R&D of gating GEM(thin GEM)

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Why gating GEM

simulation study

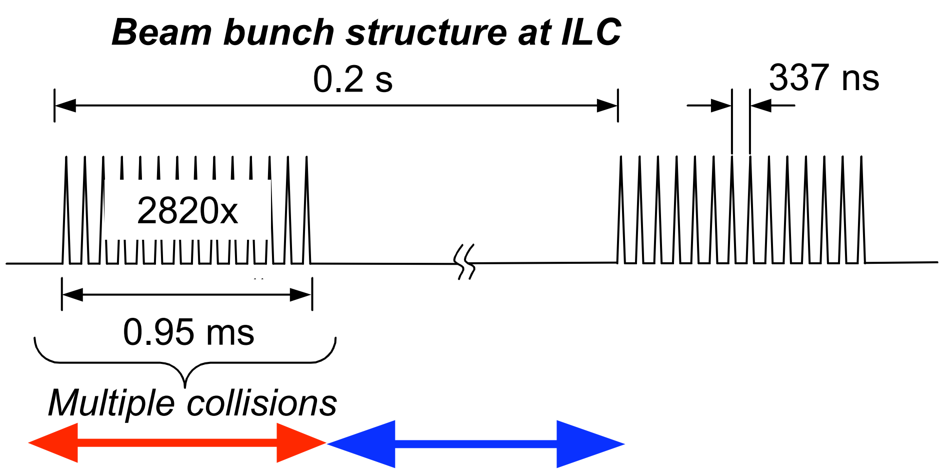
Measurement of electron transmission

Comparison of measurements and simulations

R&D of very thin GEM

Micro Pattern Gas Detector Workshop(RD-51)@NIKHEF 2008/4/18

Why we need gating GEM



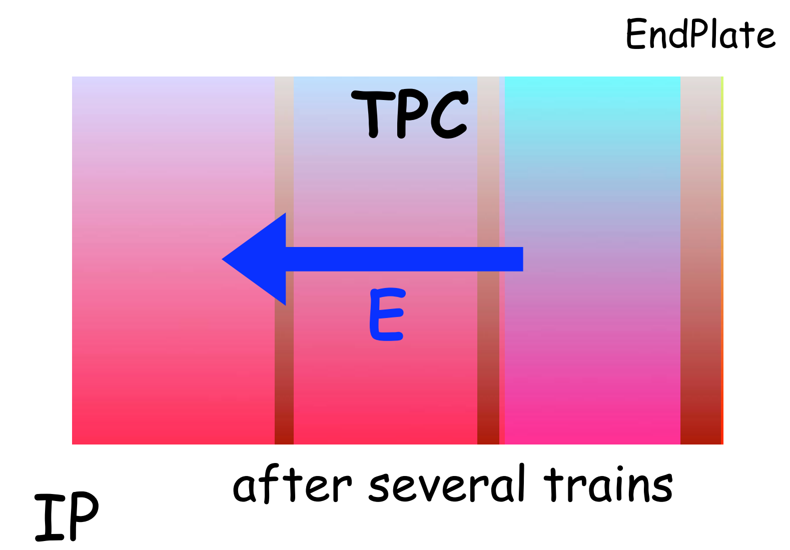
Why gating

Large pair background at ILC
and other bkg sources

primary ions are another issue

Ions produced at gas amplification build ion dense disk
and may deteriorate electric field dynamically

but ILC beam structure enable to use "gating mode"



MPGD has an inherent ability of ion blocking
3 GEM structure has a few x 10^{-3}
Micromegas has a few x 10^{-3}

Do we need GATE ??
Maybe... in case of GEM
Typical ion back drift of single GEM ~O(10%)
if we use @gain=10, same amount of ions as prim. e go back

Position Resolution

is naively expressed by $$\sigma_r = \sqrt{\sigma_0^2 + \frac{C_D^2 \cdot z}{N_{\mathrm{eff}}}}$$

$N_{prim.}$ is reduced by ionization statistics
gas gain fluctuation
finite pad size

$$N_{eff} = \frac{1}{\langle \frac{1}{N_{prim.}} \rangle} \left(\frac{1+\theta}{2+\theta} \right)$$

you can forget about a effect of finite pad size
as far as diff.@GEM > 0.3*pad pitch

in order to improve N_{eff}
we may want to increase gain at 1st GEM

Micro discharge may produce extra ions

Perfect gating can be achieved only with "GATING mode" operation.

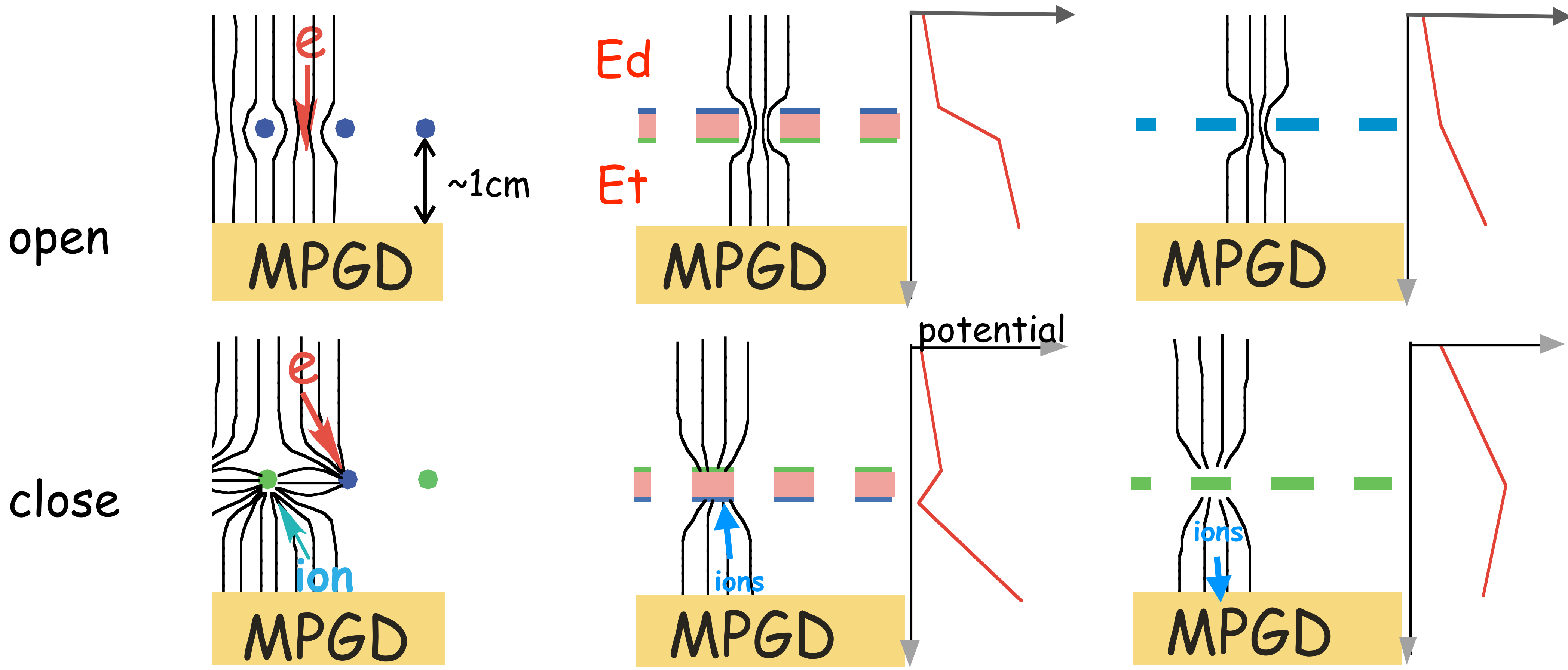
Why GEM

Gate: wire GEM micromesh

3 candidates

You may suggest us
to use wires for this.

But....



local change of E
wire tension
ExB

local change of E
electron transmission

change of drift E
electron transmission

F.Sauli, L.Ropelewski,P.Everaerts NIM A560(2006)269-277

F.Sauli show us a new usage of GEM as Gate device
with a certain gas mixture
and a possibility to improve Elec. trans.
modifying GEM struct.

