Combined Gas Electron Multipliers and MicroMeGas as Gain Elements in a High Rate Time Projection Chamber

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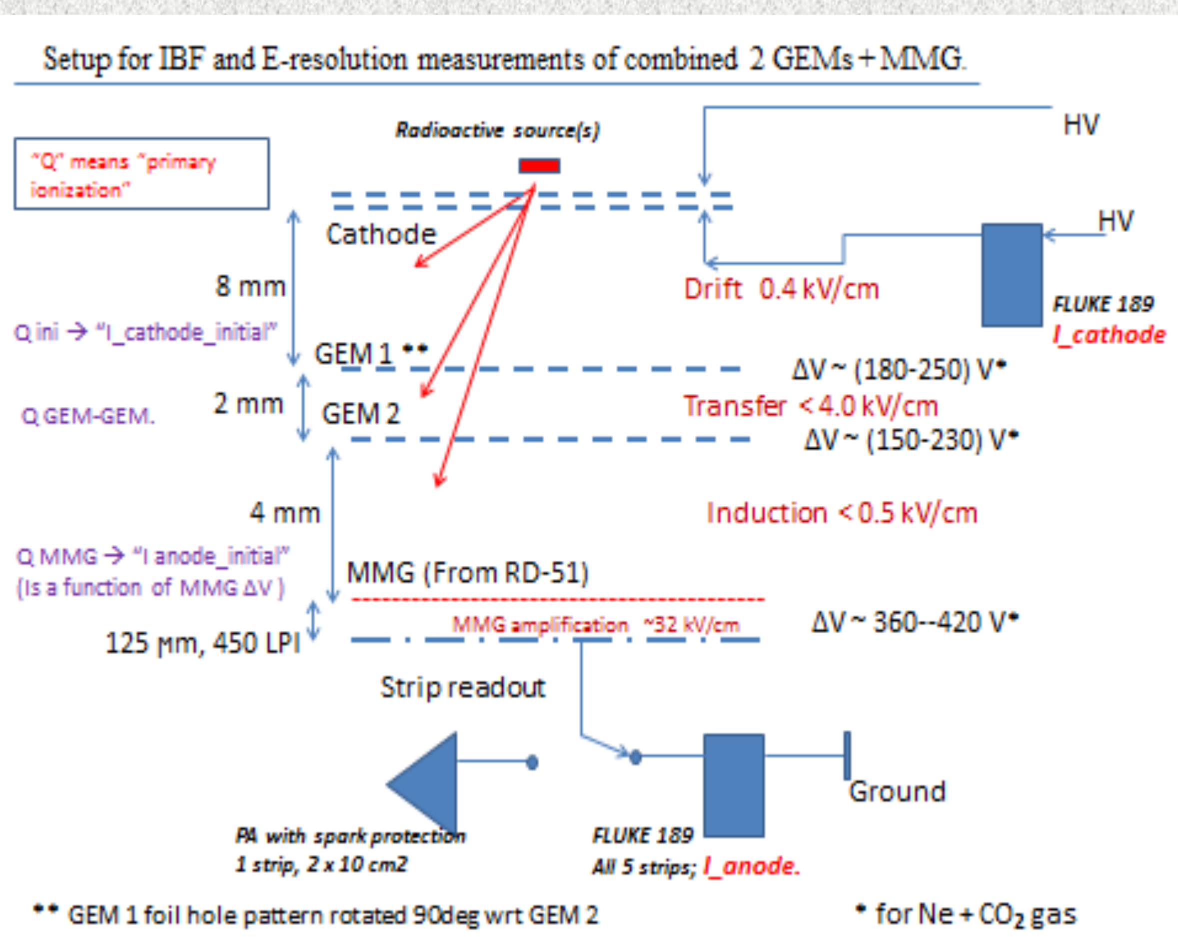
Abstract

