Characteristics of a Diamond like Carbon Coated (DLC) GEM

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outline

- Introduction
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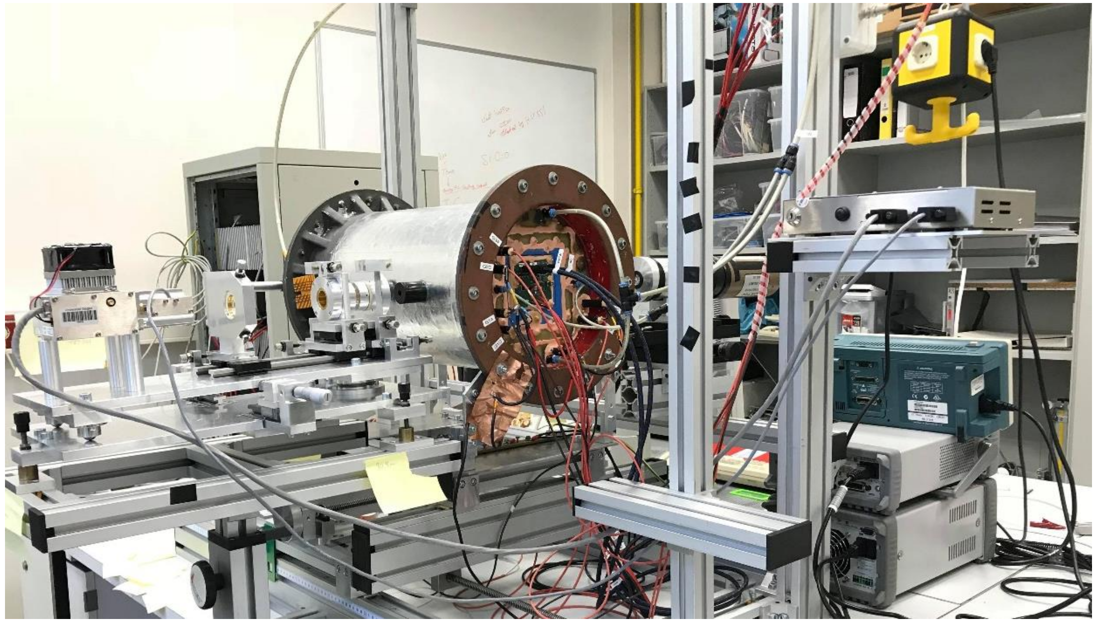
  - Gas electron multiplier (GEM)
  - Properties of diamond like carbon (DLC) coated GEM
  - Two types of DLC Coatings
- Lab in Siegen
  - Test Chamber
- Measurements and Results
  - voltages and sparks limitations
  - Gain at variants voltages
  - Energy resolution of DLC GEM
  - Developing SICON coat
- 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 potential to improve TPC performances when used as **amplification device**.

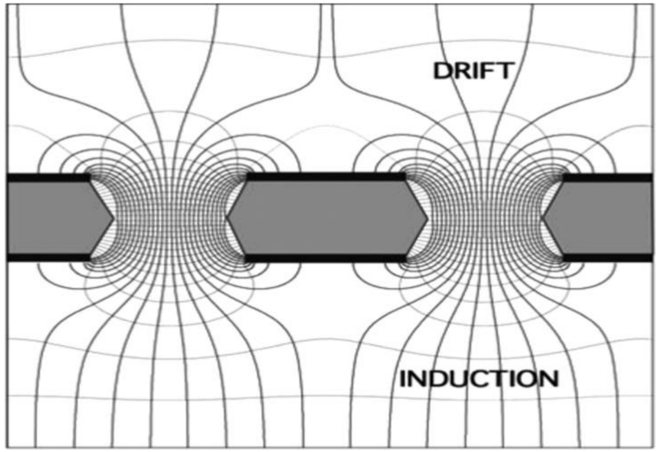


TPC prototype at university siegen Lab

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

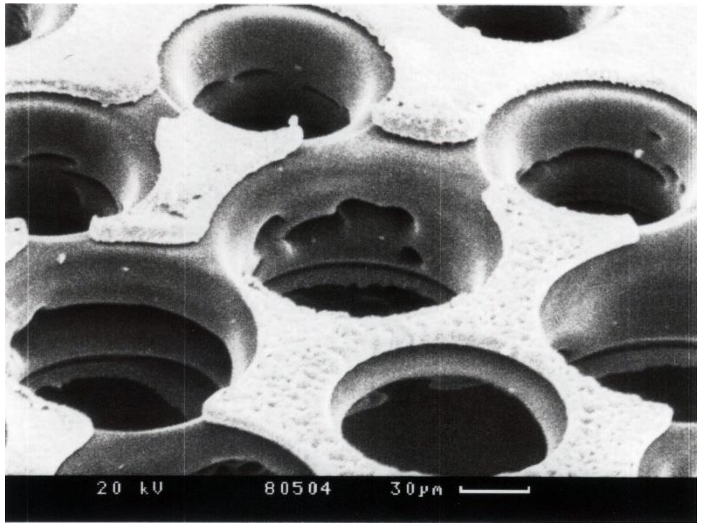
Gas electron multiplier (GEM)