High elec. transmission @ low VGEM

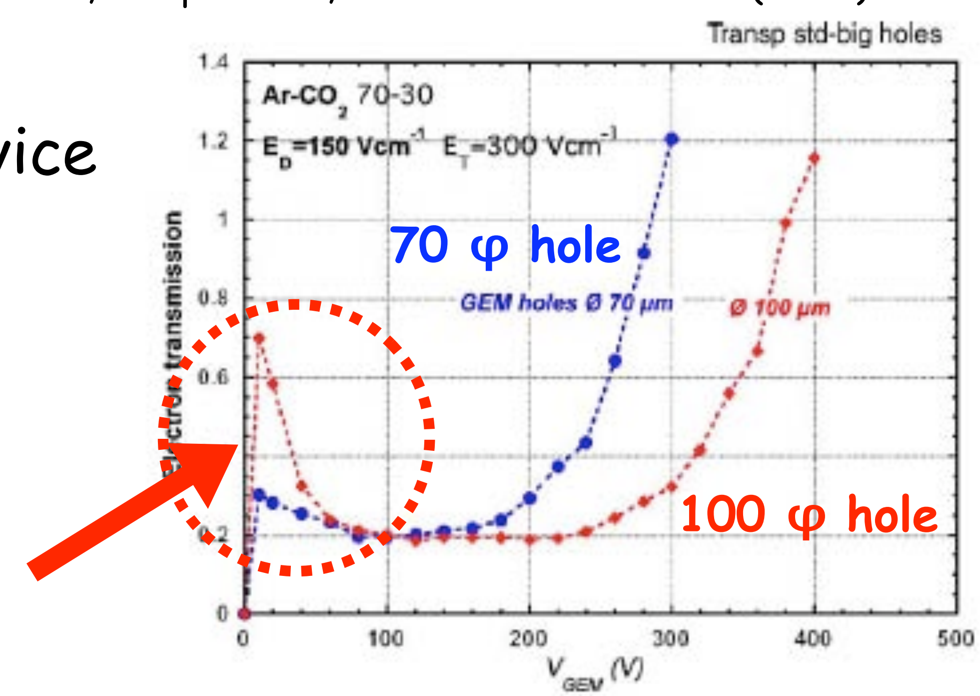


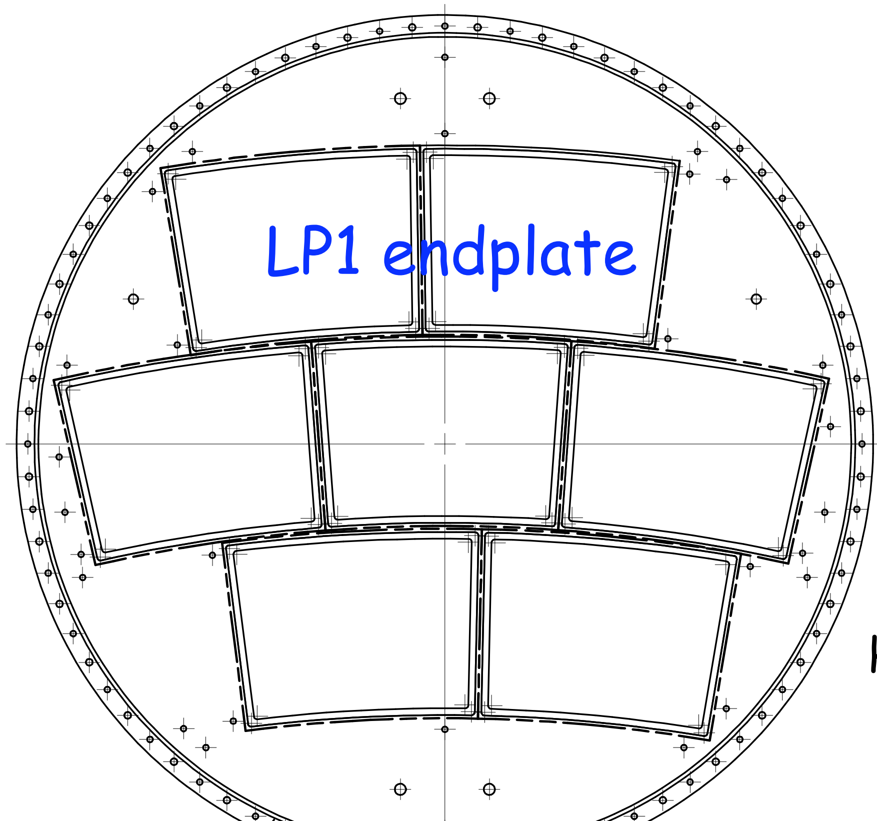
Fig. 6. Comparison of electron transmission for two GEM foils: standard

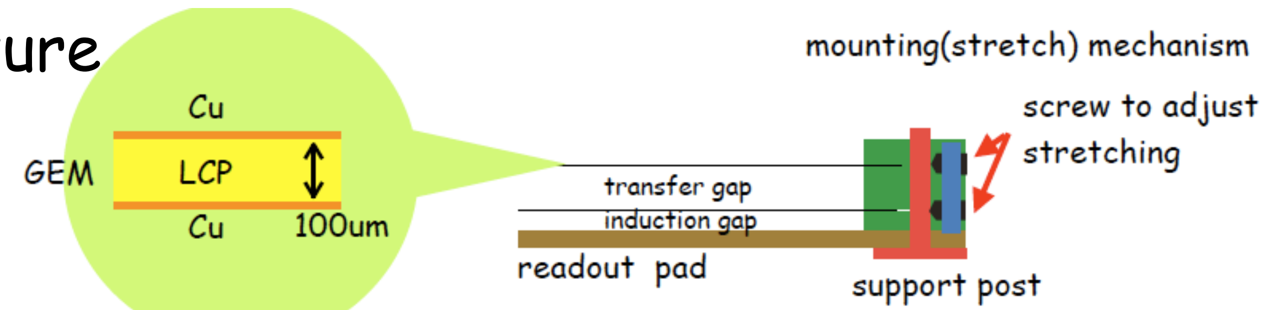
Why we don't want to use wire

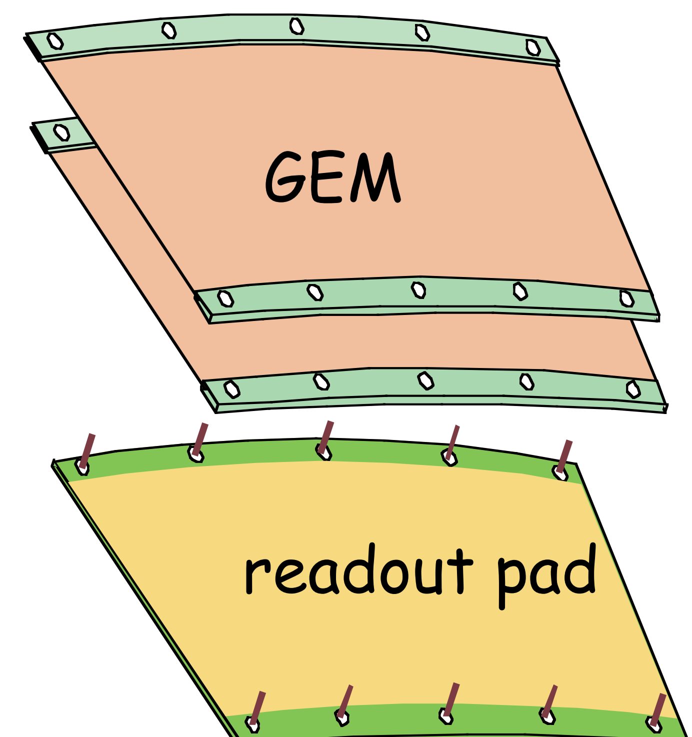
Major reason to stick with GEM as Gate instead of wires is

Wire needs frame to be hold
and
doesn't go with LP1 panel structure

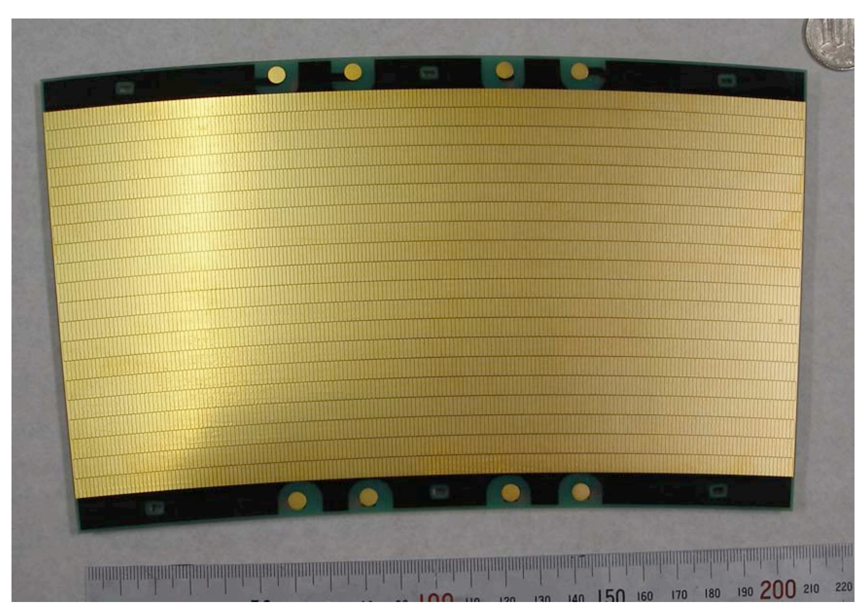
We are trying to minimize dead space pointing IP







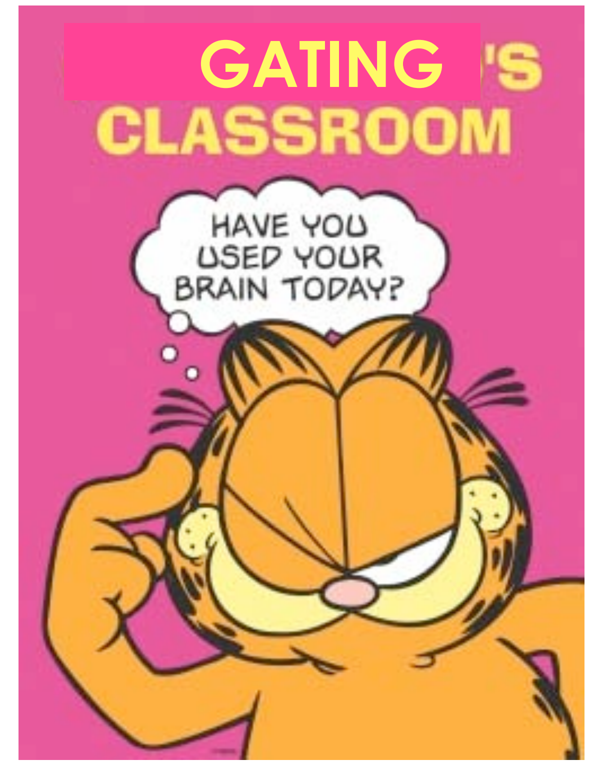
How can we string wire
fitting into this shape
w/o introducing ExB deterioration



Mechanism of GEM Gate

Why electron transmission recover at low V_{GEM} ?
What determine V_{GEM} dependence?

