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Plasma Flow Suppression in The Open Magnetic Traps by the Helical Mirror

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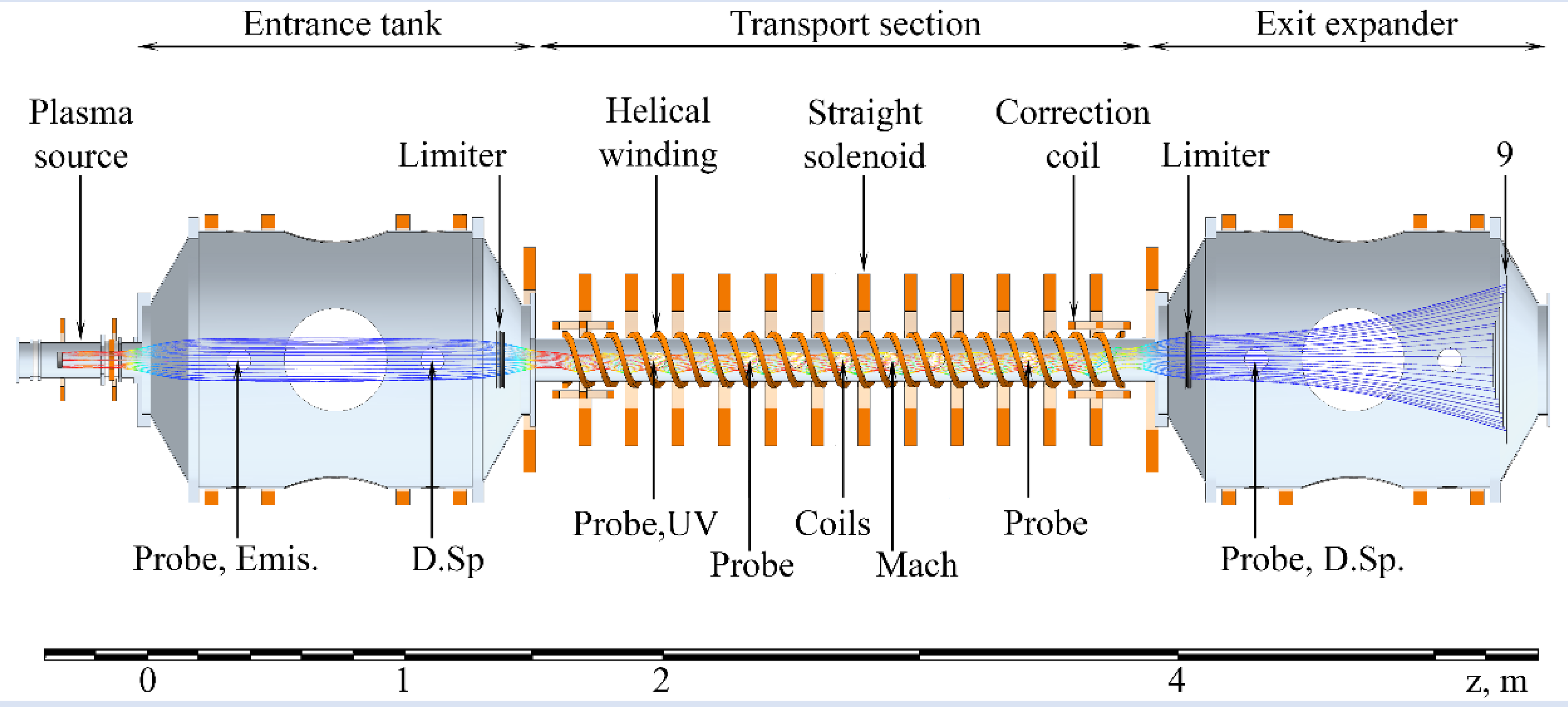
ABSTRACT

- Small-scale verification of the new technique of the active control of axial losses of the rotating plasma in the helical magnetic field
- 1.6-fold increase in plasma density between the simple mirror and the helical one. The effective mirror ratio of the helical section was $R_{eff} > 10$
- Integral flux through the helical mirror drops below the detectable level.
- Particle flux returning from the distant part of the helical mirror towards the confinement zone was observed.
- All fluxes scale linearly on the plasma density.

BACKGROUND

- Open trap with the reactor-grade plasma is achievable with specialized sections for suppression of the losses along the magnetic field.
- Basic method of suppression of the axial losses for the GDMT project is multiple-mirror confinement.
- The idea of the helical mirror renews an idea of the moving magnetic mirrors and considers a flow of a rotating plasma through a linear static magnetic system with a helical corrugation.
- Periodical variations of the magnetic field moving upstream in plasma's reference frame transfer momentum to trapped particles and lead to plasma pumping towards the central trap.
- Improvements over the multiple mirrors: the **exponential dependence** of the confinement on the system length and the **radial pinch** of the ions.
- Concept exploration helical mirror «SMOLA»: small-scale verification, started in 2017.



