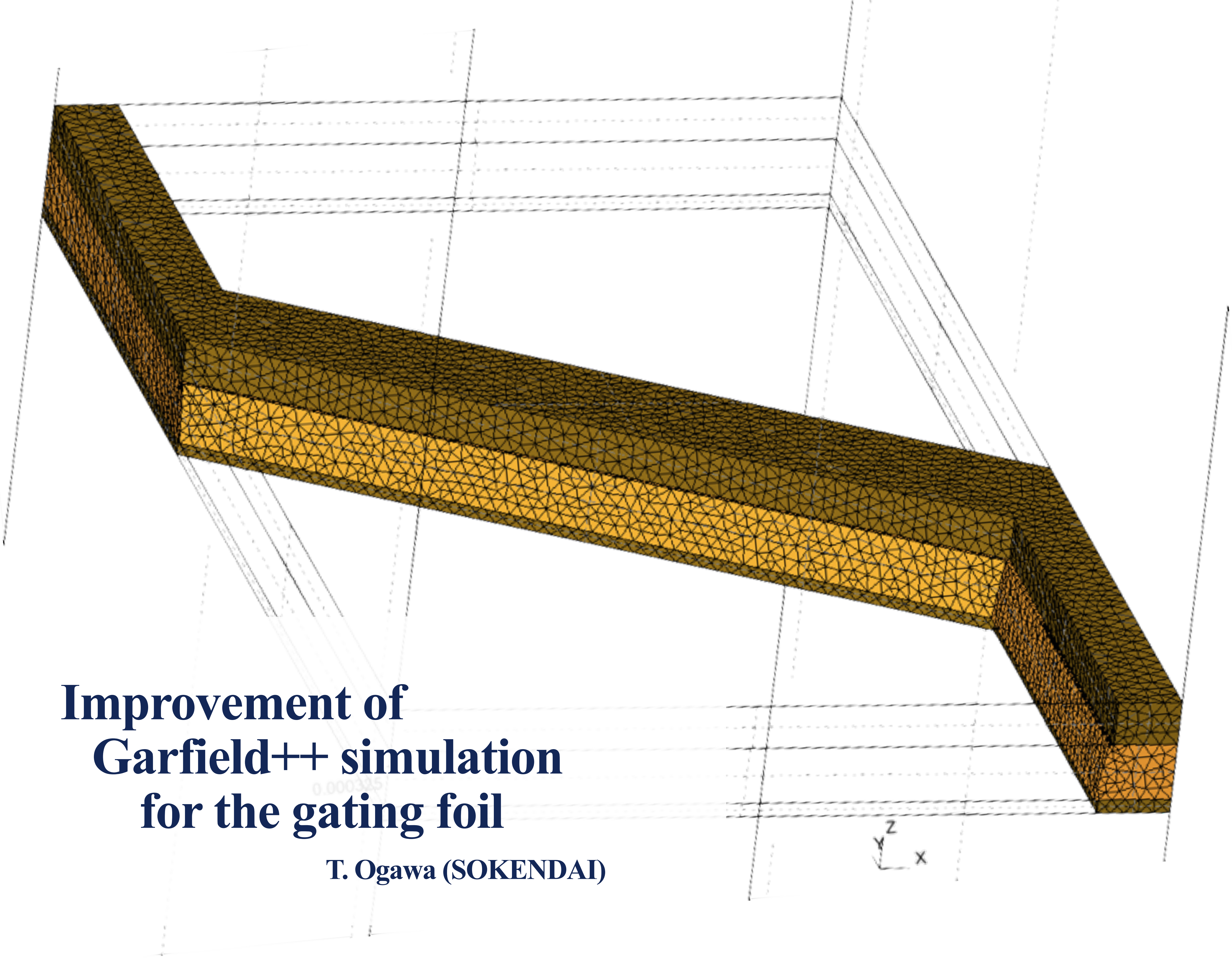


Improvement of Garfield++ simulation for the gating foil

T. Ogawa (SOKENDAI)

Status in the past 3 years

Simulation side:

> Prediction of performance
of the gating foil under higher B.
(+ understanding of behavior)

> Simulation did not fit with data
under B.

> Behavior under B is very suspicious.

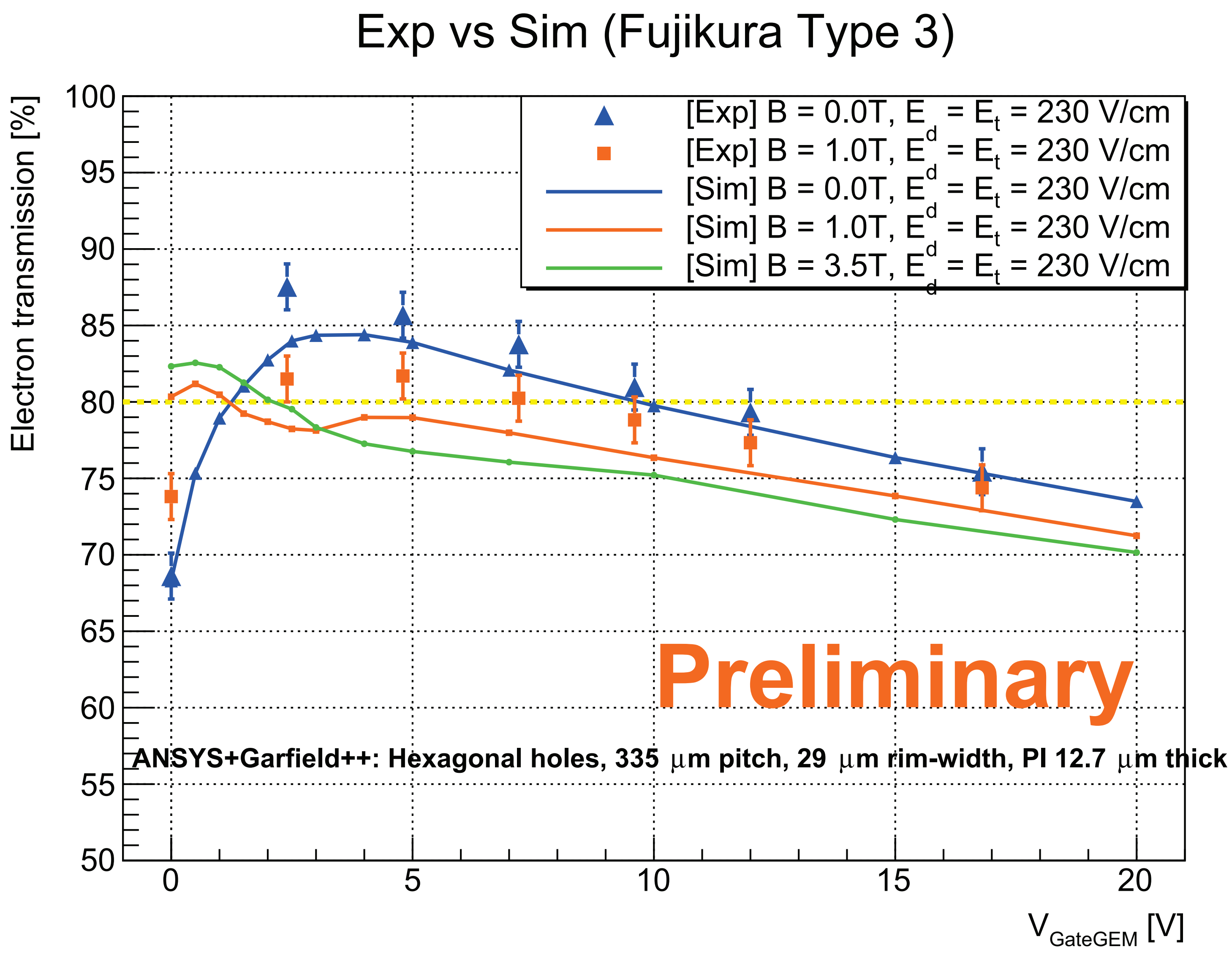
Experimental side:

> A method for evaluating transmission
has been modified:

Using only an open state data.
Two data set (normal/reverse voltage of Edrift) are not necessary.

http://www-jlc.kek.jp/jlc/sites/default/files/7.27SagaYamashita.pptx

Comparison of Electron transmission between Exp. and Sim.

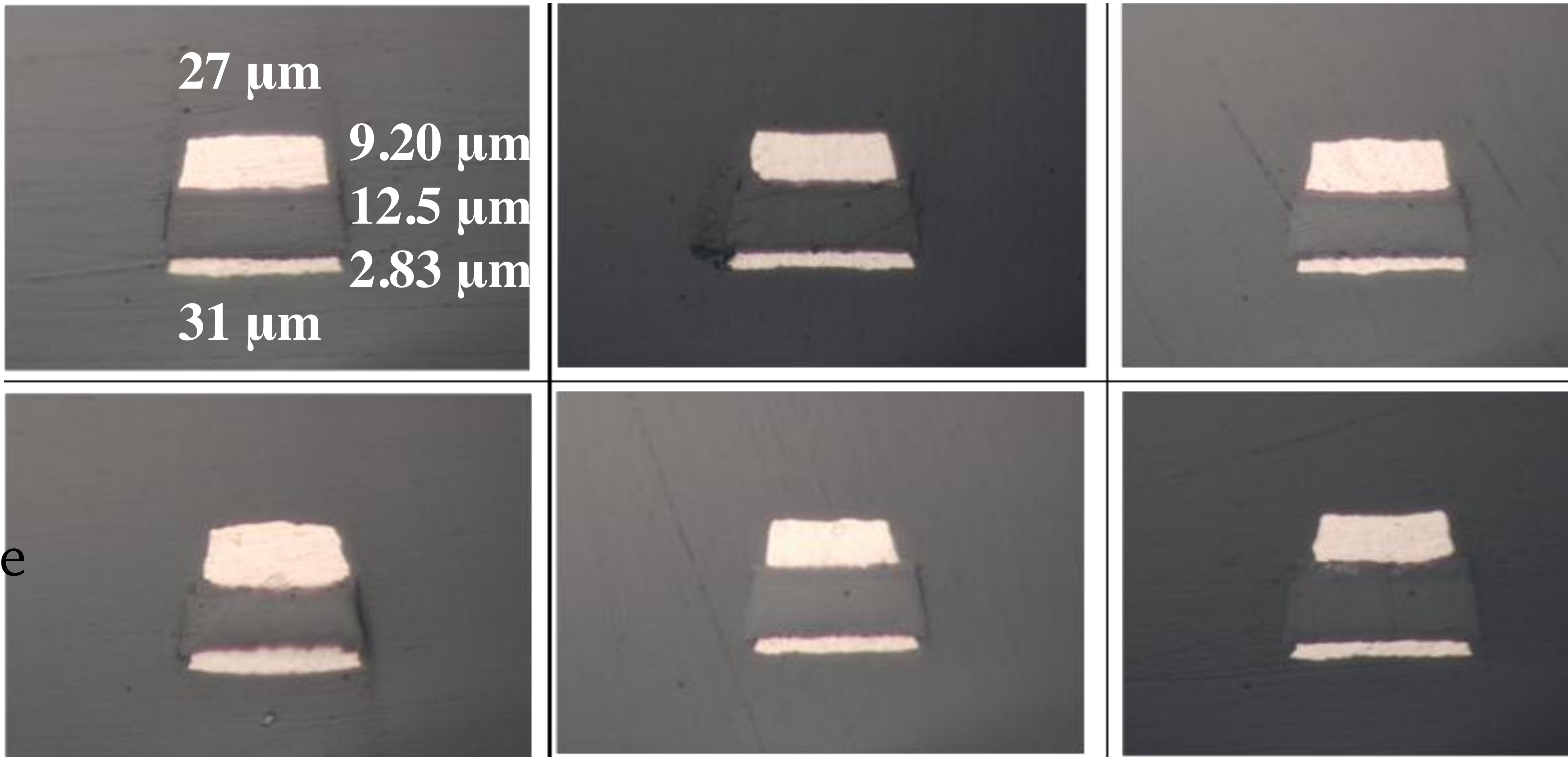

Exp vs Sim (Fujikura Type 3)

