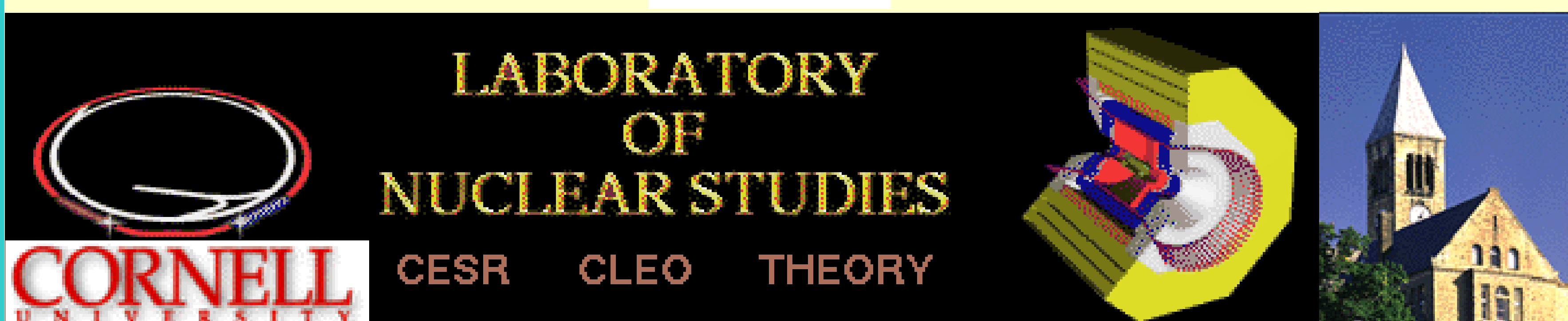
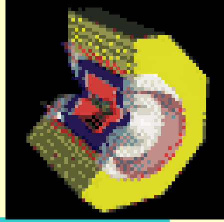
CLEO-c: A New Frontier for QCD & Heavy Flavor Physics

Brian K. Heltsley

KEK Seminar, July 2, 2001



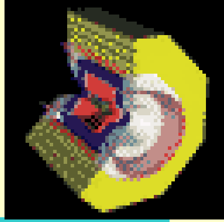
Outline



- 1st half: where should we go?
  - Whither CLEO?
  - Whither QCD?
  - Whither Flavor Physics?
- 2nd half: how to get there
  - CLEO-c & CESR-c
- Beyond CLEO & CESR?

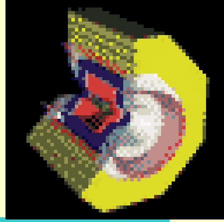
3 threads

A Short History of CESR/CLEO



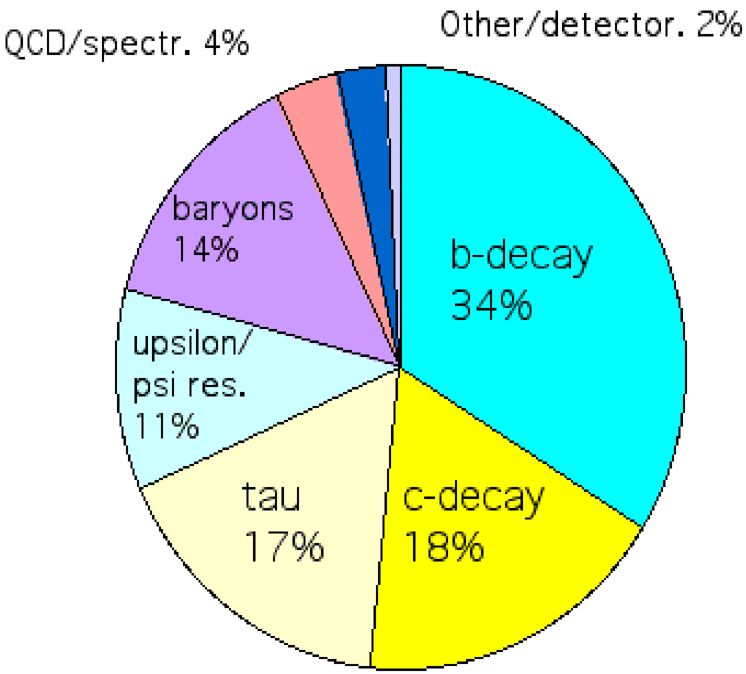
- **1968: 10 Gev e^- synchrotron built**
  - Size of ring determined by size of playing fields
- **1975: Proposal for e^+e^- storage ring in synchrotron tunnel, E_{beam}=8 GeV**
  - PEP/PETRA E_{beam}=15-20 GeV
  - SPEAR E_{beam}=2 GeV
- **1977: *b*-quark discovered at FNAL!**
- **1979: CLEO sees first collisions**
- **1980: Y(4S) discovered**
  - CLEO 1979
  - CLEO I.V 1984
  - CLEO II 1989
  - CLEO II.V 1995
  - CLEO III 1999

The CLEO Collaboration



Membership:

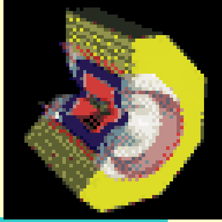
- ~20 Institutions
- ~155 physicists
- ~1/2 DOE, 1/2 NSF
- Currently expanding…



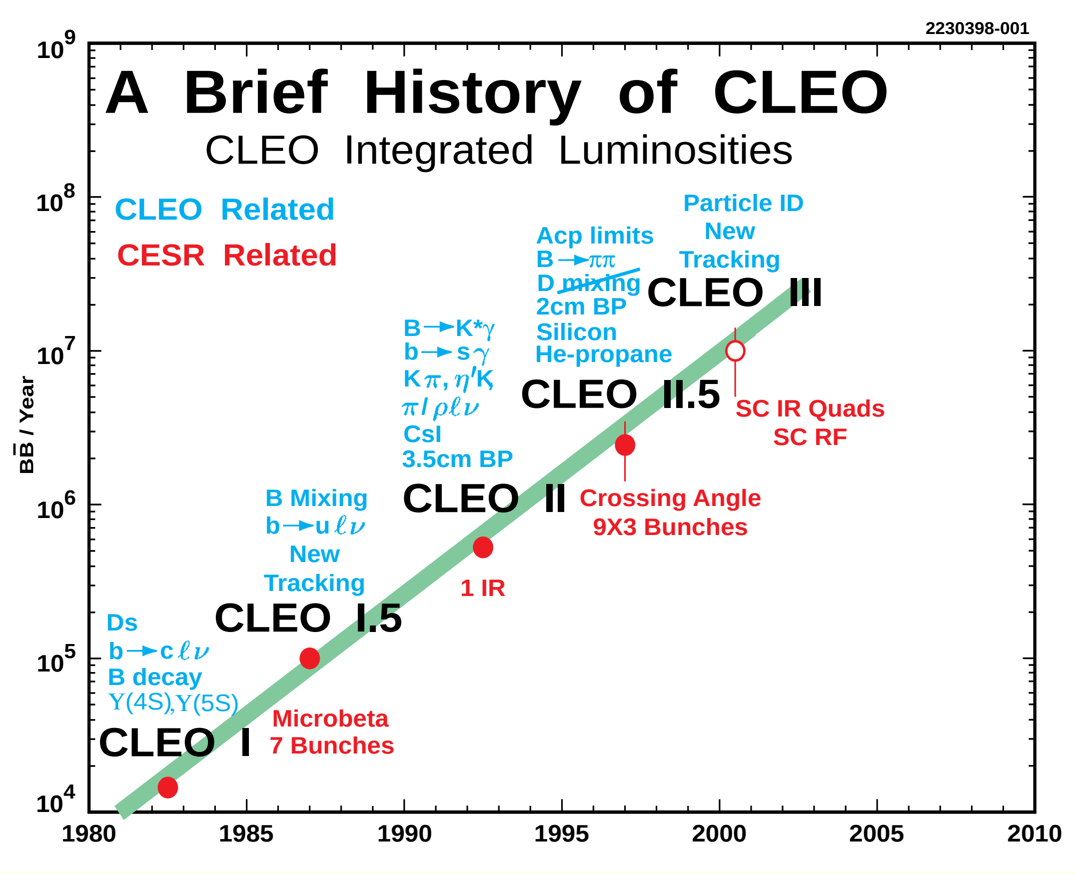
Albany	Oklahoma
Caltech	Purdue
CMU	Rochester
Cornell	SLAC
Florida	SMU
Harvard	UCSD
Illinois	UCSB
Kansas	Syracuse
Minnesota	Vanderbilt
Ohio State	Wayne State

- **Publication history 1980-**
  - ~320 papers
  - diverse physics

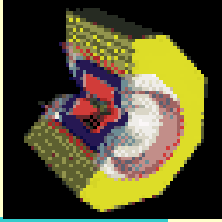
CESR/CLEO 1980-2001



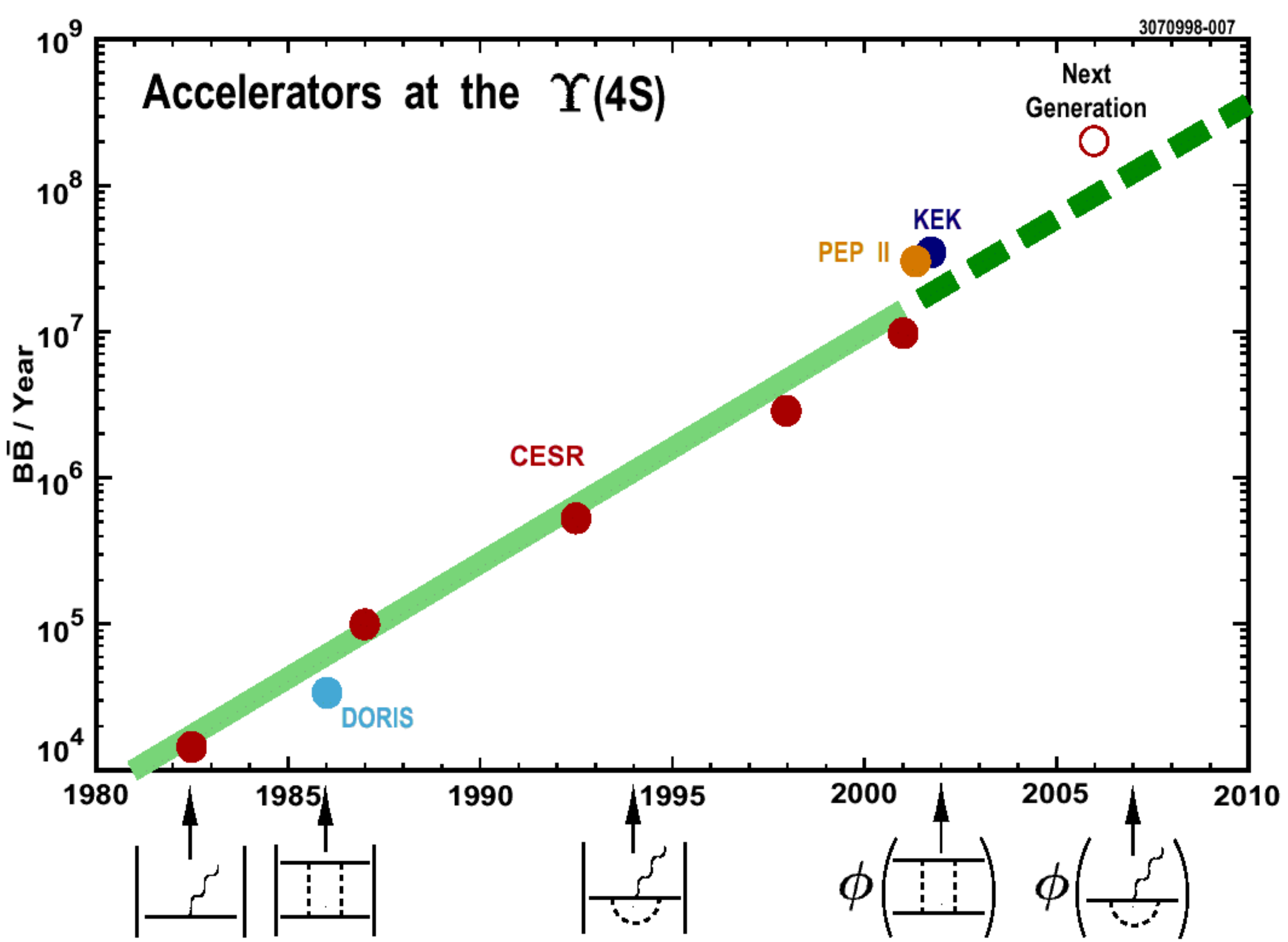
- Very(!) productive experimental program of exciting physics
- This summer :
  - V_{cb}, V_{ub}
  - $b \to s\gamma$
  - D^*width
  - $B \to \pi\pi, K\pi$
- But …



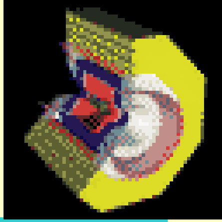
PEP-II/KEK-B 1999



- *B*-factories now do it much better!!

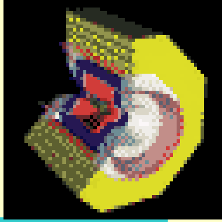


Whither CLEO?



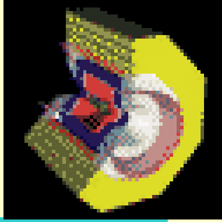
- Success of B-factories ⇒ CLEO III ceased taking data near the $\Upsilon(4S)$ last Tuesday, with ~7 fb^{-1} on the $\Upsilon(4S)$ & ~2 fb^{-1} just below.
- CLEO III results coming soon
- Install superconducting final focus quadrupoles this summer: higher *L*
- What's next?   **Thread #1**

A Short History of QCD



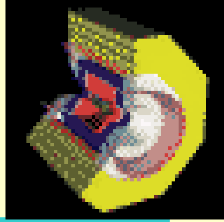
- **1960's: Beginning of modern era of SI**
  - **Quark model**
- **1970's: Gauge theory of SI: QCD**
  - **Like QED *except***
    - **Gluons carry charge -> nonlinear**
    - **Coupling is large**
- **Can't solve QCD analytically!**
  - **Asymptotic freedom saved the day**
    - **Perturbative QCD spectacularly successful**
    - **Nonperturbative regime problematic**
- **Lattice**
  - **Includes perturbative & nonperturbative**

Lattice QCD Revolution

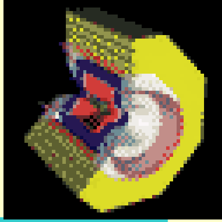


- Lattice QCD is the only complete definition of QCD: includes both perturbative & nonperturbative aspects.
- Lattice QCD is not a model.
  - Single formalism relates B/D physics to ψ/Υ physics to glueball physics to ...
  - Systematically improvable (beyond 10%)
  - Only parameters are α_s and the quark masses; no fudge factors!
- Lattice QCD has been transformed in the last decade, particularly since 1995.

