FIRST RESULTS FROM CERES/NA45 ON LOW-MASS ELECTRON PAIR PRODUCTION IN PB+AU COLLISIONS AT THE CERN SPS

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We report preliminary results of the first measurement of low-mass electron pairs in 160 GeV/nucleon Pb+Au collisions at central rapidities in a wide multiplicity range. The motivation for this effort derives from a new source of low-mass dileptons recently observed in S+Au and S+W collisions by CERES and HELIOS/3, respectively. The results obtained in the analysis of the Pb+Au data confirm our previous finding that pair production in the mass range $0.2 < m_{ee} < 1.5$ GeV/c^2 is enhanced compared to the contributions from hadron decays while no significant excess could be observed for $m_{ee} \lesssim 2m_\pi$. A comparison of the results for different multiplicity bins indicates a non-linear dependence of the e^+e^--yield on the accompanying charged particle densities.

1 Introduction

The production of lepton pairs is commonly accepted as a promising probe to study the dynamical evolution of nuclear collisions as they interact only electromagnetically. They are produced during the entire space-time evolution of the system, beginning at the early, hot stage [1] up to the point where the hadrons cease to interact. Later, a large amount of additional lepton pairs is produced by the electromagnetic decays of hadrons.

CERES is the only experiment measuring e^+e^--pairs emitted in heavy ion collisions at SPS energies. It covers the mid-rapidity region and a very broad range of transverse momenta $p_\perp$ [2,3,4]. It employs a spectrometer whose essential components are two RICH detectors, located in front of and behind a short superconducting solenoid, with external tracking provided by two silicon radial-drift detectors and a MWPC with two-dimensional pad readout.

In previous measurements it was found that the dilepton yield from S+Au [5] and S+W [6] collisions is enhanced compared to an extrapolation of the emission rate from p-induced reactions. For an overview see Refs. 7,8.

This result has triggered intense theoretical activity. The data in the mass region $0.2 < m_{ee} < 0.5$ GeV/c^2 have been quantitatively explained as resulting from $\pi\pi$-annihilation into e^+e^- in combination with a decrease of meson masses – in particular of the ρ meson – in the hot and dense fireball as a precursor of chiral symmetry restoration [9,10]. A detailed discussion of these models can be found elsewhere in these proceedings [11].

This talk reports on the first analysis of the data taken with the Pb beam at the CERN SPS taken in autumn 1995.

2 Experimental setup

The CERES spectrometer (see Fig. 1) covers the pseudo-rapidity region $2.1 \leq \eta \leq 2.7$ with full azimuthal symmetry. Following the experience gained with proton and sulfur beams the spectrometer was upgraded to cope with the much larger charged-particle densities produced in Pb-induced collisions. A detailed description of the spectrometer and its upgrade are given in Refs. 3,4,12,13. here we summarise the most relevant features of the detector and give a brief account of the 1995 running conditions.

Particle identification and tracking are based on two azimuthally symmetric RICH detectors

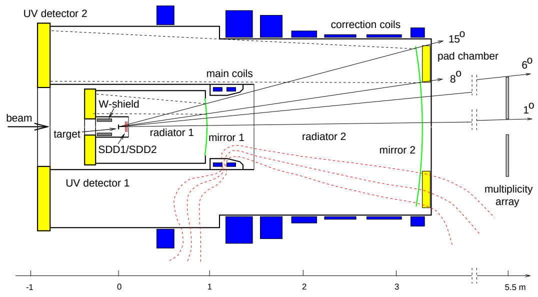

Figure 1: Schematic view of the upgraded CERES spectrometer.

with a Cherenkov threshold ($\gamma_{th} \simeq 32$) high enough to substantially suppress signals from the large number of hadrons produced in the collision. A superconducting double solenoid between the two detectors provides an azimuthal deflection for momentum and charge determination, leaving the polar angle θ unchanged. The magnetic field in the region of the inner RICH radiator is compensated to nearly zero preserving the information on the original direction of the particles. The Cherenkov photons from the RICH radiators are registered in two UV-detectors upstream of the target on two-dimensional arrays of about 50000 pads each.

