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New Results from CLEO

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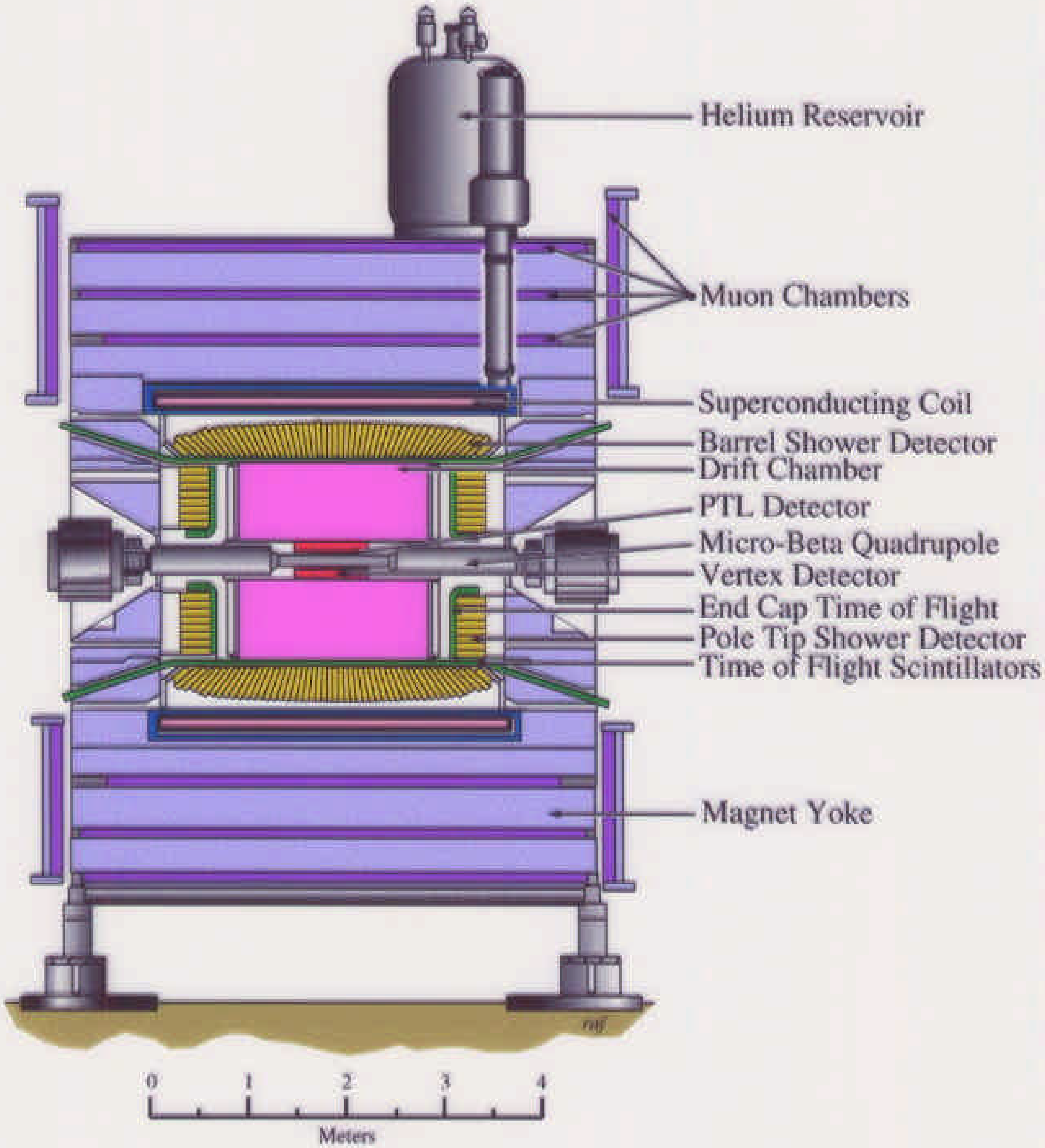
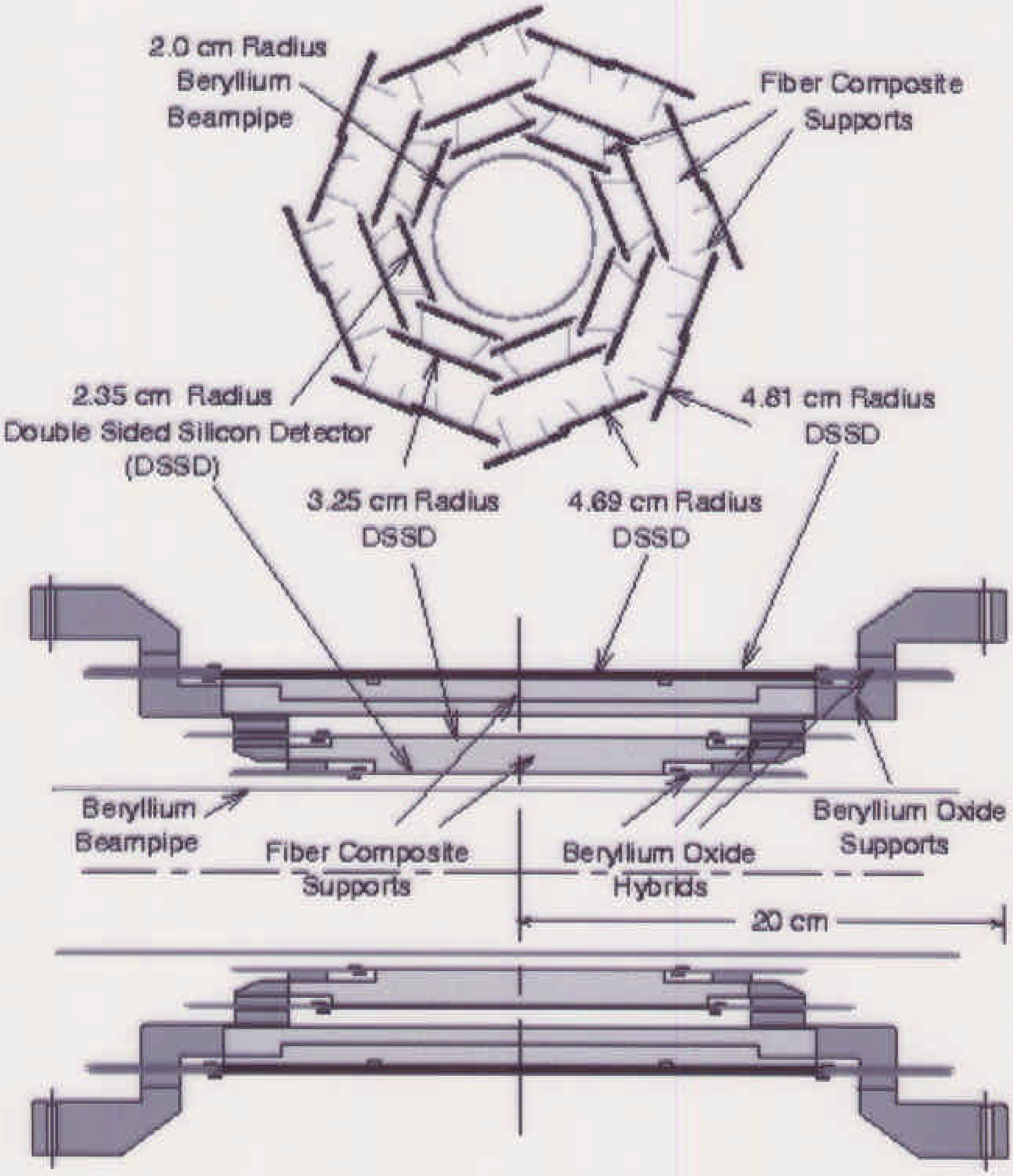
CLEO II



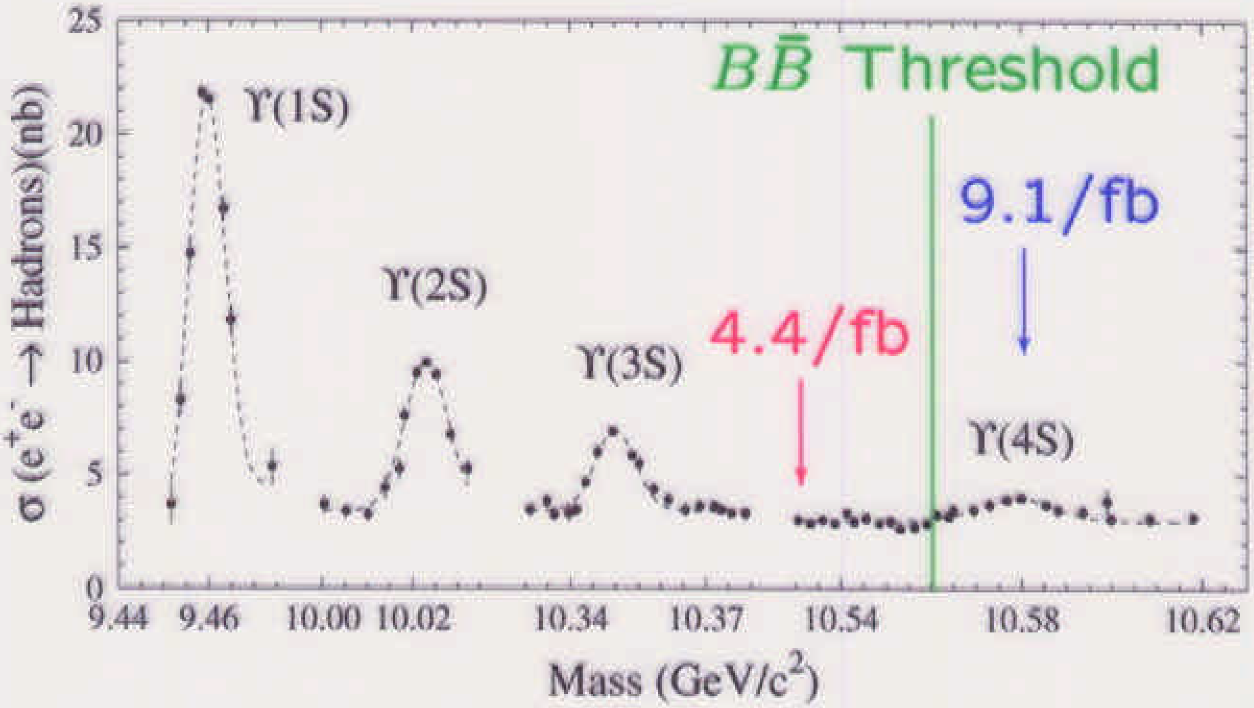
Helium Reservoir
Muon Chambers
Superconducting Coil
Barrel Shower Detector
Drift Chamber
PTL Detector
Micro-Beta Quadrupole
Vertex Detector
End Cap Time of Flight
Pole Tip Shower Detector
Time of Flight Scintillators
Magnet Yoke
0
1
2
3
4
Meters

CLEO II.V



2.0 cm Radius
Beryllium
Beampipe
Fiber Composite
Supports
2.35 cm Radius
Double Sided Silicon Detector
(DSSD)
4.61 cm Radius
DSSD
3.25 cm Radius
DSSD
4.69 cm Radius
DSSD
Beryllium
Beampipe
Fiber Composite
Supports
Beryllium Oxide
Hybrids
Beryllium Oxide
Supports
20 cm

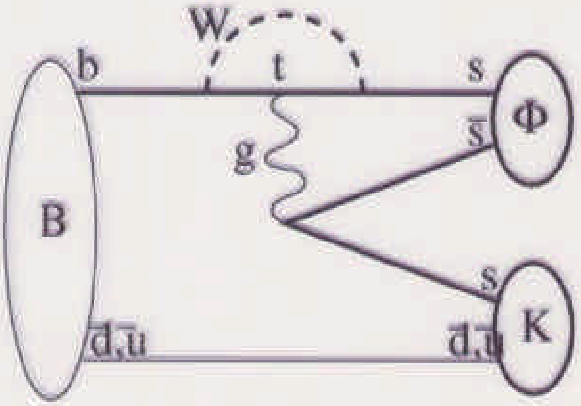
CLEO Data Set

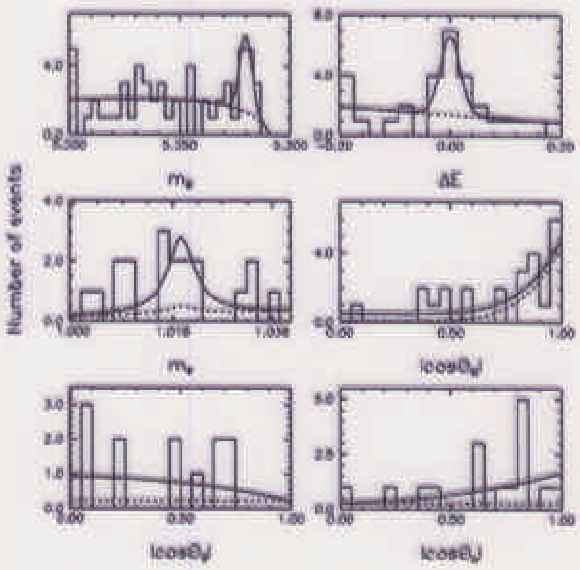


- Integrated Luminosity of 13.5/fb
- 9.1/fb on $\Upsilon(4S)$; $\sim 9.7 \times 10^6$ $B\bar{B}$ events
- 4.4/fb on continuum 60 MeV off the $\Upsilon(4S)$
- 2/3 data in II.V configuration; most analyses described here combine the samples.

