Study on the Delay Time of Current Rise in Pulsed Glow-Discharge-Driven IEC

R. Nakamatsu[1], K. Masuda[2], K. Nagasaki[2], S. Ohshima[2], R. Kashima[1]

1) Graduate School of Energy Science, Kyoto Univ., Gokasho, Uji, Kyoto 611-0011, Japan

2) Institute of Advanced Energy, Kyoto Univ., Gokasho, Uji, Kyoto 611-0011, Japan

nakamatsu.ryota.44z@st.kyoto-u.ac.jp, +81-774-38-3443

Contents

1. Background

Non-Destructive Nuclear Material Detection System

This device which can discover nuclear materials concealed in sea containers in a port

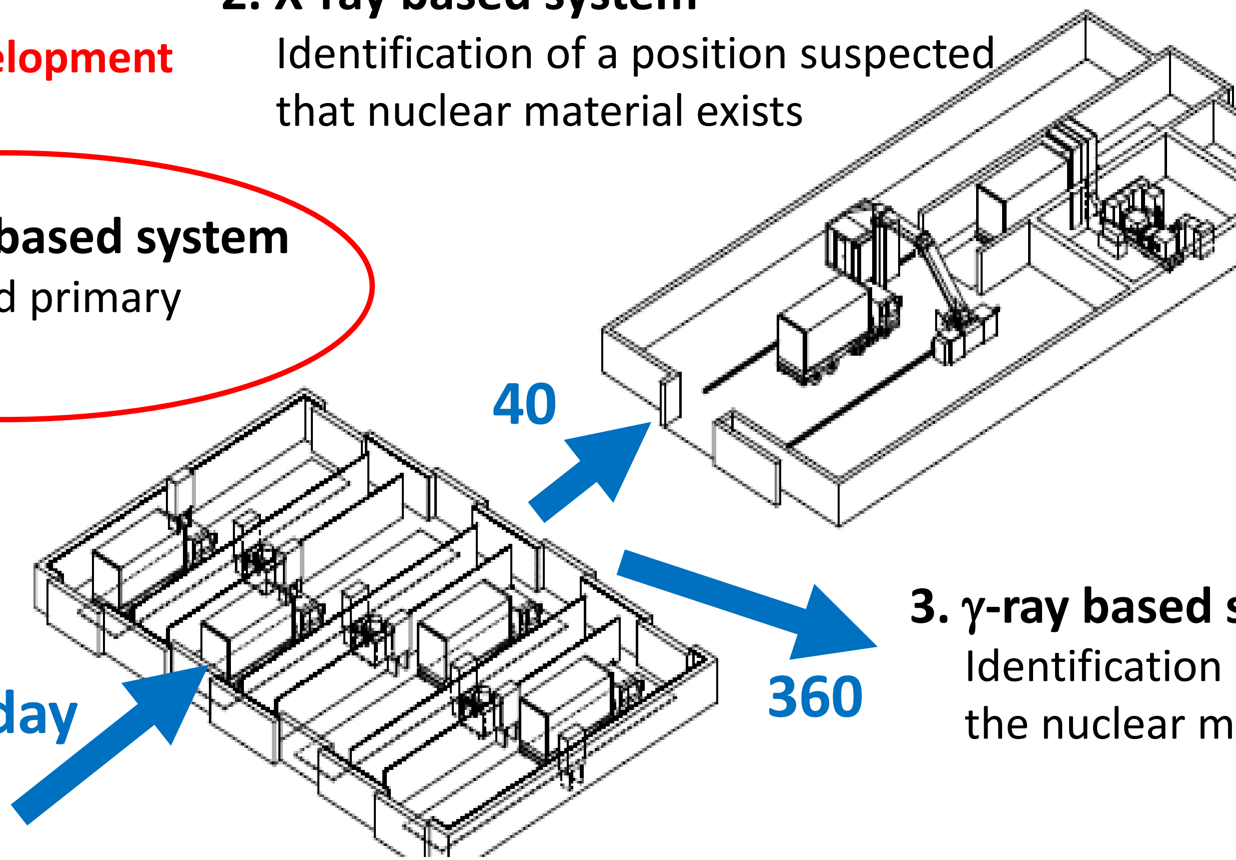
It is under development in this study

1. Neutron based system
High-speed primary screening

2. X-ray based system
Identification of a position suspected that nuclear material exists

3. γ-ray based system
Identification of the nuclear material

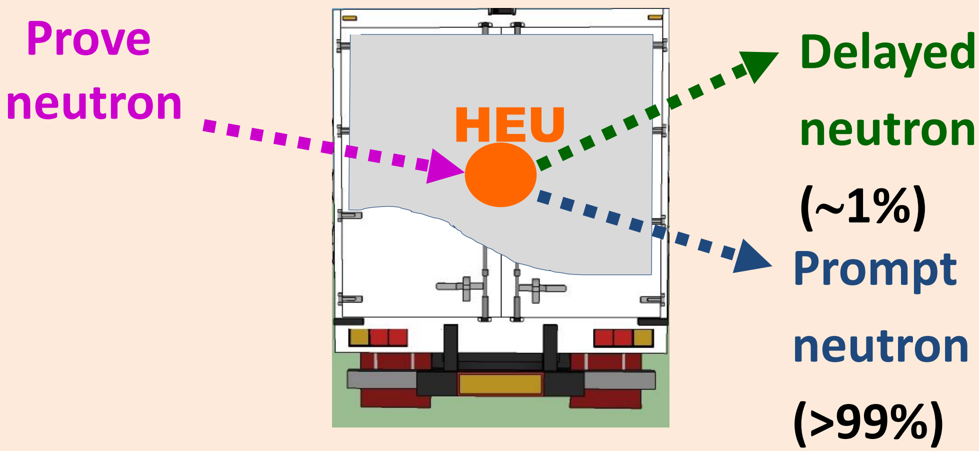
400 containers/day



2. Objective

requirement IEC neutron source

A principal challenge is to distinguish the secondary neutrons from the probing neutrons.



New inspection technology

Delayed Neutron Noise Analysis (DNNA)

The pulse irradiation of the neutron is necessary

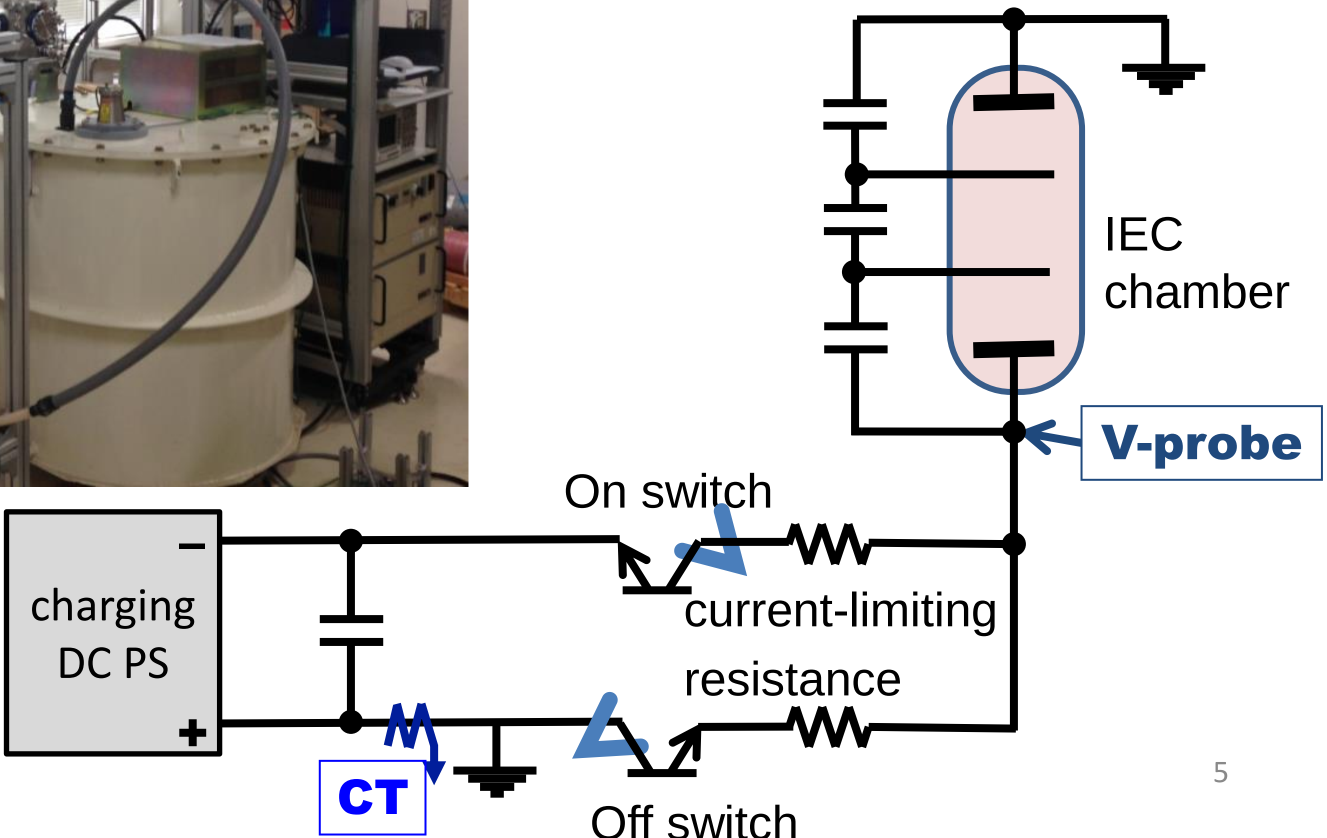
to discriminate a probe neutron from a secondary neutron

D-D Pulsed Glow-Discharge –Driven IEC

Average neutron production rate	Achievement (IEC-LM)	$10^7\ n/s$
	Target of R & D	$\mathbf{10^8\ n/s}$

