Past and Future Results from CLEO

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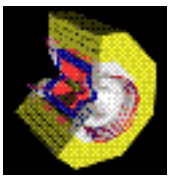
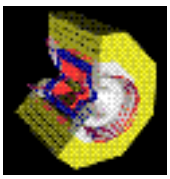
Representing: CalTech, UC San Diego, UC Santa Barbara, Colorado, Cornell, Florida, Harvard, Hawaii, Illinois, IPP, Ithaca Col., Kansas, Minnesota, SUNY Albany, Ohio State, Oklahoma, Purdue, Rochester, SLAC, SMU, Syracuse, Vanderbilt, VPI, Wayne State



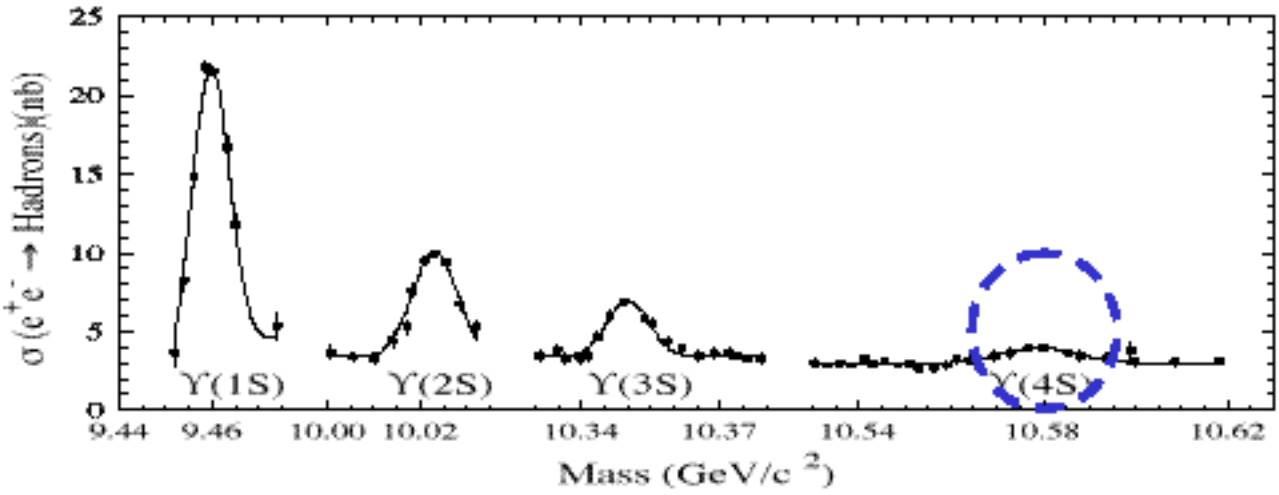
The CLEO Collaboration

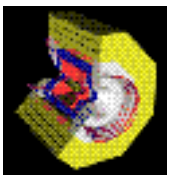
- Some CLEO Demographics:
  - Institutions...
    - Grown from 6 in 1980 to 24 today
    - By funding source...
      6 NSF supported universities (incl. Cornell)
      14 DOE supported universities
      1 DOE national lab
      3 other
    - By geography...
      7 in Northeastern US and Canada
      6 in Midwestern US
      3 in Southeastern US
      8 in Western US
  - People (217 total)...
    - 78 graduate students, 73 postdocs, 66 faculty
    - 124 @ home, 93 @ Cornell (incl. 40 Cornellians)
    - 8 per institution (excl. Cornell)



CLEO II Physics Program

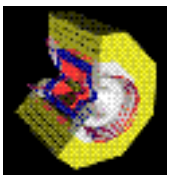
- CLEO is mated with CESR, a symmetric e^+e^- collider running at (or just below) the $\Upsilon(4S)$.
- Available Luminosity: $5fb^{-1}$ pre–SVX "old" data
  $5fb^{-1}$ post–SVX "new" data
  (2:1 ON vs. OFF resonance)
  ($1.4fb^{-1} = 10^6$ B Bbar events)
- Additional Luminosity before CLEO III = + $3fb^{-1}$
  - CLEO II running will end Feb 15 for III installation
  - Data processed in time for summer conferences!
- Record Day: 29.7 pb^{-1}, Record Month: 480.9 pb^{-1} (to tape)





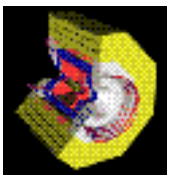
What's happening at CLEO II

- Lots of B physics:
  - Rare decay modes – possibility of direct CP violation
  - CKM matrix measurements from semileptonics
  - Amplitude analyses of hadronic decays
  - Search for new physics in penguin loops
- Charm decays (both on and off $\Upsilon(4S)$)
  - Baryon spectroscopy – many new states
  - Precision lifetime measurements with silicon vertex
  - Mixing vs. DCSD decays
  - Possibility of CP violation
- Tau physics – world's largest sample
  - Michel parameters to few percent level
  - Light hadron resonance studies
  - Search for "forbidden" decays
- Two photon physics, Υ spectroscopy,...

