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

American Physical Society

November 15-19, 1999

Seattle, Washington USA

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PPPL

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Outline

1. Introduction: Description of C82 baseline equilibrium

2. Pressure and iota profiles being studied

3. Calculations

    - VMEC equilibria for 3.8% beta

    - TERPSICHORE global mhd instability

    - CAS3D global mhd instability

    - ORBITMN energetic particle transport

4. Summary and Future Work

Introduction

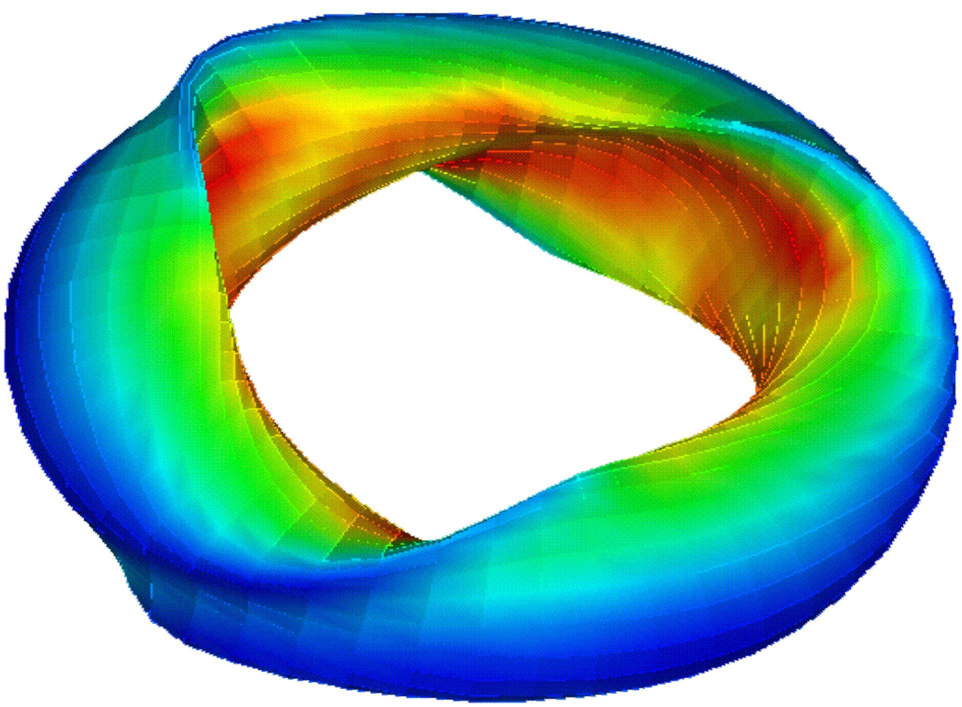
- Study the effect of pressure and q profiles on stability and energetic particle transport.
- The VMEC, CAS3D and TERPSICHORE AND ORBITMN CODES are used.
- The QAS3_C82 design for NCSX, presented at EPS '99 is the initial baseline being examined.
- Kept boundary shape, $<\beta>$, $\iota(0)$, $\iota(a)$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