Since 1994 stand-alone external tracking into RICH-1 has been incorporated by a closely spaced doublet of two silicon-drift detectors (SDD) at a distance of 10 cm from the target [14,15]. In addition to the very precise vertex reconstruction these detectors are used to identify close electron pairs from conversions and Dalitz decays; an essential tool to reduce the increased combinatorial background in central Pb+Au collisions. In order to help the pattern recognition in RICH-2 a pad chamber was installed in 1995. It consists of a MWPC with pad readout. The chamber is placed behind the mirror of RICH-2, at a distance of ~ 3.3 m from the target, and covers the pseudo-rapidity interval $2.0 < \eta < 2.7$.

The results presented here were obtained from the analysis of data taken during the SPS Pb-beam period in autumn of 1995. A total of 17 million events of Pb+Au collisions were recorded on tape, with a charged particle rapidity density $dn_{ch}/d\eta \gtrsim 100$, corresponding to the 40% most central collisions. Since the data cover a large range of impact parameters, the centrality dependence of the e^+e^--yield can be studied.

3 Data analysis

The doublet of silicon-drift detectors allows us to reconstruct the vertex for more than 98% of all interactions. The reconstruction of electron rings in the RICH detectors was done without prior knowledge of the Cherenkov ring centers. After removing electronic noise and ionization clusters, the entire plane of pads is searched for ring candidates with asymptotic radius using a point-to-ring Hough transformation. In the vicinity of these candidates, the reconstructed single-photon hits are used to determine the ring centers by a *robust* fitting procedure [16]. The rings in both RICH detectors are then combined to tracks, identified by their common polar angle with respect to the beam axis. Two tracks with opposite charge sharing the same unresolved double ring in the first RICH detector are rejected as photon conversion candidates. Requiring that every ring in RICH-1 has a corresponding hit in *both* silicon-drift detectors virtually eliminates late conversions occurring after the first silicon detector. The matching of the ring in RICH-2 to a hit in the pad chamber removes most of the fake tracks left. Finally tracks with a transverse momentum smaller than 175 MeV/c are rejected. All remaining tracks are combined into pairs, requiring a minimum opening angle of 35 mrad.

The combinatorial background originating from unrecognised partners of low-mass Dalitz and conversion pairs is *the* central problem of the experiment. It is to a large extent removed by recognising a close doublet of rings in RICH-1 and double pulse-height of hits in the two silicon drift detectors. The combinatorial background (B) in the sample is determined by the like-sign pairs, as the geometrical mean of the numbers $N_{e^+e^+}$ and $N_{e^-e^-}$, i.e., $B = 2\,(N_{e^+e^+} \cdot N_{e^-e^-})^{1/2}$. The pair signal S is then obtained by subtracting the like-sign contribution from the unlike-sign pairs as $S = N_{e^+e^-} - B$.

4 First results on e^+e^--pair production in Pb+Au collisions

After background subtraction the pair sample consists of 1330 ± 70 reconstructed e^+e^--pairs with $m_{ee} < 200$ MeV/c^2 and 640 ± 140 with $m_{ee} > 200$ MeV/c^2. The signal-to-background ratio is 1/1 and 1/15, respectively. The invariant

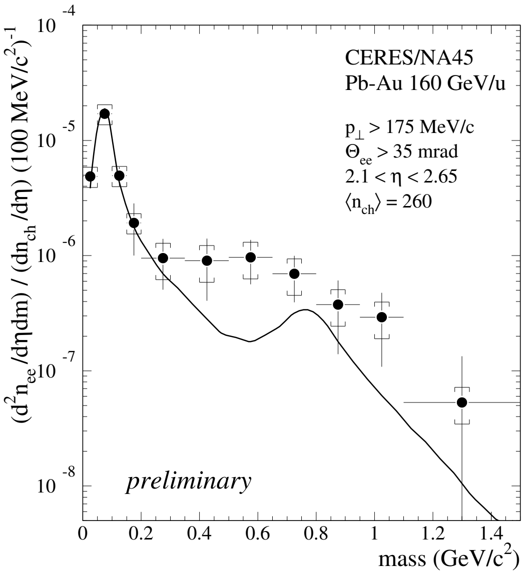

Figure 2: Preliminary mass spectrum of inclusive e^+e^--pairs in 160 GeV/u Pb+Au collisions for the full data sample. Systematic (brackets) and statistical errors (bars) are plotted independently of each other. The solid line shows the summed contributions from hadron decays.