ANSYS+Garfield++: Hexagonal holes, 335 μm pitch, 29 μm rim-width, PI 12.7 μm thick

Geometries for the simulation

Smooth trapezoidal

Not smooth trapezoidal
It seems to have protrusions..



Geometry parameters

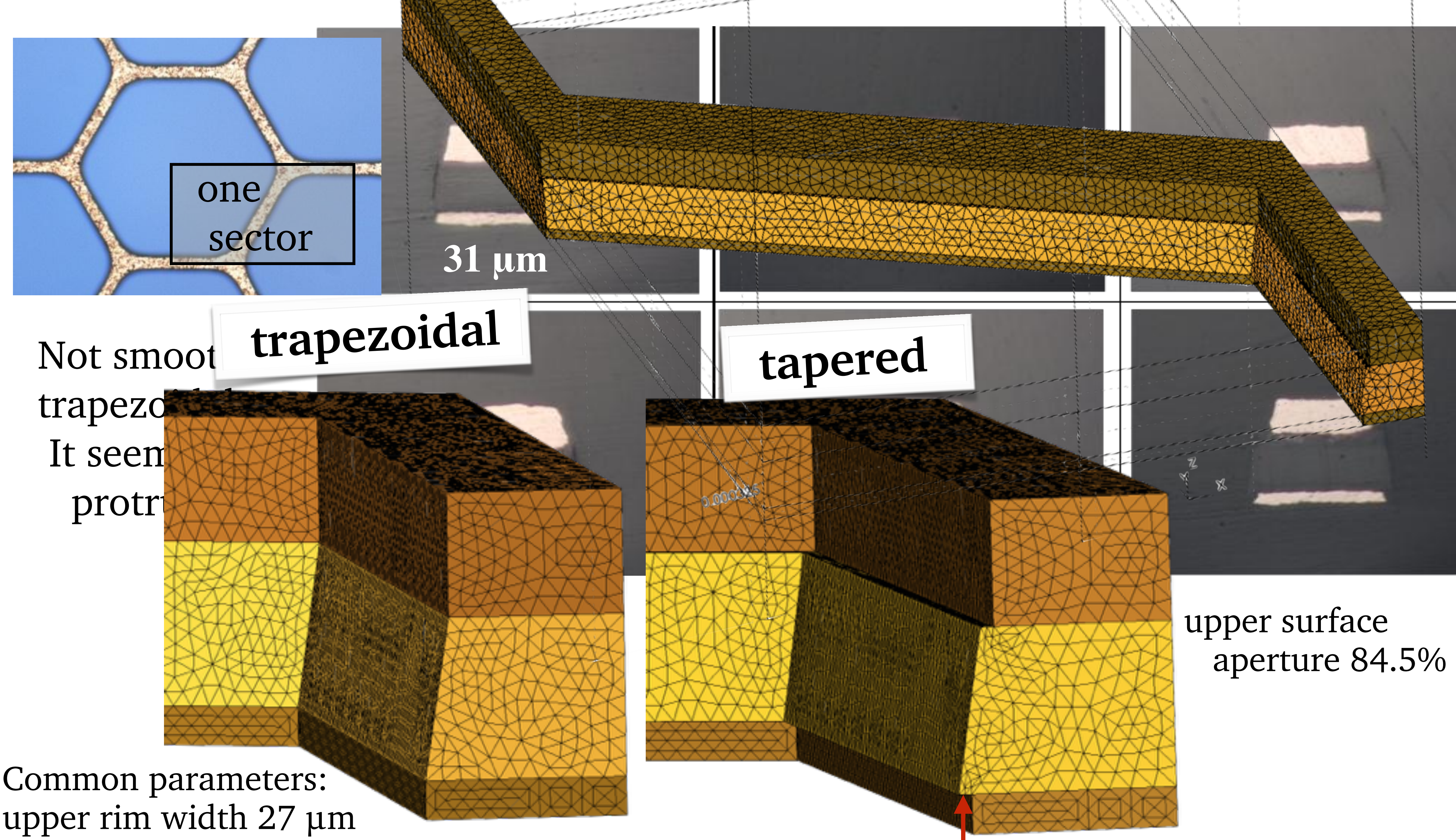
“Development of gating foils to inhibit ion feedback using FPC production techniques”
Daisuke Arai (presented at MPGD2015)

Measurement results

	Rim width (um)		Copper thickness(um)	
	F-side	B-side	F-side	B-side
Ave.	26.74	30.96	9.20	2.83
Max-Min	6.87	7.27	3.19	0.89
3σ	4.66	5.03	2.33	0.69

Item	Gating foil
Hole size	304µm
Hole pitch	335µm
Rim width : F-side	27µm
Rim width : B-side	31um
Insulator thickness	12.5µm
size	100mm x 100mm
Processing time	70min (only laser)
Optical aperture ratio	82.3%

Geometries for t simulation



Not smoot
trapezo
It seem
protr

upper surface
aperture 84.5%

Common parameters:
upper rim width 27 µm
lower rim width 31 µm
diel. thickness 12.5 µm
upper rim thick. 9.5 µm
lower rim thick. 3.0 µm

geometrical
aperture 82.3%

1 µm protrusion.

