

ABSTRACTS FOR PAPERS PUBLISHED

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Isoscalar Giant Resonances and Nuclear Matter Compressibility

D. H. Youngblood

Nucl. Phys. **A687**, 1 (2001)

Compression mode giant resonances have been measured in many nuclei from ^{12}C to ^{208}Pb with inelastic scattering of 240 MeV ∇ particles at small angles. Isoscalar monopole (GMR) distributions have been extracted for 17 nuclei and isoscalar dipole (ISDGR) distributions extracted for 11 nuclei. The isoscalar E1 strength distributions in nuclei with $A \geq 90$ are found to consist of a broad component at $E_x \approx 75/A^{1/3}$ MeV containing 15-40% of the total isoscalar E1 strength. The GMR results lead to $K_{\text{nm}} = 215\text{-}240$ MeV depending on the model used (231 ± 5 MeV if compared to microscopic calculations using the Gogny interaction). The ISDGR energies predicted by these same models are substantially higher in excitation than the high energy component of the experimental results.

Sensitivity of the Isoscalar Giant Dipole Resonance to Optical Potentials

H. L. Clark, Y. -W. Lui and D. H. Youngblood
Nucl. Phys. **A687**, 80 (2001)

The isoscalar giant dipole resonance is of particular interest because its energy is related to the compressibility of nuclear matter. We have previously reported identification of this 3ϕ resonance in a number of nuclei. However our analysis also revealed significant excess E1 strength in the region of the isovector giant dipole resonance that might also be attributed to the isoscalar giant dipole resonance.

Isoscalar Giant Dipole Resonance in ^{90}Zr , ^{116}Sn , and ^{208}Pb

H. L. Clark, Y. -W. Lui and D. H. Youngblood
Phys. Rev. C **63**, 031301 (2001)

Strength functions for isoscalar dipole excitations in ^{90}Zr , ^{116}Sn , and ^{208}Pb have been measured with inelastic scattering of 240 MeV ∇ particles at small angles. The isoscalar E1 strength distribution in each nucleus is found to consist of a broad component at $E_x \sim 72/A^{1/3}$ MeV containing 15-28% of the total isoscalar E1 strength. The higher component in the compression mode E1 strength previously reported only in ^{208}Pb , whereas the lower component may be a

new mode not reported previously, but suggested by recent RPA-HF and relativistic mean field calculations.

Giant Monopole Strength in ^{58}Ni

Y. -W. Lui, H. L. Clark, D. H. Youngblood
Phys. Rev. C **63**, 06307 (2000)

The strength distribution of the giant monopole resonance in ^{58}Ni has been measured from $E_x = 10$ to 35 MeV using small-angle scattering of 240-MeV ∇ particles. E0 strength corresponding to 74_{-12}^{+22} % of the E0 EWSR was found between $E_x = 12.0$ and 31.1 MeV with a centroid of $20.30_{-0.14}^{+1.69}$ MeV.

Asymptotic Normalization Coefficients for $^{14}\text{N} : ^{13}\text{C} + \text{p}$ from $^{13}\text{C} (^3\text{He}, \text{d}) ^{14}\text{N}$

P. Bém, B. Burjan, V. Kroha, J. Novák, ®.
Piskoč, E. ®imeková, J. Vincour, C. A.
Gagliardi, A. M. Mukhamedzhanov and R. E.
Tribble
Phys. Rev. C **62**, 024320 (2000)

The $^{13}\text{C} (^3\text{He}, \text{d}) ^{14}\text{N}$ proton transfer reaction has been measured at an incident energy of 26.3 MeV. Angular distributions for proton transfer to the ground state and excited states 2.313 and 3.948 MeV in ^{14}N are analyzed within the framework of the modified DWBA. Asymptotic normalization coefficients (ANC's) defining the amplitude of the tails of the ^{14}N bound-state wave functions in the $^{13}\text{C} + \text{p}$ channel are extracted that are in excellent agreement with values found previously with the $^{13}\text{C} (^{14}\text{N}, ^{13}\text{C}) ^{14}\text{N}$ reaction. We conclude that $C_{\text{p } 1/2}^2 = 18.2(9) \text{ fm}^{-1}$ and $C_{\text{p } 3/2}^2 = 0.91(14) \text{ fm}^{-1}$ for the virtual decay $^{14}\text{N}(\text{g.s.}) \rightarrow ^{13}\text{C} + \text{p}$. These are necessary for the analysis of the $^{14}\text{N} (^7\text{Be}, ^8\text{B}) ^{13}\text{C}$ and $^{14}\text{N} (^{11}\text{C}, ^{12}\text{N}) ^{13}\text{C}$ reactions to extract the ANC for $^7\text{Be} + \text{p}$ 6^8B and $^{11}\text{C} + \text{p}$ 6^{12}N , which determine the direct radiative capture cross sections $^7\text{Be}(\text{p}, \gamma) ^8\text{B}$ and $^{11}\text{C}(\text{p}, \gamma) ^{12}\text{N}$ at astrophysical energies.

Nuclear Astrophysics with Radioactive Beams

L. Trache, A. Azhari, H. L. Clark, C. A.
Gagliardi, Y. -W. Lui, A. M. Mukhamedzhanov,
X. Tang, R. E. Tribble, V. Burjan, J. Cejpek, V.
Kroha, S. Piskor, J. Vincour, F. Carstoiu

In *Proc.Intern.Symposium Advances in Nuclear Physics*, Bucharest, Romania, 9-10 December, 1999, D. Poenaru, S. Stoica, Eds., World Scientific, Singapore, p. 153 (2000)

A major contribution in nuclear astrophysics is expected now and in the near future from the use of radioactive beams. This paper presents an indirect method to determine the astrophysical S-factor at the very low energies relevant in stellar processes (tens and hundreds of keV) from measurements at energies more common to the nuclear physics laboratories (5-30 MeV/nucleon, e.g.). The Asymptotic Normalization Coefficient method consists in the determination from peripheral transfer reactions of the single particle wave function of the outermost charged particle (proton or alpha particle) around a core in its asymptotic region only, as this is the part contributing to nuclear reactions at very low energies. It can be applied to the study of radiative proton or alpha capture reactions, a very important class of stellar reactions. The method is briefly presented along with our recent results in the determination of the astrophysical factor S_{17} for the proton capture reaction ${}^7\text{Be}(p,0){}^8\text{B}$. The reaction is crucial for the understanding of the solar neutrino production. Our study was done at the superconducting cyclotron K500 of Texas A&M University, using the ${}^7\text{Be}$ beam produced with MARS. Two proton transfer reactions with radioactive beams were measured ${}^{10}\text{B}({}^7\text{Be},{}^8\text{B}){}^9\text{Be}$ and ${}^{14}\text{N}({}^7\text{Be},{}^8\text{B}){}^{13}\text{C}$, as well as proton transfer reactions involving stable partners. We present the experiments, discuss the results and the uncertainties arising from the use of calculated optical potentials between loosely bound radioactive nuclei. A test case for our method is included.

Asymptotic normalization coefficients from direct transfer reactions and astrophysical S factors

C. A. Gagliardi, A. Azhari, P. Bem, V. Burjan, F. Carstoiu, J. Cejpek, H. L. Clark, V. Kroha, Y. -W. Lui, A. M. Mukhamedzhanov, J. Novak, S. Piskor, A. Sattarov, E. Simeckova, X. Tang, L. Trache, R. E. Tribble, J. Vincour
Nucl. Phys. **A682**, 369C (2001)

Peripheral transfer reactions can be used to determine asymptotic normalization coefficients (ANC). These coefficients, which specify the normalization of the tail of the overlap function, determine S factors for direct capture reactions at astrophysical energies. A variety of proton transfer reactions involving both

stable and radioactive beams have been used to measure ANC'S. Tests have demonstrated that ANC's determined from proton transfer reactions can be used to calculate astrophysical direct capture rates to within 9%. The ${}^{10}\text{B}({}^7\text{Be},{}^8\text{B}){}^9\text{Be}$ and ${}^{14}\text{N}({}^7\text{Be},{}^8\text{B}){}^{13}\text{C}$ reactions have been used to measure the ANC appropriate for determining the ${}^7\text{Be}(p,0){}^8\text{B}$ rate, and the ${}^{14}\text{N}({}^{11}\text{C},{}^{12}\text{N}){}^{13}\text{C}$ reaction has been used to measure the ANC required to calculate the ${}^{11}\text{C}(p,0){}^{12}\text{N}$ rate.

Observation of Polarization in Bottomonium Production at $\sqrt{s} = 38.8$ GeV

C. N. Brown, T. C. Awes, M. E. Beddo, M. L. Brooks, J. D. Bush, T. A. Carey, T. H. Chang, W. E. Cooper, C. A. Gagliardi, G. T. Garvey, D. F. Geesaman, E. A. Hawker, X. C. He, L. D. Isenhower, D. M. Kaplan, S. B. Kaufman, P. N. Kirk, D. D. Koetke, G. Kyle, D. M. Lee, W. M. Lee, M. J. Leitch, N. Makins, P. L. McGaughey, M. Moss, B. A. Mueller, P. M. Nord, I. V. Papavassiliou, B. K. Park, J. C. Peng, G. Petitt, P. E. Reimer, M. E. Sadler, W. E. Sondheim, P. W. Stankus, T. N. Thompson, R. S. Towell, R. E. Tribble, M. A. Vasiliev, J. C. Webb, J. L. Willis, D. K. Wise and G. R. Young
Phys. Rev. Lett. **86**, 2529 (2001)

We present a measurement of the polarization observed for bottomonium states produced in p -Cu collisions at $\sqrt{s} = 38.8$ GeV. The angular distribution of the decay dimuons of the $K(1S)$ state shows no polarization at small values of the fractional longitudinal momentum x_F and transverse momentum p_T but significant positive transverse production polarization for either $p_T > 1.8$ GeV/c or for $x_F > 0.35$. The $K(2S + 3S)$ (unresolved) states show a large transverse production polarization at all values of x_F and p_T measured. These observations challenge NRQCD calculations of the polarization expected in the hadronic production of bottomonium states.

Measurement of Differences Between J/ψ and ψ' Suppression in p-A Collisions

M. J. Leitch, W. M. Lee, M. E. Beddo, C. N. Brown, T. A. Carey, T. H. Chang, W. E. Cooper, C. A. Gagliardi, G. T. Garvey, D. F. Geesaman, E. A. Hawker, X. C. He, L. D. Isenhower, D. M. Kaplan, S. B. Kaufman, D. D. Koetke, P. L. McGaughey, J. M. Moss, B. A. Mueller, V. Papavassiliou, J. C. Peng, G. Petitt, P. E.

