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

Preliminary study of statistics and isobar composition

- Study to determine the dependence of the PWA reconstruction on isobar composition and statistics

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Preliminary study of statistics and isobar composition

- Study to determine the dependence of the PWA reconstruction on isobar composition and statistics
- Study includes only MC data
- At this point, only considering signals with K^+K^- isobars, $J=L=1$ and all m values equally weighted
- At this point, acceptance calculations use only uniform phase-space distributions constructed through gen_amp

Waves included in PWA

- Included waves are chosen to be similar as prior analyses of $KK\pi$ by BESIII and E852 experiments

BESIII $J/\psi \rightarrow \gamma K^0{}_s K^0{}_s \pi^0$

In practice, the MI PWA is performed in different bins of the $K_S^0 K_S^0 \pi^0$ invariant mass, which is divided into 24 bins from 1.24 GeV/c^2 to 1.60 GeV/c^2, and the dynamic function of $K_S^0 K_S^0 \pi^0$ invariant mass in each bin is assumed to be a constant.

BESIII $J/\psi \to \gamma K^0{}_s K^0{}_s \pi^0$

Taking into account the spin-parity, charge conjugation and isospin conservation, all possible decay mode candidates are evaluated, as listed in table 1, where "S", "P" and "D" represent the mother resonance decaying with orbital angular momentum equal to 0, 1 and 2, respectively.

J^{PC}	0^{-+}	1^{++}	1^{-+}	2^{++}	2^{-+}
for $K^0_S\pi^0$	$K^*(892)^0K^0_S$ $(K^0_S\pi^0)_{\text{P-phsp}}K^0_S$ $(K^0_S\pi^0)_{\text{D-phsp}}K^0_S$ $K^*_0(700)^0K^0_S$ $(K^0_S\pi^0)_{\text{S-phsp}}K^0_S$	$K^*(892)^0K^0_S$ $(K^0_S\pi^0)_{\text{P-phsp}}K^0_S$ $(K^0_S\pi^0)_{\text{D-phsp}}K^0_S$ $K^*_0(700)^0K^0_S$ $(K^0_S\pi^0)_{\text{S-phsp}}K^0_S$	$K^*(892)^0K^0_S$ $(K^0_S\pi^0)_{\text{P-phsp}}K^0_S$ $(K^0_S\pi^0)_{\text{D-phsp}}K^0_S$	$K^*(892)^0K^0_S$ $(K^0_S\pi^0)_{\text{P-phsp}}K^0_S$ $(K^0_S\pi^0)_{\text{D-phsp}}K^0_S$	$K^*(892)^0K^0_S$ $(K^0_S\pi^0)_{\text{P-phsp}}K^0_S$ $(K^0_S\pi^0)_{\text{D-phsp}}K^0_S$ $K^*_0(700)^0K^0_S$ $(K^0_S\pi^0)_{\text{S-phsp}}K^0_S$
for $K^0_SK^0_S$	$a_2(1320)^0\pi^0$ $(K^0_SK^0_S)_{\text{D-phsp}}\pi^0$ $a_0(980)^0\pi^0$ $a_0(1450)^0\pi^0$ $(K^0_SK^0_S)_{\text{S-phsp}}\pi^0$	$a_2(1320)^0\pi^0$ $(K^0_SK^0_S)_{\text{D-phsp}}\pi^0$ $a_0(980)^0\pi^0$ $a_0(1450)^0\pi^0$ $(K^0_SK^0_S)_{\text{S-phsp}}\pi^0$	$a_2(1320)^0\pi^0$ $(K^0_SK^0_S)_{\text{D-phsp}}\pi^0$	$a_2(1320)^0\pi^0$ $(K^0_SK^0_S)_{\text{D-phsp}}\pi^0$	$a_2(1320)^0\pi^0$ $(K^0_SK^0_S)_{\text{D-phsp}}\pi^0$ $a_0(980)^0\pi^0$ $a_0(1450)^0\pi^0$ $(K^0_SK^0_S)_{\text{S-phsp}}\pi^0$

Table 1. The set of all possible decay mode candidates evaluated in the MI PWA.

BESIII $J/\psi \rightarrow \gamma K^0{}_s K^0{}_s \pi^0$

Taking into account the spin-parity, charge conjugation and isospin conservation, all possible decay mode candidates are evaluated, as listed in table 1, where "S", "P" and "D" represent the mother resonance decaying with orbital angular momentum equal to 0, 1 and 2, respectively.

J^{PC}	0^{-+}	1^{++}	1^{-+}	2^{++}	2^{-+}
for $K_S^0\pi^0$	$K^*(892)^0 K_S^0$	$K^*(892)^0 K_S^0$	$K^*(892)^0 K_S^0$	$K^*(892)^0 K_S^0$	$K^*(892)^0 K_S^0$
	$(K_S^0\pi^0)_{\text{P-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{P-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{P-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{P-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{P-phsp}} K_S^0$
	$(K_S^0\pi^0)_{\text{D-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{D-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{D-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{D-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{D-phsp}} K_S^0$
	$K_0^*(700)^0 K_S^0$	$K_0^*(700)^0 K_S^0$			$K_0^*(700)^0 K_S^0$
	$(K_S^0\pi^0)_{\text{S-phsp}} K_S^0$	$(K_S^0\pi^0)_{\text{S-phsp}} K_S^0$			$(K_S^0\pi^0)_{\text{S-phsp}} K_S^0$
for $K_S^0 K_S^0$	$a_2(1320)^0\pi^0$	$a_2(1320)^0\pi^0$	$a_2(1320)^0\pi^0$	$a_2(1320)^0\pi^0$	$a_2(1320)^0\pi^0$
	$(K_S^0 K_S^0)_{\text{D-phsp}}\pi^0$	$(K_S^0 K_S^0)_{\text{D-phsp}}\pi^0$	$(K_S^0 K_S^0)_{\text{D-phsp}}\pi^0$	$(K_S^0 K_S^0)_{\text{D-phsp}}\pi^0$	$(K_S^0 K_S^0)_{\text{D-phsp}}\pi^0$
	$a_0(980)^0\pi^0$	$a_0(980)^0\pi^0$			$a_0(980)^0\pi^0$
	$a_0(1450)^0\pi^0$	$a_0(1450)^0\pi^0$			$a_0(1450)^0\pi^0$
	$(K_S^0 K_S^0)_{\text{S-phsp}}\pi^0$	$(K_S^0 K_S^0)_{\text{S-phsp}}\pi^0$			$(K_S^0 K_S^0)_{\text{S-phsp}}\pi^0$

