## Introduction

- **Aim. Decay rate asymmetry in $D^0 \to K_S\pi^0$ and $K_L\pi^0$**

  $\Gamma_{D^0\to K_S\pi^0} = \frac{1}{2}\Gamma_{CF} - (\sqrt{\Gamma_{CF}}\sqrt{\Gamma_{DCS}})cos(\delta_{CF} - \delta_{DCS}) + \frac{1}{2}\Gamma_{DCS}$

  $\Gamma_{D^0\to K_L\pi^0} = \frac{1}{2}\Gamma_{CF} + (\sqrt{\Gamma_{CF}}\sqrt{\Gamma_{DCS}})cos(\delta_{CF} - \delta_{DCS}) + \frac{1}{2}\Gamma_{DCS}$

  $A = \frac{(\Gamma_{D^0\to K_S\pi^0}) - (\Gamma_{D^0\to K_L\pi^0})}{(\Gamma_{D^0\to K_S\pi^0}) + (\Gamma_{D^0\to K_L\pi^0})} \simeq tan^2\theta_c \simeq \mathcal{O}(5\%)$

- **Motivation. $\delta_{k\pi} = \delta_{CF} - \delta_{DCS}$ and $D^0 - \bar{D^0}$ mixing study**

  $\delta_{k\pi}$ **is important for $D^0 - \bar{D^0}$ mixing study**

- **Experimental Situation. Previous measurement at Belle in summer 2001**

  $A = 0.06 \pm 0.05(stat) \pm 0.05(syst)$ **using** $23.6\ ^{-1}fb$

  **Current Belle statistics will reduce stat error manifold**

  **New technique needed to reduce systematics**

## Strategy for the Analysis

- **Decay Modes. In addition to $D^0 \to K_S\pi^0$ and $D^0 \to K_L\pi^0$**

  **we have to study $D^0 \to (K_S\pi^-)\pi^+$ and $D^0 \to (K_L\pi^-)\pi^+$**

  **We have to tag these 4 decays by the reaction $D^{*+} \to D^0\pi^+$**

  **Henceforth can be refered as $D \to K_S\pi$, $D \to K_L\pi$, $D \to K_S\pi\pi$ and $D \to K_L\pi\pi$**

  **We assume that $K^{*-}$ decays into $(K_S\pi^-)$ and $(K_L\pi^-)$ 1:1**

  **We also assume that $\epsilon^{D^{*+}}(p_1, p_2, ...) = \epsilon^1(p_1) \times \epsilon^2(p_2) \times ...$**

  **where 1,2 etc stand for final state particles, $p_1, p_2$ etc for respective momenta**

- **Our strategy is to measure $A$ in bins of $K^0$ momenta**

  **this we hope reduces bias due to $K_L$ efficiency as it rapidly increases with momenta**

  $$\langle A\rangle = \frac{\int_a^b 1/\epsilon_{K_S\pi}(p)[\eta^{rec}_{K_L\pi}(p)/r(p) - \eta^{rec}_{K_S\pi}(p)]\,dp}{\int_a^b 1/\epsilon_{K_S\pi}(p)[\eta^{rec}_{K_L\pi}(p)/r(p) + \eta^{rec}_{K_S\pi}(p)]\,dp},\ A(p) = \frac{\eta^{rec}_{K_L\pi}(p) - r(p)\times\eta^{rec}_{K_S\pi}(p)}{\eta^{rec}_{K_L\pi}(p) + r(p)\times\eta^{rec}_{K_S\pi}(p)}$$

  **$\eta' s$ = yields and $r(p)$ = relative efficiency of $K_S$ and $K_L$ from $K^{*-}$ modes**

- **Required functions**

  **$\epsilon_{K_S\pi}(p)$ from MC($D^{*+}$ efficiency in $K_S\pi$ mode), all other functions from Data**

## Data Sample used

- **100,000 Signal MC events for each mode produced by evtgen**

  **generator $\rightarrow$ b20040727-1143, gsim $\rightarrow$ b20030807-1600, analysis $\rightarrow$ b20040727-1143**

  $e^+e^- \rightarrow c\bar{c} \rightarrow frag \rightarrow D^{*+}, incl$ **by ' inclusive particle type ' in evtgen**

  $D^{*+} \rightarrow D^0\pi^+_{slow}$, $D^0 \rightarrow$ **all 4 modes by user decay table**

  **charge conj. modes not added yet**

  $D \rightarrow K_S\pi\pi$ **mode 90,000 events (due to job crash !)**

## Reconstruction, Event Selection and Fitting

- $\pi^0$. **mdst-pi0**
- $K_S$. **mdst-vee2**

  $dr > 0.25cm, d\phi < 0.1rad, dz < 1cm$

  $0.486 < M_{K_S}$ **in** $D \rightarrow K_s\pi < 0.510$

  $0.491342 < M_{K_S}$ **in** $D \rightarrow K_s\pi\pi < 0.504038$

- $K_L$. **mdst-klong**

  $D^0$ **mass fixed to PDG value, Resulting equation gives 2 solutions for** $p_{K_L}$

  $\frac{[-b-(\sqrt{b^2-4ac})]}{2a}$ **which is always +ve, gives physical solution**

