Aalto-yliopisto
Perustieteiden
korkeakoulu

HELSINKI INSTITUTE OF PHYSICS

CERN

Rate Dependency Study on Gas Electron Multiplier Gain

Final presentation

Ella Warras

08.06.2015

Instructor: *Dr. Francisco García*

Supervisor: *Prof. Harri Ehtamo*

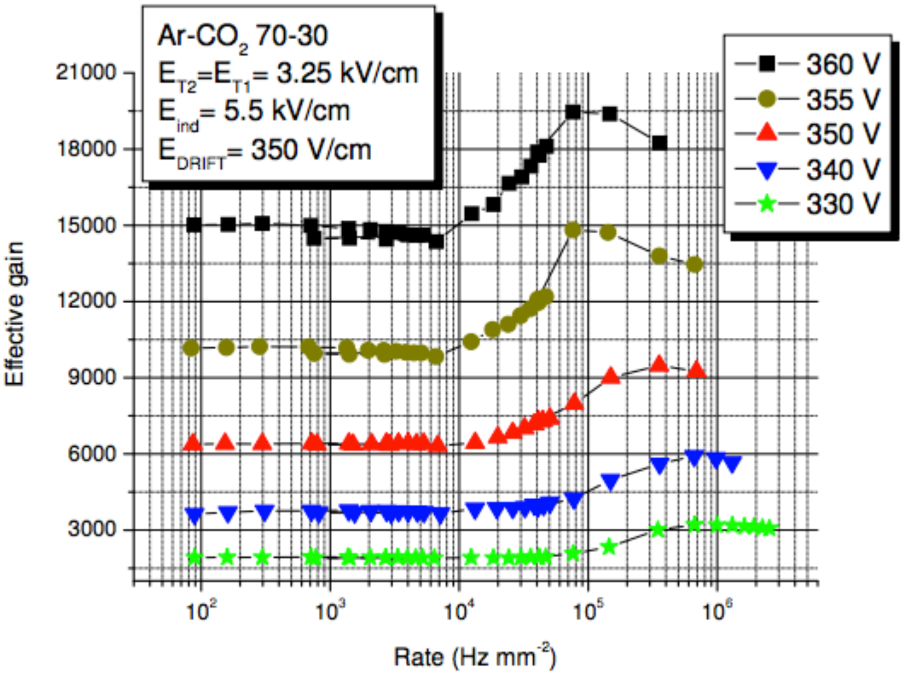
Systeemianalyysin laboratorio

Introduction

- My summer project at CERN for Helsinki Institute of Physics
  - Worked in the Gas Detectors Development laboratory
- Particle physics research: new experiments => increased requirements in the field of particle detectors
  - Rate capability = ability to cope with high quantities of incoming particles
- There are different types of particle detectors
  - Scintillation detectors
  - Semiconductor detectors
  - Gaseous detectors

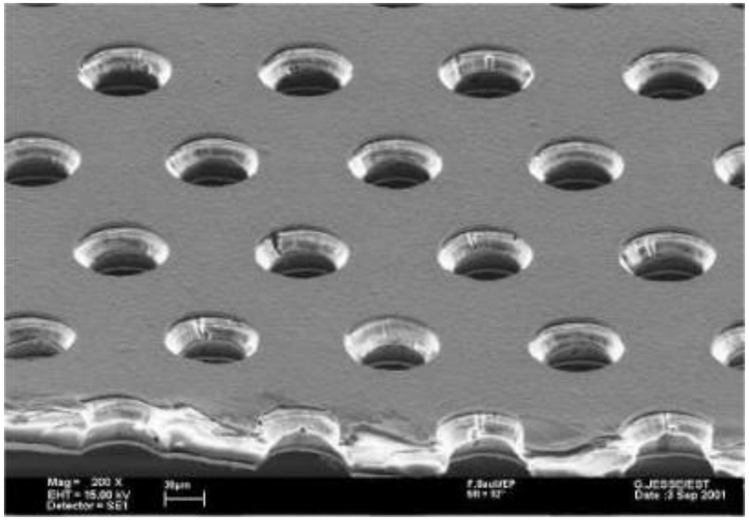
Background

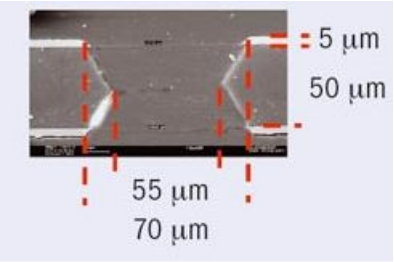
- Pieter Everaerts did his doctoral thesis in 2006 on the effect of the rate on a GEM detector
  - He found a strange change in the gain at high rates
- Systematical studies were needed



