NCSX Transport Studies

H.E. Mynick, PPPL

NCSX Project Meeting
PPPL, Sept. 23–25, 1998

o *Tools :*

o Monte–Carlo (MC) simulations:

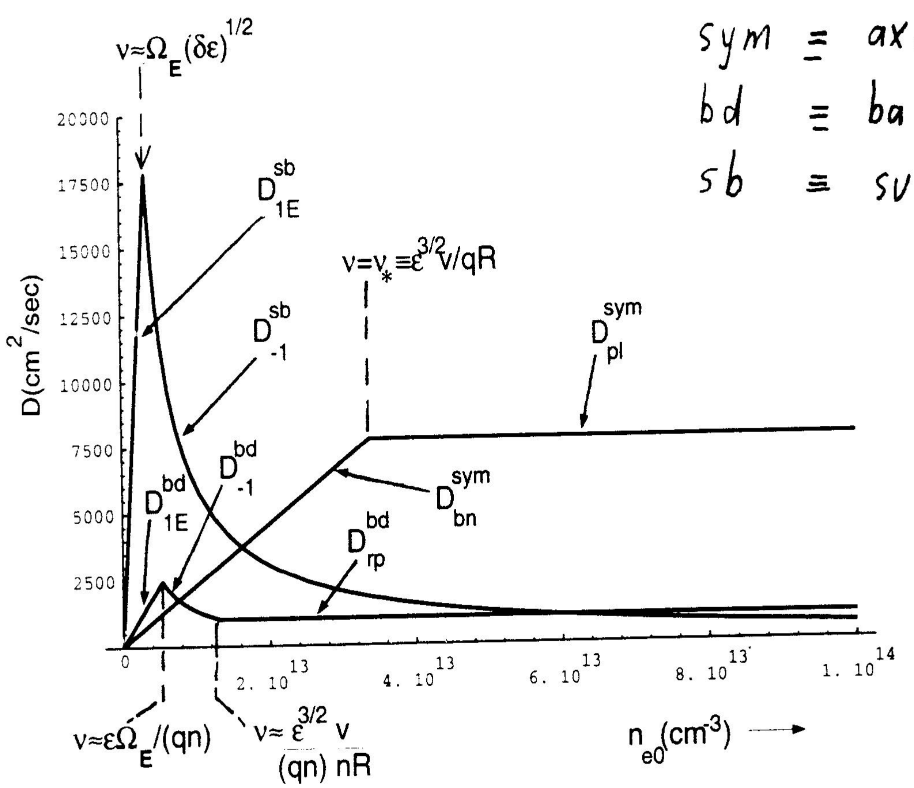
·Done with GC3, a guiding–center code in Boozer coordinates (r or $\psi_t = B_0 r^2/2, \theta, \zeta$), using some number N_h of largest–amplitude harmonics (typically, $N_h = 10$) with decomposition $B = \sum_{m,n} B_{mn}(r) \cos(n\zeta - m\theta)$.

·Fields from VMEC equilibrium, mapped to Boozer coordinates using JMC.

·Monoenergetic ensembles taken with 352 particles with kinetic energy $K = 2T$, evenly distributed in pitch $v_{\|}/v, \theta$, and ζ. Lorentz collision operator assumed.

o Analytic Theory: *Transport 'branches' :*

sym ≡ axisymmetric
bd ≡ banana drift
sb ≡ superbanana



oQA configurations considered here:

PBX–sized ($R = 1.5$ m):

1. $A \equiv R/\bar{a} \simeq 2.1$, $T_0 = 3.5$ keV, $B = 1.4$ T :

1.a. QAS2a: ($N_p = 2$, $\bar{a} = .67$ m, $\iota_{ext}/\iota = 20\%$)

1.b. QAS8: ($N_p = 8$, $\bar{a} = .70$ m, $\iota_{ext}/\iota = 54\%$).

