Title: Simulation of multi-layer GEM from single to triple GEMs

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Originally Micro-Pattern Gas Detectors (MPGDs), a type of gaseous ionization detector, were developed for high-energy physics, however applications have expanded to astrophysics, neutrino physics, neutron detection, and medical imaging. Over the past 20 years this led to the development of novel MPGD devices: the Micro-Strip Gas Chamber (MSGC), Gas Electron Multiplier (GEM), Micromegas (a type of MPGD using a parallel-plate micro-mesh avalanche counter) and many others, revolutionizing cell size limits for many gas detector applications and considerably improving reliability and radiation hardness.

In a gaseous detector a particle enters a gas cell and collides with an atom of gas, which emits a high-energy electron. This electron creates an ionization tract whose electrons are drifted by a small electric potential across a gas cell onto a bottom plate consisting of a double-layered conductor separated by an insulator with a strong electric field (50-70 kV/cm) between them. This bottom plate, called a GEM, has an array of tiny holes and the ionization tract electrons fortunate enough to pass though the holes are strongly accelerated causing them to create secondary cascades in the direction of a pixel readout array such as the CMOS ASIC chip.

With a multi-GEM layer structure, of up to 5 layers, a very high effective gain (up to 10^6 with some gases) can be attained with each GEM layer working at an individually much lower gain thus avoiding discharge problems. This is the major advantage of the GEM technology.

We have performed a simulation study for single, double, and triple GEMs with Garfield++ and ANSYS.

Figure 1 shows our simulation results. As the number of GEM layers is increased, the gain increased by using a small delta GEM voltage. On the other hand, energy resolution deteriorated as the number of GEM layers is increased at the same gain. The spatial resolution became poorer as the distance between the anode increased and the first GEM is increased. However, this difference is only about 15 μm/mm.

Lastly, there are some differences in transparency and efficiency, but single, double, and triple GEMs are pretty much the same.

a: gain b: transparency c: efficiency d: spatial resolution e: energy resolution

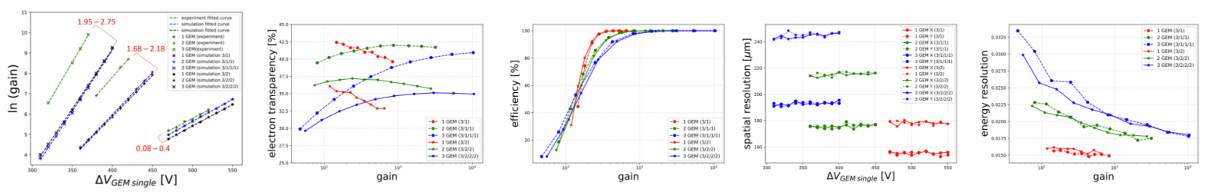

Figure 1 simulation results; (a) Gain as a function of GEM voltage. Green is the experimental data (originally from Bachmann's paper), blue is the simulation model with a transfer and induction gap of 1 mm, and black is the simulation model with a transfer and induction gap of 2 mm. Moreover, the star symbol is a single GEM, the cross symbol is a double GEM, and x symbol is a triple GEM. As the number of layers of GEM increases, the difference between experimental and simulation results increases. (b) Transparency: the total electron transparency as a function of gain for single (red), double (green), and triple (blue) GEMs. (c) Efficiency as a function of gain for single (red), double (green), and triple (blue) GEMs. (d) Spatial resolution as a function of GEM voltage between top and bottom of GEM conductive layer for single (red), double (green), and triple (blue) GEMs. (e) Energy resolution as a function of gain for single (red), double (green) and triple (blue) GEMs.