THE REVERSED FIELD PINCH PROGRESS AND PROMISE

J.C. Sprott

PLP 949

August 1985

Plasma Studies

University of Wisconsin

These PLP Reports are informal and preliminary and as such may contain errors not yet eliminated. They are for private circulation only and are not to be further transmitted without consent of the authors and major professor.

THE REVERSED FIELD PINCH

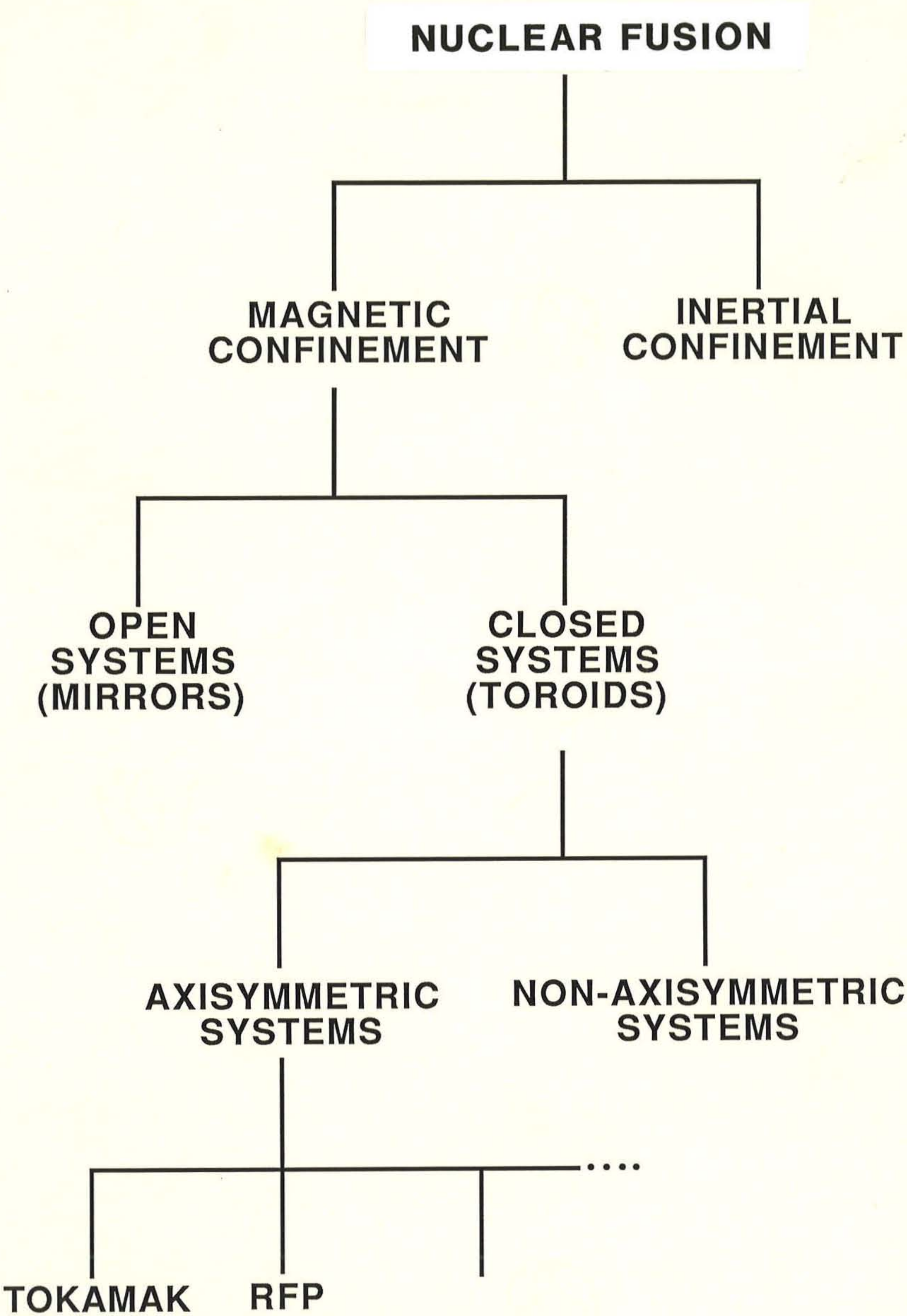
PROGRESS AND PROMISE

PROF. J. C. SPROTT

UNIVERSITY OF WISCONSIN

MADISON, WISCONSIN

