NEUTRONS: LITTLE PARTICLES WITH POWERFUL IMPACT

SNOWFLAKE AND THE MULTIPLE DIVERTORS

THE INFAMOUS LEAKY PIPELINE
A HISTORICAL SHOT, AND NOW THE ANSWERS

Yes, Wendelstein 7-X is one stellarator of a kind. Chancellor Angela Merkel inaugurated the fusion experiment with a simple push of a button releasing the first hydrogen plasma into the vessel. This push has taken international scientists more than eleven years to achieve.

Wendelstein 7-X also raises a lot of questions: are we now one step closer to fusion powered energy on Earth? How can the stellarator Wendelstein 7-X support the upcoming world’s biggest tokamak ITER? And why did the shot only last a tiny quarter of a second? This issue of ‘Fusion in Europe’ provides the answers.

The European Commission has contributed 20 percent of the stellarator’s total costs of 370 million Euros. A fact which pushed Commissioner for Research, Science and Innovation, Carlos Moedas, to speak out in favour of fusion (page 25). EUROfusion is currently readjusting its roadmap towards realising fusion energy. The main reason: ITER won’t meet its launch date in 2019 as Won Namkung, the new Chair of the ITER Council, explains in an interview (page 7).

If your immediate thought was JET, you are correct! JET is currently preparing its second deuterium-tritium campaign and we asked project leader Paola Batistoni (pages 4 – 5) why this is so important. JET’s data is a treasure trove if you know what to look for. A new dashboard developed by Anthony Shaw, Alex Meakins and Matthew Car puts all the tokamak’s data in one place (page 13).

Wendelstein 7-X will produce pulses which last about 30 minutes maximum. This will happen in about four years. The actual experimental period only continues until mid-March. Then, carbon tiles to protect the vessel walls and a so-called “divertor” for removing impurities will be installed. That is why the first shot was so short. Do you want to know what a divertor is? You will find the answer in the article “Snowflake and its several divertors” on the pages 10 – 12.

Maybe you watched the opening ceremony of Wendelstein 7-X on the live-stream feed from Max Planck Institute for Plasma Physics (IPP). While some physicists excitedly waited for a first photo of the hydrogen plasma, others implemented another historical benchmark. The picture showing Prof Sibylle Günter, Scientific Director of IPP, and Dr Angela Merkel appears to be a good example of “Girl power”. As the entire world talks about gender equality in science, the event in Greifswald with two leaders in the front row might show the female shape of things to come. On the pages 18 – 21, Prof Günter shares her thoughts of the gender issue and why JET’s environment might again serve as a role model.
What is neutronics?
Neutronics is a discipline which studies the complex diffusion of neutrons through matter and their interactions with nuclei. In a DT fusion reaction, a neutron and an alpha particle are produced. The neutron, which carries 80% of the energy produced in the plasma, is not confined within the plasma. It escapes and penetrates into the components surrounding the plasma chamber, mainly the blanket. Here it releases its energy which is then used to produce electricity. [See also the article: “Snowflake and the multiple divertors” in this issue, page 10 – 13]
However, neutrons cannot be easily stopped; they are able to penetrate several metres into materials before they come to a standstill. As they move within the materials, they produce gamma rays, secondary particles and radioactive nuclei. They also create microscopic changes in the material structure which may cause degradation of physical and mechanical properties. We, as neutronics experts, support the reactor design with complex analyses, suggesting design configurations and materials that can be used to minimise the escape of neutrons and their negative impact.

Why is the new DT campaign at JET so important?
The JET experiments are designed to reach and investigate ITER-like plasma regimes of operation. However, the project also addresses ITER-relevant technology issues, such as the validation of neutronics codes that are used in ITER. We need these to predict their effect on materials, the occupational dose and the performance of diagnostics exposed to high neutron flux.
In the new DT campaign, internally referred to as DTE2, JET will operate with tritium and generate neutron yields large enough to cause easily measured activation in materials and degradation in their physical properties, as well as dose rates in the tokamak environment. By measuring these quantities and comparing them with simulations and numerical predictions, we aim to reduce the risks and uncertainties associated with ITER operation and maintenance.

What will you investigate in particular?
Our aim is for JET to obtain the first complete and consistent “nuclear case” for a tokamak using the deuterium-tritium fuel cycle. This includes the accurate measurement
of the neutron source and radiation field in the device and the surrounding areas as well as the effects on materials exposed to 14 MeV neutrons, the tritium inventory in plasma-facing materials, the amount and type of waste produced, and the occupational radiation exposure.

