γKsKpi, γKKpi0

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$$\psi' \rightarrow \gamma\eta'_c, \eta'_c \rightarrow KK\pi^0$$

Initial Event Selection

Charged Tracks: nGood=2, nCharge=0

- $R_{vz} < 10$cm
- $R_{vxy} < 1$cm
- $cos\theta < 0.93$

Good Photons: nGam>= 3
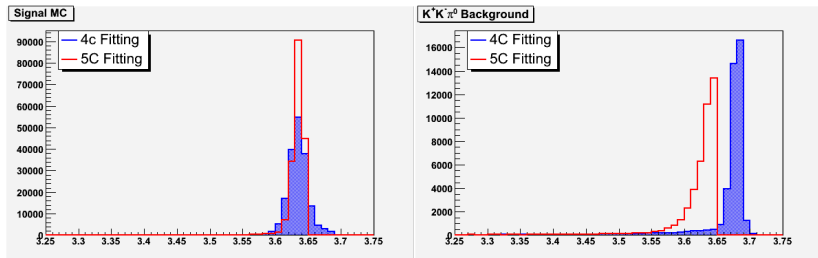
- energy> 40 MeV
- time in [0,14] (*50 ns)
- At 20 degree from the extrapolation of a MDC track.

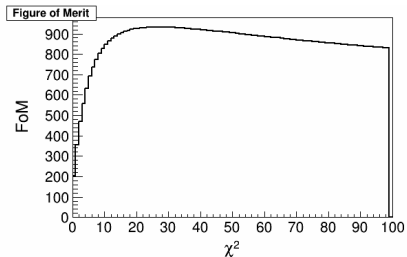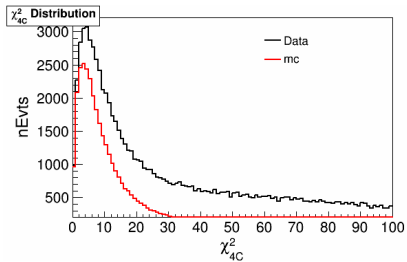PID: 1 K+, 1 K-

- TOF, dE/dx
- $p(K) > p(\pi)$, $p(K) > 0.001$

Kinematic Fit

- 5c kinematic fit(p4, mpi0) to decide the choice of γ
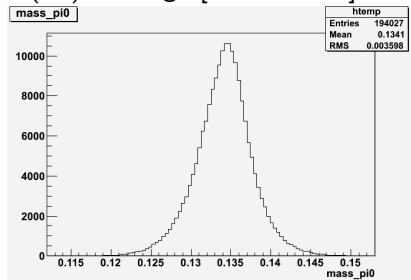- 4c kinematic fit(5C + unfix m(γ_{rad})) for mass representation
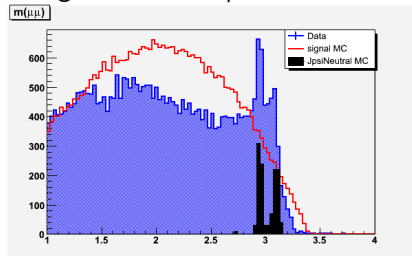
Kinematic Fit

- $\chi^2_{4c} < 30$

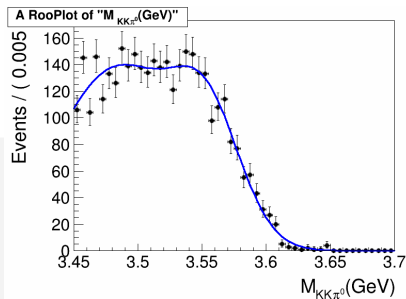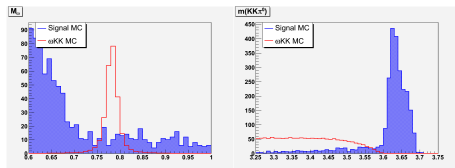# π^0 mass requirement

m(π^0) in range [0.127,0.141].

