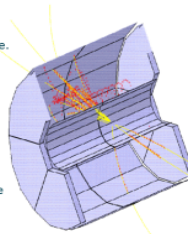
Options for Gain Elements in a High Rate Time Projection Chamber

Relativistic Heavy Ion Group, Wright Lab, Physics Department, Yale University

Motivation

The Time Projection Chamber (TPC) is the detector of choice for low mass precision tracking, pattern recognition, momentum reconstruction and particle identification.
It is crucial to keep both electric and B-fields as uniform as possible. However, the build up of positive ions in the drift volume (from "primary" ionization" and Ion Back Flow (IBF) from the gas gain structures) leads to electric field distortions and distortion of the ionization electron tracks as they drift to the endcaps (known as Space Charge Distortion: SCD) .
SCD is a "function" of many parameters: physics, beam structure and collision rate, TPC size, E-field, "working" gas, etc. IBF is the main "contributor"; it is crucial to minimize this back flow of ions. Different options have been used, proposed, tested: wire structure (gating grids), single or double MMG, multi GEMs setups with / without using a "top" foil as a gate, ... All options have pros and cons.



We are working as an R&D and "mass-production" team on:
-- multi-layer gating grids (simulation: arXiv:1603.05648v1)
-- 4-GEMS setup
-- MMG + 2 GEMs setup

IBF – E-resolution – Stability

Conclusion after 3.5 years dedicated R&D activities.
ALICE TPC upgrade team

- Following its physics demands, the ALICE collaboration decided to upgrad to a continuous readout (and eliminate the gating grid).
- TPC data taking at 50kHz Pb–Pb is possible using a 4-GEMs system
- Major challenges in calibration/reconstruction
- Continuous readout → Interaction time estimate
- Fast online reconstruction to perform compression
- Large distortions due to space-charge (20 cm max.)
- Pile-up: ~5 overlapping events
- Update calibration for data in 5 ms
- Crucial factor – tracking detectors in front of and behind (in radius) the TI
- TPC upgrade (TDR: CERN-LHCC-2013-020) was approved and recommenc "mass-production and installation".

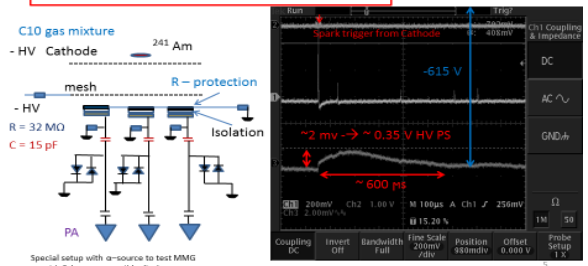
Our group was asked to consider an alternative option for ALICE TPC upgrade
We proposed and investigated the performance of a novel configuration for TP amplification: 2-GEMs plus a Micromegas (MMG).
Details can be found in NIM A834,p149.

IBF – E-resolution – Stability

	4 GEMs	2 GEMs + MMG (no R-layer)
IBF (E drift: 0.4 kV/cm)	(0.6 - 0.7)%	(0.3 – 0.4)%
<GA>	2000	2000
ε - parameter	12 - 14	6 - 8
E – resolution	<12%	<12%
Gas Mixture (3 components)	Ne+CO2+N2 (Et "problem" with + CF4)	Ne+CO2+N2, Ne+CO2, Ne+CF4, Ne+CO2+CH4
Sparking (Am241)	$<3.*10^{-9}$	$<3.*10^{-7}$ (Ne+CO2) $<2.*10^{-8}$ (Ne+CO2+C2H4)
Sparking, SPS test-beam Ne+CO2+N2	$\sim 6.4*10^{-12}$	$\sim 3.5*10^{-10}$
Possible main problem	short sector of the foil	Extremely robust. But number of hits and HV "recovery" time.
"General" problem	4 unique GEM foils/chamber IBF = F(X,Y), 20-30% variation HV > 3.5 kV. The same V on all top GEMs (TPC drift field) Gain variation: factor > 2 as F(X,Y)	Minimize all these problems

