EX/P5-25

Stability and Confinement Studies in the Gas Dynamic Trap

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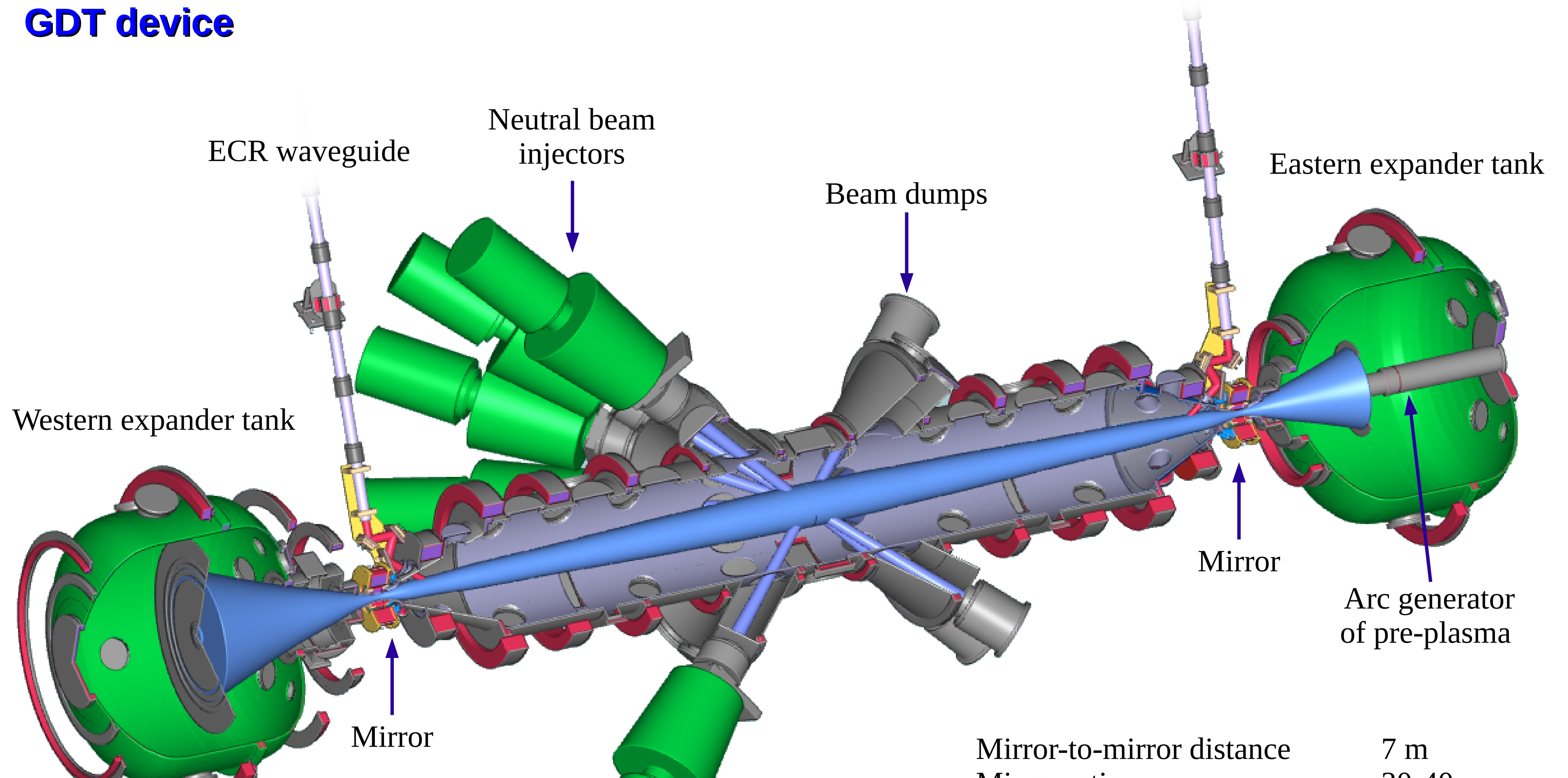
НГУ

