QA Neutral Beam Heating Model

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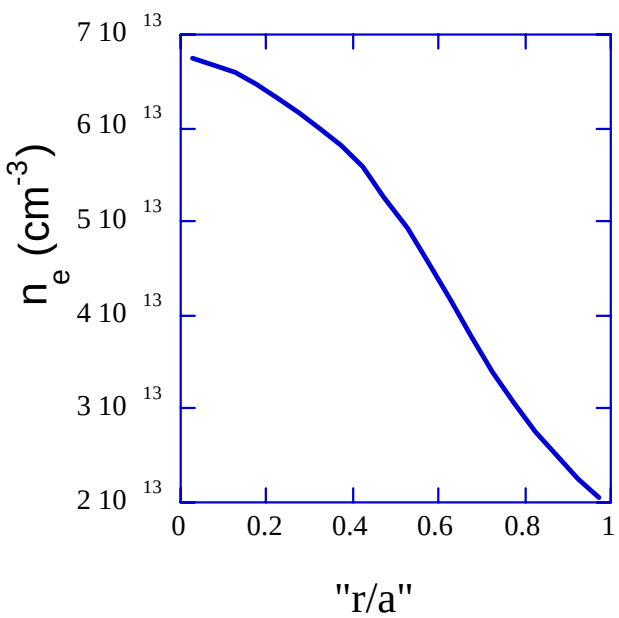
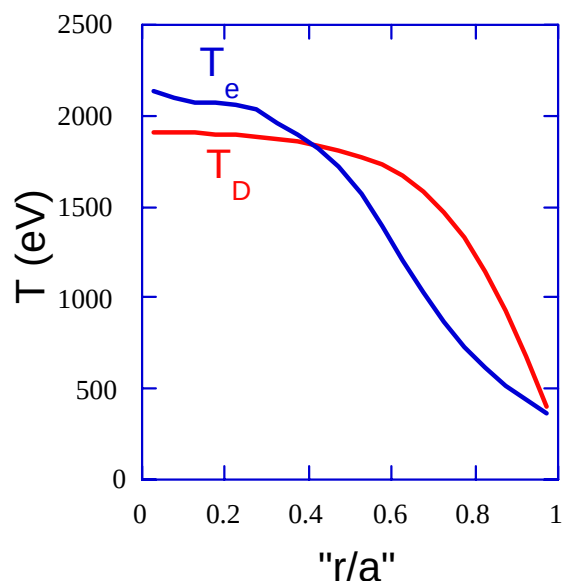
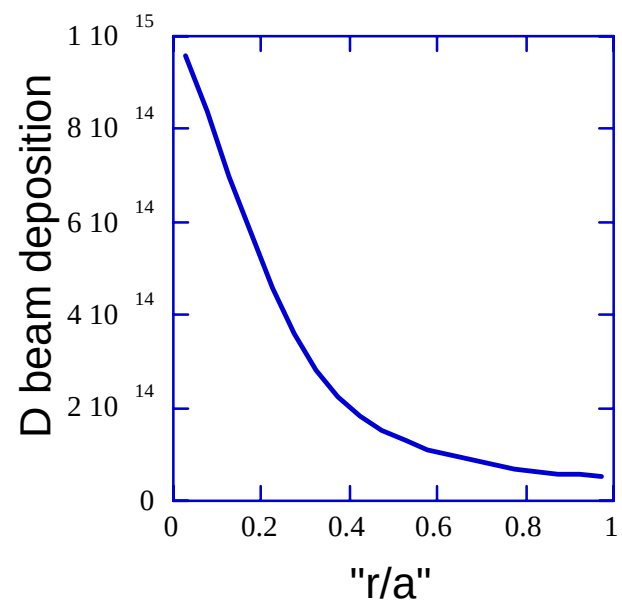
- Uses a prescribed beam ionization/deposition profile obtained from TRANSP for initial conditions
- Follows an ensemble of orbits through several slowing-down times and record:
  - time variation of average energy
  - energy losses through outer flux surface and loss patterns on outer surface
  - histograms of confinement time, energy, pitch angle of lost particles
- Future additions:
  - calculate beam-induced currents
  - more detailed analysis of lost orbit characteristics
  - Study orbits, relate to $J \approx \oint v_{\parallel} dl$
  - NBI heating efficiency dependence on plasma parameters