3. Experimental set up

the device and the circuit diagram

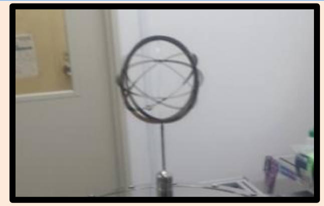


3. Experimental set up

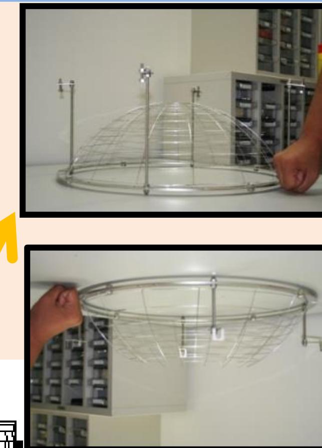
IEC chamber

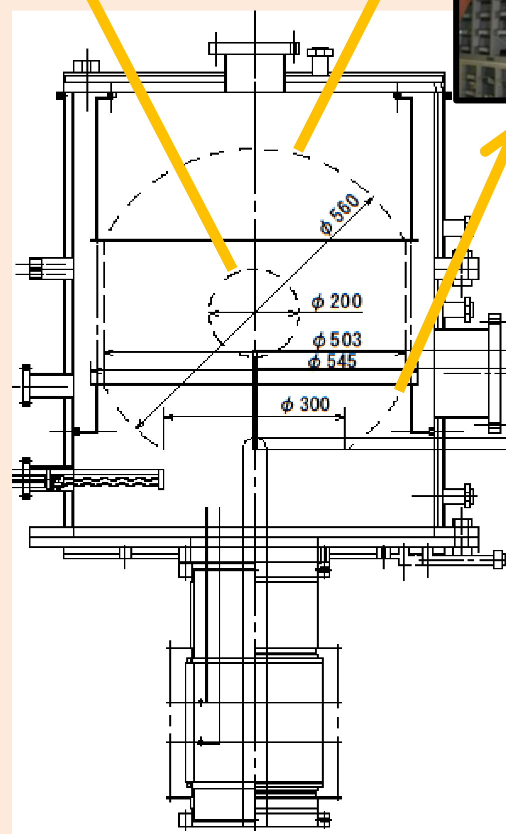
IEC chamber

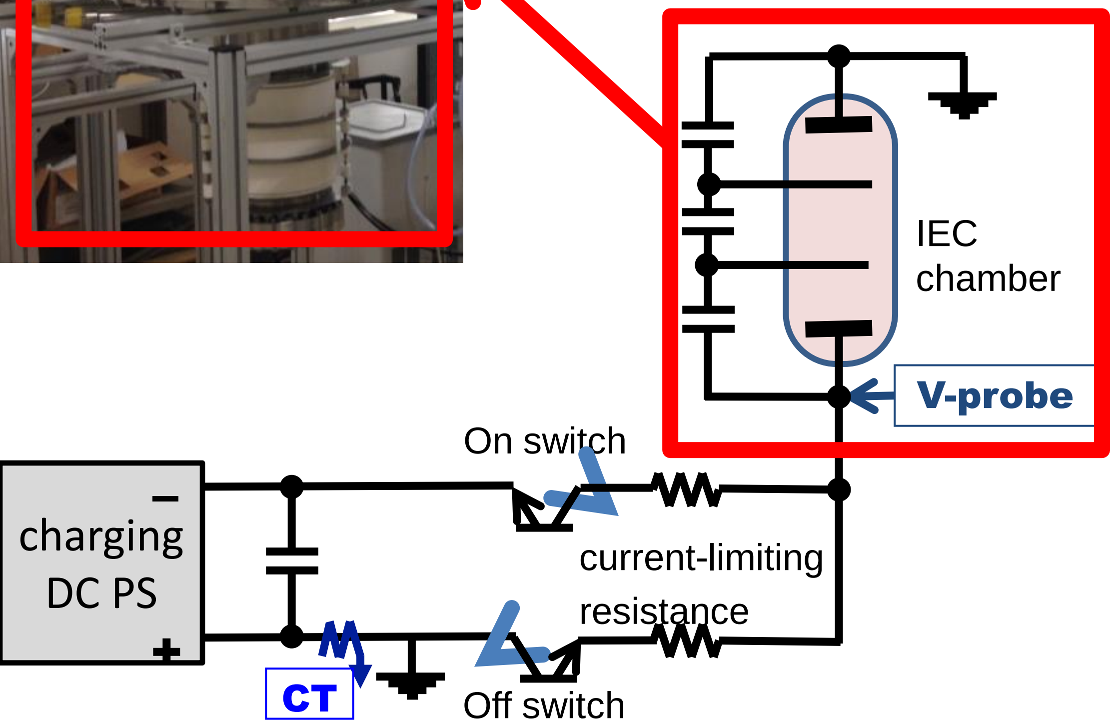
Mo spherical grid cathode ϕ 200mm



SUS spherical mesh anode ϕ 560mm



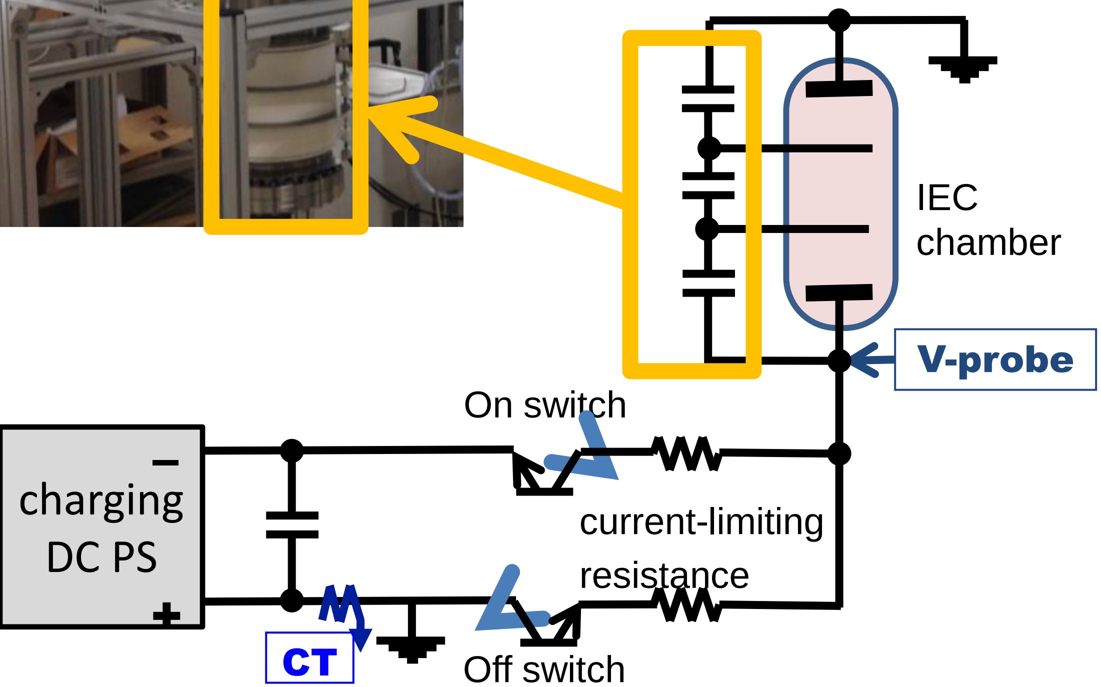


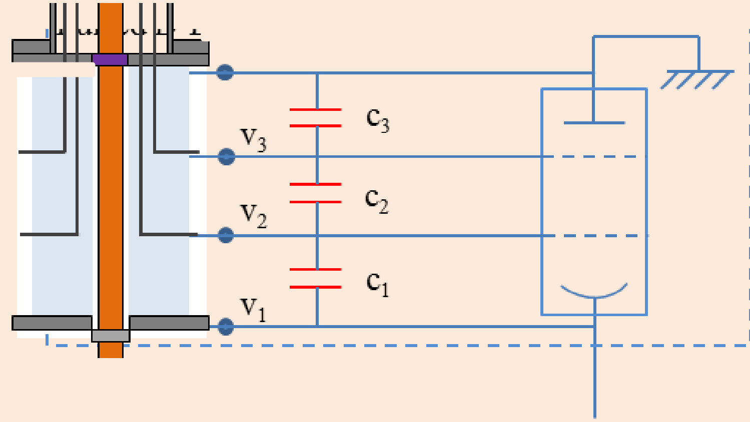


3. Experimental set up

Three-stage HV feedthrough

Three-stage HV feedthrough





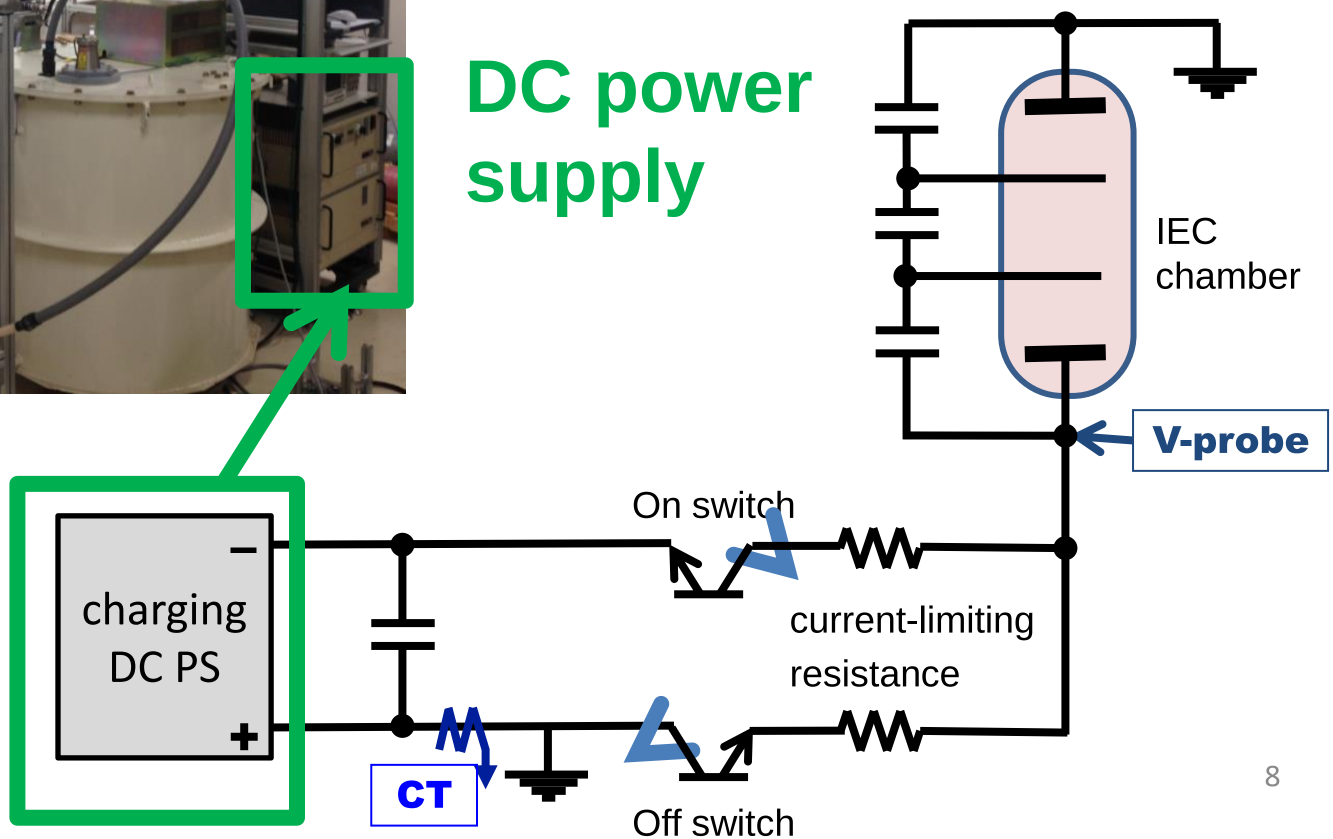
Three-stage HV feedthrough is introduced to avoid arcing

Capacitance is put on in each stage in parallel because capacitance of each stage of the feedthrough is difference

3. Experimental set up

DC power supply

Voltage	0 ~ -100kV
The voltage is applied to high voltage pulse generator by DC power supply	