I think we are addressing the key aspects of ITER for which we still have limited experience. We are working to obtain the best returns with this new set of experiments.

**What are the key aspects for ITER?**

Our experiments carried out as part of the current JET project will validate the state of art neutronics codes used in ITER. If you consider the size of ITER and the complexity of its configuration, extensive neutronics calculations are required in order to derive the neutron diffusion (and the diffusion of the secondary radiation they produce) from the plasma chamber through the device, biological shield, and the tokamak building. These calculations must be reliable and validated. We will use them to predict the lifetime of the components, the dose to workers and the amount of radioactive waste produced.

**What are the benefits and pitfalls of an international network?**

I have always appreciated working within international frameworks with people maintaining different specialisations and complementary competences. Therefore, I have always promoted the widest collaboration possible in all of the projects I have coordinated. In the current project, we benefit from all fusion nuclear technology competencies present in Europe. It would simply not be possible to find all of these competencies in any one single laboratory. Coordinating different people and teams is like conducting an orchestra that frequently performs via video-conferencing. It is not easy to keep everybody fully tuned and synchronised, but we also hold frequent meetings in person. We often gather for experiments and have the opportunity to work together, thus gaining a full common understanding of what we are doing.

**To what extent do these experiments support the progress of the European fusion programme?**

The JET experiments are devoted to the preparation of ITER, the exploitation of which is a pillar of the European fusion programme. But I would like to add that I am happy that, together with very expert senior scientists, there are many young European scientists and engineers participating in these experiments and analyses. They are gaining unique experiences working with a real fusion device that will certainly be very valuable later in ITER projects. I even would like to see more young scientists and engineers, for example, among those who work on the development of DEMO. Participating in one or more stages at JET would help them to better understand the real life situation within a tokamak working with tritium and producing high fusion power.

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**Watch the interview with Paola here:**

tinyurl.com/gqpfloe
POINTING THE FINGER AT MISMANAGEMENT
It hit as a thunderbolt, the statement in the magazine ‘Nature’ from Bernard Bigot, who was at the time the newly appointed Director-General of ITER. He pointed the finger at mismanagement in his organisation and claimed major changes which were necessary to prove the feasibility of nuclear fusion as an energy source.
Consequently, the fusion community waited impatiently for ITER’s new and official date for first plasma to be announced at the Council in November 2015. But the meeting ended without such an announcement.

REVISING THE ROADMAP
Being aware of the upcoming delay and taking a chance, EUROfusion had already decided to revise its current roadmap towards realising fusion energy in October 2015. The consortium which put ITER at its heart is currently renewing the document from 2012 with the help of five mission groups. Every three weeks, the experts meet, either in person or via video conference. “ITER’s delay is a chance to check again what can be done in a cheaper way and at any earlier time using Europe’s existing devices”, says Tony Donné, EUROfusion’s Programme Manager.

THE EVOLUTION OF THE FUSION ROADMAP
ITER’s delay necessitates to critically review EUROfusion’s fusion roadmap, finds Programme Manager Tony Donné and explains the advantages of the revision. Won Namkung, the new Chair of the ITER Council, informs in a corresponding interview why ITER’s new and official date has not been named yet.
IF EUROFUSION WON’T, ITER MUST

In particular, the latest proposal to extend the Joint European Torus (JET) schedule to 2020 will strengthen investigations into the ITER-like wall. Moreover, Tony Donné advocates internationalisation of JET. This means, training future ITER operators in JET’s control room would ease procedures. Additionally, the European community would be able to test components for ITER in all of its devices and help with the design of diagnostic systems. “If we don’t take on challenges in fusion research beforehand, ITER will have to do it”, states Donné decisively. Bernard Bigot agrees: “I appreciate the consistent support EUROfusion has shown for ITER. Clearly, the ITER project will be going through a pivotal transition for the next few years, during which we need to work jointly and closely with our partners.”

Find further information on the ITER Council and all answers from Won Namkung online:

www.euro-fusion.org/?p=75949

FEEDING THE GRID BY THE MIDDLE OF THE CENTURY

Europe’s fusion community keeps itself busy maintaining its goal to feed the grid with fusion electricity by the middle of the century. Fusion in Europe asked how the re-structuring of the ITER Organization is progressing. Won Namkung, Chair of the ITER council since the start of this year, speaks out in favour of Europe’s impact on ITER’s success.

The ITER Council in November presented a number of milestones which have been reached so far. But the community is still waiting for a new timeline in order to adjust its work properly. What can you tell them?

