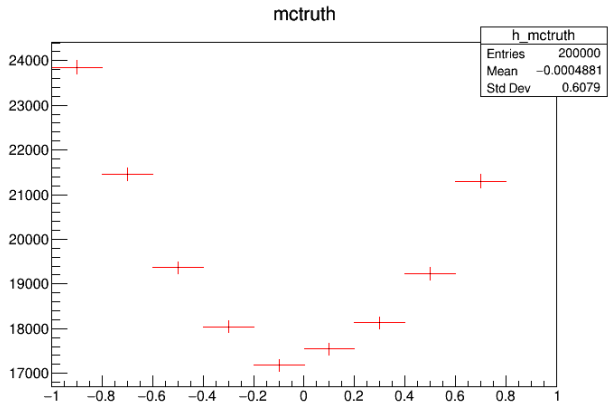
$J/\psi \to \Lambda\bar{\Lambda}$:

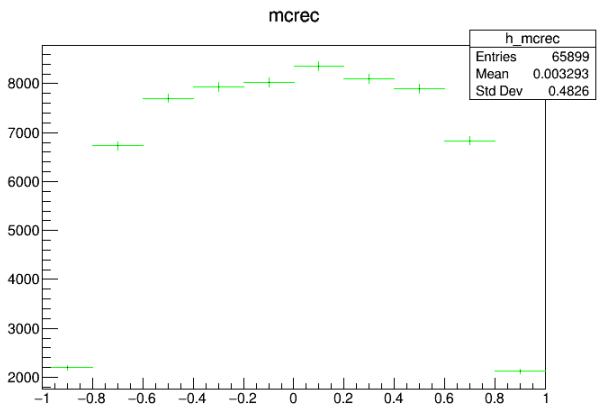
- 2009 Jpsi data
- $\Lambda(\bar{\Lambda}), \Lambda\bar{\Lambda}$ mass cut: bkg rate < 0.5%

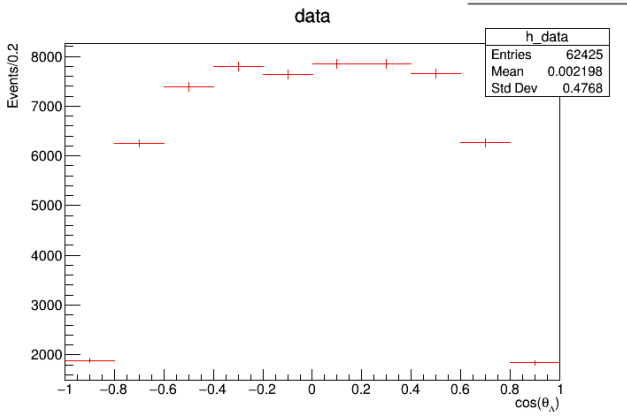
rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to J/\psi, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+\pi^- p\bar{p}$	0	59035	59035
2	$cluster \to J/\psi, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}$	4	133	59168
3	$cluster \to J/\psi, J/\psi \to \pi^- \bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}$	5	30	59198
4	$cluster \to J/\psi, J/\psi \to \Delta^{++}\bar{\Delta}^{++}, \Delta^{++} \to \pi^+ p, \bar{\Delta}^{++} \to \pi^- \bar{p}$	$\pi^+\pi^- p\bar{p}$	1	23	59221
5	$cluster \to J/\psi, J/\psi \to \pi^+ p\bar{\Delta}^{++}, \bar{\Delta}^{++} \to \pi^- \bar{p}$	$\pi^+\pi^- p\bar{p}$	10	19	59240
6	$cluster \to J/\psi, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p\gamma^f, \bar{\Lambda} \to \pi^+ \bar{p}$	$\pi^+\pi^- p\bar{p}\gamma^f$	8	10	59250

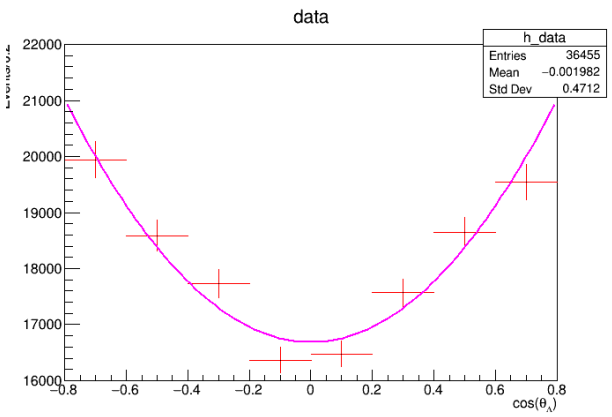
$J/\psi \to \Lambda\bar{\Lambda}$:

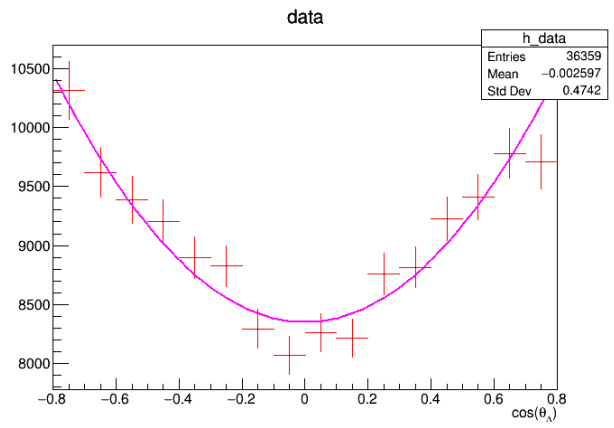
Parameter	This Letter
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0031$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0066$
α_-	$0.7519 \pm 0.0036 \pm 0.0024$
α_+	$-0.7559 \pm 0.0036 \pm 0.0030$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0012$
$\alpha_{\rm avg}$	$0.7542 \pm 0.0010 \pm 0.0024$

