

Status of Operational Windows for HIF Chamber Transport Modes

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ARIES Project Meeting

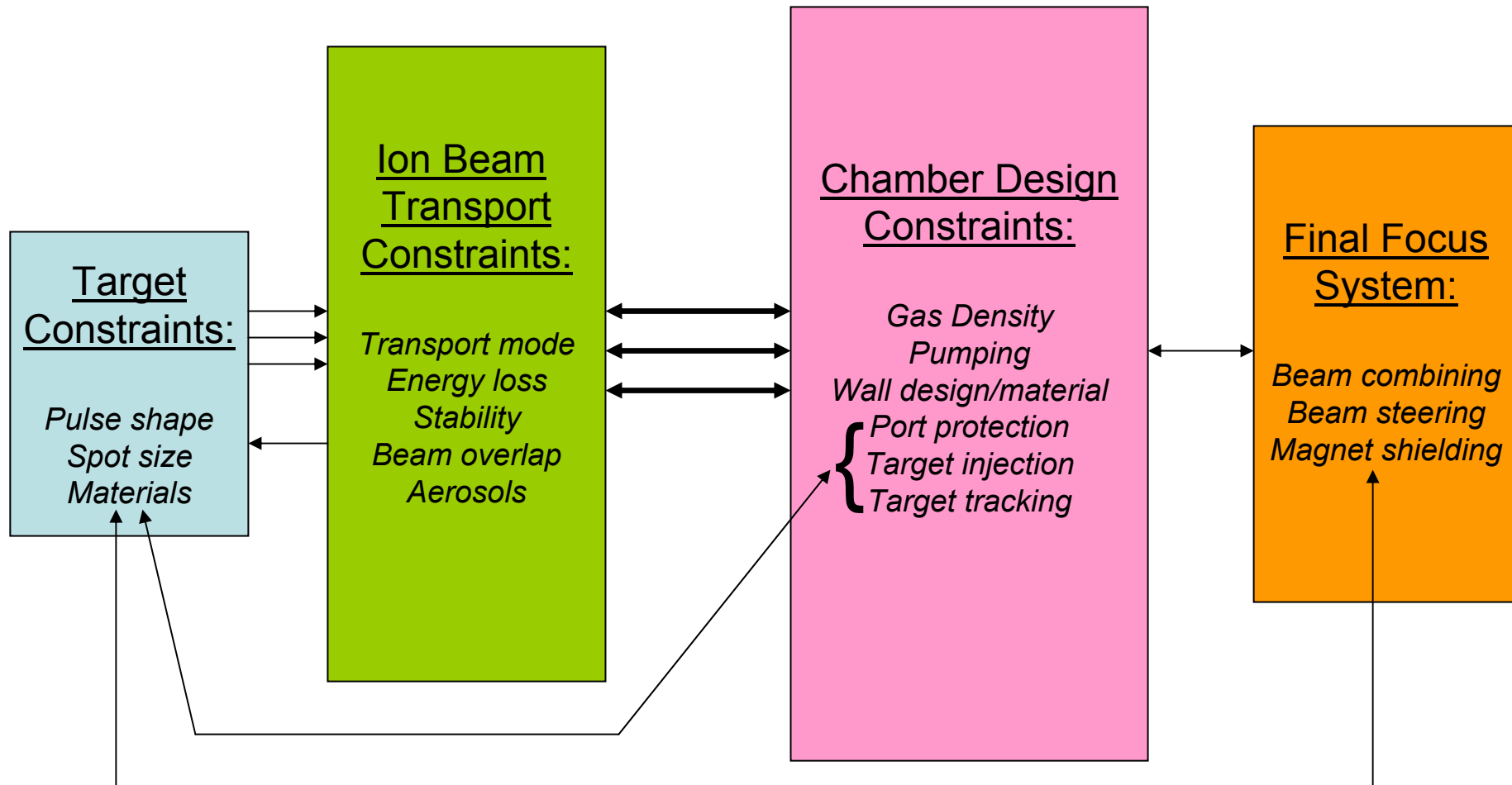
January 8, 2003

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Objectives:

- Develop meaningful ion beam transport “operational windows” to guide chamber design.
- Parameter spaces must be directly connected with chamber interface issue
 - Chamber Radius
 - Gas Pressure
 - Wall Materials, Liquids, Jets, etc.