A new baseline is being worked on, to be approved at the June 2016 ITER Council meeting. The milestones are being used by the ITER Council in the interim, as a monitoring tool, to ensure that project momentum is maintained while additional evaluation is ongoing.

Science journalist and fusion supporter Daniel Clery expects that the first plasma in ITER’s vessel will not be created before 2025. What do you say to that?

We are projecting delays beyond what was stated in the 2010 baseline, which had initially predicted First Plasma in 2019, a date that was later revised to 2020. No new official schedule has been set yet. The Director-General has made a proposal, the Council is still deliberating; and the ITER Council has agreed not to publish until we have a “consolidated” date to which all parties agree.

What is the ITER Council?

Taken together, the ITER members represent three continents, in over 40 languages, with half of the world’s population and 85 percent of global gross domestic product. 35 nations have joined forces for the world’s largest fusion experiment to come: China, India, Japan, Korea, Russia and the United States along with 28 European member states (plus Switzerland) combined under the umbrella of EURATOM. Representatives of the members form the ITER Council.
Heart shaped dust particle from JET’s divertor tile – a result of ion microbeam analysis from the Croatian Research Unit. Picture: Ruđer Bošković Institute

His Serene Highness Prince Albert II opens the Monaco ITER International Fusion Energy Days (MIIFED) and the ITER Business Forum (IBF). Picture: Christophe Roux/CEA

ITER Director-General Bernard Bigot and Prince Albert II talking on the escalator during MIIFED. Picture: Christophe Roux/CEA

First row: Albert II and Bernard Bigot listen to MIIFED’s opening speeches. Picture: Christophe Roux/CEA

A construction site: ITER’s booth at MIIFED. Picture: Christophe Roux/CEA
German Chancellor Angela Merkel during her opening speech at the Max Planck Institute for Plasma Physics (IPP) in Greifswald. Picture: EUROfusion

(from left to right) Bernard Bigot (ITER Director-General), Ed Synakowsky (DOE Fusion Energy Sciences) and Alexander Bradshaw (former IPP Director) at IPP in Greifswald. Picture: EUROfusion

Hungarian and German colleagues after the first hydrogen experiment: (from left to right) Dr Tamás Szepesi, Dr Gábor Kocsis, Dr Christoph Biedermann, Dr Ralf König. Picture: Wigner Research Centre for Physics

(from left to right): Prof Thomas Klinger (Wendelstein 7-X project leader), Prof Sibylle Günter, (IPP Director), Prof Otmar D. Wiestler (Head of the Helmholtz Association), Dr Angela Merkel, Prof Martin Stratmann (President of the Max Planck Society), Erwin Seiller (Minister-president of the German federated state of Mecklenburg-Vorpommern) and Stefan Müller (German Federal Ministry of Education and Research). Picture: Norbert Fellechner (IPP)

Picture of Wendelstein 7-X’s first hydrogen plasma on February 3, 2016. Picture: IPP

Plasma on the screen. Picture: EUROfusion
Fusion operations not only need stable and hot plasma, they also need an ashtray. An ashtray? – Right. A fusion operation produces heat but also ashes, in the form of helium. But the ‘ashes’ of a fusion operation are tricky to handle.

The ashtray of a tokamak or stellarator is called a divertor. As the name says, it diverts waste particles out of the plasma directly into the trash with the help of magnetic field lines. What sounds quite easy on paper, is actually hard to achieve since we are dealing with temperatures ten times hotter than the Sun. This process therefore requires materials that are able to resist such harsh conditions.
WHAT IS A DIVERTOR?
The ‘fusion ashtray’ at the bottom or the top of a tokamak is a specially armoured structure containing the so called divertor plates, where the diverted particles come into contact with the material. The divertor is designed to handle the heat and particle loads thrown at it, but still requires frequent maintenance. Hence, in future devices such as ITER, it is built as a cassette allowing easy removal and replacement.

WHY IS THE DIVERTOR SO IMPORTANT?
Firstly, it acts as a pump for the helium ash to prevent the dilution of the plasma. Secondly, it provides a specially armoured region to handle the power that escapes from the plasma. The energy can be thus moved away from the core plasma. This reduces the amount of impurities, as released through plasma-surface interactions, that are able to enter the core plasma.

Improving divertor designs is one of the main targets of EUROfusion’s research. Mission 2 of the European fusion roadmap prioritises the so called ‘Heat-exhaust systems’. The outcome should result in magnetic configurations that will reduce the heat loads and ensure divertor materials capable of handling them. At the moment, EUROfusion is evaluating even more research projects which deal with heat exhaust and resisting materials.

