



International collaboration at its best

Launched in 1998, MYRRHA first took shape as a purely Belgian project, though it very quickly became necessary to open the project up to international partners. There are now dozens of universities, research centres and industries collaborating on what is undoubtedly one of Europe's most innovative technological projects.

The designers of MYRRHA quickly began to dream of an international future for their project. "It was our intention to make MYRRHA an international project practically from the beginning. We wanted it to form a hub for European research and development and to then transform it into a large infrastructure for researchers from all over Europe and even from across the entire globe", Hamid Aït Abderrahim, Director of the MYRRHA project, reminisces enthusiastically.

A broad European partnership

The innovative qualities of the MYRRHA project have undoubtedly helped it to achieve recognition beyond the borders of Belgium. Since 1999, MYRRHA has held a position within the Euratom Framework programme and, since the 5th Framework Programme, the project has also received financial backing from the European Union, which remains the case with the current Horizon 2020 Programme. These various participations in European programmes have brought other benefits. "We were very quickly able to build relationships with partners at the forefront of research in their field, whether relating to the accelerator, the materials or the design of the components of the reactor or accelerator", emphasises Hamid Aït Abderrahim. The European support framework now enables the MYRRHA

project to work with the continent's largest research centres: CNRS and CEA (France), ENEA (Italy), CIEMAT (Spain), KIT (Germany) and many others. "MYRRHA is currently working with more than 20 research centres across Europe, together with around 30 universities".

Bilateral collaborations

However, MYRRHA also includes a range of bilateral partnerships. For example, MYRRHA has had an agreement in place with Japan since 2005. "They see the pre-industrial stage in our project, a stage which is absolutely vital to them before progressing to the large-scale development of their own accelerator-driven reactor. Therefore, our work is mutually beneficial and we hope that they will contribute to the construction of MYRRHA".

Another key ally is France, more specifically the CNRS, with which we have had a continuous partnership in place for 12 years! Five laboratories of CNRS work today hand in hand with MYRRHA. These collaborations, whether bilateral or not, have already delivered concrete results in various topics. "With the French company PANTECHNIK, for example, we have worked to create the very high intensity proton source. It was initially a prototype, but the high level of reliability achieved was such that it can be used directly in our accelerator".



"It was our intention to make MYRRHA an international project practically from the beginning. MYRRHA is collaborating with research centres and universities from all over the world."

Hamid Aït Abderrahim

EDITORIAL

Welcome to this 2nd edition of The MYRRHA POST, the first in 2017! This edition shows that the MYRRHA project has it all: we have Belgian, European countries, European Commission and world support through the many national and international collaborations that have successfully been established around MYRRHA and its accelerator.

Whether it be from universities, industries, European projects, bilateral projects, the testimonies given in this issue witness the maturity that has been reached in establishing the goals set for MYRRHA which aims to contribute to long term solutions in nuclear applications for society and in particular addressing the spent fuel legacy and reducing its burden. MYRRHA is a strong manifestation of the ambition of Belgium to remain a worldwide player at high level in nuclear R&D, and is a flagship project of international scale with strong innovation, economic as well as social potential for Belgium, the European Union and beyond.

2017 is a crucial year for MYRRHA: we will need continued Belgian governmental and international support and as such we have to demonstrate that the project has all the needed ingredients to fulfil the requirements to break ground with phase 1 of MYRRHA.

