VMEC Status:
NCSX Project Meeting

S. P. Hirshman

March 23-24, 2000

Progress Since Last Meeting

- Implemented V-conserving algorithm
- Formulated Hamada condition in VMEC coordinates
- Analyzed A-dependence of Force Balance
- Formulated current calculation from force balance (SVD)
- Implemented modifications to run in Free-boundary

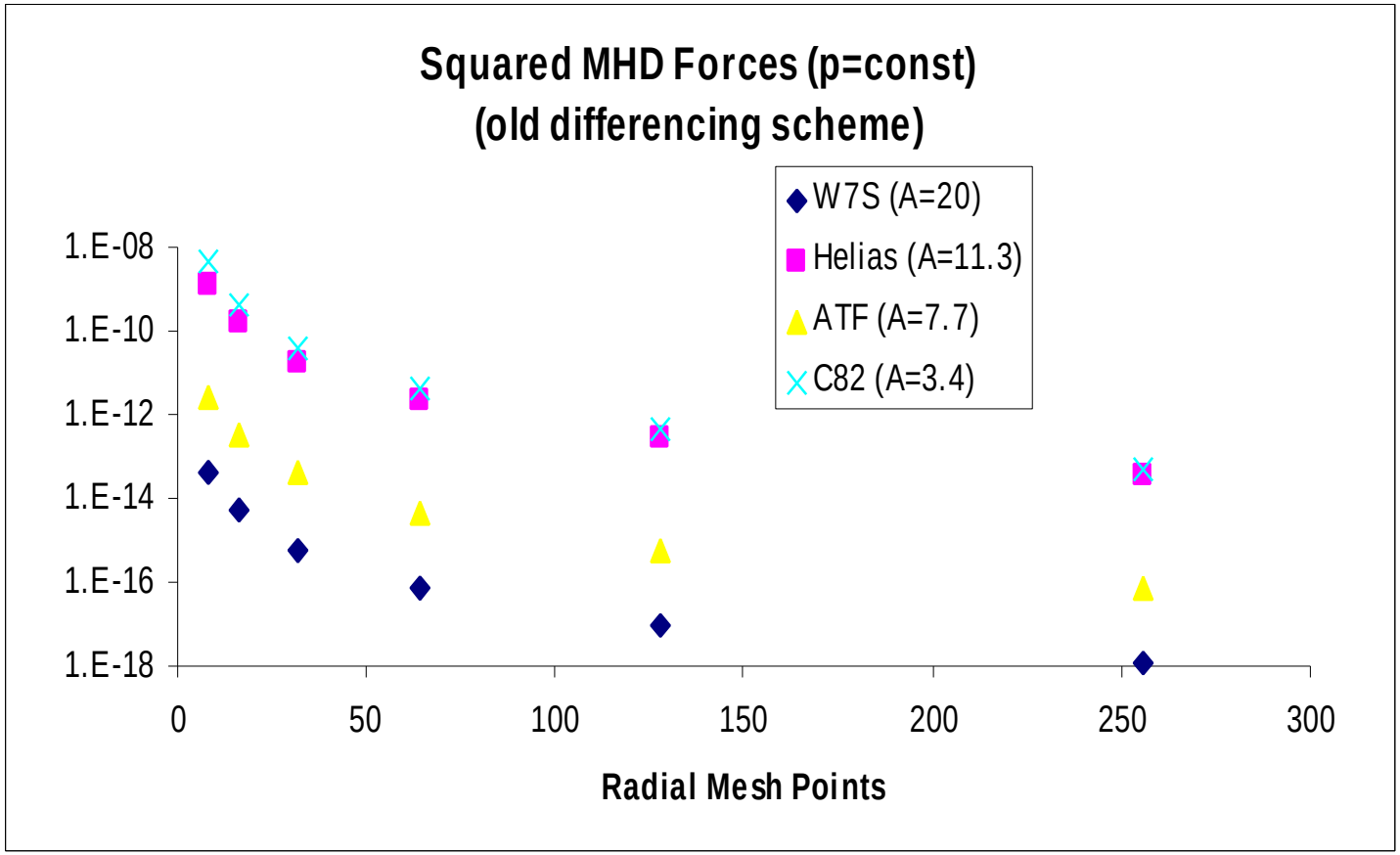
Volume Conservation

- Want ONLY dp/ds (not p) to enter MHD Forces (may impact current calculation)
- Radial discretization should preserve volume element $\sqrt{g}$ EXACTLY
- "Old" VMEC2000 conserves $\sqrt{g}/R$
- Works "best" at larger aspect ratios ($R = R_0 + O(1/A) \ldots$)