=> better Gate GEM



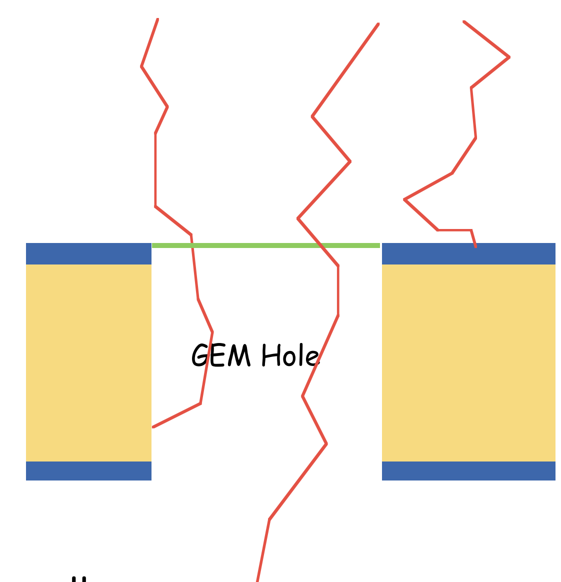
Simulation help us a lot !!

Maxwell3D + Garfield

How do we understand electron transmission in simulation

Transmission = Collection eff. x Extraction eff.

Collection eff. = #e reached to entrance of hole/#e generated
Extraction eff. = #e extracted from hole/#e reached to ent.



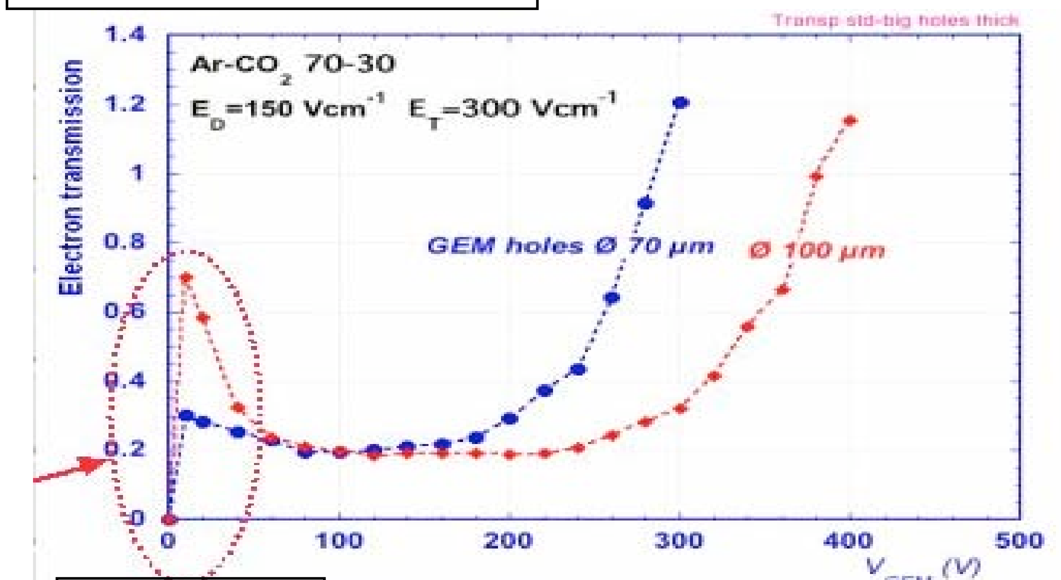
electrons are generated 500um above GEM surface uniformly on a single cell.

reproduce Sauli's exp. data by simulation

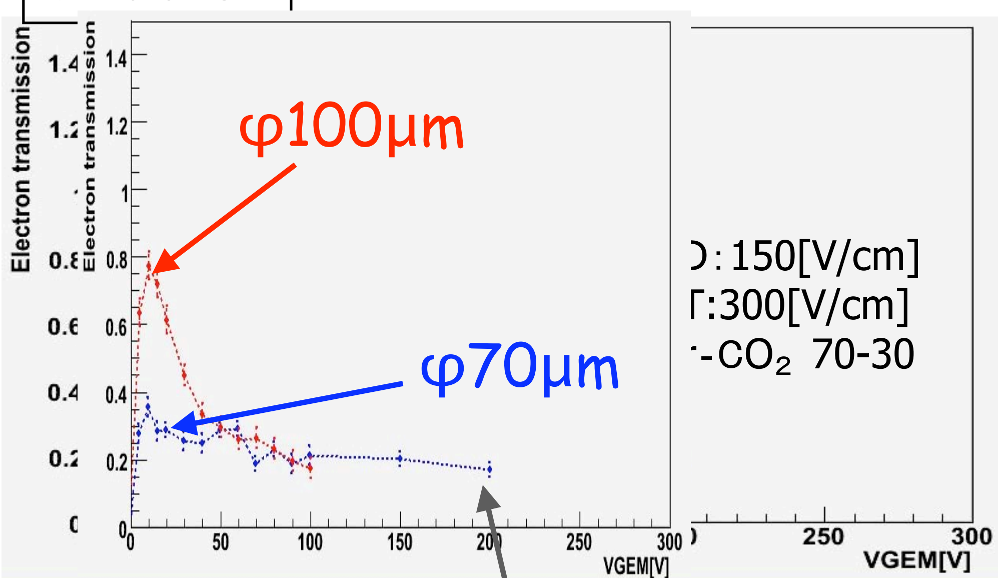
model/param. tune of Maxwell3D/Garfield

Electron transmission
Hole size dep.

