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FROM THE EDITOR

Paul Bergstrom

Mea culpa, mea maxima culpa. First for the tardiness of this edition. I have only recently found the time to get my contributions in order. Secondly to those of you who have chosen to receive the Bulletin by mail who have missed an issue or two. It is the intention of the Society to distribute the Bulletin primarily by email in order to conserve funds. I now understand that, perhaps, some of you who are supposed to receive the Bulletin by mail have not been getting it. Please let me know if this is the case and I will send back copies.

Since our last issue, the IRPS council has met in Japan. I did not attend so details will emerge at a later date. The President's column was written before this meeting and, so, does not discuss it. However, Professor Cooper does discuss other events that happened over this time frame and their ramifications on the international nature of the sciences.

Other columns in this Bulletin discuss technical issues and meetings. Dan Jones has taken a break from his duties preparing to host our 2003 symposium in Cape Town by following up his review of fast neutron therapy for cancer with one on proton therapy.

There are reports on two conferences. In the first, Ines Krajcar Bronic reports on the IRPA Regional Congress on Radiation Protection held in May 2001 in Dubrovnik. I report on the International Conference on Photonic, Electronic and Atomic Collisions which took place in July in Santa Fe, USA.

Professor Leif Gerward, has once again contributed an article. This time he discusses the reissue of the pocket-sized X-ray data booklet from Lawrence Berkeley Laboratory. The editor has also obtained this booklet and agrees with Professor Gerward's positive review of it. I also feel compelled to mention the similarly useful "Particle Physics Booklet" which was issued in June 2000 and can be obtained from

http://pdg.lbl.gov

Let me extend my, admittedly parochial, best wishes for the New Year. My IRPS resolution will be to remedy my deficiencies as editor.

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PRESIDENT'S COLUMN

Malcolm Cooper

It is difficult to write this column without making some reference to the cataclysmic events of September 11th, and it is much more difficult to know what to say from the perspective of our radiation physics community. Our society is truly international and embraces scientists of all religious and political beliefs, and those of none. The constitution of IRPS emphasises the need for international cooperation and coordination and we must all seek to maintain the global collaboration that so typifies radiation physics.

This month we have a Council meeting in Sendai, Japan, hosted by Professor Nakamura. Dan Jones, Dudley Creagh, and I have to firm up our plans for the Cape Town symposium and the associated workshop in October 2003. This may seem like a long time ahead but it is frighteningly near for those of us tasked with the planning.

There is, however, still time to consider your suggestions for speakers and topics.

Emails to

M.J.Cooper@warwick.ac.uk

will be welcomed.

BOOK REVIEW

Popular "X-Ray Data Booklet" Reissued

Leif Gerward

Department of Physics
Fysikvej 307, DK-2800 Kgs. Lyngby, Denmark

email : gerward@fysik.dtu.dk

A popular X-ray data booklet is now back in print after having been updated and revised. The original version, which was published in 1986 by the Center of X-ray Optics at the Lawrence Berkeley National Laboratory, was inspired by the Particle Properties Data Booklet, compiled and published by the Particle Data Group of the same laboratory. With a wealth of X-ray information packed into a shirt-pocket-size format, the X-Ray Data Booklet quickly became very popular among X-ray scientists and synchrotron-radiation users around the world. But the booklet has long been out of print.

The revised and updated X-Ray Data Booklet is divided into sections on the X-ray properties of the elements, synchrotron radiation, scattering processes, optics and detectors, and miscellaneous, with several chapters of text, tables and graphs in each section. For example, electron binding energies and X-ray emission energies are given in tabular form, whereas mass attenuation coefficients and atomic scattering factors are shown in graphical form with reference to published tabular data.

A comparison between the original and revised editions clearly indicates the development of X-ray science and technology during the last 15 years. Thus, in the new edition the material on synchrotron radiation has been much extended, including descriptions of first through fourth generation sources, and a review of operating and planned facilities worldwide. On the other hand, the original chapters on X-ray tubes and pulsed X-ray sources have now been omitted.

Available free of charge, the X-Ray Data Booklet can be ordered from the Lawrence Berkeley National Laboratory, or directly from the web site

http://xdb.lbl.gov

In addition, scientists at major synchrotron radiation facilities can obtain a booklet at their user office. No doubt, new generations of X-ray scientists and synchrotron-radiation users will find the revised X-Ray Data Booklet a very useful and handy companion in the years to come.

REPORTS FROM MEMBERS

Report on IRPA Congress in Dubrovnik, Croatia

Ines Krajcar Bronic

Rudjer Boškovic Institute
Zagreb, Croatia

email: krajcar@rudjer.irb.hr

The Croatian Radiation Protection Association (CRPA) organized the "IRPA Regional Congress on Radiation Protection in Central Europe". The congress had a subtitle and major topic "Radiation Protection and Health", and was held in the Excelsior Hotel, Dubrovnik, Croatia, from May 19 to May 25, 2001.

Congress participants on the terrace of the Excelsior Hotel with Dubrovnik in the background

The congress was organized under the auspices of Ministry of Science and Technology, Ministry of Health and Ministry of Economy of the Republic of Croatia, as well as State Office for Standardization and Metrology, Croatian Radiation Protection Institute (CRPI), Rudjer Boškovic Institute and Institute for Medical Research and Occupational Health.

The chairwoman of the Scientific Committee was Dr. Maria Ranogajec-Komor, the president of CRPA, and the chairman of the Local Organizing Committee was Mr. Dragan Kubelka from CRPI.

Presidents of radiation protection associations from Austria, Czech Republic, Germany, Switzerland, Hungary, Italy, Poland, Romania, Slovakia and Slovenia participated as members of the scientific committee. The members of the local organizing committee were members of CRPA from various Croatian institutions.

