Abstracts

Office of Nuclear Physics SBIR/STTR Exchange Meeting

Note: The ordering of the abstracts matches the ordering of the talks.

Day1: August 17, 2021

SBIR/STTR Program Overview

Michelle Shinn
DOE, Office of Nuclear Physics

Nuclear Physics Gamma-ray Imaging System for Real-Time Rare Isotope Harvesting, Monitoring and Radiochemical Separation

Ethan Hull, PHDs Co., TN

Grant Title: Nuclear Physics Gamma-ray Imaging System for Real-Time Rare Isotope Harvesting, Monitoring and Radiochemical Separation

NP SBIR/STTR Topic: Instrumentation

DOE Nuclear Physics missions include the production, harvesting and radiochemical separation (purification) of rare isotopes as part of both Nuclear Physics Research and Radioisotope Production. The two fields have a unique connection in the projectile-fragment harvesting research at the National Superconducting Cyclotron Laboratory (NSCL), where a recirculating aqueous beam stop captures rare isotopes from the beam and accumulates them in various collection systems including resin columns. As many as 100 different isotopes can be present with an overall activity as high as ~ 1 Ci. Direct gamma-ray imaging of the columns, beam stop, and collection vessels is extremely useful with this large plurality of gamma rays. A new high-purity germanium (HPGe) imaging detector system called the NP-Imager (Nuclear Physics Imager) provides HPGe spectroscopy and gamma-ray imaging at the same time to produce dynamic radiological-location maps of the isotope distributions during these radiochemical processes. The development of the NP Imager and some Phase-II results demonstrate great promise for this technology.

Low Cost, High-Density Digital Electronics for Nuclear Physics

Wojtek Skulski, SkuTek Instrumentation, NY

Grant Title: Low Cost, High-Density Digital Electronics for Nuclear Physics

NP SBIR/STTR Topic: Electronics

We are working on tabletop digital pulse processors for Nuclear Physics. The devices offer low noise, high speed digitization with 14 bits at 100 MSPS, suitable for both scintillators and high-resolution semiconductor detectors. The high speed 250 MSPS option is under development. The new FemtoDAQ+ is a significant improvement over the former FemtoDAQ daughter card for a BeagleBone Black. Digitizer setup, control, and monitoring is handled with embedded

Linux single board computer (SBC) running the modern version of embedded Linux for the ARM processor. Both digitizers run the newest edition of Debian 10 as well as the improved remote GUI written in JavaScript. The GUI will provide a transparent support for all major operation systems. We will review the project and present the progress achieved during the last year.

Manufacturing and Packaging of Reliable Bialkali Photocathodes via Sputtering

Harish Bhandari, Radiation Monitoring Devices, MA

Grant Title: Manufacturing and Packaging of Reliable Bialkali Photocathodes via RF Sputtering

NP SBIR/STTR Topic: Accelerator

The future upgrade for the Relativistic Heavy Ion Collider (RHIC) at BNL calls for the implementation of electron cooling strategies, where ultra-cold electron beams will be generated by photoinjectors. Bialkali photocathodes are capable of delivering these electrons with the desired average current (~50 mA) to meet the upgrade requirement. These cathodes, however, have to be replaced daily given their short lifetimes. Hence, there's a need for commercially available photocathodes than can be produced reliably and supplied in sufficient quantities. Here we report on the development of a novel and reliable manufacturing technique for bialkali cathodes via sputtering. In addition, successful strategies for sealing and unsealing of the cathodes in transportable cartridges are being developed. By doing so, these cathodes can be mass produced and stockpiled for their daily use at RHIC. The sealed cathodes can be unsealed at the accelerator and handed off easily to a photoinjector gun to produce the electron beam with the desired emittance and brightness. The cathodes grown via sputtering routinely exhibit QE of ~5 % at 532 nm and peak QE of ~20 %. It should also be noted that the cathodes grown by sputtering have ultra-smooth surface morphology which lowers their emittance. The Phase II goal is to design and build a cathode growth chamber, where the cathodes can be evaluated for QE uniformity and also sealed in a transportable cartridge. The presentation will cover the progress on the design and construction of the proposed system, along with data from the sputtered cathodes.

Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

Jennifer Lalli, NanoSonic, Inc., VA

Grant Title: Long-Term Radiation Rugged Rotary Vacuum and Water Seals in Heavy-Ion Accelerators

NP SBIR/STTR Topic: Instrumentation

The Department of Energy's Office of Nuclear Physics has identified a need for materials that will survive high radiation environments to support next generation rare isotope beam facilities such as Michigan State University's (MSU) Facility for Rare Isotope Beams (FRIB). The goal of this Phase IIA program is to conduct higher dose irradiation studies to develop a long-lifetime, rotary vacuum and water seal that can survive 0.5 – 1.5 MGy/month for up to a year to minimize maintenance within this radioactive environment. The irradiation (total dose: 0.2 MGy, 2.0 MGy, and 20 MGy) shall be conducted at Brookhaven's Linac Isotope Producer (BLIP).

Current gaskets and seals do not offer the combined mechanical and radiation survivability needed for multiple years of service. The approach for the new seals involves the extrusion of high-performance polymers compounded with radiation tolerant materials as composites that offer combined low air and water permeability with extreme radiation durability. NanoSonic's extruded compounded films have been integrated within a commercial housing. Mechanical and thermomechanical testing of the new materials are being conducted pre- and post-irradiation alongside current commercial off-the-shelf (COTS) seal materials. Radiation durable rotary vacuum and water seals shall be manufactured for use with rare isotope beam facilities for the stable production of new and rare isotopes. These isotopes shall also benefit medical accelerators, advanced imaging needs within the medical community, and military and space applications.

