Robustness and Flexibility in NCSX: Global Ideal MHD Stability and Energetic Particle Transport

NCSX Stellarator Group Meeting

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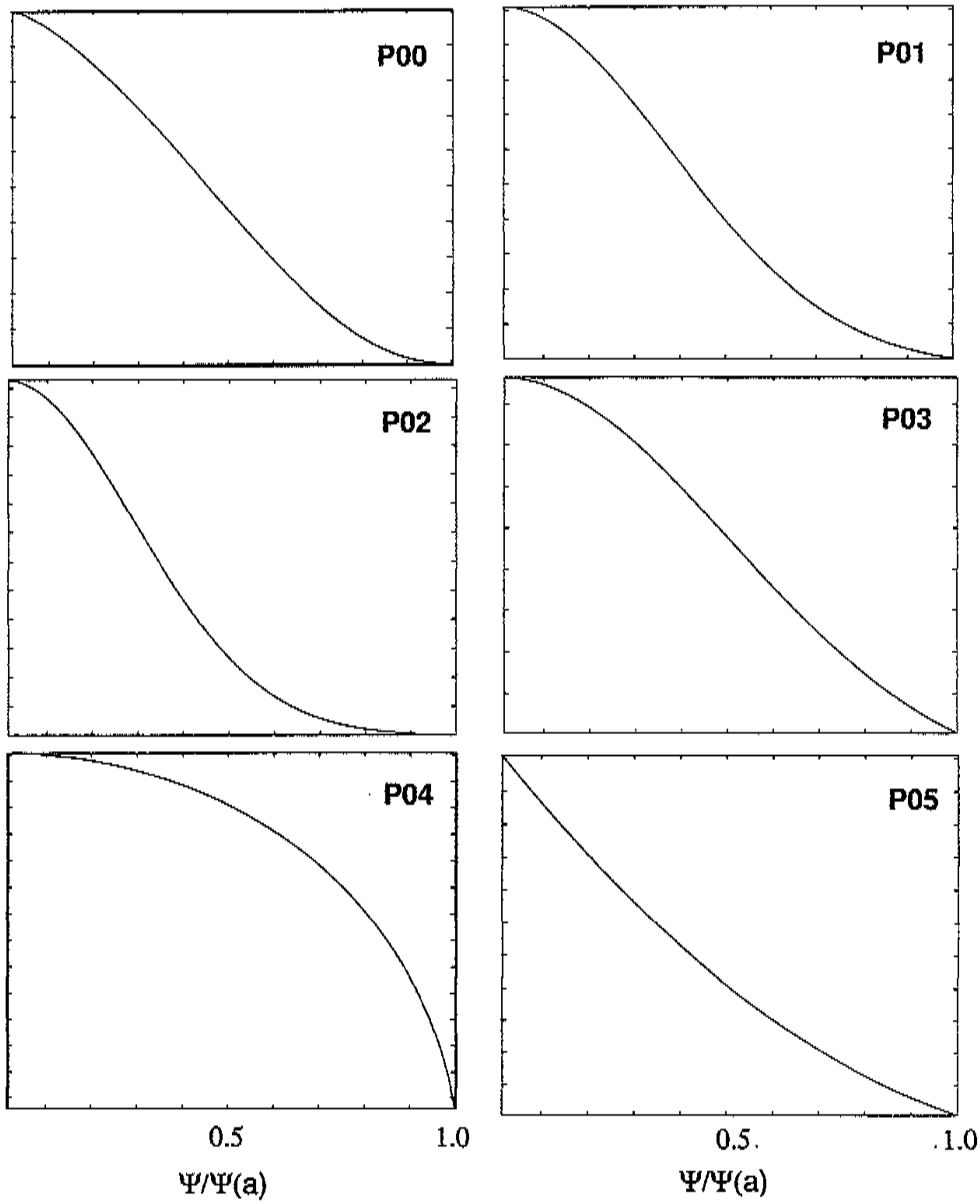
Introduction

- Study the effect of pressure and q profiles on stability and energetic particle transport.
- The VMEC, CAS3D and TERPSICHORE AND ORBITMN CODES are used.
- The QAS3_C82 design for NCSX, presented at EPS '99 is the initial baseline being examined.
- Kept boundary shape, $\langle\beta\rangle$, $\iota(0)$, $\iota(a)$ fixed.

Outline

1. Introduction: Description of C82 baseline equilibrium
2. Pressure and iota profiles being studied
3. Calculations
    - VMEC equilibria for 3.8% beta
    - TERPSICHORE kink and vertical instability
    - CAS3D kink and vertical instability
    - ORBITMN energetic particle transport
4. Summary and Future Work

