Observation of polarization in $e^+e^- \to$ baryon antibaryon reactions

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

J/ψ and ψ(2S) decays to $B_1\bar{B}_2$

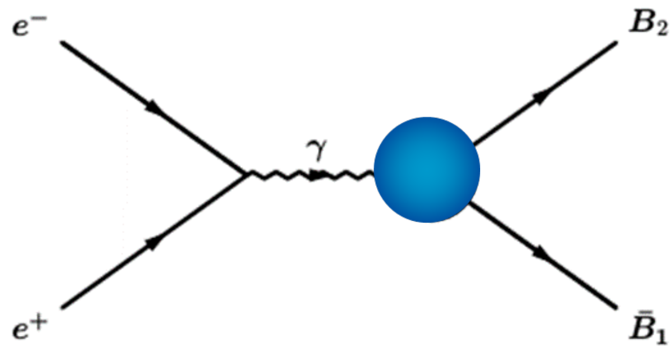
Spin polarization

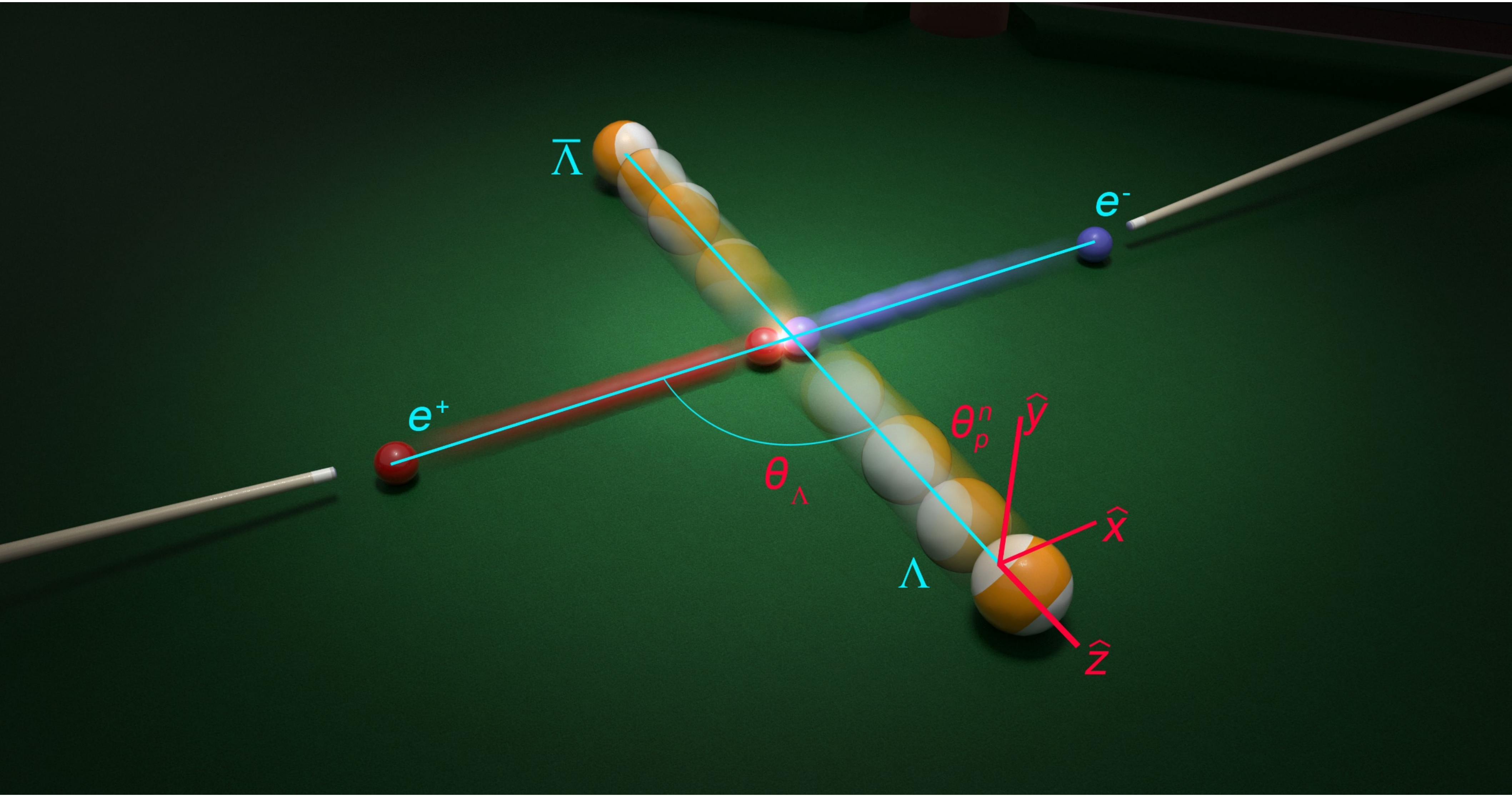
Hyperon decay parameters and CP tests

Outlook

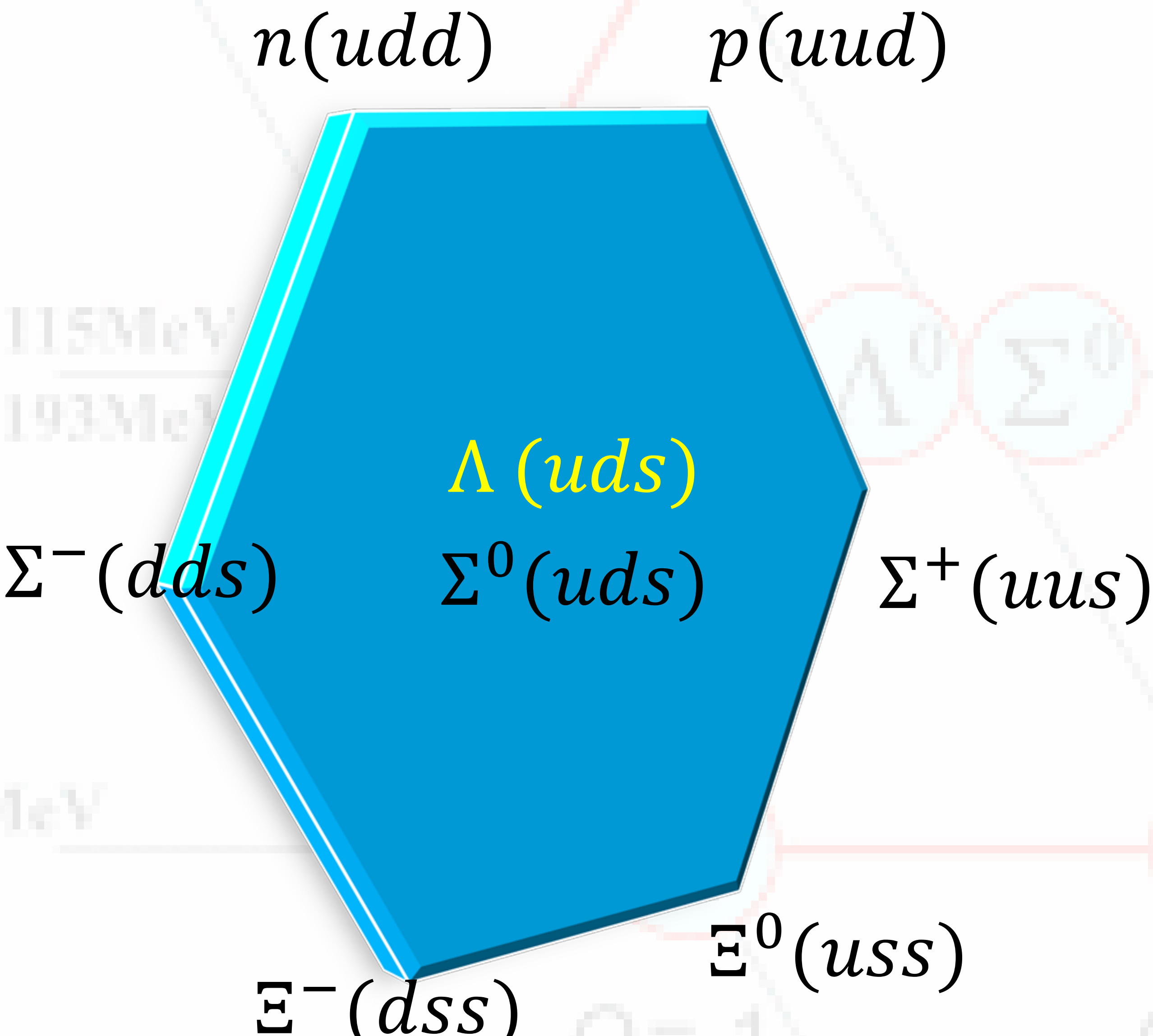
IHEP, 2018-05-10

$e^+e^- \rightarrow \mathrm{B_1\overline{B}_2}$





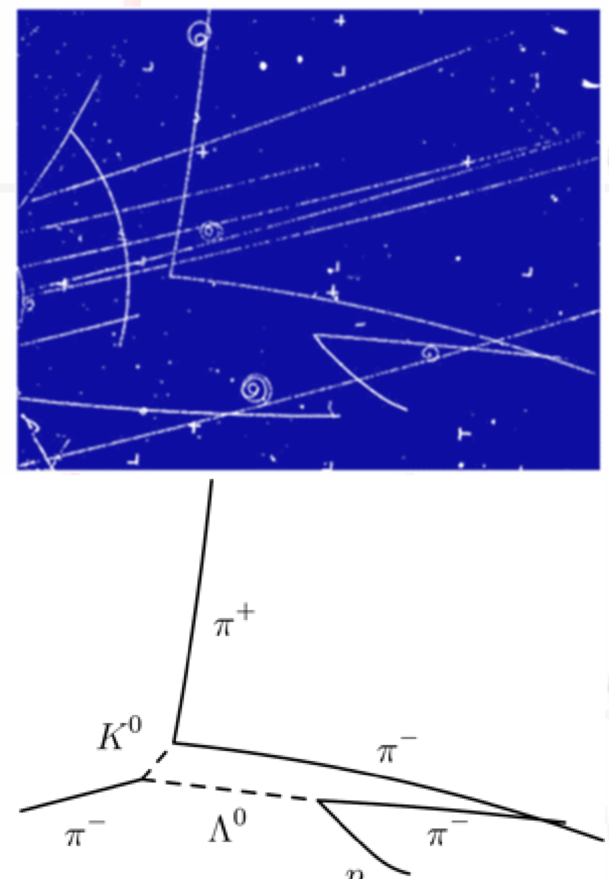
Spin ½ baryon octet:



Λ hyperon:

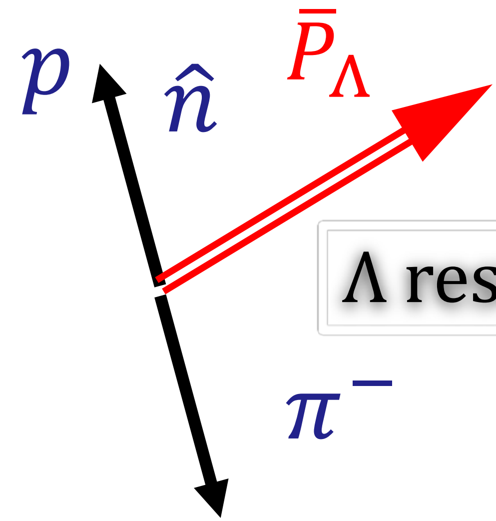
$$M_\Lambda = 1.115\ \mathrm{GeV}/c^2$$

$$c\tau = 7.9\ \mathrm{cm}$$



Weak decay $\Lambda \to p\pi^-$

$$\frac{d\Gamma}{d\Omega} = \frac{1}{4\pi}(1 + \alpha\_\hat{n}\,\bar{P}_\Lambda)$$



Λ rest frame

p=100 MeV/c

Hyperon polarization is determined from its own decay

If proton polarization could be measured there is one more decay parameter ϕ ...

$$\alpha_Y = \frac{2\mathrm{Re}(s^* p)}{|s|^2 + |p|^2}, \quad \beta_Y = \frac{2\mathrm{Im}(s^* p)}{|s|^2 + |p|^2} = \sqrt{1-\alpha_Y^2}\sin\phi_\Lambda$$

$$\gamma_Y = \frac{|s|^2 - |p|^2}{|s|^2 + |p|^2} = \sqrt{1-\alpha_Y^2}\cos\phi_Y$$

$$\boldsymbol{P}_B = \frac{(\alpha_Y + \boldsymbol{P}_Y\cdot\hat{\boldsymbol{n}})\hat{\boldsymbol{n}} + \beta_Y \boldsymbol{P}_Y \times \hat{\boldsymbol{n}} + \gamma_Y \hat{\boldsymbol{n}} \times \boldsymbol{P}_Y \times \hat{\boldsymbol{n}}}{1 + \alpha_Y \boldsymbol{P}_Y\cdot\hat{\boldsymbol{n}}}$$

