Progress on PWA of $D^0 \rightarrow K_S^0\ \pi^+\ \pi^-\ \pi^0$

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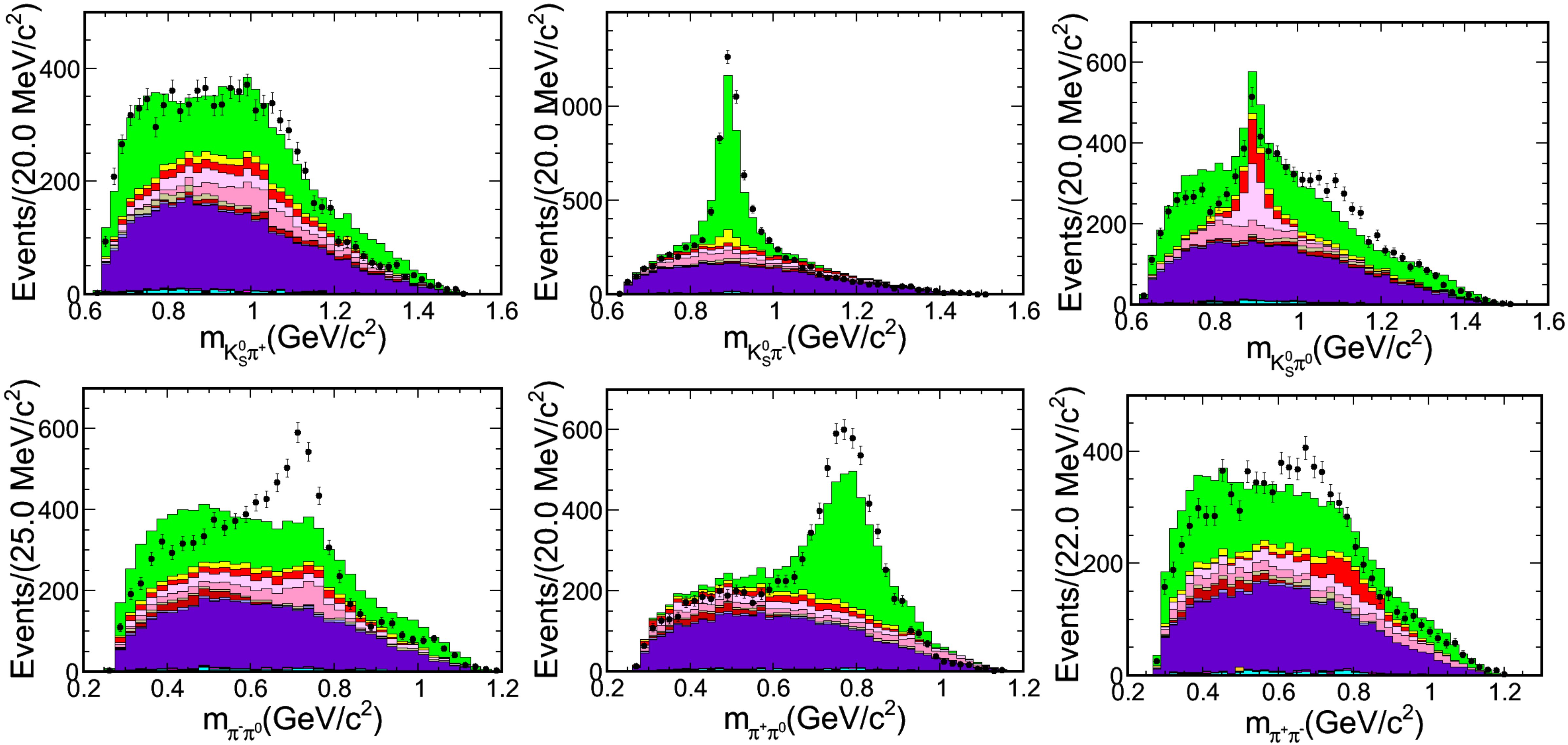
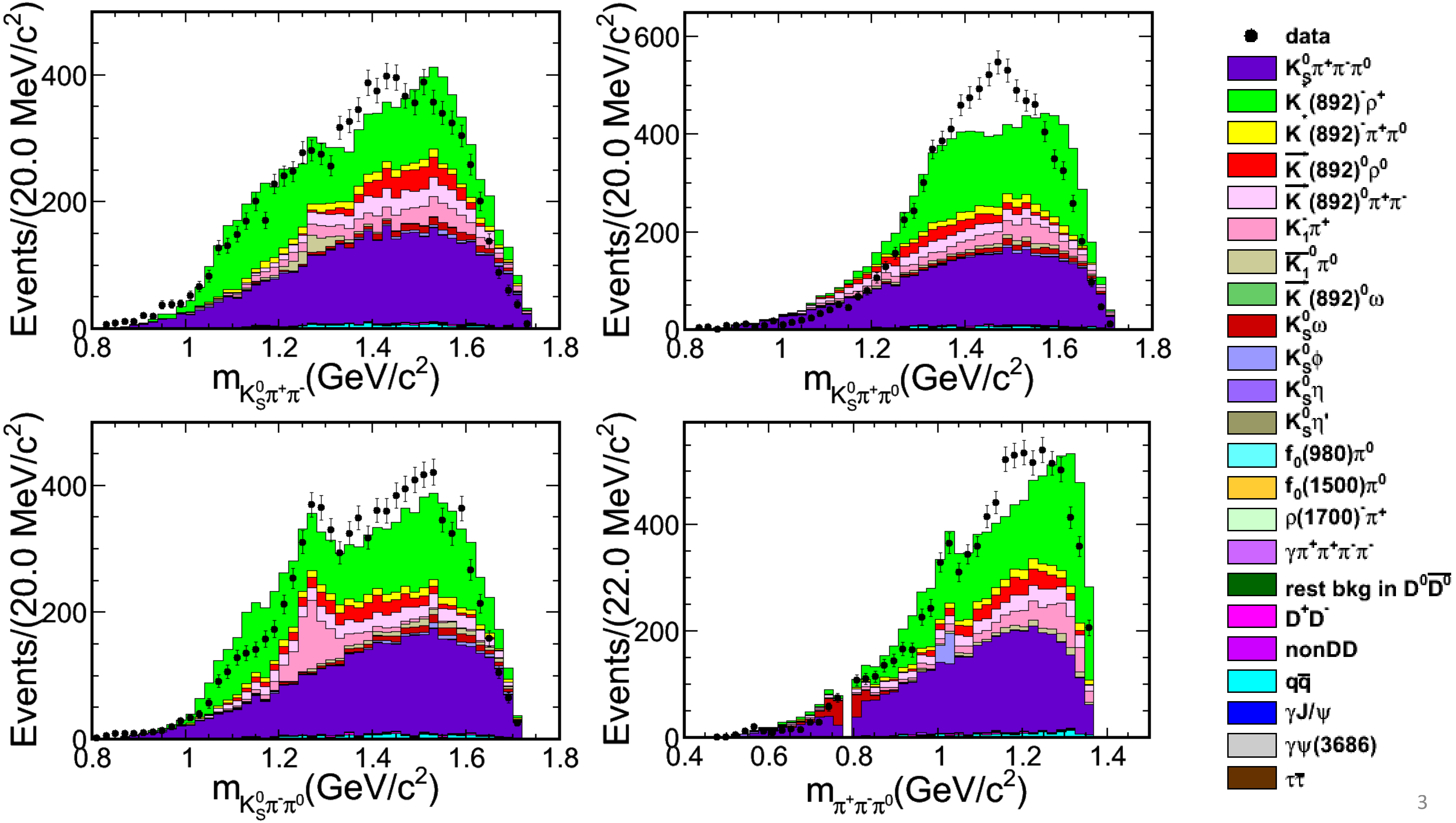
$D^0 \rightarrow K_S^0\, \pi^+\, \pi^-\, \pi^0$



