Update on ion back drift studies with GARFIELD++

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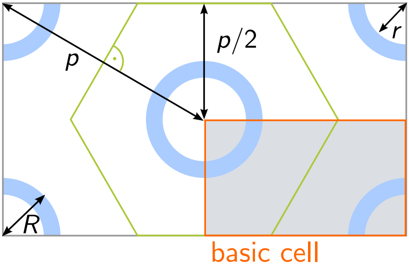
26.03.2012

GEM geometry



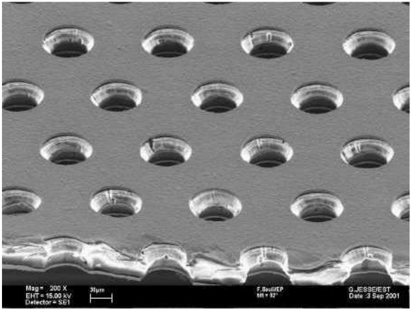


Fig.: GEM [http://gdd.web.cern.ch/GDD/]

CERN GEM:

- double conical holes
- kapton (50 µm) enclosed by copper surface (5 µm)
- $r = 25\,\mu\text{m}$, $R = 35\,\mu\text{m}$
- pitch $p = 140\,\mu\text{m}$
- optical transparency $\tau_{\text{opt.}} = \frac{A_{\text{hex.}}}{A_{\text{circ.}}} = \frac{2\pi R^2}{\sqrt{3}p^2} = 23\,\%$

Particle drift in the TPC

- ILD TPC: magnetic field lines are parallel to the electric field lines
- Due to different masses:
  - electrons follow electric field lines
  - ions follow magnetic field lines

Typical values for the drift velocity and the mobility:
$(|\overrightarrow{E}| = 250\,\mathrm{V/cm}$, $|\overrightarrow{B}| = 3.5\,\mathrm{T}$, 95 % Ar – 5 % CO_2)

	ion	electron
μ	$\approx 2\,\mathrm{cm^2/Vs}$	$\approx 1.5 \times 10^4\,\mathrm{cm^2/Vs}$
$\overrightarrow{v_\mathrm{D}}$	$\approx 5 \times 10^{-4}\,\mathrm{cm/\mu s}$	$\approx 3.5\,\mathrm{cm/\mu s}$

Challenges of the ILD TPC

- ions are produced in the amplification stage
  - $\longrightarrow$ there are three ion discs in the TPC simultaneously (due to the ILC bunch structure)
- ion density is higher for smaller radii of the TPC
  - $\longrightarrow$ field distortions are arising $\vec{E} \times \vec{B}$ effects are resulting

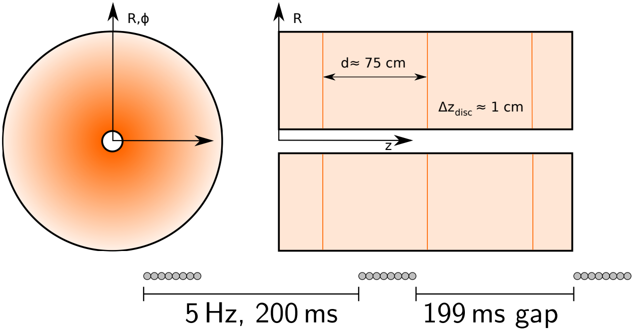
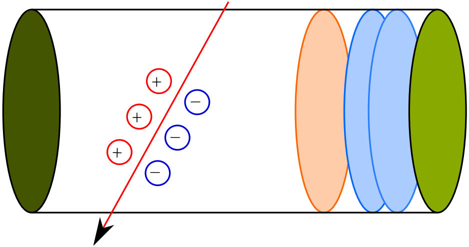


Fig.: ILC Bunch structure [DESY-THESIS-2008-036]

Optimization of the amplification stage



- cathode
- ionizing particle
- GEM tuned for ion reduction
- amplifying GEMs
- anode

GEM parameters:

- GEM voltage
- GEM geometry (influence on $\tau_{\mathrm{opt.}}$ and τ_{e^-})

set up parameters:

- transfer fields
- induction fields

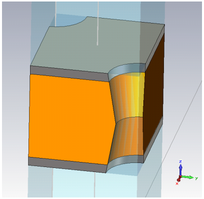
Aim of this study

- Optimization of the TPC amplification stage with regard to a minimal number of ions drifting back into the sensitive volume.

