



### Highlights

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### Dear friends of low energy antimatter and ion physics,

I have just returned from our first international [School on Antimatter Physics](#). Between 25-29 June, more than 60 students and lecturers joined this first AVA event that was open to the wider research community for a week-long series of lectures, seminars, tutorials and outreach events. The quality of the lectures was truly impressive and I would like to thank all lecturers for their contribution. You have done a fantastic job! The talk "*Physique de l'antimatière*" by Hubert Reeves was a particular highlight with all places in the Globe of Science and Innovation filled. I believe this gave an excellent message about our project and antimatter R&D in general.

Registration for our first [Topical Workshop on Detectors and Diagnostics](#) is now open. This challenge-driven workshop will be hosted by CIVIDEC in Vienna between 15<sup>th</sup> - 17<sup>th</sup> October. The registration fee includes 2 nights of accommodation in Vienna, meals and social events. The workshop will focus on the current challenges in monitoring antimatter beams in storage rings, beamlines and experiments and will discuss the state-of-the-art, as well as further R&D needs. It is open to researchers from within and outside of the AVA project.

I am delighted to see that our AVA Fellows already have contributed to first journal articles. Hot of the press, you will find an overview of some selected articles. They have also presented their initial work at international conferences and in the form of posters at the AVA School at CERN. More papers are in preparation - *watch this space!*

Finally, there is further exciting news about our [AVA project video](#). The film was submitted to a competition of science short films (maximum 3 minutes duration) earlier this year. At the end, more than 300 films were submitted. I am absolutely thrilled to announce that our film "*AVA - Nature (anti)matters*" has been the most watched of all of them and now tops the EU's [official playlist](#). Congrats to our Fellows and partner [Carbon Digital!](#)

Enjoy this issue of MIRROR.

Prof. Carsten P. Welsch,  
Coordinator

## AD Detector selected as 2017 Research Highlight

**Superconductor Science and Technology (SUST)** is an international multidisciplinary journal for papers on all aspects of superconductivity. It covers theories of superconductivity, the relation of microstructure and growth to superconducting properties, as well as R&D into the fabrication and properties of thin films and devices.

The journal has just published a collection of some of the best articles in 2017. They were chosen based on a number of criteria, including presentation of outstanding research, popularity with readership and high praise from referees.

A research article by Dr Miguel Fernandes from the [QUASAR Group](#) on “**Non-perturbative measurement of low-intensity charged particle beams**”

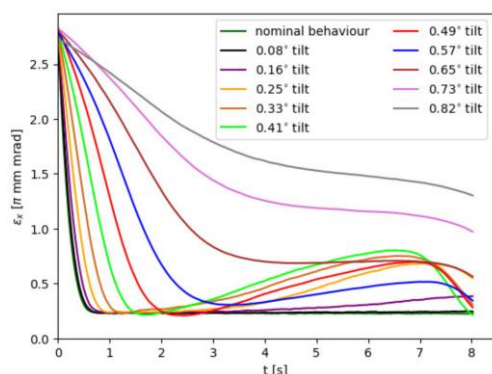
is one of the ones chosen for this special collection. It describes a novel sensor that has been installed and tested at the Antimatter Decelerator at CERN. It can measure the absolute beam intensity of pulsed and continuous beams of antiprotons and ions. This work marks a breakthrough for experiment calibration and obtaining more comprehensive information about low intensity beams.

The paper can be accessed via the following link <http://iopscience.iop.org/journal/0953-2048/page/Highlights-of-2017>, under section “large scale applications”.

**Congratulations to Miguel and all co-authors for this award!**

## Optimization of Electron Cooling in ELENA

**The Extra Low Energy Antiproton storage ring (ELENA) will further decelerate antiprotons extracted from the AD from 5.3 MeV to energies as low as 100 keV.** It will provide high quality beams for the antimatter experiments located within the AD hall.



Horizontal emittance in presence of different tilt angles on the transversal plane.

At such low energies, it is important to correctly evaluate the long term beam stability. To provide a consistent explanation of the different physical phenomena affecting the beam, tracking simulations have been performed and the results obtained by AVA Fellow Bianca Veglia and colleagues from the QUASAR Group have been presented recently at the International Particle Accelerator Conference [IPAC18](#) in Vancouver, Canada.

