SUMMARY: NON-TOKAMAK EXPERIMENTS

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Introduction

The purpose of this report is to summarize the non-tokamak experiments. The non-tokamaks naturally seek to establish reactor relevance. This applies specifically to RFPs and helical systems. With LHD, a large heliotron introduced to the international fusion community at this conference, a large step toward a stellarator power plant has been taken. Another potential of non-tokamaks is that they can contribute in a unique form to the understanding of magnetic confinement and specifically to toroidal confinement because they are not tokamaks. Most of the non-tokamaks are toroidal: helical systems, RFPs, FRCs, CTs, dipoles and sheromaks. Mirrors, traps, foci are non-toroidal systems. The Japan Times of Saturday, Oct. 24th 1998, the day of the summaries, has given me the theme of my summary on non-tokamaks*: Everything is connected in life - the point is to know it and understand it.* The main line and the non-tokamaks are closely connected when it comes to understanding.

As reported in this conference, the scope of non-tokamak devices ranges from laboratory experiments to high power fusion devices. In the area of non-tokamak experiments, where novel concepts are (nearly by definition) developed, a clear separation between experiment and theory may not always be possible because new concepts are first developed and - in case they arise interest - funded and realized. Therefore, in this report, we also summarize some of the new concepts of helical systems. The concept of quasi-symmetry has inspired novel devices.

By far, most of the non-tokamak experiments reported in this conference are helical systems followed by RFPs and Mirror devices. With TPE-RX, a new reversed-field-pinch started operation and made its first contribution. Three large RFPs in the MA-current range are now in operation.

We will summarize the major lines – mirrors, RFPs, and helical systems - because a comparative assessment is possible. There is no point in repeating the abstract of papers on individual devices that stand alone. Also non-neutral plasmas, where interesting physics is presented (e.g. the enhanced classical transport when the Debye length is larger than the gyro-radius) provides important and relevant information also for other research areas. Also in this field, a new device, PROTO-RT, which is a toroidal dipole trap with flexible field composition, was presented for the first time. The SSPX spheromak studies helicity injection and the connection of confinement and field fluctuations; the FRC studies the development of the appropriate equilibrium starting with a Θ-pinch or by the merging of two spheromaks. A question is the achieved energy content and specifically, how much of the magnetic energy is transferred into kinetic energy of the ions. Of specific interest in these studies is the reconnection zone, its width in connection with the ion Larmor radius and its resistivity in relation to the Spitzer value.

Mirror devices

- The following devices contributed with experimental results:

The Gas Dynamical Trap (GDT), and the GOL-3-II device, Novosibirsk/Russia; Qt-upgrade at Tohoku University/Japan; Gamma-10 at the University of Tsukuba/Japan.

- **Major results reported from Mirror devices**

- The Gas Dynamical Trap, which operates with a mirror ratio up to 50 reported on the benefits of well symmetrisized neutral beam injection. Beta of up to 30% has been reached; the mean ion energy is up to 6 keV. The studies on GDT have the goal to develop a neutron source.

- GOL-3-II is a 12 m long mirror with a plasma diameter of 7.5 cm. From one side, a relativistic (1 MeV) electron beam (30 kA, pulsed) can be injected along the axis. The beam heats the electrons; the ions are fully decoupled. The beam causes a two-stream instability which reduces the parallel electron heat conduction and leads to large T_e-values of up to 2 keV at the beam entrance at a plasma density of $8 - 10 \times 10^{14}$ cm^{-3}; the axial profile has a characteristic temperature decay length of about 4 m. The studies on GOL-3-II have the goal to develop an X-ray flash source, to explore the possibility to build an UV laser and to allow material tests e.g. to simulate runaway electron damage in tokamak devices.

- Qt-upgrade is a simple mirror device. Its programme is devoted to detailed studies of the formation of plug potential with thermal barriers using ECRH, injected at the field minimum. The potential structure helps to confine the hot ions to the central cell and to separate hot and cold electrons.

Another area of research is electrostatic turbulence suppression by electric shear decorrelation. The technique is to bias segmented end plates. A flute-like mode grows when the electric field is increased; a drift mode is damped when the field shear is increased.

- Gamma-10 is a tandem mirror operated at the University of Tsukuba/Japan, which is equipped with a sophisticated plug structure: a so-called anchor, which is a non-axisymmetric min-B configuration providing MHD stability for the central cell plasma; the anchor is followed by end mirror cells. The central cell plasma is heated by ICRH; the thermal plugs are produced in the symmetric end cells by ECRH. Recent system improvement was the addition of electrostatic end plates in the vicinity of the anchor to minimize radial losses and a better symmetrisation of the device, including the ECRH and ICRH systems.