For the QA beam heating studies the following model and fixed set of profiles have been used:

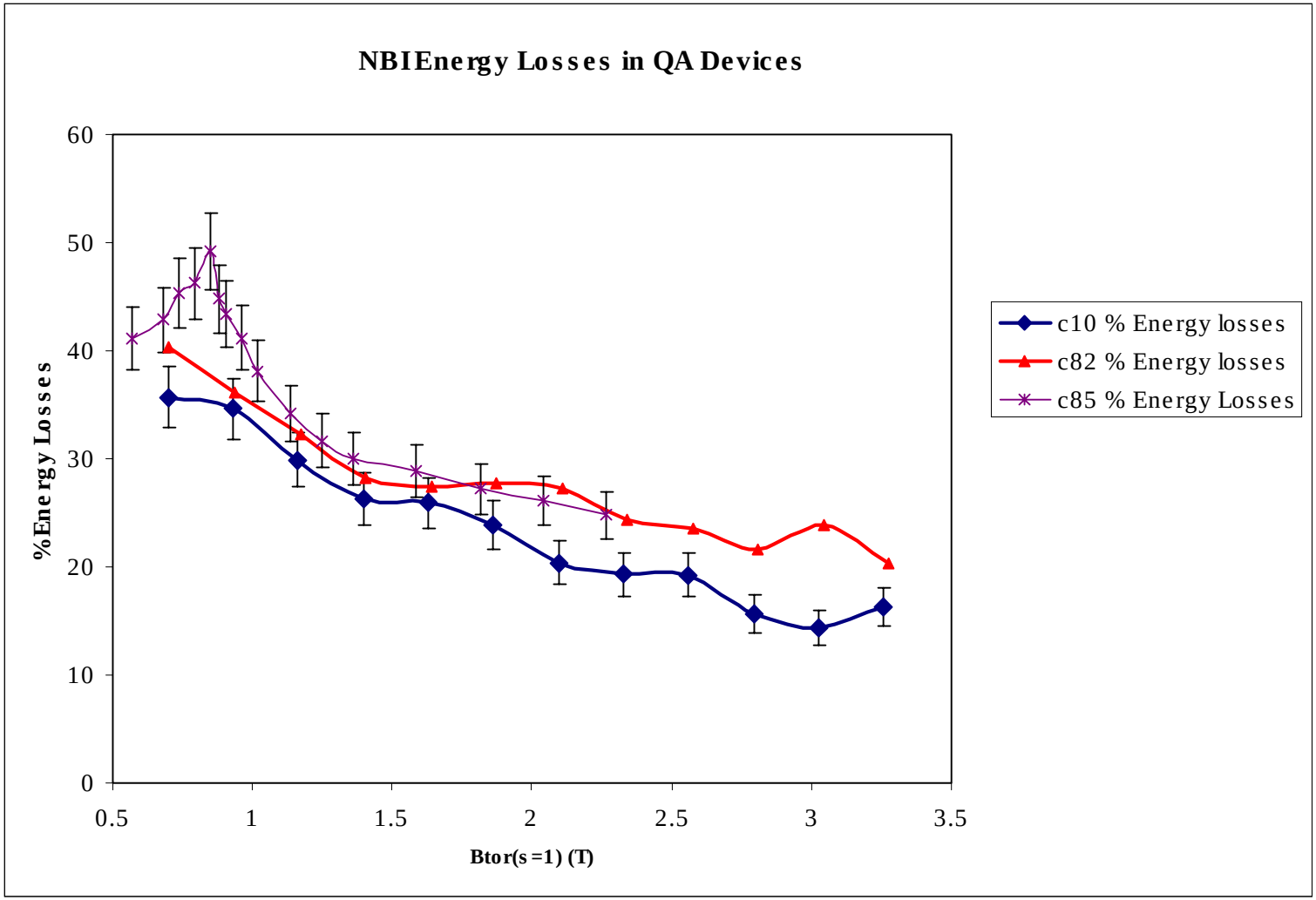
- Pencil beam - intersects flux surfaces at $\theta = 0$ plane
- Deposition profile from TRANSP
- Particles started at $\theta = 0$, $\zeta = 0$, with $v_{||}/v = R_{tan}/R$, $R_{tan} = 1.3$m
- Slowing-down followed for several τ_{sd} with beam-electron,-ion, and -impurity collisions ($Z_{eff} = 1.8$)
- Beam ions absorbed into plasma as they reach 3/2 kT_{ion}