Hyperon properties

many experiments rely on this value!

hyperon	Mass [GeV/c^2]	$c\tau$ [cm]	decay (BF)	α	ϕ
$\Lambda(uds)$	1.116	7.9	$p\pi^-$ (63.9%)	**0.642 ± 0.013**	$-6.5° \pm 3.5°$
			$n\pi^0$ (35.8%)		
$\bar{\Lambda}(\bar{u}\bar{d}\bar{s})$			$\bar{p}\pi^+$ (63.9%)	**−0.71 ± 0.08**	–
$\Sigma^-(dds)$	1.197	4.4	$n\pi^-$ (99.8%)	-0.068 ± 0.008	$10° \pm 15°$
$\Sigma^+(uus)$	1.189	2.4	$p\pi^0$ (51.6%)	-0.980 ± 0.017	$36° \pm 34°$
			$n\pi^+$ (48.3%)	-0.068 ± 0.013	$167 \pm 20°$
$\Xi^0(uss)$	1.315	8.7	$\Lambda\pi^0$ (99.5%)	-0.406 ± 0.085	$21° \pm 12°$
$\Xi^-(dss)$	1.321	5.1	$\Lambda\pi^-$ (99.8%)	-0.458 ± 0.012	$-2.1° \pm 0.8°$

$$A_{CP} = \frac{\alpha + \bar{\alpha}}{\alpha - \bar{\alpha}} \qquad B_{CP} = \frac{\beta + \bar{\beta}}{\beta - \bar{\beta}}$$

Sensitive tool to search for CP violation for baryons

Hyperons at BESIII

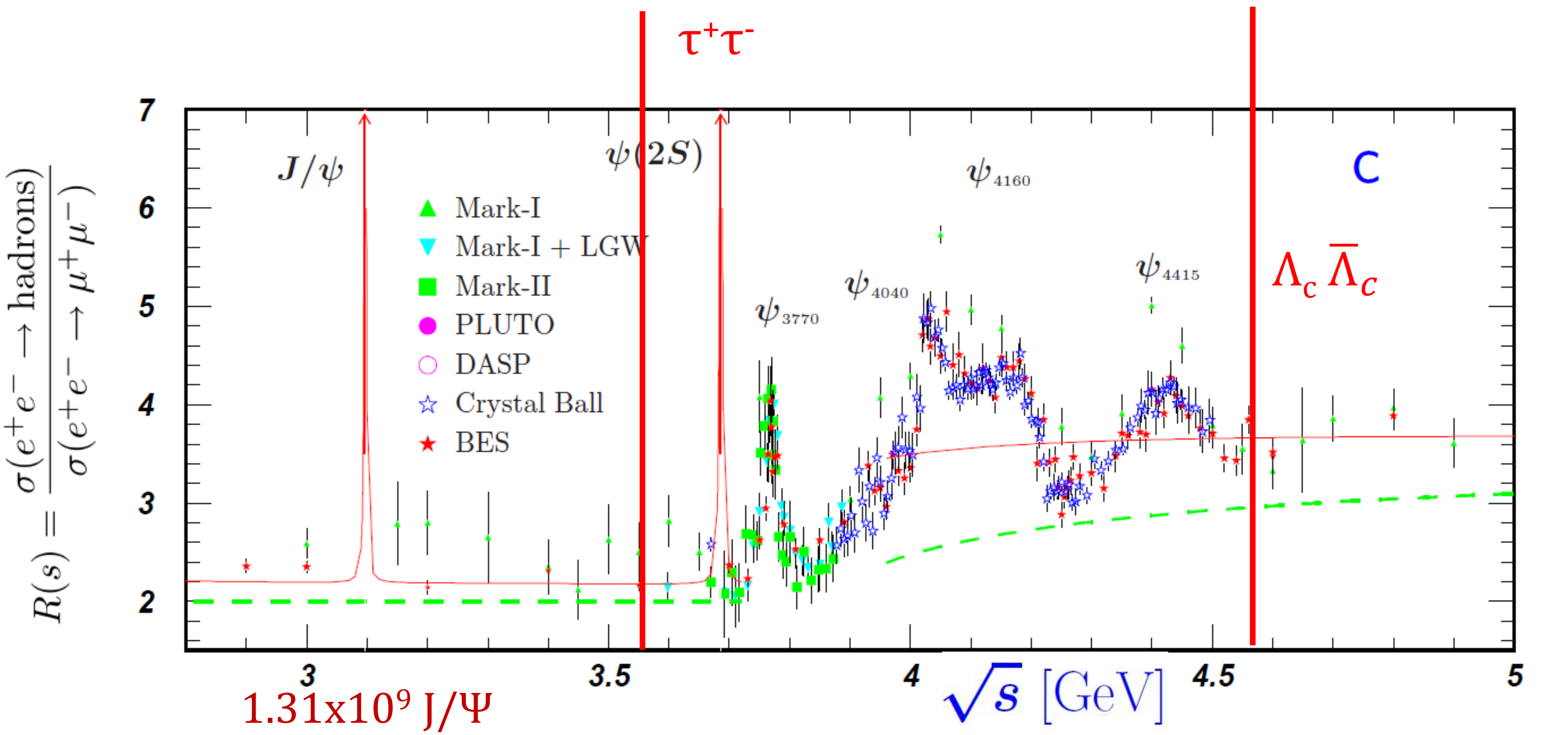
Thresholds:

$\Lambda\bar{\Lambda}$: 2.231 GeV $\Sigma^{+}\bar{\Sigma}^{-}$ 2.379 GeV

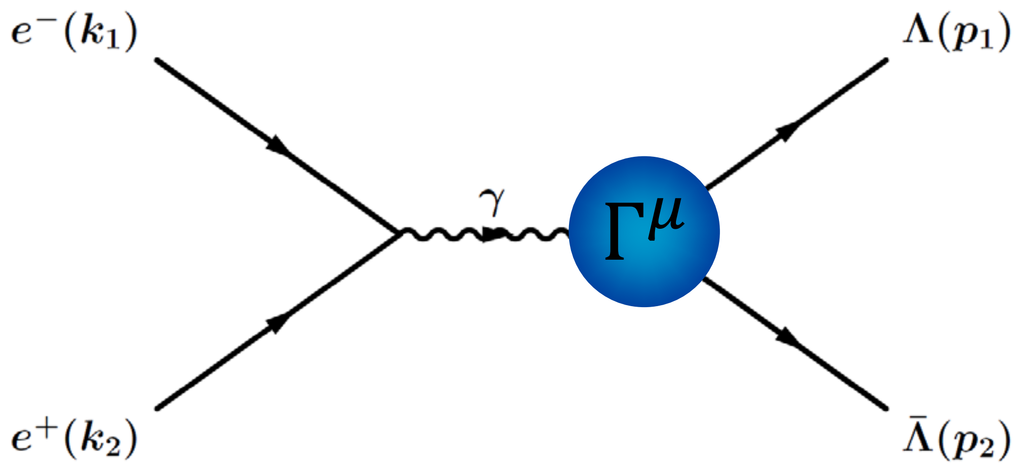
$\Sigma^{0}\bar{\Sigma}^{0}$ 2.385 GeV $\Sigma^{-}\bar{\Sigma}^{+}$ 2.395 GeV

$\Xi^{0}\bar{\Xi}^{0}$ 2.630 GeV $\Xi^{-}\bar{\Xi}^{+}$ 2.643 GeV

$\Lambda\bar{\Sigma}^{0}$ 2.308 GeV   ($\Omega\bar{\Omega}$ 3.345 GeV)



Born amplitude for $e^+e^- \to \gamma^* \to B_1\,\bar{B}_2$



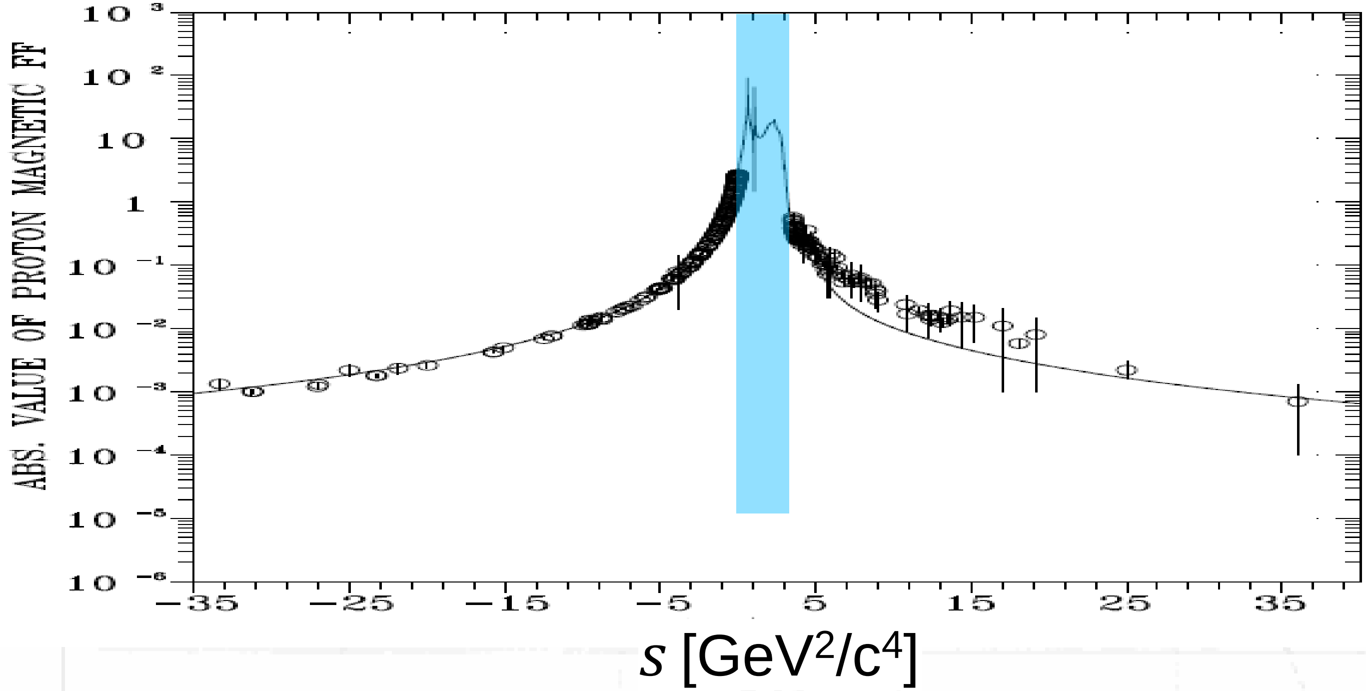
$$\Gamma^\mu(p_1, p_2) = -ie\left[\gamma^\mu F_1(s) + i\frac{\sigma^{\mu\nu}}{M_{B_1} + M_{\bar{B}_2}} q_\nu F_2(s)\right]$$

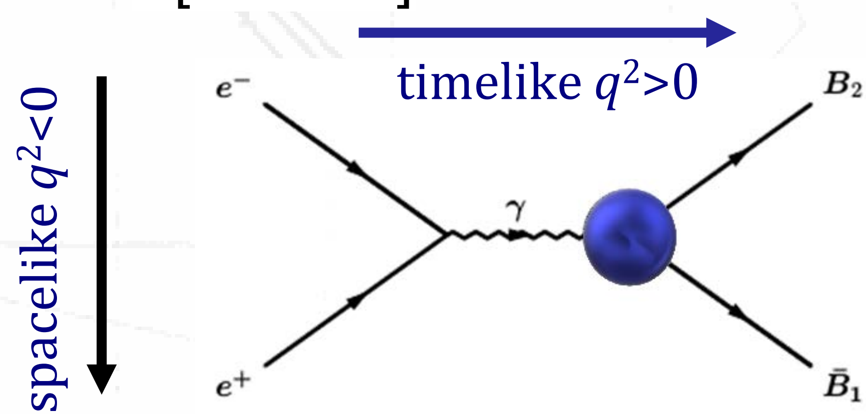
$$s = (p_1 + p_2)^2$$
$$q = p_1 - p_2$$

F_1 (Dirac) helicity conserving,
F_2 (Pauli) helicity violating Form Factors

Valid for any ½ baryon anti-baryon pair:
- charged/neutral *e.g.*: $p\bar{p}, n\bar{n}, \Lambda\bar{\Lambda}$, ...
- $B_1\bar{B}_2$ could be different baryons *e.g.*: $\Lambda\bar{\Sigma}^0$
- $F_1(s), F_2(s)$ are complex for $s > 4m_\pi^2$

