$K^+K^-\pi^0$ update

Data and cuts

Dataset:

- Spring 2018 data

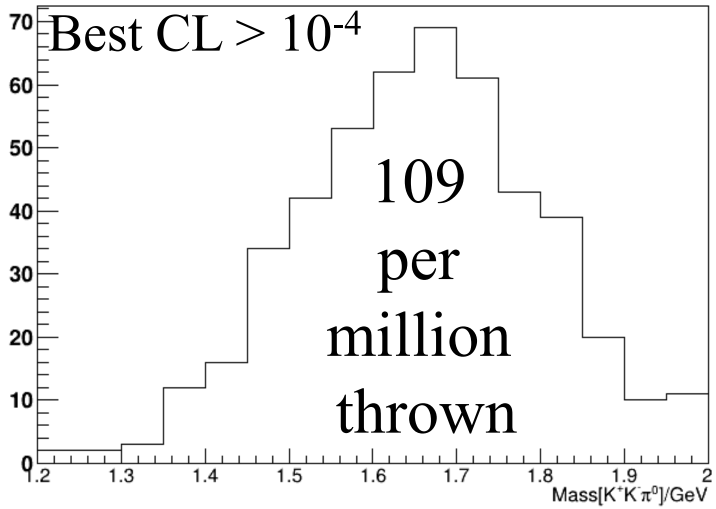
Restrictions:

- Incident photon timed to be within central peak
- Only best Confidence Level (*CL*) per event kept
- *CL* must be above 10^{-4}
- Kaons must be forward directed (seen in TOF)
- Kaons must have momentum < 3 GeV
- Missing mass within 3 standard deviations of central peak
- 0.12 GeV < Mass[π^0] < 0.15 GeV

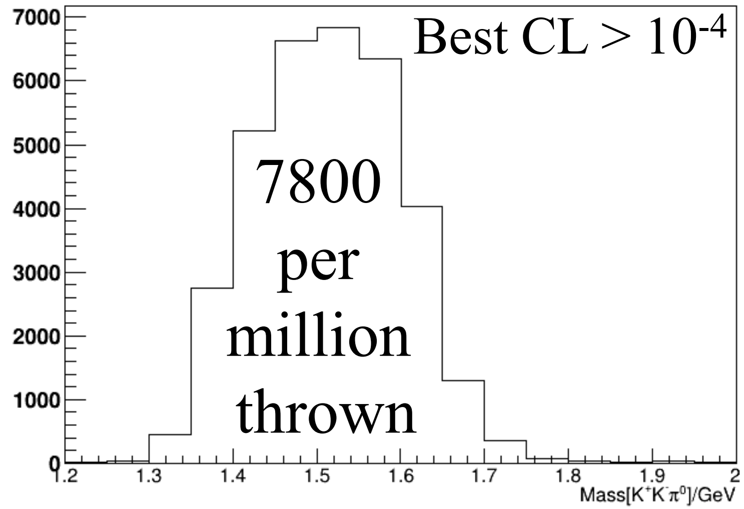
ASU

Contamination study (4.4 million thrown)

$\pi^+\pi^-\pi^0$ seen as $K^+K^-\pi^0$



$K^+\pi^-\pi^0$ seen as $K^+K^-\pi^0$



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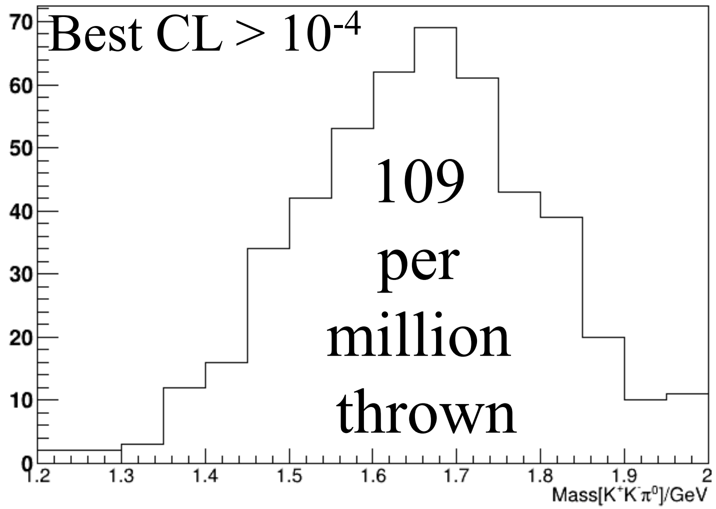
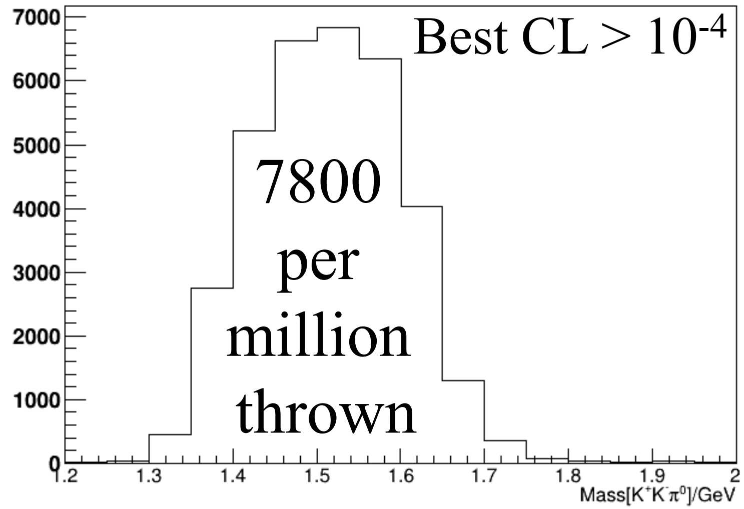
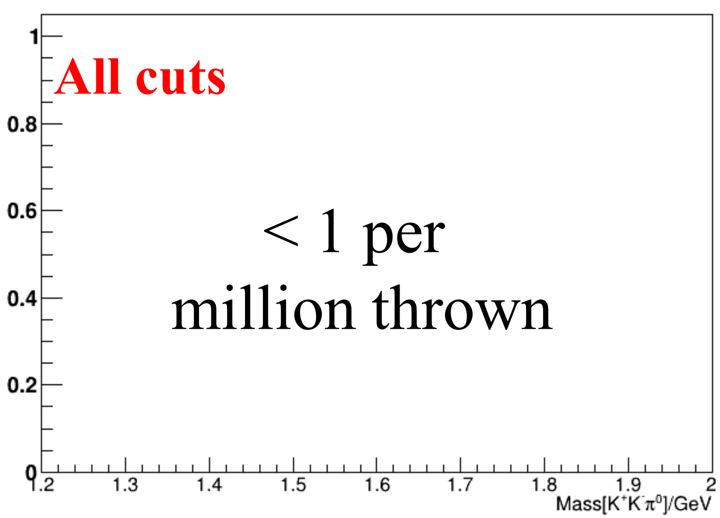


