Cross checks for BAM116

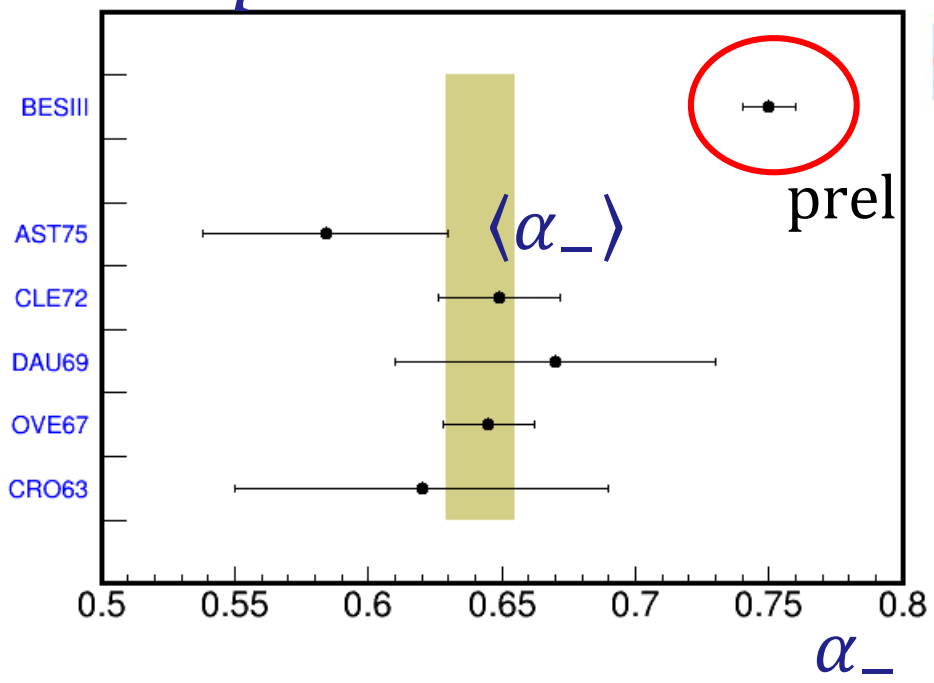
$$e^+e^- \to J/\psi \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$$

Andrzej Kupsc

Apply Jiao Jiao efficiency correction
Tools for checking efficiencies in $e^+e^- \to J/\psi \to \Lambda\,\bar{\Lambda}$
⇨ Systematical uncertainties are correct
⇨ Room for improvement with larger statistics
...

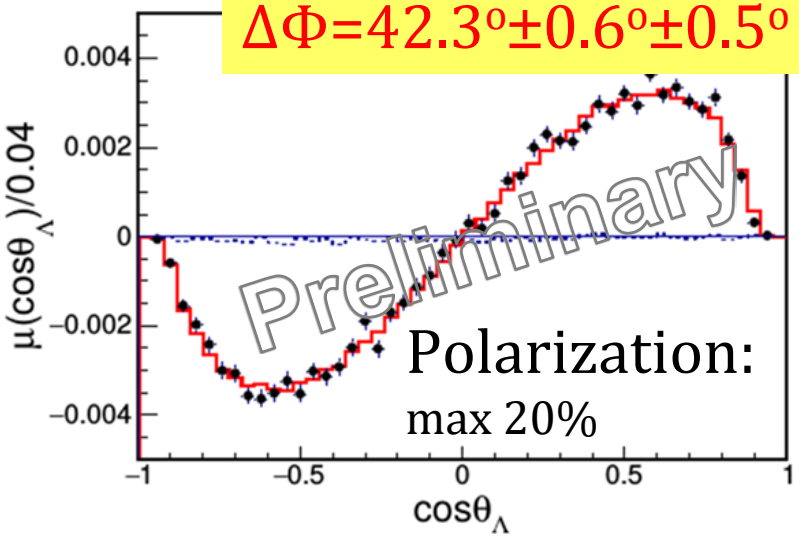
Observation of the spin polarization of Λ hyperons in the $J/\psi \to \Lambda\bar{\Lambda}$ decay

$\Lambda \to p\pi^-$: α_-



17% larger than PDG avg
> 5 σ difference

$\Delta\Phi = 42.3^o \pm 0.6^o \pm 0.5^o$



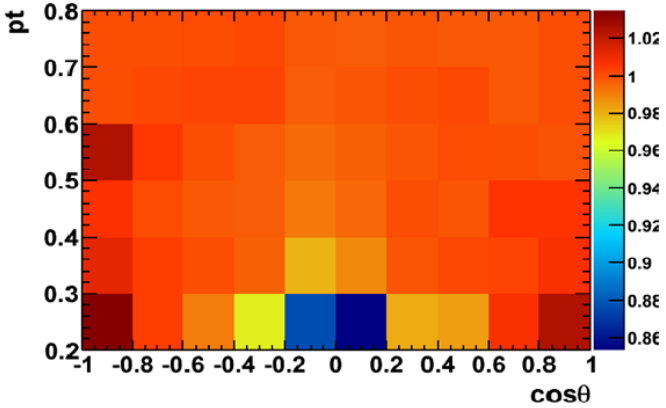
CP test

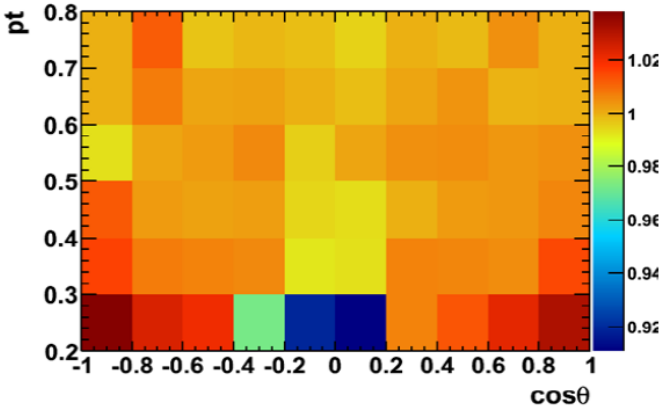
$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

$A_{CP} = -0.006 \pm 0.012 \pm 0.007$ prel

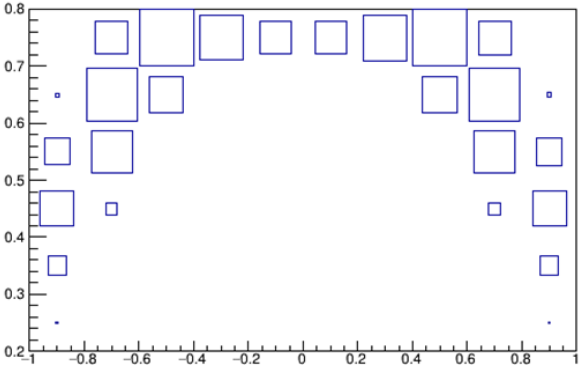
$A_{CP} = 0.013 \pm 0.021$
PS185 PRC54(96)1877
CKM $A_{CP} \sim 10^{-4}$

