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日本大学

2016 US-Japan Workshop on Compact Torus
Aug 22-24, 2016, Irvine, California, USA

Topological Transition and Inductive Current Drive of a Translated Field-Reversed Configuration

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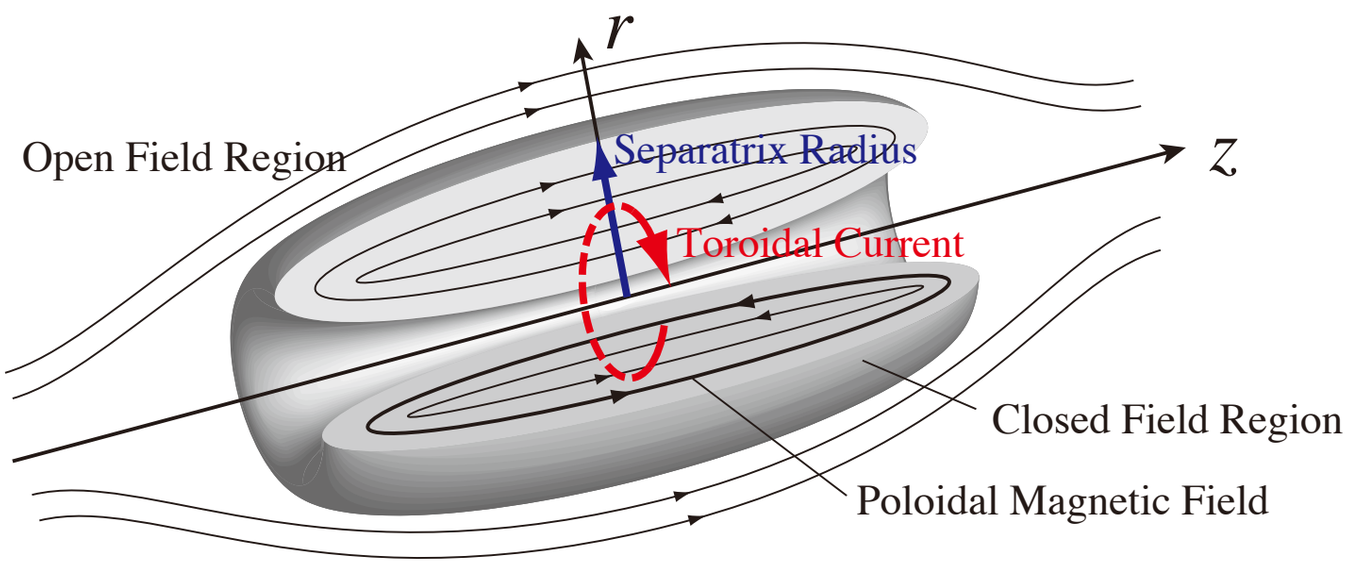
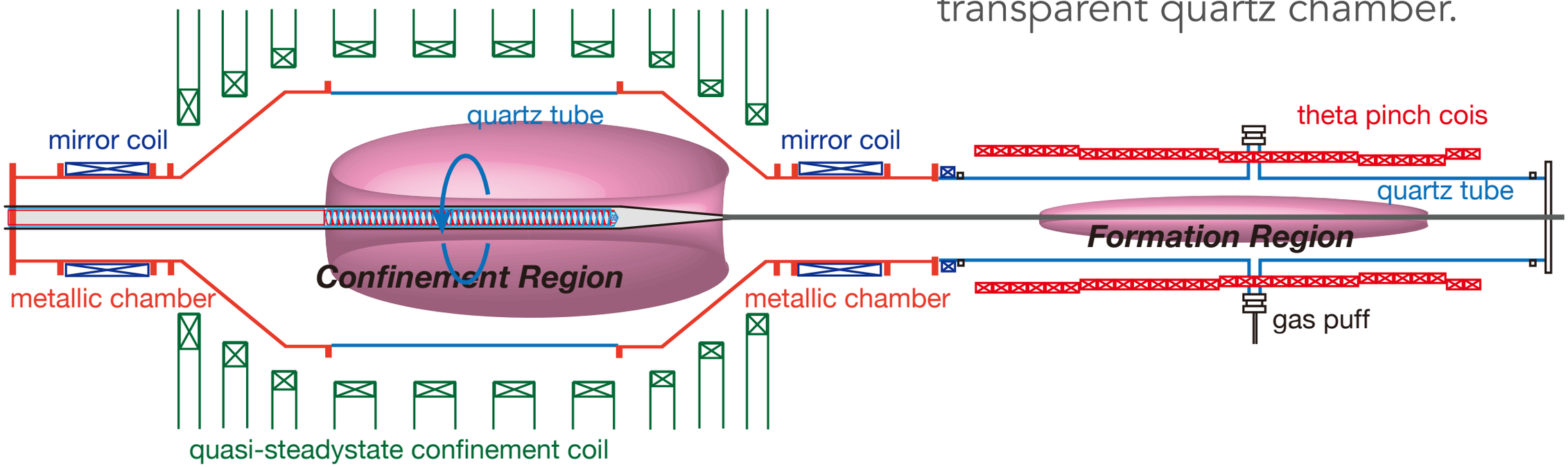
Overview of the experiment



As one of the tools to study "CT related" plasma physics, we have demonstrated application of a center structure onto a conventional theta-pinch FRC.

The series of experiments have been conducted on the FAT facility which has a theta-pinch type formation and large bore confinement region with transparent quartz chamber.



Motivations

This development has been conducted for following CT related subjects.

1. Extend FRC's lifetime by the current drive.
2. Amplify the poloidal flux to confine tangentially injected fast beam ions.
3. Study the effect of topological difference between simply-connected and torus geometry on stability.
4. Stability and relaxation study from high-beta theta-pinch FRC side.

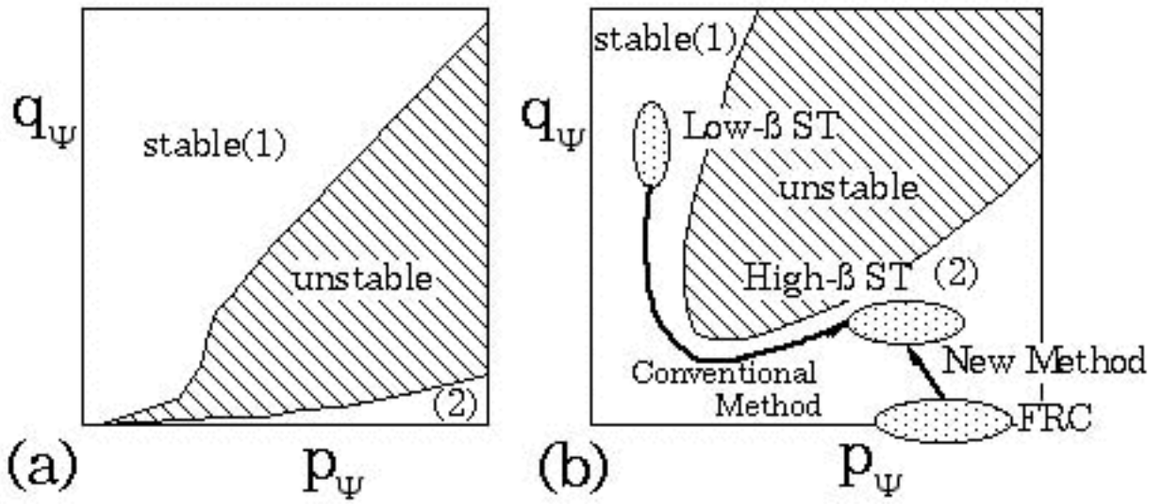
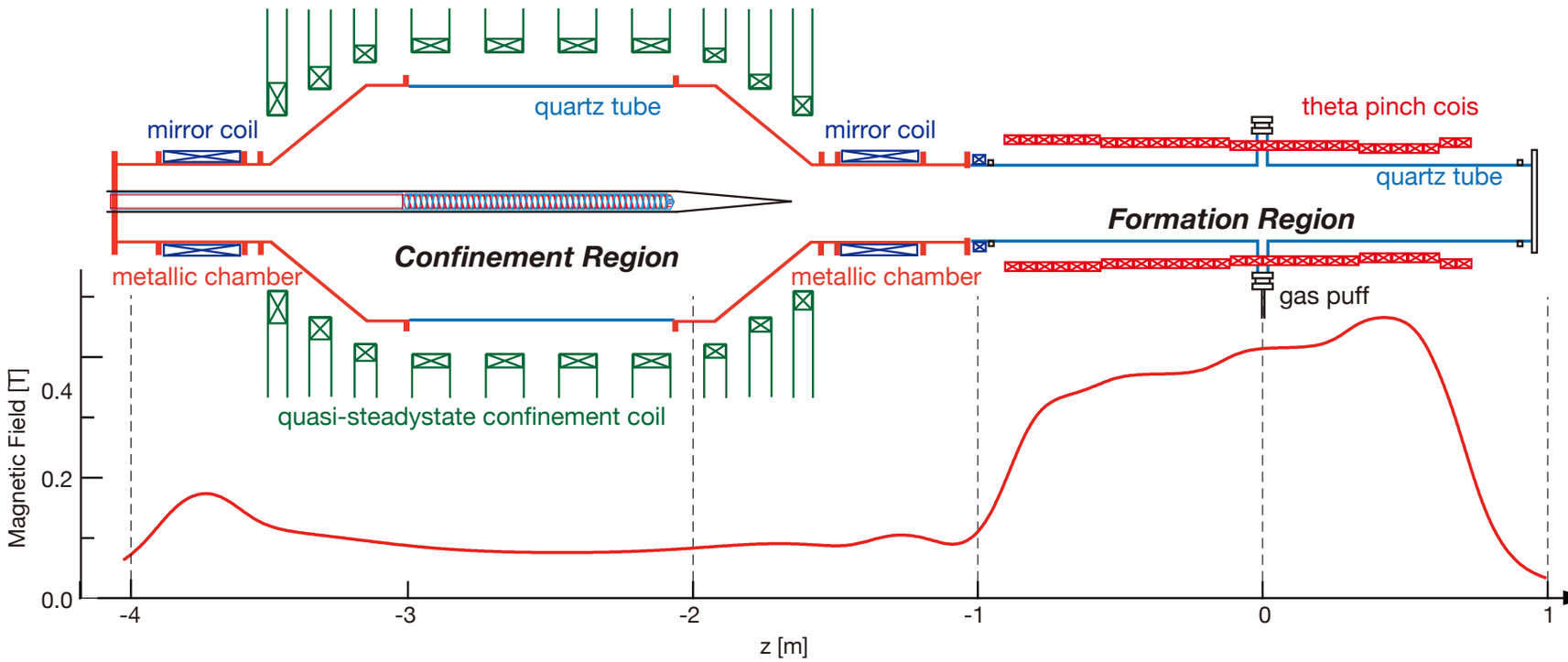


Fig. 2 q Ψ– p Ψ diagrams of (a) conventional tokamak (aspect ratio A≈5), (b) low aspect ratio tokamak (ST) (A<1.5).

