Outcome Chania Workshop

M. Vretenar, conclusions and thoughts, 04.09.17

1. **Proton therapy** is rapidly progressing, thanks to easy commercial availability (cost for single-room center based on SC cyclotrons starting from 30-40 MEUR, down from 100-200 MEUR a few years ago. For comparison, conventional X-ray systems are at about 3 MEUR. There are several vendors on the market (ProBeam from Varian, Proteus from IBA)offering complete turnkey centers equipped with one or more gantries. Other vendors are Mevion (rotating SC cyclotron) and Hitachi (synchrotron). Thenumber of facilities is rapidly increasing;it is a new instrument for doctors and leads to emulation between countries (case of Norway). Research is oriented towards delivery systems and optimizing treatment; nobody questions the accelerator.
2. While there is a lack of data for proton therapy and the diagnostics and delivery tools are still being developed, there is no evidence for a different **effectiveness** between X-rays and protons. The difference is in the quality of life (damage to healthy tissues, secondary cancer), and this is why usually protons are used for children. Example a 18-yo that was cured 10 years ago for a skull cancer. Only slightly visible effects, while X-rays would have damaged the bones and his face appearance. Quality of life studies are being started for children, but there is no interest from the doctors. Doctors remain reluctant to send patients to faraway proton therapy centers.
3. Instead, there is a clear indication that **carbon ions** have a strong potential. The damage to DNA cells cannot be repaired; they are effective with radio-resistant tumors (low oxygen) and might reduce metastasis that are the main cause of mortality (more than solid tumors or collateral damage). So far, 2/3 of cases treated at the multi-particle facilities (CNAO, HIT, etc.) are with carbon.
4. There is a need of clinical data, with carbon but as well comparing carbon and other ions. The community needs a flexible (and expensive, costs of the order of 200 MEUR) **research facility** that can make multiple ions, with the options of tests on cells, on animals and on patients, to compare carbon with other ions and to optimize doses and treatment. Options to explore is replacing p with He and C with O. A similar facility is planned in Dallas (Southwest University), and there are plans in India. A research facility should be planned in Europe, possibly with the support of the EC and using parts of the BioLEIR proposal.
5. In parallel, there is clear need for a **compact carbon accelerator** at a cost < 100 MEUR. Should be an accelerator optimized for treatment with ½ charge-to-mass particles that could allow acceleration of fully stripped carbon or helium. There are 4 accelerator options: synchrotron, cyclotron, FFAG and linac. IBA is developing within an industrial consortium a cyclotron solution based on Cyclone C400, for the hadrontherapy center in Caen; it is complex but well advanced. Synchrotrons can allow only a minimum progress from the HIT-CNAOdesign. The FFAG (PAMELA design

in the UK) is large (>100 m of accelerator) and expensive, and the technology not proven yet.

6. The **LINAC** is a valid alternative, if it can be shorter than a CNAO-type synchrotron. Circumference of HIT synchrotron is 65m, with the linac is about 80 m. A carbon therapy linac should come to about 50 m, or 800 MeV/50 m = 16 MV/m real estate, 20-25 MV/m avg. in the structures.
7. If a **PIMMS2** projects is launched, the design can become widely available as it was done for PIMMS1. A possible way to proceed would be calling for an initial workshop with all actors, and then identify partners for a collaboration and a shared workplan.