Recent advances in laser technology have made proton (light ion) acceleration possible using laser induced plasmas. In this work, we investigate the design of a new proton therapy system for radiation oncology. The system employs laser-accelerated protons. If successfully developed, the new system will be compact, cost-effective and capable of delivering energy- and intensity-modulated proton therapy (EIMPT). Since laser-accelerated protons have broad energy and angular distributions, which are not suitable for radiotherapy applications directly, we have designed a compact particle selection and beam collimating system for EIMP beam delivery. We also proposed a new gantry design to make the whole system compact and easy to operate. We have performed particle-in-cell (PIC) simulations to investigate optimal target configurations for proton/ion acceleration. We also performed Monte Carlo simulations to study the beam characteristics. A fast dose calculation algorithm has been developed for pre- and post-optimization dose calculation. We have compared prostate dose distributions using photon IMRT, conventional proton beams and EIMPT. Our results show that EIMPT using laser protons provided identical plan quality as ideal monoenergetic protons with superior target coverage and much reduced critical structure dose and integral dose. EIMPT is more dosimetrically advantageous than photon IMRT or conventional proton beams.