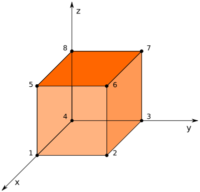
Analysis overview

1. Simulation of the electric fields:

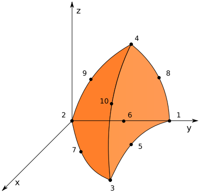
1.1 3D model of the GEM
1.2 FEM calculations of the potentials
1.3 export of the potentials, node positions and material properties



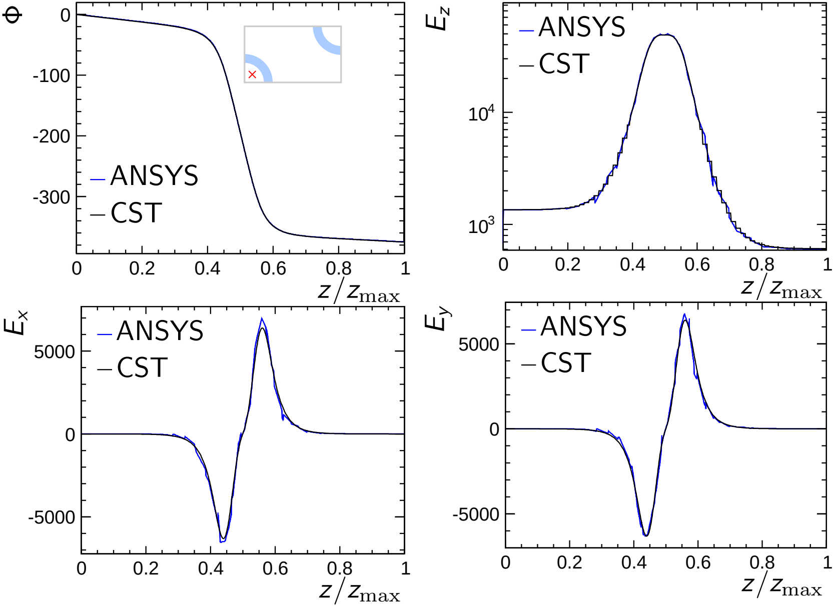
- CST Studio Suite™
  - cubic elements with 8 nodes



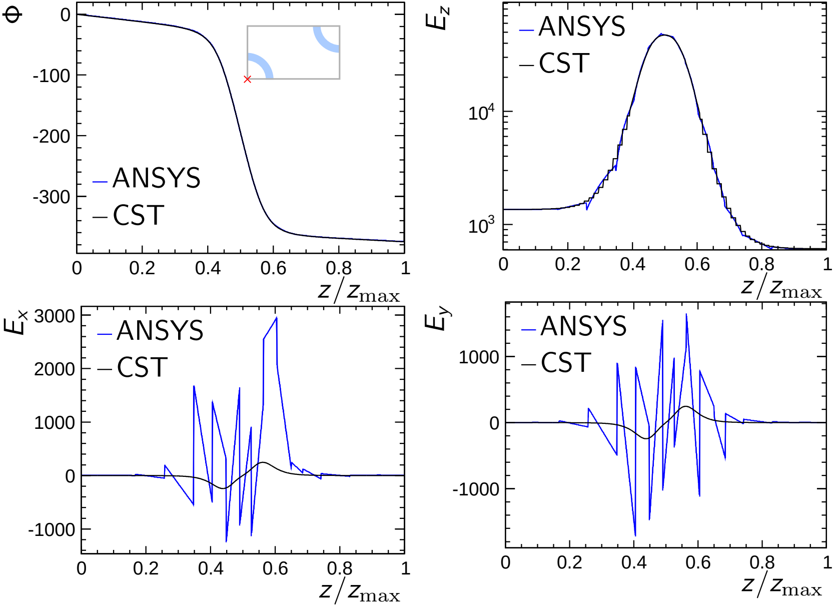
- ANSYS®
  - tetrahedral elements with 10 nodes and curved edges