Gas Electron Multiplier (GEM)

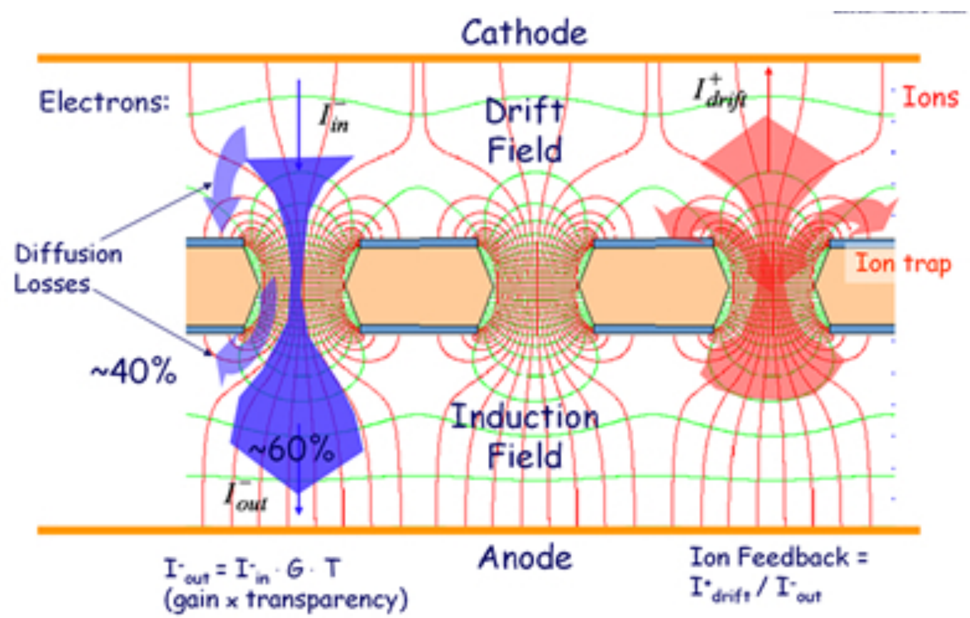
- GEM detectors are a type of gaseous detectors
- A GEM is a 50 µm thick polyamide film with a thin layer of copper on each side
- A matrix of holes is etched into the film





