High p_T π^0 Production and Angular Correlations in 158 AGeV p+A and Pb+Pb Collisions

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Recent results of the WA98 experiment with p and Pb induced reactions at 158 AGeV are presented. Azimuthal γ-γ correlations at high p_T were studied in search for a signal of jet-like structures. A clear indication for back-to-back correlations can be seen in p+A with a strong dependence on the p_T of the photons and the size of the system. In Pb+Pb collisions in plane elliptic flow has been observed. Results on transverse mass spectra of neutral pions measured at central rapidity are presented for impact parameter selected Pb+Pb collisions. In going from peripheral to medium central collisions there is a nuclear enhancement increasing with transverse mass similar to the Cronin effect, while for very central collisions this enhancement appears to be weaker than expected.

1. Introduction

The CERN experiment WA98 [1, 2] consisted of large acceptance photon and hadron spectrometers together with several other large acceptance devices which allow to measure various global variables on an event-by-event basis. The results presented here were obtained from an analysis of the data taken with p and Pb beams in 1995 and 1996 at 158 AGeV. The Pb-induced reactions have been subdivided into samples of different centrality using the transverse energy E_T measured in the MIRAC calorimeter. Photons are measured with the WA98 lead-glass photon detector, LEDA, which consisted of 10,080 individual modules with photomultiplier readout. The detector was located at a distance of 21.5 m from the target and covered the pseudorapidity interval $2.2 < \eta < 2.9$. Details about the photon measurement can be found in [2].

2. Azimuthal γ-γ-Correlations

We attempt to use azimuthal correlations of photons, which mainly originate from decays of neutral hadrons, π^0 or η, to gain information on the relative fraction of produced particles which still carry memory of the primary production process. Particles produced in a primary two-body collision of incoming nucleons must be correlated in transverse momentum due to local momentum conservation. Dominantly, especially if their individual transverse momenta are large, the particles will be anti-correlated in azimuthal angle. This is of course reminiscent of jet structure in the particle emission in high-energy physics. In fact, there is expected to be a smooth transition of this purely kinematical effect to mini-jet or jet production. At high enough transverse momenta, such an analysis

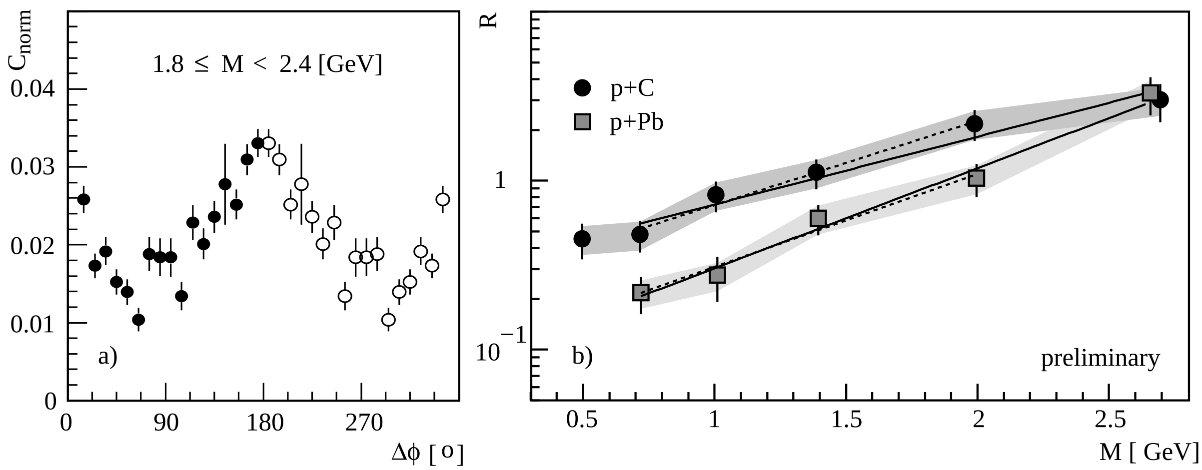

Figure 1. a) Exemplary $C(\Delta\phi)$ for p+C reactions. b) Ratio R of correlated to uncorrelated pairs at $\Delta\phi = 180°$ as function of the pseudo-mass M for p+C and p+Pb.

