Study of Ion Back Flow suppression with thick COBRA GEM

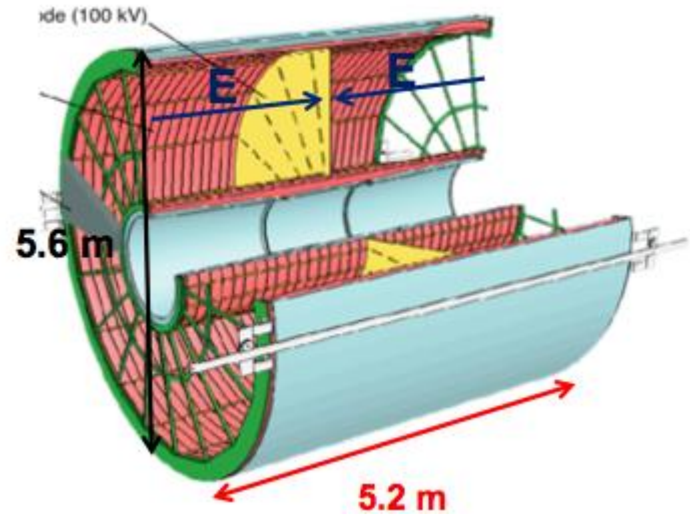
K. Terasaki for the ALICE TPC Collaboration

Center for Nuclear Study, Graduate School of Science, the University of Tokyo

2013/7/5

Introduction

- ALICE (A Large Ion Collider Experiment)
  - Dedicated experiment to study QGP via heavy ion collisions at LHC
- ALICE-TPC
  - Volume: 90 m^3
  - Drift length: 2.5 m
  - Drift field: Ed=400 V/cm
  - Acceptance: $|\eta|<0.9$, $\Delta\varphi=2\pi$
  - Gas: Ne/CO2/N2 (90/10/5)
  - Readout chambers: MWPC

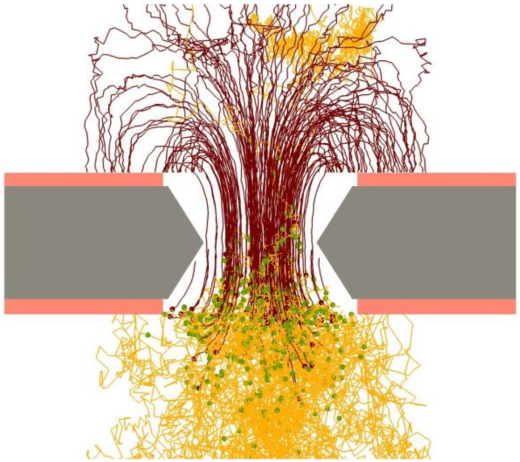


Introduction

- Current limitation for readout rate
  - Gating Grid (GG) for preventing Ion Back Flow (IBF) into the drift region
  - Unavoidable 180 μs dead time due to ion travelling to GG
  - Maximum readout rate ~ 3.5 kHz
- ALICE-TPC upgrade
  - 50kHz Pb-Pb collisions after Long Shutdown 2 in 2018
  - Continuous readout without GG
  - MWPC $\rightarrow$ GEM

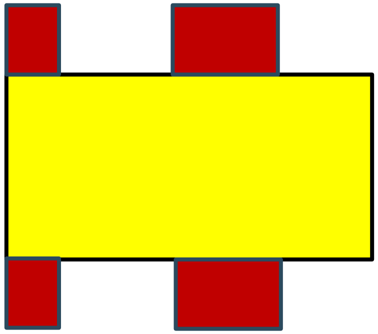
Introduction

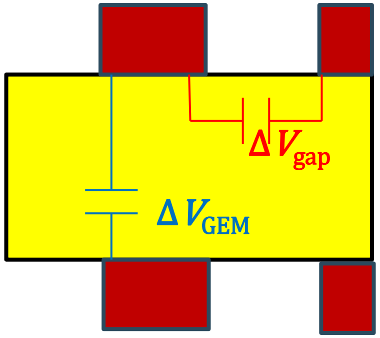
- Ion Back Flow (IBF)
  - Distorting an electric field in the drift space and worse position resolution.
  - Requirement of IBF in upgraded ALICE-TPC:
    - 0.5-1.0%
      at gain ~2000
      in $Ne/CO_2/N_2$ (90/10/5)
- Gas Electron Multiplier (GEM)
  - Ion blocking capability
  - Multi-layer configuration



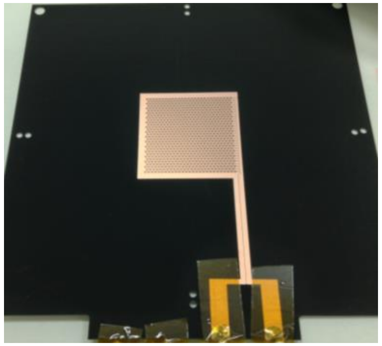
Thick COBRA GEM

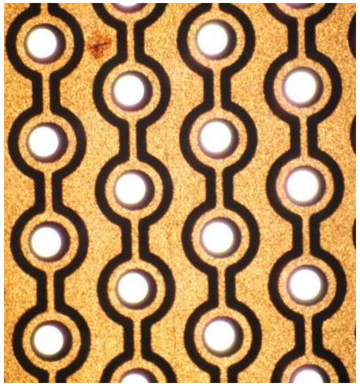
- Specially designed to improve the ion blocking capability compared to a standard GEM
- Double electrode patterns on both sides
- Ions can be efficiently absorbed by creating a voltage difference between these two COBRA electrodes (ΔVgap or Vac)





