CLEO and QCD: From Beauty to Charm

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The CLEO Collaboration stands on the brink of making major contributions in the area of QCD. With the advent of the high-luminosity asymmetric B-factories at SLAC and KEK, CLEO has ceased taking data at the Υ(4S) and begun a program that will first take large data sets at the three bound states of $b\overline{b}$ and then move to lower energies to conduct precision studies D and D_s mesons and to probe in depth the radiative decays of the J/ψ. These new measurements will confront QCD and, in particular, match the precision of Lattice predictions. This "certification" of the Lattice techniques will in turn maximize the impact of the precision experimental results from SLAC and KEK.

1. Who is CLEO?

The CLEO Collaboration, in existence since the late 1970's, currently consists of some 150 physicists from 20 North American institutions. This collaboration uses the CLEO detector, which has evolved over time, to collect data in the energy regime of the Υ system, namely $9 < \sqrt{s} < 11$ GeV. This work is performed at CESR, the Cornell Electron Storage Ring. CLEO is perhaps best known for its advances in B physics from data taken at the Υ(4S): discovery of penguin decays ($b \to s\gamma$), pioneering work (with ARGUS) on B^0 mixing, first measurements of many rare B decays (such as $\pi^+\pi^-$), precision determination of V_{ub} and V_{cb}, etc. These types of measurements have greatly enhanced our knowledge of the weak interactions and of the CKM matrix.

However, CLEO, since its inception, has over 330 published papers of which only 34% are in B physics. For example, CLEO has discovered some 16 of the 22 known charmed baryons, is a leader in the present push to see mixing in the charm sector, and, with the LEP experiments, has filled the PDG's *Review of Particle Properties*[1] with τ lepton results. This is a diverse collaboration with diverse physics interests!

CESR has performed well, delivering some 24 fb^{-1} of e^+e^- luminosity from which CLEO has harvested 17 million $B\overline{B}$ events. But BaBar/PEPII at SLAC and Belle/KEK in Japan have started up "brilliantly", collecting 10 fb^{-1} each in their first year of operation. These collaborations now have data sets approaching 100 fb^{-1} and people now speak of inverse atobarn samples!

Those new B factories are "asymmetric" so that the final state is moving in the laboratory frame. This allows them to make time-dependent decay measurements important to the study of CP-violation; CLEO cannot compete with them in this area at all. And, given the high luminosities of these new facilities, CLEO's competitive position in rare processes is fading.

So, how do CESR and CLEO continue to contribute in this new reality?

2. Lattice QCD and the B Factories

Any experimental result, x, from the new B-factories or elsewhere, carries a central value, x_0 and several uncertainties:

$$x = x_0 \pm \sigma_{stat} \pm \sigma_{sys} \pm \sigma_{oth} \pm \sigma_{th} \qquad (1)$$

Here σ_{stat} and σ_{sys} are the usual uncertainties due to limited statistics and possible systematic experimental biases, respectively. The term σ_{oth}

arises from experimental uncertainties from *other* experiments and σ_{th} is the uncertainty due to theoretical inputs. As an example of the need for σ_{oth}, consider that any result that uses $B \to D$X will ultimately be limited by the knowledge of the D decay branching fractions obtained from other experiments.

More dramatically (with few important exceptions such as obtaining $\sin(2\beta)$ from the decay $B \to J/\psi K$), weak interaction results are limited by strong, non-perturbative QCD uncertainties. We measure weak interactions by using strongly interacting particles! For example, the B-factories will ultimately measure V_{ub} from $B \to \pi \ell \nu$ to an experimental accuracy of perhaps 4%. But the form factor that governs the u-quark materializing as a pion is only known to 20% !

Lattice QCD (LQCD)has resurrected itself just in time to address these strong interaction uncertainties. Up until recently LQCD made predictions in masses, form factors and other quantities at the level of 10-20%. The question is whether LQCD is now in a position to get to a **few** percent accuracy for:

- B and D systems?
- Υ and J/ψ systems?
- Light hadron systems?
- Masses, form factors, rates, etc,?