Keynote Speaker

NP Instrumentation in the High Luminosity Era

Elke Aschenauer,
Brookhaven National Laboratory

Development of Gen-II LAPPDTM Systems For Nuclear Physics Experiments

Michael Foley, Incom Inc., MA

<u>Grant Title: Development of Gen-II LAPPDTM Systems For Nuclear Physics Experiments</u>

NP SBIR/STTR Topic: Instrumentation

Incom Inc is now producing a baseline capacitively coupled version of the Large Area Picosecond Photo-Detector (LAPPD). It is the largest commercially available planar-geometry MCP-PMT, with > 350 cm2 active area. The LAPPD features an internal resistive ground plane which is capacitively coupled to an external pixelated signal board. Pixelation can improve detection of photons in high rate environments, including Cherenkov light, and the pixelated pattern can be easily changed by the customer.

These devices have demonstrated electron gains of 10E7, low dark noise rates (15-30 Hz/cm2), single photoelectron timing resolution of < 71 picoseconds RMS, single photoelectron spatial resolution of ~2.8 mm RMS with 25 mm pixels, spatially uniform bi-alkali photocathodes with QE ~28%, and low sensitivity to magnetic fields, measured up to 0.8 T. Performance examples will be shown for a variety of signal board patterns including striplines, and pixels from 25 mm down to 3 mm in size.

LAPPDs are under consideration for particle collider experiments (e.g. SoLID, DESY, future EIC (BNL and TJNAF) and to be tested at CERN), neutrinoless double-beta decay experiments (e.g. THEIA), neutrino experiments (e.g. ANNIE, WATCHMAN, DUNE), medical (PET) and nuclear non-proliferation applications. Production of LAPPDs have increased from one/month in 2018, to two - three/month in 2020 and even higher post pandemic in 2021.

Distributed digital data acquisition system with network time synchronization

Wolfgang Henning, XIA LLC, CA

Grant Title: Distributed digital data acquisition system with network time synchronization

NP SBIR/STTR Topic: Software/Data

As radiation detector arrays in nuclear physics applications become larger and physically more separated, the time synchronization and trigger distribution between many channels of detector readout electronics becomes more challenging. Clocks and triggers are traditionally distributed through dedicated cabling, but newer methods such as the IEEE 1588 Precision Time Protocol and White Rabbit allow clock synchronization through the exchange of timing messages over Ethernet. Consequently, we report here the use of White Rabbit in a new detector readout module, the Pixie-Net XL. The White Rabbit core, data capture from multiple digitizing channels, and subsequent pulse processing for pulse height and constant fraction timing are implemented in a Kintex 7 FPGA. The detector data records include White Rabbit time stamps and are transmitted to storage through the White Rabbit core's gigabit Ethernet data path or a slower diagnostic/control link using an embedded Zynq processor. An alternative implementation moves the White Rabbit core to the Zynq processor and increases the Kintex data output to 10 gigabit/s (nominal). The performance is characterized by time-of-flight style measurements with pulsers and/or radiation from coincident gamma emitters.

Boron Nitride Nanotube Vibration Damping for SRF Structures

Roy Whitney, BNNT Materials, LLC, VA

Grant Title: Boron Nitride Nanotube Vibration Damping for SRF Structures

NP SBIR/STTR Topic: Accelerator

Boron nitride nanotubes (BNNTs) can significantly enhance the performance of SRF structures used for particle accelerators by damping and/or isolating microphonics that result in length oscillations of the accelerating structures. BNNT viscoelastic behavior is observed over a temperature range from 2 K to 700 K (-271°C to 427°C). BNNT damping reduces expensive RF power capital and operating costs that would be above what is otherwise required for accelerating the particles to keep the SRF cavities on resonance. Results to date have demonstrated the BNNT damping for Jefferson Lab CEBAF C100 cavities at room temperature and two LCLS-II cavities at 2 K in a production cryomodule. Next steps will be a near term demonstration in C100 cavities at 2 K in preparation of implementing the BNNTs in a full C100 cryomodule, plus further testing for LCLS-II-HE cavities on the path to a full cryomodule.

IP Access Gateway

Radu Radulescu, Telluric Labs, NJ

Grant Title: IP Access Gateway

NP SBIR/STTR Topic: Software/Data

Structurally, the IP access Gateway (IPAG) is a COTS, FPGA based board assembly, which integrates the Frontend, Backend, and Computer Farm subsystems into a unitary Software Defined DAQ, fully synchronized in band without additional HW, and allowing immediate event reconstruction. Current IPAG firmware runs on Ultrascale Plus FPGA family and can provide up to 96 x 25Gbps optical ports per board, for practically unlimited scalability, and flexibility for IP or other protocols.

Functionally, IPAG comprises continuous, Ergodic TDC (ETDC) engines configurable in any combination of high, sub picosecond accuracy, or 10pS, high density instances, each generating up to 2.4G timestamps per second. The in band synchronization is performed by the General Timing Synchronization subsystem, based on a passive, user traffic monitoring, non intrusive protocol. The third functional subsystem is an embedded packet switch for the 25Gbps ports allowing a faster, fully integrated network.

Radiation Hardened Infrared Focal Plane Arrays

Yong Chang, Epir, Inc., IL

Grant Title: Radiation Hardened Infrared Focal Plane Arrays

NP SBIR/STTR Topic: Instrumentation

We will present our work on the design and fabrication of mid-wavelength-infrared (MWIR) HgCdTe-based focal plane arrays (FPAs) and on assembling the neutron radiation-tolerant infrared cameras to be used in nuclear reactors and the next-generation rare isotope beam facilities. The material system (HgCdTe) that we chose for FPA fabrication is relatively insensitive to radiation effects. Additionally, we optimized the device processes to mitigate expected changes in material properties under irradiation. High sensitivity HgCdTe FPAs can be tailored for response across the entire infrared spectrum and are commonly utilized at EPIR for the fabrication of infrared cameras. During this project, we demonstrated in collaboration with Fermilab, material, device, and camera stability under 10^9 neutrons/cm2/s irradiation flux, which is four orders of magnitude higher than the typical fluxes encountered in the isotope beam facilities. Under accumulated neutron doses of larger than 1.5×10^{13} neutrons/cm2, our FPAs also demonstrated imaging capabilities. We also demonstrated material and device-level stability under 100 krad(Si) and 63 MeV proton irradiation We will present our current progress in material growth, device processing, and camera development. We optimized the design of the camera architecture and shielding so that the detectors and electronics are exposed only to a small fraction of the total neutron flux. Our designed camera will be capable of operating at standard frame rates with a radiation tolerance for prolonged operation in the presence of neutron fluxes higher than 10^5 neutron/cm2/s and a total absorbed dose of ~ 1MRad/yr. In addition, MCNP simulations were also conducted to confirm that the camera will maintain full imaging functionality under a very strong radiation environment. The energy deposition calculations considered all relevant mechanisms involved in the interactions between the FPA and the high energy electron, photon, proton, and neutron particles.

