Dilepton production in heavy-ion collisions at the CERN-SPS

presented by

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abstract

NA38 results on dimuon production in proton-uranium, oxygen-uranium, and sulphur-uranium collisions, at 200 GeV per nucleon are presented. Experimental data is consistent with the formation of a quark-gluon plasma in high energy density interactions, but other interpretations cannot be ruled out yet.

Dimuons produced in ultrarelativiste heavy-ion collisions are studied at CERN mainly in two experiments: NA34 and NA38.

NA34 experimental set-up has a large acceptance for muon pairs and has recorded a few thousand events in this very important low mass range. No report can be made yet, as the analysis is still in progress.

NA38 measures muon pairs with high luminosity. I will devote my talk to present the NA38 results obtained so far in pU, OU and SU at 200 GeV per nucleon in the following order: 1) Experimental set-up and data-taking; 2) The Psi/continuum ratio; 3) P_t distributions; 4) E_t distributions; 5) ϕ and $\omega\rho$ production; 6) The ratio ψ'/ψ; 7) Conclusions.

Due to limitations of space in the written form of this contribution I will avoid most of the figures. An updated list of references is given at the end.

1) Experimental set-up and data-taking

NA38 uses the NA10 dimuon spectrometer, an electromagnetic calorimeter build up with lead and scintillating plastic fibres and an active target. Average beam intensities used were of the order of 1.5×10^7/second (10 triggers/burst) for protons, 1.0×10^7/second (600 triggers/burst) for oxygen and 3×10^6/second (400 triggers/burst) for sulphur.

The dimuon spectrometer accepts dimuons in the rapidity region $(-0.2, 0.9)$ in the centre of mass or $(2.9, 4.0)$ in the laboratory frame.

The spectrometer, the hadron absorber geometry and the trigger accept muons with transverse momentum larger than 0.3 GeV/c and longitudinal momentum larger than 3 GeV/c.

The mass resolution at the Psi is $\sigma_\psi \approx 0.14 GeV/c^2$ (or 0.33 fwhm) and the P_t resolution $\sigma P_t \approx 0.11 GeV/c$ (or 0.30 fwhm).

The electromagnetic calorimeter is a 12 cm long instrument of lead (2/3 volume) and plastic scintillating optical fibres (1/3 volume) covering the pseudorapidity region between 1.9 and 4.1.

The active target is composed of 10 subtargets (17 for protons) accounting for 20% interaction probability.

The beam hodoscope only accepted one incoming particle in a time interval of 20 ns.

NA38 took data in 1986 (O U), 1987 (pU, SU), 1988 (pU) and 1990 (SU). The events analysed so far correspond to the 1986, 1987 and 1988 runs. They contain 6852 Psi's produced in pU collisions, 5573 in OU and 9975 in SU, after cuts. The number of opposite sign reconstructed dimuons with mass larger than $1.7 GeV/c^2$ is about 27×10^3 in pU, 48×10^3 in OU and 73×10^3 in SU.

2) The Psi/Continuum ratio

The ratio $R = N_\psi$/Ncontinuum has been measured in pU, OU and SU from the fits to the invariant dimuon spectra in the range 1.7 to $5.1 GeV/c^2$ after the subtraction of the background (estimated by $2\sqrt{N^{++} \times N^{--}}$). The number of continuum events in the denominator has been taken from the fit in the mass interval $(M_\psi - 3\sigma_\psi, M_\psi + 3\sigma_\psi)$. Results, integrated in P_t and E_t, are $R = 22.9 \pm 1.5$(pU),15.5 ± 1.0(OU) and 17.0 ± 0.8 (SU).

How do these ratios change with E_t or P_t ?

a) Fig. 1 shows the ratio R as a function of the neutral transverse energy E_t for both OU and SU collisions. The corresponding region for pU is also indicated. Experiment shows a clear Psi suppression at high E_t. A possible different behaviour between OU and SU cannot be ruled out from the data. The Bjorken energy density ε appears as a useful common variable: data points from different reactions come close to a single line.