Observation of $B \to \phi K$

Unambiguous gluonic penguin





Preliminary!

$$\mathcal{B}(B^- \to \phi K^-) = (6.4^{+2.5}_{-2.1}{}^{+0.5}_{-2.0}) \times 10^{-6}$$

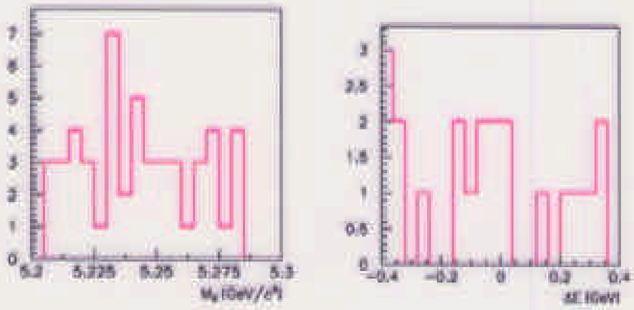
$$\mathcal{B}(B^0 \to \phi K^0) < 1.2 \times 10^{-5} \text{ 90\% C.L.}$$

$$\mathcal{B}(B \to \phi K) = (6.2^{+2.0}_{-1.8}{}^{+0.7}_{-1.7}) \times 10^{-6}$$

Consistent with theoretical expectations.

$B \to \pi^0\pi^0$ Limit

Continuing a program to search for all the $B \to \pi\pi$, $B \to K\pi$ and $B \to KK$ modes to get constraints on the angles of the unitary triangle.

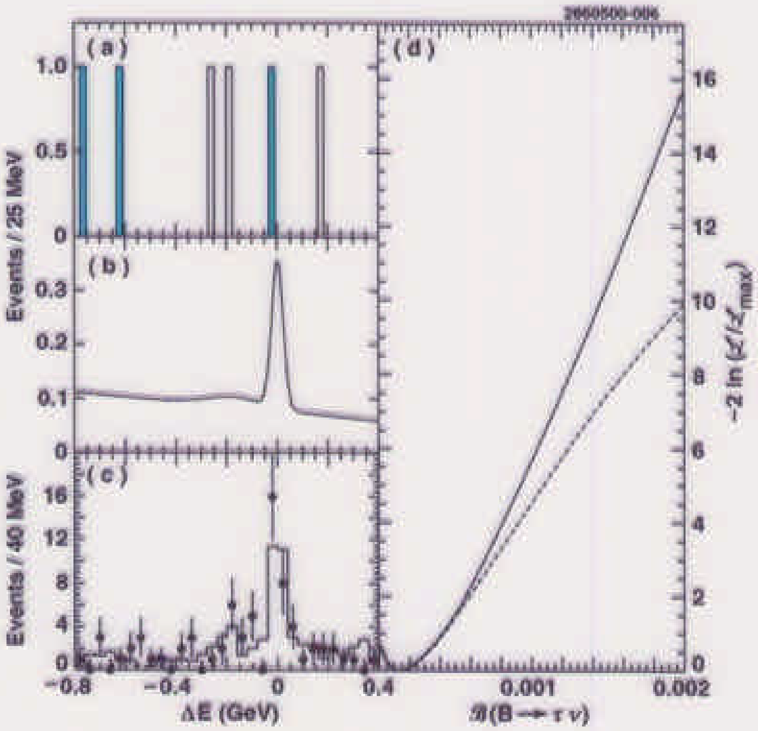


Feed down from $B^\pm \to \rho^\pm\pi^0$ is noticeable.

Mode	Events	BF $\times 10^6$
$\pi^+\pi^-$	$20.0^{+7.6}_{-6.5}$	$4.3^{+1.7}_{-1.5}$
$\pi^\pm\pi^0$	$21.3^{+9.7}_{-8.5}$	< 12.7
$\pi^0\pi^0$	$6.2^{+4.8}_{-3.7}$	< 5.6 Preliminary
$K^\pm\pi^\mp$	$80.2^{+11.8}_{-11.0}$	$17.2^{+2.8}_{-2.7}$
$K^\pm\pi^0$	$42.1^{+10.9}_{-9.9}$	$11.6^{+3.3}_{-3.0}$
$K^0\pi^\pm$	$25.2^{+6.4}_{-5.6}$	$18.2^{+4.9}_{-4.3}$
$K^0\pi^0$	$16.1^{+5.9}_{-5.0}$	$14.6^{+6.4}_{-6.1}$
K^+K^-	$0.7^{+3.4}_{-0.7}$	< 1.9
$K^\pm K^0$	$1.4^{+2.4}_{-1.3}$	< 5.1

$B \to \tau\nu,\ K\nu\nu$ Limits

Uses technique of looking opposite inclusive $B \to D^{(*)} n\pi$ signal for a single track. Checked in $B \to D^* \ell\nu$.



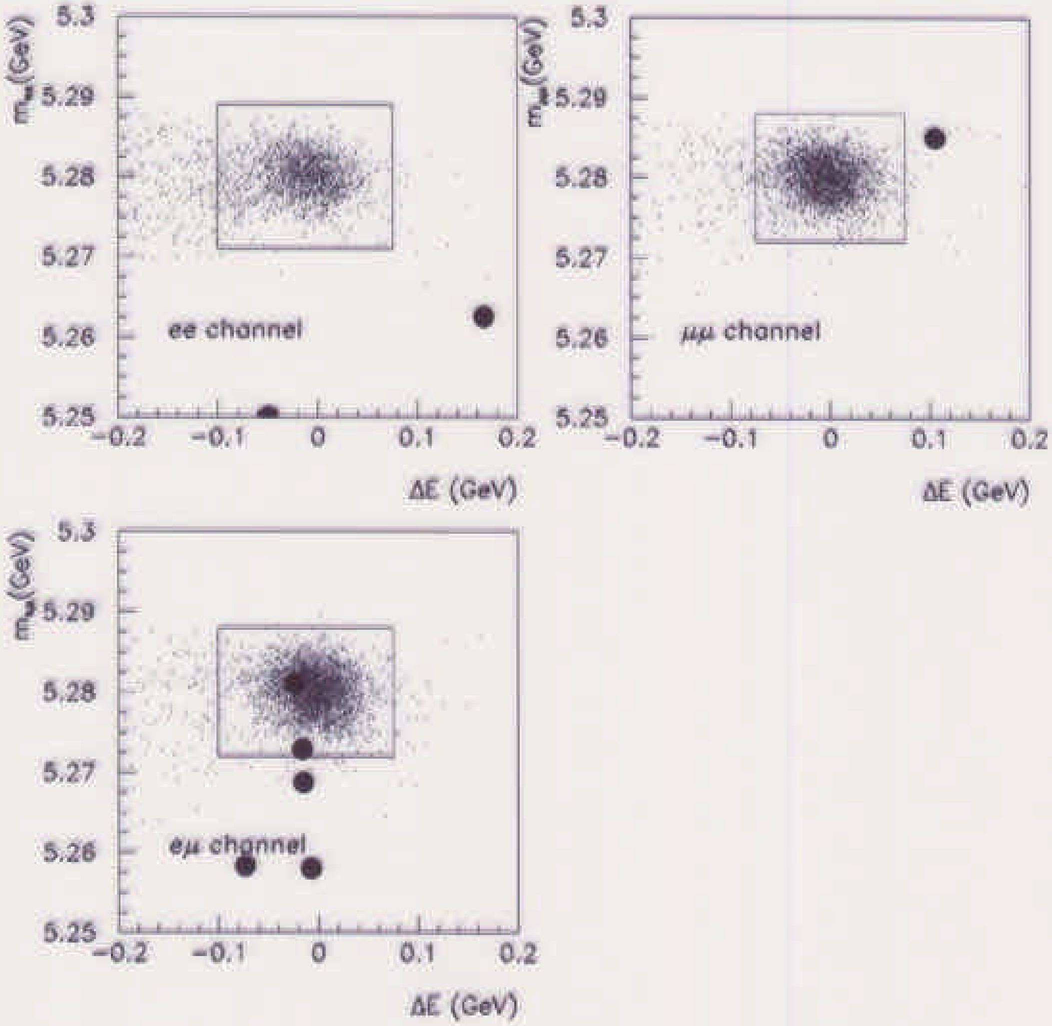
Likelihood fit finds 0.96 signal events and

$$\mathcal{B}(B^+ \to \tau^+ \nu_\tau) < 8.4 \times 10^{-4},$$

at 90% C.L. and slight modifications (take only the single tracks that are not leptons) leads to

$$\mathcal{B}(B^\pm \to K^\pm \nu\bar{\nu}) < 2.4 \times 10^{-4}.$$

$B \to \ell\ell$ Limits



		S.M. Expect
$\mathcal{B}(B^0 \to e^+e^-)$	$< 8.3 \times 10^{-7}$	$\sim 10^{-15}$
$\mathcal{B}(B^0 \to e^\pm\mu^\mp)$	$< 15 \times 10^{-7}$	$\emptyset$
$\mathcal{B}(B^0 \to \mu^+\mu^-)$	$< 6.1 \times 10^{-7}$	$\sim 10^{-10}$

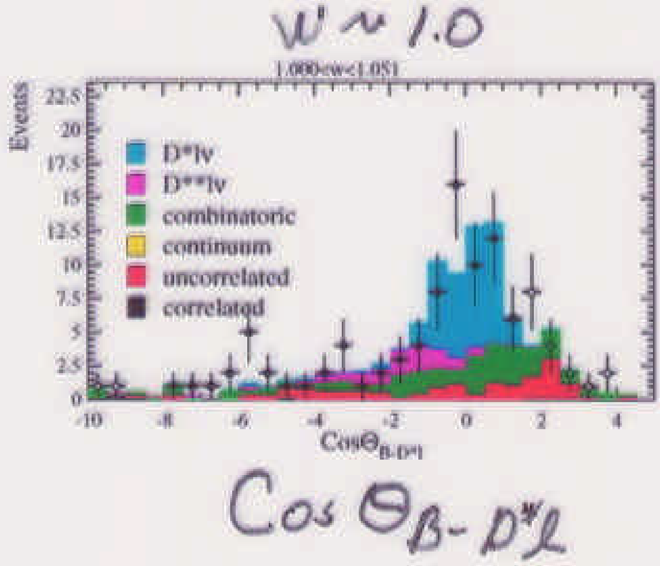
at 90% C.L.

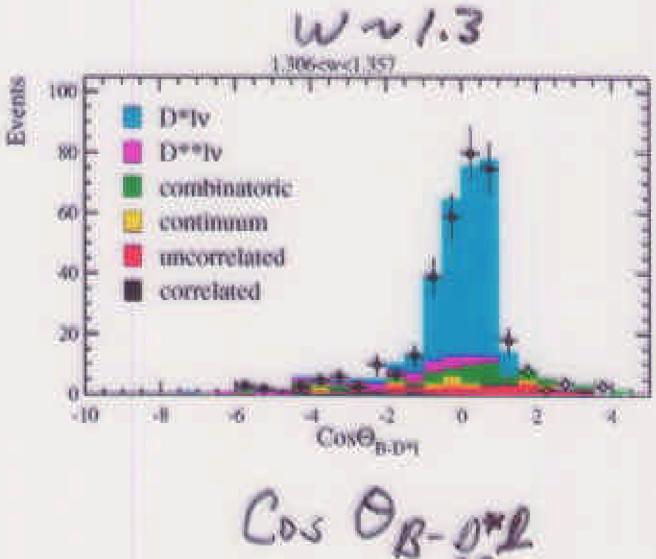
Measurement of V_{cb} in $\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}$

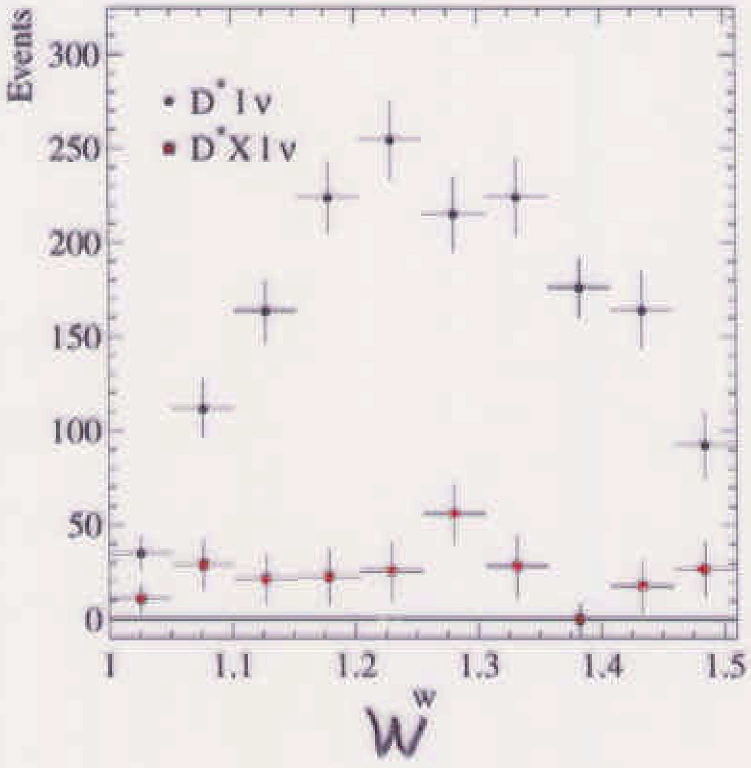
This analysis systematic limited, and only uses the $\sim 3 \times 10^6$ $B\bar{B}$ events in the CLEO-II sample.