To give a concrete example, let us look at the ρ-η plane. This is the plane in which we plot the unitary triangles that come from the CKM matrix, with the apex of such triangles lying in the region shown in Fig. 1. The areas of such triangles are the measure of CP-violation. Within the context of the Standard Model, all the measurements should agree: Δm_d from B_d mixing, $\Delta m_s/\Delta m_d$ from that and B_s mixing, $|V_{ub}/V_{cb}|$ from B decay rates, $|\epsilon_K|$ from the kaon sector, and the new CP-violating asymmetries from the B factories in ψK. As shown in this figure, the results (plotted for early 2002) have a large overlap in the region $0.07 < \rho < 0.32$ and $0.28 < \eta < 0.45$. If one were to reduce all the theoretical uncertainties to 2-3%, the area of the allowed region would shrink by a factor of about 15!

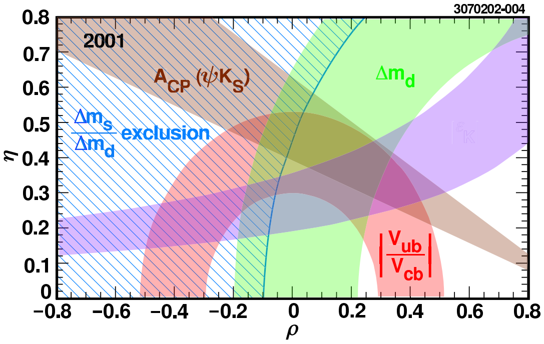

Figure 1. The ρ-η plane of the CKM matrix in early 2002. In the Wolfenstein parametrization of the CKM matrix CP violation enters through terms such as $\rho - i\eta$ in V_{ub}.

Of course, it would be even *more* interesting if, when these uncertainties are reduced, there were *no* region of overlap, indicating that physics beyond the Standard Model is necessary to explain CP-violation.

But, would the physics community believe such small systematic uncertainties from LQCD? If an experiment consistently gave results to a precision of 15% and suddenly produced an important paper with uncertainties of 3%, would not the world (or at least the PRL referees!) demand evidence that such a good precision be attained for processes that are well understood? Therefore, LQCD will need to show that it gives the “right” answer for a number of diverse quantities in $b-$ and $c-$ physics.

That is where the CESR-c/CLEO-c program fits into the picture. It will provide, in a fixed term, 3-4 year program, precision measurements on which to test LQCD in the 3-12 GeV range.

To show the power of this, compare Fig. 1 to Fig. 2. This latter figure now shows how the sizes of the various constraints are reduced if the B factories at KEK and SLAC each have data samples of 0.4 ab^{-1} *and* CLEO-c has verified that LQCD can provide the necessary theoretical inputs at the 2-3% level. Now, given the present central

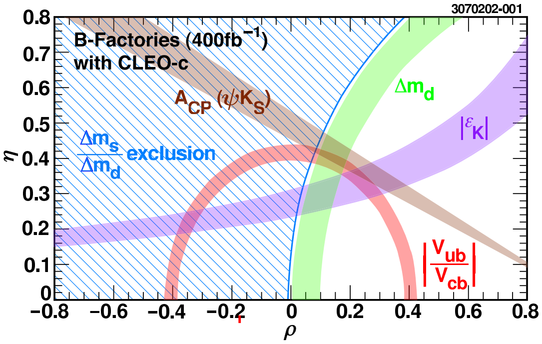

Figure 2. The ρ-η plane after several years of B-factory data and 2-3% theoretical accuracies verified by CLEO-c.

values, there would indeed be no overlap region at all.

3. The CLEO-c Program

The CLEO-c program has four major parts: Υ resonances, D physics at threshold, D_s physics (also at threshold), and J/ψ radiative decays. In the first of these, which is ongoing, CLEO will collect 5-20 million decays of *each* of the three Υ bound states of $b\bar{b}$.

Then, taking 3 fb^{-1} of data at the $\psi(3770)$, CLEO would collect some 30 million events, yielding six million *tagged* D meson decays. Such a data sample is some 300 × that of MARKIII. A similar luminosity at $\sqrt{s} \sim 4100$ MeV would yield 1-2 million $D_s\overline{D_s}$ events (480 × MARKIII and 130 × BESII) and 300,000 *tagged* D_s decays. Finally, some six months running could produce up to 10^9 J/ψ decays!

3.1. Preparing CESR and CLEO

To accomplish this program, the CESR accelerator will have to be able to run with beam energies from 1.5 GeV to 6.0 GeV. That is an unprecedented requirement of dynamic range of operation. Superconducting interaction region magnets were installed in 2001 that have elements for tight focusing, steering, and correction of typical aberrations. These work extremely well and provide greatly increased flexibility. As an example, we show in Fig. 3 a recent scan of the lineshape of the $\psi'(3686)$. The energy calibration and cross section look fine in this brief test.