IECEC AUGUST 22, 1985


NUCLEAR FUSION
MAGNETIC CONFINEMENT
INERTIAL CONFINEMENT
OPEN SYSTEMS (MIRRORS)
CLOSED SYSTEMS (TOROIDS)
AXISYMMETRIC SYSTEMS
NON-AXISYMMETRIC SYSTEMS
TOKAMAK
RFP

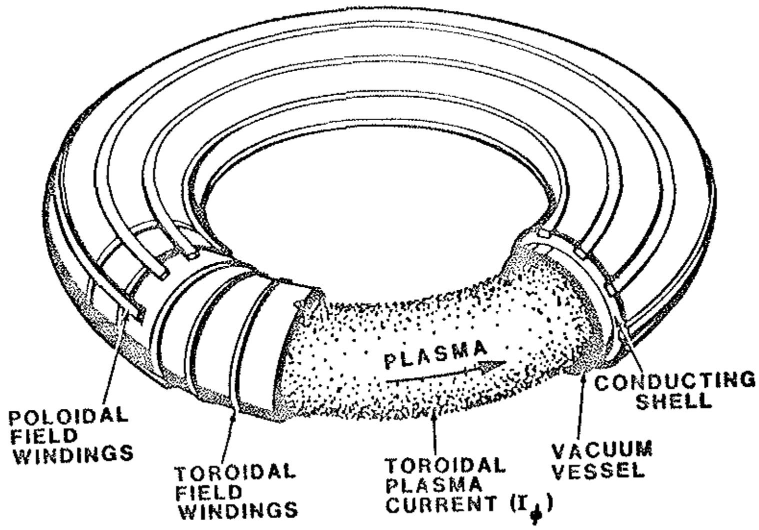
REVERSED FIELD PINCH REACTOR

ATTRACTIONS

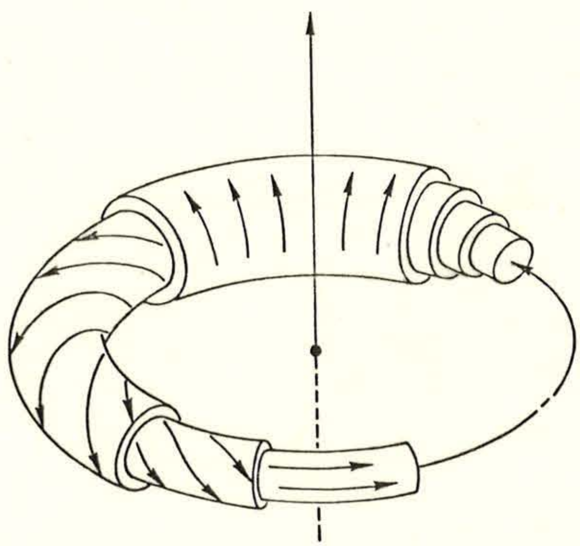
* HIGH POWER DENSITY
* NON—SUPER CONDUCTING MAGNET COILS
* OHMIC HEATING TO IGNITION

DIFFICULTIES

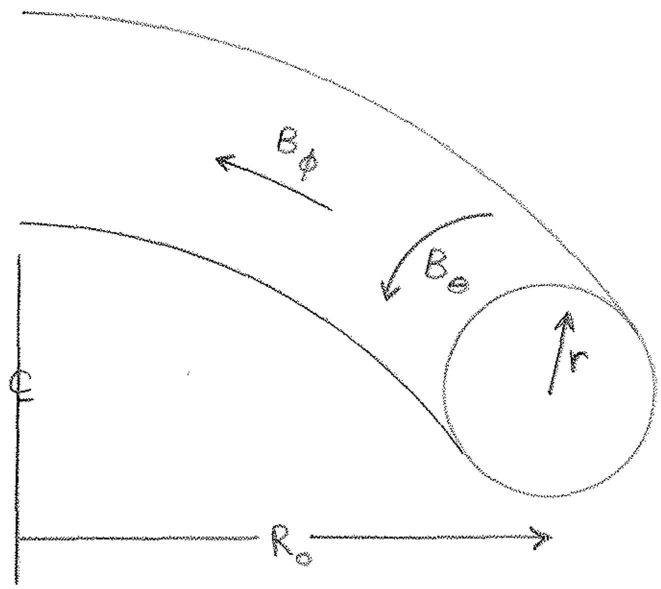
* CLOSE—FITTING CONDUCTING SHELL
* PULSED OPERATION