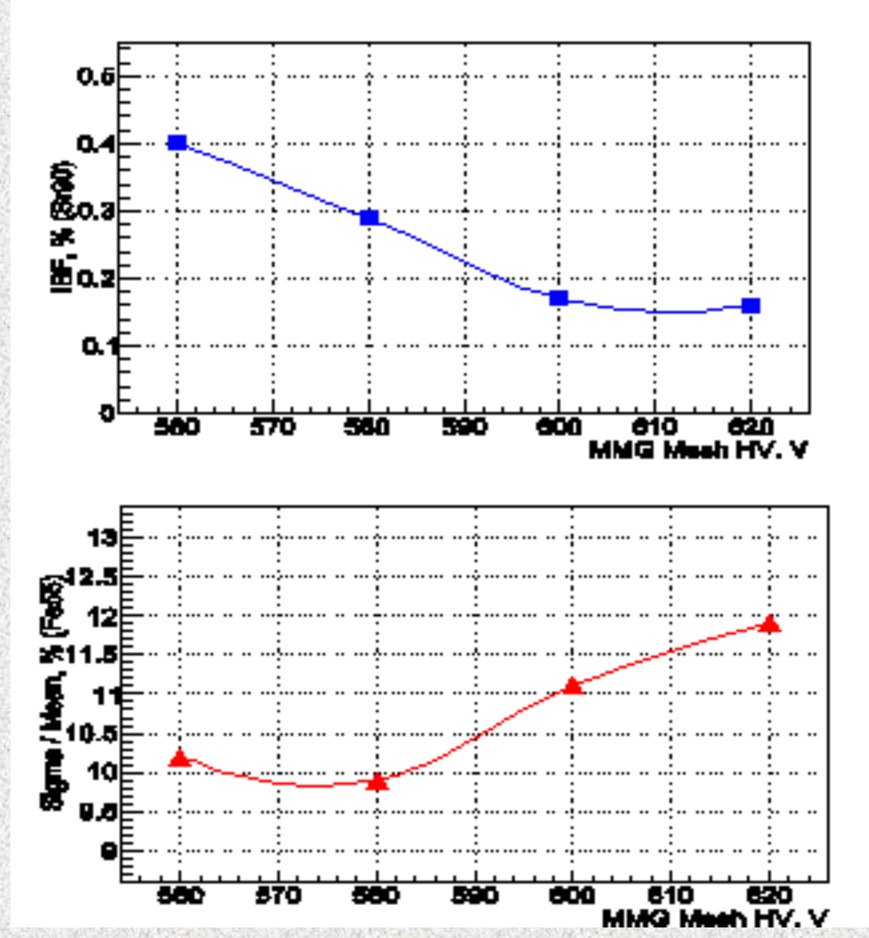
A new generation of Time Projection Chamber (TPC) has been proposed for an ALICE (A Large Ion Collider Experiment at CERN) upgrade for continuous readout at high luminosity. Such a continuously sensitive high-rate imaging detector is also highly desirable as a central tracking detector for a future electron-ion collider and a linear electron collider. This device would rely on the intrinsic ion back flow suppression of micro-pattern gas detectors to minimize space charge build-up in the main drift volume and thus would not require the standard gating grid and the resulting intrinsic dead time. We have proposed, simulated, and measured the properties of a combination of a MicroMeGas (MMG) detector with two Gas Electron Multipliers (GEM) for this application. We have measured the positive ion backflow (IBF) and energy resolution of this structure at various settings of the gains of the elements and the electric field between elements with different working gases. At a gain of 2000, this configuration allows achievement of both an IBF < 0.4% and an energy resolution < 12% (standard deviation) for an ^{55}Fe source. Spark rates measured for a variety of conditions will also be presented.

Motivation and goals: find a solution for a TPC working in pipe-line mode (with no gating-grid): minimize IBF, maintain good energy resolution.

Proposed solution: utilize a combination of a MMG detector with two GEM detectors as the gas amplification option for the TPC readout.
This allows:

- using a MMG as the "main" gas amplification step with a maximal ratio of E-fields in the amplification gap vs induction gap (& minimize MMG IBF)
- using the "top" GEM with convenient E-fields in the drift and transfer (to "middle" GEM) gaps, and with voltages providing an effective gain (5 — 10) and good energy resolution (amplification and transmission of primary ionization electrons), and to minimize the IBF through the "top" GEM.
- using the "middle" GEM with an effective gain ~1 to transfer electrons from a strong E-field to lower one in front of the MMG, smearing electrons in space, and to provide additional IBF suppression due to "hole geometry" and any misalignment (foil rotation and/or difference in hole structure)
- all gas amplification elements to operate at modest voltage and gain values thus minimizing the discharge probability.

