A Simulation Study of GEM gating at ILC-TPC

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This is my first talk in English in my life.
Please forgive me, if something is wrong

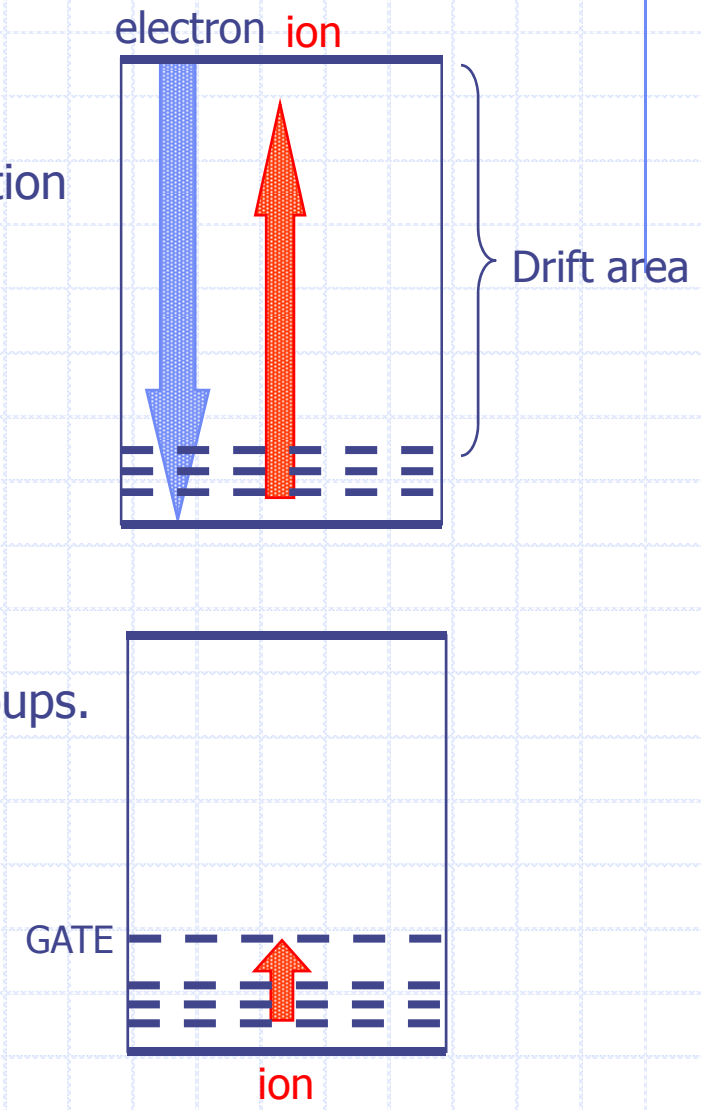
Why do we need Gating for TPC?

A lot of ions are produced at MPGD gas multiplication region
as well as many primary ions at the drift region.
We want to decrease ion density at drift region as small as possible.

Though MPGD has self-absorbing ability of ion feedback,
the best efficiency has been measured as $O(10^{-3})$ by several groups.

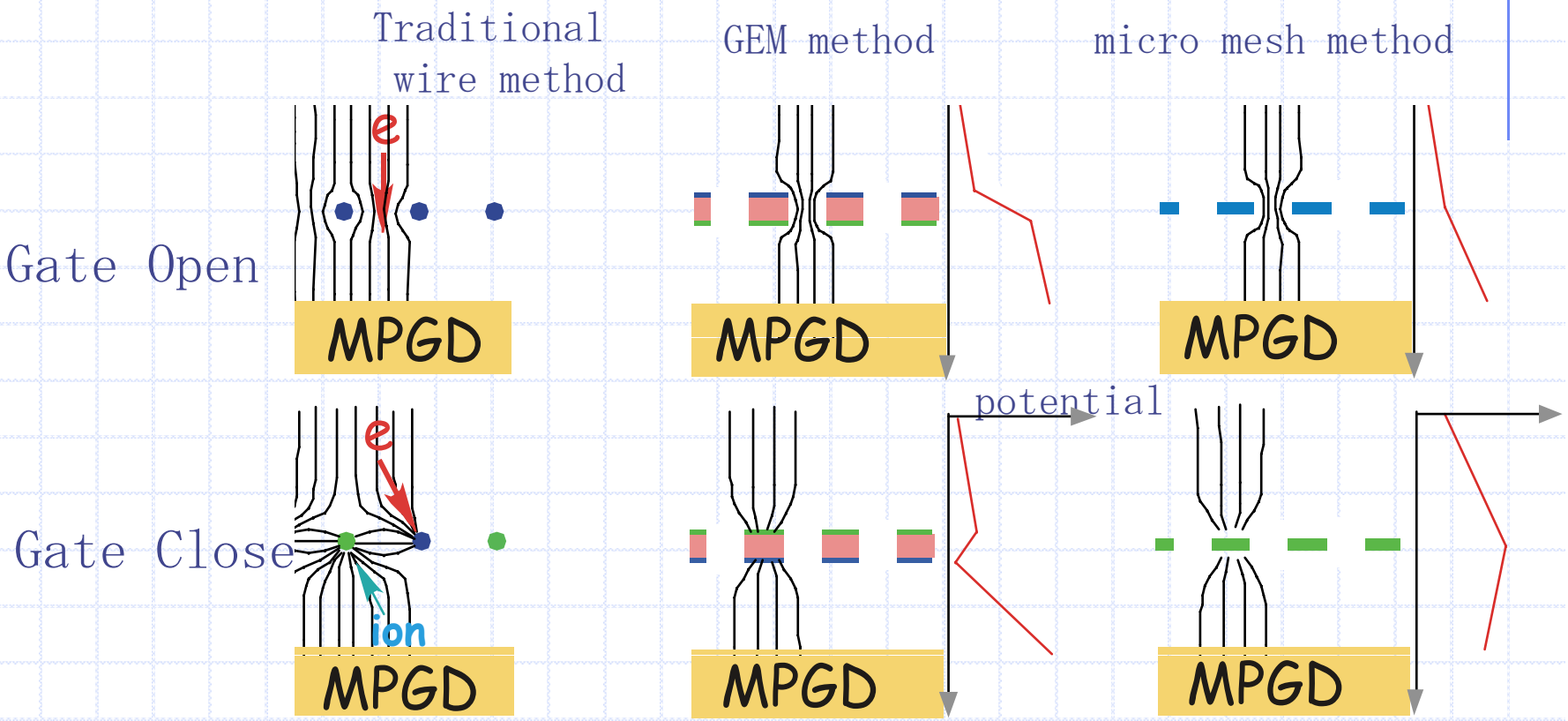
As ILC-TPC requires a few x 10^3 gain,
extra "Gating" mechanism may be necessary !!

We should prepare gate mechanism



How can we achieve "Gating" for TPC?