$D^0 \rightarrow K_S^0\, \pi^+\, \pi^-\, \pi^0$



Amplitude Analysis

➢ Likelihood Construction

It is a fit method;
MINUIT is used to determined the fit parameters;
Background is subtracted with negative weight method.

$$\ln L = \sum_{i}^{N_{data}} w_i^{data} \ln S(a_i, p_j) - \sum_{i}^{N_{bkg}} w_i^{bkg} \ln S(a_i, p_j)$$

PDF is calculated by

$$S(a_i, p_j) = \frac{\epsilon(p_j)|A(a_i, p_j)|^2 R_4(p_j)}{\int \epsilon(p_j)|A(a_i, p_j)|^2 R_4(p_j) dp_j}$$

4-momentum dependent

MC integration

$$\frac{1}{N_{mc}} \sum_{j}^{N_{mc}} |A(a_i, p_j)|^2$$

$\epsilon(p_j)$: efficiency; $R_4(p_j)$: four-body phase space;
$A(a_i,p_j)$: total amplitudes.

Amplitude Analysis

➢ Amplitude Construction

Total amplitudes is modeled as the sum over all the partial wave amplitudes;

$$A(a_i, p_j) = \sum_i a_i A_i(p_j)$$

$a_i = \rho_i e^{i\phi_i}$: the complex coefficient;

$A_i(p_j)$: the i^th^ partial wave amplitude.

$$A_i(p_j) = P_i^1(p_j) P_i^2(p_j) S_i(p_j) F_i^1(p_j) F_i^2(p_j) F_i^D(p_j)$$

- $P_i^1(pj)$ and $P_i^2(pj)$ are the propagators of intermediate resonances 1 and 2;
- $F_i^1(pj)$, $F_i^2(pj)$ and $F_i^D(pj)$ are the Blatte-Weisskopf barriers (PRD 86, 010001 (2012));
- $S_i(p_j)$ is the spin factor and constructed with the covariant tensors. (Eur. Phys. J. A16, 537 (1992))

A Trick to Save Computing Resource

- **PDF** is calculated by

$$S(a_i, p_j) = \frac{\epsilon(p_j)|A(a_i, p_j)|^2 R_4(p_j)}{\int \epsilon(p_j)|A(a_i, p_j)|^2 R_4(p_j) dp_j}$$

MC integration

$$\frac{1}{N_{mc}} \sum_j^{N_{mc}} |A(a_i, p_j)|^2$$

ϵ(p_j): efficiency; *R_4(p_j)*: four-body phase space;
A(a_i,p_j): total amplitudes.

