Getting to the heart of antimatter

The imbalance between matter and antimatter in the observable universe is one of the enduring mysteries in the physical sciences. An antimatter particle can be described as a sort of mirror particle of what is found in conventional matter. When the two meet – a matter particle and its antimatter counterpart – they annihilate into pure light, and there’s a 100 percent conversion into energy.

The observable universe is comprised largely of conventional matter, yet it is thought that the big bang should have created equal amounts of matter and antimatter, raising a number of fundamental questions about our understanding of physical laws and energy production.

Why didn’t the big bang create equal amounts of matter and antimatter? Is there some level of uncertainty in the overall production of energy? Is there something wrong with our current understanding of the fundamental laws of physics?

The Accelerators Validating Antimatter (AVA) project aims to make an important contribution in these terms, bringing together academic and commercial partners to train 15 fellows in antimatter research, laying the foundations for continued development. Researchers will utilise the new ELENA research infrastructure at CERN to investigate fundamental questions around antimatter – work which could lead to new scientific and technical breakthroughs. We spoke to project coordinator Professor Carsten Welsch, Head of Physics at the University of Liverpool and member of the Cockcroft Institute, about the project’s research, the challenges they face, and the implications of their work for the future of science and industry.

Antimatter research

EU Researcher: What are the fundamental difficulties in researching antimatter?

Professor Carsten Welsch: It really starts with the production of the antimatter in the first place, as you need a very large accelerator facility.

The big problem is that, according to Einstein’s famous equation $E=mc^2$, in order to create a massive particle like an antiproton you need to first have a reasonably high energy in your particle beam. This high energy means that when you produce the antiproton, it will basically come out of that generation process as a very hot particle – high in velocity and energy – and that’s exactly not the type of particle that we want in research.

EUR: Does this mean that you can get more antiprotons?

CW: Yes, we can get more antiprotons, but we can also get more of them at a much better beam quality, and the better the beam quality, the deeper we can look into antimatter. This really will – I believe – enable us to gain new insights into antimatter.

For example, once we have captured these antiprotons, they can be merged with a cloud of positrons – the antiparticle of the electron. When an antiproton and a positron meet, they form antihydrogen, which is antimatter. That would then allow us to compare antihydrogen and hydrogen in very fundamental ways.

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compare antihydrogen and hydrogen in very fundamental ways, looking into the atomic structure, doing laser spectroscopy and measuring the atomic levels.

AVA project

EUR: What is the overall goal of the AVA project?

CW: There are three different work packages in the project, and the aim is to bring together different antimatter research communities, who before had possibly not talked enough to each other. One work package looks at the design and optimisation of the accelerator, another looks into the diagnostics that are required to measure the beam, and the third addresses novel experiments that haven’t previously been possible.

EUR: So is there interest from the commercial sector in your research?

CW: There are 25 partners in the project, of which roughly a third are universities, a third are research centres, and a third is from industry. Our industrial partners are primarily looking into the development of diagnostics and detectors; antimatter beams at low energies are very difficult to measure.

The goal for industry is that once they have demonstrated that their detectors work with such a complicated beam, then they can also use that kind of technology and apply them in other fields and hopefully find new markets and new customers.

EUR: What implications does this research hold for industry?

CW: The primary focus is on training the fellows – we hope to recruit fifteen highly qualified and dynamic individuals from all over the world, who will be working on these research challenges. Over the next three years, we aim to train them in these fields and establish a strong network between them, so that there’s a coherent group of fellows who like working with each other and producing outstanding research results.

Beyond that, I hope that we can build bridges between these different research communities, who at the moment work rather independently of each other. This would be a good platform to start new collaborative research projects.

At a glance

Full Project Title
Accelerators Validating Antimatter physics (AVA) – A European Training Network

Project Objectives
AVA will enable an interdisciplinary and cross-sector program on antimatter facility design and optimisation, advanced beam diagnostics and novel antimatter experiments.

Project Funding
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Beneficiary Partners
• University of Liverpool, UK
• CERN European Organization for Nuclear Research, Switzerland
• CIVIDEC Instrumentation GmbH, Austria
• Cosylab d.d., Slovenia
• FOTON s.r.o, Czech Republic
• FZJ Forschungszentrum Juelich, Germany
• GSI Helmholtzzentrum fuer Schwerionen Forschung GmbH, Germany
• Max Planck Institute for Nuclear Physics (MPIK), Germany
• OEAW Austrian Academy of Sciences/Stefan-Meyer-Institute, Austria
• Stahl-Electronics, Germany
• University of Manchester, UK

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Professor Carsten Welsch studied at the Universities of Frankfurt and Berkeley. His further career brought him to RIKEN in Japan, the Max Planck Institute for Nuclear Physics in Germany and to CERN. He joined the University of Liverpool in 2008. In September 2016 he became Head of the Physics Department.

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