THE ROLE OF INDUSTRY AND ACCELERATOR LABORATORIES IN FUTURE PARTICLE BEAM FACILITIES FOR CANCER THERAPY

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1 ABSTRACT

If a nuclear physics laboratory builds its first accelerator or a new and different type of accelerator, it usually benefits from the design expertise and component technology available from other laboratories around the world. This transfer can be arranged, as well, from the laboratory or individuals of it to an industrial partner in an extend determined by the partner according to its competence gained in previous, similar activities. Therefore one cannot speak about industry in general. For a possible ion synchrotron at the Radiological Clinic of the Heidelberg University, for carbon or oxygen beams the GSI laboratory has studied a strategic plan how to realize such a facility under the assumption of a consortium of component manufacturers, linked to GSI and to the clinic. In this model, and it might be restricted to the construction of the first machine of its kind, the laboratory plays a strong role in the intital project stage and in the final running-in phase.

2 CONVENTIONAL RADIO-THERAPY

Industry has delivered several thousands of small electron accelerators for photon and electron therapy and a few hundreds of small proton cyclotrons of around 20 MeV for a hospital based radio-nuclide production. Superconducting cyclotrons are available. Industry delivers these units turn-key-ready with all accessories. A few proton cyclotrons in the range of 45 to 65 MeV with an external beam for neutron therapy have also been delivered, they are similar to those machines, which were pioneered in accelerator laboratories. Because neutron therapy will be restricted for few incidences of radio-resistant tumors seated close to the body surface, a further demand of those models is not likely to be important and the existing machines will continue to be used for isotope production and proton therapy of ocular melanomas.

All these above mentioned machine types are described in Waldemar Scharfs book on Biomedical Particle Accelerators [1] in which a manufacturers list is appendixed. They are not meant as ″future″ facilities in the context of this paper. However, there exists a continous demand for replacing older models and the demand for radiopharmaka supply units will still increase for the raising number of diagnostic facilities using the PET technique.

3 FUTURE PARTICLE BEAM FACILITIES

Here proton and light ion accelerators are considered with particle energies elevated enough, to irradiate deep-seated localized tumors. They are termed ″non-conventional″ facilities for the time being and they are not considered to replace conventional therapy with electron machines (though they could!). This is because of their high initial investment cost and their floor space requirement, the latter being a formidable problem in existing hospital buildings. The fact that they were not widely considered so far in new hospital installations is not - as it is often said - their certainly higher treatment cost per patient, to which the accelerator amortisation contributes only 20 - 30 % anyway. Though 10 % of local tumor incidences cannot at all be saved without these beams, neither by surgery nor by conventional radiotherapy, there was a reluctance in the past to operate complicate installations in a hospital.

A speculation on the future evolvement of these accelerators should be based on the present state of evidence, and this account is different for proton machines and heavy ion accelerators.

About 15 thousand patients have been successfully treated in the past 30 years at proton cyclotrons in nuclear physics laboratories. These machines have been built by the laboratories and are no more on the frontier of physics research. The treatment of patients out-doors of a hospital remains a logistical problem and the desire for a hospital based facility developed. The scientific case for proton therapy is well promoted and this modality is world wide acknowledged by the health insurance authorities. But who can build and install these machines in a hospital? The industry! Accelerator laboratories have the competence to design such a machine and even to manage the component procurement. But they do not have the ability and the motivation to integrate such a machine including the vast variety of accessories in a hospital. There is one example in this line: the Loma Linda proton synchrotron was designed and built by Fermi Lab and then installed and complemented with beam transport and beam manipulation devices by an industrial partner. This kind of share is no more mandatory in future. Industry can build proton cyclotrons of 230 MeV and integrate them with all accessories in a hospital, turn-key-ready at fixed cost and guarantied performance data. The customer might have an involvement in subcontracting the project to several companies according to impositions of the financial ressources. But one company will practically act as the responsible contractor. This project configuration is presently underway for a cyclotron installation at the MGH in Boston. Several companies, so far suppliers of small isotope producing cyclotrons, are elegible also for larger and non-state of the art cyclotrons. The component categories and the logistics of their integration are the same. The particle dynamics of a relativistic beam isocronous machine is sufficiently developed and needs no further involvement of an accelerator physics laboratory. In the US, interest for eight machines of this type is reported and an equivalent number for Europe, as well.

For heavy ion machines, which must be of the synchrotron type, the situation is not this far advanced. The heavy ion beams offer a better control of radioresistant tumors because of the eleveted RBE and a less damage is preluded in surrounding tissue compared to proton beams. But this is not exclusively required for all tumor incidences. A consensus evolved that in Europe eight proton facilities and two heavy ion installations are desirable. Certainly, a heavy ion machine can deliver proton beams, as well, and a heavy ion beam can accomplish a typical proton treatment in a shorter time. Two reasons have hampered the construction of dedicated medical heavy ion facilities. First, the clinical experience with high RBE beams is limited to about 500 patients, treated with neon beams at the Bevalac in Berkeley. Secondly, these machines and their much more expensive beam application components (Gantry) are not readily available from the industry. One heavy ion installation is in operation in Japan at NIRS since two years. Clinical results are such promising that two more heavy ion facilities are under consideration in Japan at considerably reduced investment cost compared to the NIRS installation, which evolved from a nuclear physics synchrotron.

The NIRS facility, named HIMAC (Heavy ion medical accelerator at Chiba), had strong support from a Japanese accelerator laboratory and the technical advice from foreign heavy ion laboratories. It was built by a consortium of few Japanese companies. This venture was a real success. Employees of these companies came to GSI for collecting drawings of linac cavities, ring magnets, RF stations and vacuum components. This example looks to be a model for the role of industry and accelerator laboratories.