Layout of the SMOLA device

METHODS

Main parameters

Asymmetric mirrors of the confinement zone: R ≈ 8 (towards the plasma source) and R ≈ 3 (towards the transport section). Guiding field B_z = 40–100 mT, mean corrugation depth R_{mean} = 1–1.7, density $n = (1–4)\cdot10^{18}$ m^{-3}, temperatures $T_i \approx 4$ eV and $T_e \approx 30$ eV, rotation velocity up to $\omega = 1.2\cdot10^6$ s^{-1}.

Focus of the experimental campaign

Thorough investigation of the axial plasma fluxes in the transport section. The detailed radial profiles of the plasma parameters were measured and integrated in the assumption of the azimuthal symmetry.

ACKNOWLEDGEMENTS

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OUTCOME

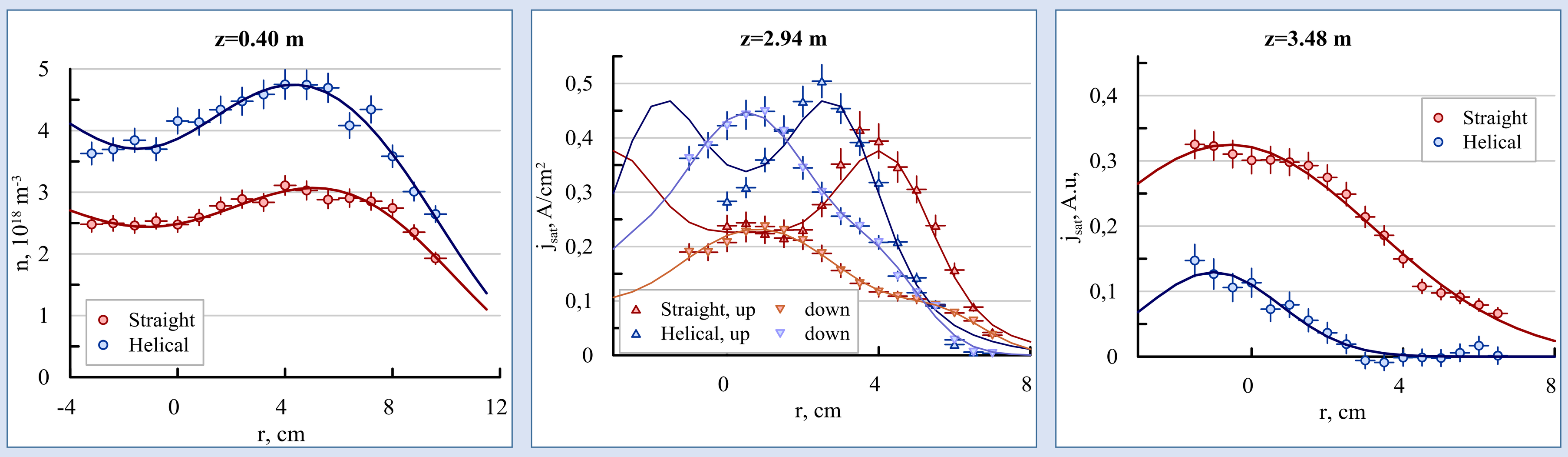
The clearest evidences of the helical mirror effect are 1.6-fold rise in the number of the confined particles and the suppression of the integral flux through the end of the transport section.

The flux towards the plasma source with the local density exceeding the density of the flux in the forward direction was observed directly. This flux is generated close to the axis in the qualitative agreement with the theory.

