The HSX Experimental Program

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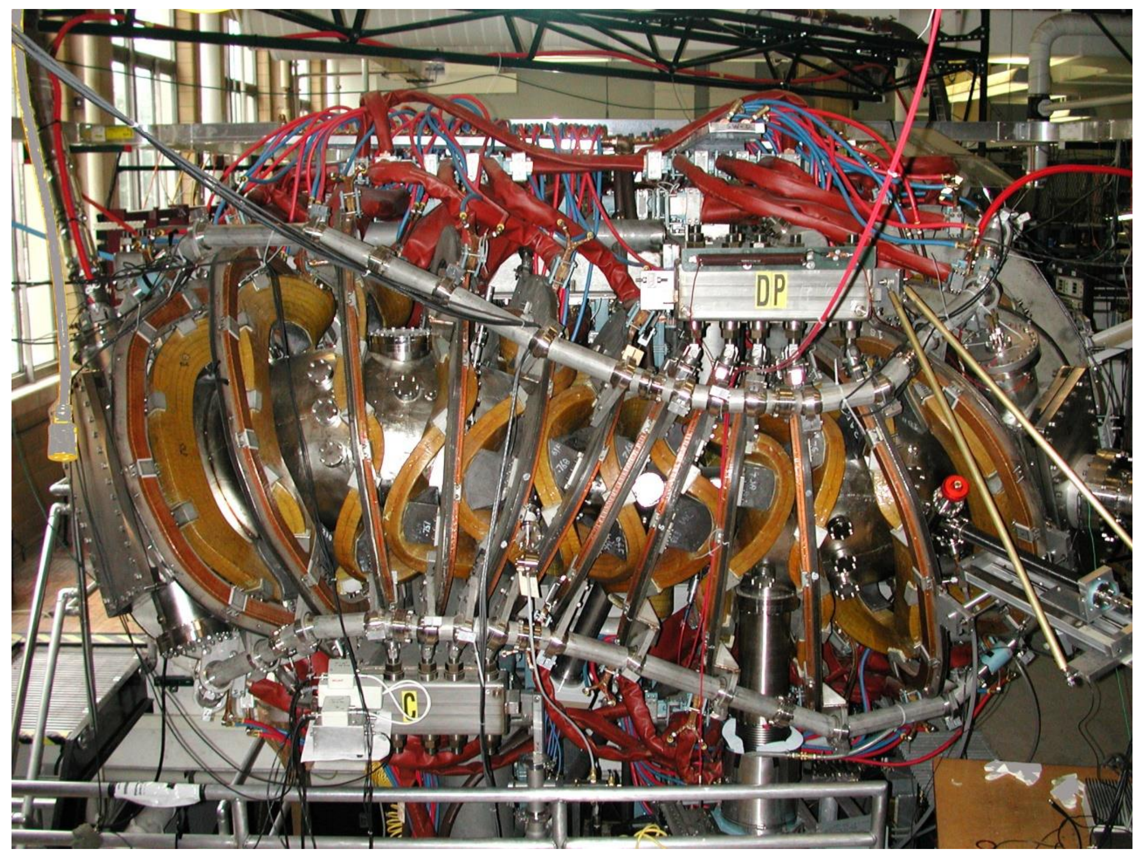
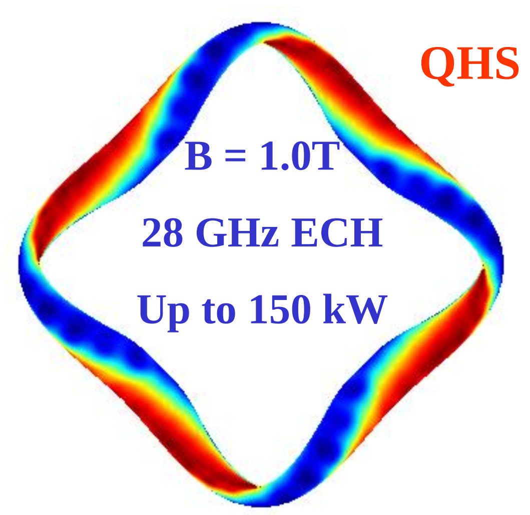
Program

