Status of HVP muon activities Uppsala/Warsaw

UPPSALA UNIVERSITET

Andrzej Kupść

NCBJ ŚWIERK

Liverpool, November 8th 2022

Uppsala UU/Warsaw NCBJ groups

Uppsala:

Stefan Leupold (phen)

Dispersion relation for hadronic light-by-light scattering: pion pole
JHEP 10 (2018) 141

Lars Eklund (LHCb, NNbar @ESS)

KLOE-2: $\eta \to \pi^+\pi^-\pi^0, e^+e^- \to \pi^+\pi^-\pi^0$

Uppsala/Warsaw

Andrzej Kupsc: KLOE-2, BESIII

Light-by-Light (exp+phen),

MesonNet,

PrecisionSM (STRONG2020)

$e^+e^- \to B\bar{B}$ (exp+phen)

Warsaw: KLOE-2, LHCb:

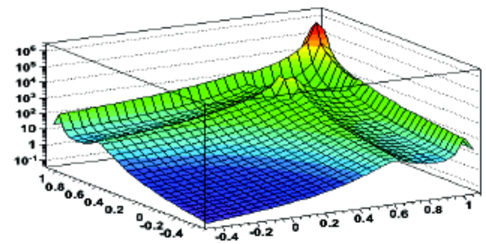
Wojtek Wislicki (prev: SMC, COMPASS, NA48)

V. Batozskaya, M.Berłowski, PhD students: N.Salone

+computing

Workshop on Meson Transition Form Factors

May 29-30, 2012 in Cracow, Poland



Information | References (115) | Citations (1) | Files | Plots

MesonNet Workshop on Meson Transition Form Factors.

E. Czerwinski, S. Eidelman, C. Hanhart, B. Kubis, A. Kupsc, S. Leupold, P. Moskal, S. Schadmand.

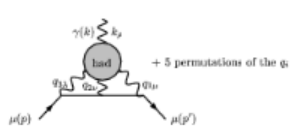
Jul 2012
69 pp.

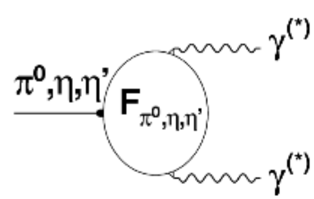
e-Print: arXiv:1207.6556 [hep-ph] PDF

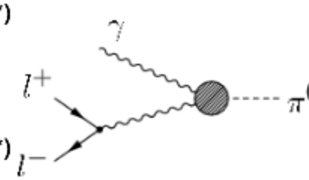
Abstract: The mini-proceedings of the Workshop on Meson Transition Form Factors held in Cracow from May 29th to 30th, 2012 introduce the meson transition form factor project with special emphasis on the interrelations between the various form factors (on-shell, single off-shell, double off-shell). Short summaries of the talks presented at the workshop follow.

Note: * Temporary entry *; 69 pages, 14 figures/ all talks can be found at http://www2.fz-juelich.de /ikp//mesonnet/meetings/2012_ff_workshop.shtml

Keyword(s): INSPIRE: conference | form factor: transition | meson







Show more plots

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The strong interaction at the frontier of knowledge:
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JRA3-PrecisionSM

Precise determination of the muon anomalous magnetic moment (g-2)μ; the CKM matrix element Vud from beta decay, and the weak mixing angle from parity-violating electron scattering. Associated novel constraints (or discovery) of physics beyond the SM.

NA4-PREN

Address the “proton-radius puzzle” via combined data-theory

http://www.strong-2020.eu/

Recent activities Uppsala/Warsaw

- Hyperon-antihyperon system at e^+e^- colliders
- Determination of amplitudes of hyperon decays, CP tests in baryon decays

Methods:

1. G.Fäldt, AK PLB **772** (2017) 16 *Hadronic structure functions in the* $e^+e^- \to \Lambda\bar{\Lambda}$ *reaction*
2. E.Perotti,G.Fäldt,AK,S.Leupold,JJ.Song PRD**99** (2019)056008 *Polarization observables in e+e− annihilation to a baryon-antibaryon pair*
3. P.Adlarson, AK PRD **100** (2019) 114005 *CP symmetry tests in the cascade-anticascade decay of charmonium*
4. N.Salone, P.Adlarson, V.Batozskaya, AK, S.Leupold, J.Tandean *PRD* **105** (2022) 116022 *Study of CP violation in hyperon decays at super-charm-tau factories with a polarized electron beam*

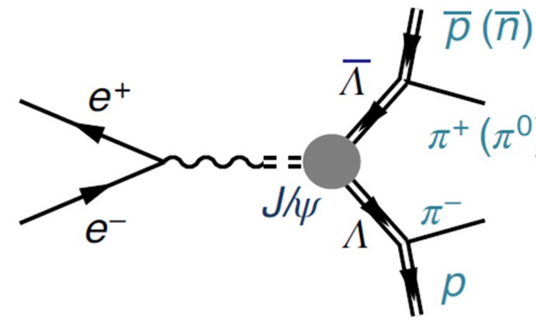
$$e^+e^- \rightarrow J/\psi \rightarrow \Lambda\bar{\Lambda}$$

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*

Nature Phys. 15 (2019) 631



Phys.Rev.Lett. 129 (2022) 131801

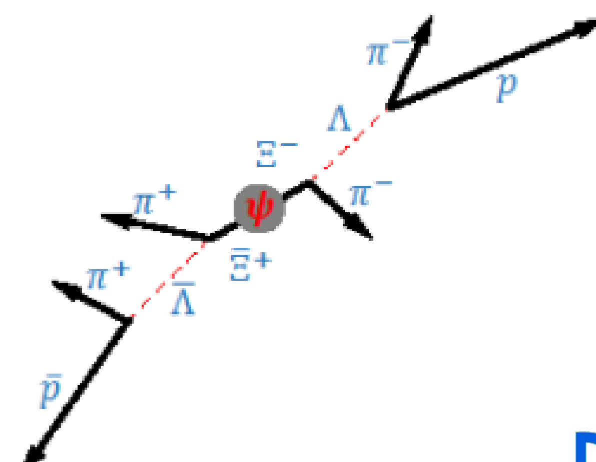
$$e^+e^- \rightarrow J/\psi \rightarrow \Xi^-\bar{\Xi}^+$$