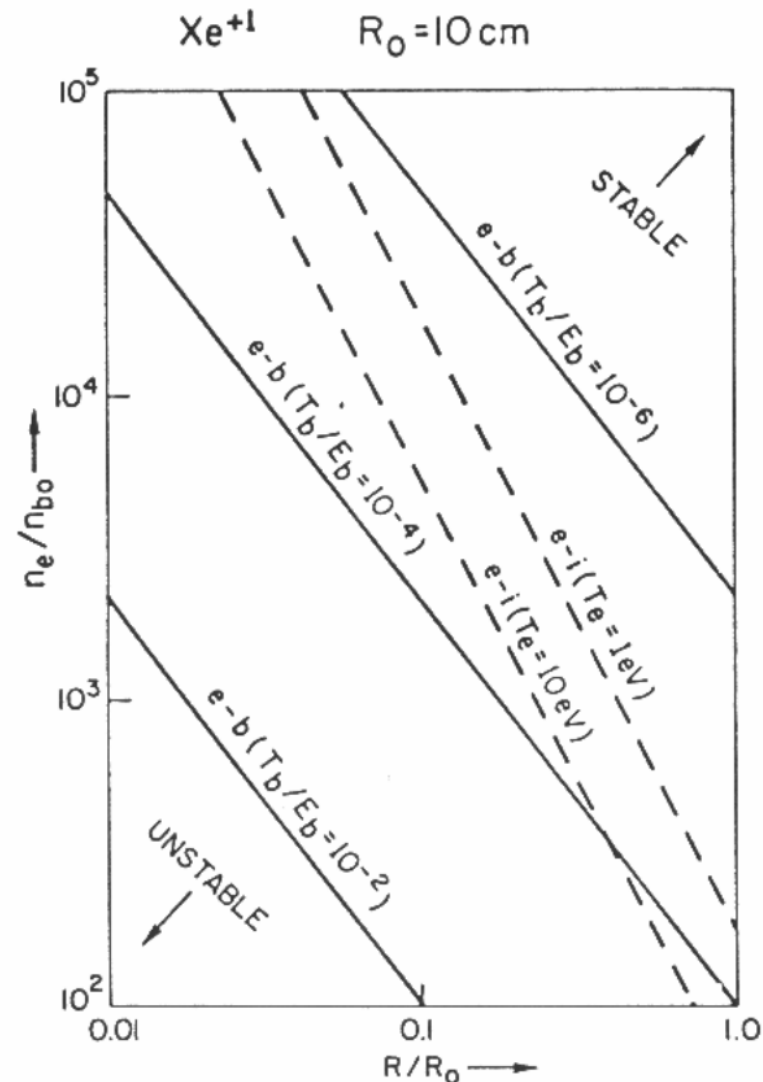
Beam Transport and Chamber Interface Issues Involve Many Constraints



Early HIF beam transport operational windows dealt with stability:

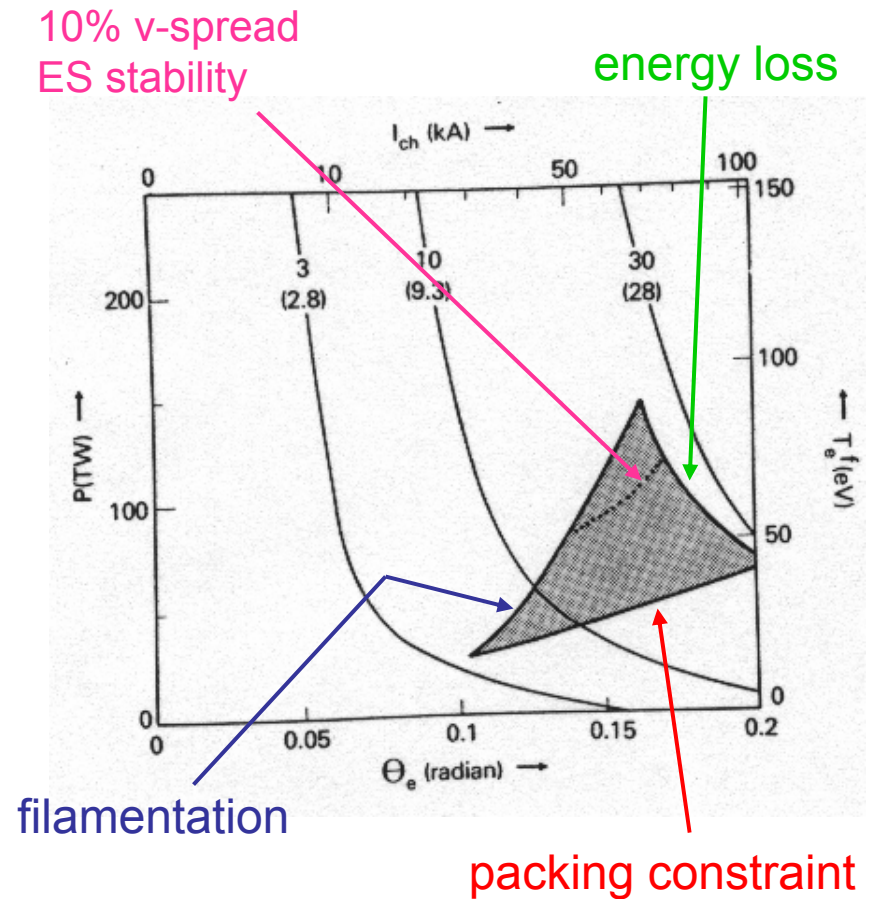
- Early HIF work (1970's - 1980's) examined beam stability and stripping for high energy (~ 10 GeV) beam transport.
- Example of an operational window (P. Ottinger and D. Mosher, Proc. Heavy Ion Fusion Workshop, Brookhaven Natl. Lab., 1977, p. 61) for 7 GeV Xe at 14 kA assuming preformed background plasma.

