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REVIEW OF EXPERIMENTAL RESULTS ON ALTERNATE MAGNETIC SYSTEMS

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REVIEW OF EXPERIMENTAL RESULTS ON ALTERNATE MAGNETIC SYSTEMS

by
R S Pease

Introduction

Experimental contributions at this conference have maintained generally the numbers as at previous conferences, about 50 papers and much excellent and exciting new work on alternate magnetic systems has been reported. Perhaps we can look forward to an IAEA conference when the labels "Alternate" and "Supporting" will be applied to papers on Tokamaks. There is some change in the distribution of topics: Mirrors, Stellarators, Z-pinches and plasma foci are well represented; there has been some expansion of work on the reverse field pinch, and on the newer ideas such as Spheromaks and Compact Tori.

Open-ended Systems

The main theme of the experiments presented here (C-I-1→5, C-II-1→5) on open-ended systems has been that of blocking the losses of particles (and power) from the ends. The tandem mirror, the principal representative, is characterized by a central solenoid, which should in due course contain the main reacting plasma: at each end a special system is developed to block the loss of particles. To do this, electrostatic potentials have to be developed at different points along the line of force. The essential features of the scheme, as characterized by the Γ10 (C-I-3) and TMX-U (C-I-1) experiments are shown in Figure 1. The purpose of the negative potential relative to ϕ_e) called the thermal barrier, is to reduce the number of high energy ions in the plug, hence lead to lower power consumption.

The central achievements reported in the two papers (C-I-1,3) describing complete experiments, is that the potentials required have at least qualitatively been achieved as shown by direct measurements of the potential - using escaping ions formed by diagnostic neutral atom beams directed at the appropriate axial regions of the column. It is clearly established that the end loss of ions through the plug is sharply reduced - by the order of a factor of 10 in each experiment provided that both the hot electrons and the hot (so-called sloshing) ions are present in the plug region. And the objective of reducing the ion density in the plug region to a value much less than in the central region has been achieved.

These improvements are achieved by heating the electrons in the barrier with ECRH at a level of hundreds of kilowatts. The total power absorbed is about 1 megawatt. The central cell plasmas were heated to the values shown in Table I by ICRH by about 100 kW power absorbed. This qualitative improvement in the plugs is the main advance. Values of the potentials and of the temperature in the central cell which they have to confine are shown in the Table I. In a reactor the potentials will have to be about six times kT/e (see the figure for the Mars reactor study). The achieved potentials seem sufficient for the electrons, but perhaps marginal for the ions. The main central cell parameters are summarized in Table II. They do not in themselves represent great advances on previous results.

The subjects requiring further work in this area are numerous. In the first place, there can be a serious radial loss of ions from the central cell because of the rotation due to the plasma potential with respect to the walls. A reduction of this loss of about a factor of two has been achieved by applying a voltage to annular end-plates; a non-ambipolar radial loss time of about 14 msec is recorded in TMX-U for the most favourable comparison. But in the Γ10 this loss is reported to be much less severe, perhaps as a result of using an axisymmetrized magnetic field configuration, i.e one where the field curvature and the geodesic curvature counteract each other.

In the second place, the ion energy confinement time in the central cell is in fact not dominated by radial particle loss, but by electron drag or charge exchange from the low electron temperature in the central cell; and these restrict the central confinement time to no more than 5 msec. Thirdly the duration of the plugs is short (3msec in Γ10; and up to 15 msec in the experiments on TMX-U). The only improvement in the central plasma parameters recorded as a result of the end plugging is a 20% improvement in the density in the case of Γ10. It therefore seems a task of great importance for these machines to establish an energy and particle balance of the central cell plasma when the plug time is sufficiently long, so that a clear picture of an improvement in plasma parameters as a result of the electrostatic confinement can be obtained.

In the RFC-XX-M experiment at Nagoya, (C-II-3) a cusp-ended magnetic geometry is used for the plugs and ICRH is applied at the ring cusp plugs to provide blocking. In this case, the variation in confinement times with and without end-plugging is well-documented as a function of central cell ion temperature. In this case the plugging is accompanied by a rise in electron temperature from 20 to 50eV. The ion-energy-confinement time of the central cell, measured by diamagnetic loops improves to about 1 msec but is very close to that expected from the electron drag due to low central cell temperatures. The complete axisymmetry of RFC-XX is obviously a great advantage; but the field zero of the cusp gives a qualitatively different feature though this is not reflected in any actual observation. In the experiment evidence of MHD fluctuations are found.

In all the mirror machine experiments reported, I am greatly impressed by the skill of the experimentalists in operating such complex apparatus. The plugging cells themselves are complicated magnetic field coils; they require neutral beam injection, electron cyclotron heating at substantial power; ICRH and NBI are used for the central cell; gas feeds have to be adjusted to get the densities, and charge-exchange pumping is needed to exhaust slow ions from negative potential regions; end plate potentials have to be adjusted to decrease crossfield losses.