Baseline Case
for Stability and Transport Simulations

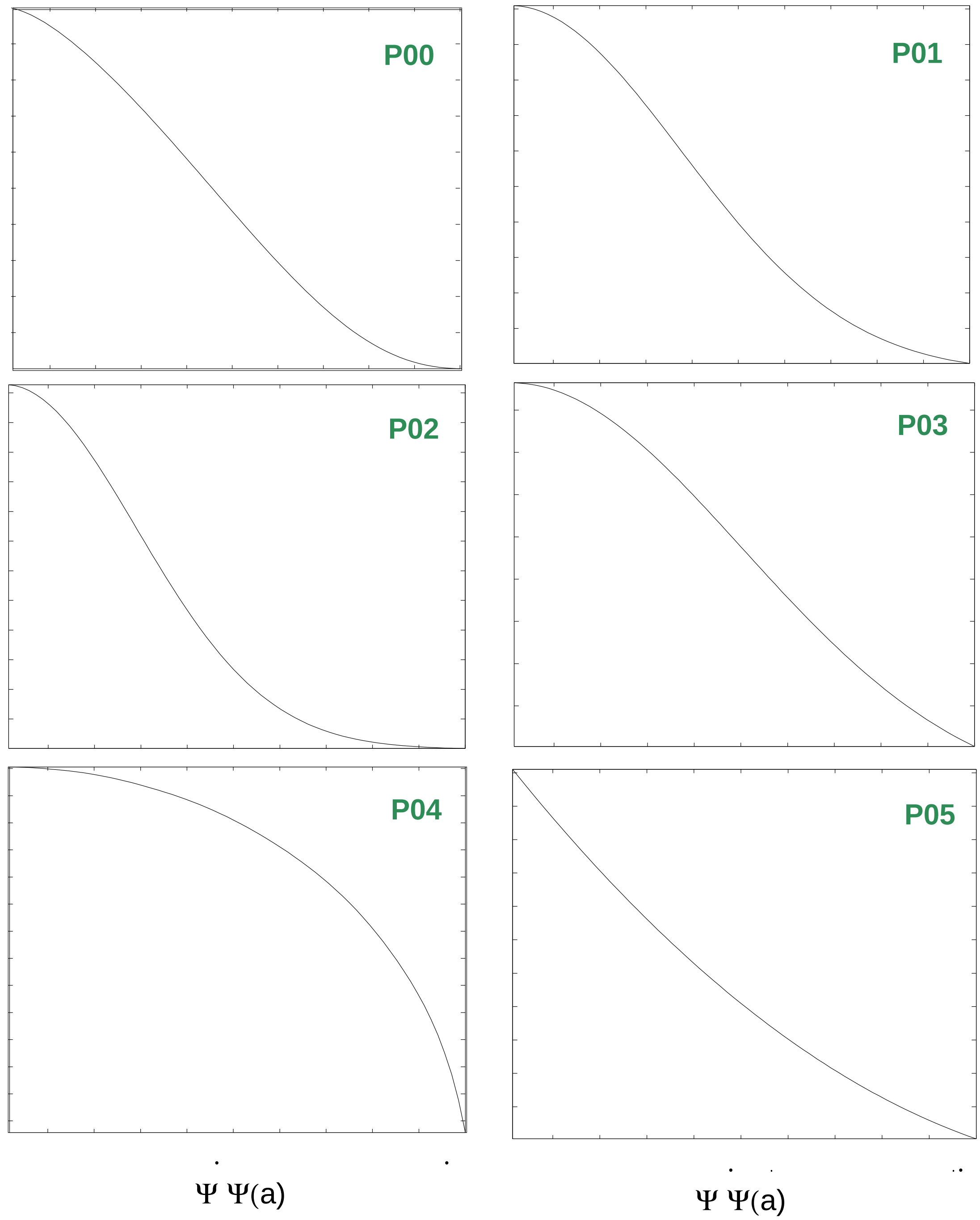
QAS3_C82

R = 1.6 m, aspect ratio 3.5, B_axis = 1T

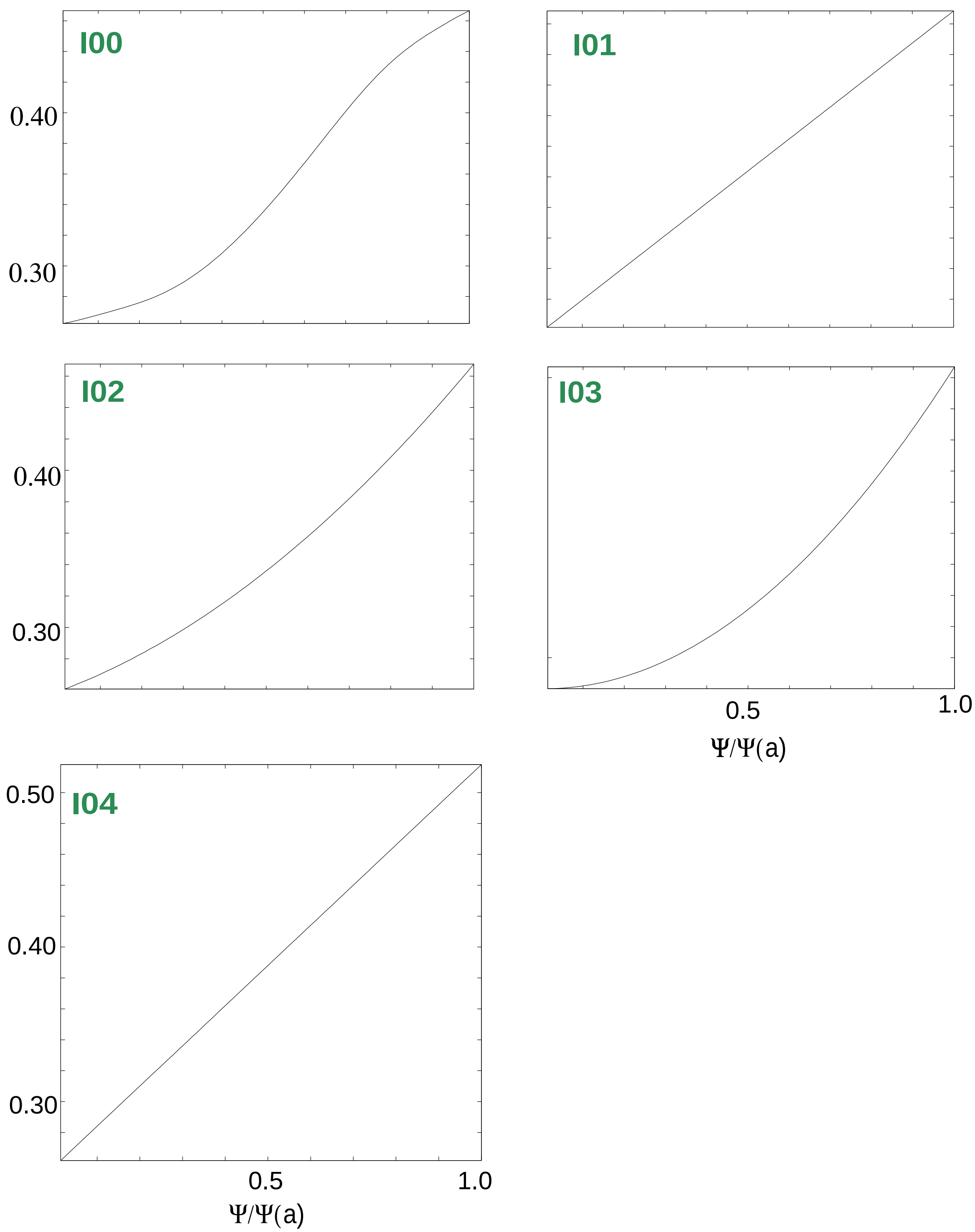
Ballooning, kink and vertically stable without a conducting wall



Pressure Profiles



Iota Profiles



Pressure and Iota Profiles

- QAS3_C82 profile designated P00/I00
- P01 is analytic approximation to P00.
- P02 is steeper and P03 is broader than P01
- P04 is very broad H-mode like.
- P05 is Helias reactor profile based on W7X
- Iota(0) is fixed for all iota profiles.
- Iota(a) is fixed for all iota profiles except for I04 where it is above 0.5
- I01 and I04 are linear.
- I02 and I03 have edge shear increased to 1.5x and 2x the edge shear of I01.

Mode Selection Table for QAS Instabilities

- Tokamaks: toroidal modes are not coupled
- Stellarators: toroidal modes are coupled by magnetic field periodicity
- For stellarators, N_T=number of field periods,
- There are $1+[N_T/2]$ independent mode families for decoupled problems
- For three field periods, $N_T=3$,

  N=0 mode family includes vertical instability (n=0)

  and includes periodicity-preserving kink eigenmodes with

  n = ±/3, ±6, ±9...

