ABSTRACTS FOR PAPERS PUBLISHED
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High Lying *E*0 Strength in ^{12}C

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Phys. Rev. C **57**, 2748 (May 1998)

The excitation region in ^{12}C from 7 MeV<E_x<60 MeV was studied with inelastic scattering of 240-MeV α particles at small angles including 0° where *E*0 strength is enhanced. The strengths of known 0^+ states at E_x=7.655 MeV and E_x= 10.3 MeV were obtained and *E*0 strength was observed to be distributed between E_x=14 MeV and E_x=30 MeV with a centroid of 21.5±0.4 MeV and an rms width of 3.1±0.2 MeV containing 14.5±4.0% of the isoscalar *E*0 energy-weighted sum rule. Angular distributions and strengths of the E_x=4.439 MeV 2^+, 9.641 MeV 3^- and 10.844 MeV 1^- states were also obtained.

Folding Model Analysis of the Excitation of Low-lying States and the High Energy Octupole Resonance in ^{116}Sn by 240 MeV α Scattering

H.L. Clark, Y.-W. Lui, and D.H. Youngblood

Phys. Rev. C **57**, 2887 (June 1998)

The sum rule strength of the high energy octupole resonance and the transition rates of low-lying 2^+ and 3^- states of ^{116}Sn, excited by 240 MeV α scattering, have been determined from deformed potential and folding model analyses. Deformed potential cross sections for both the low-lying 3^- state and the HEOR are greater than folding cross sections by a factor of 1.18. The high energy octupole resonance was found to exhaust (70±15)% and (83±15)% of the *E*3 energy weighted sum rule from the two analyses, respectively. The data for the low-lying states is fit well by the calculations made with both models using electromagnetic values for the transition rates. Optical-model parameters were obtained from fits to elastic scattering data. The differential cross sections for the elastic scattering and inelastic scattering exciting the low-lying 2^+ and 3^- states in ^{116}Sn were measured over the angle range from $\theta_{c.m.}$=1.6° to 35.2°.

Incompressibility of Nuclear Matter from the Giant Monopole Resonance

D.H. Youngblood, H.L. Clark, and Y.-W. Lui

Phys. Rev. Lett. **82**, 691 (January 1999)

*E*0 strength distributions in ^{90}Zr, ^{116}Sn, ^{144}Sm, and ^{208}Pb have been measured with inelastic scattering of 240-MeV α particles between $0° \le \theta_{lab} \le 6°$ to greater precision than previously available. In Sn, Sm, and Pb, *E*0 strength was concentrated in approximately symmetric peaks, whereas in ^{90}Zr it had a significant high energy tail. Comparing with microscopic calculations using the Gogny interaction, these and our previously reported results for ^{40}Ca are consistent with a nuclear matter incompressibility of 231±5 MeV. Previous data gave an average of 215 MeV and the value for different nuclei disagreed by up to 40 MeV.

Hardward Trigger System for Fermilab E866

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Nucl. Instrum. Methods A **418**, 322 (1998)

E866 is the fourth experiment to be performed with the Fermilab Meson East spectrometer. Originally constructed in 1980 for E605, this spectrometer has since been used for E772 and E789. During these three experiments, the hardware trigger has depended on components dating from the early 1970's. The trigger system was rebuilt for E866 to improve its reliability and increase its flexibility. The new system incorporates several new modules designed and built specifically for this experiment. Notably, a custom Track Correlator combines the features of a 16-bit memory lookup and a 12-bit prescaler into a single extremely fast CAMAC module. The new hardware trigger system and modules are described, and the system performance during E866 is discussed.

Construction and Performance of MEGA's Low Mass, High-rate Cylindrical MWPCs

V. Armijo, J.K. Black, R.D. Bolton, S. Carius, M.D. Cooper, C. Espinoza, G. Hart, G.E. Hogan, A. Gonzales, M.A. Kroupa, R.E. Mischke, J. Sandoval, S. Schilling, J. Sena, G. Suazo, D.A. Whitehouse, C.A. Wilkinson, K. Stantz, J.J. Szymanski, C.C. Jui, C.A. Gagliardi, R.E. Tribble, X.-L. Tu, R.J. Fisk, D.D. Koetke, R.W. Manweiler, P.M. Nord, S. Stanislaus, L.E. Piilonen, and Y.D. Zhang

Nucl. Instrum. Methods A **417**, 24 (1998)

A design for extremely low mass, high resolution multiwire proportional chambers (MWPC) was achieved by the MEGA collaboration in its experiment to search for the lepton family number violating decay $\mu \to e\gamma$. To extend the present branching ratio limit by over an order of magnitude, these MWPC's were operated in high particle fluxes. They showed minimal effects of aging, and evidenced spatial and energy resolutions for the orbiting positrons from muon decay which were consistent with our design parameters. The unique features of these chambers, their assembly into the MEGA positron spectrometer, and their performance during the experiment are described in this paper.

Measurement of the Light Antiquark Flavor Asymmetry in the Nucleon Sea

E.A. Hawker, T.C. Awes, M.E. Beddo, C.N. Brown, J.D. Bush, T.A. Carey, T.H. Chang, W.E. Cooper, C.A. Gagliardi, G.T. Garvey, D.F. Geesaman, X.C. He, L.D. Isenhower, S.B. Kaufman, D.M. Kaplan, P.N. Kirk, D.D. Koetke, G. Kyle, D.M. Lee, W.M. Lee, M.J. Leitch, N. Makins, P.L. McGaughey, J.M. Moss, B.A. Mueller, P.M. Nord, B.K. Park, V. Papavassiliou, J.C. Peng, G. Petitt, P.E. Reimer, M.E. Sadler, J. Selden, P.W. Stankus, W.E. Sondheim, T.N. Thompson, R.S. Towell, R.E. Tribble, M.A. Vasiliev, Y.C. Wang, Z.F. Wang, J.C. Webb, J.L. Willis, D.K. Wise, G.R. Young

Phys. Rev. Lett. **80**, 3715 (1998)

A precise measurement of the ratio of Drell-Yan yields from an 800 GeV/c proton beam incident on hydrogen and deuterium targets is reported. Over 140,000 Drell-Yan muon pairs with dimuon mass $M_{\mu+\mu^-} \geq 4.5$ GeV/c^2 were recorded. From these data, the ratio of anti-down ($\bar{d}$) to anti-up ($\bar{u}$) quark distributions in the proton sea is determined over a wide range in Bjorken-x. A strong x dependence is observed in the ratio $\bar{d}/\bar{u}$, showing substantial enhancement of $\bar{d}$ with respect to the $\bar{u}$ for $x < 0.2$. This result is in fair agreement with recent parton distribution parameterizations of the sea. For $x > 0.2$, the observed $\bar{d}/\bar{u}$ ratio is much nearer unity than given by the parameterizations.

Asymptotic Normalization Coefficients and Astrophysical Radiative Capture Reactions

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

Nucl. Phys. A **631**, 788c (1998)

The differential cross section for the reactions ^{9}Be(^{10}B,^{9}Be)^{10}B at an incident ^{10}B energy of 100 MeV and ^{16}O(^{3}He,d)^{17}F*(0.495 MeV, 1/2^{+}) at an incident ^{3}He energy of 29.75 MeV were measured. By normalizing the theoretical DWBA proton exchange cross sections to the experimental ones, the asymptotic normalization coefficients (ANC's) for the virtual decays ^{10}B$\to^{9}$Be+p and ^{17}F*(0.495 MeV, 1/2^{+})$\to^{16}$O + p have been found. These ANC's are used to calculate the astrophysical S(0)-factors for the direct radiative captures ^{9}Be+p$\to^{10}$B+γ and ^{16}O+p$\to^{17}$F*(0.495 MeV, 1/2^{+})+γ.

Population of ^{10}Li by Fragmentation

M. Thoennessen, S. Yokoyama, A. Azhari, T. Baumann, J.A. Brown, A. Galonsky, P.G. Hansen, J.H. Kelley, R.A. Kryger, E. Ramakrishnan, and P. Thirolf

Phys. Rev. C **59**, 111 (January 1999)

The decay structure of the particle-unstable nucleus ^{10}Li was studied using the method of sequential neutron decay spectroscopy (SNDS) at 0°. The decay energies of ^{10}Li can be derived from the relative velocity spectrum of the ^{9}Li daughter and the neutron measured in coincidence. Evidence for low-lying s-wave strength was observed with a scattering length of <-20 fm, corresponding to a peak energy of <50 keV.

