Preliminary results from the 2000 run of CERES on low-mass e^+e^- pair production in Pb-Au collisions at 158 A GeV

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Abstract. CERES has measured low-mass e^+e^- pairs in Pb-Au collisions at 158 A GeV in the year 2000 Pb run at the SPS with the goal of shedding more light onto the origin of the previously observed low-mass pair enhancement. The spectrometer was upgraded with a radial TPC to improve the mass resolution. A very effective rejection of the combinatorial background is achieved using the combined information of the two RICH detectors, the dE/dx signal of the doublet of silicon drift chambers, and the TPC track dE/dx information. The various steps and the current status of the data analysis are presented.

1. Introduction

The main aim of the CERES experiment is to investigate the behavior of nuclear matter under extreme conditions of density and temperature. The experiment is dedicated to the measurement of low-mass ($m_{ee} \lesssim 1GeV/c^2$) e^+e^- pair production in heavy-ion collisions at the CERN SPS. Previous CERES results [1, 2, 3] show a strong enhancement of e^+e^- pair production in the mass region m $= 200-600MeV/c^2$ over the expectation from meson decays. Possible explanations of the CERES results (discussed in section 4) invoke the in-medium modifications of the ρ meson and hint at chiral symmetry restoration. The best way to further explore this topic is to study the dilepton decays of the ρ, ω and ϕ mesons. The original design of the CERES spectrometer didn't allow for that due to the low mass resolution of order of $\sim$ 7% at the ρ mass. To improve the mass resolution, the CERES spectrometer has been upgraded by the addition of a radial TPC downstream of the original spectrometer. The upgraded spectrometer offers also the unique possibility of measuring simultaneously the leptonic and charged kaon decay modes of the ϕ meson which is very sensitive to chiral symmetry restoration effects [4]. Low-mass pairs in $Pb-Au$ collisions at 158 $A\ GeV$ were measured with the upgraded spectrometer at the end of year 2000.

2. Experimental set-up

The year 2000 setup of the CERES spectrometer is shown in Figure 1. A closely-spaced doublet of Silicon Drift Chambers (SiDC), located about 10 cm downstream

§ For the full CERES collaboration list see A. Marin (D. Adamova *et al.*) in this volume.

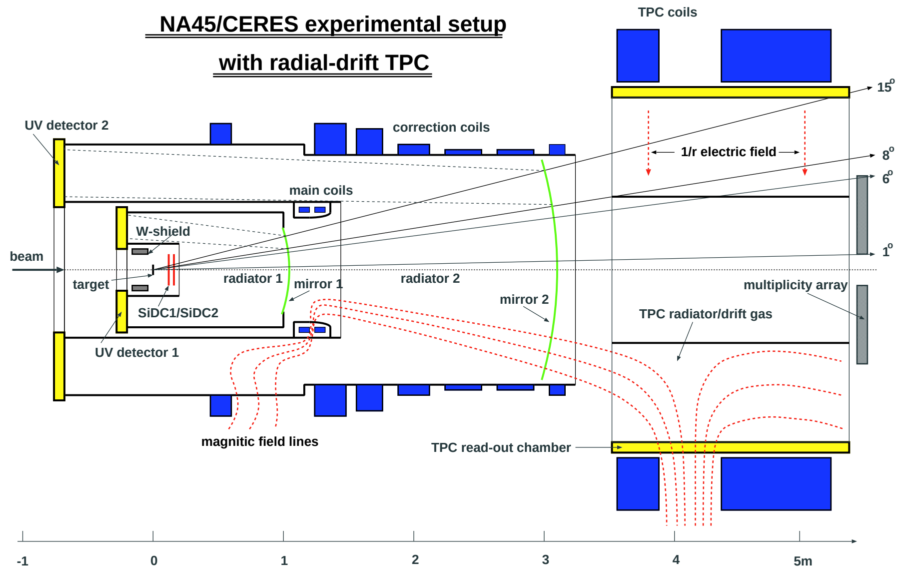

Figure 1. Schematic view of the upgraded CERES spectrometer.

of the target, provides a very precise vertex position and track angle reconstruction. Two Ring Imaging Cherenkov (RICH) counters covering the pseudorapidity region $2.1 \leq \eta \leq 2.7$ with full azimuthal symmetry are used for the electron identification. The Cherenkov threshold of the CH_4 radiator gas ($\gamma_{th} \simeq 32$) is high enough to suppress signals from the large number of hadrons produced in the collision. The absence of magnetic field (present in the original CERES setup) between the counters allows us to use them as a single unit thereby improving the electron ring reconstruction efficiency.