Pressure Profiles



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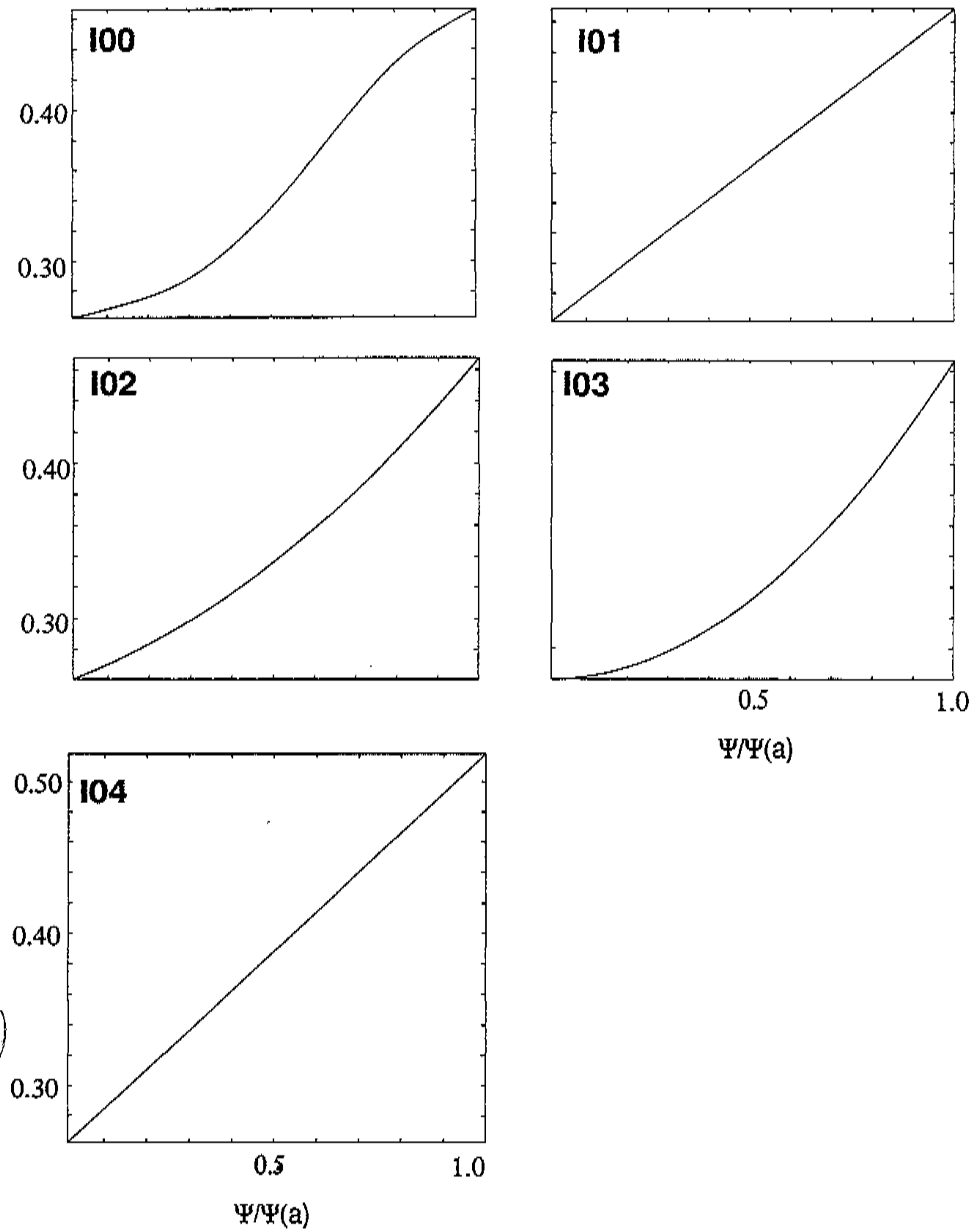
Iota Profiles



A. DIALLO, page 1

Procedure for Stability Calculations.

- **Analytic function Setup** :

Pressure profile	Cases	Variable
$P = \frac{P_0(e^{-(x/\sigma)^2} - e^{-1/\sigma^2})}{1 - e^{-1/\sigma^2}}$	P01, P02, P03	σ
$P = P_0(1 - x^2)^\alpha$	P04	α
$P = P_0(1 - \frac{11}{7}x + \frac{4}{7}x^2)$	P05	

Iota profile

By definition iota $\iota = 1/q$
Consider a linear approximation

$$\iota(x) = \iota_0 + \frac{[\iota_a - \iota_0]}{a} x \qquad \text{I01, I05} \qquad \iota_a$$

Where ι_a, ι_0 are respectively iota at the center and at the edge.

$S_r = \frac{r}{q}\nabla q \Rightarrow S_r = -\frac{r}{\iota}\frac{d\iota}{dr}$ (1) defines the Shear at r.

$S_a = \frac{(\iota_a - \iota_0)}{\iota_a} a$ We are considering the absolute value

Let Iota be a quadratic

$$\iota(x) = \iota_0 + cx + dx^2$$

$$\iota_a = \iota_0 + ca + da^2 \Rightarrow c = \frac{1}{a}\{(\iota_a - \iota_0) - da\}$$

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Applying equation (1) to the quadratic we obtain

$$S_a = \frac{\delta + da^2}{\iota_0 + \delta} \quad \text{Where } \delta = \iota_\alpha - \iota_0$$

$$d = \frac{S_a(\iota_0 + \delta) - \delta}{a^2}$$

Now let's vary d in order to obtain c

$$d = 0 \Rightarrow S_a = S_0 = \frac{\delta}{\iota_0 + \delta}$$

We have then considered S_a being 1, 1.5, 2 for our cases.

$$\iota(x) = \iota_0 + \frac{1}{a^2}\left[\delta(a + 1 - S_a) - S_a \iota_0\right]x + \frac{S_a(\iota_0 + \delta) - \delta}{a^2}x^2$$

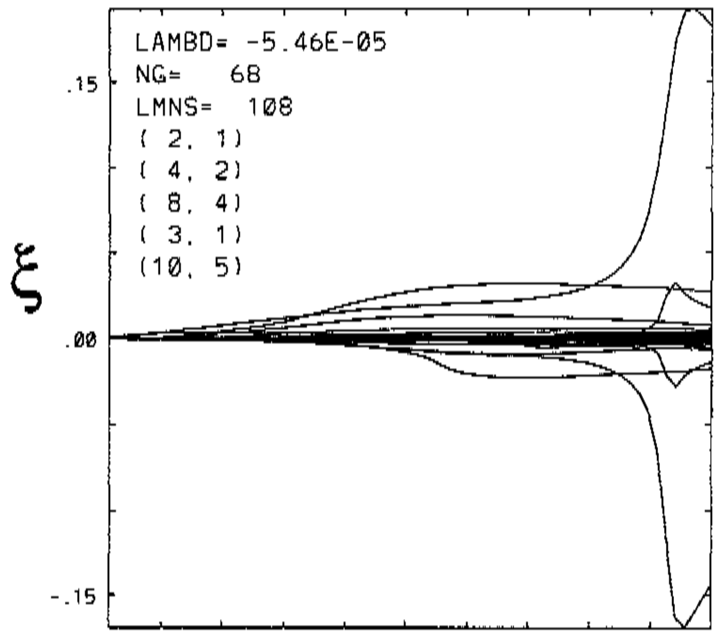
We varied then S_a to obtain I02, I03 profile.

