NSTX

Supported by U.S. DEPARTMENT OF ENERGY Office of Science

Generation and Sustainment of Rotation in Tokamaks

Joint NSTX/DIII-D talk

Wayne Solomon, PPPL

and the NSTX Research Team

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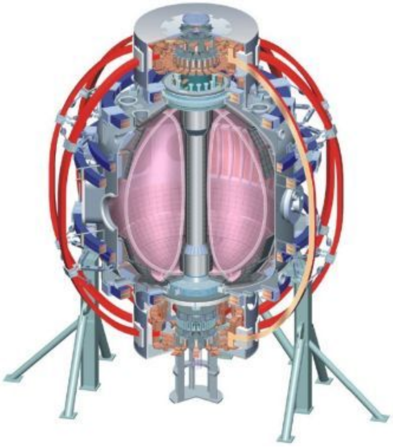
APS invited talk discussion
April 23, 2009



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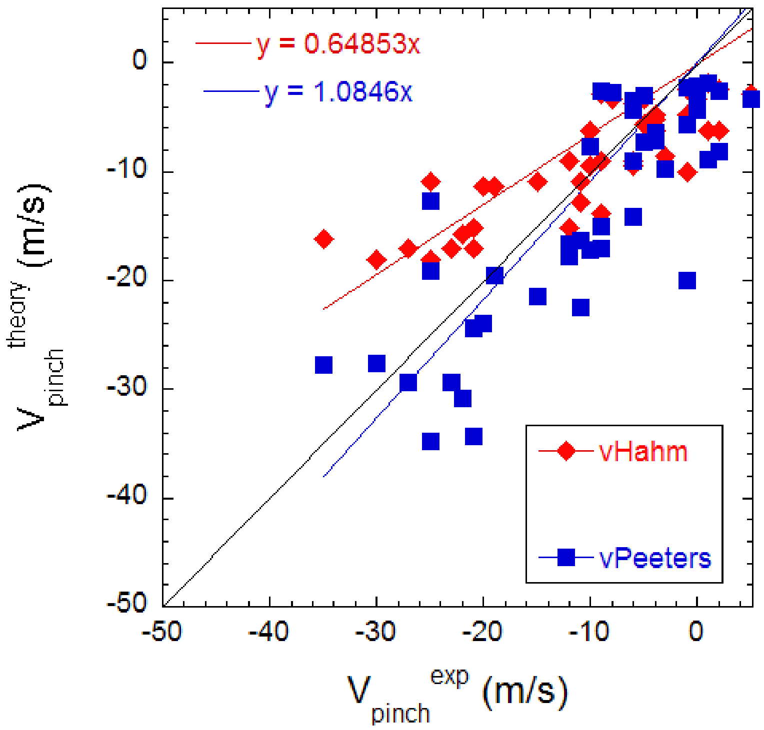
Key themes

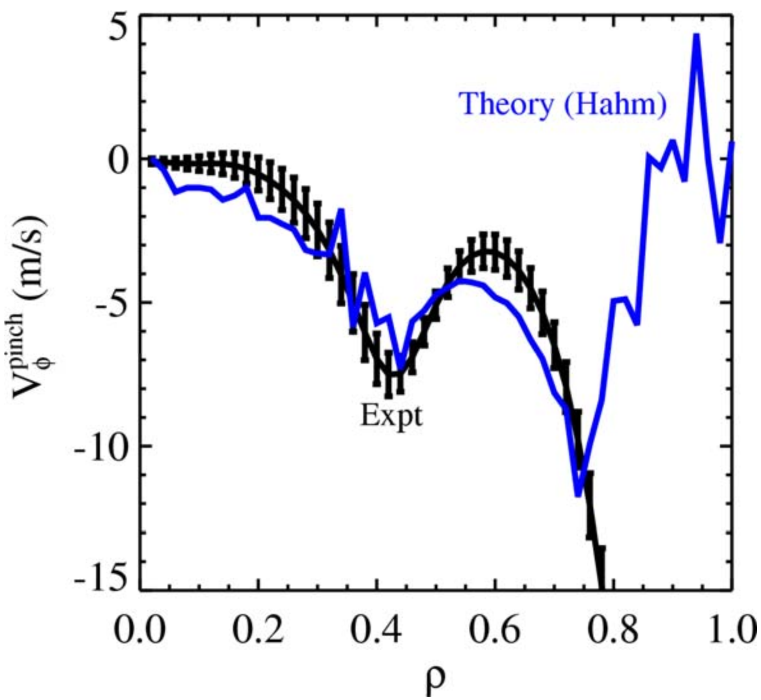
- Existence of momentum pinch velocity and compatibility with simple theoretical model
  - Momentum pinch affects peakedness of rotation profile in plasmas with limited external torque
- Comparisons of momentum transport with neoclassical and/or gyrokinetic simulations
- Intrinsic rotation generation through “residual stress”
- Perhaps include effect of rotation on confinement?

