

論文 / 著書情報
Article / Book Information

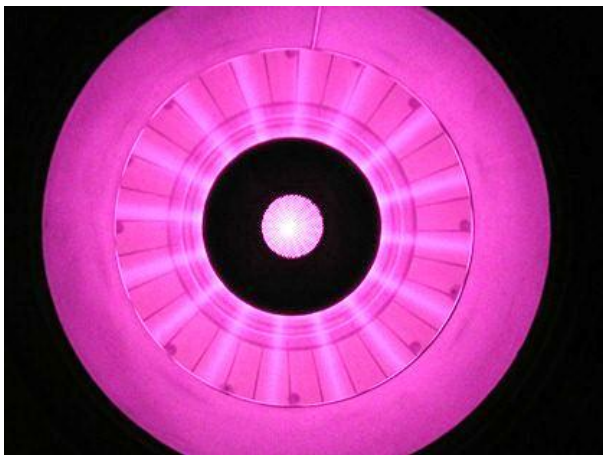
Title(English)	Effects of axial magnetic field on neutron production rate in a cylindrical IECF device
Authors(English)	Hiroki Imaji, Keita Nobe, Nanjou Kazuki, Wantapon Ngamdee, Masato Watanabe, Eiki Hotta
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Effects of axial magnetic field on neutron production rate in a cylindrical inertial electrostatic confinement fusion device

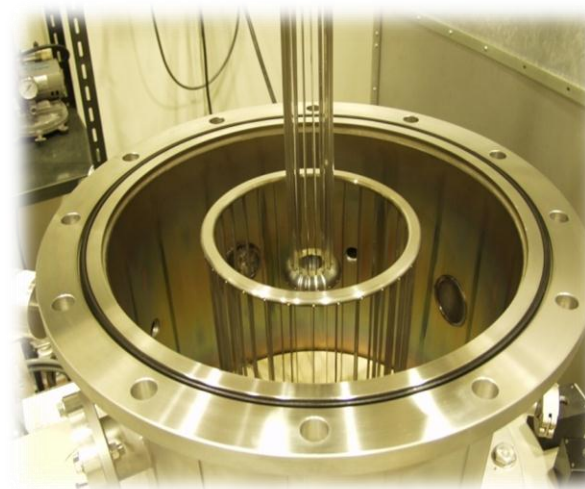
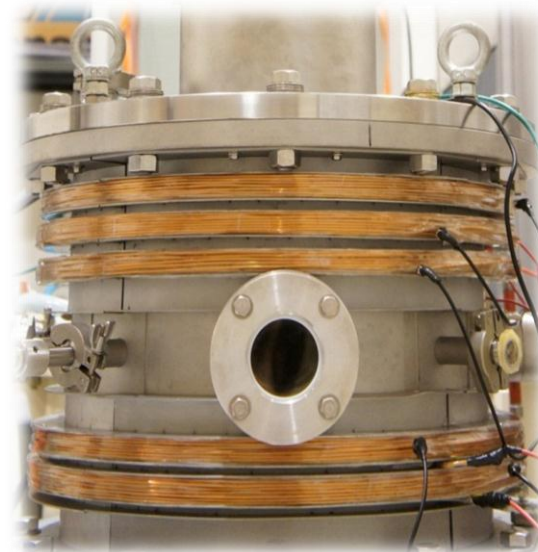
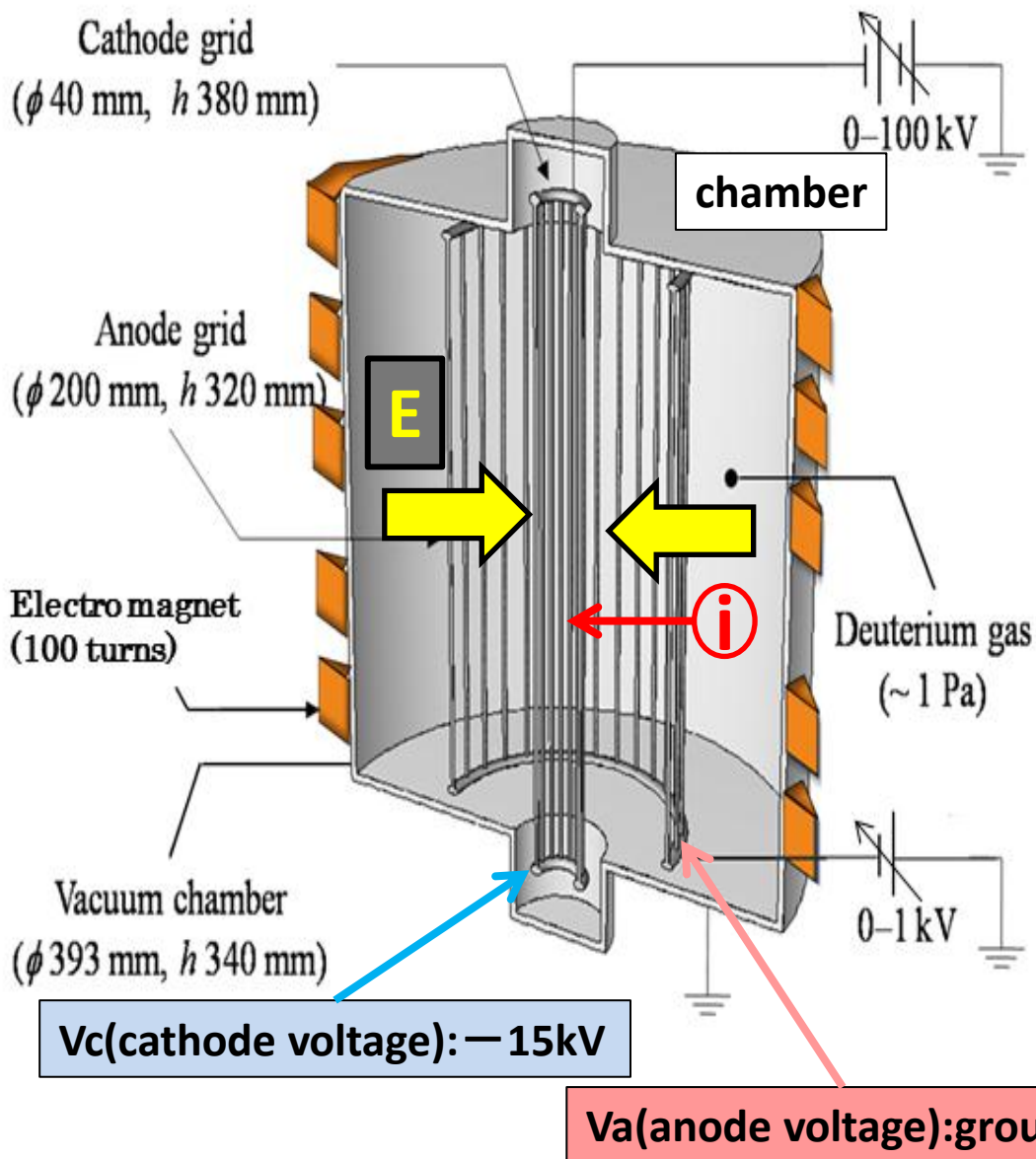
Hiroki Imaji*, Keita Nobe, nanjou kazuki
Wantapon Ngamdee, Masato Watanabe,
and Eiki Hotta

*Department of Energy Sciences,
Tokyo Institute of Technology*

14th US-Japan IEC Workshop
Maryland, USA, Oct. 14-16, 2011



Experimental setup



Motivation

NPR of IEC
 $\sim 10^9$ [1/s]

Need to increase NPR



Cancer therapy (BNCT)
 $> 10^{12}$ [1/s]

(NPR: Neutron Production Rate)

The ways to enhance NPR

◆ To increase ion density

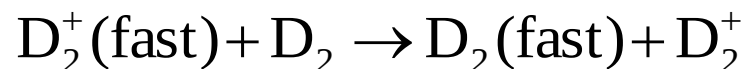
◆ To increase ion energy

✓ Low pressure operation

⇒ To reduce ion energy loss by **charge exchange** reaction

Charge exchange reaction

Charge exchange reaction is dominant atomic process.



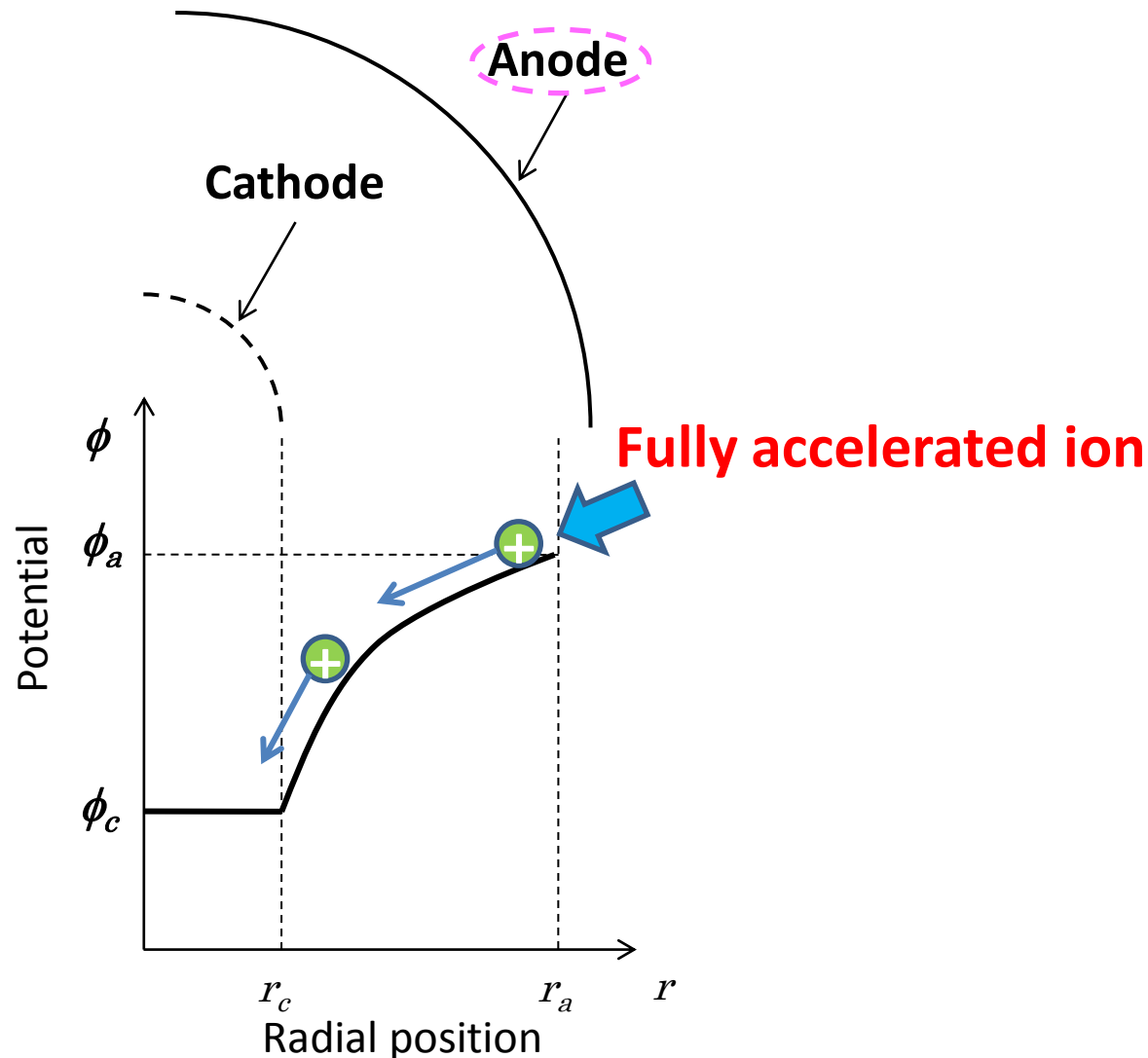
Mean free path of charge exchange $\lambda_{cx} = \frac{1}{n\sigma_{cx}(E)} = \frac{k_B T}{p} \frac{1}{\sigma_{cx}(E)}$

→ Low pressure operation reduces charge exchange reaction.



