EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Proposal to the ISOLDE and Neutron Time-of-Flight Committee

Spectroscopy of ^{8}Be: Search for Rotational Bands Above 16 MeV
Letter of Clarification

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From the minutes of the 65th meeting of the INTC:
INTC-P-572 Spectroscopy of 8Be: Search for Rotational Bands above 16 MeV (15 shifts requested)

… snipped

"However, the committee had some concerns about the running conditions for the experiment. To avoid the presence of ^{7}Li, it is recommended to run in "winter physics" mode with a pre-irradiated target. This would require irradiation of an ISOLDE target for an estimated 13 days. The committee would like to receive clarification on whether the collaboration would accept this option or whether they would prefer to run with protons in which case the level of ^{7}Li contamination which can be accepted should be addressed".

We submit the following clarification:

The INTC is correct in addressing the required purity of the ^{7}Be beam (as we did when formulating our proposal). The ^{7}Li(d,p) reaction has a small negative (ground state) Q-value: -0.192 MeV, as compared to the large (ground state) Q-value of the ^{7}Be(d,p) reaction at +16.674 MeV. Consequently, proton kinematics for populating high lying states in ^{8}Be, at for example E*(^{8}Be) = 20.0 MeV, are identical to populating low lying states in the continuum of ^{8}Li at E*(^{8}Li) = 20.0 – 16.674 – 0.192 = 3.134 MeV, as shown in Fig. 1. These very broad states in ^{8}Li that decay to ^{7}Li+n (threshold at 2.033 MeV) will lead to a background in the spectrum of proton (measured in the ISS) in coincidence with ^{7}Li (measured in the recoil detector). In order to minimize, if not altogether remove this background (underneath the narrow states in ^{8}Be that we propose to measure), the best "pure" ^{7}Be should be chosen.

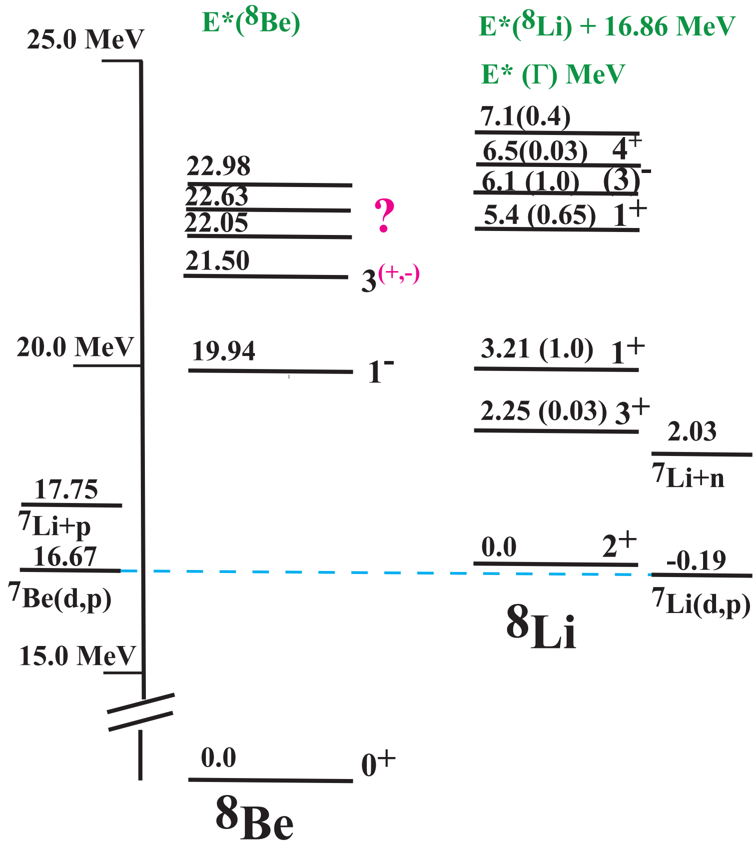

Fig. 1: A comparison of the spectra of $^{8}Be^{*}$ and $^{8}Li^{*}$, with the $^{8}Li^{*}$ spectrum shifted upward by 16.86 MeV, as discussed in the text. The 4 states we propose to measure in ^{8}Be are shown at 21.5 – 22.98 MeV.

The purity of the ^{7}Be beam in HIE-ISOLDE measured in November 2018 [1], together with our experience during the production of the implanted ^{7}Be target during IS-593 in April 2016 [2], revealed very small ^{7}Li contaminant, using the surface ionization ion-source, due to the volatility of ^{7}Li, as we show in Fig. 2 received from Sebastian Rothe, on July 9, 2020 [1].

