NCSX TRANSPORT OPTIMIZATION: THE NEO CODE FOR 1/ν TRANSPORT AND BENCHMARKS WITH GTC, DKES, ORBIT3D, AND MEASURES OF FIELD ASYMMETRY

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OUTLINE

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III. Comparisons: NEO vs. GTC, DKES, etc
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I. Introduction

- Control of stellarator particle confinement depends on sufficient edge poloidal flux (as in tokamaks) on reduced collisionless ``ripple loss''.

- Figures 1 and 2 show stellarator thermal diffusion coefficients and energetic particle loss has no dependence on edge poloidal flux.
  Equivalent tokamak confinement does improve with edge poloidal flux: axisymmetric transport.

- Design optimizer needs rapid calculation of useful figures of merit for stability, beta, transport.
  Present design has high particle transport.

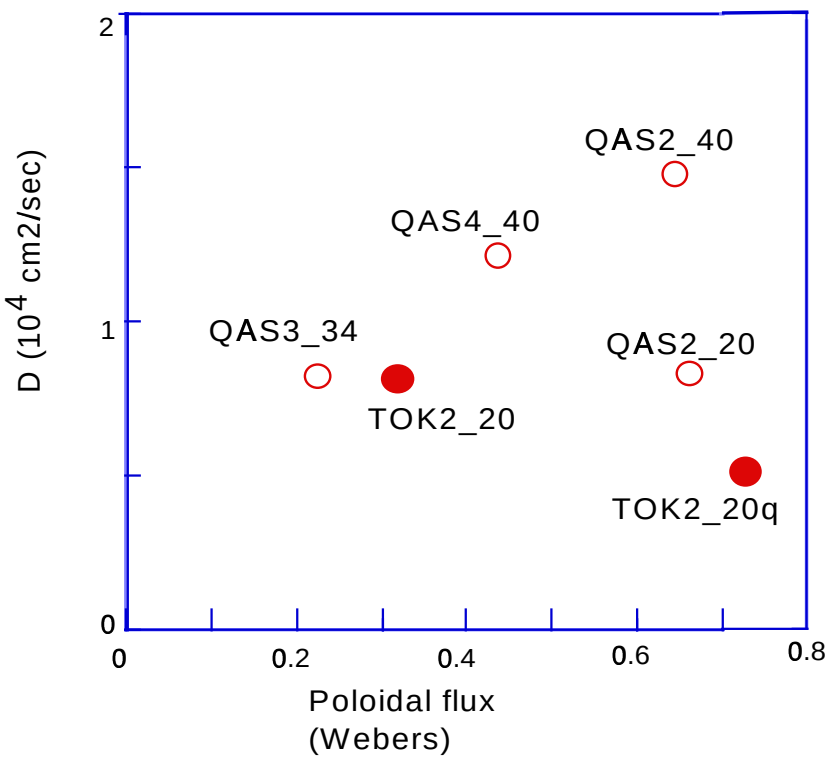
- What is the best figure of merit to use in the optimizer?

