Simulation Study of GEM gating for LC-TPC

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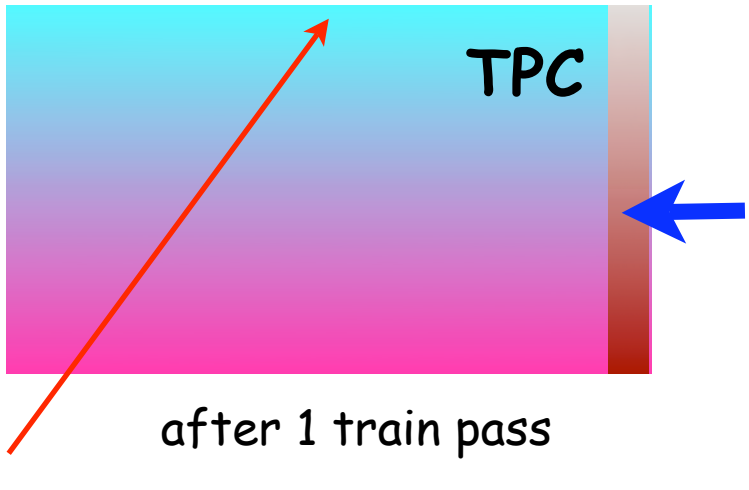
Why do we need Gate for ions ?

Ions are produced at the Drift region as primary ionization
at MPGD region from gas multiplications (1000 times larger)

Ions @ drift may be accumulate for a few trains
as ions drift is slow

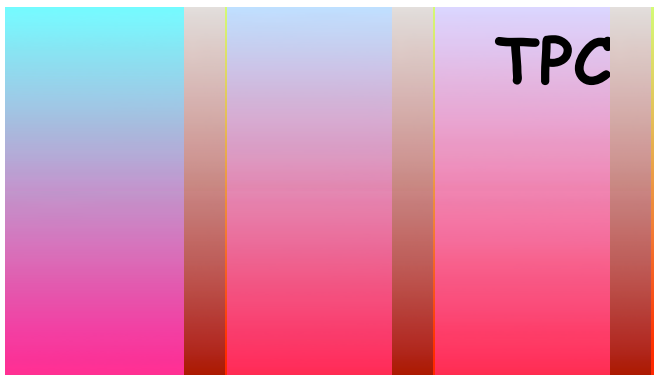


Ions produced at gas multiplications

after 1 train pass

Ions @ MPGD will form like a ion-dense disc
which travel in drift region slowly
if we don't have any gate mechanism to block ions

this disc may deteriorate drifting electron by E,
ExB ...
and these effects are not stable as ions are moving.



after several trains

Ions produced at gas multiplications
must be shut off by GATE

Gating for back-drift ions

ILC case : ions feedback must be smaller than 10^{-3}(ie. no ions from MPGD)

Gate can be open for 1 msec and be closed following 199 msec.

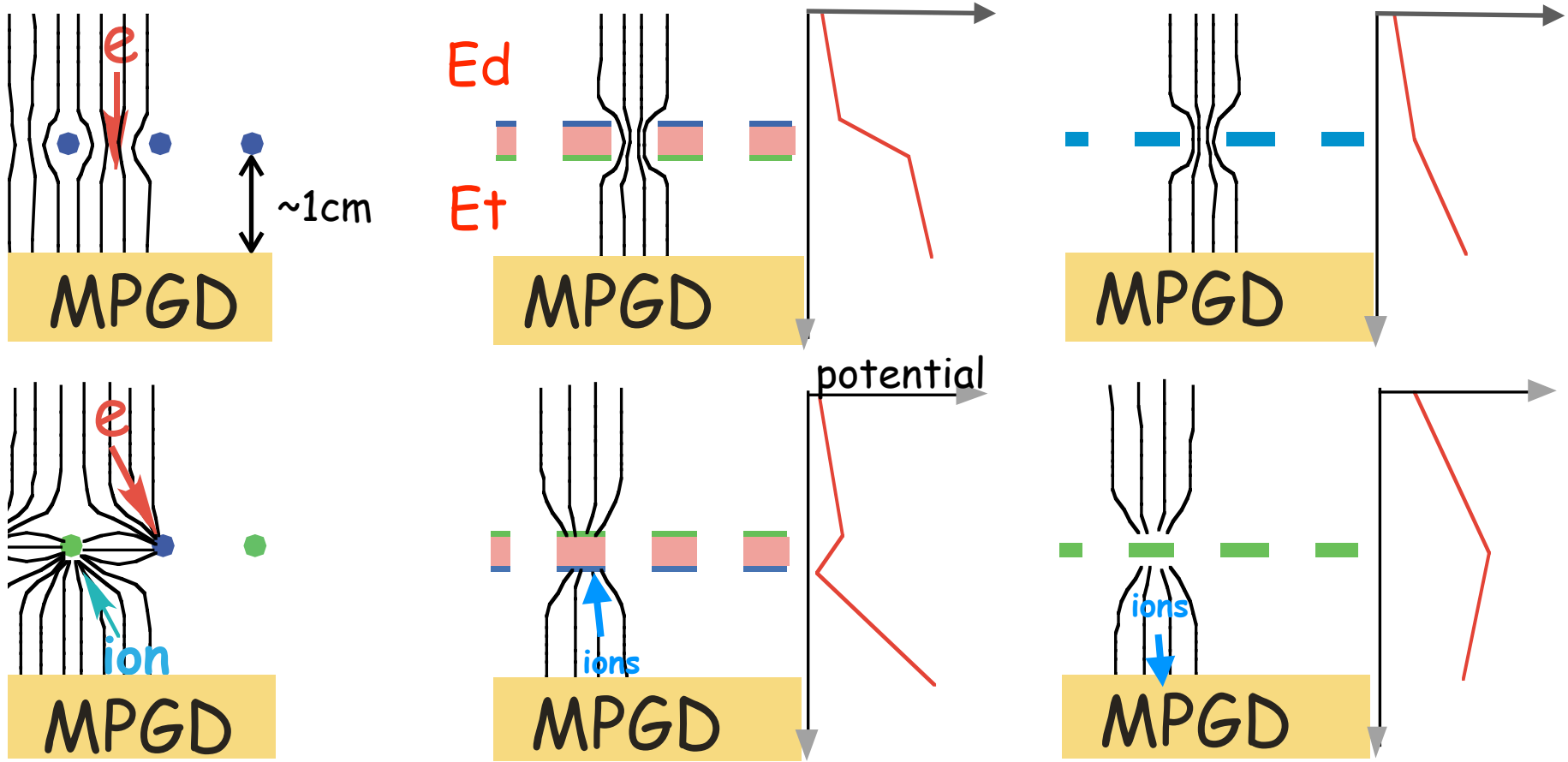
ion can dirft < 1cm

Gate: wire GEM micromesh

3 candidates

open

close



local change of E
wire tension
ExB

local change of E
electron transmission

change of drift E
electron transmission

Before going to GEM gating

Is Wire a perfect gating method ?

Existing wires deteriorate electric field around a wire.

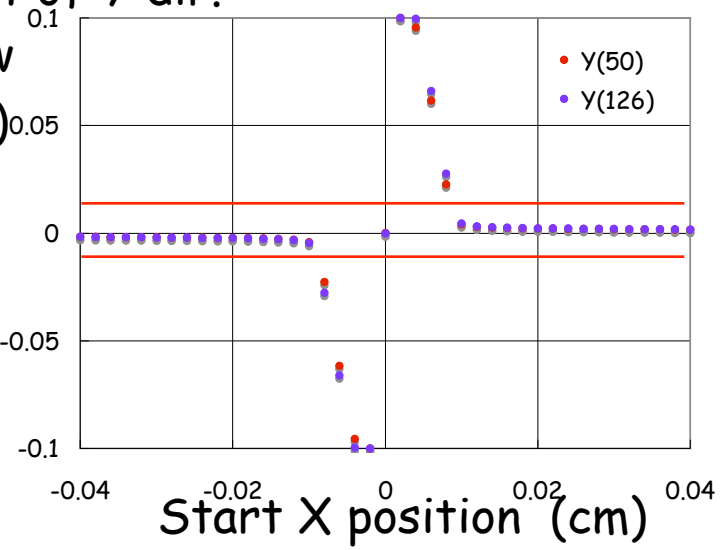
It introduces some EXB effect !!

size of ExB effect and affected area are in question

Gas:	Ar:CF4 (95:5)
Magnetic Field	4T
drift/transfer E	100V/cm (gate:open)
gate wire diam.	126um/50um
spacing	2 mm
gate-pad gap	1cm

Electron transmission (@Gate Open)

Dsiplacement of Y dir. @2mm below (cm)



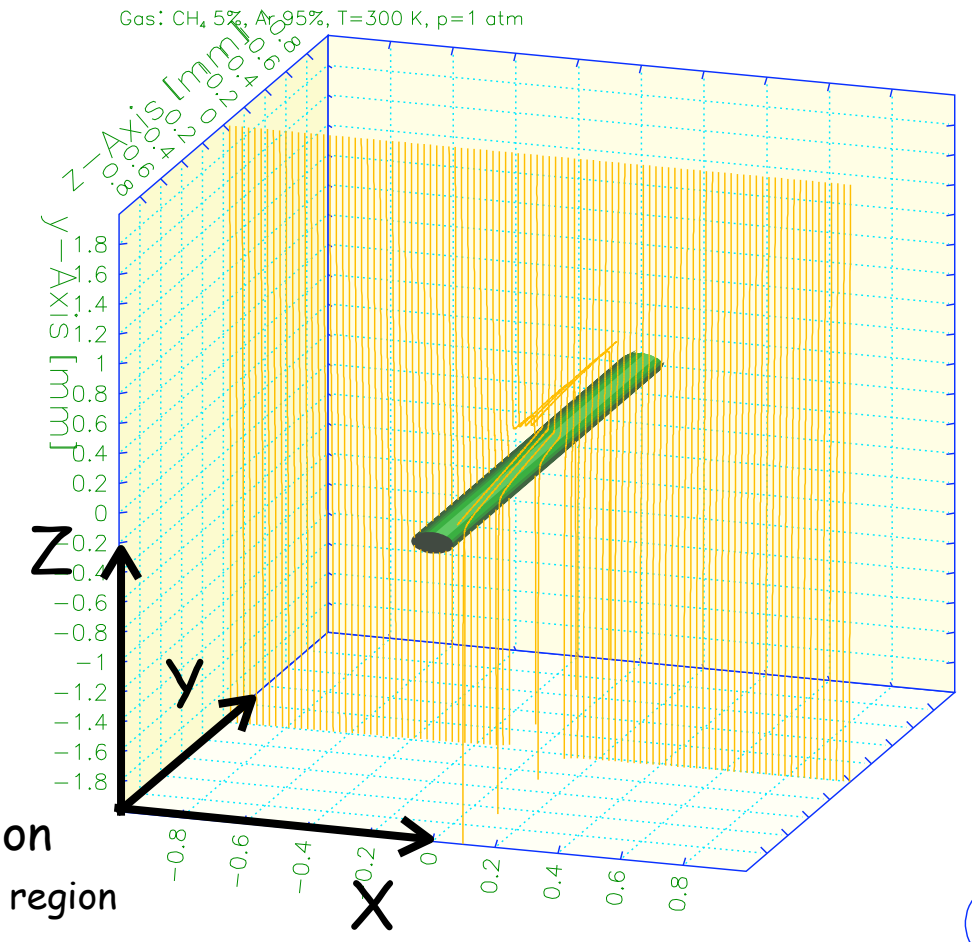
displacement > 100 um @ $|x - x_{wire}| < 100$ um

this result is not depend on wire diameter

10% of region provide deteriorated information

these electrons are also diffused @ transfer/MPGD region

Layout of the cell



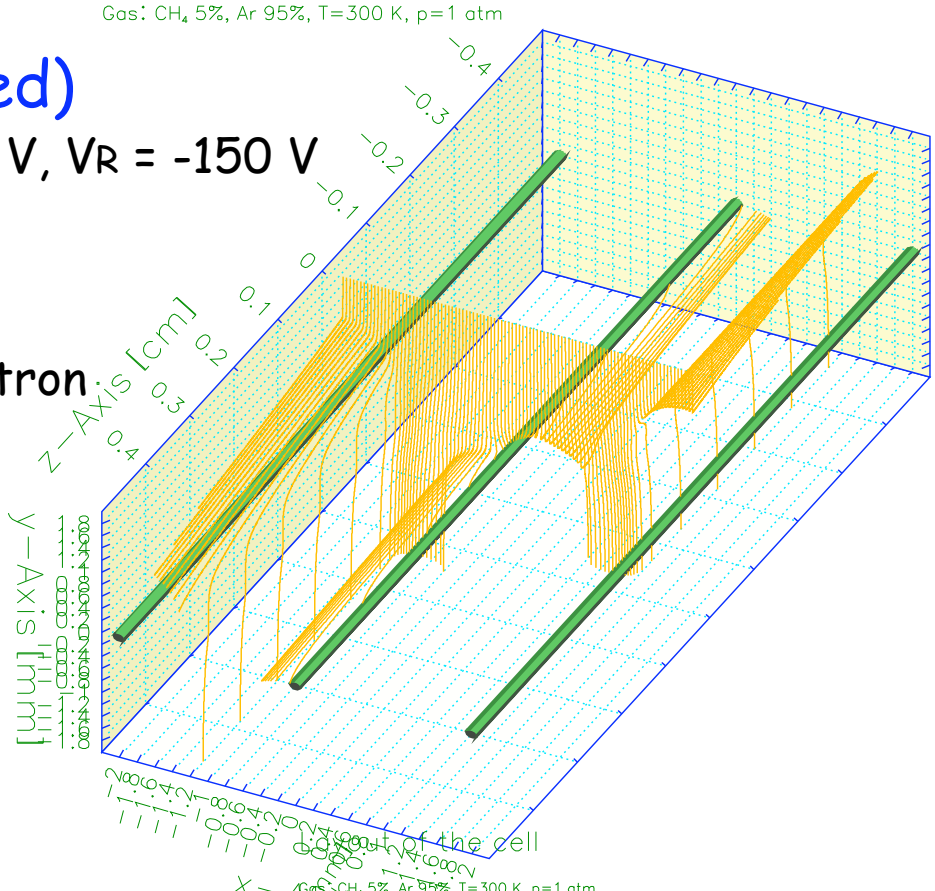
Plotted at 15:28:23 on 18/05/07 with Garfield version 7.10.

