BESIII/CLEO-c Workshop Summary

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Themes:

- General Comments
  - BESIII and CLEO-c Programs
  - BESIII and CLEO-c Detectors
- Weak Interactions
  - Motivation
  - Hadronic D Decays
  - Leptonic and Semileptonic D Decays
- QCD
  - Charmonium Spectroscopy
  - Glueball Searches
  - R Measurements
- Other Weak Interactions
  - τ Decays
  - Λ_c Decays
  - $D^0\bar{D}^0$ Mixing
  - Rare D Decays, and CP Violation

Apologies in advance to all whose talks are not covered or not covered well.

BESIII/CLEO-c Workshop, Beijing
January 15, 2004

Special Thanks to our Gracious Hosts!

- **In particular:**
  - **We all appreciate the supurb organization of the workshop.**
  - **The overseas guests appreciate help with visas, accommodation, and transportation.**
  - **We cannot adequately express our appreciation for the dinner last night!**

BESIII and CLEO-c Programs

Program overviews – not discussed individually

- **CLEO-c program – Ian Shipsey**
- **CESR-c progress – David Rubin**
- **CLEO-c detector – Steve Gray**
- **BESIII/BEPCII program – Weiguo Li**
- **BESIII detector – Yifang Wang**

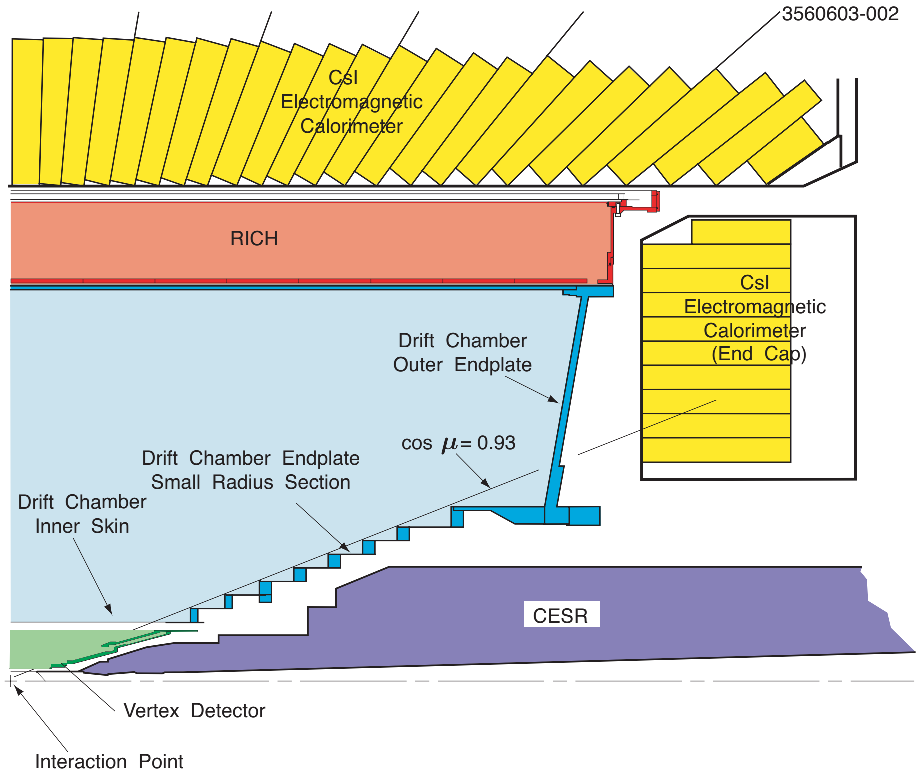
BESIII and CLEO-c Programs

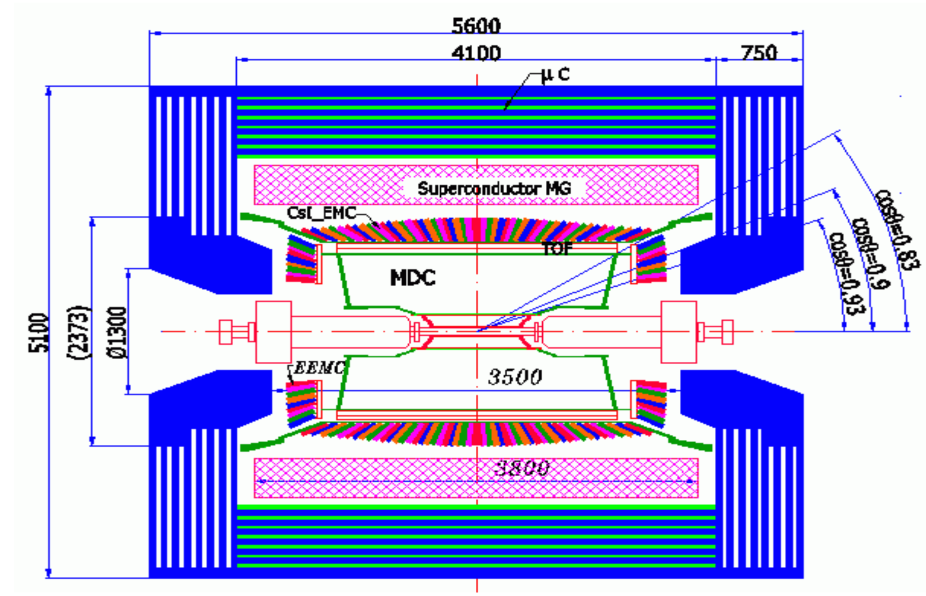
Anticipated BESIII and CLEO-c data samples

- Somewhat different assumptions were use in defining the programs.
  - Statistical errors are most important in the D decay program
  - Use 5 nb for CLEO-c to be consistent with BESIII assumptions
  - CLEO-c Core Program in red
  - BESIII data samples taken from some estimates in the BESIII Design Report

		CLEO-c			BESIII		
Channel	W (GeV)	σ (nb)	$\mathcal{L}T$ (fb^{-1})	Events	σ (nb)	$\mathcal{L}T$ (fb^{-1})	Events
J/ψ	3.097	1000	1	10^9	3400	3	10×10^9
τ	3.67				2.4	5	1.2×10^7
$\psi(2S)$	3.686				640	5	3×10^9
$D\bar{D}$	3.770	5	3	1.5×10^7	5	5	2.5×10^7
$D_s\bar{D}_s$	4.03				0.32	3	1×10^6
$D_s\bar{D}_s$	4.140	0.5	3	1.5×10^6	0.67	3	2×10^6
$\Lambda_c\bar{\Lambda}_c$	4.6		1	3.7×10^7			

BESIII and CLEO-c Detectors

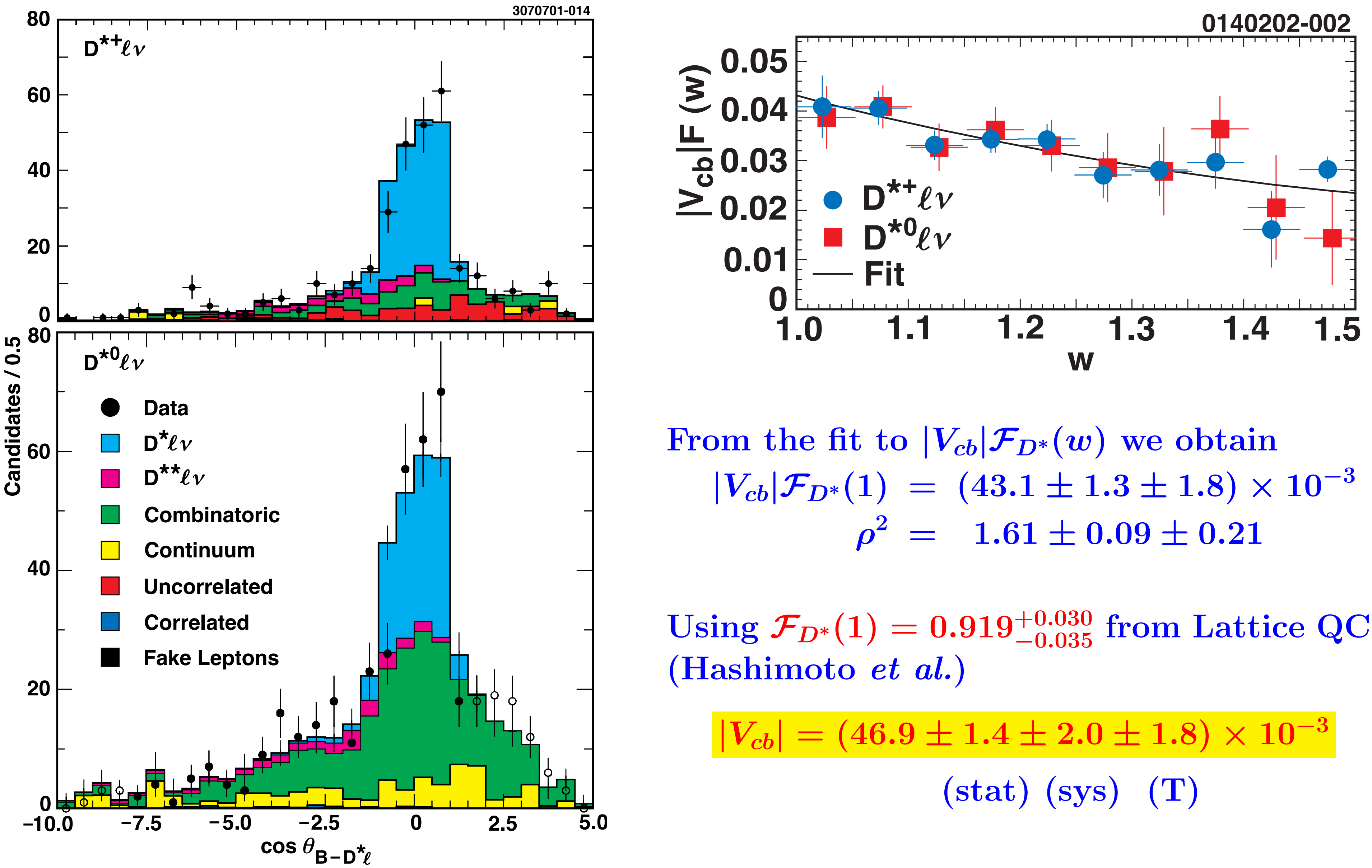




BESIII and CLEO-c Detectors

Component	Quantity	CLEO-c	BESIII
Magnet	B	1 T	1 T
Tracking	$\Delta\Omega/4\pi$	93%	93%
	σ_p/p at 1 GeV	0.35%	0.5%
	$\sigma(dE/dx)$	5.7%	(6-7)%
K Identification	$\Delta\Omega/4\pi$	80%	83%
	K Efficiency at 0.9 GeV	87%	90%
	MisID($\pi \to K$) at 0.9 GeV	0.2%	$\sim$ 1%
EM Calorimeter	$\Delta\Omega/4\pi$	93%	93%
	σ_E/E at 1 GeV	2.2%	2.5%
	σ_z at 1 GeV		0.5 cm
μ Identification	$\Delta\Omega/4\pi$	85%	90%
	Minimum p_μ	1 GeV/c	0.5 GeV/c

$|V_{cb}|$ from $\bar{B} \to D^* \ell^- \bar{\nu}$ Decay



From the fit to $|V_{cb}|\mathcal{F}_{D^*}(w)$ we obtain

$$|V_{cb}|\mathcal{F}_{D^*}(1) = (43.1 \pm 1.3 \pm 1.8) \times 10^{-3}$$

$$\rho^2 = 1.61 \pm 0.09 \pm 0.21$$

Using $\mathcal{F}_{D^*}(1) = 0.919^{+0.030}_{-0.035}$ from Lattice QCD (Hashimoto *et al.*)

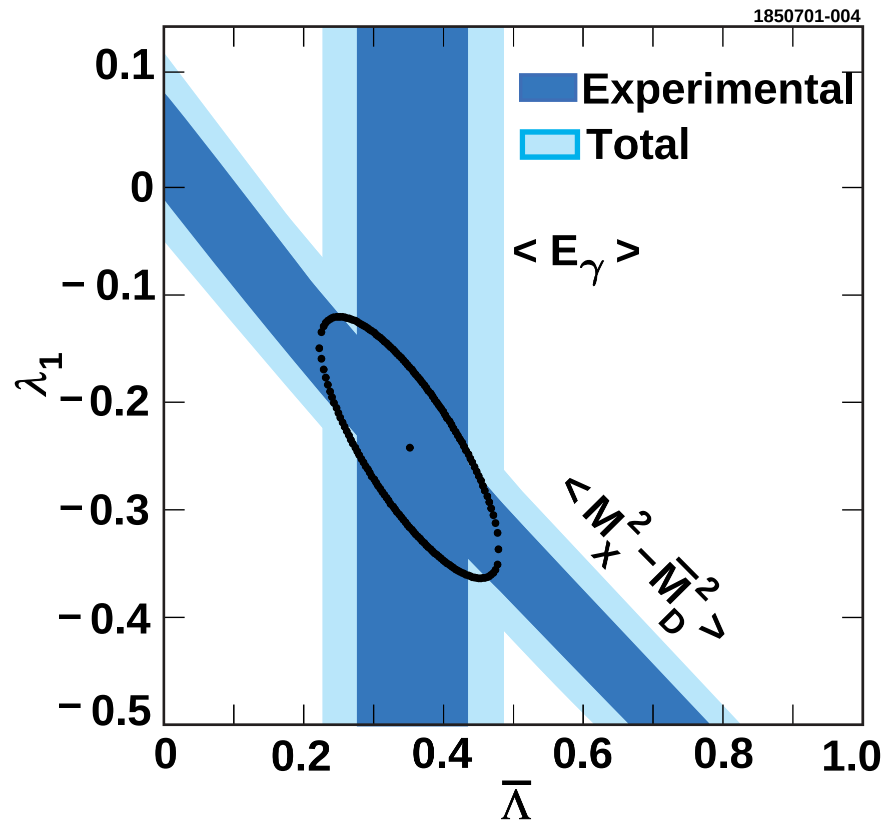
$$|V_{cb}| = (46.9 \pm 1.4 \pm 2.0 \pm 1.8) \times 10^{-3}$$

(stat) (sys) (T)

Determining $|V_{cb}|$ from Hadronic Mass Moments and $B \rightarrow X_s\gamma$

The intersection of the E_γ and M_X moments yields $\bar{\Lambda}$ and λ_1.

$$\bar{\Lambda} = 0.35 \pm 0.07 \pm 0.10 \text{ GeV}$$
$$\lambda_1 = -0.238 \pm 0.071 \pm 0.078 \text{ GeV}^2$$
(M) (T)



Then the expression for Γ^c_{SL} yields

$$|V_{cb}| = (40.4 \pm 0.9 \pm 0.5 \pm 0.8) \times 10^{-3}$$
(M) (Γ) (T)

Errors are due to

(M) moment uncertainties,

(Γ) Γ^c_{SL} uncertainties, and

(T) α_s scale and ignoring the $\mathcal{O}(1/M_B^3)$ term which contains the estimated parameters

Even with this measurement of QCD parameters, the residual theoretical uncertainties (T) are comparable to the experimental errors (M) and (Γ).

2nd Prologue

Role of Charm in Evolution of SM & its Acceptance

- introduced for specific reasons & with specific properties
- facilitated for KM to come up with KM ansatz
- observation of J/ψ shook up community
- lead to paradigm shift in accepting quarks as real entities
- MARK III established precedent for threshold factory

$$e^+e^- \rightarrow J/\psi,\ \psi'$$

$$e^+e^- \rightarrow \psi'' \rightarrow D\bar{D}$$

Charm a closed chapter?

