Joint Meeting of the Second International Atomic Energy Agency Technical Committee Meeting on Spherical Tori and the Seventh International Spherical Torus Workshop

1 – 3 August 2001
São José dos Campos, SP, Brazil

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1. Introduction

The 2nd IAEA Technical Committee Meeting (TCM) on Spherical Tori (ST) was held in conjunction with the 7th International Spherical Torus Workshop from 1 till 3 August 2001 at the campus of the Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brazil. The first TCM on Spherical Tori was held at the University of Tokyo (1998), jointly with the fifth International ST Workshop. The previous ST Workshops were held at Oak Ridge (1994), Princeton (1995), Culham (1996), St. Petersburg (1997), Tokyo (1998) and Seattle (1999). The 3-days joint meeting was organized by Gerson Otto Ludwig and his Team from the Laboratório Associado de Plasma at INPE. The joint meeting was attended by 50 scientists from nine countries (Brazil, China, Egypt, Italy, Japan, Russia, Ukraine, the United Kingdom, and the United States of America) focusing this year on the following topics: overviews on major spherical torus devices under operation or construction, experimental campaigns, dedicated diagnostics, theory, innovations, and next step spherical torus devices. 34 papers were presented as talks as well as posters displayed in front of the meeting hall, where they were appreciated by the participants supporting more detailed discussions during breaks.

The papers were selected by an international Programme Committee including the following persons: Franco Alladio, Italy; Vasily K. Gusev, Russia; Gerson Otto Ludwig, Brazil, Chairman of the Programme and Local Organizing Committee; William Morris, UK; Martin Peng, USA; Ursula Schneider, IAEA; and Yuichi Takase, Japan.

The 4-page submitted papers are being published in unedited format on CD-ROM and will be made available on the Internet (http://www.iaea.org/programmes/ripc/physics/). The authors are encouraged to publish extended versions of their papers also in international fusion related journals (Nuclear Fusion, Plasma Physics and Controlled Fusion Research) following standard submission and refereeing procedures.

2. Results

After a short welcome session, the meeting was opened by a series of eight overviews followed by sessions on dedicated topics. The following sections are divided into the topics mentioned above giving a brief summary of each presentation based on notes provided by the session chairmen.

2.1. Overviews (M. Peng, M.P.Gryaznevich, Y. Takase)

Progress on MAST, by G. Cunningham et al. – The latest results from the Mega Amp Spherical Tokamak (MAST) were reported, with particular emphasis on the analysis of measurements from the

first campaign, and data from the second campaign. The first campaign yielded plasmas with a density well in excess of the Greenwald limit, and other enhanced (H) mode plasmas with energy confinement of at least equal to the ITER PBY98 H mode scaling. In the new campaign the database of H mode discharges has been extended to 1 MA plasma current and neutral beam power injection up to 2 MW. New results have been reported of the power threshold study of the L–H (low-high) transition, plasma edge behavior, and magnetohydrodynamic (MHD) activities; particularly on the phenomenological observations related to internal reconnection events (IREs).

NSTX Overview, by M. Ono et al. – A very productive period of plasma operations has been reported on the National Spherical Torus Experiment (NSTX). The design value of 1 MA for the plasma current has been reached well ahead of the schedule and was successfully raised to 1.4 MA. Discharges at 1 MA level with a flat top duration of over 200 ms were achieved by the end of 2000 with improved vacuum conditioning, plasma control, higher toroidal magnetic field of up to 0.45 T, and 1.5 MW of neutral beam injection (NBI) auxiliary heating power. The best confinement data exceeds the ITER PB Y98 H mode scaling. Significant advances were also made in the areas of High Harmonic Fast Wave (HHFW) and Coaxial Helicity Injection (CHI) for heating and current drive. CHI successfully drove up to 0.36 MA of toroidal plasma current with a plasma current multiplicatior factor of 14. Several facility upgrades are under consideration.

Overview of Results and Program Development in Globus-M Spherical Tokamak, by V.K. Gusev et al. – Good progress has been reported from the Globus-M device presently under construction. During first tests plasma currents of up to 0.25 MA have been achieved with a flat top duration of about 25 ms by using only 1/3 of the available solenoid magnetic flux. One exciting result of the test runs was the measured runaway fraction that is far below theoretical predictions. Plasma heating systems are under construction such as neutral beam injection, ion cyclotron resonance heating, and high harmonic fast wave as well as lower hybrid injection. All graphite tiles are already mounted on the central column of Globus-M.

Overview of TST-2, by Y. Takase et al. – The Tokyo Spherical Tokamak (TS-2) device was significantly updated allowing now plasma currents of up to 110 kA with a flat top duration of 6 ms. Measurements of ion reconnection event precursors indicate a nonlinear coupling mechanism. Electron Bernstein wave emission has been observed in ohmic heated discharges for the first time.

Overview of the ETE Spherical Tokamak, by E. Del Bosco et al. – The ETE (Experimento Tokamak Esférico) device is now fully operational with a good set of "first-day" diagnostics. Plasma currents of about 10 kA have been easily achieved in first test runs and the formation of spherical plasmas was recorded using a CCD camera. The planned update of the power supplies will provide further improvements in device performance.

Recent Results from the PEGASUS Toroidal Experiment, by G.D. Garstka et al. – The PEGASUS toroidal experiment is an extremely low aspect ratio device with the goal of minimizingthe central column while maintaining good confinement and stability. PEGASUS has achieved R = 0.2-0.45 m, $A \geq 1.15$, $\beta_t \leq 25\%$, $\beta_N \leq 5$, $I_N \leq 8$, $I_p/I_{TF} < 1.2$, and $n_e \leq n_{GW}$ in ohmic plasmas. Plasmas are presently limited by MHD activities and possibly by the available input flux. Facility upgrades, including increased ohmic flux and transiently higher toroidal field, are being conducted to overcome low-n limits and flux limits, and to ease startup. These upgrades will enable PEGASUS to achieve larger values of I_N, β_N and β_t in accordance with its mission to find the beta limits at very low A.

