Systematic Uncertainties from CLEO-c $D_{(s)}$ Physics: A Perspective

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(+ CLEO-c & BESIII)

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All our science, measured against reality,
is primitive and childlike -
and yet it is the most precious thing we have.

-- A. Einstein

CLEO-c systematics, measured against reality,
are imperfect and limited -
and yet they are the most precious guide we have.

-- A. Nonymous

Learning from the Past

Let's be clear: I'm not criticizing CLEO-c !
The study of systematics is hard work, and it was done well.
But the quote was irresistible…

We should admit that evaluating systematic uncertainties is an art form, and note that CLEO-c is still the state-of -of-the-art for threshold charm.

So as we find ourselves on the doorstep of the BESIII era of threshold charm, it seems like a good time to re-study some of "the classics".

Outline

Introduction

D Tagging Issues

Systematics of Precision CLEO-c Analyses

- Absolute Hadronic BFs
- Semileptonic Form Factors
- Leptonic Decay Constants

Observations and Conclusion

From my talk at FPCP 2009…

Look at the size of the stat / syst / FSR errors from CLEO-c

$\psi(3770)$: D^0 and D^+ physics with ~ 820/280 pb^{-1}

** f_D $(D^+ \rightarrow \mu\nu)$:	± 4.1% ± 1.2%		
** $f(q^2=0)$ $(D^0 \rightarrow \pi l \nu)$:	± 5.3% ± 0.7 %	[3-par. series fit]
Br($D^0 \rightarrow K\pi$):	± 0.9% ± 1.5% ± 0.9%	[281 pb^{-1}]
Br($D^+ \rightarrow K\pi\pi$):	± 1.1% ± 1.8% ± 0.8%	[281 pb^{-1}]

@4170 MeV: D_s physics with ~ 600/300 pb^{-1}

* f_{Ds} $(D_s^+ \rightarrow \mu\nu, \tau\nu)$:	± 2.5% ± 1.2%	
* Br $(D_s^+ \rightarrow KK\pi)$:	± 4.2% ± 2.9%	[298 pb^{-1}]

Often significant gains to be made with increased data samples, even if systematic errors are simply matched, not improved.

ALSO: analyses using Quantum Correlations, CP-tags, etc. are also statistics-starved at CLEO-c

BESIII/BESPII vs. CLEO-c/CESR-c

Biggest Change:

Higher luminosity: about 7x peak,
a bit less for integrated rate
(longer fill times at BEPCII)

Other Issues:

More noise (CLEO-c had lower lumi, but at least it was relatively quiet!)

Smaller beam-energy spread: Better m_{BC} resolution

Poorer tracking resolution: Worse ΔE resolution

Weaker Particle ID (TOF instead of RICH)

Small barrel-endcap calorimeter gap

Final observation: CLEO-c detector in use for 5 years before charm !
Well-understood; only change was channing SVX to ZD in tracking

Themes

Certain themes recur, and are worth looking for

Methods for efficiency systematic studies

> What decay modes are used ?
>
> What are the statistical limitations of studies ?
>
> ***Are there systematic issues with the study methods ?***

i.e, are we studying the correct thing ?

What about systematics on fits, etc. ?

(good MC helps)

When were Data/MC corrections required ?

Interesting "tricks"

Less familiar systematics

D Tagging

For us, a "tag" is a fully-reconstructed D decay
This is generally, a hadronic final state

[but it can also be a (semi)leptonic one opposite a hadronic one]

D tag method allows an absolute normalization of BFs
Key point: D's are produced in pairs

single tags, mode i: $N_j = N_{DD}\,\varepsilon_j\,B_j$

double tags, modes i,j: $N_{ij} = N_{DD}\,\varepsilon_{ij}\,B_iB_j$

Combine and solve: $B_i = (N_{ij} / N_j)\,(\varepsilon_j / \varepsilon_{ij})$

N_{DD} cancels with algebra

- No need for more difficult normalization tricks (D*, etc.)
- low sensitivity to tag efficiency: $(\varepsilon_{ij} / \varepsilon_j) \sim \varepsilon_i$

Tags also allow for many nice systematics studies:
efficiencies, with missing mass, etc.

Standardization of D Tags

D Tags

CLEO-c had "standard" D Tags

Users still have a lot of flexibility:

- **> Select which modes to use**
- **> Choose m_{BC}, ΔE cuts**

  3σ to 2σ in 2-D can cut background

  by more than 1/2 with modest signal loss

  (and counting #tags is still low-systematics)

But beware! On "signal side", users can use other cuts.
and this is the efficiency that really matters !!!

Analyses

I will concentrate on these papers:

D^+, D^0 hadronic BFs	PRD 76, 112001 (2007)	281 pb^{-1}
D_s hadronic BFs	PRL 100, 161804 (2008)	298 pb^{-1}
$D^0 \rightarrow K e \upsilon, \pi e \upsilon$	PRD 80, 032005 (2009)	818 pb^{-1}
$D^+ \rightarrow \mu \upsilon$	PRD 78, 052003 (2008)	818 pb^{-1}
$D_s \rightarrow \mu \upsilon, \tau \upsilon$ $(\tau \rightarrow \pi \upsilon)$	PRD 79, 052001 (2009)	600 pb^{-1}
$D_s \rightarrow \tau \upsilon$ $(\tau \rightarrow e \upsilon \upsilon)$	PRD 79, 052001 (2009)	602 pb^{-1}

Omissions:

- Quantum correlation and phase analyses
- Dalitz analyses
- Rare decays, … etc.
- Possibilities for D_s at low E ($D_s D_s$ vs. $D_s^* D_s$)

Classes of Uncertainty

Reconstruction Efficiencies

> tracks, K_S, π^0, η , γ

Particle ID efficiencies

> hadrons, electrons, muon

Can add up fast:
coherent for "same" particles

Normalization

> number of tags

Yield-related efficiencies

> resolution and fitting
> background

Special Cuts

> extra shower energy

External Inputs

Theory

> Dalitz structure
> radiative effects
> interference, …

I'll use many examples from D Hadronic BF analyses: They were systematics limited, so there was motivation to push hard on systematic precision…

D Hadronic Analysis

Systematic Uncertainty Summary

TABLE VI. Systematic uncertainties and the quantities to which they are applied in the branching fraction fit. Uncertainties not correlated between decay modes are given in the first section, and correlated uncertainties in the second. The symbols y and ϵ denote *yields* and *efficiencies*, respectively. Yield uncertainties are additive and efficiency uncertainties are multiplicative. See the text for the distinction between ϵ(Charged) and $\epsilon(K^{\pm})$. The detector simulation uncertainties are determined per charged track or per neutral pion or kaon. Uncertainties for other efficiencies are determined per D. In addition to the systematic uncertainties listed here, we apply five more mode-dependent systematic uncertainties listed in Table VII.

