NEWS *letter*

MIRROR

Issue 19 May 2021

Highlights

- BASE opens up new possibilities in the search for cold dark matter
- AEgIS on track to test free-fall of antimatter
- Quantum State Distributions in Antihydrogen Beam Measured
- Fellow Interviews
- Partner News

Dear friends of low energy antimatter and ion physics,

On 30 April 2020, after more than 4 years, we submitted our final project report to the European Commission. The AVA network has a remarkable journey behind it: From recruiting a cohort of enthusiastic Fellows from all over the world, implementing a cutting-edge research program, providing comprehensive multi-sector training to the Fellows, organizing many events for the wider scientific community, all the way to engaging the general public with a multi-facetted outreach program. Over no less than 123 pages (!), our report details the many achievements of the network. It describes the research and training of each Fellow and shows just how much the whole network has enabled.

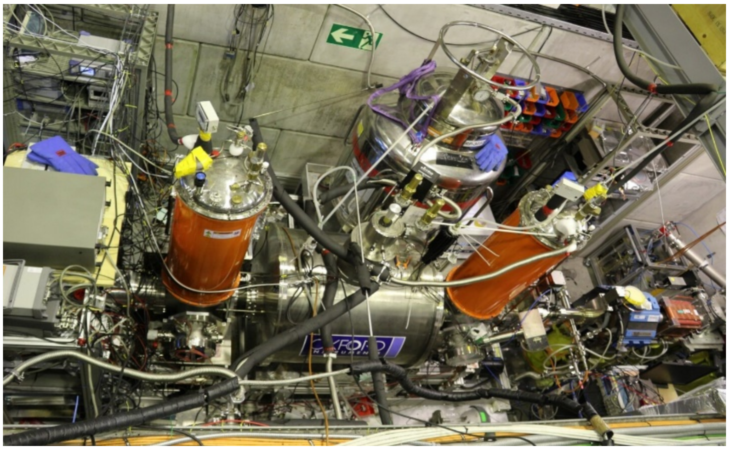
It makes me really proud to see all of the fantastic results and this seems a good moment to say a big *"thank you!"* to all our Fellows and supervisors for their excellent work, collaboration and friendship over the years. The report will now be reviewed by an external expert, and we will hear back in a few months time.

The international conference on exotic atoms and related topics (EXA 2021) will be held in the form of an online meeting between 13-17 September 2021. The scientific program includes research into antihydrogen, as well as studies of future facilities and novel instrumentation, i.e. many areas that fall in the scope of AVA which is one of the conference sponsors. I would like to encourage you to contribute to this event and present your latest research results. You will find more details about EXA in this MIRROR.

Prof. Carsten P. Welsch,
Coordinator

Research News

BASE opens up new possibilities in the search for cold dark matter



The horizontal Penning trap magnet and orange cryostats form part of the BASE experiment (Image: S. Ulmer/CERN)

AVA Supervisor Stefan Ulmer and AVA Fellow Markus Wiesinger, as part of the BASE collaboration, have co-authored a paper published in Physical Review Letters. This team of physicists has set new limits on the existence of axion-like particles and they, using a pioneering method, report on how easily those could turn into photons (the particles of light) and describe how this opens up new experimental possibilities in the search for cold dark matter.

Markus Wiesinger's project within the AVA Network focuses on advanced cooling techniques for protons and antiprotons captured in a Penning Trap with the aim of improved measurements of the proton and antiproton magnetic moment. This Penning Trap is a device that combines electric and strong magnetic fields. To avoid collisions with ordinary matter, the trap is operated at 5 kelvins (around -268 degrees Celsius), a temperature at which exceedingly low pressures, similar to those in deep space, are reached. By carefully adjusting the electric fields, individual antiprotons can be isolated and moved to a separate part of the experiment. In this region, very sensitive superconducting resonant detectors can pick up the tiny electrical currents generated by single antiprotons as they move around the trap.

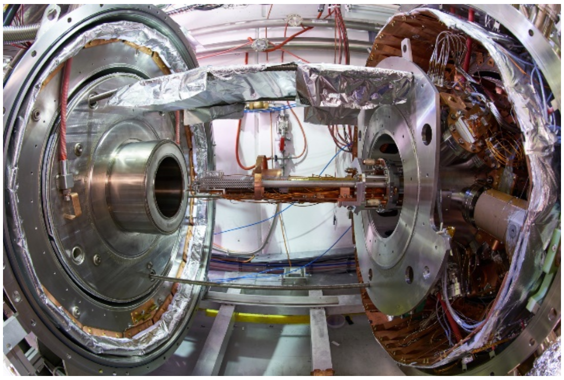
In the work published, the BASE team looked for unexpected electrical signals in their sensitive antiproton detectors. These detectors are superconducting, have almost no electrical resistance, and are extremely sensitive to small electric fields. The detectors are located in the Penning trap's strong magnetic field; axions from the dark-matter background would interact with this magnetic field and turn into photons, which can then be detected. The antiproton was used as a quantum sensor to calibrate the background noise on the detector. Next, the search began for narrow frequency signatures inconsistent with detector noise, however faint, which could hint at those induced by axion-like particles and their possible interactions with photons. Nothing was found at the frequencies that were recorded, which means that BASE succeeded in setting new upper limits for the possible interactions between photons and axion-like particles with certain masses.

With this study, BASE opens up possibilities for other Penning trap experiments to participate in the search for dark matter. Since BASE was not built to look for these signals, several changes could be made to increase the sensitivity and bandwidth of the experiment and improve the probability of finding an axion-like particle in the future. This new technique has combined two previously unrelated branches of experimental physics: axion physics and high-precision Penning trap physics. The team's laboratory experiment is complementary to astrophysics experiments and especially sensitive in the low axion-mass range. With a purpose-built instrument there is the opportunity to broaden the landscape of axion searches using Penning trap techniques.