Gamow Teller Strengths in (d,^{2}He) Reactions

C.A. Gagliardi, G.K. Ajupova, A.C. Betker, B.C. Hyman, Y.-W. Lui,
J.R. Musser, R.E. Tribble, and H.M. Xu

Proc. Int. Symp. New Facet Spin Giant Res. Nucl., Tokyo, Japan, November 1997,
ed. by H. Sakai, (World Scientific, Singapore) p. 50 (1998)

We have measured cross sections for (d,^{2}He) induced reactions on the nuclei ^{6}Li, ^{12}C, ^{13}C, ^{24}Mg, ^{26}Mg, ^{48}Ti, and ^{54}Fe at an energy E_d = 125 MeV. The data cover scattering angles from 0 - 18°. The typical energy resolution is 650 keV FWHM. The measured (d,^{2}He) excitation energy spectra on ^{6}Li, ^{12}C, ^{13}C, and ^{24}Mg at 0° are very similar to those from intermediate energy (p,n), (n,p), and higher energy (d,^{2}He) reactions on the same nuclei. We find that the 0° cross sections on these nuclei are proportional to the known B(GT) values for the various transitions. We have used this proportionality to determine the B(GT) for the transition from ^{26}Mg to the first excited state of ^{26}Na. Our result is only 60% of the value inferred from population of the analog state in ^{26}Mg(p,n)^{26}Al. We attribute this difference to difficulties estimating the background under the T = 2 state in the (p,n) reaction. At present we are analyzing data on the *fp* shell nuclei ^{48}Ti and ^{54}Fe which are important for theoretical calculations of double-beta decay matrix elements and supernova evolution, respectively. We have also begun an investigation of the energy-dependence of the (d,^{2}He) reaction mechanism over the 110 - 140 MeV energy range accessible to the Texas A&M University K500 Superconducting Cyclotron.

Measuring the $\bar{u}/\bar{d}$ Asymmetry in the Proton Sea: Fermilab E866

T. Awes, C. Brown, T. Carey, T. Chang, W. Cooper, C. Gagliardi, G. Garvey, D. Geesaman,
E. Hawker, X. He, L. Isenhower, S. Kaufman, D. Kaplan, P. Kirk, D. Koetke, G. Kyle, D. Lee, W. Lee,
M. Leitch, N. Makins, P. McGaughey, S. Mishra, C. Morris, J. Moss, P. Nord, B. Park, V. Papavassiliou,
J. Peng, G. Petitt, P.E. Reimer, M. Sadler, P. Stankus, N. Thompson, R. Towell, R. Tribble, Y. Wang,
Z. Wang, J. Webb, G. Young, B. Ziedman

XXXIInd Rencontres de Moriond, QCD and High Energy Hadronic Interactions, p. 387 (1998)

Experiment E866, conducted at the Fermi National Accelerator Laboratory, is a high statistics experiment to measure $\bar{u}(x)/\bar{d}(x)$ in the proton over a wide range of x. A review of the current evidence for $\bar{u}(x) \neq \bar{d}(x)$ in the proton is given and is followed by a short description of the spectrometer and the experimental procedures used in E866. Preliminary results are shown for the ratio of the Drell-Yan cross sections $\sigma^{pd}/2\sigma^{pp}$. Our preliminary results confirm the conclusions of both the NMC and NA51 collaborations that there is an $\bar{u}(x)/\bar{d}(x)$ asymmetry in the proton sea.

Solar Fusion Rates

E. Adelberger, S.M. Austin, J.N. Bachall, A.B. Balantekin, G. Bertsch, G. Bogaert, L. Buchmann,
F.E. Cecil, A.E. Champagne, L. de Braeckeleer, C.A. Duba, S.R. Elliot, S.J. Freedman, M. Gai,
G. Goldring, C.R. Gould, A. Gruzinov, W.C. Haxton, K.M. Heeger, E. Henley, C.W. Johnson,
M. Kamionkowski, R.W. Kavanagh, S.E. Koonin, K. Kubodera, K. Langanke, T. Motobayashi,
V. Pandharipande, P. Parker, R.G.H. Roberston, C. Rolfs, R. Sawyer, N.Shaviv, T.D. Shoppa, K. Snover,
E. Swanson, R.E. Tribble, S. Turck-Chieze and J.F. Wilkerson

Rev. Mod. Phys. **70**, 1265 (1998)

We review and analyze the information available regarding the nuclear fusion cross sections that are most important for solar energy generation and solar neutrino production. We provide best values for the low-energy cross-section factors and, whenever possible, estimates of the uncertainties. We also describe the most important experiments and calculations that are required in order to improve our knowledge of solar fusion rates.

Decay of the ^{12}O Ground State

A. Azhari, R.A. Kryger, and M. Thoennessen
Phys. Rev. C **58**, 2568 (October 1998)

The previously measured decay of the ground state of, ^{12}O was reanalyzed based on new experimental and theoretical results for the ground state of ^{11}N. In the previous analysis no evidence for diproton emission was found and the measured large decay width was inconsistent with sequential proton decay via the intermediate system of ^{11}N. The recent results on ^{11}N show evidence that the ground state of ^{11}N is at substantially lower energy allowing for a consistent explanation of the two-proton decay of ^{12}O in terms of sequential proton emission.

Proton Decay of States in ^{11}N

A. Azhari, T. Baumann, J.A. Brown, M. Hellström, J.H. Kelley, R.A. Kryger, D.J. Millener, H. Madani, E. Ramakrishnan, D.E. Russ, T. Suomijarvi, M. Thoennessen, and S. Yokoyama
Phys. Rev. C. **57**, 628 (February 1998)

The proton-unbound nucleus ^{11}N has been studied via kinematic reconstruction of the emitted proton in coincidence with the residual ^{10}C daughter nucleus. Resonances in ^{11}N were populated by using a 40 MeV/nucleon radioactive beam of ^{12}N to induce the reaction $^{9}Be(^{12}N,^{11}N)$, followed by the proton decay of ^{11}N. The decay energy spectrum was constructed from the energies and separation angle of the ^{10}C and the proton. In addition to protons from the known $1/2^-$ state, at 2.24 MeV above the proton decay threshold, another peak is seen near 1.45 MeV. This peak could potentially be due to the predicted $1/2^+$ ground state and/or due to the decay of the $3/2^-$ state to the first excited state of ^{10}C.

Proton Scattering on ^{40}S

Y. Blumenfeld, F. Marechal, T. Suomijarvi, S.E. Hirzebruch, J.A. Scarpaci, A. Azhari, D. Bazin, J.A. Brown, M. Fauerbach, T. Glasmacher, P.F. Mantica, D.J. Morrissey, M. Steiner, P.D. Cottle, J.K. Jewell, K.W. Kemper, L.A. Riley
Bull. Amer. Phys. Soc.**44**, 986 (1999)

Elastic and inelastic proton scattering at 30 MeV on the unstable neutron rich nucleus ^{40}S has been measured using reverse kinematics at the NSCL/MSU. Recoiling protons were detected in an eight member Si-strip detector array. The measured angular distributions are compared to microscopic calculations using deformed Hartree-Fock Bogoliubov densities folded with the effective JLM interaction. The ratio of neutron to proton transition matrix elements M_n/M_p is extracted for the first collective 2^+ state.

Indirect Measurements of the $^{7}Be(p,\gamma)^{8}B$ *S*-factor

A. Azhari, C.A. Gagliardi, A.M. Mukhamedzhanov, T. Sandu, X.D. Tang, L. Trache, R.E. Tribble, V. Burjan, V. Kroha, F. Carstoiu
Bull. Amer. Phys. Soc **44**, 1529 (1999)

The determination of direct capture reaction rates remains a high priority within nuclear astrophysics. These rates can be obtained indirectly through the measurement of Asymptotic Normalization Coefficients (ANC). In particular, the determination of the astrophysical S-factor for the radiative capture reaction $^{7}Be(p,\gamma)^{8}B$, $S_{17}(0)$, plays a key role in clarifying the solar neutrino problem. The reactions $^{10}B(^{7}Be,^{8}B)^{9}Be$ and $^{14}N(^{7}Be,^{8}B)^{13}C$ were studied using a ^{7}Be radioactive beam to obtain the ANC's for the direct capture reaction $^{7}Be(p,\gamma)^{8}B$. Elastic scattering events were measured simultaneously and used to verify optical model potentials which were used in DWBA calculations to predict the proton transfer cross sections. A Monte Carlo simulation of the experiment was used to obtain the experimental solid angles folded with experimental resolutions. Elastic and proton transfer cross sections were obtained and will be presented together with the extracted ANC's and the resulting $S_{17}(0)$.

Asymptotic Normalization Coefficients and Astrophysical Radiative Captures Processes

A. Mukhamedzhanov, A. Azhari, C.A. Gagliardi, L. Trache, R.E. Tribble

Bull. Amer. Phys. Soc **44**, 1529 (1999)

It has been shown that the asymptotic normalization coefficients (ANC) define the overall normalization of the astrophysical factors for the direct radiative capture at low energies to both subthreshold bound states and subthreshold resonances. The ANC's are also related to the fitting parameters in *K*- and R-matrix approaches. The ANC's for proton removal can he measured from proton transfer reactions. We present the astrophysical factors at zero energy calculated using measured ANC'S. We also present the results of the R-matrix analysis of the low-energy *S*-factor for ^{9}Be+p→^{10}B+γ with the direct part calculated using the ANC's extracted from the $^{9}Be(^{10}B,^{9}Be)^{10}B$ reaction.

