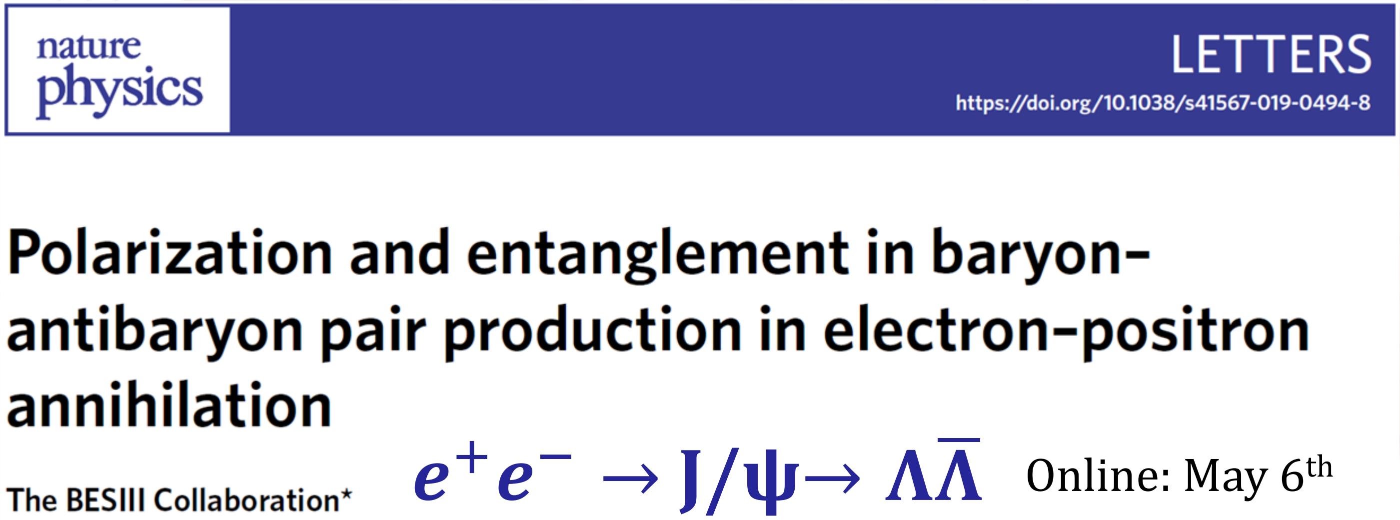
UPPSALA
UNIVERSITET

Hyperon physics at a charm factory

Andrzej Kupsc



nature physics

LETTERS

https://doi.org/10.1038/s41567-019-0494-8

Polarization and entanglement in baryon-antibaryon pair production in electron-positron annihilation

The BESIII Collaboration*

$e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$ Online: May 6th

BESIII

arXiv:1808.08917

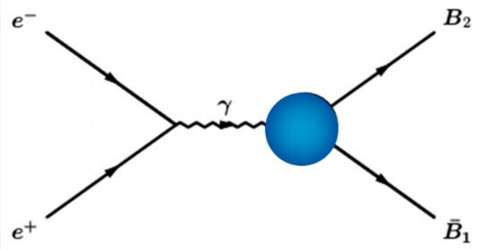
Prospects for hyperon physics at electron-positron collider

- Hyperon polarization
- Determination of hyperon decay parameters
- CP tests

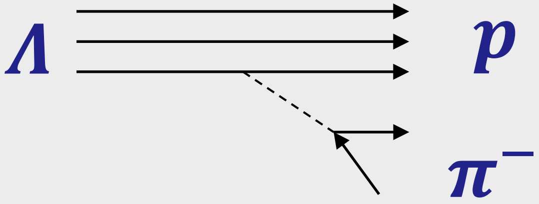
E.Perotti,G.Fäldt,AK,S.Leupold,JJ.Song PRD99 (2019)056008,
P.Adlarson,AK

Hyperons WS Fudan U. 7-8 July 2019

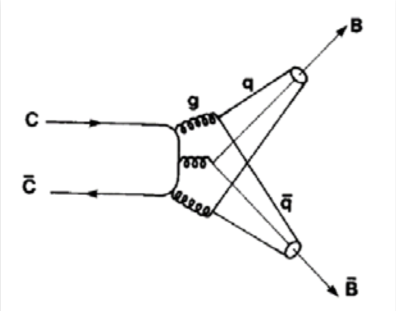
Outline:



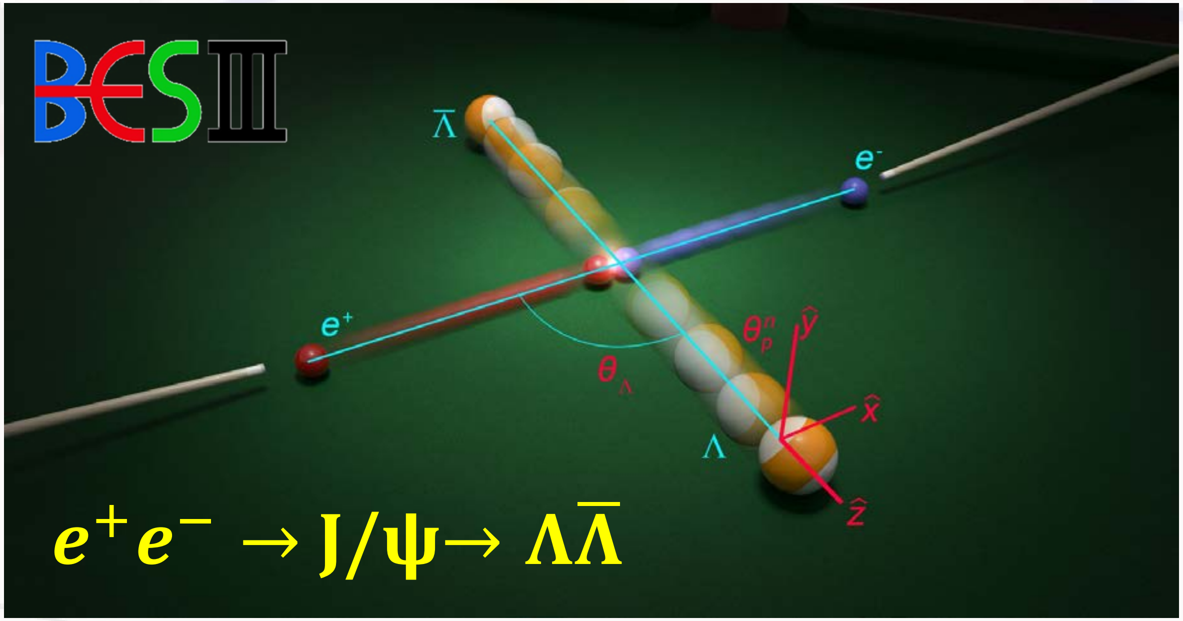
+



+



$e^+e^- \to f\bar{f}, \mathrm{B}_1\bar{\mathrm{B}}_2$ $\Lambda \to p\pi^-$ $\mathrm{J}/\psi \to \mathrm{B}_1\bar{\mathrm{B}}_2$

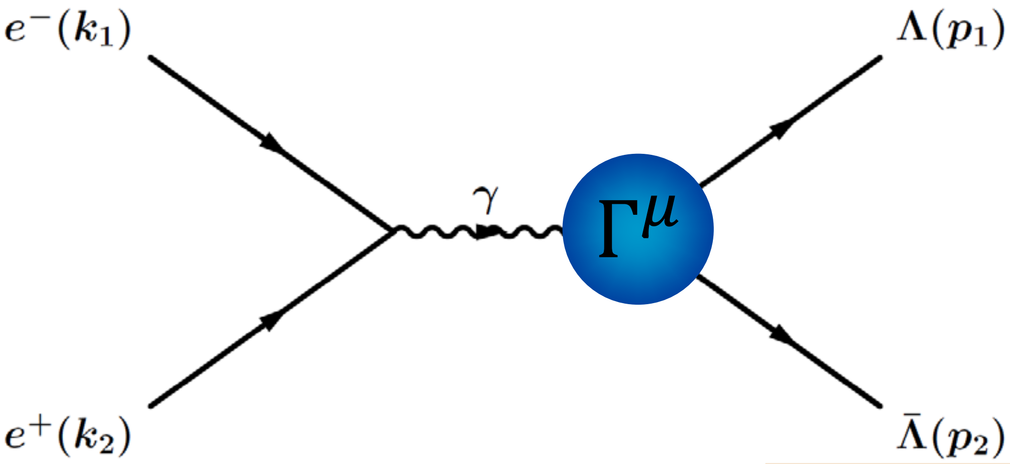


CP tests

$e^+e^- \to \mathrm{J}/\psi \to \Xi\bar{\Xi}$

Picture:Piotr Kupsc

$e^+e^- \rightarrow \gamma^* \rightarrow B\overline{B}$ (spin 1/2)



$$s = (p_1 + p_2)^2$$
$$q = p_1 - p_2$$

$$\Gamma^\mu(p_1, p_2) = -ie\left[\gamma^\mu F_1(s) + i\frac{\sigma^{\mu\nu}}{2M_B} q_\nu F_2(s)\right]$$

F_1 (Dirac) and F_2 (Pauli) Form Factors

Sachs Form Factors (FFs) ⇔ helicity amplitudes:

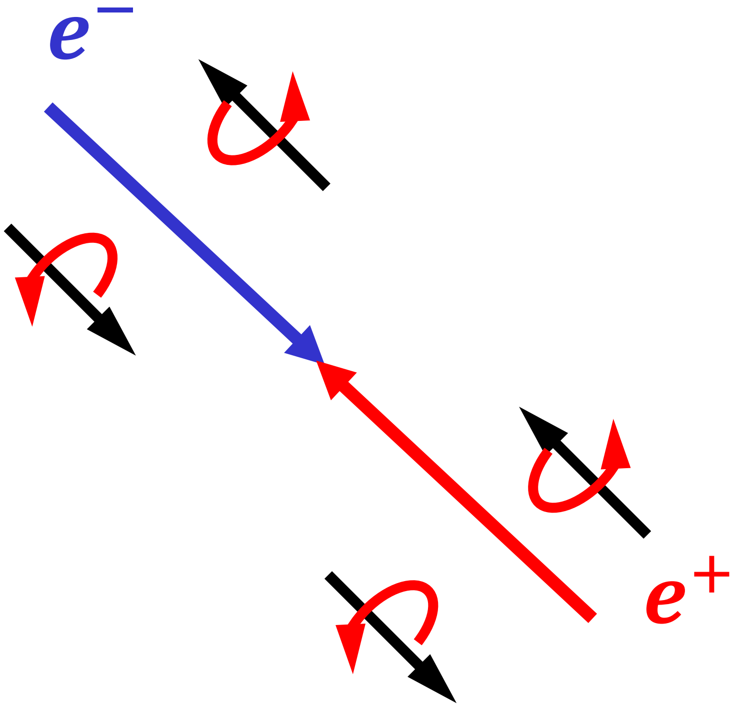
$$G_M(s) = F_1(s) + F_2(s), \quad G_E(s) = F_1(s) + \tau F_2(s)$$