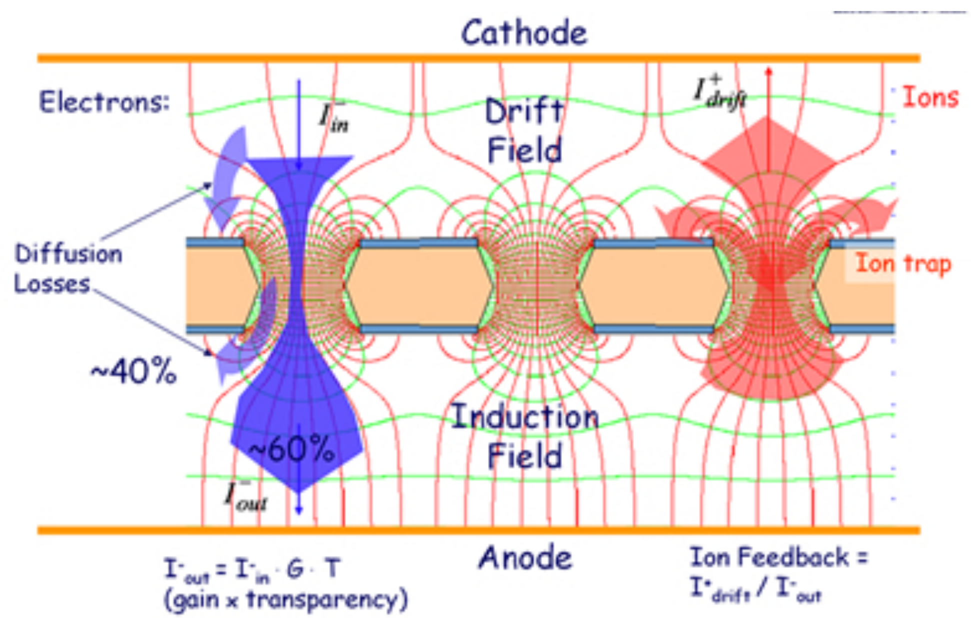
GEM detector

- Consists of gas volume, cathode window, GEM foil and readout anode
- Cathode has high negative voltage, anode is at ground
- Voltage difference between top and bottom of the GEM => electric field inside the holes



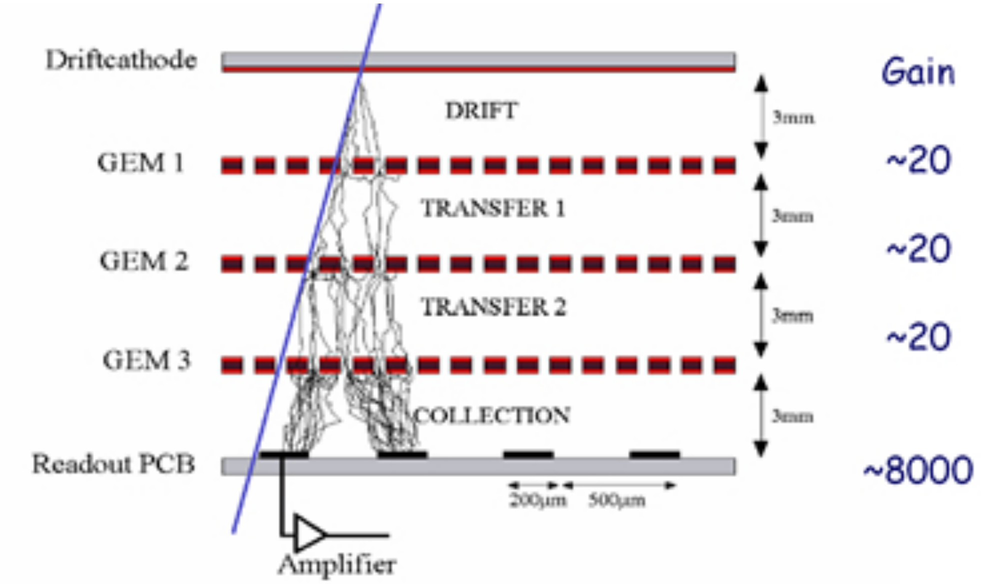
Detection process

1. Particle comes into the gas through the window
2. Ionizes atoms in the gas
   - Positive ions drift towards cathode (ion backflow)
3. Electrons drift towards the GEM and inside the holes
4. High electric field inside the hole => collisions and new ionizations
5. Avalanche of electrons occurs
   - More ion backflow
6. Electrons collected at the anode



Triple-GEM detector

- Three GEMs => the avalanche reaction multiplies



- Gas: argon 70%, carbon dioxide 30%
- X-ray sources: ^{55}Fe and X-ray tube (Cu-target)