Also see R. F. Hubbard, *et al.*, Proc. Heavy Ion Fusion Workshop, Argonne, 1978, p. 379, and, S. Yu, *et al.*, p. 403.



Light-Ion Fusion Operational Windows Also Examined Beam Stability

- Sample operational window (shaded region) for light-ion z-discharge transport [P. Ottinger, *et al.*, Proc. 5th Intl. Conf. High Power Part. Beams (1983), p. 97.]
- Modeling includes assessments of JxB driven channel expansion, beam energy loss, time-of-flight bunching, and instabilities.



Also see D. Mosher, Comm. Plasma Phys. **6**, 101 (1981)
and R. R. Peterson and C. L. Olson, Laser Interaction and
Related Phenomena: 13th Intl. Conf., edited by G. H. Miley
and E. M. Campbell (AIP, 1997), p. 259.

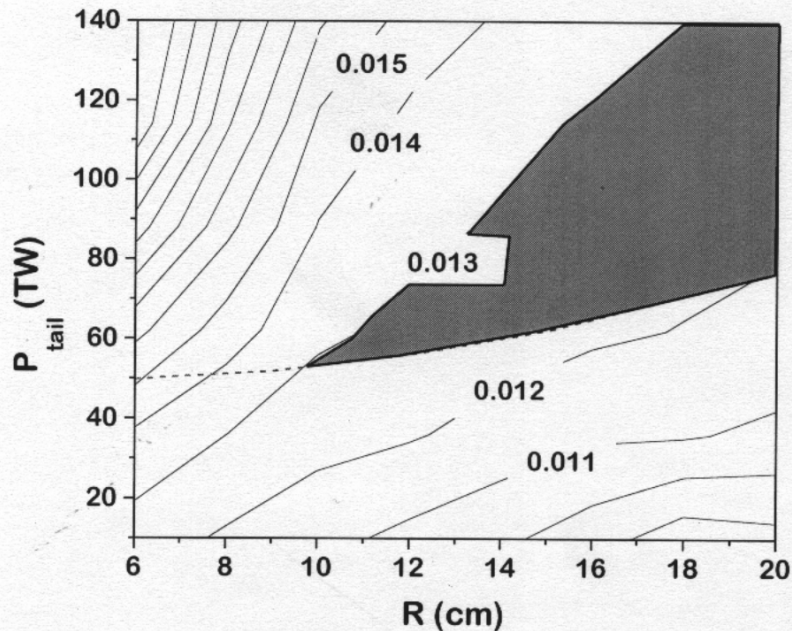
4 MeV protons, factor-of-five bunching,
beam radius = 1.5 cm

Light-Ion Ballistic Transport

- Sample windows for ballistic transport with time dependent calc. of beam power and plasma evolution in chamber and beam energy on target (focusing constraints) (D. Rose, *et al.*, APS-Div. Plasma Phys. Meeting, 1996.)

