High beta simulations of MST

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NIMROD meeting Chicago
Nov. 6, 2010

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Finite pressure effects in the RFP

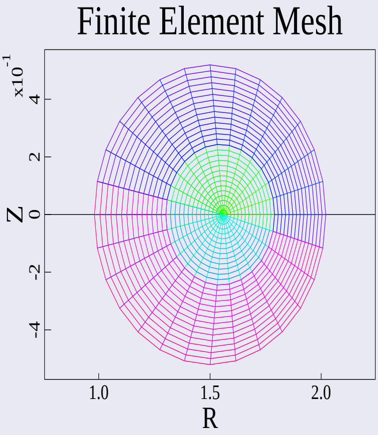
Experiment:

- The Mercier criterion parameter exceeds the stability threshold. No severe effect was observed in experiment.[M. Wyman et al. Phys. Plasmas 2008]
- Preliminary measurements show slightly higher low-n fluctuation level at high density (high pressure). New high beta experiments are underway.

Simulations:

- MHD simulations show that both localized and global pressure-driven modes remain resistive at betas several times the Suydam limit [Ebrahimi, Prager, Sovinec PoP 2002]
- Resistive interchange modes are unstable in **torus** and have growth rates close to cylindrical growth rates.
- FLR effects suppress the growth rates of interchange modes, however they are not completely stabilized.

NIMEQ solver is modified to read MSTFIT profiles.

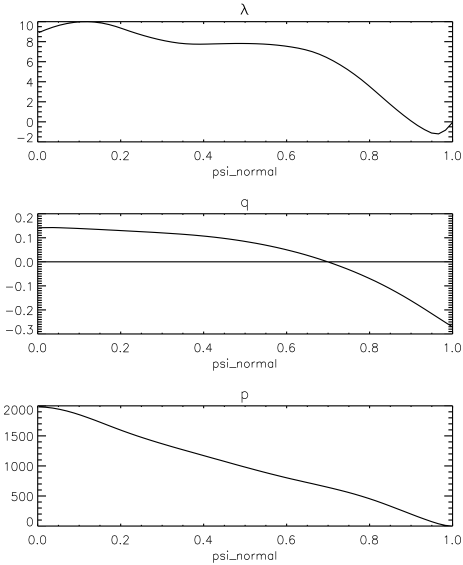


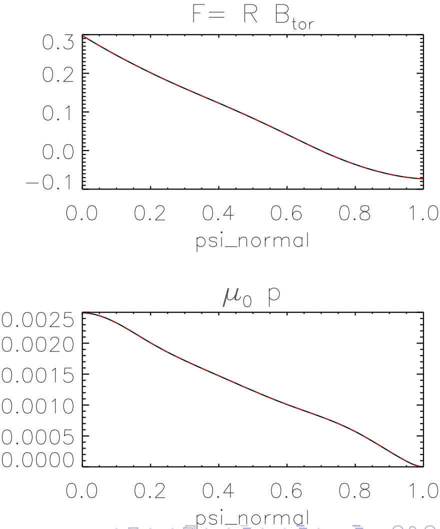
NIMEQ [Howell and Sovinec]

$$\Delta^*\psi = -F(\psi)F'(\psi) - \mu_0 R^2 P'(\psi)$$

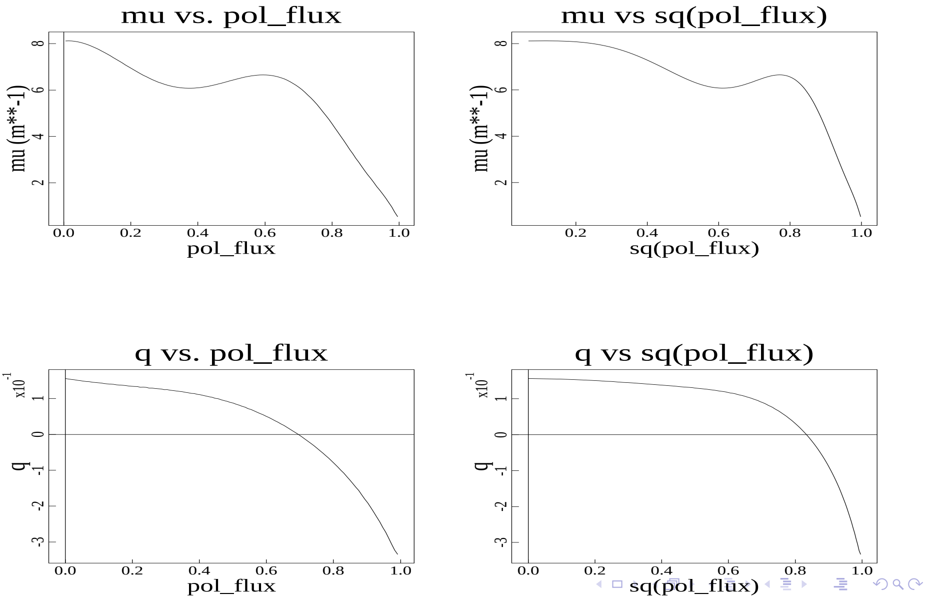
- $F(\psi) = RB_{tor}$ and $P(\psi)$ are polynomial functions. Coefficients are obtained using using least square fit to the data.