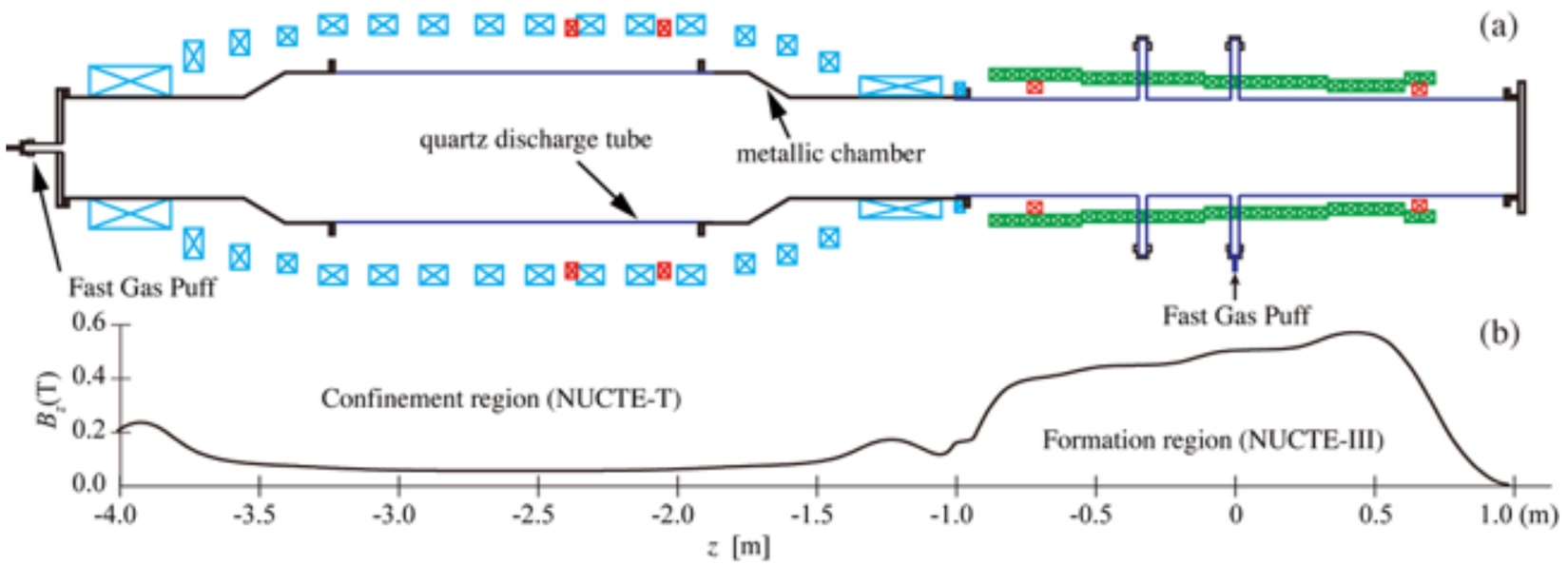
⬅ This technique can be a tool to form High-beta ST from FRC side.

Translation Facilities at Nihon Univ

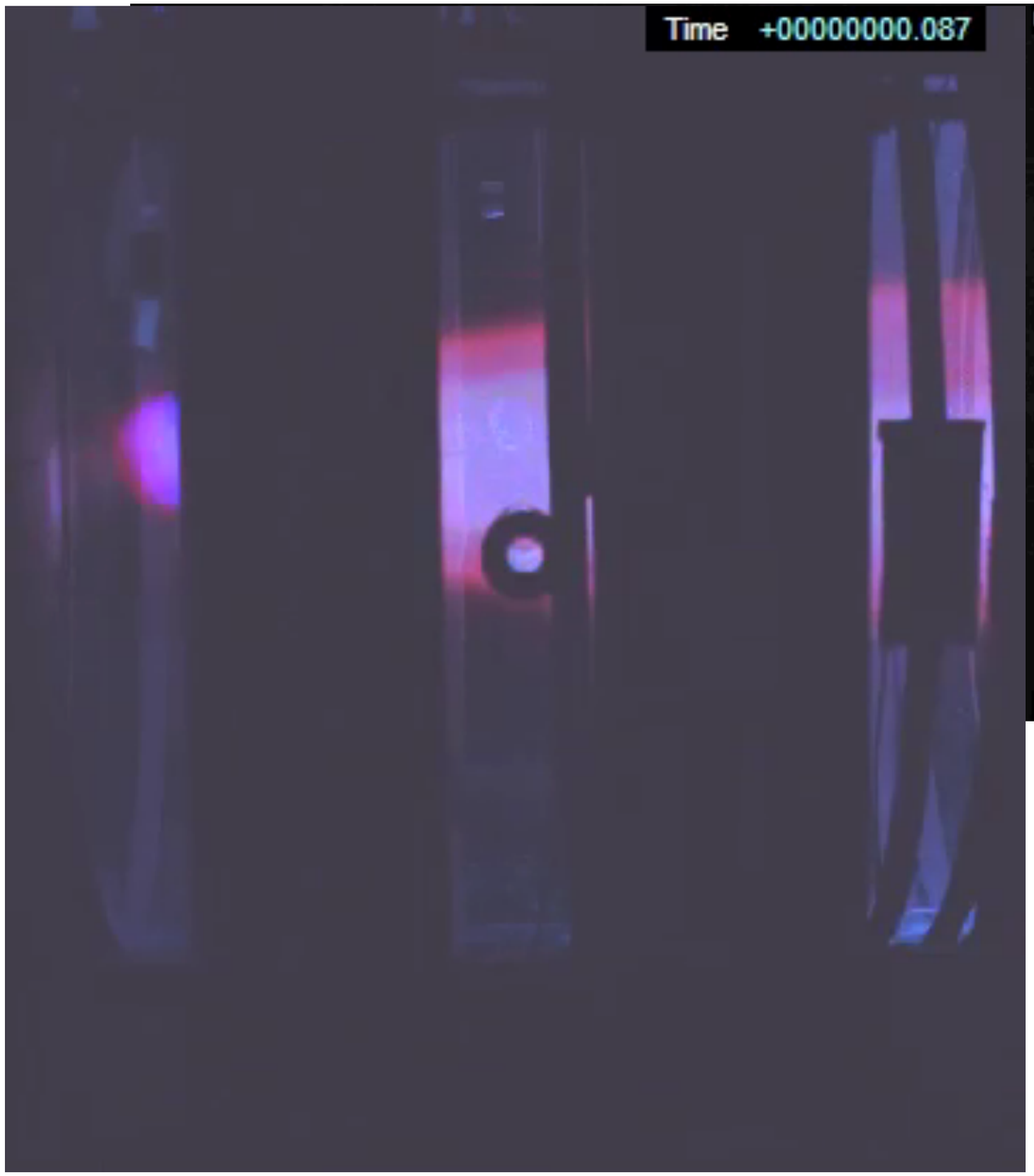
	NUCTE-T	FAT
Mirror Ratio	3 - 4	5 - 10
Aspect Ratio	4.5	2.3
B_0[T]	0.08	0.09
r_c [cm]	61	103



- "FAT" has a quasi-spherical boundary on the confinement region.
- With relatively higher mirror ratio, FRC expand radially while it keeps the length.



Translation Facilities at Nihon Univ



➡ Demonstration of a FRC translation through a guide magnetic field.

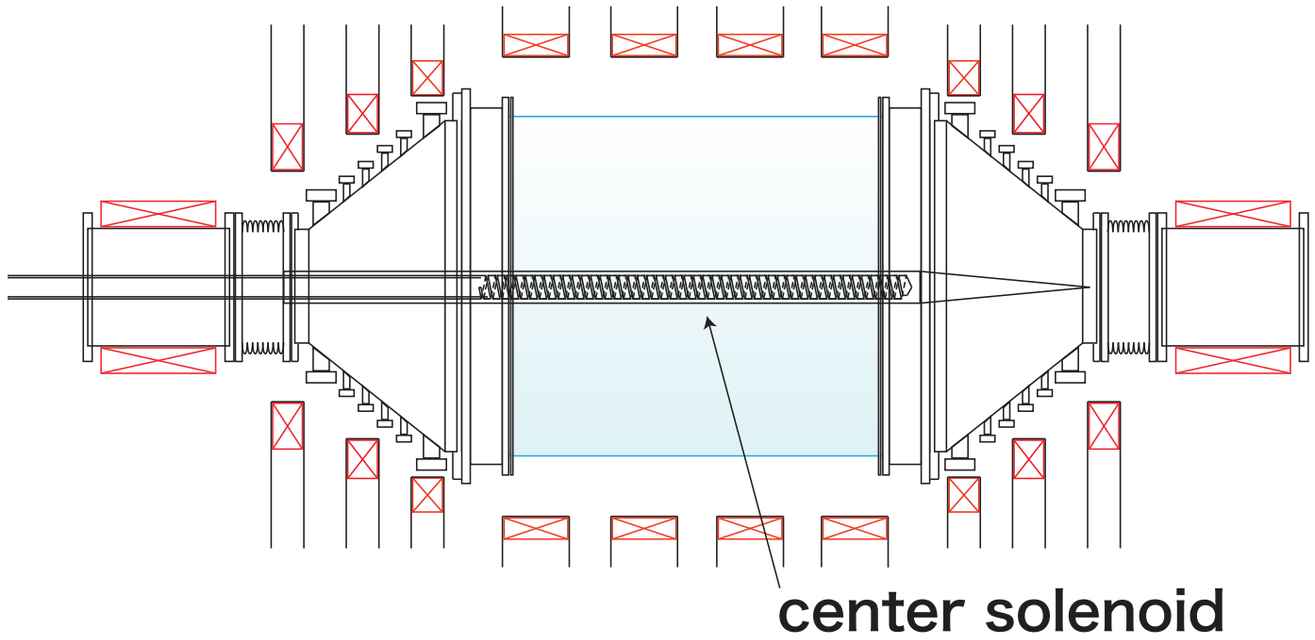
➡ On FAT, translation speed ranges from 80 - 220km/s in the current condition.

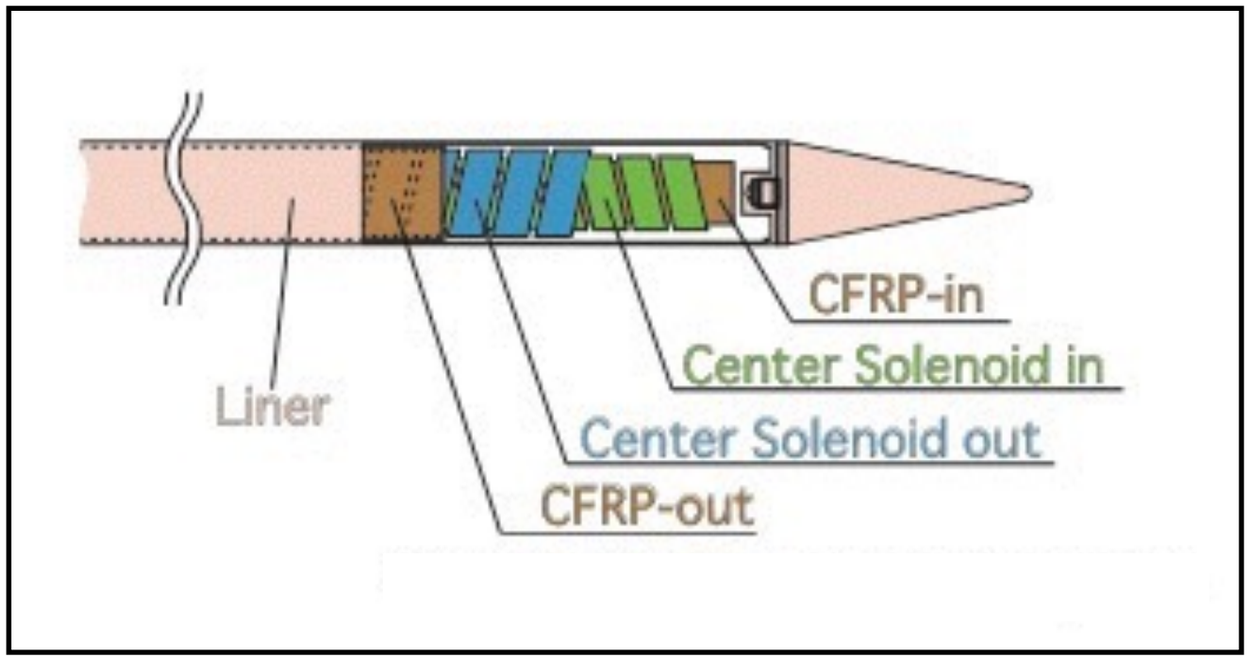
HS-106E, nac image technology inc., Max 1,250,000fps (0.8μs of repetition time)