Ultra-High-Beta Spherical Tokamak Experiments in TS-3 and 4, by Y. Ono et al. – High power heating (5–30 MW) of the magnetic reconnection has been used in TS-3 and TS-4 (Tokyo University Spherical Tori 3 and 4) ST experiments to study the high-β stability of STs. The BALOO code analysis indicates that the ultra high-β (> 40%) ST that evolved from a field-reversed configuration

(FRC) was located in the second stability regime of the ballooning instability. In agreement with the BALOO analysis, disruptions of high-β STs were documented together with high-n localized modes, when the high-β ST lost its edge pressure and also when the pressure of the low-β ST exceeded a critical value due to their co-helicity merging.

Research Program of Spherical Tokamak in China, by Yexi He – SUNIST (Sino United Spherical Tokamak), a new ST facility in China, will be operated by an experienced group on turbulence, alternating current operation, and current startup with electron cyclotron resonance (ECR) wave and electrode assisted heating on small tokamaks. The vacuum vessel has toroidal and poloidal electrical breaks to reduce eddy current effects.

2.2. Experiments in Spherical Tori (M. Ono)

Scenario of GLOBUS-M Operation in OH regime, by N.V. Sakharov et al. – The spherical tokamak Globus-M (R = 0.36 m, a = 0.24 m, plasma current of up to 0.5 MA with a toroidal magnetic field of up to 0.6 T on axis, elongation of up to 2.2, triangularity of up to 0.4) was constructed at the Ioffe Institute, St. Petersburg. The experiments performed in 2001 focused on vacuum vessel conditioning after the installation of the graphite tiles, on the study of plasma shaping and plasma position feedback control and on the optimization of the power supplies for further improvements of the plasma discharge performance. Carboran – $C_2B_{10}H_{12}$ – was utilised for vessel boronization. The system for plasma vertical and horizontal position feedback control is based on analog amplifiers and thyristor choppers with a frequency response of up to 3 kHz. The evolution of the plasma position during IREs was investigated. The power supply upgrade was performed in parallel with the plasma experiments. All existing thyristor rectifiers have been prepared for the next experimental campaign. Two 32 MVA rectifiers were connected in parallel and utilised for energising the toroidal field (TF) coils. As a result, the TF rod current of about 1 MA (B_T = 0.55 T at R = 0.36 m) was achieved. Two other high-power rectifiers were tested for a subsequent ±70 kA current swing in the central solenoid. Eight additional turns were wound in-situ in each PF3, and thus the productivity of the plasma radial position control system was increased. PF1 and PF2 will be utilised for plasma shaping. Digital control of the plasma position is planned for the end of 2001. The achieved range of plasma parameters comprises a plasma current of up to 0.25 MA, a toroidal field in the range of 0.07–0.38 T, a plasma pulse length of up to 60 ms, a vertical elongation of 1.1–1.9, a triangularity of 0.1–0.4, a safety factor $q_{95} \geq 2.1$ and a minimum $q_{cyl} \sim 0.9$.

Current Drive Experiments on the HIT-II Spherical Torus, by A.J. Redd et al. – Coaxial Helicity Injection (CHI)/Ohmic plasma performance on HIT-II (Helicity Injected Torus) discharges is significantly improved by using a double-null diverter flux boundary. A mechanism for helicity injection current drive has been developed which is consistent with experimental observations of HIT and HIT-II CHI plasmas, including the effects of reversing the polarity of the injector electrodes.

Coaxial Helicity Injection Current Drive on the NSTX and HIT-II Spherical Tori, by R. Raman et al. (presented by B. Nelson) – CHI current drive experiments have been very successful on NSTX, driving up to 360 kA of toroidal current with the current multiplication factor of up to 14. Continuous n = 1 rotating oscillations are seen (strongly correlated with high performance discharges in HIT and HIT-II CHI operation), CCD images and magnetic reconstruction show the injector flux approximately filling the vessel, and spectroscopy shows increasing temperature with time.

Initial Results from MAST Pellet Injection, by C. Ribeiro et al. – A comprehensive pellet injection programme (hardware, modeling, and several dedicated diagnostics) is currently been commissioned for MAST in collaboration with several international institutions. Near-radial mid-plane multi-pellet (8) injection experiments at the low field side (LFS) (< 1000 m/s, $0.5/1/2\times10^{20}$ atoms D pellets) are

imminent.

Non-diffusive cross-field plasma transport observations on START and MAST, by M. Gryaznevich et al. – Streamers, filaments, blobs, pin-stripes and other visible light perturbations have been observed at the edge of START, MAST and NSTX plasmas. These events imply the existence of non-diffusive cross-field transport through the scrape-off layer (SOL) and last closed flux surface (LCFS), which feeds the "halo" tenuous plasma outside the LCFS. Cross-field transport plays an important role in diverter target power loading reduction. In H mode discharges, this transport mechanism is reduced and additional measures to reduce the power loading in future burning plasma STs may be necessary (such as a natural diverter or diverter target biasing).

2.3. Diagnostics (F. Alladio)

NSTX Diagnostics and Operation: Status and Plans, by M.G. Bell et al. (presented by M. Ono) – NSTX uses a subset of the flux loops and magnetic field detectors in real-time control of the plasma current, position and shape. The full set is used with the EFIT code to provide analysis of the plasma equilibrium with a time step as small as 1 ms between plasma shots (10 min). Mirnov coils are used in combination with arrays of soft X ray detectors for characterizing MHD instabilities of up to 2 MHz in frequency. A multi-pulse 10 channels Thomson scattering system provides time resolved profiles of the electron temperature and density. The profiles of the ion temperature and the toroidal rotation are measured by charge exchange recombination spectroscopy (CHERS) from carbon impurities excited with the NBI. Spectrometers, broadband bolometers and filtered detectors, spanning the range from the near infrared to the vacuum ultraviolet, measure the radiated power and effective ion charge. Dedicated bolometers and spectrometers combined with Langmuir probes in the edge are used to measure the power and particle fluxes to the diverter and first walls. Several diagnostics and upgrades are being planned.