should allow to study minijet or jet production and eventually allow to investigate effects such as jet quenching. If the particles undergo secondary and further rescatterings, as in an equilibrated system, the memory of the correlation discussed above will be lost. Of course, anti-correlation of particle pairs will also be generated by collective effects like hydrodynamical elliptic flow. One therefore has to check how much the measured effects might be altered by flow phenomena. The γ-pairs are characterized by the difference of their azimuthal angle $\Delta\phi$ and the so-called pseudo-mass $M = p_{T1} + p_{T2}$. The correlation function C($\Delta\phi$) is introduced:

$$C(\Delta\phi) = \left.\frac{d^2N}{d\varphi_1 d\varphi_2}\right|_{p_{T1}+p_{T2}} \Big/ \left.\left(\frac{dN}{d\varphi_1}\frac{dN}{d\varphi_2}\right)\right|_{p_{T1}+p_{T2}}$$

The combinatorial background of uncorrelated pairs is obtained by event mixing taking into account different centrality and multiplicity classes. A clear correlation around $\Delta\phi = 180°$ can be seen for p+C (Fig 1a) and p+Pb reactions. It is assumed that the correlation originates from the direct production of π^0's in single binary collisions and that its strength therefore contains information about the ratio of directly produced to rescattered particles. The correlation function for the p+A data can be described by a Gaussian distribution, with the ratio R of correlated to uncorrelated pairs at $\Delta\phi = 180°$ increasing exponentially with the pseudo-mass M as shown in Figure 1b. Peripheral Pb+Pb data show a similar behaviour. Semi-peripheral and semi-central Pb+Pb data show a correlation function that is dominated by elliptic flow. The flow effects are evaluated by means of a Fourier expansion [3, 4].

$$\frac{1}{N}\frac{dN}{d(\Delta\phi)} = 1 + 2v_1^2\cos\Delta\phi + 2v_2^2\cos 2\Delta\phi, \tag{1}$$

The Fourier coefficient v_1 quantifies the directed flow, whereas v_2 quantifies the elliptic flow. The Fourier coefficients $v_n(n = 1, 2)$ can be extracted from the correlation function without determination of the reaction plane, and hence no event plane resolution correction has to be applied. Figure 2a shows v_2 for different cut-offs on the pseudo-mass as

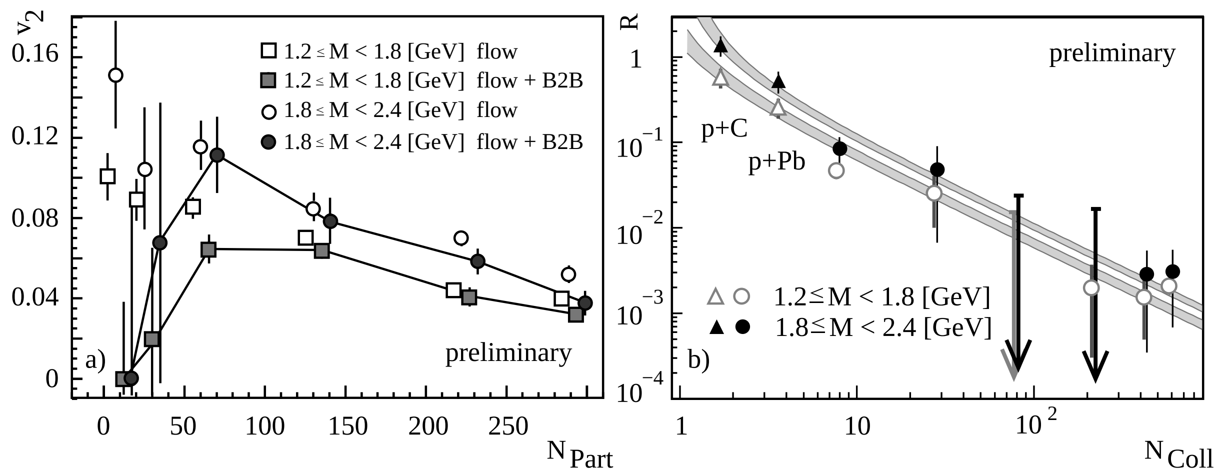

Figure 2. a) v_2 in Pb+Pb as function of the number of participants with and without consideration of back-to-back effects. b) Strength of back-to-back correlations in p+A and Pb+Pb reactions.

a function of different centralities in Pb+Pb with and without consideration of back-to-back effects. Especially in the more peripheral samples, elliptic flow does not describe the correlation completely. To compare the strength of an additional Gaussian-like correlation for different systems the ratio R of correlated to uncorrelated pairs at $\Delta\phi = 180^\circ$ is shown in Figure 2b as a function of the number of binary collisions. A parametrisation of the p+A data points with $R(N_{Coll}) = 1/(aN_{Coll} - 1)$ is extrapolated to the Pb+Pb data, which represents scaling of the number of correlated pairs with N_{Coll}. No deviation from this scaling is observed.