In order to quantify the effect of the ^{7}Li impurity, we assume the product of the ratio of the ^{7}Li(d,p)/^{7}Be(d,p) cross sections times the ^{7}Li impurity, is smaller than 10%. And in Fig. 3 we show (in red) the resulting background spectrum from the broad states in ^{8}Li shown in Fig. 1, each contributing 500 counts. The simulated spectrum includes the ISS intrinsic resolution of 100 keV. In the same figure we show the simulated spectrum previously included in our proposal, with each state in ^{8}Be contribution 5,000 counts. We note that an observation of the ^{8}Li contaminant line from the narrow 4^{+}, shown in Fig. 3, could be used to monitor the ^{7}Li impurity in the beam.

We agree with the INTC's recommendation (and in fact we prefer) to perform the measurement during the "winter Physics", with the best available pure ^{7}Be beam. We however note that by choosing a charge state 4+ of the accelerate ^{7}Be beam, the ^{7}Li contaminant will be readily removed, and in this case a measurement in the normal proton cycle could be considered, should the "winter Physics" program will be over-subscribed. We also note that should the ^{7}Li impurity produce unexpected large background, we could require coincidences between protons and ^{7}Li, in two opposite quadrants of the recoil detector. But this will reduce our statistics by approximately a factor 4.

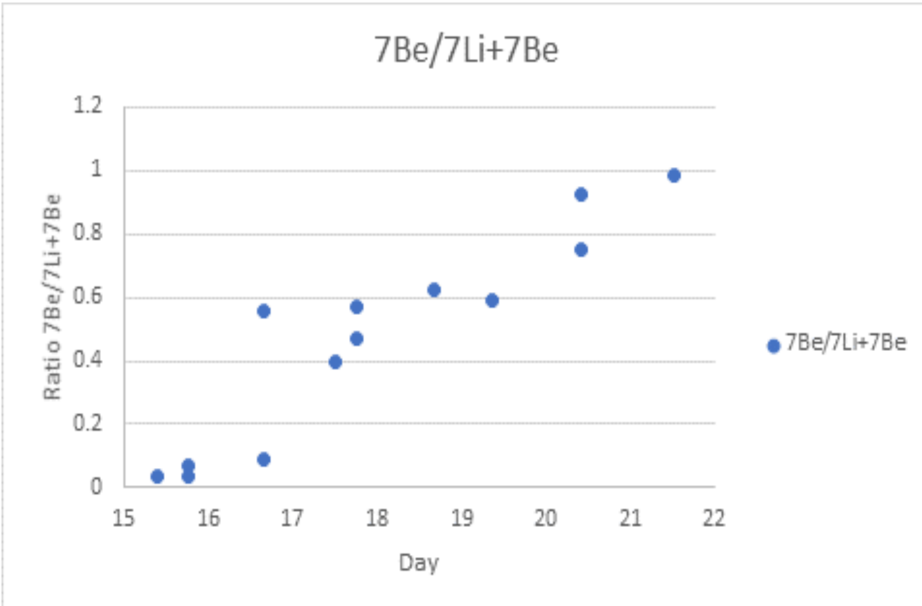

Fig. 2: The ^{7}Be beam purity measured between November 15 – 22, 2018 [1].