Further information:
J.A. Devlin, et al., "Constraints on the Coupling between Axionlike Dark Matter and Photons Using an Antiproton Superconducting Tuned Detection Circuit in a Cryogenic Penning Trap", Phys. Rev. Lett. 126, 041301
https://doi.org/10.1103/PhysRevLett.126.041301

AEgIS on track to test free-fall of antimatter

In a paper recently published in the journal Communications Physics, The AEgIS collaboration at CERN's Antiproton Decelerator (AD) has reported a major milestone in its bid to measure the gravitational free-fall of antimatter – a fundamental test of the weak equivalence principle. Using a series of techniques developed in 2018, the team demonstrated the first pulsed production of antihydrogen, which allows the time at which the antiatoms are formed to be known with high accuracy. This is a key step in determining "g" for antimatter.



The AEgIS experiment is built around two powerful superconducting solenoids. (Image: M.Brice/CERN)

AVA Steering Committee member and AEgIS spokesperson Michael Doser of CERN says: "*This is the first time that pulsed formation of antihydrogen has been established on timescales that open the door to simultaneous manipulation, by lasers or external fields, of the formed atoms, as well as to the possibility of applying the same method to pulsed formation of other antiprotonic atoms. Knowing the moment of antihydrogen formation is a powerful tool.*"

Following a proof-of-principle measurement of g for antihydrogen by the ALPHA collaboration in 2013, ALPHA, AEgIS and a third AD experiment, GBAR, are all targeting a measurement of g at the 1% level in the coming years. In contrast to AEgIS's approach, whereby the vertical deviation of a pulsed horizontal beam of cold antihydrogen atoms will be measured in an approximately 1 m-long flight tube, GBAR will take advantage of advances in ion-cooling techniques to measure ultraslow antihydrogen atoms as they fall from a height of 20 cm. ALPHA, meanwhile, will release antihydrogen atoms from a vertical magnetic trap and measure the distribution of annihilation positions when they hit the wall – ramping the trap down slowly so that the coldest atoms, which are most sensitive to gravity, come out last. All three experiments have recently been hooked up to the AD's ELENA synchrotron, which enables the production of very low-energy antiprotons.

AVA Fellow Mattia Fanì played a crucial role for this measurement. Being able to detect the pulse-formed antihydrogen atoms required working with a cold cloud of antiprotons: antihydrogen atoms with a velocity corresponding to a temperature of 1000 degrees would reach the (material) surface of the traps holding the antiprotons from which they are formed within one or two microseconds and annihilate. This annihilation signal comes on the heels of a much larger detector signal stemming from the injection (and partial annihilation) of positrons, as the AEgIS method requires formation of positronium atoms from positrons (which then subsequently interact with the trapped antiprotons to form antihydrogen atoms). Consequently, we also require detectors that are able to rapidly recover from the first blinding pulse. Mattia Fanì was involved in both the systematic study of novel scintillating detector materials that recover within a few 100 ns from the initial intense positron annihilation light flash, as well as in developing the plasma physics manipulations required to ensure that the antiprotons would be as cold as possible, ultimately reaching a temperature of a few 100 degrees.

Given that most of the mass of antinuclei comes from massless gluons that bind their constituent quarks, physicists think it unlikely that antimatter experiences an opposite gravitational force to matter and therefore “falls up”. Nevertheless, precise measurements of the free fall of antiatoms could reveal subtle differences that would open an important crack in current understanding.

Further information:

Amsler, C., Antonello, M., Belov, A. et al. Pulsed production of antihydrogen. Commun Phys 4, 19 (2021).
https://doi.org/10.1038/s42005-020-00494-z

Quantum State Distributions in Antihydrogen Beam Measured

The ASACUSA collaboration, including AVA Fellow Amit Nanda, reports on the measurement of the principal quantum number distribution of the antihydrogen beam produced by the ASACUSA Cusp trap. Another AVA Fellow, Markus Wiesinger, was also part of the ASACUSA collaboration working on this project prior to joining the AVA network.

The new study, published in The European Physical Journal D, characterises the quantum number distribution of the antiatoms in the antihydrogen beam by a method called field ionisation. Here, strong electric fields are applied which allow the positron in the antihydrogen atom to tunnel out of the potential well formed by the antiproton. However, only atoms with high principal quantum numbers are ionised, such that scanning the electric field selects the quantum number of the surviving atoms. The number of surviving antihydrogen atoms is then measured by detecting the annihilation signal of antihydrogen atoms at the end of the beamline

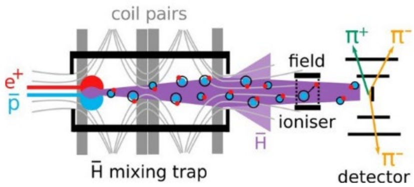


Figure1: Schematic of the ASACUSA experiment for antihydrogen beam formation and detection.

To produce the antihydrogen beam, antiprotons from the Antiproton Decelerator at CERN are caught and stored in the MUSASHI trap while positrons are obtained from a sodium-22 source and a neon moderator then stored in the positron accumulator. They are merged together to form antihydrogen atoms in a double-Cusp trap (see figure 1), which consists of a multi-ringed electrode trap housed within a magnetic field produced by a pair of superconducting coils in an anti-Helmholtz configuration. Positrons and antiprotons are mixed in a region of strong magnetic field within a nested Penning trap that lies before the first of two cusps. The cusped field helps to focus and polarise cold ground state antihydrogen atoms, thus leading to a polarised antihydrogen beam.