Abstract

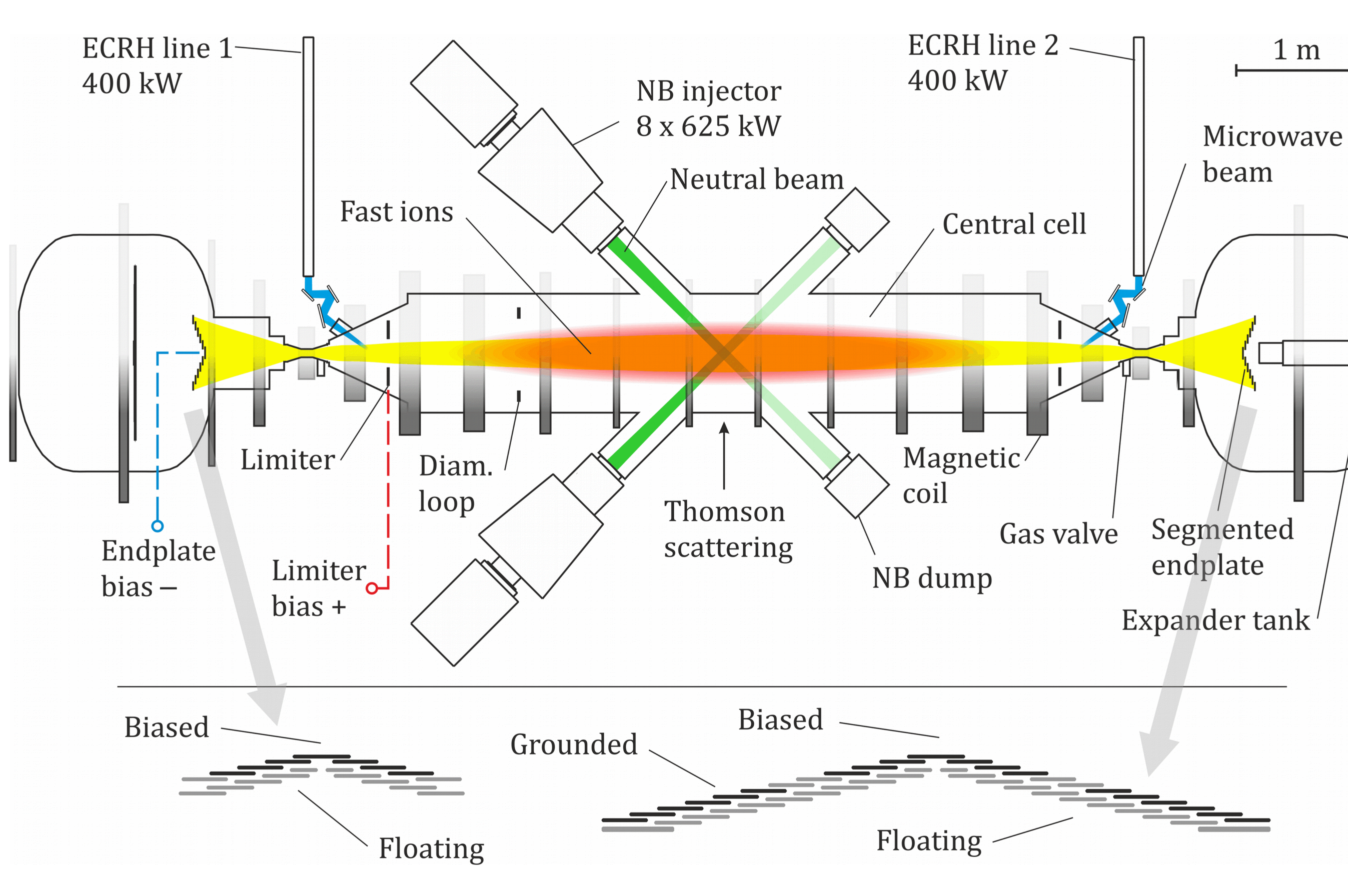
Interest to magnetic mirrors went missing in the 1980's because of three key problems: magnets' complexity, micro-instabilities, and low temperature of plasma. However, researches on the Gas Dynamic Trap (GDT) device at the Budker Institute of Nuclear Physics demonstrated the possibility to overcome these difficulties. Confinement of plasma with high energy density has been performed on GDT device with simple circular coils. "Vortex confinement" has been implemented to suppress the radial losses induced by flute-like MHD instability inherent for axially symmetric devices. This technique allowed reaching local plasma beta close to 0.6. The auxiliary microwave heating on electron cyclotron resonance (ECR) frequencies raised the electron temperature up to 0.9 keV near the device axis. Alfven ion-cyclotron (AIC) instability has been observed, but not affect to the plasma power balance. The proposed report is dedicated to three following topics. The first is optimization of the "vortex confinement" in presence of ECR heating. Introducing the additional "vortex" layer inside the existing one allows extending high-temperature phase behind the atomic beams turn off time. The second is definition of critical parameters for the divertor. It was shown, that the critical wall position corresponds to expansion ratio of magnetic field K_{crit}~40. This value is in a reasonable agreement with a simple theoretical model and remains constant in the range of electron temperature up to 700 eV. The neutral gas in the divertor does not affect the discharge until its density exceeds an order of magnitude the plasma density. The third is study of unstable modes. In addition to AIC, the new type of oscillations was observed at the range of tens of ion-cyclotron frequencies. It was preliminary identified as Drift-Cyclotron Loss-Cone instability.