Electron transmission (@Gate Closed)

V_L = -50 V, V_R = -150 V

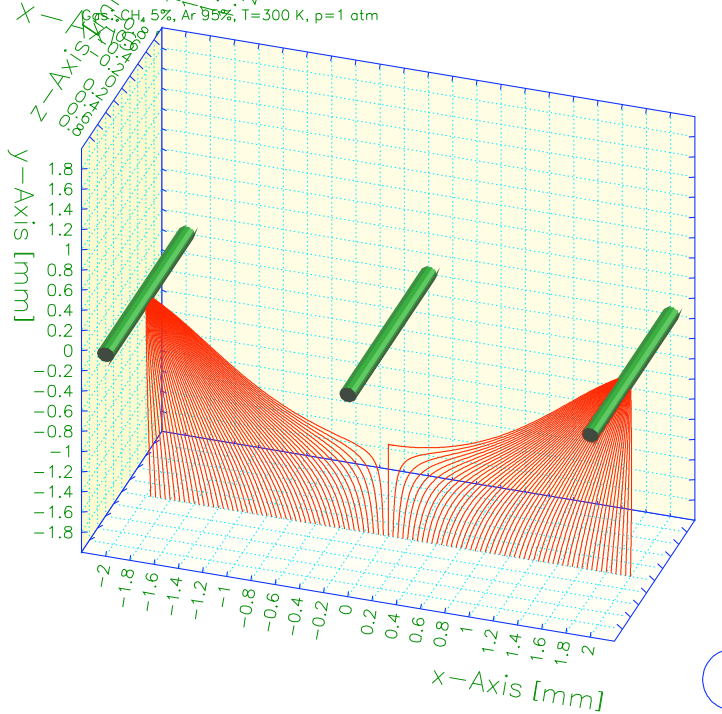
Even Gate is closed, a half of electrons can go through gate plane.

large difference of V_L and V_R may reduce electron transparency but.....



Ion blocking (@Gate Closed)

No problem about ions !!!

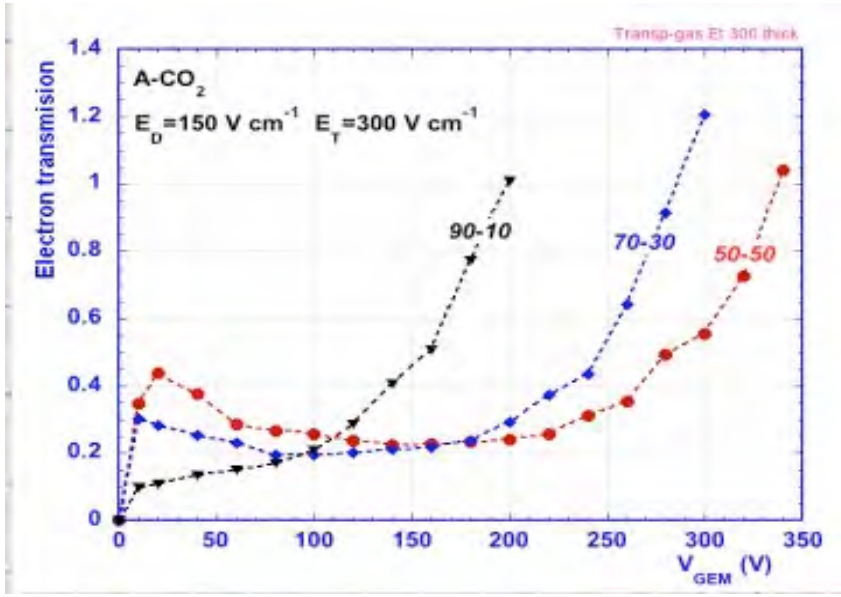


GEM gating

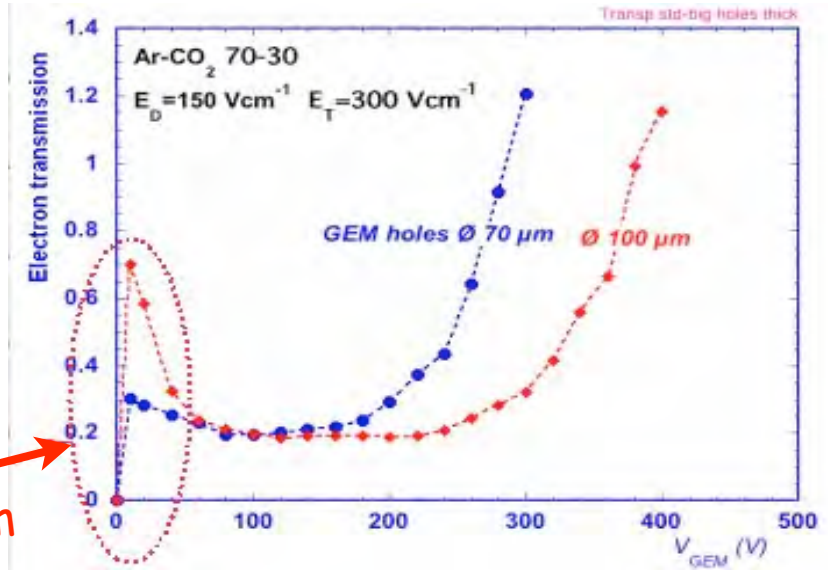
F. Sauli had proposed GEM as gating device @LBLTPC'06

Electron transmission had been measured as a function of V_{GEM}

for different Gas mixture



for different hole size



10V/50um

~ 2kV/cm

Low voltage operation may give us good electron transmission:
where no gas amplification happen.

We hope to understand this mechanism and optimize GEM for ILC gate

E field calculation and electron simulation in gas help us to do this.

Maxwell3D Garfield

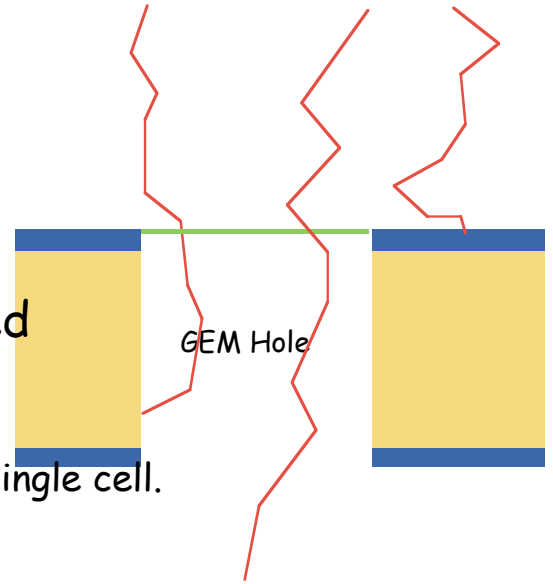
BUT We have to make sure these tools provide correct answer

How do we understand electron transmission through 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.

Cautions 1

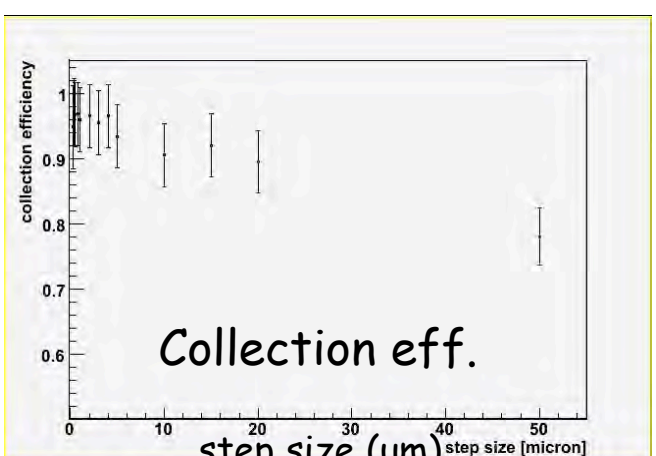
Important parameter of Garfield is STEP SIZE

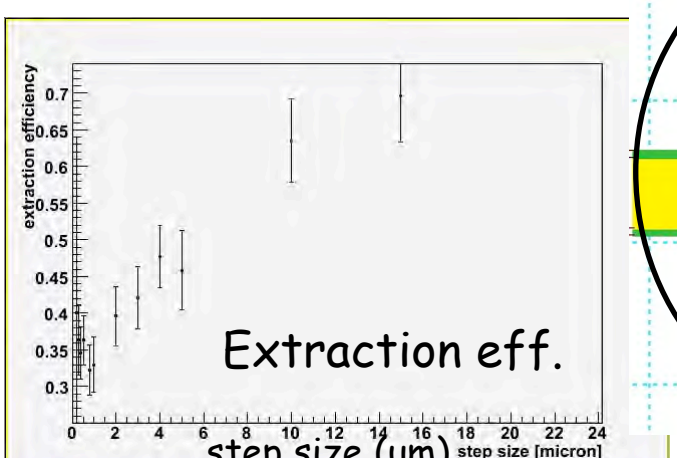
step size : interval to update electron position

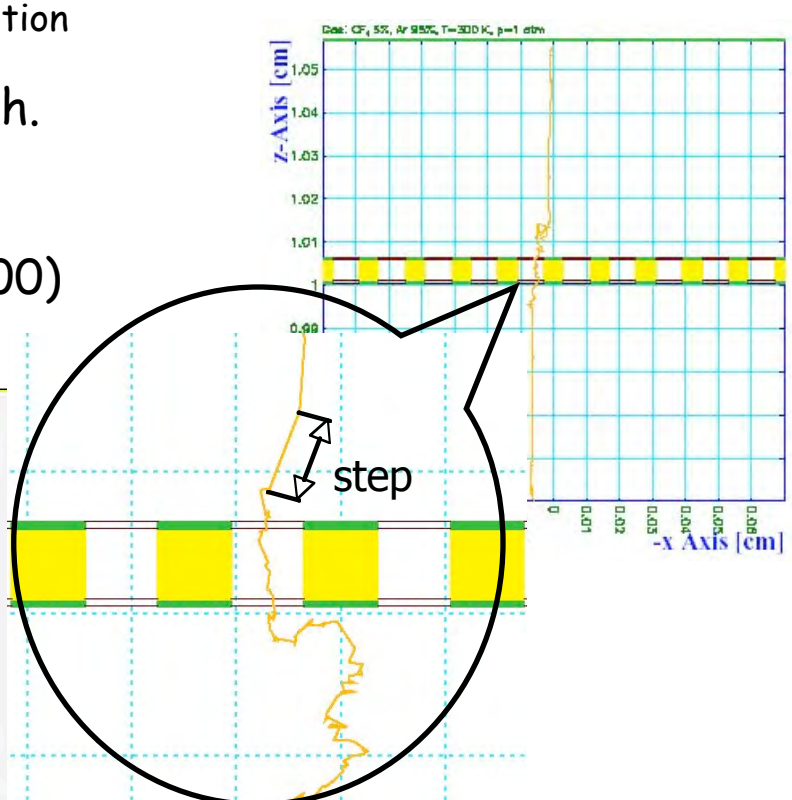
step size is controlled by # of collisions OR length.

large step size -> incorrect result

too small step size -> cal. stopped by Max. number(1000)



