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A STUDY OF ΛP MASS SPECTRUM FROM THE REACTION:

$K^- D \rightarrow \pi^- P \Lambda$ AT REST*

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An experiment to study hyperon nucleon production in K^-D interaction at rest was carried out by exposing the BNL 30-inch D_2 bubble chamber to a low energy separated K^- beam at the AGS. We present here results from the study of reaction $K^-D \rightarrow \pi^- p \Lambda$. In particular, a detailed analysis on the Λp mass spectrum near the 2129 MeV region was carried out to determine the nature of the observed enhancement.[1-3]

Figure 1 exhibits the distribution of events in the two-dimensional mass plot, $M(\Lambda p)$ vs $M(\Lambda \pi^-)$. Obvious evidence of structures in the Λp mass system appears both in the low mass region and at around 2130 MeV, while no significant amount of Y*(1385) appears to be in evidence. Strong formation of $I = 1/2$ $\pi^- p$ system is not expected in the allowed mass region.

Gaussian ideogram of events projected on the Λp mass axis is shown in Fig. 2a. The distribution contains 2470 events from sample (a) where all particles were measured, and 2431 events from sample (b) where Λ was missing. The average mass resolution from the two samples are 1.0 MeV and 2.6 MeV, respectively. The events clustering in the low mass region can be attributed to a combination of Λ production from single nucleon interaction $K^- n(p) \rightarrow \pi^- \Lambda(p)$ with and without subsequent final state Λ - (p) interaction. A detailed analysis of Fig. 1 indicates that Y*(1385) production is much less than the amount estimated in Ref. 1. The maximum estimated reflection from these events can be represented by a very slowly varying function of the mass with an average height of about 10 events per bin and extending from about 2060 to 2145 MeV. The remaining distribution features a striking enhancement with an apparent narrow width at about 2129 MeV and a shoulder that protrudes out to about 2140 MeV.

A detailed analysis with the aid of a final state interaction model such as

$$K^-D \rightarrow \pi^- \Sigma(N), \quad \Sigma(N) \rightarrow \Lambda p$$

was carried out. We followed the prescription and the approximation worked out in Refs. 4 and 5. The result is compared with Fig. 2b which includes only the higher resolution sample. We have included in the matrix element contribution from the intermediate Σ^+ and Σ^0 diagrams as well as the interference term. By assuming charge symmetry in Σ^+n and Σ^0p scatterings and by using the $\bar{K}N$ scattering information,[6] we estimated that the contribution from Σ^0 diagram is only about one-seventh the contribution from Σ^+ diagram. Furthermore, the Σ^0 contribution approximately cancels out the contribution from the interference term.

Assuming S-wave zero effective range approximation in $\Sigma - N$ scattering the complex scattering length has the form $\underline{a} + i\underline{b}$. The rate of Λ production depends primarily on $\underline{b}$, while the shape and the center of the enhancement are very sensitive to the sign and the value of $\underline{a}$. Under different assumptions we have been able to obtain a number of complex scattering lengths that will fit the data as is indicated by the solid line in Fig. 2b. If we neglect the fact that the intermediate Σ and N are both off the mass shell, then the scattering length (0.004 - i0.009) MeV^{-1} will provide a good fit to the shape of the peak. On the other hand, if the off-mass shell effects are taken into account, then the effective ΣN threshold mass is shifted lower. Subsequently, a negative $\underline{a}$ will be needed to describe the peak. Therefore, it is clear that proper consideration of the off-mass shell effect must be done before a meaningful set of complex scattering length can be deduced. However, it is possible for us to conclude on the basis of limited off-mass shell correction that our data favors a small negative value of $\underline{a}$. This implies that the observed Λp enhancement is not a bound state of Σ^+n system. A small positive value of $\underline{a}$ such as $\underline{a} = 0.004\ \text{MeV}^{-1}$ would imply a large binding energy of $(2\mu_{\Sigma N}\underline{a}^2)^{-1} = 59$ MeV, which is highly unrealistic.