Increment of Ion production near the anode

In order to accelerate ions fully by electric field





Motivation

The ways to enhance NPR

◆ To increase ion energy

✓ Low pressure operation

⇒ To reduce ion energy loss by **charge exchange** reaction

✓ Increment of Ion production more outside

⇒ To fully accelerate ion by electric field



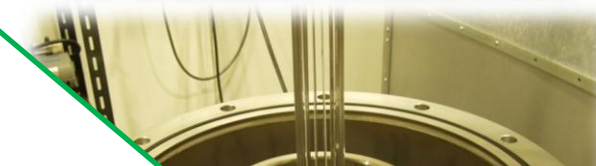
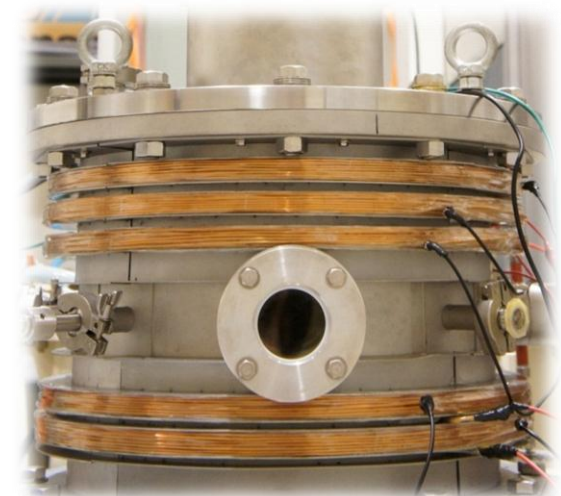
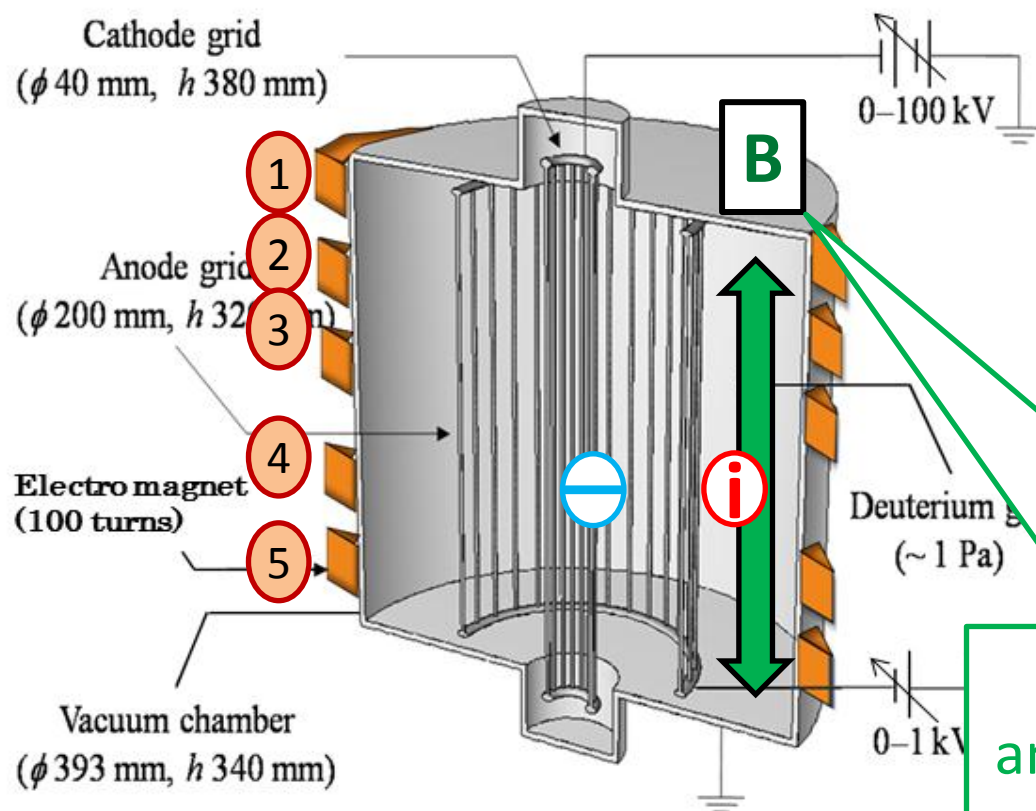
Applying **axial magnetic field**

to a cylindrical IEC device

Axial magnetic field

Cylindrical IEC device with **Axial magnetic field**

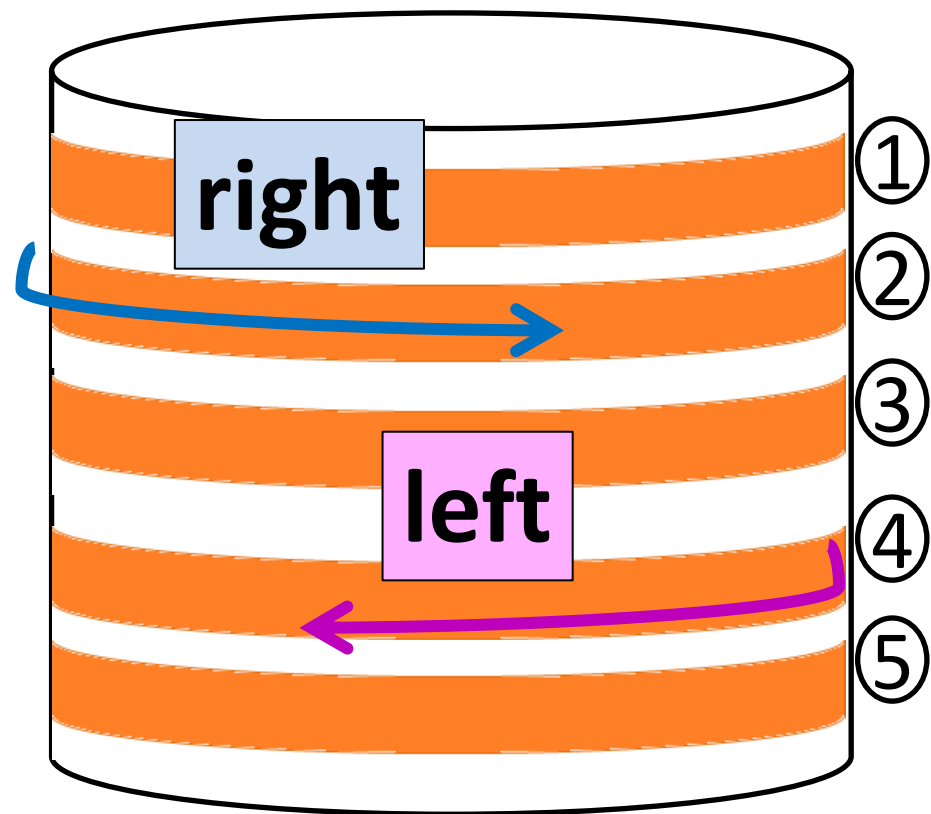
.....confines electrons and produce ions
more effectively at low pressure



to trap electrons
and enhance ion generation
near the wall

The way to use electromagnets

~ coil current direction pattern ~



⊗: right hand direction

⊙: left hand direction

· : no current

(max current : 13.5 A)