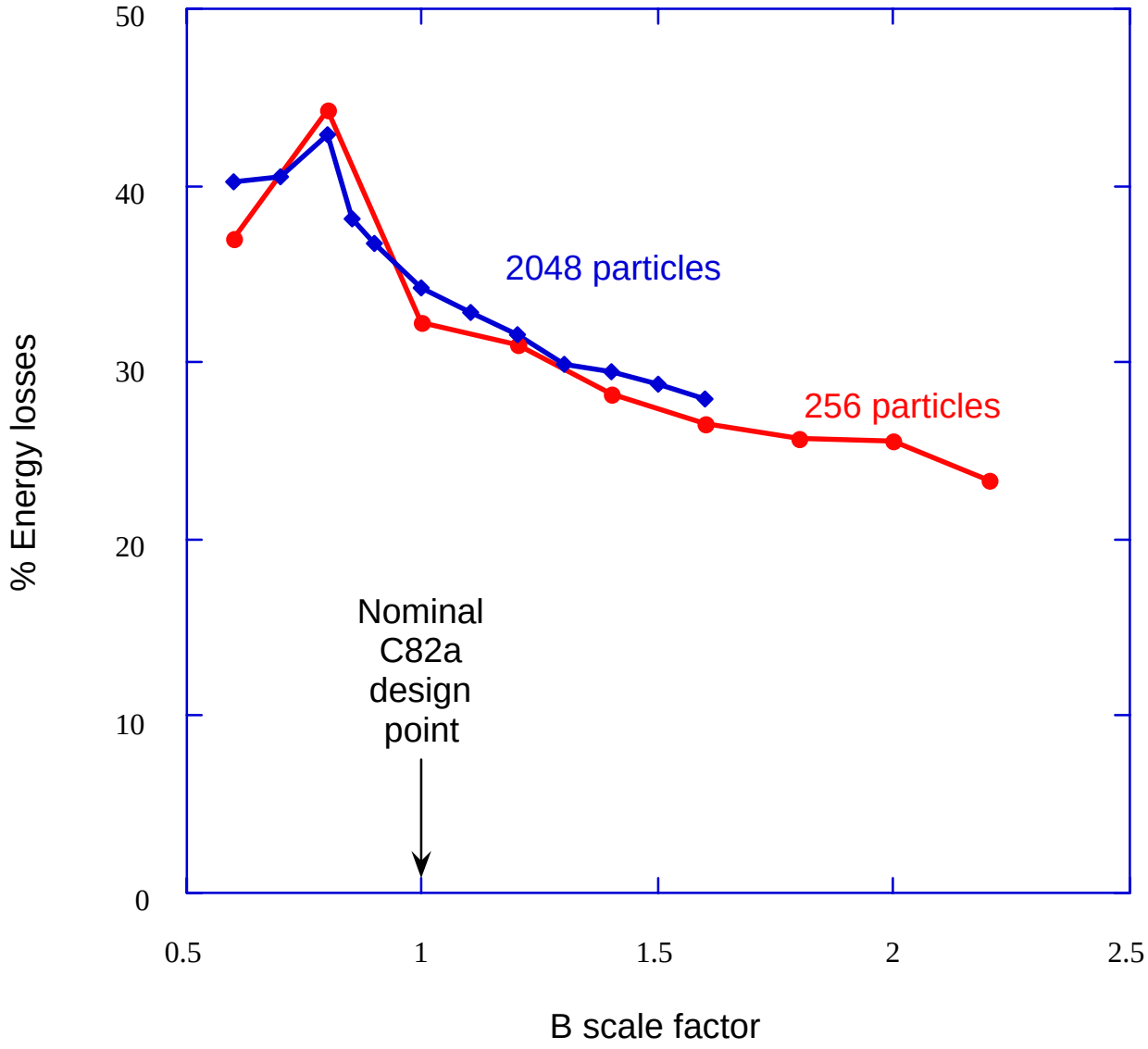


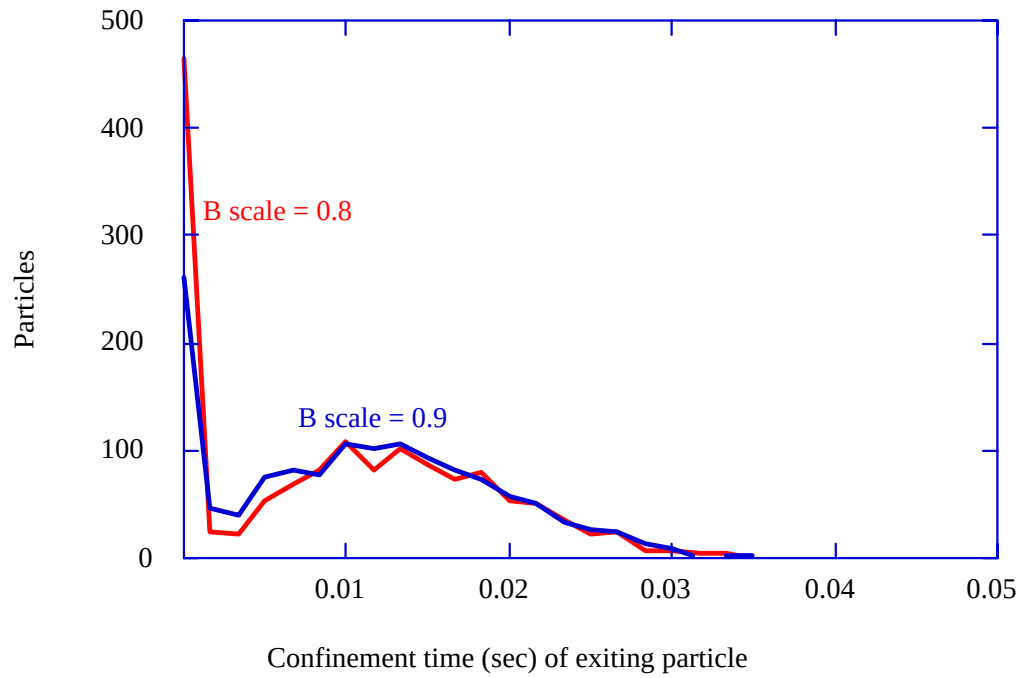


