New Results on FNC Decays

- $B \rightarrow K^{(*)} \pi^+ \pi^-$

First Measurement of "Wrong-Sign" $D^0 \rightarrow K^+ \pi^-$ Rate

New Fits to $D^0$ Proper Time and $\rho$ Measurement

CP Violation in $D^0$ Decays to Pairs of Pseudoscalar Mesons

Search for CP Violation in $\Upsilon$ Decays

CP Asymmetries in Charmless Hadronic B Decays

- $B \rightarrow J/\psi K^+$ and $B \rightarrow J/\psi (2S) K^+$

Exclusive Penguins and CP Asymmetry

Bounds on CP Asymmetry in $B^0 \rightarrow D_S^0 \ell \nu$ Decays

Searches for CP Violation and New Physics at CLEO

June 15, 2001
General Purpose e+e- Detector

- T3: beam-gas reflection (software)
  - L1 and L2: VD, CSl, TOP
  - L0: VD, TOP (or CSl)

Trigger

Time-of-flight (TOF) scintillator

Specific ionization energy losses (DEEX)

Particle identification

Muon system (85% ATr, |η| < 1.0 GEV/c)

\( \frac{(\frac{(\frac{dE}{dx})_{\text{GEV}}}{\text{cm}})_{0.0039}}{0.0016} \leq d_{\phi} \leq \frac{(\frac{dE}{dx})_{\text{GEV}}}{\text{cm}} \)

Trackings (PT/ST, VD, DR: 95% ATr)

- Muon Chambers
- Helium Reservoir

Performance of the Detector

CFO II / II'v Detector

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
New Physics: Replace W by H

SM: only effective FCNC

Flavor Changing Neutral Currents

Absence of SM CP Violation in B \bar{B} \to \psi K

BB (and DD) Mixing

CP Violation in Charmless B Decays

Describing Possible New Physics in Terms of Loops, Boxes, and Mixing

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
$A_{CP} \propto \alpha_s \ln (m^4)$

where $C_7 = q^2$, $C_8 = q^2$, $C_9 = q^2$, $C_{10} = q^2$. $C_7$ can be calculated from interferences between $C_2-C_7$ and $C_2-C_8$.

Direct CP violation from interferences between $C_2-C_7$ and $C_2-C_8$.

Four-fermion interaction.

Bounds on CP asymmetry in $b\rightarrow s\gamma$ decays.
To be published in PRD

\( V_{CP} = \frac{-0.79 \pm 0.108 \pm 0.22}{1.0 \pm 0.030} \) (small)

Particle ID and particle detection biases (small)

Systematics: mistag rate, ON-OF and BB subtractions,

Tagging is correct 89% (using lepton) and 90% (using PR)

NOT needed: good knowledge of efficiency (cancel in ratio)

Subtraction of remaining (after neural net cut) continuum

Utilizing all available background-suppression variables

Substantial background from continuum processes

Flavor tagging: either lepton or self-tag (pseudo reconstruction)

High energy photon: \( 2.5 > E_{\gamma} > 2.7 \) GeV

Bounds on CP Asymmetry in b \( \to s y \) Decays: Experiment

Searches for CP Violation and New Physics at CLEO
Simulation of $K^+ \rightarrow K\pi$ decays

- Correct $K\pi$ assignment
- KT swapped
- KT not detected

$62\%$-efficient $K^{-}\pi^{+}$ separation

Exclusive Penguin and CP Asymmetry

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
A search for CP violation in $B^+ \rightarrow J/\psi K^+$ and $B^+ \rightarrow \phi(2S) K^+$.
 recherches for CP violation and New Physics at CLEO

Bounds on CP Asymmetry in Dileptons from B_{0\to0} Decays

Vladimir Savinov, University of Pittsburgh
**PRl 85 (2000) 525**

(systematics not shown)

<table>
<thead>
<tr>
<th>$\Delta CP$</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-0.34 \pm 0.25$</td>
<td>$\pm \nu m$</td>
</tr>
<tr>
<td>$+0.03 \pm 0.12$</td>
<td>$\mu \mp K$</td>
</tr>
<tr>
<td>$+0.18 \pm 0.24$</td>
<td>$\pm \nu S K$</td>
</tr>
<tr>
<td>$-0.29 \pm 0.23$</td>
<td>$\nu \mp K$</td>
</tr>
<tr>
<td>$-0.04 \pm 0.16$</td>
<td>$\pm \nu K$</td>
</tr>
</tbody>
</table>

Self-tagging employed

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Ali et al. (PRD 59 (1999) 014005): $\Delta CP \geq 0.1$

**CP Asymmetries in Charmless Hadronic B Decays**

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
0.6 > d \sin \theta > 1.7

v \approx 0.0 \simto 0.010 = (0 < \phi \cos \epsilon) \approx 0.039

V_{\text{observed}} (\cos \epsilon) = 0.005 \approx 0.038

\text{used } K^+ \to \pi^+ \nu \text{ channel (signal and sideband of } K^+ \nu \text{)}

