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JYFL Accelerator News

– Accelerator Laboratory, Department of Physics University of Jyväskylä, Finland –

Researcher for a day

The winners of Kiihdytin hiukkasen -competition from the Kimpisen campus, Lappeenranta, together with their tutor Mikko Laitinen analysing particle induced x-ray emission spectrum from a soil sample at Pelletron.

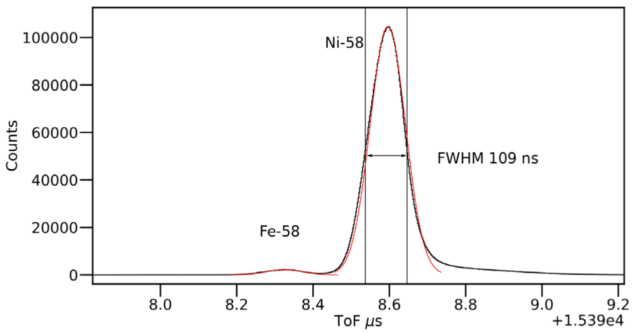
Last year the [Kiihdytin hiukkasen -competition] invited high-school students to apply for beam time at JYFL-ACCLAB. In March 2020, five groups together with their teachers and tutors from JYFL performed experiments employing instruments of the main research groups. The work conducted and reports prepared were evaluated by a jury who paid attention to the enthusiasm, scientific thinking, initiative and science communication skills of the groups.

"We wanted not only to provide a unique opportunity and experience for potential future physicists to exploit state-of-the-art instruments in the accelerator facility, but also to demonstrate scientific practices and researchers' work in general", declares Janne Pakarinen who coordinated the competition.

Unanimously, the jury selected Kimpisen campus as the winner. They had collected several different samples of soil with the aim of determining their elemental abundances at the Pelletron. The winning work produced an article that was published in Tekniikka ja talous –magazine. A Honorary mention was given to a group from the Helsinki Upper Secondary School of Languages, who explored half-lives of isotopes at the IGISOL mass separator.

NEWS

First isobaric mass separation with the JYFL multi-reflection time-of-flight mass separator at IGISOL



A time-of-flight spectrum demonstrating the mass separation of Fe-58 and Ni-58 by their time-of-flight. The RF cooler buncher and MR-ToF settings used resulted in a temporal width of 109 ns, yielding a mass resolving power of about 70,000.

The commissioning of the MR-ToF-MS at the IGISOL facility has moved a step closer to the application of the device for on-line experiments. In the recent milestone, stable Ni-58 and Fe-58 isotopes produced in a spark discharge source were mass separated by the time-of-flight method with a mass resolving power M/ΔM of 70,000. Such resolving power is already sufficient for separating or measuring masses of most exotic isotopes. The next phase in the commissioning is to transfer the ions to the downstream Penning traps.

**[Next Call for Proposals
Deadline: September 15, 2020]**

RADMEP - Erasmus Mundus Joint Master Degree programme

An Erasmus Mundus Joint Master Degree (EMJMD) programme, *RADiation and its effects on MicroElectronics and Photonics technologies* (RADMEP), was accepted for 5-year funding by the European Commission in July 2020. https://eacea.ec.europa.eu/erasmus-plus/emjmd-catalogue_en

RADMEP will provide 2-year (120 ECTS) Erasmus Mundus Joint Master Degrees in a multidisciplinary and innovative programme covering the interactions between Radiation and MicroElectronics and Photonics, two Key Enabling Technologies for the future of Europe. The objective for RADMEP is to educate students in those advanced technologies, providing methodologies and introducing practical applications for their implementation in various natural or man-made radiation-rich environments. RADMEP has two goals: first to improve career prospects for students and second to respond to the needs of the industry, agencies and society. Thanks to this EMJMD, students will develop useful professional and soft skills in the rich European cultural context. RADMEP is one of the outcomes of the RADSAGA project (https://radsaga.web.cern.ch/) during which the needs for such integrated, international study programmes have been identified by the partners.