Baryon Electromagnetic Form Factors





$\gamma^* \rightarrow B_1\overline{B}_2$

$B_1 \rightarrow B_2 e$+e-

$p\overline{p} \rightarrow e$+$e$-

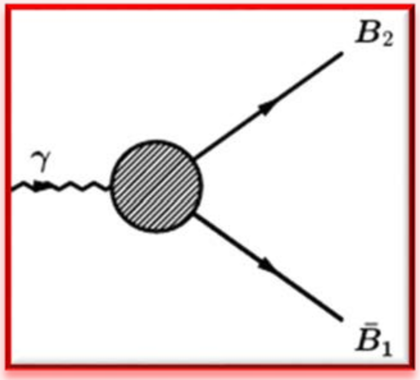
$p\overline{p} \rightarrow \pi^0 e$+$e$-

elastic: $B_2=B_1$

($B_2 \neq B_1$ transition)

Baryon Electromagnetic Form Factors

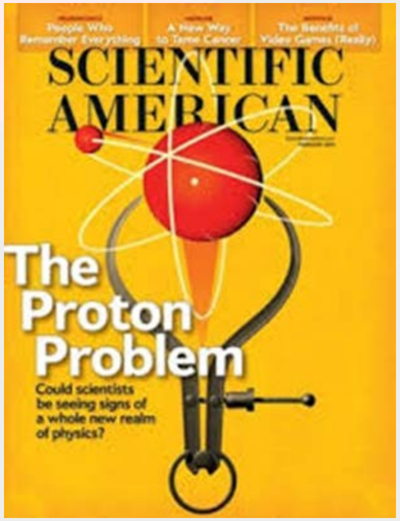
γ*BB vertex functions – Form Factors (FFs)



Baryon with spin s ⇨ $2s+1$ FFs

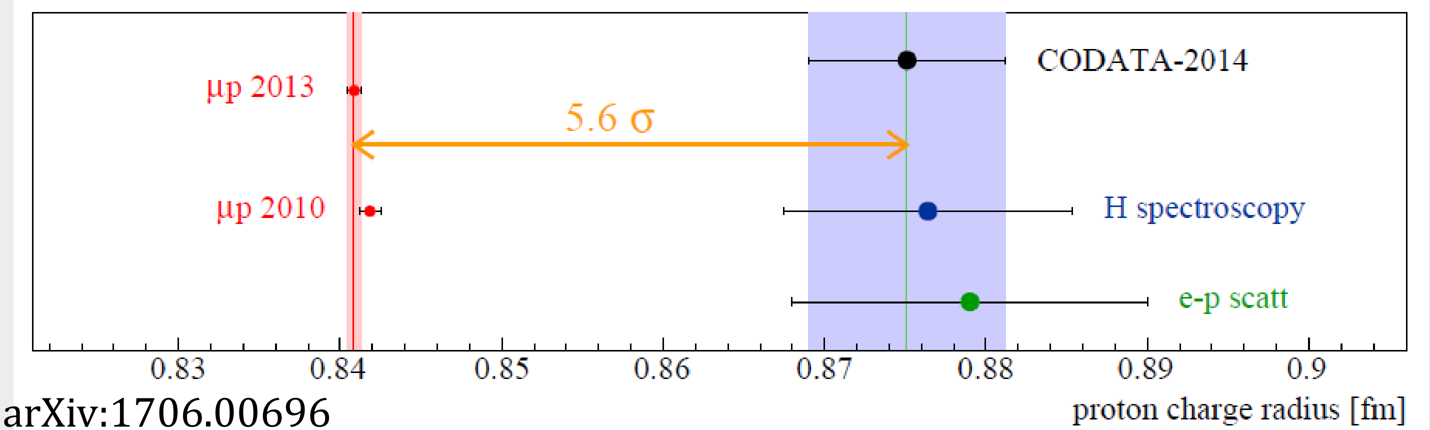
- Functions of photon virtuality q^2
- Distribution of charge + magnetization
  ⇨ radius is related to FFs slope at $q^2=0$
- Connect to distribution, dynamics of quarks in hadrons

Considered to be well understood for nucleons (space-like)



Unexpected results + old paradigms falsified:

- Proton radius puzzle
- New type of experiments
- High statistics and precision



arXiv:1706.00696

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

Sachs Form Factors (FFs):

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

$$\tau = \frac{s}{(M_{B_1} + M_{\bar{B}_2})^2}$$

$$\frac{d\sigma}{d\cos\theta} = \frac{\alpha^2\beta}{4s}|G_M|^2\left[(1+\cos^2\theta) + \frac{1}{\tau}R^2\sin^2\theta\right]$$

$$R = \left|\frac{G_E}{G_M}\right|$$

No G_M and G_E interference terms in the cross section

$$G_E = R G_M e^{i\Delta\Phi}$$

Angular distribution given by just one parameter:

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

$$\alpha_{\psi} = \frac{\tau - R^2}{\tau + R^2}$$

At threshold:

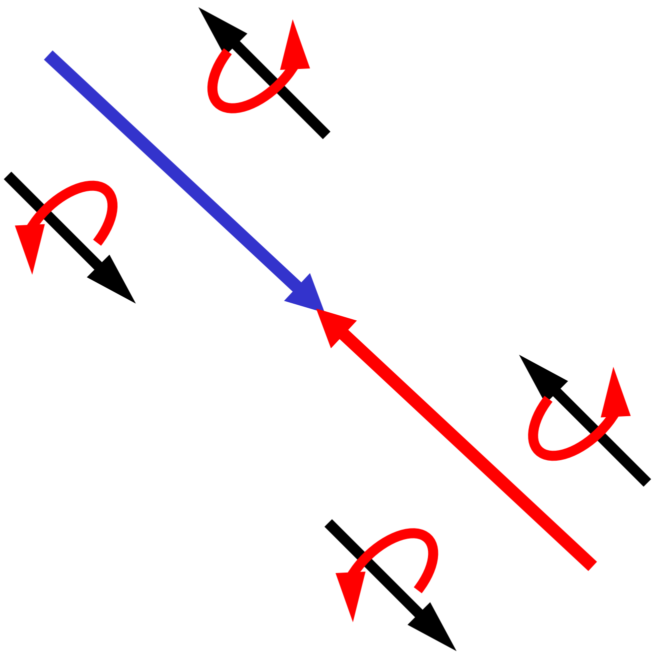
$$\tau = 1 \;\Rightarrow\; G_M = G_E \Rightarrow R = 1,\; \alpha_{\psi} = 0,\; \Delta\Phi = 0$$

Full process at Born level described by two Form Factors (two complex numbers) i.e. three real parameters:

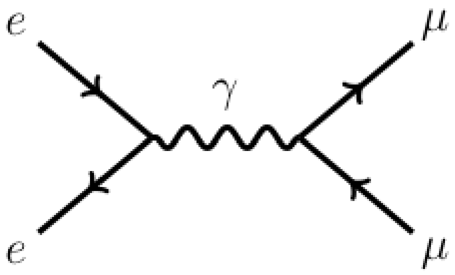
σ, α_{ψ} and phase $\Delta\Phi$

Cross-section for e+e− → μ+μ−

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

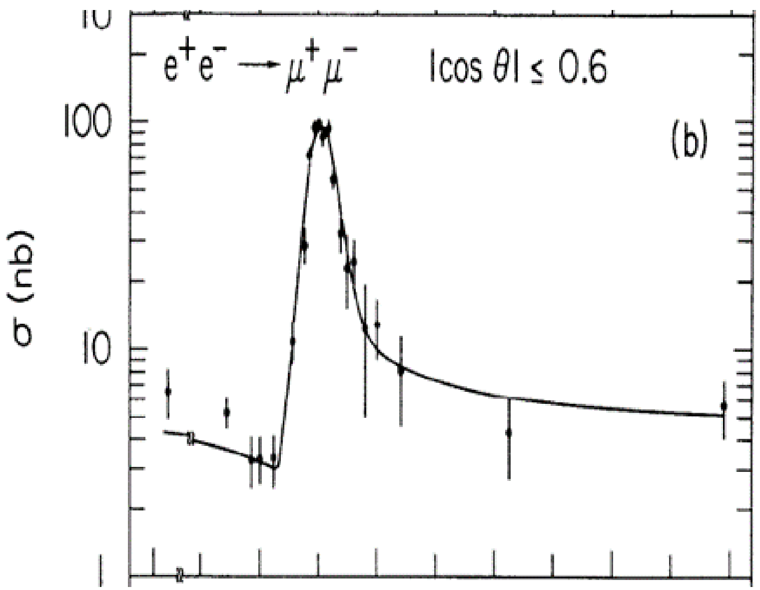


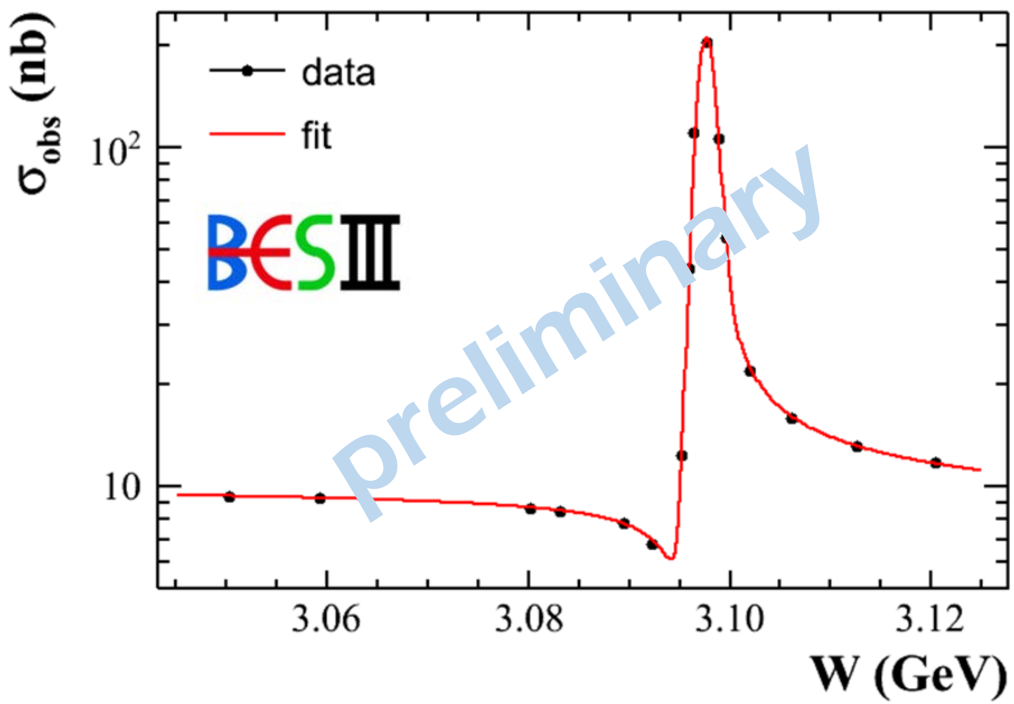
$$\frac{d\sigma}{d\Omega} = \frac{\alpha^2}{4s}(1 + \cos^2\theta)$$