12-bit 32 Channel 500MSps Low Latency ADC

Anton Karnitski, Pacific Microchip Corp., CA

Grant Title: An ASIC with a low power multichannel ADC for energy and timing measurements

NP SBIR/STTR Topic: Electronics

Pacific Microchip Corp. is developing an ASIC with a low power multichannel ADC for energy and timing measurements. It includes 32 independent 12-bit 200Ms/s ADCs with integrated digital backend for event detection and recording. Within the Phase II project, the prototype chip was designed and being fabricated. Currently the chip is being tested and characterized.

Radiation Hard High Speed Camera System for Accelerator Beam Diagnostics

Esko Mikkola , Alphacore Inc., AZ

Grant Title: Radiation Hard High Speed Camera Systems for Accelerator Beam Diagnostics

NP SBIR/STTR Topic: Instrumentation

Presentation will discuss past experience with 1mp/10Kfps second camera performance issues during testing and focus on current initiative to use Radiation Hardened Cabling and System Architecture changes to improve overall Radiation Hardening.

Resonant Polarimetry and Magnetometry.

Brock Roberts, Electrodynamic, NM

Grant Title: Resonant Polarimetry and Magnetometry

NP SBIR/STTR Topic: Accelerator

Electrodynamic has teamed with the Thomas Jefferson National Laboratory (JLAB), and Cornell's Laboratory of Elementary-Particle Physics (LEPP) to create and evaluate non-invasive resonant polarimeters and magnetometers.

Prototype resonant polarimeters and magnetometers and sensitive receivers have been designed and constructed for the polarized beam line at Jlab's Upgrade Injector Test Stand and the magnetized beamline on Jlab's Gun test stand (GTS). Progress toward beamline evaluation of these technologies will be reported.

High power fiber laser system for polarization of 3He gas

Wei Lu, Raytum Photonics LLC, VA

Grant Title: High power fiber laser system for polarization of 3He gas

NP SBIR/STTR Topic: Instrumentation

Polarizing high intensity Helium-3 gas is an extremely important task since polarized Helium-3 is an effective neutron target or filter/analyzer for a broad nuclear physics programs such as some conducted in Spallation Neutron Source (SNS) in Oak Ridge National Lab (ORNL) and Jefferson Lab's Continuous Electron Beam Accelerator facility (CEBAF). There is increasing demand for

fast production of polarized Helium-3 from various neutron instruments and high Helium-3 polarization efficiency, which is essential to any polarized neutron scattering experiment. Recently, the research groups in ORNL and National Institute of Standards and Technology (NIST) showed that pumping Potassium (K) vapor is more efficient than pumping traditional Rubidium (Rb) vapor to polarize the Helium-3 gas.
The goal of this program is to design and develop the prototype of next generation pumping laser at 770nm through frequency doubling the high power 1540nm fiber laser. Compared with traditional fiber pigtailed diode laser used in Helium-3 polarization, the prototype we develop has unique features that have never been accomplished before: the lasing linewidth is tunable from extremely narrow of sub-GHz to 10s GHz, direct linear or circular polarization output with polarization maintaining fiber delivery, and exceptional diffraction-limited output beam quality. The whole laser system not only can provide the scalable output power but also has the ability to tune and lock the center wavelength to match the exact position of absorption line.

During the Phase II, we successfully demonstrate a prototype of an integrated turn-key fiber laser system with output power of 50W at 770nm. The laser output has excellent beam quality with linear polarization. Both lasing wavelength and linewidth are tunable with the tuning range within the specifications.

Automated Preparation Of 211AT For Targeted Alpha Therapy Applications

Graham Marshall, Global FIA, Inc., WA

Grant Title: Modular Isotope Purification - the Production of At-211

NP SBIR STTR Topic: Isotope

Ionization chambers are typically used as dose calibrators, but they are expensive and bulky; a low-cost and compact alternative may be desirable for some applications.

A Geiger-Müller (GM) tube-based dose calibrator system has been constructed for use in the support of medical isotope separations of cyclotron activated At-211 targets. At present, this system has been utilized to accurately measure source activities ranging from ~0.1-200 MBq (~3-5400 µCi) with minimal user input. This system may be viable for a wide variety of potential applications where rapid determination of radionuclide activity is desired, but price and space are a consideration.

In this presentation, we will present the experimentally determined measurement efficiency values for several nuclides tested on this platform to date, and compare it to a commercially available ionization chamber-based dose calibrator system.

Supercritical Fluid Separation and Purification of Rare Earth Elements, particularly Lanthanides including 177-Lu, to Lower Energy Consumption, Reduce Processing Time and Reduce Wastes

Laura Sinclair, CF Technologies, MA

NP SBIR STTR Topic: Isotope

Lutetium 177 (177Lu) is a key ingredient in promising cancer treatments for gastroenteropancreatic neuroendocrine tumors, prostate cancer, and non-Hodgkin's lymphoma. Applications and demand for 177Lu are growing very rapidly, with several late-stage clinical trials. Current manufacturing processes for high purity 177Lu are complex and time consuming. This includes irradiation of a 176Yb target to generate a 176Yb/177Lu mixture, followed by a series of chemical purification techniques to isolate the 177Lu. This purification process can take up to several days and result in significant losses of the product as off-spec material. 177Lu has a 6.65 day half-life, and therefore this long processing time results in further losses of the product due to radioactive decay. The goal of this project is to develop an improved purification process that can be licensed to an isotope supplier to deliver 177Lu faster, at lower costs, and with higher yield, resulting in a better supply for cancer patients. Our key innovation is the use of non-polar fluids. These are compatible with a wide range of chemistries which are simply not soluble in water. We have implemented these chemistries in a chromatography process to separate Yb and Lu. In this project, we have built a working prototype which is able to achieve consistent full separation of Yb and Lu with good repeatability. Our next step is to demonstrate this technology to purify a real irradiated 176Yb target, with the first irradiation planned for October of 2021.

