

Progress on $\Lambda \rightarrow pe^-\bar{\nu}_e$ (measure the FFs directly instead of its ratio)



Semileptonic weak decay meeting
2021.08.24

- **Software environment** : BOSS 7.0.5
- **Decay channel**: $J/\psi \rightarrow \Lambda \bar{\Lambda}, \Lambda \rightarrow p e^- \bar{\nu}_e + c.c., \bar{\Lambda} \rightarrow \bar{p} \pi^+ + c.c.$
- **Data**: 10 billion J/ψ data taken by BESIII
- **mDIY MC**:
0.9M events generated by using the new formalism of version 20210630 provided by Varvara.
All input parameters are listed in the following table.

Mode	α_ψ	$\Delta\Phi$	$\alpha_{\bar{\Lambda}}/\alpha_\Lambda$	$f_1^\Lambda/f_1^{\bar{\Lambda}}$	$g_1^\Lambda/g_1^{\bar{\Lambda}}$	$f_2^\Lambda/f_2^{\bar{\Lambda}}$
$\Lambda \rightarrow p e^- \bar{\nu}_e$	0.461	0.740	-0.754	-1.225	-0.881	-1.306
$\bar{\Lambda} \rightarrow \bar{p} e^+ \nu_e$	0.461	0.740	0.754	1.225	0.881	1.306

- **PHSP MC**: 9M events.



I/O by using the MC truth



I/O by using MC truth

Mode	I/O	α_ψ	$\Delta\Phi$	$\alpha_{\bar{\Lambda}}$	f_1^Λ	g_1^Λ	f_2^Λ
$\Lambda \rightarrow pe^- \bar{\nu}_e$	Input	0.461	0.740	-0.754	-1.225	-0.881	-1.306
	Sample 1 45K mDIY 450K PHSP	0.505 ± 0.016	0.781 ± 0.036	-0.719 ± 0.018	-1.240 ± 1.329	-0.933 ± 1.007	-0.188 ± 0.625
		0.505 ± 0.016	0.781 ± 0.036	-0.719 ± 0.016	-8.760 ± 9.892	-6.596 ± 7.913	fixed
		fixed	fixed	fixed	-2.503 ± 1.927	-1.694 ± 1.408	fixed
		fixed	fixed	fixed	-1.382 ± 0.081	fixed	fixed
		fixed	fixed	fixed	fixed	-0.790 ± 0.050	fixed
		fixed	fixed	fixed	fixed	fixed	-0.504 ± 0.325
	Sample 2 0.45M mDIY 4.5M PHSP	0.460 ± 0.005	0.741 ± 0.011	-0.758 ± 0.006	-1.224 ± 0.384	-0.886 ± 0.281	-1.235 ± 0.415
		0.460 ± 0.005	0.741 ± 0.011	-0.758 ± 0.007	-1.295 ± 0.223	-0.937 ± 0.199	fixed
		fixed	fixed	fixed	-1.373 ± 0.180	-1.011 ± 0.157	fixed
		fixed	fixed	fixed	-1.226 ± 0.025	fixed	fixed
		fixed	fixed	fixed	fixed	-0.886 ± 0.021	fixed
		fixed	fixed	fixed	fixed	fixed	-1.221 ± 0.107