\text{assumed } \Theta = \pi/2 \text{ assumed}

\text{effectively, }

\sqrt{2} \left\langle \frac{C}{F} \right\rangle \sin \theta \sin \epsilon \sin \phi \cos \epsilon

Then \ A_{CP} = K_{\text{F}} F^2 \left\langle \frac{C}{F} \right\rangle

Define \ A_{CP} =

\frac{(\epsilon \cos \epsilon \cos \epsilon) - N + (\epsilon \cos \epsilon \cos \epsilon) + N}{(\epsilon \cos \epsilon \cos \epsilon) - N - (\epsilon \cos \epsilon \cos \epsilon) + N}

\text{C-even phase } \phi \text{ strong (w.r.t. vector } W \text{ coupling)}

\text{exist for } \phi \text{ w. C-odd phase } \phi \text{ and}

\text{CPV would be possible if scalar coupling}

\text{First CLEO search for CPV in } K^+ \to \pi^+ \nu \text{ Search for CP Violation and New Physics at CLEO}

Vladimir Savinov, University of Pittsburgh
Prove absence of bias! Find c from toy MC experiments.

A to first order for small Im V

where this holds

Measure \( \frac{C_{\text{odd even}}}{C_{\text{odd odd}}} = \xi \)

Cp-odd term

Cp-even term

use optimal variable (D. Atwood, A. Soni, PRD 45 (1992) 2405)

utilize the fact that t pairs are produced coherently and

achieving maximum sensitivity:

Measuring Imaginary Part of the T Scalar Coupling

New CLEO search for CPv in T Decays to \( \tau^- \nu \tau^+ \nu \)
New CLEO search for CPV in $t$ decays: check for biases

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
To come: $K^{sT}$ analysis using optimal variable.

The results of the analysis in the framework of pseudo helicity are consistent with this result:

$$-0.046 < \text{Im} \frac{V}{\text{Im} \sqrt{V}} > 0.022$$

Using (most conservative) $f^s = 1$, we obtain 90% CL interval on CP violating parameter:

$$\left[ \lambda * Z^p w - X * Z^n w \right] \frac{s f_{H w}}{\text{Im} \sqrt{V}} = V$$

This analysis done in the framework of 3HDM (see Y. Grossman, NPB 426 (1994) 355):

New CLEO search for CPV in $T$ decays: the results.$$
Mixing in $B^0$ System, $B^0$ Production Mechanism and Decays

June 15, 2001

KANON 2001, Pisa, Italy

How we interpret our results

Interpretation Framework

What we measure

Indication of large strong phase:

$$I - \frac{J}{2} \approx p \chi$$

$$\frac{J}{\sqrt{\lambda}} = \delta \left( \frac{J}{2} \right) \approx \delta$$

$$\frac{J}{\sqrt{\lambda}} = \chi \left( \frac{J}{2} \right) \approx \chi$$

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$(\sqrt{J} + \sqrt{\lambda}, x) = \frac{\sqrt{J}}{2} + \sqrt{\lambda} = \frac{\sqrt{J}}{2} + \sqrt{\lambda}$

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$$(\sqrt{J} + \sqrt{\lambda}, x) = \frac{\sqrt{J}}{2} + \sqrt{\lambda}$$
Experimental Technique, Assumptions and Relevant Quantities

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
Summary of $A^{(d)}_{v^{SD}}$

$\% (\pi^+ \mp \pi^- \mp 19,20) = (0_{v}^{\pi^{+}})^{d,0}_{d,0} A^{(d)}_{v^{SD}}$

$\% (\pi^0 \mp 1,0,1^{\pm}) = (0_{v}^{\pi^{0}})^{d,0}_{d,0} A^{(d)}_{v^{SD}}$

$\% (\pi^\pm \mp 1,0,1^{\pm}) = (0_{v}^{\pi^{\pm}})^{d,0}_{d,0} A^{(d)}_{v^{SD}}$

---

**Summary of $A^{(d)}_{v^{KK}}$**

$\% (\pi^+ \mp \pi^- \mp 19,20) = (0_{v}^{\pi^{+}})^{d,0}_{d,0} A^{(d)}_{v^{KK}}$

$\% (\pi^0 \mp 1,0,1^{\pm}) = (0_{v}^{\pi^{0}})^{d,0}_{d,0} A^{(d)}_{v^{KK}}$

$\% (\pi^\pm \mp 1,0,1^{\pm}) = (0_{v}^{\pi^{\pm}})^{d,0}_{d,0} A^{(d)}_{v^{KK}}$

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**Searches for $CP$ Violation and New Physics at CLEO**