Cross-section drawing of COBRA GEM

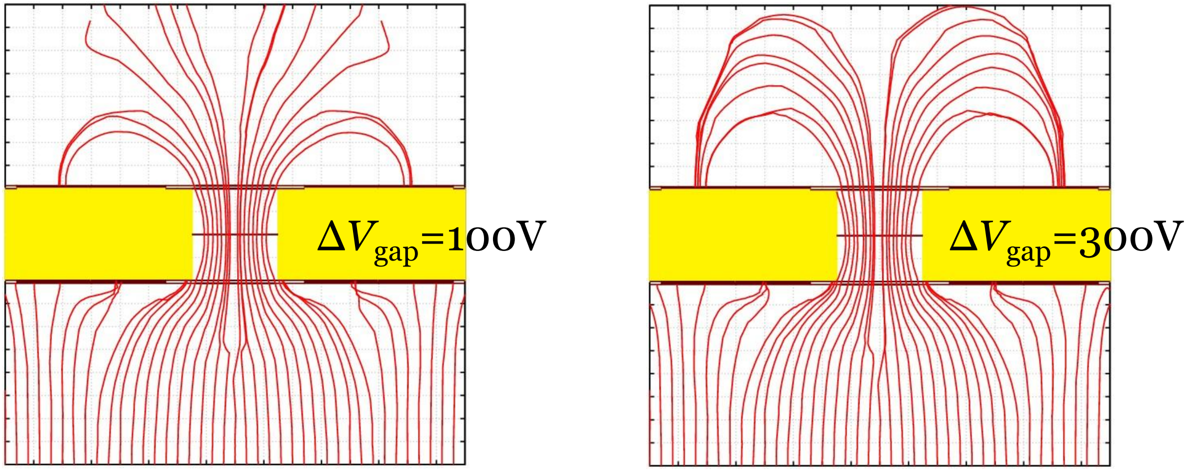




A microphotograph of COBRA GEM surface

Thick COBRA GEM

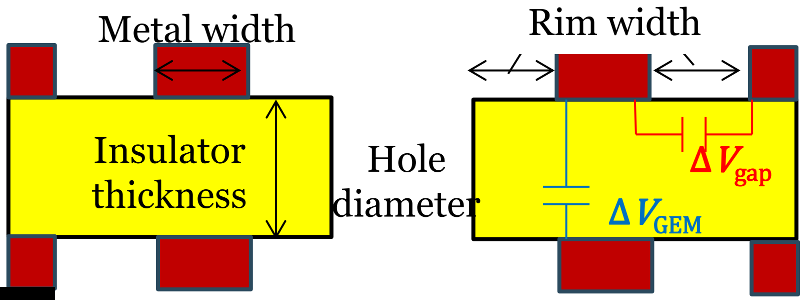
- Specially designed to improve the ion blocking capability compared to a standard GEM
- Double electrode patterns on both sides
- Ions can be efficiently absorbed by creating a voltage difference between these two COBRA electrodes (ΔVgap or Vac)



Garfield simulation of ion absorption at the COBRA electrodes

Thick COBRA GEM

- Prototype COBRA GEM
  - We have developed 200μm and 400μm-thick COBRA GEM in collaboration with SciEnergy Co., Ltd., Japan
  - Electrodes: produced by a chemical etching
  - Holes: pierced by drilling
  - Insulator: The glass epoxy laminate (FR5)
  - Metal foil: 6μm-cupper
  - Active area: 3×3 cm2



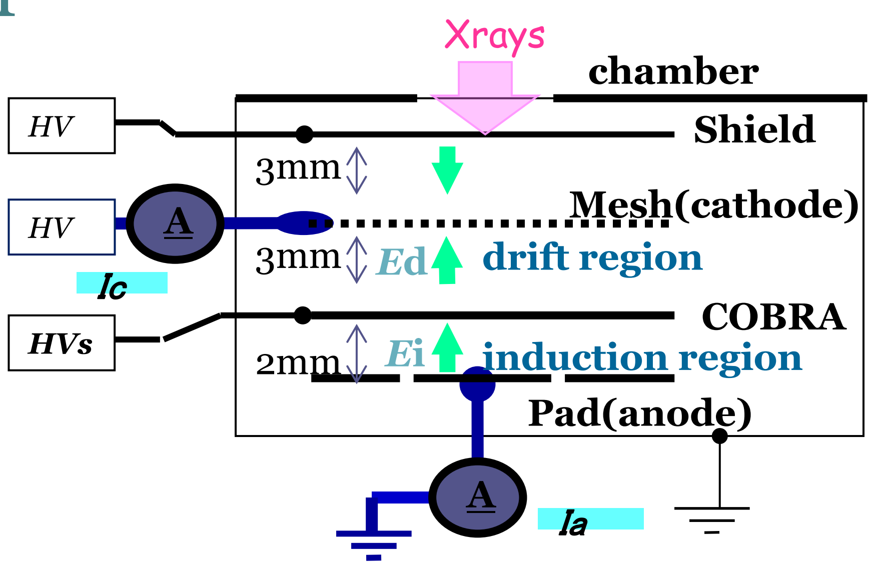
Cross-section drawing of COBRA GEM

Insulator thickness	Hole pitch	Hole diameter	Rim width	Metal width
200 μm	0.5 mm	150 μm	50 μm	50 μm
400 μm	1.0 mm	300 μm	100 μm	100 μm

Results

- Single COBRA configuration
  - GEM: 200 μm and 400 μm COBRA GEM
  - Gas: Ne/CO2 (90/10) and Ar/CO2 (70/30) at atmospheric pressure
  - X-ray beam is injected perpendicular to the surface of COBRA GEM
  - Readout pad: 3×3 cm2
  - Drift length = 3 mm
  - *E*d = 0.4 kV/cm
  - *E*i = 3.0 kV/cm
  - IBF≡(*I*c-*I*c⁰)/*I*a

