

Splitting of the Giant Monopole and Quadrupole Resonances in ^{154}Sm

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

Phys. Rev. C **60**, 067302 (November 1999)

Strength functions for the isoscalar giant monopole and quadrupole resonances in ^{154}Sm have been measured with inelastic scattering of 240 MeV α particles at small angles. The $E0$ strength distribution containing $(104^{+15}_{-20})\%$ of the energy-weighted sum rule (EWSR) is consistent with two peaks at $E_x=12.1\pm 0.4$ MeV and 15.5 ± 0.3 MeV containing $(36\pm 10)\%$ and $(68\pm 9)\%$ of the EWSR and the $E2$ strength distribution containing $(103^{+18}_{-20})\%$ of the EWSR is consistent with three peaks at $E_x=11.3\pm 0.2$ MeV, 14.5 ± 0.5 MeV, and 17.5 ± 0.5 MeV containing $(44\pm 7)\%$, $(44\pm 8)\%$ and $(15\pm 8)\%$, respectively, of the EWSR.

Giant Resonances in ^{24}Mg

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

Phys. Rev. C **60**, 014304 (July 1999)

The giant resonance region in ^{24}Mg was studied with inelastic scattering of 240 MeV α particles at small angles including 0° . The giant resonance peak was found to extend up to $E_x = 41$ MeV. Isoscalar $E0$, $E1$ and $E2$ strength corresponding to $72\pm 10\%$, $81^{+26}_{-14}\%$, and $72\pm 10\%$ of the respective energy weighted sum rules was identified in the peak with centroids of 21.0 ± 0.6 MeV, 18.8 ± 1.7 MeV and 16.9 ± 0.6 MeV and RMS widths of 7.3 ± 1.2 , 6.7 ± 1.0 and 3.4 ± 0.5 MeV respectively. Elastic scattering was measured from $\theta_{\text{cm}}=3^\circ$ to 33° and density dependent folding model parameters obtained. Inelastic scattering to states at 1.369, 4.122, 4.238, 6.010, 6.432, 7.349, 7.555, 7.616 and 8.358 MeV was measured and B(EL) values obtained.

Compression Mode Giant Resonances

Dave H. Youngblood, Henry L. Clark and Yiu-Wing Lui

RIKEN Review **23**, 159 (July 1999)

Compression mode giant resonances have been measured in many nuclei from ^{12}C to ^{208}Pb with inelastic scattering of 240 MeV α particles at small angles. Isoscalar monopole distributions have been extracted for 17 nuclei and isoscalar dipole distributions extracted for 11 nuclei. The $E0$ strength distributions in ^{90}Zr , ^{116}Sn , ^{144}Sm and ^{208}Pb have been measured precisely and in ^{116}Sn , ^{144}Sm and ^{208}Pb were found to be concentrated in symmetric peaks with the centroid of the strength distributions located at $E_x = 16.00 \pm 0.07$, 15.31 ± 0.11 , and 14.24 ± 0.11 MeV respectively. In ^{90}Zr the $E0$ distribution was found to have a high energy tail extending up to $E_x = 25$ MeV. The resulting centroid of the $E0$ strength for ^{90}Zr is $E_x = 17.89 \pm 0.20$ MeV. These results and that for ^{40}Ca lead to $K_{\text{nm}} = 231 \pm 5$ MeV by comparing to microscopic calculations using the Gogny interaction.

Isoscalar Giant Dipole Resonance in ^{90}Zr , ^{116}Sn , ^{144}Sm and ^{208}Pb Excited by 240 MeV α Particle Scattering

H.L. Clark, Y.-W. Lui, D.H. Youngblood, K. Bachtr, U. Garg,

M.N. Harakeh and N. Kalantar-Nayestanaki

Nucl. Phys **A649**, 57c (March 1999)

The giant resonance regions of ^{90}Zr , ^{116}Sn , ^{144}Sm and ^{208}Pb were investigated using 240 MeV α particle scattering at small angles including 0° . $E1$ strengths corresponding to $91\pm 11\%$, $89\pm 10\%$, $105\pm 12\%$ and $95\pm 13\%$ of the isoscalar $E1$ energy-weighted sum rule were identified between $18 \leq E_x \leq 31$ MeV, $16 \leq E_x \leq 30$ MeV, $15 \leq E_x \leq 27$ MeV and $15 \leq E_x \leq 25$ MeV with centroid energies of 24.8 ± 0.4 MeV, 22.5 ± 0.3 MeV, 21.6 ± 0.3 MeV and 19.3 ± 0.3 MeV and rms widths of 3.2 ± 0.2 MeV, 3.5 ± 0.2 MeV, 3.2 ± 0.2 MeV and 2.5 ± 0.2 MeV for ^{90}Zr , ^{116}Sn , ^{144}Sm and ^{208}Pb , respectively. Parameters obtained for the isoscalar giant monopole resonance, isoscalar giant quadrupole resonance and high energy octupole resonance are in agreement with accepted values.

Compressibility of Nuclear Matter from the Giant Monopole Resonance

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

Nucl. Phys. A649, 49c (March 1999)

The $E0$ strength distributions in ^{90}Zr , ^{116}Sn , ^{144}Sm and ^{208}Pb have been measured with inelastic scattering of 240 MeV α particles at small angles. The $E0$ strengths in ^{116}Sn , ^{144}Sm and ^{208}Pb were found to be concentrated in symmetric peaks and the centroid of the strength distributions were located at $E_x = 16.00 \pm 0.07$, 15.31 ± 1.11 , and 14.24 ± 1.11 MeV respectively. In ^{90}Zr the $E0$ distribution was found to have a high energy tail extending up to $E_x = 25$ MeV. The resulting centroid of the $E0$ strength for ^{90}Zr is $E_x = 17.89 \pm 2.0$ MeV. These results and the previously reported result for ^{40}Ca lead to $K_{\infty} = 231 \pm 5$ MeV by comparing to microscopic calculations.

Optical Model Potentials Involving Loosely Bound p-shell Nuclei Around 10 MeV/A

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 61, 024612 (February 2000)

We present the results of a search for optical model potentials for use in the description of elastic scattering and transfer reactions involving stable and radioactive p-shell nuclei. This was done in connection with our program to use transfer reactions to obtain data for nuclear astrophysics, in particular for the determination of the astrophysical S_{17} factor for $^7\text{Be}(p,\gamma)^8\text{B}$ using two ($^7\text{Be},^8\text{B}$) proton transfer reactions. Elastic scattering was measured using ^7Li , ^{10}B , ^{13}C and ^{14}N projectiles on ^9Be and ^{13}C targets at or about $E/A = 10$ MeV/nucleon. Woods-Saxon type optical model potentials were extracted and are compared with potentials obtained from a microscopic double folding model. Several nucleon-nucleon effective interactions were used: M3Y with zero range and finite range exchange term, two density dependent versions of M3Y and the effective interaction of Jeukenne, Lejeune and Mahaux. We find that the latter one, which has an independent imaginary part, gives the best description. Furthermore, we find the renormalization constant for the real part of the folding potential to be nearly independent of the projectile-target combination at this energy and that no renormalization is needed for the imaginary part. From this analysis, we are able to eliminate an ambiguity in optical model parameters and thus better determine the Asymptotic Normalization Coefficient for $^{10}\text{B}-^9\text{B}+p$. Finally we use these results to find optical model potentials for unstable nuclei with emphasis on the reliability of the description they provide for peripheral proton transfer reactions. We discuss the uncertainty introduced by the procedure in the prediction of the DWBA cross sections for the ($^7\text{Be},^8\text{B}$) reactions used in extracting the astrophysical factor $S_{17}(0)$.