Measurement by Sauli

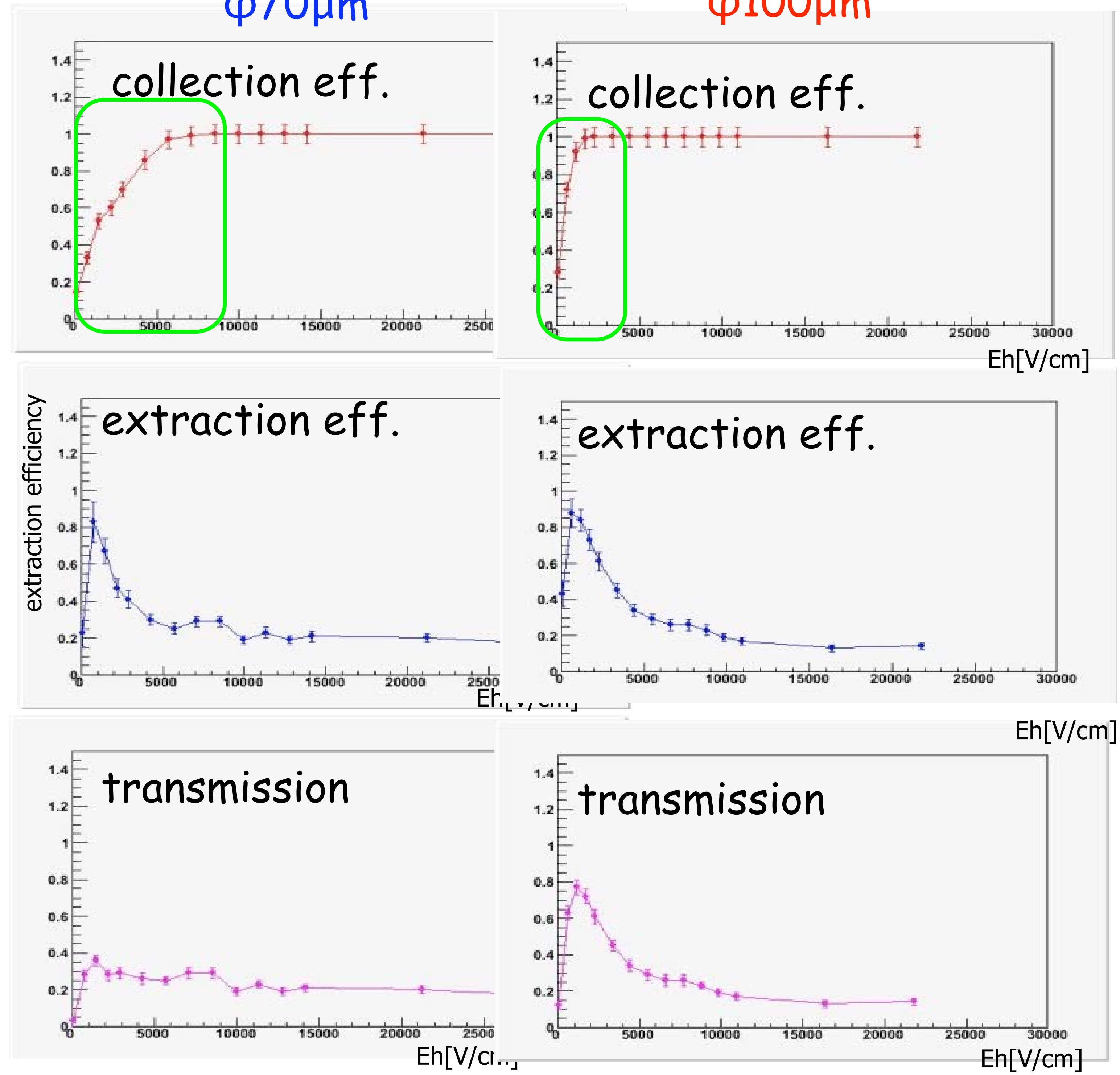


simulation



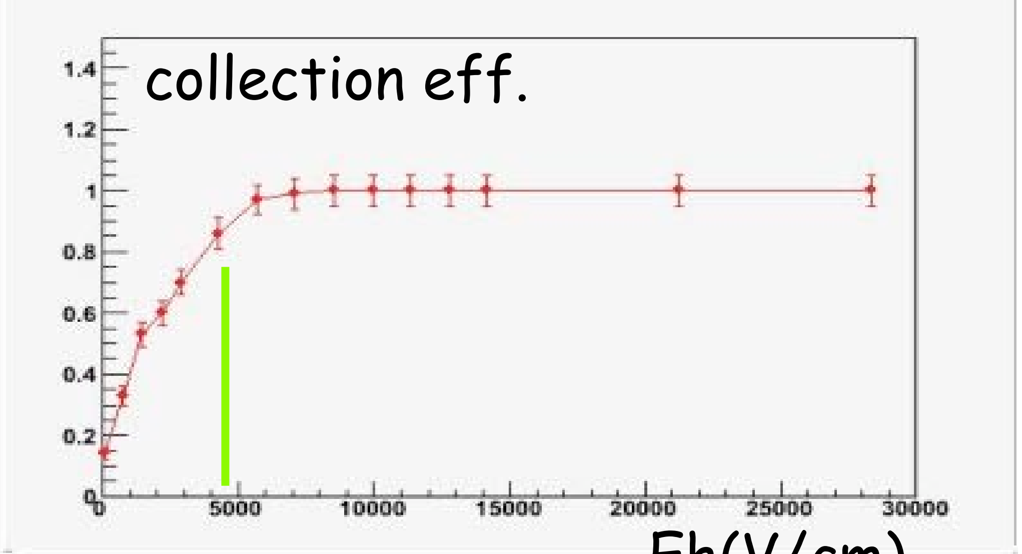
Gas gain is not included

φ70μm φ100μm



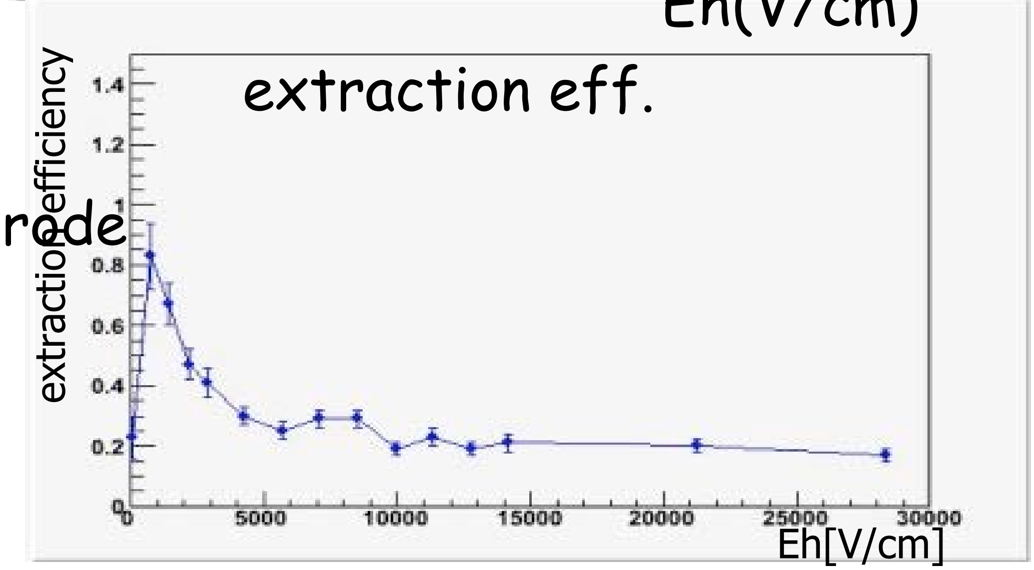
Collection eff. improve transmission
due to large aperture

Collection eff. has been studied by several groups as a func. of Ed/Eh and known to be ~1 @Ed/Eh < 0.03 (ie 4.5kV/cm here)

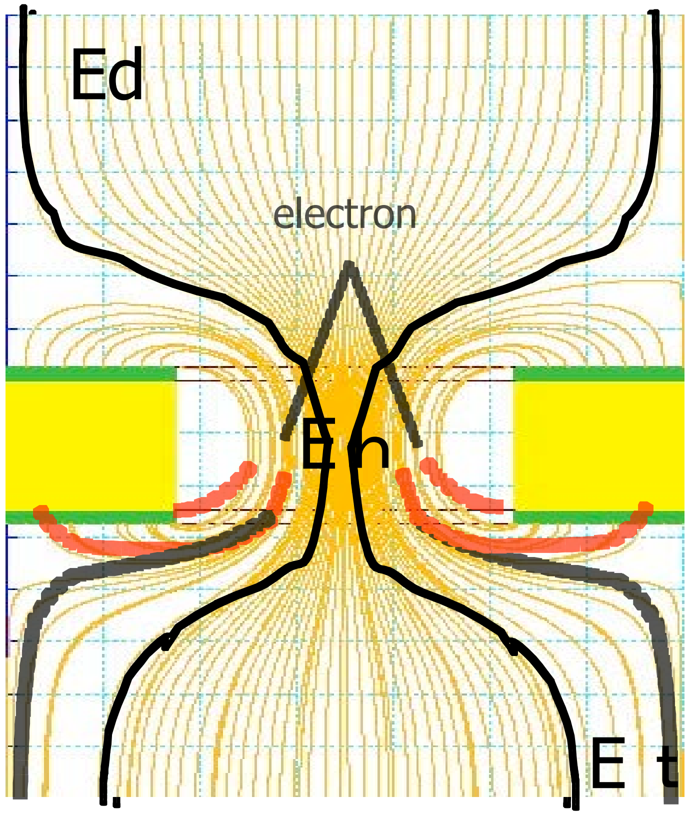


Extraction eff. behave more more complicatedly

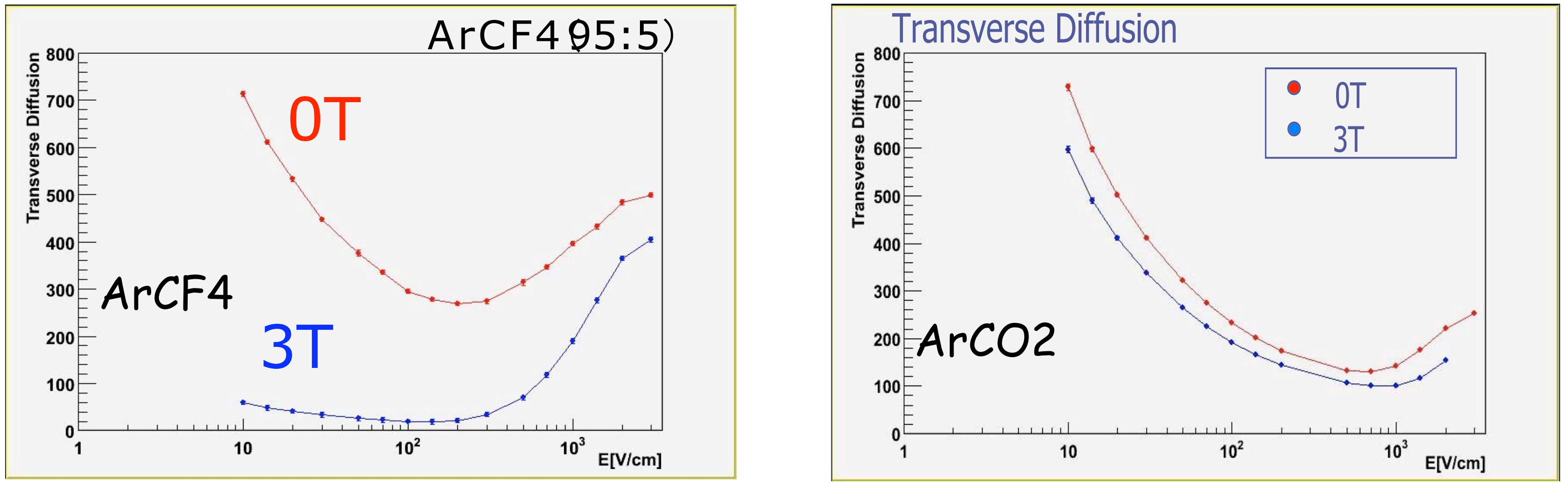
- area of penetrating field line become small as Eh
- electron can spread due to diffusion(Eh)
- some electron follow returned filed line to GEM electrode



area of penetrating field line is larger @ low Eh
higher extraction
diffusion behavior is also important !



