Experimental Goals

- Understanding of stochastic diffusion processes in an RFP.
- Calculation of particle and field diffusion coefficients.
- Confinement times of particles. (both thermal and energetic)
- Conditions that may lead to improved confinement.

Introduction

- Tearing modes create a spectrum of B_r within the plasma,

$B_r = B_0 \sin(m\theta - n\phi + \varsigma)$.

- This leads to resonances :

$$q(r) = \frac{m}{n} = \frac{rB_\theta}{R_0 B_\phi}$$

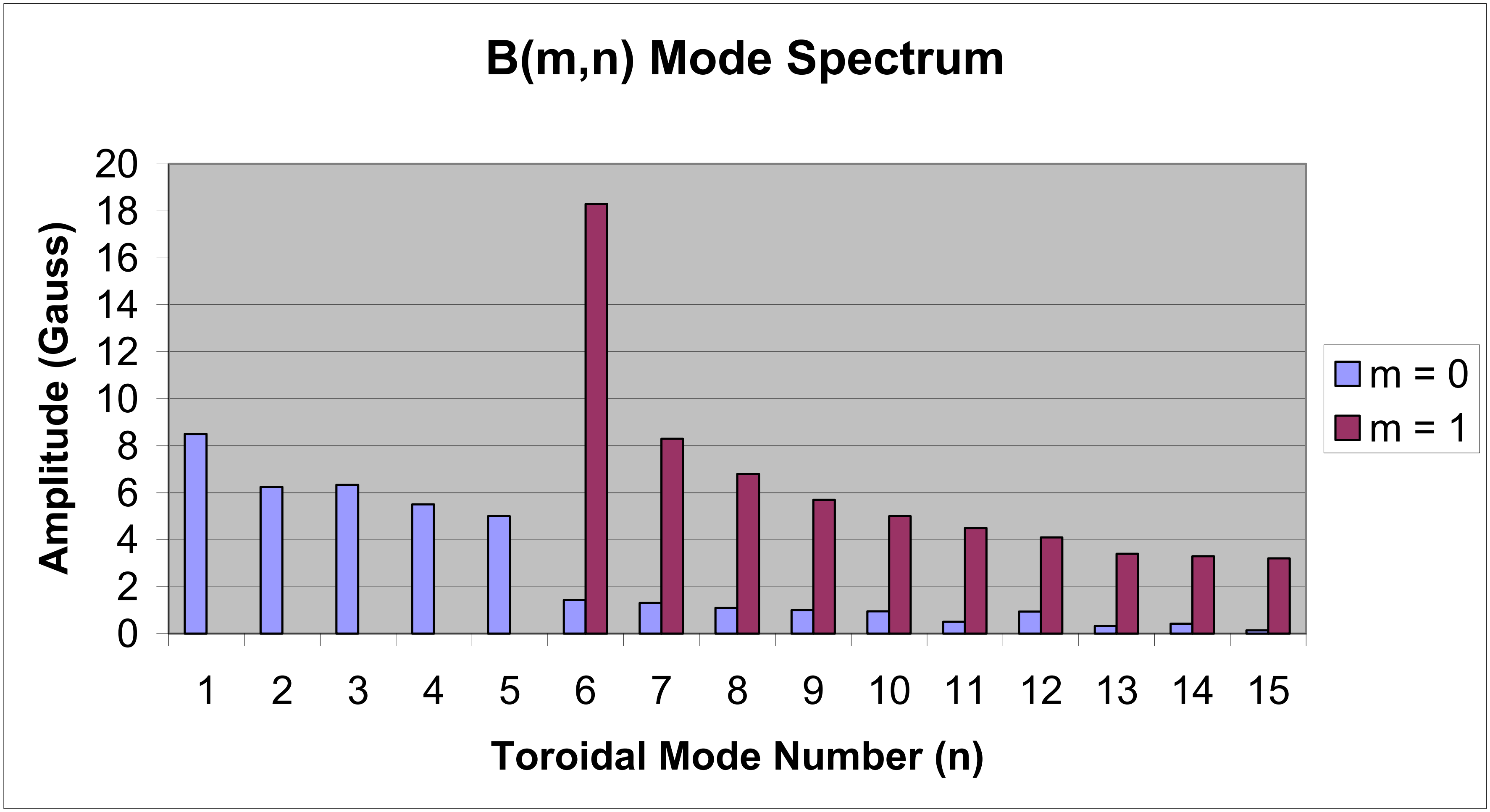
- At these resonant surfaces, islands form of width,