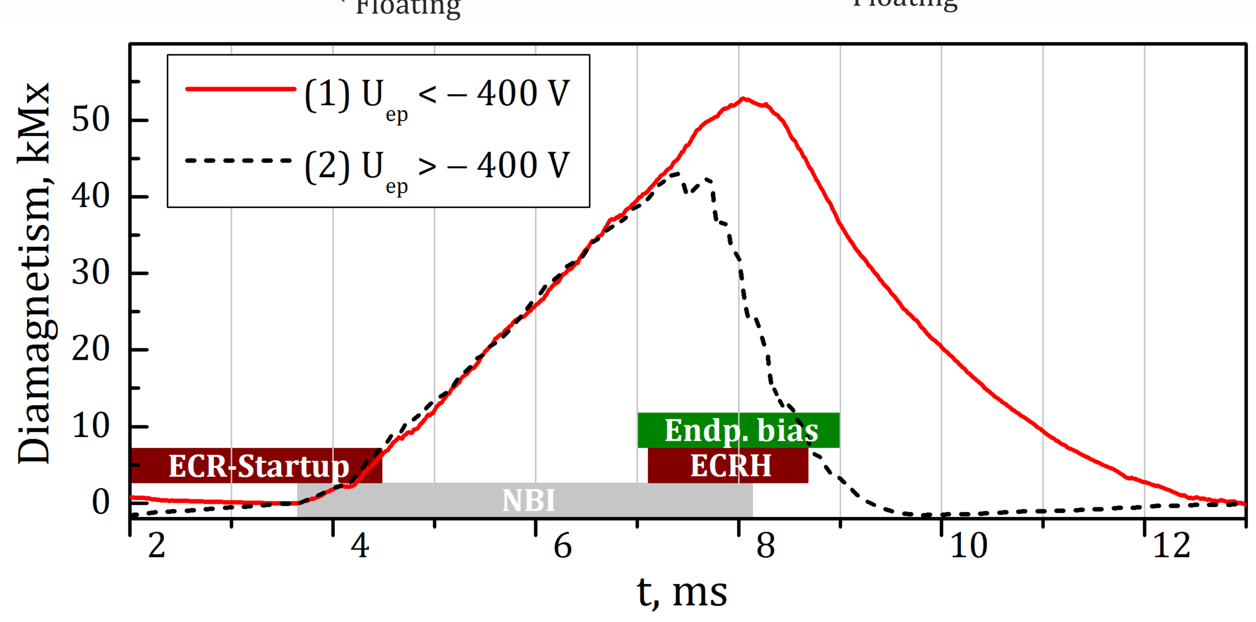
GDT device

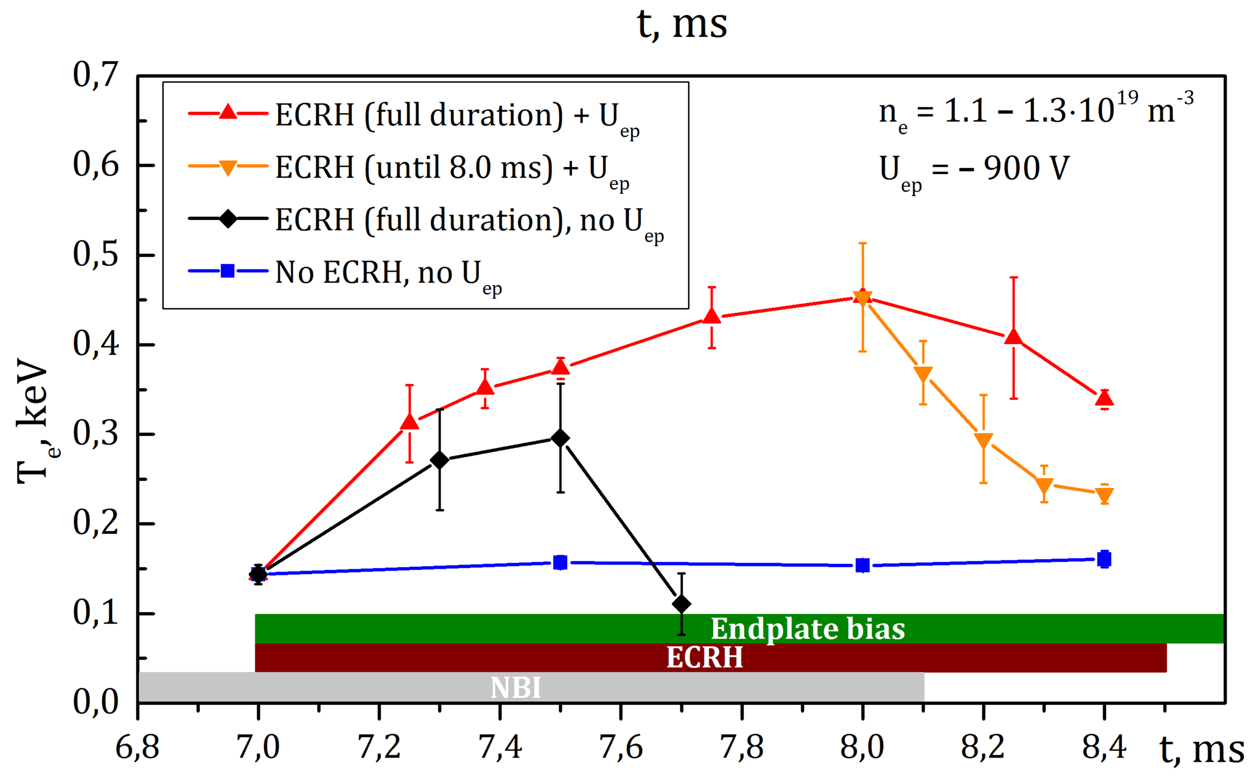


Mirror-to-mirror distance	7 m
Mirror ratio	30-40
Magnetic field at midplane	3.1-3.5 kGs
Plasma density at midplane	~ 10^{13} cm^{-3}
Electron temperature	up to 0.9 keV