Source	Uncertainty (%)	Quantity or decay mode
DT signal shape	0.2	y(All DT Modes)
Double DCSD interference	0.8	y(Neutral DT)
Detector simulation	0.3	ϵ(Charged) Tracking
	0.6	$\epsilon(K^{\pm})$ Tracking
	1.8	$\epsilon(K_S^0)$
	2.0	$\epsilon(\pi^0)$
	0.25	$\epsilon(\pi^{\pm})$ PID
	0.3	$\epsilon(K^{\pm})$ PID
Lepton veto	0.1	$\epsilon(D^0 \to K^-\pi^+)$ ST
Trigger simulation	0.2	$\epsilon(D^0 \to K^-\pi^+\pi^0)$
	0.1	$\epsilon(D^+ \to K_S^0\pi^+)$
$\lvert\Delta E\rvert$ Requirement	1.0	$\epsilon(D^+ \to K_S^0\pi^+\pi^0)$ and $\epsilon(D^+ \to K^+K^-\pi^+)$
	0.5	ϵ(All Other Modes)

Largest, but not in key modes…

D Hadronic Analysis

Methods for reconstruction efficiency uncertainties

D Dbar events for $\pi^\pm$ $K^\pm$ K_S

- **Find tag Dbar plus all but one particle in D**
- **Calculate missing-mass-squared, MM^2**
- **[Re-scale tag momentum to get correct m_{bc}; improves MM^2 resolution]**

$\psi' \rightarrow J/\psi\ \pi^0\pi^0$ events for π^0

$\psi' \rightarrow J/\psi\ \pi^+\pi^-$ events for low-momentum $\pi^\pm$

All cases: need background shapes !

MM^2 for Pion Efficiency

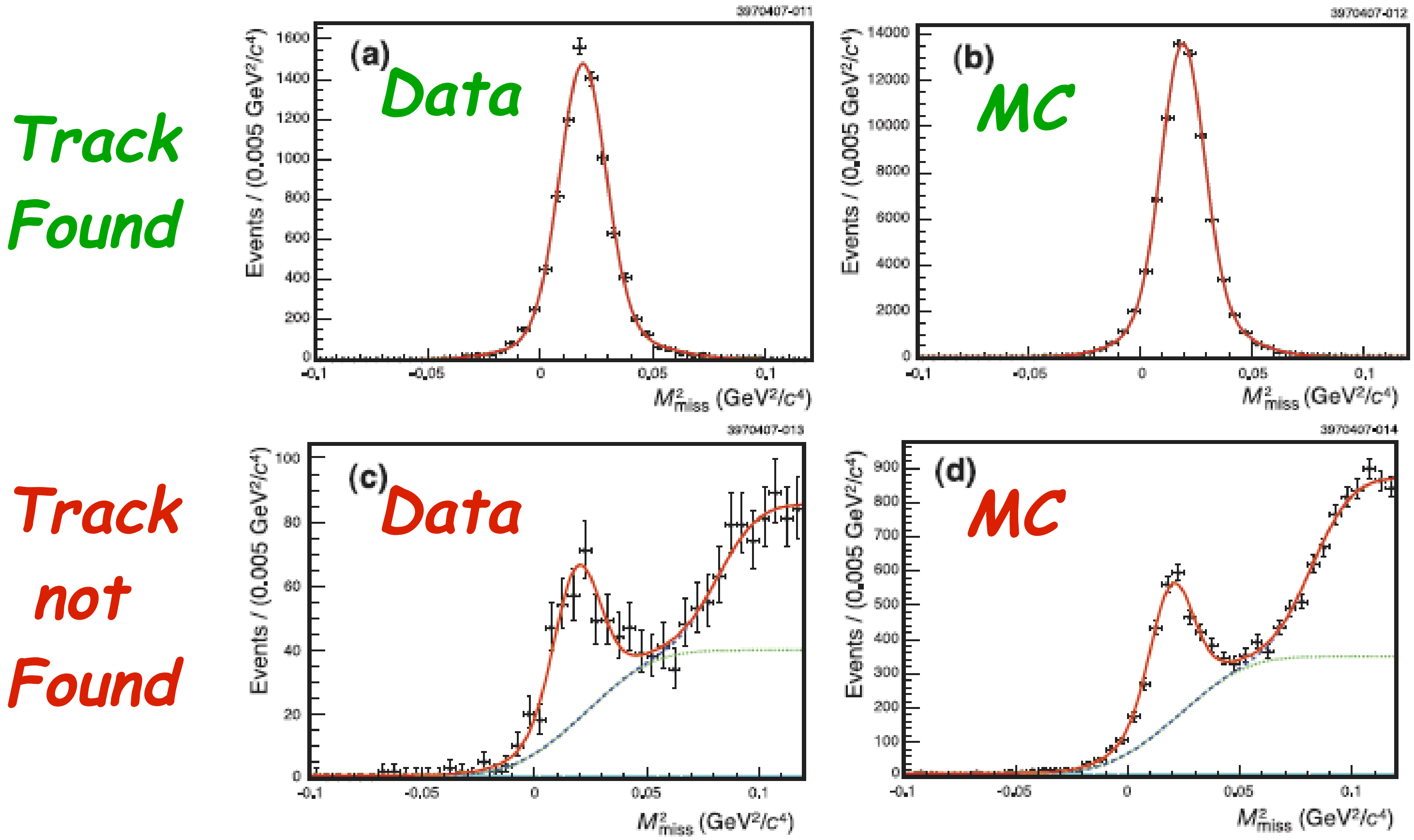


FIG. 8 (color online). Histograms of and fits to $M^2_{\rm miss}$ distributions from $D^+ \to K^-\pi^+\pi^+$ decays to determine the charged pion efficiency for $p_{\pi^+} > 0.2$ GeV$/c$. (a) and (c) are from events in data, and (b) and (d) are from events in Monte Carlo simulation. (a) and (b) are from decays in which the pion was found, while (c) and (d) are from decays in which the pion was not found. The solid curves are fits to the data or Monte Carlo sample; the dashed curves in (c) and (d) are background contributions.