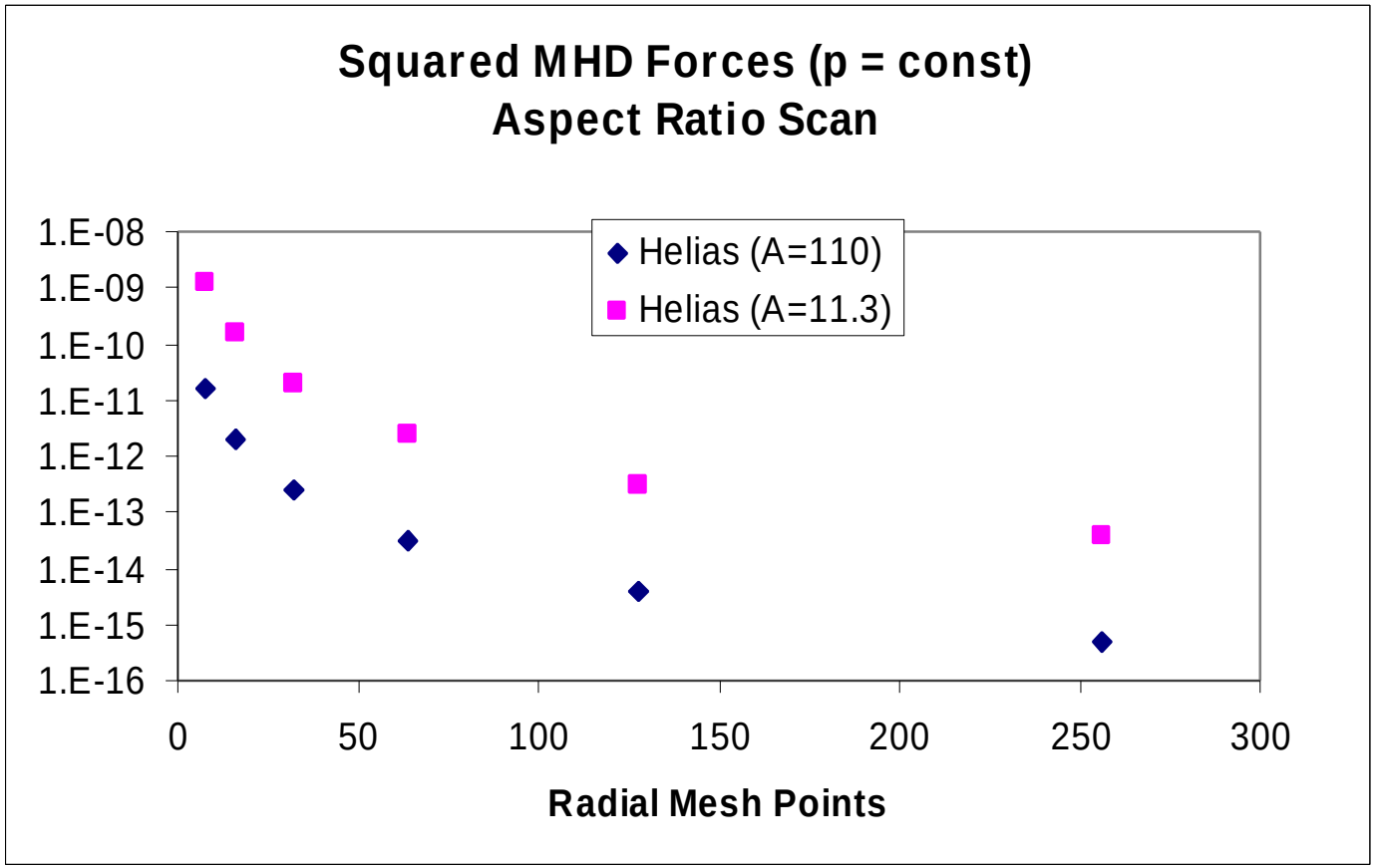
Implemented VC Algorithm in VMEC2000 code

- Method 1 (“correct way”)
  - Use $u=R^2/2$ in jacobian
  - Equations a little messier
- Method 2 (“easier way”)
  - Divide by R and re-difference
- Both Methods work, no additional computational overhead either way

p=const : Forces should vanish



Helias: A-scan has correct trend



New Differencing Schemes Eliminated Numerical Roundoff

- Machine precision errors ($F^2=10^{-30}$) for **all** Aspect Ratios when p = const

- Although clearly desirable, effect on j-calculation remains to be seen

Force Balance

- Most important for stability analyses
  - ballooning coefficients (curvature) can change sign if poor force balance (Isaev)
  - derivatives of B appear (currents…)
- Important for island suppression algorithms
  - need accurate $j_{||}$
- Less important for transport
  - |B| given fairly accurately, all that is needed