Optimization of the confinement in high-temperature regime

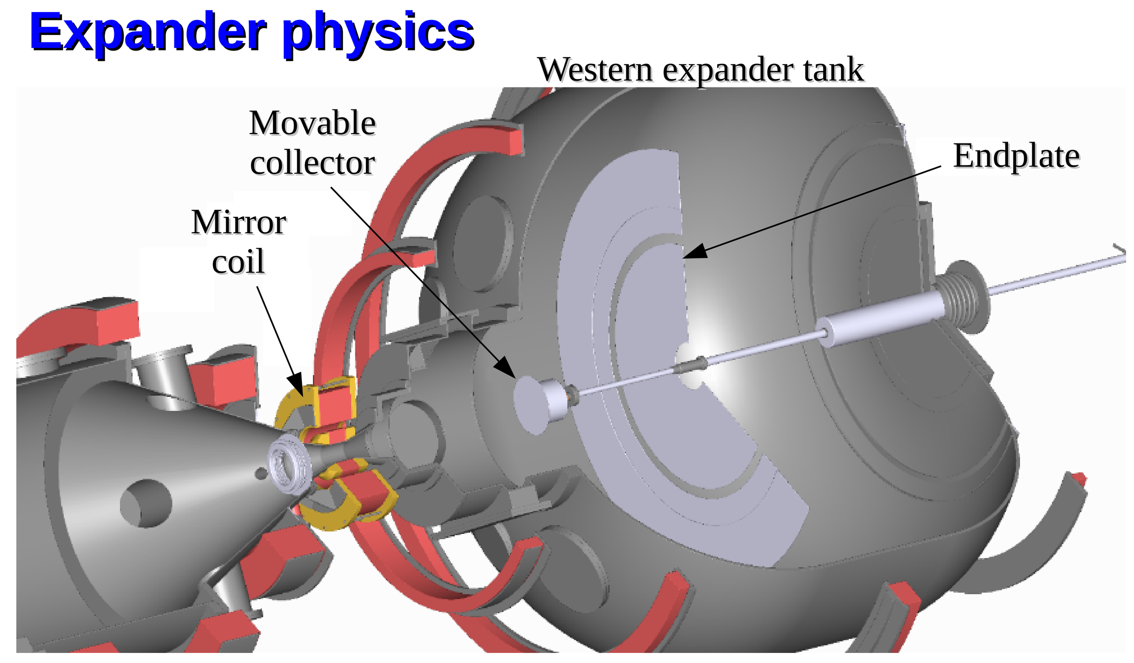






One gyrotron was used to produce pre-plasma by microwave discharge, another one heated the plasma. Central parts of segmented endplates were electrically biased to suppress MHD activity at the near-axis region. Electron axial losses: $\langle E_e \rangle = 4.6 \pm 0.4\ T_e$.