MM^2 for Kaon Efficiency

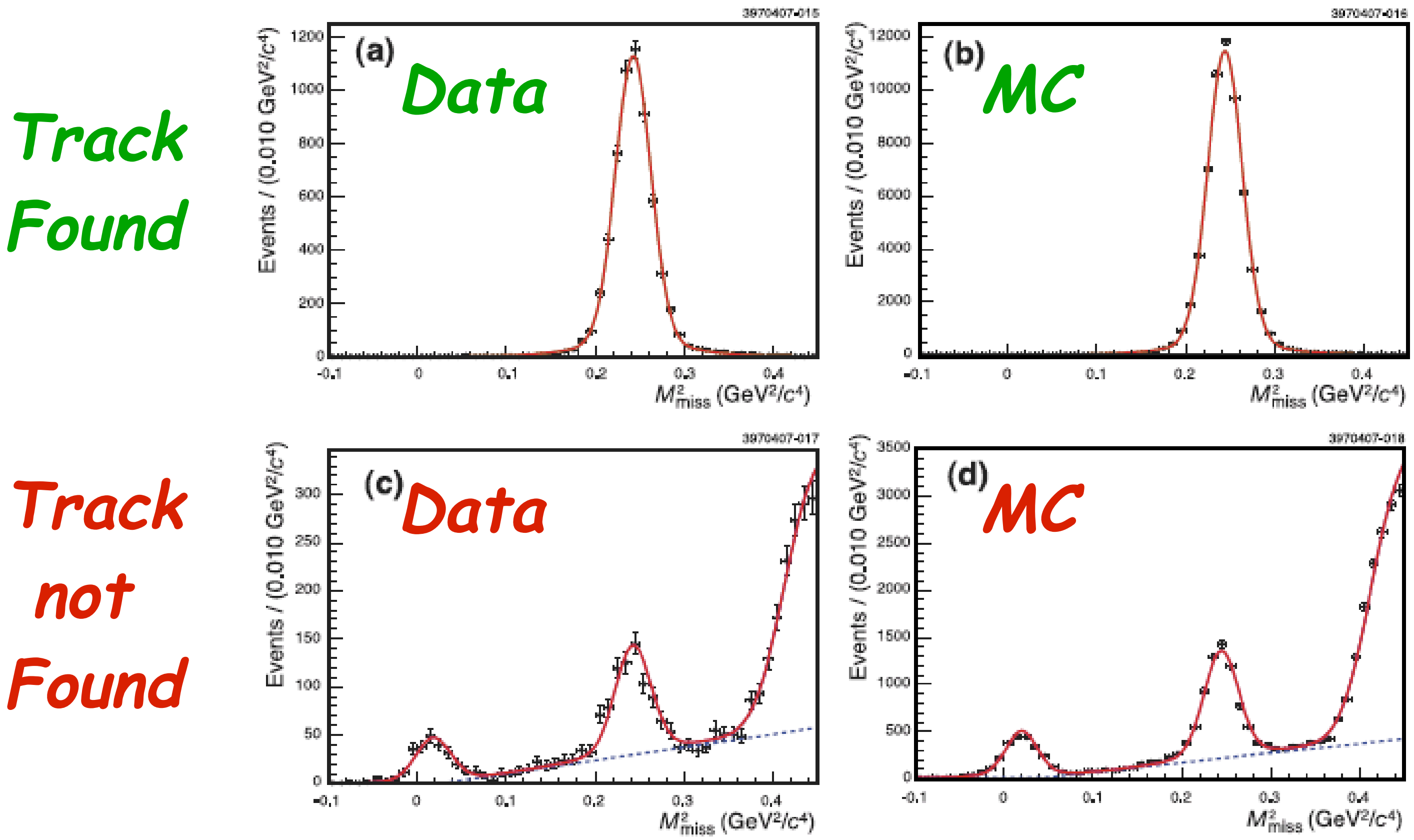


FIG. 9 (color online). Histograms of and fits to $M^2_{\rm miss}$ distributions from $D^0 \to K^-\pi^+$ decays to determine the charged kaon efficiency. (a) and (c) are from events in data, and (b) and (d) are from events in Monte Carlo simulation. (a) and (b) are from decays in which the kaon was found, while (c) and (d) are from decays in which the kaon was not found. The solid curves are fits to the data or Monte Carlo sample; the dashed curves in (c) and (d) are background contributions.

Charged Track Results

TABLE XIII. Measurements of the charged pion tracking efficiency differences between data and Monte Carlo simulations and averages of these measurements. In this table, statistical and systematic uncertainties are combined.

	$D^0 \to K^-\pi^+\pi^0$ $\epsilon_{MC}/\epsilon_{data} - 1$ (%)	$D^+ \to K^-\pi^+\pi^+$ $\epsilon_{MC}/\epsilon_{data} - 1$ (%)	Average $\epsilon_{MC}/\epsilon_{data} - 1$ (%)
$0.2 < p_{\pi^+} < 0.5$ GeV/c	-0.32 ± 1.34	-0.19 ± 0.49	-0.21 ± 0.46
$0.5 < p_{\pi^+} < 0.7$ GeV/c	-1.03 ± 2.24	$+0.57 \pm 0.41$	$+0.52 \pm 0.40$
$p_{\pi^+} > 0.7$ GeV/c	$+0.59 \pm 3.63$	$+0.38 \pm 0.85$	$+0.39 \pm 0.83$
$D^0 \to K^-\pi^+$			-1.25 ± 0.71
Overall average			$+0.02 \pm 0.26$

Pions

TABLE XV. Measurements of the charged kaon tracking efficiency differences between data and Monte Carlo simulations and averages of these measurements. In this table, statistical and systematic uncertainties are combined.

	$D^0 \to K^-\pi^+\pi^0$ $\epsilon_{MC}/\epsilon_{data} - 1$ (%)	$D^+ \to K^-\pi^+\pi^+$ $\epsilon_{MC}/\epsilon_{data} - 1$ (%)	Average $\epsilon_{MC}/\epsilon_{data} - 1$ (%)
$0.2 < p_{K^-} < 0.5$ GeV/c	$+1.64 \pm 2.31$	-2.00 ± 1.20	-1.23 ± 1.06
$0.5 < p_{K^-} < 0.7$ GeV/c	-0.78 ± 1.69	$+1.22 \pm 1.40$	$+0.41 \pm 1.08$
$p_{K^-} > 0.7$ GeV/c	$+1.04 \pm 1.55$	-0.06 ± 1.26	$+0.38 \pm 0.98$
$D^0 \to K^-\pi^+$			$+0.14 \pm 0.54$
Overall average			$+0.02 \pm 0.40$

Kaons

Tracking Efficiency: Summary

Total error is from:

1) Main studies, summarized in previous two tables:
   average error **0.22%**

2) Added uncertainty of **0.2%** for tracks near acceptance limits
   (|cosθ| from 0.90-0.93) excluded from study,
   due to resolution on direction of missing momentum
   (look at inefficiency, and at cosθ distributions)

3) Added uncertainty of **0.1%** for possible larger effects on
   the small fraction of low-momentum tracks

Total systematic of 0.3%

Tracking Efficiency: Checks

Cross-checks are done:
look for possible cosθ, momemtum, charge dependence

These all look good, with one exception:
data shows larger difference than MC between different charges of kaon, (1.23 ± 0.61)%.
BUT, charge-averaged agreement looks good !

Additional (uncorrelated) systematic of 0.6% added for kaons

It's also nice to understand the source of what's being measured, that is, why is there any inefficiency at all?
(in addition to trivia like beam holes and very soft tracks)
If we understand, we know what's important in MC, etc.