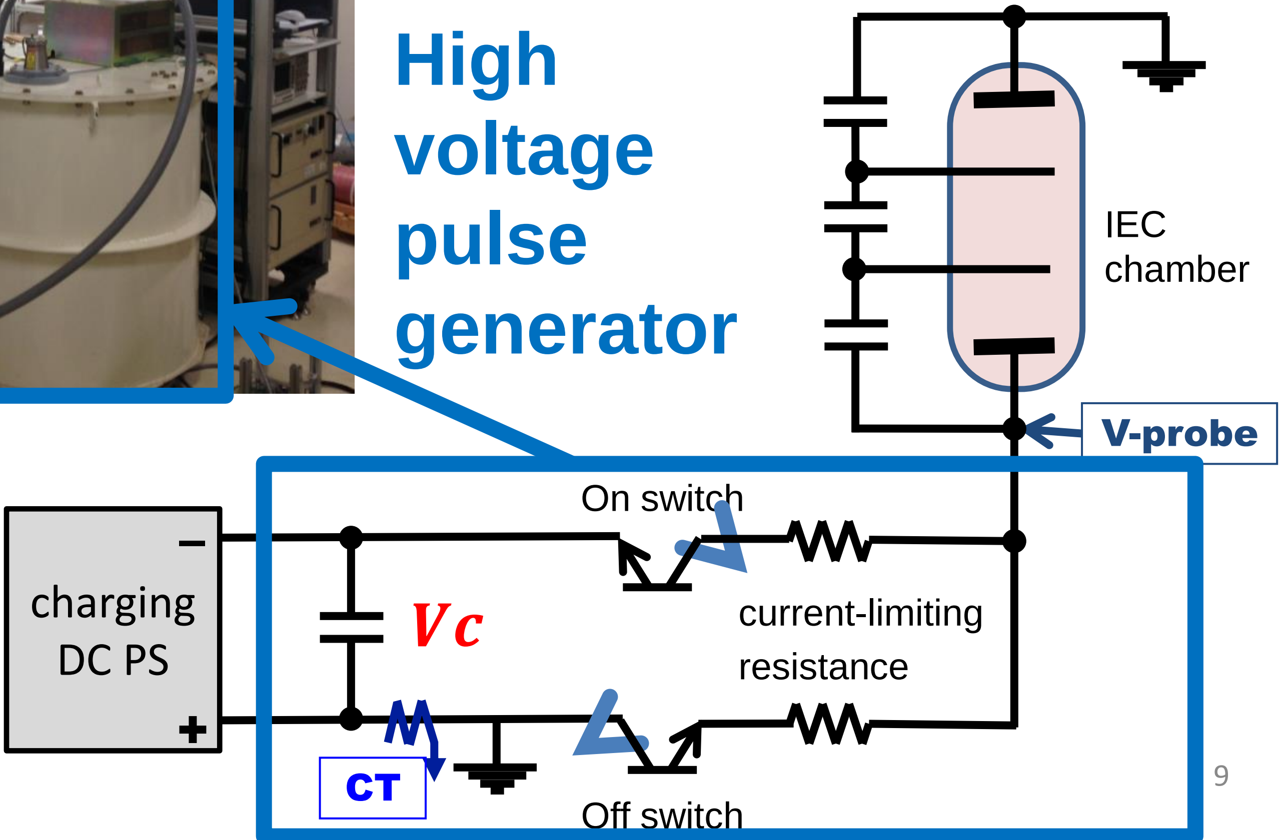


3. Experimental set up

High voltage pulse generator

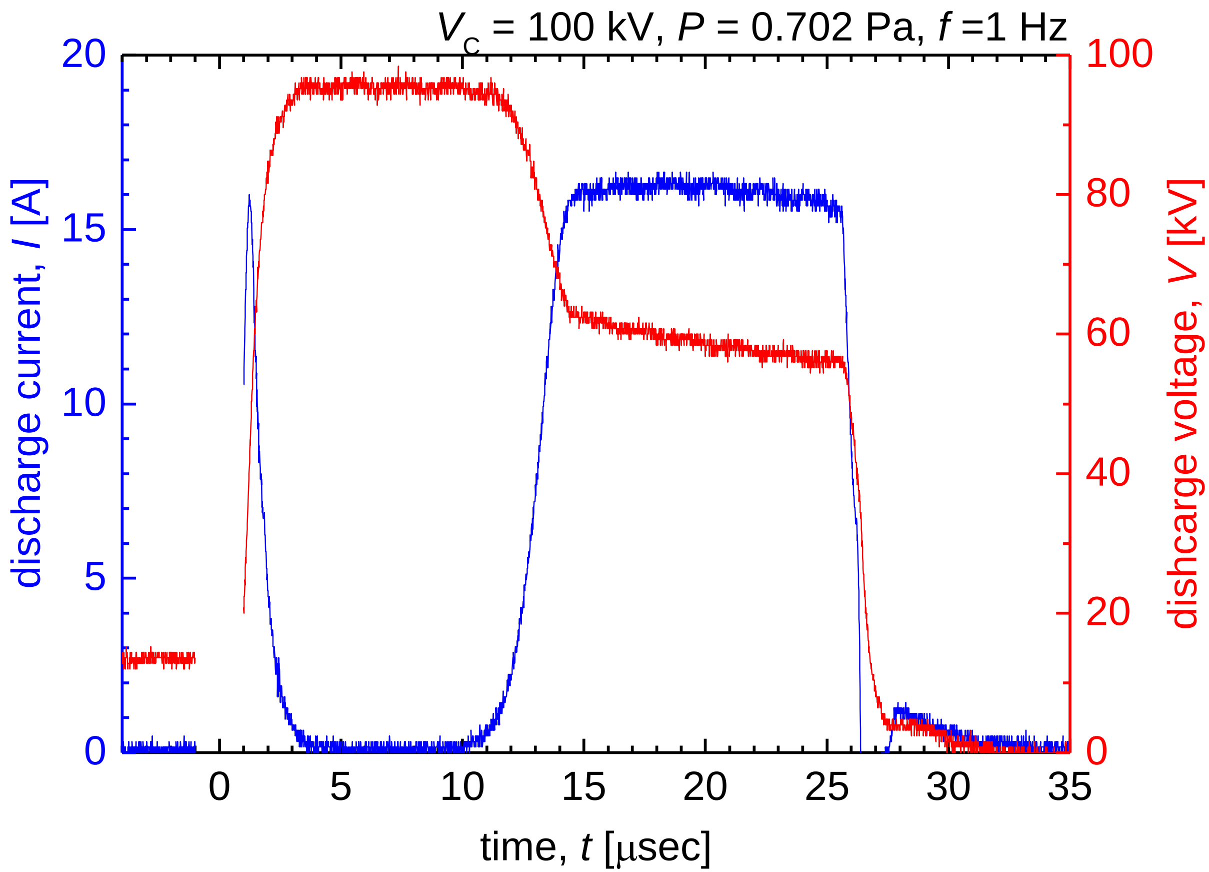
Voltage	0 ~ -100kV
Peak current	20A
Pulse rate	1 ~ 200Hz
Pulse width	1 ~ 500μs
Maximum duty ratio	0.01%