There are three candidates



Wire
wire spacing would be large ~O(1 mm)
May deteriorate resolution by ExB
stiff structure to stretch wires
Local change of E field around wires

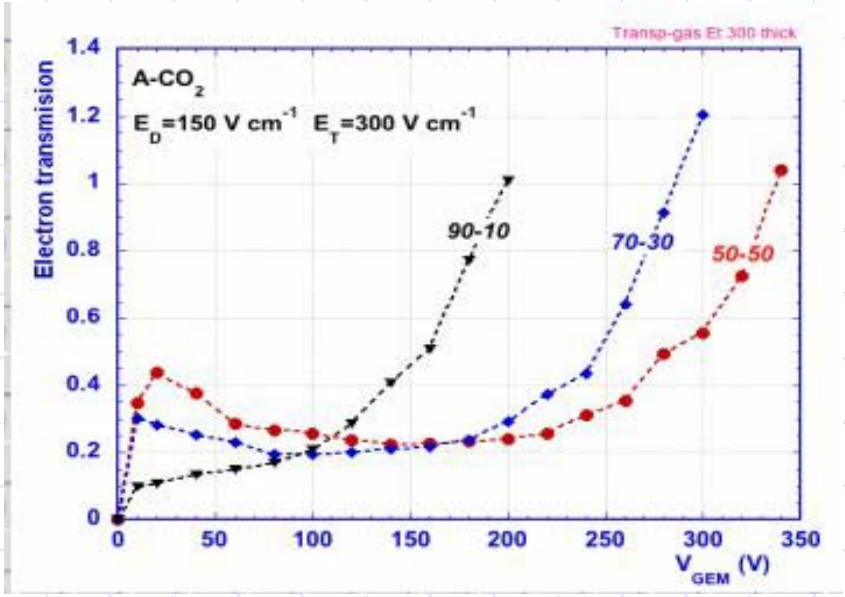
GEM
Electron transmission is in question
collection/extraction efficeincy
hole pitch ~O(100um)
need structure to hold GEM
No change of E field @ drift region

Micro mesh
need thin mesh
for higher transmission
mesh pitch ~O(50um)
Larger change of E field
@ drift region

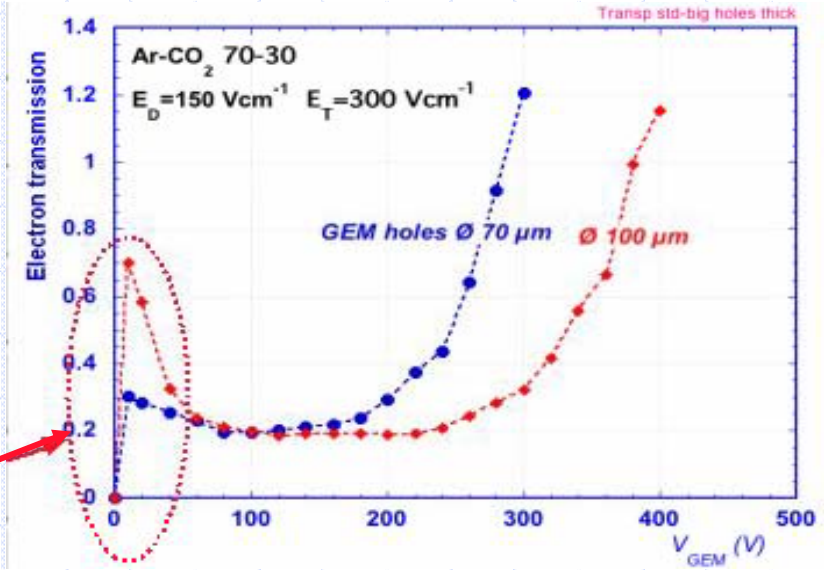
F.Sauli had proposed GEM gating @LBLTPC WS'06

These figures are picked up from his slides.

GAS EFFECT



HOLE DIAMETER EFFECT



10 V/50 µm ~ 2 kV/cm!

Why low voltage operation give us higher transmission ?
Does this work for any gas?
Is this applicable to LC-TPC?
How much electrons will be lost ? -> resolution
This affects to Gas choice of LC-TPC We have to consider seriously this issue.

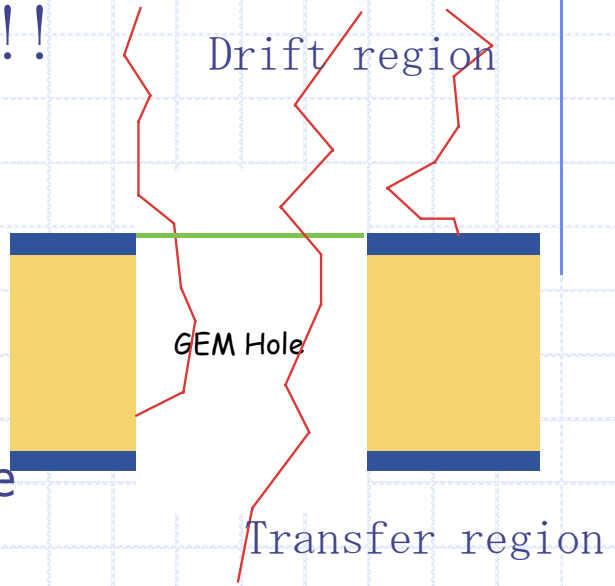
How do we understand his data ?

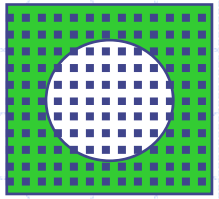
Garfield help us to understand it !!

Transmission = Collection eff. x Extraction eff.

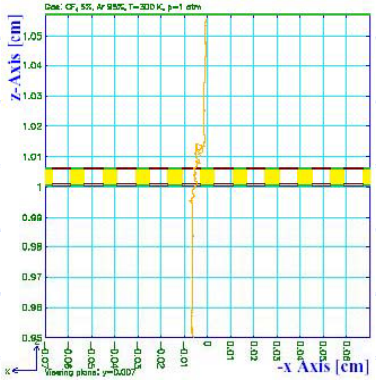
$$\text{Collection eff.} = \frac{\#\text{electrons arrived at Hole entrance}}{\#\text{ produced electron}}$$

$$\text{Extraction eff.} = \frac{\#\text{electrons coming out from GEM hole}}{\#\text{electrons arrived at Hole entrance}}$$





In the simulation electrons are generated 500um above the GEM surface, at 20x20 different positions covering the hole part of GEM.