A Precision Measurement of Muon Decay

M.A. Quraan, P. Amaudruz, W. Andersson, M. Comyn, Yu. Davydov, P. Depommier, J. Doornbos, W. Faszer, 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, T. Mathie, J.R. Musser, P. Nord, A. Olin, D. Ottewell, R. Openshaw,

L. Piilonen, T. Porcelli, J.-M. Poutissou, R. Poutissou, N.L. Rodning, 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, D. Wright

Nucl. Phys. A663 & 664, 903c (January 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 $P_{\mu e}$, ρ and δ 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 .

Nuclear Dependence of Drell-Yan and J/ψ Production in FNAL E866

R.E. Tribble, 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, S.B. Kaufman, D.M. Kaplan, D.D. Koetke, W.M. Lee, M.J. Leitch, P.L. McGaughey, J.M. Moss, B.A. Mueller, V. Papavassiliou, J.C. Peng, G. Petitt, P.E. Reimer, M.E. Sadler, P.W. Stankus, W.E. Sondheim, R.S. Towell, M.A. Vasiliev, J.C. Webb, J.L. Willis, and G.R. Young (FNAL E866/NuSea Collaboration)
Nucl. Phys. **A663 & 664**, 761c (January 2000)

Fermilab E866 has measured the target-mass dependence of Drell-Yan and J/ψ dimuon production induced by an 800 GeV proton beam on targets of Be, Fe and W. Clear evidence of nuclear shadowing is observed in the Drell-Yan cross section ratios per nucleon at small x_2 . The x_1 dependence of the cross section ratios provides a determination of the energy loss of ultra-relativistic quarks as they pass through cold nuclei. Preliminary results for J/ψ yields show maximum cross section ratios that are slightly less than 1 at an x_F value near 0.1. The yield on heavy targets is much more strongly suppressed relative to light targets at larger values of x_F .

Light Antiquark Flavor Asymmetry in the Nucleon Sea

C.A. Gagliardi, T.C. Awes, M.E. Beddo, M.L. Brooks, C.N. Brown, J.D. Bush, T.A. Carey, T.H. Chang, W.E. Cooper, G.T. Garvey, D.F. Geesaman, E.A. Hawker, X.C. He, L.D. Isenhower, D.M. Kaplan, S.B. Kaufman, P.L. 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, V. Papavassiliou, B.K. Park, J.C. Peng, G. Petitt, P.E. Reimer, M.E. Sadler, J. Seldon, W.E. Sondheim, P.W. Stankus, 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 (FNAL E866/NuSea Collaboration)
Nucl. Phys. **A663 & 664**, 284c (January 2000)

Fermilab E866 has performed a precise measurement of the ratio of Drell-Yan yields in 800 GeV/c pp and pd collisions, leading to determinations of d/\bar{u} and $\bar{d}-\bar{u}$ in the proton as functions of x . The results provide valuable information regarding the origins of the d/\bar{u} asymmetry and the antiquark sea in the nucleon.

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, and G.R. Young (FNAL E866/NuSea Collaboration)
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 $x_F > 0.6$.

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

G.V. Avakov, L.D. Blokhintsev, A.M. Mukhamedzhanov, and E.N. Voronina
"Contemporary Problems of Nuclear and Particle Physics, R.A. Eramzhyan Memorial". Russian Academy of Sciences, Institute of Nuclear Research, Moscow 1999, ed. V.A. Matveev. p. 146 (2000)

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 about 1%.

\bar{d}/\bar{u} Asymmetry in the Nucleon Sea

C.A. Gagliardi, T.C. Awes, M.E. Beddo, M.L. Brooks, C.N. Brown, J.D. Bush, T.A. Carey, T.H. Chang, W.E. Cooper, 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, M.A. Vasiliev, Y.C. Wang, Z.F. Wang, J.C. Webb, J.L. Willis, D.K. Wise, G.R. Young (FNAL E866/NuSea Collaboration)

Proc. of the International Nuclear Physics Conference '98 (INPC98) Paris, France
Nucl. Phys. A654, 487c (1999)

Fermilab E866 has performed a precise measurement of the ratio of Drell-Yan yields from an 800 GeV/c proton beam incident on hydrogen and deuterium targets, leading to the first determinations of \bar{d}/\bar{u} and $\bar{d}-\bar{u}$ in the proton as functions of x . The results show that $\bar{d} > \bar{u}$ over a broad range of x and provide valuable information regarding the origins of the \bar{d}/\bar{u} asymmetry and the antiquark sea in the nucleon.

Nuclear Dependence of J/ψ and ψ' Production

W.M. Lee, T.C. Awes, M.L. Brooks, 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, D.D. Koetke, D.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, 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, G.R. Young (FNAL E866/NuSea Collaboration)

Proc. of the International Nuclear Physics Conference '98 (INPC98) Paris, France
Nucl. Phys. A654, 623c (1999)

FNAL E866/NuSea has made a number of measurements of J/ψ and ψ' production by 800 GeV protons on fixed targets of Be, Fe and W. Preliminary results are presented and discussed in the context of nuclear effects such as energy loss and multiple scattering of the partons, absorption of the produced $c\bar{c}$ pairs, and shadowing. Production mechanisms involving color-singlet or color-octet states for the $c\bar{c}$ pair which eventually forms a J/ψ or ψ' have implications on the strength of absorption in the nucleus. These nuclear dependence studies are critical in furthering our understanding of these processes towards future measurements at RHIC and the LHC, where J/ψ suppression is predicted to be an important signature of the creation of quark-gluon plasma in heavy-ion collisions.

Proton Scattering from the Unstable Neutron-Rich Nucleus ^{43}Ar

F. Marechal, T. Suomijarvi, Y. Blumenfeld, A. Azhari, D. Bazin, J.A. Brown, P.D. Cottle, M. Fauerbach, T. Galsmacher, S.E. Hirzebruch, J.K. Jewell, J.H. Kelley, K.W. Kemper, P.F. Mantica, D.J. Morrissey, L.A. Riley, J.A. Scarpaci, H. Scheit, and M. Steiner
Phys. Rev. C 60, 064623 (December 1999)

The neutron-rich argon isotope ^{43}Ar has been studied by quasielastic and inelastic proton scattering performed in inverse kinematics. The measured inelastic angular distribution for the second excited state is in good agreement with an $L = 2$ transition. Assuming this transition to be E2, yields a β_2 value for this state of 0.25 ± 0.03 when compared with distorted-wave Born approximation calculations. This value is comparable to the one reported for the stable isotope ^{40}Ar . Moreover it is similar to those measured by Coulomb excitation for the neighboring even-even isotopes ^{42}Ar and ^{44}Ar indicating that the structure of the argon isotopes is stable as a function of neutron number.

