Update on Self Pinch Transport of Heavy Ion Beams for Chamber Transport

D. V. Rose, D. R. Welch, Mission Research Corp.
S. S. Yu, Lawrence Berkeley National Laboratory
C. L. Olson, Sandia National Laboratories

ARIES Project Meeting

Monday, 22 April 2002

University of Wisconsin, Madison

Review:

- Self-pinched heavy ion beam transport is an attractive chamber propagation scheme; small entrance holes in the chamber wall, no hardware (sacrificial structures) in chamber.
- LSP simulations have identified a window in gas pressure for self-pinched heavy ion beam transport in the reactor chamber (10-150 mTorr Xe).
- A “super-pinch” mode has also been identified in the simulations. We are presently looking into the physics of this new transport mode.

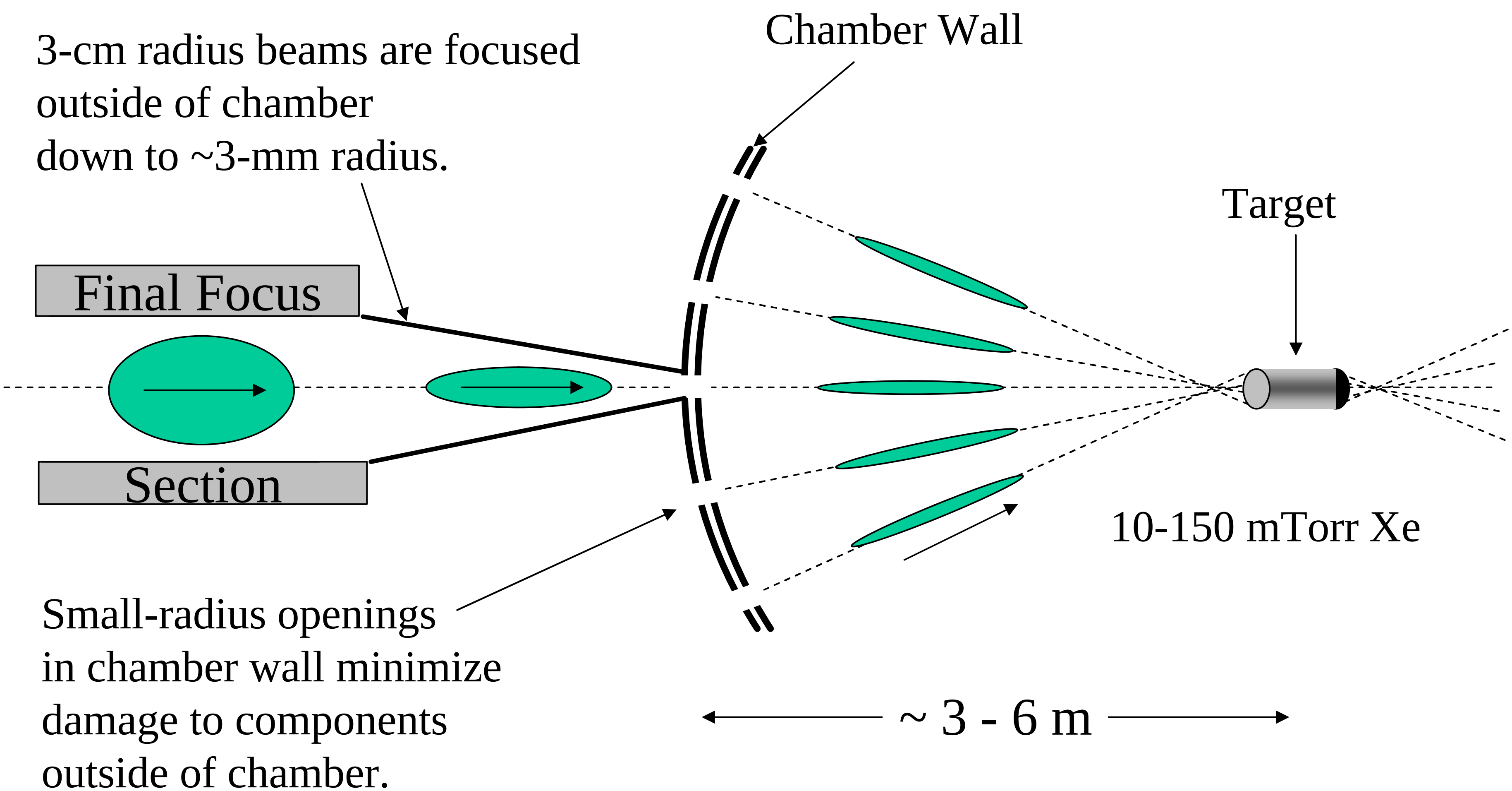
Transport for several chamber concepts currently being studied

