# DILEPTON MEASUREMENTS IN NUCLEON–NUCLEON AND NUCLEUS–NUCLEUS INTERACTIONS FROM $E_{beam}$=1 TO 5 GeV*

W.K. Wilson

for the Dilepton Spectrometer Collaboration

Wayne State University, Department of Physics and Astronomy
Detroit MI 48202, USA

(Received June 22, 1998)

Measurements of dileptons in nucleus–nucleus interactions at 1 GeV/$A$ and in $p + p$ and $p + d$ interactions from 1 to 5 GeV are reviewed. The status of attempts to model dilepton production at these energies is briefly discussed. Current models are found to under-predict dilepton production in the invariant mass range between the $\pi^0$ and the $\rho - \omega$ masses. Possible avenues for investigation of the experimental "excess" in dilepton production are discussed.

PACS numbers: 25.75.–q, 13.75.Cs, 25.40.Ve

In this talk I will summarize some results from the Dilepton Spectrometer (DLS) which took data at the Bevatron/Bevalac accelerator at Lawrence Berkeley Laboratory (LBL) during the late 1980s and early 1990s. The DLS was a two arm dipole spectrometer capable of measuring electron–positron pairs [1]. In general, the DLS data from nucleus–nucleus interaction are significantly above the predictions of theoretical simulations, a situation similar to that of data from the SPS.

I will focus on the "second generation" of measurements taken from 1990 to 1994. This data set encompasses a wide range of system sizes, from $p+p$ to Ca+Ca, and a wide range of energies, from 1 to 5 GeV beam kinetic energy [2–4]. The original goal of this work was to utilize dileptons to study the hot compressed nuclear matter formed during a collision between heavy ions. It was anticipated that dileptons should be produced primarily during the early "hot" stages of the collisions and leave the interaction region relatively undisturbed by the surrounding medium, making them a relatively

* Presented at the Meson'98 and Conference on the Structure of Meson, Baryon and Nuclei, Cracow, Poland, May 26–June 2, 1998.

clean probe of the reaction. As the low statistics first generation DLS data emerged and theory simulations grew more sophisticated, it became apparent that it would be difficult to disentangle the large number of potential dilepton sources. The spectra of many of these sources overlap in mass and are smooth and featureless. In addition, there was considerable uncertainty in both the cross sections of some sources and in the shapes of the mass spectra they produce. To clarify this situation the DLS group included in the second generation data set a study of dilepton production in $p+p$ ($pp$) and $p+d$ ($pd$) interactions at six beam energies ranging from 1.04 to 4.88 GeV kinetic energy [2, 3].

The DLS collaboration has published dilepton invariant mass spectra for Ca+Ca, $\alpha$+Ca, $d$+Ca, and C+C at 1.0 GeV/$A$ beam kinetic energy [4]. Re-

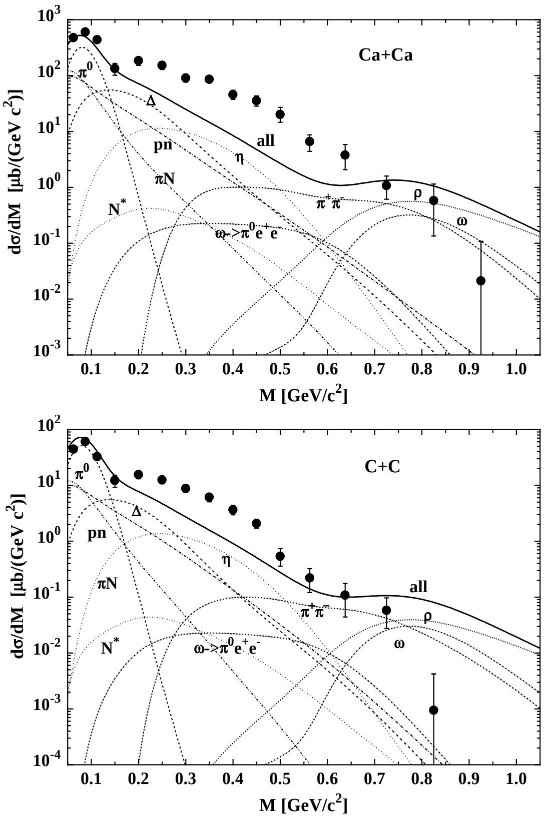


Fig. 1. The DLS Ca+Ca and C+C dilepton invariant mass spectra are compared with the predictions of a Hadron String Dynamics (HSD) transport code. This figure is taken from Bratkovskaya *et al.* [5].

cently, two theory groups have presented microscopic transport calculations for these systems which under predict the measured cross sections [5,6]. The difference between theory and experiment is largest in the Ca+Ca system where it can approach a factor of seven. As a representative example, we show the calculation of Bratkovskaya *et al.* [5] in Fig. 1 along with the DLS data for Ca+Ca and C+C. The normalization uncertainty in the data is ≈30%. Note the disagreement is not merely a question of normalization; there is reasonable agreement in the mass region dominated by $\pi^0$ Dalitz decay. The theoretical $\pi^0$ contribution agrees with direct measurements of $\pi^0$ production measured for similar systems but in a different region of phase space than the DLS acceptance [7].