Article | Open Access | Published: 01 June 2022

Probing CP symmetry and weak phases with entangled double-strange baryons

The BESIII Collaboration

Nature 606, 64–69 (2022) | Cite this article



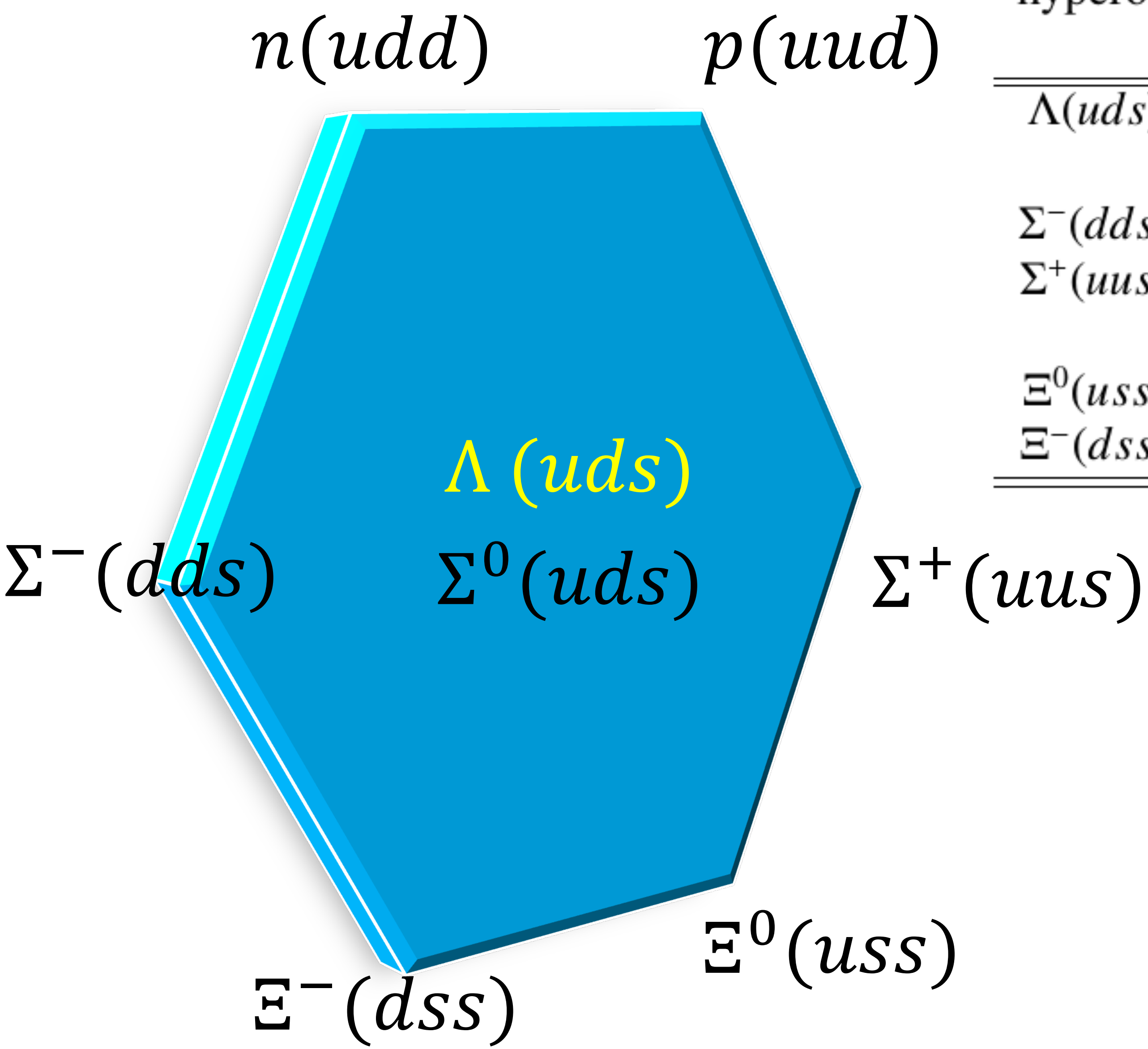
Other applications of the methods:

BESIII *Phys.Rev.Lett.* **123** (2019) 122003 :
Complete Measurement of the Λ Electromagnetic Form Factors

BESIII *Phys.Rev.Lett.* **125** (2020) 052004
Σ+ and Σ polarization in the J/ψ and ψ(2S) decays

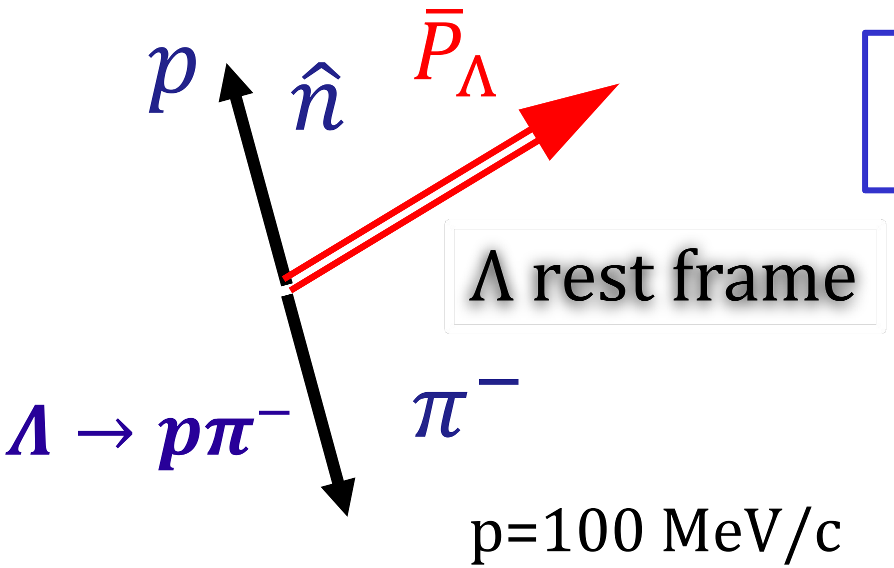
BESIII *Phys.Rev.Lett*. **126** (2021) 092002
Model-Independent Determination of the Spin of the Ω− …

Spin ½ baryon octet



hyperon	Mass [GeV/c^2]	$c\tau$ [cm]	decay (BF)
$\Lambda(uds)$	1.116	7.9	$p\pi^-$ (63.9%) $n\pi^0$ (35.8%)
$\Sigma^-(dds)$	1.197	4.4	$n\pi^-$ (99.8%)
$\Sigma^+(uus)$	1.189	2.4	$p\pi^0$ (51.6%) $n\pi^+$ (48.3%)
$\Xi^0(uss)$	1.315	8.7	$\Lambda\pi^0$ (99.5%)
$\Xi^-(dss)$	1.321	5.1	$\Lambda\pi^-$ (99.8%)