About Compactness of Faddeev Integral Equations for Three Charged Particles

A. Mukhamedzhanov, E. Alt, G. Avakov

Bull. Amer. Phys. Soc. **44**, 1009 (1999)

The incorporation of long-ranged Coulomb forces into the three-body Faddeev formalism constitutes a long standing problem. In the present investigation we explore the singular behavior of the kernels of the Faddeev type Alt-Grassberger-Sandhas (AGS) equations. The results, when the charges of all three particles have the same sign, are as follows. 1. The only noncompact singularity of the kernel is the center-of- mass Coulomb singularity in the diagonal part on the energy shell, which can be singled out and converted. 2. The strongest off-shell singularity is integrable and after a few iteration the kernels of the effective-two-body AGS equations become compact.

Evolution of the Giant Dipole Resonance in Excited ^{120}Sn and ^{208}Pb Nuclei Populated by Inelastic Alpha Scattering

T. Baumann, E. Ramakrishnan, A. Azhari, J.R. Beene, R.J. Charity, J.F. Dempsey, M.L. Halbert, P.-F. Hua, R.A. Kryger, P.E. Mueller, R. Pfaff, D.G. Sarantites, L.G. Sobotka, D.W. Stracener, M. Thoennessen, G. Van Buren, R.L. Varner, S. Yokoyama

Nucl. Phys. A **635**, 428 (1998)

The evolution of the giant dipole resonance (GDR) in ^{120}Sn and ^{208}Pb nuclei at excitation energies in the range of 30-130 MeV and 40-110 MeV, respectively, were studied by measuring high energy gamma rays from the decay of the resonance. The excited states were populated by inelastic scattering of alpha particles at beam energies of 40 and 50 MeV/nucleon for ^{120}Sn and 40 MeV/nucleon for ^{208}Pb. A systematic increase of the resonance width with increasing excitation energy was observed for both nuclei. The observed width evolution was compared to calculations employing a model that adiabatically couples the collective excitation to the nuclear shape, and to a model based on the collisional damping of nucleons. The adiabatic coupling model described the width evolution in both nuclei well, whereas the collisional damping calculation could describe the width evolution only in ^{208}Pb. Light-particle inelastic scattering populates low angular momentum states in the target nucleus. The observed width increase is therefore interpreted to be predominantly due to fluctuations in the nuclear shape induced by temperature. This interpretation is consistent with the adiabatic model calculations and with recent angular momentum-gated measurements of the GDR in excited Sn isotopes.

Proton-Deuteron Elastic Scattering for $E > 0$

E.O. Alt, A.M. Mukhamedzhanov, A.I. Sattarov

Few-Body Systems Suppl. **10**, 331 (1999)

We report on the first reliable numerical results for proton-deuteron elastic scattering observables for energies above the deuteron breakup threshold, for the Paris potential. The calculations have been performed within the screening and renormalisation approach. The theoretical results are compared with recent experimental data.

Tests of Transfer Reaction Determinations of Astrophysical *S* Factors

C.A. Gagliardi, R.E. Tribble, A. Azhari, H.L. Clark, Y.-W. Lui, A.M. Mukhamedzhanov, A. Sattarov, L. Trache, V. Burjan, J. Cejpek, V. Kroha, Š. Piskoř, and J. Vincour

Phys. Rev. C **59**, 1149 (February 1999)

The $^{16}O(^3He,d)^{17}F$ reaction has been used to determine asymptotic normalization coefficients for transitions to the ground and first excited states of ^{17}F. The coefficients provide the normalization for the tails of the overlap functions for $^{17}F \rightarrow ^{16}O+p$ and allow us to calculate the *S* factors for $^{16}O(p,\gamma)^{17}F$ at astrophysical energies. The calculated *S* factors are compared to measurements and found to be in very good agreement. This provides a test of this indirect method to determine astrophysical direct capture rates using transfer reactions. In addition, our results yield $S(0)$ for capture to the ground and first excited states in ^{17}F, without the uncertainty associated with extrapolation from higher energies.

Asymptotic Normalization Coefficients for $^{13}C+p \rightarrow ^{14}N$

L. Trache, A. Azhari, H.L. Clark, C.A. Gagliardi, Y.-W. Lui, A.M. Mukhamedzhanov, R.E. Tribble and F. Carstoiu

Phys. Rev. C **58**, 2715 (November 1998)

The $^{13}C(^{14}N,^{13}C)^{14}N$ proton exchange reaction has been measured at an incident energy of 162 MeV. Angular distributions were obtained for proton transfer to the ground and low-lying excited states in ^{14}N. Elastic scattering of ^{14}N on ^{13}C also was measured out to the rainbow angle region in order to find reliable optical model potentials. Asymptotic normalization coefficients for the system $^{13}C+p \rightarrow ^{14}N$ have been found for the ground state and the excited states at 2.313, 3.948, 5.106, and 5.834 MeV in ^{14}N. These asymptotic normalization coefficients will be used in a determination of the *S* factor for $^7Be(p,\gamma)^8B$ at solar energies from a measurement of the proton transfer reaction $^{14}N(^7Be,^8B)^{13}C$.

$\bar{d}/\bar{u}$ Asymmetry and the Origin of the Nucleon Sea

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

Phys. Rev. D **58**, 092004-1 (1998)

The Drell-Yan cross section ratios, $\sigma(p+d)/\sigma(p+p)$, measured in Fermilab E866, have led to the first determination of $\bar{d}(x)/\bar{u}(x)$, $\bar{d}(x)-\bar{u}(x)$, and the integral of $\bar{d}(x)-\bar{u}(x)$ for the proton over the range $0.02<x<0.345$. The E866 results are compared with predictions based on parton distribution functions and various theoretical models. The relationship between the E866 results and the NMC measurement of the Gottfried integral is discussed. The agreement between E866 results and models employing virtual mesons indicates that these non-perturbative processes play an important role in the origin of the $\bar{d},\bar{u}$ asymmetry in the nucleon sea.

Coulomb Corrections to the Rate of the Astrophysical Reaction $p+p \rightarrow d+e^+ + \nu_e$

L.D. Blokhintsev, G.V. Avakov, A.M. Mukhamedzhanov, E.N. Voronina

Few-Body Systems Suppl. **10**, 219 (1999)

The effect of the e^+p interaction in the intermediate state of the astrophysical reaction $p+p \rightarrow d+e^+ + \nu_e$ has been considered. The corresponding correction to the astrophysical S factor of this reaction at near-zero energy turned out to be about 1%.

Determination of $S_{17}(0)$ From Transfer Reactions

R.E. Tribble, A. Azhari, H.L. Clark, C.A. Gagliardi, Y.-W. Lui, A.M. Mukhamedzhanov, A. Sattarov, L. Trache, V. Burjan, J. Cejpek, V. Kroha, Š. Piškor, J. Vincour

Proc. of 2nd Intl. Conf. on Exotic Nuclei and Atomic Masses, June, 1998, Michigan, ed. by B.M. Sherrill, D.J. Morrissey and C.N. Davids (AIP Conference Proceedings 455, Woodbury, NY, 1998), p. 868

The S-factor for the direct capture reaction $^7Be(p,\gamma)^8B$ can be found at astrophysical energies from the asymptotic normalization coefficients which provide the normalization of the tails of the overlap functions for $^8B \rightarrow ^7Be+p$. Peripheral transfer reactions offer a technique to determine these asymptotic normalization coefficients. As a test of the technique, the $^{16}O(^3He,d)^{17}F$ reaction has been used to determine asymptotic normalization coefficients for transitions to the ground and first excited states of ^{17}F. The S-factors for $^{16}O(p,\gamma)^{17}F$ calculated from these $^{17}F \rightarrow ^{16}O+p$ asymptotic normalization coefficients are found to be in very good agreement with recent measurements. Following the same technique, the $^{10}B(^7Be,^8B)^9Be$ reaction has been used to measure the asymptotic normalization coefficient for $^7Be(p,\gamma)^8B$. This result provides an indirect determination of $S_{17}(0)$.

Asymptotic Normalization Coefficients for $^{14}N \rightarrow ^{13}C+p$ and $^{10}B \rightarrow ^9Be+p$

A. Azhari, H.L. Clark, C.A. Gagliardi, Y.-W. Lui, A.M. Mukhamedzhanov, L. Trache, R.E. Tribble, H.M. Xu, X.G. Zhou, J. Cejpek, V. Kroha, V. Burjan, F. Carstoiu

Proc. of 2nd Intl. Conf. on Exotic Nuclei and Atomic Masses, June, 1998, Michigan, ed. by B.M. Sherrill, D.J. Morrissey and C.N. Davids (AIP Conference Proceedings 455, Woodbury, NY, 1998), p.896.