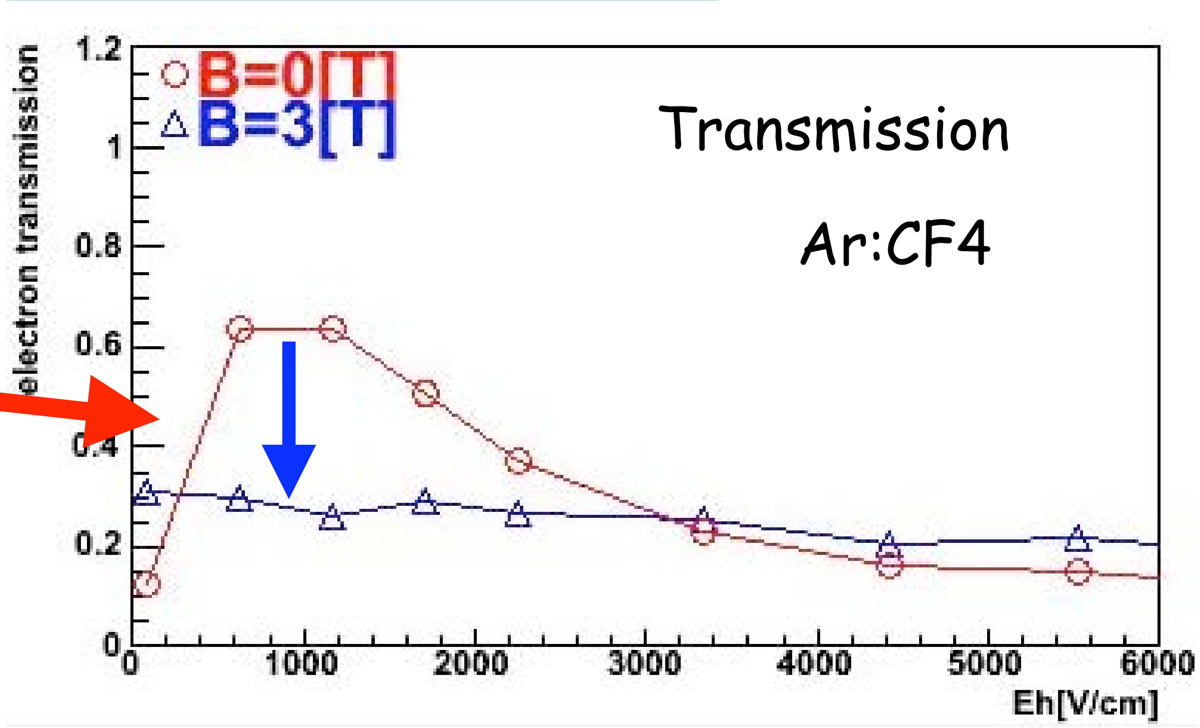
This means "transmission is largely depend on gas"



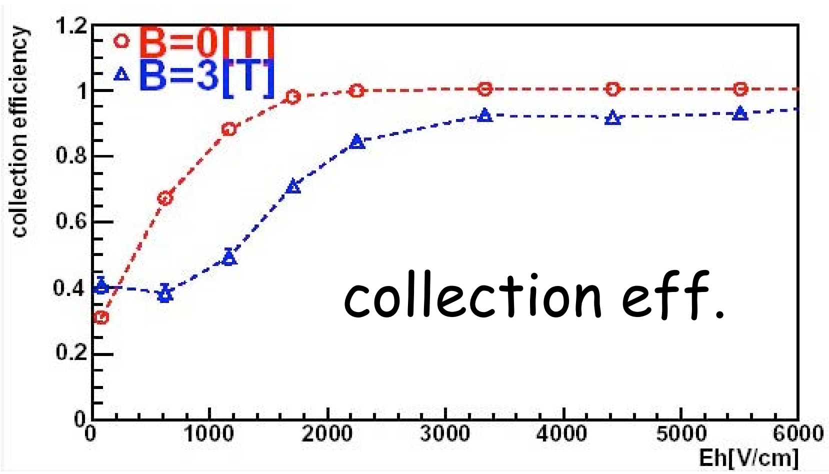
LC requires **High Magnetic Field (3~4 T)**

Transmission under B field

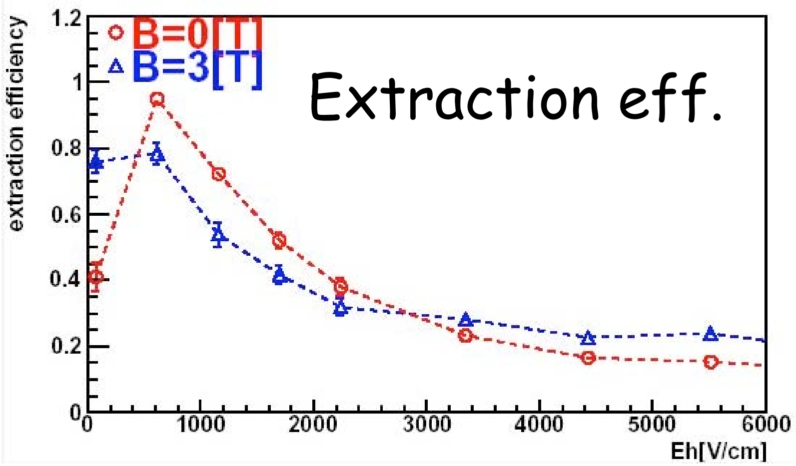
B filed change the behavior of transmission like this



due to;

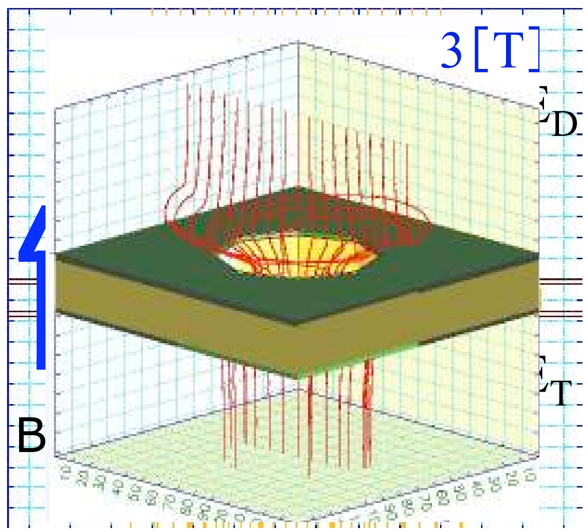


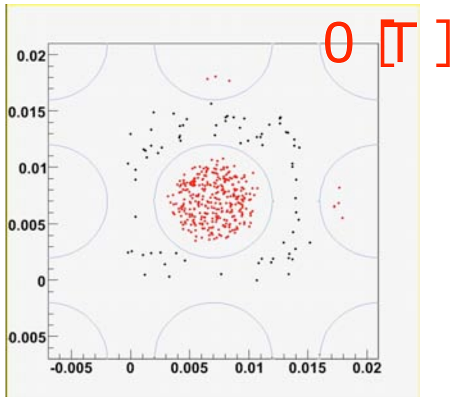
electron move along B field
due to Lorentz angle
rather than E field

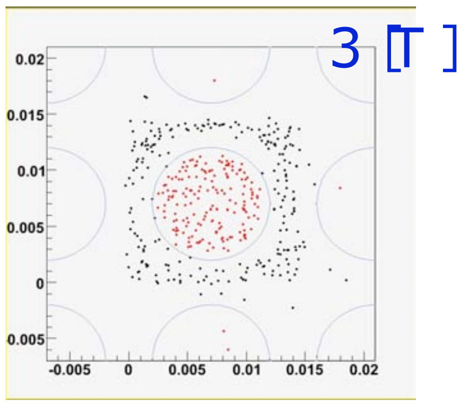


Extraction will be recovered due to Lorentz angle

But
electron position@hole entrance is spread over entire hole
-> diffusion loss in hole
(follow return line)







We cannot accept 30% transmission !

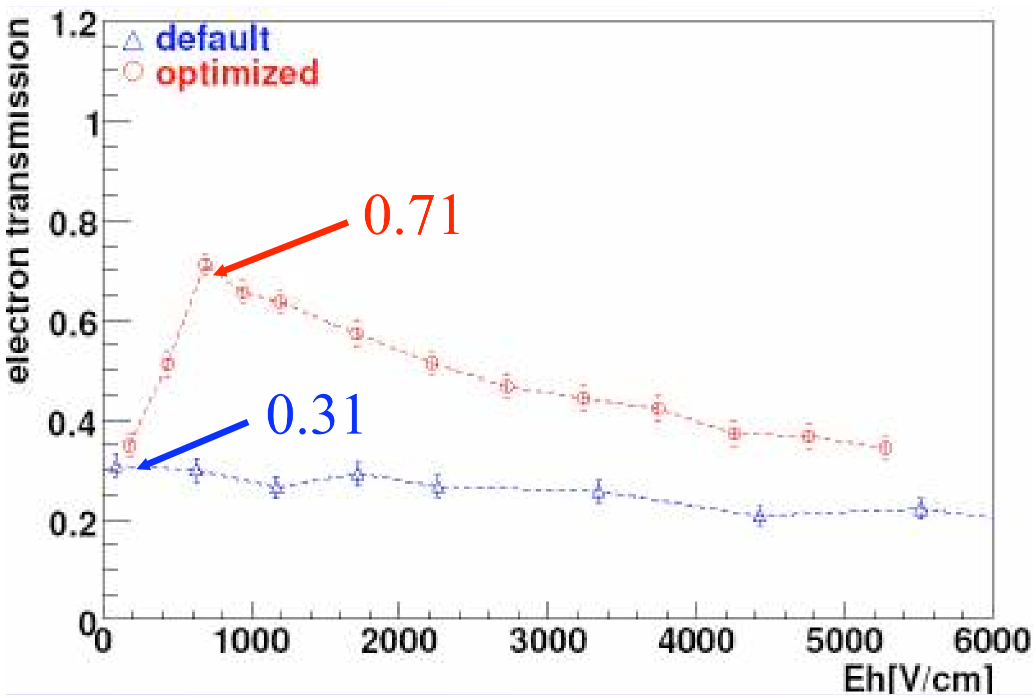
Optimization of gating GEM

We are able to change many parameters of GEM structure / operation condition in simulations

