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DIELECTRON PRODUCTION IN p+Be AND Ca+Ca COLLISIONS AT THE BEVALAC

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Dielectron production has been measured in p+Be collisions at 1.0, 2.1 and 4.9 GeV, and in Ca+Ca at 1.0 and 2.0 GeV/A. The observation of a structure in the mass cross section at about two times the pion mass suggests that pion annihilation is the dominant production mechanism in p+Be above 2 GeV. Comparison of preliminary results from p+Be and Ca+Ca at 1 GeV/A is presented.

1. PHYSICS OBJECTIVES

The DLS Collaboration has undertaken a program of measuring dielectron production in p-nucleus and nucleus-nucleus collisions at the Bevalac. In p-nucleus collisions, the program aims to establish the existence of direct electron pairs in the few GeV domain and help clarify their production mechanism(s). For details, see for instance ref. 1. In nucleus-nucleus collisions, dileptons are expected to be a good probe of the primary hot stage of the fireball. They present several advantages compared to hadrons: 1) they do not strongly interact in the nuclear medium and thus make a penetrating probe; 2) their production is biased towards the high density phase in the collision; and 3) their coupling to other particles is well known. However, their production rates are small and experimental difficulties associated with their measurement are serious. Gale and Kapusta,[2] and L.H. Xia et al.[3] have made calculations applicable to the Bevalac energy domain and pointed out possible interesting effects relevant to the pion dispersion relation in hot, dense nuclear matter. To some extent, the same dispersion relation concepts should actually apply to both p-nucleus and nucleus-nucleus cases.

2. THE DILEPTON SPECTROMETER (DLS)

The DLS experimental setup consists of a segmented target and two symetric arms, each including a large aperture dipole magnet, three drift chambers, two segmented 1-atm gas Cerenkov counters and two scintillator hodoscopes. Table 1 gives the pair statistics for the data taken so far and illustrates the false pair subtraction. The results at 1 GeV/A are still preliminary. However, the existence of a dielectron signal down to 1 GeV/A in both p+Be and Ca+Ca collisions is clearly established.

Table 1.
Pair statistics for the different DLS runs

OS = number of opposite sign pairs
LS = number of like sign pairs
F = number of false pairs in the OS sample (F = LS)
T = number of true pairs (T = OS − LS)
σ_T = sigma on T

Reaction	OS	LS	$T \pm \sigma_T$	T/F	T/σ_T
p+Be at 4.9 GeV	732	201	531 ± 31	2.6	17.4
p+Be at 2.1 GeV	567	148	419 ± 27	2.8	15.7
Ca+Ca at 2.0 GeV/A	94	45	49 ± 12	1.1	4.2
p+Be at 1.0 GeV	204	58	146 ± 16	2.5	9.0
Ca+Ca at 1.0 GeV/A	640	466	174 ± 33	0.4	5.2

3. p+Be DATA

Fig. 1 shows the cross section per nucleon (assuming an $A^{2/3}$ dependence) integrated over p_t and y as a function of the dielectron mass M for the reaction p+Be at 4.9 GeV. The shape of the spectrum has been discussed in some detail elsewhere[4]. It is in agreement with higher energy data,[5] except for the structure at about 275 MeV (about two times the pion mass). Checking the significance of this structure has surely been one of our major concern in the data analysis. Several tests using the DLS simulation code have been done to check that it is not an acceptance effect. In particular, the false pair cross section also shown in Fig. 1 exhibits the expected shape with a smooth behaviour and no break around 300 MeV, which is a good test of the acceptance calculation. We thus trust that this structure is significant. It is also observed in p+Be at 2.1 GeV but is not at 1.0 GeV.[6] It suggests that pion annihilation is the dominant dielectron production mechanism while at 1 GeV the cross section for producing $\pi^+\pi^- + X$ is very small and hadronic bremsstrahlung might become dominant.

One of us (A. L.-S.) is working on a very simple model calculation based on $\pi^+\pi^-$ annihilation to understand the 300 MeV structure without the use of any pion dispersion relationship.[7] The dielectron mass cross section is generated as follows:

$$\frac{d\sigma(e^+e^-)}{dM} = \frac{\sigma(\pi^+\pi^- + X)}{\sigma_{pp}} \frac{\sigma_{an}(M)}{\gamma(M)} \int f(E_1)\, f(E_2)\, \delta(M^2 - M_{12}^2)\, d^3p_1\, d^3p_2$$

where σ_{pp} is the inelastic pp total cross section, $\sigma(\pi^+\pi^- + X)$ the total cross section for $pp \longrightarrow \pi^+\pi^- + X$, and $\sigma_{an}(M)$ the pion annihilation cross section which only depends on the invariant mass of the pion system.[2] The term $1/\gamma$ represents the overlap of the pion wave functions that are approximated to solid spheres, one being Lorentz contracted. The momentum distributions of the two pions are taken as Boltzman distributions at a temperature T and normalized to 1. Using experimental values of σ_{pp} and $\sigma(\pi^+\pi^- + X)$, and a realistic value of T (80 MeV), we obtain the curve plotted on Fig. 2. The result is in amazingly good agreement in magnitude and shape with the experimental points of p+Be at 4.9 GeV.

