Research Objectives : P.R. Page

INTERESTS

Theoretical Elementary Particle Physics and specifically *Quantum Chromodynamics (QCD)* and *Hadron Phenomenology*. Non–perturbative gluonic excitations represent a major challenge in the Standard Model that now appear to be opening up experimentally, generating exciting new prospects that should be more closely investigated.

1. My M.Sc. focussed on the determination of the experimentally measurable quantity g_A/g_V (the ratio of the weak axial–vector and vector coupling constants) for neutron beta decay. It was calculated analytically to order α_S in the MIT bag model.

2. My D.Phil. was concerned with *hybrid mesons*, which have not yet been detected unambigously, although their existence is predicted by QCD. In the flux-tube model a hybrid meson forms if a quark-antiquark pair experiences an excited gluonic interaction. I predicted decay probabilities of hybrid mesons into other known mesons as well as their masses, so that experimentalists know how to recognize them.

3. During my postdoctoral year in Manchester I investigated the coupling of hybrid and conventional mesons to two photons and two gluons, discovered a new category of vanishing strong interaction decays governed by "symmetrization selection rules", and performed a detailed comparison between the strong decay modes of various hybrid and conventional mesons.

4. During my postdoctoral year at Jefferson Lab I investigated the strong decays of hybrid mesons in a new decay model, worked on the interpretation of the significant new data on hybrids that were emerging from Brookhaven National Laboratory, and developed a search strategy for charmonium hybrids arising from the decays of B mesons.

5. During my first postdoctoral year at Los Alamos I built a flux–tube model of hybrid baryons and proposed that the Brookhaven data can be interpreted the interference of a hybrid meson and a non–resonant background wave.

RESEARCH COMPLETED IN THE LAST 5 YEARS

1. For my M.Sc. I calculated next to leading order vertex diagrams determining g_A/g_V to order α_S. The gauge–independent logarithmic divergences from loop diagrams cancel each other for massless quarks and can be dimensionally regularized, making renormalization unnecessary. We obtained $g_A = 1.0883 + 0.2425\,\alpha_S$ and $g_V = 1$.

2. During my D.Phil. I showed in the bag model that among the low–lying charmonium hybrids there is a hyperfine splitting of ± 200 MeV. I subsequently studied hybrid meson decays in the flux–tube model. Previous work has been improved by performing the

first purely *analytical* calculation for all low–lying J^{PC} hybrids, and thus laying bare the essential dynamics. A selection rule, that hybrid meson decay to two S–wave mesons is forbidden, which is believed to be more general than the flux–tube model (conference proceeding* 12), is sometimes found to be significantly broken. This should enable enhanced production and detection of hybrids from CEBAF to ELFE.

Some recently discovered $J^{PC} = 1^{-+}, 0^{-+}$ and 1^{--} candidates for hybrid mesons are found to be in remarkable agreement with my results, indicating that gluonic excitations may finally be appearing in experiment. A detailed check that these candidates are not radially excited conventional mesons has been performed, resulting in strong evidence for the hybrid nature of $\pi(1800)$ (see conference proceeding* 13), and for hybrid / conventional meson mixing in $\rho(1450)$.

Decay calculations of hybrid charmonium are detailed in a conference proceeding* 11. I am able to account for the widths of $\psi(3770)$, $\psi(4160)$ and $\psi(4415)$ with sensible parameters; and show that, although unlikely, $\psi(4040)$ may be ordinary charmonium. However, $\psi(4040)$ and $\psi(4160)$ were subsequently argued to contain hybrid components. The possibly significant production of $2\,^3P_{1,2}$ and hybrid charmonium at CDF (with the dominant decay being radiatively to $\psi^{'}$) can account for the anomalously large production of $\psi^{'}$ at CDF. This work has directly motivated the search for $2\,^3P_{1,2}$ charmonium at CLEO.

3. In my Manchester postdoctoral year, the two–photon coupling of hybrid mesons was shown to be tiny in the flux–tube model, implying that the process is a filter in favour of conventional mesons. Two–gluon coupling of hybrid mesons was studied in a constituent gluon model and shown to be significant, implying substantial hybrid coupling in J/Ψ radiative decay. Using methods to extract two–gluon coupling from experiment, we argue for hybrid admixture in $\eta(1760)$.

   Symmetrization selection rules were derived in a completely general relativistic many–body approach and were argued to be valid in non–perturbative QCD. They were found to suppress the decay of hybrids, four–quark states and glueballs (with J^{PC} not found for conventional mesons) to pseudoscalar mesons. In the limit of non–relativistically moving quarks, the rules clearly indicate the most general conditions under which hybrid decay to S–wave mesons is forbidden.

4. During my postdoctoral year at Jefferson Lab I pointed out that B mesons which would be copiously produced at B-factories can act as an excellent way to produce charmonium hybrids. I also investigated the possibility of evidence for hybrids among excited light vector mesons. Towards the end of the period I provided theoretical guidance for the exciting claim by Brookhaven that they have uncovered evidence for particles that are not mesons - but possibly hybrids. The production of hybrids via collisions between photons and protons have been estimated in detail; and would form an important role in the proposed new experimental hall at Jefferson Lab that would aim to produce hybrids.

5. During my first postdoctoral year at Los Alamos I have interpreted the Brookhaven data

in $\eta\pi$ as arising from the interference of a J^{PC} exotic resonance at 1.6 GeV with a non–resonant $\eta\pi$ Deck background. I have also been involved in developing a realistic model motivated from QCD for states built from three quarks and a gluon: hybrid baryons. I have made predictions for hybrid baryon masses which can be tested at forthcoming experiments at Jefferson Lab.

RESEARCH PROPOSED

- The development of a flux–tube decay model of strong decays of a hybrid baryon to a conventional baryon and a meson. It is of significant interest whether a similar selection rule will be found as was operating for the decays of hybrid mesons.
- Investigations in heavy quark effective theory on the decay of hybrids made from one light and one heavy quark.
- The possible impact of the existence of the hybrid candidate $\pi(1800)$ on CP violation in D mesons.
- Calculation of the contribution of the gluon spin and angular momentum to the spin of the proton in flux–tube models of non–perturbative gluon fields.

More *generally* my *objectives and interests* are : (1) To make as general statements as possible about the interactions of strong gluonic degrees of freedom. (2) To develop rigorous techniques in quantum field theory to improve on the models used. (3) Non–perturbative TeV–scale phenomenology.