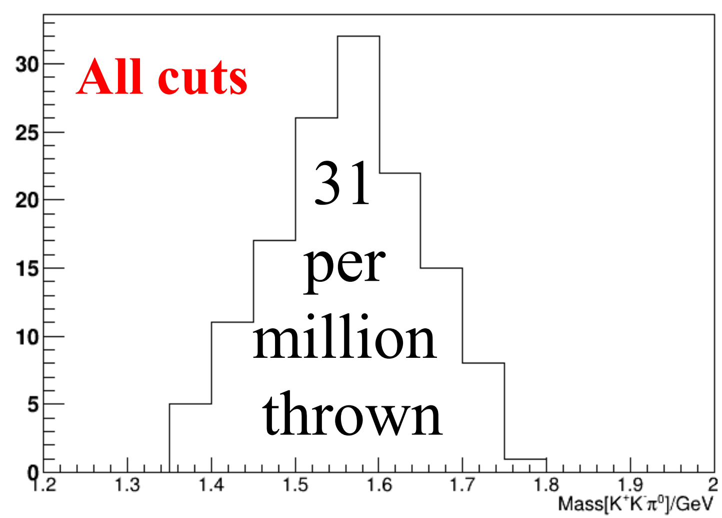
$K^+\pi^-\pi^0$ seen as $K^+K^-\pi^0$



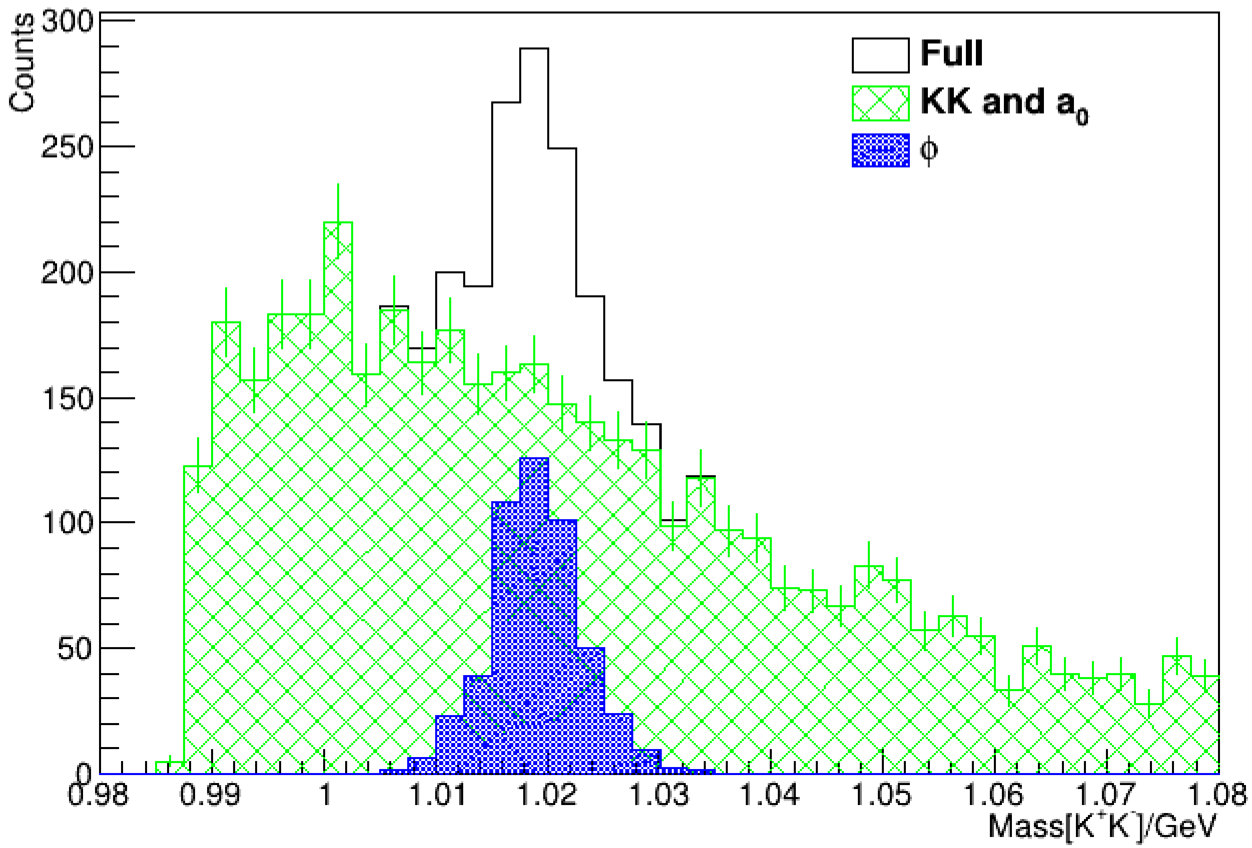
$\pi^+\pi^-\pi^0$ seen as $K^+K^-\pi^0$



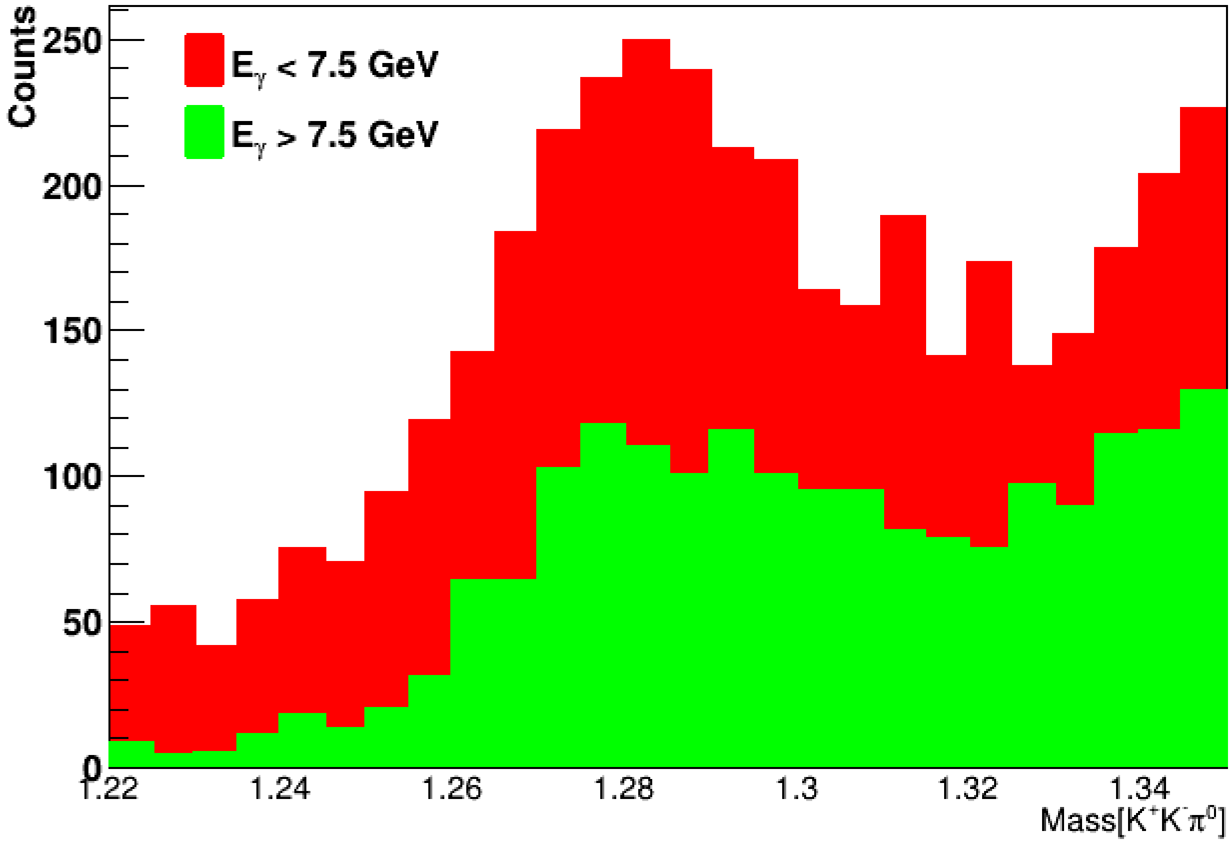
$K^+\pi^-\pi^0$ seen as $K^+K^-\pi^0$



Q-factors to separate $\varphi\pi$ from $K^+K^-\pi^0$ and $a_0\pi^0$ events

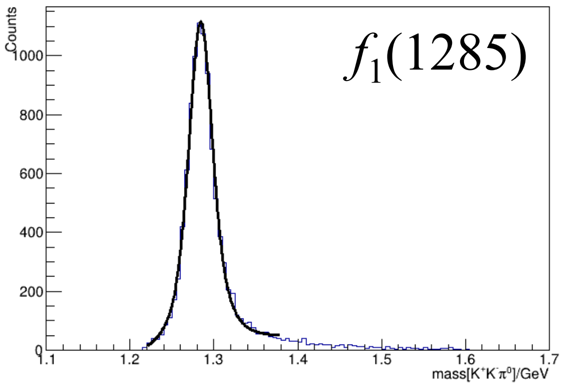


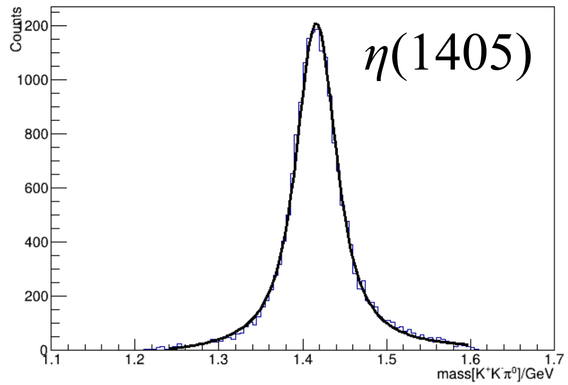
Additional E_γ cut

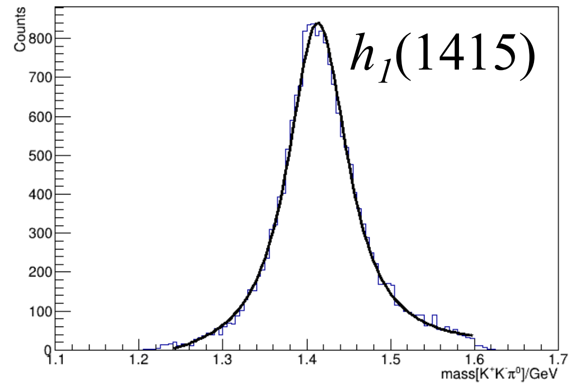


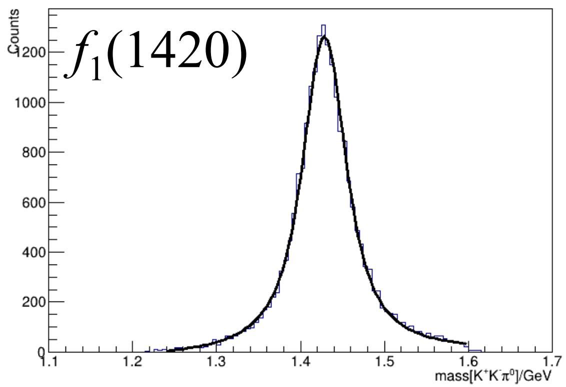
For now, only using events with E_γ below 7.5 GeV

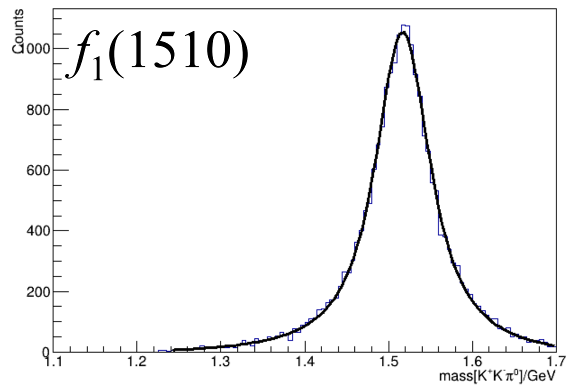
Monte Carlo peak fits





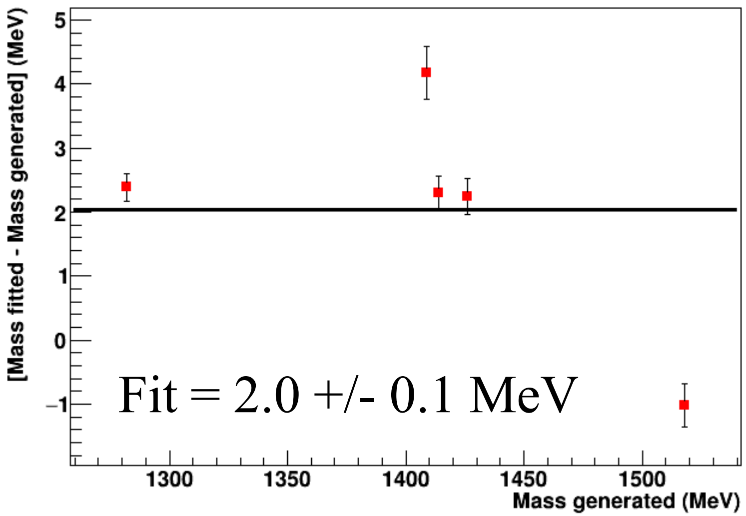


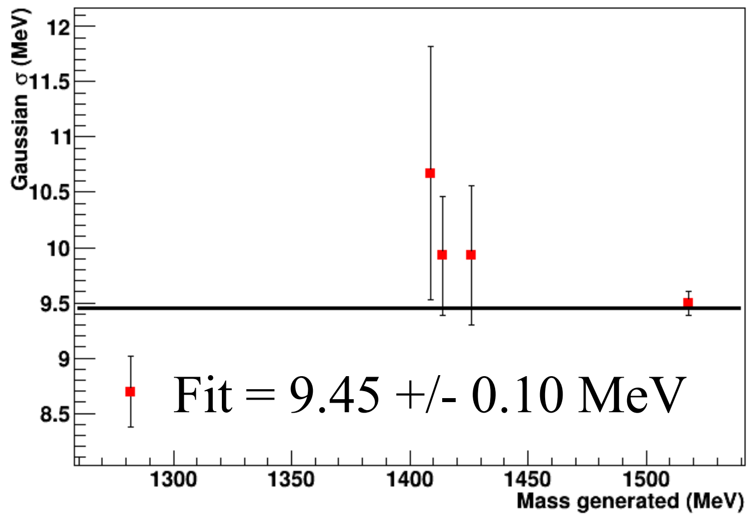




- Each mass spectrum was fit to voigtian line shape

Results of Monte Carlo peak fits





- Reconstructed masses are systematically high by about 2 MeV
- Gaussian broadening (σ) of Voigtian line shape is about 9.45 MeV

Intensity (Justin Stevens)

$$I(\Phi,\Omega,\Omega_H) = 2\kappa \sum_k$$

$$\Bigg\{(1-P_\gamma)\left[\left|\sum_{i_N,m}[J_i^N]_{m,k}^{(+)} Im(Z) + \sum_{i_U,m}[J_i^U]_{m,k}^{(-)} Im(Z)\right|^2 + \left|\sum_{i_N,m}[J_i^N]_{m,k}^{(-)} Re(Z) + \sum_{i_U,m}[J_i^U]_{m,k}^{(+)} Re(Z)\right|^2\right] +$$

$$(1+P_\gamma)\left[\left|\sum_{i_N,m}[J_i^N]_{m,k}^{(-)} Im(Z) + \sum_{i_U,m}[J_i^U]_{m,k}^{(+)} Im(Z)\right|^2 + \left|\sum_{i_N,m}[J_i^N]_{m,k}^{(+)} Re(Z) + \sum_{i_U,m}[J_i^U]_{m,k}^{(-)} Re(Z)\right|^2\right]\Bigg\}$$

The $[J_i^{N,U}]_{m,k}^{(\epsilon)}$ are the free complex parameters in the fit for a given reflectivity amplitude.

where $Z_m^i(\Omega,\Omega_H) = e^{-i\Phi} X_m^i(\Omega,\Omega_H)$ is the phase-rotated decay amplitude and *Φ* is the angle between the production plane and the photon polarization

$K^+K^-\pi^0$ update

a_0(980) mass parameterization

$a_0(980)$

Using $a_0(980)$ isobar as parameterized by BESIII:

The ordinary intermediate resonance is parametrized by a relativistic Breit-Wigner (BW) propagator with a constant-width

$$BW(s) = \frac{1}{M^2 - s - iM\Gamma}, \tag{4.2}$$

where s is the invariant mass squared of resonances, M and Γ are the corresponding mass and width. For $a_0(980)^0$ with mass near $K\bar{K}$ threshold, we use dispersion integrals to describe its lineshape

The BESIII Collaboration, arXiv:2209.11175v1

$a_0(980)$

The $a_0(980)$ amplitude is constructed using the following denominator:

$$D_a(s) = m_0^2 - s - \sum_{ch} \Pi_{ch}(s), \qquad (4)$$

where m_0 is the $a_0(980)$ mass and $\Pi_{ch}(s)$ in the sum over channels is a complex function, with imaginary part

$$\mathrm{Im}\Pi_{ch}(s) = g_{ch}^2 \rho_{ch}(s) F_{ch}(s), \qquad (5)$$

while real parts are given by principal value integrals,

$$\mathrm{Re}\Pi_{ch}(s) = \frac{1}{\pi} P \int_{s_{ch}}^{\infty} \frac{\mathrm{Im}\Pi_{ch}(s')ds'}{(s'-s)}. \qquad (6)$$

ASU

M. Ablikim *et. al.* (BESIII Collaboration), Phys. Rev. D **95**, 032002 (2017)

$a_0(980)$

In the above expressions $\rho_{ch}(s)$ is the available phase space for a given channel, obtained from the corresponding decay momentum $q_{ch}(s)$: $\rho_{ch}(s) = 2q_{ch}(s)/\sqrt{s}$. The integral in Eq. (6) is divergent when $s \to \infty$, so the phase space is modified by a form factor $F_{ch}(s) = e^{-\beta q_{ch}^2(s)}$, where the parameter β is related to the root-mean-square (rms) size of an emitting source [20]. We use $\beta = 2.0[\mathrm{GeV}/c^2]^{-2}$ corresponding to rms $= 0.68$ fm, and we verify that our results are not sensitive to the value of β. The integration in Eq. (6)

