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Title(English)	Effects of axial magnetic field on neutron production rate in a cylindrical IECF device
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Effects of axial magnetic field on neutron production rate in a cylindrical inertial electrostatic confinement fusion device

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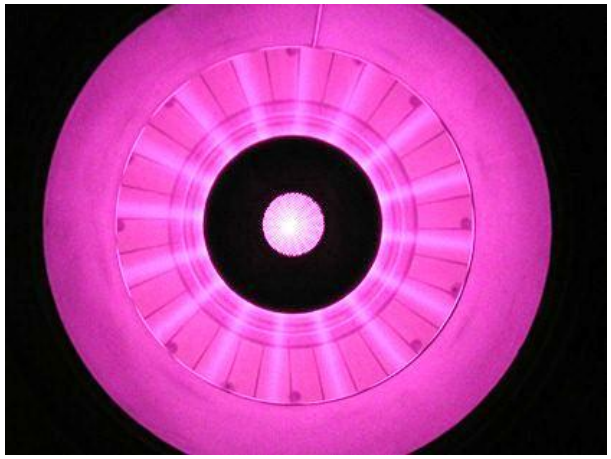
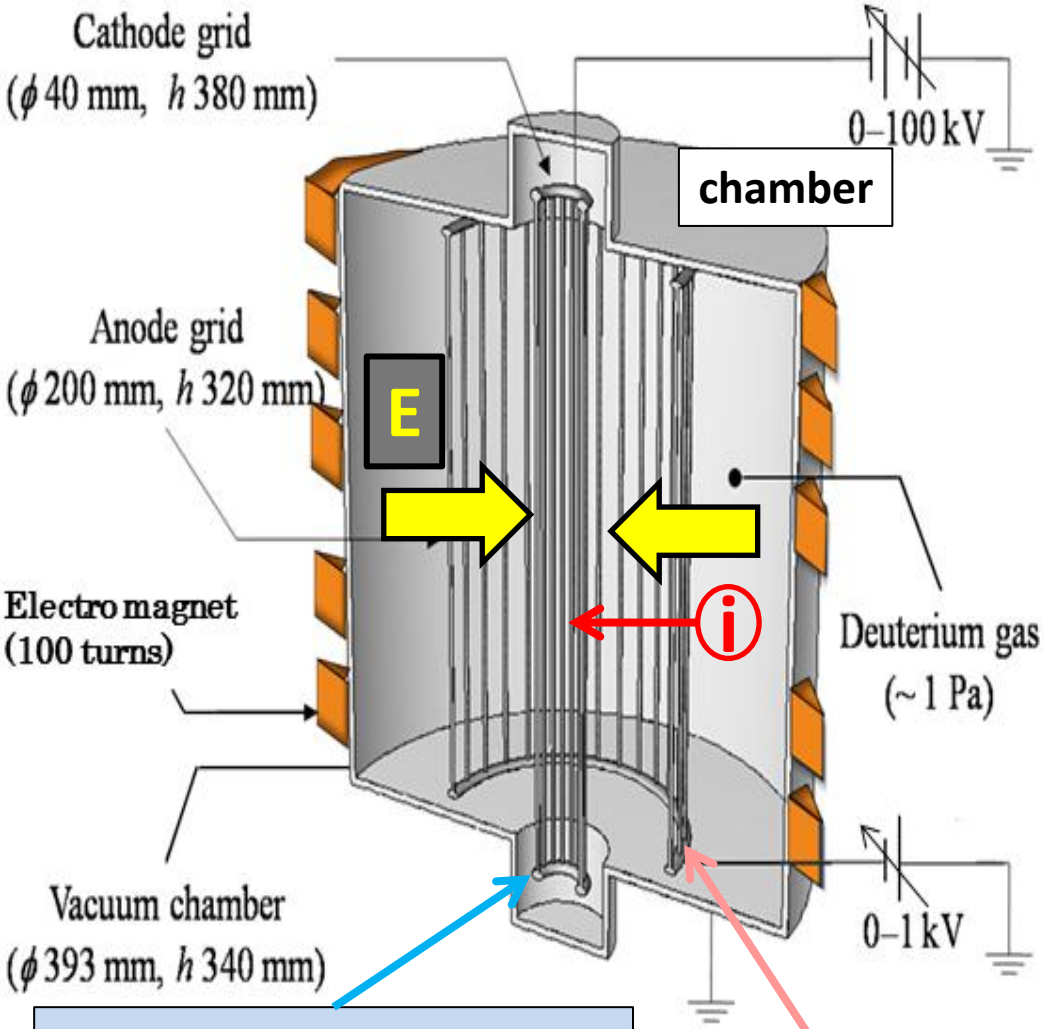
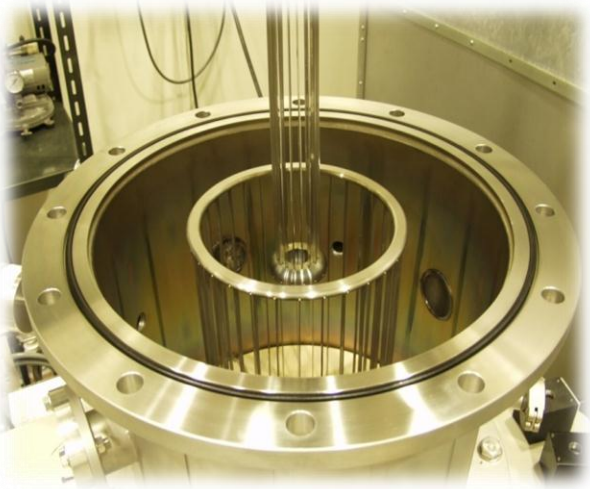


Department of Energy Sciences,
Tokyo Institute of Technology

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.

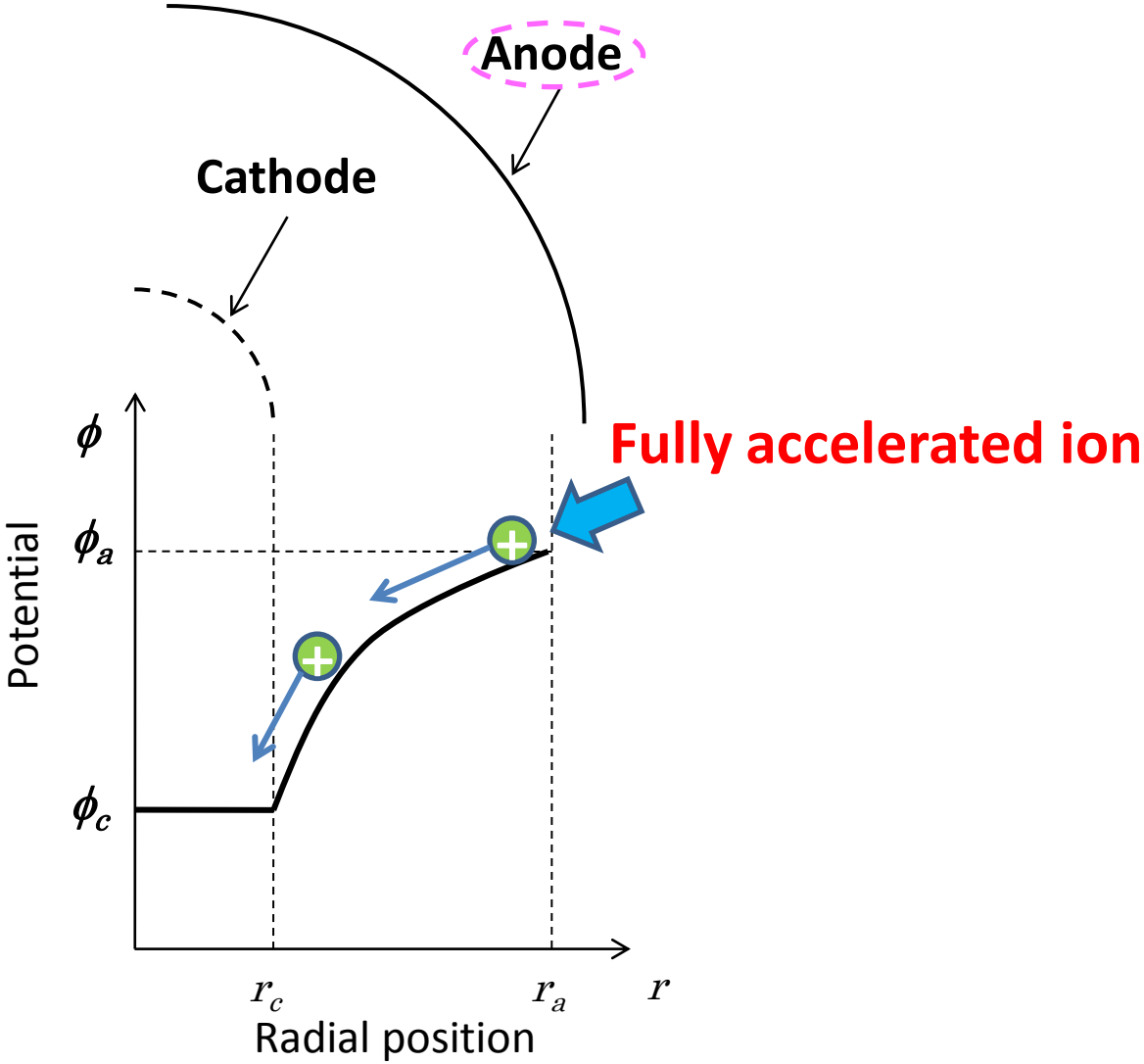
$$D_2^+(\text{fast}) + D_2 \rightarrow D_2(\text{fast}) + D_2^+$$