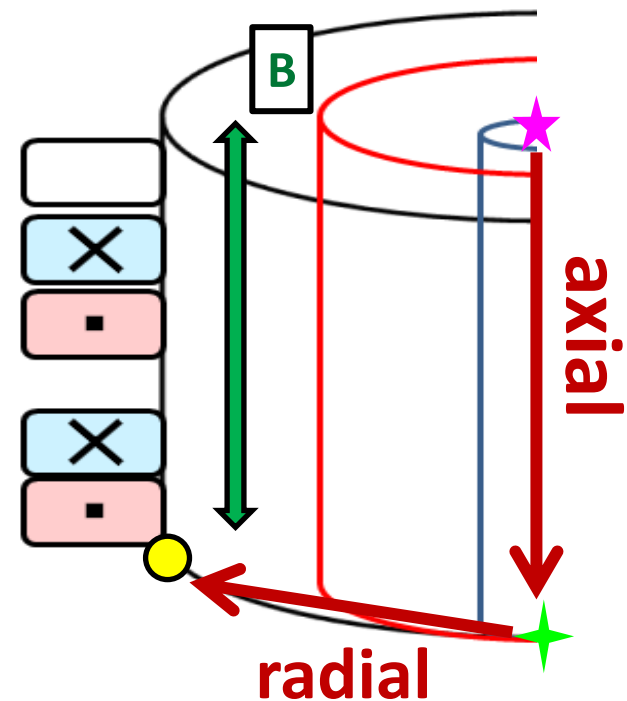
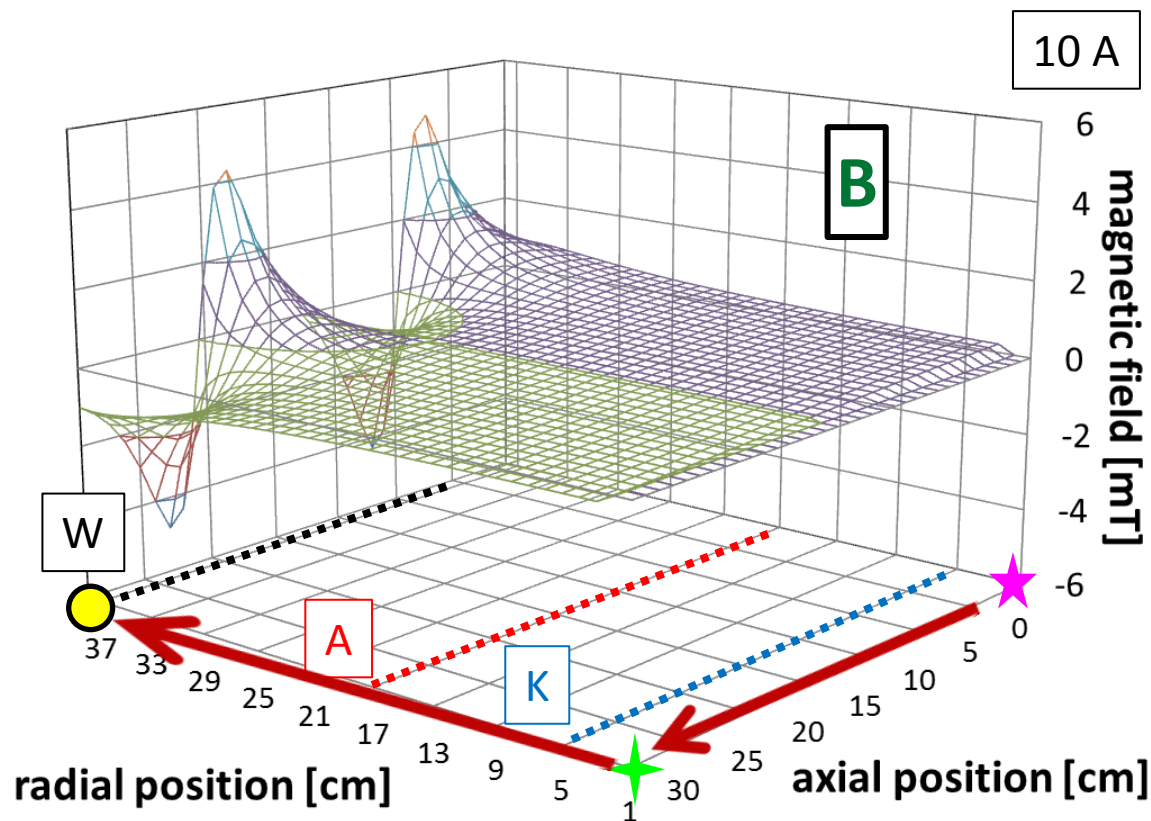
	①	②	③	④	⑤
A =	·	⊗	⊙	⊗	⊙
B =	⊗	·	⊗	⊙	⊗
C =	⊗	·	⊙	⊗	⊙
D =	⊗	·	⊗	⊗	⊗
E =	⊗	⊗	⊗	⊗	⊗
F =	⊗	⊙	⊗	⊙	⊗
G =	⊗	·	⊗	·	⊗
H =	⊗	⊙	⊗	·	⊗
I =	⊙	⊙	⊗	⊙	⊙
J =	⊙	⊗	⊗	⊗	⊙

Outline

- principle
- **experimental results**
- discussion
 - ion generation range
- pulse operation
- conclusion



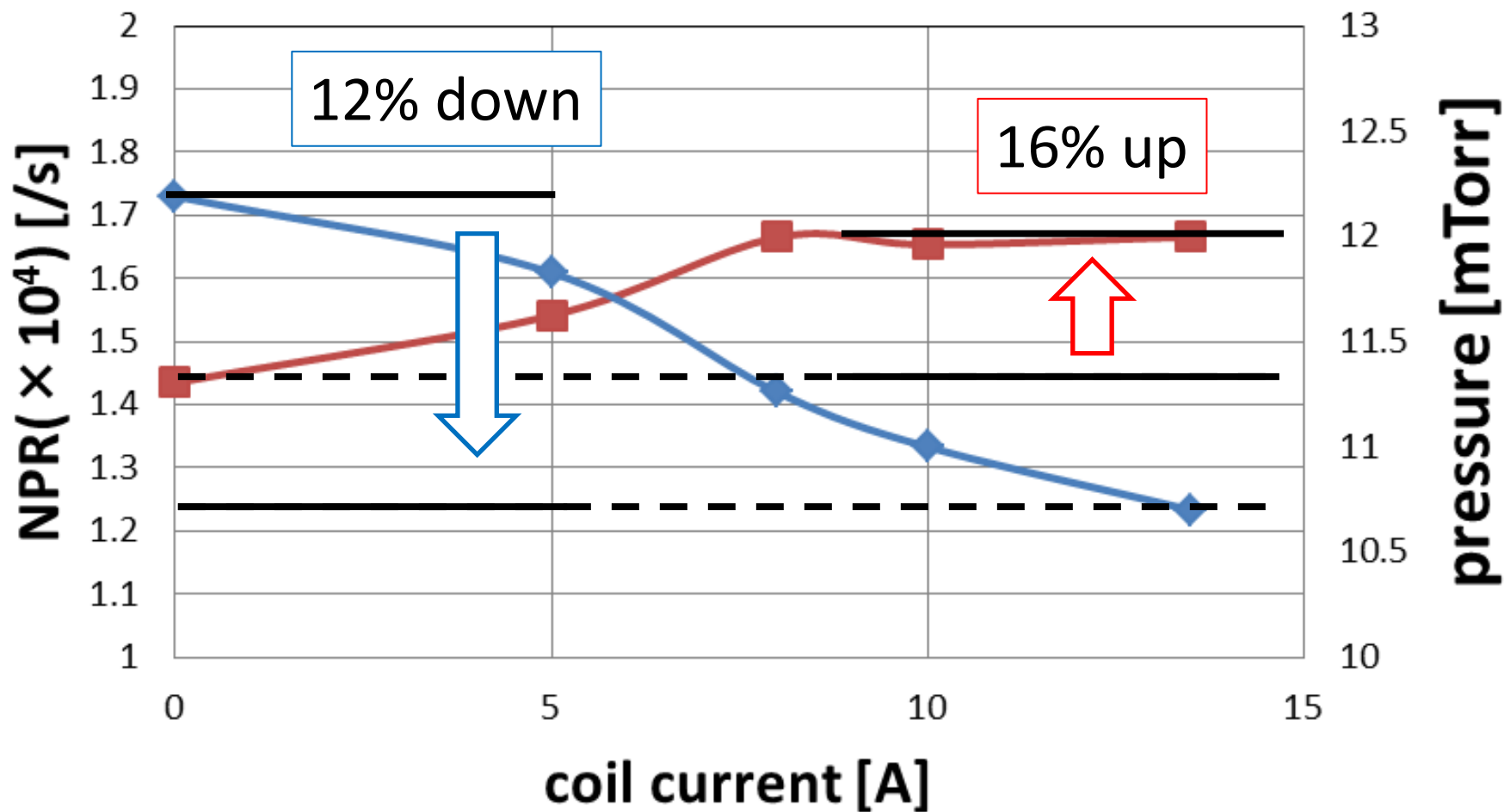
Coil pattern A



cusped magnetic field

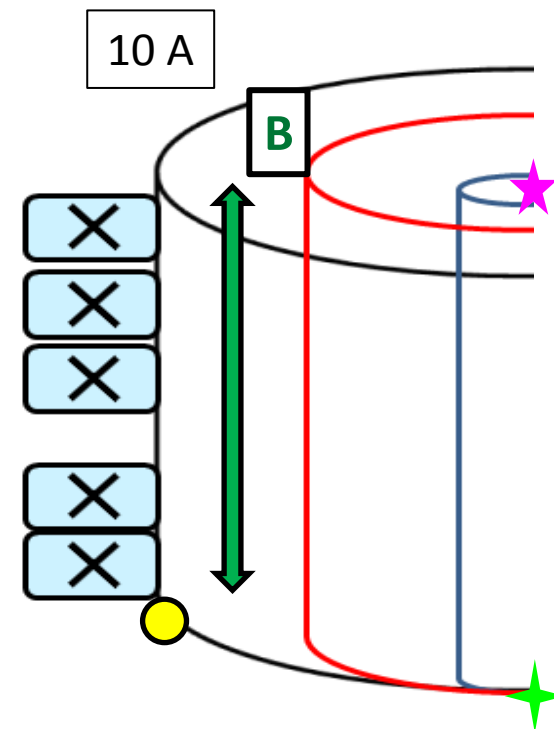
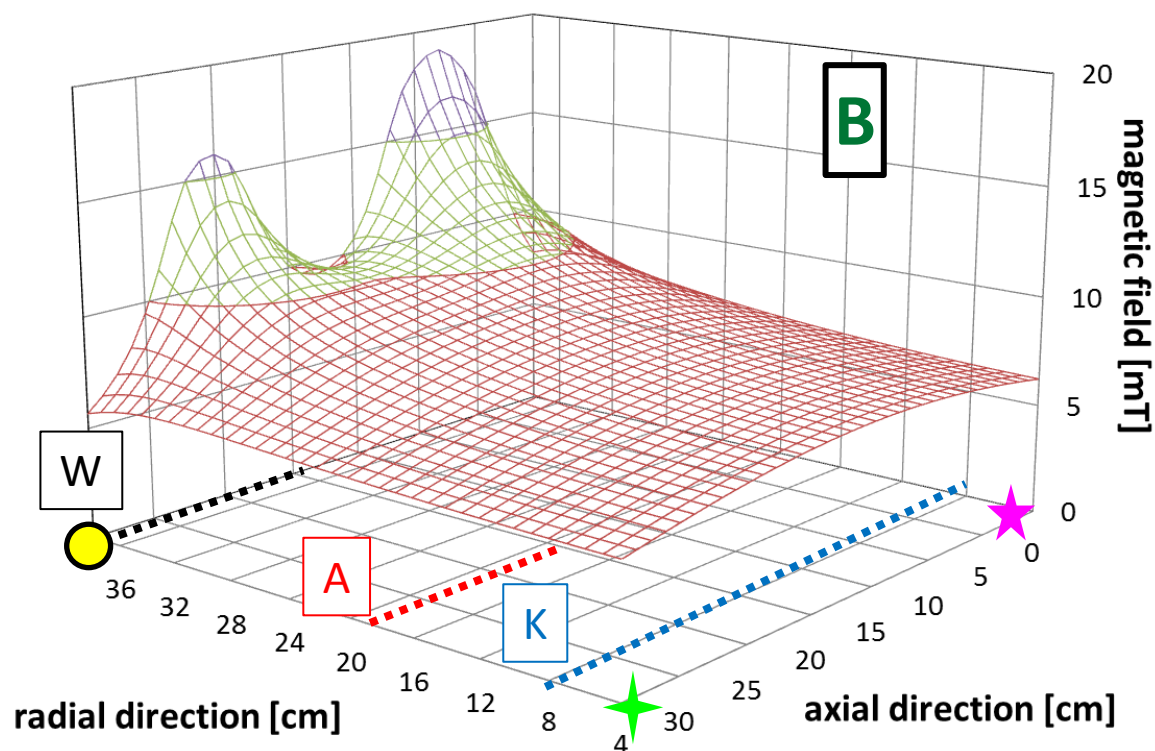
:magnetic field exists only near the wall

