Exploring the production of N*s with pion and electron beams

In the third in a series of articles on the production of N*s for *The Innovation Platform*, Lamar University's Professor Philip L Cole discusses the importance of using both high-intensity pion and electron beams for revealing the inner structure of excited protons (N*s) in the second and third resonance regions that decay through the two-pion channel

WE seek to understand how quarks and gluons self-assemble and thereby emerge in forming protons and neutrons. We therefore seek a better understanding of the nature of the proton – a particle central to physics, chemistry, and the biochemical properties of life. Recent results from interrogating protons with polarised photon and electron beams at Jefferson Lab in Newport News, Virginia, have given us precise information on the substructure of protons and their excitations, leading us to a deeper understanding of the proton. Laboratories in Germany (HADES at GSI) and soon Japan (E45 at J-PARC), however, are using pion beams to probe other aspects of the internal structure of protons. Both electron/photon and pion beams are required in order to reveal the internal

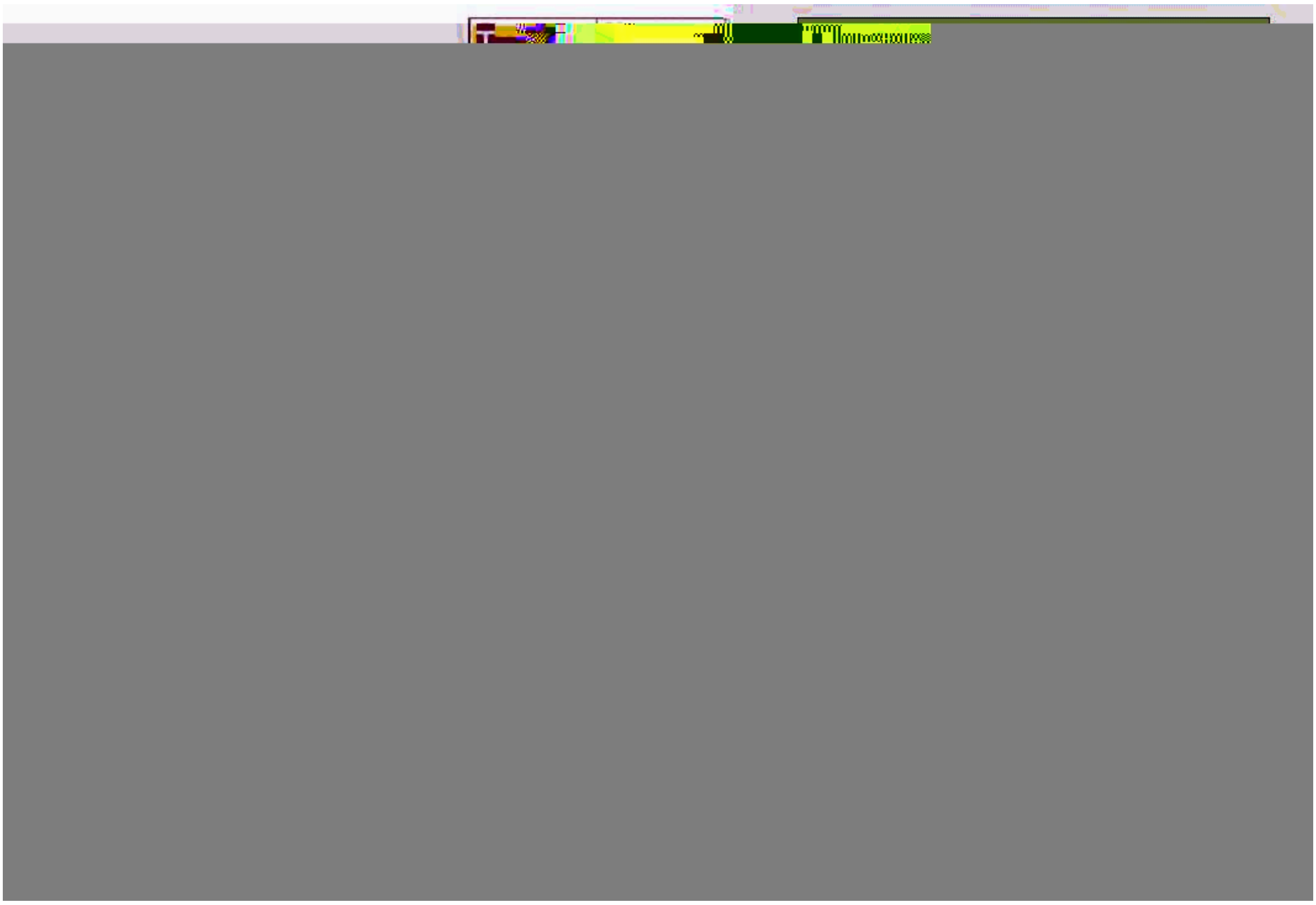

Fig. 1: (a) Baryon resonances (N*s) can decay through many channels depending on the how they are excited; (b) The various helicity amplitudes for each channel; (c) N* production with pion beams and the identified baryon resonances; and (d) the primary final states for electro-produced N*s. In the second and third N* regions, double-pion decay is dominant. This is exactly where we are looking and where the data are lacking

structure of the proton. Through a coupled-channel approach, we can identify baryon resonances in a consistent way. These data will allow us to ultimately extract combinations of the underlying amplitudes. The amplitudes govern the nature of the decay process and thereby afford us a means for understanding the physics and crack the conundrum of what makes a proton a proton.

An energetic particle, such as an electron, incident on a nucleon can interact directly with one of the valence quarks inside, causing the quark to undergo a flip in spin or endowing the quark with an orbital or radial excitation. With a quark in a higher energy state, the excited nucleon becomes more massive. Associated with the composite nature of the nucleon is a rich spectrum of excitations. These excited states are called nucleon resonances (N*s) and are short lived (10^{-24} s, on the order of the time it takes for light to traverse the diameter of the proton). These excited nucleons will dominantly decay into a ground-state nucleon, producing other strongly-interacting particles (called mesons). The types of mesons produced and how they are distributed in the phase space of the decay process provides key information on the internal symmetries of the quarks in the nucleon. The study of these excited states is

How important has international collaboration been for your work?