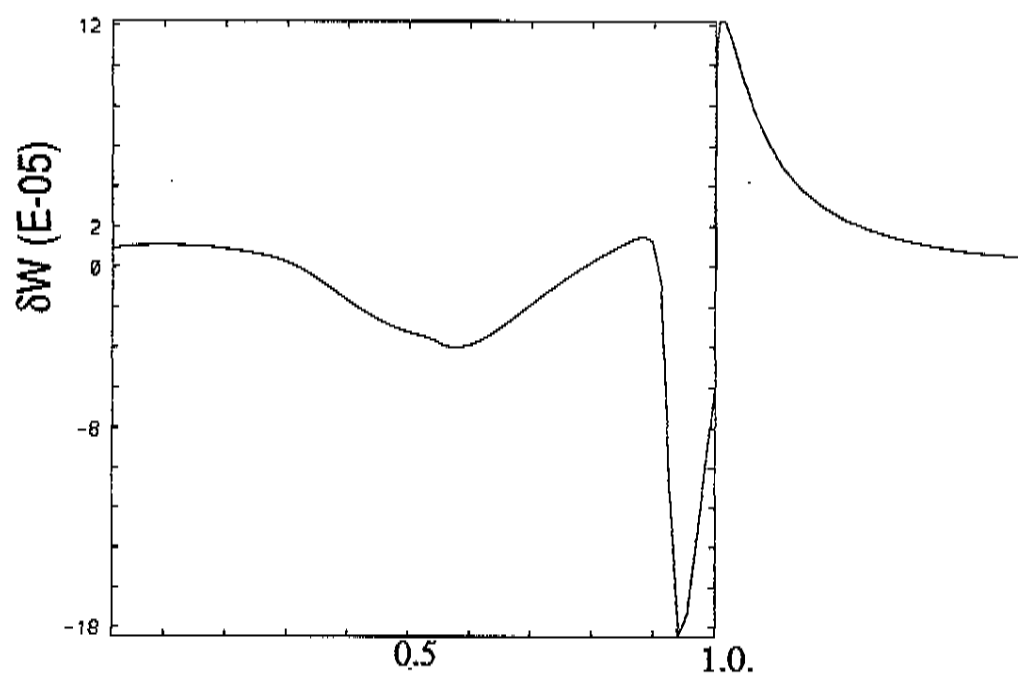
- `We then run the VMEC_77 on the DEC Alpha workstation.
- We then take a look at the fort.3 (output VMEC_77) and see if we are satisfied with the beta.
- Once we are satisfied, we use POLYFIT to fit the pressure profile with a polynom of degree 10.
- We then use these coefficients for the polynom and feed it to VMEC_90 keeping everything else the same. We should expect to have the same beta.
- We then have an output file from VMEC_90 called WOUT.runid.
- We use this file as input for TERPSICHORE for the stability runs.

This Method is efficient when we are focusing on beta since we can use VMEC_77 to have the beta desired before going through the Stability. In fact we only manipulate one parameter that could be the width or the Initial pressure instead of 10 coefficient if we were using VMEC_90.