geometrical
aperture 81.2%

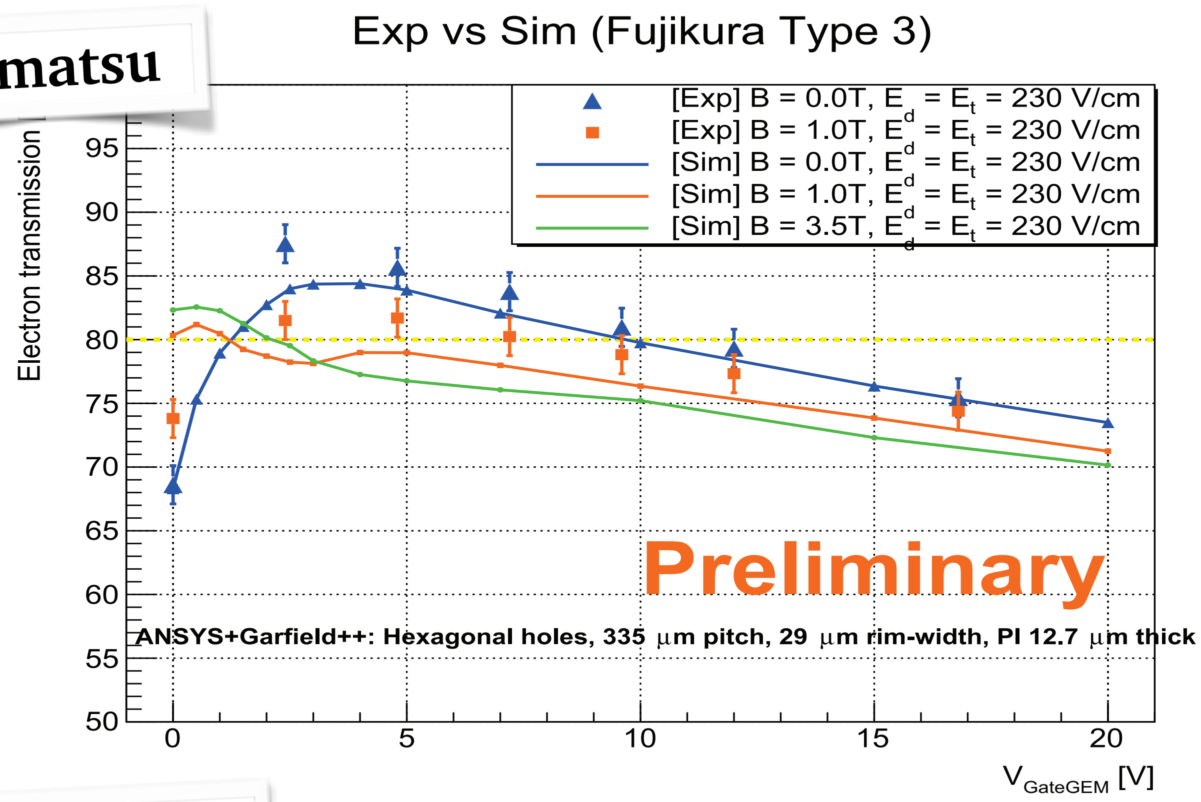
Simulation

Avalanche Microscopic,

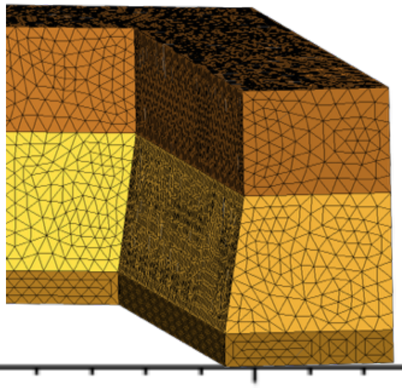
with the "default" setting

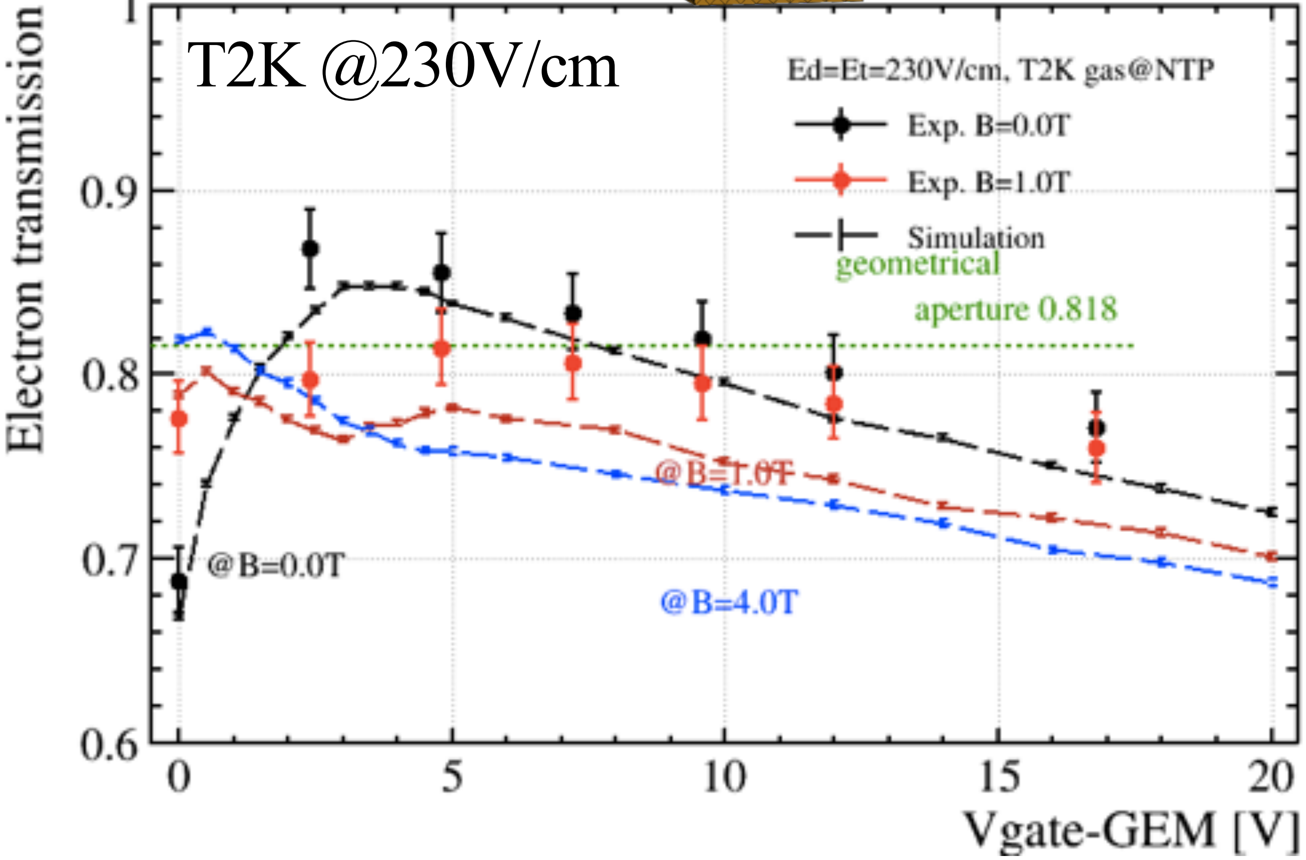
originally implemented in garfield

Ikematsu

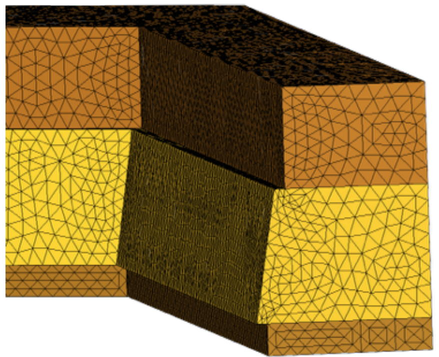


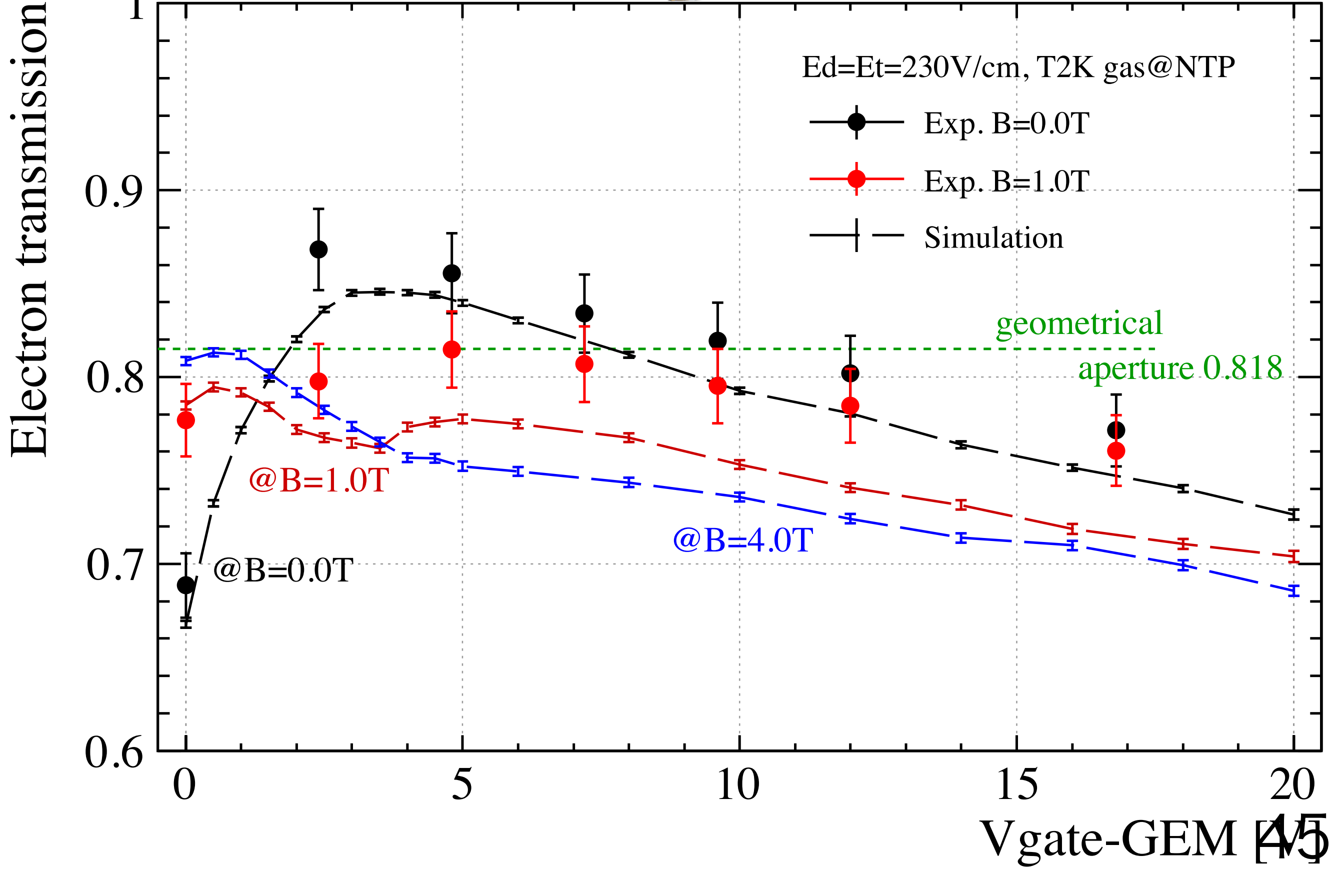
trapezoidal





tapered





Simulation

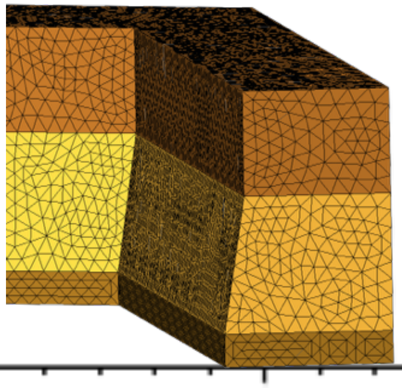
There is a switch on “Null collision steps”

E-field is updated
in each step after sampling time Δt
even if the step is null-collision.

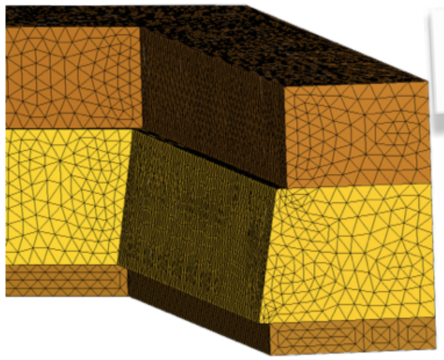
According to a developer
this was supposed that
more precise tracking is given.

Avalanche Microscopic,
with “Null collision steps”
originally implemented in garfield

