THE FFAG R&D AND MEDICAL APPLICATION PROJECT RACCAM

B. Autin, J. Collot, J. Fourrier, E. Froidefond, F. Martinache, F. Méot, LPSC, Grenoble
J. Balosso, CHU, Grenoble, P. Pommier, Anticancer Centre Léon Bérard, Lyon
J.-L. Lancelot, D. Neuveglise, SIGMAPHI, Vannes

Abstract

The RACCAM FFAG project is described, its context, partners, on-going activities, plans, etc.

THE RACCAM PROJECT

The RACCAM (Recherche en ACCélérateurs et Applications Médicales) project has recently been funded, for a three years term (2006-2008), by the French National Research Agency (ANR). RACCAM is a tripartite collaboration, involving:
(i) the CNRS Laboratory IN2P3/LPSC [1]
(ii) the French magnet industrial SIGMAPHI [2] and
(iii) the Radiation Oncology Department of Grenoble University Hospital [3].
The project concerns fixed field alternating gradient (FFAG) accelerator R&D on the one hand, from lattice design to magnet prototyping, and on the other hand their application as hadrontherapy for cancer and for radiobiological researches.

RACCAM's goal is three-fold:
(i) participate to the on-going international collaborations in the field of FFAGs and recent concepts of "non-scaling" FFAGs, with frames for instance, the Neutrino Factory (NuFact), the EMMA project of an electron model of a muon FFAG accelerator, etc.
(ii) design, build and experiment a prototype of an FFAG magnet proper to fulfil the requirements of rapid cycling acceleration with relevant momentum bite and geometrical acceptance
(iii) develop the concepts, and show the feasibility, of the application of such FFAG beams to anti-cancer hadrontherapy and to researches in radiobiology.

The RACCAM project has its web site, http://wwwlpsc.in2p3.fr/RACCAM/, where various information, schedules, meetings, on-going activities, etc. are regularly up-dated.

CONTEXT

FFAGs are based on the use of magnets with field constant in time, by contrast with pulsed synchrotrons (e.g. recent hadrontherapy installations, LHC) of which magnetic field increases in synchronism with particle acceleration. The unique properties of FFAGs have caused a regain of interest in the last years [4], motivated in particular by recent progress in high gradient accelerating systems, in 3D magnet computation codes [5], and by modern concepts as "non-scaling" optics and fast acceleration [6].

FFAGs are fast cycling accelerators (kHz range), with enormous geometrical and momentum acceptance. The combination of these two properties yields high average intensity beams ; in addition the quality of the manipulation of beams is that of synchrotrons : strong focusing, variable energy, efficiency of transmission and extraction.

This context, as well as on-going works in the frame of the international collaboration on the rapid acceleration of muons in the neutrino factory [7, 8], has seen the birth of a project of a 10-20 MeV electron demonstrator [9]. This electron model could be based in UK [9], and would aim at proving the feasibility of the innovative concepts of "non-scaling" optics and fast acceleration.

FFAGs are in various types of applications a credible concurrent of cyclotron, Linac and pulsed synchrotron accelerators, as an answer to the present needs in high average intensity beams, and offers variable energy as desirable in medical applications.

The goal of the RACCAM project is to contribute to the FFAG R&D within the on-going international collaborations, in Europe by contributing to the electron model of a non-scaling FFAG, in domains as beam dynamics studies, machine design, and by the realisation of a prototype of an FFAG magnet. In addition, RACCAM has the ambition of studying the application of FFAGs in the medical domain, as a second generation proton and light ion accelerator for cancer treatment by radiotherapy.

If a technological breakthrough could make proton beams easily available to radiotherapy, protons would totally dominate radiotherapy and would undoubtedly represent in the future more than two thirds of the indications, if not even more. This is a domain with potentially very strong development, with purely technical and economical constraints.

