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Status Report to the ISOLDE and Neutron Time-of-Flight Committee

Isolde Decay Station - IDS

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G. Benzoni [1], U. Datta Pramanik [2], H. De Witte [3], L. Fraile [4], H. Fynbo [5], P. Greenlees [6], J.Konki [6], J. Kurcewicz [7], I. Lazarus [8], R. Lica [7], M. Madurga [7], A. Negret [9], Z. Podolyak [10], E. Rapisarda [7], C. Sotty [3], O. Tengblad [11], P. Van Duppen [3], V. Vedia [4], N. Warr [12], for the IS476, IS545, IS577, IS579, IS588, IS590 collaborations and the IDS collaboration.

[1] INFN sezione di Milano, Milano, Italy
[2] Saha Institute of Nuclear Physics, Kolkata, India
[3] IKS – KU Leuven, Leuven, Belgium
[4] Universidad Complutense, Madrid, Spain
[5] Århus University, Aarhus, Denmark
[6] University of Jyväskylä, Jyväskylä, Finland
[7] CERN, Geneva, Switzerland
[8] STFC, Daresbury, UK
[9] IFIN-HH, Bucharest, Romania
[10] University of Surrey, Guildford, UK
[11] CSIC, Madrid, Spain
[12] Universität zu Köln, Cologne, Germany

Abstract

The Isolde Decay Station - IDS project aims at providing a permanent, yet flexible, experimental set-up for decay studies using the radioactive ion beams from ISOLDE. The basic approach of IDS is the combination of a High Purity Ge-detector array (consisting of 4 Clover detectors and up to 3 Miniball type germanium detectors) and ancillary detectors ($LaBr_3$, neutron detectors, silicon and plastic scintillator detectors) surrounding a tape station or windmill-type implantation chamber (or any other compatible implantation chamber). It includes also the electronic read-out system, the data acquisition system (DAQ) and the ancillary equipment (like beam diagnostics, LN_2 automatic filling system, flexible support structure). A variety of physics experiments has been conducted during its first on-line period using the IDS phase I configuration.

1. Motivation, experimental setup/technique

The IDS set-up is conceived as a flexible experimental set-up for a large variety of decay studies using the Isolde low-energy beams.

A picture of the IDS set-up in its phase I configuration is shown in Fig. 1. It shows the tape station, surrounded by the Clover HPGe detectors, two of which equipped with a thin carbon epoxy window to allow the measurement of low-lying X and γ rays. These detectors represent the core of the IDS set-up. During the different experiments in 2014, different ancillary detectors were added, as described in Sect. 3.

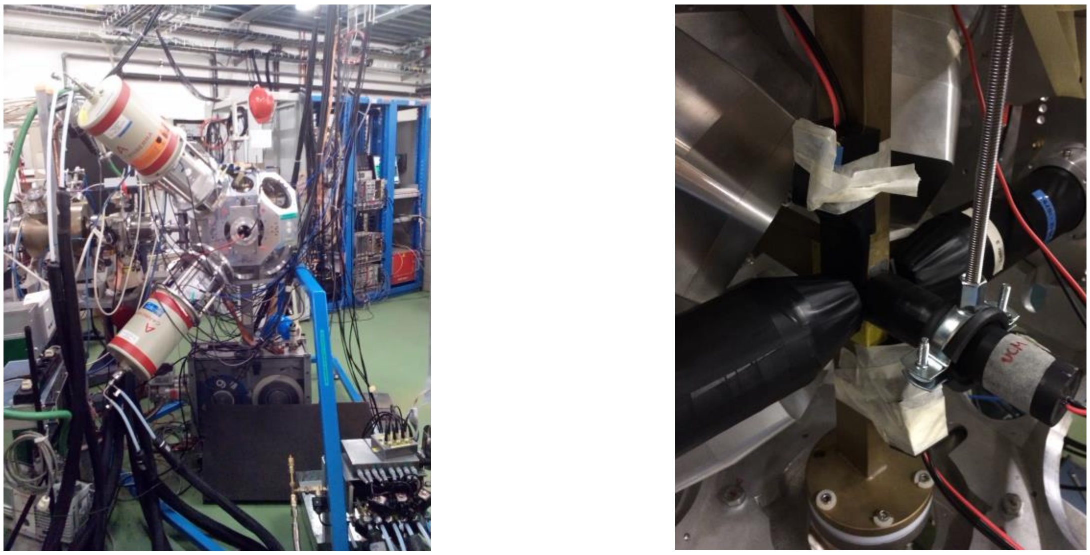

Figure 1: Left: Picture of the IDS set-up showing the tape station, surrounded by the Clover HPGe detectors. Right: Close view of the fast-timing ancillary detector set-up.