Solving the problems of getting all these systems working together with the diagnostics is a major achievement. Moreover, the multi-dimensional nature of parametric space variations that are possible makes interpretation and comparison with theory in these early stages very complex. It seems to me that these systems are very much at the physics research stage; and indeed one might say that the whole subject of electrostatic confinement is in the process of being put on a systematic basis. It is as yet too early to draw firm conclusions on the ultimate effectiveness of the one-dimensional electrostatic confinement.

STELLARATORS

I believe all of us were impressed by the outstanding results achieved by the experiments on Stellarators. Moreover, most of the results are in remarkably good accord with one another. All the experiments used so-called currentless plasmas, and this represents the main advance from earlier conferences.

Table III shows the main experimental assemblies reported on, and tries to summarize the main features. First, all the main variants of helical winding configurations are represented, including the Torsatron (D-I-3), the Heliotron (D-I-2, F-I-4) $\ell = 2$, (D-I-1.1) $\ell = 3$, with and without shear. The CLEO configuration (A-IV-1) is a mean magnetic well of the type proposed by Taylor. Heliotron E is a magnetic mountain with strong shear. Secondly, all the main heating methods are represented; by a tour de force of experimentation Heliotron E has used three methods and has included pellet injection experiments. WVIIA has ECRH and neutral beam injection.

It is difficult to characterize these Stellarators by a single figure, but on the scale of poloidal field times radius, an equivalent current can be obtained which gives some rough indication of confinement potential. On this scale the Heliotron E would appear to be the most powerful; and indeed it produced the highest reported value of $n\tau_e \sim 5\text{x}10^{12}\text{cm}^{-3}\text{s}$ and also the highest value of $\bar{\beta}$ (D-I-2). The other experimental assemblies correspond in this sense to rather small Tokamaks by the standards summarized by Dr Yoshikawa. On only one of the experiments did the authors volunteer some disappointment with the results: in the case of Uragan III, the perfection of the magnetic surfaces is said to be suspect and is thought to be responsible for the relatively poor confinement times achieved.

As regards an explanation of the confinement times, I am fortunate that Dr Kovrizhnykh in paper E-1-5 produced some detailed predictions of neo-classical theory as applied to these experiments. In his analysis particularly of the Heliotron E and of the L2 results, he reports that the results are close to those expected from his prediction of neo-classical theory.

The following main conclusions may be offered:
First, in the shearless case of WVIIA the presence of the low (m,n) resonances in the field structure is dangerous and can lead to low confinement times. Provided these resonances are avoided, the confinement times are close to those of other stellarators. The confinement time improves with ι.

Secondly, the detailed predictions of $T_e(r)$ and $T_i(r)$ profiles as a function of heating power, by Dr Kovrizhnykh agree within some tens of percent in the case of Heliotron E and in the case of L2, for a given density distribution. The agreement in these cases is both for the ion thermal conductivity and for the electron thermal conductivity; the theory includes a self-consistent radial electric field and an estimate of the effect of impurities. The absolute energy confinement time for L2 is 2-2.4 msecs. in close agreement with that observed. The WVIIA analysis based on the theory of Houlberg, and of Hinton and Hazeltine shows three components: Figure 2 shows a simple neo-classical conductivity, a contribution from the super-banana orbits and, in the outer regions an anomalous loss of the order $\chi_e = 1 \times 10^{18} . n^{-1} T_e^{-0.6}$ derived from earlier measurements with ohmic heating.

Thirdly the experimenters agree that, provided the obvious MHD-type instabilities are avoided ohmically heated plasmas do not appear to give very different results, although direct comparison of the two heating methods in identical conditions was not presented.

Fourthly the possibility that in low $\bar{\beta}$ stellarator experiments true neo-classical conditions are being approached, is supported by the evidence of

a current in the NBI heated WVIIA (D-I-1) which is in qualitative agreement with neo-classical theory of the Bootstrap current although leaving some room for doubt on the magnitude. Also extremely low level of fluctuations are reported at low β. The main reason for the relatively high neo-classical electron thermal conductivity is the calculated contribution from the super-banana orbits of the electrons. There is a difficulty in that the conductivity coefficients encountered in the plateau regime are difficult to distinguish from anomalous values. In his recent review paper (Nuclear Fusion 24, 851, 1984) Kovrizhnykh has estimated that taking all the difficulties and uncertainties into account, the collisional transport coefficients in Stellarators can be calculated with an error of perhaps up to 2 or three times; so that the agreement is better than we had the right to expect.
Moreover, it is legitimate for the experimentalists to ask their theoretical colleagues: what has happened to all those micro instabilities with which we used to be terrorized?