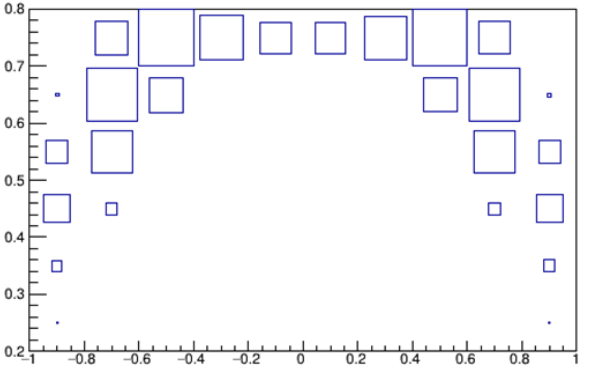
$p, \bar{p}$ track eff pT vs cos(θ)



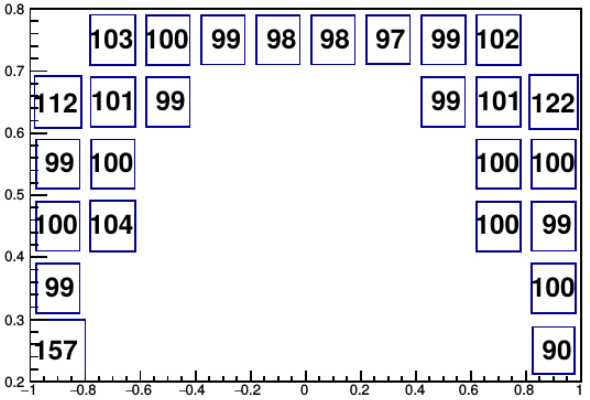


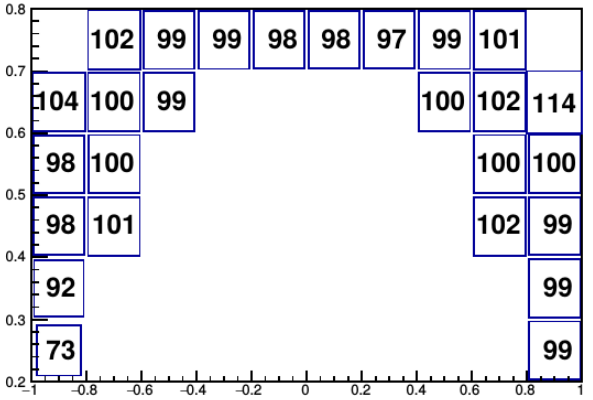
Jiaojiao





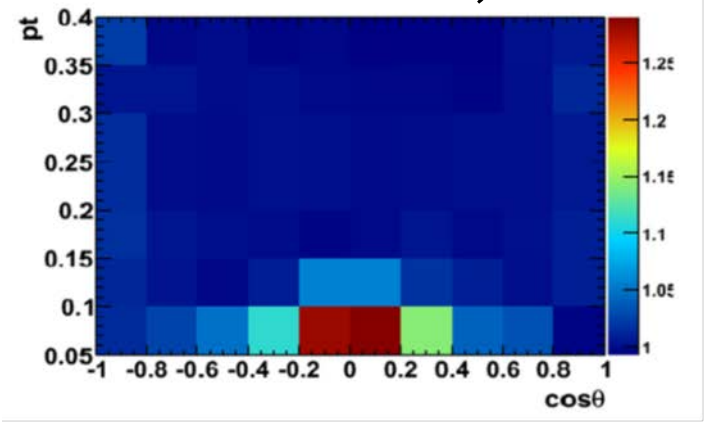
Data

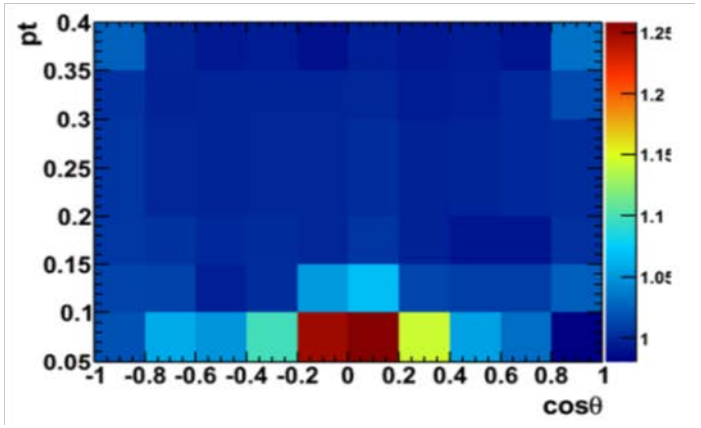




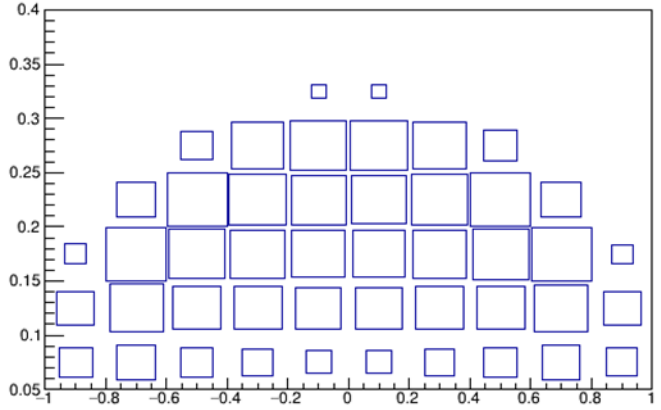
Data/MC

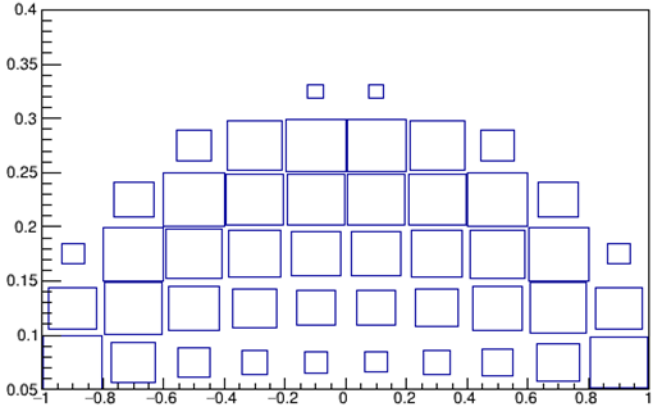
π^-, π^+ track eff pT vs cos(θ)



