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Implementing Capillary Design for Reliable VHEE Beam Delivery

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Very High Energy Electron (VHEE) radiotherapy is gaining attention for its potential to revolutionize cancer treatment [1]. VHEE employs high-energy electrons (~250 MeV) accelerated to extremely high speeds, which are precisely targeted at deep-seated tumors. This method offers significant penetration and optimal dose distribution, effectively targeting tumors while sparing healthy tissues. The precision of VHEE supports high dose-rate irradiation, promising improved treatment outcomes and fewer side effects. However, the widespread adoption of VHEE is currently limited by the availability of hospital-scale accelerators, a challenge being addressed by advancements in high-gradient laser-plasma accelerators (LPAs) [2].

Our proposed method focuses on accelerating electrons using lasers in capillary discharge [3] at I-LUCE (INFN-Laser indUCEd radiation production), a new laser facility in Catania, Italy. We are designing a capillary system there for generating electrons optimized for dual FLASH/VHEE modes. Different capillary geometries (length, diameter, channel shape) will be studied to enhance high-quality electron beam production.

Capillaries demonstrate exceptional capability in producing high-quality electron beams with precise energy control, despite requiring meticulous laser focusing and a complex setup. They effectively guide and confine laser pulses and plasmas over extended distances, facilitating higher acceleration gradients and superior control over beam emittance. The use of capillaries for e-LPAs holds particular promise for VHEE applications within the Laser Wakefield Acceleration (LWFA) scheme, enabling energies and fluxes reaching several GeV to be achieved [4]. Therefore, by leveraging the I-LUCE laser's characteristics—50-350 TW power, 1-7 J energy, 23-150 fs pulse duration, 10^17-10^19 W/cm^2 intensity, and 1-10 Hz repetition rate—along with a plasma density of 10^17-10^19 cm^(-3), we can produce electron beams with energies ranging from 0.1 to 3 GeV. These beams will have a charge of 30-400 pC and contain 10^8-10^9particles per pulse.

References

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Autore principale: Dr. ARJMAND, Sahar (INFN-LNS)

Coautore: Dr. SCIUTO, Alberto (INFN-LNS); Dr. PAPPALARDO, Alfio Domenico (INFN-LNS); Sig. HASSAN, Ali (INFN-LNS); Sig.na KURMANOVA, Alma (INFN-LNS); Sig. AMATO, Antonio (INFN-LNS); Sig. MANNA, Carmelo (INFN-LNS); Sig. OLIVA, Demetrio (INFN-LNS); Dr. ABUBAKER, Farmesk (INFN-LNS); Dr. FAROKHI, Fateme (INFN-LNS); Sig. VINCIGUERRA, Francesco (INFN-LNS); Dr. CIRRONE, GA Pablo (INFN-LNS); Dr. CUTTONE, Giacomo (INFN-LNS); Dr. PETRINGA, Giada (INFN-LNS); Sig. CANTONE, Giovanni (INFN-LNS); Dr. SUAREZ, Jose (INFN-LNS); Dr. GUARRERA, Mariacristina (INFN-LNS); Dr. CATALANO, Roberto (INFN-LNS); Dr. FATTORI, Serena (INFN-LNS)

Relatore: Dr. ARJMAND, Sahar (INFN-LNS)

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