The proton exchange reactions $^{13}C(^{14}N,^{13}C)^{14}N$ *and* $^9Be(^{10}B,^9Be)^{10}B$ were studied at energies where they are peripheral. Angular distributions for elastic scattering and proton transfer were measured, and the results were used to extract ANC's by comparison with modified DWBA calculations. These ANC's will be used together with proton transfer reactions with radioactive beams to determine astrophysical S-factors for radiative capture reactions, in particular $S_{17}(0)$ for $^7Be(p,\gamma)$.

Measurement of the Flavor Asymmetry in the Nucleon Sea

M.A. Vasiliev, T.C. Awes, M.E. Beddo, C.N. Brown, 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, S.B. Kaufman, D.M. Kaplan, P.N. Kirk, D.D. Koetke, G. Kyle, D.M. Lee, W.M. Lee, M.J. Leitch, N. Makins, P.L. McGaughey, J.M. Moss, B.A. Mueller, P.M. Nord, B.K. Park, V. Papavassiliou, J.C. Peng, G. Petitt, P.E. Reimer, M.E. Sadler, J. Selden, P.W. Stankus, W.E. Sondheim, T.N. Thompson, R.S. Towell, R.E. Tribble, Y.C. Wang, Z.F. Wang, J.C. Webb, J.L. Willis, D. Wise, G.R. Young

Lake Louise Winter Institute, Canada, Feb. 1998 (World Scientific, Singapore, 1999) p.314.

A precise measurement of the ratio of Drell-Yan yields from an 800 GeV/c proton beam incident on hydrogen and deuterium targets is reported. Over 140,000 Drell-Yan muon pairs with dimuon mass $M_{\mu+\mu} \geq 4.5$ GeV/c^2 were recorded. From these data, the ratio of anti-down ($\bar{d}$) to anti-up ($\bar{u}$) quark distributions in the proton sea is determined over a wide range in Bjorken-x. A strong x dependence is observed in the ratio, $\bar{d}/\bar{u}$ showing substantial enhancement of $\bar{d}$ with respect to $\bar{u}$ for $x < 0.2$.

About Compactness of Faddeev Integral Equations for Three Charged Particles

A.M. Mukhamedzhanov, E.O. Alt, and G.V. Avako

Few-Body Systems Suppl. **10,** 97 (1999)

Momentum space three-body integral equations of the Faddeev type can not be used for Coulomb-like potentials, for energies above the breakup threshold. The reason is the occurrence of singularities in their kernels which destroy the compactness properties known to exist for purely short-range interactions. Using the rigorously equivalent formulation in terms of an effective-two-body theory, we prove that the nondiagonal kernels occurring therein possess on and off the energy shell only integrable singularities, provided all three particles have charges of the same sign (i.e., only repulsive Coulomb interactions). In contrast, if some of the charges have opposite signs the nondiagonal kernels develop nonintegrable singularities which destroy the compactness properties.

Three-Body Coulomb Effects in the Direct Coulomb Breakup of ^{8}B into ^{7}Be+p in the Field of a ^{208}Pb Ion

B.F. Irgaziev, E.O. Alt, A.M. Mukhamedzhanov

Few-Body Systems Suppl. **10**, 379 (1999)

The amplitude for the Coulomb breakup of a light nucleus in the field of a highly charged ion is considered in the framework of the distorted wave approach, with particular emphasis being laid on correctly taking into account the three-body Coulomb interactions in the final state. Numerical calculations have been performed for the double differential cross section for the reaction ^{208}Pb(^{8}B,^{7}Be p)^{208}Pb. They clearly demonstrate the importance of long-range three-body Coulomb correlations in the astrophysically interesting regime when the ejectiles have the extremely small relative energies.

Evidence for Two-Proton-Radioactivity of the First Excited State of ^{17}Ne

M.J. Chromik, P.G. Thirolf, M. Thoennessen, A. Azhari, R.A. Kryger, D.J. Morrissey, H. Scheit, M. Steiner, P.J. Woods, S. Yokoyama

Contrib. Nuclear Structure 1998, Gatlinburg, TN, p.17 (1998)

(No Abstract Available)

Single-particle Energies in the N=83 Isotones From ^{133}Sn to ^{153}Yb

A. M. Oros, K. Heyde, C. de Coster, B. Decroix, L. Trache, P. von Brentano

Proceedings Santa Agata Conference, May 1998, ed. A. Covello

Neutron single-particle energies are studied in eleven N=83 isotones which cover the whole region between ^{133}Sn and ^{113}Yb. The experimental level energies and spectroscopic factors are compared with Particle-Core Model calculations. The model provides a very accurate description of the low-energy properties of these nuclei. The single-particle energies are extracted from the experimental data, by correctly taking into account—and correcting for—the effects of the Particle-Vibration Coupling. Further information on single-particle energies is extracted from the data available on two N=84 isotones, ^{154}Yb and ^{156}Hf, by comparison with model calculations.

Superallowed Fermi Beta Decay

J.C. Hardy and I.S. Towner

Proc. of ENAM98: Exotic Nuclei and Atomic Masses, Bellaire, MI, June 23-27, 1998, eds. B.B. Sherrill, D.J. Morrissey and C.N. Davids, AIP Conference Proceedings 455 p. 733 (1998)

Superallowed $0^{+}\rightarrow 0^{+}$ nuclear beta decay provides a direct measure of the weak vector coupling constant, G_V. We survey current world data on the nine accurately determined transitions of this type, which range from the decay of ^{10}C to that of ^{54}Co, and demonstrate that the results confirm conservation of the weak vector current (CVC) but differ at the 98% confidence level from the unitarity condition for the Cabibbo-Kobayashi-Maskawa (CKM) matrix. We examine the reliability of the small calculated corrections that have been applied to the data, and assess the likelihood of even higher quality nuclear data becoming available to confirm or deny the discrepancy. Some of the required experiments depend upon the availability of intense radioactive beams. Others are possible today.

Superallowed Fermi Beta Decay

I.S. Towner and J.C. Hardy

Physics in Canada **55**, 91 (1998)

The current world data on superallowed Fermi beta decay are tantalizingly close to a result in definitive disagreement with unitarity of the Cabibbo-Kobayashi-Maskawa matrix.

Status of the Canadian Penning Trap Mass Spectrometer at the Argonne National Laboratories

K.S. Sharma, R.C. Barber, F. Buchinger, J.E. Crawford, X. Feng, H. Fukutani, S. Gulick, G Hackman, J.C. Hardy, D. Hofman, J.K.P. Lee, P. Martinez, R.B. Moore, G. Savard, D. Seweryniak and J. Uusitalo

Proc. of ENAM98: Exotic Nuclei and Atomic Masses, Bellaire, MI, June 23-27, 1998, eds. B.B. Sherrill, D.J. Morrissey and C.N. Davids, AIP Conference Proceedings 455 p. 130 (1998)

The Canadian Penning Trap (CPT) mass spectrometer has been modified and reassembled at the ATLAS facility of the Argonne National Laboratory. It is currently being commissioned there. With this apparatus, we expect to be able to measure the masses of a wide variety of nuclides having half-lives greater that 0.1 s, to an accuracy of better than 10 ppb of the mass. The planned program of measurements is aimed at improving our knowledge of the nuclear mass surface in general and to provide precise mass data of relevance to tests of the Standard Model and fundamental symmetries. This report describes the current status of the instrument.

Multifragraentation: Thermal vs. Dynamic Effects

K. Kwiatkowski, W.-C. Hsi, V.E. Viola, G. Wang, D.S. Bracken, H. Breuer, E. Cornell, E. Renshaw Foxford, F. Gimeno-Nogues, D.S. Ginger, S. Gushue, R.G. Korteling, W.G. Lynch, K.B. Morley, E.C. Pollacco, E. Ramakrishnan, L.P. Remsberg, M.B. Tsang, C. Volant, S.J. Yennello, H. Xi and N.R. Yoder (ISIS Collaboration)

Nuclear Physics **A630,** 168c (1998)

Reactions of 1.8 - 4.8 GeV ^{3}He, 5.0 - 9.2 GeV/c π^- and 6.0 - 14.6 GeV/c protons with ^{nat}Ag and ^{197}Au targets have been studied with the ISIS 4π detector array. From reconstructed events, excitation-energy distributions have been determined and combined with a ^{2,3}H/^{3,4}He isotope-ratio thermometer to study the heating curve for the thermal-like component of these reactions. Dynamic effects also manifest themselves in the data, as evidenced by deposition-energy saturation above ~5 GeV, IMF emission during expansion, and sideways peaking of the IMF angular distributions for beam energies $E_b \geq 10$ GeV.

Sideways-peaked Angular Distributions in Hadron-induced Multifragmentation: Shock Waves, Geometry, or Kinematics?

