European Coordination for Accelerator Research and Development

PUBLICATION

EuCARD Newsletter Issue 3

Kahle, K L M (CERN) *et al*

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EuCARD Newsletter

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European Coordination for Accelerator Research and Development Newsletter

Issue 3: October - December 2009

A word on behalf of the Steering Committee

The end of 2009: time to look forward to events of 2010 and reflect on EuCARD results so far. Jean-Pierre Koutchouk, project coordinator and chairman of the Steering Committee, summarizes the recent reports of activities. ***Read more >>***

Cryocatcher in the GSI

The challenge was to develop and test a prototype ion catcher under realistic conditions. The result? Peter Spiller and Lars Bozyk showcase designs for a cryocatcher chamber, under development at FAIR in GSI, Germany as part of EuCARD's collimator research. ***Read more >>***

Strategy and the Spallation Source

It's been a busy time for neutrino networking. NEu2012's Silvia Pascoli summarises involvement in neutrino workshops on future strategy, next generation detectors and the European Spallation Source in Lund, Sweden. ***Read more >>***

Accelerators for hadron therapy

EuCARD is co-sponsoring *Physics for Health in Europe* in 2010 (see **events**). Ugo Amaldi from University Milano Bicocca and TERA Foundation, explains the rationale and challenges for accelerators in the field of hadron therapy. ***Read more >>***

For EuCARD members

A common quote in the world of science is "publish or perish". But what do EuCARD members need to know about publications? Read our FAQ of what, how and why. ***Read more >>***

Upcoming events

17-18 Dec 09 PPA09 Proton-Driven Plasma Wakefield Acceleration, Switzerland

02-04 Feb 10 Physics for Health in Europe Workshop, Switzerland

(13)14-16 Apr 10 EuCARD Annual meeting (13 for parallel sessions, 14-16 for meeting), UK

23-28 May 10 IPAC10 International Particle Accelerator Conference, Japan

Read more >>

Project Results

Publications are now listed in the **publications database**, recent submissions include: *Characterization of superconducting multilayers samples*, *Development of the C-Band BPM System for ATF2*, *Photon backgrounds at the CLIC interaction point*. ***Read more*** >>

Monographs Volume 5 of the EuCARD monograph series is now available: *Some topics in beam dynamics of storage rings* ***Read more*** >>

Deliverables and **milestones** have been successfully completed.

Read more >>

Please contact the EuCARD editor with any news, events, achievements, images and ideas that you would like publicized.

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A word on behalf of the Steering Committee

At the start of November, the EuCARD Steering Committee met at INFN Frascati in Italy.

Coordinators of each of the 11 Work Packages (WP) reported on the first 6 months of activities (April-September 2009) of this 4-year project.

The meeting, and the interim reports that preceded it, gave an opportunity to reflect on the progress, adjust the actions and communicate.

The overall impression is of a dynamic project reaching an impressive level of activity and a large number of publications after only 6 months (see summary below).

EuCARD Steering committee at INFN Frascati, 5th November 2009. Names and the Work Packages (WP) they represent are as follows:

*Front (l-r): I Efthymiopoulos, CERN, **WP5:HiRadMat**; V Palladino, INFN, **WP3:NEU2012**; R Assmann, CERN, **WP8:ColMat**; F Zimmermann, CERN, **WP4:AccNet***

*Middle (l-r): O Brunner, CERN, **WP10:SRF**; F Kircher, CEA, **WP7:HFM**; K Kahle, CERN, **WP2:DCO**; A Variola, CNRS-IN2P3, **WP4:AccNet**; J-P Koutchouk, CERN, **WP1:Management;** M Biagini, INFN, **WP11:ANAC**; S Stavrev, CERN, **WP1:Management**; T Ekelof, UU, **WP1:Management**; R Romaniuk, WUT, **WP2:DCO***

*Back (l-r): O Napoly, CEA, **WP10:SRF**; E Jensen, CERN, **WP9:NCLinac**; N McCubbin, STFC, **WP6:MICE**; G Blair, RHUL, **WP9:NCLinac**; J Stadlmann, GSI, **WP8:ColMat***

*Absent: S Pascoli, IPPP Durham University, **WP3:NEU2012**; G de Rijk, CERN, **WP7:HFM**; R Edgecock, STFC, **WP11:ANAC***

Annual Meeting 2010

I'd like to also take this opportunity to highlight the **EuCARD Annual Meeting** in the UK from 14-16 April 2010, with 13 April available for WP meetings.

This first important event will combine WP reports with highlighted talks.

To open perspectives, they will be complemented by invited talks by the host laboratory (**STFC**-RAL), by other EU accelerator projects and proposals, and a visit to RAL machines is being arranged. The local RAL organizing committee is working hard for all participants to enjoy this event.

Synergies and sincerities

In addition to its solid R&D program, EuCARD is due to look sideways to other possibly interesting fields where synergies could be identified. I wish to point to your attention two fields where events will soon take place, publicised in the **former** and in **this** newsletter: **plasma wave acceleration** and **applications of accelerators to cancer therapy**. Those EuCARD partners having competence and interest in these fields are invited to express interest to prepare, together with WP4, a follow-up of these **events**.

This newsletter will reach you soon before the end of the year holidays. It is thus an opportunity for me and for the coordination office to wish you a merry Christmas and happy New Year.

