Lawrence Berkeley National Laboratory

Recent Work

Title

THE BACKGROUND IN MISSING MASS EXPERIMENTS

Permalink

<https://escholarship.org/uc/item/3h455091>

Author

Bishari, Mordechai

Publication Date

1971-12-01

Submitted to Physics Letters B

LBL-546
Preprint

c.1

RECEIVED
LAWRENCE
RADIATION LABORATORY

FEB 4 1972

LIBRARY AND
DOCUMENTS SECTION

For Reference

Not to be taken from this room

THE BACKGROUND IN MISSING MASS EXPERIMENTS

Mordechai Bishari and Harry J. Yesian

December 1, 1971

AEC Contract No. W-7405-eng-48

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

THE BACKGROUND IN MISSING MASS EXPERIMENTS*

Mordechai Bishari[†]Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

and

Harry J. Yesian[‡]Department of Physics
University of California
Berkeley, California 94720

December 1, 1971

ABSTRACT

We propose a mechanism whereby one can determine the background in missing mass experiments in the resonance region by extending two component duality to absorptive amplitudes with external reggeons. It is shown to explain naturally the very different trend of the background in the reactions $p + p \rightarrow p + X$ and $\pi^- + p \rightarrow p + X$ at available energies. The implications and limitations of this mechanism for the analysis of the spectrum are discussed.

* Work supported in part by the U. S. Atomic Energy Commission.

[†] On leave of absence from the Weizmann Institute of Science, Rehovoth, Israel.

[‡] Participating guest, Lawrence Berkeley Laboratory. Research supported in part by the Air Force Office of Scientific Research, Office of Aerospace Research, USAF, under contract number F44620-70-C-0028.

Missing Mass Experiments [1-3] (MME) were originally designed for exploring new resonant states and studying their production mechanisms. Recently, the accumulated data from these experiments (including the production of nonresonating missing mass) have been extensively analyzed [4-6] and some conclusions were drawn in relation to limiting distributions [7,8] and triple reggeon couplings [9,10]. In particular, the analysis performed near the forward direction is consistent with a small triple Pomeranchon coupling [11,12].

A prominent feature which characterizes the cross sections in MME is the presence of a large nonresonating background component [13] upon which resonance "bumps" may be superposed when certain quantum number considerations are satisfied (exoticity!). In order to investigate the nature of these resonating states, one has to know how to subtract the background from the total spectrum. The procedure of extracting the resonating spectrum has been generally carried out in two ways [1,2]; (i) assuming a reasonable hand drawn background, (ii) making a best fit to the data with a sum of Breit-Wigner terms and polynomial background with no interference terms between the resonances themselves and with the background.

The purpose of this paper is to propose a definite way for building the background in MME. Alternatively, we present a mechanism by which one is able to distinguish the smooth part of the spectrum from the resonating one. As will be shown below, the very different behavior of the background in two specific processes is naturally explained in the context of the present approach.

Let us denote the relevant process by (see fig. 1a)

$$a + b \rightarrow c + X$$

(1)

where c is the "fast" detected particle and X denotes the missing mass. The variables describing the process (1) will be chosen as,

$$\begin{aligned} s &= (p_a + p_b)^2 \\ t &= (p_a - p_c)^2 \\ M^2 &= (p_a + p_b - p_c)^2. \end{aligned} \quad (2)$$

Most of the MME, in which the incident energy is high enough ($p_{lab} \gtrsim 15$ GeV/c), are characterized by high s/M^2 ($\gtrsim 8$) and small $|t|$ ($\lesssim 1$ GeV²). In this region of phase-space of reaction (1), the dominant mechanism is a peripheral one and is depicted in fig. 1b. Then the quantity of interest, $d^2\sigma/dtdM$, is given by,

$$\frac{d^2\sigma}{dtdM} \approx \frac{M}{s^2} \sum_{i,j} \beta_i^{ac}(t) \beta_j^{ac*}(t) \left(\frac{s}{M^2}\right)^{\alpha_i(t)+\alpha_j(t)} A(i+b \rightarrow j+b). \quad (3)$$