Technique is to measure the $D^{*+}\ell^-\bar{\nu}$ yield as a function of $w = v_B \bullet v_{D^*} = (m_B^2 + m_{D^*}^2 - q^2)/(2m_B m_{D^*})$. At maximum q^2 or minimum w the normalization is proportional to $|V_{cb}|$ times a form factor that can be well calculated by theory.

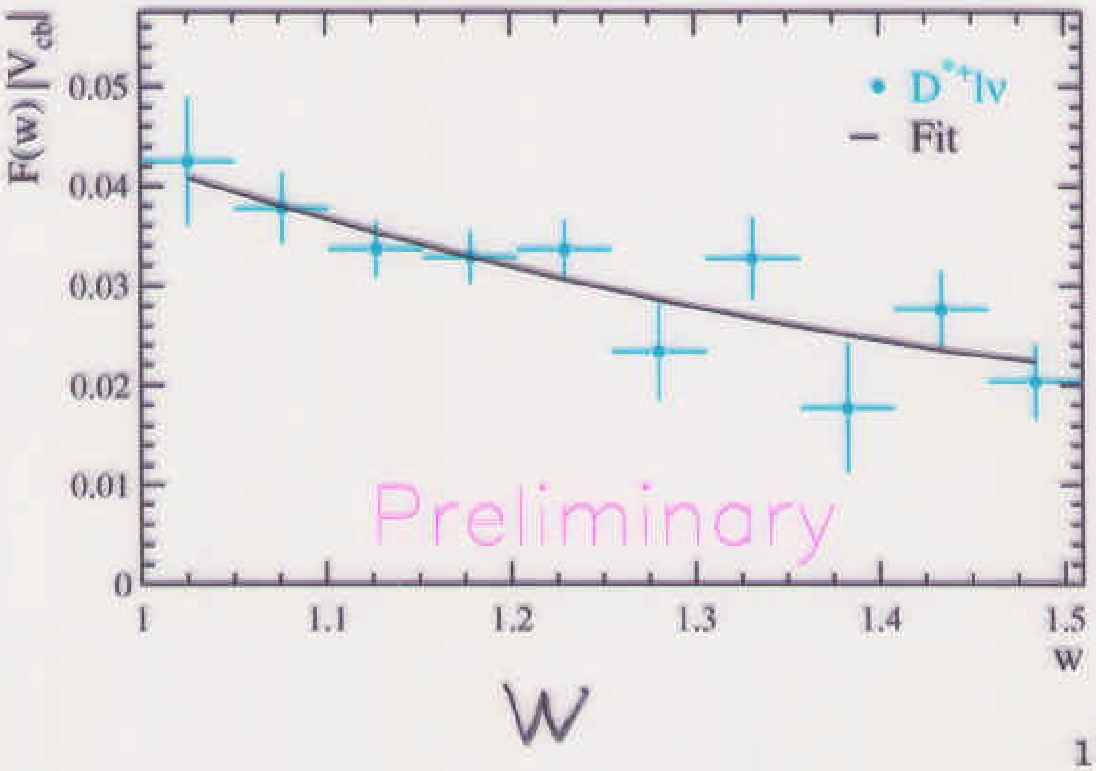
The yield is determined by fitting the $\cos\theta_{B-D^*\ell}$ distribution of candidate $D^* - \ell$ pairs in w bins.







This is then fit taking into account backgrounds, efficiency, and the w resolution.



Systematic errors in %.

Source	$\lvert V_{cb}\rvert h_{A_1}(1)$	ρ^2	$\Gamma(B \to D^* \ell\nu)$
Comb Back	1.4	1.8	1.2
Uncorr Back	0.7	0.9	0.7
Corr Back	0.4	0.3	0.5
Slow π finding	3.1	3.7	2.9
K, π & ℓ finding	1.0	0.0	1.9
Lepton ID	1.1	0.0	1.9
B mom & mass	0.3	0.5	0.4
$D^* X \ell\nu$ model	0.2	1.9	1.9
Number of $B\bar{B}$	0.9	0.0	1.8
Subtotal	3.8	4.7	5.0
B($D^* \to D\pi$)	0.4	0.0	0.7
B($D \to K\pi$)	1.2	0.0	2.3
τ_B	1.0	0.0	2.1
$R_1(1)$ & $R_2(1)$	1.4	12.0	1.8
Subtotal	2.2	12.0	3.7
Total	4.4	13	6.2

$$\frac{d\Gamma}{dw} = \frac{G_F^2|V_{cb}|^2}{48\pi^3}(m_B - m_{D^*})^2 m_{D^*}^3 \sqrt{w^2-1}(w+1)^2$$
$$(1 + 4\frac{w}{w+1}\frac{1-2w(m_{D^*}/m_B)+(m_{D^*}/m_B)^2}{(1-(m_{D^*}/m_B))^2})$$
$$F(w)^2$$

where the form factor $F(w)$ depends on two form factor ratios $R_1(w)$ and $R_2(w)$, and a normalization $h_{A_1}(w)$. These can be constrained with dispersion relations (Caprini *et al.*, hep-ph/9705252). The dependence can then be reduced to a "slope," ρ^2, and $R_1(1)$, and $R_2(1)$.

We find (Preliminary!)

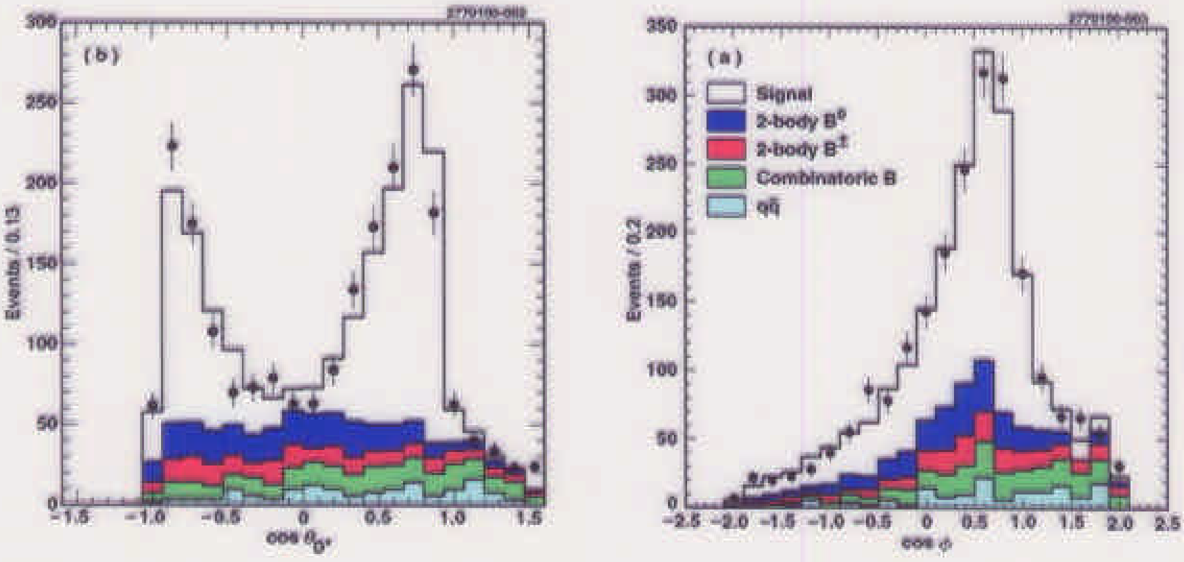
$$|V_{cb}|h_{A_1}(1) = 0.0424 \pm 0.0018 \pm 0.0019$$
$$\rho^2 = 1.67 \pm 0.11 \pm 0.22$$
$$\mathcal{B}(\bar{B}^0 \to D^{*+}\ell^-\bar{\nu}) = (5.66 \pm 0.29 \pm 0.33)\%$$

and using $h_{A_1}(1) = 0.913 \pm 0.042$ we find

$$|V_{cb}| = 0.0464 \pm 0.0020 \pm 0.0021 \pm 0.0021$$

B_d Mixing

Uses high momentum lepton tag versus partially reconstructed $\bar{B} \to D^{*\pm}\pi^{\mp}$ or $D^{*\pm}\rho^{\mp}$ to increase statistics and remove dilution from charged B's.



Sample has $\sim$ 2000 events with 13% dilution and 3% mistagging.

$$\chi_d = 0.198 \pm 0.013 \pm 0.014$$

from $++$ versus - - events see no evidence of CP violation and limit

$$|\Re(\epsilon_B)| < 0.034$$

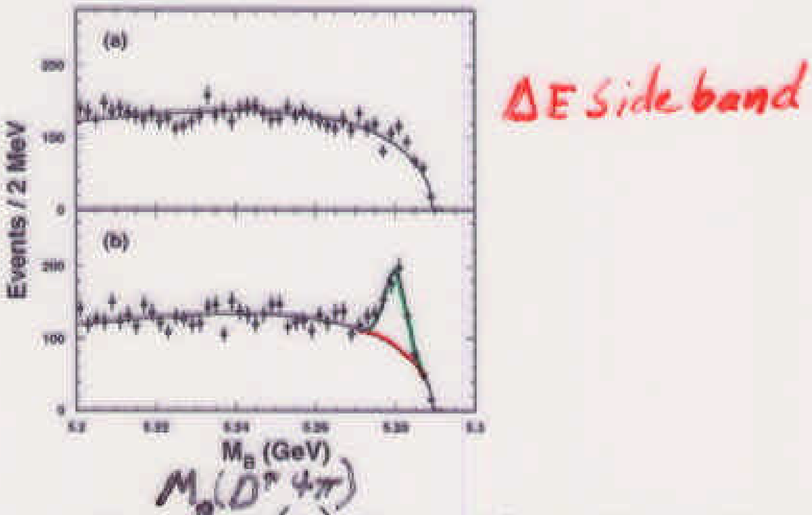
and with LEP measures of Δm_d and lifetime

$$\Delta\Gamma_d/2\Gamma_d = |y_d| < 0.41$$

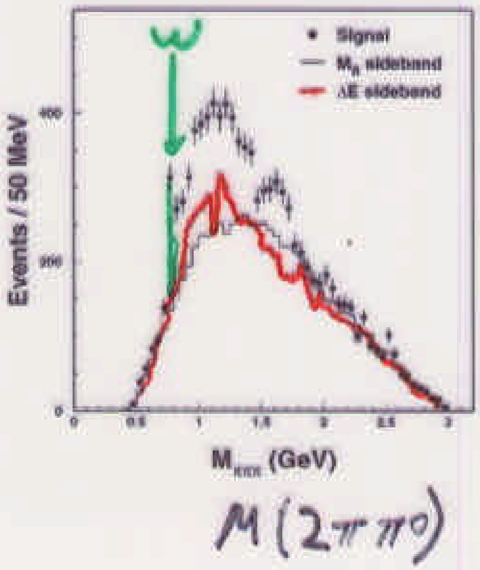
both at 95% C.L.

Observation of $B \to D^{(*)} 4\pi$

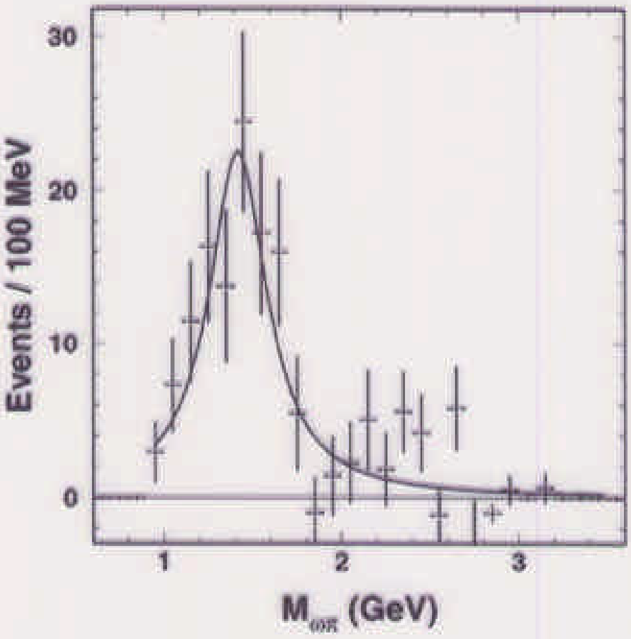
Still many B decay modes to be investigated; total measured branching fraction $\sim 35\%$, only 10–12% is hadronic, and hadronic-B decay multiplicity ~ 5 motivates such a search.