Summary of EuCARD activities in the first six months

The results obtained in this first period somewhat exceeded expectations. The **project web site** had been delivered since the beginning of the project, i.e. 1 month in advance, while the **network** web sites were successfully delivered: **AccNet** at M2 and **NEu2012** at M6, one of them with a minor delay to solve a remote access issue. The project largely makes use of the **Intranet** collaborative work spaces in addition to more traditional web pages.

On the **communication** side, two issues of the EuCARD **newsletter** have already been published and one paper in the **CERN Courier**. The publishing of **scientific booklets** appears on good track. Statistics of the number of hits to communication media (web sites, newsletter) show a marked increase from both inside and outside the project.

Building on the experience of **CARE**, the **NEu2012** and **EuroLumi** networks have sharply started, supporting or already organizing several workshops. Amongst others, the **workshop on crab cavities** for the LHC upgrade has already triggered decision making by the CERN management. The **RFTech** network is totally new and, in this first period, participates in existing events.

The activity in **Joint research** has had a remarkable start, thanks to its deep rooting in the workplan of the partners. Although no deliverables were foreseen and only one **milestone**, almost all tasks have reported fast progress. While a large fraction of this work is preparatory (e.g. writing specifications, selecting solutions to be studied, calls for tenders, installation of beam instrumentation,...), a few non-exhaustive examples are given for tangible intermediate results:

- **HFM (WP7)**: The 2D design of the high field magnet model could be initiated in advance. The study shows an interesting equivalence between block and cosθ designs.
- **ColMat (WP8)**: the very large collaboration (11 partners) has organized itself around collimation studies and the work is advancing on all aspects. An advanced LHC collimator has been mostly assembled and qualified, before closing its tank.
- **NCLinac (WP9)**: A record stabilization to 1.2 nm rms was obtained on a LC mock-up without a specific heavy table.
- **SRF (WP10)**: The very stringent LHC space requirements could be satisfied by a new compact four-rod crab cavity design. For thin film RF cavity technology, thin and ultra-thin superconducting layers have been deposited by magnetron sputtering, showing good quality.
- **ANAC (WP11)**: Both crab waist studies and **EMMA** beam line installation are ahead of schedule.

The project collaborators have already **published** more than 70 papers, mostly scientific papers in conferences. This exceptionally large number shows that the activity at the partners has been anticipated, and their willingness to associate this work to the EuCARD project.

The difficulties encountered in a small number of tasks are related to personnel. Some postdoc positions are not yet filled (e.g. tasks 10.3, 11.2), one task leader has left one of the partners (10.8) while a key expert sadly passed away at the beginning of the project (Jonathan Sladen, CERN, task 9.5).

A **milestone** of task 9.3 was delayed by 2 months due to the non-availability of a monitor at ATF2 (which is not in EuCARD). The only technical difficulty has been with the planning of the **HiRadMat@SPS access (WP5)** following the LHC incident that is a case of force majeure. A significant delay (one year assuming an aggressive planning) is expected. Nevertheless, all steps are made by the access coordinator to be able to deliver close to the number of access units planned. In all cases, active steps are being made in the collaborations or at the partners to solve the issues. No impact of the planning of deliverables is anticipated, except for the HiRadMat access. In contrast, applications have already arrived for **MICE access (WP6)** and are currently being processed.

The collection of data on the use of resources at the partners has been more laborious and remains incomplete for this first period. Even though these indicators are complex to collect and to interpret, they already point to some minor issues that shall be followed up by the WP and Project coordinators. Simpler indicators will be proposed for the next report.

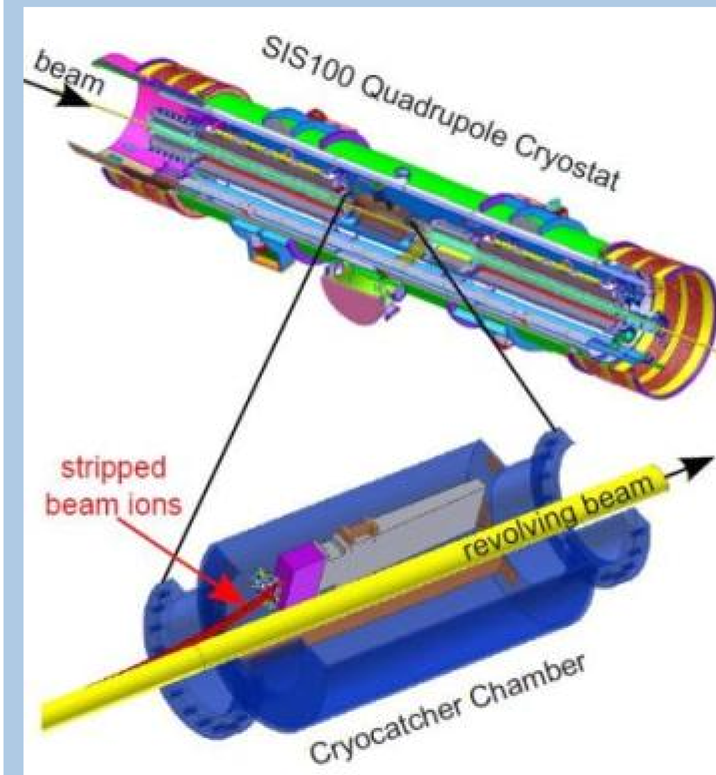
Overall the activity reporting of this first period shows a project well on track and on schedule.

