# NCSX
# Transport & Requirements

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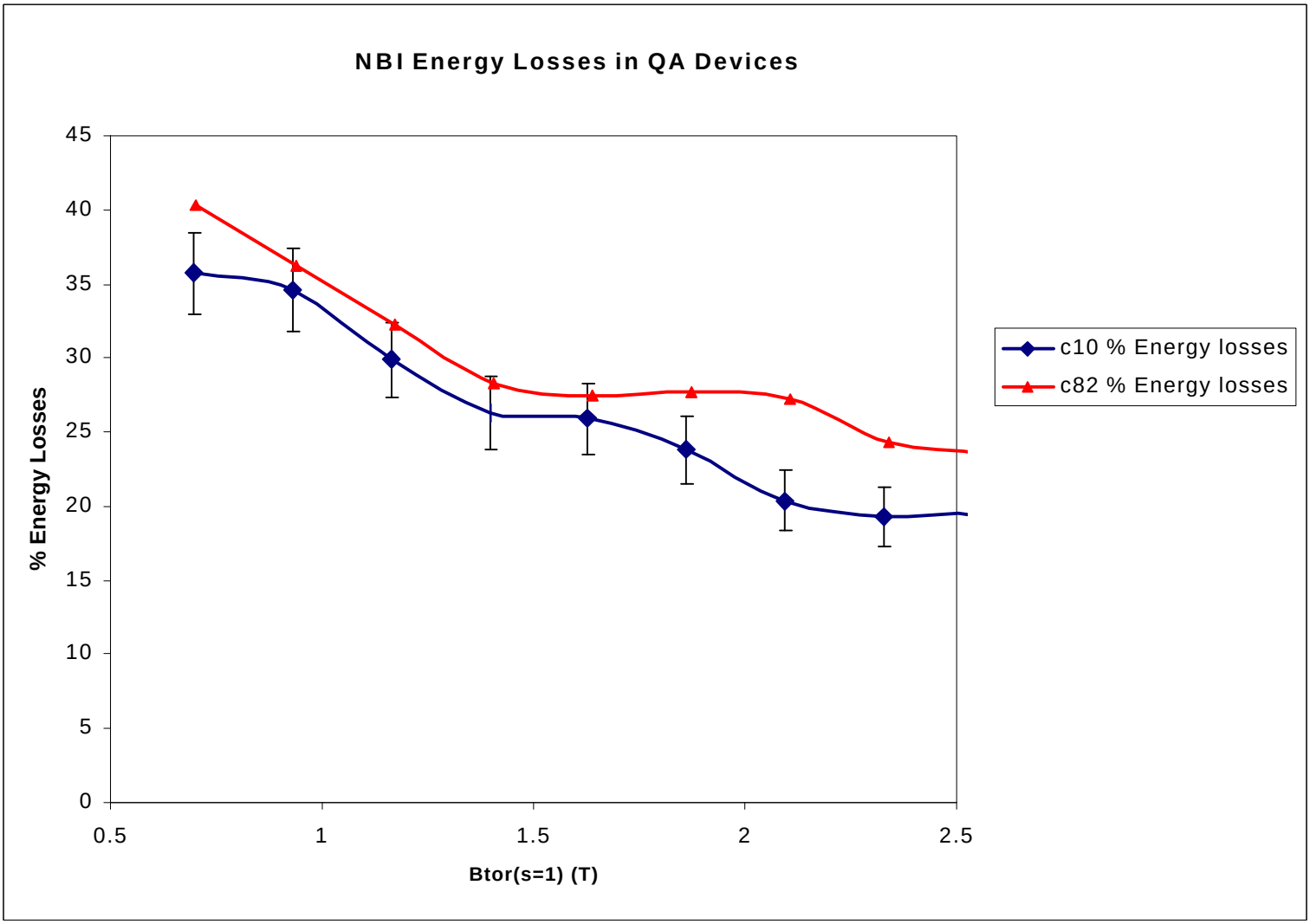
# Outline

- Transport Analysis of Current Configurations
  - Beam & Thermal confinement
  - Operating Points
  - Transport simulation & optimization

- Requirements update
  - Startup strategy
  - Eddy currents

- Flexibility/robustness strategy

# Similar NB Losses Calculated for all NCSX Configurations




D. Spong

- Full 3D orbit following calculation, with full collision operator

- $H^0 \rightarrow H$, co-only NBI

# Thermal Neoclassical Transport Calculated by 3D Gyrokinetic Code

Use GTC gyrokinetic code to calculate neoclassical losses for each species.