M. Ablikim *et. al.* (BESIII Collaboration), Phys. Rev. D **95**, 032002 (2017)

$a_0(980)$

BESIII

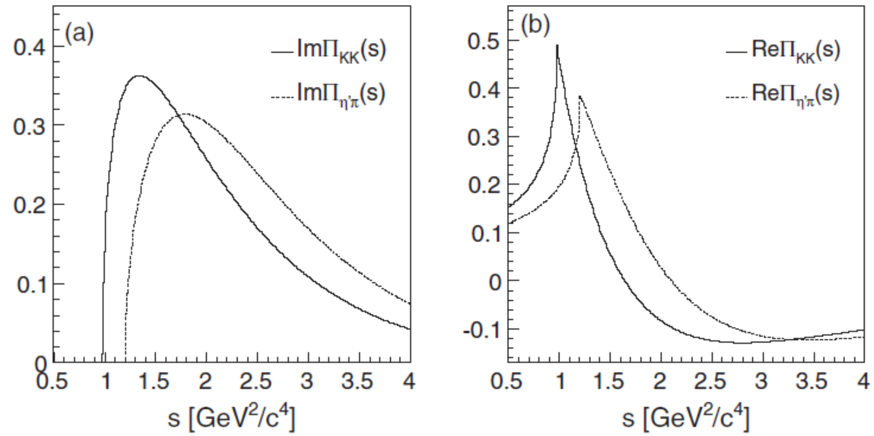
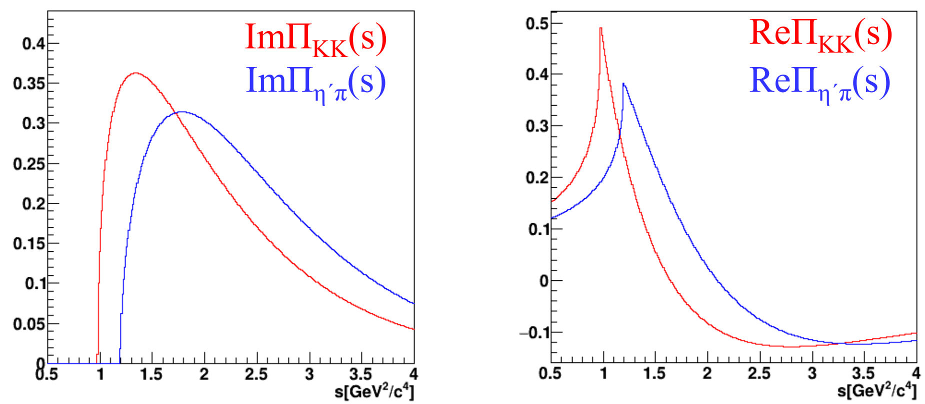


FIG. 4. Line shapes of (a) $\mathrm{Im}\Pi(s)$ and (b) $\mathrm{Re}\Pi(s)$ for the $K\bar{K}$ and $\eta'\pi$ production with arbitrary normalization.

I used Mathematica to perform the principal value integrals

GlueX



Isobar fits

Included waves

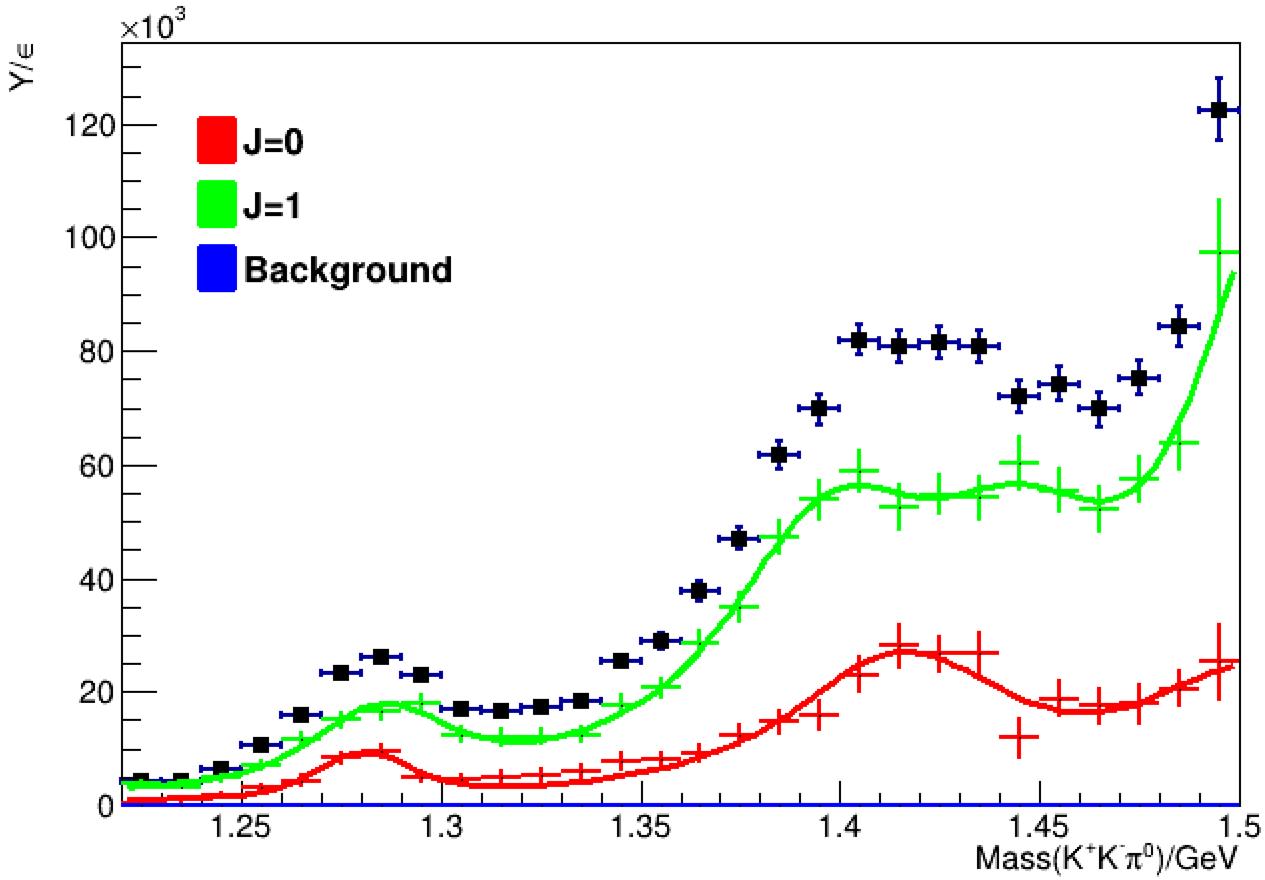
- Uniform background

- $J = 0$:
  - $a_0\pi^0$
  - $K^{*+}K^-$
  - $K^{*-}K^+$

- $J = 1$:
  - $a_0\pi^0$
  - $K^{*+}K^-$ (L=0, and L=1)
  - $K^{*-}K^+$ (L=0, and L=1)

PWA Results for $J = 0,1$ and background

Isobar fit results



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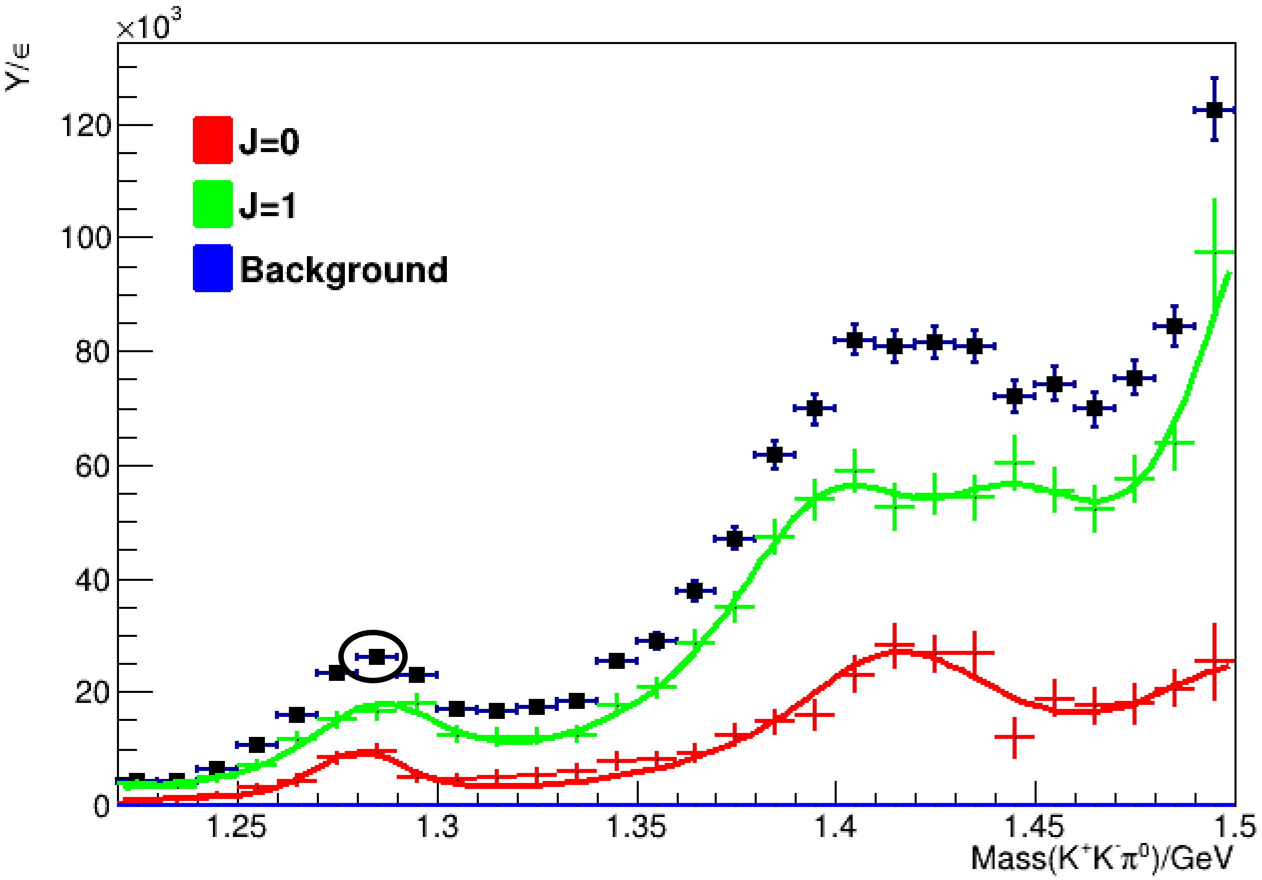
Isobar fit results