4 THE ROLE OF THE INDUSTRY IN CASE OF A LIGHT ION SYNCHROTRON

Of course, one can not speak of the industry in general and not of a permanent policy of an individual company. Therefore the following statements summarize informal discussions with representatives from industry.

European and US companies have built synchrotron light sources at fixed cost and aggreed performance dates. The envisaged development of a substantial market for these facilities did not materialize. In case of a heavy ion medical synchrotron the industry will offer their particular skills, but will possibly be reluctant to enter into a design effort resulting in a performance guarantee. Though a formal relation to an accelerator laboratory with a well defined role sharing is not deemed essential for industry, the expertise of laboratory individuals is searched for one or the other field. Beam dynamics and shielding calculations are typical examples, the field of computer control in the reverse. Industry has its own pattern of selecting consultants and subcontractors, they do not need recommendation of the laboratories. Industry can provide planning capacity for buildings and conventional facilities, but these services are likely to be matter of clinical agencies. The same is true for the licensing procedures, such paperwork does not belong to the technological skills of the industry. Also the recruitment and instruction of the operators belong to the responsibility of the clinical institution, but an accelerator laboratory could help in this way early at an existing machine.

In one, though temporary activity, the involvement of an accelerator laboratory is absolutely mandatory: the commissioning of the machine with beam. Each new type of machine presents its own set of headaches. Accelerator laboratories, when they have temporarily no demanding new project, can provide such a service because their experts have not frequently enough access to their own machine for desirable developments.

One final remark on the role of industry goes to the financement of the investment expenditure. Though it is said that in Japan accelerator component companies prefinance the investments and get refunded from the operations budget, such a model could not be indentified in the western world. Medium sized companies do not want to take a risk, large companies tend to avoid an involvement in a non series production.

5 THE GSI MODEL

As part of its fundamental research program with heavy ions, the GSI laboratory supports bio-physical experiments since 20 years. A medical irradiation facility is nearing completion. Patient treatment will be performed under the responsibility of the Radiological Clinic of the Heidelberg University. Since mid of 1995 beam commissioning for the medical cave is performed in regular intervals [2]. Much had to be learned about the synchrotron and the beam lines, which is now rewarding for the physics program, as well.

The irradiation campaign at GSI is ment as a clinical study over 5 years and not as a continuing medical care service. It was desirable therefore that GSI elaborates a suggestion about how to intergrate a heavy ion facility into a hospital. A proposal of a light ion medical synchrotron [3] has been completed earlier in the context of the EULIMA study in order to compare a cyclotron solution with a synchrotron choice [4]. For the latter, the feasibility and the attainability of performance data was out of question. But the pesistent question was: ″How small can it be in size?″ Cost figures were derived from the GSI synchrotron project, completed in 1989. Independently, a similar synchrotron study was made at CERN [5]. The cost figures came out comparable in a few percent range. Because both studies aimed at a comparison of accelerator types, they did not cover the issue of the beam transport and beam application devices (gantry, dosimetry).

As the radiological clinic at Heidelberg developed some interest in a light ion machine, GSI was asked to draw up an organisational plan for aquiring such a facility. Before doing this, it had to be checked by the physicians and the civil engineering group of the clinic, whether such a facility fits on the site. Physicians had requirements about the patient flow, the engineers contributed their knowledge about existing underground structures (service tunnels) and on acknowledged space claims for other building extensions. After clearing up some unexpected circumstances the answer was: ″Yes, it can be done″. Electrical power and cooling capacity could be made available, watertable and soil compound are adequate to maintain the precision of the synchrotron component alignment. An empty cyclotron voult was available for a two story irradiation room. A gantry installation was excluded due to space restrictions.

From the administrative side two points became clear:

1. The clinic has not the infrastructure to purchase and install the components according to specifications and part lists of GSI, this role must be taken over by industry including project management and control. These services can hardly been taken over by a laboratory. GSI ist not entitled to invest a sizable amount of manpower in a project, which is not on the line of its traditional fundamental research program.
2. The clinic can not transfer the responsibility for the building planning and construction supervision. This is inherently the privilege of the University administration or of a department of the state finance ministry. The clinic can also not transfer its responsibility for all licensing procedures, and there are several! This activity is time consuming and unpredictable in its progressing. In fact, this point must be initiated at the earliest, and the machine designer has the tough duty to deliver the input data including a dependable shielding design and a preliminary building lay out, including the surveying concept.

By a facility description, necessary for the safety report, an industrial partner should be in the position to submit an offer for the turn-key-ready machine complex. The laboratory would submit, in case of a first installation, a part list and examples of similar part specifications and drawings. The industrial partner has to convert these documents to the actual parameters and to translate them to manufacturing documentations. The industrial partner is in charge of ordering those components, of supervising the production, of performing the acceptence tests and the final assembly. The laboratory could become involved in magnet measuring and other critical testing procedures. It was mentioned above that for the running-in of a synchrotron the expertise of an accelerator laboratory is advantagous.

6 CONCLUSION

The above outlined role sharing was adjusted to a particular constellation between the radiological clinic at Heidelberg and the GSI, with its competence in synchrotron construction and beam delivery for patient care. This might be a dependable model for the first synchrotron installation of its kind. For subsequent facilities the role of industry is much broader:

1. Machine specifications, site study and preliminary building conception for budgetary assesments and licensing initiatives.
2. Construction of the facility, turn-key-ready. The assistance of an accelerator laboratory is not a necessity.
3. Commissioning of the machine and instruction of the operating personel during this period.
4. Routine maintenance can be offered, but not easily a quick repair service.
5. A financement service is not likely to be contributed by the industrial partners.

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