Status and Development of Globus-M Diagnostics, by Yu.V. Petrov et al. – A full set of flux loops, magnetic probes and Rogowski coils is used in Globus-M for magnetic reconstruction measurements combined with the EFIT code. Diagnostics comprising of visible spectrometers, a hard X ray spectrometer, a soft X ray filter spectrometer and diamagnetic loops are now in operation. The plasma density is monitored using a 1 mm microwave interferometer (3 vertical channels in operation and one horizontal channel being installed). HCN laser and scanning pulse radar reflectometers are under construction. By the end of 2001 the Thomson scattering system, two soft X ray pinhole cameras, a high-speed CCD video camera and a 4-channel pyroelectric bolometer should enter operation. Other advanced diagnostics are being planned.

Present Status of ETE Diagnostics, by L.A. Berni et al. – ETE has recently started its operation. A basic set of diagnostics has been implemented comprising magnetic detection (Rogowski coils, flux loops, few magnetic probes), mass and visible spectroscopy, and a CCD camera for optical imaging. A Thomson scattering system capable to measure electron temperatures in the 20 eV to 2 keV range is ready to start operation. This system can be upgraded to observe up to 22 spatial positions along the laser line. Other diagnostics as the fast lithium beam probe for plasma edge studies, the CO_2 interferometer, and the soft X ray camera are under development.

Predicting the Onset of Plasma Disruptions in Tokamaks Using Artificial Neural Networks, by A. Vannucci et al. – It has been possible to forecast disruptions in tokamaks 1 ms in advance by using magnetic signals in an artificial neural network. When using magnetic and soft X ray signals the predicting time extends to 3 ms. More recently, this forecasting time interval was extended even further, up to 8 ms, by the introduction of a variety of diagnostic signals. These results indicate that a defensive mechanism could be designed to avoid the undesirable effects of a major disruption.

First Results from Heavy Ion Beam Probe Diagnostics on the TUMAN-3M Tokamak, by

L.I. Krupnik et al. – The heavy ion beam probe (HIBP) diagnostic provides a direct means of measuring the local potential within a wide range of plasma parameters and spatial locations. The results of the first observations using an 80 keV K^+ ion beam on the TUMAN-3M tokamak (plasma current up to 160 kA and toroidal magnetic field 0.8 T) were reported.

2.4. Theory

2.4.1. Radio Frequency (M.C.R. Andrade)

Calculations of Alfvén Wave Heating in Low Aspect Ratio Tokamak, by A.G. Elfimov et al. – A.G. Elfimov showed results provided by a two dimensional code (ALTOK code) designed for calculations of plasma heating in the Alfvén wave (AW) and ion cyclotron range of frequencies in axisymmetric tokamaks. The fluid plasma model used in the code includes electrons and two ions species and is valid for magnetic surfaces of arbitrary cross-sections. According to Elfimov this code helps to overcome difficulties by numerically solving the Maxwell equations in the vicinity of the ion cyclotron resonance. These difficulties usually arise due to nonlocal effects in the kinetic tensor mainly caused by the presence of impurities in the plasma that can introduce zones of ion cyclotron resonance in the AW continuum. By using this code, Elfimov showed that the surface Alfvén wave excited by the M = 1, N = 2, 3 antenna modes are found to be the best candidates for plasma heating in the i-i hybrid Alfvén continuum in low aspect ratio tokamaks.

Electron Bernstein Wave Heating and Emission in Spherical Tokamaks, by A.K. Ram et al. – In this talk, A.K. Ram has reinforced the fact that due to the overdense character of ST plasmas, electron cyclotron heating and current drive can be accomplished by mode converting the X mode or the O mode into Electron Bernstein Waves (EBW). Ram reported on analytical and numerical models that have been developed to study the mode conversion of the X mode and the O mode of electron cyclotron waves to EBWs, showing that both processes have a different optimum regime in the frequency and parallel wavelength space. In particular, the X mode couples efficiently to EBWs for longer parallel wavelengths and smaller frequencies than the O mode. Ram also stressed the fact that – as EBWs damp strongly on electrons near the Doppler-shifted electron cyclotron resonance or its harmonics – the thermal emission of EBWs occurs for frequencies corresponding to the local Doppler-shifted electron cyclotron frequency. For this reason, EBW emission may have the potential to be used for diagnosing the electron plasma temperature. Finally, as the EBW emission coefficients are the same as the EBW excitation coefficients, observations of EBW emission from ST plasmas can provide a useful guide for the design of EBW heating and current drive experiments.

Radio Frequency Wave Dissipation by Electron Landau Damping in Elongated Spherical Tokamaks, by N.I. Grishanov et al. – This talk and the following one reported on the effect of radio frequency wave dissipation when trapped and untrapped particles are present in the plasma. The main motivation of both papers is to study the electron Landau damping of waves due to the resonance interaction of the parallel electric field with trapped and untrapped electrons. These resonance conditions are different for each of these particles and are modified in relation to cylindrical (or large aspect ratio) geometries due to the strong modulation of the parallel particle velocities in small aspect ratios. N.I. Grishanov presented the derivation of the parallel dielectric tensor components for radio frequency waves and for trapped and untrapped particles in a two-dimensional axisymmetric tokamak with elliptic magnetic surfaces. According to him the parallel permittivity elements derived in his paper are valid for large and low aspect ratio machines with elliptic magnetic surfaces and are suitable to study the wave propagation and dissipation during plasma heating and current drive generation.

Permittivity Tensor and RF Dissipation in Plasmas of Low Aspect Ratio Toroidal Devices, by F.M. Nekrasov et al. – F.M. Nekrasov presented an analytical solution of the Vlasov equation in the drift approximation in order to derive a full set of permittivity tensor components for solving the Maxwell equations in low aspect ratios with circular magnetic surfaces. Numerical calculations of the

imaginary part of the parallel tensor component – including trapped and untrapped particles – show that the wave dissipation is enhanced for waves with phase velocities larger than the thermal velocity and is strongly modified near rational magnetic surfaces due to the strong modulation of the parallel velocity of electrons in low aspect ratio. Nekrasov concluded that this phenomenon could be used for radio-frequency (RF) plasma heating and current drive as well as for stabilization of drift instabilitiesat the rational magnetic surfaces.