In a detailed sequence of experiments, the effectiveness of the thermal barrier to enhance the central cell energy and particle confinement was demonstrated. With the application of ECRH, a thermal plug is established. Accessible diagnostically i.a. was the central cell density (representing particle confinement), the diamagnetic energy content and the direct parallel loss fluxes via an ion energy analyzer. With ECRH induced thermal barrier at one of the end sections, the outflow is strongly reduced whereas it increases in the other one; the plasma in the central cell remains basically unchanged. Thermal barriers with ECRH at both ends cause a strong reduction of the plasma outflow and a corresponding increase in central density and in diamagnetic signal. The impact of the plug potential formation is directly seen in the spectrum of loss ions; low energy ions are electrostatically confined and disappear from the loss flux. The plug potential scaled with the ECRH power in the expected manner. With an ECRH power of 140 kW, a plug potential of 0.6 keV could be achieved and this doubled the density. In comparison to a simple mirror, the development of the proper tandem mirror potential gave rise to an increase of confinement by an order of magnitude reaching values of 40 ms for particle and 10 ms for energy confinement times. The radial particle losses correspond to about 3% of the total loss rate. With ICRH in the central cell, ion temperatures up to 10 keV and beta values up to 10% have been achieved. Strong Alfvén ion cyclotron modes are observed at high T_i because strong temperature anisotropy increased the end-losses of high-energy ions.

Reversed Field Pinch (RFP)

- The following devices contributed with experimental results:

EXTRAP-T2, Stockholm/Sweden; MST in Madison/USA; RFX in Padua/Italy; STE-2, Kyoto/Japan; TPE-RX, TPE-IRM 15, TPE-IRM 20, TPE-2M, all in Tsukuba-shi/Japan.

- A new device: TPE-RX.

TPE-RX (R = 1.72 m, a = 0.45 m) started operation in March 1998. It is designed with a thick stabilizing wall and specific care towards compensating error fields (e.g. resulting from poloidal shell gap error field) was taken. Results from initial operation were reported. At 270 kA, a reversal parameter F = 0.1, and a pinch parameter $\Theta = 1.6$ have been achieved. At $\langle n_e \rangle$ Å 5×10^{18} m^{-3}, T_e =1-1.2 keV, T_i Å 0.13 keV have been measured.

- **Major results reported from Reversed Field Pinches**

With RFX, MST, and TPE-RX, there are now three RFP's of the MA level in operation. With RFX, 1MA has been achieved whereas a low Z_{eff} Å 1.5 can be maintained. For further improvements in plasma purity, TPE-2M has tested a poloidal field divertor.

- Locked modes

The m=1 dynamo-modes inside the reversal surface non-linearily interact and develop the poloidal electric field and the toroidal flux. This interaction also leads to a phase-locking of the modes which ultimately gives rise to a helical deformation of the plasma torus. The helical deformation may lock to the wall causing rather local heat deposition and enhanced wall erosion. Up to 50% of the impurity influx can be tracked back to this process. A conducting shell close to the plasma reduces the radial magnetic field component and affects strongly the locking of the helical deformation to the wall. A sensitiv dependence on wall proximity, poloidal gaps and diagnostic holes is given. Low current operation or discharge development with low filling pressure are measures to avoid locking.

An active way to affect the mode locking has been demonstrated by RFX. Locally, the toroidal magnetic field was perturbed. Under static conditions, the perturbation caused the locking; under dynamic conditions, the perturbation was dragged toroidally. Thus, localized heating could be avoided and the discharges could be expanded toward higher current.

- Confinement

- Particle confinement

Density profiles are generally flat and turn hollow towards higher density. The density gradients reside basically near the edge. The hollow density profile can only be explained by an outward directed convectiv flow. The overall profile can be reproduced by a transport which has, besides the particle source, diffusive and concective flows. Thecore diffusion coefficient D reaches up to 10 m^2/s and D and the convective flow velocity agree satisfactorily with those obtained from Rechester and Rosenbluth on the basis of transport in a stochastic magnetic field. The outward flux is caused by a temperature gradient. The particle flux in the edge region (r/a > 0.9) in caused by electrostatic turbulence. The diffusion coefficient D decreases with rising density.