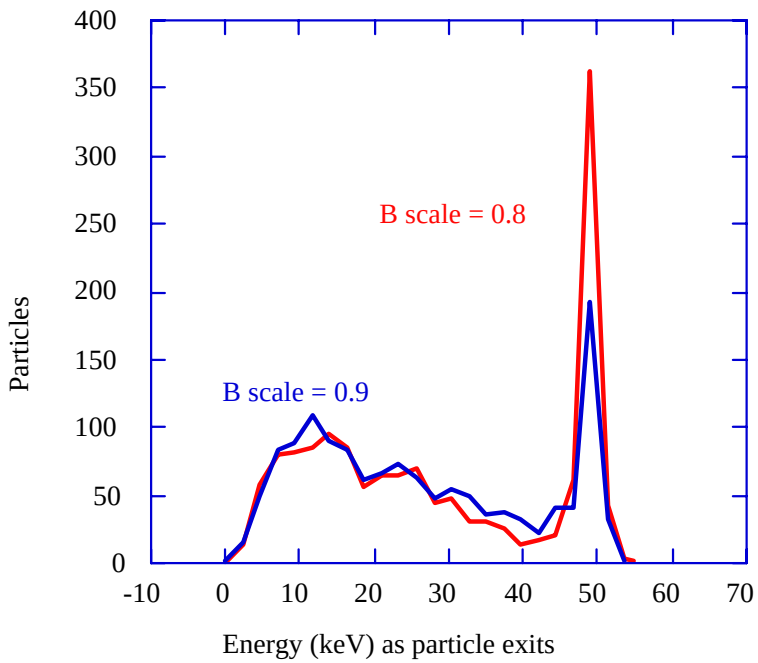
Neutral beam energy losses fall within a similar level for a range of QA devices