Glue



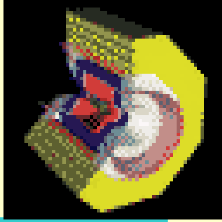
- **Glueball, Hybrid States**
  - **Fascinating states: only known theory in nature where gauge particle is also a constituent.**
- **Previous theoretical work frustrated by ambiguous &/or highly incomplete data.**
  - **Dramatic improvement in data needed**
- **Theorists are certain these states exist (extra states, beyond quark-model states). If they don't, will stimulate major effort in nonperturbative QCD.**



Future of Lattice QCD
(Cornell Workshop, Jan 2001)

- **1-3% accuracy possible now for:**
  - Masses, decay constants, semileptonic form factors, and mixing amplitudes for D, D_s, D*, D_s*, B, B_s, B*, B_s*, and corresponding baryons.
  - Masses, leptonic widths, electromagnetic form factors, and mixing amplitudes for any meson in ψ and Υ families below D and B threshold.
  - Masses, decay constants, electroweak form factors, charge radii, magnetic moments, and mixing angles for low-lying light-quark hadrons.
  - Gold-plated processes for *every off-diagonal* V_{ij}^{CKM}
- **Pace dictated by improved algorithms & theoretical physics. Not limited by CPU.**

Nonperturbative QFT

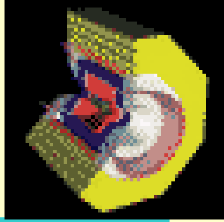


- **Nonperturbative, strongly-coupled field theory is an outstanding challenge to all theoretical physics**

  Thread # 2

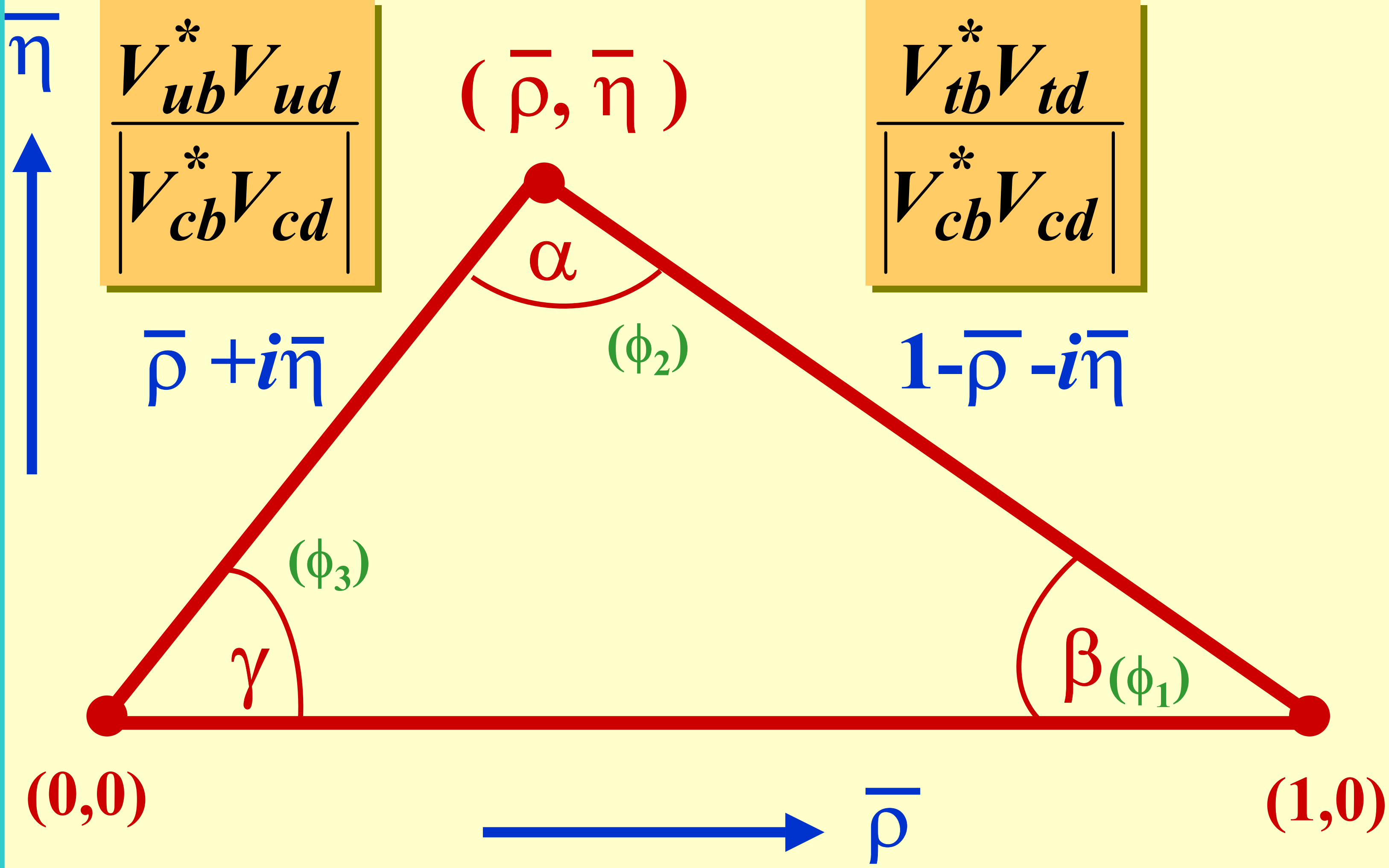
  - **Field theory is generic; weak-coupling is not**
- **QCD & gravity are strongly-coupled**
  - **Strong coupling at LHC & beyond: SUSY / Technicolor?**
- **Critical long-term need for:**
  - **Detailed experimental data on all sectors of QCD.**
  - **Reliable theoretical techniques for analyzing strongly-coupled theories.**

Flavor Physics



- **Standard Model Successes…**
  - **Impressive precision in EW sector: $W^{\pm}$, Z^{0} , $\tau^{\pm}$**
  - **Discovery of top quark**
  - **Tantalizing suggestion of Higgs observation**
- **Certainty of new physics – but where?**
- **B-physics, factories have come of age**
- **Imminent 2nd example of SM ~~CP~~ ?**
- **Precision in heavy quark physics?**

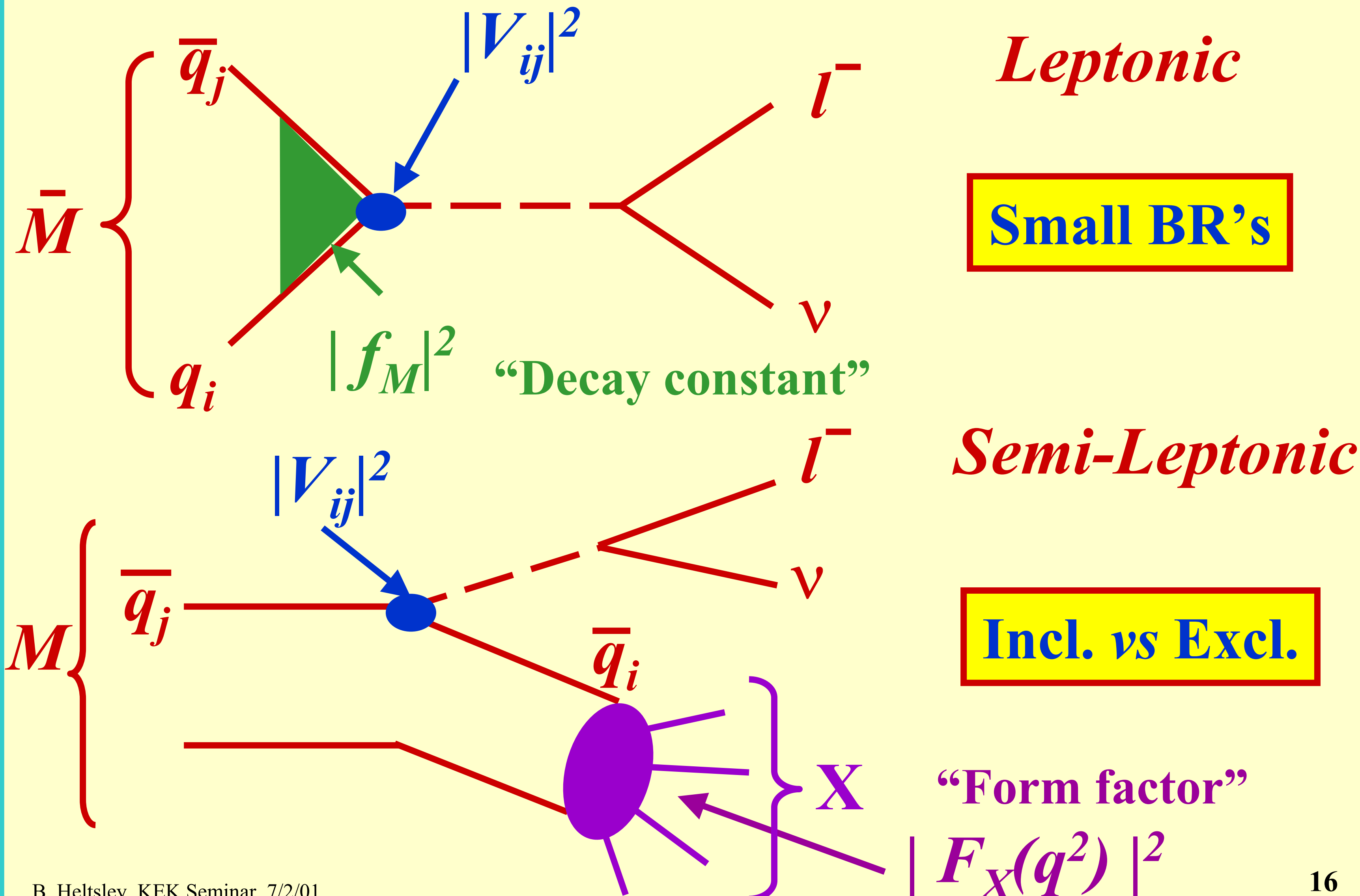
SM Unitarity Triangle



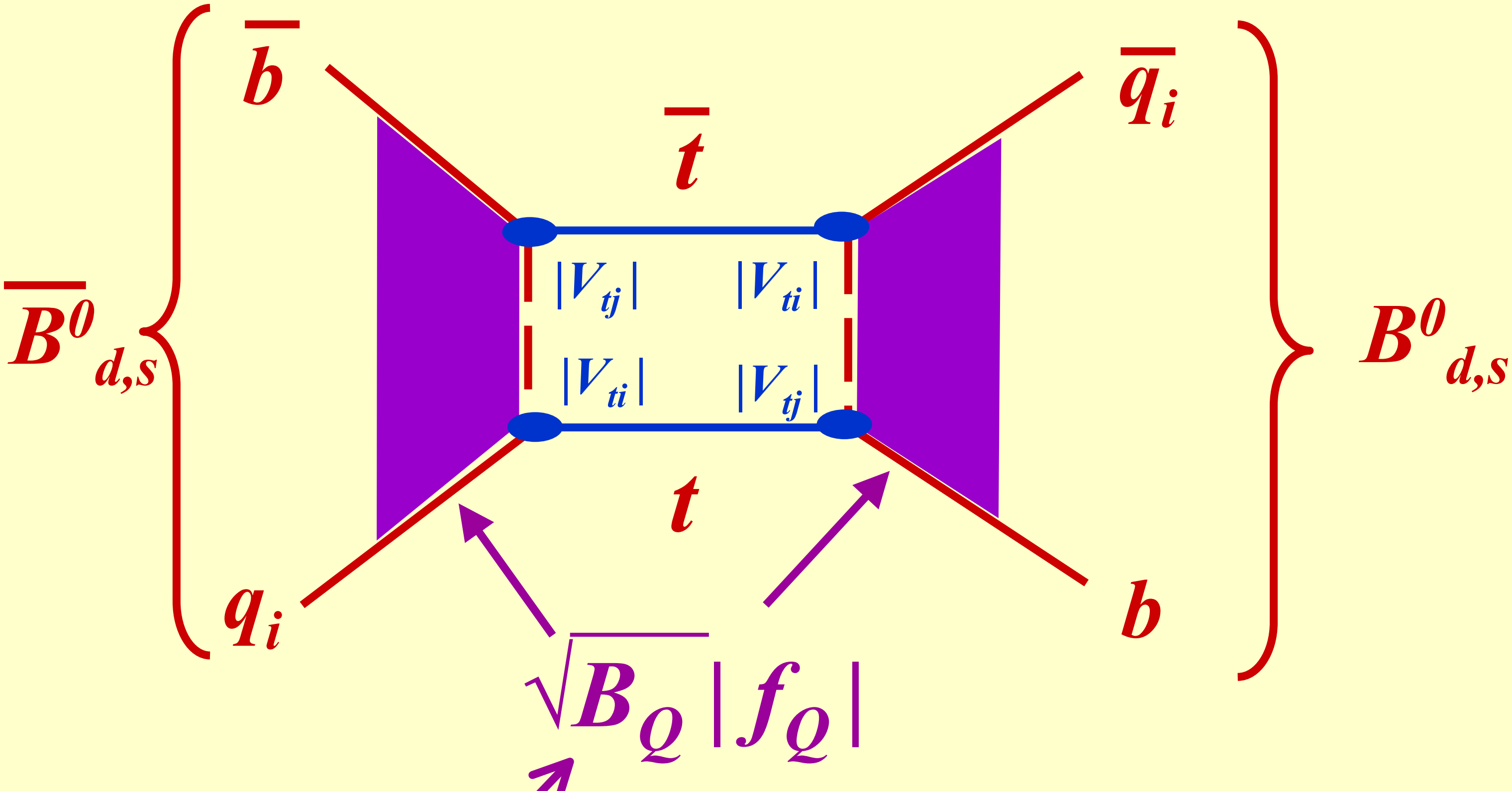
Just 4 parameters?!

- **Just four parameters: λ, A, $\bar{\rho}$, $\bar{\eta}$**
- **Measure them as <u>fundamental constants of nature</u> – "metrology"**
  - **Now, semi-leptonic decays & mixing provide best access**
- **With a rich diversity of quark decays, can <u>overconstrain</u> them – "global fit" to data**
- **Inconsistencies seen at any level means New Physics outside SM**
- **BUT, hadrons, not *q*'s, are detected**

CKM⇔QCD in (Semi)Leptonic Decay



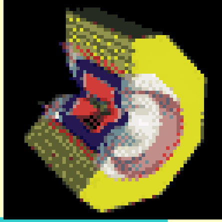
CKM ⇔ QCD in B_d, B_s Mixing



"Bag parameter"

$\Delta m_{d,s}$ sets oscillation rate

Experiment ⇔ Theory



CP-violating parameter from K decay:

$$\varepsilon_K = C_\varepsilon B_K \lambda^6 \ \ \bar{\eta}\,[C_1 A^2 \lambda^4 (1-\bar{\rho}) + C_2 + C_3] \Rightarrow \textit{hyperbola}$$

(b→u lν) /(b →c lν)

$$|V_{ub}/V_{cb}|^2 = \lambda^2(\rho^2+\eta^2) \Rightarrow \textit{circle}\ \ @\ (0,0)$$

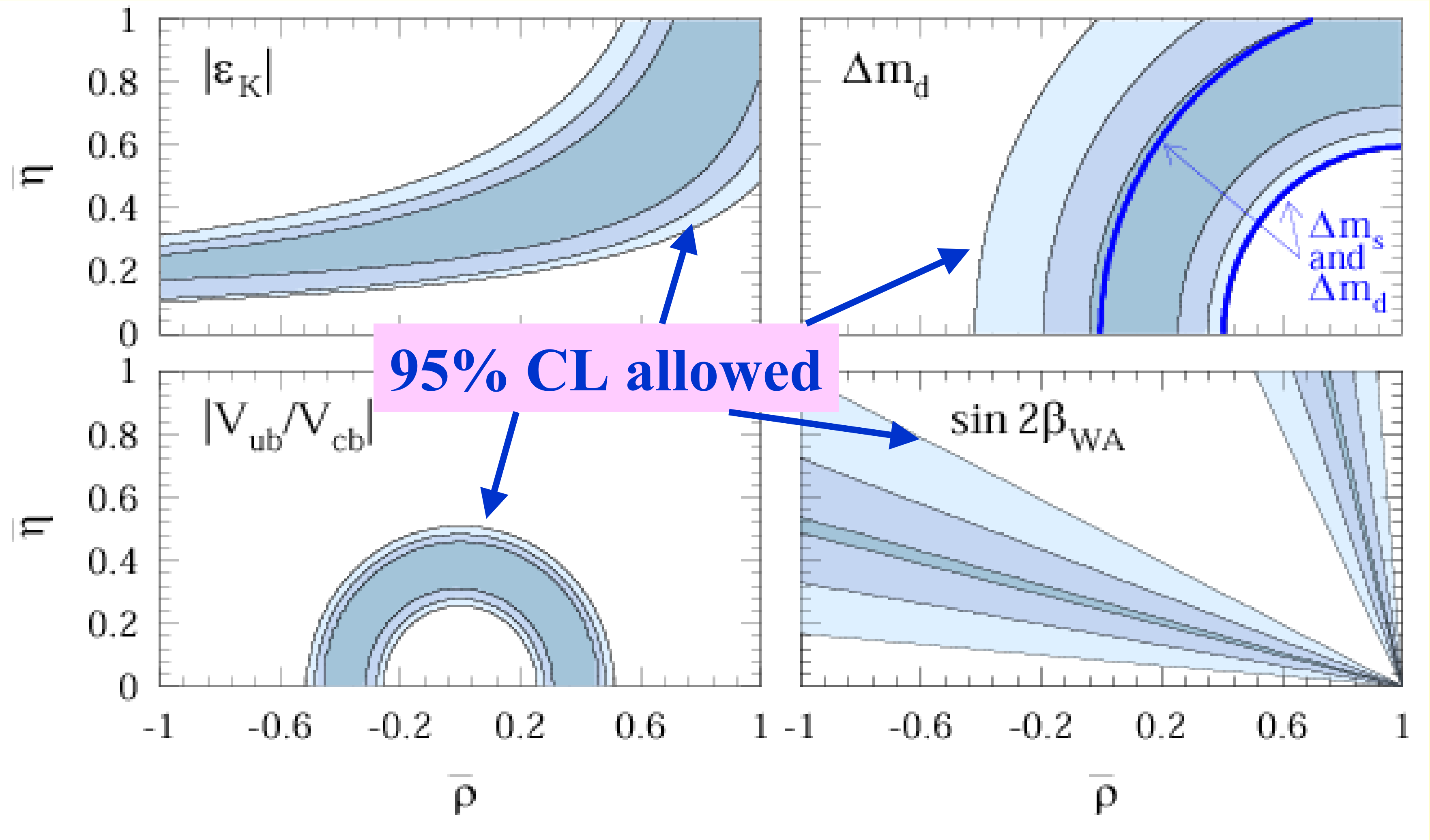
B_d-mixing frequency = mass difference

$$\Delta m_d = C_d B_d f_{B_d}^2 A^2 \lambda^6 [(1-\bar{\rho})^2 + \bar{\eta}^2] \Rightarrow \textit{circle}@(1,0)$$

B_s-mixing frequency: $\Delta m_s \propto B_s f_{B_s}^2 A^2 \lambda^4$

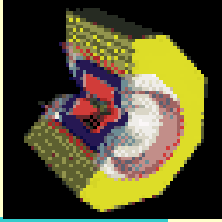
$$\frac{\Delta m_d}{\Delta m_s} = \frac{m_d}{m_s}\frac{\lambda^2}{\xi^2}[(1-\bar{\rho})^2 + \bar{\eta}^2)] \Rightarrow \textit{circle}\ @\ (1,0),\ \xi = \frac{f_{B_s}\sqrt{B_s}}{f_{B_d}\sqrt{B_d}}$$