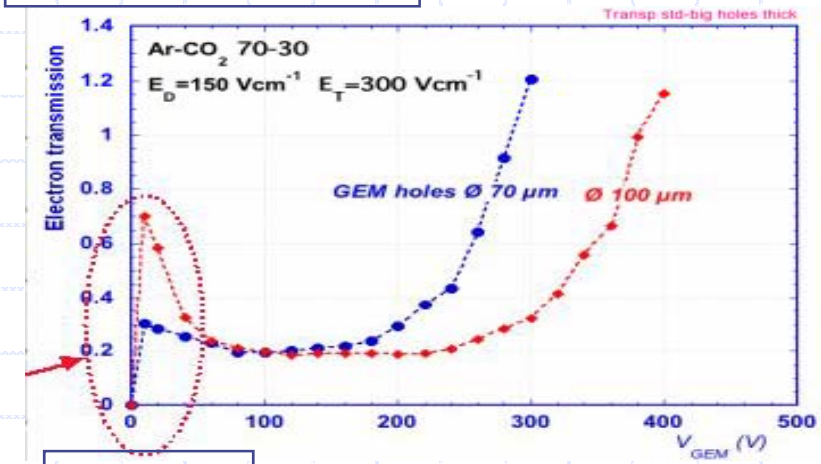
Simulation results are compared to Sauli’s measurement

*remarks: you have to choose proper “step size”
we finally chose 2um as step length

Comparison with measurements

- HOLE DIAMETER EFFECT

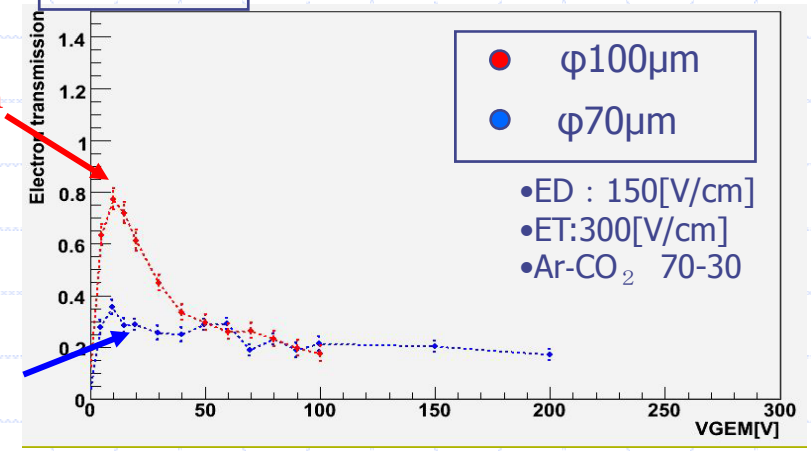
Measurement by Sauli



simulation

Φ100μm

φ70μm



The figure shows transmission as a function of VGEM for Ar:CO2=70:30, where Ed is set to 150V/cm and Et is set to 300V/cm.

Blue line shows the case of hole diameter = 70um and red line shows 100um in φ.

Red line(100um) has a peak at VGEM=10V.

Simulation results show the same behavior for both cases. Red line has a peak at 10V.

Absolute values of transmission are also reasonably reproduced.

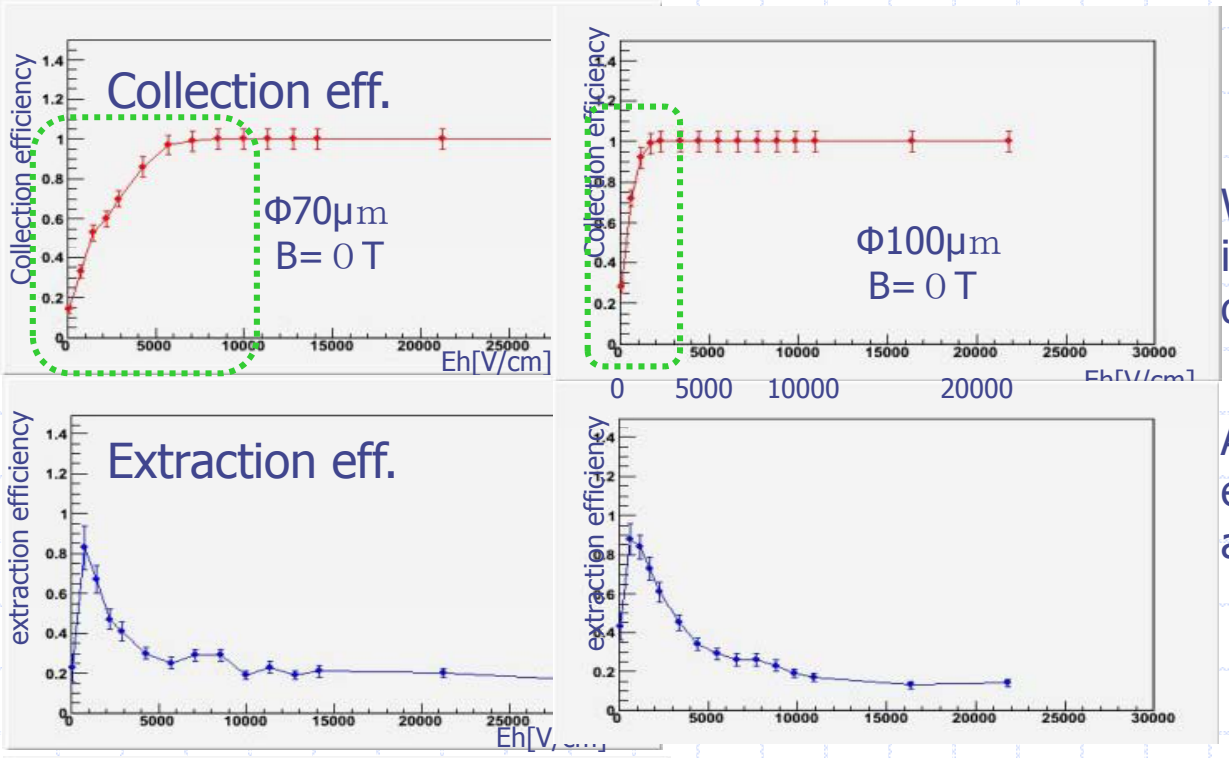
Difference above VGEM=200V between measurements and simulation is a effect of gas gain which is not included in the simulation at this study.

Hole size effect

GAS Ar-CO2
70 : 30

- Ed : 150[V/cm]
- Et : 300[V/cm]

Horizontal axis is Electric field at hole center instead of VGEM (Eh depends on a hole size even with the same VGEM)

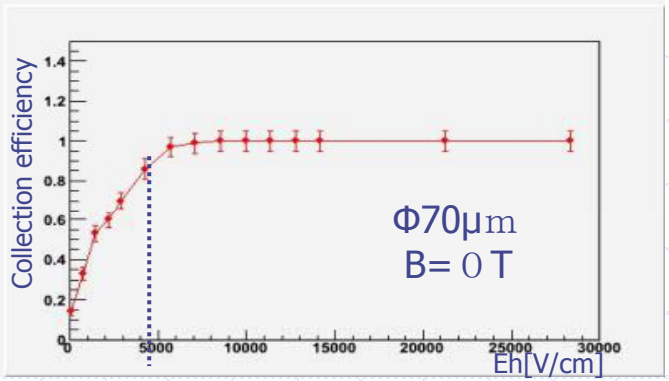


We clearly see a big difference in collection efficiency between different hole sizes

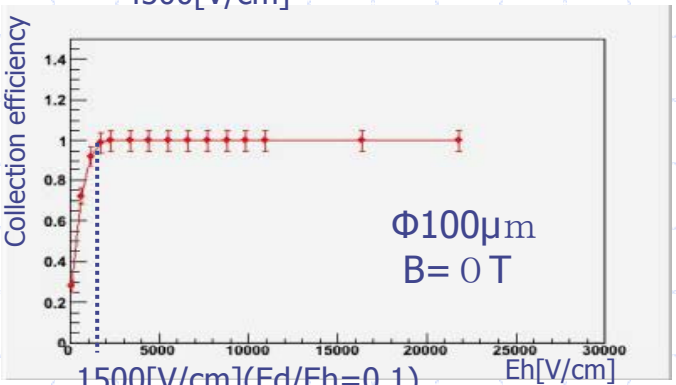
A slight difference exist in extraction efficiency if we look at carefully.

