DESY Summer Student Program report

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INTRODUCTION

This reports is dedicated to my summer internship at **DESY**(Deutsches ElektronenSynchrotron) in Hamburg. The subject of my study was the Gas Electron Multiplier(GEM) module which is going to be used for Time Project Chamber(TPC) at the future International Linear Collider(ILC).

DESY

DESY is a national research center in Germany that operates particle accelerators used to investigate the structure of matter. It conducts a broad spectrum of inter-disciplinary scientific research in three main areas: particle and high energy physics; photon science; and the development, construction and operation of particle accelerators. DESY's function is to conduct fundamental research. It specializes in:

- Particle accelerator development, construction and operation.
- Particle physics research to explore the fundamental characteristics of matter and forces, including astroparticle physics
- Photon science research in surface physics, material science, chemistry, molecular biology, geophysics and medicine through the use of synchrotron radiation and free electron lasers

In addition to operating its own large accelerator facilities, DESY also provides consulting services to research initiatives, institutes and universities. It is closely involved in major international projects such as the European X-Ray Free-Electron Laser, the Large Hadron Collider in Geneva, the IceCube Neutrino Observatory at the South Pole and the International Linear Collider.

INTERNATIONAL LINEAR COLLIDER

The ILC is a proposed linear particle accelerator. It is planned to have a collision energy of 500 GeV initially, with the possibility for a later upgrade to 1000 GeV (1 TeV). The ILC would collide electrons with positrons. It will be between 30 km and 50 km long, more than 10 times as long as the 50 GeV Stanford Linear Accelerator, the longest existing linear particle accelerator. The proposal is based on previous similar proposals from Europe, the U.S., and Japan. It is widely expected that effects of physics beyond that described in the current Standard Model will be detected by experiments at the proposed

ILC. In addition, particles and interactions described by the Standard Model are expected to be discovered and measured. At the ILC physicists hope to be able to:

- Measure the mass, spin, and interaction strengths of the Higgs boson
- If existing, measure the number, size, and shape of any TeV-scale extra dimensions
- Investigate the lightest supersymmetric particles, possible candidates for dark matter

To achieve these goals, new generation particle detectors are necessary, and the new TPC is believed to become one.

TIME PROJECT CHAMBER

The idea of TPC is to calculate momentum of a particle from it's trajectory curvature by deflecting it with magnetic field. The TPC is a cylindrical chamber where one base is a cathode and another is a position sensitive anode. A homogeneous electric field is created between them along the axes of the chamber. At the same time, the chamber is placed in a solenoid with magnetic field for particle deflecting.

When particle flies through the chamber it ionizes the gas along it's track, creating ions and the primary electrons. The curve of electron-ion pairs then start to drift in TPC's electric field. Ions drift to the cathode and electrons drift to an anode holding the shape of the trajectory curve. We can define r and phi cylindrical coordinates when electron is detected on the position sensitive anode. A two-dimensional projection of the initial curve is reconstructed from coordinates of all electrons. After we reconstruct z coordinate from the time lag between electrons registration.

GAS ELECTRON MULTIPLIER

When electrons reach the anode we must detect them precisely, but the current is low, and hard to define it from electric noise, so we need to amplify the current of electrons. That is why we are using the electron multiplication structure

Multiplication structure consist of three Gas Electron Multipliers called GEM. Each GEM is a layer of insulator between two layers of conductor. The voltage is applied between these conducting layers. GEM is whole covered with tiny holes, so all the primary electrons are pulled into these holes by local electric field created by GEM voltage.

