Carbon Coated Gas Electron Multipliers for Time Projection Chamber Prototype

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UNIVERSITÄT SIEGEN

Experimental Particle Physics

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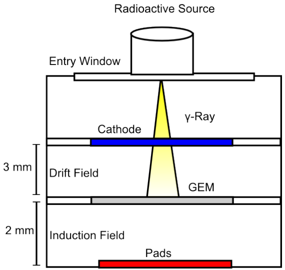
PHYSICS AT THE TERA SCALE
Helmholtz Alliance

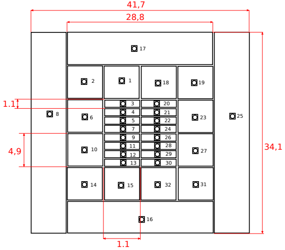
LCTPC

Outline

Small Test Chamber

- Motivation: Small drift distance → high drift fields for measurement of ion back drift
- Different pad sizes
- Used for testing GEMs before inserting into TPC prototype





Parameters of Small Chamber

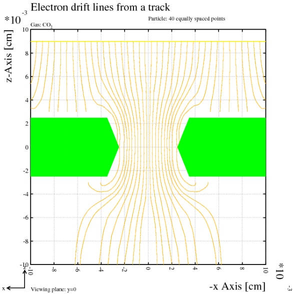
Parameters for data taking with small chamber:

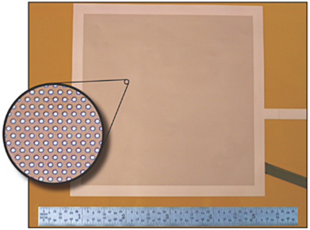
Active GEM area	$50 \times 50\,\mathrm{mm}^2$
Gas mixture	$ArCO_2$ 80:20
Drift field	50 V/mm
Induction field	300 V/mm
GEM voltage	variable
Drift length	5.4 mm
Distance Pads – GEM	2.4 mm
Ionization source	Fe-55 (γ energy 5.1 keV)

Gas Electron Multipliers

- Standard GEMs from CERN: Two copper layers divided by a thin plastic layer (Kapton) containing small holes
- Potential difference between both sides
- Electric field lines concentrated in middle of hole and → Acceleration of electrons and creation of electron avalanches
- Typical amplification factors around 1000
- Exponential relation between GEM voltage and gas gain:

$$G = \alpha \exp(\beta U_{\mathrm{GEM}})$$



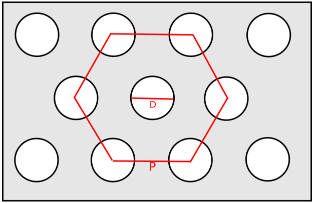


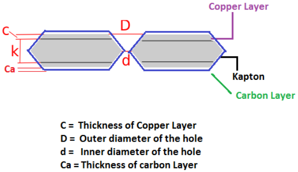
Carbon Coated GEMs

Small Test Chamber
Gas Electron Multipliers
Carbon Coated GEMs
Analysis with TPC Prototype
Summary & Outlook

Geometrical Details of GEMs

- Geometry of standard CERN GEMs
  - Thickness of kapton: $k = 50\,\mu$m
  - Thickness of copper: $c = 5\,\mu$m
  - Pitch: $P = 140\,\mu$m
  - Outer hole diameter $D = 70\,\mu$m
  - Inner hole diameter $d = 50\,\mu$m
- Coating GEMs with carbon (approx. $0.1\,\mu$m) at Fraunhofer Institut für Schicht- und Oberflächentechnik



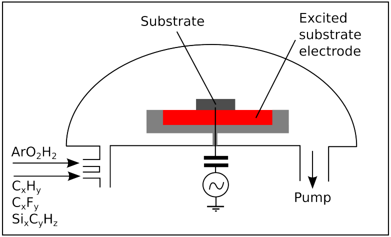


Motivation for Carbon Coating

- Main limitation of gas gain is possibility of discharges between GEM surfaces
- Kapton layer between GEM surfaces can also charge up $\rightarrow$ leading to inhomogeneous electric fields inside TPC
- Reduction of these effects possible with thin layer of conductive material (carbon) $\rightarrow$ electric connection with high resisitivity between both GEM sides
- Leading to higher gain stability in time and space
- Also minimizing effect of varying energy resolution throughout the GEM surface
- Two possible carbon coatings: SICON (a-C:H:Si:O) and SICAN (a-C:H:Si) GEM surface