Reimer, M. E. Sadler, W. E. Sondheim, P. W. Stankus, R. S. Towell, R. E. Tribble, M. A. Vasiliev, J. C. Webb, J. L. Willis, G. R. Young
Phys. Rev. Lett. **84**, 3256 (2000)

Measurements of the suppression of the yield per nucleon of J/ψ and ψ' production for 800 GeV/c protons incident on heavy relative to light nuclear targets have been made with very broad coverage in x_F and p_T . The observed suppression is smallest at x_F values of 0.25 and below and increases at larger values of x_F . It is also strongest at small p_T . Substantial differences between the ψ' and J/ψ are observed for the first time in p-A collisions. The suppression for the ψ' is stronger than that for the J/ψ for x_F near zero, but becomes comparable to that for the J/ψ for $x_F > 0.6$.

Experiment E614 at TRIUMF: A Close Look at Muon Decay

N. L. Rodning, P. Amaudruz, W. Anderson, M. Comyn, Yu. Davydov, P. Depommier, J. Doornbos, W. Faszler, C. A. Gagliardi, D. R. Gill, P. Reen, P. Gumplinger, J. C. Hardy, M. Hasinoff, R. Helmer, R. Henderson, A. Khruchinsky, P. Kitching, D.D. Koetke, E. Korkmaz, Y. Lachin, D. Maas, J. A. Macdonald, R. Manweiler, T. Mathie, J. R. Musser, P. Nord, A. Olin, D. Ottewell, R. Openshaw, L. Piilonen, T. Porcelli, J.-M. Poutissou, R. Poutissou, M. Quraan, J. Schaapman, V. Selivanov, G. Sheffer, B. Shin, F. Sobratee, J. Soukup, T.D.S. Stanislaus, G. Stinson, R. Tacik, V. Torokhov, R. E. Tribble, M. A. Vasiliev, H. -C. Walter and D. Wright

In *Electroweak Physics, Proceedings of the fourteenth Lake Louise Winter Institute*, World Scientific (2000) 510-519

Muon decay, a process which involves only the weak interaction, is precisely described within the Standard Model. Therefore a precision measurement of the decay distribution will provide an unambiguous test of physics beyond the Standard Model. Experiment E614, an experiment under preparation at TRIUMF, will determine the energy and angular distributions of positrons from $+\mu$ decay to a precision of one part in 10^4 . After discussing the general framework for muon decay, the experiment and its sensitivity to new physics are described.

Precise Half-Life Measurement for the Superalloyed $0^+ \rightarrow 0^+$ Emitter ^{74}Rb : First

Results From Isac, the new Radioactive Beam Facility at TRIUMF

G. C. Ball, S. Bishop, J. A. Behr, G. C. Boisvert, P. Bricault, J. Cerny, J. M. D'Auria, M. Dombisky, J. C. Hardy, V. Jacob, J. R. Leslie, T. Lindner, J. A. Macdonald, H. -B. Mak, D. M. Moltz, J. Powell, G. Savard and I. S. Towner
Phys. Rev. Lett. **86** 1454 (2001)

Presently, the world data for superallowed beta decay leads to a result in disagreement (at the 98% confidence level) with the predictions of the Cabibbo-Kosabayashi-Maskawa matrix. Precise data for the superallowed $0^+ \rightarrow 0^+$ beta decay of ^{74}Rb would provide a critical test of the nucleus-dependent isospin symmetry-breaking corrections that must be calculated for these superallowed Fermi beta decays. The present work reports the first precise measurement of the half-life for ^{74}Rb ($t_{1/2} = 64.761 \pm 0.031$ ms). The data were obtained at the radioactive beam facility (ISAC) at TRIUMF using a beam facility of ~ 4000 ^{74}Rb ion s^{-1} .

Beta-Delayed Proton Emission

J. C. Hardy

In *Proton-Emitting Nuclei* ed. J.C. Batchelder, AIP Conference Proceedings 518 (2000), pp. 229-238

Beta-delayed proton emission was first observed thirty-six years ago. At the time, its unique signature opened a window onto a new world of exotic nuclei: on-line isotope separation was not yet available to isolate newly produced nuclei, but a readily separable decay mode was a fine alternative. In the first two decades after its discovery, beta-delayed proton decay was a rich source of spectroscopic information on nuclei far from stability, yielding everything from analog states and atomic masses to level densities and excited-state lifetimes in the femtosecond region. However, with the advent of more sophisticated methods for the production and isolation of exotic nuclei, the importance of beta-delayed protons as an identifier of new nuclei effectively disappeared. Nevertheless, the potential spectroscopic value of the process remains undiminished. In fact, as the number of known beta-decaying nuclei steadily increases, beta-delayed proton emission, its occurrence, its usefulness and its potential for the future.

Testing Binomial Reducibility and Thermal Scaling in Hadron-Induced Multifragmentation

L. Beaulieu, T. Lefort, K. Kwiatkowski, W. -C. Hsi, L. Pienkowski, R. G. Korteling, R. Laforest, E. Martin, E. Ramakrishnan, D. Rowland, A. Ruangma, V. E. Viola, E. Winchester, S. J. Yennello
 Phys. Rev. C **63**, 031302 (2001)

A binomial reducibility and thermal scaling analysis is performed on well-characterized thermal-like sources formed in 8 GeV/cB⁻¹⁹⁷Au reactions. The fragment probability distributions are shown to be binomial when plotted as a function of the measured excited energy E* and the binomial elementary probability p is shown to follow the expected Boltzmann factor: $\ln(p) \propto \exp(-B/\sqrt{E^*/A})$. Binomial reducibility and thermal scaling are explored also using global variables other than E*, and the effect of source size on the binomial parameter p and m is shown. Finally, the extracted probability p is found to be correlated with the experimentally deduced fragment emission time up to about 6A MeV of excitation energy, hinting at a possible transition in decay mechanism above that excitation energy.

Distribution of Isospin During Fragmentation of Excited Quasiprojectiles from the Reactions of ²⁸Si + ^{112,124}Sn at 30 and 50 MeV/Nucleon

S. J. Yennello, M. Veslesky, R. Laforest, D. Rowland, E. Ramakrishnan, A. Ruangma, E. M. Winchester and E. Martin
 Nucl. Phys. **A681** 1 (2001)

We have created quasiprojectiles of varying isospin via peripheral reactions of ²⁸Si + ^{112, 124}Sn at 30 and 50 MeV/nucleon. An enhanced neutron richness is observed in the light fragments with a corresponding decrease in neutron content of the heavier fragments. The enhancement of the neutron-rich light fragments changes dramatically with the N/Z of the reconstructed quasiprojectile. This non-homogeneous distribution of isospin is larger at the lower energy.

Effect of System N/Z on the Enhanced Production of Even-Z Fragments Observed in Heavy Ion Reactions

E. M. Winchester, J. A. Winger, R. Laforest, E. Martin, E. Ramakrishnan D. J. Rowland, A. Ruangma, S. J. Yennello, G. D. Westfall, A. Molen Vander, E. Norbeck,

Phys. Rev. C **63**, 014601 (2001)

The enhancement in the production of even-Z nuclei observed in nuclear fission has also been observed in fragments produced from heavy ion collisions. Beams of Ar-40, cl-40, and Ca-40 at 25 MeV/nucleon were impinged on Fe-58 and Ni-58 targets. The resulting fragments were detected using the MSU 4 B detector array, which had additional silicon detectors for better isotopic resolution. Comparison of the ratios of yields for each element showed enhancement of even-Z fragment production. The enhancement was more pronounced for reactions with a greater difference in the N/Z of the compound system. However, this effect was less for systems that were more neutron rich. The average N/Z for fragments also displayed an odd-even effect with a lower average N/Z for the even-Z fragments. This is related to the greater availability of neutron-poor isotopes for even-Z nuclei.

Signals for the Transition from Liquid to Gas in Hot Nuclei

V. E. Viola, T. Lefort, L. Beaulieu, K. Kwiatkowski, G. Wang, R. de Souza, L. Pienkowski, A. Botvina, H. Breuer, D. Durand, R.G. Korteling, R. Laforest, E. Martin, E. Ramakrishnan, D. Rowland, A. Ruangma, E. Winchester, S. J. Yennello
 Nucl. Phys. **A681** 267 (2001)

Hot nuclei produced in 5-15 GeV proton-, pion- and antiproton-induced reactions on ¹⁹⁷Au have been studied with the Indiana Silicon Sphere (ISiS) charged-particle detector array at the Brookhaven AGS accelerator. Each event has been reconstructed from the data to determine the excitation energy, charge and mass of the emitting source. Using E*/A as a sorting variable, the IMF kinetic energy spectra have been examined to assess the degree of thermal expansion in these reactions. Relative to SMM and SIMON-explosion calculations, the data suggest a weak extra thermal expansion energy above E*/A.2-5 MeV IMF-IMF correlation functions show an order-of-magnitude decrease in the relative emission in the interval E*/A.2-5 MeV. Above this value, a constant limiting time of 20-50 fm/c is found. These observations are consistent with the transition from liquid to vapor due to thermal heating.

Effect of Nucleon Exchange on Projectile Multifragmentation in the Reactions of ²⁸Si+ ¹¹²Sn and ¹²⁴Sn at 30 and 50 MeV/Nucleon

M. Veselsky, R. W. Ibbotson, R. Laforest, E. Ramakrishnan, D. J. Rowland, A. Ruangma, E. M. Winchester, E. Martin, S. J. Yennello
Phys. Rev. C **62**, 064613 (2000)

The multifragmentation of quasiprojectiles was studied in the reactions of a Si-28 beam with Sn-112 and Sn-124 targets at projectile energies of 30 and 50 MeV/nucleon. The quasiprojectile observables were reconstructed using isotopically identified charged particles with Z (f) less than or equal to 5 detected at forward angles. The nucleon exchange between projectile and target was investigated using the isospin and the excitation energy of the reconstructed quasiprojectile. For events with total reconstructed charge equal to the charge of the beam ($Z(\text{tot}) = 14$), the influence of the beam energy and target isospin on the neutron transfer was studied in detail. Simulations were carried out employing a model of deep inelastic transfer was studied in detail. Simulations were carried out employing a model of deep inelastic transfer, a statistical model of multifragmentation, and a software replica of the FAUST detector array. The concept of deep inelastic transfer provides a good description of the production of highly excited quasiprojectiles. The isospin and excitation energy of the quasiprojectile were described with good overall agreement. The fragment multiplicity, charge and isospin were reproduced satisfactorily. The range of contributing impact parameters was determined using a backtracing procedure.