I/O by using MC truth

Mode	I/O	α_ψ	$\Delta\Phi$	α_Λ	$f_1^{\bar{\Lambda}}$	$g_1^{\bar{\Lambda}}$	$f_2^{\bar{\Lambda}}$
$\bar{\Lambda} \rightarrow \bar{p}e^+\nu_e$	Input	0.461	0.740	0.754	1.225	0.881	1.306
	Sample 1 45K mDIY 450K PHSP	0.471 ± 0.016	0.751 ± 0.036	0.737 ± 0.019	1.173 ± 0.795	0.841 ± 0.570	2.032 ± 1.469
		0.471 ± 0.016	0.751 ± 0.036	0.737 ± 0.019	0.754 ± 0.162	0.540 ± 0.155	fixed
		fixed	fixed	fixed	0.693 ± 0.062	0.474 ± 0.016	fixed
		fixed	fixed	fixed	1.054 ± 0.095	fixed	fixed
		fixed	fixed	fixed	fixed	1.092 ± 0.167	fixed
		fixed	fixed	fixed	fixed	fixed	2.221 ± 0.374
	Sample 2 0.45M mDIY 4.5M PHSP	0.462 ± 0.005	0.754 ± 0.011	0.746 ± 0.006	1.210 ± 0.315	0.905 ± 0.235	1.175 ± 0.373
		0.462 ± 0.005	0.754 ± 0.011	0.746 ± 0.006	1.345 ± 0.175	1.005 ± 0.162	fixed
		fixed	fixed	fixed	1.223 ± 0.117	0.889 ± 0.104	fixed
		fixed	fixed	fixed	1.214 ± 0.027	fixed	fixed
		fixed	fixed	fixed	fixed	0.891 ± 0.024	fixed
		fixed	fixed	fixed	fixed	fixed	1.334 ± 0.110



I/O by using the selected reconstructed MC

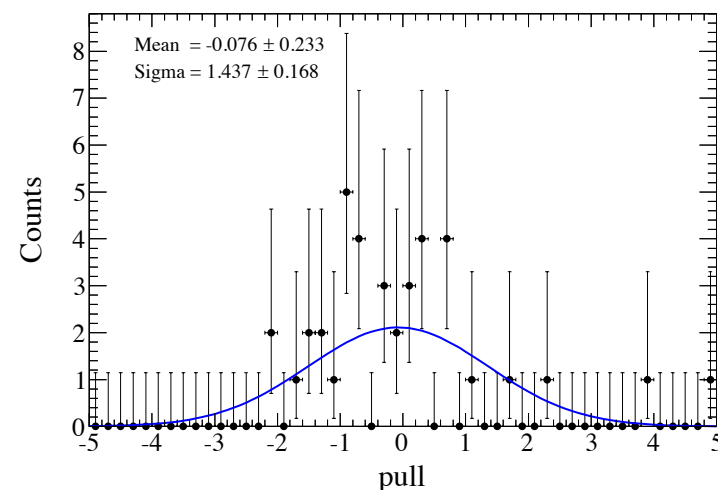
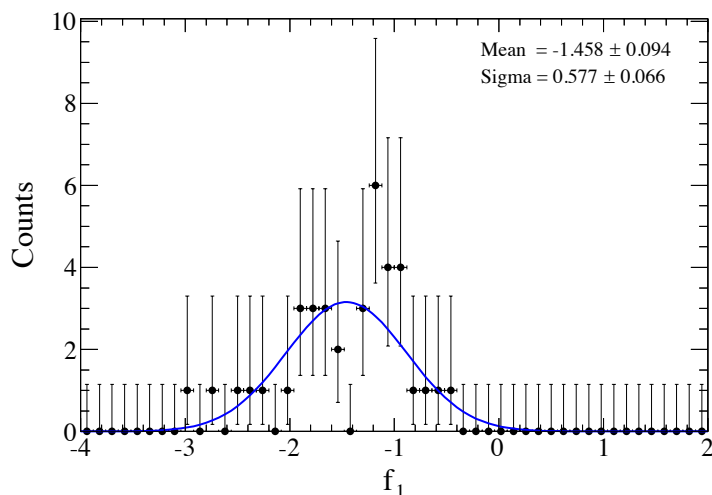
I/O by using the selected reconstructed MC