It is not clear at the moment whether or not the excess of events in the 2140 MeV region has any physical significance, although the shoulder becomes more prominant when the number of events is increased by a factor of 2 (see Fig. 2a). We have attempted to reproduce the shoulder by introducing an effective range term into a. Under our present scheme, no satisfactory solution has been obtained.

So far, our analysis does not preclude the possible existence of a Λp resonance. If we choose to fit the distribution in Fig. 2a to Breit-Wigner resonance functions and allowing a slowly varying background distribution, then two resonances are found to be necessary to describe the spectrum. The fitted shape parameters for the two resonances are: $M_1 = 2128.7 + .2$, $\Gamma_1 = 7.0 \pm .6$, and $M_2 = 2138.8 \pm .7$, $\Gamma_2 = 9.1 \pm 2.4$ MeV. The fitted curve is shown in Fig. 2a. However, further interpretation of these peaks must await more information from ΛN and ΣN interactions.

We have investigated the directional angular distribution of Λ in the rest frame of Λp system with respect to the incident intermediate hyperon direction as well as the polarization of the Λ. Figures 3a, and 3b show the forward-backward and the polar-equatorial distribution of the Λ-direction as a function of Λp mass. Figure 3c exhibits the up-down asymmetry of the decayed pion from Λ with respect to the normal to the Λ-intermediate hyperon plane. At $M = 2129.0$ MeV, the directional angular distribution is isotropic which is consistent with the assumption of S-wave scattering. The Λ is observed to be unpolarized. At around $M = 2140$ MeV, however, both the forward-backward and up-down distribution indicate a possible asymmetry of about 0.16. It is worth pointing out that similar amount of asymmetry was reported in the study of the reaction $\Sigma^- p \rightarrow \Lambda\pi^0$ at around 160 MeV/c.[7]

ACKNOWLEDGEMENT

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REFERENCES

1. O. Dahl et al., Phys. Rev. Letters 6, 142 (1961).
2. D. Cline et al., Phys. Rev. Letters 20, 1452 (1968).
3. G. Alexander et al., Phys. Rev. Letters 22, 483 (1968).
4. R. Karplus and L. Rodberg, Phys. Rev. 115, 1058 (1959).
5. T. Kotani and M. Ross, Nuovo Cimento XIV, 1282 (1959).
6. J. K. Kim, Phys. Rev. Letters 14, 29 (1965).
7. R. Engelmann et al., Phys. Letters 21, 587 (1966).

FIGURE CAPTIONS

1. "Dalitz Plot" $M(\Lambda\pi^-)$ vs $M(\Lambda p)$.
2. a) Λp combined mass ideogram for all events.
   b) Ideogram for events with all tracks measured.
3. a) Λ angular distribution in the form (F-B)/(F+B) is a function of Λp mass.
   b) Plotted as (P-E)/(P+E).
   c) Decayed π^- angular distribution with respect to axis normal to Λ production plane.