The paper presents a new approach as to how electron cooling and various scattering effects can be considered for realistic long-term beam dynamics simulation. The paper also discusses the observed effects of several imperfections in the electron cooling process and presents analytical approximations of the temporal variation of emittance under these conditions.

In a next step, collaboration is planned with AVA Fellow Bruno Galante and co-workers at CERN in order to benchmark all analytical and simulation models against experimental data.

Further information:

B. Veglia, et al., “Beam tracking studies of electron cooling in ELENA”, Proc. IPAC18, Vancouver, Canada (2018),

<http://ipac2018.vrws.de/papers/thpaf015.pdf>

## Timepix3 successfully used for antiproton detection

In a paper just published in the *Journal of Instrumentation*, AVA Fellow Mattia Fani and colleagues from the AEgIS collaboration demonstrate a new method using a position-sensitive detector to measure the annihilation point of antihydrogen.



Horizontal emittance in presence of different tilt angles on the transversal plane.

In their study, antiprotons from the Antiproton Decelerator at CERN were used to obtain data on direct annihilations on the surface of a silicon pixel sensor with Timepix3 readout.

The experimental setup was established in the GRACE beamline at the Antiproton Decelerator, where approximately  $3 \times 10^7$  antiprotons with a kinetic energy of 5.3 MeV are delivered from the AD every  $\approx 100$  seconds. The above figure shows the Timepix3 detector mounted in GRACE.

This obtained data was used in a subsequent step to develop and verify a detector response model for annihilation of antiprotons in this detector. Using this model and available antiproton data it is shown that a tagging efficiency of  $50 \pm 10\%$  and a vertical position resolution of  $22 \pm 0.5 \mu\text{m}$  can be obtained.

The AEgIS experiment at CERN aims at measuring the gravitational fall of antihydrogen in order to determine the gravitational force on antimatter. The collaboration expects to measure a vertical fall of  $\approx 20 \mu\text{m}$  over a length of 1 m, as the antihydrogen beam has a velocity of less than 500 m/s. The position resolution now demonstrated in their studies is low enough for such a fall to be observed.

### Further information

S. Aghion, et al., "Antiproton tagging and vertex fitting in a Timepix3 detector", JINST 13 P06004 (2018),

<https://doi.org/10.1088/1748-0221/13/06/P06004>

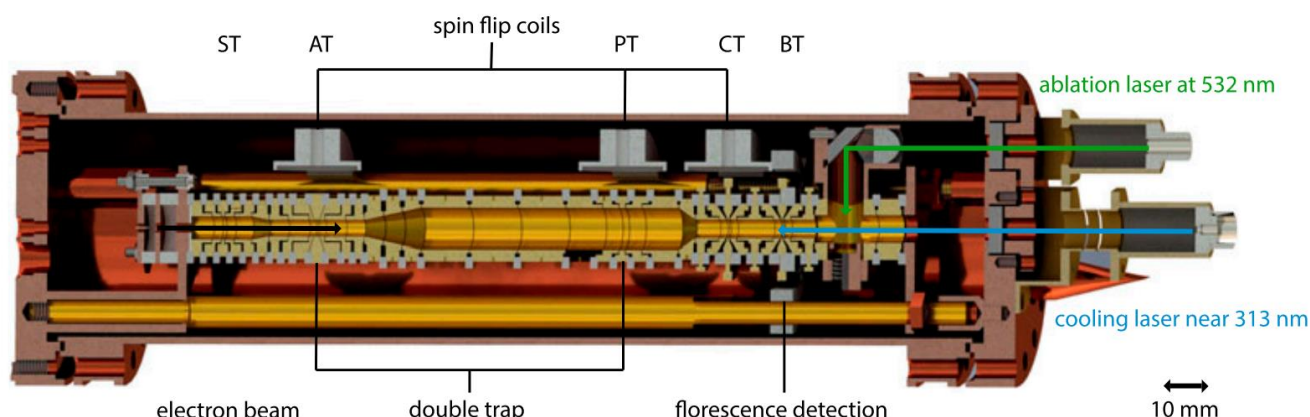
## On the way to making antiprotons 'cooler'

**Antimatter experiments are ideally suited to compare the basic properties of matter/antimatter counterparts with high precision.** They hence allow stringent tests of charge-parity-time (CPT) invariance.

As the fundamental symmetry of the Standard Model, any measured CPT-violation would provide a clear indication of new physics and is in the focus of experimental collaboration around the world.