HSX – Designed to demonstrate the potential benefits of quasisymmetry in general, and specific properties of quasihelical symmetry

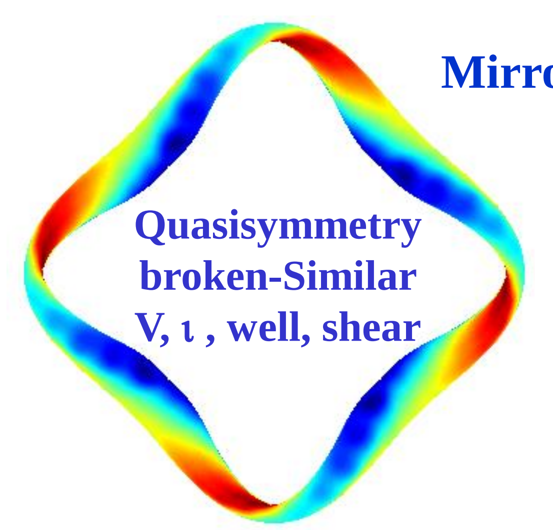
•HSX has resumed operation after repairs to a failed coil feed region, reinstallation and alignment, and redesign of an improved coil feed was implemented on all coils.
•Measurements of the Bootstrap current and the helical nature of the Pfirsch-Schluter current have been made and compare well to calculations from V3FIT.
•Strongly peaked electron temperature profiles and large positive radial electric field and flow predictions support the presence of a neoclassical central transport barrier (CERC) for QHS plasmas.
•Turbulent transport simulations reproduce full radial T_e profiles – thermal transport is dominated by ITG/TEM turbulence in the outer region and core ExB shear stabilization.

The HSX Stellarator





$$B = B_0[1+\varepsilon_h \cos(N - m\iota)\phi]$$



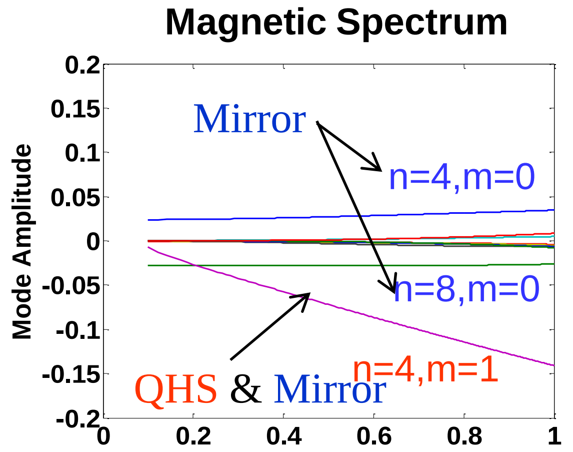
$$B = B_0[1+\varepsilon_h \cos(N - m\iota)\phi + \varepsilon_M \cos(N\phi)]$$

HSX has a helical axis of symmetry in |B|, low magnetic field ripple, high effective transform, and very low toroidal curvature

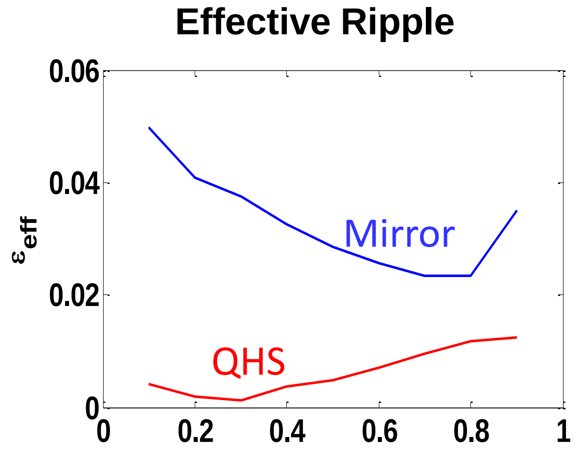
- Reduction of direct loss orbits
- Improvement in low ν neoclassical transport
- Small viscous damping of plasma flow

For experimental flexibility, the quasi-helical symmetry can be broken by adding a mirror field.