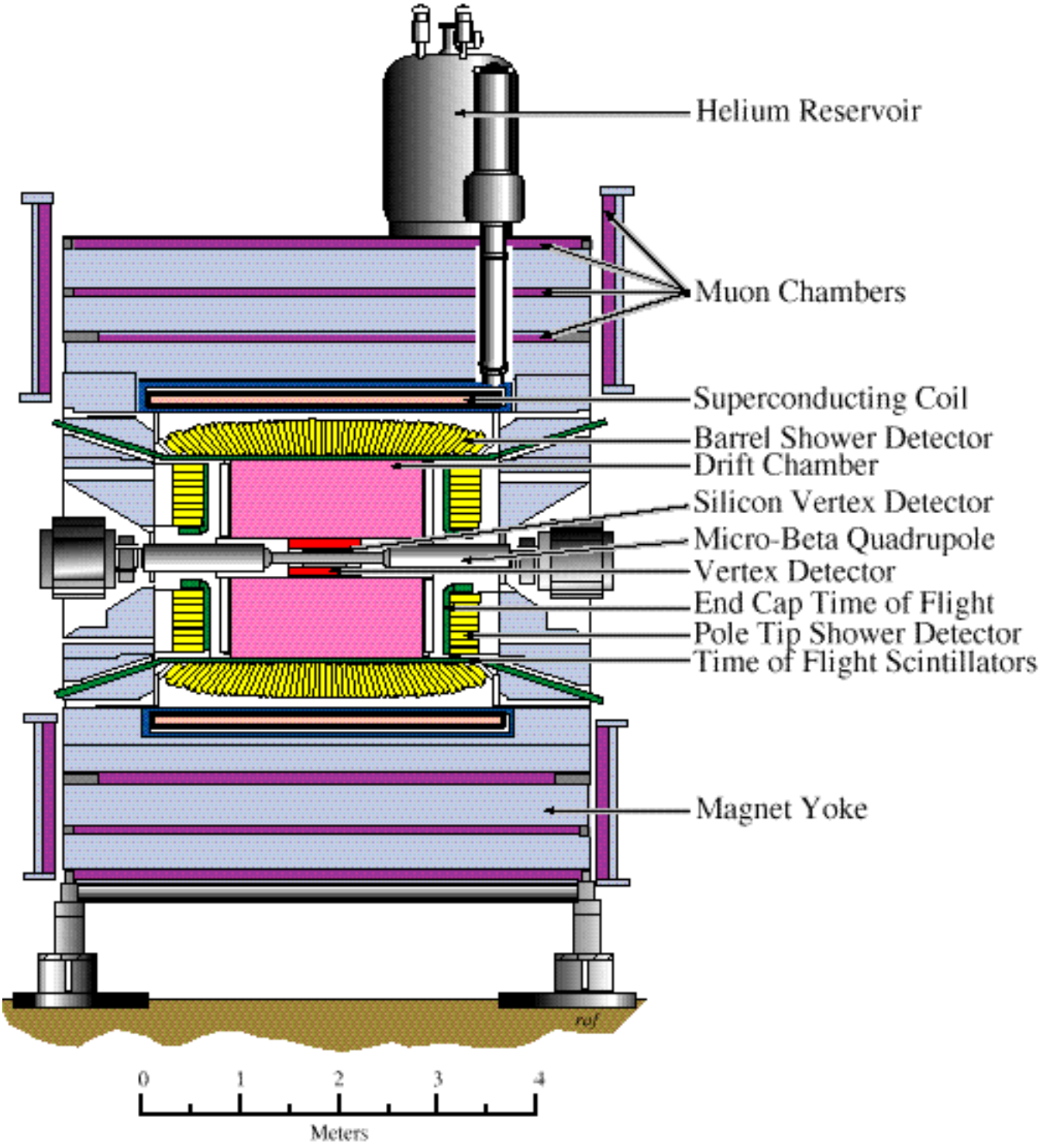


What's Coming with CLEO III

- More Luminosity...
  - Needed for detailed study of "rare" channels
  - Peak Lum : $6 \cdot 10^{32}$ –> $2 \cdot 10^{33}\ cm^{2}s^{-1}$ as soon as possible
  - Total integrated Lum: $15\ fb^{-1}$ –> $75\ fb^{-1}$
  - N (B-Bbar): $10 \cdot 10^{6}$ –> $50 \cdot 10^{6}$
- Much better Particle ID...
  - We do well now for p < 1 GeV/c with dE/dx and TOF
  - Need good K/π separation for p > 1 GeV/c
  - Examples:
    - B –> two body final states ($K\pi/\pi\pi, K\rho/\pi\rho, DK/D\pi$) which are important for CP angle measurements
    - tagging D's via $K\pi$ identification, not just D* parentage
- New, more integrated Tracking System...
  - Better tracking efficiency and resolution
  - Improved charm vertexing for signal and background tags
  - Time to replace aging detectors
  - Need space for PID addition before calorimeter
  - New SC final focus quads won't fit in old system



CLEO II/SVX Detector



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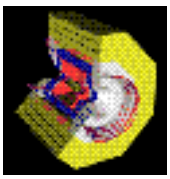
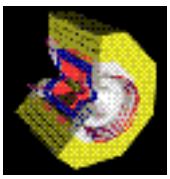
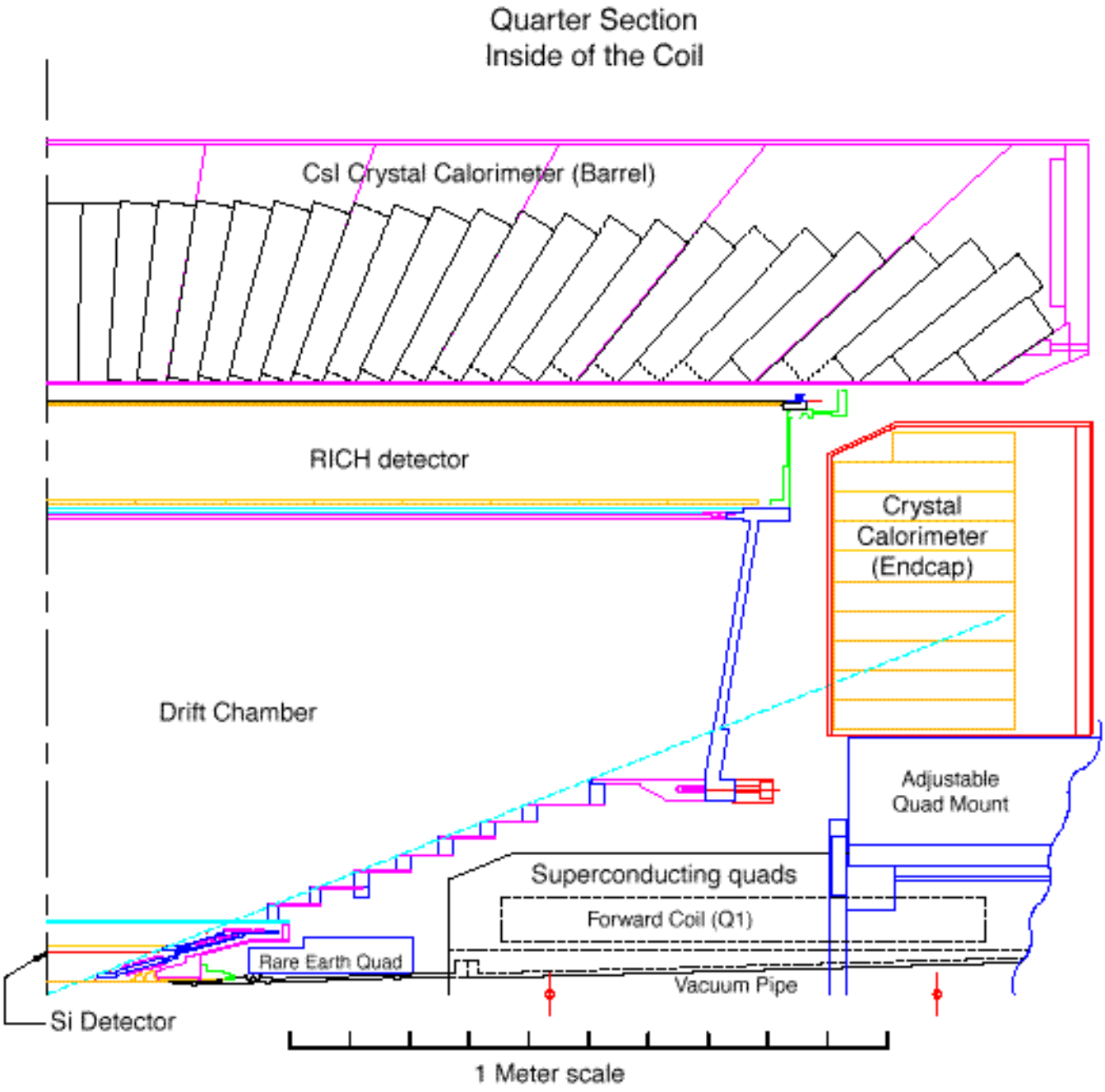