Nonetheless, the advances made in these experiments towards agreement between theory and experiment, whilst they must be regarded with caution, are extremely encouraging; they not only justify vigorous pursuit of Stellarator research both in the direction of achieving higher temperatures and greater confinement parameters in larger systems, but also in the direction of understanding of transport processes which to some of us seemed almost impossible of solution in nonsymmetric systems, but which now seems possible. Stellarators have an obvious supporting role in helping with the problems of experimental confinement observations in Tokamaks.

As regards reactor potential, these experiments also yielded important advances in the value of beta achieved. The average value of 2% in Heliotron E approaches the best achieved in Tokamaks. In the data presented by the groups, there is an essentially linear increase of beta with heating power up to the maximum beta reported. The possibility of going further is however, limited by the observation in Heliotron E of the onset of some MHD-type activity; and in the case of WVIIA, by the approach towards the various theoretical stability limits derived from Tokamak theory. In Heliotron E the observed fluctuations are in good agreement with an m=1 resistive interchange mode at the beta value near to the limit for the ideal mode. This is a matter of interest to the shear stabilized Reverse Field Pinch. As has been known from the earliest days of Stellarator investigations, it will be both important and difficult to find configurations in which the beta is raised to a value of practical use. But it appears that such new configurations are being devised.

Bumpy Torus

We have heard two papers on the bumpy torus systems (D-III-4, D-III-5). The main important result is a downward revision of the electron temperature to 80eV and of experimental confinement times in EBT which is requiring a reappraisal of the main framework of interpretation of this experiment. Research on bumpy tori is nonetheless of great interest because, it seems, that one of the many methods of improving confinement in the stellarator configuration is the inclusion of field components corresponding to the bumpy torus effects; and therefore a clear understanding of the processes in bumpy tori should prove of great value.

Axi-symmetric Current-Carrying Toroidal Systems

A.Reversed Field Pinches

The reversed field pinch configuration (RFP) was originally predicted to be stable on ideal MHD theory by Rosenbluth in 1958, and found to occur spontaneously in the Zeta machine in 1963-68, a phenomenon now described as a relaxation to a minimum energy state. The pressure gradients are stabilized by high shear against adverse field line curvatures associated with the desirable low external field strengths.

The field configuration in the outer regions is particularly important. Three versions are experimentally studied as shown in Figure 3. The first, which is MHD stable, is provided by a reverse B_ϕ with a reverse E_ϕ; the second, the OHTE configuration (D-II-1) also stable, is provided by currents in helical windings, and permits sustained operation. The third configuration arising with positive E_ϕ has a zero in the shear; and therefore a sustained RFP is liable to instability. Unfortunately measured details of the outer field configurations are not displayed, but the main experiments reported were of the sustained reverse field pinch (D-II-2, D-II-3, D-II-5,6). Eta Beta II reported a comparison of positive E_ϕ with negative E_ϕ. This Eta Beta comparison is at rather low current (100kA) but in this experiment essentially no difference in the confinement was found. The main results are summarized in Table IV and are characterized by a substantial increase in electron temperature and in the confinement parameters associated with operation at high currents. Some years ago, the high electron temperature initially found on TPE 1 RM in Japan were greeted with great scepticism. Now they are general, although they are often associated with relatively high Z_{eff}.

Favourable scaling with current is found; namely

$$T_e \propto I^\alpha, \alpha \sim 1$$

$$N \propto I$$

$$n\tau_e \propto I^\gamma; \quad \gamma - 2 - 3.$$

Figure 4 & 5 show the advances achieved.

The fact that the highest β_Θ and confinement parameters are found in OHTE may be associated with the more favourable configuration, but the advantage is small and not decisively proved. All these configurations are sustained for up to 20 msec, many times the energy confinement time. As explicitly shown in ETA BETA II (D-II-6) the radial thermal conduction is anomalous - Dr Ortolani indicated a factor of 30 compared to neo-classical ion thermal conduction and fluctuation levels are anomalous. If we think in terms of the plausible tangled discharge model, the 100 volts or so required to produce temperatures of 500eV indicate that on average, each electron (or line of force) can go some 10 times round the torus, before striking or at least losing its energy to the wall.

All the experiments showed high ion temperatures with some non-Maxwellian ion velocities and shifted mean energies which promise to clear up some of the mysteries left by the pioneer observations on ion temperatures in Alpha and ZETA. (ref. Bodin and Newton Nuclear Fusion 20 1255 (1980)). Both theory and experiment in general indicate a reduction of magnetic fluctuations as the magnetic-Reynolds number is increased (as $S^{-\frac{1}{2}}$).

Some explanations are offered for the parameters of Table IV. The value of theta is close to that required to reverse the field (1.4) without going over the kink stability limit (1.8). The values of density generally accord with the empirical formula I/N = 10^{-14} ampere m for optimized operation. The temperatures are arrived at by the balance of ohmic heating with an unknown loss mechanism probably associated with fluctuations and an effective beta-limit. The beta observed is well below the ideal limit but above that at which resistive modes might be serious, (though decreasing with S). The duration of the pulse 20 msec, requires a dynamo mechanism to sustain the reverse field in the simple RFP, but not in OHTE. Detailed measurements of the magnetic fluctuation spectra provide evidence of resistive tearing modes which presumably must disappear as the configuration approaches the Taylor ideal.