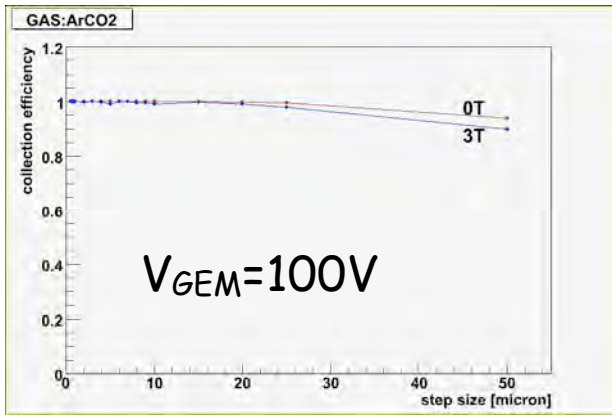


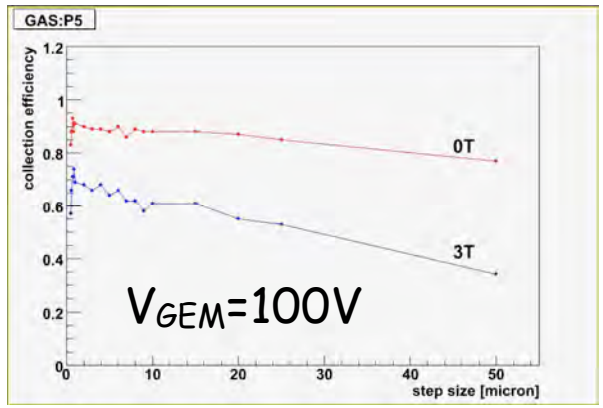


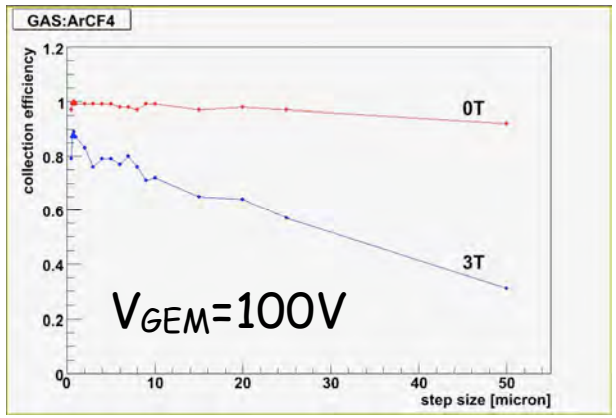
More example of step size effect **Cautions !**

Ar:CO2 | Ar:CH4(P5) | Ar:CF4

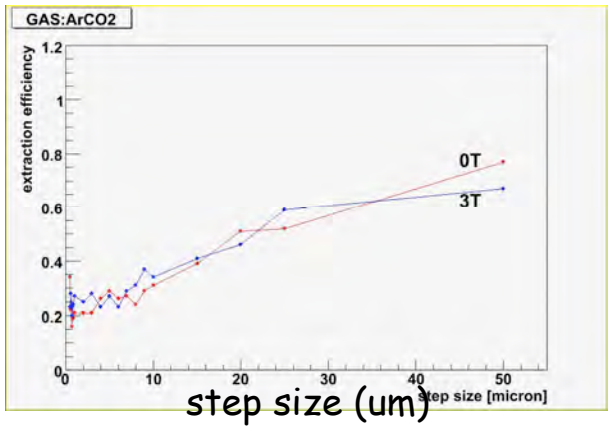
collection eff.



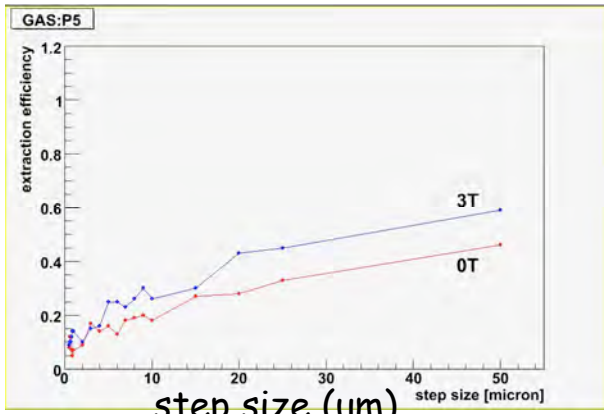




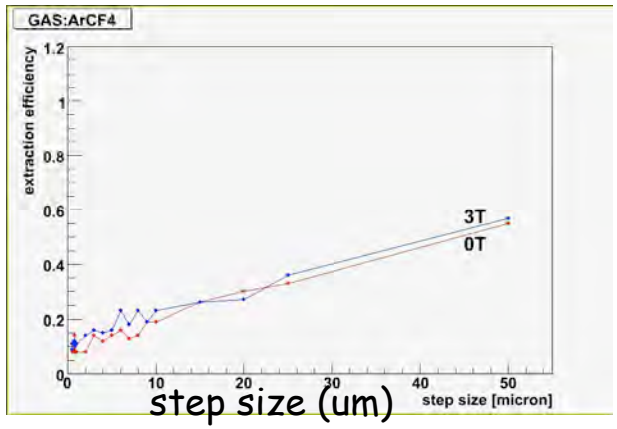
extraction eff.



step size (um)



step size (um)



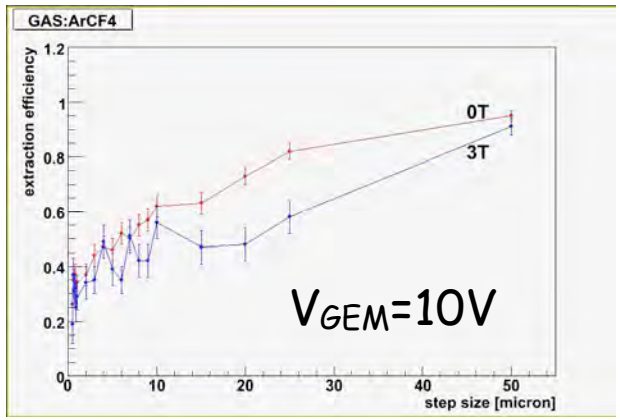
step size (um)

In any case, result change as step size

result @ 0 step size must be close to true value !

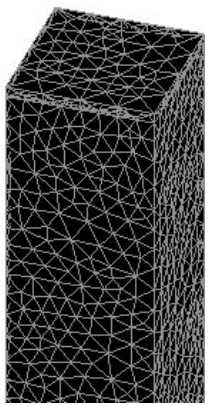
We chose 2 um step size

as the result may be close enough to true answer

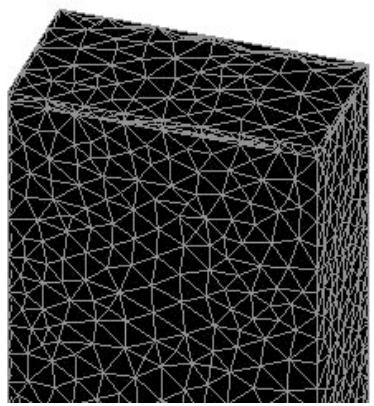


Size of Field map **Cautions 2**

Field map used in garfield can be provided from Maxwell3D.
but acceptable size is limited to ~ 10^5 elemtents



Blue line



Red line

mesh size ~ 2x Blue

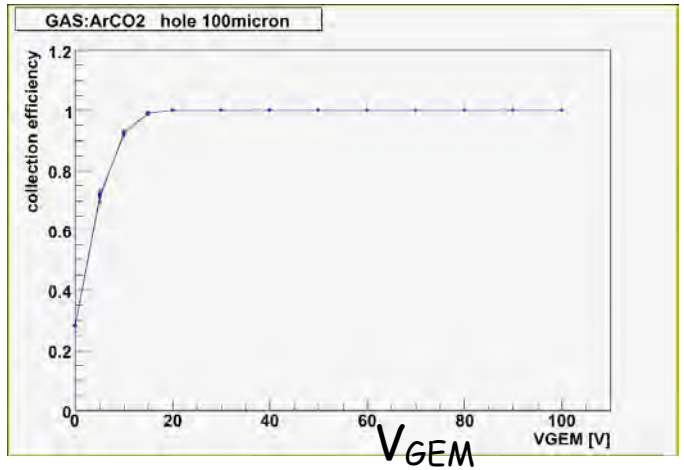
Collection eff. is same each other
ie. E filed @ collection seems to be precise enough
Extraction eff. provides ~10% diff.
ie. E field is not precisely calculated in hole
or interpolation of E field doesn't work in garfield

In Maxwell3D, mesh is automatically generated
we cannot quote exact volume of mesh

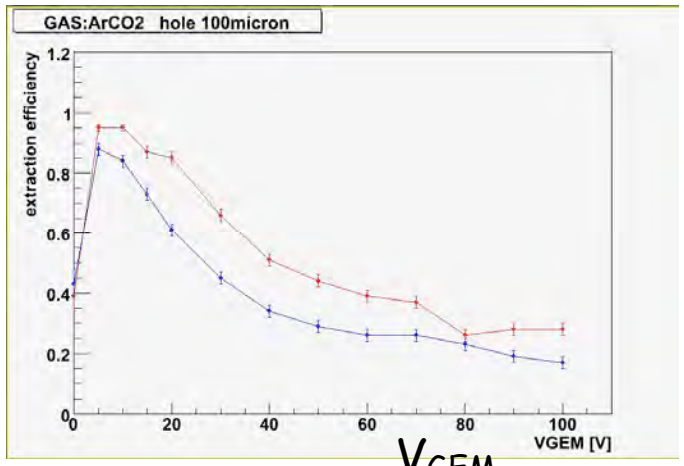
We have to remember accuracy of result
when we use garfield

ArCO2

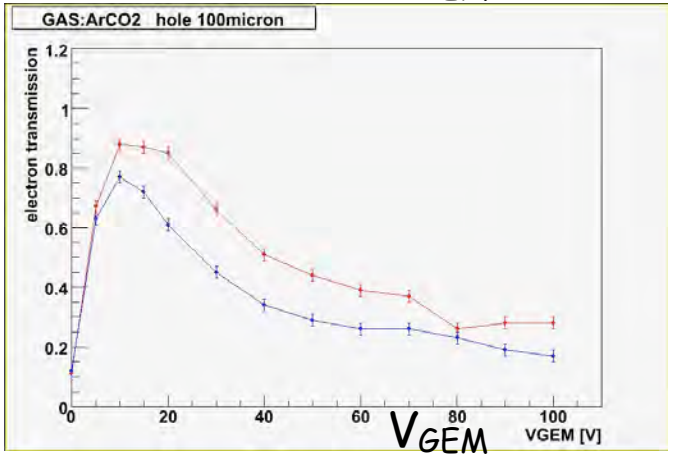
collection eff.



extraction eff.



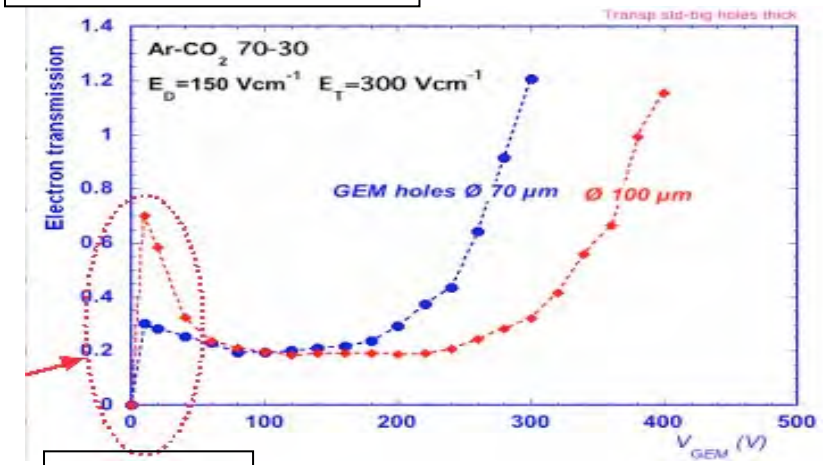
transmission



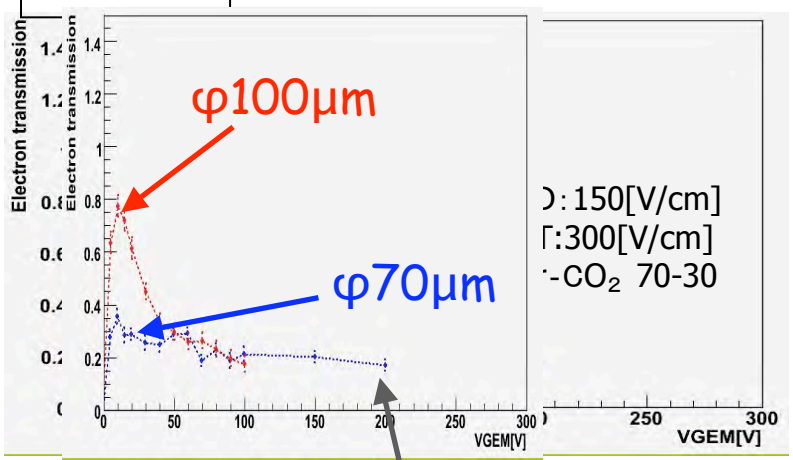
Comparison to exp. results

Electron transmission
Hole size dep.