Data from the different detectors are collected with the MIDAS data acquisition system [1], using NUTAQ (formerly Lyrtech) VHS-ADC digitizers. This system is supported by the Liverpool-Daresbury and the JYFL-Jvaskyla groups. While in close consultation with the Miniball collaboration, discussions are ongoing to acquire a new DAQ system, no major changes to the DAQ are foreseen in 2015. Charged particle (and possibly, in 2015, neutron) experiments still need their own DAQ, due to the large number of channels.

The decay station is permanently stationed on the RC4 beam line. The transmission to the IDS tape station Faraday cup (5mm diameter, right in front of the tape) varied between 65 and 80% (relative to GPS.FC5580) for the different experiments.

2. Status of the setup (including plans for 2015)

2.1 Background conditions

Different background measurements have been performed at the end of the RC4 beam line where the IDS setup is positioned. The aim of the measurements was to investigate the natural and implanted backgrounds.

Concerning the natural background, the 1461-keV line from the ^{40}K decay is well observed and is the most intense (few gamma/s). Other decay lines (in keV) are observed, the most intense ones being from the following nuclei: ^{214}Bi(Ra): 609, 1120, 1238,1729, 2204; ^{214}Pb(Ra): 352; ^{208}Tl(Th): 511, 861, 1592, 2103, 2614; ^{228}Ac(Th): 911, 969, 1588; Annihilation: 511.

The presence of the 511-keV line is fluctuating. Its origin is not certain but the detection of 511-keV lines have long time correlations with the proton impacts. Moreover, its intensity varied quite drastically when changing the proton beam settings (from ~ 1000 counts/min to ~10000 counts/min). We expect that it is due to activation in the primary target area.

It should be noticed that during the 2014 and the first part of the 2015 campaign, the HIE-ISOLDE LINAC is still not operational. The accelerator will induce X-rays produced by electron bremsstrahlung from the resonant cavities. From the last measurement performed with the old REX-LINAC, we observed around 4 times more low-energy background due to the X-rays with the LINAC on. Once HIE ISOLDE is operational this background will have to be examined carefully.

Remaining activities in the implantation chamber after turning the tape have been observed for some experiments. A rudimentary lead shielding was installed in front of the collimator (just outside the detection cube, see Fig. 1), but it is clear that the setup would benefit of a more advanced shielding. A better alignment and beam tuning would also help to improve this. This will be part of the IDS phase II upgrade plans.

2.2 IDS upgrade plans for 2015

Although the IDS core will stay unchanged, several upgrades are foreseen for the 2015 and later campaigns.

- The control system of the IDS tape station, although reliable throughout the campaign, will be renewed. Moreover changing stepping motors that drive the tape movement is under consideration.

- Different options are being investigated for a new compact silicon and plastic based set-up (for alpha-decay, beta-delayed fission, high-resolution electron spectroscopy studies) including a tape for source collection.

- On the longer term, a newly designed HPGe holding structure is foreseen, for easy access to the implantation point. This is of particular importance because of the frequent changes in the ancillary detectors close to the implantation point.

- If beam time is allocated, we plan to couple the VANDLE neutron detector to the IDS in 2015. As mentioned above, a separate DAQ will be used to readout the neutron detectors.

- In close consultation with the Miniball collaboration a new DAQ system is envisaged that can handle the requested number of channels.

3. Status of already accepted proposals and LOIs

In the following paragraphs we present an overview of the results of the different experiments carried out at IDS during the 2014 campaign.

3.1 IS588: Core breaking and octupole low-spin states in ^{207}Tl

The experiment aimed to establish the level scheme of ^{207}Tl from the beta decay of ^{207}Hg.