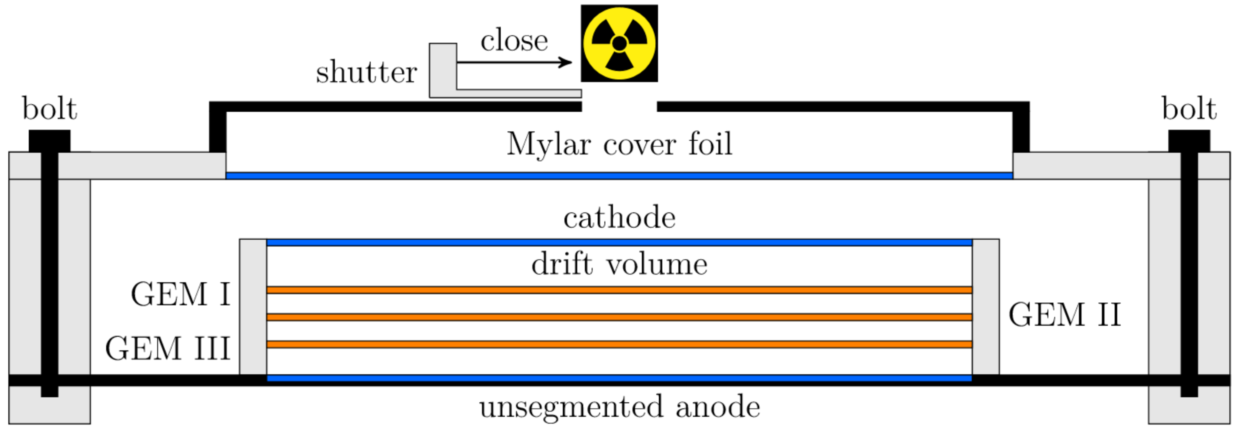
In the hole the GEM's electric field accelerates primary electrons, they collide with gas molecules and ionize them, causing electron avalanche and producing secondary electrons and ions. Secondary ions are pushed backwards with GEM electric field towards the cathode, while secondary electrons are extracted further. The ratio between the number of electrons extracted and the number of electrons pulled into the GEM hole is called effective gain of the GEM. After triple multiplication electrons reach the anode.

The bigger voltage we apply to the GEM the bigger effective gain we are able to get. But the problem is in discharges between GEM's conductive layers. They happen sometimes when electrons are flying through the GEM creating plasma which reduces gas resistivity. As we increase voltage between them the current of discharges increases. These discharges can damage the middle layer of insulator and can cause the insulator material to become conductive. If we got connection between up and down layers there will be no gain anymore.

One of the possible ways to avoid insulator damage is to make GEM's copper electrodes covered with copper oxide by placing them in the oven with high temperatures, which will increase GEM surface resistivity and reduce the discharge current. But we can't be sure that the gain coefficient will be conserved, so we need to test oxidized GEM for sufficient gain.

TEST CHAMBER

The setup that is used here consist of a TPC prototype with a stack of three 10cm×10cm GEMs. Main parts of the TPC prototype were constructed and designed at *Forschungszentrum Karlsruhe* and modified at the University of Aachen and Bonn. The TPC walls are made of glass fibre resin compound Stesalit. Furthermore, the anode is a single copper surface and the cathode is made of an aluminium coated Mylar foil. On top of the chamber is an additional aluminium coated Mylar foil closing the gas volume.