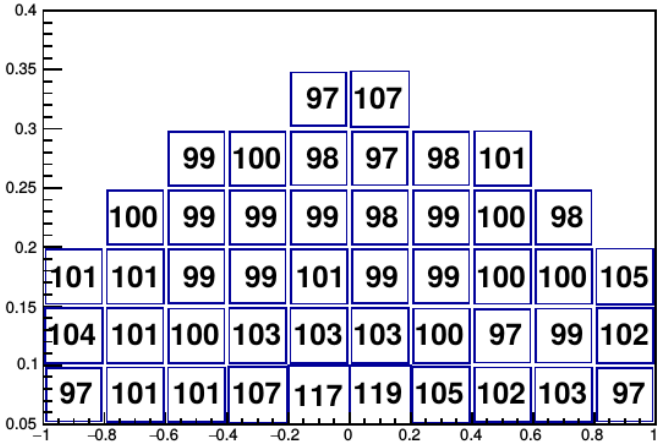


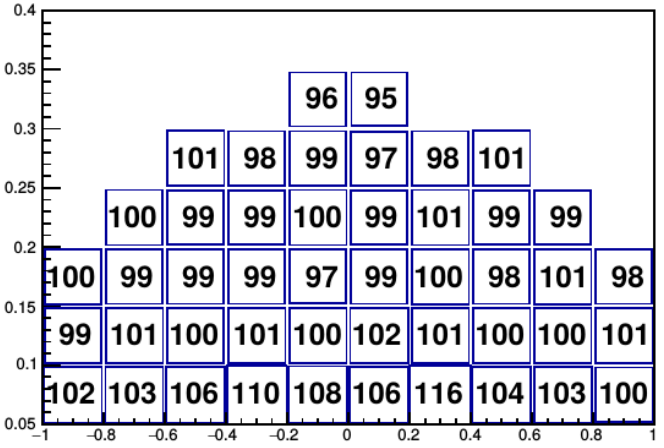
Jiaojiao





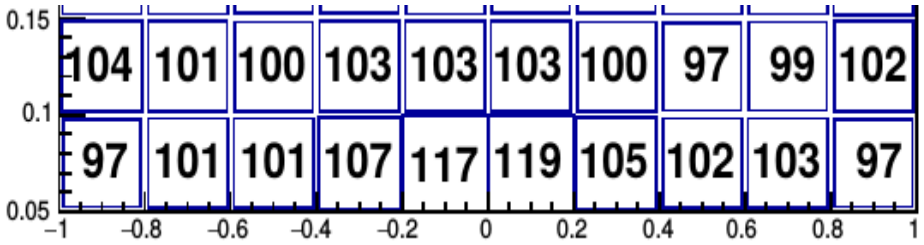
Data

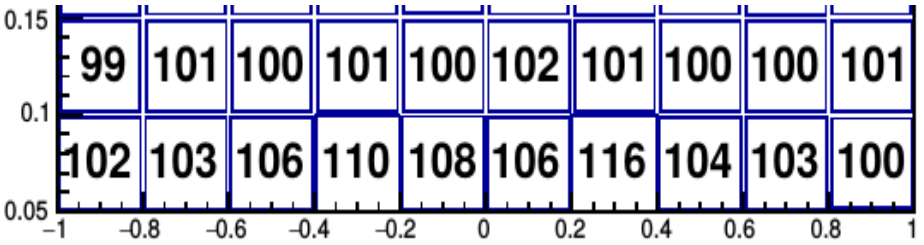


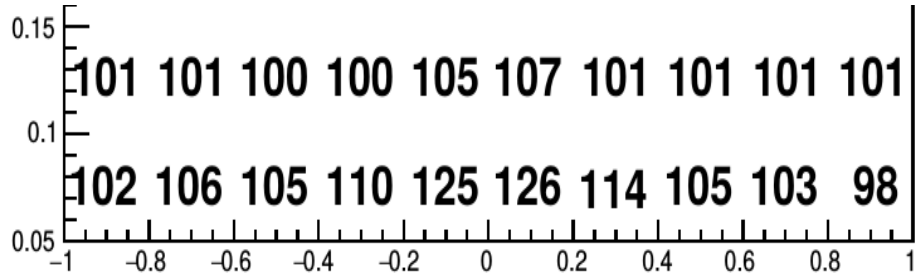


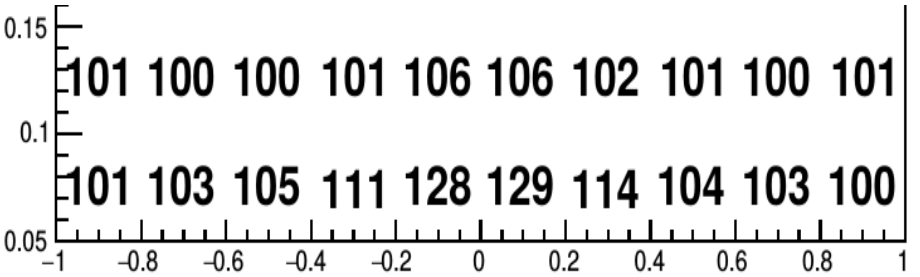
Data/MC

π^-, π^+ track eff pT vs cos(θ)