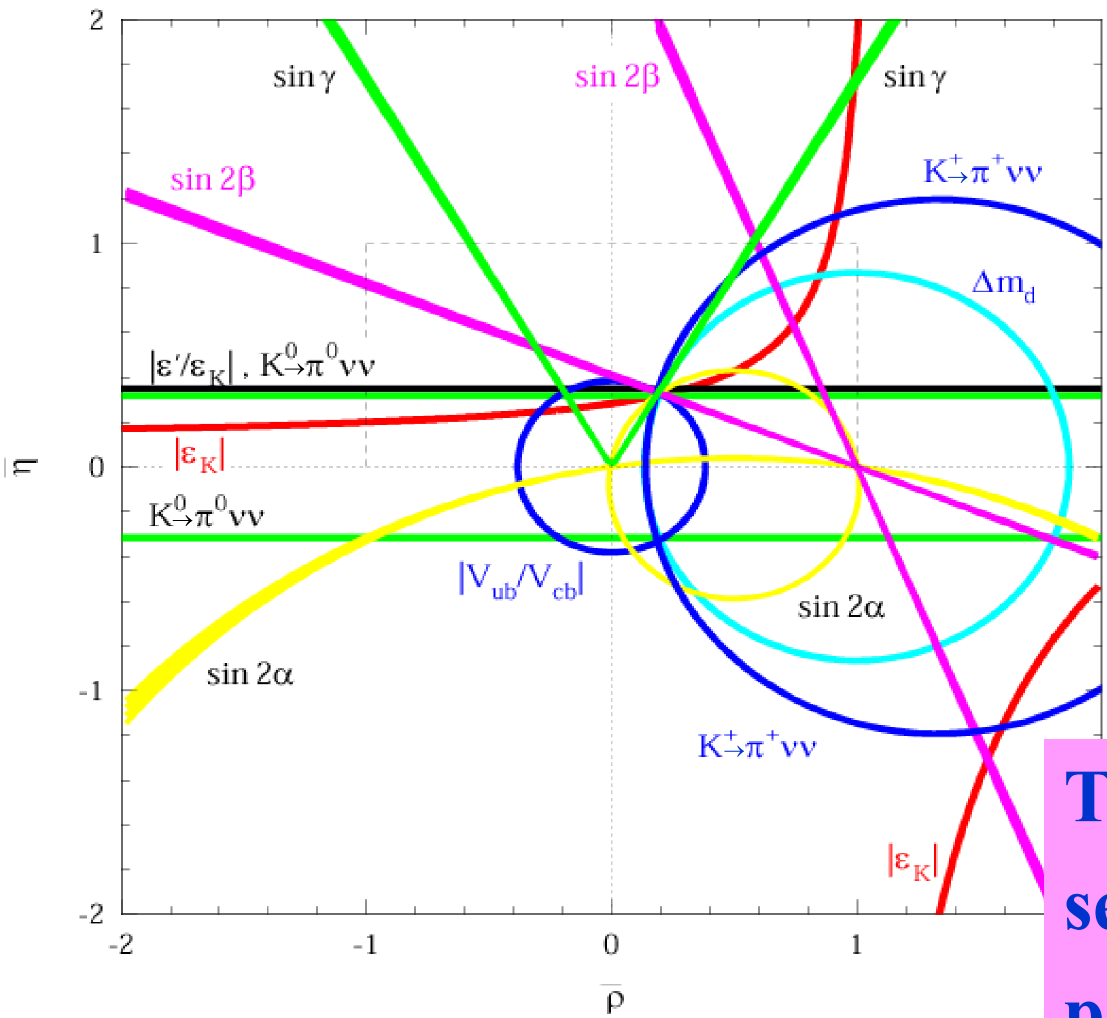
UT Constraints



From A. Hocker, et al. hep-ph/0104062

More UT Constraints





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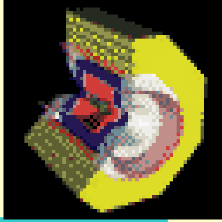
α, β, γ **constrained from 2-body hadronic *B*-decays (rare):**
B*→*ππ*, *Kπ*, *ρπ*, *DK* , *J/ΨK

Help from (rare) *K*→πνν after 2005

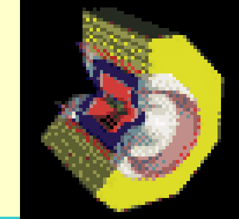
Today mixing & semi-leptonic decays provide best precision

~ | V_{ij} | (accuracy) [*=assumes Unitarity]

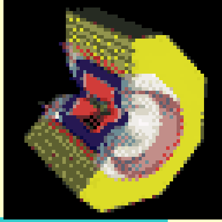


ud: β-decay 0.1% 0.9739 ± 0.0009	*us*: $K \to \pi e \nu$ 1.1% 0.2200±0.0025	*ub*: $b \to u l \nu$ & 17% $B \to \pi(\rho) l \nu$ 0.0035± 0.0006
cd: $\nu d \to l c \to l l X$ 6% 0.224 ± 0.014	*cs*: $D \to K e \nu$, 6% $W \to X_c X$ 0.97 ± 0.06	*cb*: $b \to c l \nu$, 7% $B \to D l \nu$ 0.041 ± 0.003
td: B_d mixing 19% $D_s \to \mu \nu$ 0.0083 ± 0.0016	*ts*: B_s mixing 25%* 0.04 ± 0.01 *	*tb*: $t \to b l \nu$ 15%* 0.99 ± 0.15 *

Global fits: Simmering tempest



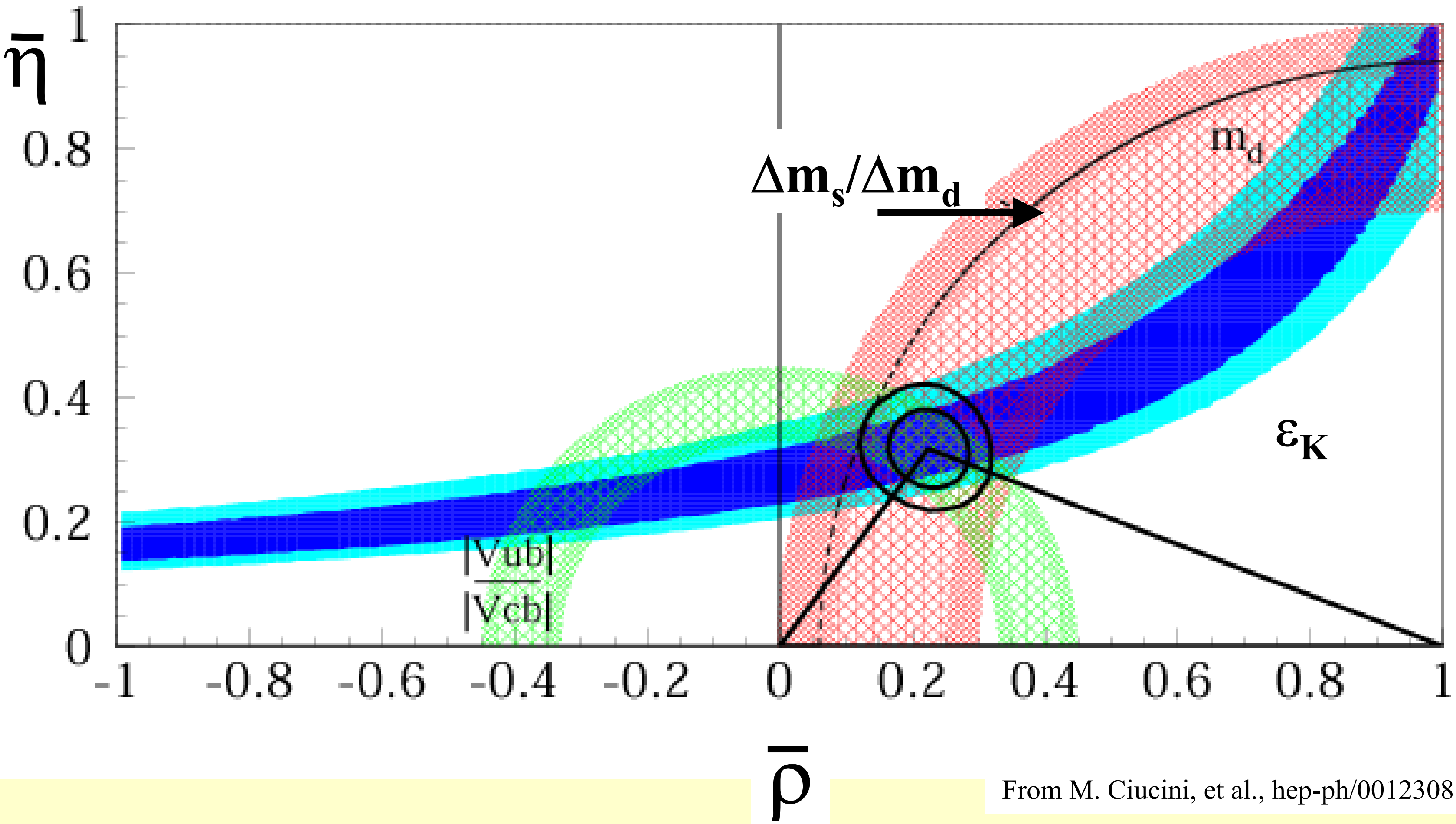
- **Conservative Frequentists**
  - A. Hocker, et al., hep-ph/0104062 (BaBar)
  - S. Stone, hep-ph/0012162 (Beauty 2000)
  - A. Falk, hep-ph/9908520, Aug. 1999 (LepPho 1999)
  - J. Rosner, hep-ph/0011184, Aug. 1999 (Beauty 2000)
- **Optimistic Bayesians:**
  - A. Stocchi, hep-ph/0010222 (ICHEP 2000), NIM A462 (2001) 318 (Beauty 2000).
  - F. Parodi (CPV 2000)
  - M. Ciuchini, et al., hep-ph/0012308 (Moriond 2001)
- **Issue: How to treat theoretical QCD predictions (TP's) & associated uncertainties in a global CKM fit?**



Standard vs 95% CL Scanning

- **Standard method advocates similar treatment of uncertainties for data and TP's with Gaussian (or even flat) PDF's (Bayesian)**
  - **LQCD is mature enough to trust results**
  - **Know the sign & rough magnitude of corrections**
  - **Can assign reasonable σ's: don't throw away information!**
- **95% CL Method advocates cautious approach to TP's by restricting them to a "95% CL interval", with no preferred central value $\Rightarrow V_{ij}$: contours or intervals with no preferred ctrs (Frequentist)**
  - **Even combining flat PDF's is treacherous!**
  - **In multi-dimensional problems Bayesian treatment unfairly predicts a narrowing of possible results, not a broadening**

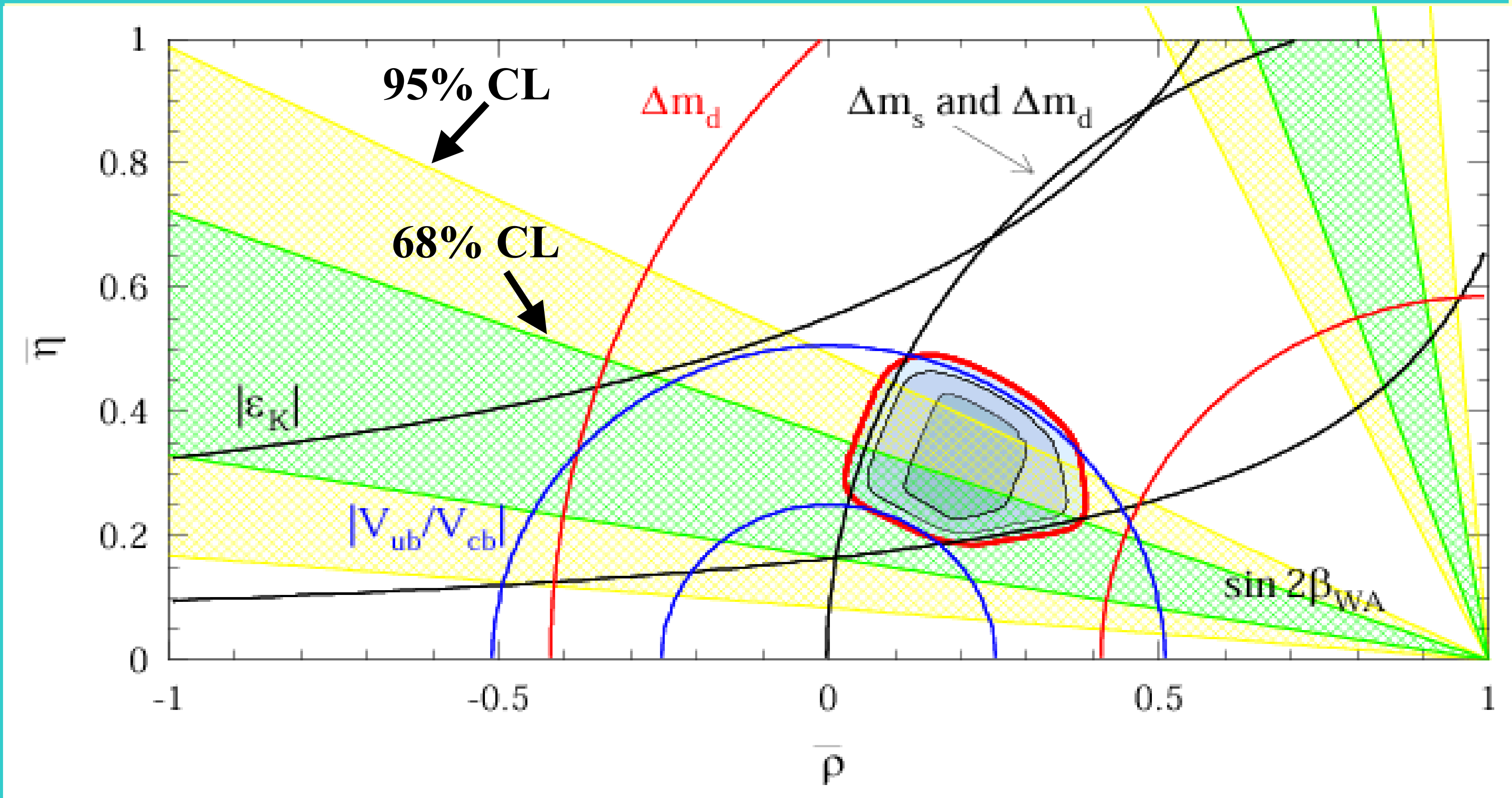
Standard Method Global Fit



From M. Ciucini, et al., hep-ph/0012308

No sin2β constraint

"95% Scanning" Global Fit



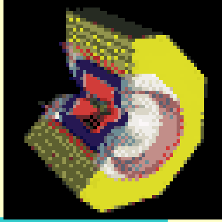
From A. Hocker, et al. hep-ph/0104062

No $\sin 2\beta$ constraint

Global Fitting Conclusions

- No consensus on QCD uncertainties
  - Not likely to converge without data to pin it down
- No consensus on Bayesian/Frequentist
  - Merits & difficulties on both sides
- Different methods will give much different answers as soon as the data are more precise (i.e. in a few weeks)
  - Different answers may have very different implications on whether the SM is found lacking
- Expect continuing spirited discussion

What's next?