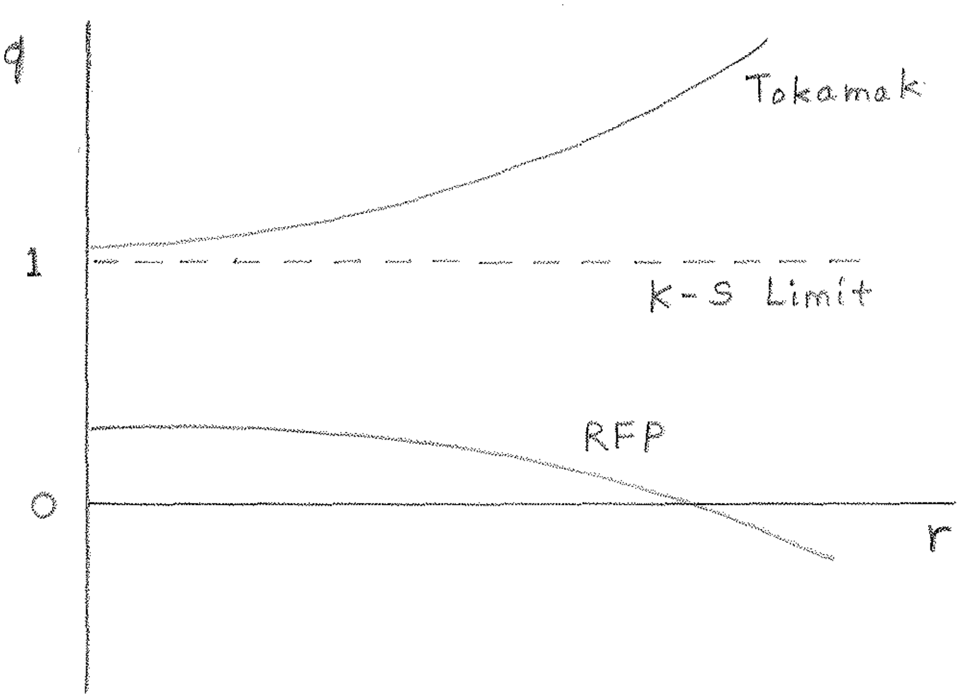
TOROIDALLY CONFINED PLASMA



A sheared magnetic field in a torus.



Safety Factor : $$q = \frac{r B_\phi}{R_o B_\theta}$$



TAYLOR STATE

Newton's Third Law: $\boxed{\vec{J} \times \vec{B} = \nabla p}$

Ampere's Law: $\boxed{\nabla \times \vec{B} = \mu_0 \vec{J}}$

For a low pressure plasma ($\nabla p = 0$),

$\vec{J}$ is parallel to $\vec{B}$.

Thus, $\boxed{\nabla \times \vec{B} = \lambda \vec{B}}$ where $\lambda = \mu_0 J/B$

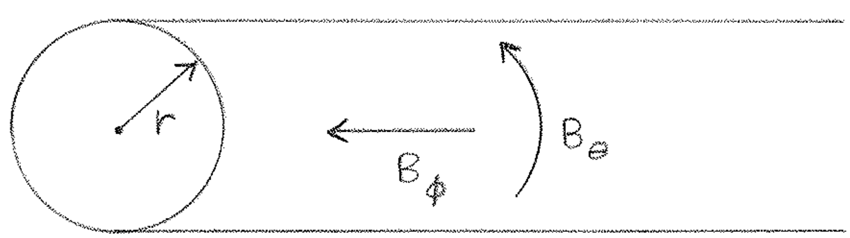
The miminum energy state has $\lambda = \text{const}$