- $K^{*-}$. **Mass window cuts**

  **(0.751683, 1.03164) in** $K_L$ **mode, (0.750, 1.000) in** $K_S$ **mode**

- $D^0$. **Mass cuts and constraints**

  **3** $\sigma$ **cuts on** $M_{D^0}$ **for** $K_S$ **modes, fixed to PDG value for** $K_L$ **modes**

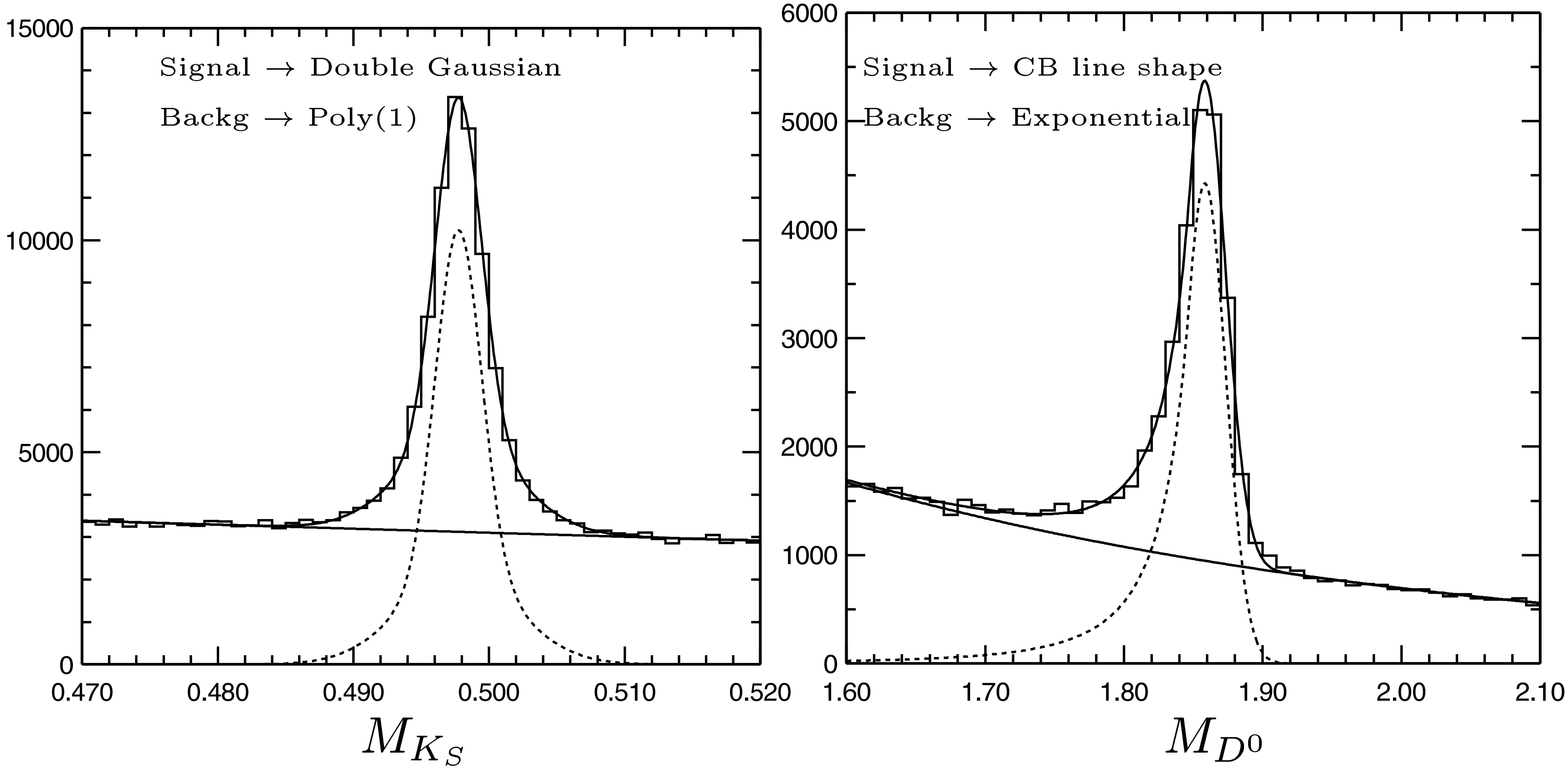
- $D^{*+}$. **Signal selection cuts**

  **3 $\sigma$ cuts on $M_{D*+}$ for $K_L$ modes**

  $\delta M = M_{D*+} - M_{D0}$

  $0.144 < \delta M < 0.147$ **for** $D \to K_S\pi$ **mode,** $0.143 < \delta M < 0.148$ **for** $D \to K_S\pi\pi$ **mode**