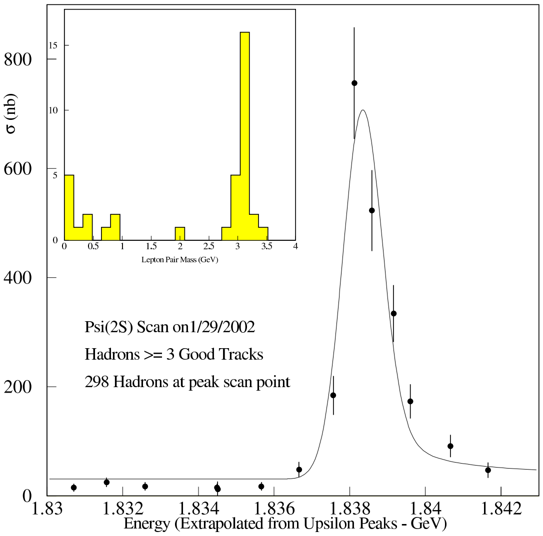

Figure 3. Scan of the ψ' lineshape is recent CESR running *without* any of the new superferric wigglers. The insert shows the subset of events consistent with $\psi' \to \pi^+\pi^- J/\psi$.

While CESR, as presently configured, *can* run at charm energies, it cannot run well. The ability of the beams to "cool" themselves is a strong function of beam energy so that in the charm regime the luminosity is severely limited by the long damping times involved. To increase the damping from the synchrotron radiation one installs "wigglers" - closely spaced dipoles of alternating sign that force the beams to undulate and hence radiate.

These wigglers are similar to the devices inserted in storage rings to produce synchrotron light sources. They also are crucial for the beam dynamics of any future linear collider. The CESR-c design is super-ferric at 2.1 Tesla and ultimately would have 14 units, each 1.4m in length.

The prototype as been built and tested and will be installed in Aug-Sept 2002. Five more will be constructed and tested in the fall of this year, to be installed in early 2003. These six will allow CESR to achieve more than half of its instantaneous luminosity goals for the D and D_s running.

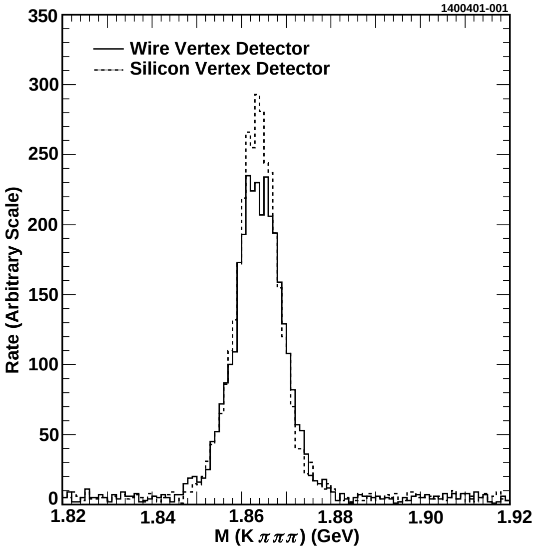

Figure 4. A comparison of the mass resolution for $D \to K\pi\pi\pi$ in the all-charged mode. In dashed line is the invariant mass distribution with the present silicon detector, with the assumption of little further radiation damage. The solid line is for a system that includes the new six-layer wire chamber.

The CLEO detector[3] has a high quality crystal electromagnetic calorimeter, greatly enhanced particle identification by means of a new ring-imaging Cerenkov (RICH) detector[4], perhaps the world's best large drift chamber[5] and a trigger and data acquisition system up to the task of CLEO-c[2]. However, the silicon vertex detector installed in CLEOIII has shown premature aging and needs to be replaced. In that the physics emphasis of CLEO-c does not require precision vertexing, this inner tracker is being replaced with a small, 6-layer, all-stereo wire chamber. Extensive simulation studies have shown little loss in performance of the CLEO-c goals by this change; an example is shown in Fig. 4. This new detector is built and starting tests under voltage; it will be installed during the shutdown of early 2003 in which the five new wigglers are put into CESR.