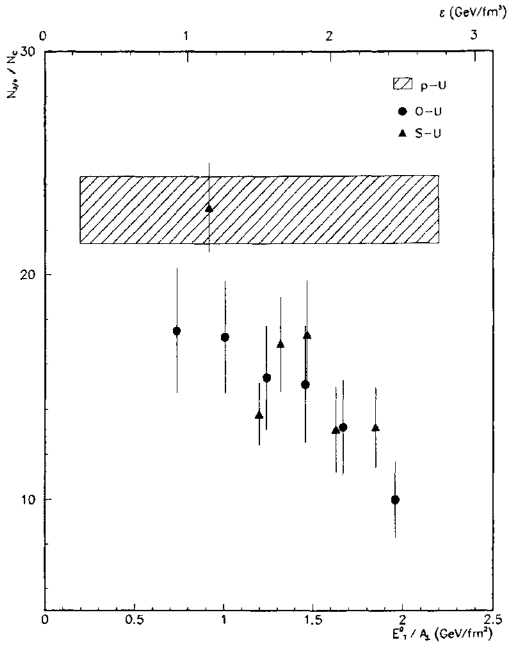

Fig.1 . Ratio N_ψ/Ncontinuum as a function of E_t (divided by the overlap area $A_\perp$) for pU, OU, and SU collisions. The Bjorken energy density scale is also given ($\tau_0 = 1 fm$).

b) Fig. 2 shows the ratio R' of two P_t distributions for the Psi, corresponding to two extreme E_t^0 bins ($E_t^0 < 20$GeV and $E_t^0 > 52$GeV), normalized to the number of continuum events. The suppression of the Psi is large at low P_t but diminishes at large transverse momentum. From the data one cannot conclude if $R'(P_t)$ exceeds 1 with increasing P_t (as one could expect from parton scattering) or if $R'(P_t)$ approaches 1 as a limit (as implied by QGP models).

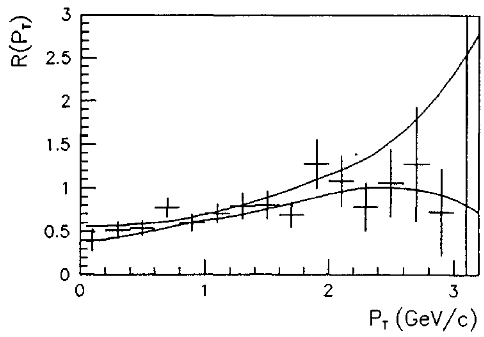

Fig.2 . $R'(P_t) = (N_\psi/N_c)_{E_t^0>52\text{GeV}}/(N_\psi/N_c)_{E_t^0<20}$ GeV for OU collisions.

3) P_t distributions

Data on $< P_t >$,$< P_t^2 >$ as a function of E_t can be found in (5) for OU and SU collisions at 200 GeV, both for the Psi and the dimuon continuum. It may be interesting to fit the transverse mass squared distributions $dN/dm_t^2 = dN/dp_t^2$ to the form $\exp(-m_t/T)$ where T has the meaning of a temperature in termodynamical models. This has been done for the Psi produced in OU collisions. As a function of the energy density ε, using the relation $\varepsilon = kT^\alpha$, the result of the fit was, surprinsingly, $T = 3.9 \pm 0.6$ (Fig. 3). If the fitted value of k, on the other hand, is interpreted as a Boltzmann constant then the formation time τ_0 used to determine the volume in the denominator of the expression
$\varepsilon = E_t/\text{volume} = \Delta E_t/(\Delta y \cdot \text{Transverse area} \cdot \tau_0)$
is about 1/4 fermi.