Day Two: August 18, 2021

HOM Absorber Design for eRHIC ERL Cavity

Tom Schultheiss, TJS Technologies, NY

Grant Title: HOM Absorber Design for eRHIC ERL Cavity

NP SBIR/STTR Topic: Accelerator

The Office of Nuclear Physics plans include allocation of resources to develop technology for a polarized electron-ion collider. In January 2020 the DOE awarded the Electron Ion Collider, EIC, to Brookhaven National Lab using its RHIC infrastructure. One of the components that requires significant development is the high current electron SRF cavity. To preserve the beam and its characteristics requires higher order mode absorbers both in-line and cavity damped. This SBIR is focused on the design and development of HOM absorber modules to be used in waveguides and in beamlines. In Phase 1 TJS Technologies LLC designed both a waveguide and beamline absorber that were based on a similar core of backers and tiles. In Phase II we developed prototypes for each. For the waveguide absorber housing we used brazing techniques that we are very familiar with, however, the design resulted in a relatively heavy waveguide prototype, over 200 pounds. Developing a lower weight waveguide absorber in Phase IIA using forming methods will improve design options. The Phase IIA program includes RF testing HOM modules and thermal testing backer-tile assemblies. RF tests will be to sweep through the frequencies

of significance and measure S11 of each. This will indicate the RF efficiency of the modules. BNL has RF hardware that was used to measure the power absorbed into the NSLSII HOM absorber backer-tile assemblies. We plan to modify the hardware to accept the new backer-tile assemblies and measure RF power absorption limits of the individual assemblies.
Using the backer-tile cores enables design of round HOMs as well as waveguide HOMs. We are exploring HOMs for Crab-Cavities using the tile-backer core design. Waveguide absorbers or coax fitted with a beamline type absorber could be used.

Scintillating Bolometer Crystal Growth and Purification for Neutrinoless Double Beta Decay Experiments

Joshua Tower, Radiation Monitoring Devices Inc., MA

Grant Title: Scintillating Bolometer Crystal Growth and Purification for Neutrinoless Double Beta Decay Experiments

NP SBIR/STTR Topic: Instrumentation

In the search to better understand the fundamental physics of our universe, a crucial goal is elucidating the nature of the neutrino. Although our understanding of the physics of the neutrino is improving, many questions remain.

Research at the frontier of nuclear physics is often limited by the capabilities of available detectors. More sensitive detectors are required to detect and characterize very rare nuclear events. This SBIR project will lead to the production of such high sensitivity detectors needed for elucidating the nature of the neutrino.

The objective of the program is to develop the capability to produce Li_2MoO_4 (LMO) crystals suitable for neutrinoless double-beta decay experiments. A major component of the project is to improve crystal purity for reduced radioactive background, and for optimizing bolometric and scintillation performance at cryogenic temperatures. Another key aspect of the project is the optimization and scale-up of the crystal growth process.
This project is being performed in collaboration with MIT and the CUPID Collaboration. This presentation will discuss significant progress made in crystal quality and size, and the steps being taken towards commercializing the technology.

High Performance FPGA-based Embedded System for Decision Making in Scientific Environments

Dantong Yu, Sunrise Technology, Inc.

Grant Title: High Performance FPGA-based Embedded System for Decision Making in Scientific Environments

NP SBIR/STTR Topic: Software/Data

All nuclear and particle physics experiments world-round are using various types of ``Trigger-based'' Data Acquisition (DAQ) systems to select only a small fraction of events of interest from the vast amount of data produced by the detectors, as limited hardware and data bandwidths prevent the readout electronics from collecting all of the data into local storage (tapes or disks). In this project, we develop an intelligent trigger system based on advanced Deep Neural Networks (DNN) to identify the events of interest in real-time before putting the raw data into tape/storage. Notably, we use Graph Convolutional Neural Network (GCN) to handle the highly sparse detector images with only hundreds to thousands of hits. The type of image fails the commonly used Convolution Neural Networks (CNN) and Recurrent Neural Networks (RNN).

We collaborated with BNL and LANL and co-designed a physics-aware sPHENIX trigger detection pipeline that resembles a rare physics event collection and analysis workflow in high-energy proton-proton collisions at RHIC: track hit clustering, noise removal, tracking, and making trigger decisions. To meet the real-time requirement for an online trigger system, we integrate (work in progress) this pipeline into FPGA. We adopt the high-level synthesis and use the community developed HLS4ML to compile the high-level neural network models into the low-level FPGA bitstream. This approach dramatically reduces hardware programming complexity and increases the flexibility of the triggering system for machine tuning, performance improvement, and new physics event selection in real-time. Performance analysis shows that the trigger detection accuracy reaches 73% and AUROC 78%. Preliminary speed on FPGA shows that our tracking algorithm reconstructs 13K (13Khz) events per second, slightly lower than 15Khz, the designed sPHENIX experiment trigger capability. We will continue optimizing the FPGA design and tune the pipeline to reach the designed sPhenix triggering rate.