trapezoidal



seems to be buggy ?
results are strange …
even for 0 T …



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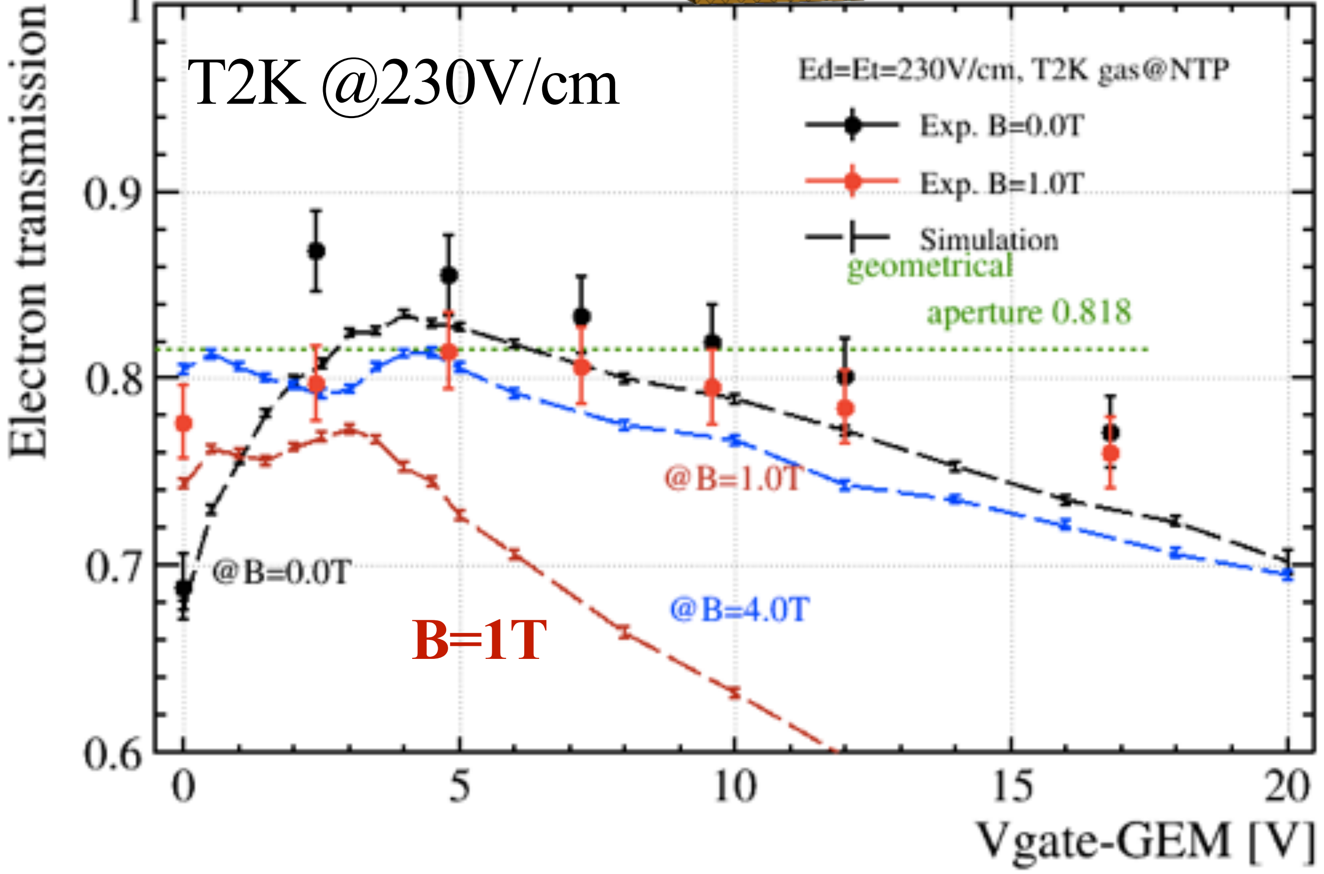

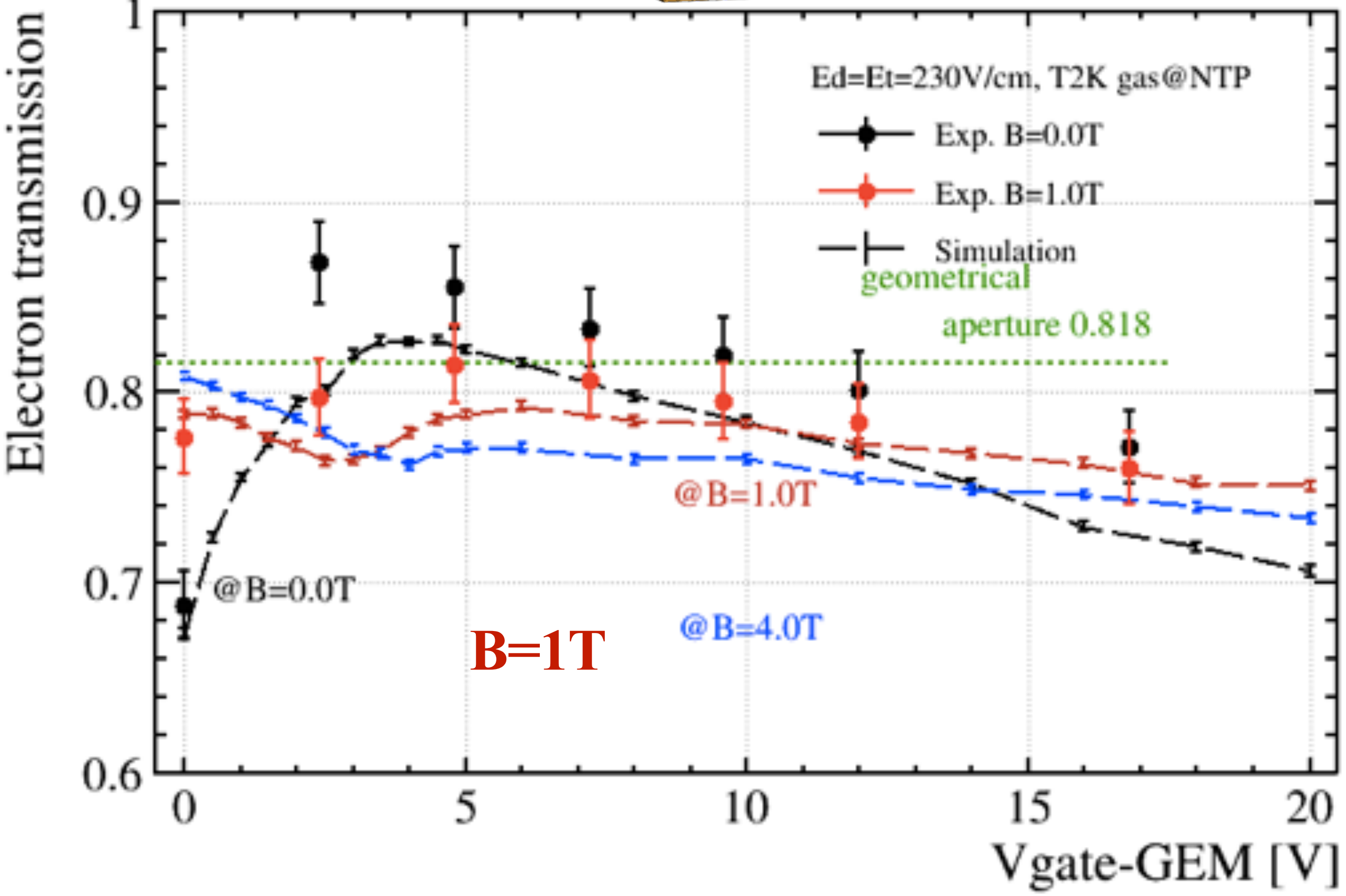

Simulation: AvalancheMicrosopic

Avalanche Microscopic function,

1). An electron trajectory is calculated based on given sampling time Δt (= -<τ> log(u) u[0,1]) ,

2). Electron kinetic energy ε’ after Δt is evaluated

$$\epsilon' = \epsilon + \underbrace{q\mathbf{v}\cdot\mathbf{E}\Delta t + \frac{q^2}{2m_e}\mathbf{E}^2\Delta t^2}_{\text{A change of the kinetic energy after } \Delta t}.$$

https://cds.cern.ch/record/1500583/files/CERN-THESIS-2012-208.pdf
Heinrich Schindler,
Ph.D thesis ``Microscopic Simulation of Particle Detector",
CERN-THESIS-2012-208, 13/12/2012

p22 ~ p25

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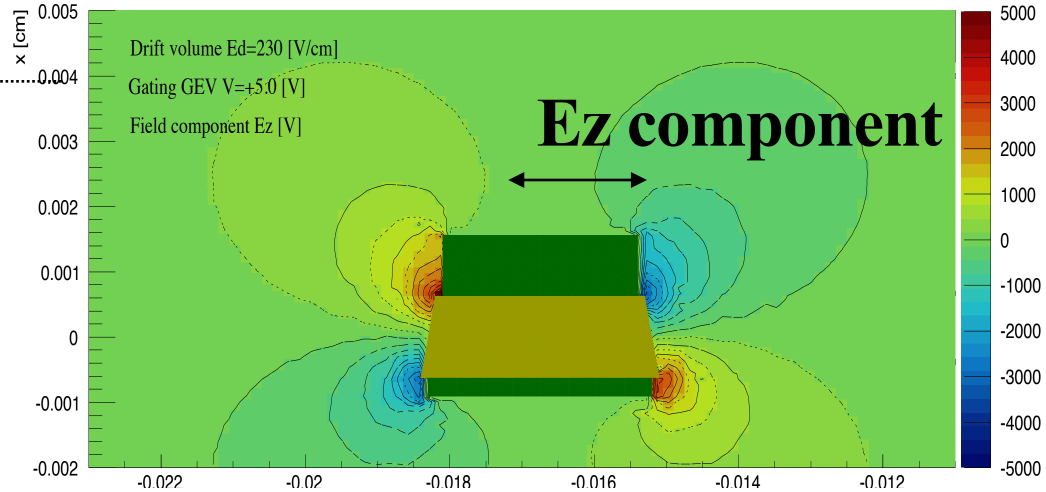
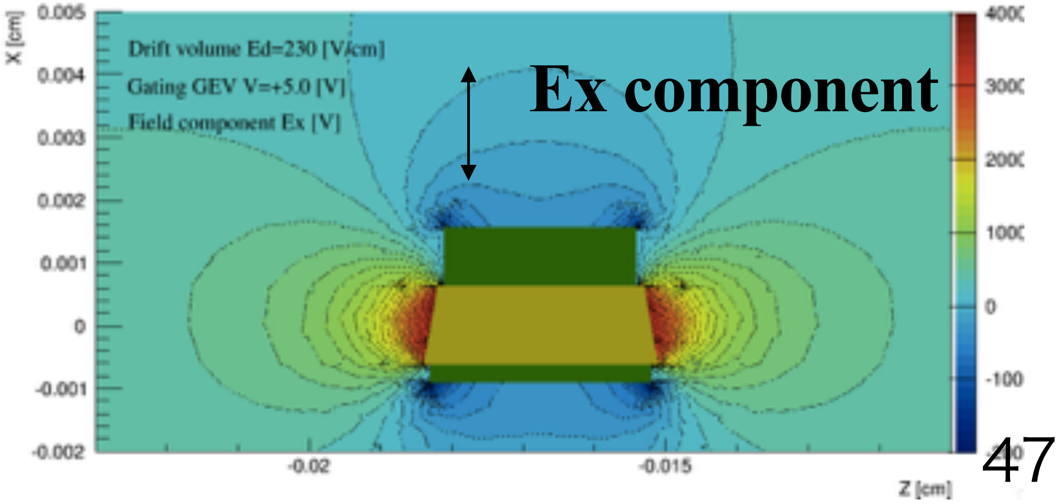
v and E do not have time dependence,
initial information are continuously used during Δt

(acceleration and deceleration are not sufficient.)

