

Results of Spin- Parity Study

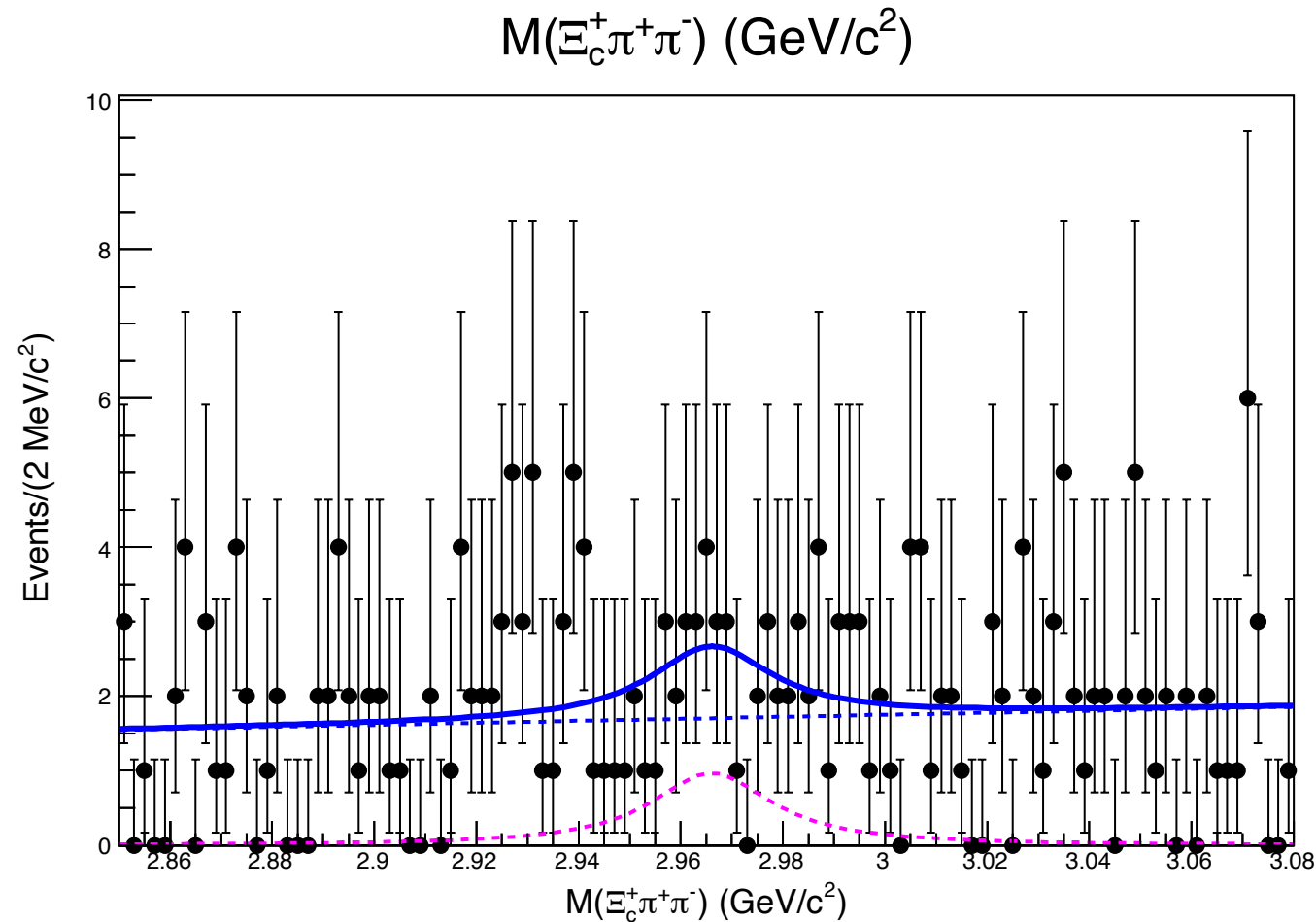
Taejin Moon
19 Feb, 2020

Sideband Subtraction

Signal Region & Sideband

- For $\Xi_c(2970)^+ \rightarrow \Xi_c(2645)^0 \pi^+ \rightarrow \Xi_c^+ \pi^- \pi^+$,
 - Signal region : $| M(\Xi_c^+ \pi^-) - M_0 | < 5 \text{ MeV}$
 - Sideband: $15 \text{ MeV} < | M(\Xi_c^+ \pi^-) - M_0 | < 25 \text{ MeV}$
- ,where M_0 is PDG mass of $\Xi_c(2645)^0$

Sideband Fitting



- Mass window for $\Xi_c(2645)^0$: $15 \text{ MeV} < | M(\Xi_c^+\pi^-) - M_0 | < 25 \text{ MeV}$
- Total entries : 216
- Yield : 20.0351 ± 11.777
 - $\rightarrow$ Normalized by 2 : 10.0176 ± 5.888

Sideband Fitting

- Angle-integrated Configuration
 - Total entries : 216
 - Yield : 20.0351 ± 11.777
 - $\rightarrow$ Normalized by 2 : 10.0176 ± 5.888 $\rightarrow$ applied for Parity study
- For cos angle bins,
 - Too small yield -- can not extract reliable yield.
 - Negative yield from fitting
 - No choice but to use average value
 - this assume flat angular distribution
- Yield : 20.0351 ± 11.777
 - $\rightarrow$ Normalized by 20 : 1.00176 ± 0.5888 $\rightarrow$ applied for Spin study

Relative BR.