- Jean-Pierre Koutchouk, CERN, EuCARD Project coordinator

Cryocatcher in the GSI

A new design for a cryogenic collimator - or cryocatcher - could hold the key to controlling ionization beam loss to protect the machine at the Facility for Antiproton and Ion Research (**FAIR**) at **GSI** in Germany.

With the basic layout of the collimator now ready, researchers plan to test a prototype under realistic conditions.



An illustration of the cryocatcher chamber within the SIS 100 Quadropole Cryostat. The SIS100 is one of the main accelerators at FAIR in GSI. The cryocatcher chamber is shown in blue at the bottom of picture, the revolving beam is shown in yellow with the ions trajectories with changed charge state shown in red, the cryocatcher is violet and grey, desorbed gases are shown as coloured balls and additional cold surfaces are coloured brown. *Image courtesy of* ***GSI****; Thumbnail image on main page of "Catcher in the rye" book cover courtesy of Wouter Olthuis.*

An intense afFAIR

At FAIR, due to the intensity goals for heavy ions, intermediate charge states have to be used (e.g. Uranium ions U^{28+} instead of U^{73+}).

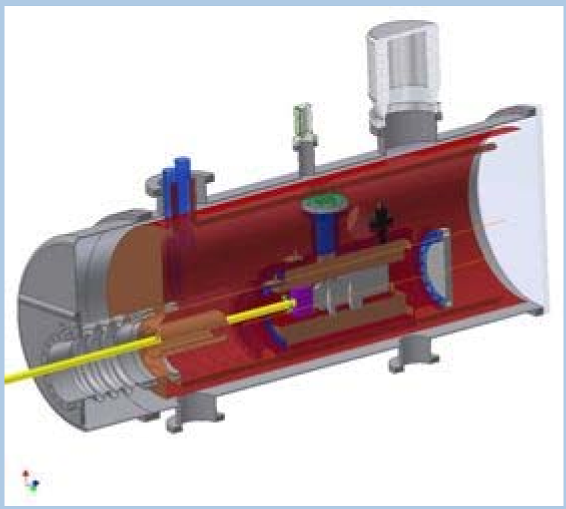
With this reduction in charge state, higher beam intensities can be reached by shifting the space charge limit to a higher number of particles. This also reduces stripping losses (at the generation of the highly charge ions) - when the beam ions lose electrons as they pass through a foil in the accelerator. Ions do not all lose the same number of electrons, resulting in a distribution of charge states. One charge state is selected for further acceleration and the rest are lost.

FAIR won't be the first synchrotron to operate with intermediate charge state heavy ions. Already the **AGS booster** (BNL), the **LEIR** (CERN) and the **SIS18** (GSI) are running with typical intensities in the range of 109 ions/cycle.

However, the challenge for the future FAIR SIS18 and SIS100 synchrotron operation shall be to work with an intensity around 5 hundred times greater: 5x1011 ions/cycle and 3x1011 ions/s.

Catching the beam

Though intermediately charged heavy ions give a more intense beam than highly charged ions, the problem operationally is the significantly higher cross section for electron loss or electron capture (depending on the beam energy). With a higher cross section, more ions hit the walls of the beam pipe setting weakly bound molecules free in a process called ion induced gas desorption that builds up gas pressure. Major beam loss and a so called vacuum instability may develop.



Cryocatcher test setup, planned for 2010: yellow=Test-beam, violet=cryocatcher, red= thermal copper shield, grey= cryostat.
Image courtesy of ***GSI***

By means of a dedicated catcher system for ionized particles, the beam can be filtered and thereby the desorption is significantly reduced and the pressure stabilized. To be useful, the ion catcher system has to provide a significantly lower effective desorption yield than the simple (typically grazing) accelerator beam pipe.

Tests have shown that for perpendicular incidence on specially coated surfaces, the yield of desorbed gases can be reduced drastically (from 1E4 down to ~50). Thereby, the installation of an ion catcher system at the positions of beam loss stabilizes the residual gas pressure and increases the limit for stable high intensity operation.

In order to catch as much ionized beam ions as possible, a special lattice design has been developed for SIS100, offering a catching efficiency of almost 100% for the charge exchange process U^{28+} to U^{29+}.

The development and test of a prototype ion catcher under realistic conditions is part of the **ColMat** work package of EuCARD.

Since SIS100 will be a superconducting synchrotron, the ion-catchers have to be installed in a cryogenic environment. The cold environment acts as a powerful cryo pump. The cryocatcher itself will be kept at a higher temperature to avoid freezing out of gases on the area of ion impact.

Testing times

A test setup of the SIS100 cryocatcher will be built at GSI and tested with heavy ion beam from SIS18 under realistic conditions. The setup includes the cryocatcher with suspensions, the liquid helium cooled catcher chamber and a surrounding cryostat. The tendering process for construction and manufacturing is under way and the test setup is expected to be completed in the middle of 2010.

*- Peter Spiller and Lars Bozyk, GSI, EuCARD-**ColMat (WP8)**.*

Strategy and the Spallation Source

With so many recent events in neutrino physics, it has been a busy time for EuCARD's **NEu2012** members. High-profile international workshops have brought together the worldwide neutrino community to discuss recent developments and the strategy for the future in accelerator and non-accelerator neutrino physics.