Keynote Speaker

NP Accelerator Needs at the Dawn of the EIC Era

Andrei Seryi
Thomas Jefferson National Accelerator Facility

A Multi-channel Radiation-tolerant, Low power, High-speed, and Resolution Analog-to-Digital Converter for Nuclear Physics Detectors

Ping Gui, TallannQuest LLC DBA Apogee Semiconductor, TX

<u>Grant Title: A Multi-channel Radiation-tolerant, Low-power, High-speed, and Resolution Analog-to-Digital Converter for Nuclear Physics Detectors</u>

NP SBIR/STTR Topic: Electronics

This presentation covers two 12-bit GS/s Radiation-Tolerant ADC designs for Nuclear Physics Detectors, including one single-channel ADC operating at 1GS/s implemented in 28nm CMOS, and the other interleaving 8 sub-ADC channels to achieve a sampling rate 2.56GS/s in 65nm CMOS process. The circuit design, silicon measurement results as well as Total Ionization Dose (TID) measurement results for both ICs will be presented.

An RF beam Sweeper for Purifying In-Flight Produced Rare Isotope Beams

Alexander Smirnov, Radiabeam Technologies, LLC, CA

<u>Grant Title: An RF beam Sweeper for Purifying In-Flight Produced Rare Isotope Beams</u>

NP SBIR/STTR Topic: Accelerator

At ATLAS, the in-flight production method of radioactive beams provides access to more than 100 short-lived isotopes in the mass range up to A~60. After the production target, the primary beam is energy degraded and acquires a long low-intensity energy tail, which can dominate the radioactive beam of interest. To handle the large divergence and energy spread of the in-flight produced beam, an inflight beam separator (AIRIS) has been recently installed and commissioned. First, the secondary beam passes through a momentum achromat, and then, an RF sweeper provides contaminant beam reduction through velocity difference: a time difference eventually develops between the beam components due to the velocity difference and resulting in different deflection and separation in the time-dependent electric field. In this paper, we present the design of a high voltage RF sweeper, operating at two frequencies – 6 and 12 MHz, each delivering 150 kV deflecting voltage. We will discuss the RF and engineering design considerations of the deflecting cavity.
*This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under SBIR grant DE-- SC0019719.

Ultrafast High Voltage Kicker System Hardware for Ion Clearing Gaps

Alexander Smirnov, Radiabeam Technologies, LLC, CA

Grant Title: Ultrafast High Voltage Kicker System Hardware for Ion Clearing Gaps

NP SBIR/STTR Topic: Accelerator

The ionization scattering of the electron beam with residual gas molecules causes ion trapping in the electron rings, both in the collider and electron cooling system. The trapped ions may cause emittance growth, tune shift, halo formation, and coherent coupled bunch instabilities. Therefore, the beam temporal structure needs gaps to clear the ions to prevent them from accumulating turn after turn. Typically, the gap in the bunch train has a length of a few percent of the ring circumference. In those regions, extraction electrodes are introduced with pulsed voltages applied. In this paper, we present the design of a high voltage pulsed kicker hardware, that includes the vacuum device and the pulsed voltage driver. By design, the system must show over 3 kV of deflecting voltage amplitude, rise and fall times of less than 10ns, 100ns flat-top duration at 1.4 MHz repetition rate. This work was supported by the U.S. Department of Energy, Office of Nuclear Physics, under SBIR grant DE- SC0019719.

High Performance Scintillator and Beam Monitoring System

Peter Friedman, Integrated Sensors, LLC, OH

Grant Title: High Performance Scintillator and Beam Monitoring System

NP SBIR/STTR Topic: Instrumentation

The thin-scintillator ion beam imager (SIBI) is a novel charged particle imaging detector developed by our group for various applications. It uses proprietary high light-yield, very thin (<500 µm) hybrid inorganic scintillator sheets or ultra-thin (3-200 µm) organic scintillator films. The scintillation elements are coupled by low f-number optics to high sensitivity, low-noise or ultra-low noise machine vision cameras. The initial application is for beam imaging and profile analysis at the DOE Facility for Rare Isotope Beams (FRIB) and other ion beam laboratories. For FRIB, we are developing the SIBI towards maximizing sensitivity to low rate and low energy ion beams with real-time feedback while limiting beam degradation for moderate energy FRIB beams over a large dynamic range from single particles up to ~10^10 pps. The SIBI has demonstrated detection sensitivity to single 5 MeV alpha particles with a position resolution of 5 µm, while for heavier ions, the position resolution is ~2 µm. Other SIBI applications are being developed for conventional proton/ion beam therapy and for the newly emerging cancer treatment modality known as FLASH radiotherapy (RT), which delivers approximately four (4) orders-of-magnitude higher dose rates than conventional RT. We will describe system designs and report preliminary performance results.

Design and fabrication of the "AODS": All-in-One Digitizer System-on-Chip

Isar Mostafanezhad, Naul Scientific, LLC, HI

Grant Title: DESIGN AND FABRICATION OF THE "AODS": ALL-IN-ONE DIGITIZER SYSTEM-ON-CHIP

NP SBIR/STTR Topic: Electronics

We will present progress on design and development of the All-in-One Digitizer System-on-chip "AODS": a low-cost, low power, low-noise and low channel-count Application Specific Integrated Circuit (ASIC) with a high dynamic range option specialized for reading out both Photomultiplier (PMT) and Silicon PhotoMultiplier (SiPM) type light detectors. The ASIC will be capable of analog signal conditioning and up to 2 Gigasample/sec waveform sampling with the ability to service up to 4 channels. NSL's AODS device will also have a deep sampling buffer making it suitable for a range of large and mid-high rate NP experiments such as the experiments carried out at the Relativistic Heavy Ion Collider, JLab's 12 GeV line and the ones possible at the future Electron Ion Collider.

The AODS is developed by integrating into one System-on-Chip (i) analog amplification and signal conditioning circuits, (ii) a power and geometry optimized version of the previously developed analog sampling/storage core, targeting very high dynamic range, (iii) integrated front-end and sensor element bias control and monitoring circuit, (iv) triggering mechanism with autonomous operation capabilities, and (v) digital backend for high dynamic range signal processing (vi) fast serial interface with daisy chaining capability. High levels of integration proposed for AODS will reduce the need for costly high performance Field Programmable Gate Arrays (FPGAs) which will reduce backend data congestion, power dissipation and deployment complexity while adding more flexibility and making the front-end electronics easier to use with optional user-friendly USB or ethernet based readouts in addition to custom protocols. The AODS as such will reduce the cost per channel, cost of analog and digital cabling and complexity of operation to a tenth of the currently available solutions, making it especially attractive for experiments with element spacing at 1cm-50cm and channels counts at 200-10k.

