<u>Branching Ratio Measurements of the decays</u>

$D^0 \rightarrow \pi^- \pi^+ \pi^0$ and $D^0 \rightarrow K^- K^+ \pi^0$

using 228.8 fb^{-1} of BaBar data

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Abstract

In this paper I present measurements of the relative branching ratios of the Cabibbo Suppressed decays $D^0 \rightarrow \pi^- \pi^+ \pi^0$ and $D^0 \rightarrow K^- K^+ \pi^0$ with respect to the Cabibbo favored decay $D^0 \rightarrow K^- \pi^+ \pi^0$ from a sample of 228.8 fb^{-1} data collected by the BaBar detector at the PEP-II asymmetric B Factory at SLAC. My 'very preliminary' result is : $BR(D^0 \rightarrow \pi^- \pi^+ \pi^0) / BR(D^0 \rightarrow K^- \pi^+ \pi^0) = (6.51 \pm 0.04) . 10^{-2}$ and $BR(D^0 \rightarrow K^- K^+ \pi^0) / BR(D^0 \rightarrow K^- \pi^+ \pi^0) = (2.31 \pm 0.03) .10^{-2}$. I plan to further investigate the systematic uncertainties associated with these measurements.

The Decay $D^0 \to h^-h^+\pi^0$: We study decays of the type

$D^{*+} \to D^0\pi^+$ $D^0 \to \pi^-\pi^+\pi^0$, $D^0 \to K^-\pi^+\pi^0$, $D^0 \to K^-K^+\pi^0$ $\pi^0 \to \gamma\gamma$

obtained from ccbar continuum events. The channels $D^0 \to \pi^-\pi^+\pi^0$ and $D^0 \to K^-K^+\pi^0$ are singly Cabibbo-suppressed decays, while the decay $D^0 \to K^-\pi^+\pi^0$ is Cabibbo-favored. In this analysis, I use $D^0 \to K^-\pi^+\pi^0$ as a normalization channel for the ratio of branching ratio measurements. The decay $D^0 \to K^-\pi^+\pi^0$ has been studied well previously. Our $D^0 \to \pi^-\pi^+\pi^0$ and $D^0 \to K^-K^+\pi^0$ sample sizes are more than one order of magnitude larger than what used in previously reported (Particle Data Group, S. Eidelman *et al,* Phys Letters B **592** (2004), 690). The current study is motivated by the fact that branching ratios of these two decay channels were poorly measured (until Sunil Jayatilleke's results which is still unpublished).

Detector details: Charged particle tracks are measured by a five-layers double-sided Silicon Vertex Tracker (SVT) and a 40-layer Drift Chamber (DCH) located within a 1.5 T solenoidal magnetic field. Their trajectories are found by fitting the expected helices formed by charged particles in the magnetic field to the sequences of hits. Charged hadrons are identified by combining energy-loss information from tracking with the measurements from a ring-imaging Cherenkov detector. Photons are detected by a CsI (Tl) crystal electromagnetic calorimeter. The magnet's flux return is instrumented for muon identification. We use GEANT4 Monte Carlo program to simulate the response of the detector, taking into account the varying accelerator and detector conditions.

Track Reconstruction: We require following criteria for h^- and h^+charged tracks :

- Transverse momentum of the track > 0.10 GeV/c
- Number of Drift Chamber hits > 12
- At least 6 hits in the SVT with at least 1 hit each in z plane of the first 3 inner layers

The photons making a π^0 are required to satisfy the following criteria :

- Photon reconstructed energy > 100 MeV
- Number of calorimeter hits > 0
- Calorimeter lateral moment < 0.8 (this is the ratio of sum of energies of all but the two most energetic crystals weighted by the square of the distance from the cluster center to the sum of same quantity for all the crystals)

π^0 Reconstruction : π^0 candidates are formed by combining pairs of photon candidates satisfying above criteria. The invariant mass of the photon pair is required to be within $0.115 < M_{\gamma\gamma} < 0.160$ GeV/c^2 and each photon has at least 100 MeV of energy. Selected photon candidates are kinematically fitted so that the photon-photon invariant mass is equal to the nominal π^0 mass and then a mass constrained fit for the π^0 is performed. The energy of π^0 is required to be greater than 350 MeV.

Particle Identification: For each particle hypothesis (i.e, kaon, pion, electron, muon and proton) a likelihood function (L) is calculated using the following formula :

$L = L_{DIRC} \ . \ L_{DCH} \ . \ L_{SVT}$

For the present analysis, we used tight selection using likelihood for both kaon and pion identification.

