RECENT RESULTS ON CORRELATIONS AND PARTICLE SPECTRA FROM EXPERIMENT NA44

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Recent results for both single particle spectra and two particle interferometry from CERN experiment NA44 are presented. Experiment NA44 is a focussing spectrometer with both excellent momentum resolution and particle identification. The results shown are mainly from 158 GeV/nucleon Pb+Pb running. These include single pion, kaon, proton, anti-proton, deuteron, and triton spectra and two-pion, two-kaon, and two-proton correlation functions.

1 INTRODUCTION

Experiment NA44 is a focussing spectrometer with both excellent momentum resolution and particle identification. The NA44 spectrometer was optimized for the study of single particle spectra and two-particle correlations near mid-rapidity for transverse momenta below ≈ 1 GeV/c. Recent results for both single particle spectra and two particle interferometry from NA44 are presented. The results shown are mainly from 158 GeV/nucleon Pb+Pb running. These include single pion, kaon, proton, anti-proton, deuteron, and triton spectra and two-pion, two-kaon, and two-proton correlation functions.

2 EXPERIMENTAL SETUP

Fig. 1 shows the experimental setup for the NA44 spectrometer during Pb-beam running. The NA44 Focusing Spectrometer[1,2,3] uses two dipole magnets and three quadrupoles, covering a momentum range of $\pm 20\%$ around its central momentum setting. Fig. 2 shows the spectrometer acceptance for various particles and for two momentum settings. Two spectrometer angle settings, 44 mr and 131 mr, were used to obtain the acceptances in Fig. 2 and are referred to as low p_T ($< p_T > \approx 170$ MeV/c) and high p_T ($< p_T > \approx 480$ MeV/c), respectively. For the S beam data, the tracking and time-of-flight uses three scintillator hodoscopes whose time resolution is ≈ 100 ps, with a Cherenkov beam counter[4] for the time-of-flight start ($\sigma \approx 35$ ps). Particle identification is based on time-of-flight and two gas Cherenkov counters. The first Cherenkov counter (C1) fires on pions and electrons, but not for heavier particles. The second Cherenkov counter (C2) fires for electrons, but not for heavier particles. These two Cherenkov counters give one signal per event. Fig. 3 shows the particle identification performance that is obtained in NA44 by combining information from C1 and time-of-flight. For the Pb+Pb data, the first of the three scintillator hodoscopes was replaced with a pad chamber. Two strip chambers were added between the second and third hodoscopes. Also, a threshold imaging Cherenkov counter (TIC) [5] was added to the system. The TIC gave a Cherenkov signal for individual tracks. The TIC gives a signal for pions and electrons, but not for heavier particles.

3 RESULTS AND DISCUSSION

Figs. 4-12 show NA44 results for single particle distributions and two particle correlations.

Results for single particle distributions are shown in Figs. 4-7. Fig. 4 shows m_T distributions for pions, kaons, protons and their anti-particles for Pb+Pb