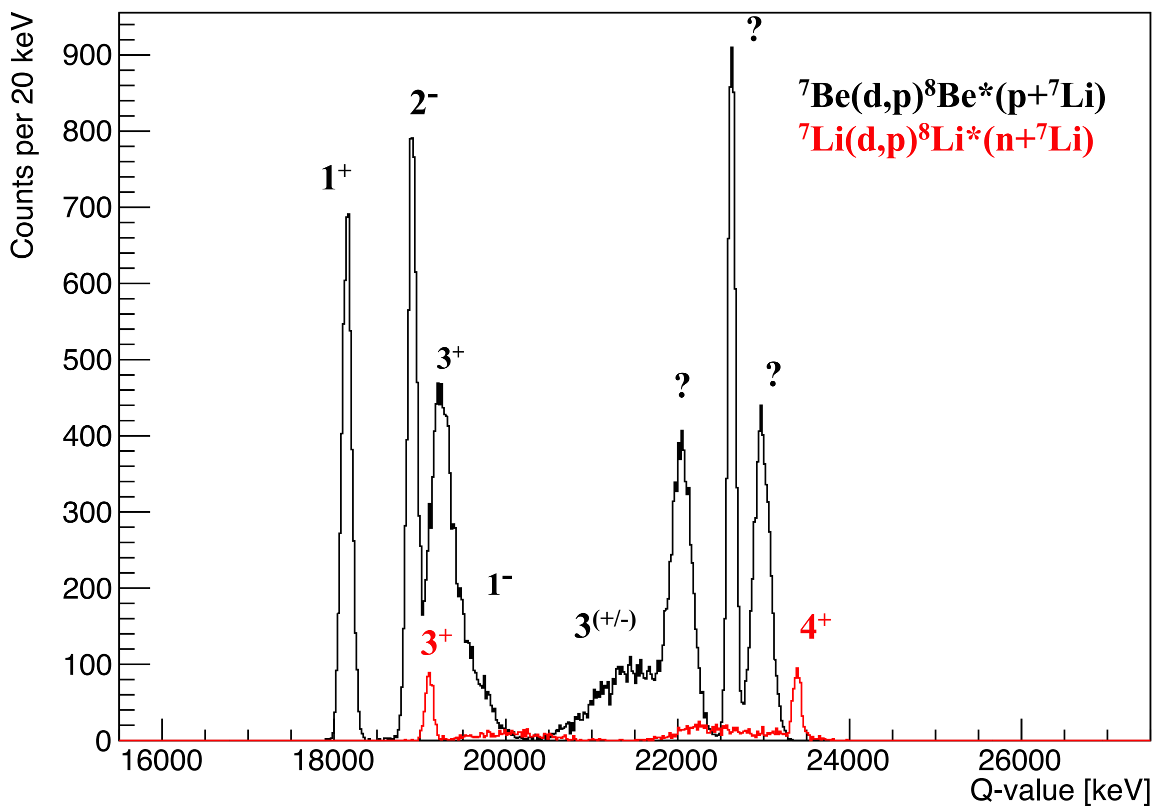

Fig. 3: The simulated proton spectrum in coincidence with ^{7}Li, from excited states in $^{8}Be^{*}$, shown together (in red) with the background from states in $^{8}Li^{*}$, due to the putative ^{7}Li impurity in the ^{7}Be beam, as discussed in the text.

In closing:

We add below a communication we received on December 5, 2021, from Sebastian Rothe:
(by permission)

"For your experiment: based on the past experience, we could speed up the evaporation of ^{7}Li until we arrive at the wanted ratios [shown in Fig. 2]. I could expect to compress this into say ~3 days. Please note that we loose Be while we do that, which gives the risk that the total amount of ions may not be delivered. To mitigate this, one might ask to irradiate rather longer than the 13 days equivalent direct irradiation at one of the two irradiation points".

We add below a communication we received on December 5, 2021, from Alberto Rodriguez:
(by permission)

"Based on the performance of the superconducting cavities during 2020, 12 MeV/u is at the high end of what we could do for an A/q=2.33. I was more optimistic when we talked during the ISS workshop. Around 11.7 MeV/u may be more realistic for that A/q".

"We are in the process of installing stripping foils before the ISS. We expect them to be available before we start the physics campaign this year. Once we do this, we will be able to deliver a clean ^{7}Be 4+ beam as you write in your email. However, even if we can get rid of ^{7}Li with the foils, reducing the amount produced in the target would still be important to avoid saturating the Penning trap before the charge breeder. Otherwise, the efficiency of the trap + charge breeder can be very low".

Conclusions:

- Beam energy of 11.7 MeV/u would be acceptable for our proposed measurement that originally assumed 12 MeV/u. Hence, we update the requested beam energy to 11.7 MeV/u.

- An irradiation (to prepare the ^{7}Be activity) longer than 13 days should be considered.

- It appears that scheduling during "winter physics" will be best for the measurement and for us (especially the for the US collaborators), but running in normal proton cycle, if required due to over subscribed "winter physics" program, can be considered.

- **The combination of HIE-ISOLDE tuned to A/q = 2.33 and the ISS 90° deflection magnet tuned to A/q = 1.75, should yield the most pure, most intense at the highest possible energy, ^{7}Be beam available in the world.**

References

[1] Sebastian Rothe, private communication, July 9, 2020.

[2] ISOLDE Experiment IS-593, Moshe Gai and Thierry Stora, CERN-INTC-2014-047; INTC-P- 411, Implanted ^{7}Be Targets for the Study of Neutron Interactions With ^{7}Be: (The "Primordial ^{7}Li Problem").