$$W = 4\sqrt{\frac{B_r(m,n)\, r_s}{B_\theta\, n \left|\frac{dq}{dr}\right|}}$$

- Large fluctuations lead to island overlapping. This breaks the "good" magnetic surfaces and the field becomes stochastic.

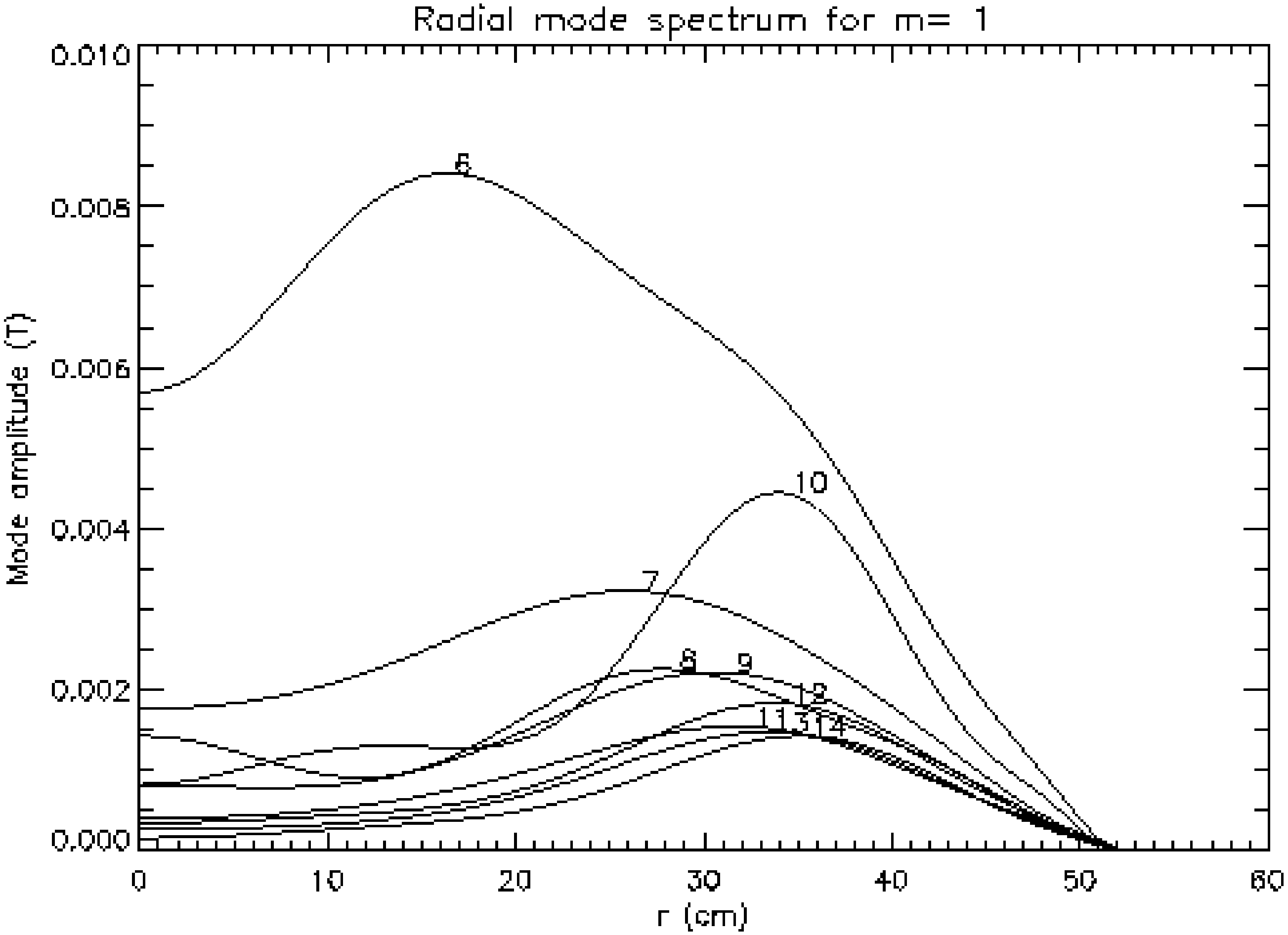
Mode amplitudes on MST

- Magnetic fluctuations mode spectra at the plasma boundary are obtained with magnetic coil arrays.



Radial mode amplitudes

- DEBS mode amplitudes are scaled by the B_ϕ spectrum.
- Magnetic fluctuation mode spectrum inside the plasma boundary is obtained by DEBS code.
- The boundary values at r = a are scaled to match experimental values.