Coil pattern A



NPR 16 % up, P 12 % down @13.5 A

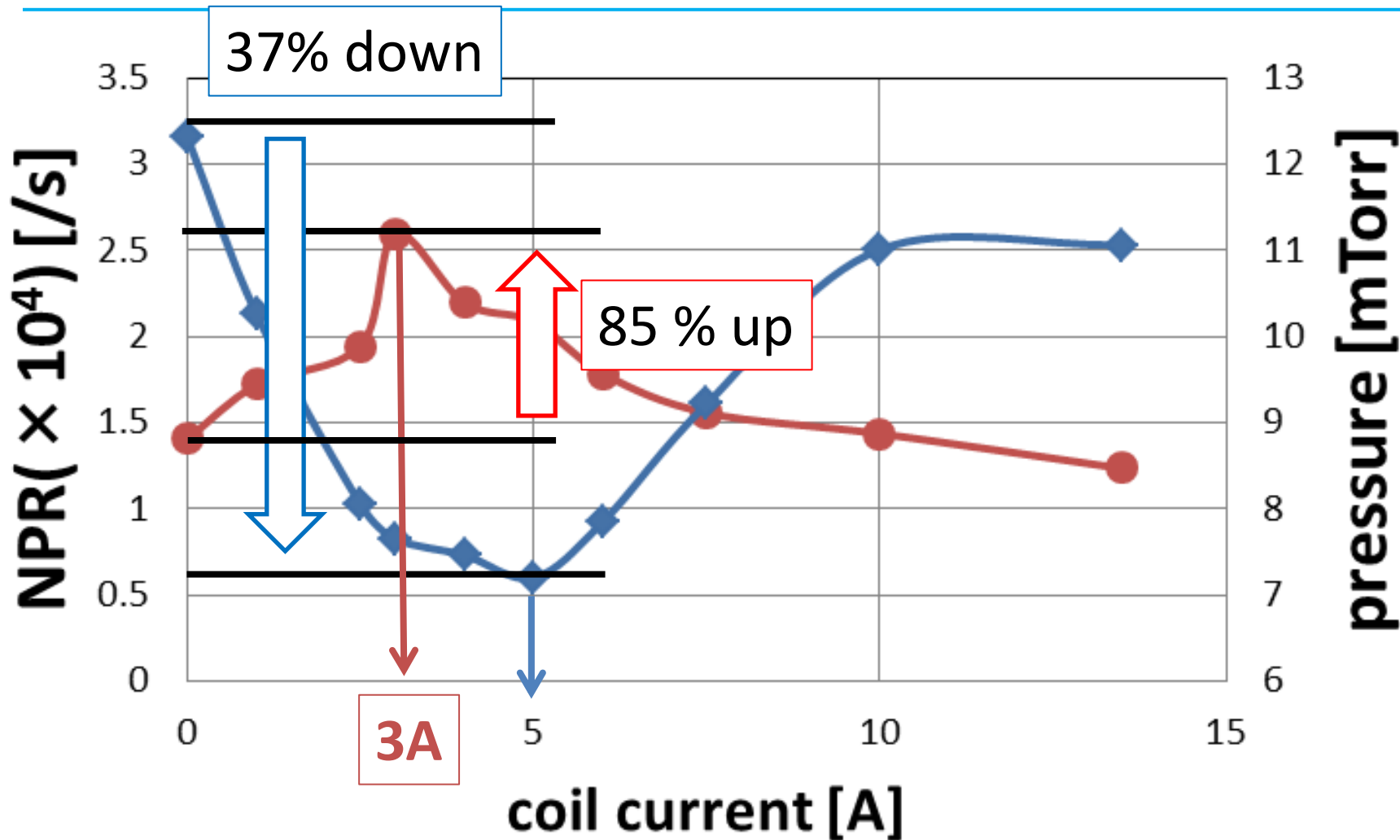
Coil pattern E



5 coils make same direction magnetic field

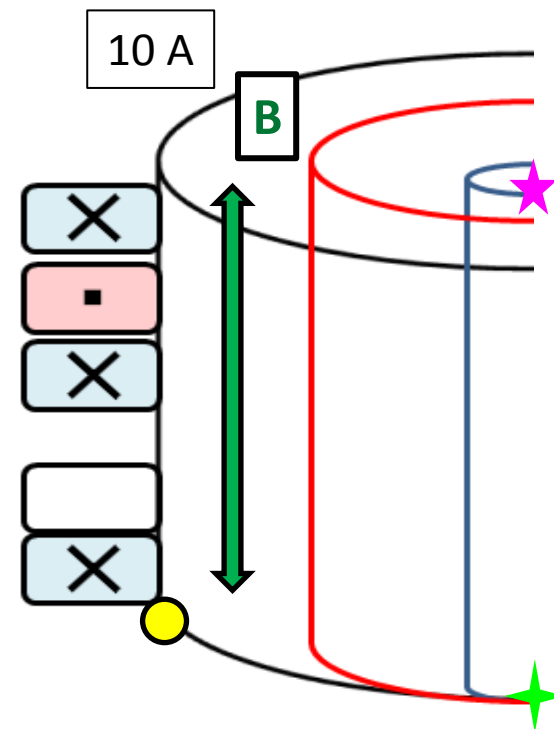
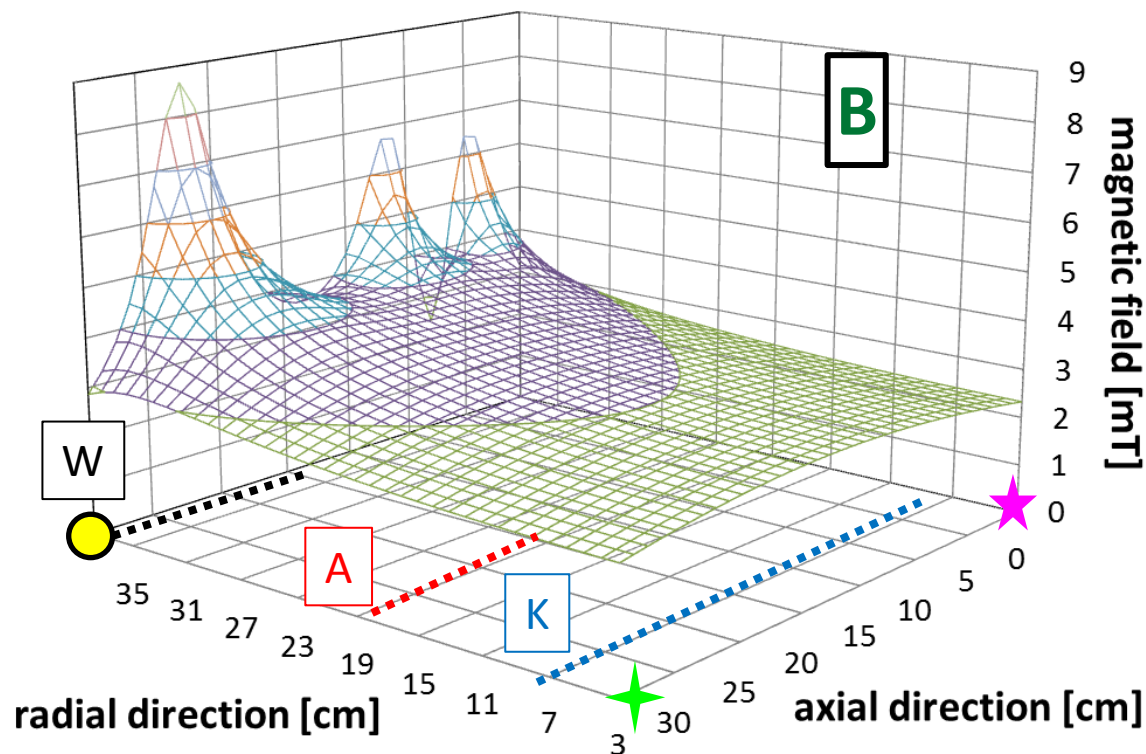
➡ most strong magnetic field from cathode to wall

