Characteristics of a Diamond like Carbon Coated (DLC) GEM

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outline

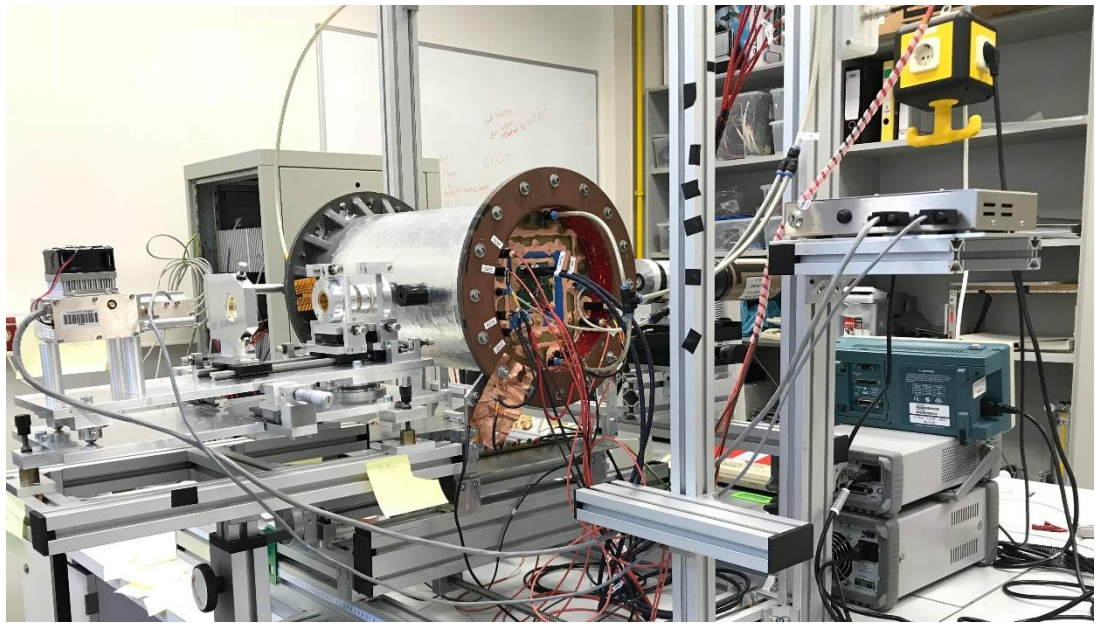
- Introduction
  - Time projection chamber (TPC)
  - Gas electron multiplier (GEM)
  - Properties of diamond like carbon (DLC) coated GEM
  - Two types of DLC Coatings
- Lab in Siegen
  - Test Chamber
- Measurements and Results
  - voltages and sparks limitations
  - Gain at variants voltages
  - Energy resolution of DLC GEM
- Conclusion and Outlook

Time Projection Chamber (TPC)

- Proposed as a main tracker detector for The International Linear Collider (ILD)
- good track separation
- low material budget
- Resolution of 9×10^{-5} /GeV/c at planned magnetic field of 3.5 T*

Gas Electron Multiplier (GEM)

has great effort to improve TPC performances when used as **amplification device**.

