

Time Projection Chamber Workshop 2023 Abstract Booklet

Title: CAEN project for DAQ

Presenter: Greg Kibilko

Affiliation:

Abstract:

Title: Scientific opportunities with TPCs at the FRIB High Rigidity Spectrometer

Presenter: Remco Zegers

Affiliation: FRIB/MSU

Abstract: The High Rigidity Spectrometer (HRS) at FRIB will greatly enhance the scientific reach for experiments with fast beam of rare isotopes (RI) at FRIB. The key characteristic of the HRS is its ability to facilitate experiments at magnetic rigidities for which RI beam production is maximal (up to 8 Tm). The design also allows for a wide range of experimental programs with different setups, including for experiments after a future energy upgrade at FRIB. TPCs play an important role in the envisioned scientific program with the HRS. For example, they can be used as targets and to analyze recoil particles produced in direct reaction studies, and to reconstruct tracks of particles used in central heavy-ion collisions. This is an excellent time to consider what next-generation TPCs will be optimal for use with the HRS. The presentation will focus on the scientific opportunities with TPCS at the HRS and also provide an overview of the HRS, and its different modes of operation.

Title: The Active Target Time Projection Chamber

Presenter: Daniel Bazin

Affiliation: FRIB/MSU

Abstract: In this talk I will present the Active Target Time Projection Chamber, its principle of operation, data analysis, and performance. Technological advances in electron amplification devices is allowing the use of pure gaseous targets such as hydrogen, deuterium or helium, radically reducing the source of background in many experiments. The challenges of data analysis are being met with various algorithms and techniques, that were developed specifically for this type of detector. The effect of various operational parameters on the final resolution are being studied both with simulations and different running conditions. The results obtained so far are extremely encouraging, and future experimental work taking advantage of previous experience, as well as upgrades to the detector will be presented.

Title: Future Perspectives on GET electronics

Presenter: Lolly Pollacco

Affiliation:

Abstract:

Title: From NSCLDAQ to FRIBDAQ: new solutions for data acquisition and analysis

Presenter: Giordano Cerizza

Affiliation: FRIB/MSU

Abstract: With the beginning of the FRIB scientific experimental program, the increase in complexity of experimental setups and the advance of data acquisition (DAQ) system technologies introduced a need to upgrade the supported data acquisition/data analysis frameworks. New DAQ solutions are being explored and tools have been developed will be presented.

Title: Design and Fabrication of LAMPS TPC

Presenter: CheongSoo LEE

Affiliation: Institute for Basic Science (IBS), KOREA

Abstract: LAMPS TPC has been developed at IBS for studying the equation of state of nuclear matter. LAMPS TPC has a GEM-based multiplication and every parts are composed of non-magnetic materials, because it will be placed inside of a superconducting solenoid magnet. In addition, the material budget of the gas vessel of TPC should be minimized to obtain information for a wide range of recoil energies. LAMPS TPC has been built in last year with a fulfillment of above conditions. In this presentation, design and fabrication of LAMPS TPC will be given in detail.

Title: R&D and test of LAMPS TPC

Presenter: HyoSang Lee

Affiliation: IBS

Abstract: RAON is the RI beam accelerator facility in Korea. LAMPS is the nuclear science facility to study EoS via heavy-ion collisions at RAON. A TPC will be placed inside cylindrical solenoid magnet of 0.5 T for charged particle tracking and particle identification. R&D and test result of LAMPS TPC will be presented.

Title: Novel MPGD structures for Active-Target TPC application

Presenter: Marco Cortesi

Affiliation: Facility for Rare Isotope Beams (FRIB)

Abstract: Rare isotope beams (RIs) are now critical tools in nuclear physics. The Facility for Rare Isotope Beams (FRIB), located on the campus of Michigan State University, is a world-leading user facility for the study of RIs using the in-flight fragmentation method. The unprecedented potential discovery of a modern rare isotope beam facility, such as FRIB, can only be realized by implementing state-of-the-art experimental equipment capable of studying these isotopes at a high beam rate and high performance.

Originally developed for high-energy physics (HEP), implementation of MPGD technology as gas avalanche readouts has expanded to other fields, including nuclear physics, astrophysics, neutrino physics, material science, neutron detection, and medical imaging. MPGDs offer great flexibility and allow geometry and performance to be tailored to specific working conditions and requirements. The requirements of a typical low-energy nuclear physics experiment (LENP) with rare isotope beams are generally very different from HEP fixed-target experiments, so that substantial efforts and resources are necessary to develop new MPGD architectures optimized for LENP environments.