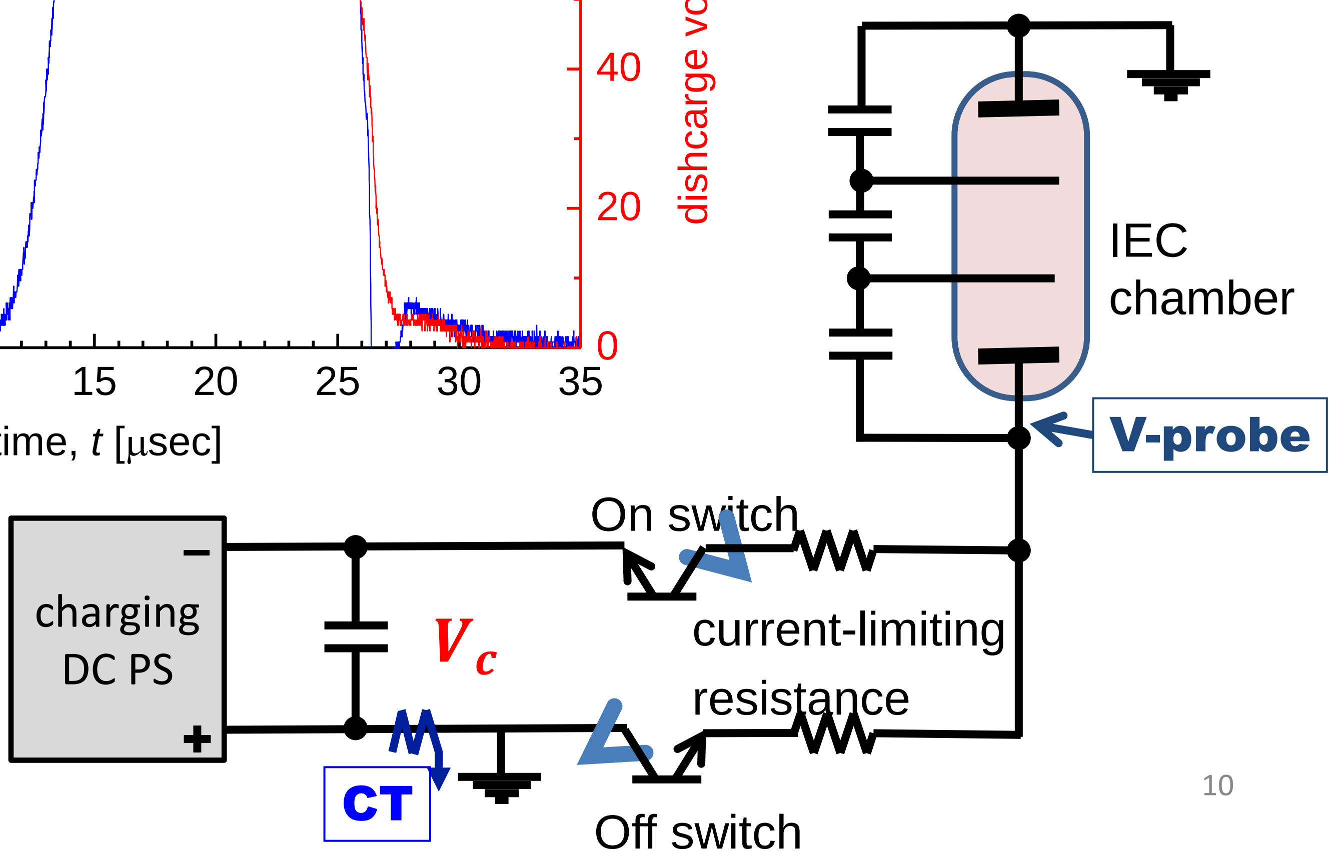
High voltage pulse generator



4. Current rise in pulsed-glow-discharge-driven-IEC

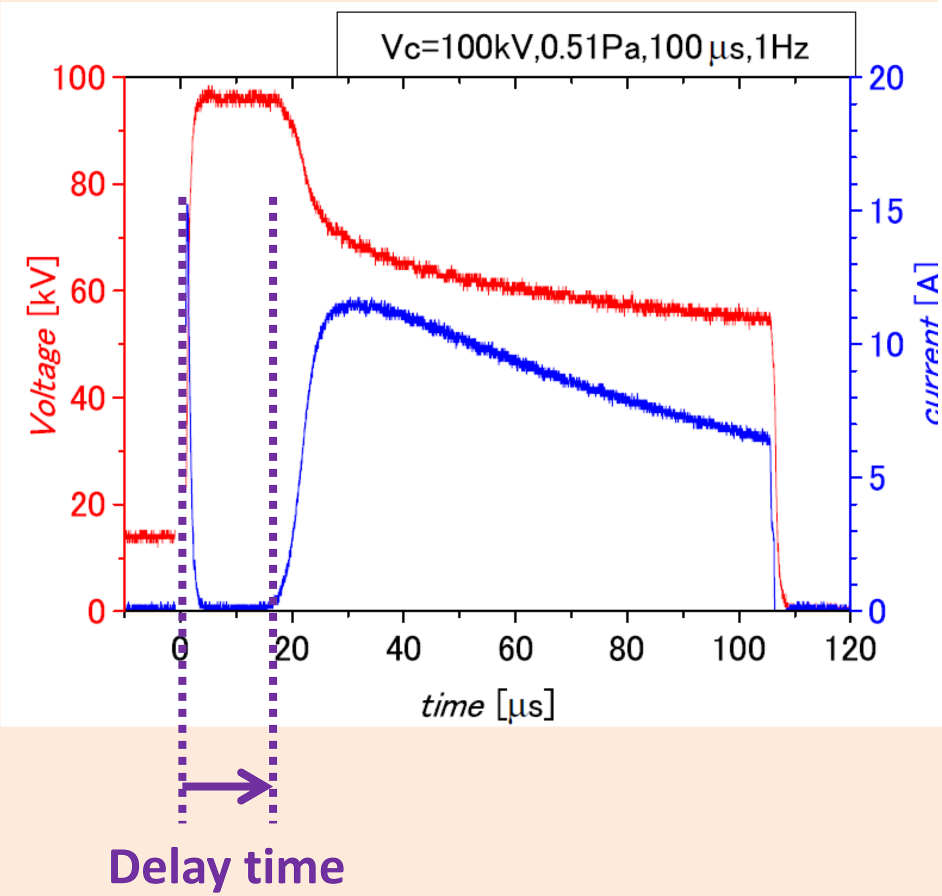
Pulse waveform

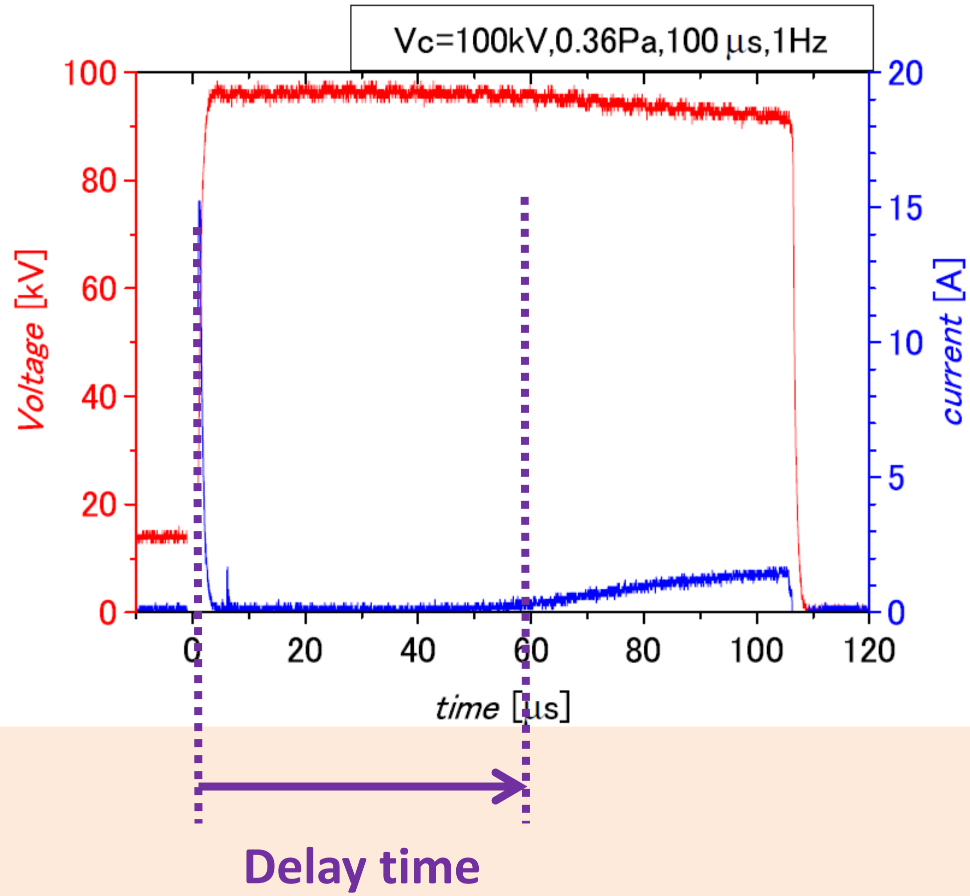




4. Current rise in pulsed-glow-discharge-driven-IEC

Delay time



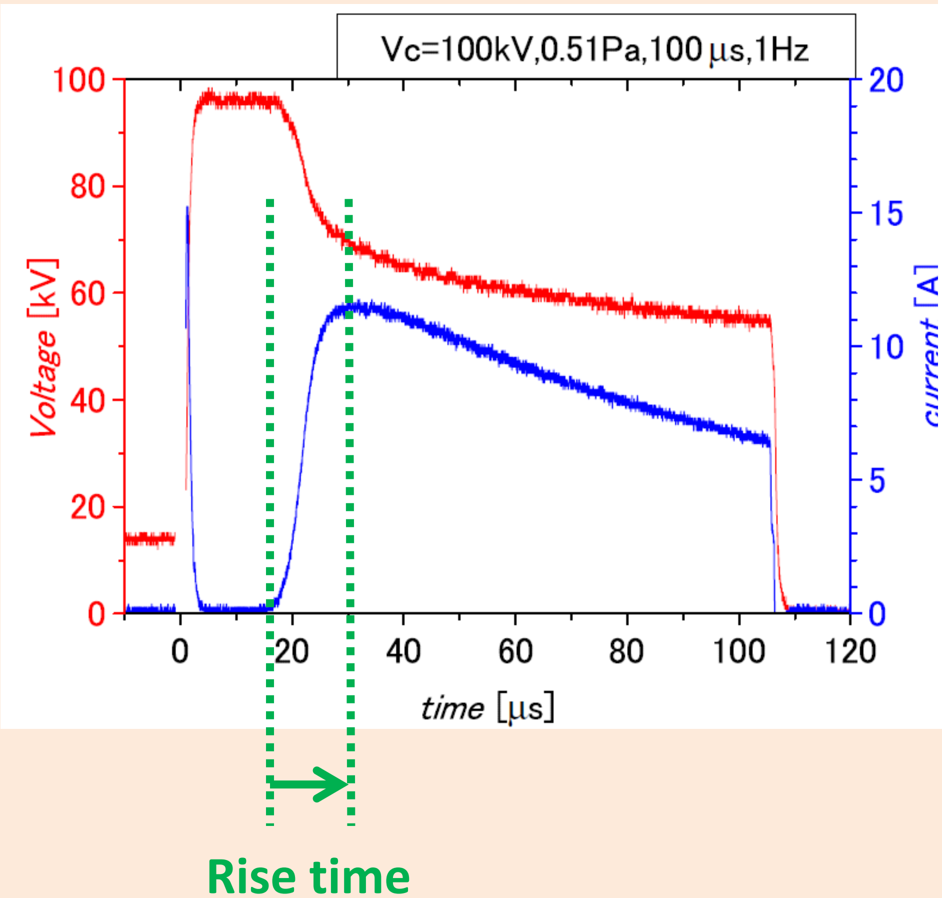


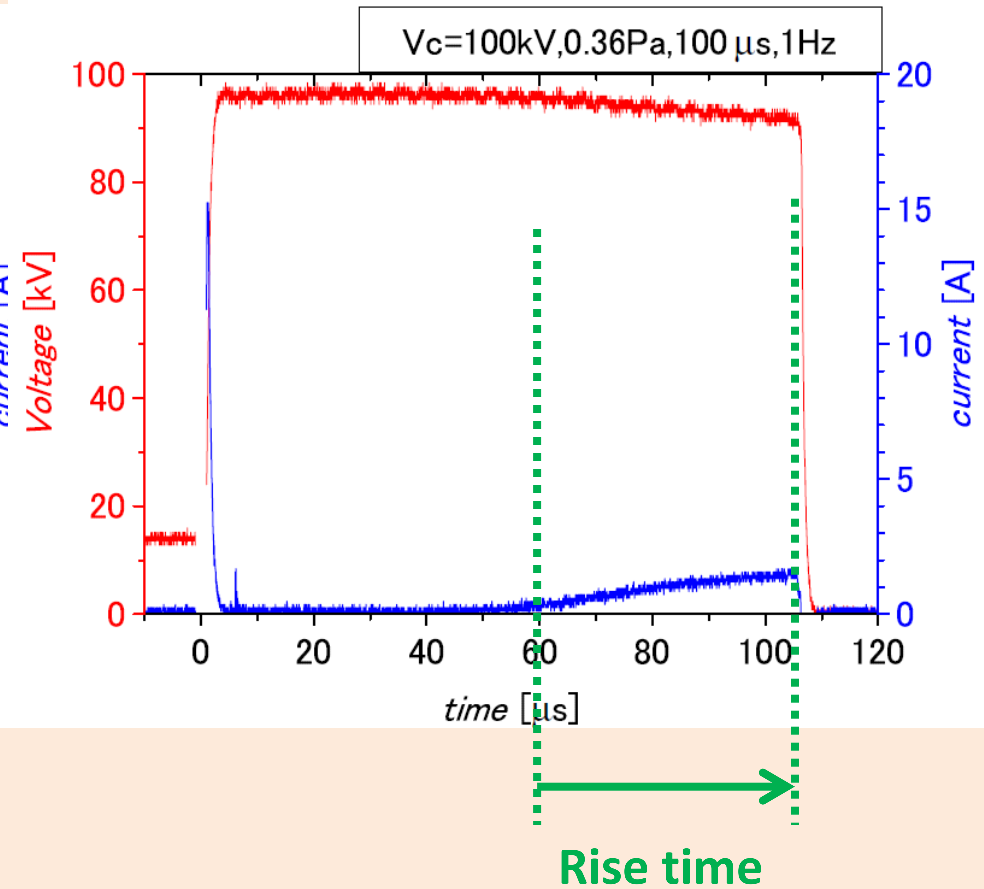
Delay time

greatly varies according to gas pressure

4. Current rise in pulsed-glow-discharge-driven-IEC

Time of current rise



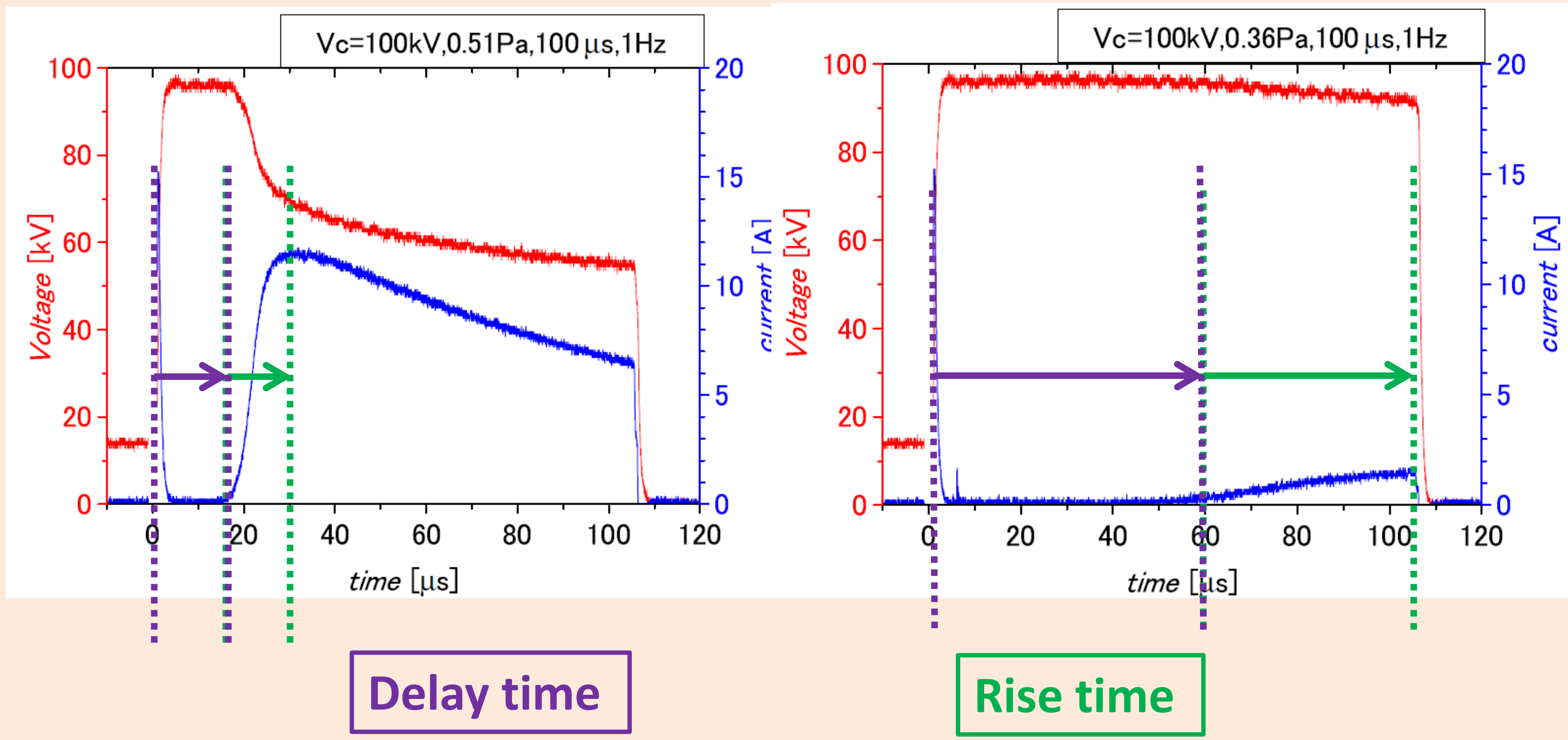


Rise time

greatly varies according to gas pressure

4. Current rise in pulsed-glow-discharge-driven-IEC

Importance of study on the delay time of current rise

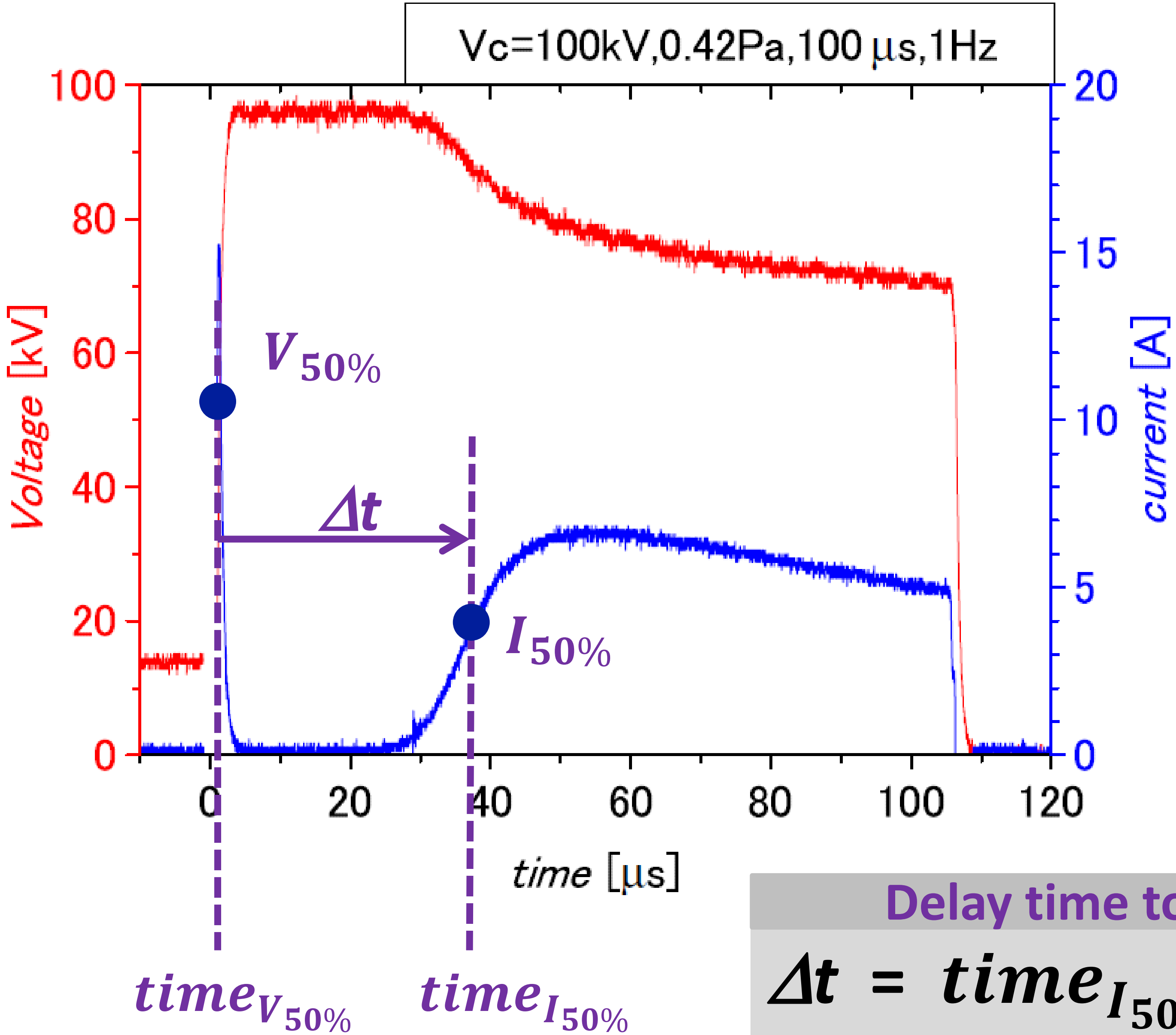


The pulse width might be limited

