Time-of-flight based Prompt Gamma detection with TIARA

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Particle Therapy (PT) exploits the high ballistic precision of light ion beams to selectively irradiate tumours. With a sharp maximum (Bragg peak) at the end of their range, charged particles offer limited entrance dose and nearly zero dose deposition after the Bragg peak. These figures are ideal to deliver highly conformal irradiations, however, PT accuracy is still limited by multiple sources of uncertainties preventing the reliable prediction of the particle range in-vivo, especially in presence of anatomical modifications occurring between treatment planning and delivery.

Among the various techniques that are being proposed for particle range monitoring, Prompt Gamma Timing (PGT) potentially offers considerable advantages.
In PGT, the existing correlation between the incident ion path and the overall ion-plus-PG Time-Of-Flight (TOF) can be exploited to simply measure the ion range, or to retrieve a spatial information on tissue heterogeneities within the patient. The detection principle is trivial, requiring lighter and more compact detectors than other techniques, as no collimation system is necessary. The consequent higher detection efficiency and limited neutron background typical of PGT-based systems are expected to favourably impact on the technique sensitivity.
However, numerous limitations/challenges still remain to be addressed to fully exploit PGT potential, some of which are inherent to the technique while others are currently being overcome by different research groups.

Within our collaboration, we propose a novel prompt gamma (PG) detection system: TIARA, for Tof Imaging ARrAy. By employing Cherenkov radiators instead of conventional scintillators, the system achieves enhanced background rejection and improved time resolution, thereby increasing the signal-to-noise ratio. This improvement enables statistically significant particle range measurements with a reduced number of incident ions.
Simultaneously, we are developing an innovative reconstruction technique, PGTI (Prompt Gamma Time Imaging), to transform the measured TOFs into PG vertex distributions and, more importantly, to derive the ion velocity curve within the patient. This information could potentially enable TIARA to serve as the first detector for online dosimetry in the future.

Starting from the first proof of principle experiments, I will present the efforts that have been made to improve the detection system and its possible use to reduce PT uncertainties from treatment planning to treatment delivery.