Next-Generation Technology for the Extremely Efficient Storage, Distribution, and Processing of Nuclear Physics Data

Juan Gonzalez, Accelogic, LLC, FL

Grant Title: Next-Generation Technology for the Extremely Efficient Storage, Distribution, and Processing of Nuclear Physics Data

NP SBIR/STTR Topic: Software/Data

Millions of dollars are spent every year in generating the tons of data that are necessary for addressing nuclear physics grand challenge problems at DOE facilities. Due to inherent technical and financial limitations at the “last- mile” of the data delivery pipeline, only a small fraction of these expensive Peta bytes of data is available for immediate access by Nuclear Physicists and end-users at any given time. This not only renders the users’ work inefficient, but also risks the waste of significant amounts of information that could very well contain the keys to answering grand challenge questions. This project aims at solving this issue by providing the ground-breaking data compression technology able to multiply the capacity of existing (and future) last mile “live storage” facilities by factors larger than 4x and up to 9x without any additional investment in hardware. The technology will be packaged as an open-source set of tools and integrated in a transparent manner with ROOT/IO. We will discuss the different thrusts of this research, as well as the philosophy for maximizing impact and dissemination inside the Nuclear Physics community, as well as the current status of the project.

Radiation Hardened Opto-atomic Magnetometer

Jae Choi, Hedgefog Research Inc., CA

Grant Title: Radiation Hardened Opto-atomic Magnetometer

NP SBIR/STTR Topic: Instrumentation

Hedgefog Research Inc. (HFR) is developing a Radiation Hardened Opto-atomic Magnetometer (RHOM) for magnetic-field sensing applications in high-radiation environments. RHOM is a new approach to magnetometry that offers intrinsic radiation hardening by design, and RHOM probes will enable long, uninterrupted magnetic-field sensing operation in radiation-rich environments. In Phase II, HFR has developed a fully packaged probe module with supporting hardware/software components for system control and data acquisition. The Phase II prototype offers automated, real-time monitoring of a local magnetic field with high precision.

Modeling Plasma Discharge Cleaning of SRF Cavities

Jarrod Leddy, Tech-X Corporation, CO

Grant Title: Modeling Plasma Discharge Cleaning of SRF Cavities

NP SBIR/STTR Topic: Accelerator

Superconducting radio frequency (SRF) cavities, such as the continuous electron beam accelerator facility 7-cell C100 cavity, rely on high field generation.

Surface contamination of the superconducting vessel walls due to initial conditioning and regular operation can severely impact the field strength through field emission and surface arcing. Therefore, efficient and effective cleaning of the cavity surfaces is necessary to maintain optimal acceleration gradients. In situ cleaning techniques involve generating plasma discharges that remove the impurities through mostly chemical and some mechanical processes, but the generation of these plasmas is not well understood. We have made efforts towards the simulation of the formation of these plasmas via PIC simulation with Monte Carlo reactions. Additionally, we have implemented a hybrid model to simulate the longer timescale steady-state behavior of these plasmas. We will present a summary of these efforts and key results.

Low Cost Data Acquisition Synchronization for Nuclear Physics Applications

Wojtek Skulski, Sku Tek Instrumentation, NY

Grant Title: Low Cost Data Acquisition Synchronization for Nuclear Physics Applications
NP SBIR/STTR Topic: Electronics

We are working on interfacing and synchronizing SkuTek digitizers with the digital acquisition framework at Argonne National Laboratory. The project will bring significant improvements of the digitizer architecture, readout speed, and online control. The digitizer will provide 32 channels of low noise digitization with 14 bits at 100 MSPS, suitable for both scintillators and high-resolution semiconductor detectors. The trigger and timing control link (TTCL) will be based on fast point-to-point serial links compatible with Gamma Ray Tracking Array (GRETA). The event readout will be performed over copper Ethernet at 1 Gbps, or optical fiber Ethernet at 10 Gbps. Digitizer setup, control, and monitoring will be handled with embedded Linux single board computer (SBC) running the modern version of embedded Linux for the ARM processor. We will review the project and present the progress achieved during the last year.

Low RF loss DC conductive Ceramic for High Power Input Coupler Windows for SRF Cavities

Ben Freemire, Euclid Techlabs, LLC, OH

NP SBIR/STTR Topic: Accelerator

Ceramic RF windows used in power couplers for superconducting cavities are prone to accumulate volume and surface charges. The electric field generated by charging builds up until it discharges, with the resultant arc damaging or destroying the window. Euclid Techlabs has developed a new ceramic composition that exhibits low losses at high frequencies and is conductive at DC. This allows the charge to drain off rather than being accumulated in the material, which was confirmed via a beam charging test of both conductive and non-conductive versions of the ceramic. Windows made of this conductive ceramic were fabricated for use in 1.5 GHz and 650 MHz RF couplers at JLab and FNAL. Two pairs of coaxial RF window assemblies have been fabricated for FNAL and two waveguide window assemblies have been fabricated for JLab. Several brazing methods were used, indicating a promising method for producing a hermetic seal. The window brazing process is being formalized, leveraging Euclid's furnaces. The first waveguide window assembly was tested at JLab, which put an upper bound on the conductivity and RF loss feasible for high power window operation. Additional window assemblies are in production, with testing at FNAL and JLab to follow. Prototypes of RF coupler windows for the EIC and LHC will also be designed. Finally, this technology will be applied to normal conducting cavity couplers for wider use in industry.