4. Ca+Ca DATA

Fig. 3 shows the cross section dσ/dM for the 2.0 GeV/A Ca+Ca data. For comparison to p+Be, the Ca+Ca cross sections are normalized with $(A_p\, A_t)^{2/3}$, where A_p and A_t are the projectile and target masses, respectively. We refer to this so normalized cross sections as "cross sections per nucleon". The shape of the Ca+Ca cross section is similar to those of the p+Be data above 2 GeV but the statistical accuracy is not good enough to give a clear evidence of a structure at about 300 MeV.

The 1.0 GeV/A data analysis is still preliminary. However, we can already make some comparison between p+Be and Ca+Ca cross sections. Fig. 4 shows the mass

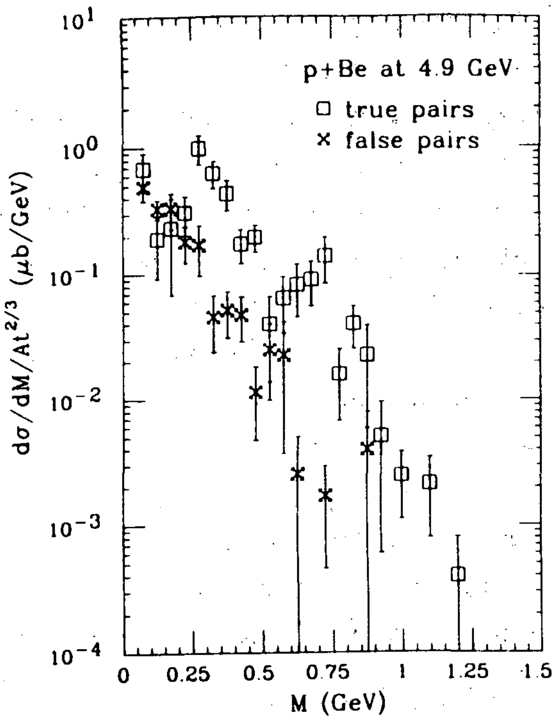


Fig. 1.

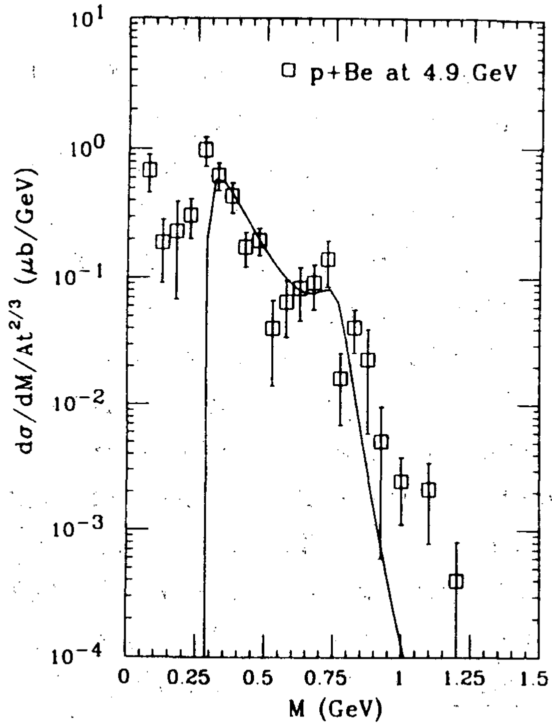


Fig. 2.

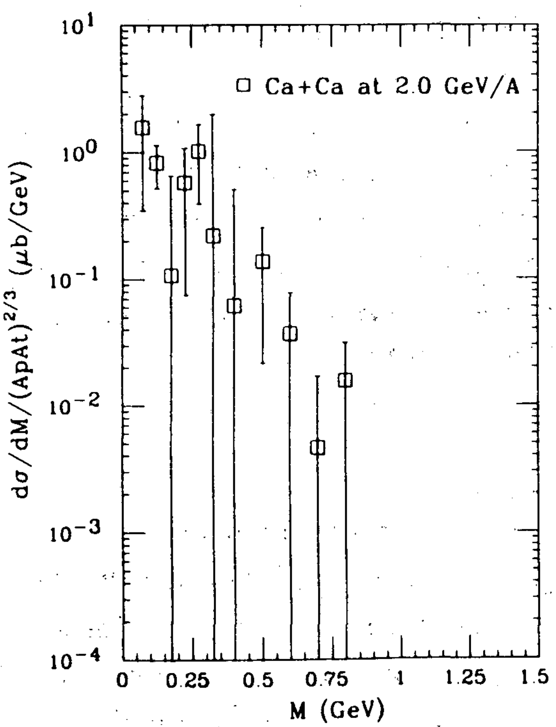


Fig. 3.