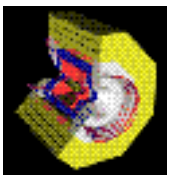
CLEO II/SVX –> III

- Muon Detectors will remain in the iron return yoke...
  - Prop tube layers at 3, 5, 7 interaction lengths
  - Pion–>muon fake rate ≈ 1.5% at 1.5 GeV/c
  - New electronics for higher DAQ readout rates (Cornell)
- CsI Calorimeter remains inside solenoid coil...
  - 6144 crystals in barrel, 2*828 in endcaps
  - Typical energy resolution ≈ 2.2% at 1 GeV
  - Endcap being rebuilt to accommodate SC quads (Minn)
  - New electronics for higher DAQ readout rates (Cornell)
- Inner tracking will be replaced (along with RE Quads)...
  - 51 layer central drift chamber
  - 10 layer vertex drift chamber
  - 3 layer silicon vertex detector
  - Double-walled, water-cooled Be beampipe & masks



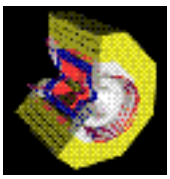
CLEO III Inner Detector





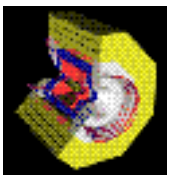
New in CLEO III

- RICH system for particle ID (Syracuse, SMU, Minn, Alb)
  - LiF radiator cylinder inside γ detector cylinder
  - Detectors are 30 TEA-methane wire chambers
  - Material minimized: 5% X_0 in front, 13% X_0 in RICH
  - Excellent K/π sep. (≥4σ) for full B decay mom. range
- Drift Chamber (DR3) (Cornell, Roch, Vand)
  - 16 axial inner layers (1696 cells) followed by 8 stereo super layers (8100 cells)
  - "Wedding cake" axial section to fit SC Quads
  - Conical endplate reduces material before Endcap Cal
  - HeProp. mix (in use now) reduces mult scat., Lorentz ang.
  - Resolution ≈ 120μ per hit
- Silicon Vertex Det. (Si3) (OSU, Cor, Pur, Har, Okla, Kan)
  - 4 layers of double sided detectors – 125K channels
  - Good thermal control and alignment
  - Well matched to DR3 for tracking (slow tracks & z)
  - S/N > 20 for all layers with rφ hit resolution ≈ 6μ



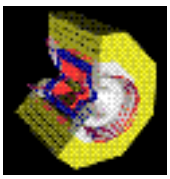
New in CLEO III (cont.)

- Interaction Region and Beampipe (Cornell, Wayne St.)
  - Double-Wall Be Beampipe thinner: 0.6%–>0.45% X_0
  - Magic flange for rapid/safe assembly, PF200 cooling
  - Masks, coatings carefully designed to reduce background
- Trigger System (Illinois, Cornell)
  - Axial tracking uses all axial wires for rφ tracks
  - Stereo tracking uses 4x12 wire sectors
  - Calorimeter sums formed with 4x4 crystal arrays
- DAQ System (OSU, Caltech, Cornell, SMU, Kan)
  - Unified VME/Fastbus readout system all detectors
  - New online software with flexible user interface (GUI)
  - Commissioning will begin in March with Cal and Muons
- Software (Cornell, Florida, plus everyone else eventually)
  - "SUEZ" framework flexibly includes user written reconstruction/analysis modules
  - Extensive use of Objectivity database (data, const,...)
  - Existing FORTRAN analysis modules wrapped in C++



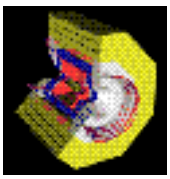
CLEO III Upgrade Summary

Component	Features	Ready
Int. Region	Liquid-cooled Be beampipe with coatings for background reduction	Nov 98
DAQ	Unified VME/Fastbus system with modern user interface	Feb 99 (partial)
Trigger	Axial tracking plus calorimeter (eventually stereo tracking)	Feb 99 (partial)
Silicon VD	4 layers, 125K channels, with low noise (S/N > 20), high res ($\sigma \approx 6\mu$)	Mar 99
DR Chamb	16 axial layers (1696 cells) and 8 stereo super layers (8100 cells)	Mar 99
RICH	LiF radiators, TEA-meth chamb, excellent K/π sep. for B decays	Jun 99
Calorimeter	New readout plus repackaged endcap region	Jun 99
Software	New architecture with tried and true routines wrapped in C++	Feb 99... (ongoing)