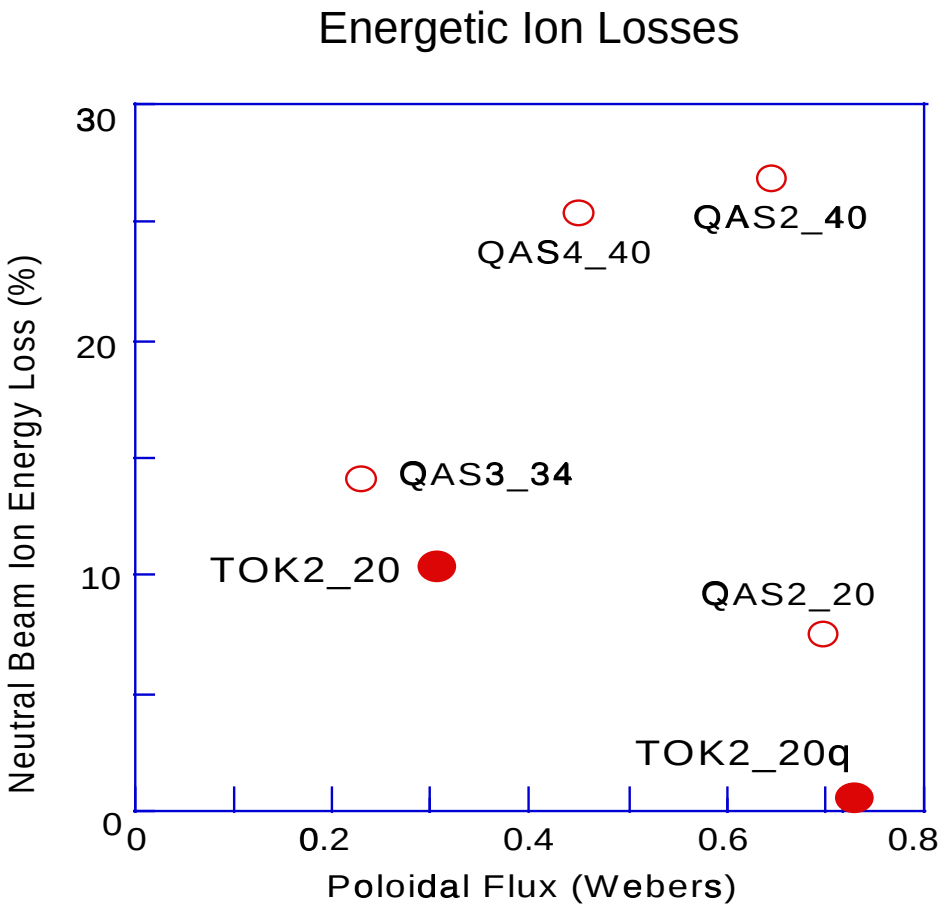
- To target "ripple loss" directly, have used "water" and $\chi^2 = \Sigma B_{mn}^2$, for $n \neq 0$, normalized by B_{oo}^2.
  B_{mn}^{max} / B_{00} does not correlate well with transport, "water" shows some correlation (Fig. 3 and 4).

- ORBIT3D, GTC accurate, but take ~ hours/case

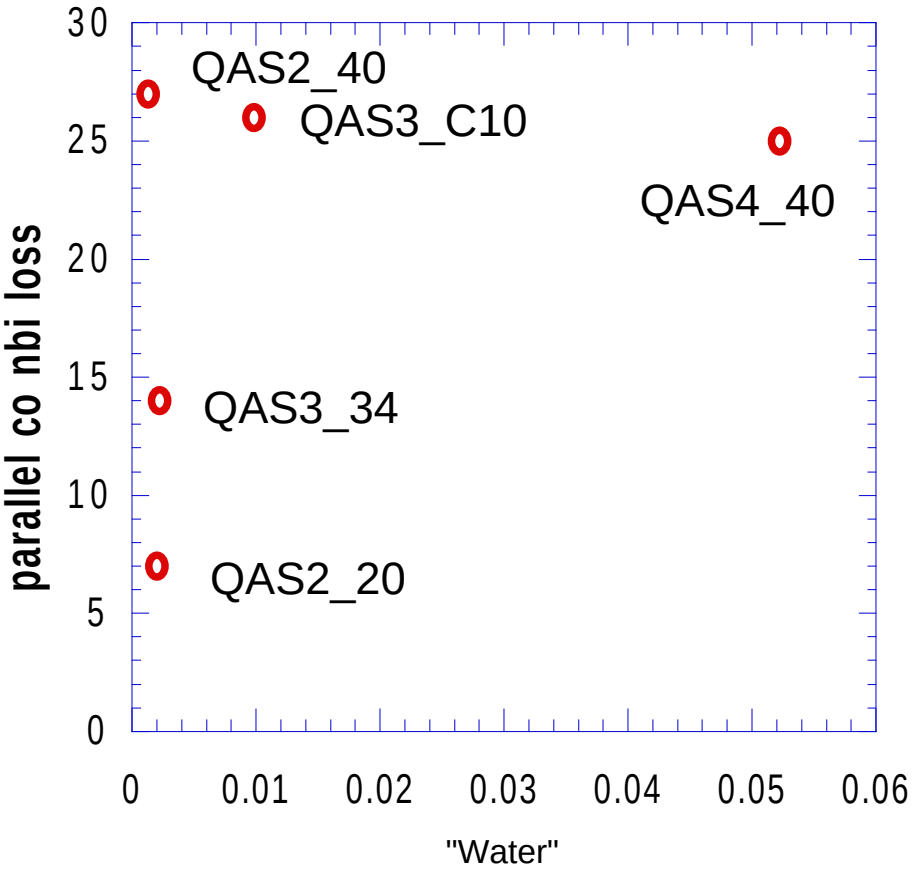
- NEO code calculates $1/\nu$ transport rapidly, looks promising. Comparison with fast and slow methods follows.