Isospin Dependence of Isobaric Ratio $Y(^3\text{H})/Y(^3\text{He})$ and its Relation to Temperature

M. Veselsky, R. W. Ibbotson, R. Laforest, E. Ramakrishnan, D. J. Rowland, A. Ruangma, E. M. Winchester, E. Martin and S. J. Yennello
Phys. Lett. **B497** 1 (2000)

A dependence of the isobaric ratio $Y(^3\text{H})/Y(^3\text{He})$ on the N/Z ratio of the reconstructed quasiprojectile for the reaction of ^{28}Si beam with $^{112, 124}\text{Sn}$ targets at two different projectile energies of 30 and 50 MeV/nucleon is presented. We demonstrate a linear dependence of the observable $\ln(Y(^3\text{H})/Y(^3\text{He}))$ on the N/Z ratio of the quasiprojectile and show the dependence of the slope on the reconstructed excitation energy of the quasiprojectile. We relate this slope dependence at a given excitation energy to the temperature of the fragmenting system. Using the model assumptions of the statistical multifragmentation model, a method of temperature determination is proposed. A caloric curve is

constructed and compared to the result of the double isotope ratio method for the same set of the data and to the results of other studies.

Inhomogeneous Isospin Distribution in the Reactions of $^{28}\text{Si}+^{112}\text{Sn}$ at 30 and 50 MeV/Nucleon

M. Veselsky, R. W. Ibbotson, R. Laforest, E. Ramakrishnan, D. J. Rowland, A. Ruangma, E. M. Winchester, E. Martin, S. J. Yennello
Phys. Rev. C **62**, 041605 (2000)

We have created quasiprojectiles of varying isospin via peripheral reactions of Si-28 + Sn-112 and Sn-124 at 30 and 50 MeV/nucleon. The quasiprojectiles have been reconstructed from completely isotopically identified fragments. The difference in N/Z of the reconstructed quasiprojectiles allows the investigation of the disassembly as a function of the isospin of the fragmenting system. The isobaric yield ratio $H-3/He-3$ depends strongly on N/Z ratio of quasiprojectiles. The dependences of mean fragment multiplicity and mean N/Z ratio of the fragments on N/Z ratio of the quasiprojectile are different for light charged particles and intermediate mass fragments. Observation of a different N/Z ratio of light charged particles and intermediate mass fragments is consistent with an inhomogeneous distribution of isospin in the fragmenting system.

Thermal Expansion Effects in the 8 GeV/c $\text{B}^-+^{197}\text{Au}$ Reaction

T. Lefort, L. Beaulieu, A. Botvina, D. Durand, K. Kwiatkowski, W. -C. Hsi, L. Pienkowski, H. Breuer, R. G. Korteling, R. Laforest, E. Martin, E. Ramakrishnan, D. Rowland, A. Ruangma, V. E. Viola, E. Winchester, S. J. Yennello
Phys. Rev. C **62**, 031604 (2000)

Fragment kinetic energy spectra for reactions induced by 8.0 GeV/c B^- beams on a ^{197}Au target have been analyzed. The average fragment kinetic energies are observed to increase systematically with fragment charge but are nearly independent of excitation energy. Near $E^*/A = 5$ MeV, the data are well accounted for by two statistical multifragmentation models, SMM and Simon-explosion. However, at higher excitation energies, a small amount of extra energy, proportional to the fragment mass, is required in the models in order to match the experimental fragment's kinetic energies. This extra expansion energy is small relative to the radial expansion observed in heavy-ion-induced reactions, consistent with the interpretation that the latter expansion may

be driven primarily by collective dynamical effects that are not present in light-ion-induced collisions.

Transition in Isospin Behavior Between Light and Heavy Fragments Emitted from Excited Nuclear Systems

E. Martin, R. Laforest, E. Ramakrishnan, D. J. Rowland, A. Ruangma, E. M. Winchester
Phys. Rev. C **62**, 027601 (2000)

The isospin dependence of light and heavy fragments emitted from excited nuclear systems and the change in isospin behavior between light and heavy fragments are studied in this report. The $[N/Z]$ is calculated using data reported in the literature and from the results of the simulation code SMM. A transition in the isospin behavior between light and heavy fragments may support the recently reported two-phase bifurcation of excited nuclear matter into a neutron-rich gas phase and a more symmetric liquid phase.

Signals for a Transition from Surface to Bulk Emission in Thermal Multifragmentation

L. Beaulieu, T. Lefort, K. Kwiatkowski, R. T. de Souza, W. C. Hsi, L. Pienkowski, B. Back, D. S. Bracken, H. Breuer, E. Cornell, F. Gimeno-Nogues, D. S. Ginger, S. Gushue, R. G. Korteling, R. Laforest, E. Martin, K. B. Morley, E. Ramakrishnan, L. P. Remsberg, D. Rowland, A. Ruangma, V. E. Viola, G. Wang, E. E. Winchester, S. J. Yennello
Phys. Rev. Lett **84**, 5971 (2000)

Excitation-energy-gated two-fragment correlation functions have been studied between $E^*/A = (2-9)A$ MeV for equilibriumlike sources formed in 8-10 GeV/c B^- and $p + {}^{197}\text{Au}$ reactions. Comparisons with an N-body Coulomb-trajectory code shows an order of magnitude decrease in the fragment emission time in the interval $E^*/A = (2-5)A$ MeV, followed by a nearly constant breakup time at higher excitation energy. The decrease in emission time is strongly correlated with the onset of multifragmentation and thermally induced radial expansion, consistent with a transition from surface-dominated to bulk emission expected for spinodal decomposition.

A Precision Measurement of Muon Decay

M. A. Quraan, A. Gaponenko, P. Green, P. Kitching, R. MacDonald, G. Price, N. L. Rodning, J. Schaapman, F. Sobratee, J. Soukup, G. Stinson, A. Khruichinsky, V. Selivanov, V.

Torokhov, C. A. Gagliardi, J. C. Hardy, J. R. Musser, R. E. Tribble, M. A. Vasilyev, W.

Anderson, M. Comyn, Y. Davydov, J. Doornbos, W. Faszer, D. R. Gill, P. Gumplinger, R. Henderson, J. A. Macdonald, G. Marshall, A. Olin, D. Ottewell, R. D. Maas, P. Depommier, E. Korkmaz, T. Porcelli, T. Mathie, R. Tacik, Y. Shin, D. D. Koetke, R. Manweiler, P. Nord, T.D.S. Stanislaus
Nucl. Phys. **A663-664** (2000)

The V-A structure of the weak interaction was put into the standard model by hand in order to obtain agreement with experiments. These experiments, however, do not rule out relatively large deviations from this structure. Muon decay provides an ideal laboratory to test this structure, being a purely leptonic process. TRIUMF experiment E614 will measure both the energy and emission-angle distribution of positrons from the decay of polarized muons. This will provide a simultaneous determination of the Michel parameters $P^{\geq}\Delta$, and Φ describing muon decay with a precision of a few parts in 10^4 . Stringent limits may then be placed on the coupling constants, as well as the mass and mixing angle of a possible right-handed W boson (W_R). In this paper the formalism for muon decay is presented, the E614 experiment is described, and the sensitivity expected from E614 is compared to present limits on the values of the coupling constants and the mass and mixing angle of W_R .

Coulomb Breakup of ${}^7\text{Li}$ for Nuclear Astrophysics

Y. Tokimoto, H. Utsunomiya, T. Yamagata, M. Ohta, Y. -W. Lui, R. P. Schmitt, S. Typel, Y. Aoki, K. Ieki and K. Katori
Phys. Rev. C **63**, 035801 (2001)

A new Coulomb breakup experiment was performed for ${}^7\text{Li}$ with an improved experimental technique and theoretical treatment. Energy spectra of \forall particles and tritons were examined to find the signature of post-Coulomb acceleration in the breakup of ${}^7\text{Li}$ at $E_{\forall f}=0$. The data revealed the delayed nature of nonresonant breakup of astrophysical relevance that stems from quantum tunneling. Semiclassical discussions are presented of the lifetime of continuum states in ${}^7\text{Li}$ and distortion of relative kinetic energies between \forall and t by post-Coulomb acceleration. Dynamical calculations of Coulomb breakup were performed by solving a time-dependent Schrödinger equation. A simple potential model of ${}^7\text{Li}$ was employed. The dynamical calculations

reasonably reproduced experimental cross sections for both resonant and nonresonant breakup with two key ingredients: higher order effects and mixture of $E1$ and $E2$ multipoles. Considering the dominant role of the first-order $E1$ nature in adiabatic Coulomb breakup, cross sections in the $v_{\nu} \geq v_t$ branch at 7° - 15° for ^{64}Zn and ^{90}Zr were used to deduce astrophysical S factors $S(E)$ for $t(\nu, \gamma)^7\text{Li}$. They exhibit a moderate energy dependence at small energies. The strongly energy-dependent $S(E)$ resulted from the previous Coulomb breakup experiment based on cross sections with $v_{\nu} \leq v_t$; they are most likely Coulomb distorted and are revised in the present work.

Binary and Ternary Fission Studies with ^{252}Cf
 A. V. Ramayya, J. H. Hamilton, J. K. Hwang, C. J. Beyer, G. M. Ter-Akopian, A. V. Daniel, J. O. Rasmussen, S. -C. Wu, R. Donangelo, J. Kormicki, X. Q. Zhang, A. Rodin, A. Fomichev, J. Kliman, L. Krupa, Yu.Ts. Oganessian, G. Chubarian, D. Seweryniak, R. V. Janssens, W. C. Ma, R. B. Piercey, and J. D. Cole
 Progress in Part. and Nucl. Phys. **46**, 221 (2001)

The spontaneous fission of ^{252}Cf has been studied via γ - γ coincidences and γ - γ -light charged particle coincidences with Gammasphere. The yield of correlated Mo-Ba pairs in binary fission with 0-10 neutron emission have been remeasured with an uncompressed γ - γ coincidence data. The previous hot fission mode with 8-10 neutron emission seen in the Mo-Ba split is founded to be smaller than earlier results but still present. New 0n binary SF yields are reported. By gating on the light charged particles detected in ΔE -E Si detectors and γ - γ coincidences with Gammasphere, the relative yields of correlated pairs in alpha ternary fission with zero to 6n emission are observed for the first time. A number of correlated pairs are identified in ternary fission with ^{10}Be as the LCP. We observed only cold, 0n ^{10}Be and little, if any, hot, xn ^{10}Be channel.