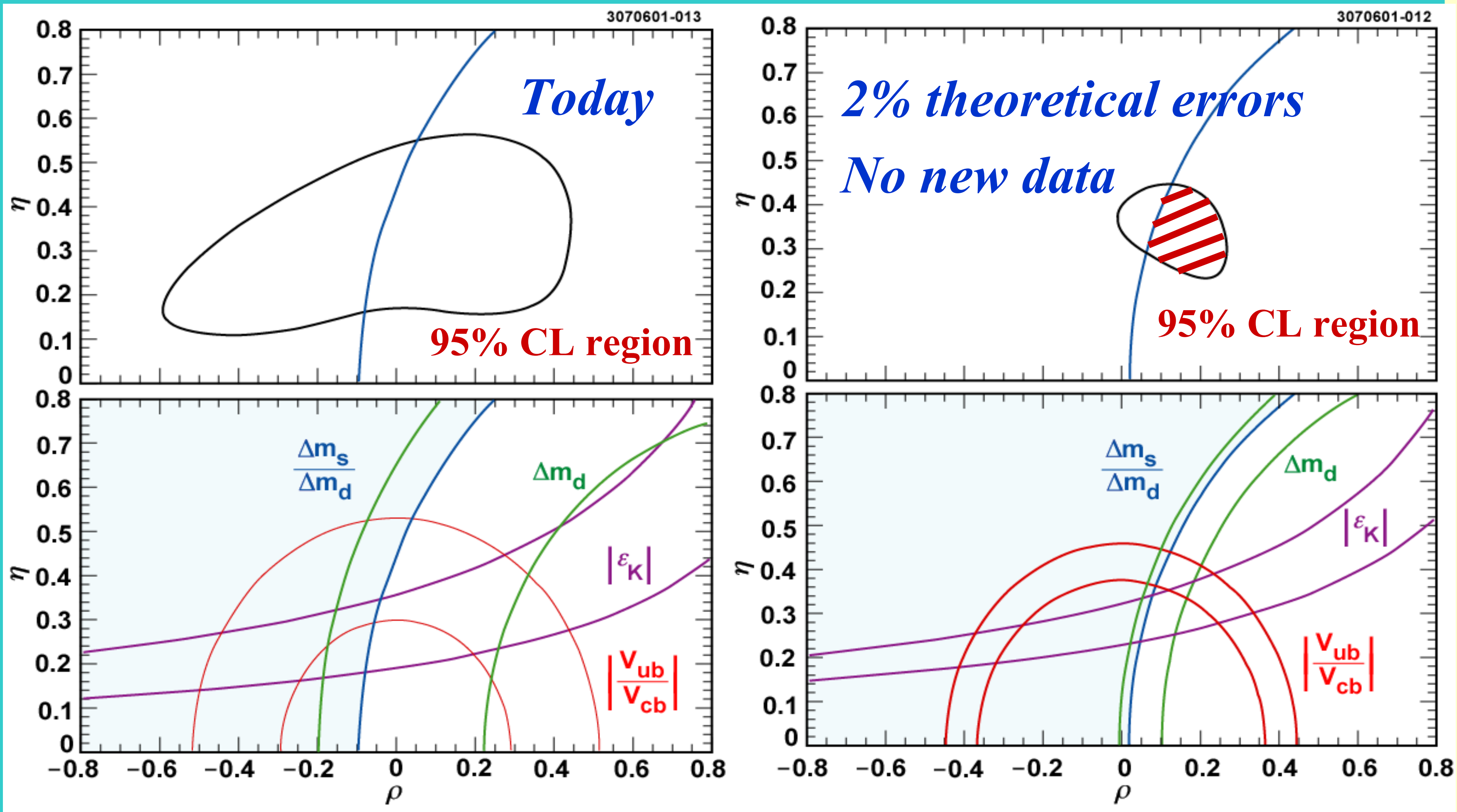


- B-factories in 5 years: ~0.5 ab^{-1}

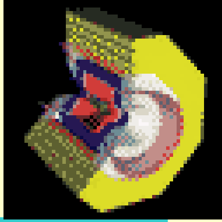
  $\Rightarrow$ ~1/10 statistical σ's
  - *D* BR's become limiting to *B*-decay precision
  - Charm physics could become less precise than *b*-physics: need better V_{cd} & V_{cs}
- Theoretical uncertainties dominate even now

  Thread # 3
  - But Lattice QCD & models promise big improvements

Just imagine …

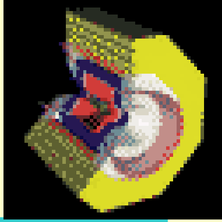


The Role of CLEO-c



- **Modify CESR for E_{cm}=3-11 GeV: L=2-4×10^{32}**
- **High precision charm data**
  - **Measure *D* BR's for input to *B*-decay studies**
  - **Establish successful precision testing ground of QCD for *D*'s to give credibility to those for *B*'s**
- **High precision quarkonia spectroscopy & decay data at ψ & Υ resonances**
  - **Provide much needed experimental basis for non-perturbative QCD tests. Glueballs/Hybrids?**
- **Searches for non-SM phenomena in *D*-mixing, CPV in *D* decay, & rare decays**

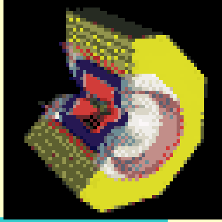
The CESR-c Accelerator



- **Since $L \sim E_b^4$ without artificial radiation: wigglers for transverse cooling: $L \sim E_b$**
  - **2T peak field with 40 cm period**
  - **~16 superconducting, 1.3m modules inserted: $5M**
  - **$\Delta E_{beam} \approx 1.2$ MeV @ J/ψ**

$\sqrt{s}$	L (10^{32} cm^{-2} s^{-1})
4.1 GeV	3.6
3.77 GeV	3.0
3.1 GeV	2.0

A CLEO-c Program



2002

- $\Upsilon(1S)$, $\Upsilon(2S)$, $\Upsilon(3S)$ ~1-2 fb^{-1} each
  - **Spectroscopy, Matrix elements, Γ_{ee}:(>10×world)**

2003

- $\psi(3770)$ -- 3 fb^{-1}, 30M events
  - **6M *tagged* D decays (310 × Mark III)**

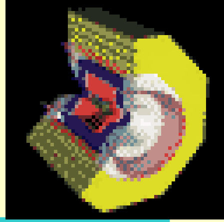
2004

- **$\psi(4100)$ -- 3 fb^{-1}, 1.5M** $D_s\overline{D}_s$
  - **0.3M *tagged* D_s decays (480×Mark III, 130×BESII)**

2005

- $\psi(3100)$ -- 1 fb^{-1}, 10^9 J/ ψ decays
  - **(170 × Mark III, 20 times BES II)**

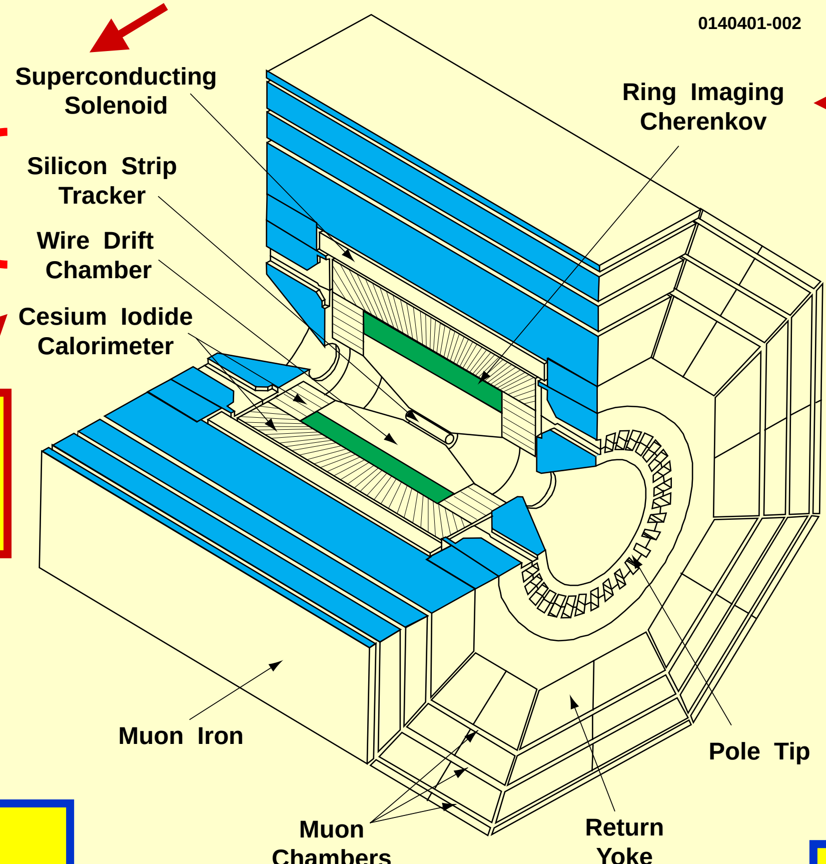
The CLEO III Detector



1.5 T now,... 1.0T later

93% of 4π
σ_p/p = 0.35% @1GeV
dE/dx: 5.7% π @minI

93% of 4π
σ_E/E = 2% @1GeV
= 4% @100MeV



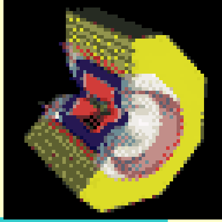
83% of 4π
87% Kaon ID
with
0.2% π fake
@0.9GeV

Data Acquisition:
Event size = 25kB
Thru-put < 6MB/s

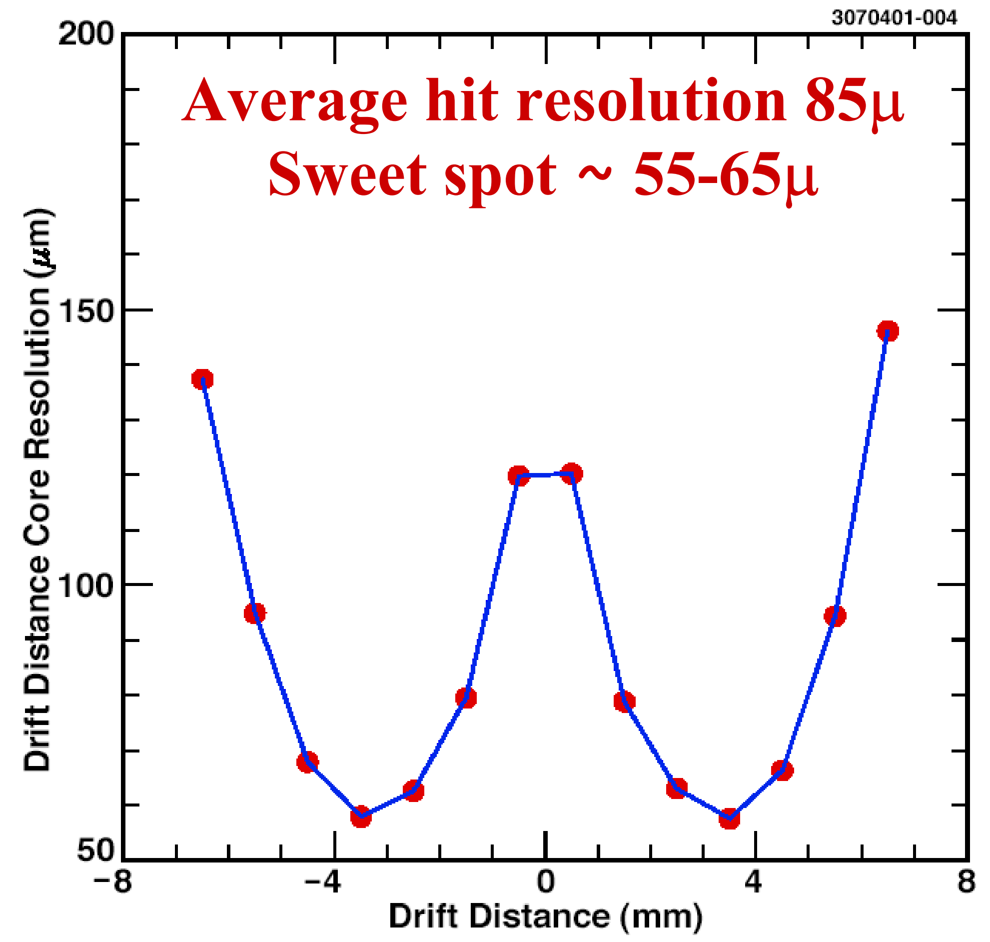
85% of 4π
For p>1 GeV

Trigger: Tracks & Showers
Pipelined
Latency = 2.5μs

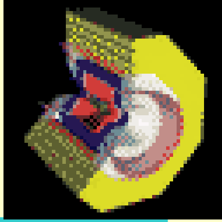
CLEO III/c Drift Chamber



- **$D \rightarrow K\pi$: σ_M=5.5 MeV**
- **$K_S \rightarrow \pi\pi$: σ_M=3.1 MeV**
- **σ_p/p=0.35% @ 1 GeV**
- **dE/dx: 5.7% π@minI**

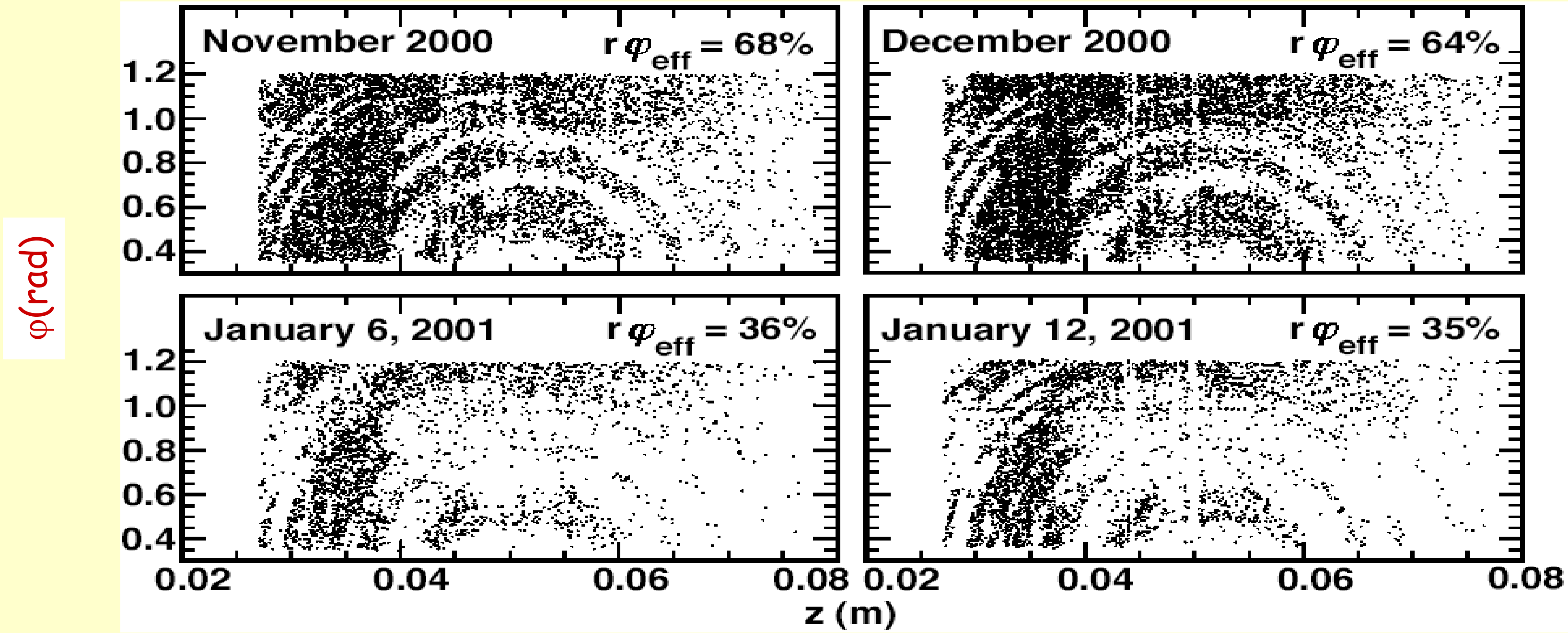


CLEO III Silicon

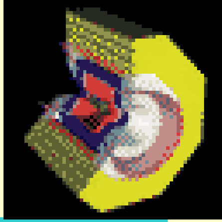


- **Silicon efficiencies continue to drop**
  - **Layer 1 rφ view: >85% to 9% in <1 yr**
  - **Other layers following**

Single wafer efficiency **(black = good)**

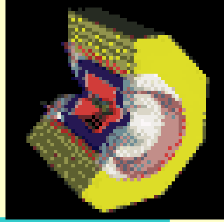


Inner Tracking ($2<r<12$cm)