2.4.2. Equilibrium (A.G. Elfimov)

Chandrasekar-Kendall-Furth Configurations for Magnetic Confinement, by P. Micozzi et al. – P. Micozzi presented results of equilibriumand stability studies in Chandrasekar-Kendall-Furth (CKF) toroidal force-free fields with two " secondary tori ". The unrelaxed (non-zero grad p) CKF equilibrium, topologically similar to the relaxed one, is found to be stable in low-m ideal MHD modes up to beta values of about 1. Possible advantages of CKF unrelaxed fusion reactors (unimpeded outflow of fusion products easing direct energy conversion) were also discussed. A force-free screw-pinch is proposed to replace the central conductor in the PROTO-SPHERA experiment.

Comparison of Bootstrap Current Models in a Self-Consistent Equilibrium Calculation for Tokamak Plasmas, by M.C.R. Andrade and G.O. Ludwig – M. Andrade compared two bootstrap current models in self-consistent equilibrium calculations of spherical tokamaks (ST). The Hirshman-Sigmar-Shaing model considers more accurately the multi-species effects, but an approximated collision operator gives errors of up to 20% in the viscosity coefficients in collisional regimes while Sauter's model (fitted formulation) uses the full Coulomb collision operator, which is computed approximately four times faster than the H-S/Shaing model. According to these models, the bootstrap current may roughly represent 10 to 35% of the total plasma current in the first phase of operation of the ETE experiment (ST/Brazil) where a higher elongation provides a higher bootstrap current while the presence of impurities causes a slight decrease in the bootstrap current contribution.

Eigenvalues of Relaxed Compact Tori of Arbitrary Cross-Section , by S.M. Khalil – S.M. Khalil presented results of theoretical equilibrium calculations in force-free compact tori with arbitrary cross-sections. A very simplified method is used to calculate eigenvalues of tori with an infinite conductivity boundary condition. The same method is proposed for calculating unrelaxed tori equilibria.

2.4.3 Stability (V.K. Gusev)

Ideal MHD Stability of Flux-Core Spheromaks, by F. Alladio et al. – F. Alladio analyzed the ideal stability of the so-called soft-core spherical torus. This device differs from the usual spherical tokamak by the absence of a rigid TF central conductor and the toroidal magnetic field is created by an electrode screw pinch (SP) discharge. Ideal MHD instabilities in such system limit the ratio between the toroidal ST current, I_p, and the longitudinal SP current, I_e, depending upon the beta of the ST. At a beta of 30%, the limit is $I_p/I_e \leq 1$ at an aspect ratio of A=1.3. It increases up to $I_p/I_e \leq 4$, if beta-toroidal is below 10% and stabilizing plates near the SP electrodes are added.

Effect of Shafranov Shift on the Fishbone Mode Induced by Circulating Particles in Spherical Tori, by V.S. Marchenko et al. – V.S. Marchenko analyzed the fishbone instability in high beta ST. He showed that a high beta in low aspect ratio geometry tends to stabilize the fishbone instability in a plasma with energetic circulating ions. The stabilization results from the enhancement of toroidal drift motion by the Shafranov shift, which makes it difficult to reconcile the condition of the considerable energy exchange between the ions and the internal kink perturbation with the condition of the resonant wave-particle interaction.

Energetic Particle-Driven MHD Observations on STs and their Relevance to a Next Step

Burning Plasma ST, by M.P. Gryaznevich et al. – The talk given by M.P. Gryaznevich aimed to clarify to what extent the results of stability investigations obtained in the present generation of ST are relevant to burning ST plasma experiments. It was shown that MHD perturbations excited by energetic particles do not influence significantly the performance of modern ST s , however, such conclusion needs justification at higher beta values and higher input power.

Microstability Analysis of NSTX Plasmas, by C. Bourdelle et al. – C. Bourdelle presented results of microstability studies of high beta, low aspect ratio plasmas of the NSTX ST using a linear electromagnetic gyrokinetic code. Collisions and high T_i/T_e stabilize low $k_?$ modes, called Trapped Electron Modes (TEM) and Ion Temperature Gradient (ITG) modes. High T_i/T_e on the contrary destabilizes high $k_?$ modes, called Electron Temperature Gradient (ETG) modes, and high beta values also destabilize such modes. These observations are consistent with evidence that electron heat transport dominates the plasmas studied. The stabilization of short wavelength ($k_?\rho_i>>1$) modes is strongly dependent on the critical value of the toroidal beta. Such critical value increases with aspect ratio decrease; e.g. beta critical is 4% for the Tokamak Fusion Test Reactor (TFTR) case and 20% for the NSTX case. The stabilization effect is mostly due to passing particles spending more time in the good curvature region in the ST case.

Study of Electromagnetic Drift Instabilities in High ? Plasmas, by Zhe Gao et al. – Zhe Gao presented a study of electromagnetic drift modes for the case of arbitrary toroidal beta. A simple slab geometry model was developed for the analyses not taking into account trapped particles and toroidal effects. The influence of electron and ion betas and T_i/T_e on the plasma stability was discussed. It was shown that a finite beta value weakens the driving mechanism of the parallel velocity shear and strengthens the stabilizing effect of the plasma current. The finite beta stabilization is subtle for low frequency modes only, but in some cases higher order modes may be more important.

2.5 Innovations and Next Steps (G. Cunningham, E. Del Bosco)

The innovations session was reduced to only two papers, as Y.-S. Hwang (Feasibility Study of AC Spherical Tokamak with a Small Tabletop Device) and A. Mancuso (Electrodes for the PROTO-SPHERA Experiment) were unable to attend.

Initial Results of the TS-4 Spherical Tori Merging Experiment, by M. Tsuruda et al. – M. Tsuruda presented a description of TS-4 and a review of the first results. This machine will continue the work described by Y. Ono on high beta (second stability regime) ST plasmas in TS-3, with a larger device using flux cores instead of electrodes. TS-4 differs from MRX in having "separation coils" to keep the two spheromaks apart during formation and has successfully demonstrated such formation and merging to form a FRC.