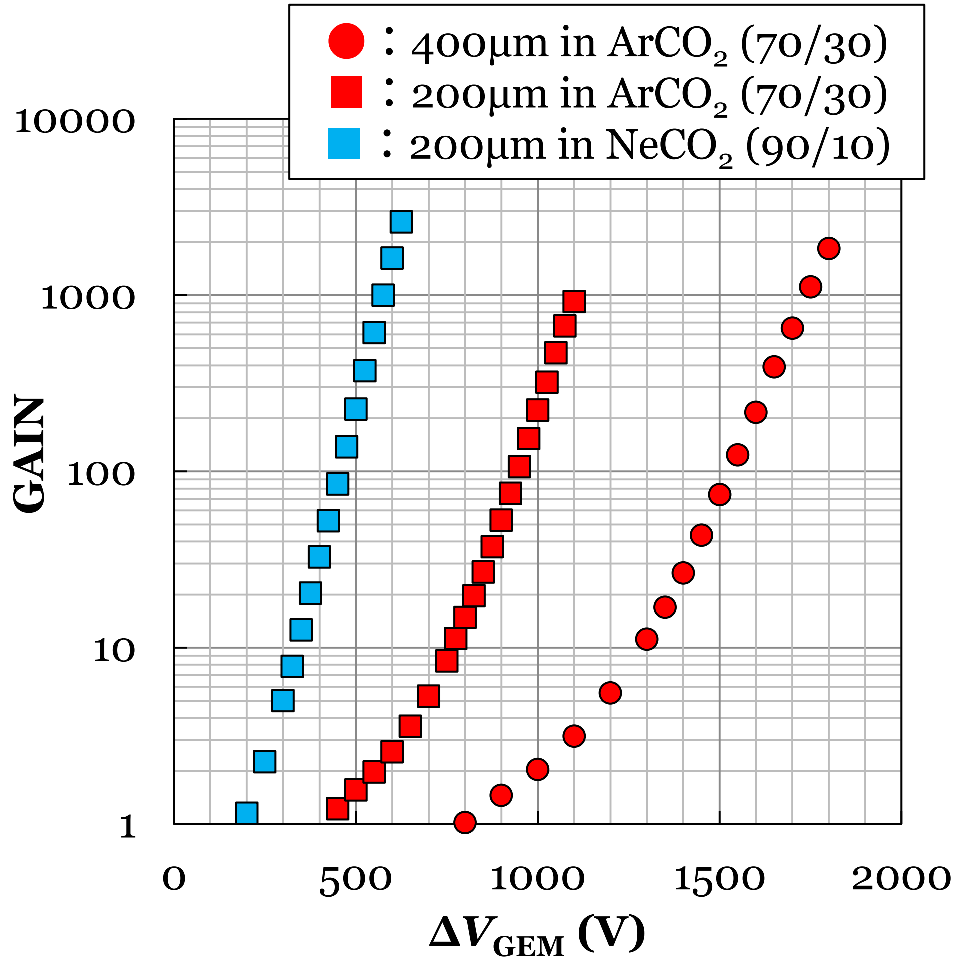
    *I*c⁰: primary ion current



A schematic view of the single configuration

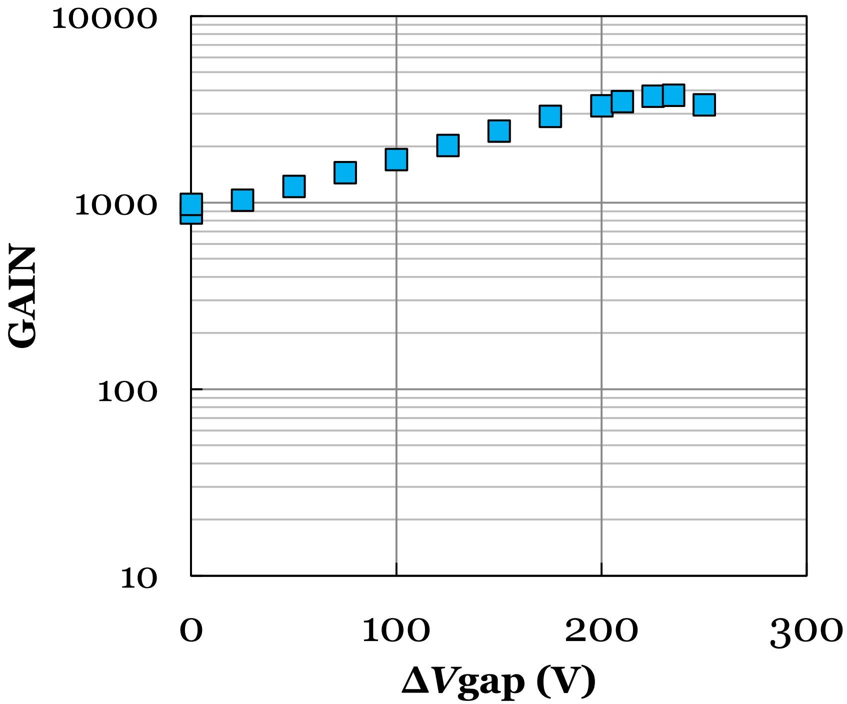
GAIN curve (single COBRA)

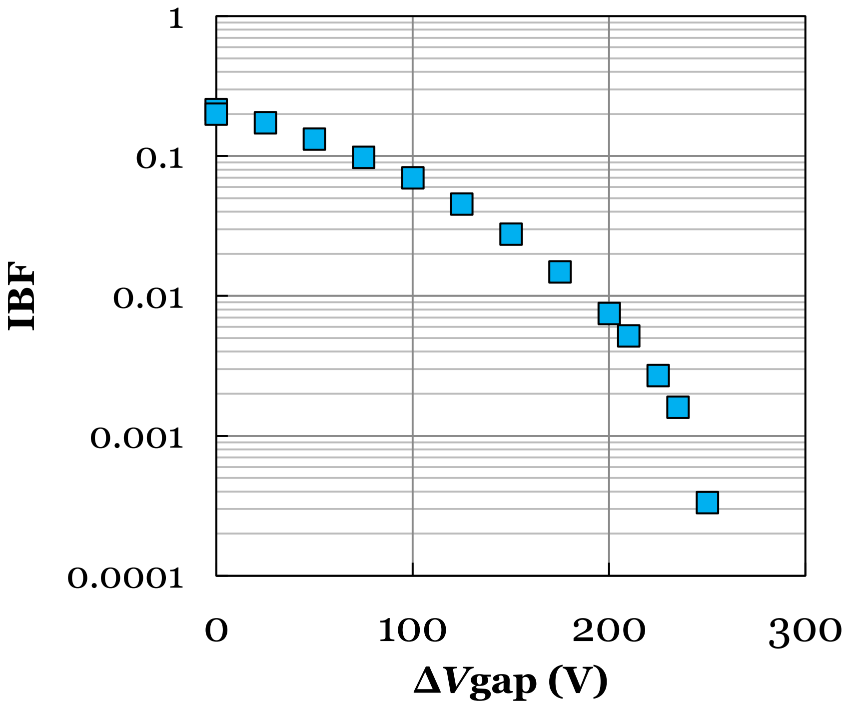
- No ΔVgap mode (like Thick-GEM)
  - Drift length = 3 mm
  - Ed=0.4 k/cm
  - Ei=3.0 kV/cm
- Gain can reach more than 10^3 with a single COBRA.
- IBF ~ 20% at gain~ 10^3



GAIN and IBF (single COBRA)