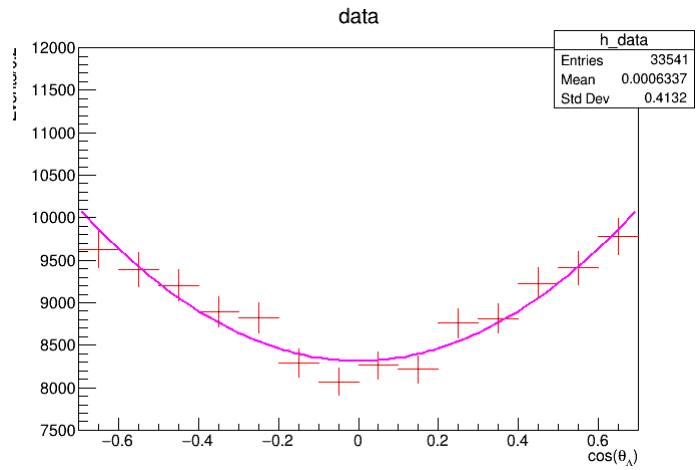










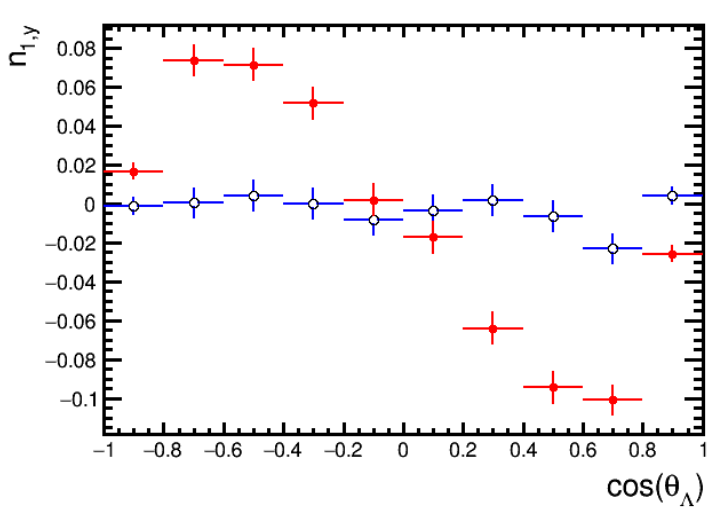


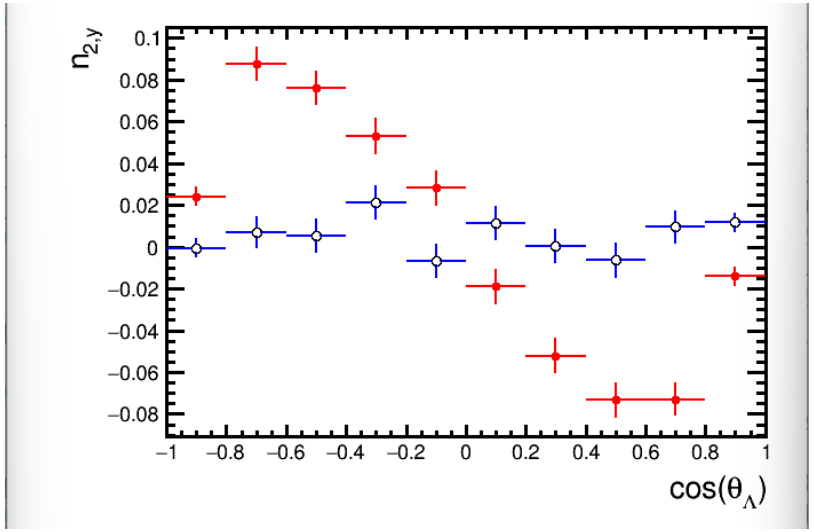

```
FCN=12.3548 FROM MINOS     STATUS=SUCCESSFUL     14 CALLS         210 TOTAL
                     EDM=3.67502e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  p0           4.05291e-01   3.48759e-02  -3.46744e-02   3.50801e-02
  2  p1           1.66878e+04   1.29705e+02  -1.29701e+02   1.29709e+02
```

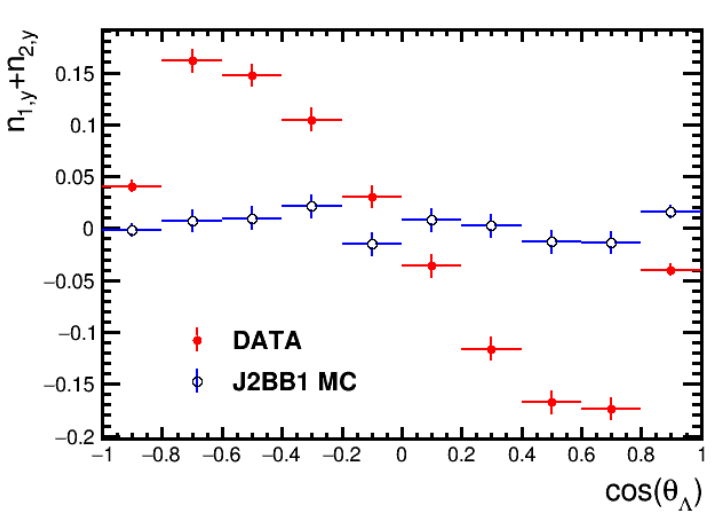
```
FCN=17.9436 FROM MINOS     STATUS=SUCCESSFUL     14 CALLS         207 TOTAL
                     EDM=1.66156e-11    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  p0           3.93393e-01   3.42246e-02  -3.40292e-02   3.44227e-02
  2  p1           8.35029e+03   6.44638e+01  -6.44635e+01   6.44634e+01
```

```
FCN=12.0105 FROM MINOS     STATUS=SUCCESSFUL     14 CALLS         197 TOTAL
                     EDM=2.59684e-08    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  p0           4.40338e-01   4.51117e-02  -4.48391e-02   4.53884e-02
  2  p1           8.31491e+03   6.80128e+01  -6.80054e+01   6.80194e+01
```

$J/\psi \to \Lambda\bar{\Lambda}$:





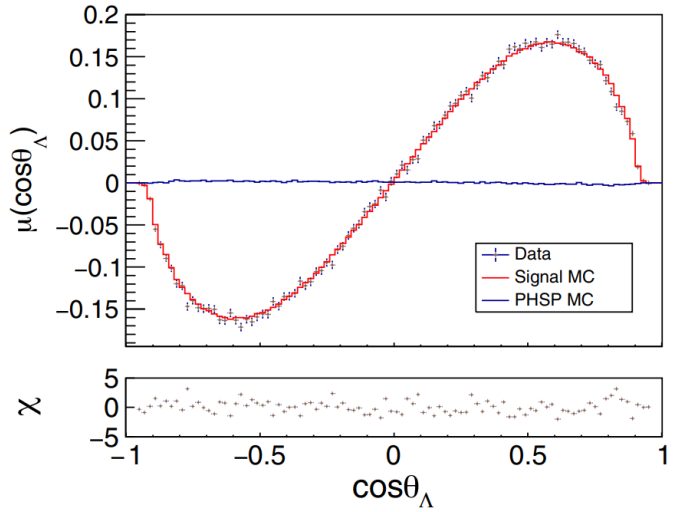


The moment

$$\mu[\cos(\theta_\Lambda)] = (m/N)\sum_{i=1}^{N_k}(n_{1,y}^{(i)} - n_{2,y}^{(i)}), \qquad (5)$$

which related to the polarization, is used to compare the consistency between the data and the fit results. Hereby, N is the total number of events in the data set, and $m = 100$ is the number of bins in $\cos(\theta_\Lambda)$ for calculating the moment. N_k denotes the number of events in the kth $\cos(\theta_\Lambda)$ bin. The expected angular dependence of the moment for the acceptance-corrected data reads

$$\mu(\cos\theta_\Lambda) = \frac{\alpha_- - \alpha_+}{2}\frac{1 + \alpha_{J/\psi}\cos^2\theta_\Lambda}{3 + \alpha_{J/\psi}}P_y(\theta_\Lambda). \qquad (6)$$