It is important to take into account above two factors in designing a pulse power supply to operate IEC

4. Current rise in pulsed-glow-discharge-driven-IEC

Definition of delay time to current rise (Δt)



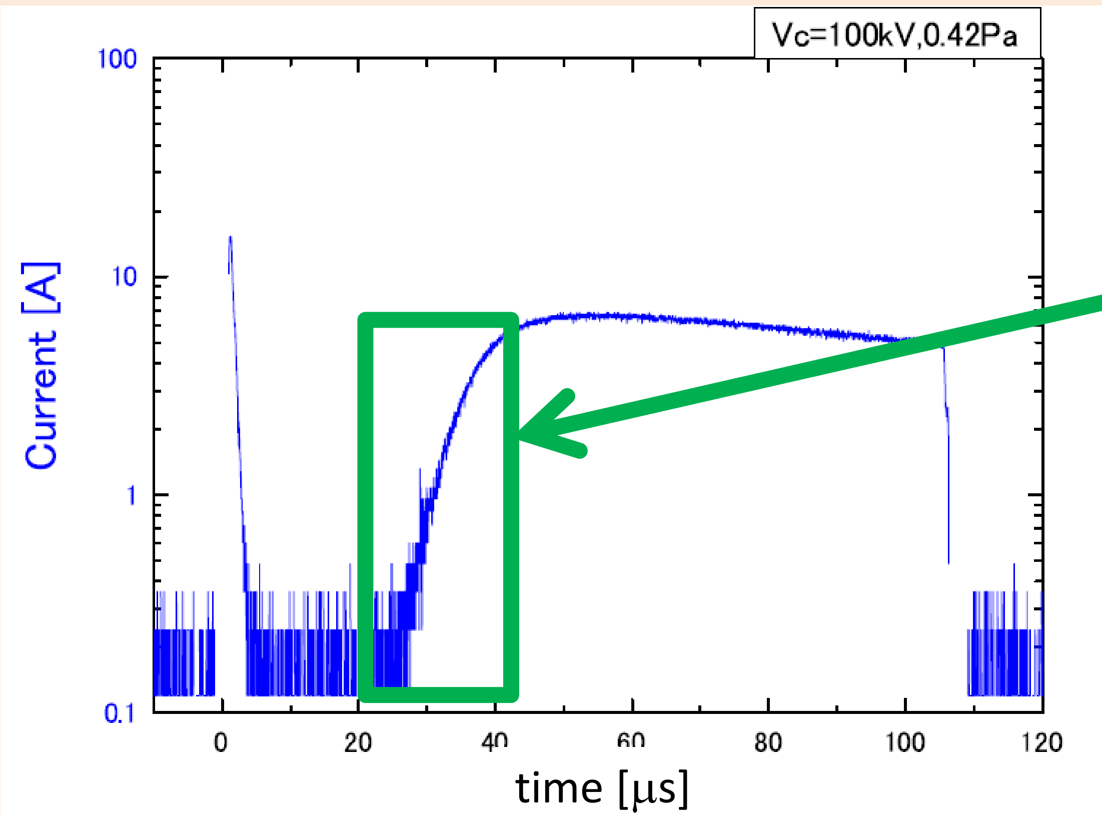
Delay time to current rise

$$\Delta t = time_{I_{50\%}} - time_{V_{50\%}}$$

4. Current rise in pulsed-glow-discharge-driven-IEC

the pulse discharge current on the log scale

Pulse discharge current on the log scale



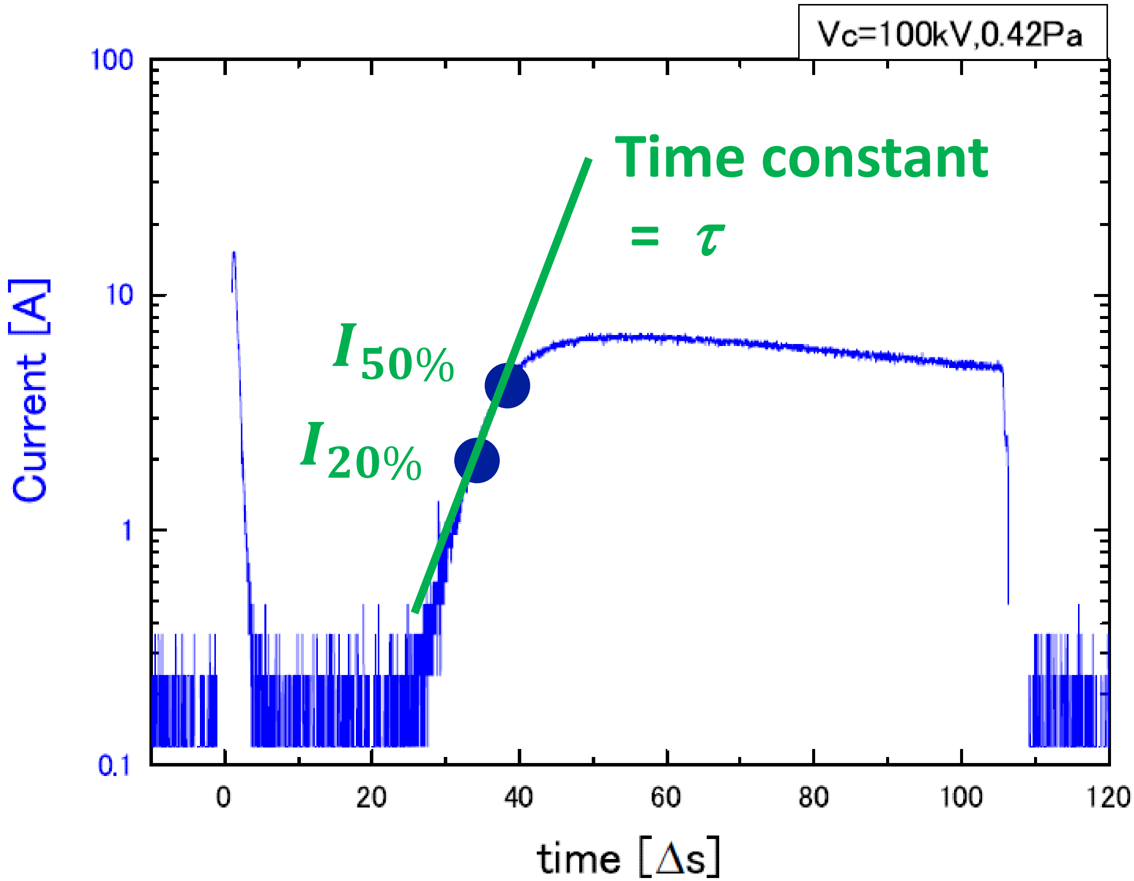
Current rise seems exponential

***Δt* might be decided by this exponential function**

We define the rise time constant (τ) to check the above

4. Current rise in pulsed-glow-discharge-driven-IEC

Definition of time constant (τ)



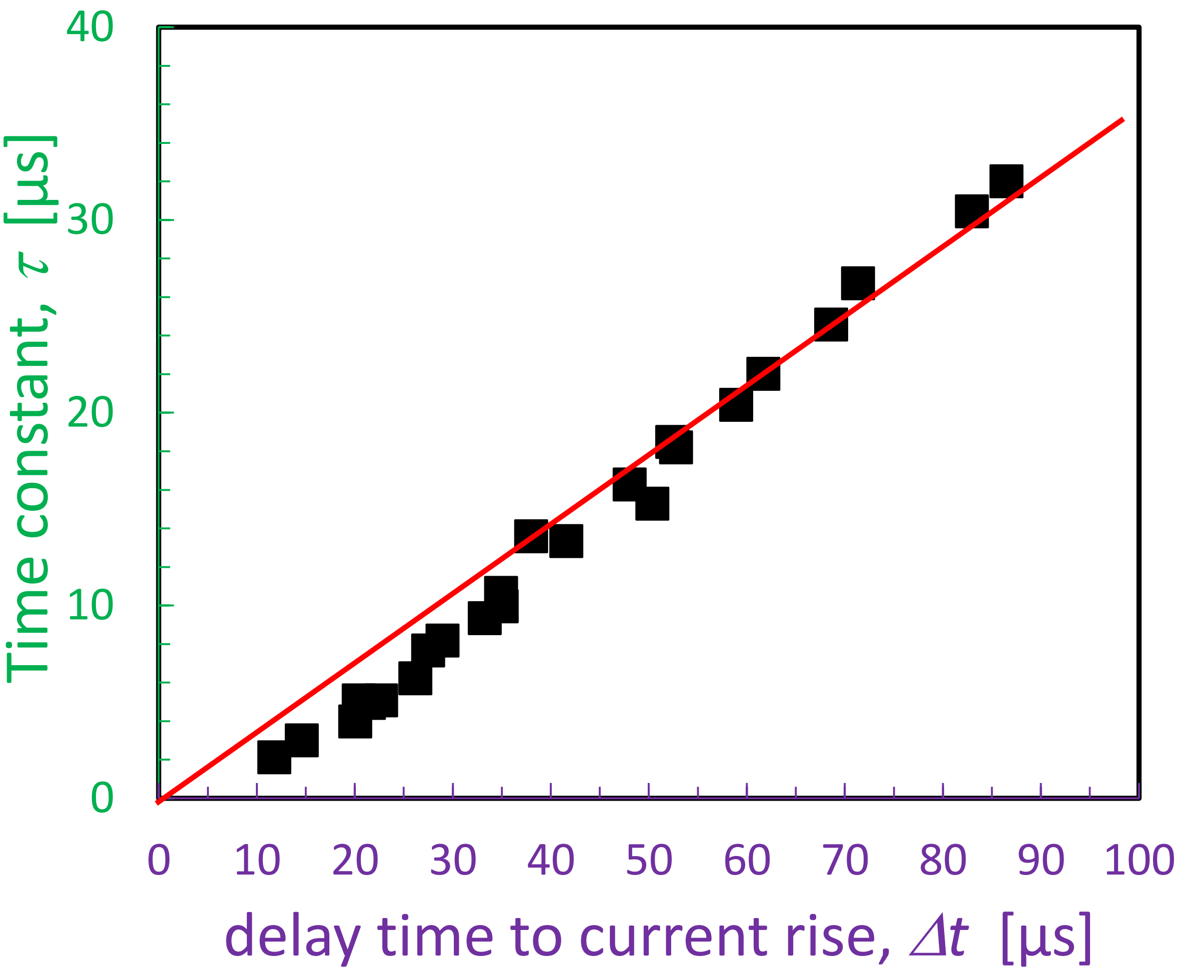
*I used linear fitting to give a slope
*It is a fitting with all the points between two points