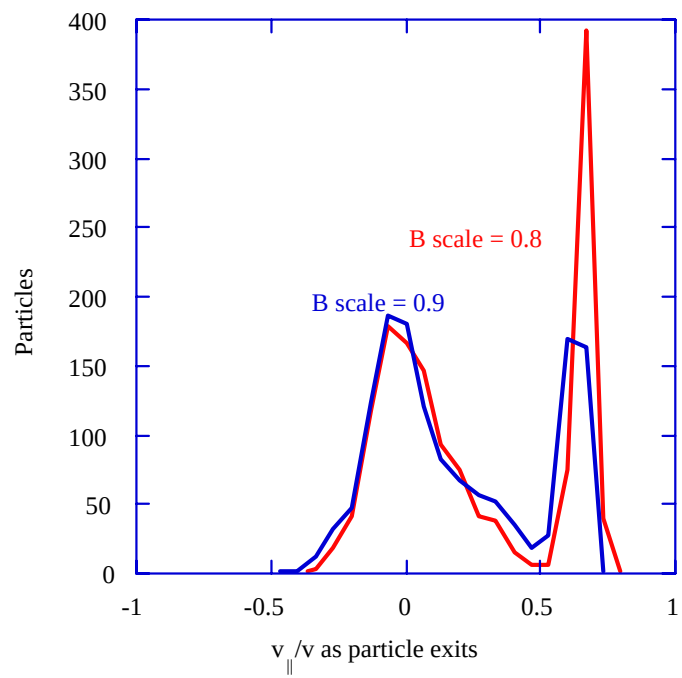


Convergence with respect to particle number of NBI losses in c82a at 50 keV injection energy