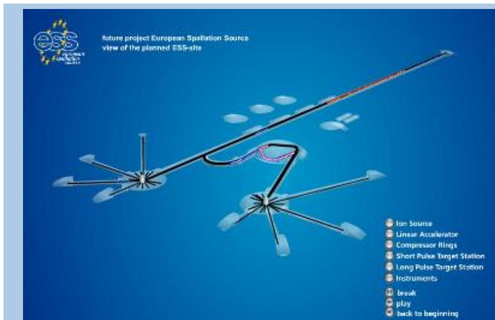


Diagram of the future European Spallation Source (ESS) to be based in Sweden. ESS will fire protons at a target material to knock off its neutrons in a process known as spallation. Scattered neutrons will then be used to examine different materials. **Read more >>**. *Image courtesy:* ***European Neutron Portal****. Thumbnail image main page courtesy of* ***ESS Scandanavia***

Making an impact at the European Spallation Source

The most recent event was the workshop on **Neutron, Neutrino, Nuclear, Muon and Medical Physics at ESS**, which took place at the European Spallation Source, Lund, Sweden, 2-4 December 2009. It was aimed at identifying unique experimental opportunities for the different communities of neutron, neutrino, nuclear, muon and medical physics at the new European facility.

“The ESS facility is expected to run by 2018 at 2 GeV, with a 5 MW proton beam on a mercury target to produce spallation neutrons," explains Mauro Mezzetto, convener of the Neutrino Physics session.

Mezzetto, keen to emphasis the importance for the neutrino community, adds: "This facility will produce for free a large flux of neutrinos generated from pion decays, either in flight or at rest, with energies from about 10 to 100 MeV." ESS can complement experiments already performed e.g. LSND at Los Alamos Meson Physics Facility (**LAMPF**), USA and Karmen at **Isis**, UK, as well as newly proposed experiments such as **OscSNS** at the SNS facility at Oak Ridge, USA.

"They allow a precise measurement of neutrino cross sections at an energy range not accessible by reactor or accelerator neutrinos," continues Mezzetto. "These energies are of great interest for neutrino processes during a SuperNova explosion. These experiments can also check the anomaly detected by LSND. Although not confirmed by **MiniBoone**, it is not yet fully excluded and a direct check with a more sensitive experiment could definitely close this physics topic.”

Members of NEu2012 made important contributions, both at the initial phases by participating in the International Advisory Board and during the workshop itself, giving some of the key talks in the neutrino session.

Shaping the future of neutrino physics

Before this, the most important event of the year for NEu2012 was the **SPC Neutrino** Workshop (European Strategy for Future Neutrino Physics) at CERN, Geneva, Switzerland, 01-03 October, explicitly focusing on the strategy of the future neutrino programme in Europe and worldwide. It was soon followed by the **NNN09** Workshop (Workshop on Next Generation Nucleon decay and Neutrino Detectors), The Stanley Hotel, Colorado, USA, 09-11 October.

The EuCARD network **NEu2012** (Neutrinos for Europe in 2012) refers to the date set by the European Strategy for Particle Physics, by which time the network should deliver an agreed programme of neutrino experiments, based on upgrades of existing infrastructures and/or on the proposal of a new one. *Logo courtesy of* ***NEu2012***

The SPC neutrino workshop was organised jointly by the CERN Management, the Scientific Policy Committee and the European Committee for Future Accelerators. It put the emphasis on accelerator based neutrino physics, following up on a recommendation of the 2006 CERN strategy document stating: "Council will play an active role in promoting a coordinated European participation in a global neutrino programme".

The workshop presented a detailed overview of the present status in neutrino physics from a theoretical, accelerator and detector point of view. It offered a unique opportunity to discuss a future short and long term neutrino programme, and the role CERN could play in it. The event was well attended, with more than 250 participants from Europe, North America, India, Iran and Japan.

The workshop was partially supported by NEu2012, which funded a limited number of young participants. Scientists from NEu2012 were conveners of various sessions, helping in the shaping and the organisation of the workshop. Many of the key talks were presented by NEu2012 researchers who also contributed significantly to the interesting physics discussions. Alain Blondel chaired a round table in which leading neutrino scientists confronted different opinions for the future strategy in neutrino physics.

Prompted by the workshop, ECFA also organised a neutrino session on the 27 November, reviewing and warmly encouraging the combined efforts of the EUROneutrino Design Study and of the NEu2012 network.

The NNN workshop is one of the two main yearly R&D workshops for NEu2012. While the NuFact workshop focuses more on novel neutrino beams, NNN focuses more on detector R&D and underground detector sites for neutrino physics, as well as proton decay, supernova studies and high energy cosmic ray sources. The workshop aims at an international coordination between Europe, Asia, and the Americas. NNN09 was the tenth workshop of this series and was well attended by world-leading scientists in all these areas, various spokespersons of major experiments, coordinators of international projects and directors of scientific institutes.

Most notably Pier Oddone gave the concluding talk on the perspective of the field and Young-Kee Kim, Andre Rubbia replacing Stavros Katsanevas and Takaaki Kajita formed a round table discussing the issues related to this ambitious experimental programme.

NEu2012 actively contributed to the discussions with the coordinator Vittorio Palladino and other NEu2012 scientists participating in the workshop and Silvia Pascoli, deputy coordinator, giving the key talk on the present theoretical status of neutrino physics and its development in the past ten years.