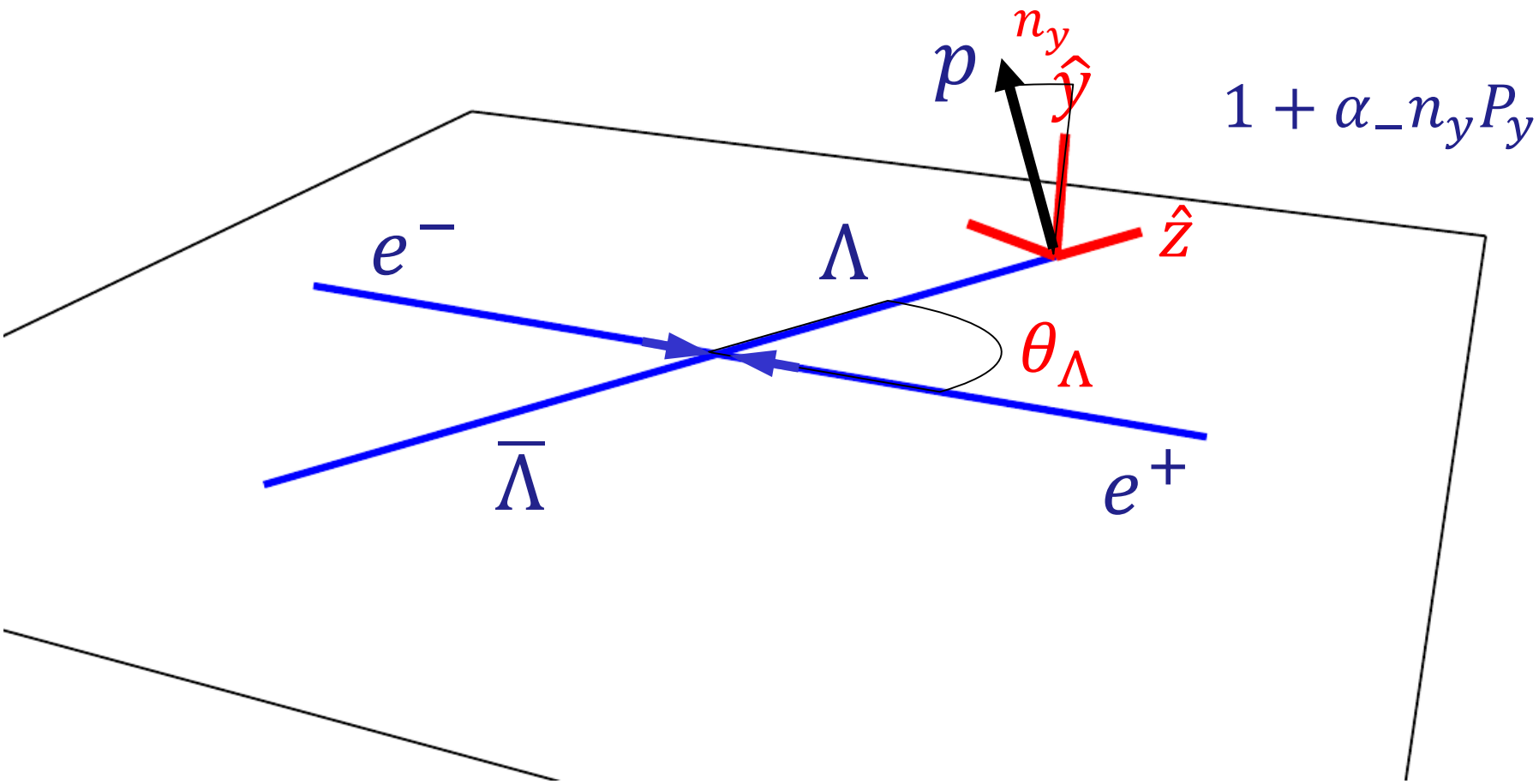




Only pions are affected

Apply Jiaojiao correction (eff1)
or first iteration to self consistent method (eff2)

$e^+e^- \to (\Lambda \to p\pi^-)\bar{\Lambda}$



$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha\_$

Hyperon polarization determined using
angular distribution of the baryon from the weak decay

Exclusive decay distributions

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$

$$d\Gamma \propto \mathcal{W}(\boldsymbol{\xi})d\boldsymbol{\xi} = \mathcal{W}(\boldsymbol{\xi})d\cos\theta_\Lambda d\Omega_1 d\Omega_2 \qquad \boldsymbol{\xi} : (\cos\theta_\Lambda, \Omega_1, \Omega_2)$$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha_-$

$\bar{\Lambda} \to \bar{p}\pi^+ (or\ \bar{n}\pi^0)$: $\Omega_2 = (\cos\theta_2, \phi_2)$

$\bar{\Lambda} \to \bar{p}\pi^+$: $\alpha_2 \to \alpha_+$

$$\begin{aligned}
\mathcal{W}(\boldsymbol{\xi}) = 1 &+ \alpha_\psi \cos^2\theta_\Lambda \\
&+ \alpha_1\alpha_2 \left(\sin^2\theta_\Lambda \sin\theta_1 \sin\theta_2 \cos\phi_1 \cos\phi_2 + \cos^2\theta_\Lambda \cos\theta_1 \cos\theta_2\right) \\
&+ \alpha_1\alpha_2 \sqrt{1-\alpha_\psi^2} \cos(\Delta\Phi) \left\{\sin\theta_\Lambda \cos\theta_\Lambda \left(\sin\theta_1 \cos\theta_2 \cos\phi_1 + \cos\theta_1 \sin\theta_2 \cos\phi_2\right)\right\} \\
&+ \alpha_1\alpha_2 \alpha_\psi \left(\cos\theta_1 \cos\theta_2 - \sin^2\theta_\Lambda \sin\theta_1 \sin\theta_2 \sin\phi_1 \sin\phi_2\right) \\
&+ \sqrt{1-\alpha_\psi^2} \sin(\Delta\Phi)\ \sin\theta_\Lambda \cos\theta_\Lambda \left(\alpha_1 \sin\theta_1 \sin\phi_1 + \alpha_2 \sin\theta_2 \sin\phi_2\right)
\end{aligned}$$

Spin correlations

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Exclusive decay distributions

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$

$$d\Gamma \propto \mathcal{W}(\boldsymbol{\xi})d\boldsymbol{\xi} = \mathcal{W}(\boldsymbol{\xi})d\cos\theta_\Lambda d\Omega_1 d\Omega_2$$

$\boldsymbol{\xi}: (\cos\theta_\Lambda, \Omega_1, \Omega_2)$

$\Lambda \to p\pi^-$: $\Omega_1 = (\cos\theta_1, \phi_1)$: $\alpha_1 \to \alpha_-$

$\bar{\Lambda} \to \bar{p}\pi^+ (or\ \bar{n}\pi^0)$: $\Omega_2 = (\cos\theta_2, \phi_2)$

$\bar{\Lambda} \to \bar{p}\pi^+$: $\alpha_2 \to \alpha_+$

Just 4 (3) global parameters

$$\mathcal{W}(\xi) = 1 + \alpha_\psi \cos^2\theta_\Lambda$$

Spin correlations

$$+ \alpha_-\alpha_+ \left[\sin^2\theta_\Lambda \left(n_{1,x}n_{2,x} - \alpha_\psi n_{1,y}n_{2,y}\right) + \left(\cos^2\theta_\Lambda + \alpha_\psi\right) n_{1,z}n_{2,z}\right]$$

$$+ \alpha_-\alpha_+ \sqrt{1-\alpha_\psi{}^2}\cos(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda \left(n_{1,x}n_{2,z} + n_{1,z}n_{2,x}\right)$$

$$+ \sqrt{1-\alpha_\psi{}^2}\sin(\Delta\Phi)\,\sin\theta_\Lambda\cos\theta_\Lambda \left(\alpha_- n_{1,y} + \alpha_+ n_{2,y}\right).$$

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General two spin ½ particle state

$$\rho_{1/2,\overline{1/2}} = \frac{1}{4}\sum_{\mu\nu} C_{\mu\bar{\nu}}\sigma_\mu \otimes \sigma_{\bar{\nu}}$$

16 parameters for each θ:
I(θ), polarizations (6)
Spin correlations (9)

$$\mathcal{W}(\boldsymbol{\xi}) = \mathcal{I}(\theta)\left\{1 + \alpha_\Lambda \sum_k P_k(\theta)\mathbf{n}_k + \alpha_{\bar{\Lambda}} \sum_{\bar{k}} P_{\bar{k}}(\theta)\mathbf{n}_{\bar{k}} + \right.$$

$$\left. \alpha_\Lambda \alpha_{\bar{\Lambda}} \sum_{\bar{k}k} C_{\bar{k}k}(\theta)\mathbf{n}_{\bar{k}}\mathbf{n}_k \right\}$$

polarizations (6)