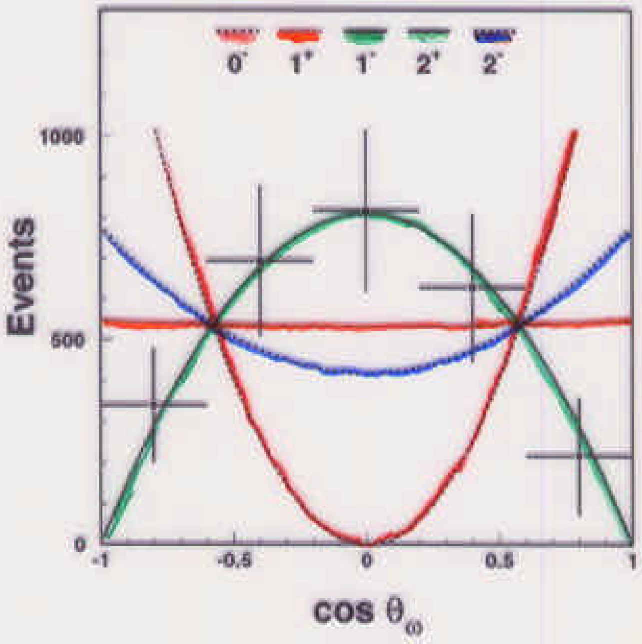
Observation from $B \to D^{(*)}(2-3)\pi$ that 2 body decay modes dominate. We look for substructure. In the $2\pi\pi^0$ mass:



Combining the ω with the remaining π:



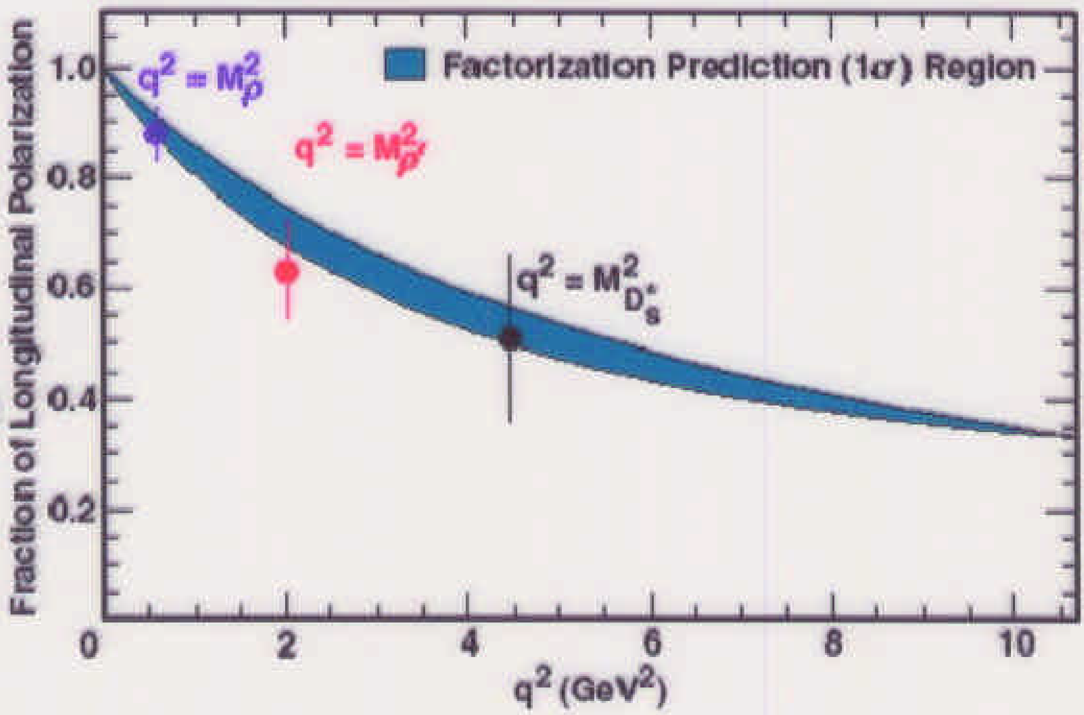
and observe a resonance with $m = 1419 \pm 33$ and $\Gamma = 382 \pm 44$ MeV. We investigate the angular distributions:



and find $J^P = 1^-$ and identify this resonance as the ρ'. CLEO also observes the ρ' in τ decay.

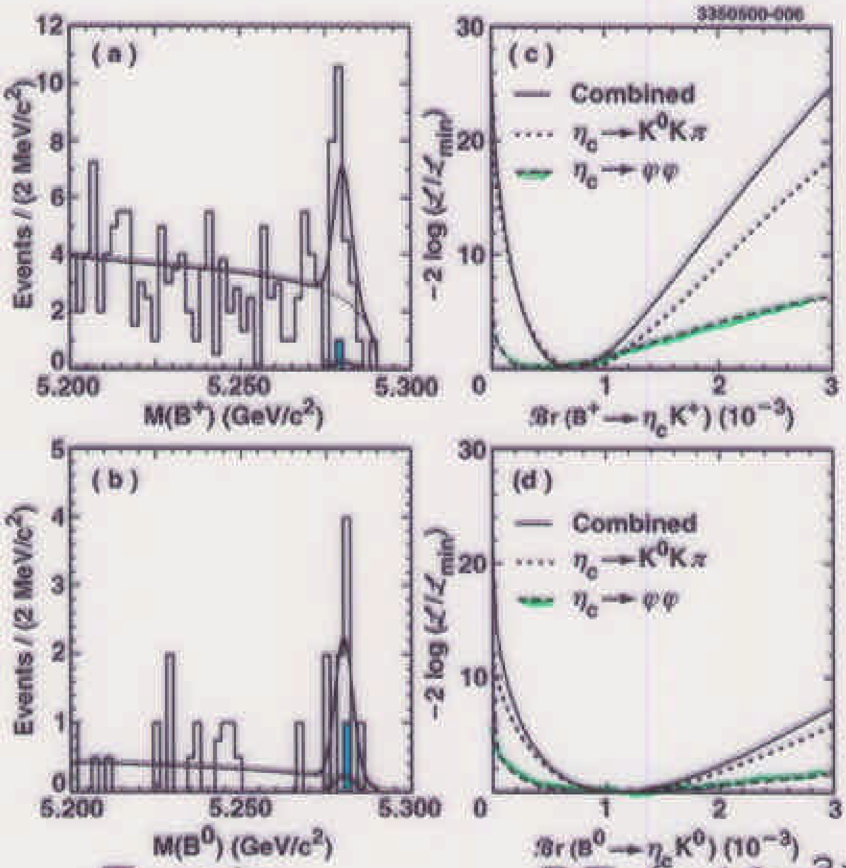
Mode	Events	BF (%)
$D^{*+}\pi^+\pi^-\pi^-\pi^0$	1230 ± 70	$1.72 \pm 0.14 \pm 0.24$
$D^{*+}\omega\pi^-$	136 ± 15	$0.29 \pm 0.03 \pm 0.04$
$D^+\omega\pi^-$	91 ± 18	$0.28 \pm 0.05 \pm 0.03$
$D^{*0}\pi^+\pi^-\pi^-\pi^0$	195 ± 26	$1.80 \pm 0.24 \pm 0.25$
$D^{*0}\omega\pi^-$	26 ± 6	$0.45 \pm 0.10 \pm 0.07$
$D^0\omega\pi^-$	88 ± 14	$0.41 \pm 0.07 \pm 0.04$

The ρ' saturates the $\omega\pi$ final state. We also measure the polarization of the D^* at 63±9%. We can combine this with previous results on $D^*\rho$ and new results on D^*D_s to test prediction of factorization.



$B \to$ Charmonium

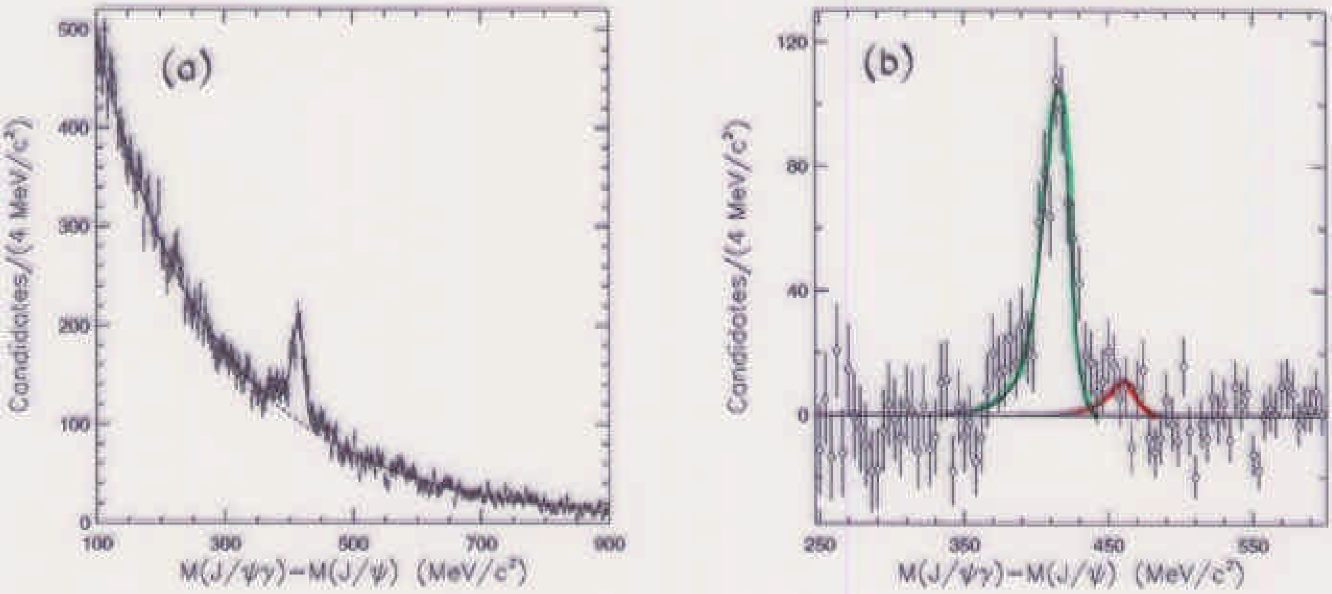
First observation of $B \to \eta_c K$ and search for $\chi_{c0} K$:



Mode	Events	BF ($\times 10^{-3}$)
$\eta_c K^+$	19.5 ± 6.0	$0.69 \pm 0.24 \pm 0.08 \pm 0.20$
$\eta_c K^0$	8.5 ± 3.8	$1.09 \pm 0.49 \pm 0.12 \pm 0.31$
$\chi_{c0} K^+$	0	< 0.48
$\chi_{c0} K^0$	0	< 0.50

limits at 90% C.L. Also measure $f_{\eta_c} = 335 \pm 75$ MeV assuming factorization. Implies no enhancement of η' due to charm content.

Measurement of inclusive $B \to \chi_{c1}$ and χ_{c2}. Test of charmonium production models.



Measure the direct rate for χ_{c1} by subtracting off the contribution from $J/\Psi(2S) \to \chi_{c1}\gamma$.

$$\mathcal{B}(B^0 \to \chi_{c1}X) = (4.14 \pm 0.31 \pm 0.40) \times 10^{-3}$$

$$\mathcal{B}(B^0 \to \chi_{c1}[\text{direct}]\text{X}) = (3.83 \pm 0.31 \pm 0.40) \times 10^{-3}$$

$$\frac{\mathcal{B}(B^0 \to \chi_{c2}[\text{direct}]\text{X})}{\mathcal{B}(B^0 \to \chi_{c1}[\text{direct}]\text{X})} < 0.44$$

Color Octet?

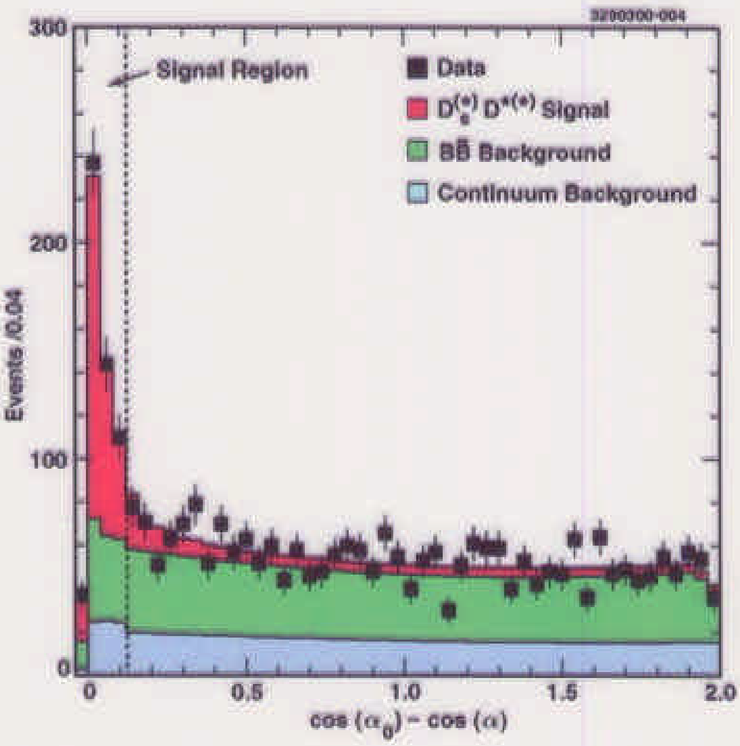
Limit at 95% C.L.