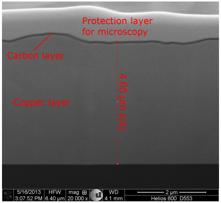
Creation of Carbon Coating

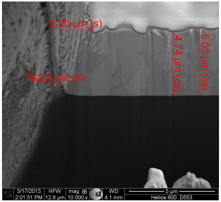
- Used method for coating: Plasma-Assisted Chemical Vapour Deposition (PACVD)
- Probe is placed inside chamber
- Pulsed electric field (frequency 30...300 kHz) between probe and chamber applied → Ionisation of gas atoms with electrons from probe and deposition of gas ions on probe surface



Analysis with Mass Spectrometer

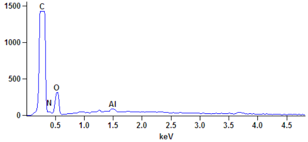
Group of Surface and Materials Technology (University of Siegen)



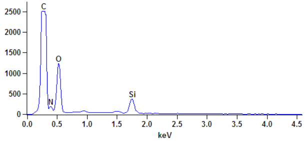


Institute for High Frequency and Quantum Electronics(University of Siegen)

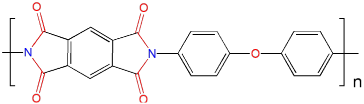
GEM hole without carbon coating



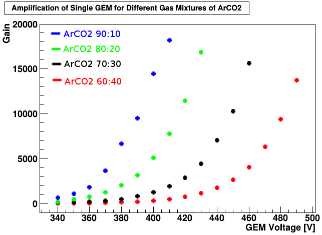
GEM hole with carbon coating

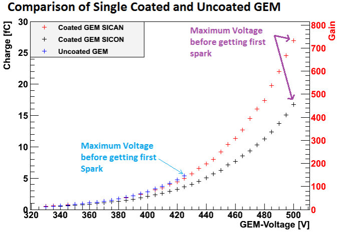


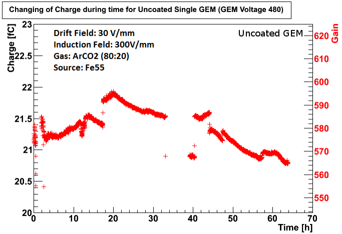
Structure of kapton

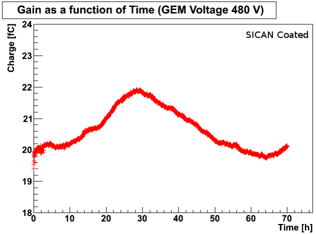


Results for Carbon Coated GEMs









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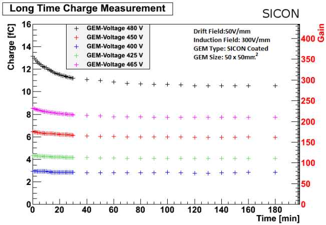
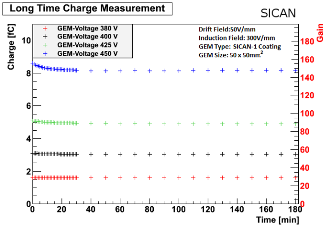
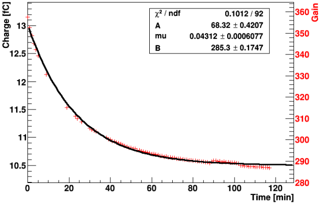
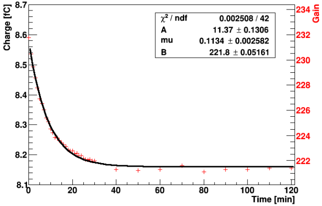




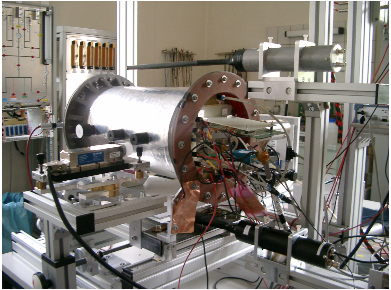
Fit function: $\Delta G(t) = A\exp(-\mu t) + B$

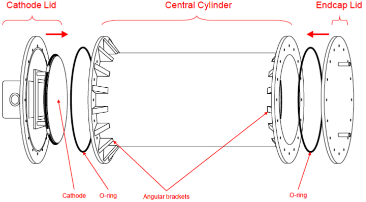


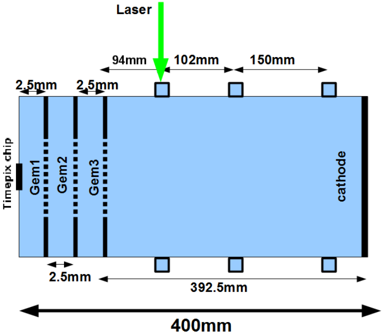


TPC Prototype

- Diameter: 240 mm
- Conducting outer material
- 3 entry holes for laser and beta-ray-source
- Two transfer fields and one induction field