J/ψ and ψ' Suppression in p-A Collisions at 800 GeV/c

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, S.B. Kaufman, D.M. Kaplan, 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, P.W. Stankus, W.E. Sondheim, R.S. Towell, R.E. Tribble,

(Abstract not available.)

The $^{14}\text{N}(^7\text{Be}, ^8\text{B})^{13}\text{C}$ Reaction and the $^7\text{Be}(p, \gamma)^8\text{B}$ S-Factor

A. Azhari, V. Burjan, F. Carstoiu, C.A. Gagliardi, V. Kroha,
A.M. Mukhamedzhanov, X. Tang, L. Trache and R.E. Tribble
Phys. Rev. C **60**, 055803 (November 1999)

The $^{14}\text{N}(^7\text{Be}, ^8\text{B})^{13}\text{C}$ reaction was studied using an 85 MeV ^7Be radioactive beam. The asymptotic normalization coefficients for the virtual transitions $^7\text{Be}+p \rightarrow ^8\text{B}$ were determined from the measured cross section. These coefficients specify the amplitude of the tail of the ^8B overlap function in the $^7\text{Be}+p$ channel, and were used to calculate the astrophysical S factor for the direct capture reaction $^7\text{Be}(p, \gamma)^8\text{B}$ at solar energies $S_{17}(0)$. We find that $S_{17}(0) = 16.6 \pm 1.9$ eV b.

Proton Scattering by Short Lived Sulfur Isotopes

F. Marechal, T. Suomijarvi, Y. Blumenfeld, A. Azhari, E. Bauge, D. Bazin, J.A. Brown, P.D. Cottle,
J.P. Delaroche, M. Fauerbach, M. Girod, T. Galsmacher, S.E. Hirzebruch, J.K. Jewell, J.H. Kelley,
K.W. Kemper, P.F. Mantica, D.J. Morrissey, L.A. Riley, J.A. Scarpaci, H. Scheit, and M. Steiner
Phys. Rev. C **60**, 034615 (September 1999)

Elastic and inelastic proton scattering has been measured in inverse kinematics on the unstable nucleus ^{40}S . A phenomenological distorted wave Born approximation analysis yields a quadrupole deformation parameter $\beta_2 = 0.35 \pm 0.05$ for the 2^+ state. Consistent phenomenological and microscopic proton scattering analyses have been applied to all even-even sulfur isotopes from $A = 32$ to $A = 40$. The second analysis used microscopic collective model densities and a modified Jeukenne-Lejeune-Mahaux nucleon-nucleon effective interaction. This microscopic analysis suggests the presence of a neutron skin in the heavy sulfur isotopes. The analysis is consistent with normalization values for λ_v and λ_w of 0.95 for both the real and imaginary parts of the Jeukenne-Lejeune-Mahaux potential.

Astrophysical S -factor for $^9\text{Be}(p, \gamma)^{10}\text{B}$

A. Sattarov, A.M. Mukhamedzhanov, A. Azhari, C.A. Gagliardi, L. Trache, R.E. Tribble
Phys. Rev. C. **60**, 035801 (September 1999)

The $^9\text{Be}(p, \gamma)^{10}\text{B}$ reaction plays an important role in primordial and stellar nucleosynthesis of light elements in the p -shell, but the energy-dependence of $S(E)$ has not been well-understood. We re-analyze the existing $^9\text{Be}(p, \gamma)^{10}\text{B}$ experimental data within the framework of the R -matrix method. The direct capture part of the S -factor is calculated using the experimentally measured asymptotic normalization coefficients for $^{10}\text{B} \rightarrow ^9\text{Be} + p$. The fitted parameters of the low-lying ^{10}B resonances are also required to be consistent with previous measurements of $^6\text{Li}(\alpha, \gamma)^{10}\text{B}$. A good simultaneous fit to both radiative capture reactions is found, in contrast to previous analyses. These results demonstrate that experimentally measured asymptotic normalization coefficients, coupled to the R -matrix method, can provide a reasonable determination of direct radiative capture rates, even when the captured proton is tightly bound in the final nucleus.

Parton Energy Loss Limits and Shadowing in Drell-Yan Dimuon Production

M.A. Vasiliev, 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, W.M. Lee, M.J. Leitch, P.L. McGaughey, J.M. Moss, B.A. Mueller, V. Papavassiliou,
J.C. Peng, G. Petit, P.E. Reimer, M.E. Sadler, W.E. Sondheim, P.W. Stankus, R.S. Towell, R.E.
Tribble, J.C. Webb, J.L. Willis and G.R. Young (FNAL E866/NuSea Collaborators)
Phys. Rev. Lett. **83**, 2304 (September 1999)

A precise measurement of the ratios of the Drell-Yan cross section per nucleon for an 800 GeV/c proton beam incident on Be, Fe, and W targets is reported. The behavior of the Drell-Yan ratios at small target-parton momentum fraction is well described by an existing fit to the shadowing observed in deep-inelastic scattering. The cross-section ratios as a function of the incident-parton momentum fraction set tight limits on the energy loss of quarks passing through a cold nucleus.

New Limit for the Family-Number Non-conserving Decay $\mu^+ \rightarrow e^+ \gamma$

M.L. Brooks, Y.K. Chen, M.D. Cooper, P.S. Cooper, M. Dzemidzic, A. Empl, C.A. Gagliardi, G.E. Hogan, E.B. Hughes, E.V. Hungerford III, C.C.H. Jui, J.E. Knott, D.D. Koetke, M.A. Kroupa, K.A. Lan, R. Manweiler, B.W. Mayes II, R.E. Mischke, L.E. Piilonen, T.D.S. Stanislaus, K.M. Stantz, J.J. Szymanski, R.E. Tribble, X.L. Tu, L.A. Van Ausdeln, W.H. von Witsch, S.C. Wright and K.O.H. Ziock (MEGA Collaboration)
Phys. Rev. Lett. **83**, 1521 (August 1999)

An experiment has been performed to search for the muon- and electron-number nonconserving decay $\mu^+ \rightarrow e^+ \gamma$. The upper limit for the branching ratio is found to be $\Gamma(\mu^+ \rightarrow e^+ \gamma) / \Gamma(\mu^+ \rightarrow e^+ \nu \bar{\nu}) < 1.2 \times 10^{-11}$ with 90% confidence.