In this work, we will describe the latest results and progress obtained with novel gas avalanche concepts designed to target applications at the Facility for Rare Isotope Beam (FRIB). In particular, we will describe recent progress in the development of Multi-layer THGEM (M-THGEM) structures, for application in active-target TPC readout, as well as tracking at the focal-plane of high-rigidity spectrometers. This also includes a recently conducted evaluation of the Multi-mesh THGEM, multi-layer THGEM with embedded electrode meshes, in terms of gas gain and ion backflow suppression.

Title: Charge-exchange reactions with AT-TPC

Presenter: Zarif Mubassir Rahman

Affiliation: Michigan State University/FRIB

Abstract: Electron-capture (EC) rates play a decisive role in core-collapse and thermonuclear supernovae, the crust of accreting neutron stars in binary systems, and the final core evolution of intermediate mass stars. Charge-exchange reactions (CERs) at intermediate energies (~100 MeV) are crucial in extracting information for neutron-rich nuclei as the EC Q-values are positive for such nuclei. The differential cross-sections in CERs at zero momentum transfer are proportional to the Gamow-Teller strength, $B(GT)$, from which the EC rates can be calculated. In a first of a kind experiment, the S800 spectrometer at National Superconducting Cyclotron Laboratory (NSCL) along with Active-Target Time Projection Chamber (AT-TPC) setup was used to run an experiment with $(d,2\text{He})$ probe in inverse kinematics to study unstable nuclei. Data from the experiment for the $^{13}\text{N}(d,2\text{He})^{13}\text{C}$ reaction was analyzed to extract the differential cross-section for ground and excited states which has been utilized in measuring the $B(GT)$.

Title: Analysis of ^{11}Be excited states via the $^{10}\text{Be}(d,p)$ reaction

Presenter: Michael Serikow

Affiliation: MSU/FRIB

Abstract: The $^{10}\text{Be}(d,p)$ reaction was studied in inverse kinematics with the Active Target Time Projection Chamber (AT-TPC) in the SOLARIS solenoid at the NSCL. This marked the first time the AT-TPC observed a transfer reaction in inverse kinematics at a low beam intensity (1-2 kHz). A beam of ^{10}Be was accelerated to about 9 MeV/u in the ReA6 linac and delivered to the AT-TPC placed in a 3 Tesla magnetic field provided by SOLARIS. The AT-TPC was filled with pure deuterium gas at 600 Torr pressure. The $^{10}\text{Be}(d,p)$ reaction populated both bound and unbound states in ^{11}Be , and we particularly focus on a 3.41 MeV state for which the parity is still an open question. The primary goal of the analysis is to create angular distributions for various populated states in ^{11}Be and compare them to theoretical models to extract the angular momentum of the transferred neutron and determine the spectroscopic factors. Key elements of this process will be presented, including the drift velocity calculation, excitation energy spectrum construction, and reaction channel selection. The preliminary angular distributions will be shown, and that of the 3.41 MeV state in ^{11}Be supports the assignment of a negative parity.

Title: An active target time projection chamber for fast rare isotope beam experiments

Presenter: Zbigniew Chajęcki

Affiliation: Western Michigan University

Abstract: Many experiments with fast energetic beams require an open geometry allowing, in some cases, the identification of heavy residues downstream in a magnetic spectrometer or detection of particles in ancillary detectors. An optimized and portable Active Target detector is essential to accommodate a broad experimental program and the coupling to a wide range of equipment the science requires. We present a cost effective solution to these challenges by developing the Active Target time projection chamber to be used to study reactions induced by fast rare isotope beams at the Facility for Rare Isotope Beams (FRIB). The technical details of the project as well as its physics motivation will be discussed.

Title: The SPiRiT TPC for heavy ion collision experiments at RIKEN-RIBF

Presenter: Tadaaki Isobe

Affiliation: RIKEN

Abstract: The SPiRiT Time Projection Chamber (TPC) was designed and constructed for the detection of multiple charged particles produced in heavy ion collisions to constrain the symmetry term of nuclear Equation of State. The state-of-art readout electronics, GET readout system, was employed as the readout system for SPiRiT-TPC 12k readout pads.