Center solenoid

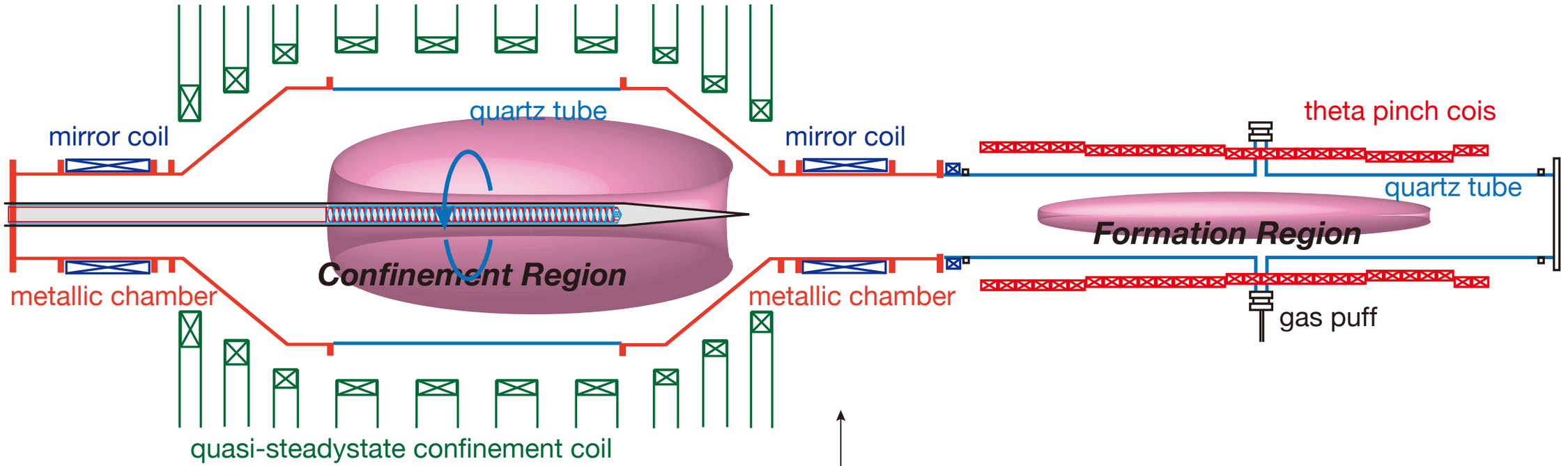
A “cantilever” center solenoid is installed on the geometrical axis of a quasi-spherical confinement region.

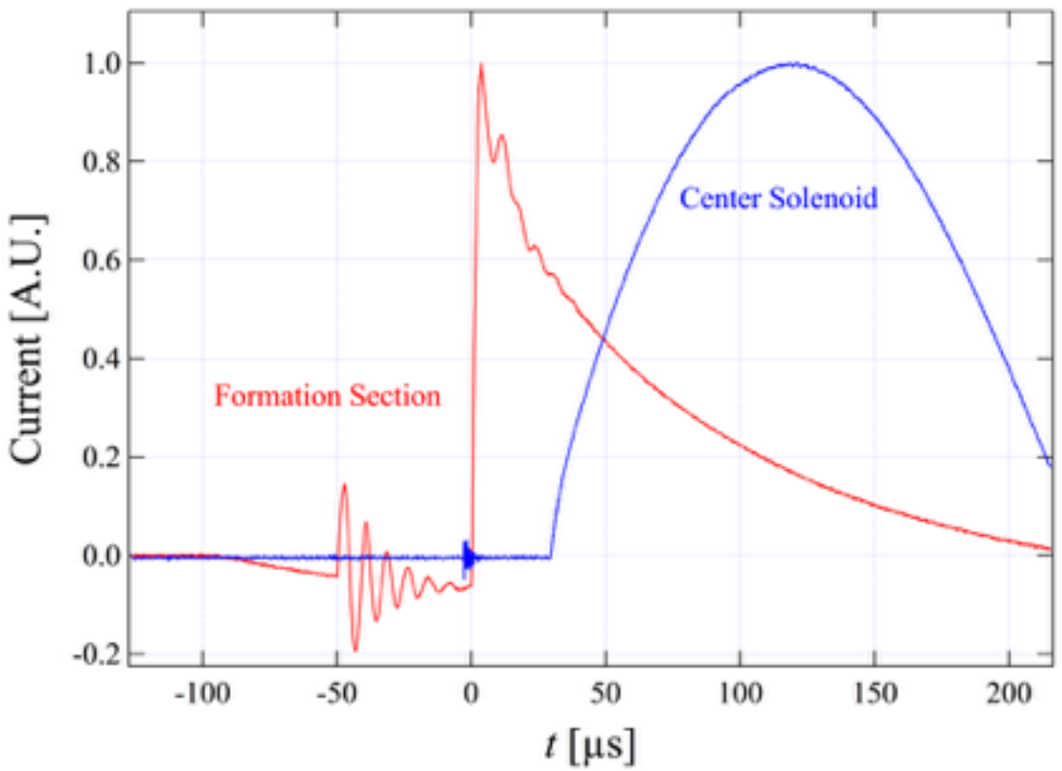
	φ (mm)	Length (mm)
Liner	60.5	2100
Outer layer	55	990
Inner layer	45	