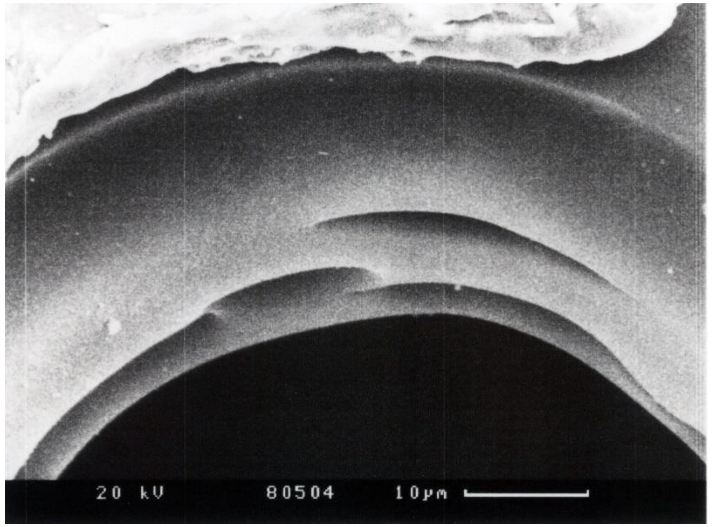
- Invented by F. Sauli at 1996 in CERN
- Consist of **two conductor** layers (copper) separated by an **insulator** (Kapton) with a high density of holes.
- High voltage applied between both conductors thus producing high electric field inside the holes.
- **Problem**: **limitation in gas gain due to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



Electric field lines inside the GEM holes*

Electric field within hole not well defined





Electron microscopic pictures for uncoated GEM with 50 µm thickness, holes diameter of 70 µm, pitch of 140 µm.

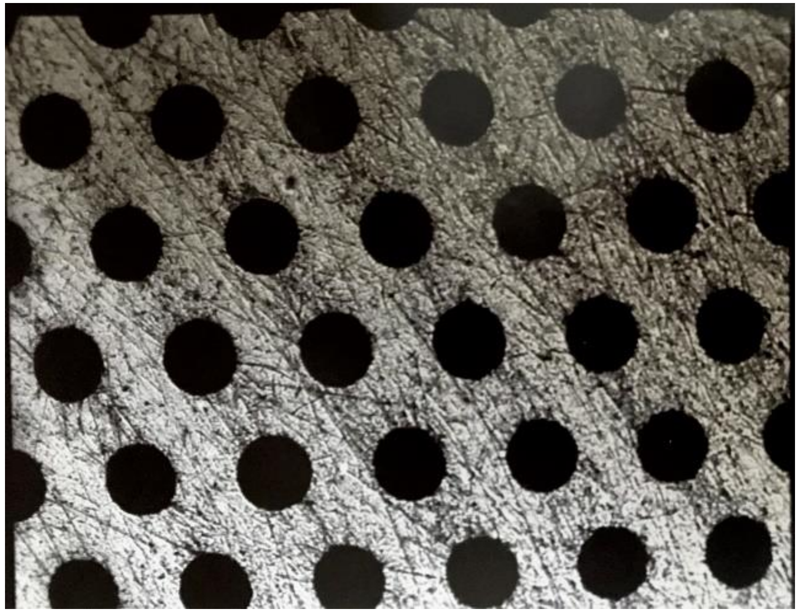
*F. Sauli, Nuclear Instruments and Methods in Physics Research A 805 (2016) 2-24

Diamond Like Carbon coated (DLC) GEM

- **Purpose of this coating** **to better define electric field within holes** by reduces 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 and Kapton inside holes covered by a layer of diamond like carbon with thickness of ≈ 50 - 300 nm**

- Coating done by **Fraunhofer-Institut für Schicht- und Oberflächentechnik** using **Plasma-assisted Chemical Vapor (PACVD) procedure.**



Microscopic picture for DLC coated GEM

UNIVERSITÄT SIEGEN

A Time Projection Chamber for a Future Linear Collider

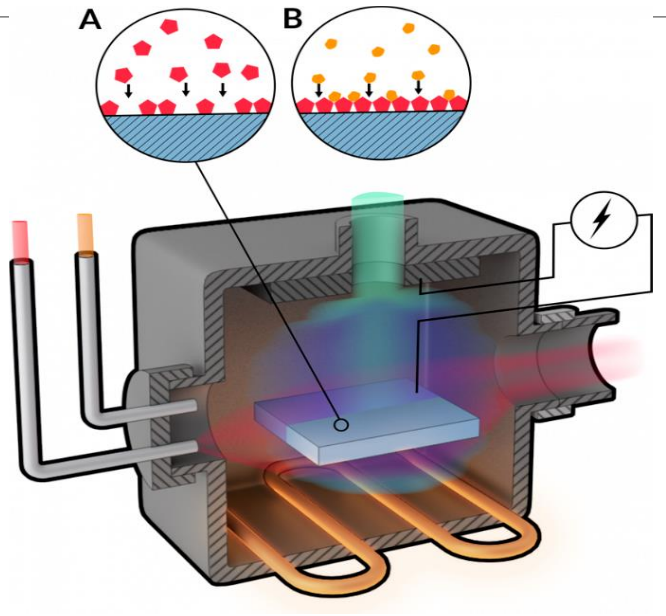
Types of coatings

SICON (a-C:H:Si:O) & SICAN (a-C:H:Si), the difference is the presence of oxygen in SICON coating.

A. One gas mixture is flushed, reacts, and coats the surface of the GEM supported by the plasma.

The remaining gas mixture is then flushed out again with a vacuum pump.