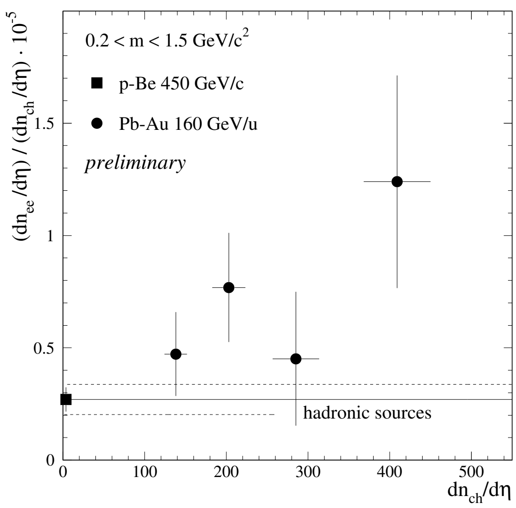

Figure 3: Pair density per charged particle density as a function of charged particle density for $0.2 < m_{ee} < 1.5$ GeV/c^2 (right); the first data point indicates the result for p+Be [5].

mass spectrum for the full data sample is shown in Fig. 2. It is normalised to represent *pair density per charged-particle density* within the rapidity acceptance of $2.1 < y < 2.65$ at an average charged-particle density of $dn_{ch}/d\eta = 260$. The data are corrected for pair reconstruction efficiency. Since the efficiency drops by 70% over the observed $dn_{ch}/d\eta$ range we split the data into 4 multiplicity bins and corrected each bin individually. In this preliminary analysis, the systematic error has been estimated conservatively to be ±35% of the e^+e^--pair yield for $m_{ee} > 0.2$ GeV/c^2; it is dominated by uncertainties in the multiplicity dependence of the reconstruction efficiency.

Also shown in Fig. 2 is the sum of all contributions from hadron decays. It has been calculated including all known hadronic sources, i.e., the π^0, η, η', ρ, ω, and ϕ. The information on cross section, branching ratio, form factors, rapidity and $p_\perp$distributions needed was measured by several experiments (see also Ref. [13]). The particle ratios of these "conventional" sources are assumed to be independent of the collision system and to scale with the number of produced particles. This is in general supported by the available data [7].

We observe that for masses above 200 MeV/c^2 the mass spectrum deviates from the expectations and the observed yield is much larger than the one predicted from hadron decays. The excess sets in at masses of about 200 MeV/c^2 and persists up to the highest masses covered in the experiment. This enhancement is very similar in shape to that observed in the S+Au case [5]. The enhancement factor, defined as the ratio of the integral of the data over the integral of the predicted sources, is found to be $2.6 \pm 0.55(\textit{stat.}) \pm 1.0(\textit{syst.})$ in the mass region $0.2 < m_{ee} < 1.5$ GeV/c^2.

The dependence of the observed yield on the associated hadron multiplicity density in the event may help to disentangle different contributions to the radiation of e^+e^--pairs. Thermal radiation from either partons or pions should show a quadratic dependence with the charged particle rapidity density for a fixed interaction volume [18], reflecting the emission rate to be proportional to the product of the particle- and anti-particle densities in the reaction. Quantitative studies of this characteristic behaviour suffer from the limited statistics of our present Pb+Au data sample. However, one can derive a first indication of a non-linear dependence as illustrated in Fig. 3 where the obtained pair density per charged particle density for 4 equally populated bins in multiplicity is presented. The first data point indicates the result from our p+Be data sample where no excess over hadronic sources has been observed [5]. The horizontal line represents a linear scaling with multiplicity. The Pb+Au data, however, favour a nonlinear dependence on the accompanying particle densities; the hypothesis of *linear* scaling can be excluded at a 90% confidence level.