Three-body Approach to Proton-hydrogen Charge Exchange and Elastic Scattering

E.O. Alt, A.S. Kadyrov and A.M. Mukhamedzhanov
Phys. Rev. A **60**, 314 (July 1999)

The impact-parameter Faddeev approach to atomic three-body collisions which has been developed for, and successfully applied to, ion-atom scattering processes, has now been developed further by including, instead of the Coulomb potentials, the full two-particle off-shell Coulomb T matrices in all "triangle" contributions to the effective potentials. Results of calculations of proton-hydrogen collisions with only the ground states of the hydrogen retained in both the direct and the rearrangement channels are presented. Total and differential electron transfer, as well as differential elastic scattering cross sections, are obtained simultaneously in very good agreement with experiment, over a wide range of (nonrelativistic) incident energies.

Connection Between Asymptotic Normalization Coefficients, Subthreshold Bound States and Resonances

A.M. Mukhamedzhanov and R.E. Tribble
Phys. Rev. C **59**, 3418 (June 1999)

We present here useful relations showing the connection between the asymptotic normalization coefficient (ANC) and the fitting parameters in K- and R-matrix theory methods which are often used when analyzing low energy experimental data. It is shown that the ANC of a subthreshold bound state defines the normalization of both direct radiative capture leading to this state and resonance capture in which the state behaves like a subthreshold resonance. A determination of the appropriate ANC(s) thus offers an alternative method for finding the strength of these types of capture reactions, both of which are important in nuclear astrophysics.

The $^{10}\text{B}(^7\text{Be}, ^8\text{B})^9\text{Be}$ Reaction and the $^7\text{Be}(p, \gamma)^8\text{B}$ S Factor

A. Azhari, V. Burjan, F. Carstoiu, H. Dejbakhsh, C.A. Gagliardi, V. Kroha, A.M. Mukhamedzhanov, L. Trache, R.E. Tribble
Phys. Rev. Lett. **82**, 3960 (May 1999)

The $^{10}\text{B}(^7\text{Be}, ^8\text{B})^9\text{Be}$ reaction has been studied with an 84 MeV ^7Be radioactive beam. The measured cross section determines the asymptotic normalization coefficients for the virtual transitions $^7\text{Be} + p \rightarrow ^8\text{B}$. These coefficients specify the amplitude of the tail of the ^8B wave function in the two-body channel $^7\text{Be} + p$, and may be used to calculate the S factor for the direct capture reaction $^7\text{Be}(p, \gamma)^8\text{B}$ at solar energies, $S_{17}(0)$. We find that $S_{17}(0) = 17.8 \pm 2.8$ eVb.

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,

The $^{16}\text{O}(^3\text{He},d)^{17}\text{F}$ 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 $^{17}\text{F} \rightarrow ^{16}\text{O} + p$ and allow us to calculate the S factors for $^{16}\text{O}(p,\gamma)^{17}\text{F}$ 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.

Astrophysical S-factors from Asymptotic Normalization Coefficients

R.E. Tribble, A. Azhari, H.L. Clark, C.A. Gagliardi, Y.-W. Lui, A.M. Mukhamedzhanov, A. Sattarov, X. Tang, L. Trache, V. Burjan, J. Cejpek, V. Kroha, Š. Piskoř, J. Vincour, F. Cârstoiu
Pramana J. of Phys. **53**, 585 (1999)

S-factors for direct capture reactions can be found at astrophysical energies from asymptotic normalization coefficients which provide the normalization of the tail of the overlap function. For example the overlap for $^8\text{B} \rightarrow ^7\text{Be} + p$ defines the S-factor for $^7\text{Be}(p,\gamma)^8\text{B}$. Peripheral transfer reactions offer a technique to determine these asymptotic normalization coefficients. As a test of the technique, the $^{16}\text{O}(^3\text{He},d)^{17}\text{F}$ 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 $^{16}\text{O}(p,\gamma)^{17}\text{F}$ calculated from these $^{17}\text{F} \rightarrow ^{16}\text{O} + p$ asymptotic normalization coefficients are found to be in very good agreement with recent measurements. Following the same technique, 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 asymptotic normalization coefficient for $^7\text{Be}(p,\gamma)^8\text{B}$. This result provides an indirect determination of $S_{17}(0)$.

Measurements of the Light Quark Flavor Asymmetry in the Nucleon Sea

J.C. Peng, 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, 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. MeGaughey, J.M. Moss, B.A. Mueller, P.M. Nord, B.K. Park, V. Papavassiliou, G. Petitt, 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, G.R. Young
(FNAL E866/NuSea Collaboration)

Proc. of the 29th Intl. Conference on High Energy Physics (ICHEP '98), Vancouver, BC (1998)
High Energy Physics **1**, 854

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 $0.02 \leq x \leq 0.345$. 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 the E866 results and models employing virtual mesons indicates these non-perturbative processes play an important role in the origin of the \bar{d} , \bar{u} asymmetry in the nucleon sea.

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

R.E. Tribble, A. Azhari, V. Burjan, F. Carstoiu, J. Cepek, H.L. Clark, C.A. Gagliardi, V. Kroha, Y.-W. Lui, A.M. Mukhamedzhanov, S. Piskor, A. Sattarov, L. Trache, J. Vincour
June 1999, Sevilla, Spain, ed. By B. Rubio, M. Lozano and W. Gelletly (AIP Conference Proceedings 495, Woodbury, NY 1999), *Proc. Exp. Nucl. Phys. Eur.*, p. 361

(Abstract not available.)

Fast CAMAC and PC -based Multiparametric Acquisition System

V.E. Iacob, R. Burch, J.C. Hardy, P. Lipnik, L. Trache

A small multiparametric acquisition system for a Windows NT machine, based on the KmaxNT software is presented. The main goal is to reduce to minimum the dead-time, which is essential for accurate measurements. The acquisition system introduces essentially no extra dead-time relative to that corresponding to the analog-digital converters. The system includes converters with a wide range of conversion times (e.g. the ORTEC ADC type AD413A and the LeCroy QDC type 4300B). The events are buffered in two dual port memories (FERA/CAMAC). The system uses the FERA bus for the readout of the converters and the CAMAC bus for the buffered readout of the events.

The Current Status of V_{ud}

I.S. Towner and J.C. Hardy

Proc. of the Fifth Intl. WEIN Symposium: Physics Beyond the Standard Model, Santa Fe, New Mexico, (June 1998) eds. P. Herczerg, C.M. Hoffman and H.V. Klapdor-Kleingrothaus, World Scientific, Singapore (1999) pp. 338-359

The value of the V_{ud} matrix element of the Cabibbo-Kobayashi-Maskawa (CKM) matrix can be derived from nuclear superallowed beta decays, neutron decay, and pion beta decay. We survey current world data for all three. Today, the most precise value of V_{ud} comes from the nuclear decays; however, the precision is limited not by experimental error but by the estimated uncertainty in theoretical corrections. The neutron data are approximately a factor of four poorer in precision but this could change dramatically in the near future as planned experiments come to fruition. The nuclear result (and the most recent of the neutron decay results) differ at the 98% confidence level from the unitarity condition for the 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 and Coulomb Mixing in Nuclei

J.C. Hardy and I.S. Towner

Nuclear Structure '98, Gatlinburg, Tennessee, *AIP Conference Proc. 481*, ed. C. Baktash, pp. 129-140

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 conclude that there are no evident defects although the Coulomb correction, δ_C , depends sensitively on nuclear structure and thus needs to be constrained independently. The potential importance of a result in disagreement with unitarity, clearly indicates the need for further work to confirm or deny the discrepancy. We examine the options and recommend priorities for new experiments and improved calculations. Some of the required experiments depend upon the availability of intense radioactive beams. Others are possible with existing facilities.