- Use $e\Phi = T_i$ to approximate electric field effect increases confinement by ~30%
- Electron neoclassical transport negligible compared to ion transport
- Scales as ~ $B^2$ (c10)
  - Use in 0D spreadsheet model to identify operating points, or
  - Iterate profiles $\rightarrow \tau_{Ei}^{neo}$ in 1D transport solution, using empirical Te or anomalous transport simulation
  - Simplified Monte-Carlo transport estimator being benchmarked for inclusion in optimizer

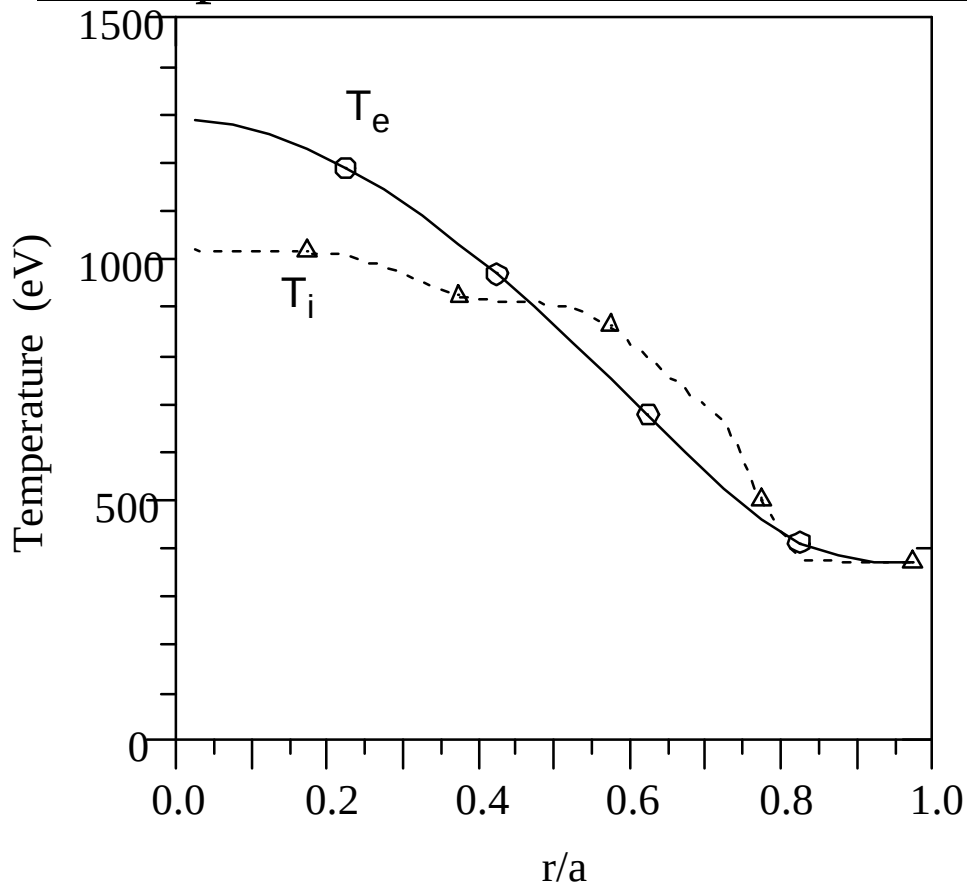
H. Mynick, Z. Lin, I. Zatz

# Available Power Allows Achievement of Goals

| | QAS3-c85 max β | QAS3-c85 reactor collision. |
|---|---|---|
| R (m) | 1.45 | 1.45 |
| <a> (m) | 0.42 | 0.42 |
| | | |
| B(T) | 1.2 | 1.2 |
| P (MW) | 5.6 | 5.6 |
| $\tau_E$ (sec) | 0.045 | 0.031 |
| β | 4.0% | 2.7% |
| | | |
| n (10^19/m^3) | 10.2 | 4.6 |
| To (2<T>) (keV) | 1.4 | 2.1 |
| n R / $T^2$ | 7.4 | 1.5 |
| | | |
| L-mode multiplier | 1.6 | 1.2 |

0-D Model of Plasma, using 3D calculations of NB losses and thermal confinement
Zeff=2 assumed
Includes 10% beam-beta
Density constrained by Sudo limit
$\tau_E$ = min( 2.3xISS95, $\tau_E$-neo/2 )

# Transport Simulation for 1D Profiles




C82

As suggested by PAC, last meeting

- Example with $n_e(0) = 6.7 \times 10^{13}$
- $\chi_e$ from Lackner-Gotardi, with H=2.3 matching $\tau_{Ei}^{neo}$ from GTC gyrokinetic simulation
- Gives $\beta \sim 2\%$

– Profiles not fully converged between GTC and transport-solver

Exploring range of densities and profiles

Adding ITER transport models

# Startup strategy

- Now:
  Snapshots identified for physics/engineering design

  – Vacuum transform, low $\beta$
    target for current ramp, low-power heating

  – Final edge $\iota$, low $\beta$
    target for high power heating

  – Final $\iota$, full $\beta$

- In progress:
  Model current and equilibrium evolution during startup
  (Along with transport model)

  – Put offset iota in 2D axisymmetric flux diffusion models (TRANSP, TSC): approximate calc.