B. Then the second base mixture is flushed into the chamber which then reacts and builds on the previous coating



The principle of plasma-assisted electron beam evaporation*

Coatings names	Chemical composition	Element concentration/atom-%			
		C	H	Si	O
SICON	a-C:H:Si:O	41–43	22–23	23–24	10–11
SICAN	a-C:H:Si	63–65	21–24	12–13	–

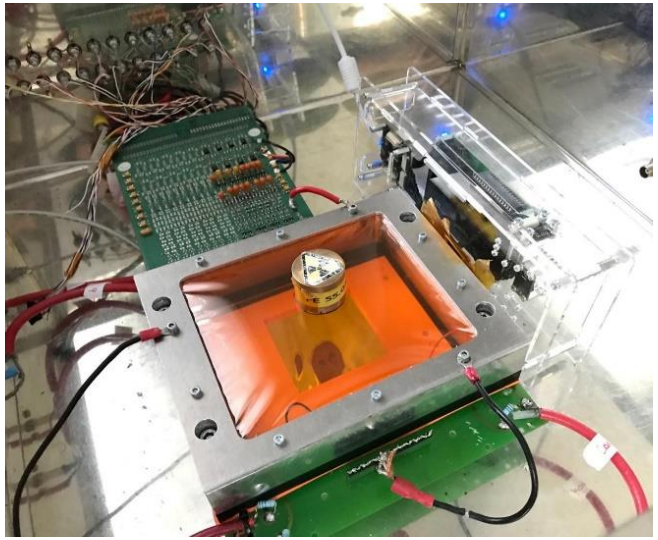
Typical element concentrations in SICON and SICAN coatings [1]

[1] K. Bewilogua et al. / Surface & Coatings Technology 206 (2011) 623–629

*https://www.manufacturingguide.com/en/plasma-assisted-chemical-vapor-deposition-pacvd