P01I04

N=1, Kink





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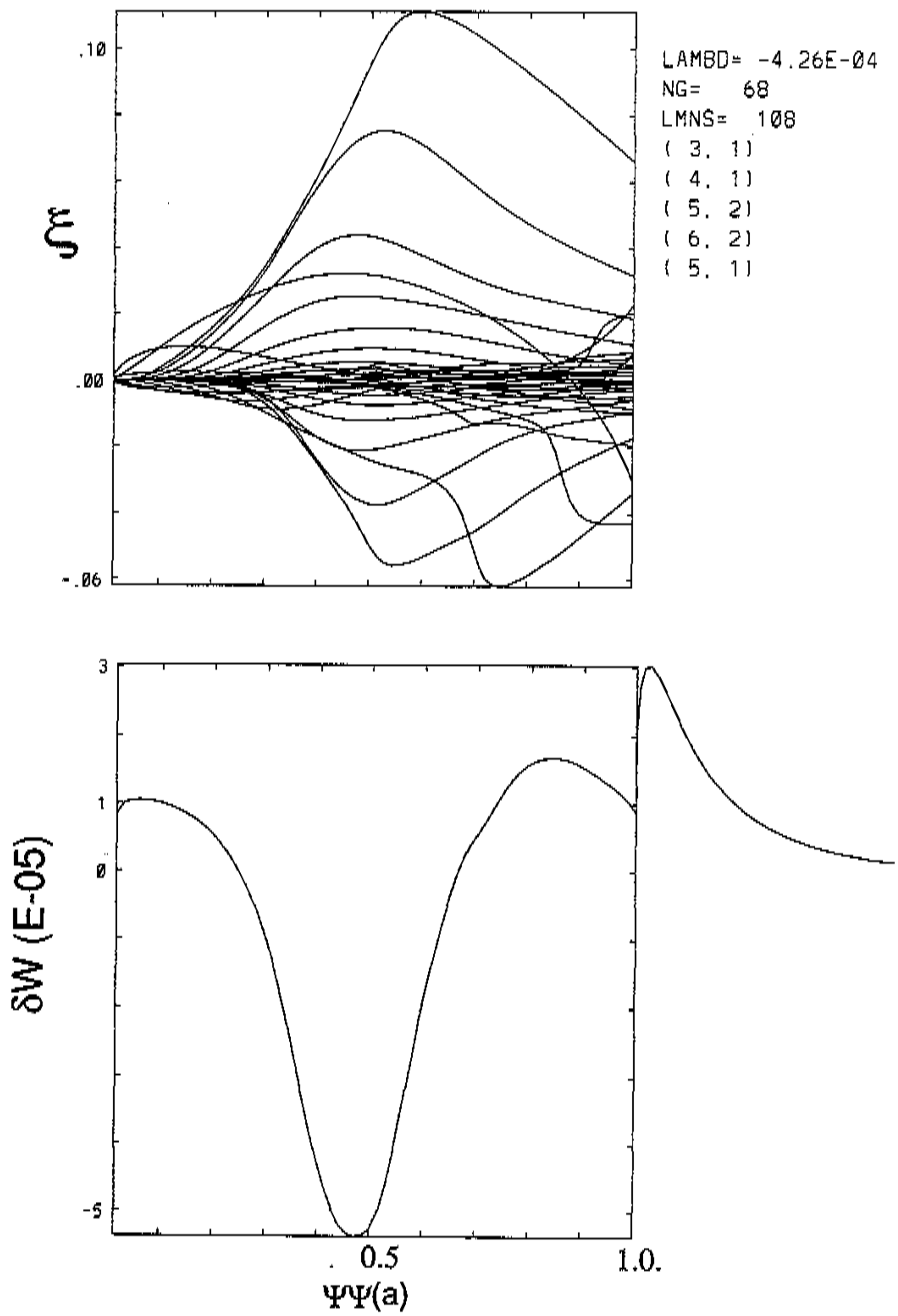
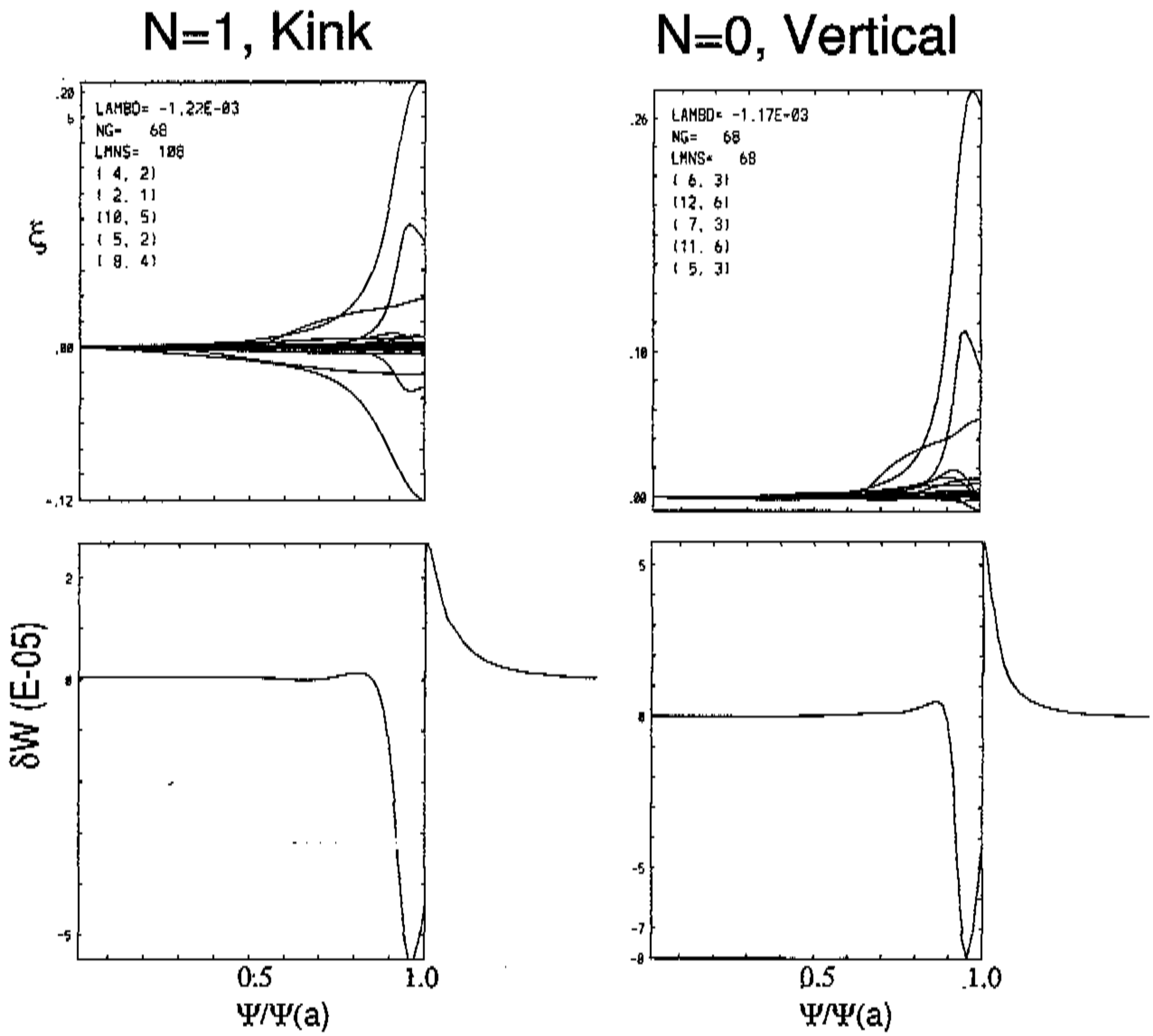
P02I00