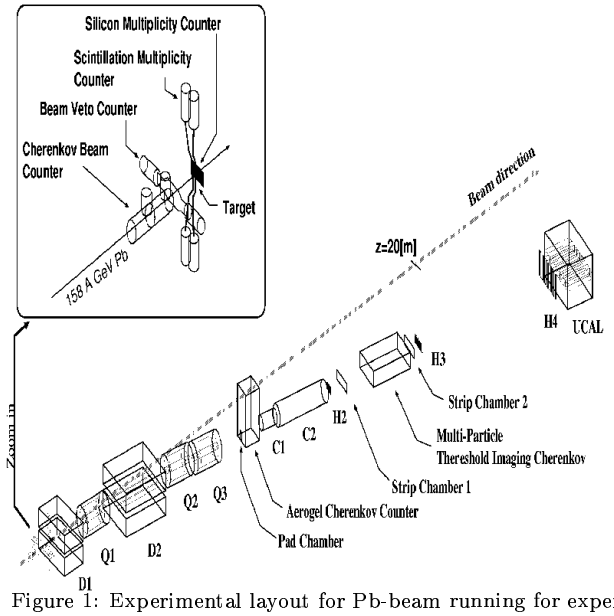

Figure 1: Experimental layout for Pb-beam running for experiment NA44

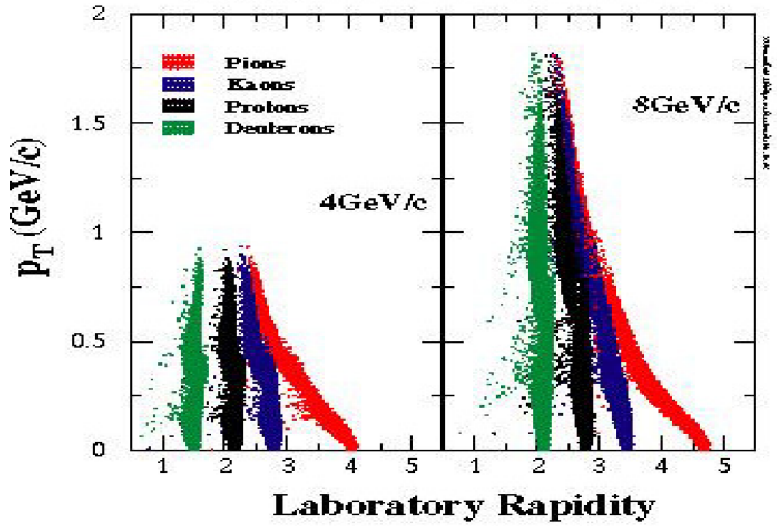

Figure 2: NA44 acceptance for various particles for the 4 and 8 GeV/c settings

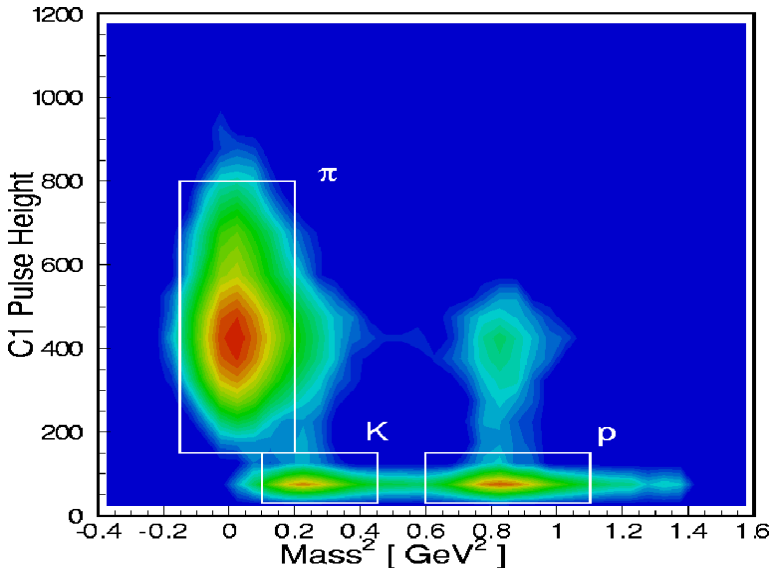

Figure 3: Particle identification in NA44 using the C1 Cerenkov and time-of-flight

collisions from NA44. The dashed lines are exponential fits to the data of the function

$$\frac{1}{m_T}\frac{dN}{dm_T} = A\exp(-\frac{m_T}{T}) \tag{1}$$

where $m_T = \sqrt{p_T^2 - m^2}$ is the transverse mass, p_T is the transverse momentum, m is the particle rest mass, T is the slope parameter, and A is a normalization constant. The extracted slope parameters for Pb+Pb collisions along with those extracted from S+S and p+p are plotted in Fig. 5 as a function of particle mass [6]. Whereas for p+p collisions there is no mass dependence for T, as the colliding system or the particle mass becomes heavier the slope parameter increases. This behaviour is suggestive of hydrodynamic flow in the heavy-ion collisions studied [6]. Since this dependence can be qualitatively described by a cascade code [7] and a "pure" final-state rescattering model [8] another way to account for this behaviour is that it is due to final-state rescattering of the produced particles.

