HAVING A BLAST WITH EXCITED BARYONS

Nimai C. Mukhopadhyay and R.M. Davidson

Department of Physics, Applied Physics and Astronomy
Rensselaer Polytechnic Institute, Troy, NY, 12180, U.S.A.

1 Introduction

The study of excited baryons provides a window to look at the chromodynamic structure of hadrons. It is a severe test of our ability to apply the standard model to hadronic systems, and eventually to nuclear systems. BLAST can play a small, but special and significant, role in the valuable kinematic window of low $W$ and low $Q^2$.

2 Low $W$ and Low $Q^2$

Given the energy of the upgraded Bates facility, at the real photon point we can explore there in detail the first resonance region, and perhaps the Roper and a bit of the $N^*(1535)$ and $N^*(1520)$. How much can be learned about the latter three resonances will require a careful study of the accelerator and detector capabilities at their extreme ranges, and therefore lots of extra planning by the experimentalists as to how use BLAST best in this difficult domain. Apart from resonance physics, the pion threshold region is also accessible and of interest as a test of the chiral perturbation theory (CHPT).

At the real photon point, it will be difficult for BLAST to compete with facilities like Mainz, GRAAL, LEGS, etc., but perhaps it could be complementary. It would also provide vital checks on the BLAST system by comparing with standard results obtained elsewhere. As one moves away from the real photon point, there are many windows of opportunity. For example, CHPT calculations of the pion threshold region are currently believed to valid up to about $Q^2$ of 0.2 GeV$^2$. Although some data in this region already exist from NIKHEF and Mainz, a thorough study of this region, including polarization measurements, would be extremely useful. Such measurements would severely test CHPT, and therefore, QCD itself.

As one moves away from the threshold region and into the first, and perhaps second resonance regions, the physics becomes of interest to hadron models, lattice calculations and eventually a test of non-perturbative QCD.

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*aInvited talk at the MIT BLAST workshop, presented by NCM*
Indeed, low $Q^2$ data, up to roughly 0.5 GeV$^2$ are extremely important for testing nonrelativistic hadron models, since their predictions become unreliable at large $Q^2$. Even for a relativistic model such as the bag model, low $Q^2$ tests are important since the center of mass corrections are not perfectly under control and become increasingly important as $Q^2$ increases.

3 Low $Q^2$: Example from $\Delta(1232)$

The current status of $E2/M1$ at low $Q^2$, shown in Fig. 1, is rather chaotic. In particular, it appears to be changing from negative to positive at about 0.15 GeV$^2$, and then becoming negative again at about 0.4 GeV$^2$. Since as $Q^2 \to \infty$, this ratio becomes +1, according to the pQCD counting rules, it must change sign at least one more time. Needless to say, this structure is very difficult to explain in any hadron model. It must be pointed out that this ratio has been extracted from a meagre set of old electroproduction data totally lacking in polarization observables. In addition, the systematic errors are probably quite substantial, but are not shown in Fig. 1. Therefore, this is a region where BLAST can make a big impact.

Regardless of the current status of $E2/M1$ as a function of $Q^2$, it is clear that the best tests of QCD-inspired hadron models are in the low $Q^2$ domain.

Figure 1: The $E2/M1$ ratio at small $Q^2$ extracted using the effective Lagrangian approach.
where the models are most reliable. At present, the quark model (in various versions) is the only practical description of the resonance region. However, for the $N - \Delta(1232)$ transition, there are predictions from the bag model, Skryme model, and pioneering calculations have been done on the lattice. Note that while the lattice results are normally quoted at $Q^2 = 0$, in fact the calculations have been done at nonzero $Q^2$ and an extrapolation has been made to the real photon point.

Figure 2: Predictions for the differential cross section based on the effective Lagrangian approach. In these figures, $Q^2 = 0.5 \text{ GeV}^2$, $W = 1.23 \text{ GeV}$ and $\epsilon = 0.5$. The solid curve is with $E2/M1 = 0\%$, the dashed curve with $E2/M1 = -10\%$, and the dotted curve is with $E2/M1 = +10\%$.

Thus, in the case of the $N - \Delta$ transition, BLAST can provide precise tests of these QCD-inspired models. In the Roper region, the nature of this
resonance needs to be studied in detail in order to address the hypothesis that it is a hybrid state. Precise experiments on the $N^*(1535)$ would also be of interest since its transition form factor seems to be falling more slowly than a dipole.

Some simple model studies, based on the DMW approach, for pion electroproduction at kinematics relevant to the BLAST project are shown in Fig. 2. More of these can be obtained from the authors on request.

4 Conclusions

Though the $W$ and $Q^2$ range accessible with BLAST is very narrow, this is precisely the $Q^2$ range where model calculations are most reliable. Thus, for the first few resonances, BLAST can provide valuable data to test CHPT and QCD-inspired models, and ultimately QCD itself. It is of importance to emphasize that only very high precision experiments would be of interest to the physics community, and anything less would not be useful and would be wasting time and effort.

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12. Please contact us by email at davidr@rpi.edu.