Narodowe Centrum Badań Jądrowych
National Centre for Nuclear Research
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Phenomenology of hyperon non-leptonic decays

Nora Salone

National Centre for Nuclear Research

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2023

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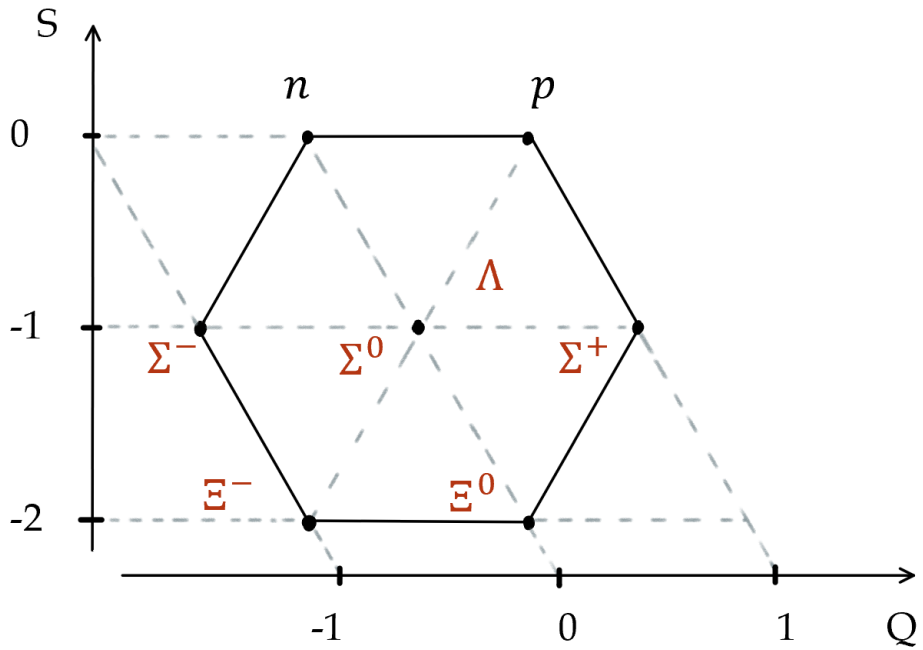
- **Non-leptonic** ! *1c*
- S = 1 transitions of lowest-lying *B*-baryons



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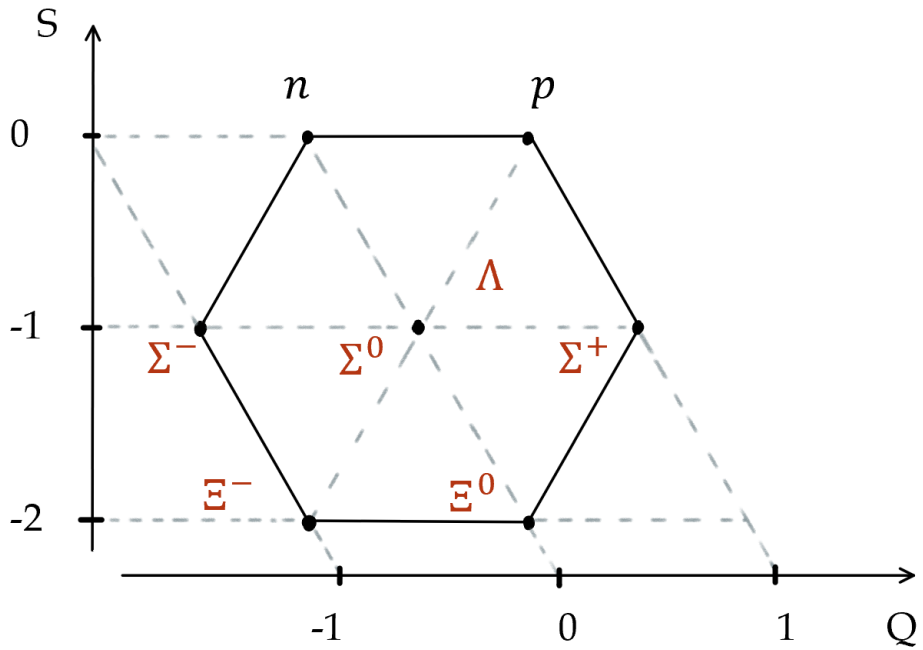

Focus on:

- $\bar{\ }$ spin-entangled pairs produced at $4 \cdot 4$ collider: feasibility studies.

