Category:_____ Proposal #: 37-_____

LBL 88-Inch Cyclotron Beam Time Request Form
For the period of December 4, 2000 through May 28, 2001
To be submitted electronically by Tuesday, October 24, 2000

Experiment Title: Properties of $h_{11/2}$ Proton Bands in the Vicinity of ^{141}Ho

Spokesperson:	**Co-Spokesperson (if applicable)**
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# of 8 hour shifts requested (including tuning time): 15

Beam Ion: ^{54}Fe	Energy: 230-245 MeV	Intensity: 3-5 pnA	Target: ^{92}Mo
Beam Ion:	Energy:	Intensity:	Target:

Dates that are best for you: Dates that you cannot run:	Major Facilities:		Gammasphere Auxiliary Detectors:	
	BEARS	❑	CHICO	❑
	BGS	❑	ICEBall	❑
	+RTC Chem.	❑	**Microball**	✷
	Gammasphere	✷	**Neutron Detectors**	✷
	Hevimets ON	❑	Plunger	❑
	Hevimets OFF	✷		

Abstract of Proposal

We propose to measure excited states in nuclei lying near the deformed proton emitter ^{141}Ho. The nuclei of most interest are ^{139}Tb, ^{140}Dy and ^{143}Ho. The production cross-sections for these nuclei are expected to range between 1-100 μb and will require the use of both microball and the neutron shell to be used in conjunction with Gammasphere in order to isolate gamma-rays associated with these residues. The goal of this experiment is to provide a better understanding on the evolution of shape and its influence on the Coriolis mxing of the $h_{11/2}$ proton bands lying near the vicinity of ^{141}Ho

Brief description of the status of any PAC-approved experiments from the last period

Other Participants	Institution	Status (i.e. Faculty, Grad Student)	E-Mail
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(attach additional page if not enough room)

For requests for beams of rare isotopes, can you supply it? Otherwise, please justify your need for that particular ion(s).

Group Safety Person: _____ Phone# _____

Safety Considerations (please circle):

Radioactive Targets	N	if Y: Total Activity of the targets _____Ci		
User-supplied Apparatus	N	Beam wobbler		N
Flammable or Toxic Substances	N	Slammer Valve		N
Pressure Vessels	N	Unsealed Sources		N
High Voltage Equipment	N	Sealed Sources	Y	
Microwave Sources	N	Activation Products		N
Biohazards	N	Other		N

Please explain any Yes answers: Gamma sources for calibration and efficiency measurment of Gammasphere.

Properties of $h_{11/2}$ Proton Bands in the Vicinity of ^{141}Ho

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Abstract: We propose to measure excited states in nuclei lying near the deformed proton emitter ^{141}Ho. The nuclides of most interest are ^{139}Tb, ^{140}Dy and ^{143}Ho. The production cross-sections for these nuclei are expected to range between 1-100 μb and will require microball and the neutron shell to be used in conjunction with Gammasphere in order to isolate gamma-rays associated with these residues. The goal of this experiment is to provide a better understanding on the evolution of shape and its influence on the Coriolis mixing of the $h_{11/2}$ proton bands lying near the vicinity of ^{141}Ho.

Physics Motivation:

Over the last several years, our collaboration has attempted to enhance information obtained in proton decay work by measuring the level structure built on top of these proton emitters. These studies have been performed by coupling a gamma-ray array with the Fragment Mass Analyzer. Of particular interest has been the A~140 region where one observes a transition from spherical to deformed emitters as one moves from Lu to Eu nuclei. For example, a study of excited states in the proton emitter ^{147}Tm (N=78) by our collaboration [1] using the Recoil Decay Tagging technique was able to demonstrate the onset of modest deformation ($\beta_2 \sim 0.13$) in this nucleus where the observed gamma-ray sequence is interpreted as a rotationally-aligned $\pi h_{11/2}$ configuration coupled to the 0^+, 2^+, 4^+, and 6^+ states of the core. A similar situation is also observed in ^{145}Ho [2] where the level sequence built on the $h_{11/2}$ bandhead is very similar to that found for the ground-state band of the isotone ^{147}Tm. It has been shown that good agreement for the proton decay rates of the ^{147}Tm ground and isomeric states can be achieved assuming deformations in the range $\beta_2 \sim 0.1$-0.2 [3]. However, calculations using spherical shell model basis states are also able to reproduce the decay rates well.