Weak Interaction Studies With an On-line Penning Trap Mass Spectrometer

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

Proc. of the International Nuclear Physics Conference, Paris, France
Nucl Phys. A654, 961c (1999)

Superallowed β decays are a sensitive probe of the fundamental aspects of the weak interaction. Such decays are used to stringently test the CVC hypothesis, deduce a precise value of the weak vector coupling constant, test the unitarity of the CKM matrix and look for deviation from the V-A structure for the weak interaction. The ability to efficiently capture and store short-lived superallowed beta emitters in ion traps will help to elucidate discrepancies in the most precise unitarity test of the CKM matrix and tighten the present limits on interactions outside the standard V-A form.

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. B 473, 29 (2000)

Self-consistent coalescence model analyses of light particle emission have been used to follow the evolution of the temperatures and densities of $A \sim 120$ nuclei produced in violent collisions induced by four different 47 A MeV projectiles. The degree of expansion of the emitting system increases with increasing projectile mass. The caloric curve derived for these expanding $A \sim 120$ nuclei plateaus near $T=7$ MeV. The plateau extends from 3 to 7.4 MeV/u excitation energy.

Energy Deposition and GDR Emission in the Reaction $^{209}\text{Bi}(\alpha, \alpha')$ at 240 MeV

G. Viesti, M. Lunardon, D. Fabris, G. Nebbia, 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, T. Ho
Nucl. Phys. A. 652, 17 (May 1999)

Neutron fold distributions measured for the reaction $^{209}\text{Bi}(\alpha, \alpha')$ at 240 MeV have been analyzed with the help of Statistical Model calculations to determine the distribution of excitation energy, E_x , in the primary target fragments as a function of the projectile energy loss, EL. The reconstructed distributions in excitation energy feature a plateau which extends from the kinematical limit $E_x = EL$ to very small excitations, indicating a variety of interactions of the beam particles with the target nucleus. The requirement of an additional coincidence with a light charged particle leads to the selection of a significant higher average excitation energy. Those results are extrapolated to explore the effects of including the excitation energy distributions in the analysis of previous measurements of GDR in ^{208}Pb . Corrections of the derived GDR parameter due to the partial transfer of excitation energy are suggested.

Energy Deposition and GDR Emission in Inelastic Alpha Particle Scattering

G. Viesti, M. Lunardon, D. Fabris, G. Nebbia, 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, T. Ho
Nucl. Phys. A 649, 165c (March 1999)

Neutron fold distributions measured for the reaction $^{209}\text{Bi}(\alpha, \alpha')$ at 240 MeV have been analyzed with the help of Statistical Model calculations to determine the distribution of excitation energy in the primary target fragments as a function of the projectile energy loss, EL. Results show that the distributions in excitation energy feature a plateau which extends from the kinematical limit $E_x = EL$ to very small excitations, suggesting a variety of interactions of the beam particles with the target nucleus. Requiring an additional coincidence with a light charged particle leads to the selection of a significant higher average excitation energy. This effect is extrapolated to explore the results of previous GDR decay measurements in the case of a ^{208}Pb target. Corrections of the derived GDR parameters due to the partial transfer of excitation energy are suggested.

Thermal and Dynamical Properties of Fusion-fission and Fusion-Evaporation Processes in $^{20}\text{Ne}+^{159}\text{Tb}$ and $^{20}\text{Ne}+^{169}\text{Tm}$ Reactions Between 8 and 16 MeV/nucleon

Th. Keutgen, J. Cabrera, Y. El Masri, C. Ghisalberti, I. Tilquin, L. Lebreton, A. Ninane, J. Lehmann, V. Roberfroid, L. Michel, R. Regimbart, J.B. Natowitz, K. Hagel, R. Wada and R.J. Charity
Nucl. Phys. A654, 878 (August 1999)

We have undertaken a study of the thermal and the dynamical properties of fission and evaporation processes through the observation of neutron and light charged particle (LCP) emission (p, α) in collisions of $^{20}\text{Ne}+^{159}\text{Tb}$ and $^{20}\text{Ne}+^{169}\text{Tm}$ at 8, 10, 13 and 16 MeV/nucleon using the neutron multidetector DEMON. Both systems lead to the formation of compound nuclei (CN) with initial excitation energies (E_x^*) ranging between 100 and 250 MeV. These CN, formed through complete (CF) or incomplete (IF) fusion reactions, decay through either fission or evaporation residue (ER) formation. Our experimental goal in this study is to establish, as a function of E_x^* , i) $\sigma_{ER}/\sigma_{fission}$ cross-section ratios, ii) pre- and post-scission neutron and LCP multiplicities with a clear cut assignment to CF and IF processes and iii) to try to consistently interpret these data in the framework of the recently modified statistical code GEMINI, including

time-dependent fission width probabilities in order to establish the fission time scales.

Coalescence, Interferometry and Flow

I. Bearden, H. Bøggild, J. Boissevain, L. Conin, J. Dodd, B. Erasmus, S. Esumi, C.W. Fabjan, D. Ferenc, D.E. Fields, A. Franz, J.J. Gaardhøje, 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.L. Kopytine, M. Leltchouk, A. Ljubicic, Jr., B. Lörstad, 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. Reichhold, A. Sakaguchi, J. Schmidt-Sørensen, J. Simon-Gillo, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, W.J. Willis, K.L. Wolf, N. Xu, D.S. Zachary
(The NA44 Collaboration)

Proc. of the 14th International Conference on Ultra-Relativistic Nucleus-Nucleus Collisions, Torino, Italy, Ed. By L. Riccati, M. Masera and E. Vercellin, p. (May 1999)
Nucl. Phys. A661, 456c (December 1999)

NA44 has measured proton and deuteron distributions for *SS* and *SPb* collisions at 200 GeV/c and *PbPb* collisions at 158 GeV/c. The mean p_T of both protons and deuterons grows with system size but the deuterons are somewhat slower than the protons. The phase space density of protons falls with m_T but increases for larger systems. The phase space density of $\bar{p}s$ is much lower than of protons while their average freeze-out radii are similar. The proton source size increases with system size but not as rapidly as the pion source. For *PbPb* collisions, all radii lie on a single curve.