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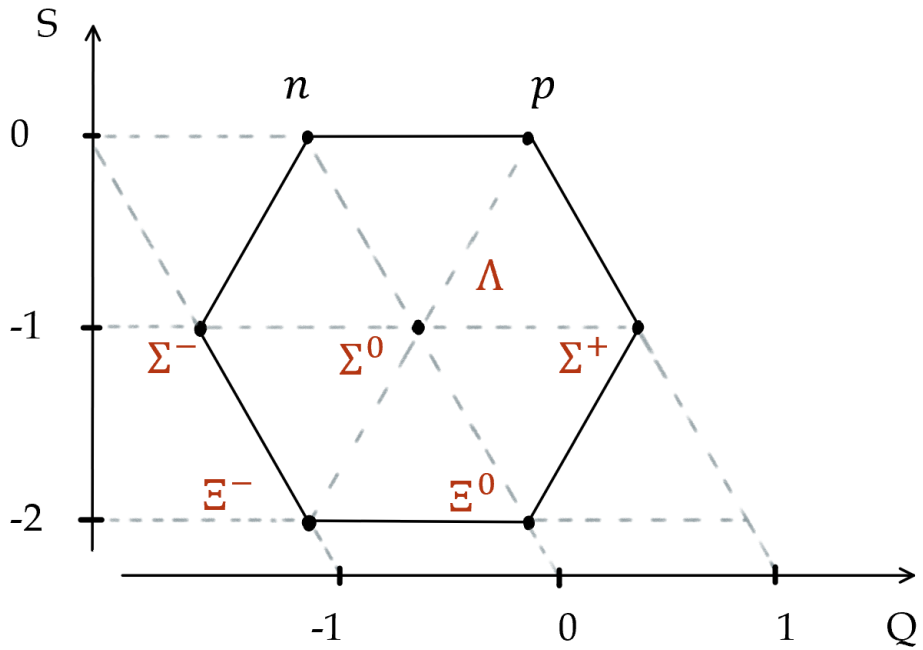

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- . decays theoretical description in jPT.

Hyperon decay formalism

Weak parity-conserving (P)
and -violating (S) amplitudes

$$A = (\; , \; \%\mathfrak{G} \quad \triangleq$$

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CP-odd and final state interaction phases
[Donoghue et al.(1986)]

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Two measurable parameters

$$U = \frac{2<{}^{1}(\ \%^{\mathrm{o}}}{\mathrm{j}(\mathrm{j}^{2}\ ,\ \mathrm{j}\%\mathrm{j}^{2}}$$

Two CP violation tests

$$_{\mathrm{CP}} = \frac{U\ ,\ \bar{U}}{U\quad \bar{U}}$$

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$$V = \frac{2 = {}^{1}(\; \%^{\mathrm{o}}}{\mathrm{j}(\mathrm{j}^{2} \; , \; \mathrm{j}\%\mathrm{j}^{2}} = \frac{\mathrm{p}}{1 \quad U^{2}} \sin q$$

Two CP violation tests

$$_{\mathrm{CP}} = \frac{U \; , \; \bar{U}}{U \quad \bar{U}}$$

$$_{\mathrm{CP}} = \frac{q \; , \; \bar{q}}{2}$$

Motivation: new data landscape

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*

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Article | Open Access | Published: 01 June 2022

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

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Nature **606**, 64–69 (2022) | Cite this article
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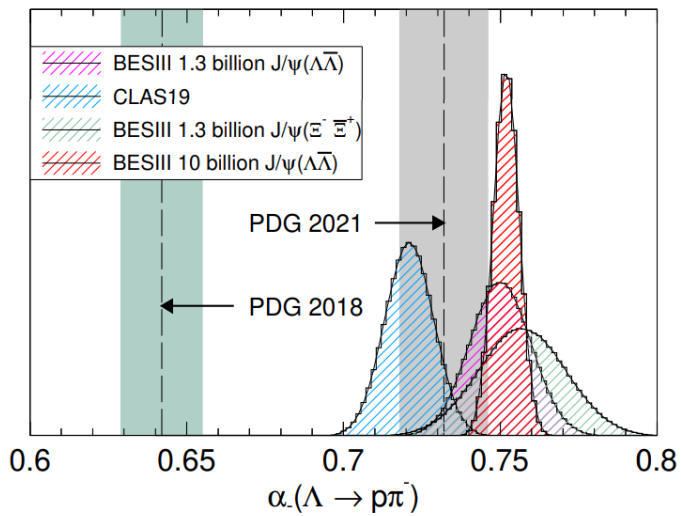
Precise Measurements of Decay Parameters and CP Asymmetry with Entangled Λ–$\bar{\Lambda}$ Pairs