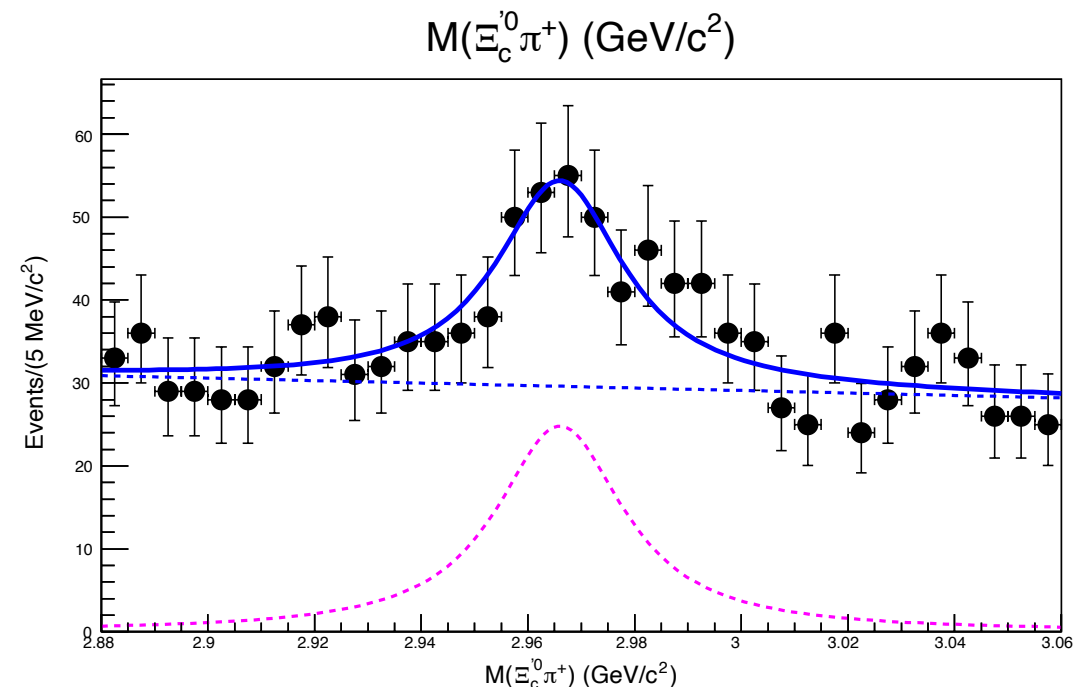
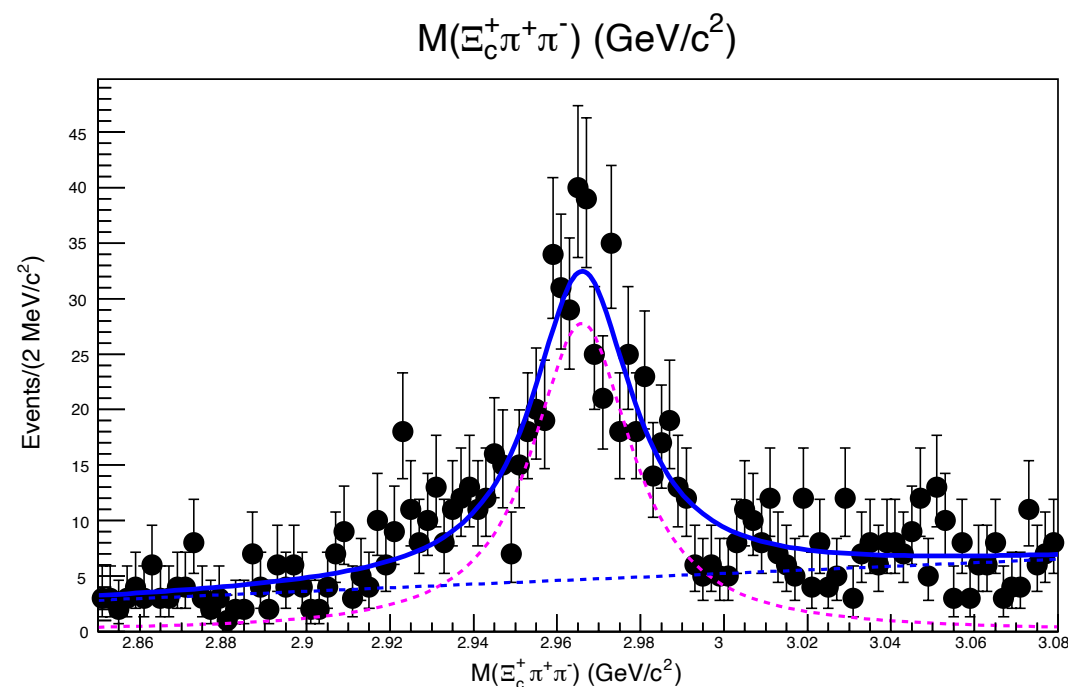
$$R = \frac{\Gamma(\Xi_c(2970)^+ \rightarrow \Xi_c(2645)^0 \pi^+)}{\Gamma(\Xi_c(2970)^+ \rightarrow \Xi_c'^0 \pi^+)}$$

- Using decay branching fraction of the Ξ_c ground states -

Parity

- Sideband subtracted -

- $\Xi_c(2970)^+ \rightarrow \Xi_c(2645)^0 \pi^+ \rightarrow \Xi_c^+ \pi^- \pi^+$
- $\Xi_c(2970)^+ \rightarrow \Xi_c'^0 \pi^+ \rightarrow \Xi_c^0 \gamma \pi^+$



- Mass and width : fixed as Yelton's value
 Mass : 2966.0 MeV/c²
 Width : 28.1 MeV
- Branching fraction of Ξ_c^+ / Ξ_c^0 : fixed as Belle papers
 $B(\Xi_c^+ \rightarrow \Xi^- \pi^+ \pi^+) : 2.86\%$ (PhysRevD.100.031101)
 $B(\Xi_c^0 \rightarrow \Xi^- \pi^+) : 1.80\%$ (PhysRevLett.122.082001)
 with $B(\Xi^- \pi^+) : B(\Omega^- K^+) = 1 : 0.2937$

	Yield	Stat. Error	Recon.Eff . (%)	BR of Ξ_c ground state (%)
$\Xi_c(2645)^0 \pi^+$	566.546	34.254	2.836	2.86
$\Xi_c' \pi$	201.445	33.296	2.176	2.32866

$$R = 2.06 \pm 0.49 \text{ (Stat. Error only)}$$

Systematic Uncertainty List

- Parity Analysis -

Category	Source of sys. uncertainty	Δ to be applied	remark
Resolution Function (double Gaussian)	Resolution of core Gaussian (σ_1)	10% increase	
	Ratio of resolutions (σ_1/σ_2)	$\pm 1\sigma$	
	Ratio of yield (N_1/N_2)	$\pm 1\sigma$	
Yield Correction	Reconstruction Eff.	$\pm 1\sigma$	
	Branching fraction of Ξ_c ground state	$\pm$ errors in references	
Background PDF			
	1st order chebychev polynomial	1st --> 2nd / 0st	
Convolution	Intrinsic width of $\Xi_c(2970)^+$	$\pm$ errors in references	
	Mass of $\Xi_c(2970)^+$	$\pm$ errors in references	

Systematic Uncertainty List

- Parity Analysis -

	xic2645 pi	xic' pi			change both
s1 * 1.1	0.001	-0.003		bkg 1st --> 0st	-0.018
s2os1 + 1 σ	0.000	0.003		bkg 1st --> 2nd	0.131
s2os1 - 1 σ	0.000	0.000		m+1 σ	-0.010
peak_ratio + 1 σ	0.000	0.000		m-1 σ	0.012
peak_ratio - 1 σ	-0.001	0.000		w+1 σ	-0.031
eff + 1 σ	-0.002	0.002		w-1 σ	0.077
eff - 1 σ	0.002	-0.004			
br + 1 σ	-0.620	0.469			
br - 1 σ	1.609	-0.934			

R = 2.06 $\pm$ 0.49 $^{+1.68}_{-1.12}$ (w/ sideband subtraction)

Systematic Uncertainty =
 $^{+0.15}_{-0.04}$ (other than br)
 $^{+1.68}_{-1.12}$ (br)