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

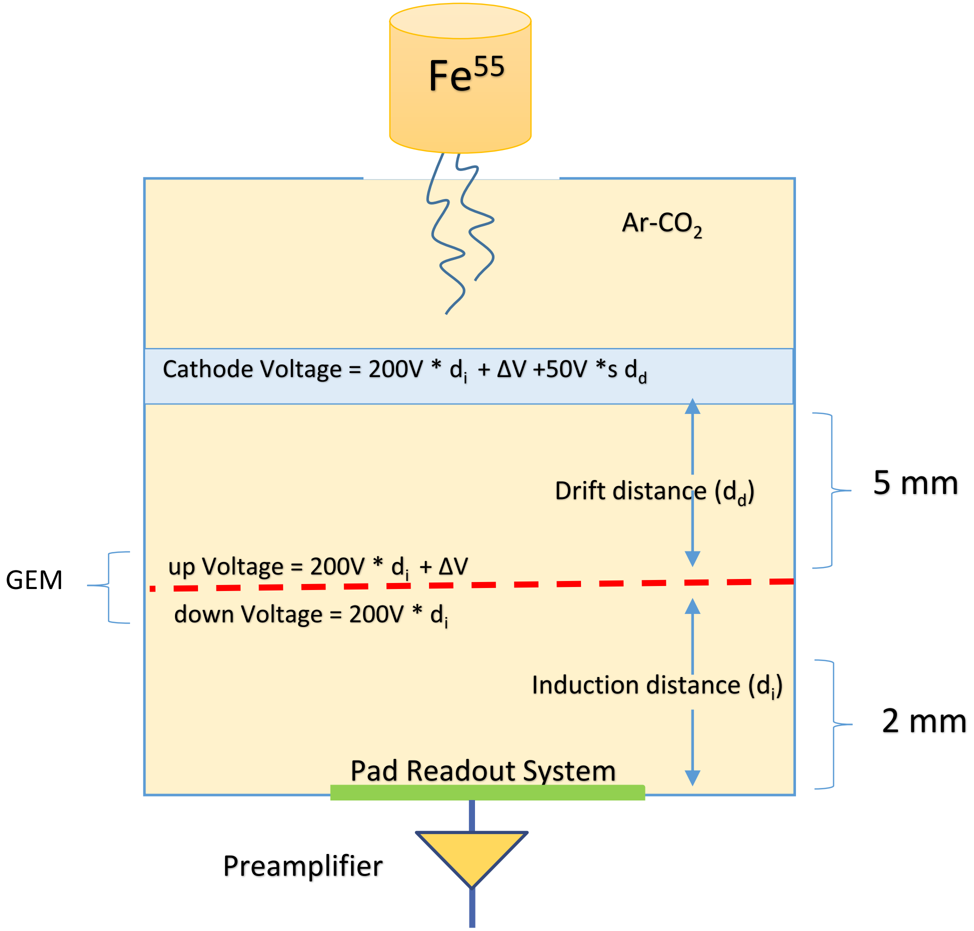


Illustration for the distances and voltages inside test chamber

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

Form the Fe^{55} source

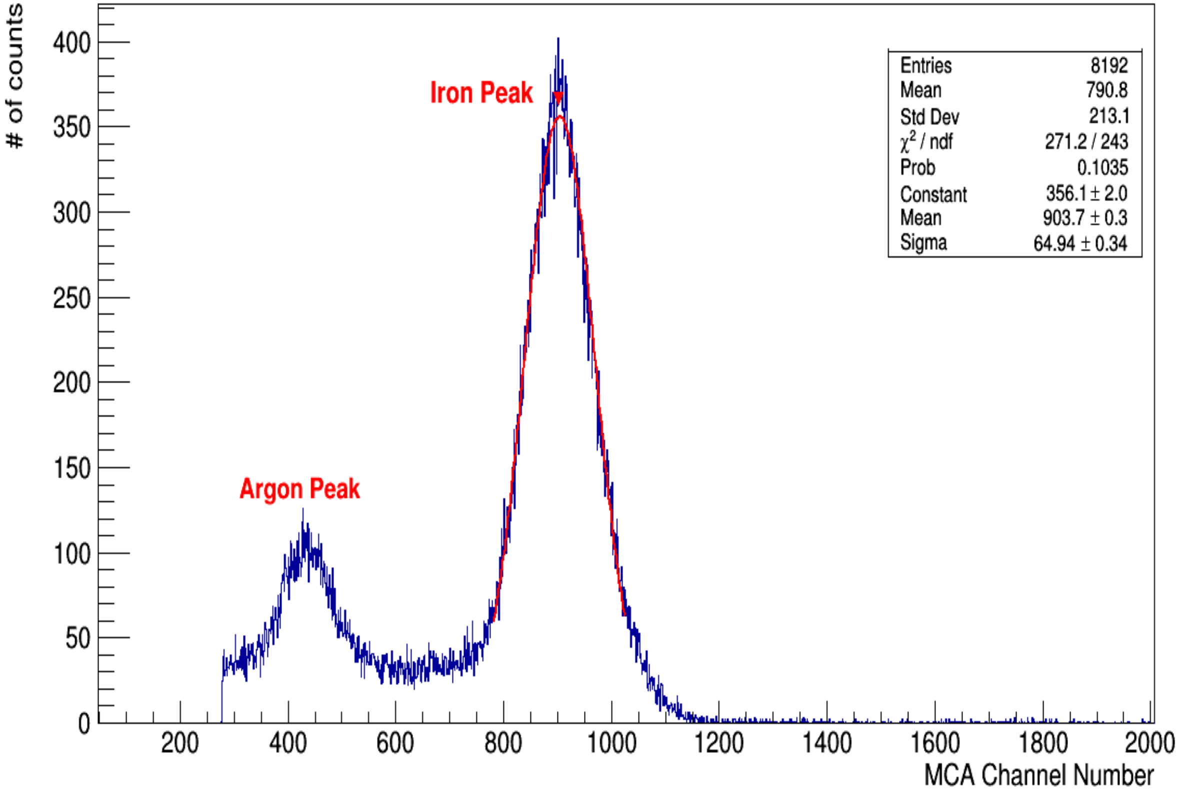
$$N_i = \underbrace{\frac{5900\ \text{eV}}{26\ \text{eV}} \times 0.80}_{Ar} + \underbrace{\frac{5900\ \text{eV}}{34\ \text{eV}} \times 0.20}_{CO_2} = 216\ \text{electron}$$

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

- total charge after amplification is given by:

1. $Q = N_f \times e$;

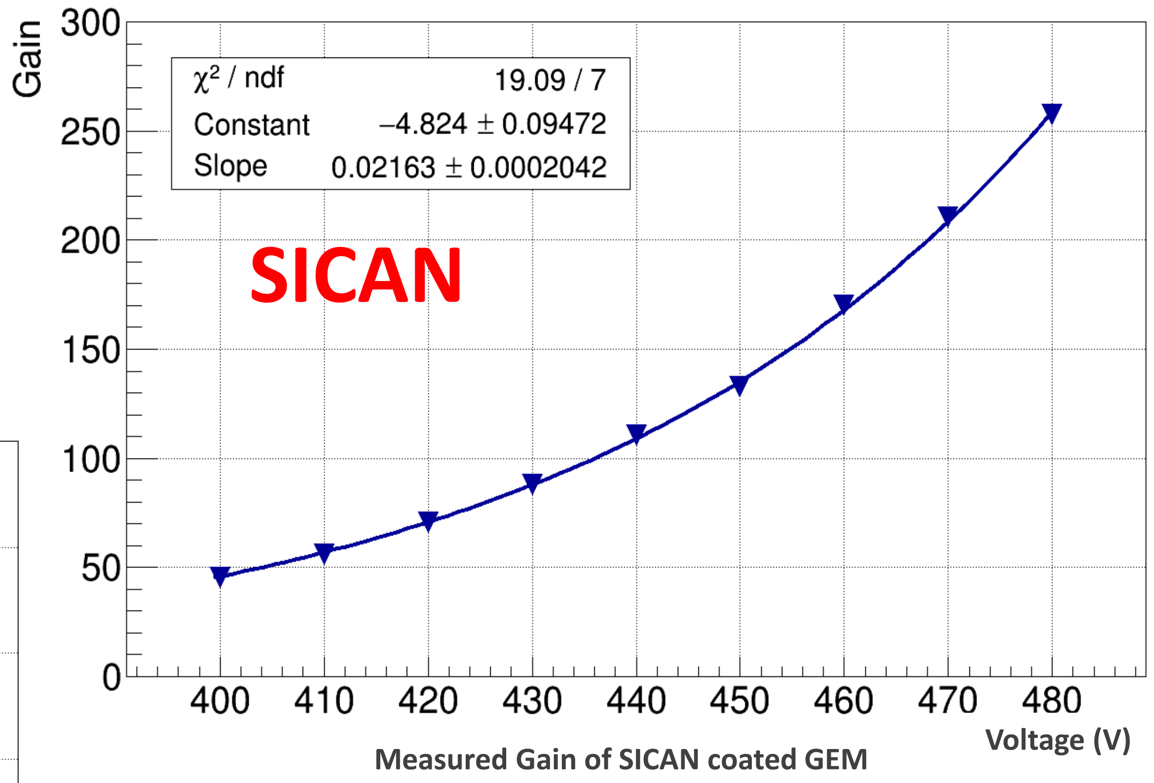
where **e** is the electron charge 1.6×10^{-19} C