ARIES-IFE Study of HIF

Transport Mode / Chamber Concept	**Ballistic Transport** *chamber holes ~ 5 cm radius* *most studied*		**Pinch Transport** *chamber holes ~ 0.5 cm radius* *higher risk, higher payoff*	
	Vacuum-ballistic *vacuum*	**Neutralized-ballistic** *plasma generators*	**Preformed channel** **("assisted pinch")** *laser + z-discharge*	**Self-pinched** *only gas*
Dry-wall *~6 meters to wall*	**Not considered now: Requires ~500 or more beams**	**Not considered: insufficient neutral-ization for 6 meters**	**Option: uses 1-10 Torr** *2 beams*	**Option: uses 1-100 mTorr** **~2-100 beams**
Wetted-wall *~ 4-5 meters to wall*	HIBALL (1981) **Not considered: Needs £ 0.1 mTorr leads to ⇦**	OSIRIS-HIB (1992) **Possible option: but tighter constraints on vacuum and beam emittance**	**Option: uses 1-10 Torr** *2 beams*	PROMETHEUS-H (1992) **Option: uses 1-100 mTorr** **~2-100 beams**
Thick-liquid wall *~ 3 meters to wall*	**Not considered: Needs £ 0.1 mTorr leads to ⇧**	HYLIFE II (1992-now) **Main-line approach: uses pre-formed plasma and 1 mTorr for 3 meters** *~50-200 beams*	**Option: uses 1-10 Torr** *2 beams*	**Option: uses 1-100 mTorr** **~2-100 beams**

Self-pinched chamber transport scheme

Charge and partial current neutralization provided by impact ionization of highly stripped ion beam in 10's mTorr gas

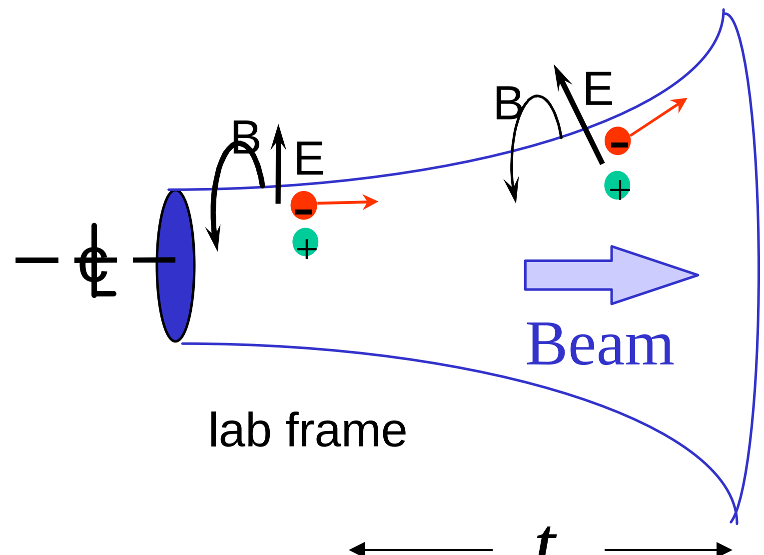


Self-pinched transport is predicted to occur within a gas pressure window:

- Maximum pinch force occurs when beam-impact ionizes a plasma density roughly that of the beam on time-scale of beam density rise length, τ
- Optimized for normalized trumpet length*:

  $$R = \tau \sigma n_g / 4Z = 1$$
- Trumpet shape and non-local secondary ionization supply neutralization without $v_e = v_b$

Electron orbits are mainly E×B



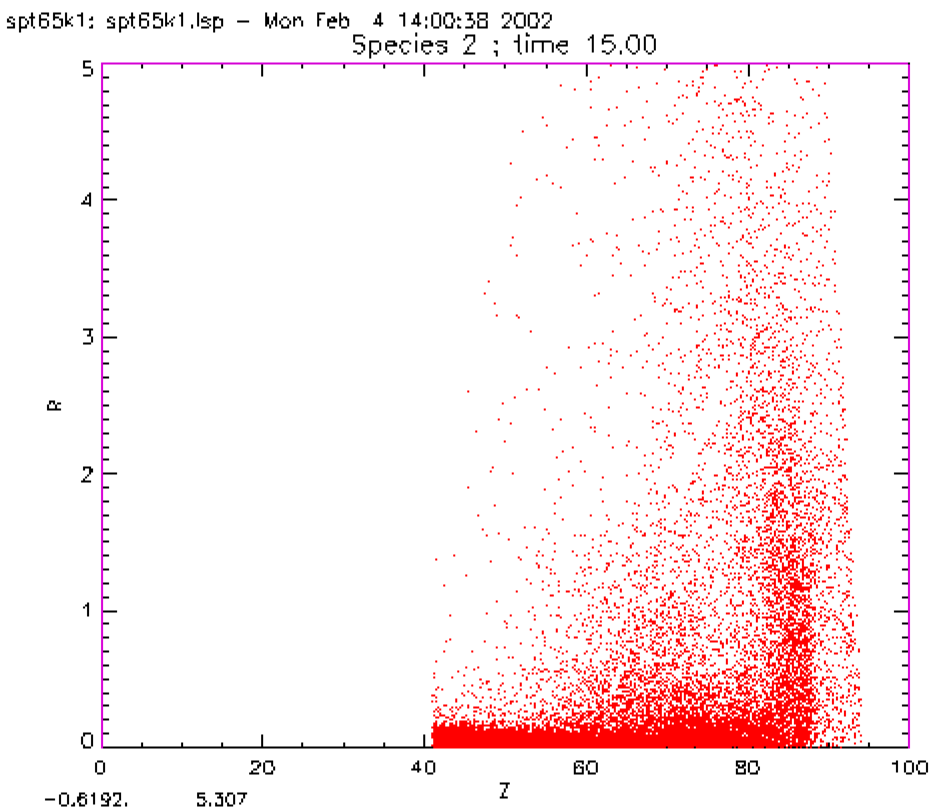
* D.R. Welch and C.L. Olson, Fusion Eng. and Des. **32-33**, 477, 1996.

For relatively small beam temperatures, a highly pinched transport mode has been observed in recent LSP simulations.