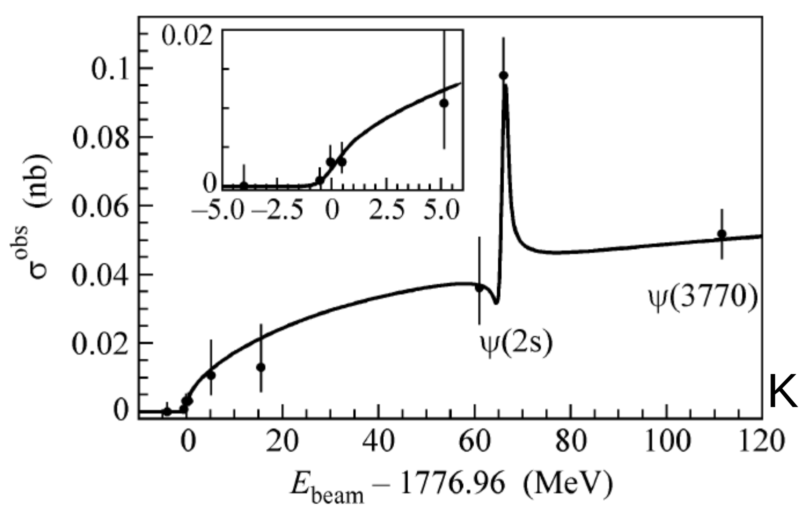


$$F_1(0) = 1, \quad F_2(0) = a_\mu$$

Cross-section for $e^+e^- \to \mu^+\mu^-$



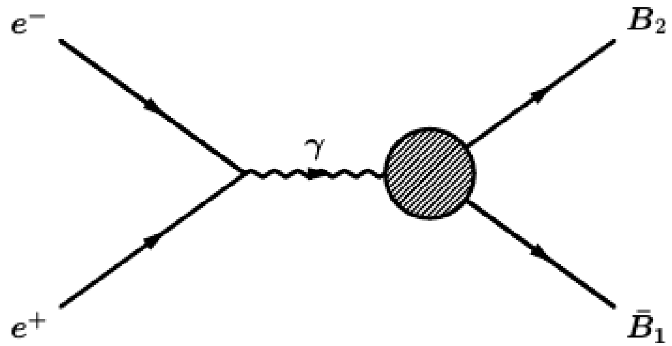




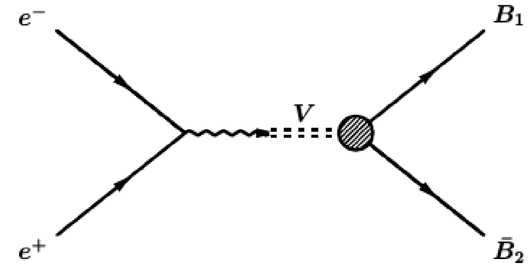
KEDR, JETP Lett. 85, 347

for $e^+e^- \to \tau^+\tau^-$

Baryon FFs: (elastic and transition FFs)



$$= \sum_V$$

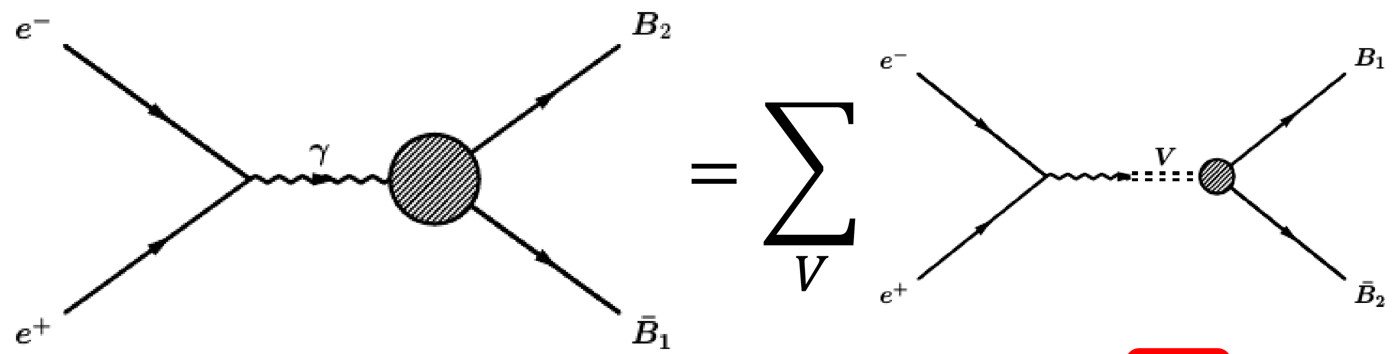


Baryons B_1 and $\bar{B}_2$
(spin 1/2, 3/2, ...)

$V = \rho, \omega, \varphi, \ldots, J/\psi, \psi(2S), \ldots$

Polarization in baryon FFs:
Dubnickova, Dubnicka, Rekalo
Nuovo Cim. A109 (1996) 241
Gakh, Tomasi-Gustafsson Nucl.Phys. A771 (2006) 169
Czyz, Grzelinska, Kuhn PRD75 (2007) 074026
Fäldt EPJ A51 (2015) 74; EPJ A52 (2016)141

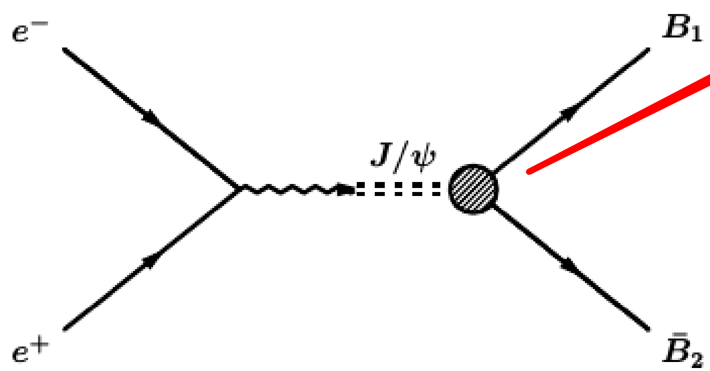
Baryon FFs: (elastic and transition FFs)



Baryons B_1 and $\bar{B}_2$ (spin 1/2, 3/2, ...)

$V = \rho, \omega, \varphi, \ldots, J/\psi, \psi(2S), \ldots$

vs J/ψ decay:



Processes described by two Form Factors (two complex numbers) i.e. three real parameters:

BF, α_ψ and phase $\Delta\Phi$

Fäldt, Kupsc PLB772 (2017) 16

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

Decay mode	Events	$\mathcal{B}(\times 10^{-4})$
$J/\psi \to \Lambda\bar{\Lambda}$	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	$2.44 \pm 0.03 \pm 0.11$
$J/\psi \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	102762 ± 852	10.71 ± 0.09
$J/\psi \to \Xi^0\bar{\Xi}^0$	134846 ± 437	11.65 ± 0.04
$\psi(2S) \to \Sigma(1385)^0\bar{\Sigma}(1385)^0$	2214 ± 148	0.69 ± 0.05
$\psi(2S) \to \Xi^0\bar{\Xi}^0$	10839 ± 123	2.73 ± 0.03
$J/\psi \to \Xi^-\bar{\Xi}^+$	42811 ± 231	10.40 ± 0.06
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$	42595 ± 467	10.96 ± 0.12
$J/\psi \to \Sigma(1385)^+\bar{\Sigma}(1385)^-$	52523 ± 596	12.58 ± 0.14
$\psi(2S) \to \Xi^-\bar{\Xi}^+$	5337 ± 83	2.78 ± 0.05
$\psi(2S) \to \Sigma(1385)^-\bar{\Sigma}(1385)^+$	1375 ± 98	0.85 ± 0.06
$\psi(2S) \to \Sigma(1385)^+\bar{\Sigma}(1385)^-$	1470 ± 95	0.84 ± 0.05

Only α_ψ extracted

BESIII

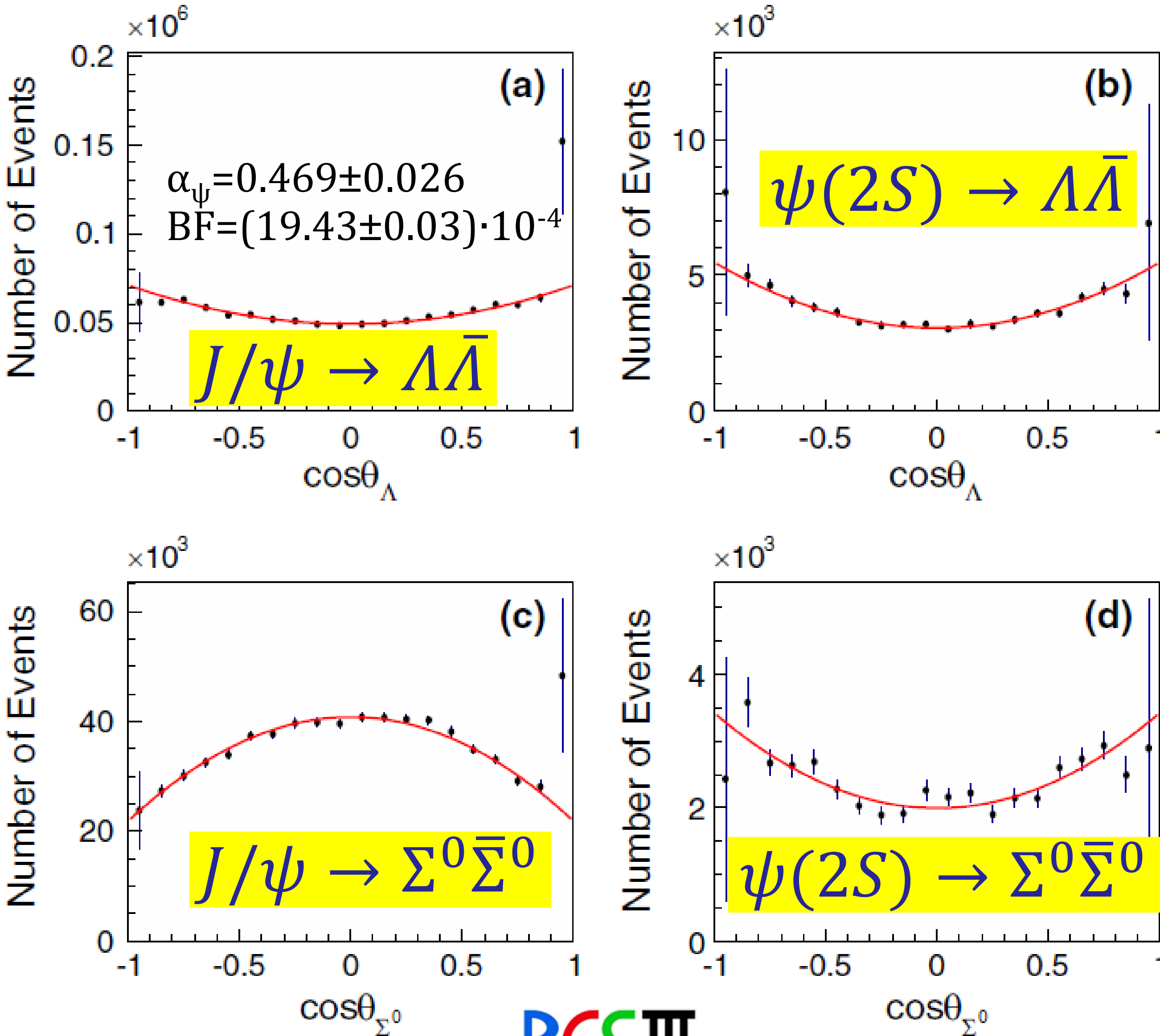
Phys. Rev. D 93, 072003 (2016)
PLB770(2017)217

Phys. Rev. D 95, 052003 (2017)

J/ψ and $(4.48)\times10^8$ ψ(2S)

	$\mathcal{B}(\times 10^{-4})$
$J/\psi \to \Xi(1530)^-\bar{\Xi}^+$	5.9 ± 1.5
$J/\psi \to \Xi(1530)^0\bar{\Xi}^0$	3.3 ± 1.4
$J/\psi \to \Sigma(1385)^-\bar{\Sigma}^+$	3.1 ± 0.5
$\psi(2S) \to \Omega^-\bar{\Omega}^+$	0.47 ± 0.10