Magnetic Spectrum



Effective Ripple

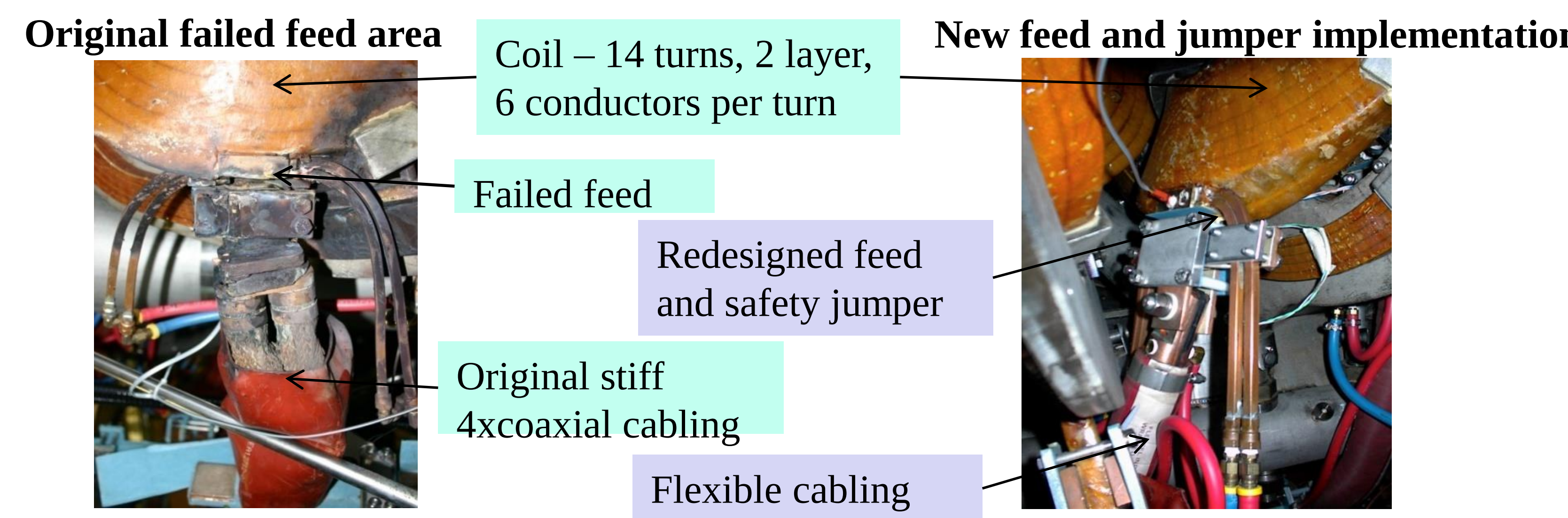


Parameters

<R>	1.2 m
<a>	0.12 m
ι	1.05 →1.12
B_0	0.5 -1.0 T
ECRH 28 GHz	<150 kW

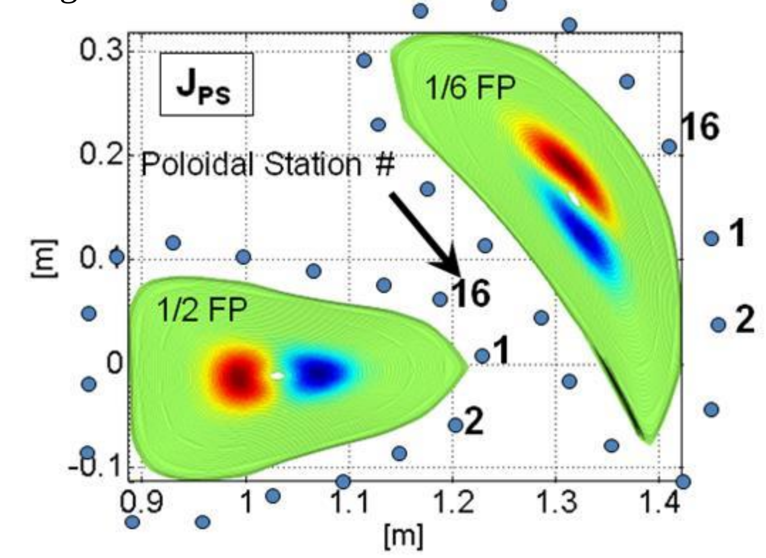
Coil repair and Feed/Bus Redesign

One coil feed failed under 1Tesla operation – 11kA/turn, 14 turns/coil, current risetime 1 second.
•High mechanical stress caused by non flexible cable to bus connection
Failed area repaired, and new feed and cabling implemented on all 48 coils
•Water cooled flexible cables, with internal triplet of twisted pair conductors
•Safety jumper from cable to central coil-pack conductors (2 out of 6) can carry load under main feed failure