- Changing Δ*V*gap

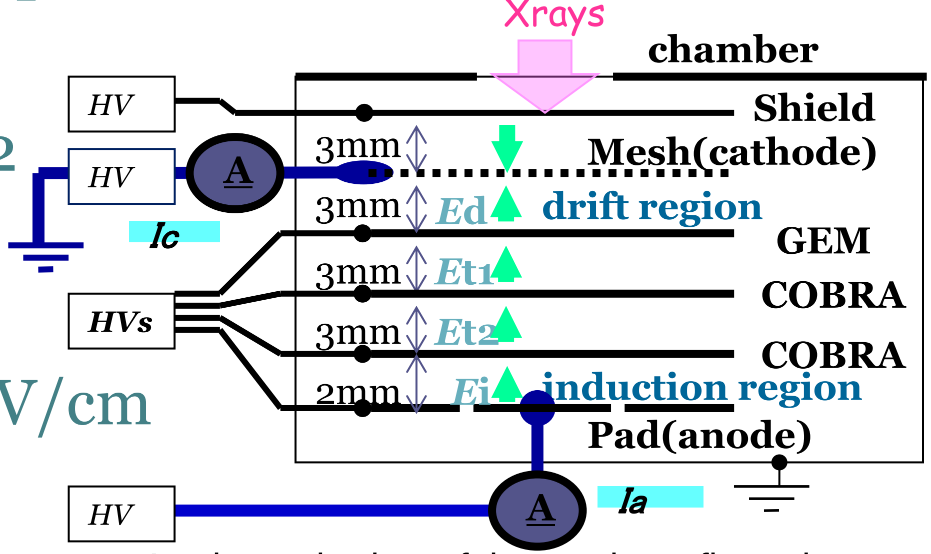




- ΔV_{GEM}=550V, 200μm COBRA in NeCO2 (90/10)
- Tube current=0.03 mA (The rate is comparable to that expected in ALICE TPC)
- Strong suppression of IBF as Δ*V*gap goes to higher
- Increase of gain due to improvement of electron collection
- Decrease of gain due to reversed potential between drift plane and COBRA

Results

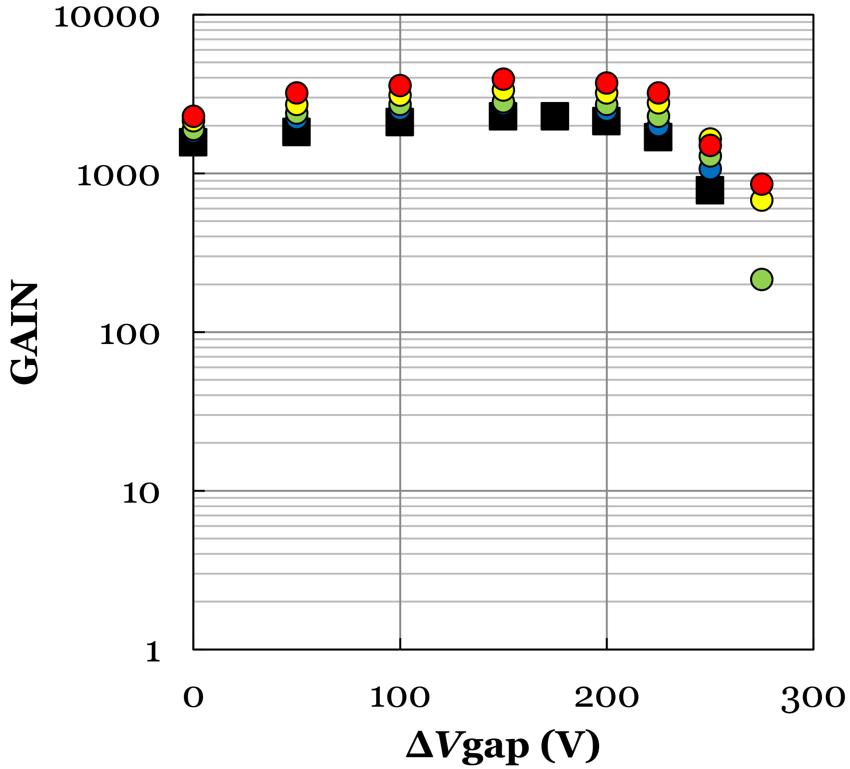
- Stack configuration (standard-COBRA-COBRA)
  - GEM: 50μm standard GEM and 200 μm COBRA GEM
  - Gas: Ne/CO_2 (90/10) at atmospheric pressure
  - X-ray beam is injected perpendicular to the surface of COBRA GEM, and its rate is comparable to that expected in ALICE TPC
  - Readout pad: 3×3 cm^2
  - Drift length = 3 mm
  - ΔV_{GEM1} = 200 V
  - Ed = Et1 = Et2 = 0.4 kV/cm
  - Ei = 3.0 kV/cm

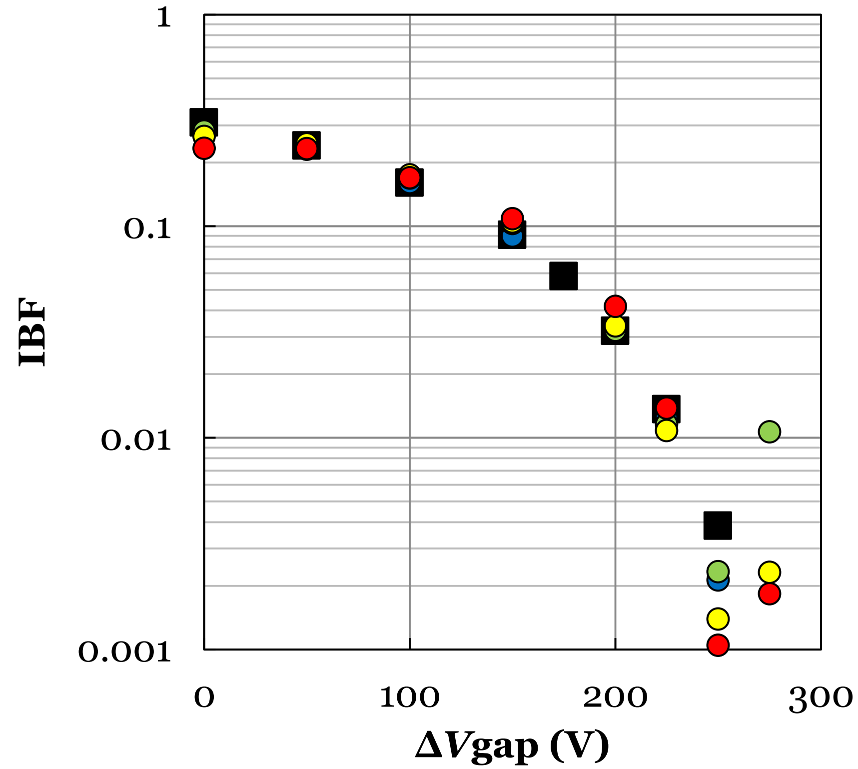


A schematic view of the stack configuration

GAIN and IBF ($\Delta V_{\mathrm{GEM2\&3}}$ scan)

■: $\Delta V_{\mathrm{GEM2,\,3}}$ = 430, 430 V
●: 390, 470 V, ●: 350, 510 V, ●: 310, 550 V, ●: 260, 590 V





- V_{GEM1} = 200 V, Drift=3 mm
- Strong IBF suppression (0.1-0.5%) when Δ*V*gap=250V

Summary and outlooks

- We have successfully developed COBRA GEMs with two different geometries.
- The gain with the single COBRA GEM configuration reached to more than 10^3 and the COBRA GEM achieved 10 times better IBF suppression compared to the standard GEM with the stack configuration.

