Electron Transmission Measurement of GEM Gate

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Introduction

- Gating for LC-TPC
  - TPC has to take data for a whole train (≒1msec)
  - If we have imperfect gating device, locally dense ions produce non-uniform E field
- Gating device is necessary for GEM module at LC-TPC
  - Gating device ⇒ wire, micromesh, GEM

Dead region due to the frame to support wires

Change E_D

Local change of E at GEM gate

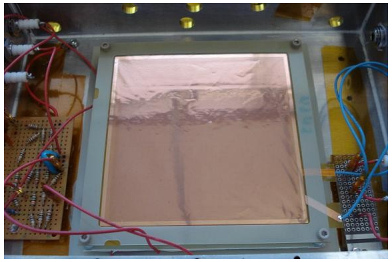
Motivation

- GEM Gate
  - Ion feedback < 10^{-4} at reverse bias (by sim.) ← O.K.
  - Electron transmission eff. is important
    - More N_{eff} is better for resolution

$$\sigma^2 = \sigma_0^2 + \left(C_D \middle/ \sqrt{N_{eff}} \right)^2 z$$

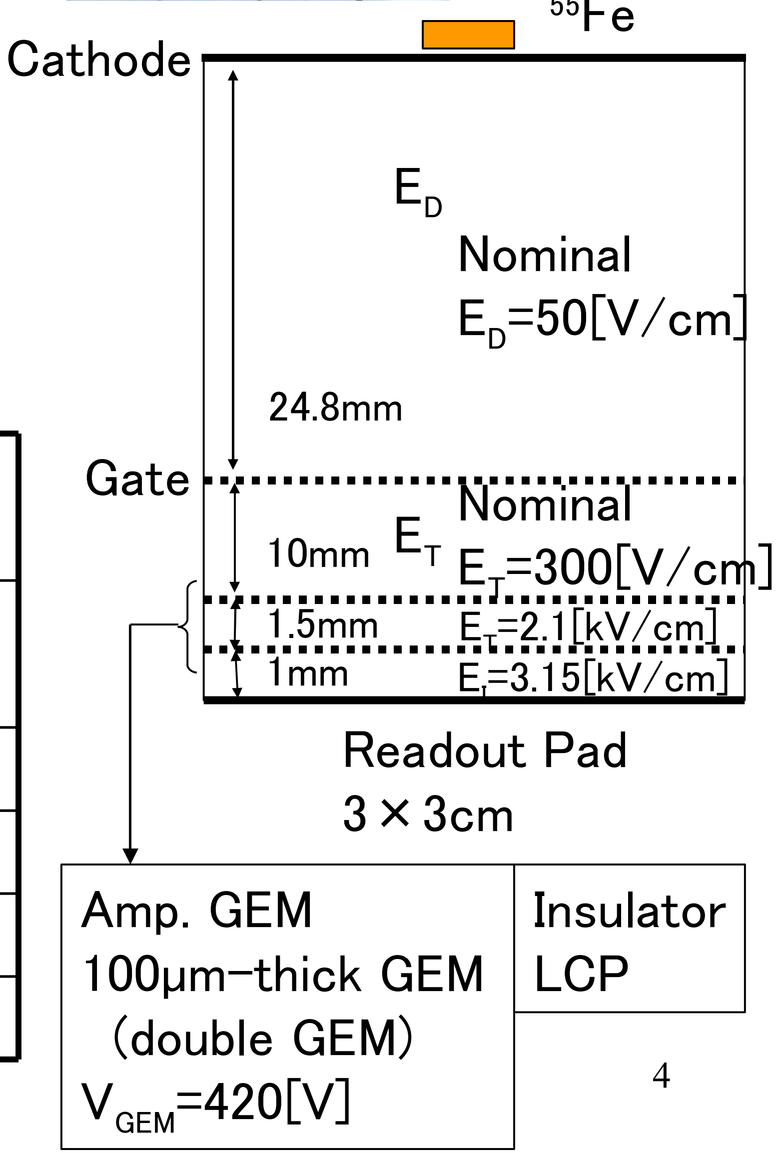
- Electron transmission measurement of GEM gate
  - w/wo B field
  - Systematic study of transmission
  - Comparison simulations with measurements

Experimental Setup



- $Ar:isoC_4H_{10}$ (90:10)
- B = 0 and 1T (at KEK C.C.)
- Using 3 kinds of GEM

Gate GEM	Standard	Thin	Thin – Wide
Insulator Thickness	50[μm]	25[μm]	25[μm]
Hole diameter	70[μm]	70[μm]	90[μm]
Cu thickness	5[μm]		
Hole pitch	140[μm]		
Insulator	polyimide		



^{55}Fe

Cathode

E_D

Nominal

E_D=50[V/cm]

24.8mm

Gate

Nominal

10mm E_T E_T=300[V/cm]

1.5mm E_T=2.1[kV/cm]

1mm E_I=3.15[kV/cm]

Readout Pad

3×3cm

Amp. GEM

100μm-thick GEM

(double GEM)

V_{GEM}=420[V]

