**Introduction**
**April 1, 2017 – March 31, 2018**

Progress in research and operations at the Texas A&M Cyclotron Institute is summarized in this report for the period April 1, 2017 through March 31, 2018. The format 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.*

For 50 years scientists at Texas A&M have been exploring the nuclear frontier. The first cyclotron beam was extracted in December 1967 and throughout 2017 we marked the occasion of 50 years of beam. Additionally, we are pleased to celebrate that former TAMU graduate student Zilong Chang (Ph.D., Dec 2016) won the 2017 RHIC & AGS Thesis Award.

The K500 provided an impressive 5,921 hours of beam for both science and radiation effects testing. The K150 cyclotron provided again, a record 4,291 hours of beam on target and continues to be used by external users for radiation effects testing with its proton beams. The growing list of beams from the K150 includes protons (strip extracted), deuterons (strip extracted), $^{4}$He, $^{6}$Li, $^{7}$Li, $^{10}$B, $^{12}$C, $^{14}$N, $^{16}$O, $^{18}$O, $^{19}$F, $^{20}$Ne, $^{22}$Ne, $^{23}$Na, $^{25}$Mg, $^{27}$Al, $^{28}$Si, $^{32}$S, $^{40}$Ar, $^{63}$Cu, and $^{84}$Kr. Proton beams from the K150 (strip extracted) are now available from 3 MeV to 49 MeV. We continue to make progress with the light-ion guide (LIG) project: using a $^{114}$Cd target, we produced radioactive $^{114}$In, which then charge bred and accelerated to 11 MeV/nucleon with the K500 cyclotron. Transporting the accelerated $^{114}$Cd/$^{114}$In beam to MARS, we were able to verify the identity of the beam and that it originated from the LIG gas cell.

As in previous reports, I include here some highlights.

- Published the first ever direct measurement of the $^{19}$Ne(p,$\gamma$)$^{20}$Na, significantly reducing uncertainties on the production of fluorine in classical novae.

- Verified the mass separation capabilities of the MDM spectrometer up to A=63 for inverse-kinematics (d,p) reactions, opening the door for future RIB experiments in the A~60 mass region.

- Developed a method of determining the reactor type, burnup, and time since irradiation of used nuclear fuel in collaboration with the Department of Nuclear Engineering.

- Studied the mechanism of extraction of indium and thallium from hydrochloric acid by a variety of organic solvents.

- Demonstrated successful track reconstruction with TexAT for $^{8}$B+p and $^{8}$Li+p.

- Completed the analysis of the first precise measurement of the superallowed branching ratio for $^{26}$Si. With this result, precise *ft* values are now known for the mass-26 pair of $0^{+}\rightarrow 0^{+}$ superallowed transitions. The result is consistent with the only other measured pair of such transitions (at $A$=38) and together they act to significantly constrain calculations of the isospin-symmetry-breaking corrections, which are required to extract $V_{ud}$, the upper-left element in the CKM matrix.

- Published the first-ever observation of the Collins effect in pp collisions, enabling tests of universality and factorization of transverse momentum dependent (TMD) fragmentation functions, and the first-ever limits on gluon linear polarization in transversely polarized protons.

- An earlier developed self-consistent many-body approach to the strongly interacting Quark-Gluon Plasma has been deployed to analyze its transport properties. A maximally strongly-coupled solution is necessary to generate a small viscosity-to-entropy ratio and heavy-quark diffusion coefficient as required by phenomenological analyses of light- and heavy-flavor hadron observables in ultrarelativistic heavy-ion collisions.

- Performed a broad investigation with several research groups (with TAMU leadership) within an EMMI rapid reaction task force to scrutinize the theoretical components in the extraction of heavy-flavor transport coefficients in QCD matter from heavy-ion collisions; the leading model uncertainties have been identified and systemic procedures for their improvement established.

- Constructed a new class of hot and dense matter equations of state that simultaneously satisfy constraints from microscopic many-body theory, nuclear experiments, and neutron star observations.

- Computed neutron star tidal deformabilities based on dense matter equations of state constrained by chiral effective field theory and confronted these predictions with observational data from gravitational wave event GW170817.

- Derived an analytical expression which provides a good approximation for the effect of two-body short-range correlations on the one-body matter distributions in nuclei.

- Adopted the thermodynamical approach for the statistical level density in nuclei and carried out calculations within the self-consistent mean-field approach using the extended Thomas-Fermi approximation, which accounts for the liquid drop and the shell models.

- Using 33 commonly employed energy density functionals, we carried out Hartree-Fock based

random phase approximation calculations of the centroid energies of isoscalar and isovetor giant resonances of available experimental data for a wide range of nuclei and studied their sensitivities to properties of nuclear matter and thereby deduced constraints on these properties.

- Suggested and developed a new indirect method in nuclear astrophysics: indirect radiative capture reactions. This method will allow us for the first time in 50 years of hunting to measure the astrophysical factor of the radiative capture $^{12}C(^{4}He,\gamma)^{16}O$ at the most effective astrophysical energy of 300 keV.

- Established a connection between mirror resonance widths which can be used for experiments at the Cyclotron Institute to determine an unknown resonance width through the known ones.

- Reproduced the binding energies of light nuclei in the constrained molecular dynamics model by including the Heisenberg principle and (iso)spin-(iso)spin forces which has application to fusion, fission and fragmentation reactions.

- Performed search for Efimov states in hot nuclei from 3 alpha correlations in $^{70}Zn+^{70}Zn$ at 35MeV/nucleon using the NIMROD 4π detector.

- Measured fusion reactions in strongly compressed plasmas using 8 laser beams (<3ns pulse duration and <20kJ energy) in cylindrical symmetry.

- Commissioned the ParTI Array and measured upper limit of pionic fusion in reaction of $\alpha+^{12}C$.

- Demonstrated ability to do elemental analysis through PIXE and PIGE with K150.

- Demonstrated that the vorticity field produced in non-central heavy ion collisions within the chiral kinetic theory leads to polarizations of quarks and antiquarks and thus of Lambda and anti-Lambda hyperons along its direction as observed in experiments by the STAR Collaboration at the Relativistic Heavy Ion Collider.

- Demonstrated that Including the energy conservation condition in scattering and decay processes in the transport model is necessary for obtaining the correct equilibrium particle distributions and is thus important for extracting the nuclear symmetry energy at high density from the ratio of charged pions produced in high energy heavy ion collisions.

Institute scientists remain active in a number of collaborative research efforts around the world. Major programs include: mass measurements using the Penning Trap at the University of Jyväskylä; continued work with the STAR collaboration at RHIC; measurements of beta decays with the TRINAT

collaboration at TRIUMF; ANASEN at MSU; and participation in the SAMURAI collaboration at RIBF in Tokyo, Japan.

I am indebted to Dr. Y.-W. Lui for assembling this report.

S.J. Yennello
July 1, 2018