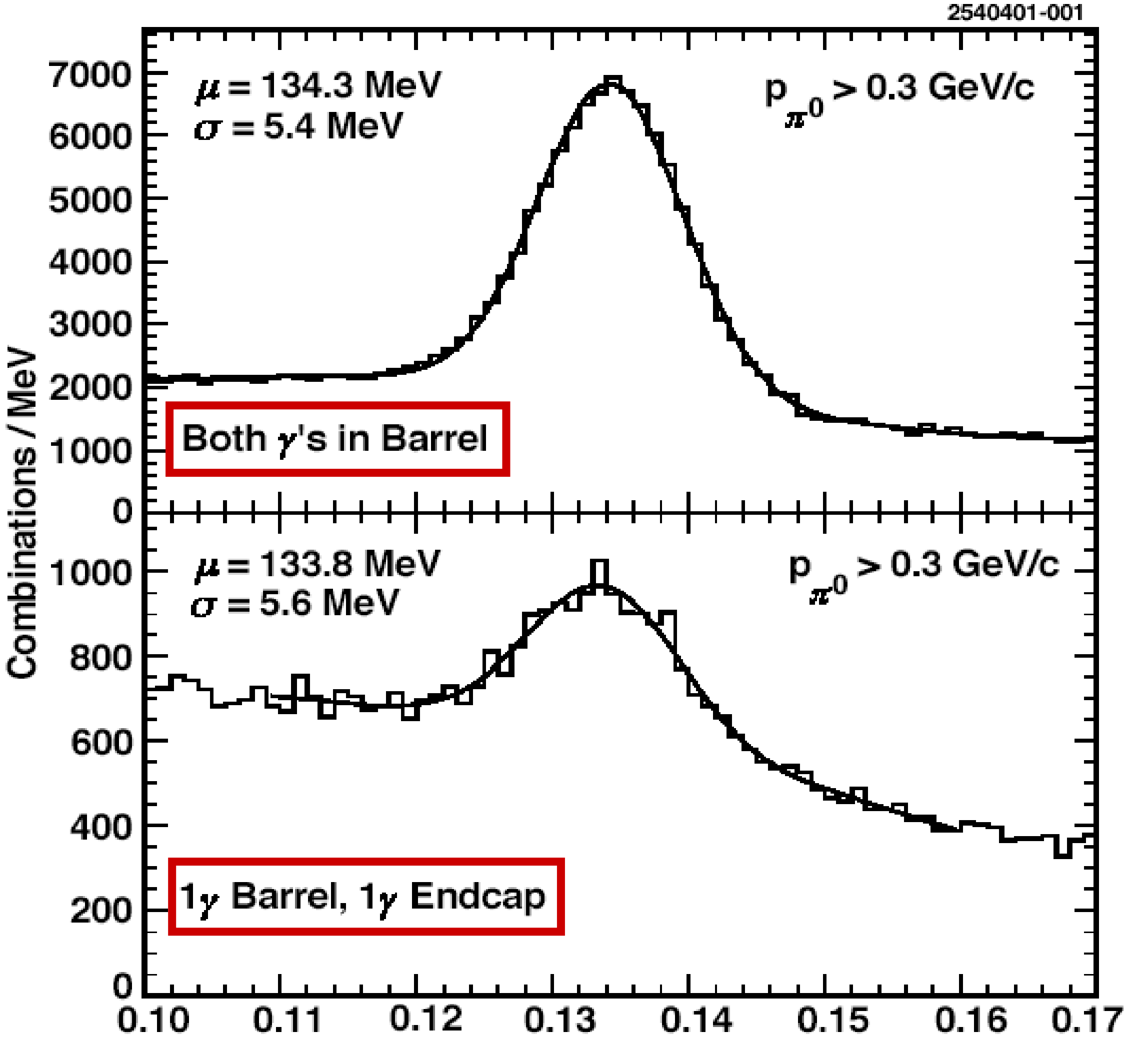


- **Now: 4-lyr, 2-sided Si, 125K ch, 1.6% X_0**
  - **Early radiation damage: Lyr 1+2 r-phi $\varepsilon \rightarrow 0$**
- **Proposed: 6-lyr all-stereo (10-15^o) drift chamber**
  - **1.1% X_o inner wall + 0.1% X_o gas: improves σ_p/p**
  - **Preserves mass resolution despite larger σ_Z**
  - **Smaller event size**
  - **Build from spare parts – install late 2002**

CLEO III CsI Calorimeter

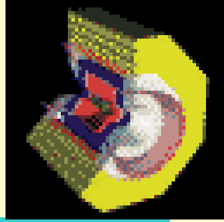


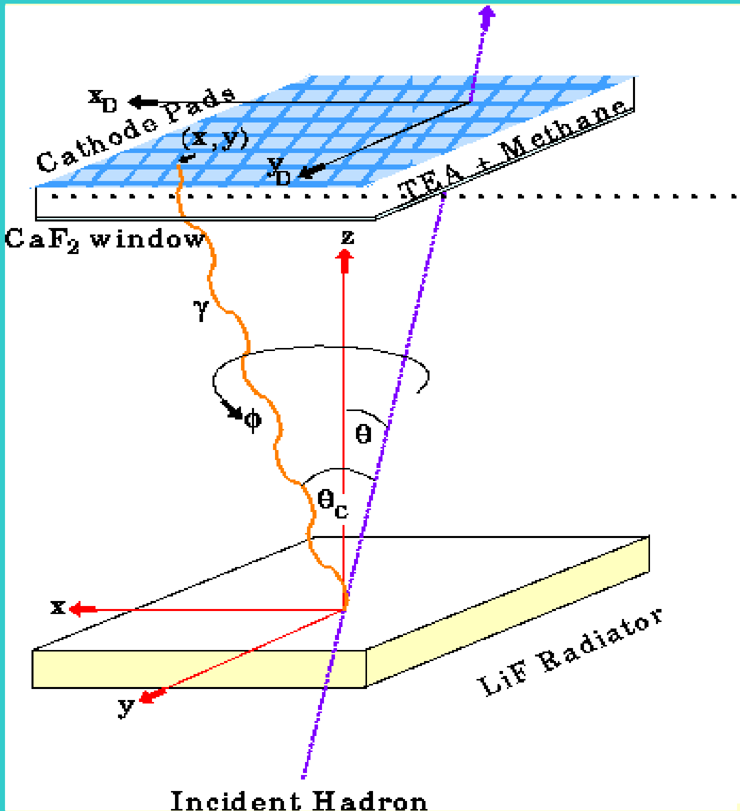
- 93% solid angle
- good resolution in both barrel & endcaps
- σ_E/E = 4% at 100 MeV
- σ_E/E = 2% at 1 GeV
- $\sigma_{M(\gamma\gamma)} \sim$ 5.5 MeV π^0 mass resolution

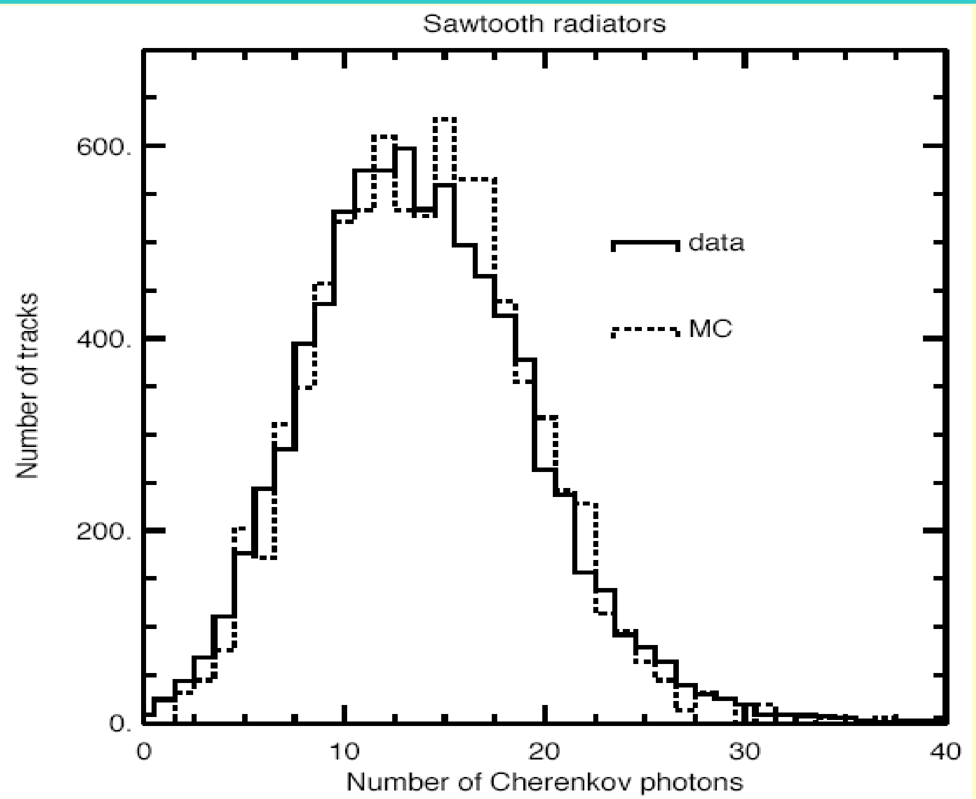


$M_{\gamma\gamma}$ (GeV)

RICH Particle Id

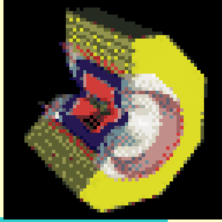






$\langle n_\gamma \rangle$ ~ 11-12
Cherenkov angle Resolution (mrad):
12.2 (sawtooth LiF)
14.7 (flat LiF)

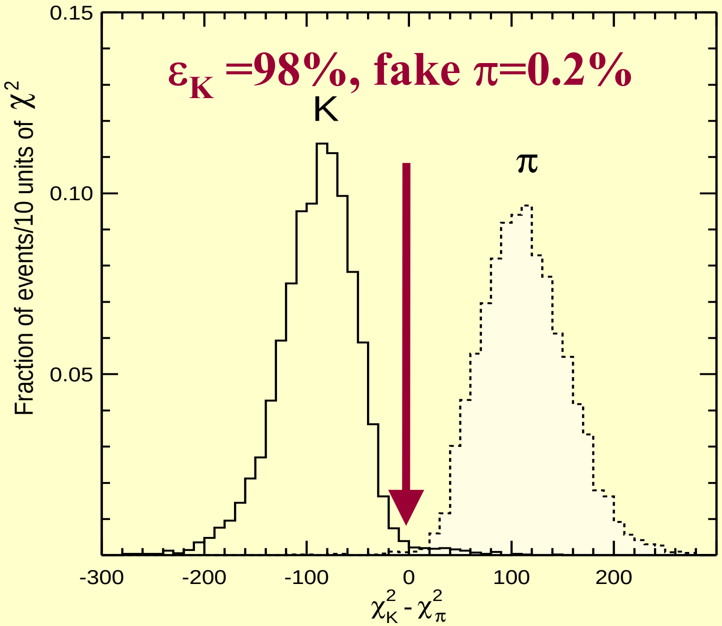
CLEO III Particle ID - RICH

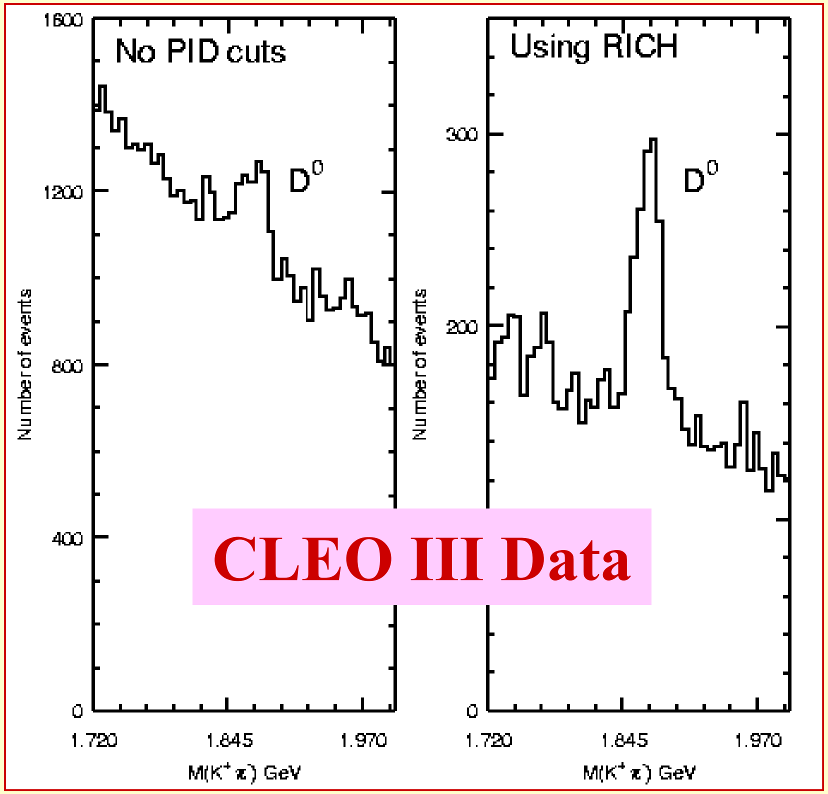


- $\langle n_\gamma \rangle = 12$
- 10-200σ K-π separation for p>0.5 GeV

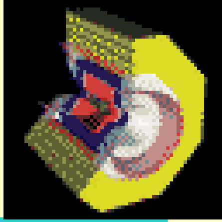
CLEO III Full GEANT

$e^+e^- \to \psi'' \to D^o\overline{D^o}$, $D^o \to K^-\pi^+$





Trigger & DAQ



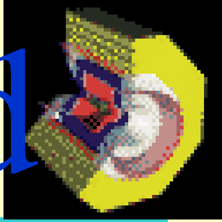
Trigger

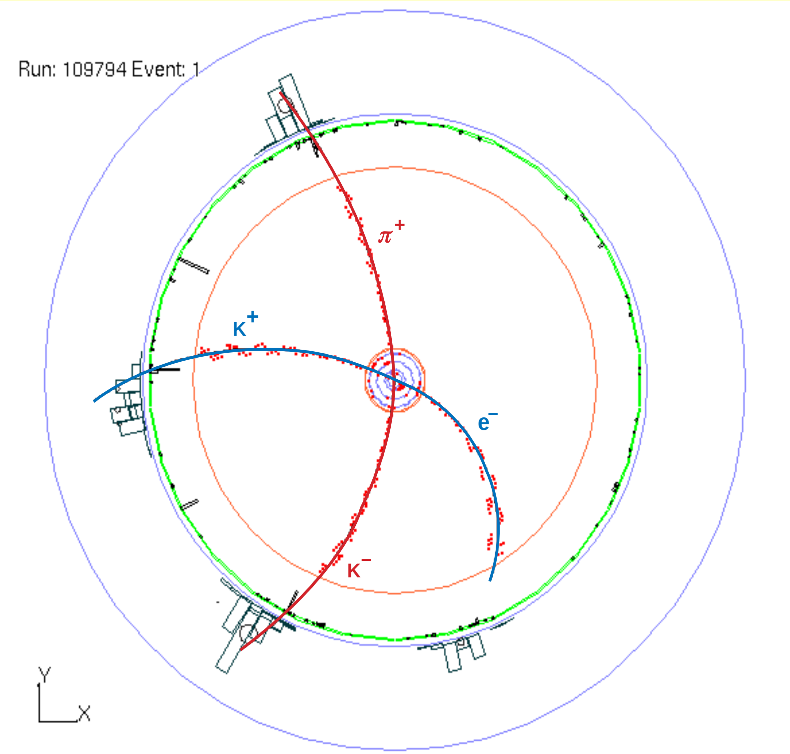
- Flexible & programmable
- Now: 100 Hz
- Loose trigger pre-scaling for ε studies

Data Acquisition

- Designed for 1000 Hz for CLEO III / ϒ(4S)
- CLEO-c: no problems handling increase rate
  - Smaller event size
  - Lower backgrounds
  - Rate at J/ψ < 250 Hz
  - Bhabha rate < 120 Hz before pre-scaling

Tagging at Threshold



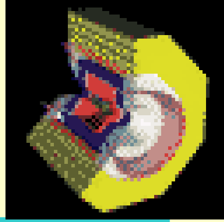


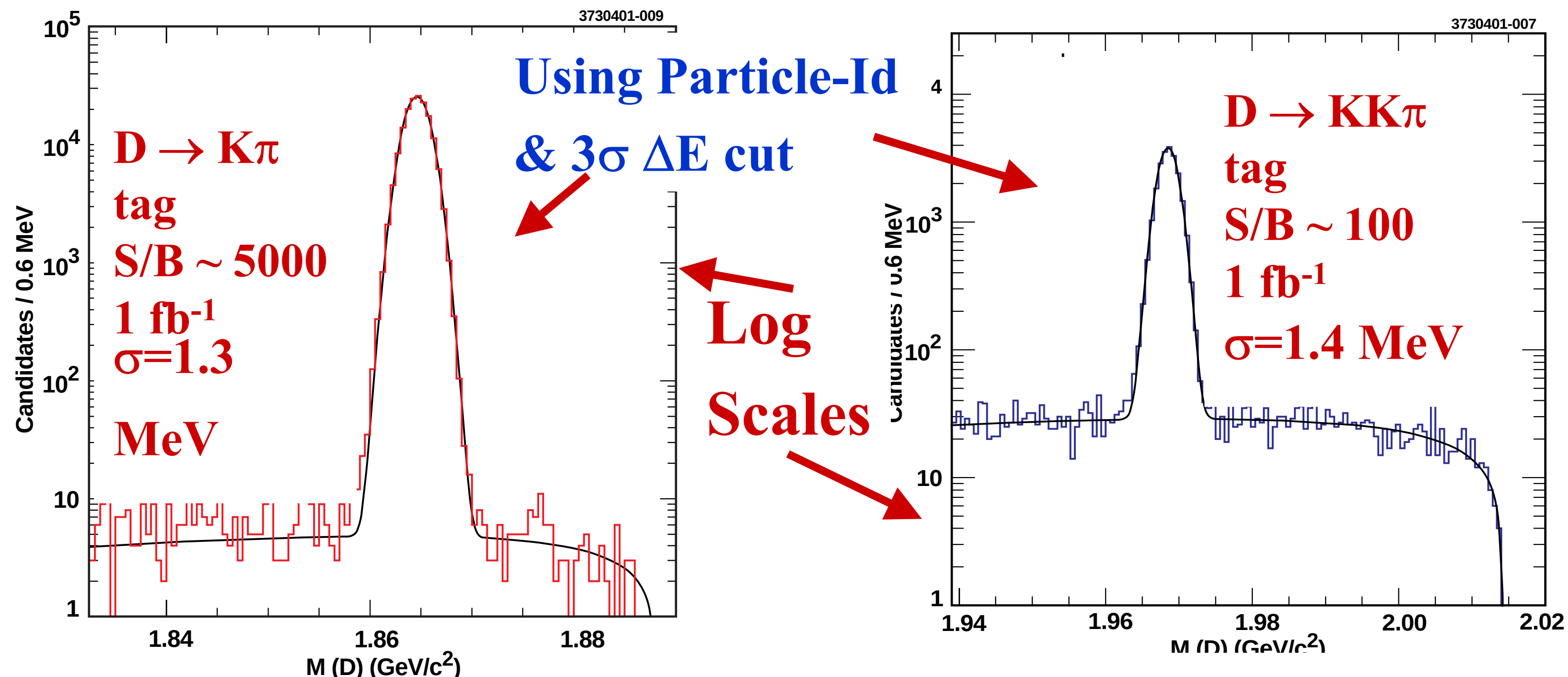
$D^0 \rightarrow K^- \pi^+$ $\bar{D}^0 \rightarrow K^+ e^- \nu$