W.-c. Hsi, K. Kwiatkowski, G. Wang, D.S. Bracken, E. Cornell, D.S. Ginger, V.E. Viola, N.R. Yoder, R.G. Korteling, F. Gimeno-Nogues, E. Ramakrishnan, D. Rowland, S.J. Yennello, R. Huang, W.G. Lynch, M.B. Tsang, H. Xi, H. Breuer, K.B. Morley, S. Gushue, L.P. Remsberg, W.A. Friedman and A. Botvina

Phys. Rev. C **58**, R13 (July 1998)

Exclusive studies of sideways-peaked angular distributions for intermediate-mass fragments (IMFS) produced in hadron-induced reactions have been performed with the Indiana silicon sphere (ISIS) detector array. The effect becomes prominent for beam momenta above about 10 GeV/c. Both the magnitude of the effect and the peak angle increase as a function of fragment multiplicity and charge. When gated on IMF kinetic energy, the angular distributions evolve from forward peaked to nearly isotropic as the fragment energy decreases. Fragment-fragment correlation studies show no evidence for a preferred angle that might signal a fast dynamic breakup mechanism. Moving-source and intranuclear cascade simulations suggest a possible kinematic origin arising from significant transverse momentum imparted to the recoil nucleus during the fast cascade. A two-step cascade and statistical multifragmentation calculation is consistent with the data.

Neutron Yields From 435 MeV/nucleon Nb Stopping in Nb and 272 MeV/nucleon Nb Stopping in Nb and Al

L. Heilbronn, R. Madey, M. Elaasar, M. Htun, K. Frankel, W.G. Gong, B.D. Anderson, A.R. Baldwin, J. Jiang, D. Keane, M.A. McMahan, W.H. Rathbun, A. Scott, Y. Shao, J.W. Watson, G.D. Westfall, S. Yennello, and W.-M. Zhang

Phys. Rev. C **58**, 3451 (December 1998)

Neutron fluences were measured from 435 MeV/nucleon Nb ions stopping in a Nb target and 272 MeV/nucleon Nb ions stopping in targets of Nb and Al for neutrons above 20 MeV and at laboratory angles between 3° and 80°. The resultant spectra were integrated over angles to produce neutron energy distributions and over energy to produce neutron angular distributions. The total neutron yields for each system were obtained by integrating over the angular distributions. The angular distributions from all three systems are peaked forward, and the energy distributions from all three systems show an appreciable yield of neutrons with velocities greater than the beam velocity. Comparison of the total neutron yields from the two Nb+Nb systems suggests that the average neutron multiplicity decreases with decreasing projectile energy. Comparison of the total yields from the two 272 MeV/nucleon systems suggests that the total yields show the same dependence on projectile and target mass number as do total inclusive neutron cross sections. The data are compared with Boltzmann-Uehling-Uhlenbeck model calculations.

Neutrons From Multiplicity-selected La-La and Nb-Nb Collisions at 400A MeV and La-La Collisions at 250A MeV

M. M. Htun, R. Madey, W.M. Zhang, M. Elaasar, D. Keane, B.D. Anderson, A.R. Baldwin, J. Jiang, A. Scott, Y. Shao, J.W. Watson, K. Frankel, L. Heilbronn, G. Krebs, M.A. McMahan, W. Rathbun, J. Schambach, G.D. Westfall, S. Yennello, C. Gale, and J. Zhang

Phys. Rev. C **59**, 336 (January 1999)

Triple-differential cross sections for neutrons from high-multiplicity La-La collisions at 250 and 400 MeV per nucleon and Nb-Nb collisions at 400 MeV per nucleon were measured at several polar angles as a function of the azimuthal angle with respect to the reaction plane of the collision. The reaction plane was determined by a transverse-velocity method with the capability of identifying charged-particles with $Z= 1$, $Z= 2$, and $Z> 2$. The flow of neutrons was extracted from the slope at mid-rapidity of the curve of the average in-plane momentum vs. the center-of-mass rapidity. The *squeeze-out* of the participant neutrons was observed in a direction normal to the reaction plane in the normalized momentum coordinates in the center-of-mass system. Experimental results of the neutron squeeze-out were compared with BUU calculations. The polar-angle dependence of the maximum azimuthal anisotropy ratio $r(\theta)$ was found to be insensitive to the mass of the colliding nuclei and the beam energy. Comparison of the observed polar-angle dependence of the maximum azimuthal anisotropy ratio $r(\theta)$ with BUU calculations for *free* neutrons revealed that $r(\theta)$ is insensitive also to the incompressibility modulus in the nuclear equation of state.

Coalescence Model Analyses of Reaction Dynamics at 47A MeV

K. Hagel, J. Cibor, R. Wada, M. Lunardon, N. Marie, R. Alfaro, W. Shen, Y. Zhao, J. Li, B.-A. Li, M. Murray, J.B. Natowitz, Z. Majka and P. Staszel

Proc. of the International Workshop XXVII on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg, Austria, p. 145 (January 1999)

The coalescence model for light cluster production provides a natural vehicle for following the time evolution of light composite particle emission from the first emission of such particles through freeze-out. Application of such an analysis to particles produced in violent collisions of 47A MeV ^{12}C, ^{22}Ne, ^{40}Ar, and ^{54}Zn projectiles with intermediate mass targets provides information on the degree of expansion of the hot medium mass nuclei produced and allows derivation of a caloric curve with minimum interference from secondary decay processes.

Experimental Determination of Fragment Excitation Energies in Multifragmentation Events

N. Marie, A. Chbihi, J.B. Natowitz, A. Le Fèvre, S. Salou, J.P. Wieleczko, L. Gingras, M. Assenard, G. Auger, Ch.O. Bacri, F. Bocage, B. Borderie, R. Bougault, R. Brou, P. Buchet, J.L. Charvet, J. Cibor, J. Colin, D. Cussol, R. Dayras, A. Demeyer, D. Doré, D. Durand, P. Eudes, J.D. Frankland, E. Galichet, E. Genouin-Duhamel, E. Gerlic, M. Germain, D. Gourio, D. Guinet, K. Hagel, P. Lautesse, J.L. Laville, J.F. Lecolley, T. Lefort, R. Legrain, N. Le Neindre, O. Lopez, M. Louvel, Z. Majka, A.M. Maskay, L. Nalpas, A.D. Nguyen, M. Parlog, J. Péter, E. Plagnol, A. Rahmani, T. Reposeur, M.F. Rivet, E. Rosato, F. Saint-Laurent, J.C. Steckmeyer, M. Stern, G. Tabacaru, B. Tamain, O. Tirel, E. Vient, C. Volant, R. Wada

Phys. Rev. C **58**, 256 (July 1998)

For 50 MeV/nucleon $^{129}Xe+^{nat}Sn$ multifragmentation events, we deduced, by means of correlation techniques, the multiplicities of the hydrogen and helium isotopes which were emitted by the hot primary excited fragments produced at the stage of the disassembly of an equilibrated hot source. We also derived the relative kinetic energy distributions between the primary clusters and the light charged particles that they evaporate. From the comparison between the secondary multiplicities observed experimentally and the multiplicities predicted by the GEMINI model, we concluded that the source breaks into primary fragments which are characterized by the same N/Z ratio as the combined system. Knowing the secondary light charged particle multiplicities and kinetic energies, we reconstructed the average charges of the hot fragments and we estimated their mean excitation energies. The fragment excitation energies are equal to 3.0 MeV/nucleon for the full range of intermediate mass fragment atomic number. This global constancy indicates that, on the average, thermodynamical equilibrium was achieved at the disassembly stage of the source.

Entrance Channel Dynamics in $^{40}Ca+^{40}Ca$ at 35A MeV

R. Wada, K. Hagel, J. Cibor, J. Li, N. Marie, W.Q. Shen, Y. Zhao and J.B. Natowitz

Phys. Lett. B **422**, 6 (March 1998)

The entrance channel dynamics of the $^{40}Ca+^{40}Ca$ reaction at 35A MeV is modeled with the recently developed QMD codes, EQMD and AMD-V. Drastic differences are observed in the entrance channel dynamics calculated by two models. AMD-V with a Gogny force reproduces the experimental results over all. The importance of the introduction of the diffusion process to the centroid motion of wave packets is suggested.

Excitation Energy Deposition in $^{209}Bi(\alpha,\alpha')$ Reactions at 240 MeV

D. Fabris, M. Lunardon, G. Nebbia, G. Viesti, M. Cinausero, E. Fioretto, D.R. Napoli, G. Prete, K. Hagel, J.B. Natowitz, R. Wada, P. Gonthier, Z. Majka, R. Alfaro, Y. Zhao, N. Mdeiwayeh and T. Ho

Phys. Rev. C **58**, R624 (August 1998)

The energy deposition associated with inelastic α particle scattering on ^{209}Bi at 240 MeV has been determined using the TAMU neutron ball. Comparison of the reconstructed average excitation energies with the beam energy losses demonstrates that all of the missing beam energy is not usually deposited as thermal excitation in the target nucleus. Requiring an additional coincidence with a light charged particle or fission fragment leads to selection of a significant higher average excitation energy.