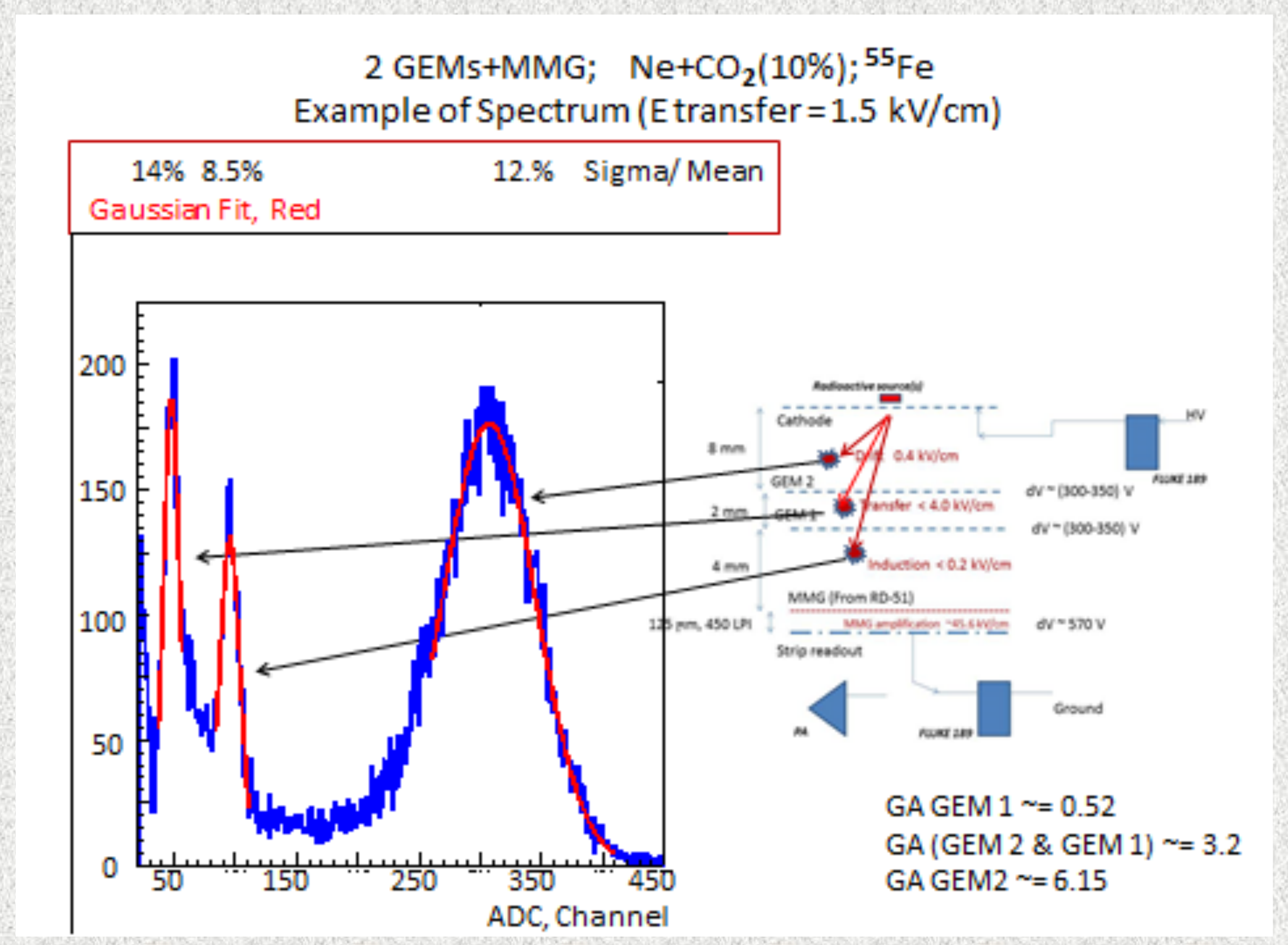




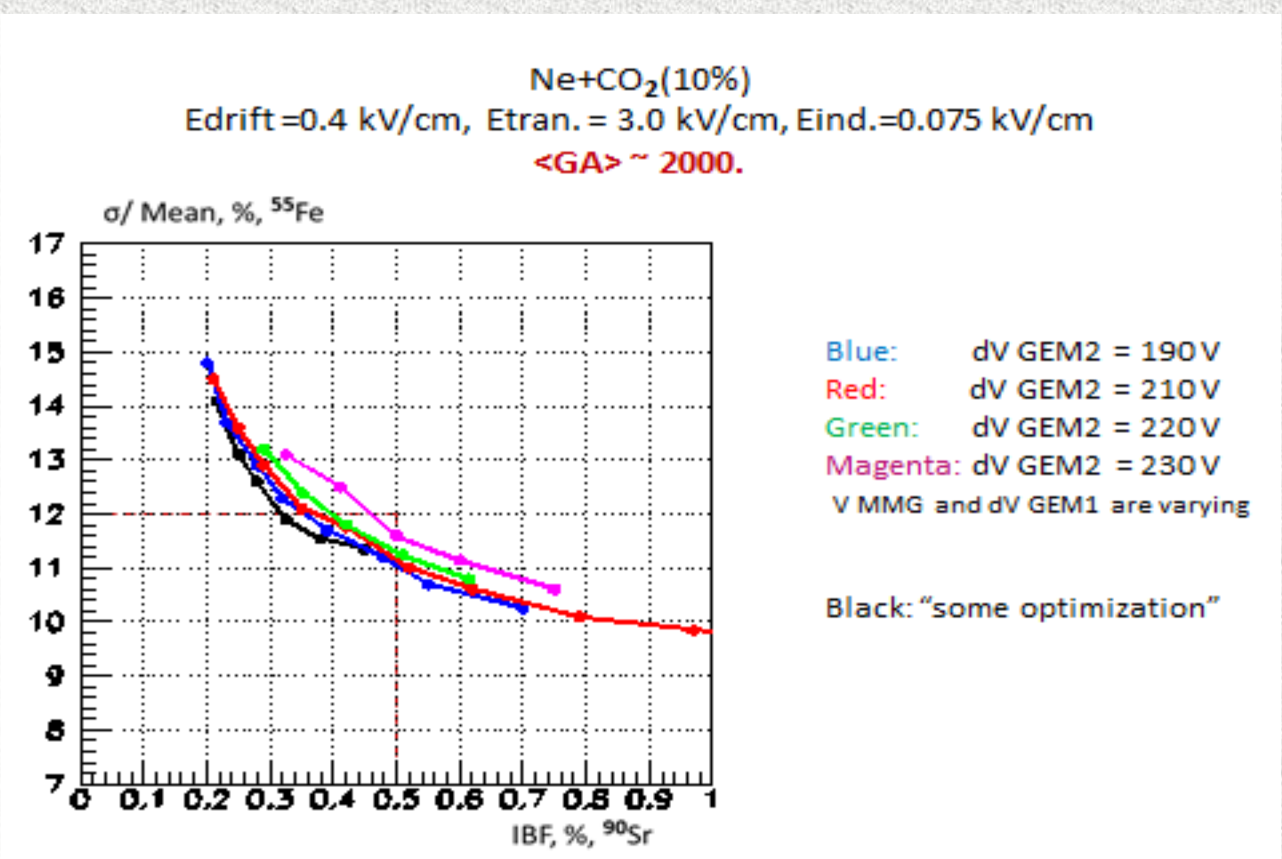
First measurements with *Ar+CO$_2$(30%)* ^{55}Fe and ^{90}Sr sources.