Fission Modes in the Reaction $^{208}\text{Pb}(^{18}\text{O}, f)$
 I. V. Pokrovsky, M. G. Itkis, J. M. Itkis, N. A. Knodratiev, E. M. Kozulin, E. V. Prokhorova, V. S. Salamatin, V. V. Pashkevich, S. I. Mulgin, A. Ya. Rusanov, S. V. Zhdanov, G. G. Chubarian, B. J. Hurst, R. P. Schmitt, C. Agodi, G. Bellia, L. Calabretta, K. Lukashin, C. Maiolino, A. Kelic, G. Rudolf, L. Stuttge, F. Hanappe
 Phys. Rev. C **62**, 014615 (2000)

Results of fission fragment mass-energy distributions of the compound ^{226}Th nucleus formed in the sub-barrier fusion reaction $^{18}\text{O}+^{208}\text{Pb}$ at an energy of ^{18}O ions $E_{lab}=78$ MeV are reported. The reaction has been studied twice using two different accelerators, and both sets of experimental data agree quite well. Performed analysis of the experimental data with the use of a new multicomponent method has shown that alongside the well-known modes, *S*.e., the symmetric (S) and two asymmetric modes standard-one and standard-two, a high-energy mode standard-three has manifested itself. The last named mode appears due to the influence of the close-to-sphere neutron shell with $N \approx 50$ in the light fission fragment group. Theoretical calculations of the precision shapes of the fissioning nuclei $^{224,226}\text{Th}$ confirm this conclusion.

Reaction Mechanisms and Multifragmentation Process in $^{64}\text{Zn}+^{58}\text{Ni}$ at 35A-79A MeV

K. Hagel, R. Wada, J. Cibor, and J. B. Natowitz
 Phys. Rev. C **62**, 034601 (2000)

Reaction mechanisms and multifragmentation processes have been studied for $^{64}\text{Zn}+^{58}\text{Ni}$ collisions at intermediate energies with the help of antisymmetrized molecular dynamics (AMD-V) model calculations. Experimental energy spectra, angular distributions, charge distributions, and isotope distributions, classified by their associated charged particle multiplicities, are compared with the results of the AMD-V calculations. In general the experimental results are reasonably well reproduced by the calculations. The multifragmentation observed experimentally at all incident energies is also reproduced by the AMD-V calculations. A detailed study of AMD-V events reveals that, in nucleon transport, the reaction shows some transparency, whereas in energy transport the reaction is much less transparent at all incident energies studied here. The transparency in the nucleon transport indicates that, even for central collisions, about 75% of the projectile nucleons appear in the forward direction. In energy transport about 80% of the initial kinetic energy of the projectile in the center-of-mass frame is dissipated. The detailed study of AMD-V events also elucidates the dynamics of the multifragmentation process. The study suggests that, at 35A MeV, the semitransparency and thermal expansion are the dominant mechanisms for the multifragmentation process, whereas at 49A MeV and higher incident energies a nuclear compression occurs at an early stage of the reaction and plays an important roll in

the multifragmentation process in addition to that of the thermal expansion and the semitransparency.

Light Particle Probes of Expansion and Temperature Evolution: Coalescence Model Analyses of Heavy Ion Collisions at 47A MeV

K. Hagel, R. Wada, J. Cibor, M. Lunardon, N. Marie, R. Alfaro, W. Shen, B. Xiao, Y. Zhao, Z. Majka, J. Li, P. Staszal, B. -A. Li, M. Murray, T. Keutgen, A. Bonasera, and J. B. Natowitz
Phys. Rev. C **62**, 034607 (2000)

The reaction $^{12}\text{C}+^{116}\text{Sn}$, $^{22}\text{Ne}+\text{Ag}$, $^{40}\text{Ar}+^{100}\text{Mo}$, and $^{64}\text{Zn}+^{89}\text{Y}$ have been studied at 47A MeV projectile energy. For these reactions the most violent collisions lead to increasing amounts of fragment and light particle emission as the projectile mass increases. This is consistent with quantum molecular dynamics (QMD) model simulations of the collisions. Moving source fits to the light charged particle data have been used to gain a global view of the evolution of the particle emission. Comparisons of the multiplicities and spectra of light charged particles emitted in the reactions with the four different projectiles indicate a common emission mechanism for early emitted ejectiles even though the deposited excitation energies differ greatly. The spectra for such ejectiles can be characterized as emission in the nucleon-nucleon frame. Evidence that the ^3He yield is dominated by this type of emission and the role of the collision dynamics in determining the $^3\text{H}/^3\text{He}$ yield ratio are discussed. Self-consistent coalescence model analyses are applied to the light cluster yields, in an attempt to probe emitter source sizes and to follow the evolution of the temperatures and densities from the time of first particle emission to equilibration. These analyses exploit correlations between ejectile energy and emission time, suggested by the QMD calculations. In this analysis the degree of expansion of the emitting system is found to increase with increasing projectile mass. The double isotope yield ratio temperature drops as the system expands. Average densities as low as $0.36\Delta_0$ are reached at a time near 100 fm/c after contact. Calorimetric methods were used to derive the mass and excitation energy of the excited nuclei which are present after preequilibrium emission. The derived masses range from 102 to 116 u and the derived excitation energies increase from 2.6 to 6.9 MeV/nucleon with increasing projectile mass. A caloric curve is derived for these expanded A~110 nuclei. This caloric curve exhibits a plateau at temperatures near 7 MeV. The plateau extends from ~ 3.5 to 6.9 MeV/nucleon excitation energy.

Probing Dynamic Evolution in Intermediate Energy Collisions

J. Cibor, A. Bonasera, and J. B. Natowitz
ACTA Phys. Pol. B **31**, 1449 (2000)

Molecular dynamics calculations which are employed to model light particle emission in nuclear collisions at intermediate energies suggest that coalescence model analyses may be used to probe the time evolution of these systems and to provide information on the degree of thermal, chemical and isospin equilibrium achieved at particular stages of this evolution. This talk discusses the application of coalescence model analyses to explore light particle emission in reactions between 47A MeV projectiles and medium mass targets. The results provide evidence for increasing expansion of the hot composite nuclei as the projectile mass increases. Densities and temperatures of the freeze-out configurations in multi-fragmenting systems are derived.

Dynamic Evolution and the Caloric Curve for Medium Mass Nuclei

J. Cibor, R. Wada, K. Hagel, M. Lunardon, N. Marie, R. Alfaro, W. Shen, B. Xiao, Y. Zhao, J. Li, B. -A. Li, M. Murray, J. B. Natowitz, Z. Majka, P. Staszal
Phys. Lett. **B473**, 29 (2000)

Self-consistent coalescence model analyses of light particle emission have been used to follow the evolution of the temperatures and densities of $A \approx 110$ nuclei produced in violent collisions induced by four different 47 AMeV projectiles. The degree of expansion of the emitting system increases with increasing projectile mass. The caloric curve derived for these expanding $A \approx 110$ nuclei plateaus near $T=7$ MeV. The plateau extends from 3.5 to 6.9 MeV/u excitation energy.

Space-time Evolution of the Hadronic Source in Peripheral to Central Pb+Pb Collisions

I. G. Bearden, H. Boggild, J. Biossevain, P. H. L. Christiansen, L. Conin, J. Dodd, B. Erasmus, S. Esumi, C.W. Fabjan, D. Ferenc, A. Franz, J. J. Gaardhoje, A. G. Hansen, O. Hansen, D. Hardtke, H. van Hecke, E. B. Holzer, T. J. Humanic, P. Hummel, B. V. Jacak, K. Kaimi, M. Kaneta, T. Kohama, M. Kopytine, M. Leltchouk, A. Ljubicic Jr., B. Lorstad, N. Maeda, L. Martin, A. Medvedev, M. Murray, H.

Ohnishi, G. Paic, S. U. Pandey, F. Piuz, J. Pluta, V. Polychronakos, M. Potekhin, G. Poulard, D. Reichold, A. Sakaguchi, J. Schmidt-Sorensen, J. Simon-Giillo, W. Sondheim, T. Sugitate, J. P. Sullivan, Y. Sumi, W. J. Willis, K. Wolf, N. Xu, D. S. Zachary
 Eur. Phys. J. C **18**, 317 (2000)

Two-particle correlations of negative pions as a function of charged particle multiplicity are studied in Pb + Pb collisions at $\sqrt{s} = 17.3$ GeV per nucleon using the NA44 experiment at the CERN Super Proton Synchrotron (SPS). We find that the source size parameters increase with the charged particle multiplicity. However the slope of the source size parameters plotted as a function of charged multiplicity is slightly larger at high multiplicity than at low multiplicity. The value of 8 is independent of charged multiplicity. For Pb + Pb collisions, R_L is larger than R_{TS} and R_{TO} for all multiplicity intervals, whereas these three radius parameters were approximately equal in S+Nucleus collisions. The ratios (R_L/R_{TS}) and (R_L/R_{TO}) for Pb + Pb data show almost no dependence on charged multiplicity. The duration of pion emission τ is constant at 3.81 ± 1.1 fm/c as a function of the charged multiplicity in Pb + Pb collisions. Effective volume (V) is also calculated as $V = B \times R_{TS}^2 \times R_L$, assuming a cylindrically shaped source. We found, with in the limited statistics, the effective volume rapidly increases at high multiplicity.

(Anti) proton and Pion Source Sizes and Phase Space Densities in Heavy Ion Collisions
 M. Murray and Barbara Holzer
 Phys. Rev. C **63**, 054901 (2001)

NA44 has measured midrapidity deuteron spectra from AA collisions at $\sqrt{s_{nn}} \approx 18$ GeV at the CERN SPS. Combining these spectra with published p , \bar{p} , and \bar{d} data allows us to calculate, within a coalescence framework, p and \bar{p} source sizes and phase space densities. These results are compared to B^\pm source sizes measured by Hanbury Brown-Twiss (HBT) interferometry and phase space densities produced by combining pion spectra and HBT results. We also compare to pA results and to lower energy (AGS) data. The \bar{p} source is larger than the proton source at $\sqrt{s_{nn}} = 17.3$ GeV. The phase space densities of B^+ and p are not constant but grow with system size. Both B^+ and proton radii decrease with

m_T and increase with $\sqrt{s_{nn}}$. Pions and protons do not freeze out independently. The nature of their interaction changes as $\sqrt{s_{nn}}$ and the B/p ratio increases.

Target-Atom Inner Shell Distributions Created in Collisions with Heavy Ion Projectile

V. Horvat, R. L. Watson and J. M. Blackadar
 Nucl. Instr. and Meth. **B170** (2000)

A model of the evolution of Cu atom inner-shell electron configurations was developed in order to establish the relationship between the original populations created in K-vacancy producing collisions with fast heavy-ion projectiles and those that exist at the time of Cu K-alpha and K-beta X-ray emission. The model takes into account multi-step vacancy rearrangement processes that may occur prior to K X-ray emission. An interactive procedure is employed in which a set of trial parameters that define the original inner-shell population distributions are varied to obtain satisfactory agreement of the calculated K-alpha satellites relative intensities and energies as well as the overall intensity ratio of K-beta to K-alpha satellites, with the experimental data. In addition to deducing the properties of the original L- and M-shell population distribution, this procedure also provides the average value of the fluorescence yield for conversion between X-ray and K-vacancy production cross sections.