In reality,
E-field dramatically varies.
especially at around geometry.
v and E should be time-dependent variables
like v(t) and E(r(t)),





Simulation: AvalancheMicrosopic   w/ sub-step

https://cds.cern.ch/record/1500583/files/CERN-THESIS-2012-208.pdf
Heinrich Schindler,
Ph.D thesis ``Microscopic Simulation of Particle Detector",
CERN-THESIS-2012-208, 13/12/2012

p22 ~ p25

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Defined sub-step time δt $\delta t (= \Delta t / N)$ recover above First approximation with N=1

$$\epsilon^{'} = \epsilon \;+\; \sum_{i}^{N} \underbrace{q\boldsymbol{v}_i(\boldsymbol{E}_{i-1}, \delta t_i)}_{\text{time dependent v}} \cdot \underset{\text{time dependent E}}{\boldsymbol{E}_i(\boldsymbol{r}_{i-1}(\delta t_{i-1}))}\delta t_i$$

$$+ \sum_{i}^{N} \frac{q^2}{2m_e}\boldsymbol{E}_i(\boldsymbol{r}_{i-1}(\delta t_{i-1}))^2 \delta t_i^2$$

subscripts i, i-1 is not checked carefully

v depends on E and δt
E depends on r
r depends on δt

A program has to access a field map many times
Huge CPU consumption and time is necessary.
If the field map is precisely generated, more time is needed

Simulation: AvalancheMicrosopic w/ sub-step approx.

https://cds.cern.ch/record/1500583/files/CERN-THESIS-2012-208.pdf
Heinrich Schindler,
Ph.D thesis ``Microscopic Simulation of Particle Detector",
CERN-THESIS-2012-208, 13/12/2012

p22 ~ p25

Avalanche Microscopic function,

1). An electron trajectory is calculated based on given sampling time Δt (= -<τ> log(u) u[0,1]) ,

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Defined sub-step time δt $\delta t (= \Delta t/N)$ recover above First approximation with N=1

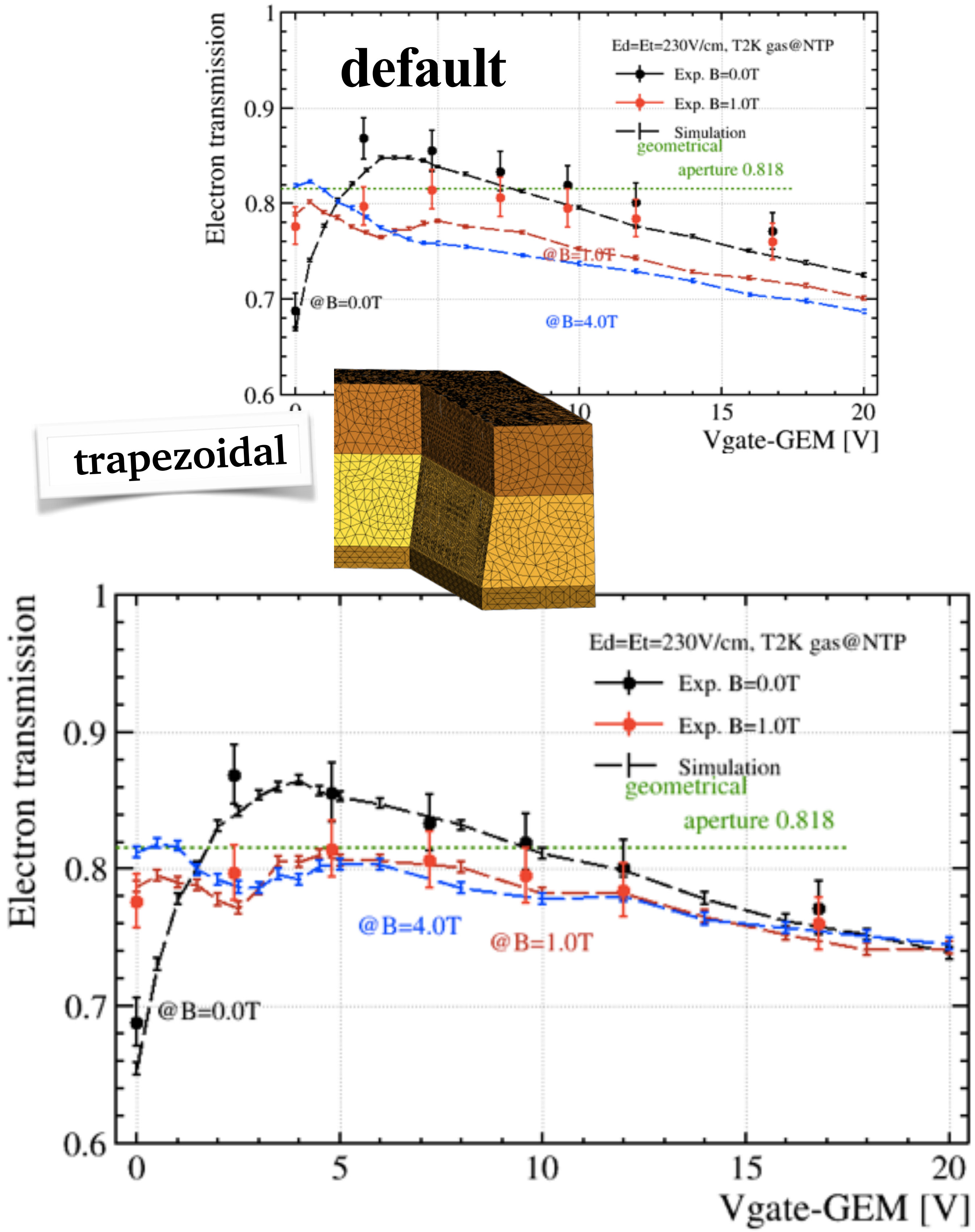
I check E' (v(initial) * Δt)

→ $\underset{\text{initial}}{d\boldsymbol{E} = \boldsymbol{E}} - \underset{\text{after } \Delta t}{\boldsymbol{E}'}$ → **continuously include the variation as** $\boldsymbol{E} - \frac{d\boldsymbol{E}}{N}i$

$$\epsilon' = \epsilon + \sum_i^N q\underbrace{\boldsymbol{v}_i\left(\boldsymbol{E} - \frac{d\boldsymbol{E}}{N}i, \delta t_i\right)}_{\text{time dependent v}}\cdot\left(\boldsymbol{E} - \frac{d\boldsymbol{E}}{N}i\right)\delta t_i + \sum_i^N \frac{q^2}{2m_e}\left(\boldsymbol{E} - \frac{d\boldsymbol{E}}{N}i\right)^2\delta t_i^2$$

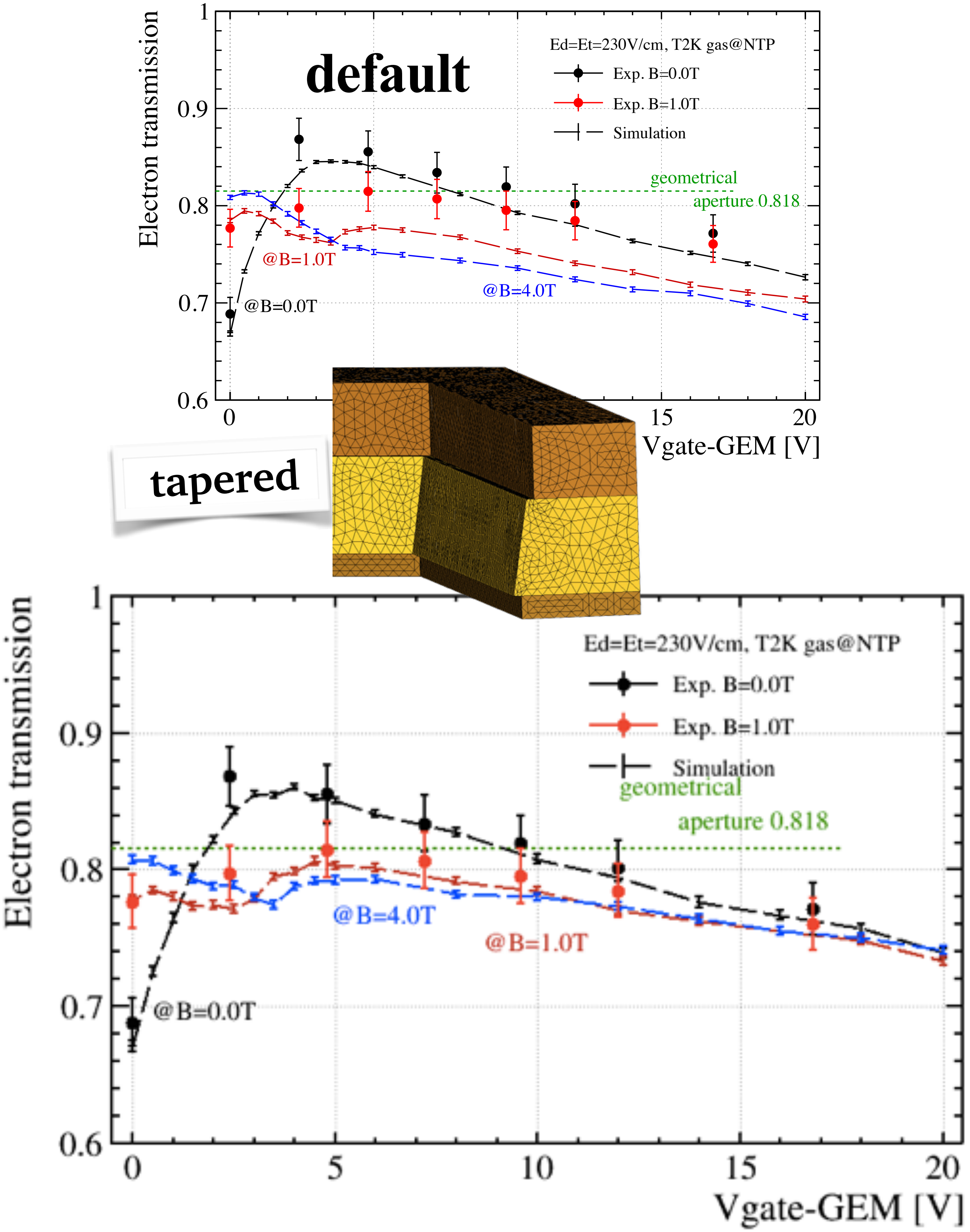
Under the assumption :
the variation of the E-field
b/w E(r) and E'(r') (within Δt)
is linearly changed.