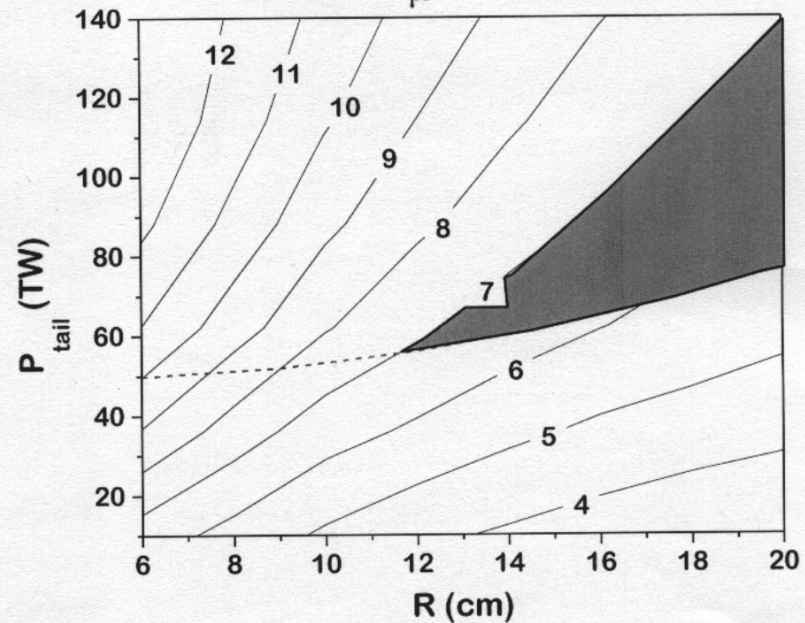
Two-stream

Sample operational window
for $\Delta V_{bz}/V_b = 0.013$



Filamentation

Sample operational window
for $\theta_\mu = 7$ mrad

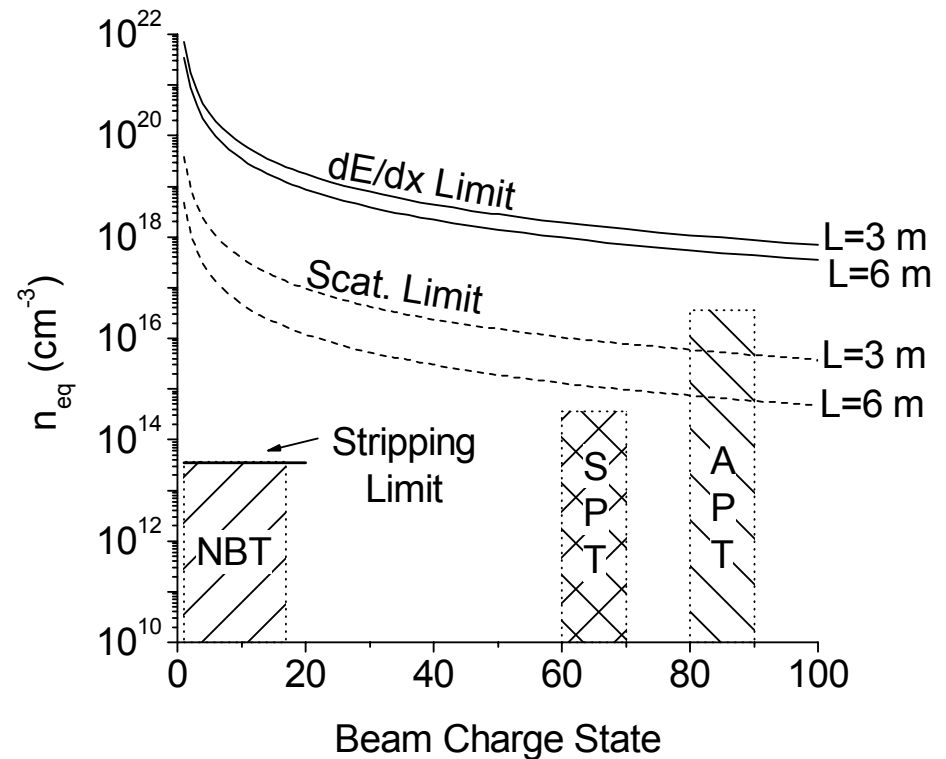


Status of Operational Windows for ARIES-HIF

- Stability constraints are being examined through a combination of analytic modeling and detailed numerical simulations (e.g., time-dependent stripping, ionization, etc.).
- Examination of chamber design constraints is emphasized in concert with target and final-focus constraints.
- End-product: operating windows that explicitly map out chamber initial conditions (wall-radius, gas density, aerosol concentrations, etc.)

A first look at beam/aerosol interactions suggest that NBT places the tightest constraints on aerosol density in the chamber.