PWA Results for $J = 0,1$ and background

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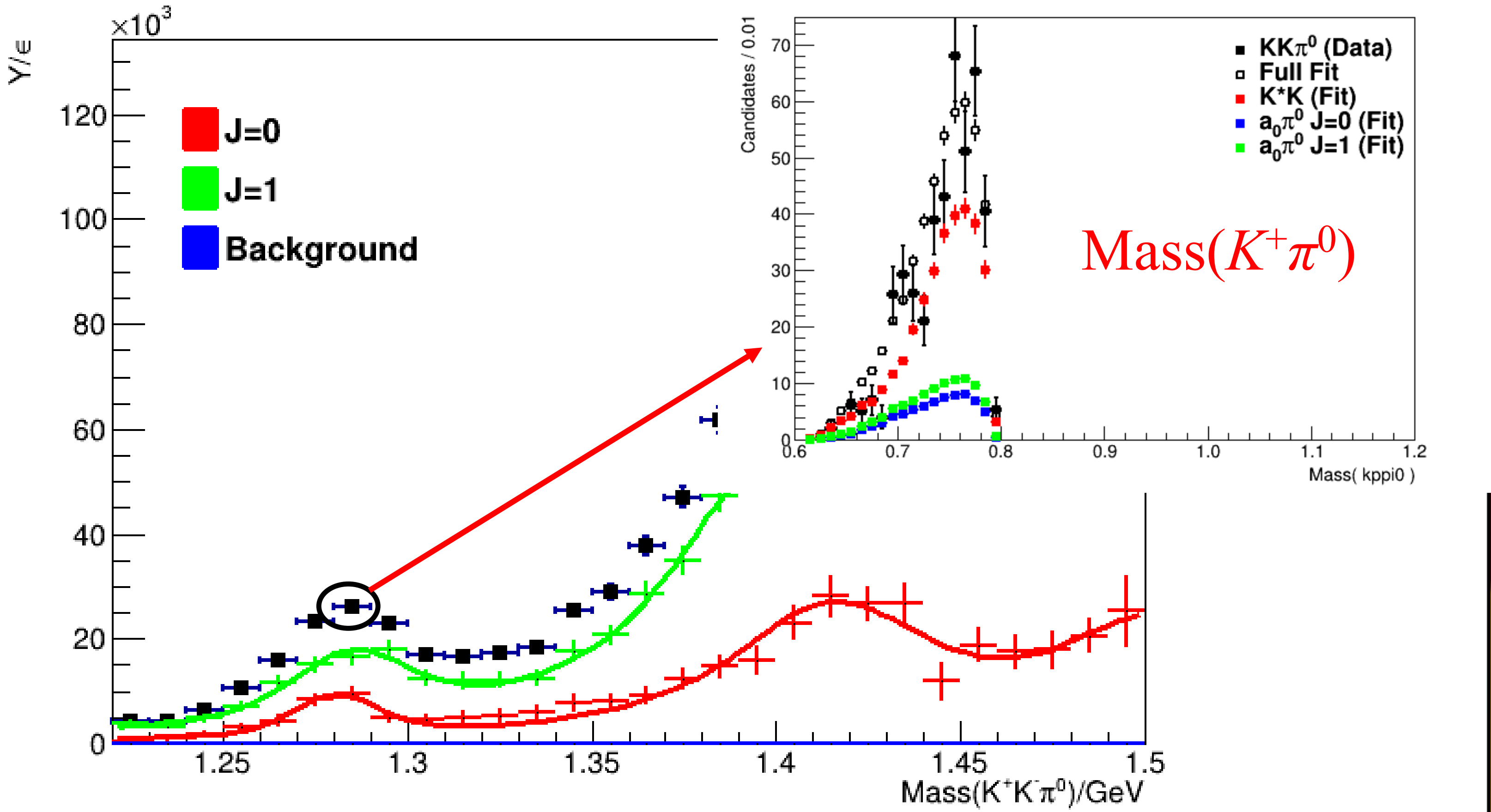

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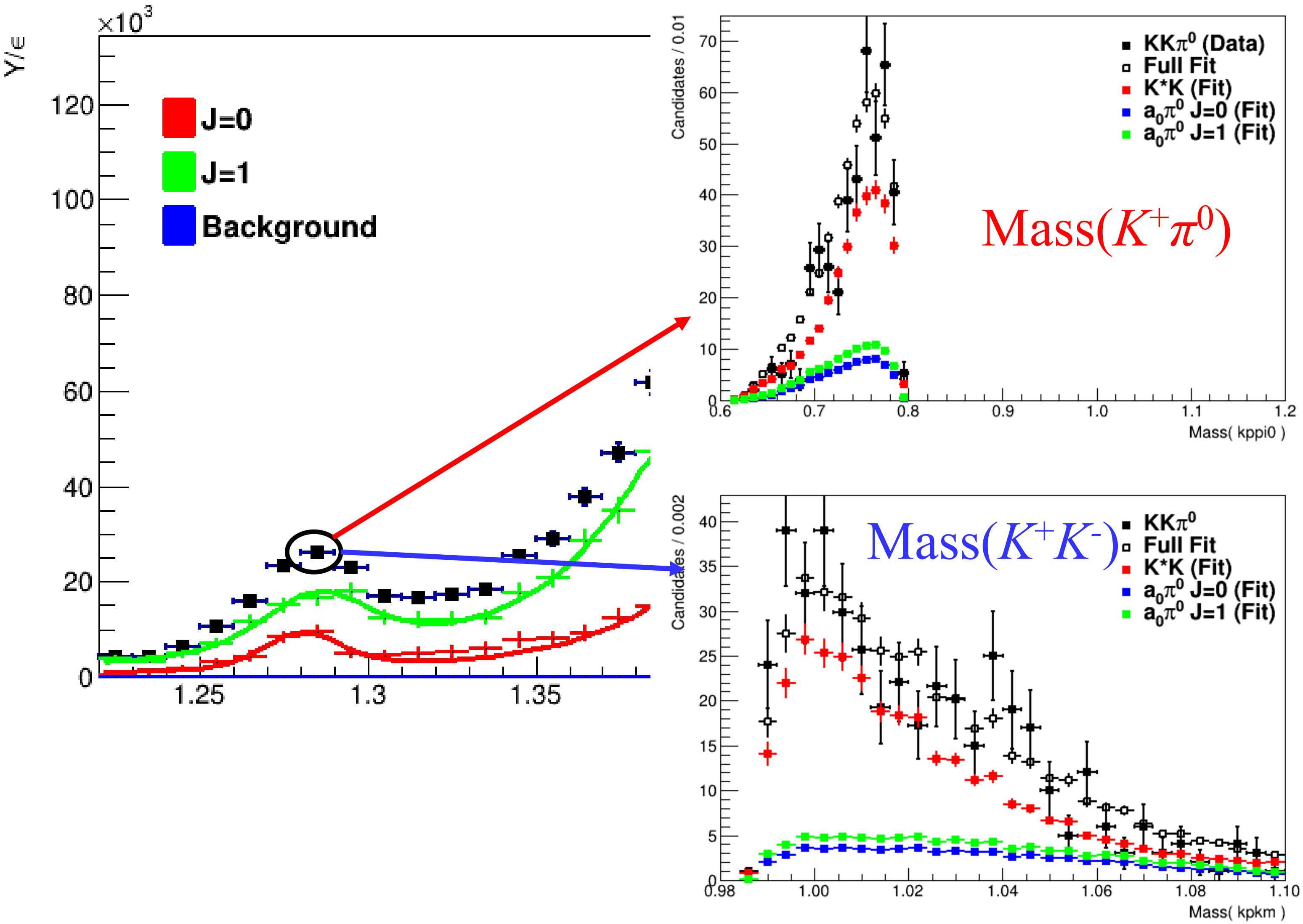

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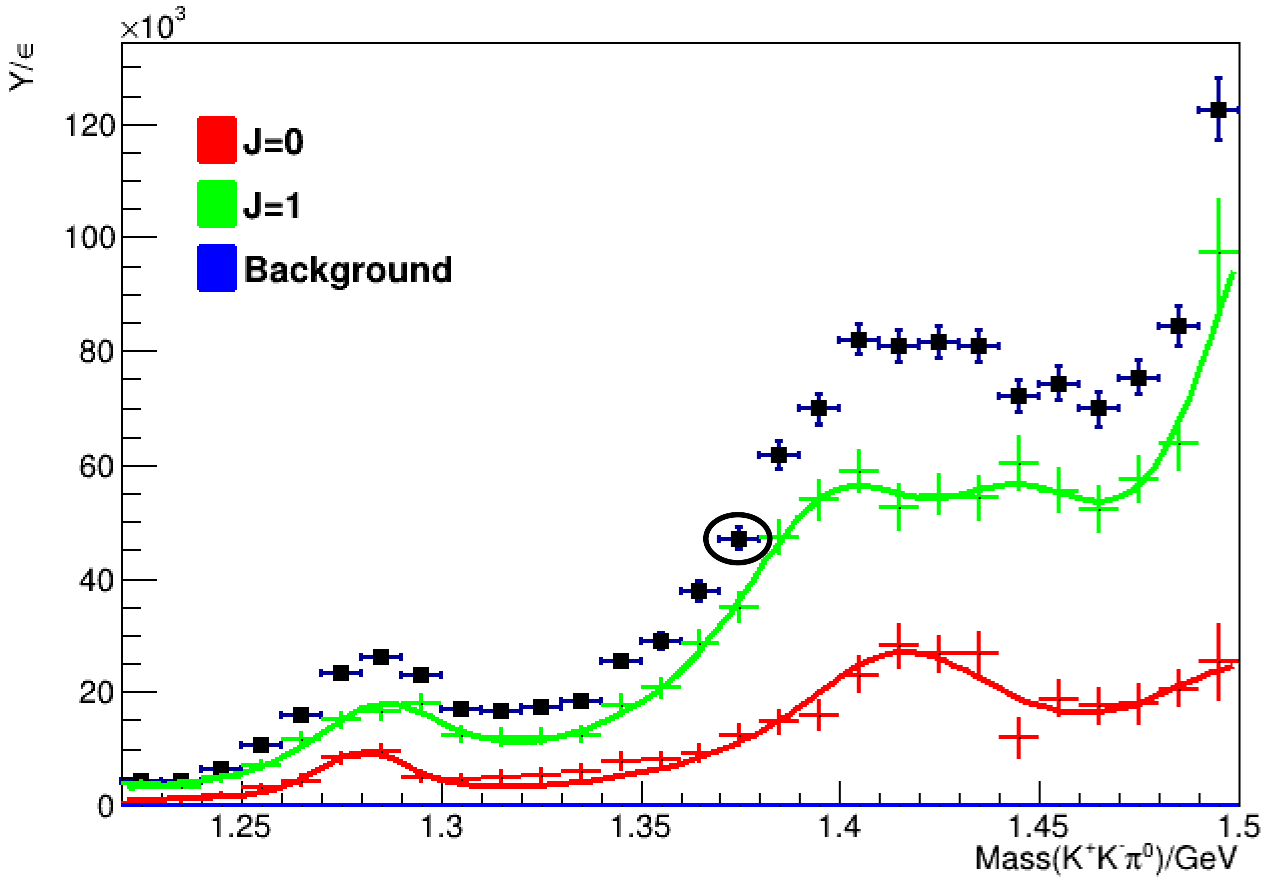

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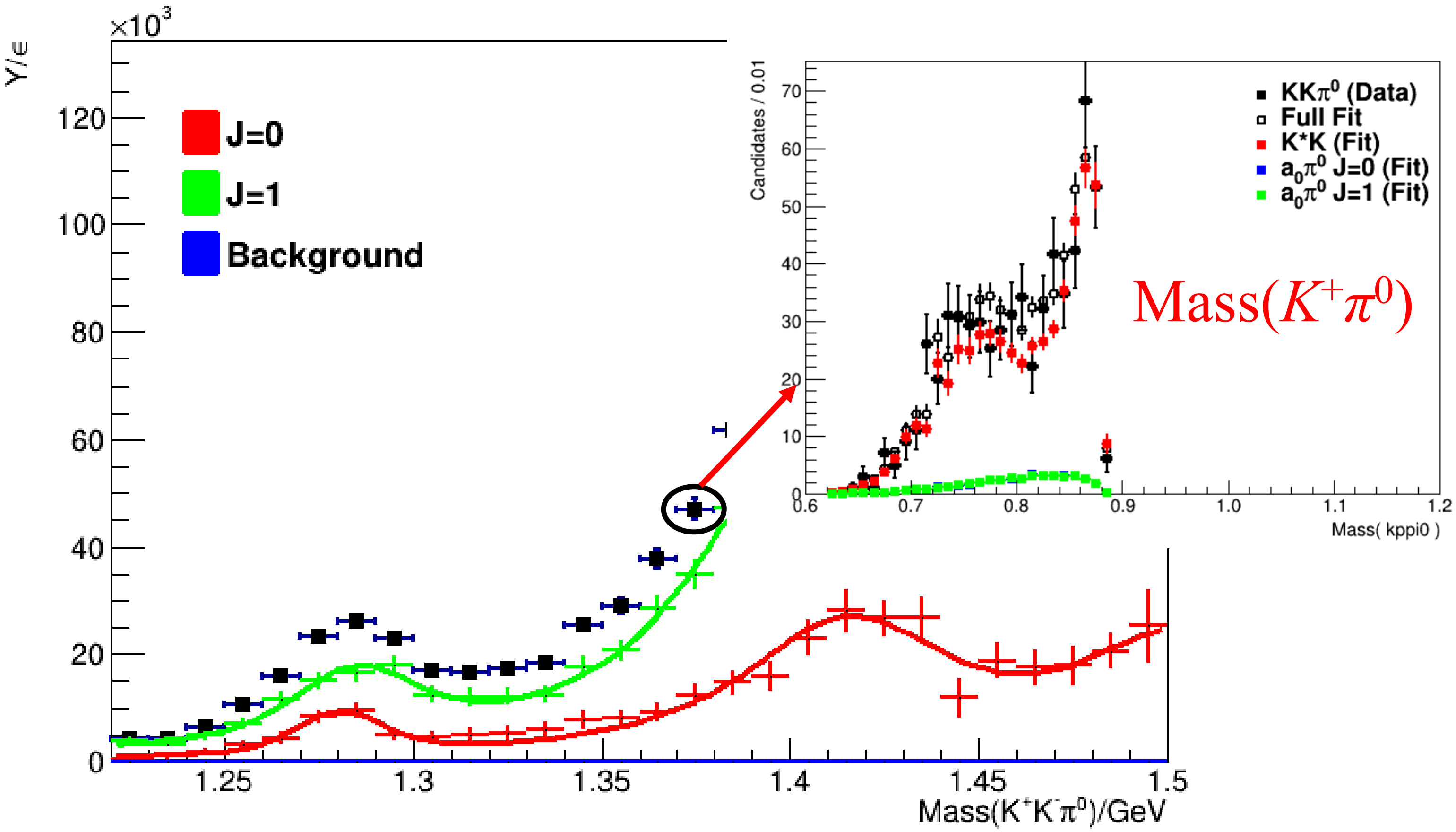