In the spring of 2016, first campaign of heavy ion collision experiments was conducted at RIKEN-RIBF. In this experiment, $\sim 10\text{kHz}$ Sn isotope beams of $E = 270$ MeV/u were bombarded to Sn target. I will present the overview of SPiRiT-TPC system, its in-beam performance, and recent result of heavy ion collision experiments in terms of detector technology mainly.

This presentation is based on the work supported by the DOE under Grant No. DE-SC0014530, DE-NA0002923 and NSF under Grant No. PHY-1102511 and the Japanese MEXT Grant-in-Aid for Scientific Research on Innovative Area Grant No. 24105004.

Title: Outlook for an Equation of State TPC with the High Rigidity Spectrometer

Presenter: Kyle Brown

Affiliation: Facility for Rare Isotope Beams

Abstract: The Facility for Rare Isotope Beams will provide a unique opportunity to study the nuclear equation of state at both super-saturation density, as well as large isospin asymmetry. This is particularly true as we look forward to the upgrade to 400 MeV/u. In order to leverage those available beams, we plan to utilize a SPiRiT-like TPC inside of the large dipole magnet of the planned High Rigidity Spectrometer. In

this talk I will discuss the physics motivation of the work, the technical requirements, and the possibilities for retrofitting the SPIRIT TPC for this work.

Title: Discussion of how design and physics are connected

Presenter: William Lynch

Affiliation: Michigan State University

Abstract: The SpiRIT TPC was designed to fit into the SAMURAI spectrometer where it will be used to constrain the EoS of neutron rich matter via comparisons of central collisions involving two neutron-rich heavy nuclei to those involving two deficient heavy nuclei. I will discuss how this science program influenced its design and how the TPC performed in that roll. The first SpiRIT campaign focused on measurements of pion production and has provided a constraint on the symmetry energy at about 1.5 times saturation density. When combined with other experimental constraints and existing astronomical constraints, the EoS can be constrained from 0.2-3.0 times saturation density. I will discuss how this constraint compares with other constraints, and what it may suggest about the likelihood of URCA supercooling. I will also discuss a recent attempt to constrain the isovector nucleon effective mass and the present plans for the next SpiRIT campaign.

Title: DAPPER TPC: A new active target device for transfer reactions with the Detector Array for Photons, Protons and Exotic Residues.

Presenter: Alan B. McIntosh

Affiliation: Texas A&M University

Abstract: We have developed and commissioned DAPPER to measure (d,p) reactions in inverse kinematics, allowing use of rare ion beams. DAPPER is distinguished by its ability to simultaneously measure total photon energy, individual photon energies, and excitation energy. We propose to develop an active target TPC at the heart of the detector array. The TPC would be compact, with active volume on the order of 10cm diameter and 10 cm long, and lightweight to allow measurement of gamma rays with high efficiency and minimal scattering. The DAPPER TPC should provide a thicker target to improve yield, improve resolution of excitation energy, remove background reactions, extend the measurable range of excitation energy, and eliminate target lifetime issues. With these improvements, tighter constraints on level densities and photon strength functions should be achieved, impacting models of neutron capture relevant to basic nuclear science, nucleosynthesis, stockpile science, and advanced reactor design.

Title: ATOM-X and TPC development at CENS

Presenter: Sunghoon (Tony) Ahn

Affiliation: Center for Exotic Nuclear Studies, Institute for Basic Science

Abstract: Type I X-ray bursts are well known explosive stellar events in the Universe. While the bursts are powered by many nuclear reactions including the triple-alpha reaction, the p- and the rp-process, large uncertainties of their reaction rates cause difficulties when predicting X-ray burst light curves to compare with observations. Recent sensitivity studies showed that many (a,p) reactions are very important affecting a large variation of energy generation and final ash in X-ray burst models. In order to constrain the astrophysical reaction rate, the total cross section measurement along the large center-of-mass energy range is necessary and many upgrades of the Texas Active Target detector (TexAT_v2) has been performed by the Texas A&M University and the Center for Exotic Nuclear Studies (CENS). Furthermore, a new detector, Active Target for Multiple nuclear astrophysics eXperiments (AToM-X), is also under development providing high resolutions for charge particle tracks, energy and position of detected particles. In this talk, possible important nuclear astrophysics studies using the TexAT_v2 and AToM-X detector will be discussed as well as the status of the detector development.

