First results from a 4-channel charged fusion

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Introduction

• Determine the time dependent fusion rate profile
• Check of TRANSP simulations
• Study MHD instabilities: TAE, NTM, EPM, IRE
• Study effect of instabilities on fast ion redistribution and loss
• Probed ion distribution function weighted toward high energies, complements FIDA and ssNPA
• Expected to work well at high densities
• Cross check to total neutron rate measurements
Principle

Detect charged particles from:

\[ d + d \rightarrow p + ^3H \]

\[ d + d \rightarrow n + ^3He \]

dominated by neutral beam and plasma ion interactions

Advantage at NSTX and MAST:

- Proton/triton is not confined in the magnetic field of NSTX/MAST
- Proton/triton is quickly lost
- Trajectory similar to a view chord of neutral particle detection system
- Observed particle rate is a measure of the integrated emissivity along the trajectory path

Proton measurements have been carried out previously:
Particle Types:

- **Protons**
  - Highest energy (3MeV, p = 75 MeV/c, q = 1)
  - Easy to detector with surface barrier detectors
  - 100% efficient
  - Future: diamond detectors (less sensitive to radiation damage)

- **Tritons:**
  - Same orbit as protons (1 MeV, p = 75 MeV/c, q = 1)
  - More sensitive to electrical noise
  - Provide more statistics

- $^3$He:
  - Lowest energy (0.82 MeV, p = 67.9 MeV/c, q = 2)
  - Different orbits than tritons and protons
  - Provide additional orbit data

Focus on protons
Surface Barrier Detectors

- Commercially available Ortec/Canberra
- Bakeable (up to 200 C)
- Can be operated in UHV
- Have been used previously
- Good energy resolution (1%)

Detectors used: CU-014-050-100-S ULTRA by AMETEK/ORTEC
Original Prototype

- Prototype: 2 detectors
- Flexible orientation around 3 axes
- Study signals and rates
- Optimize detector arrangement and location for full array of 8 detectors
- Location: Bay K
- Mounted on moveable probe shaft
- IN-position: $R=1.7m, Z = 0.286m$

Could not be tested

Detector at $R = 1.7m$
Array can be move radially

Trajectories intersect mid-plane approx. vertically
The density ranges from 0.1 to 1 T and with plasma currents up to 1.3 MA; the plasma is 0.5 s long, with a toroidal field on the axis between 0.3 and 0.5. A typical discharge is approximately 2.6 m long, with a major radius of 0.85 m and a minor radius of 0.65 m capable of reaching plasma temperatures of 2–3 keV. Additional heating is provided by deuterium neutral beams co-injected with a tangency radius of 0.7 m. MAST is equipped with a wide set of diagnostics including two Thomson scattering systems for the electron density and temperature profile measurements.

In order to measure the neutron emissivity profile and its differences in efficiency between the detectors in the different sections, neutrons are collected charge for each recorded interaction. For pulse shape discrimination methods are applied in which neutron scintillators are sensitive to both gamma rays and neutrons to different locations on the rail in between pulses. The liquid emission profile monitor, also known as a neutron camera, has been recently installed and commissioned for the measurement of the current profile, a high time resolution magnetic fluctuations up to 250 kHz (standard coils) and up to 10 MHz (outboard Mirnov array high frequency acquisition).

Approx. location of probe arm

Central Orbits

Figure 1.
Acceptance: Poloidal

Central orbits
Radial Positions: +/- 3cm

Detector array

Integration region
(not weighted by acceptance)
Acceptance: Toroidal View
$^3$He Orbits

Very small $^3$He rate
$^3$He rate about 3 – 10 times higher than proton/triton rate
Proton Detector (PD)

4-channel system, each channel having a unique angular orientation.
PD Assembly

185 mm

Reciprocating Probe

110 mm

Particles

Detector with BN shield on

12/9/13

NSTX-U Physics Meeting December 2013
Cross-Sectional View

Particle trajectories

Collimator
SSB detector
BN heat shield