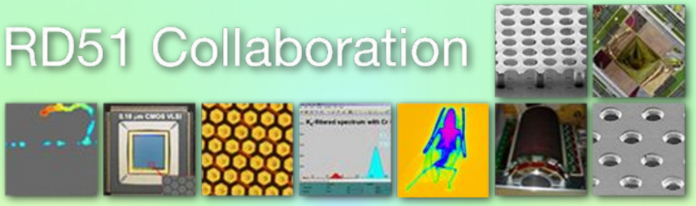
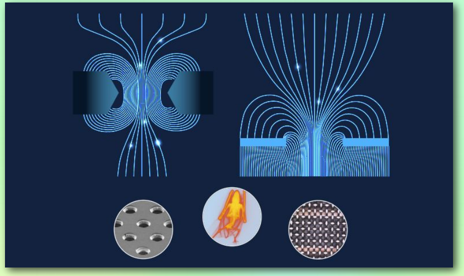




RD51 Micro Pattern Gaseous Detector School

LAB 2: DETECTOR OPERATION

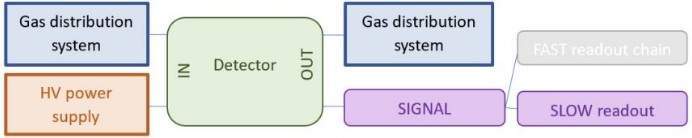
Chiara Alice

On behalf of the group 5:

Sapphira Akins | Chiara Alice

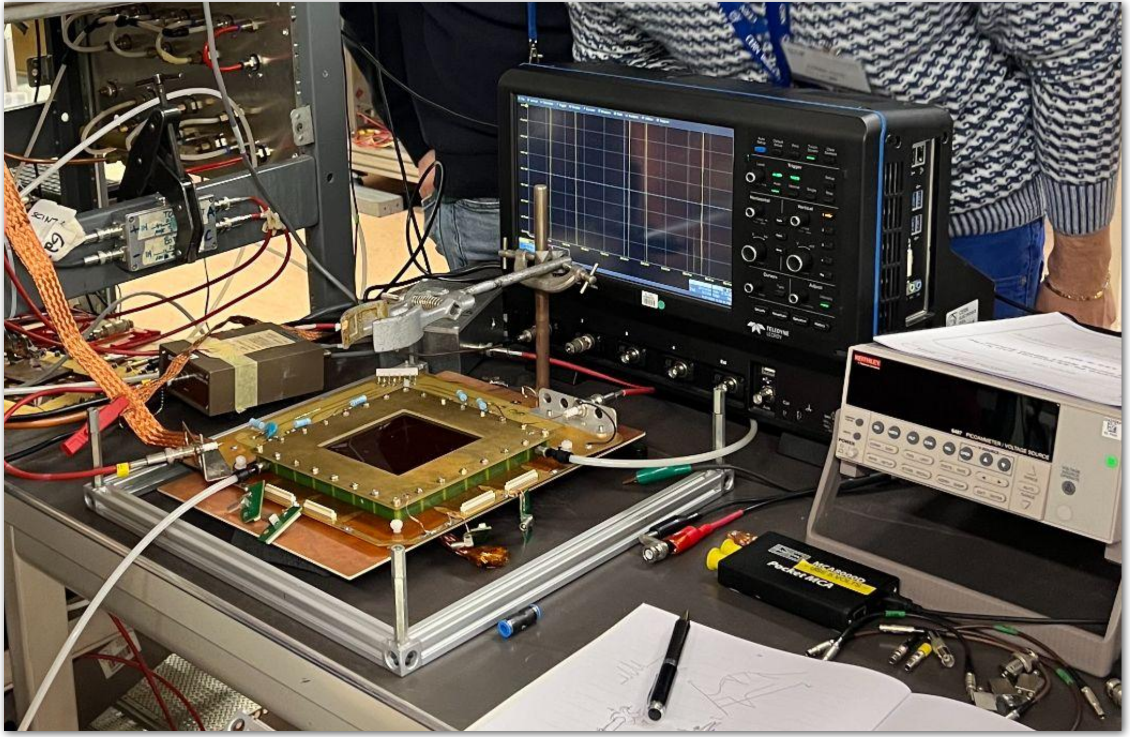
David J. G. Marques | Joseph Dopfer

Operating a Triple-GEM detector

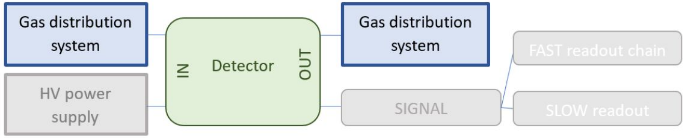


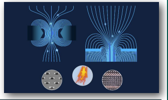
The lab consisted of the following work plan:

1. Prepare the gas setup
2. Connect the HV source
3. Connect the readout chain
4. Grounding improvements
5. Ramp up the voltage
6. Measure signals with a source
7. Define the effective gain



Operating a Triple-GEM detector: gas setup





Understand operating condition:

- Ar/CO2 (70/30) gas mixture have been used for the triple-GEM detector
- Gas distribution, gas purity and detector gas tightness issues have been discussed[1] ⟶ properly flushing, input and output flowmeters

Oxygen effect

In the presence of electronegative components or impurities in the gas mixture, the drifting electrons may be absorbed by the formation of negative ions.

Halogenides (e.g. CF4) and oxygen have particularly strong electron affinities.

Humidity

Addition of water vapour is reducing the discharges, introducing some conductivity

GEM current decreasing while flushing the detector, as humidity is removed

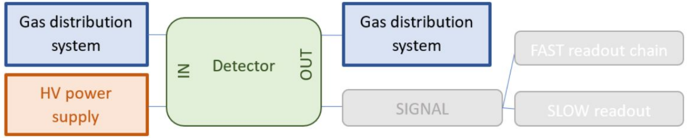
Aging

Other sources of gas contamination have been discussed such as:

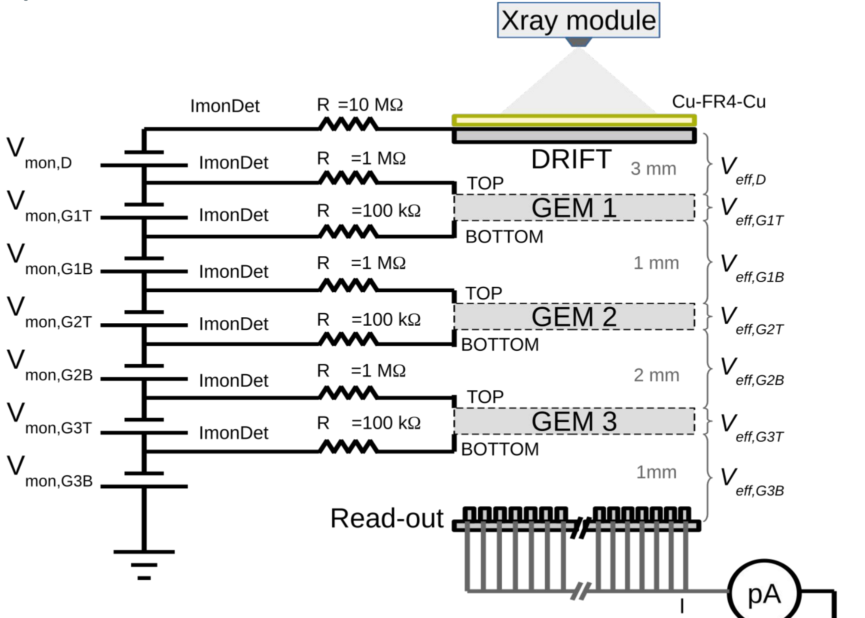
- Outgassing building materials
- Polymerizing additives
- CF4 discussion: high electron drift velocities vs fluorine etching [2]
- Si impurities

[1] Gaseous Detectors, H. J. Hilke and W. Riegler
[2] Irradiation effects on GEM detectors operated at RUN1 and RUN2 at the LHCb experiment, M. Poli Lener, 3rd detector ageing conference

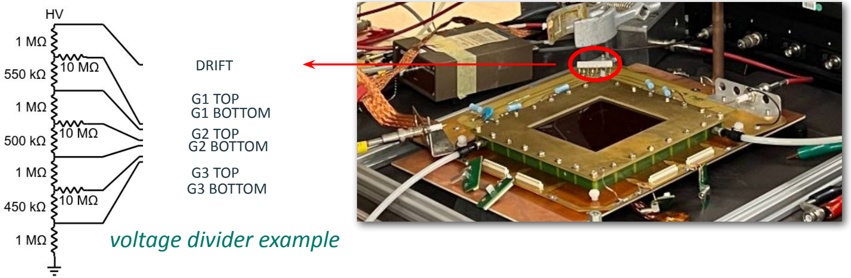
Operating a Triple-GEM detector: HV connection



Triple GEM HV scheme:



CMS Triple GEM ME0 Rate capability measurement setup scheme from [3]

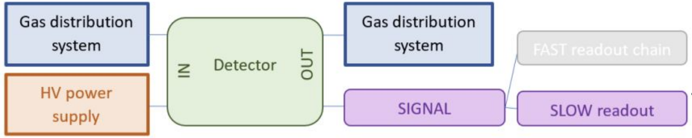


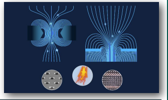
voltage divider example

- Discussion on HV distribution → voltage divider
- Common ground identification
- Protection resistors role have been discussed
- Parasitic capacitances
- HV settings explored: current limits, ramping up/down speeds, trip time

[3] M. Bianco *et al.*, "Rate Capability of Large-Area Triple-GEM Detectors and New Foil Design for the Innermost Station, ME0, of the CMS Endcap Muon System," *2021 IEEE Nuclear Science Symposium and Medical Imaging Conference (NSS/MIC)*, Piscataway, NJ, USA, 2021, pp. 1-5, doi: 10.1109/NSS/MIC44867.2021.9875626.

Operating a Triple-GEM detector: detector gain





In gaseous detectors, the ***gain*** can be explicitly calculated using the formula:

$$G = \frac{I}{R\, q_{e^-}\, n_p}$$

where:

- ***I*** is the **current** induced by the ^{55}Fe source and read by the ***ammeter***
- ***R*** is the **activity** of the ^{55}Fe source
- q_e is the electron **charge**
- n_p is the number of **primary electron-ion** pairs produced by the 5.9 keV photon emitted by the source that can be calculated by:

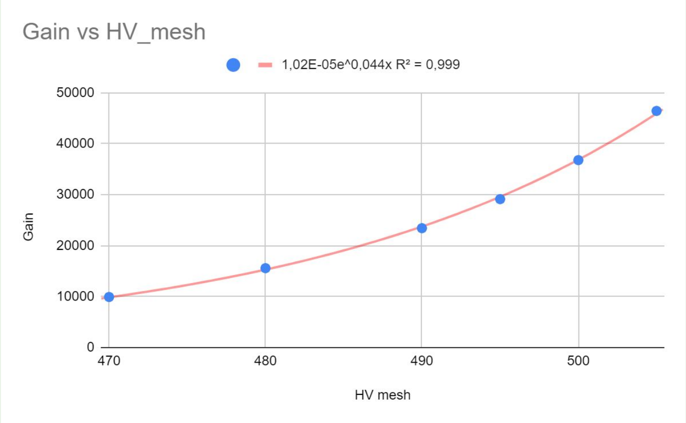
$$n_p = W / 5.9\ \text{keV}$$

where W is the ***average energy*** needed to create an ***electron-ion pair***, around ~30 eV for $Ar:CO_2$ 70:30

At the end, our gain is given by:

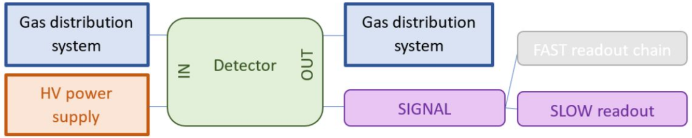
$$G = \frac{I}{R \cdot q_{e^-} \cdot 226}$$

The ***gain curve*** is expected to be **exponential** with the increase of the voltage applied at the amplification stage.



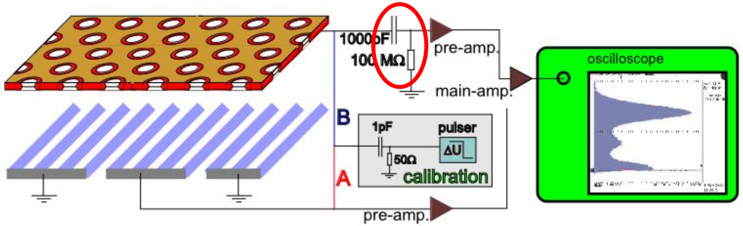
*Example of a gain curve we obtained with a **MicroMegas-based** detector used in **LAB3***

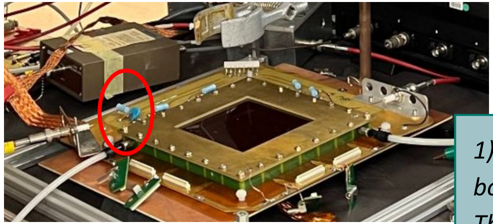
Operating a Triple-GEM detector: readout chain



Reading out G3 BOTTOM signal:

The signal on the anodes is induced by the moving charge from the last GEM foil. Alternatively the same signal with opposite polarity can also be observed on the GEM foil.