NOTE: PHSP = uniform in PHase SPace

BESIII $J/\psi \to \gamma K^0{}_s K^0{}_s \pi^0$

RED : Background

Components
(1). $J/\psi \to \gamma \mathrm{PHSP}(0^{-+}) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(2). $J/\psi \to \gamma \mathrm{PHSP}(1^{++}) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(3). $J/\psi \to \gamma \eta(1405) \to \gamma K_S^0 (K_S^0 \pi^0)_{\text{P-wave}} \to \gamma K_S^0 K_S^0 \pi^0$
(4). $J/\psi \to \gamma \eta(1475) \to \gamma K_S^0 (K_S^0 \pi^0)_{\text{P-wave}} \to \gamma K_S^0 K_S^0 \pi^0$
(5). $J/\psi \to \gamma f_1(1420) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(6). $J/\psi \to \gamma f_2(1525) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(7). $J/\psi \to \gamma \mathrm{PHSP}(0^{-+}) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(8). $J/\psi \to \gamma \mathrm{PHSP}(2^{-+}) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(9). $J/\psi \to \gamma \eta(1405) \to \gamma (K_S^0 K_S^0)_{\text{S-wave}} \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(10). $J/\psi \to \gamma \eta(1475) \to \gamma (K_S^0 K_S^0)_{\text{S-wave}} \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(11). $J/\psi \to \gamma f_1(1285) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(12). $J/\psi \to \gamma f_1(1420) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(13). $J/\psi \to \gamma \eta(1405) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(14). $J/\psi \to \gamma \eta(1475) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$

BESIII $J/\psi \rightarrow \gamma K^0{}_s K^0{}_s \pi^0$

RED : Background

BLUE: Generic isobars

Components
(1). $J/\psi \to \gamma\text{PHSP}(0^{-+}) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(2). $J/\psi \to \gamma\text{PHSP}(1^{++}) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(3). $J/\psi \to \gamma\eta(1405) \to \gamma K_S^0 (K_S^0 \pi^0)_{\text{P-wave}} \to \gamma K_S^0 K_S^0 \pi^0$
(4). $J/\psi \to \gamma\eta(1475) \to \gamma K_S^0 (K_S^0 \pi^0)_{\text{P-wave}} \to \gamma K_S^0 K_S^0 \pi^0$
(5). $J/\psi \to \gamma f_1(1420) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(6). $J/\psi \to \gamma f_2(1525) \to \gamma K^*(892)^0 K_S^0 \to \gamma K_S^0 K_S^0 \pi^0$
(7). $J/\psi \to \gamma\text{PHSP}(0^{-+}) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(8). $J/\psi \to \gamma\text{PHSP}(2^{-+}) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(9). $J/\psi \to \gamma\eta(1405) \to \gamma (K_S^0 K_S^0)_{\text{S-wave}} \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
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(12). $J/\psi \to \gamma f_1(1420) \to \gamma a_0(980)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(13). $J/\psi \to \gamma\eta(1405) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$
(14). $J/\psi \to \gamma\eta(1475) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K_S^0 K_S^0 \pi^0$

BESIII $J/\psi \to \gamma K^0{}_S K^0{}_S \pi^0$

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(1). $J/\psi \to \gamma \mathrm{PHSP}(0^{-+}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(2). $J/\psi \to \gamma \mathrm{PHSP}(1^{++}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(3). $J/\psi \to \gamma \eta(1405) \to \gamma K^0_S (K^0_S \pi^0)_{\text{P-wave}} \to \gamma K^0_S K^0_S \pi^0$
(4). $J/\psi \to \gamma \eta(1475) \to \gamma K^0_S (K^0_S \pi^0)_{\text{P-wave}} \to \gamma K^0_S K^0_S \pi^0$
(5). $J/\psi \to \gamma f_1(1420) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(6). $J/\psi \to \gamma f_2(1525) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(7). $J/\psi \to \gamma \mathrm{PHSP}(0^{-+}) \to \gamma a_0(980)^0 \pi^0 \to \gamma K^0_S K^0_S \pi^0$
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(9). $J/\psi \to \gamma \eta(1405) \to \gamma (K^0_S K^0_S)_{\text{S-wave}} \pi^0 \to \gamma K^0_S K^0_S \pi^0$
(10). $J/\psi \to \gamma \eta(1475) \to \gamma (K^0_S K^0_S)_{\text{S-wave}} \pi^0 \to \gamma K^0_S K^0_S \pi^0$
(11). $J/\psi \to \gamma f_1(1285) \to \gamma a_0(980)^0 \pi^0 \to \gamma K^0_S K^0_S \pi^0$
(12). $J/\psi \to \gamma f_1(1420) \to \gamma a_0(980)^0 \pi^0 \to \gamma K^0_S K^0_S \pi^0$
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(14). $J/\psi \to \gamma \eta(1475) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K^0_S K^0_S \pi^0$

RED : Background

BLUE: Generic isobars

GREEN: Non-background a_0 isobars

BESIII $J/\psi \to \gamma K^0{}_S K^0{}_S \pi^0$

Components
(1). $J/\psi \to \gamma \text{PHSP}(0^{-+}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(2). $J/\psi \to \gamma \text{PHSP}(1^{++}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(3). $J/\psi \to \gamma \eta(1405) \to \gamma K^0_S (K^0_S \pi^0)_{\text{P-wave}} \to \gamma K^0_S K^0_S \pi^0$
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(14). $J/\psi \to \gamma \eta(1475) \to \gamma a_2(1320)^0 \pi^0 \to \gamma K^0_S K^0_S \pi^0$