Thermal Ion Diffusion Coeffiecients

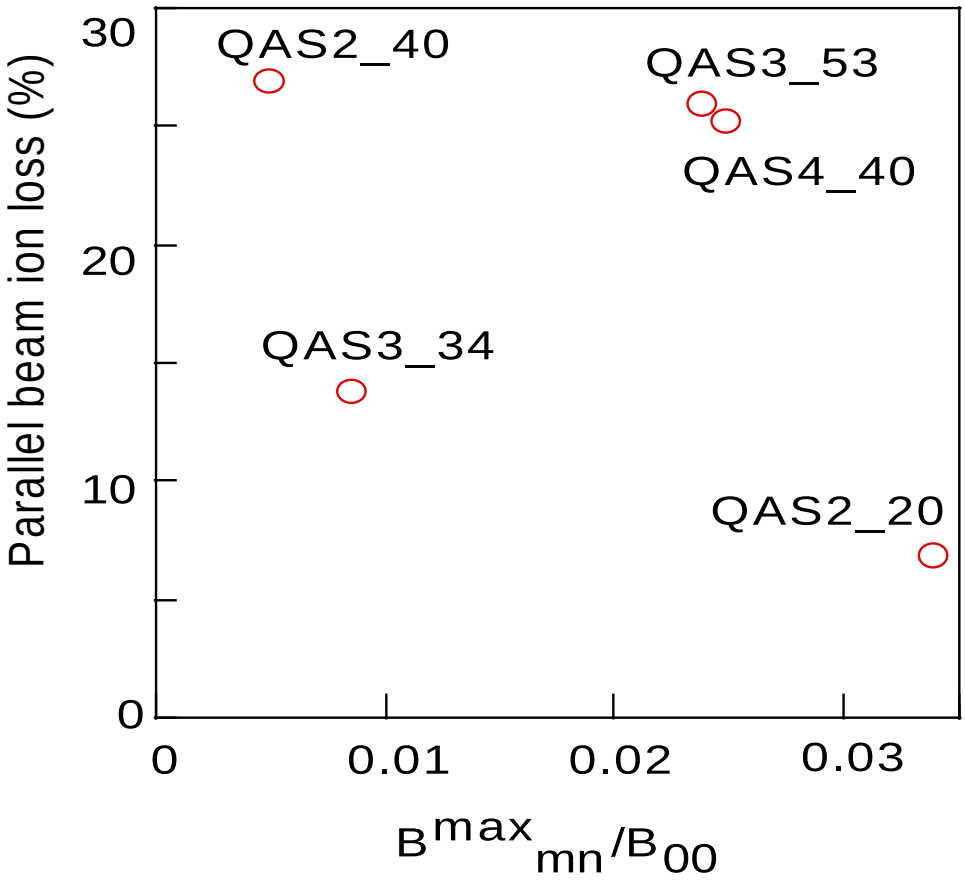



Energetic Ion Losses
Neutral Beam Ion Energy Loss (%)
30
20
10
0
0
0.2
0.4
0.6
0.8
Poloidal Flux (Webers)
QAS2_40
QAS4_40
QAS3_34
TOK2_20
QAS2_20
TOK2_20q

"Water" Shows Correlation with High Beam Ion Loss



Not Good Correlation of Beam Ion Loss with Bmax(mn)/B(00)



II. NEO Code

- NEO estimates trapped particle, non-axisymmetric transport, calculates an effective ripple $\varepsilon^{1.5}$, ~ particle flux density crossing a surface.

- V. V. Nemov, S. V. Kasilov, W. Kernbichler, M. F. Heyn, Phys. Plas. 6, 4622 (1999); also EPS and ISW 1999 conferences.