The field of radiation effects on components and systems is historically linked to space and nuclear power plants. With technological integration, components and systems have become sensitive to the natural atmospheric environment. In the 1990s, the effect of atmospheric neutrons started to be considered in the development of aircraft electronics. The integration of electronic and photonic technologies continues to evolve, today it is the electronic systems at ground level that are sensitive to natural radiation. Digital data storage has been an issue for some years now, and it is necessary to bury computers and data centers underground in order to protect them. In the context of the energy transition, where we are developing more electric aircraft, electric and autonomous mode of transportation, it is necessary to take this new constraint into account to ensure the reliability of the systems. The dismantling of nuclear power plants will require radiation-resistant optoelectronic and electronic systems, first to observe what needs to be dismantled and then to have the tools to dismantle the sites. Space is undergoing a revolution with New Space, which consists in using commercial components to make satellites more intelligent and give them unequalled observation and analysis capacities, but which requires the reliability of these technologies, which were not originally intended for space. It will no longer be possible to develop an electronic or photonic system for which the safety of people is essential without recourse to the radiation analysis, of which the students trained by the RADMEP Master's degree will be capable.

Thanks to RADMEP, students will obtain fundamental knowledge and experience in those two technologies, their behavior under radiation. During the 2-year Master studies within the programme (intakes annually in falls of 2021-24), the first semester will take place at *Jyväskylän yliopisto (JYU, Finland)* and the second semester at *Katholieke Universiteit Leuven (KUL, Belgium)*. For the third semester, a choice between two different specializations will be offered to the RADMEP students. One, taking place at *Université Jean Monnet Saint-Etienne (UJM, France)* will focus its programme on Radiation Effects on Photonics technologies while the other one will focus on Radiation Effects on Microelectronics and Advanced Electronic Technologies and will take place at *Université de Montpellier (UM, France)*. RADMEP students will undertake a 6-months master thesis either in an industrial, an agency or in a research center, for example from the large RADMEP network of more than 35 associate partners.