Information about the congress, the final list of participants and some photographs can be found on our web page :

http://www.hzzz.hr/crpa_dubrovnik/info.html

Regional IRPA congresses for Central Europe (CE) are regularly organized every two years in one of the Central-European countries. However, although formally intended for CE countries, this congress was literally international: 230 participants from 28 countries from Western, Central and Eastern Europe, as well as from the United States, Japan and Australia were present in Dubrovnik. Representatives of international organizations were also present: Dr. Geoff A. M. Webb, the president of IRPA (International Radiation Protection Association), Dr. Jack Valentin, the scientific secretary of ICRP (International Commission on Radiological Protection), and Dr. Monica Gustafsson, the representative of IAEA (International Atomic Energy Agency) gave invited plenary lectures on subjects of general interest for radiation protection.

The scientific work of the congress was divided into 9 sections:

general aspects of radiation protection
basic physical effects
biological effects of radiation
radiation protection in medicine
radiation protection and the environment
radiation protection at workplaces
radiation dosimetry
instrumentation and methods
non-ionizing radiation.

Each section had an introductory talk (of 20 minutes) followed by 15-minute-long oral presentations. In the two afternoon poster sections, about 100 posters from all sections were presented.

Within the congress a Technical Exhibition was also organized. Sixteen companies from Europe, Japan and the USA presented their radiation-measuring equipment and recent developments in dosimetry and radiation protection. An additional 5 companies presented their products through advertising material or brochures distributed to each participant with the congress material.

In spite of the full scientific program of the congress, social activities were not forgotten.

On Monday evening the participants were invited to the Rector's Palace (generously offered by the Mayor of Dubrovnik) for a concert held under the auspices of the Prefect of Dubrovnik-Neretva County. The wind-instrument quintet Collegium Musicum - Dubrovnik performed pieces of the Croatian composer Luka Sorkocevic, Estonian composer Villem Kapp and Hungarian composer Ferenc Farkas. The auditorium was delighted by the music and the acoustics of the Palace. The concert was followed by a reception given by the mayor of Dubrovnik.

On Tuesday a sightseeing tour was organized for accompanying persons - the walking tour included a walk on the medieval walls around the old city of Dubrovnik.

On Wednesday afternoon, all participants were invited to a half-day excursion by boat to Cavtat, a small and beautiful town south of Dubrovnik. After the walk around the city, we enjoyed local specialties - fish and wine.

According to the tradition of such events, on Thursday evening the banquet was organized in the beautiful City Coffee-Shop. Participants enjoyed the Dalmatian fish menu and local wines, as well as live national music. Organizers took the opportunity to thank their sponsors for their organizational help.

Also, the awards for the best poster
winner: Dr. Yoshimune Ogata, Japan

for the first received abstract
winner: Dr. Saner Perle, USA

for the first received full paper
winner: Dr. Konrad Mück, Austria

were given.

The winner of the award for the best poster presentation,
Dr Yoshimune Ogata from Japan, proudly presents his award.

The next regional IRPA congress was announced - it will be held in Slovakia.

Finally, all participants contributed to the success of the congress together with the members of the scientific and organizing committees, who put a lot of effort into the organization of such an international event.

There are too many names to be mentioned, but one of them deserves special mention - the president of CRPA and the chairwoman of the Scientific Committee, Dr. Maria Ranogajec-Komor, was a real "spiritus movens" of the whole organization.

Special thanks are due also to the Travel Agency Atlas that organized the social program, excursion and accommodations.

Among the congress material, each participant received the Proceedings with 220 submitted abstracts. Publication of the full papers on CD-ROM is foreseen for the end of the year. The talks and posters presented at the congress showed the high quality of the research in the field of radiation sciences with the aim to improve radiation protection of the environment, for professionals at the work place and for patients.

In the future much more effort should be put into studies of non-ionizing radiation (radio-waves, electromagnetic fields, microwaves, laser radiation).

Closing ceremony of the Congress

Left to Right :
Dr Geoff A.M. Webb, President of IRPA,
Dr Maria Ranogajec-Komor, President of CRPA and the Scientific Committee,
Dr Ines Krajcar-Bronic, organisation of the Technical Exhibition,
Dr Bogomil Obelic, Proceedings Editor.

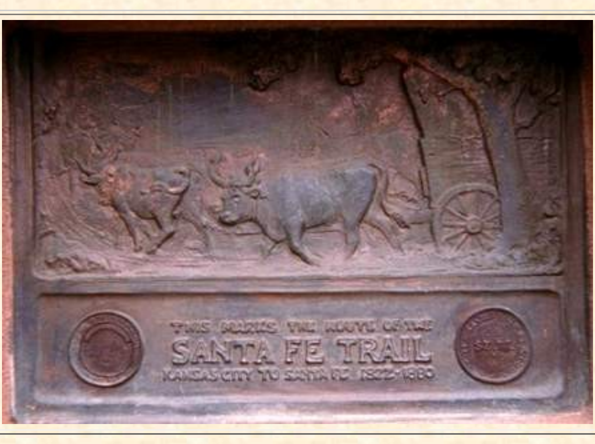
ICPEAC XXII
The Conference at the end of the Santa Fe Trail

Paul M. Bergstrom, Jr.

100 Bureau Drive,
Stop 8460 Gaithersburg, MD 20899-8460, U.S.A.

e-mail: palko@nist.gov

The dust clouds from the wheels of the traders' wagons are a thing of the past. The lonely song of the cowboy has given way to a renowned summer opera season. The legendary path that outlaws once rode now ends at the upscale La Fonda Hotel in Santa Fe. That is where the biennial gathering of physicists known as the International Conference on Photonic, Electronic and Atomic Collisions took place in July 2001.



Plaque marking the southern terminus of the Santa Fe Trail.

The adobe exterior of the La Fonda Hotel :

This conference concentrates on experimental and theoretical work that elucidates the nature of basic atomic processes. The conference usually starts on a Wednesday and runs through to the following Tuesday, incorporating a couple of weekend days for touring and informal discussions. Each day starts with a plenary lecture before adjourning to parallel sessions of invited talks. There are poster sessions, usually with refreshments, most days. Some posters are typically picked for short oral presentation in a hot topics session. The plenary lectures and poster sessions were held at the Sweeney Convention Center which was only a short walk across the historic Plaza from the La Fonda.

Sweeney Convention Center in Santa Fe

Unfortunately, I arrived in Santa Fe in time only to join the conference in its second day. The plenary lecture was given bright and early by Dr. Reinhard Dorner of the University of Frankfurt on ionization in strong fields. In particular, he discussed the use of the COLTrims apparatus that has proven quite useful in recent years in measuring the detailed differential cross sections of ionizing processes. After coffee, the participants could choose from parallel sessions on either cold collisions of heavy particles or on photoionization and photodissociation. Sessions on ion-surface interactions and on positron impact physics were held in the afternoon, followed late in the day by posters from all conference fields. In the evening, Professor Michael Zeilik of the University of New Mexico gave a public lecture on "Astronomy in the Pueblo World" that concentrated on the use of stars in determining the seasons and the holy days for the native people. He also discussed the significance of the Sun Dagger petroglyph and other features in Chaco Canyon.

Friday again started with a plenary lecture. This one was given by Leon Sanche of the Universite of Sherbrooke in Montreal. This lecture centered on his group's experiments investigating the damage caused to DNA by low energy electrons. These experiments were performed at energies well below those at which most codes that simulate electron transport cease to be valid. Invited parallel sessions in the morning considered heavy ion and electron impact processes. After lunch, invited parallel sessions considered heavy particle processes and photon impact processes. A poster session was again held in the late afternoon.

As mentioned above, Saturday and Sunday were days open for conference participants to attend working meetings, to have informal discussions or to participate in one of the many activities that had been organized by the conference committee. These activities included a tour to Taos, home to many artists. Other activities that were available included whitewater raft trips on the Rio Grande and tours of the ruins of the Anasazi Indians in Bandelier National Monument, which is quite near Los Alamos. Even those who chose not to partake of one of these tours could still find plenty to do locally. Santa Fe is situated in an area of great natural beauty, at the foot of the Sangre de Cristo mountain range. Numerous opportunities to hike and bicycle are available.

The view from the top of the 12,622 ft mountain called Santa Fe Baldy.
A nice hike just outside of Santa Fe

Santa Fe is also home to a number of museums and an active arts community. Native pueblos are a short distance by automobile from the and many native Americans sell their crafts on the town plaza.

Returning to the formal sessions of the conference on Monday, one had the opportunity to hear Dr. McCurdy of the Lawrence Berkeley National Laboratory discuss the work he and his colleagues published in Science and the Physical Review over the past few years that used big computers and excursions into the complex plane to solve the three-body Coulomb problem for electron-impact ionization of hydrogen. A morning poster session followed as did parallel afternoon sessions on femtosecond photon processes, electron impact ionization processes, ion-atom collisions and on electron-electron correlation in atomic processes. A very nice conference banquet was held that evening at the convention center.

The last day of the conference was quite full, running the gamut from the plenary lecture on fullerene physics and the "hot topics" sessions in the morning, through the parallel sessions of invited talks in the afternoon and ending with a poster session in the late afternoon.

The limited flight schedule out of Santa Fe's airport and the 2 hours of travel to Albuquerque's bigger airport made it likely that those who stayed for the last day of conference activities enjoyed one last evening in this picturesque town.

As is noted in the Calendar section of this Bulletin, the next ICPEAC will be held in Stockholm in July 2003. Hope to see you there!

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MEMBER'S PAPER

PROTON THERAPY
The Promise of Precision

Dan T L Jones

Head : Medical Radiation Group
National Accelerator Centre, Old Cape Road
P O Box 72, Faure 7131, South Africa

email : jones@nac.ac.za

1. Cancer Incidence and Treatment

Cancer can broadly be defined as the uncontrolled growth and proliferation of groups of cells, the triggering of which is not yet fully understood. In industrialised societies about 30% of people suffer from cancer and about half of these die from the disease. More than half of all cancer sufferers receive radiation therapy (possibly in conjunction with surgery and chemotherapy). The prognosis in individual cases varies greatly and depends on tumour type, stage of diagnosis, environment, lifestyle and general health of the patient, etc. A patient who survives for 5 years after commencement of treatment without further symptoms is regarded as having been cured. The overall 5-year surival rate of all treated cancer sufferers is about 45% [1].

Cells from the primary tumour can metastasize (spread to other parts of the body) and about 30% of all cancer patients have metastases at diagnosis. Radiotherapy and surgery are both localised forms of treatment. They are used, alone or in combination, to treat the primary tumour and are responsible for about 90% of cancer cures (50% surgery, 40% radiotherapy alone or combined with surgery). In addition radiotherapy, even at moderate doses, is particularly effective for palliative treatment of metastases (i.e. for pain relief.) Chemotherapy is used to treat metastases and the 5-year survival rate is about 5% (about 10% of all cures) [1].

From the above it is clear that even modest improvements in cancer treatment will benefit a large number of people. A very important factor to also consider when assessing the cost-benefit of cancer treatment is the cost of not curing a patient. This can be very high and may involve risky salvage surgery, chronic health care, etc. The cost may be as much as 4-5 times the cost of curing a patient.

The objective of radiation therapy is to maximise the effect of the radiation on the target lesion and to minimise the effect on surrounding normal tissue. This is done by increasing either the physical dose differential or the biological effect differential between the target and normal tissue.

2. Proton Therapy : Technical Aspects

Robert Wilson first proposed the use of protons and heavier ions for therapy in 1946 [2]. The pioneering experimental work of Tobias and his associates at Berkeley CA a few years later confirmed Wilson's predictions [3]. Between 1954 and 1957 30 patients were treated on the 184 inch synchrocyclotron at Berkeley [4]. The machine was upgraded and the energy became too high for proton therapy and from 1957 alpha particles were used for therapy. Proton therapy continued in the USA (Harvard University, Cambridge MA) in 1961; began in Europe (Uppsala, Sweden) in 1957; Russia (Dubna) in 1967; Japan (Chiba) in 1979 and in South Africa (Faure) in 1993.