What we've got

- insulator must be **thinner** to improve extraction eff.
- hole diameter must be **larger** to improve collection eff./ limited by pitch
- hole shape not done yet but straight hole would be better
- thickness of metal must be thinner
- Ed<Et Et is limited by diff. / Ed is limited by Vd in LC application

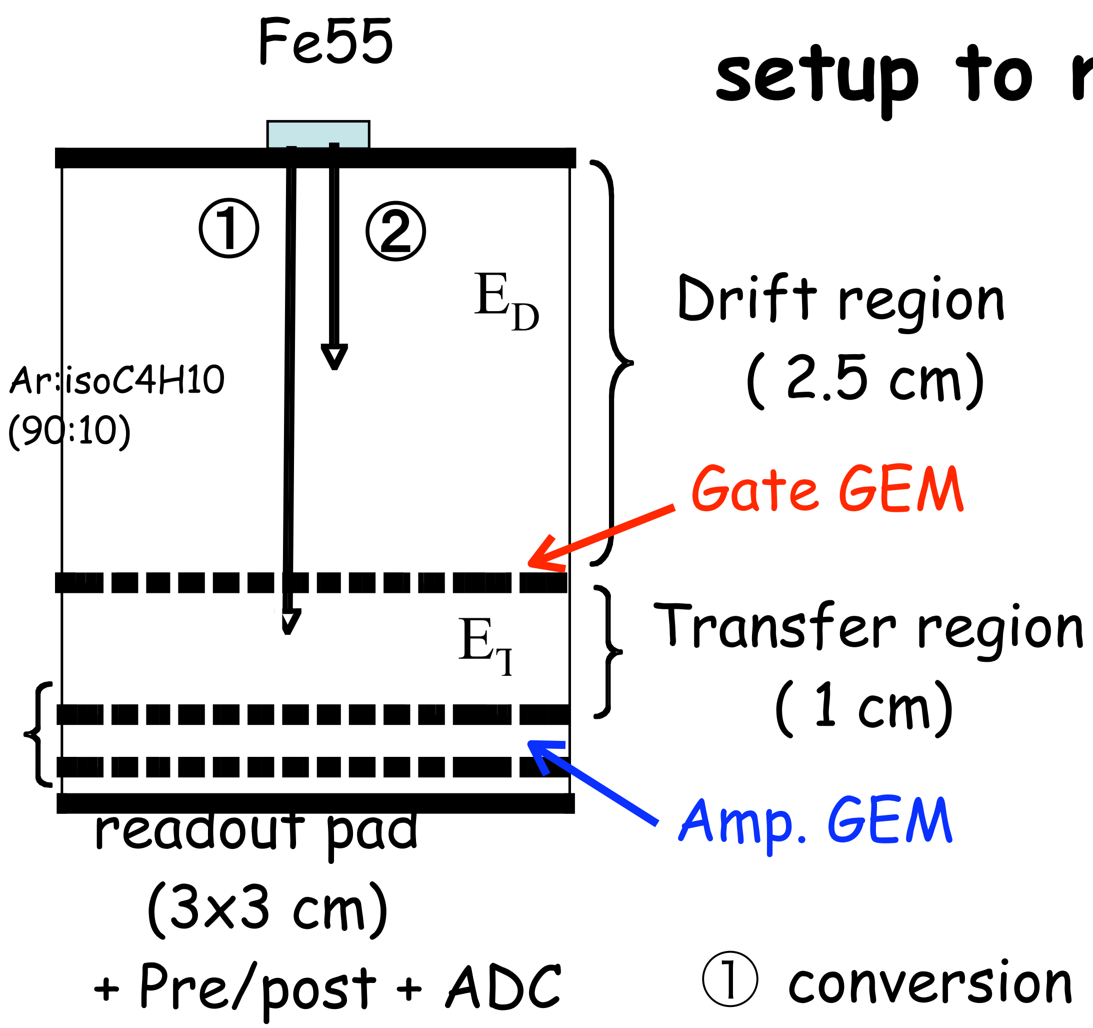
70% of electron transmission can be achieved



w/
- 12um thick insulator
- 100um hole diameter
- Ar-CF4 gas mixture
- low Ed operation(Ed=120V Vd=5cm/usec)
- under 3T B field

Simulation is correct ??/ Can we make this kind of GEM ??

Electron transmission measurement



setup to measure transmission

The most of X-ray is converted at drift region

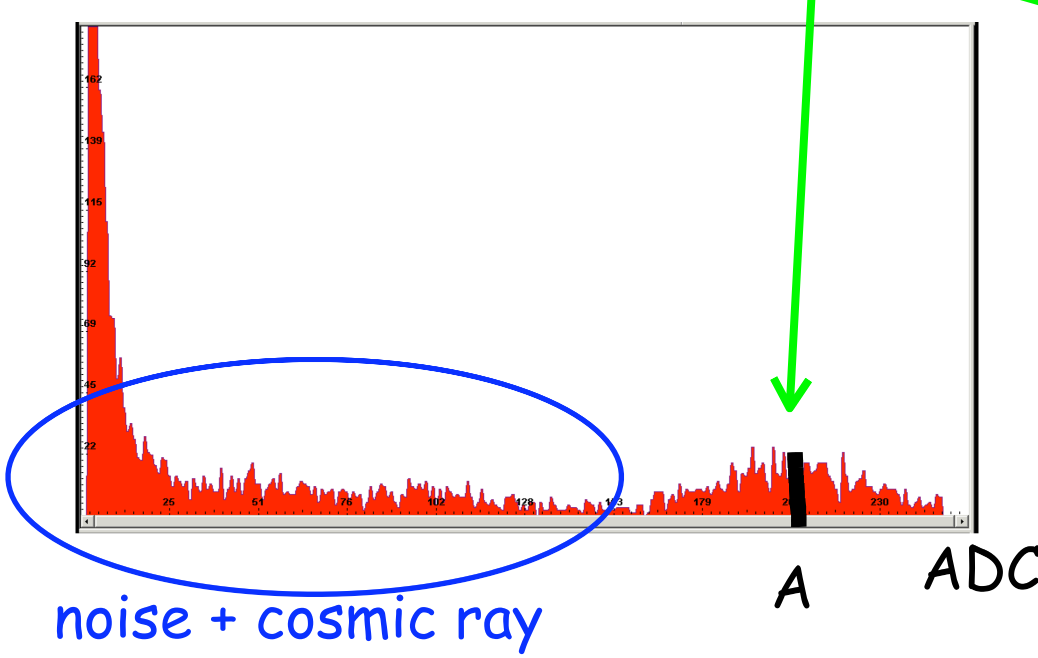
N_{pi} x eff.(transmission) = B

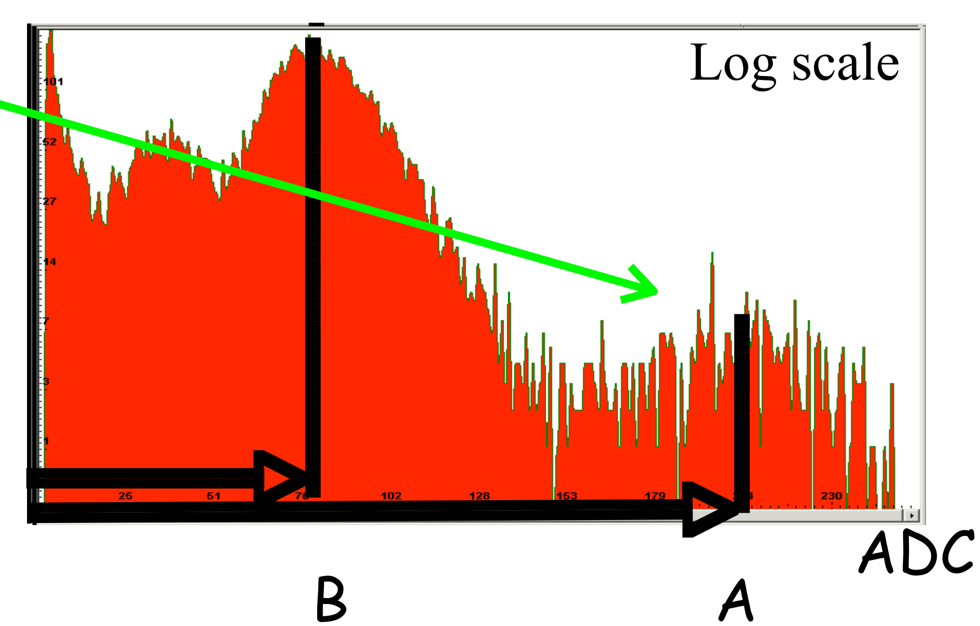
Some of X-ray can go into the transfer region through GEM holes

N_{pi} = A

② conversion @ drift region

① conversion @ transfer region





Transmission = B/A

A peak was always monitored

Spec. of Gate GEM

insulator thickness [um]	hole diameter [um]	name
50	70	nominal
25	70	thin
25	90	thin-wide

All GEMs are produced by Sciencrgy co.