The BASE collaboration, which includes AVA Fellow Markus Wiesinger, has already performed proton and antiproton magnetic moment measurements with fractional uncertainties on the parts per billion (10) and parts per million level (11), respectively.

These experiments were limited by the energy in the harmonic modes of the particle in the trap and



The new apparatus for an improved proton g-factor measurement. The five traps are labelled from right to left, as the source trap (ST), analysis trap (AT), precision trap (PT), coupling trap (CT), and beryllium trap (BT).

would benefit from experimental techniques that provide a fast and deterministic way to reduce the energy of the particle to  $E/kB < 100$  mK.

A new experiment to sympathetically cool protons and antiprotons by resonantly coupling the axial motion of the particles to that of laser-cooled beryllium ions with a common endcap technique was now described in an article published in *Journal of Modern Optics*.

The article summarizes the proposed experiment and highlights that the preparation of (anti)protons at mK temperatures on timescales of tens of seconds seems feasible.

If this technique can be successfully implemented, it will have significant impact on high-precision studies into the fundamental properties of protons and antiprotons. This in turn will then provide new and fascinating opportunities for tests of the fundamental symmetries of the Standard Model.

#### Further information:

M. Bohman, et al., "Sympathetic cooling of protons and antiprotons with a common endcap Penning trap", *J Modern Optics* 65, 5–6, p. 568–576 (2018), <https://doi.org/10.1080/09500340.2017.1404656>



## Network News

### Antimatter School held at CERN



**AVA has held a week-long School on Antimatter Physics at CERN between 25<sup>th</sup> – 29<sup>th</sup> June 2018.** The training event was open to all AVA Fellows, as well as to external participants and focused on low energy antimatter physics. The School brought together more than 60 participants and covered all research areas within AVA. It saw research leaders from the various AD experiments give lectures about all important aspects of antimatter R&D.



Lectures covered the fundamentals of accelerator design and operation, invasive and non-invasive diagnostic techniques, spectroscopy

measurements, antimatter gravity studies, as well as electron cooling.



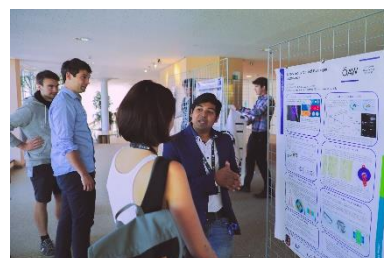
Lectures on ion traps and associated theories, as well as special industry talks were also part of the interesting and intense programme. Special highlights were a seminar talk about the proton-driven wakefield experiment AWAKE, as well as a public talk on antimatter physics by Professor Hubert Reeves, a well-known science communicator. The latter was offered on the Tuesday evening to the general public in CERN's globe of science and innovation. This event was fully booked shortly after registration opened and considered a great success.

A tour of the AD facility and the experiments gave all participants an excellent opportunity to visit the world's only low energy antimatter physics facility and engage in interesting discussions.

The School was considered a great success by the participants. The external participants ensured knowledge exchange with a wider community and the week was found to be ideal for establishing

links to other researchers working on similar topics. All lectures are now available via the School indico page: <https://indico.cern.ch/event/677170>

**A huge THANK YOU to our fantastic speakers and special thanks to Maxine, Javier and Michael for their help in the organisation!**



Images Indrajeet Prasad

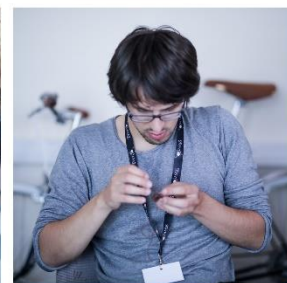
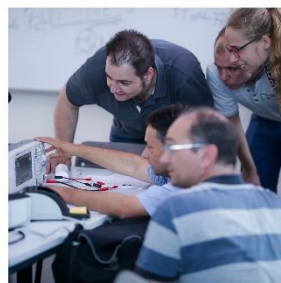
## AVA Fellows get their hands 'dirty'

**Around half of the members of the AVA network are from industry.** The network has developed its research and training program involving all consortium members with important input from industry to enhance the employability of Fellows. Several industry partners have kindly agreed to contribute to offer specific training events. Two of these have now been offered as satellite events to the network's first international School.