These effects result in a difference in transmission.

collection efficiency



4500[V/cm]



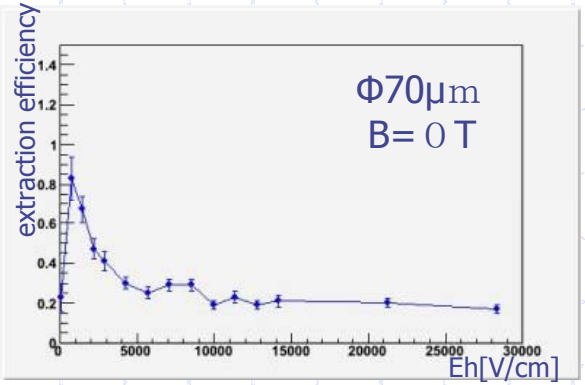
1500[V/cm](Ed/Eh=0.1)

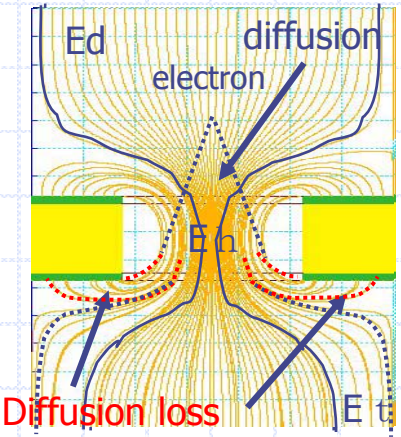
Collection efficiency has been studied by many groups and is known to be 1 at Ed/Eh<~0.03

Which almost corresponds to 4.5 kV for 70um hole.

In 100um φ case, collection efficiency reach to 1 at Ed/Eh<0.1.

extraction efficiency





In the case of extraction efficiency, the area of pass-through field lines from drift region would shrink as Electric field in the hole.

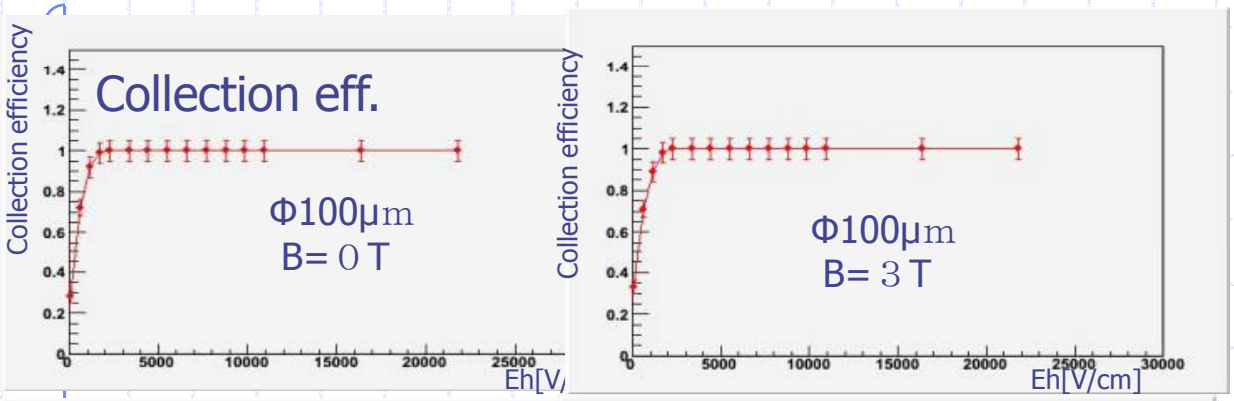
And Diffusion under high electric field becomes larger and electrons may escape into return line.

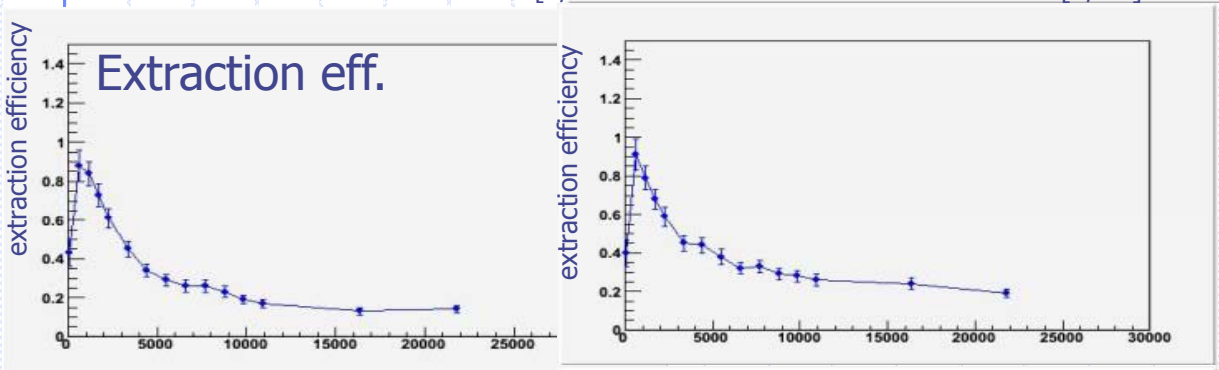
Effects of shrinking electric filed lines and diffusion may determine this behavior.

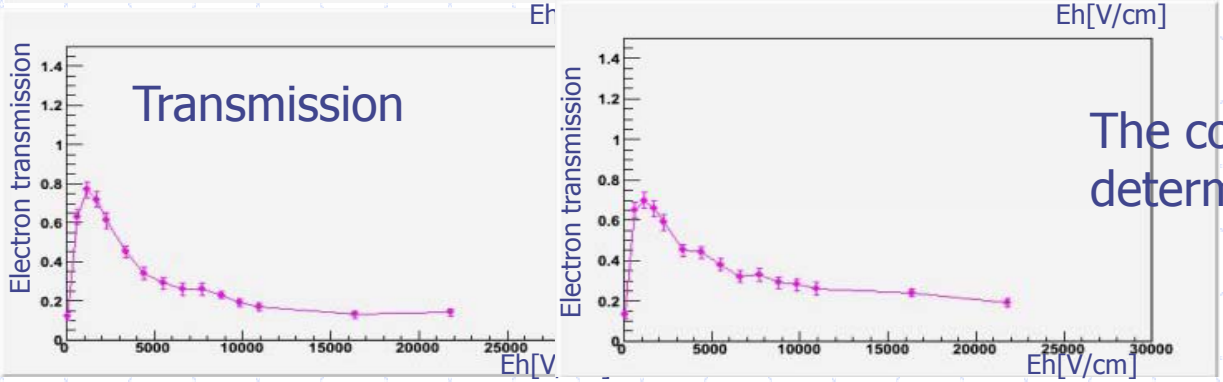
Effect of magnetic field （Ar-CO2　70：30）

- Ed：150[V/cm]
- Et：300[V/cm]

As the magnetic field is necessary for LC-TPC, how the magnetic field affect to transmission is another important issue.