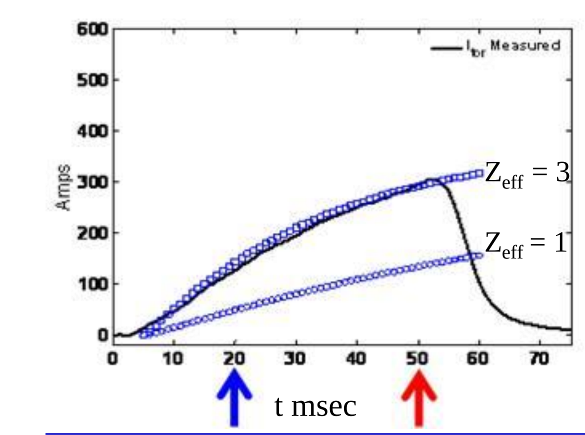


Current Measurements (J Schmitt)

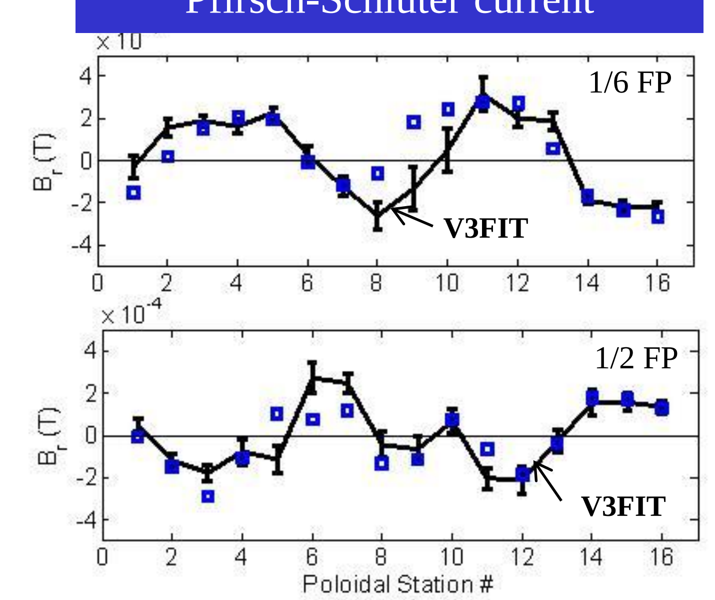
•An array of 16 3-axis pick-up coils are used to measure the current evolution at two toroidal locations
•Magnetic signals are analyzed using the V3FIT code suite for 3D toroidal device equilibrium reconstruction
•Pfirsch Schluter currents calculated from VMEC using measured Thomson scattering T_e & n_e profiles – helical nature demonstrated by B_r phase at 1/6 and 1/2 Field Period locations
•Bootstrap current calculated using BOOTSJ code – evolves on a slower timescale seen by increasing B_0 offset, magnitude and direction consistent with V3FIT calculation