## Reconstruction of $D^0 \to K_S\pi^0$




- Dotted → Signal

## Reconstruction of $D^0 \rightarrow K_S\pi^+\pi^-$

Signal → Double Gaussian

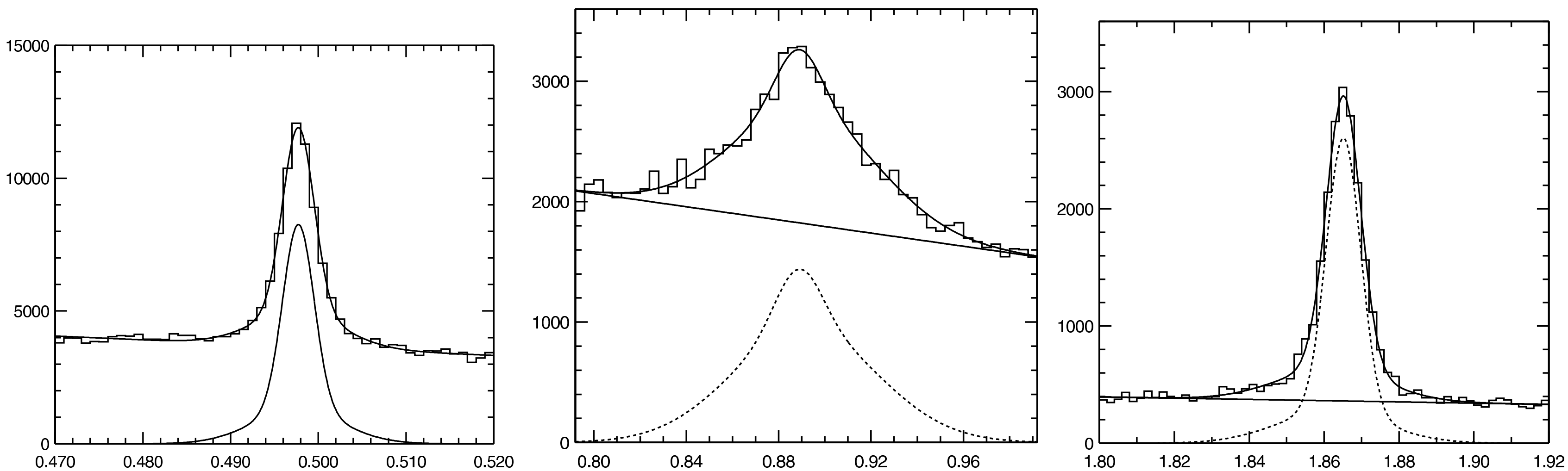
Backg → Poly(1)

Signal → Double Gaussian

Backg → Poly(1)

Signal → Double Gaussian

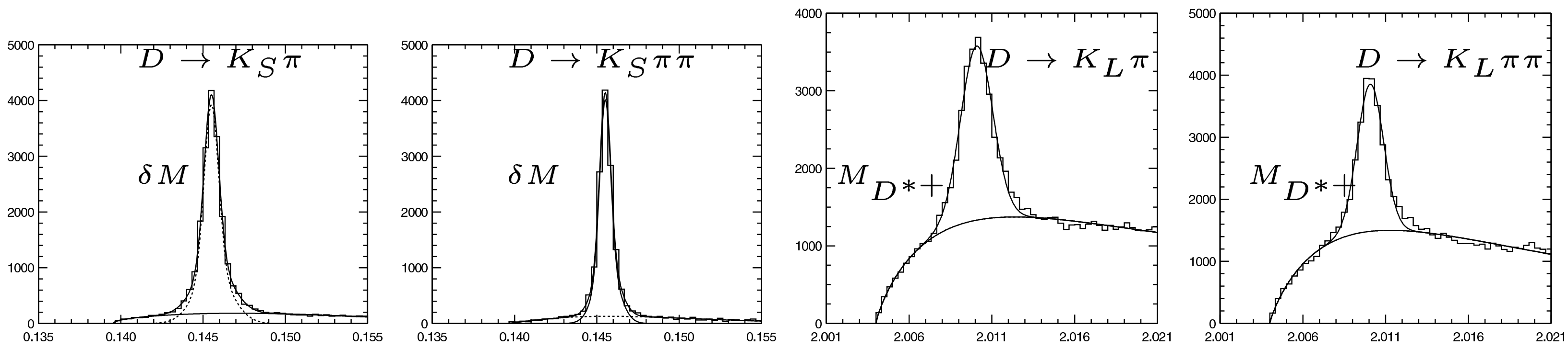
Backg → Poly(1)




$M_{K_S}$ $M_{K^{*-}}$ $M_{D^0}$

- Dotted → Signal

## Signal shapes for 4-modes




- $\delta_M$, Signal $\to$ Double Gaussian, Backg $\to$ Threshold function
- $M_{D*+}$, Signal $\to$ Gaussian, Backg $\to$ Threshold function

**Reconstruction efficiencies and assumption of factorizability**

$$\epsilon^{D^{*+}}(p_1, p_2, \ldots) = \epsilon^1(p_1) \times \epsilon^2(p_2) \times \ldots$$

- **Efficiency study is done in momentum bins to validate factorizability assumption**

  **To match reconstructed info with MC truth**

  **get-hepevt() function is used for $K_S, \pi^0$ and angular cuts for $K_L$ matching**

  **Plot the generated lab momenta**

  **Count the matching number of events reconstructed in each bin**

  **This gives 1d efficiencies as function of momenta eg $\epsilon^1(p_1)$ etc**

  **Scatter plot the generated lab momenta pair wise**

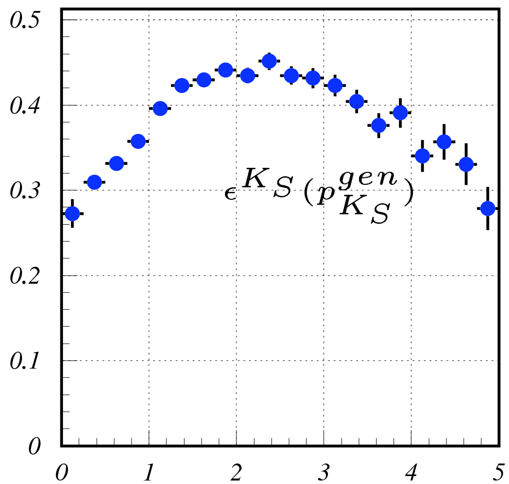
  **Count the matching number of $D^{*+}$ events reconstructed in each 2d bins**

