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SEARCH FOR NARROW RESONANCES PRODUCED BY NEUTRON DISSOCIATION

E. J. Bleser
Fermi National Accelerator Laboratory, Batavia, Illinois 60510

B. Gobbi, L. Kenah, J. Keren, J. Rosen,
R. Ruchti, H. Scott, and D. Spelbring
Northwestern University, Evanston, Illinois 60201

J. Biel, C. Bromberg, T. Ferbel, P. Slattery, and D. Underwood
University of Rochester, Rochester, New York 14627

and

D. Freytag
Stanford Linear Accelerator Center, Stanford, California 94305

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Search for Narrow Resonances Produced by Neutron Dissociation*

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We present the results of a search for charged two-body decays of neutral high mass resonances produced via neutron dissociation. The experiment was executed with a vee spectrometer in the M-3 neutral beam at Fermilab; the incident neutrons had an average momentum of ~200 GeV/c. The detector was sensitive to final states with charged multiplicity $\lesssim 4$, produced forward in the center of mass ($x > .3$). We find no significant enhancements in the high mass $K^{+}\pi^{-}$, $K^{-}\pi^{+}$ or pK^{-} systems. We estimate an upper limit for cross section times branching ratio of any narrow $K^{+}\pi^{-}$ state to be $\lesssim$ 50 nb/nucleon for masses between 2 and 3 GeV.

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The known properties of the recently discovered J-particle [1] or ψ (3100), and of the ψ(3700)[2] suggest the existence of an additional selection rule which governs the interaction of elementary particles. A possible explanation for the unusually narrow decay widths of these particles is that they are bound states of two quarks having a quantum number called charm.[3] If such an hypothesis is correct, then it implies a new hadron spectrum with the lowest lying meson states characterized by unit charm quantum number, very narrow width, and masses greater than ~1.85 GeV.

In analogy with the diffraction-dissociation of neutrons into nucleon-pion or hyperon-kaon systems, one expects charmed particles to be associatively produced in reactions such as:

$$n + Be \rightarrow B^o_c + M^o_{\bar{c}} + \text{anything} \qquad (1)$$

$$n + Be \rightarrow n + M^o_c + M^o_{\bar{c}} + \text{anything} \qquad (2)$$

where M, B, and c refer to meson, baryon, and charm, respectively. Since the diffraction process involves large cross sections at high energy ($\sim$ 3 mb for $n \rightarrow N\pi$ + anything, and $\sim$ 200μb for $n \rightarrow KY$ + anything), it is a logical domain to search for charmed objects.

We report here a search for the charged two-body decays of neutral high mass particles produced by neutron dissociation. The experiment was performed at the Fermi National Accelerator Laboratory in the M3 neutral beam. Neutrons were produced at 1 mrad and had a maximum momentum of 300 GeV/c, with 200 GeV/c the average value. The photon component of the beam was suppressed by 15 radiation lengths of lead followed by sweeping magnets. The number of K^o_L mesons with momenta greater than 50 GeV/c was less than 1% of the total beam.[4] The neutron flux was continuously monitored by two systems of detectors: a hadron calorimeter consisting of 21 scintillation counters equally spaced within five interaction lengths of iron, which provided absolute normalization; and a relative monitor telescope, consisting of 3 scintillation counters and lucite converter, which sampled 3/4% of the beam. Neutron fluxes were typically 2×10^6 neutrons per pulse. The "vee" spectrometer, shown in Figure 1, consisted of a BM109 analyzing magnet (which provided 1 GeV/c of transverse momentum), 20 gaps of wire spark chambers with magnetostrictive readout, and a variety of scintillation counters and hodoscopes for trigger requirements. The 2 cm Be target was surrounded by a system of scintillation counters and lead converters (A), except for openings for beam entrance and exit. Information from these counters was recorded during each trigger, and was used to study the coherence of reactions (1) and (2) in the off-line analysis.

The trigger consisted of a neutral particle interacting in the target (T), a positive signal in the S counter immediately downstream, and at least one (detected) particle in the left (H0L, H1L, H2L) and one in the right (H0R, H1R, H2R) halves of the spectrometer. The H0R, H0L, and $\overline{V1}$[5] counters imposed a minimum opening angle of 20 mrad on the vee, and consequently suppressed low mass, large x background (primarily neutron dissociation into nucleon-pion systems).[6] High multiplicity events produced at small x were eliminated by the $\overline{V2}$ counter and by pulse height cuts applied to the H0R and H0L signals, which limited the number of particles allowed in each counter to $\lesssim 2$.