Simulation w/ sub-step approx.



default

trapezoidal

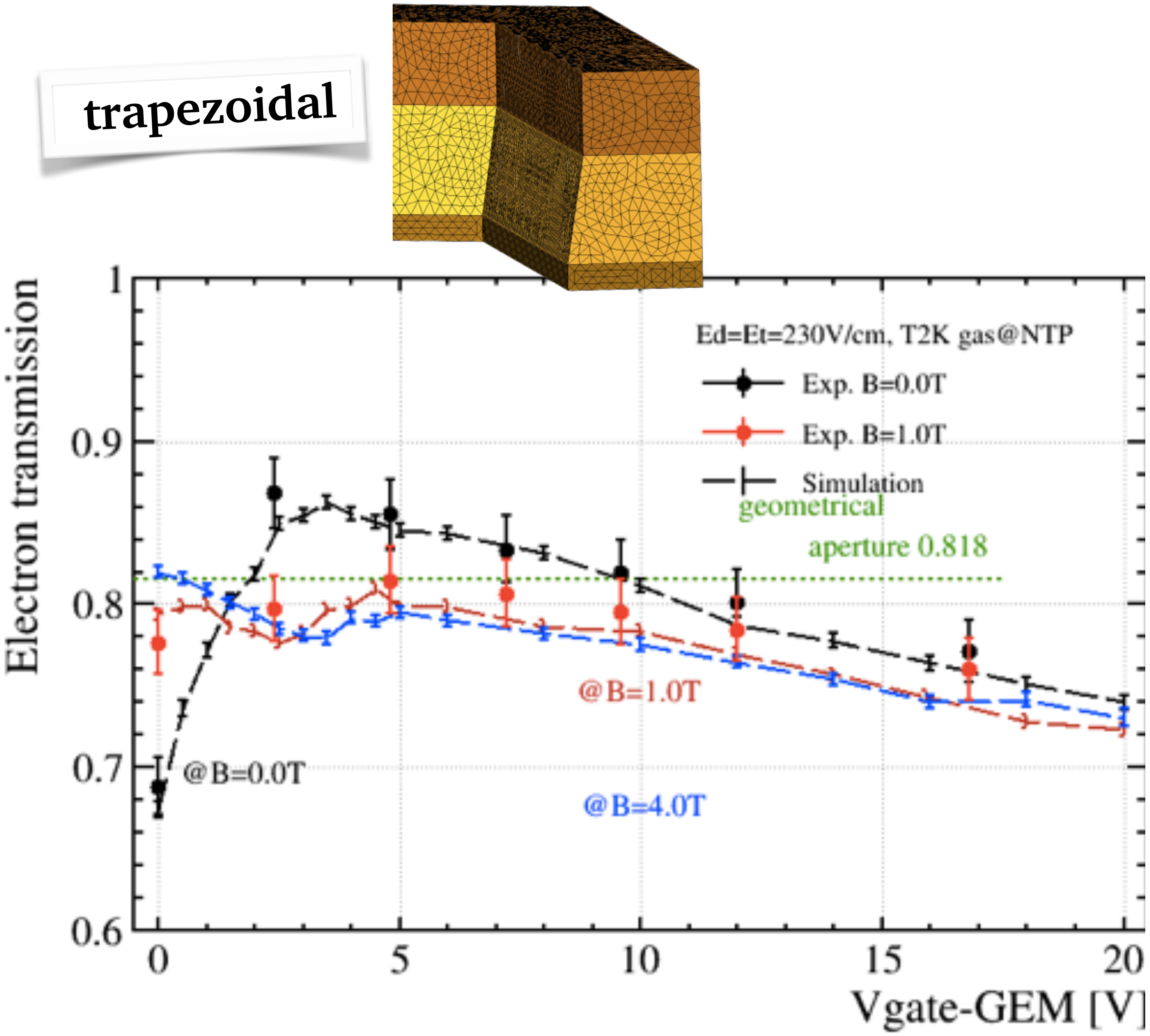


default

tapered

Simulation w/ sub-step

trapezoidal



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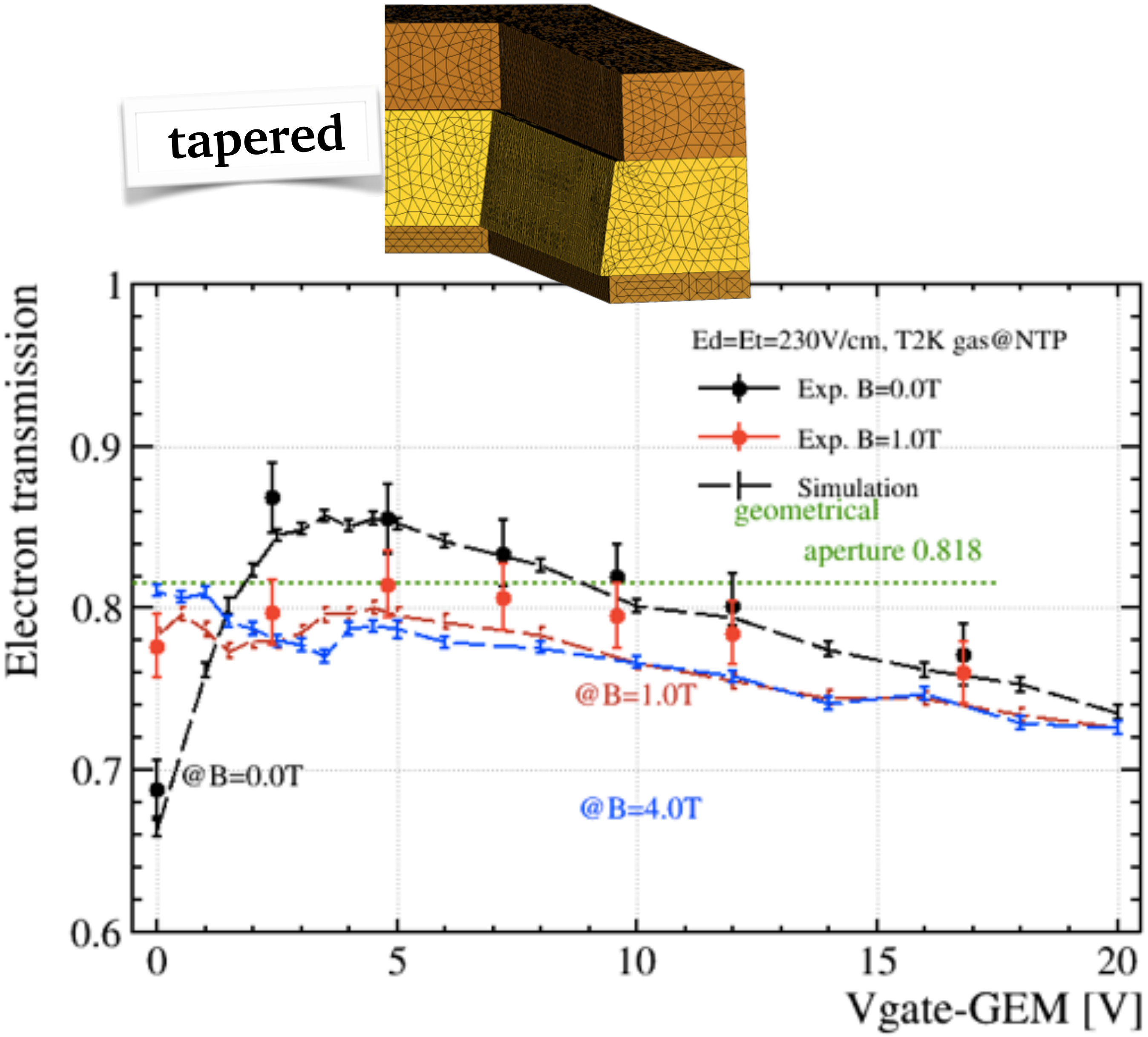


Another simulation is the closed state

Textbook
Particle Detection
with Drift Chambers

Ion blocking measurement (exp. data is with an electron)
→ The key point is diffusion.

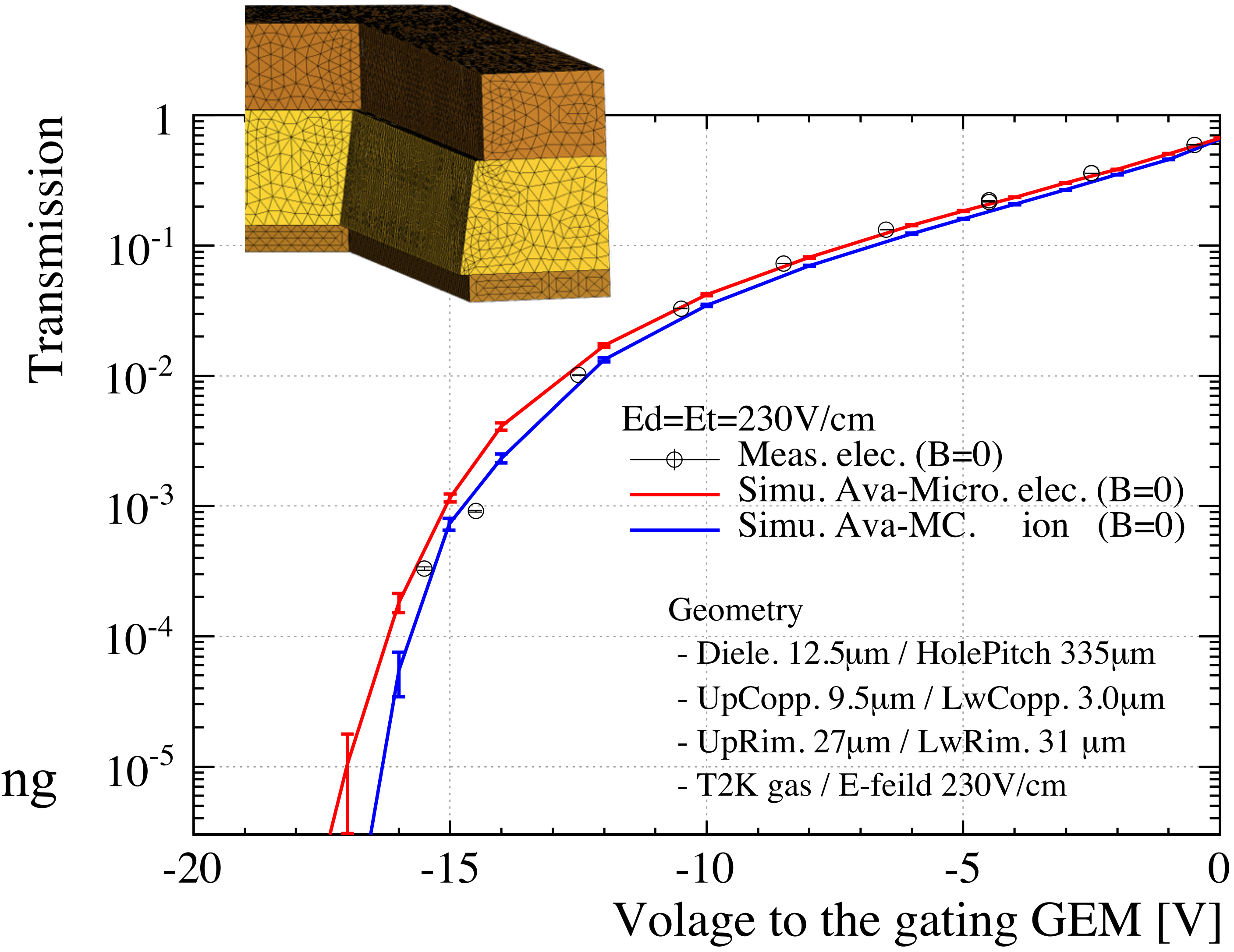
t2k@ 0.0T ***e-*** **~ 300 μm/√cm (Magboltz.) 230v/cm**
Ar+,iC4H10+ ~ 142 μm/√cm (textbook, Dt^2 ~ 1/E-field
an ion has thermal energy
(thermal balance))

$$\frac{D_\mathrm{T}(\omega)}{D_\mathrm{T}(0)} = \frac{1}{1+\omega^2\tau^2}, \quad \text{textbook}$$

$$\omega\tau = B\mu \simeq \begin{cases} 10^{-4} & \text{for ions} \\ 1 & \text{for electrons} \end{cases}$$