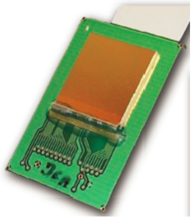


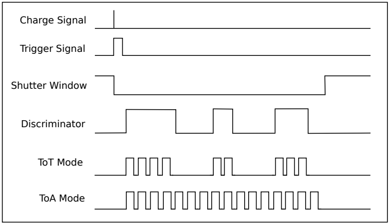




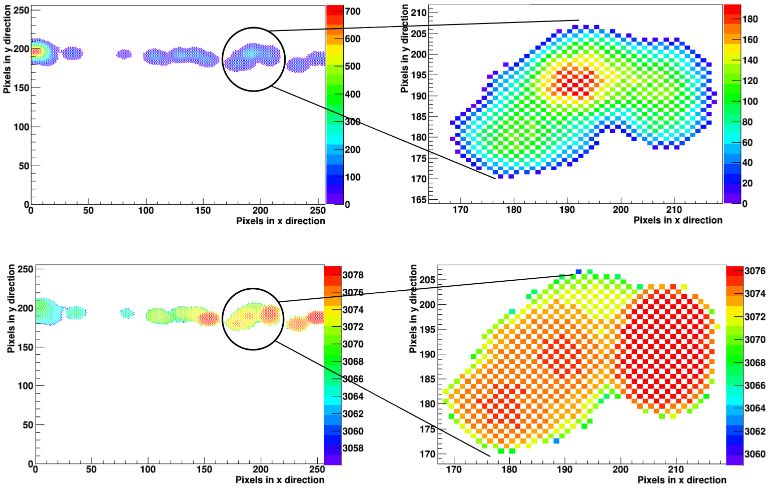
Timepix Chip

- 256×256 pixels
- Pixelsize: $55 \times 55\ \mu m^2$
- Active area: $1.4 \times 1.4\ cm^2$
- Record either charge or time
- Using only one threshold
- Two important pixel modes:
  - Time-Over-Threshold (ToT): Information of deposited charge
  - Time-Over-Amplitude (ToA): Information of drift time

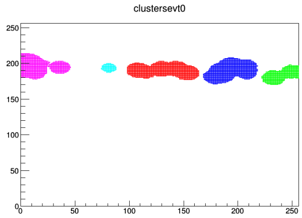


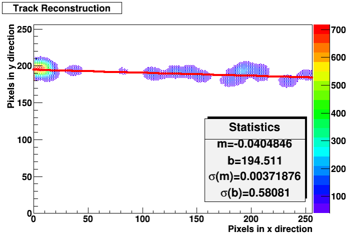


Example for ToT (up) and ToA (down) pixels:

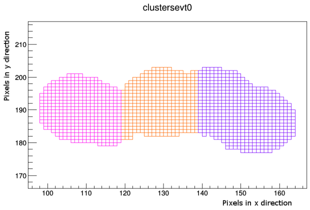


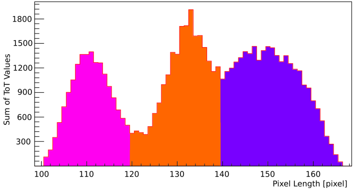
Track reconstruction and cluster fining:





Cluster Separation:





Measuring Diffusion Coefficient

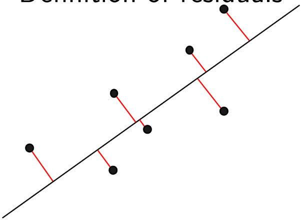
- Fit function for diffusion coefficient:

$$\sigma = \sqrt{\sigma_0^2 + D^2 z}$$

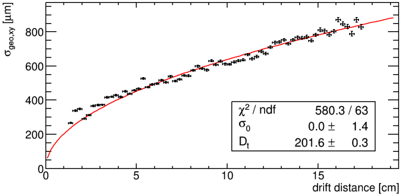
- Linear regression to find residual σ_N for data point N and σ_{N-1} with ignoring point N
- Exact value σ equal to geometric mean

$$\sigma = \sqrt{\sigma_N \cdot \sigma_{N-1}}$$

Definition of residuals



Transversal diffusion coefficient



- Carbon Coated GEMs successfully tested in TPC prototype (3 GEMs) and small test chamber (1 and 2 GEMs)
- Spark reduction at higher voltages with carbon coated GEMs experimentally proved.
- Gain stability increased with diamond like carbon coating
- Other coatings have to be tested to increase performance
- Atmospheric effects (changes of temperature and pressure) have to be investigated

Thank you very much for your attention!