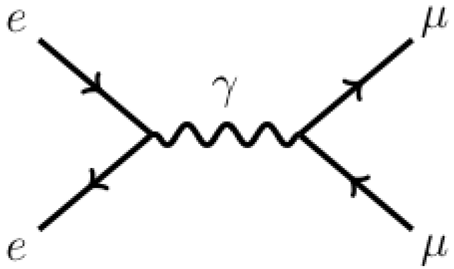
helicity non-flip helicity flip

$$\tau = \frac{s}{4M_B^2}$$

$e^+e^- \to \mu^+\mu^-$

At high energies annihilating e+e- have opposite helicities.





$$F_1(0) = 1, \quad F_2(0) = a_\mu$$

$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s}(1 + \cos^2\theta)$$

γ^* has ± 1 helicity

$$\rho_1(\theta) = \begin{pmatrix} \frac{1+\cos^2\theta}{2} & -\frac{\cos\theta\sin\theta}{\sqrt{2}} & \frac{\sin^2\theta}{2} \\ -\frac{\cos\theta\sin\theta}{\sqrt{2}} & \sin^2\theta & \frac{\cos\theta\sin\theta}{\sqrt{2}} \\ \frac{\sin^2\theta}{2} & \frac{\cos\theta\sin\theta}{\sqrt{2}} & \frac{1+\cos^2\theta}{2} \end{pmatrix}$$

$e^+e^- \to \gamma^* \to B\bar{B}$

For spin ½ $B\bar{B}$ production two complex FFs: $G_M(s)$, $G_E(s)$

⇨ process described by three parameters at fixed $\sqrt{s}$:

☐ cross section (σ)

☐ FFs ratio R or angular distribution parameter α_ψ

☐ relative phase between FFs (ΔΦ)

$$R = \left|\frac{G_E}{G_M}\right| \quad \left(\alpha_\psi = \frac{\tau - R^2}{\tau + R^2}\right) \qquad G_E = R G_M e^{i\Delta\Phi}$$

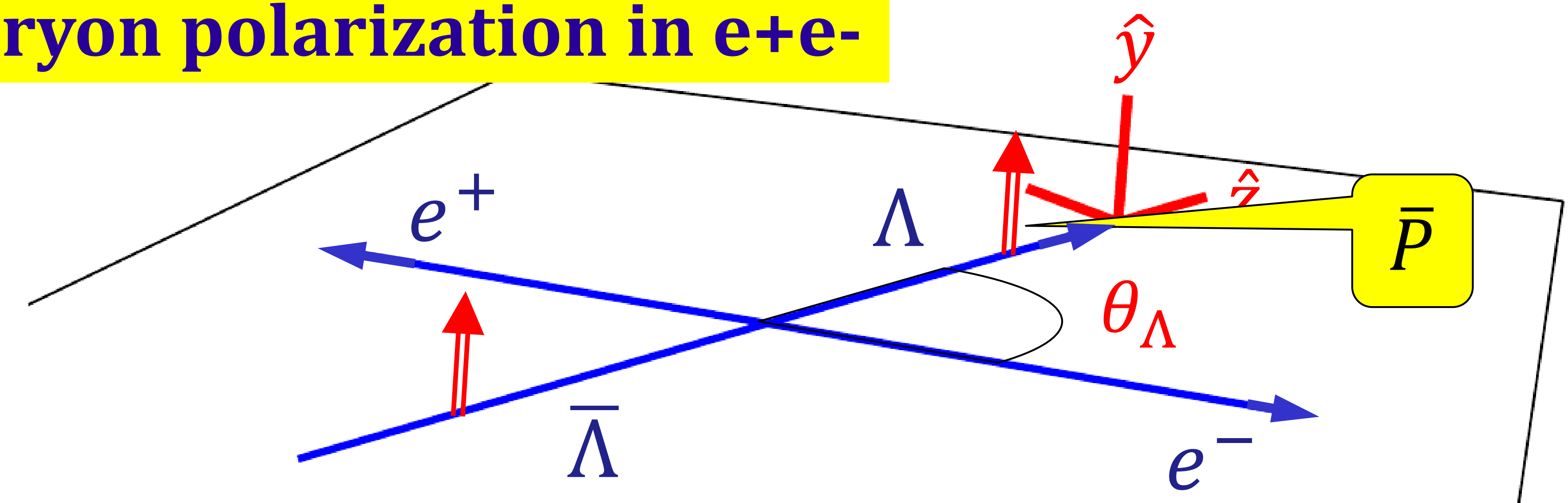
$$\tau = \frac{s}{4M_B^2}$$

Angular distribution:

$$\boxed{\frac{d\Gamma}{d\Omega} \propto 1 + \alpha_\psi \cos^2\theta \qquad -1 \le \alpha_\psi \le 1}$$

Phase ***ΔΦ*** expected/predicted for continuum but neglected/not expected for the decays

Baryon polarization in e+e-



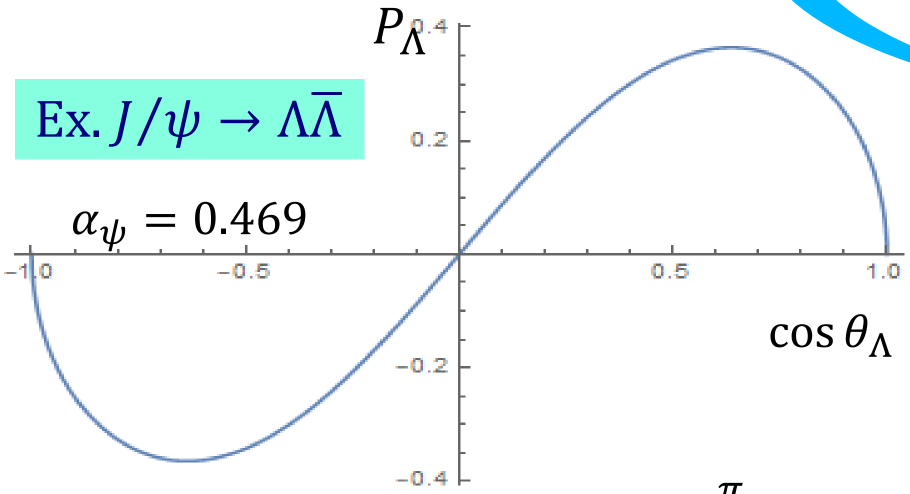
Unpolarized e+e- beams ⇨ transverse polarization:

$$P_y\left(\cos\theta_\Lambda\right) = \frac{\sqrt{1-\boldsymbol{\alpha_\psi}{}^2}\cos\theta_\Lambda\sin\theta_\Lambda}{1+\boldsymbol{\alpha_\psi}\cos^2\theta_\Lambda}\sin(\boldsymbol{\Delta\Phi})$$

$\Delta\Phi \neq 0$

Ex. $J/\psi \rightarrow \Lambda\bar{\Lambda}$

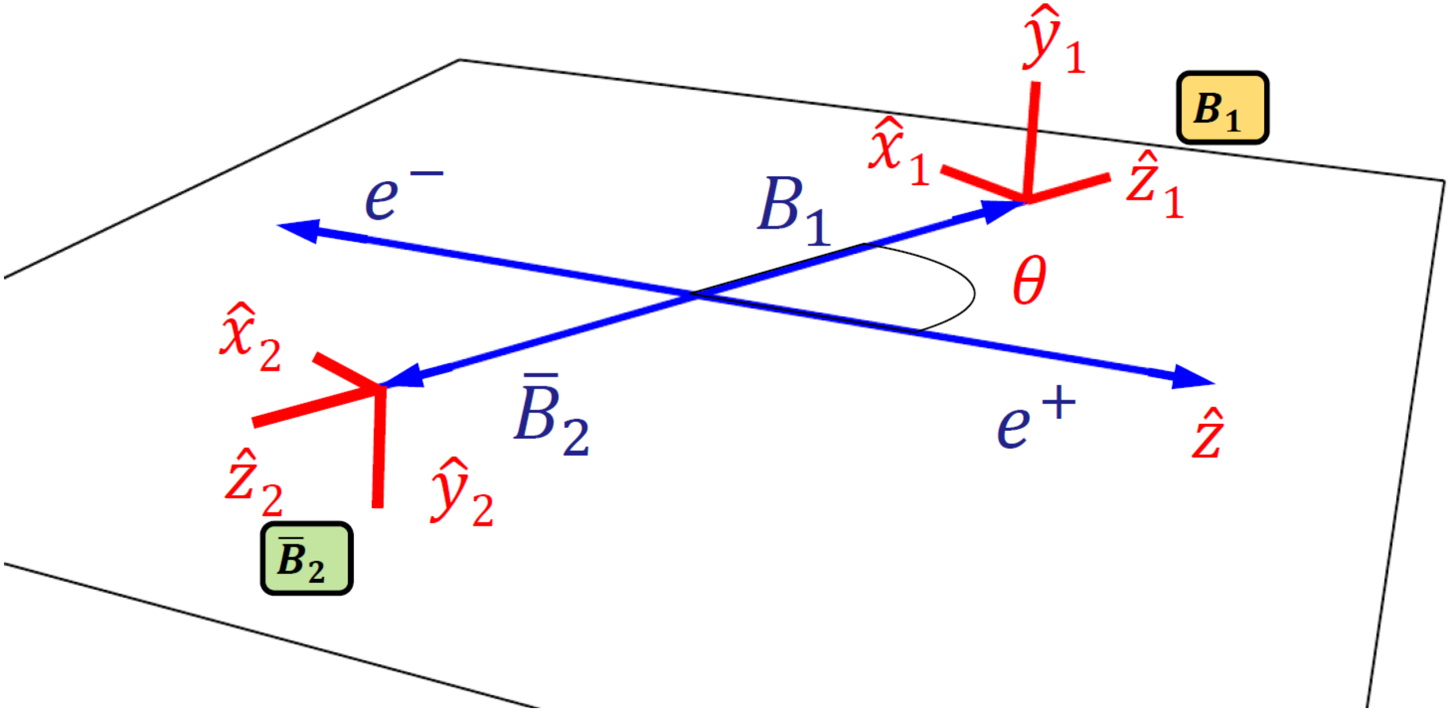
$\alpha_\psi = 0.469$



Max P_Λ= 36.4%

if $\Delta\Phi = \frac{\pi}{2}$

$e^+e^- \to B_1\bar{B}_2$



Baryon-antibaryon spin density matrix

$$e^+e^- \to B_1\bar{B}_2$$

General two spin ½ particle state:

$$\rho_{1/2,\overline{1/2}} = \frac{1}{4}\sum_{\mu\bar{\nu}} C_{\mu\bar{\nu}}\ \sigma_{\mu}^{B_1} \otimes \sigma_{\bar{\nu}}^{\bar{B}_2}$$

