

# High power and long pulse negative ion production by suppressing of arcing for JT-60SA

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## Summary

- From experimental result, it is found critical arc power is dependent on the amount of electrons flowing into chamber wall. Decreasing magnetic field around filaments can improve critical arc power: less |B| than 15 mT has arc power over 240 kW to applied to JT-60 ion source.
- By suppression of arcing caused by interaction between filament and chamber wall, long pulse, 100 s, plasma operation with high arc power of 50 kW/m<sup>2</sup> (equivalent to 180 kW for JT-60 original arc chamber) was achieved without breakdown.

## Introduction

For JT-60SA neutral beam injector (NBI), the world largest negative ion source is being developed.

### Requirements:

- Beam energy: 500 keV
- Beam current: 22 A (130 A/m<sup>2</sup>)
- Pulse width: 100 s

### Achievements (individually achieved)

Energy	500 kV	10 kV	10 kV
Current	2.8 A	15 A	32 A
Pulse	1 s	100 s	1 s

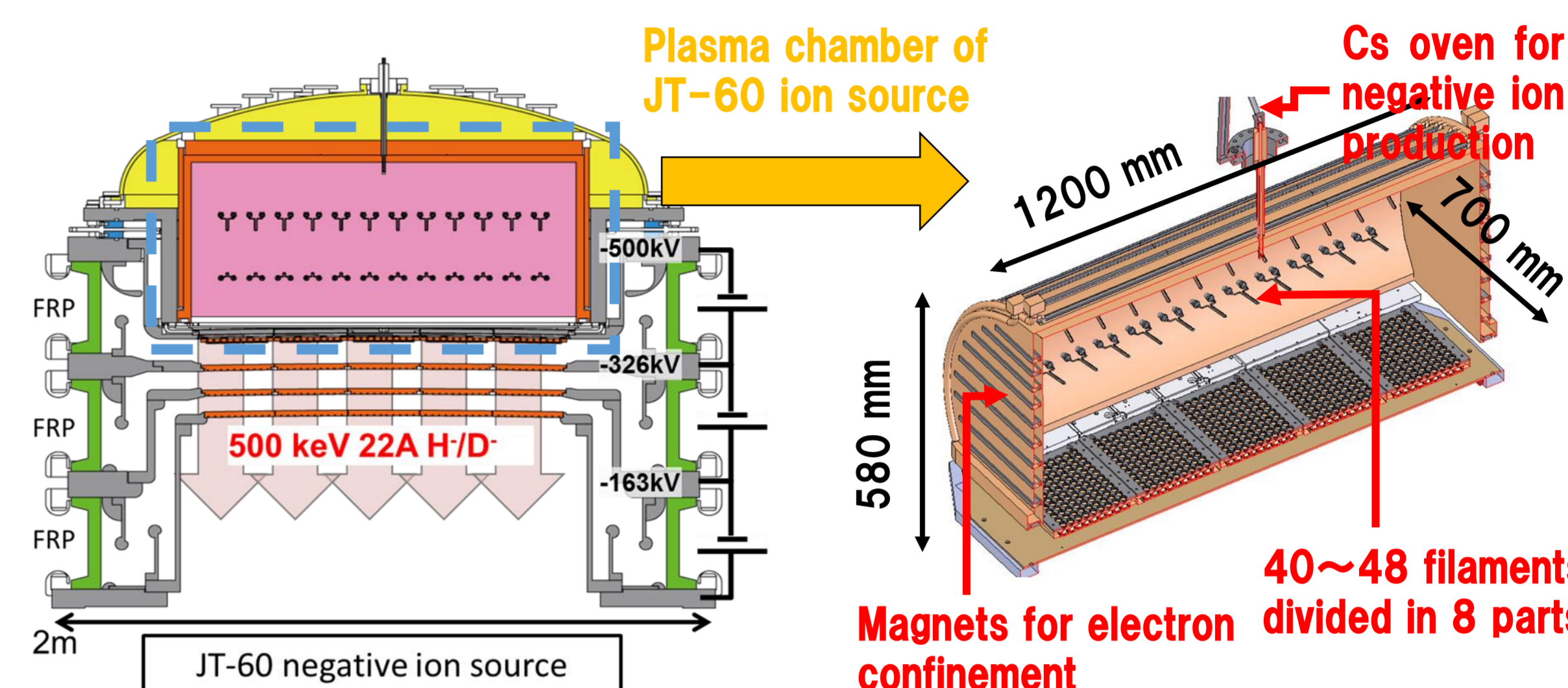
### Issue

Causes of unstable discharge in plasma chamber, so-called "Arcing", has not been fully clarified yet.

- Applicable arc power has been limited in 15 A in current for 100 s by arcing in the high-power long-pulse arc discharge.
- Arcing was induced by Cs seeded to enhance the negative ion production.