$J/\psi \to \Lambda\bar{\Lambda}$:

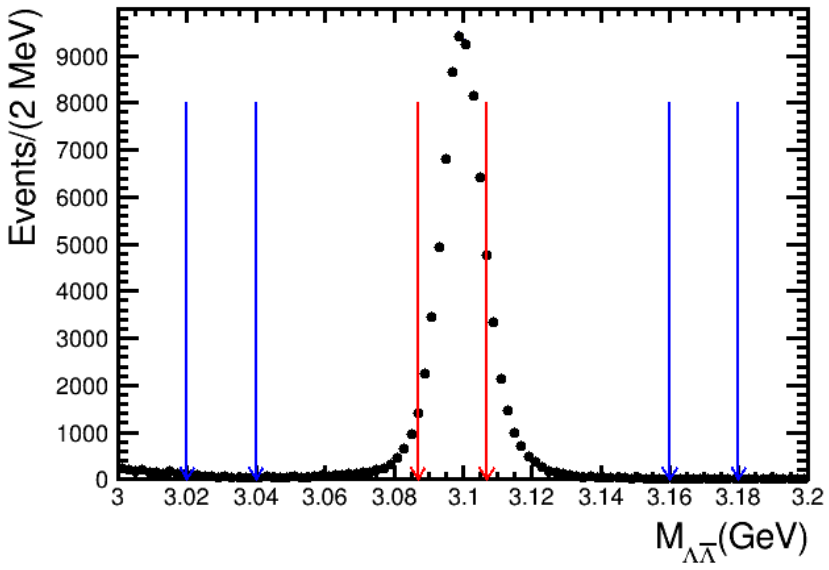
```
FCN=-7842.58 FROM MINOS     STATUS=SUCCESSFUL    100 CALLS         164 TOTAL
                     EDM=2.68331e-06    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  a0           3.71856e-01   1.50821e-02  -1.50455e-02   1.51094e-02
  2  phi          7.12474e-01   2.68735e-02  -2.65151e-02   2.72336e-02
  3  a1           7.39046e-01   7.20726e-03  -7.24780e-03   7.16123e-03
```

More mc integral:

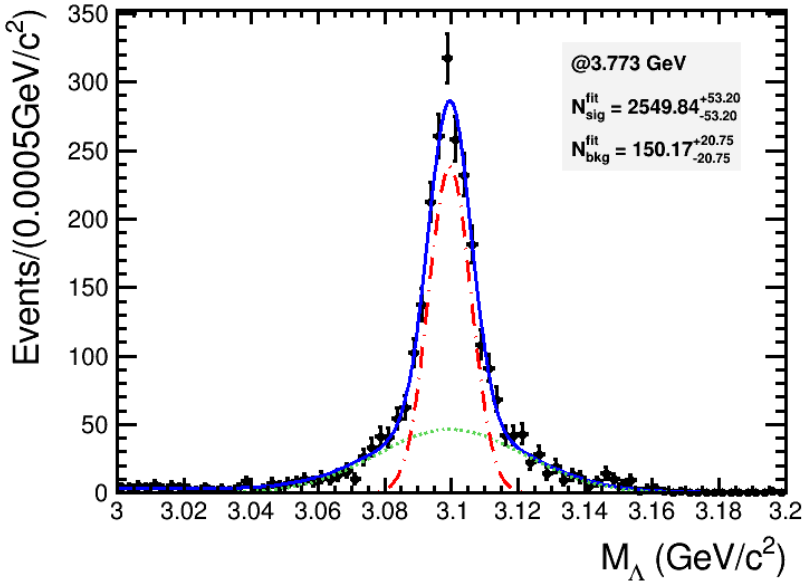
```
FCN=-8357.64 FROM MINOS     STATUS=SUCCESSFUL    222 CALLS         330 TOTAL
                     EDM=9.01878e-07    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  a0           3.88541e-01   1.50199e-02  -1.49618e-02   1.50704e-02
  2  phi          7.33311e-01   2.72348e-02  -2.68418e-02   2.76313e-02
  3  a1           7.81009e-01   2.57734e-02  -2.53593e-02   2.62770e-02
  4  a2          -7.05108e-01   2.34189e-02  -2.37301e-02   2.31831e-02
```

Parameter	This Letter
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0031$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0066$
α_-	$0.7519 \pm 0.0036 \pm 0.0024$
α_+	$-0.7559 \pm 0.0036 \pm 0.0030$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0012$
$\alpha_{\rm avg}$	$0.7542 \pm 0.0010 \pm 0.0024$

$J/\psi \to \Lambda\bar{\Lambda}$:



Mean is 3.09956 GeV/c2

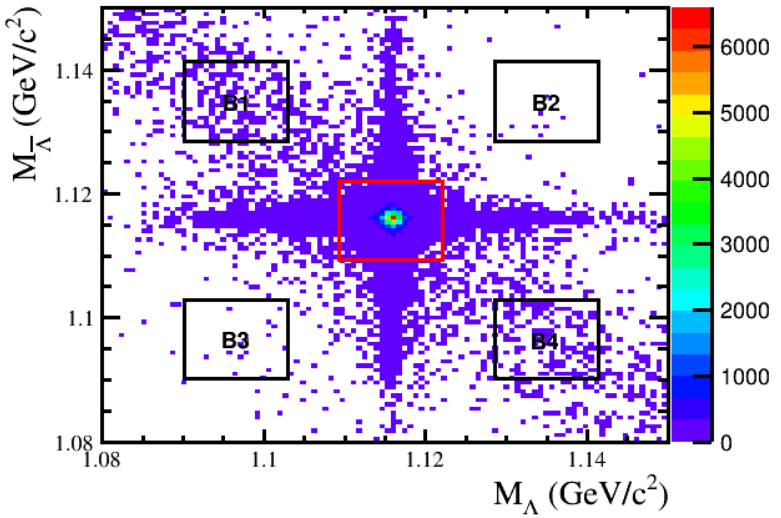



```
COVARIANCE MATRIX CALCULATED SUCCESSFULLY
FCN=-26066 FROM HESSE     STATUS=OK             50 CALLS        1342 TOTAL
                     EDM=1.42459e-05    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                                   INTERNAL      INTERNAL
 NO.   NAME      VALUE            ERROR          STEP SIZE       VALUE
  1  a0          -3.12204e-01   5.98614e-04   2.64019e-07  -3.12255e-02
  2  frac         4.04139e-01   2.69375e-02   1.47979e-04   3.33451e+00
  3  mean         3.09956e+00   2.00801e-04   4.46116e-05  -4.43967e-03
  4  nbkg         1.50169e+02   2.07535e+01   6.45664e-06  -1.54629e+00
  5  nsignal      2.54984e+03   5.32012e+01   4.53560e-06  -1.46976e+00
  6  sigma1       2.21203e-02   9.92035e-04   4.71669e-05  -8.92746e-01
  7  sigma2       6.36610e-03   2.79820e-04   2.43718e-05  -1.92954e+00
```