Insulator

LCP

Method of Measurement

- Electron transmission efficiency
  - Ratio of ❷ to ❶

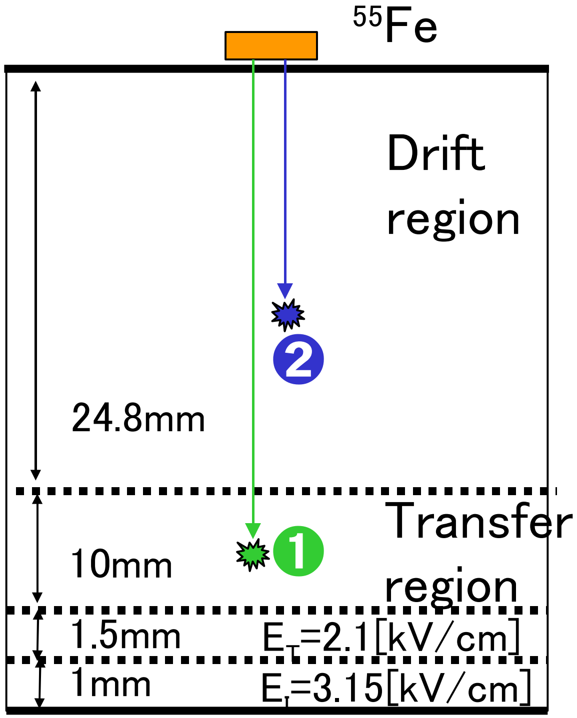
❷conversion at drift region

Electron loss by Gate

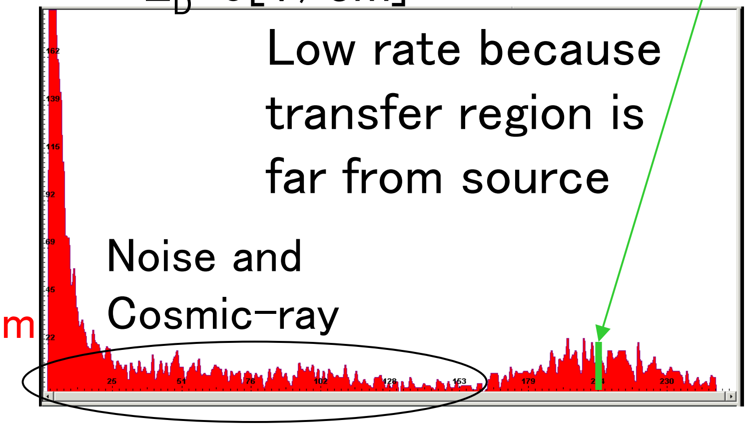
❶conversion at transfer region

No effect by Gate
(ie. trans. eff. = 1)
E_D=0[V/cm]

Gate

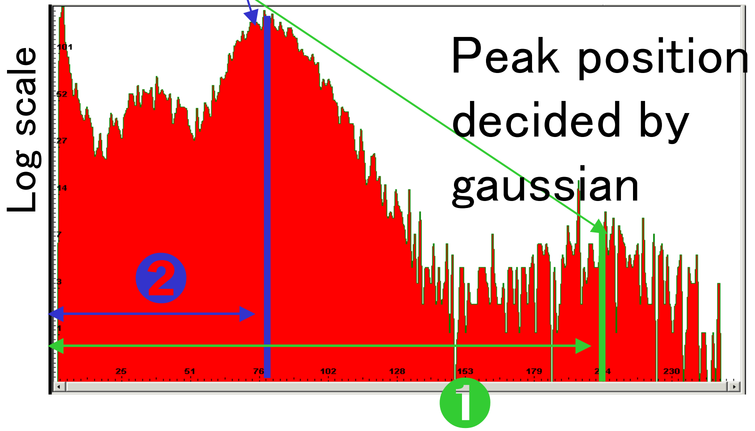


Signal charge spectrum



Low rate because transfer region is far from source

Noise and Cosmic-ray



Peak position decided by gaussian

Measured Transmission

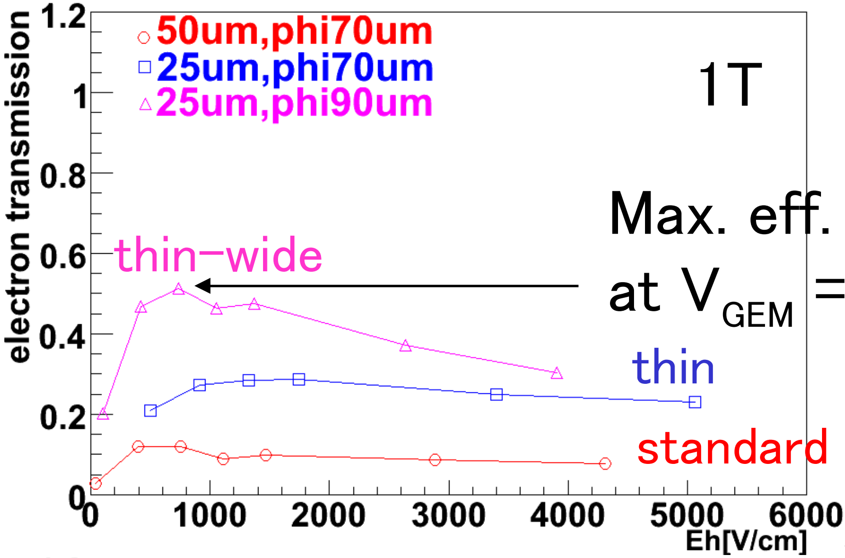
Nominal
E_D=50[V/cm]
E_T=300[V/cm]