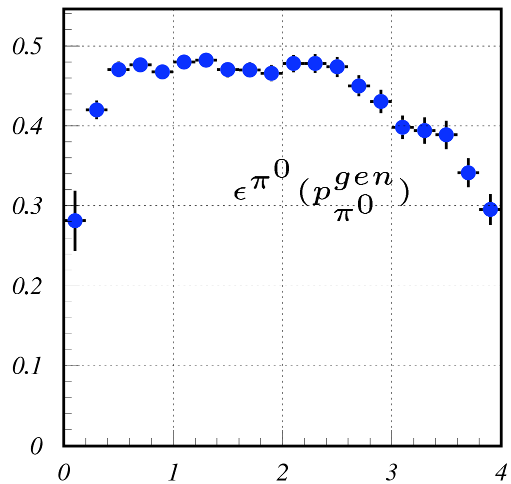
  **This gives efficiency of $D^{*+}$ as function of 2 momenta eg $\epsilon^{D^{*+}}(p_1, p_2)$**

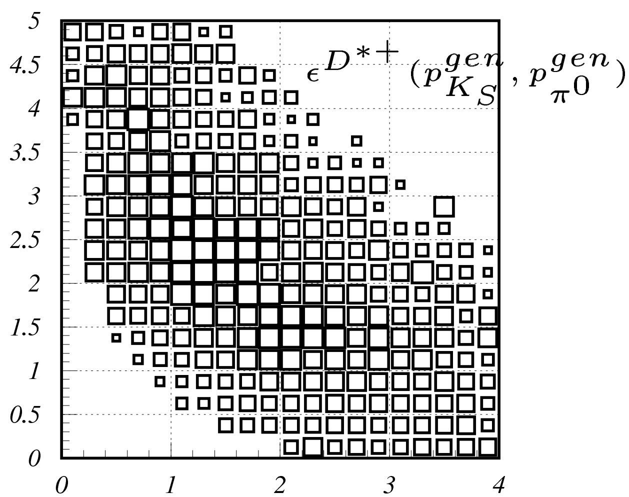
  **plot $\epsilon^1(p_1)$, $\epsilon^2(p_2)$, $\epsilon^{D^{*+}}(p_1, p_2)$ and $\epsilon^1(p_1) \times \epsilon^2(p_2)$**

  **compare $\epsilon^{D^{*+}}(p_1, p_2)$ and $\epsilon^1(p_1) \times \epsilon^2(p_2)$**

## Factorizability in $D^0 \to K_S\pi^0$

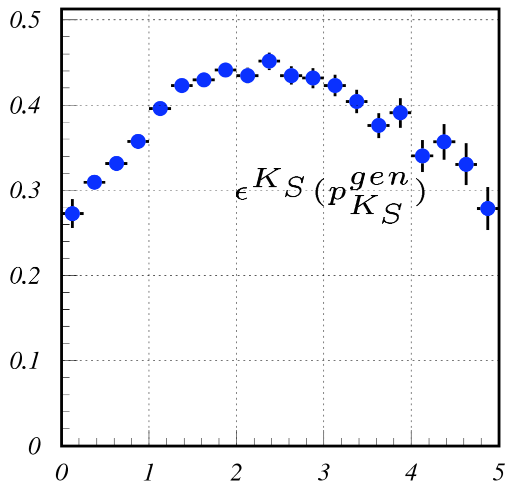


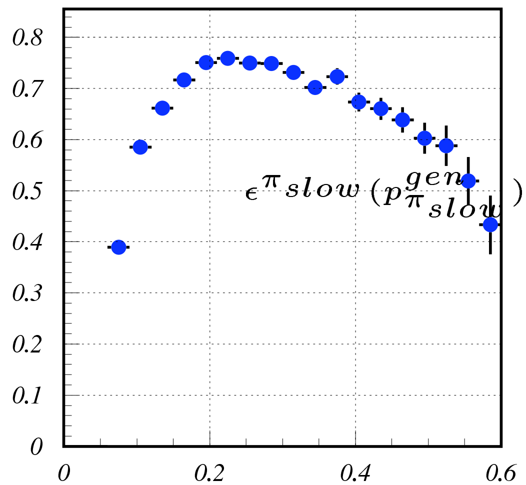




$\epsilon^{K_S}(p^{gen}_{K_S}) \times \epsilon^{\pi^0}(p^{gen}_{\pi^0})$ here

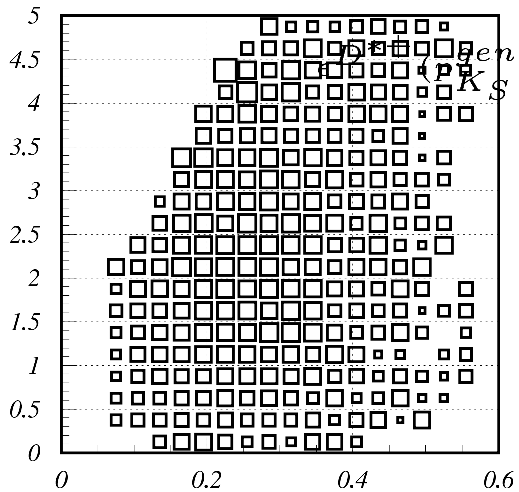
## Factorizability in $D^0 \to K_S\pi^0$ continues...