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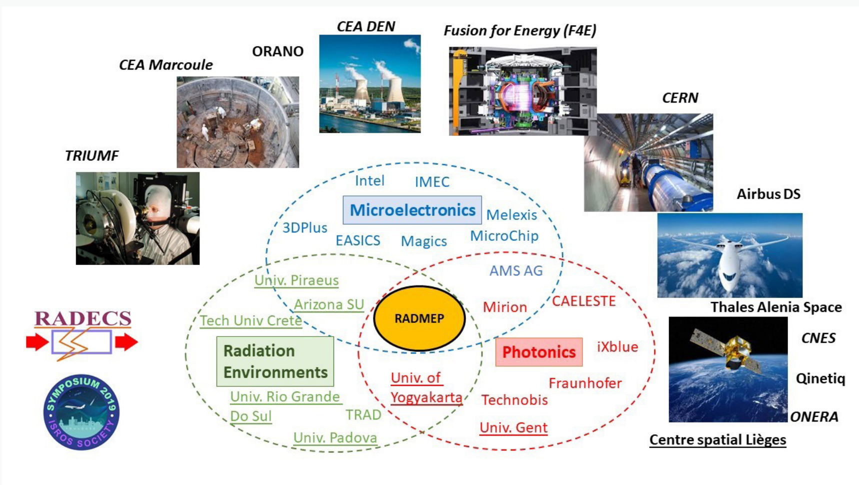
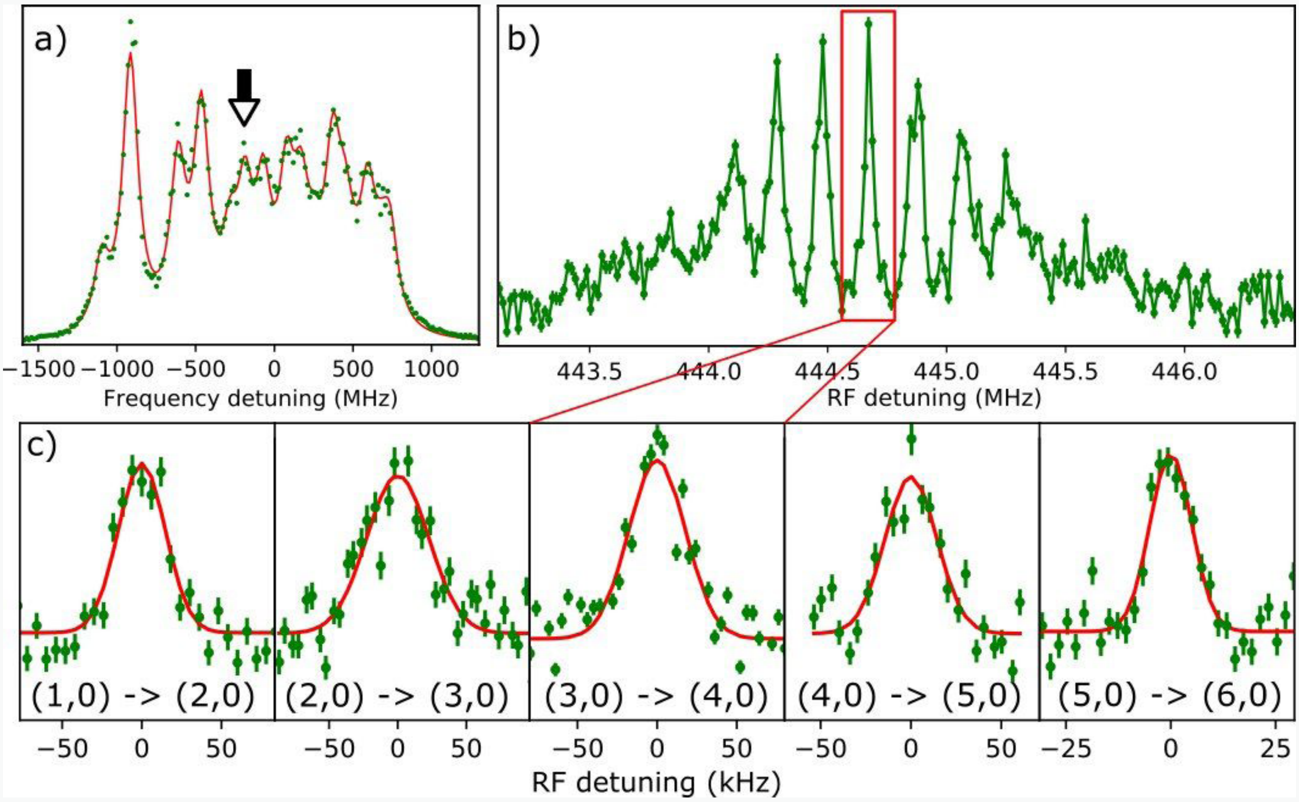
RADMEP Consortium



High-precision laser-RF double resonance spectroscopy



Overview of experimental results. The top-left panel shows a laser scan of the first step of the three-step RIS scheme. The top-right plot shows an RF scan of one of the transitions within the ground-state hyperfine manifold. Different lines can be seen due to the Zeeman splitting. The bottom plots show one of these Zeeman components for all five transitions within the ground-state hyperfine manifold, with (F, m_F) values indicated. More details can be found in [1].

A new program is now underway at the IGISOL facility, to develop and exploit higher precision atomic techniques for the study of exotic nuclei. In a first proof-of-principle of such a measurement, we extracted the magnetic octupole moment, Ω, of ^{45}Sc [1]. Current methods of optical spectroscopy at radioactive ion beam facilities generally provide measurements of hyperfine frequency splittings with a precision of ~1 MHz, with the exception of some specialized methods. This limitation in precision restricts the exploration of higher-order nuclear moments. In a push to address this limitation, we have recently demonstrated the feasibility of combining the efficiency of resonance ionization spectroscopy (RIS) with the precision of radiofrequency (RF) spectroscopy, the latter promising a dramatic improvement in precision of measurements of exotic nuclei by three orders of magnitude.