3.2. Υ Resonance Physics

As noted above, we are now in the midst of collecting data in the Υ resonance region. By the shutdown of mid-August we will have roughly 20, 4, and 6 million events from the Υ(1S), Υ(2S) and Υ(3S) on tape. There are an additional six weeks of running in this region in Fall 2002 as CESR makes the transition to charm running. In addition to these data samples at the three resonances, we have significant data in the four-flavor continuum and in scanning the resonance line shapes.

Our program in Υ resonance physics falls into two broad categories - "discovery" and "precision". Both are very important to QCD.

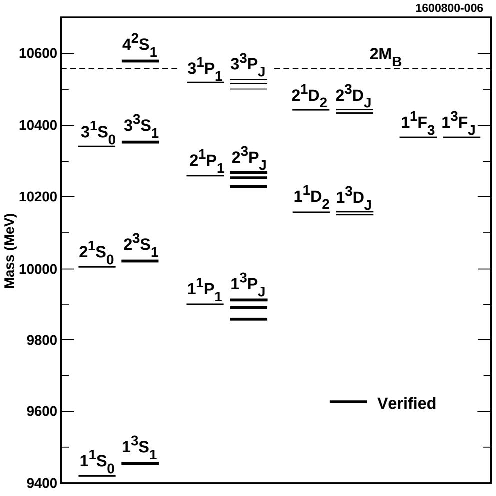

Figure 5. The energy levels of the $b\bar{b}$ system. Only the three $^3S_1$ "Υ" and the six ^3P_J "χ_b'' states have been observed.

The rich spectrum of $b\bar{b}$ is shown in Fig. 5. Only the three $^3S_1$ "Υ" states directly produced in e^+e^- collisions and the six ^3P_J"χ_b" states related to them via E1 radiative transitions have been observed. Among the states and processes for which we are searching are:

- The L=2 "D" states. There are no other such stable $q\bar{q}$ states in nature, with the unique feature of so much angular momentum between the constituents.
- The two singlets $\eta_b(1^1S_0)$ and $h_b(1^1P_1)$ and their radial excitations. The hyperfine splitting between these and their well-established partners is a particularly good test of LQCD (and of potential models as well.)
- Rare transitions. These include not only hadronic transitions such as Υ(3S)$\rightarrow$ Υ(1S)η, but also E1 transitions such as that from the χ_{b0} (1^3P_0) which is suppressed by the large gluonic width of that state.

The Υ(3S) data has been sufficiently processed that results will be shown at `ICHEP02` for three of these discovery areas[6]. Others should be forthcoming as the calendar year progresses.

The large data sets also allow us to make precision measurements with which to test LQCD and other aspects of theory. Perhaps the most significant is a program to measure Γ_{ee} for each of the three narrow bound states to a precision of 2-3%, with the ratios of these to be determined even a bit better than this. In Fig. 6 we give the uncorrected lineshape for the Υ(3S), showing that our statistical uncertainties will be small - below one per cent. Many different scans were taken to help us understand and minimize systematic uncertainties in these determinations.

We should also be able to measure $\mathcal{B}_{\mu\mu}$ for each of the three resonances to 3-4% and this obtain Γ_{tot} values to the level of 5%.

Another area in which we can make big improvements in our understanding is in the $\pi\pi$ transitions among the three Υ states. Not only will we have high-precision distributions of the di-pion invariant masses in both the charged and neutral modes, but can also look at angular correlations to better determine the decay mechanisms at work.

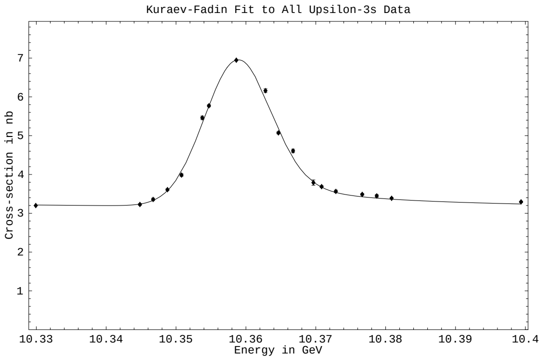

Figure 6. The CLEO-III data taken for the Υ(3S) line shape. The results of the ten scans have been combined for this plot and the theoretical shape, including radiative corrections, has been applied. These data are largely uncalibrated at this point.