My intention

`I have come to praise C. -- not to bury it!'

charm dynamics full of challenges -- & promises

triple motivation for further dedicated studies

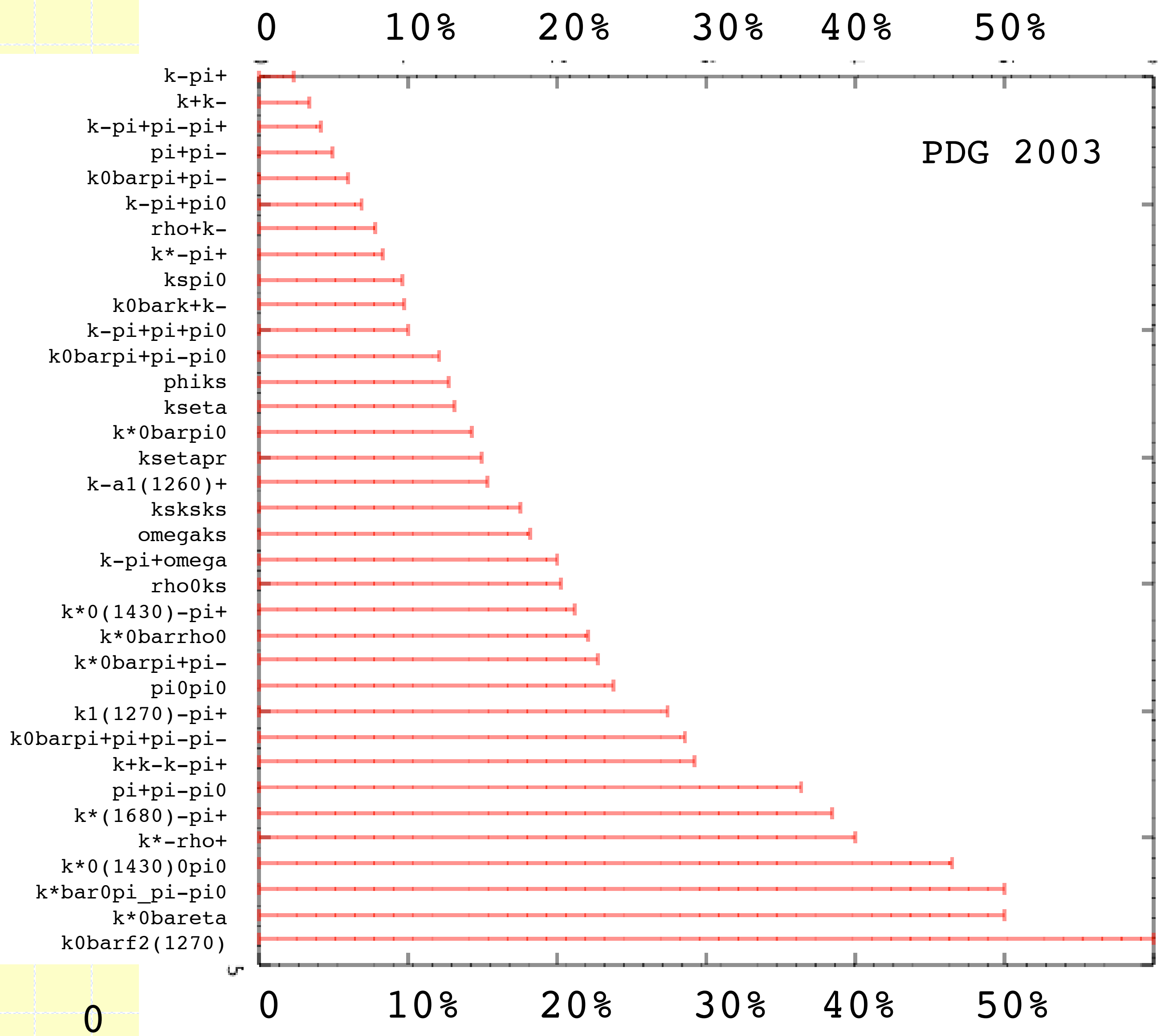
❶ *QCD (& `beyond')*: understanding nonperturb. dynamics & establishing theoretical control over it

❷ *B dynamics*: calibrating theoret. tools for B studies

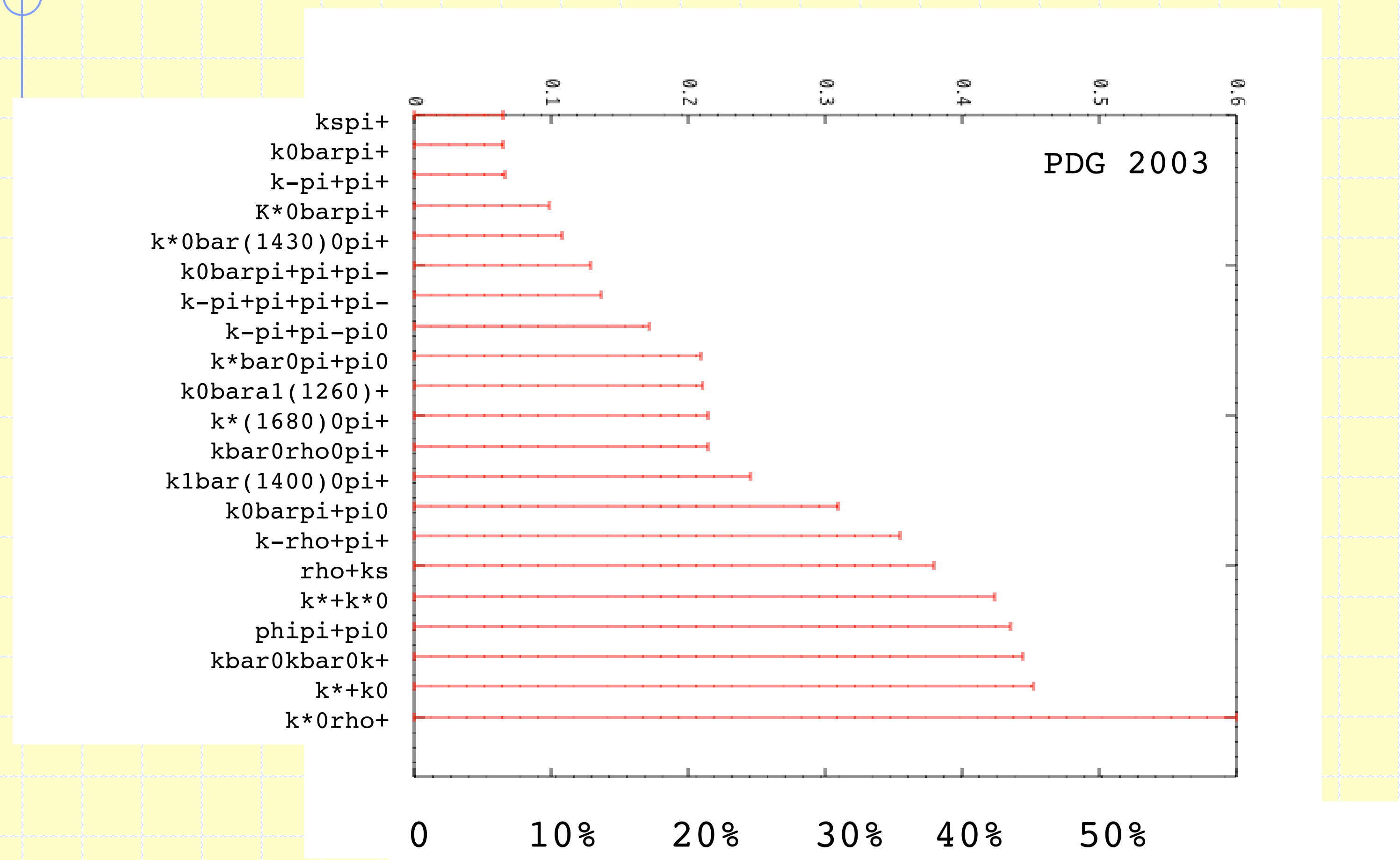
❸ *New Physics*: charm transitions a novel window onto New Physics

accuracy of theoretical description of essential importance!

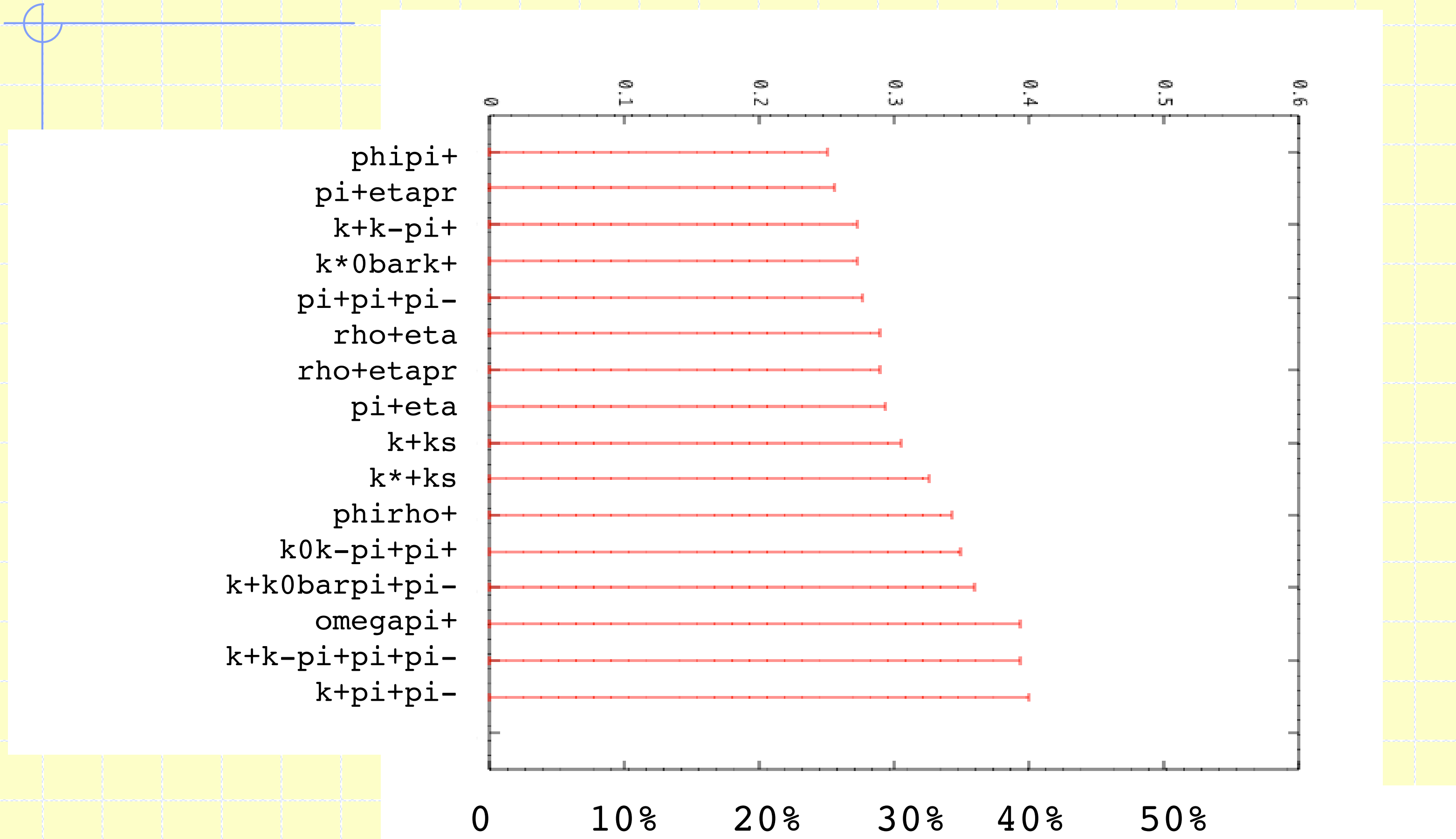
Relative Precision: $\delta Br/Br$ (D^0)



Hadronic D+ δBr/Br



Hadronic D_s $\delta Br/Br$



Reach of double tag technology

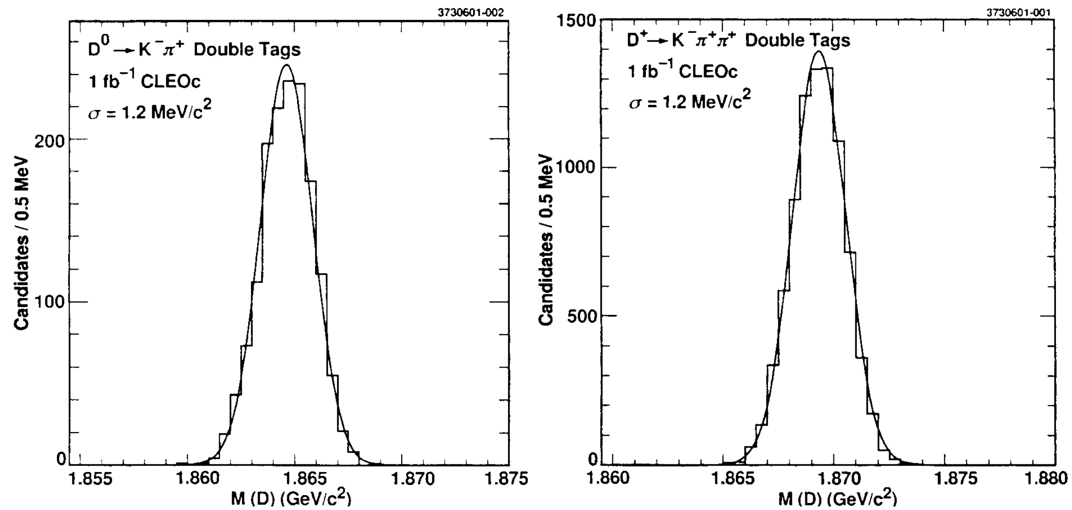


TABLE 15. Total number of double tag events and statistical precisions on absolute charm branching fractions for 3 fb^{-1} of data for each type of D meson.

Particle	# of Double tags	Statistical Error	Systematic Error	Background Error	Total Error
D^0 $K\pi$	53,000	0.4%	0.4%	0.06%	0.6%
D^+ $K\pi\pi$	60,000	0.4%	0.6%	0.1%	0.7%
D_s^+ $\phi\pi$	6,000	1.3%	1.1%	0.9%	1.9%

Charm Physics Potential at BESIII

Kanglin He

Jan. 2004, Beijing

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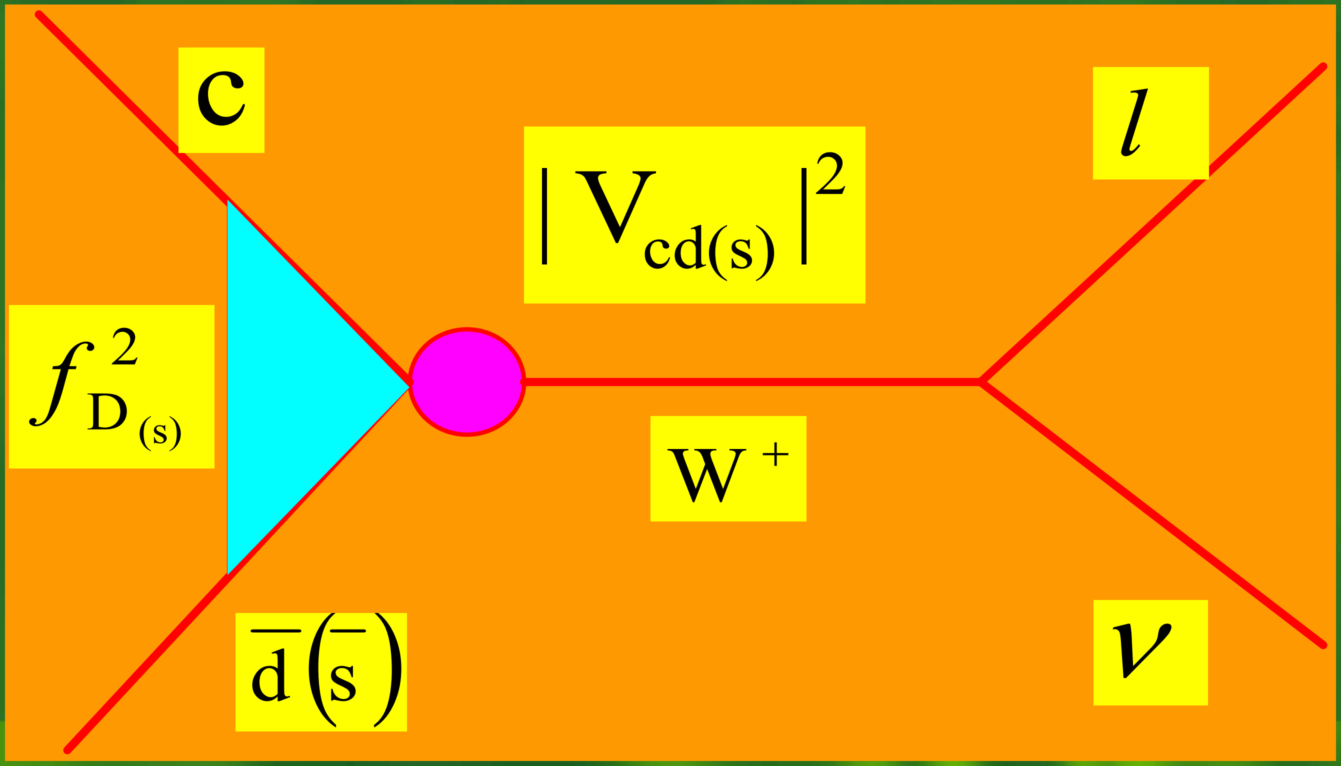
Leptonic Decay and Decay Constant

$$\mathrm{Br}(\mathrm{D}^+_{(s)} \to l^+ \nu_l) \propto \tau_{\mathrm{D}^+_{(s)}} f^2_{\mathrm{D}_{(s)}} \, |\mathrm{V}_{cd(s)}|^2$$