$\psi' \rightarrow Neutral + J/\psi$, $J/\psi \rightarrow \mu\mu/KK$ background

Require $M(\mu\mu) < 2.9$, where $M(\mu\mu)$ is calculated by assuming the two charged tracks as μ.

$\psi' \to \omega KK$ background

Require M(3γ) outside of [0.74, 0.82]. The remaining spectrum is fit to double gaussian.
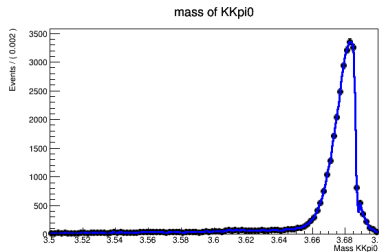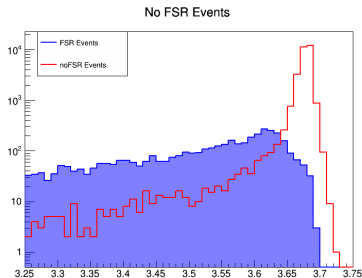
$\pi^0 KK$ background shape

f_{FSR} describe the difference of FSR ration in data/MC. Calculating from existing result:

$$f_{\gamma KK\pi^0} = 2 * f_{\gamma KK\pi\pi} - f_{\pi\pi\pi\pi} = 1.08 \pm 0.15 \qquad (1)$$

Get the lineshape from the reweighted sum of the FSR and no-FSR events.
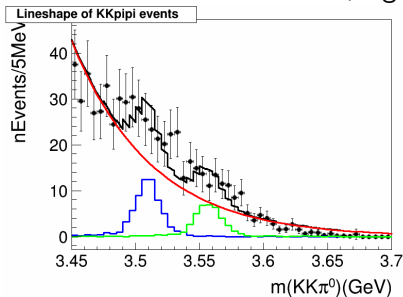
$\pi^0\pi^0 KK$ background

Run $KK\pi\pi$ algorithm on data, re-weight the mass spectrum with the ratio of efficiency when $KK\pi^0\pi^0$ MC events try to pass the $\gamma KK\pi^0$ and $KK\pi\pi$ algorithms, to get the $KK\pi^0\pi^0$ contribtution in $\gamma KK\pi$ Alg's result. The mass in $KK\pi\pi$ algorithm is calculated from a 5C kinematic fit (the best fit when missing 1 photon in $KK\pi^0\pi^0$ candidates) without chisquare requirement.
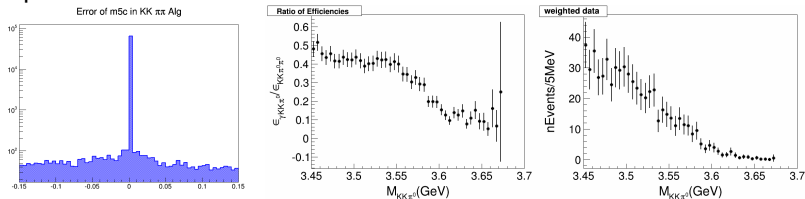
$\pi^0\pi^0 KK$ background shape

The $KK\pi\pi$ background is described with a Gaussian Function. To get its parameters, the χ_{cj} background are considered by using MC shape.
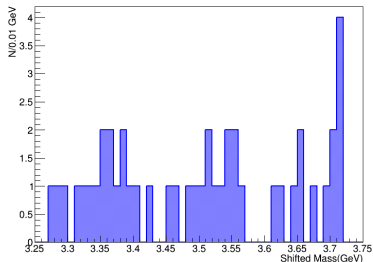Fit Result: mean=0.0 $\pm$ 8.8, sigma=0.464 $\pm$ 0.000

Continuum Background

Estimated from $42.6 pb^{-1}$ data @ 3650 MeV.