Projectile Z-Dependence of Al K-Shell Vacancy Production in 10 MeV/amu Ion-Solid Collisions

R. L. Watson, V. Horvat, J. M. Blackadar and K. E. Zaharakis
 Phys. Rev. A **62**, 2709 (2000)

Beams of 10-MeV/amu Ne, Ar, Cr, Kr, Xe, and Bi ions have been employed to examine the dependence on projectile atomic number (Z1) of Al K-shell vacancy production in nearly symmetric (Z1/Z2=0.8) to highly asymmetric (Z1/Z2 = 6.4) collisions. Aluminum K x-ray yields were measured with a Si(Li) detector as a function of target thickness to establish cross sections for charge equilibrated projectiles. Average target atom L-shell vacancy distributions excited in K-shell vacancy-producing collisions and x-ray yield corrections for contributions from photoionization and secondary electron impact were deduced from high-resolution

spectral measurements performed with a curved-crystal spectrometer. Knowledge of the average L-shell vacancy distributions provided the means for estimating the appropriate fluorescence yields needed to convert the x-ray yields to K-shell vacancy production cross sections. Theoretical cross sections greatly overestimate the experimental results for $Z > 10$. The Z dependence of the K-shell vacancy production cross sections for both Al and Cu (from a previous study) are well characterized by a simple empirical scaling law.

Hadronic Scattering of Charm Mesons

Z. W. Lin, C. M. Ko, and B. Zhang
Phys. Rev. C **61**, 024904 (2000)

The scattering cross sections of charm mesons with hadrons such as pion, rho meson and nucleon are studied in an effective Lagrangian. In heavy ion collisions, rescattering of produced charm mesons by hadrons affects the invariant mass spectra of both charm meson pairs and dileptons resulting from their decays. These effects are estimated for heavy ion collisions at SPS energies and are found to be significant.

Multi-Phase Transport Model for Relativistic Nuclear Collisions

B. Zhang, C. M. Ko, B. A. Li, and Z. W. Lin
Phys. Rev. C **61**, 067901 (2000)

To study heavy ion collisions at energies available from the Relativistic Heavy Ion Collider, we have developed a multi-phase transport model that includes both initial partonic and final hadronic interactions. Specifically, the parton cascade model ZPC, which uses as input the parton distribution from the HIJING model, is extended to include the quark-gluon to hadronic matter transition and also final-state hadronic interactions based on the ART model. Predictions of the model for central Au on Au collisions at RHIC are reported.

Role of Gluons in Thermal Dilepton Production from the Quark-Gluon Plasma

Z. W. Lin and C. M. Ko
Nucl. Phys. **A671**, 567 (2000)

We study high mass dilepton production from gluon-induced processes, $gq \rightarrow q\gamma^*$, $g\bar{q} \rightarrow \bar{q}\gamma^*$, and $gg \rightarrow q\bar{q}\gamma^*$, in a thermally equilibrated but chemically under-saturated partonic matter that is expected to be created in the initial stage of ultra-relativistic heavy

ion collisions. Regulating the divergence in these processes by the thermal quark mass, we find that gluon-induced processes are more important than the leading-order $q\bar{q}$ annihilation process as a result of the larger number of gluons than quarks in the partonic matter. The dependence of the thermal dilepton yield from the partonic stage of heavy ion collisions on the initial conditions for the partonic matter is also studied. We further discuss the feasibility of observing thermal dileptons from the quark-gluon plasma in heavy ion experiments.

Directed Flow of Neutral Strange Particles at AGS

B. Zhang, C. M. Ko, B. A. Li, and A. T. Sustich
J. Phys. G **26**, 1665 (2000)

The directed flow of neutral strange particles in heavy ion collisions at the Alternating Gradient Synchrotron (AGS) the Brookhaven National Laboratory is studied in the ART transport model. Using a lambda mean-field potential that is 2/3 of the nucleon potential as predicted by the constituent quark model, lambdas are found to flow with protons but with a smaller flow parameter as observed in experiments. For kaons, their repulsive potential, which is calculated from the impulse approximation using the measured kaon-nucleon scattering length, leads to a smaller anti-flow than that shown in the preliminary E895 data. Implications of this discrepancy are discussed.

Model for J/P Absorption in Hadronic Matter

Z. W. Lin and C. M. Ko
Phys. Rev. C **62**, 034903 (2000)

The cross section for J/P absorption by B and Δ mesons are studied in a meson-exchange model that includes not only the pseudoscalar-pseudoscalar-vector-meson couplings but also the three-vector-meson and four-point couplings. We find that they are much larger than in a previous study where only pseudoscalar-pseudoscalar-vector-meson couplings were considered. Including form factors at interaction vertices, the J/P absorption cross sections Φ_{BP} and $\Phi_{\Delta P}$ are found to have values on the order of 7 mb and 3 mb, respectively. Their thermal averages in a hadronic matter at temperature $T = 150$ MeV are, respectively, about 1 mb and 2 mb.

J/P Suppression in Relativistic Nuclear Collisions

B. Zhang, C. M. Ko, B. A. Li, Z. W. Lin, and B. H. Sa

Phys. Rev. C **62**, 054905 (2000)

Using a multiphase transport model, we study the relative importance of J/P suppression mechanisms due to plasma screening, gluon scattering, and hadron absorption in heavy ion collisions at the Relativistic Heavy Ion Collider. We find that for collisions between heavy nuclei such as Au+Au, both plasma screening and gluon scattering are important. As a result, the effect due to absorption by hadrons becomes relatively minor. The final J/P survival probability in these collisions is only a few percent. In the case of collisions between light nuclei such as S+S, the effect of plasma screening is, however, negligible in spite of the initial high parton density. The final J/P survival probability thus remains appreciable after comparable absorption effects due to gluons and hadrons.

Antiflow of Kaons in Relativistic Heavy Ion Collisions

S. Pal, C. M. Ko, Z. W. Lin, and B. Zhang
Phys. Rev. C **62**, 161902 (2000)

We compare relativistic transport model calculations to recent data on the sideward flow of neutral strange K_s^0 mesons for Au+Au collisions at 6 AGeV. A soft nuclear equation of state is found to describe very well the positive proton flow data measured in the same experiment. In the absence of kaon potential, the K^0 flow pattern is similar to that of protons. The kaon flow becomes negative if a repulsive kaon potential determined from the impulse approximation is introduced. However, this potential underestimates the data which exhibits larger antiflow. An excellent agreement with the data is obtained when a relativistic scalar-vector kaon potential, that has stronger density dependence, is used. We further find that the transverse momentum dependence of directed and elliptic flow is quite sensitive to the kaon potential in dense matter.

A 2- Level of ^8B and the $^7\text{Be}(p, \gamma)^8\text{B}$ S Factor

F. C. Barker and A. M. Mukhamedzhanov
Nucl. Phys. **A673**, 1 (2000)

A 2- level at 3.0 MeV in ^8B has been suggested from $^7\text{Be} + p$ elastic scattering measurements. The effect of such a level on the low-energy $^7\text{Be}(p, \gamma)^8\text{B}$ S factor is discussed, using R-matrix formulae with parameter values chosen to fit $^7\text{Li} + n$ data. It is concluded that the level must be broad ($\Gamma^0 \ni 4$ MeV).

Asymptotic Normalization Coefficients, Spectroscopic Factors, and Direct Radiative Capture Rates

A. M. Mukhamedzhanov, C. A. Gagliardi and R. E. Tribble
Phys. Rev. C **63**, 024612 (2001)

We compare the use of asymptotic normalization coefficients (ANC's) and spectroscopic factors determined from peripheral transfer reactions for determining the overall normalization of peripheral direct radiative capture reaction processes. We demonstrate the ANC's provide a natural way to parametrize the rates of both peripheral transfer and direct capture reaction. Furthermore, ANC's inferred from one reaction may be used in the analysis of a second reaction without further knowledge regarding their origin, and independent measurements of a given ANC may be combined to give an overall "best value" in a straightforward manner. In contrast, a spectroscopic factor derived from analysis of a peripheral transfer reaction can only be used in subsequent calculations if one has detailed knowledge of the single-particle bound state orbital that was assumed when the spectroscopic factor was obtained.

Momentum Space Integral Equations for Three Charged Particles: Nondiagonal Kernels

A. M. Mukhamedzhanov, E. O. Alt and G. V. Avakov
Phys. Rev. C **61** 064006 (2000)

Standard solution methods are known to be applicable to Faddeev-type momentum space integral equations for three-body transition amplitudes, not only for purely short-range interactions but also, after suitable modifications, for potentials possessing Coulomb tails provided the total energy is below the three-body threshold. For energies above that threshold, however, long-range Coulomb forces have been suspected to give rise to such severe singularities in the kernels, even of the modified equations, that their compactness properties are lost. Using the rigorously equivalent formulation in terms of an effective-two-body theory we prove that, for all energies, the nondiagonal kernels occurring in the integral equations which determine the transition amplitudes for all binary amplitudes for all binary collision processes, possess on and off the energy shell only integrable singularities, provided all three particles have charges of the same sign, i.e., all

Coulomb interactions are purely repulsive. Hence, after a few iterations these kernels become compact. The case of the diagonal kernels is dealt with in a subsequent paper.

Isoscalar Compression Modes within Fluid Dynamic Approach

V. M. Kolomietz and S. Shlomo
Phys. Rev. C **61**, 064302 (2000)

We study the nuclear isoscalar monopole and dipole compression modes in nuclei within the fluid dynamic approach (FDA) with and without the effect of relaxation. For a wide region of the medium and heavy nuclei, the FDA predicts that the isoscalar giant monopole resonance (ISMGR) and the isoscalar giant dipole resonance (ISGDR) exhausts about 90% of the corresponding model independent sum rules. In the case of neglecting the effect of relaxation, the FDA, when adjusted to reproduce the centroid energy $E0$ of the ISMGR, results with centroid energy $E1$ of the ISGDR which is in agreement with the predictions of the self-consistent Hartree Fock (HF) random phase approximation (RPA) calculations and the scaling model but significantly larger than the experimental value. We also show that the FDA

leads to the correct hydrodynamic limit for the ratio $(E1/E0)_{FDA}$. We find that the ratio $(E1/E0)_{FDA}$ depends on the relaxation time and approaches the preliminary experimental value $(E1/E0)_{exp} = 1.5 \pm 0.1$ in a short relaxation time limit.

Structure and Direct Nucleon Decay Properties of Isoscalar Giant Monopole and Dipole Resonances

M. L. Gorelik, S. Shlomo and M. H. Urin
Phys. Rev. C **62**, 044301 (2000)

Strength function and partial widths for the direct nucleon decay of the isoscalar giant monopole and dipole resonances are analyzed within an extended continuum-random-phase-approximation (CRPA) approach. Calculations are performed for several medium and heavy mass nuclei with the use of a phenomenological nuclear mean field, Landau-Migdal particle-hole interaction and some partial self-consistency conditions. Calculation results are compared with available experimental data.