Here $A(i+b \rightarrow j+b)$ is the absorptive part of the forward amplitude describing the process; "Reggeon i " + $b \rightarrow$ "Reggeon j " + b and its contribution to $d^2\sigma/dtdM$ is schematically represented by fig. 1c. It should be clear that in the present discussion, we limit ourselves to the portion of phase space in which expansion (3) is applicable, i.e., $s/M^2 \gtrsim 8$ and $|t| \lesssim 1$ GeV².

From eq. (3), we see that the structure of $d^2\sigma/dtdM$ as a function of the missing mass, especially in the resonance region, is dictated by the structure of $A(i+b \rightarrow j+b)$. Therefore, since $d^2\sigma/dtdM$ is related linearly to $A(i+b \rightarrow j+b)$, eq. (3) provides a justification for the procedure of fitting the data with a sum of Breit Wigner terms and a polynomial background with no interference at all [1-3].

At this point, we come to the discussion of building the background (BG) in MME. For simplicity, let us first consider a process in which only one reggeon is exchanged at the $a\bar{c}$ vertex (e.g., $\pi^- + p \rightarrow p + X$ - see below). In such a case, the missing mass spectrum is determined by $A(R+b \rightarrow R+b)$, where R is the exchanged reggeon. For $M \gtrsim 2$ GeV, a single Regge expansion is used to obtain [14].

$$\begin{aligned} A(R+b \rightarrow R+b) &\approx \gamma_P^{RR}(t) \beta_P^{bb}(0) (M^2)^{\alpha_P(0)} \\ &+ \gamma_{R'}^{RR}(t) \beta_{R'}^{bb}(0) (M^2)^{\alpha_{R'}(0)} \end{aligned} \quad (4)$$

where P denotes the Pomeron and R' is a nonleading reggeon which is not necessarily identical to R . From (4) and (3) one obtains the complete dependence of $d^2\sigma/dtdM$ on M (for $M \gtrsim 2$ GeV). Of course eq. (4) [via (3)] builds the entire spectrum, i.e., resonances (in some average sense) and background.

To separate the BG from the "bumps" we employ the "two-component duality" [15,16] to the absorptive amplitude [17] in (4). Then the first term in (4) substituted in eq. (3) will lead to an expression for the BG in the missing mass spectrum. This expression was derived for $M \gtrsim 2$ GeV as long as $s/M^2 \gtrsim 8$. Now the crucial property of the BG comes into play; since the BG has presumably a smooth behavior in M we can safely extrapolate the expression (derived for $M \gtrsim 2$ GeV) into the resonance region. Then the explicit form of the proposed BG is [18];

$$\left(\frac{d^2\sigma}{dtdM}\right)_{BG} \approx \frac{M}{s^2} |\beta_R^{ac}(t)|^2 \gamma_P^{RR}(t) \beta_P^{bb}(0) \left(\frac{s}{M^2}\right)^{2\alpha_R(t)} (M^2)^{\alpha_P(0)}. \quad (5)$$

For a given fixed s and t we can write for the M -dependence,

$$\left(\frac{d^2\sigma}{dt dM}\right)_{BG} \propto M(M^2)^{\alpha_P(0)-2\alpha_R(t)} \quad (6)$$

It is important to remark that the proposed BG represents the difference between the total missing mass spectrum and all the resonances including daughters. The BG derived from fitting the data [1-3] is, however, equal to the difference between the total spectrum and only the parent resonances. Therefore we may conclude that; (i) the fitted BG should always lie above the proposed BG and (ii) if the two differ significantly then the difference, which has obviously a broad structure, can be attributed to the presence of daughter resonances.

