Current status of MPGD simulation in negative ion gas for direction-sensitive dark matter search

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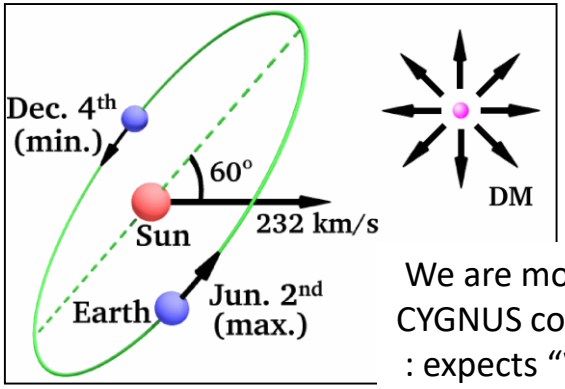
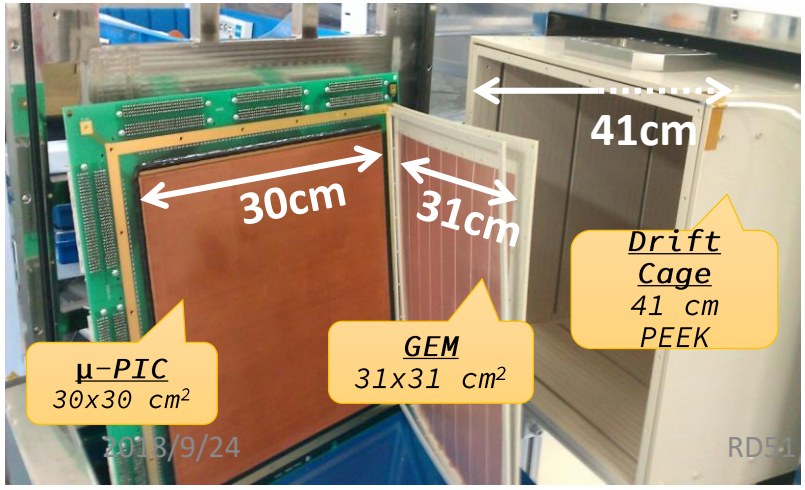
NEWAGE

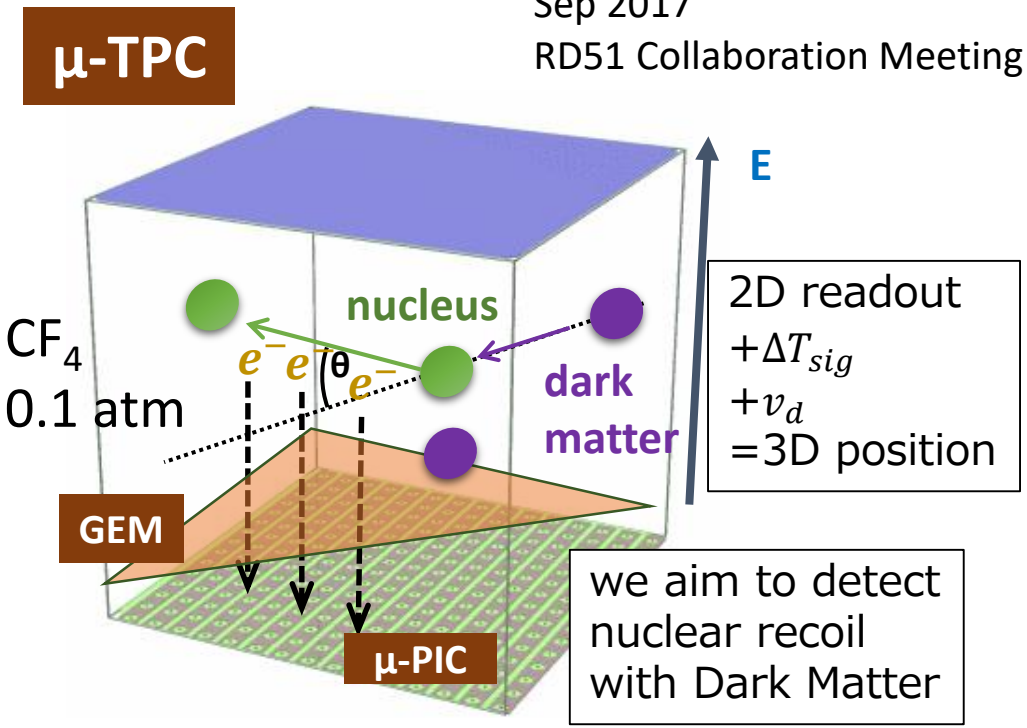
- Direction-sensitive dark matter search at Kamioka Observatory, Japan
- uses gaseous TPC "μ-TPC" with μ –PIC and low pressure gas
- expects "WIMP-wind" - directional recoil angle distribution



We are moving toward CYGNUS constellation
: expects "WIMP-wind"

please see
Kentaro Miuchi
Sep 2017
RD51 Collaboration Meeting



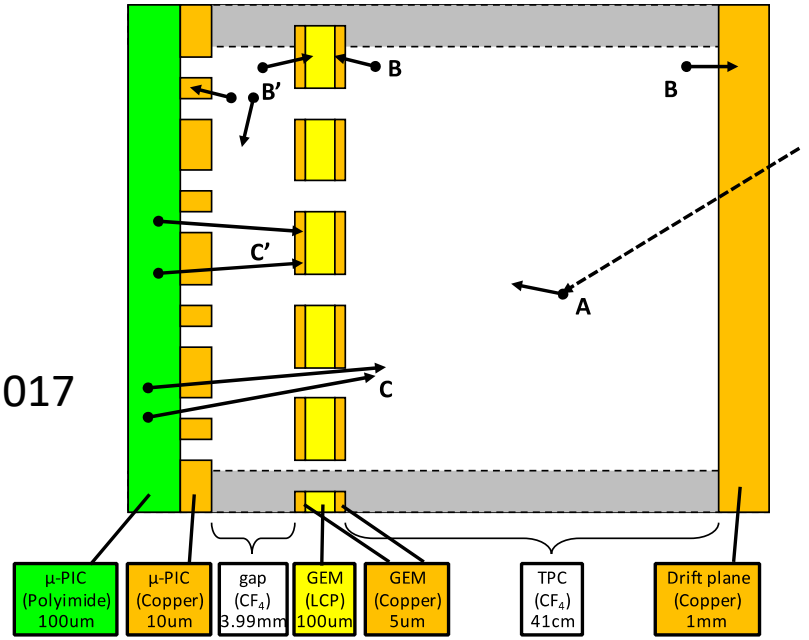


Negative Ion TPC for Dark matter search

- Problem : background
  - α-ray backgrounds from U/Th in glass fiber of μ-PIC (radioactive contamination)