$\epsilon^{K_S}(p^{gen}_{K_S})$



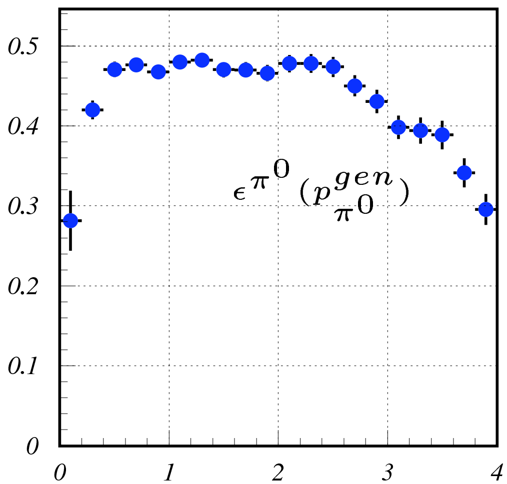
$\epsilon^{\pi_{slow}}(p^{gen}_{\pi_{slow}})$

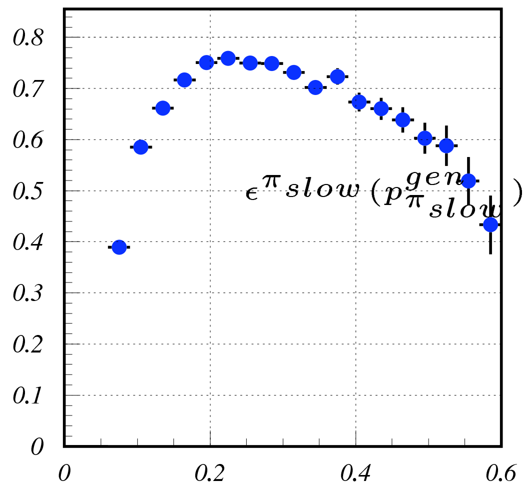


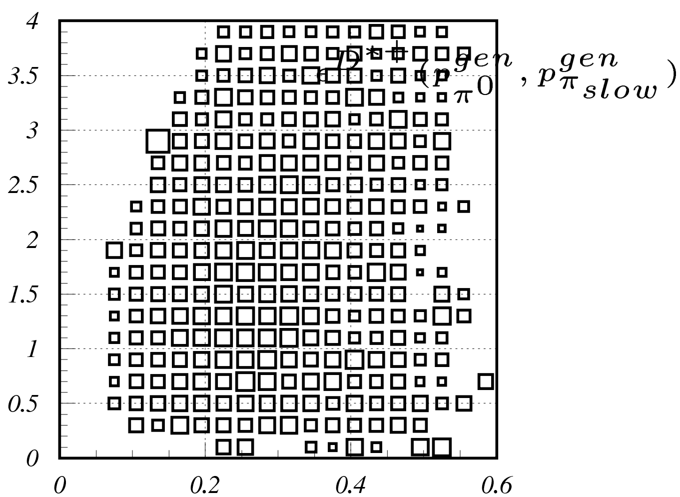
$\epsilon^{D^*tag}(p^{gen}_{K_S}, p^{gen}_{\pi_{slow}})$

$\epsilon^{K_S}(p^{gen}_{K_S}) \times \epsilon^{\pi_{slow}}(p^{gen}_{\pi_{slow}})$ here