  – Modify 3D WHIST to evolve 3D equilibrium along with current profile, correctly model || current evolution in 3D

  Will depend on transport models for $T_e(r)$ evolution

# Conducting wall/eddy-current Requirements

- Concern due to conducting shell designs for coil support

- Two separate requirements:

  – Eddy currents due to equilibrium changes should not produce islands ( < 0.1 of flux)

  – Penetration of kink must be fast enough to see it grow during high-beta phase of experiment to test 3D stabilization.

    Want 10 growth (~ wall) times in expected high-beta phase of 100 – 150 msec

    ⇨ need wall penetration time of kink to be 10 – 15 msec.

- see A. Brooks: plan and initial analysis

# Flexibility/Robustness Strategy

Identify Profiles to test coil flexibility

- Reactor-like target
  – ARIES-RS profiles
  – Ongoing stellarator reactor study, see J. Lyon

- Empirical
  - e.g. as on PBX-M at similar power and density, typical Ip(t) (long flattop, heat during rise, etc.)

- Modeled
  - Anomalous + neo. transport model
  - current evolution, for typical Ip(t)

Identify range of equilibrium shapes:

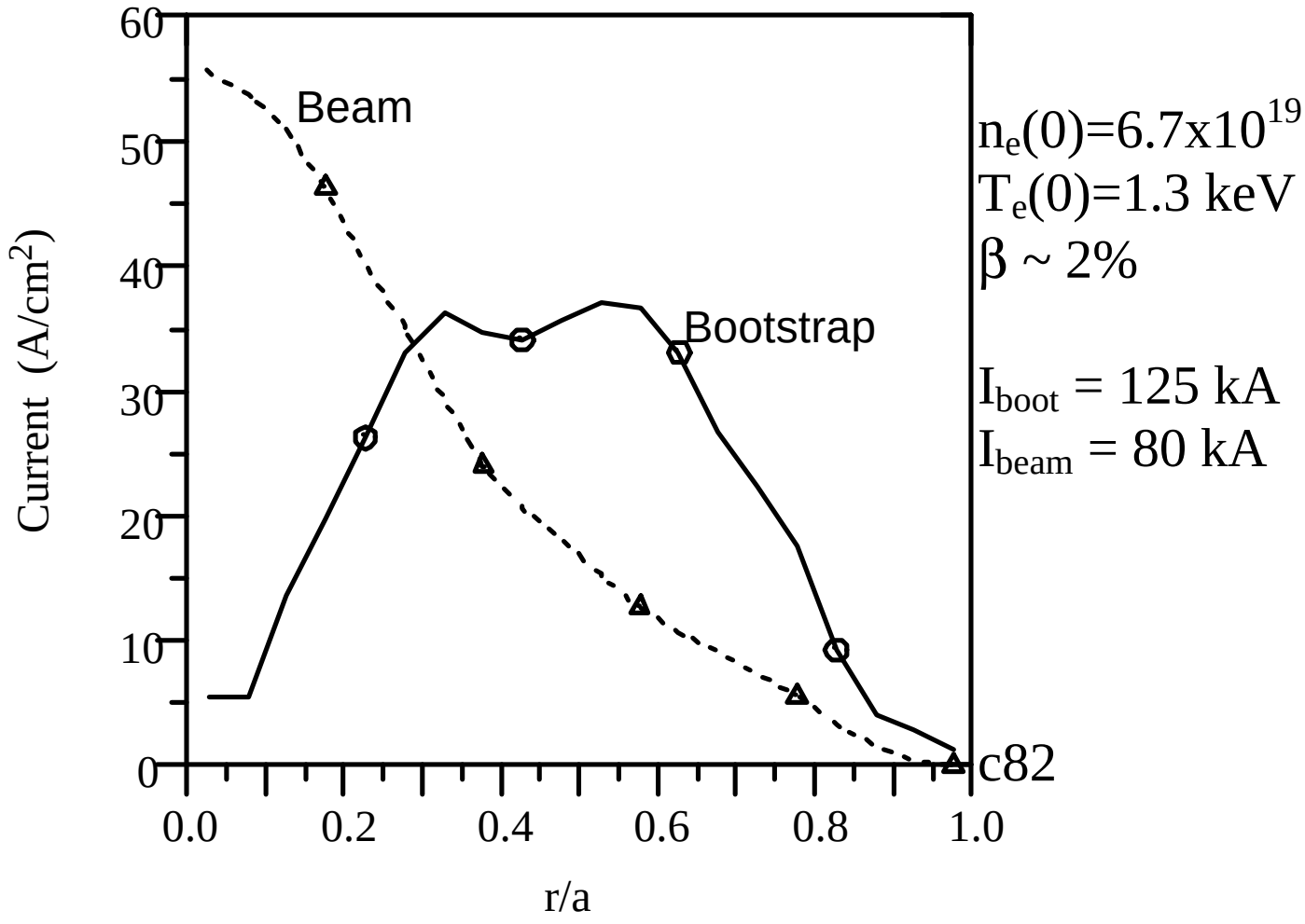
- combination of shaping parameters that maximally affects kink or ballooning stability