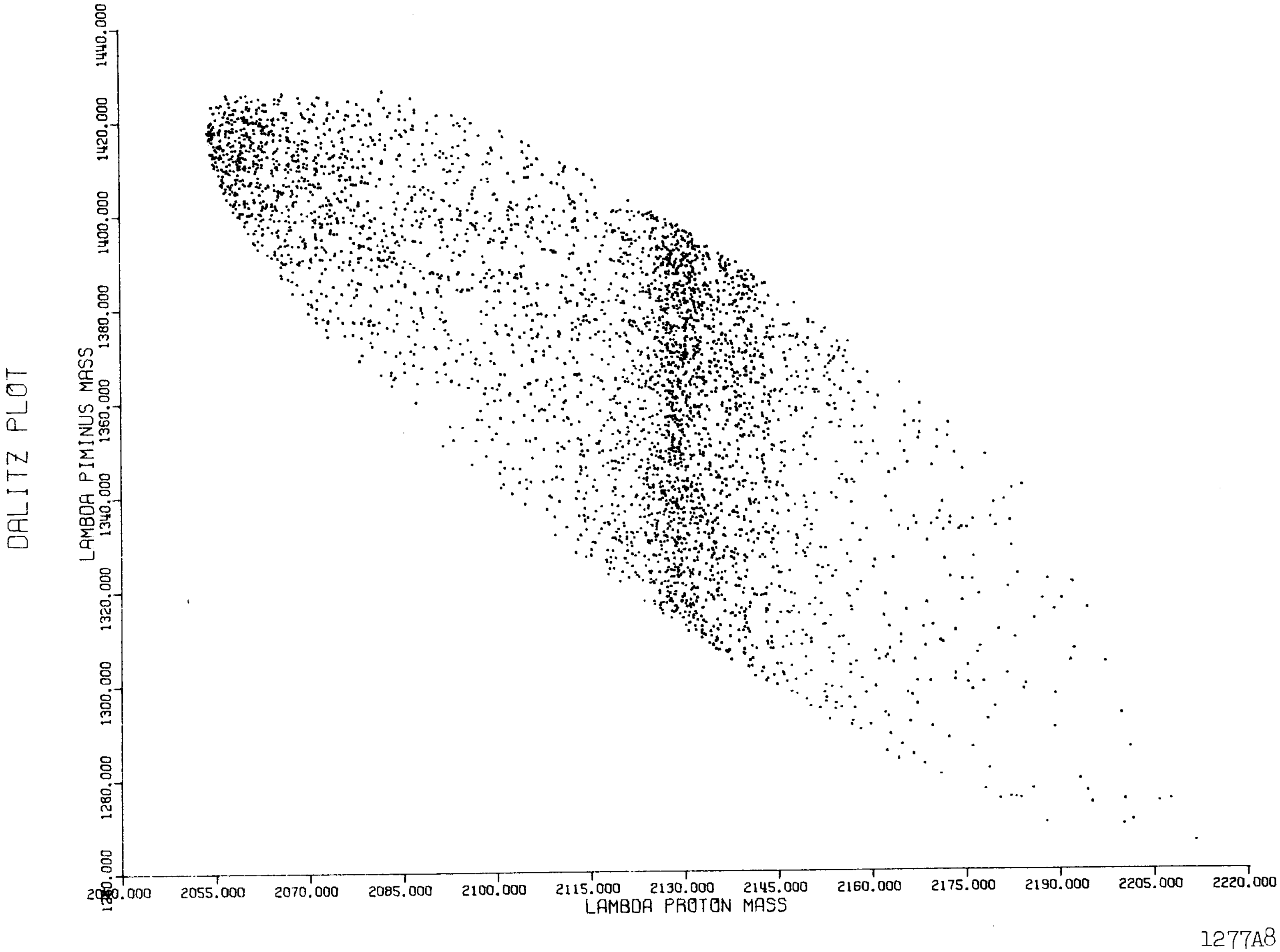