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**

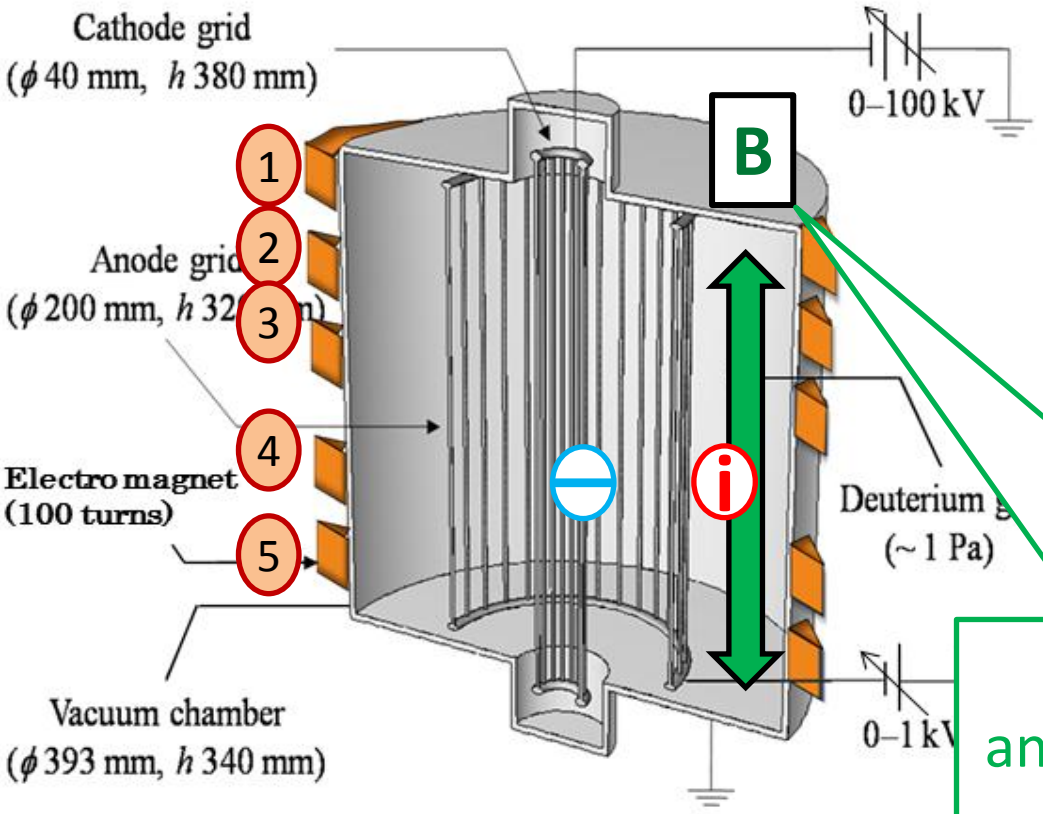
- ✓ **Low pressure operation**
  - ⇨ **To reduce ion energy loss by charge exchange reaction**
- ✓ **Increment of Ion production more outside**
  - ⇨ **To fully accelerate ion by electric field**

Applying **axial magnetic field**
to a cylindrical IEC device

Axial magnetic field

Cylindrical IEC device with Axial magnetic field

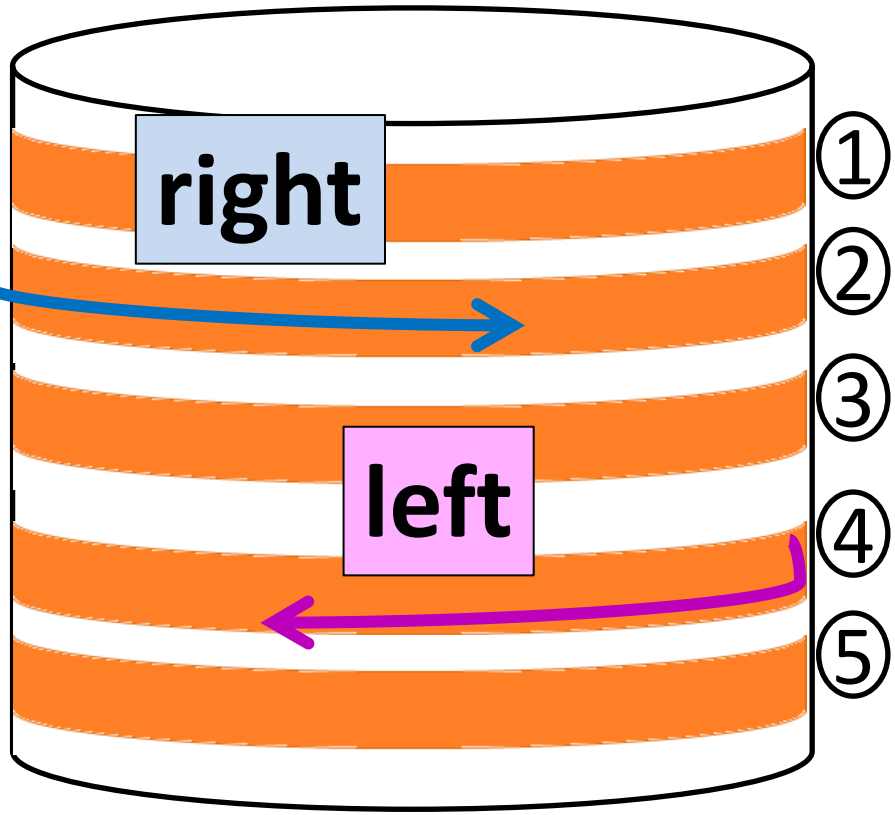
…..confines electrons and produce ions more effectively at low pressure



to trap electrons
and enhance ion generation
near the wall

The way to use electromagnets

～coil current direction pattern～



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

⊗:right hand direction

⊙: left hand direction

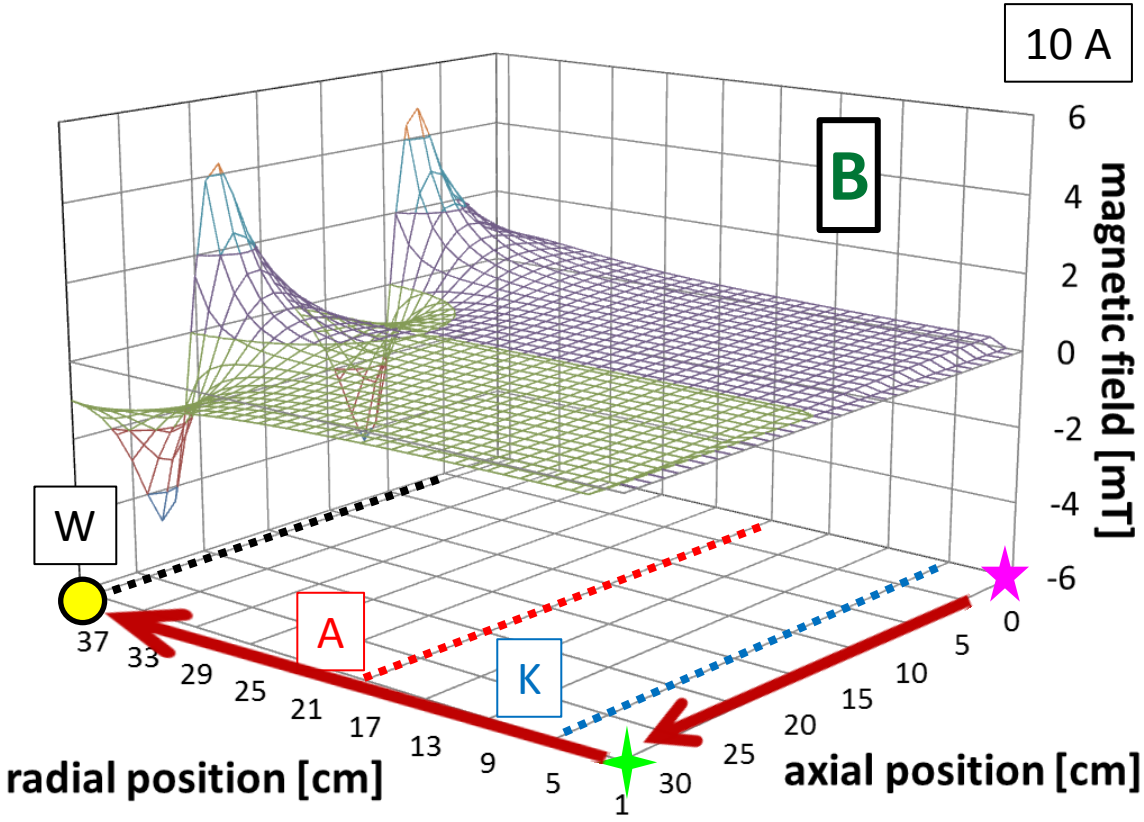
· : no current

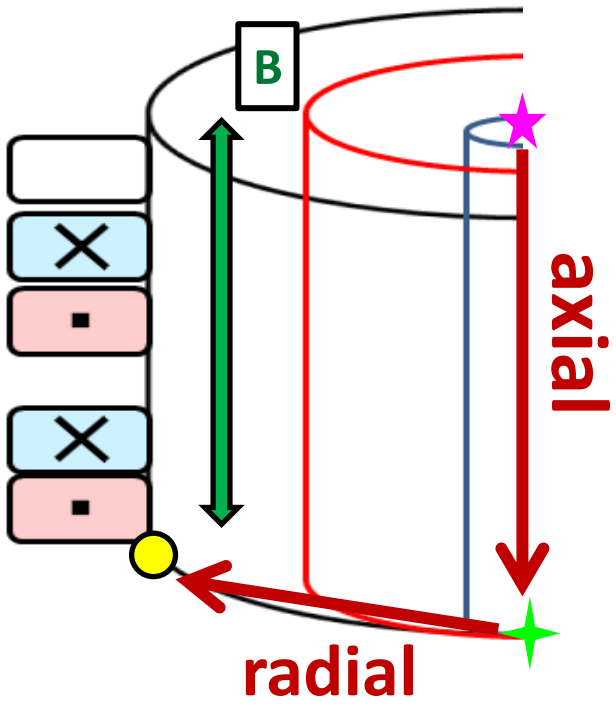
(max current : 13.5 A)