Hamada Condition Evaluation from VMEC equilibria

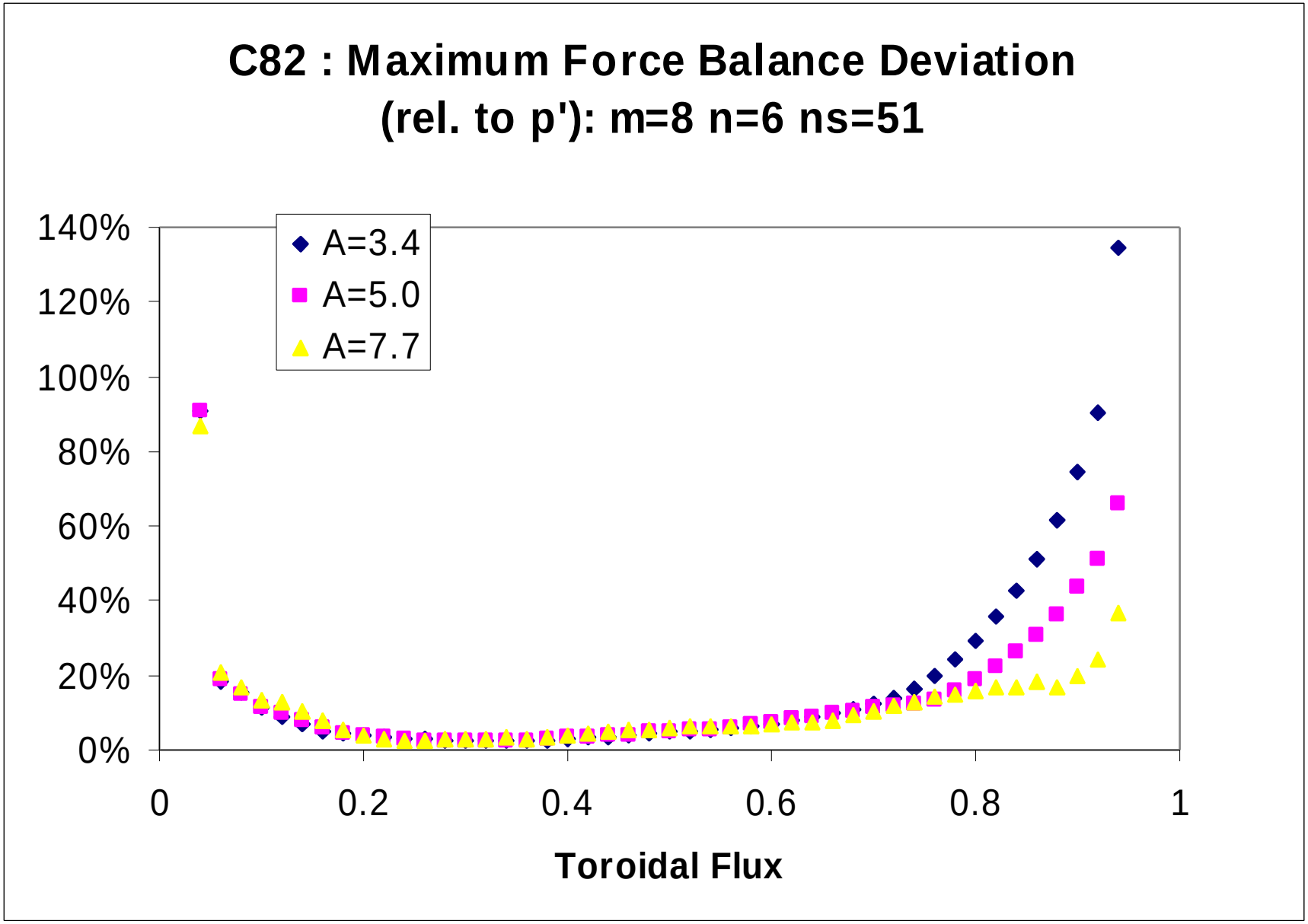
- Measure of force balance
- From dl/B = const on rational surface we find, noting $B^q = 1/\sqrt{g}$

