LOW-MASS ELECTRON PAIR PRODUCTION IN Pb-Au COLLISIONS AT THE CERN SPS

JANA SLÍVOVÁ FOR THE CERES/NA45 COLLABORATION
Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

Recent results from the CERES experiment are reported. Improvements in external particle tracking and detailed Monte Carlo studies of combinatorial background were essential for progress in many directions. The enhancement of low-mass e^+e^- pair production in 158 AGeV/c Pb-Au collisions has been corroborated with the new data set and we will report in some detail on its dependence on pair mass, transverse momentum and centrality. The enhancement of the dilepton yield cannot be explained without the inclusion of non-trivial modifications of the in-medium properties of the vector mesons created in hot and dense hadronic matter. To discriminate between different theoretical approaches, the CERES spectrometer was upgraded recently with a radial drift TPC to improve considerably the mass resolution.

1 Introduction

Ultra-relativistic heavy-ion collisions are the only tool to study in the laboratory nuclear matter at high density and temperature and to verify lattice QCD predictions of a phase transition into a plasma of deconfined quarks and gluons. Approaching the phase boundary at T$\approx$150 MeV also restoration of chiral symmetry is predicted to happen. Close to this point properties of vector mesons are likely to be affected.

An ideal probe of such extreme states of matter seems to be dileptons. Since produced during the whole evolution of the collision, dileptons are a window to several stages that the interacting system undergoes. Their mean free path is much larger than the size of fireball and thus they carry direct information from the earliest stages of the collision to the detectors. Moreover they offer the possibility to study vector mesons via their electromagnetic decays into dileptons.

2 CERES Experimental Setup

CERES is an experiment dedicated to the measurement of low-mass e^+e^- pairs including the low pair-$p_\perp$ region. It is optimized to measure e^+e^- pairs in the mass range from about 50 MeV/c^2 up to 2 GeV/c^2 near mid-rapidity ($2.1< \eta <2.65$) with full azimuthal acceptance.

There are two main experimental difficulties in the low-mass region which CERES has to deal with. The number of produced e^+e^- pairs compared to the number of charged hadrons is only of order 10^{-5}. This was attacked by using two RICH detectors with high Čerenkov threshold ($\gamma_{th} \approx 32$) and the spectrometer is 95 % hadron blind. The large amount of photons produced in the collision and e^+e^- pairs coming from their conversions causes the second difficulty. That we fight by minimizing material within the spectrometer acceptance.

The external tracking is provided by two radial silicon drift detectors (SDD) placed about 10 cm behind the segmented Au target and a multi-wire proportional chamber at the end of the spectrometer. The SDD's allow not only precise vertex determination but they are also a powerful tool for rejection of γ-conversions by dE/dx cut and for measurement of charged particle multiplicity.

For momentum determination, there is an azimuthally symmetric magnetic field between the two RICH detectors. The first RICH remains free of magnetic field, which is very important for recognition and rejection of π^0-Dalitz decays and γ-conversions.

3 Low-mass e^+e^- pair analysis

Due to the finite acceptance and track reconstruction efficiency, it happens frequently that only one particle from an e^+e^- pair is reconstructed. Partially reconstructed pairs give rise to combinatorial background and have to be rejected, while keeping a high reconstruction efficiency for the pairs of interest.

For an accurate understanding of background sources detailed Monte Carlo studies were done [1] [2]. Electron pairs of different origin are passed through a GEANT simulation of the spectrometer and the output is digitized in the same way as data. Finally we overlay the results on real events. The data and simulation are in very good agreement and we understand all significant sources of background and rejection mechanisms. We found out that 70% of the remaining background originates from π^0-Dalitz decays and 30% from γ-conversions.

After all steps the signal-to-background ratio for pairs with m_{ee}>200 MeV/c^2 is 1/13 and mean reconstruction efficiency 13%. The signal is obtained by subtracting the number of like-sign and unlike-sign pairs. Assymetry between these two samples is less than 1%.

4 Results

As previously reported [3] [4] CERES observed enhanced e^+e^- production in the mass region between $2m_\pi$ and the ρ/ω pole. In 1996 we took 42 million events in Pb-Au collisions at 158 AGeV/c.

