Hyperon spectroscopy and decays at BESIII

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Outline

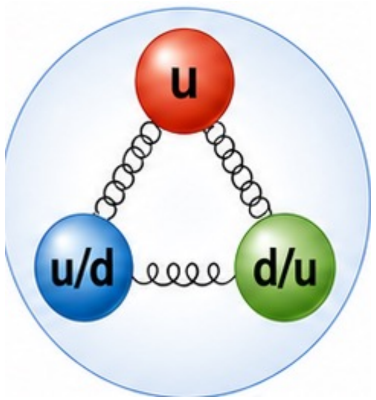
1. Introduction
2. The BESIII Experiment
3. Key Spectroscopy Results
4. Radiative Decays
5. Summary & outlook

Introduction

01 From Nucleons to SU(3) Flavor Sector

Nucleon sector (SU(2))

Nucleons (p, n)

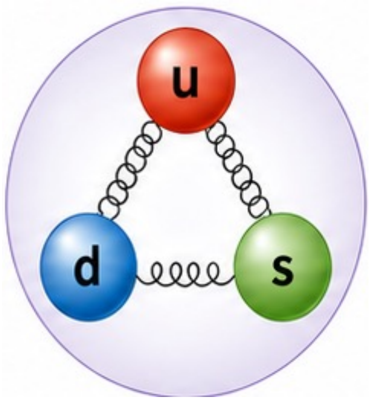


- Well-established spectrum
- Many states observed
- Quantum numbers relatively well determined

Extend to SU(3) flavor sector

Strange baryons (SU(3))

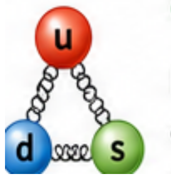
Hyperons (Λ, Σ, Ξ, Ω, ...)



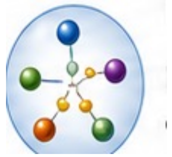
- Rich predicted spectrum
- Many states unobserved
- Quantum numbers & decays poorly determined

What we learn

Flavor symmetry breaking



Quark dynamics



Baryon structure

Strange baryons probe flavor-symmetry breaking and quark dynamics in the SU(3) sector.

01 Hyperon Status

BESIII

PDG(2026)

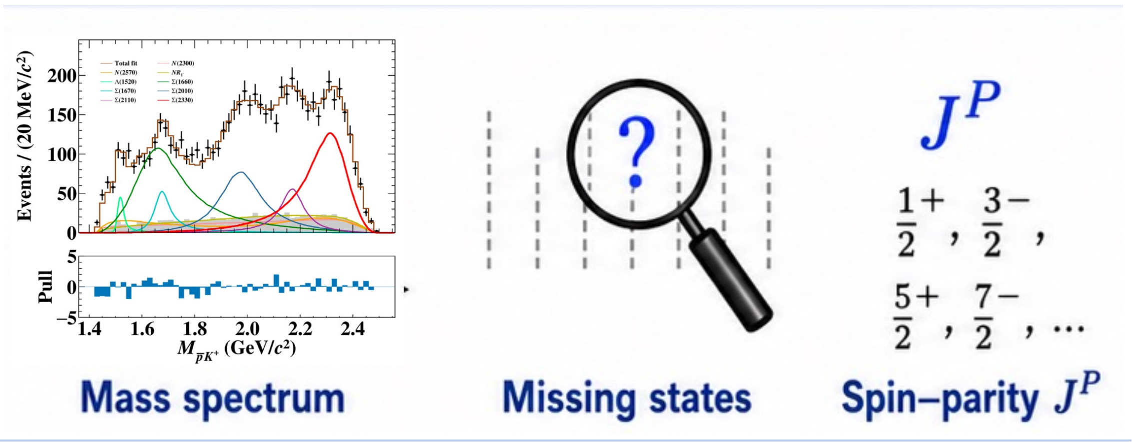
Hyperon family (Strangeness S)	Λ (S = −1) I = 0	Σ (S = −1) I = 1	Ξ (S = −2) I = 1/2	Ω (S = −3) I = 0	Total (All families)
★★★★ Established	10 states (43.5%)	8 states (28.6%)	3 states (25.0%)	1 state (16.7%)	22 states (31.9%)
★★★ Very likely	4 states (17.4%)	4 states (14.3%)	4 states (33.3%)	2 states (33.3%)	14 states (20.3%)
★★ Fair evidence	2 states (8.7%)	3 states (10.7%)	3 states (25.0%)	2 states (33.3%)	10 states (14.5%)
★ Poor evidence	7 states (30.4%)	13 states (46.4%)	2 states (16.7%)	1 state (16.7%)	23 states (33.3%)
Total (all ratings)	23 states	28 states	12 states	6 states	69 states

As the strangeness increases from S = -1 to S = -3, the experimental knowledge decreases rapidly, while the opportunities for discovery increase dramatically.

01 Two Complementary Questions

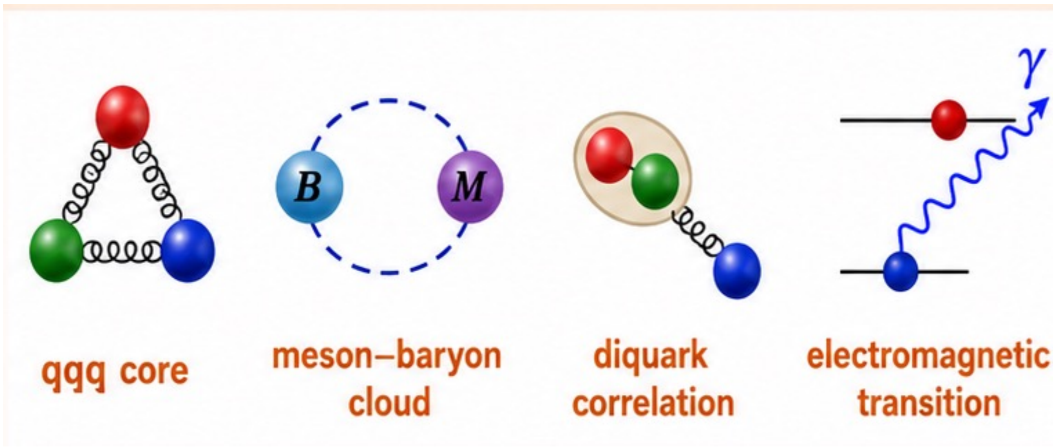
BESIII

Which excited states exist?



- Many predicted hyperons remain unobserved
- Masses, widths, J^P and decay modes require PWA

How are they structured?