## Factorizability in $D^0 \to K_S \pi^0$ continues...

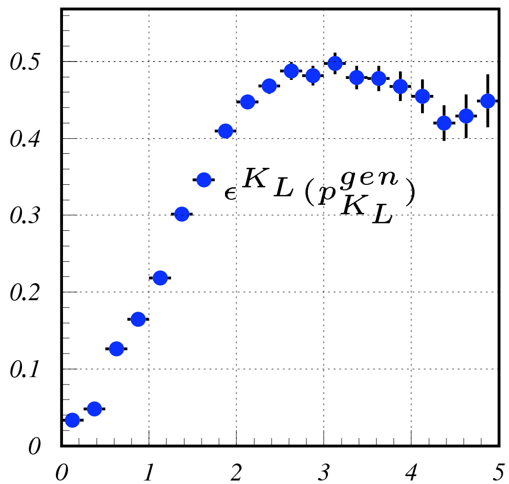


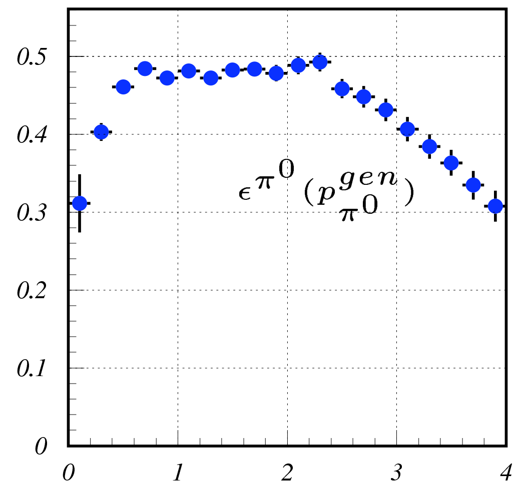



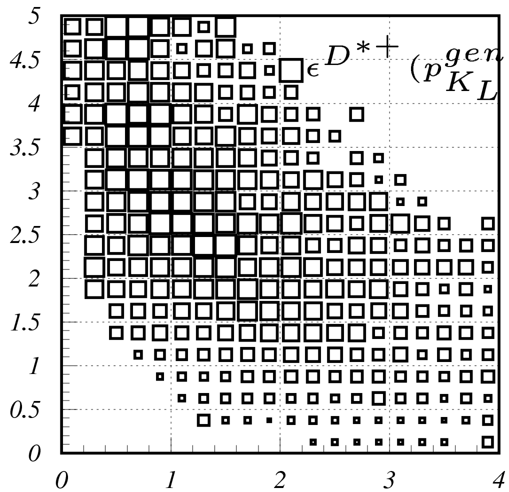




$\epsilon^{\pi^0}(p^{gen}_{\pi^0}) \times \epsilon^{\pi_{slow}}(p^{gen}_{\pi_{slow}})$ here