The interest of these accelerators is in there potentiality to being simpler to build and to operate, more compact, more performing, cheaper than conventional synchrotrons, with proton dose rates comparable to cyclotron ones, and with variable energy allowing 3D conformational irradiation of tumors ("active scanning").

RECENT ACTIVITIES, PLANS FOR FUTURE

In matter of lattice design the RACCAM team is collaborating within the Neutrino Factory, the ISS-NuFact [7, 8] and the EMMA [9] networks.

The main activities for the moment are related to computer code developments, and in general application to transmission simulations and other design optimizations. They have concerned up to now most types of lattices encountered in these domains : linear non-scaling [10, 11], scaling [12], isochronous pumplet and electron model [12, 13].

An important orientation of the project has been decided, from the very beginning : dedicate substantial work to spiral scaling type FFAG lattice, as it is liable to yield very compact machines, consistent with the medical applications foreseen within RACCAM. It is worth noting that this type of lattice belongs in many projects as the acceleration of muons in the Japanese version of the neutrino factory [14], proton drivers [15], proton beams for hadrontherapy. As a consequence, design activities, computing tools developments, are being started.

In matter of magnet design and prototyping, a consequence of the interest of spiral type of scaling lattice, is that RACCAM now foresees magnet prototyping in this area. Various directions of studies have been launched, from formal modelling [16] to 2-D and 3-D computations, which should lead in the coming months to a viable design of a spiral magnet in the 100 MeV region of optics.

On the other hand, works are undertaken to explore the FFAG applications for anti-cancer treatments. The originality of FFAG as compact machines with high dose rate proton beam of various energies offers a new point of view to look at tomorrow's radiotherapy. Biological conditions for high dose rate treatments will be studied, including cell radio-sensitivity alterations according to the dose rate, the dose per fraction and the tumor biology. The public health impact and the economical conditions of the deployment of this next generation of machines will be studied. Finally, specifications of the prototype will take into account the requirements for medical and biological experimental applications. As a first approach, a 10 X 10 cm beam with at least 70 MeV/u of energy (permitting a depth of 35 to 40 mm in human tissues), able to deliver 1 to 10 Gy / sec/litre or 1 to 2 Gy / bunch of protons will be tentative characteristics of the prototype.

REFERENCES

[1] http://lpsc.in2p3.fr/

[2] http://www.sigmaphi.fr/

[3] http://www.chu-grenoble.fr/

[4] The rebirth of the FFAG, CERN Courier, M.K. Craddock, Vol.44 No.6. July 2004.

[5] Development of FFAG Accelerators, Y. Mori, Proc. 17th Int. Conf. on Cyclotrons and Applications, 18-22 October, 2004,Tokyo, Japan.

[6] Review of current FFAG lattice studies in N. America, J.S. Berg, ibid.

[7] http://lpsc.in2p3.fr/usine-neutrino/

[8] http://www.cap.bnl.gov/mumu/project/ISS/

[9] http://hepunx.rl.ac.uk/uknf/wp1/emodel/

[10] 6-D transmission in a linear non-scaling FFAG, F. Lemuet, F. Méot, these Proceedings.

[11] Computer codes comparisons in linear FFAG lattice design, J. Fourrier and S. Machida, to be published.

[12] Developments in the ray-tracing code Zgoubi for 6-D tracking in FFAG rings, F. Lemuet, F. Méot, NIM A (2005).

[13] 6-D beam dynamics in an isochronous FFAG ring, F. Lemuet, F. Méot, G. Rees, Procs PAC05 Particle Accelerator Conference.

[14] NuFACTJ report Page, http://www-prism.kek.jp/nufactj/index.html

[15] R&D for ADSR in KURRI, http://j-parc.jp/Transmutation/ja/pdf2/asiaads2-2-1.pdf

[16] Magnetic Field Created by a Distribution of Conductor, B. Autin and E. Froidefond, Int. Mathematica Symposium, Avignon (June 2006), and these Proceedings.