GEM Simulation Studies (FLC)

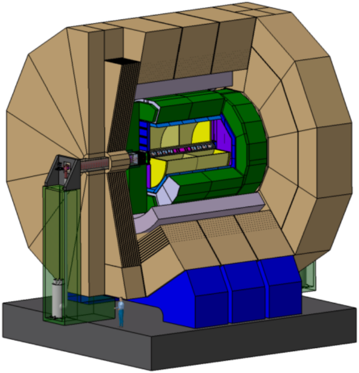
Constanze Hasterok, Technische Universität Dresden, Germany
Supervisor: Klaus Zenker

07/09/2011

Table of contents

International Large Detector

- Vertex detector around the beam axis
- Yellow: Time Projection Chamber (TPC)
- Blue: ECAL
- Green: HCAL
- Violet: Magnet coil and cryostat
- Brown: Muon detector



Time Projection Chamber

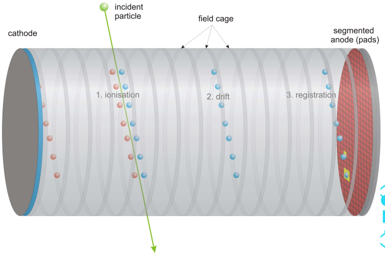
Measurement of charged particle trajectories in 3D and $\frac{dE}{dx}$

- Signal amplification with GEMs
- Segmentation of the anode → coordinates in x and y

$$z = v_D \cdot (t_1 - t_0)$$

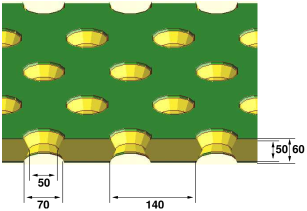
v_D... Drift velocity of e^-
t_1... Arrival time at the anode
t_0... Time of particle passage

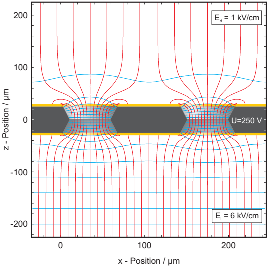
$L = 4.3$m
$\o = 3.6$m



Gas Electron Multipliers (GEMs)

- Setup: Kapton foil (50μm) enclosed by two copper layers (5μm), double conical holes
- GEM voltage: 100 V ⇔ $15\text{kV}/\text{cm}$
- Typical amplification up to $\sim 10^3$
- GEM stack: To achieve amplifications of $\sim 10^4$ with low GEM voltage (more stable)





Amplification Paramters

gain

$$\text{Gain} = \frac{\text{Number of produced electrons}}{\text{Number of initial electrons}}$$

Ion-Backdrift

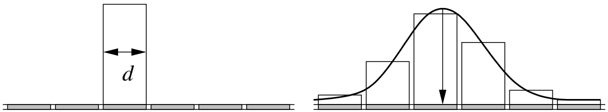
$$\text{Ion-Backdrift} = \frac{\text{Number of ions entering drift volume}}{\text{Number of produced ions}}$$

Electron-Transparency

$$C = \frac{\text{Number of collected electrons}}{\text{Number of electrons in drift volume}}$$

Advantages of GEM stacks

- Many free parameters available (GEM voltages, transfer fields...)
- Good intrinsic ion feedback suppression
- Low discharge probability
- Wide signal on the anode (good for pad-readout)



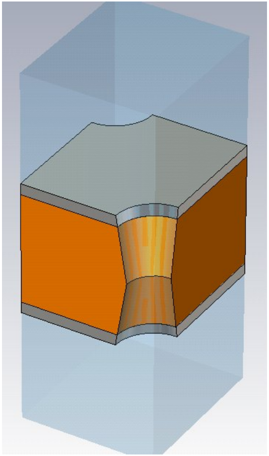
Charge-sharing for a good spatial resolution using pad-readout

Simulation with Garfield

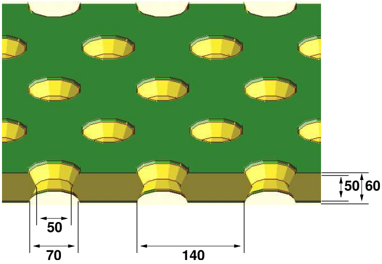
- Simulation of detectors which use gas and semi-conductors as sensitive medium
- Propagation and interactions of electrons, ions and photons
- Input: Potential (simulated by FEM programmes e.g ANSYS, CST)
- Output e.g.
    - drift lines
    - Visualtization of electric field
    - Number of ions/electrons produced in avalanches ...