CLEO-c MC

- **Large σ**
- **Low multiplicity**
- **Pure $D\bar{D}$ init. State**
- **High recon. eff's ~ 20%**
- **6×10^6 D tags**
- **0.3×10^6 D_s tags**
- **Almost no bgd**
- **Clean ν-reconst.**
- **Coherent init state**

Tagged Branching Ratios



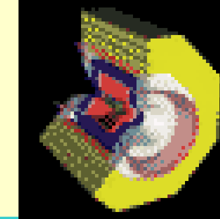


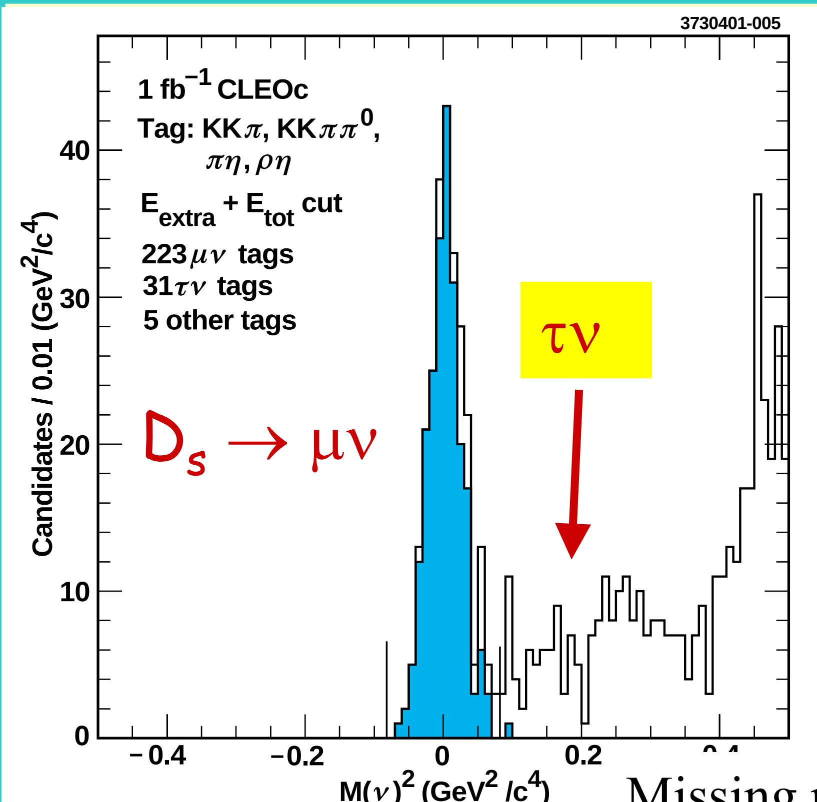
Beam-energy constrained mass

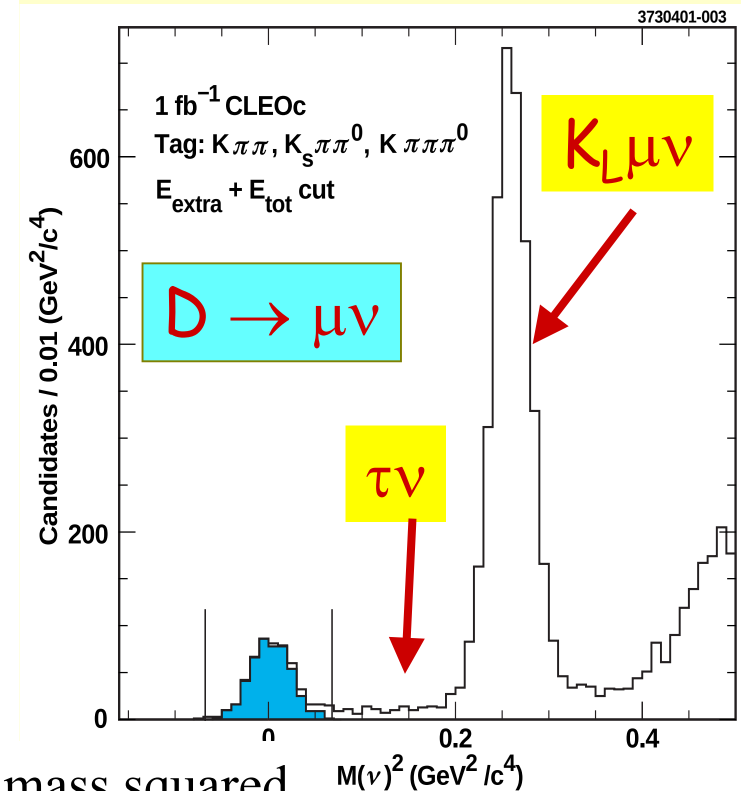
Set absolute BR's for $B \to$ "D"

Decay Mode	PDG2000 ($\delta B/B$ %)	CLEOc ($\delta B/B$ %)
$D^0 \to K\pi$	2.4	0.5
$D^+ \to K\pi\pi$	7.2	1.5
$D_s \to \phi\pi$	25	1.9

Leptonic Decays





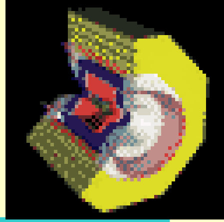


Missing mass squared

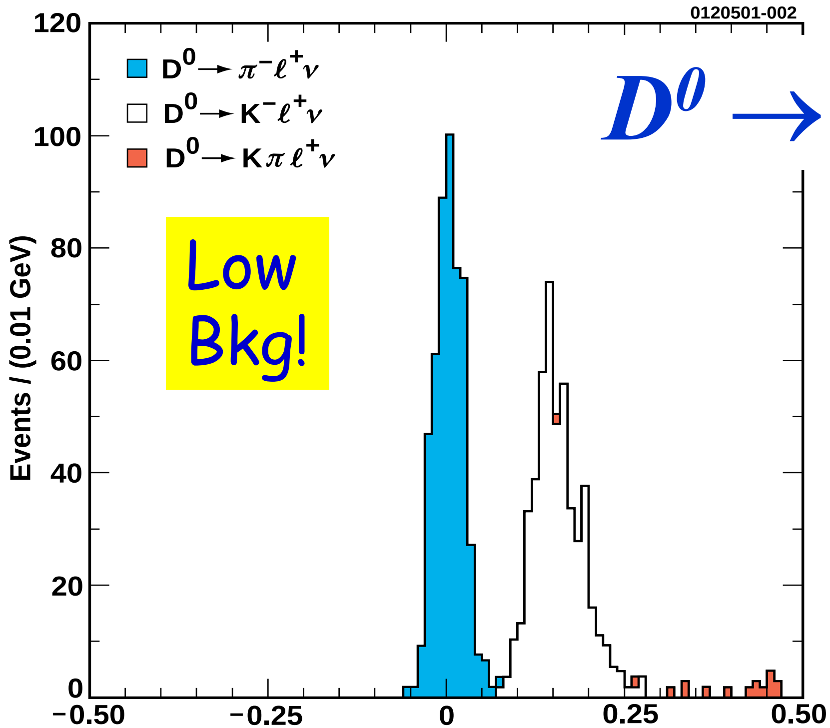
$$\frac{\delta f_{D_s}}{f_{D_s}} \approx 2.1\%$$ (Now: ±35%)

$$\frac{\delta f_D}{f_D} \approx 2.6\%$$ (Now: ±100%)

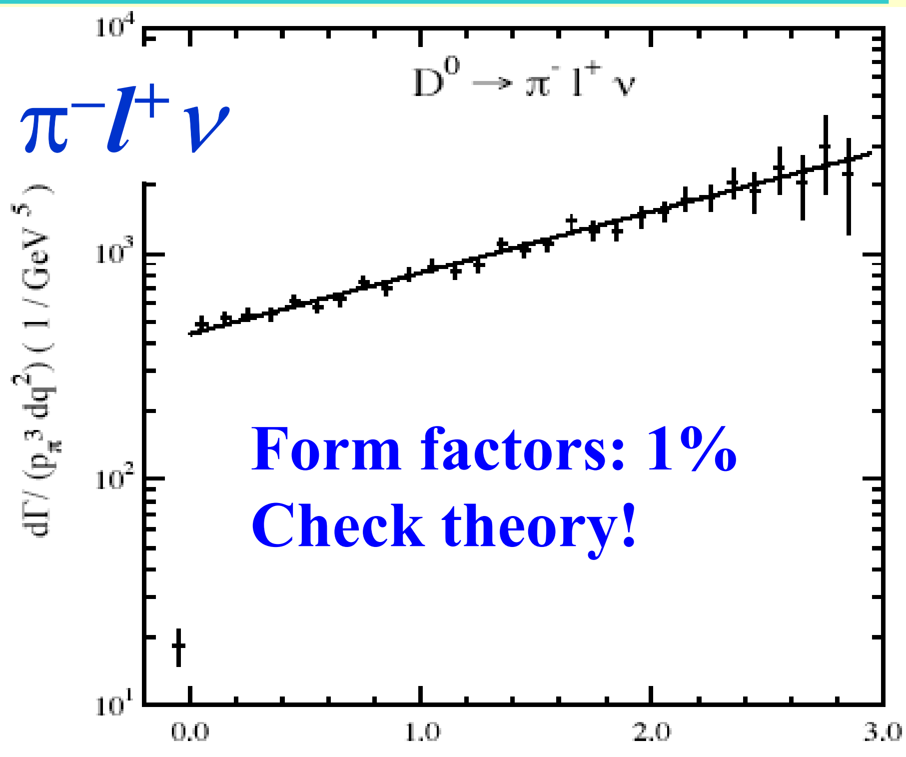
Semi-leptonic Decays



$D^0 \to \pi^- l^+ \nu$

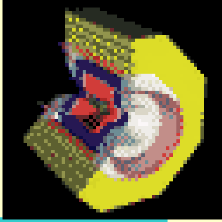


$U = E_{miss} - P_{miss}$



q^2 (GeV^2)

Semi-leptonic (cont'd)



Decay Mode	PDG2000 (δB/B %)	CLEOc (δB/B %)
$D^0 \to K l \nu$	5	1.6
$D^0 \to \pi l \nu$	16	1.7
$D^+ \to \pi l \nu$	48	1.8
$D_s \to \phi l \nu$	25	2.8

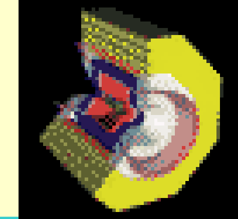
Plus vector modes...