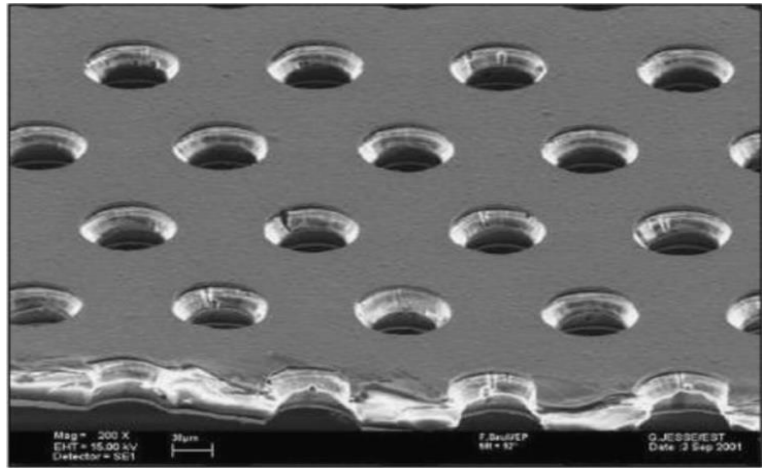


TPC prototype at university siegen Lab

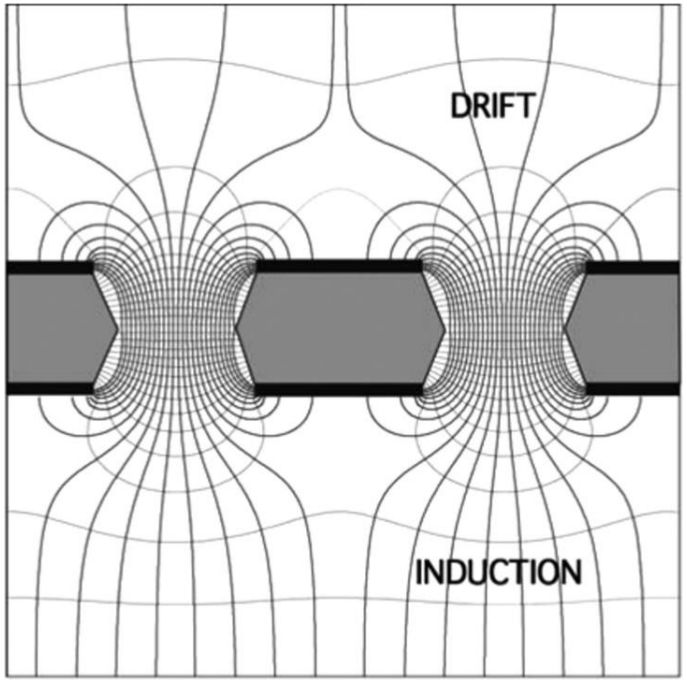
*R. Diener, Physics Procedia, 00 (2012) 1-8

Gas electron multiplier (GEM)

- Invented by F. Sauli at 1996 in CERN
- Consist of **two conductor** layers (copper) separated by an **insulator** (Kapton) with a high density of holes.
- High voltage applied between both conductors thus producing high electric field inside the holes.
- **Problem**: **limitation in gas gain due to electrical discharges.**



Electron microscopic picture for typical GEM with 50 µm thickness, holes diameter of 70 µm, pitch of 140 µm. *

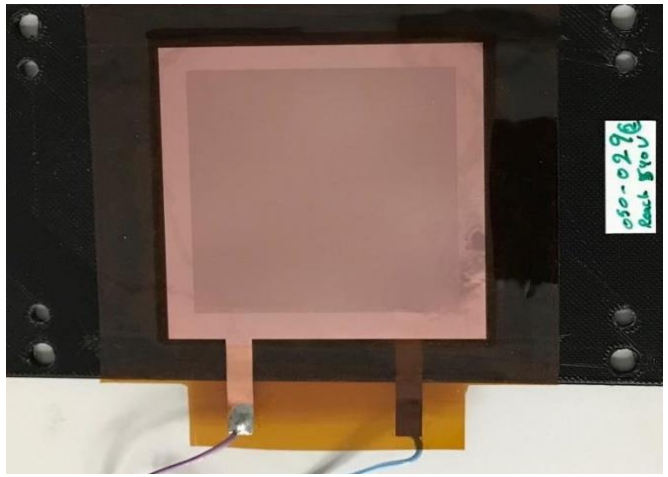


Electric field lines inside the GEM holes*

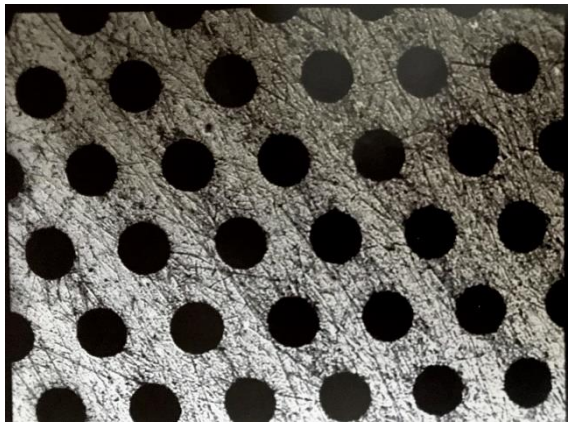
*F. Sauli, Nuclear Instruments and Methods in Physics Research A 805 (2016) 2-24

Diamond Like Carbon coated (DLC) GEM

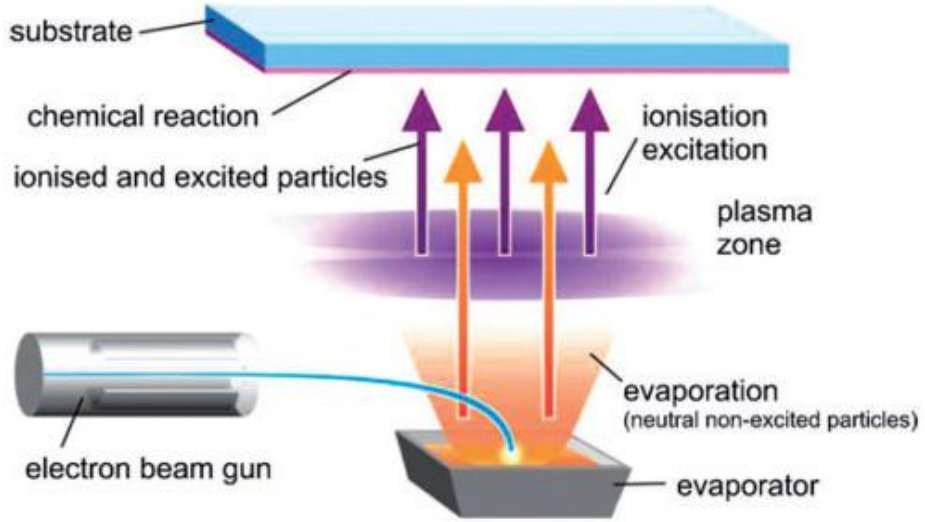
- **Purpose of this coating** is to reduce the **probability of discharge** and thus allowing us to **increase the GEM voltage** to **reach higher gain**
- **Diamond Like Carbon coated GEM**: **Both electrodes of GEM covered by a layer of diamond like carbon** with thickness of ≈ 0.1 µm
- Coating done by **Fraunhofer Institut für Oberflächentechnik** using **Plasma-assisted Chemical Vapor (PACVD) procedure.**
- Types of coatings: **SICON** (a-C:H:Si:O) & **SICAN** (a-C:H:Si), the **difference is the existence of oxygen in SICON coating.**