Fig. 6 shows a proton rapidity distribution for Pb+Pb collisions from NA44. The open circles are the mirrored points about mid-rapidity. Statistical errors are shown as vertical bars and the systematic errors are shown by the vertical brackets. Two model calculations, RQMD[9] and FRITIOF(Lund)[10], are

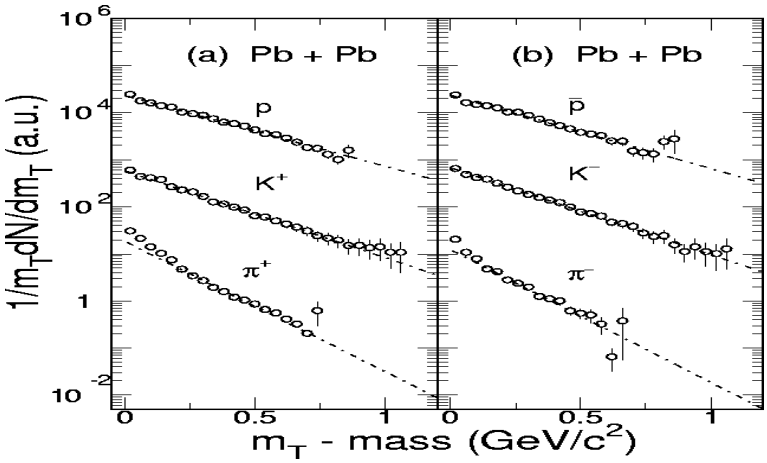

Figure 4: Transverse mass distributions for pions, kaons, protons and their anti-particles for Pb+Pb from NA44

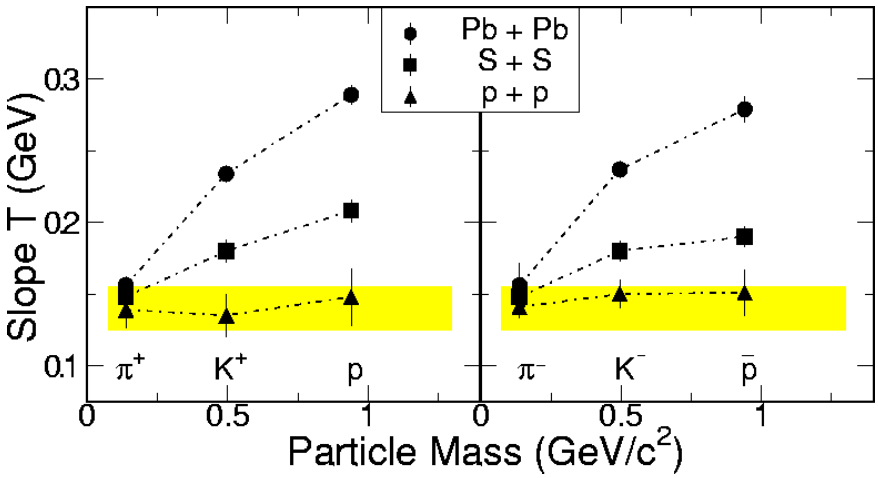

Figure 5: Transverse mass distribution slope parameters for various particles and reaction systems from NA44

also compared with these data. As seen, the models overpredict and underpredict, respectively, the data.

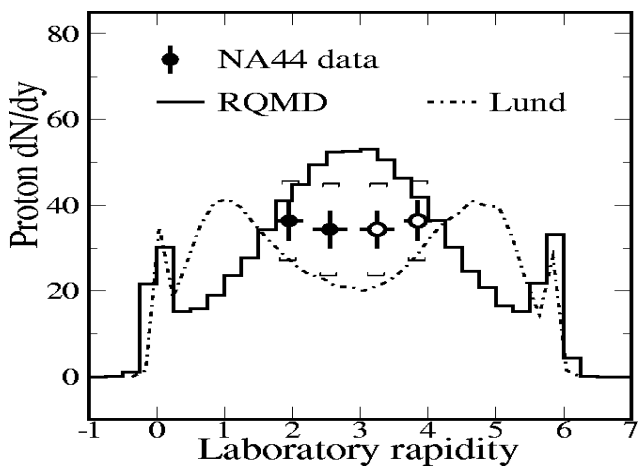

Figure 6: Proton rapidity distributions from central Pb+Pb collisions

Fig. 7 shows preliminary NA44 transverse mass distributions for deuterons and tritons from Pb+Pb collisions. The slopes from these heavier particles are consistent with the trend of increasing slope with increasing particle mass as seen in Figs. 4 and 5.