Potential and electric field close to the hole center



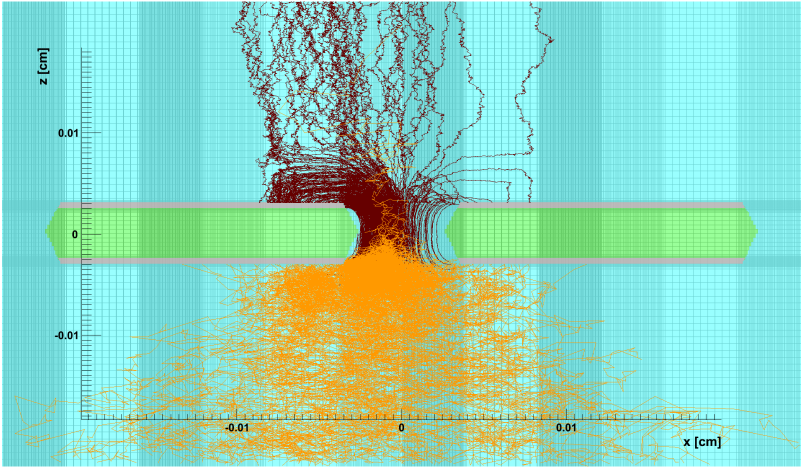
Potential and electric field at the hole center



Analysis overview

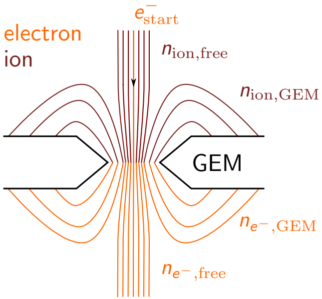
2. electron/ion drift in gases:

- GARFIELD++
  - treats all ionisation processes in gases
  - can be used to calculate electron transparency, gain, ion back drift ...

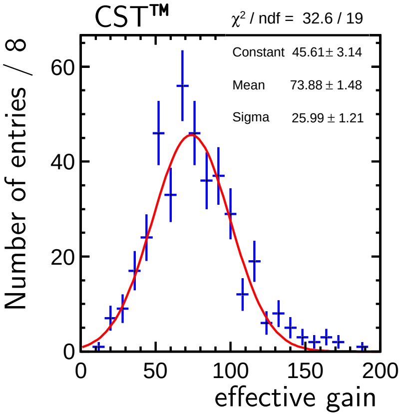


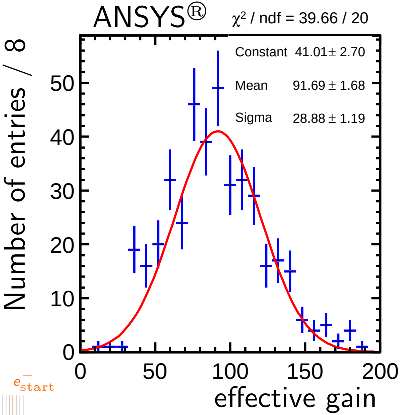
Setup of the simulation

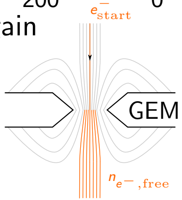
- amplification with a single GEM
  - $E_{\mathrm{drift}} = 250\,\mathrm{V/cm}$
  - $E_{\mathrm{induction}} = 1000\,\mathrm{V/cm}$
  - $U_{\mathrm{GEM}} = 350\,\mathrm{V}$
  - gas: 95 % Ar, 5 % CO_2
- simulated event ≡ one electron is freed in the drift volume
- event definition in the analysis ≡ aggregation of 5 simulated events