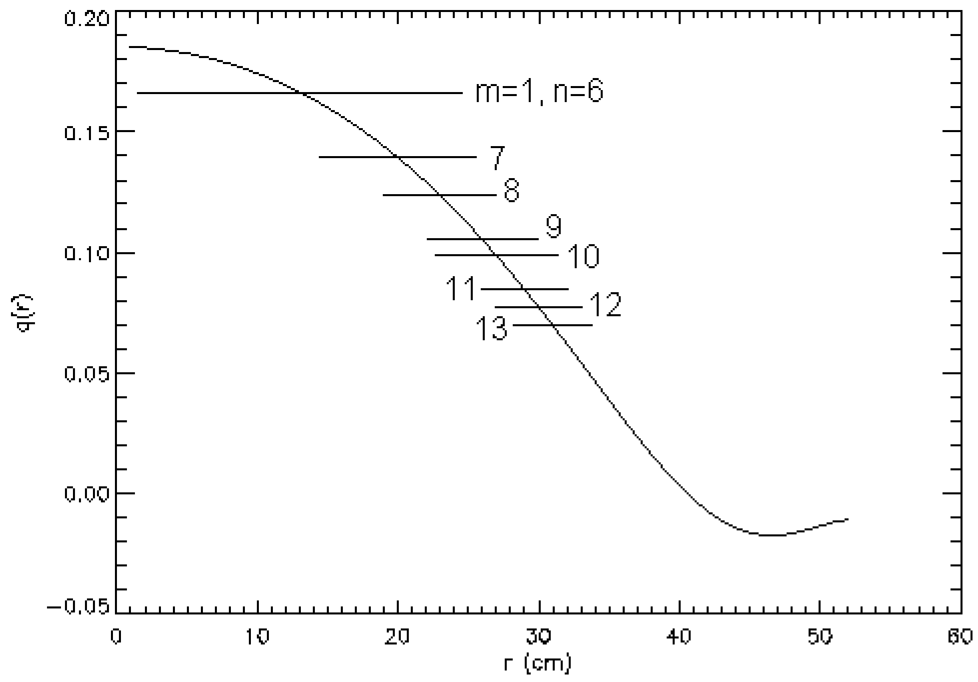
Island Overlapping

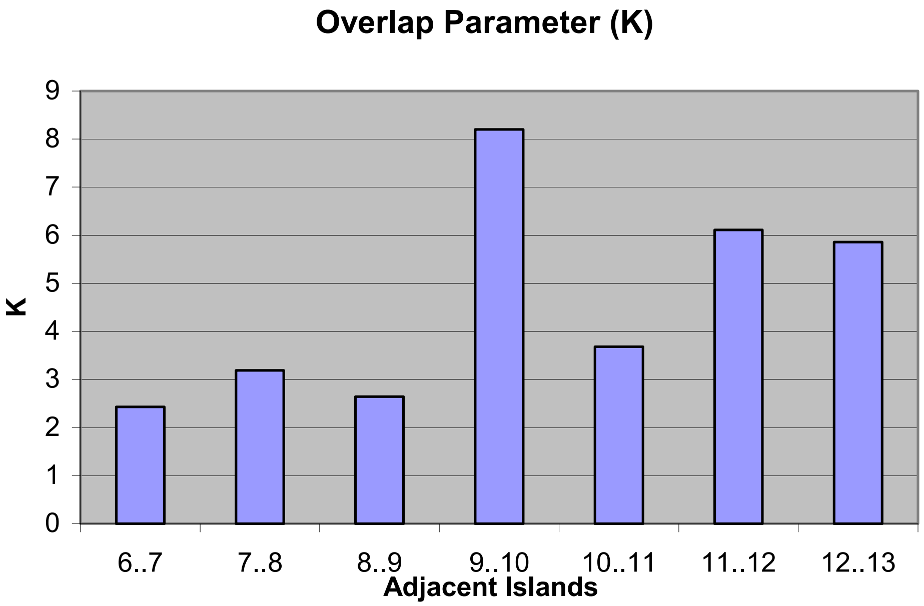
Island overlapping is given by the parameter:

$$K = \frac{\delta W_1 + \delta W_2}{2d}$$

where W_1 and W_2 are the island widths and d is the distance between them.