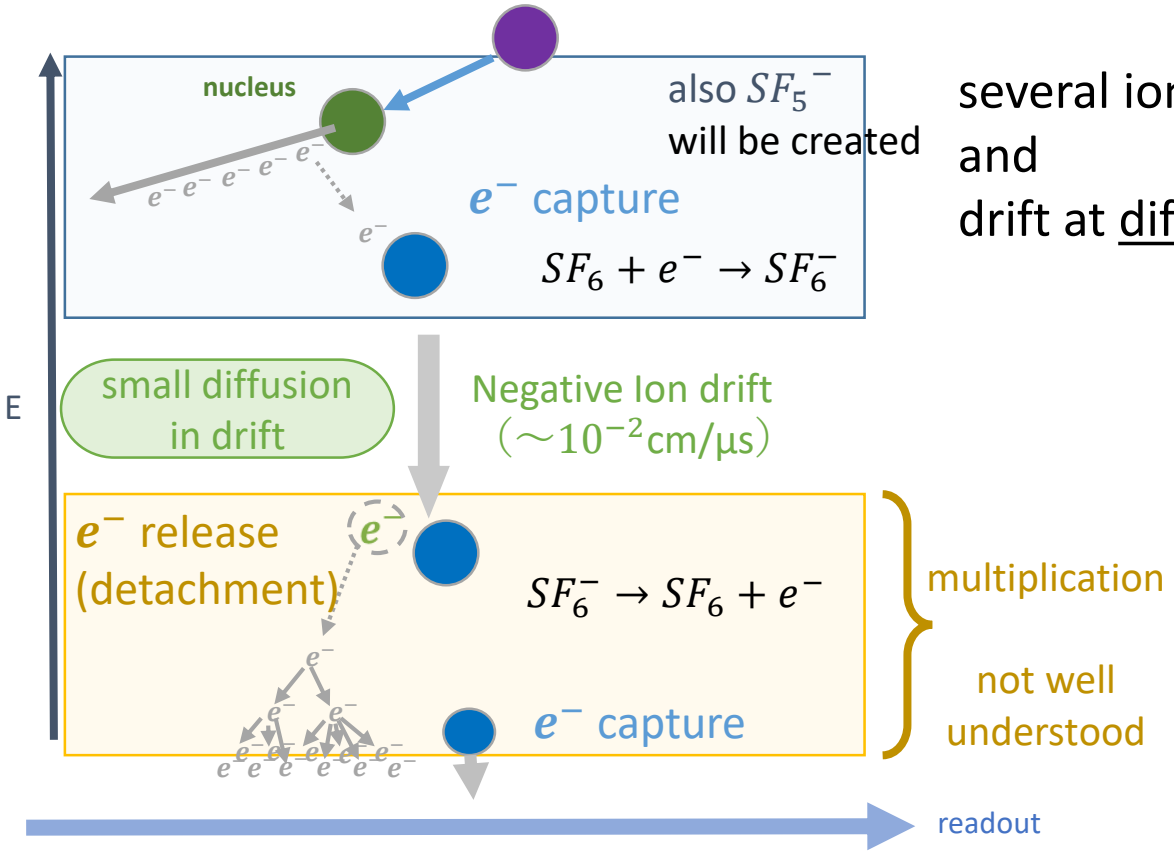
Takashi Hashimoto LRT2017
arXiv:1707.09744

- Solution:
  - production of low-alpha μ-PIC (Low contamination of U/Th)

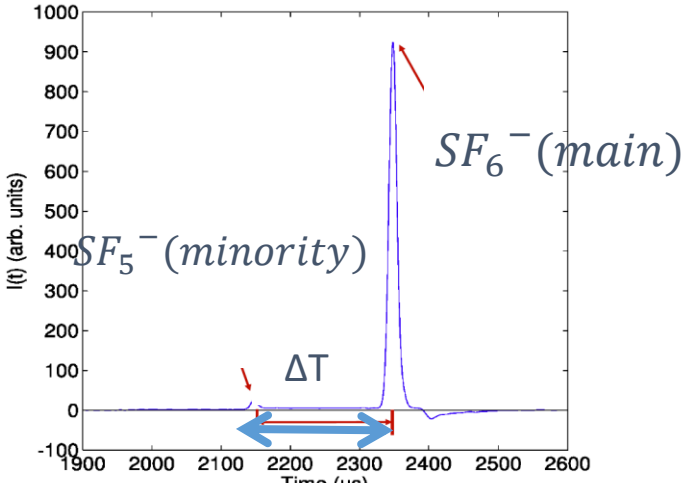


  - full-fiducial analysis with Negative Ion TPC with Negative Ion gas (CS2, SF6,…) (Related to this talk)

Negative Ion TPC principle



several ion species are created
and
drift at <u>different</u> velocity



[N.Phan Talk/CYGNUS2015]

$$z = (t_a - t_b)\frac{v_a v_b}{v_b - v_a}$$

Using time difference to determine <u>absolute z position</u>
→ full-fiducial analysis

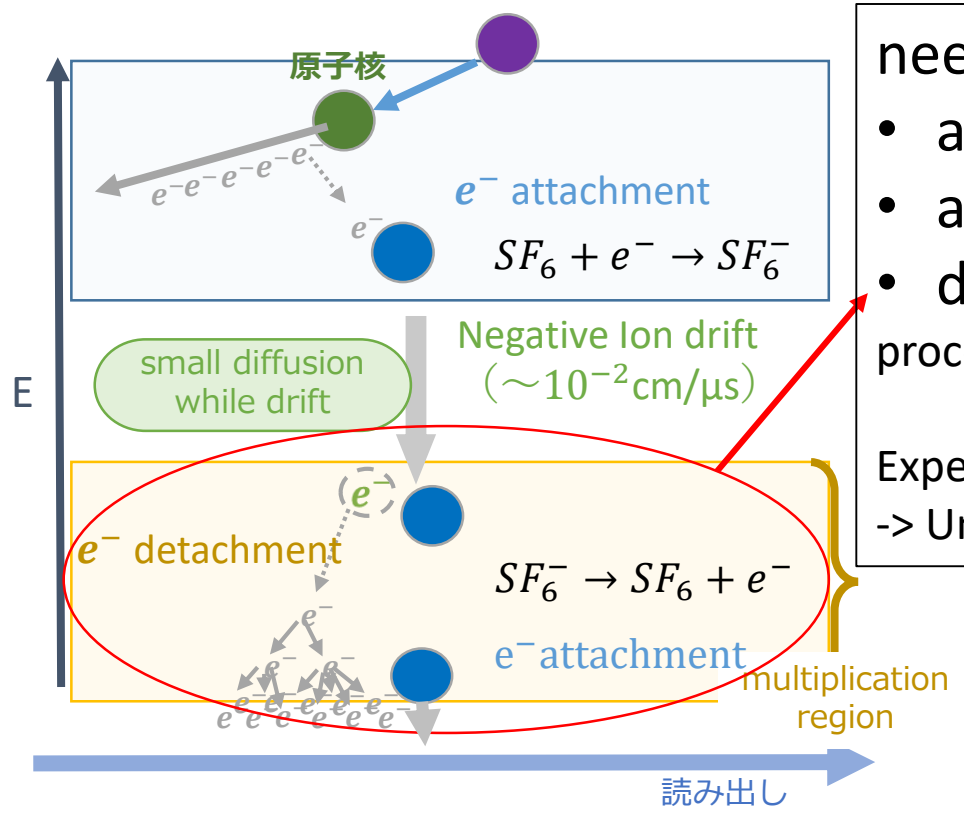
MPGD in negative ion gas

Goal: Background reduction with Negative Ion μTPC

- Understanding of MPGD characteristics in NI gas

➢ Detector Optimization for DM search

->Started research with SF_6 (one of the NI gases)



need to consider…

- avalanche
- attachment
- detachment

process

Experiment & Simulation & other research
-> Understanding of MPGD characteristics in NI gas