Analysis Technique

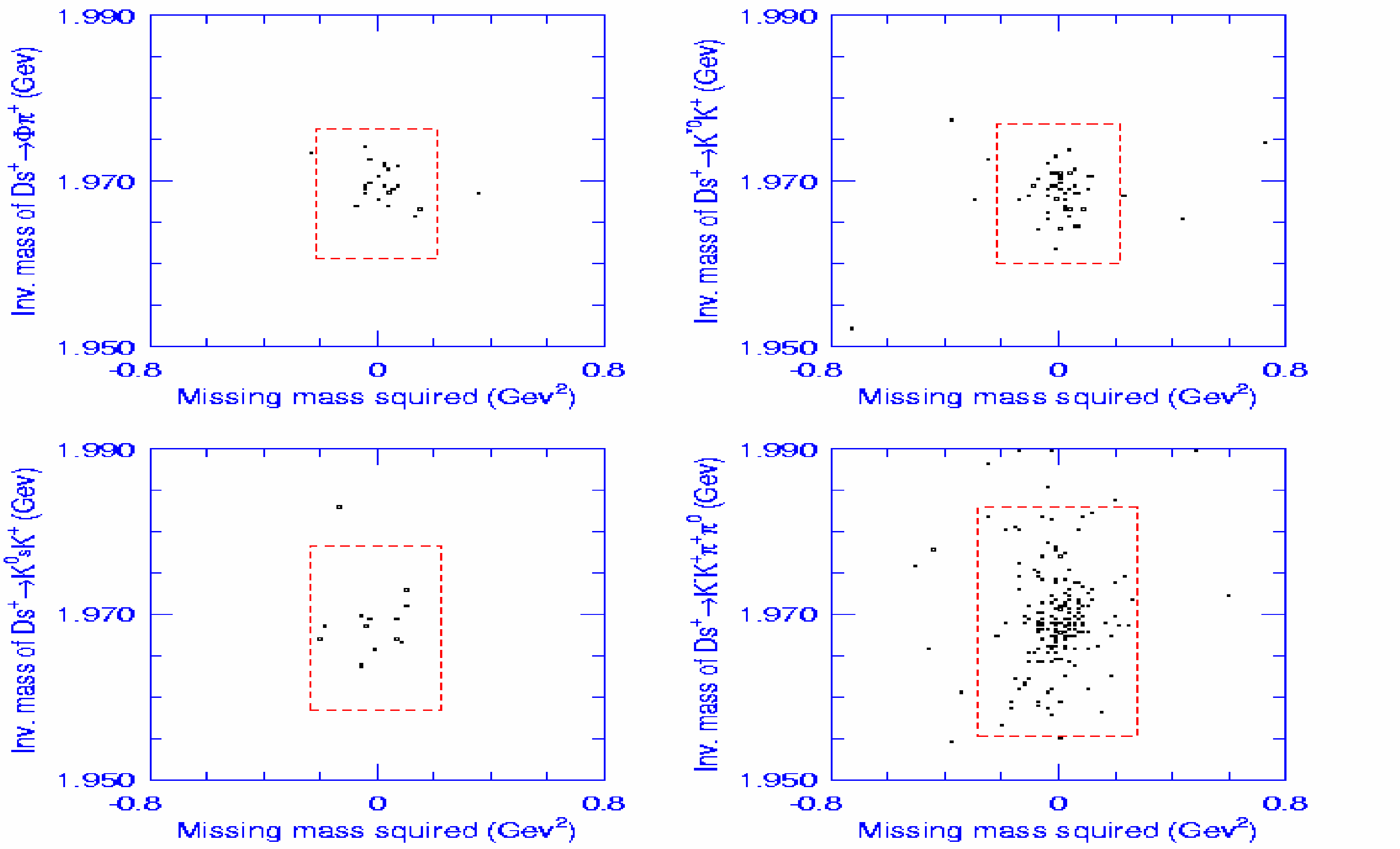
- Double tag measurements
  - Tagged D(s) with hadronic decay modes
  - muon identification
  - Absent of isolated photons
- Reconstruction of missing mass square $\rightarrow 0$

$$M^2(\nu) = E^2(\nu) - p^2(\nu)$$

$$E(\nu) = E_{\text{missing}} = (E_{\text{beam}} - E_{\mu})$$

$$p(\nu) = -p_{\text{missing}} = -(p_{\text{tag}} + p_{\mu})$$

Measurement of f_{Ds}



Precision of $f_{D(s)}$ (1)

$$\frac{\Delta f_{D_{(s)}}}{f_{D_{(s)}}} = \sqrt{\left(\frac{1}{2}\frac{\Delta \tau_{D_{(s)}}}{\tau_{D_{(s)}}}\right)^2 + \left(\frac{1}{2}\frac{\Delta B}{B}\right)^2 + \left(\frac{\Delta |V_{cd(s)}|}{|V_{cd(s)}|}\right)^2}$$

$$\frac{\Delta \tau_D}{\tau_D} \approx 0.6\% \qquad \frac{\Delta \tau_{D_s}}{\tau_{D_s}} \approx 1.0\%$$

$$\frac{\Delta |V_{cd}|}{|V_{cd}|} \approx 1.8\% \qquad \frac{\Delta |V_{cs}|}{|V_{cs}|} \approx 1.6\% \ \text{(at BESIII)}$$

$$\frac{\Delta B}{B} \approx 2 \sim 3\% \ \text{Level (at BESIII)}$$

Major Uncertainty

Precision of $f_{D(s)}$ (2)

$$\frac{\Delta f_{D}}{f_{D}} \approx \begin{array}{ll} 3.0\% & \text{BESIII} \\ 100\% & \text{Now} \end{array}$$

$$\frac{\Delta f_{D_s}}{f_{D_s}} \approx \begin{array}{ll} 2.5\% & \text{BESIII} \\ 35\% & \text{Now} \end{array}$$

Great improvement after BESIII

Precision Charm Experiment and Precision LQCD

Shoji Hashimoto (KEK)

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BESIII/CLEO-c Workshop,

at IHEP Beijing, Jan 13–15, 2004

Ideally ...

To reproduce the real world, one needs

- unquenched, N_f = 2+1.
- L = 5 fm.
- a = 0.02 fm;
  or a^{-1} = 10 GeV.
- m_{ud} = several MeV,
  m_s = 100 MeV.
- statistics $\sim$ 10K.

Empirial law : the computational demand scales as

$$\left[\frac{m_\pi/m_\rho}{0.6}\right]^{-6}\left[\frac{L}{3\ \mathrm{fm}}\right]^{5}\left[\frac{a^{-1}}{2\ \mathrm{GeV}}\right]^{7}$$

For this example, we need

10^{10} TFlops · year

Theoretical/algorithmic improvements are crucial.

Improved actions

Order counting assuming $\Lambda_{\rm QCD} = 400$ MeV:

a (fm)	0.2	0.1	0.05
$1/a$ (GeV)	1	2	4
$O(a\Lambda_{\rm QCD})$	40%	20%	10%
$O((a\Lambda_{\rm QCD})^2)$	16%	4%	1%
$O((a\Lambda_{\rm QCD})^3)$	6%	1%	$<$ 1%
$O((a\Lambda_{\rm QCD})^4)$	3%	$<$ 1%	$<$ 1%

To achieve the 1% accuracy,

- $O(a)$-improved action + extrapolation in a^2
- $O(a^2)$-improved action at a = 0.1 fm.

Perspectives (1)

I don't see any fundamental problems to achieve the goal, *i.e.* the 1% accuracy for charm physics.

- $O(a^2)$-improved action at $a = 0.1$ fm.
- $O((\Lambda_{\rm QCD}/m_Q)^3)$ action for c quark. (Without HQET, we need the $O(a^2)$-improved action at $a = 0.03$ fm.)
- two-loop matching at $a \lesssim 0.1$ fm.

All these iterms are within reach. Actually, they are on the program of the HPQCD-UKQCD-MILC-Fermilab group.

This argument is based on an order counting. Scaling test will be needed to convince ourselves.

Fully leptonic and semileptonic decay

Jim Wiss
University of Illinois

CLEO-c and BESIII
Joint workshop on
charm, QCD and tau physics
Jan. 13-15, 2004 in Beijing, China

Acknowledgements and Full Disclosure

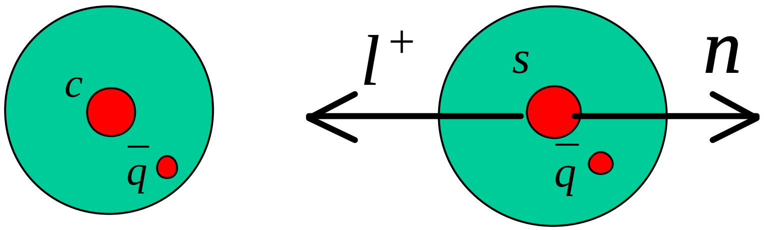
1. This talk is from the perspective of a <u>brand new</u> CLEO-c member
2. It borrows <u>very</u> heavily from an excellent longer talk of Ian Shipsey
3. I have worked on semileptonic decays from the Fermilab FOCUS (fixed target) experiment with vastly different systematics and very complementary techniques.

Allowed transition

$f(q^2)$ models of the past

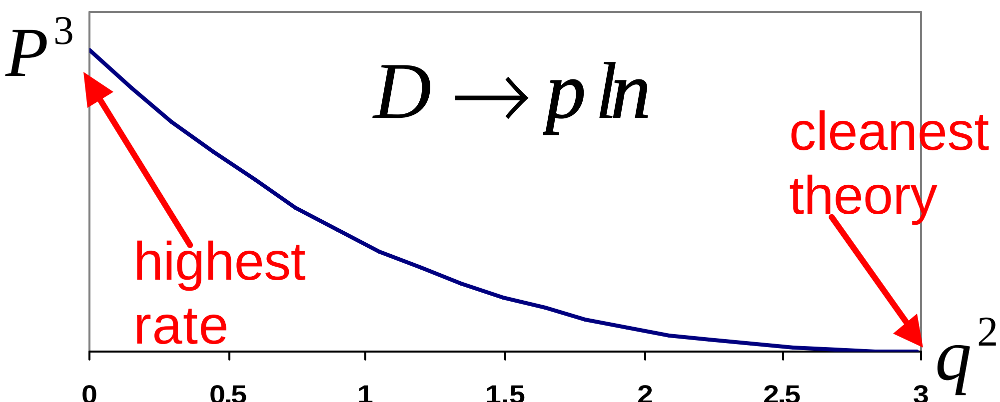
A major disconnect between experiment and theory afflicts published data

$q^2 = q^2_{\max}$ is easiest for LQCD



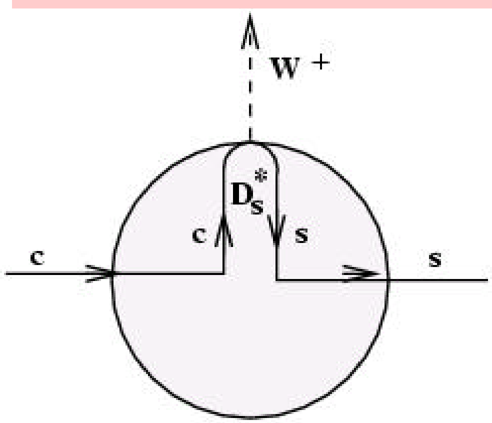
$a_{\text{lattice}} \ll l_{\text{daughter}}$

$$\frac{d\Gamma\left(D \to P\ell n\right)}{dq^2} = \frac{G_F^2 \left|V_{cq}\right|^2 P_P^3}{24p^3} \left|f_+(q^2)\right|^2$$



An incisive test of LQCD requires one to measure $f(q^2)$ where there is still rate and compare in a theoretically controlled q^2 region

Previous data had low rates and <u>terrible</u> q^2 resolution which required a parametric form for meaningful measurement



ISGW

$$f_+ \propto \frac{1}{q^2 - m^2_{\text{pole}}}$$

$$f_+ \propto \exp\left(a\,q^2\right)$$

Exclusive Charm Semileptonic Signal Yields in 3 fb^{-1}

D^0 Modes	B (%)	Detection "efficiency"	N Detected Xen	tagging fraction	N Detected Xen + Tag	CKM
$K^- e^+ n$	3.47	46%	559,500	≈14%	77,670	V_{cs}
$K^{*-} e^+ n$	2.02	12%	28,200		3,900	V_{cs}
$p^- e^+ n$	0.37	63%	81,000		11,190	V_{cd}
$r^- e^+ n$	0.20	23%	15,600		2,190	V_{cd}
D^+ Modes						
$K^0_S e^+ n$	3.40	37%	219,000	≈7.5%	16,560	V_{cs}
$K^{*0} e^+ n$	4.65	19%	151,500		11,250*	V_{cs}
$p^0 e^+ n$	0.31	44%	34,500		2,580	V_{cd}
$r^0 e^+ n$	0.25	38%	24,000		1,770	V_{cd}

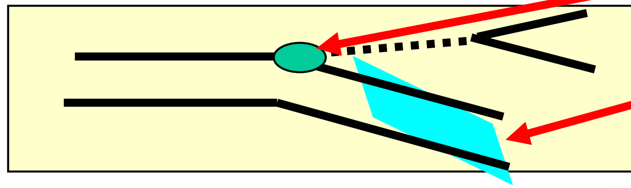
yellow book

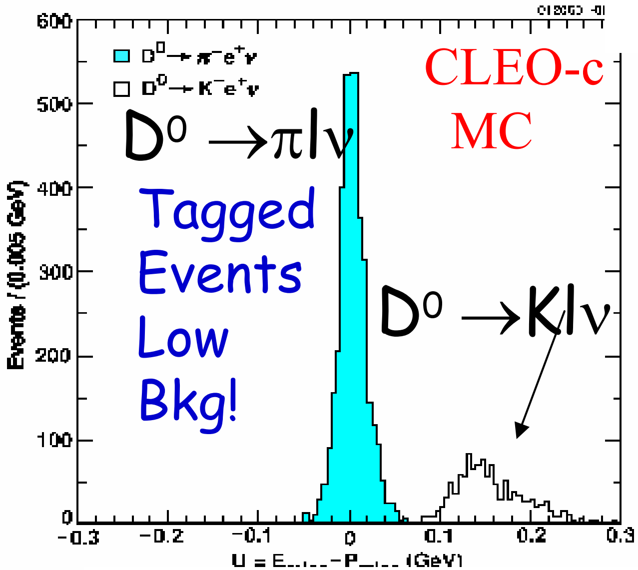
yields with 3 fb^{-1}

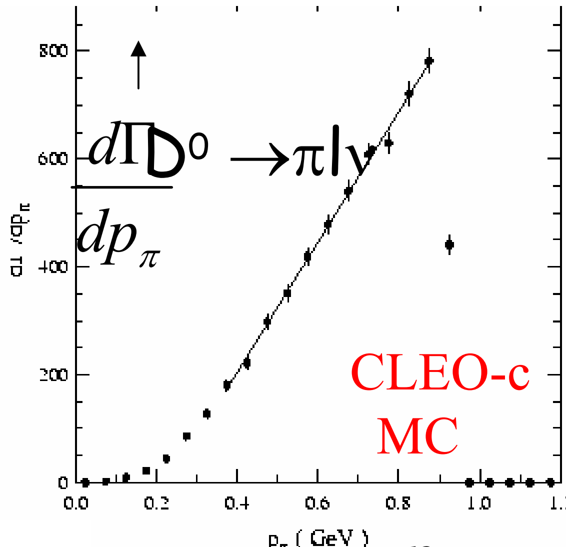
*≈Focus $K^*\mu\nu$ FF sample

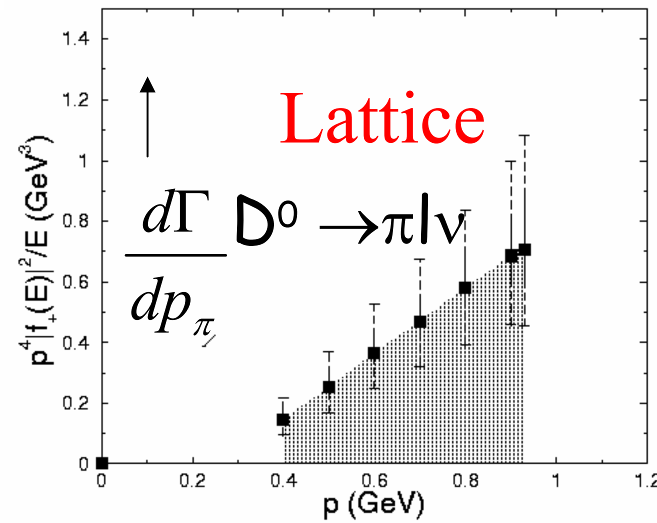
The BESIII yields are likely to be 5 to 10 times larger!