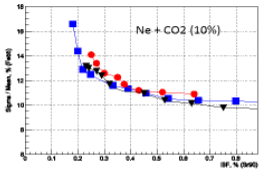
MMG mesh Voltage drop measurement,
10x10 cm2 MMG with Pad (4x7.5 mm2) readout and with Resistive layer protection,
Spark trigger – from Cathode. V Mesh = -615 V. Sparking rate: ~1 /20 s.
Signal from R-divider (1:100) connected to MMG mesh

HV drop: ~ 0.4 V, Practical "invisible" for Detector performance
Recovery time: ~ 600 μs *)

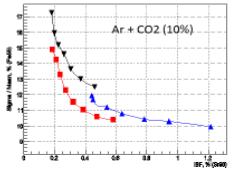


Special setup with α–source to test MMG with R-layer on possible discharges

E-resolution vs. IBF for a MMG+2 GEMs chamber with/without Resistive layer protection.

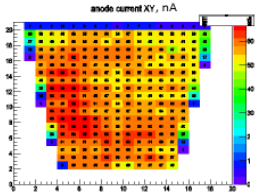


Red: standard setup (NIM A834, p149)
Blue: with R-layers, #1
Black: with R-layers, #2
need increase voltage on MMG and GEMs

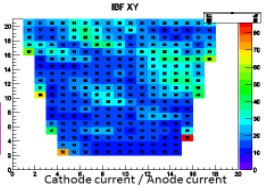


IBF – E-resolution – Stability

Standard MMG+2 GEMs (not rotated) setup, IROC ALICE TPC size ("HIROC")
X-ray gun X,Y scan with 1" step, ~1. cm diameter ionization spot
Ne+CO2+N2 (90-10-5)



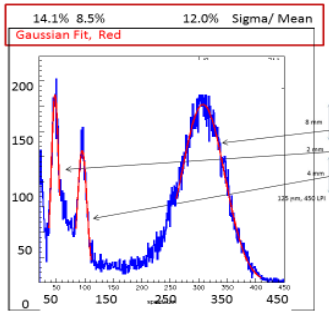
Good gain uniformity (F(X,Y))
Very low and uniform IBF
Max HV 2600 V
Possible to tune one transfer field to get (needed) same voltage on all "top GEMs" and keep the same detector performance

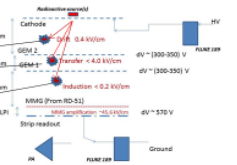


Passed "standard" stability test with X-ray gun. No discharges during 6 hours run with Anode current ~10 nA/cm2

Cathode current / Anode current
"20" means 0.2%

2 GEMs+MMG; The same setup can be used to measure / control Gain both GEMs and MMG; Ne+CO_2(10%); ^{55}Fe. Example of Spectrum (E transfer = 1.5 kV/cm) or / and currents measurements during X-ray scan





Gain GEM mid ~= 0.52
Gain (GEM top & GEM mid) ~= 3.2
Gain GEM1 top ~= 6.15

Summary

- Setup with MMG + 2 GEMs can (should) be added to the "list" of possible TPC gain elements.
  -- factor 2-3 IBF improvement (smaller) in comparison with 4-GEMs setup. The same: E-resolution and Gain.
  -- extremely robust
  -- passed "standard" stability test with X-ray gun. Confirm that the main "source" of MMG sparking is interaction of high momentum particles with the mesh material.
  -- with Resistor-protection there is no HV recovery "dead" time in case of a spark
  -- most probable GEM foils (IROC size) do not need "support structure (ribs)"; distance between foils can be increased, and very low E-field in a front of MMG
- More R&D to check an "optimal" MMG Resistor-protection option (if it is used).
- Stability test – as realistic as possible.

Multi-layer gating grid option is under investigation