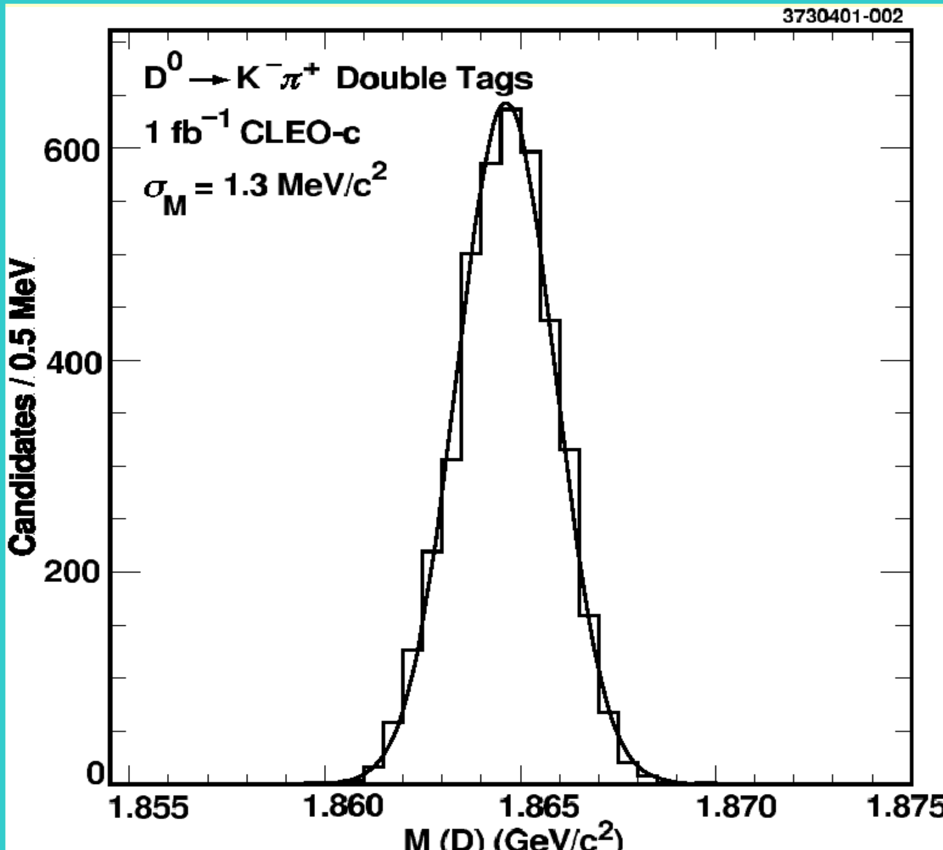
Systematics limited

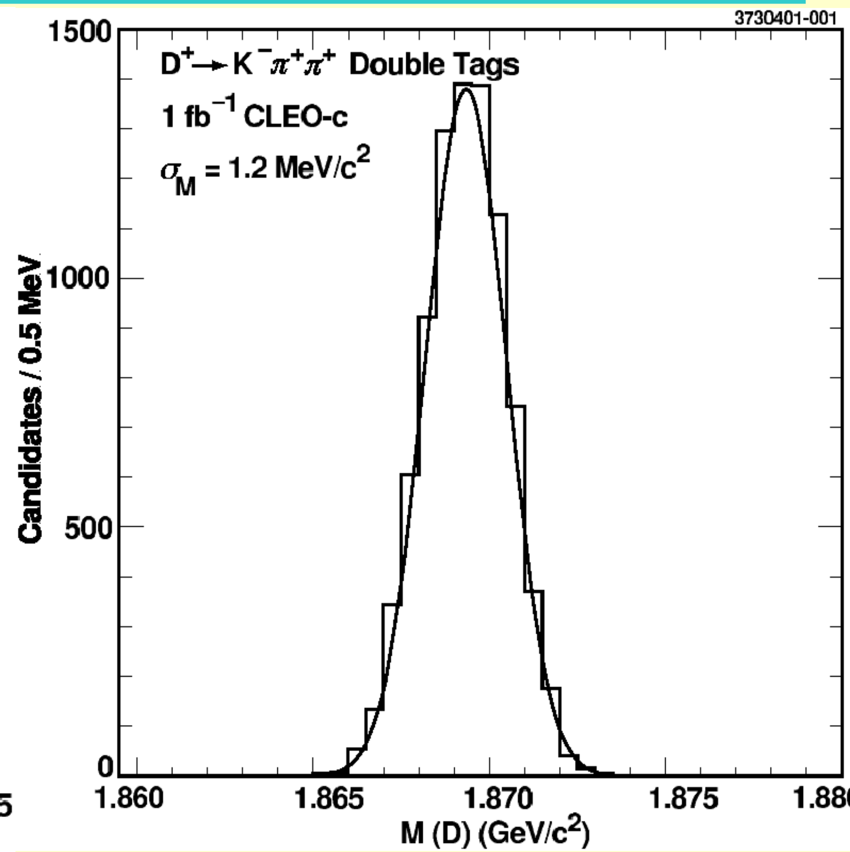
V_{cd}, V_{cs} to ~1.5%, ratio to <1%

Cancelling systematics

Double Tags



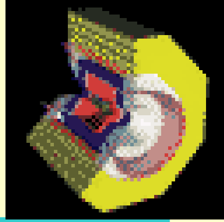


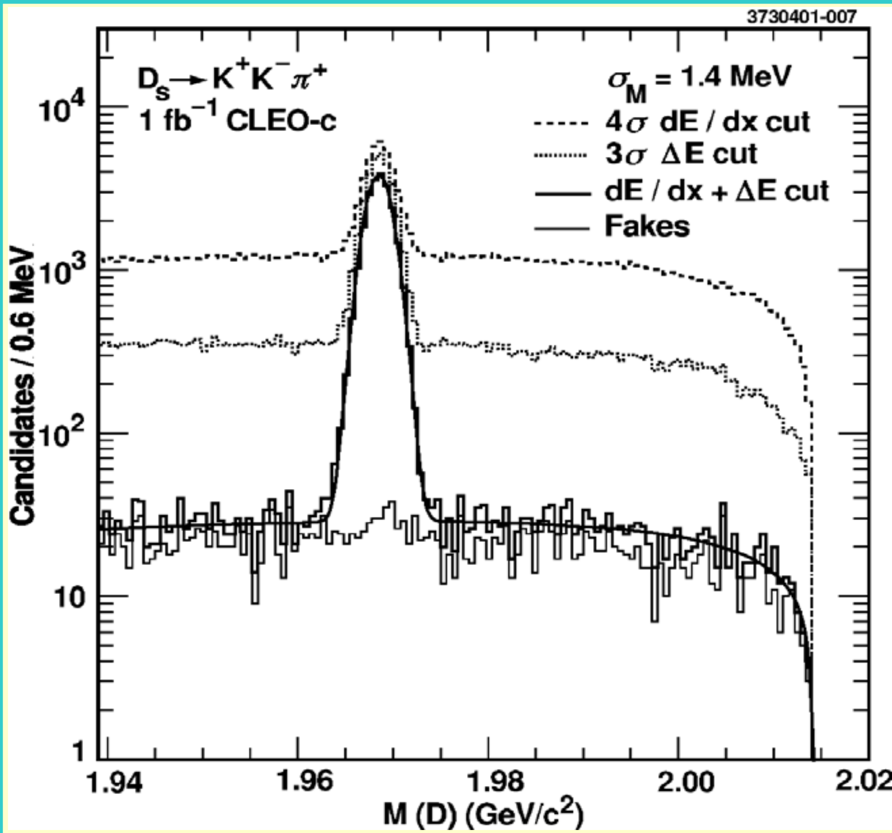


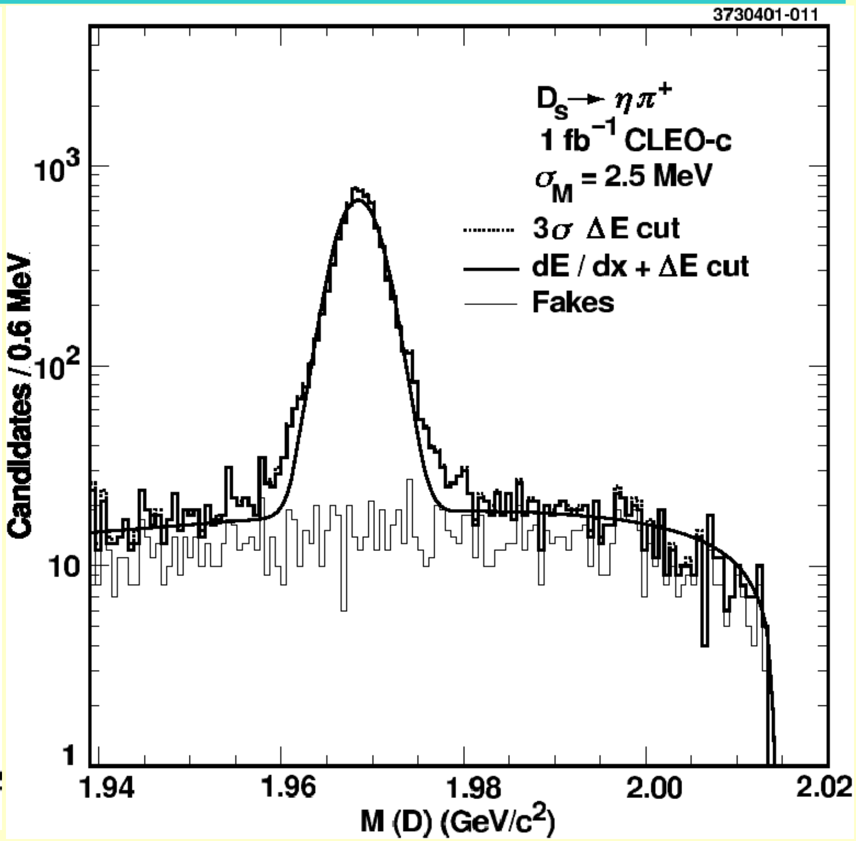
$D^+ \to K^-\pi^+\pi^+$

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

Clean D_s Tagging as Well



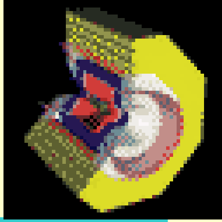




$D_s \to \eta\pi^+$

$D_s \to K^+K^-\pi^+$

Absolute Branching Fractions

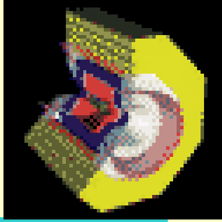


- **Use double tags**
  - $D \to X_l,\ D_{tag} \to X_m$
    - $N_{DT} = 2N_\psi B_l B_m \varepsilon_{lm}$
    - $N_{ST} = 2N_\psi B_m \varepsilon_m$

$$B_l = \frac{N_{DT}}{\varepsilon_{lm}} \Big/ \frac{N_{ST}}{\varepsilon_m} \approx \frac{N_{DT}}{N_{ST}} \frac{1}{\varepsilon_l}$$

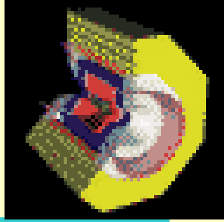
- **Measure absolute D^0, D^+ scale to ~1%**
- **Measure absolute D_s scale to ~1-2%**

What do we learn from these?

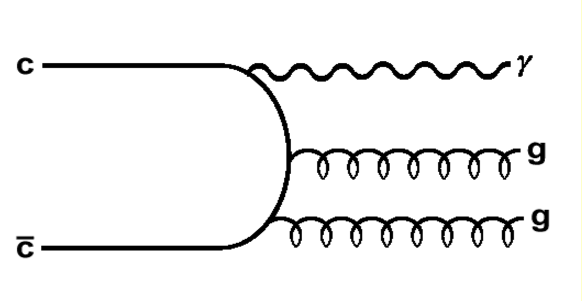


- **Semileptonic decays: $|V_{CKM}|^2\ |F(q^2)|^2$**
  - Form factor *shapes* & *normalizations*
  - Calibrate theory!
  - Extract $|V_{cd}|$, $|V_{cs}|$
  - Theory $\rightarrow$ Extract $|V_{ub}|$ from B
- **Leptonic Decays: $|V_{CKM}|^2\ |f_D|^2$**
  - Decay constants
  - Calibrate theory!
  - Extract $|V_{cd}|$, $|V_{cs}|$
  - Theory $\rightarrow$ Extract $|V_{td}|$, $|V_{ts}|$ from B
- **Hadronic decays:**
  - Set scale of heavy quark decays
  - Enables precision tests in B decays
  - Strong phases: Extract γ from $B \rightarrow DK$

Hybrids and Glueballs



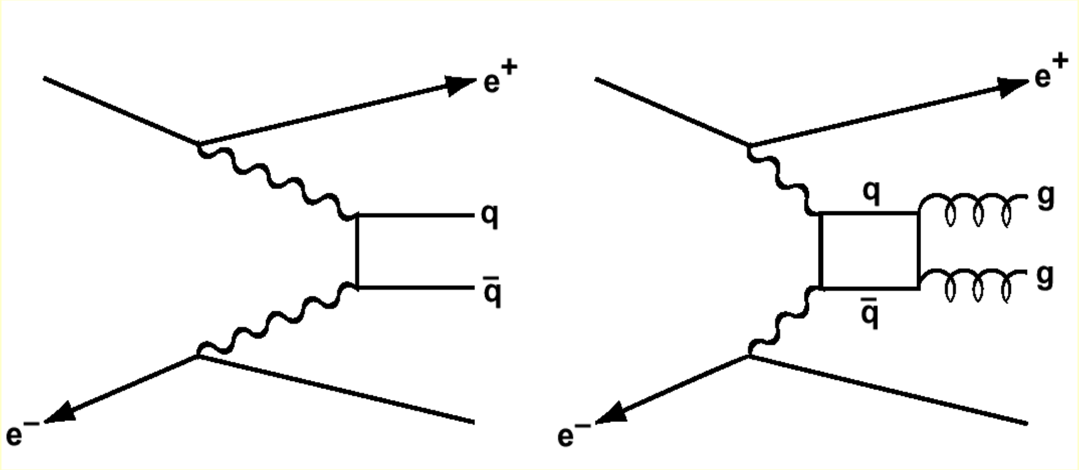
- **Strategy Part 1: 1fb^{-1} on J/Ψ**



  - **Search for states in glue rich environ**
  - **B(J/Ψ -> γ X) ~ 6%**
    - Copious source of color singlet gg pairs
    - $J^{PC}=0^{++},0^{-+},2^{++}$
  - **PWA to get QN of states**
    - Hermetic detector / Low background
  - **Absolute BR's: ππ, KK, pp, ηη,….**
  - **If see state in J/Ψ -> γ X, how do you know what it is?**

More Hybrids, Glueballs

- **Strategy Part 2: Current Data!**
  - **Anti-search in glue-poor environment**
    - **Eg. e^+e^- -> $e^+e^-\gamma\gamma$ -> e^+e^-X**
  - **Compare: $\gamma\gamma$ -> M vs. $\gamma\gamma$ -> G**



  - **Candidate states rich in glue seen at Ψ should not be copiously produced in $\gamma\gamma$ collisions!**
    - **Photons couple to charge!**

More Hybrids, Glueballs

- **Strategy Part 3: 1fb^{-1} on Υ(1S)**
  - **Compare Γ(J/Ψ -> γX) and Γ(Υ(1S) ->γX)**
  - **The Υ(1S) is also glue rich but…**

$$\frac{\Gamma(\Psi \to \gamma X)_{1-2GeV}}{\Gamma(\Upsilon \to \gamma X)_{1-2GeV}} \sim \frac{\sigma_\Psi}{\sigma_\Upsilon}\left(\frac{q_c}{q_b}\right)^2 \frac{\dfrac{\Psi \to \gamma X_{1-2GeV}}{\Upsilon \to \gamma X_{1-2GeV}}}{\dfrac{\Psi \to \gamma X}{\Upsilon \to \gamma X}}$$

$$\sim 10^2 \bullet 4 \bullet 10$$

$$\sim 4000$$

  - **No PWA at Υ(1S)!**
    - **Can confirm existence of states**
    - **Probe details of wave functions**
      - **Measure wf at different x**
    - **Test conclusions drawn from J/Ψ & γγ data**

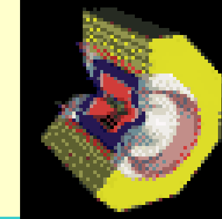
Current Status

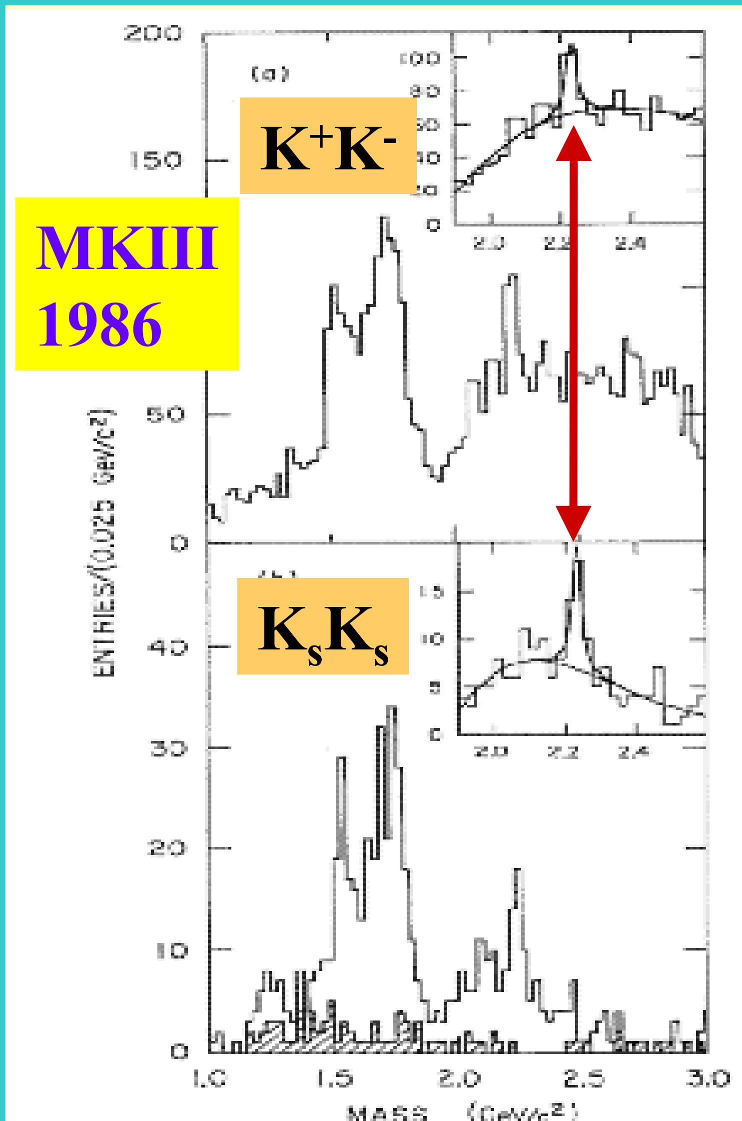
Experimental

- **Far from clear!**
- **List of "glue ball" suspects**
  - **η(1400) region**
  - **f_0(1500)**
  - **f_J(1710)**
  - **ξ(2220) or f_J(2220)**

- **The situation is complicated and experimental results are contradictory**
- **Sorting it out will be challenging!**
  - **Looks messy now due to <u>insufficient statistics</u>**

The vanishing $f_J(2220)$





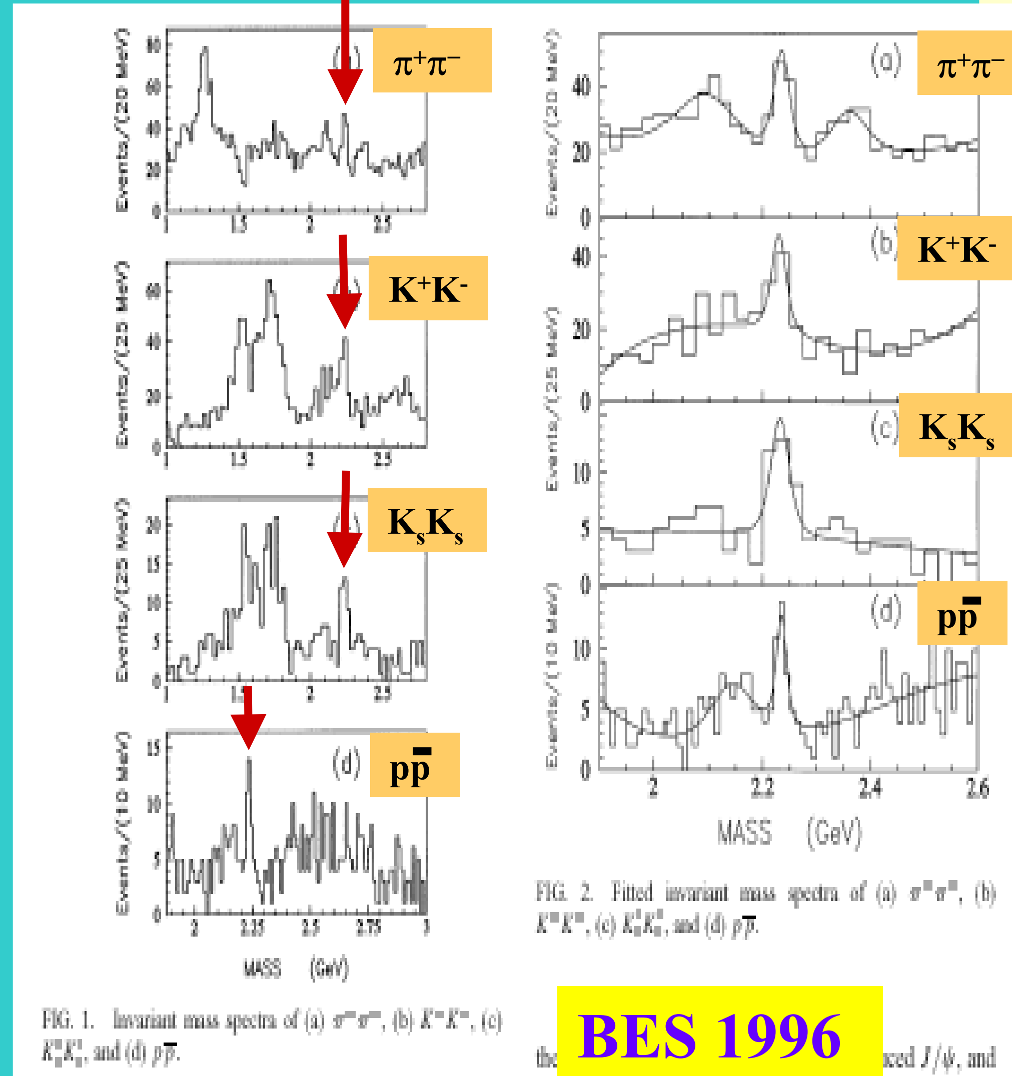
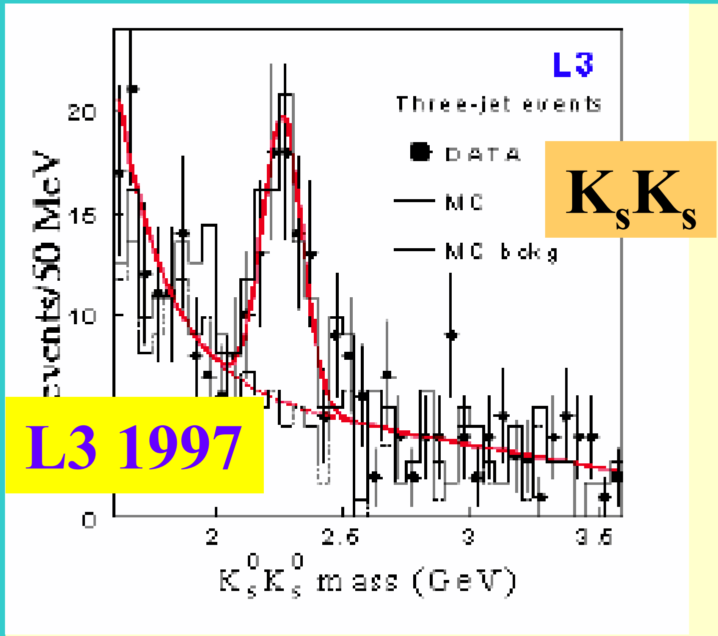
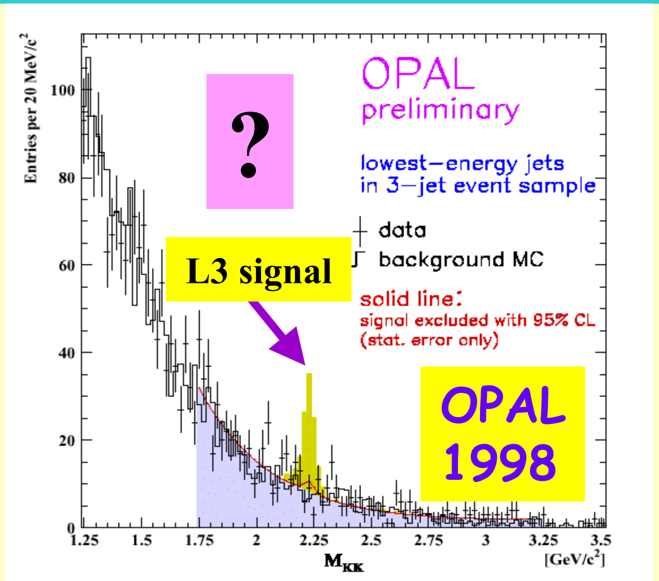