The main advances reported at the conference are due to the increased currents obtained, to the improved equilibrium control with a vertical field, to the extensive use of carbon to protect the walls, and to the continued process of reducing the field errors due to small misalignments of coils and the skin currents around breaks in the solid wall.

The main route forward, from the results, is undoubtedly that of increasing current - simply to provide stronger fields for confinement. Such a device (RFX) aiming at 2MA is now under construction at Padua.

The key issue, in my view, is to establish whether or not the resistive interchange modes limit beta to an unacceptably low value. However, it should also be possible to exploit some of the diagnostic and technical advances obtained on Tokamaks to broaden the experimental attack on the RFP. One such possibility is reported from Los Alamos where the first experiments on an idea for sustaining the relaxed discharges by oscillatory voltages is being explored.

B. Spheromak, and Field Reversed Systems.

1. The papers in this area (D-III-1,3), (D-IV-7) describe experiments of essentially exploratory nature with cold plasma and no records to break. The Spheromak was introduced to us by Harold Furth and colleagues at the Innsbruck conference. The configuration can be described as a toroidal pinch with theta value of 1.4, so that the axial field is zero at the outside and the central hardware removed.

The central problems of the configuration are (i) setting it up and (ii) sustaining it against resistive losses and (iii) suppressing the flip instability. In all three experiments, ring currents of the order of 100kA have been set up in cylindrical vacuum vessels characterised by 1 metre dimensions.

The trapped toroidal field yields q values varying from 0 at the edge to about 0.5 in the middle, so they are liable to m=1 and n=0,1,2 instabilities, some of which are seen. Beta values of about 10% are reported.

The main advance reported from the newly started S1 spheromak is that by the addition of new figure of eight windings - the configuration is preserved against gross instability for the full decay time as predicted. The experiments show elegant flux plots (Fig.6 of D-III-3) of the Spheromak configuration.

In the Japanese CTCC-1, stabilization against the flip and slide modes is achieved by conductor inserted along the axis. No attempt has so far been made to maintain the currents in the configuration in either experiment.

In the Los Alamos CTX experiment, the spheromak configuration is formed by a Marshall gun plasma injector; and is then sustained by leaving the voltage on the gun electrode. The process of sustainment is identified as being a relaxation to a Taylor minimum-energy state and sustained presumably by the same process as in the Reverse Field Pinch. Although quite large currents have to be drawn, the 100kA toroidal spheromak configuration can be sustained for 10ms. This phenomenon, known as helicity injection, by which quite small currents can in principle be used to sustain relaxed current configurations in any flux containment is clearly of great general interest. However it must be said that the 100MW power and 1kV potential I am told is required to sustain the configuration in CTX seem to be some way from the ideal of a magnetic genie created in an Aladdins bottle by a thin wisp of helicity injected by electrodes at the top and bottom.

Reverse Field Configurations

Plasma experiments of the reverse field Θ-pinch type are reported by four groups.(D-III-2-1,2-2, D-IV-1,12,13) The rotational instability familiar from early days is stabilized by either quadrupole or helical windings added externally. The theory and experiment of the suppressive fields necessary are reported to be in good agreement from Osaka. It is not clear that the stabilization at the edges of the plasma annulus where there is strong adverse curvature, is achieved, but Los Alamos report new theoretical results which qualitatively support the slow growth rates inferred.

To provide conducting-wall stabilization and compression, both the Los Alamos group and the Nihon university group have moved the RFC plasma configuration along distances of 4 metres at 7×10^6cm s^{-1} without loss of coherence.

In general these configurations last about 100μsec, with somewhat shorter energy confinement times and with densities of 10^{15} cm^{-3}, several hundred eV ion temperature, 100 eV electron temperture and β of 1. Some favourable scaling characteristics of the configuration are reported. Table V summarizes the impressive achievements in the configuration.

Plasma Focus

The plasma foci experiments were the subject of several papers (D-III-6, D-IV-8, 9, 10, 11). All the three experiments agree that the main part of the neutron yield is due to accelerated deuterons. In the biggest experiment 10^{11} neutrons are produced by ion beams with energies up to 450 keV. In the smaller machines reported from Japan, even higher energy particles are observed (1MeV). There is no adequate theory of the acceleration mechanism, and the theoretical papers from the Soviet Union agree that the basic assumption of 10^{-2} classical conductivity unsatisfactory. Experimentally some beautiful laser diagnostics are reported by the Stuttgart group (D-III-6-3) for measuring density and temperatures and the Japanese group for measuring field strength (D-III-6-2). And it is these which establish that the temperature and densities measured are inadequate for a thermonuclear process. Nonetheless these small pulsed machines provide fusion power at about 1 MW, although for extremely short times.

