Baryon Polarization in the coherent $B\bar{B}$ pairs

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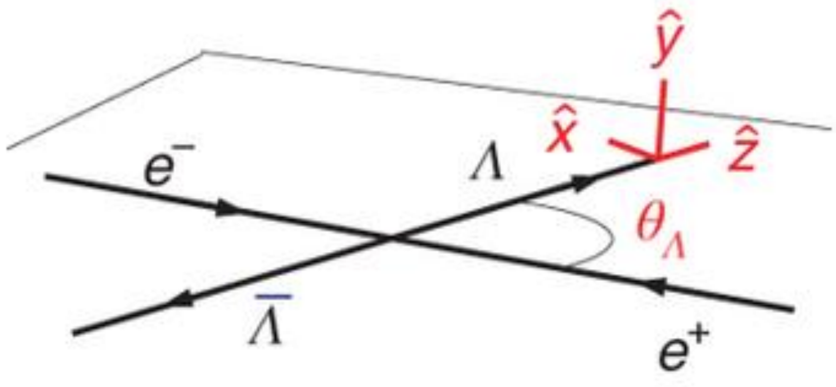
$B\bar{B}$ producted

- Decay from $J/\psi, \psi(2S)$
  - $e^+e^- \to \psi \to B\bar{B}$
- Produce by e^+e^- annihilation directly
  - $e^+e^- \to \gamma^* \to B\bar{B}$

$B\bar{B}\ J^{CP}: 1^{--}$



Polarization and spin

- Only s_x or s_y or s_z could be known
- All three competences of polarization could be known
  - $p_i = < \hat{s}_i >$

Look into polarization of B

-take Λ for instance

- Decay Amplitude of Λ
  - $|M|^2 \sim 1 + \alpha_- \hat{s}_\Lambda \cdot n_p$
  - n_p is the flight direction of proton
- Angle distribution
  - $\frac{dN}{d\Omega} \sim 1 + \alpha_- P_\Lambda . n_p$
  - $< n_p^i n_p^j > = \delta^{ij}$
- So observable n_p^x, n_p^y, n_p^z for P_x, P_y, P_z

Polarized B produced in e^+e^- annihilation

- Total amplitude

$$M = \frac{ie^2}{q^2} j_\mu \bar{u}(p_1) \left(F_1 \gamma_\mu + \frac{F_2}{2m} p_\nu \sigma^{\nu\mu} \gamma_5 \right) \nu(p_2)$$

- electric and magnetic form factors

$$G_M = F_1 + F_2, G_E = F_1 + \tau F_2 \quad \text{with } \tau = \frac{(p_1+p_2)^2}{4M^2}.$$

$$d\sigma \sim 1 + \alpha_\psi \cos^2\theta_{\bar{\Lambda}} + \left(\alpha_\psi + \cos^2\theta_\Lambda\right) s^z_\Lambda s^z_{\bar{\Lambda}} + \sin^2\theta_{\bar{\Lambda}} s^x_\Lambda s^x_{\bar{\Lambda}} - \alpha_\psi \sin^2\theta_{\bar{\Lambda}} s^y_\Lambda s^y_{\bar{\Lambda}}$$