The NA44 two-pion data have been analyzed in terms of three components[11,12] of the two-particle momentum difference ($\vec{Q} = \vec{p_1} - \vec{p_2}$). The data are analyzed in the frame in which the z-component of the pair momentum ($p_{z1} + p_{z2}$) is zero (the longitudinally co-moving system, or "LCMS"). The momentum difference is resolved into a component (Q_L) parallel to the beam direction and a component perpendicular to the beam direction. The perpendicular component is further resolved into Q_{TO} parallel to the sum of the pair momentum and Q_{TS}, which is perpendicular to the sum and to the beam. Three corresponding source size parameters (R_L, R_{TO}, R_{TS}) are determined by fitting eq. 2:

$$C(Q_{TO}, Q_{TS}, Q_L) = A(1 + \lambda_{3D} e^{-Q_{TO}^2 R_{TO}^2 - Q_{TS}^2 R_{TS}^2 - Q_L^2 R_L^2}) \qquad (2)$$

to measured 3D correlation functions from two different spectrometer settings. The "horizontal" focus spectrometer setting optimizes the acceptance for R_{TO}, while the "vertical" focus spectrometer setting is for R_{TS}. For the S beam data, the resolution in Q_{TO} and Q_L is $\approx$15 MeV/c and in Q_{TS} is $\approx$30 MeV/c. For

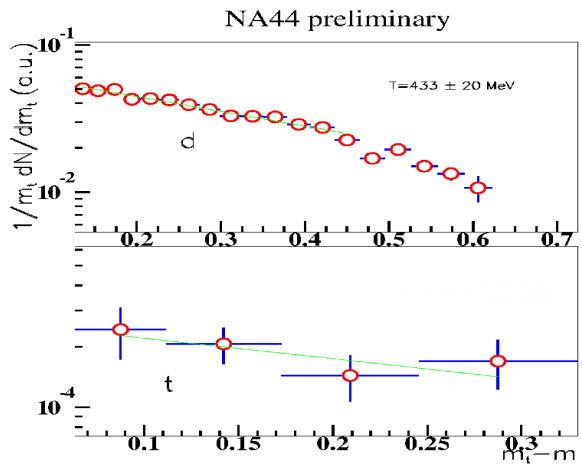

Figure 7: Preliminary deuteron and triton transverse mass distributions for Pb+Pb collisions

Pb+Pb, the resolution is ≈15 MeV/c for all three components. One dimensional correlations functions are also shown. These data are fit to

$$C(Q_{INV}) = A(1 + \lambda_{INV} e^{-Q_{INV}^2 R_{INV}^2}) \tag{3}$$

where $Q_{INV} = \sqrt{\vec{Q}^2 - Q_0^2}$.

The one-dimensional fits and projections of the three-dimensional fits onto the three axes are shown together with the Coulomb wave corrected Pb + Pb data [13] in Fig. 8. For the three-dimensional projections, the data from the horizontal and vertical settings are both shown. The top row shows the correlation function and fit for the low p_T $\pi^-\pi^-$ data, the middle row shows the low p_T $\pi^+\pi^+$ data, and the bottom row shows the high p_T $\pi^+\pi^+$ data.

Fig. 9 shows a preliminary three-dimensional two-kaon correlation function from Pb+Pb collisions projected onto the same axes as shown in Fig. 8. Figs. 10 and 11 summarize the boson source parameters extracted from NA44 and compare them with model predictions from RQMD [7] and a rescattering model [8], respectively. In Fig. 10 the comparison between data and RQMD is carried out in one dimension. It is seen that RQMD predicts the trends of the data well but systematically overpredicts the actual values of the source parameters.

Fig.11 compares HBT-extracted pion and kaon source parameters measured in the NA44 experiment [21 41 3] with those calculated with the rescattering model for Pb+Pb collisions. Comparisons are also shown for S+S and S+Pb

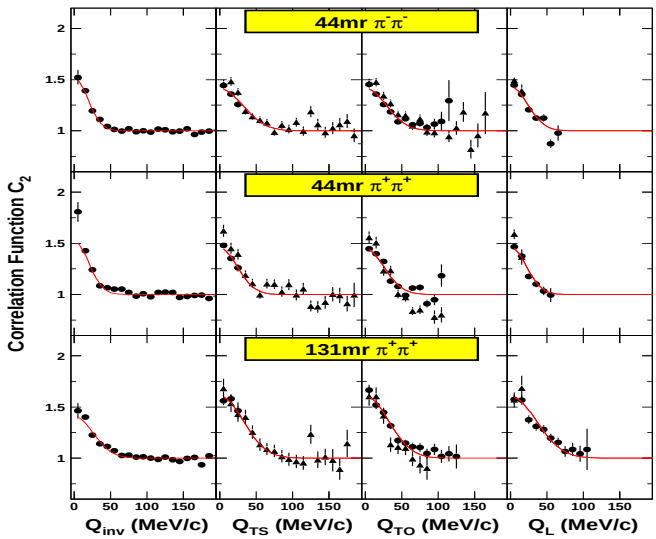

Figure 8: One-dimensional and projected three-dimensional two-pion correlation functions for Pb+Pb collisions from NA44