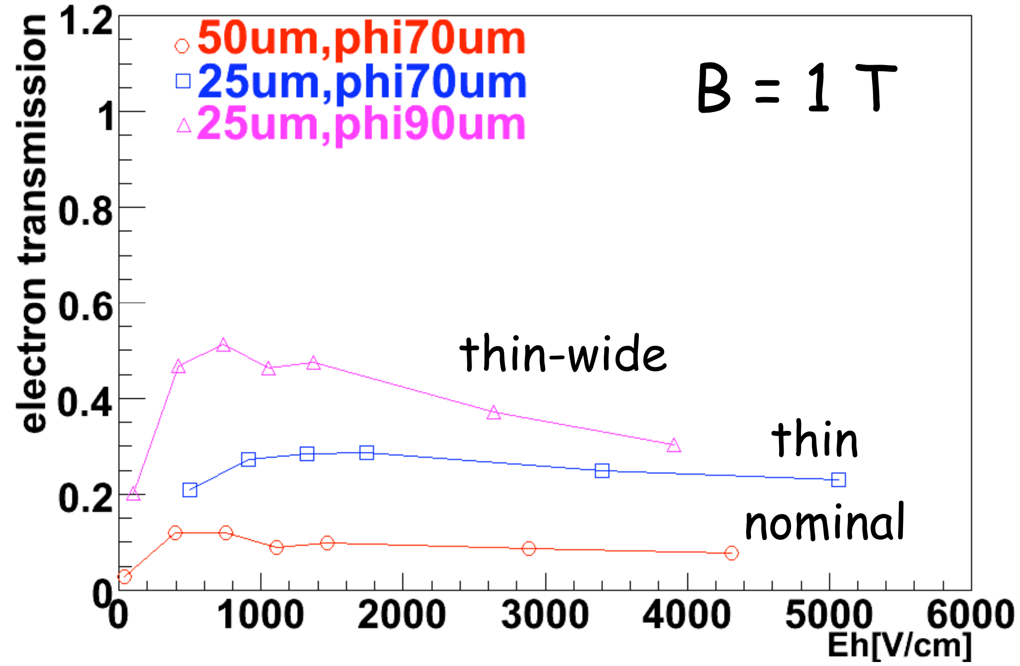
Ar:isoC_4H_{10} = 90:10
Ed = 50 V/cm*
Et = 300 V/cm

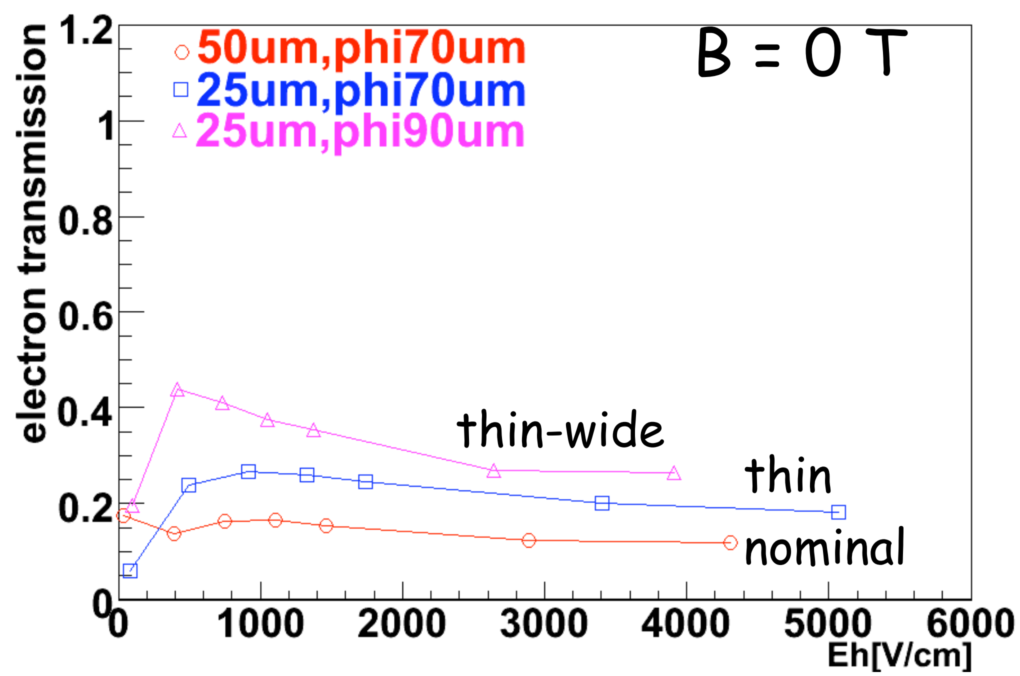
* Ed is lowered to see higher transmission

