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Status of the high-resolution magnetic proton recoil neutron spectrometer for SPARC burning plasma diagnosis

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This contribution presents the status of the magnetic proton recoil (MPR) neutron spectrometer being developed for SPARC, a high-field tokamak under construction in Devens, MA, USA expected to achieve burning plasma conditions and produce up to 140 MW of DT fusion power. This high-resolution neutron spectrometer will enable critical measurements core plasma performance, including ion temperature, fuel ion ratio, nonthermal fusion due to radio frequency and alpha heating, and an independent measure of the total fusion power. The MPR views the plasma core along a radial midplane line of sight defined by a 3 cm diameter collimator through the tokamak hall wall, and constitutes the central line of sight of the poloidal neutron camera. Collimated neutrons are incident on a thin polyethylene conversion target, located 16 m from the plasma, where they scatter elastically on protons. A target swapping mechanism is planned to enable shot-to-shot selection of conversion target geometry, giving flexibility to tailor the sensitivity-resolution trade off to meet a variety of experimental conditions and goals. Forward scattered protons receive up to the full neutron energy and are selected by an aperture to enter an ion optical beamline consisting of 3 electromagnets which focus and disperse protons according to their momentum. Thanks to its electromagnetic design, the spectrometer can be tuned to observe the neutron spectrum from 1-20 MeV, with an energy bite of ±25% of the chosen central energy. The beamline has been optimized to correct nonlinear ion optical aberrations, achieving an ion optical energy resolution $dE/E < 1\%$ over much of the energy bite. The magnets are currently being manufactured by Buckley Systems, and the mechanical design gives excellent agreement to the idealized ion optical calculations. The focal plane of the beamline is tiled with plastic scintillators whose dimensions are optimized to maximize the signal-to-background ratio. We present calculations of the instrument response function and quantify the performance of the spectrometer's operating modes in terms of energy resolution, sensitivity, and signal to background ratio.

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