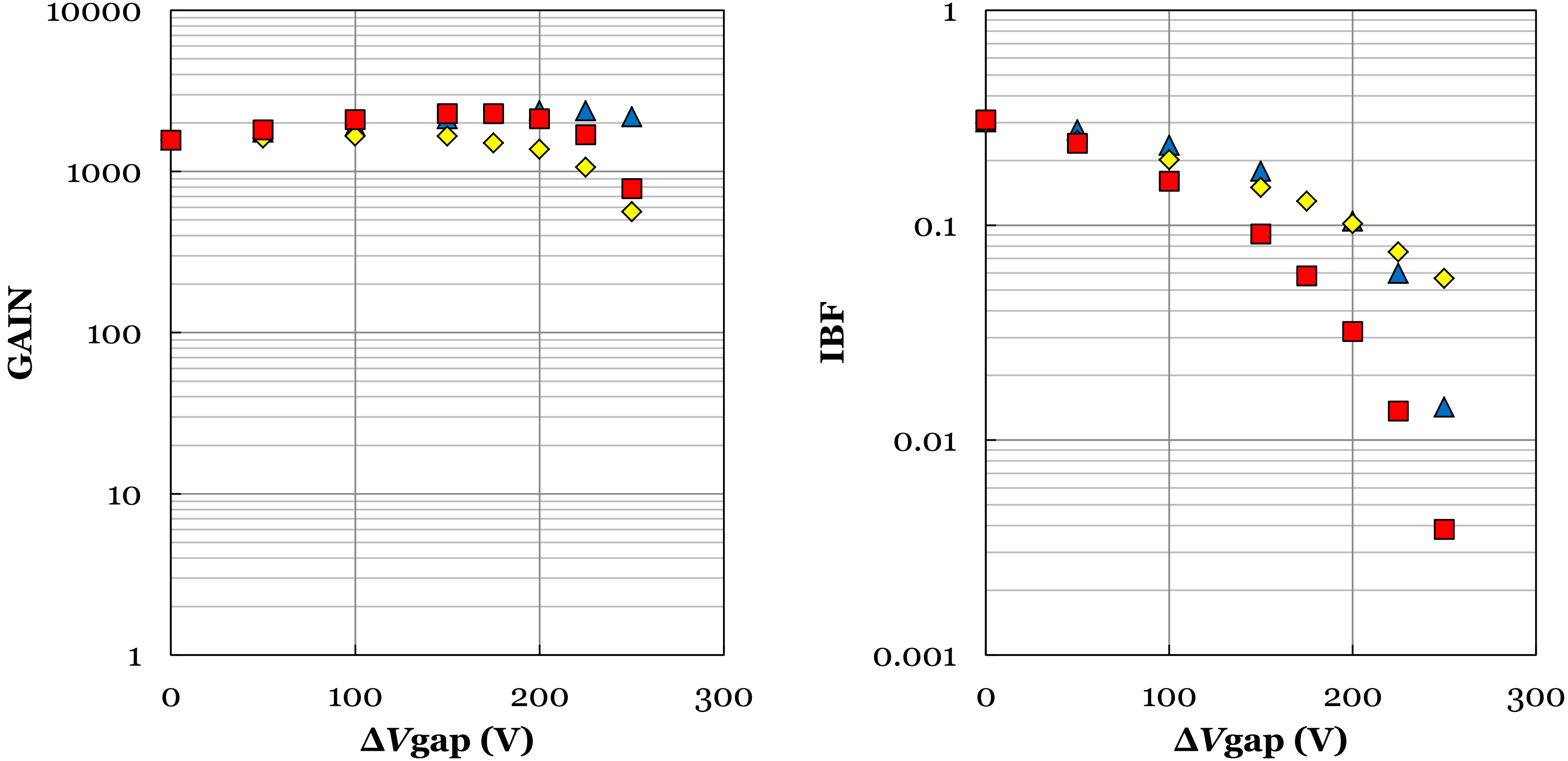
- The optimization for IBF suppression are being studied.
- We are going to evaluate gain stability and energy resolution.
- In addition, we are developing a 100 μm-thick COBRA GEM without rim.