Semileptonic Decays $|V_{CKM}|^2\ |f(q^2)|^2$









$U = E_{miss} - P_{miss}$ $\quad p_\pi \longrightarrow \quad p_\pi \longrightarrow$

Assume 3 generation unitarity: for the first time measure complete set of charm PS $\rightarrow$ PS & PS $\rightarrow$ V absolute form factor magnitudes and slopes to a few% with almost no background in one experiment.

Stringent test of theory!

CLEO-c Impact semileptonic dB/B

1 : $D^0 \to K^- e^+ \nu$

2 : $D^0 \to K^{*-} e^+ \nu$

3 : $D^0 \to \pi^- e^+ \nu$

4 : $D^0 \to \rho^- e^+ \nu$

5 : $D^+ \to \bar{K}^0 e^+ \nu$

6 : $D^+ \to \bar{K}^{*0} e^+ \nu$

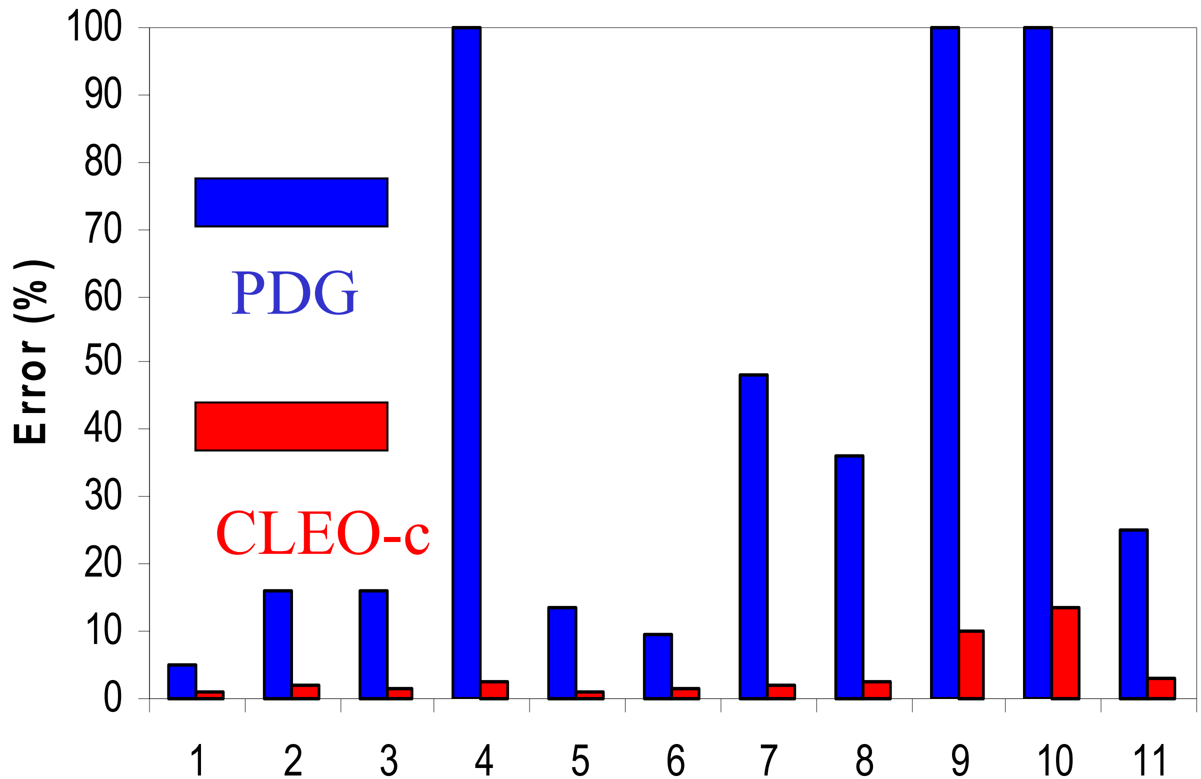
7 : $D^+ \to \pi^0 e^+ \nu$

8 : $D^+ \to \rho^0 e^+ \nu$

9 : $D_s \to K^0 e^+ \nu$

10 : $D_s \to K^{*0} e^+ \nu$

11 : $D_s \to \phi e^+ \nu$



CLEO-c will make *significant* improvements in the precision with which each absolute charm semileptonic branching ratio is known

Even with 50 pb^{-1} already accumulated CLEO-c will improve on the PDG value of dB/B for *every* D^+ and D^0 exclusive semileptonic and inclusive branching ratio. and will have ~x10 the statistics of the DELCO D➔eX inclusive spectrum (important for B semileptonic decays studies).

Pakhlov Pavel
(ITEP, Moscow)

(for Belle collaboration)

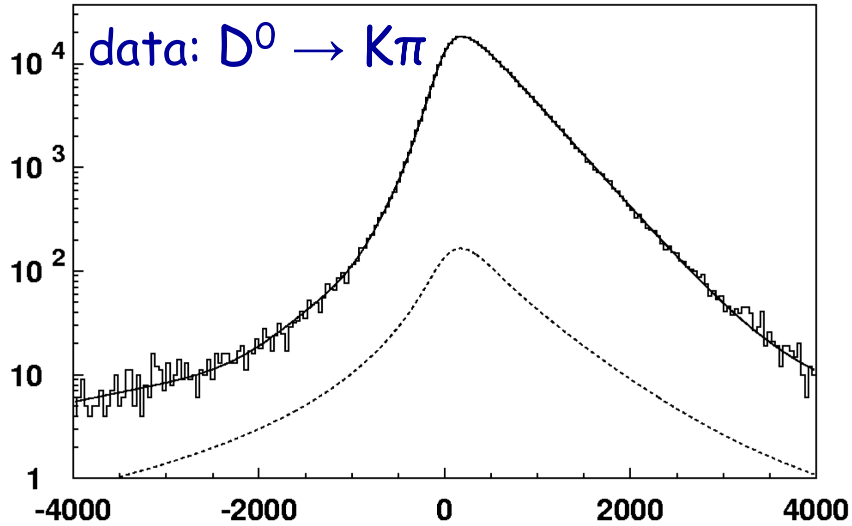
CHARM PHYSICS AT BELLE

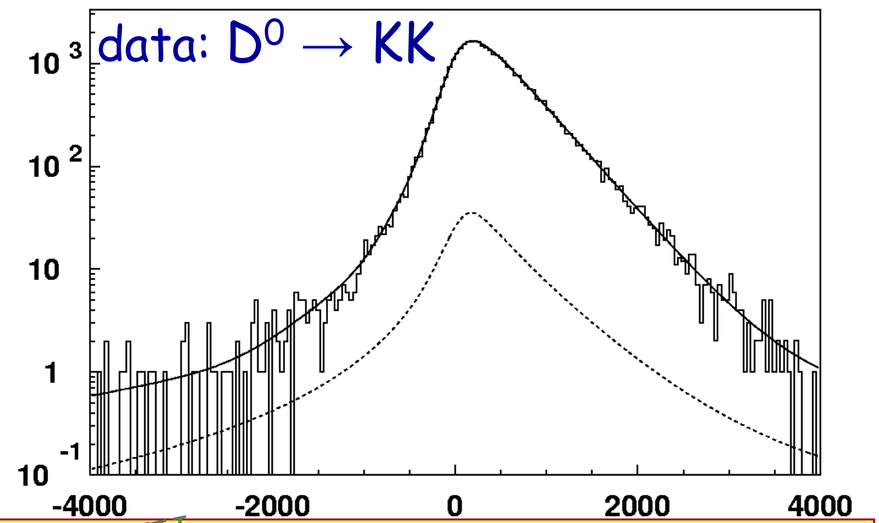
CLEOc & BESIII Joint Workshop on charm, QCD and tau physics
13-15 January 2004

- Charm physics at B factories
- Belle detector
- D^0-$\overline{D}^0$ mixing
- Rare D decays
- Spectroscopy
- Charm Production
- Future plans

y_{CP}: $D^0 \to KK$ *vs* $D^0 \to K\pi$

- Data fit signal $\mathcal{R}$ free: Gaussian weights f_i, off set X_0, common scale factor for 5 σ_i
- backgrounds: exp $\otimes$ Gauss + BW (fixed from sidebands)
- Simultaneous ***binned*** fit to $K\pi$ and KK samples: *CL=94%*





τ ($D^0 \to K\pi$) = 412.6 ± 1.1 fs preliminary **y_{CP} = (1.15 ± 0.69) %**

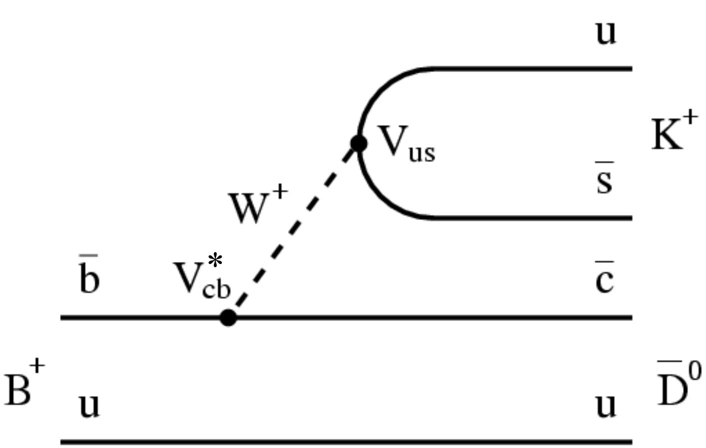
How charm data may help for φ_3 measurement at B-factories

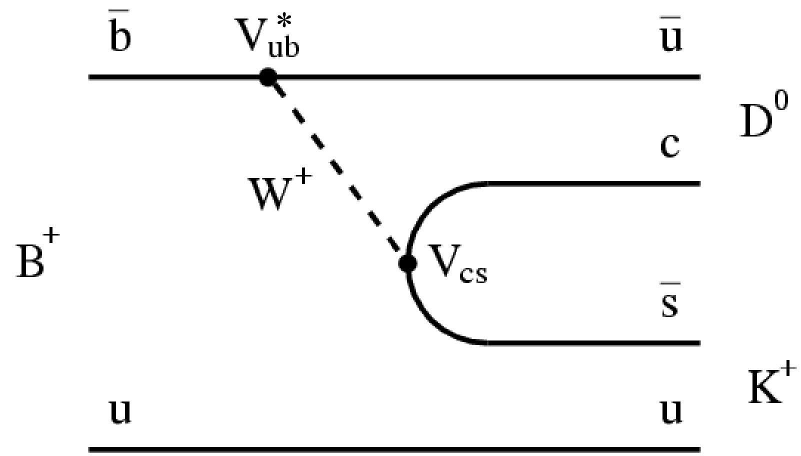
Alex Bondar (BINP, Novosibirsk)

BELLE collaboration

1. Short description of the method
2. First results from Belle
3. Model uncertainties of the method
4. Model-independent approach using CP-tagged data from Charm Factories
5. Conclusion

$B^+ \to D^0 K^+$ decay





$$M_1 \sim V_{cb}^* V_{us} \sim A\lambda^3$$

$$M_2 \sim V_{ub}^* V_{cs} \sim A\lambda^3(\rho + i\eta) \sim e^{i\phi_3}$$

If both D^0 and $\bar{D}^0$ decay into the same final states

$B^+ \to D^0 K^+$ and $B^+ \to \bar{D}^0 K^+$ amplitudes interfere.

Mixed state is produced: $\left|\tilde{D}^0\right\rangle = \left|\bar{D}^0\right\rangle + ae^{i\theta}\left|D^0\right\rangle$

Total phase $\theta = \phi_3 + \delta$

Ted Barnes
Physics Div. ORNL
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Charmonium

Physically allowed hadron states (color singlets)

$q\bar{q}$

q^3

Conventional quark model
mesons and baryons.

100s of e.g.s

$(q^3)^n$, $(q\bar{q})(q\bar{q})$, $(q\bar{q})(q^3)$, …

Basis state mixing may be
very important in some sectors.

nuclei / molecules

”exotica” :

ca. 10^6 e.g.s of $(q^3)^n$, maybe 1-3 others

g^2, g^3, …

$q\bar{q}g$, q^3g, …

$(q^2\bar{q}^2)$, $(q^4\bar{q})$, …

glueballs

hybrids

multiquark clusters

multiquarks

maybe 1 e.g.

maybe 1-3 e.g.s

controversial
e.g. $\Theta(1542)$

$c\bar{c}$ mesons quantum numbers

Parity $P_{q\bar{q}} = (-1)^{(L+1)}$ C-parity $C_{q\bar{q}} = (-1)^{(L+S)}$

The resulting $c\bar{c}$ NL states $N^{2S+1}L_J$ have J^{PC} =

1S: $^3S_1\ 1^{--}$; $^1S_0\ 0^{-+}$ 2S: $2^3S_1\ 1^{--}$; $2^1S_0\ 0^{-+}$ …

1P: $^3P_2\ 2^{++}$; $^3P_1\ 1^{++}$; $^3P_0\ 0^{++}$; $^1P_1\ 1^{+-}$ 2P …

1D: $^3D_3\ 3^{--}$; $^3D_2\ 2^{--}$; $^3D_1\ 1^{--}$; $^1D_2\ 2^{-+}$ 2D …

J^{PC} forbidden to $q\bar{q}$ are called "J^{PC}-exotic quantum numbers".

0^{--}; 0^{+-}; 1^{-+}; 2^{+-}; 3^{-+} …

Plausible J^{PC}-exotic candidates =

hybrids, glueballs (high mass), maybe multiquarks (fall-apart decays).

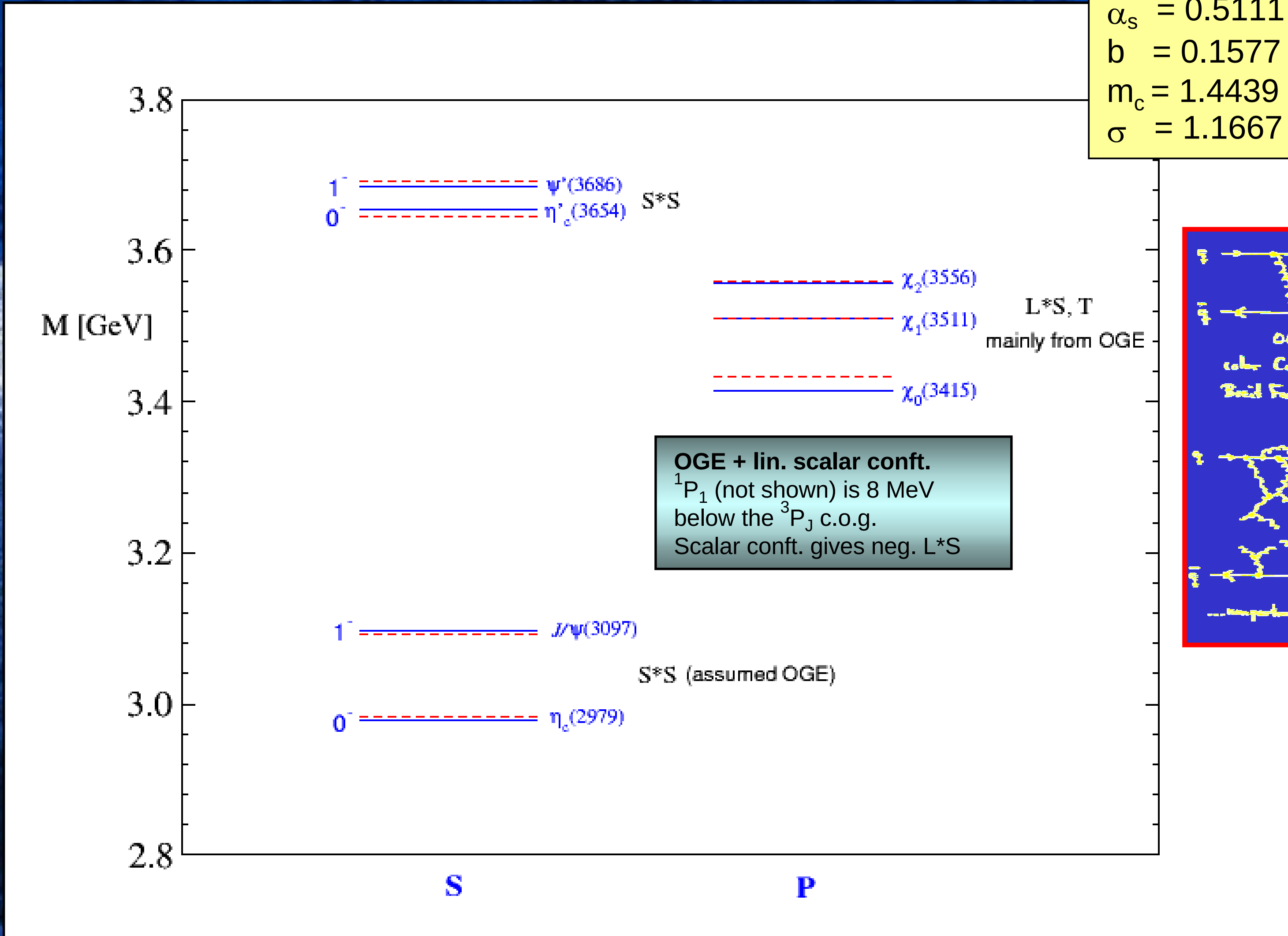
Predicted spin-dependent $c\underline{c}$ 1P multiplet splittings

(sensitive test of OGE)

Parameters α_s, b, m_c, σ fixed from 1^3P_J c.o.g. and all 1S, 2S masses, prev slide.

blue = expt, red = theory.