- Transition amplitudes probe wave functions
- Radiative decays test quark models and SU(3)

Spectroscopy + decays ⇒ spectrum and internal structure

The BESIII Experiment

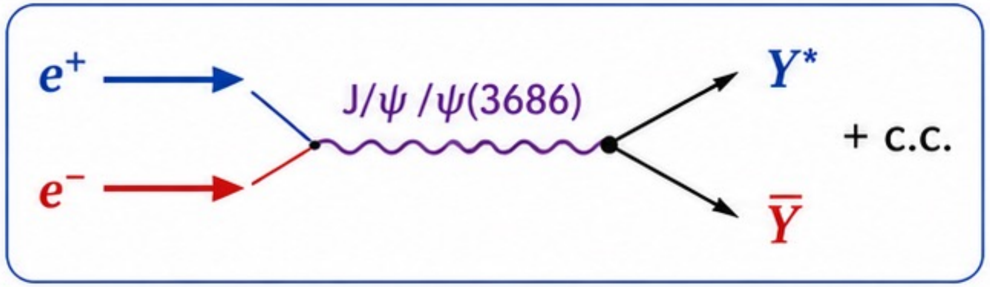
02 BESIII: Hyperon Factory

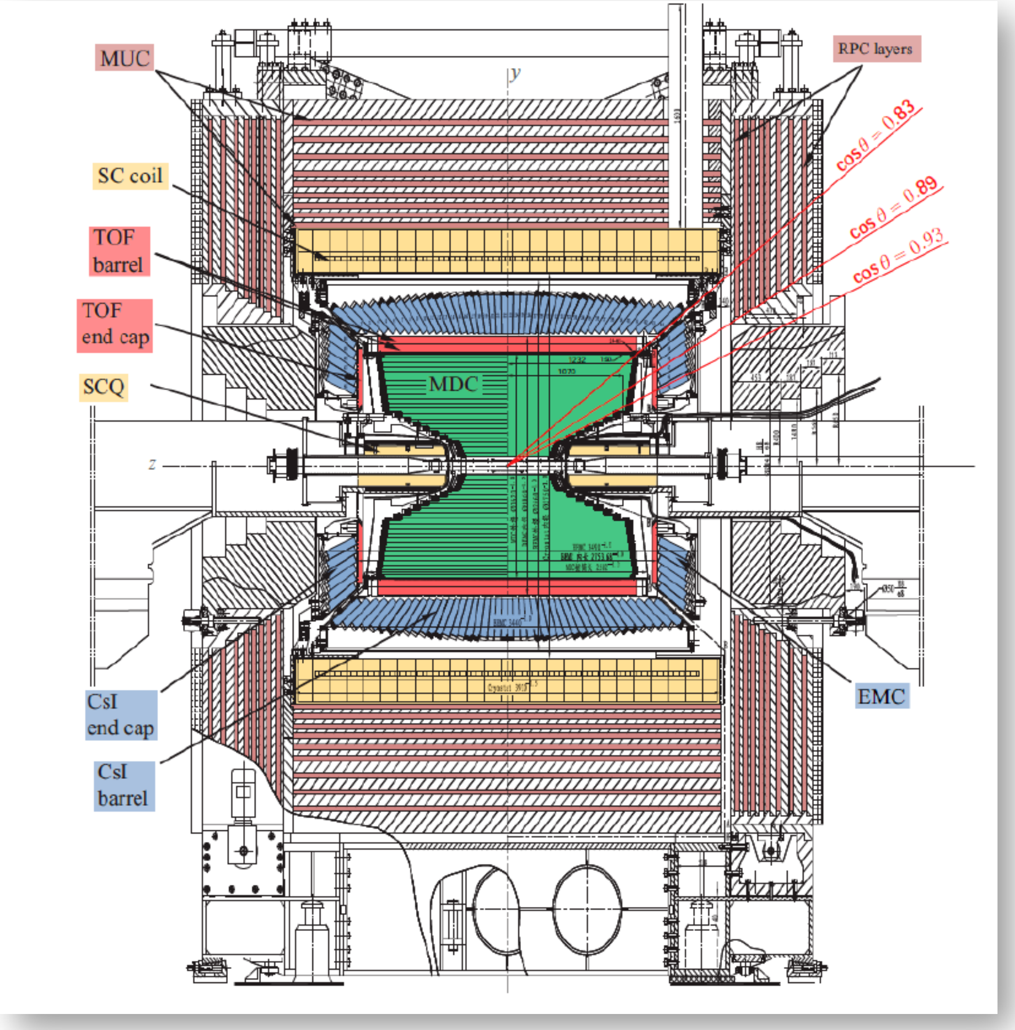
10.1 billion J/ψ events

2.7 billion $\psi(3686)$ events

e^+e^- clean environment

Excellent tracking, PID and photon detection



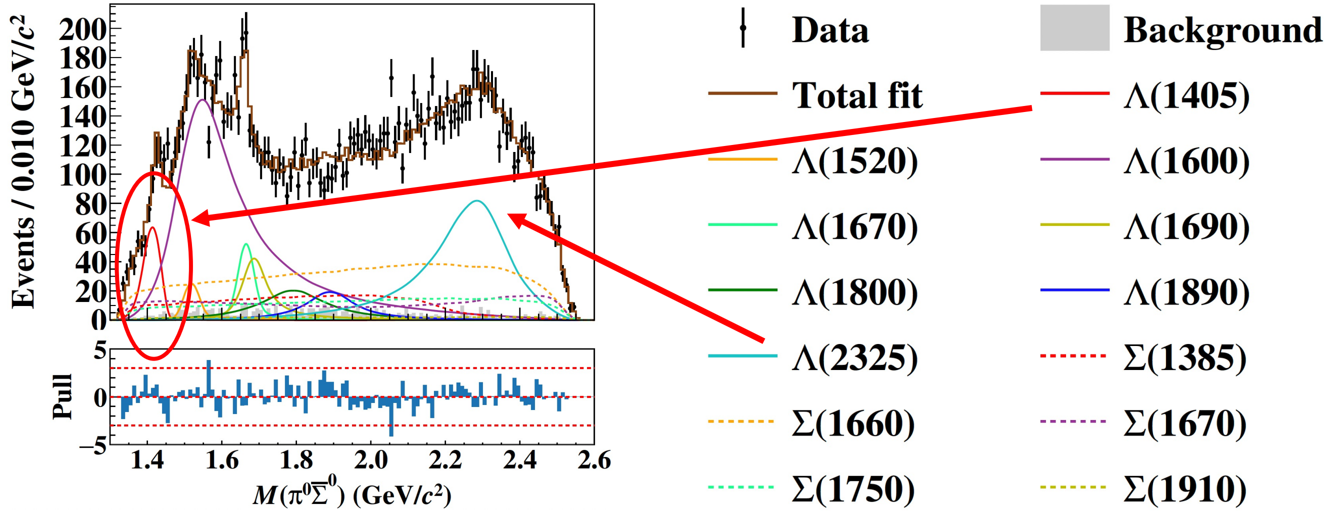


Large data samples enable rare channels and amplitude analyses.