Spin correlations (9)

$$P_y(\theta) = \sqrt{1-\alpha_\psi^2}\,\frac{\cos\theta\sin\theta}{1+\alpha_\psi\cos^2\theta}\sin(\Delta\Phi)$$

$$P_{\bar{y}}(\theta) = P_y(\theta).$$

$$\mathcal{I}(\theta) = 1 + \alpha_\psi\cos^2\theta.$$

$$C_{\bar{z}z}(\theta)\mathcal{I}(\theta) = -\alpha_\psi + \cos^2\theta$$

$$C_{\bar{x}x}(\theta)\mathcal{I}(\theta) = -\sin^2\theta$$

$$C_{\bar{y}y}(\theta)\mathcal{I}(\theta) = -\alpha_\psi\sin^2\theta$$

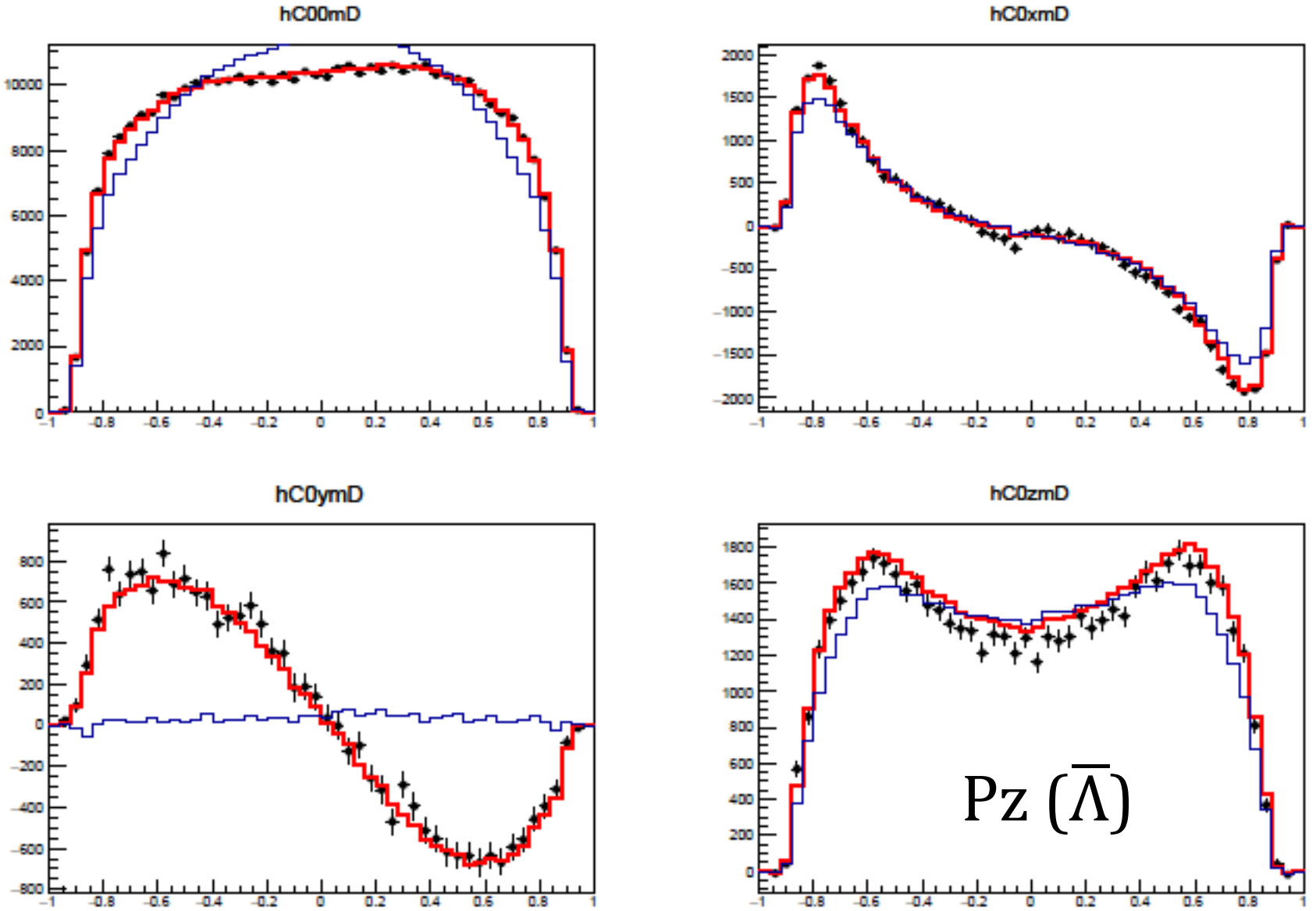
$$C_{\bar{x}z}(\theta)\mathcal{I}(\theta) = -\sqrt{1-\alpha_\psi^2}\cos\theta\sin\theta\cos(\Delta\Phi)$$

$$C_{\bar{z}x}(\theta) = C_{\bar{x}z}(\theta)$$

moments: $$M(\theta) = \sum_i^{N(\theta)} \mathbf{n}_\mu^i \mathbf{n}_\nu^i$$

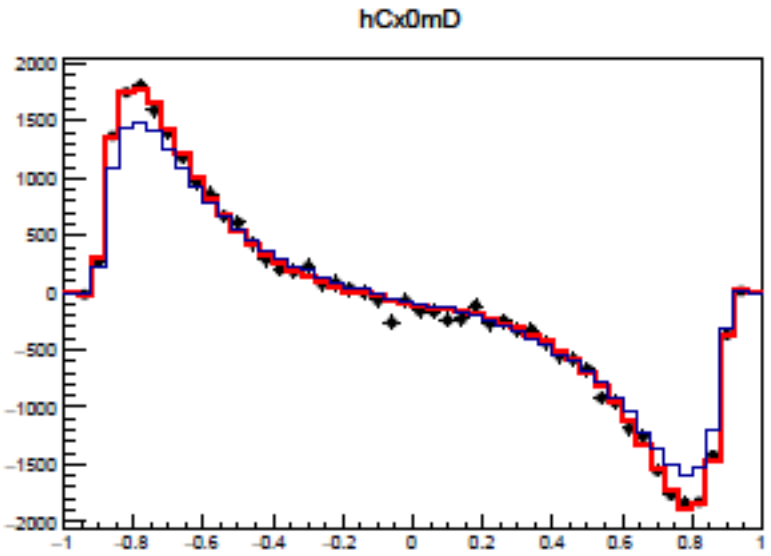
(uncorrected for acceptance)

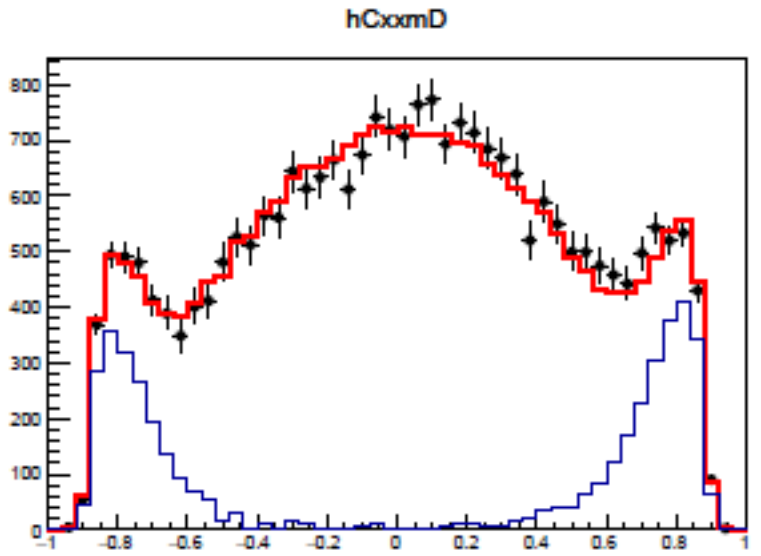
$$e^+e^- \to J/\psi \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\,\pi^+)$$