The kinematic domain allowed by the trigger was for particles (vees) produced forward in the center-of-mass ($x \gtrsim .3$). The geometrical acceptance of the apparatus was defined by the limiting aperture of the BM109 magnet, less the solid angle subtended by the $\overline{V1}$ counter: $20 < |\theta| < 75$ mrad horizontally, $|\theta| < 25$ mrad vertically. This translates into an acceptance of 10% for an object of 3 GeV mass decaying into two bodies. The mass resolution for a 3 GeV $K\pi$ state was estimated to be ±20 MeV from Monte Carlo calculations based on spark resolution and spark chamber placement; this value is consistent with the observed width of detected $K^0_S \to \pi^+\pi^-$ decays. Data acquisition was handled by a PDP-15 computer which also monitored the on-line performance of the equipment.

Roughly one in 5×10^3 interactions satisfied the trigger requirement, and over a two-week running period 7.5×10^5 triggers were recorded. Two thirds of the events yielded more than two tracks in the spectrometer, the multiplicity being limited by the triggering requirements. Multiple track efficiency has been estimated by comparing the number of reconstructed tracks to the number of hodoscope counters latched, and was found to be ~ 80% for 6 tracks.

Events were analyzed via a pattern recognition and fitting program which searched for charged two-body configurations. Since the spectrometer provided no particle identification, the invariant mass of a given two-body combination was calculated using various mass assignments. Using the formula for the effective mass of a two-body system, it is straightforward to show that if a specific two-body mode contains a narrow resonance, then the corresponding mass peak will be the sharpest when the decay products are assigned their correct masses. Had a significant mass peak been observed, this property would have been used to identify the specific mode involved.

Assuming a $K^+\pi^-$ mass assignment, 1.5×10^4 events were obtained having invariant masses greater than 1.85 GeV. Figure 2 displays the $K^+\pi^-$, $K^-\pi^+$, and pK^- invariant mass distributions in bins of 20 MeV for accepted vees having a Q value $\gtrsim$ 0.8 GeV. Each distribution was fitted with a fourth order polynomial in the mass variable. The deviation of the observed mass distribution from the smooth polynomial fit, in numbers of standard deviations, is shown underneath each mass distribution. No significant signal is observed. We also divided the data into coherent and incoherent samples using the latched information from the counters surrounding the target. The mass spectra were similar in both samples and revealed no significant enhancements.

An upper limit for the cross section (σ) times branching ratio (BR) for the production of a neutral high-mass particle and its subsequent decay into two hadrons has been calculated from the neutron flux, the number of target nucleons, d the spectrometer acceptance. Making the assumption that a positive result uld have been reported had we observed at least a four standard deviation effect a mass interval whose size is given by four times the experimental resolution

, we obtain Figure 3, which displays σ·BR as a function of ivariant mass. A value of σ·BR greater than that shown would have resulted in statistically significant signal. This curve includes a factor of 3 correction or the probability of vetoing a good charmed-vee event by having the associated harmed particle in reactions (1) or (2) strike one of the veto counters.[7] These pper limits are an order of magnitude smaller than previous theoretical estimates ased on a $1/M^2$ dependence of the mass spectra for diffractive processes.[8]

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References

[1]J. J. Aubert, et al., Phys. Rev. Letters 33, 1404 (1974); J. E. Augustin, et al., Phys. Rev. Letters 33, 1406 (1974); C. Bacci, et al., Phys. Rev. Letters 33, 1408 (1974).

[2]G. S. Abrams, et al., Phys. Rev. Letters 33, 1433 (1974).

[3]S. L. Glashow, Experimental Meson Sepctroscopy, Boston (1974), D. Garelick ed.; M. K. Gaillard, B. W. Lee, and J. L. Rosner, Fermilab-Pub-74/86-THY, (August 1974); M. K. Gaillard, B. W. Lee, and J. L. Rosner, Fermilab-Pub-75/14-THY, (January 1975); A. De Rujula and S. L. Glashow, Phys. Rev. Letters 34, 46 (1975); S. Borchardt, V. S. Mathur, and S. Okubo, Phys. Rev. Letters 34, 38 (1975).