The magnetic octupole moment can be extracted from the third-order term in the hyperfine multipole expansion, provided accurate atomic theory calculations of the required atomic matrix elements are performed. The required state-of-the-art atomic calculations were provided by our collaborators.

Scandium was chosen out of a nuclear structural interest, as it has one proton outside of the magic Ca (Z=20) closed proton shell. The sensitivity of the atomic structure of Sc to its octupole moment was however found to be rather small. Nevertheless, Ω could be extracted. Detailed comparisons to nuclear shell-model and density functional theory (DFT) calculations were also performed. The goal here was twofold; to explore possible explanations for the somewhat large value of Ω that was obtained experimentally, and secondly, for the first time to evaluate the use of DFT to investigate magnetic octupole moments. Since DFT provides a global description of isotopes throughout the nuclear chart, such developments will be valuable once measurements on radioactive systems become possible.

[1] R. P. de Groote et al., arXiv preprint arXiv:2005.00414, (2020).

NEWS

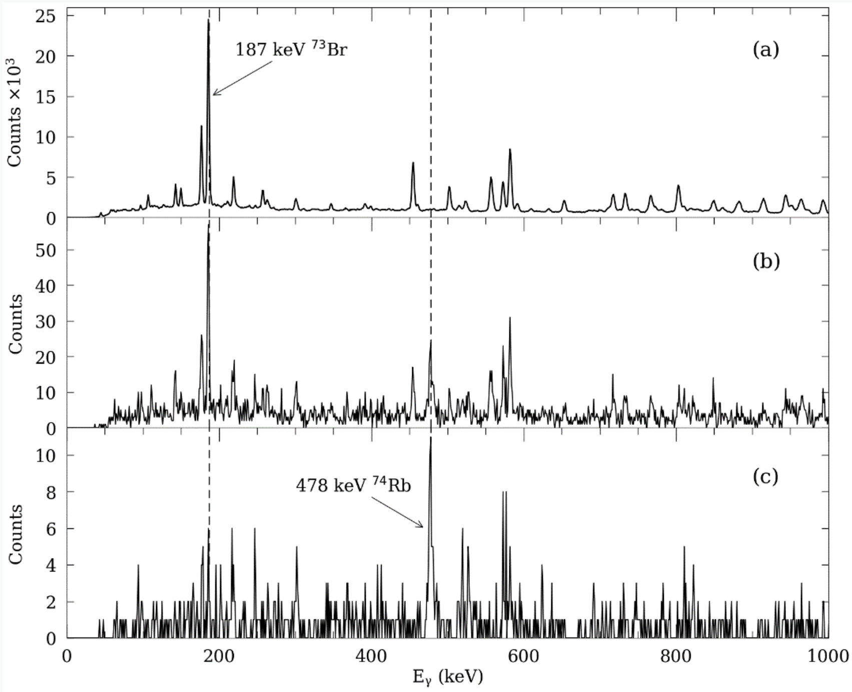
RADEF subcontracting in ESA projects

RADEF group has signed two subcontracts for 2-year ESA projects. One project is with RUAG Space Finland (located in Tampere) "*Radiation Characterisation of EEE Components*" that will involve heavy-ion testing to be performed at RADEF. This project will strengthen the national collaboration base for RADEF. The other project is with ALTER Technology (formerly Hirex Engineering), France. This project is "*Estimation of proton induced Single Event Effect rates in very deep submicron technologies*" which involves Monte Carlo simulations, numerical modeling as well as experimental proton and heavy-ion testing at RADEF.