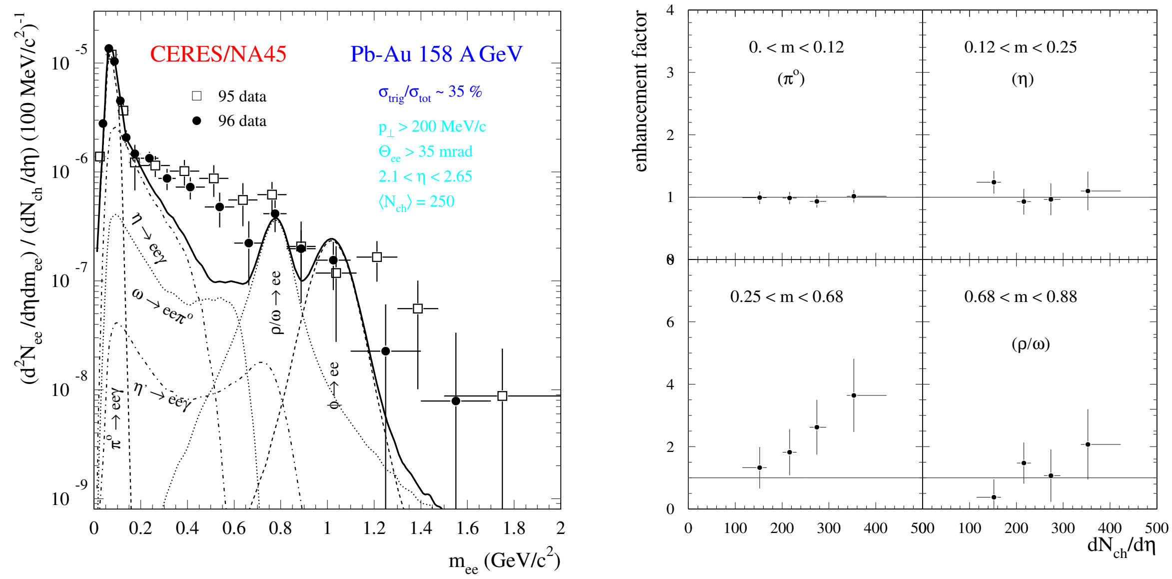

Figure 1: Inclusive e^+e^- mass spectrum compared to the expected contribution from hadron decays (left). Enhancement factor $= (N^{exp}_{e^+e^-})_m/(N^{hadr}_{e^+e^-})_m$ in different mass ranges as a function of $dN_{ch}/d\eta$ (right).

Fig.1 (left) shows the resulting inclusive e^+e^- mass spectrum for '96 data and the lower statistics '95 data. They are compared with the expectations from hadron decays, taking into account all known properties of the parent particles observed by other CERN experiments in Pb-induced collisions. The enhancement factor defined as $N^{exp}_{e^+e^-}/N^{hadr}_{e^+e^-}$ within the mass range $0.25<m_{ee}<0.7$ GeV/c^2 is 2.6±0.5(stat.)±0.6(syst.) for '96, respectively 3.9±0.9(stat.)±0.9(syst.) for '95 data.

The centrality dependence of the pair yield is an important tool to investigate the origin of the e^+e^- pairs. If hadron decays are the only source, the data should scale linearly with charged multiplicity as indicated by the horizontal line in Fig.1 (right). Since the enhancement factor is normalized to hadronic sources, there must be no enhancement for Dalitz decays, which is confirmed in the two lowest mass bins in Fig.1 (right). However, the mass bin between 250 MeV/c^2 and $m_{\rho/\omega}$ shows stronger than linear dependence on centrality.

We also observe that the enhancement is most pronounced for pairs with a small transverse momentum: for pairs with $p_\perp^{ee}<500$ MeV/c the enhancement factor is 5.0±1.5, while for pairs with $p_\perp^{ee}>500$ MeV/c is only very modest.

5 Conclusion and Outlook

The '96 data corroborated the enhancement of low-mass e^+e^- pair yield in the mass region between $2m_\pi$ and ρ/ω resonance. It is most pronounced for low pair-$p_\perp$ and has stronger than linear multiplicity dependence.

In order to explain the observed enhancement, an inclusion of $\pi\pi$ annihilation of thermal origin is not sufficient and non-trivial modifications of the in-medium properties of vector mesons created in hot and dense hadronic matter have to be taken into account [5]. The Brown-Rho scaling approach within which the mass of ρ meson drops linearly with baryon density gives succesful description of the data. However, models including hadronic rescattering processes (collisional broadening) describe the observed data equally well.

To discriminate between different theoretical approaches and to study properties of ω and ϕ mesons the spectrometer was upgraded with a radial TPC of considerably improved mass resolution ($\sigma_m/m < 2\%$ in the $\rho/\omega/\phi$ mass region) and CERES will continue till year 2000 at two different beam energies 40 AGeV/c and 158 AGeV/c and high statisctics.

Acknowledgments

The authors wish to thank the CERN staff for the good support. We are grateful for the financial support by the German BMBF, the US DoE, the MINERVA foundation, the Israel Science Foundation and the EC under contract FMBICT972104.

References

1. B. Lenkeit, Doctoral Thesis, Heidelberg, 1998.
2. B. Lenkeit et al. (CERES Collaboration), Proceedings Quark Matter, Torino, 1999.
3. G. Agakichiev et al. (CERES Collaboration), *Phys. Rev. Lett.* **75**, 1272 (1995).
4. G. Agakichiev et al. (CERES Collaboration), *Phys. Lett.* B **422**, 405 (1998).
5. R. Rapp, Proceedings Quark Matter, Torino, 1999.