4-momentum dependent

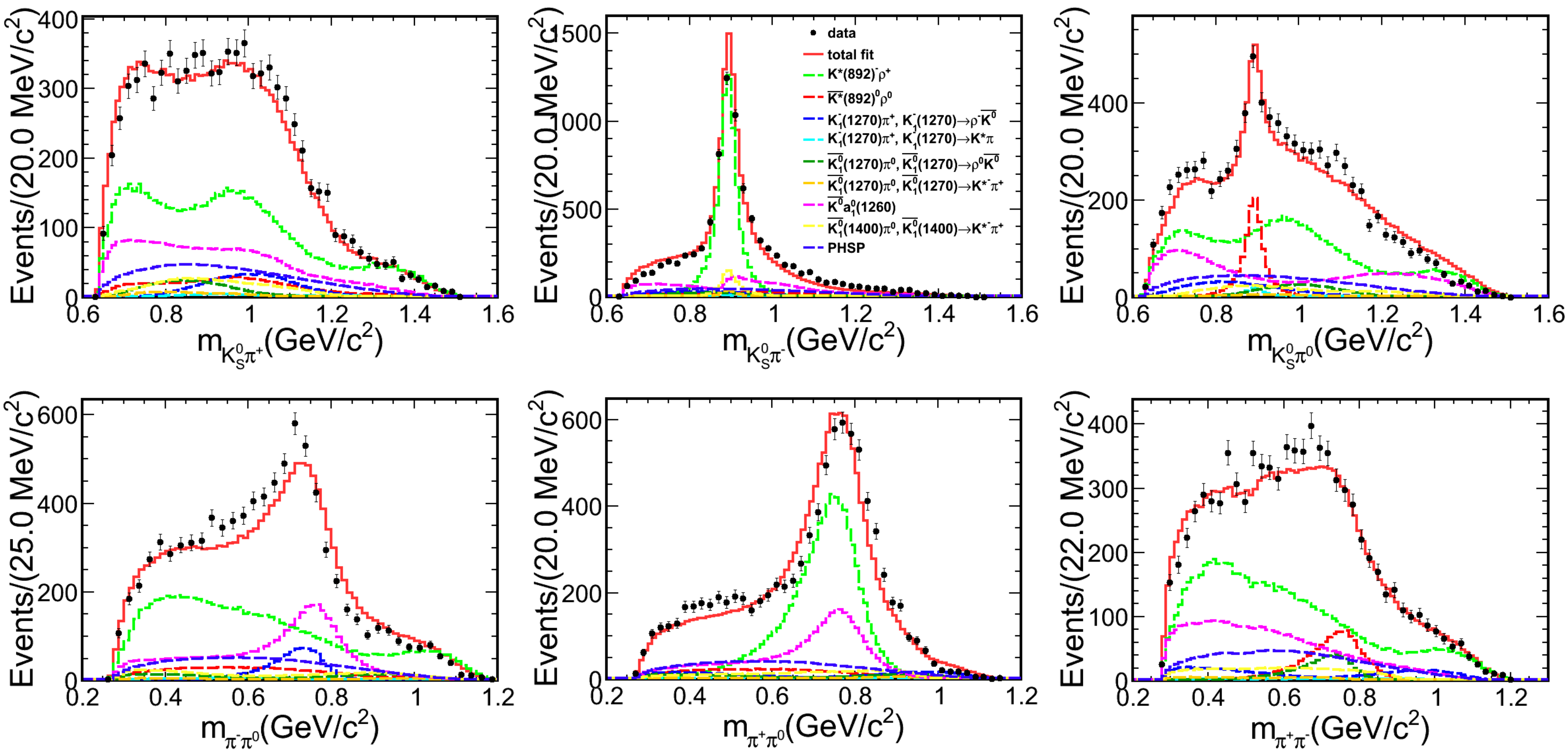
$$\frac{1}{N_{g,ph}} \sum_j^{N_{s,ph}} |A(a_i, p_j)|^2 = \frac{1}{N_{g,ph}} \sum_j^{N_{s,ph}} \sum_\alpha a_\alpha A_\alpha(p_j) \sum_\beta a_\beta A_\beta^*(p_j)$$

$$= \frac{1}{N_{g,ph}} \sum_{\alpha,\beta} a_\alpha a_\beta \sum_j^{N_{s,ph}} A_\alpha(p_j) A_\beta^*(p_j)$$