$D^0 \to h^-h^+\pi^0$ Reconstruction: We select hadronic events which have at least three charged tracks. These events are then selected so that $D^0 \to h^-h^+\pi^0$candidates come from

D^{*+} decays. Two distinct pairs of oppositely charged tracks with $\pi^{\pm}$ and $K^{\pm}$ mass hypothesis and a π^0 are formed to create D^0 candidates by adding their 4-momenta and requiring that the resultant momentum vector points to the beam-spot.

At this stage, the candidates are required to pass the selection criteria:

- $1.70 < \text{Mass}(h^-h^+\pi^0) < 2.0$ GeV/c^2
- D^0 Center-of-mass momentum in Y(4S) frame > 2.77 GeV/c

The vertex fit is required to have probability > 1%. The selected D^0 candidates after the above requirements are combined with soft pion (π_{soft}^+) candidate to make a D^{*+} candidate. The tracks are required to originate close to the beam-spot. If the D^{*+} candidate's vertex fit has probability > 1% and the invariant mass-difference between D^* and D^0 minus its nominal value is less than 1 MeV, then these events are selected as $D^0 \to h^-h^+\pi^0$ candidates.

Multiple Candidates: We observed that there are multiple $D^0 \to h^-h^+\pi^0$ candidates per event, the multiplicity being at the level of 7 – 8 %. This multiplicity is due to one of the following reasons:

- Right D^0 combined with a fake π_{soft}^+ to make a D^{*+}.
- Charged track combinatorics.
- More than one π^0 candidates with or without a shared photon.

When we have overlapping candidates we choose the one with smallest χ^2 at the D^{*+} vertex (this χ^2 includes the contributions from the whole decay chain).

Signal events for the three modes are extracted (from real data, see Figures 1-2-3) and event reconstruction efficiencies are calculated (from the respective signal Monte Carlo generated with a uniformly populated Dalitz plot). The ratio of branching ratios and statistical and systematic errors associated with them are determined.

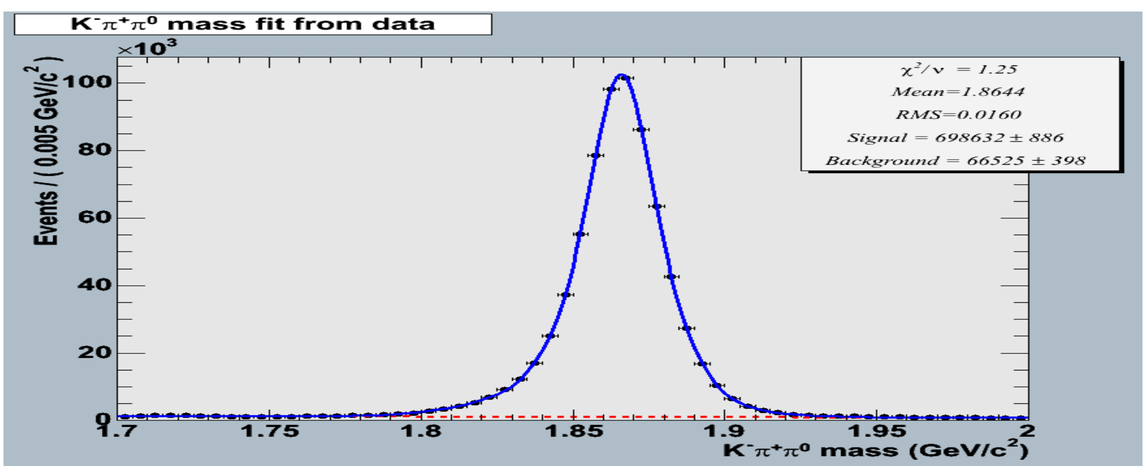

Fig1. $K^-\pi^+\pi^0$ mass distribution (dots) and the result of the fit (blue line) with three Gaussians for the signal and a second order polynomial for background (red broken line)