ABSTRACTS FOR PAPERS SUBMITTED
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Drift Chambers for a Precision Measurement of the Michel Parameters in Muon Decay

W. Anderson, M. Comyn, Y. Davydov, P. Depommier, J. Doornobs, W. Faszler, C. A. Gagliardi, D. R. Gill, P. Green, P. Gumplinger, J. C. Hardy, M. Hasinoff, R. Helmer, R. Henderson, A. Kruchinsky, P. Kitching, D. D. Koetke, E. Korkmaz, Y. Lachin, D. Maas, J. A. Macdonald, R. Manweiler, E. L. Mathie, L. Miassoedov, J. R. Musser, P. Nord, A. Olin, D. Ottewell, R. Openshaw, T. Porcelli, J. -M. Poutissou, R. Poutissou, N. L. Rodning, M. A. Quraan, J. Schaapman, V. Selivanov, G. Sheffer, B. Shin, F. Sobratee, J. Soukup, T. D. S. Stanislaus, G. Stinson, R. Tacik, V. Torokhov, R. E. Tribble, M. A. Vasiliev, H. -C. Walter and D. Wright
Nucl. Inst. (In Press)

TRIUMF experiment E614 has as its goal the precise definition of the Michel parameters of muon decay by measuring the entire energy and emission angle distribution of the positrons. This will be done using a spectrometer consisting of high precision planar drift chambers placed in a uniform 2 T solenoidal magnetic field. Chambers based on circular frames with cathode diameter of about 40 cm are grouped in modules which comprise two highly symmetric upstream and downstream parts divided by the muon stopping target. Each model consists of a pair of anode and three foil cathode planes with 2mm anode-cathode gap. Such a structure puts strict requirements on the positioning accuracy of both the wire and the cathode planes. This achieved by using precision ceramic glass spacers which provide the required accuracy during chamber production and the assembly into modules. This work presents the features of the chamber design and the results of both bench and beam tests of the prototypes.

Radioactive Beams at Texas A&M University

R. E. Tribble, A. Azhari, C. A. Gagliardi, J. C. Hardy, A. Mukhamedzhanov, X. Tang, L. Trache and S. J. Yennello
Proceedings of RNB2000 Conference, Nucl. Phys. A (To Be Published)

The combination of the K500 superconducting cyclotron and the recoil spectrometer MARS has been used to generate secondary radioactive beams

ranging from ${}^7\text{Be}$ at 12 MeV/u to ${}^{62}\text{Ga}$ at 37 MeV/u. Secondary beams are produced via transfer reactions in inverse kinematics using stable beams from the cyclotron on gas targets. The radioactive beams have been used for reaction measurements and beta-decay studies.

Astrophysical S-factors from peripheral transfer reaction with radioactive beams

L. Trache, A. Azhari, C. A. Gagliardi, A. M. Mukhamedzhanov, X. D. Tang, R. E. Tribble, and F. Carstoiu

In Proc. International Symposium Nuclear Structure Physics 2001, University of Goettingen (March 2001), R. Casten et al., Eds., World Scientific Publ. Co., Singapore (In Press)

We have shown in the last years that one can determine astrophysical S-factors for proton radiative capture reactions using the precise knowledge of the tail of the wave function of the last proton in the final nucleus. We first show that from peripheral transfer reactions we can extract more precisely and parameter independent the Asymptotic Normalization Coefficients rather than the spectroscopic factors. Peter Von Brentano made this observation in the early years of his stripping reaction studies. Using reactions induced by radioactive beams at Texas A&M University we extracted the S-factors for the ${}^7\text{Be}(p,0){}^8\text{B}$ reaction, crucial for the solar neutrino problem, for the ${}^{11}\text{C}(p,0){}^{12}\text{N}$ reaction (hot pp chain in novae) and a few other reactions.

Refractive Elastic Scattering of ${}^{16}\text{O}$ by ${}^{12}\text{C}$ at 300 MeV

M. E. Brandan, A. Menchaca-Rocha, L. Trache, H. L. Clark, A. Azhari, C. A. Gagliardi, Y. -W. Lui, R.E. Tribble, R. Varner, J. Beene and G. R. Satchler
Nucl. Phys. A, (2001) (In Press)

The ${}^{16}\text{O}+{}^{12}\text{C}$ elastic cross section at 300 MeV has been measured over a wide angular range, displaying the shoulder of a nuclear rainbow. The optical model analysis was done using a microscopic as well as phenomenomenological real potentials. The results of this study confirm the potential characteristics found in previous studies at higher and lower energies.

Radius Of ^8B Halo from the Asymptotic Normalization Coefficient

F. Carstoiu, L. Trache, C. A. Gagliardi, R. E. Tribble, and A. M. Mukhamedzhanov
Phys. Rev. C **63** (2001) (In Press)

The experimental asymptotic normalization coefficient determined from peripheral transfer reactions is used to obtain the root mean square radius of the wave function for the loosely bound proton in ^8B . It is shown that the asymptotic region contributes most and that matching of the interior wave function with the asymptotic part yields a nearly model-independent radius. We obtain $\langle r^2 \rangle^{1/2} = 4.20 \pm 0.22$ fm for the root mean square radius of the last proton, much larger than the rms radius of the ^7Be core. This large value and the fact that the asymptotic part of the proton wave function contributes 85% to the rms radius are good signatures that ^8Be is a halo nucleus.

Nuclear Physics with Radioactive Beams at TAMU

L. Trache, A. Azhari, C. A. Gagliardi, A. M. Mukhamedzhanov, R. E. Tribble, X. D. Tang
In *Proc. of the XXXV-th Zakopane School of Physics, Zakopane, Poland, Sept. 2000*
Acta Physica Polonica (2001) (In Press)

A major contribution in nuclear astrophysics is expected now and in the near future from the use of radioactive beams. This paper presents an indirect method utilizing radioactive beams to determine the astrophysical S-factor at the very low energies relevant in stellar processes (tens and hundreds of keV) from measurements at energies more common to the nuclear physics laboratories (10 MeV/nucleon). The Asymptotic Normalization Coefficient method consists of the determination from peripheral transfer reactions of the single particle wave function of the outermost charged particle (proton or alpha particle) around a core in its asymptotic region only, as this is the part contributing to nuclear reactions at very low energies. It can be applied to the study of radiative proton or alpha capture reactions, a very important class of stellar reactions. The method is briefly presented along with our recent results in the determination of the astrophysical factor for the proton capture reactions $^7\text{Be}(p, \gamma)^8\text{B}$ and $^{11}\text{C}(p, \gamma)^{12}\text{N}$. The first reaction is crucial for the understanding of the solar neutrino production, the second is a reaction that would bypass the mass A=8 gap in the hot pp chains. Our study was done at the K500 superconducting cyclotron of Texas A&M

University. Proton transfer reactions with radioactive beams ^7Be and ^{11}C produced with MARS were measured, as well as proton transfer reactions involving stable partners. We present the experiments, then discuss the results and the uncertainties arising from the use of calculated optical potentials between loosely bound radioactive nuclei.

Isoscalar E0, E1 and E2 Strength in ^{40}Ca

D. H. Youngblood, Y. -W. Lui and H. L. Clark
Phys. Rev. (Submitted February 2001)

The giant resonance region from 10 MeV $< E_x < 55$ MeV in ^{40}Ca has been studied with inelastic scattering of 240 MeV ∇ particles at small angles including 0° . Strength corresponding to $97 \pm 11\%$, $108 \pm 12\%$, and $62 \pm 10\text{--}20\%$ of the isoscalar E0, E2, and E1 sum rules respectively was identified with centroids of 19.18 ± 0.37 MeV, 17.84 ± 0.43 MeV 23.36 ± 0.70 MeV and RMS widths of 4.88 ± 0.57 MeV, 2.89 ± 0.60 MeV, and 5.34 ± 0.90 MeV.

The Michel Parameters from $^+\text{Decay}$

N. L. Rodning, W. Anderson, Y. Davydov, P. Depommier, J. Doornbos, W. Faszer, C. A. Gagliardi, A. Gaponenko, D.R. Gill, P. Green, P. Gumplinger, J.C. Hardy, M. Hasinoff, R. Helmer, R. Henderson, P. Kitching, D. D. Koetke, E. Korkmaz, A. Khurchinsky, D. Maas, J. A. Macdonald, R. Macdonald, R. Manweiler, G. Marshall, T. Mathie, J. R. Musser, P. Nord, A. Olin, R. Openshaw, D. Ottewell, T. Procelli, J. -M. Poutissou, R. Poutissou, G. Price, M. Quraan, J. Schaapman, V. Selivanov, G. Sheffer, B. Shin, F. Sobratee, J. Soukup, T. D. S. Stanislaus, G. Stinson, R. Tacik, V. Torokhov, R. E. Tribble, M. A. Vasilyev, H. -C. Walter, S. -C Wang and D. Wright
Proceedings of Tau2000, Victoria, B. C.,
(September 2000) (In Press)

We propose to make the first high precision measurements of nearly the entire differential spectrum (in energy and angle) of positrons from the decay of polarized muons. The main goal of the experiment is the precise testing of the (V-A) structure of the electroweak interactions in the framework of the $\text{SU}(2)_L \times \text{U}(1)$ model. Highly polarized "surface" $^+\text{Decay}$ from the TRIUMF M13 beamline will enter a large volume, high field superconducting magnet on axis and will stop in a thin target at its center. The e^+ from the muon decay

will be precisely tracked in the magnetic field using small-cell planar drift chambers. This spectrometer has been simulated with GEANT and EGS4 and has been demonstrated to meet the precision requirements.

Productions of ^{60}Co Sources for High-Accuracy Efficiency Calibrations of Gamma-Ray Spectrometers

E. Schoenfeld, H. Janssen, R. Klein, J. C. Hardy, V. Iacob, M. Sanchez-Vega, H. C. Griffin and M. A. Ludington

13th International Conference on Radionuclide Metrology and its Applications, Braunschweig, Germany (May 2001)

Activity determination by gamma-ray spectrometry is a valuable aid which is widely used where radioactive sources are applied. For the construction of an efficiency curve vs. energy in a standard geometry, the accuracy is limited not only by the uncertainty of peak area determination and the knowledge of the relevant emission probabilities but also by the uncertainties of the activity values applied to efficiency calibration with standard sources.