3.3. Charmed Meson Physics

Historically one gets the smallest systematic uncertainties by studying decays of hadrons produced at or near threshold. Events are then uncomplicated by extra particles from the hadronization process. Therefore, to study D^0 and D^+ mesons (and their conjugates, of course) CLEO-c will collect some 3 fb^{-1} at the $\psi(3770)$, which decays essentially only to $D\overline{D}$. This amount of data will take roughly a year to collect[2], and is presently planned for 2003-2004. This will produce some 30 million events that have nothing but a D and a $\overline{D}$ in them. Then, having determined the optimal beam energy in a prior scan, there will be another 3 fb^{-1} taken to collect some 2 million $D_s\overline{D}_s$ events. This data collection is tentatively scheduled for 2004-2005.

The key to the CLEO-c program is the ability to fully reconstruct one D (or D_s) so as to be able to investigate the other in an unbiased fashion. This reconstructed hadron is called the "tag". *E.g.,* one would study D decays in events with a $\overline{D}$ tagged in $K^+\pi^-$.

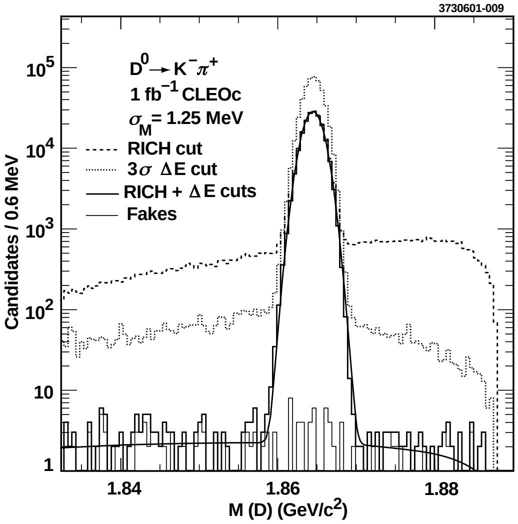

Figure 7. Example of tagging in CLEO-c. Note the log scale! In this simulation we see the effect of the few selection criteria needed to get a very clean sample of D^0 mesons in the $K^-\pi^+$ mode.

In Fig. 7 we show how such a tag would look in CLEO-c running at the $\psi(3770)$. Clearly we can get very clean samples. There are many large ($\sim 5\%$) branching fractions of these hadrons, the reconstruction efficiency for such low-multiplicity events is high, and we have two chances per event to establish as "tag". We therefore have overall efficiencies in the 20% range, yielding some 6 million tagged D decays and some 1.5 million tagged D_s decays.

Below are three examples from the wide array of physics topics with these charmed mesons:[2]

- Branching fractions from Double Tagged events

  As noted above, all measurements of B decays to D mesons are ultimately limited by knowledge of the D branching fractions to the observed stable final state particles.

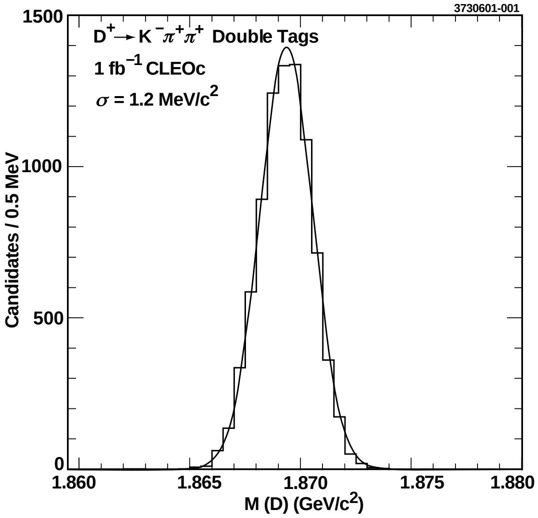

Figure 8. Double tags at the $\psi(3770)$. In this simulation, both hadrons have been tagged in the same decay mode namely $K^\mp\pi^\pm$.

  One impressive use of tagging is to "double tag", finding both particle and anti-particle with conjugate final states. This leads to very clean signals (as shown in Fig. 8 from simulation), reasonably large samples (due to the high efficiencies described above), and extremely small systematic uncertainties. In Table 1 we show the improvement over the present situation[1] for a number of modes predicted for CLEO-c. See Ref.[2] for a more complete list and description.

Mode	PDG2000	CLEO-c
	$(\delta\mathcal{B}/\mathcal{B})\%$	$(\delta\mathcal{B}/\mathcal{B})\%$
$D^0 \rightarrow K\pi$	2.4	0.5
$D^+ \rightarrow K\pi\pi$	7.2	1.5
$D_s \rightarrow \phi\pi$	25	1.9

Table 1
Selected charm meson branching fractions from CLEO-c double tagging.