Mode	I/O	α_ψ	$\Delta\Phi$	$\alpha_{\bar{\Lambda}}$	f_1^Λ	g_1^Λ	f_2^Λ
$\Lambda \rightarrow pe^- \bar{\nu}_e$	Input	0.461	0.740	-0.754	-1.225	-0.881	-1.306
	Sample 1 739 mDIY 3.1M PHSP	failed	failed	-failed	failed	failed	failed
		0.428 ± 0.147	1.292 ± 0.728	-0.716 ± 0.140	-1.587 ± 9.517	-0.823 ± 4.878	fixed
		fixed	fixed	fixed	-1.141 ± 3.308	-0.620 ± 1.640	fixed
		fixed	fixed	fixed	-1.663 ± 0.555	fixed	fixed
		fixed	fixed	fixed	fixed	-0.661 ± 0.206	fixed
		fixed	fixed	fixed	fixed	fixed	failed
	Sample 2 28K mDIY 3.1M PHSP	failed	failed	-failed	failed	failed	failed
		failed	failed	-failed	failed	failed	fixed
		fixed	fixed	fixed	-2.036 ± 2.282	-1.293 ± 1.442	fixed
		fixed	fixed	fixed	-1.389 ± 0.099	fixed	fixed
		fixed	fixed	fixed	fixed	-0.783 ± 0.056	fixed
		fixed	fixed	fixed	fixed	fixed	-0.796 ± 0.604

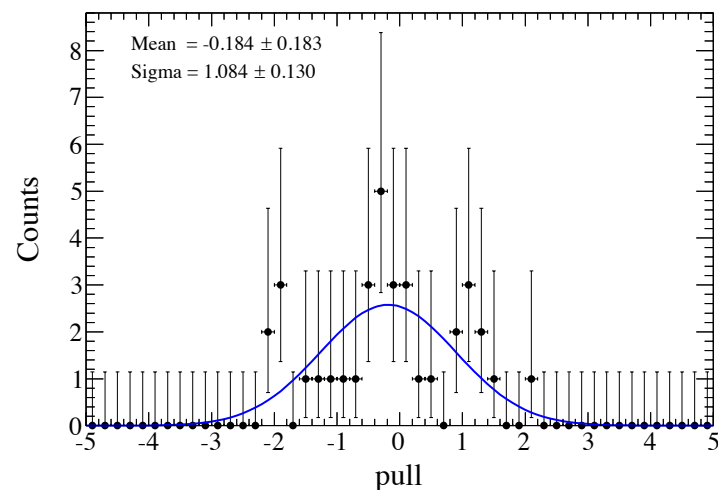
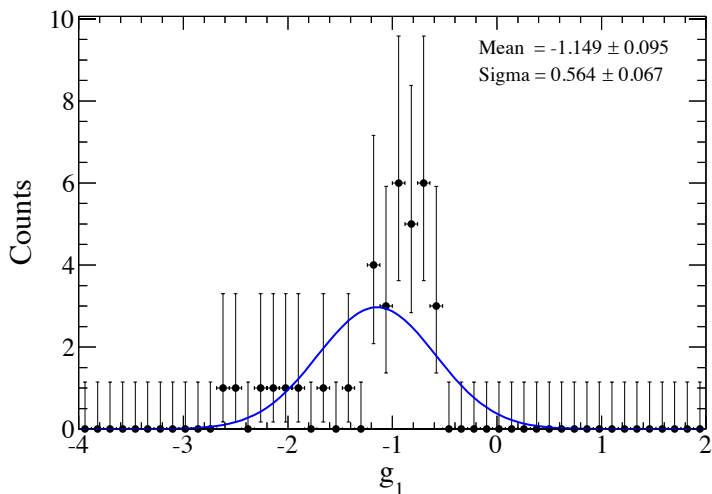
I/O by using the selected reconstructed MC

For $\Lambda \rightarrow pe^- \bar{\nu}_e$, with same statistics to the real data.