M. Ablikim *et al.* (BESIII Collaboration)
Phys. Rev. Lett. **129**, 131801 – Published 22 September 2022

[Phys.Rev.Lett. 129 (2022) 131801]



CPV in hyperon decays

$(-\% = 5^{1} b_{(-\%} - X_{(-\%}{}^{o} \quad =)$

$($
$U \; / \; <^{1}(\; \%^{o}$
$\sin q \; / \; =^{1}(\; \%^{o}$

(- % amplitudes expanded up to LO
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[Salone et al. (2022)]

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$$_{CP} = \tan^{1}X_{\%} \quad X_{(}{}^{o} \tan^{1}b_{\%} \quad b_{(}{}^{o}$$

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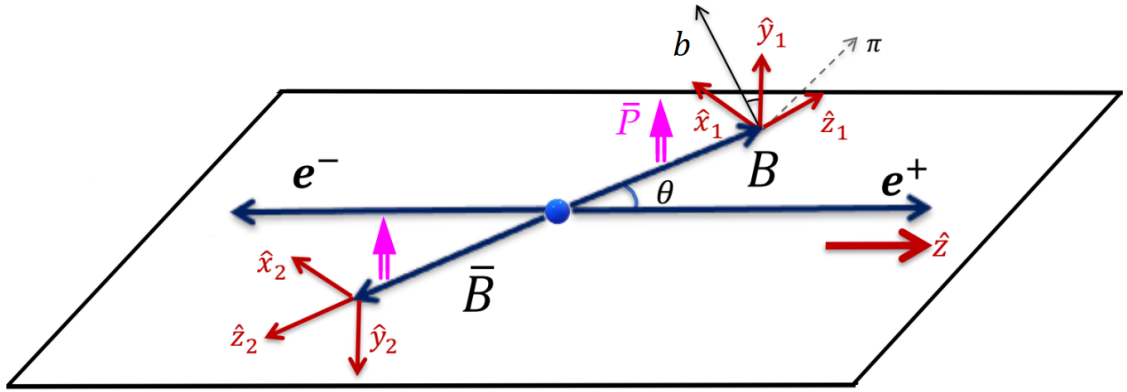
- first measurement of CP-odd phase difference

[BESIII collab. (2022)] : $b_{\%} \quad b_{(} = {}^{1}1{\bullet}2 \quad 3{\bullet}4 \quad 0{\bullet}8^{o} \quad 10^{\ 2}$ rad

SM : $b_{\%} \quad b_{(} = {}^{1} \ 2{\bullet}1 \quad 1{\bullet}7^{o} \quad 10^{\ 4}$ rad

Lowest-lying hyperons @ BESIII

- World's largest charmonia sample in BESIII - 10^{10} •k, 3 10^9 k¹2(º
- Baryon-antibaryon production in spin-entangled state



[V. Batozskaya, BEACH22]

Decay	B¹ 10 ⁴º	U_k	(rad)	BESIII collaboration
•k ! ¯	19•43¹3º	0•461¹9º	0•740¹13º	[2019, 2017a]
•k ! ¯	15•0¹24º	0•508¹7º	0•270¹15º	[2008, 2020]
•k ! ¯	..	..	..	ongoing analysis
•k ! 0 ¯ 0	11•64¹4º	0•449¹20º	..	[2017a]
•k ! 0 ¯ 0	11•65¹43º	0•66¹6º	..	[2017b]
•k ! ¯	9•7¹8º	0•586¹16º	1•213¹48º	[2020, 2022]

Baryon polarization @ BESIII

Λ polarization:

$$P_{-H}{}^{1}\cos\backslash^{o} = \frac{q\ \_\_\_\_\_}{1 \quad U_k{}^{2}\cos\backslash\ \sin\backslash} \sin^{1}$$