ω :cyclotron frequency
τ : mean free time

Dt of the ion does not change under B



→ B=0 give enough prediction
for the ion blocking,

Exp. with the electron.
can give the lower limit for the ion blocking

The modified version gives similar result
(electron)

Summary

Simulation was modified for predictions of the behavior of the gating foil
(I need to have discussion with a developer)

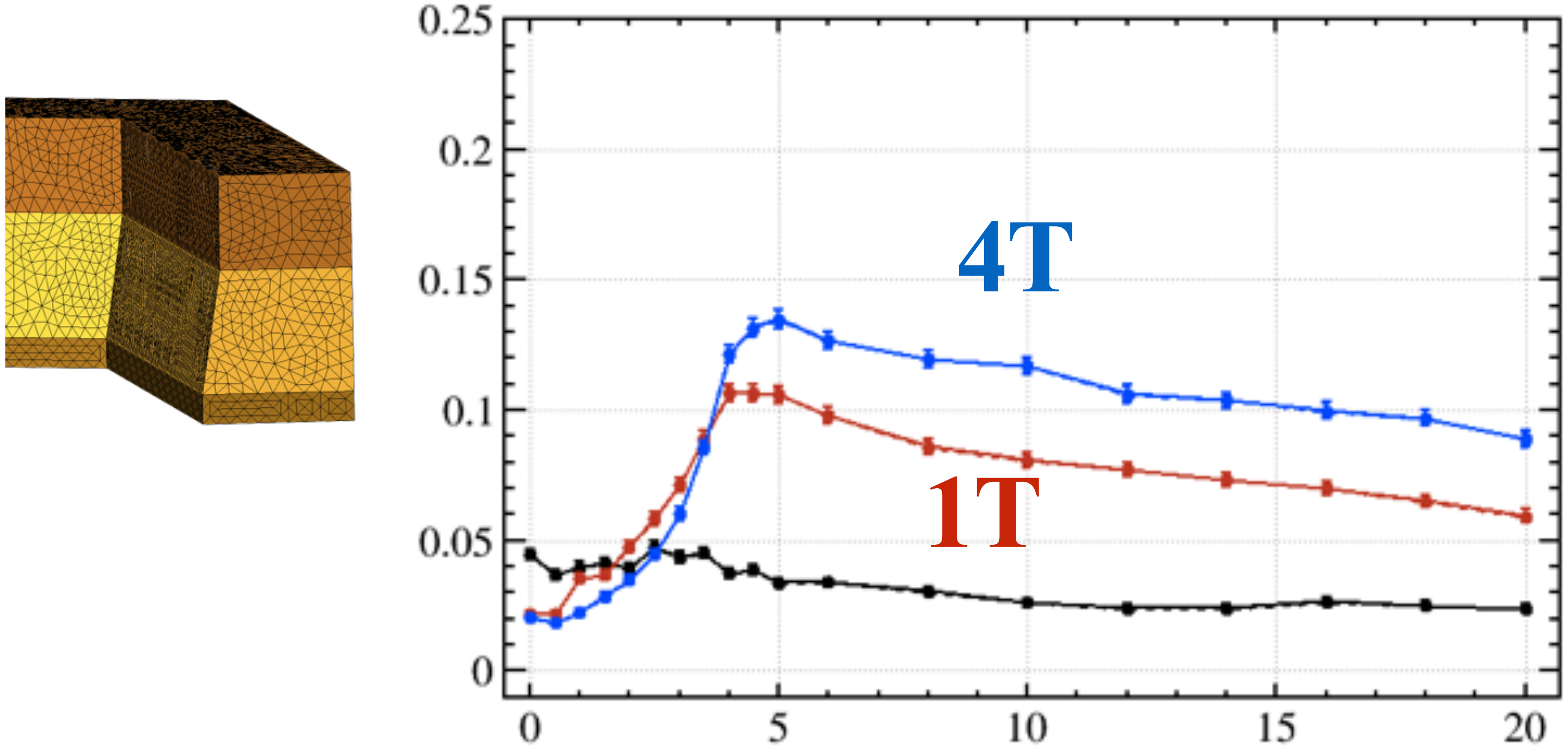
The Results reproduce experiment to some extent for 0 and 1 T.
With 0-1 V operation the transmission of >80% is
PROBABLY achievable under ~3.5/4.0 T.

Simulation indicate that ion blocking of <10^-5 even for <10^-6 is
PROBABLY achievable for a higher B field
with the applied voltage of < -20V.

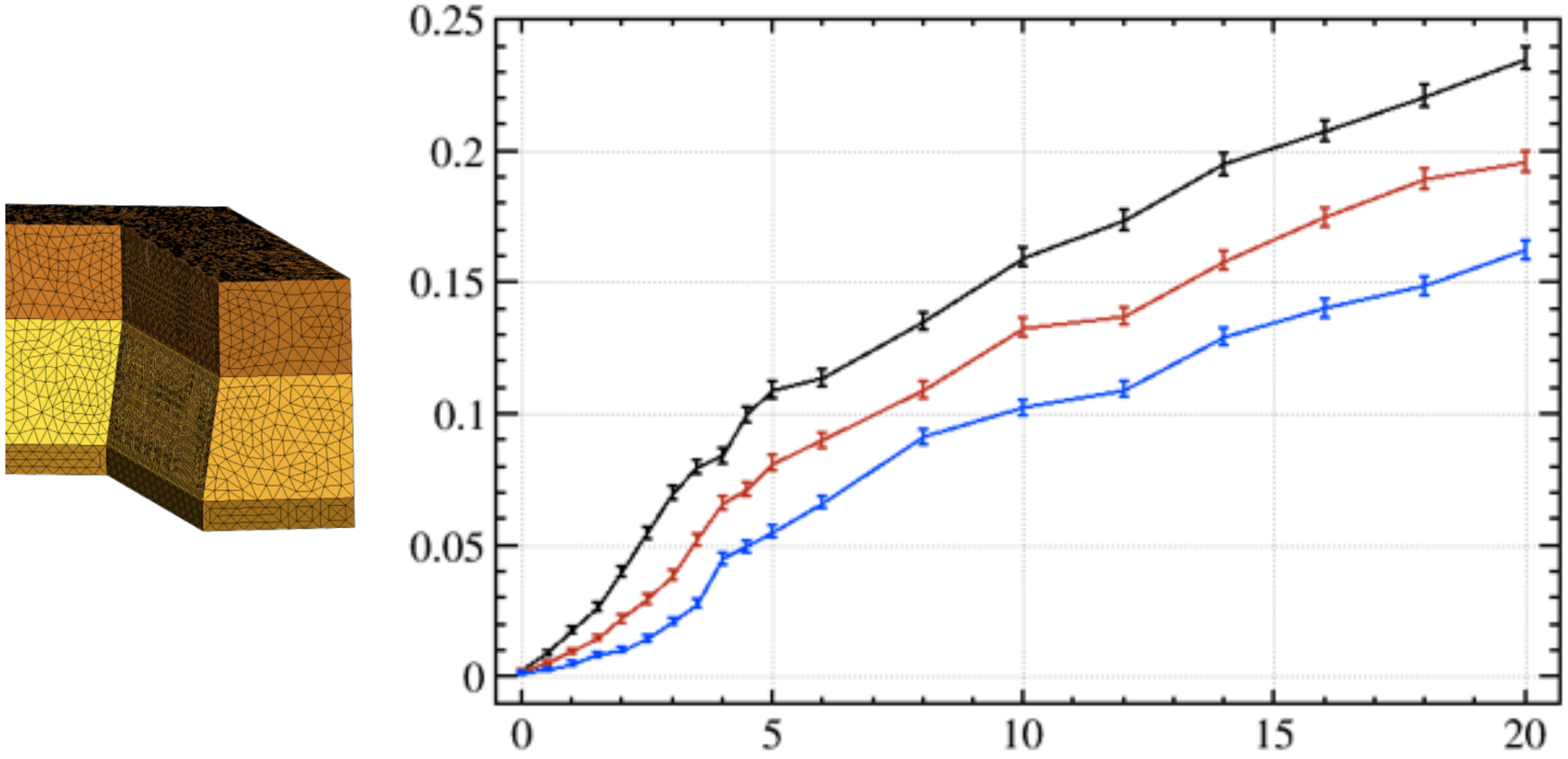
Remaining tasks are 1). direct measurement of ion blocking using the ion itself.
and compare with the simulation (confirmation).