The main rationale for using proton beams lies in their physical selectivity (i. e. the ability to conform the dose to the target volume). Beams of these particles have unique dose distributions ***(Figs. 1, 2)*** which exhibit a relatively flat entrance dose region (plateau) followed by a sharp dose peak (the Bragg peak) in which the particles lose most of their energy. The dose distributions have sharp distal and lateral dose fall-offs, which are illustrated in the case of a 200 MeV proton beam in Fig 2. There is no radiation beyond range end. Ideally to adequately treat all lesions a range of greater than 26 cm in tissue (corresponding to a beam energy of 200 MeV) is required. The physical properties of proton beams are best utilized for eradication of well-delineated lesions close to critical structures, which in principle can be relatively easily avoided.

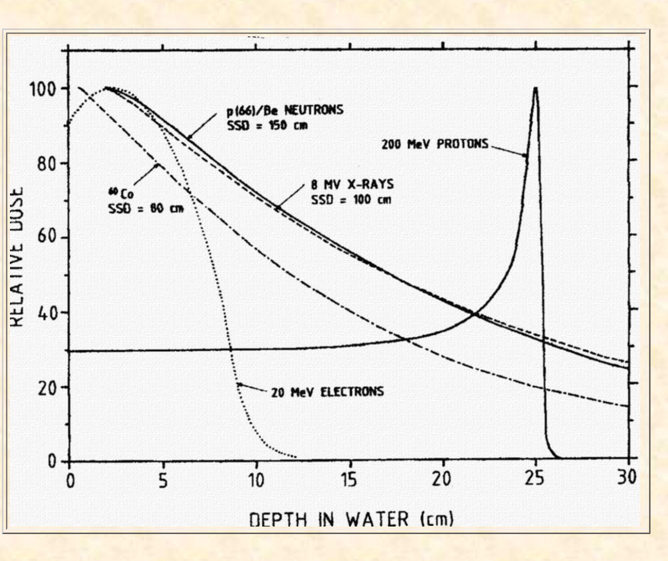

Fig. 1. Depth dose curve for a 200 MeV proton therapy beam [5, 6] compared with other typical radiotherapy beams.

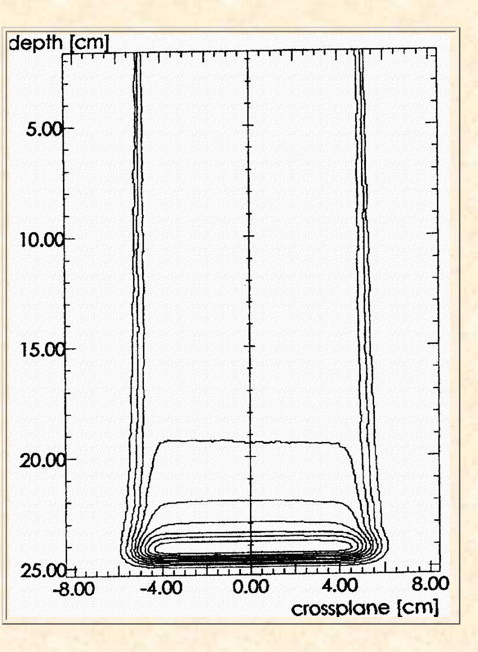

Fig. 2. Isodose (10%-90%) curves for a 10 cm diameter monoenergetic 200 MeV proton therapy beam [6,7]

The biological effects of protons are not very different from those of conventional radiations (photons, electrons) and treatment protocols can be based directly on more than 100 years' experience with these latter radiations. To take full advantage of the potential of proton therapy requires, inter alia, an accurate beam delivery system, precise tumour and critical structure localization, accurate and reproducible patient set-up, accurate three dimensional treatment planning, including compensation for tissue heterodensities and allowance for organ movement during treatment sessions. If all these requirements cannot be met, the quality of the treatment could be compromised.

Beam Delivery

Because the maximum dose occurs at the end of the range isocentric beam delivery (irradiation from any direction) is not quite as important as for x-ray and for neutron therapy, but is nevertheless desirable for proton therapy and three types of gantries, all with very different design criteria, have been built to date: the corkscrew gantry (Loma Linda University, USA [8]) the compact eccentric gantry (Paul Scherrer Institure (PSI), Villigen, Switzerland [9]) and the conventional 90 gooseneck gantry (Northeast Proton Therapy Center, Boston, USA and National Cancer Center, Kashiwa, Japan [10]). Non-orthogonal fixed beam arrangements (Hyogo Ion Beam Medical Center, Japan [11]) and at the National Accelerator Centre, South Africa [12] are also being designed. Together with a versatile patient support system and sophisticated beam delivery, such facilities provide a viable cost-effective alternative to isocentric facilities, albeit with limited applications.

The dimensions of high-energy proton beams emanating from an accelerator are quite small (10 mm in diameter) and the Bragg peak of monoenergetic beams is narrow (~20 mm full width at half maximum) and so the beam has to be modified to deposit the required dose over the whole 3-dimensional target volume. Either passive scattering (broad beams) or dynamic beam scanning (pencil beams) can be used. Modulating both broad and pencil beams in depth involves the superposition of suitably weighted proton beams of different energies (ranges) resulting in a uniform dose over the target region ***(Fig. 3)***.