[4]M. J. Longo, et al., University of Michigan Report UM-HE-74-18 (1974).

[5]The bar above V1 indicates the counter is a veto counter.

[6]Here x is the Feynman variable $P_{\parallel}^{cm}/p_{max}^{cm}$.

[7]This correction assumes that one half of the decays of charmed objects will be into two or three bodies and that the decays will be isotropic.

[8]G. Snow, Nucl. Phys. B 55, 445 (1973) and references 3. It should also be pointed out that more recent theoretical estimates based on the charm model suggest that the branching ratio of charmed mesons into the Kπ channel may be rather small. See M. B. Einhorn and C. Quigg, Fermilab-Pub-75/21-THY (February 1975).

Figure Captions

Fig. 1 Plan view of the experimental apparatus.

Fig. 2 Mass spectra for (a) $K^+\pi^-$, (b) $K^-\pi^+$, and (c) pK^- mass hypotheses in 20 MeV bins. The difference between the number of events in each bin and the number expected based on a fourth order polynomial fit to the overall mass distribution is shown, in units of standard deviations, under each mass plot.

Fig. 3 Upper limits for cross section times branching ratio as a function of invariant mass for (a) $K^+\pi^-$ and (b) pK^- final states. The mass scale is in GeV.

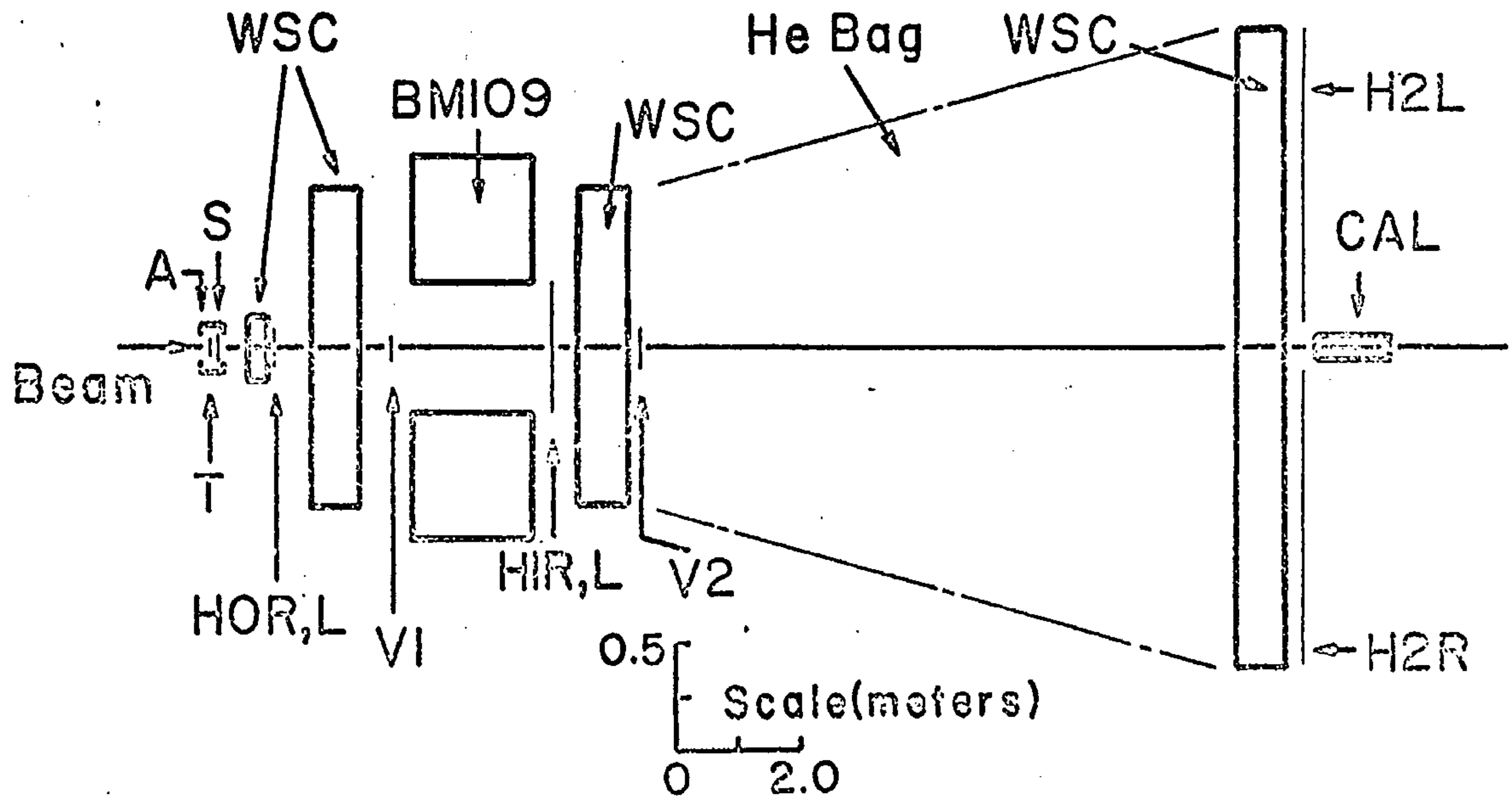
WSC
BMIO9
WSC
He Bag
WSC
H2L
S
A
CAL
Beam
T
HOR,L
VI
HIR,L
V2
0.5
Scale(meters)
0
2.0
H2R