For f_1 , the input value equals to -1.225



For g_1 , the input value equals to -0.881



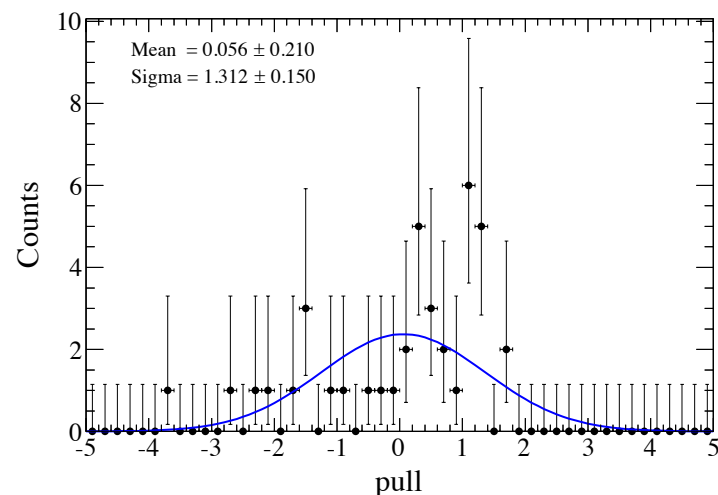
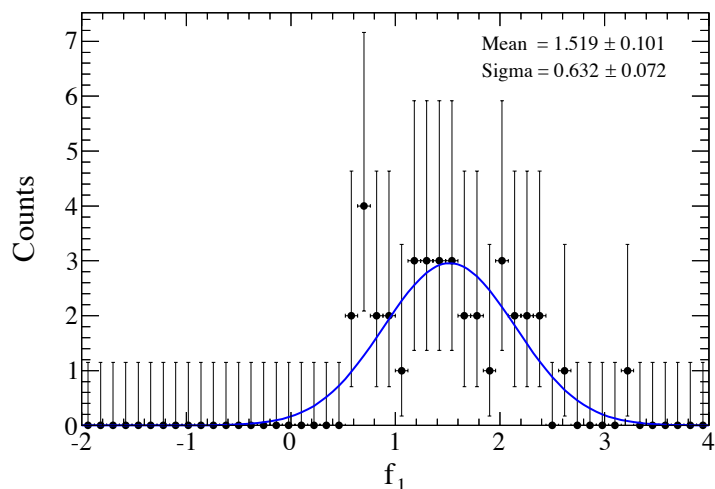
I/O by using the selected reconstructed MC

Mode	I/O	α_ψ	$\Delta\Phi$	α_Λ	$f_1^{\bar{\Lambda}}$	$g_1^{\bar{\Lambda}}$	$f_2^{\bar{\Lambda}}$
$\bar{\Lambda} \rightarrow \bar{p}e^+\nu_e$	Input	0.461	0.740	0.754	1.225	0.881	1.306
	Sample 1 695 mDIY 3.1M PHSP	0.690±0.213	0.844±0.757	0.606±0.175	0.596±13.03	0.788±16.13	1.803±29.61
		0.690±0.212	0.843±0.755	0.606±0.175	0.432±0.566	0.572±1.000	fixed
		fixed	fixed	fixed	0.674±1.358	1.105±2.483	fixed
		fixed	fixed	fixed	0.553±0.184	fixed	fixed
		fixed	fixed	fixed	fixed	2.113±0.731	fixed
		fixed	fixed	fixed	fixed	fixed	failed
	Sample 2 28K mDIY 3.1M PHSP	0.477±0.024	0.712±0.045	0.695±0.035	1.111±1.175	0.776±0.812	0.616±0.991
		0.477±0.024	0.712±0.045	0.695±0.027	2.357±1.658	1.647±1.351	fixed
		fixed	fixed	fixed	1.237±0.337	0.700±0.199	fixed
		fixed	fixed	fixed	1.536±0.112	fixed	fixed
		fixed	fixed	fixed	fixed	0.692±0.050	fixed
		fixed	fixed	fixed	fixed	fixed	1.058±0.389