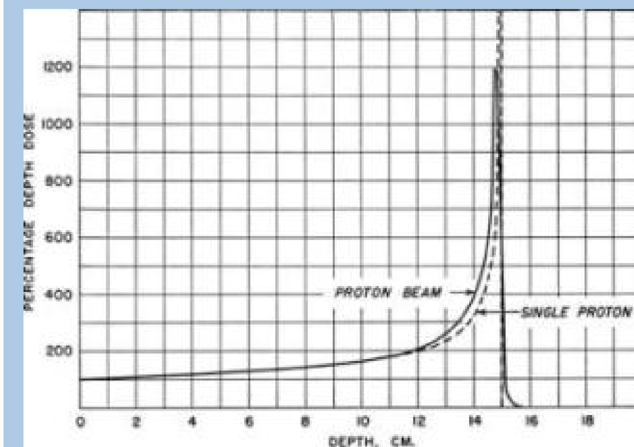
A look ahead to 2010

The year 2010 will see many new activities in neutrino physics. New experiments as T2K and reactor experiments will start physics operations, a promise of imminent exciting new data and of a new understanding of neutrino properties. Interesting workshops and discussions in the community will take place. NEu2012 will continue to contribute to all these activities, ultimately helping to shape the future neutrino experimental programme. Its first yearly meeting is now firmly planned for 13 April at **STFC-RAL**.

*- Silvia Pascoli, IPPP Durham University, EuCARD-**NEu2012 (WP3)***

Accelerations for hadron therapy

The workshop ***Physics for Health in Europe*** will be bringing together the physics and medical communities at CERN in February 2010. One aspect of this workshop will be the role of accelerators in cancer treatments and for that reason EuCARD is co-sponsoring the event.



As a proton beam passes through matter, it loses most of energy (at the "Bragg peak") just before coming to rest. In cancer treatment, this allows a proton beam to pass through healthy tissues with minimal effects to reach and treat a tumour. *Image courtesy: R. R. Wilson's paper on proton therapy. (Radiology 47, pp. 487–491, 1946). Thumbnail image main page courtesy of* ***PARTNER***

X rays or hadron beams

Hadron therapy is a modern cancer radiotherapy technique that exploits the "Bragg peak", the point at which charged hadrons leave the largest fraction of their energy density. At present two hadrons are most used in clinical treatments: protons and fully stripped carbon ions.

Proton beams have essentially the same clinical effects as the conventional X ray beams (with which 20,000 European patients are treated every year in a population of 10 million people). But in contrast to X rays, proton beams spare much more of the healthy tissues close to the tumour, due to the Bragg peak.

The X rays are produced by 3 GHz linacs, accelerating electrons to 5-20 MeV. Today there are almost 15,000 electron linacs installed in the world hospitals each treating about 300-400 patients per year. The number looks small but it correspond to 9,000-12,000 sessions, as every patients comes back typically five days a week for six weeks. The fractionation of the dose is essential to treat about 90% of all the solid tumours whose cells repair the radiation damage less effectively than the surrounding healthy tissues. By repeating the treatment thirty times with relatively low doses (2 J/kg, or ‘gray’, per day) even a small difference between ‘radiosensitive’ tumour cells and more ‘radioresistant’ healthy tissues is enhanced and the tumour can be controlled without serious damage to the healthy tissues.

Since proton treatments produce the same effects as X rays, they are also delivered in many sessions (typically 20-25) to profit of the differential repair mechanism. The range in water of a 200 MeV proton is 26 cm, so that the accelerators used in proton therapy have energies in the range 200-250 MeV. The challenge is the energy, not the current, since – to deliver the typical 2 Gy/min to a 1 liter volume – a very small current is needed: about 1-2 nA.

Proton therapy centres on the increase

At the end of 2009, the number of proton-treated patients has passed the 60,000 milestone and increases by about 15% every year. Patients were initially irradiated in a dozen subatomic physics laboratories, which have now stopped these treatments, and in more than ten hospital-based proton therapy centres, the first one (the **Loma Linda University Centre**) becoming active fifteen years ago. Another ten centres are under construction or planned around the world as five companies now supply turn-key facilities. This single number justifies the statement that proton therapy is booming.

All the existing centres are based either on cyclotrons (normal or superconducting) or on synchrotrons. New types of accelerators are also considered. In the last years high-frequency high-gradient linacs have been prototyped and various groups have designed FFAGs (Fixed-field alternating-gradient), of the scaling and non-scaling type. The injector can be either a cyclotron or a small FFAG. Linacs and FFAGs are the new accelerators that are closest to realization and have clear advantages with respect to conventional ones because the extraction can run at hundreds of hertz. Such fast-cycling accelerators are best suited to deliver the dose with the 'spot scanning' technique in the 'multipanting mode', thus covering in a couple of minutes the tumour volume more than ten times and following it when – due to the respiration cycle - it moves. Both machines have difficulties in accelerating protons for speeds smaller than $\beta = 0.2$. Thus new concepts in the design of *compact low-energy proton accelerators to be used as injectors* to fast cycling accelerators would have a great impact on these recent developments.

An ENLIGHTened approach to carbon ions

According to studies performed in the framework of the European Network for Light Ion Therapy (**ENLIGHT**), co-ordinated by Manjit Dosanjh of CERN, groups of Austrian, French, German and Italian radiation oncologists came to the conclusion that about 12% of the 20,000 X ray patients mentioned above would have an advantage if treated with carbon ions, large enough to justify the increased cost for an advanced Intensity Modulated Radio (or Particle) Therapy: from 8-10 thousand Euros to 20-25 thousand Euros.