DIFFERENT DIVERTOR CONCEPTS
The team of the newly set up MAST Upgrade is very proud of its flexible divertor concepts. Indeed, the tokamak will be able to transition smoothly from one configuration to the other by changing the magnetic fields appropriately. Those configurations have lovely names such as the Super-X divertor or the Snowflake divertor approach. The names are assigned according to the characterisation of the ‘diverted’ field lines, which form what are known as legs below the X-point. The magnetic fields can be adjusted so that the length of these legs varies.

X MARKS THE SPOT
Instead of adding just another wall, the fusion experts decided to try working with magnetic confinement again. By adding magnetic coils they were able to create a zone where the field lines crossed, known as an X-point. The field lines are ‘diverted’ to form a so called scrape-off layer (SOL). This appears then at both outer edges of the D-shaped plasma. Inside this layer, which is separated from the core plasma, charged particles follow magnetic field lines into the divertor where they hit the above-mentioned divertor plates. Here, the diverted particles transfer their energy.
In a conventional divertor, these legs are typically quite short and hence the particles do not have far to go before reaching their target and so do not lose much energy on the way.

**One or two X-points?**
The divertor can be located on top of the fusion device or at the bottom or even at both ends. ITER will have the divertor at the bottom of the tokamak just like JET (Joint European Torus) which is the only divertor device that has operated a deuterium-tritium campaign so far. As a result, ITER features a conventional “one X-point and one divertor” structure. However, there is interest in plasma systems with two X-points and two divertors. ASDEX Upgrade and MAST Upgrade, for instance, have this capability. Two X-points are known scientifically as “Double null divertors”.

**The Super-X divertor**
The Super-X configuration extends the legs and thus the particles travel a longer distance before reaching the target plates and accordingly interact more often with other particles along the way. In fusion terms, this essentially means that the power which hits the divertor plate is reduced greatly. It requires a set of divertor coils that extends and controls a long plume of exhaust plasma. The length of the plume allows high radio-active cooling before the plasma reaches the target.

**The Snowflake divertor**
The Snowflake variation creates more than the two usual legs. The power is separated into many snowflake-like branches which spread the particles out and reduce the load so that the existing materials are able to tolerate it.

EUROfusion’s researchers have been investigating the Snowflake divertor already. The recently enhanced TCV (Tokamak à Configuration Variable) in Switzerland is able to employ this special divertor approach.

For further information see the article “Snowflakes spread the heat” in Fusion in Europe, Issue 09/2012, page 13 or scan the QR code www.euro-fusion.org/?p=11437

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**Background**
A fusion reaction occurs when two light nuclei fuse and kinetic energy is exchanged between the products. This energy results in heat. The temperatures created in a fusion device are, on average, ten times hotter than the Sun. Future fusion plants will fuse deuterium and tritium and generate alpha-particles and neutrons. The neutrons carry 80 percent of the total energy. This energy is harvested for electricity production via the vessel blanket. The alpha-particles or the produced helium ash, still carry 20 percent of the fusion energy and will be diverted into the ashtray, the divertor, of fusion experiments.
“I wanted such a tool to exist!” – after two years of work at the Culham Centre for Fusion Energy (CCFE), Anthony Shaw was keen to browse through the pulse data at the Joint European Torus (JET) just as conveniently as he can browse through data on the internet. Together with Alex Meakins and Matthew Carr, the group developed a website which provides information about every pulse that has been fired in JET’s vessel.

The main page enables the user to search through pulse meta-data to narrow down the 90,000 JET pulses to a more manageable subset. If the user then clicks on one entry they will find the detailed pulse data including, for instance, a plasma equilibrium reconstruction and some overview plots. The Dashboard also includes the names of the personnel involved on the day, along with pre- and post-pulse comments, experiment names and some high-level numerics.

COMPLEMENTS CURRENT TOOLS
“The Dashboard is seen as a ‘breadth’ tool to some of our existing ‘depth’ tools” – says Anthony. A large proportion of the data analysis tools used at JET are designed to delve deep into the specific physics data of a single pulse to really analyse what is going on. The Dashboard, conversely, is designed to represent a broad overview of many pulses in a way that is easy to browse and search, thus allowing users to pinpoint which pulses to analyse in depth. This has the potential to save the researchers a lot of time.

A SHARED SOLUTION
This is not unique to JET; Matthew encountered the same problem with the Mega Ampere Spherical Tokamak (MAST) – “MAST also has a large amount of data which can be difficult to navigate for new users”. He developed an early prototype for MAST which was then shared with and expanded upon by the JET team. Since then, they have added new features which are flowing back to the MAST group. “By exchanging developments, we have been able to advance both platforms very rapidly”, says Alex proudly.