### Objective

To achieve 22 A for 100 s, suppression of arcing based on understanding of the cause of arcing is aiming.



## Model of arcing

**Demerged filament (exp. with Cs)**

Arcing spots concentrate at 2 region

**Demerged filament (exp. w/o Cs)**

Arcing spots concentrate at 1 region

Arcing may occur in two different mechanism.

**(1) Caused by interaction with plasma (arcing at top side of filament)**

If there are impurities (Cs, O, etc.): changing of plasma condition caused by impurities may induce arcing.

Plasma density increased

Critical arc power decreased

**(2) Caused by interaction with chamber wall (arcing at root side of filament)**

Electrons flowing into chamber wall are strongly dependent on magnetic field

Arcing may be depends on magnetic field around filaments

Arcing based (2) was considered it occurred even if Cs is not injected. This arcing which can occur in any environment must be suppressed for stable long pulse operation without breakdown.

Experiment in which the magnetic field around filaments has been changed by changing filament position to investigate arcing caused by interaction with chamber wall.

## Result

**Relation between electrons and critical arc power**

Changing magnetic field around filaments by changing insert depth of filaments, "L", caused changing the orbits of emitted electrons from filaments. The orbits of the emitted electrons was obtained using particle orbit calculation software "Omnitrak".

The orbits belonged one of three categories.

- Electrons flowing across plasma
- Electrons flowing longer than mean free path
- Electrons flowing into chamber wall directory

This electrons caused arcing caused by interaction with chamber wall

**Omnitrak simulation**

Short flight path electrons decrease with insert depth of filaments

**Experimental result**

At maximum, difference might be 30 %

Parc.crit increase with insert depth of filaments

**Magnetic field along filament direction B [T]**

Deeper insert depth gave less magnetic field

**P\_arc,crit against L was measured**

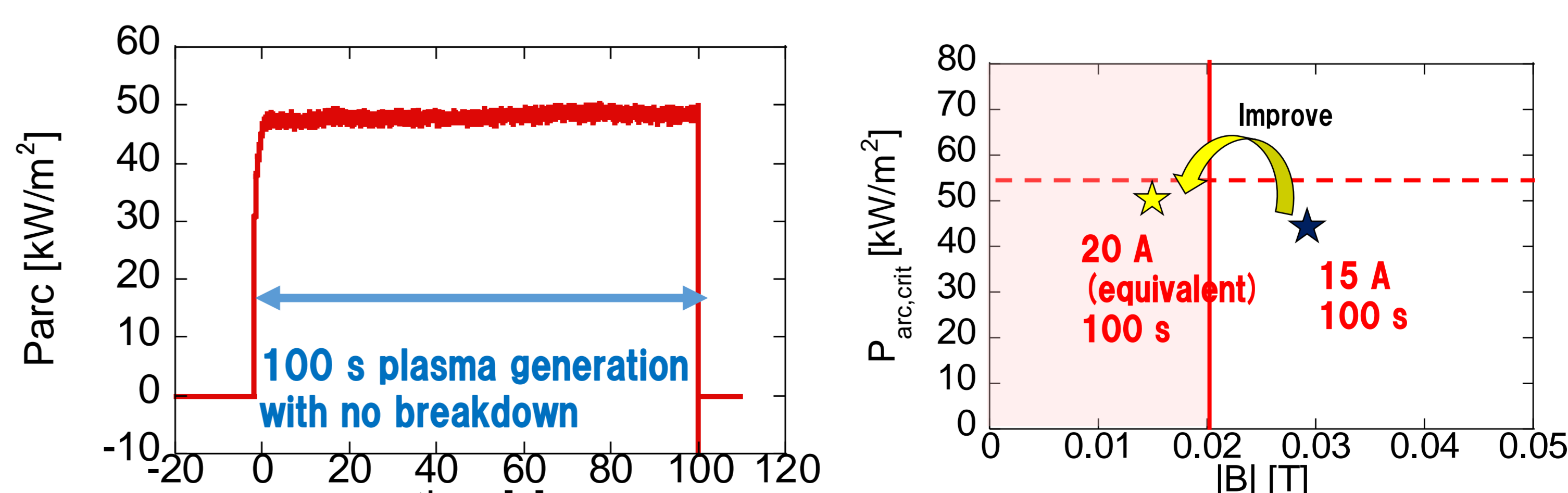
Equivalent to 200 kW for JT-60SA

Suitable to 60SA operation

If average magnetic field less than 20 mT, applied arc power of 200 kW may be achieved in JT-60 ion source.