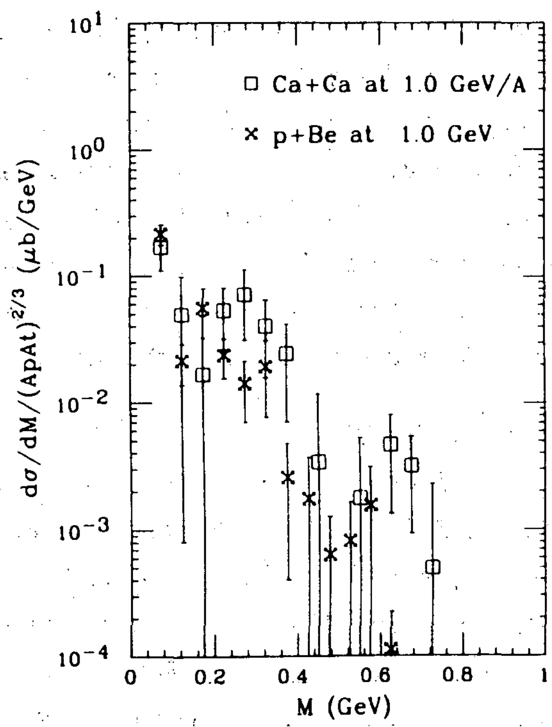


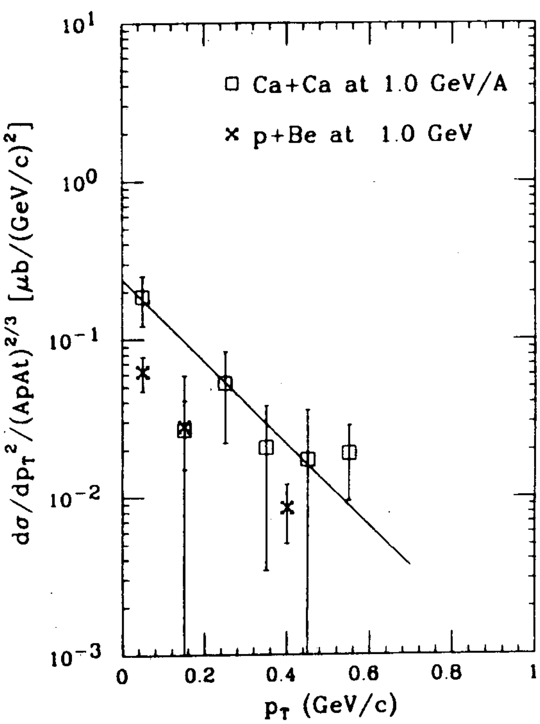
Fig. 4.

spectra for both reactions. The stucture at a mass of 300 MeV is not seen in p+Be and seems to be apparent in Ca+Ca. There is a higher yield at higher masses in Ca+Ca which is clearly seen in the ρ/ω region. The cross section per nucleon $d\sigma/dp_t^2$ as a function of p_t plotted in Fig. 5 for both p+Be and Ca+Ca are similar in slope. The Ca+Ca data is adequately fit by $exp(-\alpha\, p_t)$ with $\alpha = 6$ (GeV/c)$^{-1}$, the solid line on the figure. It is interesting to note that this agrees well with the higher energy e^+e^- data and the well known low p_t hadronic dependence. The difference in yield on Fig. 5 is partly due to the mass cut at 200 MeV which reduces more the p+Be cross section than the Ca+Ca one. This cut has been applied because of the limited p_t acceptance at very low masses.

5. CONCLUSION AND DEVELOPMENT OF THE PROGRAM

The most important results obtained so far with the DLS are 1) the observation of a structure in the mass cross section at about two times the pion mass and 2) the existence of a dielectron signal at 1.0 GeV/A which opens up the DLS program over the entire projectile mass range available at the Bevalac. Even though the preliminary model calculation presented above suggests that there is no need to introduce any pion dispersion relationship to generate the 300 MeV structure, we want to experimentally check this possibility by measuring dielectron production in pp collisions. We are also planning to go up in projectile/target mass combination, starting with Nb+Nb, and studying the possibility of going up to Au+Au.

Fig. 5.



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FOOTNOTES AND REFERENCES

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