Many other recent Charmonium results:

- Two Body Charmonium
  - $\mathcal{B}(B \to J/\psi K^0) = (9.5 \pm 0.8 \pm 0.6) \times 10^{-4}$
  - $\mathcal{B}(B \to J/\psi \pi^0) = (2.5 \pm 1.0 \pm 0.2) \times 10^{-5}$
  - $\mathcal{B}(B \to \chi_{c1} K^0) = (3.9 \pm 1.6 \pm 0.4) \times 10^{-4}$
- Limits on $\mathcal{A}_{CP}$
  - $\mathcal{A}_{CP}(B^\pm \to J/\psi K^\pm) = (+1.8 \pm 4.3 \pm 0.4)\%$
  - $\mathcal{A}_{CP}(B^\pm \to J/\psi(2S) K^\pm) = (+2.0 \pm 9.1 \pm 1.0)\%$
- Precision B mass measures in $B \to \psi^{(\prime)} K$
  - $m(B^0) = 5279.1 \pm 0.7 \pm 0.3$ MeV
  - $m(B^+) = 5279.1 \pm 0.4 \pm 0.4$ MeV

$B \to D_s^{(*)} D^{*(*)}$

Partial reconstruction of D^* combined with the D_s.

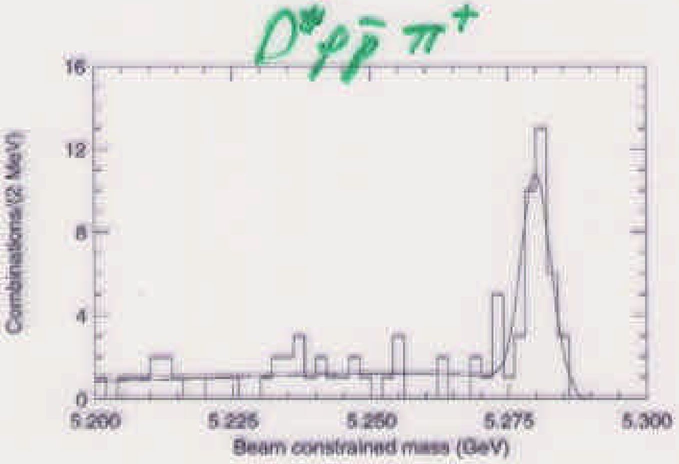


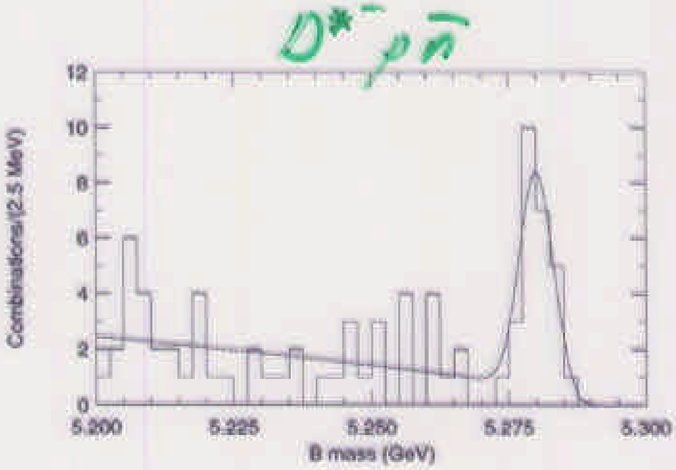
Mode	Events	BF (%)
$D_s D^{*-}$	93 ± 18	$1.01 \pm 0.18 \pm 0.10 \pm 0.28$
$D_s^* D^{*-}$	149 ± 37	$1.82 \pm 0.37 \pm 0.24 \pm 0.46$
$D_s^{(*)} D^{**0}$	82 ± 28	$2.73 \pm 0.78 \pm 0.48 \pm 0.68$

and measure the longitudinal polarization of the D_s^* at $(51 \pm 14 \pm 4)\%$.

$B^0 \to D^{*-} p\bar{p}\pi^+$ and $D^{*-} p\bar{n}$

First observations of both modes and first observation of exclusive B decays to nucleons.

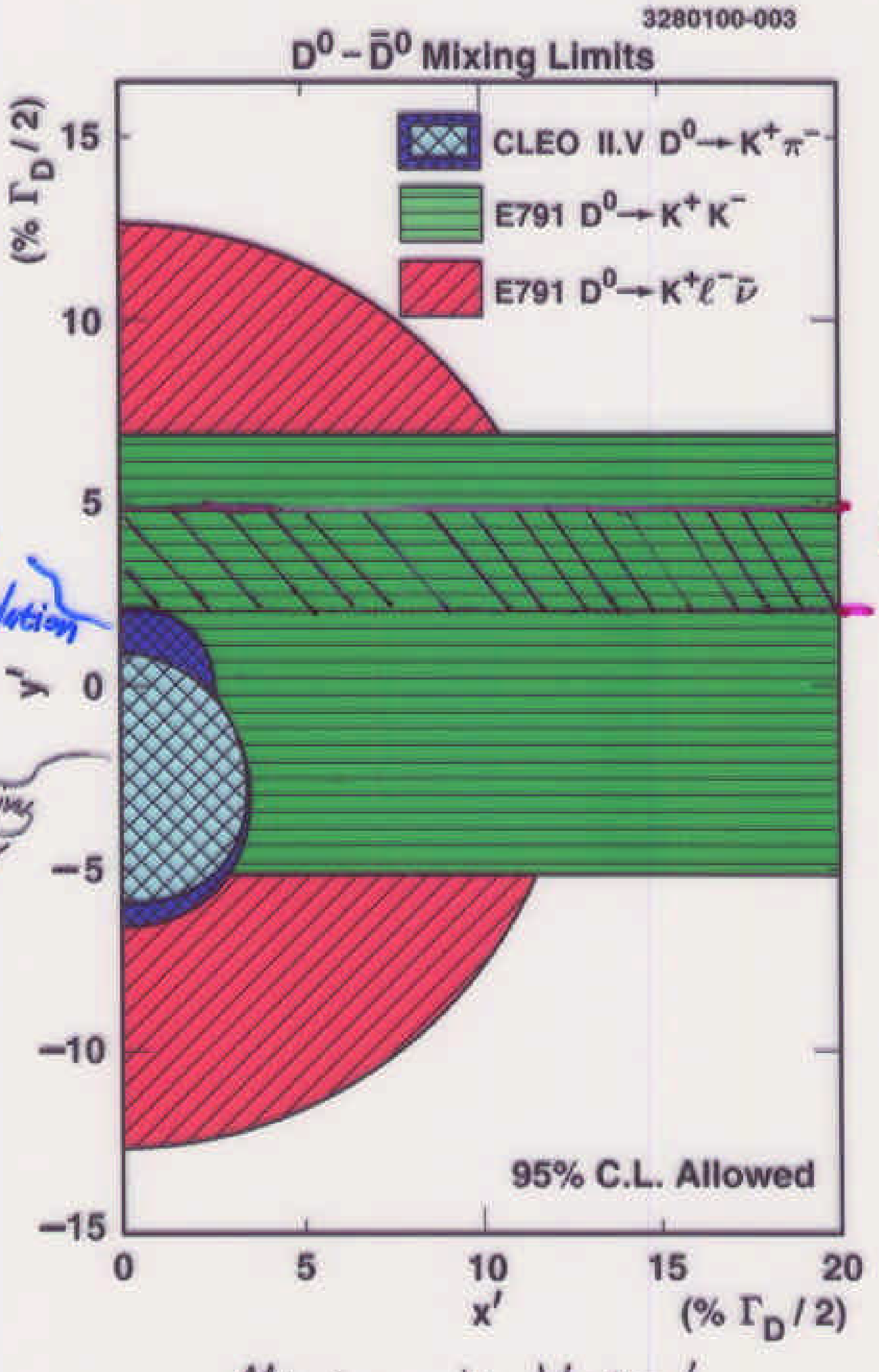




Antineutrons are identified by their annihilation in the calorimeter.

$$\mathcal{B}(B^0 \to D^{*-} p\bar{p}\pi^+) = 6.6 \pm 1.4 \pm 1.0 \times 10^{-4}$$
$$\mathcal{B}(B^0 \to D^{*-} p\bar{n}) = 14.5 \pm 3.2 \pm 2.7 \times 10^{-4}$$

D^0 Mixing and CP-Violation



Allow CP Violation

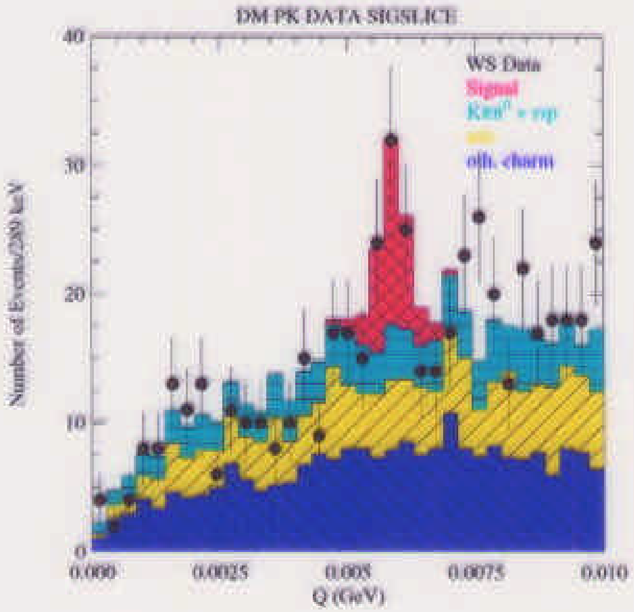
Assuming No CP

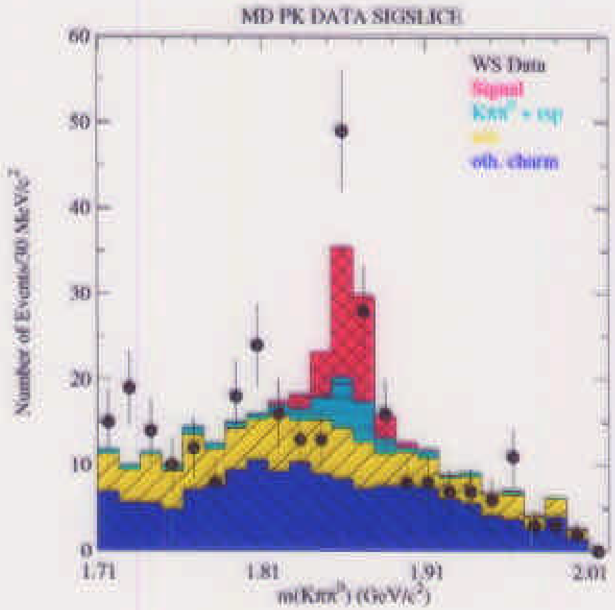
FOCUS $D^0 \to K^+K^-$

Mixing via Real States (Lifetime Splitting)