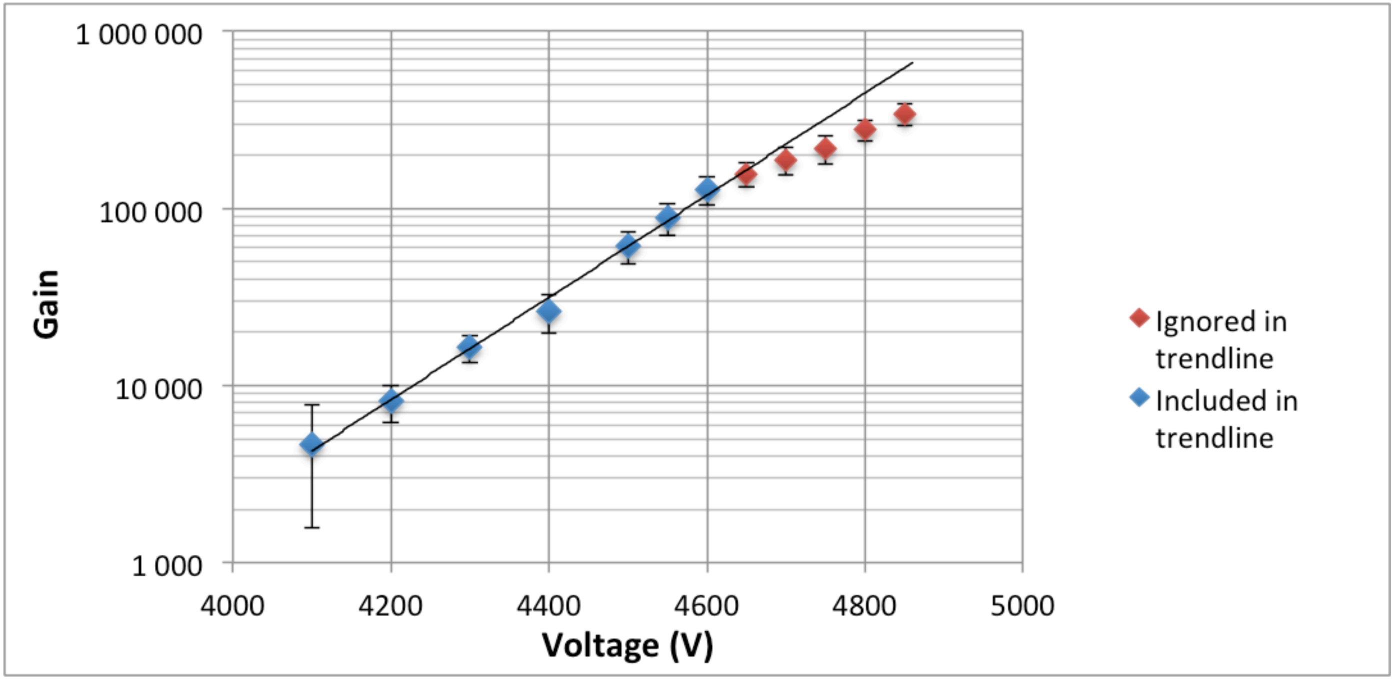
Gain

- Describes how many electrons are collected on the anode for each initial electron that is generated in the drift region
  - I = total current collected on the anode
  - f = rate of the x-rays (number of incident photons per second)
  - e = elementary charge of an electron
  - n = number of primary electrons created per incident photon
    - n is calculated by dividing the energy of a photon with the effective ionization energy of the gas

