Introduction
April 1, 2021 – March 31, 2022

Progress in research and operations at the Texas A&M Cyclotron Institute is summarized in this report for the period April 1, 2021 through March 31, 2022. The period covered by this report was impacted as the COVID-19 pandemic continued to impact the world. The CI continued operations throughout this time with new procedures to ensure that we could run as safely as reasonably achievable. The CI has had a remarkably productive year despite the circumstances and I am indebted to the dedicated operations staff that kept the facility running during this challenging period.

The discovery science program continues to produce exciting results. Additionally new equipment has been brought on –line that expands the scientific capability of the institute. TexNuet and Dapper have both been fully commissioned and utilized in first experiments.

The Cyclotron Institute continued to explore the capability of producing radioisotopes for medicine, in particular the alpha particle emitter ^{211}At. Several runs were conducted, the highest quantity of ^{211}At produced in one run being approximately 100 mCi. We have been able to purify the At-211 on a column and ship an air-dried column to MD Anderson. An automated target retrieval system will be a future priority in this project.

During this period the K500 provided 6246.5 hours and the K150 provided 5416 hours of beam for both science and radiation-effects testing. The new ECR4 ion source was able to take over in supplying injected beam for the K500 while the damaged ECR1 ion source was being rebuilt. Development has continued with the K150, most notably with a program dedicated to detecting faint beams and their contaminants after acceleration. A minor upgrade to the ECR2 ion source injecting the K150 has increased its magnetic containment field with the goals of greater stability and larger intensities of high-charge states, and indeed several higher charge-state, accelerated beams have been detected after this upgrade.

As in previous reports, I include here a few scientific highlights.

- The long-standing problem of the importance of the neutron up-scattering process in nucleosynthesis of carbon in a stellar environment was resolved by directly measuring the cross section for this process using an active target detector (TexAT). It turned out that this process does not play an as significant role as previously assumed. (Nature Communications **13**, Article number: 2151 (2022)).
- Evidence against additional resonances below the Hoyle state in carbon-12, which were previously suggested and linked to the Efimov effect, was presented in the 12N beta-decay study with an active target detector (TexAT). (Phys. Rev. C **103**, L051303 (2021).
- Direct measurements of the ^{8}B+^{40}Ar fusion excitation function found no evidence for a previously suggested sub-Coulomb enhancement, which was linked to the special ground state proton-halo structure of ^{8}B.

- STAR Time-of-Flight analysis code improvements developed at TAMU and intended for use with pp and p+Au data were adopted by the collaboration for analysis of all the Beam Energy Scan II data that STAR recorded in 2019-21.
- Completed the construction, installation, and commissioning of the STAR Forward Upgrade, and utilized it to take data throughout RHIC Run 22.
- Two new Trojan horse measurements were suggested to pinpoint the low-energy S-factor for ^{12}C-^{12}C (Eur. Phys. J. A **58**, 29 (2022).
- Demonstrated via a transport model that the ratio N_tN_p/ N_d^2 of the triton yield Nt, deuteron yield Nd, and proton yield Np in relativistic heavy ion collisions is enhanced by the spinodal instability if the produced quark-gluon plasma undergoes a first-order transition to a hadronic matter.
- Showed via the RVUU transport model the need of reduced Delta production cross section from the nucleon-nucleon inelastic scattering for describing the yields and spectra of charged pions measured by the HADES Collaboration from Au+Au collisions at the nucleon-nucleon center-of-mass energy of 2.4 GeV.
- Performed a first demonstration of the use of self-assembled monolayers on gold-coated silicon detectors to measure chemical properties of nuclides produced in a gas-filled separator.
- Developed techniques to forensically analyze a sample of legacy radium pigment
- Calculated the effects of shell-structure and isotopic asymmetry on nuclear level density, within the semiclassical micro-macroscopic approach MMA and compared with experimental data.
- Carried out mean-field based random-phase-approximation calculations of centroid energies and branching ratios of direct one nucleon decay of isoscalar giant multipole resonances of 208Pb and compared with experimental data.
- Developed a new microscopic global optical potential with quantified uncertainties from chiral effective field theory (Phys. Rev. Lett. **127**, 182502 (2021)).
- Implemented a new machine learning algorithm for the efficient evaluation of high-dimensional integrals arising in many-body perturbation theory (Phys. Rev. Lett. 127, 062701 (2021)).
- Implemented transported charm-quark phase space distributions into the calculation of J/ψ regeneration in Pb-Pb collisions at the LHC, synergizing open and hidden heavy-flavor transport, which led to a decisive improvement in the description of the elliptic flow (v_2) data at the LHC, resolving the so-called "J/ψ v_2 puzzle". (Phys. Rev. Lett. **128**, 162301 (2022).
- Carried out detailed predictions for production of the excited y(2S) state in Pb-Pb collisions at the LHC, whose small binding energy provides high sensitivity to in-medium kinetics. The predictions for the centrality and pT dependence turned out to be in excellent agreement with new ALICE data, providing strong support for the TAMU transport approach.
- Used ^{25}Mg(*d*,*p*) reaction measurement to establish the existence of a new resonance in ^{25}Al proton capture, with potential relevance for ^{26}Al synthesis in novae.
- Commissioned phoswich focal plane detector for the MDM and used it a measurement of ^{21}Ne(*p*,*t*) in inverse kinematics.
- An automated apparatus for rapid astatine recovery has been developed (Chem. Eng. J. **442**, 136176 (2022)).

Institute scientists remain active in a number of collaborative research efforts around the world. Major programs include: measurements of beta decays with the TRINAT collaboration at TRIUMF; nuclear structure measurements with TexAT at TRIUMF; continued work with the STAR collaboration at RHIC; fusion studies at MSU; and participation in the SAMURAI collaboration at RIBF in Tokyo, Japan.

The format of this report follows that of previous years. Sections I through III contain reports from individual research projects. Operation and technical developments are given in Section IV. Section V lists the publications with Cyclotron Institute authors and outside users and the Appendix gives additional information including talks presented by members of the Institute during the past year. Once again, the full volume of this year's Progress in Research is available only on our web site (http://cyclotron.tamu.edu). *Since most of the contributions presented here are truly reports on progress in research, results and conclusions should not be quoted from the report without the consent of the authors*.

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