長期課題管理番号	
共通利用番号	
受理年月日	

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大強度陽子加速器施設（J-PARC）　物質・生命科学実験施設

一般利用課題（長期）・個別テーマ課題申請書

Form of Final Application for Long-Term Proposal at MLF (Individual Experiments)

J-PARC センター長殿

To Director of J-PARC center

Date of Application: (17/05/2023)

(*)マークは入力必須項目です。[(*) Mandatory]

０）個別課題の研究代表者情報　[Information of individual experiment's principal investigator]

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所属機関・部局　Affiliation(*)	Indiana University Department of Physics
職名　Status(*)	Professor and Center Director
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１）基本情報　[Basic information]

ｉ）研究課題名（英語）(*)　[Title of project research (in English)]

Transmission Measurements with Polarized Epithermal Neutrons and Unpolarized (n, γ) Angular Distribution Measurements for Parity Violation and Time Reversal Violation Physics

ii）研究概要（英語）(*)　[Abstract of project research (in English)]

We propose to search for new p-wave resonances in several heavy nuclei using two different techniques: parity-odd total cross section through the (n, γ) channel and parity-even (n, γ) angular distributions. If we discover evidence for large mixing of opposite parity levels in one or more of these nuclei they could become new candidates for our planned search for time reversal violation in polarized neutron/polarized nucleus transmission by the NOPTREX collaboration. This information will also help test the existing theory for parity-odd mixing in heavy nuclei. We will look for P-odd asymmetries and for new p-wave resonances using (n, γ) angular distributions in ~15 nuclei with 140<A<180A and nonzero spin, with emphasis on nuclei with I=1/2. This proposal builds on our successful series of measurements on ANNRI of gamma angular distributions which determine the κ(J) parameter on many p-wave resonances using (n, γ) reactions, on the recent JPARC advancements in the development of neutron polarizers based on transmission through polarized ^{3}He gas, and on our successful optimization of the germanium gamma detector array on ANNRI. We have recently proven that all required apparatus components are ready by measuring the P-odd asymmetry in ^{139}La in the ANNRI Ge detector array.

iii）利用ビームライン（実験装置）（複数不可）と所要日数(*)　[Requested beamline and beamtime]

Beamline	Beamtime
BL04	3 年目（3rd year）2023B 9 日
主要 BL かどうか（Main instrument）？	（days）
（ yes / no ）	2024A 9 日
	（days）

2）リエゾン　[Liaison(s)]

氏名 Name(*)、職位 Status(*)、所属 Affiliation(*)、E-mail(*)
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3）共同研究者　[Collaborator(s)]

氏名 Name(*)、職位 Status(*)、所属 Affiliation(*)、E-mail(*)、役割 Role(*)
William Michael Snow, Professor, Indiana Univ., wsnow@indiana.edu, Management, Experimental Design, Measurement, Analysis Clayton Auton, Graduate Student, Indiana University, cauton@iu.edu, Measurement, Analysis, ^{3}He R&D Kylie Dickerson, Graduate Student, Indiana University, kyadi@iu.edu, Measurement, Analysis Gabe Otero, Graduate Student, Indiana University, goterom@iu.edu, Measurement, Analysis Mofan Zhang, Graduate Student, Indiana University, zhangmo@iu.edu, Measurement, Analysis Ivan Novikov, Professor, Western Kentucky University, ivan.novikov@wku.edu, Design, Measurement, Analysis David Bowman, Senior Scientist, Oak Ridge National Lab, bowmanjd@ornl.gov, Design, Analysis. Seppo Penttila, Senior Staff Scientist, Oak Ridge National Lab, penttilasi@ornl.gov, Design, Measurement, Analysis Vladimir Gudkov, Professor of Physics, University of South Carolina, vgudkov0@mailbox.sc.edu Analysis, Theoretical Support Jason Fry, Assistant Professor, Eastern Kentucky University, jason.fry@eku.edu, Design, Measurement, Analysis Danielle Schaper, Postdoc, Los Alamos National Lab, dcsc225@g.uky.edu, Measurement, Analysis Paul King, Lecturer, Ohio University, kingp1@ohio.edu, Measurement, Analysis Chris Crawford, Professor, University of Kentucky, cbcraw2@g.uky.edu, Measurement, Analysis Libertad Barron Palos, Professor, National Autonomous University of Mexico, libertad.barron@mail.com, Measurement, Analysis Luis Charon Garcia, Graduate Student, National Autonomous University of Mexico, lcharon1991@gmail.com, Analysis Alberto Perez Martin, Graduate Student, National Autonomous University of Mexico, albepm89@gmail.com, Analysis Damon Spayde, Professor, Hendrix College, Spayde@hendrix.edu, Analysis Katsuya Hirota, Associate Professor, Nagoya Univ., hirota@phi.phys.nagoya-u.jp, Design Masaaki Kitaguchi, Associate Professor, Nagoya Univ., kitaguchi@phi.phys.nagoya-u.jp, Design Tamaki Yoshioka, Associate Professor, Nagoya Univ., yoshioka@phys.kyushu-u.ac.jp, Design Tatsushi Shima, Associate Professor, Nagoya Univ., shima@rcnp.osaka-u.ac.jp, Design Hiroyuki Fujioka, Associate Professor, Tokyo Institute of Technology, fujioka@phys.titech.ac.jp, Design Takashi Ino, Lecturer, KEK, takashi.ino@kek.jp, Design