Coil pattern E



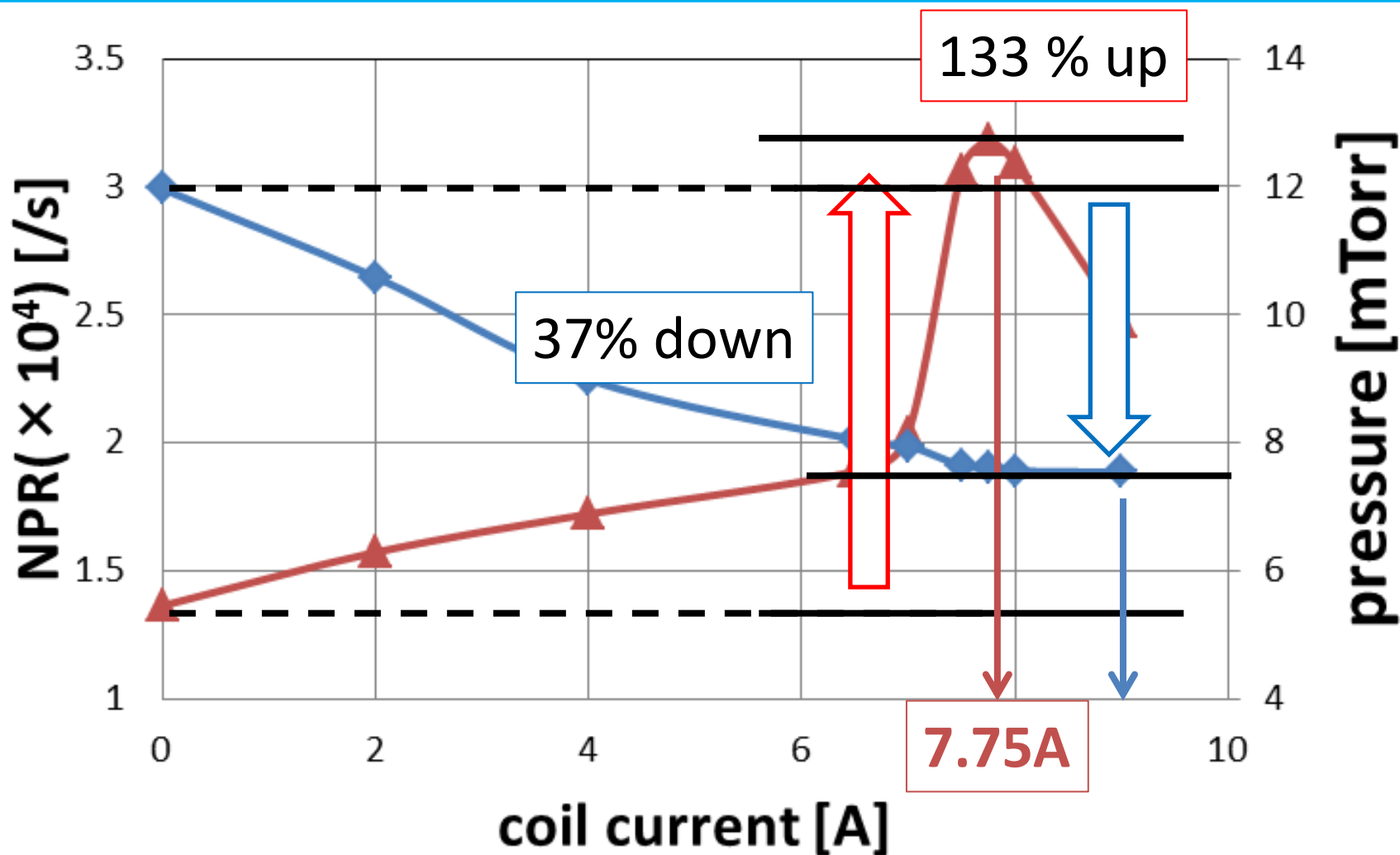
NPR 85 % up @3 A, P 37 % down @5 A

Coil pattern H



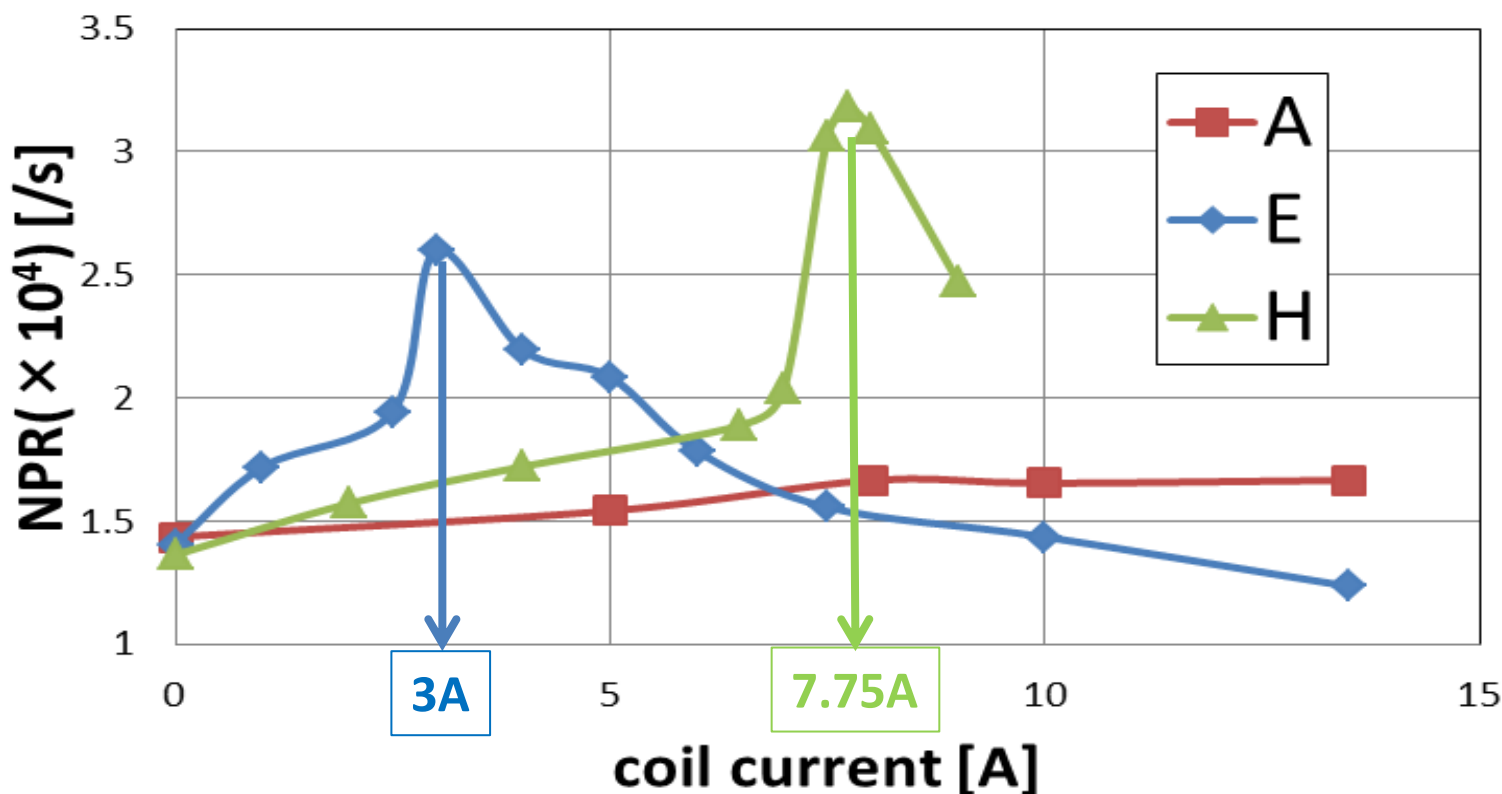
anomalous magnetic field
: more magnetic field exists near the cathode ($r=4$ cm) than pattern A

Coil pattern H



NPR 233 % up, P 36 % down @7.75 A

Experimental results



NPR has peak point in pattern E, H

Why NPR has peak point or not ?



discussion

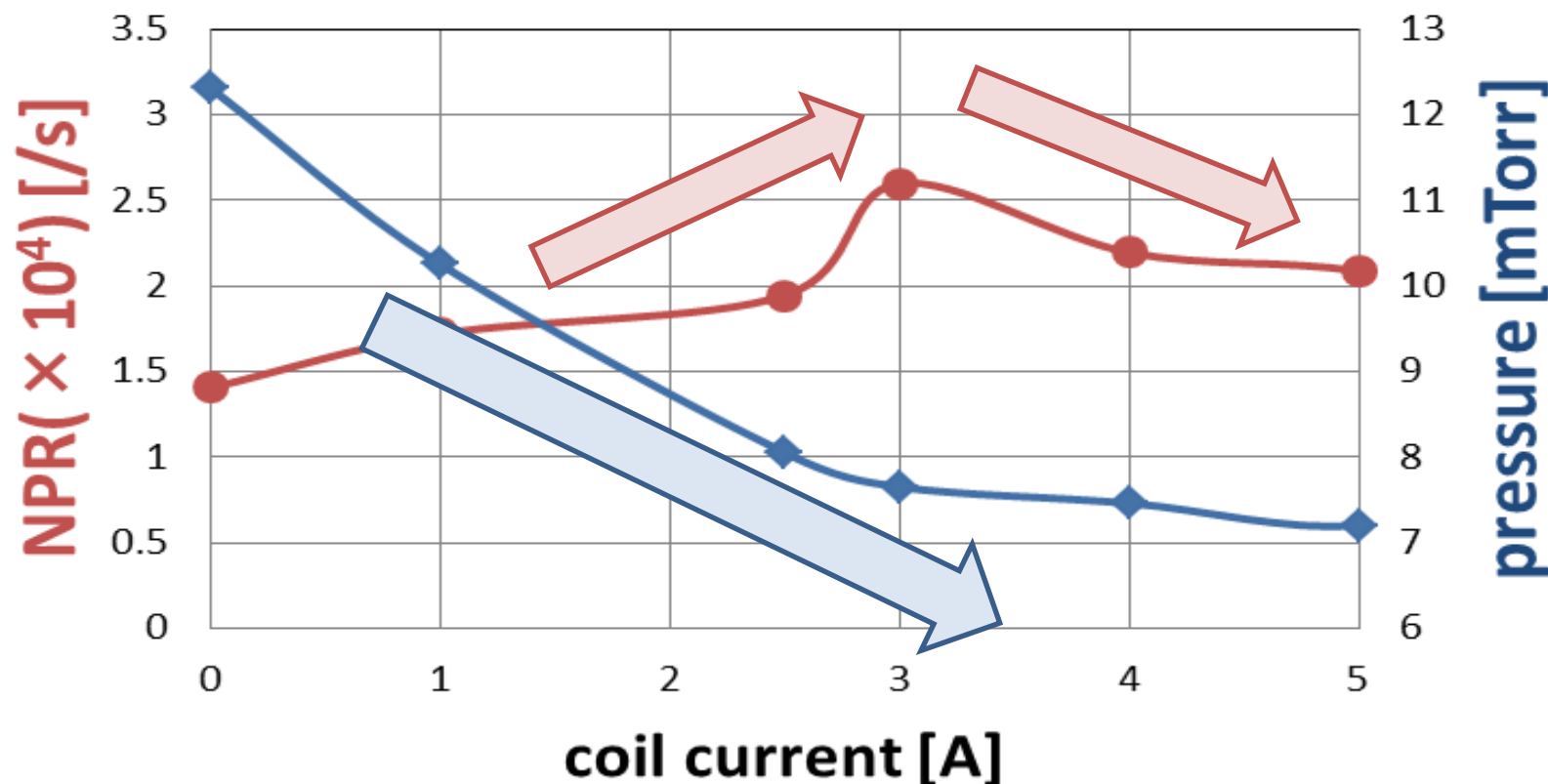


Outline

- principle
- experimental results
- **discussion**
 - pressure
- pulse operation
- conclusion

effect of pressure on NPR

coil pattern E (0 ~ 5 A)