EVEN MORE POWERFUL
Alex, Anthony and Matthew now meet with stakeholders every quarter in order to improve their site. And the enhancements are ongoing. Currently, they are exploring which additional data might be useful to add to the page. Culham scientists are happy with the Dashboard – Physicist Michele Romanelli looks forward: “Including physics parameters in future searches will make this tool even more powerful”. Right now, the homepage is only accessible if the user’s computer is logged into Culham’s network. But this is about to change. The three researchers are working on a login based solution to make the data accessible to scientists beyond Culham.

The JET dashboard can be found online under http://data.jet.uk/dashboard, but so far it is only available to researchers at Culham.
PRACTICAL:
NEW MASTER OF FUSION
INvolves Industry

If fusion is going to power the future, it needs a generation of well-trained fusion researchers and engineers. With fully dedicated Master studies in The Netherlands, The United Kingdom and the Erasmus Mundus Fusion Programme based in Ghent, Europe has already started to pave the way for a sound and organised fusion training programme. Specialisation programmes have also been set up in France, the Czech Republic, Hungary, Bulgaria, Romania, Switzerland, Portugal and Germany.
Now Italy has introduced an innovation. In March, the one-year Master in Fusion Energy – Science and Engineering will commence at the Tor Vergata University in Rome. Its unique approach: To incorporate fusion related industry at a very early stage of research.

Francesco Romanelli, former EFDA (European Fusion Development Agreement, now EUROfusion) Leader, has spearheaded the creation of the Italian Master programme which is strongly dedicated to the European fusion roadmap. His priority was to educate employees who had already enjoyed practical training during their studies and who have been trained by experienced industrial experts. Fusion in Europe talks to him about the challenges, the European lead in fusion research and what it takes to be a good fusion student.

The newly set up Master at the Tor Vergata University in Rome will be financed by Italian companies. Why do you involve the industry at this early point? There is a strong incentive, also coming from the European policy on education, to achieve the objective of ‘employability’ for students coming out of a Master and PhD course. Our Master/PhD track, linking the Master in Fusion Energy to the PhD in Industrial Engineering is one of the first of such attempts in Italy. It has already raised interest among Italian businesses. They will finance six PhD positions which are reserved for those in possession of our new Master in Fusion Energy.
But can you maintain your scientific independence while having the industry so closely involved in your studies?
Scientific independence is not at risk here. I rather see the benefit of experience that will be brought to the students. Practical experience which is gained by the industry involved in manufacturing ITER components.

What is the most challenging task in setting up a new Master lecture?
Such a new Master course must have a well-defined target. Our objective is not only to create personnel who are directly employable by industry but also to communicate a build-oriented approach to the students who will remain in research. The Fusion Roadmap sets this as one of the main targets. We have to move from being science-driven and laboratory-based towards an industry-driven and technology-driven venture. Dedicated training and education initiatives are the main pillars enabling the facilitation of this transition. The proximity and strong connections between Tor Vergata and the laboratories of ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development in Italy) ensure that all areas relevant to fusion research, and specifically those related to fusion technology, are properly addressed.

To what extent are you collaborating with other European Master studies?
Tor Vergata is part of FuseNet and shares its experience with the other Master courses held on fusion energy in Europe.

Are you complementary or competitive?
We are complementary. Our Master differs from those currently in existence insofar as it is mostly devoted to the training of highly qualified personnel for industry. It has a duration of one year and it requires a qualification equivalent to a second level degree also known as laurea magistrale in Italy.

What are you especially focussing on?
The Master will give all the notions needed for a preliminary design of all the components of a fusion power plant. In each of the ten modules, the students will learn how to estimate all the relevant quantities that characterise each component of a fusion plant.

To what extent is EUROfusion involved in your master programme?
Most of the lecturers come from the Italian universities, ENEA, CNR and Consorzio RFX. All of them are directly involved in the EUROfusion programme.

Are there any exchanges planned with EUROfusion’s research facilities?
We have already a number of students working for example under the Erasmus program in EUROfusion research laboratories outside Italy. I am sure that such an involvement can be further strengthened with the help of the Master/PhD track.

Will there even be scientific exchanges beyond European borders?
Fusion is a global enterprise and China, India, Korea and Japan have a very ambitious programme in fusion. I look forward to an increased participation of non-European students.