**Presentation at KAON-2001, Pisa, Italy, June 15, 2001**

**CP Violation in $D^0_D$ Decays to Pairs of Pseudoscalar Mesons**

HEP-EX/0105002

PRD 63 (2000) 071101 (R)
Mass Distribution

\[ \text{K}^+ \pi^- \text{Proper Time Distribution} \]

\[ \text{K}K \text{ Mass Distribution} \]

\[ \text{K}K \text{ Proper Time Distribution} \]

\[ \text{K} \pi^- \text{Proper Time Distribution} \]

\[ \pi\pi \text{ Mass Distribution} \]

\[ \pi\pi \text{ Proper Time Distribution} \]

\[ \text{CP} = \frac{\text{CP}^-}{\text{CP}^+} \]

\[ \text{Time evolution of a mixed CP state:} \ \langle R(t) \rangle \sim e^{-\frac{t}{\tau}} \]

\[ \text{Time evolution of CP eigenstate:} \ \langle R(t) \rangle \sim e^{-\frac{t}{\tau}} \]

\[ \text{CP violation} \]

\[ \text{New Fits to } D^0 \text{ Proper Time and } \gamma \text{ Measurement} \]
CLEO CONF 01-1: Preliminary results

Sources of systematics

<table>
<thead>
<tr>
<th>Fixed</th>
<th>Fixed</th>
<th>Fixed</th>
<th>Fixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.38 ± 0.09</td>
<td>3.8 ± 0.9</td>
<td>0.376 ± 0.030</td>
<td>18.1 ± 4.8</td>
</tr>
<tr>
<td>0.24 ± 0.07</td>
<td>0.24 ± 0.07</td>
<td>0.24 ± 0.07</td>
<td>0.24 ± 0.07</td>
</tr>
<tr>
<td>2.463 ± 65</td>
<td>2.463 ± 65</td>
<td>2.463 ± 65</td>
<td>2.463 ± 65</td>
</tr>
<tr>
<td>920 ± 37</td>
<td>920 ± 37</td>
<td>920 ± 37</td>
<td>920 ± 37</td>
</tr>
<tr>
<td>π+</td>
<td>π+</td>
<td>π+</td>
<td>π+</td>
</tr>
</tbody>
</table>

Parameter

Number of Signal

New Fits to D0 Proper Time and y Measurement (cont.)

\[
\frac{y}{c_D} = 0.011 \pm 0.025^{+0.025}_{-0.014} \text{(stat)} \pm 0.014 \text{(syst)}
\]
Assume no mixing: $R_d = (1.7 \pm 0.4 \text{ (stat)} \pm 0.3 \text{ (syst)})/0.3$ (syst) $= 0.0043 \pm 0.0011$ Data

$R = 0.0043 + 0.0007$ (syst) $= 0.0043 \pm 0.0007$ (syst)

$\theta _{\text{ewp-ex/O10502}}$

First Measurement of "Wrong-Sign" $K^+ \, \pi^- \, \pi^0$ Rate

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, University of Pittsburgh
MC based on work of all et al. (PRD 61 (2000) 074024)

<table>
<thead>
<tr>
<th>E (GeV)</th>
<th>S1 (ns)</th>
<th>S2 (ns)</th>
<th>T</th>
<th>S1 + S2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.28</td>
<td>3.98</td>
<td>5.42</td>
<td>4</td>
<td>9.40</td>
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<tr>
<td>3.28</td>
<td>5.10</td>
<td>7.31</td>
<td>0</td>
<td>12.41</td>
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<tr>
<td>4.28</td>
<td>6.20</td>
<td>8.41</td>
<td>0</td>
<td>14.61</td>
</tr>
<tr>
<td>5.28</td>
<td>7.30</td>
<td>9.51</td>
<td>1</td>
<td>16.81</td>
</tr>
<tr>
<td>6.28</td>
<td>8.40</td>
<td>10.61</td>
<td>3</td>
<td>21.01</td>
</tr>
</tbody>
</table>

To suppress virtual $K^*$ we know about CLEO making best of what Blind analyses.

Fisher discriminant technique employed to suppress backgrounds.

Selection criteria optimized for discovery and best upper limits (took average)

Is better than $K^*$: at large dilepton mass no hadronic uncertainties sensitive to New Physics (i.e. phenomena that not in the Standard Model)

New Results on FCNC Decays $B ightarrow K^{(*)}(1+1)$

Searches for CP Violation and New Physics at CLEO

Vladimir Savinov, Universitv of Pittsburgh
Almost no model dependence in efficiency

Signal boxes shown (shifted by 5 MeV for electrons)

Internal and external bremsstrahlung recovery employed

3) Missing energy (semileptonic decays)

Solutions: 1) Vetoes, 2) Fisher discriminant and

3) Dileptons from BB decays

2) Dileptons from continuum

1) J/ψ and γ (Z^0)

Major sources of background are real dileptons:

New Results on FCNC Decays B → K^{(*)}_{+1+1}
Conclusions