# Proton and Pion Source Sizes in Ultrarelativistic Nucleus Nucleus Collisions

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Nucleus-nucleus collisions at ultrarelativistic energies create hadronic matter at high energy density. Because of their large mass proton and deuterons are particularly sensitive to collective expansion effects.

Near central rapidity most deuterons should be produced by coalesance since direct production will be suppressed by phase space and few pre-existing deuterons can survive the many collisions required to move them from the target or projectile into central rapidity. Since coalesance depends on the distribution of protons it is possible to derive a source size from the $d/p^2$ ratio. To compare with our HBT data we assumed a gaussian source, [1]. One can also derive the density of protons in phase space assuming that deuterons coalesce from protons and neutrons.

NA44 is a focussing spectrometer that has been described in detail elsewhere, [2, 3, 4, 5]. We compare protons and deuterons at y=2.1 and $p_T/A = 0. - 0.8$ GeV/$c$. We have assumed that the proton and neutron distributions are identical. The data are compared to RQMD with a coalesance after burner,[6].

The transverse mass distributions are approximately exponential over most of the NA44 acceptance and become harder for larger systems. However below $m_T = 50$MeV/$c$ the proton spectrum for $PbPb$ flattens out. One measure of the shapes of the spectra is the mean $p_T$ per nucleon (which is related to the average transverse velocity) for protons and deuterons. The $< p_T > /A$ for both p and d increases slowly with system size and is always smaller for deuterons than for protons both for data and RQMD. This could be due to the necessity of a third particle to carry away the binding energy. However the protons that we see in deuterons may have suffered fewer scatterings , and thus have a lower $< p_T >$, than the average proton. This could arise because once a deuteron is formed any further interactions will almost certainly break it up. A similar effect was observed when comparing proton and antiproton spectra, [3].

Since deuterons are slower than protons one might expect the phase space density to be larger at low $p_T$. Figure 1 shows that this is indeed the case. RQMD gives a good description of the $SS$ data but underestimates the phase space density for $PbPb$ and does not predict its $p_T$ dependence.

Figure 2 shows that $\bar{p}$s freeze-out at a lower phase space density and larger radius than protons. This seems resonable in light of the large $p\bar{p}$ annihilation cross section. Figure 3 shows that the ratio between pion and proton invariant radii increases from $SS$ to $PbPb$.

Several features of the data suggest a strong build up of rescattering and hence energy density From $SS$ to $PbPb$ collisions both the size of the proton source and its phase space density increase. It appears that different particles freeze-out at different times; $p\bar{p}$s freeze-out somewhat later than protons while

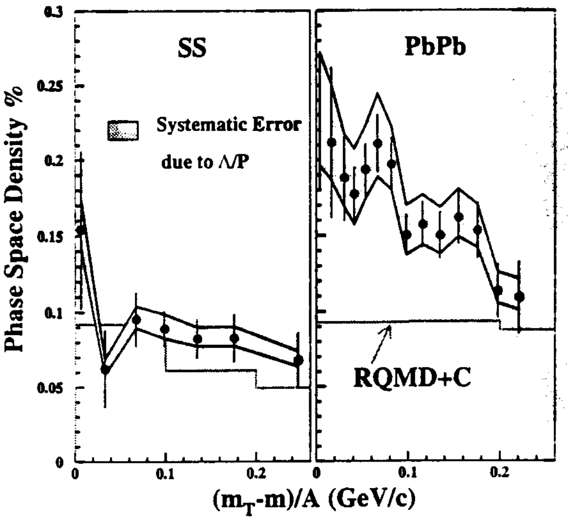


Figure 1: Phase space density versus $(m_T - m)/A$

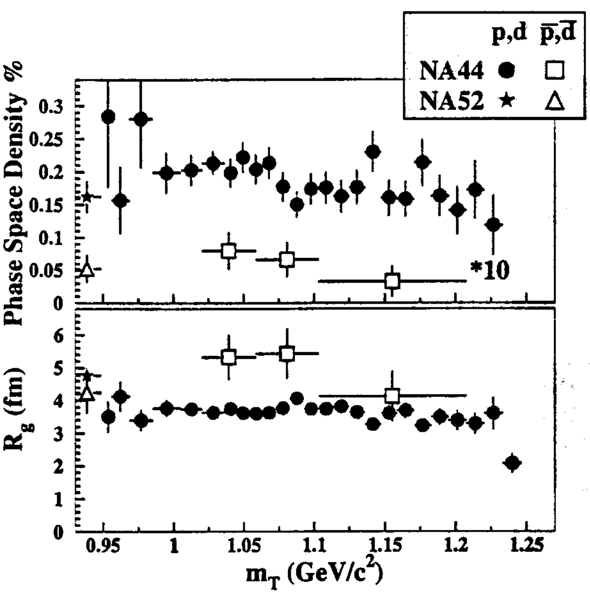


Figure 2: Radii and phase space density versus $(m_T - m)/A$ for protons and antiprotons.

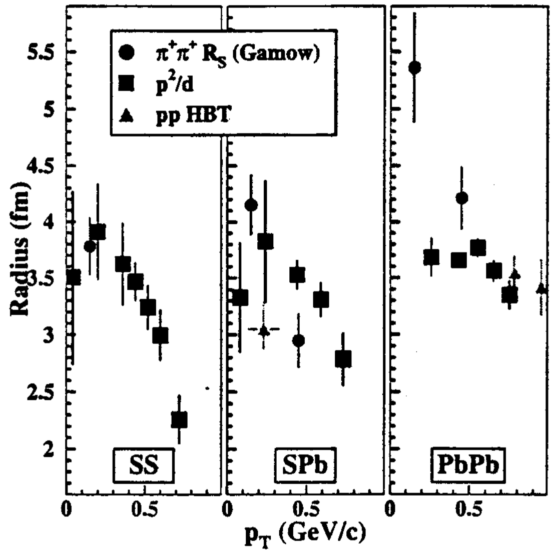


Figure 3: Pion and Proton radii versus $p_T$ for different systems

the pion source size grows more quickly with the number of participants than the proton source.

## References


[1] W. J. Llope et al., Phys. Rev. C. 52 2004 (1995).

[2] H. Beker et al., *Phys. Rev. Lett.* **74**, 3340 (1995).

[3] I. Bearden et al., *Phys. Rev.* C **57**, 837 (1998), nucl-ex/9711004.

[4] I. G. Bearden et al., *Phys. Rev.* C **58**, 1656 (1998)

[5] H. Bøggild et al., *Phys. Rev.* C **58**, 328 (1999), nucl-ex/9808002

[6] J. L. Nagle, B. S. Kumar, D. Kusnezov, H. Sorge and R. Mattiello *Phys. Rev.* C **53** 367 (1996)