“*Knowing the exact state the antihydrogen atoms are in is an essential prerequisite for using the antihydrogen beam for spectroscopy experiments*“, says CERN physicist Bernadette Kolbinger, the first author of the study. In the future, the ASCACUSA collaboration is planning to use the beam of antihydrogen atoms for antihydrogen hyperfine splitting measurements and to compare these with measurements on hydrogen in order to test the CPT symmetry. For these measurements, the antihydrogen atoms need to be in the ground state. The results (see figure 2) show that antihydrogen atoms with a wide range of principal quantum number are available, so de-excitation to the ground state will be necessary.

Currently, upgrades are being performed at CERN’s Antiproton Decelerator in order to increase the number of antiprotons available to experiments for antihydrogen formation. At the same time, ASACUSA is using the matter counterpart of antihydrogen atoms - hydrogen atoms - to study and improve the antihydrogen production and beam formation process, including ways to de-excite Rydberg atoms by plasma collisions or using laser light. In addition, ASACUSA is improving the efficiency of the experiment by upgrading the antihydrogen detector: faster timing and higher position resolution will improve the reconstruction of antihydrogen annihilation events and thus overall detection efficiency.

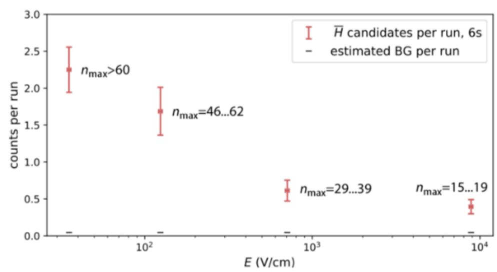


Figure 2: Principal quantum number distribution of antihydrogen atoms in the ASACUSA antihydrogen beam

Further information:
Kolbinger, B., Amsler, C., Cuendis, S.A. et al. Measurement of the principal quantum number distribution in a beam of antihydrogen atoms. Eur. Phys. J. D 75, 91 (2021).
https://doi.org/10.1140/epjd/s10053-021-00101-y

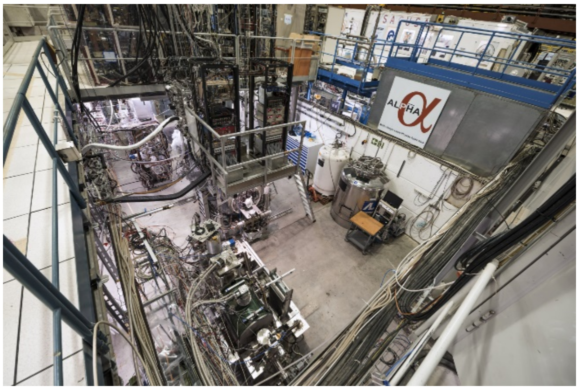
ALPHA cools antimatter using laser light for the first time

The ALPHA collaboration at CERN has succeeded in cooling down antihydrogen atoms – the simplest form of atomic antimatter – using laser light. The technique, known as laser cooling, was first demonstrated 40 years ago on normal matter and is a mainstay of many research fields. Its first application to antihydrogen by ALPHA, described in a paper recently published in Nature, opens the door to considerably more precise measurements of the internal structure of antihydrogen and of how it behaves under the influence of gravity. Comparing such measurements with those of the well-studied hydrogen atom could reveal differences between matter and antimatter atoms. Such differences, if present, could shed light on why the universe is made up of matter only, an imbalance known as matter–antimatter asymmetry.

Within the AVA network, 16 Fellows and antimatter experts at partner institutions across Europe work together on antimatter research and development using accelerators. AVA Supervisor, and deputy spokesperson for the ALPHA collaboration, Dr William Bertsche (University of Manchester/CERN) works on plasma physics and accelerator topics associated with the study of fundamental properties of antimatter in the ALPHA experiment at CERN.

The ALPHA team makes antihydrogen atoms by binding antiprotons, taken from CERN's Antiproton Decelerator, with positrons originating from a sodium-22 source. It then confines the resulting antihydrogen atoms in a magnetic trap, which prevents them from coming into contact with matter and annihilating. Next, the team typically performs spectroscopic studies by measuring the anti-atoms' response to electromagnetic radiation – laser light or microwaves. These studies have allowed the team to, for example, measure the 1S–2S electronic transition in antihydrogen with unprecedented precision. However, the precision of such spectroscopic measurements and of planned future measurements of the behaviour of antihydrogen in the Earth's gravitational field in ongoing experiments is limited by the kinetic energy or, equivalently, the temperature, of the antiatoms.
By using the laser cooling technique, laser photons are absorbed by the atoms, causing them to reach a higher-energy state. The anti-atoms then emit the photons and spontaneously decay back to their initial state. Because the interaction depends on the atoms' velocity and as the photons impart momentum, repeating this absorption–emission cycle many times leads to cooling of the atoms to a low temperature.

In their new study, the ALPHA researchers were able to laser-cool a sample of magnetically trapped antihydrogen atoms by repeatedly driving the anti-atoms from the atoms' lowest-energy state (the 1S state) to a higher-energy state (2P) using pulsed laser light with a frequency slightly below that of the transition between the two states. After illuminating the trapped atoms for several hours, the researchers observed a more than tenfold decrease in the atoms' median kinetic energy, with many of the anti-atoms attaining energies below a microeletronvolt (about 0.012 degrees above absolute zero in temperature equivalent).
Having successfully laser-cooled the anti-atoms, the researchers investigated how the laser cooling affected a spectroscopic measurement of the 1S–2S transition and found that the cooling resulted in a narrower spectral line for the transition – about four times narrower than that observed without laser cooling.



View of the ALPHA experiment (Image: CERN)

A decade ago laser cooling of antimatter was in the realm of science fiction. The collaboration's demonstration of laser cooling of antihydrogen atoms and its application to 1S–2S spectroscopy represents the culmination of many years of antimatter research and developments at CERN's Antiproton Decelerator. This new development is a game-changer for spectroscopic and gravitational measurements, which could lead to new perspectives in antimatter research.