Strange Meson Enhancement in PbPb Collisions at 158 GeV/c

I. Bearden, H. Bøggild, J. Boissevain, L. Conin, J. Dodd, B. Erasmus, S. Esumi, C.W. Fabjan, D. Ferenc, D.E. Fields, A. Franz, J.J. Gaardhøje, 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.L. Kopytine, M. Leltchouk, A. Ljubicic, Jr., B. Lörstad, 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. Reichhold, A. Sakaguchi, J. Schmidt-Sørensen, J. Simon-Gillo, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, W.J. Willis, K.L. Wolf, N. Xu, D.S. Zachary
(The NA44 Collaboration)
Phys. Lett. B 471, 6 (December 1999)

The NA44 Collaboration has measured yields and differential distributions of K^+ , K^- , π^+ , π^- in transverse kinetic energy and rapidity, around the center-of-mass rapidity in 158 A GeV/c Pb+Pb collisions at the CERN SPS. A considerable enhancement of K^+ production per π is observed, as compared to $p+p$ collisions at this energy. To illustrate the importance of secondary hadron rescattering as an enhancement mechanism, we compare strangeness production at the SPS and AGS with predictions of the transport model RQMD.

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

H. Bøggild, J. Boissevain, L. Conin, J. Dodd, B. Erasmus, 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, J. Schmidt-Sørensen, M. Spiegel, J. Simon-Gillo, W. Sondheim, T. Sugitate, J.P. Sullivan, Y. Sumi, H. van Hecke, W.J. Willis, K. Wolf, N. Xu (NA44 Collaboration)
Phys. Lett. B 458, 181 (July 1999)

Correlations of two protons emitted near midrapidity in $p + Pb$ collisions at 450 GeV/c and $S + Pb$ collisions at 200 A GeV/c are 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 increase with decreasing impact parameter.

Proton source sizes near midrapidity appear to be smaller than those of pions in the same interactions. Quantitative agreement with the results of RQMD (v1.08) 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, implying either a larger source size or larger contribution of protons from long-lived particle decays.

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)
Phys. Lett. B **455**, 77 (May 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.

Excitation of Continuum States in ${}^7\text{Li}$ and Their Decay by Quantum Tunneling

H. Utsunomiya, Y. Tokimoto, T. Yamagata, M. Ohta, Y. Aoki, K. Hirota, K. Ieki, Y. Iwata, K. Katori, S. Hamada, Y.-W. Lui, R.P. Schmitt, S. Typel, and G. Baur
Nucl. Phys. **A654**, 928c (1999)

Strong forward-backward asymmetries were found in the recent $\alpha - t$ coincidence measurement of Coulomb breakup of 42 MeV- ${}^7\text{Li}$ via continuum states. The competition between E1 and E2 multipolarities and higher order effects in Coulomb excitation were investigated by solving the time-dependent Schrödinger equation. It is shown that higher order effects are an essential ingredient to the observed large asymmetries. The relevant reaction mechanism is discussed.

${}^5\text{He}$ Ternary Spontaneous Fission of ${}^{252}\text{Cf}$ and ${}^{235}\text{U}$

J.K. Hwang, A.V. Ramayya, J.H. Hamilton, C.J. Bayer, J. Kormicki, X.Q. Zhang, A. Rodin, A. Fomichev, J. Kliman, L. Krupa, G.M. Ter-Akopian, Y. Oganessian, G. Chubarian, D. Severnyi, C.J. Lister, R.V.F. Janssens, I. Ahmad, W.C. Ma, R.B. Piercy, J.D. Cole
Phys. Rev. **C61**, 047601 (April 2000)

The relative ${}^4\text{He}$ and ${}^5\text{He}$ ternary fission yields were determined from a careful analysis of the energy distribution of spectra from a new measurement with a ${}^{252}\text{Cf}$ source and from published data on ${}^{252}\text{Cf}$ and ${}^{235}\text{U}(n,f)$. The kinetic energies of the ${}^5\text{He}$ and ${}^4\text{He}$ ternary particles were found to be approximately 11 and 16 MeV, respectively. ${}^5\text{He}$ particles contribute 10–20 % to the total alpha yield with the remainder originating from ${}^4\text{He}$ accompanied fission.

Cold Fission Studies With Large Detector Arrays

A.V. Ramayya, J.K. Hwang, J.H. Hamilton, C.J. Bayer, J. Kormicki, X.Q. Zhang, A. Rodin, A. Fomichev, J. Kliman, L. Krupa, G.M. Ter-Akopian, Y. Oganessian, G. Chubarian, D. Severnyi, R.V.F. Janssens, W.C. Ma, R.B. Piercy, J.D. Cole, Proceedings Second International Conference on Fission and Neutron-Rich Nuclei, St. Andrews, Scotland, June 1999.
Eds. J. Hamilton, W.R. Phillips, H.K. Carter, World Scientific (2000) p. 246.

The high selectivity and sensitivity offered by large arrays such as Gammasphere enables one to identify gamma rays from individual fission fragments. Rare processes such as cold (neutronless) binary and ternary fission in spontaneous fission of ${}^{252}\text{Cf}$ were experimentally observed by the triple gamma coincidence technique with Gammasphere. Many correlated pairs for both binary and ternary fission were observed in the spontaneous fission of ${}^{252}\text{Cf}$. Yields for cold ternary fission and cold binary fission were extracted from intensities of γ -ray transitions originated from the de-

excitation of primary and secondary fragments. The relative ${}^4\text{He}$ and ${}^5\text{He}$ ternary fission yields were determined from careful analysis of the energy distribution of α spectra from new measurement with ${}^{252}\text{Cf}$ source and from published data on ${}^{252}\text{Cf}$ and ${}^{235}\text{U}(n,f)$. The kinetic energies of the ${}^5\text{He}$ and ${}^4\text{He}$ ternary particles were found to be approximately 11 and 16 MeV, respectively. ${}^5\text{He}$ particles contribute 10-20% to the total alpha yield with the remainder originating from ternary fission accompanied by the emission of ${}^4\text{He}$.

Fission Fragment Mass-Energy Distributions and Gamma Ray Multiplicities in Multimodal Fission of Light Thorium Isotopes

G. G. Chubarian, M.G. Itkis, N. A. Kondratiev, E. M. Kozulin, Yu. Ts. Oganessian, V. V. Pashkevich, I.V. Pokrovsky, V. S. Salamatin, A.Ya. Rusanov, B. J. Hurst, D. O'Kelly, R. P. Schmitt, F. Hanappe, E. Liatard, A. Huck, L. Stuttgé, L. Calabretta, C. Maiolino, K. Lukashin, C. Agodi, G. Bellia, "The 4th International Conference on Dynamical Aspects of Nuclear Fission," Casta-Papiernicka, Slovak Republic, October 19-23, 1998. World Scientific (1999) p. 293.