- Aerosol equivalent density mapped for three transport modes
- Basic assumptions about beam interactions with charged droplet confirmed with LSP simulations.
- Note that beam charge state for pinched modes is likely to be similar. Number used here are copies from assumed values in recent beam transport simulations.



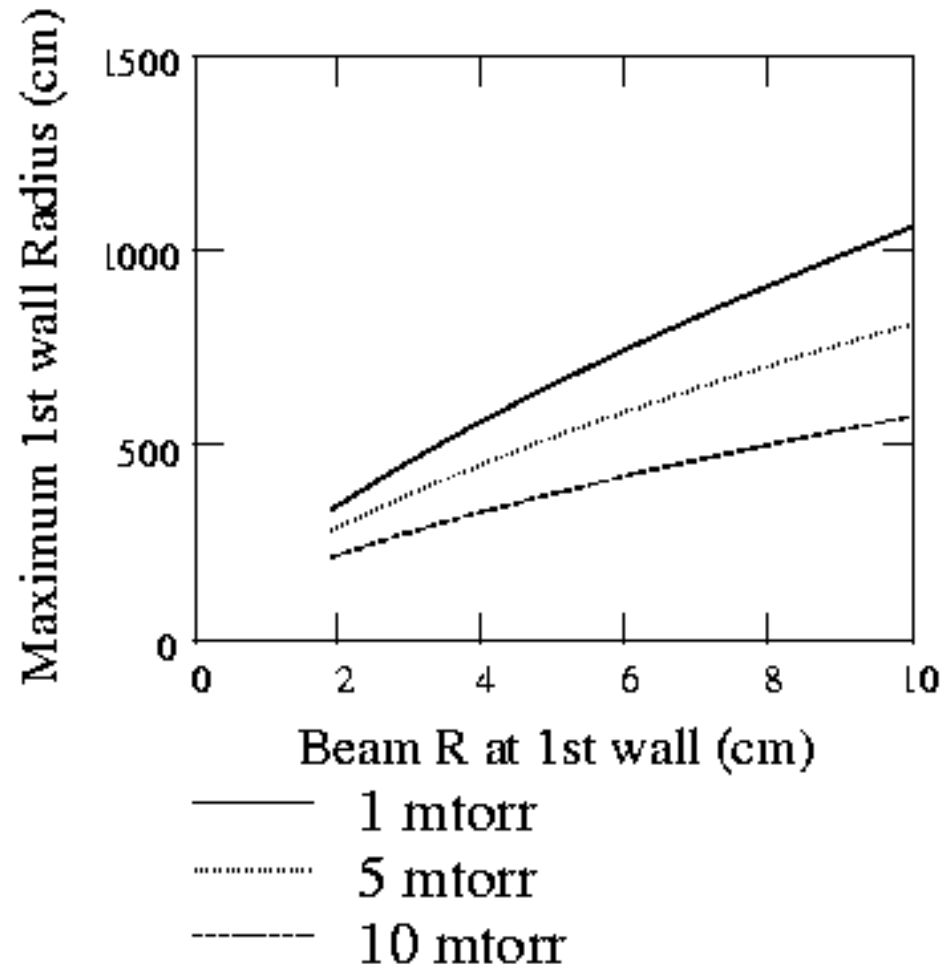
NBT operational window efforts:

- ES stability is being assessed through a detailed comparison between analytic models [Stroud, Laser Part. Beams (1986)] and numerical simulations.
- EM stability will be assessed in a similar manner (requires large-scale 3-D simulations).
- Assessment of NBT spot size as constrained by first wall radius being assessed (next slide).

An envelope analysis for an NBT operational window (D. Welch)

Calculation uses the radial space-charge spreading current, and beam stripping as a function of distance and gas pressure.

Assumptions are made for neutralization fraction (assumed constant) and stability (always stable). These assumptions can and will be checked as part of our ongoing work.



We will continue quantitatively develop an NBT Operational Window:

- Mapping out a region of chamber design space that takes into account NBT physics.
- Most simulation work to date has centered around a limited range of beam and chamber parameters. Recent work has suggested that this propagation mode has a modest operational window.
- Beam stability presently being addressed.

Pinched Mode Operational Windows

- APT: significant progress has been made via numerical simulations in exploring parameter sensitivities in this transport mode. All results suggest a broad operational parameter space (presented in previous talks by D. Welch).
- SPT: A broad gas pressure window has been identified for transport, however, significant work remains to assess transport efficiency and stability.