RED : Background

BLUE: Generic isobars

GREEN: Non-background a_0 isobars

BLACK: Non-background K^* isobars

BESIII $J/\psi \to \gamma K^0{}_s K^0{}_s \pi^0$

Components
(1). $J/\psi \to \gamma \mathrm{PHSP}(0^{-+}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
(2). $J/\psi \to \gamma \mathrm{PHSP}(1^{++}) \to \gamma K^*(892)^0 K^0_S \to \gamma K^0_S K^0_S \pi^0$
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RED : Background

BLUE: Generic isobars

GREEN: Non-background a_0 isobars

BLACK: Non-background K^* isobars

PURPLE: Non-background a_2 isobars

E852 : $\pi^- p \rightarrow K^+ K^- \pi^0 n$

Table 1
Partial waves used in the amplitude analysis. Note that the $K^*\overline{K}$ partial waves were used only for masses greater than 1.375 GeV/c^2

J^{PC}	M^{ϵ}	L	Decay mode
0^{-+}	0^+	S	$a_0(980)\pi^0$
		P	$K^*(892)\overline{K}$
1^{++}	0^+	S	$K^*(892)\overline{K}$
	$0^+, 1^{\pm}$	P	$a_0(980)\pi^0$
1^{+-}	0^+	S	$K^*(892)\overline{K}$
1^{--}	0^-	P	$K^*(892)\overline{K}$
2^{++}	$0^-, 1^+$	D	$K^*(892)\overline{K}$

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1^{+-}	0^+	S	$K^*(892)\overline{K}$
1^{--}	0^-	P	$K^*(892)\overline{K}$
2^{++}	$0^-, 1^+$	D	$K^*(892)\overline{K}$

Included in BESIII

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	$0^+, 1^\pm$	P	$a_0(980)\pi^0$
1^{+-}	0^+	S	$K^*(892)\bar{K}$
1^{--}	0^-	P	$K^*(892)\bar{K}$
2^{++}	$0^-, 1^+$	D	$K^*(892)\bar{K}$

BESIII used $(KK)_{\text{s-wave}}\pi^0$

BESIII used $(K\pi^0)_{\text{p-wave}}\,K$

Included in BESIII

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1^{+-}	0^+	S	$K^*(892)\overline{K}$
1^{--}	0^-	P	$K^*(892)\overline{K}$
2^{++}	$0^-, 1^+$	D	$K^*(892)\overline{K}$

BESIII used $(KK)_{\text{s-wave}}\pi^0$

BESIII used $(K\pi^0)_{\text{p-wave}} K$

Included in BESIII

- BESIII had small $a_2\pi^0$ partial wave contribution not used in E852

E852 : $\pi^- p \rightarrow K^+ K^- \pi^0 n$

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1^{++}	0^+	S	$K^*(892)\bar{K}$
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1^{+-}	0^+	S	$K^*(892)\bar{K}$
1^{--}	0^-	P	$K^*(892)\bar{K}$
2^{++}	$0^-, 1^+$	D	$K^*(892)\bar{K}$

BESIII used $(KK)_{\text{s-wave}}\pi^0$

BESIII used $(K\pi^0)_{\text{p-wave}} K$

Included in BESIII

- BESIII had small $a_2\pi^0$ partial wave contribution not used in E852
- I'm using same set as shown here for E852

Statistical study

- Signal:
  - $a_0\pi$ signal with J=L=1 and all m values equally weighted.

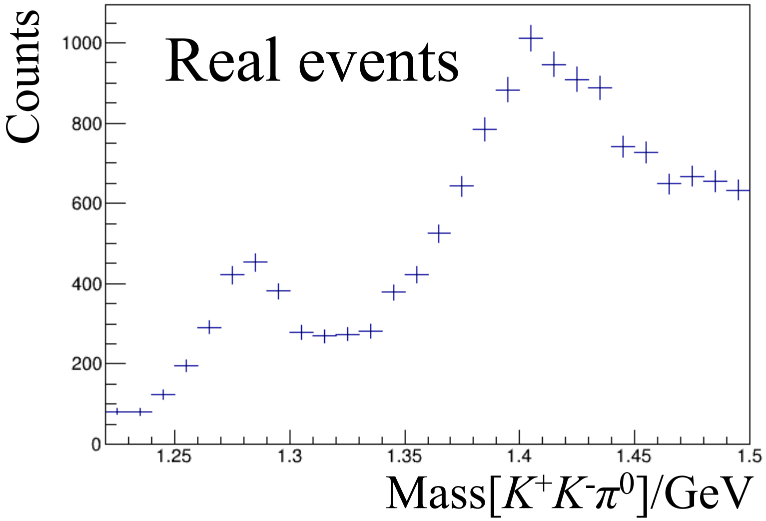
Statistical study

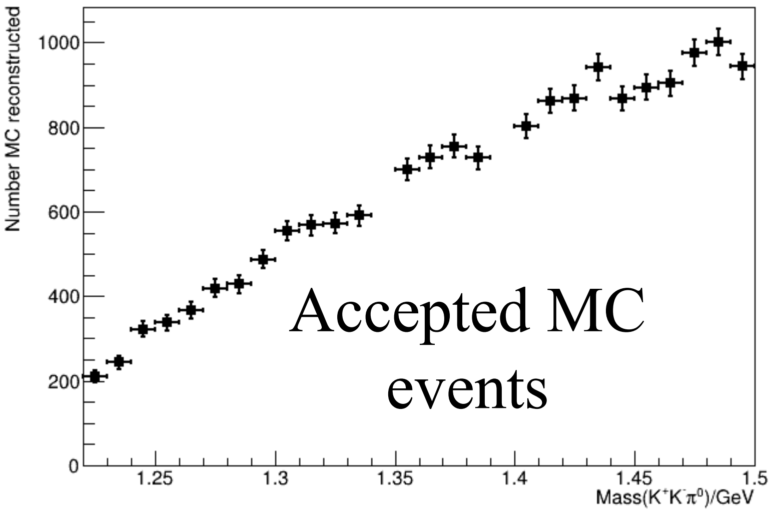
- Signal:
  - $a_0\pi$ signal with J=L=1 and all m values equally weighted.
  - 200,000 thrown in each mass bin