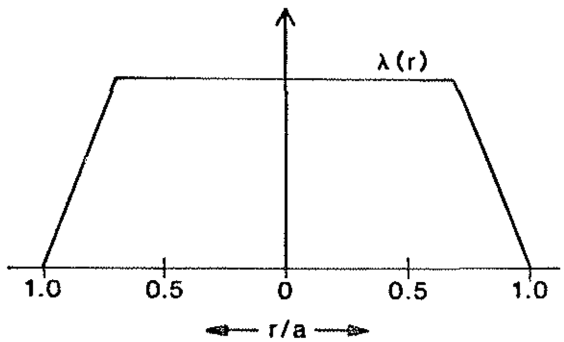
and a solution:

$$B_\phi = B_0 J_0(\lambda r)$$

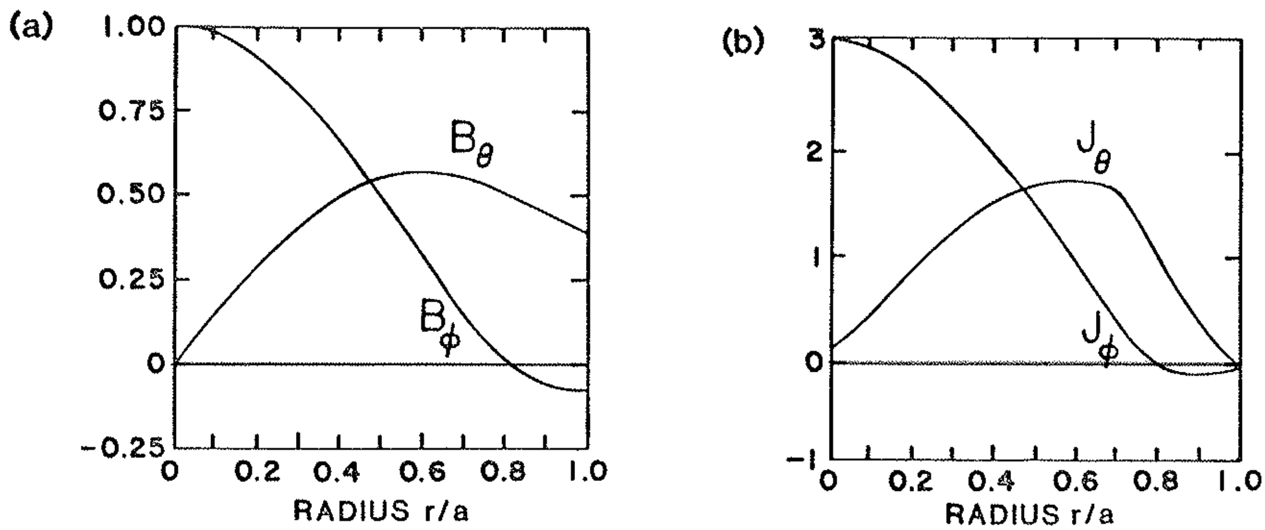
$$B_\theta = B_0 J_1(\lambda r)$$

} Bessel function model

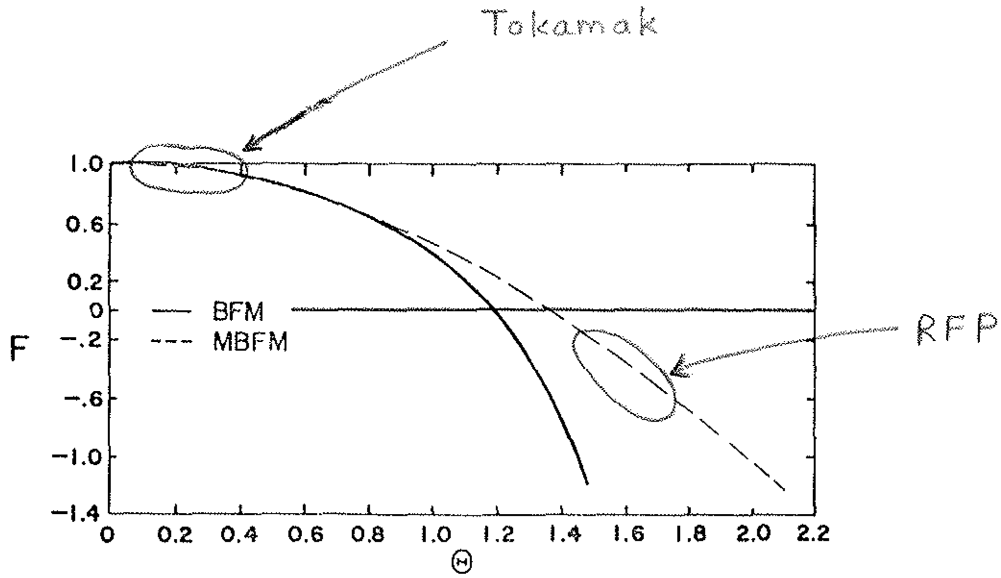




Modified Bessel function model of J/B vs plasma radius