$(\sigma_0 = \mathbf{1}_2, \sigma_1 = \sigma_x, \sigma_2 = \sigma_y, \sigma_3 = \sigma_z)$

$$C_{\mu\bar{\nu}} = \begin{pmatrix} 1+\alpha_\psi \cos^2\theta & 0 & \overset{P_y}{\boxed{\beta_\psi \sin\theta\cos\theta}} & 0 \\ 0 & \sin^2\theta & 0 & \gamma_\psi \sin\theta\cos\theta \\ -\beta_\psi \sin\theta\cos\theta & 0 & \alpha_\psi \sin^2\theta & 0 \\ 0 & -\gamma_\psi \sin\theta\cos\theta & 0 & -\alpha_\psi - \cos^2\theta \end{pmatrix}$$

$$\beta_\psi = \sqrt{1-\alpha_\psi^2}\sin(\Delta\Phi) \qquad \gamma_\psi = \sqrt{1-\alpha_\psi^2}\cos(\Delta\Phi)$$

E.Perotti, G.Faldt, AK, S.Leupold,JJ.Song PRD99 (2019)056008

Polarization of daughter baryons:

$$Y \to B\pi$$

$$\mathbf{P}_B = \frac{(\alpha + \mathbf{P}_Y \cdot \hat{\mathbf{n}})\hat{\mathbf{n}} + \beta(\mathbf{P}_Y \times \hat{\mathbf{n}}) + \gamma\hat{\mathbf{n}} \times (\mathbf{P}_Y \times \hat{\mathbf{n}})}{1 + \alpha \mathbf{P}_Y \cdot \hat{\mathbf{n}}}$$

PDG

$$\mathbf{P}_Y = 0 \;\Rightarrow\; \mathbf{P}_B = \alpha\, \hat{\mathbf{n}}$$

Density matrix for a spin ½ particle in the rest frame:

$$\rho_{1/2} = \frac{1}{2}\sum_{\mu=0}^{3} I_\mu \sigma_\mu = \frac{1}{2} I_0 \begin{pmatrix} 1 + P_z & P_x - iP_y \\ P_x + iP_y & 1 - P_z \end{pmatrix}$$

$$\sigma_0 = \mathbf{1}_2, \sigma_1 = \sigma_x, \sigma_2 = \sigma_y, \sigma_3 = \sigma_z$$

Transformation of base matrices:

$$\frac{1}{2}^+ \to \frac{1}{2}^+ + 0^- \quad e.g.\ \Lambda \to p + \pi^-$$

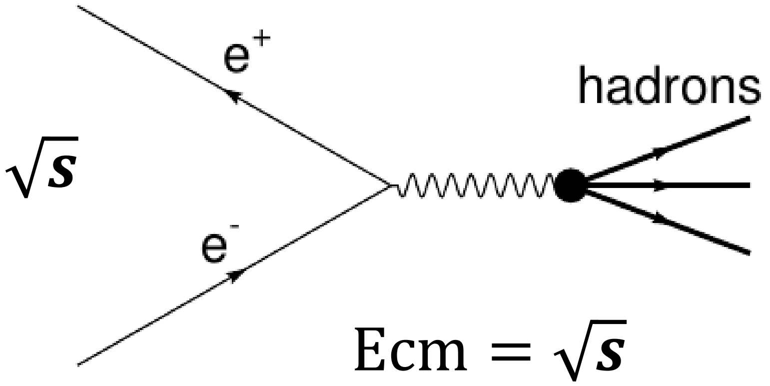
Decay matrices

$$\boxed{\sigma_\mu \to \sum_{\nu=0}^{3} a_{\mu,\nu} \sigma_\nu^d}$$

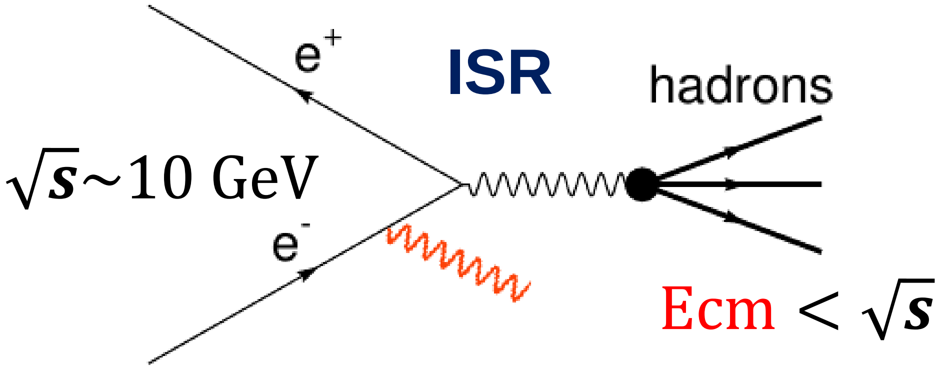
4×4 decay matrix: $a_{\mu,\nu}$

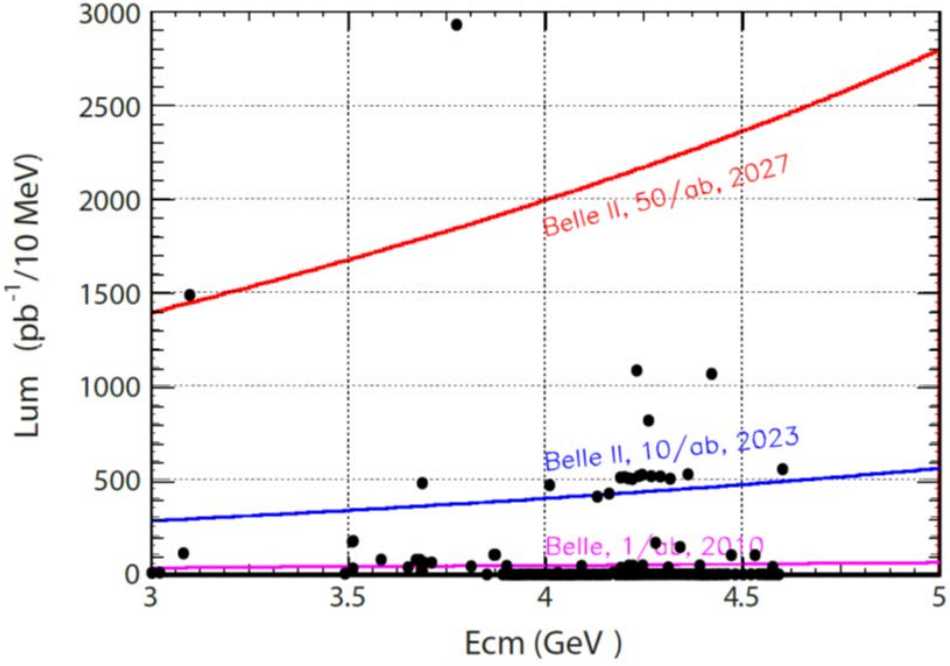
E.Perotti, G.Faldt, AK, S.Leupold,JJ.Song PRD99 (2019)056008

Direct scan BESIII



ISR BelleII





Picture:Wolfgang Gradl

Direct scan

- (very) high luminosity at selected c.m. energies
- better resolution: at J/ψ 0.9 MeV: 10^{10} J/ψ

ISR

- ISR: many Ecm simultaneously
- reduced point-to-point systematics
- mass resolution limited by detector
- boost of hadronic system may help efficiency

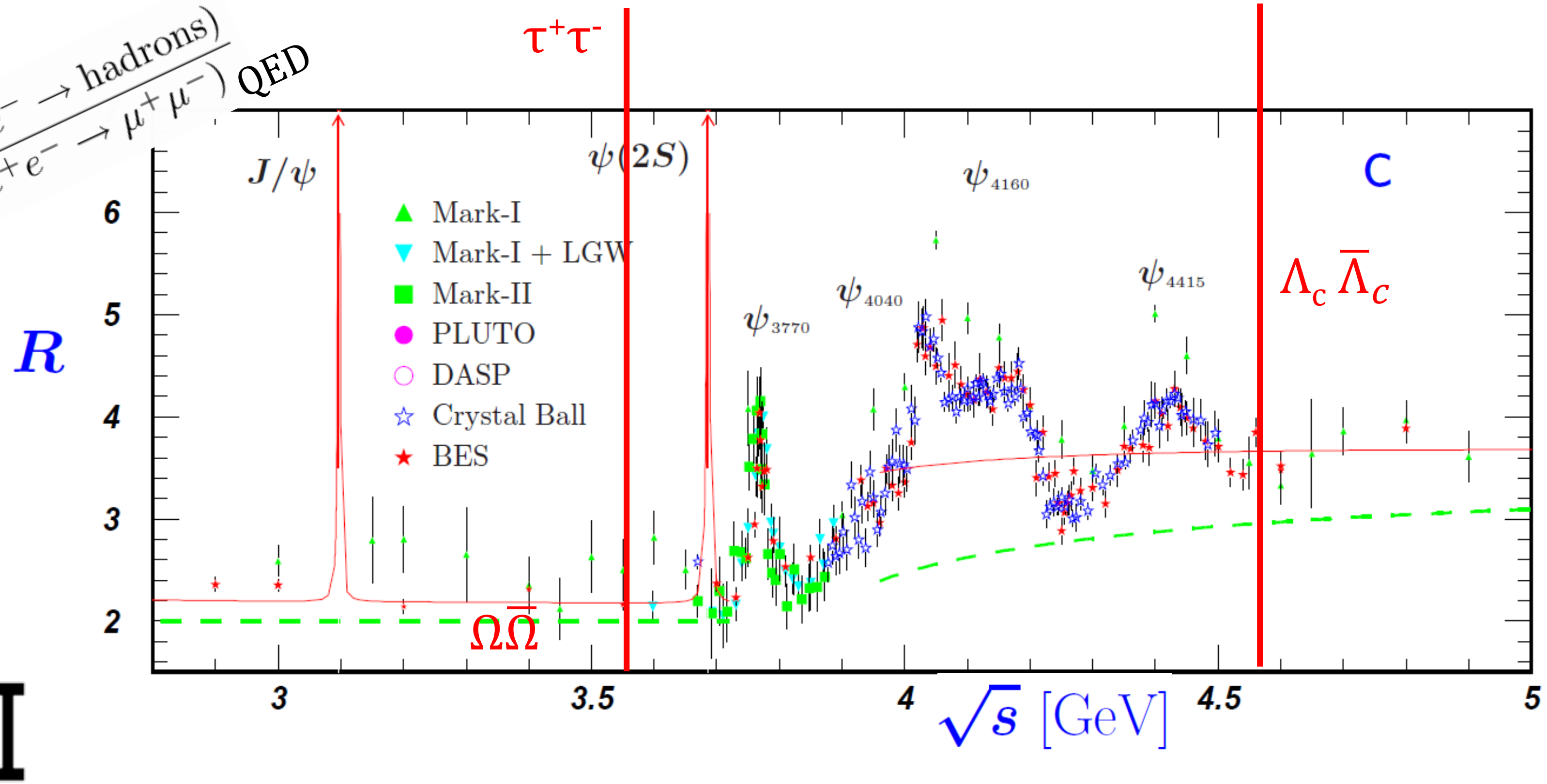
Hyperon-$\overline{\text{hyperon}}$ pair production at BESIII