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合計 42 名 [Total number of collaborator(s)]

４）研究計画（5 ページ以内）(*) ［ Research Plan (within 5 pages) ］

The purpose of experiments in cycle 2023B is to use the apparatus components tested in 2023A to search for parity violation in selected 140<A<180 nuclei with nonzero spin and reasonable isotopic abundances which could be used in the NOPTREX experiment if a p-wave resonance with a large P-odd asymmetry is discovered. The first two nuclei to be measured will be ^{169}Tm and ^{171}Yb, both I=1/2. The next priorities are ^{149}Sm, ^{151}Eu, ^{167}Er, and ^{165}Ho. In addition this experiment can at the same time search for asymmetries in unpolarized parity even (n, γ) angular distributions by properly averaging the data from the two spin states. Both of these measurements can be performed using the ANNRI Ge detector and a thin target.

The purpose experiments in cycle 2024A is to continue the search for parity violation in selected 140<A<180 nuclei with nonzero spin and reasonable isotopic abundances which could be used in the NOPTREX experiment if a p-wave resonance with a large P-odd asymmetry is discovered. The nuclei to be measured will be chosen from the list: ^{141}Pr, ^{143}Nd, ^{145}Nd, ^{153}Eu, ^{155}Gd, ^{157}Gd, ^{159}Tb, ^{161}Dy, ^{163}Dy, ^{173}Yb, ^{175}Lu, and ^{179}Hf. In addition this experiment can at the same time search for asymmetries in unpolarized (n, γ) angular distributions by averaging as mentioned above. This second measurement can also be performed using the ANNRI Ge detector and a thin target.

This plan is slightly modified based on results from the 2023A beam cycle. The instrumentation for parity violation measurements on ANNRI was successfully tested in cycle 2023A on the NOBORU beamline, and we verified that our apparatus can measure the well-known parity-odd asymmetry on the 0.7 eV p-wave resonance in ^{139}La very recently on the ANNRI Ge detector array. This success means that we can achieve the scientific goals of the original long-term proposal in a technically simpler way by using the polarized ^{3}He neutron spin filter and the ANNRI germanium array, which will be much easier to implement. This conclusion is based on 5 days of unpolarized neutron data taken on BL10 on ^{113}Cd and ^{127}I nuclei, which both have known p-waves in our neutron energy range of interest, and on 2 days of polarized neutron data on ^{139}La. By optimization of the upstream attenuator made of the same material as the target, we showed that we can increase the count rate in the germanium detectors enough to see P-odd effects in the size range of interest. More documentation on these results can be found in the Research Plan for Application document. After deciding to use the Ge array for the P-violation measurements, we have also decided not to pursue the original plan to search for p-wave resonances in nuclei with I=1/2 and 80<A<130 as we cannot implement the required CsI(Tl) downstream detector to enable this part of the original plan.

＜＜1 年目 First Year＞＞

＜＜2 年目 Second Year＞＞

ｉ）実験・解析方法［ Experimental and data analysis methods ］

For these experiments we assume that the ^{3}He for the SEOP polarizer will be pre-polarized before the experiment to save laser optical pumping time on the beamline. Previous work on BL04 and BL10 has shown that we can operate the ^{3}He spin filter and use NMR on the ^{3}He spins to flip the neutron polarization, and that this procedure easily measured the known 10% P-odd asymmetry on ^{139}La. A. Kimura has been consulted in the past on the use of the ^{3}He SEOP polarizer and the insertion of the upstream sample attenuators and it has now been done successfully more than once in BL10.

