LETTER OF CLARIFICATION

INTC-P-592 *Probing the largest core-breaking prediction towards ^{100}Sn: proton single-particle strength in ^{110}Sn* (21 shifts requested)

Dear members of the PAC, please find below our answers to your questions.

It is proposed to study the proton single-particle structure of ^{110}Sn. In particular, the first 4^+ excited state of ^{110}Sn will be populated via proton transfer on ^{109}In(^{3}He, d), performed in inverse kinematics, using a HIE-ISOLDE beam of ^{109}In accelerated to 7.38 AMeV. This reaction should be dominated by a $\Delta\ell$ =2 transfer. The proponents plan to infer the spectroscopic factor of the low-lying ^{110}Sn states through a DWBA analysis of their planned measurement. Various issues seem unclear to the INTC: clarifications about this proposal are required prior to taking a decision.

1) First, experiments with stable In beams have shown that this reaction populates various final states, and with the limited resolution given by the thick secondary target, it might be difficult to separate them (see for example Fig. 2 of Nucl. Phys. A 510, p70).

A: in the suggested reference, Shippers et al., Nucl. Phys. A 510, p70, used a proton transfer reaction, ^{115}Sn(^{3}He, d), to populate ^{116}Sn. In Fig. 2 of the paper, it is possible to see that 2_2^+ and $0_{2,3}^+$ states are not populated and a 2_3^+ is only marginally populated. At variance, a 3_1^- state is populated in ^{115}Sn(^{3}He, d)^{116}Sn with similar strength than 4_1^+. Since this 3^- state in ^{110}Sn is not resolved according to the expected ISS experimental resolution, we performed a realistic simulation including also this state, which is mostly populated with a $\Delta\ell = 1$ proton transfer reaction. The result is shown in the Fig. 1 below. Using as a simulation input for the 3^- the same number of events of the 4^+ state (for $\Delta\ell = 2$ component, which is the largest from the theory), it is evident that there is no impact to the angular distribution of the 4^+ state because of the shape of the $\Delta\ell = 1$ distribution.
In fact, the $\Delta\ell = 1$ cross section, peaked at more forward angles, is much largely suppressed because of the solid angle and the geometrical efficiency of the array, compared to $\Delta\ell = 2$ distribution. Therefore, the possible interference of the $\Delta\ell = 1$ component that might populate the 3^- state in ^{100}Sn is negligible (not visible in the Fig. 1 being largely below the lower value of Y scale) in the angular range of interest for the $\Delta\ell = 2$ component of the 4^+ state in ^{110}Sn. In conclusion, we do not expect significant problems in case we would not be able to discriminate the unwanted 3^- state by energy argument.

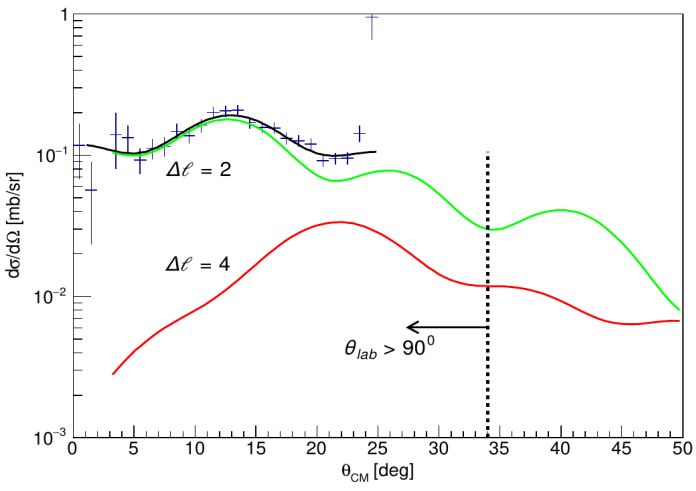

Fig. 1

2) Second, as was asked during the open session: what are the predictions for spectroscopic factors of these states? The INTC would like to have more information on this issue. Related to this point, a question was raised about the DWBA calculations performed in preparation to this experiment. The proponents indicate that a mere Woods-Saxon potential was used to simulate the interaction between the proton and the deuteron within the description of ^{3}He used for the DWBA calculation. The parameters of that potential have been chosen such as to reproduce the one-proton separation energy of ^{3}He and the asymptotic normalisation coefficient (ANC) predicted by a calculation of the Argonne group (see Ref. [12] of the proposal). If only the asymptotic part of the < 3He|d+p> overlap wave function matters in this calculation, viz. if the reaction is mostly peripheral, are we sure that this method can be used to infer a spectroscopic factor? What difference does it make to use the actual overlap wave function from Ref. [12]? Fresco, the program the proponents have used in their calculations, should enable them to read that wave function as an input to their calculation. This should be tested.