3. Centrality Dependence of π^0-Production

Already from the experimentally determined shape of transverse mass spectra of hadrons it is evident that heavy ion reactions are not merely a superposition of nucleon-nucleon collisions [5]. In p+A collisions the flattening of the transverse mass spectra compared to p+p (Cronin effect [6]) has been attributed to initial state multiple scattering of partons [7]. In the analysis of central reactions of Pb+Pb at 158 AGeV, however, it is seen that both predictions of perturbative QCD [8] and hydrodynamical parameterizations [9] can describe the measured neutral pion spectra reasonably well. The understanding of the relative contributions of the various soft and hard processes in particle production is especially important in view of the recent interest in the energy loss of partons in dense matter [10, 11], generally referred to as *jet quenching*, as a possible probe for the quark gluon plasma. Since one of the suggested experimental hints of jet quenching is the suppression of particle production at high transverse momenta, it is important to understand other possible nuclear modifications of particle production in detail.

More information in this respect may be gathered from the variation of the particle spectra for different reaction systems or different centralities [12]. Here we study the variations in absolute multiplicities. Especially at high transverse momentum one naïvely expects an increase of the multiplicity proportional to the number of collisions due to the importance of hard scattering. In fact, it was already observed in p+A collisions at beam energies of $200-400\,\mathrm{GeV}$ [6] that the increase in cross section at high transverse momenta is even stronger than the increase in the target mass. The ratios of the measured pion multiplicity distributions for two different samples (labeled X and Y) normalized to the number of collisions

$$R_{XY}(m_T) \equiv \frac{\left(E\frac{d^3N}{dp^3}(m_T)/N_{coll}\right)_X}{\left(E\frac{d^3N}{dp^3}(m_T)/N_{coll}\right)_Y} \qquad (2)$$

is introduced.

The ratio of peripheral Pb+Pb collisions to p+p increases strongly with increasing transverse mass – this is in line with the Cronin effect discussed above. A similar trend is observed when going from peripheral to medium-central data. In addition, the pion production is seen to increase roughly proportional to the number of collisions even at low transverse mass. Going from medium central to central the trend is reversed: the ratio decreases with increasing transverse mass and the pion multiplicities increase more weakly than the number of collisions. The ratio of very central to central collisions shows an indication of a similar effect although not very significant.

Neither results of HIJING[13] calculations nor a more refined pQCD calculation [14] can reproduce the experimental data. Here the ratios are all ≥ 1 and thus do not explain the centrality dependence observed.

REFERENCES

1. WA98 Collaboration, *Proposal for a large acceptance hadron and photon spectrometer*,1991, Preprint CERN/SPSLC 91-17, SPSLC/P260; WA98 Collaboration, M.M. Aggarwal et al., Nucl. Phys. **A 610**, 200c (1996).
2. WA98 Collaboration, M.M. Aggarwal et al, nucl-ex/0006007, submitted to Phys. Rev. C.
3. A. M. Poskanzer ans S. A. Voloshin, Phys. Rev. **C58**, 1671 (1998).
4. J. Y. Ollitrault, Phys. Rev. **D 46**, 229 (1992).
5. WA80 Collaboration, R. Albrecht et al., Eur. Phys. J. C **5**, 255–267 (1998).
6. D. Antreasyan, et al., Phys. Rev. D **19**, 764 (1979).
7. M. Lev and B. Petersson, Z. Phys. **C21** (1983) 155–161; A. Krzywicki et al., Phys. Lett. **B85** (1979) 407–416.
8. WA98 Collaboration, M. M. Aggarwal et al., Phys. Rev. Lett. **81** (1998) 4087; Phys. Rev. Lett. **84** (2000) 578 (erratum); X.-N. Wang, Phys. Rev. Lett. **81** (1998) 2655.
9. WA98 Collaboration, M. M. Aggarwal et al., Phys. Rev. Lett **83** (1999) 926.
10. X.-N. Wang and M. Gyulassy, Phys. Rev. Lett. **68** (1992) 1480; X.-N. Wang, Phys. Rev. C **58** (1998) 2321.
11. R. Baier, D. Schiff, and B. G. Zakharov Ann. Rev. Nucl. Part. Sci. **50** (2000) 37-69 and references therein.
12. M. M. Aggarwal et al., Eur.Phys.J. **C 23** (2002) 225-236.
13. X.-N. Wang and M. Gyulassy, Phys. Rev. **D 44**, 3501 (1991); Comp. Phys. Comm. **83**, 307 (1994).
14. E. Wang, and X.-N. Wang, preprint nucl-th/0104031.