- GEM structure
  - Thinner GEM with larger holes is better for transmission

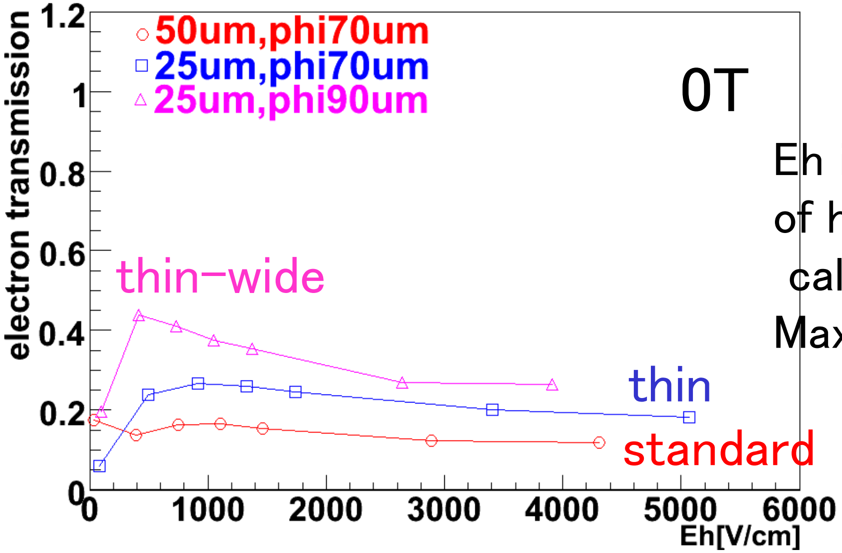
Thinner ⇒ transmission increase

Larger hole ⇒ # of electrons into the hole increases

Higher Eh ⇒ area of penetrating field line is narrower and some electrons return to GEM electrode by diffusion



Max. eff. > 50 % at V_{GEM} = 5 V

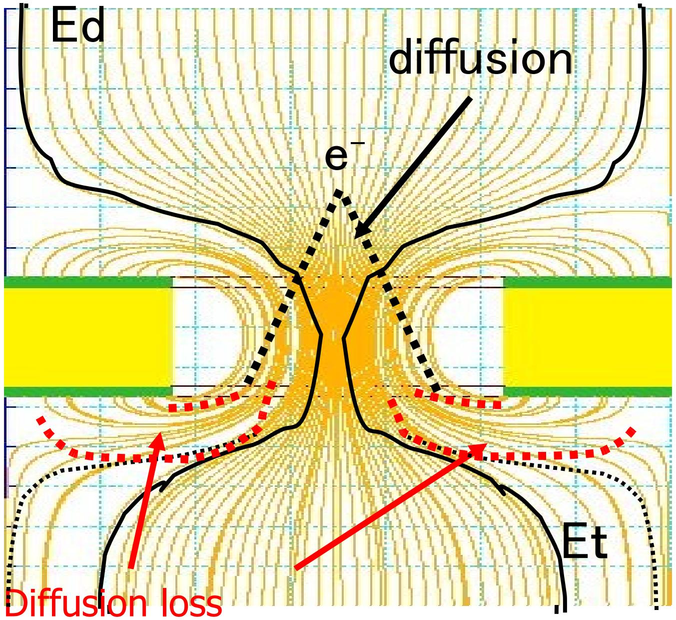


Eh is E field of hole center calculated by Maxwell3D

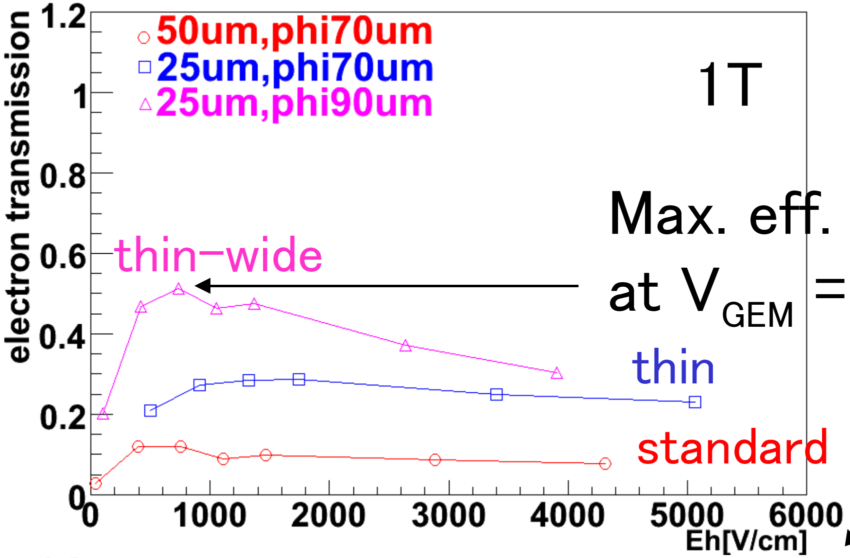
Measured Transmission

Nominal
E_D=50[V/cm]
E_T=300[V/cm]