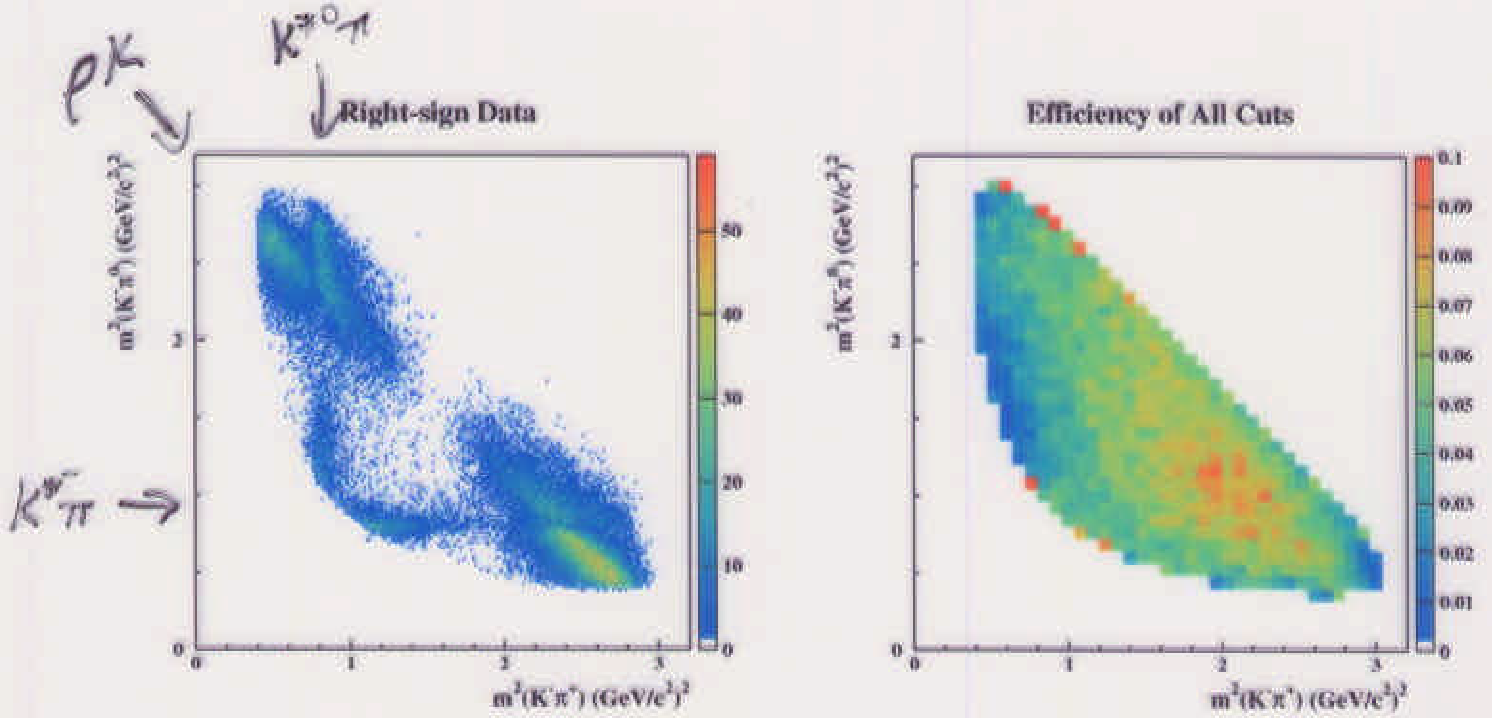
Mixing via Virtual States (Mass Splitting) ($x \neq 0 \Rightarrow$ New Physics)

Latest result is the observation of a wrong signal in $D \to K\pi\pi^0$.





The wrong side yield is $39 \pm 10 \pm 7$, right sign is 9045. Now conducting a Dalitz plot analysis of this signal to extract R_{ws}.



Need to take care as $\epsilon_{DCSD} \neq \epsilon_{mix}$. We are also working on lifetime analyses of this mode, CP even eigenstates KK and $\pi\pi$, and CP odd eigenstates $K_s^0\phi$, $K_s^0\rho^0$, and $K_s^0\omega$, and semileptonics $K\ell\nu$ and $K^*\ell\nu$.

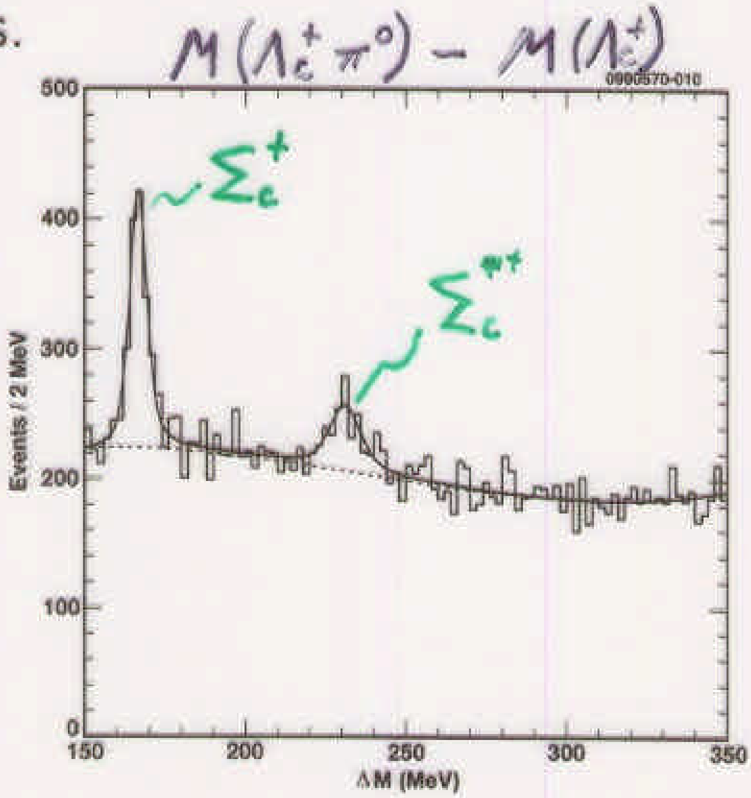
We have new measurements of: (Preliminary!)

$$\mathcal{A}_{CP}(D^0 \to KK) = (+0.04 \pm 2.18 \pm 0.84)\%$$
$$\mathcal{A}_{CP}(D^0 \to \pi\pi) = (+1.94 \pm 3.22 \pm 0.84)\%$$

Charm Baryons

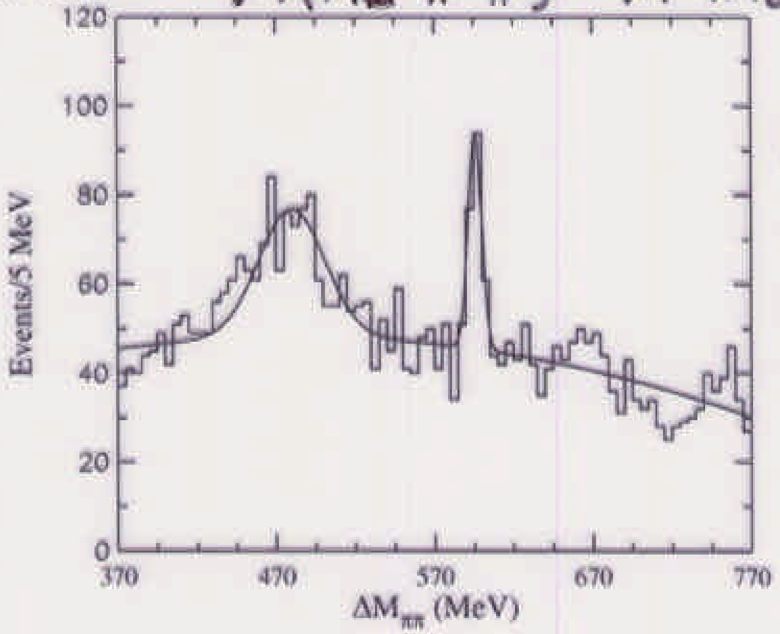
Many new results.

- Observation of the Σ_c^{*+} and new measure of Σ_c^+ mass.



- Observation of the $J^P = \frac{1}{2}^-$ pair Ξ_{c1}^+ and Ξ_{c1}^0.

- Observation of new states in $\Lambda\pi\pi$; wide decaying to Σ_c and Σ_c^*, possibly an orbitally excited Σ_{c1}, and narrow decaying to $\Sigma_c\pi$ and non-resonant, possibly an $L = 1$ between the light quarks.



- CLEO observation of Ω_c, $m(\Omega_c) = 2694.6 \pm 3.5$ MeV.
- New Λ_c results; lifetime, absolute branching fraction, and correlated production.

Measure of $f+-/f00$

From relative rates for $B^0 \to J/\Psi K^{(*)0}$ and $B^+ \to J/\Psi K^{(*)+}$ we extract:

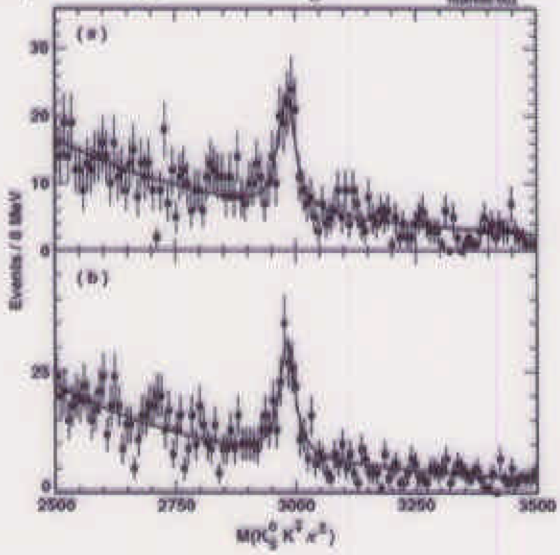
$$\frac{f+-}{f00} \equiv \frac{\Gamma(\Upsilon(4S) \to B^+B^-)}{\Gamma(\Upsilon(4S) \to B^0\bar{B}^0)} = 1.04 \pm 0.07 \pm 0.04$$

and assuming $f+- \; + \; f00 = 1$

$$f+- \; = 0.49 \pm 0.02 \pm 0.01$$
$$f00 \; = 0.51 \pm 0.02 \pm 0.01$$

η_c in 2γ

Observe 300 $2\gamma \to \eta_c \to K^0_s K^{\mp}\pi^{\pm}$



$$m(\eta_c) \; = (2980.4 \pm 2.3 \pm 0.6) MeV$$
$$\Gamma(\eta_c) \; = (27.0 \pm 5.8 \pm 1.4) MeV$$
$$\Gamma_{2\gamma}(\eta_c) \; = (7.6 \pm 0.8 \pm 0.4 \pm 2.3) keV$$

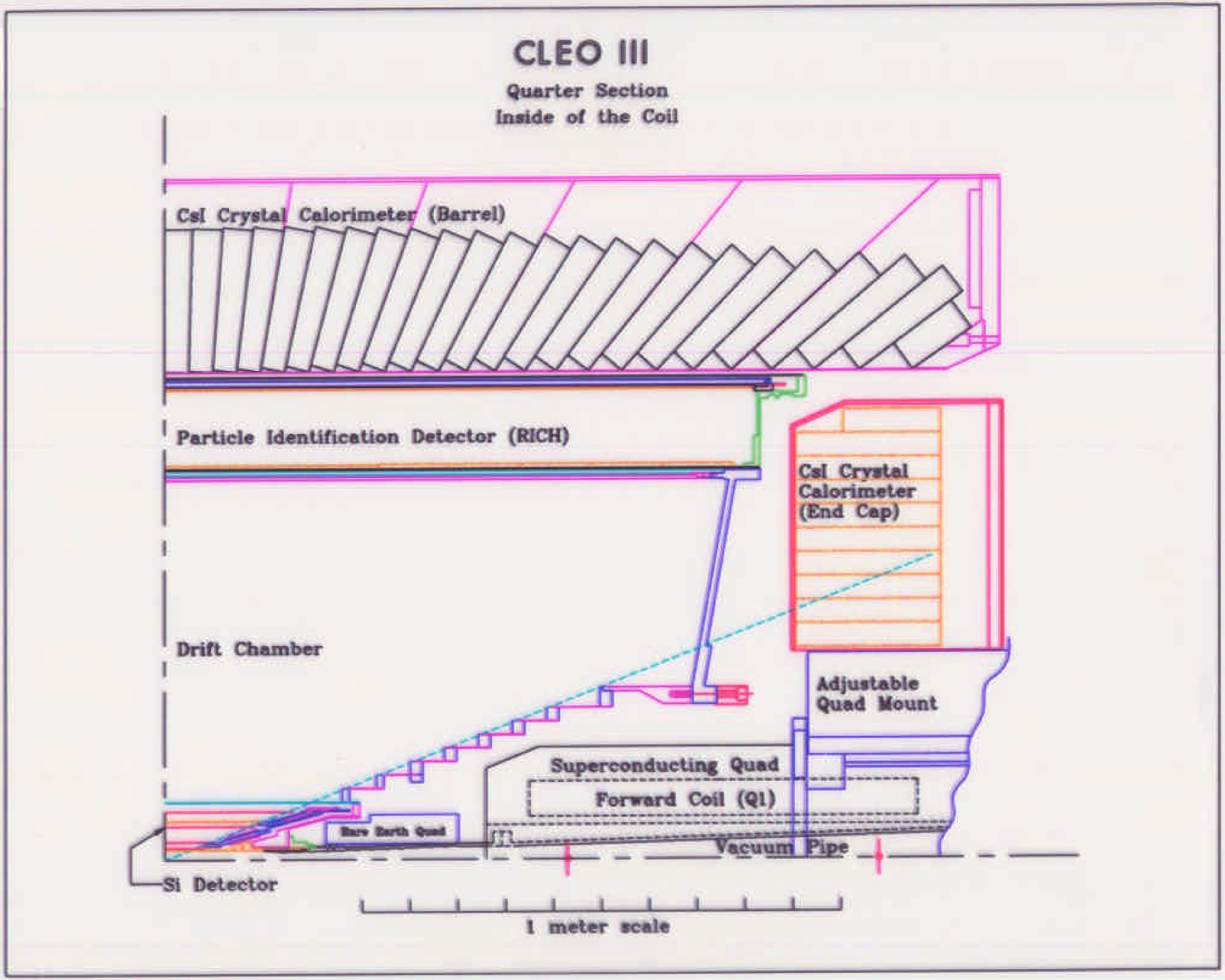
Resolves outstanding disagreement with PQCD.