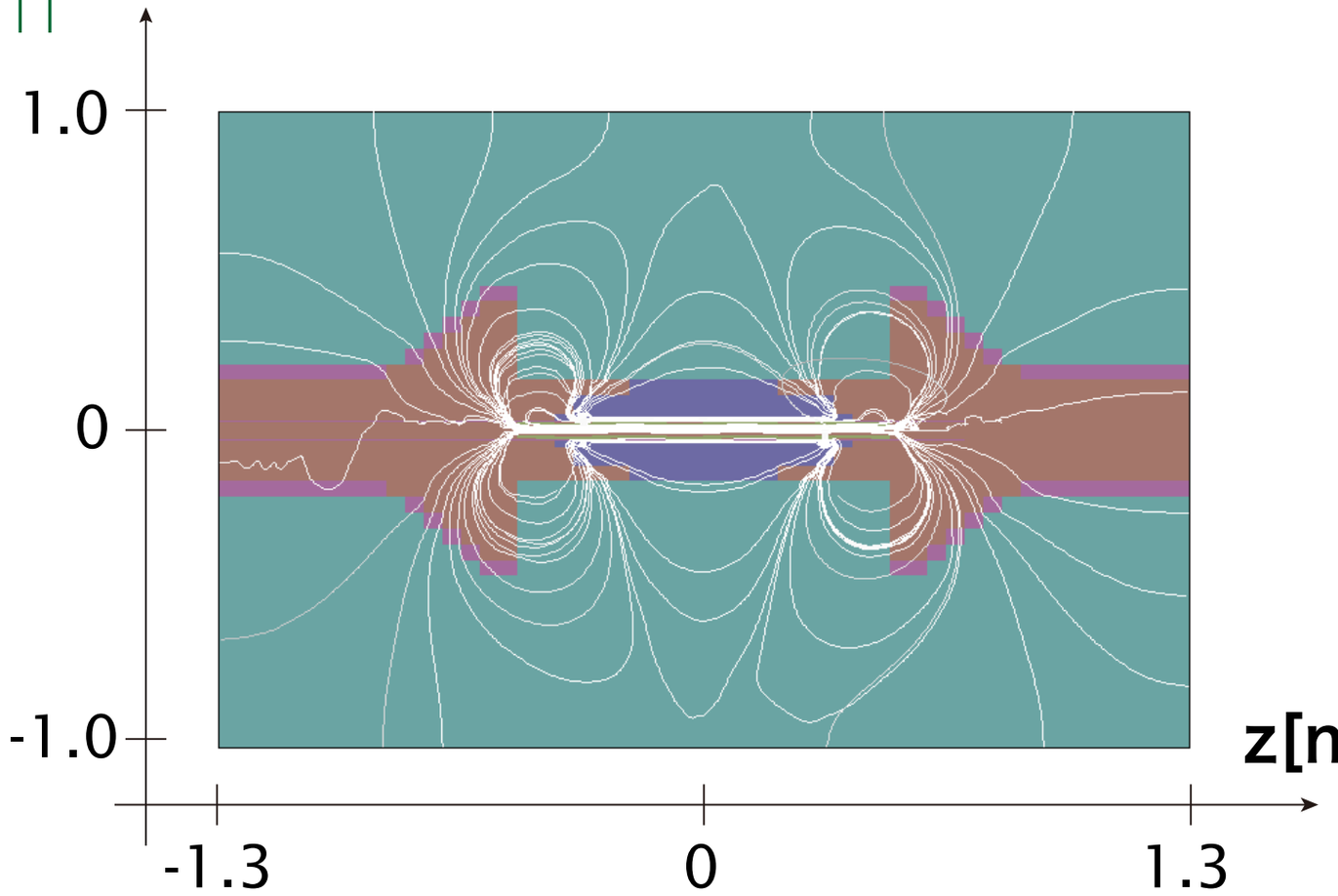




Sequence of Formation and Current Drive



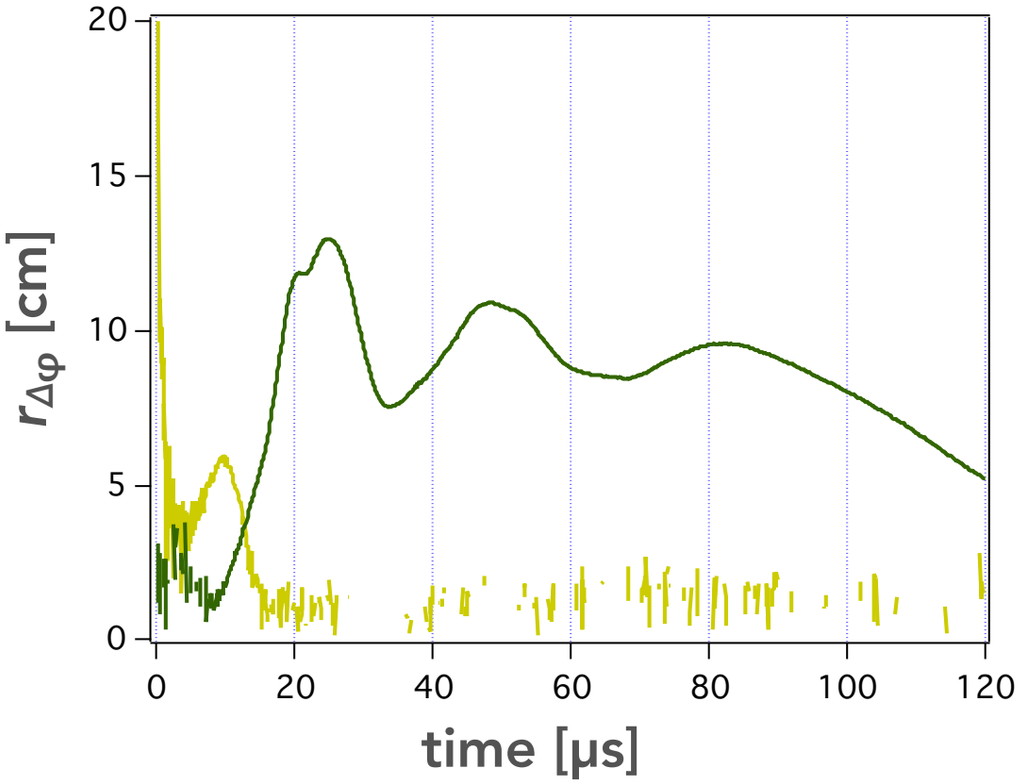


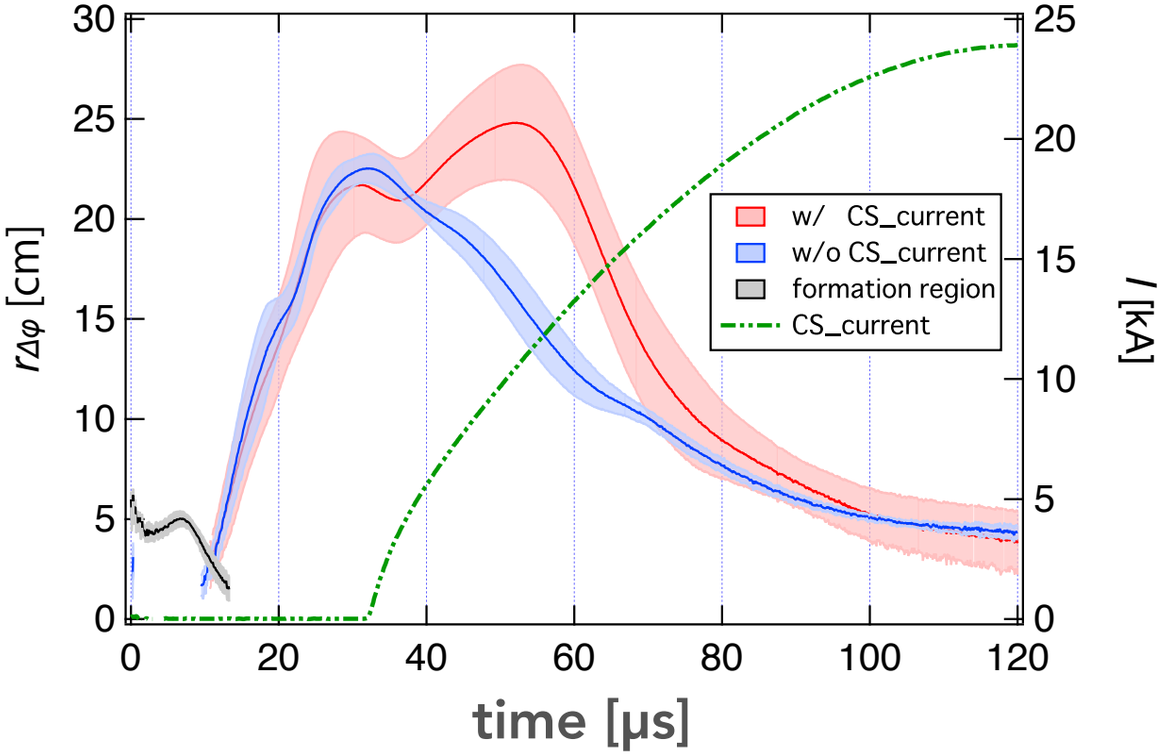


Injection of FRC into the torus boundary

- An FRTP-generated FRC is translated w/o any disruptive perturbation.
- The FRC with $10^{21}m^{-3}$ of electron density and ~ 40 eV in ion temperature is translated into the confinement region with a CS installed.
- The range of translation velocity is between 150 – 200km/s.

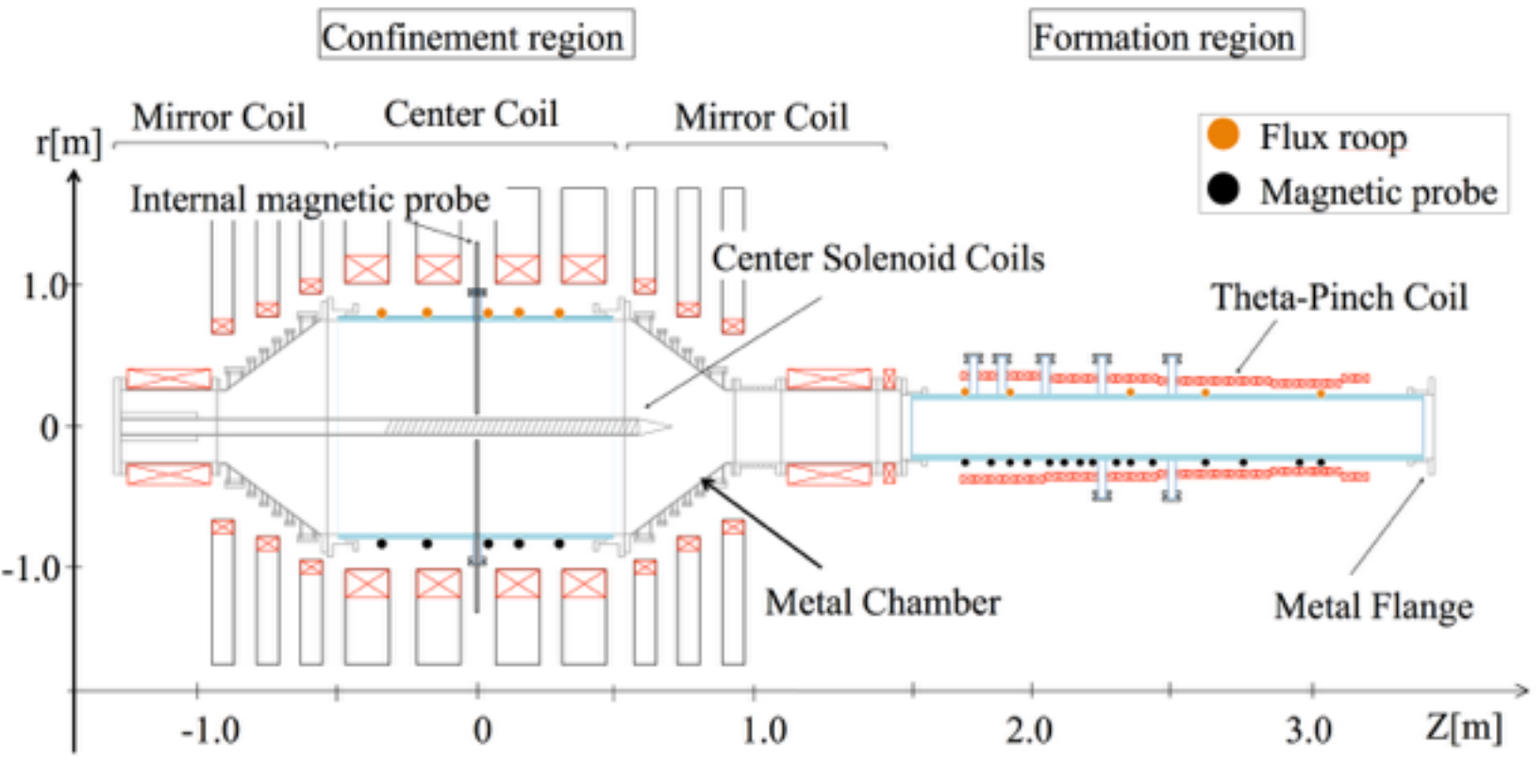
➡ CS amplifies poloidal flux (toroidal current) , then a FRC dies quickly….

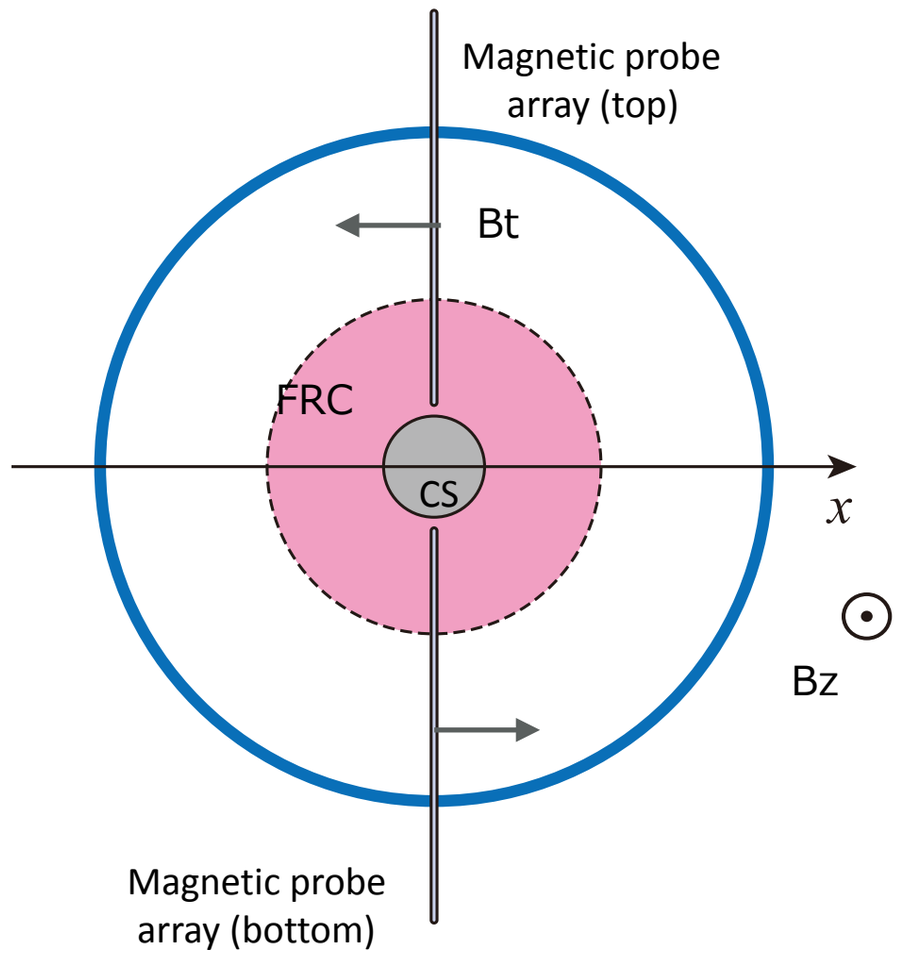




Time evolutions of (a) plasma radius (z = 0.30 m) and input current on a center solenoid.