Expander physics

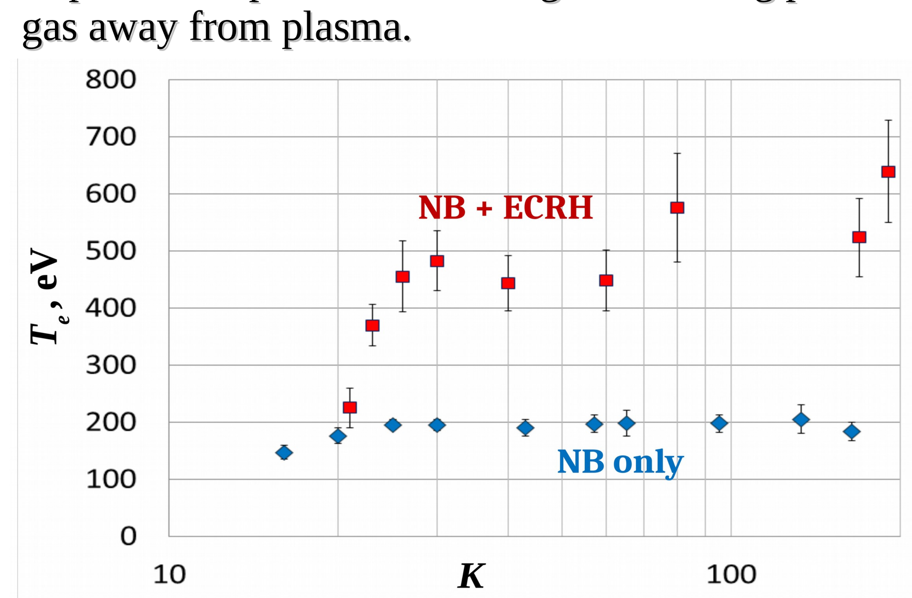


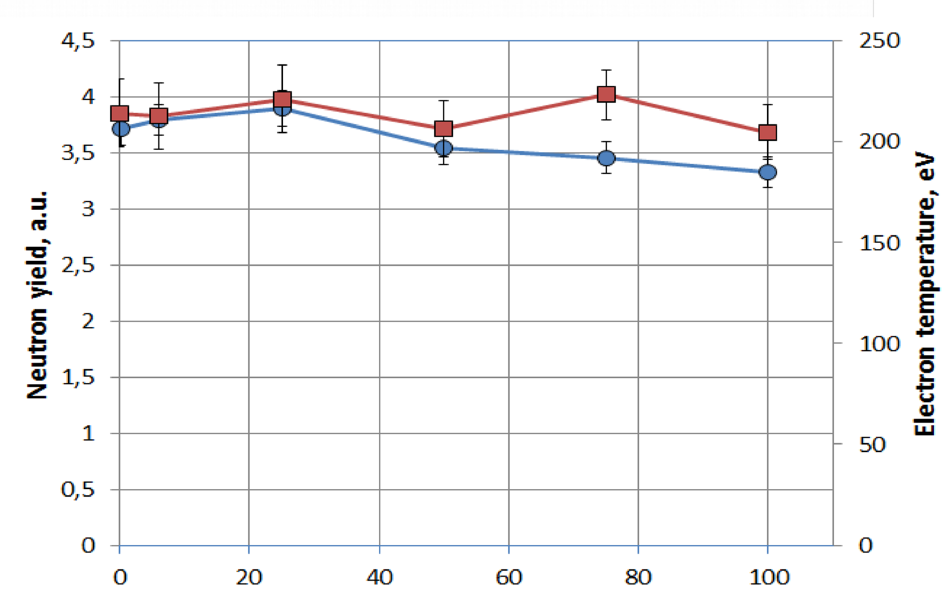
Movable collector experiments (heat by NBI + ECR):

- The collector position is defined by $K = B_{mirror} / B_{wall}$.
