Introduction
April 1, 2015 – March 31, 2016

Progress in research and operations at the Texas A&M Cyclotron Institute is summarized in this report for the period April, 1, 2015 through March 31, 2016. 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.*

We are pleased to announce that we have successfully hired three new tenure track faculty. Dr. Gregory Christian and Dr. Ania Kwiatkowski are both outstanding young experimentalists that relocated from TRIUMF to join Texas A&M in the fall. Additionally Dr. Jeremy Holt, an excellent theorist from the INT joined us in January.

The K500 provided a record 6,400 hours of beam for both science and radiation effects testing. The K150 cyclotron provided a record 3,800 hours of beam on target. The list of beams from the K150 included protons (strip extracted), ^{4}He, ^{6}Li, ^{7}Li, ^{22}Ne, ^{26}Mg, ^{27}Al, ^{28}Si, and ^{32}S. As the light ion guide (LIG) continues to progress toward eventual production of radioactive beams, we tried an exercise on how to re-accelerate and transport weak beams. Using $^{16}O^{3+}$ ions as the pilot beam, we have accelerated and transported much weaker $^{86}Rb^{16+}$ ions from the CBECR ion source and through the K500 cyclotron and then to the MARS spectrometer. The intense oxygen beam was used to tune the injection line and the K500 cyclotron (set for 14 MeV/nucleon) and the beam transport to MARS, and then a simple shift of the K500 RF frequency, by +56 kHz, was all that was needed to bring the Rb beam to the MARS target. We hope to do the same when the radioactive ^{64}Ga ions are identified after the CBECR ion source.

As in previous reports, I include here some highlights of work carried out over the past year.

- A good candidate for a state analogous to the ^{12}C Hoyle in ^{16}O has been identified via the thick target inverse kinematic measurement of ^{20}Ne + alpha at an excitation energy of 15 MeV.

- The Heavy Elements Group has reported the first extraction of a metal (indium) using a deep eutectic solvent, which may have both fundamental and practical applications.

- The neutron-proton equilibration in dynamically-deformed atomic nuclei has been measured on a sub-zeptosecond timescale and shown to follow first-order kinetics with a mean equilibration time of 0.3 zs.

- Collective effects were shown to have a significant influence on fusion-evaporation reactions, and may substantially affect the likelihood of discovering the next new element.

- The first direct measurement of the $E_r \sim 450$ keV resonance in the $^{19}Ne(p,\gamma)^{20}Na$ reaction put past uncertainties related to the resonance properties to rest and significantly improved constraints on the production of ^{19}F in classical novae.

- Precise (±~1%) measurements of K-shell internal conversion coefficients (ICCs) for *E*3 and *M*4 transitions for a range of nuclei, $48 \leq Z \leq 78$, have demonstrated the need to include the K-shell vacancy in the theory used to calculate ICCs and have supported use of the "frozen orbital" approximation.

- The astrophysically important reaction rates for the s-process neutron source reactions $^{13}C(\alpha,n)$ and $^{22}Ne(\alpha,n)$ have been constrained by measuring alpha asymptotic normalization coefficients of the near threshold states in ^{17}O and ^{26}Mg using the sub-Coulomb (^{6}Li,d) alpha-transfer reactions.

- A long standing discrepancy in the structure of ^{9}He has been resolved by the measurement of narrow (~100 keV) states in the low energy spectrum of ^{9}He and that the spectrum is dominated by a broad 1/2+ states located at ~3 MeV above the neutron decay threshold.

- The astrophysical factor and reaction rates of the synthesis of primordial (Big Bang) ^{6}Li isotopes were calculated with high accuracy and confirmed by recent LUNA (Italy) experiment.

- The scaling energies of the giant monopole resonances in ^{40}Ca, ^{56}Ni, ^{60}Ni and ^{68}Zn were found to agree nicely with HF-RPA calculations using SkM* (K_{NM}=216.6 MeV) while those for ^{44}Ca, ^{54}Fe, ^{58}Ni, ^{64}Zn and ^{90}Zr agreed with calculations using the KDE0v1 interaction (K_{NM}=227.5 MeV), suggesting a need to go beyond the HF-RPA in calculating these excitations with possible implications for the resultant value for K_{NM}.

- Within the Born approximation, we have shown that the microscopic mean-field based RPA projected (one-body) transition density provides a good approximation for the hadron excitation cross section of isoscalar giant monopole obtained using the energy-average double transition density, which is not the case for the semi-classical collective model transition density.

- We have carried out HF based RPA calculations of isoscalar giant resonances of multipolarities L=0 – 3 for the Zr and Mo isotopes for over 30 commonly employed Skyrme-type interactions and compared with experimental data, obtaining good agreement for the energies of the monopole (L=0) and the dipole (l=1) but not for L= 2 and 3.

- We have extracted from realistic chiral nuclear interactions the quadratic, quartic, and sextic terms in the isospin-asymmetry expansion of the free energy of nuclear matter at finite temperature, from second-order many-body perturbation theory.

- The spectral functions resulting from the implementation of the Massive Yang-Mills approach for vector and axial vector mesons in vacuum exhibit a tendency toward chiral restoration whereby both a1 and rho mesons broaden while the a1 mass approaches the free rho mass; this is consistent with the phenomenology of dilepton production in heavy-ion experiments.

- Using an in-medium T-matrix approach to calculate the free energy of a heavy quark-antiquark pair in the quark-gluon plasma reveals an underlying interaction potential which retains a long-range string force in medium, suggestive for a strongly coupled medium with important consequences for the heavy-flavor transport coefficient.

- Preliminary simulations to investigate a hybrid EBIT/Penning trap for nuclear lifetime measurements of highly charged ions indicate switching between modes effectively acts as evaporative cooling.

- We have made the first measurement of fusion cross sections in laser produced plasma for the $d+d \rightarrow n+{}^{3}He$ and $d+{}^{3}He \rightarrow p+\alpha$ reactions.

- We have investigated the competition of Bosons and Fermions in nuclear dynamics using quantum fluctuations and Landau's approach.

- The spinodal instability of baryon-rich quark matter has been studied in the linear response theory using the Polyakov-Nambu-Jona-Lasinio model, which has added to the understanding of how unstable modes in the quark matter lead to large density fluctuations in a relativistic heavy ion collision.

- A hybrid model based on quark recombination and string fragmentation has been devised for the hadronization of perturbative parton showers in jets, which reproduces results from pure string fragmentation and can be easily generalized to include partons from an ambient medium.

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.

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