Day 3, August 19, 2021

TTDAQ: A CONTINUOUS FLOW, TIMING AND TRIGGER DAQ SYSTEM

Radu Radulescu, Telluric Labs LLC, NJ

Grant Title: TTDAQ: A CONTINUOUS FLOW, TIMING AND TRIGGER DAQ SYSTEM

NP SBIR/STTR Topic: Electronics

The Continuous Flow TTDAQ is the next generation, triggerless, continuous readout, fully optical network DAQ for Pbps transfer rates, which is made possible by the development of a DWDM 25Gbps per channel, radhard, Photonics Integrated Circuit (Tb PIC), remotely illuminated by lasers located outside the radiation zone. The Tb PIC is designed to be used in both digital and linear (analog) signal transport, for up to 1.6 Tbps per fiber. The internal structure is based on MicroRing Resonators (MRR) used for both modulation and demodulation, using a novel topology and architecture, which provides stability and high immunity to noise. MRRs have several advantages, featuring native wavelength filtering, high sensitivity, small dimensions (~10um), tunability, low power, and lower cost. The Tb PIC uses 100G ITU DWDM grid. Our topology allows upgrade for the denser 50G ITU grid. . Tb PIC works seamlessly with the IPAG system. Currently the PIC is being characterized in preparation for radiation tests.

Additively Manufactured Z-Channel Detectors for Heavy Ion Accelerator Diagnostics

Jerome Moore, Robot Nose Corporation, IL

Grant Title: Additively Manufactured Z-Channel Detectors for Heavy Ion Accelerator Diagnostics

NP SBIR/STTR Topic: Instrumentation

Robot Nose and Argonne have been jointly exploring a new approach to making fast particle detectors. Additive manufacturing on the submicron scale allows the creation of microchannel plates (MCP) with tailored shapes. By forming channels with multiple "Z" chicanes, we expect to focus the transit time spread as gain builds through successive wall collisions in the channel. The resulting fast output pulse is preserved, counted and displayed quickly using an embedded computer with time-to-digital converter. The detector, electronics and software forms a system intended for beam diagnostics at heavy-ion user facilities and will be extensively tested at ATLAS in opportunistic beam mode. The unprecedented time resolution and fast response of the system is expected to give machine operators an improved way to tune the beams at these facilities compared to conventional detectors.

Cold Spray Technology Applications for SRF Cavity Thermal and Mechanical Stabilization.

Alex Kanareykin, Euclid Techlabs, LLC, OH

Grant Title: Cold Spray Technology Applications for SRF Cavity Thermal and Mechanical Stabilization

NP SBIR/STTR Topic: Accelerator

This presentation outlines the results of the period 04/05/2020- 07/30/2021 of Phase II of a three-phase program for the development of a new concept: the application of cold-spray technology for SRF cavity stiffening and thermal stability. The use of Nb/Cu cladding material can provide both thermal and mechanical stabilization, and thus stiffening rings will be avoided. The proposed technology will lead to a significant cost reduction in the following ways: the reduction in the Nb material thickness, the reduction in the number of manufacturing steps, and the improved thermal stabilization by the use of thin Nb/thick copper, allowing higher Q0 at higher gradient and lower losses. One of the potential applications is the possible industrial use of SRF accelerators, where the cavities are cooled by conduction using cryocoolers.

Dynamic friction in magnetized electron coolers for relativistic beams

David Bruhwiler, RadiaSoft LLC

Grant Title: Dynamic friction in magnetized electron coolers for relativistic beams

NP SBIR/STTR Topic: Accelerator

Effective cooling of high-intensity relativistic ion beams is important for achieving the luminosity goals of the Electron Ion Collider (EIC). One approach is to scale magnetized electron cooling techniques from existing nonrelativistic systems to the fundamentally different parameter regime of electron bunches with relativistic gamma factors of order 40. Because the technique would be applied in a previously untested parameter regime, accurate calculations of both magnetized and unmagnetized friction are required. We present new analytic and numerical friction calculations for this parameter regime, showing areas of agreement and disagreement with previous work. We also present optimized JSPEC simulations of intrabeam scattering (IBS) and electron cooling for the BNL EIC design, emphasizing 25 GeV proton beams (i.e., at injection into the collider ring). We also discuss the important question of non-Gaussian IBS models. Commercialization of our Sirepo.com technology and associated expertise is briefly discussed.

Highly Transparent Aerogel with Refractive Index < 1.01 for High Energy Particle Detection

Tanja Horn, Scintilex, LLC, VA

Grant Title: Highly Transparent Aerogel with Refractive Index < 1.01 for High Energy Particle Detection

NP SBIR/STTR Topic: Instrumentation

Aerogel of high optical quality is needed for hadron identification in nuclear physics experiments in the momentum range 3   8 GeV/c, where other techniques are not effective. The large-volume aerogel Cherenkov detectors for the Electron-Ion Collider (EIC) and those in three halls at the Jefferson Lab require high-quality, hydrophobic aerogel material. This Phase I/II project addresses this need with the development of aerogels with a refractive index as low as 1.008 to identify particles at the higher momenta and with increased tile sizes up to 20 x 20 x 3 cm3 while maintaining good optical and hydrophobic properties. In addition, a novel method was developed to mechanically reinforce low refractive index aerogels, which could improve their fabrication, handling, and use in Cherenkov detectors.

Keynote Speaker

Microelectronics for Nuclear Physics Instrumentation

Gabriella Carini

Brookhaven National Laboratory

A novel injection-locked amplitude-modulated magnetron at 1497 MHz

Michael Neubauer, Muons, Inc., IL

Grant Title: A NOVEL INJECTION-LOCKED AMPLITUDE-MODULATED MAGNETRON AT 1497 MHZ

NP SBIR/STTR Topic: Accelerator

Present status of Magnetron R&D at Muons, Inc will be presented. This includes the NRL tunable magnetron at 3 GHz as well as the 1497 MHz standard and amplitude modulated magnetrons.