Magnetic field (a) and current density (b) profiles vs plasma radius



$$F = \frac{B_\phi(a)}{\langle B_\phi \rangle}$$

$$\Theta = \frac{B_\theta(a)}{\langle B_\phi \rangle}$$

MINIMUM ENERGY STATE OF TOROIDAL PLASMA

RFP SCALING LAWS

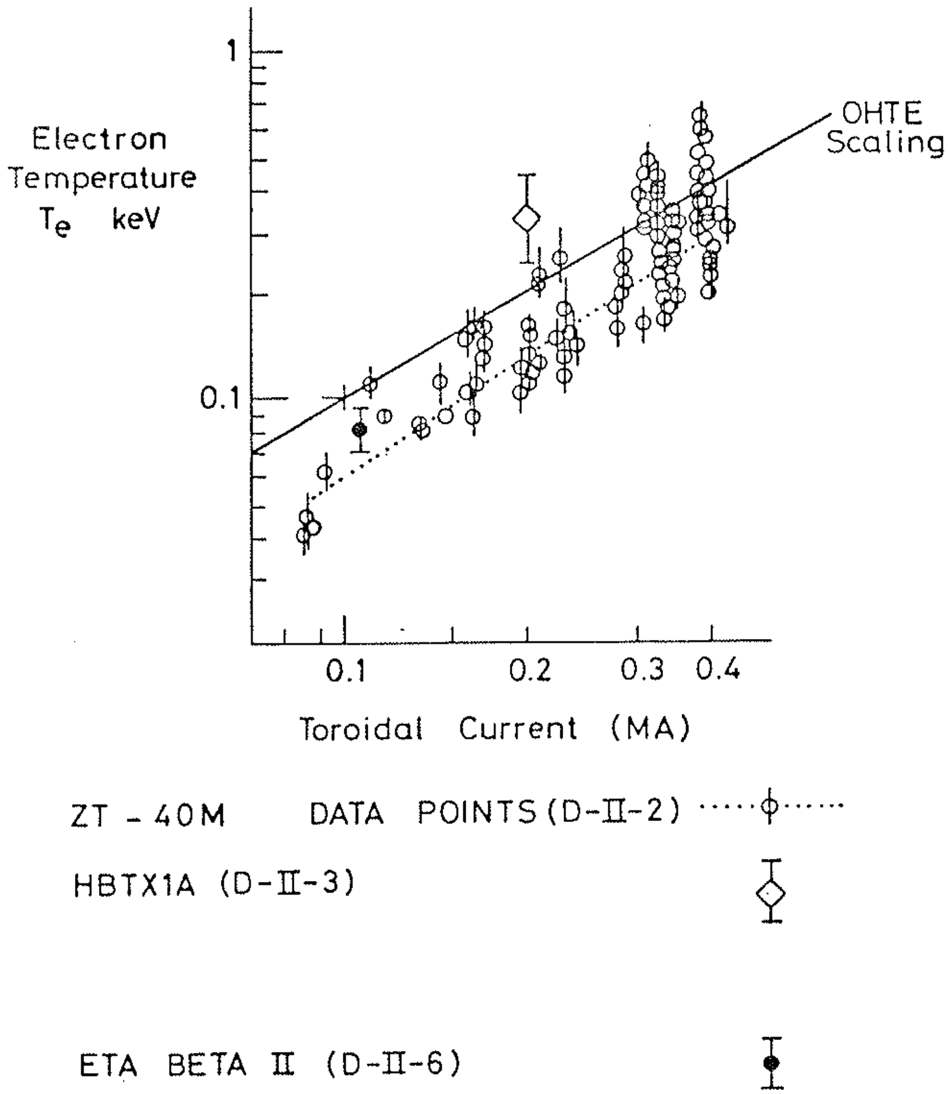