N=1, Kink



(b)

P03I04


N=1, Kink
N=0, Vertical
LAMBD= -1.22E-03
NG= 68
LMNS= 108
(4, 2)
(2, 1)
(10, 5)
(5, 2)
(8, 4)
LAMBD= -1.17E-03
NG= 68
LMNS= 68
(6, 3)
(12, 6)
(7, 3)
(11, 6)
(5, 3)
δW (E-05)
0.5
1.0
Ψ/Ψ(a)
Ψ/Ψ(a)

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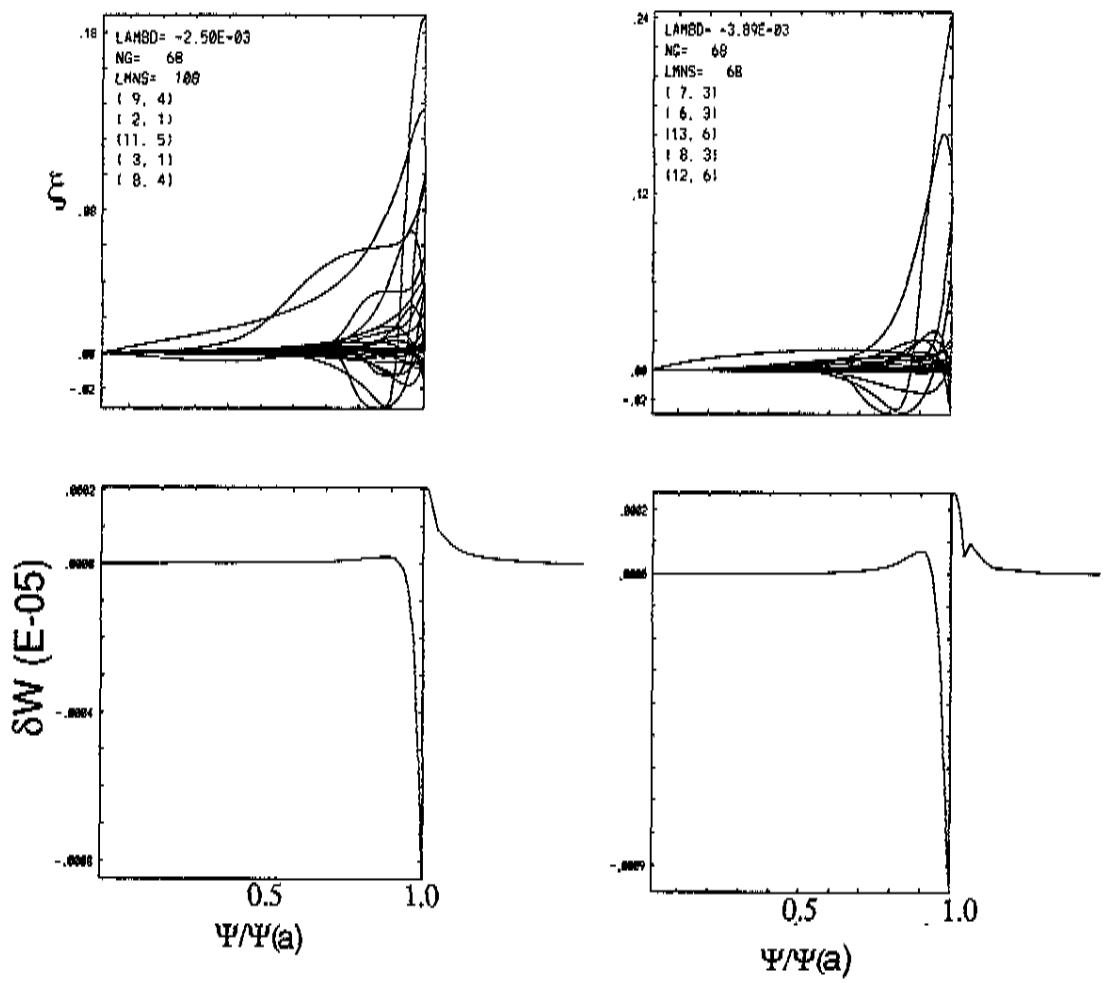
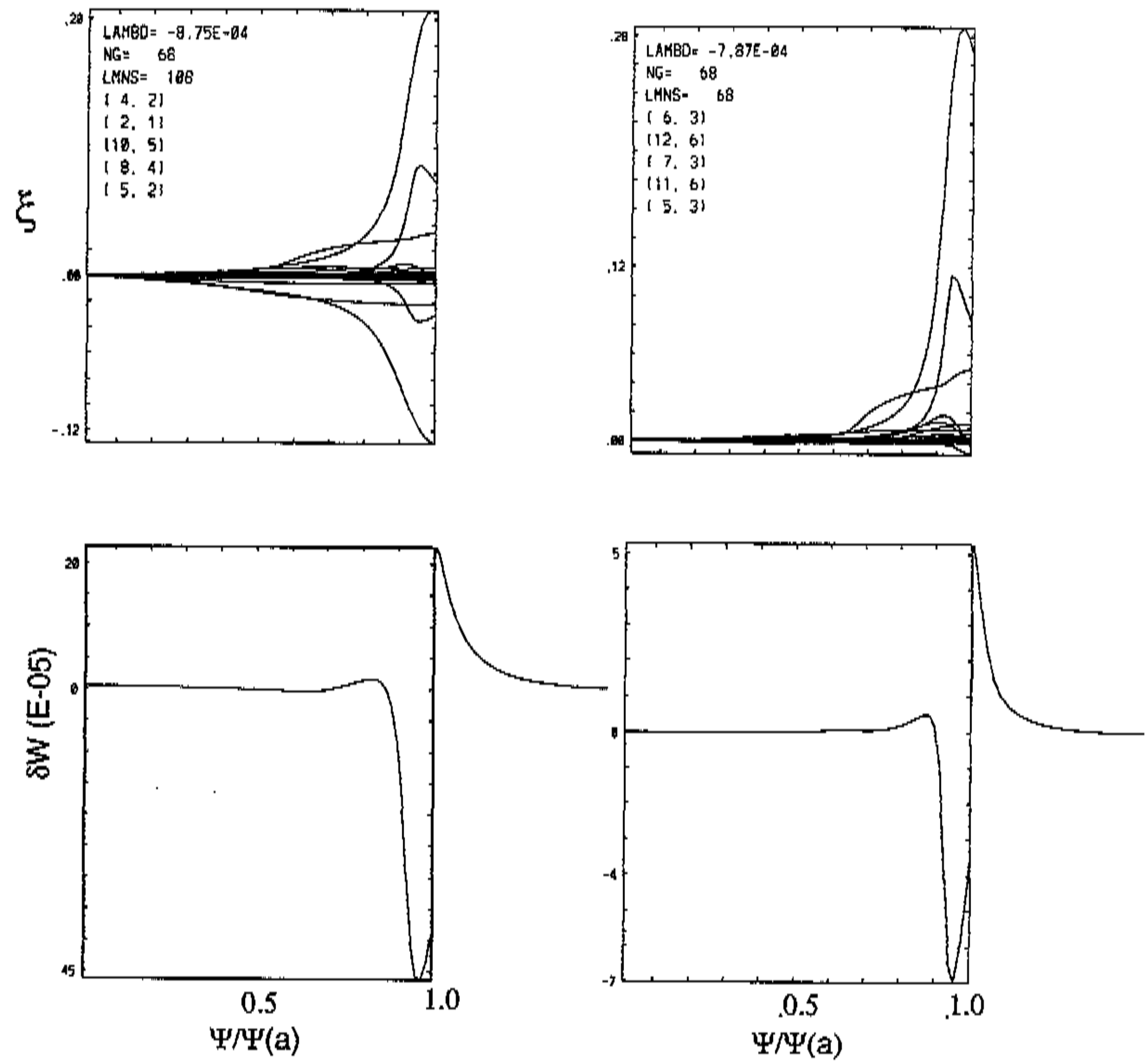
P04I02