Angular Distribution

$$\Xi_c(2970)^+ \rightarrow \Xi_c(2645)^0 \pi^+$$

Systematic Uncertainty List

- Angular Analysis -

Category	Source of sys. uncertainty	Δ to be applied	remark
Resolution Function (double Gaussian)	Resolution of core Gaussian (σ_1)	10% increase	
	Ratio of resolutions (σ_1/σ_2)	$\pm 1\sigma$	
	Ratio of yield (N_1/N_2)	$\pm 1\sigma$	
Yield Correction	Reconstruction Eff.	$\pm 1\sigma$	
Background PDF	1st order chebychev polynomial	1st --> 0st	
Convolution	Intrinsic width of $\Xi_c(2970)^+$	$\pm$ errors in references	
	Mass of $\Xi_c(2970)^+$	$\pm$ errors in references	

Fitting Functions

$$W_{\frac{1}{2}} = 1$$

$$W_{\frac{3}{2}} = \rho_{33} \left\{ 1 + T \left(\frac{3}{2} \cos^2 \theta_h - \frac{1}{2} \right) \right\} + \rho_{11} \left\{ 1 + T \left(-\frac{3}{2} \cos^2 \theta_h + \frac{1}{2} \right) \right\}$$

$$W_{\frac{5}{2}} = \frac{3}{32} [\rho_{55} 5 \{ (-\cos^4 \theta_h - 2 \cos^2 \theta_h + 3) + T(-5 \cos^4 \theta_h + 6 \cos^2 \theta_h - 1) \} \\ + \rho_{33} \{ (15 \cos^4 \theta_h - 10 \cos^2 \theta_h + 11) + T(75 \cos^4 \theta_h - 66 \cos^2 \theta_h + 7) \} \\ + \rho_{11} 2 \{ (-5 \cos^4 \theta_h + 10 \cos^2 \theta_h + 3) + T(-25 \cos^4 \theta_h + 18 \cos^2 \theta_h - 1) \}]$$

$$T = \frac{|T(p, \frac{3}{2}, 0)|^2 - |T(p, \frac{1}{2}, 0)|^2}{|T(p, \frac{3}{2}, 0)|^2 + |T(p, \frac{1}{2}, 0)|^2}$$

$W_{3/2} : \rho_{33} = (1/2 - \rho_{11})$

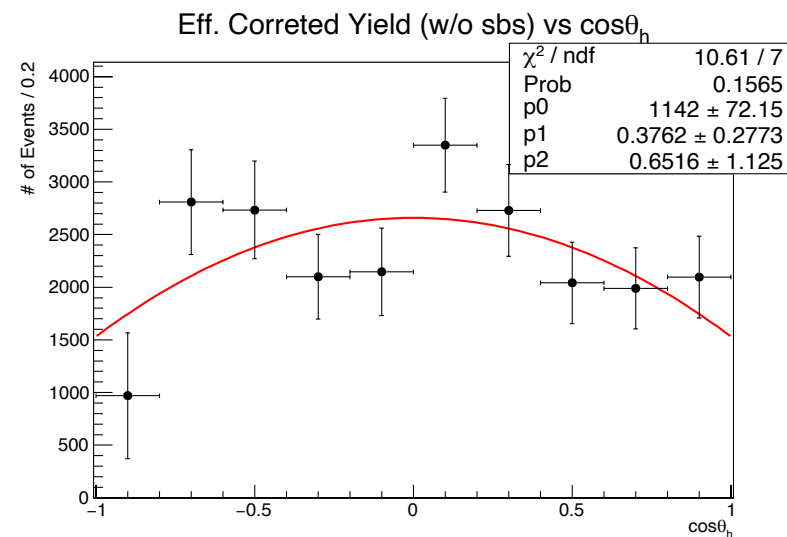
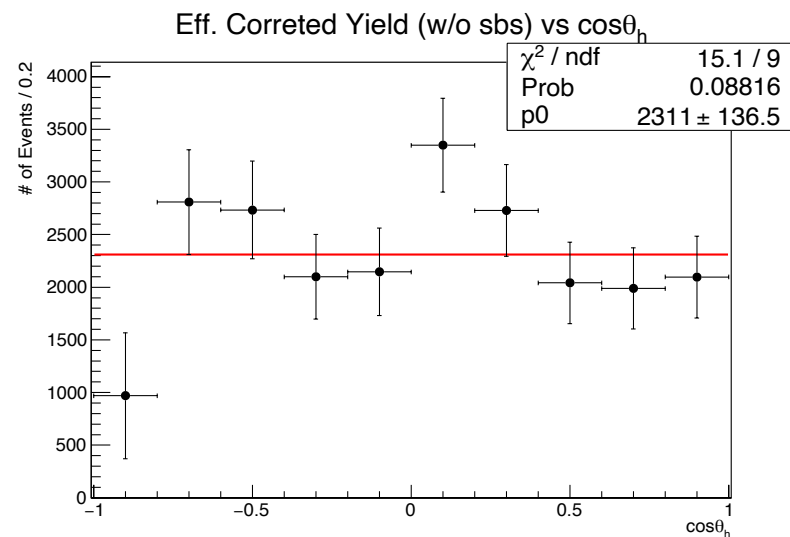
Parameters: {Scaling constant, ρ_{11} , T }

$W_{5/2} : \rho_{55} = (1/2 - \rho_{11} - \rho_{33})$

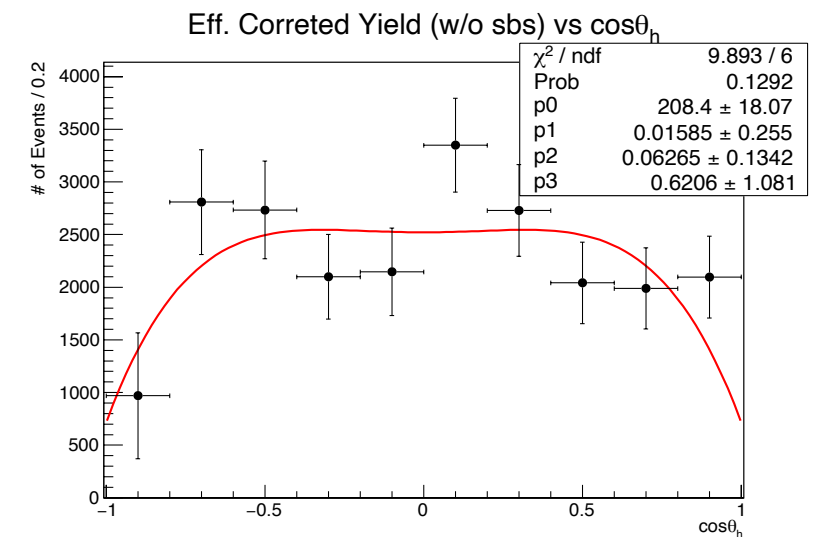
Parameters: {Scaling constant, ρ_{11} , ρ_{33} , T }