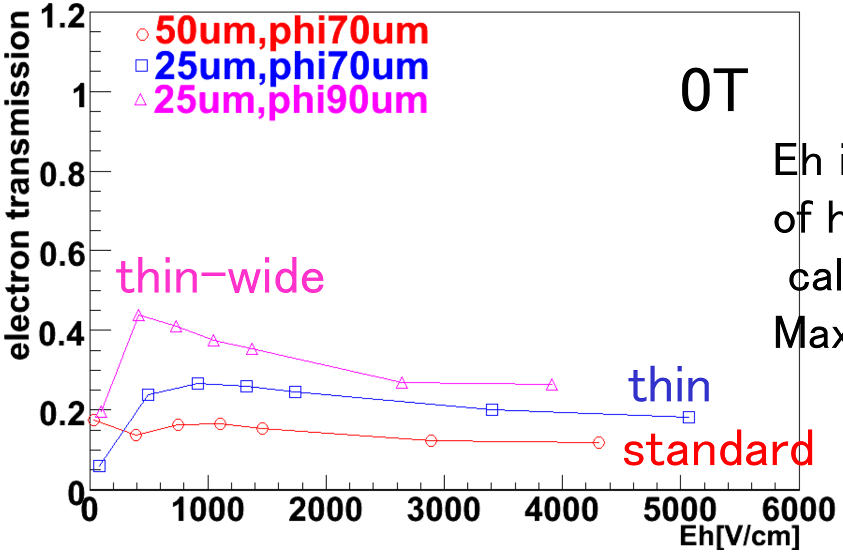
- GEM structure



Higher Eh ⇒ area of penetrating field line is narrower and some electrons return to GEM electrode by diffusion



Max. eff. > 50 % at V_{GEM} = 5 V



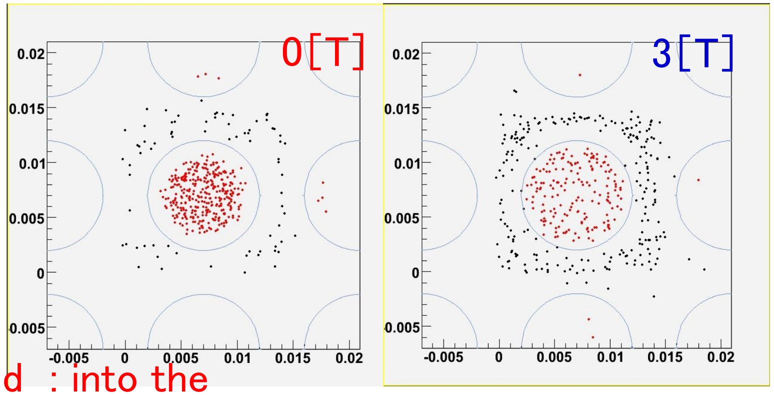
Eh is E field of hole center calculated by Maxwell3D

Measured Transmission

Nominal
E_D=50[V/cm]
E_T=300[V/cm]

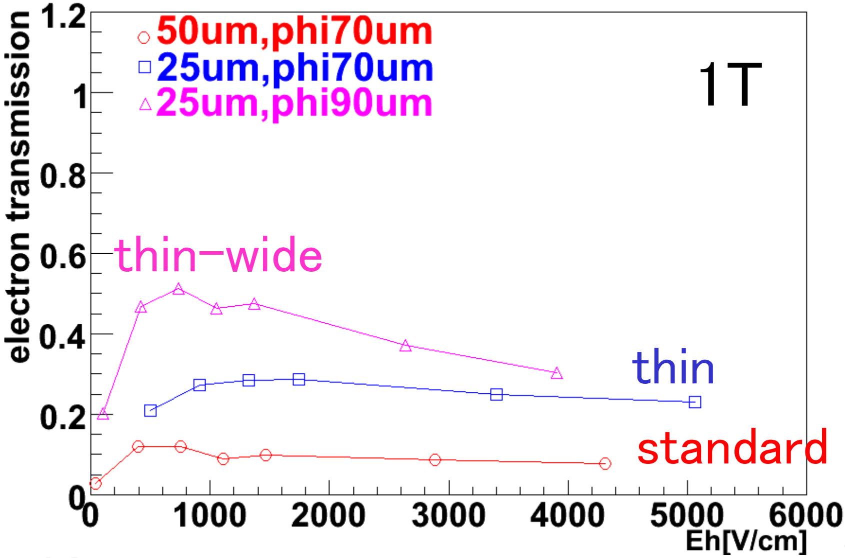
- B field dependency

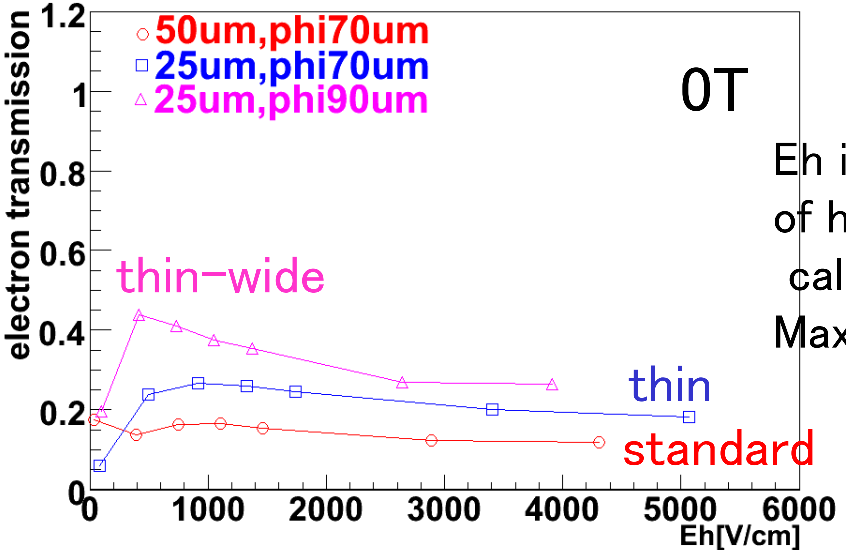
High B field ⇒ Electrons move along B field due to lorentz angle, # of electrons into the hole decreases