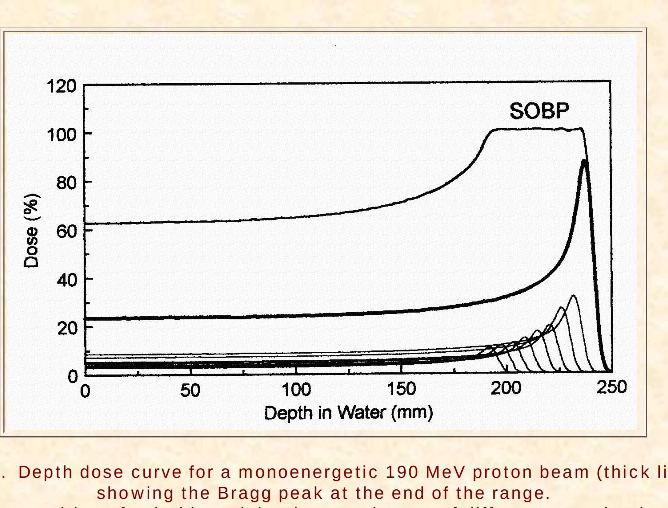

Fig. 3. Depth dose curve for a monoenergetic 190 MeV proton beam (thick line) showing the Bragg peak at the end of the range.
The superposition of suitably weighted proton beams of different energies (ranges) results in a spread-out-Bragg-peak (SOBP) which provides a uniform dose over the target region

Passive Scattering

The traditional way of "painting" the beam (i.e. spreading it laterally and in depth) to ensure that the high-dose region covers the target volume is to use passive mechanical techniques which rely on scattering and differential absorption respectively. Typically a contoured scatterer or a double scatterer with concentric occluding rings (to remove portions of the beam) is used to spread the beam laterally and provide a uniform dose profile at the treatment position [13]. A field-specific collimator tailors the lateral dimensions of the beam to that of the target.

The Bragg peak is modulated in depth over the longitudinal extent of the target volume by varying the energy (range) of the incident protons using a variable thickness rotating "propeller" [2, 14] ***(Fig. 3)*** or a ridge filter [15, 16]. In addition a field-specific absorber (compensator), shaped in 3-dimensions, can be used to tailor the range of the protons to conform the high-dose contour to the distal surface of the target volume. The problem with this passive technique is that there is constant modulation (neglecting inhomogenities) of the Bragg peak over the lateral extent of the target volume and no proximal surface dose conformation can be achieved ***(Fig. 4)***. Therefore, while the situation is still greatly superior to what can be realized in conventional therapy, some of the high dose region still falls in healthy tissue proximal to the target.

Beam Scanning

Instead of using passive techniques to "paint" the target volume with a uniform high-dose, it is possible (since protons are positively charged particles) to magnetically deflect the elemental pencil proton beam. The dose is deposited by scanning the dose "spot" (Bragg peak) of the pencil beam in all three dimensions inside the target volume [17]. Through the superposition of a very large number of such individual elemental dose distributions conformation of the dose to the target volume can be achieved. Scanning can be done either in a continuous (raster scan) or discrete (spot scan) fashion. The beam can be scanned in the two dimensions perpendicular to the beam axis by two orthogonal magnets.

Alternatively, one magnet can be used to scan the beam in a strip in one dimension and either the patient or another magnet can be translated to advance the strip to the next position in the patient. Depth variation is done by interposing degraders in the beam (cyclotrons) or by changing the beam energy (synchrotons). Scanning is used for both beam "painting" and for intensity modulated beam delivery. The latter technique allows treatment planning to be optimized by delivering non-uniform dose distributions for each field to create a uniform dose in the target volume. Scanned beams reduce the integral dose to normal tissue because dose conformation to the proximal surface of the tumour can be achieved ***(Fig. 4)***. Because all the protons are used there is less activation of components and therefore less exposure of patients to background radiation.

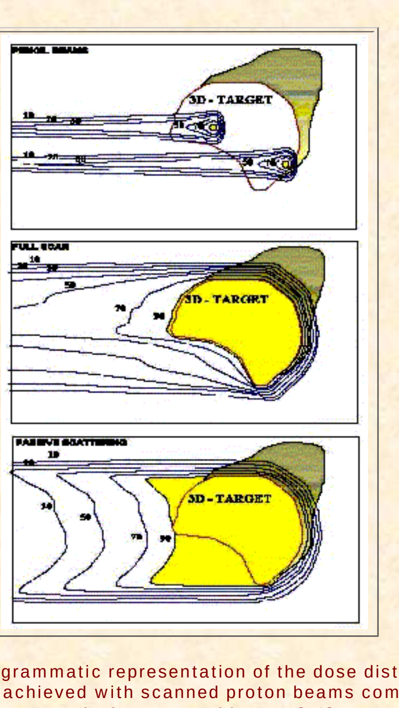

Fig. 4. Diagrammatic representation of the dose distribution which can be achieved with scanned proton beams compared with passively scattered beams [19]

Although beam scanning is likely to be the standard method of beam delivery of charged particle therapy beams in the future, at present only two scanning systems for ion beams are in routine clinical use, viz those at PSI, Villigen, Switzerland (proton beams) [9] and at the Gesellschaft für Schwerionenforschung (GSI), Darmstadt, Germany (12C beams) [18].

Figure 5 shows comparative proton and x-ray treatment plans for a typical tumour (Ewing's sarcoma) using the best available techniques for proton therapy (scanned beams) and x-ray therapy (Intensity modulated beams). It is clear (editor notes: particularly in color originals) that the proton dose distribution is superior to the x-ray distribution in terms of conforming the maximum dose to the target volume and minimizing the dose to the surrounding normal tissue. Because of the physical characteristics of proton beams proton therapy will almost always be better than x-ray therapy if both are delivered under optimum conditions. Under such circumstances, as illustrated here, proton therapy will also be more efficient in terms of number of fields required to treat a lesion with optimum efficacy.