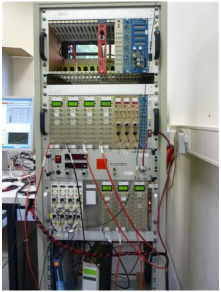
Backup Slides

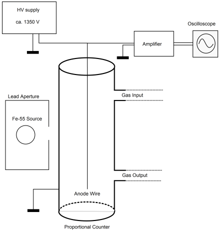
High Voltage System:

- 7 power supplies: one supply for for upper and lower side of each GEM (maximum 3 GEMs) and one for cathode
- 7 current meters for current check

Gas System:

- Two tasks: gas mixing and gas monitoring
- Gas monitor works like proportional counter
- Gas mixing possible for different combinations





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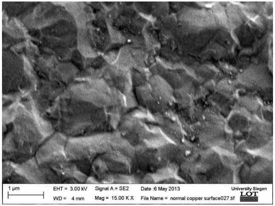
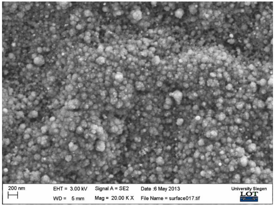
Summary & Outlook

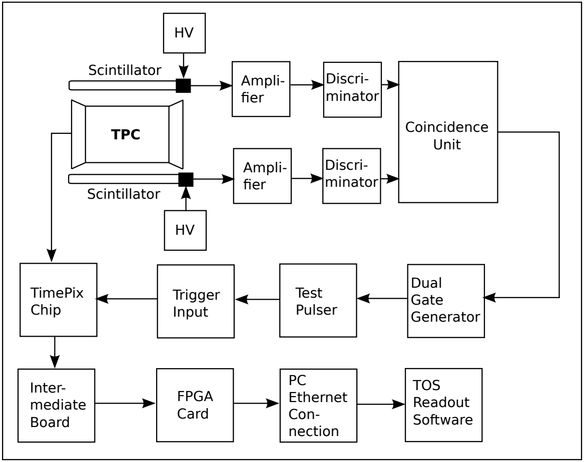
Creation of Carbon Coating

- Production made by *Fraunhofer Institut für Schicht- und Oberflächentechnik*
- Used method: Plasma-Assisted Chemical Vapour Deposition (PACVD) for Diomond Like Carbon (DLC):
  - Probe is connected to a high potential inside a gas chamber
  - Emitted electrons interact with surrounding gas atoms
  - Positively charged ions stuck on probe
- Two possible carbon coatings: SICON (a-C:H:Si:O) and SICAN (a-C:H:Si)





Hodoscope for Cosmic Muons



Parameters for data taking with cosmic muons:

Type of GEMs:	Carbon Coated GEMs
Gas mixture:	Argon-CO_2 80:20
GEM voltages:	420 V (GEM 1) 410 V (GEM 2) 400 V (GEM 3)
Drift field:	15.82 V/mm
Induction field:	300 V/mm
Transfer field 1:	200 V/mm
Transfer field 2:	200 V/mm
Outside temperature:	22° C
Pressure:	Normal atmospheric pressure
Distance Timepix chip – GEM 1:	2 mm
Distance GEM 1 – GEM 2:	1 mm
Distance GEM 2 – GEM 3:	1 mm
Drift distance:	290 mm
Ionisation Source:	Laser (for measuring drift velocity) Cosmic Muons (for data taking)
Laser properties:	Wave length: 266 nm Pulse frequency: variable between 1 Hz and 2.5 kHz Pulse energy: 10 μJ Area of laser beam: 0.85 mm^2
Clock frequency:	40 MHz
Shutter window::	variable

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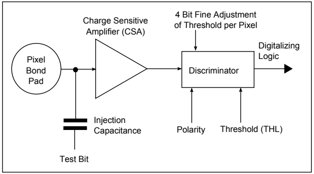
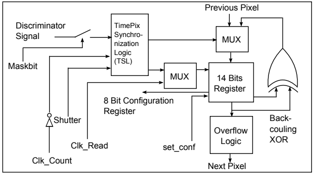
- Every pixel contains full readout system
- Electronics divided into analogue and digital part
- Analog part amplifies signal and converts it into a two level discriminator signal (high potential 3.3 V or ground potential) for signals above a global threshold (THL)
- Digital part consists of logic gates for incrementing a 14 bit register depending on the mode of the pixel cell





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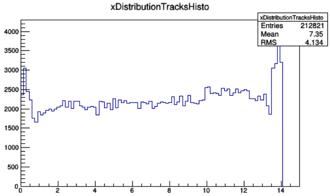
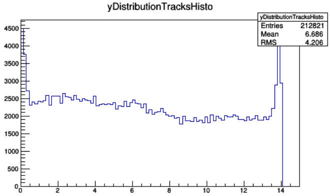
x- and y-distribution:





z-distribution: