

2023 RaDIATE Collaboration Meeting



Report of Contributions

Contribution ID: 3

Type: **not specified**

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Presenter: PELLEMOINE, Frederique (fpellemo@fnal.gov)

Contribution ID: 5

Type: **not specified**

Measurement of displacement cross section for high-energy protons and future plan for material damage using 400 MeV protons at J-PARC

Wednesday, 28 June 2023 11:20 (30 minutes)

The material damage index of displacement per atom (dpa) is obtained by the particle flux and the displacement cross section. However, the experimental data of the displacement cross section was scarce. The measurements using proton beams were conducted, and so far, the experimental data of protons up to 30 GeV have been obtained in J-PARC and other Japanese facilities. The displacement cross section was almost constant regardless of the projectile proton energy above several GeV, which is against the expectation because the heat deposition given by the proton increases as projectile energy due to the relativistic theory. The experiment with 120 GeV protons at Fermi National Laboratory (FNAL) was conducted to obtain the data for high-energy regions. In this talk, the experimental data will be presented. To extend the energy region, the experiment with 430-GeV protons at HiRadMat in CERN is planned for the following year.

Additionally, a new beam irradiation facility plan at J-PARC with 400-MeV protons to study material radiation damage will be presented in this talk. In 2022, the user community of the facility was established. New users, especially those outside of Japan, will be welcomed.

Primary author: Dr MEIGO, Shin-ichiro (J-PARC/JAEA)

Presenter: Dr MEIGO, Shin-ichiro (J-PARC/JAEA)

Session Classification: Talks

Contribution ID: 6

Type: **not specified**

Material Irradiation Studies at ISAC-TRIUMF: Progress, Highlights, and Prospects

Monday, 26 June 2023 14:40 (30 minutes)

Following the successful implementation of the ISAC parasitic irradiation pilot program in 2021, material irradiation targets have become a routine part of the ISAC target operational schedule. To date, a total of 12 in-beam parasitic targets have been irradiated, resulting in the examination of approximately 300 samples irradiated up to 3.5 DPA-NRT and 100 appm He/DPA. The materials studied comprise five different metallic material candidates for beam intercepting components including additive manufacturing aluminum alloy and high entropy alloys. Furthermore, off-beam irradiation of polymeric materials has been conducted to evaluate the use of PEEK (Polyether Ether Ketone) in future ARIEL target vessels to doses up to 100MGy. Mechanical and microstructural characterization of the irradiated metallic samples has been performed using small punch testing (SPT) at TRIUMF and transmission electron microscope (TEM) in collaboration with Canadian Nuclear Laboratories (CNL). Analysis of PEEK degradation has been performed by He-leak testing of spring energized PEEK seals, SPT and size exclusion chromatography (SEC). Moving forward, collaboration with CNL and other external institutions in the field of small modular reactors (SMRs) have the prospects of irradiating materials at high temperatures for which upgraded capabilities will be required. This overview will highlight findings from previous studies and discuss the plans for future irradiation campaigns and system upgrades for material irradiation studies at TRIUMF.

Primary authors: Dr GOTTBURG, Alexander (TRIUMF); Dr PAMIES, Ferran (TRIUMF)

Presenter: Dr PAMIES, Ferran (TRIUMF)

Session Classification: Talks

Contribution ID: 8

Type: **not specified**

RaDIATE activities at J-PARC

Monday, 26 June 2023 13:40 (30 minutes)

J-PARC (Japan Proton Accelerator Research Complex) consists of a series of world-class proton accelerators and the experimental facilities that make use of the high-intensity proton beams. Recently, higher intense proton beams are requested due to requirement of further physics research. However, irradiation damage and thermal shock in the target, beam window, and other beam-intercepting components limit the beam intensity and the operation time in future facility. Research of material resistance to irradiation damage and thermal shock is an important issue common to all advanced accelerator facilities in the world. J-PARC officially participated in the international cross-disciplinary collaboration, RaDIATE, Radiation Damage In Accelerator Target Environments, in December 2017. So far, J-PARC has conducted the research mainly under collaboration with Fermi National Accelerator Laboratory by performing high-energy proton irradiation at Brookhaven National Laboratory, Post Irradiation Examination at Pacific Northwest National Laboratory, and thermal shock experiments at CERN-HiRadMat. Furthermore, consisting of experimental facilities such as Neutrino Experimental Facility, Hadron Experimental Facility, and Materials and Life Science Experimental Facility, accelerator facilities such as Linac, Rapid Cycle Synchrotron, and Main Ring, including Cryogenic Section, and Radiation Control Section, the entire J-PARC began to move as a project organized by the Director of J-PARC Center in April 2023. These activities also play an important role in the construction of the J-PARC proton beam irradiation facility. In this presentation, recent RaDIATE activities at J-PARC will be reported.

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Presenter: Dr MAKIMURA, Shunsuke (J-PARC Center, High Energy Accelerator Research Organization)

Session Classification: Talks

Contribution ID: 9

Type: **not specified**

Updates in Material R&D for multi-MW Accelerator Components under US-Japan and RaDIATE Collaboration in High Energy Physics

Monday, 26 June 2023 15:10 (30 minutes)

With the projected increase in beam intensities at forthcoming multi-megawatt accelerator facilities, it is crucial to address the challenges posed by greater thermal stress waves and dynamic loads experienced by beam intercepting components like beam windows and targets. Additionally, these components are susceptible to radiation damage, which can significantly impact their operational lifespan. Therefore, understanding the mechanisms behind such damage in accelerator conditions and implementing effective mitigation strategies become imperative. US Japan collaboration in high energy physics has been instrumental in supporting this research over the past several years and committed to do so in future. With its support we have carried out several activities in material testing, focusing on characterizing damage induced by proton beam irradiation and its consequent effects on mechanical properties of both existing and novel materials. A Thermal-shock experiment was carried out using intense pulsed proton beam at CERN on variety of novel materials and alloy to check the survivability of potential novel materials in future high-power accelerators and preliminary results are presented. Future research activities are planned and funding is secured from the funding agency for the next two years.

Primary author: BIDHAR, Sujit (Fermi National Accelerator Lab)

Co-authors: SENOR, David (Pacific Northwestern National Lab); CASELLA, Andrew (2Pacific Northwestern National laboratory); ROY, Ankit (2Pacific Northwestern National laboratory); PELLEMOINE, Frederique (Fermi National Accelerator laboratory); YONEHARA, Katsuya (Fermi National Accelerator laboratory); AMMIGAN, Kavin (Fermi National Accelerator laboratory); KIM, Dohyun (Brookhaven National Lab)

Presenter: BIDHAR, Sujit (Fermi National Accelerator Lab)

Session Classification: Talks

Contribution ID: 10

Type: **not specified**

Crystal damage and porosity evolution in proton irradiated POCO graphite

Wednesday, 28 June 2023 10:50 (30 minutes)

We present post irradiation examination (PIE) results of a piece of fractured POCO ZXF-5Q graphite fin that was extracted from the NuMI beamline of U.S. FermiLab. This piece of specimen has been irradiated by 340 kW, 120 GeV pulsed protons for producing neutrinos for MINOS/MINERvA high energy physics experiment use. PIE was conducted on this specimen using a novel approach with micro-Raman spectroscopy to quantify total graphite crystal damage evolution across proton irradiation damage gradient. Alongside with this, porosity evolution across this gradient was examined by six high resolution focused ion beam-scanning electron microscopy tomography (FIB-SEM tomography). Results from both techniques purvey notable findings.

Specifically, G-band positions derived from a large number of spectra collected from the POCO graphite specimen possessing proton irradiation damage gradient were plotted with open literature Raman data on HOPG, BEPO, PCEA and IG-110 graphite as a function of carefully calibrated dpa levels. The total damage level within 2σ beam radius in this POCO graphite was estimated to be equivalent to $\sim 2 - 5$ dpa at $\sim 350 - 370^\circ\text{C}$. Derived G-band positions were then mapped to the three-stage amorphization trajectory model indicating beam centre area has entered the second stage, i.e., transitioning from nanocrystalline graphite into amorphous carbon. G-band position relative shift (ΔG) curve with a 'turn-around' peak as a function of total damage can be used for damage monitoring and lifetime prediction at proton beamline in future. The developed methodology has the potential to 'unify' total damage levels across different grades of nuclear graphite subjected to different irradiation species including ions, neutrons and protons at different temperatures.

Porosity studied by FIB-SEM tomography from six locations across damage gradient has been segmented and quantified with a deep learning-based tomographic image segmentation technique. It has been found that there is a decrease in the total volumetric percentage of the porosity at proton beam centre ($\sim 8 - 8.4$ vol.%), by comparing to un-irradiated POCO ($\sim 12 - 13$ vol.%) and to beam 2σ and 5σ radii (~ 12 vol.%). This decrease in porosity volume percentage was found to be caused by the reduction in pores with volumes $> 0.1 \mu\text{m}^3$. The underlying mechanism causing this reduction is not clear in such complicated proton beamline irradiation environment and further investigations are still needed.

Primary author: JIANG, Ming (University of Bristol)

Presenter: JIANG, Ming (University of Bristol)

Session Classification: Talks

Contribution ID: 11

Type: **Invited Talk**

Thermal shock study of clad and bare tungsten target samples

Thursday, 29 June 2023 14:00 (30 minutes)

The Second Target Station (STS) of the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory is currently in the preliminary design phase where extensive research and development is ongoing in support of the progressing target design. Short pulse spallation targets like SNS require an understanding of high cycle fatigue behavior due to the repeated thermal shock from the proton beam. An accurate strain prediction is critical for fatigue life assessment of STS target blocks as they will be subjected to approximately 10^8 beam pulses per lifetime. The Los Alamos Neutron Sciences Center Target 2 (blue room) facility was used to test the strain response of clad and bare tungsten target samples to the thermal shock of a proton pulse. Strain measurements on the outer surface of three target samples (bare tungsten, tantalum-clad tungsten, and niobium-clad tungsten) were recorded for comparison with structural simulations. In general, excellent agreement was achieved between measurement and prediction confirming analysis methods. An overview of the experiment preparation, execution, post-processing, and results will be discussed.