Eric van Walle

Director General at SCK•CEN

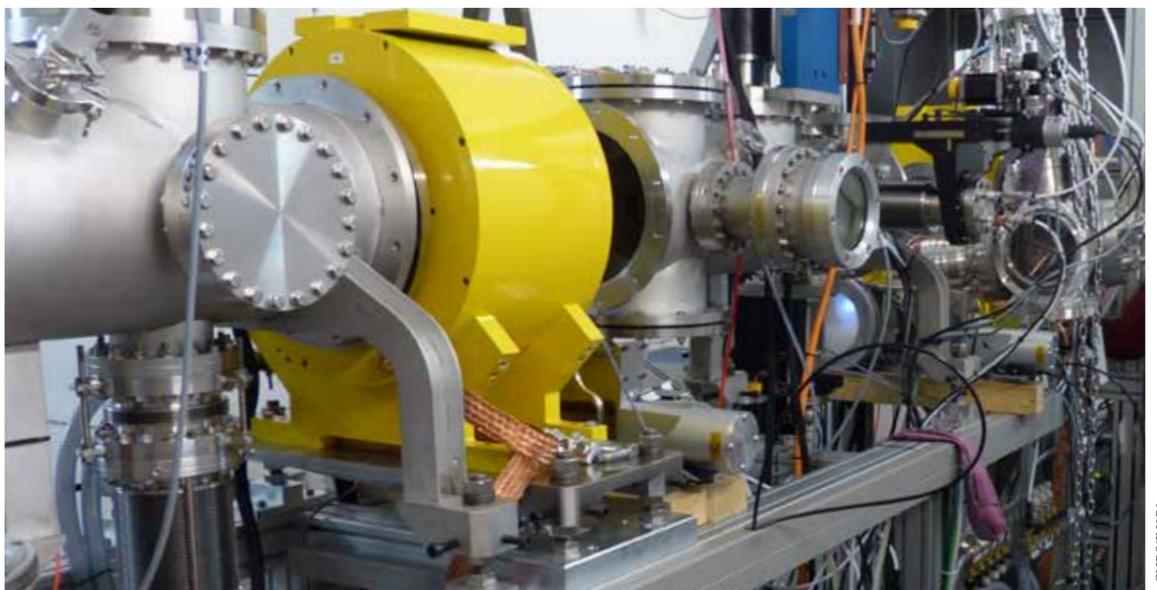


Creating a problem-free accelerator... or almost!

Innovative in more ways than one, the MYRRHA project will be driven by a proton accelerator. The development of this key component is the result of intense international collaboration, including the work carried out by the IN2P3, the French National Institute of Nuclear Physics and Particle Physics, seeking to design an accelerator that is clearly more reliable than the current models.

The large particle accelerators stop working at least two thousand times per year. Unfortunately, the reliability of these complex pieces of equipment is not the number one priority of fundamental physics. The same cannot be said for the accelerator that will drive the future MYRRHA research reactor. Untimely beam failures, at least those that last longer than three seconds, result in too much cooling of the heat transfer fluid, which would then expose the structures of the reactor to thermal shocks, resulting in premature wear.

such authorised stoppages by a factor of twenty. This considerable technological challenge, is an area of focus for the French researchers of the IN2P3 in particular, as part of multiple areas of collaboration with the SCK•CEN. "We are collaborating at Europe-wide level as part of the European MYRTE project, as well as under a bilateral agreement aimed at developing the accelerator that will drive the subcritical MYRRHA reactor", stated Jean-Luc Barriotte, the Deputy Scientific Director of the IN2P3.



Therefore, the MYRRHA specifications provide for reducing

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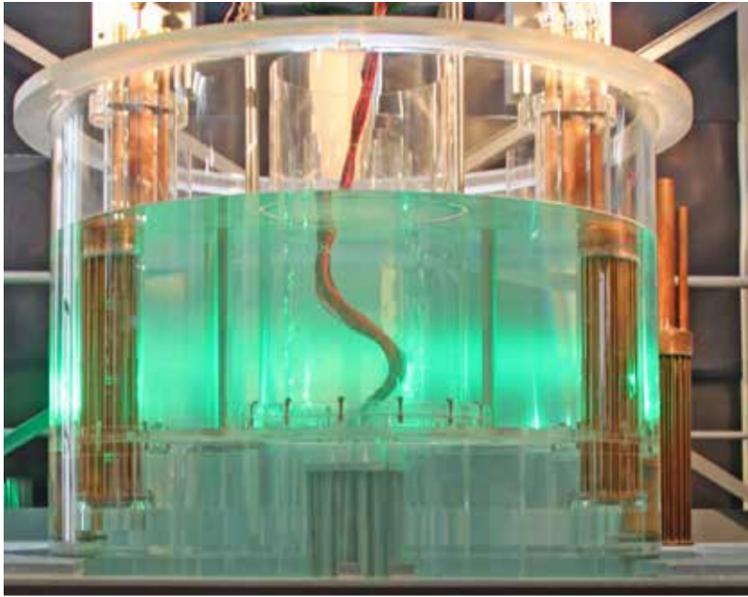
VKI: a Belgian key contribution

The von Karman Institute has provided its unique experience in fluid dynamics for the MYRRHA project. Experimental testing on three scale models and advanced digital simulations have made it possible to confirm certain behaviours of the future reactor.