With pellet injection the flat or even hollow density profile becomes tansiently peaked and, as observed in other toroidal systems, the confinement increases transiently by a factor of typically 50%. The density peaking factor $n_{e0}/\langle n_e \rangle$ Å 1.5-2.

- Core transport

Core energy transport is caused by resistive MHD fluctuations which yield a stochastic magnetic field. The ratio of χ_e /D corresponds to the square root of the mass ratio. χ_e increases to the core and has a minimum close to the edge. Velocity fluctuations correlate with the magnetic ones; they reach amplitudes of several km/s. The dynamo which results from these fluctuations reaches up to 15 V/cm.

- Edge transport

Edge transport is predominantly by electrostatic turbulence specifically affecting particle and to a lesser extent energy transport. Magnetic turbulence does no longer play a major role. The radial variation of the turbulent flux is related to the edge neutral source. D at the edge - caused by electrostatic turbulence - is comparable to the value found in the core - caused by magnetic turbulence. At the edge of RFX, there are two zones of strongly sheared E×B flows. At the LCFS, a shearing rate of 10^6 m^{-1} is found. The second flow zone has a negative radial electric field gradient compatible with unconfined ion orbits. Velocity shear is at a rate where it is known to affect turbulence. A reduction of the coherence between density and velocity fluctuations caused by sheared flow has been observed giving rise to improved confinement.

- Scaling

The global confinement scales with density owing to the favourable density dependence of the edge transport. Detailed scaling of the relative fluctuating field amplitude b/B with the Lunquist number S (ratio of resistive diffusion to poloidal Alfvén time) has been carried out on MST. A weaker S scaling than originally reported on smaller devices, limited to lower S values, has been observed. The MST studies extended the range of S from originally $S = 10^4$ to $S = 10^6$. From smaller devices, a favourable b/B Å $S^{-0.5}$ has been reported. Depending on I_p/N a scaling b/B Å $S^{-0.07...-0.18}$ is found on MST. The less favorable scaling may have implications for the reactor operational conditions; external means to reduce the fluctuation level may be necessary.

- Bifurcations and enhanced confinement

Improved confinement states are accessible either by external means or they develop spontaneously. As the dynamo-action leads to tearing-mode activity, the bulk confinement can be improved when the dynamo-drive is reduced. A successful technique is pulsed poloidal current drive (PPCD). This technique can reduce both the magnetic fluctuation amplitued by a factor of 2 and the width of the magnetic islands so that overlap and stochastisation in the core is reduced. As a consequence, electron temperature gradients in the core region develop, χ_e drops in agreement with Rechester Rosenbluth`s stochastic field model, the energy content increases (poloidal-β by 30-40 %), the ohmic power input decreases and in the sum the energy confinement time rises by up to a factor of 5. PPCD is technically carried out by the injection of current at the plasma edge using an electron gun. The experiment is a manifestation of the connection and interplay between plasma edge and plasma core.

Another technique which leads to improved confinement is the polarisation of the plasma edge as successfully demonstrated on tokamaks. Biasing inserted probes leads to a strong flow (Å 25 km/s) which damps electrostatic turbulence residing at the plasma edge. Thus specifically the edge density gradient increases and the particle confinement improves. As more the flow and to a lesser extent the flow shear is increased, further studies are necessary to clarify their mutual impact on turbulence.

Besides the driven transitions, spontaneous ones are observed. A strongly sheared E×B flow can spontaneously develop over a restricted radial range at the edge. This transition specifically occurs at low density with deep field reversal and under clean wall conditions. Both the broad band global magnetic and the electrostatic fluctuations are reduces in a radial range larger than the sheard layer. The confinement time can increase by a factor of 3.

Another spontaneous transition is the α-mode of RFX. It develops in a phase where the current is ramped down and the current profile peaks. The toroidal n-spectrum of the m=1 dynamo-modes shrinks to single helicity at n=8-9. Thus, the stochasticity of the plasma core is reduced and confinement is improved.

Helical systems

- The following devices contributed with experimental results:

LHD, CHS, Toki-City/Japan; He-E, Kyoto/Japan; W7-AS, Garching/Germany; TJ-II, Madrid/Spain; L2-M, Moscow/Russia; H-1, Canberra/Australia. Two new devices have started operation recently and were reported at an IAEA conference the first time: The Large Helical Device, LHD, of Japan and TJ-II of Spain.

- New devices: LHD and TJ-II.