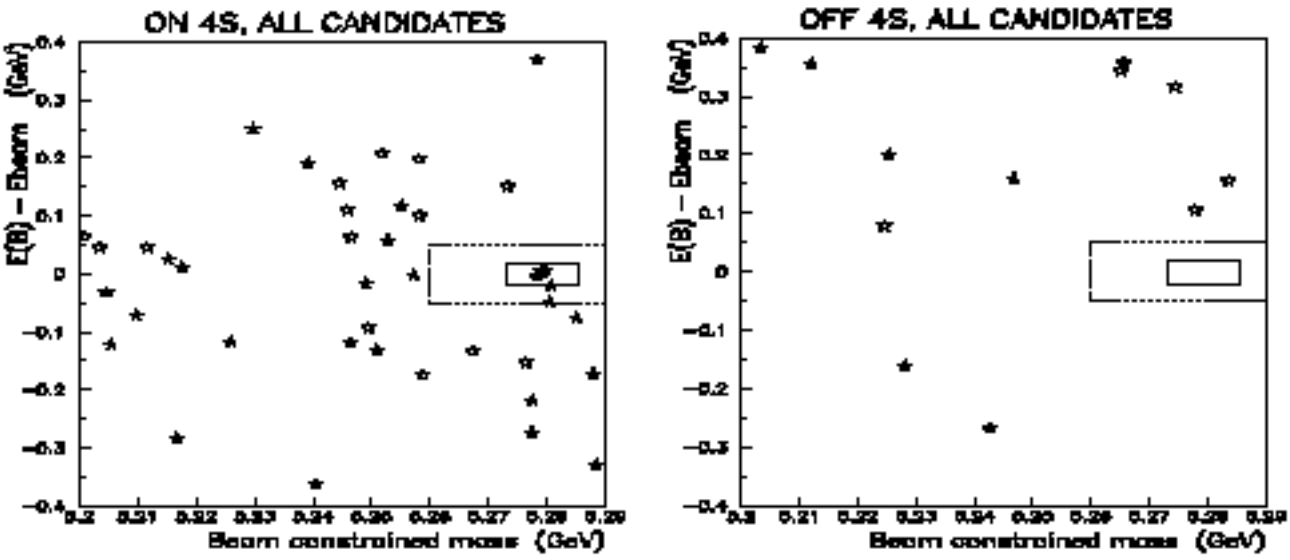
A Sampling of CLEO II Results

- Latest (Preliminary!) results for the following
  - First observation of $B^0 \rightarrow D^{*+} D^{*-}$
    (CLEO CONF 98-07, 8.5 fb^{-1}, paper draft underway)
  - Amplitude analysis in $B \rightarrow D^* \rho^-$
    (CLEO CONF 98-23, 5 fb^{-1})
  - V_{ub} measurement in $B \rightarrow (\rho,\omega)\, l\, \nu$
    (CLEO CONF 98-18, 5 fb^{-1})
  - Observation of $B \rightarrow K\, \pi$ channels
    (CLEO CONF 98-20, 8.5 fb^{-1})
  - Electromagnetic Penguins in $b \rightarrow s\, \gamma$
    (CLEO CONF 98-17, 5 fb^{-1})
  - Precision measurement of D lifetimes
    (CLEO CONF 98-15, 4 fb^{-1}, paper draft underway)
  - Observation of "Wrong-Sign" $D^0 \rightarrow K^+ \pi^-$
    (brand-new at FNAL fixed target workshop)
  - $\tau \rightarrow \pi^- \pi^0 \pi^0 \nu_\tau$ Structure
    (CLEO CONF 98-19, 5 fb^{-1})
- And much more that I don't have time to cover

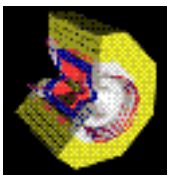


First observation of $B^0 \rightarrow D^{*+} D^{*-}$

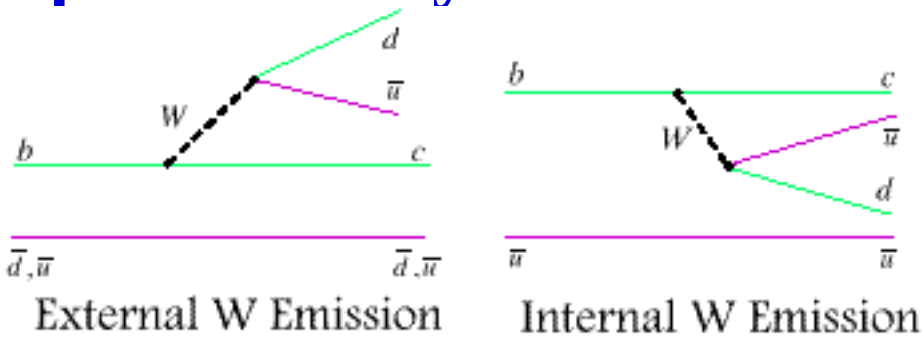
- Potential channel for time-dependent CP violation studies
  - Measures β as with $B \rightarrow J/\psi K^0$
  - Mixture of CP–even and CP–odd
  - Angular correlations can separate CP states
- Event selection using dE/dx, TOF, and SVX (when available)
- Kinem. cuts using $\Delta E = E - E_{beam}$ and $M_{BC} = \sqrt{(E^2_{beam} - \mathbf{p}^2_B)}$
  - Background estimated using "grand side band"



- Preliminary BR = [6.2 +4.0/–2.9 (stat) ± 1.0 (syst)] x 10^{-4}
  - Four events with est. background of 0.3 ± 0.1 events
  - Total BR (D* incl.) comparable to $B \rightarrow J/\psi K^0$, but lower eff.



Amplitude analysis in B → D* ρ

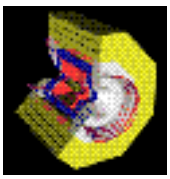


- Partial Wave Anal. done for complete angular distribution
  - $B^0 \rightarrow D^{*-} \rho^+$ involves only External W emission
  - $B^+ \rightarrow D^{*0} \rho^+$ involves both Ext. and Internal W emission

(Preliminary)

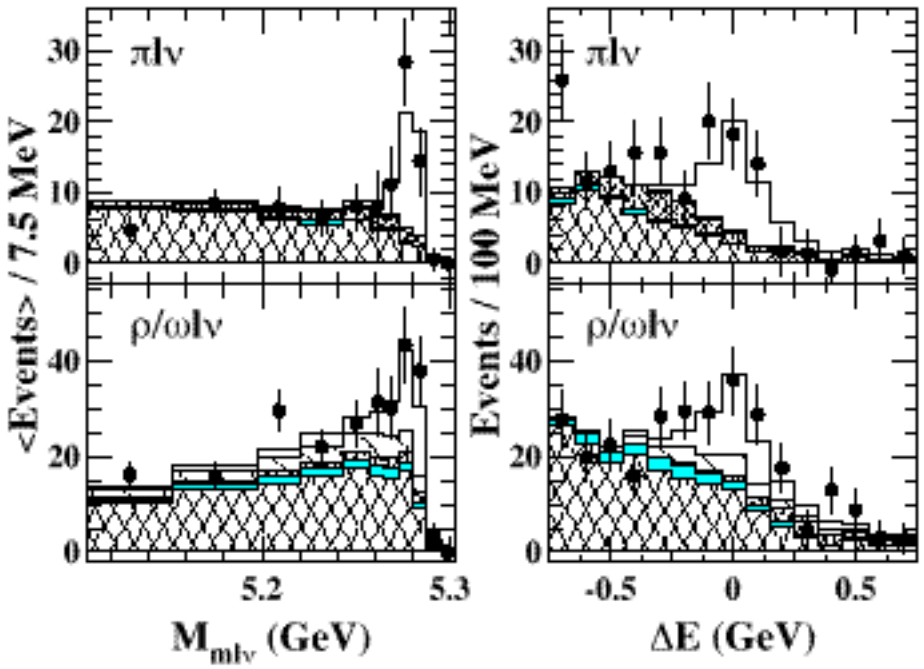
$B^0 \rightarrow D\rho^+$	magnitude	phase
H_0	0.936	0
H_-	$0.317 \pm 0.052 \pm 0.013$	$0.19 \pm 0.23 \pm 0.14$
H_+	$0.152 \pm 0.058 \pm 0.037$	$1.47 \pm 0.37 \pm 0.32$
$B^+ \rightarrow \bar{D}^0\rho^+$	magnitude	phase
H_0	0.932	0
H_-	$0.283 \pm 0.068 \pm 0.039$	$1.13 \pm 0.27 \pm 0.17$
H_+	$0.228 \pm 0.069 \pm 0.036$	$0.95 \pm 0.31 \pm 0.19$