While 200 MeV are needed to reach deep-seated tumours with protons, 4,800 MeV (i.e. 400 MeV/u) are necessary for carbon ions - an energy 24 times greater. The current is correspondingly smaller: about 0.1 nA is sufficient.

With carbon ions, the clinical results obtained in Japan and Germany on head and neck, lung, liver, and prostate tumours confirm predictions that they have a larger biological effectiveness than protons. This is due to their twenty times higher ionization producing multiple double-strand breaks and clustered damages in the DNA of the traversed cell. These damages cannot be repaired by the usual cellular mechanism and, as a consequence, carbon ions are suited to control the tumour cells that, instead of being more radiosentive than the surrounding healthy tissues, are more radioresistant. These types of tumours, which the ENLIGHT study quantified to be about 3% of the 20,000 patients on 10 million inhabitants, are thus the targets of choice in a carbon-ion facility.

Gantry Treatment Room of the Heidelberg Ion Therapy (HIT) centre, Germany. *Image courtesy:* ***HIT***

In the past five years Europe has made important steps in the development and construction of hospital-based 'dual' centres for carbon ions and protons. In particular in November 2009 the **Heidelberg Ion Therapy** centre has treated its first patient, and **CNAO** (the Italian Centro Nazionale di Adroterapia Oncologica in Pavia) should start treating patients at the end of 2010.

Synchrotrons are at the heart of the European facilities since the magnetic rigidity of 400 MeV/u carbon ions is about three times larger than for 200 MeV protons, for which both cyclotrons and synchrotrons are in use. In the future, things will change since at present the Belgian company **IBA** is offering a novel 6-metre diameter superconducting cyclotron that accelerates carbon ions up to 400 Mev/u.

The challenges of size and cost

If 200 MeV proton accelerators would be as cheap and small as the 5-20 MeV electron linacs used in conventional radiotherapy, at least 90% of the patients would be treated with proton beams. Instead the accelerators used today are large and expensive (about 20 and 40 M€ for protons and carbon ions respectively). To make good use of them, facilities feature 3-5 treatment rooms. Moreover a proton centre features from two to four 10-m diameter ‘gantries’ that support beam transport systems to transform the horizontal extracted accelerator beam into beams rotating around the patient's bed. Each gantry costs 10-12 M€ when the patient alignment system is included. In the case of carbon ions, the rigidity is 3 times larger than for protons with an obvious escalation in dimensions and cost. In fact only one ion gantry has been built by HIT: it weighs 600 tons and consumes 400 kW. Thus one of the challenges facing hadron therapy is the reduction of the ion gantry dimensions, possibly by using superconducting magnets.

Two other routes are also open and valid for protons: either the use of a *limited number of fixed beams* pointing to the patient bed or a *clever way of moving the patient* without a gantry. These two possibilities have been considered for a long time but radiation oncologists unfortunately resist treating patients who are not laying on a bed.

Another related challenge is posed by the dimensions of the building, which typically covers 3,000-4,000 square metres and needs investments in the 20-40 M€ range, the largest figure being needed for ‘dual’ centres that treat patients with both carbon ions and protons. The building contains not only the treatment rooms, but also the reception and visit areas, the common areas and the offices for the medical doctors, nurses and technical staff. The overall cost of a proton facilities, which can be as high as 130 -150 M€, hampers the development of hadron therapy; sizeable cost reductions would foster a wider application of these techniques.

One solution under active development is the construction of novel accelerators suited for installation in *single room facilities*. The reason is shown in the table below, which presents the number of treatment rooms needed in five/ten years for a population of 10 million people living in a developed country. Two hypotheses have been made: (i) the number of sessions scales as 1:2:3 and (ii) a photon (hadron) session lasts 15 min (20 min).

Radiation treatment	**Patients per year in 10^7 inhabitants**	**Av. number of sessions per patient**	**Sessions / d in 1 room (d = 12 h)**	**Patients / y in 1 room (y=230 d)**	**Rooms per 10 million people**	**Relative ratio**
X rays	20,000	30	48	370	54	8^2
Protons (12%)	2,400	24	36	345	7.0	8
C ions (3%)	600	12	36	690	0.87	1

Table showing the estimated number of X ray and hadron treatment rooms.

The estimated numbers of rooms turn out to be in the easy to remember proportions $1:8:8^2$. Since a typical hadron therapy centre has 3-4 rooms, the above figures show that a proton (carbon ion) centre would be needed roughly every 5 (40) million people. If the carbon centre is ‘dual’ and patients are also treated with protons, the second number decreases to about 30 million.