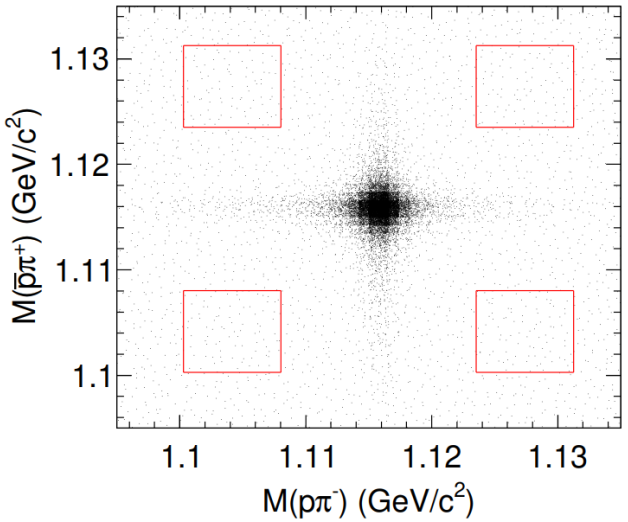
$J/\psi \to \Lambda\bar{\Lambda}$:

```
FCN=-1022.57 FROM MINOS     STATUS=SUCCESSFUL    273 CALLS         388 TOTAL
                     EDM=7.62284e-09    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                          PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE                    ERROR       NEGATIVE       POSITIVE
  1  a0           4.18152e-01   4.37350e-02  -4.34372e-02   4.40513e-02
  2  phi          9.10454e-01   9.90488e-02  -9.34870e-02   1.06169e-01
  3  a1           7.36505e-01   6.14661e-02  -5.94595e-02   6.41932e-02
  4  a2          -7.07920e-01   5.92073e-02  -6.15742e-02   5.74860e-02
```

data

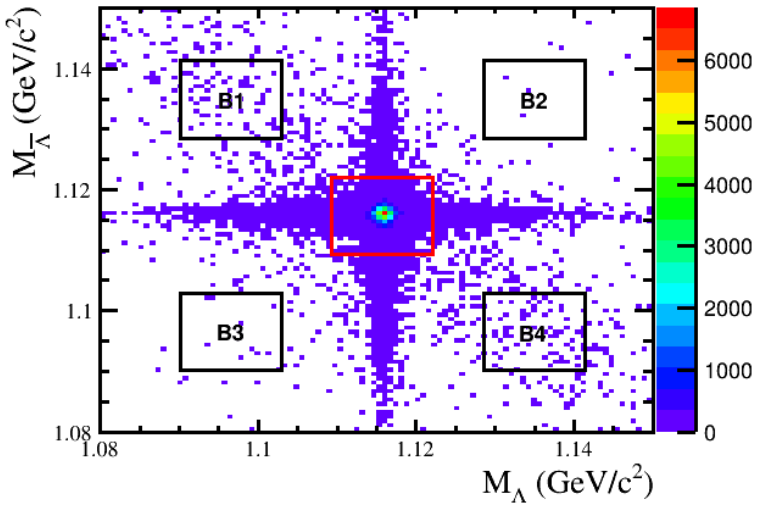


B1: 186
B2: 8
B3: 17
B4: 162
Bs: 62425

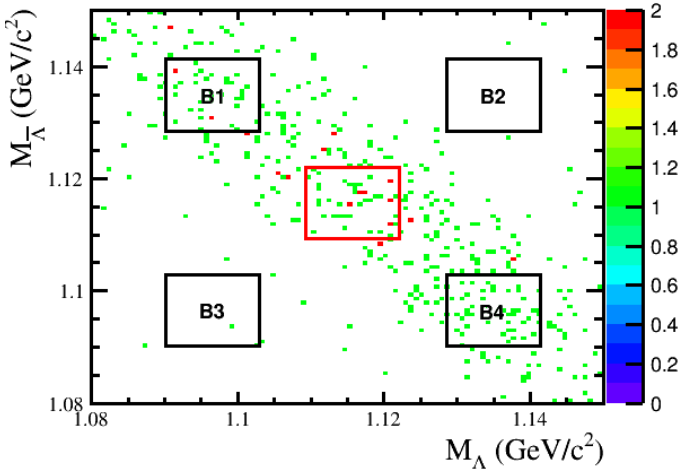


$M_{\Lambda/\bar{\Lambda}}$ cut smaller (0.5x)
$M_{\Lambda\bar{\Lambda}}$ cut smaller (0.1x)