Angular Distribution

- Without Sideband subtraction
- Statistical error only



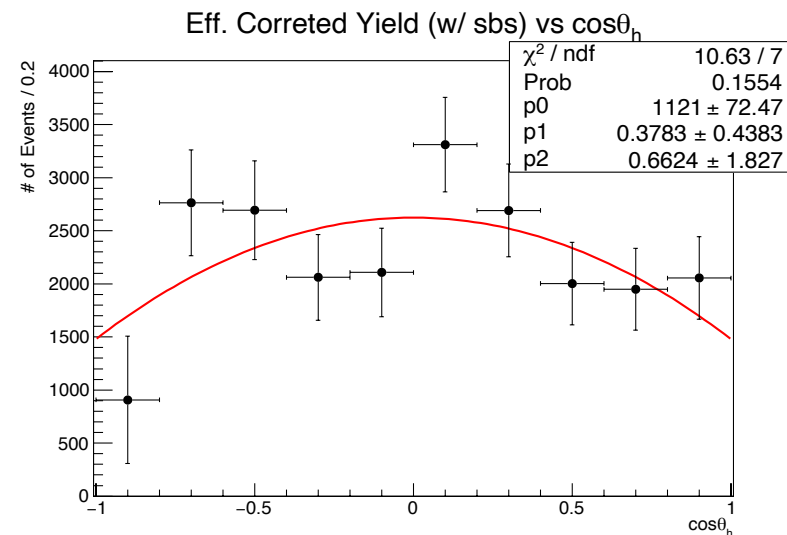
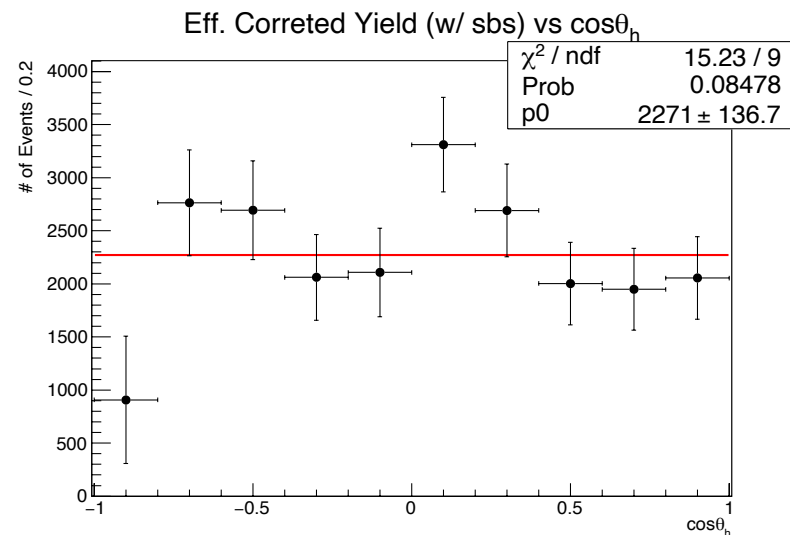
p1 = ρ_{11}
p2 = T



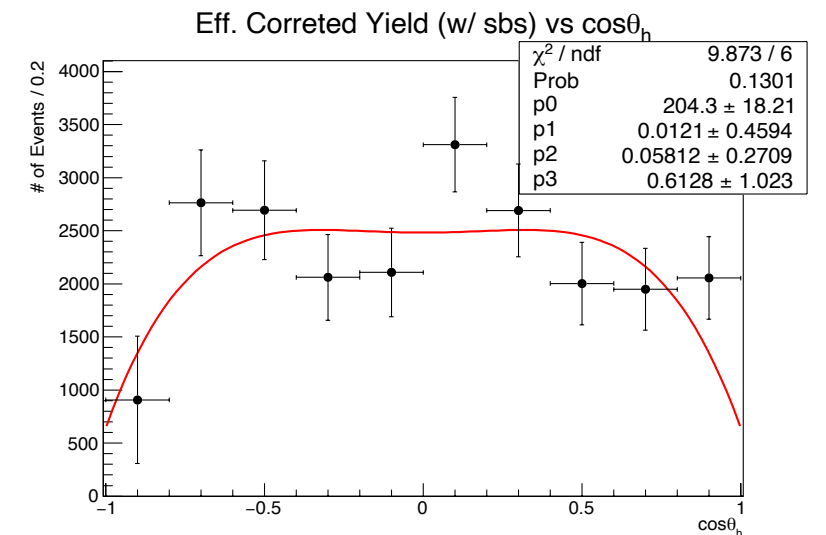
p1 = ρ_{11}
p2 = ρ_{33}
p3 = T

Angular Distribution

- With Sideband subtraction
- Statistical error only



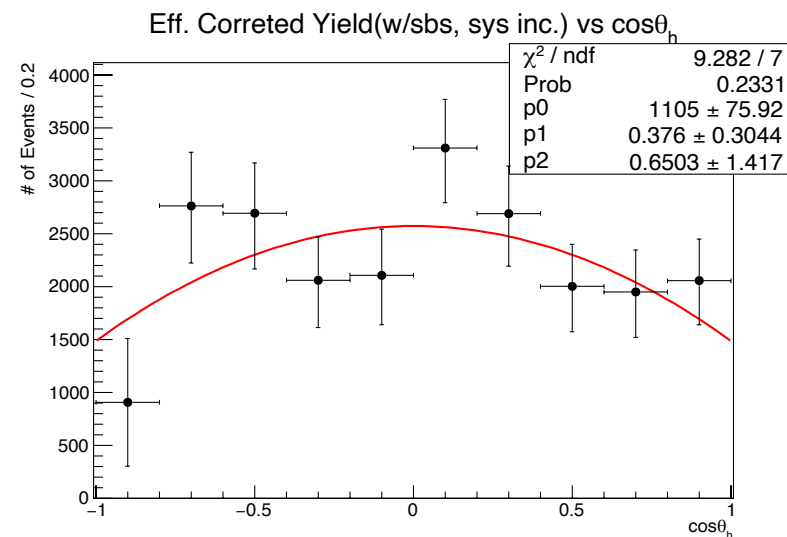
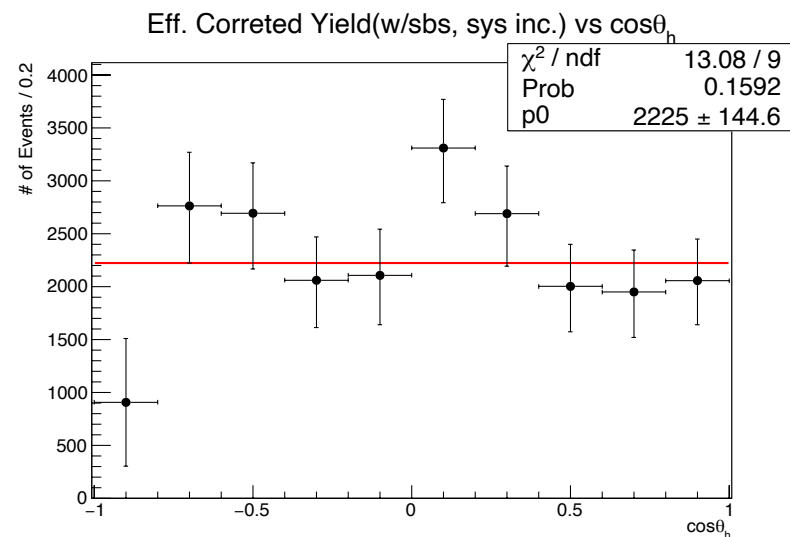
p1 = ρ_{11}
p2 = T