- Non-trivial phases show hint of final state interaction
- D^{*-} long. polarization (H_0^2) measured to be 87.8 ± 4.5%
  - Compare: D* l ν at $q^2 = m_\rho^2$ (.85−.88)– factorization OK

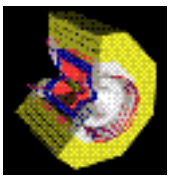


V_{ub} measurement in $B \rightarrow (\pi,\rho,\omega)\, l\, \nu$

- Exclusive decays with missing neutrino reconstruction
  - BR was measured to 12% – limited by ν reconstruction eff.
  - V_{ub} extraction had 20% systematic error from models
  - $|V_{ub}| = (3.3 \pm 0.2 \pm 0.4 \pm 0.7) \times 10^{-3}$



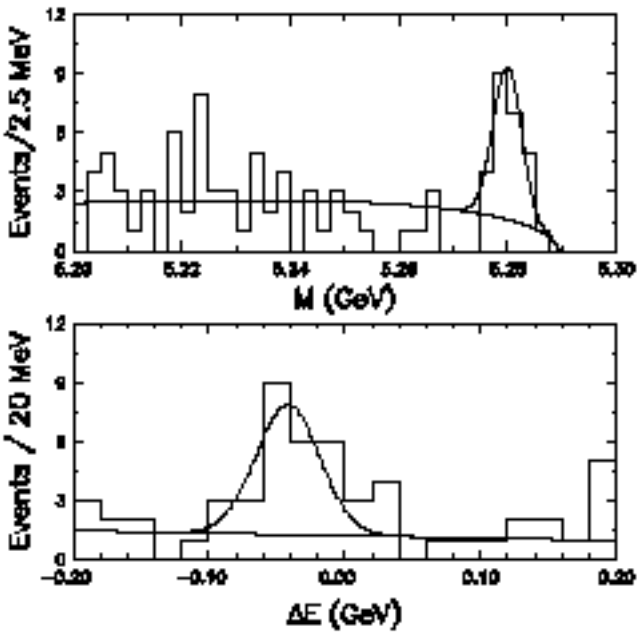
- New analysis with high mom. leptons (p>2.3), looser ν cuts
  - Preliminary $|V_{ub}| = (3.2 \pm 0.3 \pm 0.3 \pm 0.6) \times 10^{-3}$
  - ρlν form factor also measured: $\rho^2 = .52 \pm .11 \pm .09 \pm .05$
- Both CLEO meas. are consistent (not totally indep) – need better modelling and form factor calculations to improve



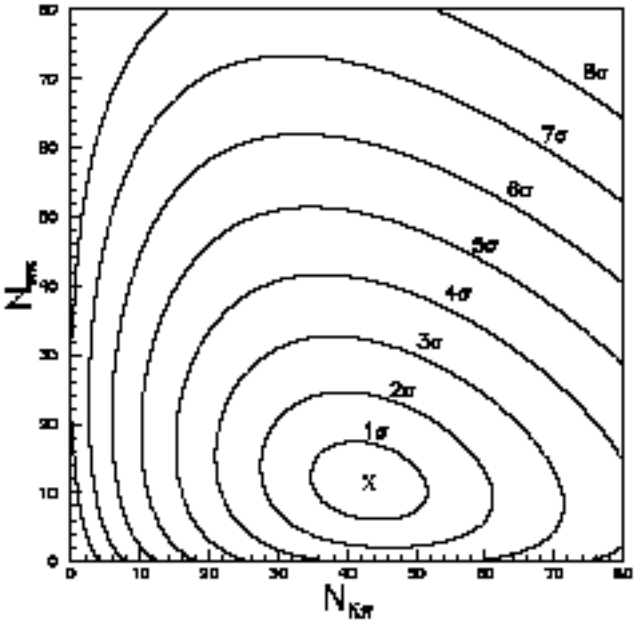
Observation of B → K π channels

- New results available for $K^+\pi^-$ and $\pi^+\pi^-$ (preliminary)
  - $K^+\pi^-$ proceeds primarily by penguin diag, $\pi^+\pi^-$ by tree
  - $K^+\pi^-$ fit projections shown below, but no evidence for $\pi^+\pi^-$
  - Penguin dominance makes CP angle meas. more difficult