Tracking Efficiency: Sources

Mostly due to interactions and decay in flight

Kaon inefficiencies are <u>much larger</u> than pion:

In $D \rightarrow K\pi$ case, kaon inefficiency is ~6% larger than pion

For lower momenta, 0.2-0.5 GeV, the difference is ~17%

To set the scale:

Kaon $c\tau$ = 3.71 m

14% decay in 1.0 m at 0.86 GeV

Pion $c\tau$ = 7.80 m

2% decay in 1.0 m at 0.86 GeV

[0.86 GeV is the Center-of-mass momentum for $D^0 \rightarrow K\pi$]

Pions benefit not only from longer $c\tau$, but larger $\beta\gamma = p/m$

Also note that polar angle and curvature add to track length

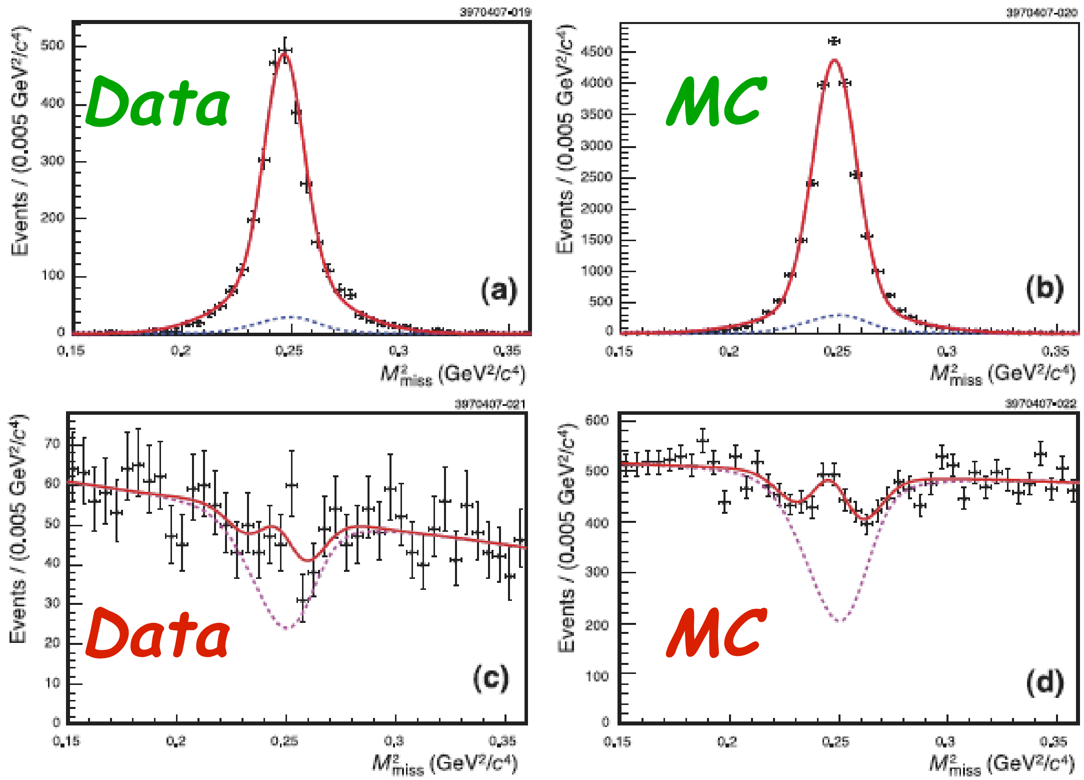
(it's not just radial motion…)

MM^2 for K_S Efficiency

Measured as an additional systematic after two pion tracks are found
Complicated by fake K_S

K_S Found

K_S not Found



Final result: 1.9% error

No data-MC correction

FIG. 10 (color online). Histograms of and fits to M^2_{miss} distributions to determine the K^0_S efficiency. (a) and (c) are from events in data, and (b) and (d) are from events in Monte Carlo simulation. (a) and (b) are from decays in which the K^0_S was found, while (c) and (d) are from decays in which the K^0_S was not found. The background peak and deficit are determined by searching for K^0_S candidates in high and low sidebands of the K^0_S mass. In (a) and (b), the dashed curves are the contributions from fake K^0_S candidates. In (c) and (d), the dashed curve is the background—a linear function with a deficit due to events in which a fake K^0_S candidate was found—and the solid curve is the total fit function including the signal peak. The area between the curves is proportional to the number of K^0_S mesons not found.

MM^2 for K_S Efficiency

Mode used is $K_S\pi^+\pi^-$

Complicated by related process without $K_S \to \pi^+\pi$

Both $K_L\pi^+\pi^-$ and $K_S \to \pi^0\pi^0$ can cause trouble:

Both cause a MM^2 peak in the "not found",

and don't contribute (or add very little due to CPV) to the "found" peak…

So we require that two tracks are found that *could* be the K_S.

Complicated by fake K_S (studied with mass side-band):

Peaking backgrounds in "found", corresponding dip in "not found"

i.e., $K_S\pi^+\pi^-$ can be faked by $\pi^+\pi^-\pi^+\pi^-$

Replacing K_S by a prompt $\pi\pi$ pair will change a Cabibbo-allowed mode into a suppressed one, but this is still at a problematic rate…