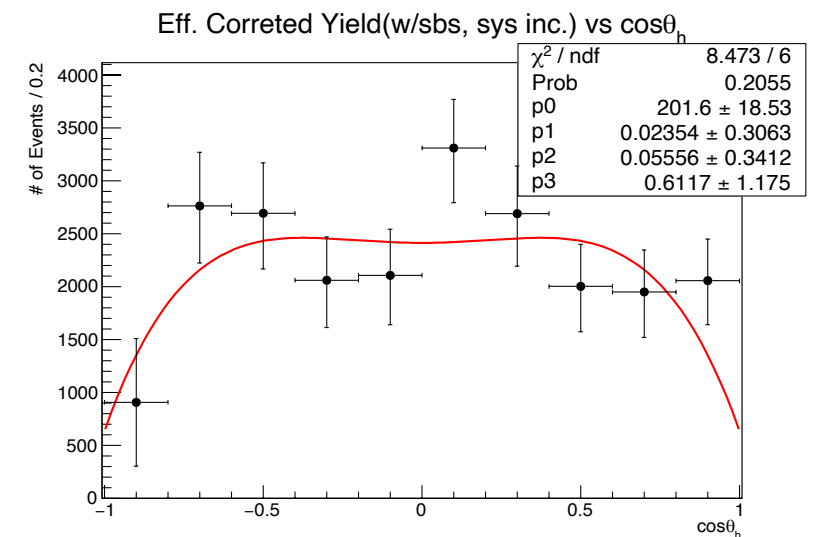
p1 = ρ_{11}
p2 = ρ_{33}
p3 = T

Angular Distribution

- With Sideband subtraction
- Systematic error included



p1 = ρ_{11}
p2 = T

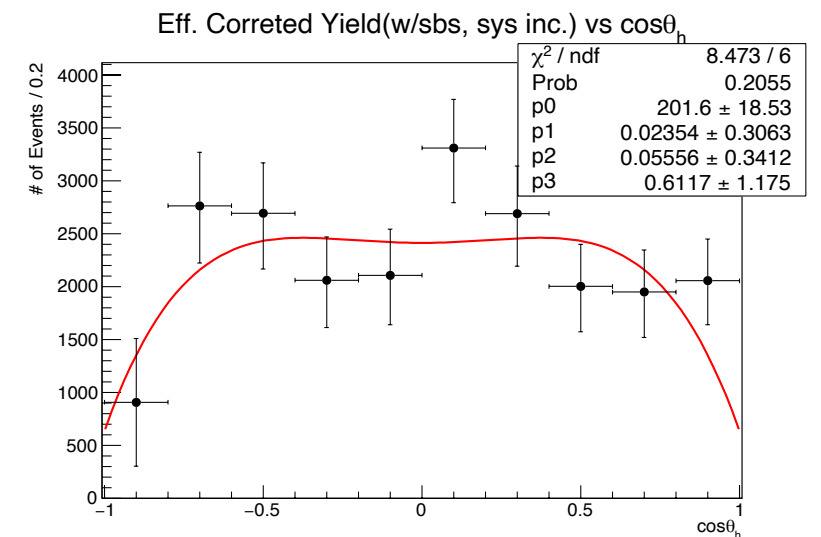
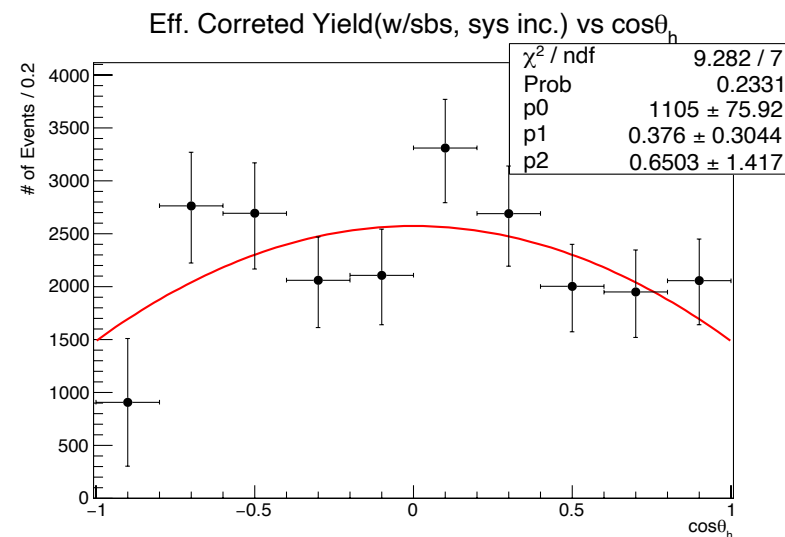
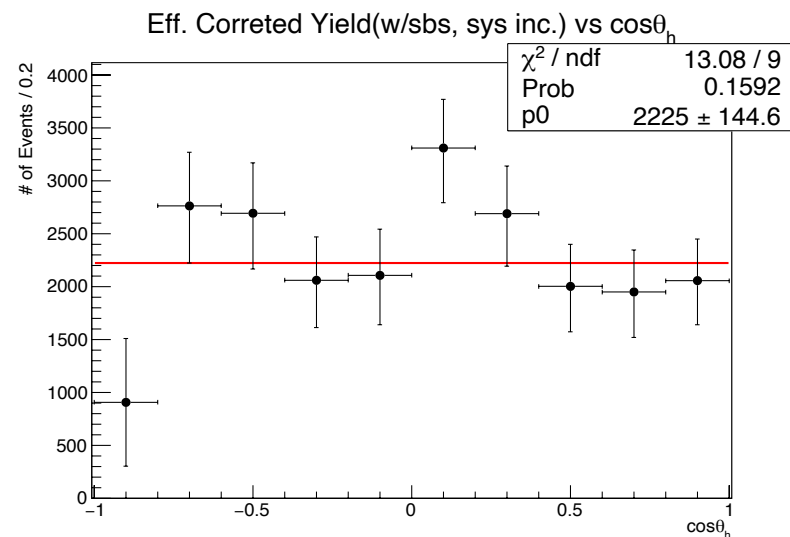


p1 = ρ_{11}
p2 = ρ_{33}
p3 = T

J = 3/2 is favored.