To sum it up: what does it take to be a good fusion student?
Fusion is one of the big challenges of science in the 21st century. A student must enter this field with a strong interest for innovation and for the interdisciplinary aspect of fusion.
Luxherta, when did you first hear about fusion in general?
I have always been fascinated by science because it feeds my curiosity for discovery and understanding. Fusion research is particularly interesting because it concerns the future of humanity. I was first intrigued by it during my high school studies. While learning about the phases of matter, I asked my physics professor what happens to a gas if you heat it to extremely high temperatures. At that time the explanation I received was the basic definition of plasma as an ionized gas and the terrestrial confinement with magnetic fields. Since plasma physics is not taught as a Master’s programme in Albania, I decided to apply for a European Erasmus Mundus scholarship.

Why is your research important for fusion?
This work addresses the effects of high energetic plasma particles on tungsten, which is the selected material for the high heat load components in ITER.

What are you currently investigating?
After my PhD I was given a great opportunity to join the Princeton University. I am currently interested in doing experiments on liquid metals, deuterium retention and the effects of impurities on lithium deuterium intake at the thus supporting the research goals of NSTX-U, the newly set up spherical tokamak in the US.

What are your future goals?
In the future, I see myself continuing with research that supports fusion programmes and other plasma applications. But fusion needs collaboration and for this reason I am happy to see that EUROfusion brings together researchers from many different European research units.

Luxherta Buzi’s private fusion map is already quite well explored. Having been to Germany, Belgium, France, The Netherlands and the United States of America, the 28 year old fusion scientist is a world citizen on a mission. The Albanian is chasing her dream of joining ITER while currently working at the Princeton Plasma Physics Laboratory, which enabled her to study the particle flux impact on tungsten surfaces.
Some say gender equality in physics can only be reached long after ITER and DEMO have come to life. You might debate the question of whether a gender balance should be mandatory for natural sciences; nevertheless, women still suffer a pay gap. Moreover, willing female researchers may get lost along their career path. The approach by the Culham Centre for Fusion Energy (CCFE) now officially tries to remove discriminating obstacles within their organisation. A problem that not only Britain must tackle. Prof Sibylle Günter from the German Max Planck Institute for Plasma Physics (IPP) was just honoured with a prize for being a role model for women in physics.
GIRL POWER ON THE WALL

“It feels good to hear that I encourage young women in science”, says Prof Sibylle Günter. The current Director of the Max Planck Institute for Plasma Physics sips tea at the wooden table in her office. She is just winding down from a busy working week. Last Wednesday all eyes within the fusion world were on her as the world’s biggest stellarator Wendelstein 7-X was inaugurated with the assistance of no other than the Chancellor of Germany, Angela Merkel. Günter is rather touched when she speaks about an email she received the following day. “One female colleague wrote to me explaining that she has put the picture of Merkel and me on her wall and named it ‘Girl power!’”. Günter can be called a ‘certified’ role model. At the beginning of this year, the European Physical Society honoured her with the Emmy Noether Prize for her “solid scientific record, many leadership roles and mentoring of researchers and students”.

Sibylle Günter.
Picture: IPP
ROLE MODELS TO ATTRACT ATTENTION
The Emmy Noether Distinction for Women in Physics identifies role models able to attract women to enter into a career in physics. It addresses the fact that women are underrepresented in what is called the STEMM careers. STEMM stands for Science, Technology, Engineering, and Mathematics and Medicine. Studies have revealed that factors such as encouragement from parents, interactions with maths and science teachers, curriculum content, hands-on laboratory experiences, high school achievement in maths and science, as well as resources available at home, play an important role when it comes to raising interest among young girls.

20% OF EUROFUSION WORKERS ARE WOMEN
Following on from the latest survey carried out by EUROfusion, which collected data from 25 of the 29 members, merely 20% of fusion personnel are women. Men outnumber women in EUROfusion when it comes to engineers, physicists or technicians. A higher proportion of women hold administration or legal roles. The EUROfusion ad-hoc group which conducted the survey of human resources compared the numbers from 2004. Twelve years ago, the proportion of female professionals was only around 12%. This has improved but is still barely above 18%. In general, the survey revealed that southern European countries do better in terms of gender balance in fusion research than northern European ones.

10% IN STEM ROLES AT CCFE
EUROfusion’s member CCFE in England can prove the lack of female participation. The workforce on site comprises approximately 620 employees and 500 contractors. In addition, Culham sees around 400 European scientists visiting each year to conduct research, primarily on the Joint European Torus (JET), and many from outside Europe. According to figures from 2014, 530 of the employees hold in STEM (Medicine is not provided) roles, of which 190 are scientists and 340 are in engineering or technical positions. But the overall percentage of women in STEM roles at CCFE is only 10%. Taking the technical positions into account, women on site make 14.2%.