Statistical study

- Signal:
  - $a_0\pi$ signal with J=L=1 and all m values equally weighted.
  - 200,000 thrown in each mass bin
- Varied the number of phase space events used for acceptance

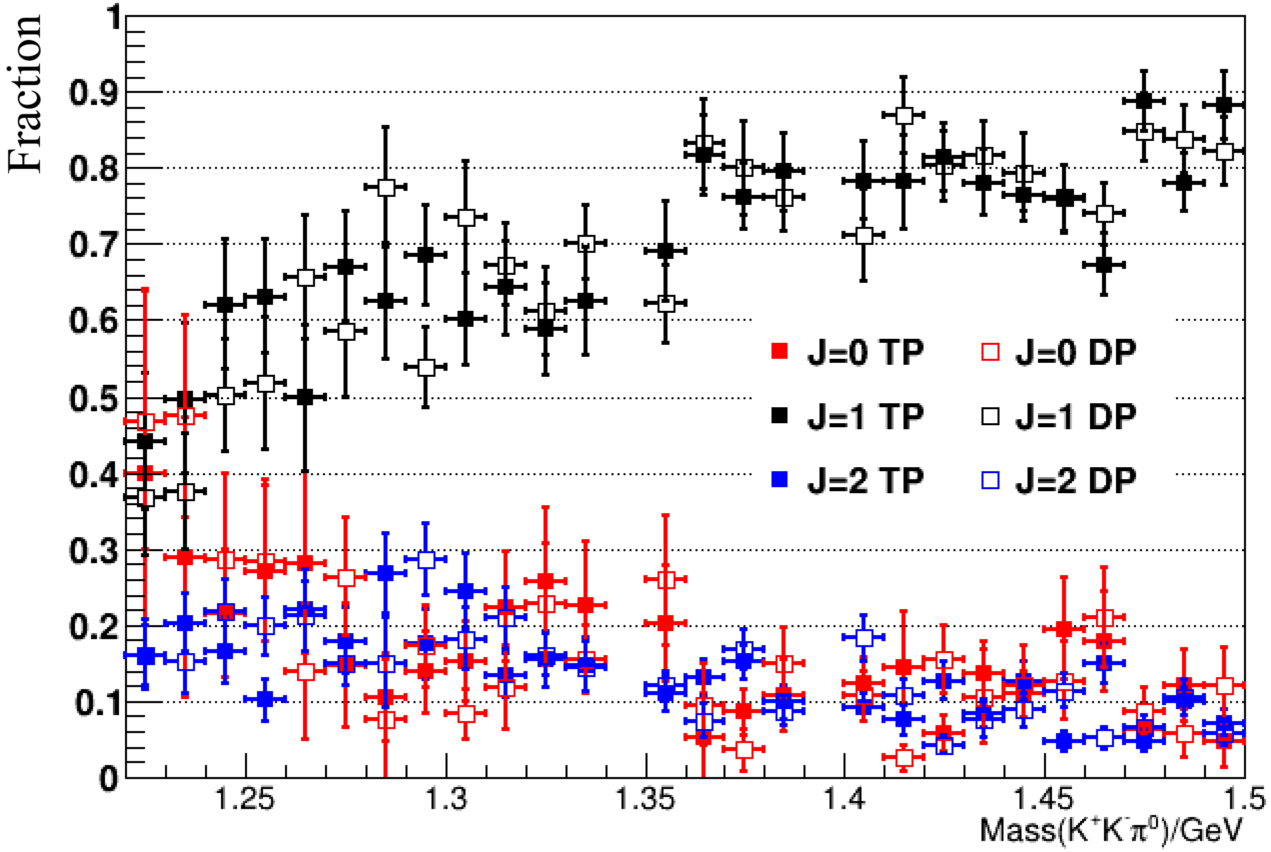
Mass[$K^+K^-\pi^0$]





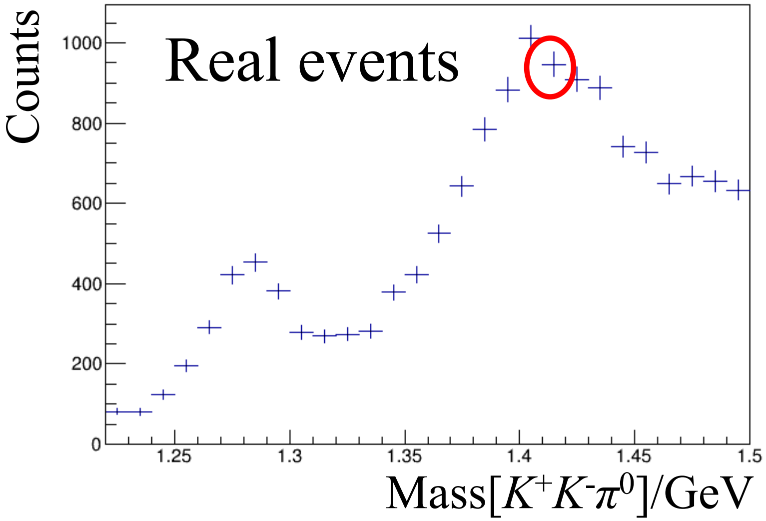
- Acceptance MC events: 200,000 events thrown for each mass bin

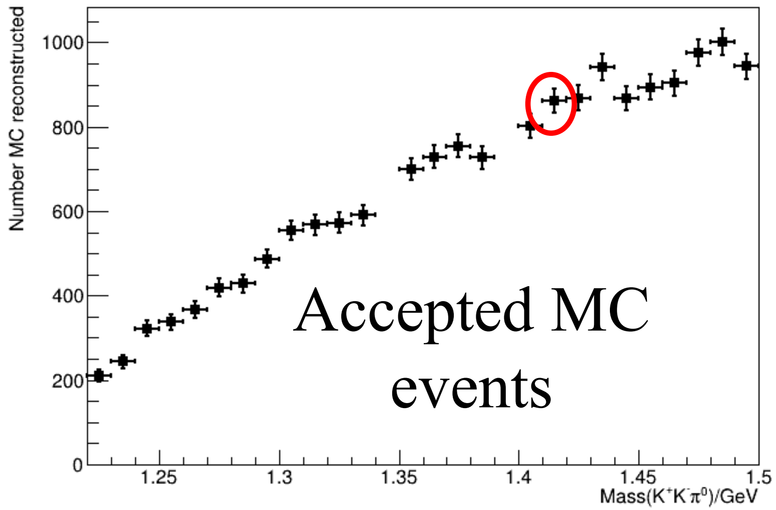
Fraction of $J = 0, 1, 2$ events identified