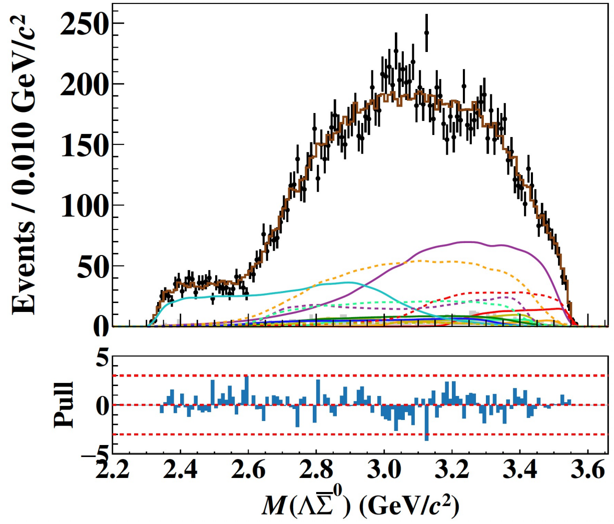
Key Spectroscopy Results

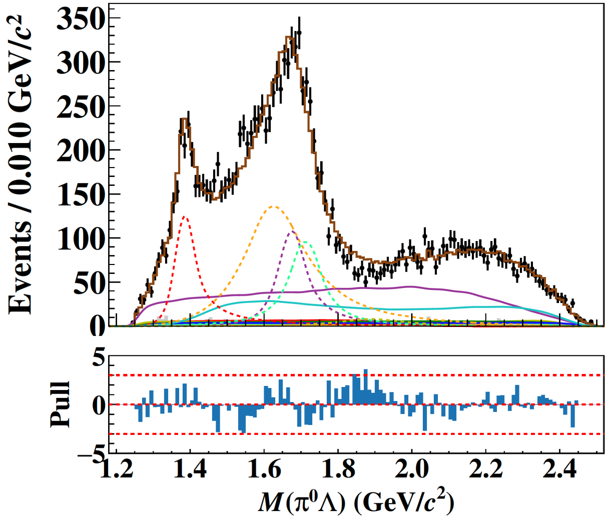
03 Key Results I: Confirmation of $\Lambda(2325)$

$\psi(3686) \to \Lambda\bar{\Sigma}^0\pi^0$: 2.7 B $\psi(2S) \Rightarrow 15561 \pm 131\ \Lambda\bar{\Sigma}^0\pi^0$



Resonance	Mass (MeV/c^2)	Width (MeV)	$\mathcal{B}$ ($\times 10^{-5}$)
$\Lambda(1405)$	...	...	$0.44 \pm 0.05 \pm 0.12$
$\Lambda(1520)$	$1519.9 \pm 1.6 \pm 4.8$	$20.6 \pm 1.9 \pm 0.6$	$0.19 \pm 0.05 \pm 0.05$
$\Lambda(1600)$	$1570.5 \pm 4.6 \pm 12.1$	$228.1 \pm 11.9 \pm 34.8$	$4.49 \pm 0.25 \pm 1.23$
$\Lambda(1670)$	$1667.5 \pm 2.3 \pm 3.6$	$30.2 \pm 4.2 \pm 8.7$	$0.33 \pm 0.07 \pm 0.09$
$\Lambda(1690)$	$1691.1 \pm 4.4 \pm 15.7$	$72.3 \pm 4.7 \pm 18.3$	$0.55 \pm 0.11 \pm 0.10$
$\Lambda(1800)$	$1800.9 \pm 13.3 \pm 12.6$	$208.8 \pm 14.5 \pm 36.7$	$0.60 \pm 0.15 \pm 0.18$
$\Lambda(1890)$	$1897.2 \pm 9.6 \pm 6.2$	$149.2 \pm 13.5 \pm 4.1$	$0.47 \pm 0.10 \pm 0.09$
$\Lambda(2325)$	$2306.5 \pm 6.3 \pm 17.1$	$227.1 \pm 12.2 \pm 47.8$	$2.93 \pm 0.20 \pm 0.26$
$\Sigma(1385)$	$1388.2 \pm 1.9 \pm 3.3$	$60.5 \pm 3.6 \pm 6.3$	$1.30 \pm 0.11 \pm 0.19$
$\Sigma(1660)$	$1643.2 \pm 4.5 \pm 7.6$	$221.3 \pm 13.1 \pm 41.1$	$3.53 \pm 0.29 \pm 0.63$
$\Sigma(1670)$	$1679.7 \pm 3.4 \pm 4.3$	$87.0 \pm 6.4 \pm 8.9$	$1.60 \pm 0.25 \pm 0.38$
$\Sigma(1750)$	$1714.9 \pm 4.2 \pm 7.3$	$97.2 \pm 9.8 \pm 9.7$	$1.39 \pm 0.23 \pm 0.32$
$\Sigma(1910)$	$1912.1 \pm 10.6 \pm 33.6$	$225.1 \pm 24.5 \pm 46.0$	$0.23 \pm 0.10 \pm 0.06$

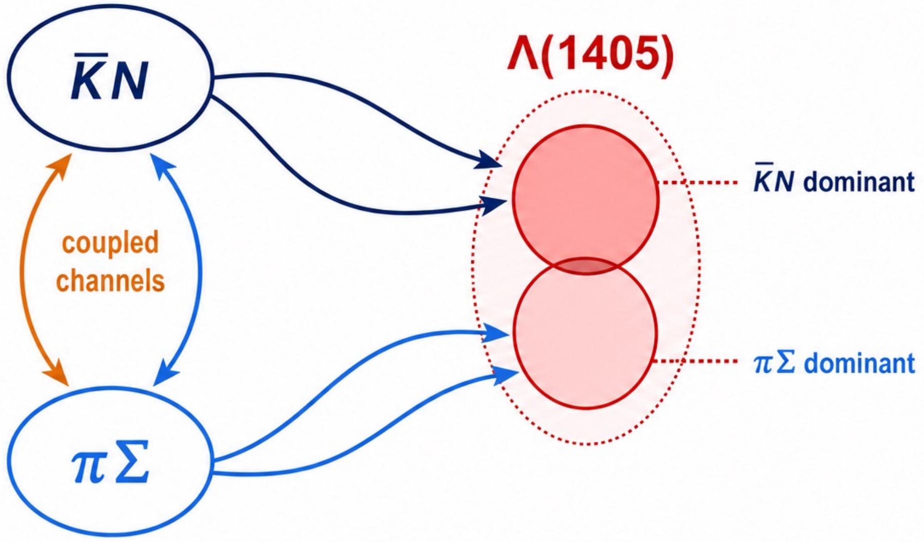




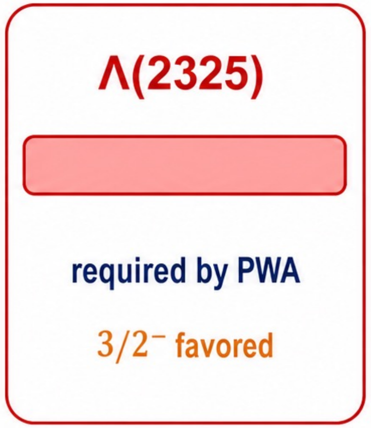
- 13 resonances detected
- **Strong existence of $\Lambda(2325)$: $J^P = \frac{3}{2}^-$**
- Flatté-like and chiral dynamics model for $\Lambda(1405)$ dipole structure $\Rightarrow$ distinguishable due to the limited statistics