DLC Coated GEM



Microscopic picture for DLC coated GEM

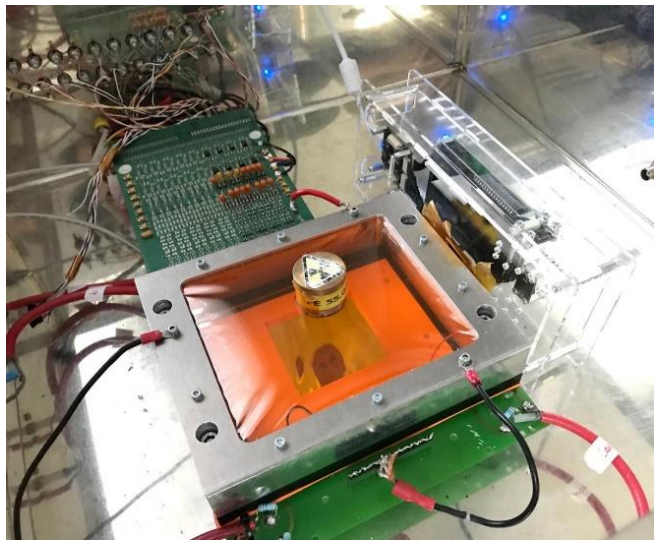


The principle of plasma-assisted electron beam evaporation*

*Daniela G Coblas, Aurelian Fatu, Abdelghani Maoui, Mohamed Hajjam, Manufacturing textured surfaces: State of art and recent developments, Proceedings of the Institution of Mechanical Engineers, Journal of Engineering Tribology, 2015

Lab of university of Siegen

- **Test Chamber**: small gas drift detector (120 mm×184 mm)
- **Purpose** : investigate the GEM's performance
- **Ar-CO_2** gas mixture **(80%-20%)** respectively
- **Fe^{55}** emits gamma with **5.89 keV**
- **Pad Readout** system coupled to very sensitive **preamplifier**.



The Test Chamber at University of Siegen

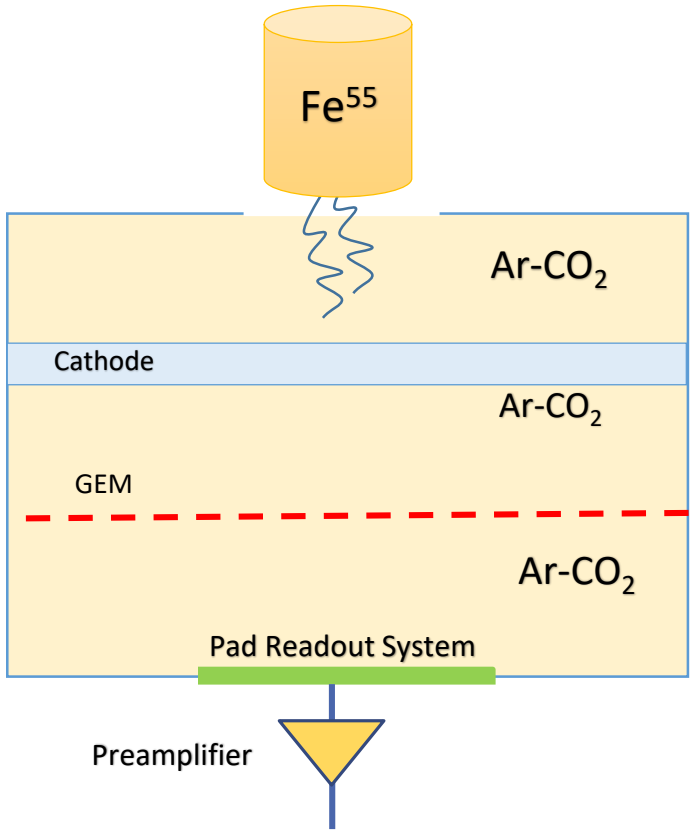


Illustration for the GEM inside the chamber

Measurements and Results

- GEM Voltage
  - **SICON**
    - Varied **voltages** between **(370 V – 540 V)**
    - **Sparks** observed for larger than **510 V**
    - **Breakdown voltage** is **(525 V - 545 V)**
    - **Safe voltage** is **510 V**
  - **SICAN**
    - Varied **voltages** between **(370 V – 480 V)**
    - **No sparks** observed below **480 V**
    - **Breakdown voltage ≥ 480 V**