AVA coordinator Professor Carsten P Welsch says: "'*These measurements mark a very important milestone towards studying antimatter in unprecedented detail. Whilst laser cooling is an established technique in atomic physics, it has been a significant challenge to adapt it for use with antihydrogen. Congratulations to the ALPHA collaboration for this excellent result!*"

Further information:
Baker, C.J., Bertsche, W., Capra, A. et al. Laser cooling of antihydrogen atoms. Nature 592, 35–42 (2021).
https://doi.org/10.1038/s41586-021-03289-6

Network News

Final Report of AVA submitted to the European Commission

The AVA consortium is pleased to announce that it has submitted its final report to the European Commission at the end of April. This submission marked the official end of a hugely successful project that has seen 35 universities, research centers, and leading industry partners, joining forces to train 16 early stage researchers in the field of antimatter research.

The Berlaymont building, and seat of the European Commission, features in the EC's logo (Image: Pixabay).

The Fellows have undertaken a 3 year-long formation plan through beyond state-of-the-art research, and an intensive program of training events. The cross-sector interdisciplinary environment created by AVA, facilitating secondments and collaborations, has boosted the career and employability of the researchers.

AVA Coordinator Professor Carsten P Welsch said: *"AVA enabled an interdisciplinary and cross-sector R&D program on antimatter research which has already led to 19 high impact articles in peer-reviewed journals and 23 conference proceedings. The project has realized enormously successful outreach and dissemination activities that had global reach. The project has also expanded the AVA network with new partners, and have helped to raise awareness among the general public in general, and school children in particular, on the challenges of antimatter research."*

The over 120 pages-long final report is a comprehensive summary of all the activities and achievements of AVA, including a detailed account of the research carried out by each of the fellows, the list of publications, milestones and deliverables, a description of all the training and management activities organized, dissemination and outreach, as well as the overall impact of the project on science and society.

With the final AVA report submitted this means the end of a chapter, but not the end of the network that has been established. The consortium has decided to continue its communication and dissemination activities which includes the publication of the MIRROR newsletter– please stay in touch by sending us your stories!

We also plan to organize a number of workshops and events for the antimatter and low energy ion communities. And with AVA's final conference in 2020 being postponed due to the pandemic, the AVA network will try to bring the Fellows together again in the future.

To be continued!

Fellows Activity

Dominika Alfs successfully completes PhD

In February, Dominika Alfs, AVA Fellow based at Forschungszentrum Jülich, defended her thesis *Search for Polarization Effects of Antiprotons Produced in pA Collisions* and earned her PhD at the Ruhr-Universität Bochum. Dominika worked under supervision of Dr. Dieter Grzonka and Prof. James Ritman. A brief introduction into the subject of her thesis is given below.

Even though several methods have already been proposed, the preparation of a sufficiently polarized antiproton beam, useful for further experiments, remains a challenge. The goal of the P349 antiproton polarization experiment is to investigate if antiprotons produced in a high energy proton beam collision with an unpolarized solid target are polarized. If the antiproton production process results in a significant degree of polarization, this method could be used to prepare antiproton beams in the existing and planned antiproton facilities.

Three beam times have been performed at the T11 beamline of the East Area at European Organization for Nuclear Research (CERN) and were the first attempt to measure antiproton polarization in the production process. Dominika analyzed the existing data which resulted in a very good understanding of the measurement conditions and design of an improved measurement setup. Furthermore, Dominika prepared detailed Monte Carlo simulation studies to investigate the required statistics for a given sensitivity of a polarization determination.

The achieved statistics was not sufficient to extract an upper limit for the polarization but the analysis and simulation studies have shown that a measurement of the antiproton polarization via elastic antiproton-proton scattering at the T11 beam line at CERN is achievable with sufficient statistics. Currently the test measurements with the improved setup are ongoing at the Cooler Synchrotron (COSY) at Forschungszentrum Jülich and a next measurement at CERN is planned in the nearest future.

Congratulations!

AVA Fellow Interviews – A look back and into the future

Now the formal period of the project has come to an end, this is a good moment to look back at the Fellows' time with AVA. We have asked the Fellows a few questions as part of the AVA Spotlight Interview series; this will give you a more personal insight into their motivation, achievements and outlook.

Spotlight on Volodymyr Rodin

For this interview we have spoken with Volodymyr Rodin who joined the AVA Network in October 2017 where he studies collision dynamics of correlated quantum systems. These can be undertaken by crossing a gas jet target with a beam of low energy antiprotons. However, this requires beam compression to a diameter of around 1 mm and a pulse length of 1-2 ns. At the Cockcroft Institute / University of Liverpool, Volodymyr worked on developing a comprehensive simulation framework to enable these studies under both ELENA and FLAIR conditions.

What did attract you to the AVA network? Has it fulfilled your expectations?

"The first thing that caught my attention in this program was the novelty of the research and work with low energy antiprotons. From previous experience, most of the people focused their views on high energy physics and the opposite side was still a mystery in some cases."

Why did you choose to go to the University of Liverpool?

"Professor Carsten P. Welsch from the University of Liverpool directly contacted me after my application. Once I became more familiar with the QUASAR group and previous Marie Curie programs he coordinated I knew going to Liverpool was a good opportunity, and to also participate in many additional activities linked to the project."

Can you explain in a few words what your project was about and what have you achieved?

"My project was aiming to find efficient ways to compress the antiproton bunch size transversely and shorten them by a factor of 100. That would allow studying the many-body Coulomb problem and obtain fully differential cross sections via collisions with atomic gases. This work included a more realistic description of storage rings and beamlines than was done before. In the end, besides other outcomes, I have demonstrated and published the results of how we can achieve this."

