Proposal for ISOLDE Solenoidal Spectrometer

Probing the largest core-breaking prediction towards ^{100}Sn: proton single-particle strength in ^{110}Sn

Reporter : Zhang Guangxin (Padova-INFN)

Spokesperson: Guangxin Zhang, Daniele Mengoni

Local Contact person: Liam Gaffney

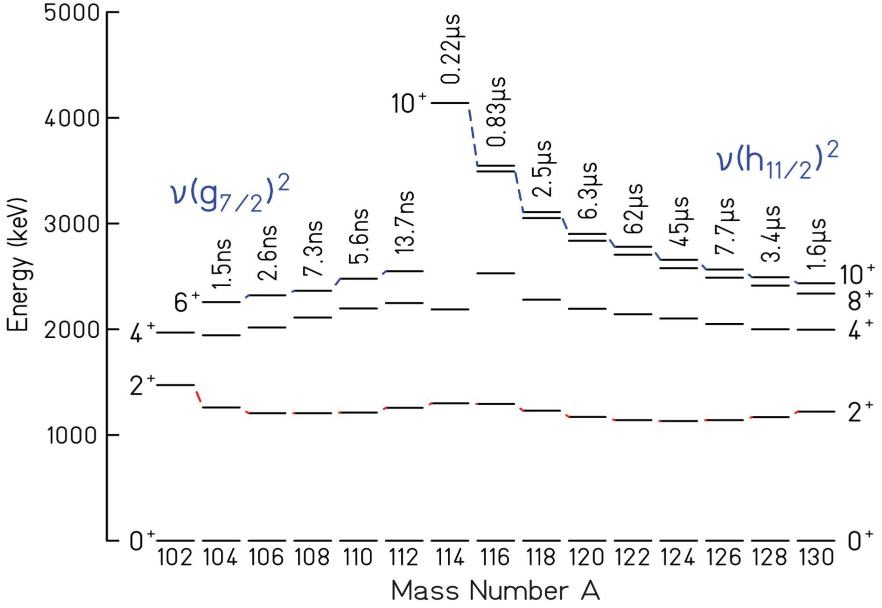
G. Zhang[1,2], D. Mengoni[1,2], S. Bottoni[3,4], A. Gottardo[5], L. Gaffney[6], M. Assié[7], D. Beaumel[7], G. Benzoni[4], Y. Blumenfeld[7], A. Bracco[3,4], D. Brugnara[1,5], P. Butler[6], F. Camera[3,4], S. Capra[3,4], J. Casal[1,2], F.C.L. Crespi[3,4], G. de Angelis[5], F. Flavigny[8], L. Fortunato[1,2], S. Freeman[9], F. Galtarossa[7], A. Goasduff[5], F. Gramegna[5], J. Ha[1,2], M. Labiche[10], J.A. Lay Valera[11,12], I. Lazarus[10], S.M. Lenzi[1,2], S. Leoni[3,4], T. Marchi[5], A. Matta [8], M. Mazzocco[1,2], R. Menegazzo[2], G. Montagnoli[1,2], D.R. Napoli[5], B. Olaizola[13], R. Page[6], G. Pasqualato[1,2], R. Pérez[5], A. Pullia[3,4], R. Raabe[14] F. Recchia[1,2], D.K. Sharp[9], F. Soramel[1,2], J.J. Valiente Dobón[5], I. Zanon[5]

[1] *Dipartimento di Fisica e Astronomia, Università di Padova, Italy.*
[2] *INFN, Sezione di Padova, Padova, Italy.*
[3] *Dipartimento di Fisica, Università degli Studi di Milano, Italy.*
[4] *INFN Sezione di Milano, Italy.*
[5] *INFN, Laboratori Nazionali di Legnaro, Legnaro (Padova), Italy.*
[6] *University of Liverpool, UK.*
[7] *IJCLab, Orsay, France.*
[8] *LPC Caen, France.*
[9] *University of Manchester, UK.*
[10] *STFC Daresbury, UK.*
[11] *Departamento de FAMN, Universidad de Sevilla, Spain.*
[12] *Instituto Interuniversitario Carlos I de Física Teórica y Computacional (iC1), Seville, Spain.*
[13] *CERN, Geneva, Switzerland.*
[14] *KU Leuven, Belgium.*

Motivation

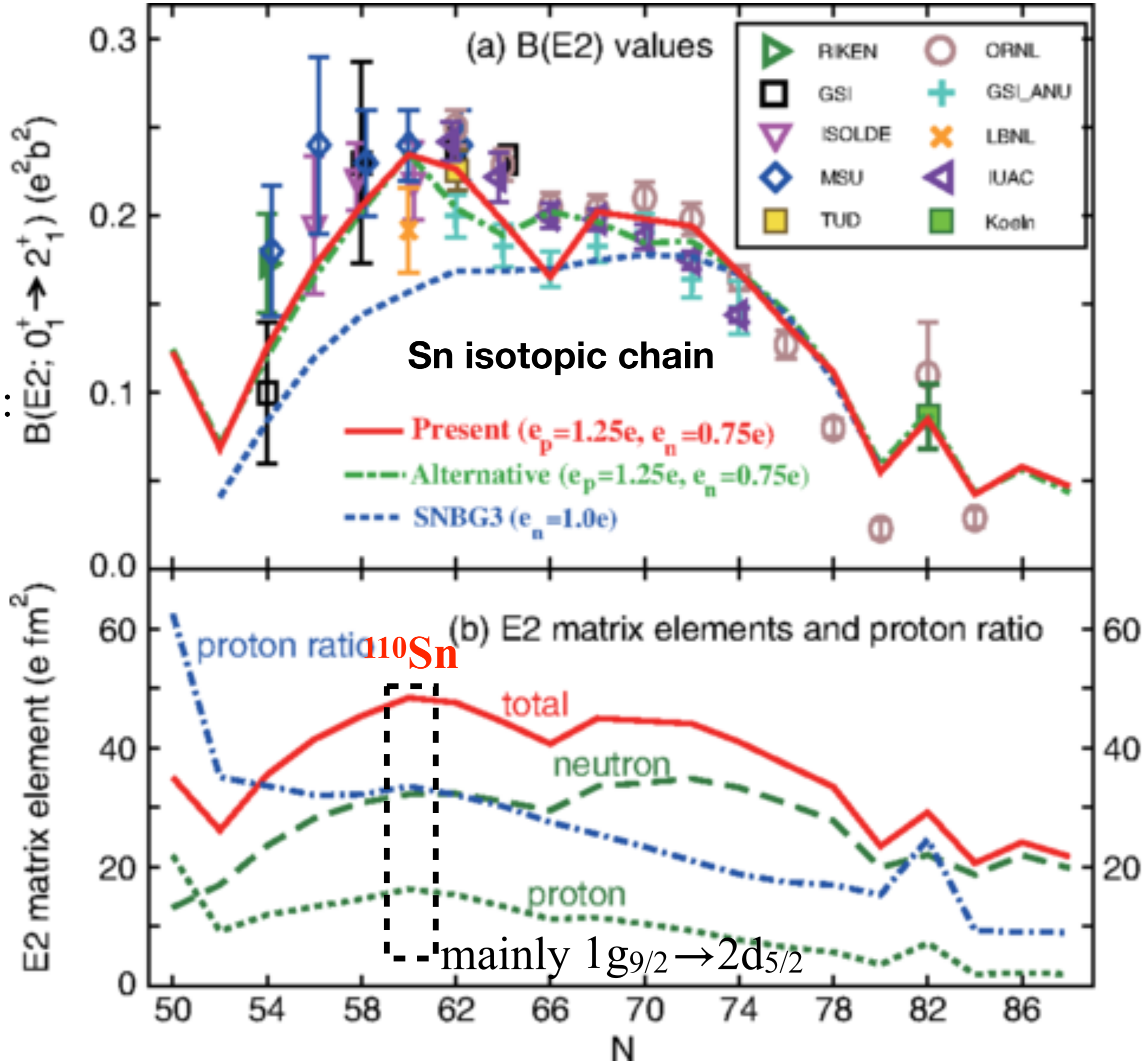
- E(2^+,4^+,…) between ^{102}Sn and ^{130}Sn in agreement with the seniority scheme
- ^{100}Sn, only beta-decay channel reported, doubly-magic nature
- Significant increment of the B(E2;$0^+ \rightarrow 2^+$) value approaching ^{100}Sn: ***a major puzzle***
- MCSM calculation has explained the anomalous trend : ***core breaking contribution***

Sn (Z = 50) isotopic chain



Consistent with previous prediction

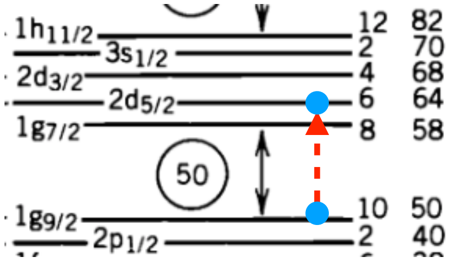
Monte Carlo shell-model

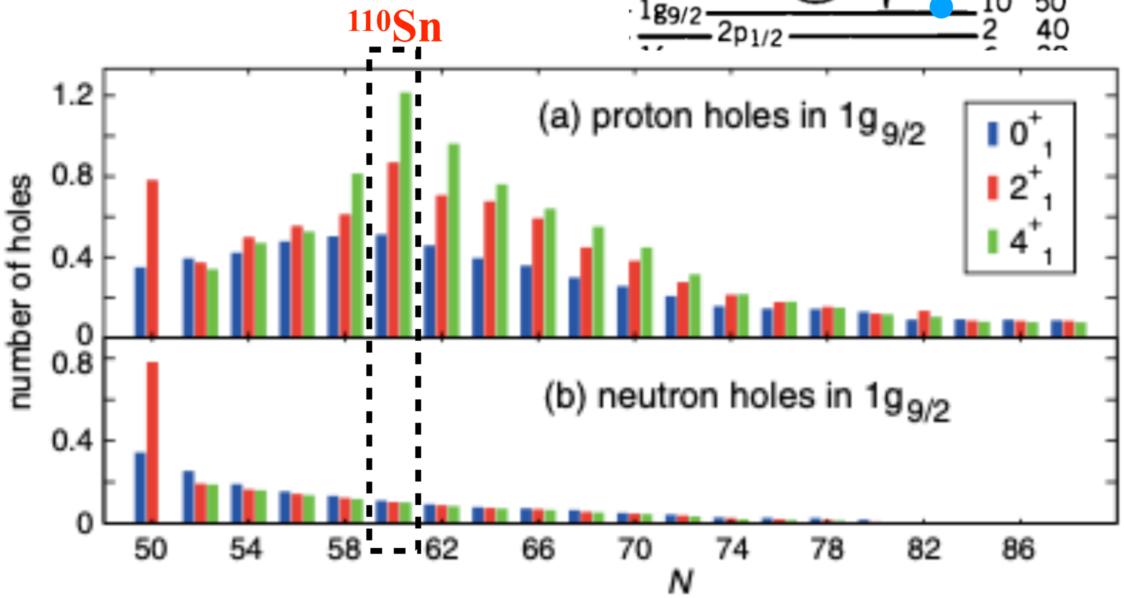


T. Togashi,et al., PHYSICAL REVIEW LETTERS 121, 062501 (2018)

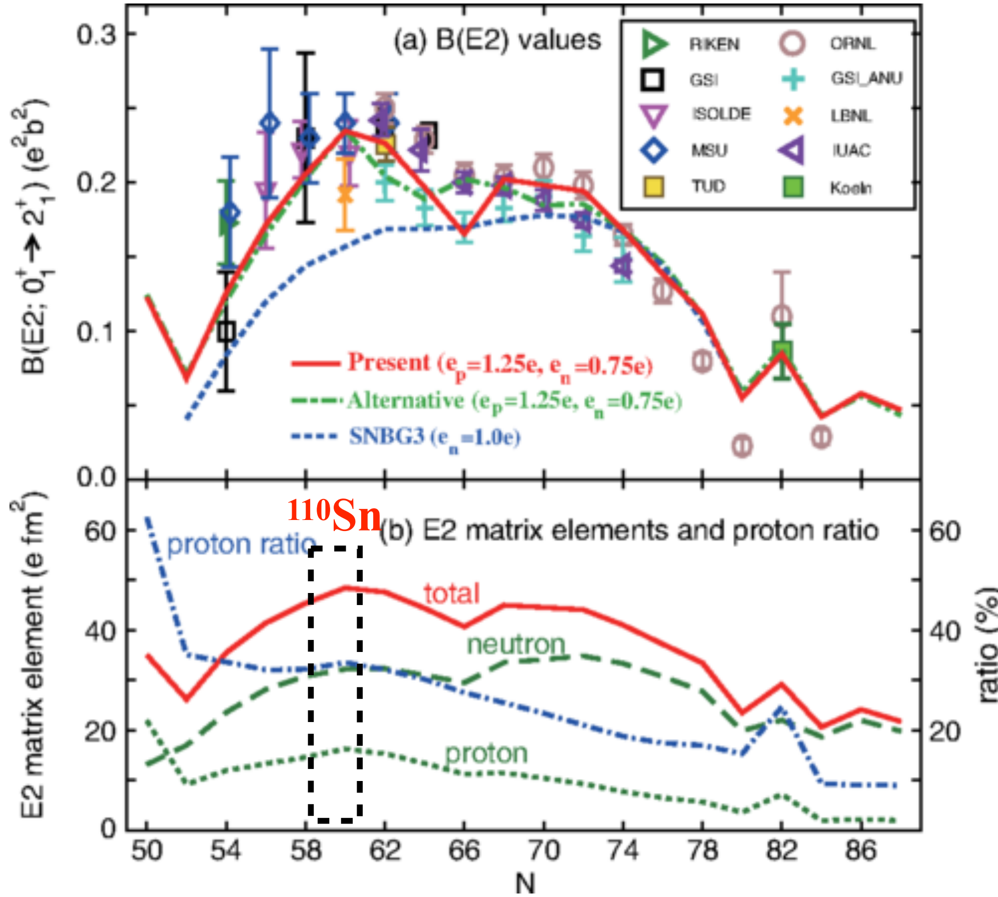
Motivation

- The robustness of Z=50 shell closure by investigating proton configurations in neutron-deficient Sn isotopes
- The proton hole in $1g_{9/2}$ orbital: being maximum in 4+ of ^{110}Sn, which should be zero if closed shell



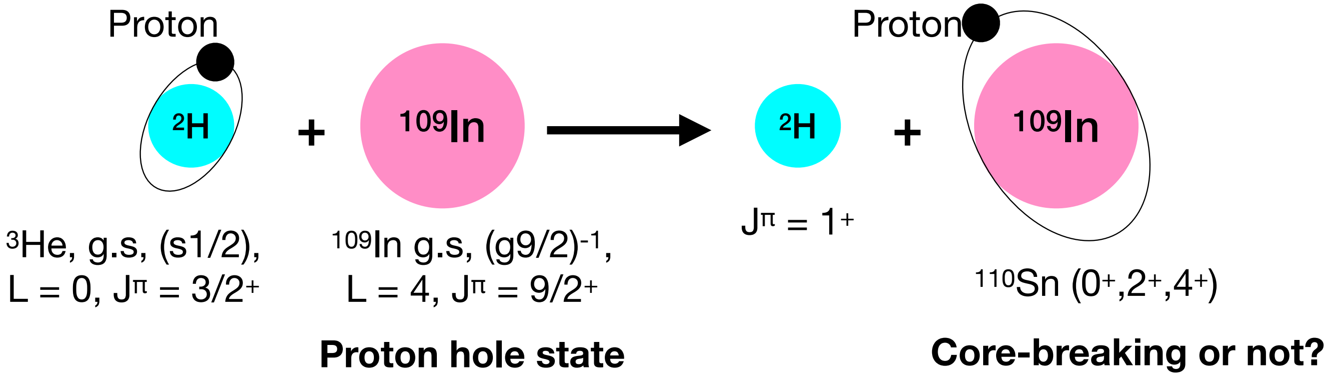


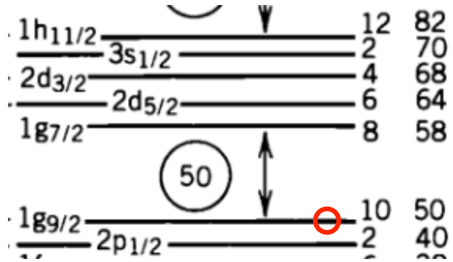
Monte Carlo shell-model



T. Togashi, et al., PHYSICAL REVIEW LETTERS 121, 062501 (2018)

Proposed measurement: ^{109}In(^{3}He,^{2}H)^{110}Sn





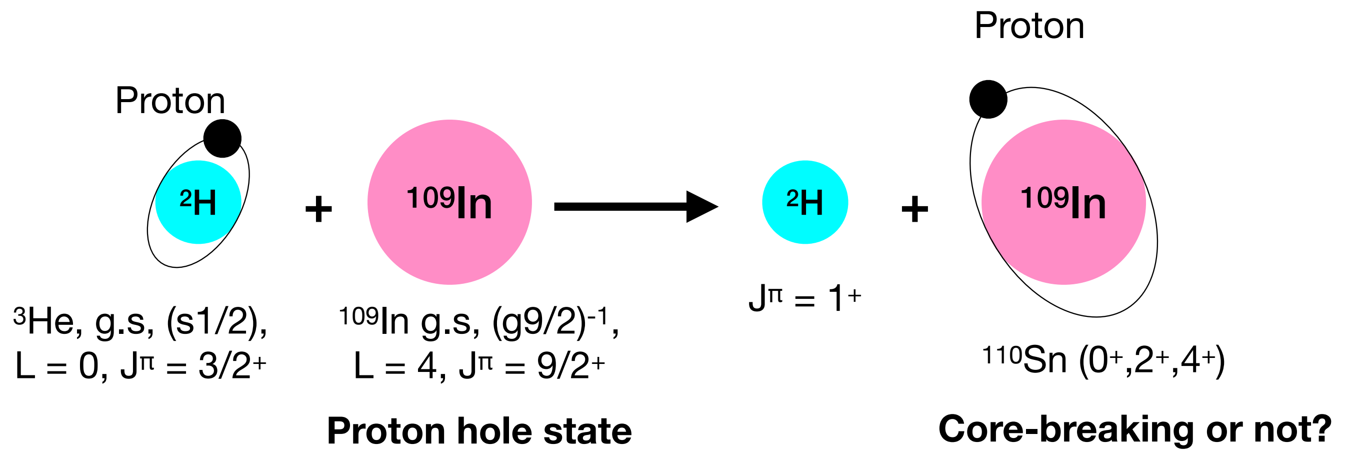
Initial state: |**^{109}In(g.s)>= ν(0+) $\otimes$ π(g9/2)$^{-1}$;**

Final state: 0+,2+,4+ states in ^{110}Sn

If there is no Z=50 core-breaking:

>> Only 0+ state (among 0+,2+,4+ states) can be populated ($\Delta l = 4$)

Proposed measurement: ^{109}In(^{3}He,^{2}H)^{110}Sn



Initial state: $|^{109}\mathrm{In(g.s)}\rangle = \nu(0+) \otimes \pi(g9/2)^{-1}$;

Final state: 0+,2+,4+ states in ^{110}Sn

If there is Z=50 core-breaking:

>> 0+, 2+ and 4+ states can be populated
>> Δl =0, 2 and 4

Experimental observables:

1. Integral cross sections: σ_{0+}, σ_{2+} and σ_{4+}
2. Differential cross section for 4+ state: $\dfrac{d\sigma(\theta)}{d\Omega}$

The population of 2+ and 4+ states will already be the proof of proton core-breaking effect

Experimental details: beam, target and detector setup

Beam

- ✓ ^{109}In at ground state ($9/2^+$) @ 804 MeV~7.38 MeV/u
- ✓ Proton beam + LaC_x target: the expected production yield of ^{109}In is 5×10^9 pps (recent CRIS),
- ✓ Transmission efficiency and post acceleration, the beam intensity on secondary target is estimated be to~1×10^7 pps.

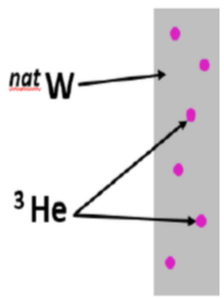
Target

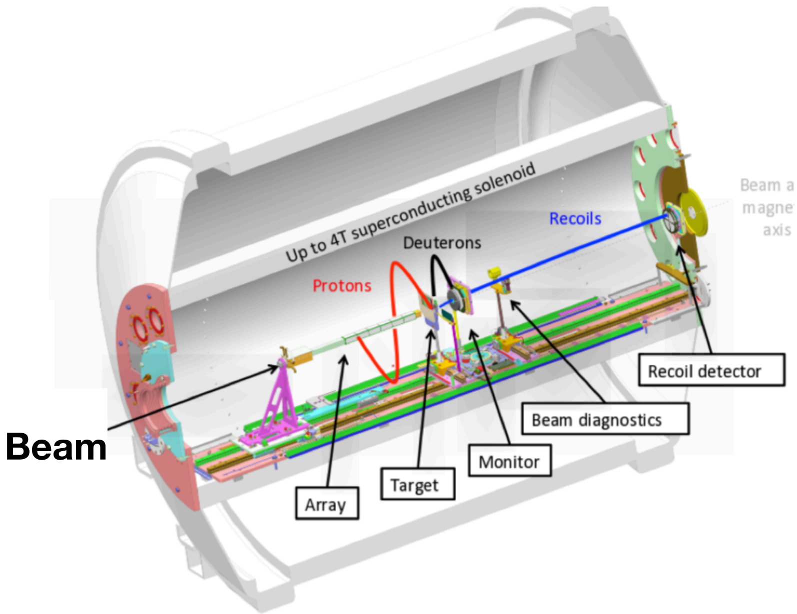
- ✓ ^{3}He @ 0.3×10^{18} atoms/cm^2, Substrate W thickness 0.66 μm
- ✓ Tested at LNL-INFN, intense Zn tandem beam

[A. Fernandez et al., Materials and Design 186, 108337 (2020).]

ISS detector setup

- ✓ Magnetic field : 1.8 T
- ✓ Z position: Around -200 mm — -800 mm
- ✓ Covering angle: Lab 98—160 degree

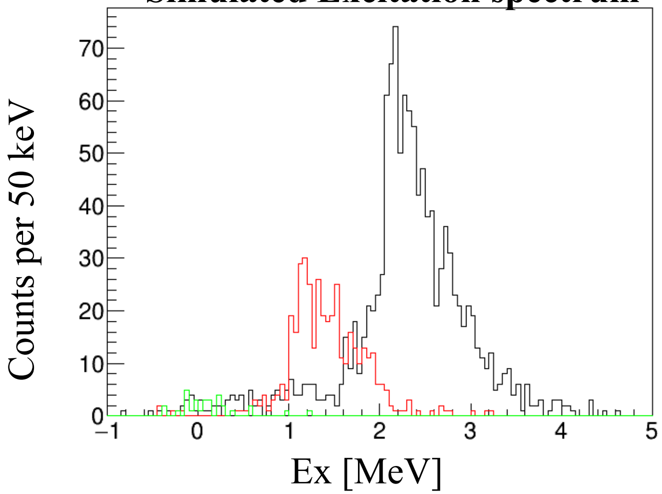




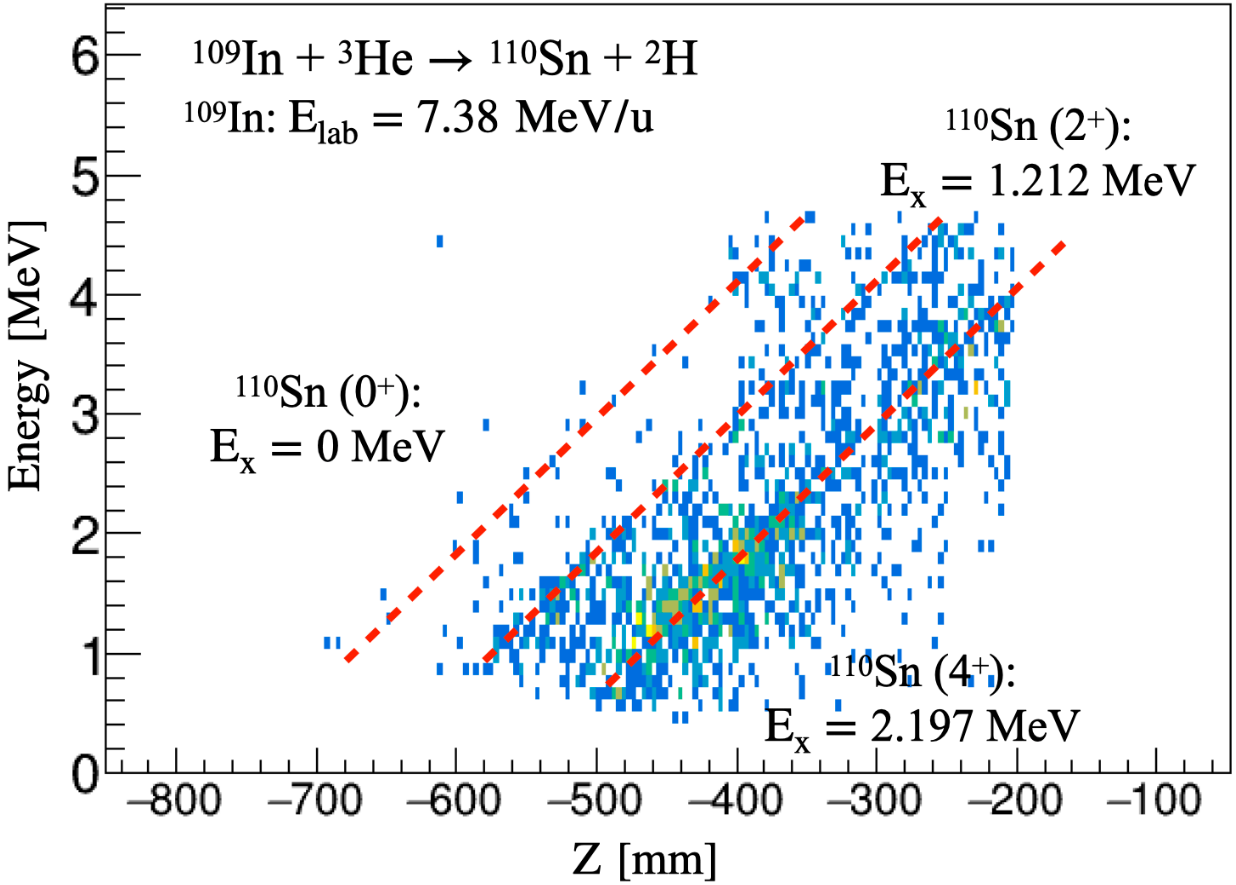
First goal of $^{109}In(^{3}He,^{2}H)^{110}Sn$ measurement: **integral cross section**

- ✓ Realistic Monte-Carlo simulation
- ✓ Using a one-step DWBA approach, cross sections were calculated to be **0.01 mb, 0.25 mb and 0.75 mb** for the **0^+, 2^+, 4^+** states
- ✓ From simulation the 4^+ and 2^+ states can be separated

Simulated Excitation spectrum



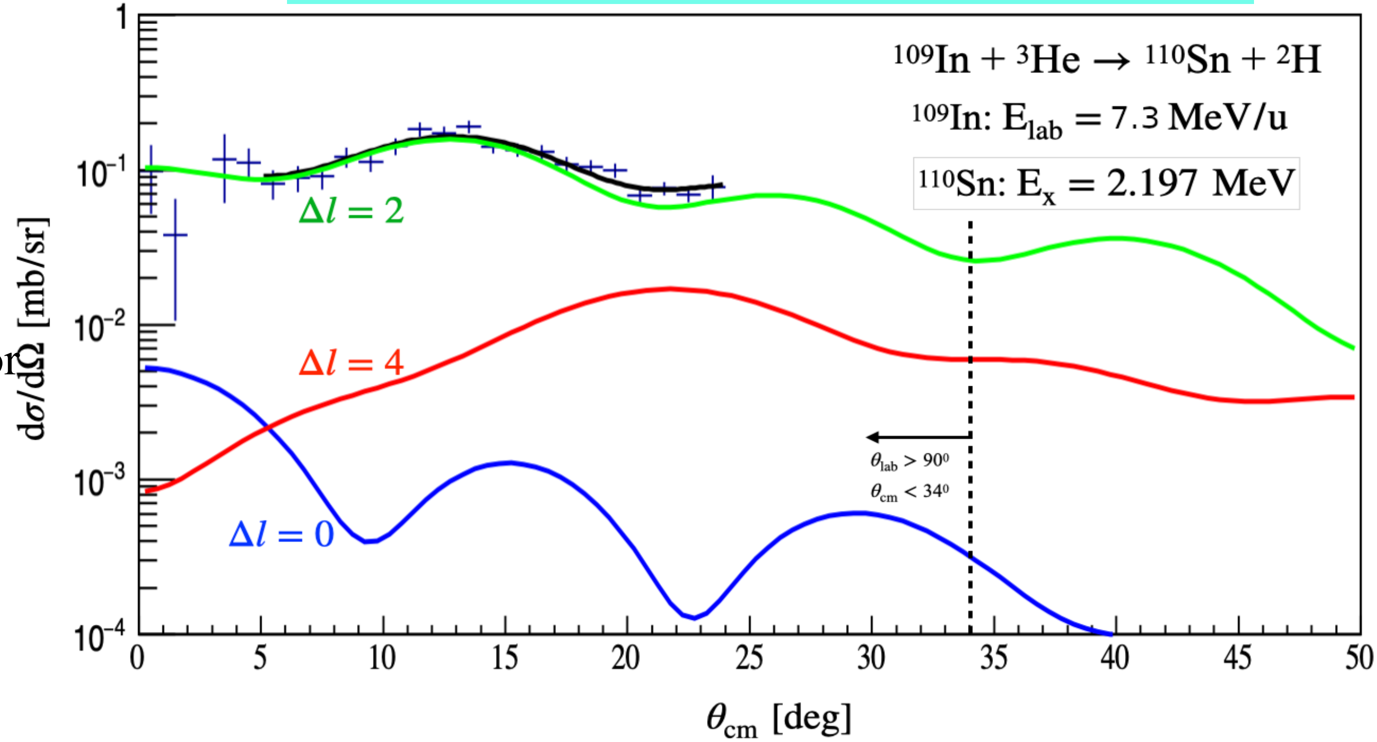
Energy-Z plot of ^{2}He obtained from nptool simulation



Second goal of $^{109}In(^{3}He,^{2}H)^{110}Sn$ measurement: **differential cross section**

- ✓ Realistic Monte-Carlo simulation for the deconvolution of different Δl contributions
- ✓ Each Δl contribution was provisionally taken proportional to the relative s,d,g composition of *4+* wave function (priv. commu. with author of T. Togashi,et al., prl 121, 062501 (2018))
- ✓ Relative weights are **7%, 80%** and **13%** for **s1/2, d5/2+d3/2, g7/2** of proton core-breaking configurations
- ✓ Fitting the simulated result shows: Δl =2 deconvolution is dominant, and its ratio is revealed within 20% error bar

Differential angular distribution of 2He from Nptool simulation



TAC questions:

(1)The TAC notes that there are some concerns with the proposal. The ratio of isomers needs to be addressed.

Answer: The isomer (1/2-) ratio of ^{109}In is ***3%*** measured the recent CRIS experiment (using RILIS), thus the main component would be ^{109}In with the ground state ($9/2^+$), which is needed for the experiment. The error introduced by the isomer will be ***within the statistic error***.

(2)The minimum intensity should be discussed given the strength of the primary beam, if lower rates can be accepted a re-classification of the hall may not be required.

Answer: The intensity of ^{109}In cannot be decreased for preserving the scientific goals.

Summary of $^{109}In(^{3}He,^{2}H)^{110}Sn$ measurement

- ✓ ^{109}In @ 804 MeV~7.38 MeV/u, beam intensity on secondary target~1x10^{7} pps
- ✓ Secondary target: ^{3}He @ 0.3×10^{18} atoms/cm^{2}, Substrate W thickness 0.66 μm
- ✓ Beam time request: 21 shifts
- ✓ Cross section: (predicted) 0.75 mb for the 4+ state in ^{110}Sn
- ✓ Detected ^{2}H populating 4+ state in ^{110}Sn: 500 counts

Aim and Key observable

(1) The 2^{+} and 4^{+} states in ^{110}Sn can be populated or not?

➡ If not: No proton-holes configurations for 2^{+} and 4^{+} states in ^{110}Sn.

➡ If ***yes***: Experimentally confirmation of proton core-breaking effect.

(2) Measuring the differential cross sections of ^{2}H: Individual $\Delta l =$ **0, 2 or 4** contributions in the population of 4^{+} state.