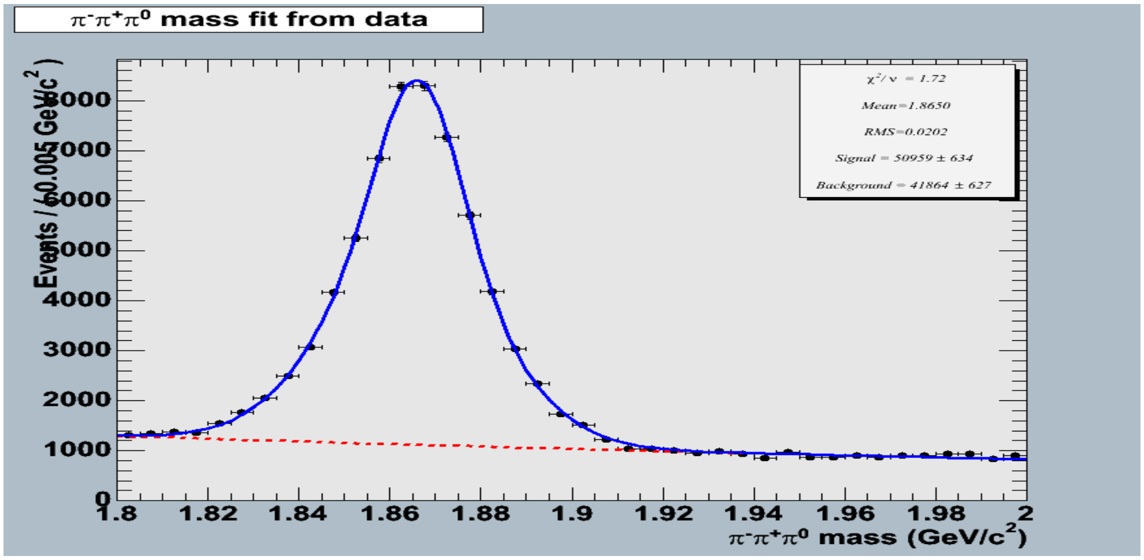

Fig2. $\pi^-\pi^+\pi^0$ mass distribution (dots) and the result of the fit (blue line) with two Gaussians for the signal and an exponential term for background (red broken line)

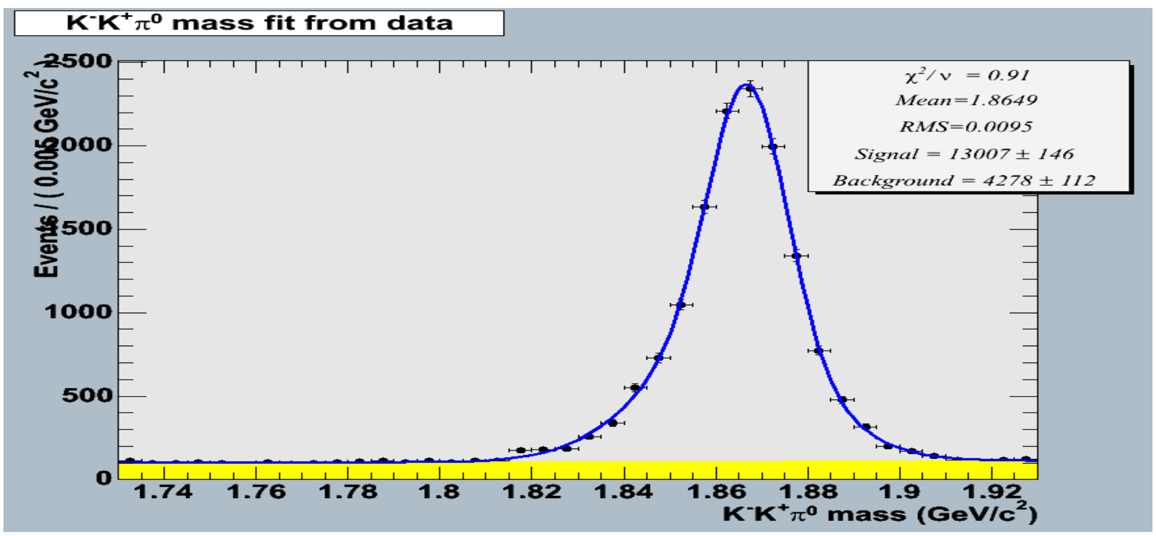

Fig3. $K^-K^+\pi^0$ mass distribution (dots) and the result of the fit (blue line) with two Gaussians for the signal and an exponential term for background (yellow color)