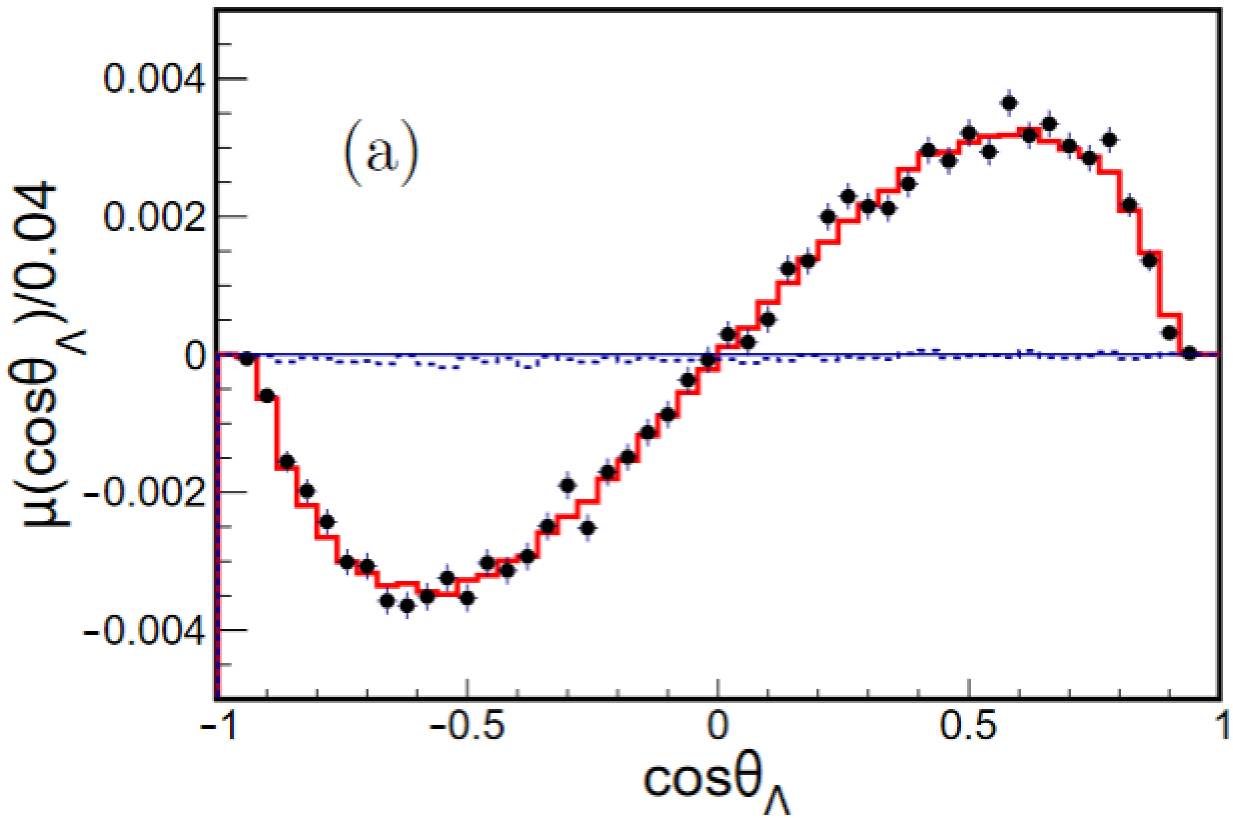
$$+ \sqrt{1-\alpha_\psi^2} \cos\Phi \sin\theta_{\bar{\Lambda}} \cos\theta_{\bar{\Lambda}} \left(s^x_\Lambda s^z_{\bar{\Lambda}} + s^z_\Lambda s^x_{\bar{\Lambda}}\right) + \sqrt{1-\alpha_\psi^2} \sin\Phi \sin\theta_{\bar{\Lambda}} \cos\theta_{\bar{\Lambda}} (s^y_\Lambda + s^y_{\bar{\Lambda}})$$

$e_y = e_{e^+} \times e_\Lambda$

- Only $< s^y >$ could be none zero, if $\sin\Phi \neq 0$

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

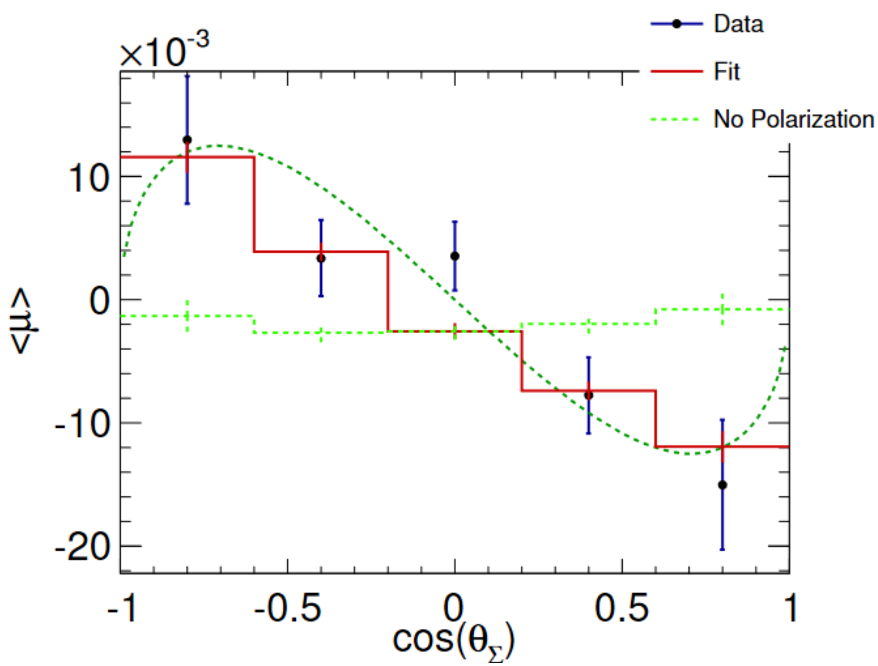
Nature Physics (2019)



$$\mu(\cos\theta_\Lambda) = (1/N)\ \sum_i^{N(\theta_\Lambda)} (n_{1,y}^{(i)} - n_{2,y}^{(i)}),$$