- Meson constants from leptonic decays

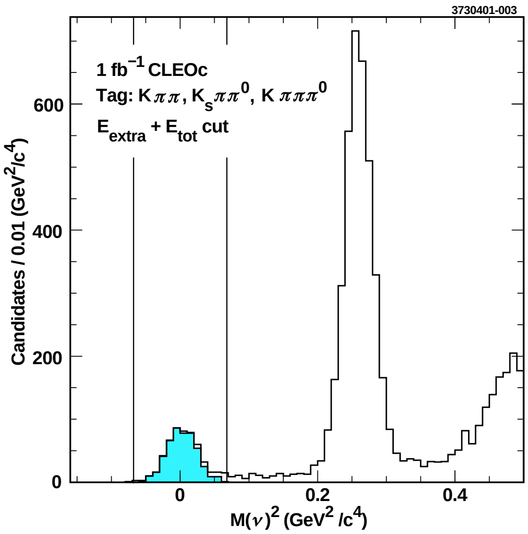

Figure 9. Decay constant from leptonic events. In this simulation we show the missing mass against a single charged track in events tagged by a charged D meson in three modes. A clear enhancement at the neutrino mass of zero is observed in what would be 1/3 of the CLEO-c data sample. The large peak is from $D \to K_L \mu\nu$.

One of the keys to understanding B physics is the value of the meson decay constant f_B, which is effectively a measure of the overlap of the constituent wave functions in a pointlike decay process. LQCD will be able to tell us f_B and, with even better precision, ratios such as f_B/f_D.

CLEO-c will help here by giving high-precision values of f_D and f_{Ds} from measuring the branching fractions $\mathcal{B}(D^+_{(s)} \to \ell^+\nu_\ell)$. The present CLEO uncertainty in f_{Ds} is roughly 13%; the asymmetric B factories will reduce this to $\sim 8\%$ using similar techniques and perhaps as good as $\sim 4\%$ with as-yet-unknown, clever analyses. Similarly, we expect $\sim 7\%$ precision from BaBar/Belle on f_D.

In Fig. 9 we give an example of the capabilities of CLEO-c, as determined from Monte Carlo simulation. Here we have tagged the event by reconstructing a charged D meson in one of three modes. We then demand there be only one additional charged track and plot the missing mass for the event, clearly seeing the neutrino. The large peak near 0.25 $(\mathrm{GeV/c^2})^2$ is from $D \to K_L\mu\nu$. The signal:background ratio is roughly 9:1 and most of that background is from a variant on the signal, namely $D^+ \to \tau^+\nu_\tau$. We would have some 800 such events in 3 fb^{-1} of data.

Decay Const and Mode	$\delta\mathcal{B}/\mathcal{B}$ (%)	$\delta\tau/\tau$ (%)	$\delta V/V$ (%)	$\delta f/f$ (%)
f_D:$D^+ \to \mu\nu$	3.9	1.2	1.1	2.3
f_{Ds}:$D_s^+ \to \mu\nu$	3.3	2.0	0.1	1.9
f_{Ds}:$D_s^+ \to \tau\nu$	2.5	2.0	0.1	1.6

Table 2
Uncertainties in the determination of the charmed meson decay constants in 3 fb^{-1} each of $D\overline{D}$ and $D_s\overline{D}_s$ data. Here τ is the charmed meson lifetime and V the CKM element associatd with the decay.

While we measure branching fractions, what we want to derive are the decay constants, which means knowledge of the meson lifetime (to go from $\mathcal{B}$ to Γ) and the appropriate CKM matrix element (giving the strength of the $c\overline{d}$ or $c\overline{s}$ interaction at the vertex). In Table 2 we show the CLEO-c prospects for f_D and f_{Ds} in the three dominant modes, including uncertainties on the lifetimes and weak couplings. Much more detailed information is available in Ref.[2].

- Semi-leptonic decays

Over the years the biggest impact on the CKM matrix elements has come from semi-leptonic decays, which has certainly been

Decay Mode	PDG2000 $(\delta\mathcal{B}/\mathcal{B})\%$	CLEO-c $(\delta\mathcal{B}/\mathcal{B})\%$
$D^0 \to K\ell\nu$	5	2
$D^0 \to \pi\ell\nu$	16	2
$D^+ \to \pi\ell\nu$	48	2
$D_s \to \phi\ell\nu$	25	3

Table 3
Selected semi-leptonic charm meson branching fractions from CLEO-c.

true in the B sector for V_{cb} and V_{ub}. CLEO-c will continue this tradition by using charm meson semi-leptonic decays to investigate V_{cd} and V_{cs}. The idea is again to tag the event and look at the semi-leptonic rate of the "other" D or D_s meson. As with the purely hadronic cases, CLEO-c will make great improvements in these branching fractions, as seen in Table 3.