$$G = \frac{I_{\mathrm{d}}}{n \cdot f \cdot e}$$

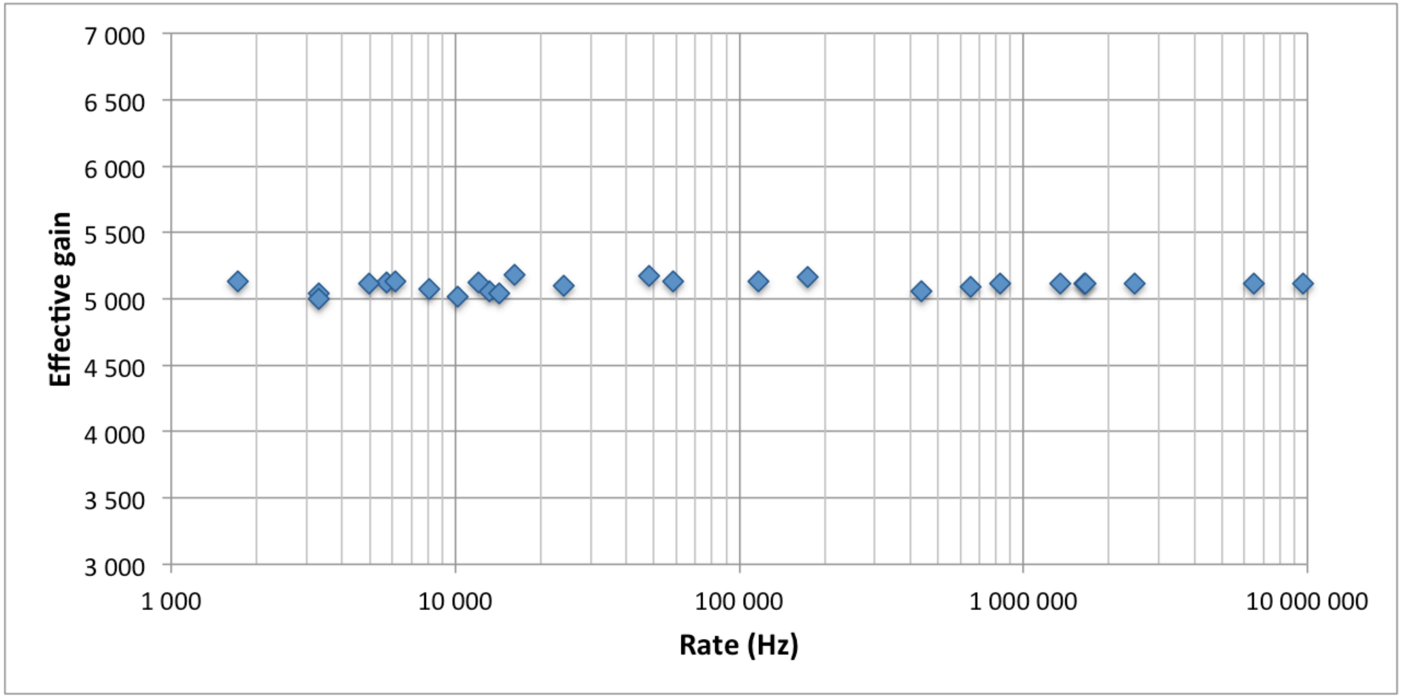
Gain calibration

- The gain as a function of the input voltage
- Some saturation at the upper end



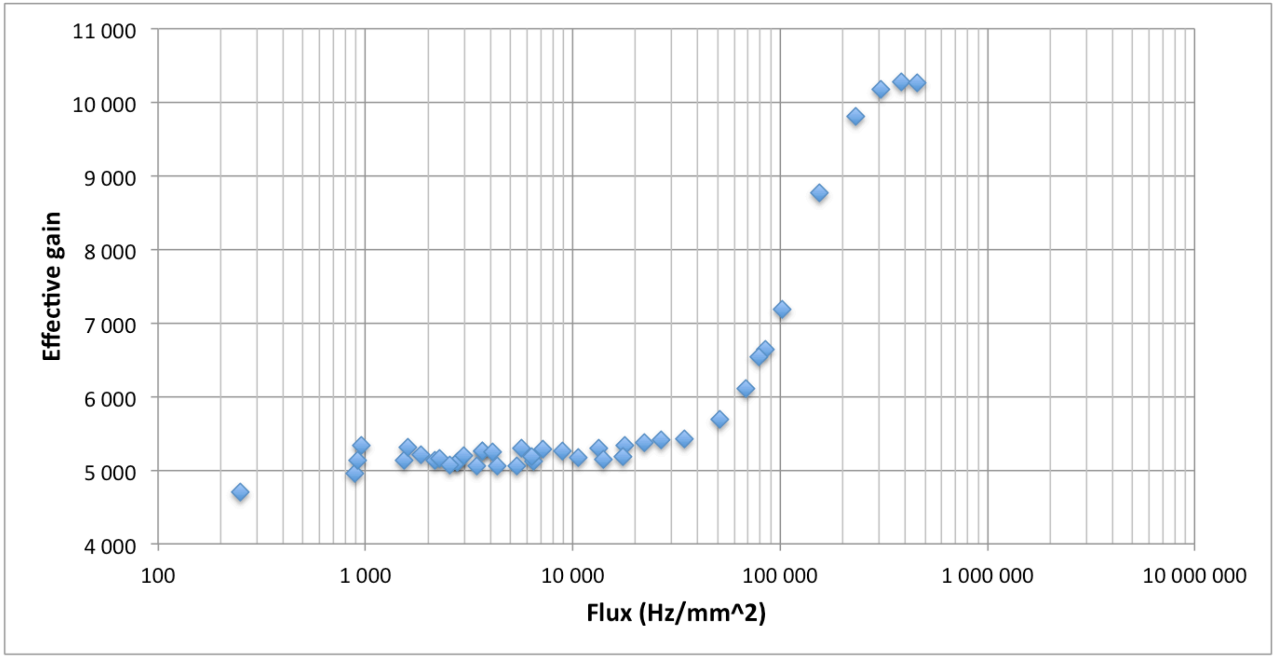
Rate capability