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

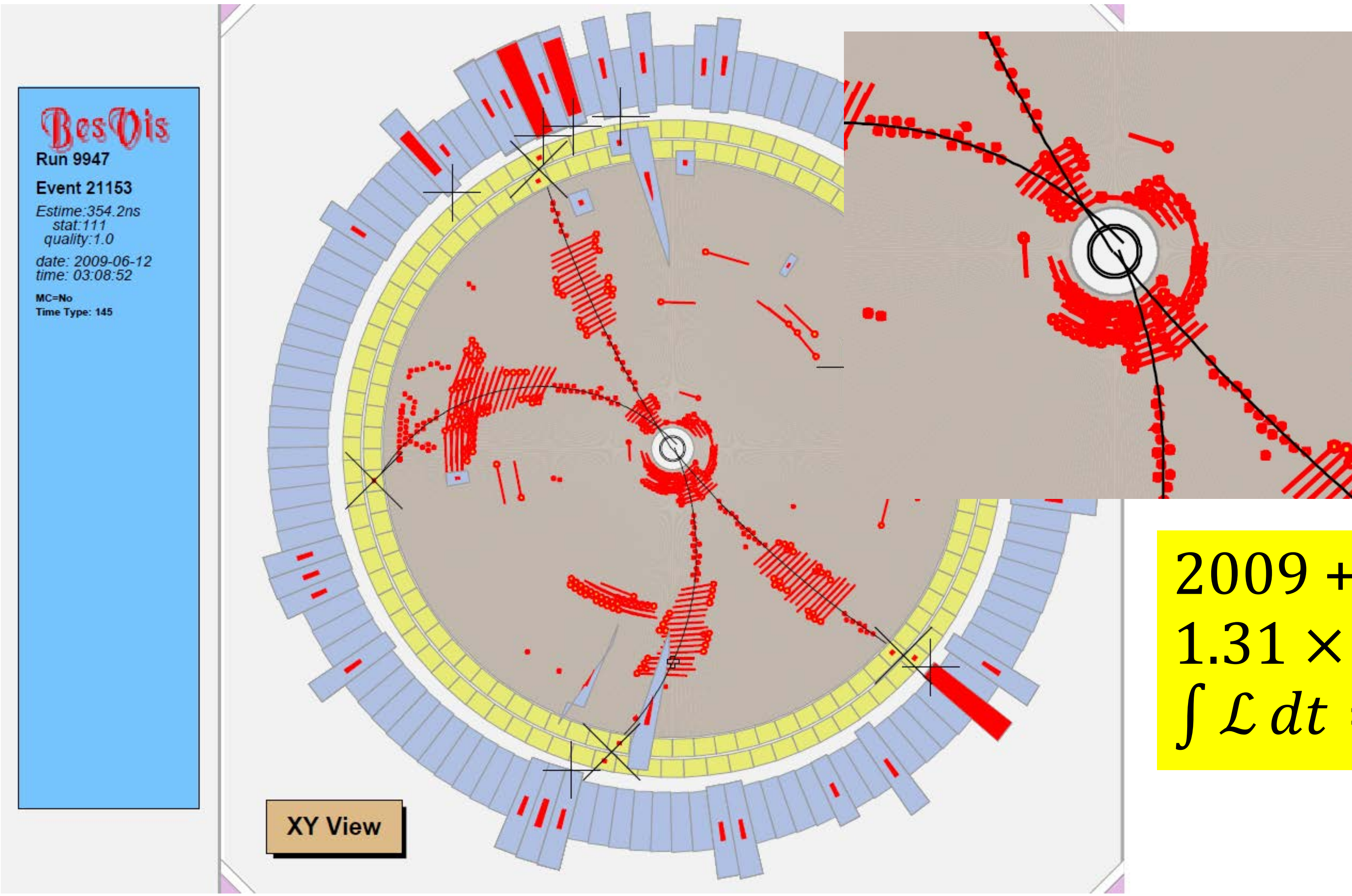


α_ψ measurements at BESIII

BESIII,PRD 95, 052003 (2017)

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

event in BESIII detector



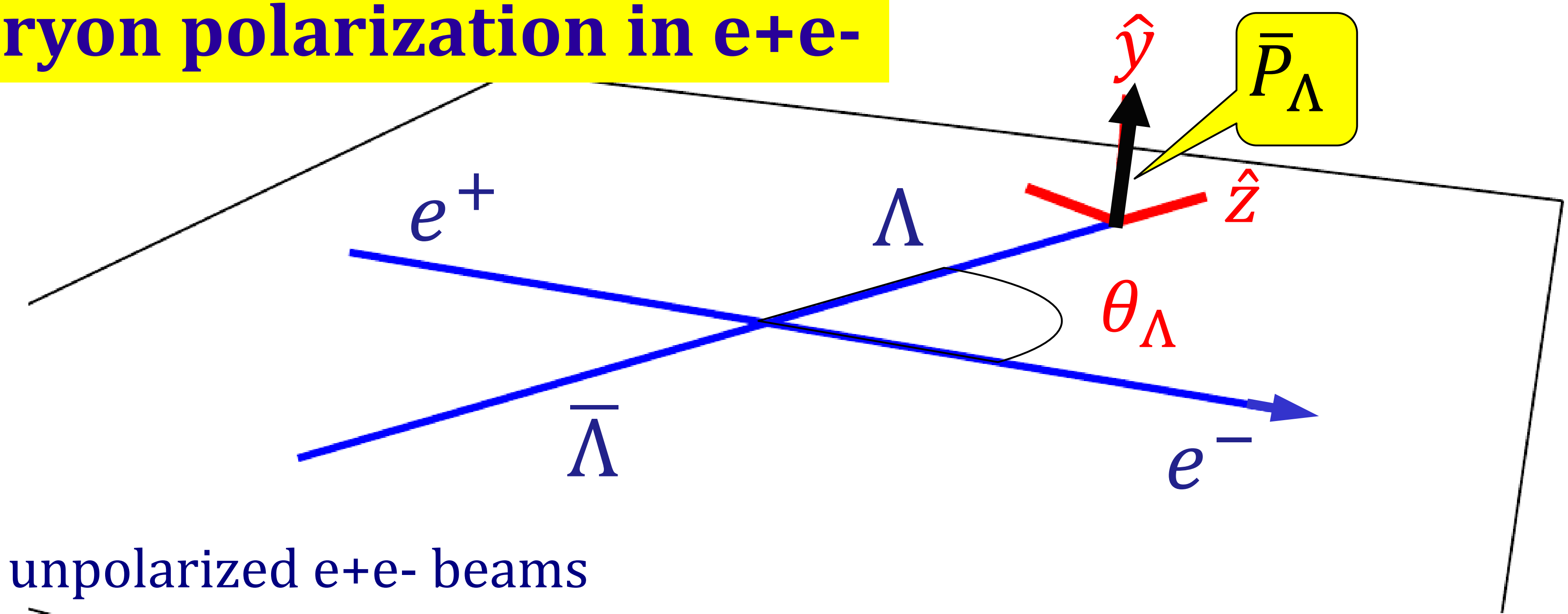
2009 + 2012 Data

1.31×10^9 J/ψ

$\int \mathcal{L}\, dt = 386.0$ pb^{-1}

Jianbin

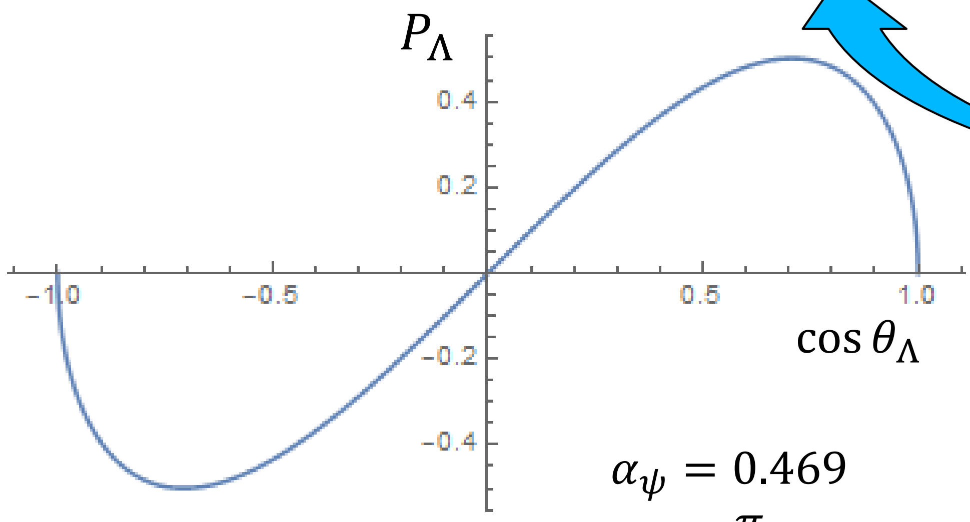
Baryon polarization in e+e-



For unpolarized e+e- beams

$$\bar{P}_\Lambda(\theta_\Lambda) = \frac{\sqrt{1-\alpha_\psi}\cos\theta_\Lambda \sin\theta_\Lambda}{1+\alpha_\psi \cos^2\theta_\Lambda} \sin(\Delta\Phi)\hat{y}$$

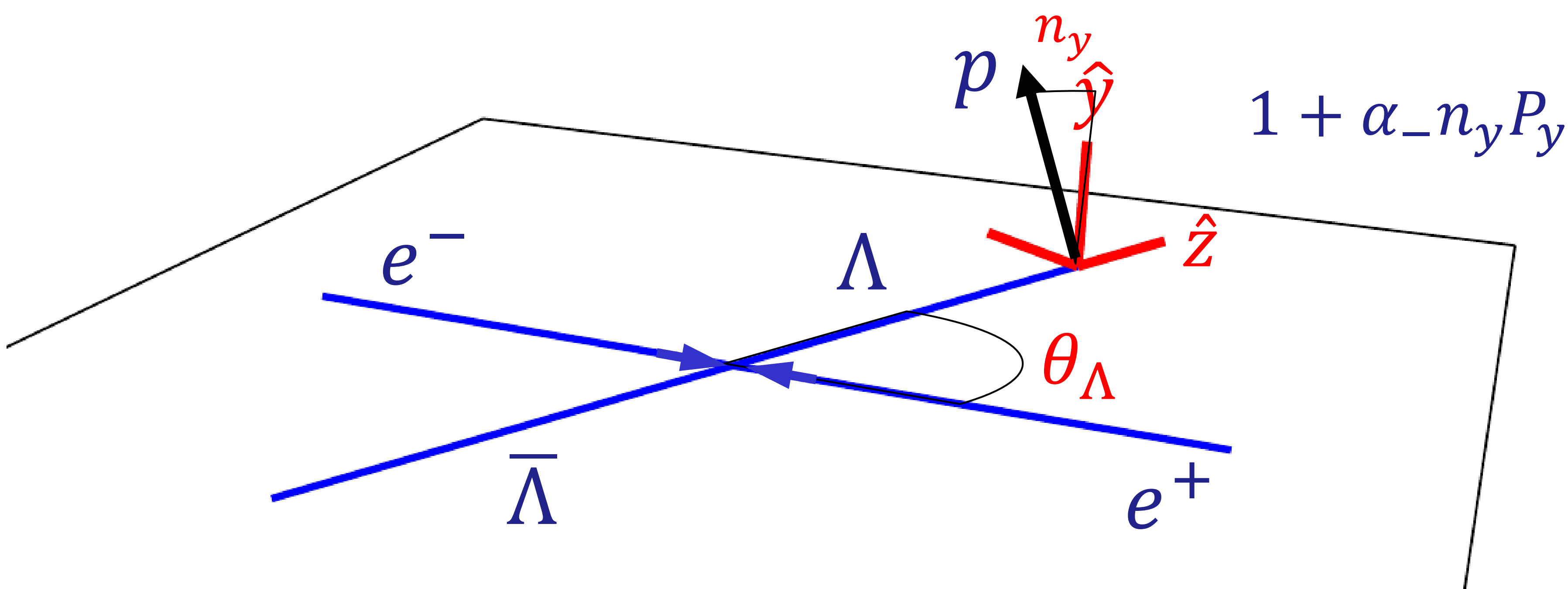
$\Delta\Phi \neq 0$



$\alpha_\psi = 0.469$

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

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



$$\frac{d\Gamma}{d\cos\theta_\Lambda d\Omega_1} \propto \left(1 + \alpha_\psi \cos^2\theta_\Lambda\right) \left\{1 + \alpha_1 P_\Lambda(\theta_\Lambda) \sin\theta_1 \sin\phi_1\right\}$$

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

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

Exclusive decay distributions

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$ $e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{n}\pi^0)$

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

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

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

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

$\bar{\Lambda} \to \bar{n}\pi^0$: $\alpha_2 \to \bar{\alpha}_0$ $\bar{\Lambda} \to \bar{p}\pi^+$: $\alpha_2 \to \alpha_+$

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

Spin correlations

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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)

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

polarizations (6)

Spin correlations (9)