Thank you for your kind attention

Back up

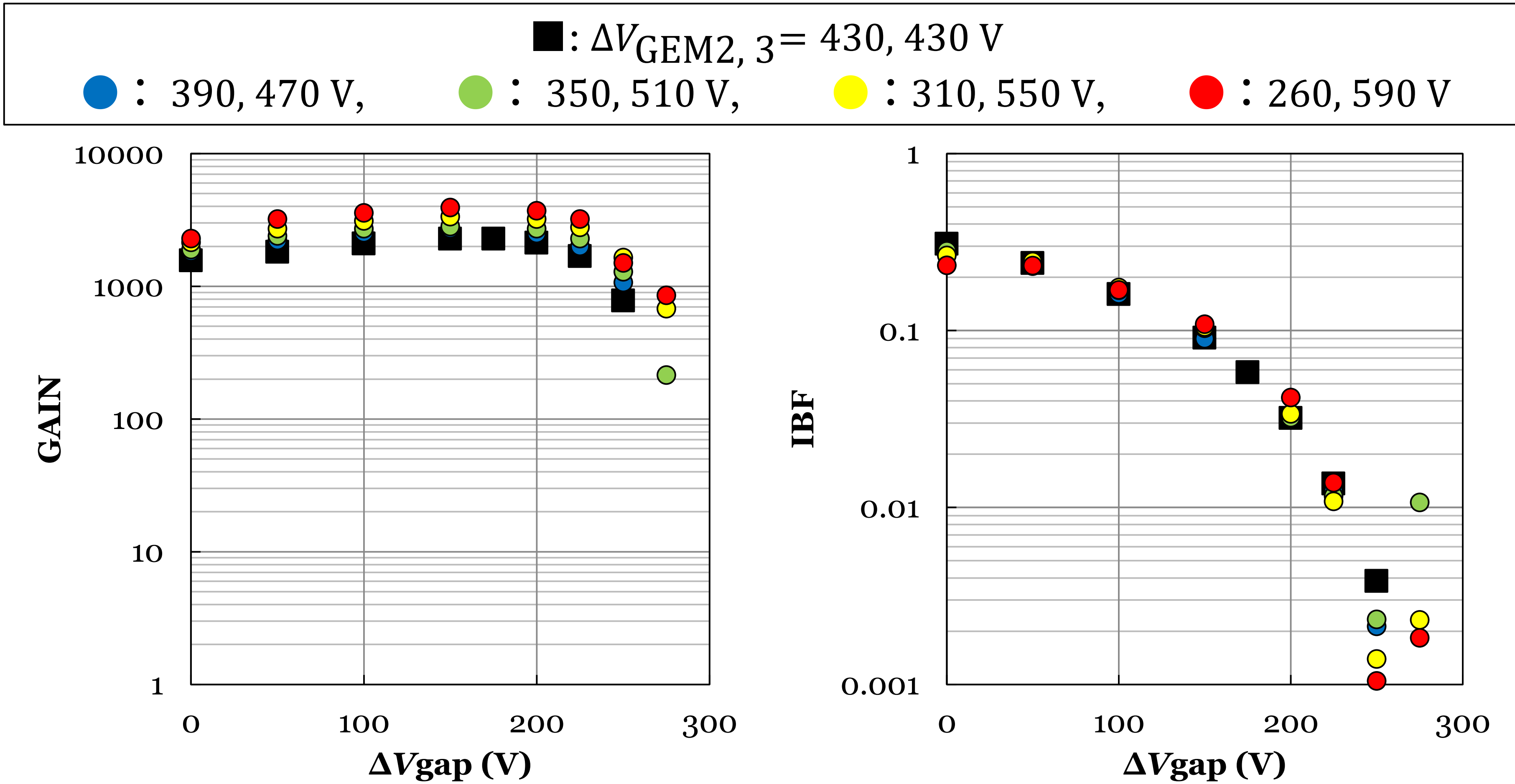
GAIN and IBF (Changing ΔV_{gap})

▲:Change ΔVgap of only COBRA2, ◆:only COBRA3, ■:COBRA 2 and 3



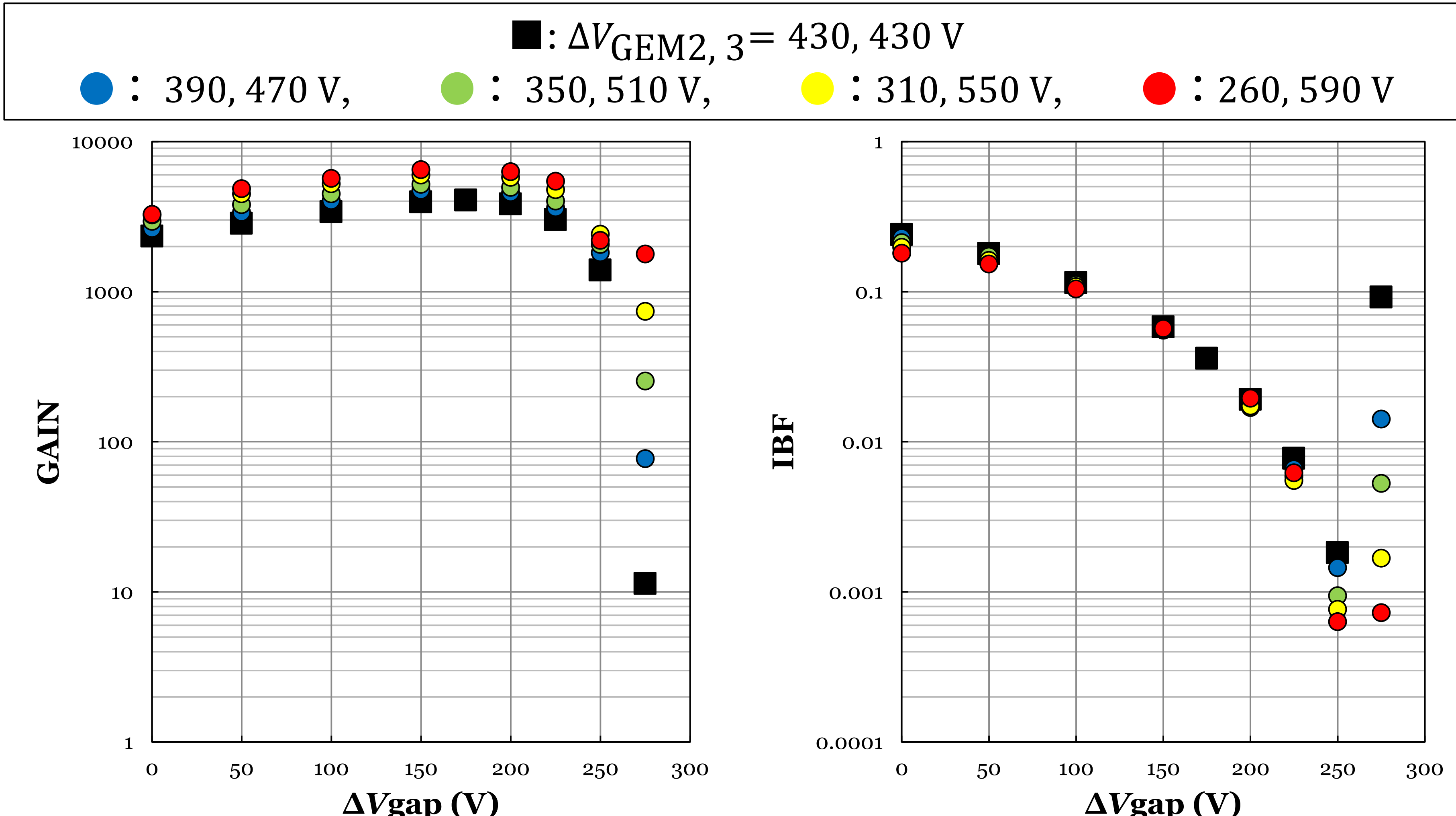
- $V_{GEM1,GEM2,GEM3}$ = 200 V, 430 V, 430 V, Drift=3 mm
- Tube current= 0.03 mA (The rate is comparable to that expected in ALICE TPC)
- E_d = 0.4 kV/cm, E_{t1} = 0.4 kV/cm, E_{t2} = 0.4 kV/cm, E_i = 3.0 kV/cm

GAIN&IBF ($\Delta V_{GEM2\&3}$ scan)