JHEP. 02, 212 (2025)

Key Results I: Confirmation of $\Lambda(2325)$



- Chiral: 11.1σ
- Flatté: 11.2σ
- Cannot be distinguished

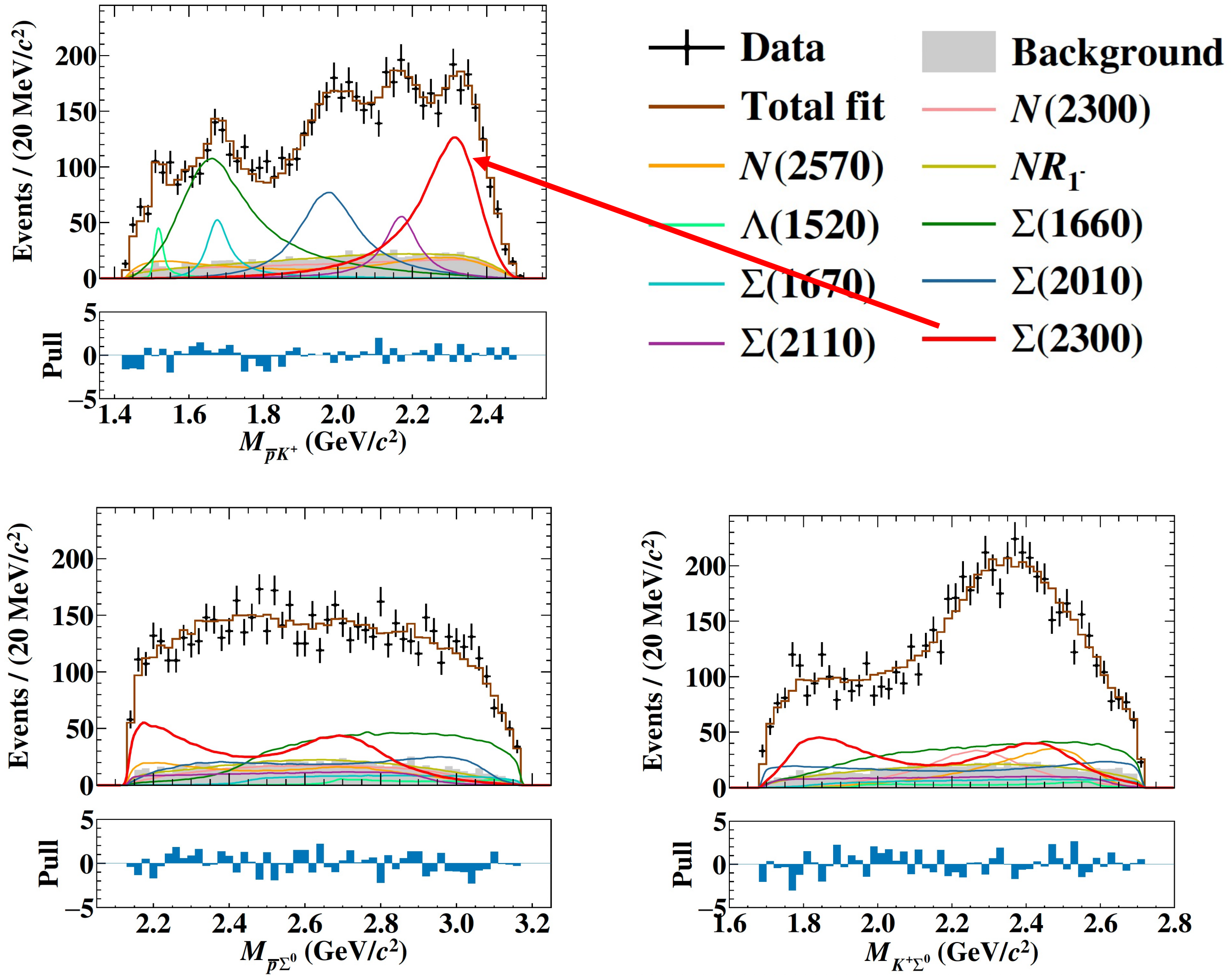


Λ	$1/2^+$	****
$\Lambda(1380)$	$1/2^-$	**
$\Lambda(1405)$	$1/2^-$	****
$\Lambda(1520)$	$3/2^-$	****
$\Lambda(1600)$	$1/2^+$	****
$\Lambda(1670)$	$1/2^-$	****
$\Lambda(1690)$	$3/2^-$	****
$\Lambda(1710)$	$1/2^+$	*
$\Lambda(1800)$	$1/2^-$	***
$\Lambda(1810)$	$1/2^+$	***
$\Lambda(1820)$	$5/2^+$	****
$\Lambda(1830)$	$5/2^-$	****
$\Lambda(1890)$	$3/2^+$	****
$\Lambda(2000)$	$1/2^-$	*
$\Lambda(2050)$	$3/2^-$	*
$\Lambda(2070)$	$3/2^+$	*
$\Lambda(2080)$	$5/2^-$	*
$\Lambda(2085)$	$7/2^+$	**
was $\Lambda(2020)$		
$\Lambda(2100)$	$7/2^-$	****
$\Lambda(2110)$	$5/2^+$	***
$\Lambda(2325)$	$3/2^-$	*
$\Lambda(2350)$	$9/2^+$	***
$\Lambda(2585)$		*

$\Lambda(1405)$: structure unresolved | $\Lambda(2325)$: existence strengthened

03 Key Results II: Observation of $\Sigma(2330)$

$\psi(3686) \to \bar{p}K^+\Sigma^0$: 2.7 B $\psi(2S) \Rightarrow 6100 \pm 86\ \bar{p}K^+\Sigma^0$



J^P scan for $\Sigma(2330)$

J^P	ΔNLL	$\Delta N_{\rm dof}$	S (σ)
$1/2^-$	20.1	6	5.1
$1/2^+$	48.9	6	8.9
$3/2^-$	85.7	8	11.9
$3/2^+$	71.2	8	10.7
$5/2^-$	74.1	8	11.0
$5/2^+$	53.7	8	9.1
$7/2^-$	44.3	8	8.0

?

