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The SHIP experiment at GDT: First experimental results.

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Last year, at the GDT facility of the Budker Institute (Novosibirsk), which is an axially symmetric linear system of gas dynamic trap type, first campaign of the **S**ynthesised **H**ot **I**on **P**lasmoid (SHIP) experiment was completed. It is aimed at the investigation of plasmas in the region of high neutron production in a GDT based fusion neutron source proposed by the Budker Institute [1].

The concept of the SHIP experiment was presented at the 29th EPS Conference [2].

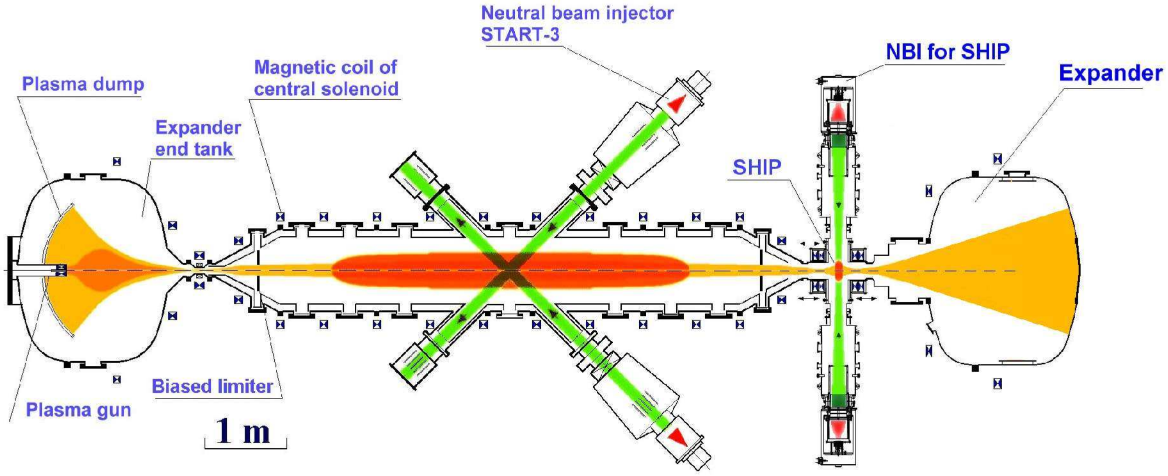

Fig. 1 *SHIP experiment at the GDT device*

The experiment is performed in a small mirror section that is installed at one side of the GDT (see Fig.1). The magnetic field on the axis approximately 2.5 Tesla and the mirror ratio amounts ≈ 2. The section is filled with background plasma streaming in from the central cell. The density of streaming plasma is $\approx 10^{13}$ cm^{-3} and electron temperature about 100 eV. Two neutral beams perpendicularly inject a total current 15 Atom Amperes of hydrogen with the energy of 16 keV in the 0.8 ms pulse. Ionisation of the beams generates the high-energetic ion component with the density $n_{fi} \approx 10^{13}$ cm^{-3}, which is close to the target plasma density, and mean energy about 6 keV.

Fig. 2 presents time evolutions of electron linear density during Neutral Beam Injection (NBI) into SHIP cell (red line) and without injection (black line) measured by dispersion interferometer [3]. Enhancement of electron density caused by neutral beams (red line) indicates build up and confinement of fast ions in this region. Comparison of electron linear

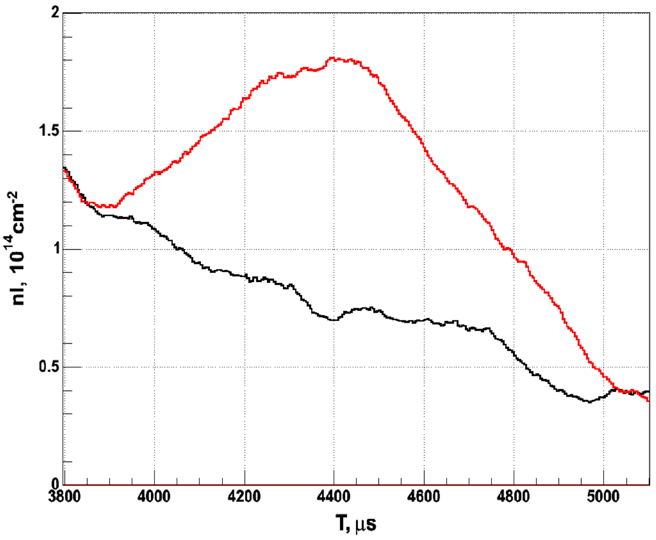

Fig. 2 *Time evolutions of electron linear density in the SHIP cell during Neutral Beam Injection (red line) and without injection (black line).*

densities with NBI and without NBI allowed us to estimate the maximal value of fast ion linear density $\langle n_{fi}l\rangle=1.4\cdot10^{14}$cm^{-2} and linear density of the streaming plasma $\langle n_{sp}l\rangle=0.4\cdot10^{14}$cm^{-2} during NBI pulse. Unperturbed value of streaming plasma linear density (without NBI) is $\approx 0.8\cdot10^{14}$cm^{-2} (see black line on Fig. 2 at the time moment 4.4 ms). Taking into account the results of estimation we can conclude that the average value of fast ion density is two times greater than density of unperturbed streaming plasma and three times exceeds the warm ion density in the presence of NBI.