Red : into the hole
Black: arrived at electrode

- Data of 0 and 1T are not so big difference





Eh is E field of hole center calculated by Maxwell3D

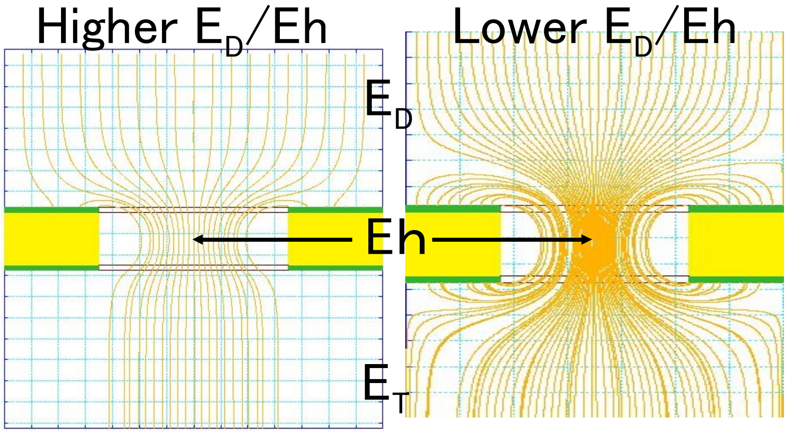
Measured Transmission

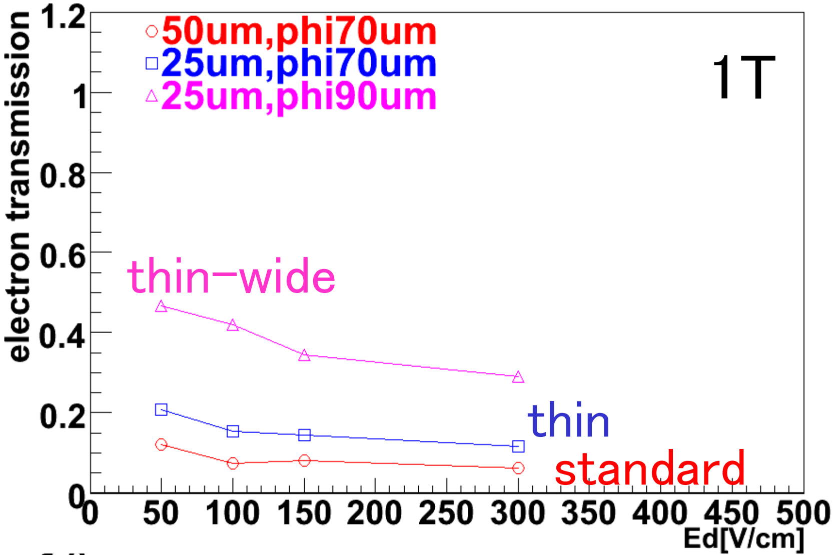
Nominal
E_T=300[V/cm]

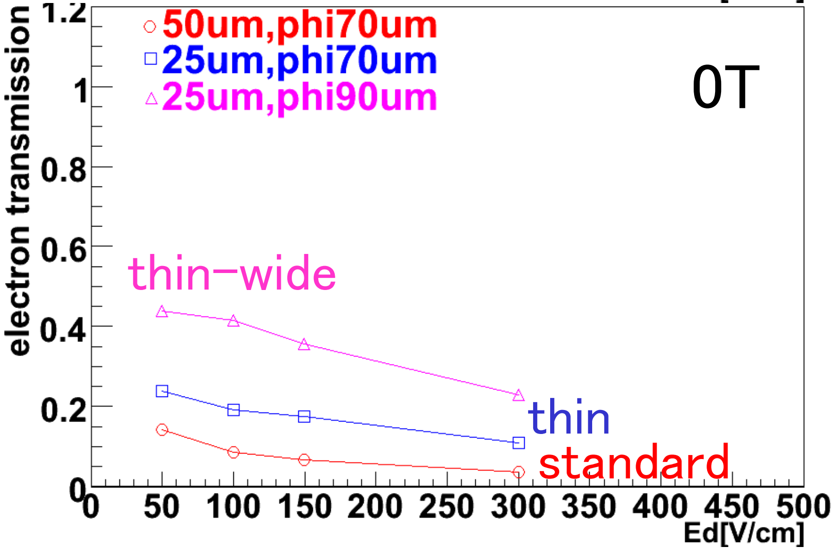
- E_D dependency
  - Lower E_D is better for transmission