q(r) and island widths

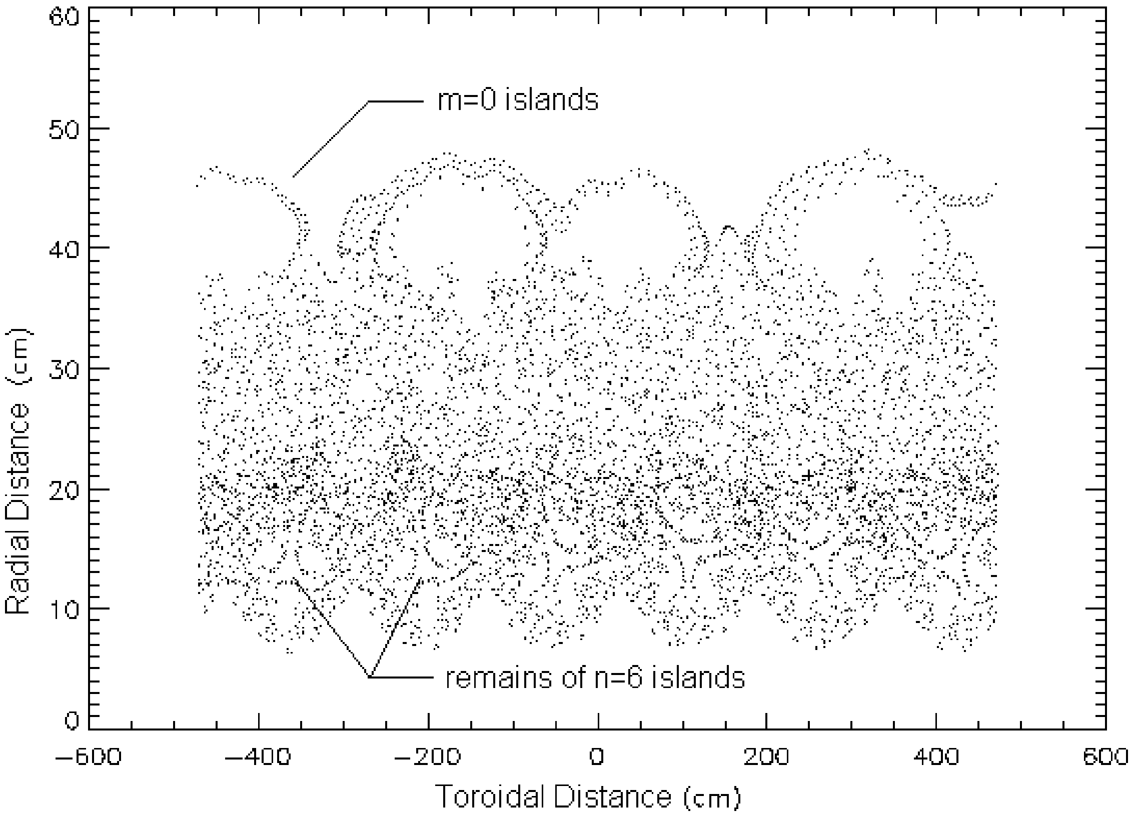




Code MAL/RIO

- Takes output of full 3-D DEBS simulation.
- Decomposes data to attain an analytical expression for both equilibrium and perturbed fields.
- Traces both magnetic field lines and particle motion.
- Calculates field line diffusion coefficients, mean lifetimes, and Lyapanov exponents.

Poncarè plot of the stochastic RFP



- Stochastic region enclosed by good flux surfaces for $S=10^4$
- Agrees with expectations of island overlapping.

Magnetic diffusion coefficient vs. r