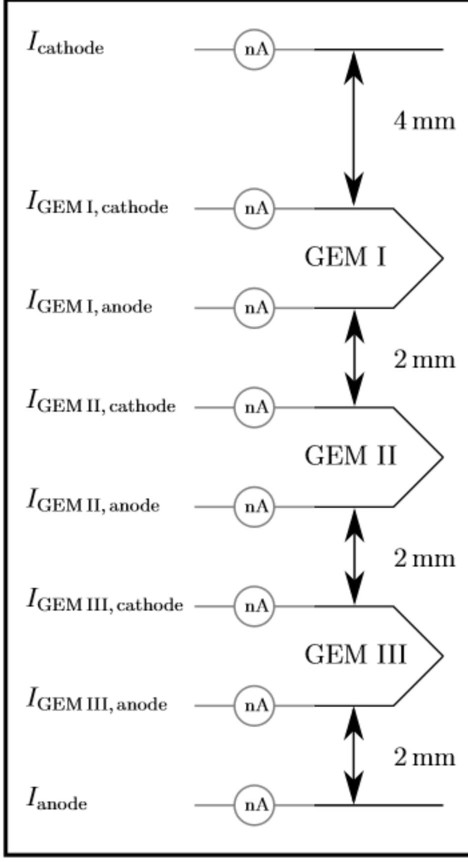


All GEM electrodes as well as the cathode and anode electrode are powered by individual channels of a CAEN SY2527 power supply. Furthermore, all electrodes are protected with an 10MO resistor. Thereby, in case of a discharge in a GEM the current I(trip) = U(GEM)/20MO is limited by the two resistors in series. If such a case, called trip, is recognised by the power supply, which happens if a current larger than 4μA is present for more than 0.2s, all channels are ramped down in order to protect the setup. During the measurements presented here, the power supply was completely controlled by remote. After a trip all voltages are ramped up again automatically in order to recover the operating conditions prior to the trip. If during the ramp up again a trip occurs only one additional ramp up is attempted. Finally, if the last ramp up also fails the measurement is stopped. The T2K gas in used inside the chamber

Here are the parameters of the measurement setup including current definitions. The voltages given for individual GEMs reflect the voltage difference between the anode and cathode of the GEM.

Left-hand fields/voltages show default settings. Right-hand fields/voltages show the ion back flow settings (IBF).

currents	distance	fieldstrength/voltage [V/cm]/[V]		



E_{drift}	250	250
$U_{GEM\,I}$	U_{GEM}	230
$E_{transfer,\,I}$	1500	2500
$U_{GEM\,II}$	U_{GEM}	260
$E_{transfer,\,II}$	1500	290
$U_{GEM\,III}$	U_{GEM}	290
$E_{induction}$	3000	4500

SIGNAL CREATION

The gas ionization in the TPC prototype is done using a 55Fe source with an activity of 30MBq, which is located on top of the Mylar foil closing the gas volume of the TPC prototype. It decays via electron capture leaving a vacancy in the K shell of the atom. Subsequently this vacancy is filled with an electron from a higher shell. The concerned energy difference can be released in two ways. Either it is released via a photon or the energy is transferred to an electron of a higher shell, which is released. The release of such an electron, called Auger electron, is most probable. But due to the Mylar foil between the source and the gas volume Auger electrons will not reach the sensitive volume of the TPC. Therefore, the process with the second highest probability of 24.4% is of interest here. It is characterised by a photon with an energy of Eγ =5.9keV and it can be written as:

$$^{55}\mathrm{Fe} + e^- \longrightarrow {}^{55}\mathrm{Mn}^* \longrightarrow {}^{55}\mathrm{Mn} + \gamma.$$

Such photons reaching the sensitive volume of the TPC prototype have enough energy to ionize the drift gas, since the mean ionization energy W of argon based gas mixtures is below 30eV [30]. Therefore, the number of electrons Ne− = Eγ/W per ionization is in the order of O(200).

In order to do also measurements without the photon signals, a shutter consisting of a motor and an aluminium sheet with a thickness of 1mm is used. When the shutter is closed, the Aluminium sheet is pushed in between the source and the Mylar foil of the chamber. Thereby the photons are blocked and cannot reach the TPC gas volume anymore. The shutter is also controlled by the XTC software via the parallel port of the DAQ computer.