Conclusions

Let us try to stand back a little, and look at the development of fusion research as a whole. It is natural, in Imperial College, for us to recall the beginnings of magnetic confinement physics - in a shed at Princeton or in a basement here in Imperial College by Dr Ware. We can then see that indeed a new branch of physics has been created; and we can identify the various architectural features or specialities which make it up, and the efforts that have gone into its construction.

Almost twenty years ago a pattern began to emerge, partly as a result of improved experimental and diagnostic techniques, i.e. correspondence between experiment and theory, first in the open-ended systems, and somewhat later with the Tokamaks, which led to a grasp of the essential physical qualities of these systems.

It seems to me that of the work reported at this conference, similarly great importance may be attached to the development of research on Stellarator systems which at one time seemed to defy analysis and which even now defy accurate mathematical statements. But the experiments now all agree with each other and in several striking cases there is encouraging correspondence with neo-classical theory which, though not yet certain, can surely be pressed to a conclusion. As the same time record new parameters have been obtained which however do remind us of the potential difficulties of the present Stellarator systems. Stellarator research can indeed support both Tokamaks and the reverse field pinch.

The Reverse Field Pinch, and related spheromaks are MHD-stable axisymmetric systems on which great progress has been made but it is here that major understanding of the system is still to be achieved, especially of the relaxation and dynamo processes.

New features of the one-dimensional electrostatic confinement system now in Mirrors has been qualitatively established. The task for the immediate future is to show that corresponding significant advances in the plasma parameters of the centre cell can be achieved.

Over the years we have learned of the difficulties indeed disappointments, that can come from relying on special effects to overcome predicted MHD instabilities; such means must not be regarded as an impossibility. We must nonetheless applaud the striking parameters achieved in the Field Reverse System, the plasma focus and perhaps the Z-pinch. But in those systems progress will depend on getting a firm understanding of the important non-fluid effects to provide gross stability, which remains a formidable field of research.

May I thank all who provided such interesting papers for my review: May I apologise for errors and omissions and especially to those whose excellent work I have found too little time to discuss.

TABLE I

MIRROR MACHINES : PLUG POTENTIALS

Potential	Central Cell-Wall	Plug/cc	Thermal Barrier/cc		
Purpose	- Stops electrons	Stops Ions	Stops Electrons		
ref. to Figure	ϕ_e kV	ϕ_c kV	ϕ_b kV	T_i (keV)	T_e keV
TMX-U	0.9	1.5	-0.45	2-3	0.1-0.2
Γ 10	0.7	0.40	-0.3	0.2	0.05
Phaedrus	0.06	0.04	0	No thermal barrier	
RFCXX	0.10	0.25	0	" "	"
[Mars	+ 160	+ 150	-120	28	24]

TABLE II

TANDEM MIRRORS: Central Cell Conditions

	B (T)	n_e 10^{12} cm^{-3}	T_e (eV)	T_i (keV)	Length m	Radius m	β %	τ_e ms
Γ-10 (Tsukuba)	0.5	1.8	50	0.2 (Axisymmetrized)	6.0	0.20		1
TMX-U (Livermore)	0.3	2-6	100-200	2-3	8.0	0.15	6	3-5
Phaedrus (Wisconsin)		6	30 single-end	0.5 operation only	1	0.15	8	—
RFC-XX-M (Nagoya)	0.35	6	10-30	0.3-0.5	2	.05		1
Tara (MIT)	0.2-1.5		20-60	1.2	10	0.12	3	0.5

τ_e = energy confinement time of plasma in the centre cell

TABLE III

STELLARATOR EXPERIMENTS

Machine	$\bar{r}/R$ (cm)	ℓ/m	$\bar{\iota}_a$	shear	$I_{equiv.}$ kA	n_e $10^{13}\,cm^{-3}$	T_e/T_i keV	τ_e ms	$\beta(o)$ %
Hel.E. ECRH/NBI	20/220	2/19	2.5	High	400-200	2-9	1/0.9	40-60	3.6
ICRH/ECRH					400	2.5	0.4/0.4	-	-
WVIIA NBI	10/200	2/5	0.5	None	40	10	0.6/1.2	10-20	1
ECRH			0.63		17	0.5	1.2/0.2*	1-2	0.3
Uragan III ICRH/AW	13/100	3/9	0.6	High	45	1.5	0.06/0.27	0.2	0.6
L-2/ECRH	11/100	2/14	0.7	Modest	(45)	0.7	0.5/0.06*	2-2.5	-
CLEO/ECRH	10/ 90	3/7	0.6	High	27	0.5	1.2/ -	0.6	0.5