Outline

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

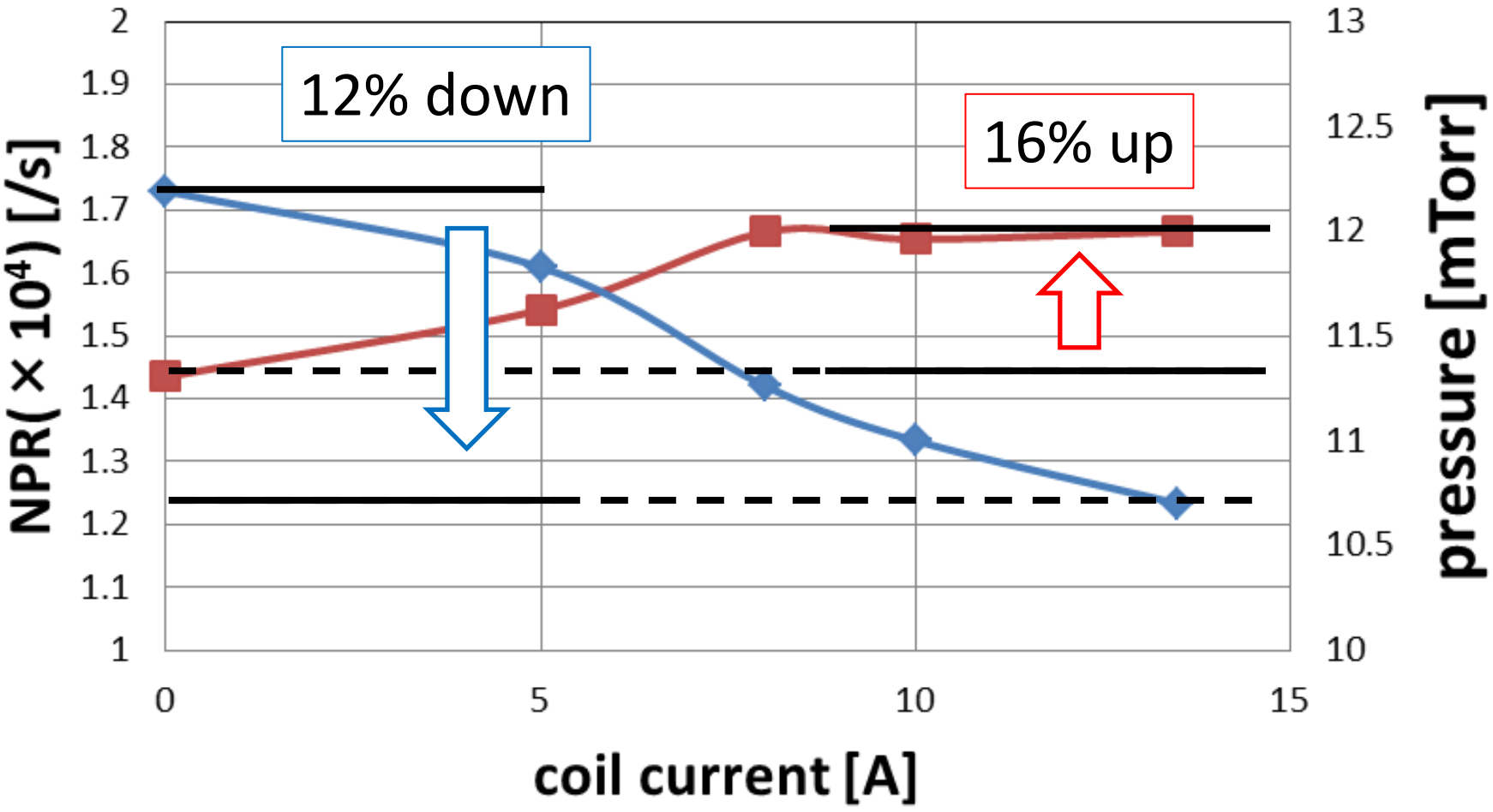
Coil pattern A





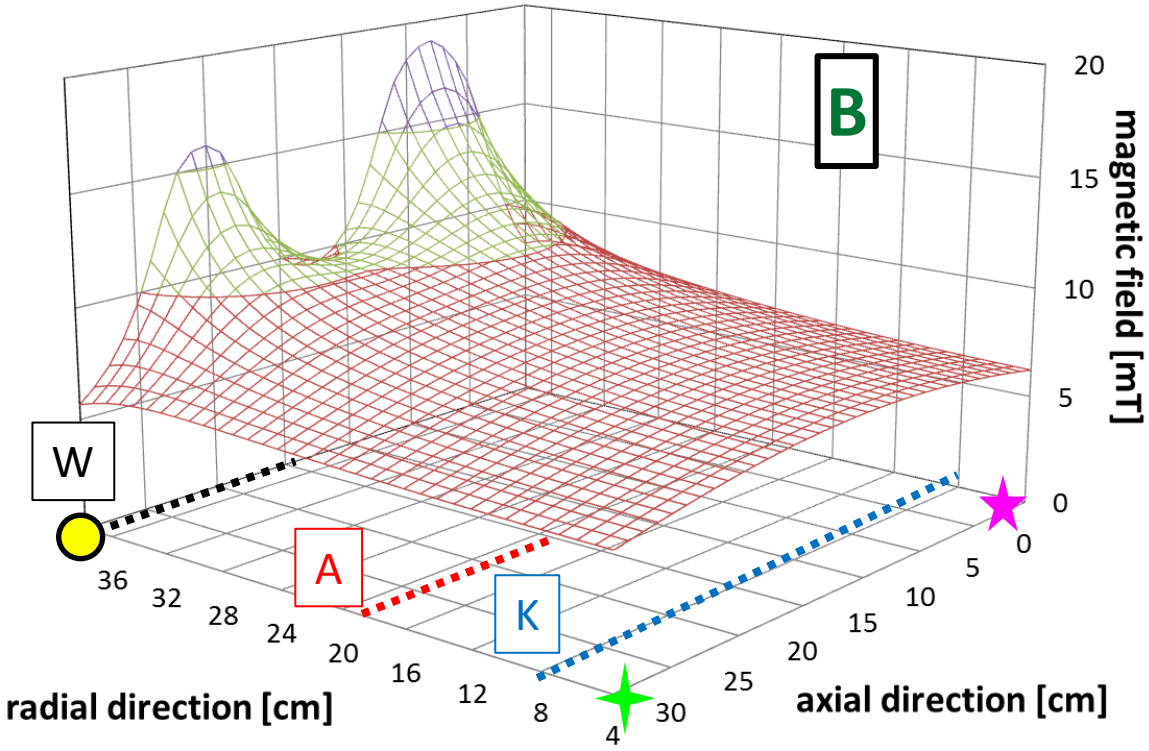
cusp magnetic field
:magnetic field exists only near the wall