  N=1 mode family includes external kink mode

  includes non-periodicity-preserving eigenmodes

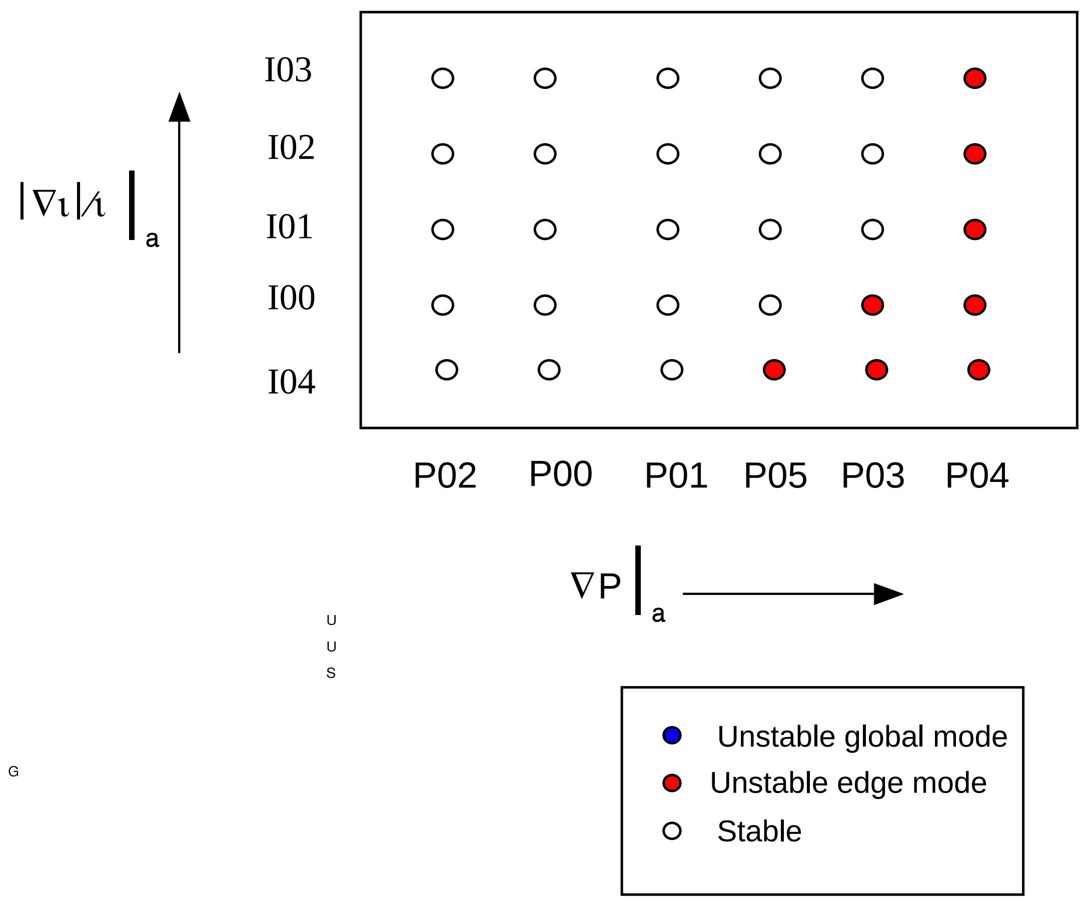
  n = ±1, ±2, ±4, ±5, ±7, ±8...
- Iota ranges from 0.25 to 0.5, then resonant n/m ~ 4 to 2 allows a mode selection table to be constructed.