Bergoz instrumentation offered a full day of hands-on training in beam diagnostics at their premises in Saint Genis, France on Monday, 1<sup>st</sup> July 2018. Our Fellows learned about the design of robust electronics that can be operated in an (often harsh) accelerator environment. They soldered a PCB of a WiFi receiver and assessed its performance. This allowed them to learn about the challenges related to beam intensity measurements and electronics integration in accelerators.

They then spent another full day learning about the specific challenges related to cryogenic detector design, electronics and signal processing. This was

offered by experts from Stahl Electronics on Tuesday, 2<sup>nd</sup> July 2018 and helped raise awareness of the particular challenges coming from the integration of high-sensitivity diagnostics in adverse environments.



Images Indrajeet Prasad

## Course set for exciting times in AVA Network

**The Steering Committee of the AVA Network met on Thursday 28<sup>th</sup> June 2018 at CERN to critically review overall project progress.** On the basis of reports received from Fellows and partner organizations, the group noted that the submission deadlines for all project deliverables were met and that the network was well on track. All Fellows except the one based at COSYLAB had now been recruited and were well-integrated in their R&D projects and host institutions.

The Steering Committee also found that even more training than originally envisaged in the Career Development Plans had been provided since project start and noted the excellent atmosphere between the Fellows.

In terms of events, the initial skills trainings in Liverpool and Manchester were found to be efficient in providing highly relevant skills. The international

school held at CERN was well attended and the outreach lecture a great success. In holding the upcoming workshop at CIVIDEC earlier than originally foreseen, the project was now even ahead of its ambitious schedule.

A meeting of the Supervisory Board, comprising representatives from all beneficiary and associate partners, followed on Friday 29<sup>th</sup> June 2018. This allowed all Fellows to introduce themselves to this project governing board, as well as present their background and research progress to date. The AVA Coordinator then gave an overview of progress made based on the Steering Committee meeting results from the day before. The administrative meetings were an ideal opportunity to answer a range of questions from Fellows and supervisors and jointly plan upcoming trainings and events.

## AVA brochure now published

**The brand-new brochure for the AVA project has just been published and is available to download.**

It gives a broad overview of the AVA project R&D programme, describing each work package and the AVA Fellow's projects. It also describes the Fellow's training, outreach activities and the project partners.

The [AVA brochure](#) was produced in collaboration with our network partners and was launched at the industrial exhibition of IPAC'18 in Vancouver, where it had a warm reception from the accelerator community.





## AVA Film tops EU's playlist!



A video competition of EU-funded research projects has just ended and the AVA project entry "[AVA – Nature \(anti\)matters](#)" was the most viewed of over three hundred entries.

All of the AVA Fellows attended a bespoke Media Training event hosted by award winning AVA project partners [Carbon Digital](#) at the UK's premier media hub, MediaCityUK.

They all played an active part in scripting, filming and producing the film and their efforts have not gone unnoticed - their video is currently the #1 most watched video on the EU's [official playlist](#)!

## Meet our AVA Fellows (cont.)

Below we present the Fellows that have recently started work in their host institutions.

Welcome to AVA!



**Amit Nanda** obtained his Master's Degree in Physics from the National Institute of Science Education and Research, India. His thesis focused on the measurement of  $\phi$  meson production at the ALICE detector at CERN. He has worked on the quality control and quality assurance of the MICROMEGAS readout boards for the ATLAS New Small Wheel and the design for an automated tool to measure electrical properties of the readout anode boards. Amit has published research in optimizing the gas flow rate, characterizing and performing the long term stability tests of a triple-GEM detector prototype for ALICE. He has also worked on dissipative coefficients of hadronic matter.

Amit Nanda is based at the Stefan Meyer Institute and studies a *Ramsey Technique to Measure Ground-state Hyperfine Structure of Antihydrogen*.





**Milena Vujanovic** received her Bachelor's Degree in Physics from the Faculty of Natural Sciences and Mathematics at the University of Montenegro. After spending three months as a CERN summer student with the Radiation Protection group, she enrolled at the University of Belgrade, Department of Theoretical and Experimental Physics. Milena was part of the AEGLS experiment at CERN for 15 months where she gained expertise in positronium physics, magnetic and electrostatic positron transport, ultra-high vacuums, cryogenic operations, screening of magnetic fields and gamma radiation.

Milena Vujanovic is based at the University of Liverpool / Cockcroft Institute and develops an *Advanced Optical Beam Halo and Emittance Monitor*.