SINGLE GEM GAIN

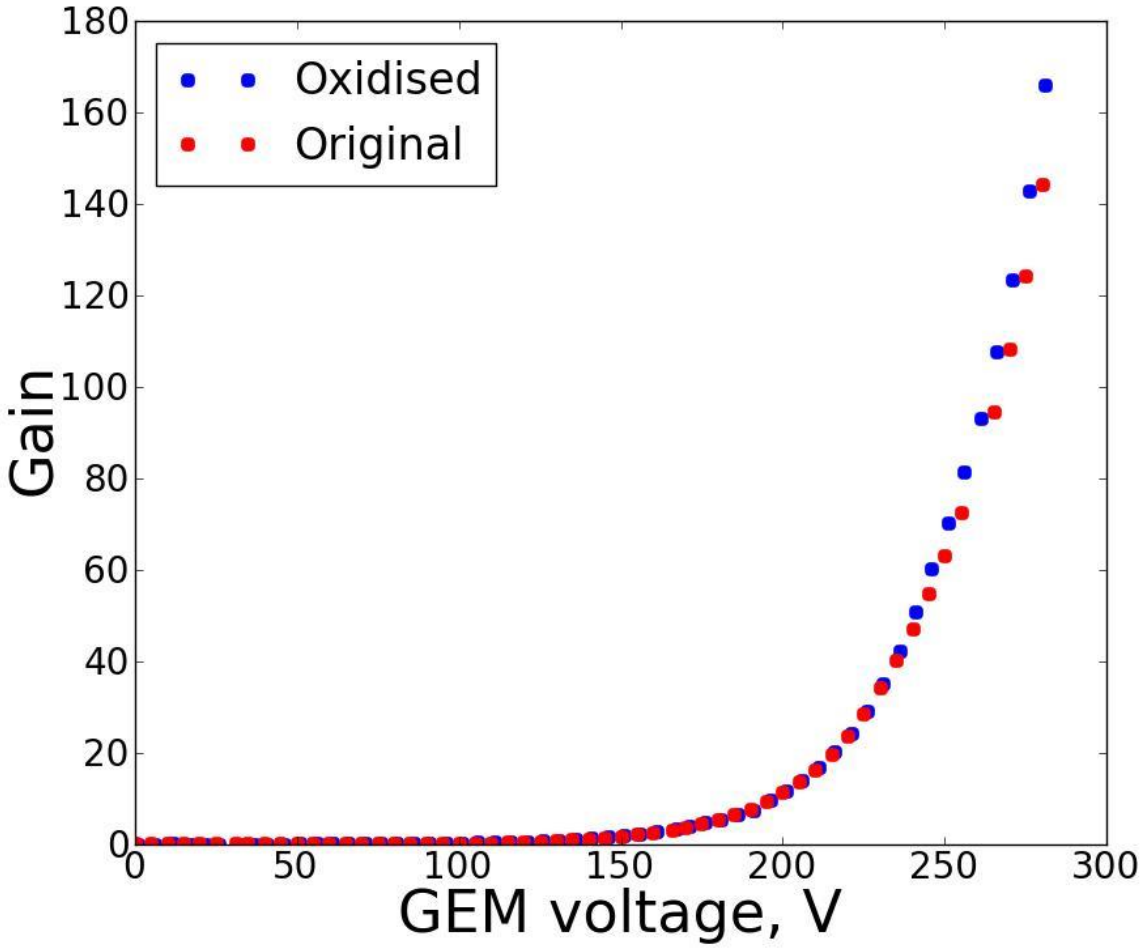
The single GEM gain can be calculated with respect to GEM III. First of all a measurement is done when GEM III is switched off by setting the voltage of its anode to its cathode voltage. The current that is measured now on its cathode corresponds to the number of electrons reaching GEM III for the chosen settings of the setup. Afterwards the same measurement is repeated when GEM III is amplifying. All amplified electrons end either on the anode of GEM III or the anode. Therefore, the gain of GEM III can be calculated as:

$$G_{\mathrm{GEM\,III}}(U_{\mathrm{GEM}}) = \frac{I_{\mathrm{anode}} + I_{\mathrm{GEM\,III,\,anode}}}{I^0_{\mathrm{GEM\,III,\,cathode}}}.$$

For this definition it is assumed that the electron collection efficiency of GEM III is 100%. If this is not the case, some electrons are lost on the cathode electrode of GEM III, which cannot be amplified.

GAIN MEASURMENTS

We have measured the gain of standard GEM and GEM after oxidation. Second one was placed in the oven for three hours with temperature about 200 degrees Celsius. For each GEM the plot is been built. The X axe is voltage applied inside the GEM and the Y is gain coefficient.



As we can see, gain does conserves in GEM after oxidation procedure. This opens us new perspectives to use this oxidation technology to increase GEM stability against discharges.