Kink Vertical

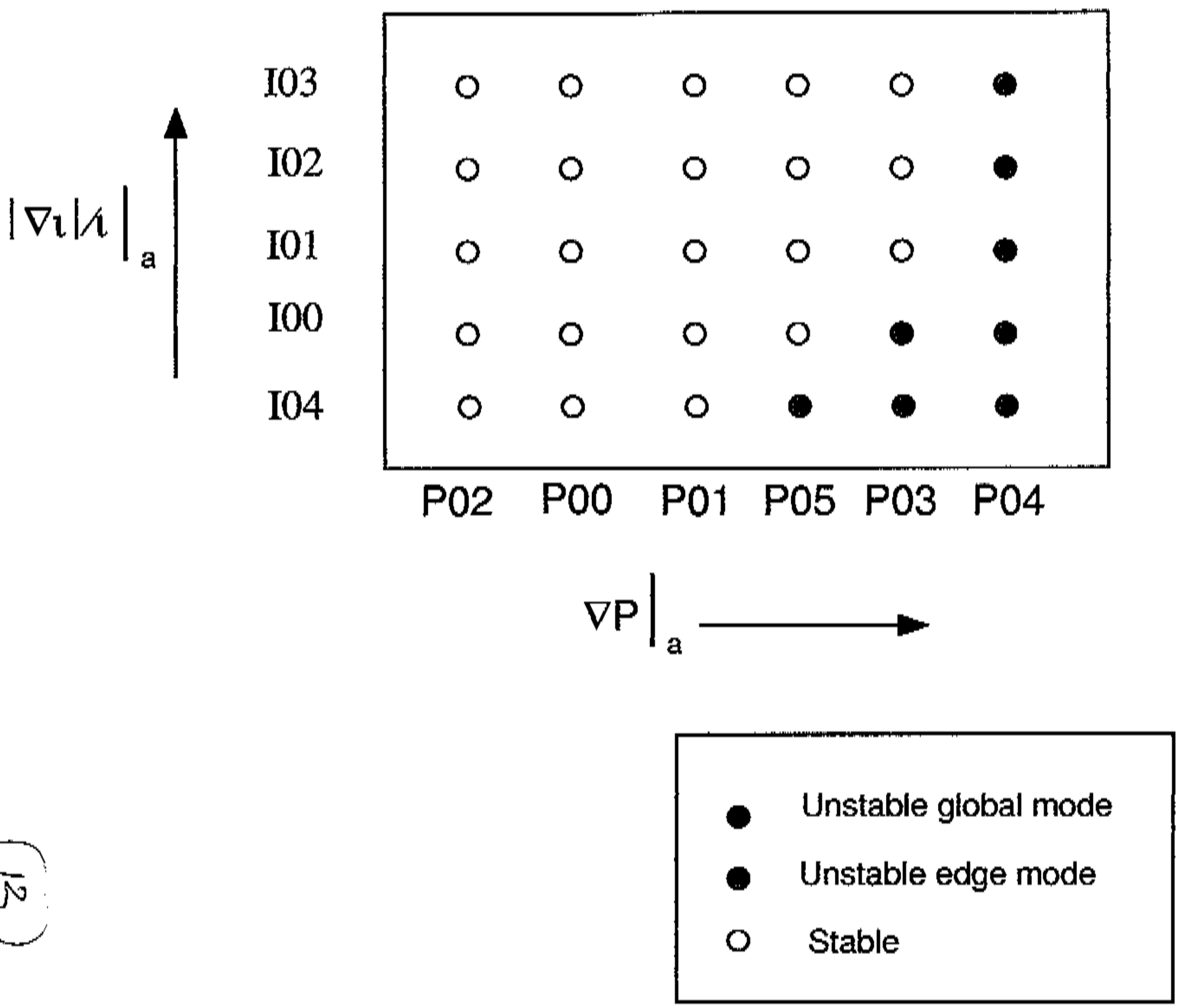


P05I04

N=1, Kink N=0,Vertical

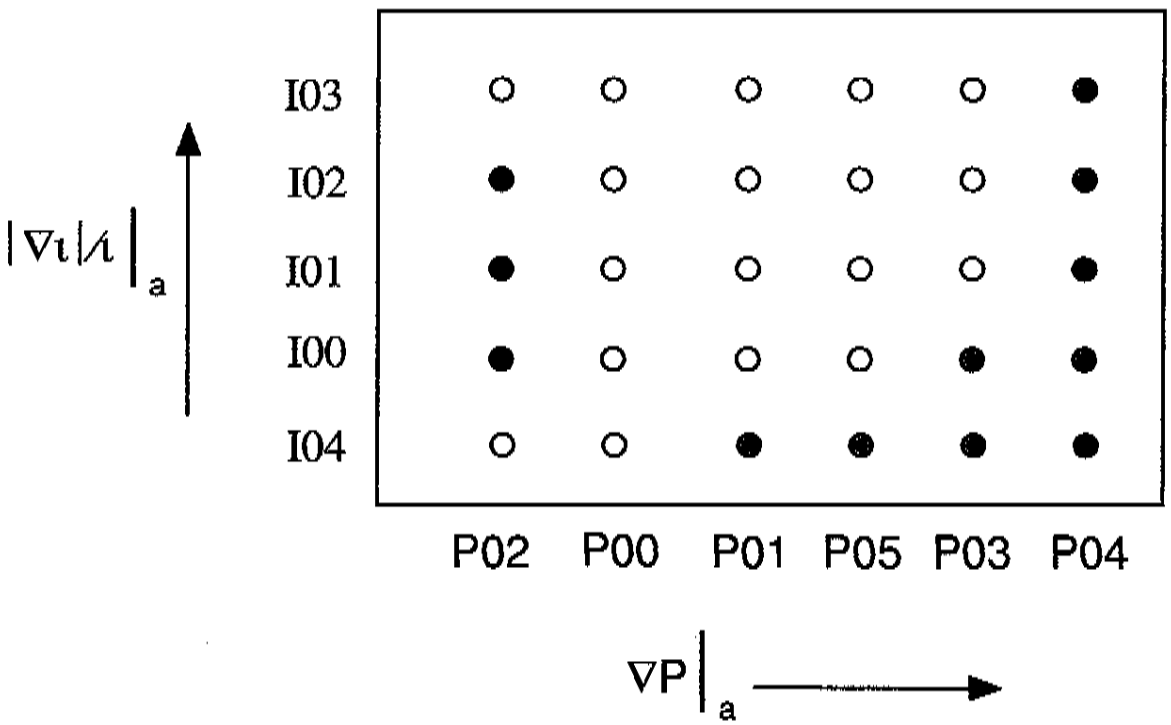


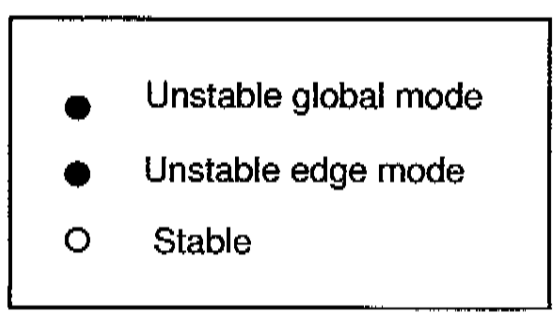
"Vertical" Stability Results Summary for NCSX Maintaining $\langle\beta\rangle$=3.8% and Boundary Shape, with $\iota(0)$ and $\iota(a)$ fixed.



N=0, Periodicity-preserving mode stability increases with lower pressure gradient and higher magnetic shear