Hyperon decay parameter α



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

α_Λ =0.750(10)

value before 2018: α_Λ =0.642(13)

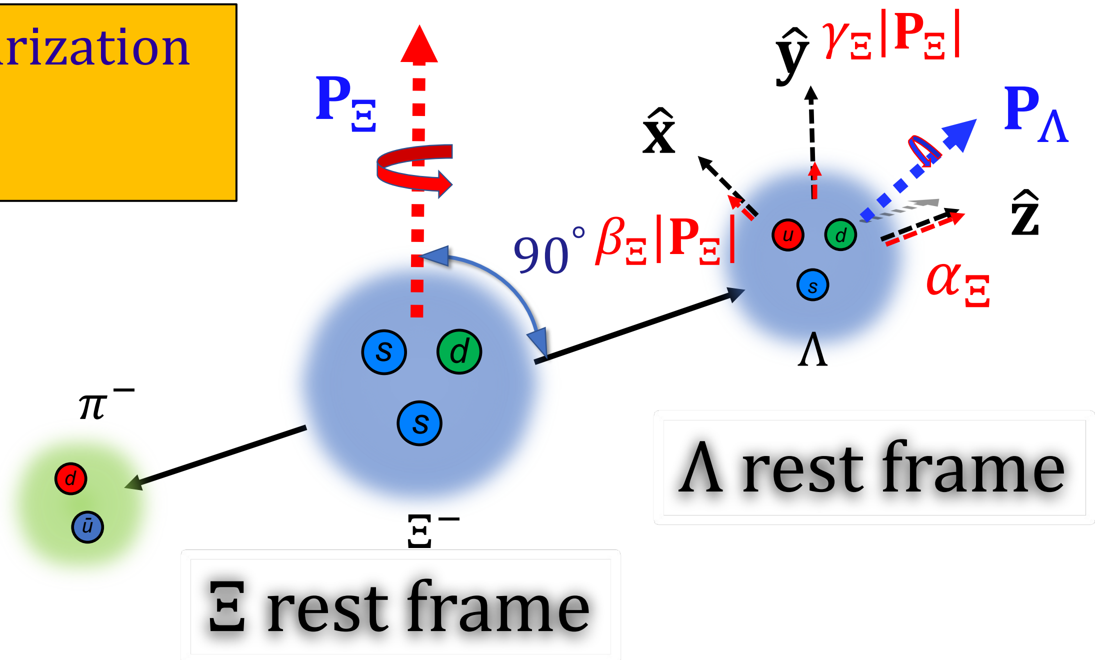
$\alpha_\Xi = -0.392(8)$

Hyperon decay parameter ϕ

$\Xi \to \Lambda\pi, \Lambda \to p\pi$

Accesible if daughter baryon polarization is measured eg decay sequence:
$\Xi \to \Lambda\pi, \Lambda \to p\pi$

$$\mathbf{P}_\Xi = 0 \;\Rightarrow\; \mathbf{P}_\Lambda = \alpha\,\hat{\mathbf{z}}$$



$$\mathbf{P}_\Lambda^{||} = \alpha_\Xi \hat{\mathbf{z}}$$
$$\mathbf{P}_\Lambda^{\perp} = |\mathbf{P}_\Xi|\,(\beta_\Xi \hat{\mathbf{x}} + \gamma_\Xi \hat{\mathbf{y}})$$
$$= |\mathbf{P}_\Xi|\sqrt{1-\alpha_\Xi^2}(\sin\phi_\Xi \hat{\mathbf{x}} + \cos\phi_\Xi \hat{\mathbf{y}})$$

Lee, Yang PR 108(1957)1645

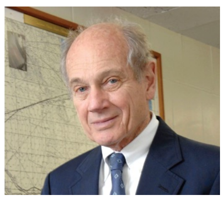
$$a_{\mu\nu}^{\Xi}(0,0) = \begin{pmatrix} 1 & 0 & 0 & \alpha_\Xi \\ 0 & \gamma_\Xi & -\beta_\Xi & 0 \\ 0 & \beta_\Xi & \gamma_\Xi & 0 \\ \alpha_\Xi & 0 & 0 & 1 \end{pmatrix}$$

$$\phi_\Lambda = -0.11(6)$$

$$|\phi_\Xi| = \mathcal{O}(0.01)$$

α, β, γ measurements for $\Lambda \to p\pi^-$

James Cronin
1931-2016



Oliver Overseth
1928-2008

PHYSICAL REVIEW VOLUME 129, NUMBER 4 15 FEBRUARY 1963

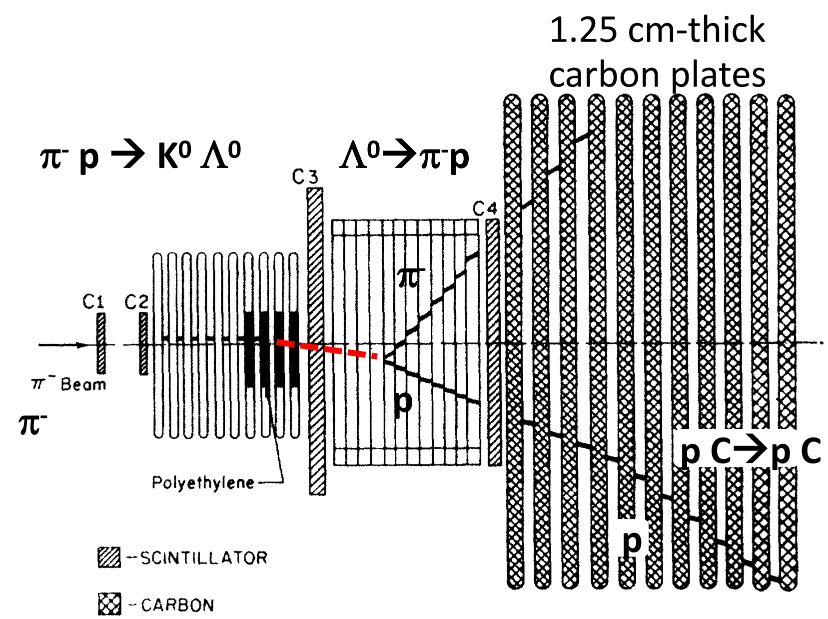
Measurement of the Decay Parameters of the Λ^0 Particle*