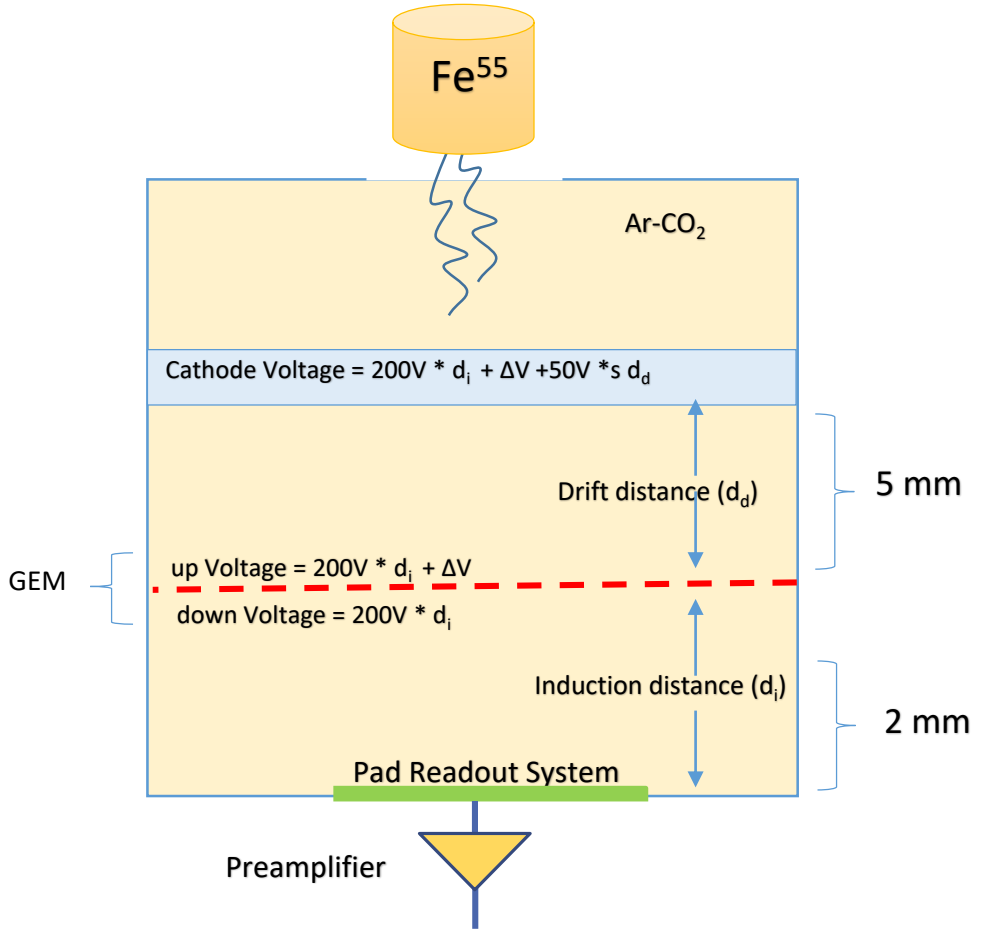


Illustration for the distances and voltages inside test chamber

DLC Coated GEM Gain Calculation

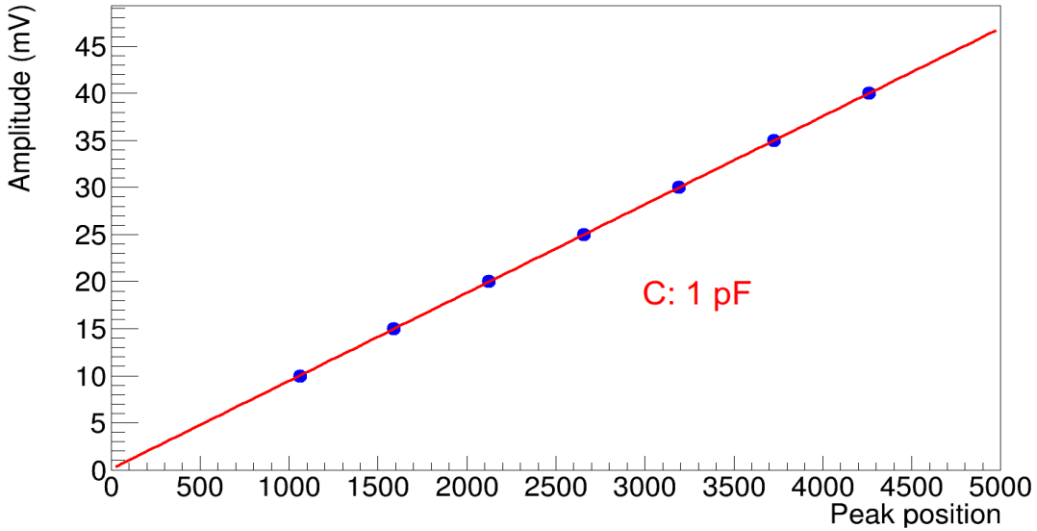
- **Gas Gain** given by the equation: $G_g = \frac{N_f}{N_i}$

