Report on LZ10772, Adams et al, Confirmation of a $\pi_1^0 \dots$

This paper presents high statistics data from E852 on $\pi^- p \to \eta\pi^0 n$, $\eta \to \pi^+\pi^-\pi^0$. The claim is made that an exotic 1^{-+} resonance is required with mass/width = 1257/354 MeV. There have been earlier claims in a 1999 paper of Chung et al. and from Crystal Barrel. VES observe a definite $\pi^0\eta$ amplitude in the same partial wave but do not claim it is resonant. A subset of the E852 collaboration, Dzierba et al. have reported in 2003 a definite attractive amplitude in this partial wave in $\eta\pi$, but they question whether it is a resonance. This point is therefore controversial.

My comments are as follows:

1) The work certainly should be published. However, I see many reasons why a full length PRD paper is preferable. I reached this conclusion by comparing with the 2003 paper of Dzierba et al. They presented the moments $H(10, 11, 30, 31, 32)$ from which the $\eta\pi$ P-wave is derived. They compared their fits directly with these moments. This comparison is needed for the present work, otherwise the reader cannot juege the quality of fit, i.e. who to believe. Presently the paper makes a strong claim, but very little comparison is made with data.

2)There are multiple solutions for the magnitude of the crucial P_+ wave. The present work relies on the mean of these multiple solutions, but it is not obvious that this necessarily reflects the moments accurately.

3) In view of the controversy with other groups, a full presentation seems essential to me. This controversy has lasted for nearly 10 years, and seems to make little progress, so PRL does not seem the right journal.

4) There are some details needing extra space:

(a) page 3, 7 lines from the foot of column 1, "Breit-Wigner amplitudes are used with mass dependent widths and Blatt-Weisskopf factors." It really puzzles me what mass dependence. For example, have the authors treated the $\eta\pi$ and $\rho\pi$ decays of $a_2(1320)$ with their full mass dependence? The reader also needs to know how the mass dependence might affect the $\eta\pi$ P-wave; e.g. is it given the correct threshold behaviour?

(b) The analysis "was carried out with the assumption that a spin-density matrix of rank 1 was suufficient." This might be questioned by others, so some justification is needed.

(c) In earlier work (Chung et al, 1999) it was shown that a pure D_+ wave can leak into P_+ because of incomplete acceptance. The claim is now made that this leakage is negligible. This is something of a surprise and justification is needed.

These details may appear tedious, but in view of disagreements with other groups about interpretation, a full presentation is desirable (and straightforward).

5) On page 4, in paragraphs 5 and 6, the authors speculate that there may be two resonances at $\sim$ 1280 and 1380 MeV, to account for the mass difference with Crystal Barrel results. I think this speculation is unwise. The paper already says that these results agree within errors, and it will be difficult to get readers to swallow 2 resonances, let alone one. If such a claim is made, the authors need to make a comparison between their data and a fit using Crystal Barrel parameters. That would be interesting for completeness, so that the reader can see by eye how well the Crystal Barrel parameters fit the data.

5) There is one final major point. Dzierba et al commented that there is no clear evidence for a phase variation in P_+ exceeding 90° over the available mass range. That is how the new results tend to look to my eye: in Fig. 2(c) there seems to be a 60° phase change in the points from 1.1 to 1.7 GeV. Remembering that the P wave increases as k^3 near threshold, its phase must be rather small at 1.1 GeV.

I see a serious possibility that the structure around 1300-1400 MeV is not a true resonance, but arises from the opening of the $b_1(1235)\pi$ and $f_1(1285)\pi$ thresholds. It seems to be agreed by all groups that there is a 1^{-+} resonance at $\sim$ 1650 MeV, decaying strongly (dominantly?) to $b_1\pi$. The S-wave threshold for this channel opens at 1365 MeV. So the $\eta\pi$ channel becomes strongly inelastic soon after this threshold. The resulting 90° turn in the amplitude towards the centre of the Argand diagram looks quite like a resonance (as pointed out earlier by Phillip Page). Unless the authors can differentiate between a resonance and this threshold, they would do better to refer to the observations as 'resonance-like'.

It would be possible for the present work to be published without examining this point, but it would be a poor paper in my opinion. The authors remark at the end of their first paragraph that "the exotic state observed at 1400 MeV is still not understood." Unless someone studies the possibility of a threshold effect (and it must be one of the experimental groups because the data are not accessible to others), there will not be any progress, just confrontation between groups. Perhaps there is just one exotic resonance at 1650 MeV plus an inelastic threshold at 1350 MeV. Or perhaps there really are two resonances. The point needs to be settled.

As encouragement, I will provide the necessary formulae, which are really quite simple and could be evaluated with a week or two's work. They are given by Tornqvist in Z. Phys. C68 (1995) 647, eqns (4-6). His formulae can be improved by making a subtraction on resonance, where the real part of the resonance amplitude is zero. Then the Breit-Wigner denominator becomes

$$Denom = m^2_{BW}(s) - s - Re\ \Pi(s) - i\, m_{BW}\Gamma_{tot}(s), \quad (1)$$

$$Re\ \Pi(s) = \frac{s - m^2_{BW}}{\pi} P \int_{threshold}^{\infty} ds' \frac{m_{BW}\Gamma_{tot}(s')}{(s'-s)(s'-m^2_{BW})}. \quad (2)$$

It is necessary to integrate $\Gamma_{tot}(s')$ over the line-shapes of $b_1(1235)$ and $\rho(770)$, e.g.

$$\Gamma_{b_1\pi} = \int_{(m_\omega+m_\pi)^2}^{s'-m_\pi} ds''\rho(s'')|f_{b1}(s'')|^2, \quad (3)$$

where $\rho(s'')$ is the usual phase space factor $2k/\sqrt{s}$ for decays to $\omega\pi$; f_{b1} is the Breit-Wigner amplitude of $b_1 \rightarrow \omega\pi$ at mass s''.

Relative contributions from $b_1\pi$, $\rho\pi$, $\eta'\pi$, $f_1\pi$ and $\eta\pi$ may be taken from world averages for branching ratios, including the dependence of each channel on phase space for decays and centrifugal barriers.

Library routines are available for doing the principal value integral. So this is a straightfoward calculation. No new fitting of data is required: simply a comparison of a calculation from first principles with data. Such a calculation would increase the value of the paper considerably by closing an important loop-hole.