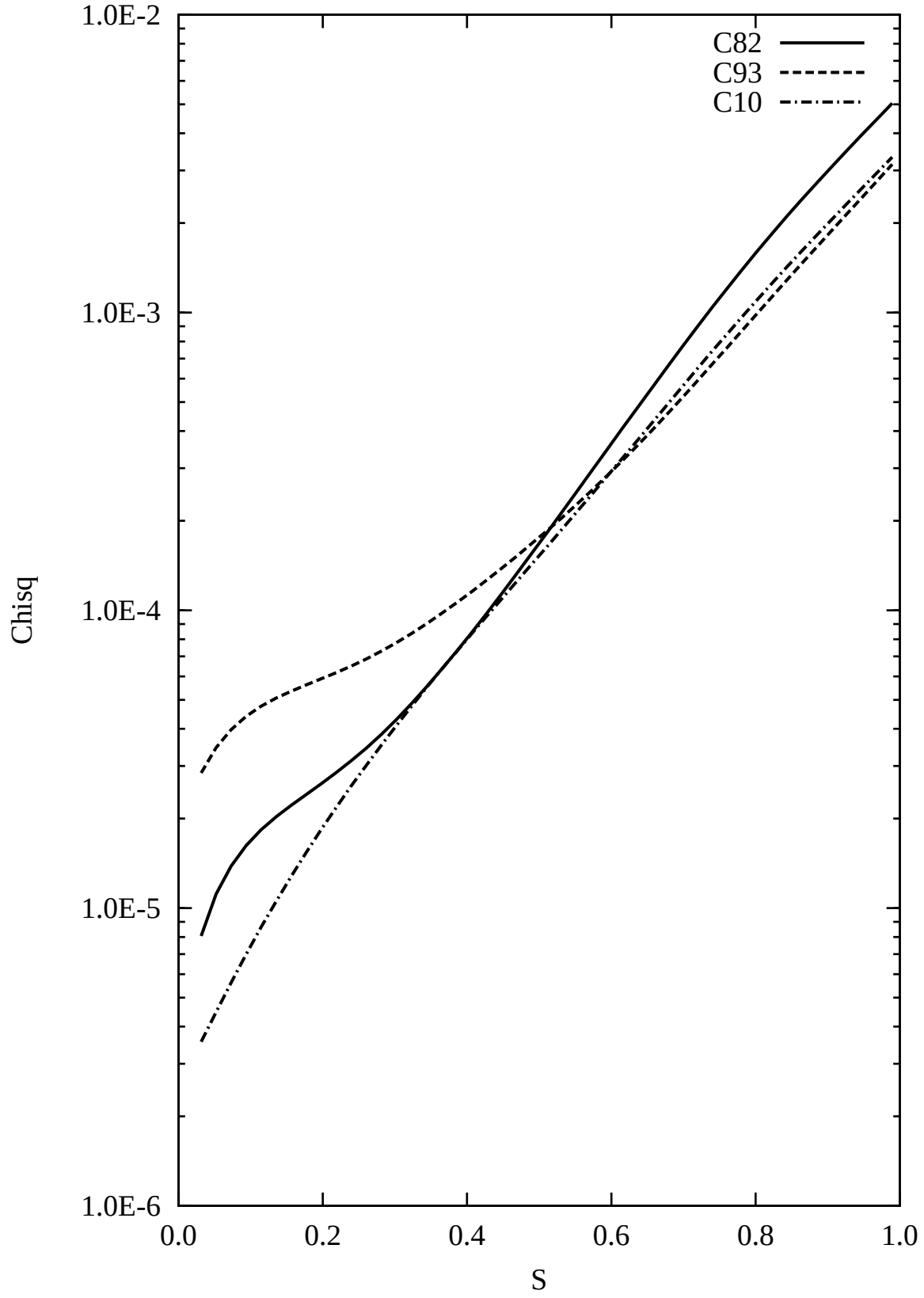
- The code was written by W. Kernbichler and S. Nemov.

- Source code has been run on PPPL MARS DEC alpha. Identical results to those from Graz in December, 1999. Roughly 30 seconds per flux surface on a DEC alpha.