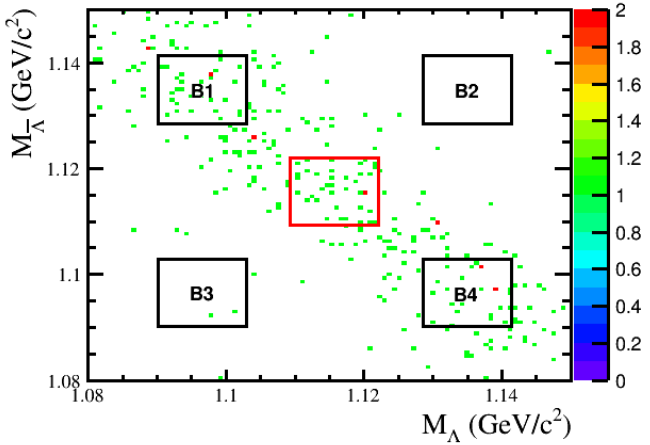
Inclusive mc



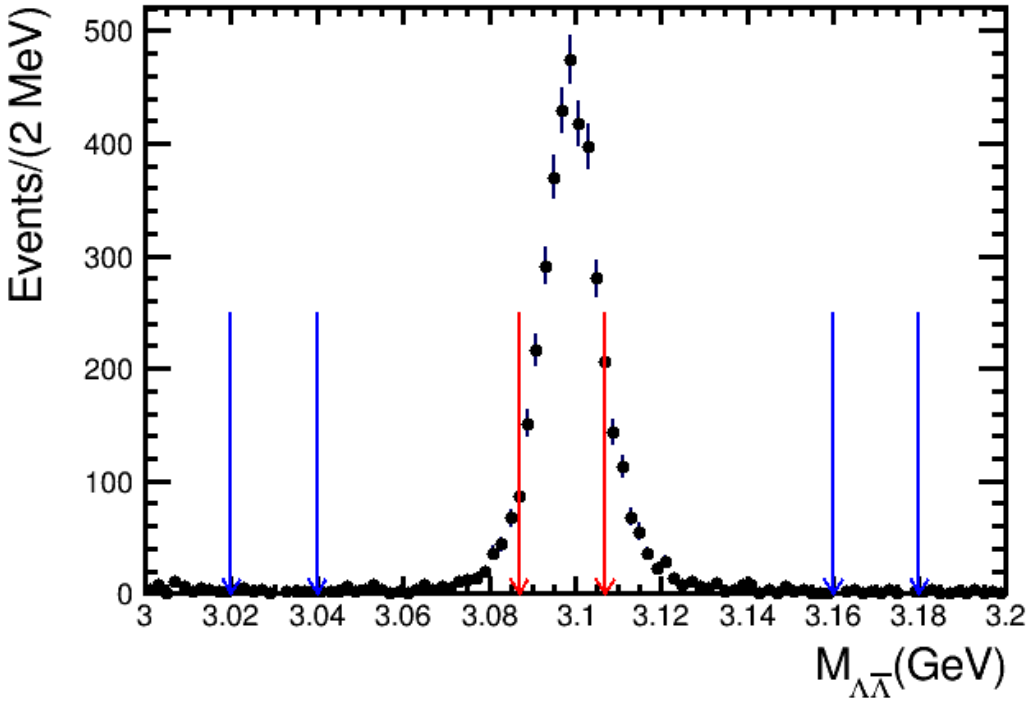
$pp\pi\pi$



$p\pi\Delta$, $\Delta\Delta$



Use $e^+e^- \to \gamma_{ISR} J/\psi \to \gamma_{ISR} \Lambda\bar{\Lambda}$ to check boost

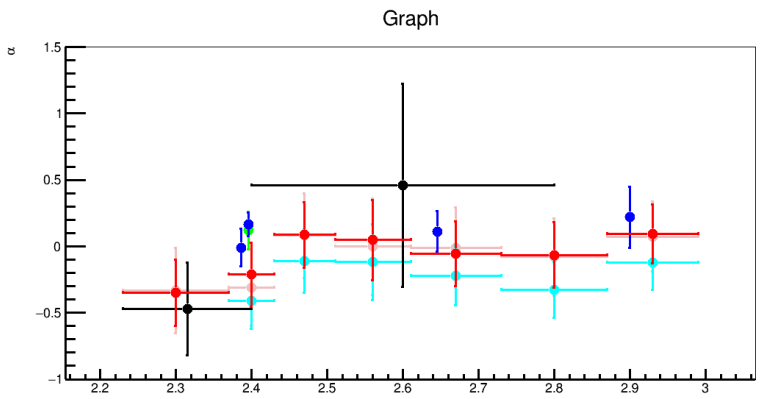


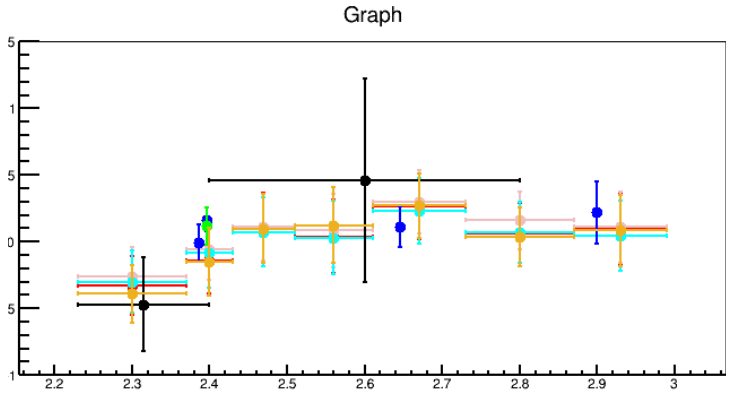
Use $e^+e^- \to \gamma_{ISR} J/\psi \to \gamma_{ISR} \Lambda\bar{\Lambda}$ to check boost

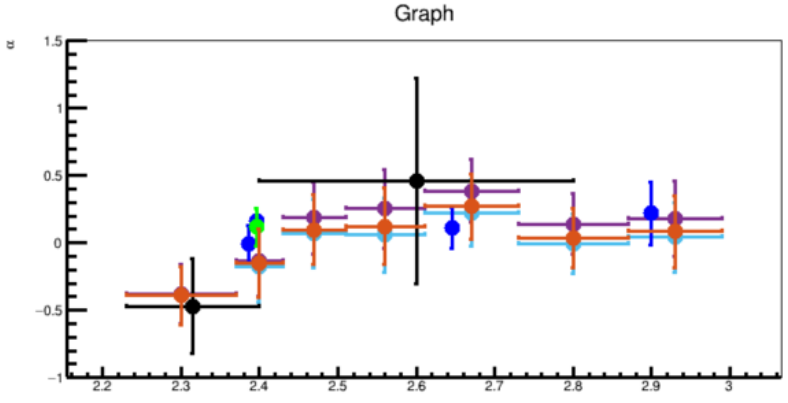
$M_{J/\psi} - 10\ MeV \leq M^{cor}_{\Lambda\bar{\Lambda}} \leq M_{J/\psi} + 10\ MeV$ (~3200 events)

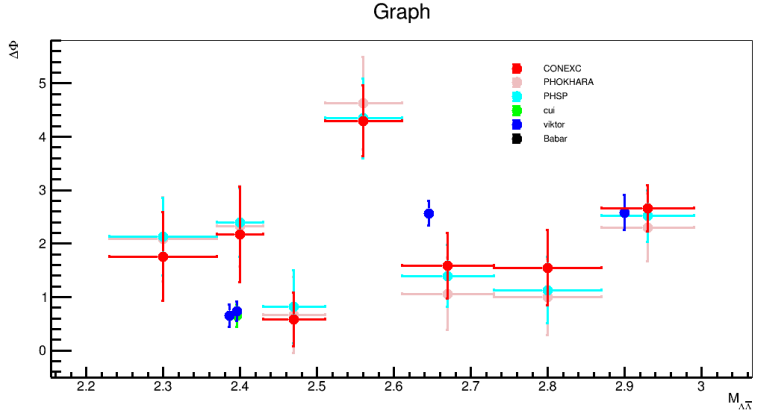
```
FCN=-412.919 FROM MINOS     STATUS=SUCCESSFUL    136 CALLS         204 TOTAL
                     EDM=2.02962e-08    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR       NEGATIVE      POSITIVE
  1  a0           4.27629e-01   5.66516e-02  -5.69542e-02   5.65049e-02
  2  phi          8.44224e-01   1.68325e-01  -1.53419e-01   1.94692e-01
  3  a1           7.56691e-01   3.03684e-02  -3.13280e-02   2.94852e-02
```