MM^2 for π^0 Efficiency

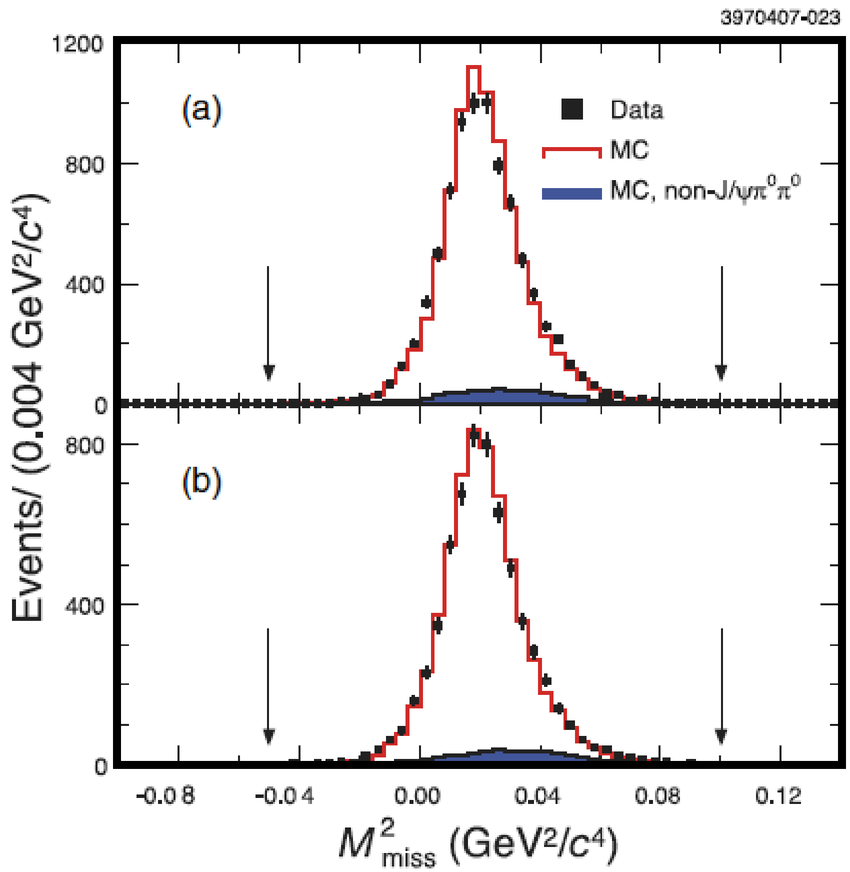


FIG. 11 (color online). Distributions of π^0 missing mass squared in candidate $\psi(2S) \rightarrow J/\psi\pi^0\pi^0$ events for data (points) and Monte Carlo events (histogram). The predicted background level is also shown. The vertical arrows demarcate the signal region. Events in which the second π^0 was found are shown in (a) whereas the events where the second π^0 was not found are shown in (b).

$\eta \equiv \varepsilon_{Data}\varepsilon_{MC} - 1$

(unfortunate notation?
there is also an η for η mesons…)

Study with $\psi' \rightarrow J/\psi\ \pi^0\pi^0$

$\eta(\psi') = (-4.37 \pm 0.72 \pm 0.41)\%$

Main error on *final result* comes from extrapolating the low π^0 momenta in the ψ' decays to the higher momenta in the D decays we care about*

$\eta(D) = (-3.9 \pm 2.0)\%$

***One of many "are we studying the right thing" issues that frequently arise…**

Hadronic Particle ID

Efficiencies are studies vis m_{BC} peaks in fully-reconstructed D tags:

Fitting "pass" and "fail" samples is simplest,

to avoid very large corrections between "all" and "pass"

On the other hand, "fail" sample hav huge backgrounds…

Data-MC corrections are needed:

1) average of -0.5% (-1.0%) for π (K) used in the D hadronic analysis.
2) momentum-dependent corrections in the D_s hadroinc analysis (done later)
   These varied from (-0.2 ± 0.2)% to (-3.7 ± 1.4)% , depending on mode
   $\pi^+ \eta$ — **$K^- K^+ \pi^+ \pi^0$**

D Hadronic Analysis

Largest mode-dependent uncertainties are highlighted for the "golden mode" branching fractions

TABLE VII. Mode-dependent systematic uncertainties. The systematic uncertainties for the signal shapes are correlated among all ST modes. The systematic uncertainties for FSR are correlated among all ST and DT modes. Other uncertainties are uncorrelated. The background and signal shape uncertainties are uncertainties on the yields, the other uncertainties in the table are uncertainties on the efficiency. Yield uncertainties are additive and efficiency uncertainties are multiplicative.

Mode	Background shape (%)	ST signal shape (%)	FSR (%)	Resonant substructure (%)	Multiple candidates (%)
$D^0 \to K^-\pi^+$	0.4	0.3	0.9	…	0.0
$D^0 \to K^-\pi^+\pi^0$	1.0	0.5	0.3	0.3	0.8
$D^0 \to K^-\pi^+\pi^+\pi^-$	0.4	0.7	0.8	1.2	0.0
$D^+ \to K^-\pi^+\pi^+$	0.4	0.3	0.7	0.6	0.0
$D^+ \to K^-\pi^+\pi^+\pi^0$	1.5	1.3	0.3	0.5	0.5
$D^+ \to K_S^0\pi^+$	0.4	0.4	0.5	…	0.2
$D^+ \to K_S^0\pi^+\pi^0$	1.0	0.5	0.1	1.2	0.0
$D^+ \to K_S^0\pi^+\pi^+\pi^-$	1.0	0.6	0.6	0.5	0.0
$D^+ \to K^+K^-\pi^+$	1.0	0.6	0.3	1.3	0.2

D_s Hadronic Analysis

Generally similar to D^+ & D^0, so I will only note a few differences

No systematics from "transition γ" from $D_s^* \rightarrow D_s \gamma$:

γ is not required, since recoil mass can separate $D_s^* D_s$ from $D_s D_s$

[Not true for (semi)leptonic decays, where the photon is needed]

η mesons are very important in D_s decays:

for η mesons, the data-MC efficiency difference is (-5.7 ± 4.0)%

$D^0/D^+/D_s$ "Golden Mode" Summary

B($D^0 \to K\pi$):

CLEO-c: (3.891 ± 0.077)% [(± 0.035 ± 0.059 ± 0.035*)%]

PDG: (3.87 ± 0.05)%

B($D^+ \to K\pi\pi$):

CLEO-c: (9.14 ± 0.20)% [(± 0.10 ± 0.16 ± 0.07*)%]

PDG: (9.13 ± 0.19)%

B ($D_s^+ \to KK\pi$): ± 4.2% ± 2.9%

CLEO-c: (5.50 ± 0.28)% [(± 0.23 ± 0.16)%]

PDG: (5.49 ± 0.27)%

(*3rd CLEO-c error is FSR systematic)

CLEO-c dominates 2 of 3 "golden modes"; D_s is still statistics-limited !

Updates to the full 818 (600) pb^{-1} D (D_s) datasets are in progress…
Some systematics may be improved.

Hadronic Conclusions

Most of the improvement of BESIII will come in the statistics-limited (semi)leptonic analyses.

But the hadronic BFs share many systematics with these, so they were still a good place to start

Some of the key issues included:

> Being aware if one is studying the correct thing
> Helpful to understand key origins of inefficiencies
> Systematics work becomes an entire mini-analysis
> Always nicer if no data-MC correction is required

Track finding:	(**0** ± 0.3)%	Pion PID:	(-0.50 ± 0.25)%
Kaon finding:	(**0** ± 0.6)%	Kaon PID:	(-1.00 ± 0.30)%
K_S finding:	(**0** ± 1.9)%	π^0 finding:	(-3.9 ± 2.0)%
		η finding:	(-5.7 ± 4.0)%

$D^0 \rightarrow \pi^- e^+ \upsilon$

Systematics are done in bins of $q^2 = M_{e\nu}^2$

One major new item: electron ID

But statistics are really dominating here !

TABLE VII. Summary of partial rate ($\Delta\Gamma_i$) uncertainties in percent for $D^0 \to \pi^- e^+ \nu_e$ and $D^0 \to K^- e^+ \nu_e$. The sign gives the direction of change relative to the change in the first q^2 bin.