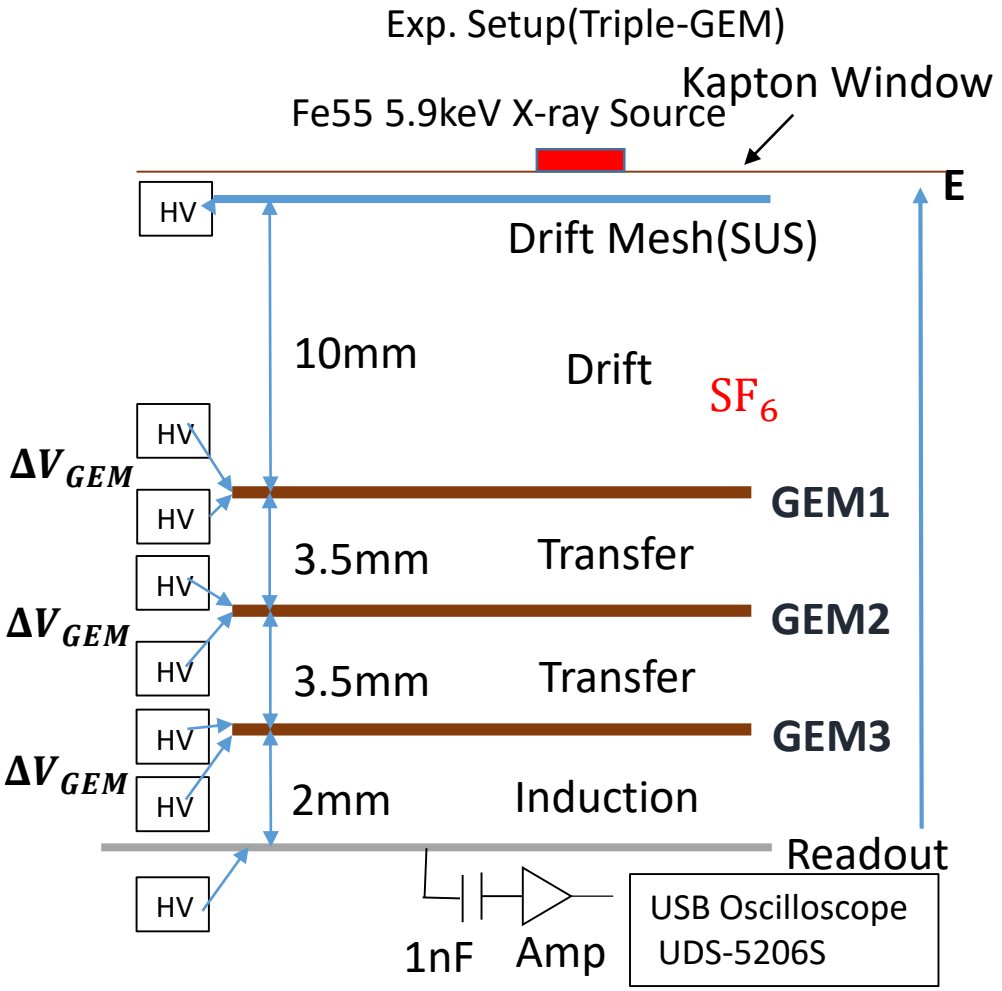
There are 50μm & 400μm thickness GEM results (done by other groups)
+ 100μm results
-> better understanding of MPGD in NI gas

GEM Gain measurement in SF_6

- Double/Triple-GEM
(Scienergy LCP 100µmGEM)

- SF_6 100%
- parameters:

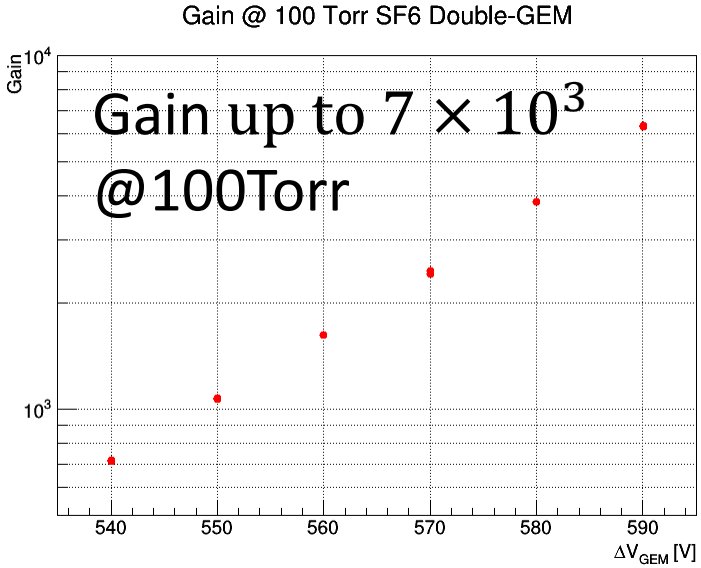
pressure, electric field



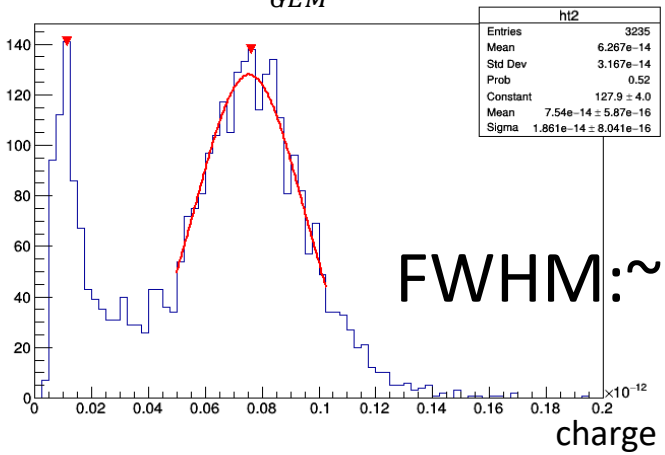
Amp： CREMAT CR-110, Gain : 1.4V/pC , time constant:140µs
Readout：400µm pitch strip readout 24strip(9.6mm)
HV: Drift, GEMx3のTop&Bottom, Readout