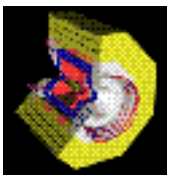
$K^+\pi^-$ M_{BC} and ΔE



$N_{\pi\pi}$ vs. $N_{K\pi}$



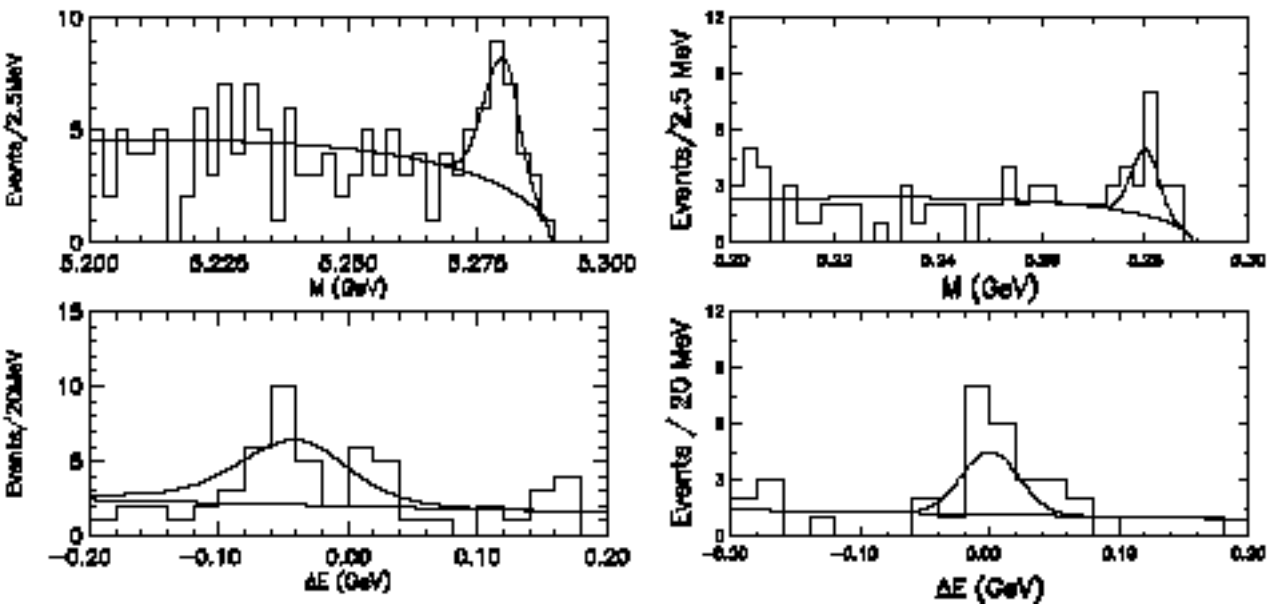
- Also have K^0 and π^0 channels...



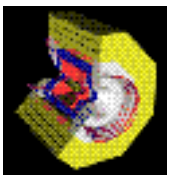
B → K π (cont.)

- Adding K_S and π^0 yields two addtional K π channels
  - First observation of $K^+\pi^0$
  - $K_S\pi^-$ channel (pure penguin)

$K^+\pi^0$ $K_S\pi^-$

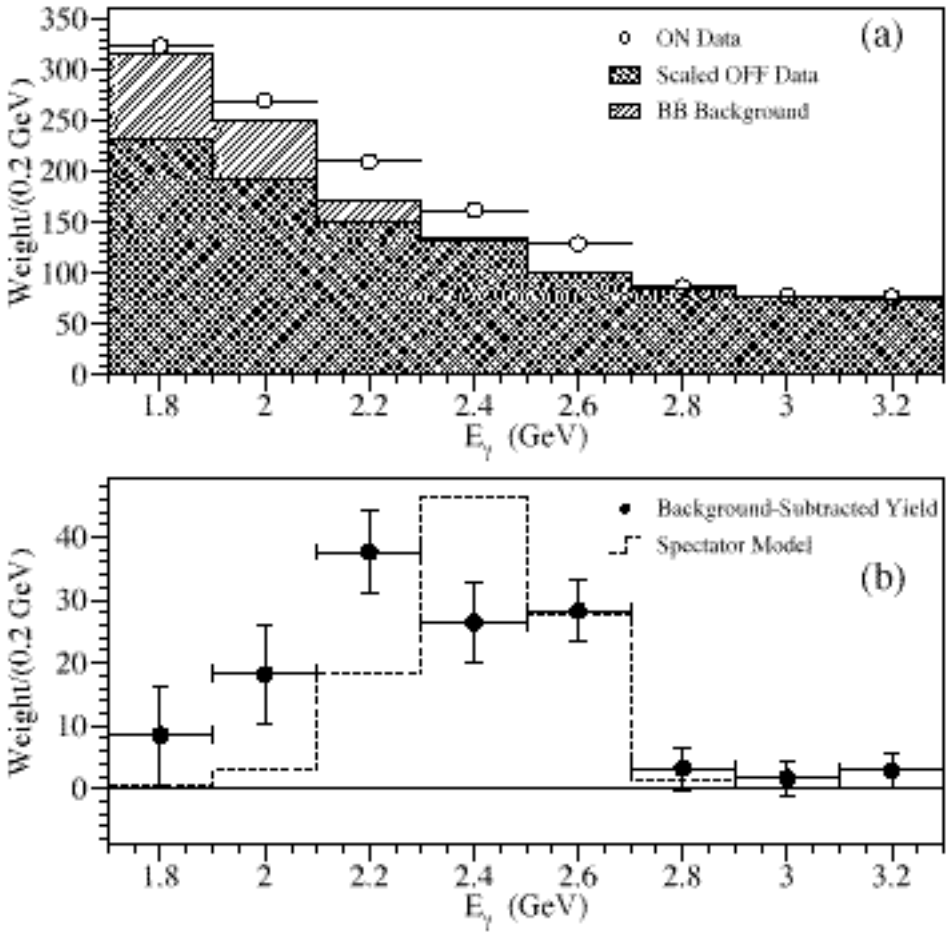


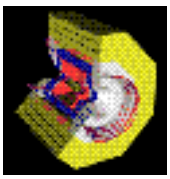
- Preliminary branching ratios:
  - $BR(K^+\pi^-) \times 10^5 = 1.4 \pm 0.3 \pm 0.2$ (theory 0.7–2.4)
  - $BR(K^+\pi^0) \times 10^5 = 1.5 \pm 0.4 \pm 0.3$ (theory 0.3–1.3)
  - $BR(K^0\pi^+) \times 10^5 = 1.4 \pm 0.5 \pm 0.2$ (theory 0.8–1.5)
  - $BR(\pi^+\pi^-) \times 10^5 < 0.84$ (theory 0.8–2.6)
  - $BR(\pi^+\pi^0) \times 10^5 < 1.6$ (theory 0.4–2.0)