The ^{207}Hg beam was produced in a molten-lead target. The yield at IDS, determined from both gamma and beta-decay rates, was in order of 10^5/s. A preliminary gamma-ray spectrum is presented in Fig. 2. All previously known transitions in ^{207}Tl are identified. In addition several new transitions can be already attributed to ^{207}Tl, and some of them even placed in the level scheme.

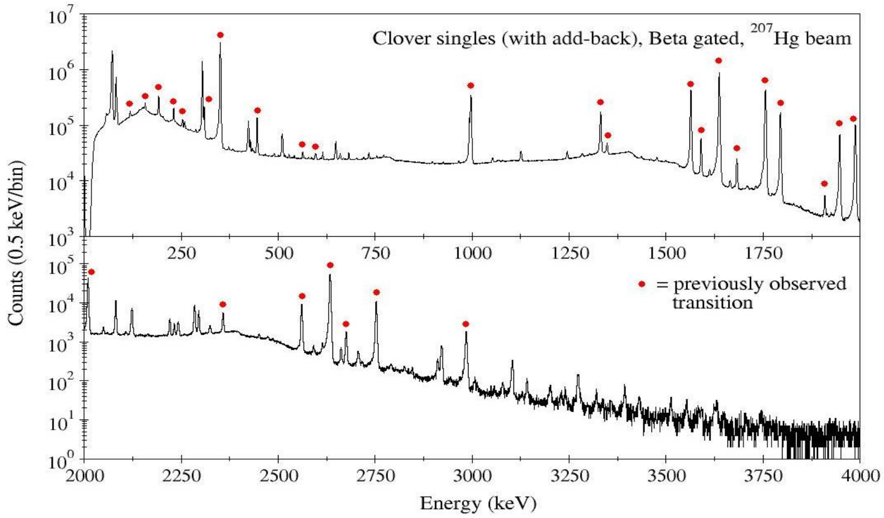

Figure 2: Gamma-ray spectrum following the beta decay of ^{207}Hg into ^{207}Tl. The previously known transitions [2] are indicated.

The level scheme will be determined from gamma-gamma coincidences. Spin-parity assignments will be guided by angular correlations and decay patterns.

The aim is to get a good understanding of the structure of ^{207}Tl, in particular the interplay between the three-quasiparticle states and collective octupole states. Ideally we would like to get information about the details of the Δl=Δj=3 composition of the octupole states.

In addition a feasibility test to produce ^{208}Hg beam was performed. While some gamma rays were detected, at this moment we are not sure whether ^{208}Hg was populated. The data is under analysis.

3.2 IS590: Characterization of the low-lying 0+ and 2+ states of ^{68}Ni

The IS590 experiment aimed to characterize the 0^+ and 2^+ excited states in the ^{68}Ni. Unfortunately, due to low ^{68}Mn yields observed at the start of the experiment (^{68}Mn: <1 pps instead of 5 pps expected), the experiment had to be cancelled. A Rubidium dispenser might have (partially) caused these low yields.

In order to identify the origin of such low production rates, a yield test was performed on the neutron rich ^{64,66}Mn isotopes. The yield test has been performed with the original UCx GPS target (#512) used for the run and a UCx target previously mounted on HRS (#509) and were validated on ^{64,66}Mn. A neutron converter and resonant laser ionization was used (RILIS) for both systems. These tests showed that the requested 5 pps for the production of ^{68}Mn should be possible with an optimized target.

During the same beam time the commissioning of the fast-timing configuration has been accomplished with the study of ^{129}In. The proton beam was sent directly to the UCx target (#512) without using the neutron converter. The ^{129}In atoms were surface ionized using the W ion source. Experimental data was recorded during a 12 hours run, having an average proton current of 1μA and an extraction yield of ~$1.2x10^4$ ions/second taking into account the ~70% beam-transport efficiency between GPS and IDS.

The detector system consisted of 4 HPGe Clover-type detectors (4% absolute efficiency at 1 MeV), 2 $LaBr_3(Ce)$ (1.5% at 1 MeV) and a ~12% absolute efficiency plastic scintillator as a fast beta detector. Using the fast-timing technique we were able to measure the half-life of the $1/2^+$ 315.3-keV level in ^{129}Sn and we report the preliminary value of 30(10)ps. This result represents the first successful fast-timing measurement at the IDS and gives the possibility for the first estimation of the M1 effective operator for neutron holes in the doubly-magic ^{132}Sn region.