N=0 Periodicity Preserving Kink Stability

Results Summary for

NCSX Maintaining < β>=3.8%

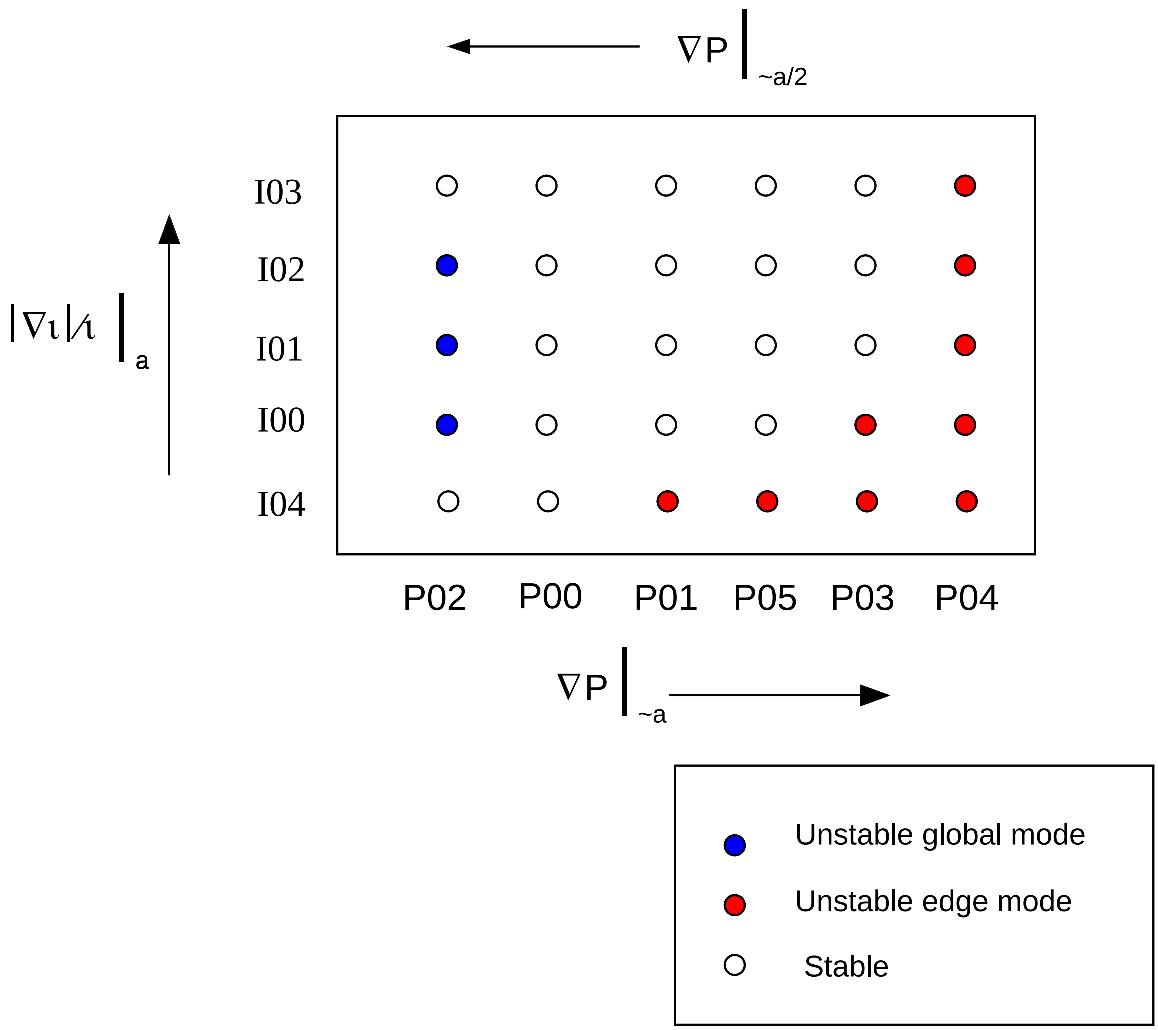
and Boundary Shape



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

Non-Periodicity-Preserving N=1 Mode

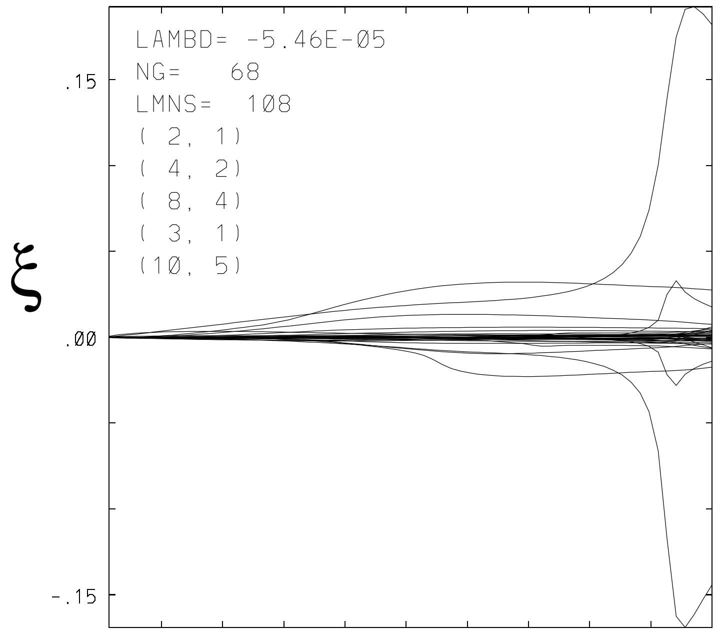
Kink Stability Results Summary for NCSX Maintaining < β>=3.8% and Boundary Shape