Time constant

$$I = e^{\frac{t-t_0}{\tau}}$$

4. Current rise in pulsed-glow-discharge-driven-IEC

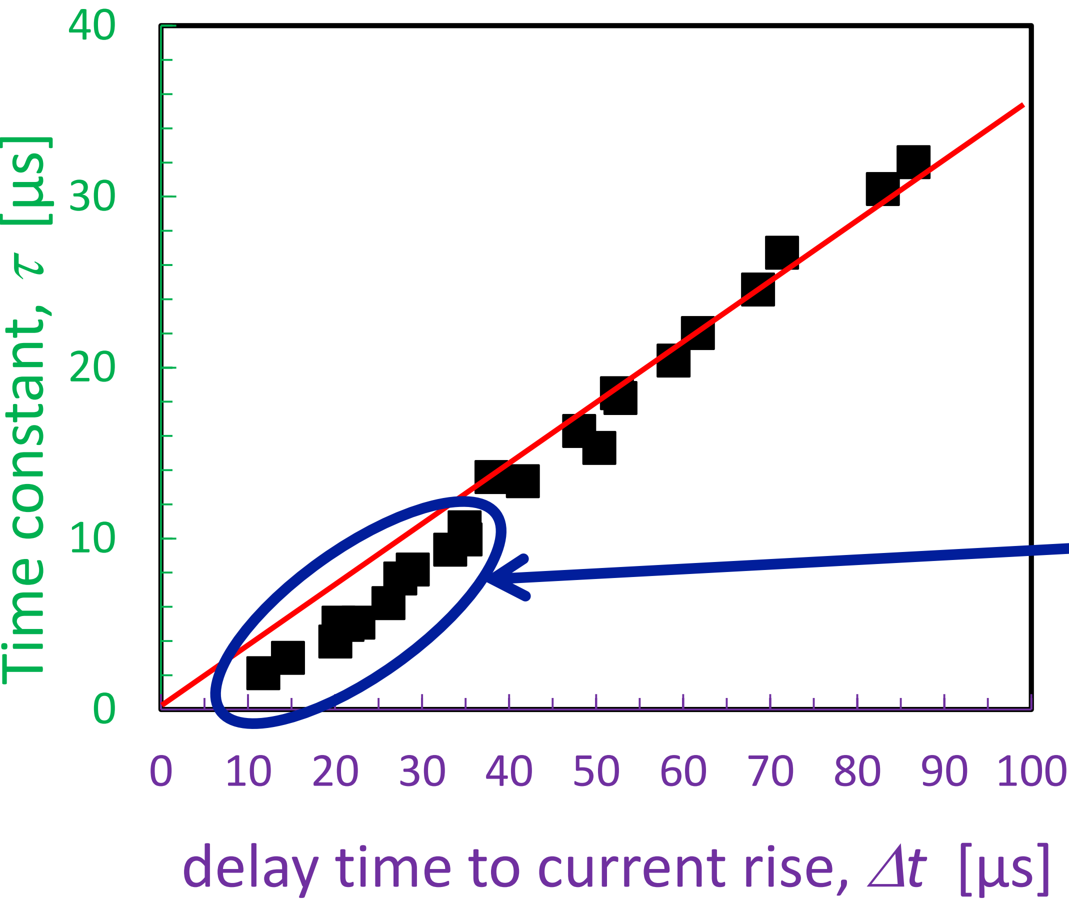
Relationship of Δt and τ



Δt seems linear to τ

4. Current rise in pulsed-glow-discharge-driven-IEC

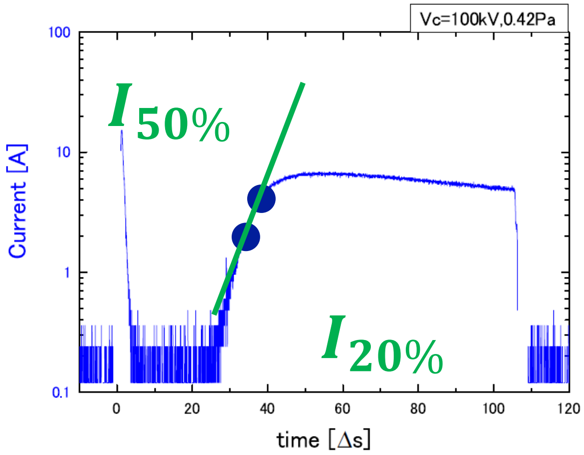
Consideration of the reason that there is not τ and Δt on the linear line



When τ and Δt are short, they are not on the linear line

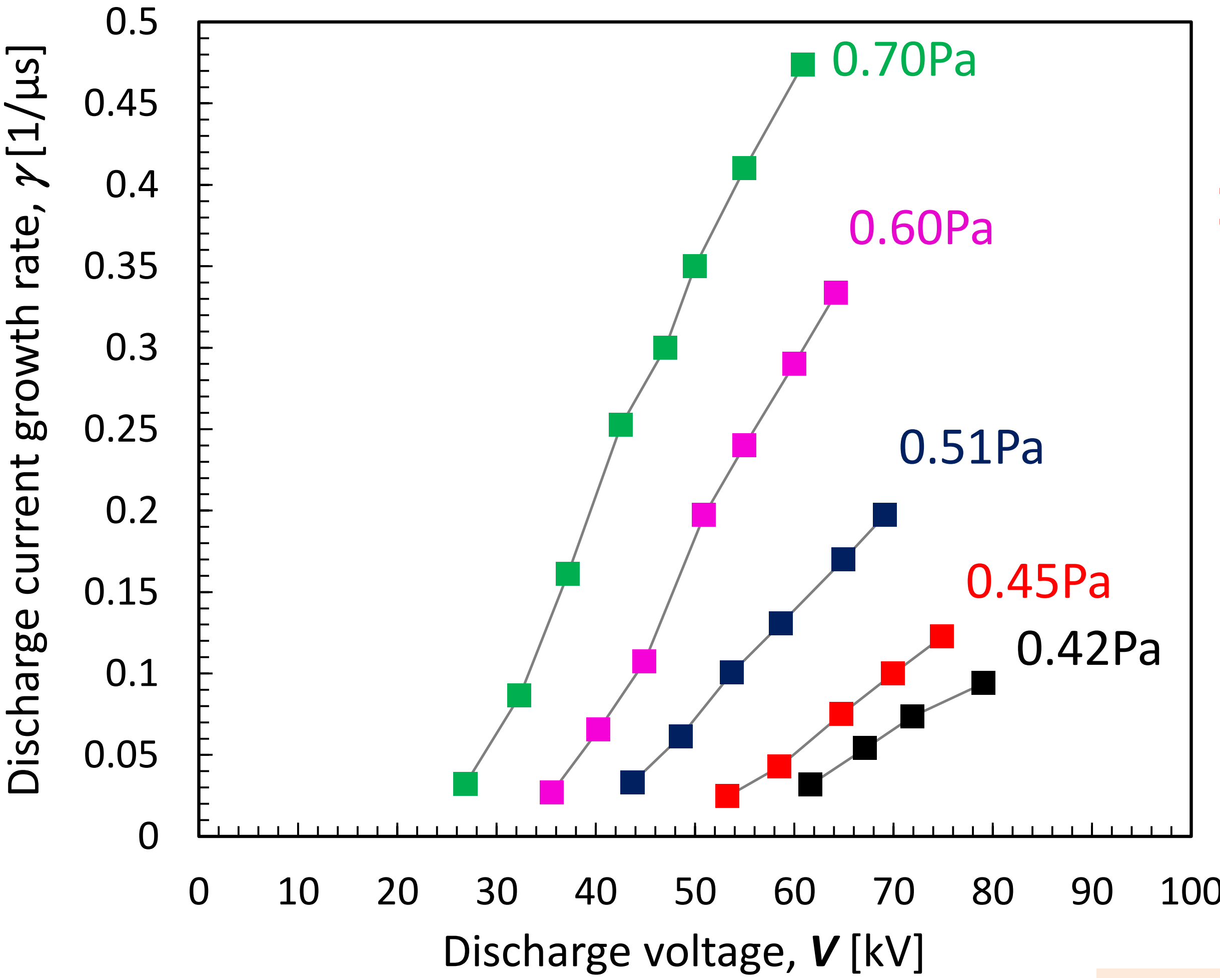
1.The time constant of the external circuit seems to have influence

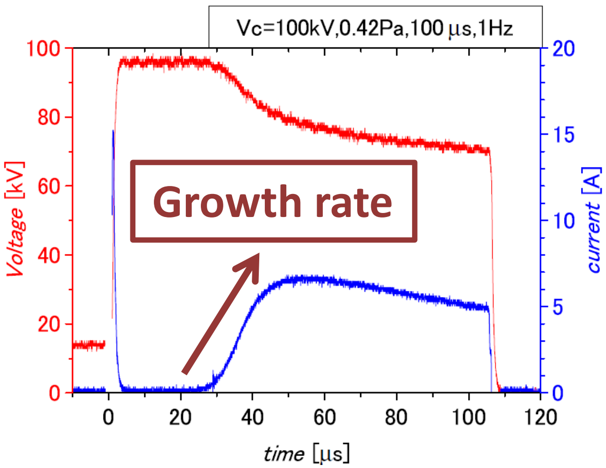
2. $I_{50\%}$ which we choose in the definition of τ might be too large



4. Current rise in pulsed-glow-discharge-driven-IEC

Relationship of γ and V





Growth rate

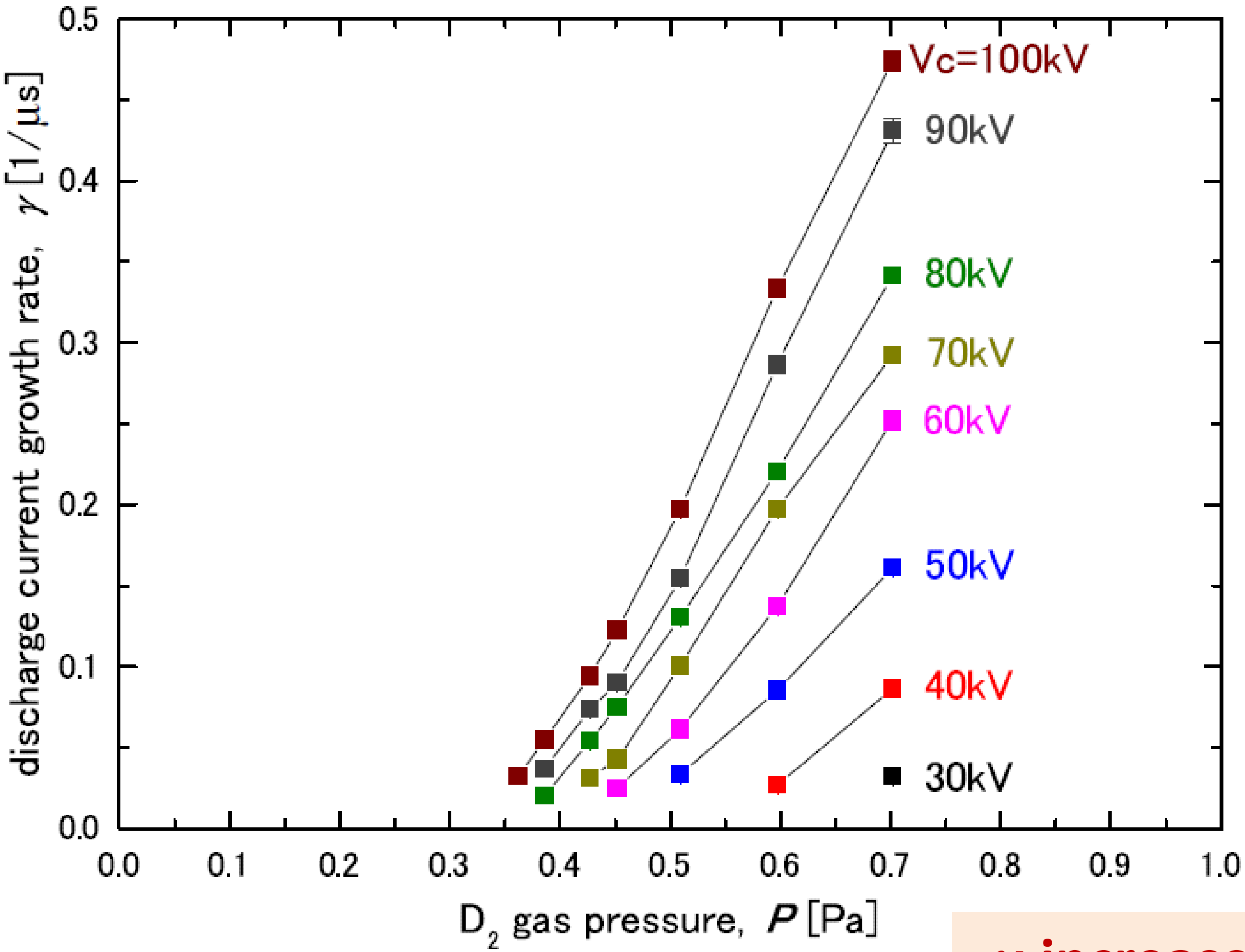
$$\gamma = \frac{1}{\tau}$$

γ increases linearly to *V*.