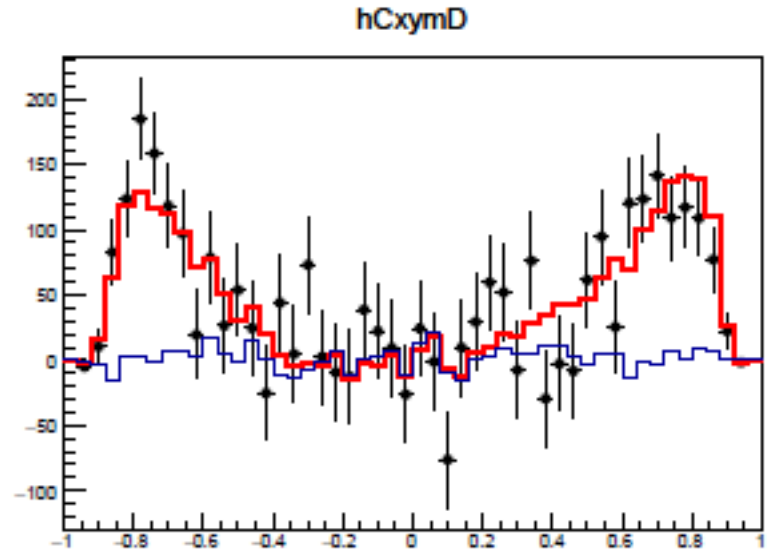


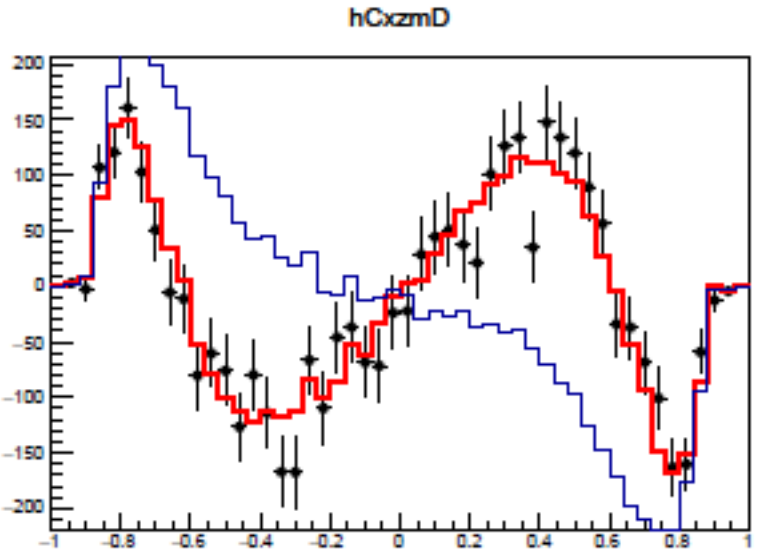
(blue) Phase Space (red) Fit

$$e^+e^- \to J/\psi \to (\Lambda \to p\pi^-)(\overline{\Lambda} \to \overline{p}\,\pi^+)$$