$$= \frac{1}{N_{g,ph}} \sum_{\alpha,\beta} a_\alpha a_\beta U_{\alpha,\beta},$$

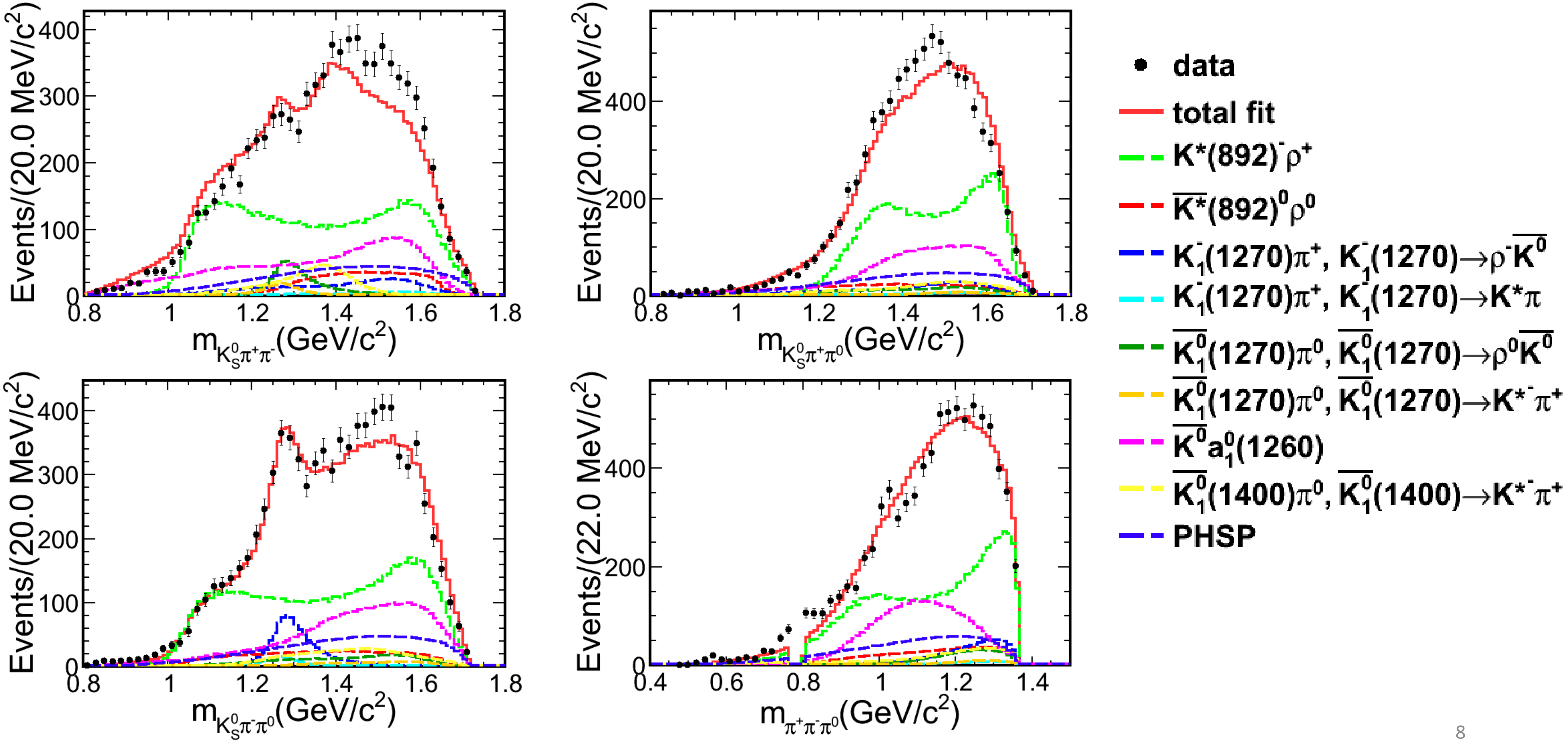
Here, presume the masses and widths of resonances are fixed

Projection



data
total fit
$K^*(892)^-\rho^+$
$\overline{K^*}(892)^0\rho^0$
$K_1^-(1270)\pi^+$, $K_1^-(1270)\to\rho^-\overline{K^0}$
$K_1^-(1270)\pi^+$, $K_1^-(1270)\to K^*\pi$
$\overline{K_1^0}(1270)\pi^0$, $\overline{K_1^0}(1270)\to\rho^0\overline{K^0}$
$\overline{K_1^0}(1270)\pi^0$, $\overline{K_1^0}(1270)\to K^{*-}\pi^+$
$\overline{K^0}a_1^0(1260)$
$\overline{K_1^0}(1400)\pi^0$, $\overline{K_1^0}(1400)\to K^{*-}\pi^+$
PHSP
Events/(20.0 MeV/c^2)
Events/(25.0 MeV/c^2)
Events/(22.0 MeV/c^2)
$m_{K_S^0\pi^+}$(GeV/c^2)
$m_{K_S^0\pi^-}$(GeV/c^2)
$m_{K_S^0\pi^0}$(GeV/c^2)
$m_{\pi^-\pi^0}$(GeV/c^2)
$m_{\pi^+\pi^0}$(GeV/c^2)
$m_{\pi^+\pi^-}$(GeV/c^2)