- Whenever a line crosses a chosen radial location, it is divided into lengths of a$*2^n$; a, 2a, 4a, 8a... For each of these lengths, code MAL evaluates $\frac{(\Delta r)^2}{\Delta l}$.

- These are ensemble averaged to give a value of the diffusion coefficient.

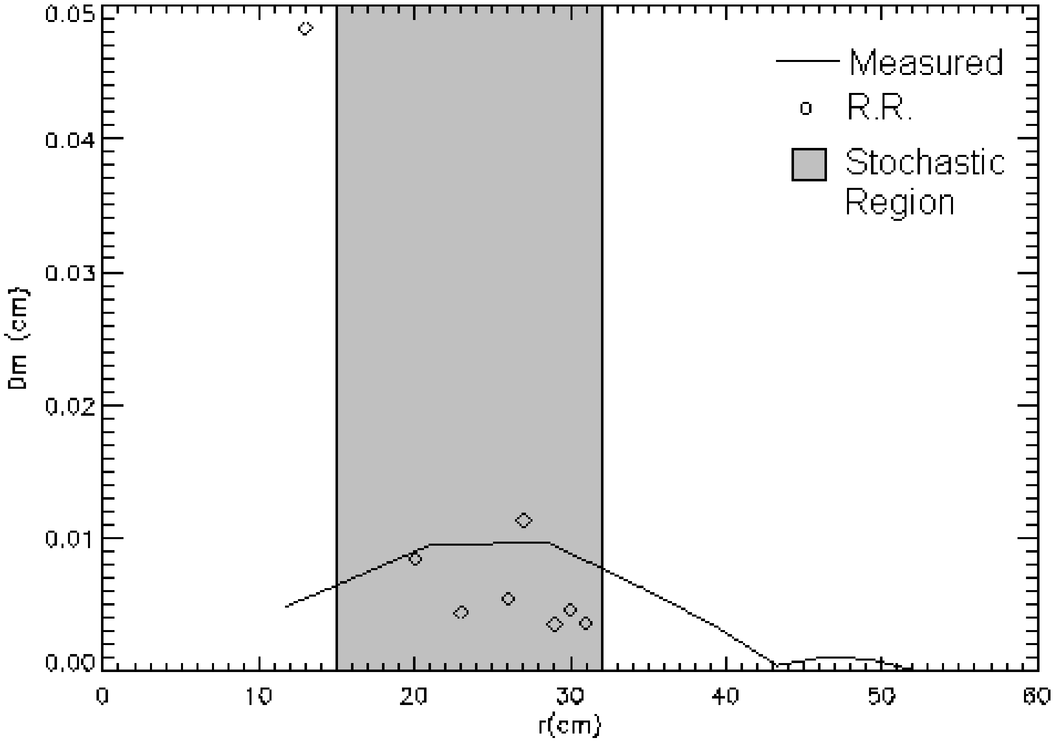
- A line of intermediate length must be examined to avoid ballistic motion as well as finite radial distance effects.

- Rechester-Rosenbluth diffusion is given by: $D_m = \left(\frac{B_r^n}{B_0} \right)^2 L_c$

- L_c is the autocorrelation length ~ 100cm.