Electromagnetic Penguins in b → s γ

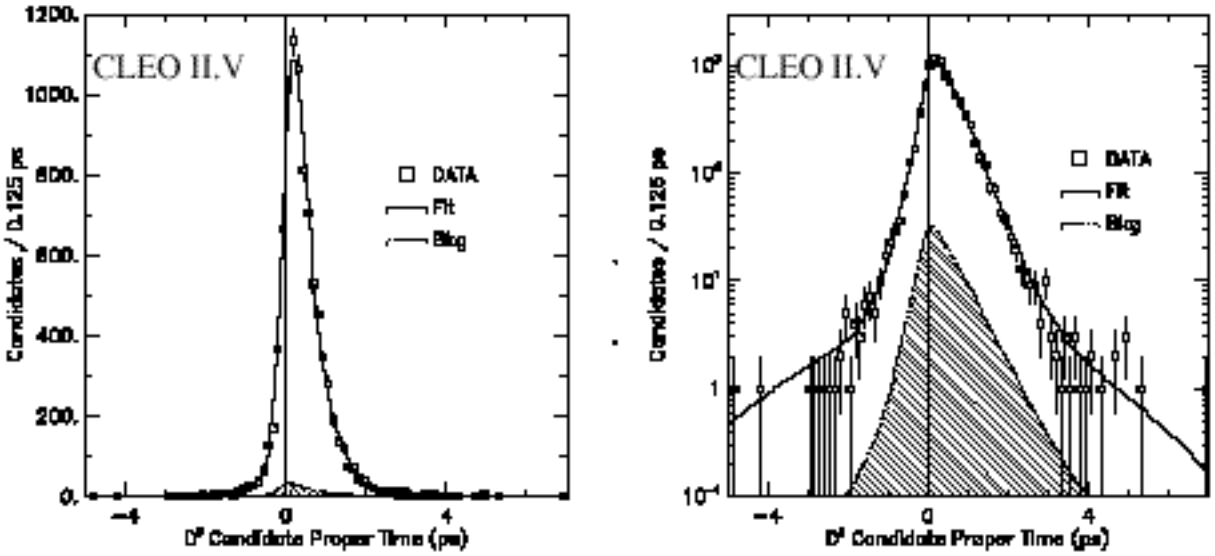
- Important for physics beyond SM, e.g. SUSY Higgs
- New analysis combines features (weights) of both old ones
  - Largest backgrounds: continuum, init-state radiation
  - Neural net weight uses event shape to reject contin.
  - Reconst. weight based on exclusive K channel existence
- Preliminary result BR = $(3.15 \pm 0.35 \pm 0.32 \pm 0.36) \times 10^{-4}$



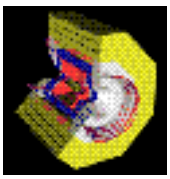


Precision measurement of D lifetimes

- Utilizing new silicon vertex detector
  - $D^0 \rightarrow K^-\pi^+$ tagged via D* decay
  - D flight path intersected with flat beam spot
  - 2-D info used in max. likelihood fit
  - Preliminary $\tau\ (D^0) = 408.5 \pm 4.1 \pm 3.0$ fs (comp to PDG av)

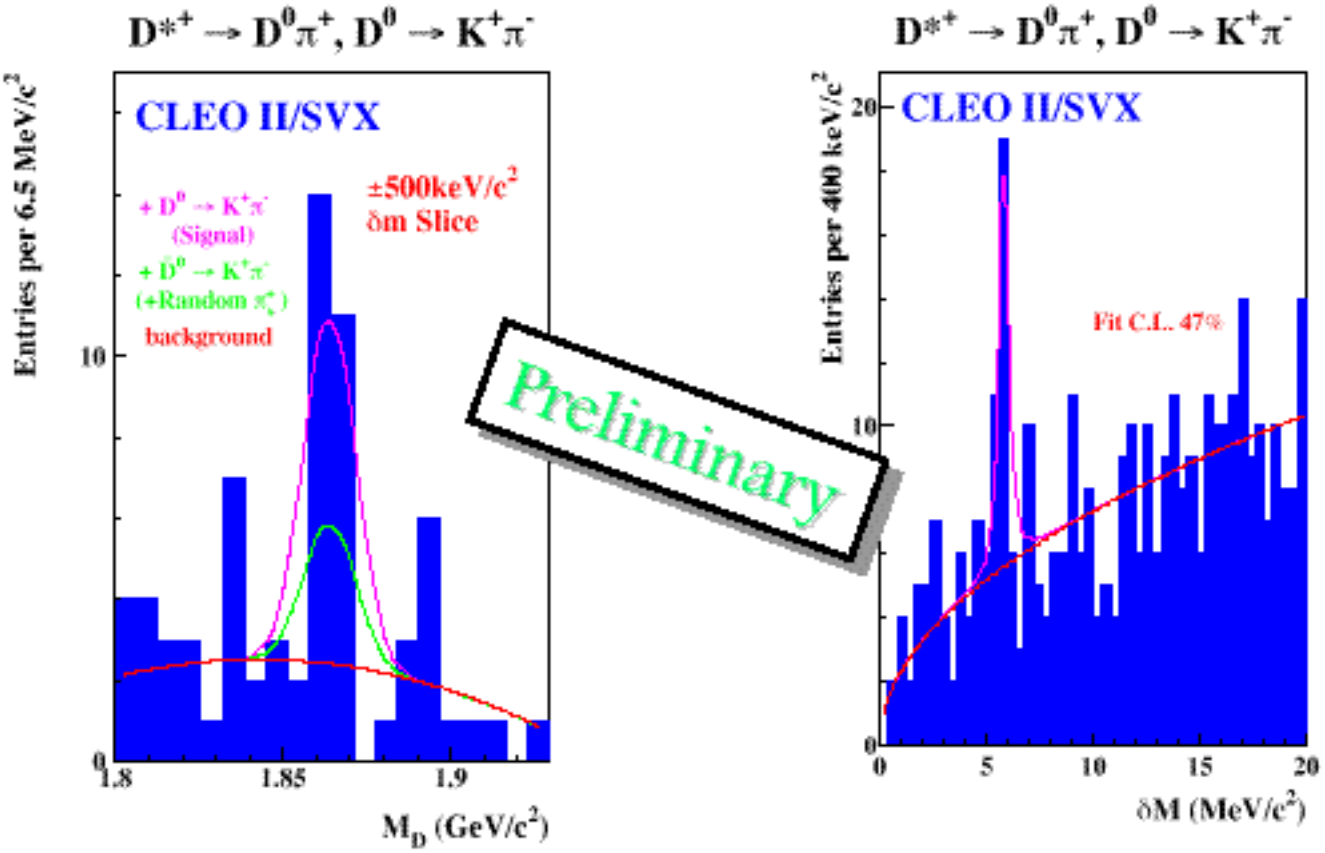


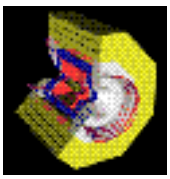
- Preliminary D^+ and D_S^+ lifetimes also measured
  - $\tau\ (D^+) = 1033.6 \pm 22.1\ ^{+7.4}_{-10.9}$ fs
  - $\tau\ (D_S^+) = 486.3 \pm 15.0 \pm 4.0$ fs (better than PDG av!)