Ratio of E_D and Eh

# of field line to the GEM electrode increases at higher E_D







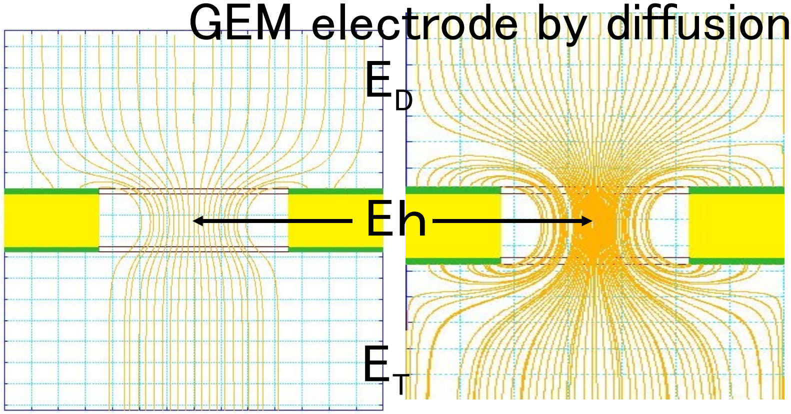
Measured Transmission

Nominal
E_D=50[V/cm]

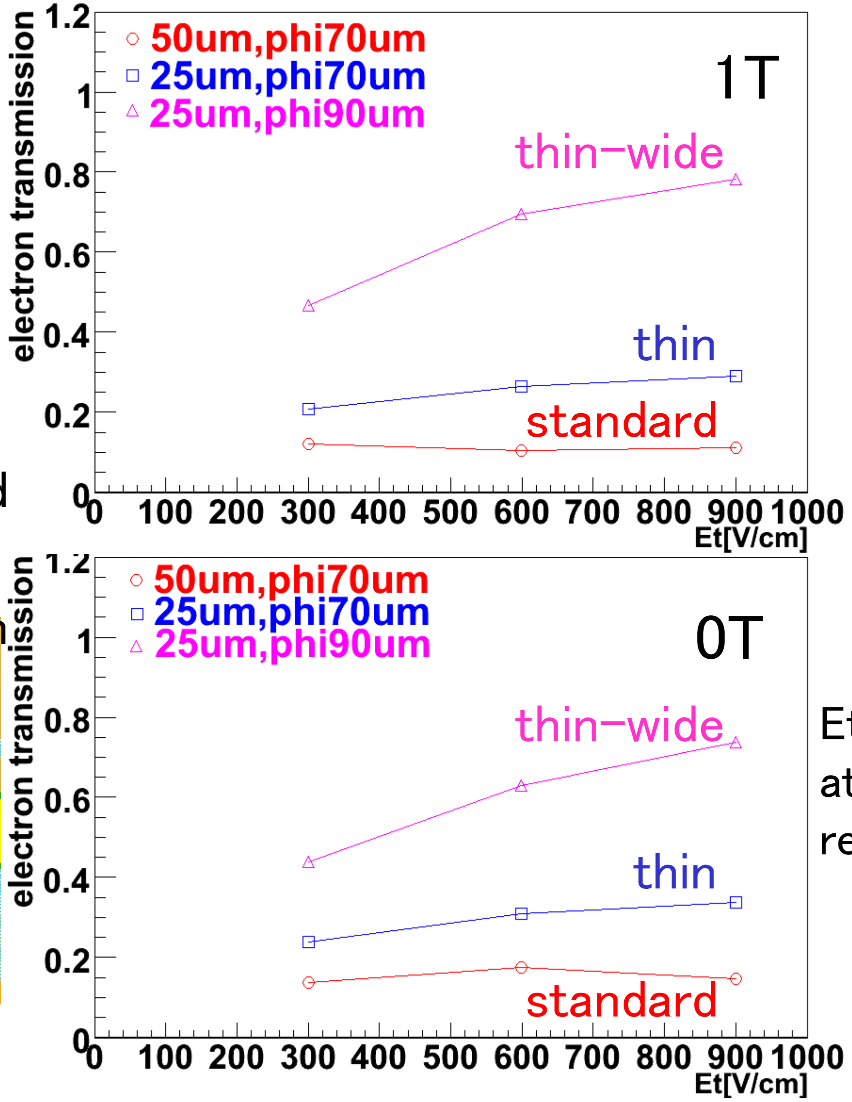
- E_T dependency
  - Higher E_T is better for transmission

Ratio of E_T and Eh

Area of penetrating field line is narrower at lower E_T and some electrons return to GEM electrode by diffusion



Higher E_T/Eh　　Lower E_T/Eh



Et is E field at transfer region

Short Summary of Results

- Electron transmission becomes better
  - at thinner GEM with larger holes
  - at lower E_D
  - at higher E_T

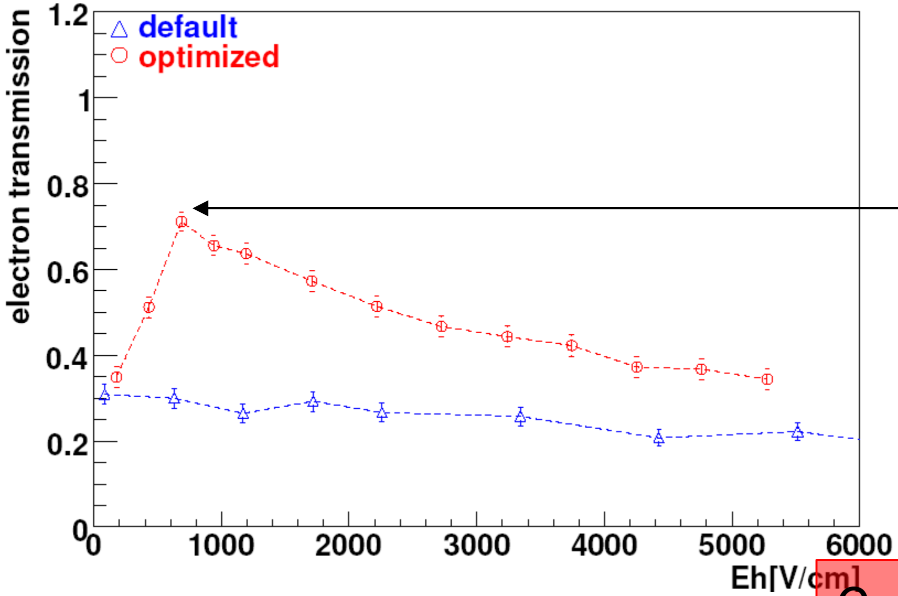
can not change E_D and E_T freely because of V_D and C_D

