28
7-29-75
2648 NTIS

BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

INFORMAL REPORT

June 1975

Resonance Detection Method by Background Suppression
through t-Dependence

W.N. Schreiner, P. Schübelin*, F. Turkot†

Department of Physics

ABSTRACT

A new method to obtain greatly enhanced signal to background ratios of resonances is described. The detection of a decay product at large t from a peripherally produced resonance (transverse decay) in a trigger spectrometer and the measurement of the other decay product(s) in a vertex spectrometer allow for the observation of resonances with the background suppressed by orders of magnitude over its natural abundance. The method is useful principally in the detection of high mass resonances having two-body decay modes.

*Present Address: High Energy Group, Centre de Recherches Nucléaires, Strasbourg, France

†Present Address: FNAL, Batavia, Illinois 60510

MASTER

DISTRIUTION OF THIS DOCUMENT UNLIMITED

Many resonances discovered in the past have been found using one of the standard techniques: total cross-section, missing mass or effective mass. With the first method the incident and target particles resonate and an enhancement in the total scattering cross-section is observed at the threshold. In the typical missing mass experiment a single particle is detected and the mass spectrum of the recoiling system is searched for enhancements. This method requires that all unobserved particles be decay products of the resonance. With the effective mass technique one triggers upon one particle and searches among the others for a resonating system or sub-system. In all methods the non-resonant background is often much larger than the resonance itself and in the effective mass method the background is further increased by the number of possible permutations. When searching for low cross-section resonances, this means either doing a very high statistics experiment or looking in some kinematical region where the background is suppressed relative to the resonance. In this report we suggest a method of the latter variety.

Suppose that the phase space background has a certain t -dependence and that the resonance has a significant two-body decay mode with substantial Q value. The method we propose is to utilize the Q value of the decay to project one of the decay products to large transverse momentum where it can be triggered upon. Evidently only that fraction of resonances that decays sideways will be seen. However, the background, due to its exponential t -dependence, will be greatly suppressed with respect to that under the peripherally produced resonance. The larger the Q value of the decay, the larger the background suppression becomes.

2.

Finally, a vertex spectrometer must measure the remaining member(s) of the decay and standard effective mass techniques used to isolate the resonance.

There are, of course, advantages and disadvantages to this scheme. The most serious limitation is probably that the trigger scheme biases the decay product angular distributions making spin-parity analysis difficult, if not impossible. Nevertheless, if one is initially only interested in detecting possible new resonances (bump hunting), the price to be paid may well be worth the effort. A compensating advantage is that with greatly suppressed background a better signal to background ratio and therefore a better measurement of the width and mass of the enhancement can be obtained. There are also limitations on the type of resonances which may be efficiently found with this method:

- (1) If the resonance decays predominantly into ≥ 3 bodies there will be less likelihood of observing a high transverse momentum decay product.
- (2) If the resonance is singly charged then the two-body decay will include a neutral particle and kinematic fitting will be required; conversely, neutral or doubly charged resonances with two-body decay modes require only geometrical fitting.

As an example, we consider the investigation of known nucleon resonances using the reaction $p_1 p_2 \rightarrow N_3^* p_4$ at 28.5 GeV/c and look for the decays $N_3^* \rightarrow p_3 \pi^0$. In this case one would trigger on p_3 at large transverse momentum, $p_{3\perp}$. An N^* of mass 2.5 GeV/c produced in the forward direction and decaying transversely would produce a proton p_3 with an apparent four momentum transfer squared, t_{13} , of 2.3 (GeV/c)^2 which, assuming a background t -dependence of e^{-4t} , gives an effective

3.

background suppression of $\sim 10^4$, multiplied by the probability for decay near 90° . In effect, the larger the mass of the resonance being sought, the larger the t_{13} of the triggering proton can be and therefore the larger the background suppression will be.

In Fig. 1 we show the kinematics of p_3 for this reaction. In the Peyrou plot the circles centered at the origin are lines of constant missing mass to p_3 , the parabolas are lines of constant t_{13} , and the ellipses are possible locations of p_3 resulting from the decay of a given mass N^* produced in the forward direction. The N^* mass lines tend to smear out vertically if the N^* is not produced forward.

To indicate the effectiveness of this scheme we present in Fig. 2 some recent data taken with the Multiparticle Argo Spectrometer System, MASS. Although MASS was not run with the intention of searching for resonances, the data dramatically demonstrate background suppression. The data are fitted events of the reaction $p_1 p_2 \rightarrow p_3 p_4 \pi^0$ at 28.5 GeV/c divided into three t_{13} regions and the number of events observed is plotted vs. the effective mass of the $p_3 \pi^0$ system. For $t_{13} < 0.7$ (GeV/c)² practically no beam excitation is observed. For t_{13} between 0.7 and 2.0 GeV/c the well-known 1520 and 1688 resonances are seen. The minimum mass which a forward produced N^* needs to project a proton into this region is 1.43 GeV. However, N^* 's produced at non-zero angles have the effect of making the cut-off lower and fuzzy. The mass acceptance within this t range extends up to the kinematic limit (>6 GeV). However, presumably the relative production cross-section of higher mass N^* 's multiplied by their probability for decay into two prongs is small in relation to the comparable 1688 signal and this has the effect of producing the peak between 1 and 2 GeV.

For $t_{13} > 2.0$ GeV/c the "mass acceptance" ranges from ~ 1.9 GeV upwards. The 1920 and possibly still some 1688 signal (from 1688's produced at substantial t) can be seen below 2.0 GeV. However, in this t range the weaker higher mass N^* 's (mass > 2.0 GeV) produce a significant signal. A properly designed experiment could acquire sufficient statistics to discern individual resonances in this spectrum.

Additional cuts may be useful in rejecting the lower mass N^* "background" signals. It can be seen from Fig. 1 that the lowest mass N^* 's entering a given t_{13} interval come from backward decaying N^* 's. If one used $P_{3\perp}$ intervals instead, the major contribution would come from those lower mass N^* 's like the 1688 which are themselves produced away from the forward direction at substantial transverse momentum. Probably a combination of t_{13} and P_3 cuts would be the most effective way to reject lower mass N^* 's and thereby further enhance the high mass N^* signals beyond the basic method we suggest.

Figure Captions

Fig. 1. Peyrou plot for p_3 in pp interactions at 28.5 GeV/c. The circles are lines of constant missing mass to p_3 , the parabolas are lines of constant four momentum transfer squared to p_3 (t_{13}) and the ellipses are possible locations of the proton if it originated from an N^* of given mass produced in the forward direction. The dashed line gives the proton's location if the N^* decays at 90° in its rest frame (measured with respect to its direction of motion).

Fig. 2. Effective mass of the $p_3\pi^0$ system in the reaction $p_1p_2 \rightarrow p_3p_4\pi^0$ at 28.5 GeV/c for three intervals of four momentum transfer from p_1 to p_3 , t_{13} .

Fig. 1

Fig. 2