Measurement by Sauli

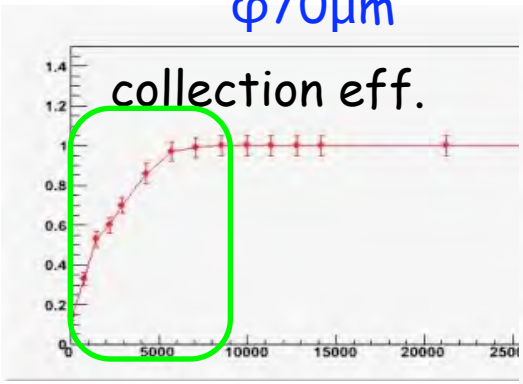


simulation

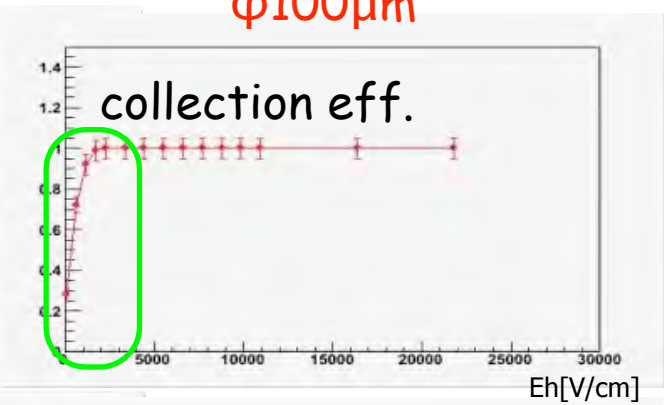


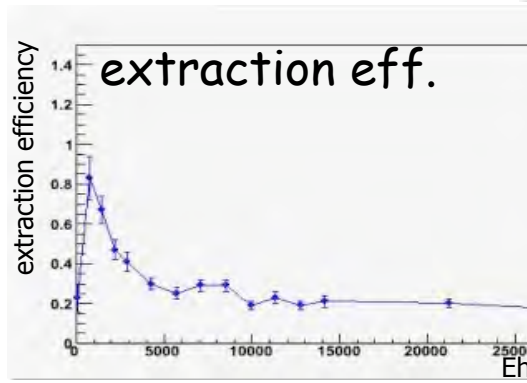
Gas gain is not included

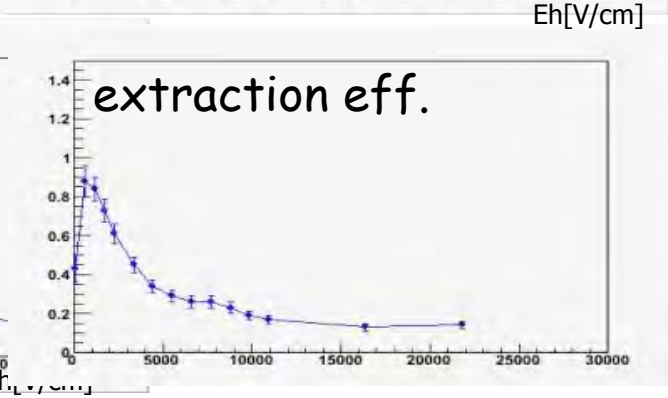
φ70µm

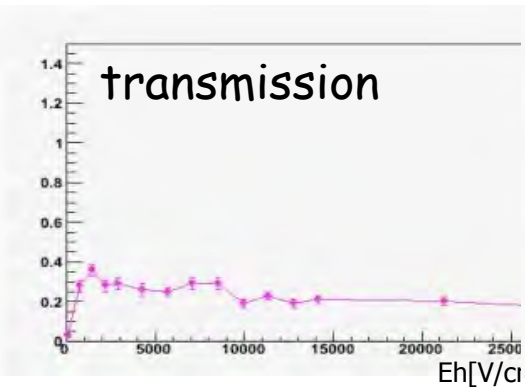


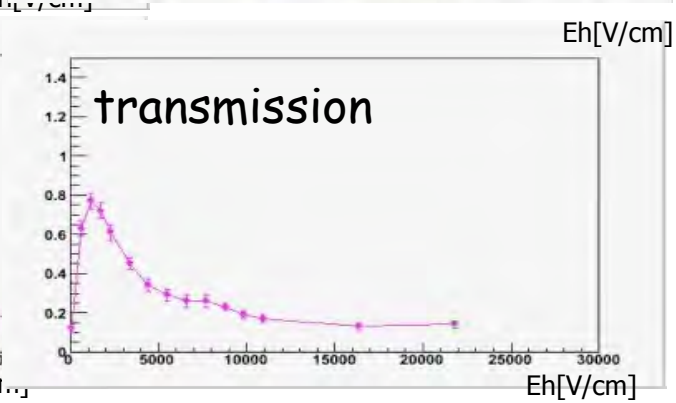
φ100µm





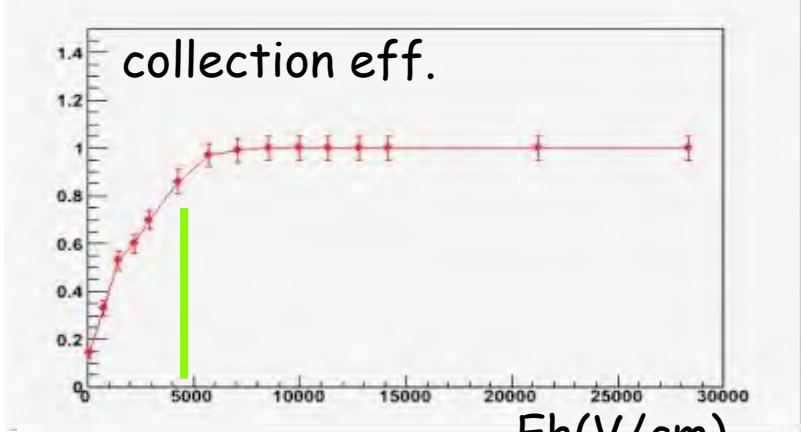






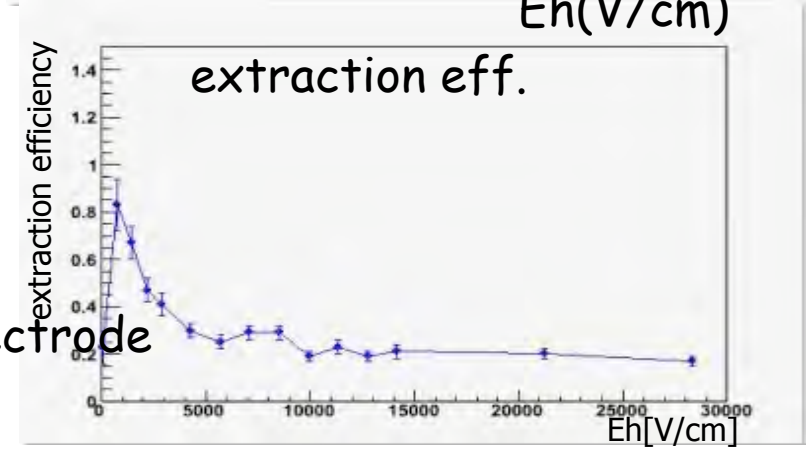
Collection eff. improve transmission
due to large aperture

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)
it is relaxed when hole become larger.



Extraction eff. behave more complicatedly

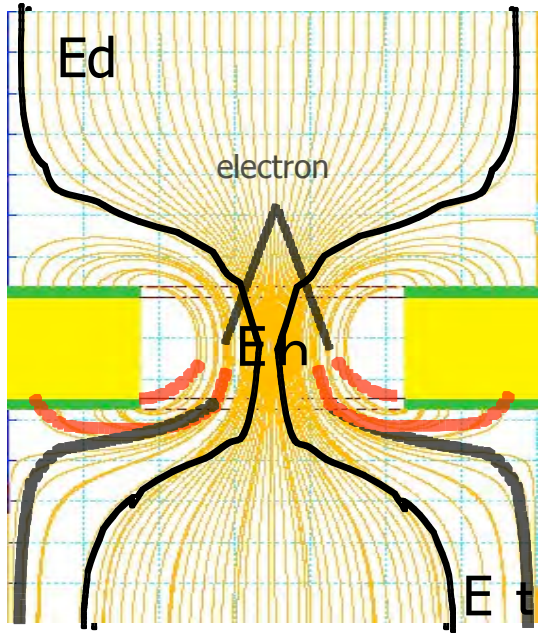
- area of penetrating field line become small as Eh
- electron can spread due to diffusion(Eh)
- some electron follow returned filed line to GEM electrode



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

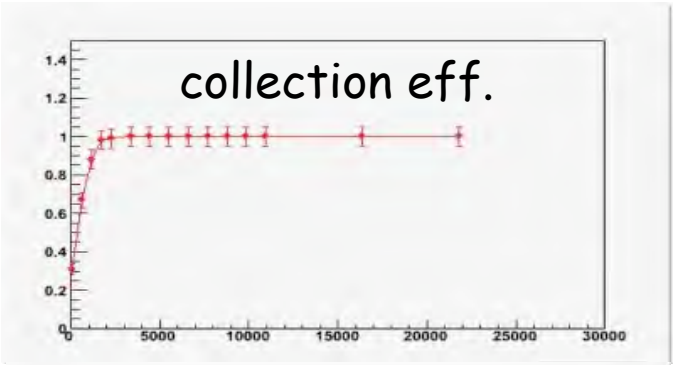
This means "transmission is largely depend on gas"

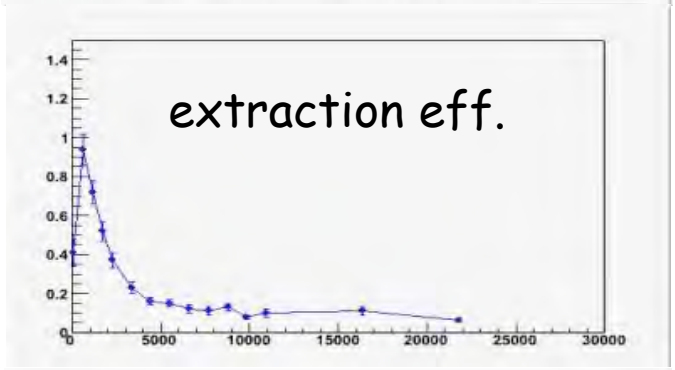
LC also requires High Magnetic Field (3~4 T)

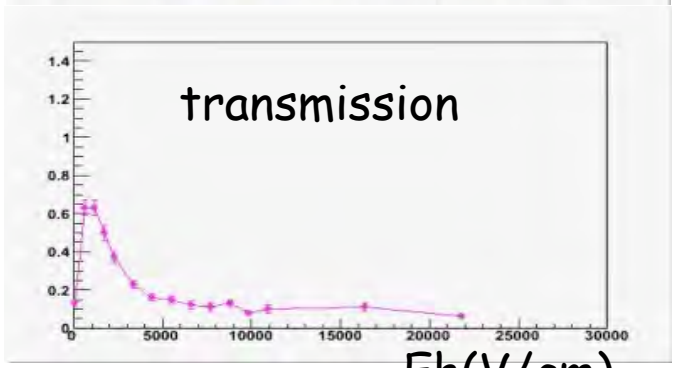


Effect of Magnetic Field

Ed=150V/cm
Et=300V/cm
F.Sauli's choice
φ 100μm hole
B = 0 T





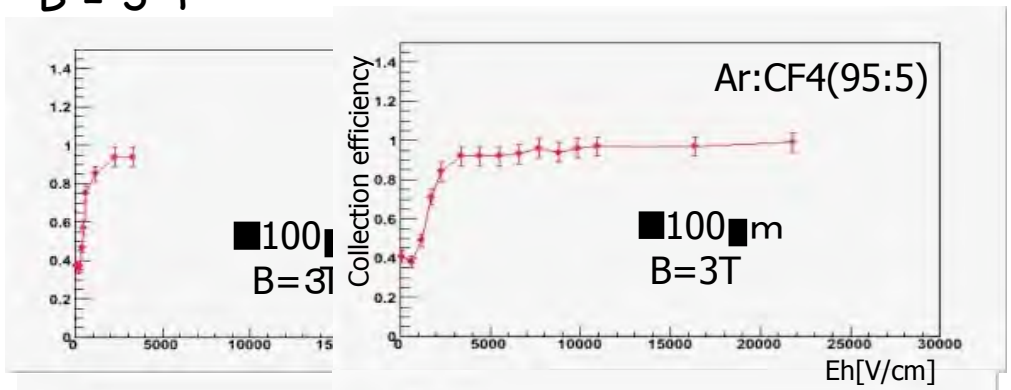


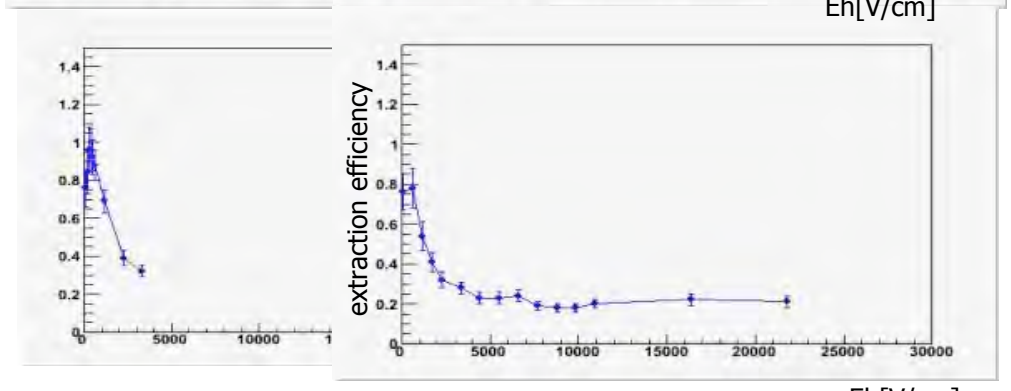
Eh(V/cm)