Transmission is always better
@ thin-wide > thin > nominal

as expected from simulations

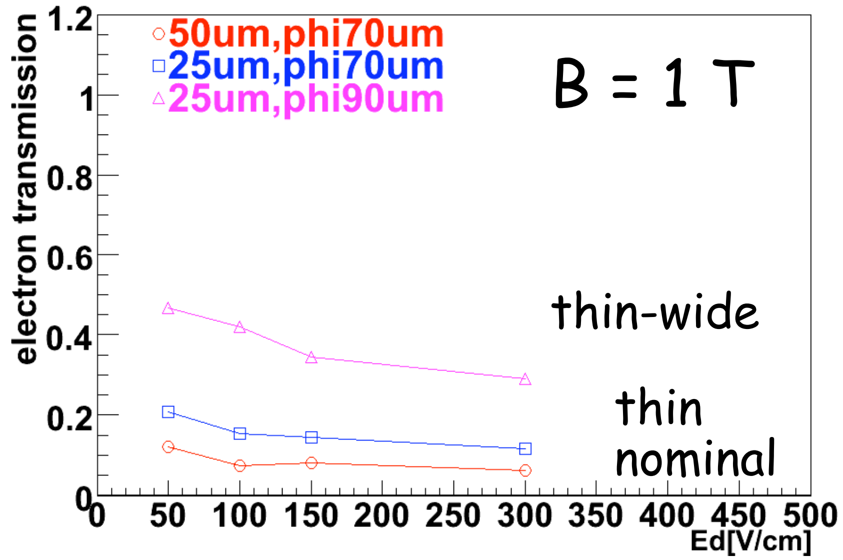
Observed transmission



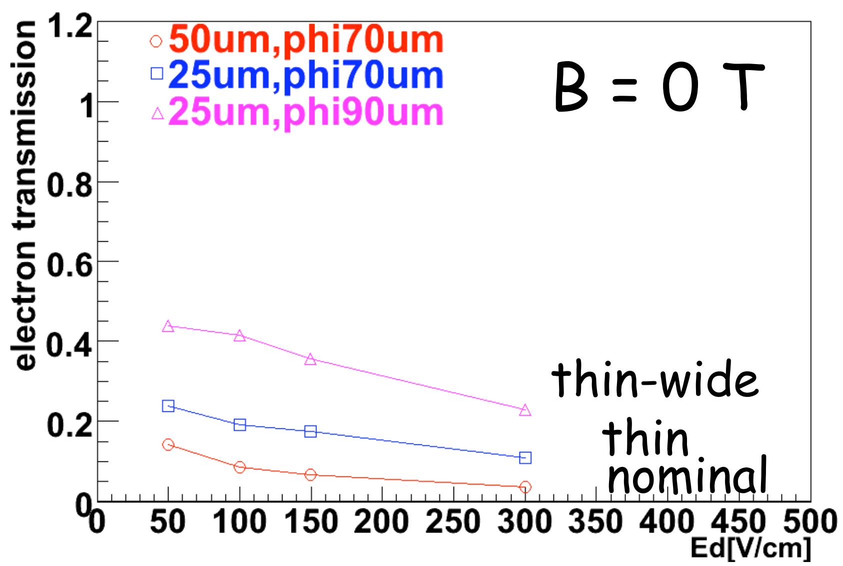


Other behaviors of Gate GEM

Ed dependence

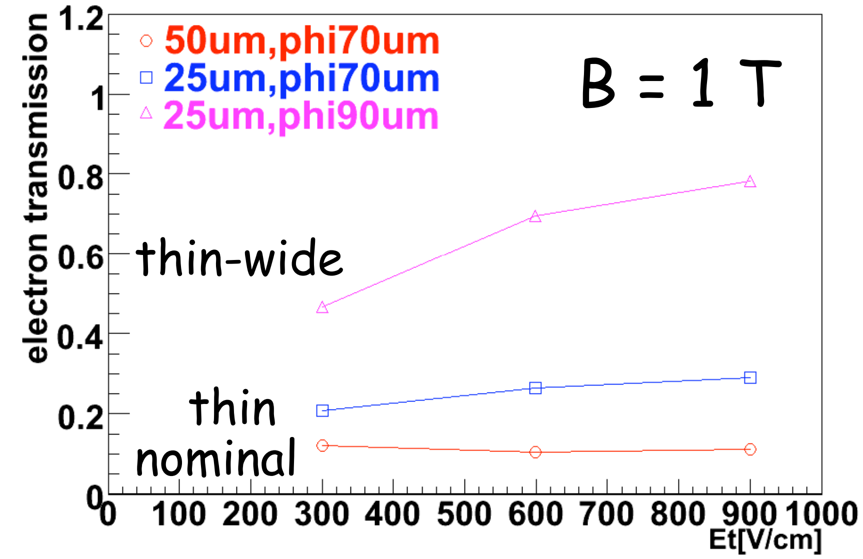


Ed

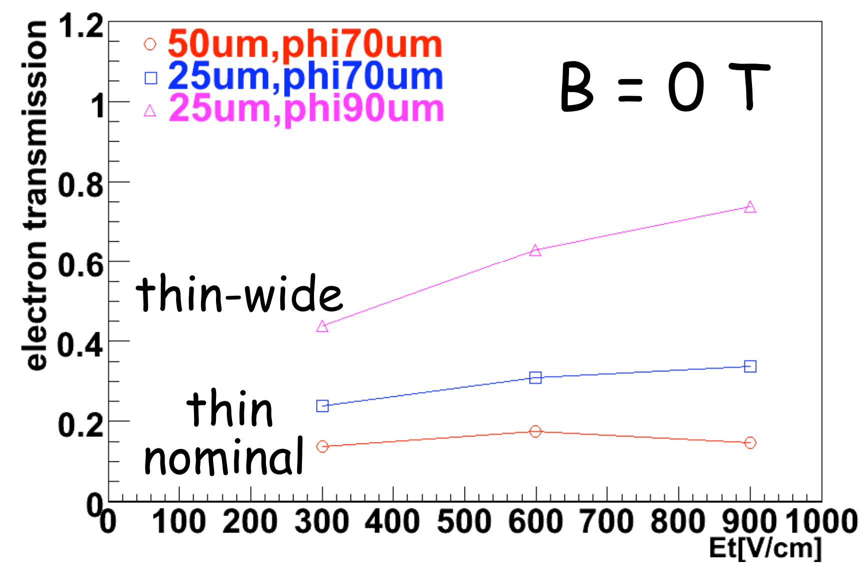


Ed

Et dependence



Et



Et

comparison to simulation

Good agreement @ B = 1 T

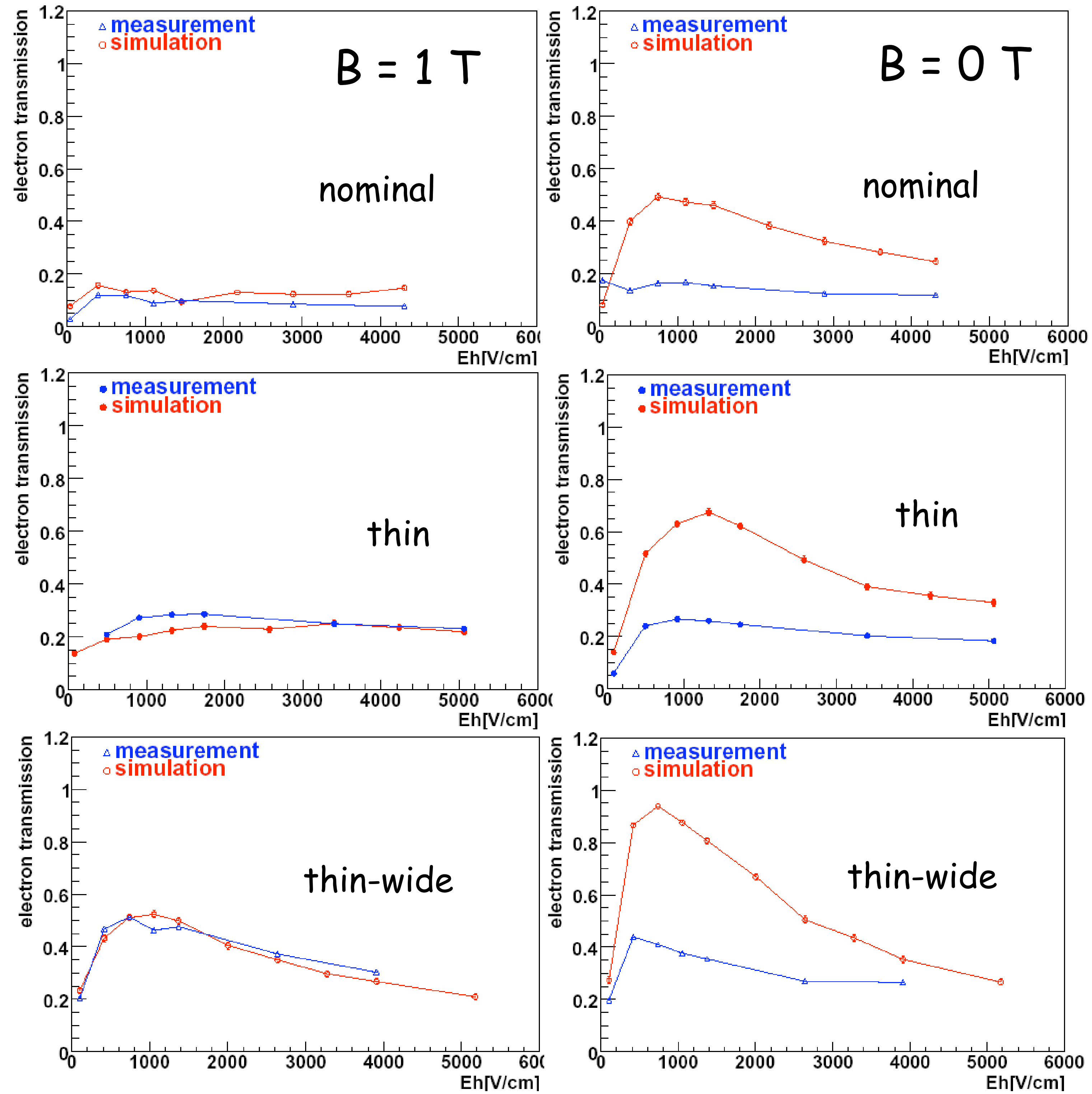
behavior

absolute value

quite different for B = 0 T

Agreement @1T is too good
just to be an accidental

How can we understand these ?



What's going on in GARFIELD ??

Good agreement

Sauli's data
($Ar:CO_2$=70:30)

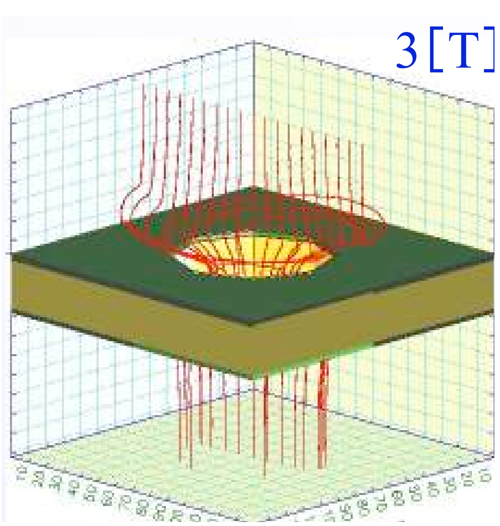
$Ar:isoC_4H_{10}$@B=1T

modest change of E in each step
due to slow gas(large σ)
or ExB effect

Poor agreement

$Ar:isoC_4H_{10}$@B=0T

large change of E in each step
due to fast gas



rotation by ExB prevent
large E change in drift

large E field difference in each step
may deteriorate simulation results

~~Interpolation of E field from element to element
is good enough??~~

New version of "microscopic tracking"
may solve this

Rob Veenhof's talk at yesterday

Production of very thin GEM

in order to achieve higher transmission

Material

thin Polyimide(12.5um) TORAY co.

Cu : spattering

Cr layer (1000A)

Cu layer (2000A) not tolerable for wet/dry etching

additional coating w/ Cu (2um) layer

--> Cu layer peeling off

under study

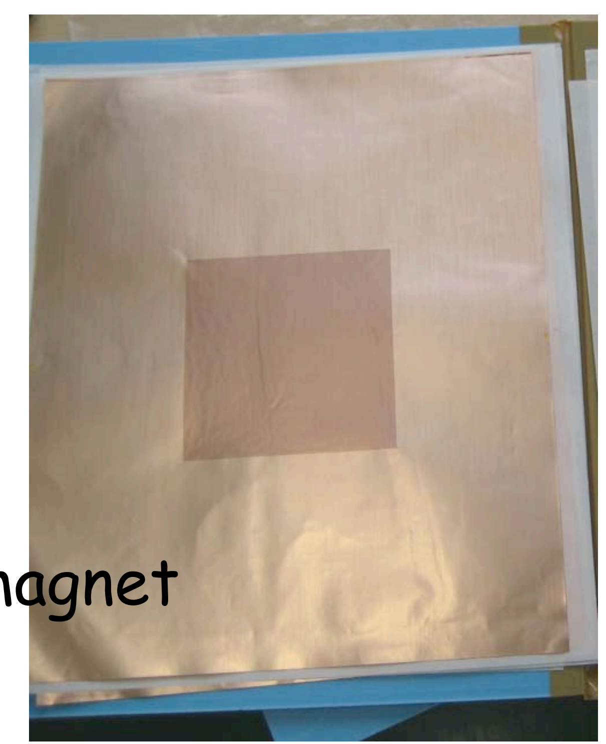
Cu laminated foil (PI 14um:FELIOS) Panasonic

Laser etching

Cu layer(9um) thinning to 1~2 um

processed and

(supposed to be)delivered



we will measure transmission soon @ KEK magnet

Summary

We are trying to find good gate device for ILC-TPC

Simulation was used to understand the mechanism
and to find better shape of structure

Electron transmission is measured
and compared with simulation
transmission data agree with simulation @ B=1T
not @ B=0T

We will use new "microscopic tracking" version

We have to make sure agreement holds @ higher B