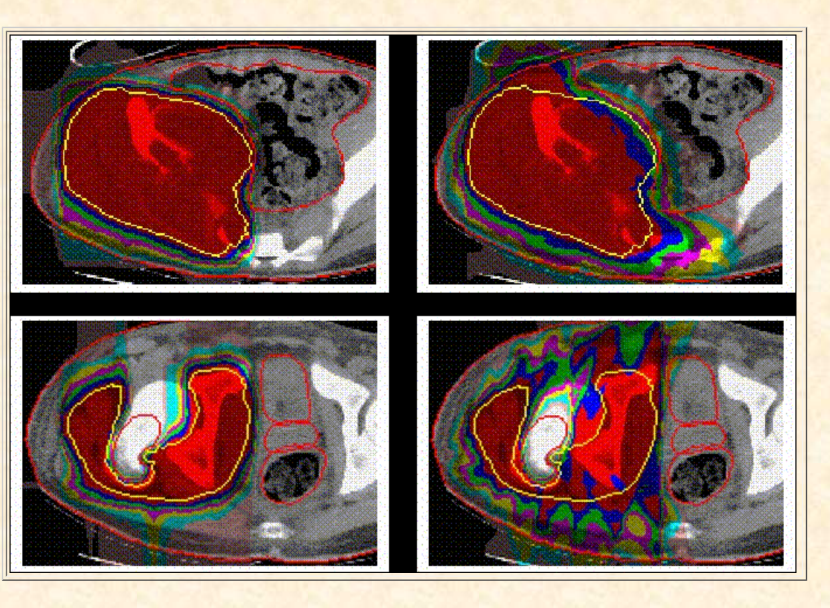

Fig. 5. Comparative treatment plans (at 2 different levels) for scanned-beam proton therapy
(3 fields) [left side] and intensity-modulated x-ray therapy (9 fields) [right side] for an Ewing's sarcoma [19].

3. Proton Therapy Facilities

Both cyclotrons and synchrotrons are used to produce proton beams for therapy. Tables 1 and 2 [11] show existing low-and high-energy proton therapy facilities respectively. The former are used almost exclusively for the treatment of eye lesions [mainly uveal melanoma and age-related macular degeneration (ARMD)]. Proton beams are most suitable for treating lesions (not necessarily malignant) close to critical structures such as uveal melanoma, ARMD, pituitary adenoma, meningiomas, arteriovenous malformation, acoustic neuroma, chondrosarcoma and chordoma; and prostate, cervix and paranasal sinus tumours. The latest available statistics (Tables 1 and 2) show that nearly 30 000 patients had received proton therapy up to July 2001 [11].

4. The NAC Experience

Proton therapy was first undertaken at the National Accelerator Centre (NAC) in 1993. The horizontal 200 MeV proton therapy facility ***(Fig. 6)*** is used mainly for irradiations of intracranial and head and neck lesions. Standard passive scattering techniques are used from beam modification.

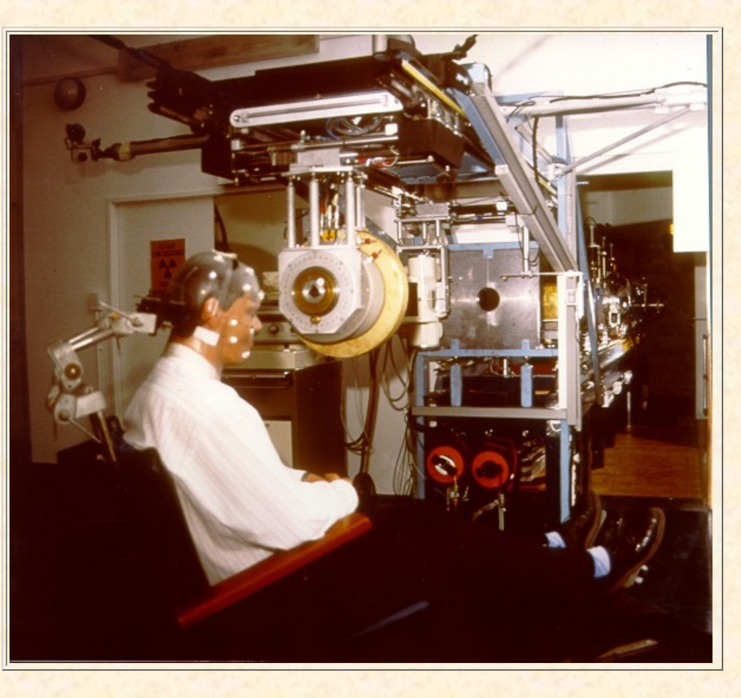

Fig. 6. Horizontal proton therapy treatment station.

A unique patient support and positioning system is based on real-time digital stereophotogrammetry (SPG) techniques (which are commonly used in land surveying) and CT scan information [20]. Patients are fitted with rigid custom made plastic masks, which carry radiopaque and retro-reflective markers. Position information calculated from the reflective marker images obtained by CCD cameras is used to automatically move the treatment chair to align the lesion in the beam with an accuracy of about 1 mm (1 standard deviation).

The treatment planning system is based on VOXELPLAN, obtained from the German Cancer Research Center, Heidelberg. Treatment plans based on Monte Carlo calculations are also done for special cases. For most treatments spread-out Bragg peaks are used but for smaller lesions (<20 mm diameter) crossfire plateau irradiations are given. Most treatments have been stereotactic radiosurgical procedures given in 3-4 fractions. Such fractionated treatments are possible because of the non-invasive nature of the patient immobilization and positioning system. Patients are treated for a variety of conditions (Table 3), most commonly ateriovenous malformations, brain tumours, pituitary adenomas, acoustic neuromas, meningiomas and brain metastases. Treatment sessions are currently on Mondays and Fridays.

A new dual fixed-beamline treatment station [12] is under development. Two fixed beam lines with a common isocentre will be installed : one horizontal line and one line inclined at an angle of 60° to the horizontal ***(Fig. 7)***.