Title: The NIFFTE fissionTPC

Presenter: Lucas Snyder

Affiliation: Lawrence Livermore National Laboratory

Abstract: The goal of the Neutron Induced Fission Fragment Tracking Experiment (NIFFTE) is to measure precision fission cross sections. The tracking capabilities of this device allow for the full reconstruction of charged particles produced by neutron beam induced fission from a thin central target. The wealth of information gained from this approach allowed cross section systematics to be studied in detail and allowed for a variety of other measurements to be performed. Here we present a brief history of this unique instrument and some of the lessons learned from design and operation.

Title: Studying Asymmetric Fission near ^{197}Pb with AT-TPC

Presenter: Curtis Hunt

Affiliation: Michigan State University

Abstract: In the region of the neutron deficient pre-actinides, around ^{197}Pb and ^{180}Hg , is an unexpected island of asymmetric fission. To study the transition between symmetric and asymmetric fission near ^{197}Pb , the fusion-fission reaction of heavy nuclei on He gas was performed with the Active Target Time Projection Chamber (AT-TPC) at NSCL (now FRIB). To identify beam particle species, a new particle identification system, HEavy ISotope Tagger (HEIST), was created for the experiment. A combination of analytical and machine learning methods have been used to identify fission events. Space charge in the TPC resulting from the heavy beam particles was a problem for event reconstruction and had to be corrected for from calculations with the Langevin equation. To determine charge distributions of the fission fragments to measure fragment asymmetry, a modified method of deconvolution of the shaped signals was employed.

Title: Using Neon for Active-Target TPCs: Development using the ND-Cube

Presenter: Tan Ahn

Affiliation: University of Notre Dame

Abstract: The use of heavier noble gases in active-targets opens up possibilities for a larger array of reaction studies. Some examples include the study of fusion with stable and unstable isotopes with Ne targets, some of which are important for understanding fusion dynamics with implications for nuclear astrophysics such as reactions that are predicted to occur in neutron star crusts. A challenge for using pure Ne as a target is the tendency for sparking at voltages that are needed for sufficient amplification in TPCs. The use of hydrocarbon quench gases are a solution, but can introduce unwanted background reactions on carbon and oxygen. One solution that we have employed is the use of a small amount of H_2 gas in a Ne: H_2 gas mixture in conjunction with a multi-layer TH-GEM. The H_2 gas increases amplification gain by acting both as a quench gas and Penning mixture. The use of Ne: H_2 in current fusion studies with the ND-Cube active-target TPC will be presented along with future needs for the simulation and modeling of micropattern gas detector amplification.

Title: Nuclear physics with SpecMAT

Presenter: Oleksii Poleshchuk

Affiliation: KU Leuven, Instituut voor Kern- en Stralingsfysica, Celestijnenlaan 200d, 3001 Leuven, Belgium

Abstract: SpecMAT is an active target developed for studying the shell evolution in exotic isotopes and observing the fundamental aspects of the nuclear structure far from stability via transfer reactions carried in inverse kinematics. The SpecMAT is currently at its final developmental stage undergoing characterisation measurements at KU Leuven and ISOLDE, CERN. During the most recent characterisation, SpecMAT was installed in the ISOLDE Solenoidal Spectrometer, which generated a magnetic field of 2.5 T. This characterisation was performed off-line using a standard alpha source. In this measurement spiral tracks of alpha particles were successfully observed in the time projection chamber of the detector. Gamma rays emitted in the decay chain of ^{241}Am were detected in coincidence with the particle tracks by the scintillation array. With this characterisation, we demonstrated that all detector components could operate in the strong magnetic field and are ready for future on-line experiments. In this talk recent Geant4 simulations of transfer reactions that can be studied with SpecMAT also will be presented. Using the newly developed simulation toolkit, SpecMATscint, we demonstrated the feasibility of studying the shell evolution in the chain of neutron-rich copper isotopes via a $(d,^3\text{He})$ transfer reaction.