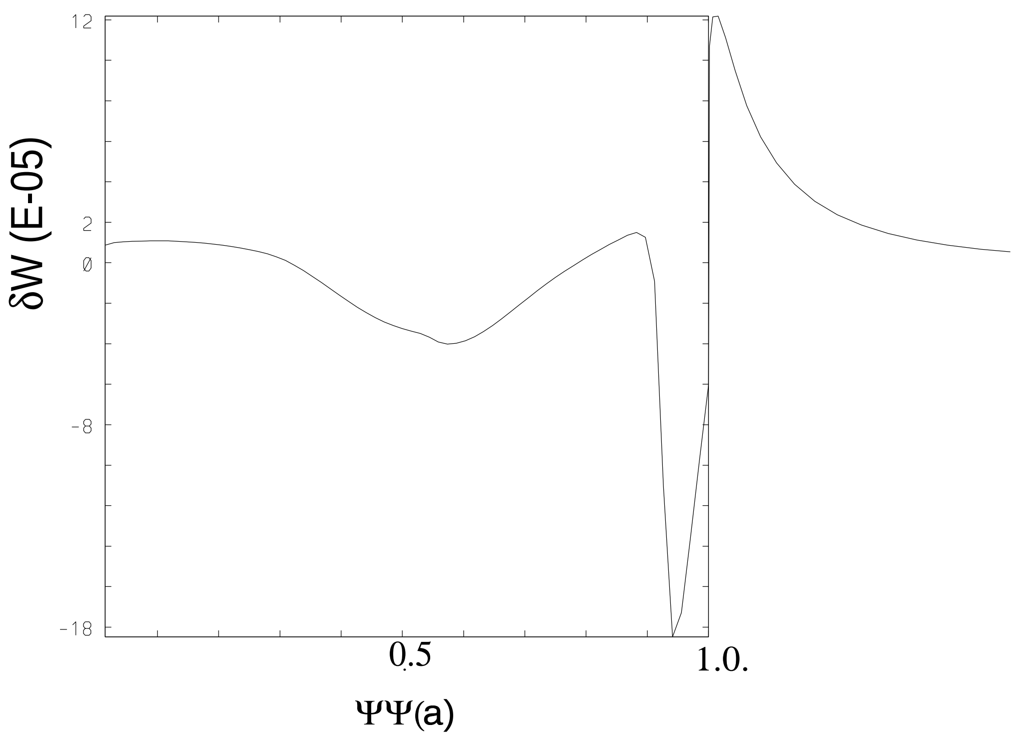


N=1, External kink stability increases with lower pressure gradient and higher magnetic shear