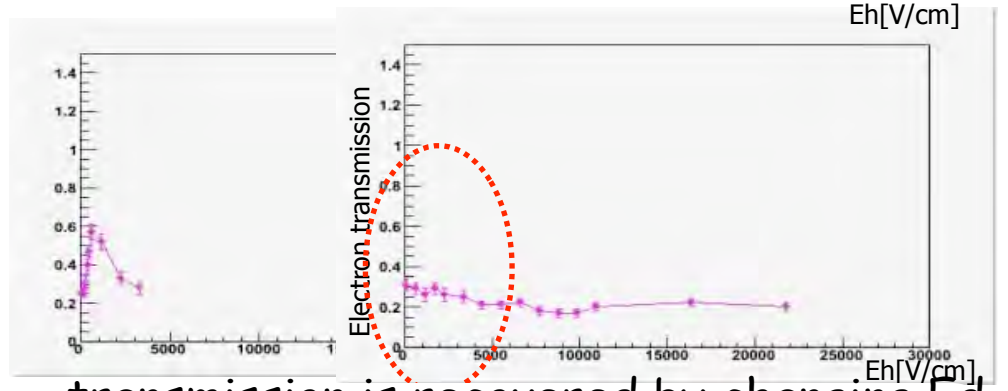
ArCF4 : candidate of LC-TPC Gas

Ed= 50V/cm
Et=300V/cm
B = 3 T

Effect of 3T magnetic field





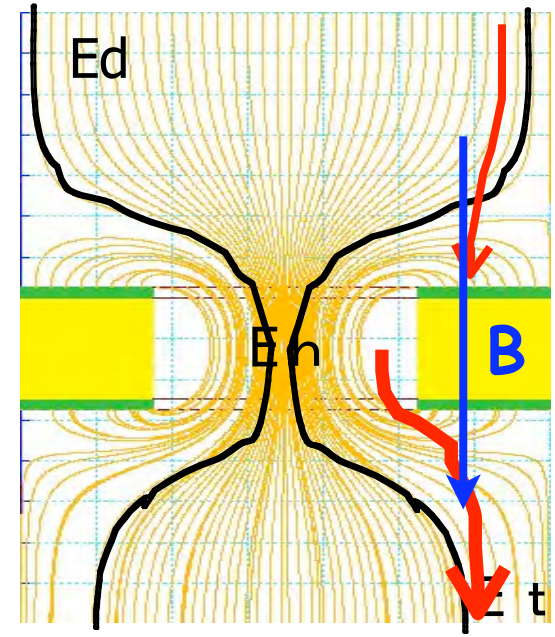


transmission is recovered by changing Ed
But not enough yet

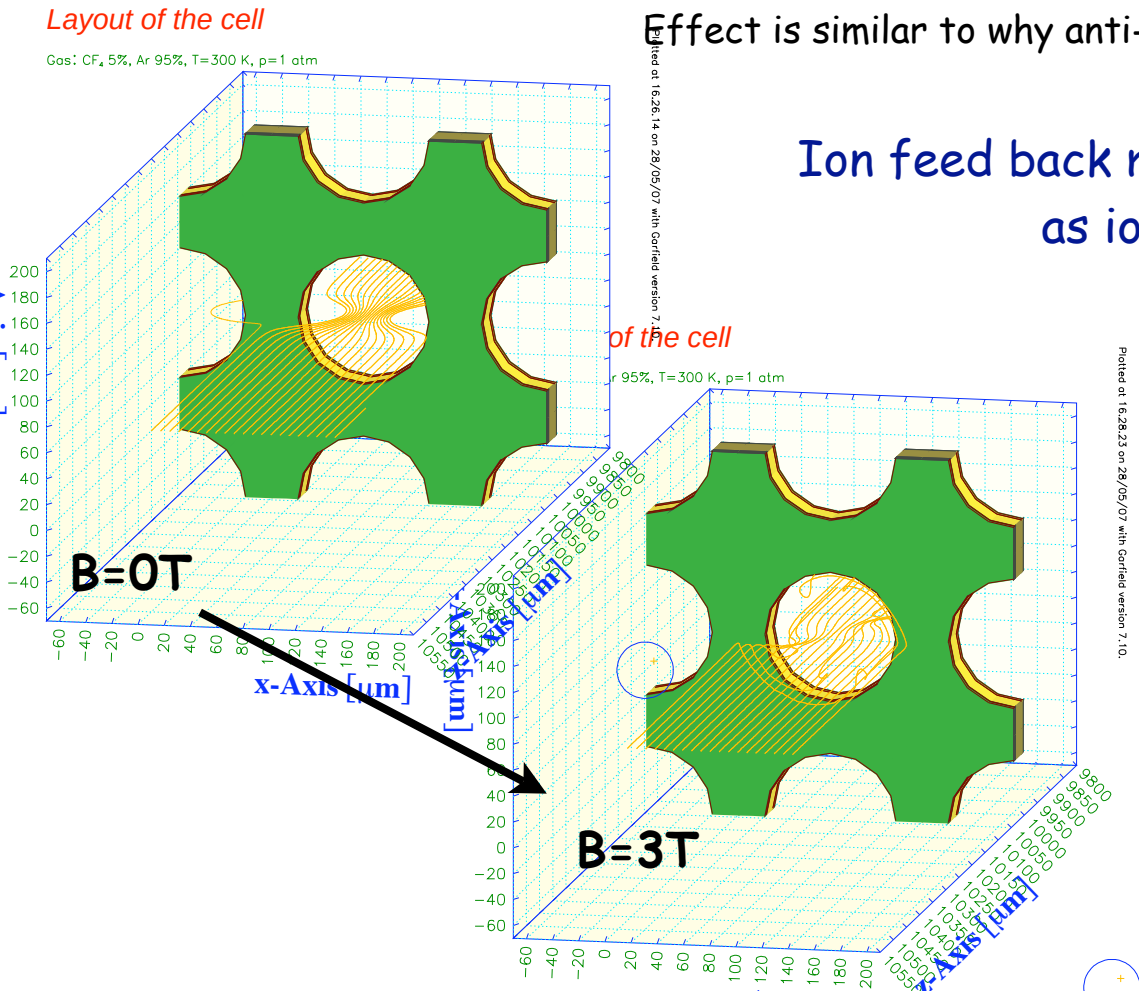
What's happening in B field ?

Collection

Once electron is attracted to the hole,
ExB effect make electron rotate around the hole
Increasing Eh field produce more line from upper GEM electrode and make this effect mild.
So, electrons are spread over whole hole under High B field



Effect is similar to why anti-DID is useful for extraction



Ion feed back must be smaller under B field as ions follow e-filed line.

Extraction

Opposite things happen in extraction.
Even electron exist on return field line,
B field make electron go along the magnetic field line.

B field help to increase extraction eff. though electron loss in hole may happen.

Optimization of GEM Gating for LC-TPC

High Magnetic Field (3 ~ 4 Tesla)
High $\omega\tau$ gas

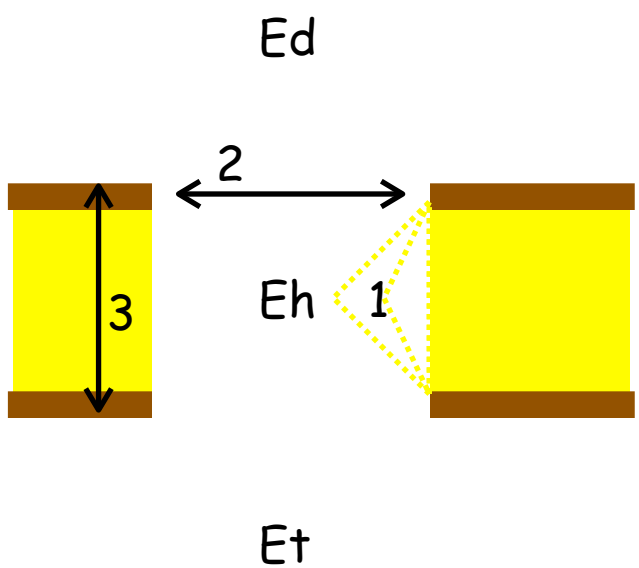
Ar:CF4 is the first candidate for this (w/ iso-C4H10)

Optimization of GEM itself

1. Hole shape
2. Hole Size/pitch
3. thickness

Optimization of operation condition

1. Drift E field : Ed
2. Hole E field (V_{GEM}) : Eh
3. transfer E field : Et



Thickness of GEM Gate

Gas: Ar:CF4 (95:5)