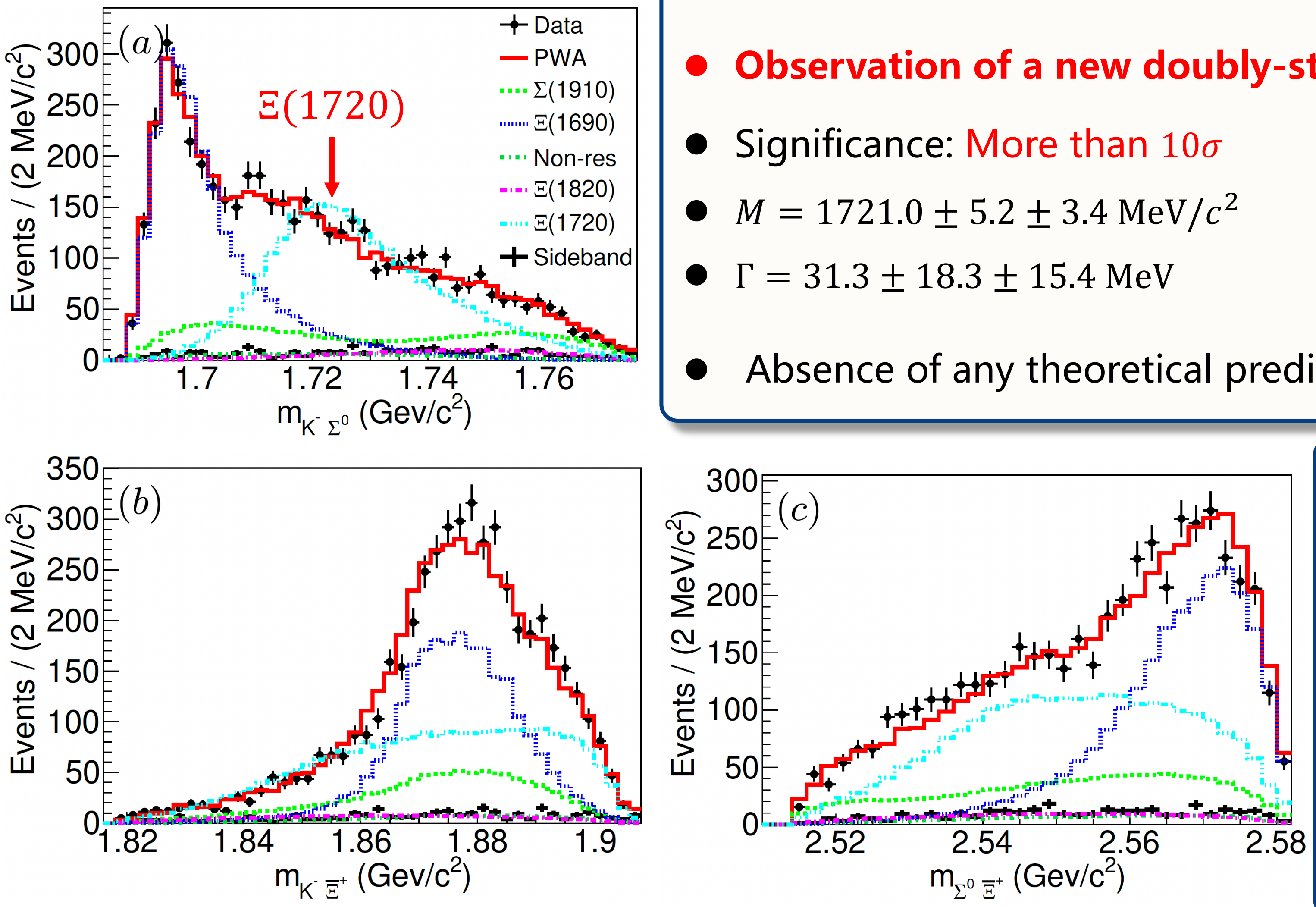
- **Observation of a new excited state**

  $\boldsymbol{\Sigma(2330)}$: $J^P = \frac{3}{2}^- \Rightarrow \mathbf{11.9\sigma}$
- $M = 2334.7 \pm 7.9 \pm 16.0\ \mathrm{MeV}/c^2$
- $\Gamma = 206.3 \pm 9.5 \pm 18.4\ \mathrm{MeV}$
- Compatible with the predicted $1F(3/2^-)$ state within $8\ \mathrm{MeV}/c^2$ Few Body Syst. 65, 63 (2024)

arXiv:2602.11501

03 Key Results III: Observation of Ξ(1720)

$J/\psi \to K^-\Sigma^0\bar{\Xi}^+$: 10 B $J/\psi \Rightarrow 4545 \pm 73\ K^-\Sigma^0\bar{\Xi}^+$



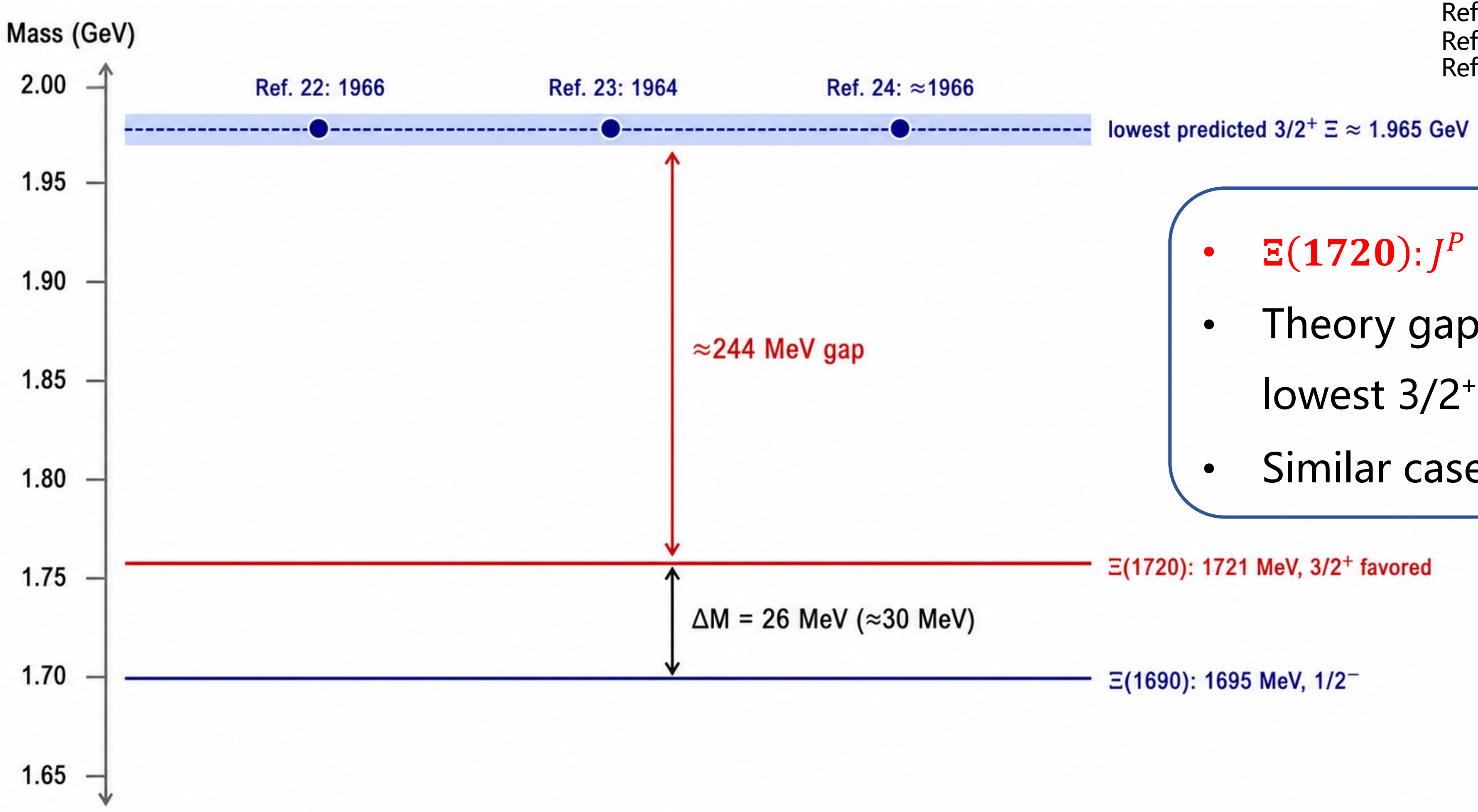
- **Observation of a new doubly-strange hyperon Ξ(1720): $J^P = \frac{3}{2}^+$**
- Significance: More than 10σ
- $M = 1721.0 \pm 5.2 \pm 3.4\ \mathrm{MeV}/c^2$
- $\Gamma = 31.3 \pm 18.3 \pm 15.4\ \mathrm{MeV}$
- Absence of any theoretical prediction for such a state near $1.7\ \mathrm{GeV}/c^2$ ($J^P = \frac{3}{2}^+$)