ⅱ）希望する利用時間と算出根拠［Beamtime request and justification ］

For experiments in 2023B we need 1/2 day for installation of the ^{3}He SEOP system, samples, and upstream attenuator. We can be sensitive to P-odd asymmetries between 1-10 eV neutron energy of about 1% at 4σ significance. This sensitivity is high enough that we can catch any p-wave resonances that could be of interest for NOPTREX. This estimate is based on our measured count rates on ANNRI in the Ge detector on known p-wave resonances in ^{113}Cd and ^{127}I nuclei and using the largest upstream collimation of 2.5 cm diameter, combined with the measured performance of the ^{3}He neutron spin filter at the NOBORU test beam measurement, which showed a ^{3}He polarization of 70%, larger than assumed in our original proposal. We need one day of measurement devoted to each of the nuclei of interest: ^{169}Tm, ^{171}Yb, ^{149}Sm, ^{151}Eu, ^{167}Er, ^{165}Ho, and ^{141}Pr. We also need a small amount of time to recalibrate the apparatus by measuring parity violation in our standard nucleus ^{139}La at its 0.7 eV p-wave resonance. There is also the time to change the both the samples and also the upstream attenuators for each element needed to optimize the signal/noise ratio in the Ge array. We will need also 1/2 day to return the apparatus to the beginning state. We ask for 9 days in 2023B. We can also measure the angular distributions on p-wave resonances in the Ge detector array by averaging the data from the two spin states properly.

ⅲ）散乱実験で希望する Q（または d）領域、またはイメージング実験で希望する空間分解能 （単位を付けること）［ Q (or d) range (scattering experiment) or spatial resolution (imaging experiment) with unit(s) ］

ⅳ）非弾性散乱実験で希望するエネルギー領域か入射エネルギー、またはエネルギー分析イメージング実験で希望するエネルギー（または波長）（単位と分解能を付けること）[Energy range or incident neutron energy/wavelength with unit(s) and resolution ］

full neutron TOF window for all measurements associated with this collective proposal

ⅴ）実験条件［ Experimental conditions ］

{X} 温度［ Temperature range ］: 300 K- 500 K

{X} 圧力［ Pressure range ］: 1x10^{5} Pa- 4 x 10^{5} Pa

{X} 磁場［ Magnetic-field strength］ : 最大［Max］ 0.2 T

{X} ガス［ Gas ］: (使用ガス名) (name of gas) ^{3}He

{ } 危険性［ Possible hazards ］: (化学反応等) (e.g. chemical reaction)

ⅵ）試料および持ち込み機器の準備状況等［ Preparation status of experimental samples and equipment ］

[試料] [Sample] 2023B: ^{169}Tm, ^{171}Yb, ^{149}Sm, ^{151}Eu, ^{167}Er, ^{165}Ho, ^{141}Pr, ^{139}La

準備状況(Preparation status)：{ }いつでも実験可(ready)、{X}現在作成中(＊月までに準備可能) (now preparing (It will be ready by 7/2023.))

放射化(Radioactivity)：{ }なし(None)、{ }放射線同位体(Radioisotope)、{X}放射化物(Activated material) (from previous MLF experiment)

格子パラメーターと空間群（結晶構造解析の場合、分かる範囲で単位を付けて記述すること）Lattice parameter(s) and Space group (for only crystallography users) with unit(s) :

特記事項(Specific note) :

[持ち込み機器] [Equipment which you intend to bring in MLF] (1) ^{3}He spin filter, current mode neutron beam monitor

準備状況(Preparation condition)： {X}いつでも実験可(ready)、{　}現在製作中(＊月までに準備可能) (Now preparing (It will be ready by ___.))

放射化(Radioactivity)： {　}なし(None)、{　}放射化物(Activated material)

特記事項(Specific note)：

＜＜3 年目 Third Year＞＞

ⅰ）実験・解析方法［ Experimental and data analysis methods ］

For these experiments we assume that the ^{3}He for the SEOP polarizer will be pre-polarized before the experiment to save laser optical pumping time on the beamline. Previous work on BL04 and BL10 has shown that we can operate the ^{3}He spin filter and use NMR on the ^{3}He spins to flip the neutron polarization, and that this procedure easily measured the known 10% P-odd asymmetry on ^{139}La. A. Kimura has been consulted in the past on the use of the ^{3}He SEOP polarizer and the insertion of the upstream sample attenuators and it has now been done successfully more than once in BL10.

ⅱ）希望する利用時間と算出根拠［Beamtime request and justification ］

For experiment in 2024A we also assume 1/2 day for installation. To get the same accuracy as in 2023B we need one day of measurement devoted to each of the 8 elements with the 11 isotopes of interest: ^{143}Nd, ^{145}Nd, ^{153}Eu, ^{155}Gd, ^{157}Gd, ^{159}Tb, ^{161}Dy, ^{163}Dy, ^{173}Yb, ^{175}Lu, and ^{179}Hf. We also need some time to recalibrate the apparatus by measuring parity violation in our standard nucleus ^{139}La at its 0.7 eV p-wave resonance. In addition this experiment can at the same time search for asymmetries in unpolarized (n, γ) angular distributions by properly averaging the results in the two spin states in the same nuclei. There is also the time to change the both the samples and also the upstream attenuators for each element needed to optimize the signal/noise ratio in the Ge array. We will need also 1/2 day to return the apparatus to the beginning state. We ask for 9 days. The justification for the beamtime estimates is the same as for 2023B.