drift Ed 150V/cm
trans. Et 300V/cm

thickness

- 50 um
- 25 um
- 12.5 um

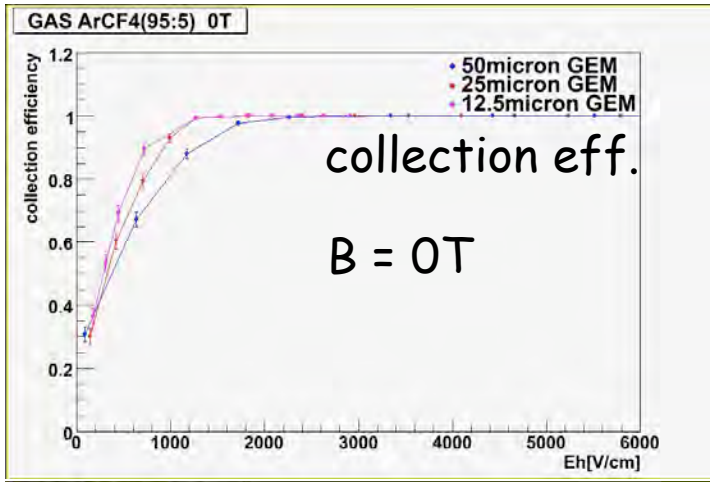
some improvement @ collection

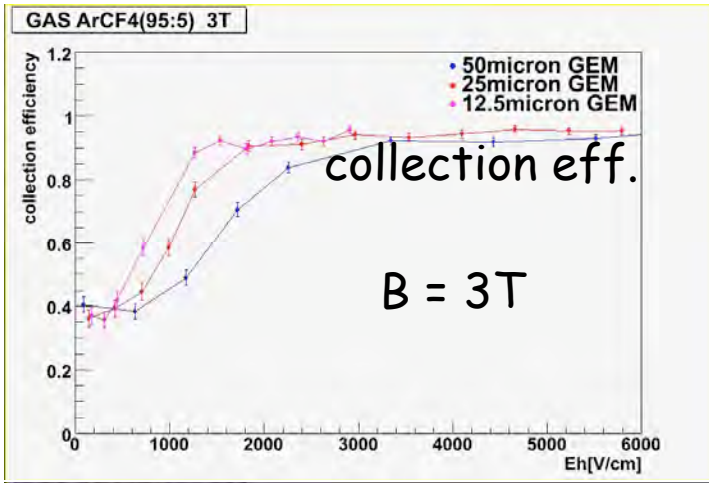
=>

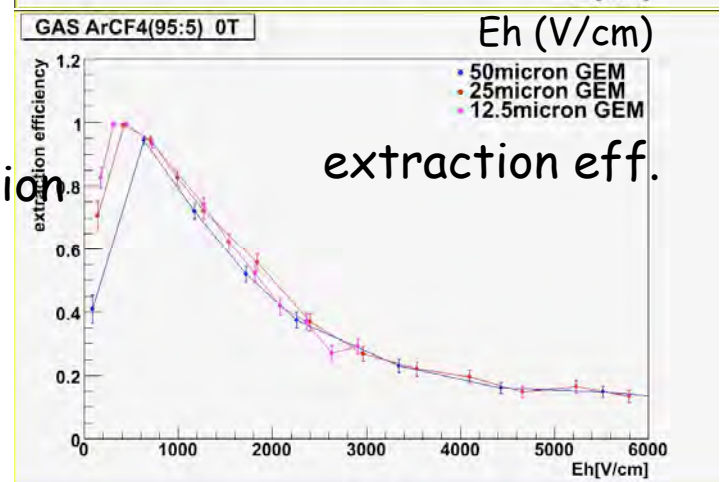
Eh becomes lower

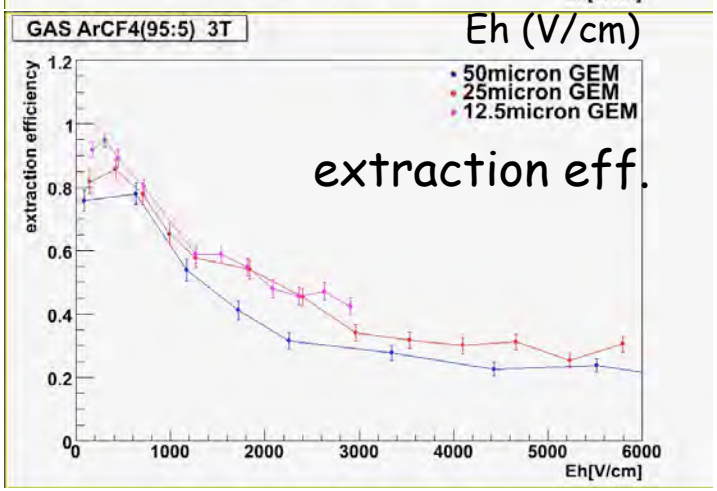
due to thinner gap

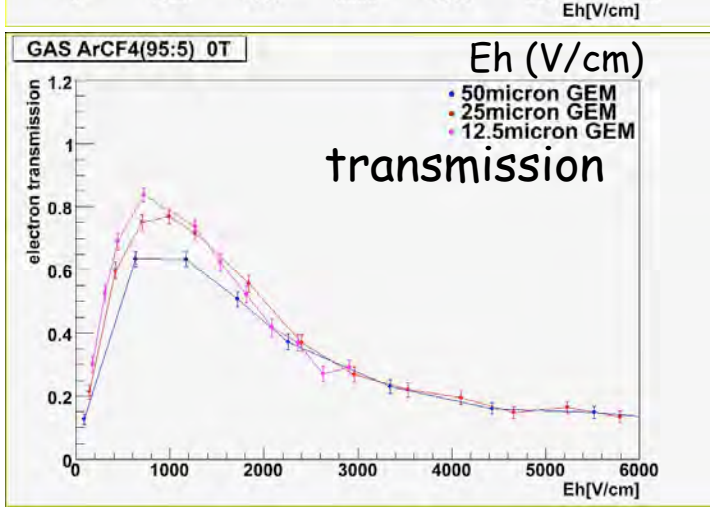
(ratio of hole size to thicknes)

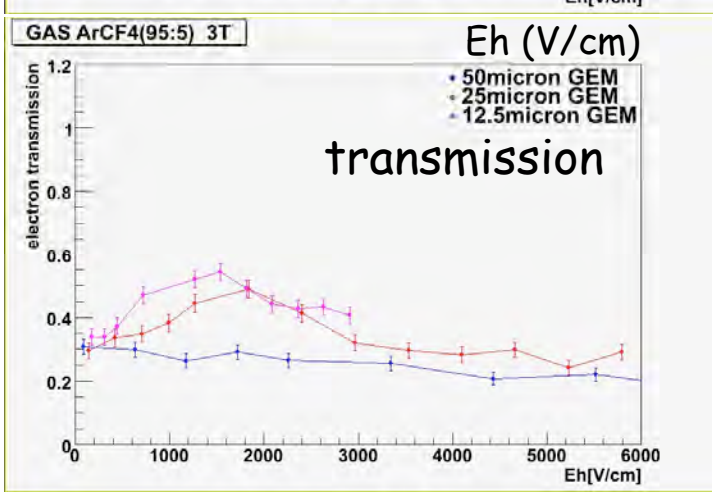












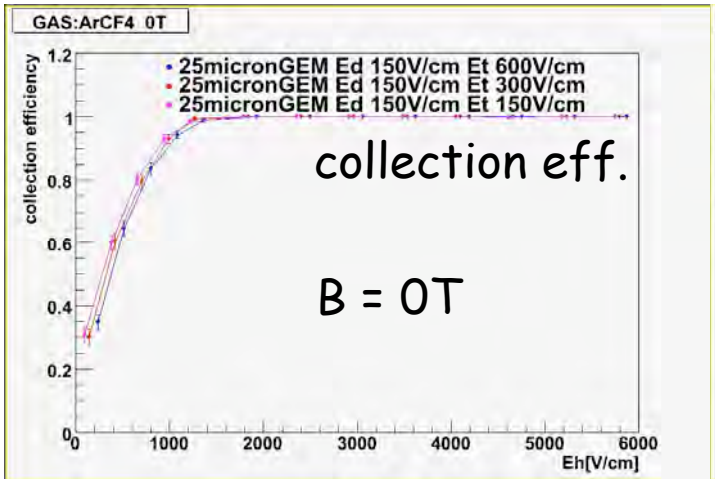
Effect of Et @25 um thick GEM

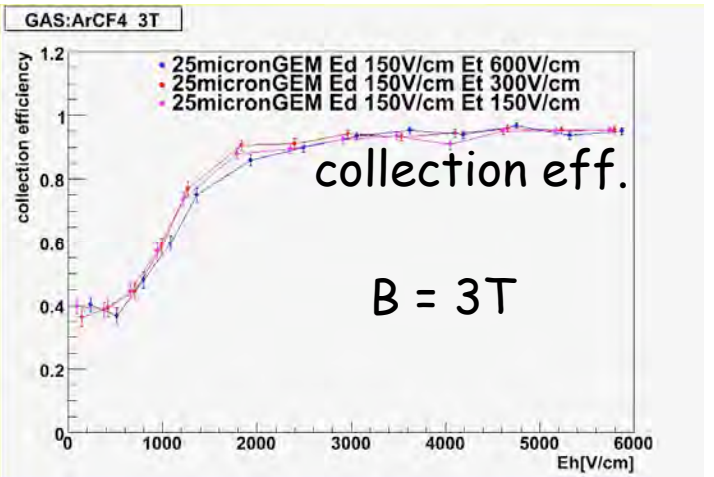
drift Ed 150V/cm

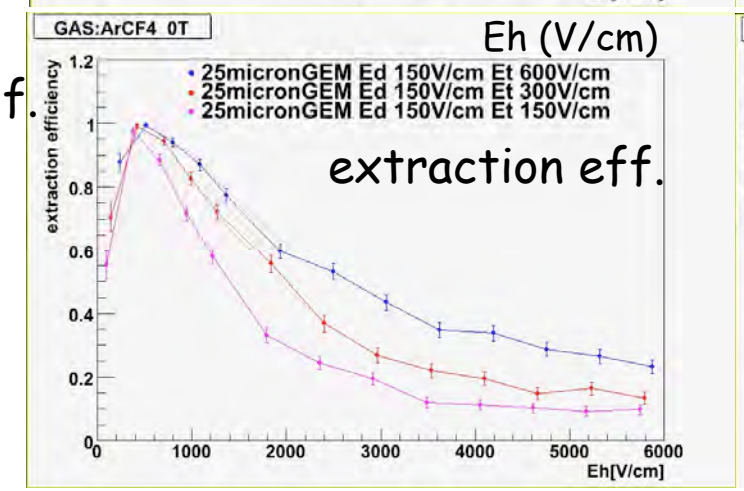
trans. Et
- 600 V/cm
- 300 V/cm
- 150V/cm

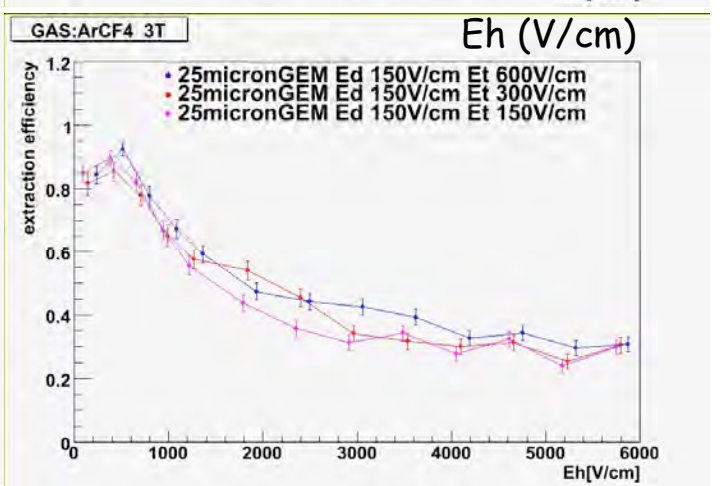
High Et improve extraction eff. very well @ B=0T

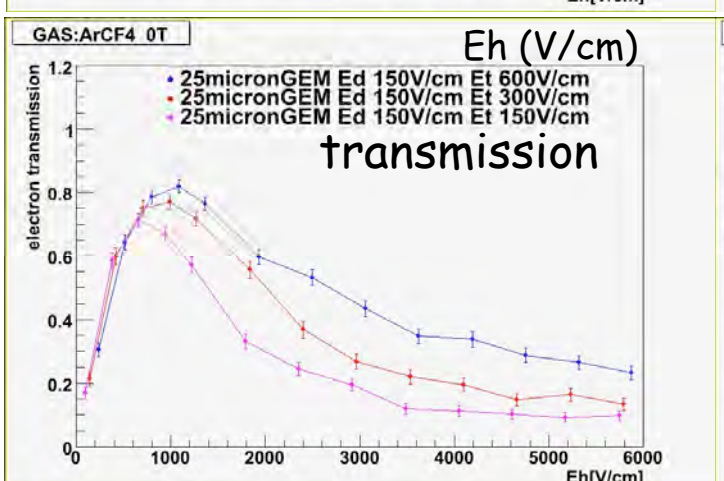
No improvement is observable @B=3T, as extraction eff. is already good