- Ξ(1690): $J^P = \frac{1}{2}^-$
- $M = 1695.0 \pm 0.9 \pm 0.9\ \mathrm{MeV}/c^2$
- $\Gamma = 12.8 \pm 1.8 \pm 7.6\ MeV$
- Consistent with the previous results
- No established such a state Ξ(1690) with $J^P = \frac{1}{2}^-$ has been theoretically anticipated.

arXiv:2604.27028

03 Key Results III: Observation of $\Xi(1720)$

Ref. 22: Phys. Rev. D 92, 054005 (2015)
Ref. 23: Int. J. Mod. Phys. A 38, 2350053 (2023)
Ref. 24: Nucl. Phys. A 1035, 122658 (2023)



- $\Xi(1720): J^P = 3/2^+$ favored
- Theory gap: models place the lowest $3/2^+$ Ξ near 1.95 GeV
- Similar case for $\Xi(1690)$

A state at 1.72 GeV with $3/2^+$ was not predicted Ξ spectrum remains incomplete

Radiative Decays

Radiative decays for $\Lambda(1520/1690) \to \gamma\Lambda/\gamma\Sigma^0$

- Theoretical predictions:
  - Differ significantly
  - Assuming $\Lambda(1520)$ to be a SU(3) singlet:

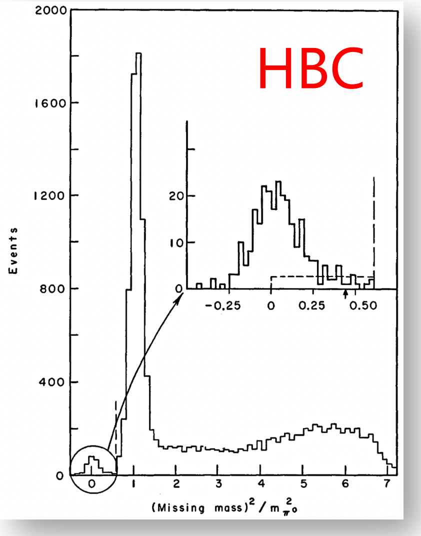
Phys.Atom.Nucl. **59**, 2080 (1996)

$$\mathcal{R} \equiv \frac{\mathcal{B}(\Lambda(1520)\to\gamma\Lambda)}{\mathcal{B}(\Lambda(1520)\to\gamma\Sigma^0)} \approx 0.3$$

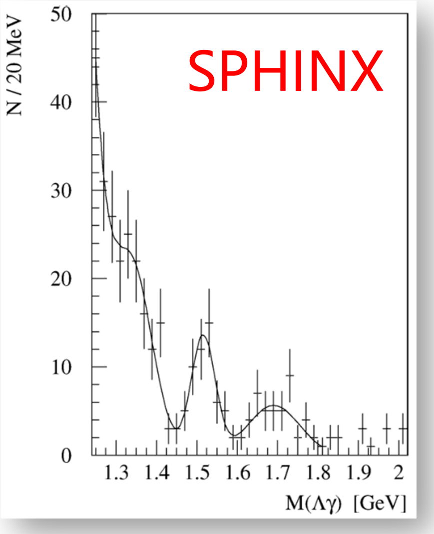
Phys. Rev. D **73**, 114001 (2006)

$B_i \to B_f + \gamma$	$\Lambda(1520) \to \gamma\Lambda$	$\Lambda(1520) \to \gamma\Sigma^0$
χQM [3]	134	92
$NRQM$	156 [6],96 [7]	55 [6], 74 [7]
$RCQM$[8]	215	293
$MIT\ Bag$[6]	46	17
$Chiral\ Bag$[9, 10]	32	51
$Algebraic\ model$[11]	85.1	180.4
CLAS [5]	$167 \pm 43^{+26}_{-12}$	

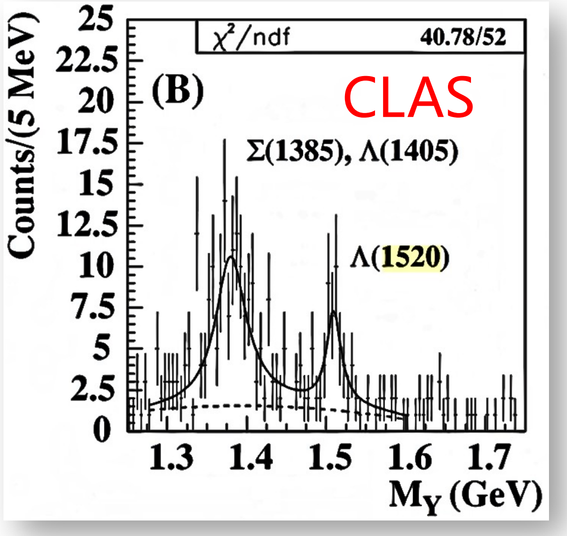
- Experimental measurements:
  - ✅ $\Lambda(1520) \to \gamma\Lambda$
  - ? $\boldsymbol{\Lambda(1520) \to \gamma\Sigma^0}$



Phys. Rev. Lett. **21**, 1715 (1968)