Projection



Events/(20.0 MeV/c^2)
$m_{K_S^0\pi^+\pi^-}$(GeV/c^2)
$m_{K_S^0\pi^+\pi^0}$(GeV/c^2)
$m_{K_S^0\pi^-\pi^0}$(GeV/c^2)
Events/(22.0 MeV/c^2)
$m_{\pi^+\pi^-\pi^0}$(GeV/c^2)
data
total fit
$K^*(892)^-\rho^+$
$\overline{K^*}(892)^0\rho^0$
$K_1^-(1270)\pi^+$, $K_1^-(1270)\to\rho^-\overline{K^0}$
$K_1^-(1270)\pi^+$, $K_1^-(1270)\to K^*\pi$
$\overline{K_1^0}(1270)\pi^0$, $\overline{K_1^0}(1270)\to\rho^0\overline{K^0}$
$\overline{K_1^0}(1270)\pi^0$, $\overline{K_1^0}(1270)\to K^{*-}\pi^+$
$\overline{K^0}a_1^0(1260)$
$\overline{K_1^0}(1400)\pi^0$, $\overline{K_1^0}(1400)\to K^{*-}\pi^+$
PHSP

Amplitude Analysis

$D^0 \to K^{*-}\rho^+$	$D^0[S] \to K^{*-}\rho^+$ $D^0[P] \to K^{*-}\rho^+$ $D^0[D] \to K^{*-}\rho^+$
$D^0 \to \bar{K}^{*0}\rho^0$	$D^0[S] \to \bar{K}^{*0}\rho^0$ $D^0[P] \to \bar{K}^{*0}\rho^0$ $D^0[D] \to \bar{K}^{*0}\rho^0$
$D^0 \to K_1^-(1270)\pi^+$	$D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[S] \to K^{*-}\pi^0$ $D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[D] \to K^{*-}\pi^0$ $D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[S] \to \bar{K}^{*0}\pi^-$ $D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[D] \to \bar{K}^{*0}\pi^-$ $D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[S] \to \bar{K}^0\rho^-$ $D^0 \to K_1^-(1270)\pi^+,\ K_1^-(1270)[D] \to \bar{K}^0\rho^-$
$D^0 \to \bar{K}_1^0(1270)\pi^0$	$D^0 \to \bar{K}_1^0(1270)\pi^0,\ \bar{K}_1^0(1270)[S] \to K^{*-}\pi^+$ $D^0 \to \bar{K}_1^0(1270)\pi^0,\ \bar{K}_1^0(1270)[D] \to K^{*-}\pi^+$ $D^0 \to \bar{K}_1^0(1270)\pi^0,\ \bar{K}_1^0(1270)[S] \to \bar{K}^0\rho^0$ $D^0 \to \bar{K}_1^0(1270)\pi^0,\ \bar{K}_1^0(1270)[D] \to \bar{K}^0\rho^0$
$D^0 \to \bar{K}^0 a_1^0(1260)$	$D^0 \to \bar{K}^0 a_1^0(1260),\ a_1^0(1260)[S] \to \rho^+\pi^-$ $D^0 \to \bar{K}^0 a_1^0(1260),\ a_1^0(1260)[D] \to \rho^+\pi^-$ $D^0 \to \bar{K}^0 a_1^0(1260),\ a_1^0(1260)[S] \to \rho^-\pi^+$ $D^0 \to \bar{K}^0 a_1^0(1260),\ a_1^0(1260)[D] \to \rho^-\pi^+$
$D^0 \to \bar{K}_1^0(1400)\pi^0$	$D^0 \to \bar{K}_1^0(1400)\pi^0,\ \bar{K}_1^0(1400)[S] \to K^{*-}\pi^+$ $D^0 \to \bar{K}_1^0(1400)\pi^0,\ \bar{K}_1^0(1400)[D] \to K^{*-}\pi^+$

Iso-spin conjugate,
C-G coefficient