GEM Gain measurement Result in SF_6

- Double-GEM

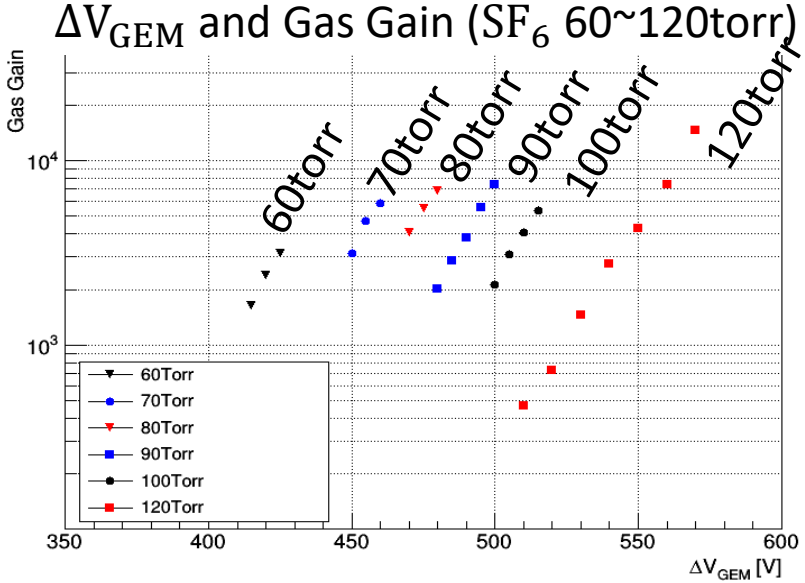


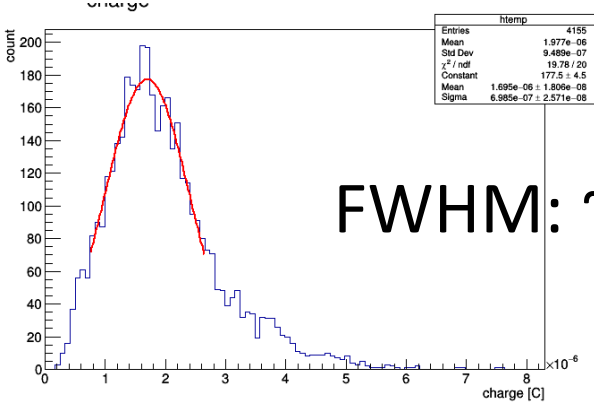
ΔV_{GEM}=550V



FWHM:~60%

- Triple-GEM





FWHM: ~80%

Note: Triple-GEM Gain FWHM: 20~30% @ $Ar + C_2H_6$ 90:10 1atm

GEM Gain measurement Result in SF_6

From 100Torr Triple/Double-GEM result,

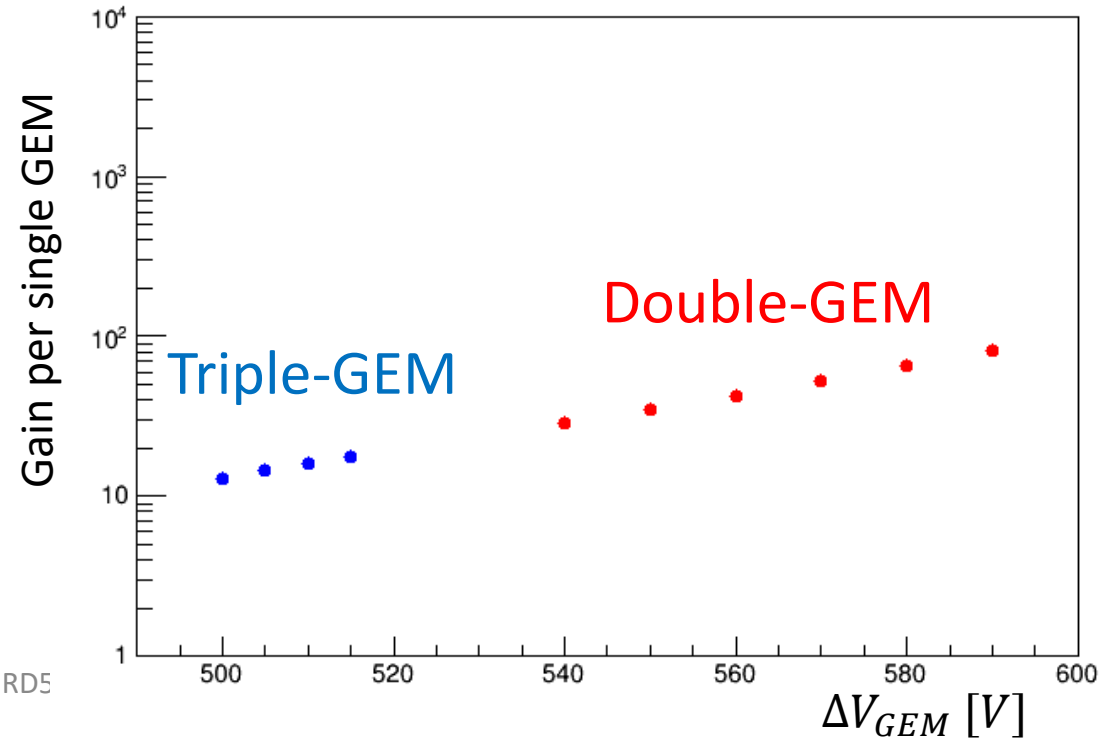
plot GEM gain per single GEM $\sqrt[3]{G_{triple}}$, $\sqrt[2]{G_{double}}$ as ΔV_{GEM} function

→<u>On the same gain curve</u>

charge loss between GEMs : negligible?

Next Step:

Can we reproduce this curve with simulation?



MPGD simulation in SF_6(Negative Ion gas)