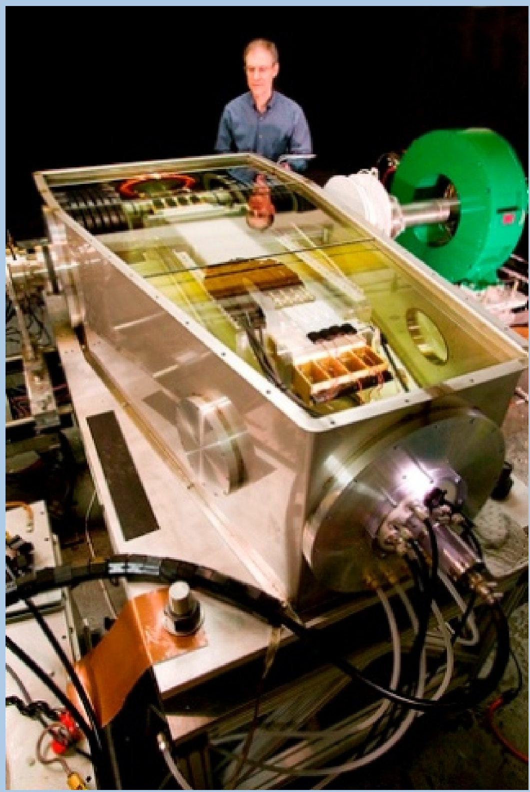
For proton therapy this indicates the fading out of the multi room 'paradigm' serving 5 million people (or more) and containing one accelerator, 3-4 gantry rooms, offices, laboratories and patient reception areas. For the long term a more flexible and patient-friendly solution will be the one based on a single-room proton accelerator/gantry system that is constructed on a relatively small area (≤500 m^2) attached to an existing hospital building. Small (large) radiotherapy departments run 1-2 (5-6) electron linacs so that, typically, 8 conventional rooms are present in 3-4 hospitals covering a population of 1.5-2 million. The single-room proton facility will be attached to one of these hospitals but serve others in addition. Such a facility should cost no more than 15 M€, which is twice the global investment needed for the 8 conventional rooms.

Current and future research and development

Already in 1993, H. G. Blosser proposed a facility based on a 200 MeV rotating superconducting synchrocyclotron. Its modern version is the single-room facility being built by **Still River Systems**. In 2009 the 15 tons **Monarch 250** synchrocyclotron has been constructed and in 2010 the company foresees the installation of the first two systems. The other single-room facility mentioned below is the 5-metre diameter fast cycling synchrotron by **ProTom International**, which aims to treat patients with a horizontal proton beam.

Two further projects that produce proton beams rotating around the patient are been studied. Lawrence Livermore National Laboratory (**LLNL**), in collaboration with **Tomotherapy** and CPAC, is developing the Dielectric Wall Accelerator (**DWA**), which accelerates protons in a non-conducting beam tube (the dielectric wall) energized by a pulsed power system. Open problems of this scheme are the focusing of the accelerated protons and the practical feasibility of a 100 MV/m gradient, which would allow having the DWA rotating around the patient in a small single-room facility.

A high-frequency proton linac rotating around the patient – according to a scheme patented by **TERA** – is a much better understood solution but it would take much more space. To reduce the length of TULIP (TUrning Linac for Protontherapy) a 6 GHz (9 GHz) frequency has been chosen by designing a CCL with an average electric field of about 40 MV/m. High-gradient linac of frequencies larger than 3 GHz are designed by TERA in collaboration with the RF group of the CERN electron-positron linear collider **CLIC**.



The Dielectric Wall Accelerator (DWA) is an induction accelerator. A classical induction accelerator has modules containing ferro-magnetic cores, which - powered in sequence - accelerate large currents with gradients of the order of 1 MV/m. According to Caporaso et al., the high-gradients (100 MV/m) and low currents needed for a medical DWA can be obtained with a coreless induction accelerator that applies the voltage on a High Gradient Insulator (HGI) made of alternating layers of conductors and insulators with periods of about one millimetre. *Image courtesy:* ***Jacqueline McBride/LLNL***.

A rotating radiofrequency linac, such as the Dielectric Wall Accelerator, can produce a proton beam cycling at hundreds of Hz. This is advantageous in spot scanning since it can apply the very powerful technique called Distal Edge Tracking (DET). Moreover there is no intense neutron flux created close to the patient typical of fixed-energy cyclotrons and also of the Still River Systems synchrocyclotron, which is in a much more advanced state of realization.

Even further in the future, the first proton single-room facility based on the illumination of a thin target with powerful (10^{18}-10^{20} W/cm^2) and short (30-50 fs) laser pulses is expected. Proton acceleration is a consequence of the violent acceleration of electrons in the laser field that draw behind them protons on the back surface of the target. The proton spectrum is continuous but the phenomenon has been studied experimentally and is reasonably well understood. Computations show that using two properly shaped targets, a 3% energy spread can be obtained. While companies are reducing the size and cost of the needed high-power lasers, many projects aim at improving the quality of the beam and transforming a general concept into a medical device. This will take many years since a single-room therapy facility requires much more than a proton beam of about 200 MeV.

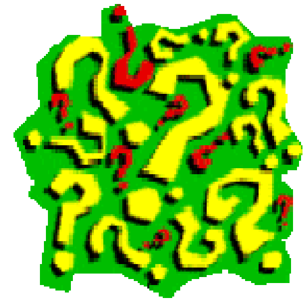
Single-room facilities will have a large role in the future of proton therapy and new ideas are certainly needed.

Instead, as far as carbon therapy is concerned the figures of the table suggest that ‘dual’ *multi-room* centres will be the only ones to be built even in the long term. Certainly synchrotrons and superconducting (synchro) cyclotrons accelerating carbon ions - and possibly other light ions - will play an important role. Also here new ideas would be essential. TERA is working on high-gradient linacs and a scheme is at present under advanced study.

A final remark: whatever the accelerator and even if carbon ion single-room facilities are difficult to conceive, the psychological and economical burden for the patient and the health service can be minimized by using, as already done at **GSI**, a carbon ion beam for a 4-5 session ‘boost’ to be delivered in one week before the conventional treatment, which can then be performed - together with the necessary follow-up - in the radiotherapy department close to the patient’s home.