1.c. QAS4a: ($N_p = 4$, $\bar{a} = .71$ m, $\iota_{ext}/\iota = 50\%$)

1.d. QAS2b: ($N_p = 2$, $\bar{a} = .67$ m, $\iota_{ext}/\iota = 40\%$)

1.e. QAS4b: ($N_p = 4$, $\bar{a} = .72$ m, $\iota_{ext}/\iota = 50\%$)

1.f. QAS4c: ($N_p = 4$, $\bar{a} = .71$ m)

2. $A \simeq 3.4$, $T_0 = 1.3$ keV, $B = 1.0$ T :

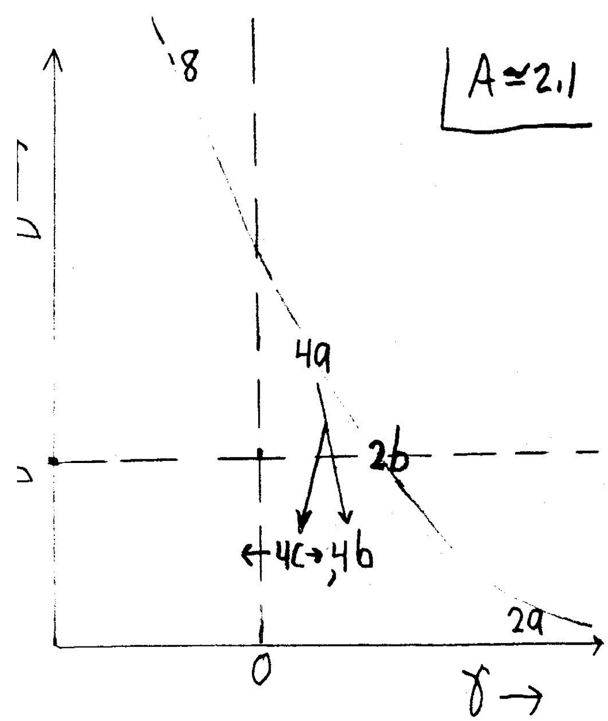
2.a. QAS3a: ($N_p = 3$, $\bar{a} = .44$ m)

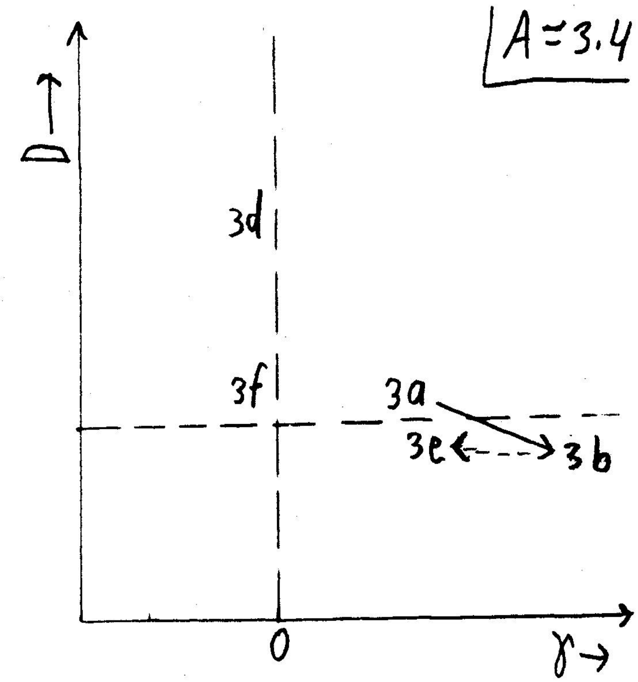
2.b. QAS3b: ($N_p = 3$, $\bar{a} = .44$ m)

2.c. QAS3d: ($N_p = 3$, $\bar{a} = .47$ m)