LHD is a large (R=3.9 m, <a> = 0.65 m) heliotron with superconducting coils designed to operate finally at 4T. The main purpose of LHD is to study net current-free helical confinement with the emphasis of demonstrating the relevance of helical systems for steady-state operation and provide essential data for a fusion power plant along this line. LHD will further narrow the gap between the tokamaks and helical systems. Its targets are $T_i > 10$ keV, $n\tau_E T_i > 10^{20}$ m^{-3} s keV , and $<\beta> > 5\%$. First experiments were at 1.5 T with ECRH (0.35 MW) and NBI (3 MW). At $<n_e>$ Å 1.5×10^{19} m^{-3}, T_e =1.5 keV, T_i = 1.1 keV have been measured. The maximal confinement time is 170 ms. A remarkable result is that the confinement data are above the stellarator scaling ISS95 by about 50%.

TJ-II (R=1.5 m, <a> = 0.22 m) is a heliac with a helical magnetic axis and low shear. The magnetic field is up to 1.2 T. Owing to the central conductor, the device has a large configurational flexibility. TJ-II will specifically address confinement at low collisionality and high-beta stability issues. The first plasmas were heated with ECRH (53.2 GHz, 0.25 MW).). At $<n_e>$ Å $0.5\text{-}1\times10^{19}$ m^{-3}, T_e =0.8 keV, T_i = 0.1 keV have been measured; τ_E = 3-4 ms.

- **Major results reported from Helical Systems**

- Magnetic configurations, equilibrium and stellarator optimization

Classical helical devices are L2-M, representing the stellarator, CHS, He-E and LHD, representing the heliotron. Low shear stellarators are W7-AS, TJ-II, and H-1. W7-AS has modular coils. TJ-II and H-1 have helically varying magnetic axis; they are heliacs. L2-M, CHS, H-E, and LHD are l=2 devices with elliptical cross-sections; the heliacs have a strong l=1 component, TJ-II has a bean-shaped cross-section; the advanced stellarator W7-AS is a mixture of l=2 and l=3 components.

New proposals have been presented in the conference, which are based on the concepts of quasi-symmetries. Quasi-symmetric systems are true 3-D geometries with a two-dimensional variation of modB in a flux surface (expressed in appropriate magnetic coordinates). The neo-classical properties of quasi-symmetric systems are principally identical to those with true symmetry and an ignorable coordinate.
Three quasi-symmetries are possible: axi-, helical-, and poloidal quasi-symmetry. Quasi-axi, and quasi-helical symmetry are governed by one dominant helicity (toroidal or helical, respectively). Particle confinement is achieved under quasi-poloidal symmetry by closed surfaces of the second adiabatic invariant $J_{||}$. The particle drifts by field inhomogeneities are strongly reduced. As the plasma flow is within a flux surface, these configurations are called more specifically quasi-isodynamic (in Europe and Japan) and quasi-omnigeneous (in USA).
Heliotron-J is a heliotron designed along the line of quasi-isodynamicity. It will be built at the Kyoto University. QOS is a stellarator designed as part of the US fusion program along the same principles. The sphellamak, developed at CRPP, Switzerland, achieves quasi-isodynamic properties by the paramagnetism

of an induced or pressure driven current. A quasi-axisymmetric stellarator has been presented by PPPL with the idea to provide rotational transform by a strong bootstrap current and to avoid possible disruptions with an external contribution to rotational transform but without the expense of enhanced 3-D particle losses.

The present devices cover a large range of magnetic topologies: stellarators, heliotrons, heliacs, devices with and without shear, with magnetic well and hill in the vacuum configuration, with bean-shaped cross-section and with partial transport optimization. Individually, the devices also have a large flexibility to change the properties of the magnetic configuration.

CHS can vary the magnetic surfaces by controllable poloidal fields. When shifted to the inside, the flux surfaces are well aligned to the drift surfaces of deeply trapped particles and a drift-optimized configuration is established. At low beta and collisionality, such a configuration displays improved confinement. This improvement originates from reduced ripple diffusion of helically trapped particles.

As the MHD stability is improved if the plasma is shifted to the outside (a well develops), CHS generally operates with a standard radial position, which is a compromise between drift orbit optimization and stability.

TJ-II can realize several iota values and can change the magnetic well in the range 0-6%.

W7-AS has a reduced ratio of $\langle j_{\|}^2\rangle/\langle j_{\perp}^2\rangle$ owing to its optimization which leads to a measurable reduction of the Shafranov shift (in comparison to a classical stellarator) up to the maximal $\langle\beta\rangle$ Å 2%.