	$\sigma(\Delta\Gamma_1)$	$\sigma(\Delta\Gamma_2)$	$\sigma(\Delta\Gamma_3)$	$\sigma(\Delta\Gamma_4)$	$\sigma(\Delta\Gamma_5)$	$\sigma(\Delta\Gamma_6)$	$\sigma(\Delta\Gamma_7)$
$D^0 \to \pi^- e^+ \nu_e$							
Tag line shape	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Tag fakes	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Tracking efficiency	0.48	0.48	0.48	0.48	0.48	0.49	0.51
$\pi^\pm$ ID	0.21	0.11	0.05	0.03	0.02	0.02	0.04
$e^\pm$ ID	0.37	0.38	0.38	0.39	0.33	0.18	−0.14
FSR	0.18	0.11	0.09	−0.02	−0.10	−0.20	−0.24
Signal shape	0.56	0.46	0.58	0.49	0.50	0.56	0.49
Backgrounds	0.39	0.43	0.60	0.61	0.58	0.52	0.76
MC form factor	0.06	−0.05	−0.05	−0.05	−0.07	−0.11	−0.04
q^2 smearing	0.84	−0.11	−0.26	−0.16	0.30	−0.60	−0.28
D Lifetime	0.37	0.37	0.37	0.37	0.37	0.37	0.37
All systematic	1.44	1.13	1.27	1.22	1.22	1.31	1.30
Statistical	6.84	7.29	7.90	8.06	8.87	8.42	8.63

Electron ID

Studied with $ee\gamma$ and $\gamma\gamma \rightarrow eeee$ processes

However, the event environment is wrong:
our study sample electrons are isolated !

So we "embed" these study tracks into hadronic events
This involves some specialized technology
(although the core of it should already exist, since one generally needs to merge in random triggers with MC to simulate noise…)

We observe data-MC differences of order 1.5%
So, corrections are applied…
errors are due to uncertainties on corrections

In the end, not a limiting systematic:
many others are at the same scale…

$D^+ \to \mu^+ \upsilon$

Error is 1/2 of this for f_D

TABLE III. Systematic errors on the $D^+ \to \mu^+ \nu$ branching ratio.

	Systematic errors (%)
Track finding	0.7
PID cut	1.0
MM^2 width	0.2
Minimum ionization cut	1.0
Number of tags	0.6
Extra showers cut	0.4
Radiative corrections	1.0
Background	0.7
Total	2.2

No single dominant error.

Also have additional external errors to get from BF to f_D :
lifetime & V_{cd}

Note on the three largest items:

The "min-I cut" (on the CsI energy) listed is one part of the muon ID used here

The "PID cut" here refers to vetoing kaons as muon candidates

The final 1.0% error, radiative corrections, is conservative…

Systematics: Resolution

Missing-mass is intrinsically very powerful,

But one needs to understand resolution, including mis-reconstruction effects

In data, tag one D:

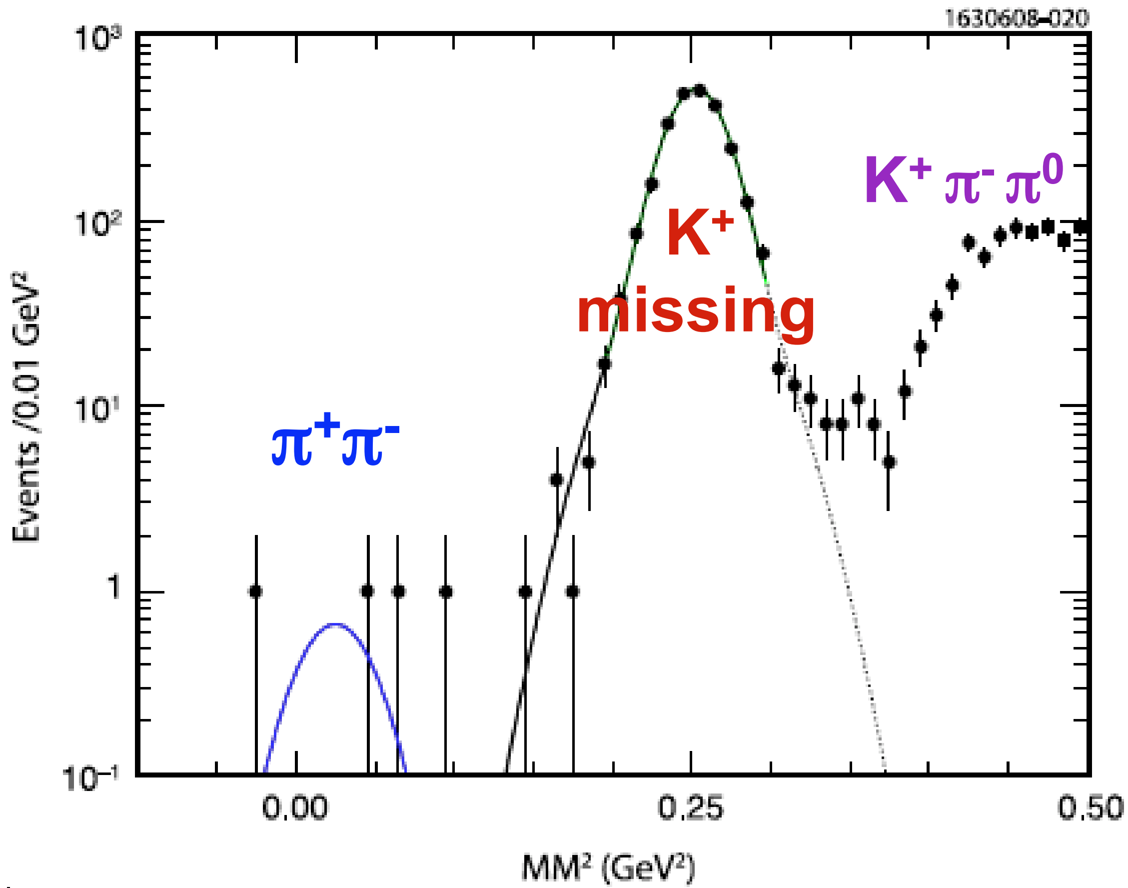
$D^0 \rightarrow K^- \pi^+$

Study other D:

$D^{0bar} \rightarrow K^+ \pi^-$

Then "ignore" a well-ID'd Kaon in the kinematics

Nice double-Gaussian resolution over 3 decades!



$D_s \to \mu^+ \upsilon$ & $\tau^+ \upsilon$ ($\tau^+ \to \pi \upsilon$)

Error on f_{Ds} is 1/2 on this

TABLE III. Systematic errors on determination of the $D_s^+ \to \mu^+ \nu$ branching fraction.

Error Source	Size (%)
Track finding	0.7
Particle identification of μ^+	1.0
MM^2 width	0.2
Photon veto	0.4
Background	1.0
Number of tags	2.0
Tag bias	1.0
Radiative Correction	1.0
Total	3.0

Largest single error is # tags: might be better at 4030 MeV, with no D_s^* (but only 30% of cross-section !)