A key location for research and experiments, the von Karman Institute (VKI), based in Rhode-Saint-Genèse, possesses a degree of knowledge and expertise in the field of fluid dynamics that is unique in Europe.

Therefore, it was entirely natural for SCK•CEN to turn to the Institute for certain updates to the future MYRRHA reactor. Launched as part of the DEMOCRITOS project, this collaboration sought to investigate five key points linked to the safety of the reactor and the behaviour of its lead bismuth heat transfer medium, an alloy ten times denser than water!

“One of our missions consisted of creating the design for the pump of the reactor’s primary circuit, to ensure that it is capable of operating with lead bismuth”, explains Philippe Planquart, a research engineer at the VKI. “We also studied the behaviours of the reactor in severe accident situations, the behaviour of coolant flows and the ultrasound monitoring



“Being involved in the MYRRHA project, at the cutting edge of progress, is very important for an institute like ours.”

Philippe Planquart

techniques, as well as the presence of opaque lead bismuth preventing all visual access. It was also necessary to analyse the behaviour of the reactor in the event of an earthquake of a greater magnitude than could occur in Belgium”.

Conducted from 2011 to 2015, DEMOCRITOS made it possible to garner crucial information for the conduct of the MYRRHA programme. “In each of the areas studied, it was possible to obtain significant results.

Our tests made it possible to confirm the design of the pump that we had proposed. We were also able to verify that the effects of the flow on the trajectory of the ultrasound beams were negligible. The simulations that we conducted also enabled us to study the amplitude of the fluid displacements within the reactor in the event of an earthquake. In the end, those effects proved to be weaker than expected and they were confirmed experimentally”.

Innovative project

From the outset, DEMOCRITOS was a groundbreaking project. “Everything that was asked of us was innovative, even though we used tools and knowledge that we deal with regularly. For example, all of the scale models used to verify the behaviour of the reactor were specially developed as part of the project, as were the digital simulations. Being involved in a project of this kind, at the cutting edge of progress, is very important for an institute like ours”.

The development of a three-dimensional vibrating table that made it possible to simulate an earthquake is one of the examples of innovations developed by the VKI for DEMOCRITOS. Unique in Belgium, it has since been used for studies associated, in particular, with satellite propulsion. Continuing under DEMOCRITOS 2, the collaboration between the two Belgian research centres certainly did not end with shaking up the field of fluid dynamics.

SCK•CEN hires



MYRRHA ADT Programme Manager

The Accelerator Design and Test (ADT) Unit is responsible for the design, construction and commissioning of the 100 MeV superconducting LINAC, in collaboration with several national and international research and industrial partners. The ADT Unit is currently based at the Cyclotron Research Centre in Louvain-la-Neuve, Belgium.

As Programme Manager of the ADT Unit you will be responsible for the management and implementation of the 100 MeV LINAC R&D program from the design to the construction phase at the SCK•CEN site.

SCK•CEN is one of the largest research institutions in Belgium. Every day, more than 700 employees dedicate themselves to developing peaceful applications of radioactivity. Our developments have already resulted in a long list of innovative and forward-looking applications for the medical world, industry and the energy sector.

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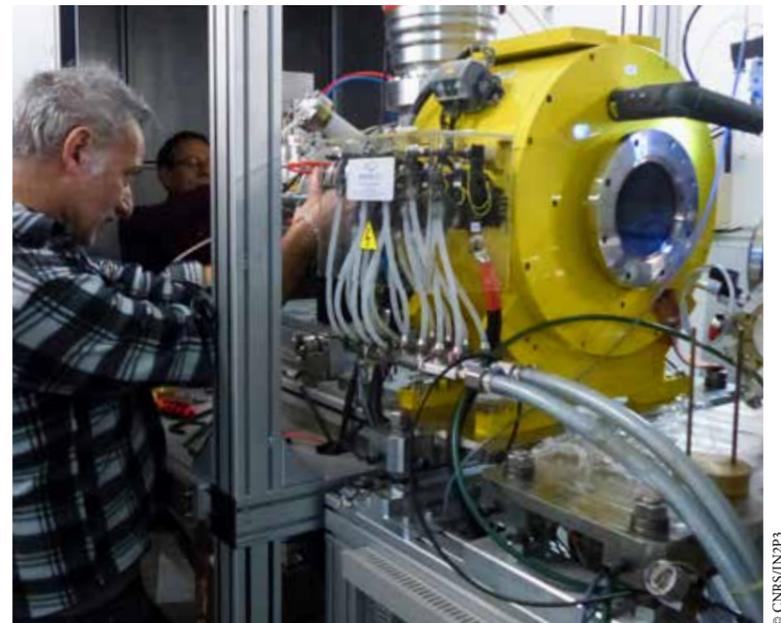
A promising start for the future MYRRHA accelerator

The super-reliable accelerator that MYRRHA will soon have his slowly nearing completion. An overview of a Franco-Belgian collaboration that has shown its worth.