In the general case where more than one trajectory can couple to the $a\bar{c}$ vertex the derivation of the BG is not straightforward. However, when the missing mass spectrum is known for several incident energies, then from the explicit s -dependence, displayed by (3), one can study the relative importance of the various absorptive amplitudes $A(i + b \rightarrow j + b)$ in determining the missing mass spectrum (see below in a specific example).

In some MME, the total spectrum is drawn [1,3] along with the fitted BG. The results of these experiments are redrawn [19] in figs. 2a and 2b for, respectively, $\pi^- + p \rightarrow p + X$ and $p + p \rightarrow p + X$. The very striking difference in the behavior of the fitted BG in these two processes calls for explanation. In the process $p + p \rightarrow p + X$ (fig. 2b), the fitted BG is not far from a straight line except for the smallest values of M where it is upward concave (perhaps partly due to threshold effects). However, in $\pi^- + p \rightarrow p + X$, the fitted BG is

upward convex and has a very different behavior from that of a straight line. In fact, if we attempt a linear extrapolation for the background in this process, we find that this leads to no excitation of background for $M \lesssim 1.1$ GeV, which of course is not conceivable (here the threshold is at the pion mass!).

Now we show how the very different trends of the fitted BG in figs. 2a and 2b are naturally explained in the present approach.

(i) $\pi^- + p \rightarrow p + X$ at 16 GeV/c; Here the detected proton is "fast" near the forward direction in the laboratory system. This process is "clean" for two reasons; firstly only the Δ trajectory can be exchanged at the $a\bar{c}$ vertex in fig. 1b and secondly, threshold effects are not important in the missing mass region of interest. The Δ trajectory function is taken as [20] $\alpha_\Delta(t) = 0.9t + 0.15$ and one obtains [19] from (6);

$$\left(\frac{d^2\sigma}{dt dM}\right)_{BG} \propto M^{3.3} \quad (\text{for } \langle t \rangle \simeq -0.2 \text{ GeV}^2). \quad (7)$$

This proposed BG is also plotted in fig. 2a where the normalization was taken from the experimental measurements at $M \simeq 1.9$ GeV. Clearly, the correct trend [21] predicted by (7) is not subject to changes in the normalization.

(ii) $p + p \rightarrow p + X$ at 24 GeV/c; In this process, many trajectories may be exchanged at the $a\bar{c}$ vertex, including the Pomeron. The dominating vector and tensor meson trajectories will be denoted by an effective trajectory $R(\alpha_R(0) \approx 0.5)$. As shown by (3), three quantities, in principle, determine the M -dependence of the spectrum; namely $A(P + p \rightarrow P + p)$, $A(P + p \rightarrow R + p)$, and $A(R + p \rightarrow R + p)$. However, the relative importance of these three quantities can be

determined by analyzing the s -dependence [which is explicit, see (3)] of the missing mass spectrum. Such an analysis was performed [4-6] at small values of t and it was concluded that at present incident energies the dominant contribution in (3) is given by the $A(R + p \rightarrow R + p)$ term [22]. Using this important information, we obtain for the proposed BG;

$$\left(\frac{d^2\sigma}{dt dM}\right)_{BG} \propto M^2)^{1-2\alpha_R(t)} \left(\frac{M^2 - M_{th}^2}{M^2}\right)^{\frac{1}{2}} \quad (8)$$

For $t = -0.1 \text{ GeV}^2$ and $\alpha_R(t) = 0.9t + 0.5$ ($M_{th}^2 = 0.88 \text{ GeV}^2$), it leads to (see fig. 2b);

$$\left(\frac{d^2\sigma}{dt dM}\right)_{BG} \propto M^{1.36} \left(\frac{M^2 - M_{th}^2}{M^2}\right)^{\frac{1}{2}} \quad (8')$$

The last factor in (8) and (8') has been introduced to partially account for threshold effects.