The fission fragment mass-energy distributions and the γ -rays from the multimodal fission of the ${}^{220,224,226}\text{Th}$ was investigated. The corresponding excitation energies at the saddle point, E_{sp}^* , ranged from 16 to 40 MeV. As E_{sp}^* decreases, an asymmetric mass component becomes visible on the predominately symmetric mass distribution. The contribution of the asymmetric mode is characterized by the total yield ratio Y_f/Y_a , which decreases rapidly for the heavier isotopes of thorium. For all isotopes studied, the subtracted asymmetric fission component, $Y_a = Y_t - Y_s$, exhibits a complex structure. The average γ -ray multiplicities and relative γ -ray energies as a function of the mass of the fission fragments also exhibit a complex structure and strong variations. Such strong variations have never been previously observed in heavy ion-induced fusion-fission reactions. Obtained results may be explained with the influence of shell effects on the properties of the fission fragments.

Hadronic Scatterings of Charmed Mesons

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

The scattering cross sections of charm mesons with hadrons such as the 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.

Isospin Dependence of Nuclear Collective Flow

B.A. Li and C.M. Ko
Nucl. Phys. A **654**, 797c (1999)

Nuclear collective flow in heavy-ion collisions at intermediate energies has been studied in an isospin-dependent transport model. It is found that both the sign and strength of collective flow are significantly affected by the isospin asymmetry of the colliding system. The predicted dependence of the balance energy, defined by the incident energy at which the collective flow disappears, on the isospin asymmetry is compared with recent experiments at NSCL/MSU.

Kaon Differential Flow in Relativistic Heavy Ion Collisions

B.A. Li, B. Zhang, A.T. Sustich, and C.M. Ko
Phys. Rev. C **60**, 034902 (September 1999)

Using a relativistic transport model, we study the azimuthal momentum asymmetry of kaons with fixed transverse momentum, i.e., the differential flow, in heavy-ion collisions at beam momentum of 6 GeV/c per nucleon, available from the Alternating Gradient Synchrotron (AGS) at the Brookhaven National Laboratory (BNL). We find that in the absence of kaon potential the kaon differential flow is positive and increases with transverse momentum as that of nucleons. The repulsive kaon potential as predicted by theoretical models, however, reduces the kaon differential flow, changing it to negative for kaons with low transverse momenta. Cancellation between the negative differential flow at low momenta and the positive one at high momenta is then responsible for the experimentally observed nearly vanishing in-plane transverse flow of kaons in heavy ion experiments.

Elliptic Flow in Heavy Ion Collisions Near the Balance Energy

Y.-M. Zheng, C.M. Ko, B.-A. Li and B. Zhang

Phys. Rev. Lett. **83**, 2534 (September 1999)

The proton elliptic flow in collisions of Ca on Ca at energies from 30 to 100 MeV/nucleon is studied in an isospin-dependent transport model. With increasing incident energy, the elliptic flow shows a transition from positive to negative flow. Its magnitude depends on both the nuclear equation of state (EOS) and the nucleon-nucleon scattering cross section. Different elliptic flows are obtained for a stiff EOS with free nucleon-nucleon cross sections and a soft EOS with reduced nucleon-nucleon cross sections, although both lead to vanishing in-plane transverse flow at the same balance energy. The study of both in-plane and elliptic flows at intermediate energies thus provides a means to extract simultaneously the information on the nuclear equation of state and the nucleon-nucleon scattering cross section in medium.

Excitation Function of Nucleon and Pion Elliptical Flow in Relativistic Heavy Ion Collisions

B.A. Li, C.M. Ko, A.T. Sustich, and B. Zhang

Phys. Rev. C **60**, 011901 (July 1999)

Within a relativistic transport (ART) model for heavy-ion collisions, we show that the recently observed characteristic change from out-of-plane to in-plane elliptic flow of protons in mid-central Au+Au collisions as the incident energy increases is consistent with the calculated results using a stiff nuclear equation of state ($K=380$ MeV). We have also studied the elliptical flow of pions and the transverse momentum dependence of both the nucleon and pion elliptic flow in order to gain further insight about the collision dynamics.

Elliptical Flow From a Parton Cascade

B. Zhang, M. Gyulassy, and C.M. Ko

Phys. Lett. B **455**, 45 (May 1999)

The dependence of elliptic flow at RHIC energies on the effective parton scattering cross section is calculated using the ZPC parton cascade model. We show that the v_2 measure of elliptic flow saturates early in the evolution before the hadronization transition to a rather large value of about 0.05-0.15 as the cross section varies from 2-10 mb and thus is a sensitive probe of the dynamics in the plasma phase.

Description of Heavy Ion Collisions

C.M. Ko

Prog. Part. Nucl. Phys. **42**, 109 (1999)

Heavy ion collisions are best described by transport models that include both mean-field potentials and two-body collisions. In particular, the relativistic transport model, which treats consistently the change of hadron masses and energies in hot dense matter, allows one to study these medium effects in heavy ion collisions. In this talk, we review the present understanding of hadron in-medium properties and the progress made in extracting such information from available experimental data using the relativistic transport model.

Microscopic Description of Excitation of Nuclear Isoscalar Giant Monopole Resonance by Inelastic Scattering of 240 MeV α -Particles

A. Kolomiets, O. Pochivalov, and S. Shlomo

Phys. Rev. C **61**, 034312 (March 2000)

A microscopic description of the isoscalar monopole resonance (ISGMR) excitations in ^{28}Si , ^{40}Ca , ^{58}Ni , and ^{116}Sn is provided based on self-consistent Skyrme-Hartree-Fock (HF) Random-Phase-Approximation calculations. A description of 240 MeV α -particle scattering by these nuclei is given within the Distorted-Wave-Born-Approximation (DWBA). The folding model is used to obtain optical potentials from the HF ground state density and a density dependent Gaussian nucleon α interaction ($V_{\alpha n}$). Parameters of ($V_{\alpha n}$) are found by fitting experimentally measured angular distributions for the case of elastic scattering. Angular distributions of inelastically scattered α -particles for

ISGMR excitations of the target nucleus are obtained using the folding model DWBA and both microscopic (RPA) and hydrodynamical (collective model) transition densities (found from HF ground state densities). Possible overestimation of the energy weighted sum rules and shifts of centroid energies due to collective-model-based DWBA reaction description is reported.

Low Density Instability in an Nuclear Fermi Liquid Drop

V.M. Kolomietz and S. Shlomo

Phys. Rev. C **60**, 044612 (October 1999)

The instability of a Fermi-liquid drop with respect to bulk density distortions is considered. It is shown that the presence of the surface strongly reduces the growth rate of the bulk instability of the finite Fermi-liquid drop because of the anomalous dispersion term in the dispersion relation. The instability growth rate is reduced due to the Fermi surface distortions and the relaxation processes. The dependence of the bulk instability on the multipolarity of the particle density fluctuations is demonstrated for two nuclei ^{40}Ca and ^{208}Pb .