Internal Magnetic Field Measurement



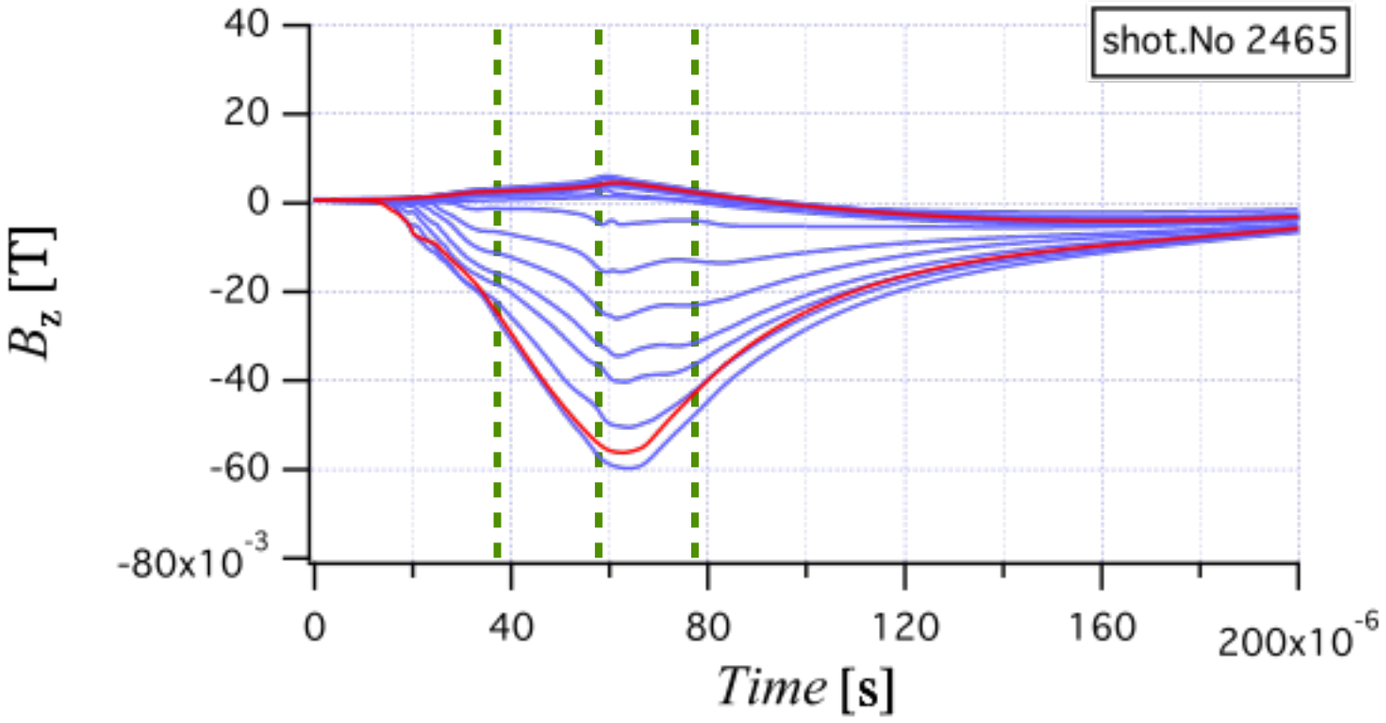


Specifications of magnetic probe

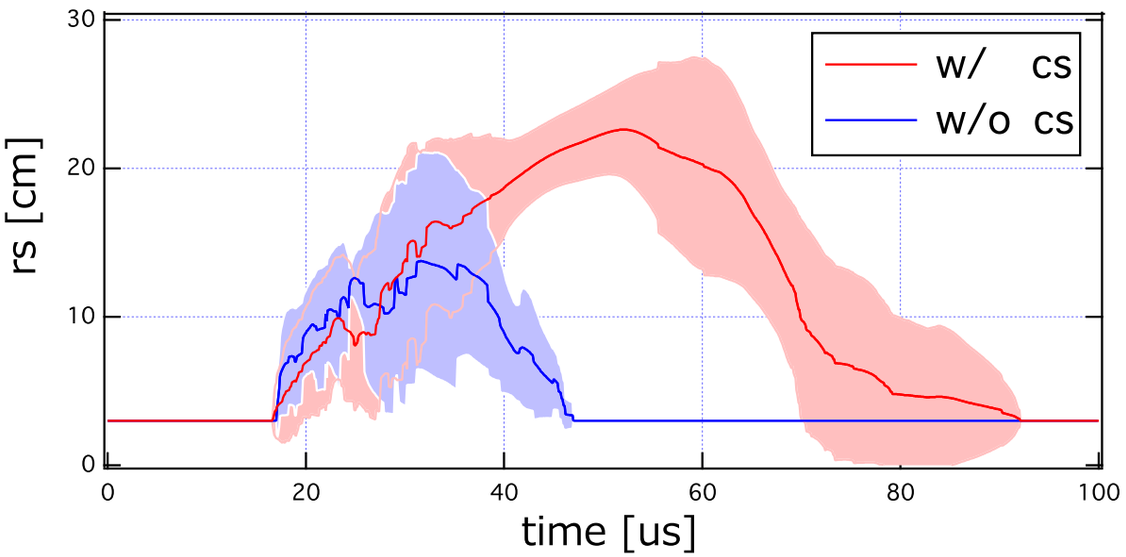
	Bz	Bt	Pitch	Turn Number	Jacket
Magnetic probe array (top)	2ch	14ch	0.5	20	Al_2O_3
Magnetic probe array (bottom)	16ch	16ch	1.0	20	Al_2O_3

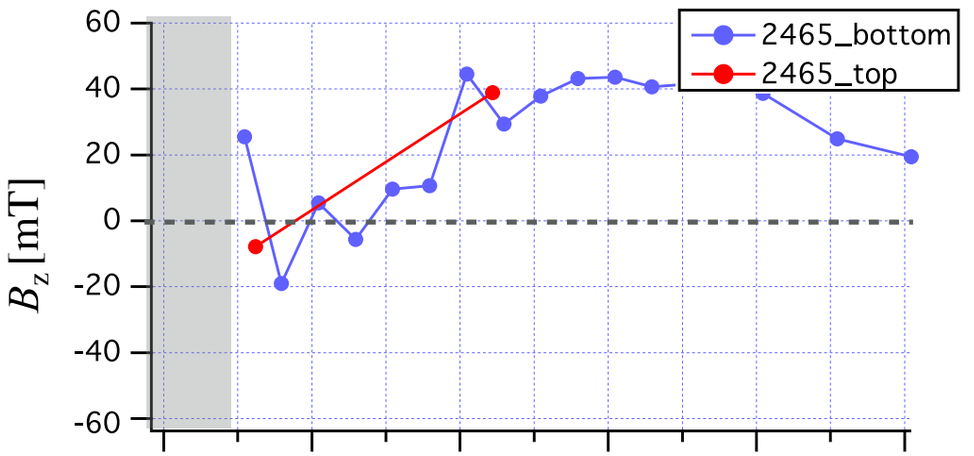
Radial profile of toroidal and poloidal magnetic field is measured at two toroidal positions .

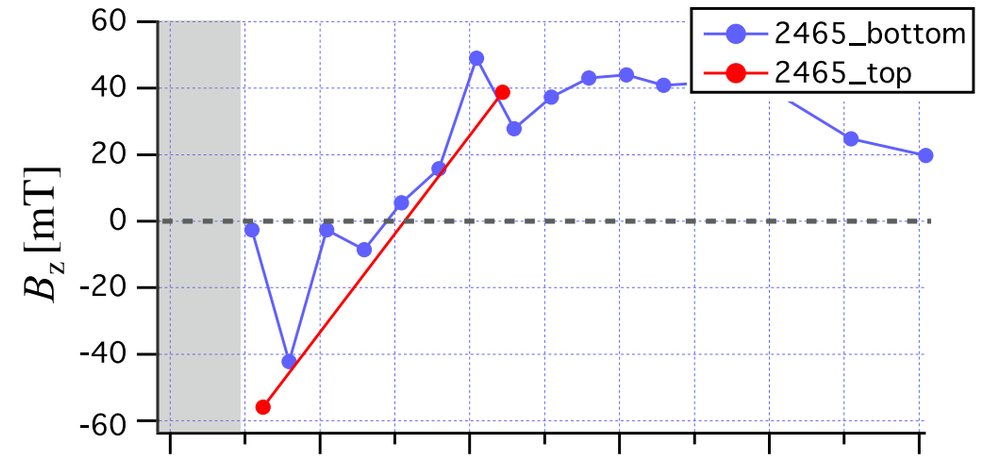
Magnetic Field Profile

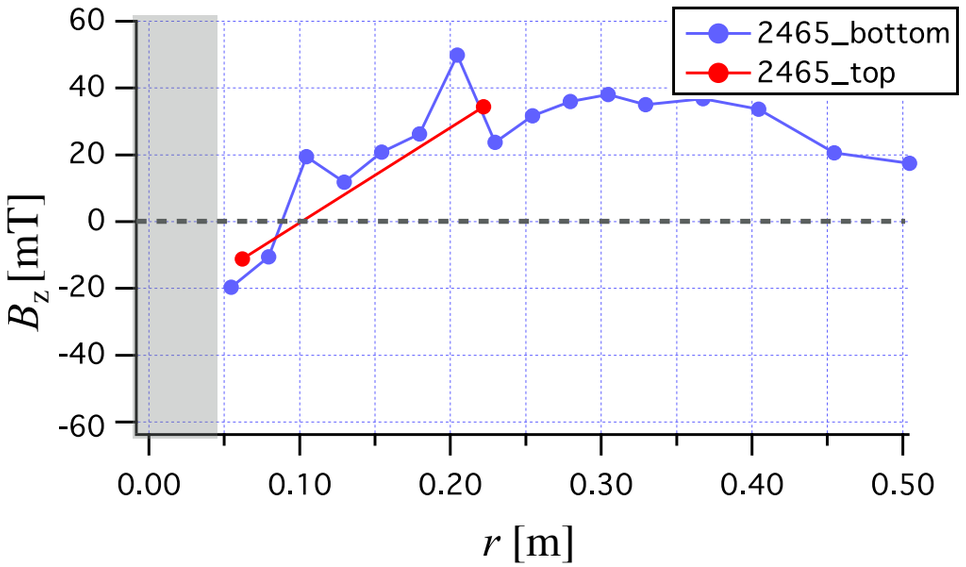


- Internal magnetic field measurement shows increased reversed component of poloidal flux.