Magnetic diffusion results

Comparison of D_m calculated vs. D_m (Rechester-Rosenbluth)



- $D_{m(\text{measured})} \approx D_{m(RR)}$ in stochastic region.
- $D_m \sim 7.0$ E-3 cm (Ave. value in stochastic region)
- D_m is small in the core where good surfaces remain.

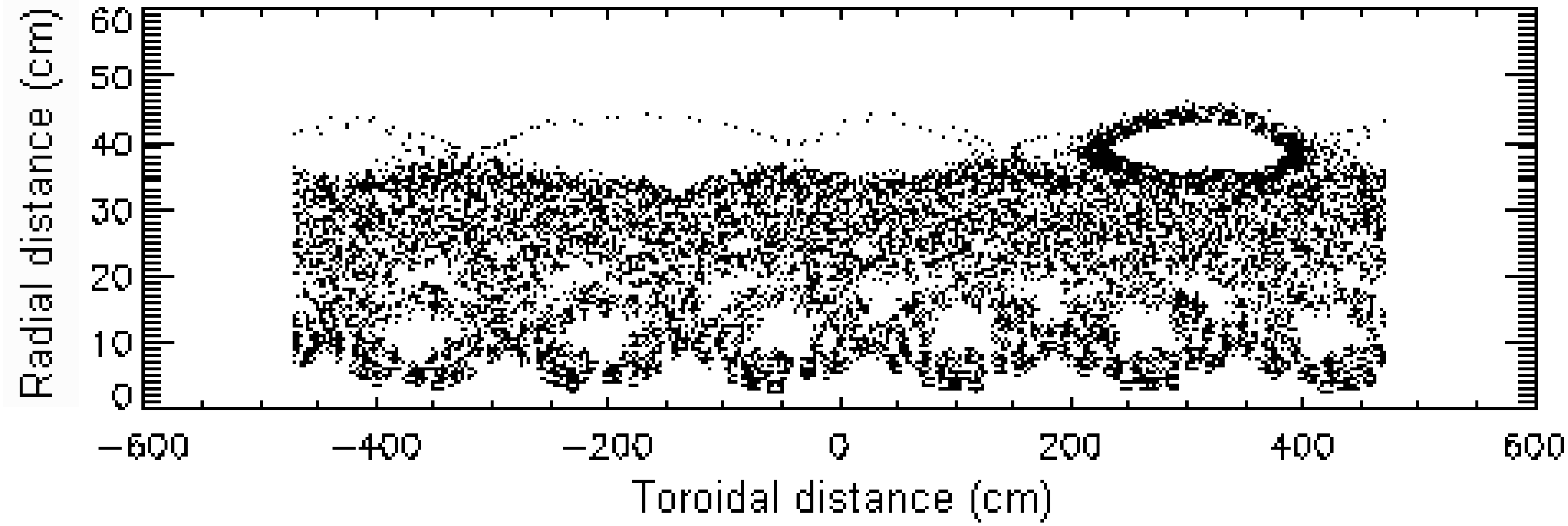
Radial confinement of particles depends on energy

- Code RIO evaluates particle trajectories and guiding centers in the same manner as the field lines.