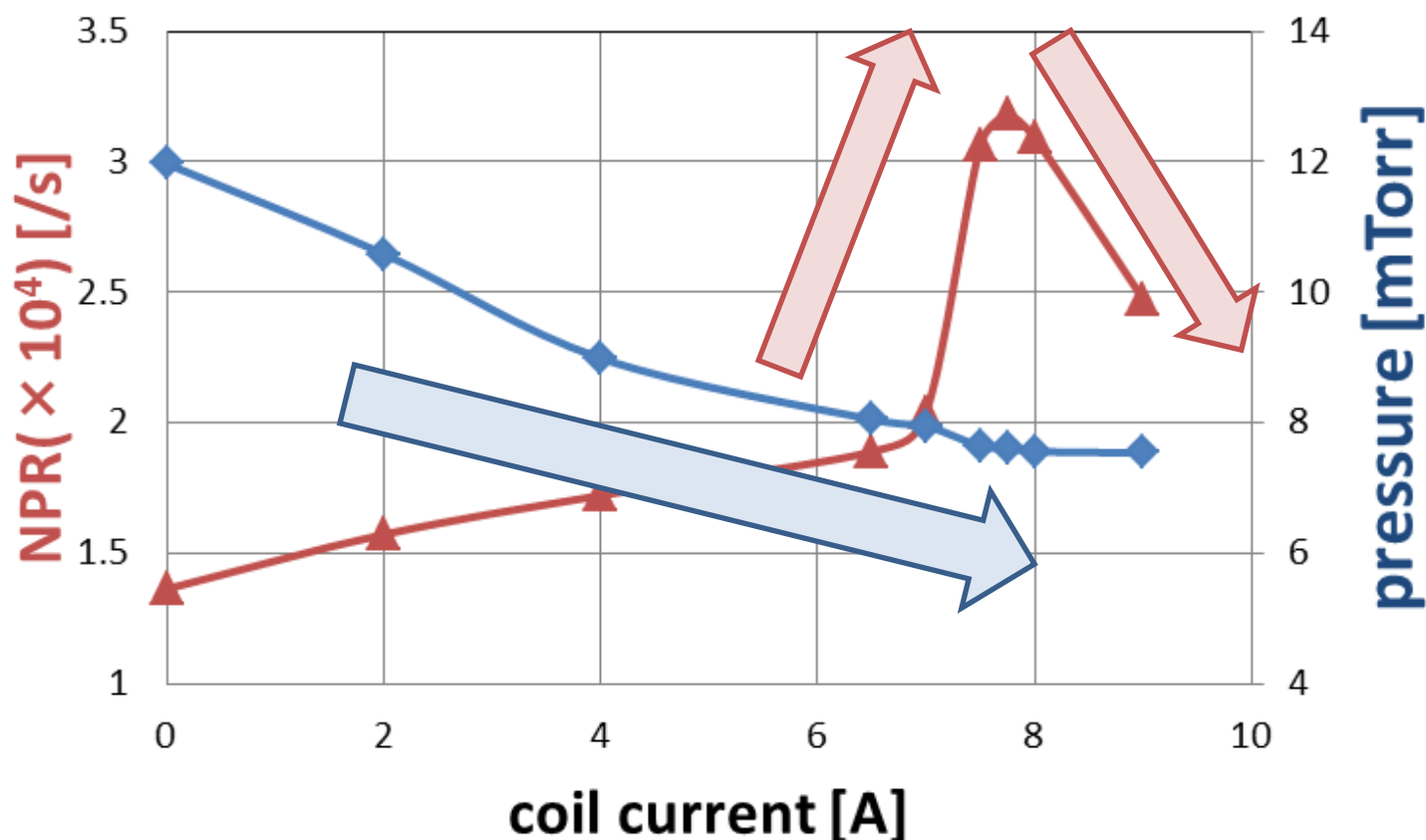
Pressure is monotonically decreased.

But

NPR has peak point

effect of pressure on NPR

coil pattern H (0 ~ 9 A)



Pressure decreasing doesn't effect on NPR very much.

Outline

- principle
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Ionization of neutral particle

NPR is dependent on ion energy.
need to consider about ion generation region

The way to calculate ion generation region

- ① calculate the electron trajectories
 - ② by using the trajectories,
ion generation region is calculated.
- ∴ Ionization occurs when electron and neutral particle collide.

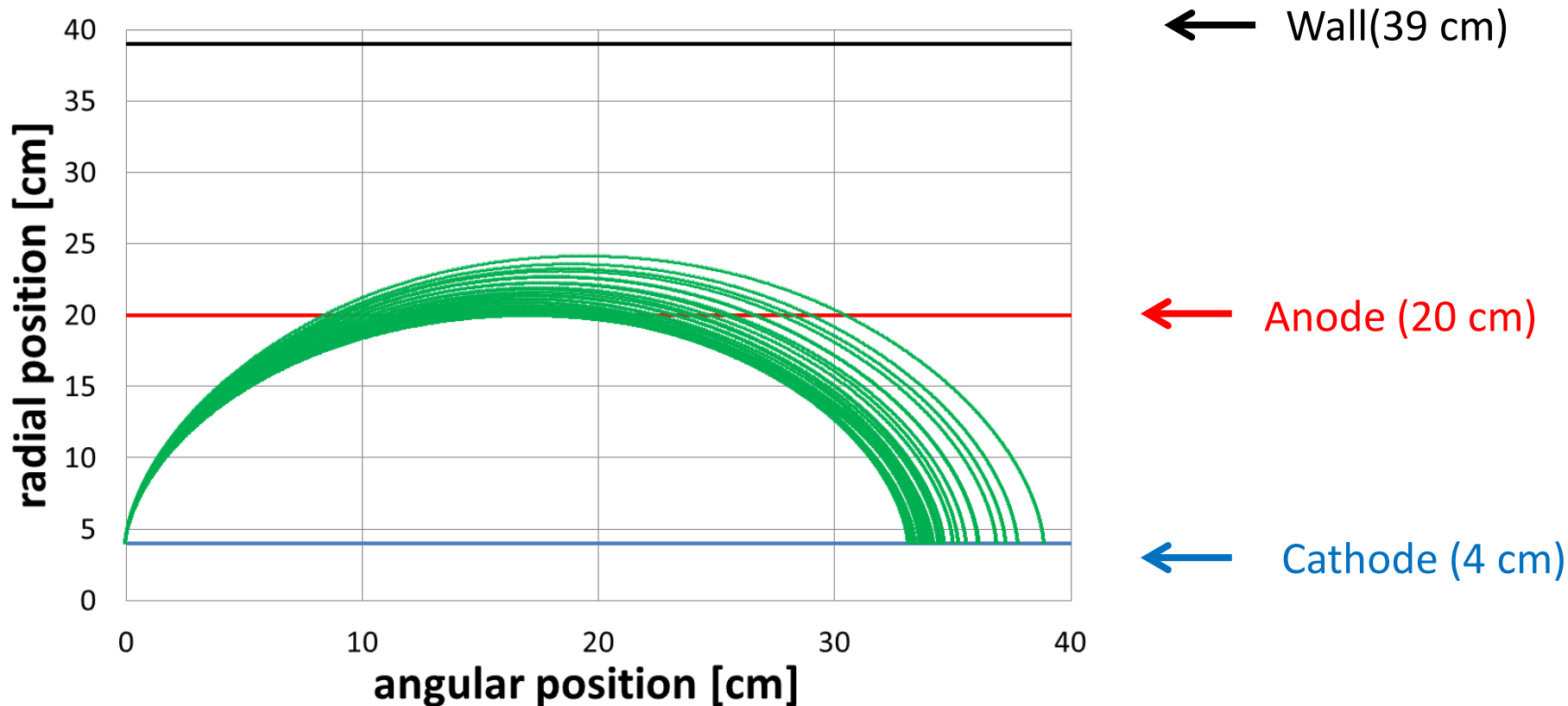


At first study about coil pattern E



Electron trap trajectory

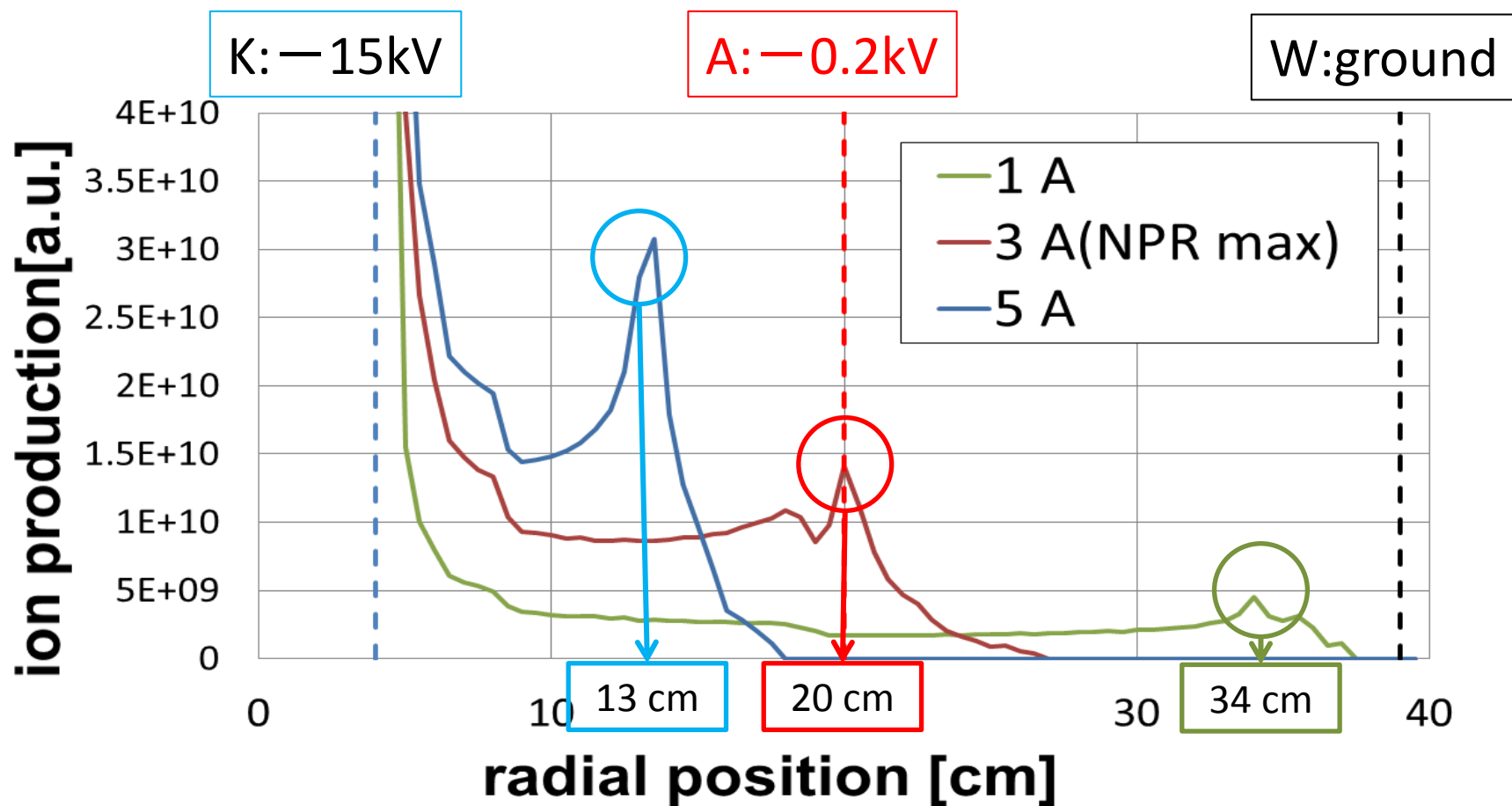
@coil current =3 A(pattern E : NPR peak)



Electron trajectories are near the anode.