In the case of ArCO2 mixture, effect of magnetic field is very little.

Slight difference for the extraction efficiency is observable and may reduce transmission a little bit, while the collection efficiency is exactly identical.

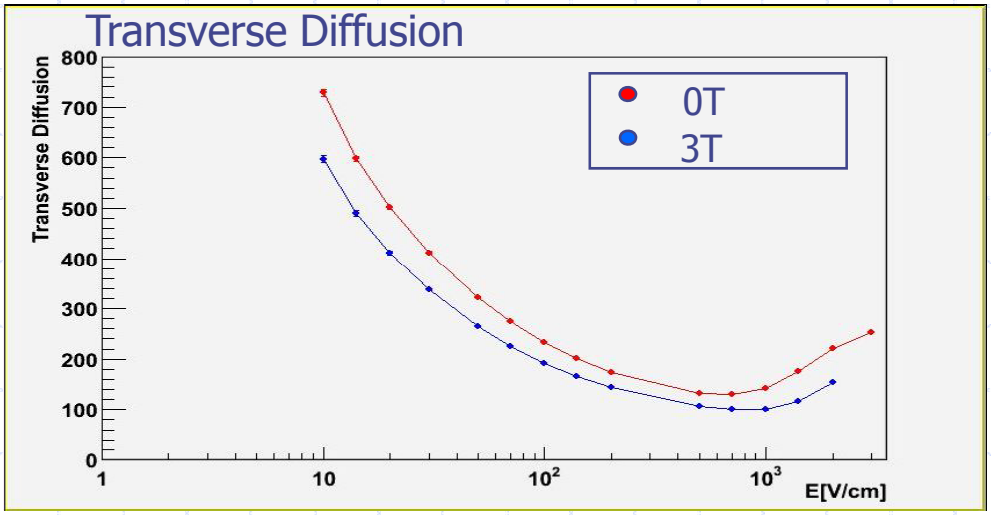
The collection efficiency may be determined by electric field only.

Effect of magnetic field（Ar-CO2　70：30）

The reason why the magnetic field doesn't change behavior of transmission is explained by the characteristics of diffusion for CO2 mixed gas.

Though extraction is depend on the diffusion, behavior of diffusion for 0T and 3T are very similar each other, it would not provide big difference.

Ar:CO2（70:30）

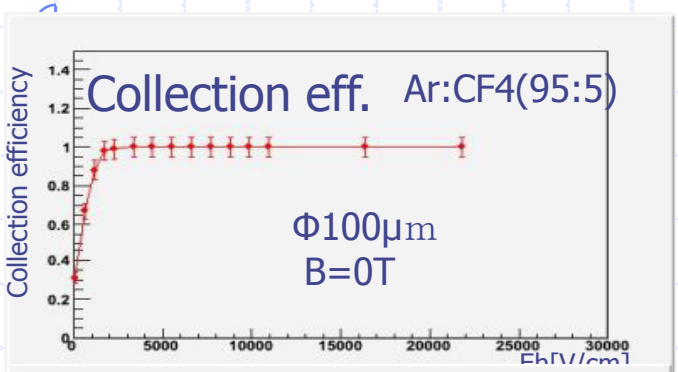


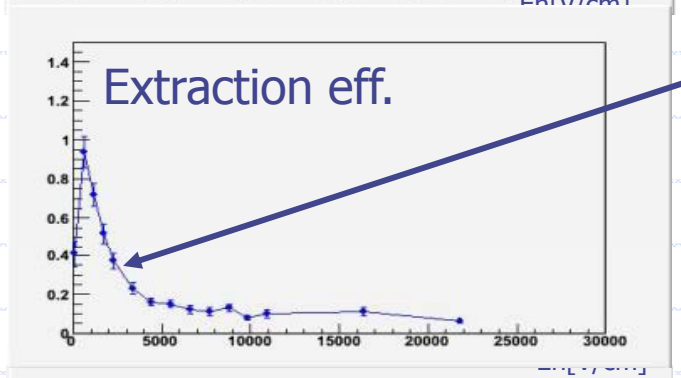
If we summarize results of ArCO2 mixture, we can conclude the best electron transmission is almost 80% because Efficient region of collection and that of extraction are overlapping each other in this gas mixture.
Unfortunately this gas is not a candidate for LC-TPC as diffusion is not low enough to assure 100um resolution.

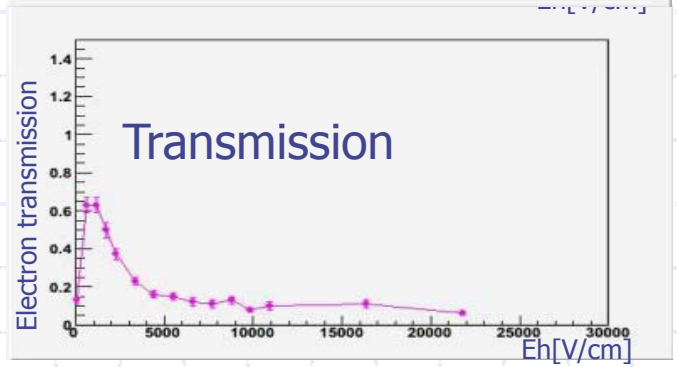
Ar-CF4 95 : 5

- Ed : 150[V/cm]
- Et : 300[V/cm]

CF4 mixture is a one of candidates gas for LC-TPC





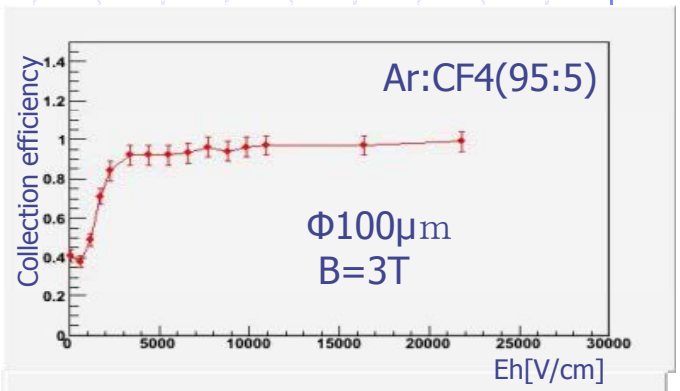


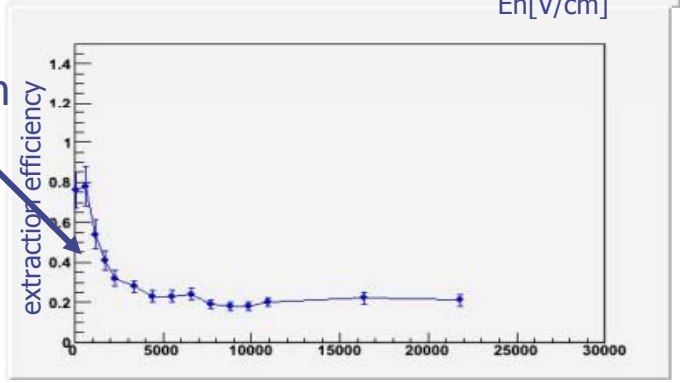
Once we apply magnetic field, collection efficiency move to high Electric field direction and