For the case of N=76, ^{145}Tm has been identified as a proton emitter [4]. Using a spherical shell model basis, one is able to reproduce the decay rate for the ground-state assuming it is built on the $h_{11/2}$ proton orbital. The ^{143}Ho nucleus (N=76) is almost certainly proton-unbound but not enough for proton radioactivity to occur and no information on excited states in this nucleus is available. Even though the proton decay rate in ^{145}Tm can be reproduced using a spherical basis, both ^{145}Tm and ^{143}Ho are predicted to be moderately deformed [5]. Evidence for this comes from the measured yrast band in ^{142}Dy whose

moment of inertia indicates a moderate deformation of β_2~0.2. Therefore, it appears that N=76 represents a transitional region between the well deformed (N<76) and near spherical regions (N>76).[1]

In the case of the proton emitter ^{141}Ho (N=74), the deduced spectroscopic factors are not reproduced for either the ground- [6] or isomeric-states [7] using a spherical shell model basis. However, the decay rates can be explained by using, for example, the mutiparticle theory of proton emission from deformed nuclei by Bugrov and Kadmensky [6]. From this type of analysis, one concludes that the ground and isomeric-state are built on the 7/2[523] and 1/2[411] Nilsson configurations, respectively, with deformations β_2 ~0.25. In order to confirm these conclusions, we have measured in-beam γ-rays emitted from ^{141}Ho using Gammasphere coupled to the FMA. From these data, a rotational band was placed on top of both states (see fig. 1), and the deduced deformations are consistent with those extracted from the proton decay rates [8]. While an analysis of the moment inertia for each band supports the Nilsson configurations assigned from the proton decay work, the large signature splitting seen for the 7/2[523] band indicates substantial Coriolis mixing in the wavefunction. Recently, calculations of lifetimes for deformed proton emitters have been carried out which include the Coriolis interaction [9]. Interestingly, the lifetimes calculated in this model for the ground-state decay of ^{141}Ho are a factor of four larger than observed experimentally, possibly indicating a problem in the treatment of the Coriolis strength.

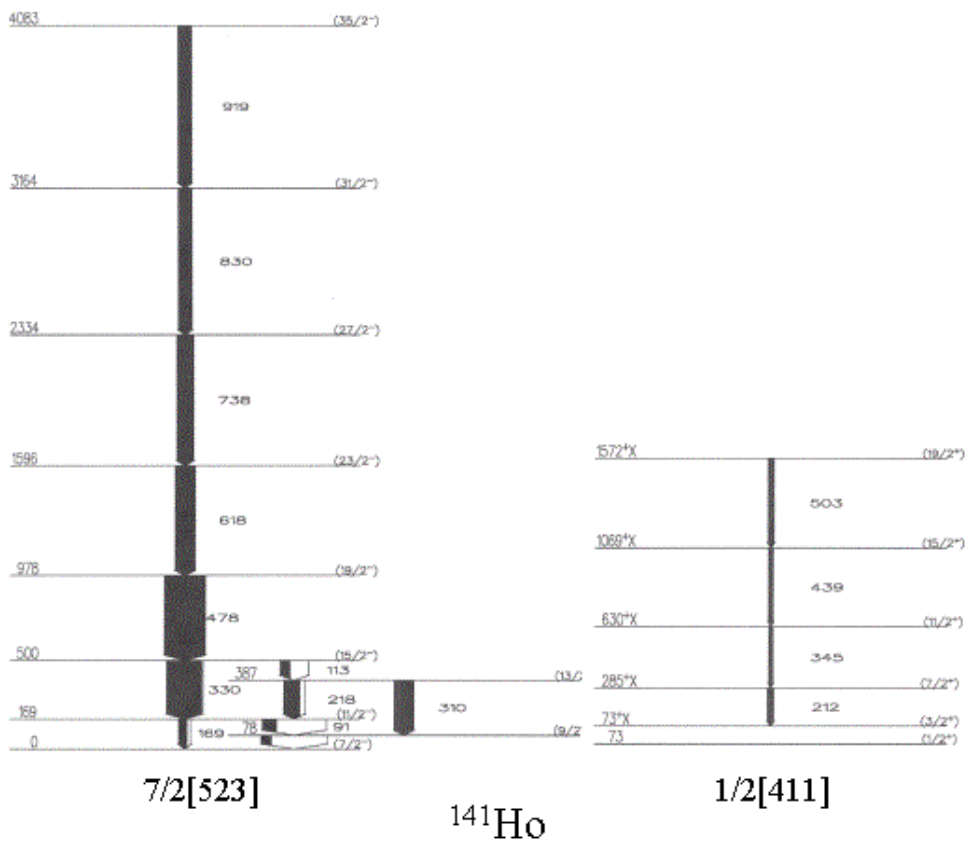

Figure 1: Level structure deduced for ^{141}Ho from the work of ref. [8]. Note the large signature splitting observed for the 7/2[523] band.