Title: Studies of capture reactions with the active target MUSIC

Presenter: Chloé Fougères

Affiliation: Physics Division, Argonne National Laboratory (ANL), 9700 S. Cass Av., Lemont, IL 60439, USA

Abstract: The measurement of capture reactions is driven by many physics problems: explosive stellar burnings, nuclear reaction theory and particle-optical-model potentials, nuclear data and reactors, among others. Such investigations are experimentally difficult because of the low cross sections (<10 mb) and the low energies (~MeV/u) within the scope of interest. In addition, reactions of astrophysical importance often involve radioactive isotopes. Advances in accelerator facilities are increasing the number of experimentally accessible reactions. In this dynamic context, active targets are becoming essential, allowing the measurement of cross sections, in inverse kinematics, at the interesting energy. The technique has many advantages: a compact set-up where the target medium is also the detection medium, an efficiency of 100 %, a self-normalization, a direct access to total cross sections at different energies from a mono-energetic beam. The MUlti Sampling Ionization Chamber (MUSIC), presenting an electrically-segmented anode, has been successfully used for this purpose at ATLAS and at FRIB. A recent upgrade of MUSIC data acquisition system (to digital electronics) allows us to run at higher beam rates (tens of kHz). The calibration of the beam energy losses in the detector has become a standard process in MUSIC experiments. Reactions of α and p captures were recently studied. The weak r-process, possibly active in CCSNe ν -winds and the uncertainties related to α -Optical-Model Potentials motivate (α, xn) measurements. The first study of the $^{88}\text{Sr}(\alpha, n)^{91}\text{Zr}$ reaction will be presented. The (p, α) and (α, p) reactions, relevant for CCSNe, type 1a supernovae, and type 1 X-ray bursts, can be investigated with MUSIC, and several experiments happened in this direction. Finally, (α, n) data needed for advanced reactors led to a recent experiment. Future experimental efforts on the weak r-process reactions and on the next generation of MUSIC with a time projection chamber under development will finally be discussed.

Title: SREFT

Presenter: Chris Prokop

Affiliation: Los Alamos National Laboratory

Abstract: The Spatially Resolved Fission Tracker (SREFT) is a time projection chamber under development at Los Alamos National Laboratory. Following commissioning in the upcoming LANSCE run cycle this instrument will address neutron-induced fission and light charged particle reaction cross sections (i.e n,a) for a variety of sponsors. The initial prototype used for benchtop testing was realized through in-house additive manufacturing. SREFT has a central cathode, made of copper, that slides in and out of the face of the instrument to facilitate easy sample changes. A polyimide flex board is used for the field cage to establish a constant and uniform drift field. SREFT utilizes a stack of up to three Gas Electron Multipliers (GEM)s that offer a wide range of achievable gain. The charge readout is accomplished using a "strip anode" whereby an array of 16200 1-mm pitch diamonds is connected electrically to form a grid of 90x90 orthogonal "strips". This reduces the channel count dramatically permitting readout by commercial preamplifiers and CAEN vx2745 digitizers. The SREFT gas handling system makes heavy use of commercial MKS components and allows up to four gases to be mixed in any proportion and flowed at some rate maintaining some constant pressure inside the instrument. A residual gas analyzer periodically samples the exhaust gas to monitor composition. In this talk additional details pertaining to the design of SREFT along with simulations and early source tests will be presented.

Title: TexAT & TeBAT - a multitude of experiments

Presenter: Jack Bishop

Affiliation: Cyclotron Institute

Abstract: TexAT (Texas Active Target) is a highly-versatile TPC that has been used to study nuclear structure and astrophysics using a wide variety of different reaction mechanisms and techniques. This talk will highlight a selection of these.

In addition, the development of the new TeBAT (Texas-Birmingham Active Target) TPC using resistive micromegas will be outlined including simulations and tests with prototype boards.

Title: TexAT-TPC and a Neutron Detector Array, TexNeut

Presenter: Dustin Scriven

Affiliation: Texas A&M University Cyclotron Institute

Abstract: Proton elastic scattering is a powerful tool for studying the structure of light nuclei. TPC based studies using RIBs in inverse-kinematics allow us to probe the structure of many rare isotopes, including unbound states. In addition to (p,p) scattering, structure measurements with (p,n) reactions also provide high-fidelity data of the same nuclear structure which together become extremely useful in an R-matrix framework. Recently, we have designed and constructed a neutron detector array, TexNeut, which can be used in conjunction with the TexAT-TPC. In this talk I will discuss design considerations, our efforts to couple the TexAT-TPC to TexNeut and I'll show some preliminary data from the coupled system.