Figure 2b shows that the proposed BG (normalized to the data at $M \simeq 2.5 \text{ GeV}$) lies below the fitted one as should be the case since the latter may contain daughter resonances. Again, the proposed BG has the same trend as the fitted BG though they become different in the low missing mass region. This difference may be due to several factors; (i) the presence of a broad structure as given by daughter resonances with large widths, (ii) because of the finite experimental resolution, the elastic peak may influence the spectrum near threshold (iii) the unknown threshold factor, and (iv) as we decrease M for fixed s , the ratio s/M^2 increases and the Pomeranchon trajectory may influence the background through the interference term $A(P + p \rightarrow R + p)$. This

interference term contributes an almost constant term in M for $d^2\sigma/dtdM$ [see eq. (3)] which may show up in the low missing mass region.

We stress that in both reactions studied here, the proposed BG, as extrapolated from high missing mass into the resonance region gives the correct trend of the data and lies below the fitted BG, lending support to the general approach we have adopted. Such an approach is meaningful (at least at present energies) because of the smooth behavior of the background which we identify with the Pomeranchon contribution to the reggeon particle absorptive amplitude $A(R + b \rightarrow R + b)$. It is amusing to note that near $t \approx 0$, the approximate behavior of the fitted BG in the "meson" missing mass spectrum ($\pi^- + p \rightarrow p + X$) is $d^2\sigma/dtdM^2 \propto M^2$ whereas in the "baryon" case ($p + p \rightarrow p + X$ or $\pi^- + p \rightarrow \pi^- + X$) it is $d^2\sigma/dtdM \propto M$. This feature is simply explained in the present context by the difference of approximately one-half unit between the dominant meson and baryon Regge trajectories.

A further test of the validity of our approach lies in comparing the BG in certain pairs of reactions. For example, we expect the BG in $\pi^- + p \rightarrow K^- + X$ to be identical to that of $K^- + p \rightarrow \pi^- + X$ and similarly for $\pi^- + p \rightarrow p + X$ and $p + p \rightarrow \pi^- + X$. However, existing data do not cover a sufficiently large range of s and M^2 to allow such a comparison to be made.

In this paper, we have focussed our attention on the smooth or background component of the missing mass spectrum and have discussed its origins in terms of an important reggeon-reggeon-Pomeranchon coupling. Nevertheless, in those processes which allow vacuum quantum numbers to be exchanged at the $a\bar{c}$ vertex (e.g., $p + p \rightarrow p + X$),

the presence of a significant energy independent resonance structure suggests also the importance of absorptive amplitudes with external Pomeranchons. Very high energy MME such as are anticipated at NAL and the CERN-ISR should teach us more about such amplitudes and in particular about the triple Pomeranchon coupling.

We would like to thank J. D. Jackson for critically reading the manuscript. We would also like to thank R. M. Edelstein for clarifying communication of some experimental results and to J. D. Jackson and C. Schmid for useful discussions. One of us (H.J.Y.) would like to thank J. D. Jackson and G. F. Chew for the hospitality of the Lawrence Berkeley Laboratory.

REFERENCES

1. E. W. Anderson, E. J. Bleser, H. R. Blieden, E. B. Collins, D. Garelick, J. Menes, F. Turkot, D. Birnbaum, R. M. Edelstein, N. C. Hien, T. J. MacMahon, J. Mucci, and J. Russ, Phys. Rev. Letters 22, 1390 (1969).
2. E. W. Anderson, E. J. Bleser, G. B. Collins, T. Fujii, J. Menes, F. Turkot, R. A. Carrigan, Jr., R. M. Edelstein, N. C. Hien, T. J. MacMahon, and I. Nadelhaft, Phys. Rev. Letters 16, 855 (1966).
3. U. Amaldi, R. Biancastelli, C. Bosio, G. Matthiae, J. V. Allaby, A. N. Diddens, R. W. Robinson, A. Klovning, J. Litt, L. S. Rochester, K. Schlupmann, and A. M. Wetherell, Phys. Letters 34B, 435 (1971).
4. R. M. Edelstein, V. Rittenberg, and H. R. Rubinstein, Phys. Letters 35B, 408 (1971).
5. P. D. Ting and H. J. Yesian, Phys. Letters 35B, 321 (1971).

