A Measurement of the Branching Ratio
of $D^0g \ K^+\pi^- \ to \ D^0g \ K^-\pi^+$

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FOCUS is a Charm Photoproduction Experiment at Fermilab

This design provides excellent vertex resolution, particle id and momentum resolution.

More than 1 million fully reconstructed $D$ mesons!
$D^0 g K^+ \pi^-$ Can Occur Through

Double Cabibbo Suppression (DCS) or Mixing Followed by a Cabibbo Favored Decay (CF)

Standard Model predictions for contributions to the relative branching ratio.

$$\tan^4 ?_c \approx 0.25\% \quad 10^{-7} \text{ to } 10^{-3}$$

In this study we measure the branching ratio $r_{DCS} = DCS/CF$. 
Event Selection

- Very loose Cerenkov based particle id cuts on $K$ and $\pi$.
- The $D^0$ candidate is used as a seed to find the production vertex.
- The production vertex has at least 2 tracks in addition to the $D^0$.
- The production vertex is required to be within $1\sigma$ of target material.
- Production and decay vertices are required to be well formed (CL>1%).
- $D^0$ daughter tracks inconsistent with coming from the production vertex.
- The vertex separation $L/\sigma_L>5$.
- Cut $K\pi$ pairs with high momentum asymmetry and low $D^0$ momentum.
First You Have to Tag the $D^0$ Flavor

- The decay $D^{+*}g \ D^0\pi^+$ is used to identify the $D^0$ flavor.
- So we study the $D^*-D^0$ mass difference.
Monte Carlo Background Studies

Backgrounds from other $D^0$ decays peak in the $D^*$ signal region!

If not dealt with these backgrounds could seriously bias an analysis.
The Worst BG is CF $K\pi$ Double Mis-id

The double mis-id $\Delta m$ is indistinguishable from the correctly identified signal.

So we use a tight Cerenkov based mis-id cut in a $\pm 4\sigma$ window about the $D^0$ with $K\pi$ reconstructed as $\pi K$. 
How do we Treat These Mis-id BG’s?

• We could target $K^+K^-$ and $\pi^+\pi^-$ just like we did with $K^-\pi^+$.  
  This carves holes in the $D^0$ sidebands.

• We could use hard Cerenkov based id cuts everywhere.  
  A big hit in yield and very little improvement in S/N.

• Try something completely different.
A New Method

- Divide the data into 1 MeV wide bins in $\Delta m$, and fit the $D^0$ in each bin.
- Fit the $KK$ and $\pi\pi$ reflections with Monte Carlo events.
- Fit $D^0$ to a gaussian.
- Fit BG to a polynomial.

A total of 80 fits!
Fit the $\Delta m$ Distributions

- Fitted $D^0$ yields are plotted in the appropriate $\Delta m$ bins.
- Background is fit to: $f(m) = a(m-m_\pi)^{1/2} + b(m-m_\pi)^{3/2}$.
- DCS signal is fit directly to the CF histogram signal region.

$\begin{align*}
\text{Yield} &= 35901 \pm 196 \\
\text{Yield} &= 172.9 \pm 33.7 \\
\end{align*}$

$r_{\text{DCS}} = (0.482 \pm 0.093)\% \quad \text{Preliminary!}$
Possible Effects of Mixing

• If charm mixing is significant then decay rate as a function of time is:

\[ r(t/\tau) = \left\{ r_{DCS} + \sqrt{r_{DCS}} y'(t/\tau) + \left(\frac{y'^2+y'^2}{4}\right)(t/\tau)^2 \right\} e^{(-t/\tau)} \]

• With \( x' \equiv x \cos d + y \sin d \), \( y' \equiv y \cos d - x \sin d \),

\( x \equiv \frac{\Delta m}{\Gamma} \), \( y \equiv \frac{\Delta \Gamma}{2\Gamma} \) and \( \delta \) is the strong phase.

• The measured BR depends on the lifetime acceptance of the analysis.

• We use a \( D^0g K^-\pi^+ \) Monte Carlo to study the effects of mixing on the measured BR \( (r_{meas}) \).

\[ \left( D^0 \rightarrow K^+p^- \right)_{\text{data}}^{\text{expected}} = \sum_i W(t_i, x', y', r_{DCS})^{\text{MCaccepted}} \]

• Where

\[ W(t, x', y', r_{DCS}) = \left( \frac{CF_{\text{data}}^{\text{accepted}}}{CF_{\text{MC}}^{\text{accepted}}} \right) \left( r_{DCS} + \sqrt{r_{DCS}} y'(t/\tau) + \left(\frac{y'^2+y'^2}{4}\right)(t/\tau)^2 \right) \]
Effects of Mixing Continued

• We find…

\[ r_{meas} = r_{DCS} + \sqrt{r_{DCS}} y′⟨t / t⟩ + \frac{(x′^2 + y′^2)}{4} ⟨(t / t)^2⟩ \]

Average lifetime and average lifetime squared in units of the \(D^0\) lifetime for accepted events in the Monte Carlo.

• When solved for \(r_{DCS}\) as a function \(x′, y′\) and \(r_{meas}\) yields:

This measurement

FOCUS

\(y\) from Lifetime Difference \((δ = 0)\)

CLEOII.V

True \(r_{DCS}\) as a function of \(y′\) with \(x′ = 0\)
Conclusions and Future Prospects

• We measure, in the absence of mixing,
  \[ r_{\text{DCS}} = (0.482 \pm 0.093)\% \text{ (Statistical Error Only)} \]
  Preliminary!

• This measurement is statistically on par with the recent
  CLEO II.V result of \( r_{\text{DCS}} = (0.332 \pm 0.064 \pm 0.040)\% \).
  (No Mixing)

• Mixing studies based on the lifetime dependence of \( r_{\text{DCS}} \).

• Study other \( D^0 \) DCS decay modes (\( K^+\pi^-\pi^0 \) and \( K^+\pi^-\pi^+\pi^- \)).