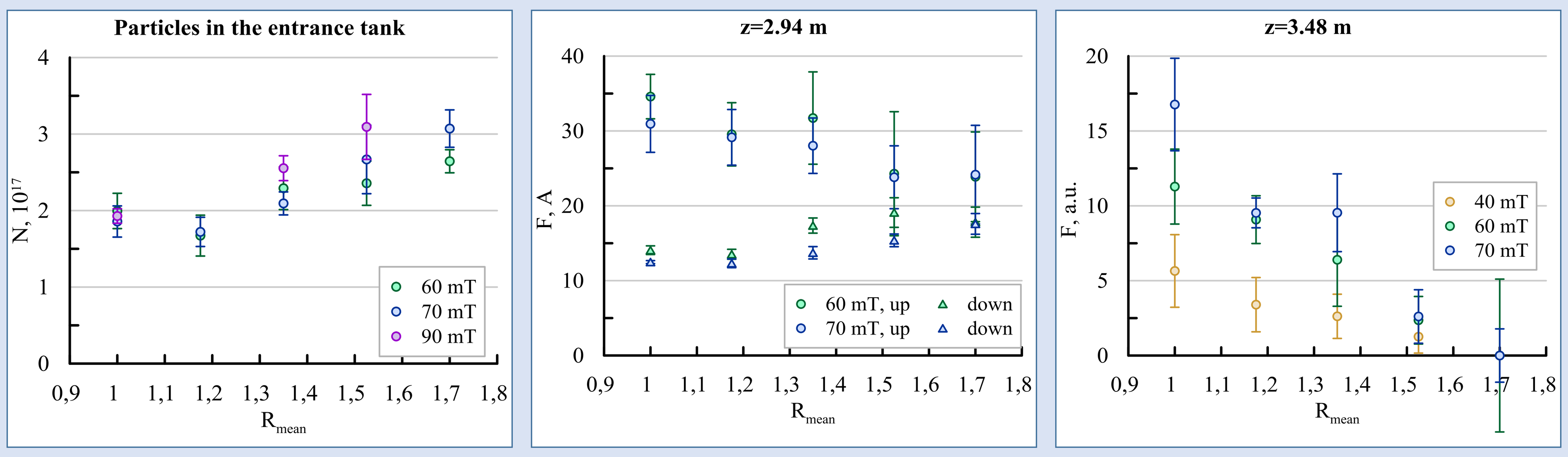
In model it has the mean velocity comparable to the axial velocity of the multiple mirror movement. Such flux by itself can be a source of the energy for the microinstabilities which lead to the anomalous scattering.

Presence of the anomalous scattering is required for the multiple mirror confinement of the fusion plasma to reduce mean free path.

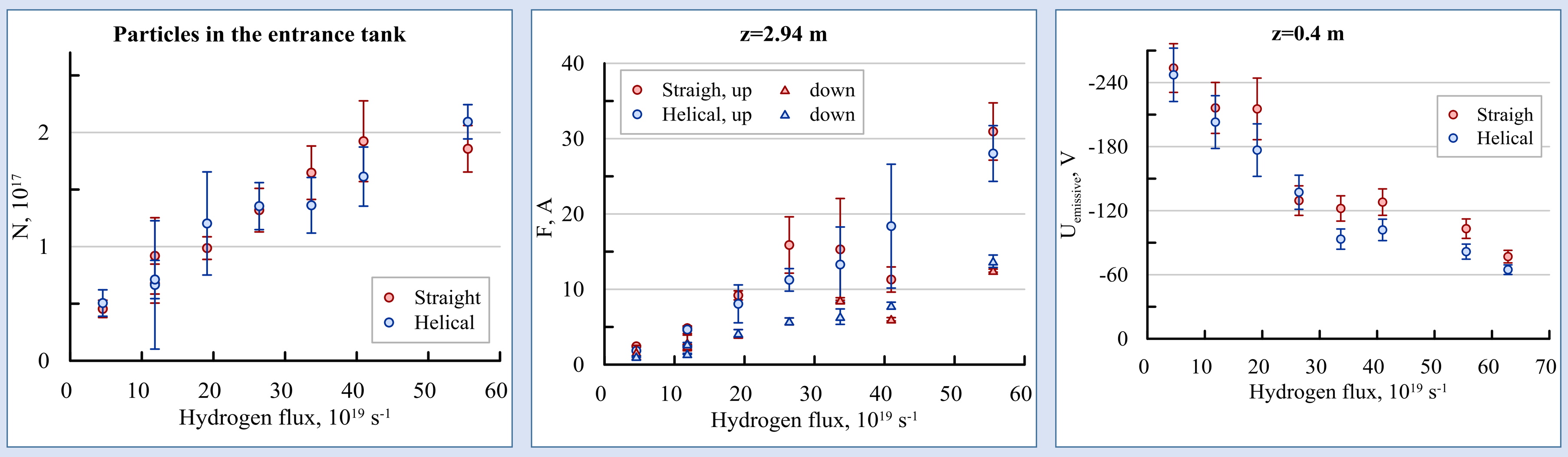
Linear dependence of the experimentally measured particle fluxes on the plasma density and higher level of the noise in the probe data in the helical configuration may be the indirect evidences of this process.



Typical radial profiles of the plasma density and fluxes



Dependencies of the plasma density and fluxes on the corrugation ratio



Density dependencies of the plasma density, fluxes and potential

CONCLUSION

- High rotation velocity and high mean corrugation ratio made it possible to observe the effect of the helical mirror clearly and achieve effective mirror ratio of the helical section $R_{eff} > 10$. Integral flux through the end of the section was below detectable.
- The flux of the particles which changed their direction in the helical mirror was observed directly.
- All fluxes scale linearly on the plasma density, even if the mean free path of the ion is 4–8 times higher than the period of the corrugation.
- The question of the microinstability level requires further investigations.