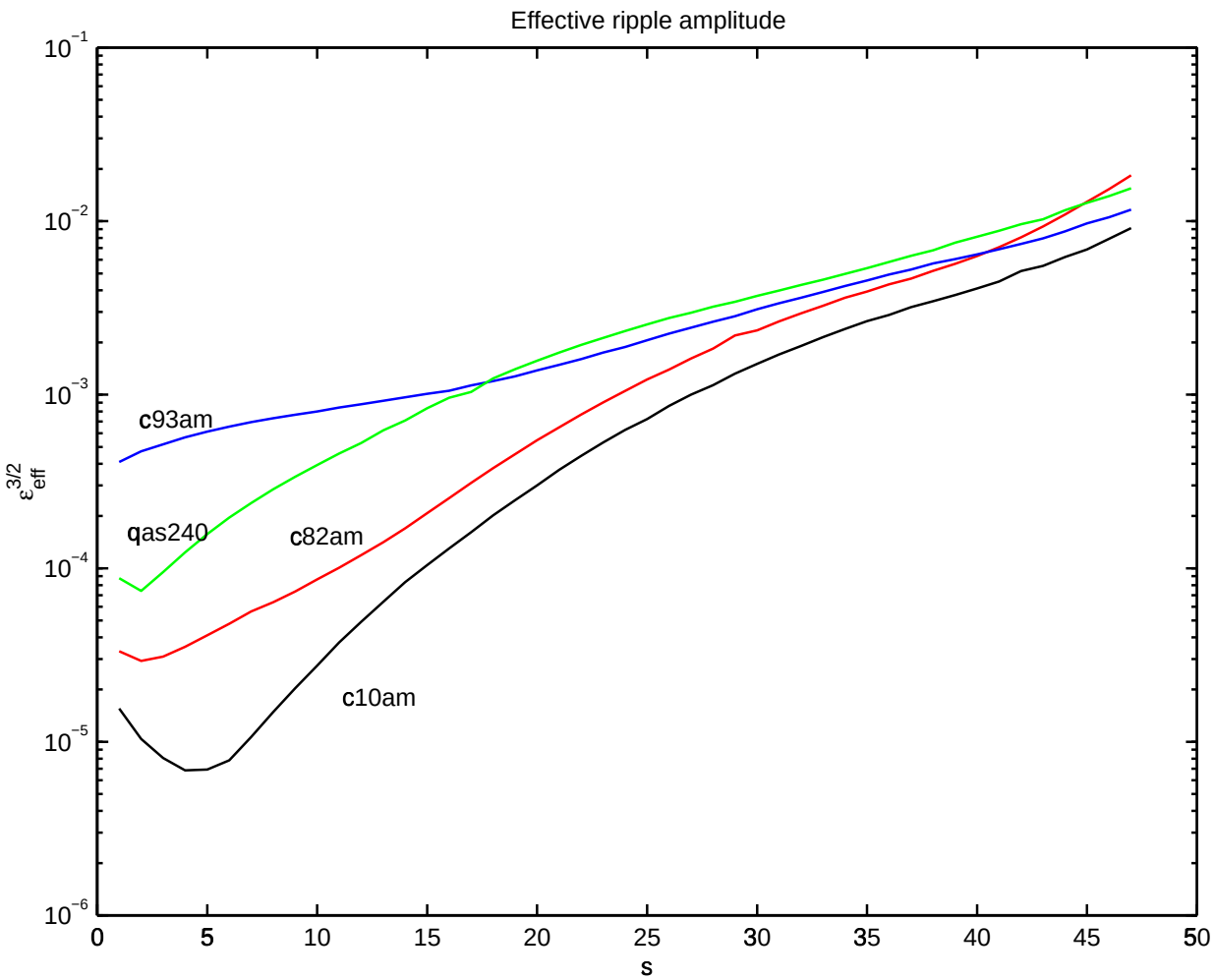
- Sample NEO results:

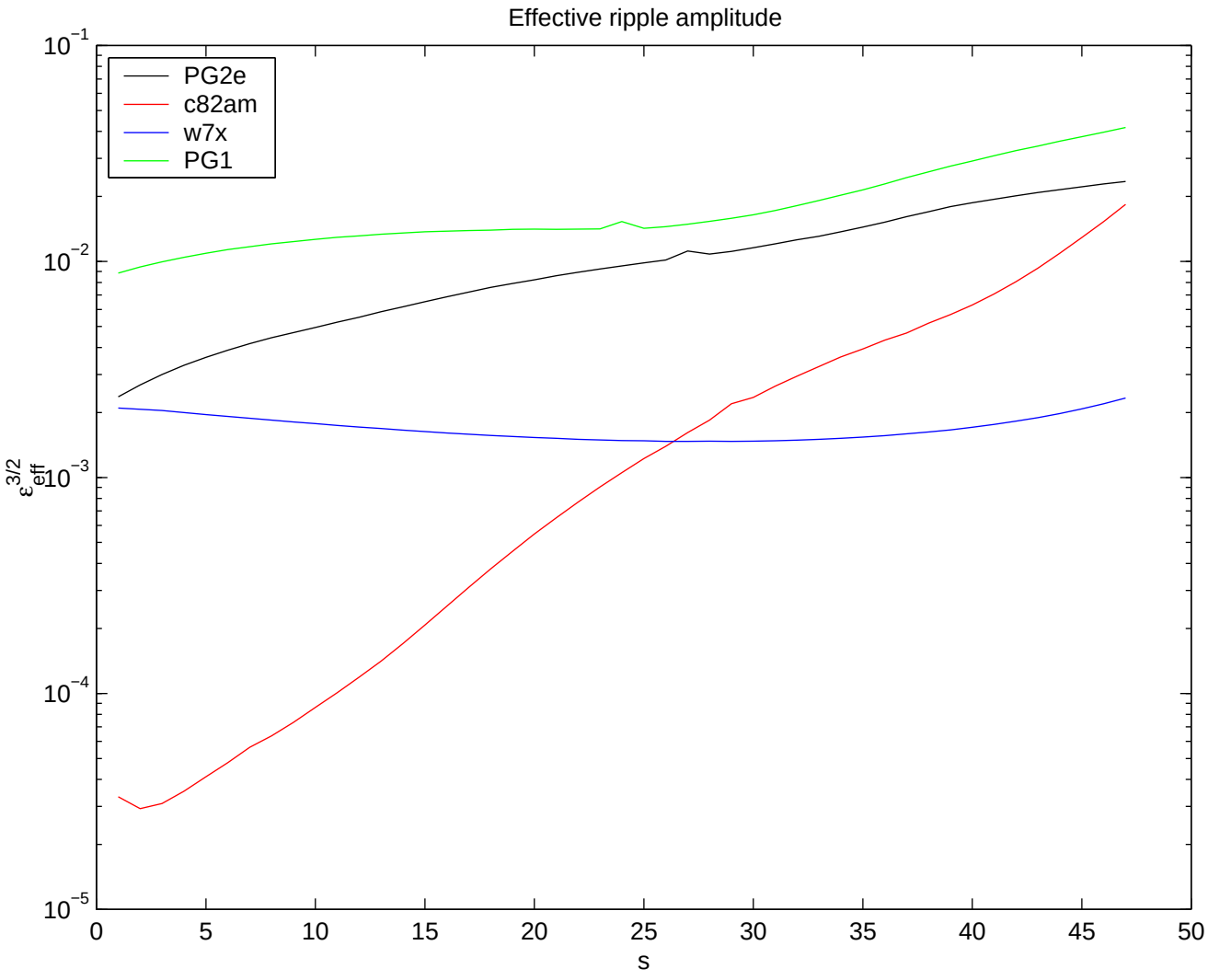
Figures 5 and 6 show χ^2, NEO comparisons; Similar radial behavior. Crossing points differ.

Figure 7 shows NEO results for PG and W7X cases. Good W7X transport evident.


1.0E-2
1.0E-3
1.0E-4
1.0E-5
1.0E-6
Chisq
0.0
0.2
0.4
0.6
0.8
1.0
S
C82
C93
C10

NEO calculations of effective ripple on log plot




Effective ripple amplitude
PG2e
c82am
w7x
PG1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
$\varepsilon_{eff}^{3/2}$
0
5
10
15
20
25
30
35
40
45
50
s

III. Comparison of NEO and GTC, etc.

Comparison of Four Three-field-period Cases:
QASC10, QASC93, QASC82, QASI63.

- Tables: data from Figs 5-6 at plasma edge, GTC and DKES results (Ku), χ_J^2 from 1/11/00 Project Meeting (Spong) and results of ORBIT3D (Redi, Zatz).
  - Table I shows code results.
  - Table II results normalized to C82 for each method.

  - GTC is an enhanced, parallelized Monte Carlo code calculates the global flux, confinement time; f method. (Z. Lin, et al. Phys. Plas. in press)

  - DKES calculates the flux solving for the distribution function on one flux surface. (S. P. Hirshman, et al., Phys. Fluids 29 (1986) 29-51). GTC and DKES include electric field. Results for two values of ν/v.

- χ_J^2 is a measure of the adiabatic invariant $J = \int v_{//} dl$ is the deviation of J within a flux surface, only for trapped particles, does not include the effects of electric fields. χ_J^2 weights the whole volume equally.