## Factorizability in $D^0 \to K_L\pi^0$

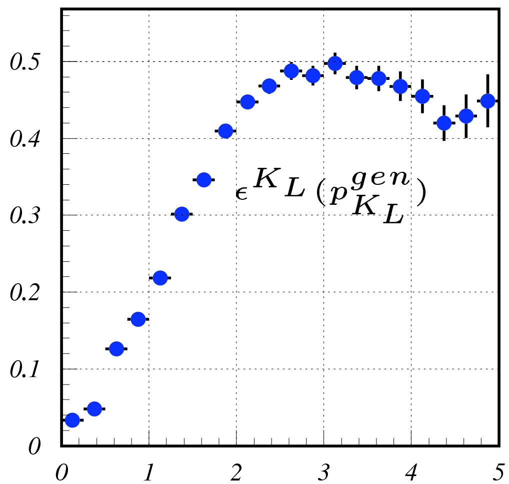


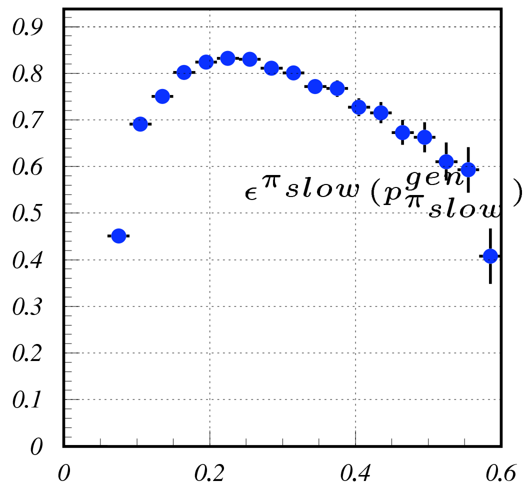



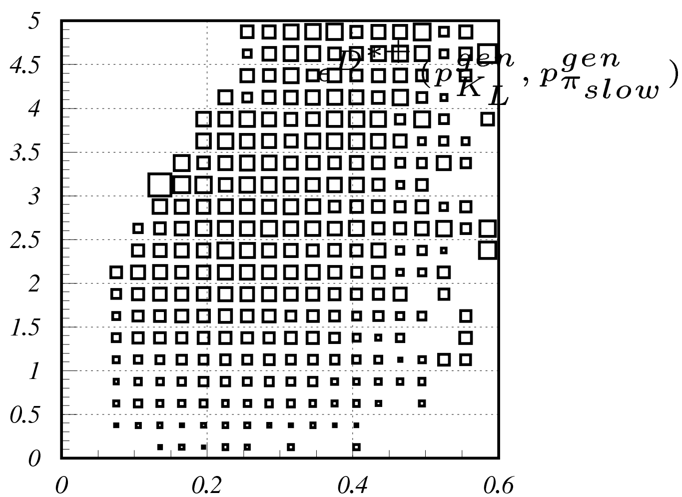




$\epsilon^{K_L}(p^{gen}_{K_L}) \times \epsilon^{\pi^0}(p^{gen}_{\pi^0})$ here

## Factorizability in $D^0 \to K_L\pi^0$ continues...

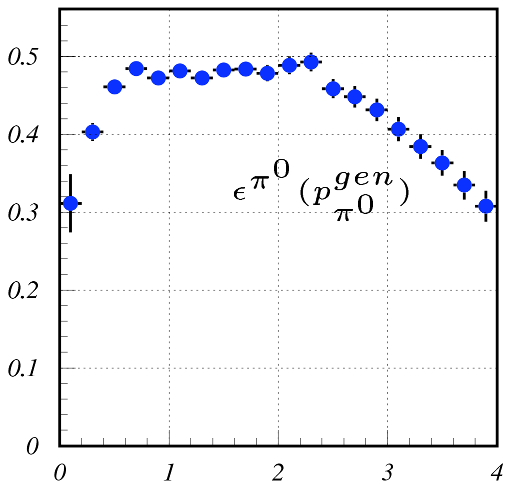


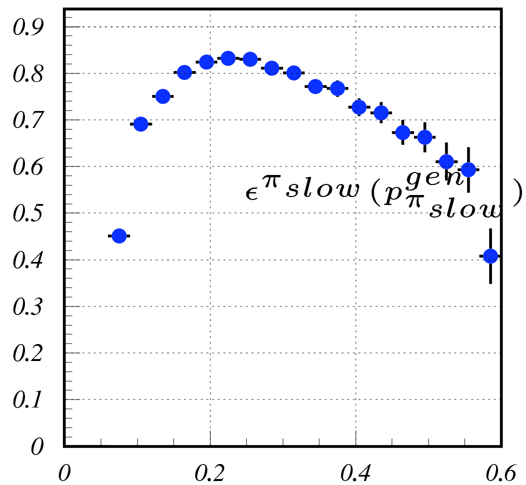



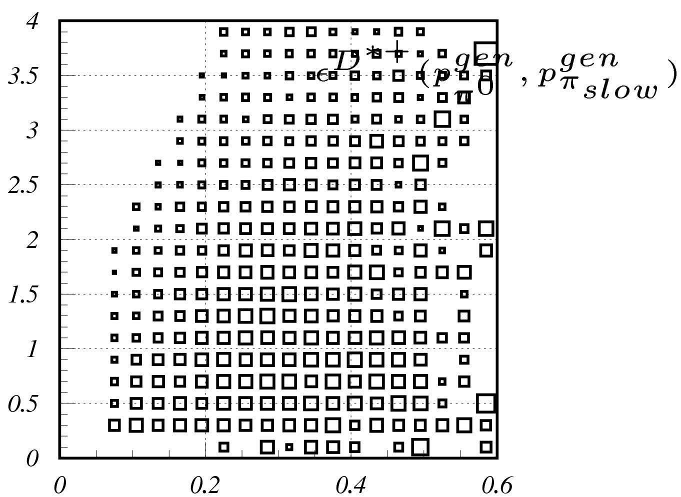




$\epsilon^{K_L}(p^{gen}_{K_L}) \times \epsilon^{\pi slow}(p^{gen}_{\pi slow})$ here

## Factorizability in $D^0 \to K_L\pi^0$ continues...

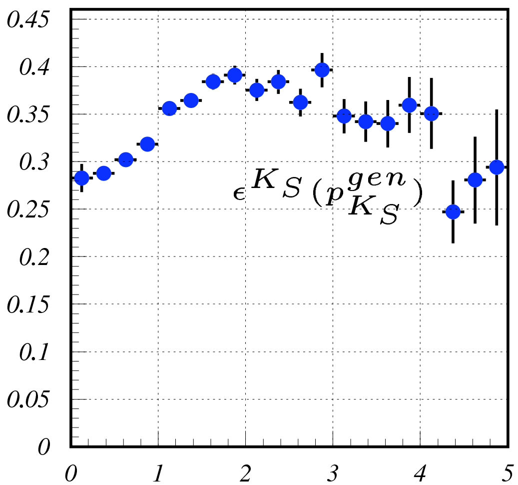


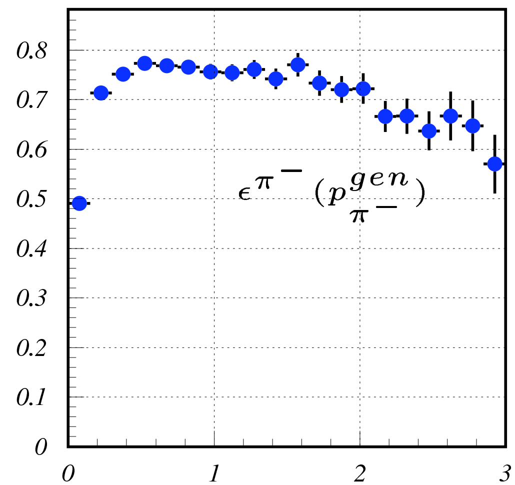



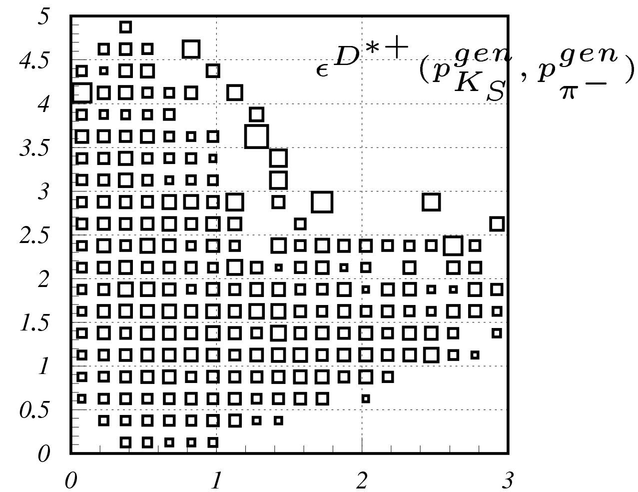




$\epsilon^{\pi^0}(p^{gen}_{\pi^0}) \times \epsilon^{\pi_{slow}}(p^{gen}_{\pi_{slow}})$ here