JAMES W. CRONIN AND OLIVER E. OVERSETH†
Palmer Physical Laboratory, Princeton University, Princeton, New Jersey
(Received 26 September 1962)

The decay parameters of $\Lambda^0 \to \pi^- + p$ have been measured by observing the polarization of the decay protons by scattering in a carbon-plate spark chamber. The experimental procedure is discussed in some detail. A total of 1156 decays with useful proton scatters was obtained. The results are expressed in terms of polarization parameters, α, β, and γ given below:

$$\alpha = 2\,\mathrm{Re}\,sp^*/(|s|^2+|p|^2) = +0.62\pm0.07,$$
$$\beta = 2\,\mathrm{Im}\,sp^*/(|s|^2+|p|^2) = +0.18\pm0.24,$$
$$\gamma = |s|^2-|p|^2/(|s|^2+|p|^2) = +0.78\pm0.06,$$

where s and p are the s- and p-wave decay amplitudes in an effective Hamiltonian $s+p\boldsymbol{\sigma}\cdot\mathbf{p}/|\mathbf{p}|$, where $\mathbf{p}$ is the momentum of the decay proton in the center-of-mass system of the Λ^0, and $\boldsymbol{\sigma}$ is the Pauli spin operator. The helicity of the decay proton is positive. The ratio $|p|/|s|$ is $0.36_{-0.06}^{+0.05}$ which supports the conclusion that the $K\Lambda N$ parity is odd. The result $\beta=0.18\pm0.24$ is consistent with the value $\beta=0.08$ expected on the basis of time-reversal invariance.



no H_2 target, no magnet; use kinematics and proton's range in carbon to infer E_p

$$P_p = \frac{(\alpha + P_\Lambda \cos\theta)\hat{z}' + \beta P_\Lambda \hat{x}' + \gamma P_\Lambda \hat{y}'}{1+\alpha P_\Lambda \cos\theta}$$

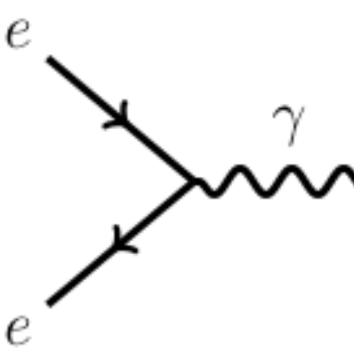
$$\alpha_\Lambda = 0.62(7)$$

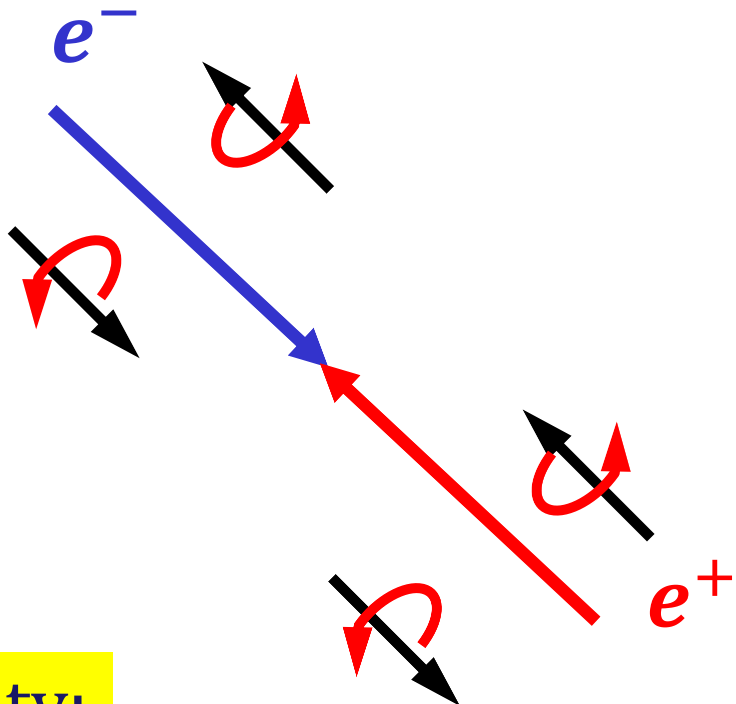
Slide from Steve Olsen

T.D. Lee, C-N Yang *Phys.Rev.* 108 (1957) 1645

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

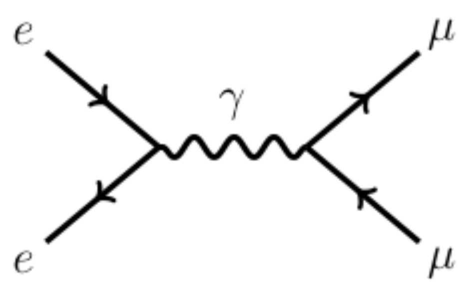
At high energies annihilating e+e- have opposite helicities.





γ^* has ± 1 helicity:

$$\rho_1(0) = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$



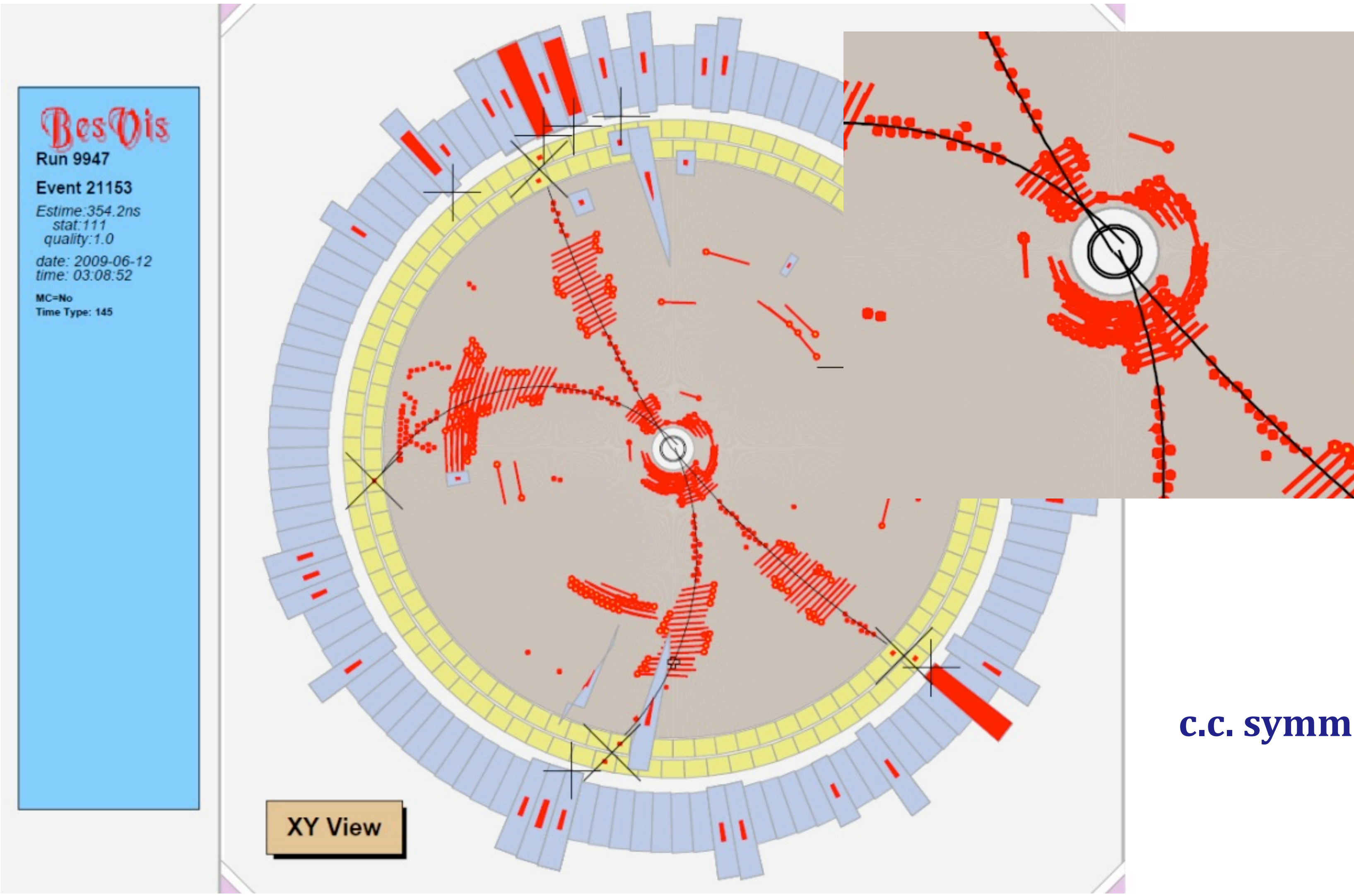
$$F_1(0) = 1, \quad F_2(0) = a_\mu$$

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

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

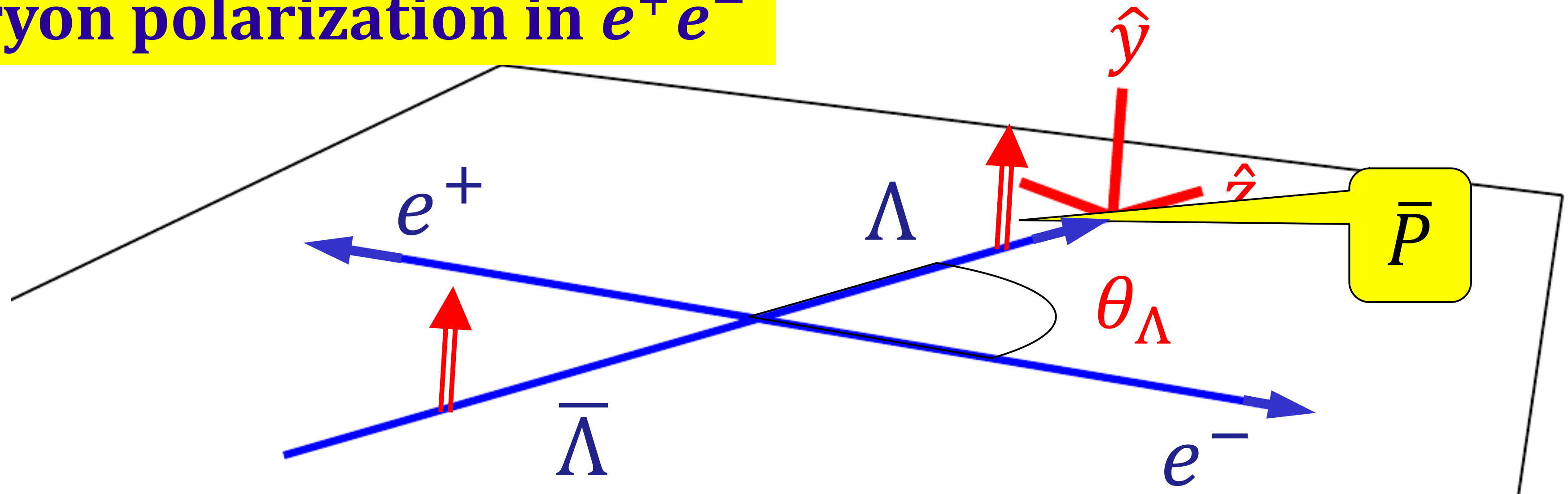
$$e^+e^- \rightarrow J/\psi \rightarrow (\Lambda \rightarrow p\pi^-)(\bar{\Lambda} \rightarrow \bar{p}\pi^+)$$

event in BESIII detector



c.c. symmetric detection

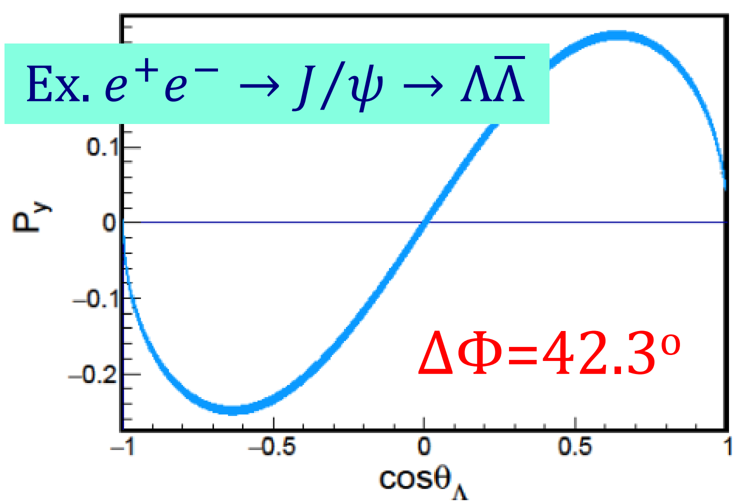
Baryon polarization in e^+e^-



Unpolarized e+e- beams ⇨ transverse polarization:

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

$\Delta\Phi \neq 0$



$\alpha_\psi = 0.469$

$$\Delta\Phi = \mathrm{Arg}(G_E/G_M)$$

Baryon-antibaryon spin density matrix

$$e^+e^- \to B\overline{B}$$

General two spin ½ particle state:

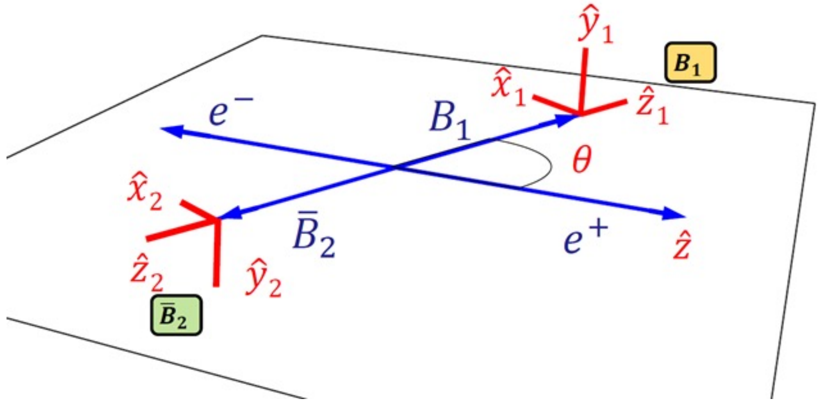
$$\rho_{1/2,\overline{1/2}} = \frac{1}{4}\sum_{\mu\bar{\nu}} C_{\mu\bar{\nu}}\, \sigma_{\mu}^{B_1} \otimes \sigma_{\bar{\nu}}^{\bar{B}_2}$$

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

$$C_{\mu\bar{\nu}} = (1+\alpha_\psi \cos^2\theta)\begin{pmatrix} 1 & 0 & P_y & 0 \\ 0 & C_{xx} & 0 & C_{xz} \\ -P_y & 0 & C_{yy} & 0 \\ 0 & -C_{xz} & 0 & C_{zz} \end{pmatrix}$$

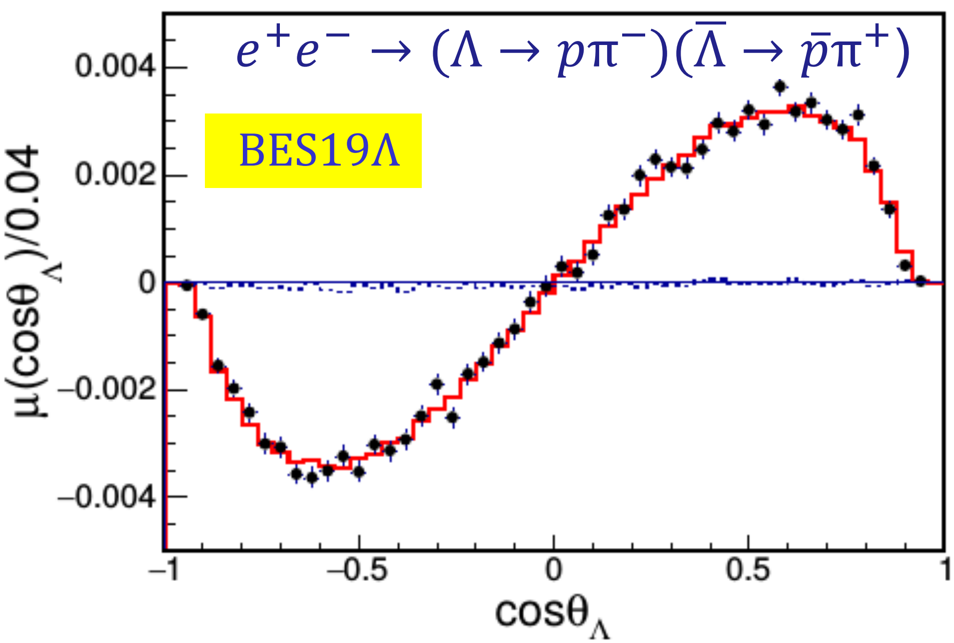
$\langle \mathbb{P}_B^2 \rangle$

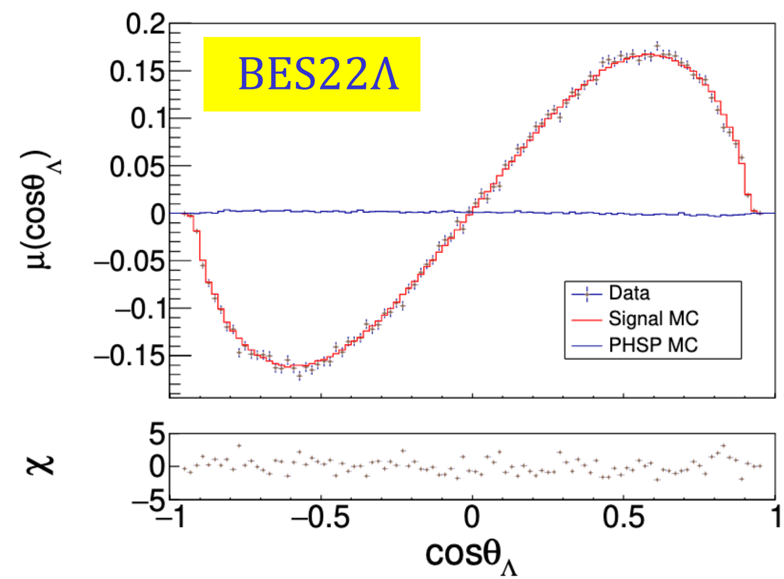
$\langle \mathbb{S}_{B\overline{B}}^2 \rangle$



Methods: Ref [1&2]