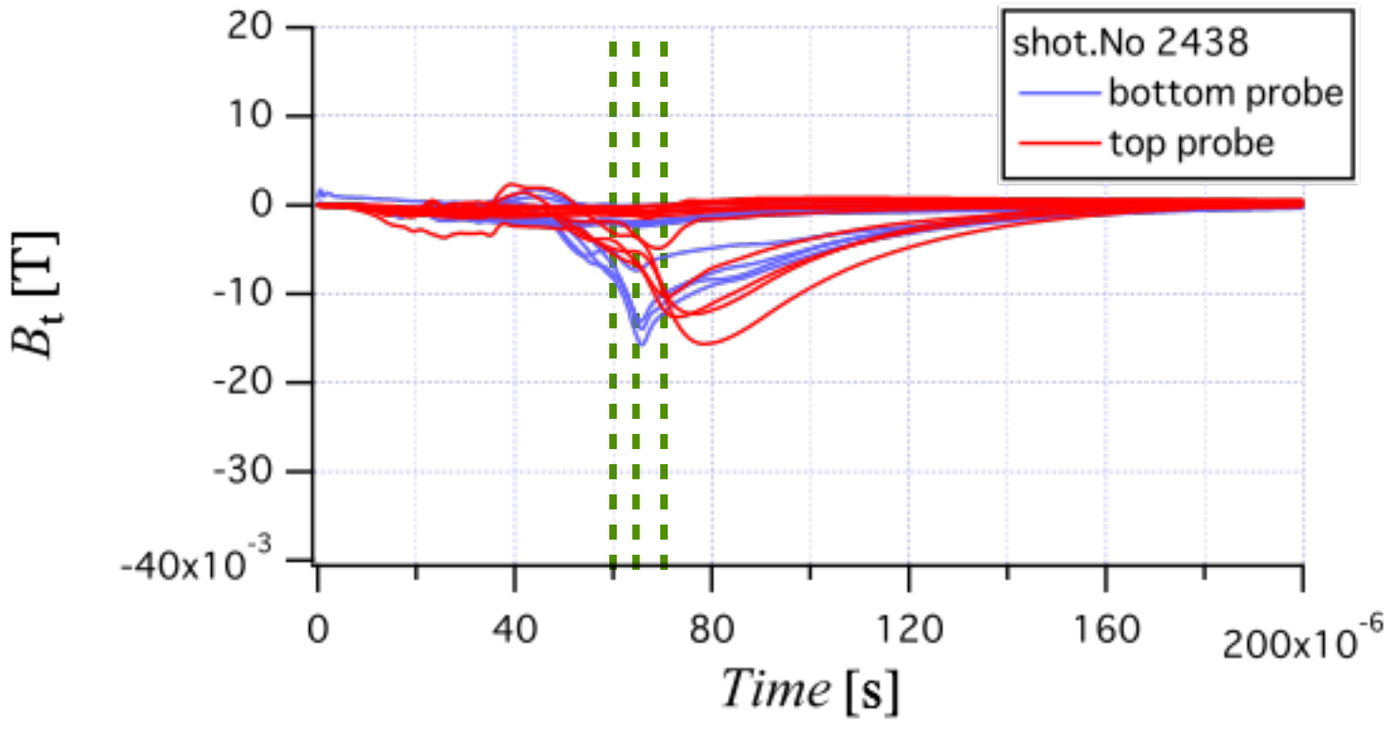








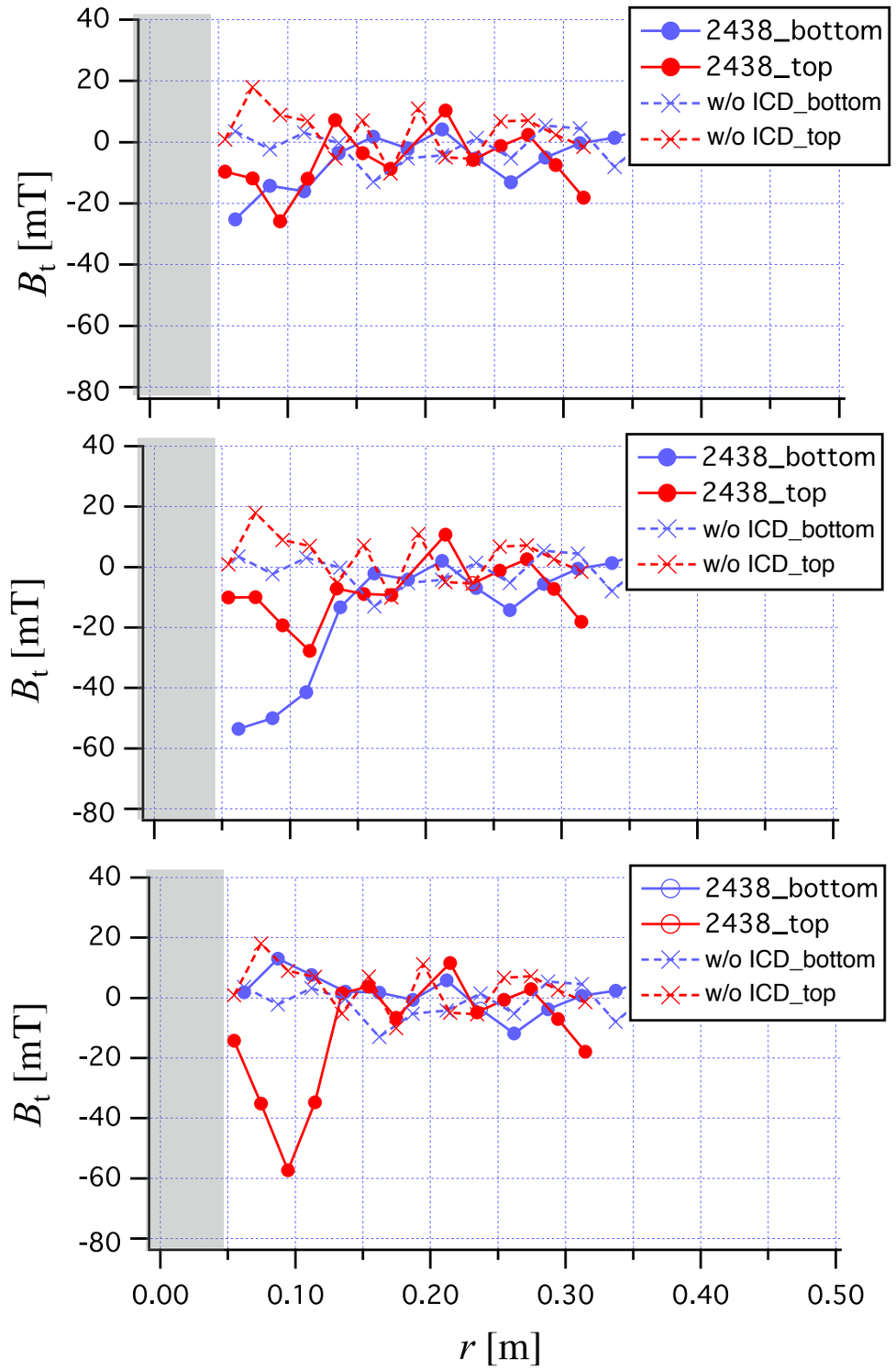
Magnetic Field Profile



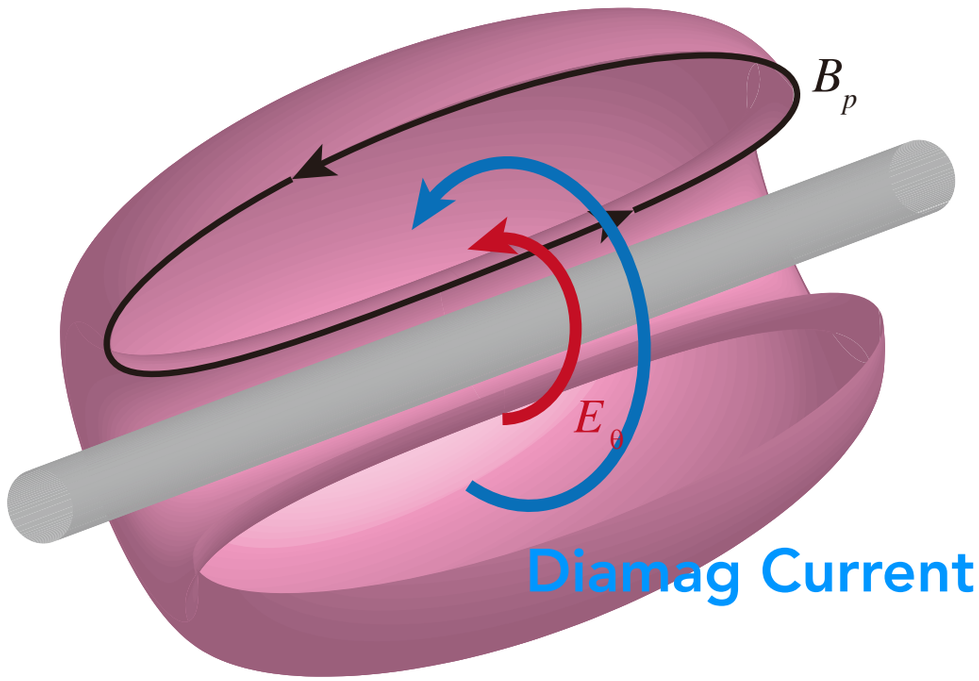
- Toroidal magnetic field is induced by OH current on the CS.

➡ Is this transient phenomena during a relaxation?

➡ It is maintained for several tens of alfven times.



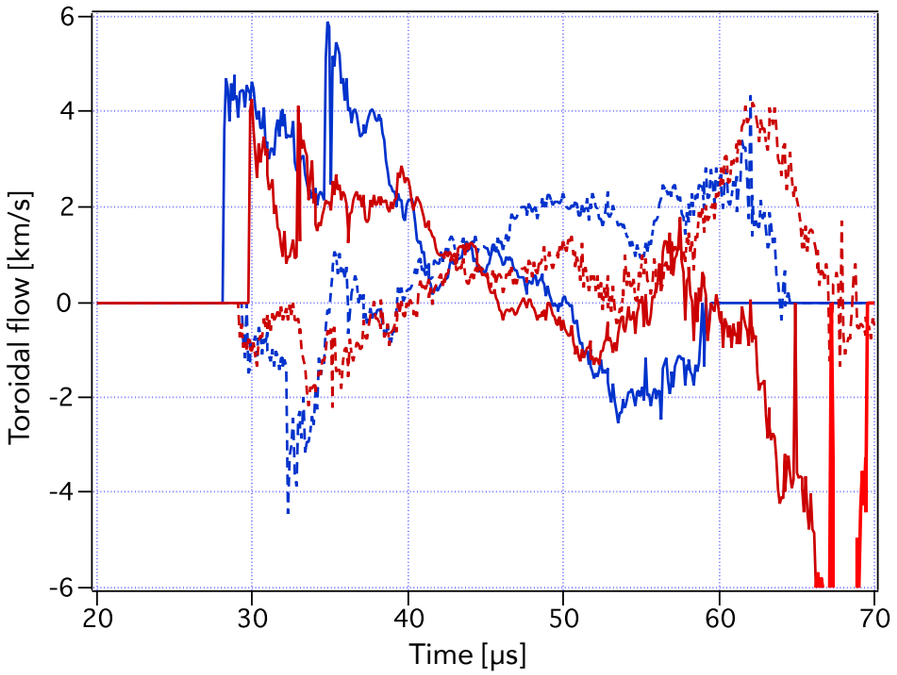
Inductive Current Drive in a FRC



- How does the toroidal electric field work onto the electrons (and ions)?
- Conventional FRC only has poloidal flux and perpendicular diamag current.

➡ E_θ cannot drive electrons directly into the toroidal direction.

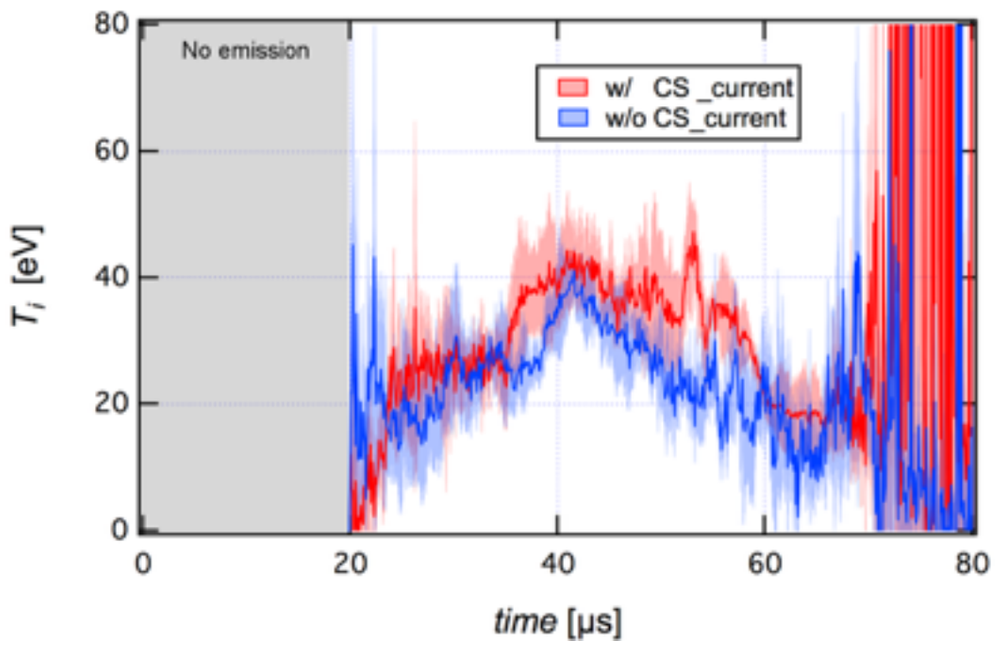
Ion Doppler Spectroscopy

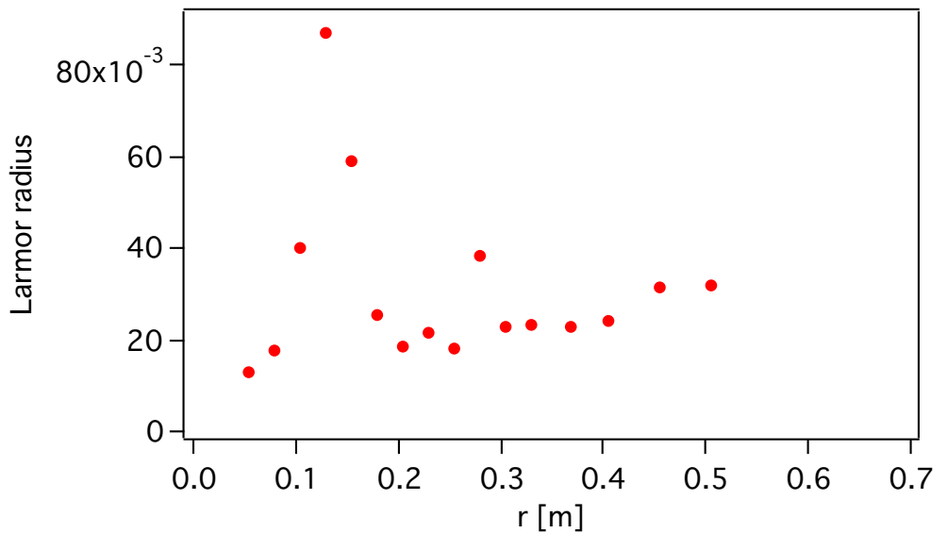


Doppler spectroscopy doesn't indicate any significant change in ion temperature and toroidal flow.

