A Nuclear Fusion Instrument Studying Plasma Instabilities in Support of ITER

Fusion research supports the need for new safer and cleaner large-scale energy fusion facilities. A deep understanding of the physics of fusion plasmas (hot ionized gas) is necessary to make fusion energy production a viable alternative energy source. Confined plasmas in an equilibrium state are required to create and sustain the nuclear fusion reactions necessary to provide energy. Therefore understanding and controlling plasma instabilities negatively affecting the equilibrium are a vital research focus. Experimentally detecting particles affected by these plasma dynamics offers insight into theoretical models of plasma parameter fluctuations in current, temperature, pressure, and magnetic flux that can cause these instabilities. Product emission profiles (containing information on the location and rate of products that have been created in the plasma) are of great importance in validating these models as evidence of these instabilities can be seen in the distribution of fusion products in space and time.

Magnetic confinement devices called spherical tokamaks are used to heat and confine plasmas. A tokamak's Neutral Beam Injection (NBI) of energetic atoms is of particular importance to bring plasmas to required temperatures (which are hotter than the center of the sun). During the NBI, my research will determine the time-dependent charged fusion emission profile from the deuterium-deuterium (DD) reaction. The instrument will detect energetic protons and tritons (charged products from the DD reaction); these ions are not confined as their gyroradius is on the order of the radius of the plasma. I will design, construct, assemble, and install a prototype instrument in the Mega Amp Spherical Tokamak (MAST) at the Culham Centre for Fusion Energy for initial testing and data collection in 2013.

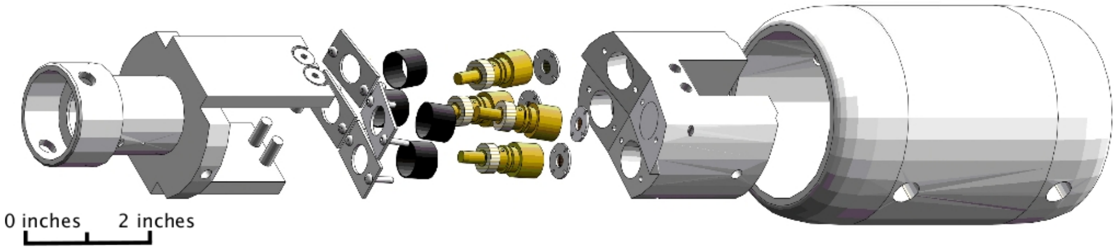

Figure 1: My instrument design concept.

The mechanical design (Figure 1) to house the detectors takes into account thermal expansion, ultra high vacuum requirements, and x-rays and light emitted from the plasma. Simulations used to calculate particle trajectories determine the detector orientations. Electronics appropriate for electromagnetically noisy environments as well as custom-written software will be used to digitize data at a rate of 60 MHz. Data analyses will reveal pulses (created by protons and tritons) to be integrated and counted for comparison to MAST global particle yield rates. Simple models for the function describing the emission profile will be fitted to this first set of data.

Worldwide, magnetic confinement devices are transitioning to higher plasma densities and reaction rates to probe physics regimes necessary to develop the International Thermonuclear Experimental Reactor (ITER). These upgrades, however, will result in current neutron emission profile instruments losing data resolution. The need for novel techniques to study emission profiles without losing resolution will be met by my instrument, which will actually have increased resolution with higher reaction rates. With less than one decade before the largest worldwide effort to demonstrate the power of fusion energy in ITER's first plasma, I aspire to the advancement of fusion research.

I am excited to present my research contribution to Edwin and Marion Link's legacy.