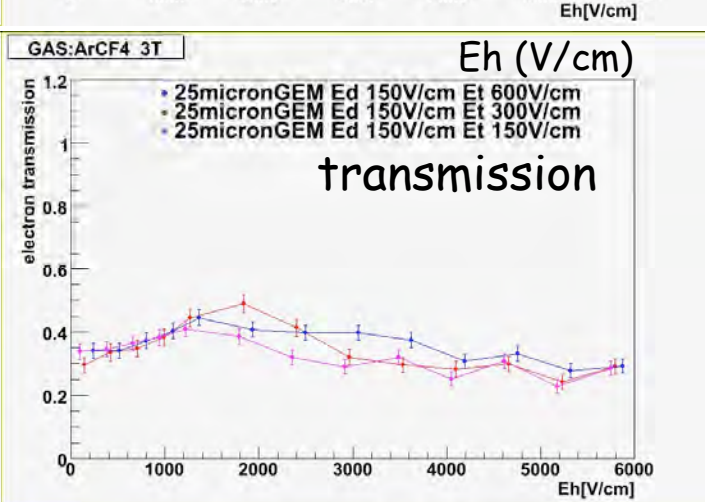












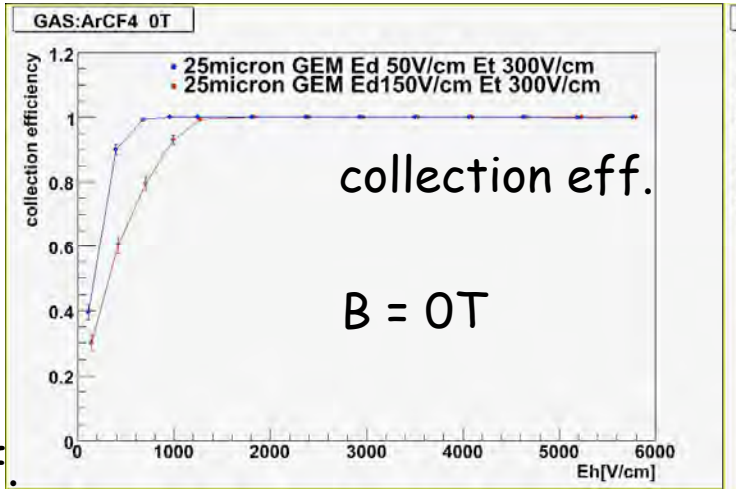
Effect of Ed @25 um thick GEM

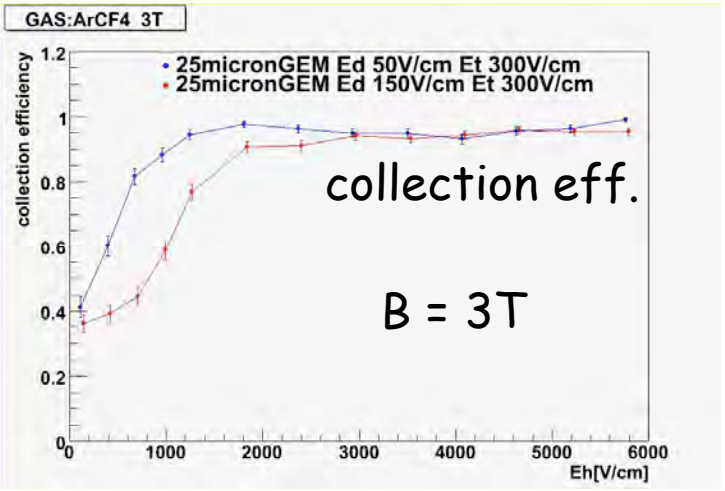
drift Et 300V/cm

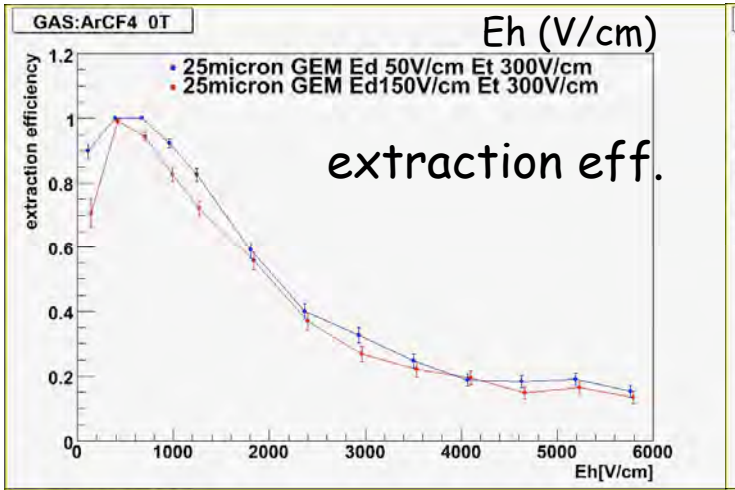
trans. Ed — 50 V/cm

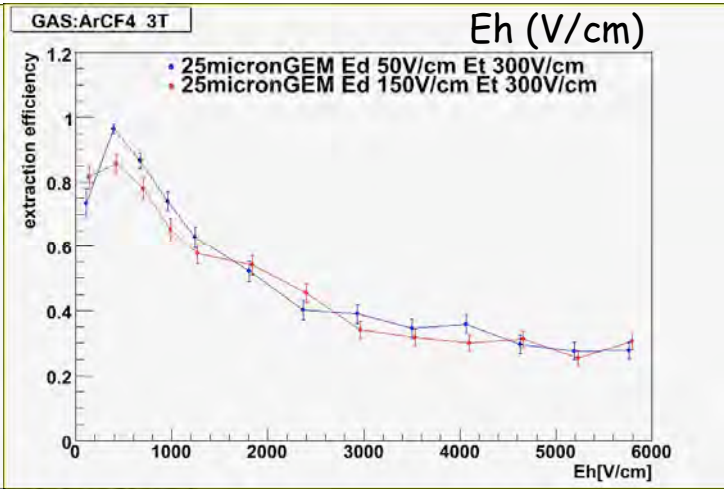
— 150 V/cm

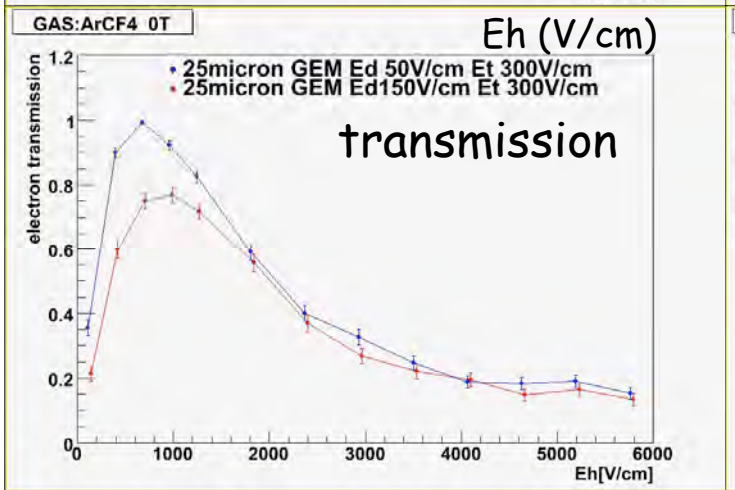
Improvement in collection eff. comes from Ed/Eh ratio !

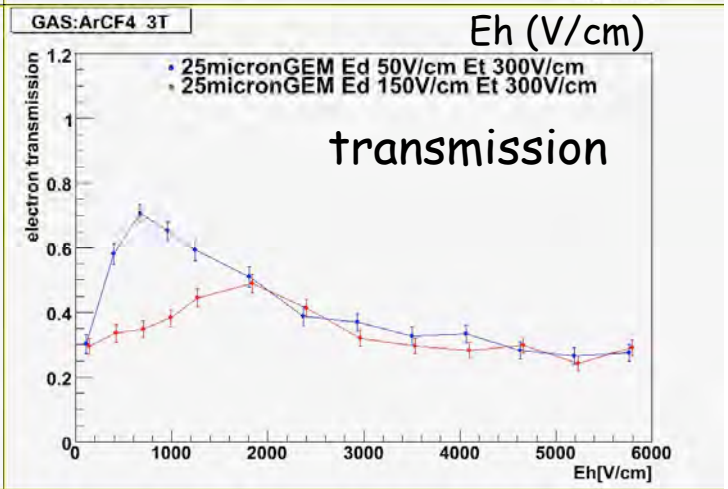












Effect of Ed @12.5 um thick GEM

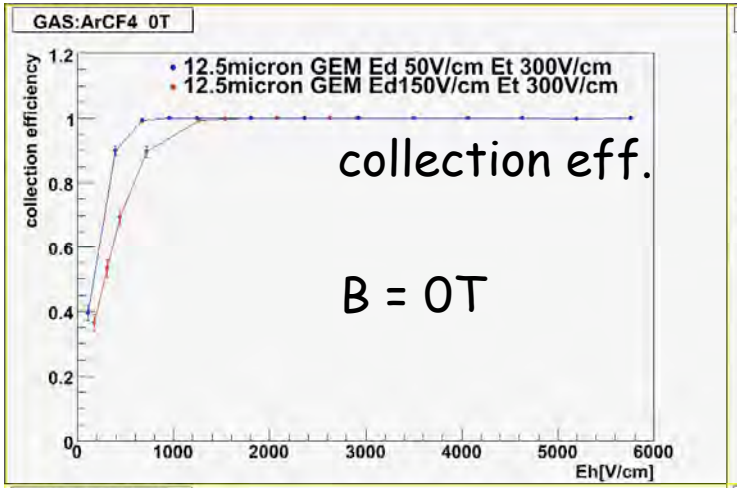
drift Et 300V/cm

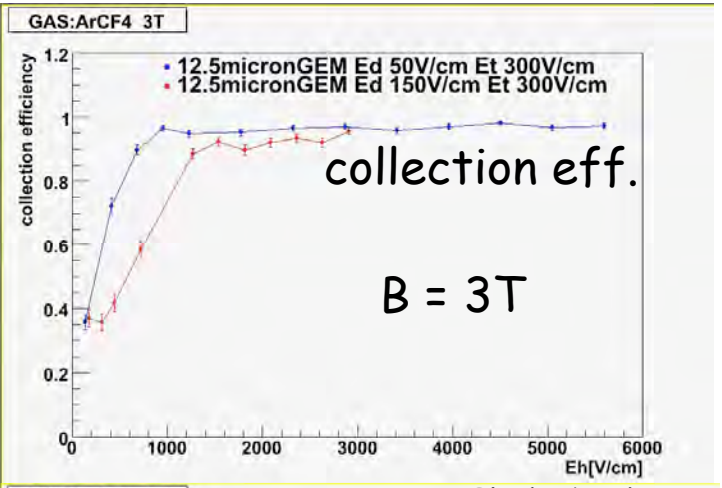
trans. Ed — 50 V/cm

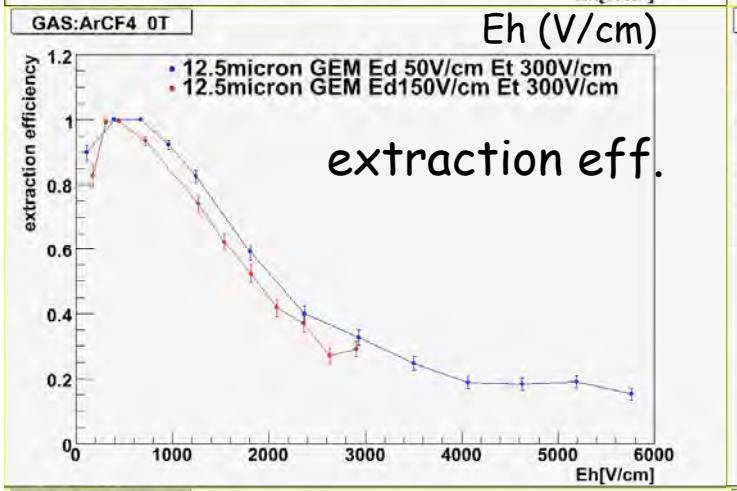
— 150 V/cm

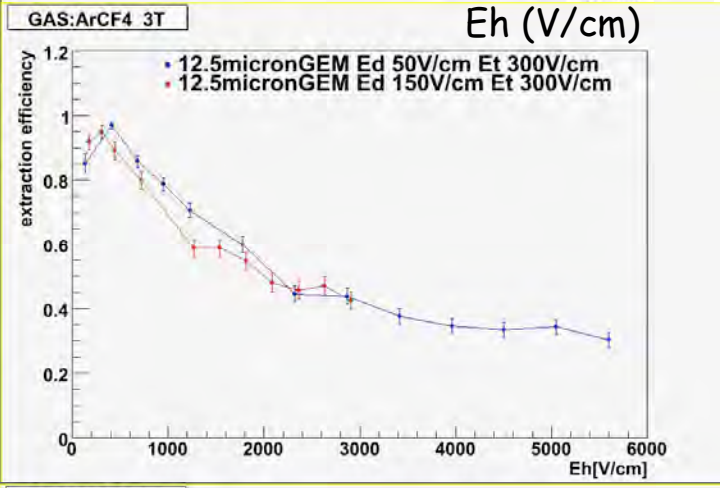
Improvement

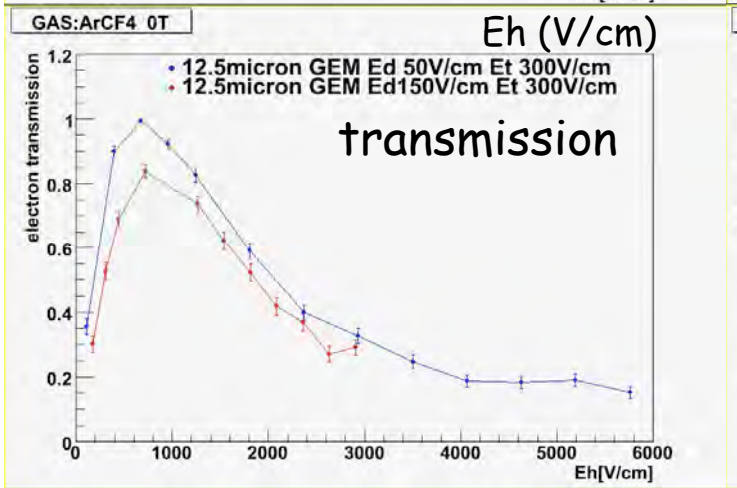
comes from Ed/Eh ratio !