Observation of "Wrong-Sign" $D^0 \to K^+ \pi^-$

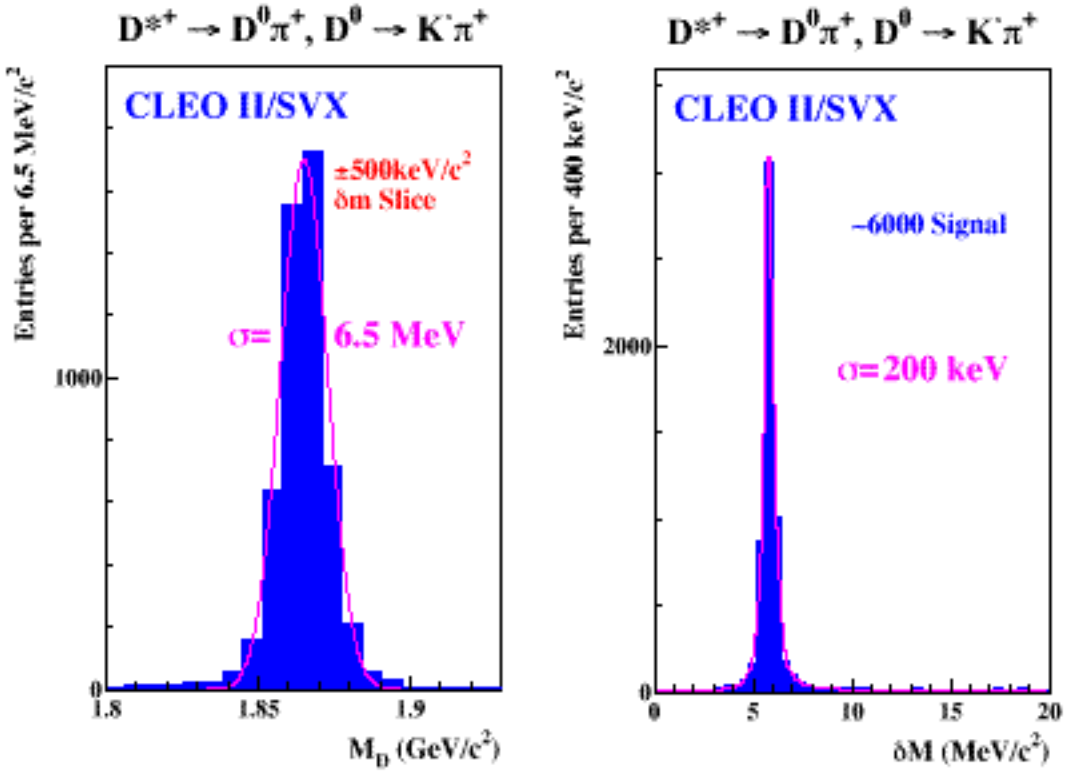
- Tagged by parent $D^{*+} \to D^0 \pi^+$ decay
  - Select using dE/dx for K/π, M_D, and $\delta m = M_{D^*} - M_D$
  - Backgrounds: uncorrelated π^+, K/π misidentification
- Preliminary result: $\Gamma(WS)/\Gamma(RS) = 0.0032 \pm 0.0012 \pm 0.0015$
  - Could be either DCSD or result of D mixing
  - Disentangle with time dependence study (in progress)

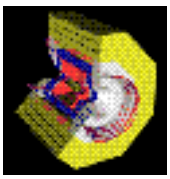




"Right-Sign" $D^0 \rightarrow K^- \pi^+$

(Preliminary)



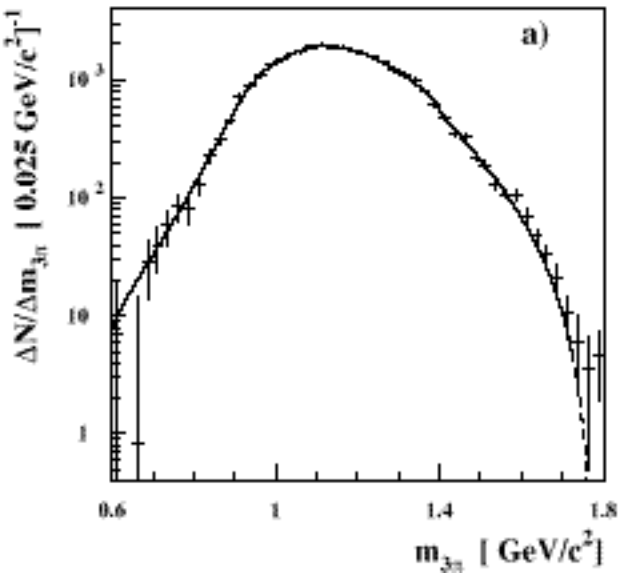


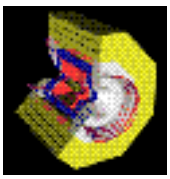
$\tau \rightarrow \pi^- \pi^0 \pi^0 \nu_\tau$ Structure

- Decay is dominated by S-wave $a_1 \rightarrow \rho \pi$
  - $a_1 \rightarrow 3\pi$ is poorly understood (since early sixties)
  - Hadronic mass shape important for ν_τ measurements
  - Double π^0 channel less confused than $\pi^+ \pi^- \pi^-$
- Preliminary results use 4.3 million τ pairs
- Partial waves rel. to ρ S–Wave:

		Signif	BR (%)
ρ	D	5.0σ	$0.36 \pm 0.17 \pm 0.06$
$\rho(1450)$	D	3.1σ	$0.43 \pm 0.28 \pm 0.06$
$f_2(1275)$	P	4.2σ	$0.14 \pm 0.06 \pm 0.02$
σ	P	8.2σ	$16.2 \pm 3.9 \pm 1.3$
$f_0(1370)$	P	5.4σ	$4.29 \pm 2.29 \pm 0.73$

3π Invariant Mass





CLEO Future Prospects

- Two more months of CLEO II/SVX data-taking
  - Expect final total luminosity of 13 fb^{-1}
  - Will have offline analysis complete by summer
  - New results will be finalized with complete data
- CLEO III commissioning begins in early fall of 99
- We're looking forward to:
  - Even more luminosity
  - Good K/π separation for all B decays
  - Excellent tracking and vertexing
  - Competition with Babar and Belle!
- Some CLEO III physics expectations
  - $|V_{ub}|$ measured to better than 10%
  - $B \rightarrow \tau\nu$ observation to ± 20% (f_B measurement)
  - $b \rightarrow s\gamma$ measured to better than 10% (new physics?)
  - $B \rightarrow K^+\pi^-$ measured to ±5%
  - Any $B \rightarrow K^+\pi^-$ asymmetry > 25% meas. with 4σ accuracy
  - And plenty more including charm and τ physics...
- In the meantime we have lots of hard work to do!