$2.0\ \text{GeV} \le \sqrt{s} \le 4.6\ \text{GeV}$

Thresholds:

$\Lambda\bar{\Lambda}$:	2.231 GeV	$\Sigma^{+}\bar{\Sigma}^{-}$	2.379 GeV	($\Omega\bar{\Omega}$	3.345 GeV)
$\Sigma^{0}\bar{\Sigma}^{0}$	2.385 GeV	$\Sigma^{-}\bar{\Sigma}^{+}$	2.395 GeV		
$\Xi^{0}\bar{\Xi}^{0}$	2.630 GeV	$\Xi^{-}\bar{\Xi}^{+}$	2.643 GeV		
$\Lambda\bar{\Sigma}^{0}$	2.308 GeV				

$$R(s) = \frac{\sigma(e^+e^- \to \text{hadrons})}{\sigma(e^+e^- \to \mu^+\mu^-)_{\text{QED}}}$$



$J/\psi, \psi(2S) \to B\bar{B}$

$\mathcal{B}(J/\psi \to p\bar{p}) = (21.21 \pm 0.29) \times 10^{-4}$

decay mode	events	$\mathcal{B}$(units 10^{-4})
$J/\psi \to \Lambda\bar{\Lambda}$	440675 ± 670	$19.43 \pm 0.03 \pm 0.33$
$\psi(2S) \to \Lambda\bar{\Lambda}$	31119 ± 187	$3.97 \pm 0.02 \pm 0.12$
$J/\psi \to \Sigma^0\bar{\Sigma}^0$	111026 ± 335	$11.64 \pm 0.04 \pm 0.23$
$\psi(2S) \to \Sigma^0\bar{\Sigma}^0$	6612 ± 82	$2.44 \pm 0.03 \pm 0.11$
$J/\psi \to \Xi^0\bar{\Xi}^0$	134846 ± 437	11.65 ± 0.04
$\psi(2S) \to \Xi^0\bar{\Xi}^0$	10839 ± 123	2.73 ± 0.03
$J/\psi \to \Xi^-\bar{\Xi}^+$	42811 ± 231	10.40 ± 0.06
$\psi(2S) \to \Xi^-\bar{\Xi}^+$	5337 ± 83	2.78 ± 0.05

PRD 93, 072003 (2016)
PLB770,217 (2017)

PRD 95, 052003 (2017)

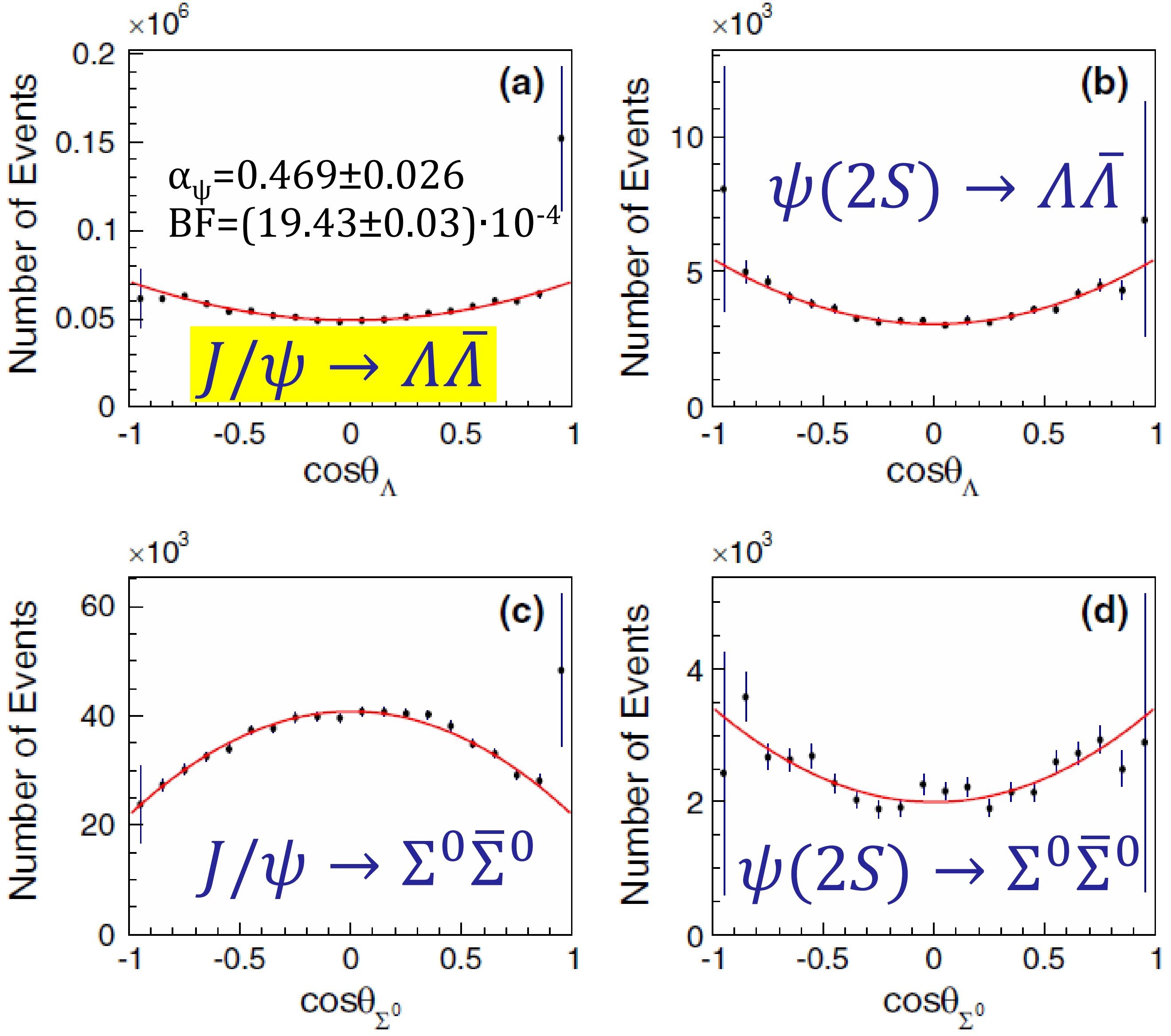
$1.31\text{x}10^9$ J/ψ

$0.223\text{x}10^9$ J/ψ

$4.48\text{x}10^8$ ψ(2S)

Angular distributions in $J/\psi, \psi(2S) \rightarrow B\bar{B}$

$$1 + \alpha_\psi \cos^2 \theta_Y$$



α_ψ=0.469±0.026
BF=(19.43±0.03)·10^{-4}

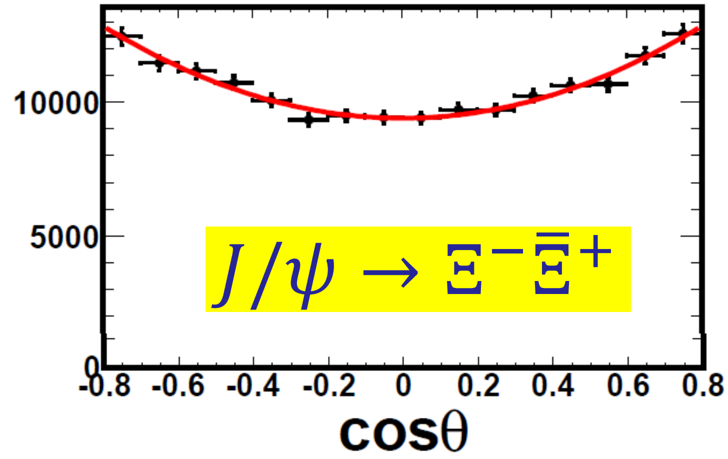
$J/\psi \rightarrow \Lambda\bar{\Lambda}$

