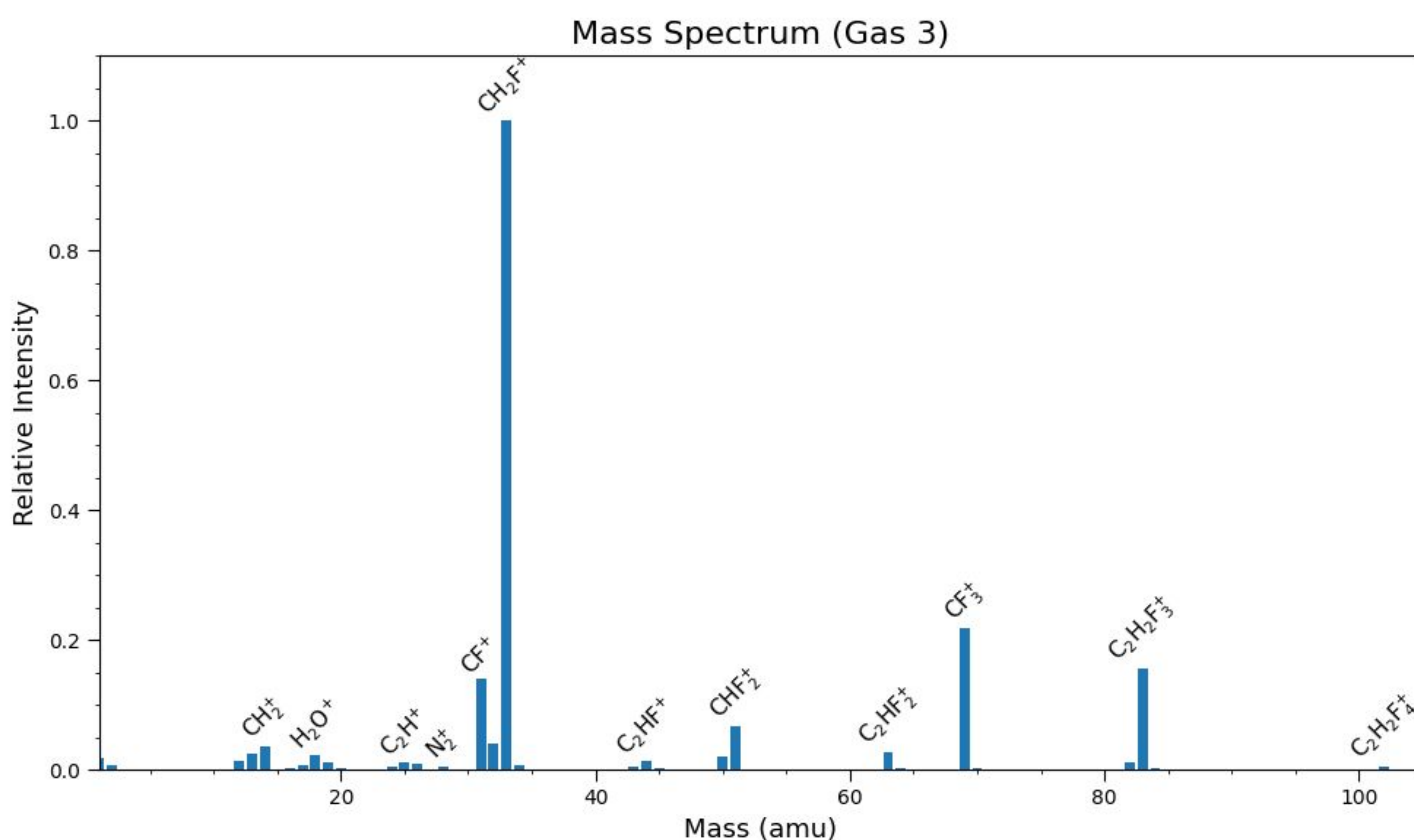


Figure 3: Mass spectrum of unexposed $C_2H_2F_4$ (Gas 3), selected for its minimal moisture and atmospheric content. Primary fragment cations are annotated to establish a reference baseline for RPC aging diagnostics. The spectrum extends up to 105 amu, as no significant contribution was found at higher mass values.

- Selection of the reference spectrum:** Gas 3 was chosen as the reference standard due to minimize moisture level and atmospheric contaminant, simultaneously. Minimizing H_2O is prioritized over N_2 because moisture directly drives hydrofluoric acid (HF) formation and electrode corrosion in active RPCs.
- Fragment Annotation:** Spectra are normalized to the dominant fluorocarbon base peak CH_2F^+ ($m/z = 33$). Key fragment cations include CF_3^+ ($m/z = 69$), $C_2H_2F_3^+$ ($m/z = 83$), CF^+ ($m/z = 31$), CHF_2^+ ($m/z = 51$), and residual parent $C_2H_2F_4^+$ ($m/z = 102$).

DISCUSSION AND CONCLUSIONS

- Purity Variance between different suppliers:** Commercial $C_2H_2F_4$ gas cylinders exhibit significant purity discrepancies across manufacturers (H_2O and N_2). Ambient-pressure QMS provides a direct, preparation-free method for screening supplies prior to detector injection.
- Moisture (H_2O) as Primary Aging Driver:** Moisture represents the critical threat to RPC longevity. Under avalanche electric fields, H_2O reacts with fluorine radicals to form hydrofluoric acid (HF), corroding electrodes, increasing dark currents, and accelerating permanent detector aging. Minimizing moisture must take absolute priority over nitrogen levels when selecting suppliers.
- Nitrogen (N_2) and Electrical Instability:** High N_2 levels (Gas 2, 1.28 ± 0.04 %) increase streamer formation. Excited N_2 molecules emit UV photons that eject secondary electrons from the cathode, inducing spurious pulses and narrowing the stable high-voltage operational range.
- Fragmentation Baseline for RPC Aging:** The fragmentation fingerprint of Gas 3 (normalized to CH_2F^+ at $m/z = 33$) establishes a vital baseline reference to identify gas breakdown, HF accumulation, and aging mechanisms in active particle detectors.

Acknowledgements



Poster presented at: RPC Conference 2026