  N_f : **number of electrons after amplification**

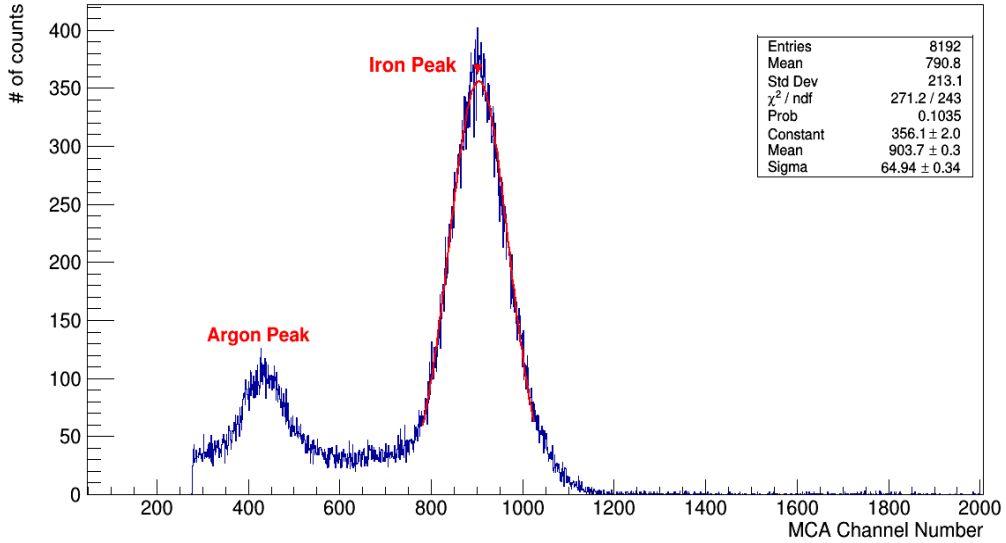
  N_i : **number of the initial electrons**

$$N_i = \underbrace{\frac{5900\ \text{eV}}{26\ \text{eV}} \times 0.80}_{\text{Ar}} + \underbrace{\frac{5900\ \text{eV}}{34\ \text{eV}} \times 0.20}_{CO_2} = 216\ \text{electron}$$

26 eV and 34 eV are average energy per ionization for Ar and CO_2 respectively.



Calibration fit with a pulse generator.*



Typical MCA spectrum of DLC GEM

- total charge after amplification is given by:

1. $Q = N_f \times e$; where eis the electron charge 1.6×10^{-19} C

2. $N_f = Q/e$

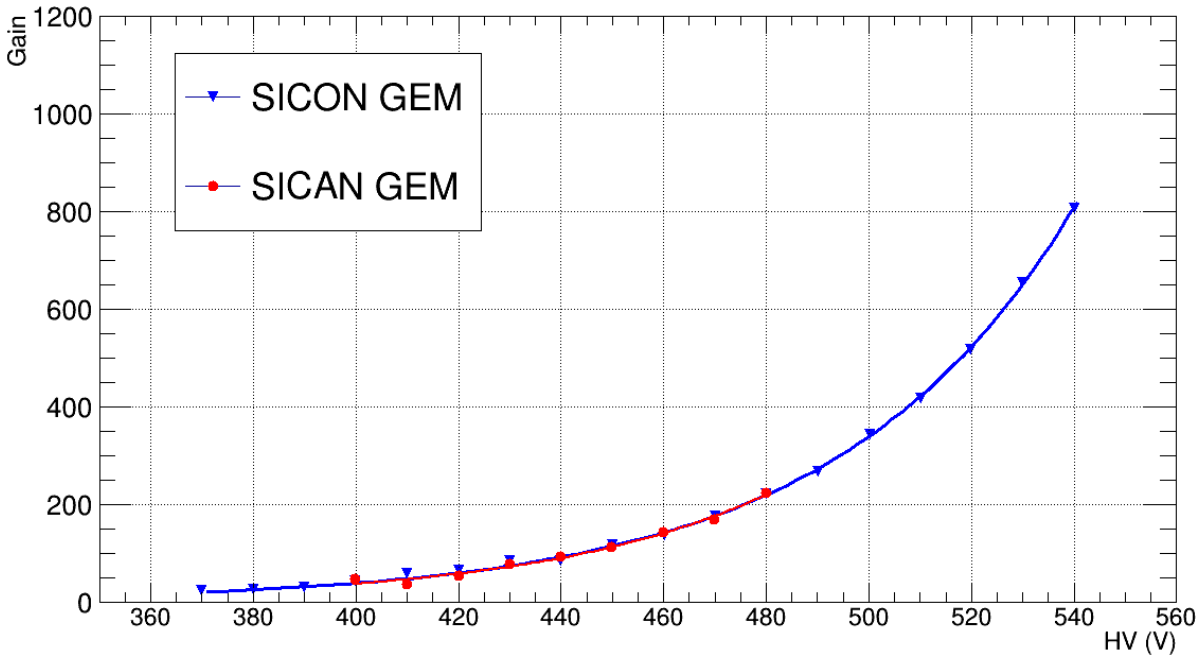
3. $Q=(P_0+P_1\times \text{Channel no.}) \times \text{Const.}$