Offset in *V* depends on *P*.

4. Current rise in pulsed-glow-discharge-driven-IEC

Relationship of γ and P

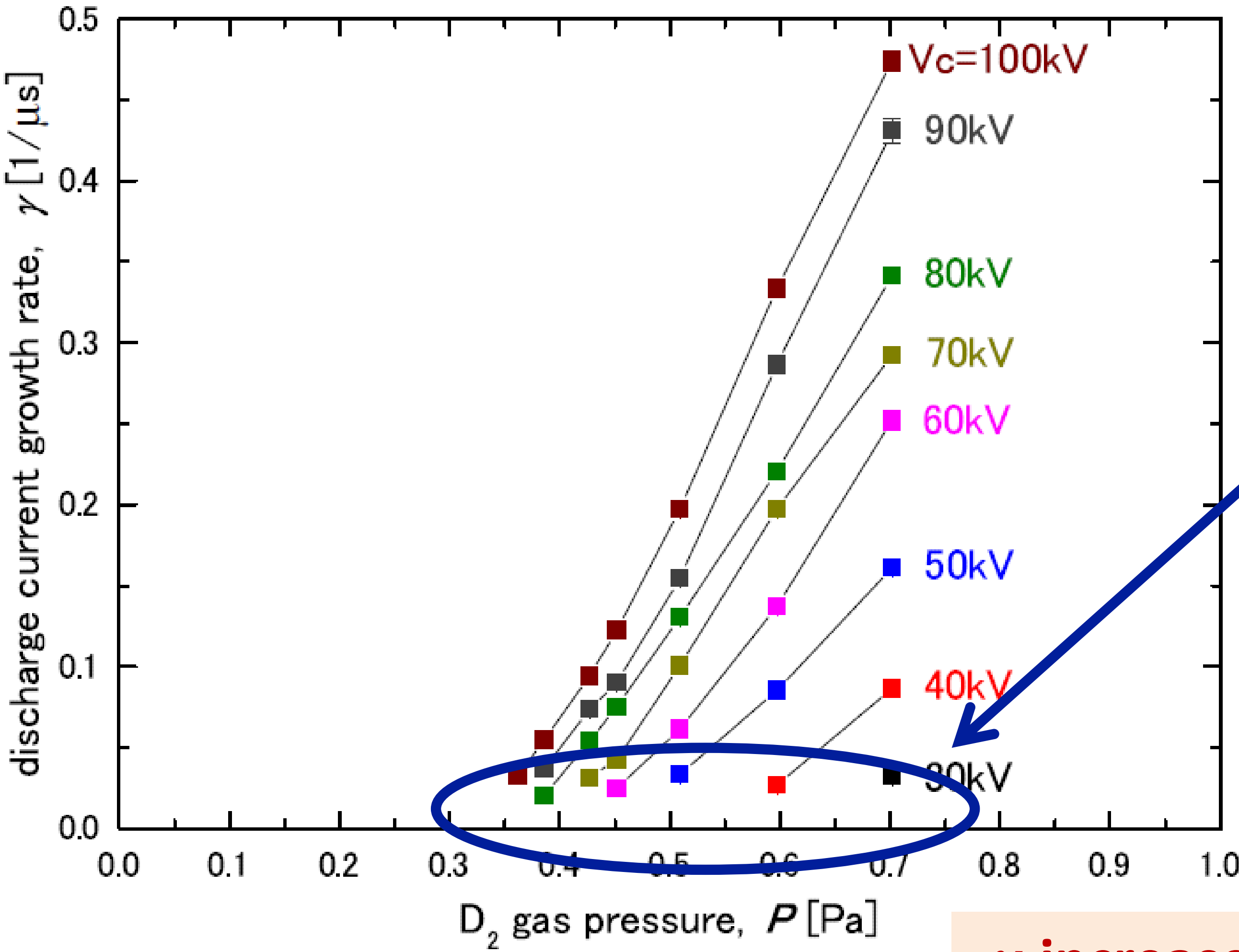


γ increases linearly to *P*.

Offset in *P* depends on *V*.

4. Current rise in pulsed-glow-discharge-driven-IEC

Relationship of γ and P



Next, we look into the offset

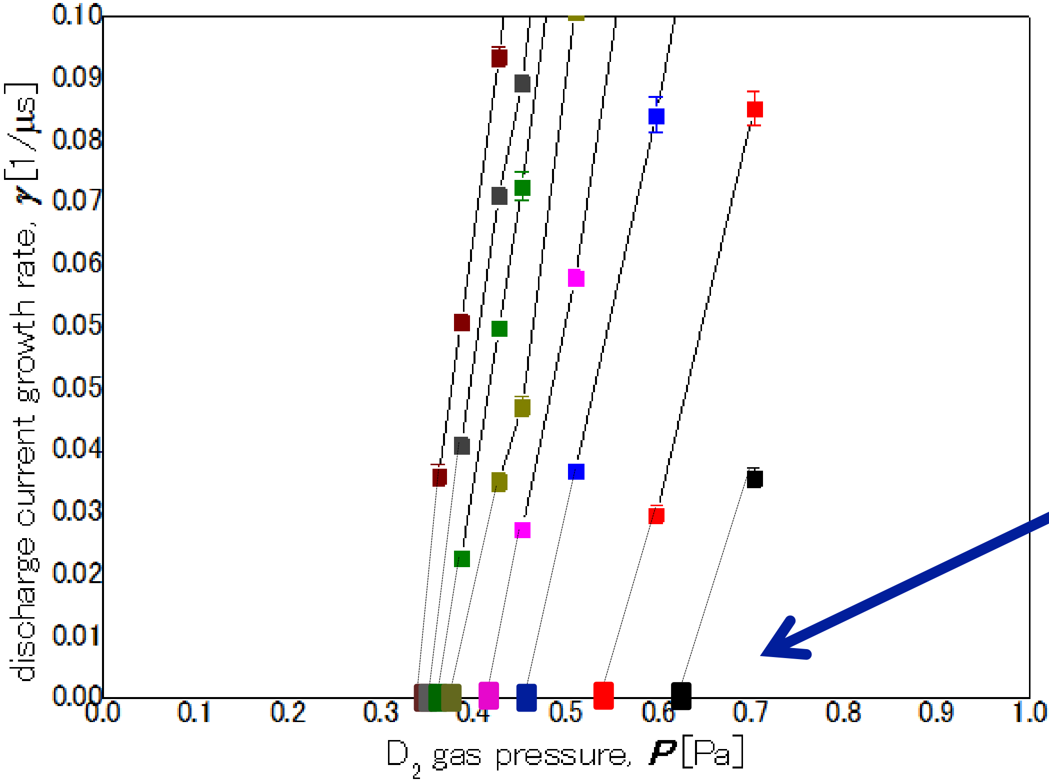
γ increases linearly to *P*.

Offset in *P* depends on *V*.

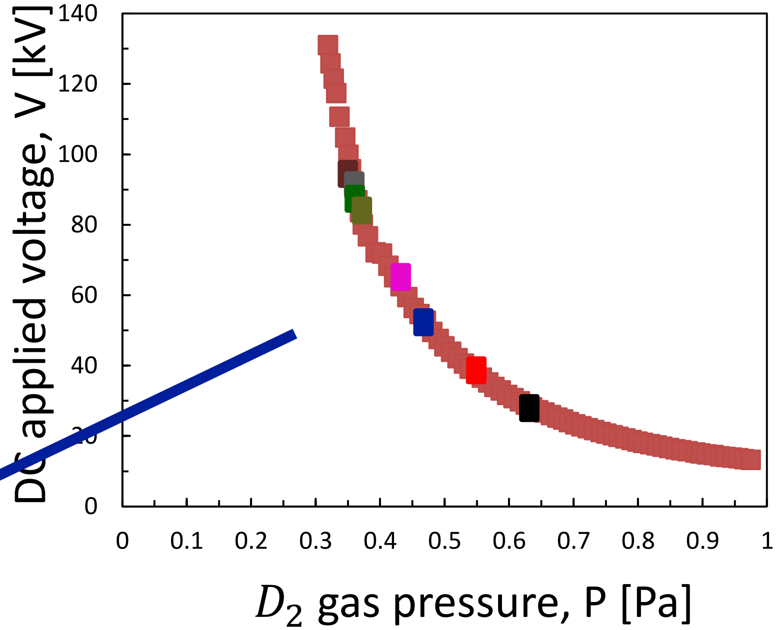
4. Current rise in pulsed-glow-discharge-driven-IEC