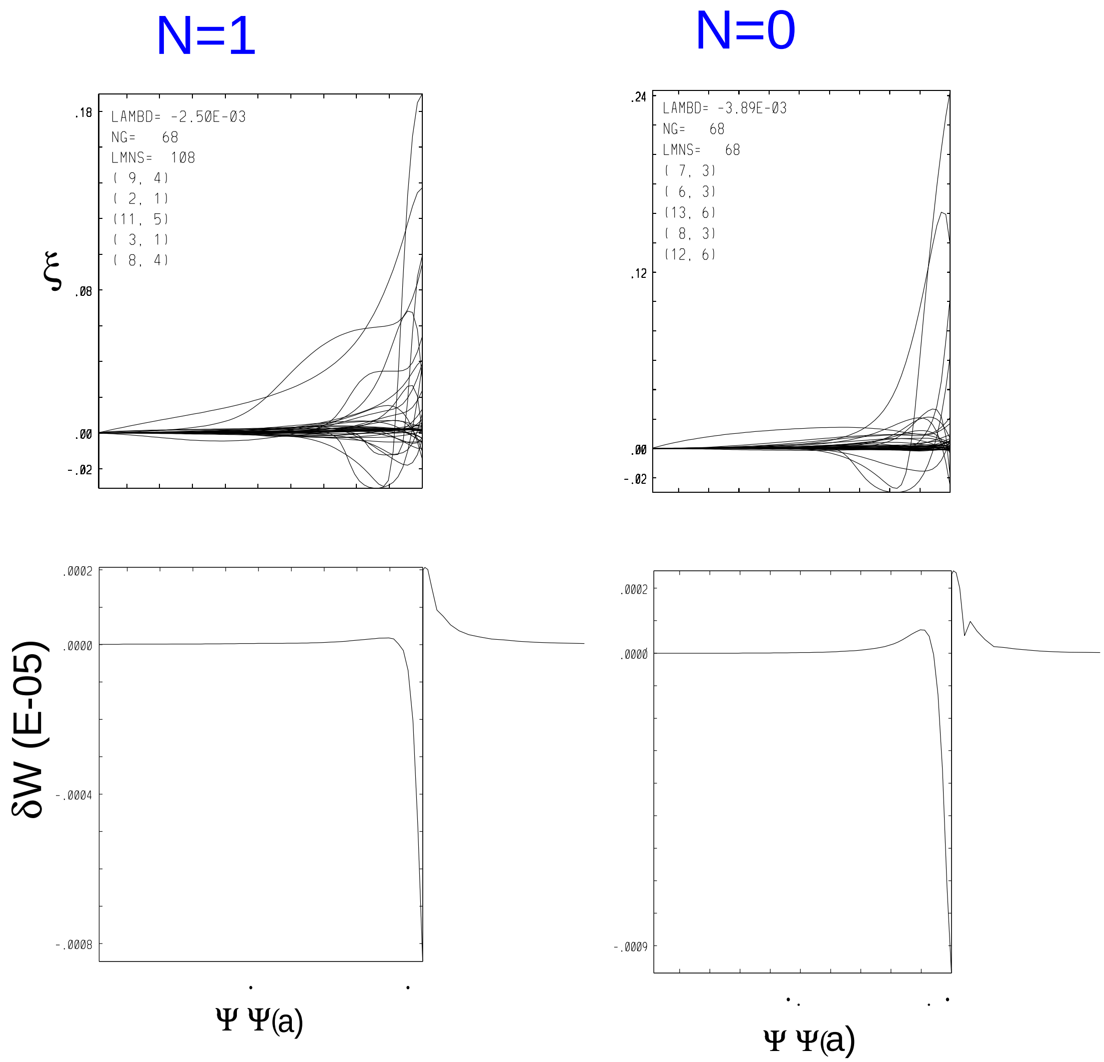
P01I04

N=1, Kink





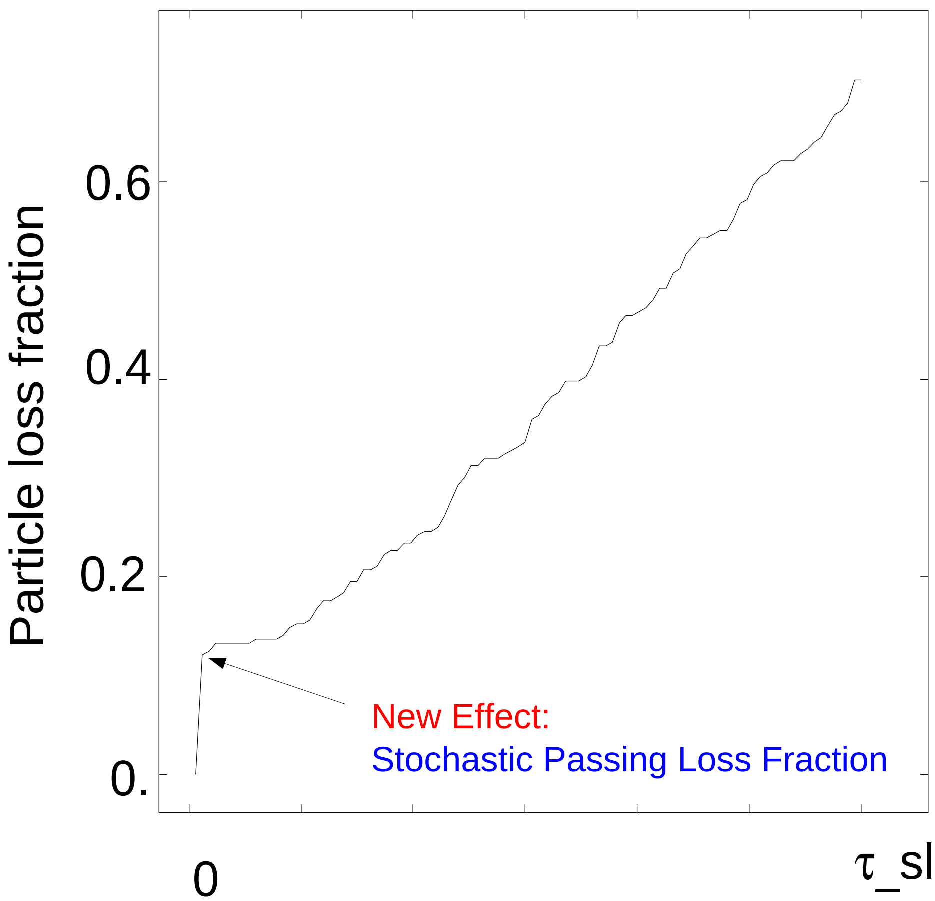
P04/I02


N=1
N=0
LAMBD= -2.50E-03
NG= 68
LMNS= 108
(9, 4)
(2, 1)
(11, 5)
(3, 1)
(8, 4)
LAMBD= -3.89E-03
NG= 68
LMNS= 68
(7, 3)
(6, 3)
(13, 6)
(8, 3)
(12, 6)
ξ
.18
.08
.00
-.02
.24
.12
.00
-.02
δW (E-05)
.0002
.0000
-.0004
-.0008
.0002
.0000
-.0009
Ψ Ψ(a)
Ψ Ψ(a)

Energetic Particle Transport

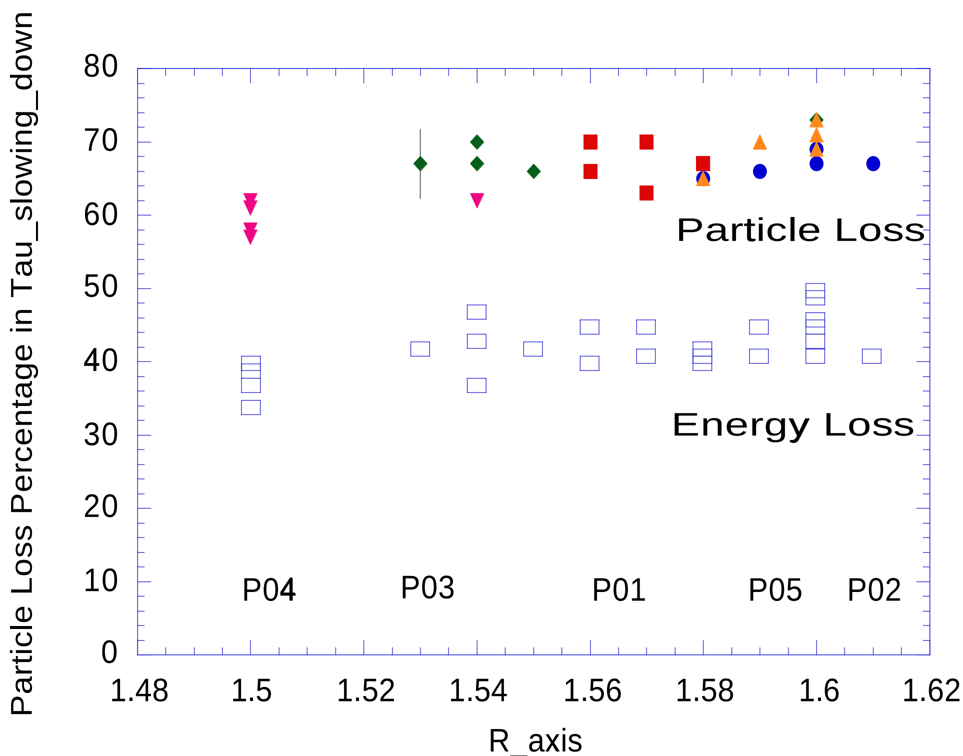
- Simulations carried out with deuterium beams and simple models for collisional effects of energy slowing down and pitch angle scattering.
- Injection radius was taken to be 1.3 meters for co-injected beams.
- Hydrogen beam losses are lower by ~30-40% with these collision models
- Optimization of injection angle can reduce losses by ~10%
- Calculations by Spong for NCSX (see Zarnstorff poster) with hydrogen beam losses and a more detailed collision model show even lower loss rates
- Sensitivity of energetic particle loss to the pressure and iota profiles will not depend on choice of beam isotope or collision models

Time evolution of energetic particle loss from equilibrium P01/I00 over one energy slowing



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



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 global mhd 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 P00/I00 plasma, β=1%: stable with reduced energetic particle loss.