- ORBIT3D Monte Carlo code that follows particles, with or without the collisional pitch angle scattering. Energetic alphas, in a size-scaled reactor. (White Chance, Phys. Fluids 27 (1984) 2455.

Table I	C10	C93	C82	I63
GTC Flux	0.9	0.95	1.0	
χ^2	0.0032	0.0031	0.005	
NEO $\varepsilon^{1.5}$	0.009	0.012	0.002	0.05
χ_J^2	2550	3100	1850	
DKES, s=0.5, ν/v=0.0001	0.87	0.95	1.0	
DKES, s=0.5, ν/v=0.001	1.0	1.20	0.97	
ORBIT3D Eloss collisional	36%		36%	36%
ORBIT3D Eloss collisionless	23%		23%	25%

Table II	C10	C93	C82	I63
GTC Flux	0.9	0.95	1.0	
χ^2	0.64	0.62	1.0	
NEO $\varepsilon^{1.5}$	0.45	0.6	1.0	2.5
χ_J^2	1.4	1.7	1.0	
DKES, s=0.5, ν/v=0.0001	0.87	0.95	1.0	
DKES, s=0.5, ν/v=0.001	1.0	1.2	1.0	
ORBIT3D Eloss collisional	1.0		1.0	1.0
ORBIT3D Eloss collisionless	1.0		1.0	1.1

IV. Summary

- Figure 8 shows trends:

  - Particle transport is best in QASC10 and becomes increasingly worse in C93 and C82.

  - GTC, ORBIT3D, NEO and DKES(ν/v=0.0001) show improvement in transport C82=>C92=>C10

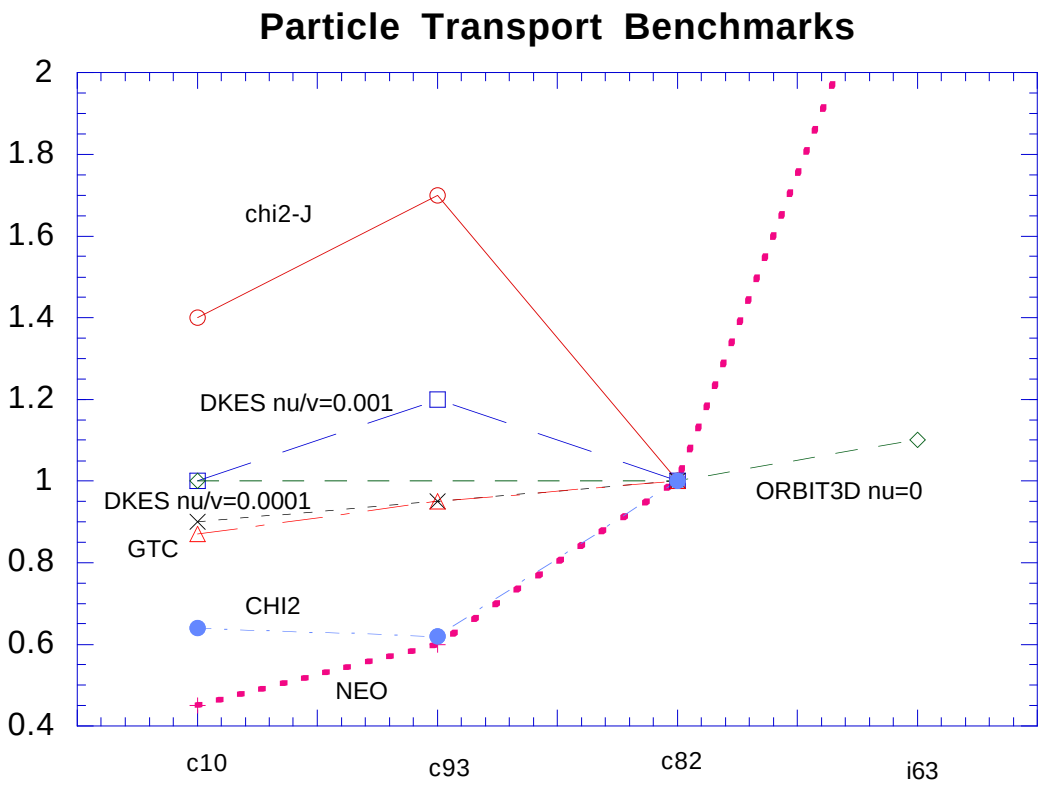
  - Only NEO is fast enough to be included in optimizer