Experimental Investigations of the Nuclear Level Density by Using Heavy Ion Reactions

G. Viesti, M. Lunardon, D. Fabris, G. Nebbia, M. Cinausero, E. Fioretto, G. Prete, J.B. Natowitz, K. Hagel, R. Wada

Pramana J. Phys. **23**, 1 (January 1999)

The transition of the level density parameter a_{eff} from the low excitation energy value a_{eff} = A/8 MeV^{-1} to the Fermi Gas value a_{FG}~A/15 MeV^{-1} was discovered a few years ago studying particle spectra evaporated from hot compound systems of A~160. A number of experiments have been recently performed to confirm the earlier findings and extend the investigation to other mass regions and to higher excitation energies. Furthermore, precision coincidence experiments have been done in the lead region in which evaporation residues are tagged by low energy gamma-rays. Those experiments open the possibility of a detailed study of the level densities in nuclei where the shell effects are important.

Three Pion Correlations in Sulphur-Lead Collisions at the CERN SPS

H. Bøggild, J. Boissevain, J. Dodd, S. Esumi, C.W. Fabjan, D. Ferenc, A. Franz , D. Hardtke, H. van Hecke, T.J. Humanic, T. Ikemoto, B.V. Jacak, H. Kalechofsky, T. Kobayashi, R. Kvatadze, Y.Y. Lee, M. Leltchouk, B.Lörstad, N. Maeda, Y. Miake, A. Miyabayashi, M. Murray, S. Nagamiya, S. Nishimura, G. Paic, S.U. Pandey, F. Piuz, V. Polychronakos, M. Potekhin, G. Poulard, D. Rahm, J.M. Rieubland, A. Sakaguchi, M. Sarabura, K. Shigaki, J. Simon-Gillo, J. Schmidt-Sorensen, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, and W.J. Willis (The NA44 Collaboration)

CERN-EP/99-18 (January 1999)

$\pi^+\pi^+\pi^+$ correlations from Sulphur-Lead collisions at 200 GeV/c per nucleon are presented as measured by the focusing spectrometer of experiment NA44 at CERN. We have investigated the three-pion correlation function at mid-rapidity and found that a genuine three-body correlation is suppressed. A possible interpretation of this result is that the emission of particles is partially coherent.

Two-Proton Correlations near Midrapidity in *p+Pb* and *S+Pb* Collisions at the CERN SPS

H. Bøggild, J. Boissevain, J. Dodd, B. Erazmus, S. Esumi, C.W. Fabjan, D.E. Fields, A. Franz, K.H. Hansen, E.B. Holzer, T.J. Humanic, B.V. Jacak, R. Jayanti, H. Kalechofsky, Y.Y. Lee, M. Leltchouk, B. Lörstad, N. Maeda, L. Martin, A. Medvedev, A. Miyabayashi, M. Murray, S. Nishimura, G. Paic, S.U. Pandey, F. Piuz, J. Pluta, V. Polychronakos, M. Potekhin, G. Poulard, A. Sakaguchi, M. Sarabura, M. Spegel, J. Simon-Gillo, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis, K. Wolf and N. Xu
(The NA44 Collaboration)

CERN-EP/98-155 (May 1998)

Correlations of two protons emitted near midrapidity in *p+Pb* collisions at 450 GeV/*c* and *S+Pb* collisions at 200*A* GeV/*c* axe presented, as measured by the NA44 Experiment. The correlation effect, which arises as a result of final state interactions and Fermi-Dirac statistics, is related to the space-time characteristics of proton emission. The measured source sizes are smaller than the size of the target lead nucleus but larger than the sizes of the projectiles. A dependence on the collision centrality is observed; the source size increases with decreasing impact parameter. Proton source sizes near midrapidity appear to be smaller than those of pions in the same interactions. Qualitative agreement with the results of RQMD simulations is found for *p+Pb* collisions. For *S+Pb* collisions the measured correlation effect is somewhat weaker than that predicted by the model simulations.

High Energy Pb+Pb Collisions Viewed by Pion Interferometry

I.G. Bearden, H. Bøggild, J. Boissevain, J. Dodd, B. Erazmus, S. Esumi, C.W. Fabjan, D. Ferenc, D.E. Fields, A. Franz, J. Gaardhøje, M. Hamelin, A.G. Hansen, O. Hansen, D. Hardtke, H. van Hecke, E.B. Holzer, T.J. Humanic, P. Hummel, B.V. Jacak, R. Jayanti, K. Kaimi, M. Kaneta, T. Kohama, M. Kopytine, M. Leltchouk, A. Ljubicic, Jr., B. Lörstad, N. Maeda, R. Malina, A. Medvedev, M. Murray, H. Ohnishi, G. Paic, S.U. Pandey, F. Piuz, J. Pluta, V. Polychronakos, M. Potekhin, G. Poulard, D. Reichhold, A. Sakaguchi, J. Simon-Gillo, J. Schmidt-Sørensen, W. Sondheim, M. Spegel, T. Sugitate, J.P. Sullivan, Y. Sumi, W.J. Willis, K.L. Wolf, N. Xu, and D.S. Zachary

Phys. Rev. C **58**, 1656 (September 1998)

Two-pion correlations from Pb+Pb collisions at 158 GeV/*c* per nucleon are measured by the NA44 experiment at CERN. Multidimensional fits characterize the emission volume, which is found to be larger than in *S*-induced collisions. Comparison to the RQMD model is used to relate the fit parameters to the actual emission volume.

Charged Kaon and Pion Production at Midrapidity in Proton-nucleus and Sulphur-nucleus Collisions

H. Bøggild, J. Boissevain, J. Dodd, S. Esumi, C.W. Fabjan, D.E. Fields, A. Franz, K.H. Hansen, T.J. Humanic, B.V. Jacak, H. Kalechofsky, Y.Y. Lee, M. Leltchouk, B. Lörstad, N. Maeda, A. Miyabayashi, M. Murray, S. Nishimura, S.U. Pandey, F. Piuz, V. Polychronakos, M. Potekhin, G. Poulard, A. Sakaguchi, M. Sarabura, J. Simon-Gillo, J. Schmidt-Sørensen, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis and K. Wolf (NA44 Collaboration)

Phys. Rev. C **59**, 328 (January 1999)

The NA44 Collaboration has measured charged kaon and pion distributions at midrapidity in sulphur and proton collisions with nuclear targets at 200 and 450 GeV/*c* per nucleon, respectively. The inverse slopes of kaons, are larger than those of pions. The difference in the inverse slopes of pions, kaons, and protons, all measured in our spectrometer, increases with system size and is consistent with the buildup of collective flow for larger systems. The target dependence of both the yields and inverse slopes is stronger for the sulphur beam, suggesting the increased importance of secondary rescattering for SA reactions. The rapidity density *dN/dy* of both K^+ and K^- increases more rapidly with system size than for π^+ in a similar rapidity region. This trend continues with increasing centrality, and according to RQMD, it is caused by secondary reactions between mesons and baryons. The K^-/K^+ ratio falls with increasing system size but more slowly than the $\bar{p}/p$ ratio. The π^-/π^+ ratio is close to unity for all systems. From *p*Be to SPb the K^+/p ratio decreases while $K^-/\bar{p}$ increases and $\sqrt{(K^+ \cdot K^-)}/(p \cdot p)$ stays constant. These data suggest that as larger nuclei collide, the resulting system has a larger transverse expansion and baryon density and an increasing fraction of strange quarks.

Excitation Energy Deposition From Neutron Multiplicity Distributions for Reactions Induced with 30 AMeV ^{14}N, ^{20}Ne, ^{63}Cu and 55 AMeV ^{4}He

B. Hurst, J. Boger, T. Botting, L. Cooke, D. O'Kelly, R.P Schmitt, B.K. Srivastava, and W. Turmel

Nucl. Phys. A **636**, 3 (June 1998)

Inclusive neutron multiplicity distributions have been measured for 30 AMeV ^{14}N, ^{20}Ne, ^{63}Cu and 55 AMeV ^{4}He beams incident on targets ranging from ^{12}C to ^{238}U. For the lightest targets, the distributions decrease approximately exponentially with increasing multiplicity. The heavier targets display an additional Gaussian component peaked at higher multiplicities, which is attributable to central collisions. In the latter cases, the most probable multiplicities, M_n^*, have been extracted by fitting the data with a simple functional form. These multiplicities are compared to the predictions of the statistical model codes GEMINI and CASCADE using a massive transfer scenario to define the initial conditions. Reasonable agreement is obtained for systems with estimated excitation energies ≈100 MeV, but the calculations consistently over-predict the most probable multiplicities for more highly excited systems. Good agreement is observed between the experimental M_n^* values and the predictions of the code EUGENE. However, this code gives M_n^* values that are consistently lower than those predicted by other statistical model calculations. An alternative procedure is utilized to extract the amount of excitation energy of the composite system. In this approach, the input excitation energy in a standard model code is varied until the predicted M_n^* value matches the experimental value. The resulting excitation energies follow systematic trends with the estimated momentum transfer and the N/Z of the system. These patterns are also observed in reactions induced with other projectiles.

