Measurements of competing structures in neutron-deficient Pb isotopes by employing Coulomb excitation

Letter of Clarification for the proposal P-260

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In the February 2009 INTC meeting we proposed to study the shape coexistence in neutron-deficient Pb nuclei. The physics case was endorsed, but a Letter of Clarification was requested by the committee. The present letter addresses the issues raised by INTC.

The even-mass $^{188-192}$Pb nuclei under study will be produced by bombarding the UC_X ISOLDE primary target with 1.4 GeV protons and subsequently ionised using the selective RILIS ionisation. However, due to high temperature of the ion source cavity, ions with low ionisation potential are ionised as well resulting in isobaric contamination of the mass separated ion beam. In Ref. [1] beam purity measurements of the even-mass $^{188-192}$Pb have been carried out. In the original proposal possible experimental issues arising from isobaric Tl contaminants were addressed. However, the committee requested clarification to the question of how and with what level of precision the beam composition can be monitored online.

The laser ionisation offers a unique tool to extract the Pb and Tl contribution to the radioactive ion beam bombarding the MINIBALL Coulomb excitation target. However, despite the use of selective laser ionisation, surface ionised contaminants from the hot cavity can be produced. The beam contribution of the surface ionised Tl contaminants can be extracted by periodically switching the laser ON and OFF with a typical periodicity of $\sim$ 20 s. The laser ON/OFF runs will be performed at regular intervals during the experiment for each Pb isotope of interest. The extra beam time required for such runs was taken into account in the total number of shifts requested in the proposal. The laser ON/OFF method has been shown to be consistent in order to monitor the purity of the radioactive ion beam online at ISOLDE and has been previously utilised in the measurements of $B(E2)$ values of Zn [2] and Sn [3] nuclei.

One should note that the target Coulomb excitation yield is only used when extracting non-diagonal matrix elements (*i.e.* $B(E2)$ values) in relative measurements where the Coulomb excitation cross sections of Pb nuclei of interest are measured relative to the known target excitation. In addition, another independent analysis will be carried out for the Pb nuclei of interest in order to extract diagonal matrix elements $\langle 2_i^+||O(\hat{E}2)||2_i^+\rangle$, corresponding to the expectation value of the quadrupole deformation. In that analysis, Coulomb excitation γ-ray yields will be investigated as a function of the scattering angle of Pb recoils. Such analysis is less sensitive to the target Coulomb excitation yield and therefore beam impurities will not introduce experimental difficulties.

As noted in the original proposal, the presence of Tl contaminants will not pose a problem for the Coulomb excitation spectra of Pb nuclei of interest since low-energy γ-ray transitions of Tl ($E_\gamma \sim$ 300 keV) can be easily distinguished from the ones associated with Pb ($E_\gamma \sim$ 700-800 keV). The yields for relevant Pb and Tl isotopes are given in Table 1.

The level of target excitations originating from the Tl impurities can be ascertained from periodical laser ON/OFF measurements by correlating γ rays from the known Tl de-excitations to those of target de-excitations. As this procedure is done when the laser is turned OFF the exact amount of target excitations induced by Tl can be extracted. Applying this information to the laser ON measurements the amount of target excitations induced by Pb, which is needed in the analysis of the $B(E2)$ values, can be unambiguously measured. In fact, the beam purity has

Table 1: ISOLDE yields for laser ionised Pb and surface ionised isobaric Tl impurities [1]. Pb yields have been taken from the ISOLDE database.

Mass number A	Tl yield (μC^{-1})	Pb yield (μC^{-1})
188	3×10^6	1.7×10^6
190	4×10^6	2.3×10^7
192	5×10^7	4.0×10^7

been determined with the laser ON/OFF method down to 2% accuracy in above mentioned previous study at ISOLDE [2].

The experimental conditions of the proposed study in terms of isobaric beam contaminants resemble closely those in Refs. [2, 3], where the $B(E2)$ values have been extracted with a relative error of approximately 10%. Moreover, such level of accuracy is obtained for Hg isotopes (IS452) and is also expected for the present study.

To conclude, the beam composition can be monitored online by periodical laser ON/OFF measurements for each Pb isotope of interest. This method has been shown to be applicable in previous studies. The accuracy of the extracted matrix elements is expected to be on the same order of magnitude as for Hg nuclei (IS452) despite the presence of isobaric contaminants. Furthermore, isobaric contaminants do not affect to the measurements of the diagonal matrix elements.

References

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