Fig. 1

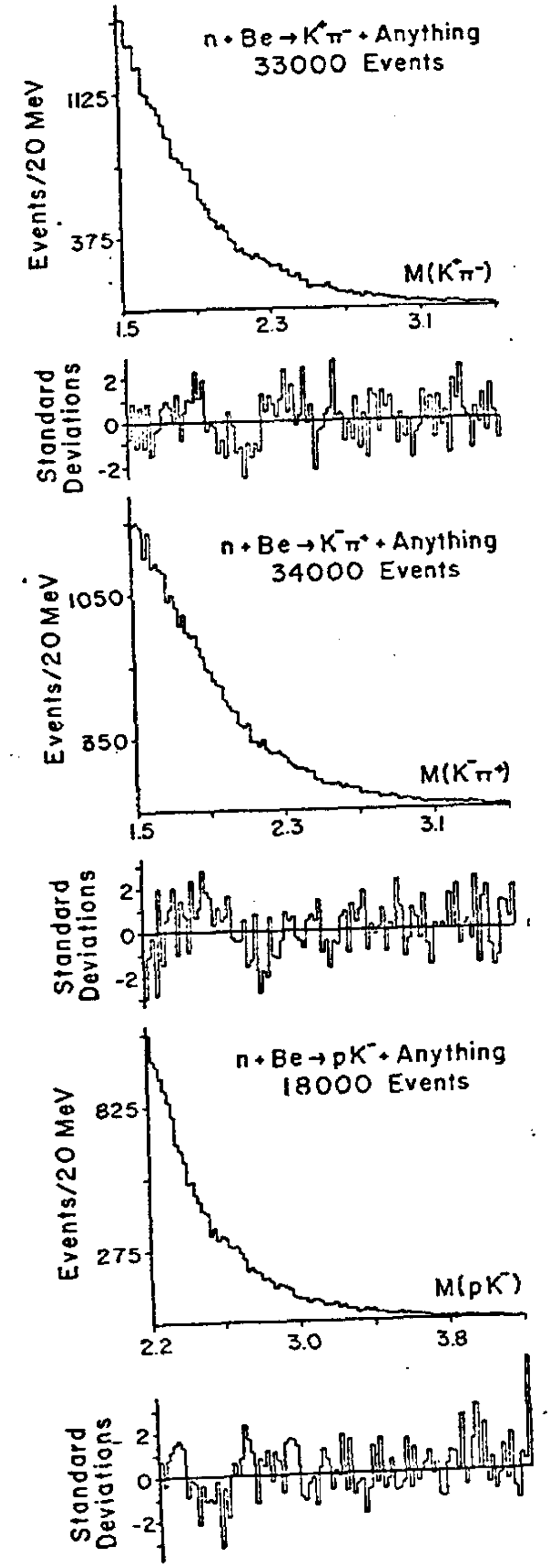
n + Be → K⁺π⁻ + Anything
33000 Events
Events/20 MeV
1125
375
M(K⁺π⁻)
1.5
2.3
3.1
Standard Deviations
2
0
-2
n + Be → K⁻π⁺ + Anything
34000 Events
Events/20 MeV
1050
350
M(K⁻π⁺)
1.5
2.3
3.1
Standard Deviations
2
0
-2
n + Be → pK⁻ + Anything
18000 Events
Events/20 MeV
825
275
M(pK⁻)
2.2
3.0
3.8
Standard Deviations
2
0
-2