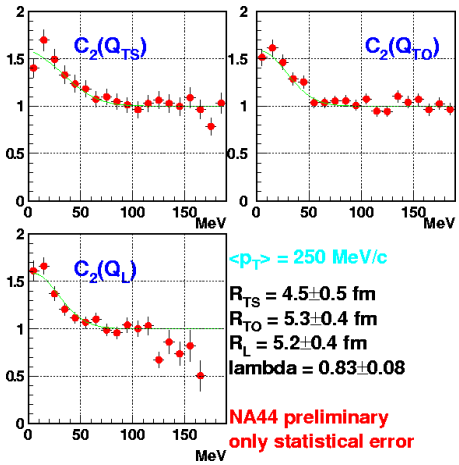

Figure 9: Projected three-dimensional two-kaon correlation function from NA44

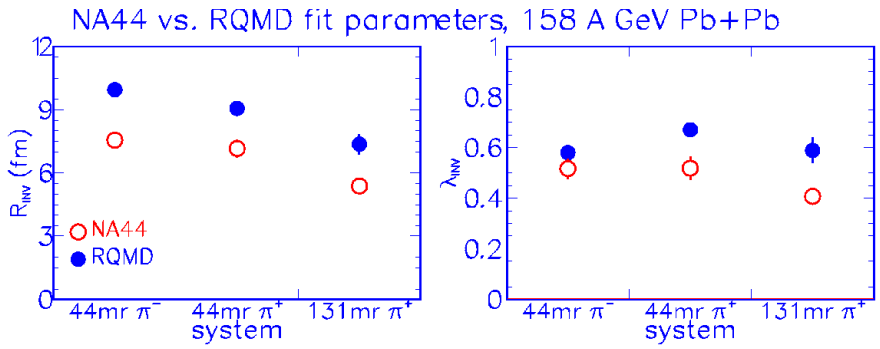

Figure 10: NA44 versus RQMD two-pion fit parameters for R_{inv} for Pb+Pb collisions

collisions. Although the agreement is not perfect, the rescattering model is seen to qualitatively describe the trends of the data. This demonstrates that rescattering is a dominant effect in determining the size and dependences of the boson source parameters.

Finally, Fig. 12 shows a two-proton correlation function measured by NA44 for the system 200 GeV/nucleon S+Pb. The data are compared with a calculation carried out with the Pratt code [15] assuming a gaussian source of radius and lifetime parameter each equal to 2.65 fm.

4 ACKNOWLEDGMENTS

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1. NA44 Collaboration, H. Beker, *et al.*, Z. Phys. **C64**, 209 (1994); NA44 Collaboration, H. Bøggild, *et al.*, Phys. Lett. **B349**, 386 (1995)
2. NA44 Collaboration, H Beker, *et al.*, Phys. Rev. Lett. **74**, 3340 (1995)
3. NA44 Collaboration, K. Kaimi, *et al.*, Z. Phys. **C75**, 619 (1997)
4. N.Maeda, *et al.*, Nucl. Inst. Meth. **A346**, 132 (1994).