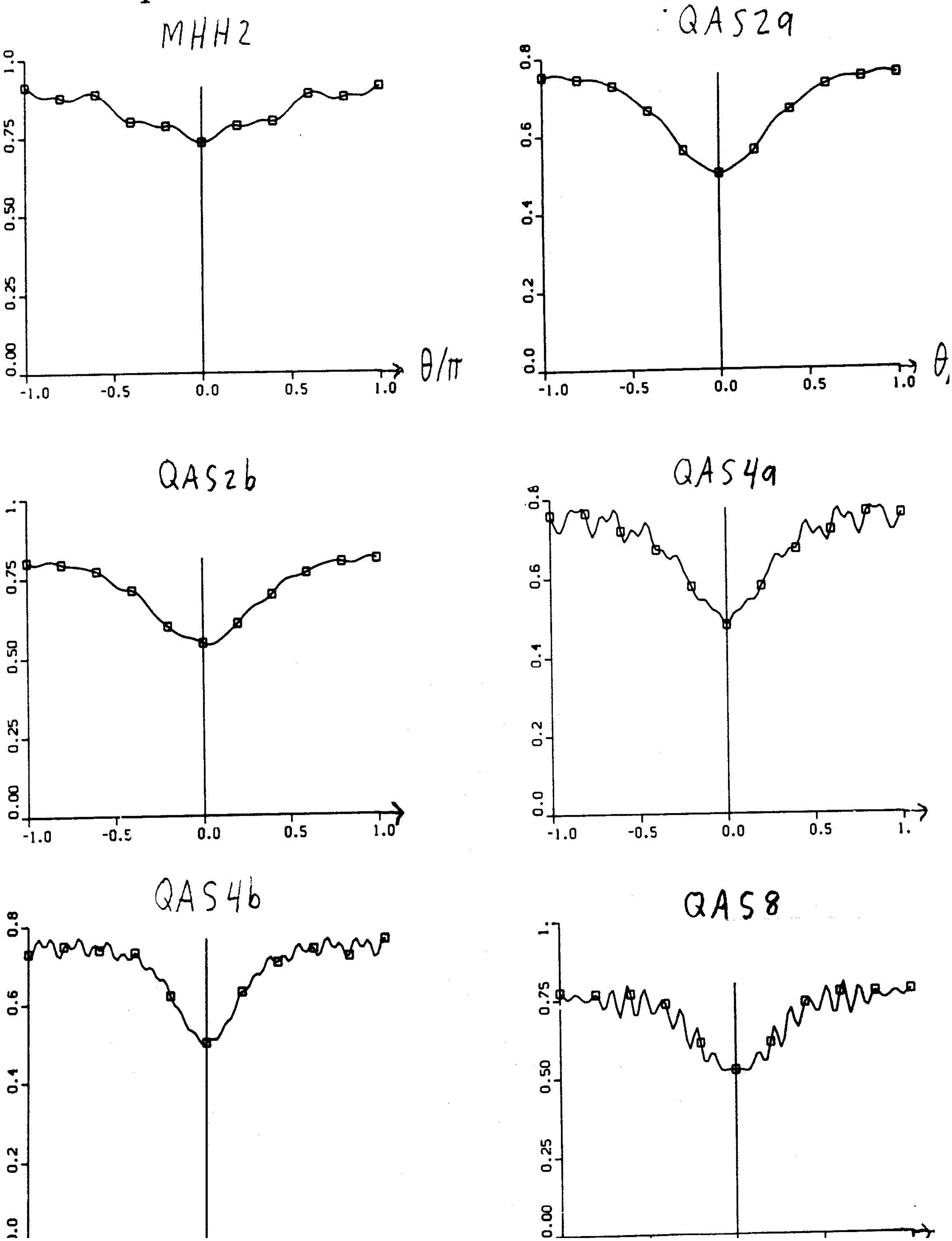
2.d. QAS3e: ($N_p = 3$, $\bar{a} = .45$ m)

2.f. QAS3f: ($N_p = 3$, $\bar{a} = .44$ m)