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

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

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

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

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

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

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

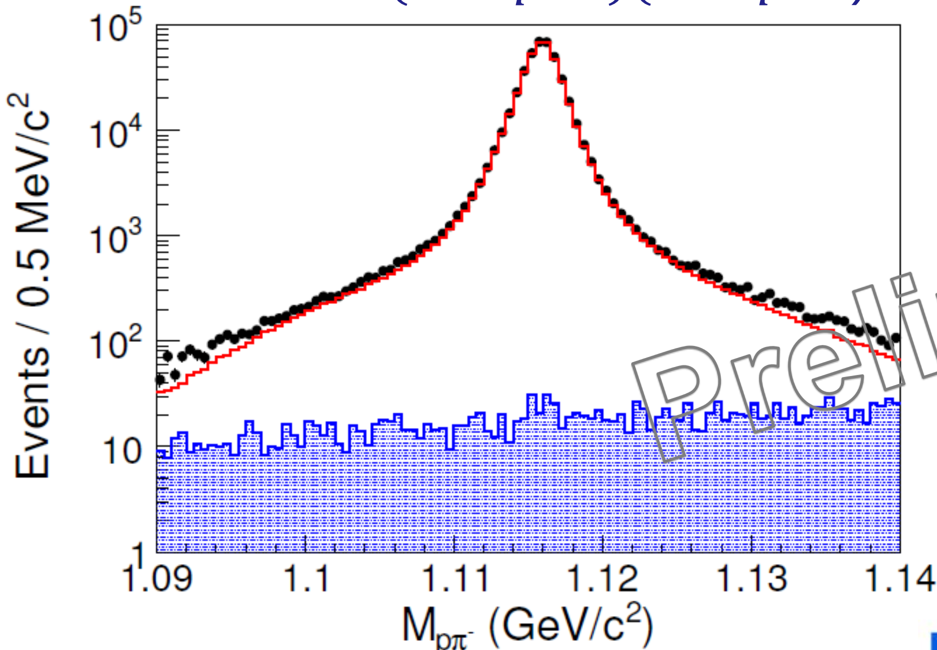
$$C_{\bar{z}x}(\theta) = C_{\bar{x}z}(\theta)$$

moments:

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

(uncorrected for acceptance)

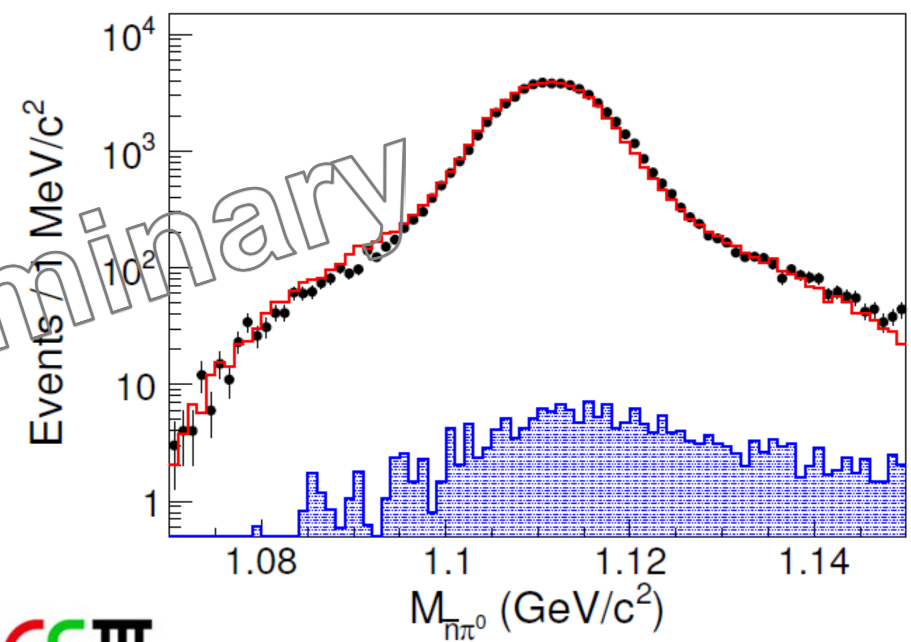
$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{p}\pi^+)$



420593 events

399 background

$e^+e^- \to (\Lambda \to p\pi^-)(\bar{\Lambda} \to \bar{n}\pi^0)$



47009 events

66 background

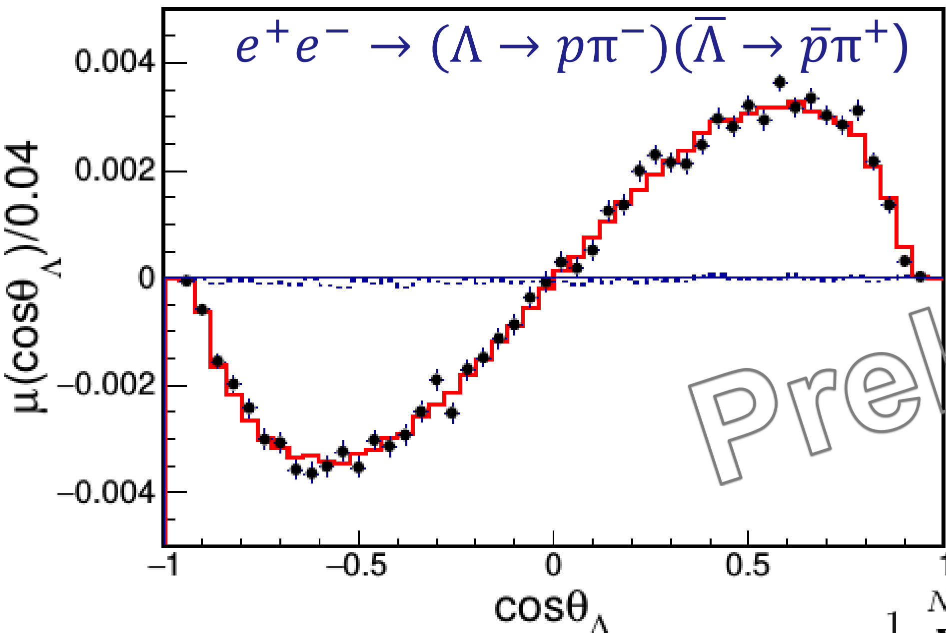
Global unbinned maximum log likelihood fit to the two data sets with the likelihood function constructed from probability function:

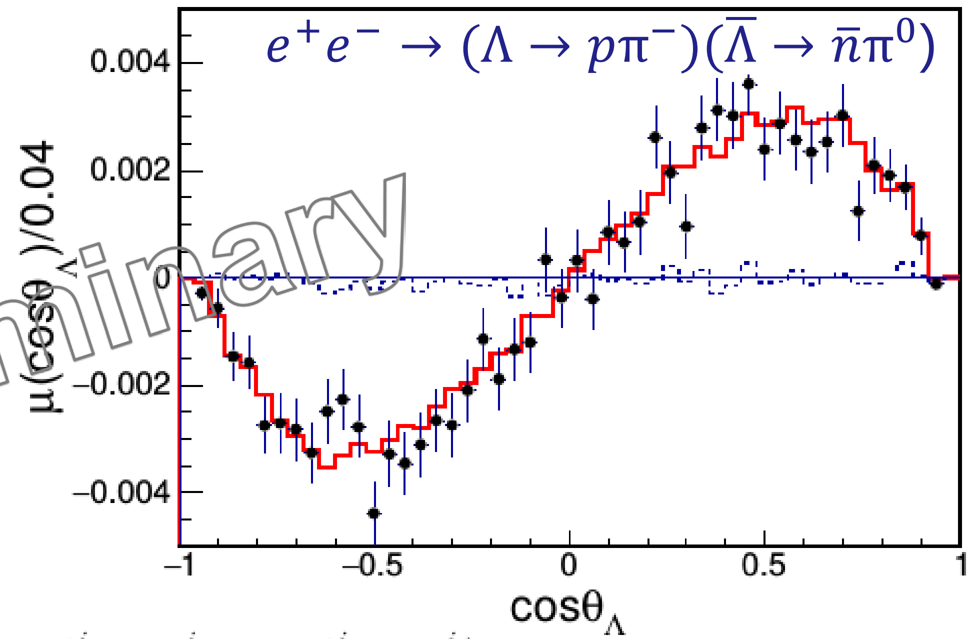
$$\mathcal{C}(\alpha_\psi, \Delta\Phi, \alpha_-, \alpha_2)\mathcal{W}(\boldsymbol{\xi}_i; \alpha_\psi, \Delta\Phi, \alpha_-, \alpha_2)$$

Where $\mathcal{C}(\alpha_\psi, \Delta\Phi, \alpha_-, \alpha_2)$ is the normalization factor obtained from $\mathcal{W}(\boldsymbol{\xi}_i; \alpha_\psi, \Delta\Phi, \alpha_-, \alpha_2)$ weighted sum for flat phase space model MC events after detector reconstruction.

Fit results

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





$$\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_{i}^{N(\theta_\Lambda)} (\sin\theta_1^i \sin\phi_1^i - \sin\theta_2^i \sin\phi_2^i)$$

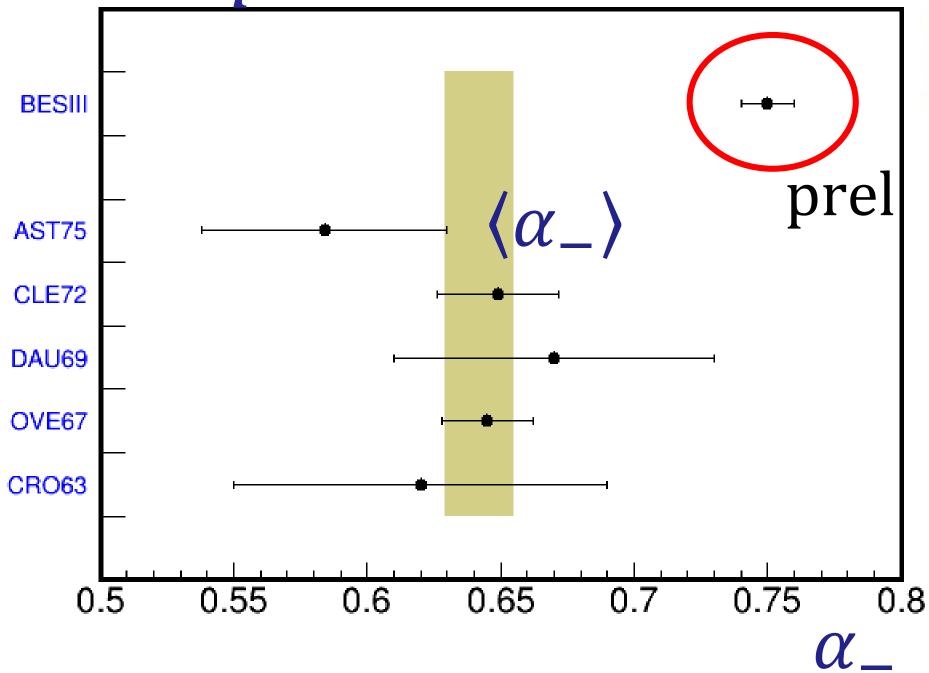
Parameters	This work	Previous results	
α_ψ	$\mathbf{0.461 \pm 0.006 \pm 0.007}$	0.469 ± 0.027	BESIII
$\Delta\Phi$ (rad)	$\mathbf{0.740 \pm 0.010 \pm 0.008}$	–	
α_-	$\mathbf{0.750 \pm 0.009 \pm 0.004}$	0.642 ± 0.013	PDG
α_+	$\mathbf{-0.758 \pm 0.010 \pm 0.007}$	-0.71 ± 0.08	PDG
$\bar{\alpha}_0$	$\mathbf{-0.692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

CP asymmetry:

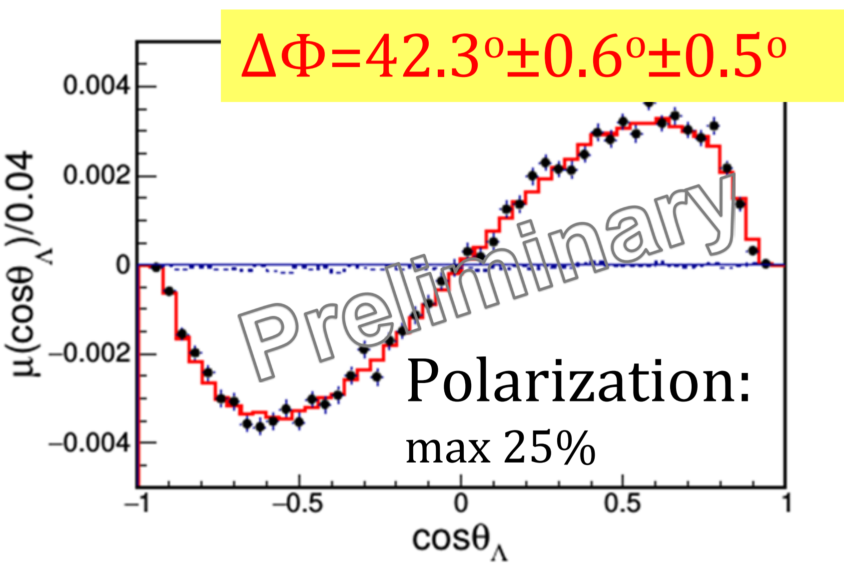
$$A_{CP} = \frac{\alpha_- + \alpha_+}{\alpha_- - \alpha_+}$$

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



CP test

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

A_{CP} = -0.006 ± 0.012± 0.007 prel

A_{CP}= 0.013 ± 0.021
PS185 PRC54(96)1877

CKM $A_{CP} \sim 10^{-4}$

Prospects of the method

What if phase is non-zero also for other hyperon antihyperon in J/ψ or $\psi(2S)$ decays?