Garfield++ Result: effective gain





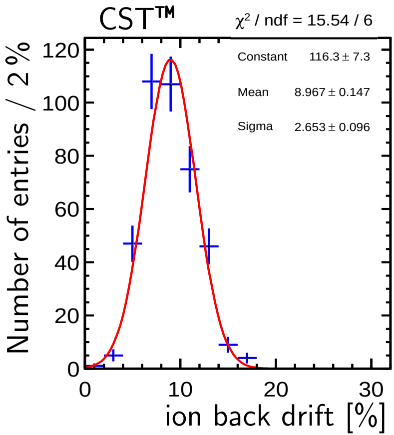


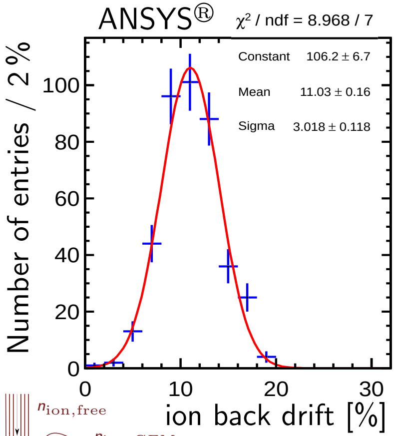
Definition

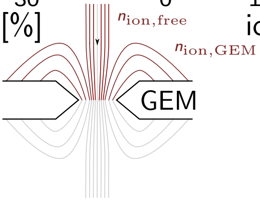
effective gain

$$\equiv \frac{n_{e^-,\text{free}}}{n_{e^-,\text{start}}}$$

Garfield++ Result: ion back drift





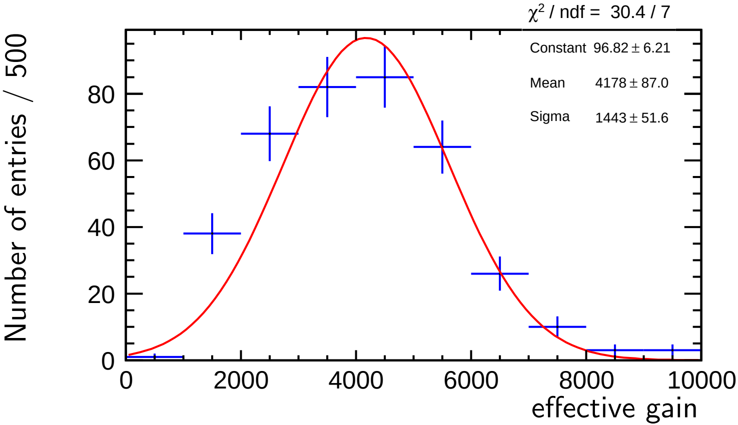


Def. as given by Sauli

ion back drift

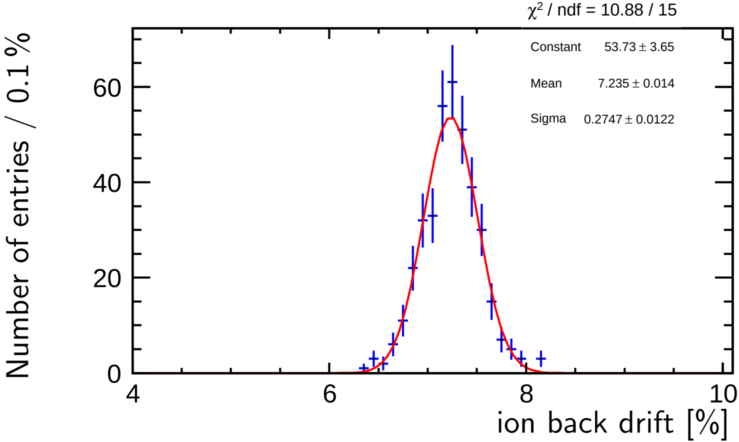
$$\equiv \frac{n_{\text{ion,free}}}{n_{\text{ion,free}} + n_{\text{ion,GEM}}}$$

GARFIELD++ Result: effective gain for a double GEM setup with CST™



- $E_{\mathrm{drift}} = 250\,\mathrm{V/cm}$, $E_{\mathrm{transfer}} = E_{\mathrm{induction}} = 1000\,\mathrm{V/cm}$, $U_{\mathrm{GEM}} = 350\,\mathrm{V/cm}$, gas: P5