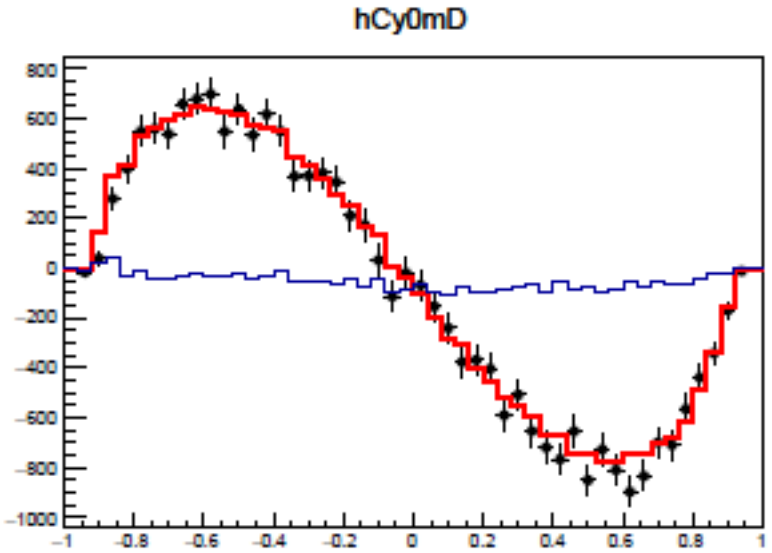


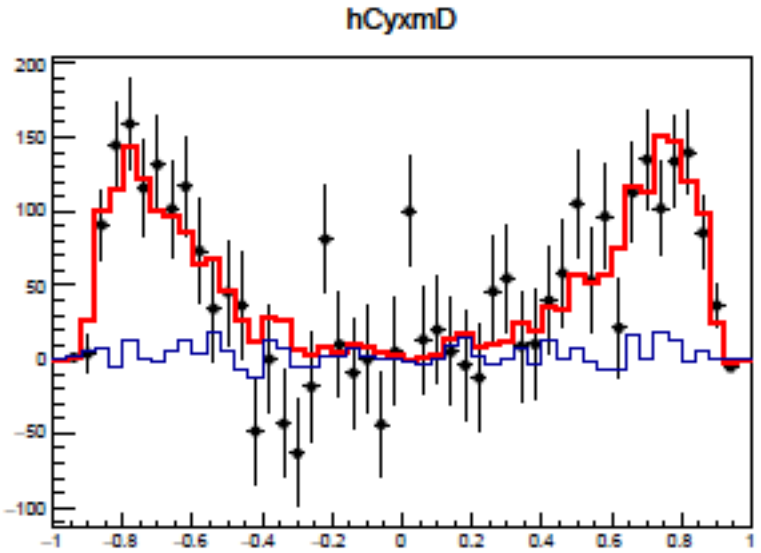


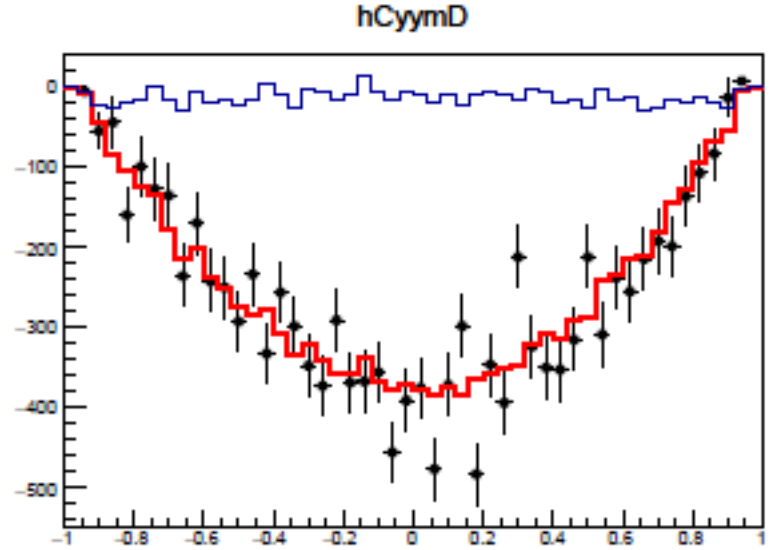


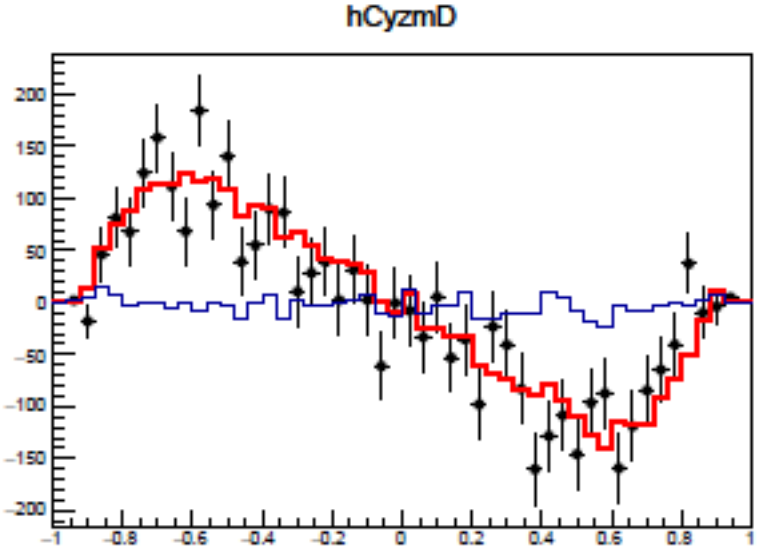
(blue) Phase Space (red) Fit

$$e^+e^- \to J/\psi \to (\Lambda \to p\pi^-)(\overline{\Lambda} \to \overline{p}\,\pi^+)$$