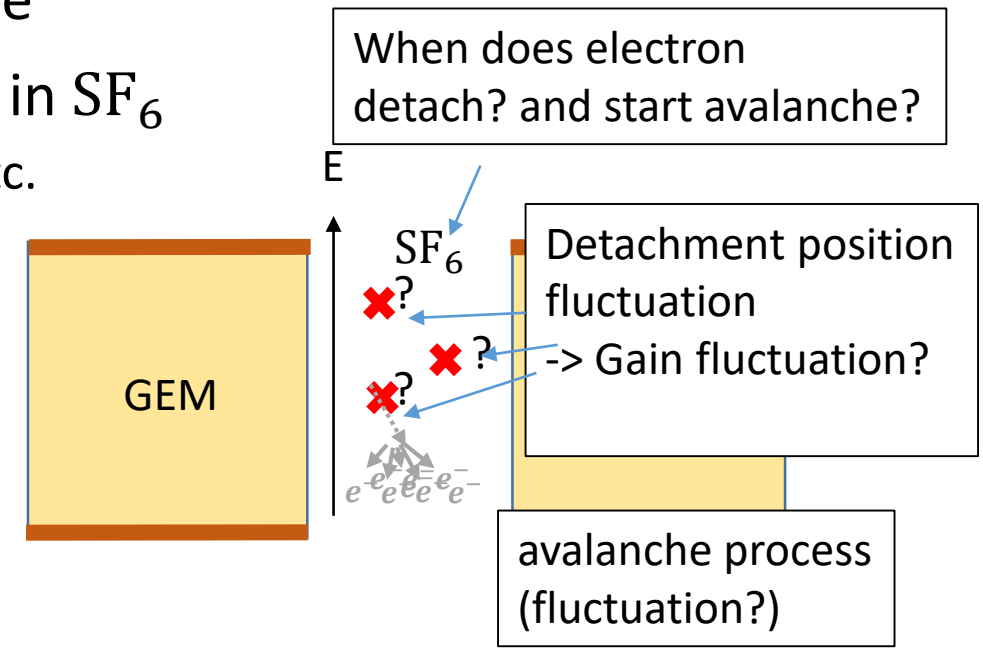
Can we describe and reproduce

- MPGD measurement results in SF_6
  - Gas gain, energy resolution etc.

by simulation ?

We want to do that with

Garfield++ or/and Magboltz



- Simulations: help us to understand MPGD characteristics in SF_6 and do optimization for DM search.

- As first step, We tried to reproduce GEM gain results with Magboltz

Garfield++/ Magboltz

About Garfield++ and Magboltz

- Garfield++
  - Gas and semi-conductor detector simulation tool kit

  with Medium characteristics(Gas, Semi-conductor), geometry, electric field calculation , calculate charge transport

- Magboltz
  - From electron/molecules cross-section, solve Boltzmann equation or Monte Carlo simulation and calculate drift velocity, diffusion, Townsend / Attachment coefficients.

Magboltz - SF_6 data

- e^-/SF_6 cross section data in Magboltz

➢Magboltz 8.97 – included in Garfield++

(ITOH ET AL J.PHYS.D. 26 (1993) 1975-1979 から)

has 5 e^-/SF_6 cross section data

➢Magboltz 10.6

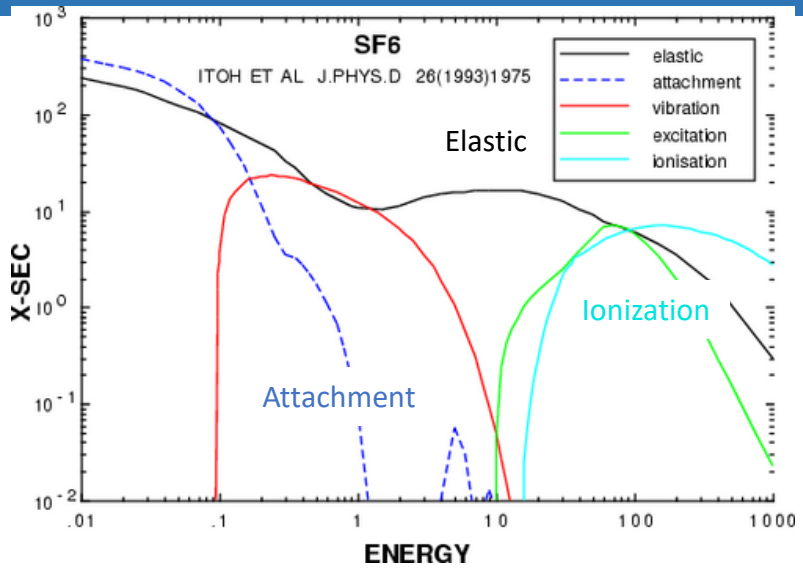
（picked up some reaction, right bottom）

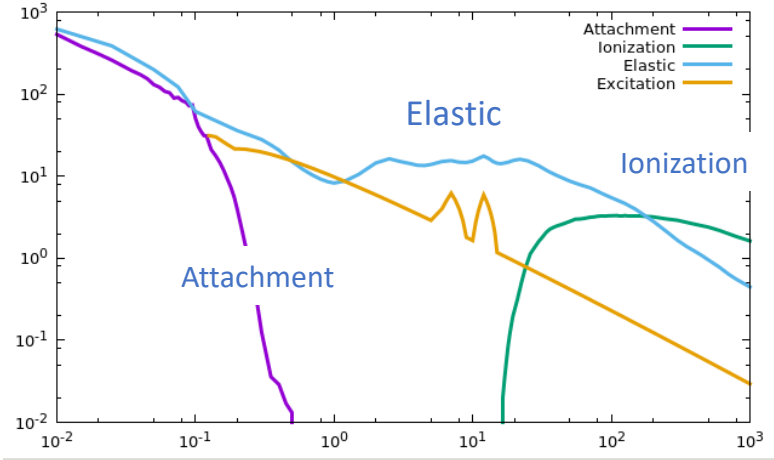
(Biagi (Magboltz 10.6 data),)

has 50 e^-/SF_6 cross section data

Does this difference make

significant difference?

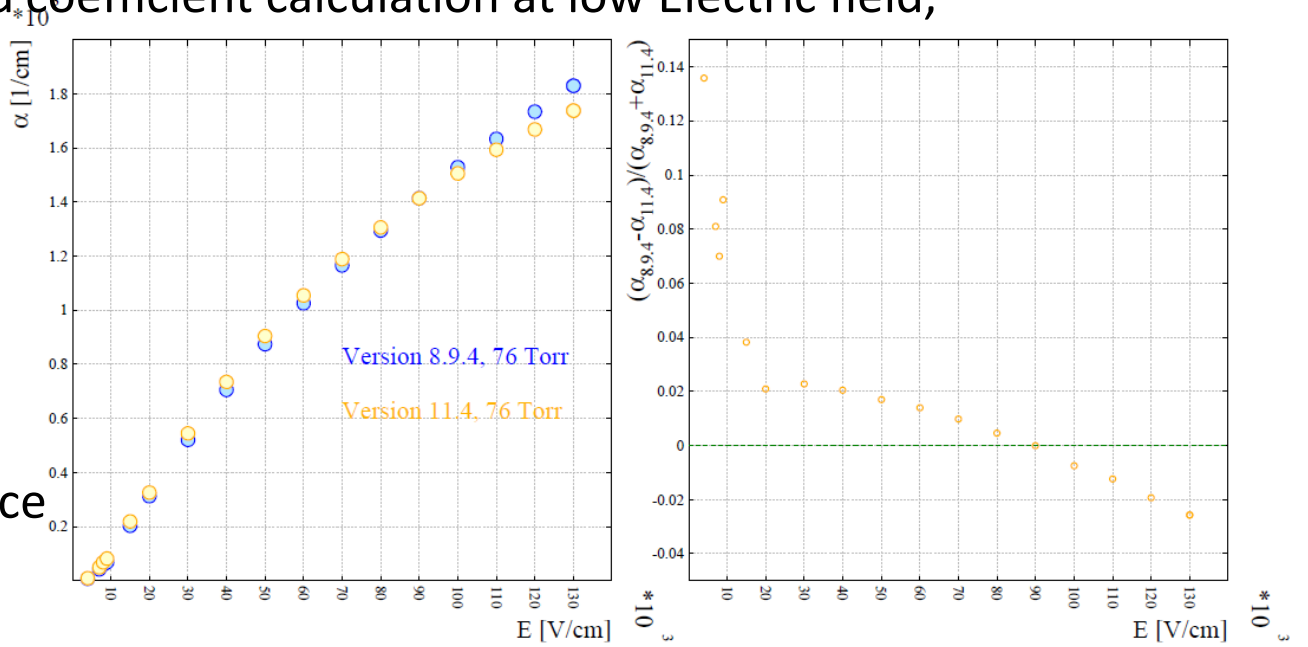




Biagi (Magboltz 10.6 data)

Result difference between Magboltz Ver.