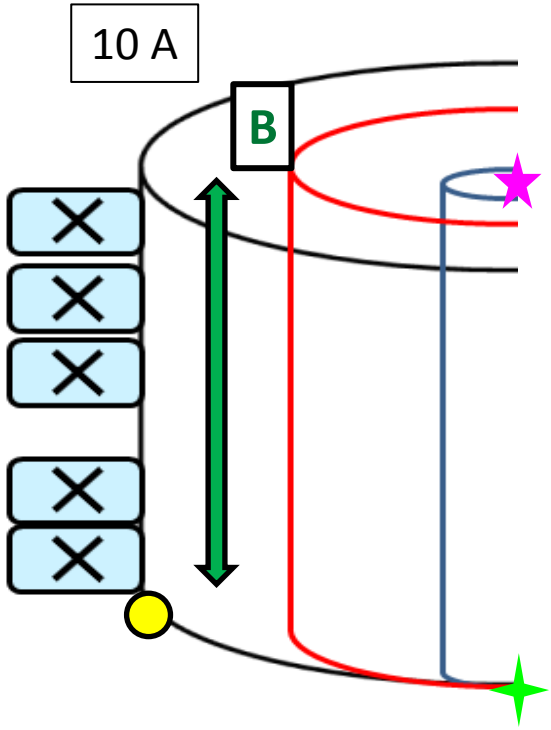
Coil pattern A



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

Coil pattern E

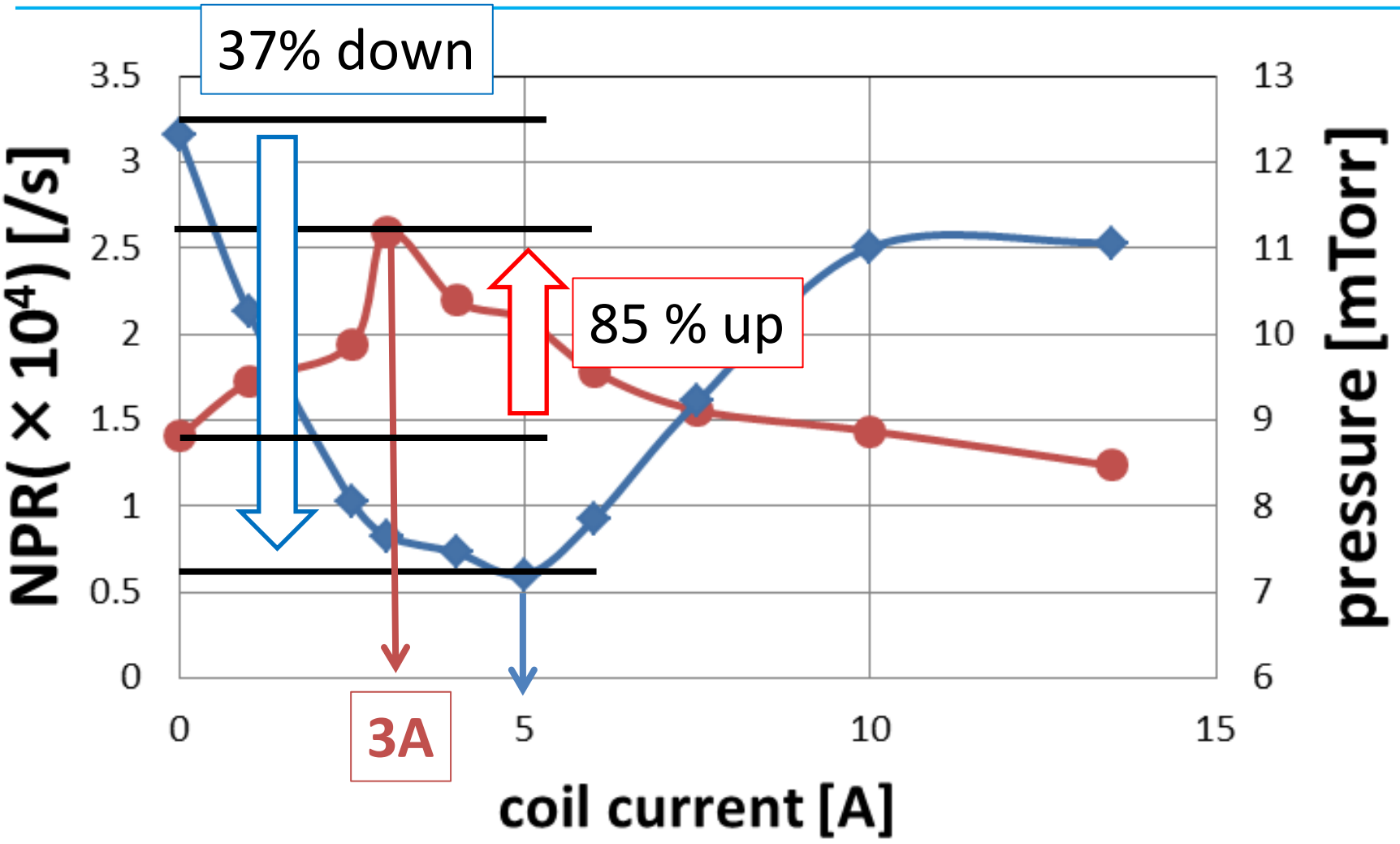




5 coils make same direction magnetic field

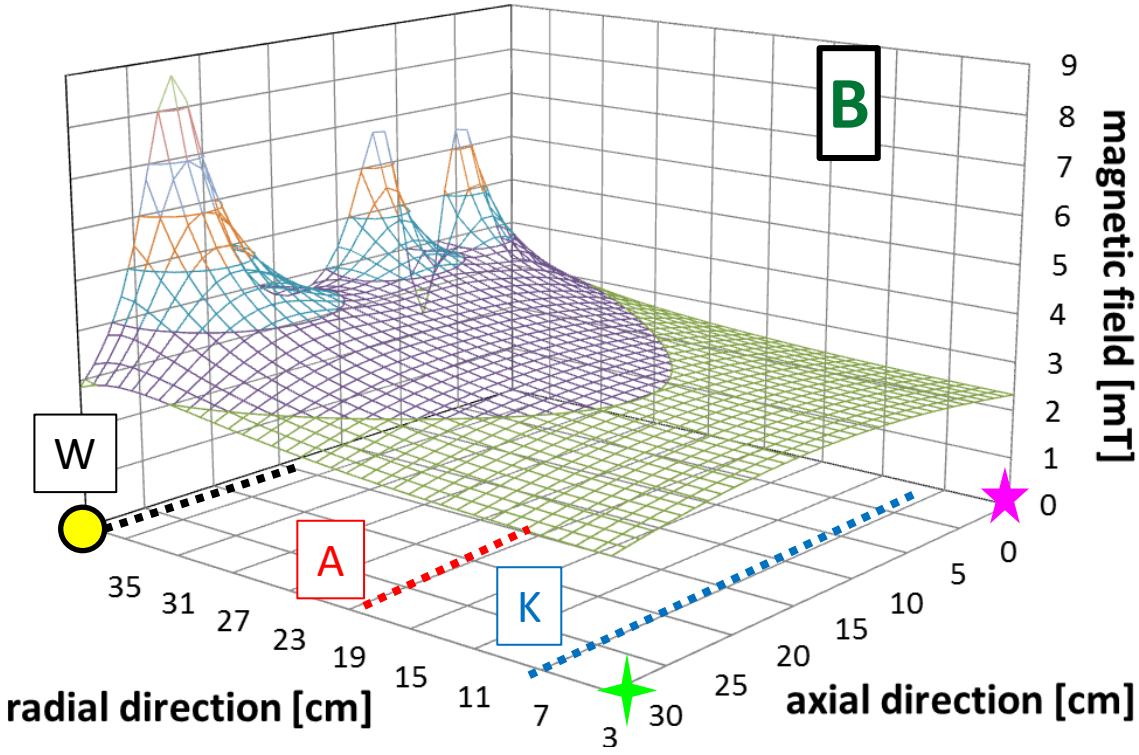
⟹ most strong magnetic field from cathode to wall