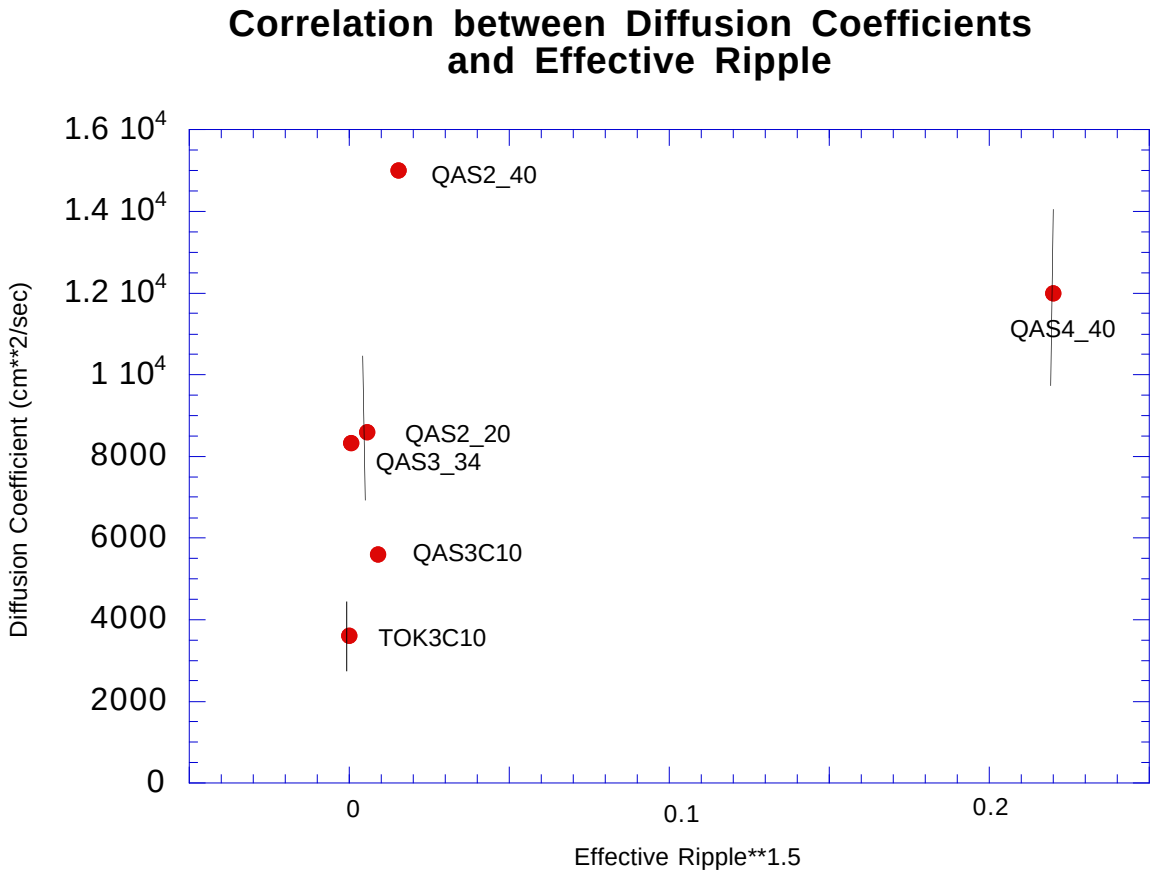
  - χ^2, χ^2_J, DKES(ν/v=0.001) are fast, but do not show the improved transport C82=>C92=>C10
    They don't do the right calculation.

- Figure 9 shows NEO ripple $\varepsilon^{3/2}$ correlation with diffusion coefficients. Includes more physics than "water".

Recommendation:

Try NEO in the optimizer instead of χ^2


Particle Transport Benchmarks
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
chi2-J
DKES nu/v=0.001
DKES nu/v=0.0001
GTC
CHI2
NEO
ORBIT3D nu=0
c10
c93
c82
i63


Correlation between Diffusion Coefficients
and Effective Ripple
Diffusion Coefficient (cm**2/sec)
1.6 10^4
1.4 10^4
1.2 10^4
1 10^4
8000
6000
4000
2000
0
QAS2_40
QAS4_40
QAS2_20
QAS3_34
QAS3C10
TOK3C10
0
0.1
0.2
Effective Ripple**1.5