Garfield++ Result: ion back drift for a double GEM setup with CST™



- $E_{\mathrm{drift}} = 250\,\mathrm{V/cm}$, $E_{\mathrm{transfer}} = E_{\mathrm{induction}} = 1000\,\mathrm{V/cm}$, $U_{\mathrm{GEM}} = 350\,\mathrm{V/cm}$, gas: P5

Summary:

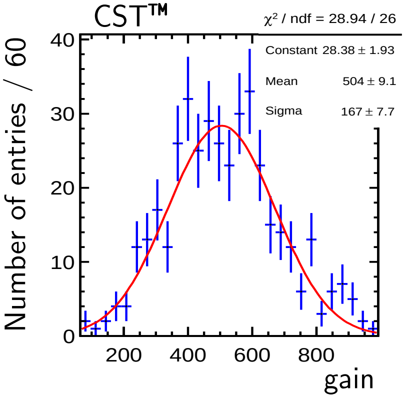
- CST™ Interface for GARFIELD++ was written
- successful simulation of a single and double GEM setup
- comparison with reference software ANSYS®

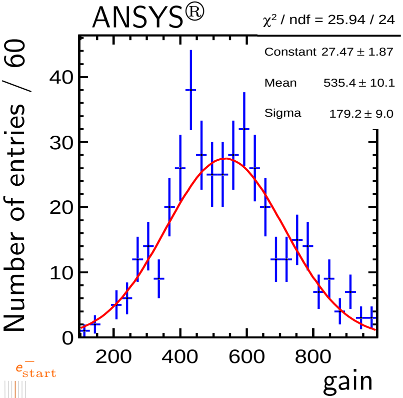
Outlook:

- experimental measurement of a double GEM setup with different GEM geometries
- simulation of these setups
- comparison of experimental results with the simulation
- optimisation of the setup with regard to a minimal ion back drift and a maximal electron transparency with GARFIELD++