- TP = Thrown-precision of 4-vectors
- DP = Detector-precision of 4-vectors

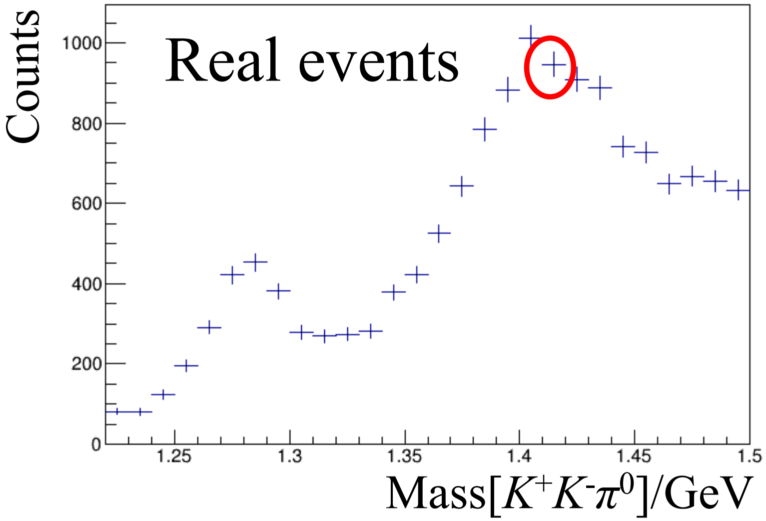
Mass[$K^+K^-\pi^0$]

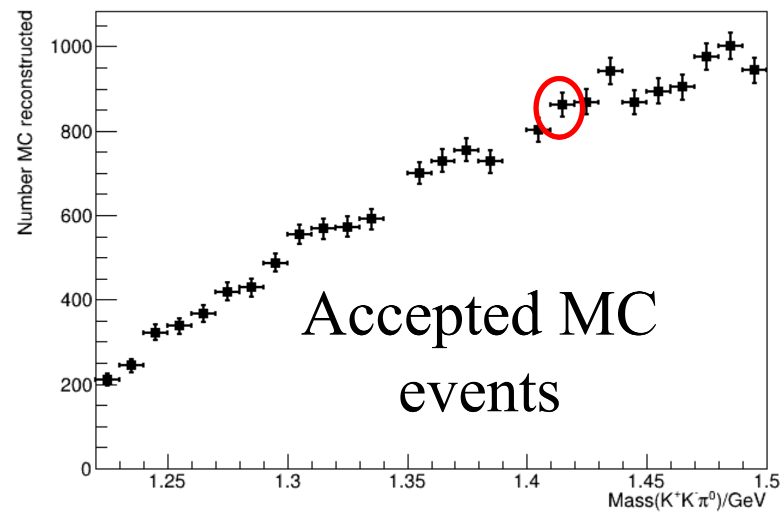




- Chose to concentrate on mass[$K^+K^-\pi^0$] = 1415 GeV

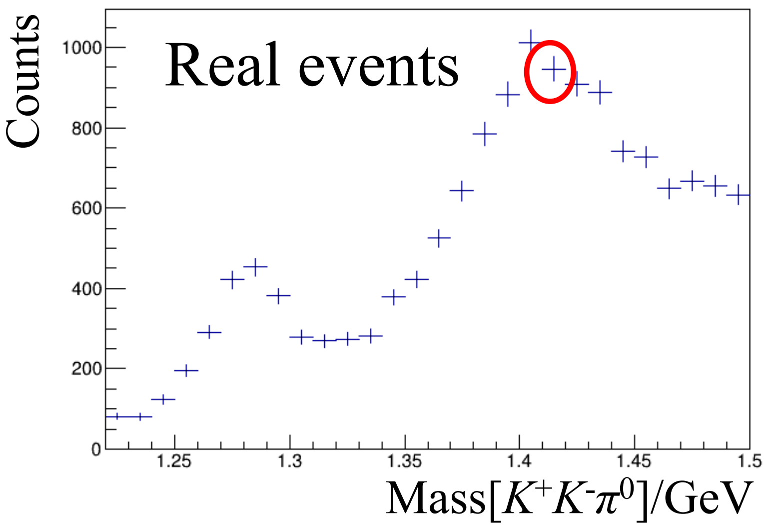
Mass[$K^+K^-\pi^0$]

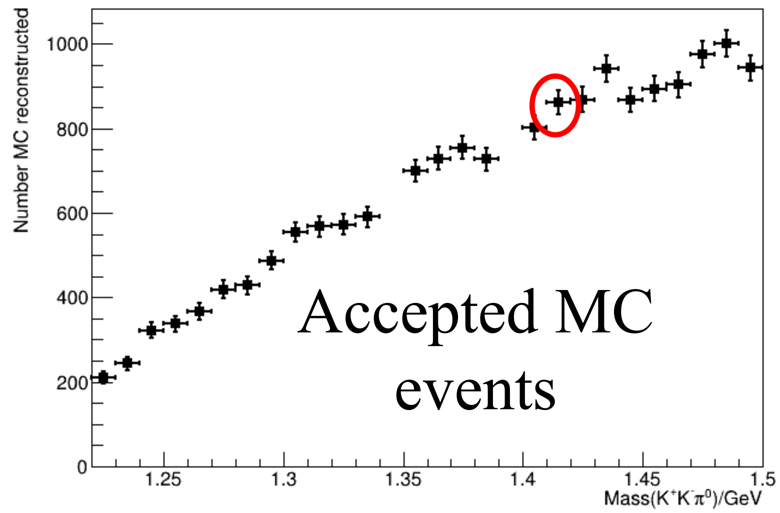




- Chose to concentrate on mass[$K^+K^-\pi^0$] = 1415 GeV
- Created J=1, L=1 $a_0\pi$ events at mass[$K^+K^-\pi^0$] = 1415 GeV