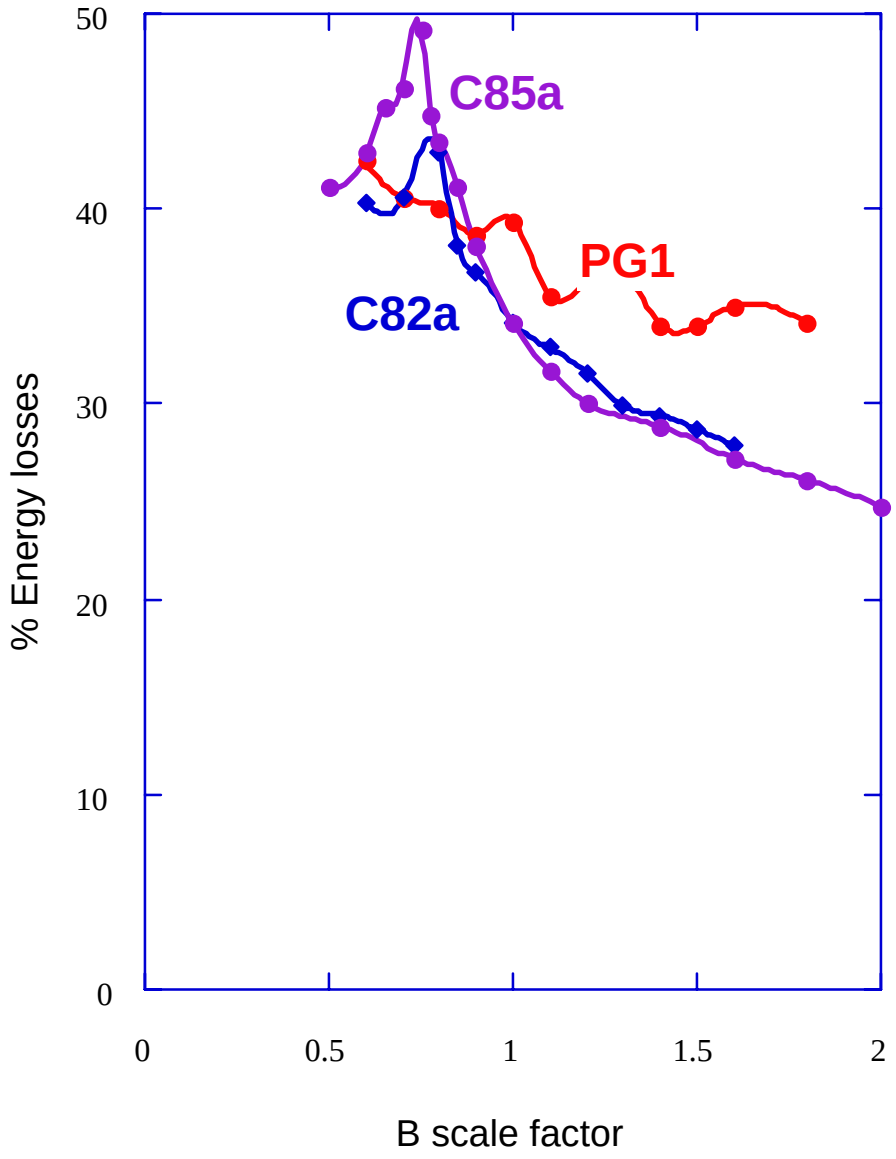


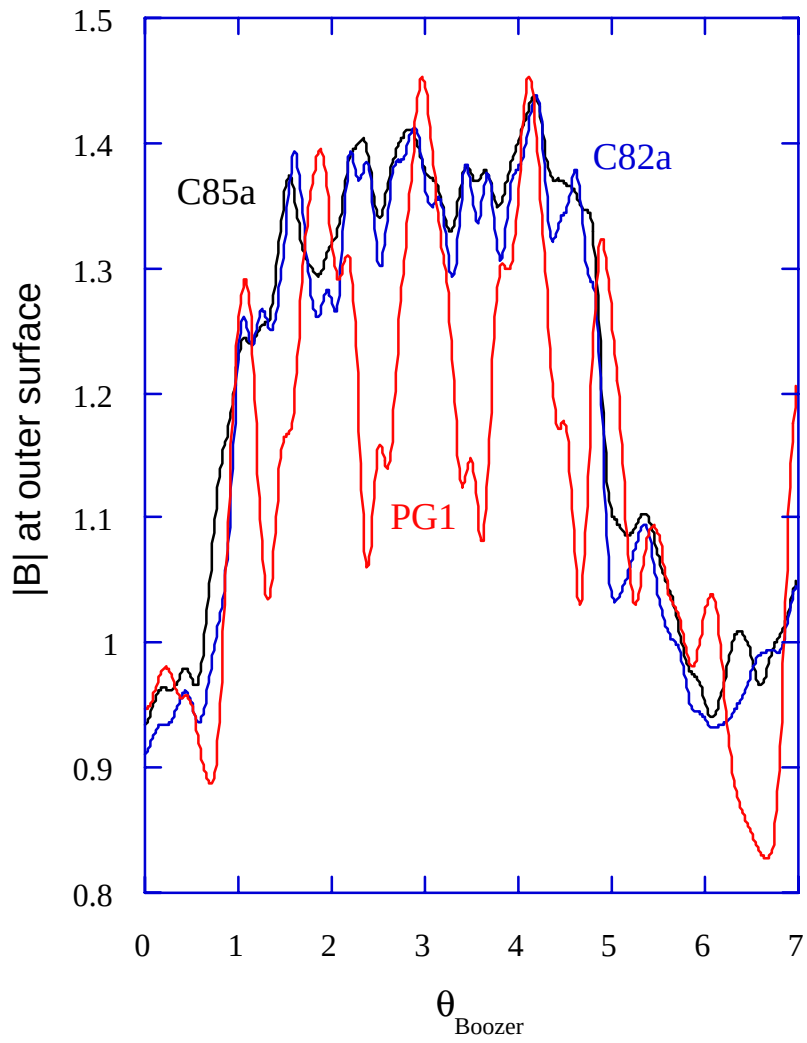

500
400
300
200
100
0
Particles
B scale = 0.8
B scale = 0.9
0.01
0.02
0.03
0.04
0.05
Confinement time (sec) of exiting particle