α_s = 0.5111
b = 0.1577 [GeV^2]
m_c = 1.4439 [GeV]
σ = 1.1667 [GeV]



OGE + lin. scalar conft.
$^1P_1$ (not shown) is 8 MeV below the ^3P_J c.o.g.
Scalar conft. gives neg. L*S

Perspectives and Challenges on:

Spectroscopy and decays of charmonia below DD threshold

Charmonium yields: B factories vs dedicated factories

Precision studies on QCD with charmonia

Unresolved issues: searches , puzzles

Technical problems, possible solutions

A wishlist

Roberto Mussa , INFN Torino
Joint CLEO-c/BES||| Workshop, Beijing, Jan.13-15, 2004

Summary 1: Milestones at 20 M $\psi(2s)$

- M1 transitions at 3%
- Total Width of η_c with 10% precision
- BR($\psi \rightarrow$ ee) @ 0.5% (now: 1.6%)
- BR($\psi' \rightarrow$ ee) @ 1.5% (now: 7%)
- BR($\psi\pi\pi$), neutral and charged.
- Angular Distributions $\psi\pi\pi$, neutral and charged.
- Tests of Isospin violation in $\psi\pi\pi$.
- Search for hc outside E760 range.
- BR($\psi\eta$) @ 1% level
- Total Width of χ_{c0} with 5% precision?
- Inclusive BR($\psi' \rightarrow \gamma\chi$) @ 3%
- Angular Distributions $\psi\gamma\gamma$. M2/E1
-

Summary 2: Milestones at 200 M $\psi(2s)$

- M1 transitions to $\eta_c(1s)$ @1%
- M1 transitions to $\eta_c(2s)$ @3% (KKπ)
- Mass + Width measurement of $\eta_c(2s)$
- Search for $\eta_c\pi\pi$ from χ_{c1}
- Search for h_c inside E760 range.
- BR($\psi\pi$) @ 1% level
- BR($\psi' \rightarrow \gamma\chi$) , BR($\chi \rightarrow \gamma\,\psi$)@ 1%
- Angular Distributions $\psi\gamma\gamma$. M2/E1 AND E3/M1
-

CHALLENGES AND OPPORTUNITIES FOR CHARMONIUM PHYSICS AT CLEO-c

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BES III/CLEO-c Workshop

Beijing 1/13-1/15/2004

CHALLENGES

Challenges are rather personal things.

What is a challenge to one person is rather boring to another.

So it is in physics!

So it is in particle physics!

- Adding the last decimal to something we know very well,like the electroweak theory, is challenging to some people. They hope it will take them beyond the Standard Model.

- Trying to understand something we do not understand at all,like confinement in QCD, is challenging to others.

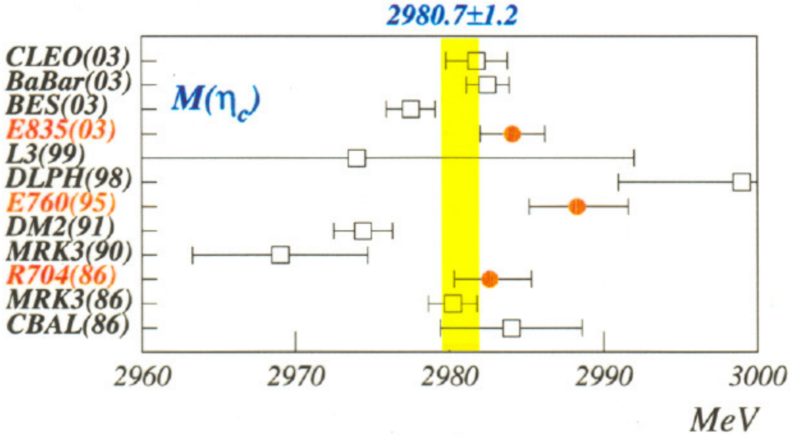
I, unapologetically, belong to the second group.

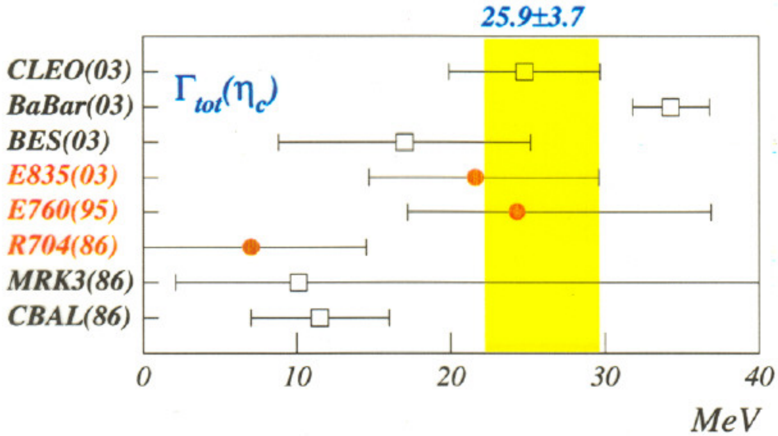
And this talk is dedicated in that spirit to the pursuit of strong interaction physics, for its own sake,not as a contaminating nuisance to the weak interaction physics.

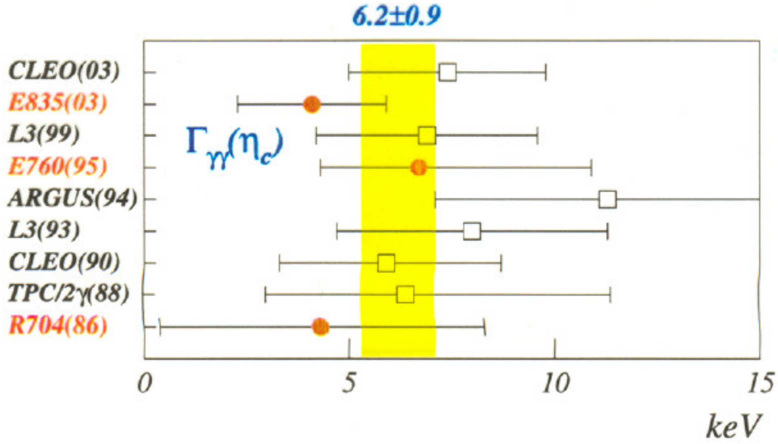
- How and where can we best confront this challenge.

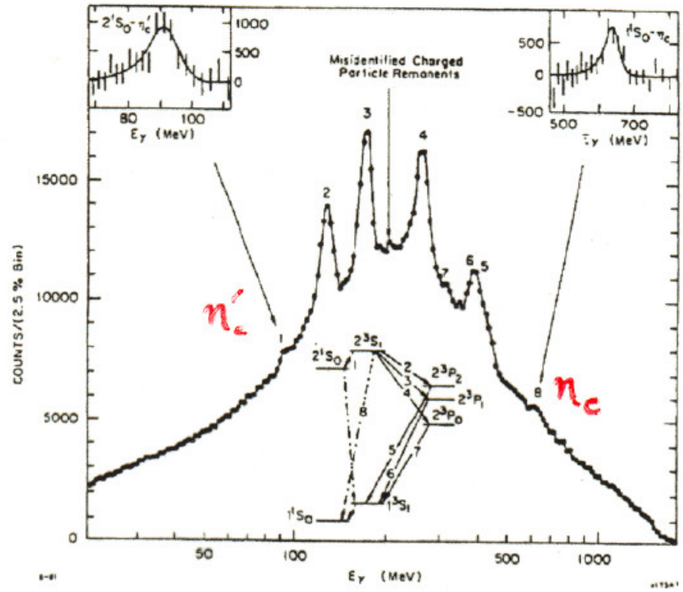
- For me the answer has been, and still is in the $c\bar{c}$ spectroscopy!

η_c


2980.7±1.2
M(ηc)
CLEO(03)
BaBar(03)
BES(03)
E835(03)
L3(99)
DLPH(98)
E760(95)
DM2(91)
MRK3(90)
R704(86)
MRK3(86)
CBAL(86)
2960
2970
2980
2990
3000
MeV


25.9±3.7
Γtot(ηc)
CLEO(03)
BaBar(03)
BES(03)
E835(03)
E760(95)
R704(86)
MRK3(86)
CBAL(86)
0
10
20
30
40
MeV

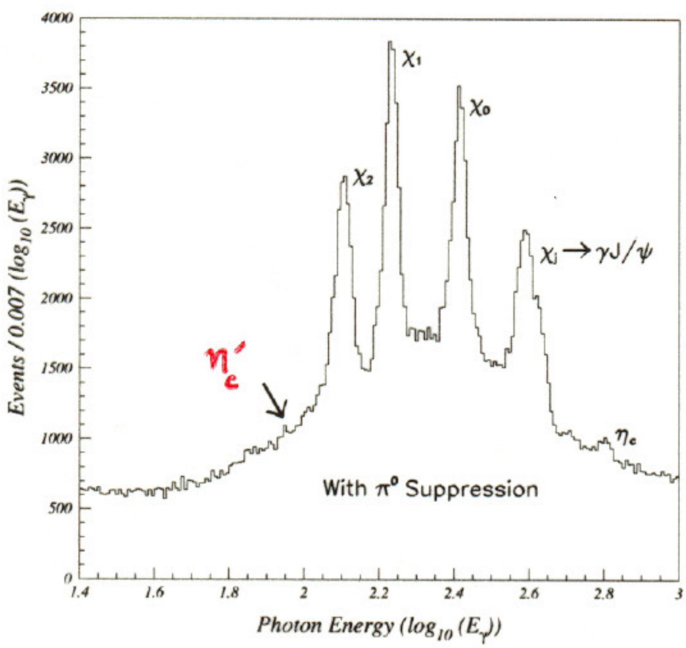

6.2±0.9
Γγγ(ηc)
CLEO(03)
E835(03)
L3(99)
E760(95)
ARGUS(94)
L3(93)
CLEO(90)
TPC/2γ(88)
R704(86)
0
5
10
15
keV



Crystal Ball

(1986)

SLAC: $E_\gamma = 91.5 \pm 5$ MeV, $M(\eta_c') = 3594 \pm 5$ MeV



CLEO III

(2003)

CLEO-III: No evidence for η_c'

Charmonium Physics at BESIII

Changzheng YUAN

IHEP, Beijing

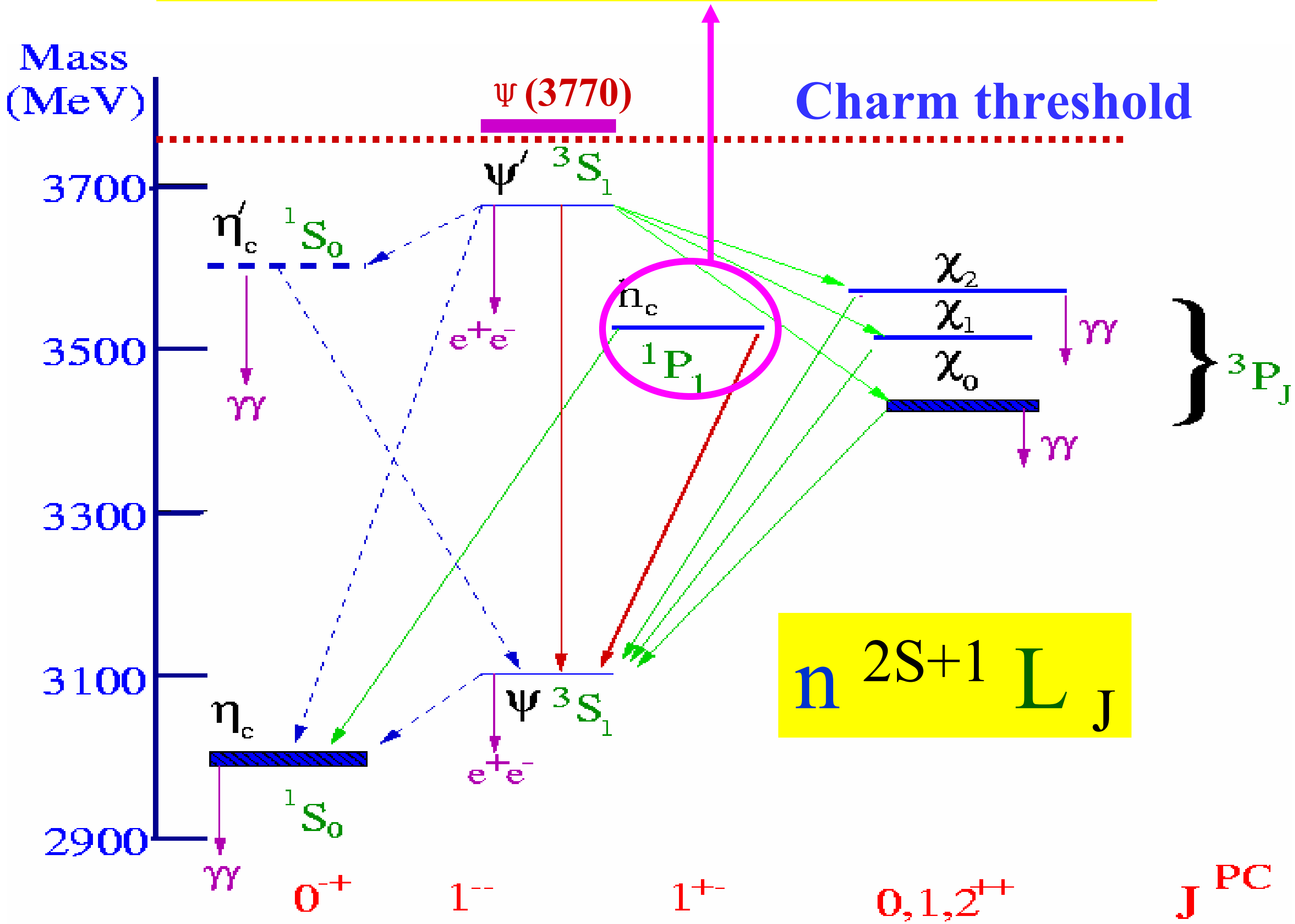
Jan. 14, 2004

Here we will focus on ---

1. Search for $h_c(^1P_1)$ state
2. Hadronic decay dynamics and "$\rho\pi$" puzzle
3. The continuum amplitude and the data taking strategy
4. J/ψ study via $\psi(2S)$ sample
5. $e^+e^- \rightarrow$ charmonium+X for a study of charmonium production mechanism

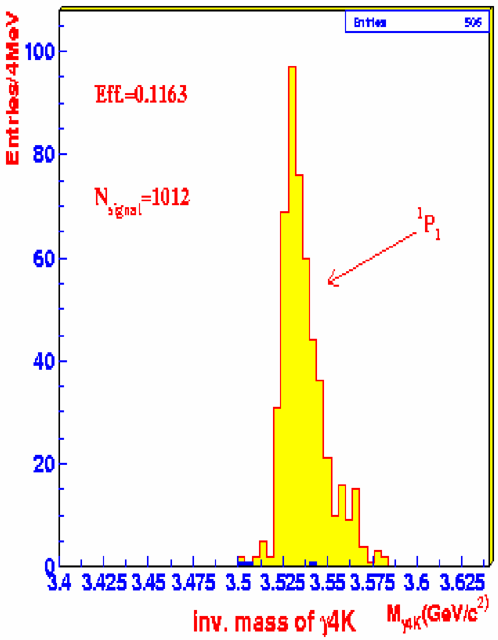
Search for $h_c(^1P_1)$ state

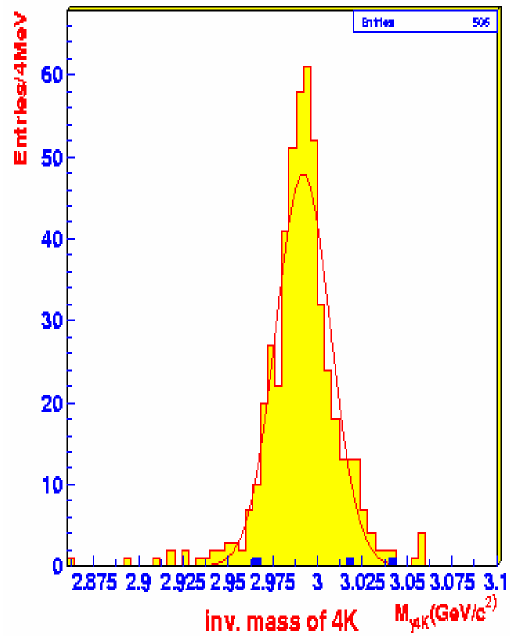
$h_c(^1P_1)$: the only missing charmonium state below charm threshold.