* But non-Maxwellian component found ~ T_{i2} - 400 eV. T_e Maxwellian

TABLE IV

Plasmas in Reverse Field Pinches

Device	I (MA)	θ	n_e $10^{14}\,cm^{-3}$	T_e keV	T_i	$\frac{\delta B}{B}$	β %P	τ_e ms
ETA BETAII	0.1-0.2	2	1	0.1	(0.1)	1%	10%	-
TPE1RM	0.14	1.4	0.3	0.4	0.7	-	-	0.1-0.2
HBTX1A	0.2	1.8	0.1	0.35	(0.1)	1%		0.1
ZT-40M	0.4	1.5	0.8	0.5	(0.5)		8-11	0.7
OHTE	0.5	-	3	0.5	0.4		20	0.3

TABLE V

FIELD REVERSE CONFIGURATION

	B_z	ℓ	T_e	T_i	n	T_e	$n\tau_e$
	T	cm	eV	eV	10^{15} cm^{-3}	µs	cm^{-3} s
NW	11	40	150	250	1	70	10^{11}
OSAKA	-	40-90	100	300-500	2-6		
NIHON	-	100	100	200	2	60	10^{11}
LOS.A.	0.4	200	125-175	200-600	5	30-100	$4\text{x}10^{11}$

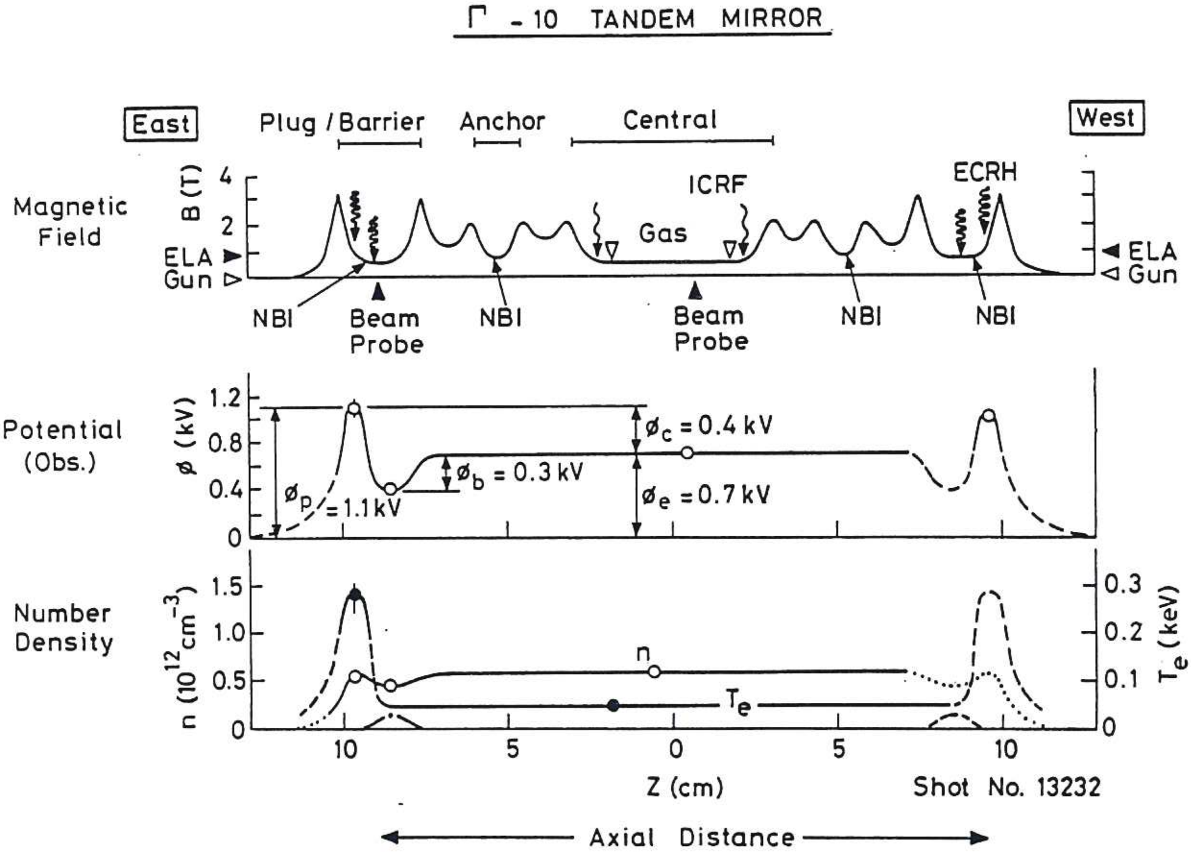

Fig. 1 The axial magnetic field strength, the electrostatic potential and the electron number density and temperature in the Γ–10 Tandem Mirror (from Paper C–I–3).

