A new fast ion source and detector for investigating the interaction of turbulence with supra-thermal ions in a simple magnetized toroidal plasma.

G.Plyushchev*, H. Boehmer[1], A. Diallo, A. Fasoli, I. Furno, W. W. Heidbrink[1], B. Labit, S. H. Müller, M. Podestà, F. M. Poli, Y. Zhang[1]

[1] Department of Physics and Astronomy, University of California, Irvine, California 92697, USA

Partly funded by the "Fonds National Suisse de la Recherche Scientifique".

*gennady.plyushchev@epfl.ch

Motivations

- Fast ions presents in many tokamaks (even with ECRH).
- The anomalous transport in tokamak could be explained by turbulence.
- Poor knowledge in fast ions – turbulence interaction in toroidal devices.

Why on TORoidal Plasma EXperiment (TORPEX) device:

- TORPEX is dedicated to turbulence investigations.
- Small temperature ➡ we do not need high value of fast ion energy
  ➡ we could use small and simple ion source (easy to install).

Objectives of investigation

1. Turbulent plasma influence on fast ions beam.
2. Fast ions beam influence on plasma turbulence.
3. Fast ions beam influence on coherent waves in regimes with closed magnetic flux surfaces.

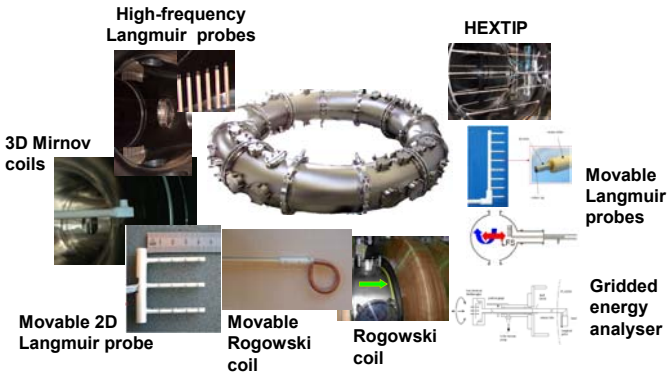
TORoidal Plasma Experiment (TORPEX)

R=1m; a=0.2m;
B_t~0.1T; B_{ver}<4mT;
Ar; H;

EC: 2.45GHz; <10kW; o–mode;
T_e~5eV; T_i<1eV;
n~$10^{17}m^{-3}$;

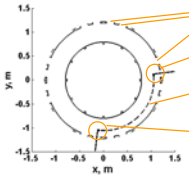
V_{loop}<10V;
I_p<1kA; ~3ms;
T_e~5eV;
n~$10^{18}m^{-3}$;

Main diagnostics of TORPEX

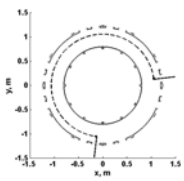


Scheme of the experiment

Toroidal cross-section of TORPEX vacuum vessel:



Another possible experiment:



Fast ions source and gridded energy analyser will be installed on 2D poloidally moving system to change fast ions deposition and to measure beam current profile from shot to shot.

Divergence of ion beam

Five possible mechanisms:

1. Space charge of the beam ions;
2. Drift motion + cyclotron motion;
3. Classical transport;
4. Inhomogeneous poloidal electric field from plasma;
5. Turbulent transport (diffusion).

Caused by plasma

Space charge

Divergence due to space charge:

$$\frac{z}{r_0} = \sqrt[4]{\frac{e}{2m}}\frac{U_a^{3/4}}{I^{1/2}}\int_1^{r/r_0}\frac{dx}{\sqrt{\ln x}} \approx \sqrt[4]{\frac{e}{2m}}\frac{U_a^{3/4}}{I^{1/2}}2\sqrt{\frac{r}{r_0}-1}$$

$z = 2\pi R_0$ ➡ $\left(\frac{r}{r_0}-1\right) \sim 3\times10^{-6}$ ➡ $\left(\frac{r}{r_0}-1\right) \ll 1$

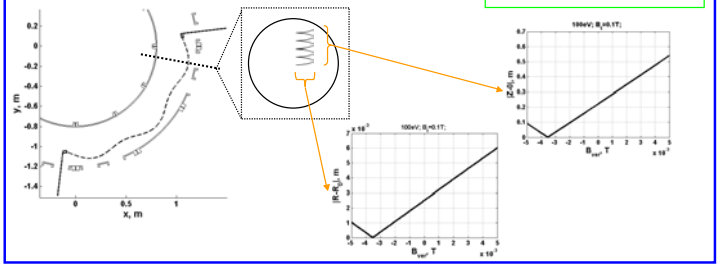
Divergence due to space charge is negligible (very small current).