Primary authors: MACH, Justin (Oak Ridge National Laboratory); LEE, Yong Joong (ORNL)

Presenter: MACH, Justin (Oak Ridge National Laboratory)

Session Classification: Talks

Contribution ID: 12

Type: **not specified**

FRIB Linac Beam-Intercepting Device Material Challenges

Thursday, 29 June 2023 13:30 (30 minutes)

The Facility for Rare Isotope Beams (FRIB) is a heavy ion accelerator facility aiming to reach 400-kW primary beams, which will extend the heavy-ion accelerator power frontier by more than one order of magnitude. FRIB's superconducting radio frequency (SRF) continuous-wave heavy-ion linear accelerator can accelerate all the ions up to uranium to energies above 200 MeV/u. The design beam power of 400 kW requires an intense beam, 8 particle μA or 5×10^{13} ions/s in the case of uranium.

FRIB's driver linac uses a charge stripper to remove electrons from the primary beam ions, which increases the energy gain of the beam being accelerated, by approximately a factor of two. The linac was designed to accelerate multiple charge states of the stripped beam. But the charge states beyond the acceptance of the linac are intercepted by a device called the charge selector. These are the two main beam-intercepting devices in the FRIB linac.

The major challenges in these devices are ultra-high volumetric heat density and intense radiation damage. To overcome these challenges, for high power and heavy ions FRIB's charge stripper uses a replenishing thin liquid lithium film, which is highly efficient in the heat removal and free from radiation damage. A rotating carbon foil is used for low power and light ions. The charge selector uses solid slits to stop and remove the unwanted charge states. The slits used currently are positional (to isolate charge states of interest), and static during intercept of beam. They are made of Glidcop and water cooled. This configuration however, has a limitation in acceptable beam power. We are exploring a new design that can support higher power operations. The design we are working on uses graphite wheels with a 150-mm or even larger diameter spinning at <1600 rotations per minute. This design is intended to distribute both thermal load and radiation damage. The greatest uncertainty in this design is the lifetime of the slits that we think is determined by the radiation damage. The radiation damage induced by heavy ions of the FRIB intensity is not well understood. The authors would like to discuss how we approach this challenge and receive valuable comments from experts in the field.

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Co-authors: Dr PLASTUN, Alexander (Michigan State University); Dr MARTI, Felix (Michigan State University); Mr LAVERE, Michael (Michigan State University); Dr BULTMAN, Nathan (Michigan State University); Dr GINTER, Thomas (Michigan State University); Dr MOMOZAKI, Yoichi (Michigan State University); Dr WEI, Jie (Michigan State University)

Presenter: Dr KANEMURA, Takuji (Michigan State University)

Session Classification: Talks

Contribution ID: 13

Type: **Invited Talk**

Irradiation campaign and PIE needs for STS target systems R&D

Tuesday, 27 June 2023 11:10 (30 minutes)

The Second Target Station (STS) at Spallation Neutron Source (SNS) will receive 700 kW proton beam with a very low duty cycle based on a microsecond long pulse with 15 Hz repetition rate. The beam intercepting materials exposed to the high-power proton beam will suffer from long-term radiation damages, including material hardening due to displacement damage, material embrittlement and swelling due to helium production, and thermal and electrical conductivity changes due to solid transmutations. On the other hand, the sub-microsecond long short beam pulses will induce highly transient prompt dynamic thermal and structural loads in the beam intercepting materials. To design a target with a high survivability and reliability, it is important to identify the needs for the irradiation campaign and post irradiation examinations of key functional materials and prototypes. In this talk we provide an overview of the R&D program at STS dedicated to understanding of the long-term and prompt behaviors of materials exposed to intense proton beam.

Primary authors: MACH, Justin (Oak Ridge National Laboratory); LEE, Yong Joong (ORNL)

Presenter: LEE, Yong Joong (ORNL)

Session Classification: Talks

Contribution ID: 14

Type: **Invited Talk**

Novel Materials R&D for Next-Generation Accelerator Target Facilities

Thursday, 29 June 2023 09:40 (30 minutes)

High-Entropy Alloys and Electrospun Nanofiber materials are two novel classes of materials that can offer improved resistance to beam-induced radiation damage and thermal shock. Research to develop these new materials specifically for multi-megawatt accelerator target applications, such as beam windows and particle-production targets, has recently begun. The research program will combine in-beam experiments with complementary simulations to tailor the microstructures of these novel materials for use in next-generation accelerator target facilities. Iterative simulations to optimize the material composition, physics performance and beam-induced thermomechanical response will guide the material design and fabrication processes based on established figures of merit. Ensuing material irradiation experiments using low-energy ions and prototypic high-energy protons, followed by extensive post-irradiation material characterization, will then assess and qualify the selected novel materials. This talk will provide an overview of the novel materials development research program initiated at Fermilab through my DOE Early Career Research Program award.