- V_{GEM1} = 200 V, Drift=3 mm
- Tube current= 0.03 mA (The rate is comparable to that expected in ALICE TPC)
- E_d = 0.4 kV/cm, E_{t1} = 0.4 kV/cm, E_{t2} = 0.4 kV/cm, E_i = 3.0 kV/cm

GAIN&IBF ($\Delta V_{GEM2\&3}$ scan)

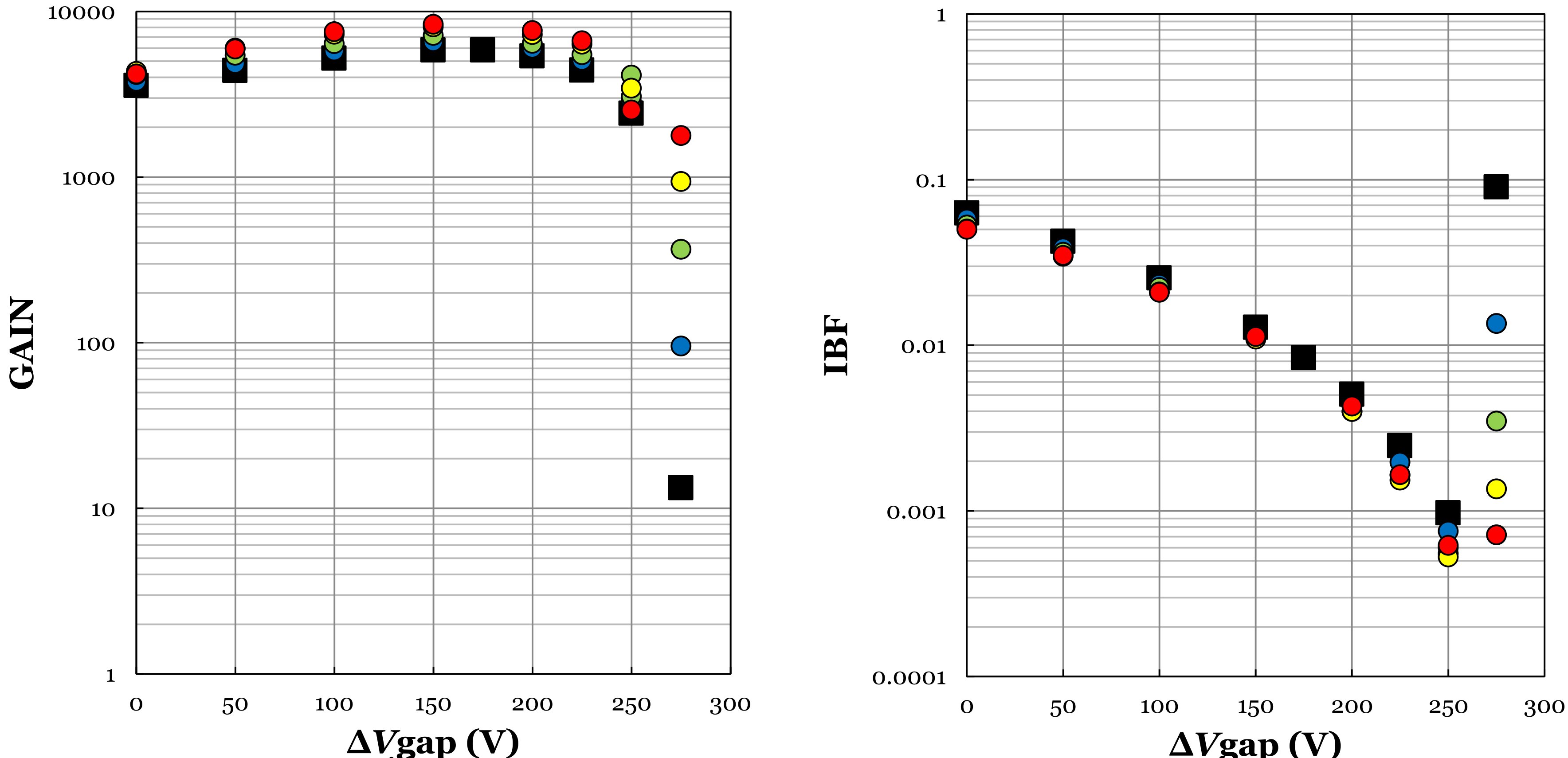


- V_{GEM1} = 200 V, Drift=3 mm
- Tube current= 0.3 mA
- E_d = 0.4 kV/cm, E_{t1} = 0.4 kV/cm, E_{t2} = 0.4 kV/cm, E_i = 3.0 kV/cm

GAIN&IBF ($\Delta V_{GEM2\&3}$ scan)