The enhancement in the mass region $0.2 < m_{ee} < 1.5$ GeV/c^2 in the 10% most central Pb+Au collisions is $4.6 \pm 1.8(\textit{stat.}) \pm 2.7(\textit{syst.})$, hence of similar magnitude and shape as in the S+Au sample, where the enhancement over the hadronic contributions was found to be $5.0 \pm 0.7(\text{stat.}) \pm 2.0(\text{syst.})$. This can be understood if the enhancement scales with the energy density since the energy density reached in central Pb+Au collisions is about the same as in central S+Au collisions [19].

5 Conclusion

First in-beam experience proves an excellent performance of the upgraded CERES experiment. During a first run in 1995 we have measured low-mass electron pairs in 160 GeV/nucleon Pb+Au collisions. Preliminary results show an excess of low-mass electron pairs over the expected contribution from hadron decays. The characteristic features of the excess are: (i) its onset at a mass $m_{ee} \sim 2m_\pi$, (ii) its extension to the region around the ρ meson, and (iii) indications of a non-linear dependence on multiplicity. These results confirm the enhancement and its characteristic features previously observed in S+Au collisions. A large fraction of the excess has been explained in theoretical studies by $\pi\pi$-annihilation into e^+e^-. However, a proper quantitative description of the excess is only achieved if a decrease of the meson masses (in particular of the ρ meson) inside the hot and dense medium is introduced. Studies to increase the pair reconstruction efficiency are in progress and we expect to double our pair sample in the current data set. After having improved the rate capability of the spectrometer, we will increase our data sample by a factor of 5-10 in the 1996 run. We are planning to improve the mass resolution to about 1% at the ρ/ω resonance by adding a TPC behind the existing spectrometer.

Acknowledgement

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References

1. E. V. Shuryak, Phys. Lett. **78B** (1978) 150
2. Proposal to the SPSC, CERN SPSC/88-25/P237 and SPSC/88-40/P237/Add 1
3. Proposal to the SPSLC, CERN SPSLC/94–1/P280
4. R. Baur *et al.*, Nucl. Inst. Meth. **A343** (1994) 87
5. G. Agakichiev *et al.*, Phys. Rev. Lett. **75** (1995) 1272
6. M. Masera *et al.*, Nucl. Phys. **A590** (1995) 93c
7. A. Drees, Quark Matter 96, Proc. Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions, Heidelberg 1996, Nucl. Phys. **A** (in print)
8. I. Tserruya, Nucl. Phys. **A590** (1995) 127c
9. G.Q. Li, C.M. Ko and G.E. Brown, Phys. Rev. Lett. **75** (1995) 4007
10. W. Cassing, W. Ehehalt and C.M. Ko, Phys. Lett. **B363** (1995) 35
11. K. Redlich, these proceedings.
12. CERES/NA45 Report to Cogne 1995, CERN SPSLC/95–20/M542
13. G. Agakichiev *et al.*, Quark Matter 96, Proc. Int. Conf. on Ultra-Relativistic Nucleus-Nucleus Collisions, Heidelberg 1996, Nucl. Phys. **A** (in print)
14. U. Faschingbauer *et al.*, Nucl. Inst. Meth. **A377** (1996) 362
15. P. Rehak *et al.*, Nucl. Inst. Meth. **A377** (1996) 367
16. G. Agakichiev *et al.*, Nucl. Inst. Meth. **A371** (1996) 243
17. M. Bourquin and J. M. Gaillard, Nucl. Phys. **B114** (1976) 334
18. V. Černý, P. Lichard und J. Pišút, Z. Phys. **C31** (1986) 163
19. S. Margetis *et al.*, Nucl. Phys. **A590** (1995) 355c