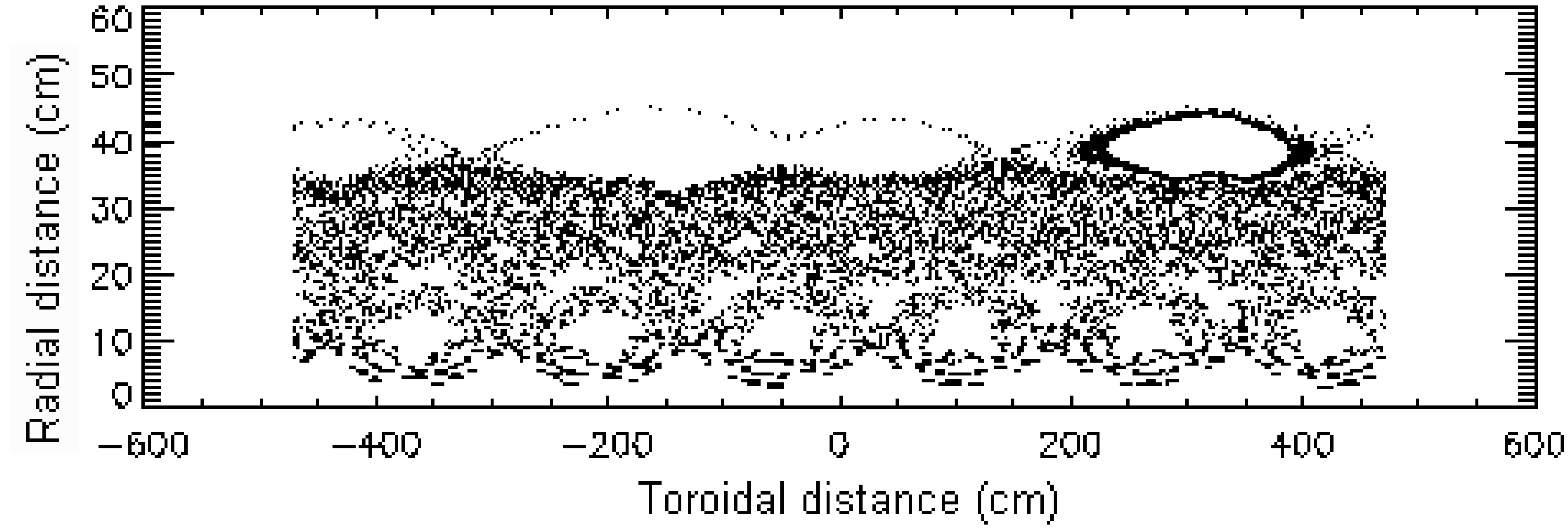
- Motion of the guiding center at low energy exhibits stochasticity similar to the field lines, while at high energy the motion tracks the equilibrium field.