Toroidal flow is in the range of 2 - 4 km/s (about 1/10 of confinement region). Accelerated in the ion diamagnetic direction.

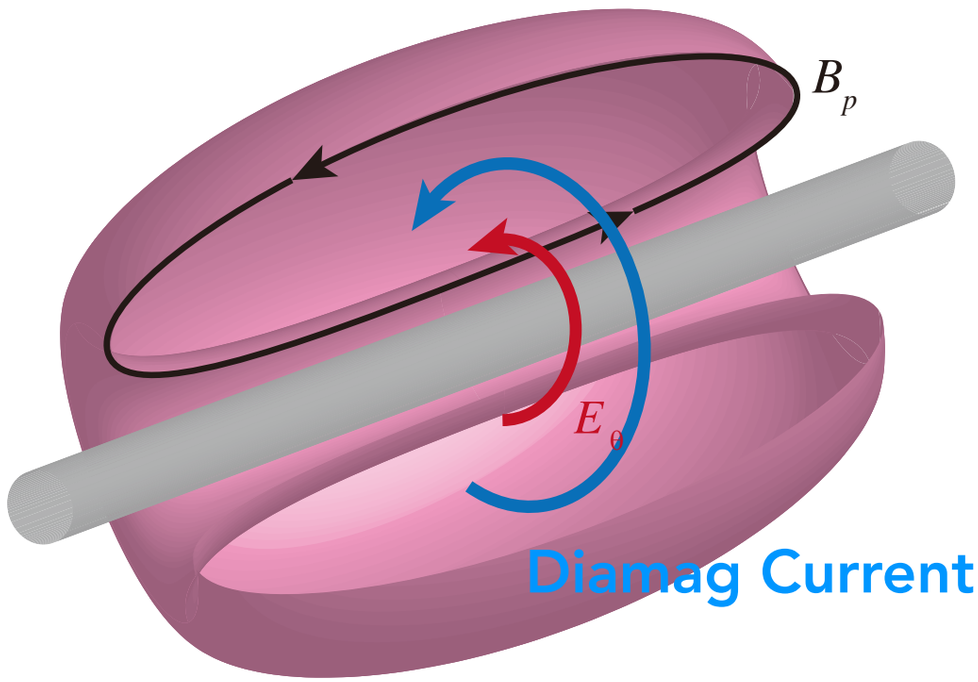
- Ion flow and temperature measures at r = 15cm (magnetic axis).

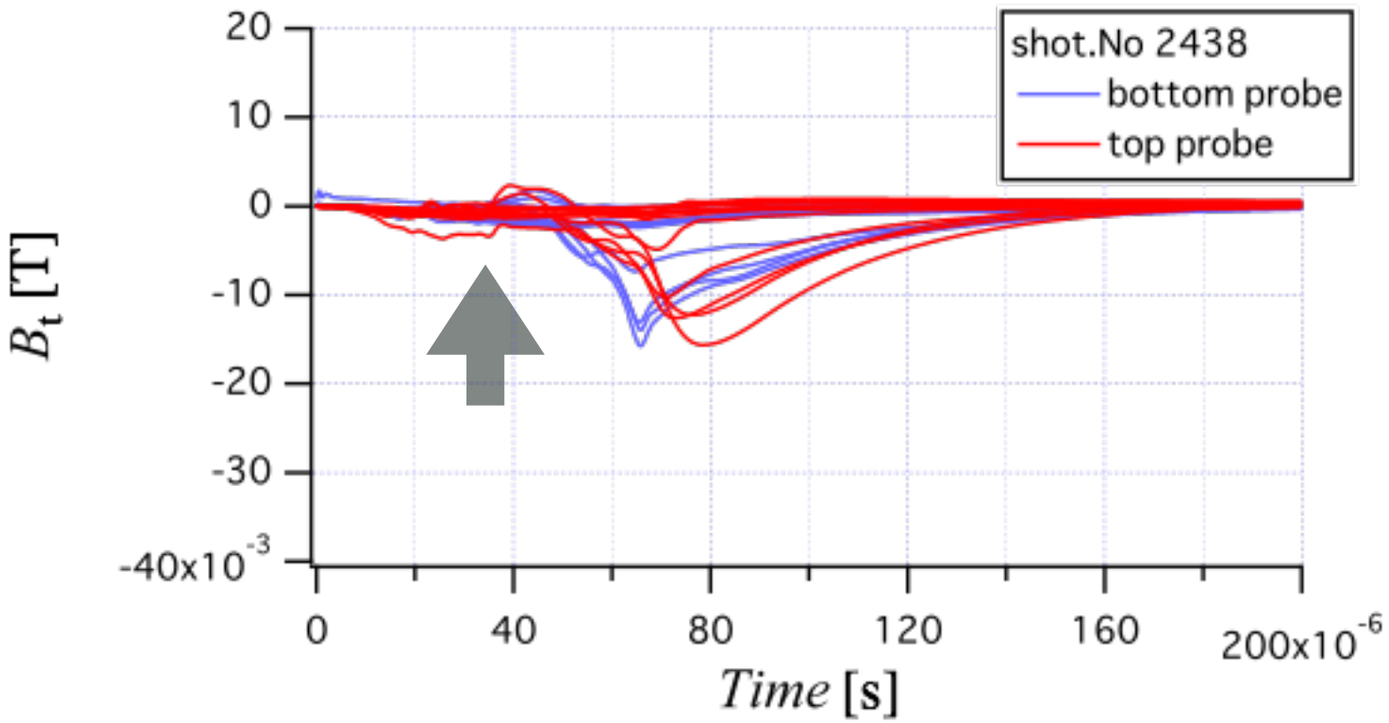




- Larmor radius of deuterium ion is around 2 - 8cm in the FRC.

Inductive current drive in a FRC



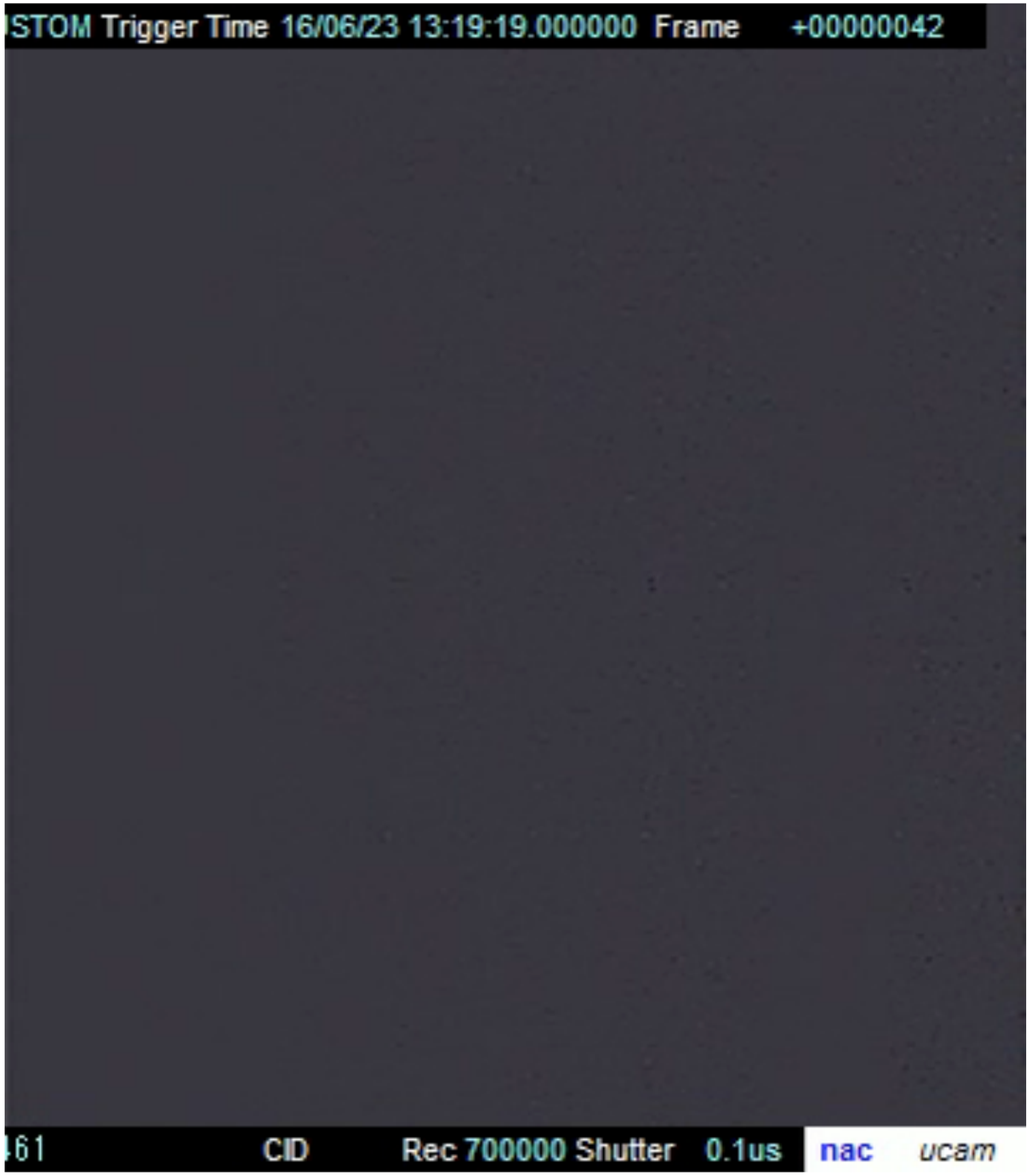


- How does the toroidal electric field work onto the electrons (and ions)?
- Conventional FRC only has poloidal flux and perpendicular diamag (dominantly electron?) current.

➡ E_θ cannot drive electrons directly into the toroidal direction.

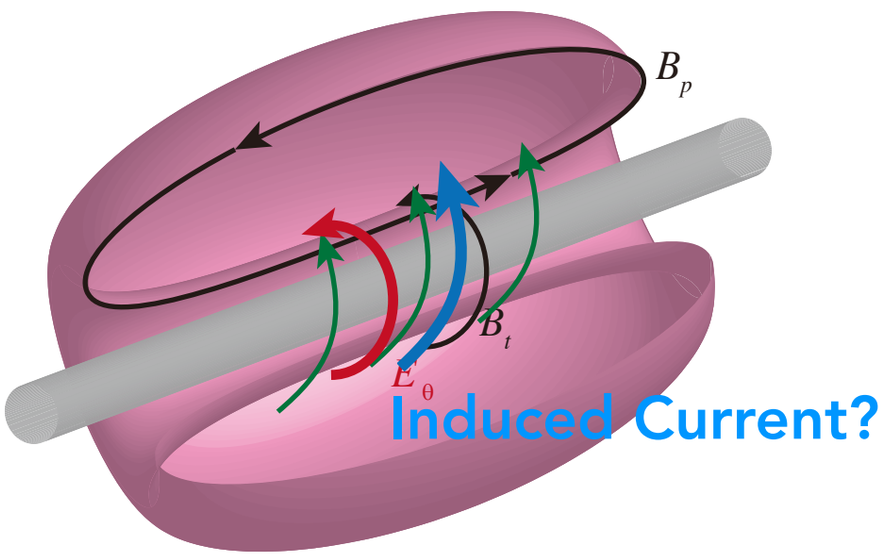
➡ Ion current is insufficient to build-up the observed poloidal flux.