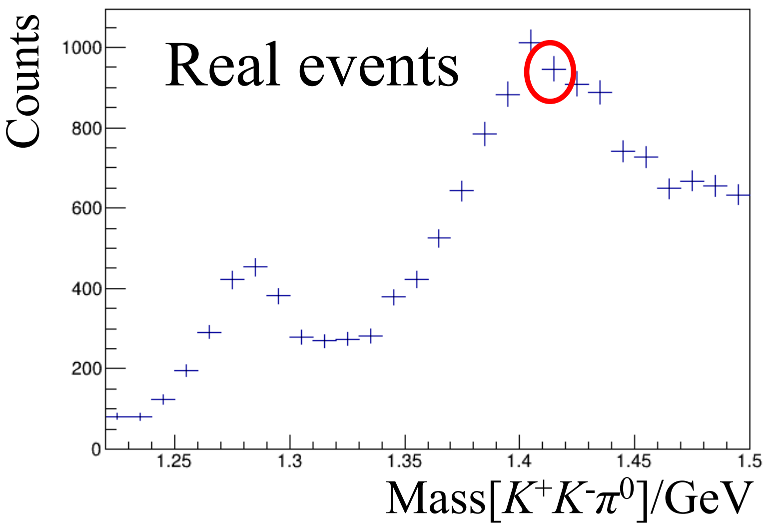
Mass[$K^+K^-\pi^0$]

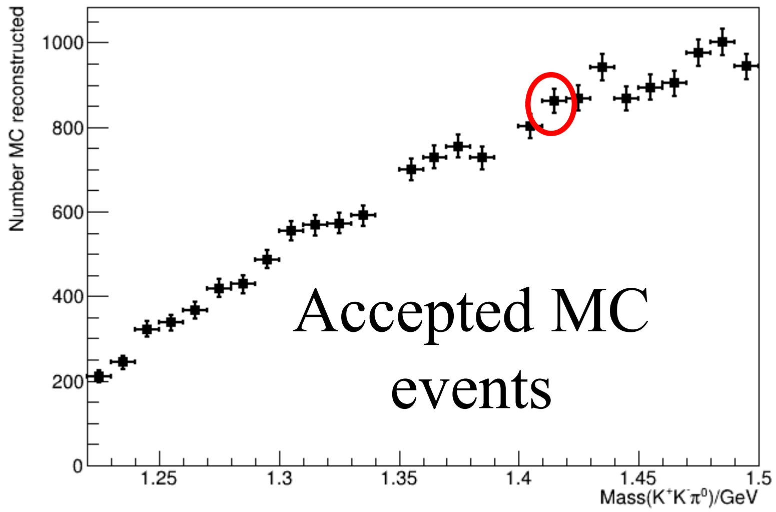




- Chose to concentrate on mass[$K^+K^-\pi^0$] = 1415 GeV
- Created J=1, L=1 $a_0\pi$ events at mass[$K^+K^-\pi^0$] = 1415 GeV
- Number of reconstructed MC <u>signal</u> events = 1587 of 200,000 thrown

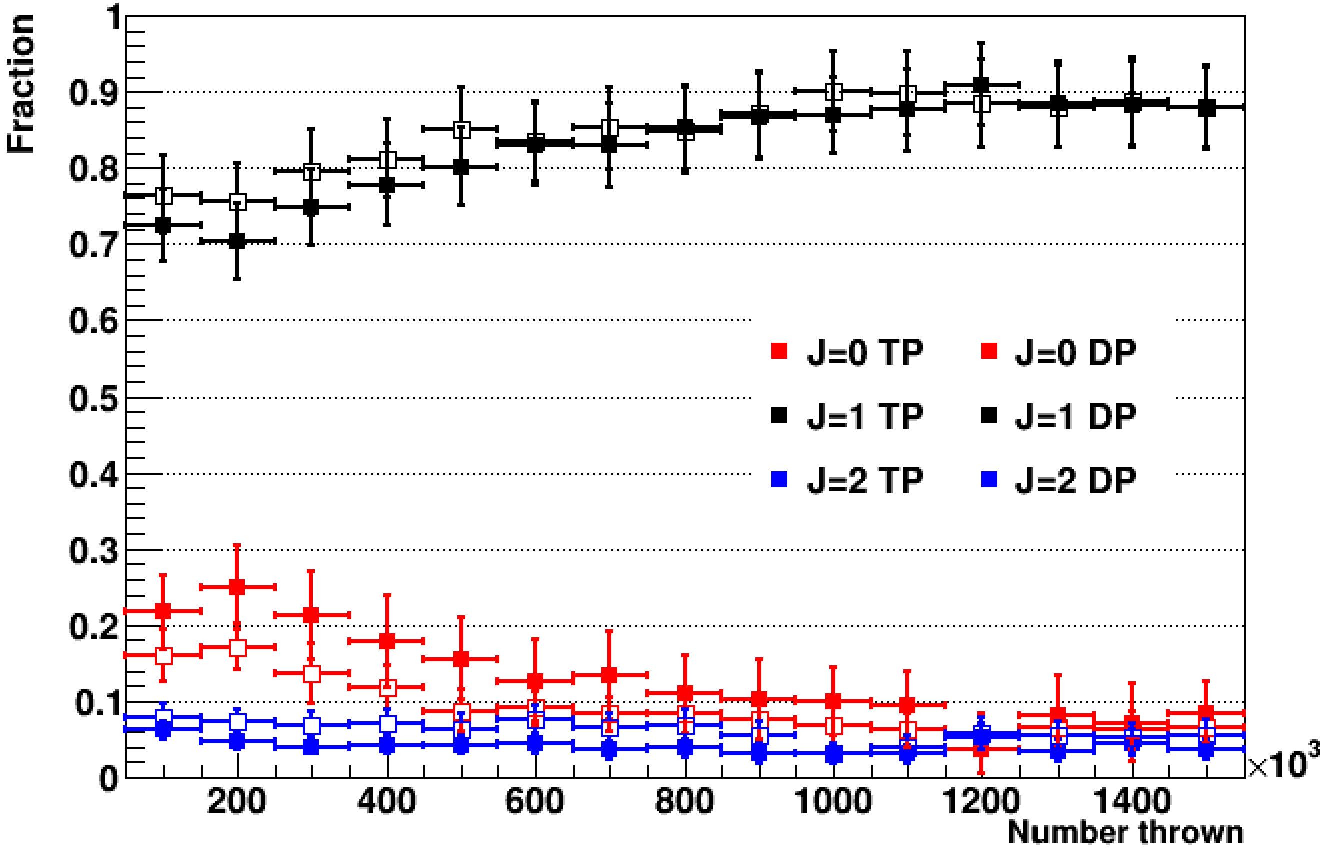
Mass[$K^+K^-\pi^0$]