- Theoretical prediction is $K_{crit} \approx \sqrt{m_i/m_e} \approx 40$.
- Experimental value is $K_{crit} \approx 30$ at $T_e \leq 700$ eV.

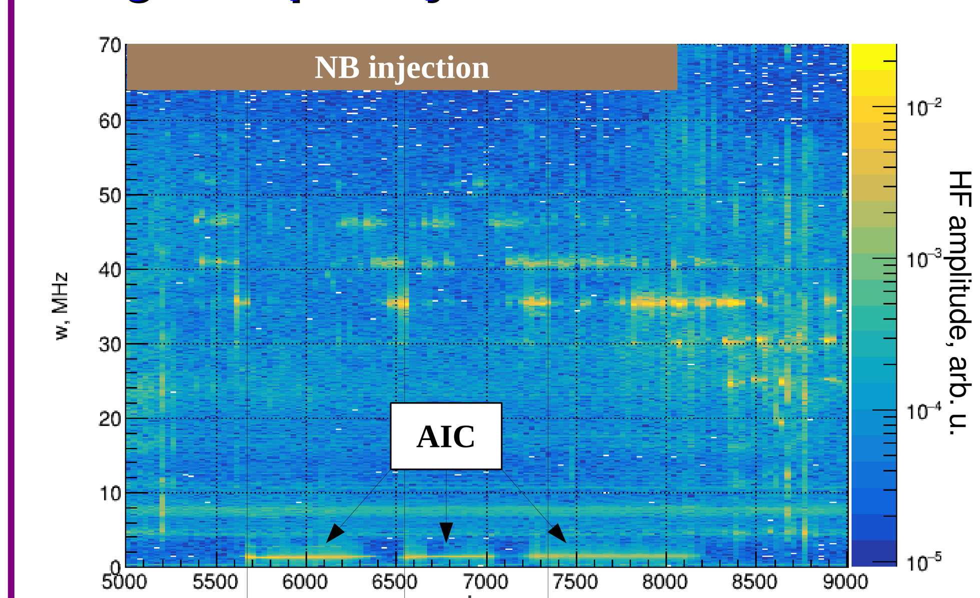
Test of vacuum conditions in the expander (heat by NBI only):