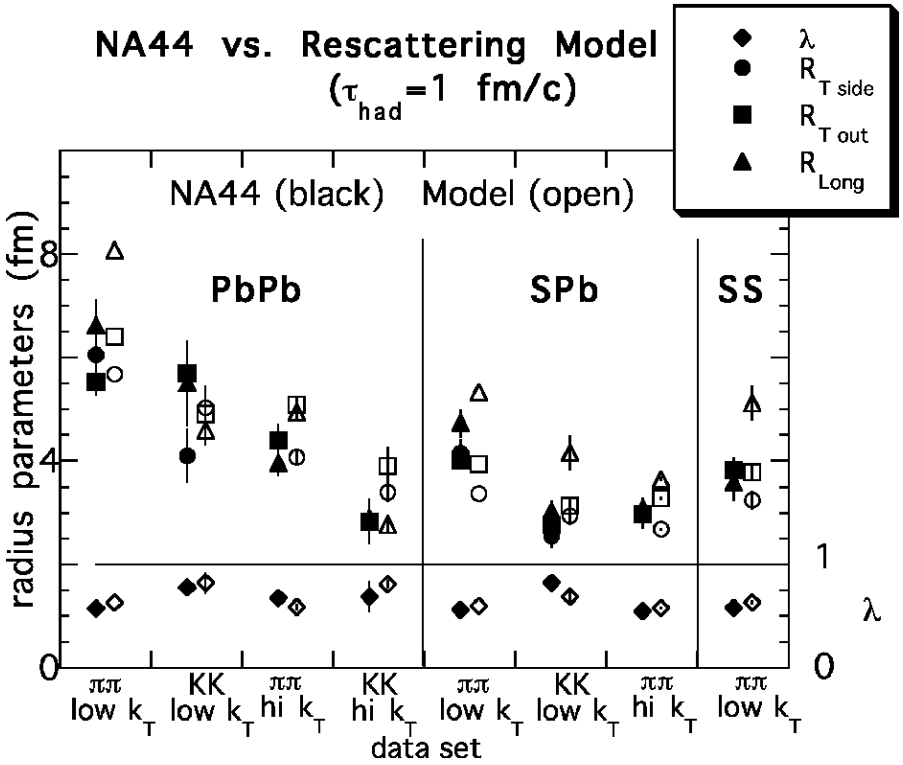

Figure 11: Comparison between HBT-extracted boson source parameters extracted from experiment NA44 and those calculated with the rescattering model

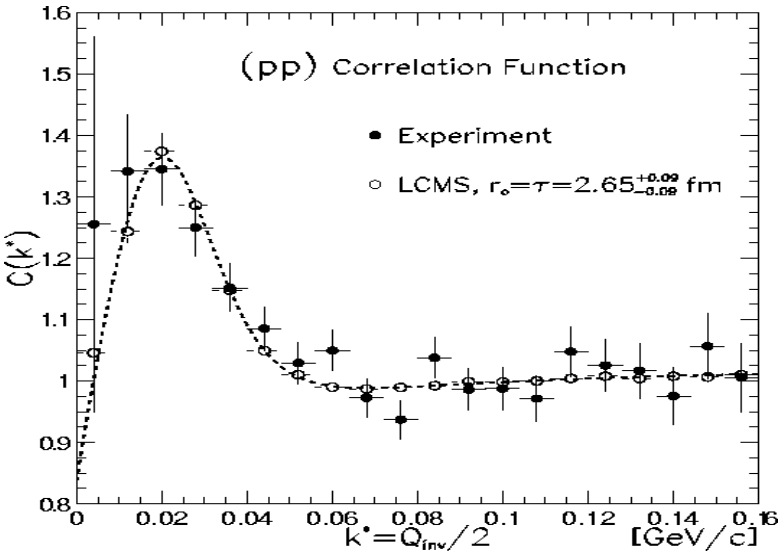

Figure 12: Two-proton correlation function for S+Pb collisions from NA44

5. C.W.Fabjan, *et al.*, Nucl. Inst. Meth. **A367**, 240 (1995); A. Braem, *et al.*, CERN-PPE/97-120
6. NA44 Collaboration, I. G. Bearden *et al.*, Phys. Rev. Lett. **78**, 2080 (1997)
7. J. P. Sullivan *et al.*, Phys. Rev. Lett. **70**, 3000 (1993)
8. T. J. Humanic, Phys. Rev. **C57**, 866 (1998)
9. H. Sorge, H. Stöcker and W. Greiner, Nucl Phys. **A498**, 567c (1989); H. Sorge *et al.* Z. Phys. C**47**, 629 (1990).
10. B. Nilisson-Almqvist and E. Stenlund, Comp. Phys. Comm. **43**, 387 (1987)
11. S. Pratt, Phys. Rev. **D33**, 1314 (1986)
12. G. Bertsch and G.E. Brown, Phys. Rev. **C40**, 1830 (1989)
13. NA44 Collaboration, I. G. Bearden *et al.*, Phys. Rev. **C58**, 1656 (1998)
14. NA44 Collaboration, A. Franz *et al.*, Nucl. Phys. **A610**, 240c (1996)
15. S. Pratt, T. Csorgo, and J. Zimanyi, Phys. Rev. **C42**, 2646 (1990)