3.3 IS476: Studies of β-delayed two-proton emission : The cases of ^{31}Ar and ^{35}Ca – IS577: beta-3p spectroscopy and proton-gamma width determination in the decay of ^{31}Ar

The IS577 experiment aimed to perform a study of the β decay of the dripline nucleus ^{31}Ar that will allow for a detailed investigation of a possible β-delayed 3p-decay branch as well as provide important information on the resonances of ^{30}S and ^{29}P, in particular the ratio between the proton and γ partial widths relevant for astrophysics.

This experiment requires high efficiency for both particles as well as for gamma identification. In order to reconstruct well the multi-particle emission the particles have to be detected in a highly segmented set-up (Fig.3) where each particle is independently detected with a high angular resolution.

This lead us to rebuild the IDS station in order to fit this specialized charged-particle chamber inside the gamma array (Fig. 3). For the 165 electronic channels of the charged particle set-up we used preamplifiers from Mesytec; 2xMPR64 and 2xMPR32, that were coupled directly onto the vacuum chamber via two printed-circuit board feedthroughs, one on each side of the beam-line. The preamplifiers were connected to Mesytec STMR16+ shapers placed in the racks by the DAQ electronics.

Due to the amount of data channels two DAQ systems were running in parallel: the ISOLDE MBS-DAQ for the charged particles and gammas using analogue electronics and the IDS NUTAQ using direct digitizing of the Germanium signals only.

The IS577 experiment collected good data, and we also learned a good deal about the performance of the CaO target used, thanks to the collaboration with the target group. The yields of ^{31}Ar were initially around 1.3 ions/μC, slowly increased during the run and ended up around 1.9 ions/ μC. We also sporadically measured the yields of ^{32}Ar (250 ions/μC) and ^{33}Ar (7.000 ions/μC) and also looked for a few other activities from this target, in particular ^{9}C (1.400 ions/μC depending slightly on target temperature). All these yields are based on particle counting in our Si-detector set-up. We are still evaluating the gamma-ray efficiencies and may obtain a few more yield numbers when this has been done.

3.4 IS545: Experimental investigation of decay properties of neutron deficient $^{116\text{-}118}Ba$ isotopes and test of $^{112\text{-}115}Ba$ beam counts

The objective of this experiment was the study of the neutron-deficient isotopes of $^{116\text{-}118}Ba$. This study is of special interest because of the vicinity to the proton dripline. This experiment used the same set-up as IS577.

In addition, beam development for neutron deficient $^{112\text{-}115}Ba$ nuclei is performed. In this first run the specific aim was to test the performance of a new target (nano-structured LaC), that could show better release of especially Ba and also, when injecting CF4, could give pure Ba, free from Cs. The target did show good Ba and Cs production, however, it was rather slow, why we could not aim for too short-lived activity. Data were taken for $^{115\text{-}116}Cs$. An estimated production of 31 ^{115}Cs/s could be made. Further, after adding CF4, files were taken with A=138(^{119}Ba+^{19}F), A=136(^{117}Ba+^{19}F) and A=133 (^{114}Ba+^{19}F); these data are being analysed.

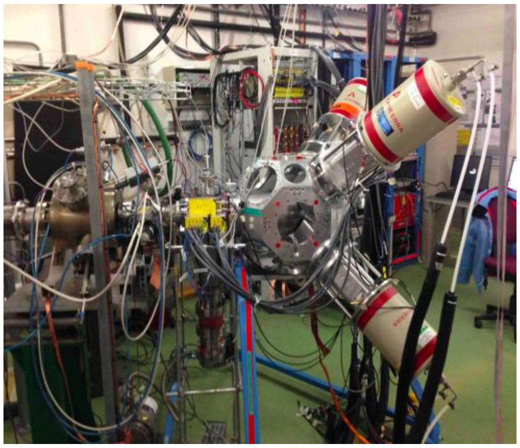 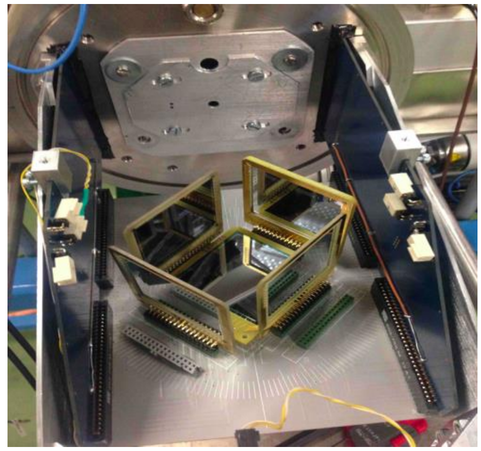