The TPC is placed right after the mirror of RICH-2. It is operated with a radial magnetic field with a maximum strength of about 0.5 T in the region between the two coils (see the field lines, indicated by the dashed lines in Figure 1). Read-out chambers provide up to 20 points per track. The current level of the momentum resolution is $\sim 4\%$ at the ϕ mass derived from the position resolution and confirmed by the line shape of the Λ and K_s. The dE/dx track information in the TPC shows a good separation between electrons and pions and it is used as an additional electron identification tool.

The present analysis is based on 20 million events triggered on the most central 8% of the geometrical cross section.

3. Analysis procedure

The experimental challenge of the CERES experiment is to detect a very weak source of e^+e^- pairs in the presence of hundreds of charged particles in central Pb-Au collisions. The relative strength of the physics signal is of the order of $4 \cdot 10^{-6}$ per π^0 for m > 200 MeV/c^2 and $p_T > 200\ MeV/c$. In addition, one has a few electron pairs per event from π^0 Dalitz decays and γ conversions. Limited track reconstruction efficiency leads to a huge combinatorial background (quadratically dependent on the event multiplicity) due to the pairing of tracks originating from misidentified π^0 Dalitz decays and γ conversions.

The analysis strategy consists of two main tasks. The first one is to reconstruct the charged particle tracks and to identify electron tracks. The second task is to identify electrons originating from γ conversions and π^0 Dalitz decays in order to exclude them from the final pairing. The physical signal is obtained by subtracting the geometrical mean of the like-sign electron pairs from the unlike-sign electron pairs as $N_{e^+e^-} - 2\sqrt{N_{e^+e^+} \cdot N_{e^-e^-}}$. The charged particle tracks are reconstructed using the local hits in each detector and the event vertex. 2σ momentum-dependent matching cuts are applied. Electron tracks are primarily identified by rings in both RICH counters supplemeted by the TPC dE/dx information. The S/B ratio obtained at this stage is typically of the order of 1/100.

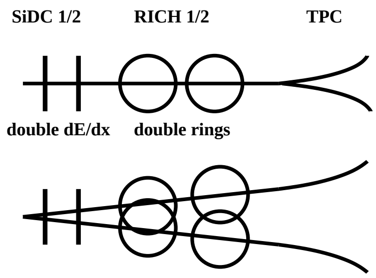

Figure 2. Fully reconstructed γ conversion (top) and π^0 Dalitz (bottom)

Fully reconstructed conversions at the target are recognized by double dE/dx signal in the two SiDC detectors, double rings in RICH-1 and RICH-2 and a V-track in the TPC, as shown in the top of Figure 2. Conversions in SiDC-1 and SiDC-2 are identified by low dE/dx tails in the SiDC dE/dx distributions. Conversions in the material before the RICH counters produce double rings. The number of hits/ring and the sum analog amplitude are used to reject most of them. Later conversions are identified and rejected by their characteristic V-pattern in the TPC.

The last step is to identify π^0 Dalitz decays. Fully reconstructed π^0 Dalitz (schematically shown in the bottom of Figure 2) are recognized by their small opening angle ($\theta < 50\ mrad$) and low invariant mass, $m < 150\ MeV/c^2$. They are excluded from further combinatorics. The rejection of partially reconstructed π^0 Dalitz where one leg in the TPC was lost due to the finite reconstruction efficiency is still under investigation. The present S/B ratio at the end of the pair analysis is 1/16.