Angular Distribution

- With Sideband subtraction
- Systematic error included



J = 3/2 is favored.

cf) R = 2.06 ± 0.49 $^{+1.68}_{-1.12}$

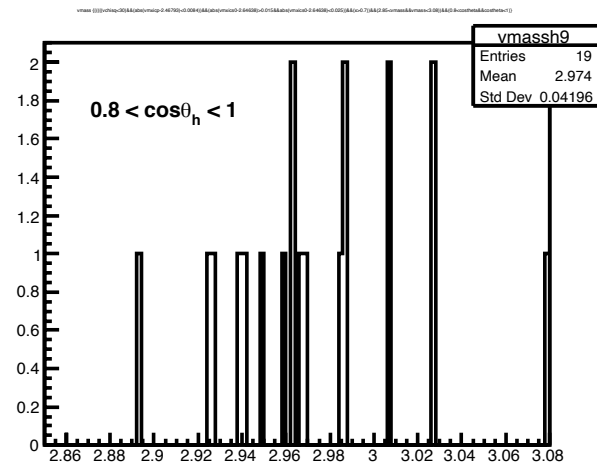
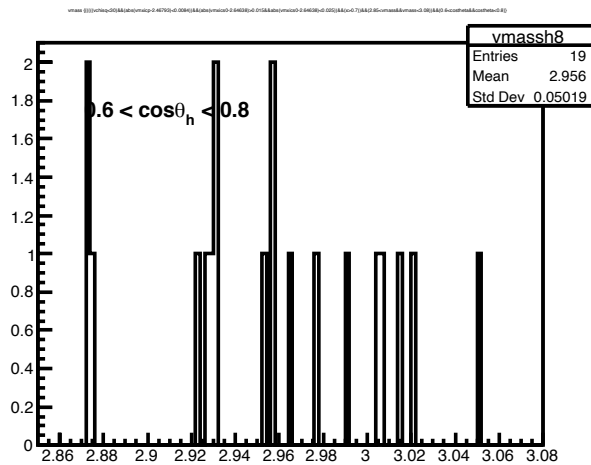
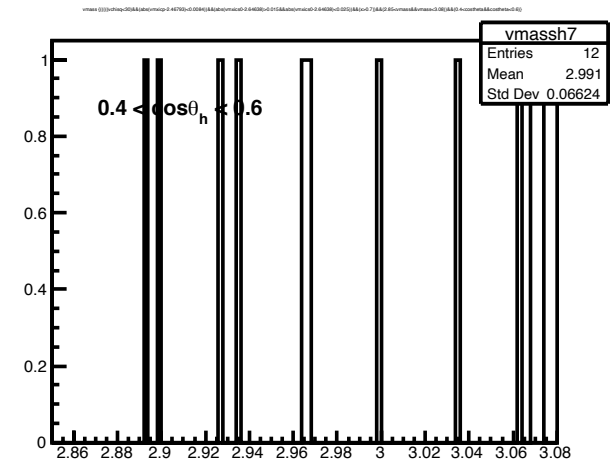
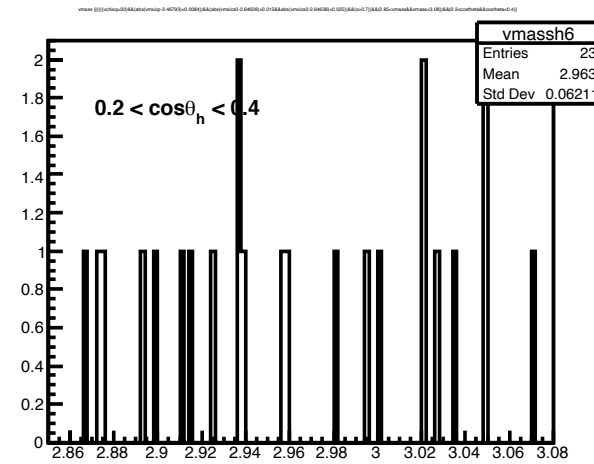
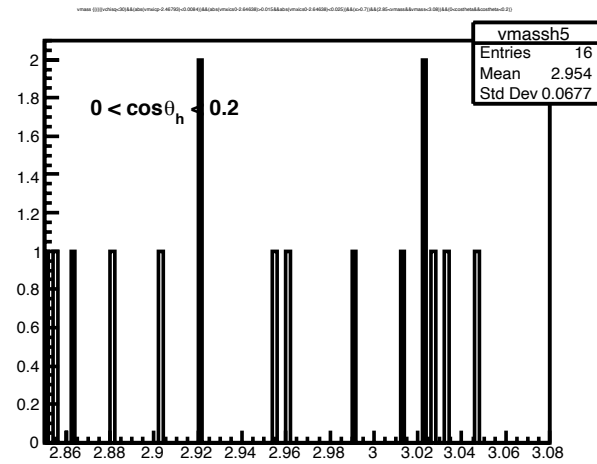
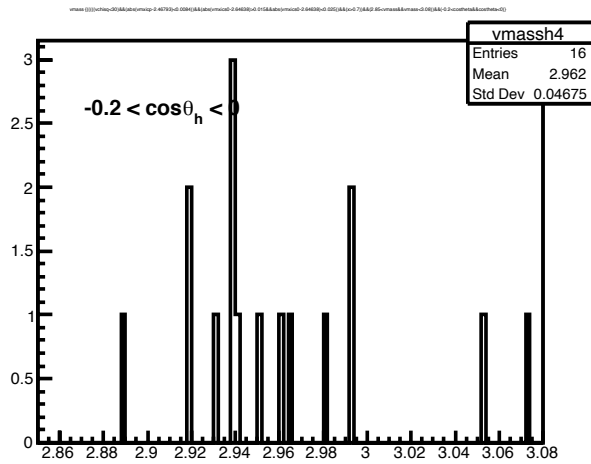
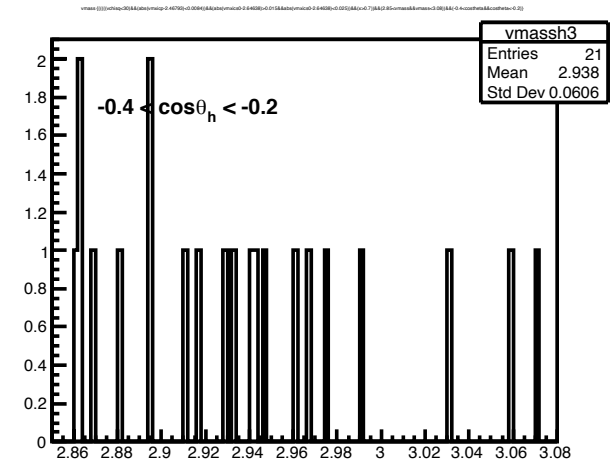
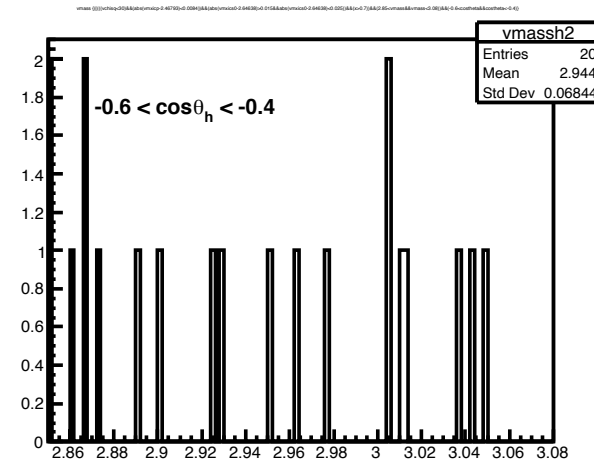
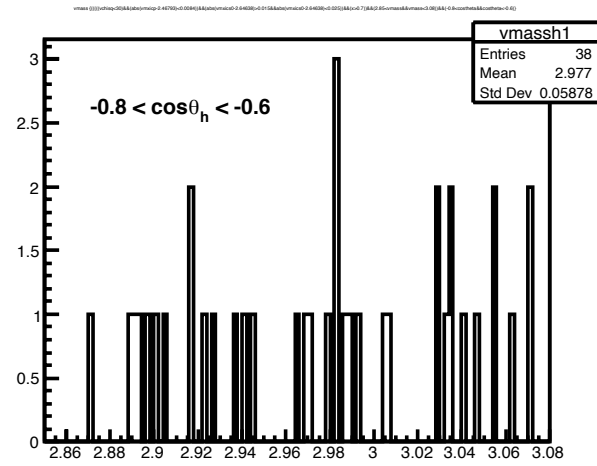
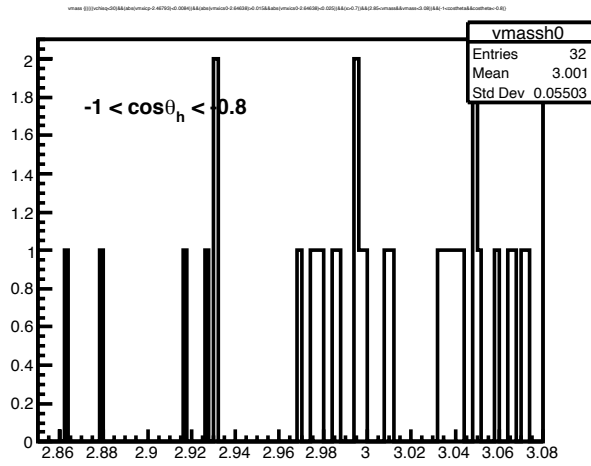
R = 2.06 $^{+1.75}_{-1.22}$