## Applying the result to long pulse operation

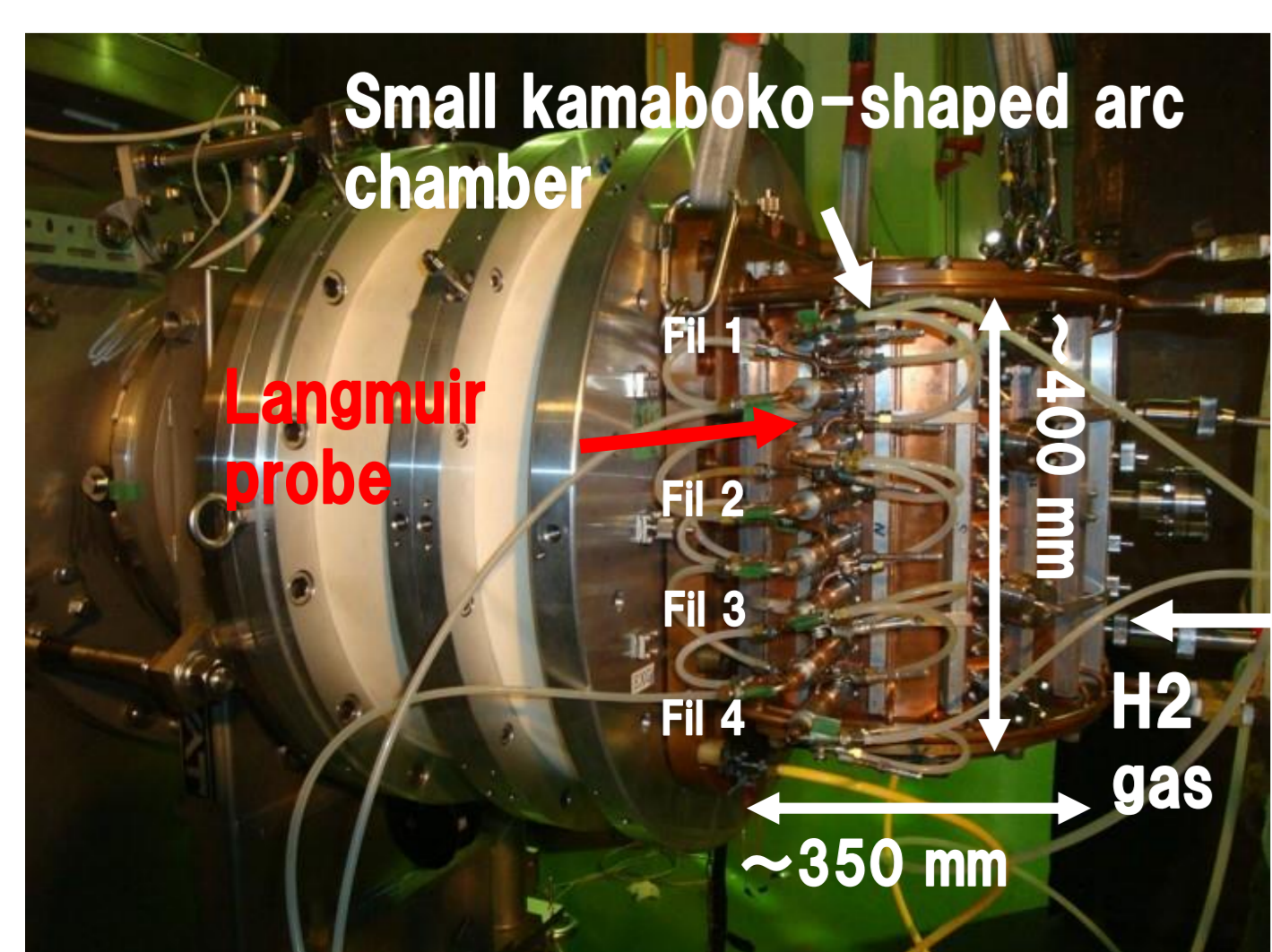
The result applied to experiment of JT60 ion source with 1/3 scale arc chamber for demonstration of high power and long pulse operation.



After improving filament position, the beam pulse has been successfully extended to 100 s with arc power of 50 kW / m<sup>2</sup> (equivalent to 180 kW for JT-60 original arc chamber), even after total Cs injection of 0.8 g.

## Experimental Set up

1/3-Scale ion source was employed  
It has same physical model as JT-60 ion source  
This ion source can simulate JT-60 ion source by scaling



Parameters	JT-60 ion source	1/3 scale ion source
Type of ion source	Arc discharge	Arc discharge
Size of chamber	φ700 mm × 1200 mm	φ350 mm × 400 mm
Surface area of arc chamber	3.45 m <sup>2</sup>	0.545 m <sup>2</sup>
P <sub>arc</sub> required for 130 A/m <sup>2</sup>	200 kW	31 kW