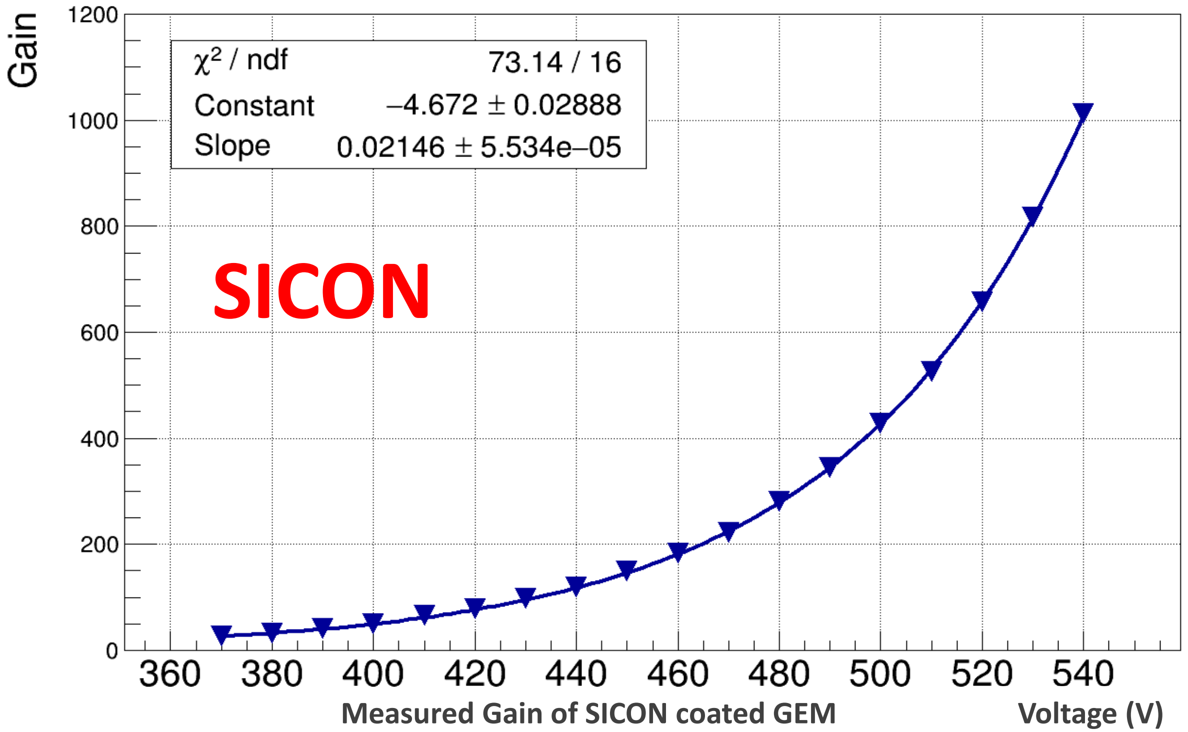


Typical MCA spectrum of DLC GEM

Measured Gain

- **SICAN ≈ 250 at 480 V**
- **SICON ≈ 1000 at 540 V**

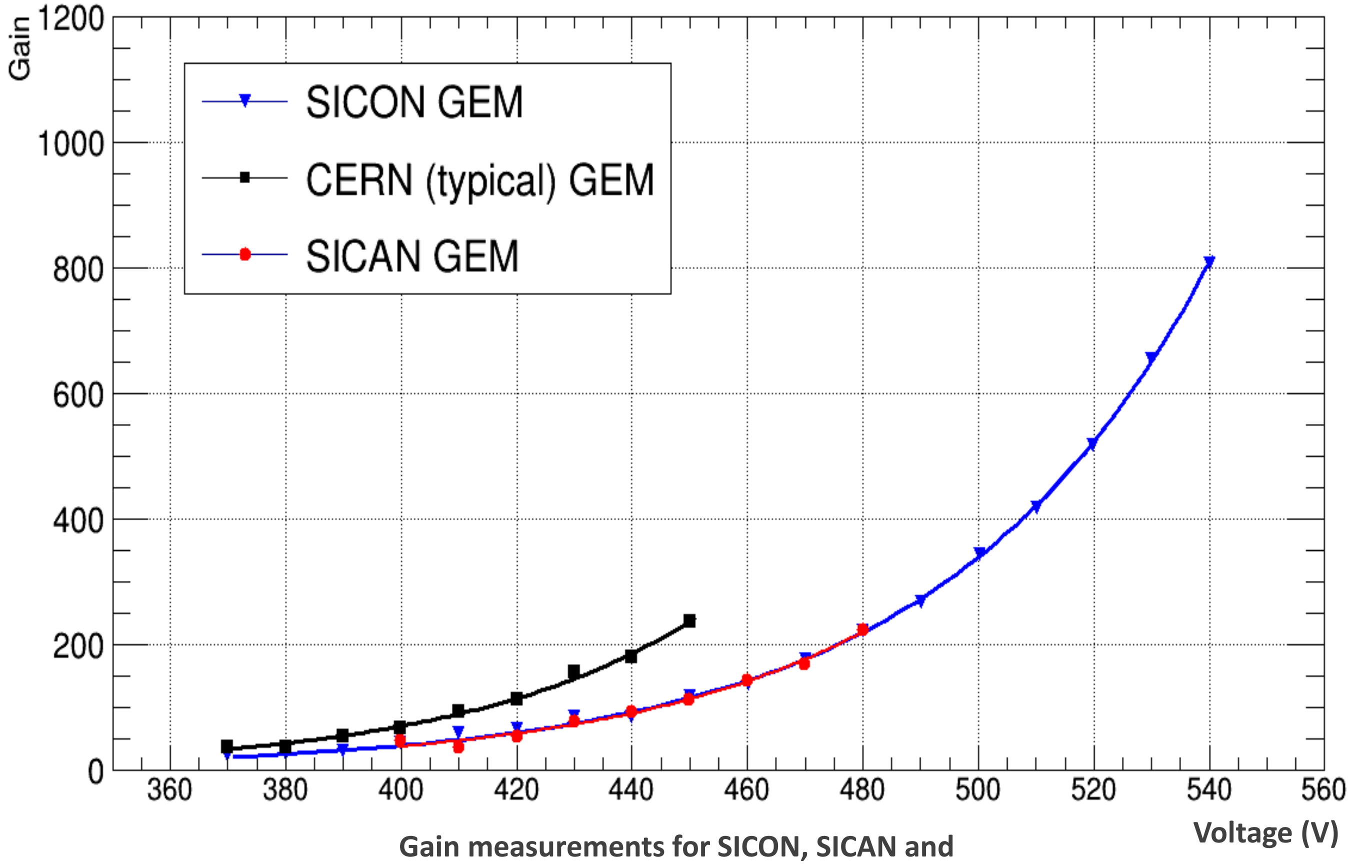




SICAN has lower breakdown voltage

DLC GEM Pressure Adjusted Gain

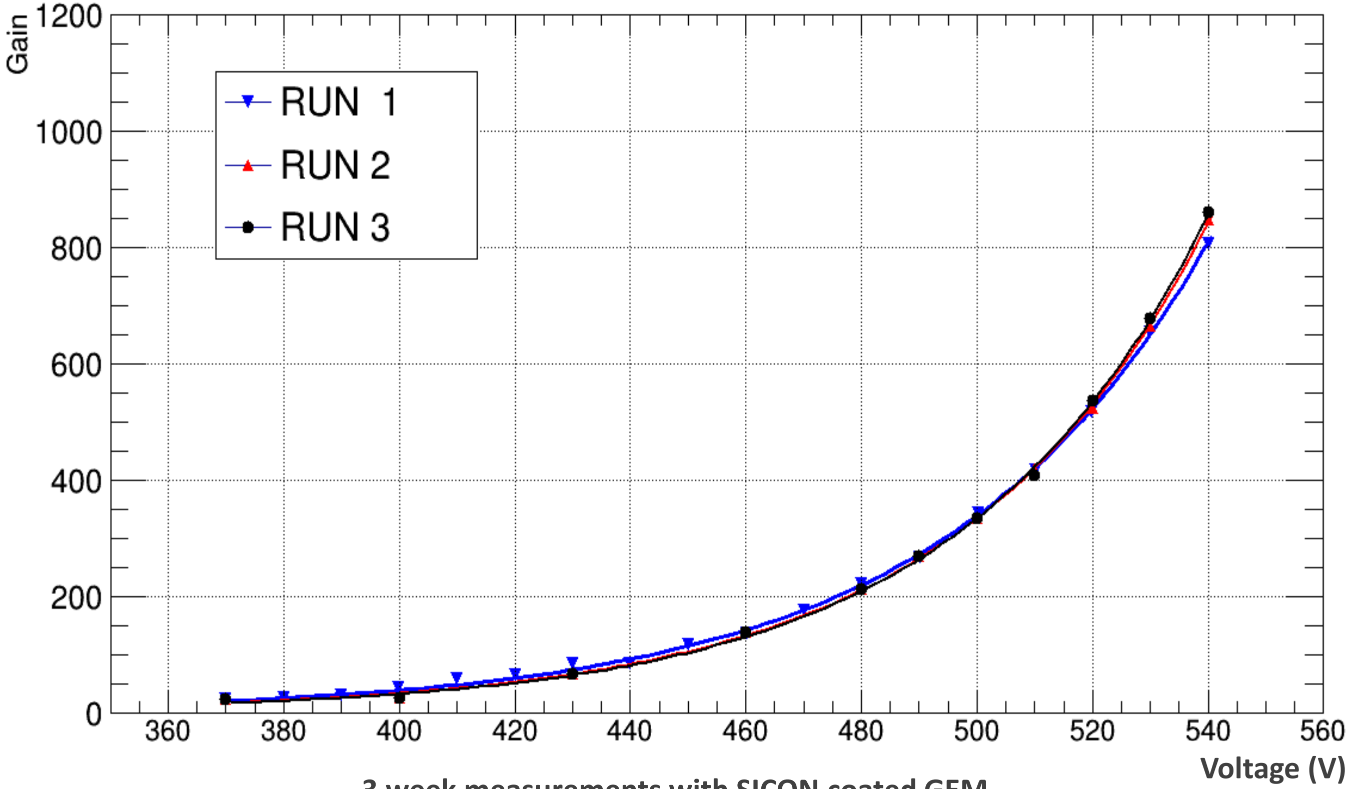
- Gas gain adjusted to 1 atm. For **purpose** of **comparing different GEMs or different measurements together**
- **SICON** & **SICAN** GEM have almost the **same gain at pressure 1 atm.**
- **Maximum gain for SICAN ≈ 200 at 480 V**
- **SICON** GEM **gain ≈ 800** at **540 V**
- **SICON** GEM affected 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!**