Primary authors: Dr COUET, Adrien; PELLEMOINE, Frederique (fpellemo@fnal.gov); Dr ARORA, Gaurav; AMMIGAN, Kavin (member@fnal.gov); Dr SZLUFARSKA, Izabela; Mr CRNKOVICH, Nicholas; BIDHAR, Sujit (Fermi National Accelerator Lab)

Presenter: AMMIGAN, Kavin (member@fnal.gov)

Session Classification: Talks

Contribution ID: 15

Type: **Invited Talk**

Exploring High Entropy Alloys for Next-Generation Beam Windows: A Computational Approach

Thursday, 29 June 2023 11:10 (30 minutes)

Beam power and runtime in high energy particle accelerators are currently limited by targets and beam windows. The existing materials used in these components have reached their maximum potential, necessitating the development of a new class of materials known as high entropy alloys (HEAs) to overcome this challenge. Numerous studies have demonstrated that HEAs possess exceptional qualities such as high strength, ductility, and radiation resistance. In this study, we propose an approach that utilizes computational techniques including CALPHAD, density functional theory (DFT), and molecular dynamics (MD) to investigate and comprehend the defect properties of suitable HEAs, which can serve as alternative materials for the next generation of beam windows. Initially, CALPHAD is employed to conduct approximately one hundred thousand simulations, enabling us to narrow down the potential compositions to a select few. Subsequently, we intend to employ a DFT-informed machine learning potential to analyze the defect properties of these narrowed compositions. During this presentation, I will outline the CALPHAD approach implemented to refine the compositions, elucidate the necessity of DFT, and demonstrate the potential usefulness of machine learning in this context.

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Presenter: ARORA, Gaurav (Fermi National Laboratory)

Session Classification: Talks

Contribution ID: 16

Type: **Invited Talk**

Design and Study of High Entropy Alloys for Next Generation Beam Windows

Thursday, 29 June 2023 10:10 (30 minutes)

Targets and beam windows are currently the limiting factors for beam power and runtime for high energy particle accelerators. Thermal shock and fatigue are the primary modes of failure for these components, which is accelerated by irradiation damage from the beam. To achieve the desired increase in beam power and runtime, new materials need to be explored and studied. High Entropy Alloys (HEAs), also known as Compositionally Complex Alloys (CCAs), are a novel class of alloy that have exhibited remarkable strength and radiation resistance. In this study, we develop novel low-density refractory CCAs by coupling CALPHAD-based thermodynamics predictions with traditional alloying principles. Beginning from a previously studied single phase BCC CrMnV ternary (alloy 1), small quantities of Ti was added to act as an impurity getter (alloy 2); Al was added to decrease density (alloy 3) and, with added Co, to promote a coherent B2 phase resulting in strengthening with minimal embrittlement (alloy 4). The first iterations of these alloys have been manufactured and characterized with SEM, TEM, micro and nanoindentation for both as-cast and ion-irradiated samples. In parallel, a study of the effects of nanocrystallinity on the radiation tolerance of beryllium, a current generation window material, is being conducted and will be outlined.

Primary author: CRNKOVICH, NICHOLAS (STUDENT@wisc.edu;MEMBER@wisc.edu;EMPLOYEE@wisc.edu)

Co-authors: COUET, Adrien; AMMIGAN, Kavin (Fermi National Accelerator laboratory); ARORA, Gaurav (Fermi National Laboratory); SZLUFARSKA, Izabela; BIDHAR, Sujit (Fermi National Accelerator Lab); PELLEMOINE, Frederique (Fermi National Accelerator laboratory)

Presenter: CRNKOVICH, NICHOLAS (STUDENT@wisc.edu;MEMBER@wisc.edu;EMPLOYEE@wisc.edu)

Session Classification: Talks

Contribution ID: 17

Type: **Invited Talk**

Developments on RaDIATE-related R&D for CERN's Beam Intercepting Devices

Monday, 26 June 2023 13:10 (30 minutes)

The presentation will cover the developments that have taken place on post-irradiation examination activities that have taken place at CERN since the last collaboration meeting.

It will cover:

- Wrap-up of PIE activities for the CERN2 BLIP capsule
- Results of PIE on Sigraflex specimens extracted from the LHC beam dump autopsy
- Preliminary results from PIE of HiRadMat-RaDIATE Sigraflex specimens
- Results of the HiRadMat-SMAUG Be and Glassy Carbon window experiment
- Progress on the BDF Target PIE

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Presenter: SOLIERI, Nicola (member@cern.ch)

Session Classification: Talks

Contribution ID: 18

Type: **Invited Talk**

Multiphysics Modeling and Simulation for the Development of a Nanofiber Target Concept

Thursday, 29 June 2023 11:40 (30 minutes)

The High Power Targetry Research and Development (HPT R&D) Group at Fermi National Accelerator Laboratory (FNAL) has been investigating a novel target concept which has the potential to withstand high intensity primary beams: a target consisting of electrospun ceramic nanofibers. If successful, these exciting new targets could support the next generation of neutrino facilities, and could have separate applications in medical isotope production as well.

Thermal shock experiments performed by the HPT R&D Group on nanofiber target samples at CERN's HiRadMat facility revealed that the survivability of the nanofiber targets has a strong dependence on the manufacturing parameters of the nanofiber mat, particularly the packing density of the fibers, as samples with a lower packing density showed no damage after beam exposure whereas samples with a higher packing density developed holes at the beam center and became brittle. In order to optimize the performance of these nanofiber targets, the dependency of the targets' performance on their construction parameters must be understood. These nanofiber targets gain advantages due to their nanostructure, such as the ability to be actively cooled by forcing gas through the pores formed by the layered fibers, but this same structure raises challenges to predicting their performance accurately.