Parity	+		-	
Brown-muck spin	1	2	1	2
R	2.62	0.105	>> 1	0.341

Backup

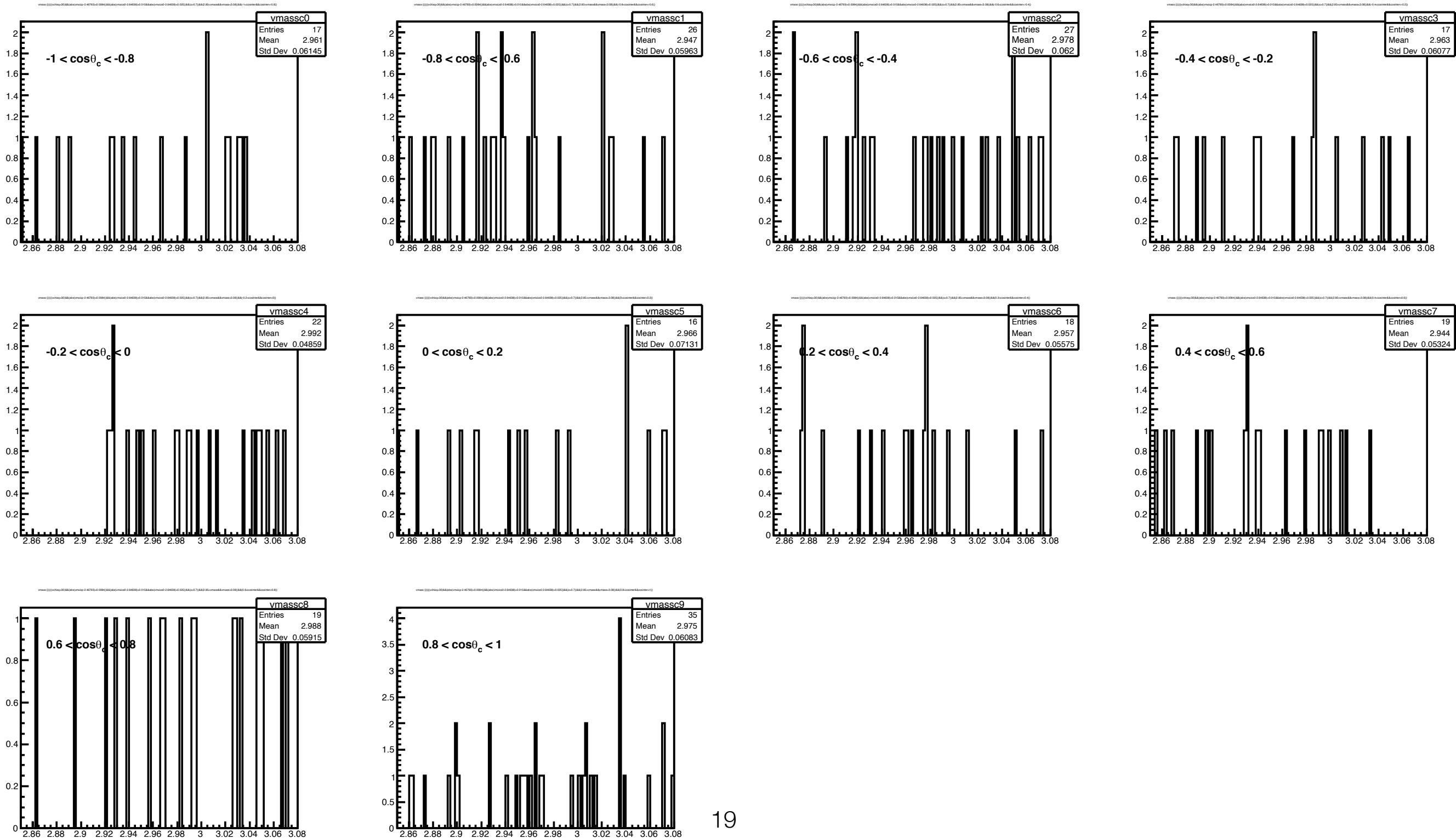
Sideband ($\cos\theta_h$ bin)