Results of multidimensional fit

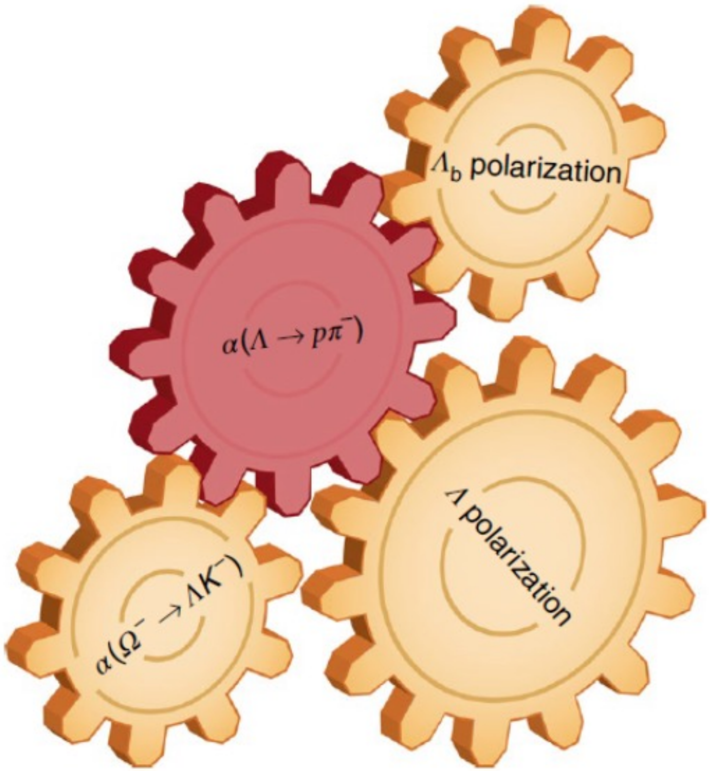


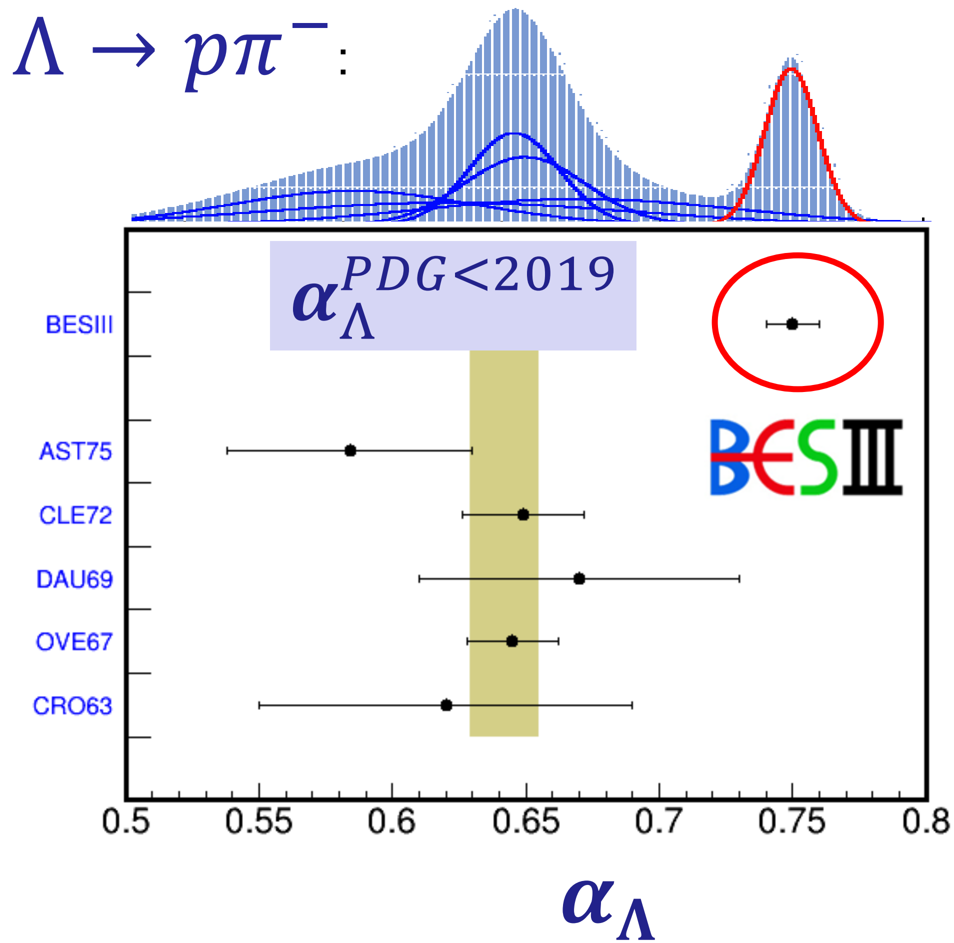


Moment μ: $\mu(\cos\theta_\Lambda) = \frac{1}{N}\sum_{i=1}^{N(\theta_\Lambda)}\left(n_{1,y}^{(i)} - n_{2,y}^{(i)}\right)$

Par.	BES22Λ	Previous results BES19Λ
$\alpha_{J/\psi}$	$0.4748 \pm 0.0022 \pm 0.0024$	$0.461 \pm 0.006 \pm 0.007$
$\Delta\Phi$	$0.7521 \pm 0.0042 \pm 0.0080$	$0.740 \pm 0.010 \pm 0.009$
α_-	$0.7519 \pm 0.0036 \pm 0.0019$	$0.750 \pm 0.009 \pm 0.004$
α_+	$-0.7559 \pm 0.0036 \pm 0.0029$	$-0.758 \pm 0.010 \pm 0.007$
A_{CP}	$-0.0025 \pm 0.0046 \pm 0.0011$	$0.006 \pm 0.012 \pm 0.007$
$\alpha_{\rm avg}$	$0.7542 \pm 0.0010 \pm 0.0020$	-