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[1]In analogy, a rapid change is observed on the other side of the N=82 gap with regards to the properties of the rotational band built on the $h_{11/2}$ orbital. In ^{155}Ho, the band head has spin $11/2^-$,large signature splitting and a corresponding deformaton of β_2~0.15. In ^{157}Ho, the band head has a spin of $7/2^-$, reduced signature splitting, and a deformation of β_2~0.25.

There are several possible explanations for the presence of signature splitting in the 7/2[523] band of ^{141}Ho. For example, an increase in signature splitting would be expected for a triaxial shape or a for large β_4 deformation. In order to better understand the underlying cause for Coriolis mixing in the ground state of ^{141}Ho, as well as to offer more stringent tests of models calculating decay rates in deformed proton emitters, we propose to measure excited states in ^{143}Ho, ^{140}Dy and ^{139}Tb. The physics motivation in studying each of the three nuclei is as follows:

- In the case of ^{143}Ho, the deformation and composition of the $h_{11/2}$ wavefunction can be inferred by measuring the rotational band built on this state and determining the moment of inertia, frequency of the first band crossing, energy splitting between the two signatures, and B(M1)/B(E2) ratios. Since we expect the properties of the $h_{11/2}$ band to be similar in ^{143}Ho and ^{145}Tm, the γ-ray data on ^{143}Ho would allow us to independently test the ground state properties deduced for ^{145}Tm from the proton decay work. In addition, new data on ^{143}Ho coupled with the recent results on ^{141}Ho will provide valuable information on the evolution of the $h_{11/2}$ band with increasing deformation. These results can then be compared to deformation self-consistent calculations in order to see if they adequately reproduce the trends in the experimental data *e.g.*, signature splitting.

- ^{140}Dy is the daughter to ^{141}Ho and no information is currently available on excited states in this nucleus. One way to measure the 2^+ energy would be to observe decays from the ground state in ^{141}Ho to the 2^+ state in ^{140}Dy. No evidence for this decay is found in our experimental data, and we have placed an upper limit on the branching ratio between 2^+ and 0^+ decays at 1%. In the proton decay models, this branching ratio depends sensitively on the configuration of the parent state as well as on the excitation energy of the 2^+ state in the daughter. Based on the deformation for the proton emitting states in ^{141}Ho, we estimate the energy for the 2^+ state in ^{140}Dy to be at 190 keV, and in the calculations of ref.~[9] this would yield an expected branching ratio of ~3% for the 7/2[523] configuration. Clearly, a measurement of the 2+ energy coupled with our upper limit on this branching ratio would provide a further test of theoretical models.

- A measurement of rotational properties of the $h_{11/2}$ proton band in ^{139}Tb (N=74) would provide further experimental information on the evolution of Coriolis mixing in the $h_{11/2}$ bands in the vicinity of ^{141}Ho. For this case, the deformations of ^{139}Tb and ^{141}Ho are expected to be similar, however, the lowering of the proton Fermi surface in ^{139}Tb should result in larger Coriolis mixing in the $h_{11/2}$ band.

Experiment:

We propose to study the exited states in ^{143}Ho, ^{140}Dy and ^{139}Tb and neighboring nuclei using Gammasphere, Microball, and the Neutron Shell. These nuclei will be produced by bombarding a 500 mg/cm^2 ^{92}Mo target with a ^{54}Fe beam. The bombarding energy (240 MeV) is chosen to produce predominately 3 and 4 particle out channels. ^{143}Ho will be produced by the p2n channel at an estimated cross-section between 50 -100 μb. ^{140}Dy and ^{139}Tb will be produced in the α2n and αp2n channels at an estimated cross-section of 1-10 μb. While it appears that the ^{143}Ho is well within the sensitivity of Gammasphere coupled to microball and the neutron shell, the other two cases are at the limit of sensitivity for this configuration of Gammasphere. It should also be noted that the optimal population cross-sections for ^{141}Ho using this same reaction is less than 500 nb. Due to the low production cross-sections expected for the nuclides of interest, we request five days of beam time for this measurement.

References

[1] D. Seweryniak *et al*., Phys. Rev C **55**, R2137 (1997).

[2] L. Goettig *et al*., Z. Phys. A 475, 569 (1987).

[3] V. P. Bugrov and S. G. Kadmenskii, Sov. J. Nucl. Phys. 49, 967 (1989).

[4] J.C. Batchelder *et al*., Phys. Rev. C **57**, R1042 (1998).

[5] P. Moller *et al*., At. Nucl. Dat. Tables **59,** 185 (1995).

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[8] D. Seweryniak *et al*., submitted for publication in Phyical Review Letters.

[9] A.T. Kruppa *et al*., Phys. Rev. Lett. **84**, 4549 (2000).