■ : $\Delta V_{GEM2,\,3}$ = 430, 430 V

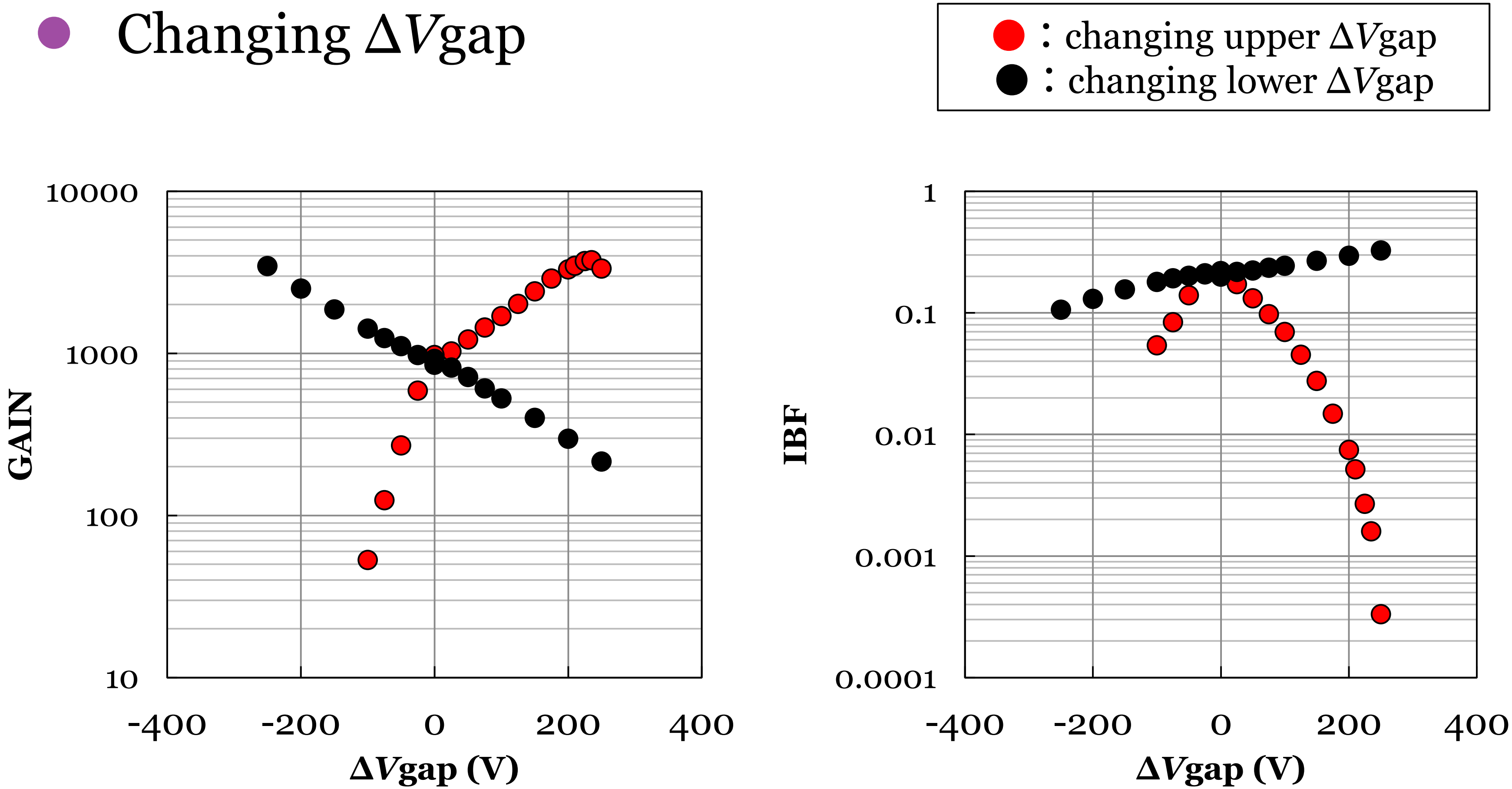
● : 390, 470 V, ● : 350, 510 V, ● : 310, 550 V, ● : 260, 590 V



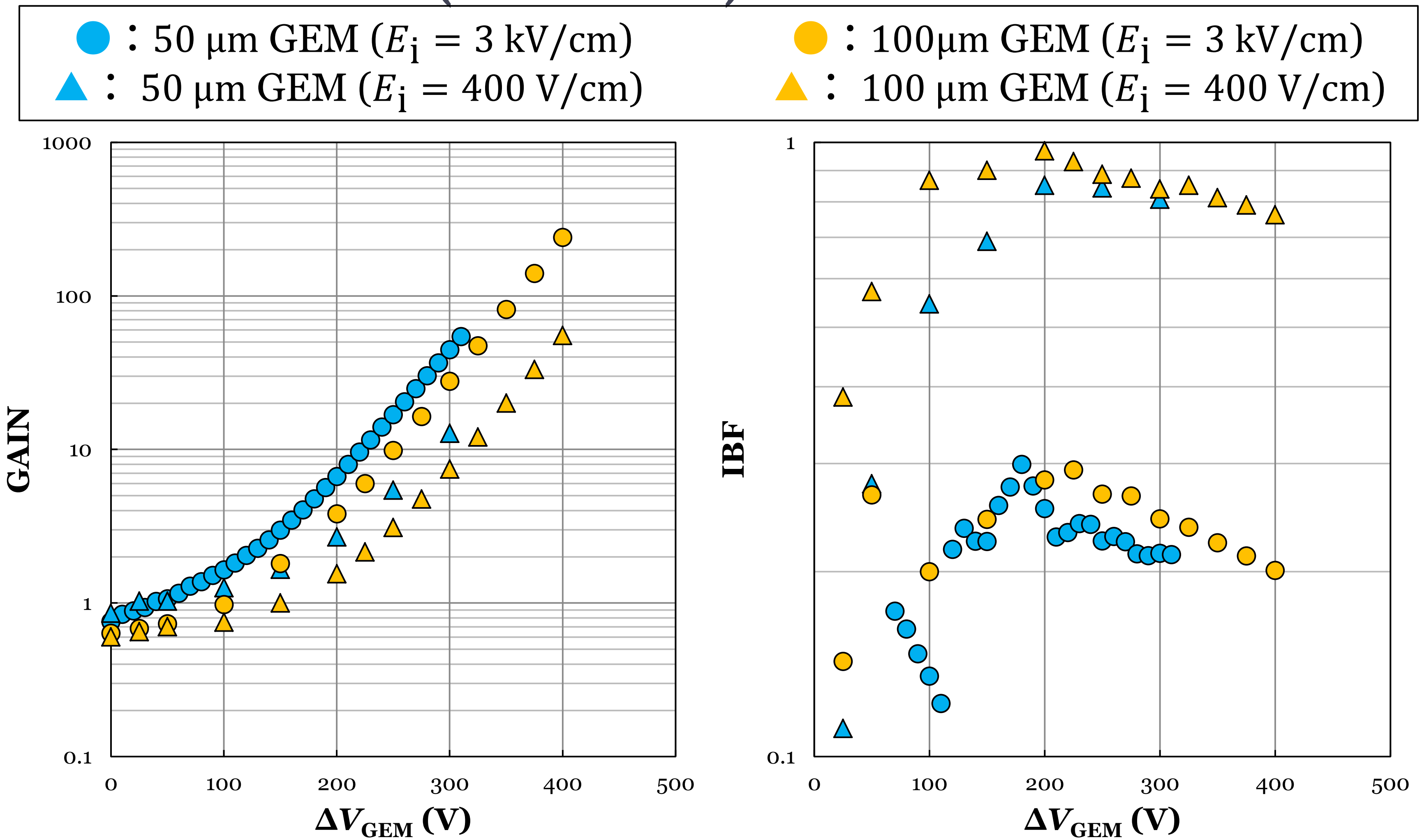
- V_{GEM1} = 200 V, Drift=3 mm
- Tube current= 3 mA
- $E_d = 0.4$ kV/cm, $E_{t1} = 0.4$ kV/cm, $E_{t2} = 0.4$ kV/cm, $E_i = 3.0$ kV/cm

GAIN and IBF (single COBRA)

- Changing Δ*V*gap



GAIN&IBF (NeCO2)



- Drift=3 mm, tube current=3 mA

Potential in induction+COBRA+drift