Implications of the BESIII 2019 result





news & views

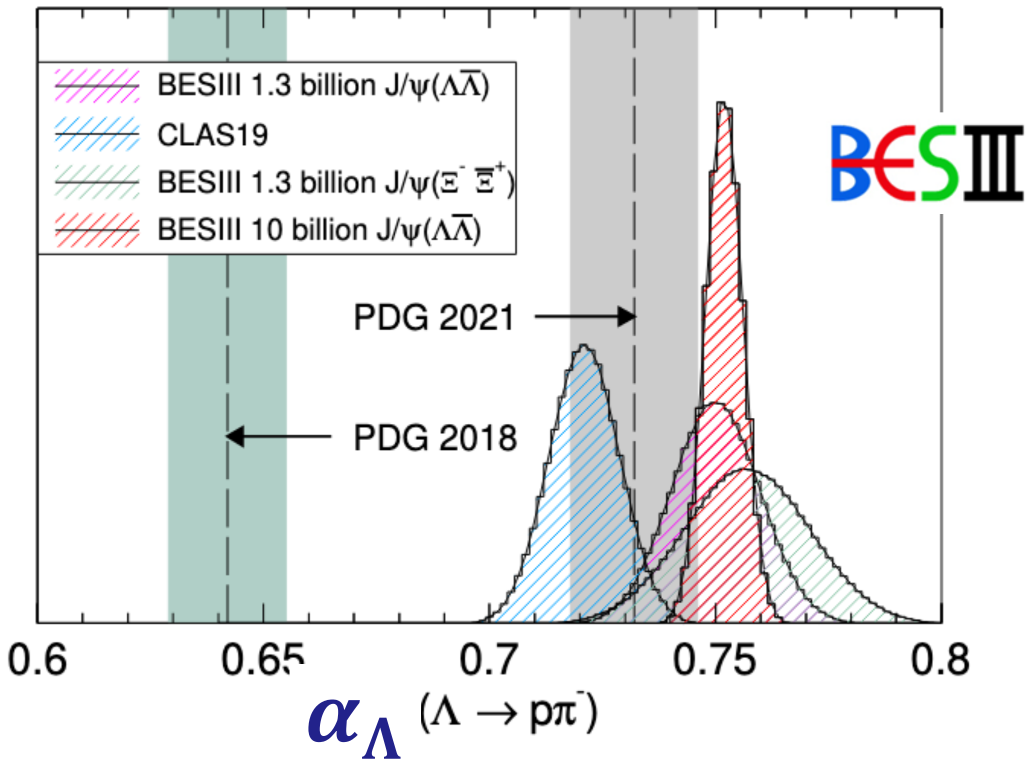
PARTICLE PHYSICS

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

Status of α_Λ measurement



$$\langle \alpha_\Lambda \rangle = \frac{\alpha_\Lambda - \bar{\alpha}_\Lambda}{2}$$

$0.7542 \pm 0.0010 \pm 0.002$

BES22Λ
10^{10} J/ψ

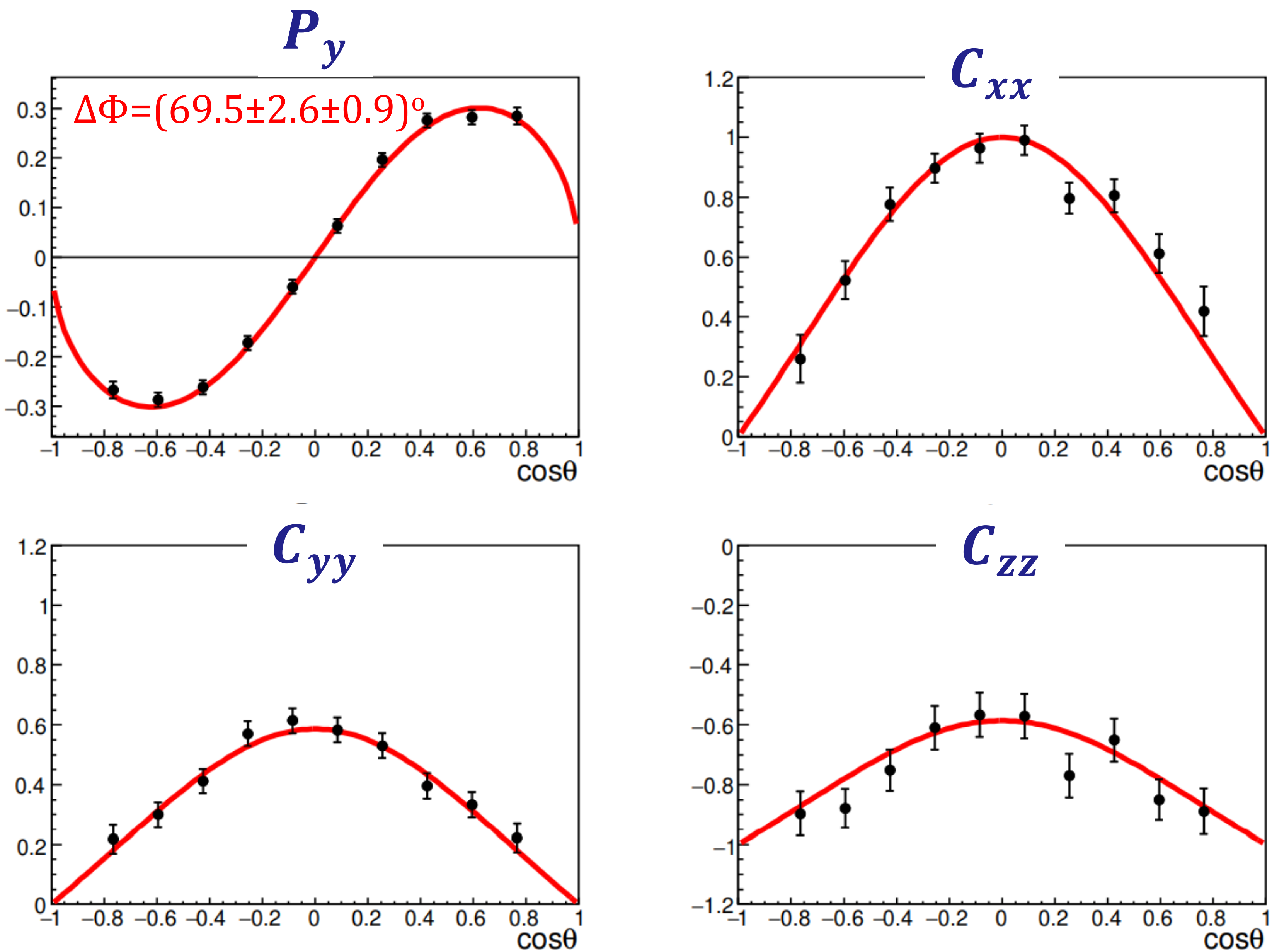
CP test: $$A_\Lambda = \frac{\alpha_\Lambda + \bar{\alpha}_\Lambda}{\alpha_\Lambda - \bar{\alpha}_\Lambda}$$

$A_\Lambda = -0.0025(46)$

$$A_\Lambda = -\tan\left(\delta_P^\Lambda - \delta_S^\Lambda\right)\ (\xi_P^\Lambda - \xi_S^\Lambda)$$

Known strong $p\,\pi^-$ s and $p-$wave phases: $= 0.12\ (\xi_P^\Lambda - \xi_S^\Lambda)$

Polarization and C_{ii} for $e^+e^- \to J/\psi \to \Xi^-\bar{\Xi}^+$



Nature 606 (2022) 64

$(g-2)_\mu$ related plans:

KLOE-2: contribution to $e^+e^- \to \pi^+\pi^-$

Modular event generators:

Combine symbolic & high performance numeric calculations

Can be used as p.d.f. fitter (unbinned MLL methods), and to extract acceptance corrected observables