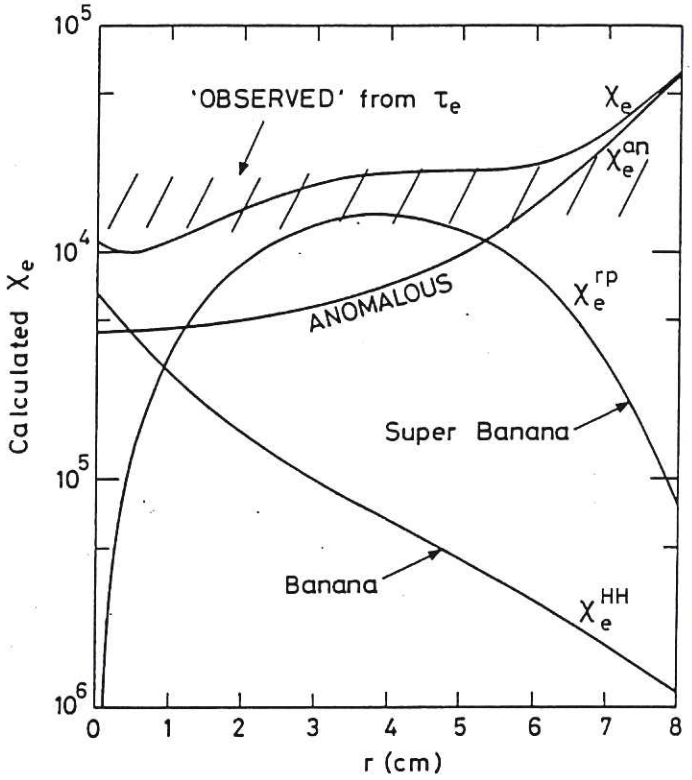

Fig. 2 Radial profile of the transport coefficient χ_e (LMFP conditions) in WVIIA (Paper D2), with a rough mean value $[(r/2)^2/\tau_e]$ shown hatched.

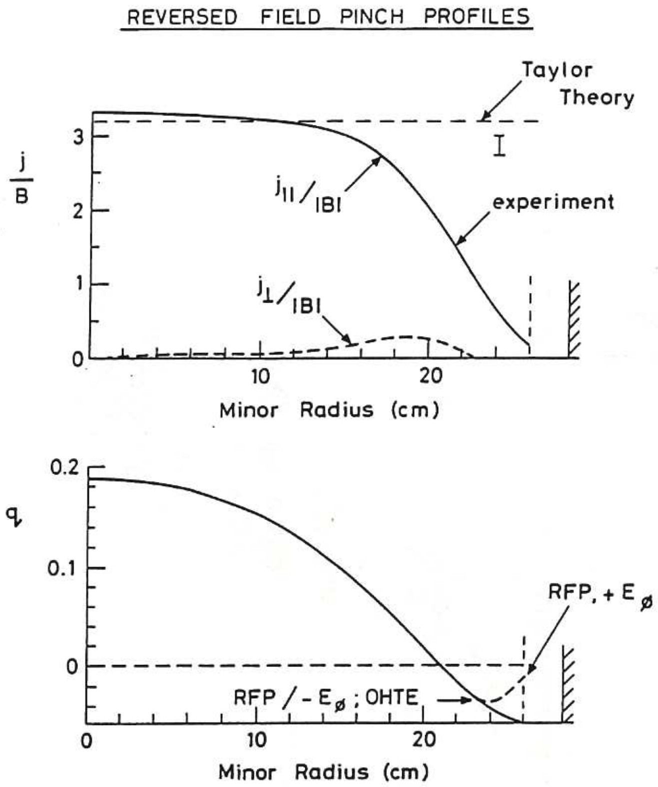

Fig. 3 Reversed Field Pinch Profiles.