MSTFIT profiles (High beta - Mercier criterion exceeds the ideal stability limit)



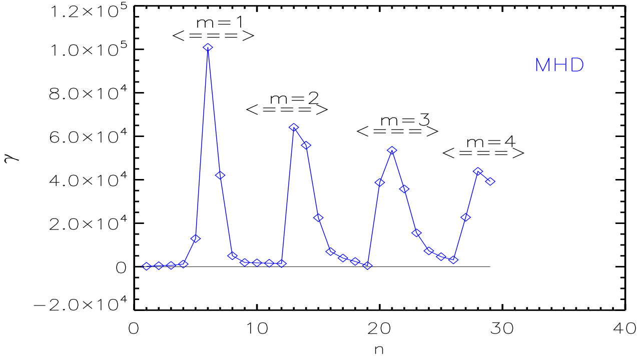


NIMEQ profiles



Resistive pressure-driven modes are unstable.

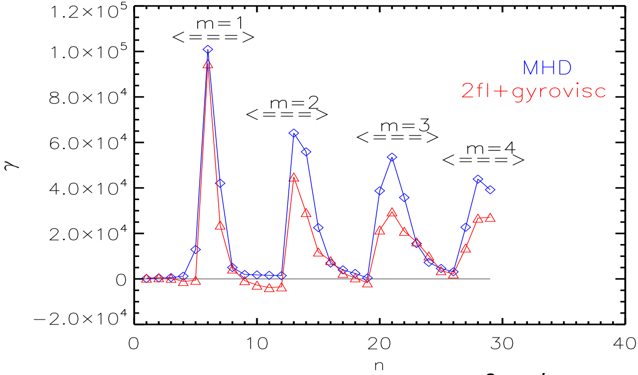
Linear growth rates



$\tau_A = 6 \times 10^{-7}$ sec, $S = 5 \times 10^5$, $n = 2.7 \times 10^{19} m^{-3}$.

- Global pressure-driven m=1 modes have tearing parity.
- Pressure-driven $m > 1$ modes have interchange parity.
- MHD toroidal growth rates are close to the cylindrical ones.
- Modes with max growth rates are resonant around r/a=0.32 (q=1/7)

The growth rates of interchange modes are reduced by 2-fluid and gyroviscosity.



- Ideal stability for $\omega^* > 2\gamma_{\mathrm{mhd}}$ or $k\rho_i > \frac{2\gamma_{\mathrm{mhd}} L_p}{v_T}$

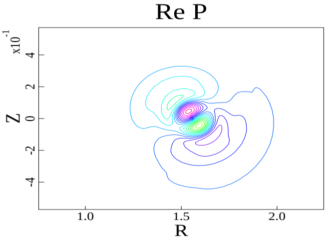
  where $\omega^* = k\rho_i v_T / L_p \sim 5 \times 10^4$

2-fluid $\mathbf{E} + \mathbf{V} \times \mathbf{B} = \eta \mathbf{J} + 1/ne\mathbf{J} \times \mathbf{B} - 1/en\nabla P_e + m_e/e^2 n\partial \mathbf{J}/\partial t$

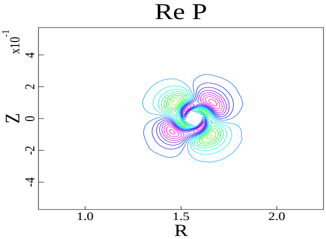
gyroviscosity $\rho(\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V}.\nabla \mathbf{V}) = \mathbf{J} \times \mathbf{B} - \nabla P - \nabla.\Pi$