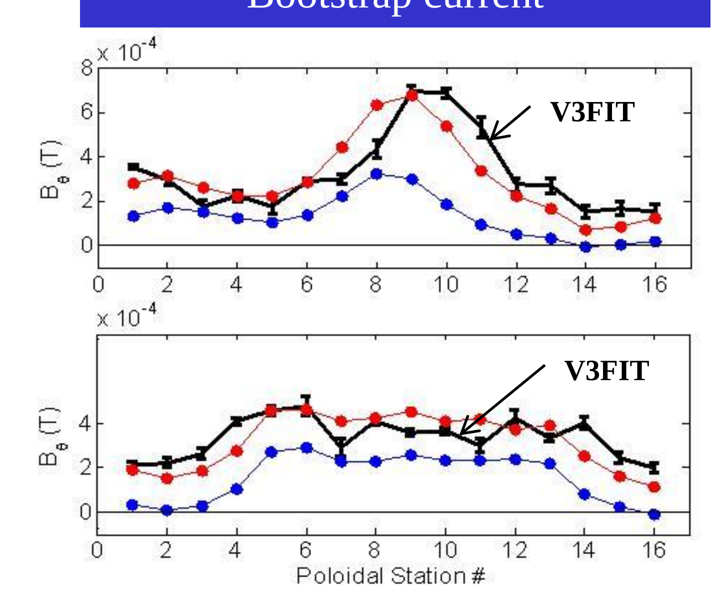
Measured toroidal plasma current



Pfirsch-Schluter current

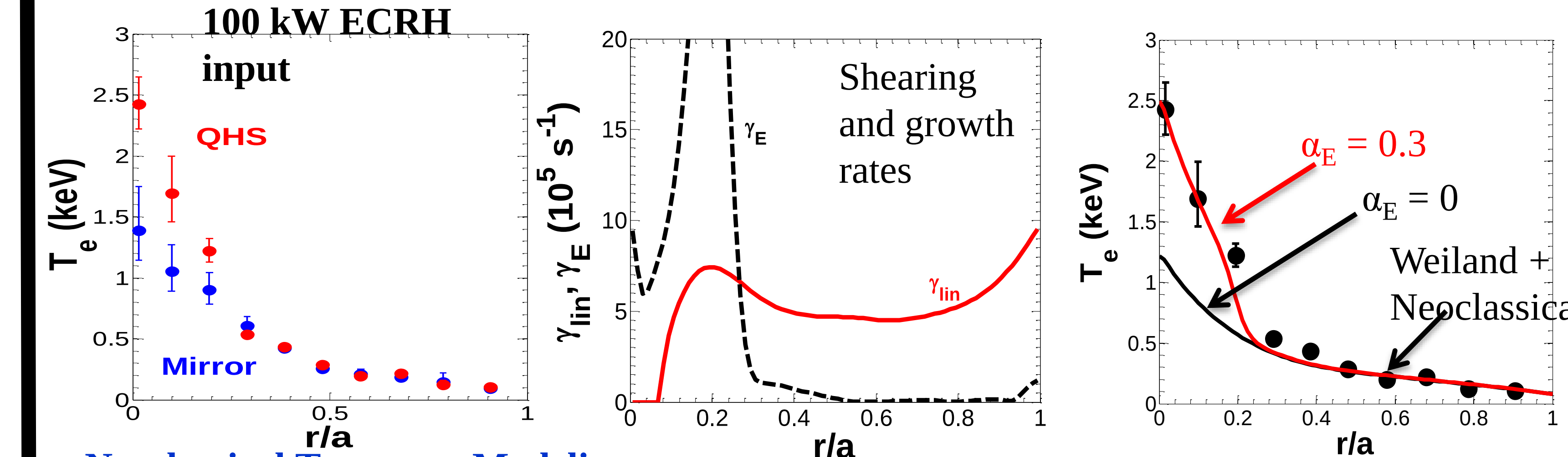


Bootstrap current



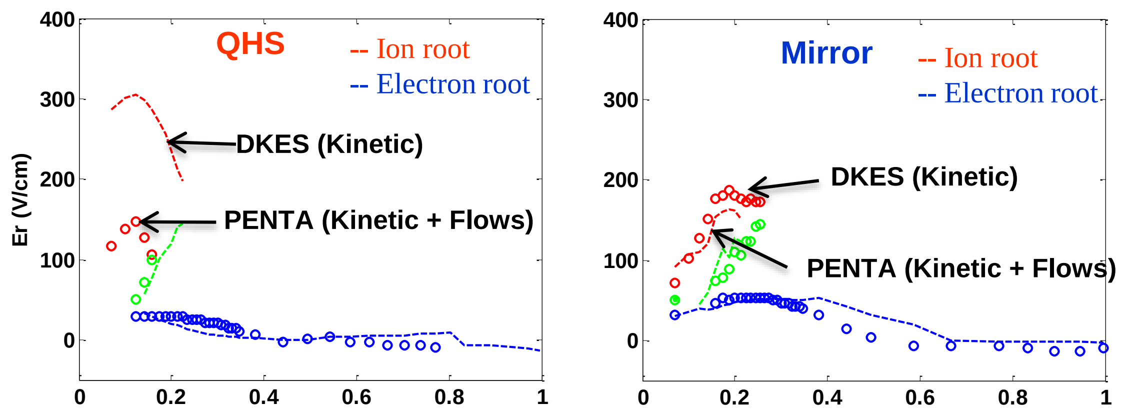
Neoclassical and Anomalous Thermal Transport (J. Lore)