Since 2015, as part of the European MYRTE project, we have been continuously developing a research programme concerning the prototyping activities for the key elements of the accelerator”, explained Jean-Luc Barriotte of the IN2P3. Objective: to demonstrate the technical feasibility of certain elements of the future accelerator intended for MYRRHA.

The accelerator brings together several European architects: France is building the injector; Germany is building its first stage and Belgium is building its energy amplifiers.

“In particular, we are building the injector, which is the low-energy part of the accelerator”. The piece of equipment in question, which is basically a source of protons, has been funded by SCK•CEN and is currently installed in Grenoble. Added to this is a low-energy beam transport line, which is also already operational. Further developments will be announced in the very near future. “Our German partner, Goethe University Frankfurt, is currently building the first stage of the accelerator, which is composed of a RFQ, a Ra-



dio Frequency Quadrupole, a fairly complex piece of equipment that they are hoping to complete by summer 2017. It should be able to accelerate the beam within a year to one and a half years”.

Bilateral collaboration

As part of the bilateral cooperation that began in 2005, SCK•CEN and the IN2P3 have also defined a broader prototyping programme aimed at preparing the first launch stage of the MYRRHA project, in its low-energy version (100 MeV). “It was important to establish

confidence in the reliability of the project. Therefore, we agreed to launch a joint R&D programme to complement MYRTE, focussed on demonstrating Spoke-type superconductive cavities, which make it possible to reach 100 MeV. This collaboration programme is on the right track towards completion. It is intended to cover all of the investigative fields that still need to be confirmed before the MYRRHA construction begins. It will involve several of our labs, including the ones in Grenoble, as well as those in Orsay and Strasbourg”.

More reliable injectors with better performance

A world leader in accelerator physics, the Institute of Applied Physics (IAP) in Frankfurt has, for several years now, been developing the most crucial components of the future MYRRHA accelerator. This very promising, cutting-edge research has already yielded several technological innovations. Meeting with Prof. Dr. Holger Podlech, the leader of the Linac work group at the IAP.

What is the focus of your collaboration with the SCK•CEN?

Holger Podlech: For 15 years now, we have been collaborating on the MYRRHA project, in particular through European Framework Programmes such as FP5, FP6, FP7 and now H2020. Our work consists of developing injectors with excellent levels of performance, reliability and quality of the beam. This is important work, insofar as these injectors constitute the most crucial part of the entire linear accelerator, the Linac, in terms of reliability.

Why are these injectors so important?

Because the reliability of everything else rests on their reliability. If there is a fault with one of the components of the injector, you lose the entire beam and the whole installation must be shut down. The injectors also play a vital role in the quality of the beam. If you start off with a poor quality beam, you have to deal with that situation all day long, without

being able to improve it. In the worst case, that can result in downtime for some of the accelerator components. Therefore, this part of the accelerator is very important for the reliability of the entire system. Therefore, in order to mitigate this type of defect, we have installed a double injector system in our project for MYRRHA. A single injector will deliver the beam to the main Linac, but in the event of a problem, the second injector will take over.

“The MYRRHA project allows us to demonstrate that research is trying to find solutions for society.”