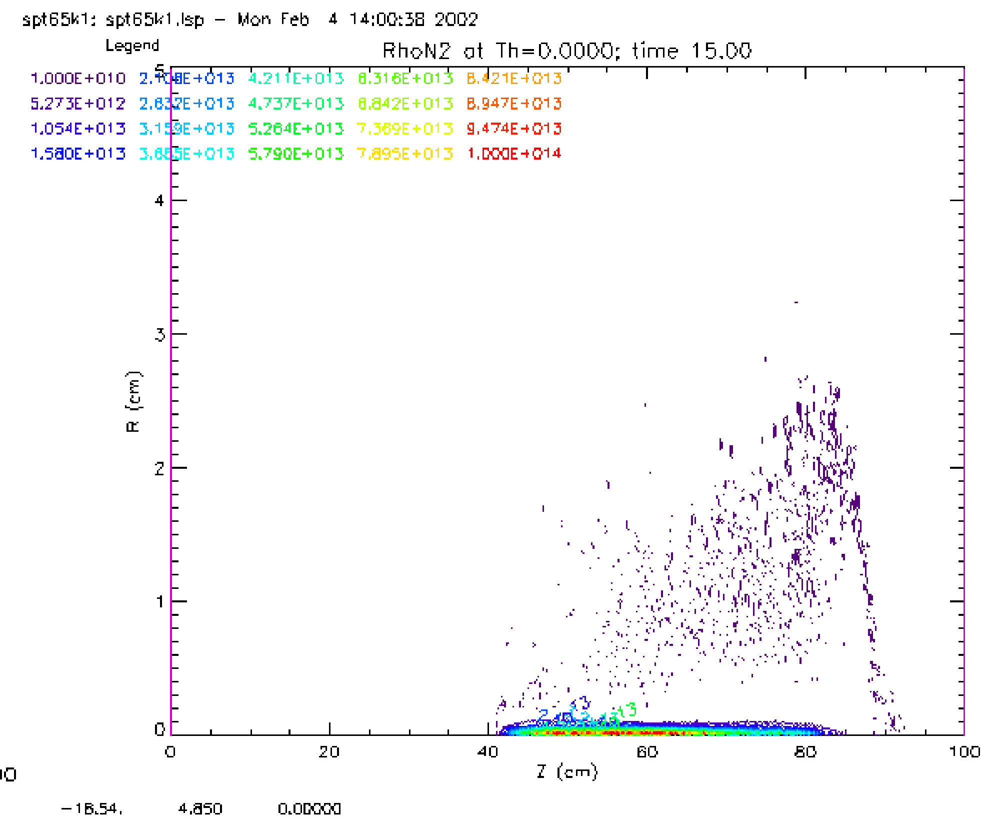
- 65 kA (electrical) of Pb^{+65} ions
- r_b = 3 mm
- Injected beam temp. of 60 keV
- 65 mTorr Xe