Figure 3 Left: IDS during IS577 and IS545 with the support frame turned by 180 degrees. Right: The charged particle set-up consisting of 5 Si-DSSD detectors of 2x60, 300, 500 and 1000 μm thickness each with 256 pixels of 3x3 mm each backed with a thick (500-1000 μm) Si-PAD detectors. Total detection efficiency of 45% and angular resolution of 3 degrees.

3.5 IS579: Study of octupole deformation in n-rich Ba isotopes populated via β decay

The experiment IS579 aimed to exploit the unique capability of the ISOLDE facility to produce $^{150-151-152}$Cs beams to investigate their radioactive β decay to $^{150-151-152}$Ba.

Besides the IDS core set-up, 3$LaBr_3$(Ce) detectors (1.5"x1.5") for fast-timing measurements, and 3 plastic detectors were installed. A close view of the setup is shown in Fig. 1.

During the experiment several decay chains have been studied: $^{148\text{-}149}$Cs→$^{148\text{-}149}$Ba was used as reference, since a number of gamma lines are already known in these decays. Most part of the shifts were devoted to the study of ^{150}Cs→^{150}Ba whose decay was not known so far. Attempts to study $^{151\text{-}152}$Cs→$^{151\text{-}152}$Ba decays have been performed but we could not see any sign of a short-living components during the on-line analysis. These decays are expected to have half-lives <50 ms. Information on the measured β decays, such as lifetimes and delayed neutron-emission probabilities, will be extracted, together with the detailed spectroscopy of the daughter nuclei, via γ − γ coincidences and lifetimes measurement of specific states, based on the fast-timing approach.

For this experiment a nano-structured UCx target has been used. The characterization of the target was not finalized before the experiment and the initial running conditions have been very conservative (*i.e*. low target temperature). The proton current was widely varying between 1.6 and 2.0 μA and was frequently lost during the last 3 nights. Moreover, several interruptions owing to other planned activities occurred, hindering optimum data taking to a certain extent.

The release of unwanted contaminant species has been observed throughout the whole experiment, in particular the presence of isotopes of Pm. In the runs at mass A=150 the presence of ^{150}Pm is clearly dominating the spectrum. This isotope cannot be produced as a grand-daughter of the decay starting from ^{150}Cs, since its mother nucleus, ^{150}Nd, is stable. The amount of ^{150}Pm seen in the spectra is also much higher than expected from direct population but this has to be evaluated further.
A gamma line at ~100 keV can be connected to the decay ^{150}Cs->^{150}Ba owing to its characteristics. The rate estimate of ^{150}Cs is then based on the accumulated intensity in this line. At an average current of 1.7 μA this results in a yield of 1.18 ions/μC of ^{150}Cs. The observed yields are lower than expected, both from yields reported in the ISOLDE website, and also from past measurements in this region.

4. Conclusion and outlook

The IDS in its phase-I configuration is now operational at the RC4 beam line at Isolde. Several experiments were performed during the 2014 campaign and the data are currently under analysis.

In 2015 IDS will run with essentially the same configuration, except for a planned tape station upgrade. From 2016 onwards more upgrades are foreseen, including a new implantation chamber (for alpha-decay, beta-delayed fission, high-resolution electron spectroscopy studies), a new HPGe holding structure and a different DAQ system (allowing for a larger number of channels).

5. References

[1] http://npg.dl.ac.uk/MIDAS/

[2] B. Jonson, O.B. Nielsen, L. Westgaard, J. Zylicz, Proc. Int. Conf. Nuclei far from stability, Helsingor, Denmark, vol.2, p.640 (1981); CERN-81-09 (1981)