Fig. 3 shows the spatial profile of fast ion density measured by imaging energy analyzer of fast neutrals [4]. Measured profile normalized to the estimated value of fast ion linear density $\langle n_{fi}l\rangle=1.4\cdot10^{14}$cm^{-2}.

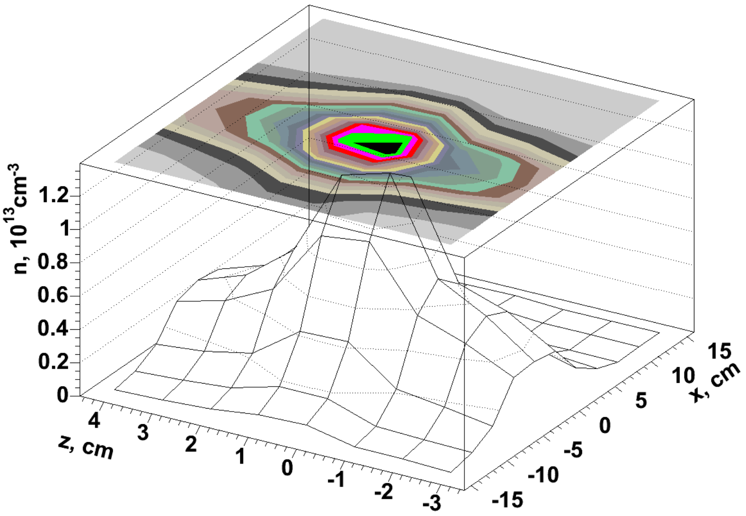

Fig. 3 *Spatial profile of SHIP fast ion density in the maximum of energy content. Z axis is the system axis.*

Characteristic dimensions of plasmoid (at the 1/e level) are: 5 cm along the axis and 13 cm in the perpendicular direction (X axis). Average energy of fast ions is 6 keV, maximal value of density - $1.2 \cdot 10^{13} cm^{-3}$. Diamagnetic perturbation of magnetic field was measured by spectroscopic diagnostic [5]. $\Delta B/B_{vac}$ is 2%, where ΔB is diamagnetic perturbation of magnetic field, B_{vac} is unperturbed vacuum magnetic field. Maximal energy content of plasmoid W_{ship}= 8 J is calculated by the diamagnetic loop signal combined with equilibrium modelling using special Monte-Carlo simulation code. At the same time, this energy content was directly calculated by the **I**ntegrated **T**ransport **C**ode **S**ystem (ITCS) [2], which was mentioned above. The model uses parameters of neutral beams and streaming background plasma in the SHIP cell. ITCS simulates Coulomb kinetics of fast ion relaxation and transport in the warm background plasma. Result of model calculation was $W_{ship} \approx 8$ J. It means that fast ion confinement determined only by Coulomb collisions and charge – exchange of fast ions on neutral beams. Accordingly, this coincidence of results gives an evidence that no MHD or micro instabilities was observed.

During the fast ion density build up in the small mirror section, development of plasma potential can be expected since background plasma has even lower density here. This potential barrier should lead to the effect known as ambipolar plugging [6]. Decrease of streaming plasma density in the SHIP during NBI cell is accompanied by decrease of plasma particle flux through the mirror. Fig. 4 shows the time evolution of on-axis ion flux density measured in the expander cell.

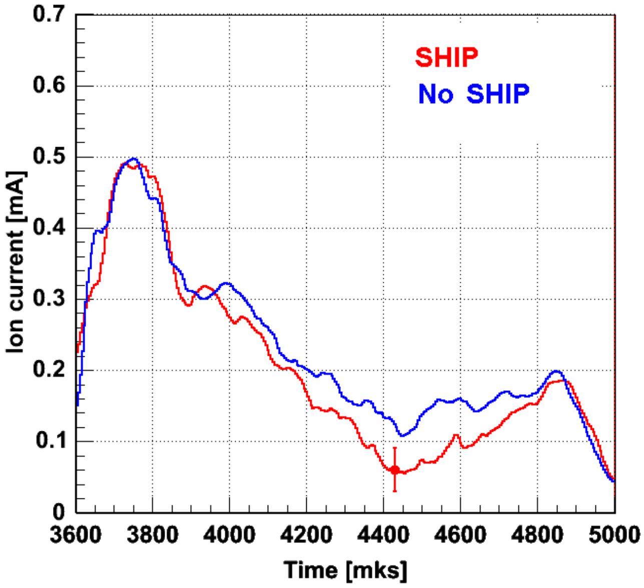

Fig. 4 *Time evolutions of ion flux density in the expander cell: with NBI in the SHIP cell - red line, without NBI – blue line. Both signals are recorded on the axis.*

At the time point of 4.4 ms particle losses from SHIP are about two times lower in the presence of NBI in comparison with regime without NBI.

Summarizing described above we can draw the conclusions as follows:

1. The **S**ynthesised **H**ot **I**on **P**lasmoid experiment with moderate Neutral Beams parameters was carried out at the GDT device;
2. The average value of fast ion density was two times greater than density of unperturbed streaming plasma and three times greater than the warm ion density in the presence of NBI.
3. Fast ion confinement was determined only by Coulomb collisions and charge – exchange of fast ions on neutral beams. No evidence of MHD or micro instabilities was observed.
4. Ambipolar plugging was demonstrated in the SHIP experiment.

Acknowledgements

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