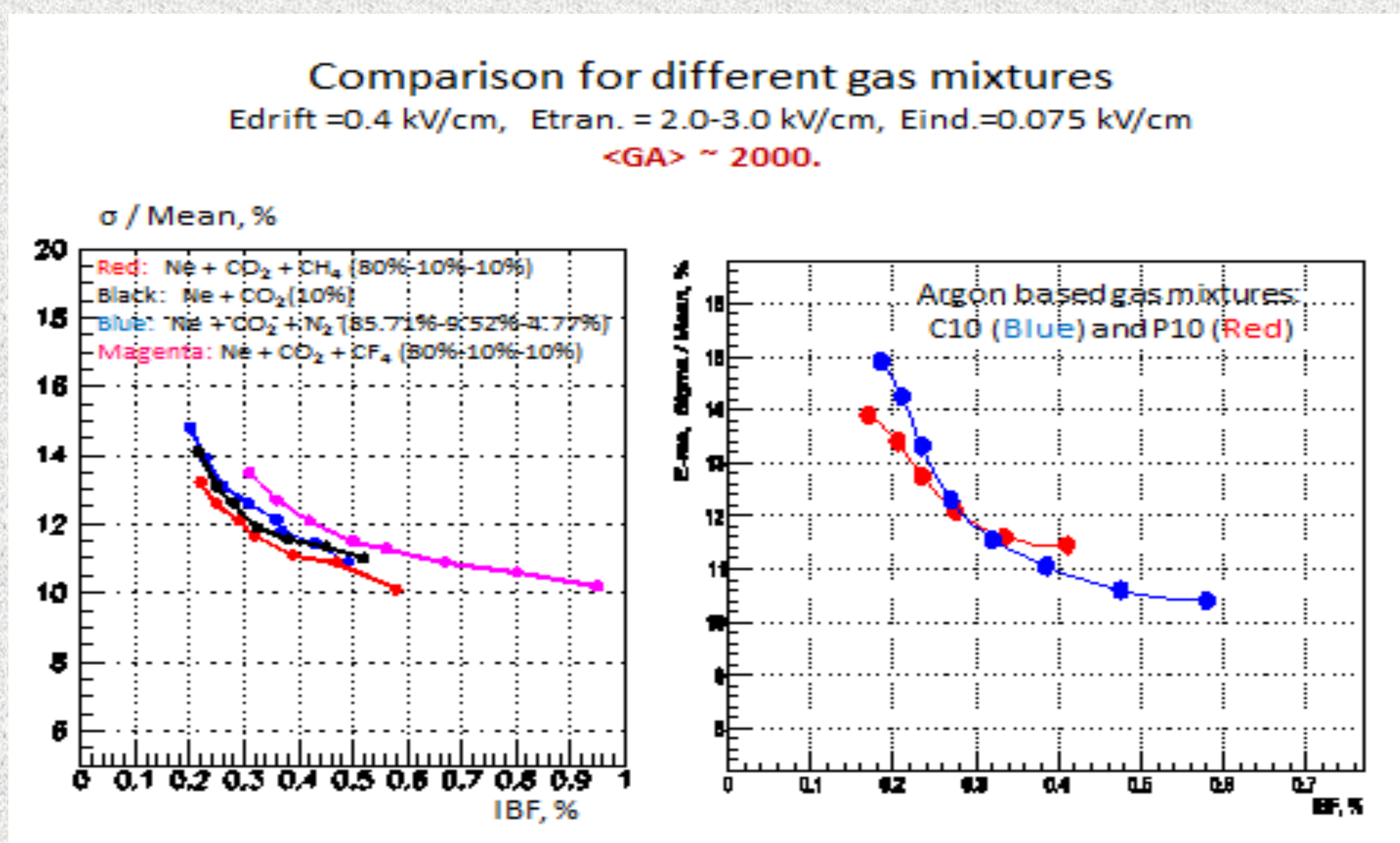
E drift = 0.4 kV / cm
E transfer = 3.5 kV / cm
E induction = 0.125 kV / cm

Gain = (5.5+/-0.5) * e3
(tune GEM voltages to the same gain)



The ***E-resolution*** (Sigma/Mean) and gain (GA) were measured with an ^{55}Fe source for 10-12 MMG mesh voltages. GEM voltages were tuned to maintain ***GA ~ 2000.***
Currents were measured with a strong ^{90}Sr source and pico-ammeters for the selected voltages (energy resolution < 16%).
The ***IBF*** was calculated as the ratio of I (cathode) – I (cathode_initial) to I (anode) – I (anode_initial(V_mesh)), where I (cathode_initial) is initial ionization in drift volume, and I (anode_initial(V_mesh)) is MMG current for ionization in induction gap. The E-field in drift gap was maintained at 0.4 kV/cm.
Additional GA was monitored and controlled by using the ratio of I (anode) – I (anode_initial) to I (cathode_initial).