4. Therefore, $G_g = \frac{(P_0+P_1\times \text{Channel no.}) \times \text{Const.}}{216 \times 1.6\times10^{-19}}$

*Done by Serhat Atay

DLC GEM Gain

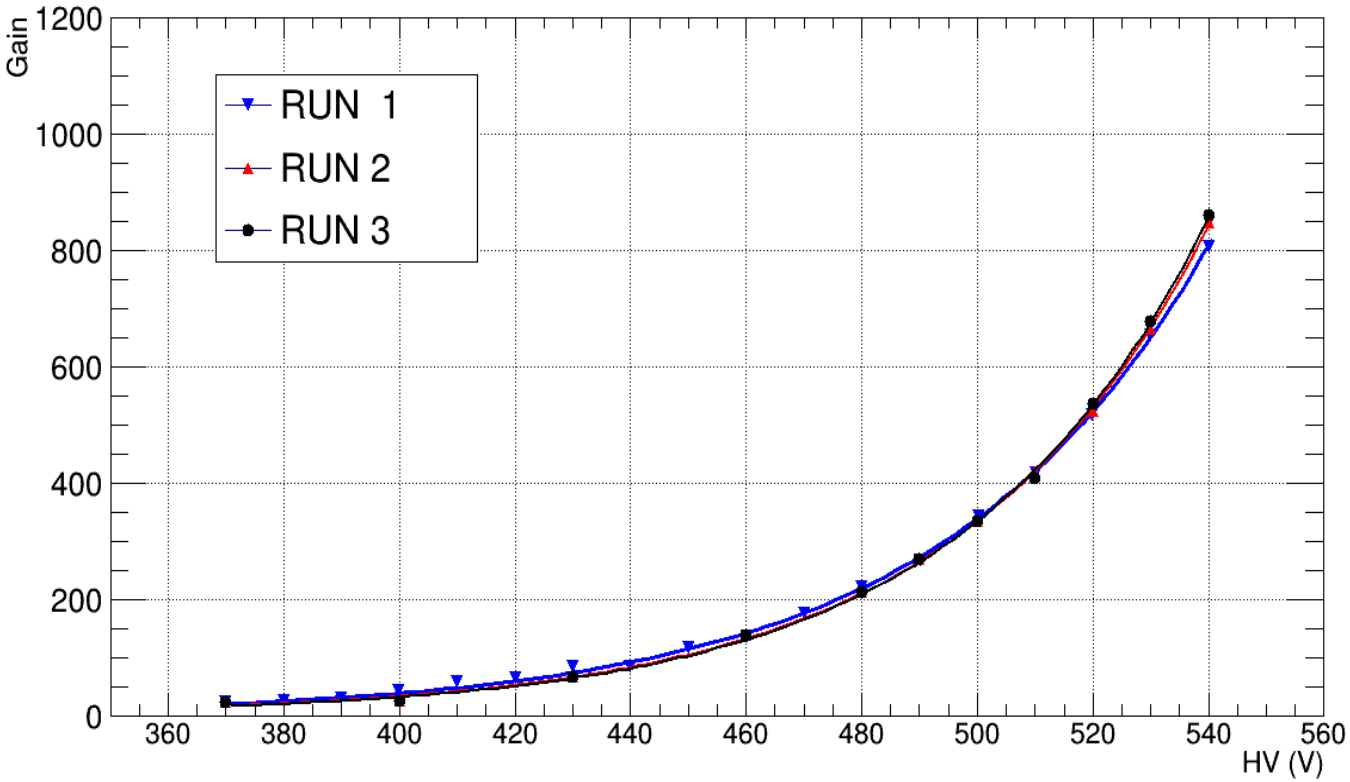
- **SICON** & **SICAN** GEM have almost the **same gain**
- **Maximum gain for SICAN ≈ 200 at 480 V**
- **SICON** GEM **gain ≈ 800** at **540 V**
- **SICON** GEM affected by several **sparks**, the maximum **voltage < 540 V**, therefor **gain < 800**
- **Safe** operating **voltage** for **SICON** GEM is **510 V**
- **because of the lower voltage, investigation on SICAN has been terminated!**