Holger Podlech

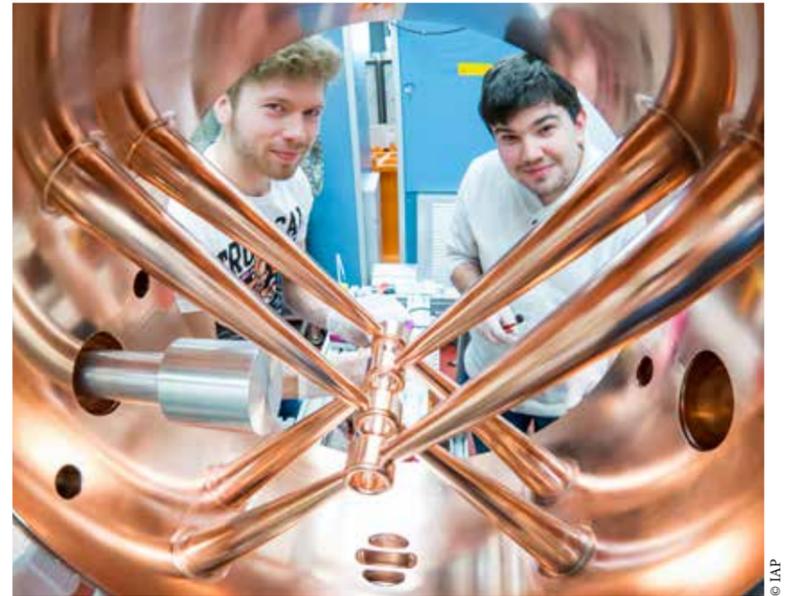
Does your collaboration with the SCK•CEN only concern research, or has it resulted in concrete developments?

Initially, this collaboration was above

all focussed on intense research. However, during the last two or three years, we have built various prototypes within our institute, such as the RFQ (Radio Frequency Quadrupole), for example, which is one of the components of the Linac. We have also built prototypes for the drift tube cavities, which we have tested in Frankfurt. Of course, the actual creation of these components will be entrusted to another partner, as we do not have the necessary infrastructures to create them properly in large numbers. Once constructed, these pieces of equipment will return to our institute for testing before being sent to Belgium.

To what extent is this partnership important to you?

The research that we carry out for MYRRHA is at the very heart of our profession. However, this collaboration is also a great opportunity for us, due to the very nature of the MYRRHA project. It enables us to demonstrate our expertise and exper-



ience, as well as giving us an opportunity to send a message to the general public, in particular concerning the aspects linked with transmutation, a technological solution to the problem of nuclear waste. It is a way of demonstrating that we can work in a positive manner for society. As you are aware, a fraction of German public opinion is highly critical to nuclear energy. It is good to be able to demonstrate that research is trying to find solutions.

So, it's a win-win collaboration?

Exactly! We have developed a series of original technologies to make the injectors very reliable. In the future, other projects will be able to benefit from these improvements. We have also developed a new technology specifically for the MYRRHA RFQ. It seeks to optimise cooling so as to obtain higher power levels. The prototype that we have constructed should provide power levels two and a half times higher than anything achieved previously!

Belgium - Sweden: a partnership with advantages all round

Bolstered by a bilateral agreement between Belgium and Sweden, relations between SCK•CEN and the European Spallation Source (ESS) have been strengthened recently. Is there a formal collaboration on the horizon? A meeting with Roland Garoby and Mats Lindroos, the Technical Director and the Head of the Accelerator Division of the ESS, respectively.



technical developments between the two projects, given the aspects that they have in common in many respects.

What are these aspects that they have in common?

Roland Garoby: There is a great deal of similarity between the design and the technology implemented in the MYRRHA accelerator and the one that we are currently installing in Lund. To a large extent, we also rely on the same international partners and their skills. In addition, the developments made for MYRRHA have already been of use to us and will be of further use to us in the future. Likewise, the lessons learned from the construction and commissioning of the ESS will should also be invaluable for MYRRHA.

“There are very specific things for us to work on together that could benefit both projects.”

Mats Lindroos

Mats Lindroos: On paper, we could also share studies into the reliability

of the accelerator. This is of essential importance to MYRRHA, but it is also very important to us.

There are also further partnership opportunities concerning the beam simulations and, of course, all of the technical aspects associated with the construction of an accelerator. In this respect, we can learn a lot from each other. In any event, there are very specific things for us to work on together that could benefit both projects.

What could ESS bring to the MYRRHA project?

Roland Garoby: We have one development area that is very important to the ESS and which could have applications for MYRRHA, and that is the area of sustainability. We were fortunate to have been able to take this concern into consideration from the time that the project was conceived. The general idea is to use as little electrical energy as possible and to recover the bulk of such energy in the form of heat. On the whole, our energy efficiency will be much better than what is currently available, something that could be of great industrial interest to MYRRHA. Each megawatt saved by the Linac is a megawatt that will not be drawn from the grid!