Status of Nuclear Matter Incompressibility Coefficient

S. Shlomo, (Summary talk), in Selected Topics in Nuclear Collective Excitations (NUCOLEX99)

RIKEN Review **23**, 176 (July 1999)

We provide a short summary of the Workshop on the nuclear matter incompressibility coefficient, K_{nm} , and review the experimental and theoretical methods used to determine the value of K_{nm} from the strength function distributions of the isoscalar giant monopole resonance (ISGMR) and the isoscalar giant dipole resonance (ISGDR) in nuclei.

Excitation of Isoscalar Giant Monopole Resonance by Inelastic Scattering of 240 MeV α -Particles

A. Kolomiets, O. Pochivalov and S. Shlomo

RIKEN Review **23**, 77 (July 1999)

We consider the excitation of the isoscalar giant monopole resonances (ISGMR) in ^{28}Si , ^{40}Ca , ^{58}Ni , and ^{116}Sn . We carry out self-consistent Skyrme Hartree-Fock (HF) Random Phase Approximation (RPA) calculations of the strength distributions $S(E)$ and the transition densities $\rho_r(r)$ as functions of the excitation energy E . Recent experimental data of 240 MeV α -particle scattering by these nuclei is analyzed within the Distorted Wave Born Approximation (DWBA) using the folding model (FM) with a density dependent Gaussian nucleon- α interaction $V(\rho, r)$. The parameters of $V(\rho, r)$ are found by fitting the experimentally measured angular cross sections $\sigma(\theta)$ for the case of elastic scattering, using the HF ground state density ρ_{HF} . The inelastic cross sections $\sigma(\theta)$ for the ISGMR are then obtained using the FM-DWBA and both microscopic (RPA) and hydrodynamical (collective model) $\rho_r(r)$ (found from $\rho_{\text{HF}}(r)$). Possible overestimation of the energy weighted sum rules and shifts of the centroid energies due to the collective-model-based DWBA reaction description are obtained.

Giant Monopole Resonance and Nuclear Incompressibility Within the Fermi-liquid Drop Model

A. Kolomiets, V.M. Kolomietz, and S. Shlomo

Phys. Rev. C **59**, 3139 (June 1999)

We study the important effects of Fermi surface distortion on the isoscalar giant monopole resonance (ISGMR), within a Fermi-liquid drop model, by considering consistently the effects on nuclear incompressibility coefficients and the boundary conditions needed to determine the energy of the ISGMR. There is a significant difference between the static nuclear incompressibility K , derived as a stiffness coefficient with respect to an adiabatic change in the bulk density, and the dynamic one K' associated with the zero sound velocity. We show that the enhancement in the energy of the ISGMR, the lowest breathing mode, which is due to the renormalisation of K into K' is strongly suppressed by the effects of the Fermi surface distortion on the boundary condition. This is not the case for higher breathing modes such as the overtone. We also discuss, in particular, the effects of the Fermi surface distortion on energy weighted sums for the monopole mode and on the constrained and the scaling incompressibility coefficients and their relation to the liquid drop one.

The 4 \hbar 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 (April 1999)

In the framework of the random phase approximation in the continuum we calculate the strength function of the 4 \hbar 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.

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

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

Phys. Rev. A **60**, 2959 (October 1999)

The dependence of Cu (target atom) K-shell vacancy production cross sections on projectile atomic number was investigated in collision systems for which the ratio of projectile-to-target atomic numbers (Z_1/Z_2) ranged from 0.34 to 2.86. A combination of energy and wavelength dispersive x-ray spectrometry was used to measure Cu K x-ray production cross sections and to determine the appropriate fluorescence yields for converting them to K-vacancy production cross sections. The high resolution spectra also revealed the presence of sizable contributions from predominately single-ionization mechanisms not directly associated with ion-atom interactions. The role of electron capture to the projectile was examined by observing the dependence of the cross sections on target thickness. The Cu K-vacancy production cross-sections determined for equilibrated projectiles display a plateau centered in the region of symmetric collisions ($Z_1/Z_2 \sim 1$) and they become essentially constant beyond $Z_1 = 54$. The cross sections for $Z_1 > 24$ fall far below a Z_1^2 scaling law and are greatly overestimated by the ECPSR theory.

Striving for Intense Beams from the Texas A&M K500 Cyclotron

G.J. Kim and D.P. May

Proc. of the 15th International Conference on Cyclotrons and their Applications,
Caen, France, p. 632 (June 1998)

Recently, our efforts on increasing the extracted beam intensity from our K500 superconducting cyclotron at Texas A&M University have increased in the interest of supporting secondary radioactive beam experiments. We are pursuing plans to upgrade our ECR ion source, such as employing two frequency microwaves for plasma heating, and to clean up our injection line optics to get more beam into the cyclotron. However, the bottleneck will be the performance of the deflectors. In this report, we will describe our general beam tuning procedures and our current cyclotron performance. We will then focus on the properties of three recent beams, two with large beam currents and one with an exceptional extraction efficiency, in order to learn and to extend the performance of our cyclotron.

ECR Ion Sources for Accelerators

D.P. May

Proc. of the 15th International Conference on Cyclotrons and their Applications
Caen, France, p. 395 (June 1998)

ECR ion sources have proven to be ideal providers of multi-charge-state beams for many cyclotrons in the world, as well as for some accelerators besides cyclotrons. The ECR ion source injecting the Super Proton Synchrotron (SPS) at CERN is a notable example of the latter case. Some ECR sources are capable of fully stripping species as heavy as argon and providing ion beams of some of the heaviest species with charge-to-mass ratios up to 1/4, while other ECR sources are designed to produce 100 mA proton beams for accelerator injection. The properties of ECR ion sources, the methods used to produce both intense and high-charge-state ion beams of many stable and radioactive species, and the methods and problems associated with optimizing these sources to match with widely varying requirements will be discussed.

The Plans for a Two-Frequency Upgrade to the Texas A&M ECR Ion Source ECR2

D.P. May and G.J. Derrig

Proc. of the 14th International Workshop on ECR Ion Sources, p. 50

CERN, Geneva, Switzerland (May 1999)

In order to expand the capability of the K500 cyclotron at Texas A&M, an upgrade involving our lower-field 6.4 GHz ECR ion source ECR2 is being carried out. The coils and yoke of ECR2 will be used to construct a source with magnetic fields higher than those of ECR1, a high-B mode 6.4 GHz ECRIS. The upgraded source will be capable of 14.5 GHz operation as well as multiple-frequency microwave heating. To boost the axial field, steel will be added to the injection and extraction ends. Using Nd-Fe-B permanent magnet material, the hexapole will have a calculated pole strength of 0.88 T on the wall and gap strength of 0.67 T while allowing some radial clearance between the magnets for pumping and for insertion of ovens and sputtering devices. Similar to ECR1 the plasma chamber, which also supports the hexapole, will be constructed of aluminum and cooled via water-carrying hollow copper tubing externally clamped to the aluminum.