Lineshape Description
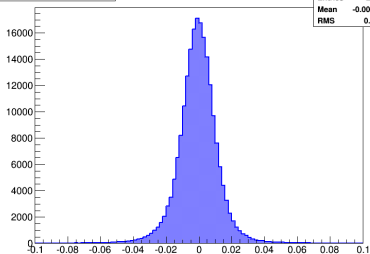
- χ_{cj}: MC shape convolved with a gaussian
- $\eta_c(2S)$: $(BW(m) \times E_\gamma^3 \times dampingFunc) \bigotimes Gaussian$
- Damping Function: $\frac{E_0^2}{E_\gamma E_0 + (E_\gamma - E_0)^2}$(KEDR) or $exp(-E_\gamma^2/8\beta^2)$ (CLEO)
- Background Shapes: ωKK as double Gaussian, $KK\pi\pi$ as Gaussian, $KK\pi^0$ as re-weighted MC shape
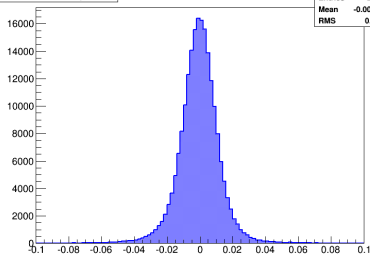- Continuum background not considered in fit.

Resolution of Gauss

χ_{c1}: width=13.08 MeV, chi_{c2}: width=13.32 MeV;
with linear extrapolation, for η_c width=13.76 MeV

Fit Result

Left: KEDR damping function; Right: CLEO damping function.
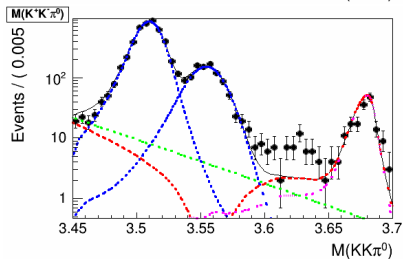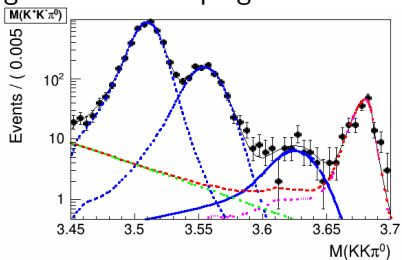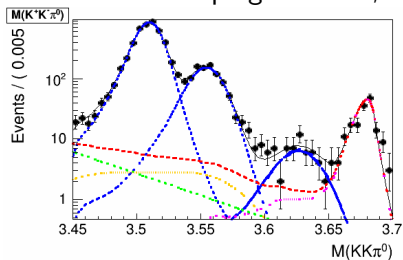
Things that needs further checking:

- $\pi^0\pi^0KK$ lineshape parameters
- Continuum Background
- CLEO damping function

$$\psi' \to \gamma\eta'_c,\ \eta'_c \to K_s K\pi$$

Event Selection

Charged Tracks: nGood=4, nCharge=0

- $R_{vz} < 10$cm
- $R_{vxy} < 1$cm
- $cos\theta < 0.93$

Good Photons: nGam>= 1

- energy> 40 MeV
- time in [0,14] (*50 ns)
- At 20 degree from the extrapolation of a MDC track.

PID:

- TOF, dE/dx
- χ_K^2, χ_π^2 of each track saved for later cuts

χ^2 of PID
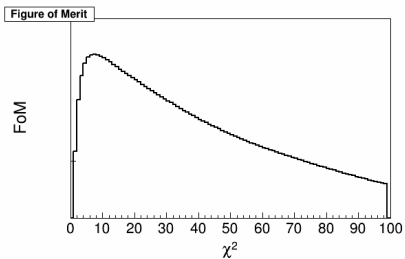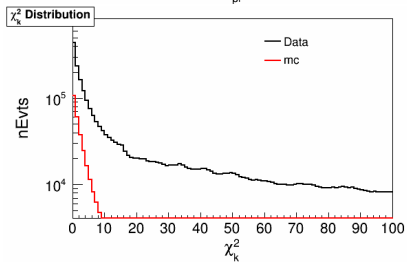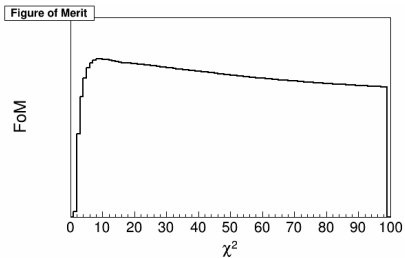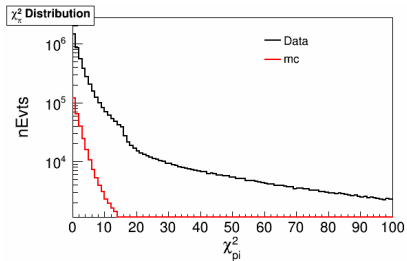
Secondary Vertex Fit

