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Development of beam monitors for Ultra High Dose Rate Radiotherapy

The paradigm of radiation therapy is the optimization of the therapeutic ratio, i.e. striking a balance between effectively damaging malignant tissue and preserving surrounding healthy tissue. Among the most promising developments are the treatment modalities exploiting the FLASH effect, a normal tissue sparing effect demonstrated in electron and proton irradiations at ultra-high dose-rate (UHDR) regimes, exceeding 40 Gy/s mean dose-rate in single fractions and lasting less than 200 ms. A large world wide effort to fully characterize the parameters triggering the FLASH effect is being carried on, aiming at validating the optimal future beam delivery to the patients.
The implementation of FLASH treatments poses several technological challenges to the established dosimetry and beam monitoring equipment. Standard transmission ionization chambers are not suitable in UHDR as they suffer from large ion recombination rate and slow response time and new technologies, or the adaptation of the existing ones, are still to be identified.

The medical physics group of the INFN and the University of Torino is developing a complete simulation tool able to describe the charge transport inside ionization chambers with varying dose-rate conditions. In addition, the response of solid state thin silicon and diamond sensors and studied as a possible alternative to gas detectors for monitoring the FLASH beams.
Tests using the LNL proton facility are highly desired as they would offer the possibility to:
1. validate simulations of ionization chamber signal responses to high-current proton beams, ensuring that numerical models accurately reflect the experimental data;
2. study the effects of signal distortion observed in silicon sensors in UHDR electron beams;
3. study the possibility to combine ionization chambers and solid-state detectors as an integrated technology, aiming at building a system able to cope with both electron and proton UHDR and conventional beams;
4. study the macroscopic effects of radiation damage on both solid state detectors and ionization chamber electrodes;
5. challenge all the electronic supply and readout chain at the high dose rates.

Primary authors: VIGNATI, Anna (Istituto Nazionale di Fisica Nucleare); FERRO, Arianna (Istituto Nazionale di Fisica Nucleare); MONTALVAN OLIVARES, Diango Manuel (Istituto Nazionale di Fisica Nucleare); DATA, Emanuele Maria (Istituto Nazionale di Fisica Nucleare); MAS MILIAN, Felix (Istituto Nazionale di Fisica Nucleare); MOSTARDI, Franco (Istituto Nazionale di Fisica Nucleare); CIRIO, Roberto (Istituto Nazionale di Fisica Nucleare); SACCHI, Roberto (Istituto Nazionale di Fisica Nucleare); GIORDANENGO, Simona (Istituto Nazionale di Fisica Nucleare); DE ASTIS, Stefano; DEUT, Umberto (Istituto Nazionale di Fisica Nucleare)

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