- Gain stays constant even at rate 10 MHz



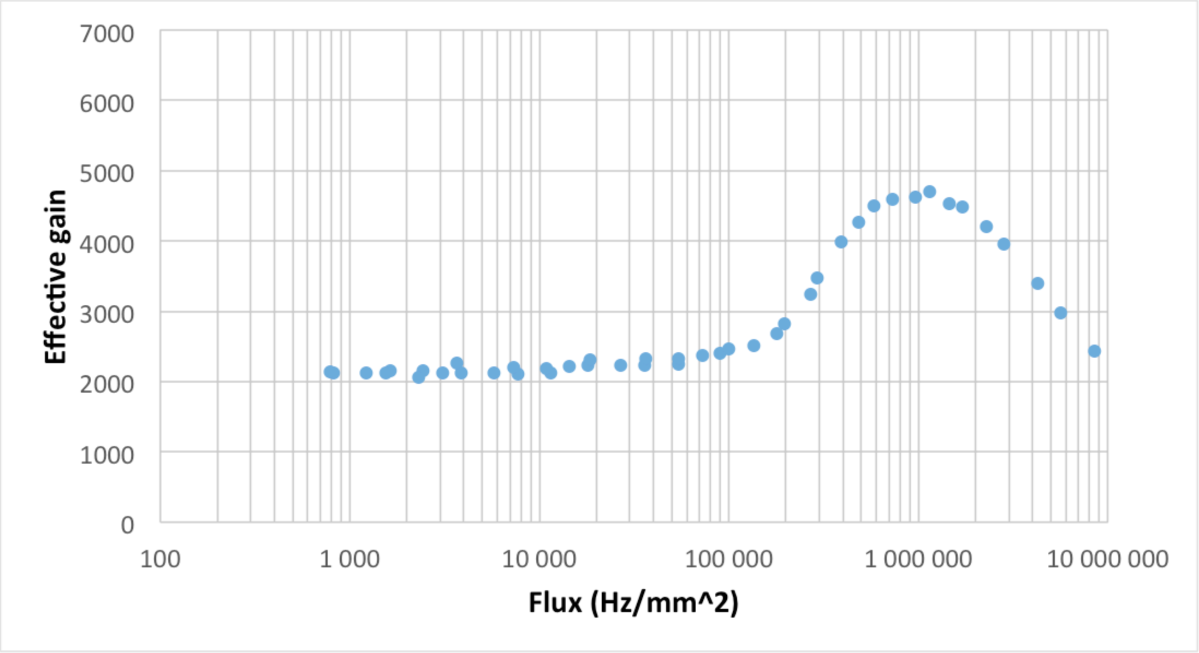
Gain dependency on rate (1/2)

- Used a collimator to know the size of the area that was radiated
- Starting gain 5000, measured up to 500 kHz/mm^2