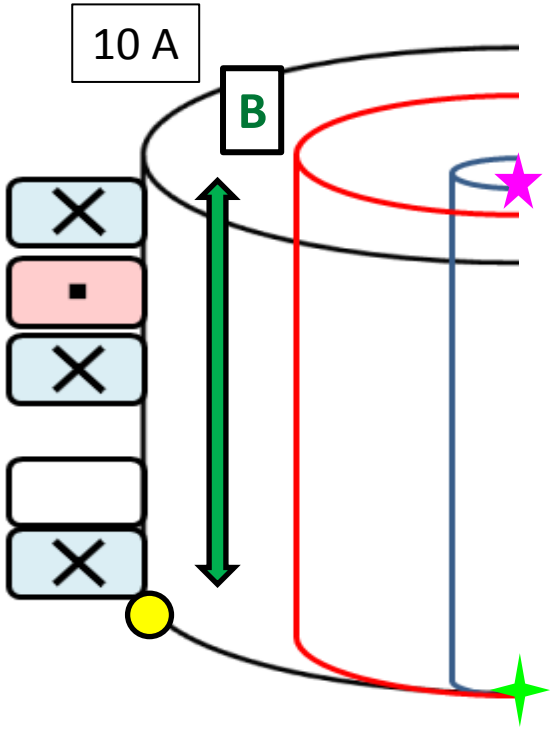
Coil pattern E



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

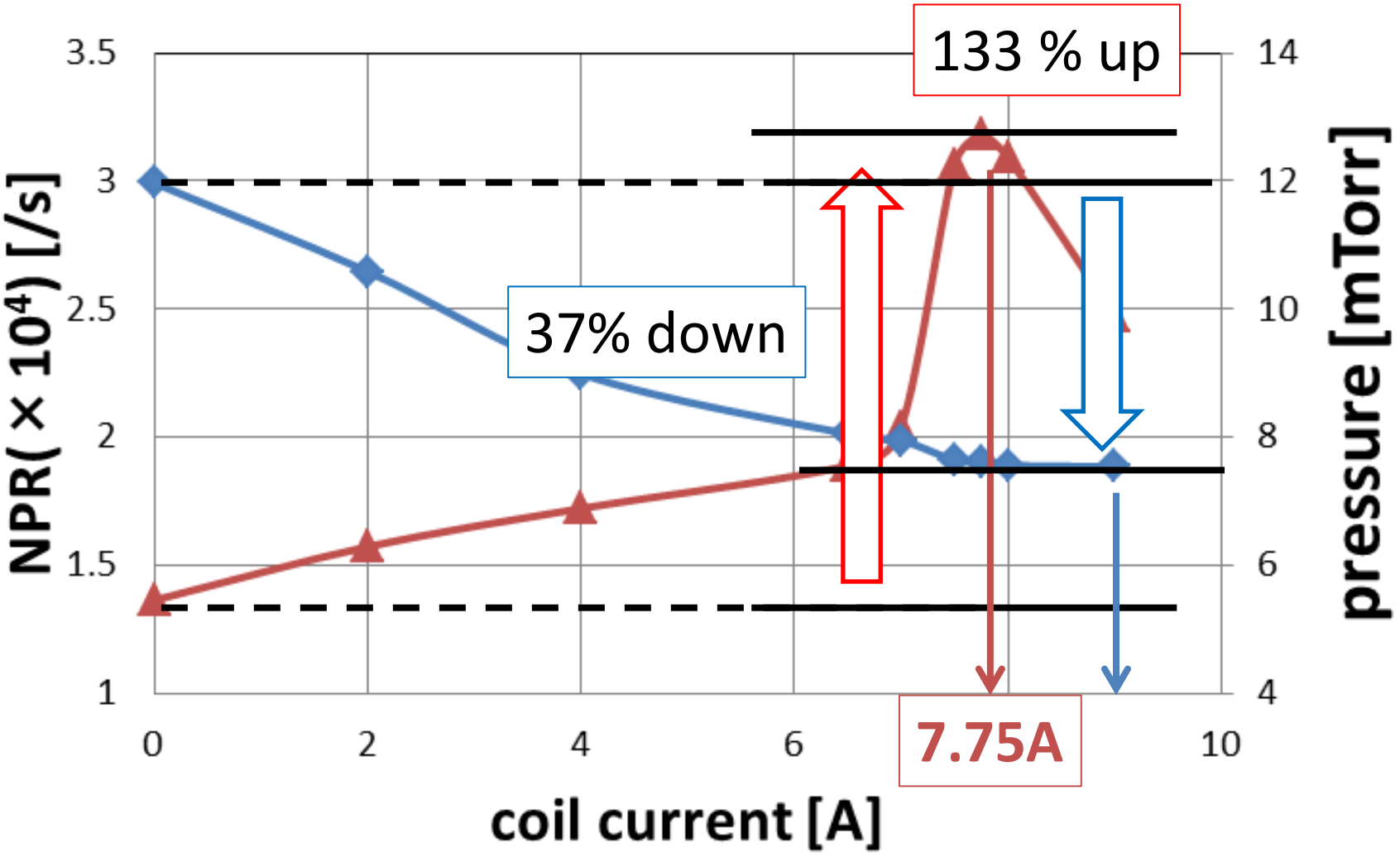
Coil pattern H





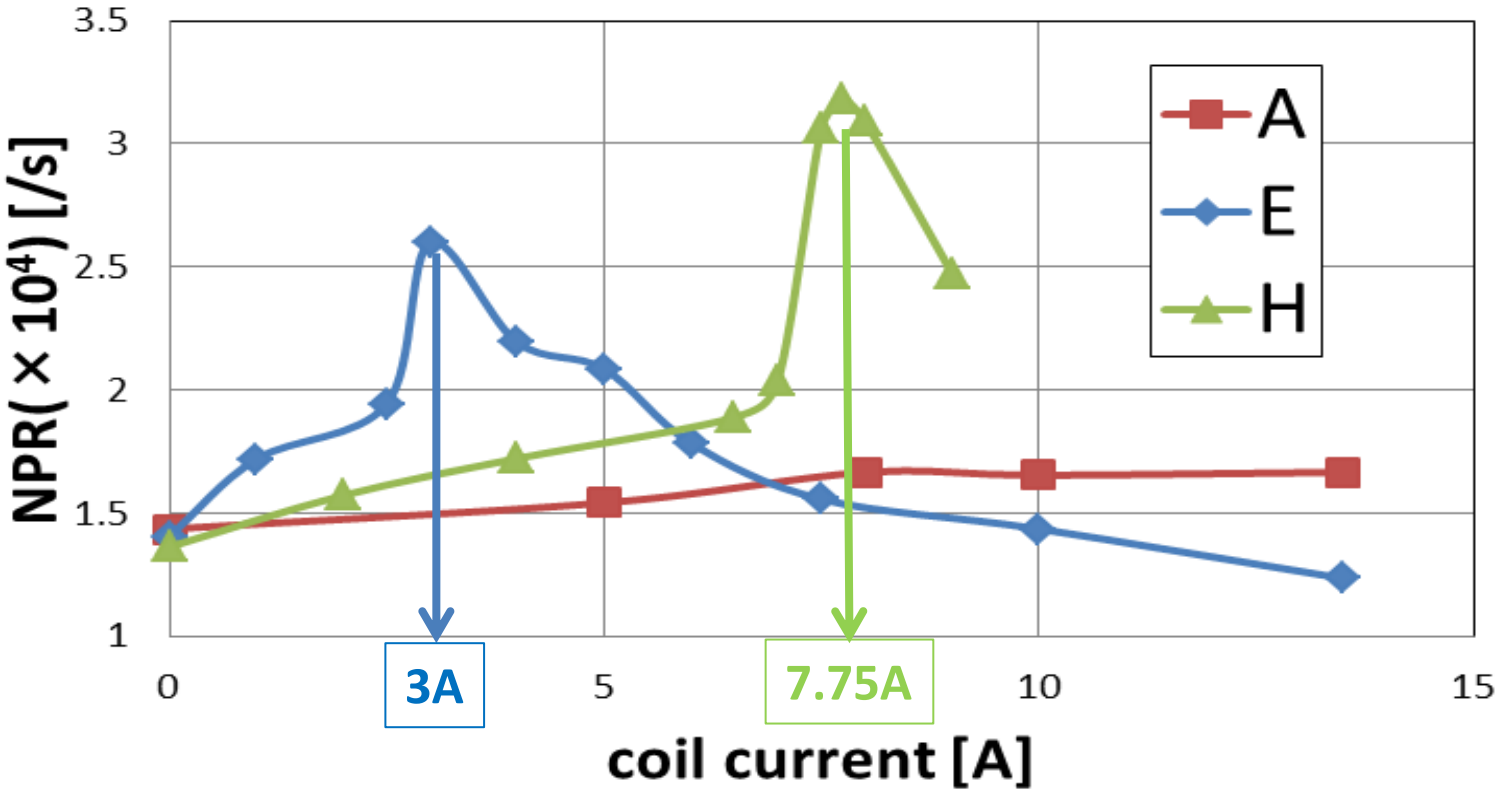
anomalistic magnetic field
: more magnetic field exists near the cathode(r=4 cm) than pattern A

Coil pattern H



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

Experimental results



NPR has peak point in pattern E, H

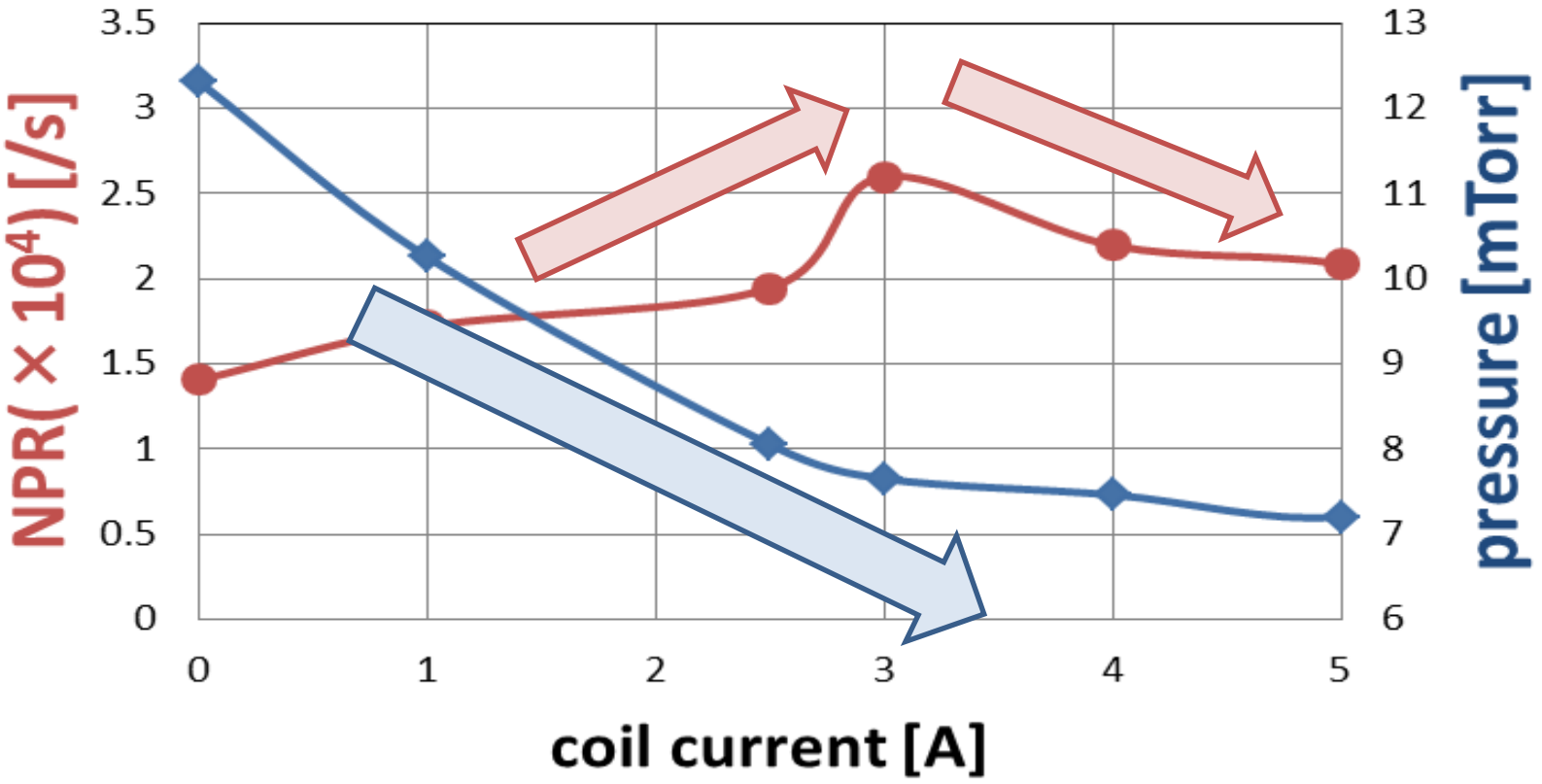
Why NPR has peak point or not ? → **discussion**

Outline

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

effect of pressure on NPR

coil pattern E (0 ~ 5 A)