Development of a High-Power Monotron for RF Applications in Spherical Tokamaks, by J.J. Barroso et al. – J.J. Barroso presented the design and model calculations for a 500 kW, 6.7 GHz monotron operating in TM_{040} using a triple electron beam. The monotron is a high power device, and is simple and compact since the elementary functions of electron bunching and energy transfer are performed in a simple cavity. The triple beam design would be a successor to an existing single beam device that is already under test.

Experimental Results from STs and their Relevance to a Next Step Burning Plasma ST, by M. Gryaznevich and the MAST Team (presented by G. Cunningham) – The operation programme for MAST in the coming year is mainly organized around planned upgrades to the NBI system. Following simultaneous demonstration of 1 MA plasma, 2-3 MW NBI and pellet injection during August/September, one injector will be taken out of service, upgraded and returned to service

by January/2002 for deuterium-deuterium (D-D) operation by May/2002. In the interim, electron cyclotron resonance heating (ECRH) operations will take place as well as upgrades to the Thomson scattering system and implementation of the X ray crystal spectroscopy, the X ray pulse analysis and edge diagnostics.

Recent Progress and Near-Term Plans of NSTX Research Program, by M. Peng for the NSTX Research Team – M. Peng presented not only the plans for NSTX but also gave an excellent overview of the physics of spherical tori already investigated in NSTX, and discussed new physics opportunities and principles. Concerning ST physics he highlighted results on topics such as coaxial helicity injection, MHD instabilities at very high beta-normalized, energetic ion-induced MHD activities, ELM-free (Edge Localized Mode) H-mode plasmas, electron Bernstein wave and high harmonic fast wave heating and current drive. The short term programme of NSTX includes upgrade of several heating schemes as well as diagnostics while the long term programme is focused on non-inductive startup and plasma sustained operation.

Acknowledgment

The 2 nd Technical Committee Meeting on Spherical Tori jointly held with the 7 th International Spherical Torus Workshop was organized in an excellent way by G.O. Ludwig and his Team from the Laboratório Associado de Plasma, Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brazil. The participants enjoyed the reception held on Wednesday evening and the tour to the ETE (Experimento Tokamak Esférico) laboratory as well as the dinner evening at Villa D'aldeia on Thursday. Additionally, many participants joined and enjoyed the 1-½ day tour to Parati and the schooner cruise to islands in the Atlantic Ocean arranged by the local organizers after the meeting.

Appendix – List of participants and official photographs of the meeting

Joint Meeting of the 2 nd International Atomic Energy Agency Technical Committee Meeting on Spherical Tori and

7th International Spherical Torus Workshop
1-3 August 2001, São José dos Campos, SP, Brazil
LIST OF PARTICIPANTS

Name	Address	FAX, E-mail	Country	Title of Paper
Alladio, Franco	CR-ENEA, CP 65 00044 Frascati, Roma	+39-06-9400-5735 alladio@frascati.enea.it	Italy	Ideal MHD Stability of Flux-Core Spheromaks
Andrade, Maria Célia Ramos (Ms)	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 mcr@plasma.inpe.br	Brazil	Comparison of Bootstrap Current Models in a Self-Consistent Equilibrium Calculation for Tokamak Plasmas
Barbosa, Luis Filipe Faria Wiltgen	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 filipe@plasma.inpe.br	Brazil	Artificial Neural Networks in the ETE Equilibrium Control (contribution included in "Overview of the ETE Spherical Tokamak Experiment" presented by Del Bosco, E.)
Barroso, Joaquim José	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 barroso@plasma.inpe.br	Brazil	Development of a High-Power Monotron for RF Applications in Spherical Tokamaks
Bell, Michael G.	Plasma Physics Laboratory Princeton University P.O. Box 451 Princeton, NJ 08543	+1-609-243- mbell@pppl.gov	USA	NSTX Diagnostics and Operation: Status and Plans (paper presented by Ono, M.)
Berni, Luiz	LAP-INPE, CP 515	+55-12-3945-6710	Brazil	Present Status of ETE