CLEO III Status

Detector upgrade completed in April 2000. New detector includes:

- New 4 layer double sided silicon strip detector
- New 47 layer drift chamber
- New barrel Ring Imaging CHernkov for particle ID
- Refurbished CsI calorimeter and muon chambers
- New DAQ and trigger system designed to function at luminosity of $5 \times 10^{33}/cm^2 - sec$

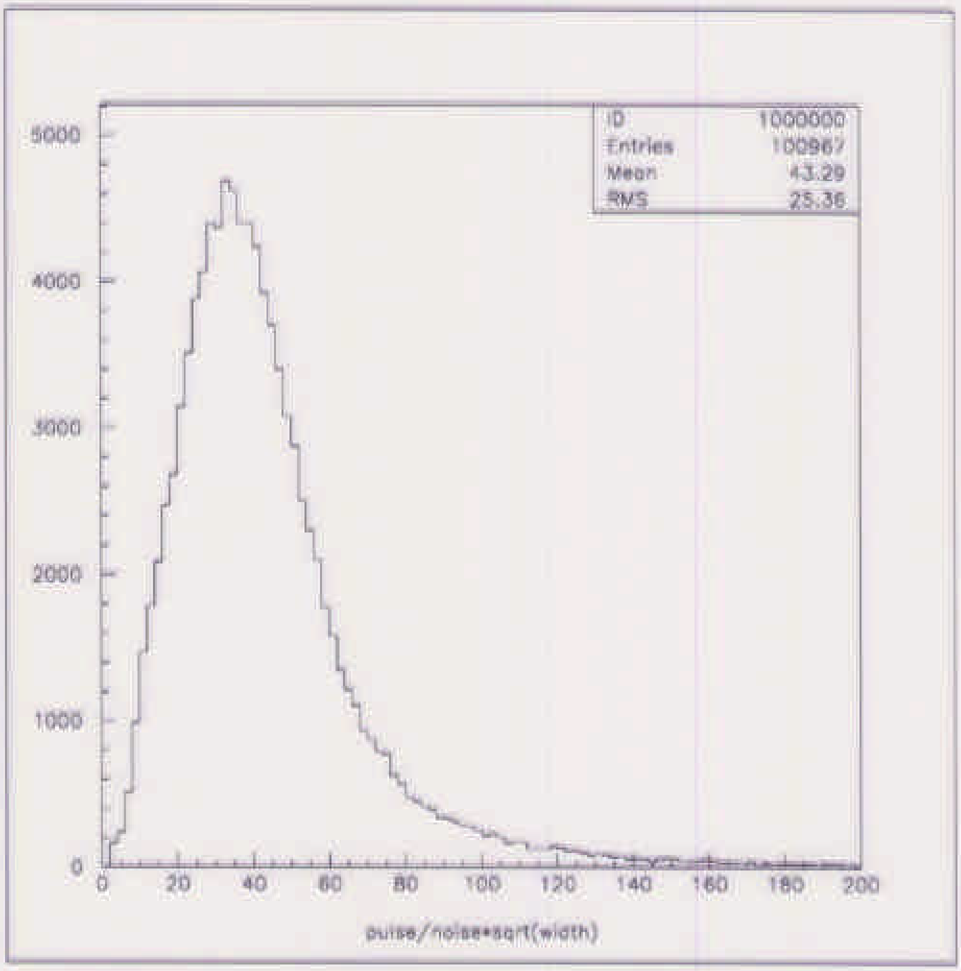
Physics running started in mid-July.



CLEO III
Quarter Section
Inside of the Coil
CsI Crystal Calorimeter (Barrel)
Particle Identification Detector (RICH)
CsI Crystal Calorimeter (End Cap)
Drift Chamber
Adjustable Quad Mount
Superconducting Quad
Forward Coil (Q1)
Rare Earth Quad
Vacuum Pipe
Si Detector
1 meter scale

CLEO III Status: Silicon

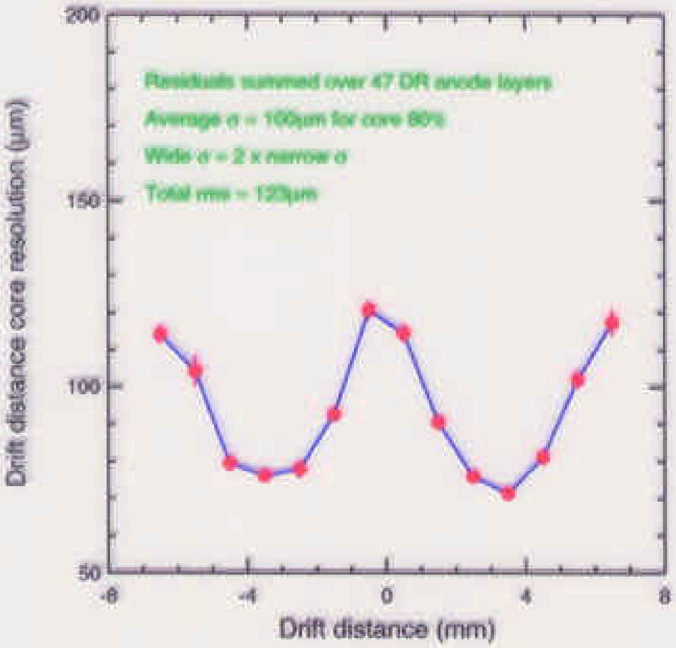
Detector looking good. S/N is 50.



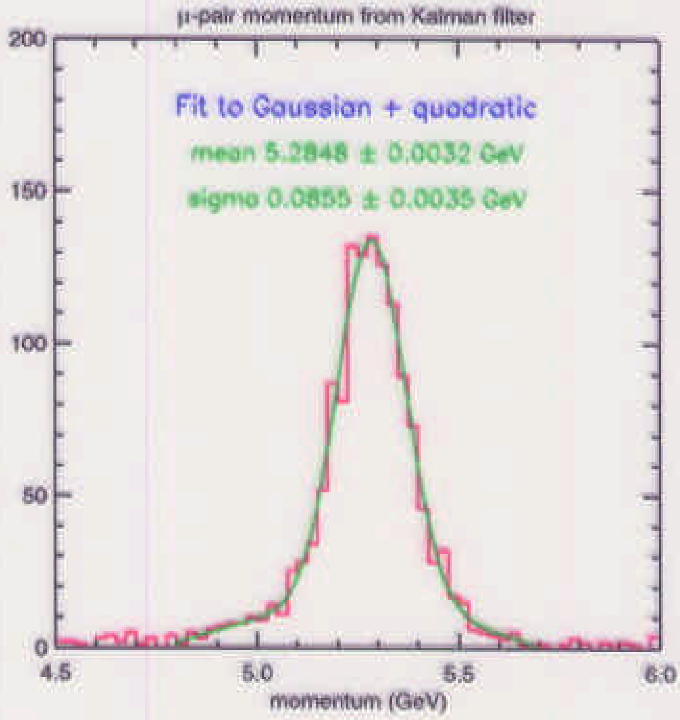
Currently being aligned. Should have point resolution $\sim 10\ \mu$m.

CLEO III Status: Drift Chamber

Working very well. It alone is giving tracking performance as good as CLEO II.

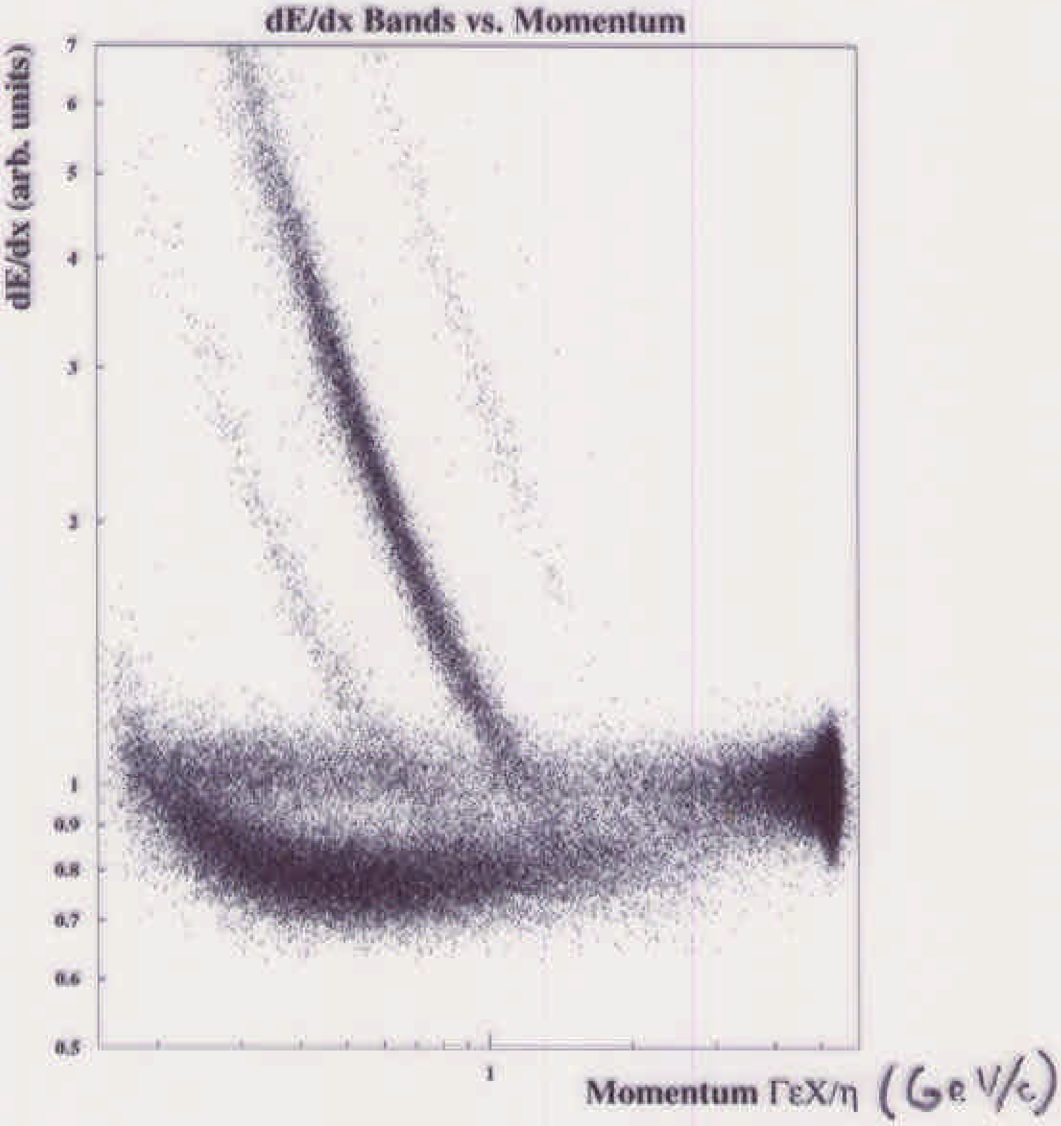


<residual> ~ 100μm



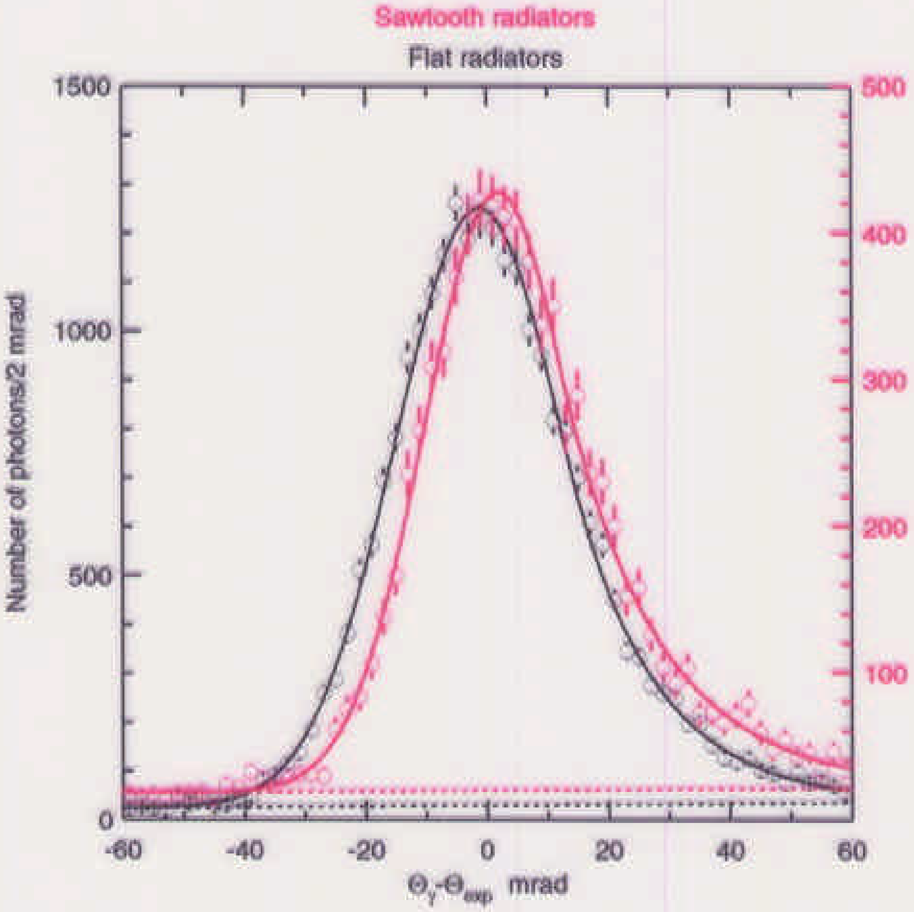
CLEO III Status: dE/dx

Also working very well. Getting 5% resolution. Nearly as good as CLEO II performance. Still more calibration to do.