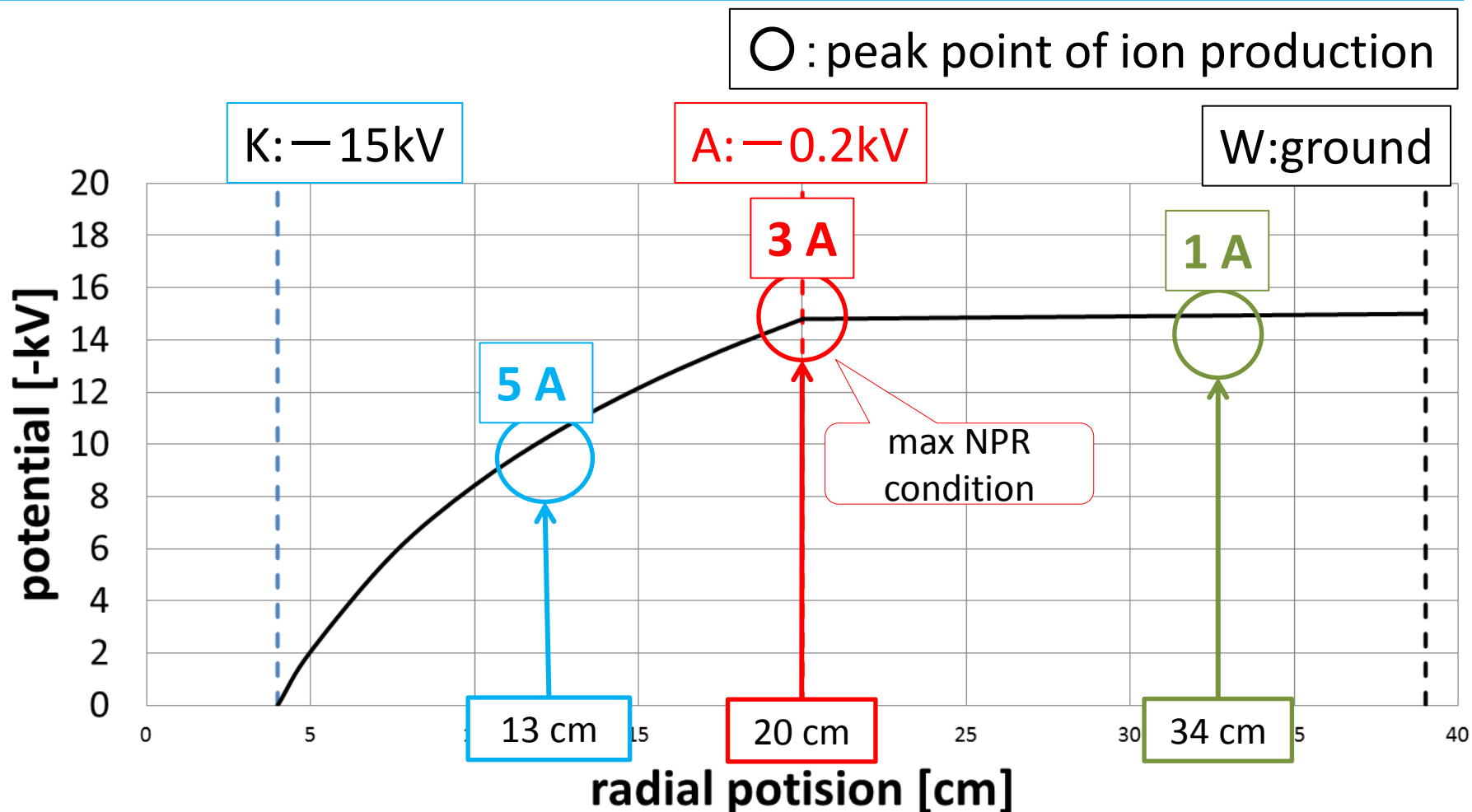
Next : ion generation region from these trajectories

Ion production position @coil pattern E



Ion production peak point is different
with coil current changing.

Potential distribution and ion peak

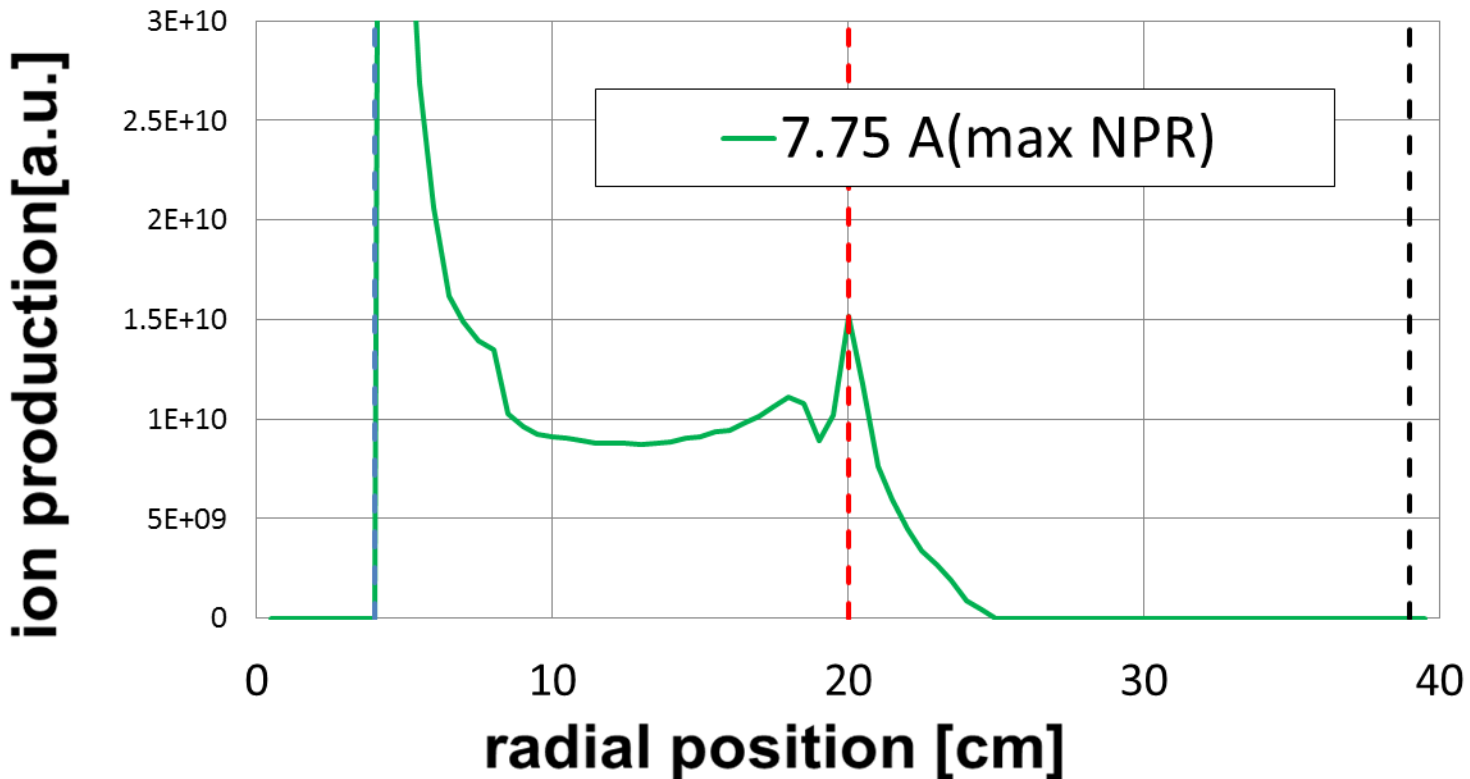


When ion peak is near the anode
ions are effectively accelerated.