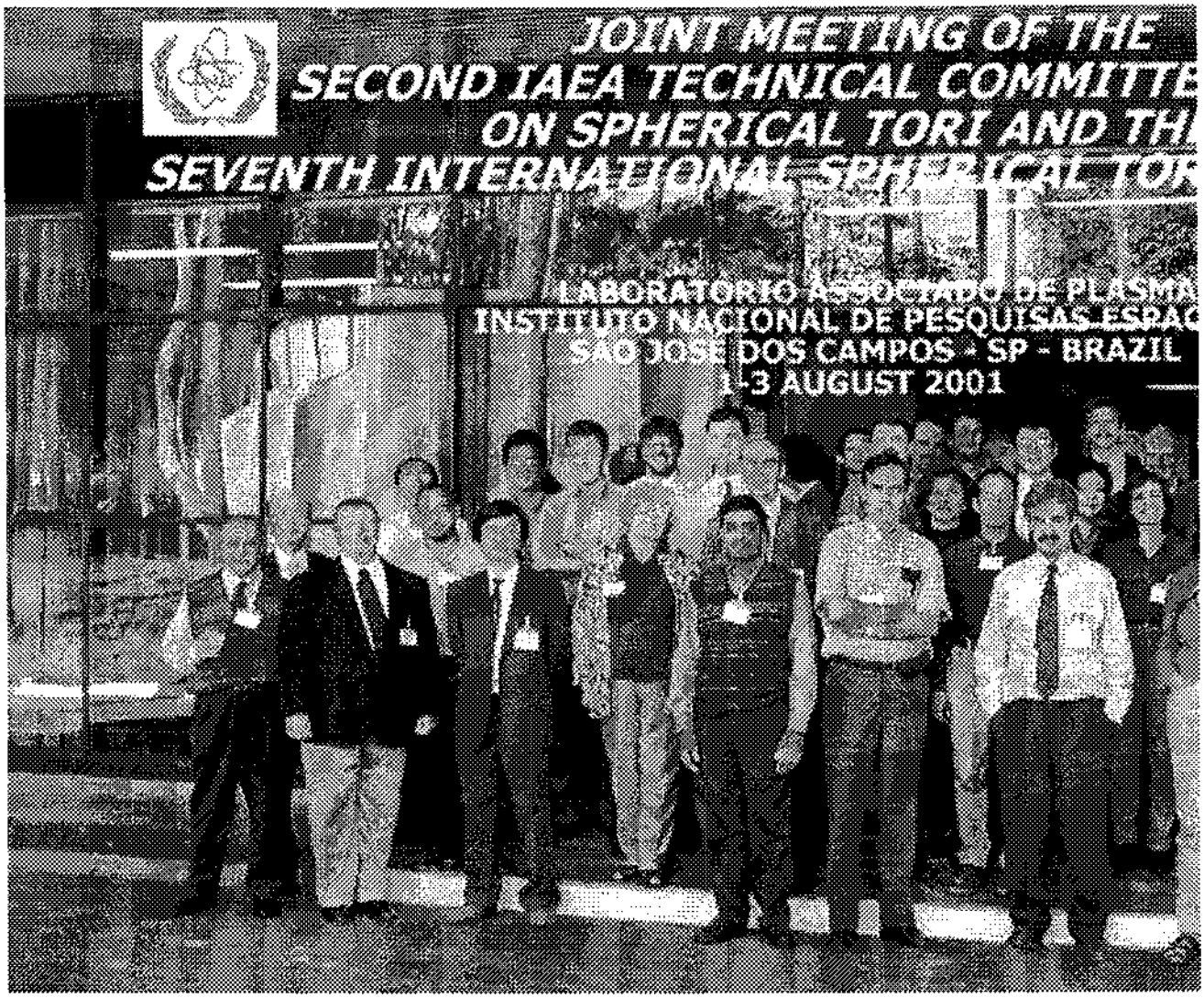
Ângelo	12201-970 S. J. Campos, SP	berni@plasma.inpe.br		Diagnostics
Bers, Abraham	Plasma Science and Fusion Center Massachusetts Institute of Technology 50 Vassar Street Cambridge, MA 02139	+1-617-253-5909 bers@mit.edu	USA	Electron Bernstein Waves in Spherical Tokamaks (paper presented by Ram, A.K.)
Bourdelle, Clarisse (Ms)	Plasma Physics Laboratory Princeton University P.O. Box 451 Princeton, NJ 08543	+1-609-243-2665 cbourdelle@pppl.gov	USA	Microstability Analysis of Experimental NSTX Plasmas
Castro, Pedro José	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 castro@plasma.inpe.br	Brazil	Monotron Development at the Associated Plasma Laboratory of INPE (contribution included in "Development of a High-Power Monotron for RF Applications in Spherical Tokamaks" presented by Barroso, J.J.)
Cunningham, Geoffrey	EURATOM/UKAEA Fusion Association Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB	+44-1235-464192 geoffrey.cunningham@ukaea.org.uk	UK	Progress on MAST Experimental Results from STs and their Relevance to a Next Step Burning Plasma ST
Daltrini, André Mascia	Institute of Physics University of Campinas 13083-970 Campinas, SP	+55-19-3788-5427 daltrini@ifi.unicamp.br	Brazil	Application of a 64-channel Photomultiplier for Thomson Scattering Diagnostics (contribution included in "Present Status of ETE Diagnostics" presented by Berni, L.A.)
Del Bosco, Edson	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 bosco@plasma.inpe.br	Brazil	Overview of the ETE Spherical Tokamak Experiment
Elfimov, Artour G.	Institute of Physics University of São Paulo 05315-970 São Paulo, SP	+55-11-3818-7014 elfimov@fap01.if.usp.br	Brazil	Calculations of Fast and Global Alfvén Wave Excitation in Low Aspect Ratio Tokamaks
Ferreira, Júlio Guimarães	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 julio@plasma.inpe.br	Brazil	Electrical Power System of the ETE Spherical Tokamak (contribution included in "Overview of the ETE Spherical Tokamak Experiment" presented by Del Bosco, E.)
Gao, Zhe	Department of Engineering Physics Tsinghua University Beijing 100084	+86-10-6278-2658 ying@dns.ep.tsinghua.edu.cn	China	Study of Electromagnetic Drift Instabilities in High-Beta Plasmas
Garstka, Gregory Douglas	Department of Engineering Physics University of Wisconsin-Madison Madison, WI	+1-608-265-2364 garstka@engr.wisc.edu	USA	Recent Results from the PEGASUS Toroidal Experiment
Grishanov, Nikolay	National Laboratory for Scientific Computation (LNCC) Rua Getúlio Vargas, 333, Quitandinha 25651-070, Petrópolis, RJ	+55-24-231-5595 nikolay@lncc.br	Brazil	Radio Frequency Wave Dissipation By Electron Landau Damping in Elongated Spherical Tokamaks
Gryaznevich,	EURATOM/UKAEA	+44-1235-464192	UK	Non-diffusive Cross-Field