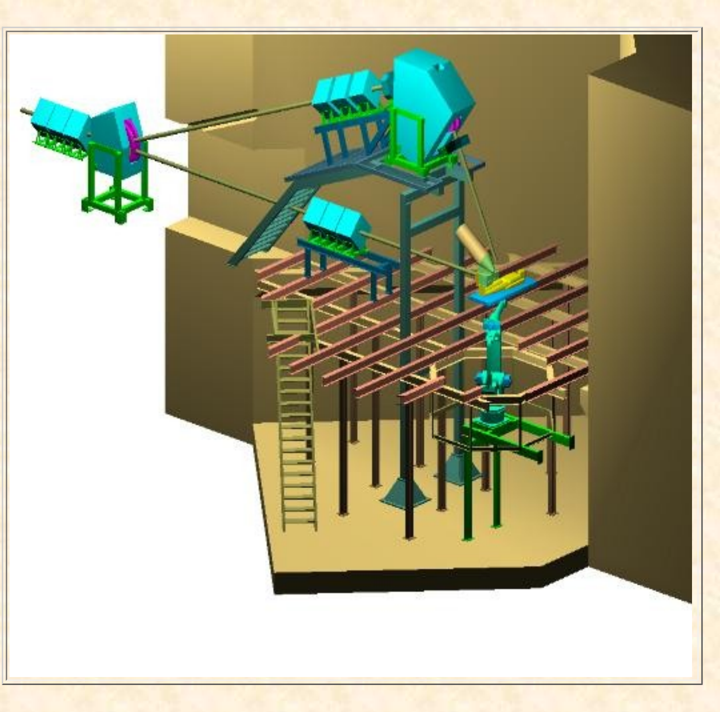

Fig. 7. Diagram of 2nd proton therapy treatment station.

Magnets from a dismantled physics experiment are being used. These two non-orthogonal beam lines and a scanning beam delivery system together with a robotic patient support system (with 6 degrees of freedom) will provide an extremely versatile treatment facility and permit the treatment of a wider range of lesions and increase patient throughput. A movable treatment nozzle, which can be used on both beam lines, is under consideration.

Beam utilization will be optimized by switching between the new treatment room and the existing one. In addition a dedicated proton therapy facility, based on a 230 MeV cyclotron, is currently being planned. This facility will include fixed beam arrangements, an isocentric gantry and both scattering and scanning beam delivery systems ***(Fig. 8)***. The existing treatment vault and the one currently under development will be incorporated in the new facility, but the beam delivery systems will be changed: the existing vault will contain an isocentric gantry and the other one will have a fixed horizontal beam. Both these stations will have scanning beam delivery. The two new vaults will contain non-orthogonal fixed beam arrangements with scattered beam delivery.

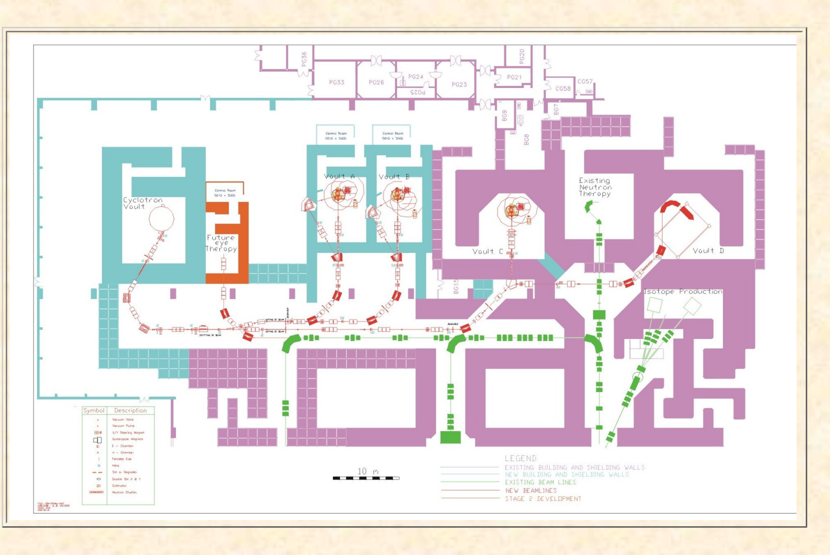

Fig. 8. Layout of the NAC's proposed new dedicated proton therapy facility. The three existing vaults are on the right (neutron therapy is in the middle). The small vault between the cyclotron and the two new vaults is for a possible future dedicated eye treatment facility, using the 66 MeV proton beam from the existing cyclotron.