- Heating

Stellarator plasmas are generally produced by ECRH, which yields low-beta, low collisionality plasmas. Operation at high β and high density is done by NBI. ICRH is being studied but it has not yet reached the working horse status.

In W7-AS high density operation beyond the X-mode cut-off of ECRH has been demonstrated by mode conversion to the electron Bernstein wave. More than 80% of the wave power could be coupled to the plasma.

ICRH showed promising application in W7-AS using an antenna positioned at the high field side which excites a narrow $k\|$ spectrum centered on $k\| = 6m^{-1}$. D (H) and He (H) minority heating, D/H mode conversion heating, and second harmonic H heating were studied. Possibly owing to the peculiarities of the antenna design, density and impurity control was possible. The low power heating efficiencies of the different schemes were in the range of present experience (mostly from tokamaks).

- Confinement

- Particle confinement

Helical systems report flat density profiles with central ECRH. With strong central ECRH, the density profile becomes even hollow. This observation does not depend on the details of the configuration and applies to low-shear stellarators as well as high-shear torsatrons. Preliminary studies on LHD confirm this general picture for a large device. With off-axis ECRH heating and rather flat central electron temperature profiles, the central density profiles are peaked though the neutral particle source can still be ignored within the plasma core. Gas-oscillation and ECRH switch-off experiments on W7-AS have shown that a thermally driven neo-classical flux (outward directed in stellarators) and a convective inward directed flux (its origin is not well understood but does not result from a toroidal electric field) govern the particle transport. The opposing effects of thermal outward diffusion and convective inward flow determine the actual core density profile.

- Electron heat transport

With strong ECRH (1.3 MW) into low density discharges of W7-AS, the core electron heat diffusivity strongly reduces and a characteristic central peak appears atop of the T_e-profile. Maximally, T_e up to 5.7 keV has been measured. Spectroscopic measurements show that a strong positive electric field (50 keV/m) develops in the plasma core, which strongly reduces the electron heat diffusivity. Transport analysis shows that χ_e is close to the respective neo-classical value and drops from the one at low electric field to the one at high electric field. There is experimental evidence that the loss of particles heated by ECRH and helically trapped represent a non-ambipolar loss, which causes the strong positive potential in the core. In this case the balance of thermal fluxes does not cause the electron root of neo-classical fluxes, rather a driven transport equilibrium is established.

- Ion heat transport

Stellarators can operate in a high ion-temperature mode, which develops along with a peaking of the density profile. This correlation is similar to the one observed in tokamaks. The causality is not clear but it is the central beam fuelling of neutral injection along with a reduction of external gas fuelling which causes the peaking. Alternatively, as He-E has shown, also pellet refueling leads to density profile peaking and increased energy content. CHS reports central ion temperatures up to 1 keV, which are achieved after a reduction of ion heat conductivity by a factor of 2-3, compared with the usual L-mode transport conditions. The density peaking factor $n_{e0}/<n_e>$ increases from 1-1.5 to 1.5-2. A similar effect has been reported by He-E with $n_{e0}/<n_e>$ up to 4.5. The reduction of χ_i leads to a peaking of the ion temperature profile.
Apart from the very core region, χ_i in CHS is clearly above the neo-classical value even in the high-T_i-mode. The improvement is attributed to the action of the electric field onto the turbulence; a more negative electric field is observed in the high T_i-mode. It is interesting to note that the high-Ti-mode as observed on W7-AS is also related to the negative electric field; in this case, however, the core transport is neo-classically limited and is reduced when the field becomes more negative.