What has AVA provided you professionally?

"During my project, I have met a lot of good colleagues with whom we have established fruitful collaborations on different topics: low energy physics, novel acceleration methods, and state-of-art measurement devices. I have obtained great experience and skills in accelerator physics, which consolidated my previous knowledge in other fields."

Can you say something about your next career move?

"My future career step will focus on further research of low-energy machines or any other projects that experience common complications. Primarily I am looking for interesting positions in the EU."

What will be your most cherished memory from AVA?

"Oh, it is hard to choose one! I liked the AVA scientific and outreach events where I worked together with other Fellows on delivering something. And of course, the taste of a good cup of coffee after a successful experiment."

Spotlight on Bianca Veglia

Bianca Veglia joined the AVA Network at the Cockcroft Institute/University of Liverpool (UK) in May 2017. She has been studying antimatter experiments on beam stability and life time in low energy storage rings. Within her project, Bianca developed realistic models for beam transport, storage, deceleration and cooling from storage rings through beam lines to experiments.

What did attract you to the AVA network? Has it fulfilled your expectations?

"Immediately after I graduated, I was curious about "real-life" working environments so I joined a consultancy company where I worked in a project on credit risk management. It was fun but I soon realised that I strongly missed physics. I found the AVA network advertised on different platforms and it offered the option to be part of research groups in university but involving also industries and laboratories and creating a solid network within the different institutions. Plus, I was definitely attracted to the charm of antimatter, which I always found deeply fascinating. I found that my expectations were proven to be true by my experience in AVA, a beautiful group of people, working on interconnected projects."

Why did you choose to go to University of Liverpool?

"Since I was a kid, I enjoyed reading and learning about the British culture and it really made me admire the country. When there was possibility to join the AVA Network, I saw this as the opportunity to join a prestigious UK based university and I couldn't miss it! And my adoration for the Beatles encouraged that choice even more."

Can you explain in a few words what your project was about and what have you achieved?

"My project was about the preparations of the antiprotons that are then used in several antimatter

experiments. We developed simulations to accurately describe the behaviour of the antiproton beam before it reaches the experiments. We managed to better explain the effects acting along the accelerator hence optimising the control over the beam."

What has AVA provided you professionally?

"Apart from the obvious technical skills developed on the job, I had to chance to visit many different institutions and start useful discussions and even collaborations. It also helped me with a set of soft skills, though the numerous schools and workshop the network organised."

Can you say something about your next career move?

"After this experience I would like to continue doing research in the academic environment, possibly collaborating with large institutions. I am in that phase where I am evaluating all the possibilities and weighing my own aspirations."

What will be your most cherished memory from AVA?

"One of the sweetest memories is my birthday at CERN a few years ago, during an AVA School. I felt so special to celebrate this in such an important scientific organization with the warmth of the entire group. It's definitely something I won't forget!"

Spotlight on Ilia Blinov

For this interview we have spoken with Ilia Blinov who joined the AVA Network in December 2017. Based at Stahl Electronics (DE), he has been working on the development of a novel detection system, which will be easier to operate, rugged under adverse conditions as found at ELENA and FLAIR and feature much higher detection sensitivity, down to single particles.

What did attract you to the AVA network? Has it fulfilled your expectations?

"I believe that for all AVA fellows, participating in this program is equivalent to winning a lottery ticket. I already had several years of experience in electronics development, and I was beginning to feel a certain ceiling over my head in a professional sense. AVA has given me a huge boost in my knowledge and professional skills, in addition, it is a great chance to live in another country, learn the local culture and language, for which I am very grateful to the AVA program."

Why did you choose to go to Stahl-Electronics?

"I've always liked working in small companies, it gives me more freedom of choice in the development process and gives me closer contact with colleagues. At Stahl-Electronics, we simultaneously develop devices and conduct

research in the semiconductor field, as well as advise on the design of an experiment. You don't have to get bored, there is always something new, something that you do for the first time, I really like it. The location of the company is worth mentioning, it is located in the wine region of Germany, among the hills, vineyards and cozy villages with a traditional flavor."

Can you explain in a few words what your project was about and what have you achieved?

"During the experiment, we can't look inside the setup, and even if we could, we still wouldn't be able to see the particles. Our eyes in this case are super-sensitive detectors. The success of the experiment and the quality of the data that we can get directly depends on detectors. This is especially important if we are working with a very small number of rare particles, such as antimatter particles. That's exactly why we created this detector. The biggest challenge in designing devices is radio frequency noise, the signals we want to amplify are so small that they can simply get lost among the internal noise of electronic components. To solve this, we cool our detector to very low temperatures, but even then there is a problem. The electronics begin to work according to different laws, or everything stops working at low temperatures. But we were very lucky and we were able to find such electronic components and conditions to make our detector work. I am very happy with our result; it is probably one of the most sensitive detectors in the world at the moment."

What has AVA provided you professionally?

"You know, there are not so many places on earth where you can do cryoelectronic, especially with good mentors. For the many things that I knew only in theory, not only could I check this in practice, but I was also able to create many new solutions. It is also worth mentioning the large number of conferences, workshops and schools that were organized during the program, which is really great. It inspires you with new ideas and plans, gives you a positive attitude and confidence in your abilities. I also realized how important good communication is. Before that, it seemed to me that this is an obvious thing, a line that is present in every resume or job posting by default. But after getting into a dense international environment, and interacting with scientific groups from all over the world from China to the United States, I realized that everything is not so simple, in fact. And you know, I think I have become much better at making new connections, it turned out to be very valuable to me."

Can you say something about your next career move?

"I very much hope that 2021 will open up more career opportunities, although for many the current situation is not encouraging. I know that some programs are currently suspended, many companies are now reluctant to resume the process of hiring new employees. Nevertheless, I feel very confident about my career future after the AVA project. In any case, it will be a combination of research and applied engineering."