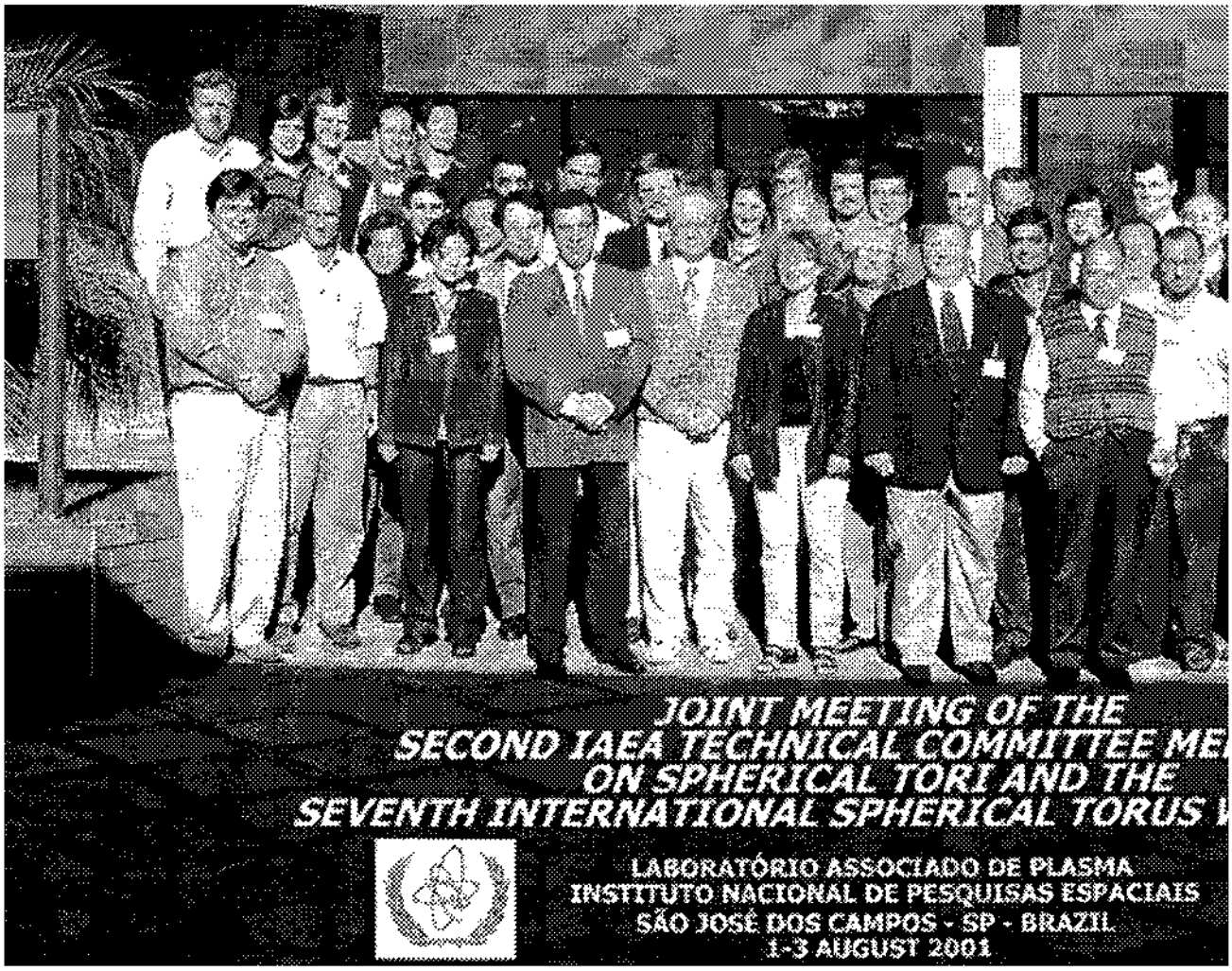
Mikhail P.	Fusion Association Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB	mikhail.gryaznevich@ukaea.org.uk		Plasma Transport Observations on START and MAST Energetic Particle-Driven MHD Observations on STs
Gusev, Vasily K.	A.F. Ioffe Physico-Technical Institute, Polytechnicheskaya st. 26 St. Petersburg 194021	+7-812-247-5416 vasily.gusev@pop.ioffe.rssi.ru	Russia	Overview of Results and Program Development in Globus-M Spherical Tokamak
He, Yexi	Department of Engineering Physics Tsinghua University Beijing 100084	+86-10-6278-2658 yexihe@mail.tsinghua.edu.cn	China	Research Program of Spherical Tokamak in China
Katsurai, Makoto	Department of Electrical Engineering University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656	+81-3-5841-8564 katsurai@katsurai.t.u-tokyo.ac.jp	Japan	Ultra-High-Beta Spherical Tokamak Experiments in TS-3 and 4 Initial Results of the TS-4 Spherical Tokamak/Merging Experiment (papers presented by Ono, Y. and Tsuruda, M.)
Khalil, Sherif Mohamed	Plasma Physics and Nuclear Fusion Department Nuclear Research Center Atomic Energy Authority 13759 Cairo	+20-2-287-6031 sherif_khalil@yahoo.com	Egypt	Eigenvalues of Relaxed Compact Toroids of Arbitrary Cross-Section
Kostov, Konstantin Gueorguiev	LAP-INPE, CP 515 12.201-970 S. J. Campos, SP	+55-12-3945-6710 kostov@plasma.inpe.br	Brazil	Prospects of the Monotron as a High-Power Microwave Tube (contribution included in "Development of a High-Power Monotron for RF Applications in Spherical Tokamaks" presented by Barroso, J.J.)
Krupnik, Lyudmila I. (Ms)	Institute of Plasma Physics of the National Science Center "Kharkov Institute of Physics and Technology" Akademicheskaya St. 1 61108 Kharkov	+380-572-35-2664 krupnik@ipp.kharkov.ua	Ukraine	First Results from Heavy Ion Beam Probe Diagnostics on the Tuman-3M Tokamak
Leite Neto, Joaquim Paulino	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 leite@plasma.inpe.br	Brazil	Monotron Development at the Associated Plasma Laboratory of INPE (contribution included in "Development of a High-Power Monotron for RF Applications in Spherical Tokamaks" presented by Barroso, J.J.)
Ludwig, Gerson Otto	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 ludwig@plasma.inpe.br	Brazil	The ETE Spherical Tokamak Experiment (contribution included in "Overview of the ETE Spherical Tokamak Experiment" presented by Del Bosco, E.) Chairman of the Meeting
Machida, Munemasa	Institute of Physics University of Campinas 13083-970 Campinas, SP	+55-19-3788-5427 machida@ifi.unicamp.br	Brazil	Application of a 64-channel Photomultiplier for Thomson Scattering Diagnostics (contribution included in