Precise Efficiency Calibration of an HPGe Detector: Source Measurements and Monte Carlo Calculations with Sub-Percent Precision

J. C. Hardy, V. E. Iacob, M. Sanchez-Vega, R. T. Effinger, P. Lipnik, V. E. Mayes, D. K. Willis, and R. G. Helmer

13th International Conference on Radionuclide Metrology and its Applications, Braunschweig, Germany (May 2001)

With the goal of measuring precise gamma-ray intensities for short-lived (<5 s) accelerator-produced activities, we have calibrated the efficiency of an HPGe detector between 53 and 1836 keV to sub-percent precision with a combination of source measurements and Monte Carlo calculations. Using known or independently measured detector dimensions, we have achieved both relative and absolute agreement (the latter, to 0.1%) between the calculated and measured efficiencies with only two adjustable detector parameters, the thicknesses of the contact dead layers.

Standard-Model Tests with Superallowed Beta-Decay: An Important Application of Very Precise Mass Measurements

J. C. Hardy, I. S. Towner
(To Be Published)

Superallowed beta decay provides a sensitive means for probing the limitations of the Electroweak Standard Model. To date, the strengths (ft -values) of superallowed $0^- \rightarrow 0^+$ beta decay transitions have been determined with high precision from nine different short-lived nuclei, ranging from ^{10}C to ^{54}Co . Each result leads to an independent measure for the vector coupling constant, G_V , and collectively the nine values can be used to test the conservation of the weak vector current (CVC). Within current uncertainties, the results support CVC to better than a few parts in 10,000 – a clear success for the Standard Model! However, when the average value of G_V , as determined in this way, is combined with data from decays of the muon and kaon to test another prediction of the Standard Model, the result is much more provocative. A test of the unitarity of the Cabibbo-Kobayash-Maskawa matrix fails by more than two standard deviations. This result can be made more definitive by experiments that require extremely precise mass measurements, in some cases on very short-lived (<100ms) nuclei. Here we present the current status and future prospects for these Standard-Model tests, emphasizing the role of precise mass, or mass-difference measurements. There remains a real challenge to mass-measurement technique with the opportunity for significant new results.

Precise Efficiency Calibration of An HPGe Detector Using the Decay of $^{180\text{m}}\text{Hf}$

M. Sanchez-Vega, J. C. Hardy, V. E. Iacob
Romanian Journal of Physics (To Be Published)

We have used the decay of $^{180\text{m}}\text{Hf}$ ($t_{1/2} = 5.5$ h) to obtain a very precise gamma-ray calibration source in the 90 to 330 keV energy range. The decay of $^{180\text{m}}\text{Hf}$ to the ^{180}HF ground state includes a cascade of three consecutive E2 gamma-ray transitions of energies 332.3, 215.4 and 93.3 keV with no other feeding of the intermediate states. Since the total transition intensities must be the same, the relative gamma-ray intensities emitted by the source are thus dependent only on the calculated E2 conversion coefficients. This provides a rather precise calibration standard.

Gamma-ray multiplicities and fission modes in $^{208}\text{Pb}(^{18}\text{O},f)$

G. G. Chubarian, M. G. Itkis, N. A. Kondratiev, E. M. Kozulin, V. V. Pashkevich, I. V.

Pokrovsky, A. Ya. Rusanov, V. S. Salamatin, R. P. Schmitt

Two components in the $M\gamma(M)$ distribution were established in detailed measurements of mean γ -ray multiplicities from fission fragments of ^{226}Th . For the first time in the $M\gamma(M)$ dependencies we were able to distinguish two components associated with primary and the final (after the neutron evaporation) fission fragments, and show that at the scission point $M\gamma$ is extremely sensitive to symmetric and asymmetric modes of fission. Theoretical calculations of the pre-scission shapes of the fissioning nuclei confirm our conclusions.

Exploring the Emission Barriers in Hot Nuclei

G. Viesti, V. Rizzi, D. Fabris, M. Lunardon, G. Nebbia, M. Cinausero, E. Fioretto, G. Prete, A. Brondi, G. La Rana, R. Moro, E. Vardaci, M. Aiche, M. M. Aleonard, G. Barreau, D. Biovin, J. N. Scheurer, J. F. Chemin, K. Hagel, J. B. Natowitz, R. Wada, S. Courtin, F. Haas, N. Rowley, B. M. Nyako, J. Gal, J. Molnar
(Submitted)

The reactions $^{30}\text{Si}+^{170}\text{Er}$ and $^{29}\text{Si}+^{170}\text{Er}$ have been studied by the particle-gamma coincidence method. By using a subtraction technique, the spectrum of the first chance alpha particles emitted in the decay of the ^{200}Pb compound nucleus has been determined. The emission barrier has been extracted from the first chance spectrum, using the second derivative analysis, commonly used in sub-barrier fusion studies. By comparing with earlier systematic it is demonstrated that the emission barriers in excited systems are lower respect to those in the inverse (capture) reaction on ground state nuclei.

First Results from BRAHMS at RHIC

M. Murray
BRAHMS Collaboration (In Press)

The BRAHMS detector at RHIC took its first data from AuAu collisions at a center of mass energy of 130AGeV this summer. Global measurements of charged particle pseudorapidity distributions were taken using the Plastic Time Multiplicity Array, the Beam-Beam counters and a TPC perpendicular to the beams. These data will be used to study widths of multiplicity distributions and will be compared to models. Using the Zero Degree Calorimeters we

have studied the correlations between charged particle multiplicity at central rapidity and the multiplicity of spectator neutrons. Finally for events in which we see no charged particles we have studied the forward neutron spectrum and compared it to models of the electromagnetic breakup of nuclei.

The RHIC Zero Degree Calorimeters

C. Adler, A. Denisov, E. Garcia, M. Murray, H. Stroebele and S. White
(Submitted August 2000)

High Energy collisions of nuclei usually lead to the emission of evaporation neutrons from both "beam" and "target" nuclei. At the RHIC heavy ion collider with 100GeV/u beam energy, evaporation neutrons diverge by less than 2 milliradians from the beam axis. Neutral beam fragments can be detected downstream of RHIC ion collisions (and a large aperture Accelerator dipole magnet) if $2 \# 4$ mr but charged fragments in the same angular range are usually too close to the beam trajectory. In this 'zero degree' region produced particles and other secondaries deposit negligible energy when compared with that of beam fragmentation neutrons. The purpose of the RHIC zero degree calorimeters (ZDC's) is to detect neutrons emitted within this cone along both beam directions and measure their total energy (from which we calculate multiplicity). The ZDC coincidence of the 2 beam directions is a minimal bias selection of heavy ion collisions. This makes it useful as an event trigger and a luminosity monitor [1] and for this reason we built identical detectors for all 4 RHIC experiments. The neutron multiplicity is also known to be correlated with event geometry [2] and will be used to measure collision centrality in mutual beam interactions.

HBT in Relativistic Heavy Ion Collisions

M. Murray
World Scientific (Submitted February 2001)

A summary of current interferometry data in relativistic heavy ions is presented. At $\sqrt{s_{nn}} = 17\text{GeV}$ a sudden increase in the pion source volume is observed for central PbPb collisions. This seems to imply that the pion phase density has reached a limit. The source of difference particles decreases with mass when the transverse velocity is held constant but increases with mass when m_T is held constant. The antiproton source radius is larger than the proton source radius. So far no long lived source has been seen. The pion source size varies slowly with rapidity but more rapidly with m_T implying strong

transverse flow. There is very slow increase of pion radii with \sqrt{s} .

Multiple Electron Stripping of 3.4 MeV/u Kr⁷⁺ and Xe¹¹⁺ in Nitrogen

D. Muller, L. Grisham, I. Kaganovich, R. L. Watson, V. Horvat and K. E. Zaharakis
(Submitted)

Uses of heavy ion beams with ~ 10 MeV/u, mass 200 u and average charge state of 1+ has been proposed as a driver for heavy-ion-driven, inertial-confinement fusion. Stripping of the ion beam by background gas results in an increase in the space charge density of the beam. This will make focusing the intense ion beam onto small targets problematic. Knowledge of the electron loss cross sections is essential to understand and address the problem. Currently, there are no 10 MeV/u, mass 200 u, charge state +1 beams available, and the theories that calculate electron loss cross sections can be experimentally tested only by using available beams of somewhat lower energy and higher initial charge state. The charge state distribution of ions produced in single collisions of 3.4 MeV/u Kr⁷⁺ and 3.4 MeV/u Xe¹¹⁺ in N₂ have been measured using a windowless gas cell. The charge states of the outgoing ions were determined by magnetic analysis using a position-sensitive microchannel-plate detector. The cross sections for single and multiple electron loss were determined. The results indicate that substantial multiple-electron loss occurs. The relative cross section for loss of $i+1$ electrons is 0.3 to 0.7 times that for i electron loss. The sum of the electron-weighted cross sections normalized to the total cross section is 1.85 for Kr and 1.97 for Xe.

Projectile and Target Z-Scaling of Target K-Vacancy Production Cross Sections at 10 MeV/amu

R. L. Watson, V. Horvat and K. E. Zaharakis
AIP Press (In Press)

Beams of 10 MeV/u, Ne, Ar, Cr, Kr, Xe and Bi ions have been employed to examine the dependence of target atom K-vacancy production cross sections on projectile and target atomic number. The collision systems studied range in Z_1/Z_2 from 0.14 to 6.4 and in relative velocity (v_1/v_2) from 0.31 to 1.87. Photoionization and ionization by electrons were found to contribute significantly to K-vacancy production in collision systems for which $Z_1/Z_2 > 1$. The cross sections for projectiles with $Z_1 > 18$ are greatly overestimated by theoretical

(PWBA/ECPSSR) calculations. Empirical scaling laws have been deduced to facilitate the prediction of K-vacancy production cross sections for other collision systems.

Target-Atom K-Shell Ionization by Binary Encounter Electrons

V. Horvat and R. L. Watson
Journal of Physics B (In Press)

Spectra of K-alpha x rays emitted from Cu atoms bombarded with 10 MeV/u beams of Kr, Xe, and Bi ions were measured with a curved crystal spectrometer. Large enhancements of the K-alpha diagram lines were observed and attributed to secondary ionization by photons and electrons. To explain these results quantitatively, contributions from binary encounter electrons have been calculated by considering their production and transport as well as the effective cross section for target K-shell ionization by electron impact. The results are in good agreement with the measurements.

Consideration of the Continuum X-Ray Background in 50-300 keV Protons on Thick Targets of Ge, Ho, and Au

S. Cipolla, V. Horvat and C. A. Quarrels
AIP Press (In Press)

We consider the continuum bremsstrahlung spectrum from the bombardment of Ge, Ho and Au thick targets with protons from 50 to 300 KeV. Two sources of the bremsstrahlung are considered. First is the bremsstrahlung from secondary electrons ejected from the target atoms in binary collisions with the projectile proton. The main contribution from secondary electrons is expected to come from collisions with inner-shell electrons that have significant momentum. The second process is polarization bremsstrahlung, the radiation from the target atom as it is dynamically polarized by the projectile charge. The data are compared with the secondary electron bremsstrahlung model developed here and with calculations of polarization bremsstrahlung.