Net currents of ~ 5-30 kA

Beam Ion Positions

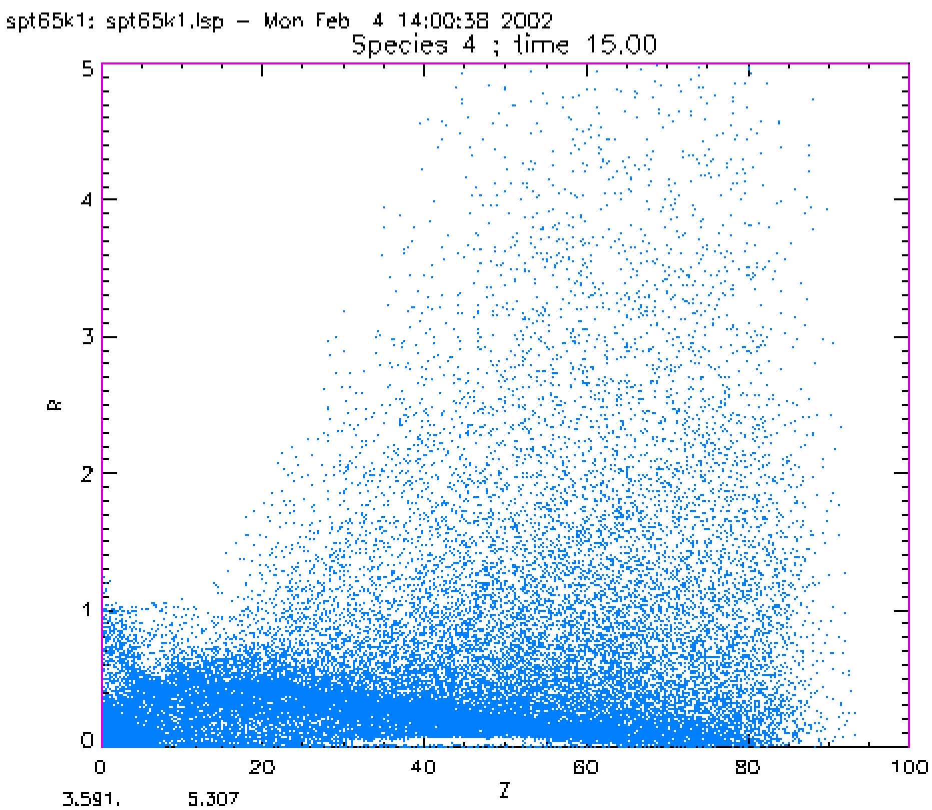


Beam Ion Density

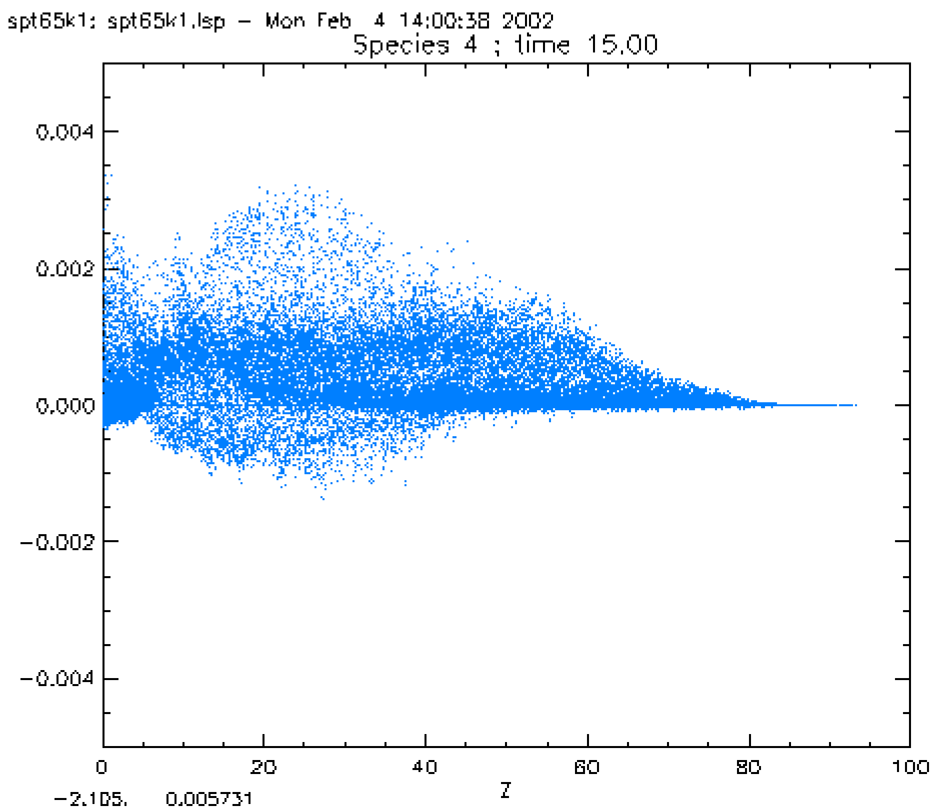


Plasma ions (created by beam impact ionization) are expelled from the channel on time scales comparable to the pulse duration.