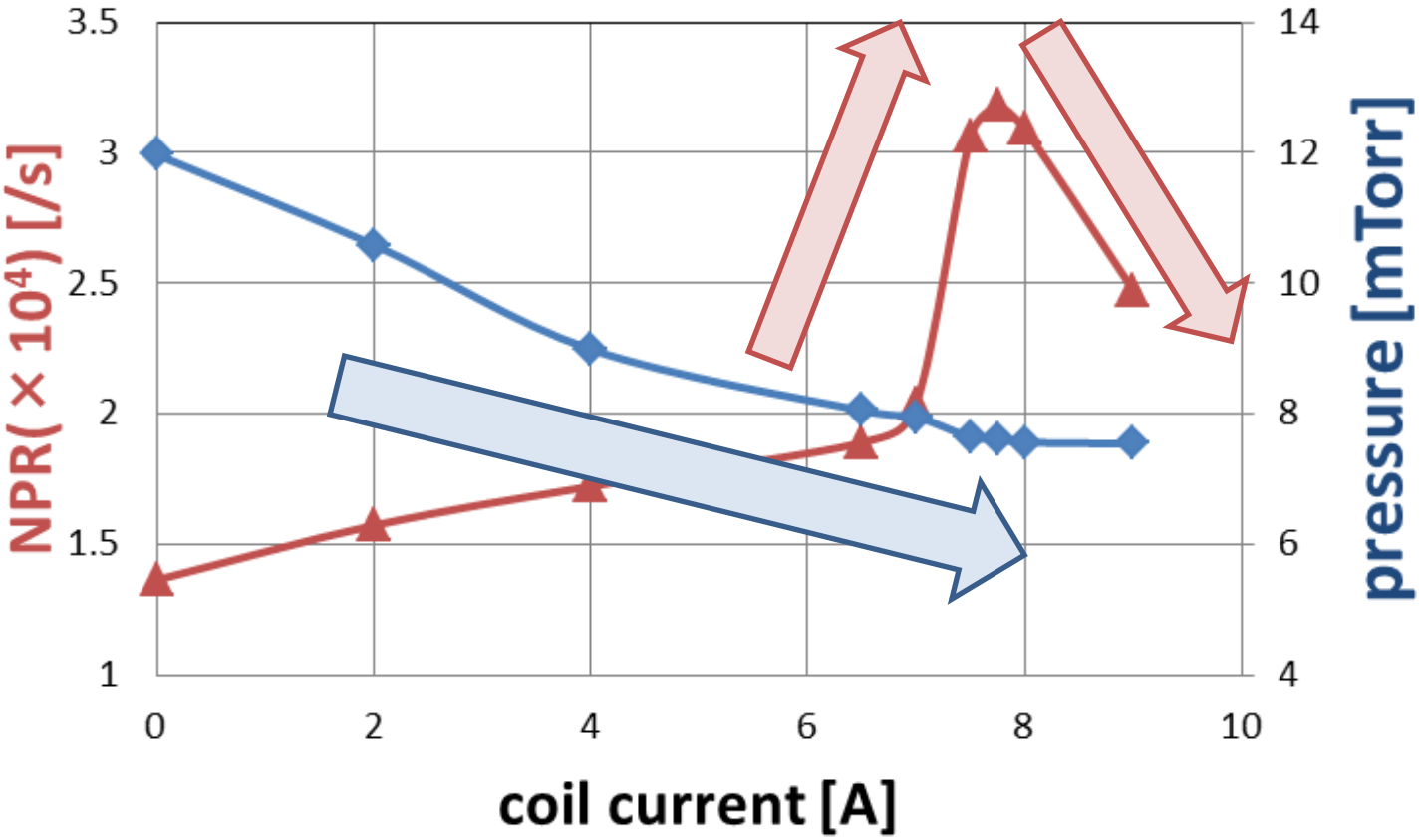


Pressure is monotonically decreased.

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
- experimental results
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  - ion generation range
- pulse operation
- conclusion

Ionization of neutral particle

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

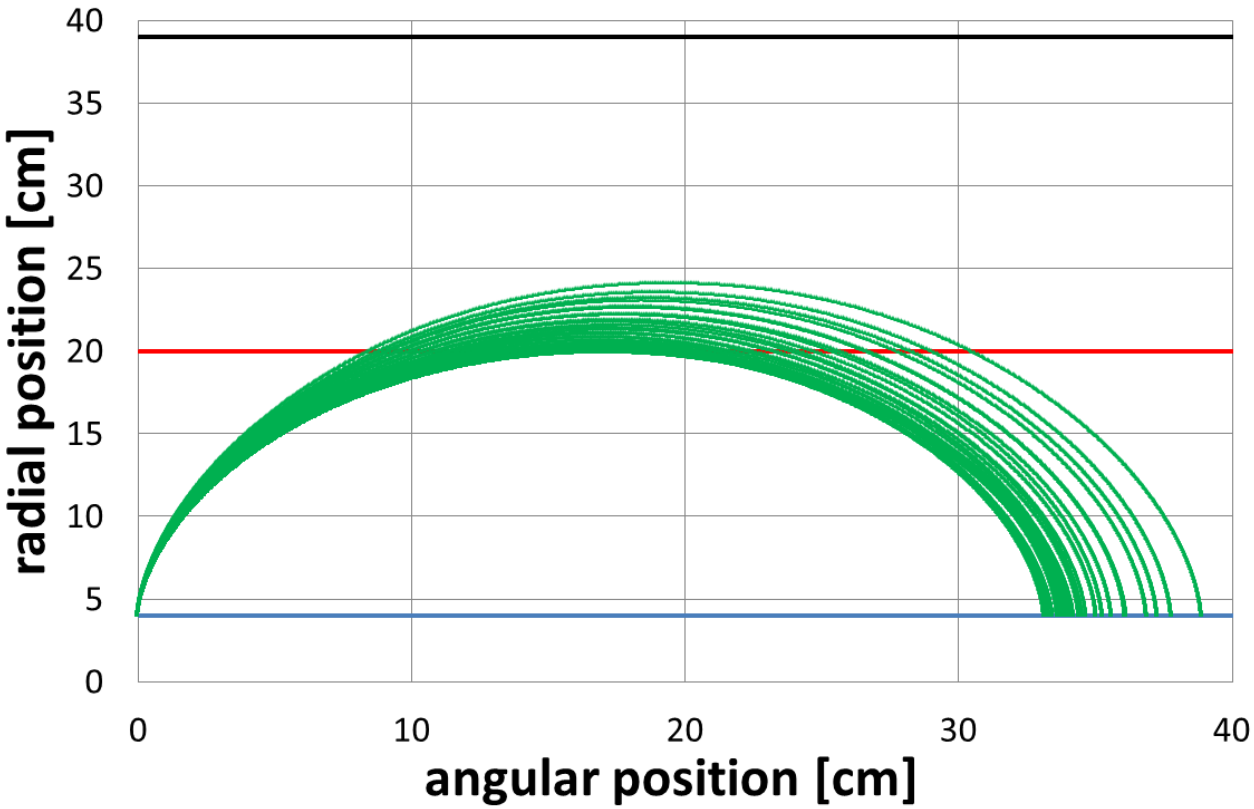
The way to calculate ion generation region

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)



Wall(39 cm)

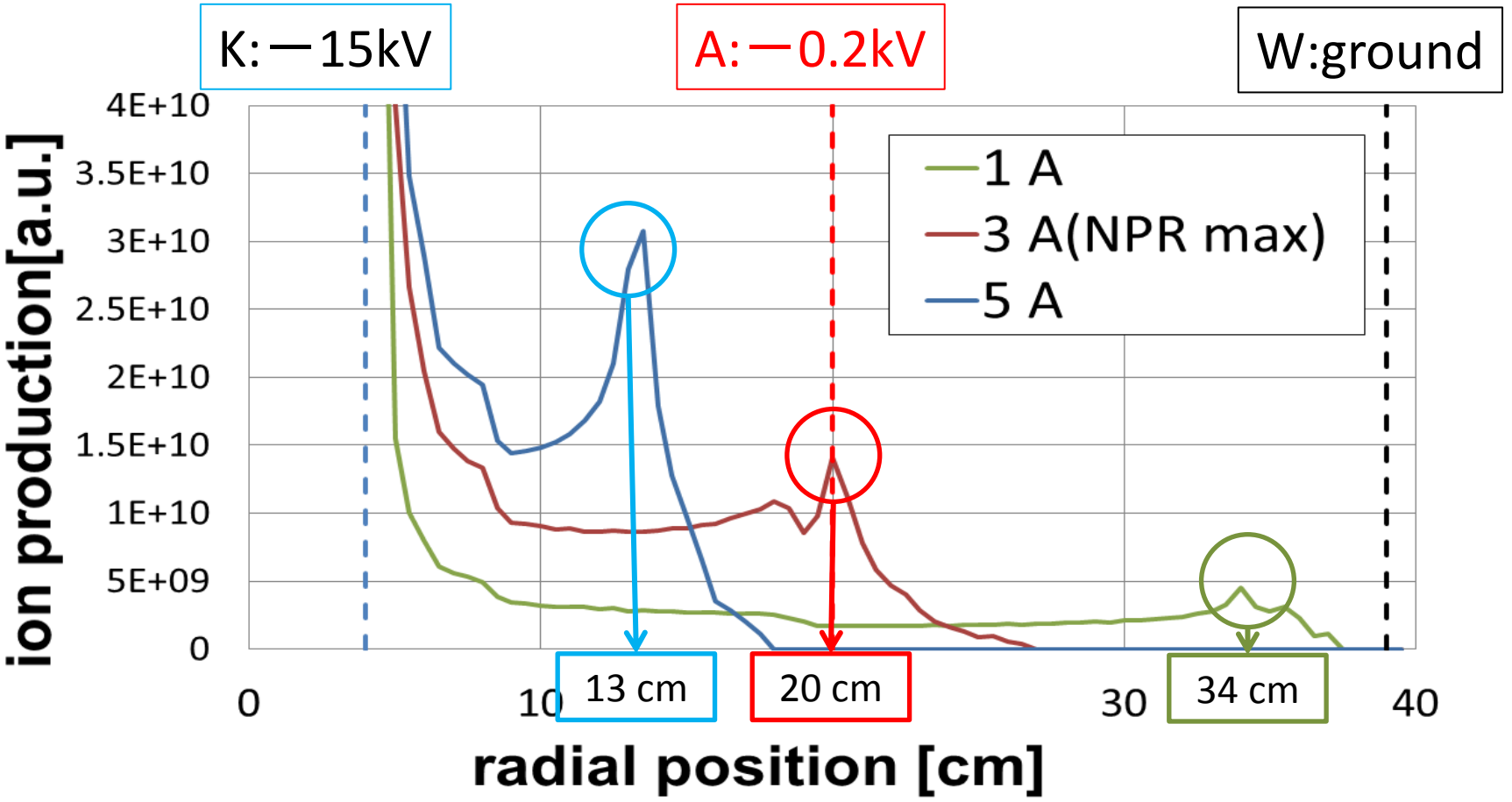
Anode (20 cm)

Cathode (4 cm)

Electron trajectories are near the anode.