Test ability of candidate coils to produce equilibria
Modify or add trim coils as necessary.

# Heating & Current Drive Options

- Examining flexibility of available techniques:

NBI

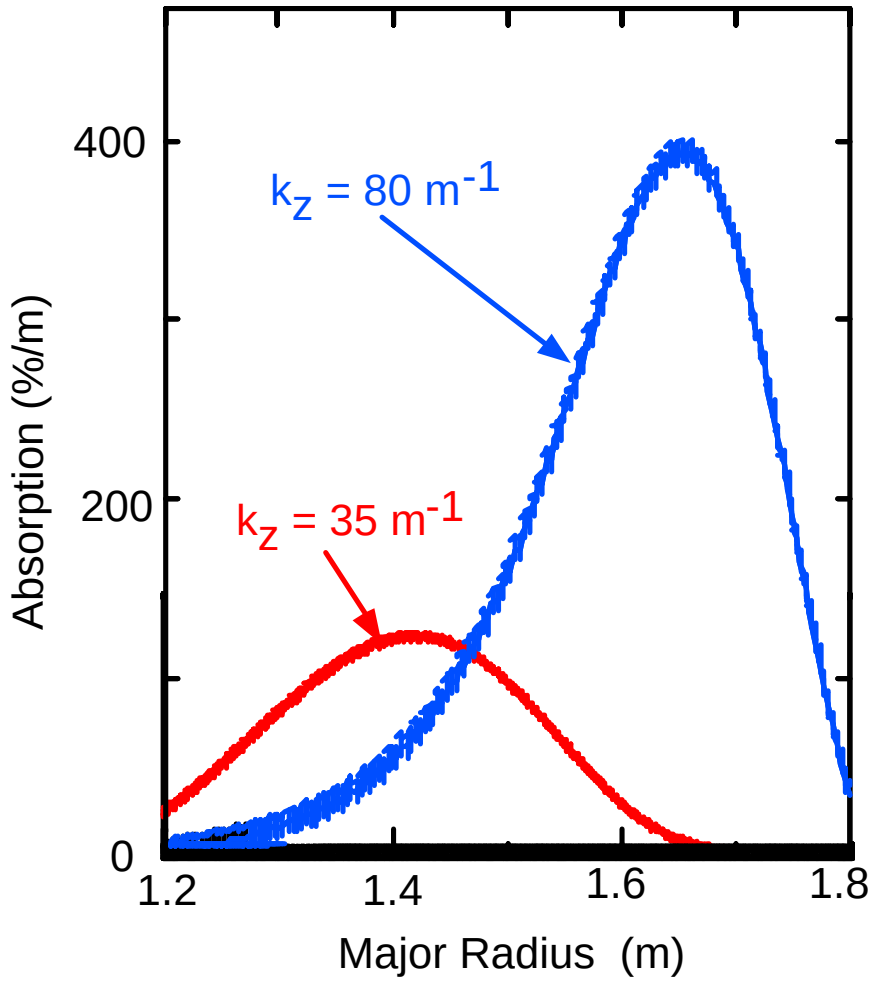



- Concern: Co-NBI produces large, peaked driven current
  May impede ability to make reactor-like broad current profiles and thus high $\beta$

- Will give shear control via core current-drive

- <u>RF Options</u>

- Started exploration of RF heating techniques to give profile control and decouple from driven rotation of NB




Damping/pass:
96%
33%

350MHz High Harmonic Fast-Wave appears promising
Good electron absorption, does not require inside launch

1D modeling indicates can control deposition profiles via $k_{||}$. Can phase to drive hollow current, if desired.

# Summary

- 0D modeling indicates $\beta$ = 4% should be accessible with available NBI, using 3D calculations of NB losses and neoclassical thermal transport

- 1D modeling of profiles using transport models has begun

- Strategies for developing profiles/equilibria for startup and robustness are underway

- Exploring heating & current drive options
  HHFW appears promising