$\psi(2S) \rightarrow \Lambda\bar{\Lambda}$

$J/\psi \rightarrow \Sigma^0\bar{\Sigma}^0$

$\psi(2S) \rightarrow \Sigma^0\bar{\Sigma}^0$

α_ψ=0.58±0.04
BF=(10.40±0.06)·10^{-4}



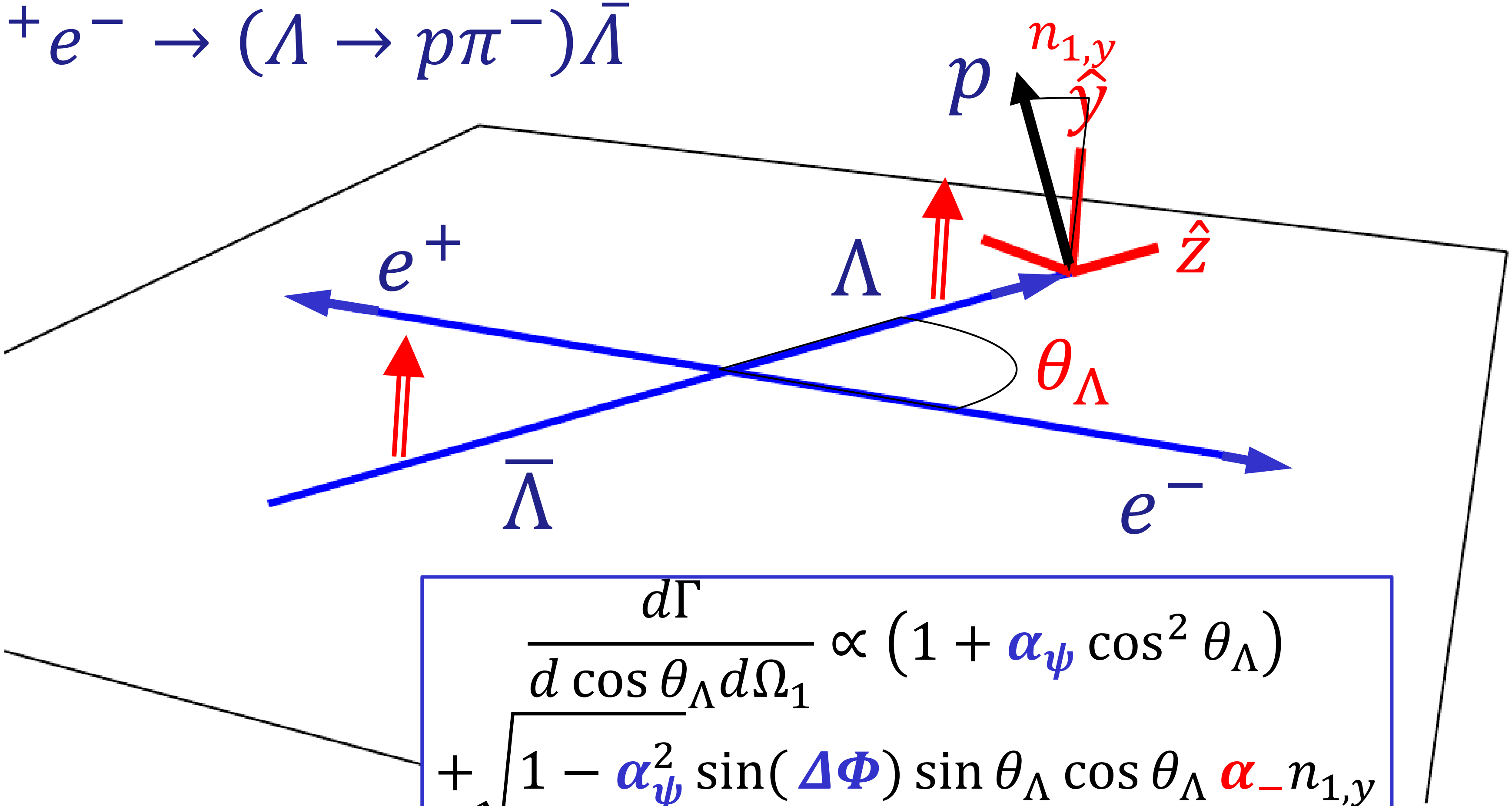
$J/\psi \rightarrow \Xi^-\bar{\Xi}^+$

α_ψ measurements at BESIII

PRD 95, 052003 (2017)
PRD 93, 072003 (2016)

Inclusive decay angular distributions

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



$$\frac{d\Gamma}{d\cos\theta_\Lambda d\Omega_1} \propto \left(1 + \alpha_\psi \cos^2\theta_\Lambda\right) + \sqrt{1-\alpha_\psi^2}\,\sin(\Delta\Phi)\sin\theta_\Lambda\cos\theta_\Lambda\,\alpha_-\,n_{1,y}$$

$\Lambda \to p\pi^-$: $\hat{\mathbf{n}}_1 \to \Omega_1 = (\cos\theta_1, \phi_1)$: α_-

⇒Determine product: $\alpha_- P_y \sim \alpha_- \sin(\Delta\Phi)$

Exclusive joint angular distribution

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

$\Lambda \to p\pi^-$: $\hat{\mathbf{n}}_1 \to (\cos\theta_1, \phi_1)$: α_- $\bar{\Lambda} \to \bar{p}\pi^+$: $\hat{\mathbf{n}}_2 \to (\cos\theta_2, \phi_2)$: α_+

$\xi : (\cos\theta_\Lambda, \hat{\mathbf{n}}_1, \hat{\mathbf{n}}_2)$ 5D PhSp

$$d\Gamma \propto W(\xi; \alpha_\psi, \Delta\Phi, \alpha_-, \alpha_+) =$$

$$1 + \alpha_\psi \cos^2\theta_\Lambda$$

Cross section

Spin correlations

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

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

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

Polarization

$\Delta\Phi \neq 0$ ⇒ independent determination of α_- and α_+

Fäldt, Kupsc PLB772 (2017) 16

Exclusive joint angular distribution (modular form)

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

General two spin ½ particle state: $$\rho_{1/2,\overline{1/2}} = \frac{1}{4}\sum_{\mu\bar{\nu}} C_{\mu\bar{\nu}}\, \sigma_\mu^\Lambda \otimes \sigma_{\bar{\nu}}^{\bar{\Lambda}}$$

$(\sigma_0 = \mathbf{1}_2, \sigma_1 = \sigma_x, \sigma_2 = \sigma_y, \sigma_3 = \sigma_z)$

$$C_{\mu\bar{\nu}} = \begin{pmatrix} 1+\alpha_\psi\cos^2\theta & 0 & \beta_\psi\sin\theta\cos\theta & 0 \\ 0 & \sin^2\theta & 0 & \gamma_\psi\sin\theta\cos\theta \\ -\beta_\psi\sin\theta\cos\theta & 0 & \alpha_\psi\sin^2\theta & 0 \\ 0 & -\gamma_\psi\sin\theta\cos\theta & 0 & -\alpha_\psi - \cos^2\theta \end{pmatrix}$$

$$\beta_\psi = \sqrt{1-\alpha_\psi^2}\,\sin(\Delta\Phi) \qquad \gamma_\psi = \sqrt{1-\alpha_\psi^2}\,\cos(\Delta\Phi)$$

Apply decay matrices:

$$\sigma_\mu^\Lambda \to \sum_{\mu'=0}^{3} a_{\mu,\mu'}^\Lambda\, \sigma_{\mu'}^p$$

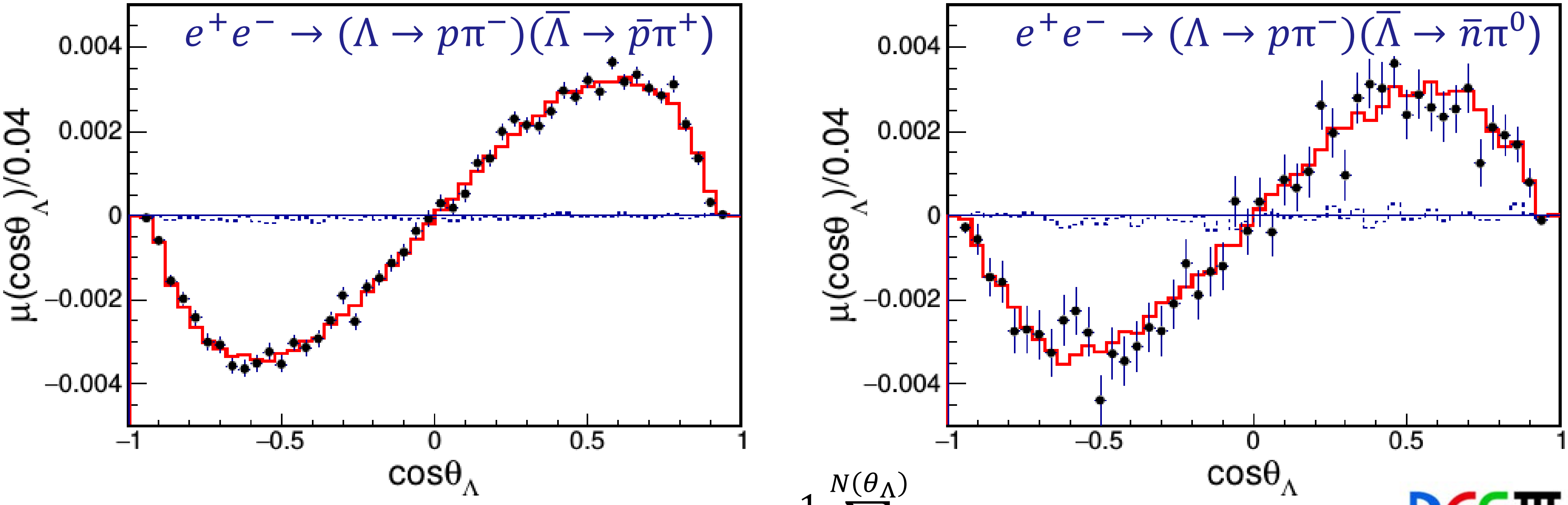
The result:

$$\boxed{W = Tr\rho_{p,\bar{p}} = \sum_{\mu,\bar{\nu}=0}^{3} C_{\mu\bar{\nu}} a_{\mu,0}^\Lambda a_{\bar{\nu},0}^{\bar{\Lambda}}}$$

E.Perotti, G.Faldt, AK, S.Leupold,JJ.Song PRD99 (2019)056008

Fit results

$\Delta\Phi=42.3^o\pm0.6^o\pm0.5^o$



moment: $$\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_{i=1}^{N(\theta_\Lambda)}\left(n_{1,y}^{(i)} - n_{2,y}^{(i)}\right)$$