Relationship of ***P*** offset and paschen's curve of DC IEC

Enlarged picture of γ - ***P***



Paschen's curve of DC IEC

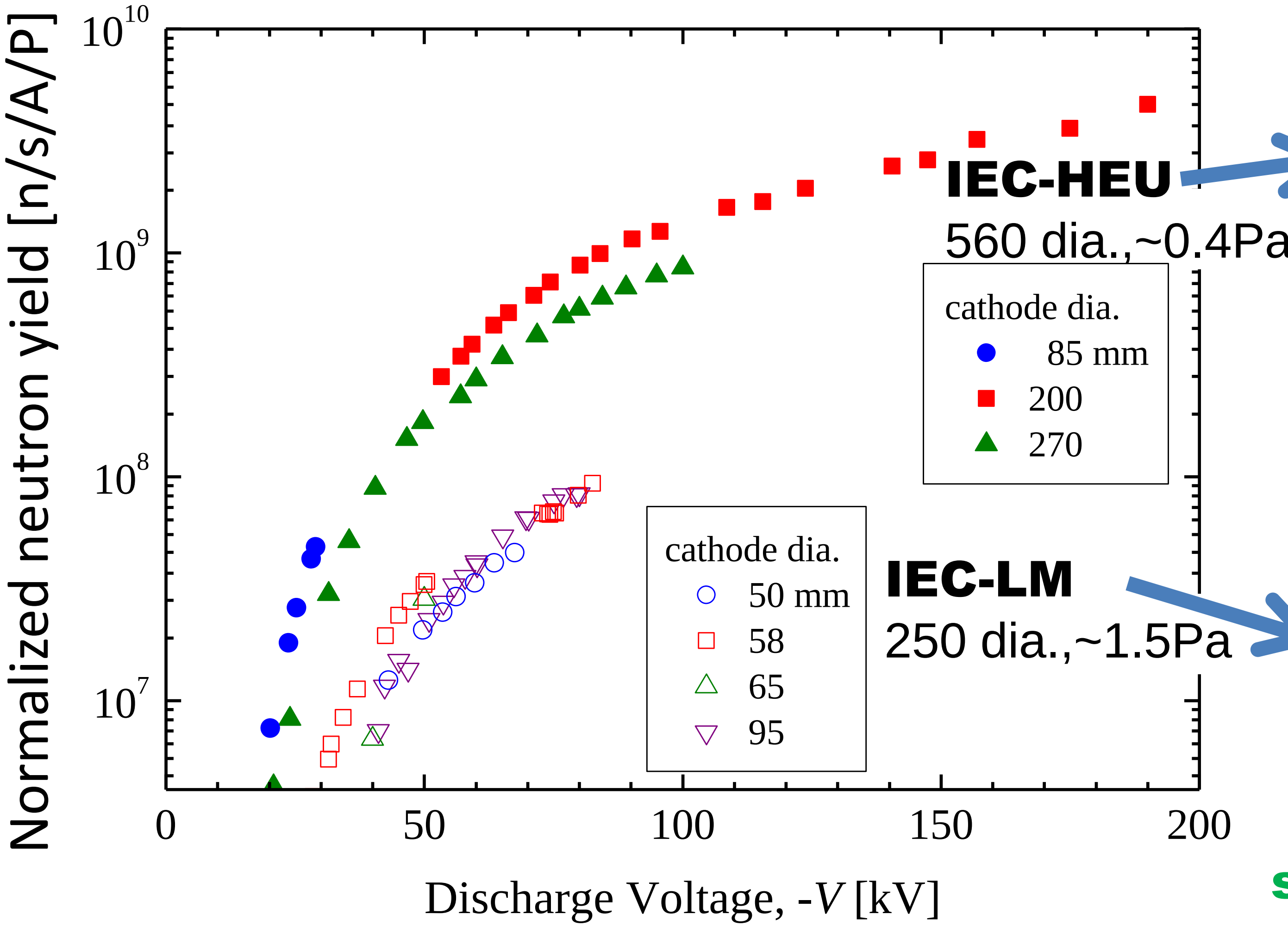


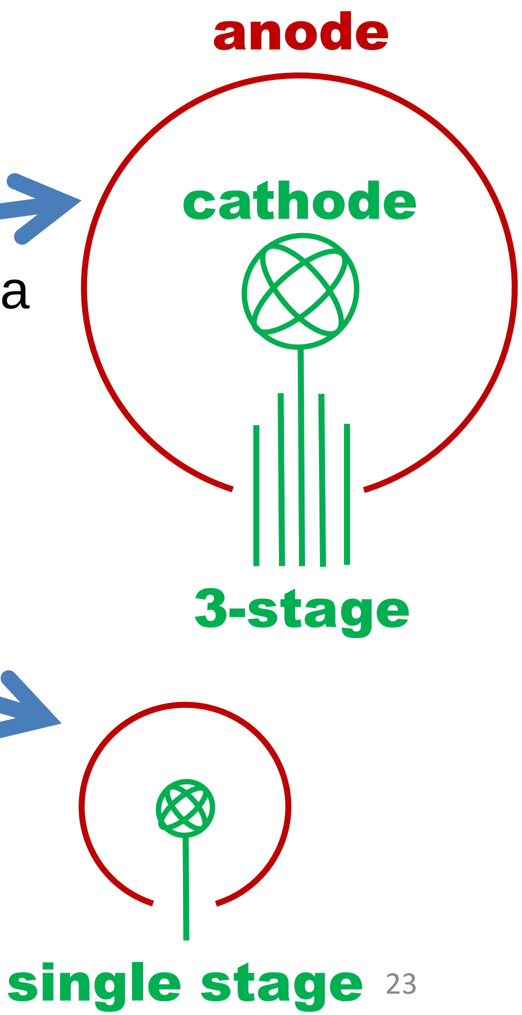
Relationship of gas pressure and discharge voltage where γ=0 agrees with the paschen's curve of DC IEC

5. Neutron production rate

Comparison between IEC-HEU and IEC-LM

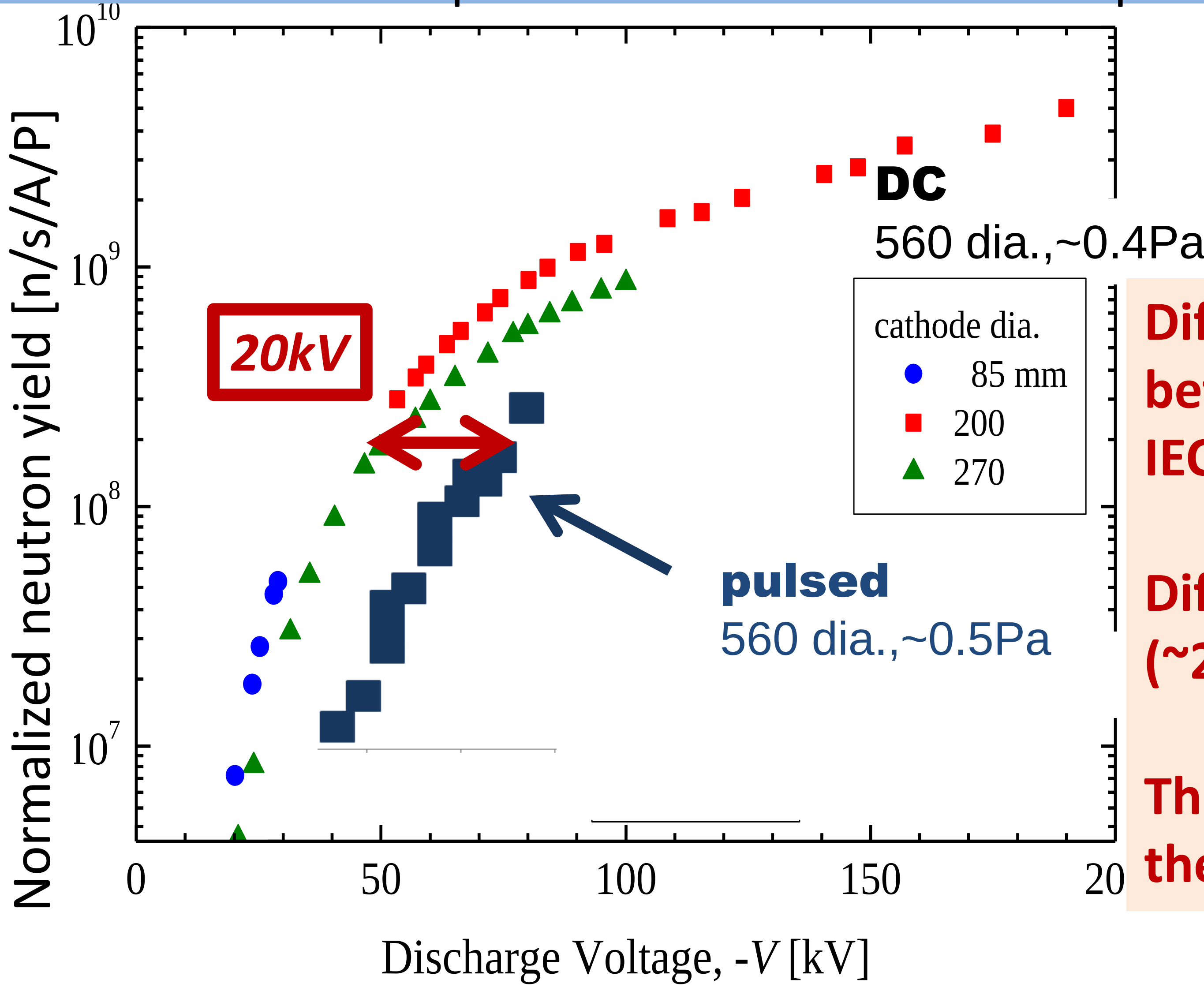
- **x5 improvement by voltage increase from 80 to 190 kV**
- **x3 improvement for the same voltage**
  (x10 improvement in NPR / P)





5. Neutron production rate

Comparison between DC-IEC and pulse-IEC



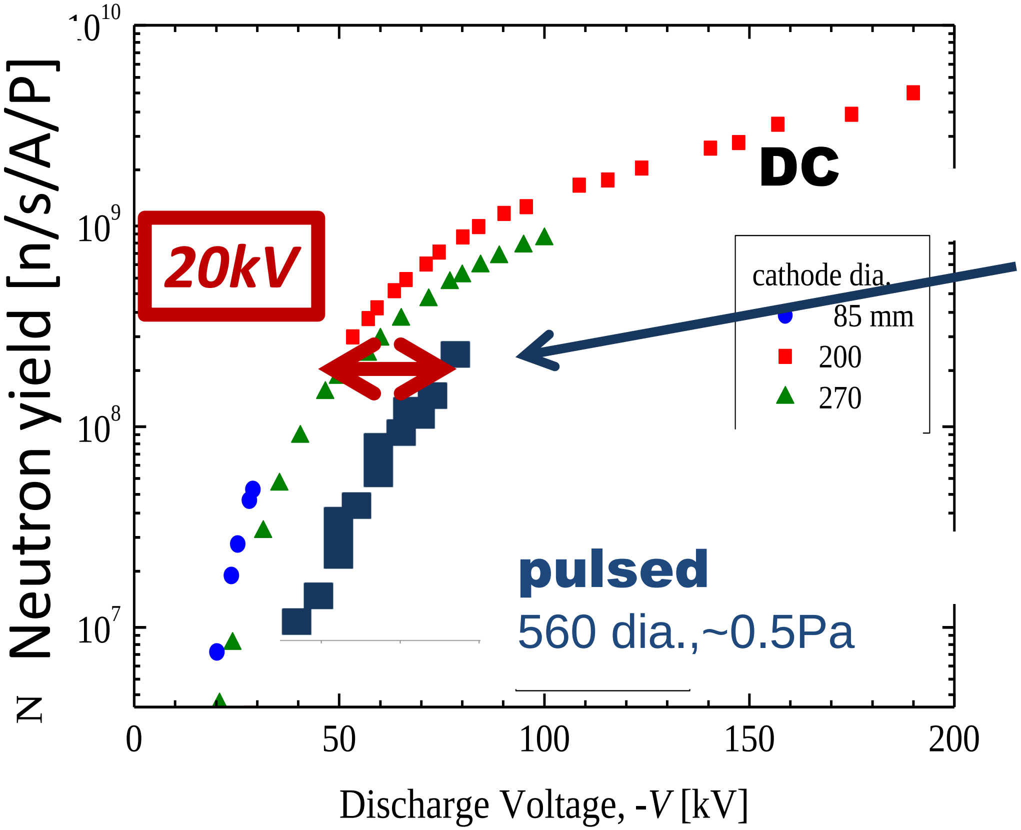
Difference in P between IEC-HEU and IEC-PS,

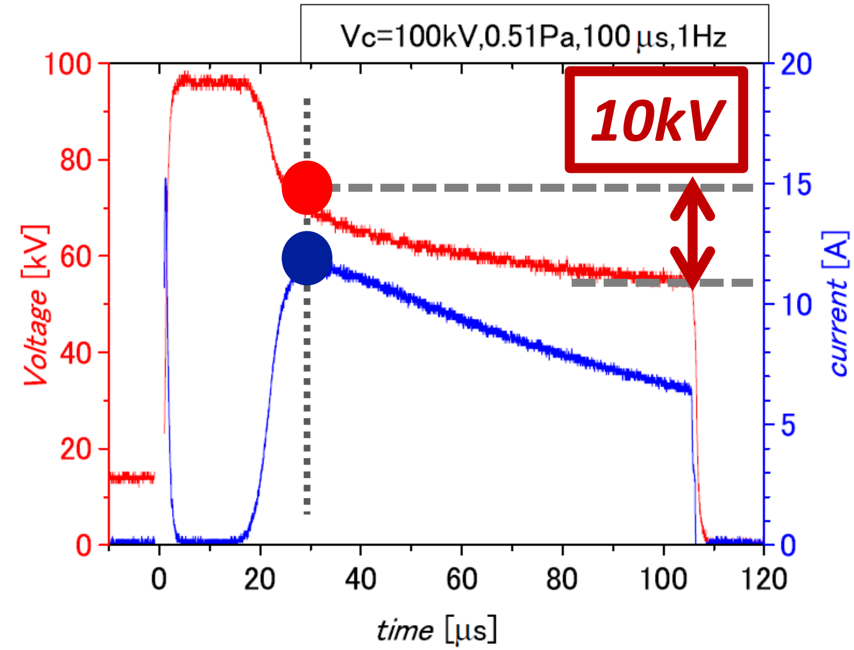
Difference in NPR/P (~20%)

This dose not explain the result

5. Neutron production rate

Consideration of the reason that the neutron yield shift





The discharge voltage drops 10kV

Difference between DC and pulsed neutron yield in IEC-HEU cannot be explained by the difference in P and drop of V

There are other factors why the neutron yield does not agree with

6. Conclusion

1.

Discharge current rises exponentially

2.

Dependence of growth rate (γ) on gas pressure and discharge voltage is made clear

- **γ increases linearly to *V and* offset in *V* depends on *P.***
- **γ increases linearly to *P and* offset in *P* depends on *V.***
- **Relationship of *P* and *V* where γ*=0* agree with the paschen's carve of DC IEC**

3.

The neutron yield of IEC-HEU and IEC-PS does not agree with the difference in consideration of gas pressure and drop of the discharge voltage. This is because there are other factors why the neutron yield does not agree with.