2) Amplification stage + shaping was implemented using the ORTEC 142PC Preamplifier (CSA) and a Shaper module (ORTEC 474):

- *We expect signals with lengths of O(10^1) ns*
- *Pre-amplifier integrates the charge signal within O (us)*
- *Shaper-integrator gets the important part of the signal, present in the initial tenths of ns of the pre-amp signal*
- *Shaper-derivator is used to "stop/close" the signal*

1) AC-coupling using a capacitance between the bottom GEM side and the amplifier input.
The coupling capacitance has to be large compared to the parasitic capacitance between the GEM foil and the signal ground.

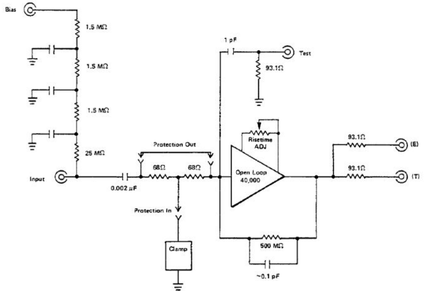
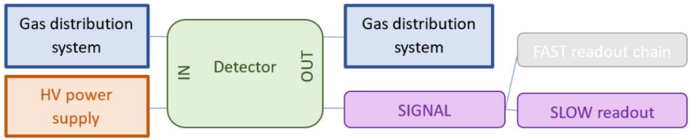


Fig. 4.1. Simplified Block Diagram of the 142PC Preamplifier.

Operating a Triple-GEM detector: Fe55 spectrum

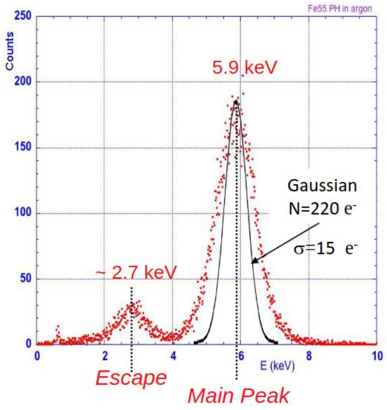


Ramp up the HV:

- During the ramp-up, the noise level has been monitored
- Grounding scheme has been discussed ⟶ **shared current paths are the most unpredictable phenomenon (not only GND)**
- HV training procedures in order to monitor the trip event rate

Fe-55 source signal measurement:

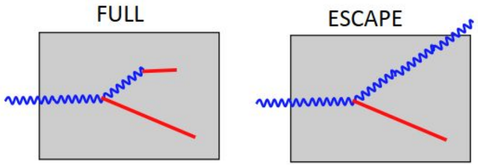
- A signal to noise ratio of 10 has been observed
- The signal characteristics have been discussed ⟶ Varying the *integration* and *differentiation* time on the shaper



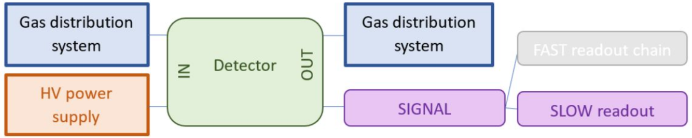
^{55}Fe predominantly decays via K electron capture to the ground state of ^{55}Mn. The energies of the $K_{\alpha1}$ and $K_{\alpha2}$ X-rays are so similar that they are commonly perceived as mono-energetic 5.9 keV photons

When a 5.9keV photon is absorbed by an Ar atom, there are two common modes of ionization: an electron from the innermost K-shell is freed, or an L-shell electron is freed.

-If the energy of the photon is fully absorbed (K-shell + Auger) (*Main*)
-If the K-shell is filled by fluorescence (L-electron drops to K) a ɣ of EK − EL = 2.9keV can escape the detector (*Escape*)



Gas detector physics 1 lecture - F.Sauli



Operating in high rate environment:

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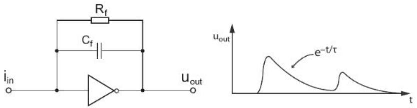
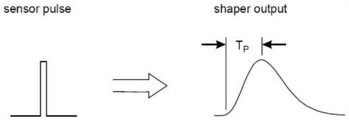
Further pulse shaping necessary for
- Reducing pile-up
- Increasing signal to noise ratio