1 T Profile Comparison
•Electron temperature profiles are strongly peaked in the core in QHS
•Steep temperature gradient is evidence of Core Electron Root Confinement (CERC) in QHS configuration
Quasi-linear Weiland model has been used to model turbulent transport
•With local geometry considerations, good agreement with 3D gyrokinetic GS2 results.
ExB shear turbulence suppression needed to model core heat transport
•Including E_r shear and quench rule in model can explain T_e peaking.



Neoclassical Transport Modeling

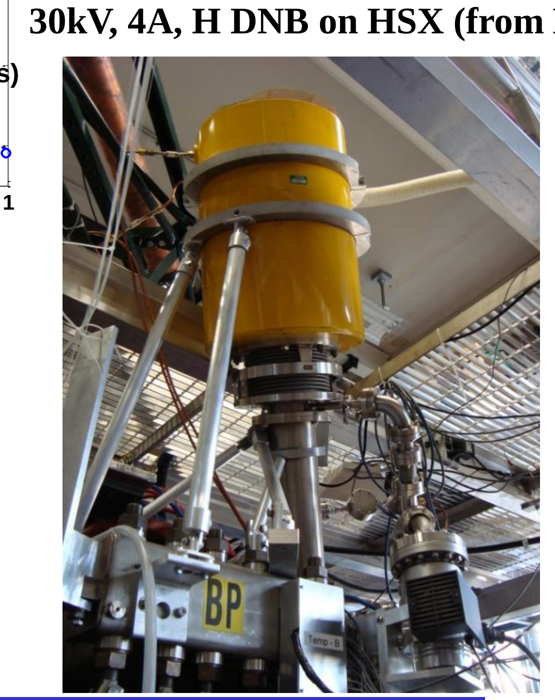
The PENTA code (D. Spong) calculates the neoclassical fluxes and flows using a momentum conserving collision operator.
•The QHS configuration has reduced flow damping due to the direction of symmetry in the magnetic field strength, has larger parallel flows, and significant E_r (but significantly reduced from DKES calculations)
•The Mirror configuration, without a direction of symmetry, does not show these effects – more like a conventional stellarator.



E_r measurements through ChERS (A. Briesemeister)

Measurements of the Electric field radial profile are crucial
•To verify CERC in QHS using radial force balance on C_{VI} emissions
•To verify PENTA application to neoclassical transport in stellarators with momentum conservation and flow
•To examine **ExB** shear suppression of instabilities and bulk flows
A ChERS system has been implemented and is hoped to soon provide this information

30kV, 4A, H DNB on HSX (from MST)



Future Plans and Directions

Extend plasma current studies
•Internal toroidal and poloidal b-dot pickup arrays have been implemented for better time response and broader machine and field-period coverage
•Include E_r in Current magnitude calculations, and improve bootstrap current modeling.
Continue examination of transport barrier, E_r, flows and neoclassical and anomalous transport
•Electric field measurements through ChERS in QHS and Mirror and under scaling studies
•Microwave reflectometer to obtain density fluctuation profiles
•16 channel ECE system to look for electron/ion root jumping and temporal T_e evolution
•Density and power scans to look for threshold behavior
•Examine effects of non resonant fields on flows in helically symmetric system
Expanded operational capabilities
•Implement a profiled graphite limiter for plasma control and edge recycling and edge interaction studies (C. Clark poster) - ORNL collaboration on EMC3/EIRENE
•Implement second ECH gyrotron with steerable launch capabilities, and improve modeling (J. Radder poster)
•Implement ICH to enter Ion root in core – effects on confinement and flows - ORNL collaboration

50th Annual Meeting of the Division of Plasma Physics, November 17-21, 2008, Dallas, Texas