What will be your most cherished memory from AVA?

"In fact, it is difficult to pick out a single memory. In my smartphone there is a function that sometimes shows me photos taken by me in the past. Among them many photos from various events with AVA fellows. These are probably the most memorable moments, we spent many wonderful days together, and it's great that AVA was, amongst other things, filled with positive emotions, amazing humour and support."

Partner News

Storage ring CRYRING in operation for the first time at GSI/FAIR

For the first time, FAIR storage ring CRYRING is available for scientific experiments. (Image: J. Hosan, GSI/FAIR)

AVA Partner GSI, based in Darmstadt, is the German national centre for heavy ion research and hosts a large accelerator facility where high beam intensities for heavy ions are accelerated up to several GeV/u. Last year, we reported on the progress of the construction of its Facility for Antiproton and Ion Research (FAIR).

The GSI/FAIR accelerator facilities have now successfully started a new operating phase to conduct scientific experiments as part of the so-called FAIR Phase 0 program. From now until July, scientists from all over the world will investigate numerous research questions in various fields such as nuclear physics, materials research, and atomic physics, in the framework of approximately 80 approved experiments.

The complete accelerator facility will be in operation: the linear accelerator UNILAC, the ring accelerator SIS18, the experimental storage ring ESR, the fragment separator FRS, the high-power laser PHELIX and, for the first time, the new FAIR storage ring CRYRING will be available for use by the researchers. The science run at the GSI facilities is part of this experimental program, which already offers excellent experimental opportunities while FAIR is still under construction.

CRYRING is a storage ring that can also decelerate particles. Within the proposed Facility for Low energy Antiproton and Ion Research (FLAIR), CRYRING would decelerate antiprotons for precision experiments in the future. Studies within AVA pave the way for advanced diagnostics of such low energy beams, as well as beyond state-of-the-art experiments with low energy antiprotons.

During the previous shutdown, numerous maintenance and modernization measures could be implemented to further prepare the existing facility for future operation as a pre-accelerator of the FAIR facility. Due to the Corona pandemic, the usual travel of domestic and foreign guest scientists remains limited during this experiment period. However, the shutdown was also used to expand remote access to parts of the facility for the researchers and improve electronic communication in order to enable the best possible performance of the scientific work.

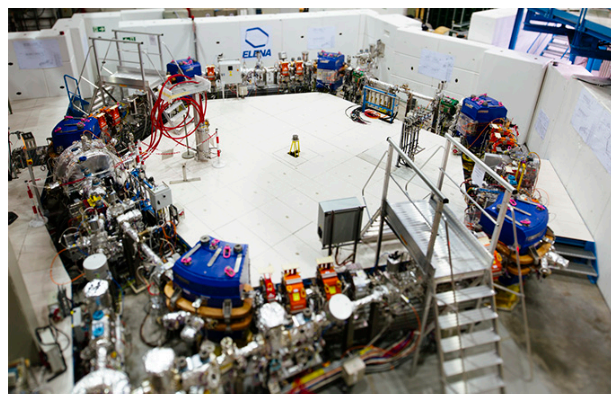
CERN approves two new experiments to transport antimatter

Earlier this year it was reported that the BASE collaboration is developing a transportable antiproton trap for higher-precision antimatter measurements. They do this at CERN's Antimatter Factory – the only place in the world where low-energy antiprotons (antimatter counterparts of protons) are produced. This month, the CERN Research Board approved the development of two new experiments to carry antiprotons from the Antimatter Factory to other facilities, for antimatter and nuclear-physics studies.

Within the AVA Network, R&D into beyond state-of-the-art beam handling, storing and analysis techniques paves the way for the design of novel low energy antimatter experiments. For example, a Fellow at GSI develops, builds and test a reservoir trap to deliver a well-defined number of antiprotons, and a Fellow at MPG, who is also a member of the BASE collaboration, focuses on advanced cooling techniques for protons and antiprotons in penning traps. These AVA projects contribute to research into an additional controllable source of antiprotons, making experiments independent of accelerator-beam cycles and shut-down periods.

The experiments now approved by CERN, to carry antiprotons to other facilities, are called BASE-STEP and PUMA and are compact enough to be transported in a small truck or van. BASE has been performing ever more precise antiproton measurements, but the precision of these measurements is limited by disturbances to the set-up's magnetic field caused by the magnetic environment of the Antimatter Factory. BASE-STEP is a variant of the BASE set-up that has been designed to be carried to a facility at CERN or elsewhere, one that has a calmer magnetic environment and thus allows higher-precision measurements to be made. The device will feature a first trap to receive and release the antiprotons produced at the Antimatter Factory and a second trap to store the antiprotons.

PUMA is based on a different transportable antiproton trap system and has a different scientific goal. It aims to transport antiprotons from Antimatter Factory to CERN's nuclear-physics facility, ISOLDE, for investigation of exotic nuclear-physics phenomena. It will consist of a first trapping zone to stop antiprotons, and a second trapping zone to host collisions between the antiprotons and radioactive atomic nuclei that are routinely produced at ISOLDE but decay too rapidly to be transported anywhere themselves.