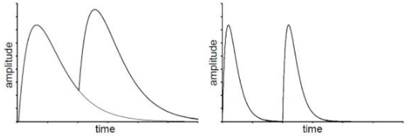


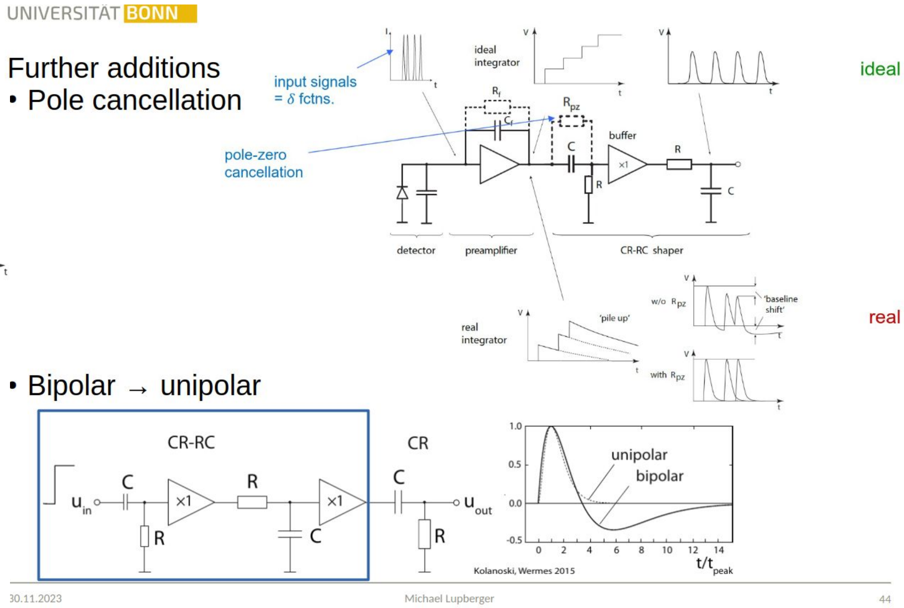
Two conflicting objectives:

- Limit bandwidth to match measurement time: too large a bandwidth will increase the noise without increasing the signal



- Constrain pulse width so that successive signal pulses can be measured without overlap (pile-up): increases signal rate, but also electronic noise





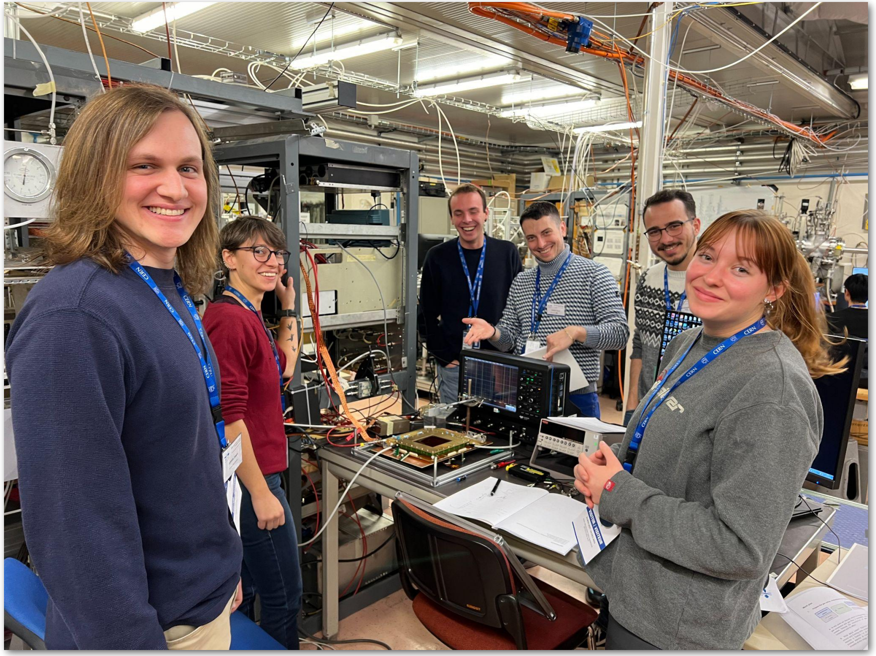
Slides from M. Lupberger lecture on RO electronics

Questions?

Summary:

A Triple-GEM detector operation steps has been explored

- Gas mixture and distribution system
- HV settings
- Readout chain
- Gain and stability



We would like to thank all the RD51 collaboration and especially Mauro and Florian for organising the RD51 MPGD School.

It was a great opportunity not only to learn and storage all the knowledge we need related to this research field but also to connect us with the MPGD community.

Thank you !