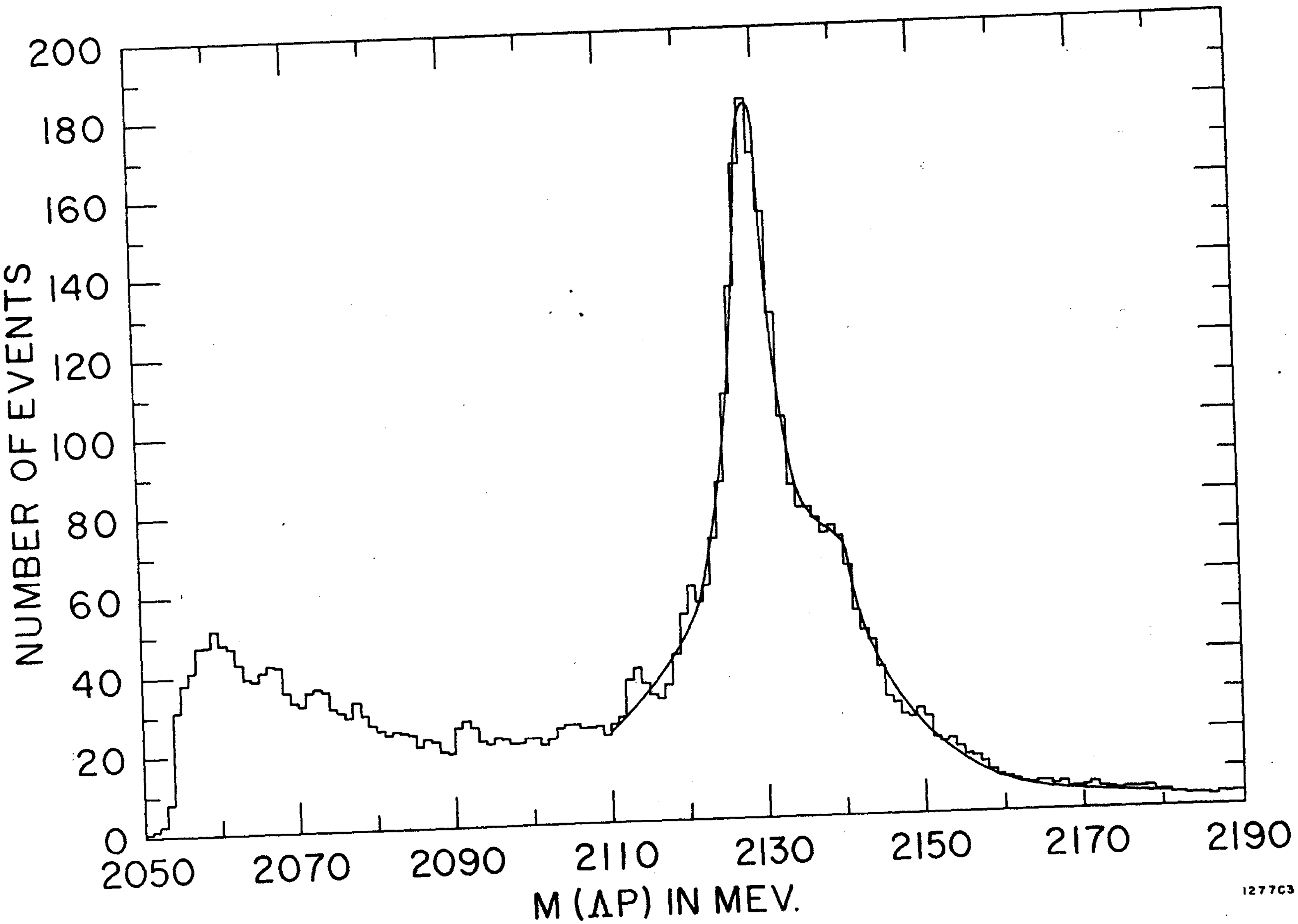