Backup

GARFIELD++ result: gain

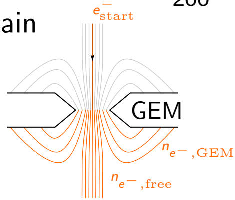




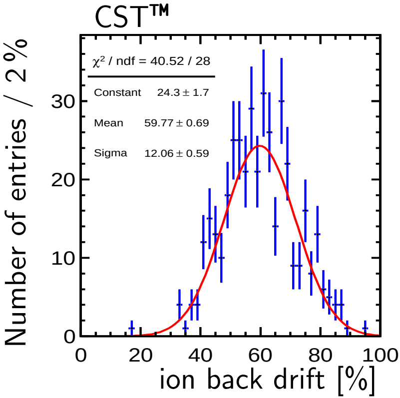
Definition

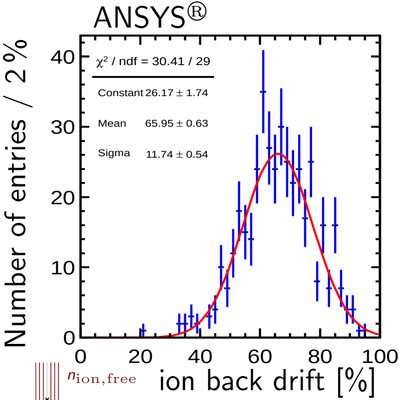
gain

$$\equiv \frac{n_{e^-,\text{free}} + n_{e^-,\text{GEM}}}{n_{e^-,\text{start}}}$$



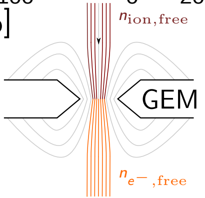
GARFIELD++ result: ion back drift



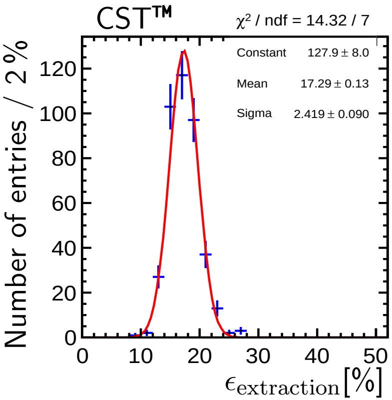


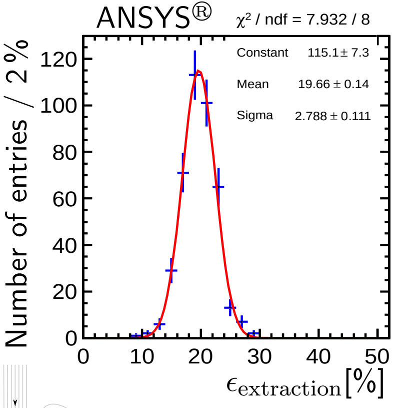
Def. by Killenberg et. al.

ion back drift $\equiv \frac{n_{ion,\mathrm{free}}}{n_{e^-,\mathrm{free}}}$



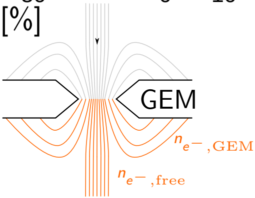
GARFIELD++ result: extraction efficiency



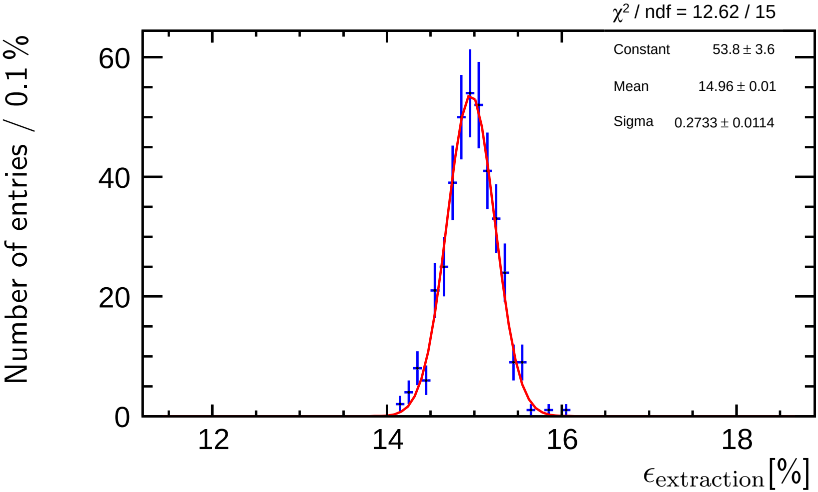


Extraction efficiency

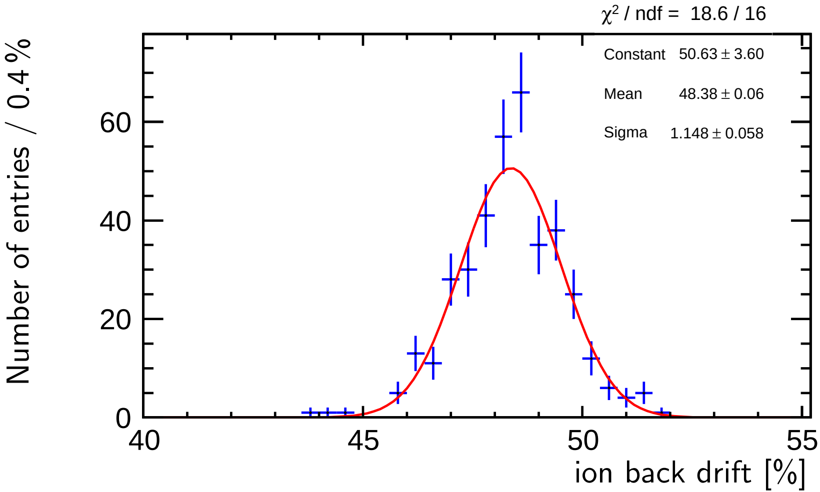
$$\epsilon_{\mathrm{eff},e^-} \equiv \frac{n_{e^-,\mathrm{free}}}{n_{e^-,\mathrm{GEM}}}$$



GARFIELD++ result: extraction efficiency of a double GEM stack (CST™)



Garfield++ result: ion back drift of a double GEM stack (CST™, Def. as given by Killenberg et. al.)