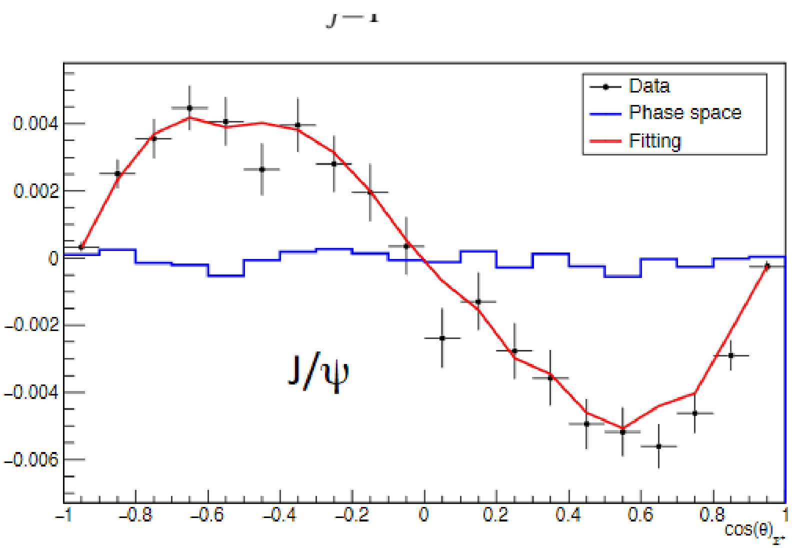
Evidence of polarization in the entangled $\Sigma^0\bar{\Sigma}^0$ *pairs produced at* $\sqrt{s} = 3.097\ GeV$

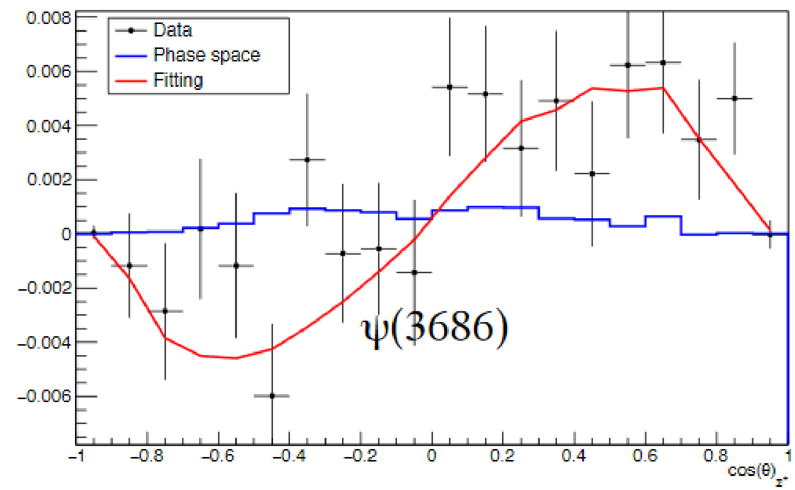
$$M(\Sigma^0 \to \gamma\Lambda, \Lambda \to p\pi) \sim 1 + \beta_1 \vec{s}_\Sigma \cdot \hat{p}_\Lambda$$
$$\sim 1 - \alpha_\Lambda cos(\theta_p) \vec{s}_\Sigma \cdot \hat{p}_\Lambda$$



$$\mu = \cos\theta_p \sin\theta_\Lambda \sin\phi_\Lambda + \cos\theta_{\bar{p}} \sin\theta_{\bar{\Lambda}} \sin\phi_{\bar{\Lambda}}$$

J/ψ and $\psi(3686)$ -> Σ^+ anti-Σ^-





$$d\mu/d\cos\theta_{\Sigma} \sim \sqrt{1-\alpha_{\psi}^{2}}\alpha_{-}\sin\Delta\Phi\cos\theta_{\Sigma}\sin\theta_{\Sigma}$$

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