Converting these branching fractions to measures of the CKM elements requires knowledge of the charm lifetimes (as in the hadronic cases above) and of the relevant form factors. If one knew these form factors to the level thought to be achievable from LQCD then CLEO-c will measure the magnitudes of V_{cd} and V_{cs} to the level of 1-2%. Because LQCD predicts the slope of the q^2 evolution of these form factors as well as their magnitudes, CLEO-c can check that the theory has the requisite precision in that in can measure such slopes to the level of few percent.

Other aspects of semi-leptonic decays are discussed in Ref. [2].

3.4. Radiative J/ψ Decay

The last portion of the CLEO-c program (and hence likely the last HEP data ever taken with CESR!) will be a very large data set at the J/ψ $c\bar{c}$ resonance. With a full complement of wiggler magnets we should be able to collect a *billion* J/ψ decays over a period of 3-4 months. Although there are many interesting channels to study at this resonance, the emphasis is on radiative decays.

Radiative J/ψ decays, in which a photon replaces one of the vector gluons in the standard hadronic process $J/\psi \to ggg$, provides a "glue-rich", experimentally clean environment in which to look for glueballs, bound states involving no valence quark constituents. Glueballs are a fundamentally new form of matter, which must exist in QCD in that the gluons can couple to each other as well as to quarks.

Present data samples, dominantly from BES, have systematic issues from the large hadronic backgrounds (such as incompletely reconstructed neutral pions) and hermiticity. Statistics on the order of a billion are needed to do Partial Wave Analysis (PWA), which typically requires a million or so events per channel with branching fractions on the order of 0.1%; today's data sets of tens of millions are just not large enough for this type of analysis.

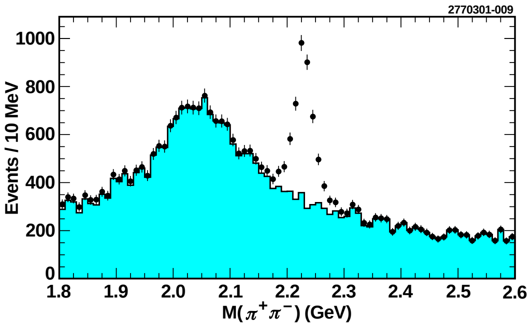

Figure 10. Exclusive spectrum for $J/\psi \to \gamma f_J$ with $f_J \to \pi^+\pi^-$. This simulation study included *all* known backgrounds and was for 170 million J/ψ decays.

In many scenarios the lowest lying glueball state is a tensor $J^{PC} = 2^{++}$ near 2.2 GeV in mass. The facts that radiative J/ψ decay is glue-rich, that this glueball is thought to be relatively narrow (enhancing signal-to-background), and that there are large branching fractions for such decays to tensors (such as $J/\psi \to \gamma f_2(1270)$)

lead one to expect to see such an object in the CLEO-c data. In the *ex*clusive decays, in which we detect the decay products of the glueball, the quality of the CLEO detector leaves us with essentially *no* hadronic background and extremely clean signatures. In Fig. 10 we show the example of finding a glueball at 2.2 GeV in the decay $J/\psi \to \gamma\pi^+\pi^-$. In this simulation of about 1/6 of the proposed data sample, we have put in all known backgrounds, including the dominant one in this analysis from $\gamma f_4(2050)$. It should be noted that other exclusive channels, such as $K\overline{K}$ or $\pi^0\pi^0$ have *different* backgrounds, so that exploring all possible final states will greatly increase our sensitivity.

In Table 4 we show the reported yields from the original 8 million J/ψ decays from BES[7] (they now have some 50 million events) and the equivalent yields for the proposed CLEO-c data sample.

Decay Mode	Published BES	Proposed CLEO-c
$\pi^+\pi^-$	74	32000
$\pi^0\pi^0$	18	13000
K^+K^-	46	18000
K_SK_S	23	5000
$p\overline{p}$	32	8000
$\eta\eta$	-	5000

Table 4
Selected decay modes of a tensor glueball with mass near 2.2 GeV. Shown are the published yields from the BES Collaboration with some 8 million J/ψ decays and the CLEO-c projections for a billion such decays.