Experiment

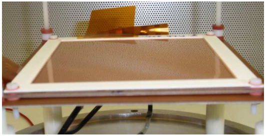


Figure: Small TPC [DESY-THESIS-10-015]

The DESY Small Prototype is being used.

- diameter of 25 cm
- drift length of 20 mm
- ^{55}Fe source on top of the cathode

Two type of GEMs will be considered in the beginning:

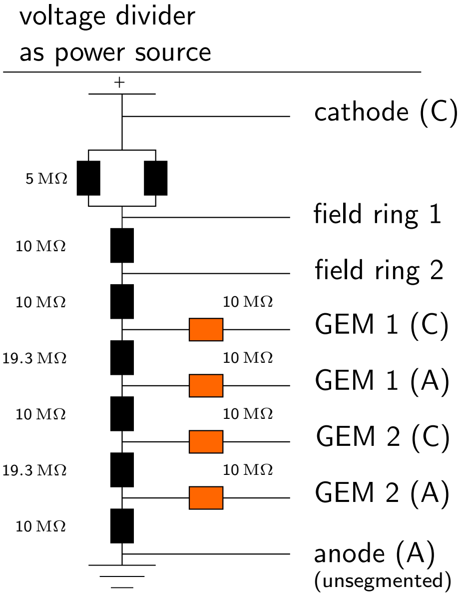
- standard CERN GEMs ($R = 35\,\mu\mathrm{m}$, $\tau_{\mathrm{opt.}} = 0.23$)
- modified CERN GEMs ($R = 50\,\mu\mathrm{m}$, $\tau_{\mathrm{opt.}} = 0.46$)

After commissioning stacks of two same type GEMs, a stack of three GEMs will be used.

In addition, we contemplate to measure the currents in the system to prove the ion suppression.