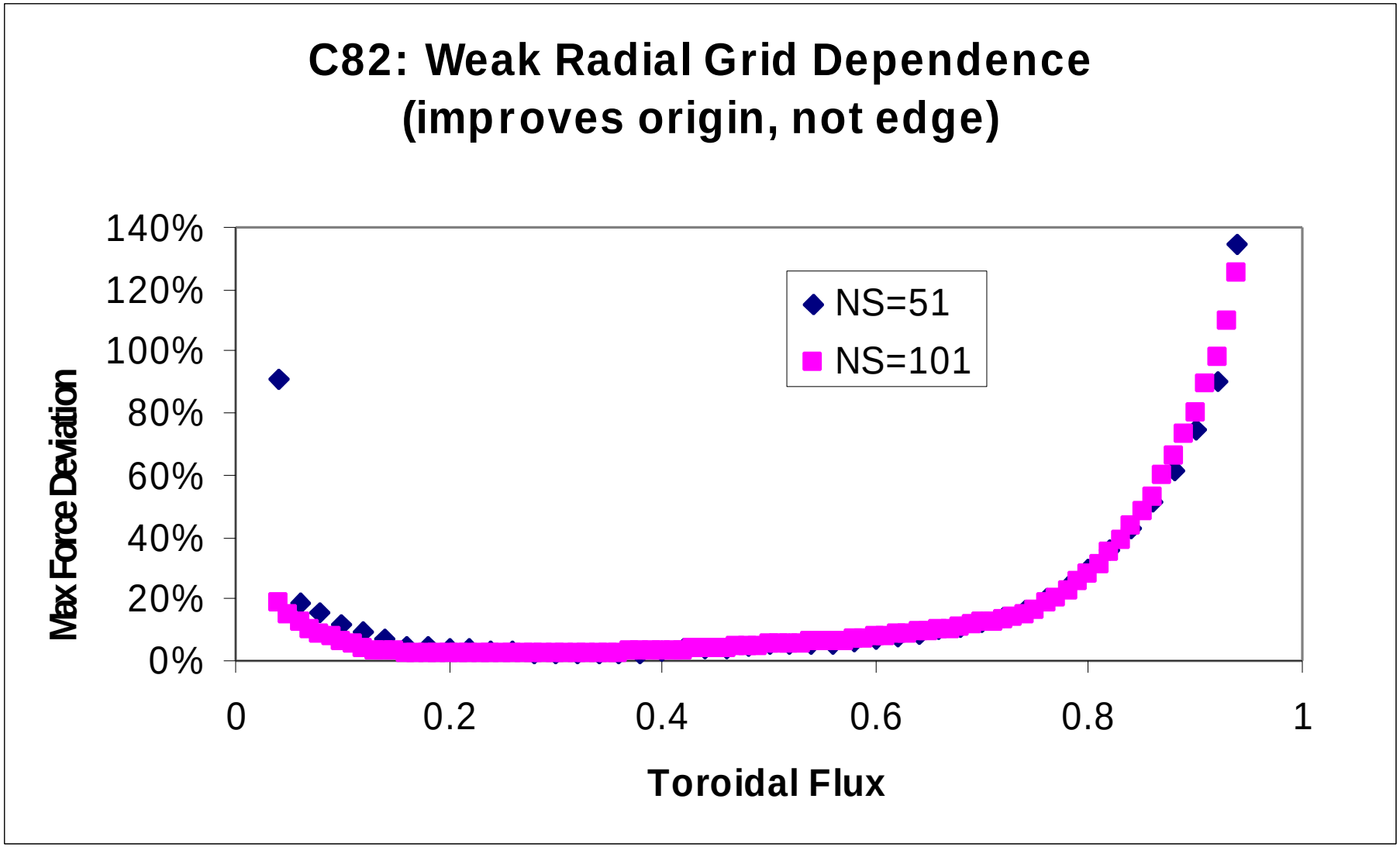
$$\sqrt{g^{straight}}_{mn} = \oint \sqrt{g^{VMEC}}\, dq\, dj\ \cos[m(q + l) + nj\ ]$$