References

1. Kogelnik,J.H. Hadron therapy - do we need it? In Advances in Hadrontherapy, eds. Amaldi, U., Larsson, B. and Lemoigne, Y. Elsevier Science BV, Amsterdam, 12-28, 1997.
2. Wilson, R.R. Radiological use of fast protons. Radiol. 47,487-491 (1946).
3. Tobias, C.A., Anger, H.O. and Lawrence, J.H. Radiological use of high energy deuterons and alpha particles. Am. J. Roetgenol. 67, 1-27
4. Raju, M.R. Heavy Particle Radiotherapy. Academic Press, New York, 1980.
5. Jones, D.T.L., Schreuder, A.N. and Symons, J.E. Particle therapy at NAC: physical aspects. In Proc. 14th Int. Conf. on Cyclotrons and their Applications, ed. Comell, J.C., World Scientific, Singapore, 491-498, 1996.
6. Jones, D.T.L., Schreuder, A.N., Symons, J.E. and Yudelev, M. The NAC particle therapy facilities. In Hadrontherapy in Oncology, eds. Amaldi, U. and Larsson, B. Elsevier Science BV, Amsterdam, 307-328, 1994.
7. Jones, D.T.L. NAC - the only proton therapy facility in the Southern Hemisphere. In Ion Beams in Tumor Therapy, ed. Linz, U. Chapman and Hall, Weinheim, Germany, 350-359, 1995.
8. Koehler A.M., Preliminary design study for a corkscrew gantry. In Proc. Fifth PTCOG Meeting and International Workshop on Biomedical Accelerators. Report No. LBL-22962, Lawrence Berkeley Laboratory CA, 147-158, 1987.
9. Pedroni, E., Bacher, R., Blattmann, H., Bohringer, T., Coray, A., Lomax, A., Lin S., Munkel, G., Scheib, S., Schreuder, U. and Tourovsky, A. The 200 MeV proton therapy project at the Paul Scherrer Institute: Conceptual design and practical realisation. Med. Phys. 22, 37-53 (1995).
10. Flanz, J., Durlacher, S., Goitein, M., Levine, A., Reardon, P. and Smith, A. Overview of the MGH/Northeast Proton Therapy Center plans and progress. Nucl. Instrum. Methods Phys. Res. B99, 830 -834 (1995).
11. Sisterson, J.M. Particles, Number 28, Northeast Proton Therapy Center, Boston, MA (2001).
12. Jones, D.T.L., Schreuder, A. N., Symons, J.E. , de Kock, E.A., Vernimmen, F.J.A., Stannard, C.E., Wilson, J.A.G. and Schmitt, G. Status report of nac particle therapy programme. Strahlenther. Onkol.. 175 Suppl. II 30-32 (1999).
13. Koehler, A.M., Schneider, R.J. and Sisterson, J.M. Flattening of proton dose distributions for large-field radiotherapy. Med. Phys. 4, 297-301 (1977).
14. Koehler, A.M., Schneider, R.J. and Sisterson, J.M. Range modulators for protons and heavy ions. Nucl. Instrum. Methods 131, 437-440 (1975).
15. Larsson, B. Pre-therapeutic physical experiments with high-energy protons. Br. J. Radiol. 34, 143-151 (1961).
16. Nakagawa, T. and Yoda, K. A method for achieving variable widths of the spread-out-Bragg peak using a ridge filter. Med. Phys. 27, 712-715 (2001).
17. Jones, D.T.L. and Schreuder, A.N. Magnetically scanned proton therapy beams: rationales and principles. Radiat. Phys. Chem. 61, 615-618 (2001).
18. Haberer, T., Becher, W., Schardt, D. and Kraft, G. Magnetic scanning system for heavy ion therapy. Nucl. Instrum. Methods Phys. Res. A330, 296-305 (1993).
19. Lomax, A. Personal communication (2000).
20. Jones, D.T.L., Schreuder, A.N., Symons, J.E., Rüther, H., van der Vlugt, G., Bennett, K.F. and Yates, A.D.B. Use of stereo-photogrammetry in proton radiotherapy. In Proc. Int. FIG. Symp. on Photogrammetry in Engineering Surveying, ed. Rüther, H., University of Cape Town, South Africa, 138-152 (1995).

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TABLES

NEW MEMBERS, ADDRESS CHANGES

Welcome to New Members :

Ms Jessica Gaskin, **U.S.A.**

Mr Johann van Rooyen, **South Africa**

New Members' addresses are listed in the Contact Members' Details (click on country next to name)

Address changes of Members :

Dr Steve Boddeker **U.S.A.**

Dr Joanne O'Meara **Canada**

Members' new addresses are listed in the Contact Members' Details (click on country next to name)

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Table 1: Low-Energy ProtonTherapy Facilities

Place	Country	Max. Clinical Energy (MeV)	Range in ICRU Muscle (cm)	Beam Direction	First Treatment	No. of Patients (July 2001)
Davis, CA	USA	60	3.1	Horizontal	1994	284
Clatterbridge	UK	62	3.3	Horizontal	1989	1033
Nice	France	65	3.6	Horizontal	1989	1590
Chiba	Japan	70	4.1	Vertical	1979	133
Catania	Italy	70	4.1	Horizontal	(2001)	--
Villigen	Switzerland	72	4.4	Horizontal	1991	3360
Vancouver	Canada	72	4.4	Horizontal	1991	57
Berlin	Germany	72	4.4	Horizontal	1998	166
Louvain-la-Neuve	Belgium	90	6.5	Horizontal	1991-1993	21
					TOTAL	6644

All accelerators are cyclotrons

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Table 2: High-Energy Proton Therapy Facilities

Place	Country	Max. Clinical Energy (MeV)	Range in ICRU Muscle (cm)	Beam Direction	First Treatment	No. of Patients (July 2001)
Cambridge MA+	USA	160	17.9	Horizontal	1961	8906
Uppsala+	Sweden	200	26.2	Horizontal	1957	309
Moscow#	Russia	200	26.2	Horizontal	1969	3414
Faure*	South Africa	200	26.2	Vertical	1993	398
Bloomington IN*	USA	200	26.2	Horizontal	1993-2000	34
Orsay+	France	200	26.2	Horizontal	1991	1894
Dubna+	Russia	200	26.2	Horizontal	1967	172
Villigen*	Switzerland	230	33.3	Isocentric	1996	72
Hyogo+	Japan	230	33.3	Isocentric, Horizontal, Vertical, 45°	2001	1
Kashiwa*	Japan	235	34.5	Isocentric, Horizontal	1998	75
Boston MA*	USA	235	34.5	Isocentric, Horizontal	(2001)	--
Loma Linda CA#	USA	250	38.3	Isocentric, Horizontal	1990	6174
Tsukuba#	Japan	250	38.3	Isocentric, Horizontal	1983	700
Berkeley CA +	USA	340	63.9	Horizontal	1954-1957	30
St Petersburg #o	Russia	1000	328.3	Horizontal	1975	1029
					TOTAL	23208

o Treatments suspended

Degraded beams * Cyclotron + Synchrocyclotron # Synchrotron

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Table 3: NAC proton therapy patients

(10 SEP 1993 - 30 SEPTEMBER 2001)

DIAGNOSIS	NUMBER OF PATIENTS
Arteriovenous malformation	75
Brain tumour	54
Pituitary adenoma	47
Acoustic neuroma	45
Meningioma	36
Metastasis	28
Orbit and eye tumour	21
Paranasal sinus	20
Skull base tumour	19
Craniopharyngioma	12
Head and neck tumour	9
Prostate tumour	4
Other	28
Total	398

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