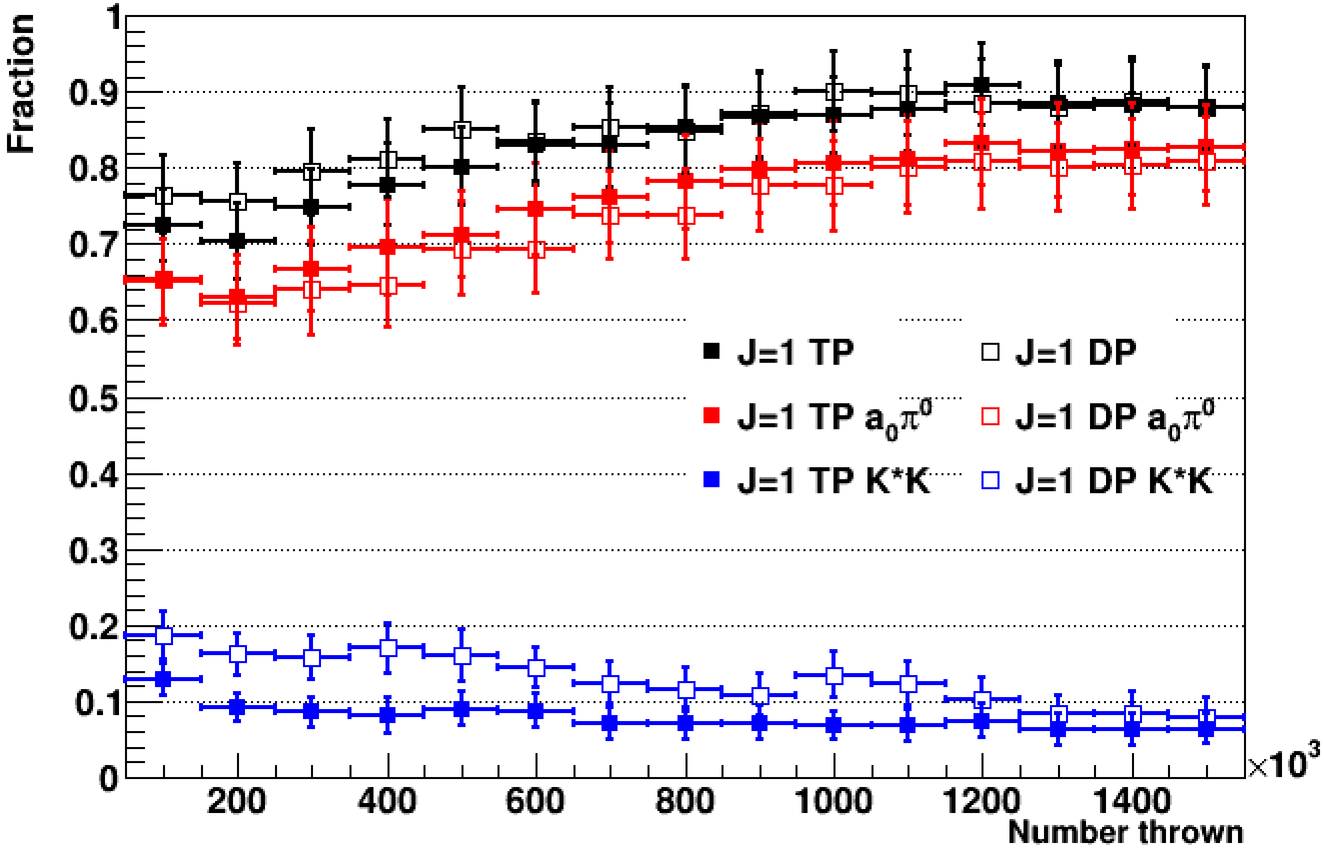
- Chose to concentrate on mass[$K^+K^-\pi^0$] = 1415 GeV
- Created J=1, L=1 $a_0\pi$ events at mass[$K^+K^-\pi^0$] = 1415 GeV
- Number of reconstructed MC <u>signal</u> events = 1587 of 200,000 thrown
- Now: Varying the number of phase space events used for acceptance

Fraction of *J*=0, 1, 2 events identified



- Identify about 90% of the *J*=1 events when throwing a million or more acceptance events

Fraction of $J = 1$ events identified by decay



Generic isobar

- Comparing prior results to signal that is comprised of a generic phase-space K^+K^- isobar along with a π^0 : $(K^+K^-)_S\pi^0$