$n\ ^{2S+1}L_J$

Search for $h_c(^1P_1)$ state





$Br = (0.5 – 7.5) \times 10^{-6}$
60-900 events/year

$\psi(2S) \rightarrow \pi^0 h_c(^1P_1) \rightarrow \gamma\gamma\gamma\ \eta_c \rightarrow \gamma\gamma\gamma\ 4K$

Backgrounds: $\psi(2S) \rightarrow \gamma\ \chi_{c1}, \gamma\chi_{c2,,}\ \eta\psi, \pi^0\pi^0\psi$

Very small!

There are many more exclusive η_c decay modes!

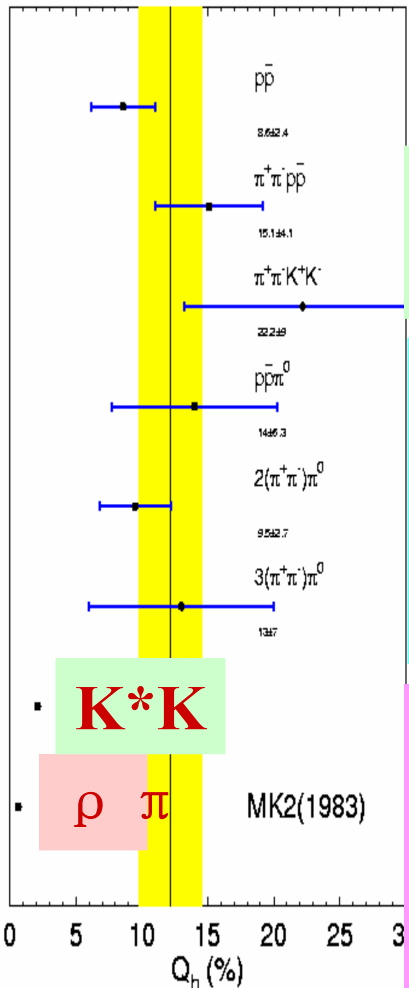
pQCD rule and “ ρ π puzzle”

Review

pQCD predicts

$$Q_h = \frac{B(\psi(2S) \to ggg)}{B(J/\psi \to ggg)} = \frac{\alpha_s^3(\psi(2S))}{\alpha_s^3(J/\psi)} \frac{B(\psi(2S) \to e^+e^-)}{B(J/\psi \to e^+e^-)}$$

$$\approx 12\%$$



“15% rule”, “14% rule”, “12% rule” in literatures

----- “pQCD rule”

Mark-II at SPEAR found while many channels give ratios around 12%, ψ(2S) and J/ψ → ρ π violate “pQCD rule”, so does K*K. ψ(2S) decays suppressed

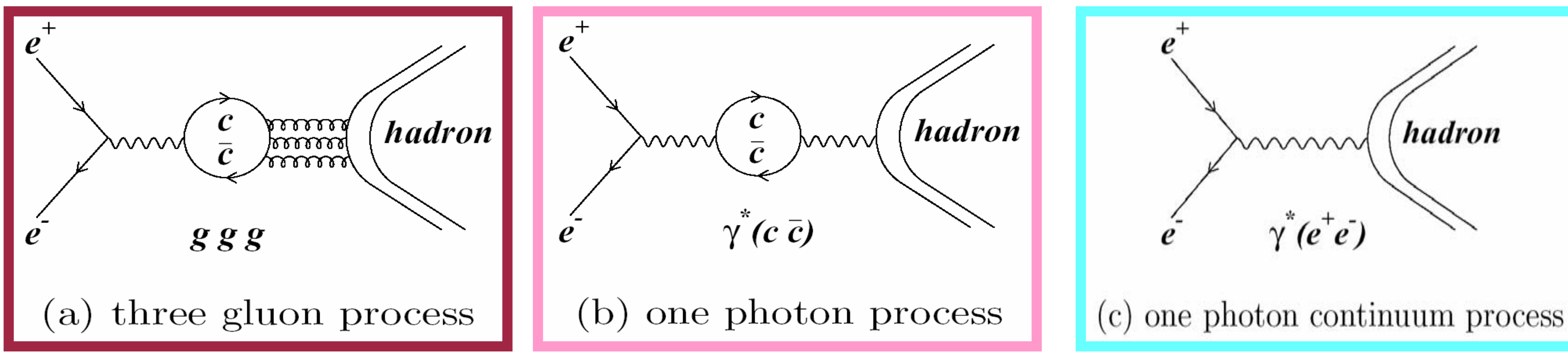
----- “ ρ π puzzle”

The assumptions:

1. *pQCD is valid at c-quark mass*
2. *“pQCD rule” derived for inclusive decays holds for exclusive channels.*

The continuum amplitude

σ_{theo}



(a) three gluon process

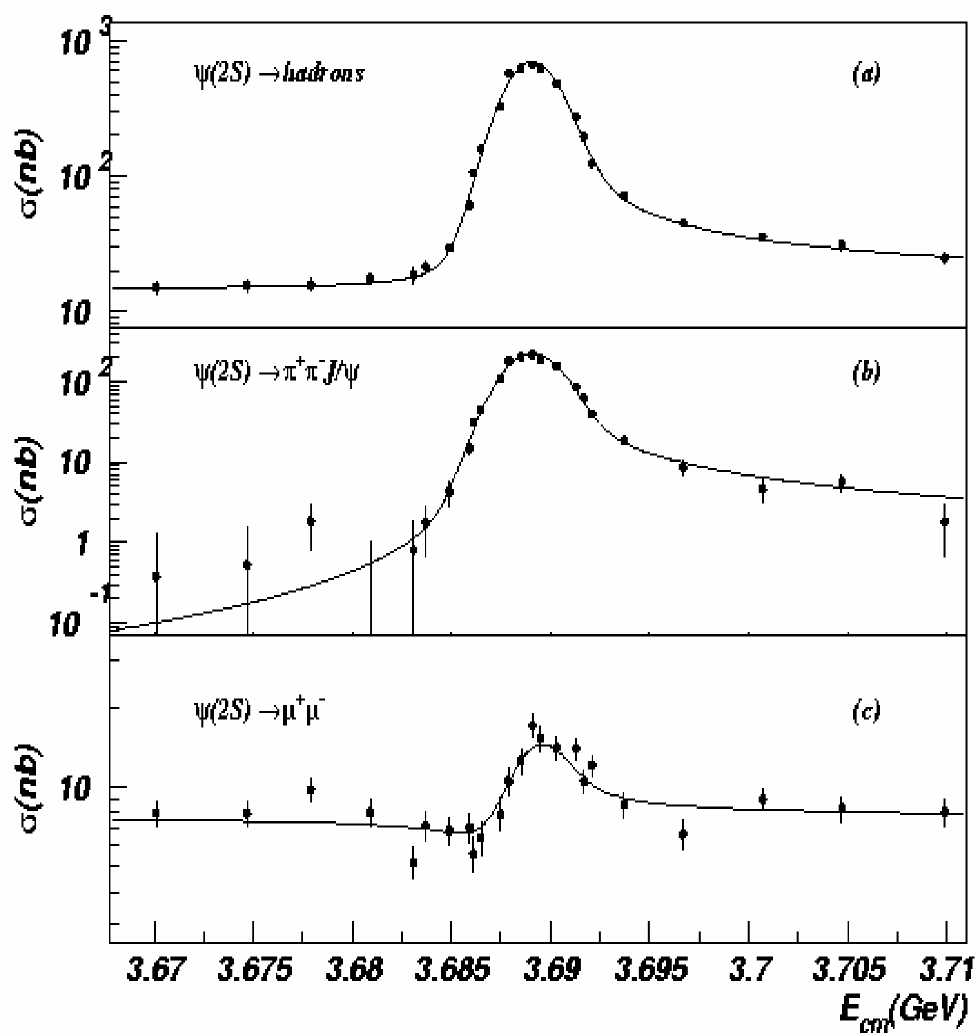
(b) one photon process

(c) one photon continuum process

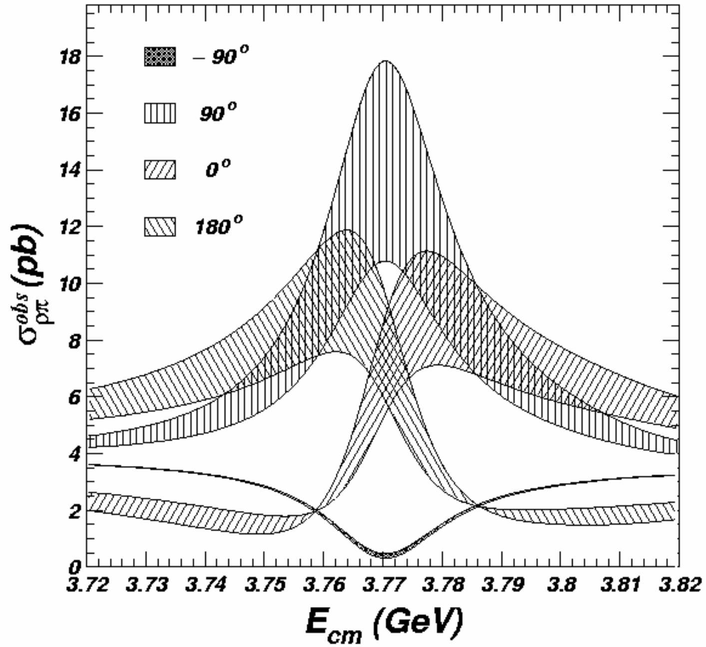
σ'_{exp}

Energy scan: the way for high precision BR measurement

$e^+e^- \rightarrow X$ @ $\psi(2S)$



$e^+e^- \rightarrow \rho\ \pi$ @ $\psi(3770)$



All the channels should be measured by a energy scan!

Data sample should be taken at a few energy points, instead of at resonance peak only.

Charmonium Physics

Open questions …

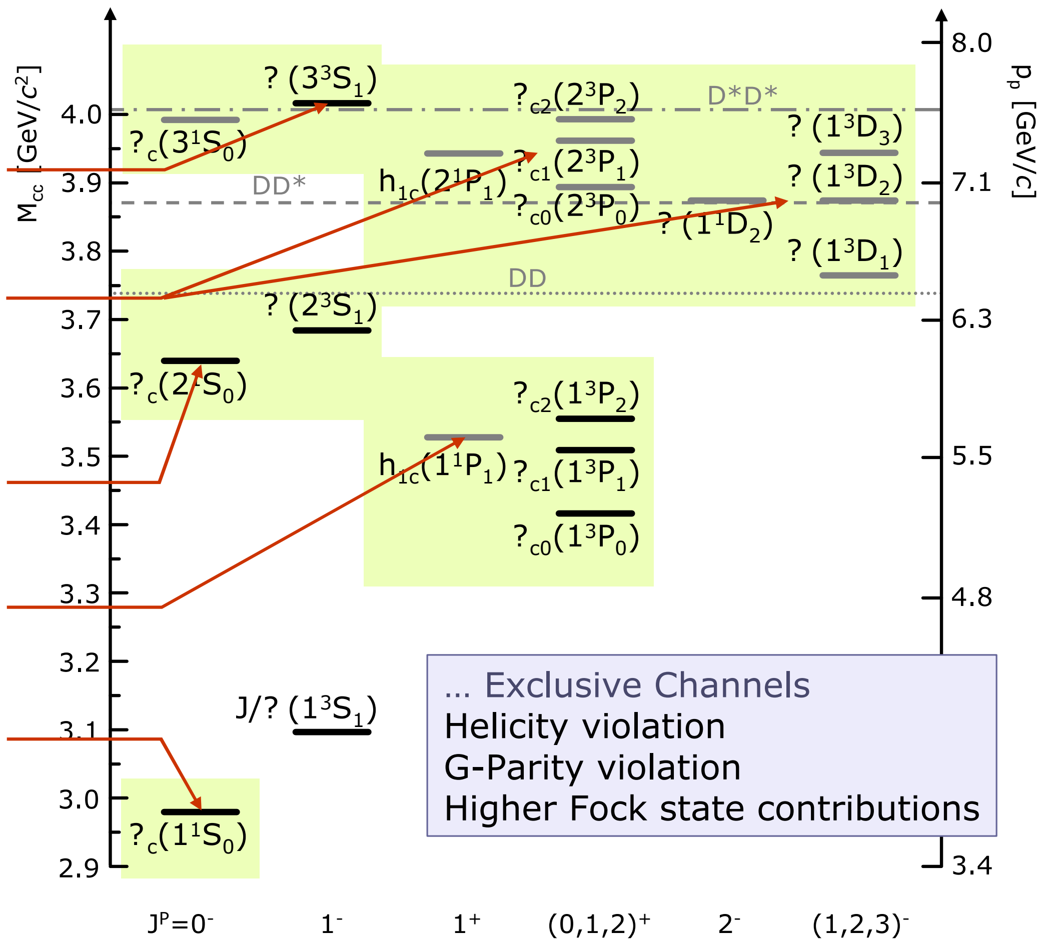
Peculiar ? (4040)

Terra incognita for 2P and 1D-States

$?_c'$ - ? (2S) splitting

h_{1c} – unconfirmed

$?_c$ – inconsistencies



… Exclusive Channels

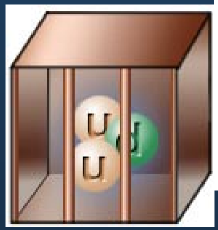
Helicity violation

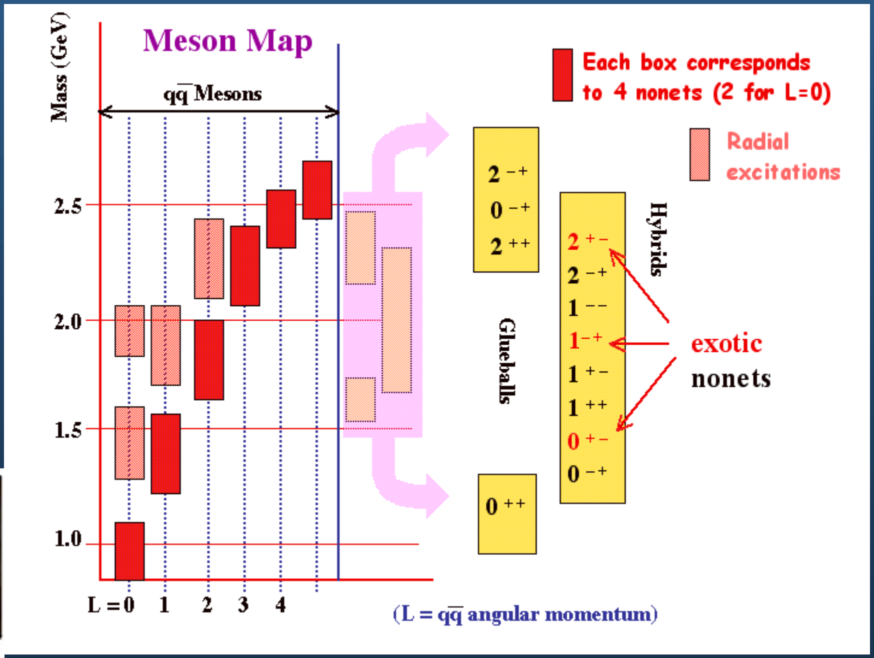
G-Parity violation

Higher Fock state contributions

Gluonic excitations (new form of matter)