Particle trajectories

Single particle approximation:

- τ_{tor}~0.11ms;
- ρ_i=3.5cm (100eV);

Toroidal cross-section: Poloidal cross-section:



Classical interaction with the main plasma

ITER Physics Base Editors, Nucl. Fusion 39, 2137 (1999)

Slowing down rate: $\frac{dE}{dt} = -\frac{2E}{\tau_s}\left[1+\frac{E_{crit}}{E}\right]^{3/2}$ $\tau_s = \frac{3\sqrt{2\pi}T_e^{3/2}}{\sqrt{m_e}m_b A_D}$ $A_D = \frac{ne^4\ln\Lambda}{2\pi\varepsilon_0^2 m_b^2}$

➡ $\tau_s \sim 30ms$

H: ➡ $E_{crit} \sim 440eV$

Ar: ➡ $E_{crit} \sim 180eV$

$E < E_{crit}$ - collisions with ions

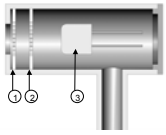
$E < 2.41E_{crit}$ - ions are heated

Fast ions source

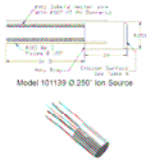
Fast ions source:

- 100eV-1keV ions energy;
- Low gas load ➡ aluminosilicate Li-6 ion emmiter;
- 10-30μA beam current (effect Schotky);
- Not sensitive to magnetic field;
- High voltage modulable poser supply;
- Light ions to facilitate the ion-electron interactions ➡ Li-6;
- Small size ➡ to minimize pertrubations;
- Screen grid at plasma floating potential;
- Focusing.

Scheme of fast ion source.



(1) Screen grid;
(2) Accelerating grid;
(3) Fast ion source.



Aluminosilicate Li-6 ion emmiter:

- 6mm beam diameter;
- ~1000°C cathode temperature;
- 10-30μA beam current;
- Life time ~1000 hours.

http://www.cathode.com/pdf/tb-118.pdf

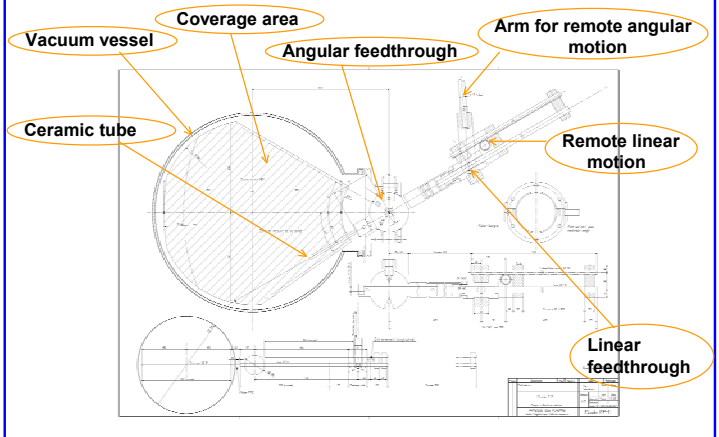
Example of aluminosilicate fast ion source:

Gridded energy analyser

- 2 grids;
- Screen grid;
- Biased with sweeping voltage (f~1kHz);
- Spatial resolution ~5mm;
- Energy resolution ~0.1V.

2D poloidally moving system

Based on sliding seal feedthroughs with differential pumping:



- Angular excursion of up to 70°;
- Ceramic probe support inside the plasma;
- Remote control;
- Accuracy of the positioning <5mm.