ESS, the most powerful source of neutrons in the world



Currently under construction in Lund, Sweden, the European Spallation Source (ESS) now includes fifteen member and observer countries. Its unique characteristics will make it the most powerful neutron source in the world, by far. Scheduled to be operational in 2025, this very large international instrument will be composed of a 500 metre-long linear accelerator that will be capable of accelerating protons to 2 GeV and directing them towards a tungsten target. The flow of neutrons produced will enable advanced research in numerous fields, from life sciences to materials engineering, in addition to energy and telecommunications.

For further information, visit: <https://europeanspallation-source.se>

What is the status of the collaboration project between the ESS and MYRRHA?

Roland Garoby: There is no formal collaboration in place yet, but there is a clear desire on both sides to come together and work together. The partnership areas identified so far relate primarily to the accelerator, but studies into materials and the consequences of irradiation could certainly also be areas for collaboration.

Mats Lindroos: There has been indirect collaboration in place with MYRRHA for many years.

We hold meetings every year that are attended by between 50 and 200 people and which provide an opportunity to discuss numerous issues. However, it has always been our desire to try to develop something more concrete. This is the case, for example, with the prototype cryomodule that we are going to test in Uppsala this summer, and which is of great interest for MYRRHA. Of course, it will need to be adapted for the production of a continuous beam. In any event, there are numerous possibilities for joint

MYRRHA and J-PARC: highly compatible cutting-edge programs

SCK•CEN and its Japanese counterpart, the JAEA, have been sharing common goals since 2005. The two research centres decided to join forces for the research and development of nuclear systems driven by a particle accelerator as part of their respective projects: the MYRRHA and J-PARC programs and more specifically the Transmutation Experimental Facility (TEF).



What does the collaboration between the JAEA and the SCK•CEN focus on?

Toshinobu Sasa, JAEA: Collaboration between the JAEA and SCK•CEN focuses on the development of the technologies to realize Accelerator Driven System (ADS). It covers both the fundamental studies for ADS design and the related engineering ones such as accelerator, spallation target, fast subcritical reactor, liquid metal handling and nuclear fuel/materials. This cooperation especially aims at realization of ADS both in real scale and in demonstration scale. The studies carried out in the context of this cooperation are still in fundamental phase and advancing to step up to the engineering test scale.

What are the R&D convergence points between the JAEA projects and MYRRHA?

TEF project aims at the preparation of irradiation database of structural materials for LBE cooled reactor systems. Especially for the proton beam

window, that is a typical component of ADS. TEF can provide the reliable data for the design of the MYRRHA proton beam window for full power operation. Another important item is the technology for application of lead-bismuth eutectic alloy (LBE). LBE is a corrosive liquid to standard reactor structural materials and should be carefully managed.

“There are many common issues for our TEF project and MYRRHA project.”

Toshinobu Sasa

What progress has been made in this collaboration until now?

Specific progress can be seen especially for liquid metal handling technology such as oxygen potential control in LBE, flow dynamics around the proton beam window, and fundamental physics tests of lead-cooled reactors. In the case of oxygen potential control in LBE, we made frequent information exchange on this field. Throughout the long collaboration, the oxygen potential sensors made by SCK•CEN are still used as a reference sensor of our experiments.

What specific knowledge and

know-how can JAEA bring to this project?

We are trying to enhance the cooperative research activities related to ADS design. Accelerator development is a typical one, which deeply related to the MYRRHA project. We hope our experiences of J-PARC accelerator will be useful for MYRRHA accelerator developments. Since March 2017, young JAEA scientist have partially joined MYRRHA team to discuss the physics of ADS. The cooperation on reactor physics related to nuclear data verification is also an important topic. Providing Japanese evaluated nuclear data and analysis result can improve the reliability of the design works.

How could collaboration with SCK•CEN be important to your own project?

To realize the ADS, step-by-step scale-up of LBE-cooled system should be required. Our Transmutation Experimental Facility (TEF) project is one of the important step on this roadmap. However, TEF is still the engineering test level to prepare the data needed to design overall ADS plant. MYRRHA project is a step ahead the real-scale ADS. There are many common issues for our projects. We think we can solve the issues through this collaboration to accelerate the realization of ADS.

J-PARC : a world-class proton accelerator facility

Joint project between KEK (High Energy Accelerator Research Organization) and JAEA (Japan Atomic Energy Agency), the J-PARC, standing for Japan Proton Accelerator Research Complex, is located at the Tokai campus of JAEA.