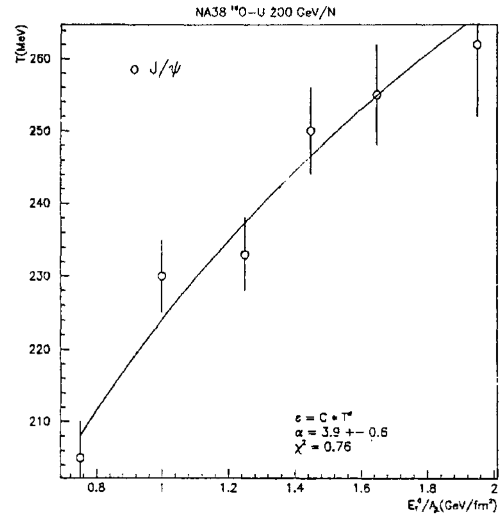

Fig.3 . Fit of the form $\varepsilon \sim T^\alpha$ for Psi events produced in OU collisions, as explained in the text.

4) E_t distributions

The Psi suppression appears as a low P_t phenomenon expressed in the depletion of the ratio Psi/Continuum with increasing E_t. Three arguments have been used against an interpretation of this depletion as a continuum enhancement. First, the continuum form dN/dM remains constant with E_t. Second, the continuum spectrum dN/dE_t can be shown to be proportional to dN/dE_t for minimum bias events (proportionality constant $\sim N_{AB}$, number of independent nucleon-nucleon collisions $\sim E_t$), as one would expect from independent collisions. Third, the dependence of the ratio R =Psi/Continuum on E_t for Psi and for continuum events (6).

5) ϕ and $\omega\rho$ production

A preliminary analysis of the low mass region in pU and SU collisions has shown the following features (fig. 4): - The ratio $(\omega+\rho)$/continuum remains constant with E_t and is identical in pU and SU collisions. - The ratios ϕ/continuum and $\phi/(\omega+\rho)$ increase with increasing E_t and from pU to SU collisions. - The ratio $\phi/(\omega+\rho)$, increasing with E_t, is larger at higher P_t.

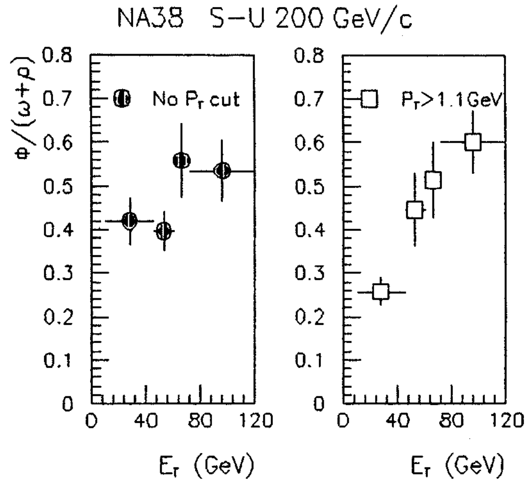

Fig.4 . Ratio $\phi/(\omega+\rho)$ in SU collisions at 200 GeV as a function of E_t, uncorrected for acceptance.

6) The ratio ψ'/ψ

Current wisdom states that if Psi suppression is caused by nuclear absorption, then the ratio $N_{\psi'}/N_{\psi}$ should be constant from pU to OU and SU collisions (as $\alpha_{\psi}=\alpha_{\psi'}$ from E772 measurements).

On the other hand, if Psi suppression is caused by a quark gluon plasma colour screening mechanism, then one should expect the ratio $N_{\psi'}/N_{\psi}$ to decrease from pU to OU and SU collisions because the radius of the ψ' is larger than the ψ radius.

With present data from NA38 we are still unable to decide between these two scenarios. One should nevertheless recall that a large fraction of Psi's come from $\chi\to\psi\gamma$ decays and that $R_{\chi}>R_{\psi}$. This could therefore limit a significant experimental signal.

7) Conclusions

NA38 results in pU, OU and SU collisions at 200 GeV/nucleon are consistent with the production of a quark-gluon plasma in high energy density interactions. But other interpretations (e.g. nuclear absorption models) cannot be completely ruled out yet. More data is surely needed.

References

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DISCUSSION

Q. **M. Jacob** *(CERN)*: The P_T cut-off on the W and the Y is introduced to extract the original from an otherwise overwhelming background.* By which magic the new values without P_T cut have been obtained?

*Ref: Baldissen's Thesis, 1990.

A. **J. M. Gago**: No magic. The values can now be extracted without P_T cut.