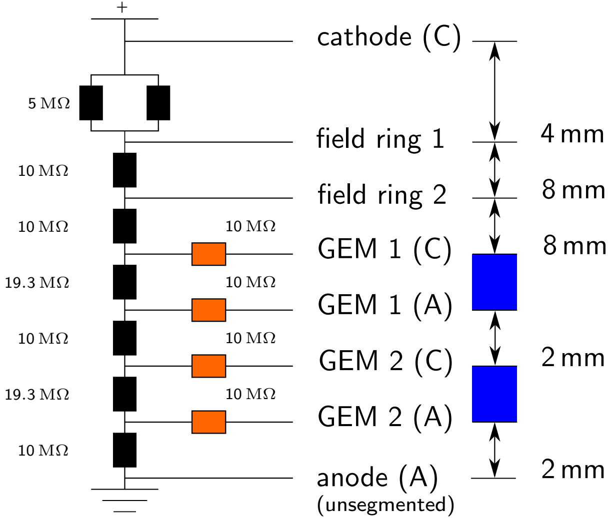
Skip details

Experimental setup

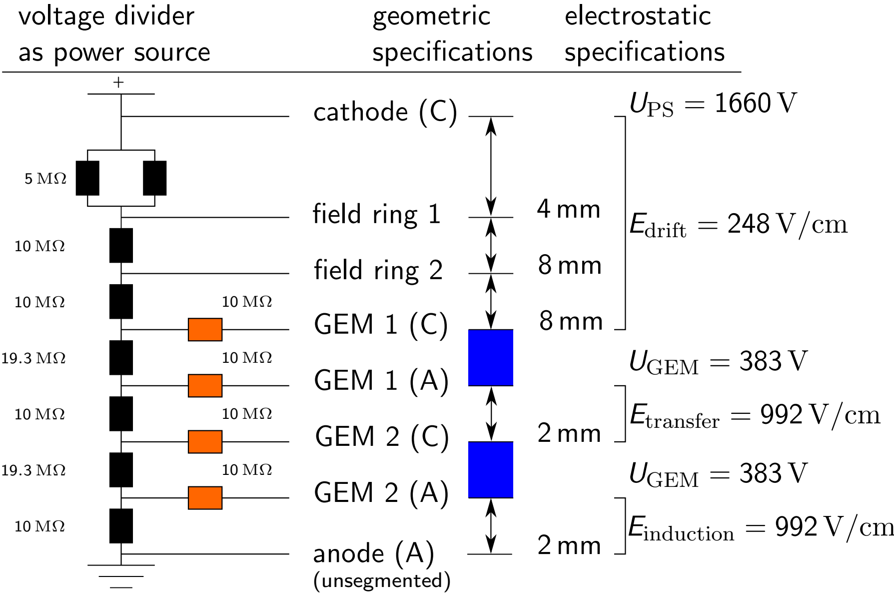


Experimental setup

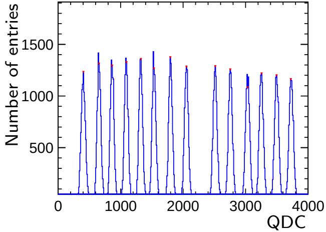
voltage divider as power source | geometric specifications

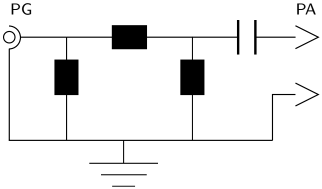


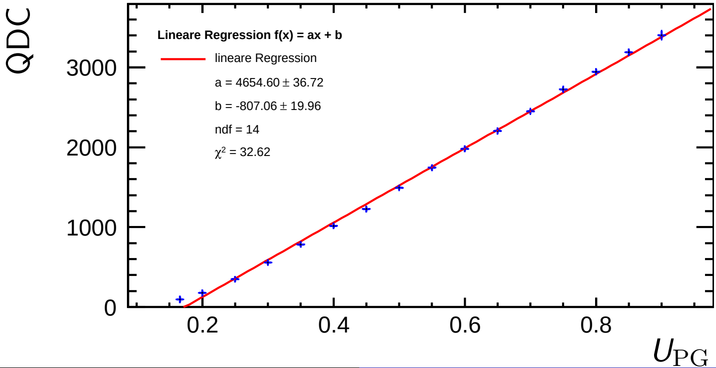
Experimental setup



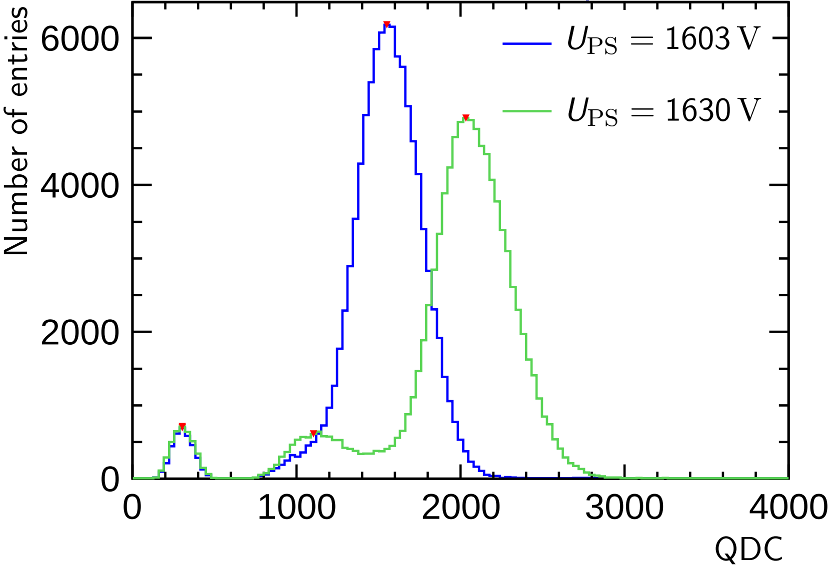
Calibration of the preamplifier (PA) with a charge injector







Results: Measurement of a Fe^{55} source spectrum



Comparison of the effective double GEM gain