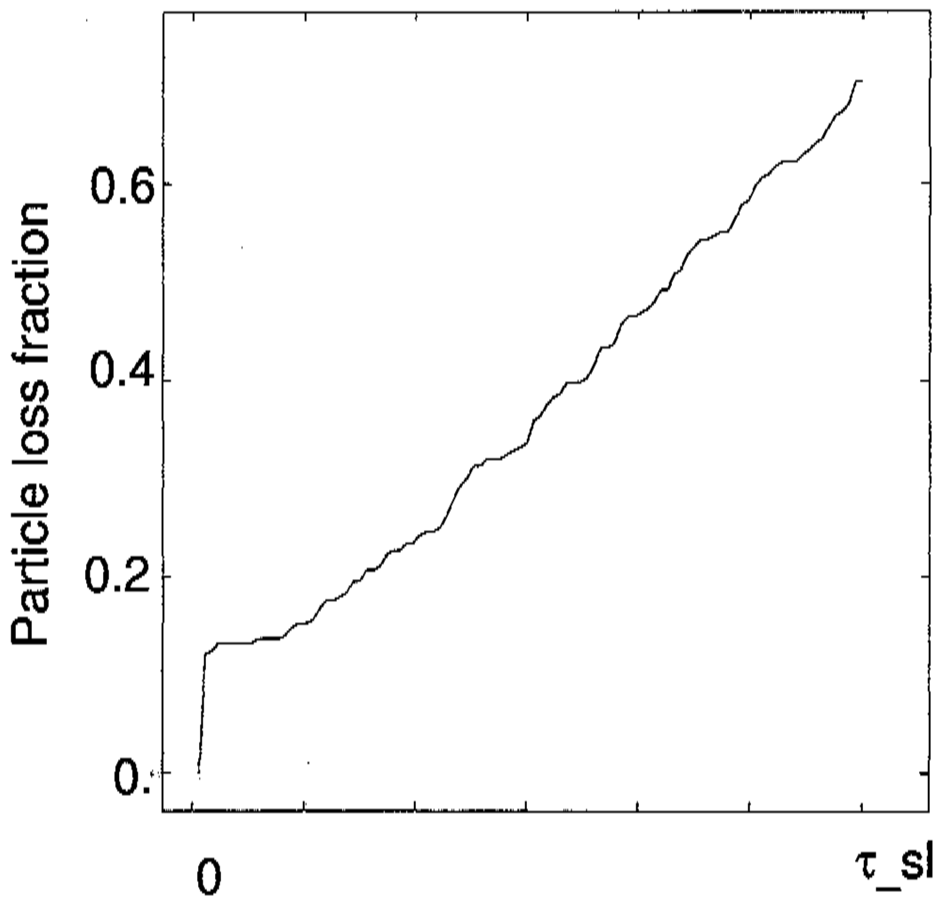
Kink Stability Results Summary for NCSX Maintaining <β>=3.8% and Boundary Shape, with ι(0) and ι(a) fixed.





N=1, External kink stability increases with lower pressure gradient and higher magnetic shear

Time evolution of energetic particle loss from equilibrium P01I00 over one energy slowing



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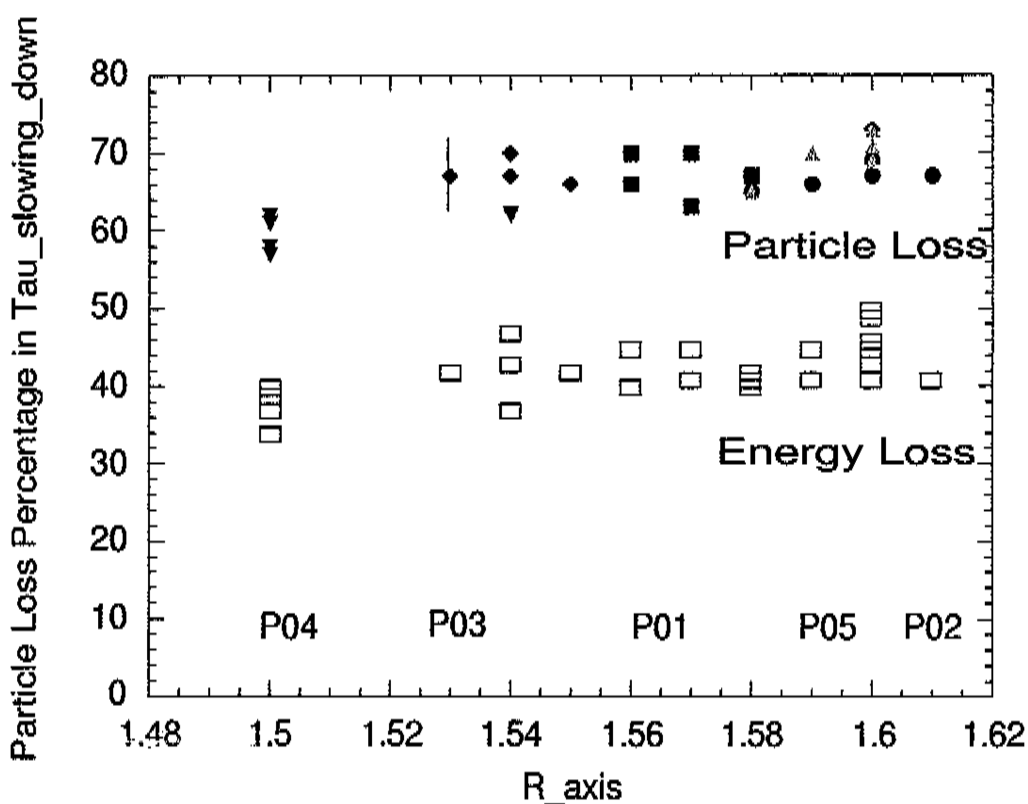
Concave shape characteristic of slow accumulative loss process for stellarator orbits.
Tokamak loss evolution due to TF ripple is convex, incremental losses decreasing in time.

Fast Particle Loss Fraction for NCSX Shows Little Variation among 30 P(r), iota(r) Configurations



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Particle Loss Increases for Configurations with Best Vertical Stability

Summary

- VMEC has been used to obtain 30 equilibria with different p and iota profiles, based on QAS3_C82
- TERPSICHORE has shown positional stability and kink stability for many of these cases
- CAS3D has extended TERPSICHORE results for C82 to show kink and vertical stability for this configuration even without a conducting wall. Further work with CAS3D should confirm the TERPSICHORE results with these pressure and q profiles, without a conducting wall.
- ORBITMN has shown quantitatively that with a given deposition profile, energetic particle transport changes little with these configuration changes
- Instability if grad P too large and too little shear.
- Tokamak intuition useful regarding MHD driving forces.
- When varying the NCSX pressure and iota profiles: improved stability is accompanied by only slightly increased particle losses.
- A startup plasma, beta=1%, was stable with reduced energetic particle loss.

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