"Tag Bias": it is easier to reconstruct a D tag vs. signal compared to inclusive tags that fix normalization

Error here is 20% of MC-predicted effect

Number of D_s Tags

Unlike for D_s hadronic BFs, the photon from the D_s^* must be found here to infer the neutrino

$D_s\gamma$ (missing mass)^2 9 tag modes

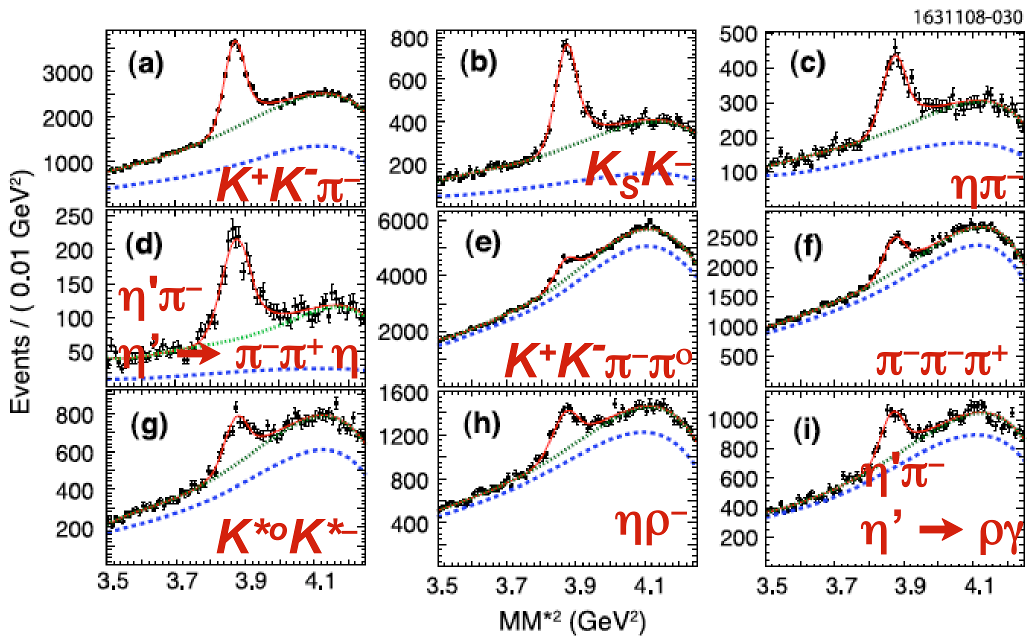


FIG. 5 (color online). The MM^2 distribution from events with a photon in addition to the D_s^- tag for the modes: (a) $K^+K^-\pi^-$, (b) $K_S^0K^-$, (c) $\eta\pi^-$, (d) $\eta'\pi^-$, (e) $K^+K^-\pi^-\pi^0$, (f) $\pi^+\pi^-\pi^-$, (g) $K^{*-}K^{*0}$, (h) $\eta\rho^-$, and (i) $\eta'\pi^-$, $\eta'\to\pi^+\pi^-\gamma$. The curves are fits to Crystal-Ball functions and two 5th order Chebychev background functions (see text).

Sum over tag modes

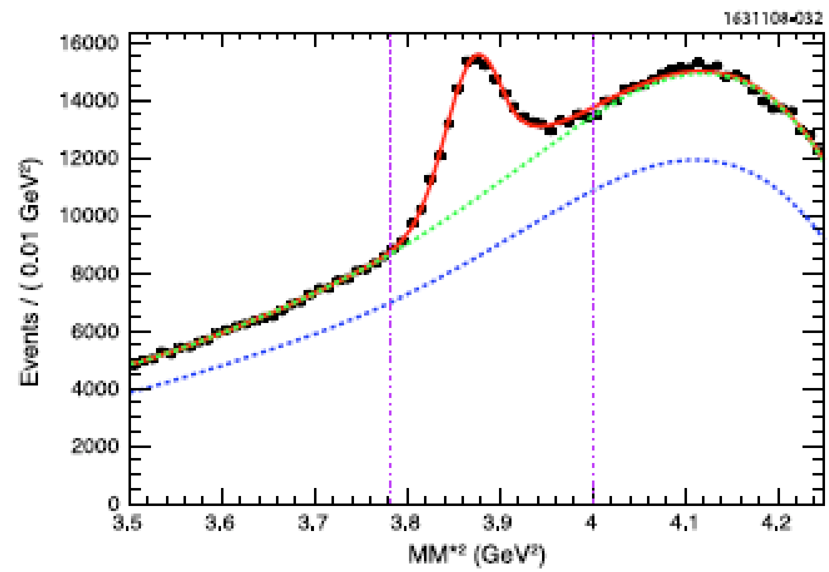
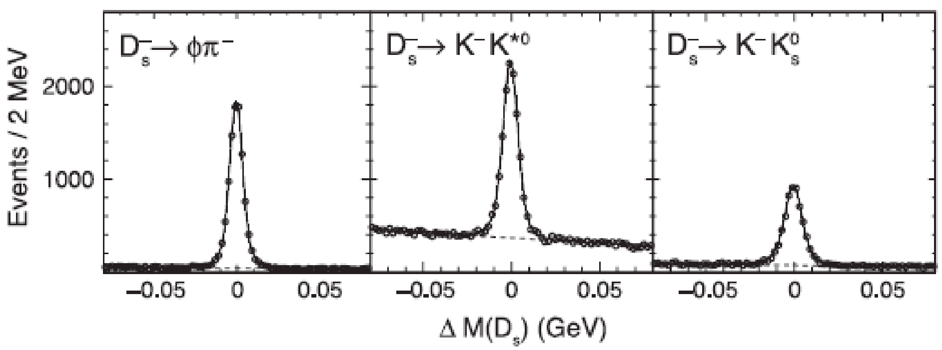


FIG. 7 (color online). The MM^2 distribution summed over all modes. The curves are fits to the number of signal events using the Crystal-Ball function and two 5th order Chebychev background functions (see text). The vertical lines show the region of events selected for further analysis.