## Factorizability in $D^0 \to K_S\pi^+\pi^-$, the study is shown partly, rest is similar

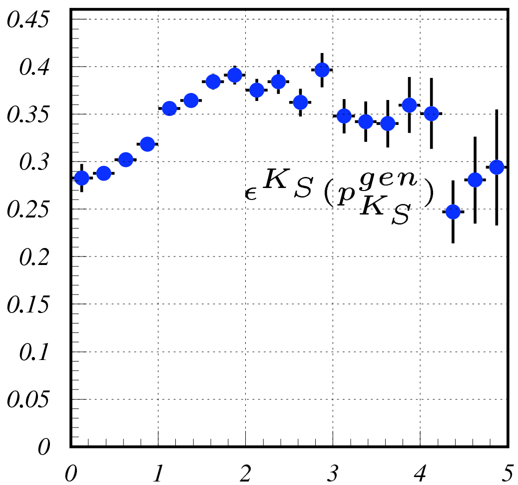


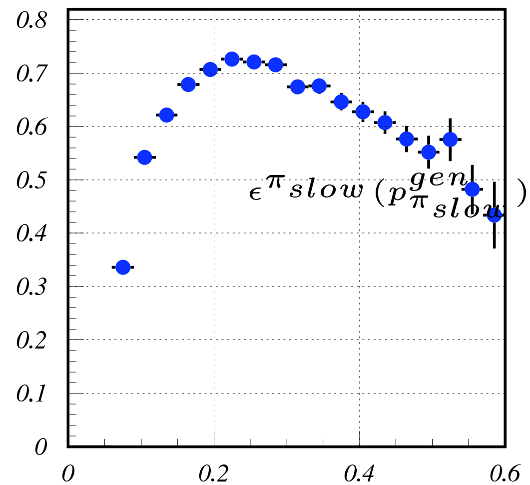



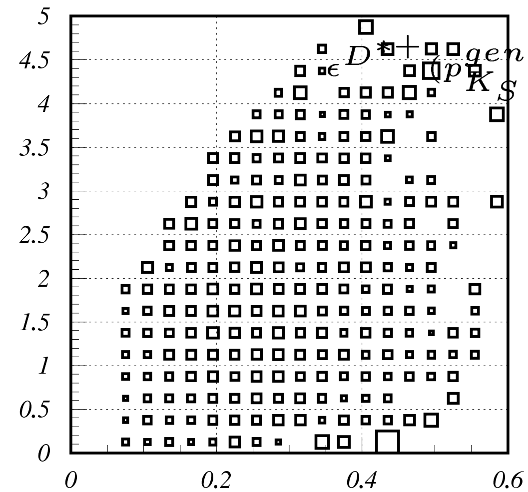




$\epsilon^{K_S}(p^{gen}_{K_S}) \times \epsilon^{\pi^-}(p^{gen}_{\pi^-})$ here

## Factorizability in $D^0 \to K_S\pi^-\pi^+$ continues...

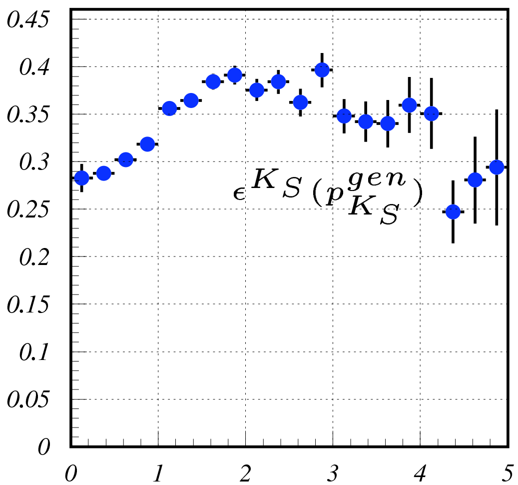


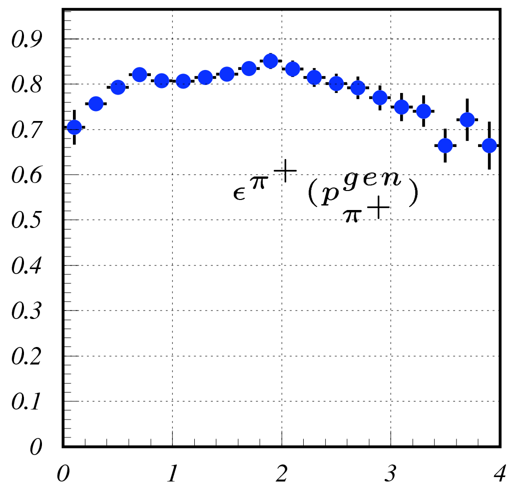



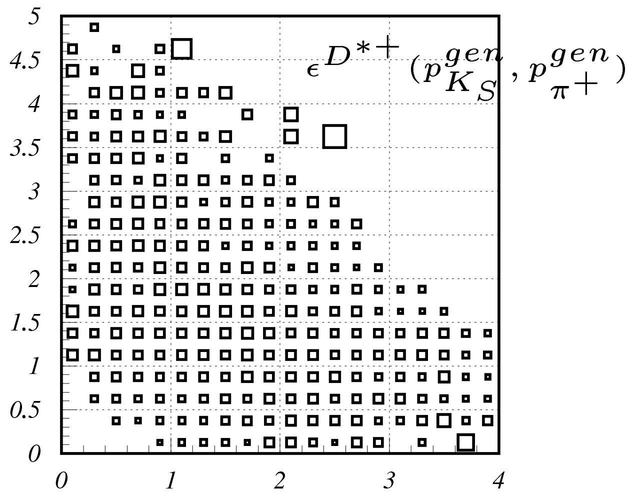




$\epsilon^{K_S}(p^{gen}_{K_S}) \times \epsilon^{\pi_{slow}}(p^{gen}_{\pi_{slow}})$ here

## **Factorizability in $D^0 \to K_S\pi^-\pi^+$ continues...**




$\epsilon^{K_S}(p^{gen}_{K_S}) \times \epsilon^{\pi^+}(p^{gen}_{\pi^+})$ here