Gain measurements for SICON, SICAN and CERN GEM

Gain reproducibility for SICON

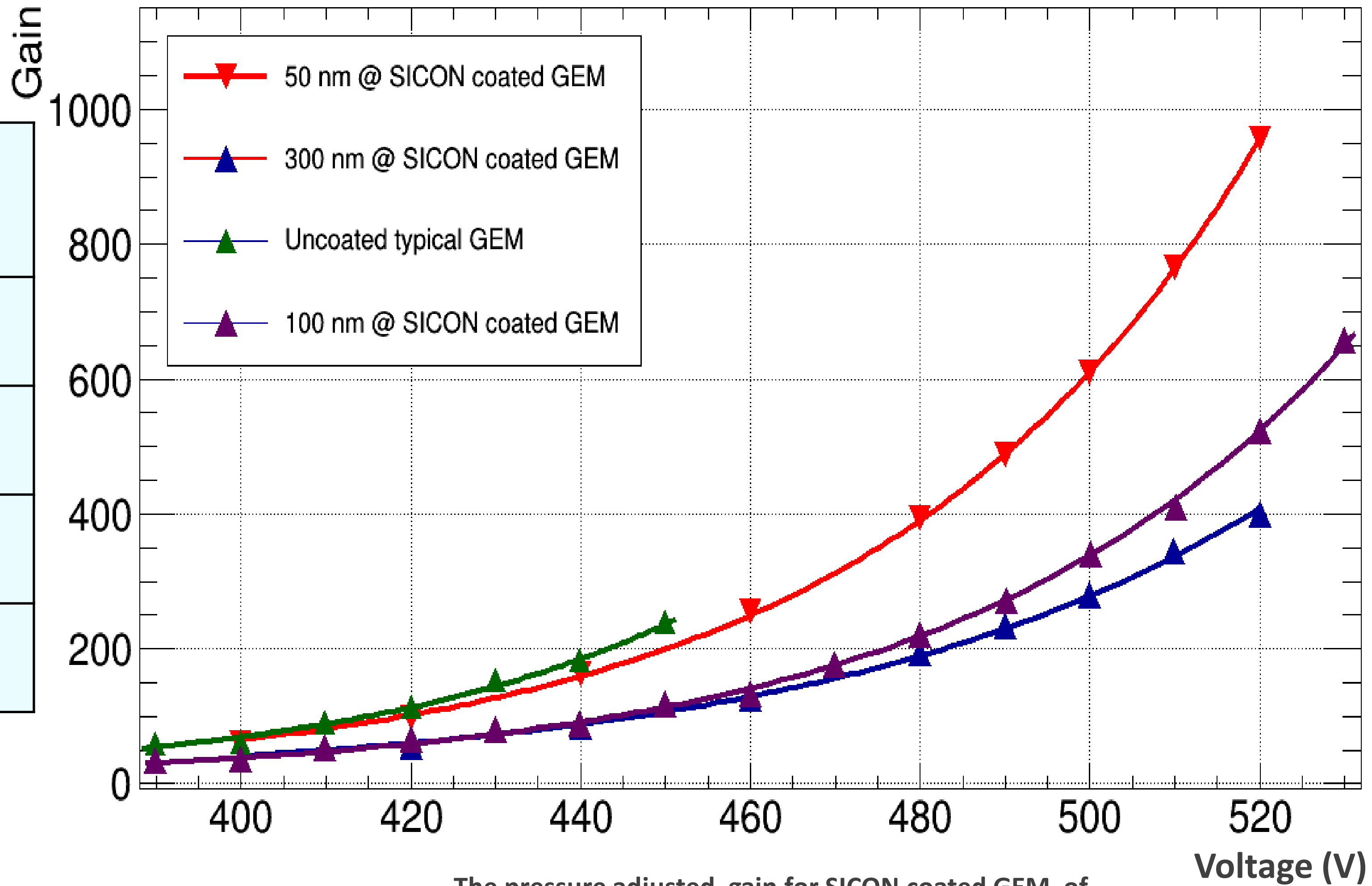
- **SICON GEM gain almost stable after 3 weeks**
- **Every point is mean of 30 min measurements**
- **Time between runs is one week**