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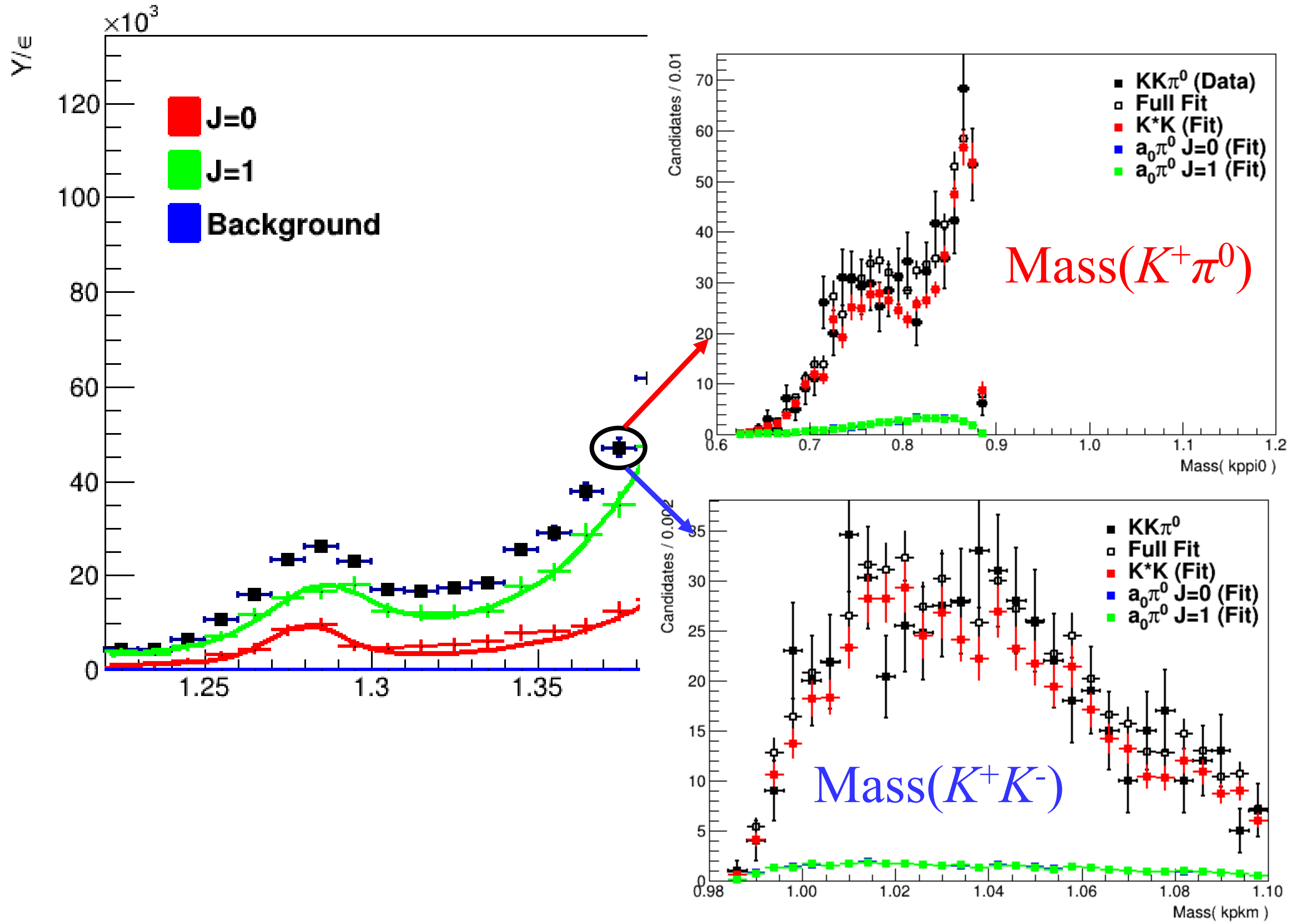

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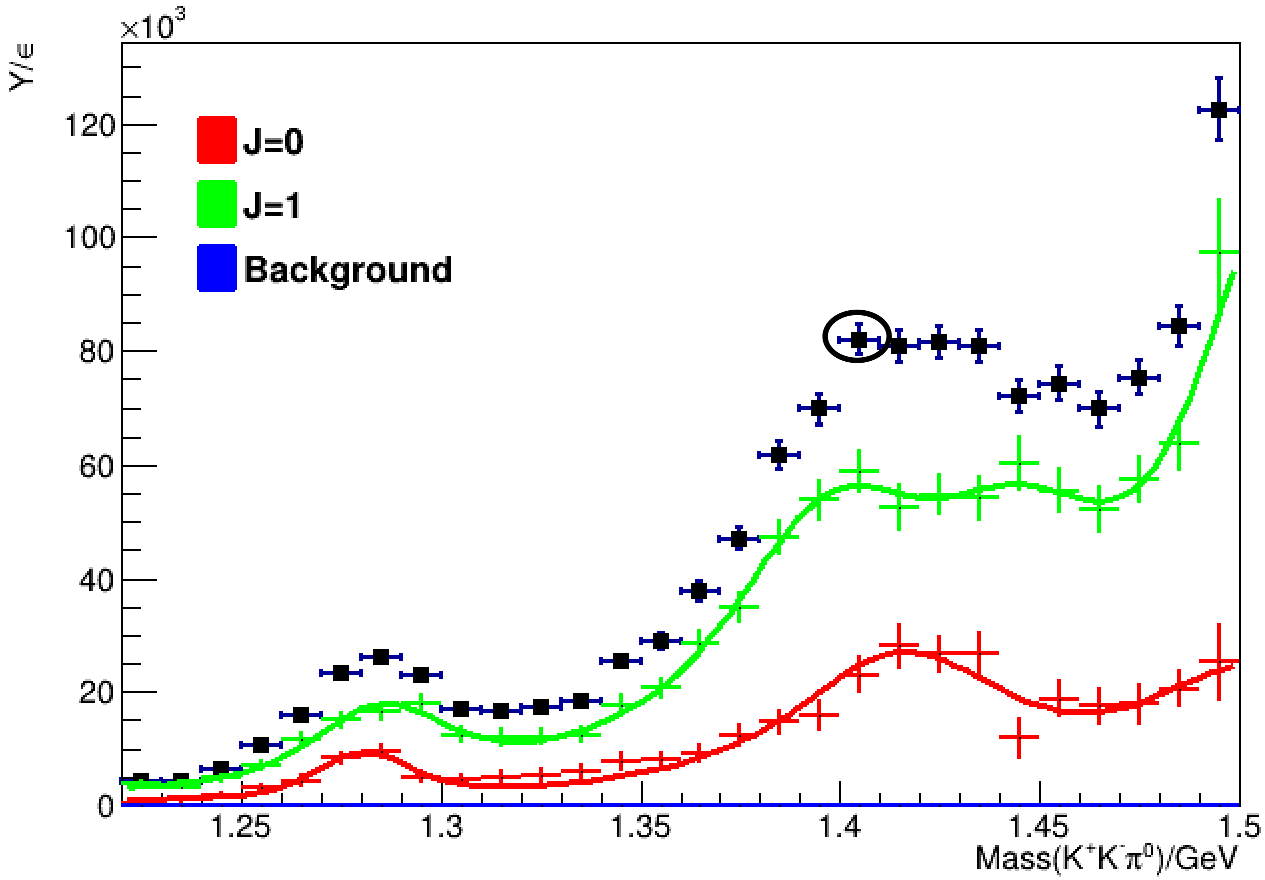

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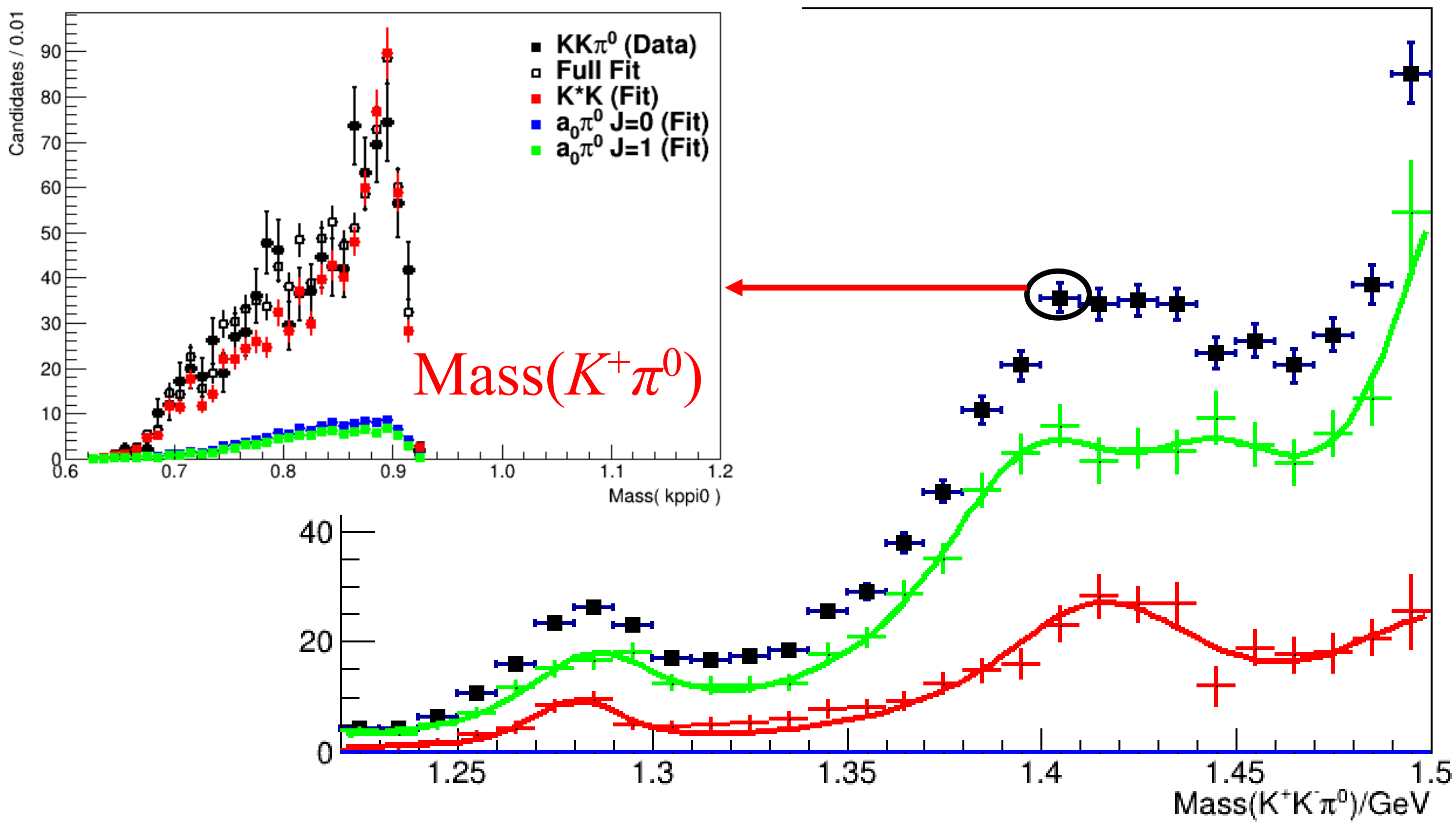