SICON Gain vs SICAN Gain

Gain stability for SICON

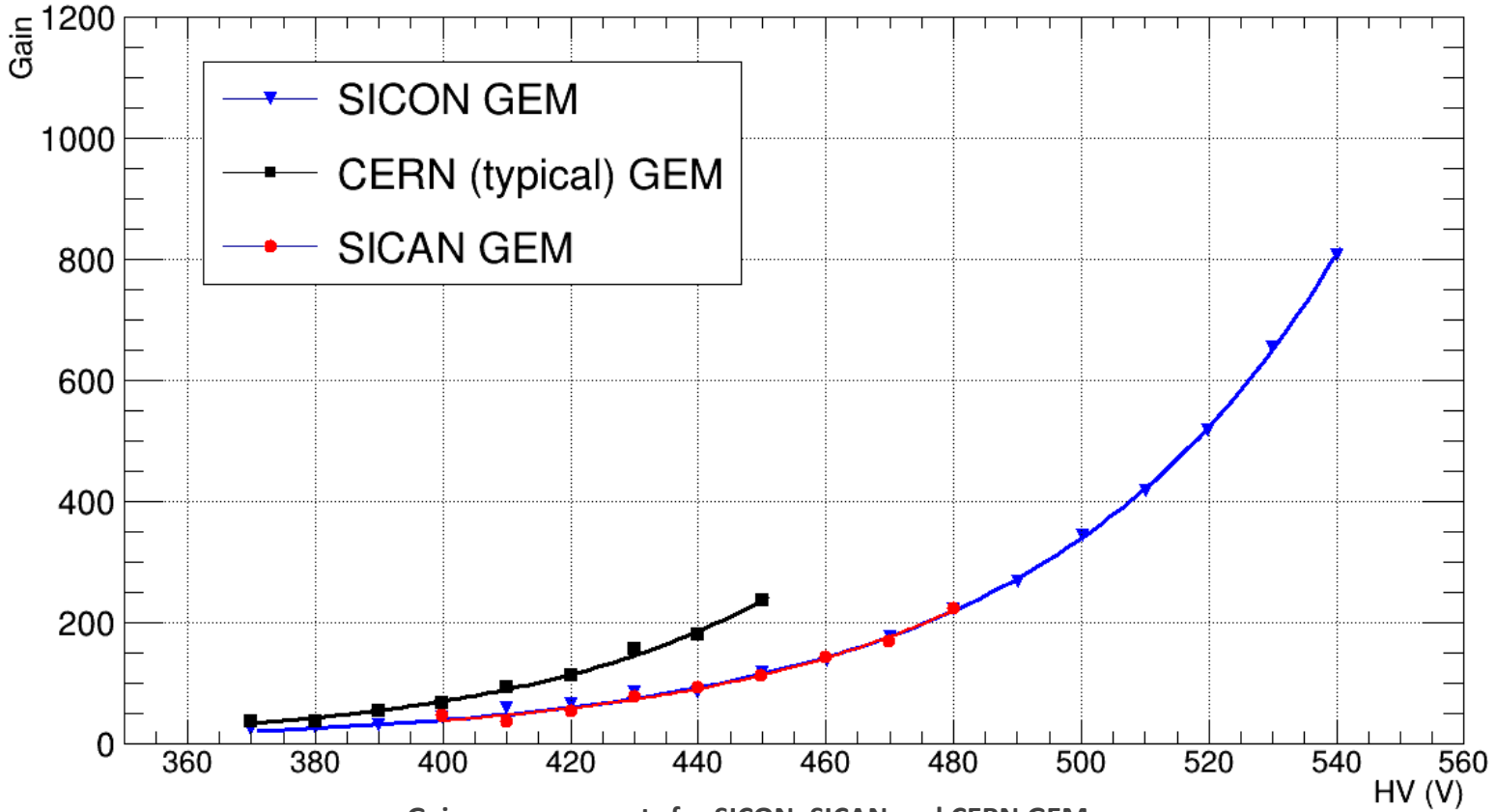
- Gain corrected to pressure 1 atm
- SICON GEM gain almost stable after 3 weeks
- every point is mean of 30 min measurements
- waiting time between runs is one week