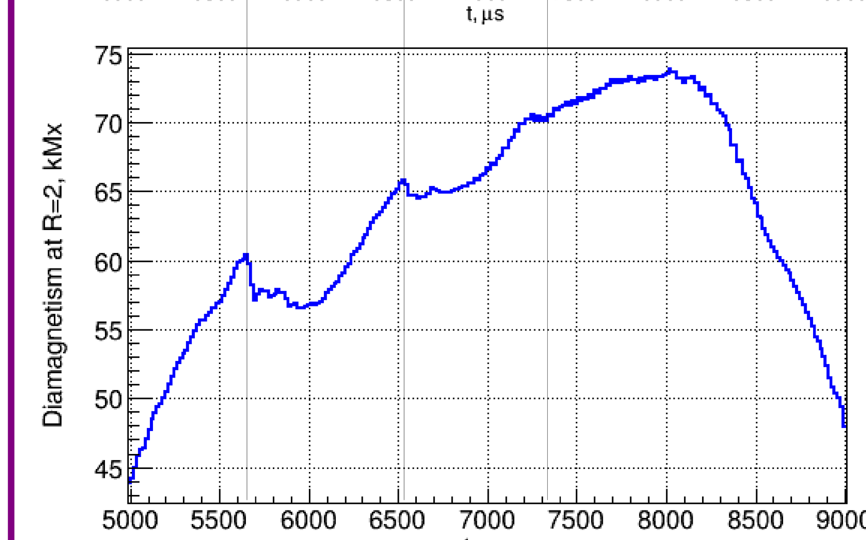
- Estimation: gas flow with density 10^{12} cm^{-3} and temperature of 300 °K will double the ion flux to the endplate.
- Experiment: gas produce no effect up to 10^{14} cm^{-3} (at higher densities vacuum conditions of central cell degrades).
- Explanation: plasma heats the gas and rising pressure extrudes gas away from plasma.



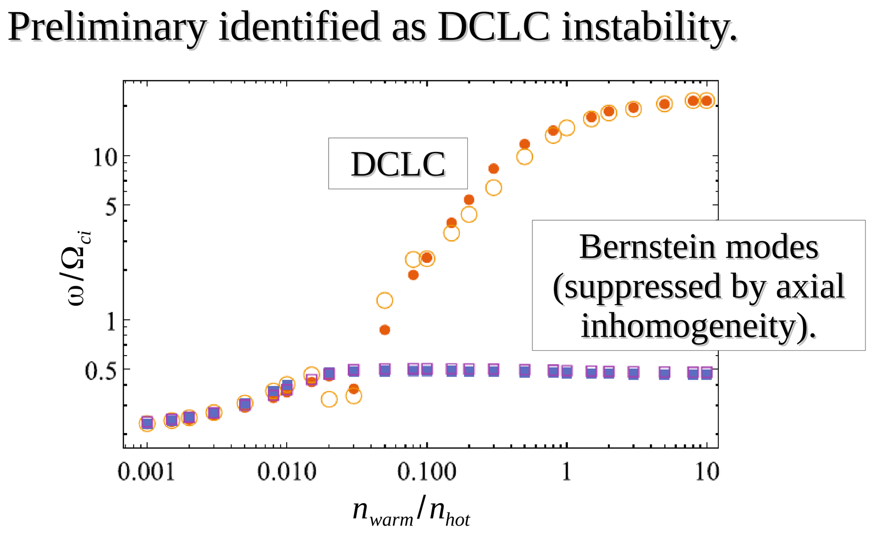


High-frequency oscillations





- Oscillations at frequencies 20-70 MHz.
- Distance between lines is 5.3-5.5 MHz, that is close to ion-cyclotron frequency at fast ions turning point.
- Preliminary identified as DCLC instability.



Example calculations of the most unstable modes for different loss cone size (R_G=2 – empty and R_G=6 – filled markers) [I.A.Kotelnikov, et. al. Phys. Plasmas 24, 122512 (2017)].

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