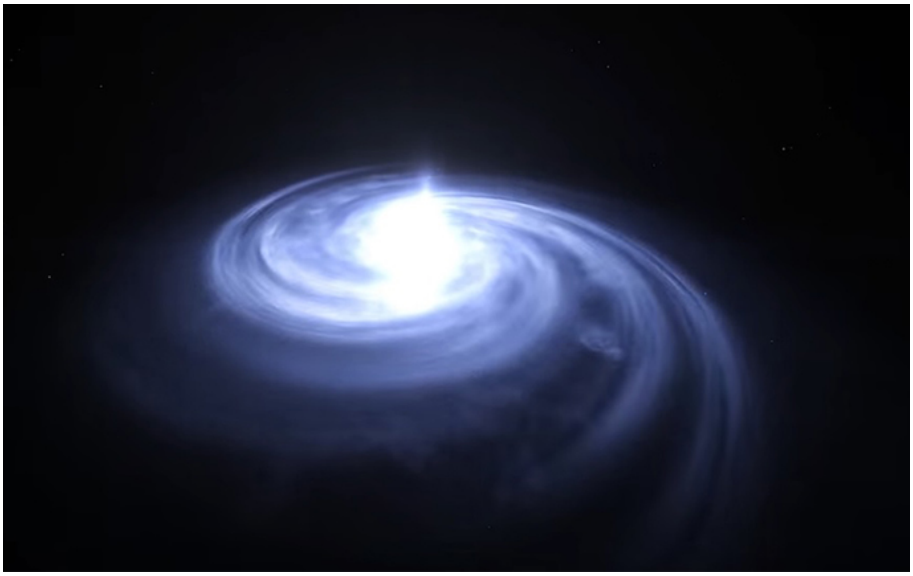


PUMA Experiment: Aims to trap antiprotons at ELENA for transport to nearby ion-beam facility ISOLDE (M. Brice/CERN)

Analysis of the outcome of these collisions will help researchers determine the relative densities of protons and neutrons at the surface of nuclei. These densities could reveal whether the nuclei have exotic properties such as thick neutron "skins" or extended halos of protons or neutrons around their core. Such knowledge could shed light on the interior of neutron stars.

PUMA and BASE-STEP are expected to be operational in 2023.

Antimatter documentary credits AVA's 'Nature (anti)matters' video



A three-part documentary series covering technical innovations and Scientific advancements in China has been published. The documentary called *'Smart China: Frontier of Science'* explores cutting-edge scientific research institutions and enterprises in China. The first two episodes focus on a changing earth and exploring the solar system. The thirds episode titled *'Unravelling the Universe'* looks at antimatter experiments. This is also one of the R&D areas of project AVA **(Accelerators Validating Antimatter physics**) where antimatter research boldly goes towards physics' final frontier.

This third and final episode focuses on China based research into the fundamentals of the universe which also covers the matter antimatter asymmetry in the universe. The documentary draws attention to this: *"Everything we know about physics says that the Big Bang should have created equal amounts of matter (e.g. protons and electrons we're all made of) and mirror image particles called antimatter. However, if matter and antimatter meet they annihilate each other very quickly so that after the start of the universe nothing should exist. Instead, everything we can see, touch and smell is made from matter. No one knows why."* The episode shows what these scientists are doing to examine the differences between matter and antimatter.

This documentary credits the research done within AVA by showcasing part of the project's very own video: AVA – Nature (anti)matters, produced by the AVA Fellows in collaboration with AVA Partner Carbon Digital as part of their media training.

The documentary has been broadcasted in China via an online platform. All episodes, which will also be broadcasted on Discovery Channel in the near future, can be watched online. The direct link to episode 3, in which AVA is credited, can be found here. The website is all in Chinese, but the finished programme is English spoken.

Spotlight on the Project T.E.A.M.

The QUASAR Group Project T.E.A.M. (Training, Education, Administration, Management) deals with large international projects in accelerator science. It specializes in communication, dissemination and outreach to maximize the impact of projects. Since 2008, the T.E.A.M. has been in charge of more than 30 M€ of research funding, collaborating with over 100 institutions and companies from more than 30 different countries. The stats speak for themselves.

The T.E.A.M. is an experienced **project management and implementation** team at the University of Liverpool, based at the Cockcroft Institute on the campus of Daresbury Laboratory in the UK. Established by Prof Carsten P Welsch in 2008, the T.E.A.M. has extensive experience in the specific needs of large scale collaborations and is responsible for the day-to-day management of research and training projects, partner contracts, science communication and outreach. As such, it has been coordinator of 5 European Research and Training Networks, including AVA, one STFC Centre for Doctoral Training, and plays important roles in management and communication activities in a variety of international projects, including EuroCirCol, EuPRAXIA, AWAKE-UK and FCCIS. In combination, it has overseen the training of more than 100 Early Stage Researchers.

In addition to fulfilling all aspects of project management, the T.E.A.M. looks after the **communication and dissemination** of research projects and their outcomes to maximize their impact. For AVA, this meant representation at relevant conferences such as IPAC, publications in mainstream and scientific media, as well as looking after a wide range of dissemination channels including the quarterly newsletter MIRROR and social media.

Furthermore, the T.E.A.M. specializes in the organization of **international conferences, workshops, training events, and symposia** for a broad range of audiences, from a few dozen to several hundreds of delegates. These include all AVA events, some of which could not have been realized without the help of the local organizers. The novel 'researcher skills' schools for early stage researchers, developed by Prof Welsch and the T.E.A.M., has been recognized by the European Commission as 'best practice'. Since its foundation, the T.E.A.M. has organized more than 50 (inter)national events.

An important mission is also to **engage the general public** with cutting edge research and to inspire the next generation of accelerator experts. The T.E.A.M. has designed and carried out outreach activities for a variety of audiences including children of different ages.

Selection of events and dissemination activities, organized by the Project T.E.A.M.

Supporting the involvement of **industry** is achieved by being a supportive partner in accessing the university's research capabilities and intellectual property as well as having the expertise to identify the most appropriate funding mechanism to suit the type and needs of external partners. The T.E.A.M. act as a broker between the University and external organizations, and recognizes the value industrial expertise brings to a research project,

Check out the full Spotlight Interview to read about who we are, what we do and how we as a partner can make joint projects stronger and more impactful: Spotlight Interview.