Reasonably Good Agreement Between Theory and Experiment on both NSTX and DIII-D

- Theory predicts drive of momentum pinch through low-*k* turbulence
  - Hahm *et al*. PoP (2007), Peeters *et al.* PRL (2007)

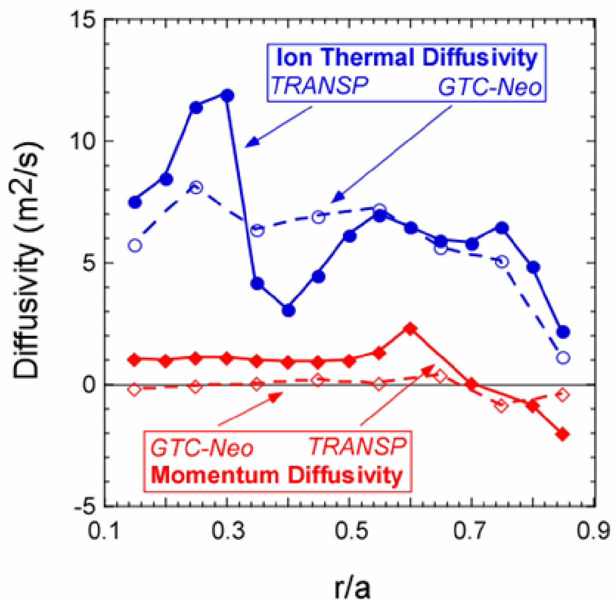


NSTX

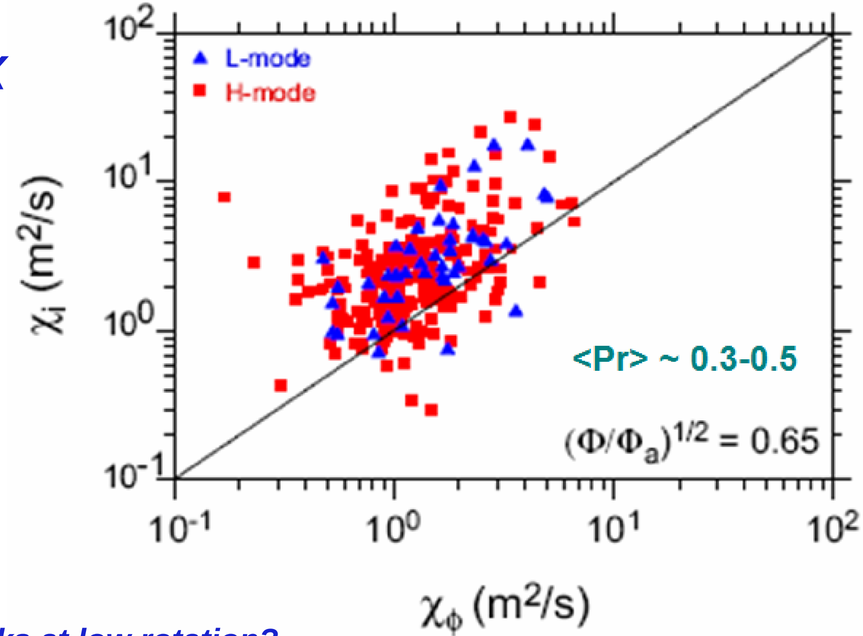


DIII-D

Correlation between momentum and ion thermal diffusivity seen at high and low aspect ratio