New position-sensitive beta detector for MARA focal plane

A new position-sensitive beta detector for the focal plane of the MARA recoil separator has been built and tested. The new detector was designed to efficiently detect beta particles at the focal plane for better separation of events relating to the nuclei of interest, usually those residing near the N=Z line. The detector is an array of plastic scintillator bars with the light collected by silicon photomultipliers, making it compact: the volume taken by the scintillators is only 14 x 8 x 3 cm, and neither the SiPMs, surrounding frame nor cables take much more room. Initial tests on its performance have proven that it has a sufficient energy resolution to separate high-energy betas and good position sensitivity. The beta detector has already been used in two recoil-beta tagging experiments. It can be seen in the figure how the detector enhances the selectivity of ^{74}Rb beta decay. The detector was the subject of a Master's thesis by Henna Joukainen, who recently started doctoral studies in the Nuclear Spectroscopy group relating to this topic.

Detector in its place in the vacuum chamber. The active area dimensions are 14 x 8 cm.



Spectra from a beta tagging test using reaction ^{40}Ca(^{36}Ar, pn)^{74}Rb with MARA from June 2020. The spectra were made requiring (a) a recoil gate, (b) recoil gate and a fast beta decay in DSSD and (c), recoil gate, a fast beta decay in DSSD and a high-energy beta in the new beta detector.

NEWS

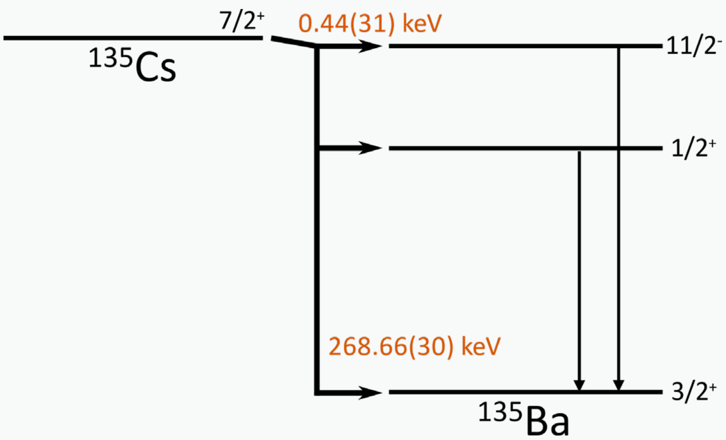
Retirement of Radiation Safety Officer Jaana Kumpulainen

Chief Engineer Jaana Kumpulainen retired at the end of August 2020, after serving as the Radiation Safety Officer since the beginning of 2007. Jaana started her physics studies at the University of Jyväskylä in September 1975 and defended her PhD Thesis "New features in systematics of low-spin states in even $^{106-120}$Cd" in 1990. Before starting as the Radiation Safety Officer at JYFL, she worked for MAP Medical Technologies where she was in charge of radioisotope production. The irradiation was done at the JYFL Accelerator Laboratory, the radioisotopes being ^{82}Rb/^{82}Sr in the beginning and ^{123}I, later. Being a nuclear physicist and having experience in radioisotopes, Jaana was a highly appreciated expert in radiation safety and hence she had several duties regarding radiation safety such as education and preparation of the recently adopted new Radiation Act.

After Jaana's retirement, Sami Rinta-Antila is our new Radiation Safety Officer. His contact information is written on the last page of this Newsletter (How to contact us).

Jaana Kumpulainen checking residual activity in a radiation therapy e-accelerator.

Caesium-135 found to be a good candidate for antineutrino mass measurements



The decay from the 7/2+ ground state of caesium-135 to the 11/2- state in barium which was found to have an ultra-low decay energy of 0.44(31) keV.