LOST ON THE WAY
But even if a female student proceeds along her way and starts a STEM career, the path might turn into a ‘leaky pipeline’, as Dr Joanne C. Flanagan would call it. Many women get ‘lost’ on their way from a PhD student to a post-graduate or even professorship. “It depends on the culture of every organisation but common barriers are, for instance, missing role models. Also, young women lack mentoring. If they want to progress in their career they need guidance”, says Flanagan decisively.

MIND THE GAP
Flanagan is not going to take this anymore, at least not at CCFE. The mother of two is a member of CCFE’s self-assessment team which has one aim: to adopt the principles of the Athena Swan charter. Athena Swan is the British industry standard for equal gender representation in the workplace. It addresses, for example, issues like the lack of gender equality in STEMM especially along the career stages, the gender pay gap, short term contracts for the retention and progression of staff and missing active commitment from seniors.
FROM BRONZE TO SILVER
The first step for Flanagan and the Athena Swan self-assessment team was to perform a gender equality ‘audit’ to identify problem areas and outline an action plan for change. A smaller work unit in the team is responsible for comprehensive data analysis. By collecting statistics of recruitment and career progression, the Athena Swan task force is able to understand how CCFE’s policies, procedures and culture impact gender balance. Flanagan and her team must have done well since 2013. In October last year, the British fusion research site achieved the Athena Swan Bronze award. “This was a way of pushing ourselves to create a better environment for everyone to work in and it should result in recruiting and retaining more women. We now need to maintain focus, fulfill our commitments, and move towards our next goal: a Silver award,” states Flanagan, while not missing a beat.

ON PATERNAL LEAVE
“From my experience, I can tell that there is a problem. We are trying to support young families within our institute”, says IPP Director Günter when it comes to difficulties for women especially after their maternity leave. When Günter had her daughter 26 years ago, she continued doing research and met her mentor at night. “Sure, I was lucky to have a boss who was understanding”, she confirms. “Nowadays the legal frame encourages dads also to take responsibility”, she proposes.

PROSPER FROM DIVERSITY
Consequently, she welcomes every male researcher who asks to take paternal leave. This year, the IPP has seven dads on parental leave or parental part-time. Günter sums up her motivation to make it easier for women to return into the lab after the maternal leave: “Women do not approach physics any differently to men. But I think that a team built of male and female scientists will definitely prosper from its diversity.”
Introducing ALTERNATIVE FUSION CONCEPTS:

GENERAL FUSION “RETHINK FUSION”

1 FACTS

Michel Laberge (Founder and Chief Scientist) and Nathan Gilliland (CEO)

General Fusion has received a total of $55 million from either governmental or private funding during passed years. Canada invested $10 million and $27 million came from Malaysia. In March this year, the company was awarded additional $12.75 million from the Canadian Government to continue doing research. Among the private investors are, for example, Chrysalix Venture Capital or Bezos Expeditions.

Burnaby, British Columbia, Canada

2 IDEA

General Fusion follows the Magnetised Target Fusion (MTF) approach. This concept is a hybrid between magnetic fusion and inertial confinement fusion. The goal is to form a compact toroid or spheromak plasma and compress it quickly. General Fusion uses a spherical tank ~3-metres in diameter and is based on LINUS which is a fusion power plant concept originating from the US Naval Research Laboratory back in the 1970s. Inside the tank, magnetised plasma is injected into a vortex of rotating liquid lead lithium. 200 pistons impact a shockwave which travels through the liquid. The wave compresses the plasma. Electric currents flowing in the plasma form the magnetic field. These are very short-lived (~500 microseconds). According to General Fusion’s CEO Nathan Gilliland, the current “is like a smoke ring, where the eddy currents in the air hold the smoke in a ring, but eventually they decay and the ring falls apart.” The centre of the plasma sphere releases neutrons which travel into the surrounding
Fusion research benefits from its wide variety of researchers and approaches. Not all of the ideas and concepts belong to EUROfusion. For several years it were mostly private companies even beyond Europe who were trying to bring fusion energy to life. Fusion in Europe introduces different approaches in series and explains precisely what is concealed behind a catchy claim to attract private investors.