- Raw histogram -

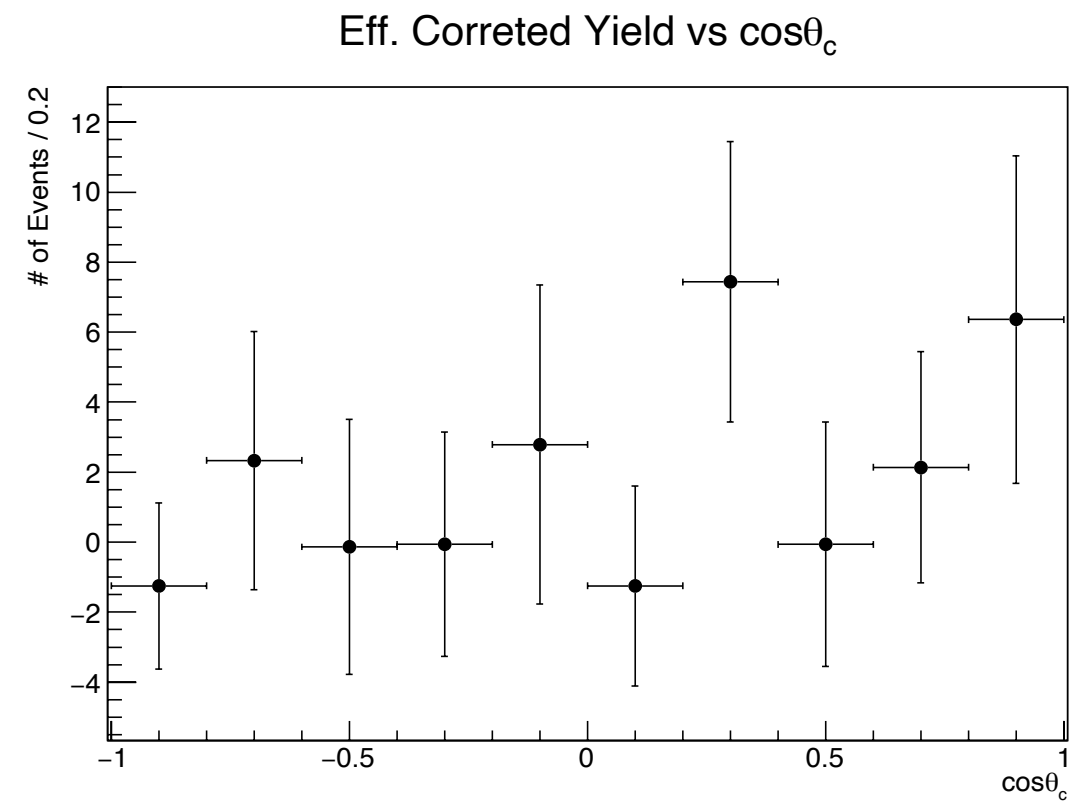
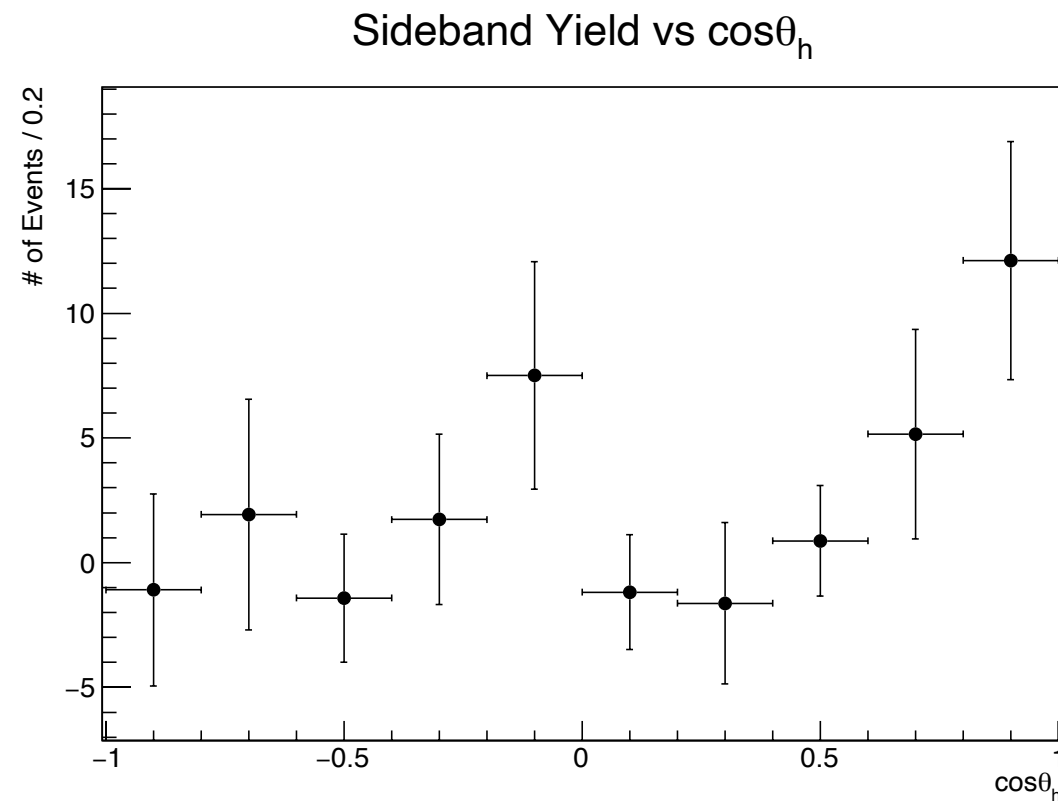


Sideband ($\cos\theta_c$ bin)

- Raw histogram -



Fitting w/ Negative Yield Allowed



cos	-0.9	-0.7	-0.5	-0.3	-0.1	0.1	0.3	0.5	0.7	0.9	Sum	
$Y_{\cos\theta_h}$	-1.09	1.93	-1.42	1.73	7.51	-1.18	-1.63	0.87	5.16	12.1	23.98	
$\Delta Y_{\cos\theta_h}$	3.85	4.63	2.56	3.42	4.57	2.30	3.24	2.22	4.20	4.77	11.68	sqrt(sum of square)
$Y_{\cos\theta_c}$	-1.25	2.33	-0.14	-0.06	2.79	-1.25	7.44	-0.06	2.14	6.36	18.3	
$\Delta Y_{\cos\theta_c}$	2.37	3.69	3.65	3.21	4.56	2.86	4.01	3.45	3.30	4.68	11.52	sqrt(sum of square)

**The values can change little bit depending on initial value of parameters.
But not so much different.**