DALITZ PLOT
LAMBDA PIMINUS MASS
LAMBDA PROTON MASS
1440.000
1420.000
1400.000
1380.000
1360.000
1340.000
1320.000
1300.000
1280.000
2055.000
2070.000
2085.000
2100.000
2115.000
2130.000
2145.000
2160.000
2175.000
2190.000
2205.000
2220.000
1277A8

Fig. 1



200
180
160
140
120
100
80
60
40
20
0
NUMBER OF EVENTS
2050
2070
2090
2110
2130
2150
2170
2190
M (ΛP) IN MEV.
1277C3

Fig. 2a

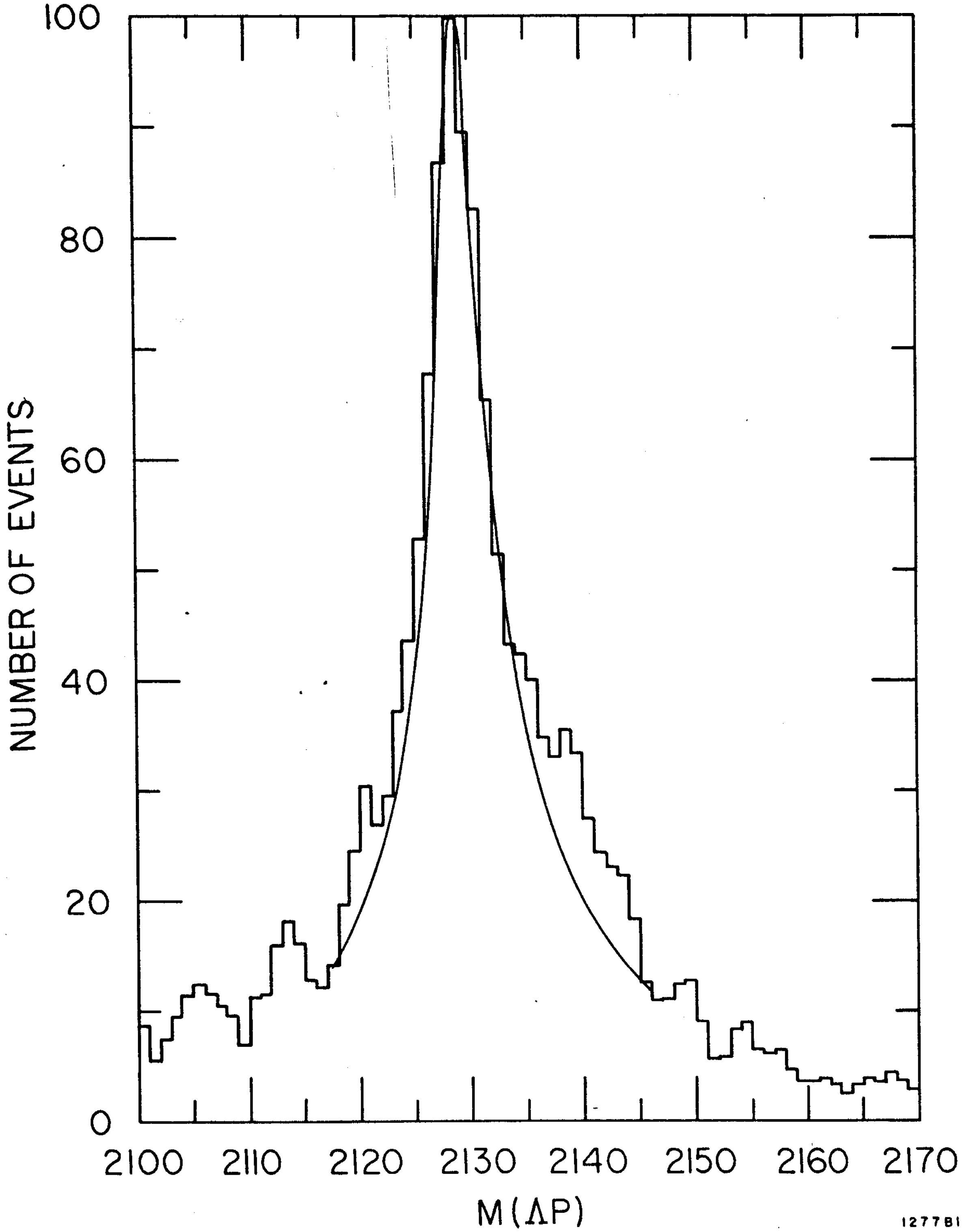
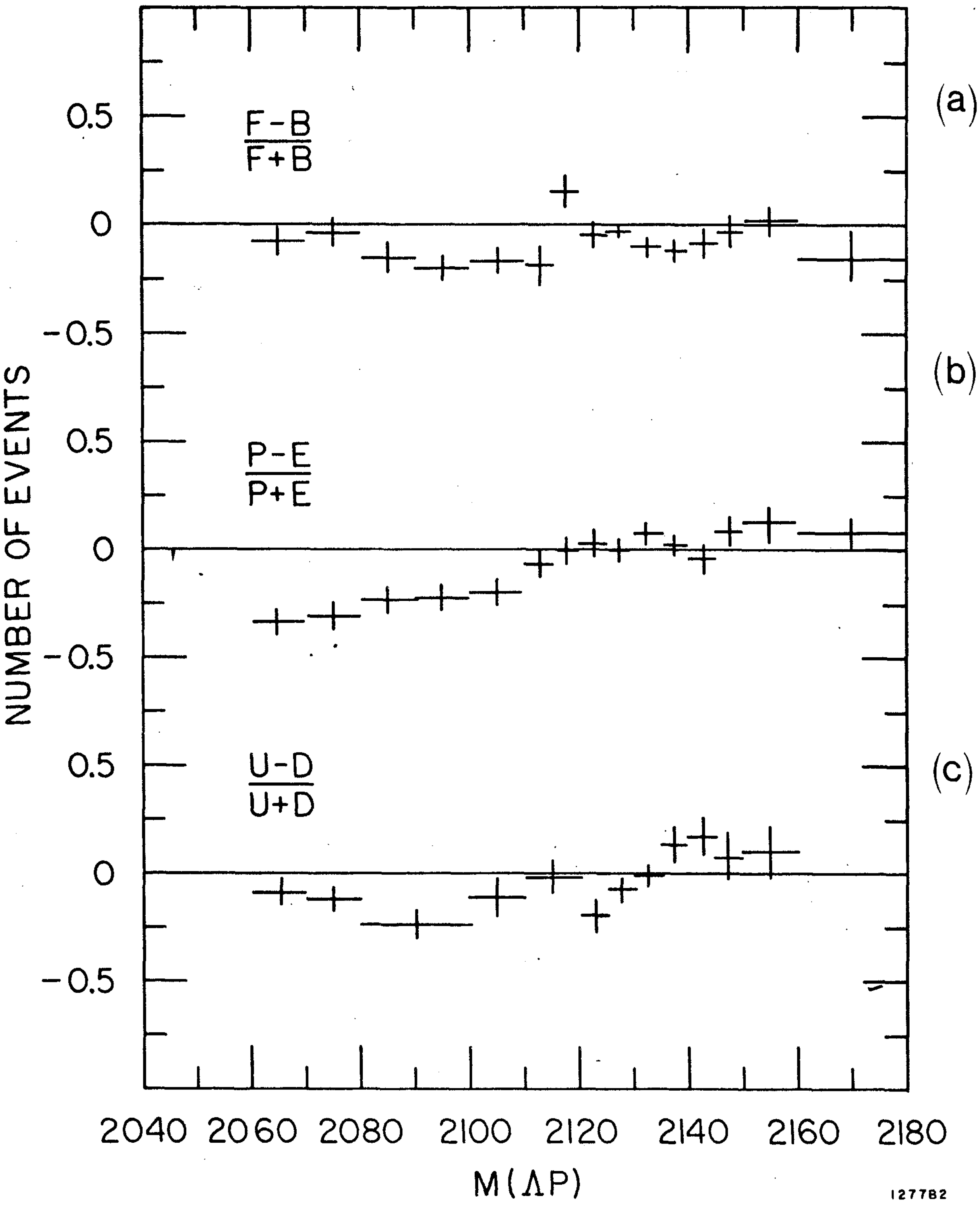

100
80
60
40
20
0
NUMBER OF EVENTS
2100
2110
2120
2130
2140
2150
2160
2170
M(ΛP)
127781

Fig. 2b



NUMBER OF EVENTS
0.5
0
-0.5
(a)
F-B / F+B
(b)
P-E / P+E
(c)
U-D / U+D
2040
2060
2080
2100
2120
2140
2160
2180
M(ΛP)
127782

Fig. 3