1 KeV H^+

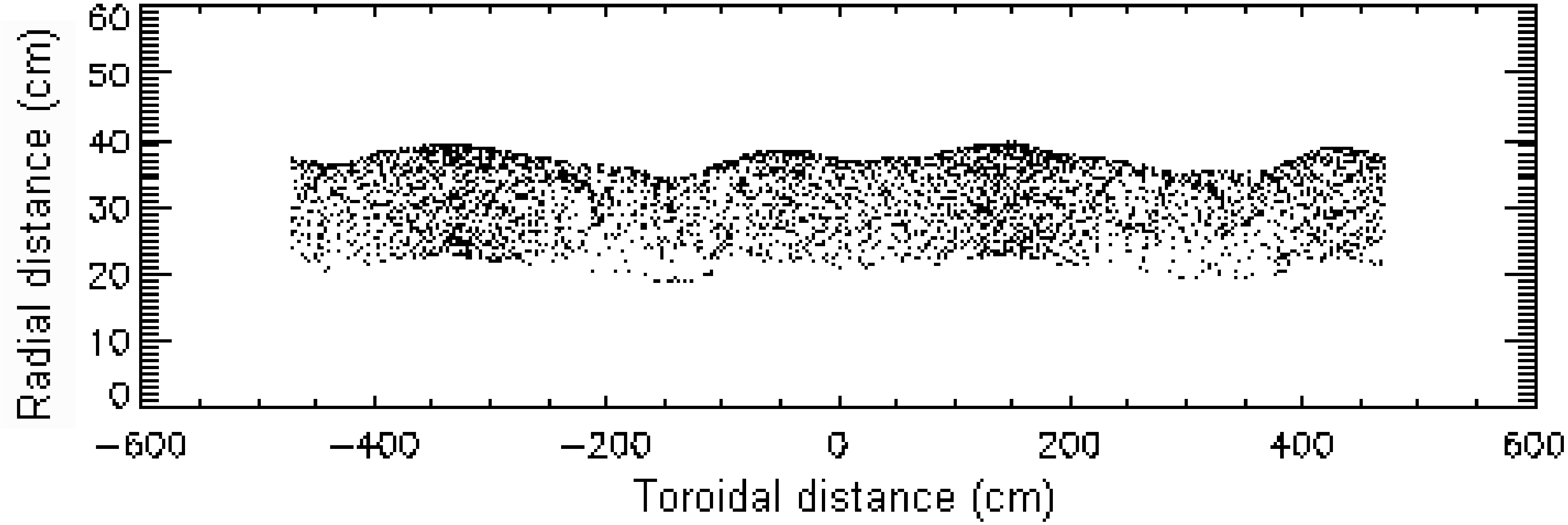
Ion Position

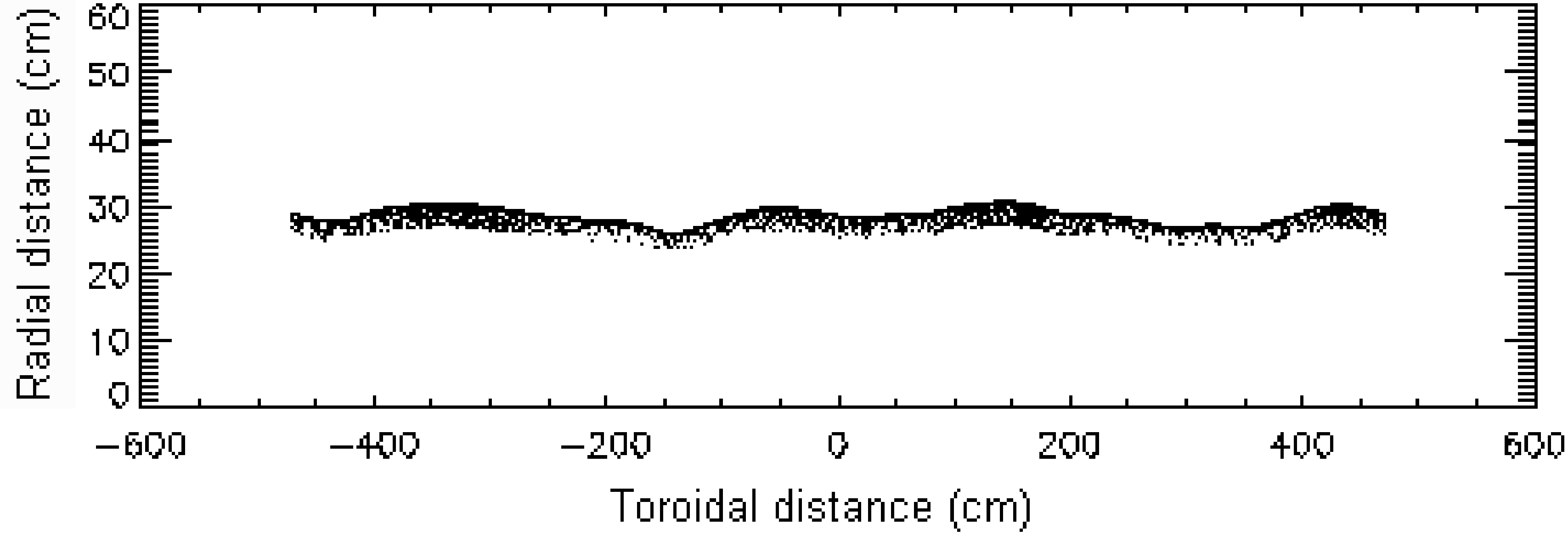


Ion guiding center position



20 KeV H^+


Ion Position


Ion guiding center position

Conclusions

- At low energies we expect the motion to follow the field lines. This qualitative motion is demonstrated by 1 KeV ion trajectories.

- At high energies the motion is mainly in response to the equilibrium field. Confinement of fast ions in an RFP will be tested with the installation of the NBI system on MST. (see poster by G. Fiksel et. al.)

Future Work

- Further tests of gyro-averaging.

- Many particle simulations. (Lifetimes, Energy confinement)

- Expansion to toroidal geometry.