These data show it is possible to achieve IBF < 0.5% with good energy resolution for a variety of gases.

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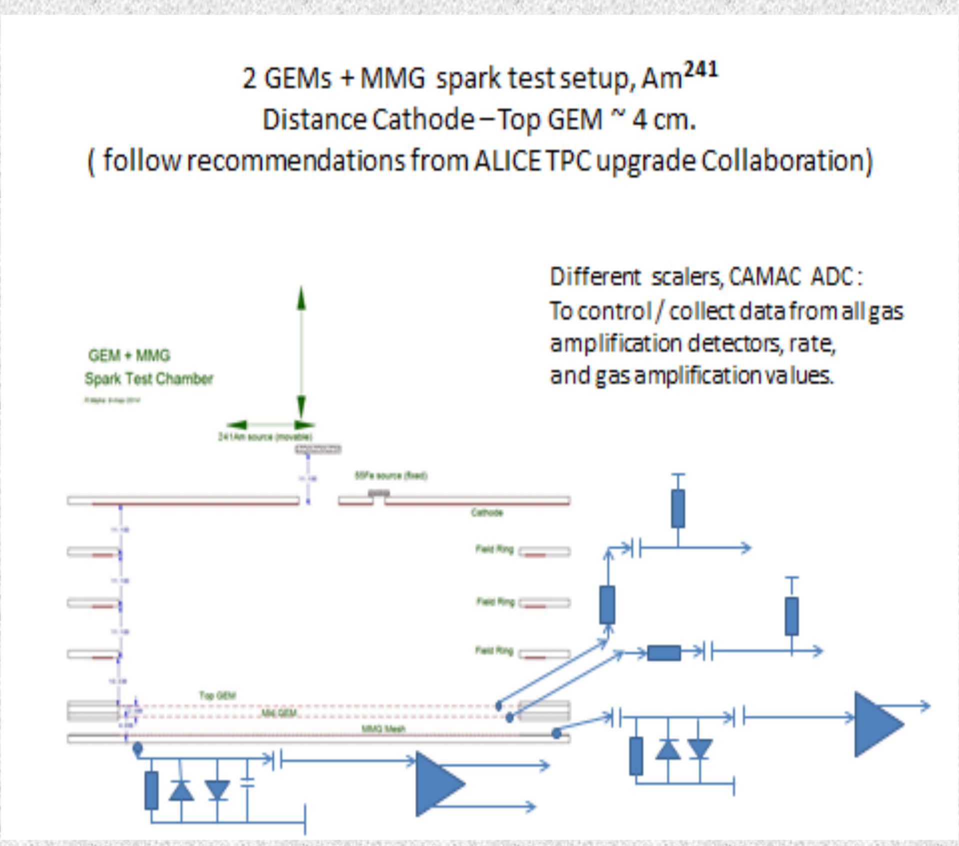
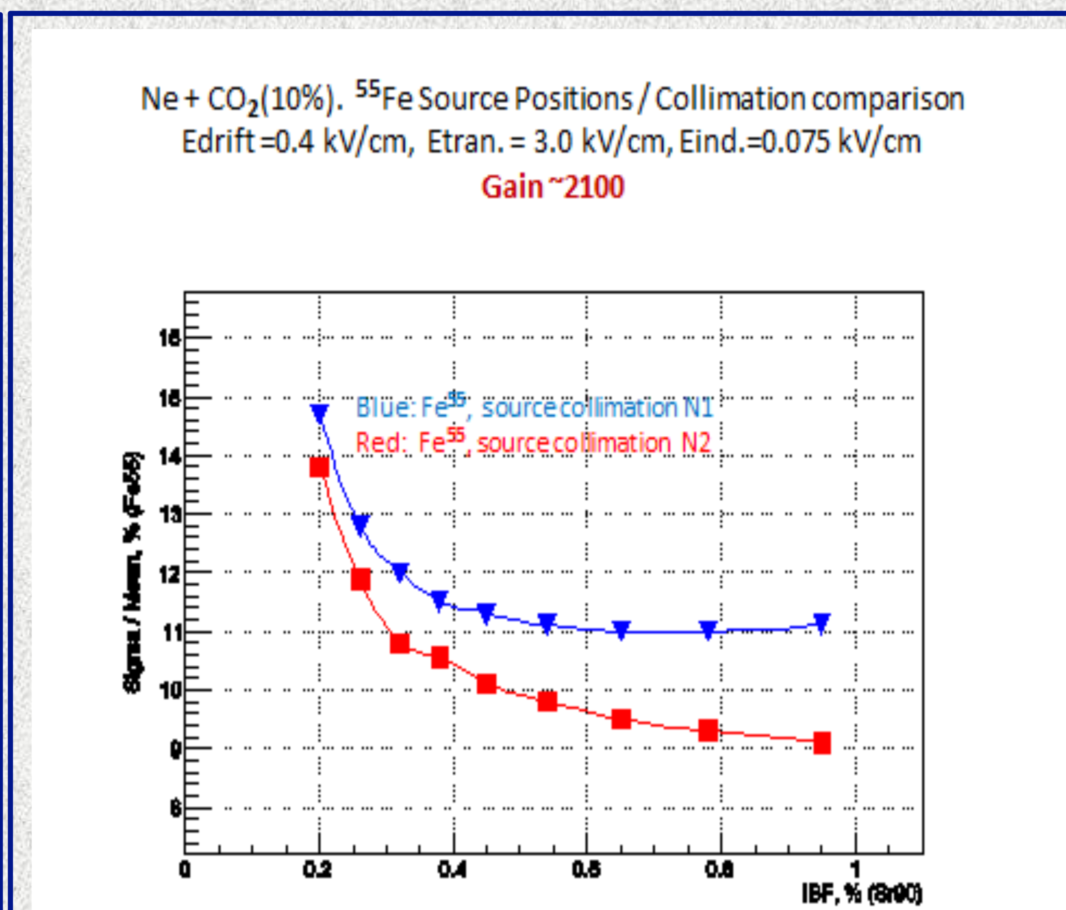