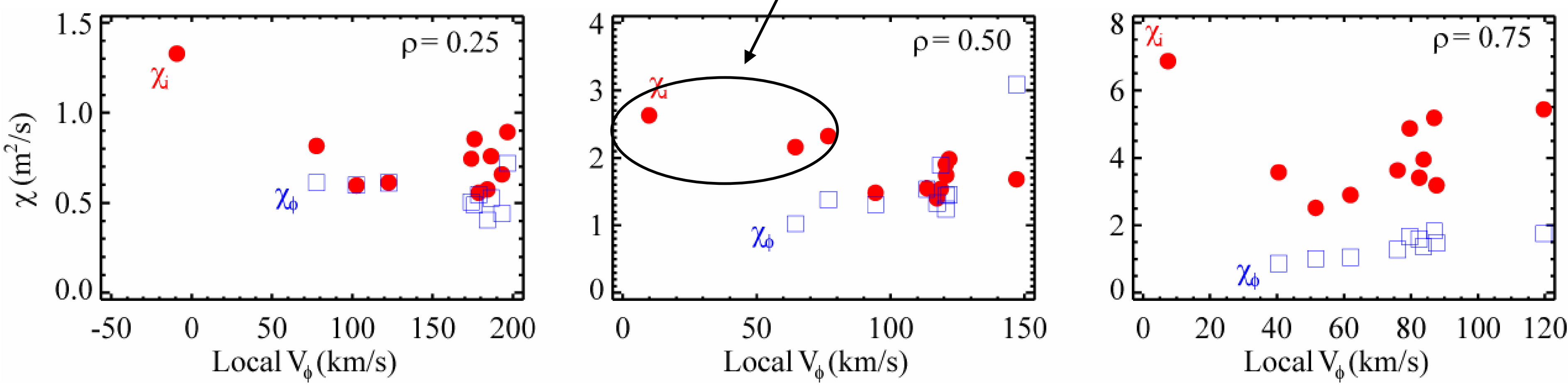


NSTX



DIII-D

•*Relationship breaks at low rotation?*



Effective torque ("residual stress") associated with intrinsic rotation measured

- From momentum balance equation

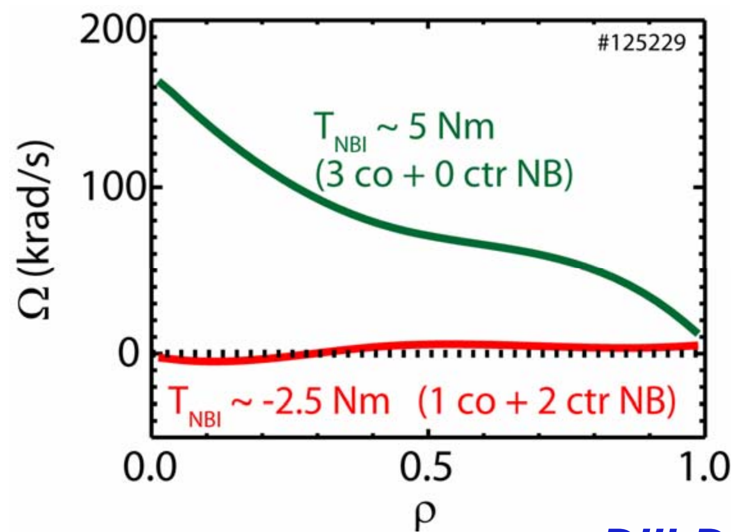
$$\underbrace{\cancelto{0}{mnR\frac{\partial V_\phi}{\partial t}}}_{\text{Rate of change of momentum}} = \underbrace{\sum\eta}_{\text{Momentum sources/sinks}} - \underbrace{\cancelto{0}{\nabla\cdot\Gamma}}_{\text{Transport}} + \underbrace{S}_{\text{"Intrinsic source"}}\ , \quad \Gamma = -mnR\left(\underbrace{\cancelto{0}{\chi_\phi\frac{\partial V_\phi}{\partial r}}}_{\text{diffusion}} - \underbrace{\cancelto{0}{V_\phi V_{pinch}}}_{\text{pinch}}\right)$$

- If V_ϕ zero and constant, then net torque to plasma must be zero

- Intrinsic source must cancel NBI torque

$$\eta_{NBI} + S = 0 \quad \rightarrow \quad S = -\eta_{NBI}$$

- Evidence of residual stress?
  - **Gurcan, Diamond, Hahm et al PoP 2007**



DIII-D

NSTX and intrinsic rotation and/or residual stress?

- Crystal X-ray spectrometer measurements?
- GTS simulations of residual stress?
- Measurements in reverse Ip?
  - Moderate stored energy with RF
  - Measure intrinsic rotation
  - Apply (counter) NBI torque to slow rotation
  - Characterize residual stress

Generation and Sustainment of Rotation in Tokamaks

W.M. Solomon, Princeton Plasma Physics Laboratory

Recent experiments on DIII-D and NSTX have led to new discoveries related to the development of the rotation profile, including evidence for an effective torque responsible for "intrinsic rotation" generation, and the existence of a strong inward pinch of angular momentum. Rotation has been recognized as an important tool for improving confinement and stability in fusion plasmas. Recently, signficant effort has been invested to understand the generation mechanisms for intrinsic rotation, since future burning plasmas are anticipated to have limited external angular momentum input. Measurements show that the intrinsic rotation is driven by an effective torque in the co-current direction, whose profile is largely localized toward the edge. This shows consistency with theoretical models of non-diffusive momentum transport such as the "residual stress", driven for example by the turbulent Reynolds stress. New data show that this effective torque can be modified by electron cyclotron heating, surprisingly resulting in a counter torque inside of the deposition radius. Experiments on both NSTX and DIII-D have demonstrated the existence of an inward momentum pinch of up 40 m/s, showing quantitative agreement, both in magnitude and profile shape, with theoretical predications originating from consideration of low-k turbulence. These results are important, since the peakedness of the rotation, and potential benefit associated with ExB shear, is determined by the inward pinch of angular momentum in the absence of external torque. In plasmas with large rotation and strong ExB shear, ion thermal transport can be reduced to neoclassical levels; however, diffusive momentum transport still remains highly anomalous. The common physics of momentum transport between the two devices is being investigated.