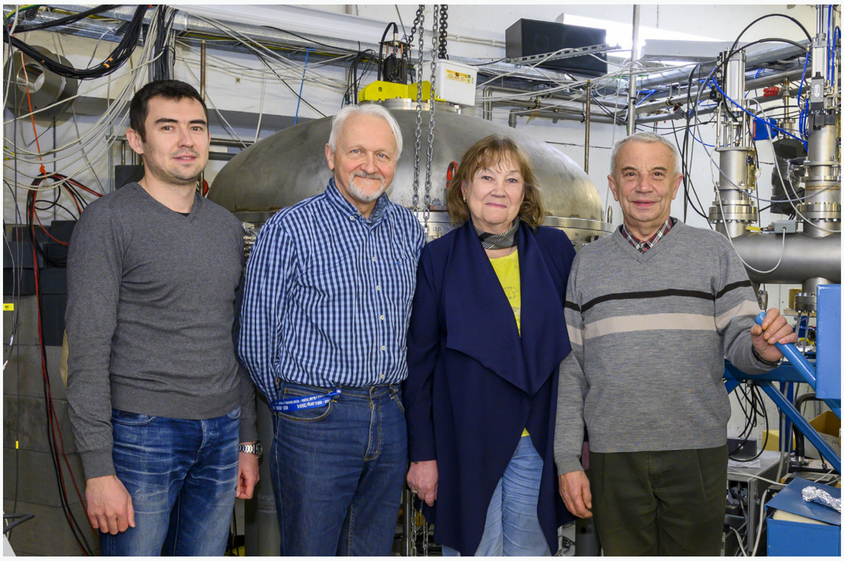
A direct decay energy measurement was performed with the JYFLTRAP Penning trap mass spectrometer at the IGISOL facility by obtaining a precise mass difference of caesium-135 and its decay-daughter barium-135. The new value, being ultra-low and approximately three times more precise than previous measurements, was used by the local nuclear theory group to deduce the partial half-life of the decay using state-of-the-art nuclear theory. Both of these findings, the ultra-low decay energy and the estimated partial half-life, support caesium-135 as a potential candidate for determining the mass of an antineutrino. The results were recently published in Physical Review Letters.

Physical Review Letters (June 2020): https://doi.org/10.1103/PhysRevLett.124.222503

preprint: https://arxiv.org/abs/2002.08282

NEWS

Possible Proton Halo in the 1^- State of ^{14}N



From the left: A. Danilow, W.H. Trzaska, A. Demyanova, and S. Khlebnikov

The Discovery at the end of the last century of a neutron halo in the ground states of some light nuclei near the neutron drip line led to a revision of many paradigms in nuclear physics. Our team is extending the search for halos into the Isobar Analog States (IAS) of light nuclei by looking for manifestations of isotopic invariance relating the properties of the neutron and proton halo. This method, based on measuring radii of the known and suspected halo states, allowed us, for instance, to detect a proton halo in an unbound state of ^{13}N [1].

To investigate IAS of A = 12 nuclei, we have measured the $^{11}B(^3He,d)^{12}C$ and the $^{11}B(d,p)^{12}B$ reaction. The RMS radii of the states with isospin T = 1 in ^{12}B, ^{12}C, and ^{12}N were determined using the Asymptotic Normalization Coefficients (ANC) and the Modified Diffraction Method (MDM). By comparing the results of these methods, we have arrived at the conclusion that the 1^- excited states in these nuclei, at E_x = 2.62, 17.23, and 1.80 MeV, respectively, have a one-nucleon (neutron or proton) halo structure. The enlarged radii and the large values of the D_1 coefficient are also found for the 2^- states of ^{12}B, ^{12}C, and ^{12}N at E_x = 1.67, 16.57 and 1.19 MeV, respectively. Consequently, these IAS are also possible candidates for one-nucleon (neutron or proton) halo states.