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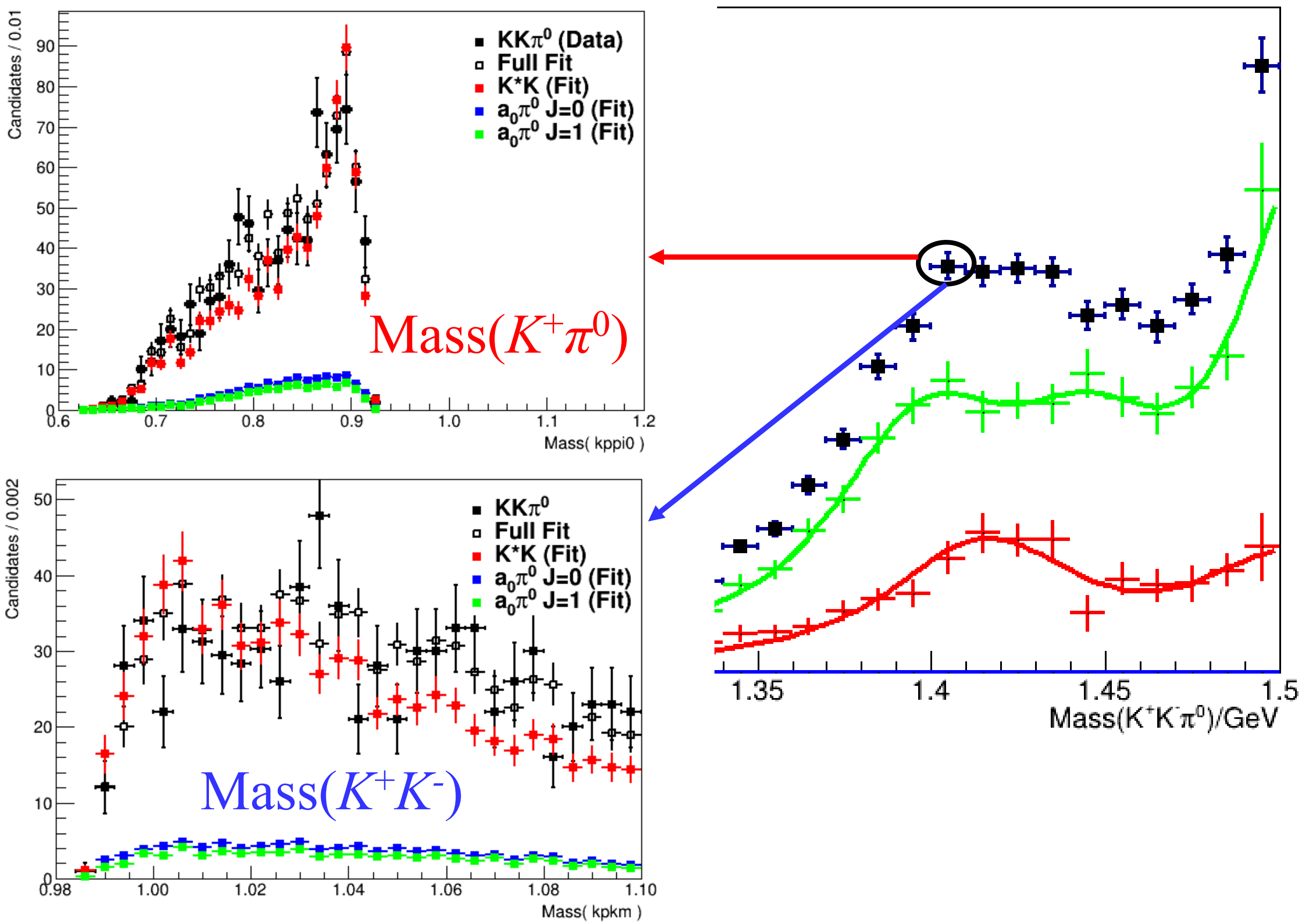


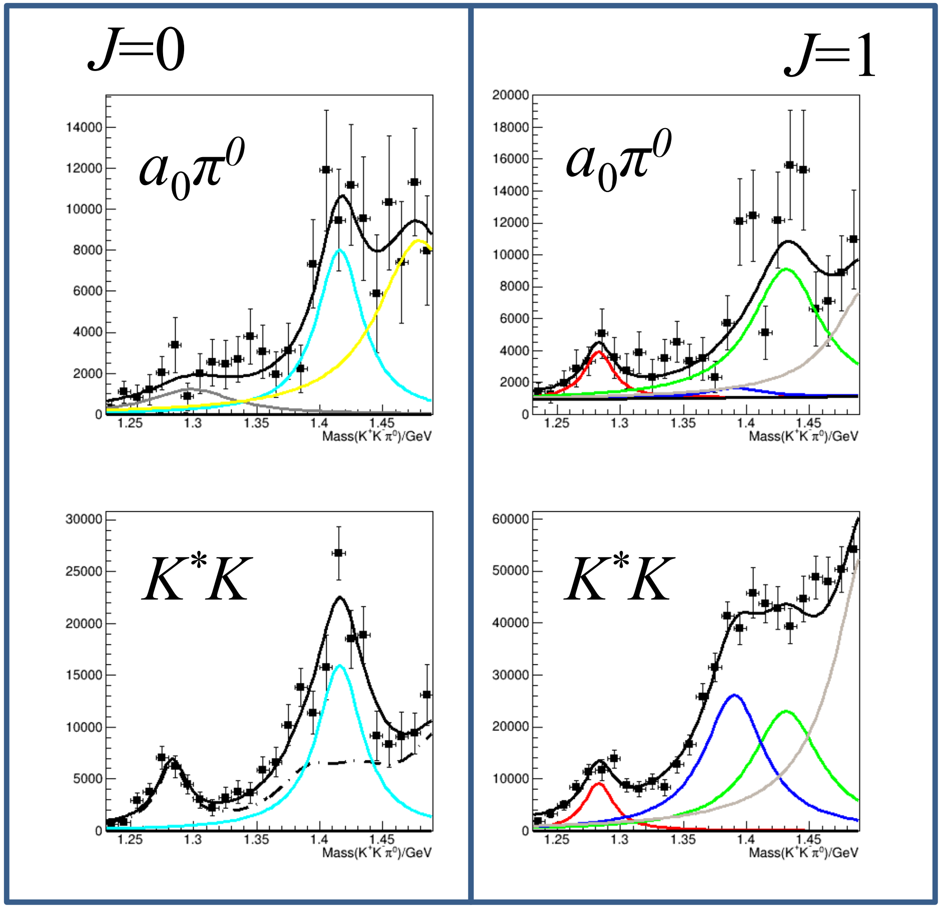
Simultaneous fit

_J=0_

Gray: $\eta(1295)$

Cyan: $\eta(1405)$

Yellow: $\eta(1475)$



_J=1_

Red: $f_1(1285)$

Blue: $h_1(1415)$

Green: $f_1(1420)$

Brown: $f_1(1510)$

- Dashed-dotted line is estimated leakage of J=1 into J=0
- Used parameters (centers and widths) of Breit-Wigners from the above fit to lock down those parameters for mass-dependent fit

Leakage study

Included waves for mass dependent fit

- $J = 0$:
  - ~~$\eta(1295)$~~ Not included
  - $\eta(1405) \rightarrow a_0\pi^0$, K^*K
  - $\eta(1475) \rightarrow a_0\pi^0$
- $J = 1$:
  - $f_1(1285) \rightarrow a_0\pi^0$, K^*K
  - $h_1(1415) \rightarrow K^*K$ (Note: $h_1 \rightarrow a_0\pi^0$ not allowed)
  - $f_1(1420) \rightarrow a_0\pi^0$, K^*K
  - $f_1(1510) \rightarrow a_0\pi^0$, K^*K

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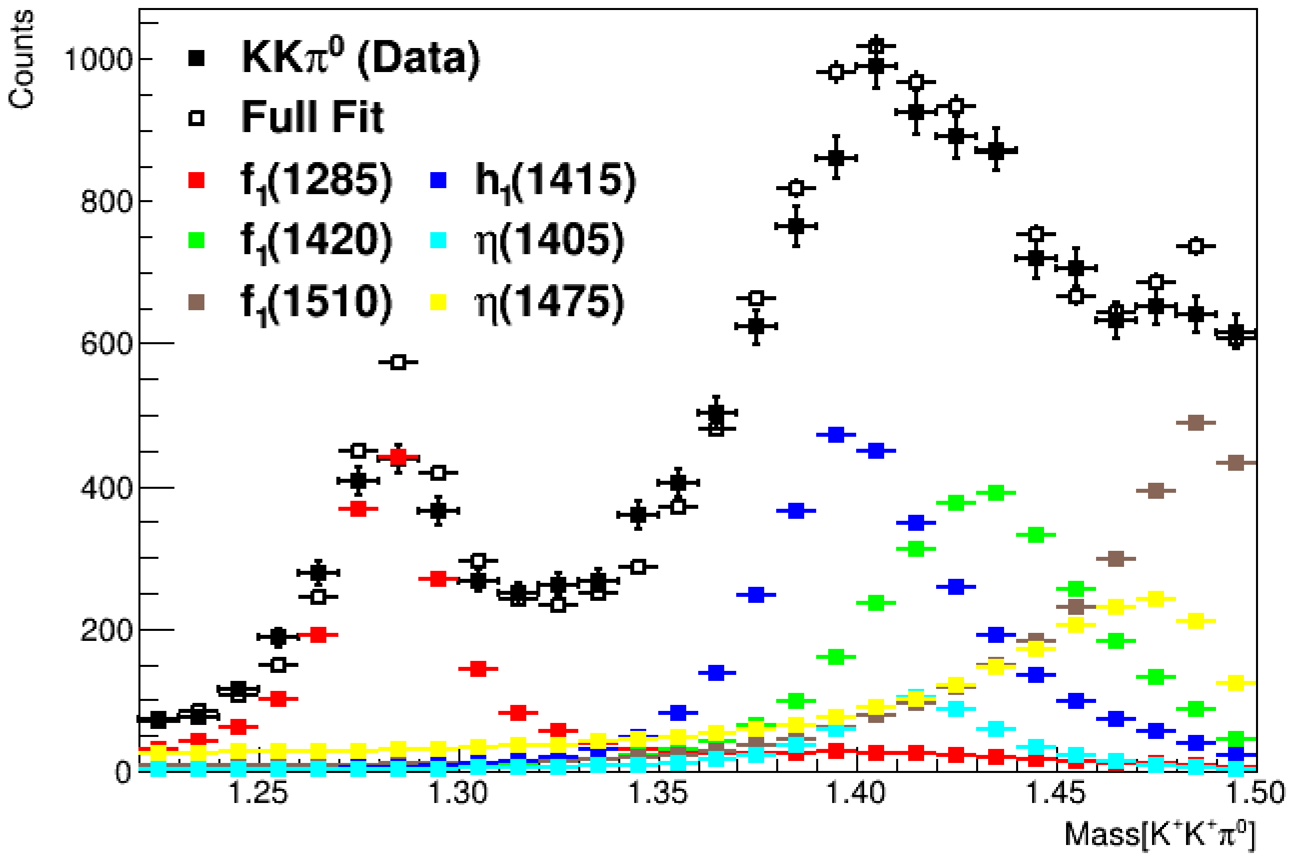
PWA mass-dependent fit



- Used fit parameters from above fit to simulate signal using gen_amp
- Did mass-independent fit using the gen_amp simulation to help verify leakage assumption

Included waves for mass dependent fit

- $J = 0$:
  - ~~$\eta(1295)$~~ Not included
  - $\eta(1405)\rightarrow a_0\pi^0, K^*K$ Branch measured
  - $\eta(1475)\rightarrow a_0\pi^0$
- $J = 1$:
  - $f_1(1285)\rightarrow a_0\pi^0, K^*K$ Branch measured
  - $h_1(1415)\rightarrow K^*K$ (Note: $h_1\rightarrow a_0\pi^0$ not allowed)
  - $f_1(1420)\rightarrow a_0\pi^0, K^*K$ Branch measured
  - $f_1(1510)\rightarrow a_0\pi^0, K^*K$

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No PDG branch, just generic $KK\pi$

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ASU

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  - $f_1(1510) \rightarrow a_0\pi^0, K^*K$

Peak outside of fit region

ASU

Included waves for mass dependent fit

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  - $\eta(1405)\rightarrow a_0\pi^0, K^*K$ Branch measured
  - $\eta(1475)\rightarrow a_0\pi^0$
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  - $h_1(1415)\rightarrow K^*K$ (Note: $h_1\rightarrow a_0\pi^0$ not allowed)
  - $f_1(1420)\rightarrow a_0\pi^0, K^*K$ Branch measured
  - $f_1(1510)\rightarrow a_0\pi^0, K^*K$

Compared to PDG

$\eta(1405)$ BRANCHING RATIOS

$\Gamma(a_0(980)\pi)/\Gamma(KK\pi)$ **Γ_3/Γ_1**

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 0.15		[1] BERTIN	95	OBLX	$0\ \bar{p}p \to K\bar{K}\pi\pi\pi$
~ 0.8	500	[1] DUCH	89	ASTE	$\bar{p}p \to \pi^+\pi^- K^\pm \pi^\mp K^0$
~ 0.75		[1] REEVES	86	SPEC	$6.6\ p\bar{p} \to KK\pi X$

[1] Assuming that the $a_0(980)$ decays only into $K\bar{K}$.