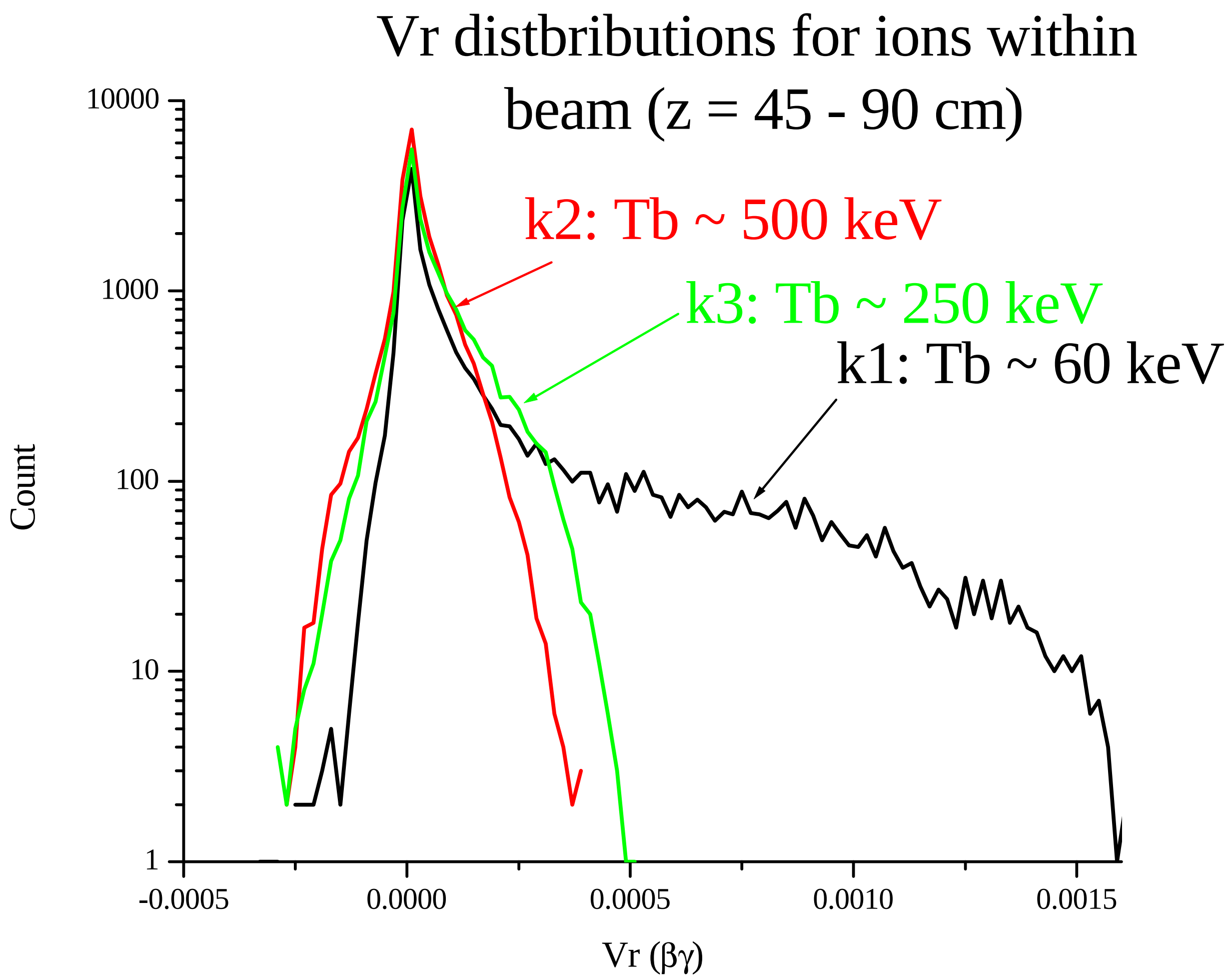
Plasma ion positions



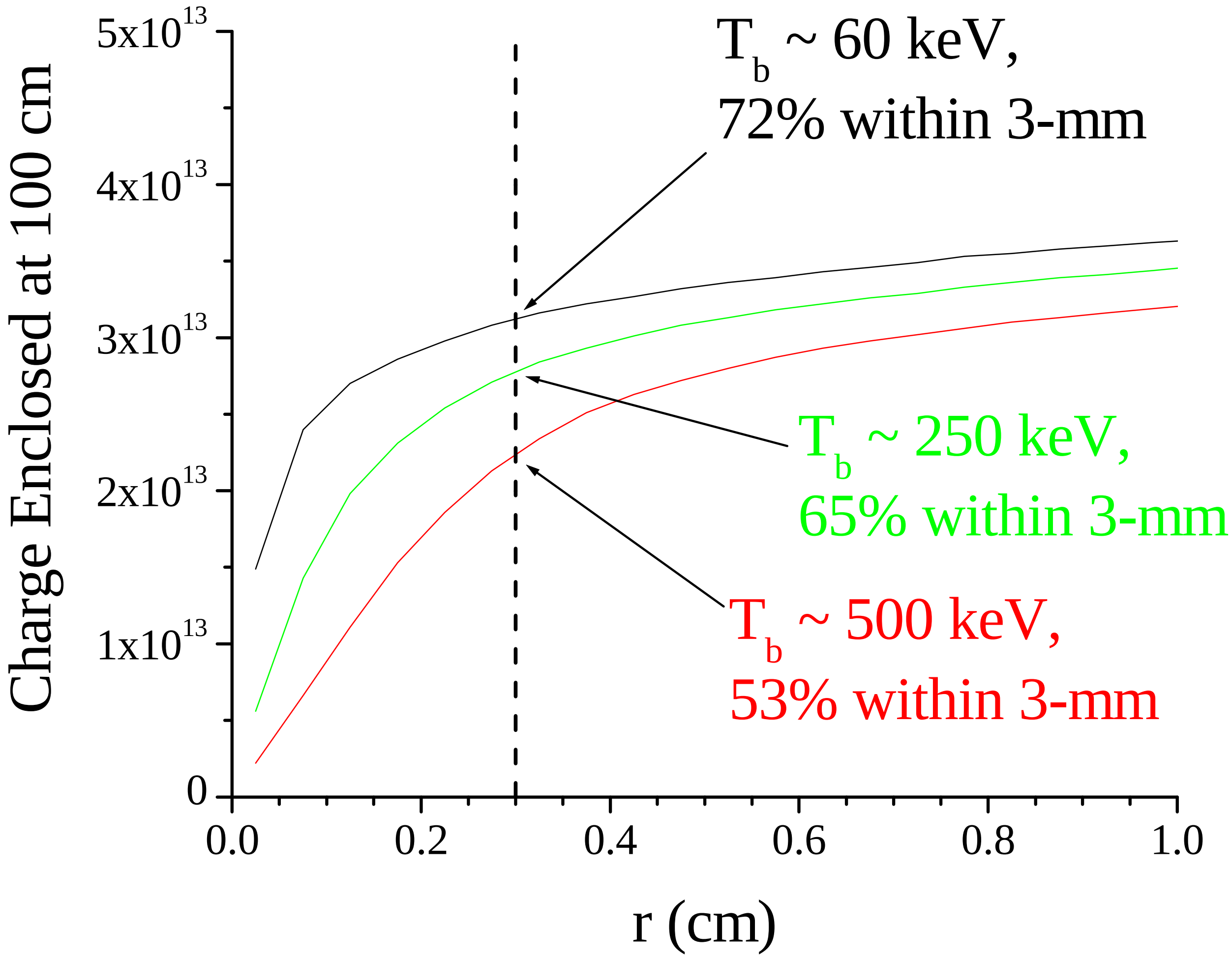
Radial plasma ion velocities



For <u>larger</u> beam temperatures, the radial plasma ion velocity is reduced (the net magnetic field is reduced and the “equilbrium” pinch radius increases)



After 1 meter, the "super-pinch" mode transports 72% of the beam within 3-mm.



Optimization of this self-pinched transport mode is being examined:

- Trumpet shape influences “normal” self-pinched equilbrium; same variations can be explored for “super-pinch” mode.
- A prescribed beam temperature profile may reduce “evaporation” losses and increase transport efficiency; we are exploring radial beam temperature profiles now.
- 3-D simulations are also being carried out to examine stability and pointing/tracking issues.