This high intensity proton accelerator facility consists of a set of proton accelerators and research facilities to explore the basic science and high-energy physics. JAEA plans to build a new experimental facility for ADS development within the J-PARC project.

The Transmutation Experimental Facility (TEF) has functions to demonstrate high power heavy metal spallation target and to study the physical properties of ADS.

For further information, visit: <https://www.jaea.go.jp>

AROUND THE WORLD



A Swedish delegation from ESS project and Oskarshamn municipality project for a Center of Excellence in the field of High-Level Waste management visited SCK•CEN for discussing the condition of a cross-participation of Belgium in ESS and Sweden in MYRRHA.



The Belgian Nuclear Research Centre had the great honor to welcome Her Royal Highness Princess Astrid of Belgium. A royal visit which has highlighted the essential role played by the BR2 reactor in nuclear medicine and the equally essential role of its successor MYRRHA in developing new types of medical radioisotopes for cancer treatment.



Every year, the MYRRHA project attracts young researchers from around the world. In 2017, about ten PhD students had the opportunity of joining the research program. “It is an intriguing challenge and a unique opportunity to participate in an innovative scientific project of this scale!”

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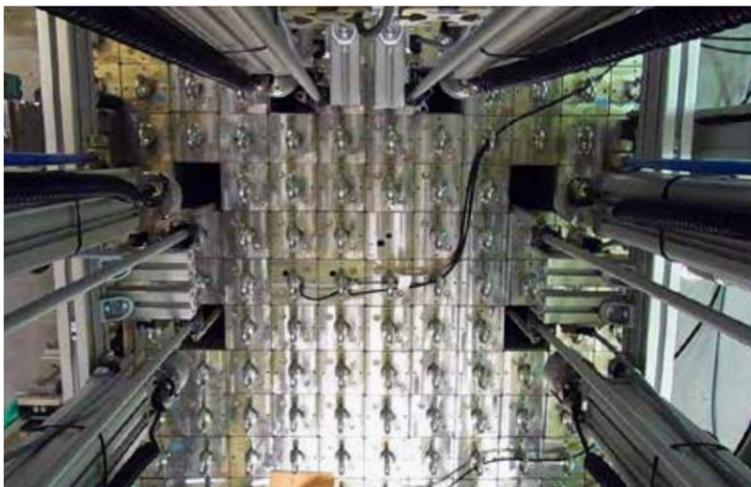
Info & Suggestions: myrrha@sckcen.be



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NEWS

First Fast Bismuth Reactor in the world



On October 2016, VENUS-F reactor reached criticality with a completely new core. A new milestone for MYRRHA with this world first.

The core of VENUS-F contains a large amount of bismuth (Bi): a unique configuration to examine the nuclear data of bismuth and to compare them with theoretical calculations. So far, nowhere in the world zero power experiments are conducted with so much bismuth.

The experimental data on bismuth are essential for the further develop-

ment of MYRRHA, but are also of interest to the broader nuclear community in the context of fast reactors and reactivity measurements.

Mid-February 2017, VENUS-F reactor get a new criticality with Pb-Bi mock-up core. This time the core is the first one in a set of configurations which will be studied till the end of 2017 with aim to simulate the MYRRHA core peculiarities such as Pb-Bi coolant, in-pile sections for Mo production and material tests and safety aspects of MYRRHA licensing.

New challenges for young researchers



A team of SCK•CEN researchers works together with CERN and several other European partners on an innovative liquid metal target for high power ISOL facilities. This target is relevant for the ISOL@MYRRHA project, which will be able to generate up to 100 times more intense radioactive ion beams than any of the currently operating European installations. Thanks to its high intensity, this next generation ISOL infrastructure offers unique opportunities for fundamental research and nuclear medicine.

“The envisaged characteristics of the proton beam set the facility into a beam power range higher than

at any currently operating ISOL facility. This means new challenges arise when trying to design targets for such a facility”, says Donald Hougbo, filled with enthusiasm. This young Beninese researcher joined the MYRRHA program in order to obtain his PhD prior to becoming part of the team to continue his research.

“The ISOL component of the MYRRHA project is an interesting one as it provides potential extra applications to the accelerator in its first phase and later. For a young researcher, this is a very interesting environment as there are still many open questions!”