Final 1 angular distribution:

$$o \qquad \frac{d}{d} / \ 1 \, , \ U \ \Lambda \quad \hat{n}$$

Baryon polarization @ BESIII

Λ polarization:

$$P_{-H}\cos\theta = \frac{\sqrt{1-U_k^2}\cos\theta\sin\theta}{1+U_k\cos^2\theta}\sin\theta$$

Final angular distribution:

$$\frac{d}{d\Omega} \propto 1+U\,\vec{P}_\Lambda\cdot\hat{n}$$

Joint density matrix [Perotti et al. (2019)]:

$$d = \sum_{\lambda-a=0} f_\lambda f_a$$

Baryon polarization with polarized beam

[Perotti et al. (2019)]

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$$\hat{a} = \begin{pmatrix} 1 + U_k \cos^2\theta & W_k + 4\sin\theta & V_k \sin\theta\cos\theta & 1 + U_k + 4\cos\theta \\ W_k + 4\sin\theta & \sin^2\theta & 0 & W_k \sin\theta\cos\theta \\ V_k \sin\theta\cos\theta & 0 & U_k \sin^2\theta & V_k + 4\sin\theta \\ 1 + 1 + U_k + 4\cos\theta & W_k \sin\theta\cos\theta & V_k + 4\sin\theta & U_k \cos^2\theta \end{pmatrix}$$

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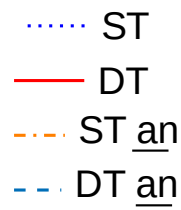
Baryon polarization with polarized beam

CP tests uncertainties α_ψ-dependent:



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- Additional information to β and spin-entanglement contributions

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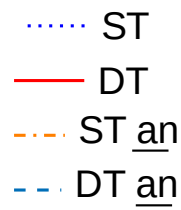

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Beam polarization: a useful tool on the road to reach SM CPV uncertainties!

Nonleptonic decays review[1]

New data situation from BESIII calls for an update of theoretical predictions:

- Focus on $S = 1$, Δ $1c$ decays in$j$ PT up to 1-loop corrections

[1] NAWA grant no. PPN/STA/2021/1/00011/U/00001

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- joint, ongoing collaboration Warsaw - Uppsala - Valencia

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How do new data + relativistic approach affect $($, $\%$-wave description?

Preliminary results

Decay	$\mathcal{B}$	$\mathcal{B}_{\text{old}}$	$\mathcal{A}_{CP}$	$\mathcal{A}_{CP\,\text{old}}$
$B^+ \to \pi^+ K^0$	$0.06^{+1.1}_{-1.0}$	$0.06^{+1.1}_{-1.0}$	$1.81^{+1.1}_{-1.0}$	$1.81^{+1.1}_{-1.0}$
$B^+ \to \pi^+ \pi^0$	$1.38^{+1.2}_{-1.0}$	$1.43^{+1.5}_{-1.0}$	$1.24^{+1.3}_{-1.0}$	$1.17^{+1.7}_{-1.0}$
$B^0 \to \pi^- K^+$	$1.88^{+1.1}_{-1.0}$	$1.88^{+1.1}_{-1.0}$	$0.06^{+1.1}_{-1.0}$	$0.06^{+1.1}_{-1.0}$
$B^0 \to \pi^0 K^0$	$1.38^{+1.1}_{-1.0}$	$1.42^{+1.1}_{-1.0}$	$0.63^{+1.1}_{-1.0}$	$0.52^{+1.2}_{-1.0}$
$B^0 \to \pi^- \pi^+$	$1.03^{+1.1}_{-1.0}$	$1.04^{+1.1}_{-1.0}$	$0.41^{+1.1}_{-1.0}$	$0.39^{+1.4}_{-1.0}$
$B^0 \to \pi^0 \pi^0$	$1.99^{+1.1}_{-1.0}$	$1.98^{+1.1}_{-1.0}$	$0.39^{+1.1}_{-1.0}$	$0.48^{+1.2}_{-1.0}$
$B^0 \to K^+ K^-$	$1.51^{+1.1}_{-1.0}$	$1.52^{+1.2}_{-1.0}$	$0.27^{+1.1}_{-1.0}$	$0.33^{+1.2}_{-1.0}$

Table: Comparison between amplitude values [Jenkins(1992)].

Conclusions and outlook

- BESIII collab.: $5f$ deviation on U value.
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