6. J. M. Wang and L. L. Wang, Phys. Rev. Letters 26, 1287 (1971).
7. J. Benecke, T. T. Chou, C. N. Yang, and E. Yen, Phys. Rev. 188, 2159 (1969).
8. R. P. Feynman, Phys. Rev. Letters 23, 1415 (1969) and in "High Energy Collisions" ed. by C. N. Yang et al. (Gordon and Breach, New York, 1969), p. 237.
9. C. E. DeTar, C. E. Jones, F. E. Low, J. H. Weis, J. E. Young, and C-I Tan, Phys. Rev. Letters 26, 675 (1971).
10. L. Caneschi and A. Pignotti, Phys. Rev. Letters 22, 1219 (1969).
11. H. D. I. Abarbanel, G. F. Chew, M. L. Goldberger, and L. M. Saunders, Phys. Rev. Letters 26, 937 (1971).
12. R. D. Peccei and A. Pignotti, Phys. Rev. Letters 26, 1076 (1971).
13. D. R. O. Morrison, Rapporteur's Talk given at the XVth International Conference on High Energy Physics, Kiev (1970), CERN/D. Ph. II/Phys 71-10.
14. Note that we do not require the dominance of the Pomeranchon singularity; otherwise M should be large (e.g., $M \gtrsim 10$ GeV).
15. H. Harari, Phys. Rev. Letters 20, 1395 (1968).
16. P. G. O. Freund, Phys. Rev. Letters 20, 235 (1968).
17. "Two component duality" has considerable success in different contexts. Since physical particles lie on "normal" Regge trajectories, we can say that the application of "two component duality" to amplitudes with external "normal" reggeons perhaps has a firmer basis than in the case of external Pomeranchons. This is so because no particle is presently known to lie on the Pomeranchon trajectory.
18. As usual, threshold effects may be important when the missing mass, M , is near threshold. This problem will not be discussed here.

19. In the case of $\pi^- + p \rightarrow p + X$, the original results were given for fixed angle in the lab system and therefore the momentum transfer varies with M . For the range of M given, t varies between $0.12 < |t| < 0.28 \text{ GeV}^2$ and the average t ($\langle t \rangle$) is taken as $\langle t \rangle \approx -0.2 \text{ GeV}^2$. The conclusions are not sensitive to variations in t along the spectrum in fig. 2a.
20. This parametrization is chosen to have a canonical regge slope $\alpha'_\Delta = 0.9 \text{ GeV}^{-2}$, and to give $\alpha_\Delta(M_\Delta^2) = 1.5$.
21. As was remarked in the text, the proposed BG is not necessarily the same as the fitted BG. However, presumably the trend of the BG will not be affected by daughter resonances.
22. Since, presumably, the triple Pomeron coupling is finite at small t , it will eventually be important for high s/M^2 . However, the exact value of s/M^2 at which the triple Pomeron coupling becomes visible is not exactly known.

FIGURE CAPTIONS

- Fig. 1. (a) Kinematics, (b) peripheral description, and (c) contribution of $A(i + b \rightarrow j + b)$ to the differential cross section for the process $a + b \rightarrow c + X$ [see eq. (3)].
- Fig. 2. Differential spectra, fitted BG and proposed BG for the process (a) $\pi^- + p \rightarrow p + X$ at 16 GeV/c and (b) $p + p \rightarrow p + X$ at 24 GeV/c.

XBL7111-4862

Fig. 1

XBL 7111 - 4863

Fig. 2

LEGAL NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Atomic Energy Commission, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

TECHNICAL INFORMATION DIVISION
LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA 94720