**3 OPINION**

“General Fusion attempts to be transparent and communicates widely within the fusion community. In attending international conferences and publishing papers in peer review journals, they are open to debate their research. Their concept is scientifically sound and seems plausible. Nevertheless, they face great challenges. For instance, they need to maintain a stable plasma state while accelerating and compressing it; and they also need to create a very smooth vortex without ripples. Also, the material used for the pistons must withstand very harsh conditions. The work is scientifically very interesting and it could well be that some of the work done by General Fusion will find its way into EUROfusion. Nevertheless, there are still so many hurdles for this concept to overcome that I am convinced that the time required to create a working reactor is much longer than what is currently being quoted.”

Tony Donné visited General Fusion in 2015 and shares opinion on the concept. Picture: EUROfusion

molten lead-lithium. The neutrons interact with lithium atoms and are absorbed. The lithium splits into helium and tritium and heats up. Neutrons that reach the steel wall have so little energy that they cause minimal structural damage. The hot lead-lithium is continuously pumped out of the tank through a heat exchanger system into a thermal energy conversion cycle. The cooled lead-lithium will then be pumped back again.
3D printing, also known as Additive Manufacturing (AM), uses successive layers of material to create a three-dimensional object. A computer controls the process. It seems weird to create a rather complex object “at home” using an off-the-shelf 3D printer but, actually, this technique is a great help when a small number of complex components needs to be produced in a short time.

**TIME IS MONEY**

“The initial drive was to reduce costs and time”, says Valeria Riccardo, Chief Engineer at the Culham Centre for Fusion Energy (CCFE). The two sets of tile support assemblies and the mirror holder have complex features to be aware of. For instance, the tile assemblies need to be able to slot into features of the vessel and then impose a large load on these so as not to slip off during disruptions.

**INTRODUCING ADDITIVE MANUFACTURING**

The 3D printed components were installed during JET’s shutdown last year. “The usual method of production would have taken ages. Also, we would lose a lot of material and the costs would have been far too high. So, for the first time, we tried the additive manufacturing with a company”, tells Valeria. And it took the team only four weeks from the idea to the product.

The tile assemblies from which each has two AM parts with a combined weight of 1.1 kg and the mirror holder (about 1.2 kg) are made of AM Inconel 718, a special nickel-chromium-based super alloy which withstands harsh conditions. It has been used widely in gas turbines, for example, but not in fusion experiments.

**LIMITED SOLUTION FOR ONE-OF-A-KIND PIECES**

The components were installed in summer of last year. Since then, they have seen a few months of plasma operation without any cause for concern. The ITER mirror assembly will be dismounted at the next shutdown, while the tile support assemblies will be used indefinitely. Depending on how many one-of-a-kind components JET would need to produce again, the engineering team might consider using additive manufacturing as a way of producing the requested bits and pieces. “3D printing takes some time. It is a rather useful way of only creating a small number of components”, adds Valeria.
Electricity demands are set to grow in the 21st century, so we will need new, clean, secure and competitive energy solutions in Europe and the world. Fusion energy is part of that global quest for a new and sustainable energy source.

Securing clean energy supplies at competitive prices is an important priority for the European Commission and part of our Energy Union strategy. If fusion power can be realised within the timescale of our current roadmap – with a demonstration power plant starting operation in the early 2040s – fusion could become a valuable energy source in the second half of this century.

Some of the world’s best scientists and engineers are now taking the first step on this journey, helping to design, construct and safely operate ITER, one of the most ambitious energy projects in the world today.

The Commission is playing its part also. As part of Horizon 2020, the EU fusion programme has set high standards in a goal-oriented roadmap and a comprehensive Joint Programme, and we are not alone. Solving global climate and energy challenges requires global action, and for this reason Euratom researchers are leading the way in the international effort to identify the right technologies to produce commercial fusion electricity.

I firmly believe that by working closely with our international partners, we can reach our goals to make fusion energy a global energy for the future: making fusion energy open to the world.

Carlos Moedas, European Commissioner for Research, Science and Innovation

The European Commissioner for Research, Science and Innovation, Carlos Moedas, was born in Beja (Portugal) in 1970. He graduated in Civil Engineering from the Higher Technical Institute (IST) in 1993 and completed his final year of studies at the École Nationale des Ponts et Chaussées in Paris.

After obtaining an MBA from Harvard Business School (USA) in 2000, he returned to Europe to work in mergers and acquisitions at the investment bank Goldman Sachs in London (UK).

He returned to Portugal in 2004 as Managing Director of Aguirre Newman and member of the Executive Board of Aguirre Newman in Spain. In 2008, he founded his own investment company, Crimson Investment management.

Three years later he was elected for the National Parliament and was called for the government to Secretary of State to the Prime Minister of Portugal in charge of the Portuguese Adjustment Programme.

In 2014, Moedas finally became Member of the European Commission.
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