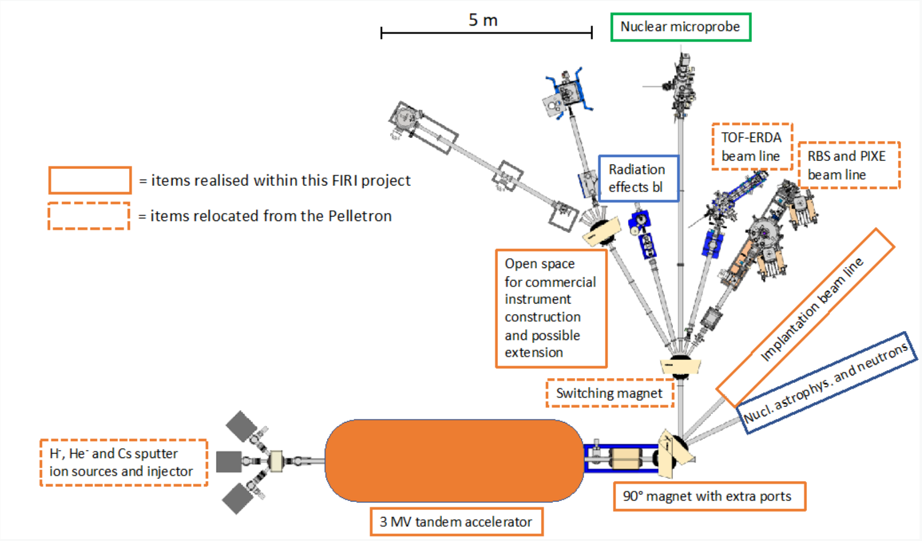
Recently we have studied IAS with isospin T = 1 in the A = 14 triplet: ^{14}C, ^{14}N, and ^{14}O. The first signs of neutron halo in the 1^- (6.09 MeV) state of ^{14}C have been revealed earlier by two independent groups. We have now made the third, independent confirmation of this result. In addition, we have studied IAS, with spin parity 1^-, of the neighboring ^{14}N and ^{14}O nuclei. The differential cross sections of the $^{14}C(\alpha,\alpha)^{14}C^*$ (6.09 MeV, 1^-) inelastic scattering, the $^{13}C(^3He,d)^{14}N^*$ (8.06 MeV, 1^-), and the $^{14}N(^3He,t)^{14}O^*$ (5.17 MeV, 1^-) reactions were analyzed by the MDM and ANC. The RMS radii for all three mirror nuclei in the studied 1^- states are found to be nearly identical. This is the first indication of a possible proton halo in the 1^- state of ^{14}N.

A.S. Demyanova, et al. (2016). JETP Letters, 104 (8), 526-530.

Looking beyond COVID-19

As discussed in the last issue of Accelerator News, over the winter the laboratory had its first extended shutdown in close to 30 years, with experiments scheduled to start again in March. However, on the 14th March, the effects of the coronavirus epidemic were finally felt in Jyväskylä and the whole Ylistö Campus where the laboratory is sited was moved to remote working. Lockdown conditions and restrictions on travelling meant that all scheduled experiments had to be cancelled and only a skeleton crew of technical staff were allowed on site. Over the summer, restrictions were slowly lifted and it became possible to start running experiments and performing irradiations for commercial customers once again. Technically, the facility is working very well and a number of experiments have been performed successfully. The resurgence of the pandemic in Europe has once again introduced travel restrictions and the majority of scheduled experiments are those led by local spokespersons with very few foreign visitors.

Looking to the future, the senior staff of JYFL-ACCLAB have been very busy over the Spring and Summer preparing various important applications for the laboratory. From 2014-2020 JYFL-ACCLAB has been one of the Research Infrastructures listed on the Finnish Research Infrastructure Roadmap. The Roadmap is currently being updated and JYFL-ACCLAB submitted a new application outlining the status and future development plans of the laboratory. One major planned upgrade is to replace the 35-year old 1.7MV Pelletron accelerator with a modern, high current, high stability 3MV accelerator to meet future demands and enable close collaboration with industry and local, national and international research groups. High-energy ion implantation will allow the expertise of the Finnish semiconductor industry to expand into new markets and will improve their competitiveness. High current proton beams and neutron converters will expand the irradiation capabilities, benefitting biomedical research, nuclear astrophysics and radiation effects testing. In the future, the new accelerator platform will also enable the use of ion-beam techniques with sub-µm lateral resolution by a employing a nuclear microprobe. Just before the summer, news came from the Academy of Finland that as a result of the government's stimulus package, an additional call for infrastructure funding was being launched. An application has been submitted to the Academy in order to secure funding for the new accelerator, which will be housed in a dedicated extension to the Accelerator Hall. The planned layout of the new facility is shown below.



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