- QCD suggests existence of states in which *gluon* field is excited
  - glueballs (*excited glue*)
  - hybrid mesons ($q\bar{q}$ + *excited glue*)
  - hybrid baryons (qqq + *excited glue*)
- such states not well understood
  - quark model fails
  - perturbative methods fail
- lack of understanding makes identification difficult!
- confront gluon field behavior
  - bags, strings, …
- clues to confinement

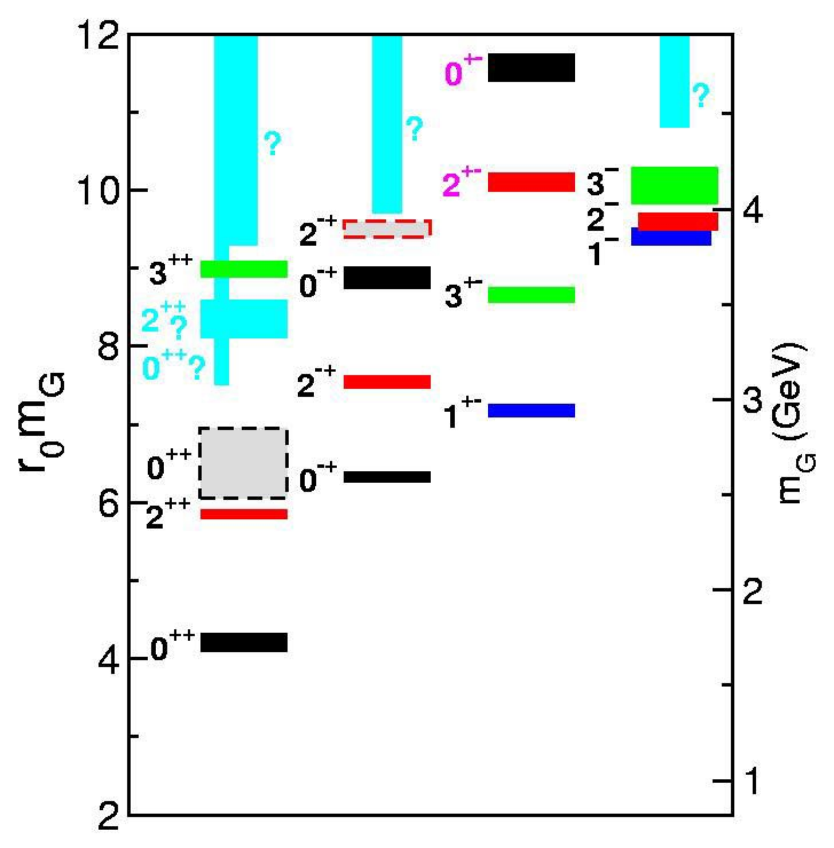




Yang-Mills SU(3) Glueball Spectrum

- pure-gauge mass spectrum well known
  - still needs some "polishing"
  - improve scalar states
- "experimental" results in simpler world (no quarks) to help build models of gluons
- glueball structure
  - constituent gluons vs flux loops?

C. Morningstar and M. Peardon, Phys. Rev. D 60, 034509 (1999)



$r_0^{-1} = 410(20)$ MeV, states labeled by J^{PC}

Glueball Searches: Experiment

Jim Napolitano (RPI & Cornell)

Outline:

- Looking for glue: Where and How
- History and puzzles
  - The scalars $f_0(1710)$, $f_0(1370)$, and $f_0(1500)$
  - The pseudoscalars $\eta(1418)$ and $\eta(1475)$
- Resolving the puzzles
  - High statistics $J/\psi \to \gamma X$ using partial waves
  - $J/\psi \to \gamma X$ followed by $X \to \gamma Y$
- $M_X \geq 2$ GeV$/c^2$: Tensor glueballs and $J = 4$ mesons

CLEO-c/BESIII Joint Workshop, Beijing, 13-15 Jan 2004

History and Puzzles

More states found than are predicted by the quark model.
$\Rightarrow$ Could the extra states be glueballs?

- The scalars $f_0(1710)$, $f_0(1370)$, and $f_0(1500)$

Quark Model predicts only two.
(These are the isoscalar $u\bar{u} + d\bar{d} \equiv n\bar{n}$ and $s\bar{s}$.)
Prime suspect for the lightest glueball.

- The pseudoscalars $\eta(1418)$ and $\eta(1475)$

Quark Model predicts only one.
(This is the $\eta'(958)$ radial excitation).
Mass disagrees with lattice QCD.

$J/\psi \rightarrow \gamma X$ is a key dynamical ingredient!

Conclusions

Radiative transitions between vector and scalar mesons will provide strong constraints on the presence and structure of glueballs with $1.3 \leq M \leq 2.0$ GeV$/c^2$.

High statistics $J/\psi \to \gamma X$, including $X \to \gamma\{\rho, \phi\}$, may be within reach of CLEO-c and BESIII.

A complete analysis will be limited by data volume.
Will likely need $\geq 10^9$ J/ψ's.

The region with $M_X \geq 2$ GeV$/c^2$ needs to be carefully explored for narrow and/or broad resonances.
Partial Wave Analysis will be a necessary tool.

High statistics are good, but excellent knowledge of the detector acceptance is also crucial.

J/ψ Physics at BESIII/BEPCII

Xiaoyan SHEN

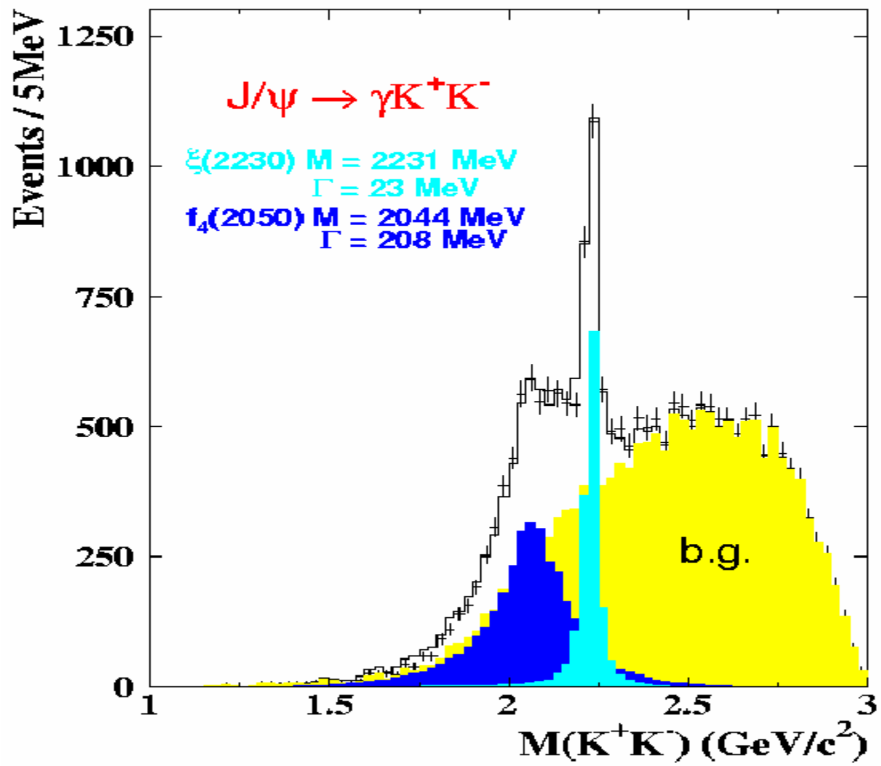
Institute of High Energy Physics, CAS

BESIII/CLEO-c Workshop, Jan. 13-15, 2004, Beijing

J/ψ Physics at BESIII/BEPCII

- Search for glueballs, hybrids and multi-quark states
- Systematic study of light hadron spectroscopy
- Study of the excited baryon states
- Search for more J/ψ decay channels
- Probing for new physics in J/ψ decays
- η_c physics

PWA Results

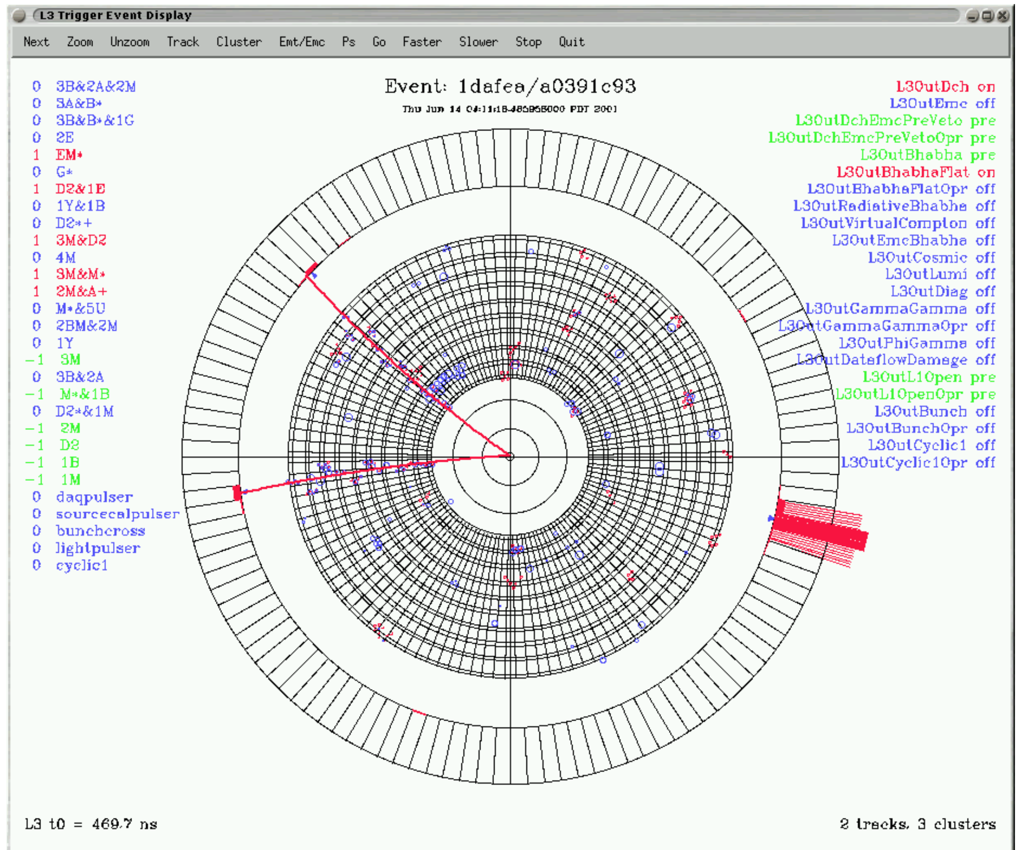


Crosses are generated Monte-Carlo data, histogram is the PWA fit projection.

- the J^{PC}s' of $\xi(2230)$ and $f_4(2050)$ being 2^{++} and 4^{++} gives the best Log Likelihood value.
- excluding either $\xi(2230)$ or $f_4(2050)$ makes the log likelihood value be worse apparently.
- 0^{++}, 2^{++} and 4^{++} can be separated clearly in the mass region over 2.0 GeV with BESIII detector.

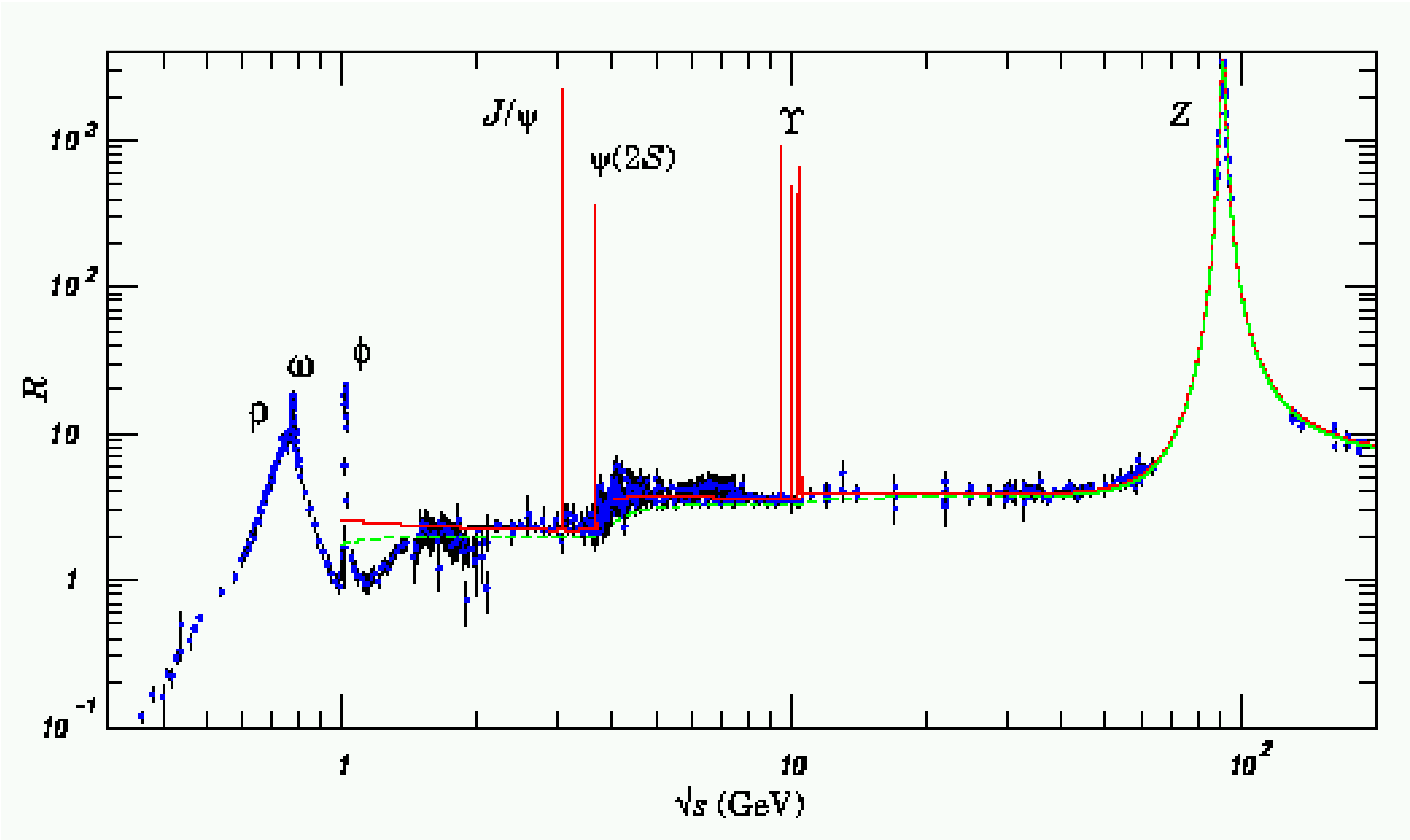
Low Energy R Measurements with ISR

Su Dong
Stanford Linear Accelerator Center



CLEO-c/BES c/τ/QCD workshop, Beijing, Jan/15/2004

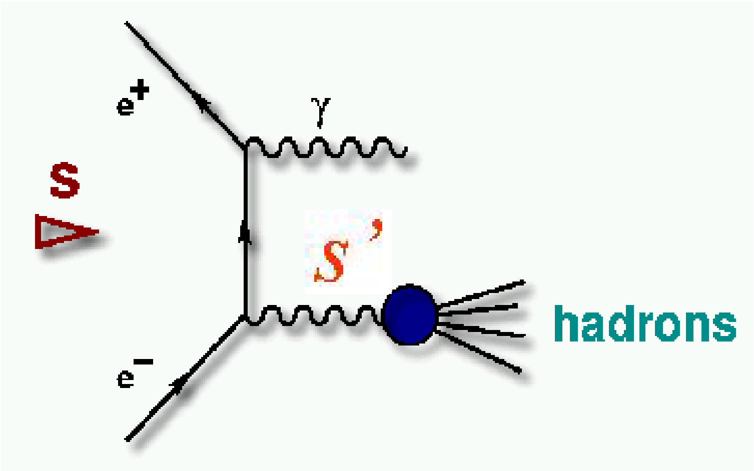
R measurements



R = σ(e^+e^- → Hadrons) / σ_0(e^+e^- → $\mu^+\mu^-$)

A large number of measurements scattered at various energy ranges, over the last 3 decades.

R Measurements: The New approach with ISR



Operating at a fixed CM energy to simultaneously explore the whole lower energy range below with initial state radiation (ISR)

(don't have to fight over when to operate on what energy. They are there all the time parasitic to whatever else you want to do !)