  - Optimization the structure of GEM gate at higher B

Optimization by Simulation

E field calculation : Maxwell3D

Electron drift sim. : Garfield



Electron transmission efficiency = 0.71

Studying possibilities to produce very thin and wide hole GEM

default

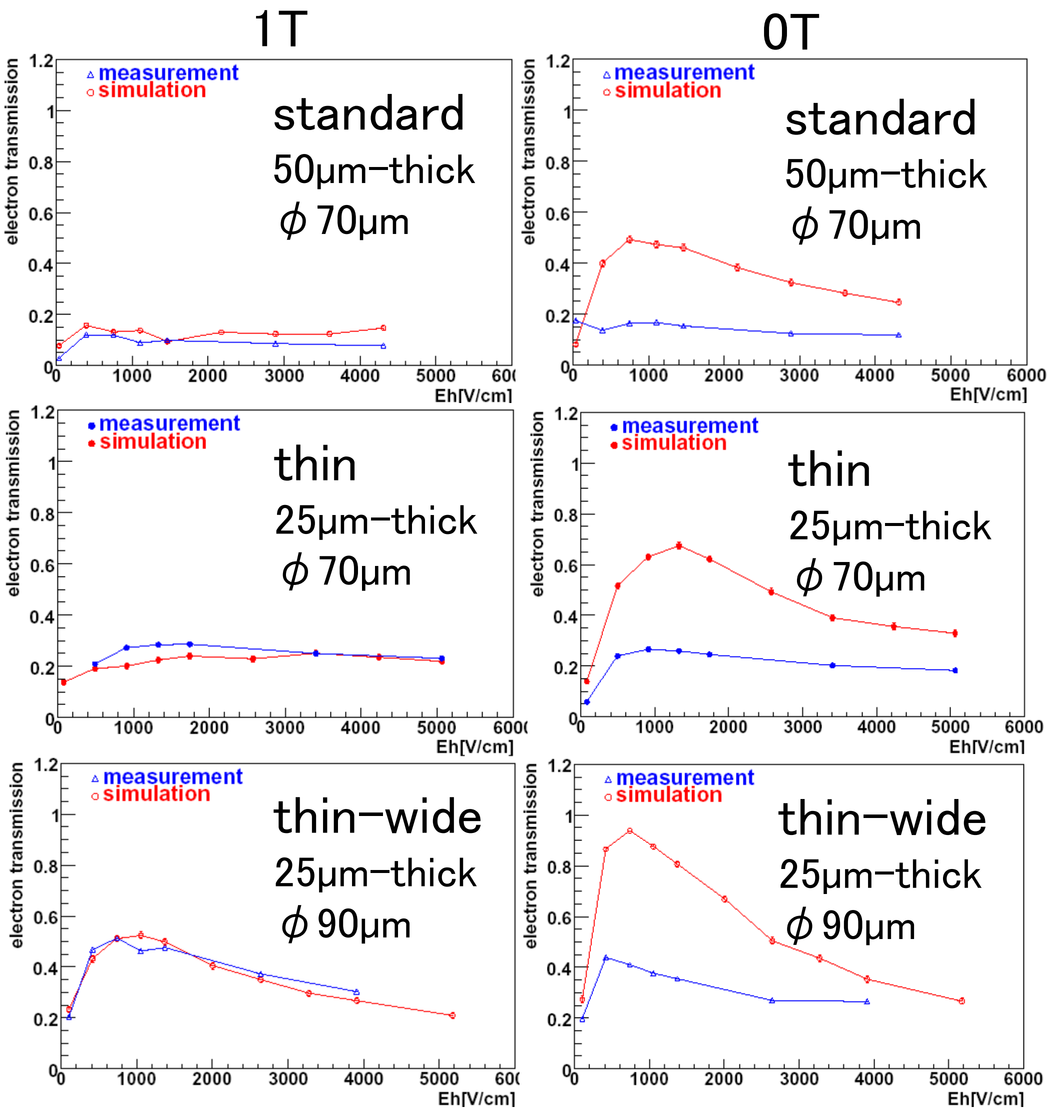
Condition gas=Ar-CF4(95:5)
E_D=150[V/cm], E_T=300[V/cm]
B=3[T]
GEM insulator thickness 50[um]
electrode thickness 5[um]
hole diameter 100[um]
hole pitch 140[um]

Optimized setup

Condition gas=$Ar-CF_4-isoC_4H_{10}$ (94:5:1)
E_D=120[V/cm], E_T=300[V/cm]
B=3[T]
GEM insulator thickness 12.5[um]
electrode thickness 1[um]
hole diameter 100[um]
hole pitch 140[um]

Comparison to Simulation

- B = 1T
  - Good agreement with sim.
- B = 0T
  - Not similar even in behavior
  - Sim. may have problem at 0T case ?