Astrophysical Implications of Non-resonant Break-up of ^{7}Li

H. Utsunomiya, Y. Tokimoto, K. Osada, T. Yamagata, M. Ohta, Y. Aoki, K. Hirota, K. Ieki, Y. Iwata, K. Katori, S. Hamada, Y.-W. Lui and R.P. Schmitt

J. Phys. G **24**, 1637 (August 1998)

Delayed nature associated with the quantum tunnelling effect was found for nonresonant break-up of ^{7}Li through the Gamow energy region. This delayed nature is discussed in the astrophysical context of the Coulomb dissociation method; post Coulomb acceleration and its effect on the energy dependence of the cross sections.

Isospin Physics in Heavy-ion Collisions at Intermediate Energies

B.A. Li, C.M. Ko, and W. Bauer

Int. J. Mod. Phys. Rev. E **7**, 147 (April 1998)

In nuclear collisions induced by stable or radioactive neutron-rich nuclei a transient state of nuclear matter with an appreciable isospin asymmetry and compression can be created. This offers the possibility to study the properties of nuclear matter in the region between the symmetric nuclear matter and the pure neutron matter. In this review, we discuss recent theoretical studies on the equation of state of such an isospin asymmetric nuclear matter and its relations to the properties of neutron stars and radioactive nuclei. Also, the chemical and mechanical instabilities as well as the liquid-gas phase transition in asymmetric nuclear matter are discussed. The in-medium nucleon-nucleon cross sections at different isospin states are reviewed as they affect significantly the dynamics of heavy ion collisions induced by radioactive beams. We then discuss an isospin-dependent transport model, which includes different mean-field potentials and cross sections for the proton and neutron, and its application to these reactions. Furthermore, we review the comparisons between theoretical predictions and available experimental data. In particular, we discuss the study of nuclear stopping in terms of isospin equilibration, the dependence of the nuclear collective flow and balance energy on the isospin-dependent nuclear equation of state and cross sections, the isospin dependence of total nuclear reaction cross sections, and the role of isospin in preequilibrium nucleon emissions and subthreshold pion production.

Seeing Phi Meson Through Dileptons in Heavy Ion Collisions

W.S. Chung, C.M. Ko, and G.Q. Li

Nucl. Phys. A **641**, 357 (1998)

Dilepton spectra from the decay of phi mesons produced in heavy-ion collisions at SIS/GSI energies (about 2 GeV/nucleon) are studied in the relativistic transport model. We include phi mesons produced from baryon-baryon, pion-baryon, and kaon-antikaon collisions. The cross sections for the first two processes are obtained from an one-boson-exchange model, while that for the last process is taken to be the Breit-Wigner form through the phi meson resonance. For dileptons with invariant mass near the phi meson peak, we also include contributions from neutron-proton bremsstrahlung, pion-pion annihilation, and the decay of rho and omega mesons produced in baryon-baryon and meson-baryon collisions. Effects due to medium modifications of the kaon and vector (rho, omega and phi) meson properties are investigated. We find that the kaon medium effects lead to a broadening of the dilepton spectrum as a result of the increase of phi meson decay width. Furthermore, the dropping of phi meson mass in nuclear medium leads to a shoulder structure in the dilepton spectrum besides the main peak at the bare phi meson mass. The experimental measurement of the dilepton spectra from heavy-ion collisions is expected to provide useful information about the phi meson properties in dense matter.

Probing the Softest Region of Nuclear Equation of State

B.A. Li and C.M. Ko

Phys. Lett. C **58**, R1382 (1998)

An attractive, energy-dependent mean-field potential for baryons is introduced in order to generate a soft region in the nuclear equation-of-state, as suggested by recent lattice QCD calculations of baryon free matter at finite temperature. Based on a hadronic transport model, we find that although this equation-of-state has negligible effects on the inclusive hadronic spectra, it leads to a minimum in the energy dependence of the transverse collective flow and a delayed expansion of the compressed matter. In particular, the transverse flow changes its direction as the colliding system passes through the softest region in the equation-of-state.

Low-Mass Dileptons and Dropping Rho Meson Mass

E.L. Bratkovskaya and C.M. Ko

Phys. Lett. **B445**, 265 (1999)

Using the transport model, we have studied dilepton production from heavy-ion collisions at Bevalac energies. It is found that the enhanced production of low-mass dileptons observed in the experiment by the DLS collaboration cannot be explained by the dropping of hadron masses, in particular the rho-meson mass, in dense matter.

Electromagnetic Probe of Dense Matter in Heavy Ion Collisions
G.Q. Li, G.E. Brown, and C.M. Ko
Nucl. Phys. **A630**, 563c (1998)

Dilepton and photon production in heavy-ion collisions at SPS energies is studied in the relativistic transport model that incorporates self-consistently the change of hadron masses in dense matter. It is found that the dilepton spectra in proton-nucleus reactions can be well described by the conventional mechanisms of Dalitz decay, primary vector meson decay, decay of charmed mesons, and the initial Drell-Yan processes. However, to provide a quantitative explanation of the observed dilepton spectra in central heavy-ion collisions requires contributions other than these direct decays and also various medium effects. Introducing a decrease of vector meson masses in hot dense medium, we find that the low-mass dilepton enhancement can be satisfactorily explained. Furthermore, to explain the intermediate-mass dilepton enhancementin heavy-ion collisions, secondary processes such as dilepton production from pion and a_1 interaction are found to be very important. Finally, the single photon spectra in our calculations with either free or in-medium meson masses do not exceed the upper limit measured by the WA80 Collaboration.

Excitation Functions of Stopping Power and Flow in Relativistic Heavy Ion Collisions
B.A. Li and C.M. Ko
Nucl. Phys. A630, 556c (1998)

Using a relativistic transport (ART) model, we study the stopping power, the formation of superdense hadronic matter as well as the strength of transverse and radial flow in central Au+Au collisions at beam momentum from 2 to 12 GeV/c per nucleon. We find that complete stopping is achieved in the whole beam momentum range. In particular, the proton rapidity distribution scaled by the beam rapidity is independent of the beam momentum, and this is in agreement with the experimental findings. Also, a large volume of superdense hadronic matter with a local energy density exceeding that expected for the transition of a hadronic matter to the quark-gluon plasma is formed in collisions at beam momenta greater than 8 GeV/c per nucleon. Furthermore, it is found that the transverse flow in these collisions is sensitive to the nuclear equation of state and decreases with increasing beam momentum. On the other hand, the radial flow is insensitive to the equation of state, and its strength increases with beam momentum.

Charmonium Production From the Hadronic Phase
C.M. Ko, X.N. Wang, B. Zhang, and X.F. Zhang
Phys. Lett. **B444**, 237-244 (1998)

Charmonium production from D meson annihilation in the hadron gas formed in ultra-relativistic heavy-ion collisions is studied. With initial conditions taken from the HIJING parton model, we have estimated the number of J/ψ produced from an expanding hadron gas, using the J/ψ absorption and production cross sections obtained from either an effective Lagrangian or the quark-exchange model. We find that J/ψ production is negligible in heavy-ion collisions at the Relativistic Heavy Ion Collider (RHIC) but may be important at the Large Hadron Collider (LHC), where more charm mesons are produced. Similar results are obtained for ψ' production from the hadron gas at RHIC and LHC.

Antikaon Production and Medium Effects in Heavy Ion Collisions at AGS
G. Song, B.A. Li, and C.M. Ko
Nucl. Phys. **A646**, 481 (1999)

Antikaon production in heavy ion collisions at energies available from the Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory is studied in a relativistic transport (ART) model. We include contributions from the baryon-baryon, meson-baryon, and meson-meson interactions. The final-state interaction of antikaons via both absorption and elastic scattering by nucleons and pions are also considered. To compare with presently available or future experimental data, we have calculated the antikaon rapidity and transverse momentum distributions as well as its collective flow. Medium effects on these observables due to mean field potentials have also been investigated. It is found that both the ratio of antikaon transverse momentum spectrum to that of kaon and their transverse flow are most sensitive to the in-medium properties of kaons and antikaons.

Properties of Hadrons in the Nuclear Medium

C.M. Ko, V. Koch, and G.Q. Li

Proc. of 5th Intl. Workshop on Relativistic Aspects of Nuclear Physics, ed. by T. Kodama, p 167 (1999)

This talk is devoted to the discussion of hadron properties in the nuclear medium and its relation to the partial restoration of chiral symmetry. In particular, we discuss medium effects on the Goldstone bosons (pion, kaon and eta), the vector mesons (rho, omega and phi), and the nucleon. Also, for each proposed in-medium effect the experimental consequence and results are surveyed.

Phi Meson Production in Hot Dense Matter

W.S. Chung, C.M. Ko, and G.Q. Li

XXXVI International Winter Meeting on Nuclear Dynamics, edited by I. Iori, 1-16 (1998)

Phi meson production from nuclear reactions are described. In particular, phi meson production from pion-baryon and baryon-baryon interactions is discussed in the framework of a boson-exchange model. For phi meson production from heavy ion collisions, results from the relativistic transport model using the cross sections predicted from the above model are reviewed. We will also discuss medium effects on phi meson and kaon masses as well as their effects on phi meson production from heavy ion collisions.