2-fluid mode structure has signature of diamagnetic rotation

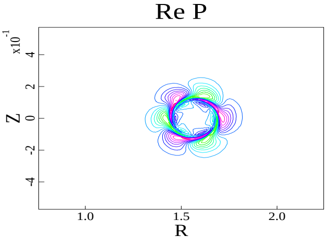
n=6



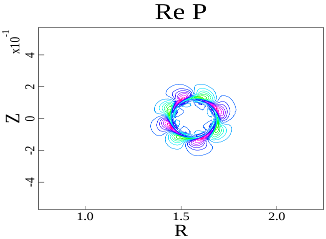
n=13



n=21

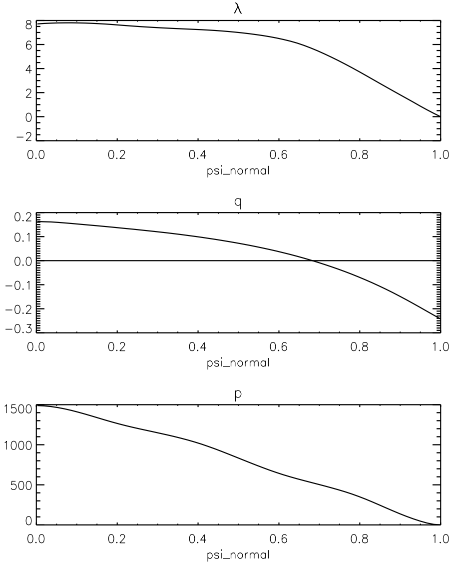


n=28

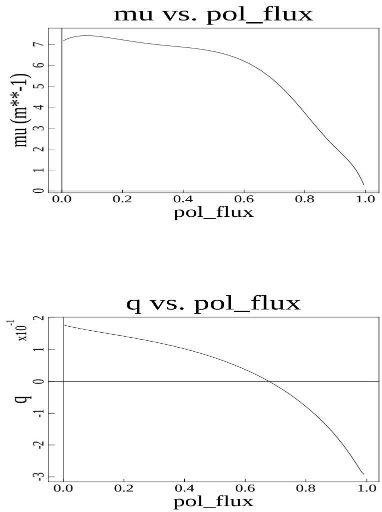


MSTFIT profiles (low beta - ideally stable)

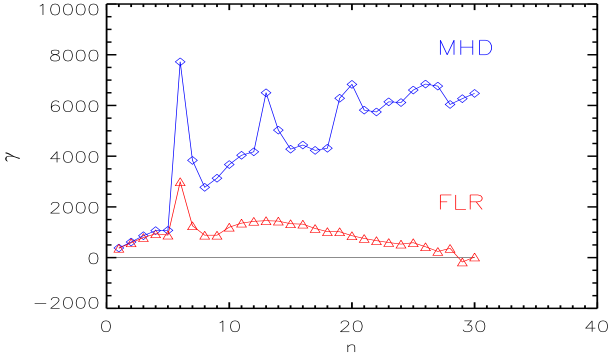
MSTFIT profiles



NIMEQ profiles



Linear growth rates

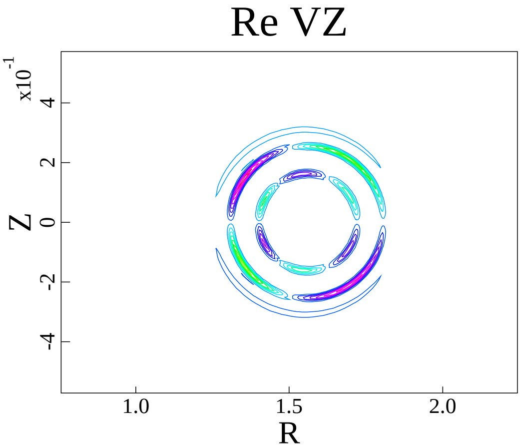


$\tau_A = 6.6 \times 10^{-7}$ sec, $S = 8 \times 10^5$, $n = 3 \times 10^{19} m^{-3}$.

- All n's are unstable, growth rates are small ($\gamma\tau_A \approx 1.e - 3$)
- For a particular n, azimuthal mode numbers m=1,2, 3 could be unstable

Mode structure

Mode structure for n=21 which is resonant at three different radii with azimuthal mode numbers m=1, 2, 3



Summary

- Resistive interchange modes are unstable in torus and have growth rates close to cylindrical growth rates.
- FLR effects suppress the growth rates of interchange modes, however they are not completely stabilized for high beta plasma in MST.
- Gyroviscosity also has strong stabilizing effect on the resistive modes at lower beta plasmas in MST.