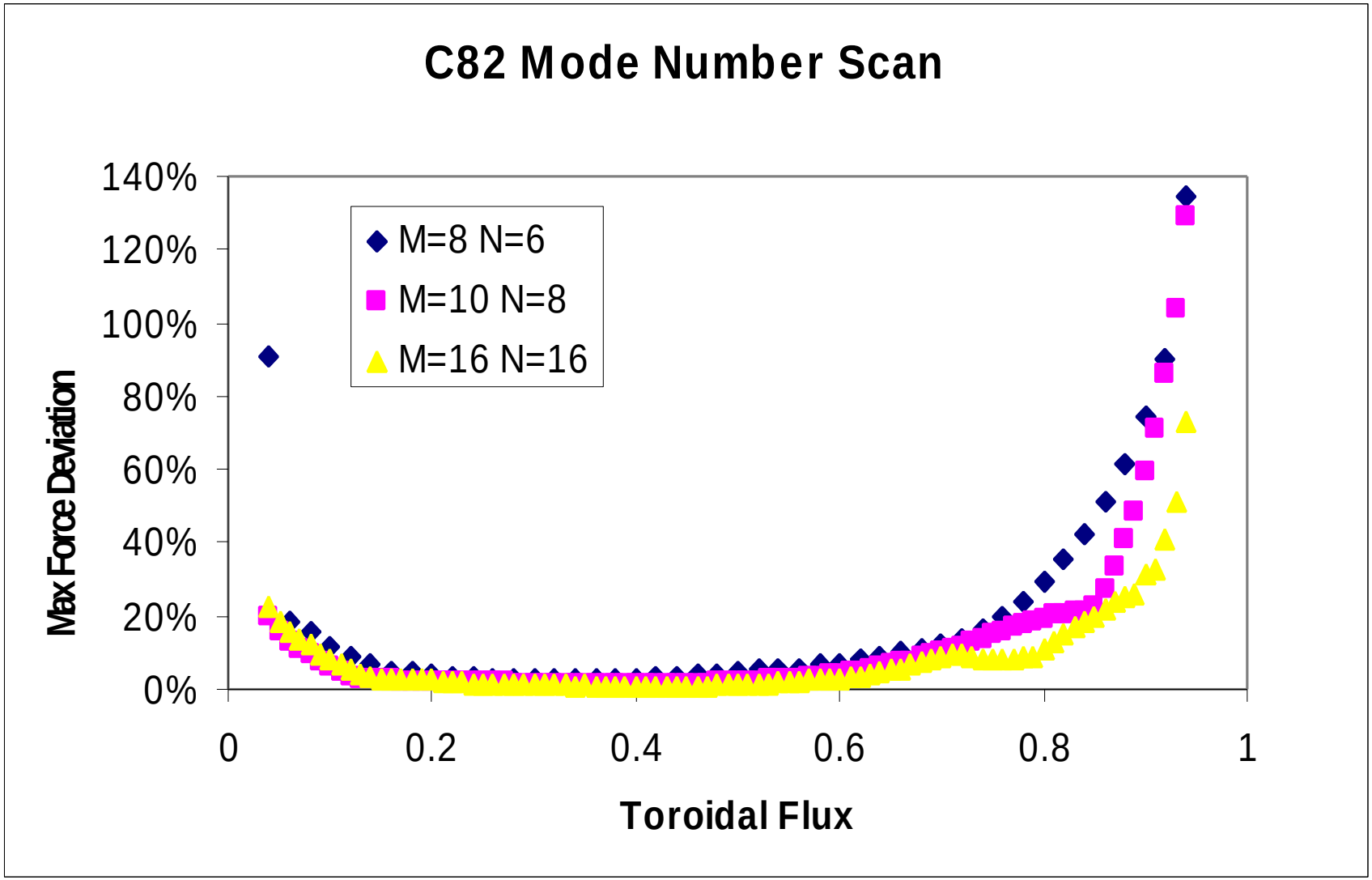
- Look for $g_{mn} = 0$ at rational surfaces

Breakdown of ***local*** force balance seems to depend on *A*

- Look at deviation from j X b - grad p = F for c82 (full current/beta) as function of aspect ratio
- Observe rise in required number of Fourier modes with lowering *A*: will it ever converge
- Can we correlate this lack of force balance with physical “stochastic sea” - is it telling us something?


C82 : Maximum Force Balance Deviation
(rel. to p'): m=8 n=6 ns=51
140%
120%
100%
80%
60%
40%
20%
0%
A=3.4
A=5.0
A=7.7
0
0.2
0.4
0.6
0.8
1
Toroidal Flux


C82: Weak Radial Grid Dependence
(improves origin, not edge)
140%
120%
100%
80%
60%
40%
20%
0%
Max Force Deviation
0
0.2
0.4
0.6
0.8
1
Toroidal Flux
NS=51
NS=101


C82 Mode Number Scan
140%
120%
100%
80%
60%
40%
20%
0%
Max Force Deviation
M=8 N=6
M=10 N=8
M=16 N=16
0
0.2
0.4
0.6
0.8
1
Toroidal Flux

Improving Local Force Balance

- Solve radial component of JXB - grad p as magnetic differential equation for B_s :

$$B \bullet \nabla B_s = dp / ds + B^J dB_J / ds + B^j dB_j / ds$$

- May require SVD pseudo-inverse to avoid resonance if near rational surface
- Compare B_s spectrum with VMEC - if small deviation, equilibrium is “good”.