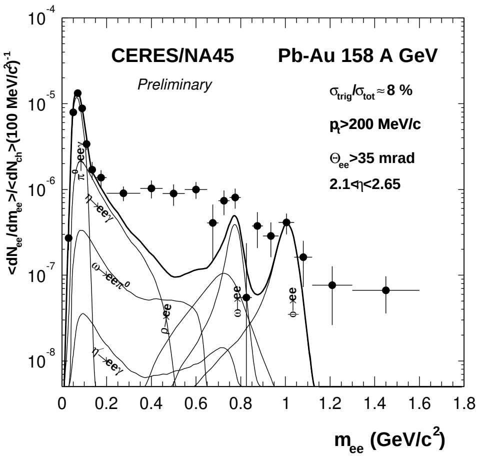

Figure 3. Normalized invariant mass spectrum of e^+e^- pairs at 158 A GeV

4. Results and comparison to theoretical models

The preliminary e^+e^- invariant-mass spectrum is shown in Figure 3. The errors are statistical only. The data points are normalized to the hadronic cocktail at the π^0 Dalitz peak. The net yield of electron pairs in different mass regions is shown in Table 1. The enhancement of the experimental data compared to the hadron cocktail in the mass range $m > 200 MeV/c^2$ is $3.1 \pm 0.3(stat.)$. It is in good agreement with the enhancement factor of $2.3 \pm 0.2(stat.) \pm 0.6(syst.)$ obtained in the combined analysis of the 1995/1996 data which triggered on

Table 1. Yield of e^+e^- pairs, S/B ratio and effective signal (background free equivalent signal) in different mass regions

Mass range, GeV/c^2	Yield	S/B ratio	S_{eff}
$m < 0.2$	2826 ± 114	$1/1.78$	614
$m > 0.2$	2023 ± 182	$1/14.6$	123
$0.9 < m < 1.12$	213 ± 79	$1/8.2$	7

30/35% of the geometrical cross-section. The shape of the excess exhibits the same behavior, *i.e.* it shows an onset at twice the π^0 mass and is most pronounced in the mass region below 0.6 GeV/c^2. The statistical significance of the present results is expected to be improved in the ongoing analysis.

Most of the theoretical interpretations of the low-mass pair enhancement observed by CERES include the modification of the ρ meson spectral shape. There are two main approaches.The first one invokes the drop of the ρ mass as a precursor of chiral symmetry restoration [5], using the Brown-Rho scaling [6] (see Figure 4). It transfers most of the ρ strength to the low-mass region. The second one is the broadening of the ρ-meson spectral shape within the dense hadron matter, suggested by Rapp and Wambach [7], transferring the strength of the yield to both lower and higher masses. Consequently, the region between the ω and ϕ masses is the most sensitive for discriminating between these two approaches. Within the current level of errors we cannot make a clear statement in favor of one of these two scenarios. Another data production scheduled to happen soon will include many improvements in the analysis. These may decrease both the statistical and systematic errors so that CERES could perhaps discriminate between these theoretical models.

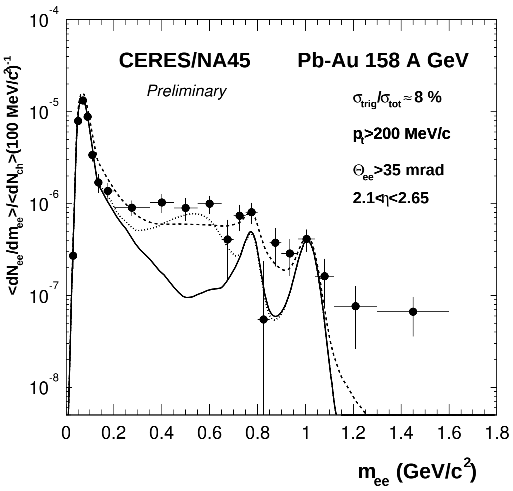

Figure 4. Comparison of the experimental data with models invoking dropping ρ mass (dotted line) and in-medium broadening of ρ mass (dashed line)

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