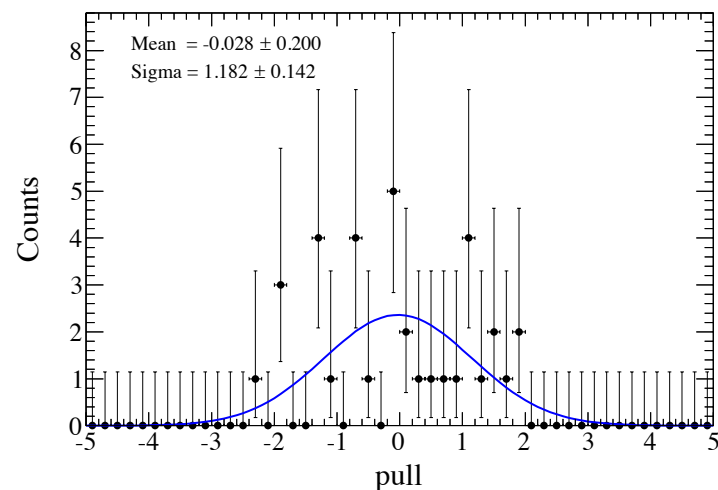
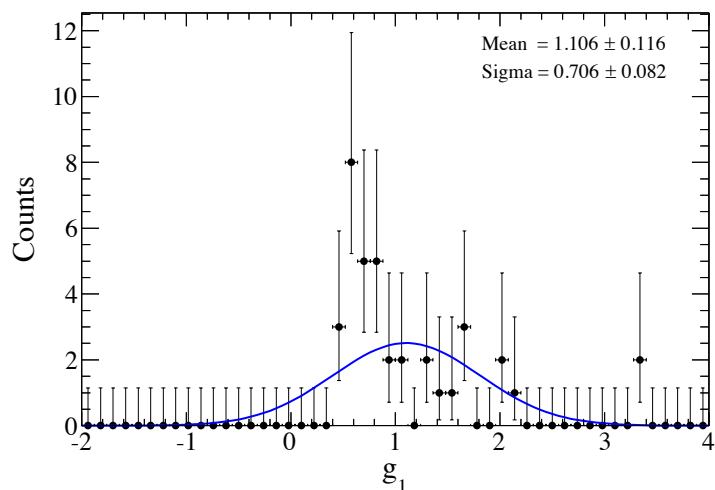
I/O by using the selected reconstructed MC

For $\bar{\Lambda} \rightarrow \bar{p}e^+\nu_e$, with same statistics to the real data.

For f1, the input value equals to 1.225



For g1, the input value equals to 0.881





Fit to the real data



Fit to the real data

Mode		α_ψ	$\Delta\Phi$	$\alpha_{\bar{\Lambda}}$	f_1^Λ	g_1^Λ	f_2^Λ
$\Lambda \rightarrow p e^- \bar{\nu}_e$	Current Results	0.461	0.740	-0.754	-1.225	-0.881	-1.306
	Data:820 MC: 3.1M PHSP 193 $p\pi$ bkg	fixed	fixed	fixed	failed	failed	fixed
		fixed	fixed	fixed	-1.780 ± 0.578	fixed	fixed
		fixed	fixed	fixed	fixed	-0.624 ± 0.208	fixed
		fixed	fixed	fixed	fixed	fixed	failed

Mode		α_ψ	$\Delta\Phi$	α_Λ	$f_1^{\bar{\Lambda}}$	$g_1^{\bar{\Lambda}}$	$f_2^{\bar{\Lambda}}$
$\bar{\Lambda} \rightarrow \bar{p} e^+ \nu_e$	Current Results	0.461	0.740	0.754	-1.225	0.881	1.306
	Data:860 MC: 3.1M PHSP 252 $p\pi$ bkg	fixed	fixed	fixed	failed	failed	fixed
		fixed	fixed	fixed	-2.868 ± 1.040	fixed	fixed
		fixed	fixed	fixed	fixed	0.392 ± 0.129	fixed
		fixed	fixed	fixed	fixed	fixed	failed



Fit to the real data

Mode	α_ψ	$\Delta\Phi$	$\alpha_{\bar{\Lambda}}$	f_1^Λ	g_1^Λ	f_2^Λ
$\Lambda \rightarrow p e^- \bar{\nu}_e + c.c.$	0.461	0.740	-0.754	-1.225	-0.881	-1.306
	fixed	fixed	fixed	failed	failed	fixed
	fixed	fixed	fixed	-2.240 ± 0.510	fixed	fixed
	fixed	fixed	fixed	fixed	-0.456 ± 0.110	fixed
	fixed	fixed	fixed	fixed	fixed	failed