- Ugo Amaldi, ***University Milano Bicocca*** *and* ***TERA Foundation***
Physics for Health in Europe Workshop, 2-4 February 2010, ***Read more >>***

For EuCARD members



Please see the questions and answers below concerning **EuCARD publications**. If you have further questions, please **contact us**. For more FAQs, see the "For EuCARD members" articles in **previous issues**

General questions

Q. Where can I find EuCARD publications?

A. Project publications are stored in the **EuCARD publications database**, linked from the **EuCARD homepage**, **Intranet homepage** and the **publications page**.

Project deliverables are linked from the **deliverables page** and are stored separately in the **EuCARD document repository**, along with internal restricted documents and interim reporting.

In addition, the series of EuCARD monographs is listed on the **booklets page**.

Q. What acknowledgement text is needed on EuCARD publications?

A. Publications generated within the EuCARD project should include acknowledgement text such as "Research co-funded by the EC within the EuCARD project http://cern.ch/eucard".

If a pdf file is submitted to the **publication database**, an automatic front page is added containing acknowledgement text. None-the-less it is advisable to also include an acknowledgement in the publication itself.

Publication database questions

Q. What can be submitted to the EuCARD publication database?

A. The **EuCARD publication database** accepts seven different types of publications: Journal Publication; Conference Paper, Scientific Reports; Notes; Academic Dissertation; Presentations; Books. Submitted publications are then publicly available and searchable.

Internal restricted documents, deliverables and interim reporting are all stored separately in the **EDMS Document Repository**.

Q. How do I submit a publication to the database?

A. To submit to the **EuCARD publication database**, follow the link from the EuCARD homepage **http://cern.ch/eucard** and then log in and click "submit". Next select the type of publication and work package/task and complete the fields. Note that the format of the author information is very specific and incorrect formatting results in error messages. Use the examples to guide you. Depending on the type of publication, different fields will need completing. If you upload a pdf file an automatic front page is added, which includes acknowledgement text.

Submissions generate automatic emails to the author, task leader, work package (WP) leader and WP1 and WP2. If you have any problems, feedback or wish lists, please contact **EuCARD**.

Q. What if more than one EuCARD work package has worked on a publication?

A. At present publications authored by two separate work packages would need to be uploaded twice, once for each work package. In 2010, EuCARD will discuss with the CDS database team whether a version 2 of the database could allow submissions from multiple work packages. If you have any problems, feedback or wish lists, please contact **EuCARD**.

Q. What if a publication is already elsewhere in the CDS system?

A. At present publications already in the CDS system would need to be uploaded again to the EuCARD database. In 2010, EuCARD will discuss with the CDS database team whether a version 2 of the database could allow CDS EuCARD publications to have multiple references. If you have any problems, feedback or wish lists, please contact **EuCARD**.

Q. How do I modify a publication that I've submitted?

A. Click on the "modify", "delete" or "resubmit" buttons on the **EuCARD publication database** main page and enter the reference number that your submitted publication has been given. You can then follow the instrcutions to make amends. If you have any problems, feedback or wish lists, please contact **EuCARD**.

Q. What reviewing do task leaders need to do?

A. Task leaders have a specific role concerning the **EuCARD publication database**. When a publication is submitted from a task, the task leader will receive an automatic email either for information or asking them to "give comments within 14 calendar days". Note: comments are requested only in certain cases: pre-prints of Journal Publications, Scientific Reports, Academic Dissertations or Books.

This light reviewing mechanism is in place as a minimum contractual requirement. Task leaders should assume that the scientific quality of a publication is guaranteed by the existing review processes of an institute and instead just check that:

(a) all contributing parties have been duly credited (i.e. check Intellectual Property issues)

(b) the EuCARD project has been mentioned, i.e. "Research co-funded by the EC within the EuCARD project http://cern.ch/eucard"

Though comments are requested, task leaders are free to give no comments. They are also welcome to add additional scientific task/work package reviewing if wished. If you have any problems, feedback or wish lists, please contact **EuCARD**.

Monograph questions

Q. What is a monograph?

A. A monograph is a scientific booklet on a specific topic. The EuCARD project is publishing a series of monographs on Accelerator Science and Technology that will evolve through the lifetime of the project. To see a list of current and planned titles, visit the **Booklets** web page.

Q. What EuCARD monographs are currently available?

A. A list of EuCARD monographs on Accelerator Science and Technology is available on the **Booklets** web page.

Q. How can I get a copy of an EuCARD monograph?

A. To request a copy of an **EuCARD monograph**, please contact **EuCARD** stating the desired publication title and your name, affiliation and mailing address.

Q. What information is there for potential authors?

A. Those interesting in writing a monograph can find more information on the **Booklets page**. For any queries, please contact the **EuCARD editor**.

Document repository questions

Q. What is stored in the EuCARD document repository?

A. Internal restricted documents, deliverables and interim reporting are all stored in the EDMS EuCARD **Document Repository**. As the project evolves this repository will be more closely linked to the Intranet and public web pages.

Q. How do I log in to EDMS?

A. If you have a CERN NICE account, you can log in to the EDMS EuCARD **Document Repository** with your regular username and password.

If you have a CERN lightweight account, you can now log in using the email address and password that you use to access the EuCARD Intranet. NOTE: the first time that you log in, EDMS registers your credentials but does not grant access. You need to wait for the system to update overnight and then log in again. For any queries, please contact the **EuCARD editor**.

The generic login username and password, available from the Intranet homepage still works, but you are encouraged to now move to using your own login and password rather than this anonymous access.