⇨ measure simultaneously for two body weak decays α and $\bar{\alpha}$ and test CP: $A_{CP}=(\alpha + \bar{\alpha})/(\alpha - \bar{\alpha})$

⇨ For cascades: $\mathbf{\Xi^-\Xi^+ \rightarrow \Lambda\pi^- \Lambda\pi^+ \rightarrow p\pi^-\pi^- p\pi^+\pi^+}$

could also measure ϕ_{Ξ^-}, ϕ_{Ξ^+} and do more sensitive (10x) CP test:

$(\beta = \sqrt{1-\alpha^2}\sin\phi)$

$$B_{CP}= (\beta_{\Xi^-} + \beta_{\Xi^+})/(\beta_{\Xi^-} - \beta_{\Xi^+})$$

⇨ For J=3/2 baryons:

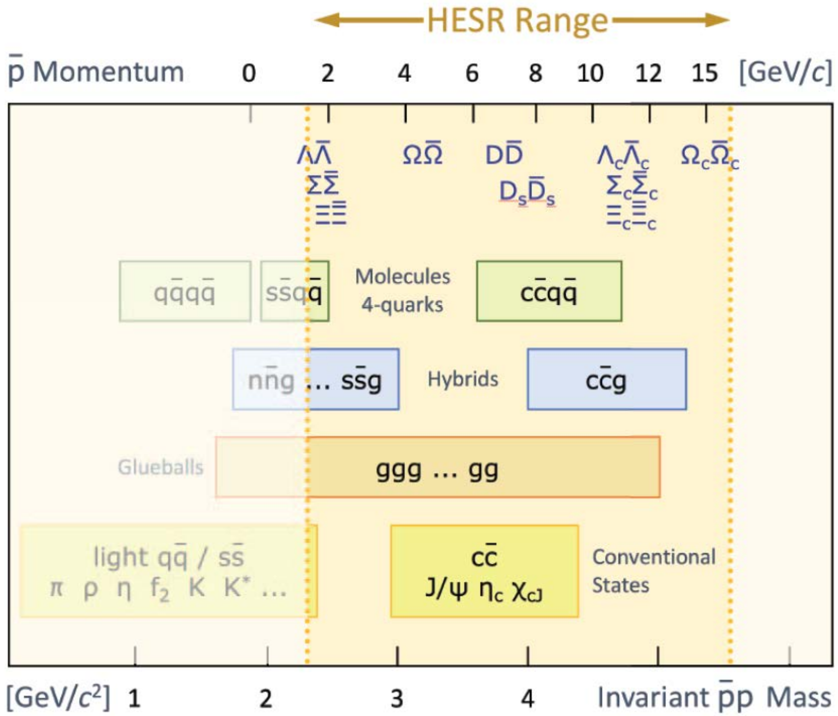
$$e^+e^- \rightarrow \gamma^* \rightarrow B_{1/2}\,\bar{B}_{1/2}$$
$$\rightarrow B_{3/2}\,\bar{B}_{1/2}$$
$$\rightarrow B_{3/2}\,\bar{B}_{3/2}$$

Initial state (e+e-) spin density matrix for single γ^* processes:

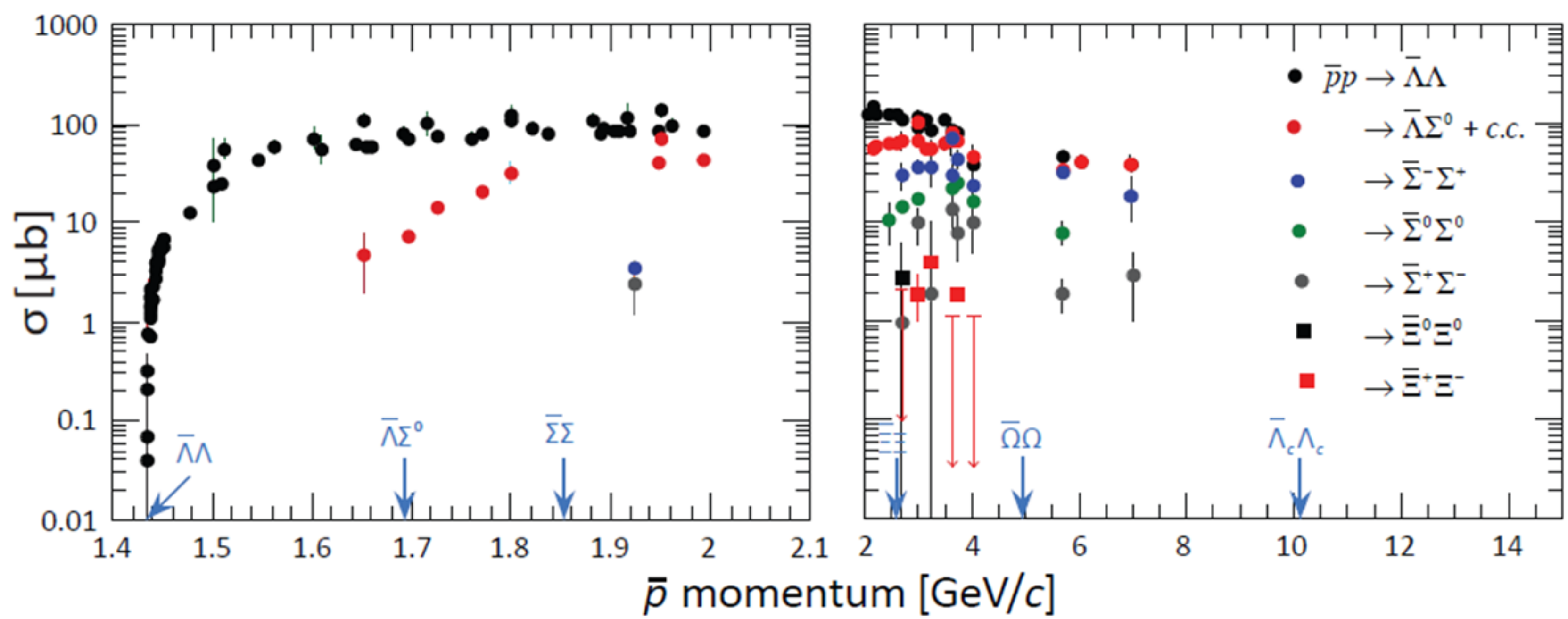
$$\rho_0^{i,j}(\theta) = \sum_{k=\pm 1} \mathcal{D}^1_{k,i}(0,\theta,0)\mathcal{D}^{1*}_{k,j}(0,\theta,0)$$

$$\rho_0 = \begin{pmatrix} \frac{1+\cos^2\theta}{2} & \frac{\cos\theta\sin\theta}{\sqrt{2}} & \frac{\sin^2\theta}{2} \\ \frac{\cos\theta\sin\theta}{\sqrt{2}} & \sin^2\theta & -\frac{\cos\theta\sin\theta}{\sqrt{2}} \\ \frac{\sin^2\theta}{2} & -\frac{\cos\theta\sin\theta}{\sqrt{2}} & \frac{1+\cos^2\theta}{2} \end{pmatrix}$$

valid for continuum
and for J/ψ, ψ(2S),....



Reaction	σ (μb)	Efficiency (%)	Rate (with 10^{31} $cm^{-1}s^{-1}$)
$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$	64	10	30 s^{-1}
$\bar{p}p \rightarrow \bar{\Lambda}\Sigma^0$	~40	30	30 s^{-1}
$\bar{p}p \rightarrow \bar{\Xi}^+\Xi^-$	~2	20	2 s^{-1}
$\bar{p}p \rightarrow \bar{\Omega}\Omega$	~0.002	30	~4 h^{-1}
$\bar{p}p \rightarrow \bar{\Lambda}_c\Lambda_c$	~0.1	35	~2 day^{-1}



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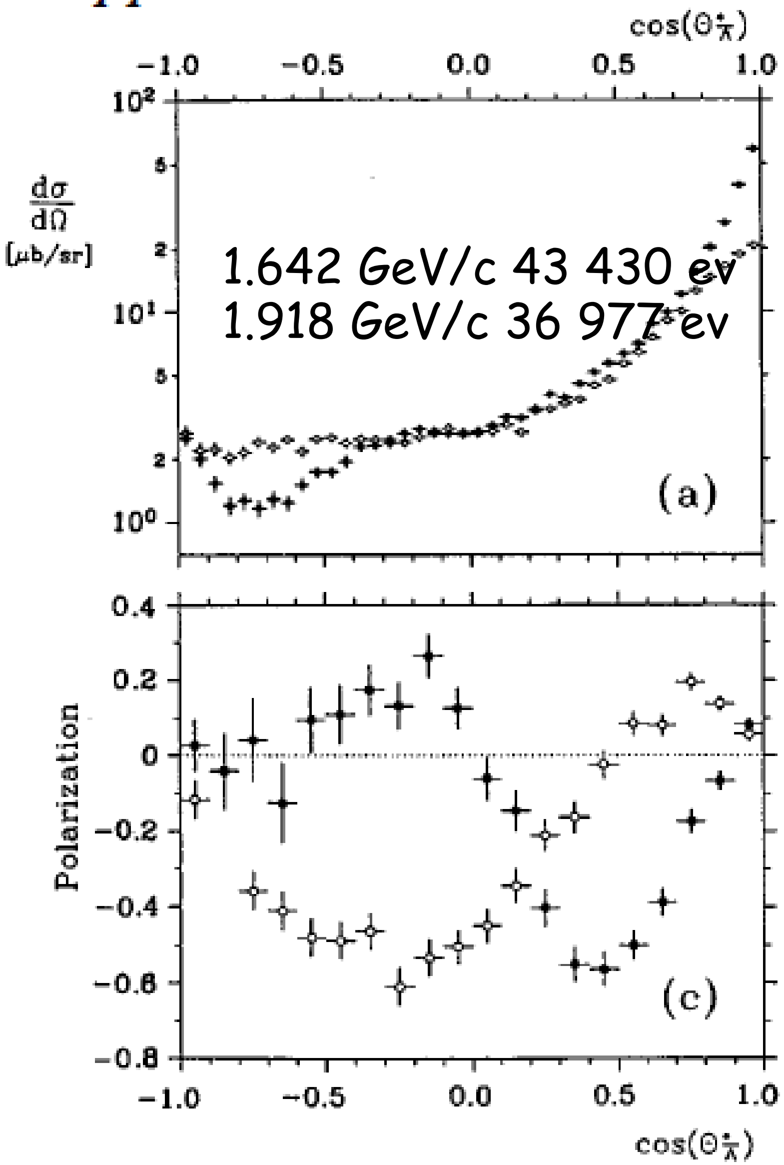
$\bar{p}p \rightarrow \bar{\Lambda}\Lambda$



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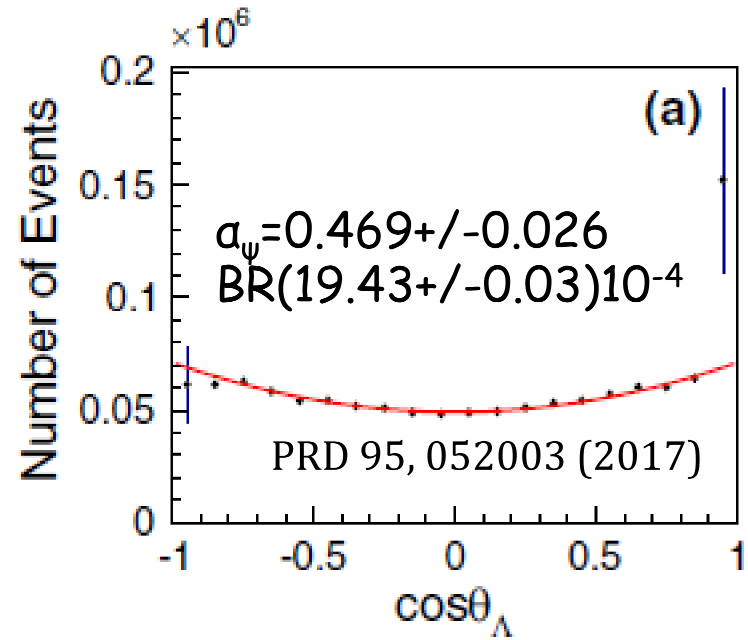
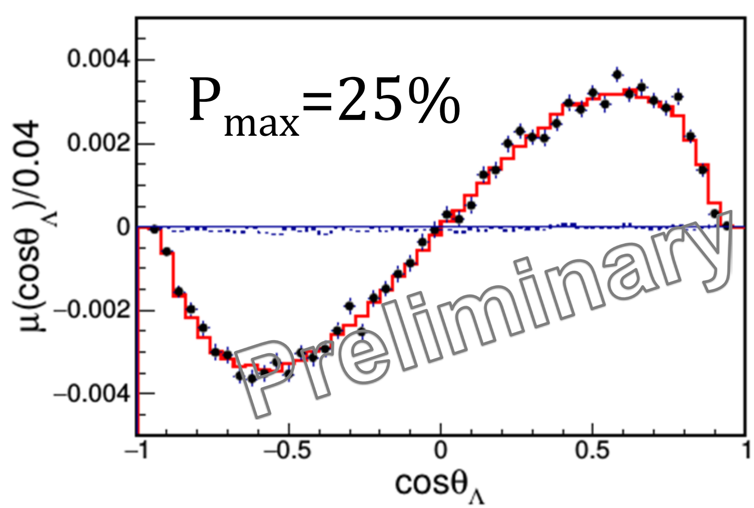
5 parameters at each θ_Λ
Can't determine Λ decay param.