Results of $g_1/f_1(g_{av})$

Mode	Old	New fix g_1 to -0.881 fix f_2 to -1.306	New fix f_1 to -1.225 fix f_2 to -1.306 (equals to fix $f_2/f_1=g_w=1.066$)
$\Lambda \rightarrow pe^-\bar{\nu}_e$	0.510 ± 0.169	0.495 ± 0.161	0.510 ± 0.170
$\bar{\Lambda} \rightarrow \bar{p}e^+\nu_e$	-0.320 ± 0.105	-0.307 ± 0.111	-0.320 ± 0.105
$\Lambda \rightarrow pe^-\bar{\nu}_e + c.c.$	0.373 ± 0.089	0.393 ± 0.089	0.372 ± 0.089

3.8σ

3.6σ

PDG: $g_{av}^\Lambda = 0.718 \pm 0.015$



Back up

TABLE 1 Cabibbo-model predictions for octet baryon beta-decay form factors^a

Decay	Scale	$f_1(0)$	$g_1(0)$	g_1/f_1	f_2/f_1
$n \rightarrow pe^- \bar{\nu}$	V_{ud}	1	$D + F$	$F + D$	$\frac{M_n}{M_p} \frac{(\mu_p - \mu_n)}{2} = 1.855$
$\Xi^- \rightarrow \Xi^0 e^- \bar{\nu}$	V_{ud}	-1	$D - F$	$F - D$	$\frac{M_{\Xi^-}}{M_p} \frac{(\mu_p + 2\mu_n)}{2} = -1.432$
$\Sigma^\pm \rightarrow \Lambda e^\pm \nu$	V_{ud}	0 ^b	$\sqrt{\frac{2}{3}}D$	$\sqrt{\frac{2}{3}}D$	$-\frac{M_{\Sigma^\pm}}{M_p} \sqrt{\frac{3}{2}} \frac{\mu_n}{2} = 1.490$
$\Sigma^- \rightarrow \Sigma^0 e^- \bar{\nu}$	V_{ud}	$\sqrt{2}$	$\sqrt{2}F$	F	$\frac{M_{\Sigma^-}}{M_p} \frac{(2\mu_p + \mu_n)}{4} = 0.534$
$\Sigma^0 \rightarrow \Sigma^+ e^- \bar{\nu}$	V_{ud}	$\sqrt{2}$	$-\sqrt{2}F$	$-F$	$\frac{M_{\Sigma^0}}{M_p} \frac{(2\mu_p + \mu_n)}{4} = 0.531$
$\Xi^0 \rightarrow \Sigma^+ e^- \bar{\nu}$	V_{us}	1	$D + F$	$F + D$	$\frac{M_{\Xi^0}}{M_p} \frac{(\mu_p - \mu_n)}{2} = 2.597$
$\Xi^- \rightarrow \Sigma^0 e^- \bar{\nu}$	V_{us}	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}(D + F)$	$F + D$	$\frac{M_{\Xi^-}}{M_p} \frac{(\mu_p - \mu_n)}{2} = 2.609$
$\Sigma^- \rightarrow ne^- \bar{\nu}$	V_{us}	-1	$D - F$	$F - D$	$\frac{M_{\Sigma^-}}{M_p} \frac{(\mu_p + 2\mu_n)}{2} = -1.297$
$\Sigma^0 \rightarrow pe^- \bar{\nu}$	V_{us}	$\frac{-1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}(D - F)$	$F - D$	$\frac{M_{\Sigma^0}}{M_p} \frac{(\mu_p + 2\mu_n)}{2} = -1.292$
$\Lambda \rightarrow pe^- \bar{\nu}$	V_{us}	$-\sqrt{\frac{3}{2}}$	$-\frac{1}{\sqrt{6}}(D + 3F)$	$F + D/3$	$\frac{M_\Lambda}{M_p} \frac{\mu_p}{2} = 1.066$
$\Xi^- \rightarrow \Lambda e^- \bar{\nu}$	V_{us}	$\sqrt{\frac{3}{2}}$	$-\frac{1}{\sqrt{6}}(D - 3F)$	$F - D/3$	$-\frac{M_{\Xi^-}}{M_p} \frac{(\mu_p + \mu_n)}{2} = 0.085$