deformations. The dose distribution is calculated using the time-dependent tetrahedral density map issued from 4D-CT scans (Petru Manescu, 2014). Unlike image-based methods, the deposited energy is accumulated inside each deforming tetrahedron of the meshes. An implementation of this dose computation method on a deformable anatomy in the case of a passive scattering beam line is demonstrated using the Geant4 code (Agostinelli, 2003). Besides, energy values in voxel-based structures are calculated for each time step and accumulated using the transformations provided by the registration. Then, values are accumulated back onto the reference image and divided by the mass to obtain the 4D dose map. Figure 1 illustrates the process used to accumulate dose in respiratory-induced simulations.

Results: The tetrahedral mesh dose distribution was compared to the conventional voxel-based structure using a thoracic 4D-CT data of a patient case. Preliminary results show that dose distributions for both representations are in a good agreement (figure 2), and dose homogeneity is about the same (table1). However, motion-induced dose accumulations are more intuitive using a tetrahedral model since they do not introduce additional uncertainties with image resampling and interpolation methods, and also for the fact that they respect mass conservation principle.

Conclusion: We have developed a 4D tetrahedral model for Monte Carlo dose calculations alongside its implementation on the Geant4 platform. Results of comparison with conventional methods based on voxels have shown that dose distributions are in good agreement. This novel structure can be of a great aid for treatment planning of moving targets. An experimental validation based on 4D anthropomorphic phantom (e.g. LuCa phantom developed in Paul Scherrer Institute) (Neihart, 2013) would draw a clear conclusion regarding the performance of the presented method in comparison with the classical methods. Nevertheless, the main advantage of this method is that, coupled with a patient-specific biomechanical model, it could be used in the future to correct motion artefacts in treatment planning.

Keywords: Dosimetry, Tetrahedral mesh, 4D-CT.

References:

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Realization of an innovative Dose Profiler for online range monitoring in particle therapy treatments
G. Battiston1, F. Collamati1,4, E. De Lucia1, R. Faccini1,2, M. Marafini1,2, I. Mattei1, S. Muraro1, R. Paramatti1, V. Patera1,4, D. Pinci1, A. Rucinski1,4, A. Russomando1, A. Sarti1,4, A. Scialabba2,4,5, E. Solfaroli Camillocci1, M. Toppo1, G. Train1,2, C. Voena2
1 Dipartimento di Fisica, Sapienza Università di Roma, Roma, Italy
2 INFN Sezione di Roma, Roma, Italy
3 Laboratori Nazionali di Frascati dell’INFN, Frascati, Italy
4 Dipartimento di Scienze di Base e Applicate per l’Ingegneria, Sapienza Università di Roma, Roma, Italy
5 Centro “E. Fermi”, Roma, Italy
6 Center for Life Nano Science@Sapienza, IIT, Roma, Italy
7 INFN Sezione di Milano, Milano, Italy

Particle Therapy (PT) exploits accelerated charged ions, typically protons or carbon ions, for cancer treatments. In PT a better dose release accuracy is achieved with respect to the conventional radiotherapy, as a consequence of the nature of energy deposition processes of charged ions, that lose most of their energy near the end of their range, in the Bragg Peak (BP) region, preserving healthy tissues and Organ At Risk (OAR) around tumor. The high cancer cells killing power of this technique requires a precise control of the ion beam delivery, and hence target voxel, to take into account a possible patient mis-positioning or biological or anatomical changes. The development of an on-line dose conformity monitoring device is of paramount importance to assure an high quality control accuracy in PT treatments.

In this contribution we propose a novel detector named “Dose Profiler” (DP) tailored for dose range monitoring applications in PT. The beam range inside the patient will be monitored detecting secondary fragments, whose emission is correlated to dose release, at large angles with respect to the beam direction. The DP is being developed in the framework of the INSIDE (Innovative Solutions for In-beam Dosimetry in Hadrontherapy) project, and will be tested at CNAO (Centro Nazionale Adroterapia Oncologica), Pavia (IT). The detector layout foresee a tracker followed by a calorimeter (as shown in Figure 1). Six layers of square scintillating fibers, whose light is collected by Silicon Photomultipliers (SiPMs), provides the x,y particles positions used for the charged particles backtracking, while a matrix of
sixteen pixellated LYSO crystals, coupled to multi-anode PhotoMultiplier, provides the particle energy measurement. The front-end electronics is composed of 4096 channels, and the read-out is performed by 128 ASICs (BASIC32-ADC), specifically designed for SiPMs read-out application [1], while trigger system and data acquisition are implemented with a system of 21 FPGAs. The detector design and optimization of the detector have been performed using Monte Carlo (MC) simulations based on the results of experimental measurements [2], [3]. The DP hardware features of DP will be reviewed. The expected performance, as resulting from the MC, will be discussed in the clinical application framework.