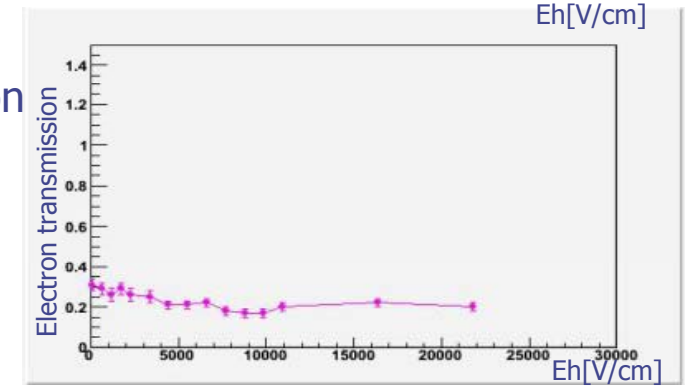
efficient extraction region become much narrower and overlap region disappear.

Why collection efficiency is changed by magnetic field is under investigation

Under magnetic field ArCF4 cannot be used with this condition.







Ar-CF4　95 : 5

In order to improve collection efficiency,

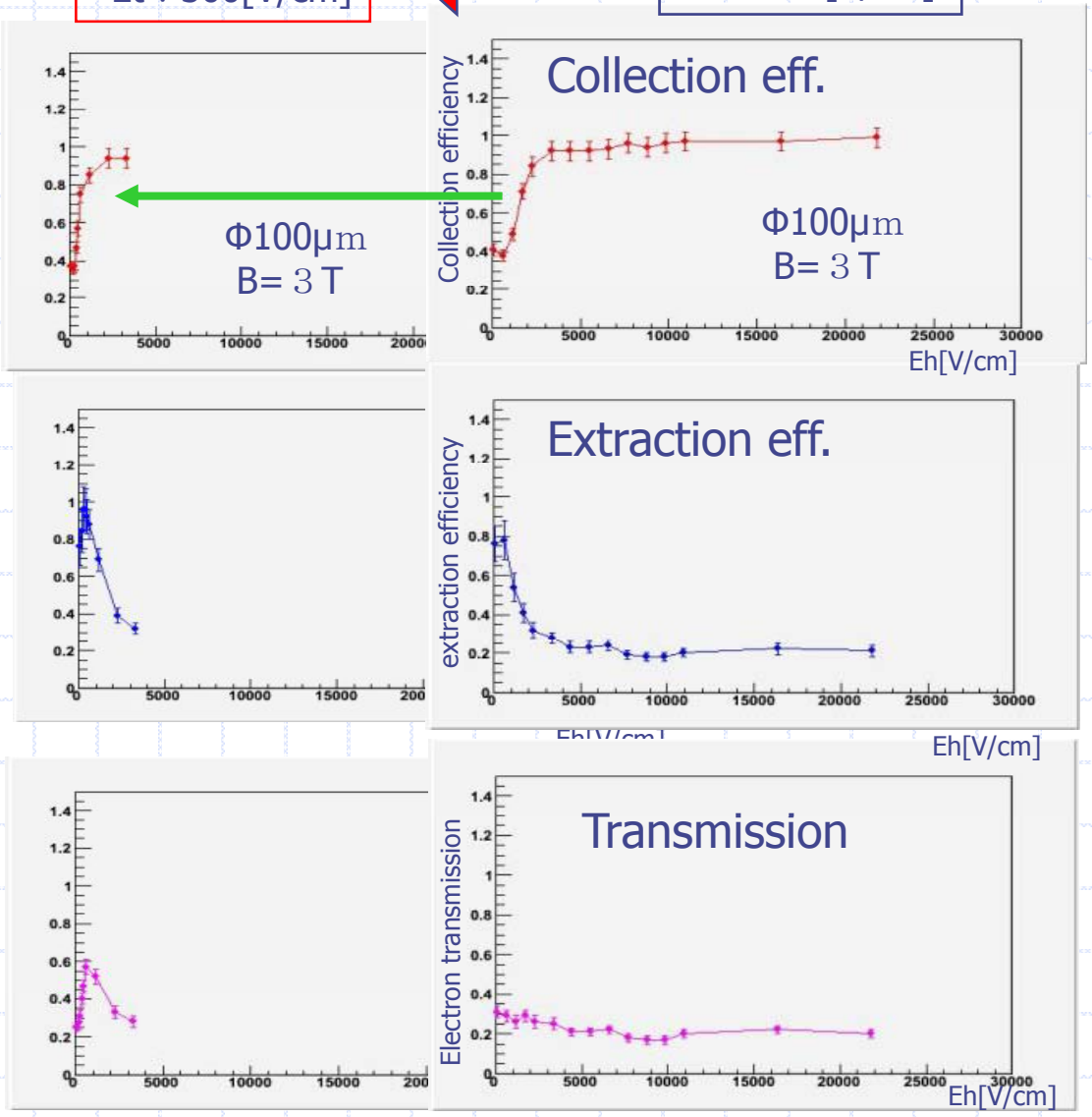
I reduce electric field of the drift region from 150V/cm to 50V/cm.

Collection efficiency is recovered at low Eh.

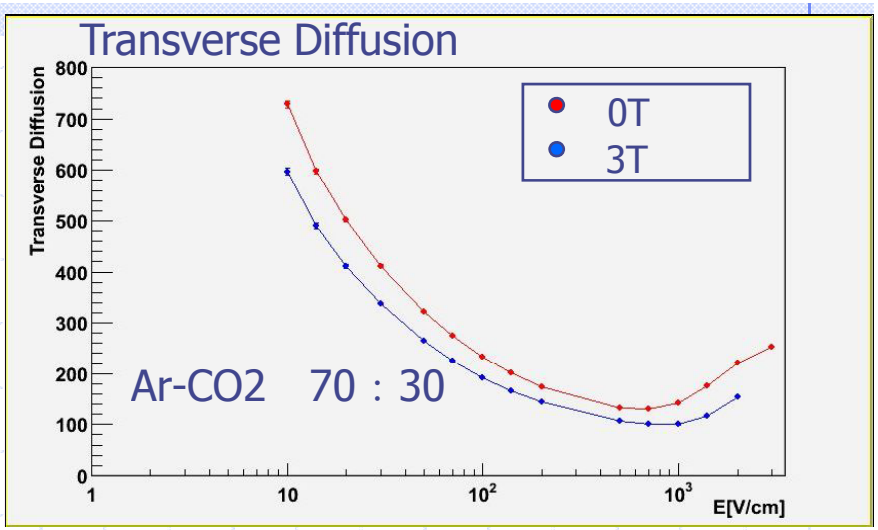
Transmission is improved up to ~60% with mag. field.