Charm Meson Scattering Cross Sections with Pion and Rho Meson

Z. W. Lin, T. G. Di, and C. M. Ko
Nucl. Phys. A, (In Press)

Using the local flavor SU(4) gauge invariance in the limit of vanishing vector meson masses, we extend our previous study of charm meson scattering cross

sections by pion and rho meson, which is based only on the pseudoscalar-pseudoscalar-vector meson couplings, to include also contributions from the couplings among three vector mesons and among four particles. We find that diagrams with light meson exchanges usually dominate the cross sections. For the processes considered previously, the additional interactions lead only to diagrams involving charm meson exchanges and contact interactions, and the cross sections for these processes are thus not much affected. Nevertheless, these additional interactions introduce new processes with light meson exchanges and increase significantly the total scattering cross sections of charm mesons by pion and rho meson.

Upsilon Absorption in Hadronic Matter

Z. W. Lin and C. M. Ko
Phys. Lett. B (In Press)

The cross sections of K absorption by \mathbb{B} and Δ mesons are evaluated in a meson-exchange model. Including form factors with a cutoff parameter of 1 or 2 GeV, we find that due to the large threshold of the reactions the thermal average of these cross sections is only about 0.2 mb at a temperature of 150 MeV. Our results thus suggest that K absorption by hadronic comovers in high energy heavy ion collisions is unimportant.

Medium Effects on the Flow of Strange Particles in Heavy Ion Collisions

C. M. Ko
J. Phys. G27 (In Press)

Strange particles such as the kaon and lambda are useful in probing the properties of dense matter formed in heavy ion collisions. We review in this talk the theoretical understandings of their properties in nuclear medium based on both the effective chiral Lagrangian and the phenomenological hadronic model. We further review the effects due to changes in their in-medium properties on their collective flow in heavy ion collisions.

Effective Hadronic Lagrangian for Charm Mesons

Z. W. Lin and C. M. Ko
J. Phys. G27 (In Press)

An effective hadronic Lagrangian including the charm mesons is introduced to study their interactions in hadronic matter. Using coupling constants that are determined either empirically or by

the SU(4) symmetry, we have evaluated the absorption cross sections of J/P and the scattering cross sections of D and D^* by \mathbb{B} and Δ mesons.

Baryonic Contributions to the Dilepton Spectra in Relativistic Heavy Ion Collisions

M. Bleicher, A. K. Dutt-mazumber, C. Gale, C. M. Ko, and V. Koch
Phys. Rev. C, (Submitted)

We investigate the baryonic contributions to the dilepton yield in high energy heavy ion collisions within the context of a transport model. The relative contributions of the baryonic and mesonic sources are examined. It is observed that most dominant among the baryonic channels is the decay of $N^*(1520)$ and mostly confined in the region below the Δ peak. In a transport theory implementation we find the baryonic contribution to the lepton pair yield to be small.

Kinetic Equation with Exact Charge Conservation

C. M. Ko, V. Koch, Z. W. Lin, K. Redlich, M. Stephanov, and X. N. Wang
Phys. Rev. Lett. (Submitted)

A kinetic master equation for multiplicity distributions is formulated for charged particles which are created or destroyed only in pairs due to the conservation of their Abelian charge. It allows one to study time evolution of the multiplicity distributions in a relativistic many-body system with arbitrary average particle multiplicities. It is shown to reproduce the equilibrium results for both canonical (rare particles) and grand canonical (abundant particles) systems. For canonical systems, the equilibrium multiplicity is much lower and the relaxation time is much shorter than the naïve extrapolation from the grand canonical ensemble results. Implications for particle chemical equilibration in heavy-ion collisions are also discussed.

Charged Particle Rapidity Distributions at RHIC

Z. W. Lin, S. Pal, C. M. Ko, B. A. Li, and B. Zhang
Phys. Rev. Lett. (Submitted)

Using a multiphase transport model (AMPT), which includes both initial partonic and final hadronic scattering, we study the rapidity distributions of charged particles such as protons, antiprotons, pions

and kaons in central Au+Au collisions at $\sqrt{s} = 56, 130, \text{ and } 200$ AGeV at RHIC. We find that present data at 56 and 130 AGeV by the PHOBOS collaboration are consistent with a rather weak jet quenching in the initial dense matter. We also find that the antiproton to proton ratio at mid-rapidity increases appreciably with \sqrt{s} , indicating the approach to a nearly baryon-antibaryon symmetric matter in high energy collisions. Furthermore, the K^+/B^+ ratio is almost constant within the energy range studied here, suggesting the approximate chemical equilibrium for strangeness production in these collisions.

Surface Instability of a Nuclear Fermi-Liquid Drop

V. M. Kolomietz and S. Shlomo
Physics of Atomic Nuclei (In Press)

The mechanical instability of the incompressible Fermi-liquid drop with respect to surface distortions is considered. It is shown that the Fermi-surface distortion (FSD) effect reduces the instability growth rate for the surface fluctuations due to its effects on both the viscosity and the increase in the stiffness coefficient. The dependence of the limiting temperature T_{lim} on the mass number and the multipolarity of the nuclear surface distortion is calculated. It is shown that T_{lim} is not influenced by the FSD effect.

Isoscalar Giant Dipole Resonance and Nuclear Matter Incompressibility Coefficient

S. Shlomo and A. I. Sanzhur
Phys. Rev. Lett. (Submitted)

We present results of microscopic calculations of the strength function, $S(E)$, and α -particle excitation cross sections $\sigma(E)$ for the isoscalar giant dipole resonance (ISGDR). An accurate and general method to eliminate the contributions of spurious state mixing is presented and used in the calculations. Our results provide a resolution to the long standing problem that the nuclear matter incompressibility coefficient, K , deduced from $\sigma(E)$ data for the ISGDR is significantly smaller than that deduced from data for the isoscalar giant monopole resonance (ISGMR).

Memory Effects on Descent from Nuclear Fission Barrier

V. M. Kolomietz, S. V. Radionov and S. Shlomo
Phys. Rev. C (Submitted)

Non-Markovian transport equations for the nuclear large amplitude motion are derived from the collisional kinetic equation. The memory effects are caused by the Fermi surface distortions and depend on the relaxation time. It is shown that nuclear collective motion and nuclear fission are influenced strongly by the memory effects at the relaxation time $\tau \geq 5 \cdot 10^{-23} \text{ s}$. In particular, the descent of nucleus from the fission barrier is accompanied by characteristic shape oscillations. The eigenfrequency and the damping of the shape oscillations depend on the contribution of the memory integral to the equations of motion. The shape oscillations disappear at the short relaxation time regime at $\tau \rightarrow 0$ which corresponds to the usual Markovian motion in presence of the friction forces. We have shown that the elastic forces produced by the memory integral lead to a significant delay for the descent of the nucleus from the barrier. Numerical calculations for the nucleus ^{236}U shows that due to the memory effect the fission time grows by a factor of about 20 with respect to the corresponding liquid drop model value calculated with friction forces.

Sound Modes in Hot Nuclear Matter

V. M. Kolomietz and S. Shlomo
Phys. Rev. C (In Press)

The propagation of the isoscalar and isovector sound modes in a hot nuclear matter is considered. The approach is based on the collisional kinetic theory and takes into account the temperature and memory effects in the collision integral. It is shown that the sound velocity and the absorption coefficient are significantly influenced by the Fermi surface distortion (FSD) and the memory effects. The corresponding influence is much stronger for the isoscalar mode than for the isovector one. The memory effects lead to the non-monotonic behavior of the absorption coefficient as a function of the relaxation time providing the zero-to-first sound transition with increasing temperature. The mixing of both the isoscalar and the isovector sound modes in an asymmetric nuclear matter is evaluated. The condition for the bulk instability and the instability growth rate in the presence of the memory effects is studied. It was shown that both the FSD and the relaxation processes lead to a shift of the maximum of the instability growth rate to the longer wave length region.

Equation of State and Phase Transitions in Asymmetric Nuclear Matter

V. M. Kolomietz, A. I. Sanzhur, S. Shlomo and
S. A. Firin
Phys. Rev. C (In Press)

The structure of the 3-dimension pressure-temperature-asymmetry surface of equilibrium of an asymmetric nuclear matter is studied within the thermal Thomas-Fermi approximation. Special attention is paid to the different values of the asymmetry parameter for the boiling and the condensation sheets of the surface of equilibrium. We derive the condition of existence of the regime of retrograde condensation at the boiling of the asymmetric nuclear matter. We have performed the calculation of the caloric curves in the case of isobaric heating. We have shown the presence of a plateau region in caloric curves at the isobaric heating of the asymmetric nuclear matter. The shape of the caloric curve depends on the pressure and is slightly sensitive to the value of the asymmetry parameter. We point out that the experimental value of the plateau temperature $T \approx 7$ MeV corresponds to the pressure $P = 10^{-2}$ MeV/fm³ at the isobaric boiling.

Coulomb Energy Differences in Mirror Nuclei Revisited

B. K. Agrawal, Tapas Sil, S. K. Samaddar, J. N. De and S. Shlomo
Phys Rev. C (In Press)

We calculate the Coulomb energy differences in mirror nuclei using the recent parameter set (NL3) in the relativistic mean field (RMF) model which includes self-coupling of the scalar meson. These results are compared with the available ones calculated in the non-relativistic Skyrme-Hartree-Fock (SHF) approach that have the best fit to the experimental data. The NL3 parameter set gives

results that are off from the SHF values by - 2.5%. Improvement is seen with the inclusion of the self-coupling of the vector meson (NL-SV2 parameter set) in the RMF theory.

Compression Modes and the Nuclear Matter Incompressibility Coefficient

S. Shlomo
Pramana - J. Phys. (In Press)

We review the current status of the nuclear matter ($N=Z$ and no Coulomb interaction) incompressibility coefficient, K , and describe the theoretical and experimental methods used to determine K from properties of compression modes in nuclei. In particular we consider the long standing problem of the conflicting results obtained for K , deduced from experimental data on excitation cross sections for the isoscalar giant monopole resonance (ISGMR) and data for the isoscalar giant dipole resonance (ISGDR).

Nuclear Fermi-Liquid Drop Model

V. M. Kolomietz and S. Shlomo
Rev. Mod. Phys. (to be published)

Nuclear many body problem is reduced to equations of motion for the local values such as particle density, velocity field and pressure tensor. The approach provides a generalization of the commonly used liquid drop model to the case of the Fermi liquid. The influence of Fermi-surface distortion, relaxation processes and memory effects on the nuclear dynamics is studied. The theory is applied to the description of the giant multipole resonances in cold and hot nuclei. Some features of the Fermi-liquid drop instability and the large amplitude motion are discussed.