Figure 6: Tracker and calorimeter detectors

Keywords: Dose range monitoring concepts and apparatus; Instrumentation for hadron therapy

References:

213 Small Large Momentum Acceptance Gantries for Proton and Carbon Cancer Therapy
D. Trbojevic, N. Tsoupas, Brett Parker, and H. Witte

We present an isocentric, carbon/proton superconducting and permanent magnet proton gantries, respectively, with a fixed magnetic field but very large momentum acceptance. During a treatment it is possible to do longitudinal and transverse spot scanning for the whole energy range required. The size and cost are dramatically reduced; for example compared to the weight of the Heidelberg 630 tons the weight is estimated to be about one tons. The proton gantry is of a size of the present PSI gantry, but it is made of small permanent Halbach magnets. It can transport very precisely the proton beam within a 30-250 MeV kinetic energy range, under the permanent magnetic field, with variation of the scanning magnets only with an infinite S.A.D.

214 The role of functional imaging for radiation oncology - The whole translational chain from animals to clinics
E.G.C. Troost1,2,3,4
1Institute of Radiooncology, Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany.
2Department of Radiation Oncology, Medical Faculty and University Hospital Carl Gustav Carus an der Technischen Universität Dresden, Dresden, Germany.
3OncoRay, National Center for Radiation Research in Oncology
4Deutsches Konsortium für Translationale Krebsforschung (DKTK), Partnerstandort Dresden und Deutsches Krebsforschungszentrum (DKFZ), Heidelberg

As opposed to surgical disciplines, radiation oncology relies on non-invasive imaging of the target volume (tumor, lymph nodes or metastases). Apart from anatomical imaging for target volume delineation (e.g., CT, MRI), functional imaging (e.g., PET, functional CT and MRI) is increasingly being integrated in modern radiotherapy techniques. Functional imaging is used prior to therapy for guidance, dose-escalation strategies and treatment selection, but also early during irradiation for response monitoring and consequently treatment adaptation. Moreover, functional imaging is incorporated in the radiotherapy chain for identification of patients at increased risk of normal tissue complications (e.g., SPECT and CT for prediction of radiation pneumonitis). This presentation will present the current status of functional imaging for radiation oncology prior to and during treatment, both for the target volume and normal tissues.

Keywords: CT, MRI, PET, target volume, normal tissues, adaptation

215 Clinical trials for carbon-ion radiotherapy in Japan
H. Tsuji1, T. Kamada1
1Research Center for Charged Particle Therapy, National Institute of Radiological Sciences, Chiba, Japan

As compared to photon beams, charged particle therapy such as both proton beam therapy (PBT) and carbon-ion radiotherapy (CIRT) offers improved dose distribution, localizing sufficient dose within a target volume while minimizing the dose to the surrounding normal tissues. In addition, carbon-ions being heavier than protons provide a higher radiobiological effectiveness (RBE), which increases with depth reaching the maximum at the end of the beam’s range. This theoretically is an ideal property from the standpoint of cancer radiotherapy.

In Japan, PBT and CIRT were both initiated at NIRS in 1979 and 1983, respectively. Since then, various types of tumors have been prospectively treated. As of December 2015, there are a total of 13 charged particle therapy facilities in operation including 9 for PBT and 4 for CIRT. Several other facilities are under construction or being planned for either PBT or CIRT. In 2003, we established JCPT (Japan Clinical Study Group of Particle Therapy) for the purpose of changing information and improving therapeutic techniques for charged particle therapy, as well as collecting clinical data from existing facilities in Japan. According to the survey of JCPT, a total of 30,850 patients were treated in Japan from 1979 to 2014, including 17,858 patients (58%) with PBT and 12,922 patients (42%) with CIRT. Male/female was 73%/27%. The age of the patients ranging <51, 51-60, 61-70, 71-80, >80 was 12%, 17%, 34%, 29%, and 8%, respectively. As with the tumor types, the major tumors for PBT were prostate (30%), liver (19%), H&N (13%), lung (12%), GI (6%) and pancreas (4%), and those for CIRT were prostate (24%), H&N (14%), B&S (11%), lung (11%), liver (10%) and rectum/pancreas (5% each). Among 4 facilities for CIRT, the largest numbers of patients were treated at NIRS, starting CIRT in 1994 using HIMAC (Heavy-ion medical accelerator in Chiba). More than 9,000 patients have been so far treated based on > 70 protocols, by which the benefit of CIRT over other modalities has been demonstrated in locally, advanced tumors and non-squamous cell types of tumors. Based on their unique biophysical characteristics, a significant reduction in overall time and fraction has been achieved with minor toxicities. This included a single-fraction RT for early-stage NSCLC, one or two-fraction RT for liver cancer and 12-fraction RT for prostate cancer. Even for other tumors, CIRT with 16 or