Secondary Vertex Fit for K_s

- decay length at least 0.5 cm
- mass within [-7 MeV, +7 MeV] around m(K_s)
- candidate with minimal ($\chi^2_{vtx} + \chi^2_{svtx}$) is chosen

Secondary Vertex Fit - K_s decay length
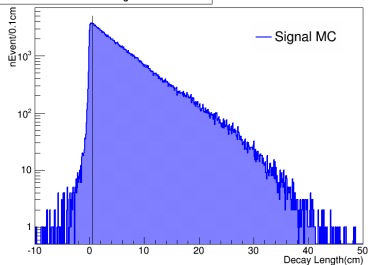
Secondary Vertex Fit - K_s Mass Window
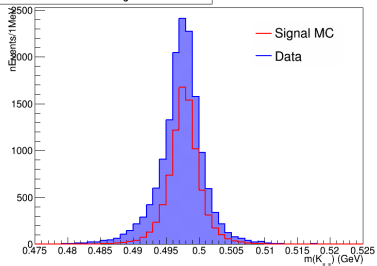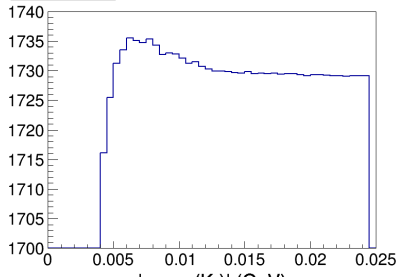
χ^2 of vertex fit and secondary vertex fit
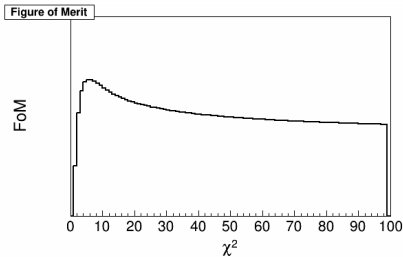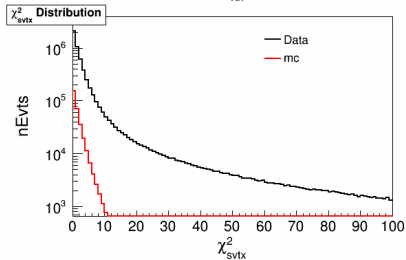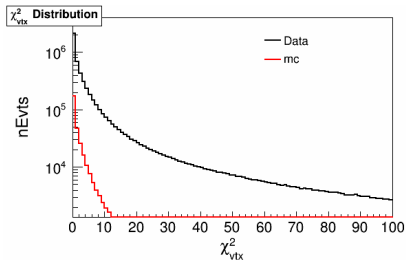
Kinematic Fit

3C: 4 momentum, loosen γ mass.
Iterating over either track being K, and over γ candidates. Combination with minimal $(\chi_\pi^2 + \chi_K^2 + \chi_{kmfit}^2)$ is chosen.