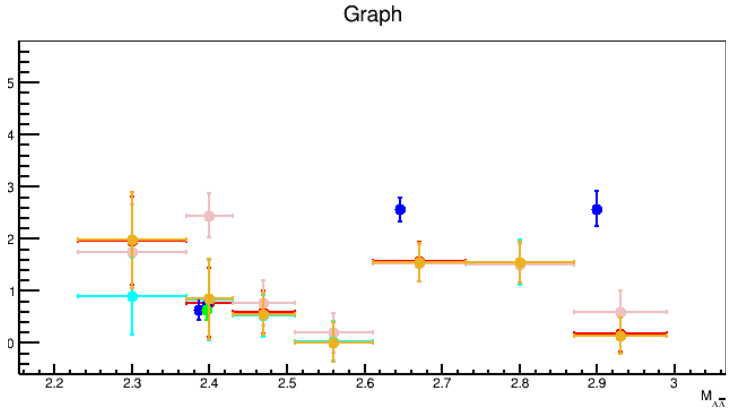
Parameter	This Letter
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0031$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0066$
α_-	$0.7519 \pm 0.0036 \pm 0.0024$
α_+	$-0.7559 \pm 0.0036 \pm 0.0030$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0012$
$\alpha_{\rm avg}$	$0.7542 \pm 0.0010 \pm 0.0024$

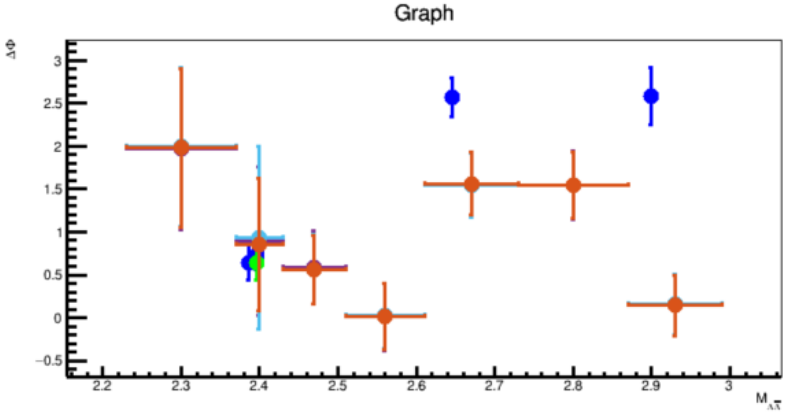

Graph
α

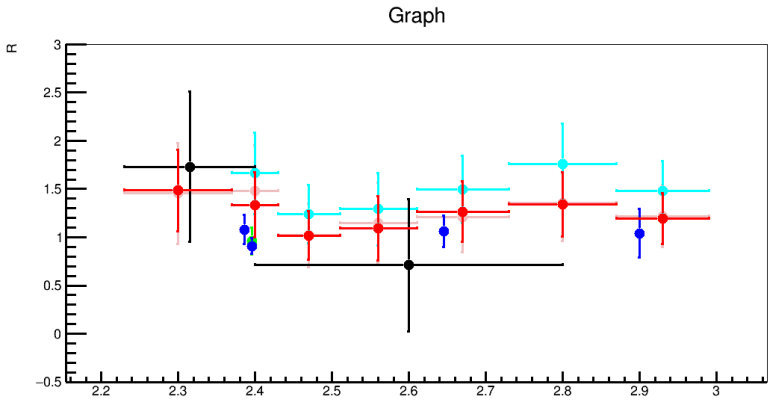

Graph

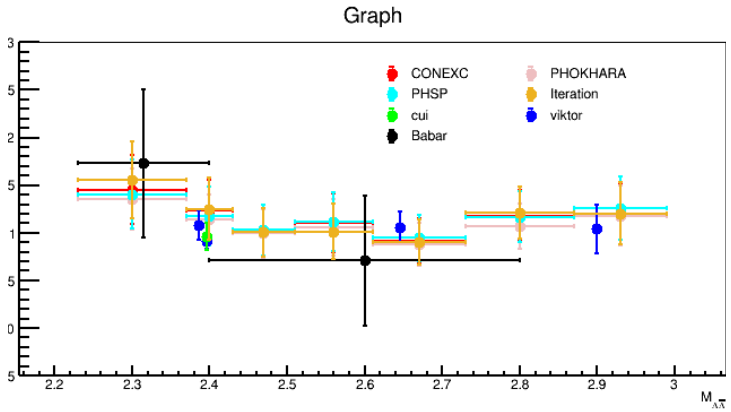

Graph
α

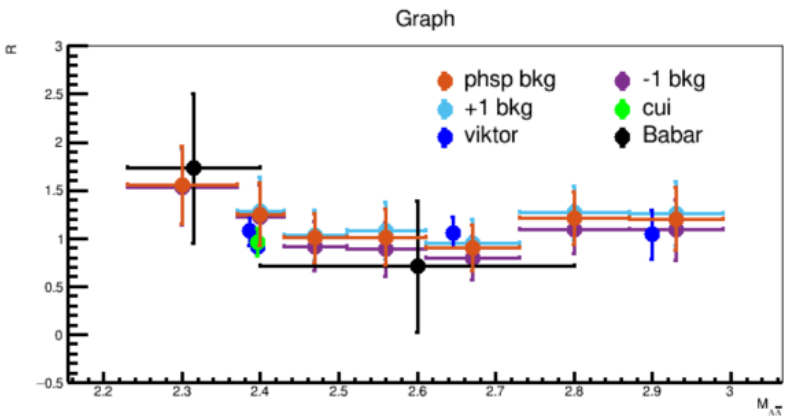

Graph
ΔΦ
CONEXC
PHOKHARA
PHSP
cui
viktor
Babar
M_ΛΛ̄


Graph
M_ΛΛ̄


Graph
ΔΦ
M_ΛΛ̄


Graph
R


Graph
CONEXC
PHOKHARA
PHSP
Iteration
cui
viktor
Babar
M_ΛΛ̄


Graph
R
phsp bkg
+1 bkg
viktor
-1 bkg
cui
Babar
M_ΛΛ̄

Fit result:

Back up

Use $e^+e^- \to \gamma_{ISR} J/\psi \to \gamma_{ISR} \Lambda\bar{\Lambda}$ to check boost

