Introduction

MST (Madison Symmetric Torus) is a reversed field pinch confinement device. A 1 MW neutral beam has been installed on MST. Operation of the beam into MST began in February, 2010.

Thomson Data shows no heating during standard plasmas, consistent with zero heating of bulk ions in standard plasmas. However, raw data shows that the Rutherford results are for additional species (such as fast hydrogen). Raw data shows no heating during standard plasmas. Thomson data shows statistically significant heating of electrons with the beam on during fast ion confinement times.

MST's 1 MW Neutral Beam

Basic Observations:
- Beam is well-centered and focused.
- Beam shine-through is typically only around 10%, but can rise to nearly 50% in low-density, high-temperature plasmas.
- Doppler broadening of the beam produces a measurable signal of ions that gives data on fast ion confinement times.

1-D Heating Model

We can write changes in stored energy to a heat flux in or out:

$$ W_f + P_f + P_{rad} + P_{abs} = W_f + P_f + P_{rad} + P_{abs} + \sum x_{VT}$$

where:
- $W_f$ is the ion and electron beam power.
- $P_f$ is the fast ion heating power.
- $P_{rad}$ is the radiation power.
- $P_{abs}$ is the absorption power.

We can create a 1-D heating model by assuming equilibrium with the NBI or, and solving for the appropriate heat diffusion coefficients.

Rutherford scattering data shows statistically significant heating of electrons with the beam on during fast ion confinement times. As the fast ions slow down and the electron temperature increases, the ratio of electrons to ions can project 40% of electron heating and 20% of ion heating.

Fast Hydrogen Complicates Rutherford Scattering Measurements of Ti

Rutherford scattered ions of 16 keV helium neutrals, which Coulomb scatter off of plasma ions. A detector at an angle relative to perpendicular measures the spatial intensity of incoming neutrals, which corresponds to a velocity spectrum of plasma ions.

Observation of NBI-Induced Electron Heating

Pulsed Poloidal Current Drive (PPCD) is a pulsed toroidal magnetic field that inductively drives poloidal current. This forces the current profile and reduces free energy that drives heating modes.

A 1 MW neutral beam can scatter out fast ion current. This results in a new temperature that is lower than the previous temperature.

PPCD Data Shows Significant Heating

As the fast ions slow down and the Rutherford signal decays, the ratio of electron heating vs. ion heating changes. This result is consistent with estimates done by TRANSP.