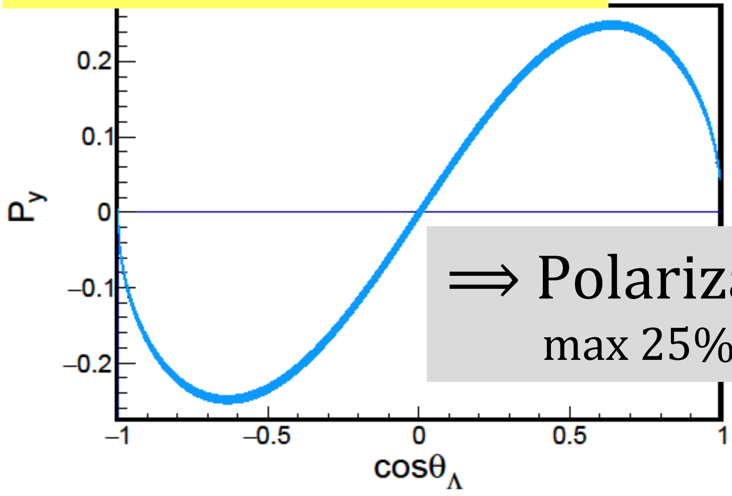
(uncorrected for acceptance)

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

BESIII Nature Phys. (2019)

Implications of the $J/\psi \to \Lambda\bar{\Lambda}$ analysis

ΔΦ=42.3°±0.6°±0.5°



$\Longrightarrow$ Polarization:

max 25%

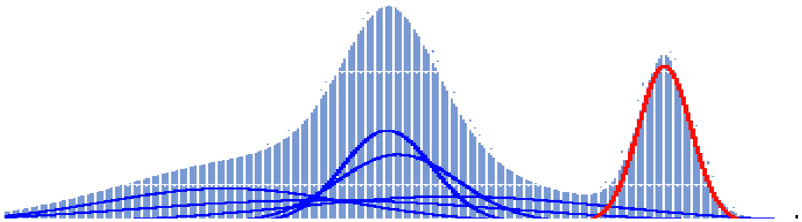
$$\langle\alpha_-\rangle_{\mathrm{BESIII}} = \frac{\alpha_- - \alpha_+}{2} = 0.754(3)(2)$$

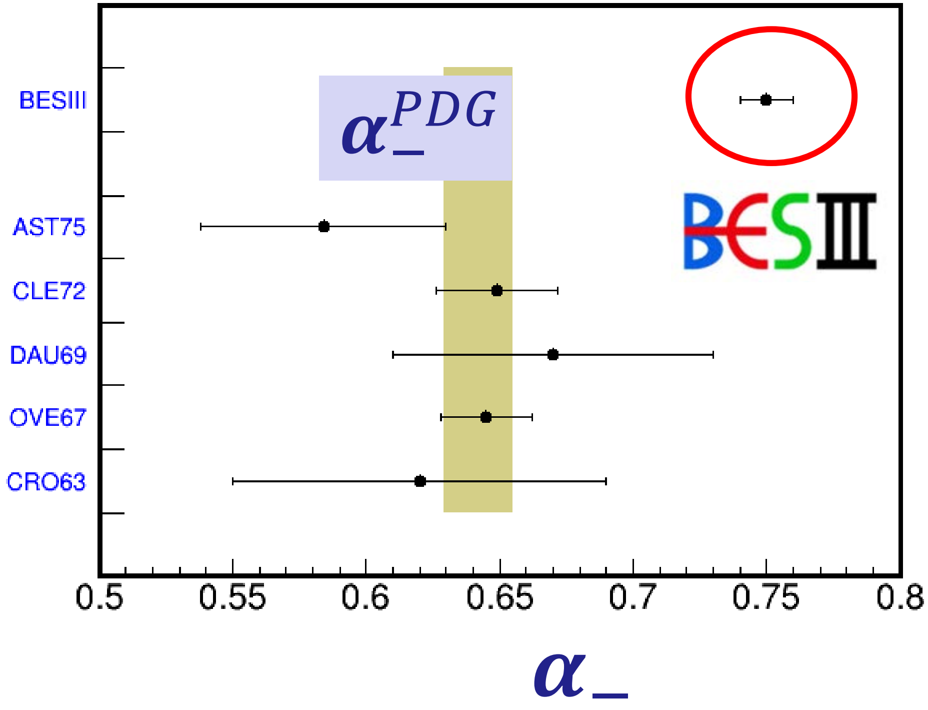
Since $\rho = 0.82$!

α_- =0.721(6)(5)

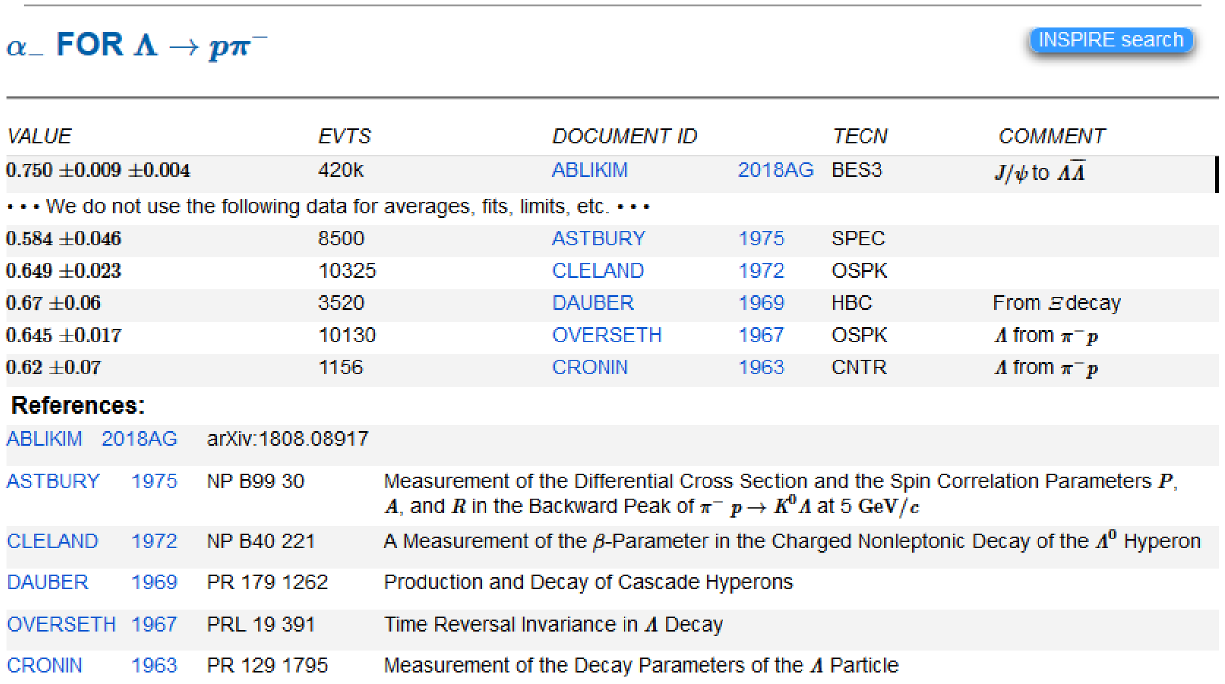
D. Ireland et al arXiv:1904.07616

$\Lambda \to p\pi^-$: $\alpha\_=0.750\pm0.009\pm0.004$





PDG 2019 update



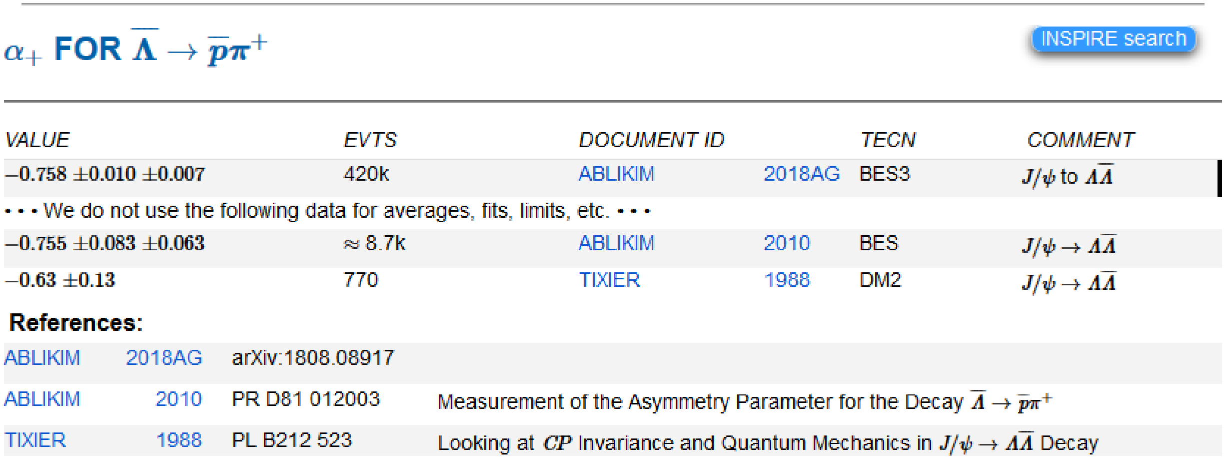
α_{-} FOR $\Lambda \to p\pi^-$

INSPIRE search

VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
0.750 ±0.009 ±0.004	420k	ABLIKIM	2018AG	BES3	J/ψ to $\Lambda\overline{\Lambda}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
0.584 ±0.046	8500	ASTBURY	1975	SPEC	
0.649 ±0.023	10325	CLELAND	1972	OSPK	
0.67 ±0.06	3520	DAUBER	1969	HBC	From Ξ decay
0.645 ±0.017	10130	OVERSETH	1967	OSPK	Λ from $\pi^- p$
0.62 ±0.07	1156	CRONIN	1963	CNTR	Λ from $\pi^- p$

References:

ABLIKIM	2018AG	arXiv:1808.08917	
ASTBURY	1975	NP B99 30	Measurement of the Differential Cross Section and the Spin Correlation Parameters P, A, and R in the Backward Peak of $\pi^- p \to K^0\Lambda$ at 5 GeV/c
CLELAND	1972	NP B40 221	A Measurement of the β-Parameter in the Charged Nonleptonic Decay of the Λ^0 Hyperon
DAUBER	1969	PR 179 1262	Production and Decay of Cascade Hyperons
OVERSETH	1967	PRL 19 391	Time Reversal Invariance in Λ Decay
CRONIN	1963	PR 129 1795	Measurement of the Decay Parameters of the Λ Particle