- In the case of Townsend coefficient calculation at low Electric field,



calculation result difference

at low Electric field

Is it because of cross section difference or algorithm change ?

->need to be investigated

And Garfield++ can't call Magboltz Ver. 10.x later because of interface change

- It is need to use newer Magboltz? (with Garfield++)
- How to call from Garfield++ ?

Now we are investigating this.

Now we use Magboltz 11.4 solely for our calculation

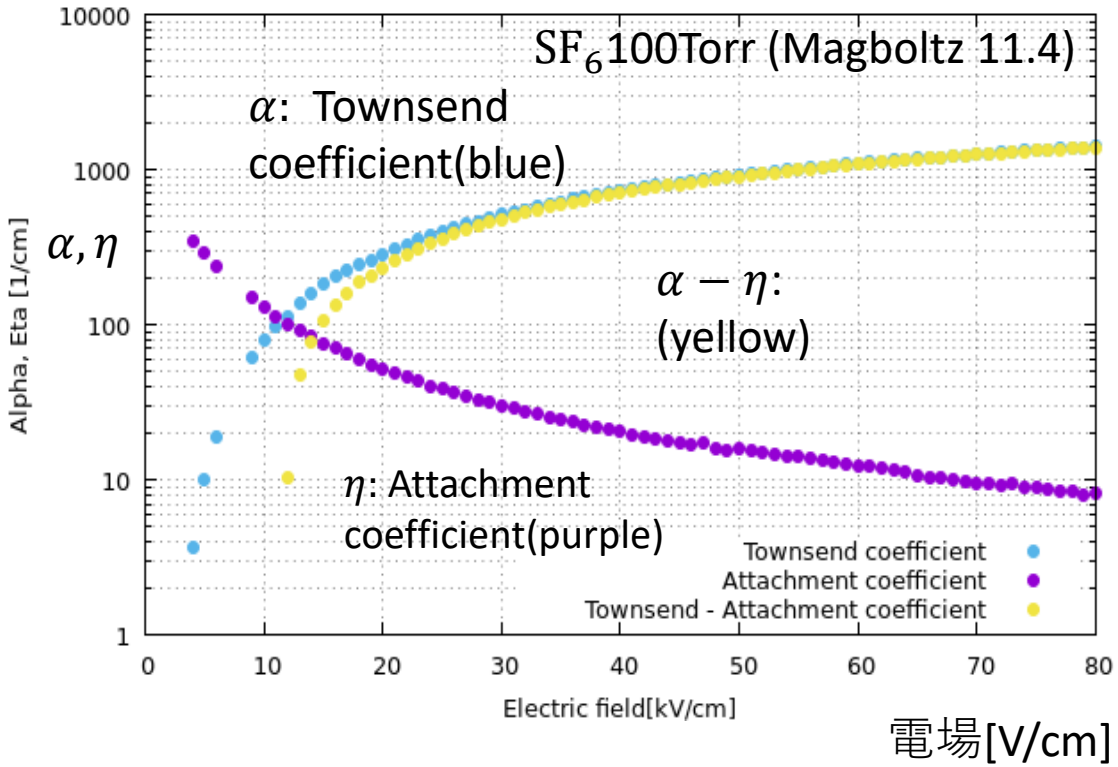
Townsend/Attachment coefficient calculation

- Townsend(α) /Attachment(η) calculation with Magboltz 11.4

Townsend(α): $[cm^{-1}]$
number of multiplied electrons per length

Attachment(η): $[cm^{-1}]$
number of attached electrons per length

Gain M is
$M = \exp((\alpha - \eta) \times gap)$



- We started Townsend/Attachment calculation with Magboltz and tried to reproduce experimental results.

Comparison between measurement and simulation

We assumed:

$$M = \exp((\alpha - \eta) \times gap) \quad (1)$$

- Electric field : E = $V_{GEM}/100\ \mu m$ (rough estimation)
- α-η : from Magboltz 11.4 at above E
- gap length : gap = 27μm from $\Delta V_{GEM} = 500\text{V}$ calculation result

$$gap = \frac{\ln M}{\alpha - \eta} \quad (2)$$

Can we reproduce gain curve ?

Result:

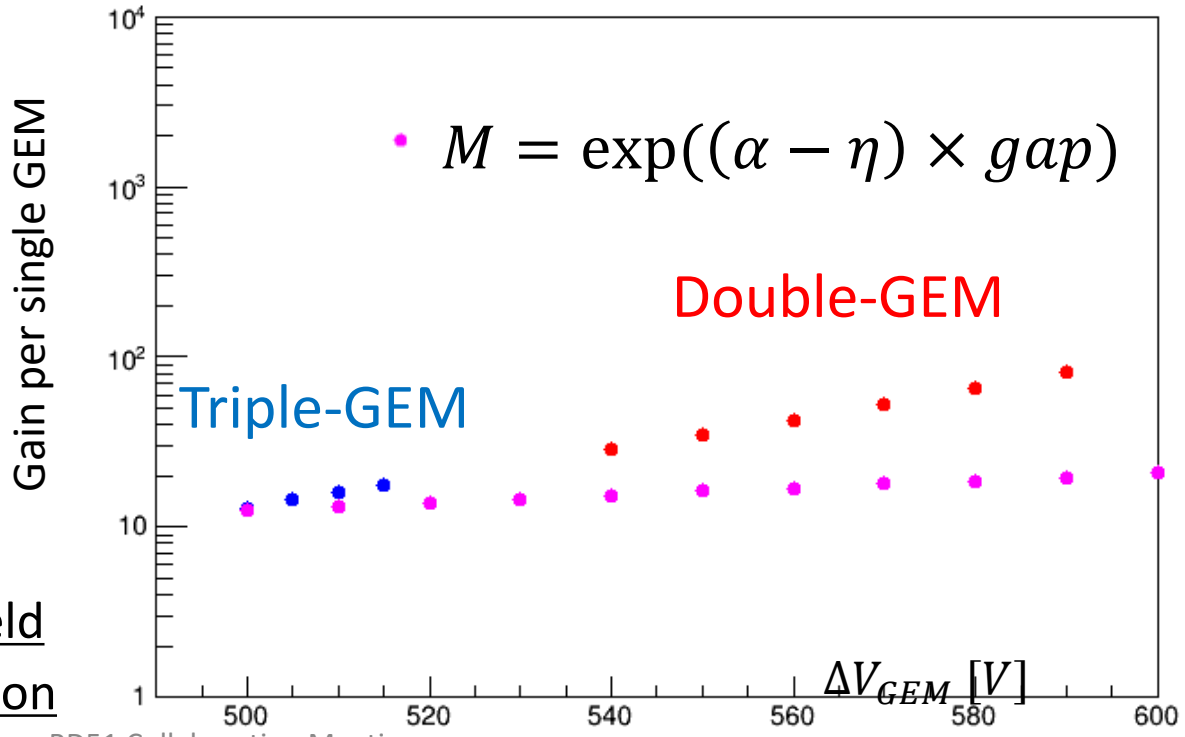
Pink dots in the right graph

-> not good agreement

with exp. results

Reason?

- detachment effect @ Low E field
- uniform electric field assumption



Detachment effect @ Low E ?

Hypothesis

- Effective Townsend coefficient is suppressed at low electric field

because of small detachment and few seed electrons ?

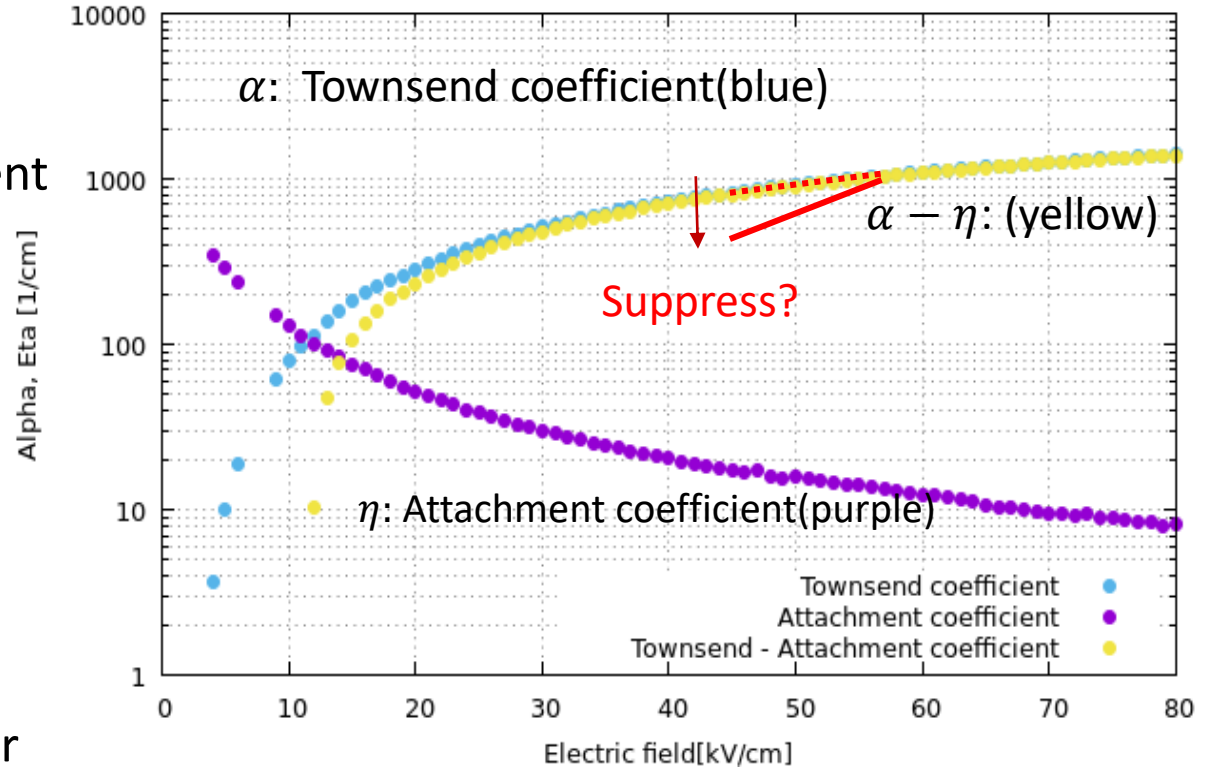
$SF_6$100Torr (Magboltz 11.4)

- Low electric field

suppresses electron detachment and there are fewer seed electrons

→also suppress avalanche?

→ steep Townsend coefficient slope

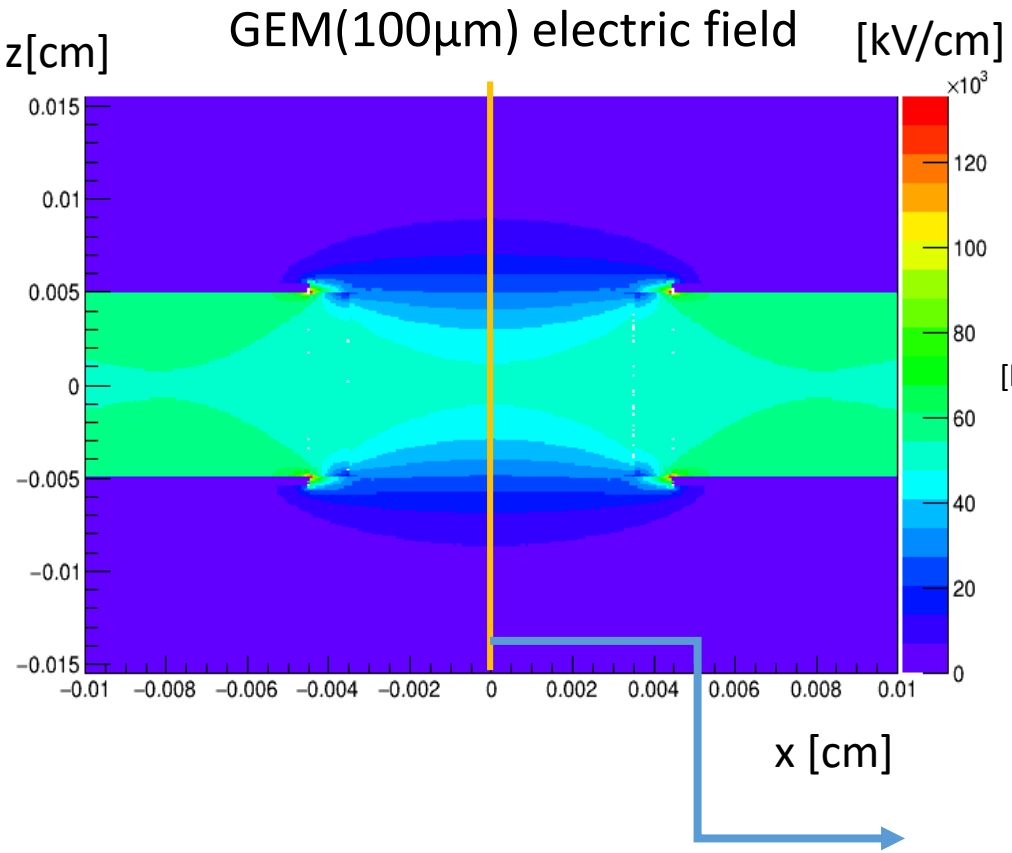


Plan:

introduce this effect parameter and try to reproduce gain curve and confirm this.