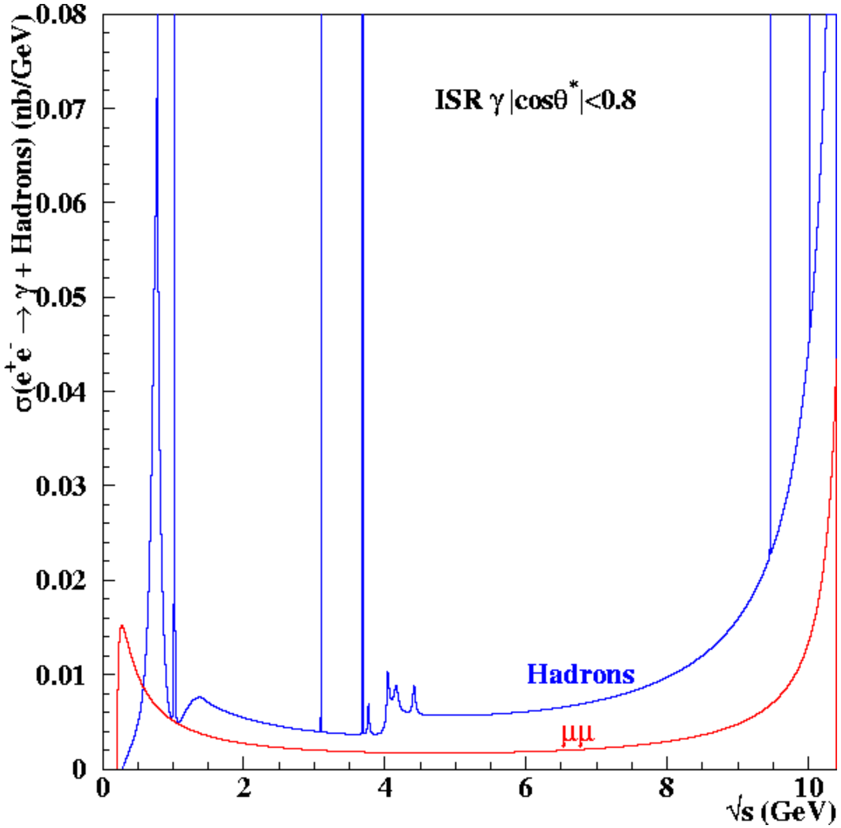
Rapid rise in both theoretical and experimental interests.

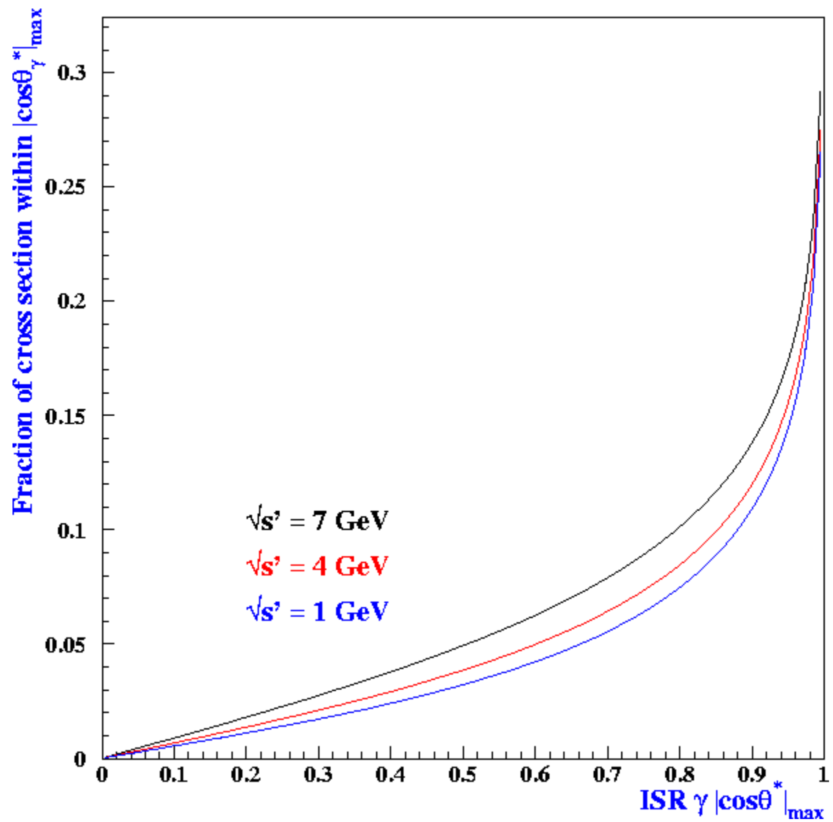
(the possibility of R measurement with ISR actually first emerged from CLEO data in 1995 as a background to the b->sγ analyses…)

Becoming truly competitive with the luminosity of the B/τ-c/ϕ factories. BaBar and DaΦne already started working at $s^{1/2}$=10.6 GeV and $s^{1/2}$=~1 GeV respectively.

It's still in the early days and there are more questions than answers.

ISR cross section at $E_{cm}=\Upsilon(4s)$





ISR photon mostly along beamline. Only using ~5-10% events with photon in calorimeter fiducial (~$|\cos\theta_\gamma^*|<0.8$ for good containment), but still integrate to ~0.05nb of γ+had events below $s^{1/2}$~7 GeV.

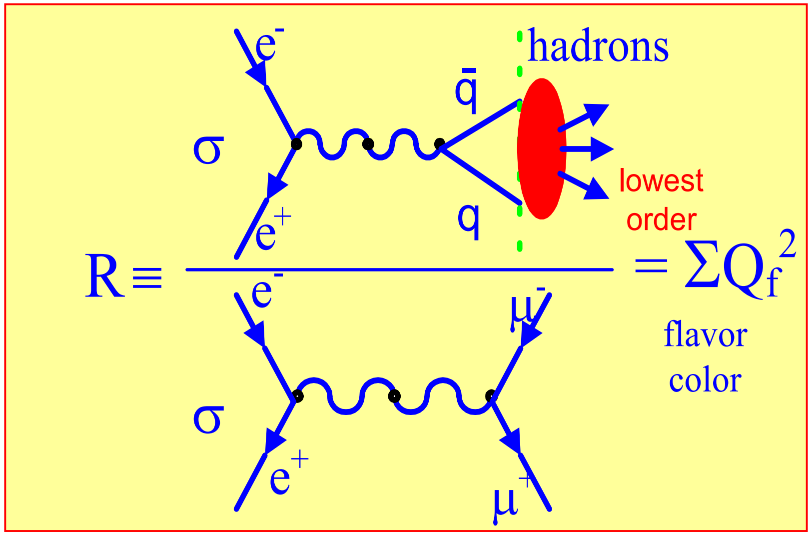
(compare to the non-radiative ~1nb BB and 3.4nb udsc at $s^{1/2}$=10.58GeV)

R in CLEO – past, present, future

S. Dytman
Univ. of Pittsburgh,
CLEO Collaboration

What is R?

$$R(s) = \frac{\sigma(e^+e^- \to hadrons)}{\sigma_0(e^+e^- \to \mu^+\mu^-)}$$



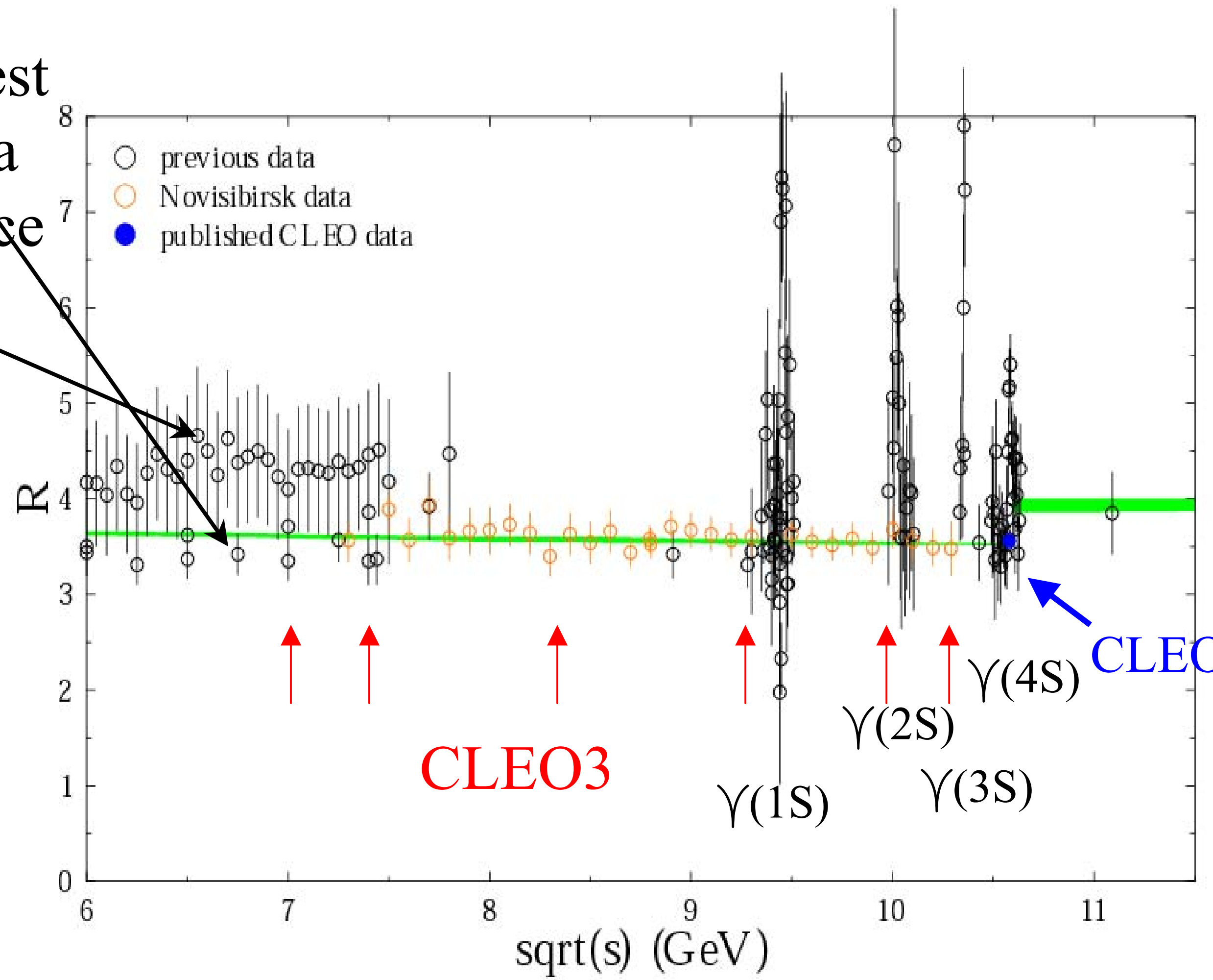
R measurements with CLEO

- Existing data (goal is σ_{syst}<3%)
  - 7.0 GeV (2.8 pb^{-1})
  - 7.4 GeV (8.9 pb^{-1})
  - 8.4 GeV (4.6 pb^{-1})
  - 9.4 GeV (194 pb^{-1}) [1S continuum]
  - 10.0 GeV (150 pb^{-1}) [2S cont.]
  - 10.3 GeV (122 pb^{-1}) [3S cont.]
  - 11.2 GeV (721 pb^{-1}) [Λ_b thresh. scan]

- Data to come (?!)
  - Modern R measurement
    - 3.8-4.6 in 10 MeV steps, ~10,000 events per step
    - Measure R to $\lesssim$ 2% accuracy
    - Measure DD, D*D, D*D* content for cc resonant structure
  - Under active consideration for CLEOc!

Previous data + pQCD prediction

- CLEO2 (2%), Novosibirsk (5-7%) best
- MARK I vs. Cryst. Ball a long-standing annoyance
- How low in energy is pQCD valid?



N.B. These are the values given by PDG, stat+syst errors. We really see the need for ϒ CLEO3 measurements!

TAU PHYSICS

A. Pich

IFIC, CSIC – Univ. Valencia

- Lepton Universality. Lorentz Structure
- Hadronic Decays: QCD Tests, m_s, $|V_{us}|$
- New Physics: Lepton Number Violation, $\not{C}\!\not{P}$, . . .

BESIII / CLEO-c Workshop, Beijing, 13–15 January 2004

Opportunities for τ Physics

- Overview of Tau's at low energy
- Tau Threshold Measurements
  - Tau Mass
  - Massive Neutrino in $\tau\rightarrow\ \nu\nu$
  - Exotic Decays: $\tau\rightarrow eX$
  - Radiative Leptonic Decays
  - Tau Atoms
- High Statistics Measurements
  - Precision Branching Fractions
  - Hadronic structure
  - Rho Line Shape
  - CP Violation
  - Lorentz Structure
  - Neutrino Mass

Conclusions

- BESIII/CLEO-c will play an important role in τ physics – no matter what BaBar/Belle do
- There are unique opportunities near threshold using the lack of ISR/FSR, and unique τ decay kinematics
- Suggested BESIII running: τ mass scan, 3.67 GeV, and τ's under charm plus background normalization below τ

Λ_c Physics at the Energy Threshold

John Yelton
U. of Florida
CLEO experiment

A review of what we know, and what we do not know, about the Λ_c , with an accent on what new knowledge can be gained by running with e^+e^- annihilations (just) above threshold.

Threshold Running

Assuming 50% reconstruction efficiency (for $pK\pi$), and 1 fb^{-1} of data, can expect 500 fully reconstructed, clean events with $e^+e^- \rightarrow \Lambda_c^+\Lambda_c^-$ (where each $\Lambda_c \rightarrow pK\pi$).

By itself, this should get a statistical uncertainty in the measurement of 4.5% of itself, and be enough for easily the best measurement in the world.

but … charm decays as a direct probe for New Physics?

basic contention:
charm transitions are a unique portal for obtaining a novel access to the flavour problem with the experimental situation being a priori favourable (apart from absence of Cabibbo suppression)!

☺ SM weak phenomenology rather dull affair with
- `slow' D^0 - D^0 oscillations,
- `small' CP asymm.
- `zero-background' search for New Physics ?

😐 yet … "how slow is `slow' and how small is `small' ?"
- x_D < 3 %; $y_{D,CP}$ = (1 ± 0.5) %
- direct ~~CP~~ < (few to several) %

- ☹ leading charm decays Cabibbo allowed
- ☺ New Physics more likely to surface in 2x[1x] Cabibbo supp.
- ☺ effective weak phase unusually small in CKM description
- ☺ charm only up-type quark allowing full range of probes of flavour couplings, including flavour-changing neutral currents
  - □^{0} decays electromagnetically, no □^{0}- □^{0} oscillations, …
  - top quarks do not hadronize
    - no T^0-T^0 oscillations
    - CP asymm. highly reduced due to lack of coherence

Summary & Outlook

Rare Decays at $\psi(3770)$ compare favorably with $\Upsilon(4S)$

- Radiative decays may be observable
- Otherwise Standard Model predictions are many orders of magnitude beyond CLEO-c+BES-III sensitivity

D-mixing at $\psi(3770)$ compares favorably with $\Upsilon(4S)$

- Exploit CP content on Dalitz plot vs flavor tag (probes $y=\Delta\Gamma/2\Gamma$)
- Correlated final states probe $R_{mix}=(x^2+y^2)/2$, $x=\Delta m/\Gamma$, $y=\Delta\Gamma/2\Gamma$
- Measure relative strong phase between $D^0 \rightarrow K^-\pi^+$ and $\overline{D}^0 \rightarrow K^-\pi^+$
- Need to evaluate ability to distinguish x vs y at $\psi(3770)$

CP Violation: Further study is required

- Best probe of CP violation in charm is interference on Dalitz plots at both B-factories and at charm threshold
- B-factories have much larger statistics and larger backgrounds
- B-factories only have flavor tag (D^{*+}): Charm threshold also has CP tag

How can we optimize physics output of BES/CLEO?

General thoughts to initiate discussion…

Complementarity:

- higher $\sqrt{s}$ …..lower $\sqrt{s}$
- few fb^{-1} …. few 10's fb^{-1}
- brief time span … open-ended
- starting now….. starting later
- no μ, no K_L, …. μ, K_L (?)

Cooperation:

- Physics Workshops
- Technical workshops (IR)
- Visiting physicist programs
- Development of common tools

Community:

- Belle, Babar,…
- Joint working groups
- Common approach to conference organizers

Competition:

- drives new ideas…

Confirmation:

- exotic signals,
- precision measurements