Status of PreSPEC Commissioning Data Analysis*

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PreSPEC-AGATA is an experiment for in-flight γ-spectroscopy at GSI to investigate the structure of exotic nuclei. Two physics campaigns were done: 2012 and 2014. This report is about the progress in the data analysis of the commissioning runs in August 2012.

Introduction

The goal of the experiment was a measurement of the performance of the PreSPEC-AGATA [1] setup, a unique combination of the GSI Fragment Separator (FRS) [2], the Advanced Gamma Tracking Array (AGATA) [3], Lund-York-Cologne CAlorimeter (LYCCA) [4], and HECTOR for in-beam γ-spectroscopy. Further details about the setup and an earlier status report about the data analysis can be found in [5]. A ^{80}Kr beam with a kinetic energy of about 150 MeV/u at the secondary target position was used to do two types of experiments: Coulomb excitation on a ^{197}Au target, and secondary fragmentation reactions on a Be target. ^{80}Kr was chosen as projectile because of its high Coulomb excitation cross-section of $\sigma_{\mathrm{clx}} \approx 550\mathrm{mb}$ for the 2_1^+ state. The challenge in the analysis of in-flight γ spectroscopic data is the large Doppler shift of emitted γ-rays at velocities of $v/c \approx 0.5$. The data is being analyzed, using a software framework described in [6].

Coulomb Excitation

If ^{197}Au is the target material, the dominating excitation mechanism of the projectile is Coulomb excitation (Coulex), i.e. exchange of virtual photons. At relativistic energies, one-step Coulex is dominating and the first excited 2_1^+ state at 616.6 keV in ^{80}Kr is populated. The observed yield in the γ line of the excited state can be used to determine the B(E2) value. Because of the strong Doppler effect at large projectile velocity, the γ-rays have to be corrected for the Doppler shift in energy before a discrete line in the γ spectrum can be seen. The strength of the Doppler shift depends also on the angle of observation in the laboratory frame, which can be seen in Fig. 1. The spectrum of γ-energy in the laboratory frame shows the emission of the excited target nuclei from the state $7/2_1^+$ at 547.5 keV. Another line is the emission from electron-positron annihilation at 511 keV. Towards lower energies (below 500 keV), the background radiation level rises very quickly because of the abundant atomic radiation emitted during the interaction of the projectile with the target electrons. The emission line of the 2_1^+ state at 616.6 keV in ^{80}Kr can only be seen after Doppler correction (Fig. 1, bottom). Simultaneous observation of emission lines from target and projectile de-excitation allows for a relative measurement of the Coulex cross-sections and thus B(E2) value of the two excited states ^{197}Au and ^{80}Kr.

Final quantitative results for total efficiency and energy resolution will be obtained after taking into account the AGATA detector efficiency at different angles and for different γ-energies. This is difficult, because efficiency is influenced by the combined effects of the Doppler shift: Change in angular distribution and in the energy of the emitted radiation.

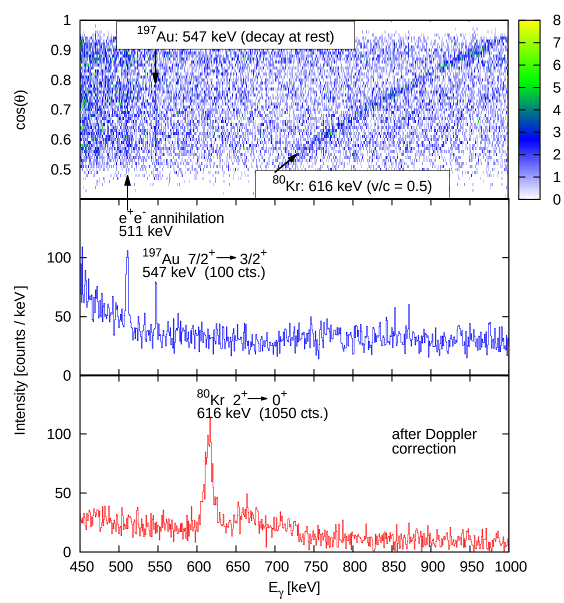

Figure 1: Top: Detected γ energy in the laboratory system as seen from different detection angles. γ-rays emitted in-flight can be seen as curved lines. Middle: The background subtracted spectrum of γ energy in the laboratory system, shows the decay from the excitation of the target material (^{197}Au). Bottom: Background subtracted spectrum of Doppler-corrected γ energy show the decay spectrum of the projectile.