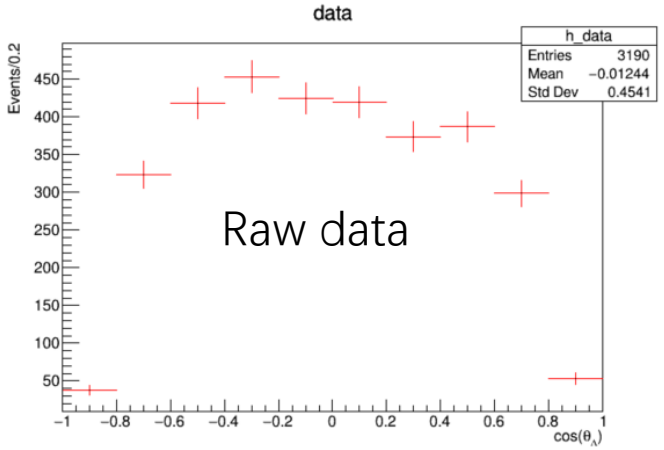
$$M_{J/\psi} - 10\ MeV \leq M^{cor}_{\Lambda\bar{\Lambda}} \leq M_{J/\psi} + 10\ MeV$$

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	17	8900	8900
2	$string \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}$	0	1229	10129
3	$string \to \bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^+\pi^- p\bar{p}\gamma$	1	47	10176
4	$string \to \Lambda\bar{\Sigma}^0, \Lambda \to \pi^- p, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	2	39	10215
5	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	20	16	10231
6	$string \to \pi^0\Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^0\pi^+\pi^- p\bar{p}$	6	12	10243
7	$string \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}$	3	10	10253
8	$string \to \pi^+ p\bar{\Delta}^{++}, \bar{\Delta}^{++} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}$	9	9	10262
9	$string \to \Sigma^0\bar{\Sigma}^0, \Sigma^0 \to \Lambda\gamma, \bar{\Sigma}^0 \to \bar{\Lambda}\gamma, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	8	5	10267
10	$string \to \pi^+\pi^- p\bar{p}$	$\pi^+\pi^- p\bar{p}$	5	5	10272
11	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \pi^-\bar{p}\Delta^{++}, \Delta^{++} \to \pi^+ p$	$\pi^+\pi^- p\bar{p}\gamma$	19	4	10276
12	$string \to \pi^0\bar{\Lambda}\Sigma^0, \bar{\Lambda} \to \pi^+\bar{p}, \Sigma^0 \to \Lambda\gamma, \Lambda \to \pi^- p$	$\pi^0\pi^+\pi^- p\bar{p}\gamma$	13	4	10280
13	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}\gamma^f$	$\pi^+\pi^- p\bar{p}\gamma\gamma^f$	26	4	10284
14	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \pi^+ p\bar{\Delta}^{++}, \bar{\Delta}^{++} \to \pi^-\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	22	3	10287
15	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to e^-\bar{\nu}_e p, \bar{\Lambda} \to \pi^+\bar{p}$	$e^-\bar{\nu}_e\pi^+ p\bar{p}\gamma$	21	3	10290
16	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \pi^-\bar{\Delta}^0 p, \bar{\Delta}^0 \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma$	18	2	10292
17	$cluster \to \psi(3770), \psi(3770) \to J/\psi\gamma, J/\psi \to \eta_c\gamma, \eta_c \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma$	25	2	10294
18	$string \to p\bar{p}h_1(1170), h_1(1170) \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+$	$\pi^0\pi^+\pi^- p\bar{p}$	10	2	10296
19	$cluster \to \psi(3770), \psi(3770) \to \psi'\gamma, \psi' \to \chi_{c1}\gamma, \chi_{c1} \to J/\psi\gamma, J/\psi \to \Lambda\bar{\Lambda}, \Lambda \to \pi^- p, \bar{\Lambda} \to \pi^+\bar{p}$	$\pi^+\pi^- p\bar{p}\gamma\gamma\gamma$	31	2	10298
20	$string \to p\bar{p}h_1(1170), h_1(1170) \to \pi^-\rho^+, \rho^+ \to \pi^0\pi^+\gamma^F$	$\pi^0\pi^+\pi^- p\bar{p}\gamma^F$	12	1	10299

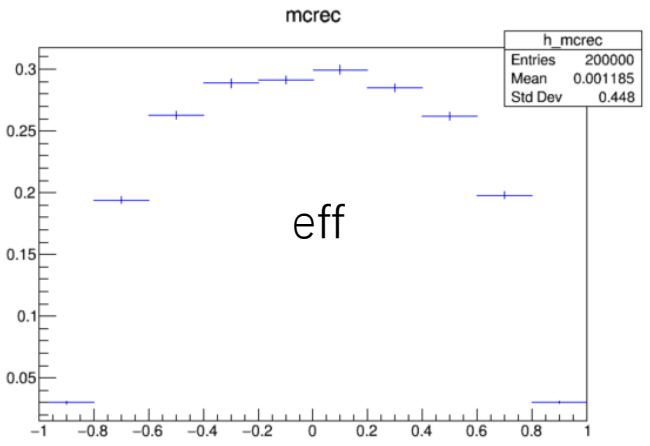
Bkg rate ~ 2% ($q\bar{q}$ bkg is over-estimated.)

Use $e^+e^- \to \gamma_{ISR} J/\psi \to \gamma_{ISR}\Lambda\bar{\Lambda}$ to check boost

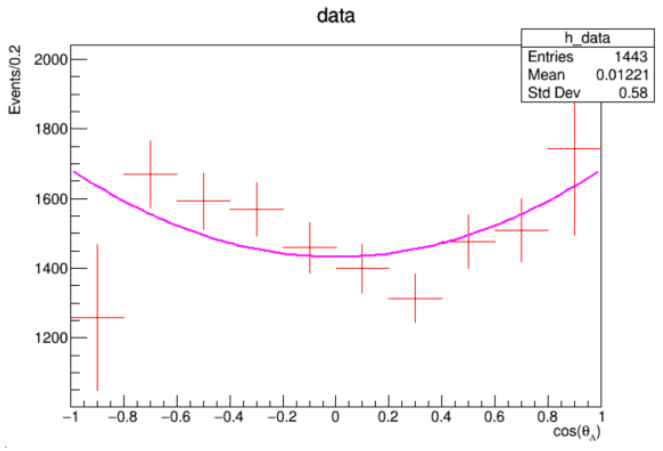
$$M_{J/\psi} - 10\ MeV \leq M_{\Lambda\bar{\Lambda}}^{cor} \leq M_{J/\psi} + 10\ MeV\ (\sim 3200\ \text{events})$$