χ^2 of 3C

χ^2 total

$(\chi_{vtx}^2 + \chi_{svtx}^2 + \chi_k^2 + \chi_\pi^2 + \chi_{3c}^2) < 30$ required

Background Composition

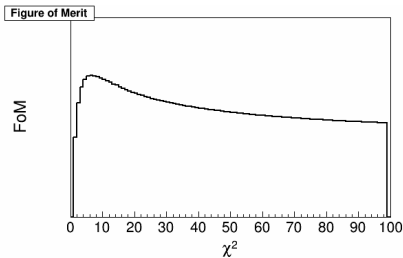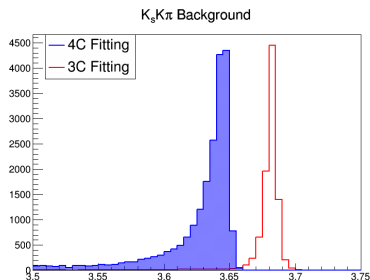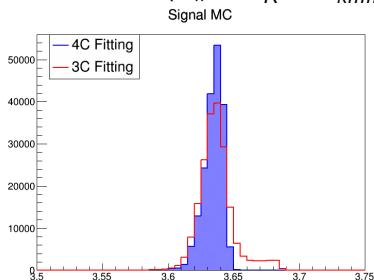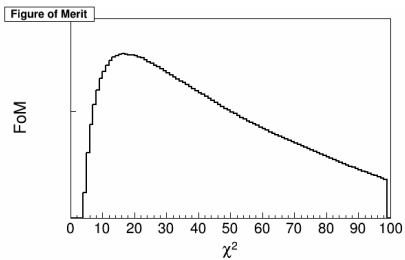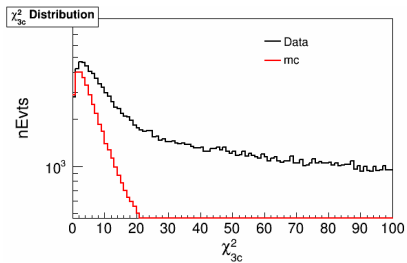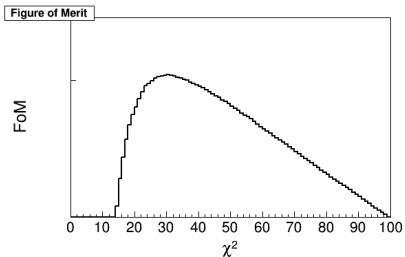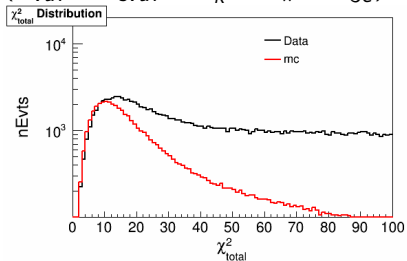| No.	decay chain	final states	iTopology	nEvt	nTot
0	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to K^-\pi^+\bar{K}^0, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	3	1938	1938
1	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to K^+\pi^-K^0, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	1	1932	3870
2	$\psi' \to J/\psi\pi^+\pi^-, J/\psi \to \mu^+\mu^-$	$\mu^+\pi^-\mu^-\pi^+$	0	1772	5642
3	$\psi' \to J/\psi\pi^+\pi^-, J/\psi \to e^+e^-$	$e^+\pi^-e^-\pi^+$	5	1209	6851
4	$\psi' \to \gamma\chi_{c2}, \chi_{c2} \to \bar{K}^0K^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	17	534	7385
5	$\psi' \to \gamma\chi_{c2}, \chi_{c2} \to K^0K^-\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	11	482	7867
6	$\psi' \to \gamma\chi_{c0}, \chi_{c0} \to K_sK_s, K_s \to \pi^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\pi^+\gamma$	9	382	8249
7	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to K^{*+}K^-, K^{*+} \to K^0\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	10	279	8528
8	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to K^{*-}K^+, K^{*-} \to \bar{K}^0\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	14	257	8785
9	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to K^*\bar{K}^0, K^* \to K^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	12	256	9041
10	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to \bar{K}^*K^0, \bar{K}^* \to K^-\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	2	209	9250
11	$\psi' \to \gamma K_sK^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	6	153	9403
12	$\psi' \to \gamma\chi_{c2}, \chi_{c2} \to K_sK_s, K_s \to \pi^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\pi^+\gamma$	8	136	9539
13	$\psi' \to K_1^+K^-, K_1^+ \to \rho^+K^0, \rho^+ \to \pi^+\pi^0, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+$	19	129	9668
14	$\psi' \to K_1^-K^+, K_1^- \to \rho^-\bar{K}^0, \rho^- \to \pi^-\pi^0, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^0\pi^+K^+$	15	128	9796
15	$\psi' \to \gamma K_sK^-\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	35	117	9913