An ASIC with a Low Power Multichannel ADC for Energy and Timing Measurements

Anton Karnitski, Pacific Microchip Corporation, CA

Grant Title: An ASIC with a low power multichannel ADC for energy and timing measurements

NP SBIR/STTR Topic: Electronics

Pacific Microchip Corp. is developing an ASIC with a low power multichannel ADC for energy and timing measurements. It includes 32 independent 12-bit 200Ms/s ADCs with integrated digital backend for event detection and recording. Within the Phase II project, the prototype chip was designed and being fabricated. Currently the chip is being tested and characterized.

Precise and ultra-stable laser polarization control for polarized electron beam generation

Yimin Hu, Raytum Photonics, VA

Grant Title: Precise and ultra-stable laser polarization control for polarized electron beam generation

NP SBIR/STTR Topic: Accelerator

Parity-violating scattering of helicity-flipping polarized electron beam has developed over the past decades into a key tool to study both the structure of electroweak interaction and the structure of nucleons. It has been used in the success of many nuclear physics programs such as HAPPEX in Jefferson Lab's Continuous Electron Beam Accelerator Facility (CEBAF). The helicity-flipping polarized electrons are generated by using circular polarized laser whose polarization is flipped by a polarization controller.

In Phase II, we will deliver a circular laser polarization flipping system with high precision, long term stability and featuring precise temperature and close loop beam quality control. The modulator will be able to operate at >2 kHz repetition rate with < 15us transition time, <1% amplitude ringing and <0.01V voltage control precision to obtain >95% duty cycle and high flipping rate desirable for MOLLER experiment. We will collaborate with Jefferson Lab to minimize the system's helicity-correlation asymmetries. First, we will optimize Pockels cell's alignment and voltage with laser-table beam evaluation setup built by Jefferson Lab; secondly, we will test our close loop control circuitry with simulated signals of beam position and current monitors provided by Jefferson Lab. The system specs will be targeted as following. The laser beam position difference will be ~ 200nm without analyzer and ~ 400nm with S1 or S2 analyzer; the spot size asymmetry shall be < 10-4 (RMS); the helicity-correlated beam intensity asymmetry will be <5000ppm for 4 peak separation with S1 analyzer and <500 ppm with S2 analyzer. The average asymmetry shall drift no more than 20000 ppm per 30 minutes with S1 analyzer.

We also combined the machine learning method with the Pockels cells control system, automatically collected data of Pockels cells asymmetry properties and PER at different orientation angles and built an artificial neural network which can determine the optimal position of Pockels cell. The trained artificial neural network can predict the PER, intensity asymmetry, beam position difference with a mean agreement around 95%, which makes it possible to find the optimal yaw/pitch/roll angles of the Pockels cells in a short time.

Low-cost and Efficient Cooling of on-Detector Electronics Using Conformal Thermoelectric Modules

Giri Joshi, Nanohmics, Inc., TX

Grant Title: Low-cost and Efficient Cooling of on-detector electronics using conformal thermoelectric modules

NP SBIR/STTR Topic: Electronics

Thermoelectric coolers (TECs) are a well-established technology. Solid-state TECs have no moving parts and provide more consistent, uninterrupted, maintenance-free, and environmentally friendly cooling when compared to traditional cooling systems such as vacuum-based refrigeration compressors. However, high costs and a slightly lower Coefficient of Performance (CoP < 1.0) relative to compression refrigeration have limited traditional TECs to niche applications such as automotive seat cooling, portable coolers, and biotech applications, though the total TEC market in 2019 exceeded $1B USD. Furthermore, conventional methods used in TE cooler manufacturing do not provide a means for production of large-area, conformal TECs to break into mainstream refrigeration, air conditioning, medical and commercial markets that include niche areas such as on-detector spectrometer electronics cooling needed desired by Department of Energy facilities such as the Thomas Jefferson National Accelerator Facility (TJNAF) and Relativistic Heavy Ion Collider (RHIC) of Brookhaven National Lab.

To address the limitation, Nanohmics Inc., working in collaboration with Prof. Mona Zebarjadi, Dr. Drew Wiesenberger, and Capstan Technologies, has been developing a novel large-area, conformal TEC technology using high-throughput, automated process and demonstrate the utility of the method for high-performance Bi_2Te_3-based thermoelectric cooling devices through construction of an electronics cooling prototype system at the end of the Phase II program. The Phase II alpha-prototype TEC cooling system will be designed and fabricated using methods developed in the Phase I program that led to a successful 3” x 6” conformal TEC unit with concept demonstration of consistent and reliable cooling below room temperature (< 20 °C). The device CoP and cooling power compared favorably to other competitive cooling systems such as vacuum compressors and Rankine coolers. Furthermore, price per square foot of these TECs will be on the order of ~$100-150, a significant reduction in the costs of present commercial modules even of low-end TE modules. When considering all the stated advantages, the proposed technology becomes cost-competitive compared to all other alternatives and immediately impact both cooling/heating (such as aerospace and defense, electronics, automotive, and biomedical cooling) as well as waste heat recovery markets (such as automotive and industrial waste heat).

A browser based toolkit for improved particle accelerator controls

Jonathan Edelen, RadiaSoft LLC, CO

Grant Title: A browser based toolkit for improved particle accelerator controls

NP SBIR/STTR Topic: Accelerator

Modern particle accelerator facilities generate large amounts of data and face increasing demands on their operational performance. These datasets can be difficult to visualize and contain complex relationships that are challenging to understand. Additionally, as the demand on accelerator operations increases so does the need for automated tuning algorithms and control to maximize uptime with reduced operator intervention. Existing tools are insufficient to meet the broad demands on controls, visualization, and analysis. Our effort is aimed at developing a web-based toolbox that features a generic virtual accelerator control room for the development of automated tuning algorithms and the analysis of large complex datasets. Here we present an update on our software development efforts in addition to results from ongoing experimental efforts to apply machine learning to accelerator facilities at Brookhaven National Laboratory and Thomas Jefferson National Accelerator Facility.

Keynote Speaker

Update on the Department of Energy SBIR/STTR Program, Q/A

Manny Oliver

DOE, SBIR/STTR Office