In this talk we share some of the multiphysics modeling and simulation work we have pursued in order to support the development of the HPT R&D Group's nanofiber target concept. To this end, we discuss porous media models and how they translate nanoscale effects to the macroscale, thus allowing us to perform multiphysics simulations of how these nanofiber targets respond to a high intensity particle beam. Using this simulation infrastructure, we return to the motivating problem of the HiRadMat tests and identify potential causes for the difference in the samples' performance.

Primary authors: PELLEMOINE, Frederique (Fermi National Accelerator Laboratory); ASZTALOS, William (Illinois Institute of Technology); RATH, Prasenjit (Indian Institute of Technology Bhubaneswar); BIDHAR, Sujit (Fermi National Accelerator Lab); TORUN, Yağmur (Illinois Institute of Technology)

Presenter: ASZTALOS, William (Illinois Institute of Technology)

Session Classification: Talks

Contribution ID: 19

Type: **Invited Talk**

RaDIATE activities in the UK – an update

Monday, 26 June 2023 11:10 (30 minutes)

There are multiple ongoing contributions to the RaDIATE materials science program from universities and public sector research establishments across the UK. Initial funding via the Hyper-K-UK project kick-started academic materials science projects, with new and outstanding research now being supported by the LBNF-UK project.

UK activities are co-ordinated by STFC at Rutherford Appleton Laboratory. The University of Bristol are focusing on graphite, whilst the University of Oxford are performing micro-mechanical studies of proton-irradiated titanium. The University of Birmingham operates the MC40 cyclotron for sample irradiation, and future irradiations are being designed as a collaboration between STFC and the University of Birmingham. Receipt and Post-Irradiation Examination of irradiated specimens will be performed at the Materials Research Facility at the UK Atomic Energy Authority.

This presentation provides an update on the activities from the UK. The motivation and strategy for the research is presented by STFC. Also presented is a sample environment for irradiation of titanium foils at the MC40 cyclotron in Birmingham, incorporating features for transport and remote handling in a hot cell. It is proposed to cool the specimens during irradiation with pressurised nitrogen gas, so an experimental setup has been produced to test this approach. Meanwhile, the University of Oxford has planned a series of experiments on the irradiated fatigue cantilevers currently held at the MRF. A summary is given of the latest investments and equipment development activities at the MRF.

Primary authors: WILKINSON, Angus J (University of Oxford); DENSHAM, Chris (STFC); EARP, Philip (UK Atomic Energy Authority); CAI, Biao (University of Oxford); LIU, Dong (University of Bristol); HARVEY-FISHENDEN, Eric (STFC); SINGH, Jatinder (University of Birmingham); GONG, Jicheng (University of Oxford); PUJILAKSONO, Lazuardi (University of Oxford); FITTON, Mike (STFC); COWAN, Richard (STFC); KUKSENKO, Slava (UK Atomic Energy Authority)

Presenter: EARP, Philip (UK Atomic Energy Authority)

Session Classification: Talks

Contribution ID: 20

Type: **Invited Talk**

Updates to the RaDIATE Collaboration from PNNL

Thursday, 29 June 2023 16:00 (30 minutes)

Since the last RaDIATE meeting in September 2022, PNNL has continued work on characterizing the samples from the BLIP irradiation experiment. Beryllium bend bar testing has been completed, titanium results have been organized, and SiC-coated graphite sample microscopy has been completed. Efforts regarding all three material investigations are at the point in which publication drafts are imminent. Planning for receipt of the HRMT60 samples is complete pending availability of the shipping container at CERN. Plans for continued work in titanium and beryllium microscopy as well as modeling of radiation damage in titanium alloys are in place, but funding for FY24 is currently sufficient for only one of these activities.

Primary authors: Dr CASELLA, Andy (Pacific Northwest National Laboratory); Dr SENOR, David (Pacific Northwest National Laboratory)

Presenter: Dr CASELLA, Andy (Pacific Northwest National Laboratory)

Session Classification: Talks

Contribution ID: 21

Type: **Invited Talk**

LBNF Nu Beamline Radiation Damage R&D Needs

Thursday, 29 June 2023 15:00 (30 minutes)

The Long Baseline Neutrino Facility (LBNF) Project, currently under final design, will deliver neutrino beam to the Deep Underground Neutrino Experiment (DUNE) utilizing 120 GeV proton beam on a graphite target at 1.2 MW in 2031 and up to 2.4 MW by 2036. The LBNF neutrino beamline utilizes several beam intercepting devices that are being designed and built to withstand the cyclic thermal shock of the pulsed beam and provide thermal management of the absorbed power. Although operating parameters have been chosen to be within the realm of previous operational experience with neutrino targets (primarily NuMI at Fermilab and T2K at J-PARC), radiation damage effects on critical properties of the chosen materials are still not fully understood, especially effects on fatigue and dimensional stability. Thus, the LBNF irradiation environment will be challenging and requires an ongoing campaign of R&D to enable stable operations at 2+ MW primary beam power. This talk will introduce the irradiation conditions for the LBNF target, target windows, and absorber and the critical material properties which must be researched. In addition, a brief discussion of how R&D studies can be incorporated into accelerator target facility operations to support codes and standards compliance efforts, which are increasingly being expected at US national laboratories.