Next discuss about coil pattern H

Ion production position @coil pattern H

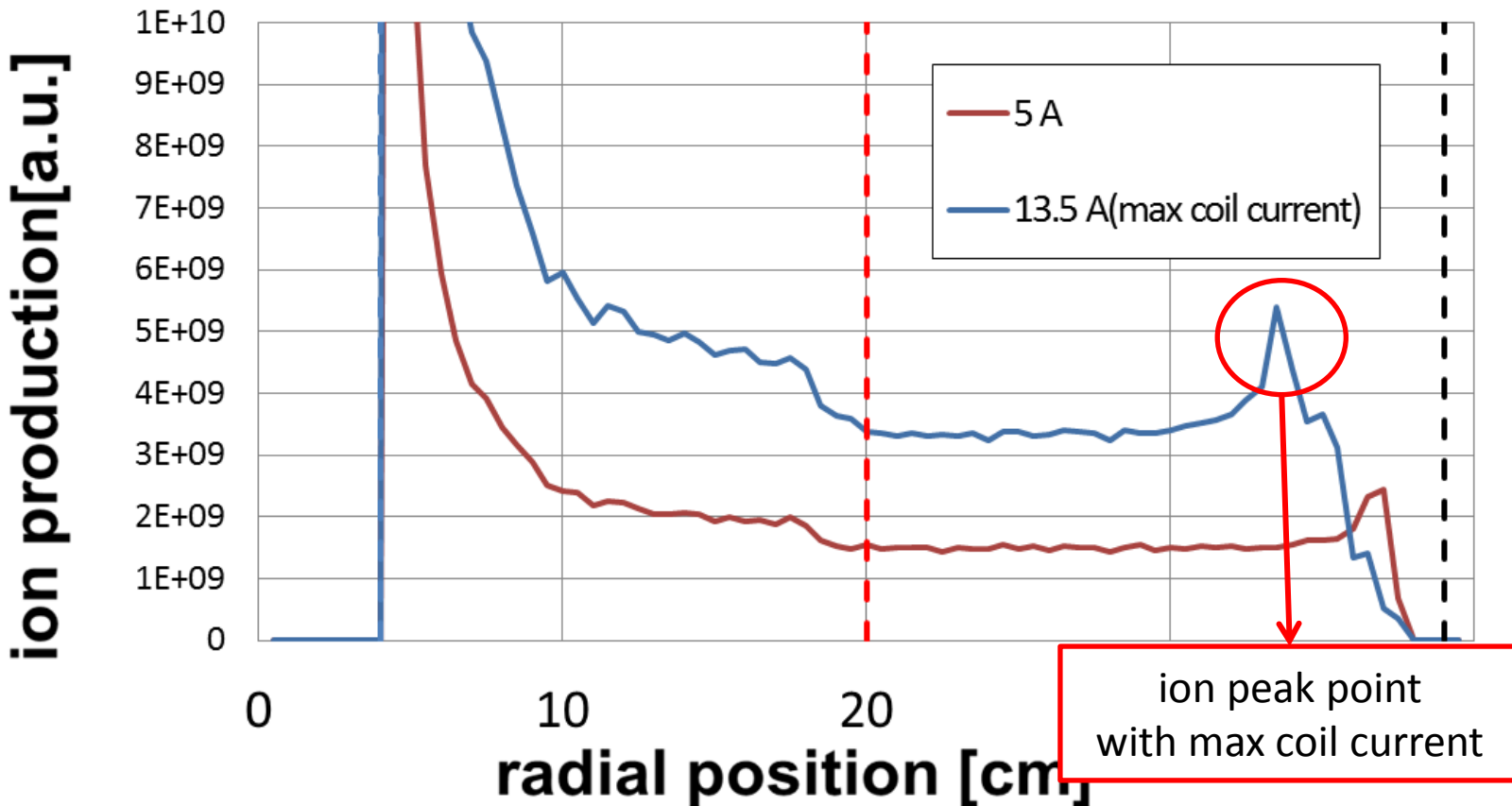


NPR has also peak point
when ion production peak is near the anode @pattern H



**Next discuss about coil pattern A
(NPR doesn't have peak point)**

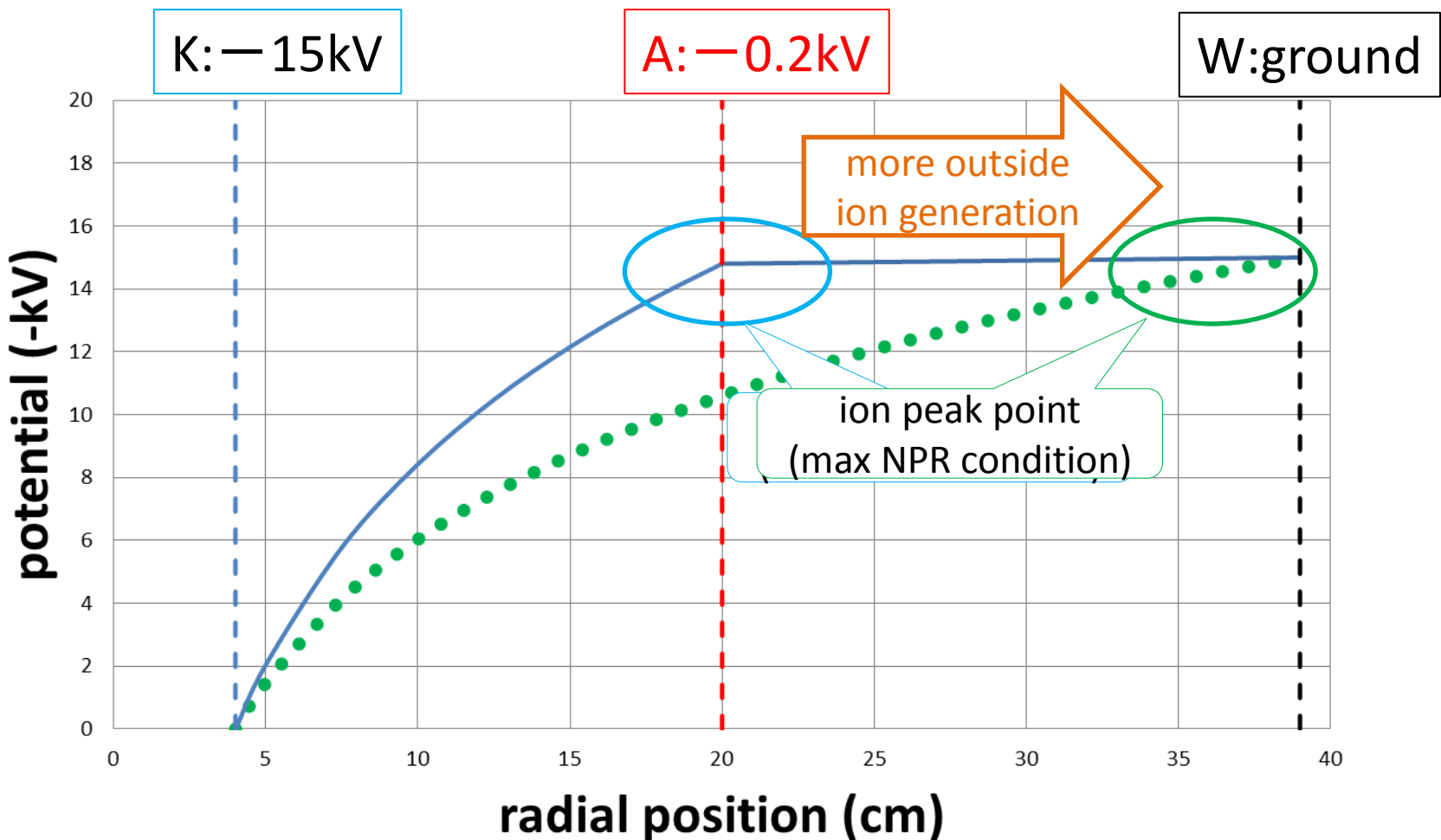
Ion production position @coil pattern H



ion peak point doesn't reach the anode
∴ NPR has no peak point

the condition with max NPR

with changing potential distribution



ions generated among anode to wall :
no acceleration and no contribution to fusion reaction.



Outline

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- **pulse operation**
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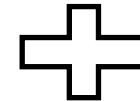


Pulse discharge operation

◆ To increase ion energy

◆ To increase ion density

magnetic field



pulse discharge

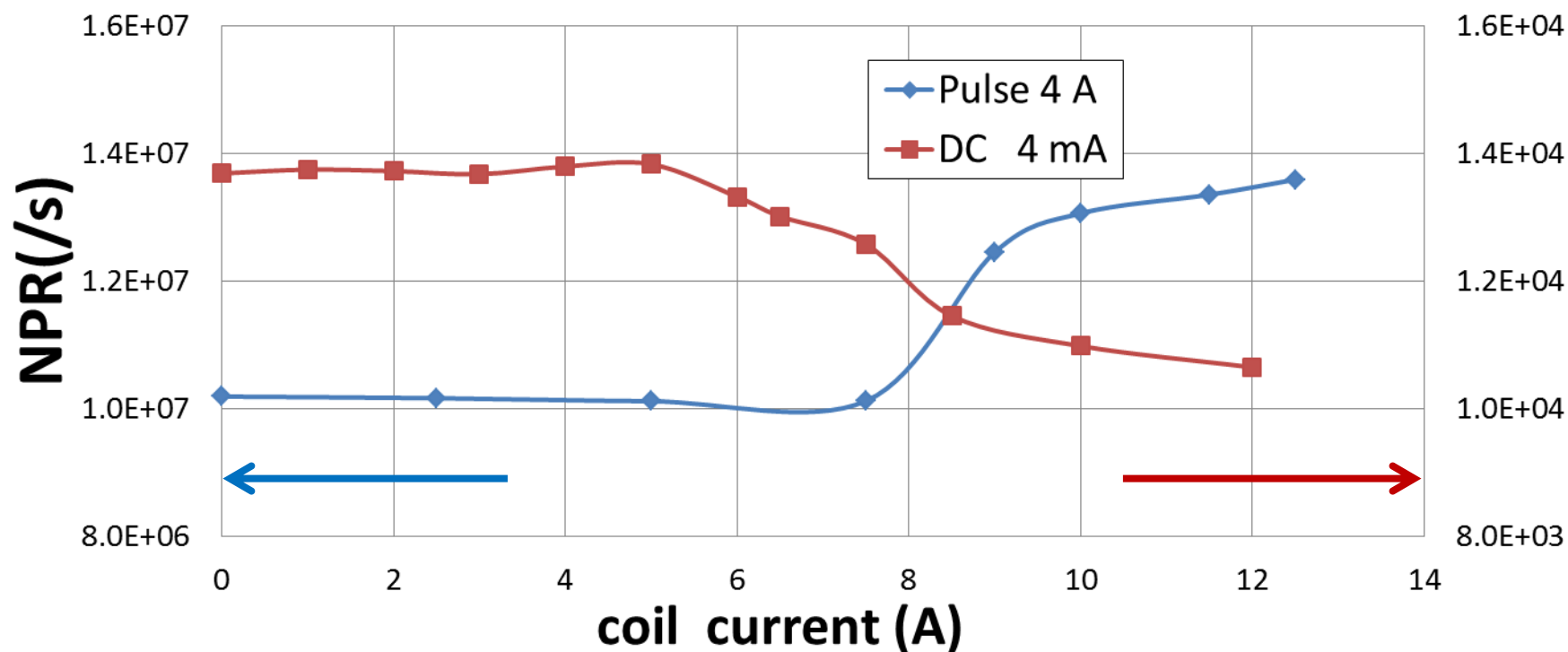
pulse operation

High cathode current can be applied.

Comparison of DC and pulse operation

same potential distribution

$V_c = -20$ kV $V_a = -4.4$ kV



Comparison of DC and pulse discharge operation
 $\Rightarrow$ dependence of NPR on magnetic field strength is different

Conclusion

With axial magnetic field,
NPR is 2.33 times, and pressure decreased 36 % down
 @coil pattern H (7.75 A)

Ion generation region

plays an important role in increasing NPR.

generate the ions more outside region?

not much effect
of pressure

Ions generated among anode to wall

don't have influence on fusion reaction,
 because electric field is weak
 and ions are not accelerated to the cathode.



Future plan

find optimal relationship
between potential distribution and ion production position

with changing anode voltage
under the condition of various ion production peak position

make sure that
how pressure effects on NPR

by analyzing effect of ion production region on NPR
or finding the way of experiment with only pressure changing

**THANK YOU
FOR YOUR ATTENTION!**

ご清聴ありがとうございました。