Fast Camera Images



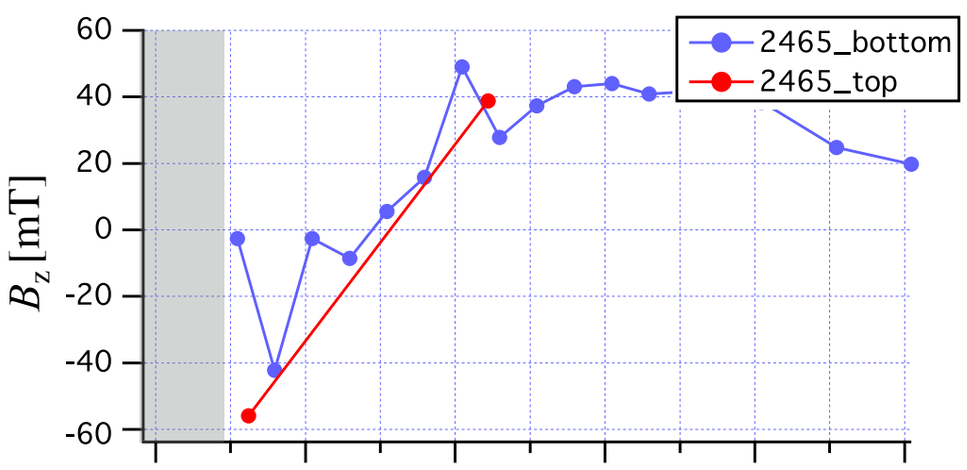
- Kink (n = 1) mode can be seen during and after translation process.
- This can be a source of observed toroidal magnetic field.

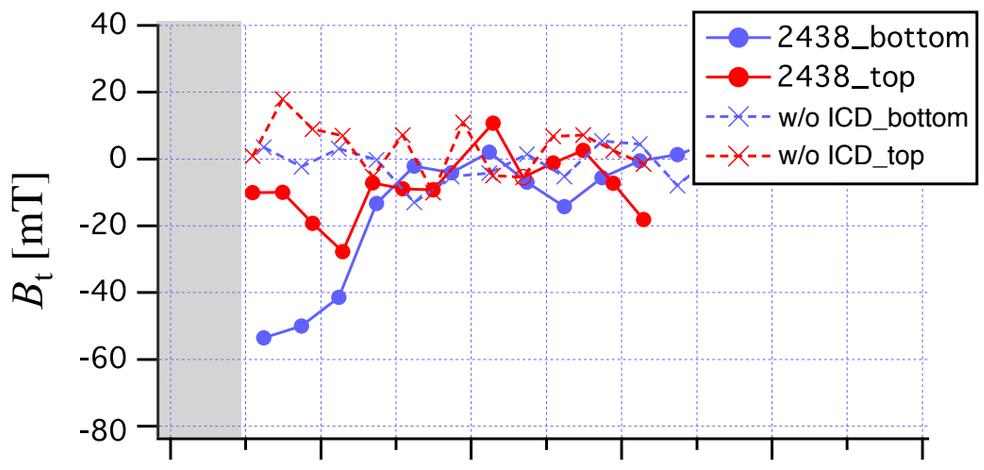
Picture of inductive current drive in a FRC



- Toroidal magnetic flux could form helical magnetic field structure.
- Electrons can be accelerated along the helical magnetic field line by induced E_θ.

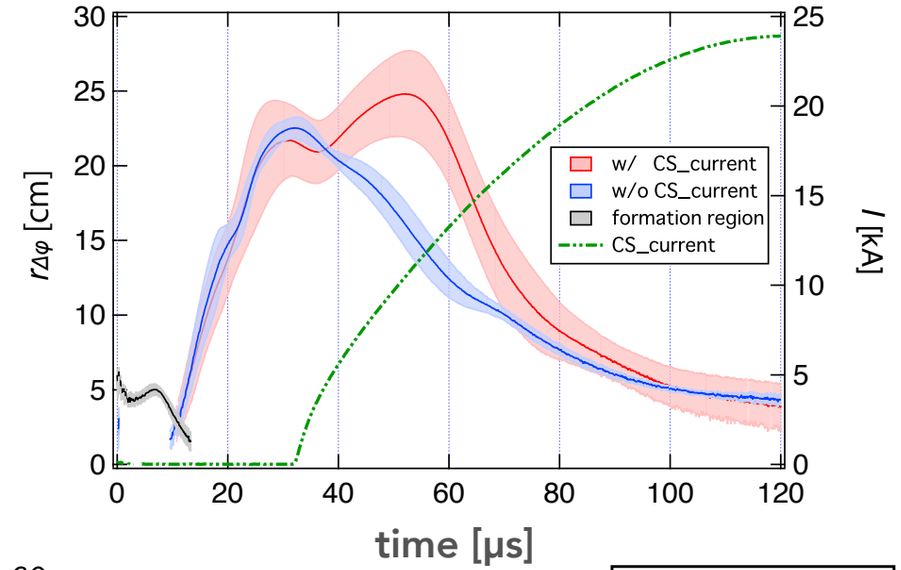
➡ *This may be a reason of increased toroidal field by driven CS current.*





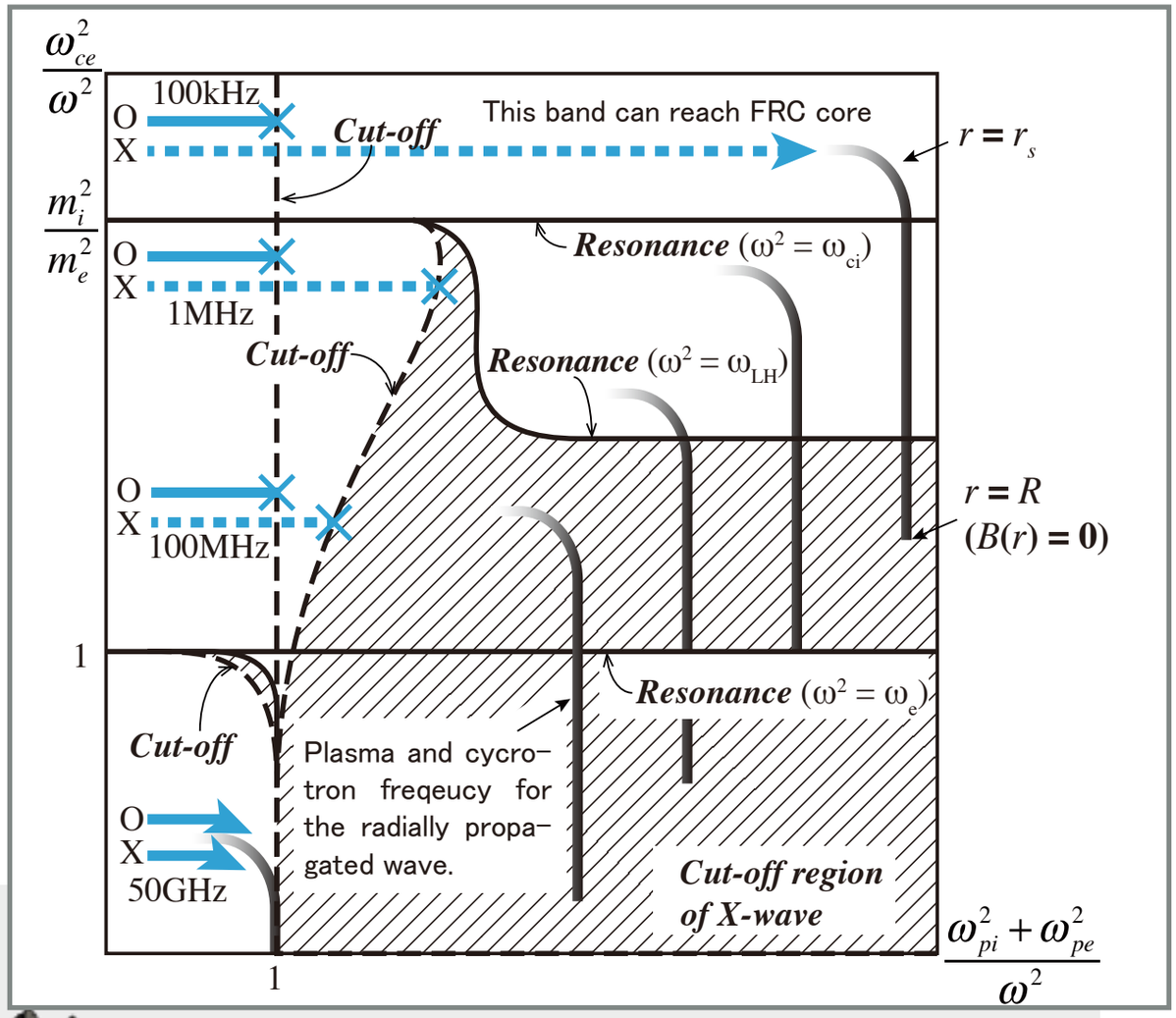
Summary + Future Plan

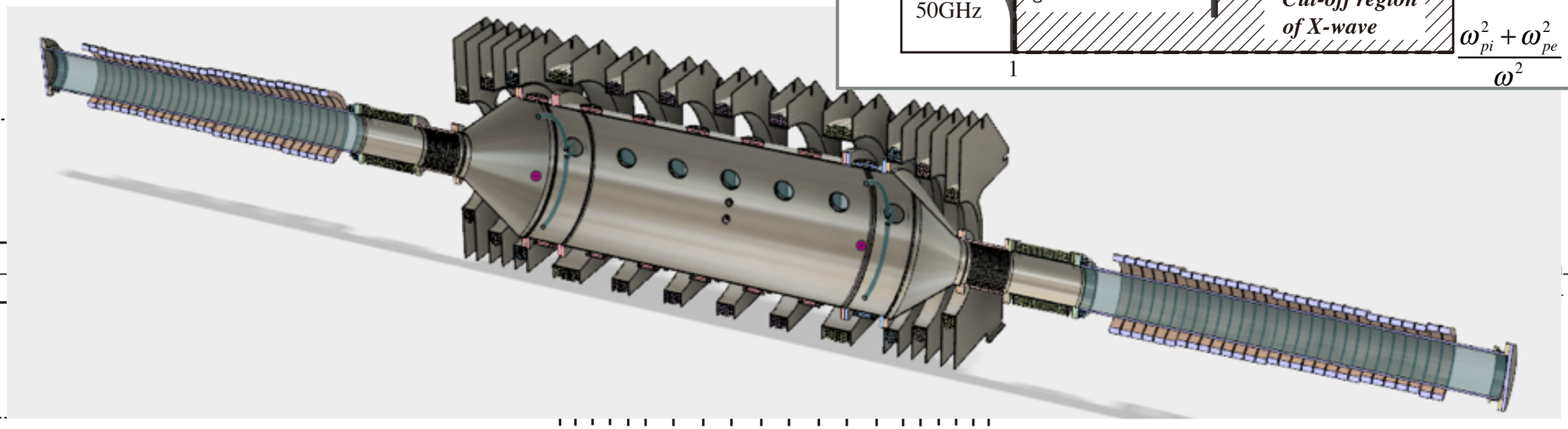
- A FRC which has simply-connected boundary can be translated into a confinement region with a center structure without disruptive perturbation.
- Pololdal flux (toroidal current) is successfully induced by driven CS. However, it may change the magnetic configuration of FRC.
- Toroidal magnetic field is also increased while the CS is being exited. The TF is maintained for several tens of alfven time.
- The spontaneously generated toroidal flux potentially realize inductive current drive by induced toroidal electric field.
- For further study, we have to maintain the FRC longer to observe relaxation process after the current drive.



Summary + Future Plan

- Collisional merging and low-frequency wave injection have been initiated at Nihon University as a heating and current drive technique.
- Because of its high beta (i.e. low magnetic field) nature, we choose low-frequency (~100kHz) range of wave.
- We will start with a pair of tandem type one-turn (n = 0) antenna.





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