16	$\psi' \to \bar{K}^*K^0, \bar{K}^* \to K^-\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+$	28	105	10018
17	$\psi' \to K^*\bar{K}^0, K^* \to K^+\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+K^+$	25	98	10116
18	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to a_0^-\pi^+, a_0^- \to K^0K^-, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^+\pi^+\gamma$	38	77	10193
19	$\psi' \to K^+\bar{K}^*\pi^-, \bar{K}^* \to \bar{K}^0\pi^0, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^0\pi^+K^+$	20	54	10247
20	$\psi' \to \gamma\chi_{c1}, \chi_{c1} \to a_0^+\pi^-, a_0^+ \to \bar{K}^0K^+, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	23	52	10299
21	$\psi' \to K^-K^*\pi^+, K^* \to K^0\pi^0, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+$	61	49	10348
22	$\psi' \to K_1^+K^-, K_1^+ \to K_0^{*+}\pi^0, K_0^{*+} \to K^0\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+$	7	42	10390
23	$\psi' \to K_1^+K^+, K_1^- \to K_0^{*-}\pi^0, K_0^* \to \bar{K}^0\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^0\pi^+K^+$	53	39	10429
24	$\psi' \to \gamma\eta_c(2S), \eta_c(2S) \to K^-\bar{K}^0\pi^+, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\pi^+\gamma$	66	30	10459
25	$\psi' \to \gamma\eta_c(2S), \eta_c(2S) \to K^+\bar{K}^0\pi^-, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^+\gamma K^+$	108	28	10487
26	$\psi' \to K_1^-K^+, K_1^- \to \bar{K}_0^{*0}\pi^-, \bar{K}_0^{*0} \to \bar{K}^0\pi^0, K_s \to \pi^+\pi^-$	$\pi^-\pi^-\pi^0\pi^+K^+$	13	23	10510
27	$\psi' \to K_1^+K^-, K_1^+ \to K^{*+}\pi^0, K^{*+} \to K^0\pi^+, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+$	65	21	10531
28	$\psi' \to \gamma\chi_{c2}, \chi_{c2} \to K^{*+}K^{*-}, K^{*+} \to K^0\pi^+, K^{*-} \to K^-\pi^0, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+\gamma$	52	21	10552
29	$\psi' \to K_1^+K^-, K_1^+ \to K^*\pi^+, K^* \to K^0\pi^0, K_s \to \pi^+\pi^-$	$\pi^-K^-\pi^0\pi^+\pi^+$	64	21	10573

Table 1:

$\gamma K_s K_s$ Background

Require that the two tracks outside the best K_s candidate can't be a K_s candidate.

It's regarded as a K_s candidate if the other two tracks can pass a vertex fit and the invariant mass is in the range of [-10 MeV,+10 MeV] around $m(K_s)$.

The efficiency for $\gamma K_s K_s component$ without and with such a cut is 1.53% and 0.86%, while it's 18.1% and 18.0% for signal.

J/ψ + Neutral Background

Require the largest recoil mass of $m(\pi\pi)$ out all π pairs to be smaller than 3.05 GeV.
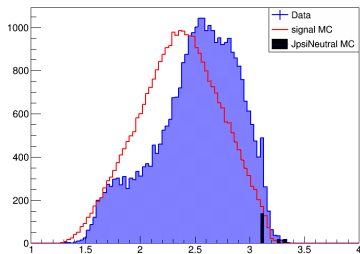
$K_sK\pi$ Background

$\pi^0 K_s K \pi$ Background