Liquid Gas Phase Transition in Nuclei

S. Shlomo, J.N. De, S.K. Samaddar and A. Kolomiets

Proc. of DAE Nuclear Physics Symposium, Bangalore University, India, December 26-30, 1997, ed. V.M. Datar and A.B. Santra, p. 225 (1998)

In recent experiments the temperature T of the disassembling nucleus was extracted from ratios of the yields of emitted fragments using the method of Albergo et al., deduced by assuming thermal and chemical equilibrium of the disassembling nucleus. The dependence of excitation energy on T was found to show irregularities, interpreted as a possible signal to liquid gas phase transition. Considering this issue we have: (1) Modified the Albergo method: (i) Assuming thermal equilibrium of the disassembling nucleus and taking into account the effect of the coulomb interaction we showed that the assumption of chemical equilibrium is not necessary. (ii) Developed a model to calculate the post emission decay of the excited fragments and shown, using the model, that the temperature extracted from the yields of various fragments is about the same (T=4 MeV). (iii) Demonstrated the important effect of flow on the value extracted for the free nucleon density of the disassembling hot nucleus. (2) Carried out Thomas-Fermi calculations of the caloric curve for finite nuclei, using a momentum and density-dependent finite range effective interaction. Without radial collective flow, the caloric curve indicates a smooth liquid-gas phase transition whereas with flow, the transition may be very sharp.

The $4\hbar\omega$ Isoscalar Monopole Giant Resonance in ^{208}Pb and Resonance Trapping

S.E. Muraviev, I. Rotter, S. Shlomo and M.H. Urin

Phys. Rev. C **59**, 2040

In the framework of the random phase approximation in the continuum we calculate the strength function of the $4\hbar\omega$ isoscalar monopole giant resonance in ^{208}Pb. The one-particle continuum plays an important role in the formation of the structure of the strength function. Most interesting is the appearance of some narrow resonances at large excitation energy. We discuss the results obtained from the point of view of resonance trapping which is known to appear due to the strong coupling of the resonance states via the continuum. Further, we discuss the possibility of studying experimentally the structure of the giant resonance considered in this paper.

Liquid-gas Phase Transition in Finite Nuclei
J.N. De, S.K. Samaddar and S. Shlomo
Nucl. Phys. A **630**, 192c (1998)

In a finite temperature Thomas-Fermi framework, we calculate density distributions of hot nuclei enclosed in a freeze-out volume of few times the normal nuclear volume and then construct the caloric curve, with and without inclusion of radial collective flow. In both cases, the calculated specific heats C_v show a peaked structure signaling a liquid-gas phase transition. Without flow, the caloric curve indicates a continuous phase transition whereas with inclusion of flow, the transition is very sharp. In the latter case, the nucleus undergoes a shape change to a bubble from a diffuse sphere at the transition temperature.

Free Surface Response in a Finite Fermi System
V.I Abrosimov, O.I. Davidovskaja, V.M. Kolomietz and S. Shlomo
Phys. Rev. C **57**, 2342 (1998)

Collective vibrations in a finite Fermi system are studied within a phase space approach which is based on the Landau-Vlasov kinetic equation. The linear response theory is used and the semiclassical internal and collective response functions are evaluated with a continuous single particle angular momentum l. We focus on the strength function and fragmentation width of the vibrations. We determine the contributions to the collective strength function which are associated with different values of relevant single particle angular momentum. Applications to the nuclear isoscalar vibrations with multipolarities $L = 0,2$ and 3 are presented.

Shell Effects on Nuclear Incompressibility
A. Kolomiets, V.M. Kolomietz and S. Shlomo
Phys. Rev. C **57**, R2808 (1998)

We present an analytical estimate for the upper limit of the shell correction, δK_A, to the compressibility coefficient, K_A, of finite nuclei. A simple model with a spherical harmonic oscillator potential was adopted and the self-consistency condition was taken into account. We find that the magnitude of the shell correction term, δK_A, is comparable to that associated with the current experimental uncertainties in determining the energy of the isoscalar giant monopole resonance.

Collisional Relaxation of Collective Motion in a Finite Fermi Liquid
V.M. Kolomietz, S.V. Lukyanov, V.A. Plujko and S. Shlomo
Phys. Rev. C **58**, 198 (1998)

Finite size effects in the equilibrium phase space density distribution function are taken into account for the calculations of the relaxation of collective motion in finite nuclei. The memory effects in the collision integral, and the diffusivity and the quantum oscillations of the equilibrium distribution function in momentum space are considered. It is shown that a smooth diffuse (Fermi type) equilibrium distribution function leads to a spurious contribution to the relaxation time. The residual quantum oscillations of the equilibrium distribution function eliminates the spurious contribution. It ensures the disappearance of the gain- and loss-terms in the collision integral in the ground state of the system and strongly reduces the internal collisional width of the isoscalar giant quadrupole resonances.

Level Density Parameter in a Refined Thomas-Fermi Theory
J.N. De, S. Shlomo, and S.K. Samaddar
Phys. Rev. C **57**, 1398 (March 1998)

We present calculations for the nuclear level density parameter over a wide range of nuclear mass and temperature. The hot nucleus is modeled in a refined Thomas-Fermi approximation that allows the confinement of the hot evaporating metastable system through an external pressure. The position and temperature dependence of the momentum and frequency dependent effective masses are taken into account. The agreement with experimental data, particularly its temperature dependence, is reasonably reproduced.

Magnetic Dipole Moments of Odd-Odd N=Z Nuclei

Y. Ronen and S. Shlomo

Phys. Rev. C **58**, 884 (1998)

The experimental data of the magnetic dipole moments of low-lying states in odd-odd $N=Z$ nuclei, which has increased recently by a factor of 2, are revisited within the simple shell model, taking the wave functions to be of the from $\psi_{core}(J = 0, T = 0)\psi_{np}(J, T = 0)$. Good agreement with the updated experimental data is obtained within the jj-coupling scheme, $\psi_{np}[(nlj)^2 J, T = 0)]$, using the Schmidt values for the g-factor and also by using effective g-factor deduced from nearby odd-A nuclei. We have also carried out a calculation of μ within the LS-coupling scheme $\psi_{np}[(1/2)^2 S(nl)^2 L, J, (T = 0)]$ and also obtained good agreement with data. The success of these simple models in reproducing the experimental data is discussed.

Large-model-space Calculation of the Nuclear Level Density Parameter at Finite Temperature

B.K. Agrawal and S.K. Samaddar J. N. De, and S. Shlomo

Phys. Rev. C **58**, 3004

We calculate the nuclear level density parameter a for a broad range of temperature-, ($0.6 \leq Ti \leq 6$ MeV) using a microscopic model which includes important ingredients like the thermal and quantal fluctuations of nuclear shapes, continuum corrections, and Coulomb interaction. Numerical calculations have been performed for ^{40}Ca and ^{56}Fe in a large model space. We find that at low temperatures, shell effects are larger for ^{40}Ca and effects of quantal fluctuations are larger for ^{56}Fe. As temperature increases, these effects tend to disappear and continuum corrections become important for T>3 MeV.

Two-Body Contribution to the Relaxation of Collective Excitations in Cold Finite Fermi Systems

V.M. Kolomietz, S.V. Lukyanov, V.A. Plujko, and S. Shlomo

Phys. Atom. Nucl. **62**, 86 (1999)

The two-body contribution to the relaxation of collective excitations in finite Fermi systems has been investigated. Special attention has been given to exploring the effect that the special features of equilibrium distribution functions in such systems may exert on this contribution. The diffuseness and oscillations of the equilibrium distribution function in momentum space have been taken into account together with retardation effects in a collision integral. A potential of the Woods-Saxon form has been used for an equilibrium mean field. It has been shown that oscillations of the equilibrium distribution function lead to a compensation of particle flows in an equilibrium system and to a significant reduction of the relaxation rate because of the diffuseness of the equilibrium distribution function. As a result the widths of giant quadrupole resonances take values that are close to those that are obtained by taking into account retardation effects in the collision integral and by using the distribution function in the Thomas-Fermi approximation.

L-and M-Electron Populations of Fast Xenon Ions Traveling in Gases

V. Horvat, R.L. Watson, and J.M. Blackadar

Phys. Rev. A **57**, 3635 (1998)

Spectra of L x rays emitted by 5.2- to 14.4-MeV/u Xe ions traveling in gaseous targets of He, Ne, and Ar have been measured with a curved crystal spectrometer. Detailed spectral analysis provided estimates of the average projectile charges and the average L- and M-electron populations *inside* the gases. In comparisons of the present results for gases with those obtained previously for solids, it was found that Xe ions emitting L x rays in solids have, on average, many more L vacancies than those that emit L x rays in gases. Average charges deduced for Xe ions traveling in Ar gas were 2.3 units lower than the average charges of Xe ions traveling in solid KCl.