A: the spectroscopic factors (SF) are being calculated by the Tokyo group, results are not available, yet. Nonetheless, to have a more realistic estimate of the cross sections in the proposal, we considered for our simulation the SF for each ℓ transfer to be proportional to the relative wave function composition, Shimizu et al., private communication, instead of taking unitary SF as typically happens in the proposal. The relative weights used as simulation input are 7%, 80% and 13% for $s_{1/2}$, $d_{5/2}$ +$d_{3/2}$, $g_{7/2}$ components, respectively. In addition, in J.C. Shippers et al., Nucl. Phys. A 510 it is clearly shown that proton transfer reactions (^{3}He, d) populate low lying yrast states in ^{116}Sn, including the 4^{+} state. This is a clear indication of the feasibility of the experiment that we are proposing.

Concerning DWBA calculations, we have compared the <^{3}He|d+p> overlap calculated with a WS potential, the latter being used to predict cross sections for the present experiment, with the one obtained by the Argonne group [Ref. 12 of the proposal], as suggested by the referee. As previously outlined, the WS parameters were adjusted to match the proton separation energy and the slope of the tail of the *ab initio* overlap, using the spectroscopic factor (SF=1.32) calculated by the Argonne group. The comparison presented in the left-hand side of Fig. 2 shows a very good agreement between the two wave functions, supporting the use of a WS potential to reproduce the d-p interaction within the ^{3}He system. In particular, the ANC arising from the WS approach is 2.01 fm^{-1}, which compares rather well to the 1.97 fm^{-1} value obtained from s wave pd-scattering analysis [see Ref. 1 and Refs. therein]. On the other hand, the ANC calculated by the Argonne group is 2.144(8) fm^{-1} [2], hence slightly higher than the one obtained with the WS potential. This can be hardly seen in the left-hand side of Fig. 2, and it results, as expected, in a little difference in the strength of the angular distributions, when the Argonne wave function is used to perform the calculations. This is shown in the right-hand side of Fig. 2, where the L=2 transfer to the 4^{+} state has been taken as an example. We note that such a small difference is well within the expected experimental error, hence we do not foresee any perceptible impact to the extraction of spectroscopic factors. However, we would like to remark that the dependence of cross sections on the choice of different wave functions, as well as scattering potentials, and the possible uncertainties originating from them are crucial and they will be carefully considered in the DWBA analysis of the experimental data.

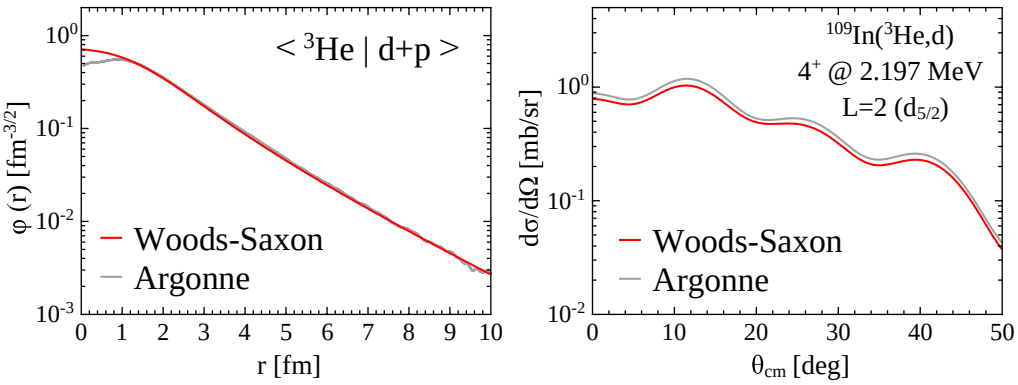

Fig. 2

3) Lastly, the experiment will be sensitive to the 1 particle-1 hole component of states only. It remains unclear how the (non)-observation of the population of the 4^+ state can be interpreted as (the absence) of core excitations. To resolve these questions, the INTC would like the proponents to submit a letter clarifying the above points.

A: the predictions of Togashi et al, in Ref [5] and in the top part of Fig. 2 in the proposal, indicate a sizable one particle-hole (1p-1h) proton core excitation in the wavefunction of the 4^+ state. In ^{116}Sn, the work of J.C. Shippers et al., Nucl. Phys. A 510 demonstrated that the transfer of 1 proton populates the 4^+ state. Calculations from Togashi et al were for the first time able to well reproduce the increased B(E2) values in neutron-deficient tin isotopes, where a part of the E2 strength comes from proton 1p-1h core excitations. The aim of this proposal is to probe the proton core breaking predicted by these Monte Carlo shell-model calculations. In this regard, a non population of the 4+ state in a 1 proton transfer reaction would put these calculations into question.

We remark that the 2p-2h intruder band in Sn isotopes has its 0^+ bandhead lower that the first 4^+ at the mid neutron shell in $^{116\text{-}118}$Sn (as a result of maximum quadrupole correlations). Going towards ^{100}Sn, such 2p-2h band goes higher in energy, above the first 4^+, and hence also the 2p-2h 4^+ will go higher in energy thereby reducing its mixing with the first 4^+, which should have 1p-1h excitations as a main component from the quoted calculations.

[1] J.T. Huang, C.A. Bertulani and V. Guimarães, At. Data and Nucl. Tab. **96**, (824) (2010).
[2] K.N. Nollett and R.B. Wiringa, Phys. Rev. C **83**, 041001(R) (2011).