Measured for charged kaons:

$\Gamma(a_0\pi^0/KK\pi^0) = 0.59 \pm 0.13$

$\eta(1405)$ BRANCHING RATIOS

$\Gamma(a_0(980)\pi)/\Gamma(KK\pi)$ **Γ_3/Γ_1**

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •					
~ 0.15		[1] BERTIN	95	OBLX	$0\ \bar{p}p \to K\bar{K}\pi\pi\pi$
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[1] Assuming that the $a_0(980)$ decays only into $K\bar{K}$.

Measured for charged kaons:
$\Gamma(a_0\pi^0/KK\pi^0) = 0.59 \pm 0.13$

$f_1(1420)$ BRANCHING RATIOS

$\Gamma(K\bar{K}^*(892)+\text{c.c.})/\Gamma(K\bar{K}\pi)$ **Γ_2/Γ_1**

VALUE	DOCUMENT ID		TECN	COMMENT
• • • We do not use the following data for averages, fits, limits, etc. • • •				
0.76 ± 0.06	BROMBERG	80	SPEC	$100\ \pi^- p \to K\bar{K}\pi X$
0.86 ± 0.12	DIONISI	80	HBC	$4\ \pi^- p \to K\bar{K}\pi n$

Measured for charged kaons:
$\Gamma(K^*K/KK\pi^0) = 0.87 \pm 0.08$

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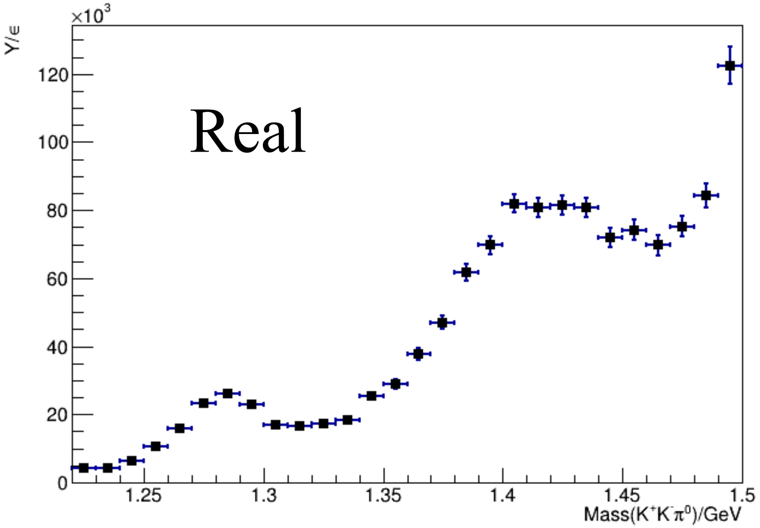
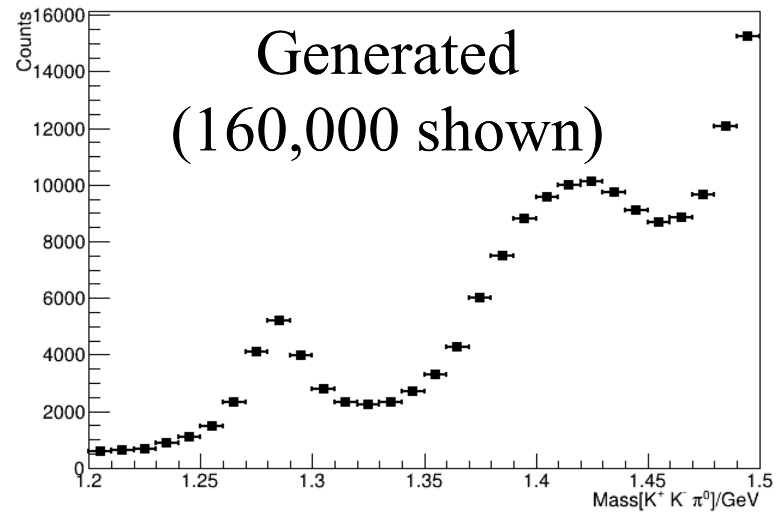
Comparison of Mass[$K^+K^-\pi^0$] between efficiency corrected real data and generated (gen_amp)

Comparison of Mass[$K^+K^-\pi^0$] between efficiency corrected real data and generated (gen_amp)

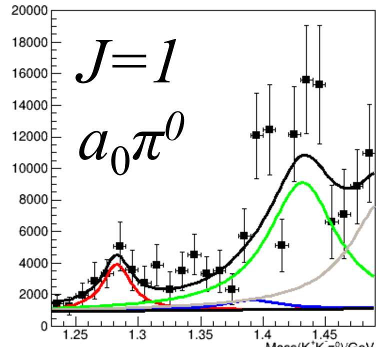




- Integral of efficiency corrected real data = 1.3 million
- More than enough generated data pushed through glueX simulation
- Next step was : PWA of the gen_amp data as though it was real

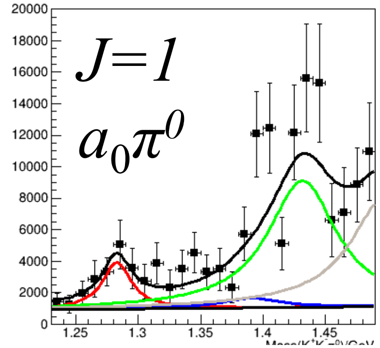
Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL

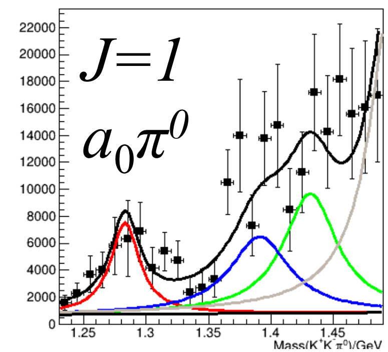


Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL



FAKE

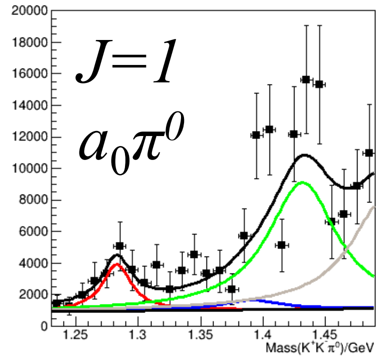


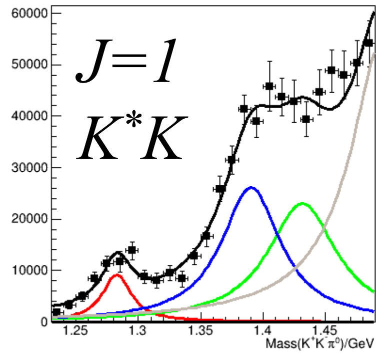
Note:

- $h_1 \rightarrow a_0\pi^0$ (**Blue**) was not generated

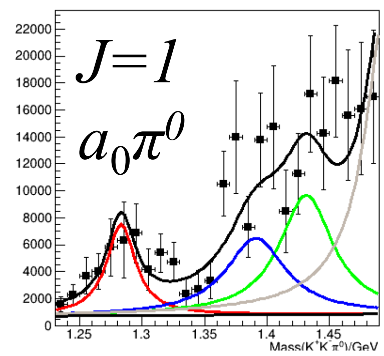
Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL





FAKE



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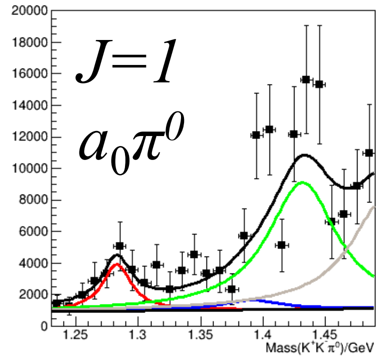
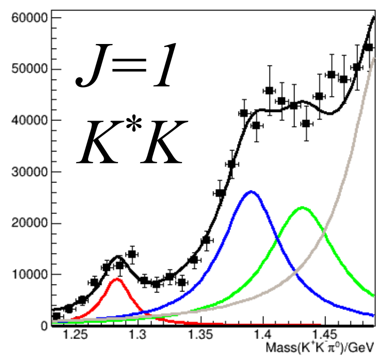
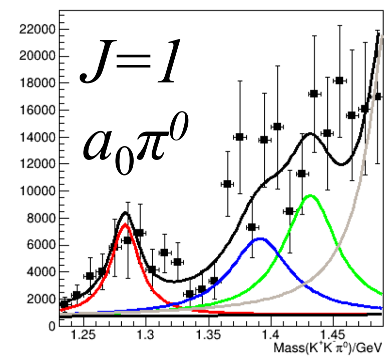
Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

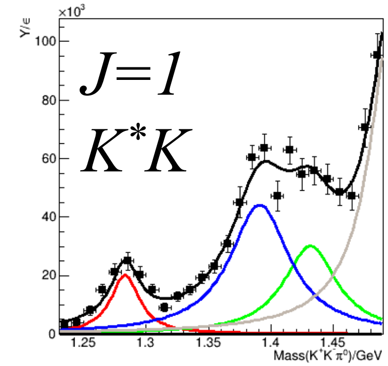
REAL





FAKE



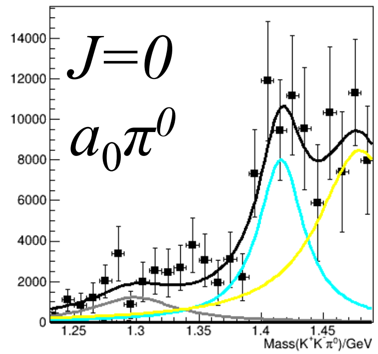


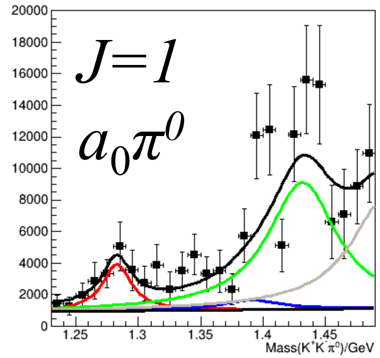
Note:

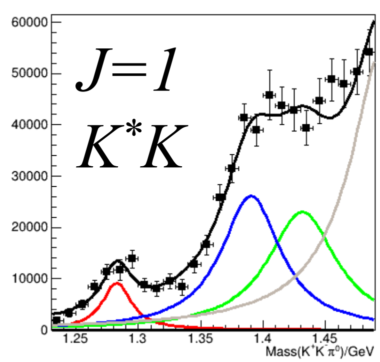
- $h_1 \rightarrow a_0\pi^0$ (**Blue**) was not generated

Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

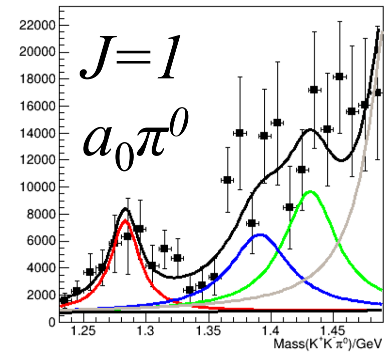
REAL

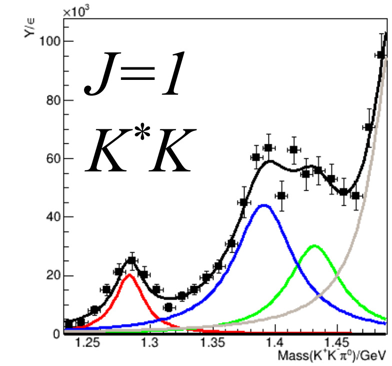






FAKE



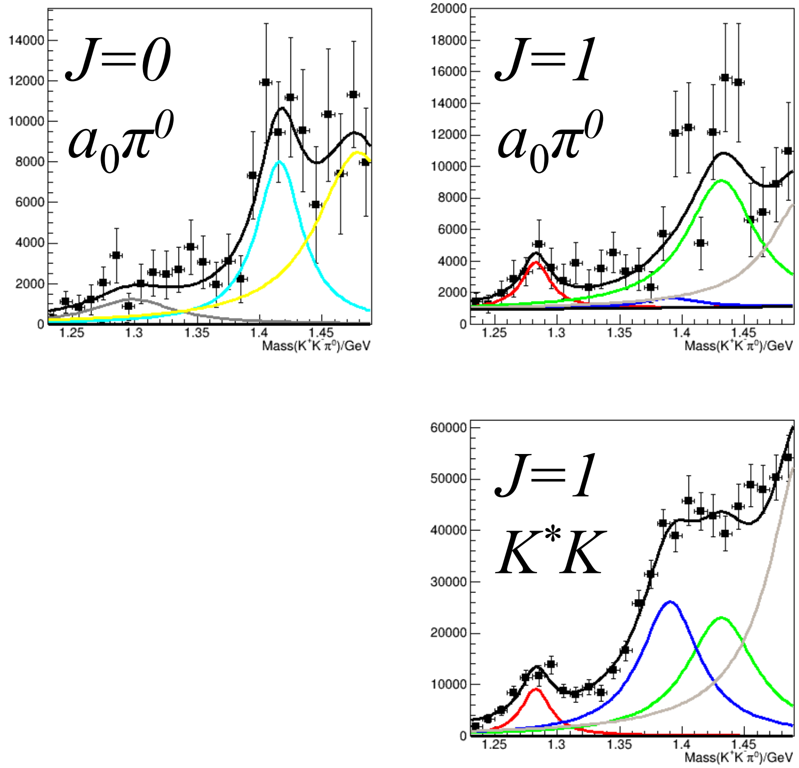


Note:

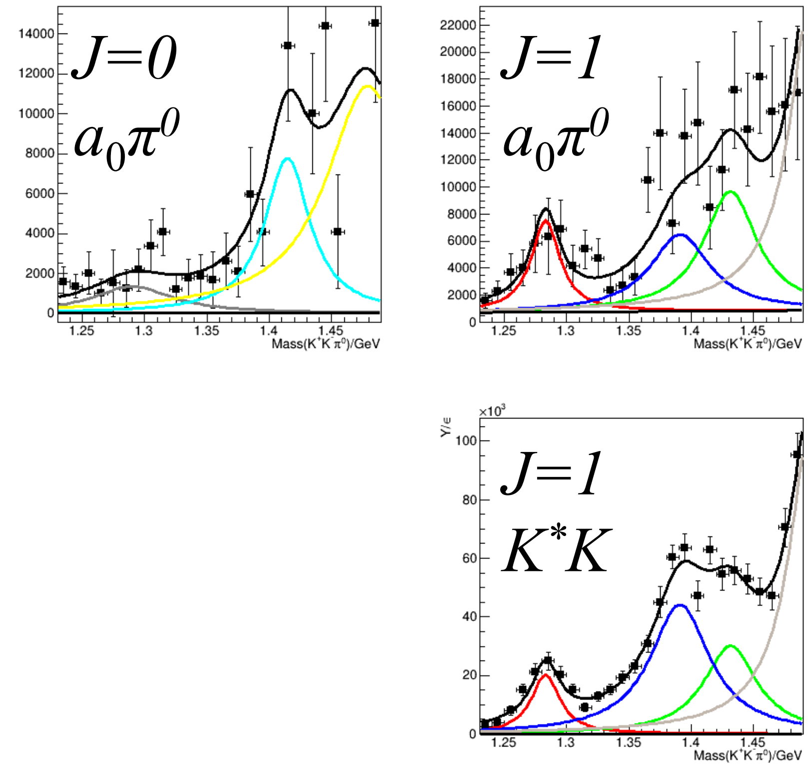
- $h_1 \rightarrow a_0\pi^0$ (**Blue**) was not generated

Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL



FAKE

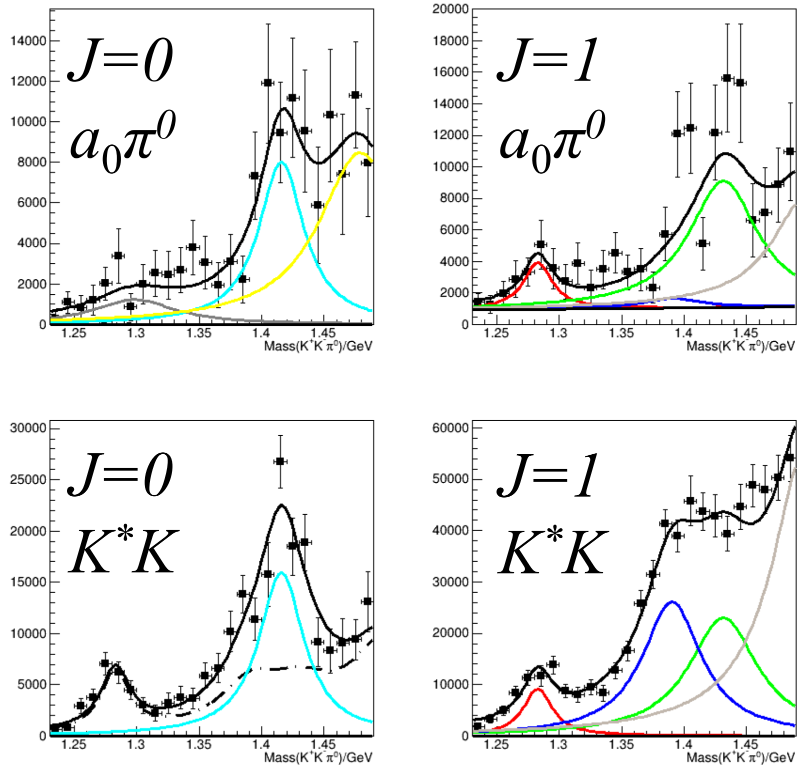


Note:

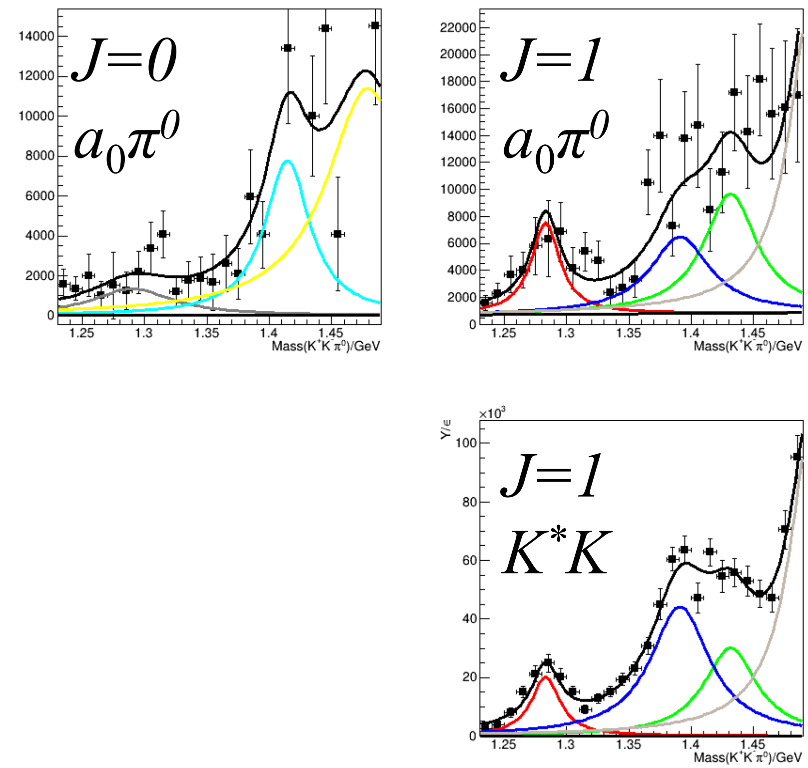
- $h_1 \rightarrow a_0\pi^0$ **[Blue]** was not generated
- $\eta(1295)$ [Gray] was not generated

Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL



FAKE



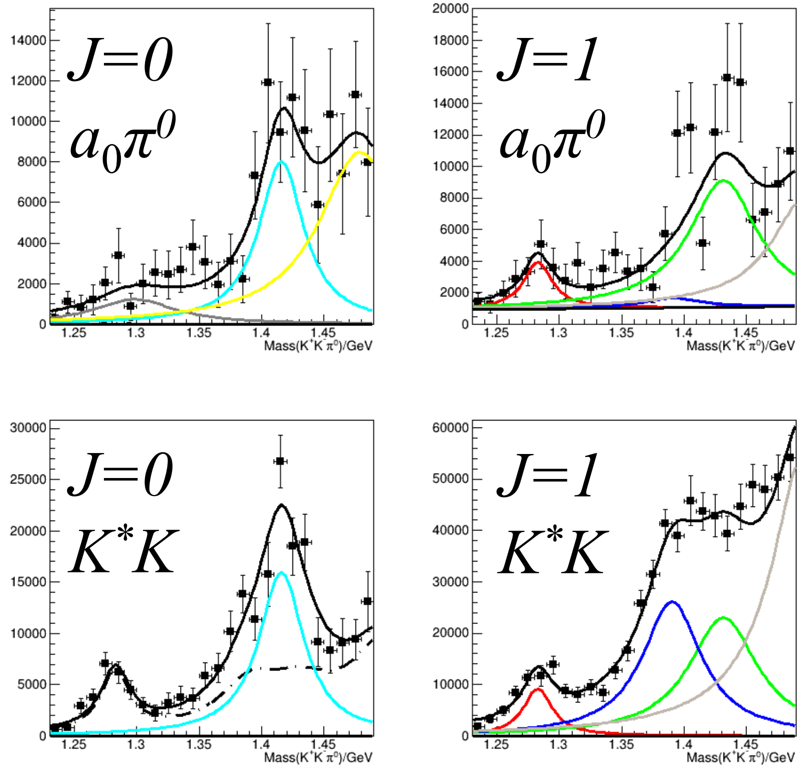
Note:

- $h_1 \rightarrow a_0\pi^0$ **[Blue]** was not generated
- $\eta(1295)$ [Gray] was not generated

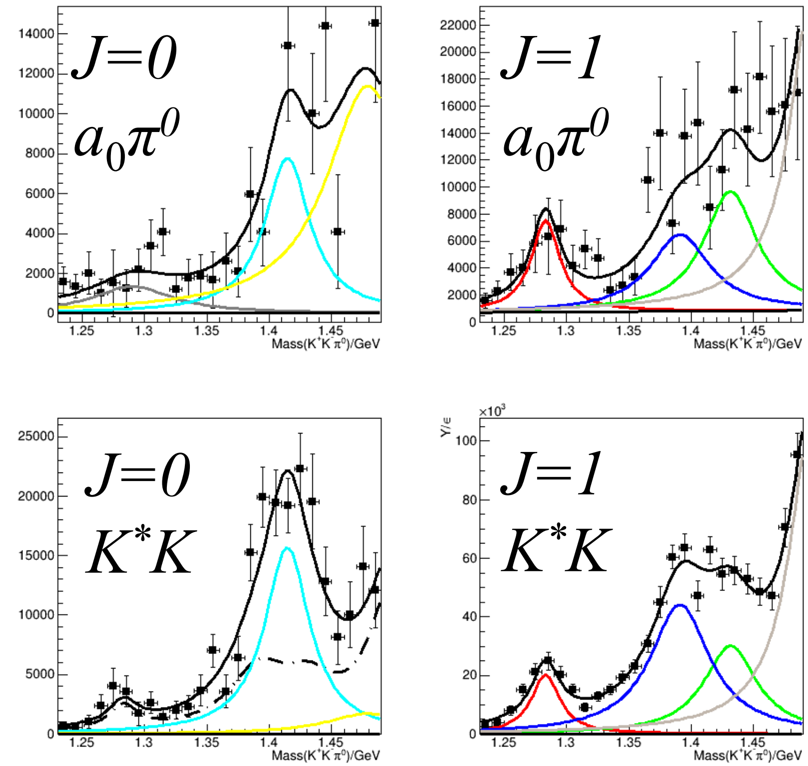
ASU

Comparison of Real to Fake: Mass[$K^+K^-\pi^0$]

REAL



FAKE



Note:

- $h_1 \rightarrow a_0\pi^0$ **[Blue]** was not generated
- $\eta(1295)$ [Gray] was not generated
- Assumed leakage (dashed-dotted lines) looks similar ☺

Title