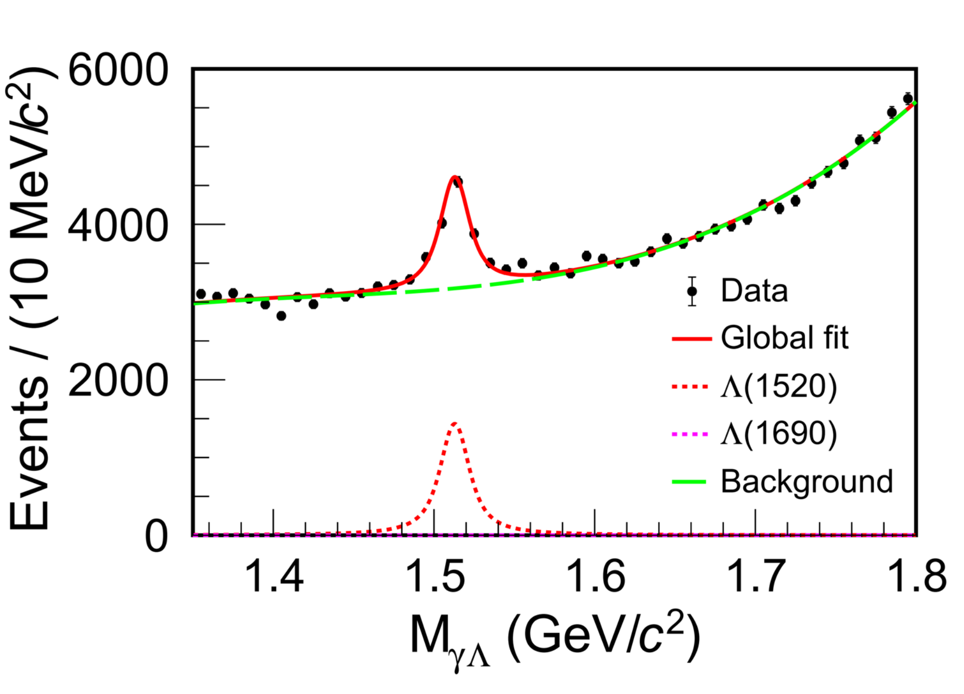
Phys. Lett. B **604**, 22 (2004)

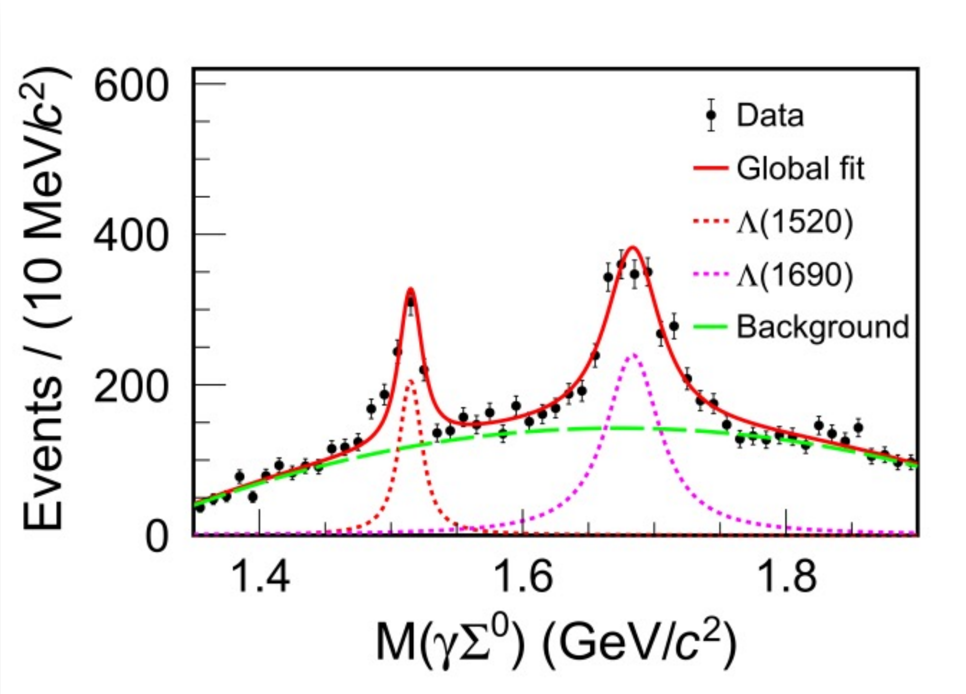


Phys. Rev. C **71**, 054609 (2005)

04 Radiative decays for $\Lambda(1520/1690) \to \gamma\Lambda/\gamma\Sigma^0$

- 10087×10^6 $J/\psi \Rightarrow$ Study resonant structure in $J/\psi \to \gamma\Lambda\bar{\Lambda}$ and $\gamma\bar{\Lambda}\Sigma^0$ processes
- Clear $\Lambda(1520)$ in **both** $M(\gamma\Lambda)$ and $M(\gamma\Sigma^0)$
  - ✓ 4043 ± 247 $\Lambda(1520) \to \gamma\Lambda$ & 621 ± 53 $\Lambda(1520) \to \gamma\Sigma^0$
- $\Lambda(1690)$ **only** in $\gamma\Sigma^0$ channel
  - ✓ 1754 ± 122 $\Lambda(1690) \to \gamma\Sigma^0$ & < 341 $\Lambda(1690) \to \gamma\Lambda$





Phys. Rev. Lett. 136, 141801 (2026)