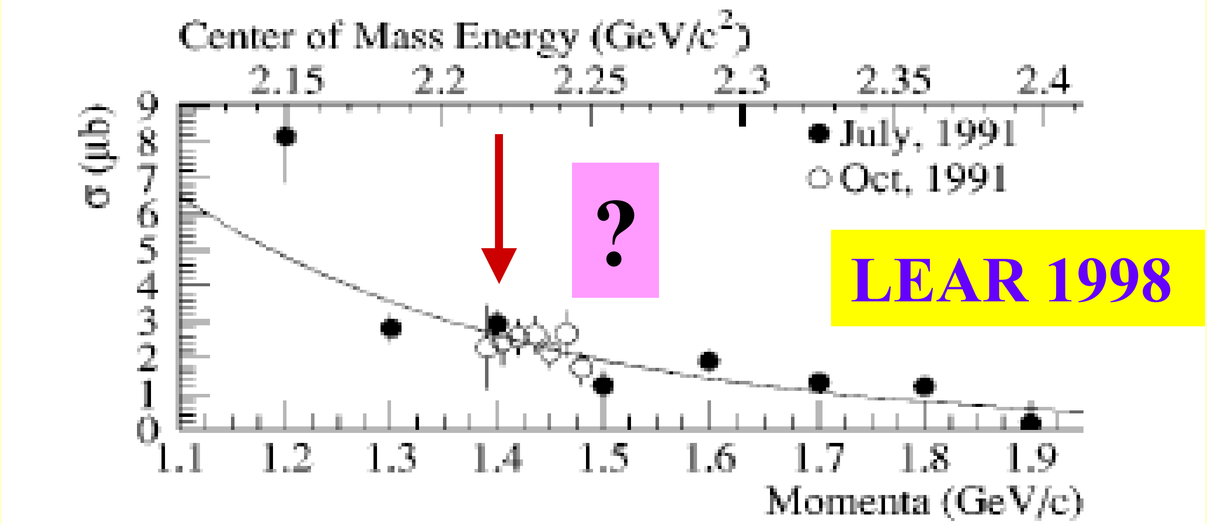
FIG. 1. Invariant mass spectra of (a) $\pi^+\pi^-$, (b) K^+K^-, (c) $K^0_S K^0_S$, and (d) $p\bar{p}$.

FIG. 2. Fitted invariant mass spectra of (a) $\pi^+\pi^-$, (b) K^+K^-, (c) $K^0_S K^0_S$, and (d) $p\bar{p}$.

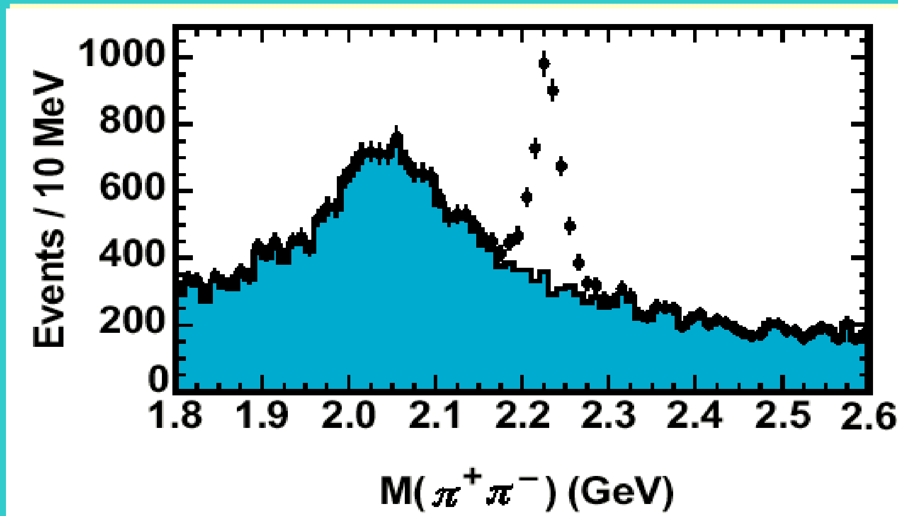
The vanishing $f_J(2220)$

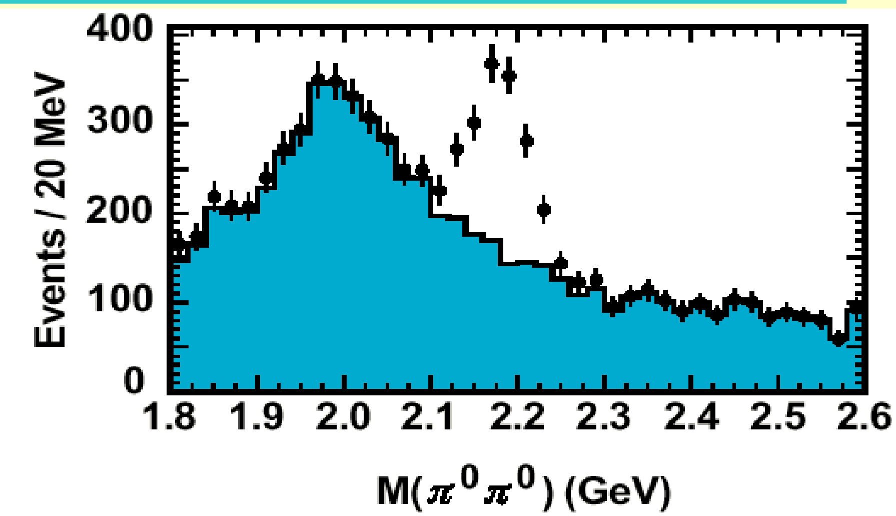


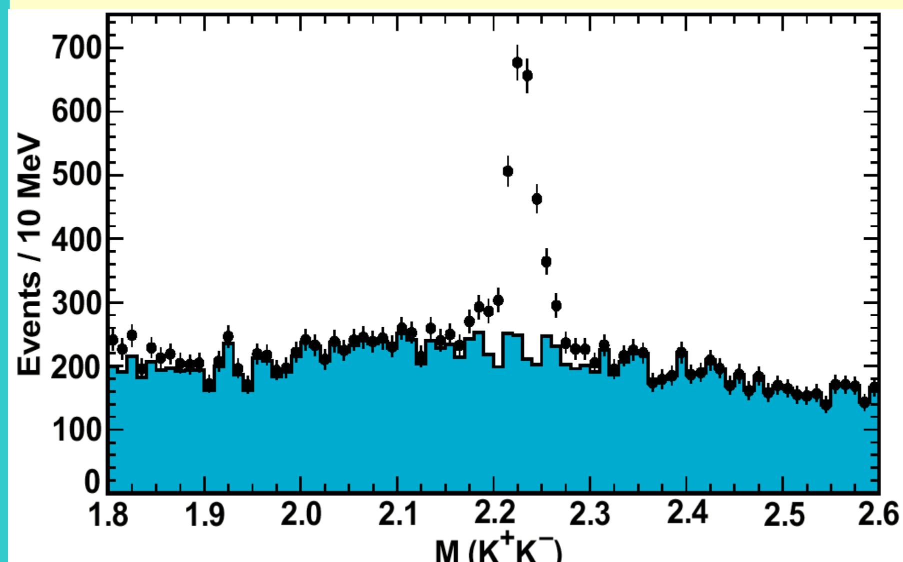




$f_J(2220)$: CLEO-c reach



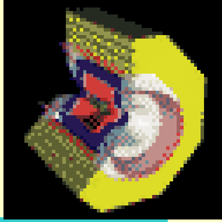


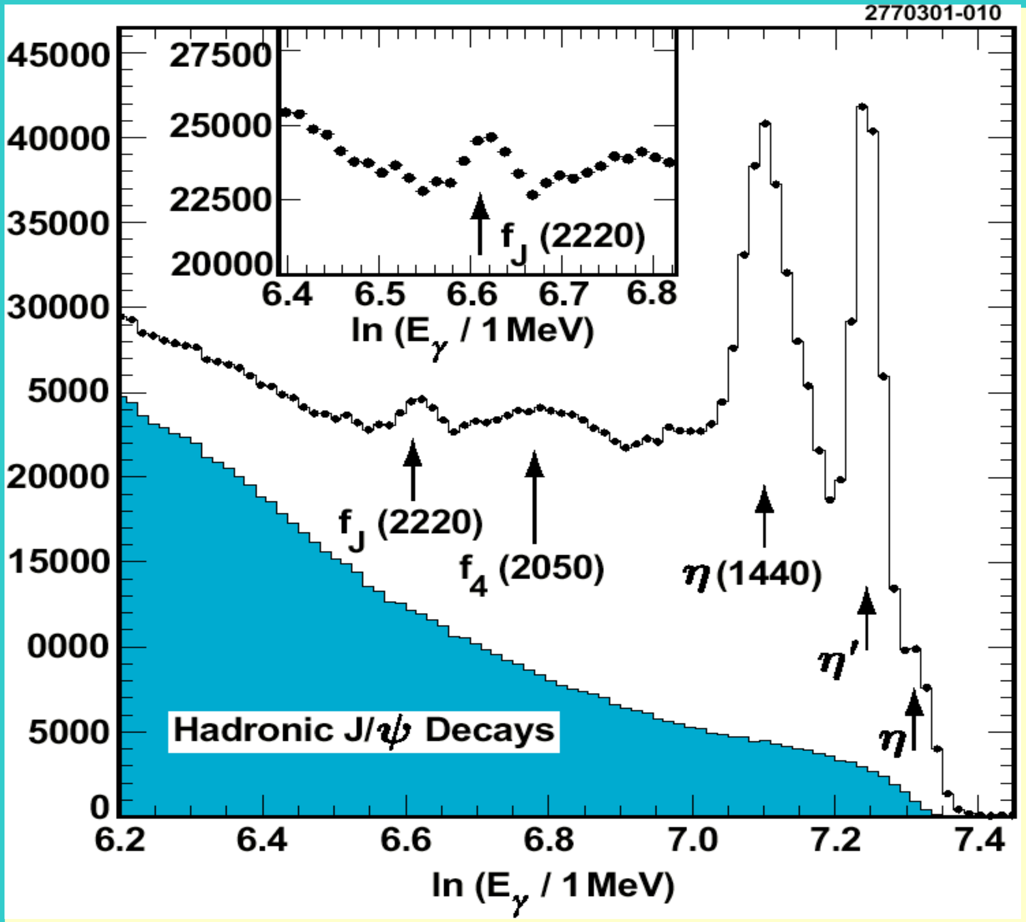


Plots show 1/6 CLEO-C assuming BES branching ratio

	Today	CLEO-C
$\pi^+\pi^-$	74	32000
$\pi^0\pi^0$	18	13000
K^+K^-	46	18600
K_SK_S	23	5300
pp	32	8500
$\eta\eta$	–	5000

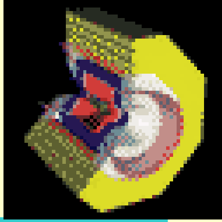
Inclusive Search





- γ spectrum from J/ψ →γX:
  - 10^{-4} sensitivity for narrow resonance
  - Eg: ~25% efficient for f_J(2220)
    - Suppress hadronic bkg: J/ψ→π^0X

Comparison w/ Other Expts

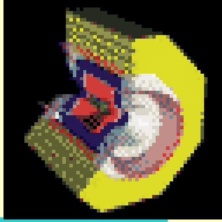


- **BES II is running now.**
- **BES III, BEPC II ($\sim 10^{32}$) upgrade proposed**
- **Physics: 2005 if approval & construction.**

Quantity	BES II	CLEO-C
J/psi yield	50M	> 1000M
dE/dx res.	9%	4.9%
K/pi separation up to	600 MeV	1500 MeV
momentum res. (500Mev)	1.3%	0.5%
Photon resolution (100 Mev)	70 MeV	4 MeV
Photon resolution (1000 Mev)	220 MeV	21 MeV
Minimum Photon Energy	80 MeV	30 MeV
Solid angle for Tracking	80%	94%
Solid angle for Photons	75%	95%

- **HALL-D @TJNAL: Light states with J^{PC} = 0+-, 1+-, … (2007+)**
- **Complementary to CLEO-C: heavy states with J^{PC}=0++, 2++, …**

What about *B*-Factories?



	CLEO-C 2-4fb-1	BaBar 400 fb-1	Current Knowledge
f_D |Vcd|	1.5-2%	10-20%	n.a.
f_Ds |Vcs|	≤ 1%	5-10%	19%
Br(D+ -> $K\pi\pi$)	1.5%	3-5%	7%
Br(Ds -> $\phi\pi$)	2-3%	5-10%	25%
Br(D-> $\pi l \nu$)	1.4%	3%	18%
Br(Λc -> p $K\pi$)	6%	5-15%	26%
A(CP)	~1%	~1%	3-9%
x'(mix)	0.01	0.01	0.03

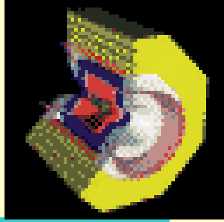
Statistics limited.

Systematics & background limited.

Possible additional topics

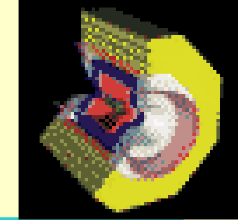
- $\Upsilon(nS)$
  - Precision partial/total width msmts
  - Discover η_b (bb ground state) in $\Upsilon(nS)\to\gamma\eta_b$
- $\tau^+\tau^-$ at threshold (0.25 fb^{-1})
  - measure m_t to $\pm$ 0.1 MeV
  - heavy lepton, exotics searches
- $\Lambda_c\Lambda_c$ at threshold (1 fb^{-1})
  - calibrate absolute $BR(\Lambda_c\to pK\pi)$
- $R=\sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$
  - spot checks

Tying the Threads



- **Direct impact on CKM**
  - Precise V_{cd} & V_{cs} & more precise V_{cs}/V_{cd}
- **Enable B-factory msmts for CKM precision**
  - Precise *D* decay rates used to tag *D*'s in *B*-decay & mixing
  - Precision form factors & decay constants for charm to give confidence for extrapolations to beauty
    - High Precision reality check for HQET & Lattice QCD.
- **QCD**
  - Υ spectroscopy, transitions; discover η_b?
  - glueballs, hybrids: corroborating datasets: 1-stop shopping (~1 fb^{-1} $\Upsilon(1S)$, 25 fb^{-1} 2γ)
- **Detector & collider capable of 100 fold or better improvement in data.**
  - Modern, well-understood detector + collaboration ready to go
  - Modest accelerator changes
  - Tightly focussed ~4-year program

Near/Far Term



- **Near**
  - Look for favorable reaction at Snowmass, just as from the HEPAP-Long Range Panel
  - Accumulate data at Υ resonances in 2001-2
  - Modify CESR with wigglers (2003)
  - CLEO-c (2003-2005)
    - Precision data that will make fundamental contributions to QCD and Flavor physics
    - Validates theoretical technology at 1-2% level
- **Far Future**
  - CESR & CLEO turn off for HEP: ~2006
  - Lab will turn its full effort to the energy frontier!