Summary

- Electron transmission eff. of GEM gate have been measured w/wo B field
  - Transmission becomes better at thinner GEM with larger holes w/wo B field　(25μm-thick, ϕ90μm)
  - Max. transmission eff. > 50 % at B = 1T
  - Transmission eff. ≒ 70 % by optimization

And…

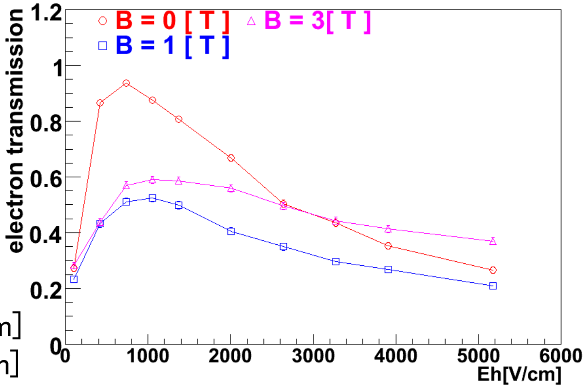
Studying to produce 12.5μm-thick and ϕ90μm GEM

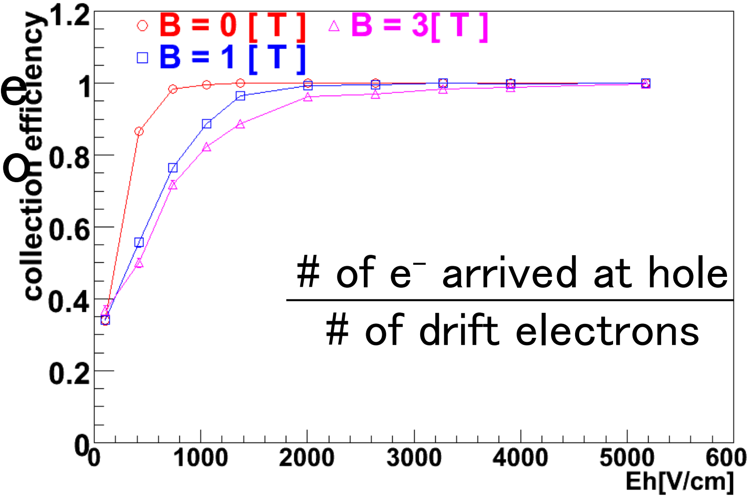
At other gas mixtures and higher field

Simulation

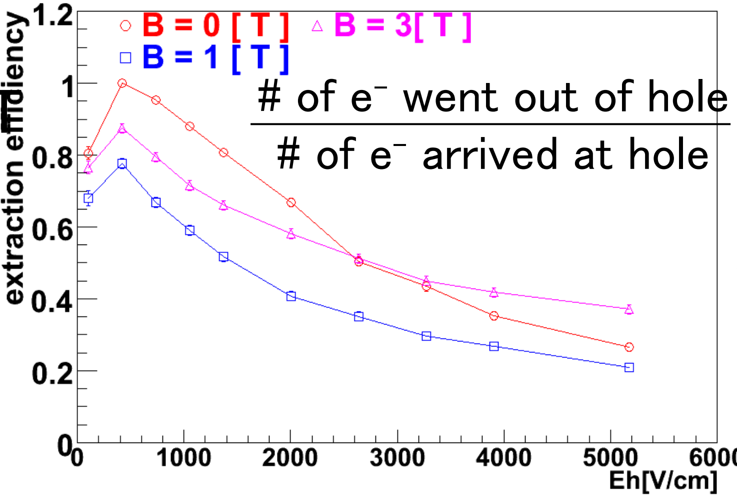
- Collection eff.
  - Electron move along B due to lorentz angle
  - seems reasonable
- Extraction eff.
  - Behavior of 0T seems to be different from with B

Simulation
Condition gas=Ar−isoC_4H_{10} (90:10)
E_D=50 [V/cm]
E_T=300 [V/cm]
B = 0 , 1 , 3 [T]
Thin−wide GEM
insulator thickness 25 [um]
hole diameter 90 [um]



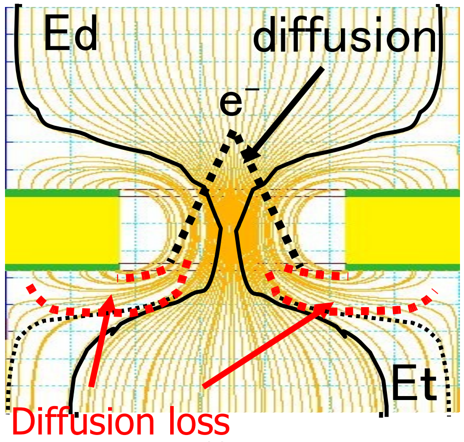


$$\frac{\text{\# of } e^- \text{ arrived at hole}}{\text{\# of drift electrons}}$$



$$\frac{\text{\# of } e^- \text{ went out of hole}}{\text{\# of } e^- \text{ arrived at hole}}$$

Collection eff.
# of field line go to GEM electrode increases at lower Eh



Extraction eff.
Area of penetrating field line is narrower at higher Eh and some electrons return to GEM electrode by diffusion