Upcoming Event

International Conference on Exotic Atoms and Related Topics - EXA2021

EXotic Atoms (EXA) is a series of international conferences on muonic, pionic, kaonic, and antiprotonic atoms and related topics. It takes place every 3 years and was scheduled to be held in Vienna, Austria, in September 2020. Due to the coronavirus pandemic, the conference EXA2021 will now take place as an online meeting from 13-17 September 2021 and is being organised by AVA Partner Stefan Meyer Institute for Subatomic Physics of the Austrian Academy of Sciences.

The AVA project is supporting EXA2021 and encourages all of its Fellows and partners to make contributions to this important conference.

The scientific program of EXA2021 comprises the following topics:

- Antihydrogen: CPT and gravity
- Leptonic atoms: QED and gravity
- Kaon-nucleon and kaon-nucleus interaction
- Low-energy QCD
- Precision experiments with cold neutrons
- Hadron physics with antiprotons
- Hadron physics at LHC
- Future facilities and instrumentation

Authors of accepted contributions will be given a dedicated break-out room during the conference to meet and discuss their contribution with other participants of the conference. To advertise the papers, the organisers will invite the authors on acceptance of the paper to submit a short teaser video which will be made available to all participants well ahead of the conference.

Plenary talks are scheduled for Monday-Wednesday and Friday. Thursday sees discussions of contributed papers in break-out rooms. The deadline for abstract submission is 1 June 2021 at midday and for registration to the conference this is 31 August 2021.

For registration and abstract submission please follow the instructions on the event's Indico page.

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More Events

12th International Particle Accelerator Conference - IPAC'21

The 12th International Particle Accelerator Conference - IPAC'21 will be held in virtual format from 24th - 28th May 2021, organized by the Brazilian Center for Research in Energy and Materials (CNPEM), located in Campinas, Brazil.

IPAC is the main international event to discuss the latest achievements in the science and technology of Particle Accelerators, promoting collaboration among scientists, engineers, technicians, students and industrial partners across the globe. There will be a number of contributions from AVA Fellows and Liverpool's project TEAM will host an industry booth throughout the week – you can arrange a live session with them through the conference interface, so please pass by!

For more information visit: https://www.ipac21.org/

International Conference on Radio Frequency Superconductivity - SRF'21

The virtual conference will take place from Monday 28th June to Friday 2nd July 2021, and will be hosted by Michigan State University (MSU).

The conference will include invited oral talks by video-conference, and several virtual reality poster sessions. With the need to accommodate different time zones, the sessions will be limited to 4 hours per day. A session for "virtual lab tours" is considered at the end of the conference, with the possibility for participants to learn about their choice of several labs around the world. Best student poster prize and best young researcher presentation prize are also planned. In addition, a tutorial program by video-conference is planned in the week preceding the conference.

More information: https://indico.frib.msu.edu/event/38/

10th International Beam Instrumentation Conference - IBIC 2021

The virtual IBIC 2021 will be held 13th - 16th September 2021, organized by PAL, Korea.

IBIC brings together the world community of experts in instrumentation for particle accelerators, to explore the physics and engineering challenges of beam diagnostics and measurement techniques for charged particle beams. The conference program will include tutorials on selected topics, invited and selected talks, as well as poster sessions.

For registration and more information visit: https://www.indico.kr/event/22/page/18-welcome

Position Vacancies

Open positions at CERN:

Experimental Physicist (EP-DI-2021-12-IC) The Experimental Physics (EP) department carries out research in the field of experimental particle physics. It aims to provide a stimulating scientific atmosphere and remains an important reference centre for the European physics community. It contributes to the education and training of young scientists. The Experimental Physics department invites applicants for the indefinite appointment of a Physicist in experimental particle physics research.

Full details: https://careers.cern/alljobs

Mechanical Technician for Beam Intercepting Devices (TTE Programme) Are you a technician looking for a challenging professional experience to further your career? If so, joining ERN's **TTE** programme may very well give you that challenge. The SY-STI-TCD (Accelerator Systems - Targets, Collimators and Dumps) section oversees the conceptual design, construction, operation, and maintenance of all beam-intercepting devices across CERN's accelerator complex, including particle-producing targets, beam absorbers/dumps, collimators, beam stoppers, and slits. The STI group, which sits within the Accelerator Systems department, is also responsible for the technical coordination of related facilities such as the Neutron-Time-of-Flight (n_TOF) and the Antiproton Target (ADT) areas.

Full details: https://careers.cern/alljobs

Open PhD positions at the Max-Planck-Institute for Physics:

Postdoc Application in the MPP Theory Department
Theory Groups at the Max Planck Institute for Physics in Munich plan to make appointments at the postdoctoral level starting in Fall 2021. The interests of the group include a wide range of topics in theoretical and phenomenological particle physics relevant for the LHC and future colliders, physics beyond the Standard Model, effective field theories, string theory, astro-particle physics and cosmology, gravitational theories, and mathematical and non-perturbative aspects of field theory.

Further details: https://www.mpp.mpg.de/en/studying-and-working/jobs/detail/postdoc-application-in-the-mpp-theory-department

Events

ongoing	OWLE Seminar Series: Online Colloquium and Seminar Series on charged particle accelerators
24th - 28th May 2021	12th International Particle Accelerator Conference (IPAC'21), online event
28th June – 2nd July 2021	International Conference on Radio Frequency Superconductivity (SRF 2021), online event
13th – 16th Sept 2021	10th International Beam Instrumentation Conference (IBIC 2021), online event
13th – 17th Sept 2021	International Conference on Exotic Atoms and Related Topics (EXA2021), online event

Notice Board

This newsletter is published on a quarterly basis. Help us keep it interesting by providing your news and updates.

DEADLINE FOR THE NEXT NEWSLETTER CONTRIBUTIONS: 15th July 2021

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