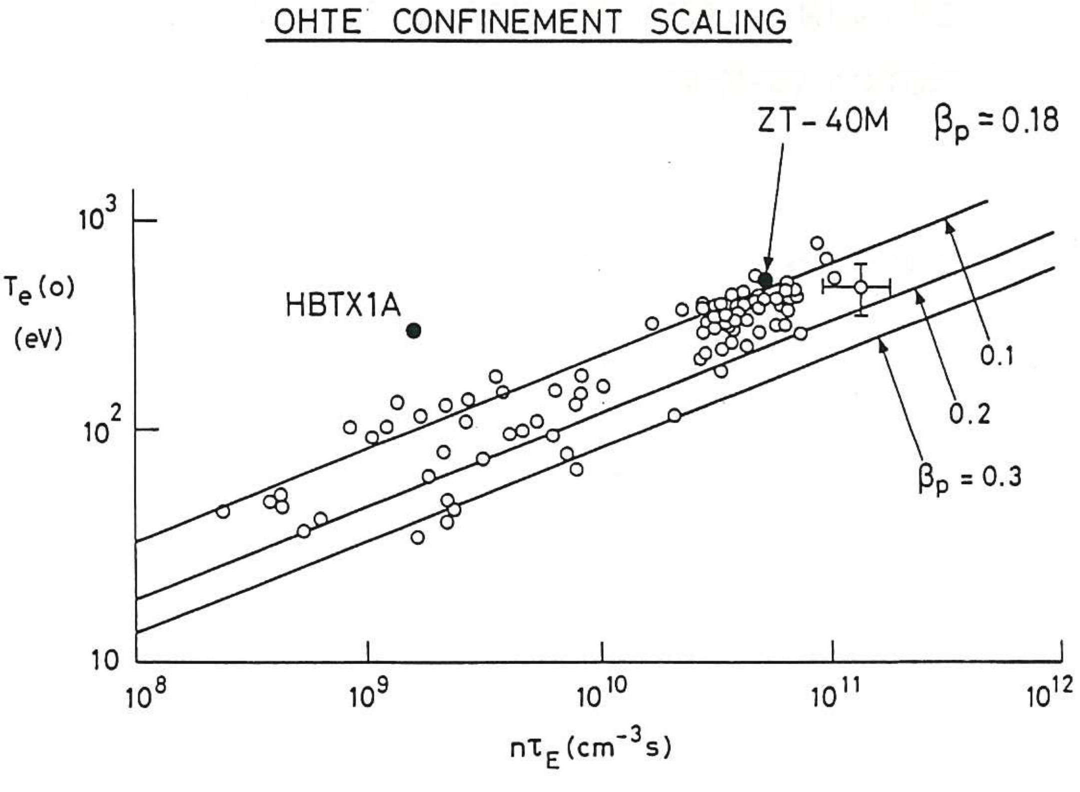

Fig. 4 Improvement of T_e with confinement (OHTE results D–II–1) including a point from ZT–40M and HBRX1A.

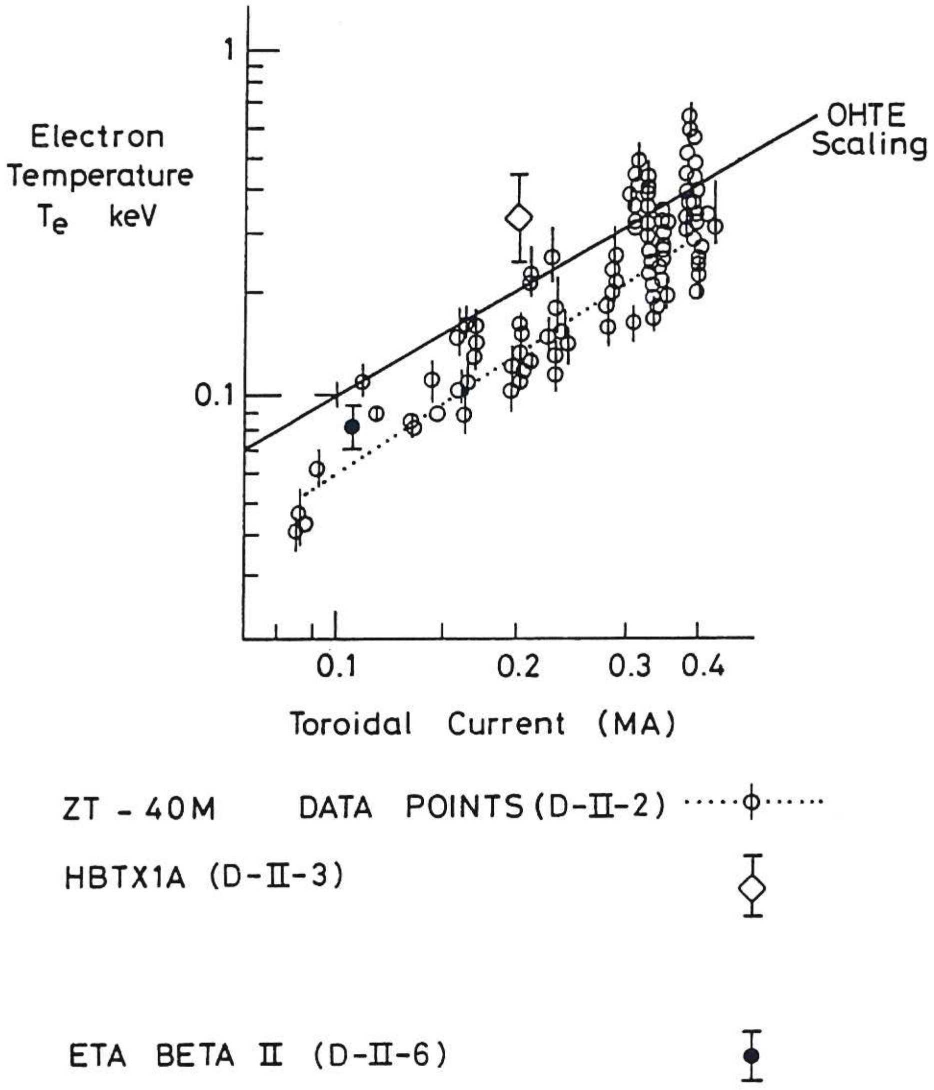

Fig. 5 Reversed Field Pinch Scaling showing the electron temperature increase with current.