**Jeffrey Klimes** earned his Bachelor's Degree from Purdue University in Physics and Nuclear Engineering. He then went to the University of Chicago where he earned his Master's Degree from the Physical Sciences Division in 2016 in collaboration with the Beta Paul Trap experiment at Argonne National Laboratory. He continued to work at Argonne as a Research Associate for the University of Notre Dame, building a beam line source used for precision mass measurements at the Canadian Penning Trap.

Jeffrey Klimes is based at GSI and registered for a PhD on a *Reservoir Trap for Penning Trap Experiments at the University of Heidelberg*.



## Upcoming Events

### 7th International Beam Instrumentation Conference, September 2018



**The 7th International Beam Instrumentation Conference (IBIC 2018) will be held in Shanghai, China, between September 9<sup>th</sup> and 13<sup>th</sup> 2018.**

Like its predecessors, this conference is also dedicated to exploring 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. During the conference, a tour to the Shanghai Synchrotron Radiation Facility (SSRF) and the Shanghai X-Ray Free-Electron Laser (SXFEL) Facility will also be included.

More details are available at:

<https://indico.sinap.ac.cn/event/3/>

## AVA Topical Workshop: Detectors & Diagnostics, October 2018

**We are delighted to announce a three-day Topical Workshop on diagnostics and detectors in storage rings, beam lines and experiments.**

The event will be hosted by AVA partner CIVIDEC in Vienna, 15<sup>th</sup> - 17<sup>th</sup> October 2018. It will cover the challenges in the design and operation of advanced detectors and beam instrumentation to optimize the performance of the AD and ELENA, as well as experimental output.

This research challenges-focused event will combined talks by research leaders, opportunities for early stage researchers to present their work, and panel discussions.

Further information and how to register can be found here

<https://indico.cern.ch/event/726019/>



## DISCRETE 2018, November 2018



**This is the Sixth Symposium on Prospects in the Physics of Discrete Symmetries.** DISCRETE 2018, will take place this year in Vienna at the Austrian Academy of Sciences from 26<sup>th</sup> to the 30<sup>th</sup> November 2018. It is organized by the Stefan-Meyer-Institute for Subatomic Physics of the Austrian Academy of Sciences.

The topics covered at the DISCRETE series of conferences are: T, C, P, CP symmetries; accidental symmetries (B, L conservation); CPT

symmetry, decoherence and entangled states, Lorentz symmetry breaking (phenomenology and current bounds); neutrino mass and mixing; implications for cosmology and astroparticle physics, dark matter searches; experimental prospects at LHC, new facilities; cosmological aspects of non-commutative space-times; PT symmetric Hamiltonians.

Further information can be found here:

<https://www.discrete2018.at/>

## Position Vacancies

**Early Stage Researcher Fellowship** within the AVA project at Cosylab d.d. '*Development of a versatile control system*' More information can be found here: <https://www.liverpool.ac.uk/ava/projects/cosylab/>

**Fully funded PhD position** on *Dielectric laser acceleration of relativistic beams* in the QUASAR Group. To find out more about the project and how to apply, please visit: <https://www.findaphd.com/search/ProjectDetails.aspx?PJID=94069>

## News from FAIR

**GSI Helmholtzzentrum für Schwerionenforschung** has made several short videos available via YouTube that outline the research goals of FAIR and highlight progress in the construction of the facility. Enjoy!

[Drone video: FAIR construction site in June](#)

[FAIR – The University in the Laboratory](#)



## Events

9 <sup>th</sup> – 13 <sup>th</sup> September 2018	7th International Beam Instrumentation Conference, Shanghai, China
15 <sup>th</sup> – 17 <sup>th</sup> October 2018	Topical Workshop: Detectors & Diagnostics, CIVIDEC, Vienna, Austria
26 <sup>th</sup> - 30 <sup>th</sup> November 2018	DISCRETE18, Vienna Austria
11 <sup>th</sup> – 12 <sup>th</sup> December 2018	3rd OMA Topical Workshop - Accelerator Design and Diagnostics, GSI, Germany

## Notice Board

There is now only one available Fellowship left within AVA. Please encourage suitable candidates to apply.

This newsletter will be published on a quarterly basis. Help us keep it interesting by providing news & updates.

**DEADLINE FOR THE NEXT NEWSLETTER CONTRIBUTIONS: 15<sup>th</sup> September 2018**



[www.ava-project.eu](http://www.ava-project.eu)

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