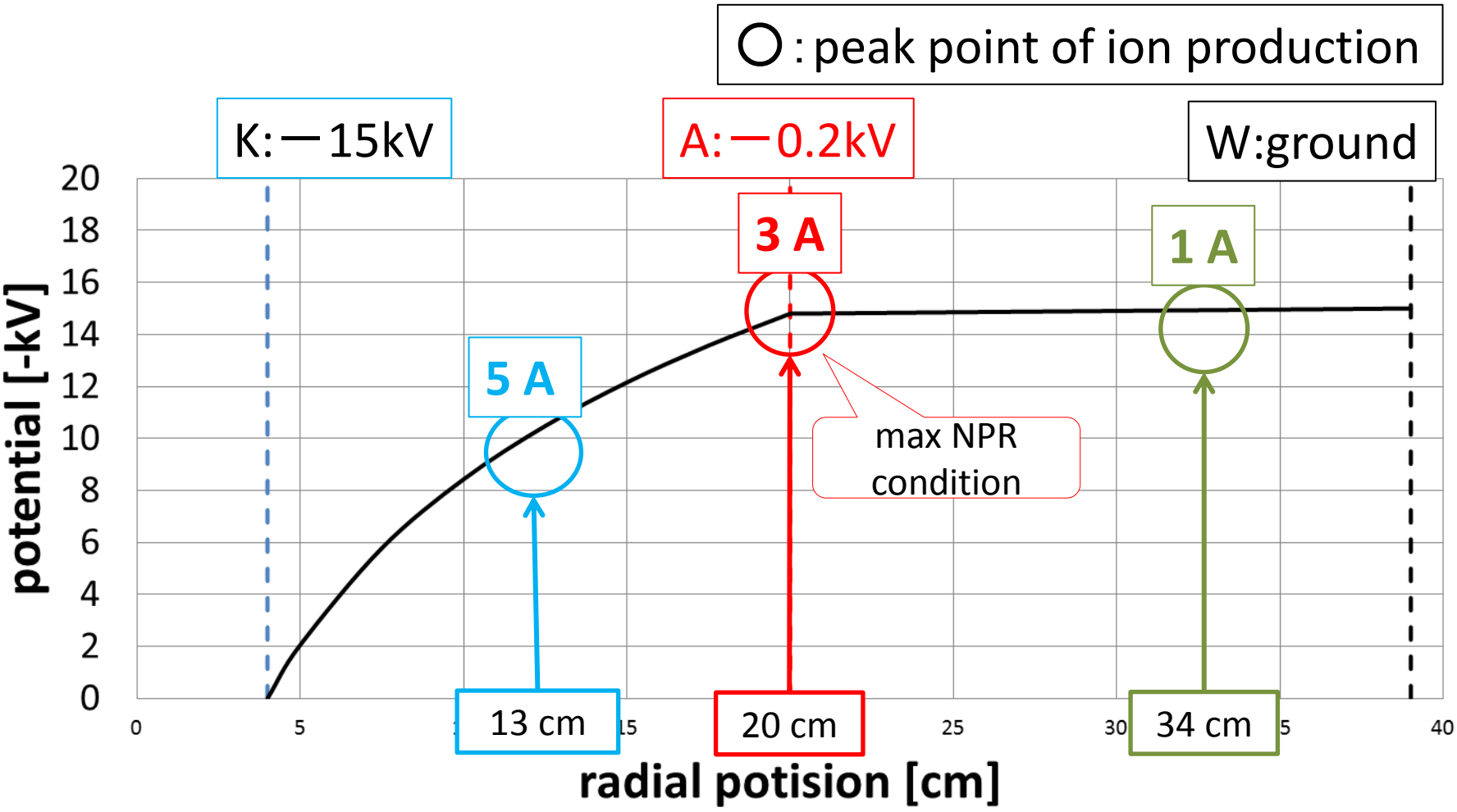
Next : ion generation region from these trajectories

Ion production position @coil pattern E



Ion production peak point is different with coil current changing.

Potential distribution and ion peak

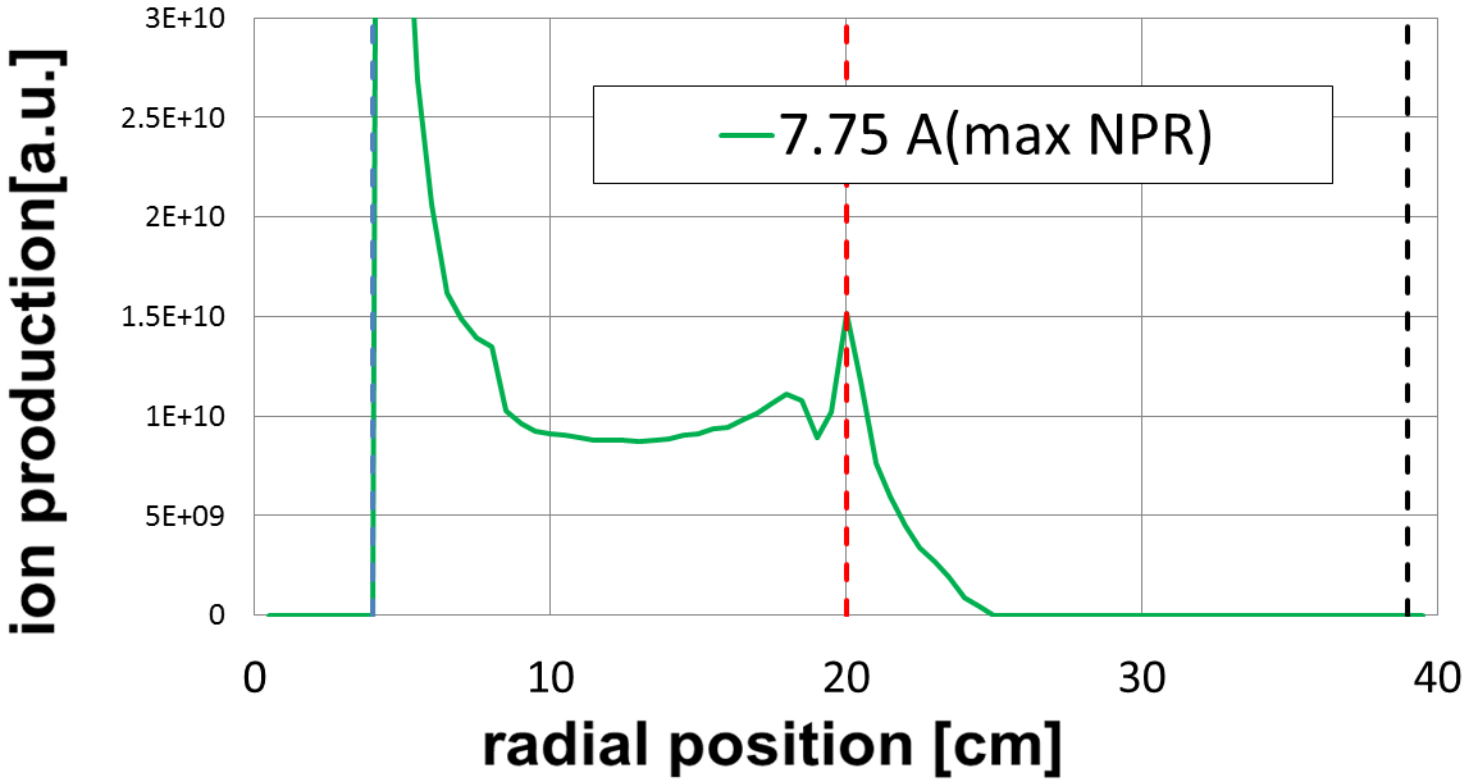


When ion peak is near the anode

ions are effectively accelerated.