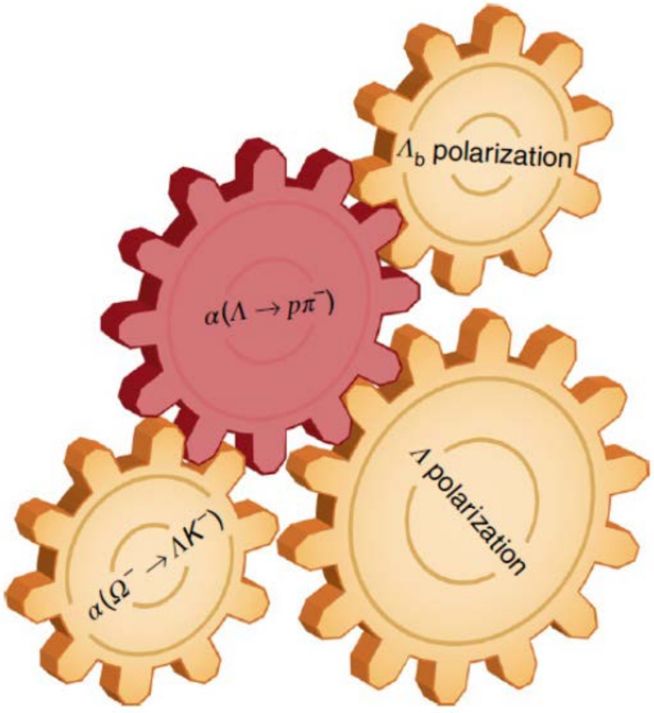
α_{+} FOR $\overline{\Lambda} \to \overline{p}\pi^+$

INSPIRE search

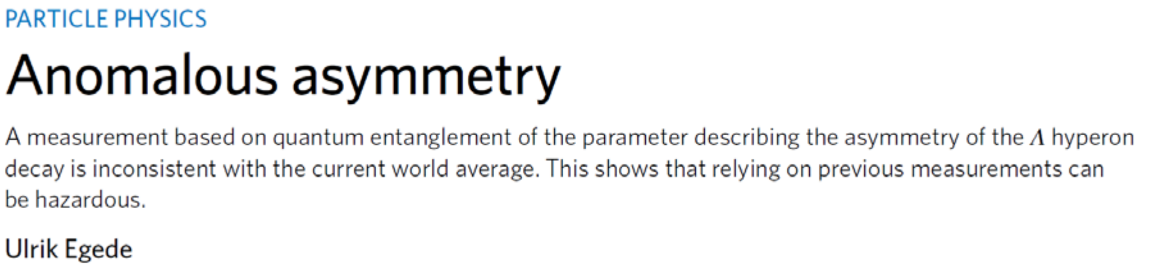
VALUE	EVTS	DOCUMENT ID		TECN	COMMENT
−0.758 ±0.010 ±0.007	420k	ABLIKIM	2018AG	BES3	J/ψ to $\Lambda\overline{\Lambda}$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
−0.755 ±0.083 ±0.063	≈ 8.7k	ABLIKIM	2010	BES	$J/\psi \to \Lambda\overline{\Lambda}$
−0.63 ±0.13	770	TIXIER	1988	DM2	$J/\psi \to \Lambda\overline{\Lambda}$

References:

ABLIKIM	2018AG	arXiv:1808.08917	
ABLIKIM	2010	PR D81 012003	Measurement of the Asymmetry Parameter for the Decay $\overline{\Lambda} \to \overline{p}\pi^+$
TIXIER	1988	PL B212 523	Looking at CP Invariance and Quantum Mechanics in $J/\psi \to \Lambda\overline{\Lambda}$ Decay



news & views



PARTICLE PHYSICS

Anomalous asymmetry

A measurement based on quantum entanglement of the parameter describing the asymmetry of the Λ hyperon decay is inconsistent with the current world average. This shows that relying on previous measurements can be hazardous.

Ulrik Egede

CP violation in hyperon decays?

CP test: $$A_\Lambda = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

A_Λ = -0.006 ± 0.012± 0.007

Previous result:

A_Λ= 0.013 ± 0.021
PS185 PRC54(96)1877

$$J/\psi \rightarrow \Lambda\bar{\Lambda}$$

	Events	Error A_Λ	
BESIII(2018)	**$4.2 \cdot 10^5$**	**$1.2 \cdot 10^{-2}$**	**$1.31\ 10^9$ J/ψ**
BESIII	$3 \cdot 10^6$	$5 \cdot 10^{-3}$	10^{10} J/ψ $L = 0.47 \cdot 10^{33}$ $\Delta E = 0.9$ MeV
SuperTauCharm	$6 \cdot 10^8$	$3 \cdot 10^{-4}$	$L = 10^{35}$ cm^{-2}s^{-1} $2 \cdot 10^{12}$ J/ψ $\Delta E = 0.9$ MeV
SuperTauCharm + reduced ΔE	$3 \cdot 10^9$	$1.4 \cdot 10^{-4}$	$L = 10^{35}$ cm^{-2}s^{-1} 10^{13} J/ψ $\Delta E < 0.9$ MeV? ?

a guess

$-3 \times 10^{-5} \leq A_\Lambda \leq 4 \times 10^{-5}$
$-2 \times 10^{-5} \leq A_\Xi \leq 1 \times 10^{-5}$
$-5 \times 10^{-5} \leq A_{\Xi\Lambda} \leq 5 \times 10^{-5}$

CKM

Tandean,Valencia PRD67, 056001

$$\sigma(A_\Lambda) = \frac{\sqrt{1+\varrho}}{\sqrt{2}\alpha_\Lambda}\sigma(\alpha_\Lambda)$$

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

$d\Gamma \propto W(\boldsymbol{\xi};\boldsymbol{\omega})$ $\boldsymbol{\xi}$ 9 kinematical variables 9D PhSp

Parameters: 2 production + 6 for decay chains

$$\boldsymbol{\omega} = (\alpha_\psi, \Delta\Phi, \overbrace{\alpha_\Xi, \phi_\Xi, \alpha_\Lambda, \bar{\alpha}_\Xi, \bar{\phi}_\Xi, \bar{\alpha}_\Lambda})$$

$$\boxed{W = \sum_{\mu,\bar{\nu}} C_{\mu\bar{\nu}} \sum_{\mu',\bar{\nu}'} a^{\Xi}_{\mu,\mu'} a^{\bar{\Xi}}_{\bar{\nu},\bar{\nu}'} a^{\Lambda}_{\mu',0} a^{\bar{\Lambda}}_{\bar{\nu}',0}}$$

$\Delta\Phi \neq 0$ is not needed!

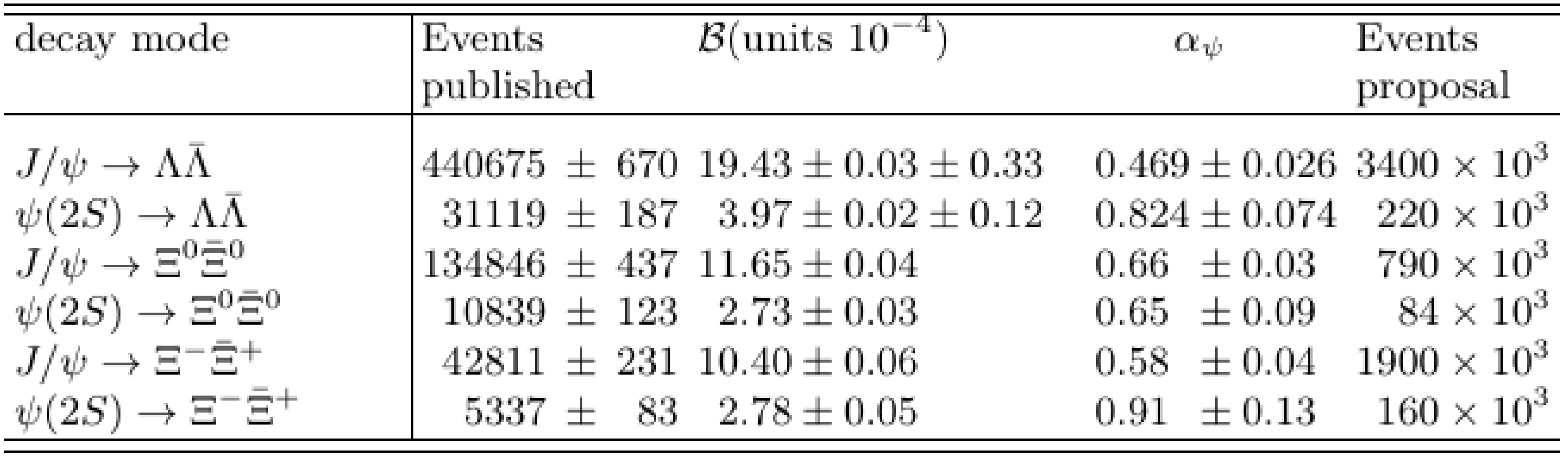
Variables and parameters factorize:

$$W(\boldsymbol{\xi};\boldsymbol{\omega}) = \sum_{k=1}^{M} f_k(\boldsymbol{\omega}) T_k(\boldsymbol{\xi})$$

	$\Xi^-\bar{\Xi}^+$	$\Lambda\bar{\Lambda}$
$\Delta\Phi \neq 0:$	$M = 72$	(7)
$\Delta\Phi = 0:$	$M = 56$	(5)

E.Perotti, G.Faldt, AK, S.Leupold,JJ.Song PRD99 (2019)056008

Expected number of events in BESIII



decay mode	Events published	$\mathcal{B}$(units 10^{-4})	α_ψ	Events proposal
$J/\psi \to \Lambda\bar{\Lambda}$	440675 ± 670	$19.43 \pm 0.03 \pm 0.33$	0.469 ± 0.026	3400×10^3
$\psi(2S) \to \Lambda\bar{\Lambda}$	31119 ± 187	$3.97 \pm 0.02 \pm 0.12$	0.824 ± 0.074	220×10^3
$J/\psi \to \Xi^0\bar{\Xi}^0$	134846 ± 437	11.65 ± 0.04	0.66 ± 0.03	790×10^3
$\psi(2S) \to \Xi^0\bar{\Xi}^0$	10839 ± 123	2.73 ± 0.03	0.65 ± 0.09	84×10^3
$J/\psi \to \Xi^-\bar{\Xi}^+$	42811 ± 231	10.40 ± 0.06	0.58 ± 0.04	1900×10^3
$\psi(2S) \to \Xi^-\bar{\Xi}^+$	5337 ± 83	2.78 ± 0.05	0.91 ± 0.13	160×10^3

scaled to

Feb 2019: 10^{10} J/ψ

BESIII Phys book 3.2×10^{9} ψ(2S)