•Ed : 50[V/cm]
•Et : 300[V/cm]

•Ed : 150[V/cm]
•Et : 300[V/cm]



Ar-CF4 95 : 5



60% transmission is achieved for ArCF4.

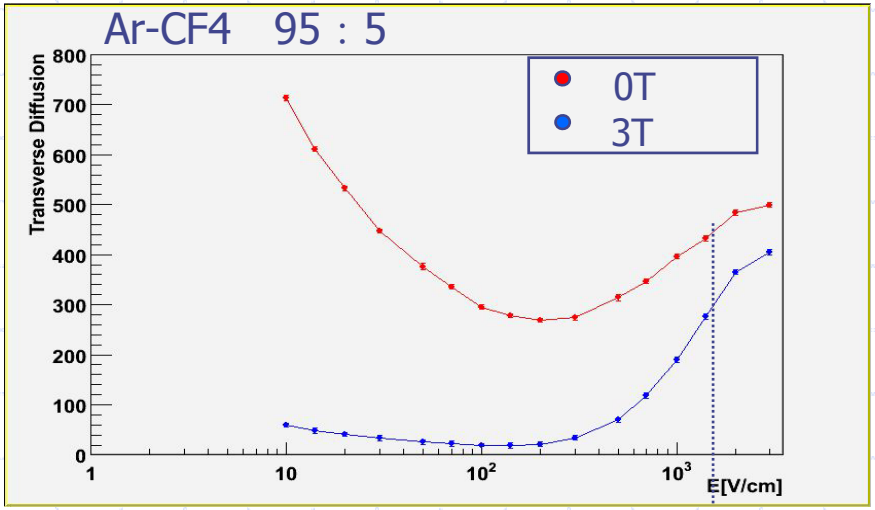
- We still want to have better transmission.

One possibility is increasing transfer field in order to improve extraction efficiency.

But we cannot chose Et freely.

Et is a incoming field for the following GEM for gas amplification, we have to Keep Et/Eh<0.03.

Et must be below 1.5kV/cm.

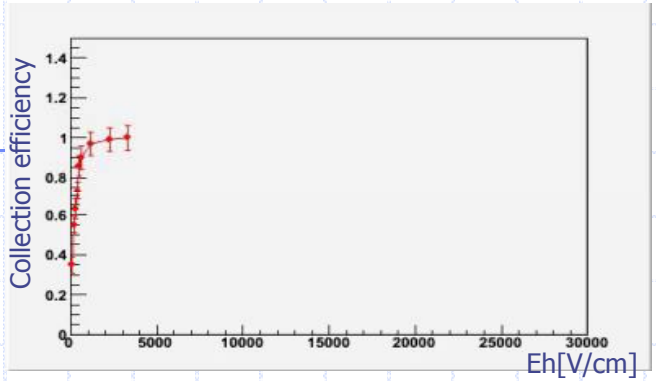


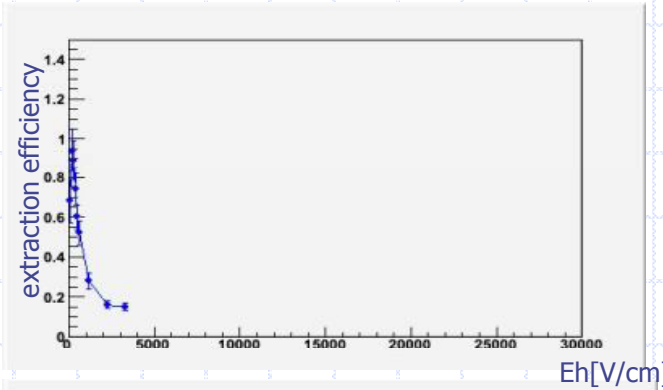
But at the same time we have to worry about higher diffusion at high Et may deteriorate the resolution again.

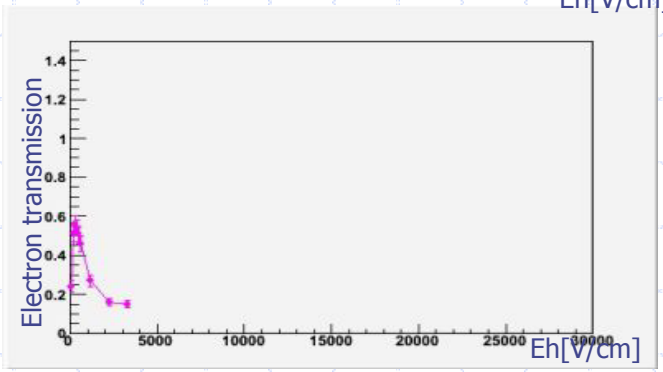
P-5

- Ed : 50[V/cm]
- Et : 300[V/cm]