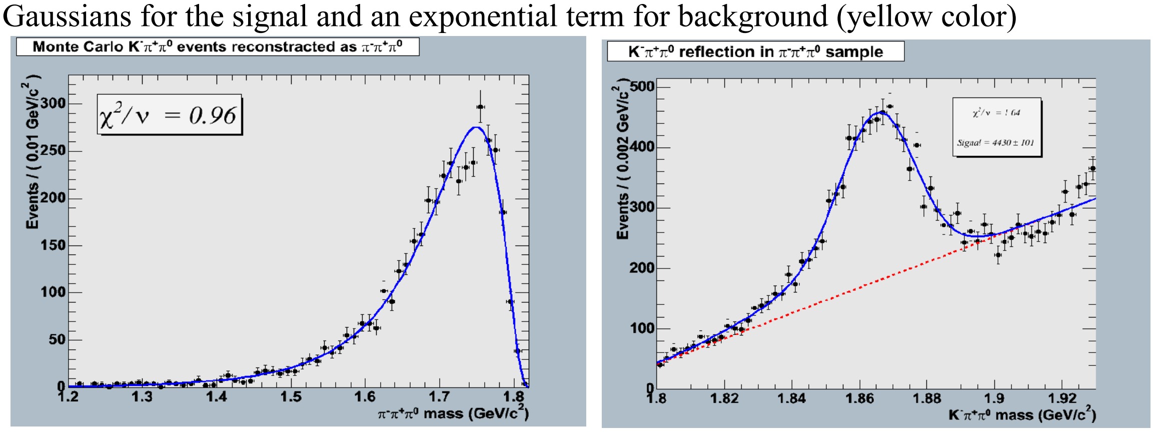

Fig4: $K^-\pi^+\pi^0$ reflection in $\pi^-\pi^+\pi^0$ sample. We get the shape of the reflection from Monte Carlo (left) and the number of reflection events from data (right).

Result: My 'primary results' are

$BR(D^0 \to \pi^- \pi^+ \pi^0) / BR(D^0 \to K^- \pi^+ \pi^0) = (6.51 \pm 0.04) \cdot 10^{-2}$
$BR(D^0 \to K^- K^+ \pi^0) / BR(D^0 \to K^- \pi^+ \pi^0) = (2.31 \pm 0.03) \cdot 10^{-2}$

At this point, the study of systematic errors is under progress. I have estimated one type of systematics, i.e, the one associated with the parametrization of the fit which I study by fitting the $\pi^- \pi^+ \pi^0$ and $K^- K^+ \pi^0$ mass plots (for real data) in two different ways – first excluding the $K^- \pi^+ \pi^0$ reflection from the fit range (see Fig-4) and later including the same but without explicitly fitting for the reflection peak. The difference in the number of extracted signal events gives an estimate of the systematics involved due to ignoring the reflection in the fit. This systematic uncertainty for the two modes are $0.20 \cdot 10^{-2}$ and $0.09 \cdot 10^{-2}$ respectively. This type of systematic uncertainty will be reduced once I include the reflection term properly while fitting $\pi^- \pi^+ \pi^0$ and $K^- K^+ \pi^0$ masses.

Sunil Jayatillke's result with 91 fb^{-1} BaBar data was :
$BR(D^0 \to \pi^- \pi^+ \pi^0) / BR(D^0 \to K^- \pi^+ \pi^0) = (9.78 \pm 0.08 \pm 0.27) \cdot 10^{-2}$
$BR(D^0 \to K^- K^+ \pi^0) / BR(D^0 \to K^- \pi^+ \pi^0) = (2.08 \pm 0.04 \pm 0.08) \cdot 10^{-2}$

My results do not agree with this for $\pi^- \pi^+ \pi^0$ relative branching ratio. The two analysis mainly differ in particle identification, calculation of efficiency across Dalitz plot and dealing with multiple candidates per event. I will do more sanity checks and systematic studies to fully understand the differences in these two results and to fully estimate systematic uncertainties in my result. This write-up represents a status-report on my work which is still in progress.

Future Plans: Several improvements to this analysis are needed:

1. To investigate further systematics : in this analysis I have assumed a uniform efficiency across the uniformly populated phase space Dalitz plot which is an approximation. I will calculate the efficiency as a function of position on Dalitz plot for the three modes.
2. To correctly account for contributions from other side of charm decay in signal Monte Carlo when calculating the efficiencies.
3. I will do exactly the same analysis for the two charges separately (D^{*+} and D^{*-}) and in five different momentum bins. This will be another study of systematics.
4. The long term plan is the extension of the present analysis to a full Dalitz analysis of Cabibbo suppressed decays $D^0 \to h^- h^+ \pi^0$ to include these results in the study of $B^- \to D^{(*)0} K^-$ with the same D^0 decays as this analysis , which will be useful to constrain the third angle of unitarity triangle γ.