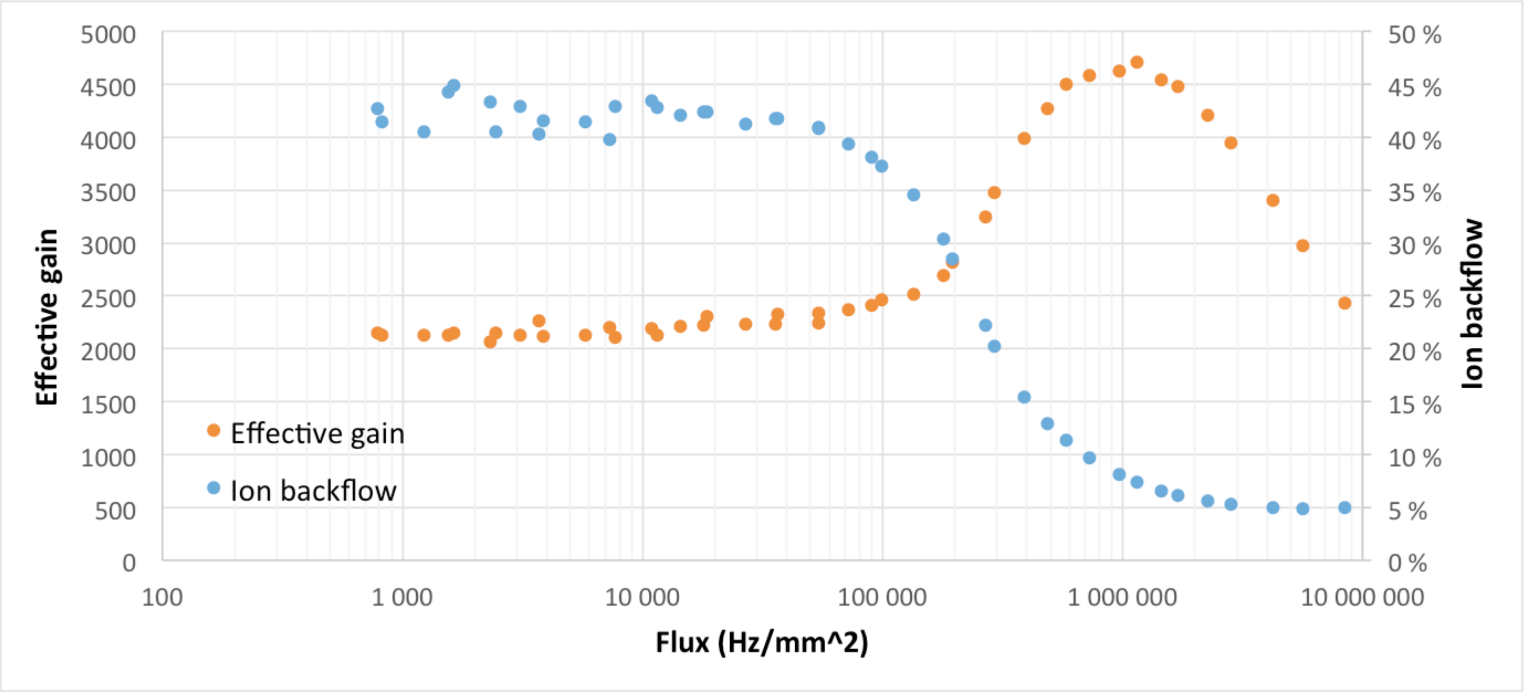
Gain dependency on rate (2/2)

- Then starting gain 2000, measured up to 10 MHz/mm^2



Effect on ion backflow

- Gain increases and ion backflow decreases
  - Then ion backflow saturates and the gain starts decreasing



Conclusions

- The gain increases at higher fluxes
  - The GEMs get more electrons inside the hole per time interval and the gain increases
- When the electrons saturate the holes, the increase in the gain slows down and stops
  - The point where the ion backflow saturates, it might well be when all three GEMs have reached saturation
  - This is also the point where the gain starts to decrease
- The electrons are saturating the holes starting from the last GEM, and blocking the ions that are moving upwards
  - Ion backflow decreases

Outlook

- More measurements at different gains, changing different parameters
- The team in the Gas Detectors Development laboratory at CERN have already continued researching this topic
  - It is going well and they are moving forward with the research

Acknowledgements

- Gas Detectors Development department at CERN
  - Especially Dr. Leszek Ropelewski and Dr. Eraldo Oliveri

- Dr. Francisco García, my supervisor and instructor from Helsinki Institute of Physics

Thank you for your attention!