3 week measurements with SICON coated GEM

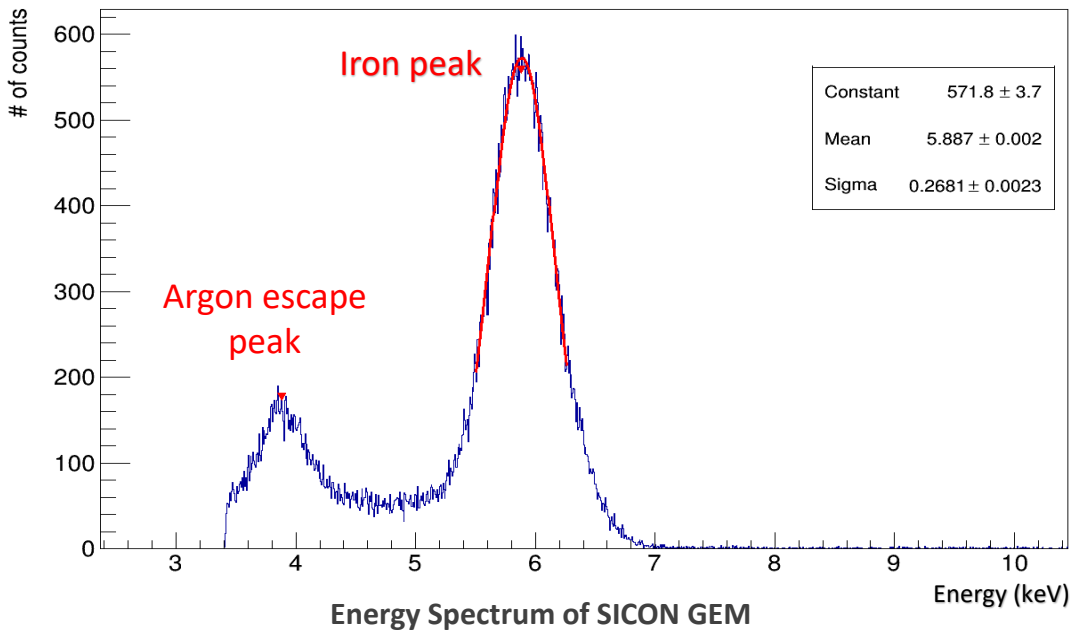
DLC Coated GEM vs CERN GEM (typical GEM)

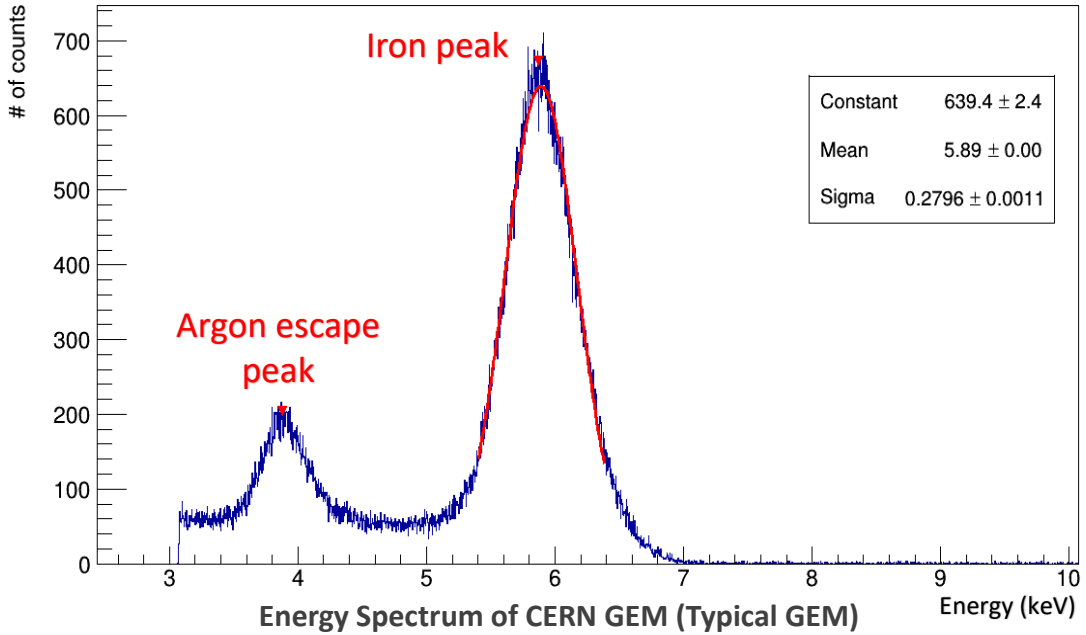
- Gain
  - **SICON** GEM reaches **higher Voltage** than CERN GEM, thus gives **higher Gain**



Gain measurements for SICON, SICAN and CERN GEM

Energy Resolution





- $Energy\ Resolution(R) = \frac{\text{FWHM}}{Mean}$

FWHM $= 2\sqrt{2\ln 2} \times \sigma$; **since the fit is Gaussian**

$$R_{(SICON)} = \frac{2.3548 \times 0.2681}{5.887} = \mathbf{0.10724}$$

$$R_{(CERN)} = \frac{2.3548 \times 0.2796}{5.89} = 0.1117$$

Conclusions

- The **goal** from Diamond Like Carbon Coated (**SICON**) **accomplished**
- **SICON** GEM reaches **540 V** with **gain = 800**
- **510 V** is the **safe operating voltage** for SICON with **gain = 400**
- **Energy resolution** for SICON GEM is **almost same** of typical GEM (CERN)
- **SICAN GEM** cannot reach higher voltages, so it is **neglected**.

Outlook

- Investigating SICON GEM gain at different drift distances.
- developing SICON coat to reach higher voltages.
- Investigating energy resolution using variant gamma source