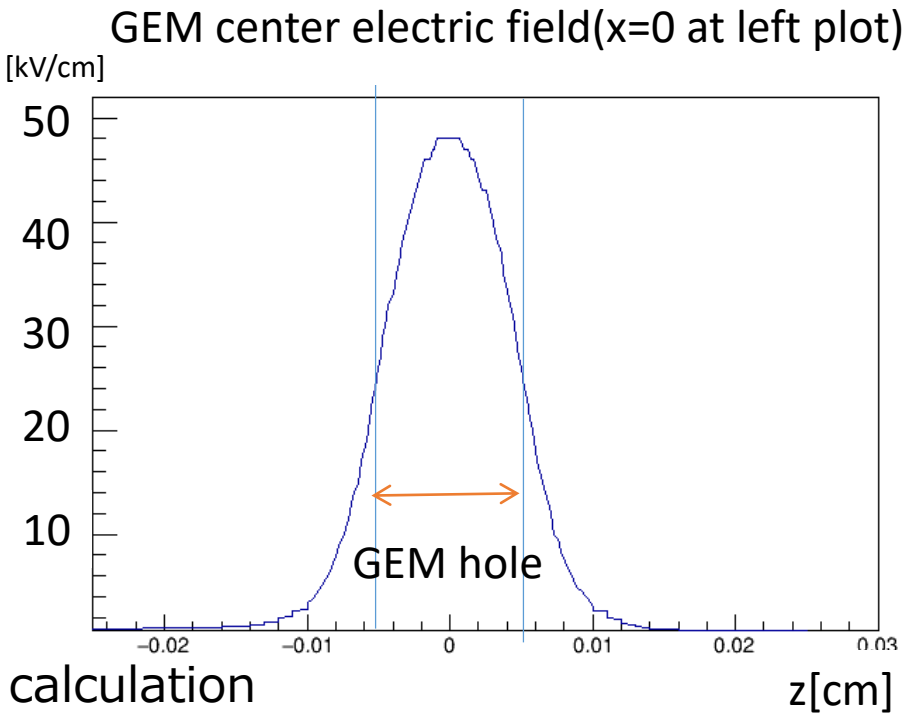
Too rough GEM electric field assumption?

- Electric field Map by Gmsh(mesh)+ Elmer （electric field）



- Not uniform
- Lower E than we assumed

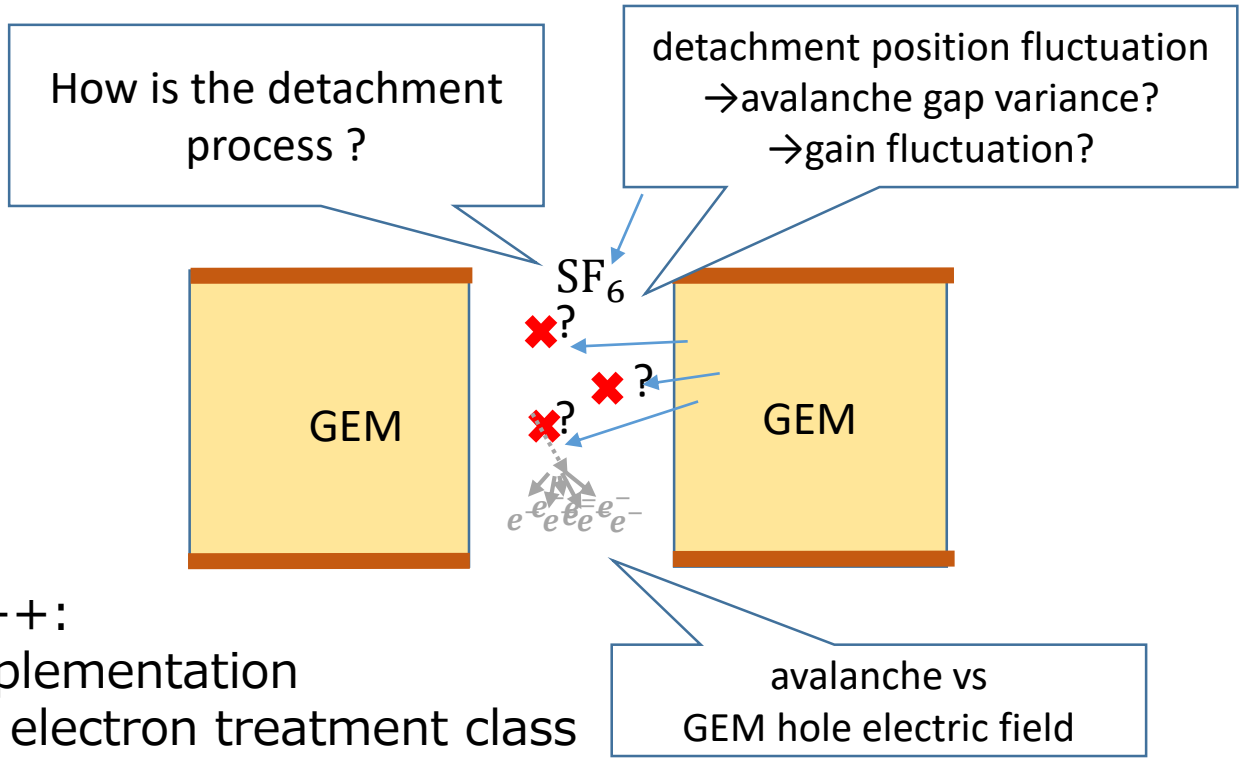
→if we did overestimate E field, Townsend coefficient slope: eepst



Future plan:
More detailed GEM electron field for Gain calculation

Toward Negative ion gas MPGD simulation…

We want to include MPGD geometry in simulation but…



- Current Garfield++:

Not detachment implementation
need negative ion / electron treatment class

- Future plan

implement these class and establish simulation method?

Future plan and conclusion

➢Future plan

- Try to do MPGD simulation with geometry using Garfied++
- compare Garfield++/Magboltz simulation with experiment result and establish negative ion model inside MPGD and confirm

➢Conclusion

- In SF_6 we measured Triple/Double-GEM Gas Gain with several parameters
- electron attachment to SF_6 could effect energy resolution
- Tried to reproduce GEM gain curve with Magboltz
- We started Garfield++/Magboltz simulation activity in SF_6