				"Present Status of ETE Diagnostics" presented by Berni, L.A.)
Marchenko, Viktor S.	Scientific Centre "Institute for Nuclear Research" Prospekt Nauki 47 Kiev, 03680	+380-44-265-1368 march@kinr.kiev.ua	Ukraine	Effect of Shafranov Shift on the Fishbone Mode Induced by Circulating Particles in Spherical Tori
Micozzi, Paolo	CR-ENEA, CP-65 00044 Frascati, Roma	+39-06-9400-5735 micozzi@frascati.enea.it	Italy	Chandrasekar-Kendall-Furth Configurations for Magnetic Confinement
Monteiro, Marcelo Jesus Rangel	Institute of Physics University of Campinas 13083-970 Campinas, SP	+55-19-3788-5427 monteiro@ifi.unicamp.br	Brazil	Application of a 64-channel Photomultiplier for Thomson Scattering Diagnostics (contribution included in "Present Status of ETE Diagnostics" presented by Berni, L.A.)
Nekrasov, F.M.	Department of Applied Mathematics National Laboratory for Scientific Computation (LNCC) Rua Getúlio Vargas, 333, Quitandinha 25651-070, Petrópolis, RJ	+55-24-231-5595 nekrasov@lncc.br	Brazil	Permittivity Tensor and RF Dissipation in Plasmas of Low Aspect Ratio Toroidal Devices
Nelson, Brian A.	Aerospace and Energetic Research Box 352250 University of Washington Seattle, WA 98195-2250	+1-206-543-4719 nelson@aa.washington.edu	USA	Coaxial Helicity Injection Experiments on NSTX
Oliveira, Rogério Moraes	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 rogerio@plasma.inpe.br	Brazil	Fast Neutral Lithium Beam for Density and Fluctuation Measurements at the Boundary Regions of the ETE Tokamak (contribution included in "Present Status of ETE Diagnostics" presented by Berni, L.A.)
Ono, Masayuki	Plasma Physics Laboratory Princeton University P.O. Box 451 Princeton, NJ 08543	+1-609-243-2222 mono@pppl.gov	USA	NSTX Project Overview NSTX Diagnostics and Operation: Status and Plans
Ono, Yasushi	High Temperature Plasma Center University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656	+81-3-5841-6790 ono@katsurai.t.u-tokyo.ac.jp	Japan	Ultra-High-Beta Spherical Tokamak Experiments in TS-3 and 4
Patire Júnior, Heitor	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 heitor@plasma.inpe.br	Brazil	(contribution included in "Overview of the ETE Spherical Tokamak Experiment" presented by Del Bosco, E.)
Peng, Martin	Plasma Physics Laboratory Princeton University P.O. Box 451 Princeton, NJ 08543	+1-609-243-2222 mpeng@pppl.gov	USA	Recent Progress and Near-Term Plans of NSTX Research Program
Petrov, Yuriv	A.F. Ioffe	+7-812-247-5416	Russia	Status and Development of

V.	Physico-Technical Institute, Polytechnicheskaya st. 26 St. Petersburg 194021	yu.petrov@pop.ioffe.rssi.ru		Globus-M Diagnostics
Ram, Abhay K.	Plasma Science and Fusion Center Massachusetts Institute of Technology 50 Vassar Street Cambridge, MA 02139	+1-617-253-5909 abhay@mit.edu	USA	Electron Bernstein Waves in Spherical Tokamaks
Raman, Roger	Plasma Physics Laboratory P.O. Box 451 Princeton University Princeton, NJ 08543	+1-609-243-3233 raman@aa.washington.edu	USA	Coaxial Helicity Injection Experiments on NSTX (paper presented by Nelson, Brian A.)
Redd, Aaron John	Aerospace and Energetic Research Box 352250 University of Washington Seattle, WA 98195-2250	+1-206-543-4719 redd@aa.washington.edu	USA	Current Drive Experiments on the HIT-II Spherical Torus
Ribeiro, Celso	EURATOM/UKAEA Fusion Association Culham Science Centre, Abingdon, Oxfordshire, OX14 3DB	+44-1235-464192 celso.ribeiro@ukaea.org.uk	UK	Initial Results from the MAST Pellet Injector
Rossi, José Osvaldo	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 rossi@plasma.inpe.br	Brazil	Monotron Development at the Associated Plasma Laboratory of INPE (contribution included in "Development of a High-Power Monotron for RF Applications in Spherical Tokamaks" presented by Barroso, J.J.)
Sakharov, Nikolay V.	A.F. Ioffe Physico-Technical Institute, Polytechnicheskaya st. 26 St. Petersburg 194021	+7-812-247-5416 nikolay.sakharov@pop.ioffe.rssi.ru	Russia	Scenario of Globus-M Operation in OH Regime
Schneider, Ursula (Ms)	IAEA, Physics Section P. O. Box 100 Wagramer Str. 5 A-1400 Vienna, Austria	+43-1-26007 u.schneider@iaea.org	IAEA	Scientific Secretary of the Meeting
Shibata, Carlos Shinya	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 shibata@plasma.inpe.br	Brazil	(contribution included in "Overview of the ETE Spherical Tokamak Experiment" presented by Del Bosco, E.)
Takase, Yuichi	Graduate School of Frontier Sciences and Graduate School of Science University of Tokyo Bunkyo-ku, Tokyo 113-8656	+81-3-5841-8386 takase@k.u-tokyo.ac.jp	Japan	Overview of TST-2
Tsuruda, Mayuko (Ms.)	Department of Electrical Engineering University of Tokyo 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8656	+81-3-5841-6790 turuta@katsurai.t.u-tokyo.ac.jp	Japan	Initial Results of the TS-4 Spherical Tokamak/Merging Experiment

Vannucci, Álvaro	Physics Institute University of São Paulo 05508-900 São Paulo, SP	+55-11-3818-6749 avanucci@mestre.if.usp.br	Brazil	Predicting the Onset of Plasma Disruptions in Tokamaks Using Artificial Neural Networks
Vilela, Waldeir Amaral	LAP-INPE, CP 515 12201-970 S. J. Campos, SP	+55-12-3945-6710 waldeir@plasma.inpe.br	Brazil	Fast Neutral Lithium Beam for Density and Fluctuation Measurements at the Boundary Regions of the ETE Tokamak (contribution included in "Present Status of ETE Diagnostics" presented by Berni, L.A.)

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ON SPHERICAL TORI AND THE
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