3 week measurements with SICON coated GEM

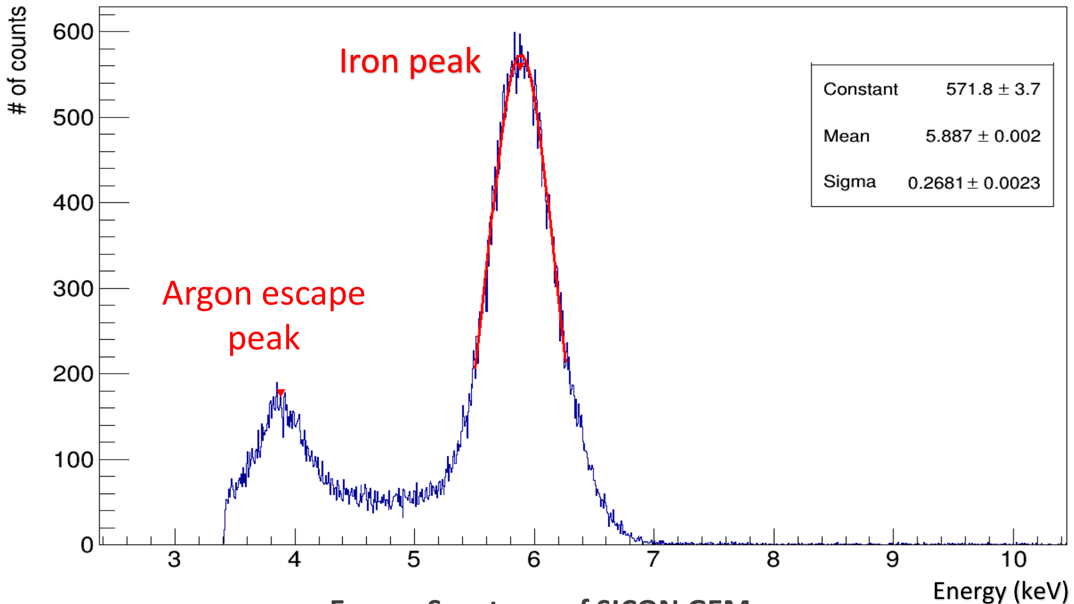
Developing SICON coating

GEMs types	Coating thickness	Gain	safe operating voltage	Break down Voltage
Uncoated GEM	n/a	≈ 250	450 V	> 450 V
SICON coated	300 nm	≈ 350	510 V	> 550 V
SICON coated	100 nm	≈ 400	510 V	> 540 V
SICON coated	50 nm	≈ 800	510 V	> 520 V

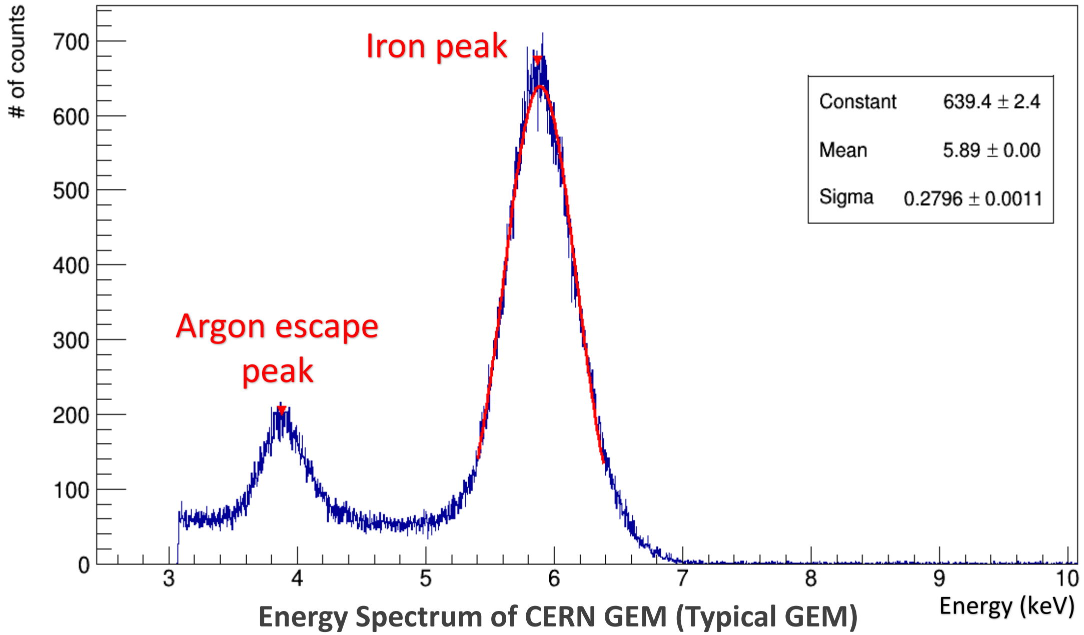


The pressure adjusted gain for SICON coated GEM of 50 nm, 100 nm, 300 nm, and uncoated GEM

Energy Resolution



Energy Spectrum of SICON GEM



Energy Spectrum of CERN GEM (Typical GEM)

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

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

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

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

Energy resolution for SICON GEM is slightly better than of typical GEM (CERN)

Conclusions

- **DLC** coated **GEMs** with coating **thickness** between **50** and **300 nm investigated**.
- **SICON** GEM reaches **520 V** with **gain = 900 at 50 nm**
- **510 V** is the **safe operating voltage** for all SICON coated GEMs
- **Energy resolution** for SICON GEM is **slightly better** than of typical GEM (CERN)
- **SICAN GEM** cannot reach higher voltages, so it is **neglected**.

Outlook

- Continue developing SICON coat to reach higher gain.
- Try to use SICON coated GEMs in another applications.
- Long term studies for SICON coated GEMs “Ageing studies”