Sensitivity estimate

detection efficiency constant

validation

$$e^+e^- \to J/\psi \to \Lambda\bar{\Lambda}$$

	$\bar{\alpha}_\Lambda$	α_ψ	$\Delta\Phi$
α_Λ	0.87	-0.05	-0.07
$\bar{\alpha}_\Lambda$		0.05	0.07
α_ψ			0.28

$$\sigma(\alpha_\Lambda) = \frac{7}{\sqrt{N}} \qquad (0.011)$$

$$\sigma(A_\Lambda) = \frac{9}{\sqrt{N}} \qquad (0.014)$$

$e^+e^- \to J/\psi \to \Xi\bar{\Xi}$

Correlation matrix:

$$\sigma(\alpha_\Xi) = \frac{2}{\sqrt{N}}$$

$$\sigma(\phi_\Xi) = \frac{6}{\sqrt{N}}$$

$$\sigma(\alpha_\Lambda) = \frac{3}{\sqrt{N}}$$

	$\bar{\alpha}_\Xi$	α_Λ	$\bar{\alpha}_\Lambda$	ϕ_Ξ	$\bar{\phi}_\Xi$	α_ψ	$\Delta\Phi$
α_Ξ	0.03	0.37	0.11	0.0	0.0	0.0	0.0
$\bar{\alpha}_\Xi$		0.11	0.37	0.0	0.0	0.0	0.0
α_Λ			0.43	0.0	0.0	-0.1	0.0
$\bar{\alpha}_\Lambda$				0.0	0.0	0.1	0.0
ϕ_Ξ					-0.15	0.0	0.0
$\bar{\phi}_\Xi$						0.0	0.0
α_ψ							0.0

$\Delta\Phi = 0$

$$\sigma(A_\Lambda) = \frac{3.3}{\sqrt{N}}$$

P.Adlarson, AK

$e^+e^- \to J/\psi \to \Xi\bar{\Xi}$

Correlation matrix:

	$\bar{\alpha}_\Xi$	α_Λ	$\bar{\alpha}_\Lambda$	ϕ_Ξ	$\bar{\phi}_\Xi$	α_ψ	$\Delta\Phi$
α_Ξ	0.03	0.37	0.11	0.0	0.0	0.0	0.0
$\bar{\alpha}_\Xi$		0.11	0.37	0.0	0.0	0.0	0.0
α_Λ			0.43	0.0	0.0	-0.1	0.0
$\bar{\alpha}_\Lambda$				0.0	0.0	0.1	0.0
ϕ_Ξ					-0.15	0.0	0.0
$\bar{\phi}_\Xi$						0.0	0.0
α_ψ							0.0

$\Delta\Phi = 0$

$$\sigma(\alpha_\Xi) = \frac{2}{\sqrt{N}}$$

$$\sigma(\phi_\Xi) = \frac{6}{\sqrt{N}}$$

$$\sigma(\alpha_\Lambda) = \frac{3}{\sqrt{N}}$$

	$\bar{\alpha}_\Xi$	α_Λ	$\bar{\alpha}_\Lambda$
α_Ξ	0.01	0.31	0.07
$\bar{\alpha}_\Xi$		0.07	0.31
α_Λ			0.39

$\Delta\Phi = \frac{\pi}{2}$

$$\sigma(A_\Lambda) = \frac{3.3}{\sqrt{N}}$$

P.Adlarson, AK

Conclusions:

Polarization in $e^+e^- \to \Lambda\bar{\Lambda}$ observed at J/ψ [phase close to 40°]

J/ψ and ψ' decays into hyperon-antihyperon:
unique spin entangled system for CP tests and for determination of (anti-)hyperon decay parameters

In progress: analysis using 10^{10} J/ψ collected, more ψ' data ...

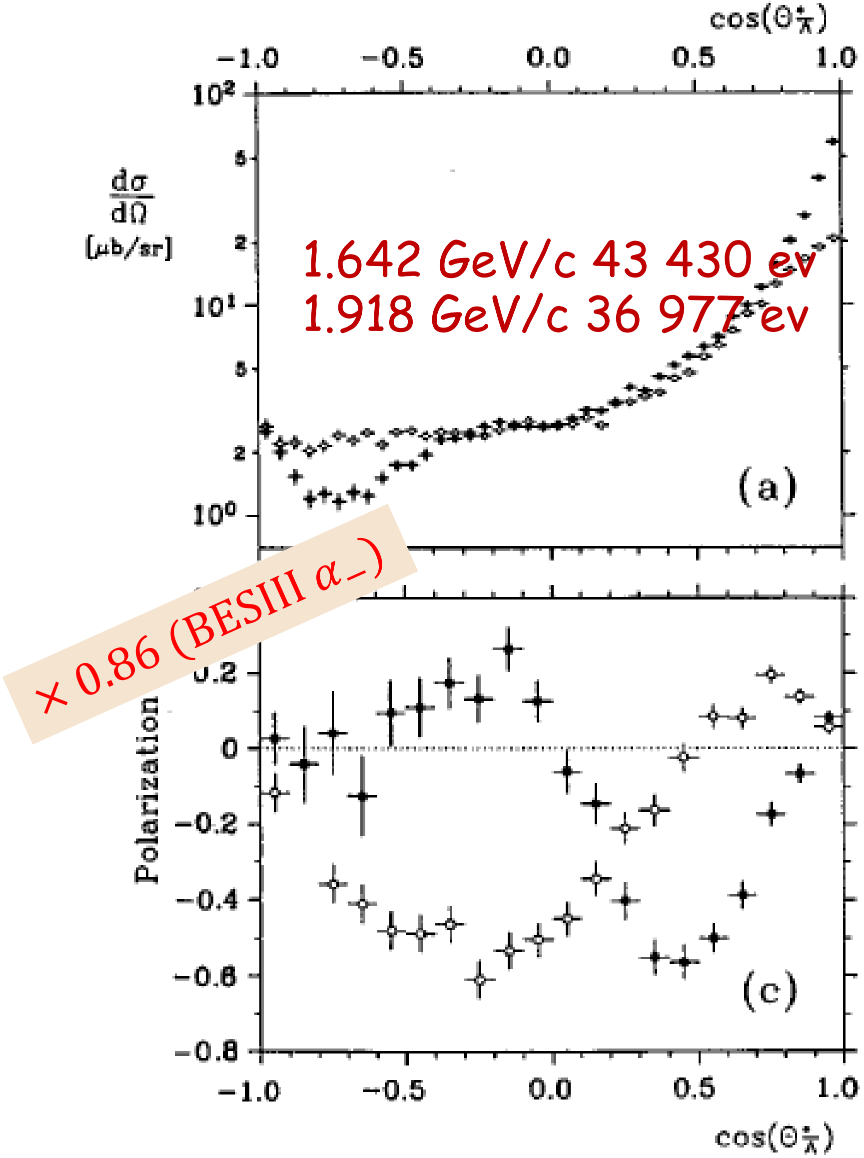
Prospect for a CP violation signal at Super Tau Charm Factories

α_-: 0.642±0.012 (PDG1978-2018) ⇨ 0.750±0.009±0.004

Reset of α_- values in PDG 2019

Thank you!

$\overline{p}p \to \overline{\Lambda}\Lambda$



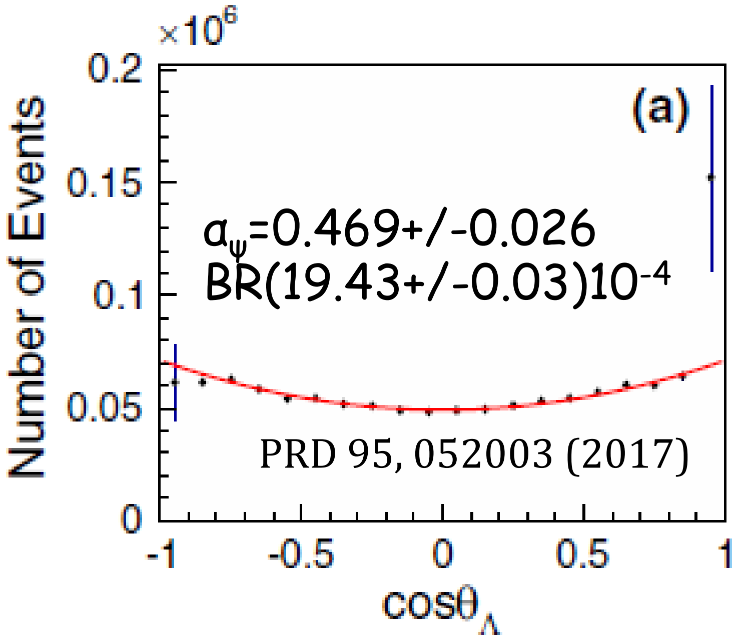
1.642 GeV/c 43 430 ev
1.918 GeV/c 36 977 ev

× 0.86 (BESIII α_-)

PS185, PRC54 (1996) 1877

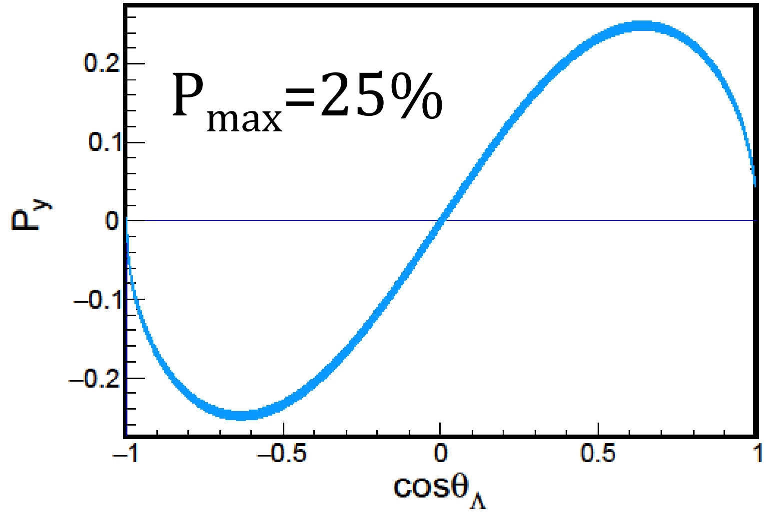
5 parameters at each θ_Λ

$e^+e^- \to \gamma^* \to J/\psi \to \Lambda\bar{\Lambda}$



α_ψ=0.469+/-0.026
BR(19.43+/-0.03)10^{-4}

PRD 95, 052003 (2017)



P_{max}=25%

2 global parameters