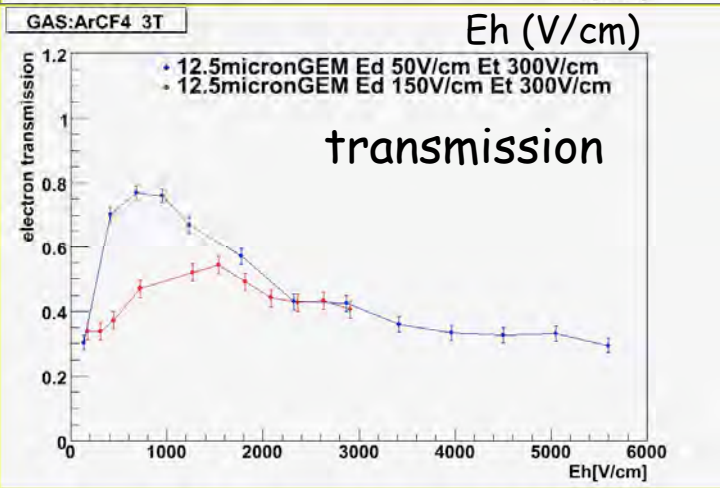












Effect of hole size/pitch @25 um thick GEM

drift Ed 50V/cm
trans. Et 300V/cm

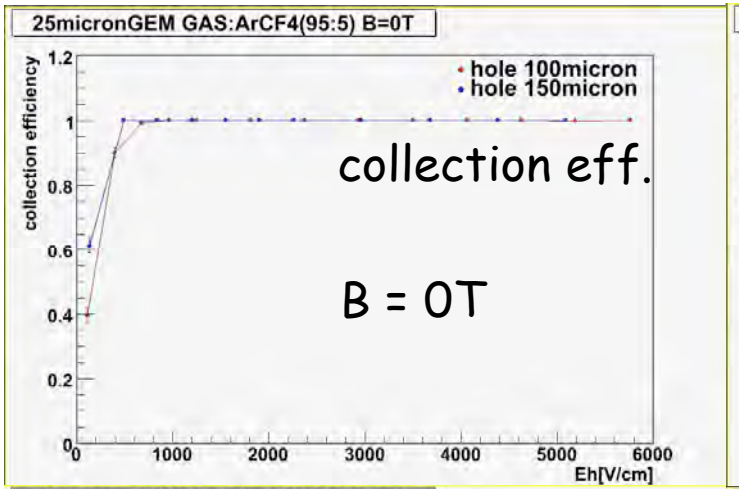
pitch/hole size

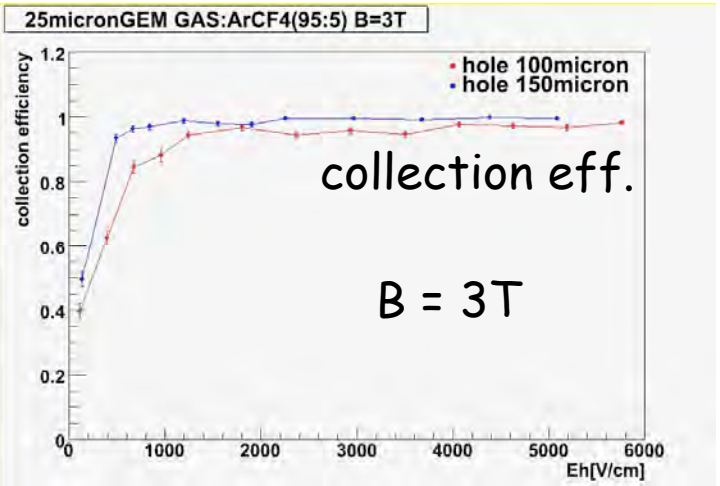
190 um/ 150 umφ

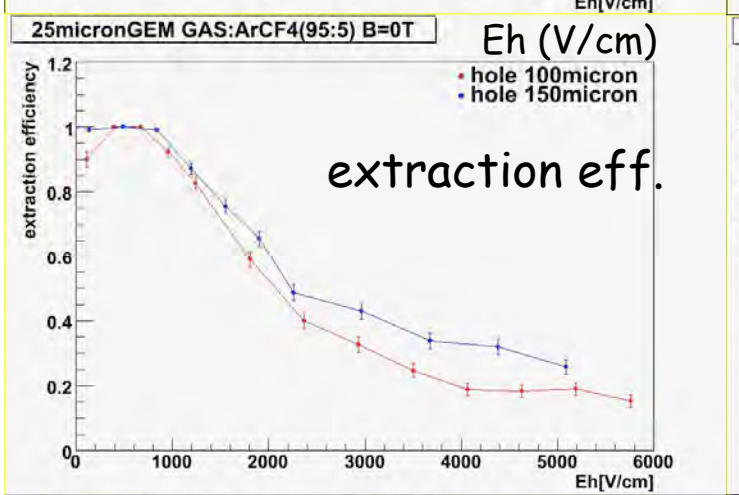
140 um/ 100 umφ

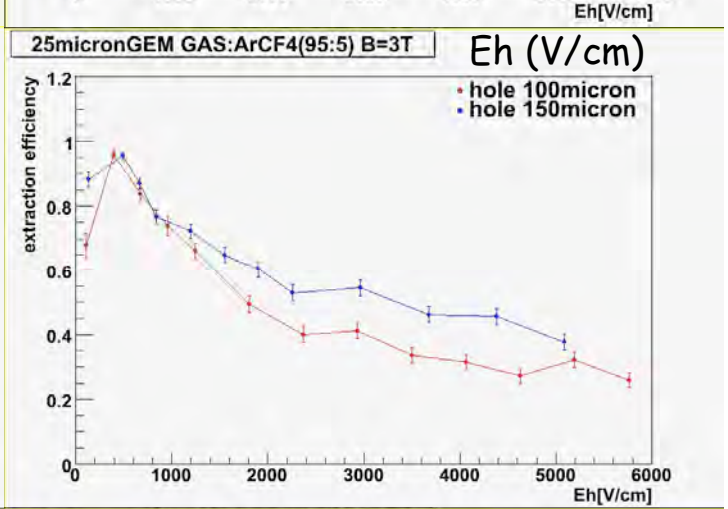
Caution !

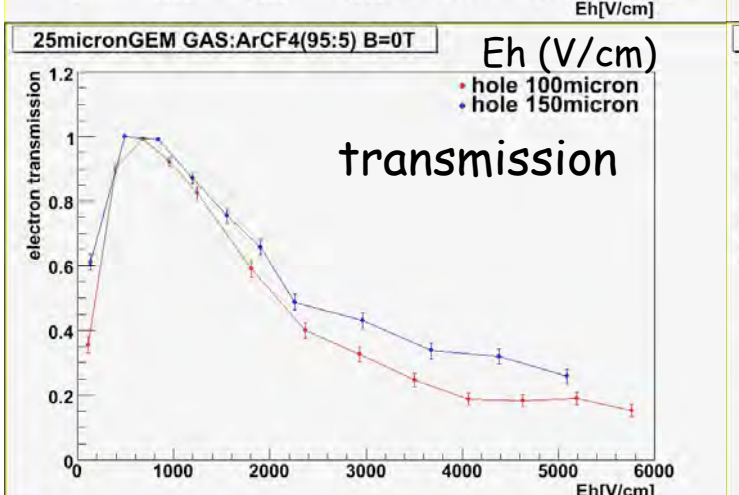
3T case some electrons
go to neighbor holes
(by ExB ...)
which make resolution worse

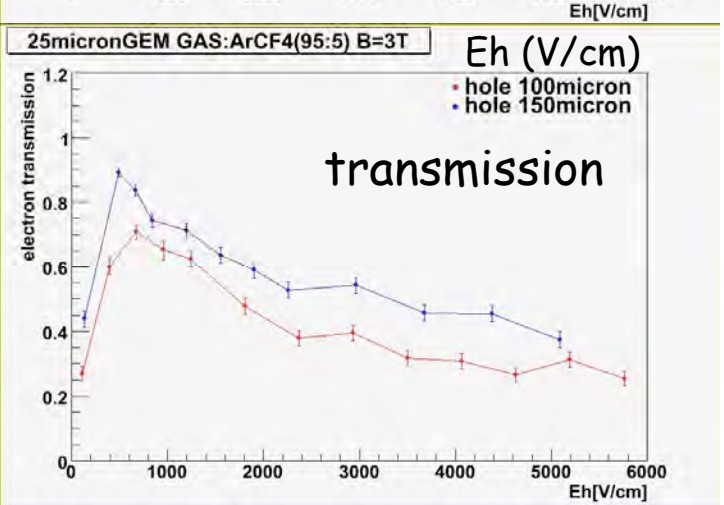












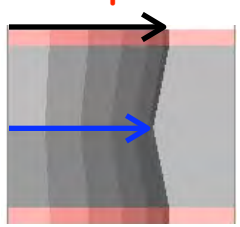
Effect of hole shape

B = 0T

Hole shape

bi-conical shape
outer phi=100 um

inner phi=90 um

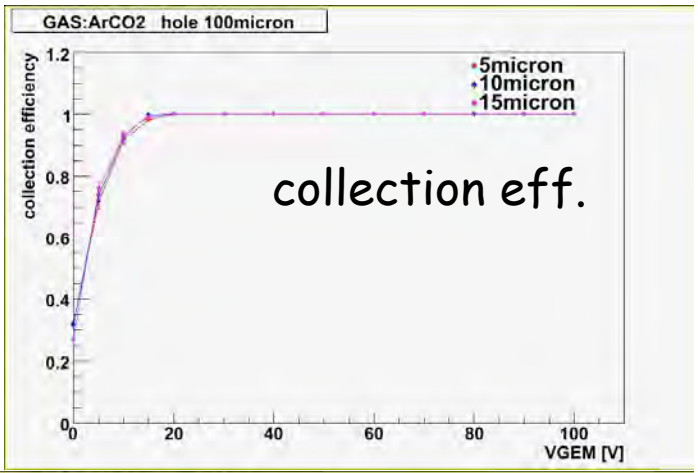


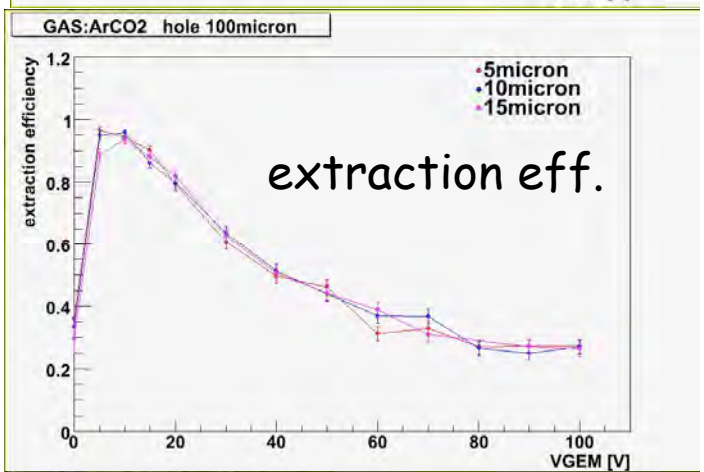
Hole shape is not a matter !
Over etching will be also not a matter
under low E field

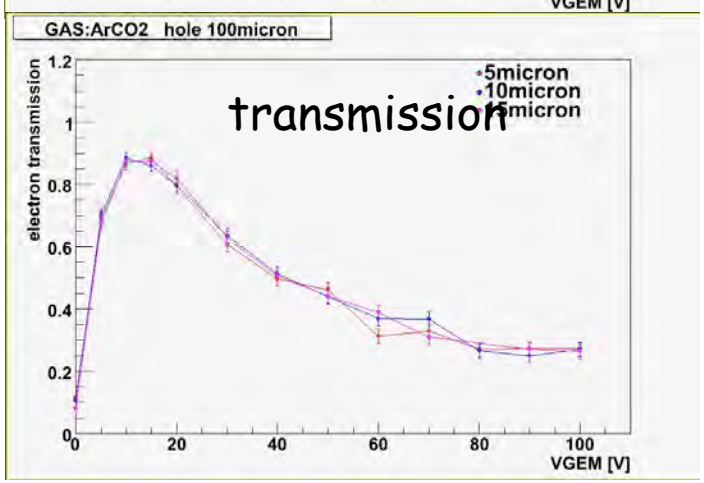
inner phi=80 um

BUT, under B field
the situation may be changed !?
as B change electron path
(not done yet,
but japanese GEM has straight hole would not be a problem)

inner phi=70 um







Summary of simulation study

If GEM would be used for GATE, it must be

Aperture must be large (larger hole size)
Thinner GEM is better for Gating
Field shaping around hole
Eh need to be kept low (diffuion)
Ed must be low (50V/cm)
Et must be high (300V/cm) (but just below diffusion rise)

We may be able to achieve 70% transmission @25um thick GEM in simulation.
(10% error may exist)

Do you accept this number ??

Confirmation is necessary ! especially under High B field

Need to establish how to measure.
25um thick GEM is available (though hole diameter is 90 um)
Do we try 12.5um for 10% improvement ?

DESY 5T magnet is necessary for this

Let's do together