But that is not the only way to investigate glueballs at the J/ψ. The quality of the CLEO crystal calorimeter allows one to pick out states *in*clusively as well, as shown for about 6% of the proposed data sample in Fig. 11. Again, all known backgrounds have been included in this simulation, with the shaded region of the plot being the hadronic component. No other experiment has the resolution to make such an inclusive study.

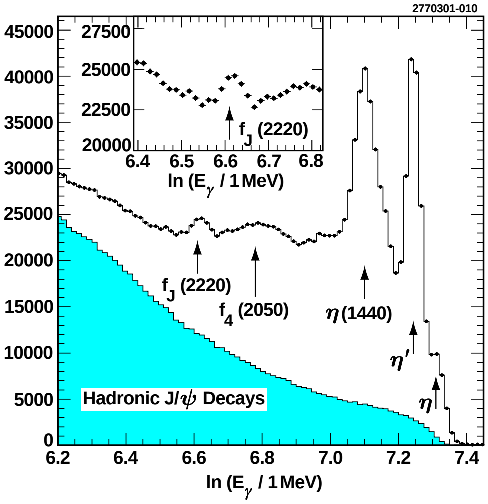

Figure 11. Inclusive photon spectrum for the J/ψ. This simulation study of 60 million J/ψ decays included *all* known backgrounds.

In addition, CLEO has some 25 fb^{-1} of data in which to "anti-search" for such glueballs in $\gamma\gamma$ interactions as well as its sample of Υ data in which to look for exclusive radiative decays from $b\bar{b}$ states.

The power of PWA will become most apparent when looking at lower-mass states such as the three f_0 resonances at 1370, 1500 and 1710 MeV. The quark model would only support two such scalars, so it is widely assumed that these three states are some mixture of $|n\overline{n}>$, $|s\overline{s}>$ and $|gg>$. Looking at exclusive and inclusive radiative decays to these in CLEO-c and measuring their two-photon partial widths from the higher-energy CLEOII data will shed a lot of light on this issue.

3.5. Other Aspects of the Program

As with any multi-purpose detector, there are many other physics topics that can be studied while collecting data in the energy range $3 < E_{cm} < 5$ GeV. Many of these were discussed at a 2001 workshop[8] and a large number have found their way into the CLEO-c Project Description[2].

Among them are:

- $\psi'(3686)$

  The ψ' is the gateway to all the $c\bar{c}$ states and should allow detailed study of many of them. It is also of interest in that there are certain decays that are plentiful for the J/ψ (such as to $\rho\pi$ or to K^*K) that have only limits for the ψ'; this is the so-called $P-V$ puzzle. In addition the plentiful dipion decays to the J/ψ will allow us to carefully study tracking and triggering effects of our J/ψ data sample.

- Measures of R

  There is a large discrepancy between the Crystal Ball and MarkI measurements of R in the range $5 < \sqrt{s} < 8$ GeV. During the Υ resonance running, CLEO has taken data to make measurements to the few percent level for $7 < \sqrt{s} < 9.5$ GeV and will take data in the range $3.7 < \sqrt{s} < 6$ GeV with the CLEO-c/CESR-c configuration. In addition to this basic scan we will conduct a "modern" scan in which we look at the final states containing $D/D^*/D_s$, shedding light on the nature of the $c\bar{c}$ states above open charm threshold and determining the optimal energy at which to run for the CLEO-c $D_s\overline{D}_s$ program.

- τ-pair Physics.

  A short period of running near $\tau\tau$ threshold would improve on the measure of the tau mass. The "low energy" Michel parameter η can also be studied very well at CLEO-c energies via the decay $\tau \to \mu\nu\overline{\nu}$. There are also some modes that remain systematics limited that would benefit from new high-statistics analysis in the CLEO-c environment.

4. Concluding Remarks

The CLEO Collaboration at CESR is embarking on a mission to make a large numbers of measurements important to QCD, and particularly LQCD, with unprecedented precision.

It is a challenge to the theoretical community to develop predictions of similar precision in order to enhance our understanding of both strong and electro-weak physics in both the charm and bottom sectors.

We at CLEO welcome theorists' ideas and active collaboration so as to maximize the impact of the CLEO-c program.

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