- Bifurcation and limit cycle oscillations

In stellarators, the H-mode develops; the transition causes a rise in density and temperature. In W7-AS, the operational window of the H-mode is limited to selected iota-ranges. In H-1 at low density and magnetic field, bifurcations are observed whereas the high confinement state is qualified by an increase in density and ion temperature, peaking of the density profile, reduction of plasma turbulence and a more negative electric field. The transition occurs beyond a threshold; limit cycle oscillations between the two states do occur. Probe studies show that pressure gradient and electric field are well in phase. TJ-II reports a connection between the strength of the magnetic well and the edge radial electric field. At a well of 6% (0.2%) a field of 20 (2) V/cm is measured.
In another regime observed on W7-AS, both the electron- and ion temperatures increase; this increase happens along a slow timescale (governed by τ_E or longer) and develops at constant density. The density profile shrinks in this phase. The highest confinement times are observed with about a factor of two above the scaling.
Transitions between confinement states at the L-mode and at a sub-L-mode level are possible on W7-AS depending on the setting of iota. Good confinement exists in the neighborhood of low rationals. The actual confinement depends on the presence of low-order rationals and the amount of shear. Bifurcation can occur because the bootstrap current can produce sufficient shear so that the energy content rises; the opposite is also possible and it depends on the selection of external iota, because shear can introduce resonances. The experimental findings can be modeled.
A detailed study on bifurcation phenomena has been presented by CHS. An electric pulsation has been observed where the plasma potential jumps back and forth between two states. Owing to its heavy ion beam probe, CHS is specifically suited for such measurements. This dynamic state develops at low density, below 10^{18} m^{-3}; a density threshold exists. Quasi-periodically within every 2 ms, the core potential jumps from about 0.6 to 2.0 kV. The plasma core up to r Å <a>/2 is affected by the pulsation. The residential time at low potential is short. The transition time scales are in agreement with neo-classical theory. Plasma parameter time scales (e.g. changes of the density profile) are short and not governed by neo-classical transport.
Also in W7-AS two transport states can develop with rather erratic transitions as soon as the heating power is set close to the bifurcation point. The core electron temperature jumps between 4 and 5 keV. A power threshold exists. The bifurcation is seen as a manifestation of the dependence of electron heat transport on electric field in a 3-D configuration whereas the potential is established by losses of energetic electrons from ECRH.

- MHD

The configuration flexibility of helical systems with low and high shear and with and without magnetic well is used to study Mercier, resistive interchange and ballooning stability in a wide parameter range up to the highest β-values up to $< \beta >$ Å 2%. Generally plasmas are stable where Mercier stability is not predicted. A rather strong MHD response is observed in cases with beam injection. In CHS, fishbone instabilities and toroidally induced Alfvén waves (TAEs) and in W7-AS, due to the low shear, globally induced Alfvén waves (GAEs) are generally observed. With shear, the transition from GAEs to TAEs is possible.

Depending on the vertical field, the plasma major radius and the resulting field properties, m=3/n=2 fishbones occur in CHS for outward, m=2/n=1 for inward shifted plasmas. Fishbones can lead to fast particle losses. The mode frequency strongly drops within one fishbone burst. From the HIBP of CHS, it is clear that it is not a potential variation, which causes the frequency sweep.

TAEs in CHS are localized in the core region. Owing to the iota-profile, there should be strong continuum damping near the edge. The measured TAE frequency is about 20% lower than expected. Modes are probably caused by side-band excitation.

In W7-AS the GAEs appear as sharp resonances localized within the continuum gaps. The frequency is typically in the range of 20-40 kHz; the activity is not causing particle losses. With shear, TAE modes appear which can be identified by a change in the poloidal mode number from m=5 to m=6 (n=2) from the inside to the outside. Mode structure and frequency can be well modeled with the CASD3 code and with a gyrofluid model, which predicts that condition for instability exists and it predicts the correct amplitude and linear growth rate.

At low density, when the Alfvén velocity rises beyond the particle velocity, a beam driven activity appears at high frequency (500 kHz) which affects plasma confinement.

Close to the high β values of W7-AS neither the low nor the high frequency Alfvénic activity plays any role. The modes are damped obviously because of the high plasma beta and the increased magnetic shear.

- Divertor

In W7-AS the natural islands of the stellarator are used for exhaust purposes. In LHD, a local island divertor (LID) will be employed. Preliminary studies are carried out on W7-AS using symmetric inner targets and the 3D EMC Monte-Carlo code linked to EIRENE models the results. Plasma diversion is possible with the islands. Modeling highlights the role of cross-field momentum diffusion; the experiments show the strong plasma E×B plasma rotation within the island. High recycling conditions are possible in the preliminary exhaust conditions; detachment is predicted for a full island divertor.

Conclusions

The non-tokamaks have further expanded their relevance by the start of new and larger devices. Within a very short time after start of operation, TPE-RX, LHD, and TJ-II have reached plasmas in the keV temperature range and contributed with new information. All non-tokamaks highlight the role of the electric field to better confine plasmas either by affecting the ”laminar” processes in the end losses of mirrors or in the neo-classical losses of 3-D systems or by spontaneous or induced damping of turbulence causing radial losses by principles and techniques which work in tokamaks, stellarators and RFPs. Further common elements are the sensitivity of the core properties on the edge conditions, the improvement of the energy confinement when the plasma density profile peaks or is peaked by central fuelling. Specifically rewarding might be a joint study on particle transport in toroidal systems – tokamaks, helical systems and RFPs.