400
350
300
250
200
150
100
50
0
Particles
B scale = 0.8
B scale = 0.9
-10
0
10
20
30
40
50
60
70
Energy (keV) as particle exits

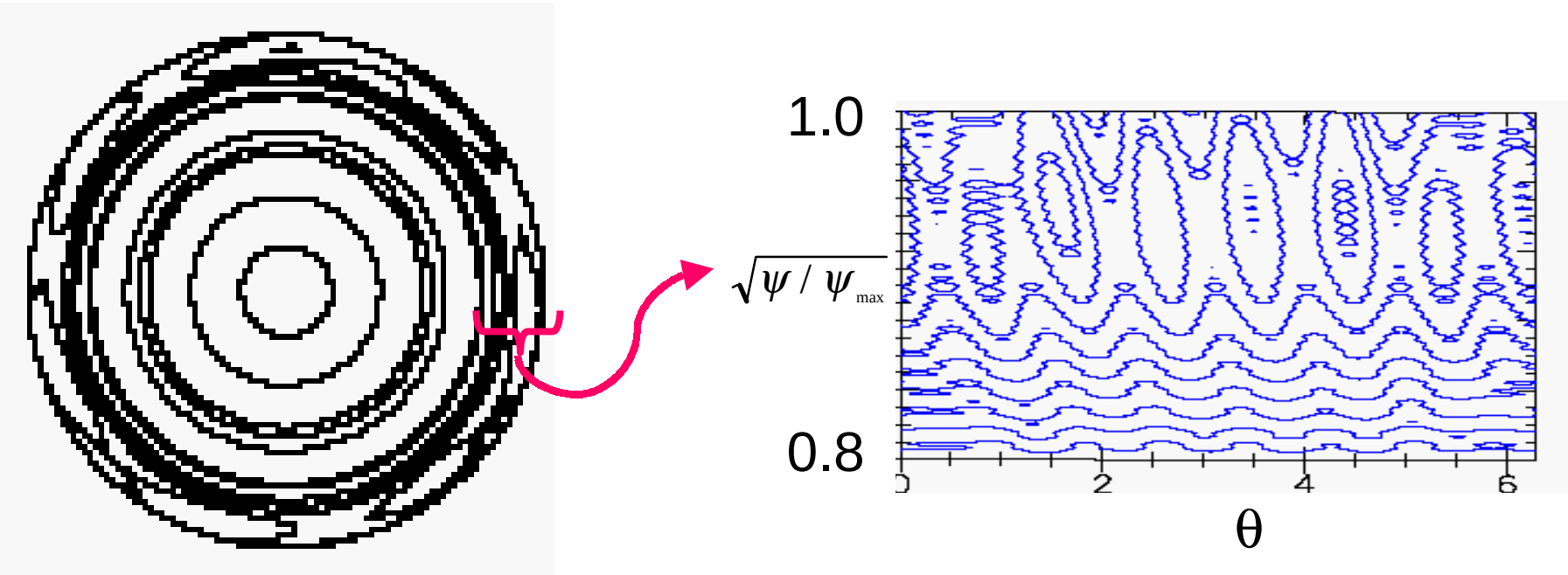

400
350
300
250
200
150
100
50
0
Particles
B scale = 0.8
B scale = 0.9
-1
-0.5
0
0.5
1
v ||/v as particle exits

Comparison of C82a, C85a and PG1Heating Efficiencies:





Preliminary calculations of $J \approx \oint v_{\parallel} dl$ contours for 5 - 50 keV barely passing particles in QA devices show loss regions at the plasma edge:



- Inclusion of J (in the plasma edge region) as an optimization target could lead to improvements in beam ion confinement

Conclusions

- A model has been developed for neutral beam heating efficiency in QA devices
  - follows an ensemble of particle orbits in the presence of collisions with a background plasma (ions, electrons, impurities)
  - Runs in parallel on the T3E for parameter scans and rapid turnaround
  - Uses TRANSP beam deposition model
- QA devices have beam energy losses in the 25 - 45% range
- Non-monotonic dependence on B may be caused by stochastic loss regions
- Initial results indicate that passing particle J (second adiabatic invariant)
  - may be useful for understanding edge loss regions
  - and as a possible new optimization target