To test the discharge probability:
1.) a special Spark Test Chamber was constructed, and an Am^{241} source used.
2.) two 20x30 cm^2 chambers were tested in the high intensity hadron beam at CERN.

Spark rates per particle:
- α-source:
  < 3 x 10^{-7} in Ne+CO$_2$(10%)
  < 2 x 10^{-8} in Ne+CO$_2$(9%) + CH$_4$(9%)
- test beam:
  ~ 3.5 x 10^{-10} (Ne+CO$_2$+N$_2$)(90-10-5)



The intrinsic MMG problem originates from possible cross-talk due to the small Mesh-Readout distance (large Capacitance). To test this problem a special chamber was constructed with 4 large size (5x5 cm^2) pads for the readout.
^{55}Fe spectra (rate ~ 1. kHz) were measured for two collimator options:
RED – ionization is only on the read-out pad (SC N2) or
BLUE – sharing of the ionization spot with neighboring pads (~50-50; SC N1).
The E-resolution degradation is due to cross-talk. The same (but smaller) effect occurs for the chamber with strip read-out.

Conclusion: These results are promising and indicate it is possible to achieve an IBF < 0.4% while maintaining an energy resolution of 12% or better. Further, the gain elements (GEM foils and MMG) all operate at individual gains well below the maximum possible, which helps to minimize the discharge probability when operating in a high flux hadron environment. We are preparing a setup with 2 GEMs+MMG with resistive strips on the readout pad structure (each pad-row with its own R-strip) to test all parameters including the MMG mesh voltage decrease during the spark (its value and timing).