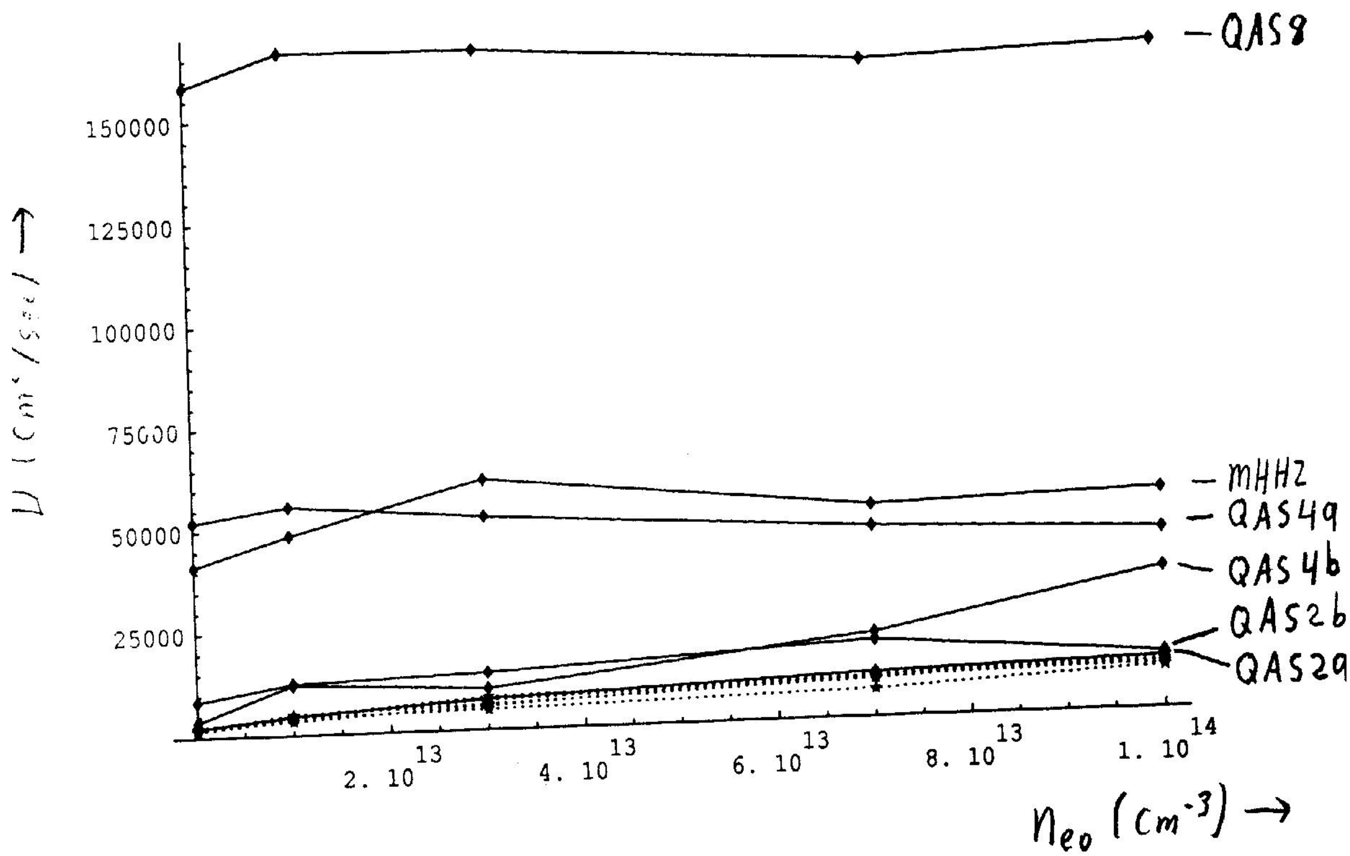
$\circ A = 2.1$ machines.
Compare configurations studied: $B(s_{\parallel} \mid \frac{r}{a} = \frac{1}{\sqrt{2}})$;



oTransport Results:

Qualitatively what one would expect from the $B(s_{\|})$ profiles:

·Numerical: Monoenergetic ensembles, $E_r = 0$:



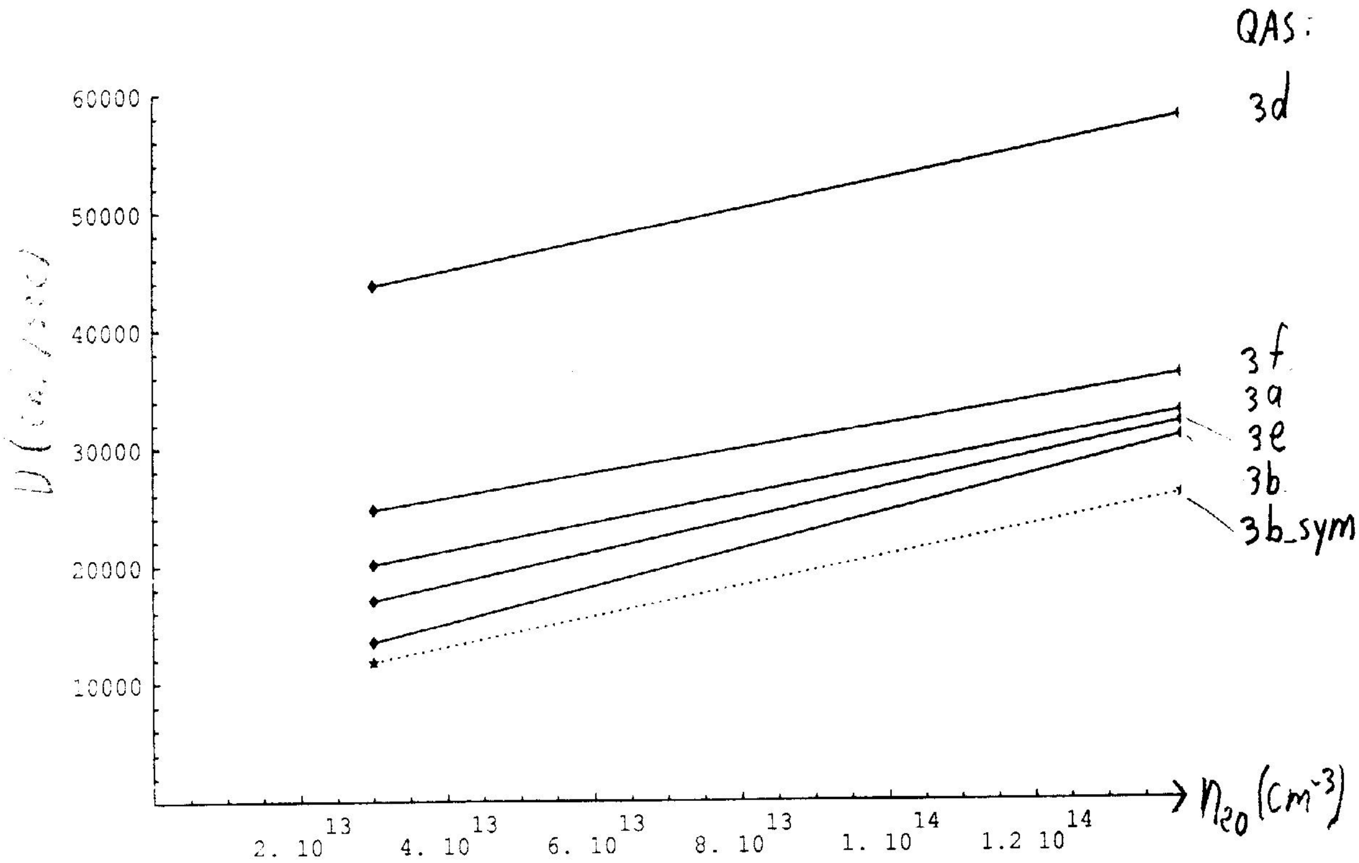
Transport Results, cont:

Analytical: Maxwellian averaged, ambipolar E_r:

$\tau_E^{ISS} \simeq 16$ msec

	τ_{Ee}^{anl}	τ_{Ei}^{anl}	τ_{Ei}^{anl} (sym)
MHH2	3.5	18	130
QAS2a	70	145	146
QAS2b	12.5	22.7	164
QAS4a	4.6	9.9	125
QAS4b	49	45	88
QAS8	3.1	7.5	126

○Transport Results–2: $(A = 3.4)$



Transport Results–2, cont:

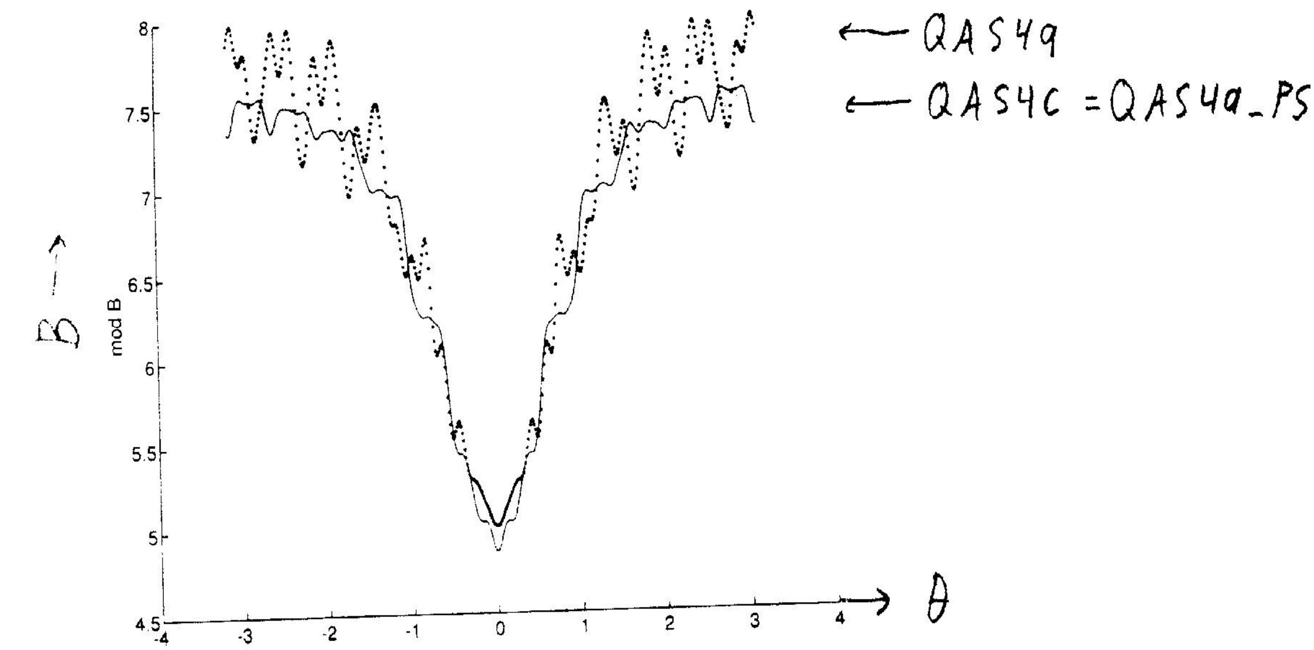
$\tau_E^{ISS} \simeq 11$ msec

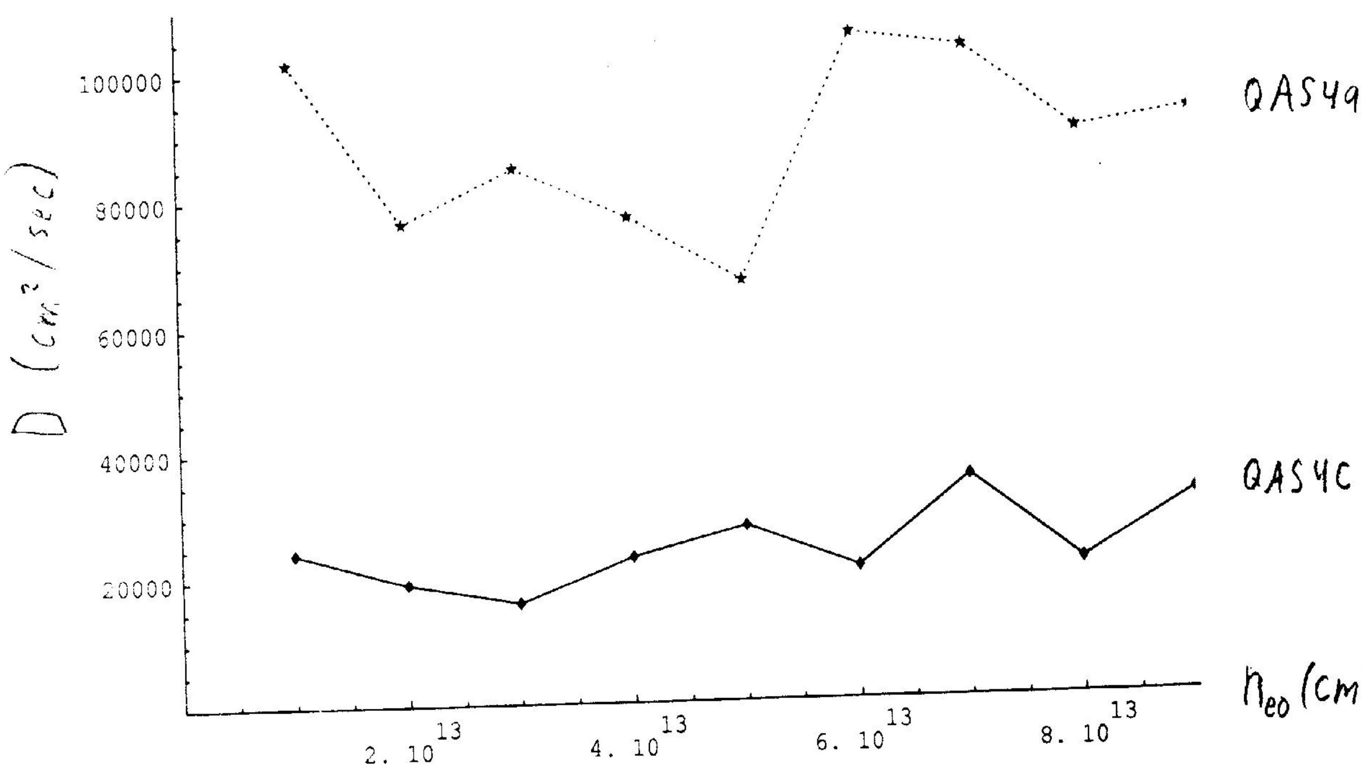
	τ_{Ei}^{anl}
QAS3a	9.4
QAS3d	5.3
QAS3f	8.6

oPseudosymmetry:

(Mikhailov,Shafranov,Subbotin,Isaev):

Remove ripple wells: Somewhat different ripple criterion from the 'Quasisymmetric' one we've used.

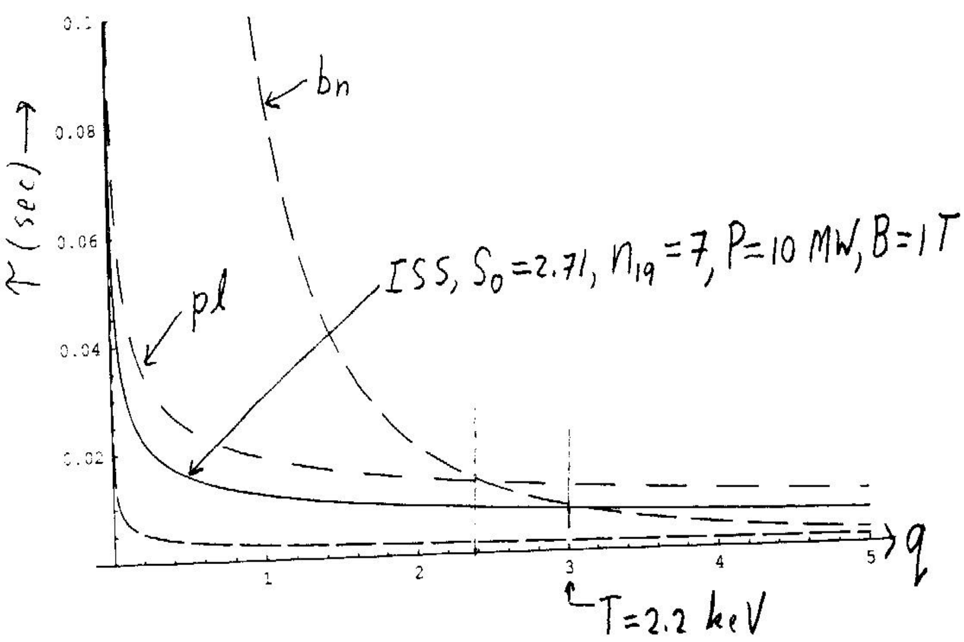




∘Lower bounds on ι:

·Since $\rho_b \sim q\rho_g$, $\iota \equiv 1/q$ cannot become too small:

·Constraint from thermal neoclassical transport:
Since $\tau_{ISS}, \tau_{pl} \sim q^{-.4}$, but $\tau_{bn} \sim q^{-4}$, as $\iota = 1/q$ drops one quickly moves from the banana to the plateau regime, where getting an appreciable J_{bs} and a large margin τ_{pl}/τ_{ISS} are difficult:
⇒For QAS3, $B = 1$ T, $P = 10$ MW, need $\iota \geq 1/2.4 \simeq .42$ to remain in banana regime:



·Beam–particle constraint (Zarnstorff, Boozer):
For 40 keV neutral beams, $B = 1$ T, $\bar{a} = .4$ m, need $\iota \geq .46$ for ρ_b(passing) ≤ 4.

oSummary:

- The neoclassical transport in 2 series of QA stellarators has been examined, having $A \simeq 2.1$ and 3.4.

- Roughly, there is a tradeoff between good confinement and good stability characteristics. The configurations closest to being adequate for both confinement and stability so far are QAS4b for $A = 2.1$ and QAS3f for $A = 3.4$.

- New means have been found which may help move to the desired quadrant in the (γ, D)–diagram:
  ·Pseudosymmetrization. (Remains to be seen how interacts with stability characteristics.)

  ·Incorporation of kink stability calculation into the optimizer. Find can stabilize kink without large shear.
  ·'Corrugation' of fields.

  ·SVD method for realizing coils for desired fields.