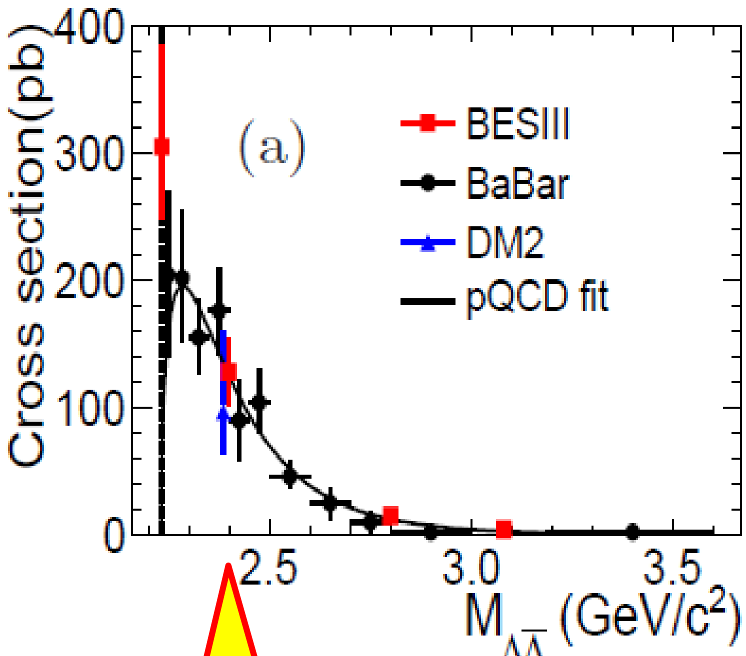
$e^+e^- \rightarrow \gamma^* \rightarrow J/\psi \rightarrow \Lambda\bar{\Lambda}$

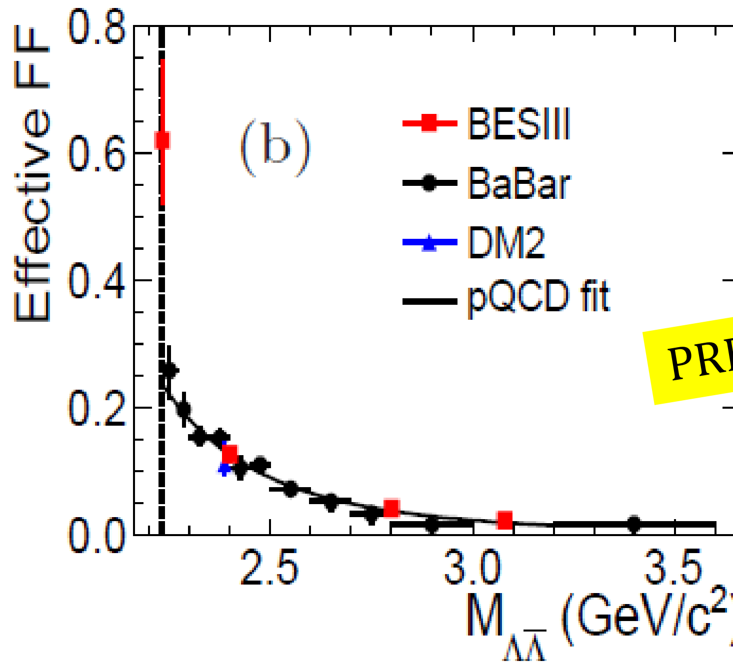




2 global parameters
extract Λ decay par. α

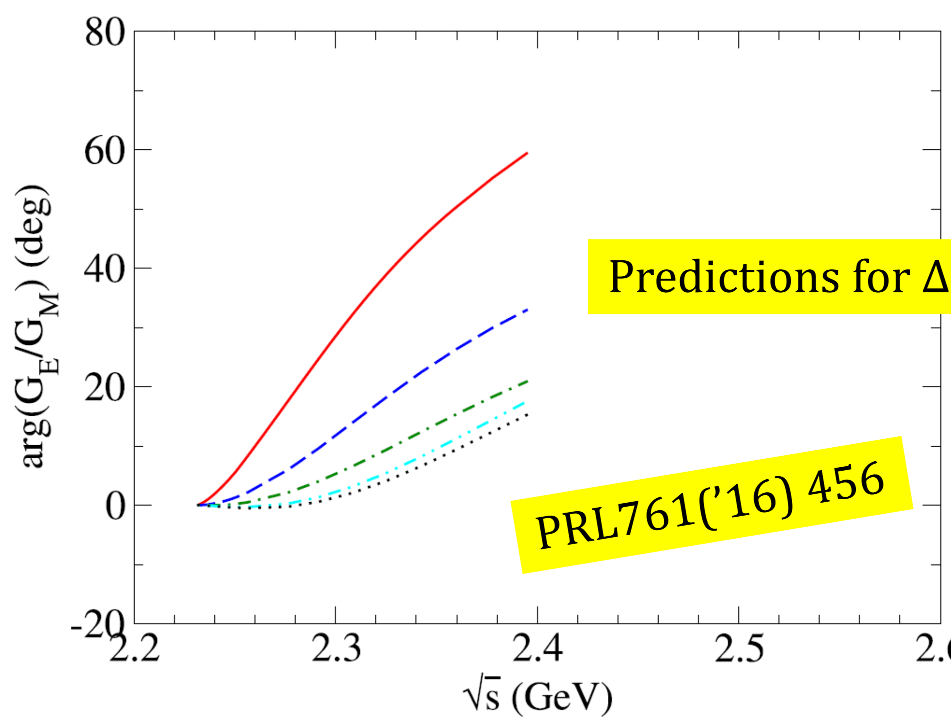
$e^+e^- \to \gamma^* \to \Lambda\bar{\Lambda}$ (continuum)





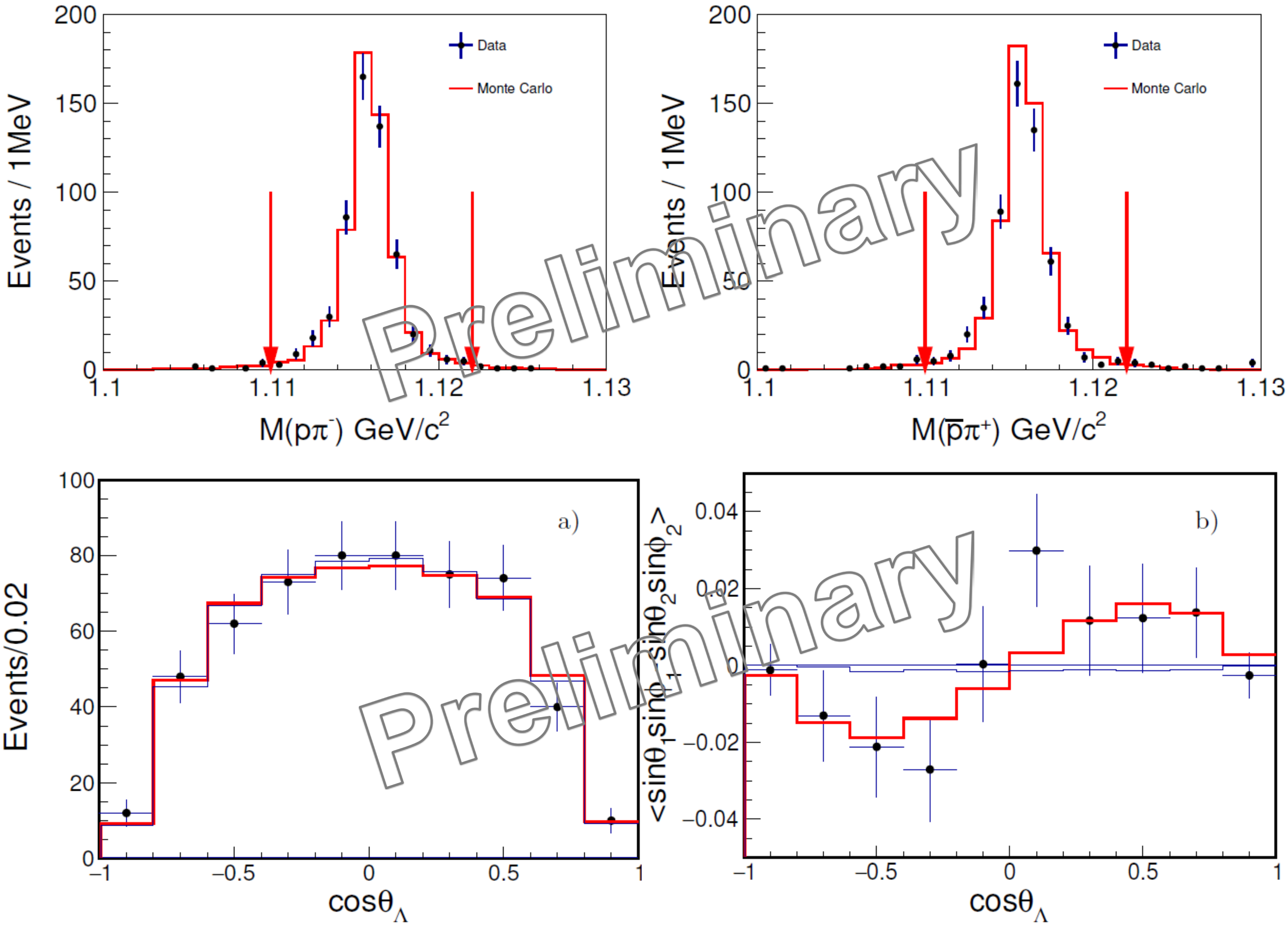
PRD97('18) 032013

$\sqrt{s} = 2.396$ GeV
66.9 pb^{-1}



Predictions for $\Delta\Phi$

PRL761('16) 456



$R = 0.94 \pm 0.16(\text{stat.}) \pm 0.03(\text{sys.}) \pm 0.02(\alpha\_)$ $\quad (\alpha_\psi = 0.13 \pm 0.16)$

$\Delta\Phi = 42^o \pm 16^o(\text{stat.}) \pm 8^o(\text{sys.}) \pm 6^o(\alpha\_)$

Conclusions:

Polarization in $e^+e^- \rightarrow \Lambda\bar{\Lambda}$ observed both at resonance (unexpected) and for continuum (expected)

Phase in both processes close to 45° (given by $\Lambda\bar{\Lambda}$ final state interaction)

Same formalism but large hyperon yields at J/ψ and ψ(2S)

Unique and simple spin entangled quantum system could be used for CP tests and for determination of (anti-)hyperon decay parameters (polarization is essential!)

A puzzle: the value of the Λ decay parmeter …

… searching for other polarized hyperons from J/ψ and ψ(2S)

Thank you!