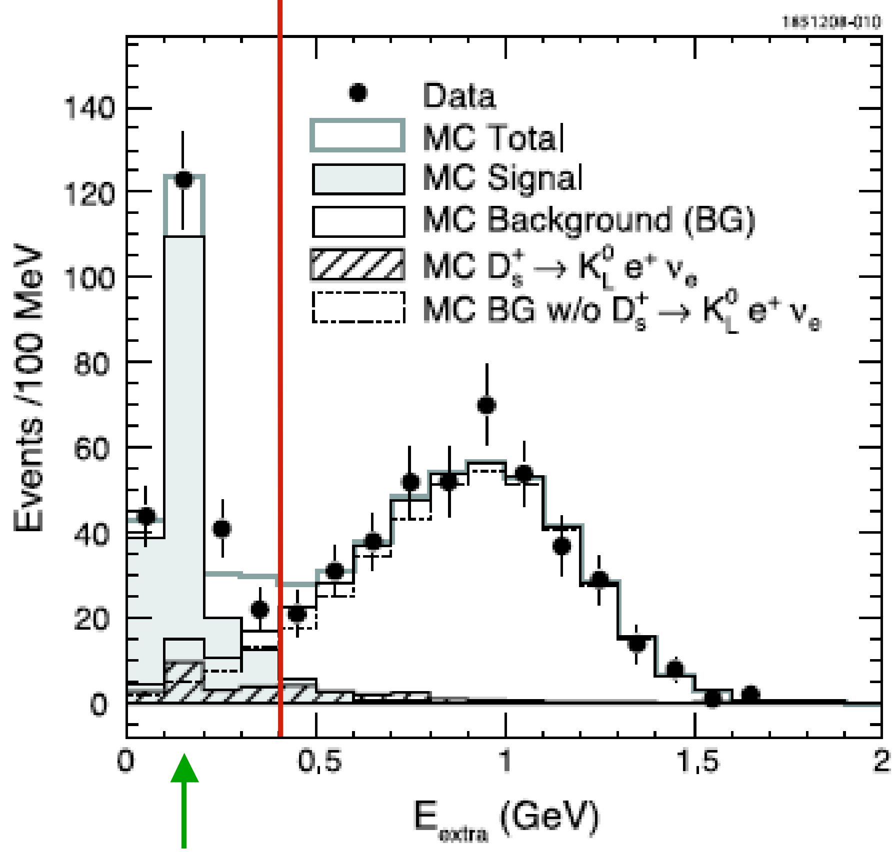
$D_s \to \tau^+\upsilon$ ($\tau^+ \to e^+\upsilon\upsilon$)

PRD 79, 052002 (2009) 602 pb^{-1}

Uses only cleanest tags:



Signal region: < 400 MeV



Always have >1 neutrino!

Abandon use of MM^2

Semileptonic events tend to have hadronic Energy in CsI (but careful re: K_L !)

Plot E_{extra} in Calorimeter

(Extra: not from tag D or e)

Peaks away from zero:

E_{extra} may include γ from D_s^* decay

$D_s \to \tau^+ \upsilon$ ($\tau^+ \to e\upsilon\upsilon$)

Error on f_{Ds} is 1/2 of this

Source	Effect on $\mathcal{B}$ (%)
Background (nonpeaking)	0.7
$D_s^+ \to K_L^0 e^+ \nu_e$ (peaking)	3.2
Extra shower	1.1
Extra track	1.1
$Q_{\rm net} = 0$	1.1
Non electron	0.1
Secondary electron	0.3
Number of tag	0.4
Tag bias	0.2
Tracking	0.3
Electron identification	1.0
FSR	1.0
Total	4.1

Errors on f_{Ds}:

1.6% from $K_L e\upsilon$

(from BR & energy deposit)

1.3% all others combined

#tag effect smaller than before: no γ from D_s^* required here…

Note: radiative correction is small, since tau has only 9 MeV of kinetic energy

Decay Constant: External Systematics

Effects on decay constants are listed; this is 1/2 of the effect on BF

these are not currently dominant

$D_{(s)}$ Lifetimes:

0.34% for D   0.7% for D_s (mainly from FOCUS)

Radiative corrections on $D_{(s)} \rightarrow \mu^+\upsilon$:

0.5%   (conservative? improvable?)

τ BFs for $D_s \rightarrow \tau^+\upsilon$ ($\tau^+ \rightarrow e^+\upsilon\upsilon$, $\pi^+\upsilon$, $\rho^+\upsilon$):

0.14%, 0.32%, 0.18%

V_{cd} : 0.5% V_{cs} , masses: negligible

Statistical Power for D_s

mean^2/σ_{stat}^2, normalized to $D_s \to \mu^+\upsilon$ ("additional luminosity" factor)

$D_s \to \mu^+\upsilon$:	1.00	Done as joint analysis
$D_s \to \tau^+\upsilon;\ \tau^+ \to \pi^+\upsilon$	0.40	
$D_s \to \tau^+\upsilon;\ \tau^+ \to e^+\upsilon\upsilon$	0.81	Doubles stat. power !
$D_s \to \tau^+\upsilon;\ \tau^+ \to \rho^+\upsilon$	0.59	

Many different systematics: not all correlated in averaging !

From $\tau^+ \to \rho^+\upsilon$ paper
[PRD 80, 112004 (2009)]

TABLE IV. Recent absolute measurements of f_{D_s} from CLEO-c.

Experiment	Mode	$\mathcal{B}$ (%)	f_{D_s} (MeV)
This result	$\tau^+\nu\ (\rho^+\bar{\nu})$	$(5.52 \pm 0.57 \pm 0.21)$	$257.8 \pm 13.3 \pm 5.2$
CLEO-c [9]	$\tau^+\nu\ (\pi^+\bar{\nu})$	$(6.42 \pm 0.81 \pm 0.18)$	$278.0 \pm 17.5 \pm 4.4$
CLEO-c [13]	$\tau^+\nu\ (e^+\nu\bar{\nu})$	$(5.30 \pm 0.47 \pm 0.22)$	$252.6 \pm 11.2 \pm 5.6$
Average	$\tau^+\nu$	$(5.58 \pm 0.33 \pm 0.13)$	$259.7 \pm 7.8 \pm 3.4$
CLEO-c [9]	$\mu^+\nu$	$(0.565 \pm 0.045 \pm 0.017)$	$257.6 \pm 10.3 \pm 4.3$
Average	$\tau^+\nu + \mu^+\nu$		$259.0 \pm 6.2 \pm 3.0$

Some Observations…

I think we are entering an era where "systematics on systematics" may become an issue…

That is, are we studying the correct thing?
And are the fits in systematic studies correct, etc.
Systematic studies become, in effect, mini-analyses !
And, as such, they have their own systematics…

Need to worry about data-set dependence of systematics

Also, systematics only apply to the studied set of cuts !
If users, say, change tracking cuts, in principle a new study is needed…

Some More Observations…

High-quality Monte-Carlo simulations help in various ways

Careful low-level tuning can avoid the need for high-level corrections

Getting kinematic dependences of effects correct is important
We may really need to show that data-MC agree in "slices",
not just integrated over momenta, angles, etc.
(and the same if corrections are needed)

Data-MC efficiency corrections are always troubling,
since one needs to insure that these kinematic dependencies
are properly included…

Question:
Which time-integrated analyses need Super-B factory luminosity?
What are the key systematics for these?

Conclusions

CLEO-c is a very useful reference point for BESIII work

There was an emphasis on data-based studies, coupled with high-quality Monte-Carlo. But in some cases, corrections were still required.

BESIII will work to push things further

- First step is to match CLEO-c's systematic precision
- More statistics will help most (all?) systematic studies

Precision analysis is always difficult, but is is also rewarding !