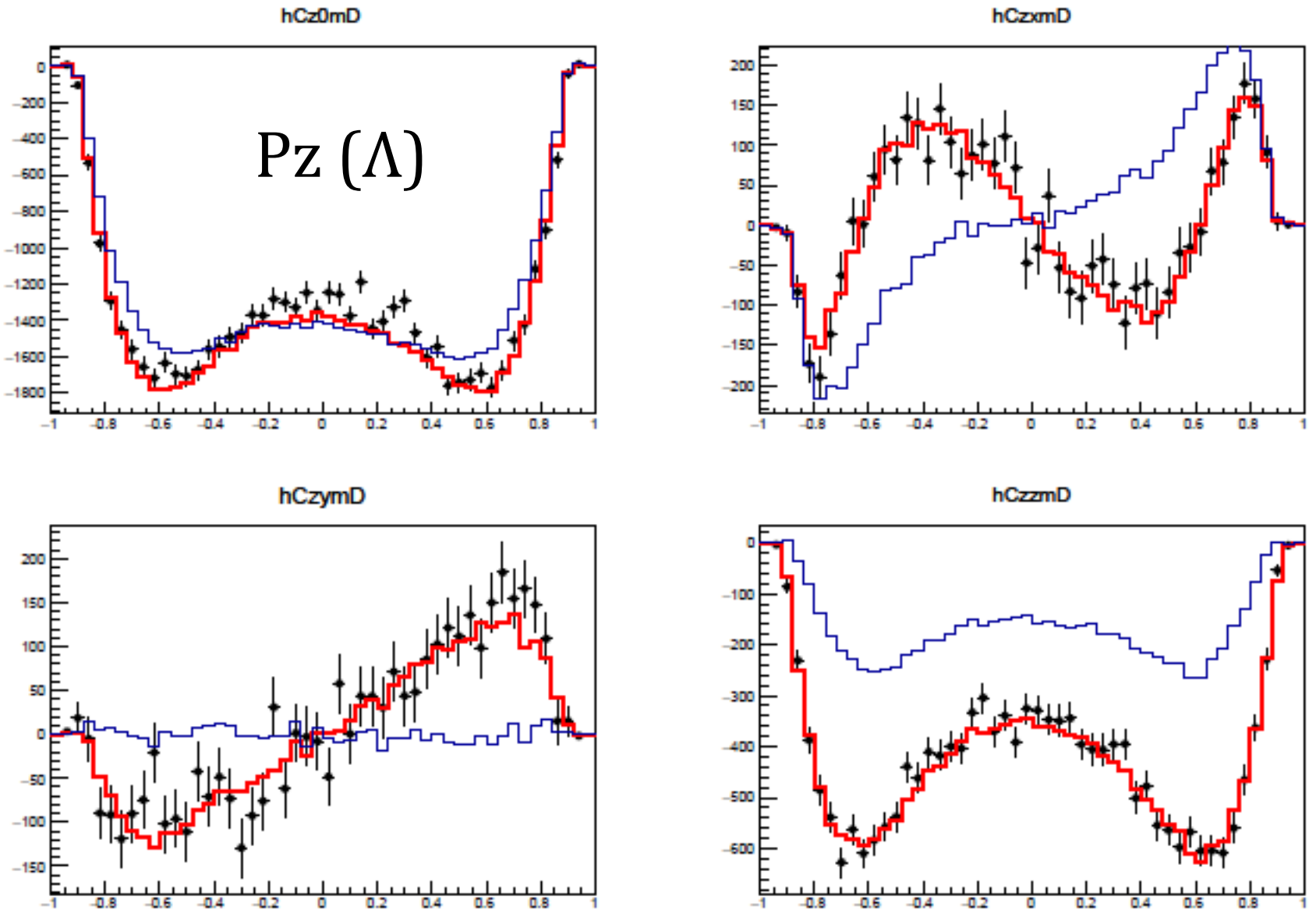






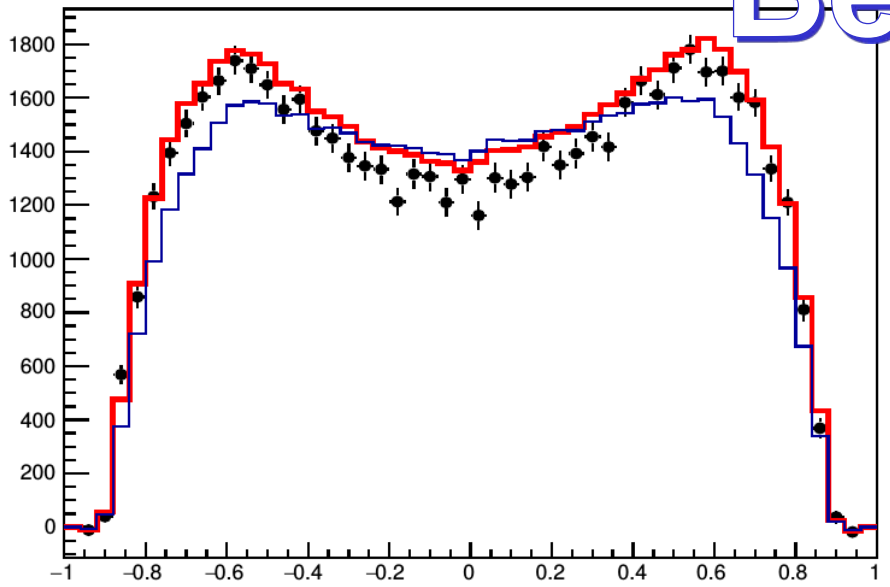
(blue) Phase Space (red) Fit

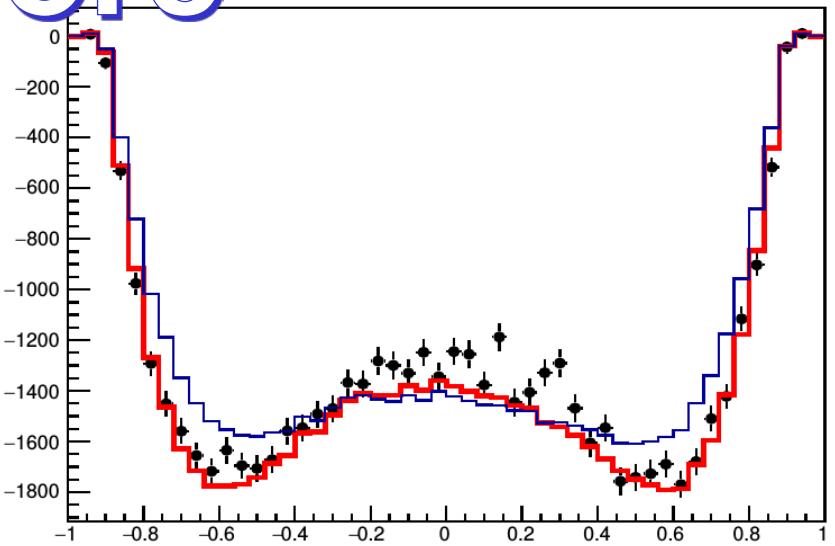
$$e^+e^- \to J/\psi \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\,\pi^+)$$



(blue) Phase Space (red) Fit

Before

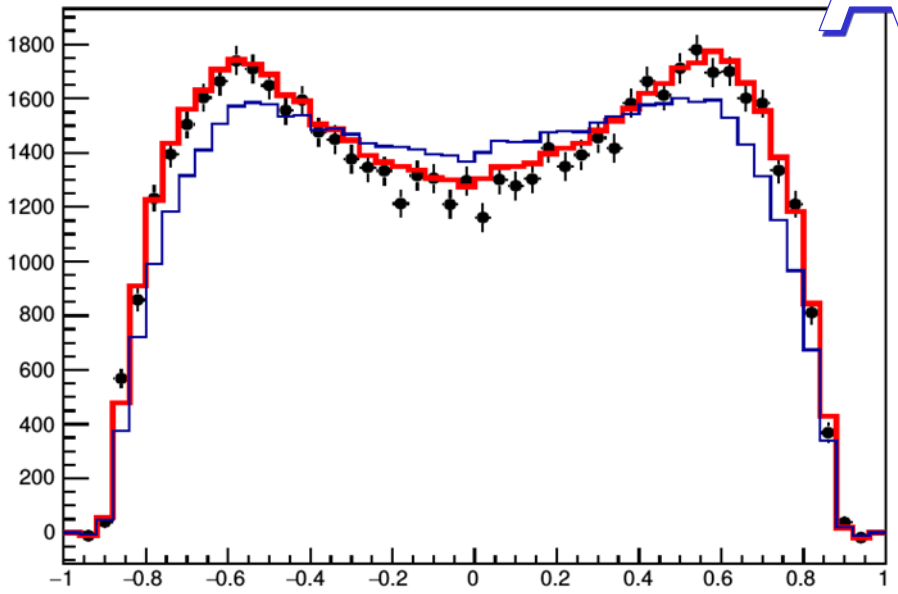


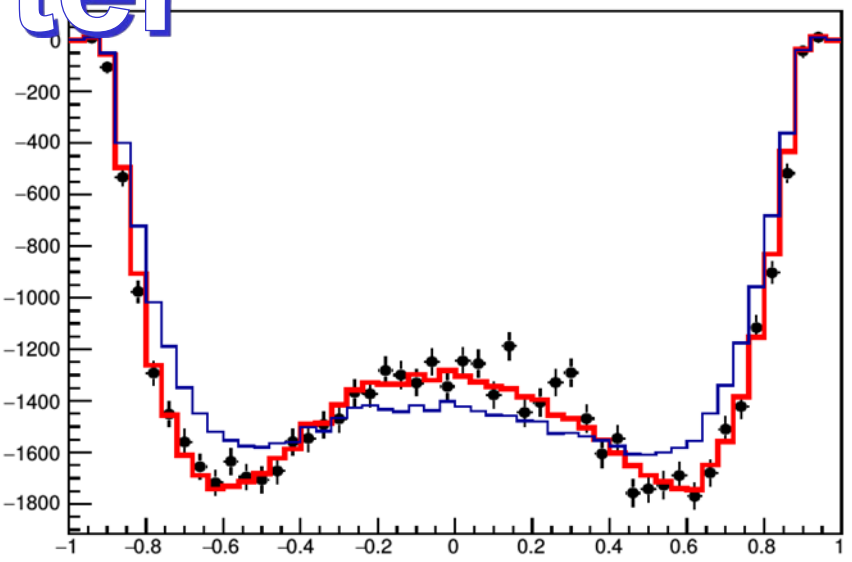


Pz ($\bar{\Lambda}$)

Pz (Λ)

After





			Stat	syst	eff 1	eff2
1	a	4.595e-01	0.0058	0.007	0.0077	-0.0013
2	a-	7.488e-01	0.0098	0.004	0.0034	0.0024
3	DPhi	7.383e-01	0.0109	0.008	0.0050	-0.0019
4	a+	-7.593e-01	0.0099	-0.007	-0.0029	-0.0025

Parameters	This work	Previous results
α_ψ	$0.461 \pm 0.006 \pm 0.007$	0.469 ± 0.027 [23]
$\Delta\Phi$ (rad)	$0.740 \pm 0.010 \pm 0.008$	–
α_-	$0.750 \pm 0.009 \pm 0.004$	0.642 ± 0.013 [25]
α_+	$-0.758 \pm 0.010 \pm 0.007$	-0.71 ± 0.08 [25]
$\bar{\alpha}_0$	$-0.692 \pm 0.016 \pm 0.006$	–
A_{CP}	$-0.006 \pm 0.012 \pm 0.007$	0.006 ± 0.021 [25]
$\bar{\alpha}_0/\alpha_+$	$0.913 \pm 0.028 \pm 0.012$	–