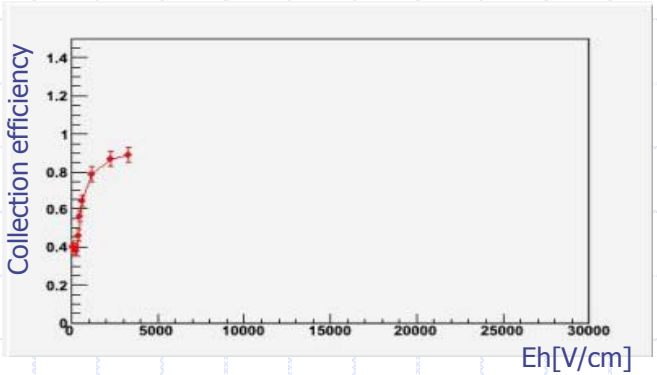
Φ100μm
B=0T

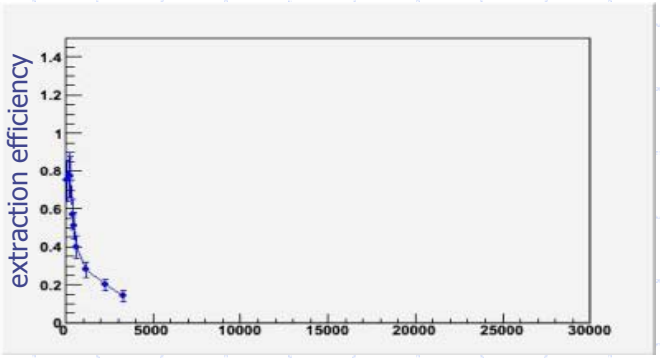


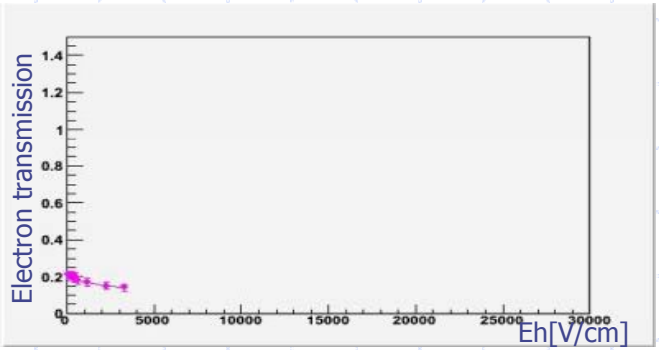




Φ100μm
B=3T





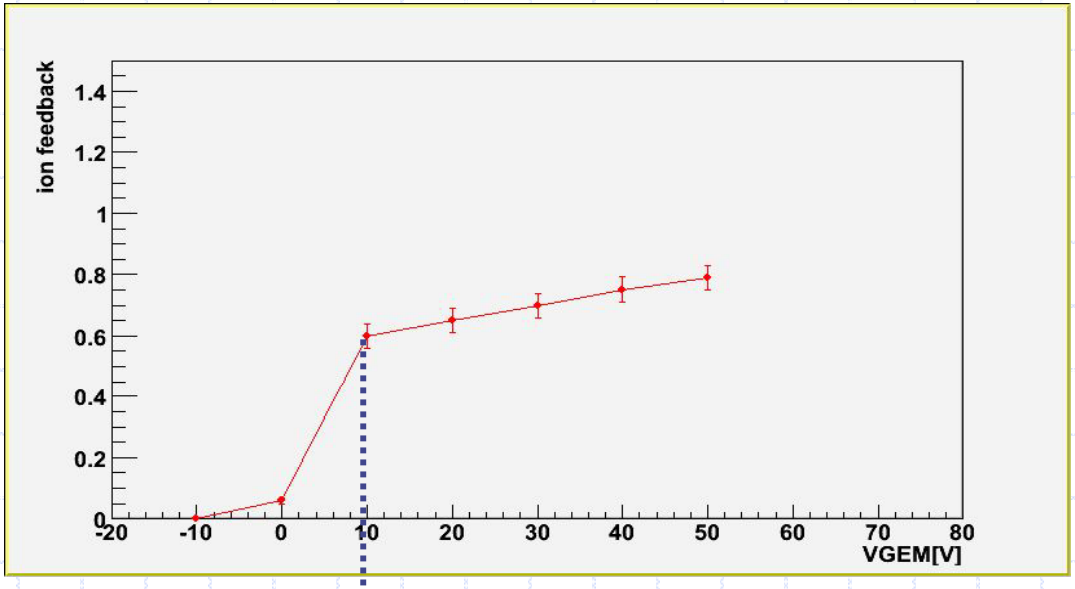


The over lapping region disappear at 3T like ArCF4 case.

We are not sure how can we improve this situation. We need to study more systematically.

Ions transmission

ArCO2(70:30)
φ100μm
B= 3 T



VGEM=10V

Ions transmission is drastically decreased below 10V at VGEM and
It become almost 0 at -10V.
But statistics is not enough to get precise value, $O(10^{-4})$.
Blocking ions is much easier.

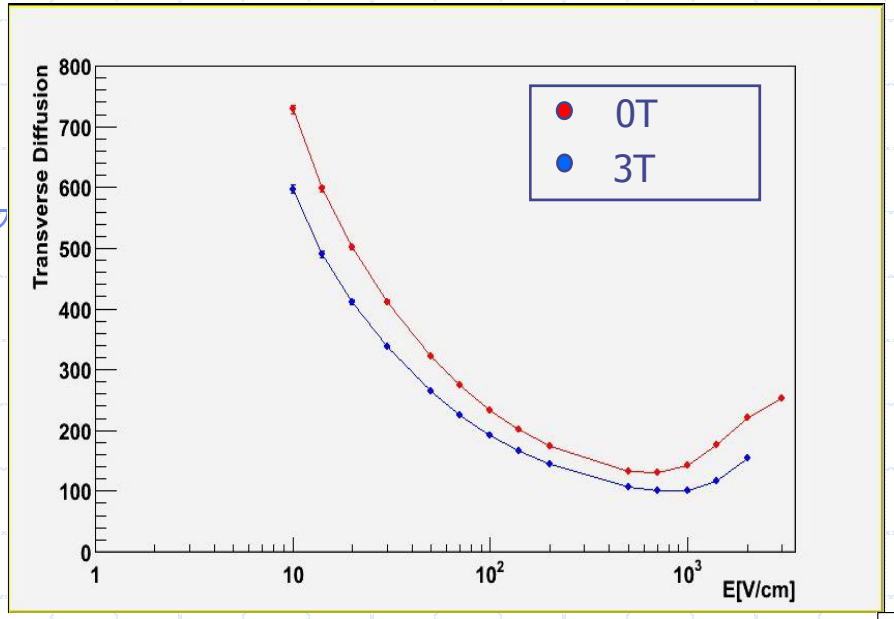
Summary

We have studied about GEM gating by the simulation.

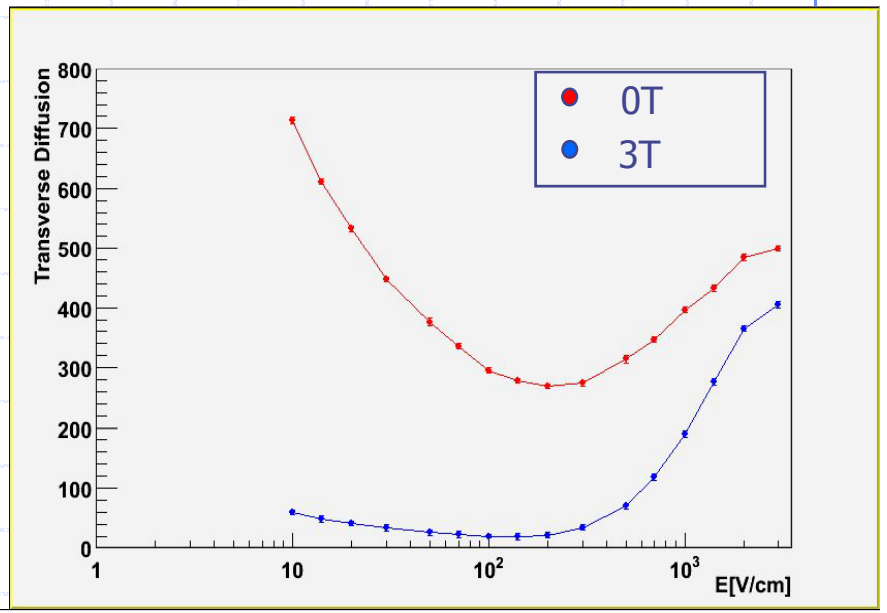
In order to get high electron transmission
We need gas whose property is
low diffusion even at high electric field
(low diffusion at low E is necessary for resolution)
But we still don't understand detail some part yet

We need to find better gas mixture or
better operation condition or
better structure (thickness, pitch) of GEM
if we use GEM as gating.

Ar-CO2 70 : 30



Ar-CF4 95 : 5



Transverse Diffusion

P5 GAS(3Tesla)