Primary author: HURH, P. (FNAL)**Presenter:** HURH, P. (FNAL)**Session Classification:** Talks

Contribution ID: 22

Type: **Invited Talk**

Production of Radioisotopes using Secondary Neutrons at the Brookhaven Linac Isotope Producer

Tuesday, 27 June 2023 10:40 (30 minutes)

The Brookhaven Linac Isotope Producer (BLIP) facility at Brookhaven National Laboratory routinely irradiates targets, using a proton beam of incrementally tunable energy (66-200 MeV) and intensity (up to 170 μA), for the creation of a host of radioisotopes for use in medical applications. During irradiation of these targets, secondary neutrons are generated by proton-induced reactions and have thus far largely been an untapped resource. These neutrons have the potential to produce additional isotopes of interest by placing targets downstream of the proton target stack after the protons have been stopped. Prior to their use for isotope production planning, the emitted neutron spectrum first needs to be characterized. To characterize this production pathway, several different elemental foils were irradiated using secondary neutrons and subsequently analyzed using gamma spectroscopy to measure activation products. After a 30-minute irradiation of the target stack at a proton energy of 200 MeV and beam current of 150 μA , the foils were measured using gamma spectroscopy for the identification and quantification of the isotopes produced during the experiment with secondary neutrons. Following gamma spectra analysis, the deduced activities of several isotopes that serve as flux monitor reaction products were used along with TENDL cross sections to determine a neutron spectrum that can be relied upon for future production planning.

Primary author: Dr SKULSKI, Michael (Brookhaven National Laboratory)

Co-authors: Dr MEDVEDEV, Dmitri G. (BNL); Dr CUTLER, Cathy S. (BNL)

Presenter: Dr SKULSKI, Michael (Brookhaven National Laboratory)

Session Classification: Talks

Contribution ID: 23

Type: **not specified**

LBNF Nu Upstream Decay Pipe Window Radiation Damage R&D Needs

Thursday, 29 June 2023 15:30 (30 minutes)

The Long Baseline Neutrino Facility (LBNF) Project, currently under final design, will deliver neutrino beam to the Deep Underground Neutrino Experiment (DUNE) utilizing 120 GeV proton beam on a graphite target at 1.2 MW in 2031 and up to 2.4 MW by 2036. The LBNF neutrino beamline utilizes several beam intercepting devices that are being designed and built to withstand the cyclic thermal shock of the pulsed beam and provide thermal management of the absorbed power. Although operating parameters have been chosen to be within the realm of previous operational experience with neutrino targets (primarily NuMI at Fermilab and T2K at J-PARC), radiation damage effects on critical properties of the chosen materials are still not fully understood, especially effects on fatigue and dimensional stability. Due to this, a key area requiring R&D studies is the Upstream Decay Pipe Window which will experience direct beam downstream of the target. This talk will introduce the irradiation conditions of the LBNF Upstream Decay Pipe Window, a discussion on areas of concern within the design and possible R&D paths that can be taken, material properties that must be researched, and a brief discussion on some preliminary thermal and structural analyses that has been conducted.

Primary author: PETERSON, Quinn (Fermilab)

Presenter: PETERSON, Quinn (Fermilab)

Session Classification: Talks

Contribution ID: 24

Type: **Invited Talk**

Non-destructive Characterization of Nuclear Materials Through X-ray Absorption And Diffraction Contrast Tomography: Case Study on Surrogate TRISO Particle

Tuesday, 27 June 2023 09:00 (40 minutes)

X-ray scattering techniques coupled with the world-class brightness of the National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory (BNL) enable exceptional opportunities for non-destructive studies of nuclear materials such as uranium alloys. Materials for Energy Applications group at Nuclear Science & Technology Department at BNL partners with 28-ID-2 beamline (XPD) of NSLS-II for providing synchrotron-based characterization resources for nuclear science community under the umbrella of Nuclear Science User Facilities (NSUF). The XPD beamline can focus the x-ray beam down to ~25 um in a high-energy regime (>60 keV) and is intended to be a crosscutting tool that will enable multi-modal studies of high-Z materials, a crucial capability for nuclear materials research. In this talk, I will present examples of previous studies conducted as a result of this partnership. Emphasis will be placed on absorption contrast and diffraction contrast tomography of a surrogate TRi-structural ISotropic particle fuel (TRISO) particle which is known as “the most robust nuclear fuel on earth.”