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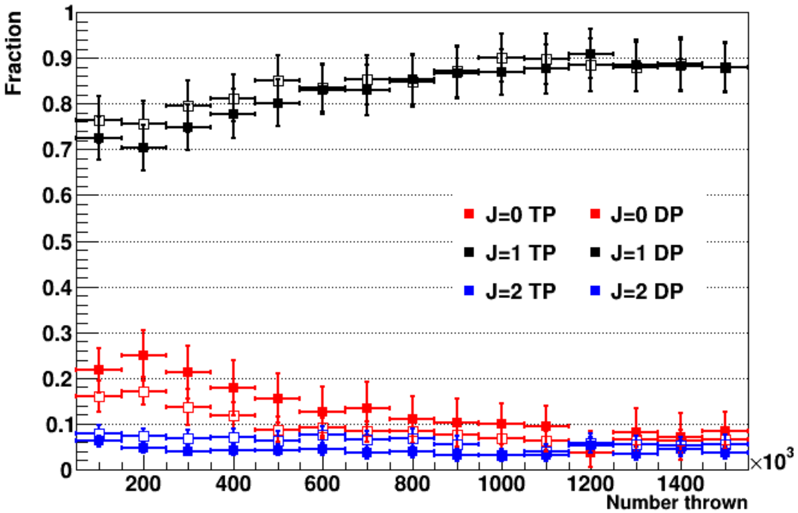
Generic isobar

- Comparing prior results to signal that is comprised of a generic phase-space K^+K^- isobar along with a π^0 : $(K^+K^-)_S\pi^0$
- For consistency, the PWA uses $(K^+K^-)_S$ isobars in place of a_0 isobars

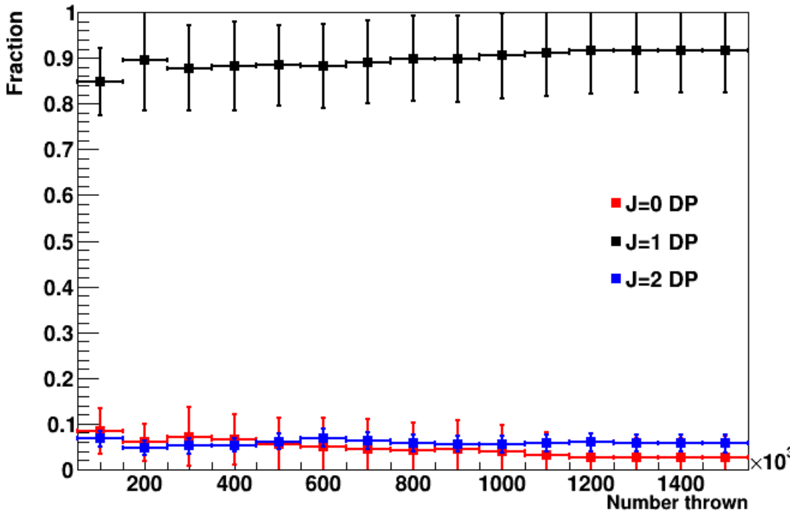
Note: For the $(K^+K^-)_S$ isobar, the thrown events for the acceptance calculation have the same mass[K^+K^-] distribution

Fraction of J=0, 1, 2 events identified

$a_0\pi^0$



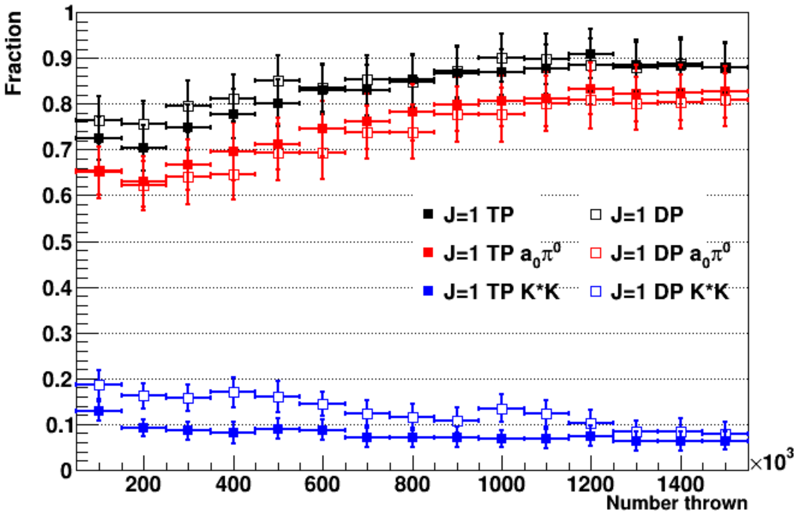
$(K^+K^-)_S\pi^0$



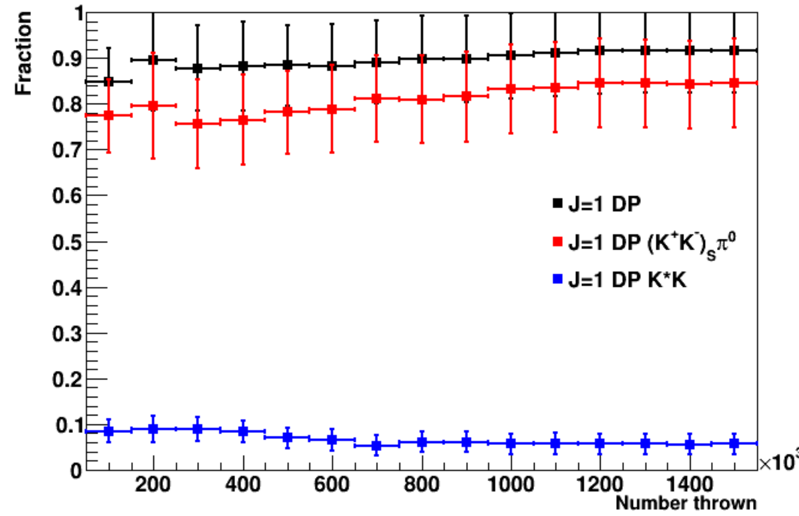
- Two types of J=1 signal events thrown:
  - $a_0\pi^0$
  - $(K^+K^-)_S\pi^0$
- Results are much more stable when the distribution of mass$[K^+K^-]$ of thrown events match the signal

Fraction of $J = 1$ events identified by decay

$a_0\pi^0$



$(K^+K^-)_S\pi^0$



- As before: results are much more stable when the distribution of mass[K^+K^-] of thrown events match the signal

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Comparison of uniform and a_0 mass[K^+K^-] distributions