ⅲ）散乱実験で希望する Q（または d）領域、またはイメージング実験で希望する空間分解能　（単位を付けること）［ Q (or d) range (scattering experiment) or spatial resolution (imaging experiment) with unit(s) ］

ⅳ）非弾性散乱実験で希望するエネルギー領域か入射エネルギー、またはエネルギー分析イメージング実験で希望するエネルギー（または波長）（単位と分解能を付けること）[Energy range or incident neutron energy/wavelength with unit(s) and resolution ］

full neutron TOF window for all measurements associated with this collective proposal

ⅴ）実験条件［ Experimental conditions ］

{X} 温度［ Temperature range ］： 300 K- 500 K

{X} 圧力［ Pressure range ］: 1x10^5 Pa- 4 x 10^5 Pa

{X} 磁場［ Magnetic-field strength］ ：最大［Max］ 0.2 T

{X} ガス［ Gas ］： (使用ガス名) (name of gas) ^{3}He

{　} 危険性［ Possible hazards ］： (化学反応等) (e.g. chemical reaction)

vi）試料および持ち込み機器の準備状況等［ Preparation status of experimental samples and equipment ］

[試料] [Sample] 2024A: ^{143}Nd, ^{145}Nd, ^{153}Eu, ^{155}Gd, ^{157}Gd, ^{159}Tb, ^{161}Dy, ^{163}Dy, ^{173}Yb, ^{175}Lu, ^{179}Hf, ^{139}La
準備状況(Preparation status)： { }いつでも実験可(ready)、{X}現在作成中(＊月までに準備可能) (now preparing (It will be ready by 9/2023.))
放射化(Radioactivity)： { }なし(None)、{ }放射線同位体(Radioisotope)、{X}放射化物(Activated material) (from previous MLF experiment)
格子パラメーターと空間群（結晶構造解析の場合、分かる範囲で単位を付けて記述すること）Lattice parameter(s) and Space group (for only crystallography users) with unit(s)：
特記事項(Specific note)：

[持ち込み機器] [Equipment which you intend to bring in MLF] (1) ^{3}He spin filter, current mode neutron beam monitor
準備状況(Preparation condition)： {X}いつでも実験可(ready)、{ }現在製作中(＊月までに準備可能) (Now preparing (It will be ready by ___.))
放射化(Radioactivity)： { }なし(None)、{ }放射化物(Activated material)
特記事項(Specific note)：

5）実験試料等　[Experimental sample(s)]

物質名、化学式（組成も記入すること。略称不可。）、物理的形態、寸法及び重量（単位を付けること。）、混合物（不純物）、試料容器 [Name of substance, Chemical formula of the sample, Form of the sample, Size and weight of the sample with unit(s), Inclusions (Impurities), Sample container]
＜＜1 年目（ First Year ）＞＞ ＜＜2 年目（ Second Year ）＞＞ ^{169}Tm, ^{171}Yb, ^{149}Sm, ^{151}Eu, ^{167}Er, ^{165}Ho, ^{141}Pr, ^{139}La, metal oxides in sealed Teflon film. All nuclei will be in natural isotopic abundance form. ＜＜3 年目（ Third Year ）＞＞ ^{143}Nd, ^{145}Nd, ^{153}Eu, ^{155}Gd, ^{157}Gd, ^{159}Tb, ^{161}Dy, ^{163}Dy, ^{173}Yb, ^{175}Lu, ^{179}Hf, ^{139}La, metal oxides in sealed Teflon film. All nuclei will be in natural isotopic abundance form.

6）必要とするその他の装置・器具　[Additional equipment(s) and consumable(s) which you need at MLF]

＜＜1 年目（ First Year ）＞＞ ＜＜2 年目（ Second Year ）＞＞ Indiana University has shipped the current-mode transmission detector. The DAQ for parity violation can be supplied by Indiana University as a copy of the same DAQ used successfully on the NOBORU test beam. JPARC will prepare the ^{3}He neutron spin filter that can be operated continuously on the ANNRI beamline. ＜＜3 年目（ Third Year ）＞＞ Indiana University has shipped the current-mode transmission detector. The DAQ for parity violation can be supplied by Indiana University as a copy of the same DAQ used successfully on the NOBORU test beam. JPARC will prepare the ^{3}He neutron spin filter that can be operated continuously on the ANNRI beamline.

7）持ち込み装置　[Experimental equipment(s) which you bring in MLF]

＜＜1 年目（ First Year ）＞＞

＜＜2 年目（ Second Year ）＞＞ Already developed and at MLF

＜＜3 年目（ Third Year ）＞＞ Already developed and at MLF