Temperature (K): $T \sim 10\, I_\theta$

Density (m^{-3}): $n \sim 10^{13}\, I_\theta / a^2$

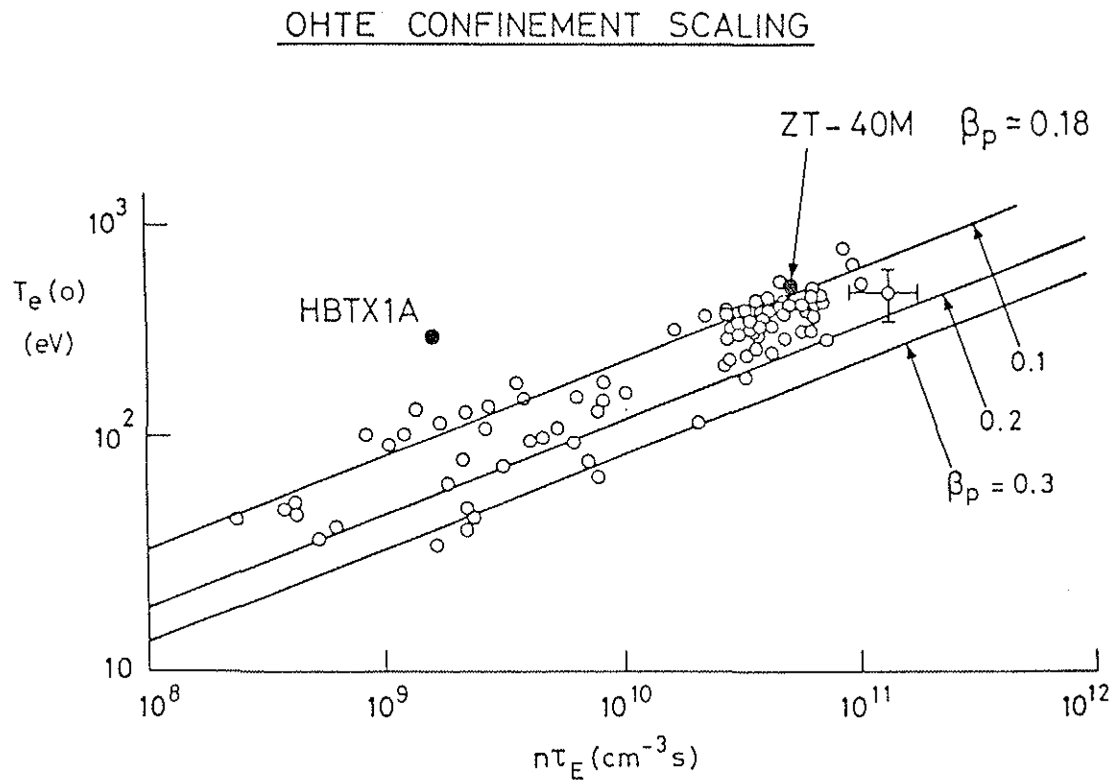
Confinement time (s): $\tau \sim 10^{-12}\, a^2\, T^{3/2}$

where I_θ = Toroidal current (Amperes),

and a = Minor radius (meters)