Primary author: Dr TOPSAKAL, Mehmet (Brookhaven National Laboratory)

Presenter: Dr TOPSAKAL, Mehmet (Brookhaven National Laboratory)

Session Classification: Talks

Contribution ID: 25

Type: **not specified**

Research and development of irradiated materials from targets and proton beam windows at the Spallation Neutron Source

Several research and development projects with samples removed from irradiated components from the Spallation Neutron Source (SNS) are underway or planned. Current projects are focused on understanding atypical radiation-induced phenomena that were observed in 316L stainless steel and solution annealed Inconel 718 after irradiation in components at the SNS. Tensile testing with digital image correlation analysis showed localized deformation band occurred in irradiated 316L specimens during testing and in some specimens the band propagated along the specimen gauge section as a deformation wave. Tensile results of Inconel 718 specimens from a proton beam window (PBW) showed an increase in elongation values with an increase in dose. Characterizations are underway to better understand these phenomena are underway including analytical electron microscopy, differential scanning calorimetry, and thermal desorption spectrometry. Results from these experiments will be presented along with plans to perform tensile tests and microscopy on specimens from irradiated 6061-T6 samples from a PBW. Options for collaborations with RaDIATE participants will also be presented and discussed.

Primary author: MCCLINTOCK, David (ORNL)

Presenter: MCCLINTOCK, David (ORNL)

Session Classification: Talks

Contribution ID: 26

Type: **Invited Talk**

Low current irradiation experiments at BLIP to address nuclear data needs

Tuesday, 27 June 2023 09:40 (30 minutes)

The efficiency of the isotope production process relies critically on the accuracy of the underlying nuclear data. Knowledge of nuclear excitation functions is particularly important for prediction and optimizing irradiation yield and radionuclidic purity of the desired radioisotope. This work is part of US DOE Isotope Program initiated joint effort between BNL, LANL and LBNL to address nuclear data needs for the proton-induced reaction relevant to the production of medical radioisotopes.

The project focuses on measuring nuclear excitation functions for several medical isotopes. The proton energy regions of interest for the excitation functions measurements were designated between the collaborating institutions to take advantage of their proton-generating capabilities. The BNL LINAC delivers up to 200 MeV protons with maximum current of 200 μA . The energy is incrementally tunable to deliver 200, 180, 160, 117, 66 MeV energy protons. The measurements of excitation functions were therefore carried out at proton energies between 100-200 MeV at BNL.

The stacked foil activation technique was employed for cross section measurements at each facility. The foils were intermingled with the beam monitors, foils, and degraders made either out of Al or Cu. BLIP experiments required either adaptation or development of housing to isolate the foils from cooling water. The foils were irradiated at 100-200 nA currents for 1-2 h. The activation of foils was measured nondestructively using gamma spectroscopy.

The obtained excitation functions were in good agreement with experimental data reported previously. Details of the experimental set up, post irradiation analysis and results will be discussed during presentation.

Primary authors: Dr CUTLER, Cathy (Brookhaven National Laboratory); Dr MEDVEDEV, Dmitri (Brookhaven National Laboratory); Dr SKULSKI, Michael (Brookhaven National Laboratory)

Presenter: Dr MEDVEDEV, Dmitri (Brookhaven National Laboratory)

Session Classification: Talks

Contribution ID: 27

Type: **Invited Talk**

Non-destructive Characterization of Nuclear Materials Through X-ray Absorption And Diffraction Contrast Tomography: Case Study on Surrogate TRISO Particle

Primary author: TOPSAKAL, Mehmet (BNL)

Presenter: TOPSAKAL, Mehmet (BNL)

Session Classification: Talks

Contribution ID: 28

Type: **Invited Talk**

The Nick Simos Effect

Tuesday, 27 June 2023 13:30 (20 minutes)

Primary author: HURH, P. (FNAL)

Presenter: HURH, P. (FNAL)

Session Classification: Nick Simos Memorial Session

Contribution ID: 29

Type: **not specified**

Effect Irradiation on Ferro Fluid Rotary Feedthrough and Permanent Magnet Performance

Tuesday, 27 June 2023 13:50 (20 minutes)

Primary author: PELLEMOINE, Frederique (fpellemo@fnal.gov)

Presenter: PELLEMOINE, Frederique (fpellemo@fnal.gov)

Session Classification: Nick Simos Memorial Session

Contribution ID: 30

Type: **not specified**

Simulation of the NuMI Target Graphite Failure Incorporating Measured Irradiated Graphite Data

Tuesday, 27 June 2023 14:10 (20 minutes)

Primary authors: AMMIGAN, Kavin (Fermi National Accelerator laboratory); BIDHAR, Sujit (Fermi National Accelerator Lab)

Presenters: AMMIGAN, Kavin (Fermi National Accelerator laboratory); BIDHAR, Sujit (Fermi National Accelerator Lab)

Session Classification: Nick Simos Memorial Session

Contribution ID: 31

Type: **not specified**

Highlights of NSLS and NSLS-II work with Nick Simos

Tuesday, 27 June 2023 14:30 (30 minutes)

Primary author: SPROUSTER, David

Presenter: SPROUSTER, David

Session Classification: Nick Simos Memorial Session

Contribution ID: 32

Type: **Invited Talk**

Open remarks and moment of silence in remembrance

Tuesday, 27 June 2023 15:00 (30 minutes)

Session Classification: Nick Simos Memorial Session

Contribution ID: 33

Type: **not specified**

Center for Functional Nanomaterials

Wednesday, 28 June 2023 09:00 (40 minutes)

Center for Functional Nanomaterials (CFN) is a DOE Scientific User Facility that provides access to state-of-the-art material characterization and synthesis tools to a scientific community. In this talk I will give an overview of the CFN user program and discuss how the facility can be accessed by external users. I will describe available instrumentation and capabilities relevant to material science and give examples of on-going research and available expertise at the center.

