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The Beam Development from the Cyclotron to Iso-center of Gantry for Proton Therapy System at CIAE

Abstract The proton therapy system based on 230 MeV superconducting cyclotron is under development at China Institute of Atomic Energy. The system consists of a 230 MeV superconducting cyclotron, an energy degrader and energy selection system (ESS), a transport beamline, a 360° rotation gantry and a beam delivery system. During the beam commissioning, the energy of 242 MeV proton beam was extracted from SC cyclotron. Then two quadruples focus the beam to form double-waist and symmetrical size around the location of degrader. The steering magnets adjust the beam centering for the degrader and beamline. Then in middle of ESS, the chromatic dispersion reaches to maximum. Momentum slits limit the momentum spread within ±0.5% to ensure the bragg-peak curve maintain a sharp peak. The ESS section is an symmetric achromatic system, and keep the energy dispersion unchanged after ESS. The percent depth dose curves for 30 energy points are precisely measured after ESS section to establish correlation between dipole current and range in water. Then the periodic transport beamline transports beam to treatment room entrance, with identical beam phase parameters and low loss, thus the beamline setup could be duplicated for each room. The periodic transport beamline contains minimum quads, with transform matrix to form phase ellipse π rotation. Then the beam reaches the gantry through the achromatic switching section. Since the gantry beamline rotates, the beam parameters should be identical in various directions. The beam here is calibrated to be a double-waist, with symmetrical size and divergence. Since the clinical requirements of spot size at ISO vary for each energy, redundant number of quadruples in switching section are used to optimize spot size at gantry entrance. The gantry beamline is designed to be point to point imaging, with a constant magnifying factor 1.6. Beam spot size at ISO is exactly proportional to spot size at gantry entrance. Thus, the beam optics of rotating beamline completely decouples with gantry angle. At the ISO plane, the 1 sigma beam size is calibrated to be 3.5mm（230 MeV）and 6mm（70 MeV），and beam sizes vary continuously for energies in between. By scanning magnet and bend/steering magnet calibration, the spot position errors fall within 0.5mm (1 sigma) for all gantry angles. By system calibration, basic beam performance parameters (range， spot size， spot position) are precisely measured and calibrated to meet clinical requireents. More other performance parameters calibrated and optimized will be also described in this paper.

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