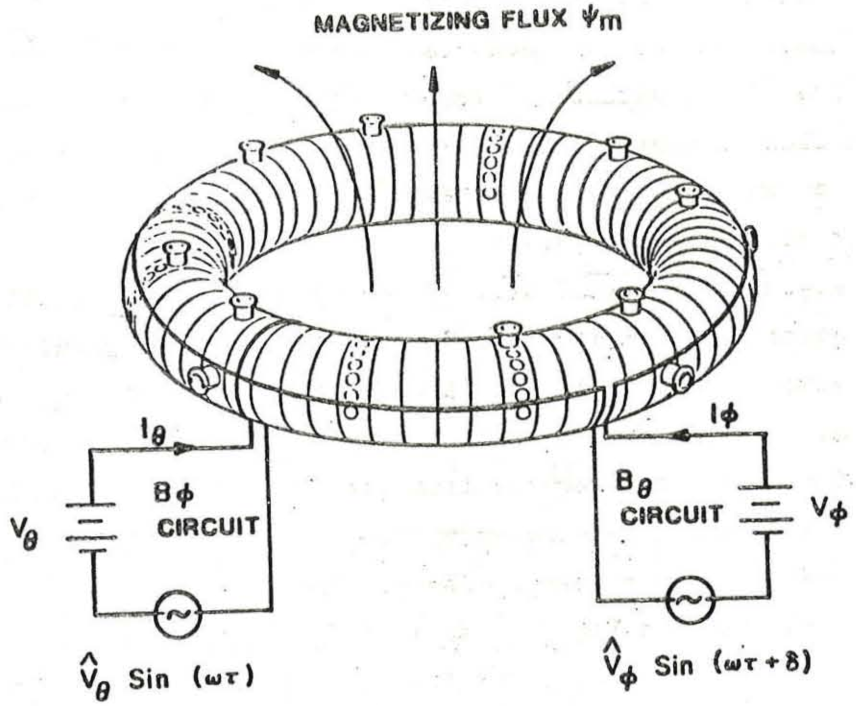
Reversed Field Pinch Scaling showing the electron temperature increase with current.



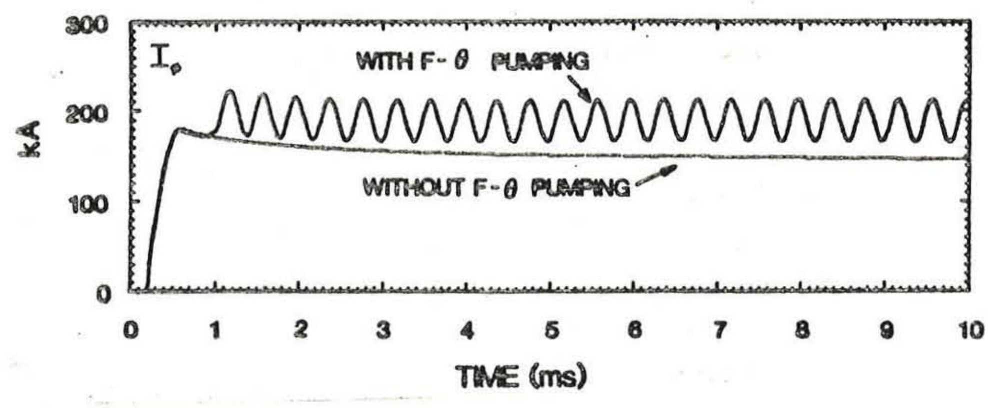
Improvement of T_e with confinement (OHTE results D–II–1) including a point from ZT–40M and HBRX1A.

TYPICAL PARAMETERS OF RFP DEVICES

	ZT-40 USA	OHTE USA	HBTX-IA UK	$\eta\beta$II ITALY	TPE-IRM JAPAN	PROPOSED	REACTOR
minor radius, a(m)	0.2	0.19	0.24	0.125	0.09	0.5	1
major radius, R(m)	1.14	1.24	0.8	0.65	0.5	2	5
plasma current, I(MA)	0.34	0.5	0.2	0.10	0.14	2	10
temperature, T(eV)	330	500	100	100	300	2000	10,000
density, $n(m^{-3})$	8×10^{19}	1×10^{20}	2×10^{19}	5×10^{19}	3×10^{19}	1×10^{20}	1×10^{20}
confinement time, τ(msec)	0.7	0.2	0.05	0.1	0.05	10	1,000



Oscillating field current-drive schematic.



CONDUCTING SHELL

How close?

How thick?

How continuous?