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Secondary Fragmentation

If the secondary target is Beryllium, the cross-section for fragmentation reactions is large. Such a setup is used to study the decay of excited fragments. In order to assign the observed γ-radiation to specific ion species, full identification of outgoing fragments is needed. This is done with the LYCCA device [4] that performs ΔE-E and precise time-of-flight measurement of the ejectiles. From these quantities, the outgoing isotopes can be identified as shown in Fig. 2. In the mass region around ^{80}Kr, Z-identification is very good while different mass peaks are overlapping. The calibration of the LYCCA DSSSD detectors was partly done using an automatic method described in [7].

After the Doppler correction of observed γ-rays in coincidence with the LYCCA identification, γ-emission spectra of selected excited ejectiles can be obtained. Yrast states of the most abundant even-even isotopes after the target can be seen in Fig. 3. The half-life $T_{1/2}$ of the excited state has an influence on the resolution that can be obtained. If T_{tar} is the time the projectile needs to travel through the target material, most de-excitation processes will happen inside the target if $T_{1/2} < T_{\mathrm{tar}}$. In this case, the particle velocity after the target is not equal to the velocity at the moment of γ emission and the Doppler correction will be done with a wrong velocity. This results in a reduced resolution for the states with shorter half-life as can be seen in Fig. 3 where $T_{1/2}$ is given in the label of each peak. On the other hand the observed line shape enables in principle the determination of lifetimes.

Furthermore, data from the ^{80}Kr fragmentation run was used to show the feasibility for new experimental techniques as described in [8].

Outlook

The analysis is ongoing. Since the AGATA detector is a complicated device, exploiting pulse-shape analysis (PSA) an γ-ray tracking, some improvements can be expected from a refined preprocessing of the detected γ-rays. This is possible, because during AGATA experiments, the preamplifier signals of all channels are written to disk. Later improvements in software algorithms for PSA and γ-tracking can be used to increase both, efficiency and energy resolution of the Doppler-corrected peaks.

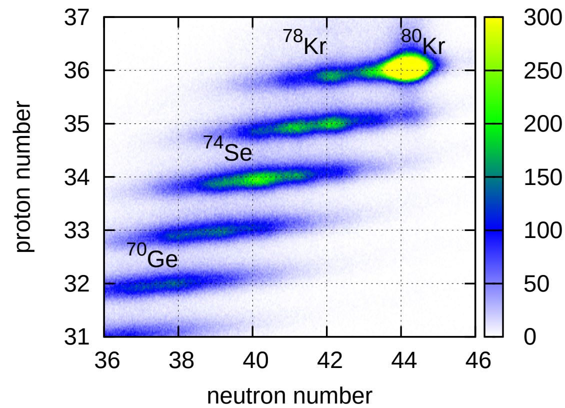

Figure 2: The charge and mass identification plot that is used to produce the gated spectra of Fig. 3. Particle charge is determined, using the E-ΔE method, while the mass is obtained from an additional time-of-flight measurement.

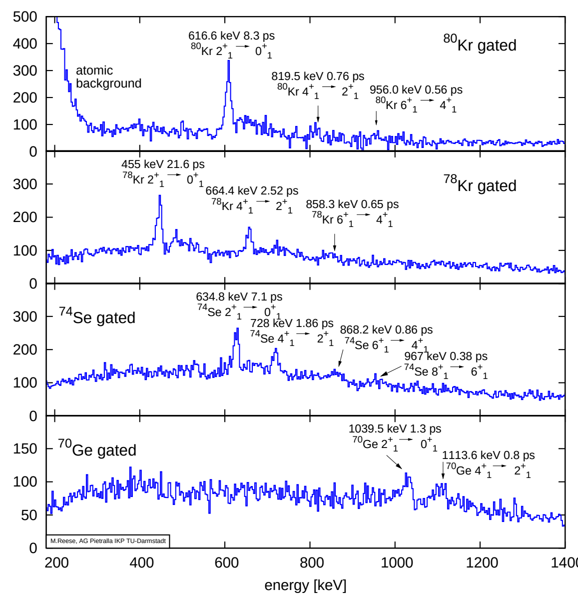

Figure 3: Doppler-corrected γ spectra for the strongest even-even nuclei identified by LYCCA. Decays of the first few Yrast states can be clearly seen. Peak labels indicate the γ-ray energy and the half-life of the initial state.

References

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