Fig. 2

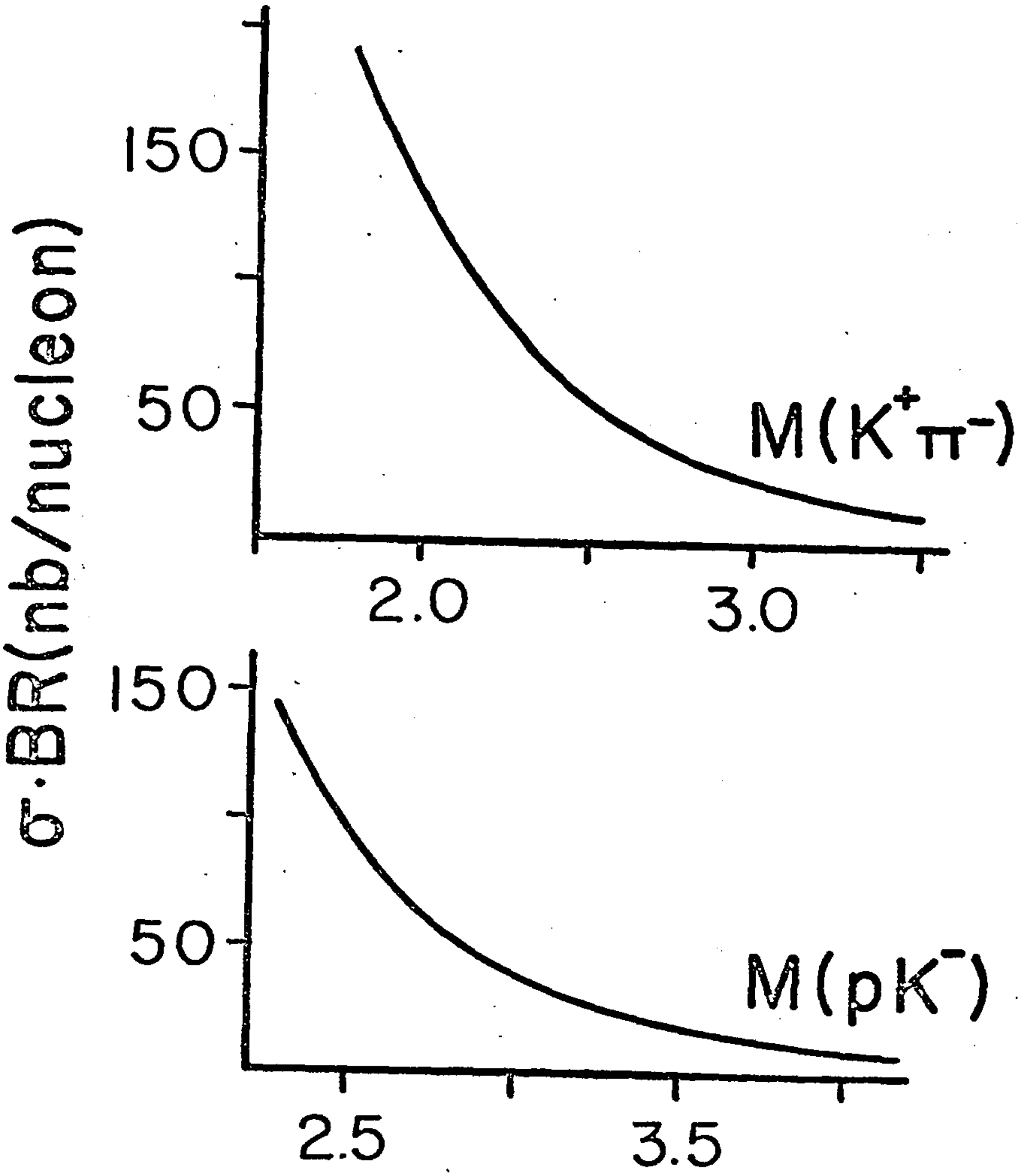

Fig. 3