Next discuss about coil pattern H

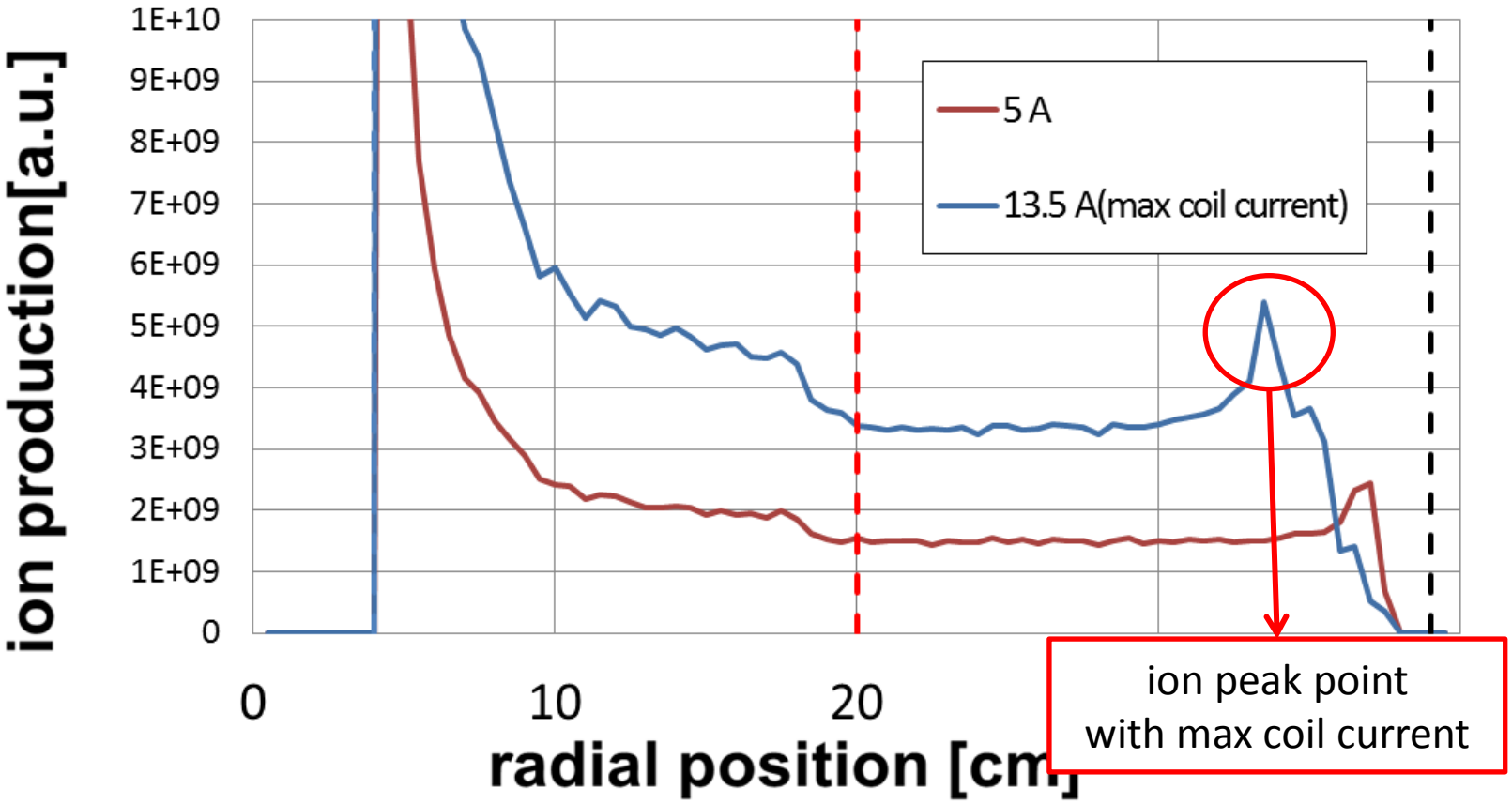
Ion production position @coil pattern H



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

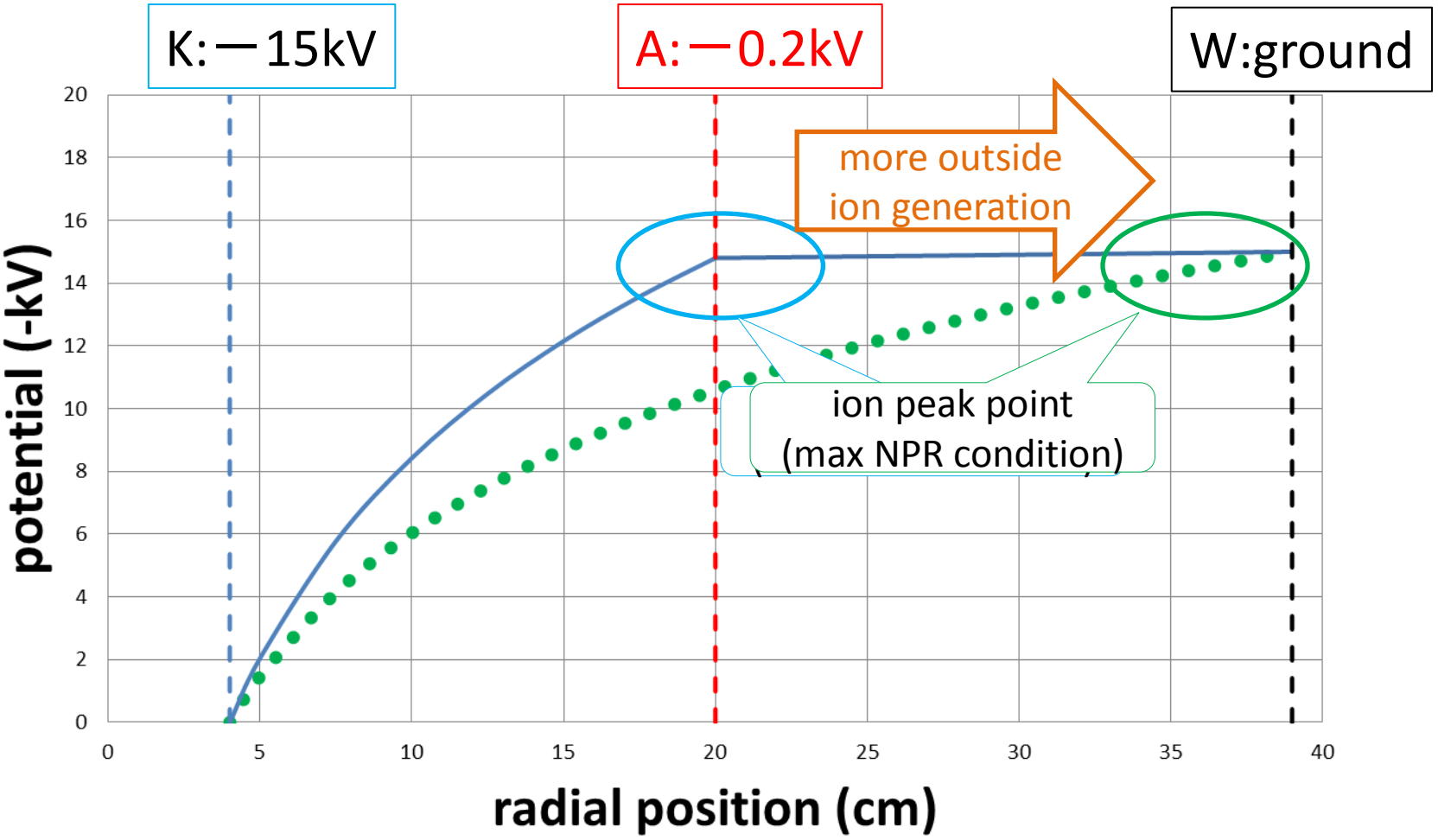


ion peak point doesn't reach the anode

∴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

- principle
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  - ion generation range
- pulse operation
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Pulse discharge operation

- To increase ion energy
- To increase ion density

magnetic field

+

pulse discharge

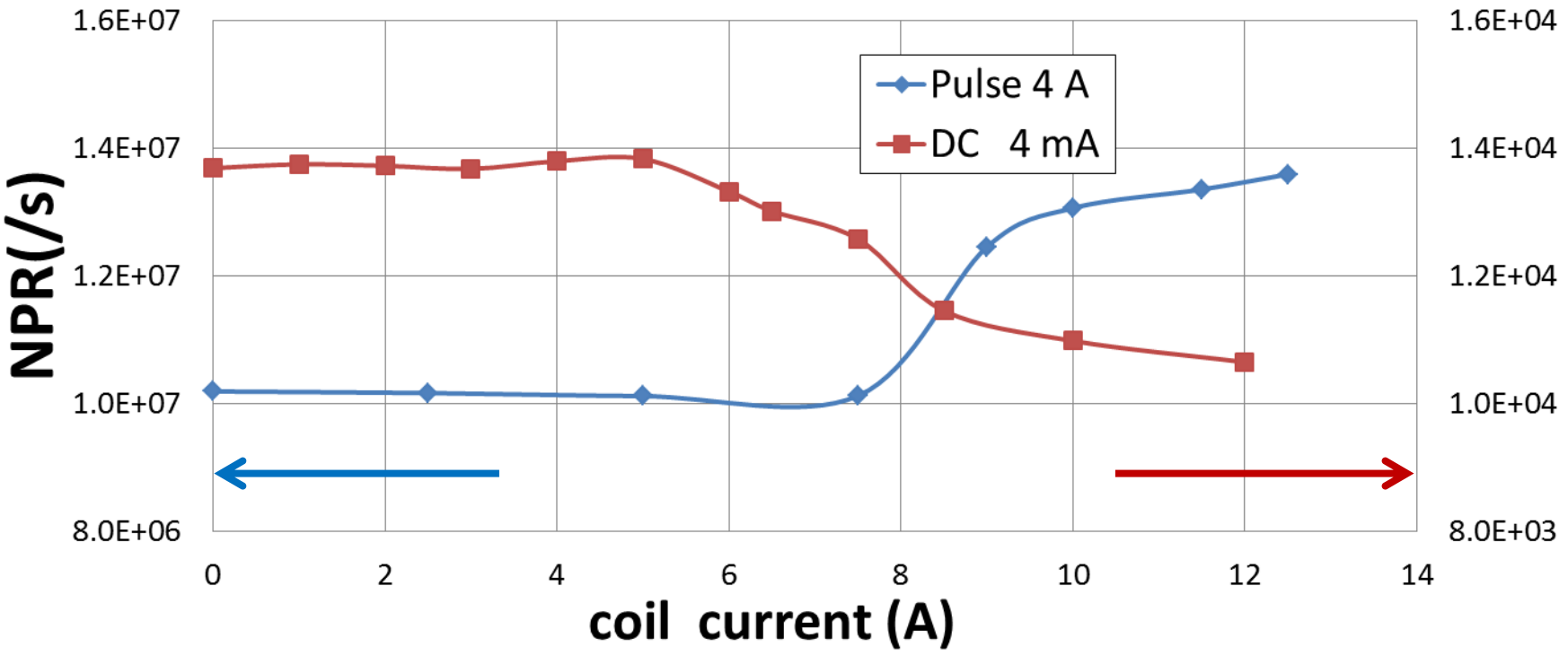
pulse operation

High cathode current can be applied.

Comparison of DC and pulse operation

same potential distribution

Vc=－20 kV　Va=－4.4 kV



Comparison of DC and pulse discharge operation
⇒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.

not much effect
of pressure

generate the ions more outside region?

Ions generated among anode to wall
don't have influence on fusion reaction,
because electric field is week
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。