2). actual measurement under the higher B field. (electron/ion)

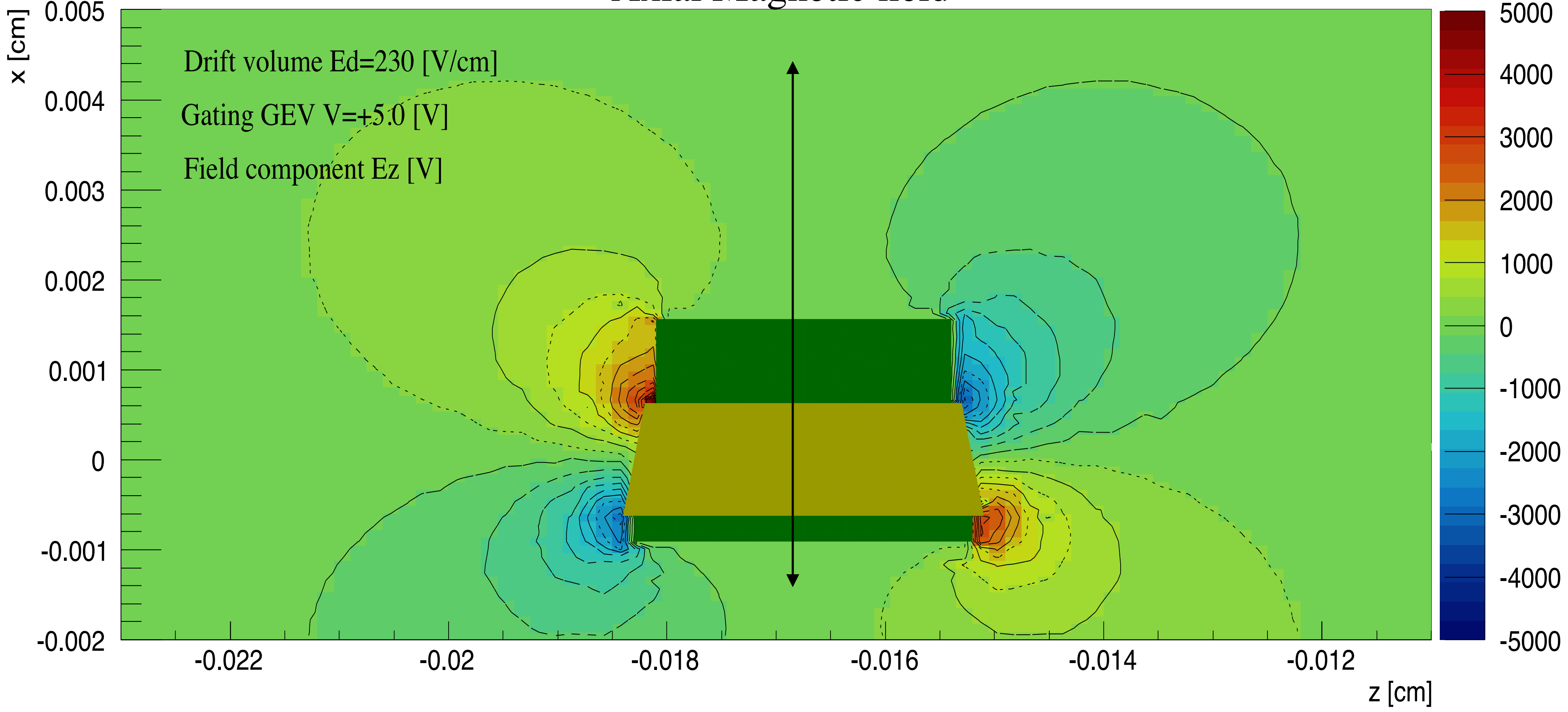
Ratio reaching to the dielectric

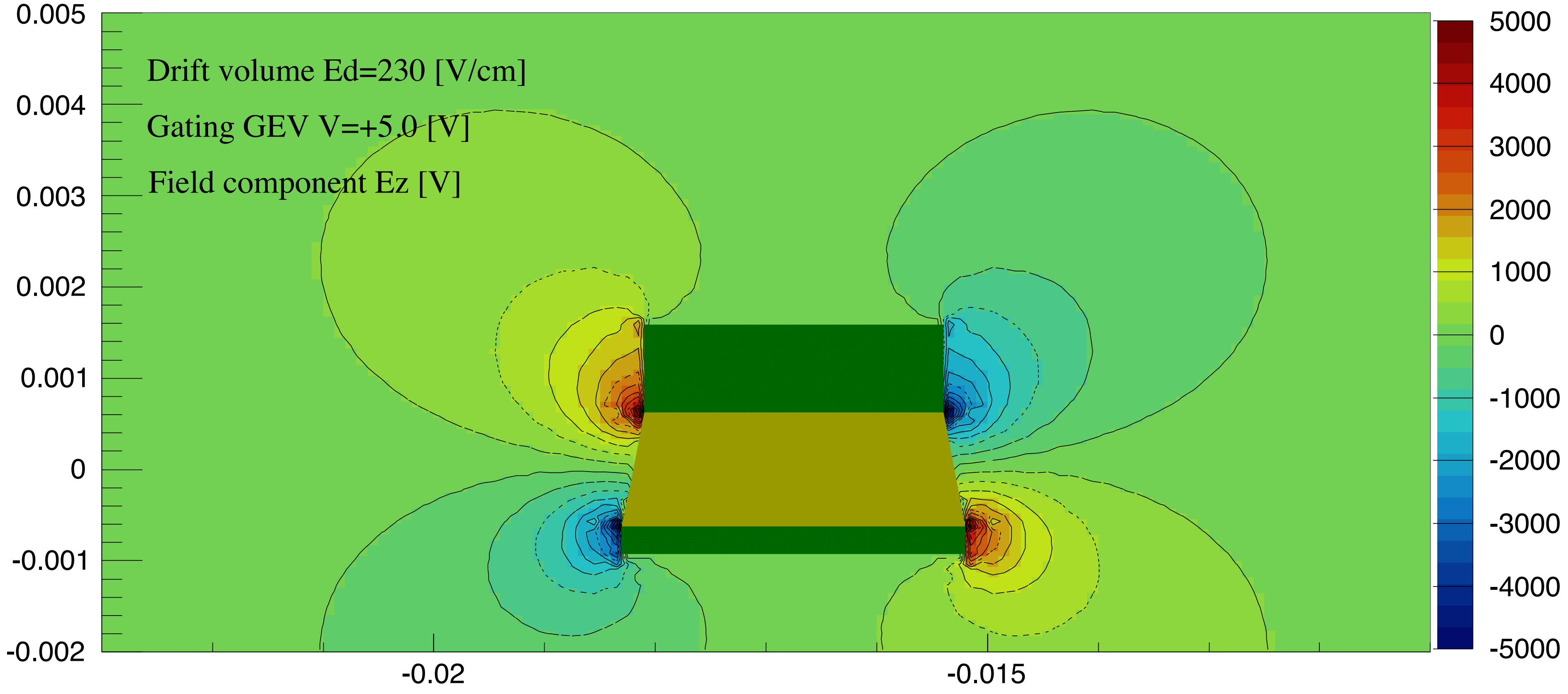


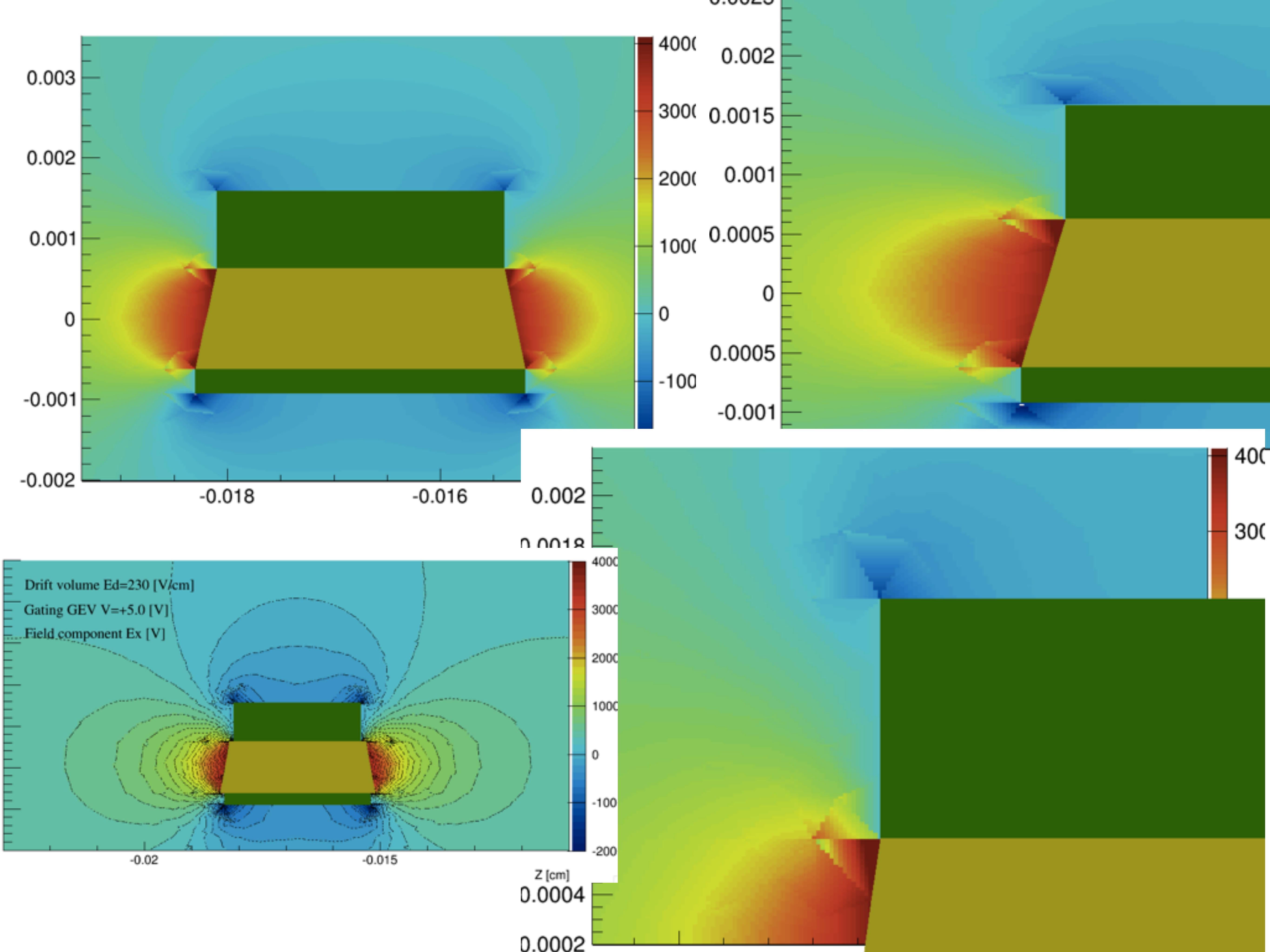
Ratio reaching to a lower copper



Axial Magnetic field






0.003
0.002
0.001
0
-0.001
-0.002
-0.018
-0.016
4000
3000
2000
1000
0
-100
0.002
0.0015
0.001
0.0005
0
0.0005
-0.001
Drift volume Ed=230 [V/cm]
Gating GEV V=+5.0 [V]
Field component Ex [V]
-0.02
-0.015
Z [cm]
4000
3000
2000
1000
0
-100
-200
0.002
0.0018
0.0004
0.0002
400
300