Approach

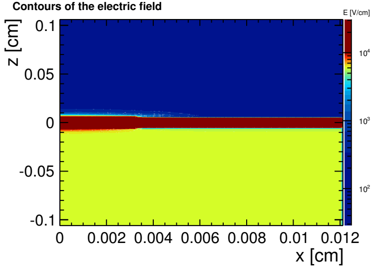
Basic cell



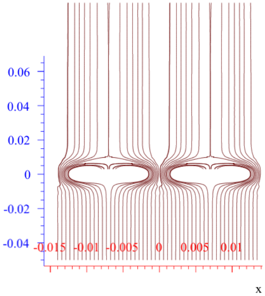
- Simulation of the electric field with ANSYS in a GEM basic cell
- Applying mirror periodicity to construct the whole plane



Electric field

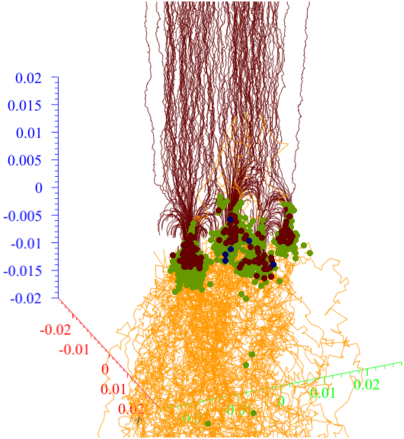


Contour Plot



Field Lines

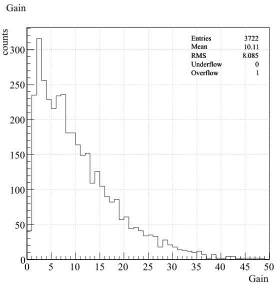
Drift Lines

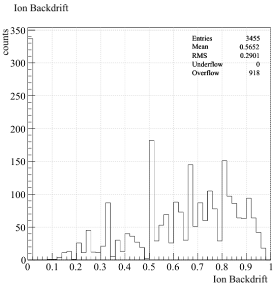


- Yellow: Electrons
- Brown: Ions
- Interaction points:
  - brown: Ionisation
  - Green: Excitation
  - Blue: Attachement

Simulation Results

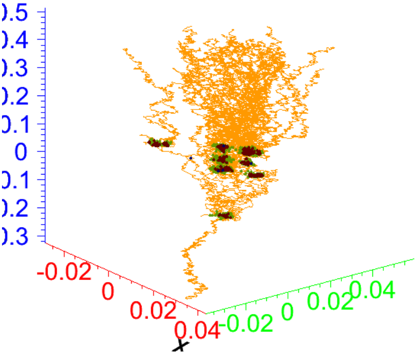
GEM voltage: $300\,V$ Gas: 80 % Ar, 20 % CO_2





Gas	Gain	Ion-Backdrift
Considered gas: 80 % Ar, 20 % CO_2	10.11	56.5%
TDR: 93% Ar, 5% Methan, 2% CO_2	$\sim$60	$\sim$70%
T2K: 95% Ar, 3% CF_4, 2% C_4H_{10}	$\sim$1000	$\sim$80%

Double GEM stack



Parameters:

E_{drift}	$240\mathrm{V/cm}$
d_{drift}	$2\mathrm{cm}$
$E_{trans/ind}$	$1000\mathrm{V/cm}$
$d_{trans/ind}$	$0.2\mathrm{cm}$

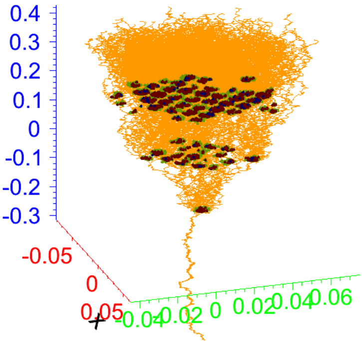
100 Events simulated

	Gain	Ion-Backdrift
Range	0-1000	0-85%
Average	249.7	60.6%

Experimental Setup: Small TPC

- Small chamber with $\o = 25\mathrm{cm}$
- Double GEM stack
- Unsegmented copper anode
- Operated with ^{55}Fe source

Triple GEM stack



Parameters:

E_{drift}	$240\mathrm{V/cm}$
d_{drift}	$2\mathrm{cm}$
$E_{trans/ind}$	$1000\mathrm{Vcm}$
$d_{trans/ind}$	$0.2\mathrm{cm}$

10 Events simulated

	Gain	Ion-Backdrift
Range	1000-5000	76-79%
Average	3625	78.22%

Outlook

- Double GEM stack: Comparision of the experimental Gain and Ion-Backdrift with the simulation → test the reliability on Garfield
- Optimize Triple GEM stack which will be used in the TPC:
  - Use upper GEM only for Ion-Backdrift reduction (low GEM voltage)
  - Optimize electron transparancy for upper GEM
  - Maximize the gain with other two GEMs