Presenter: NYKYPANCHUK, Dmytro (BNL)

Session Classification: Talks

Contribution ID: 34

Type: **not specified**

Opportunities for Materials Science at Brookhaven's Light Source (NSLS-II)

Wednesday, 28 June 2023 09:40 (40 minutes)

The National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory thrives at delivering world-class x-ray capabilities for studying complex and heterogeneous materials. NSLS-II's beamlines and experimental stations offer unique, cutting-edge research tools, enabling in-situ, operando & extreme environments studies, as well as high throughput and real-time observations. Beamlines are organized into six scientific programs, offering specialized spectroscopy, diffraction and imaging research techniques, supported by computational resources and modeling.

Primary author: DOORYHEE, Eric (BNL)

Presenter: DOORYHEE, Eric (BNL)

Session Classification: Talks

Contribution ID: 35

Type: **not specified**

Medical Isotope Research and Production/BLIP

Thursday, 29 June 2023 09:00 (40 minutes)

Primary author: CUTLER, Cathy (Brookhaven National Laboratory)

Presenter: CUTLER, Cathy (Brookhaven National Laboratory)

Session Classification: Talks

Contribution ID: **36**

Type: **not specified**

National Synchrotron Light Source II

Wednesday, 28 June 2023 13:30 (35 minutes)

Session Classification: Visits

Contribution ID: 37

Type: **not specified**

Center for Functional Nanomaterials

Wednesday, 28 June 2023 14:20 (50 minutes)

Session Classification: Visits

Contribution ID: **38**

Type: **not specified**

Radionuclide Research and Production Laboratory

Wednesday, 28 June 2023 15:30 (30 minutes)

Session Classification: Visits

Contribution ID: **39**

Type: **not specified**

Brookhaven Linac Isotope Producer

Wednesday, 28 June 2023 16:10 (30 minutes)

Session Classification: Visits

Contribution ID: 40

Type: **not specified**

The Proposed High Energy Effects Testing facility at BNL's AGS

Friday, 30 June 2023 09:00 (40 minutes)

The proposed High Energy Effects Test (HEET) facility will be designed to support the needs of the space electronics testing community. It will have high energy reach as well as simulate solar proton events and galactic cosmic rays. I will describe the community needs and the current set of facilities supporting the community and the HEET proposal.

Presenter: BROWN, Kevin (C-AD)

Session Classification: Talks

Contribution ID: 41

Type: **Invited Talk**

Opportunities for Materials Science at Brookhaven's Light Source (NSLS-II)

The National Synchrotron Light Source II (NSLS-II) at Brookhaven National Laboratory thrives at delivering world-class x-ray capabilities for studying complex and heterogeneous materials. NSLS-II's beamlines and experimental stations offer unique, cutting-edge research tools, enabling in-situ, operando & extreme environments studies, as well as high throughput and real-time observations. Beamlines are organized into six scientific programs, offering specialized spectroscopy, diffraction and imaging research techniques, supported by computational resources and modeling.

Primary author: Dr DOORYHEE, Eric (Brookhaven National Laboratory)

Presenter: Dr DOORYHEE, Eric (Brookhaven National Laboratory)

Contribution ID: 42

Type: **not specified**

The Proposed High Energy Effects Testing facility at BNL's AGS"

The proposed High Energy Effects Test (HEET) facility will be designed to support the needs of the space electronics testing community. It will have high energy reach as well as simulate solar proton events and galactic cosmic rays. I will describe the community needs and the current set of facilities supporting the community and the HEET proposal.

Primary author: Dr BROWN, Kevin (Brookhaven National Laboratory)

Presenter: Dr BROWN, Kevin (Brookhaven National Laboratory)

Contribution ID: 43

Type: **Invited Talk**

Nanoscience at Center for Functional Nanomaterials

Center for Functional Nanomaterials (CFN) is a DOE Scientific User Facility that provides access to state-of-the-art material characterization and synthesis tools to a scientific community. In this talk I will give an overview of the CFN user program and discuss how the facility can be accessed by external users. I will describe available instrumentation and capabilities relevant to material science and give examples of on-going research and available expertise at the center.

Primary author: Dr NYKYPANCHUK, Dmytro (Brookhaven National Laboratory)

Presenter: Dr NYKYPANCHUK, Dmytro (Brookhaven National Laboratory)

Contribution ID: 44

Type: **not specified**

Welcome

Monday, 26 June 2023 10:00 (10 minutes)

Presenter: KIM, Dohyun (Brookhaven National Lab)

Session Classification: Plenary Session

Contribution ID: 45

Type: **not specified**

Opening

Monday, 26 June 2023 10:10 (20 minutes)

Presenter: DENISOV, Dmitri (Brookhaven National Laboratory)

Session Classification: Plenary Session

Contribution ID: 46

Type: **not specified**

RaDIATE Collaboration Update

Monday, 26 June 2023 10:30 (40 minutes)

Presenter: PELLEMOINE, Frederique (fpellemo@fnal.gov)

Session Classification: Plenary Session