CLEO III Status: RICH

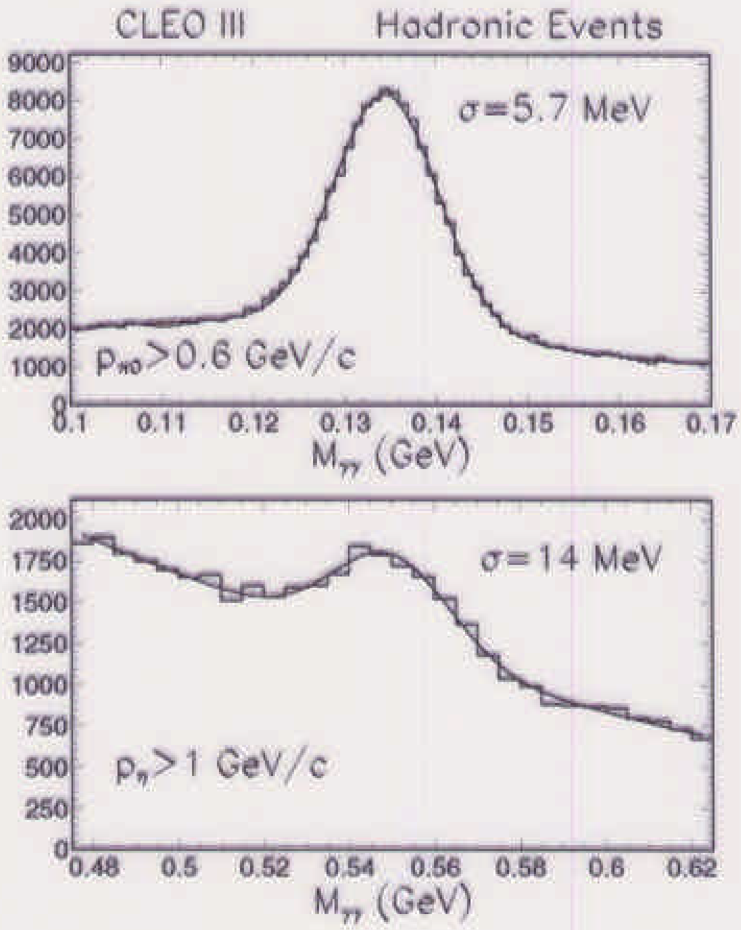
Working well. Resolution on Chernekov angle is 5-7 mrad in hadronic events. Gives 3.5σ πK separation at 3.5 GeV.



Width here dominated by track pointing resolution. Need silicon to improve. Shift is a misalignment between drift chamber + RICH.

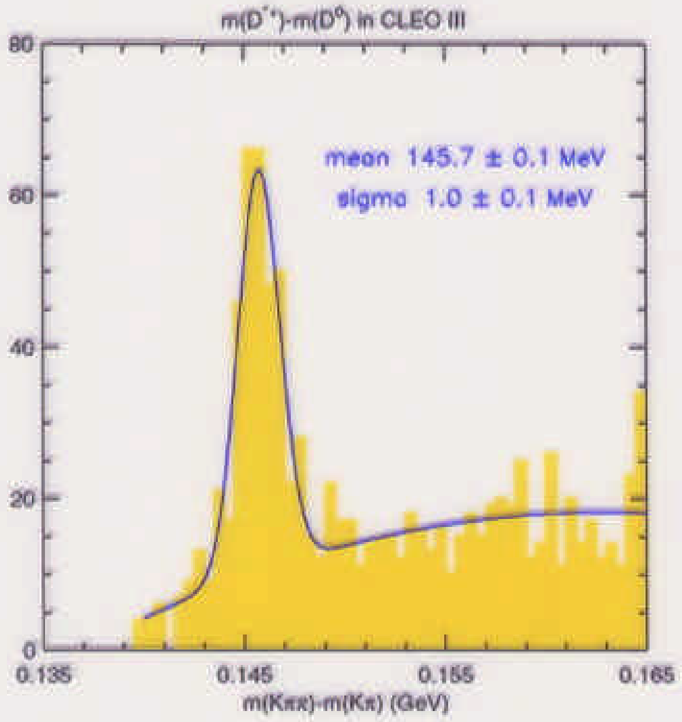
CLEO III Status: Calorimeter

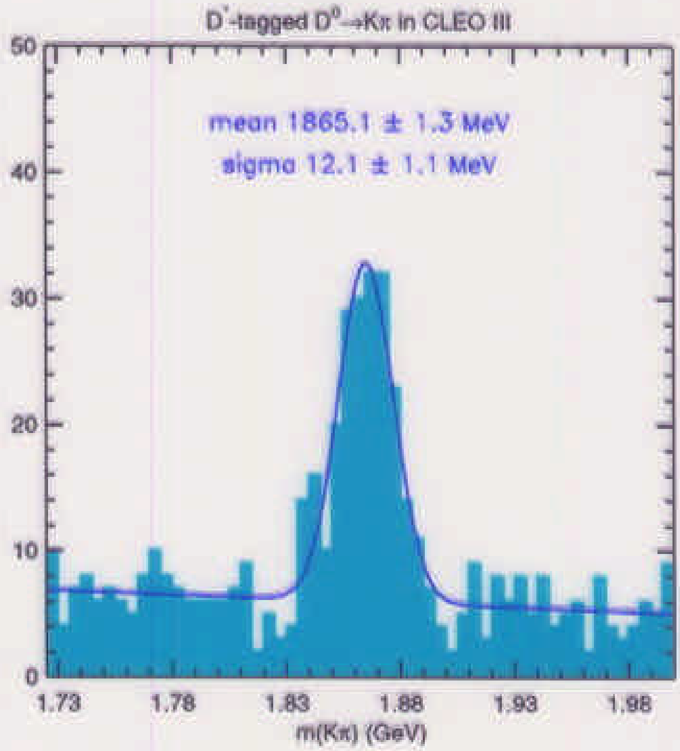
A classic that only gets better. Resolution markedly improved over CLEO II due to reduction in material in tracking volume. For 5 GeV photons 1.3% in barrel, 2.1% in transition, and 1.4% in endcap.

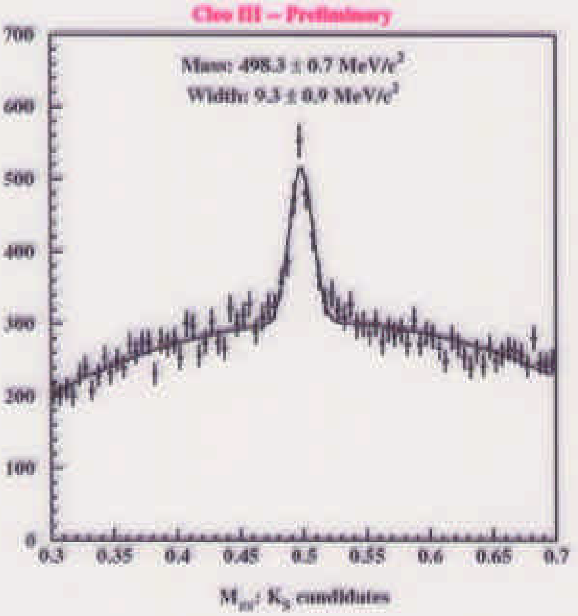


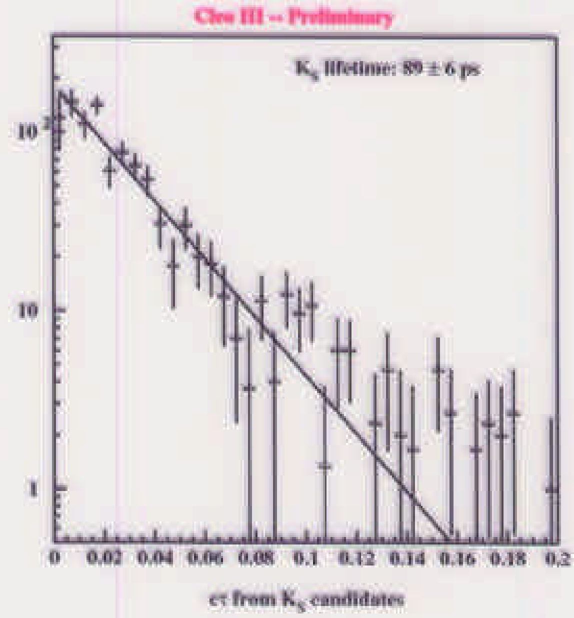
CLEO III Status: Reconstruction

Starting to process useful running taken so far. Tracking only with the drift chamber.



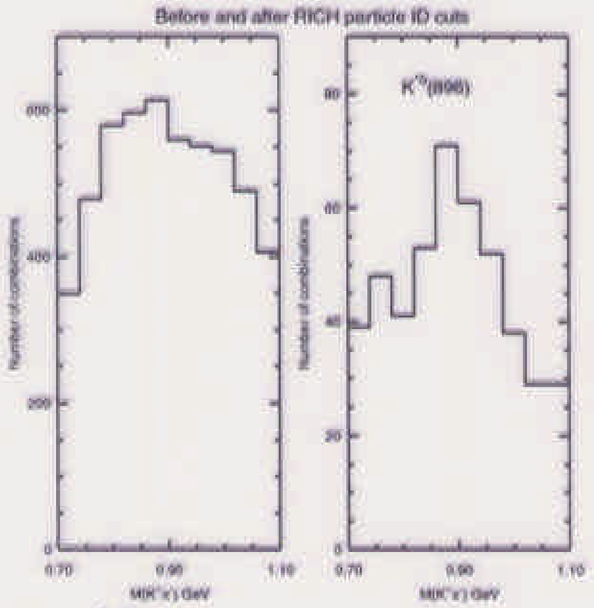






RICH in Hadronic Events

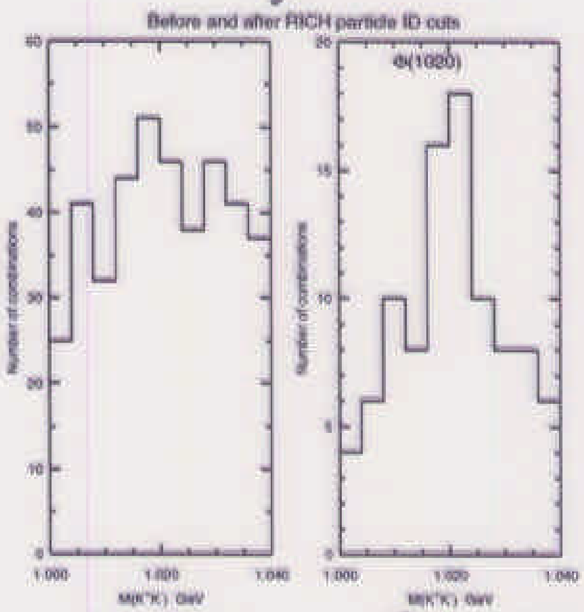
K^{*0}



No RICH

RICH PID

ϕ



No RICH

RICH PID

CESR Status

Peak luminosity for CLEO III ($0.6 \times 10^{33}/cm^2-sec$) is not as good as peak for CLEO II ($0.8 \times 10^{33}/cm^2-sec$). Some source of coupling seems to be blowing up the vertical size. Not yet understood.

Beam current peak has been 0.8 Amps and could easily be increased by as much as 1.5 by going from 9x4 bunches to 9x6. We want to understand the blow up before pushing on this.

Beam related background is not a problem. Occupancy in Silicon and Drift Chamber from beam is negligible. Radiation dose on Silicon is far less than 80 krads/year.

Upgrade of new super-conducting final focus quads and more RF to shorten the bunch can increase luminosity by a factor of two.

Conclusion

- CLEO continues to mine our data for new results. Very wide and deep program.
- Clear gluonic penguin: $B \to \phi K$; $\pi^0\pi^0$ is small.
- Best measure of V_{cb}.
- New high multiplicity hadronic mode: $B \to D^{(*)}4\pi$ and resonant substructure.
- Many other physics results.
- CLEO III detector taking physics data