Title: Development of GADGET II

Presenter: Chris Wrede

Affiliation: MSU/FRIB

Abstract: Uncertainties in the thermonuclear rate of the $^{15}\text{O}(\alpha,\gamma)^{19}\text{Ne}$ reaction have the largest influence on the modeling of observed light curves from X-ray bursts on accreting neutron stars. The rate is dominated by a single resonance whose strength can be determined by measuring the small alpha-particle branching ratio. The resonance is populated by the beta delayed proton decay of ^{20}Mg , providing an opportunity to measure the desired branching ratio. Approximately 10 years ago, a project was initiated to develop a time projection chamber (TPC) for this purpose. The project was carried out in two phases. In the first phase, a compact calorimetric gaseous detector using TPC technology similar to AstroBox at TAMU was designed and built to operate inside the Segmented Germanium Array (SeGA) at the National Superconducting Cyclotron Laboratory [1]. This Gaseous Detector with Germanium Tagging (GADGET) was used to study radiative proton capture reactions of importance to classical novae nucleosynthesis, such as $^{30}\text{P}(p,\gamma)^{31}\text{S}$ using ^{31}Cl beta-delayed proton decay [2]. In the second phase, the gaseous detector of GADGET was upgraded to operate as a TPC by installing a high-granularity readout. This "GADGET II" system became operational in 2021 and was used to complete the ^{20}Mg decay experiment in 2022 at the Facility for Rare Isotope Beams. The future program with GADGET II includes a recently approved FRIB experiment to simultaneously study the competing $^{59}\text{Cu}(p,\alpha)^{56}\text{Ni}$ and $^{59}\text{Cu}(p,\gamma)^{60}\text{Zn}$ and reaction rates in X-ray bursts using the beta decay of ^{60}Ga . Uncertainties in these reactions are currently 2nd- and 3rd-most influential on the modeled light curves.

[1] M. Friedman et al. Nucl. Instrum. Methods Phys. Res., Sect. A 940, 93 (2019)

[2] T. Budner et al., Phys. Rev. Lett. 128, 182701 (2022)

Title: Supervised Machine Learning TPC analysis for nuclear structure studies using gamma-beams

Presenter: Robin Smith

Affiliation: Sheffield Hallam University

Abstract: Alpha particle clustering is thought to be widespread throughout the nuclear chart, and light nuclei provide an ideal testing ground for state-of-the-art theoretical calculations, such as the Algebraic Cluster Model (ACM) [1]. To explore the predicted rotational states built on the Hoyle state in carbon-12 [2], an experiment was performed using the HIGS gamma-beam facility at Duke University in 2022. Gamma beams from 8.6 to 13.9 MeV were incident on a CO_2 active target contained within an electronic TPC, built by the university of Warsaw [3]. By examining the photo-dissociation of ^{12}C through an intermediate state in ^8Be , $^{12}\text{C}(g,a)^8\text{Be}$, we search for new states predicted by the ACM.

Three-alpha-particle events from ^{12}C photodissociation form a minority of measured events. This presents a significant experimental challenge, especially since typical experimental signatures, such as total charge deposition and track lengths, overlap with those of competing reaction channels, e.g. $^{16}\text{O}(g,a)^{12}\text{C}$. Two pretrained convolutional neural networks were trialed for event classification; ResNet-18 and ResNet-50. We used a pretrained version of the network trained on more than a million images from

the ImageNet database [4,5]. The pretrained network learned rich feature representations for a wide range of images and may be applied to the problem of track classification. The performance of this method comparing with a large bank of hand-categorised events. Further improvements are expected by training the neural network on a larger number of simulated events, and by applying a track deconvolution.

[1] Bijker, R., & Iachello, F. (2002). *Annals of Physics*, 298(2), 334-360.

[2] D.J. Marin-Lambarri et al. *Phys. Rev. Lett.* 113, 012502 (2014).

[3] Ćwiok, M. et al. (2023, September). *European Physical Journal Web of Conferences* (Vol. 279, p. 04002).

[4] ImageNet. <http://www.image-net.org>

[5] He, Kaiming et al. *Proceedings of the IEEE conference on computer vision and pattern recognition*, pp. 770-778. 2016.