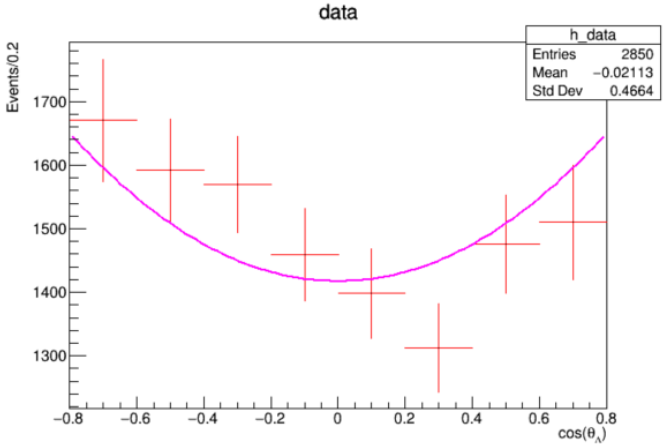


Raw data



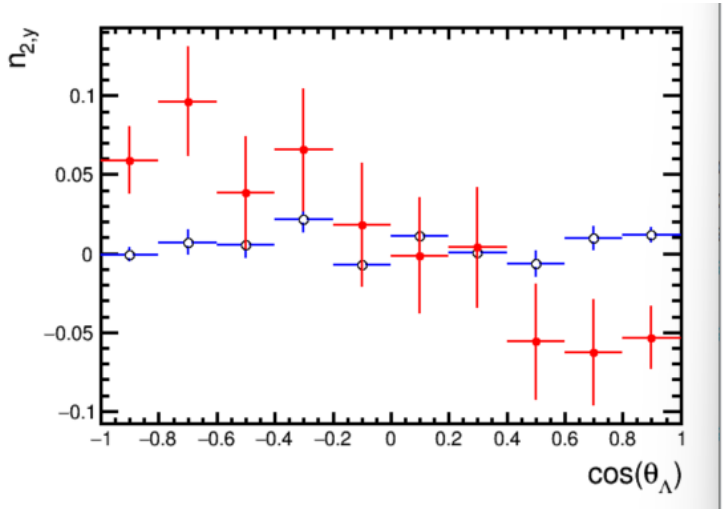
eff

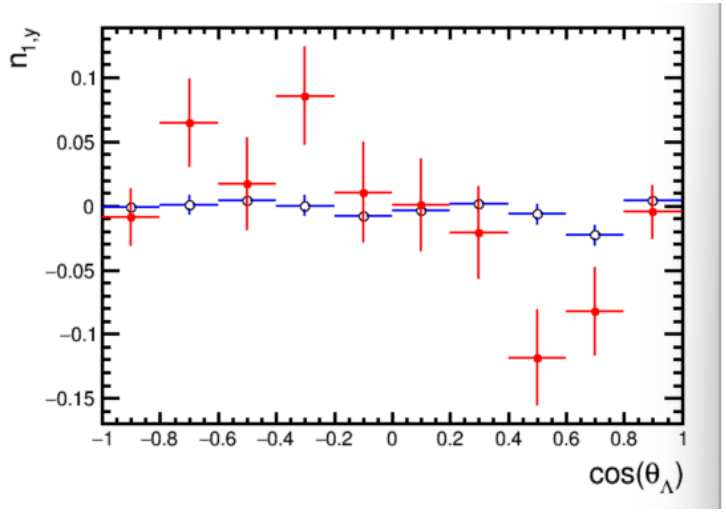


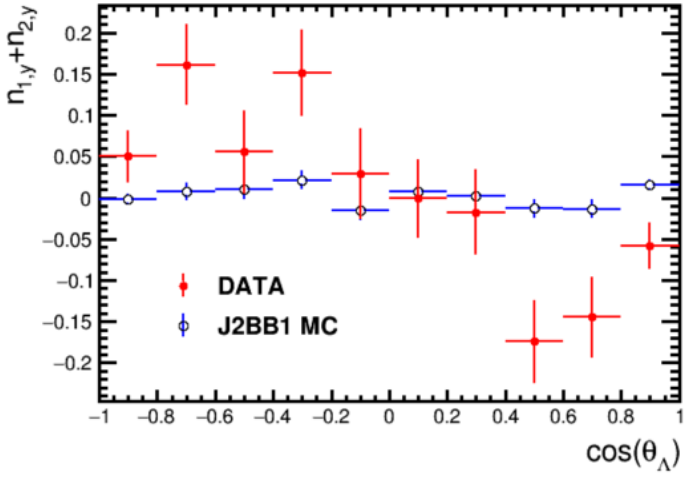



```
FCN=9.51293 FROM MINOS     STATUS=SUCCESSFUL     16 CALLS         122 TOTAL
                     EDM=1.15158e-07    STRATEGY= 1      ERROR MATRIX ACCURATE
 EXT PARAMETER                   PARABOLIC         MINOS ERRORS
 NO.   NAME      VALUE            ERROR      NEGATIVE      POSITIVE
  1  p0           2.57046e-01   1.19139e-01  -1.16732e-01   1.21685e-01
  2  p1           1.41731e+03   3.94550e+01  -3.94474e+01   3.94615e+01
```

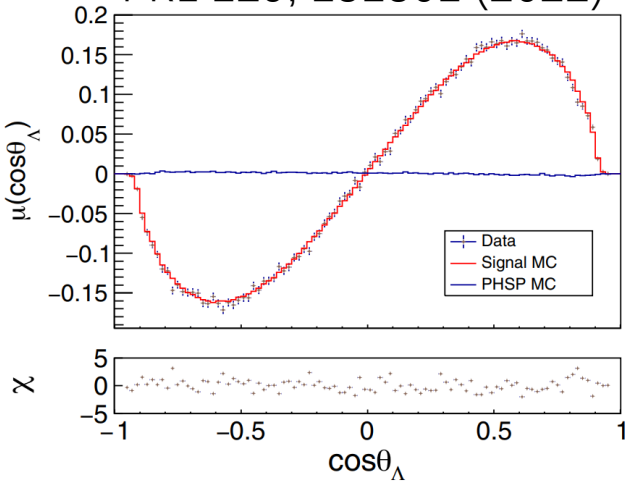
Use $e^+e^- \to \gamma_{ISR} J/\psi \to \gamma_{ISR}\Lambda\bar{\Lambda}$ to check boost







PRL 129, 131801 (2022)



The moment

$$\mu[\cos(\theta_\Lambda)] = (m/N)\sum_{i=1}^{N_k}(n_{1,y}^{(i)} - n_{2,y}^{(i)}), \qquad (5)$$

which related to the polarization, is used to compare the consistency between the data and the fit results. Hereby, N is the total number of events in the data set, and $m = 100$ is the number of bins in $\cos(\theta_\Lambda)$ for calculating the moment. N_k denotes the number of events in the kth $\cos(\theta_\Lambda)$ bin. The expected angular dependence of the moment for the acceptance-corrected data reads

$$\mu(\cos\theta_\Lambda) = \frac{\alpha_- - \alpha_+}{2}\frac{1 + \alpha_{J/\psi}\cos^2\theta_\Lambda}{3 + \alpha_{J/\psi}} P_y(\theta_\Lambda). \qquad (6)$$