In Fig. 2 the 1.0 GeV *pp* and *pd* data are compared with the C+C data. The C+C data has been normalized to the *pd* data. Note the strong resemblance between the shapes of the *pd* and C+C mass spectra throughout the region between 0.2 and 0.5 GeV/$c^2$ where the experimental "excess" is observed. The *pp* mass spectra is much steeper than the *pd*. This can be partly attributed to the smaller available energy in the *pp* system due to the lack of Fermi momentum; the kinematical upper limit on the dilepton mass is 0.459 GeV/$c^2$ in the *pp* system.

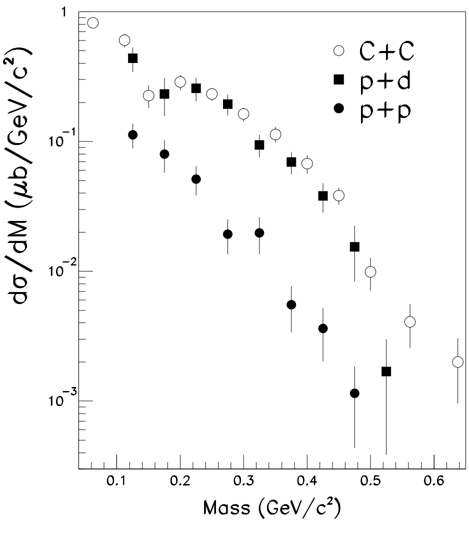


Fig. 2. DLS invariant mass spectra for the $p+p$, $p+d$, and C+C systems at $E_{\rm beam}$=1.0 GeV/$A$. The C+C has spectra has been normalized to the $p+d$ data to facilitate comparison of their shapes.

Comparisons between the nucleus–nucleus, *pp*, and *pd* data can shed light on the question of the excess. It is clear from the C+C theory calculations that there are multiple sources of dileptons in the region where the excess is apparent. The contribution from $\eta$ Dalitz at mid-rapidity is fixed by direct $\eta$ measurements and the contribution from $\Delta$ Dalitz can be related to the pion yield. However, there is considerable uncertainty about the shape of the mass spectrum produced by $\Delta$ Dalitz decay. The *pn* bremsstrahlung source is perhaps the most uncertain, both in overall cross section and in its shape. It should be useful to compare with *pp* and *pd* collisions since one can then isolate these sources. One can isolate the *pn* contribution by comparing *pp* to *pd* and taking Fermi momentum into account. One can also study the mass spectra above and below the absolute threshold for $\eta$ and $\rho - \omega$ production to isolate the contributions from their decays.

For example, at 1 GeV the only process which is expected to produce dileptons in this mass range is $\Delta$ Dalitz decay. In fact, the calculation of Ernst *et al.* [6] reproduces the DLS 1.0 GeV $p+p$ data fairly well. The same calculation does not reproduce the 1.0 GeV $p + d$ data; the data shows a modest excess above the theory in a manner somewhat similar to that seen in the nucleus+nucleus data. It is expected that the major difference between the $p+p$ and the $p+d$ data is the opening of the pn Bremsstrahlung channel in the *pd* system, so the problem may be in the Bremsstrahlung calculation.

The excess of dileptons over theory predictions observed by the CERES collaboration at SPS energies occurs over the same invariant mass range as the excess observed in the DLS data [8]. The CERES excess has prompted many to explore the question of in-medium modifications of meson properties in order to fill in the mass region between the $\pi^0$ and the $\rho - \omega$. Note, however, that there are important differences between the DLS and CERES measurements. The ultra-relativistic CERN collisions produce a system which is dominated by the production of large numbers of mesons, while the lower energy LBL nucleus–nucleus system has a strong baryonic component. Also note that at SPS energies one sees the excess only in nucleus–nucleus data; the CERES p+Be data is well described by a hadronic decay "cocktail". Therefore, for the DLS energy regeme it is important to understand the differences between theory and experiment in the *pp* and *pd* systems first. We should make sure that the basic dilepton sources are correctly described before invoking medium dependent phenomena to explain the DLS nucleus–nucleus data.

## REFERENCES


[1] A. Yegneswaran *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A290**, 61 (1990).

[2] H.Z. Huang *et al.*, *Phys. Lett.* **B297**, 233 (1992); H.Z. Huang *et al.*, *Phys. Rev.* **C49**, 314 (1994).

[3] W.K. Wilson *et al.*, *Phys. Lett.* **B316**, 245 (1993); H.Z. Huang *et al.*, *Phys. Rev.* **C57**, 1865 (1998).

[4] R.J. Porter *et al.*, *Phys. Rev. Lett.* **79**, 1229 (1997).

[5] E.L. Bratkovskaya *et al.*, *Nucl. Phys.* **A634**, 168 (1998).

[6] C. Ernst *et al.*, *Phys. Rev.* **C58**, 447 (1998).

[7] R. Holtzmann *et al.*, *Phys. Rev.* **C56**, 2920 (1997).

[8] G. Agakichiev *et al.*, *Phys. Lett.* **B422**, 405 (1998); G. Agakichiev *et al.*, *Phys. Rev. Lett.* **75**, 1272 (1995).