04 Radiative decays for $\Lambda(1520/1690) \to \gamma\Lambda/\gamma\Sigma^0$

- First observation of $\Lambda(1520) \to \gamma\Sigma^0$

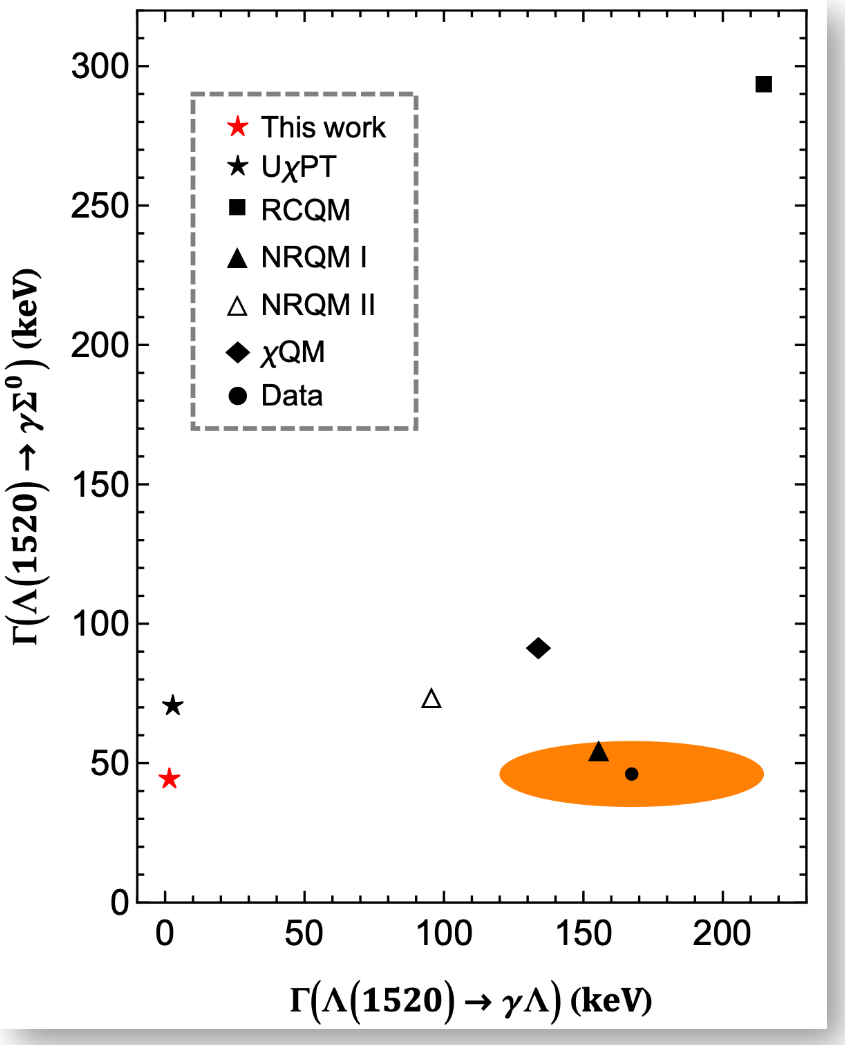
arXiv:2605.14946

  ✓ $\mathcal{R} \equiv \frac{\mathcal{B}(\Lambda(1520)\to\gamma\Lambda)}{\mathcal{B}(\Lambda(1520)\to\gamma\Sigma^0)} = 3.19 \pm 0.34(\text{stat.}) \pm 0.19(\text{syst.})$

  - About 7σ larger than the SU(3) prediction 7σ ✗

  ✓ $\Gamma(\Lambda(1520) \to \gamma\Sigma^0) = \left(46.8 \pm 6.6(\text{stat.}) \pm 9.3(\text{syst.})\right)$ keV

  - About 21σ below the RCQM prediction ✗
  - About 11σ below the Algebraic Model prediction ✗
  - Consistent with the NRQM prediction within 1σ ?



- New theoretical calculation: chiral unitary coupled-channel

  ✓ Only comparable with the result of the $\Gamma(\Lambda(1520) \to \gamma\Sigma^0)$

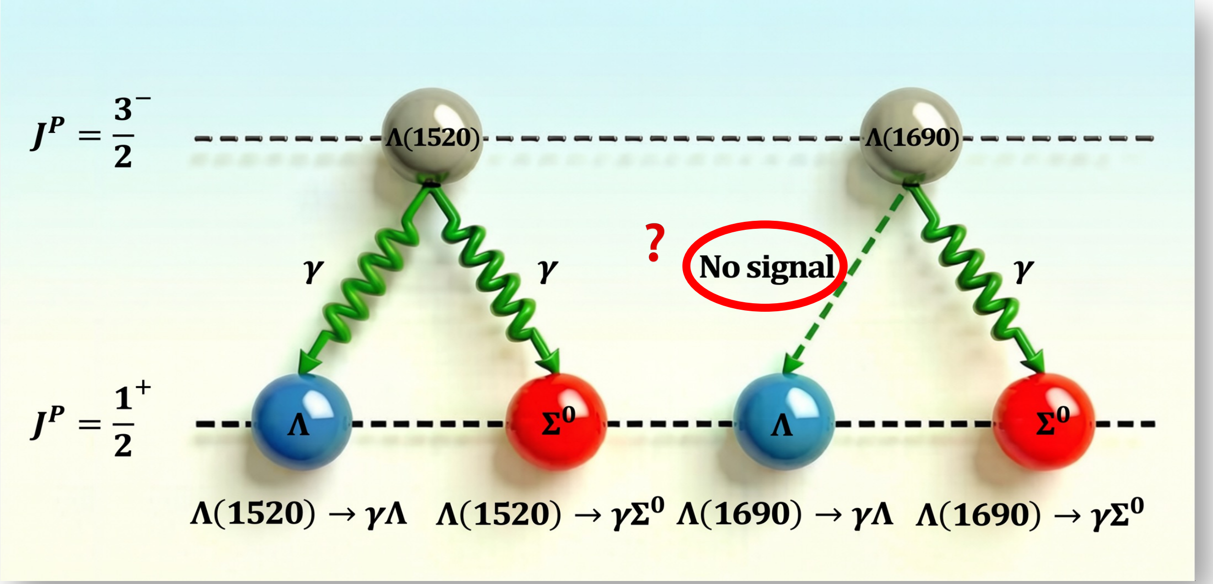
  ✓ Much smaller than the CLAS experimental value

Phys. Rev. Lett. 136, 141801 (2026)

04 Radiative decays for $\Lambda(1520/1690) \to \gamma\Lambda/\gamma\Sigma^0$

- First observation of $\Lambda(1690) \to \gamma\Sigma^0$
  - ✓ $\mathcal{B}(J/\psi \to \bar{\Lambda}\Lambda(1690)) \times \mathcal{B}(\Lambda(1690) \to \gamma\Sigma^0) = (6.05 \pm 0.42(\text{stat.}) \pm 0.39(\text{syst.})) \times 10^{-6}$
- No signal of $\Lambda(1690) \to \gamma\Lambda$
  - ✓ $\mathcal{B}(J/\psi \to \bar{\Lambda}\Lambda(1690)) \times \mathcal{B}(\Lambda(1690) \to \gamma\Lambda) < 5.08 \times 10^{-7}$ (90% C.L.)
- The two decay modes of $\Lambda(1690)$ differ significantly:
  - ✓ $\mathcal{R} \equiv \frac{\mathcal{B}(\Lambda(1690)\to\gamma\Lambda)}{\mathcal{B}(\Lambda(1690)\to\gamma\Sigma^0)} < 0.08$ (90% C.L.)
  - ✓ No viable theory

$\Rightarrow$ PWA of $J/\psi \to \bar{\Lambda}\Sigma^0\pi^0$



Phys. Rev. Lett. 136, 141801 (2026)

05 Summary & Outlook

Summary

Hyperon Spectroscopy

- $\Lambda(2325)$: existence strengthened
- $\Sigma(2330)$: compatible with $1F(3/2^{-})$
- $\Xi(1720)$: $3/2^{-}$ favored, about 240 MeV below predictions

Radiative Decays

- New $\Lambda(1520)$ and $\Lambda(1690)$ measurements provide stringent tests of their electromagnetic structure

Outlook

Quantum Numbers

Determine spin-parity of more hyperon states with future data.

New States

Search for partner states and missing excitations

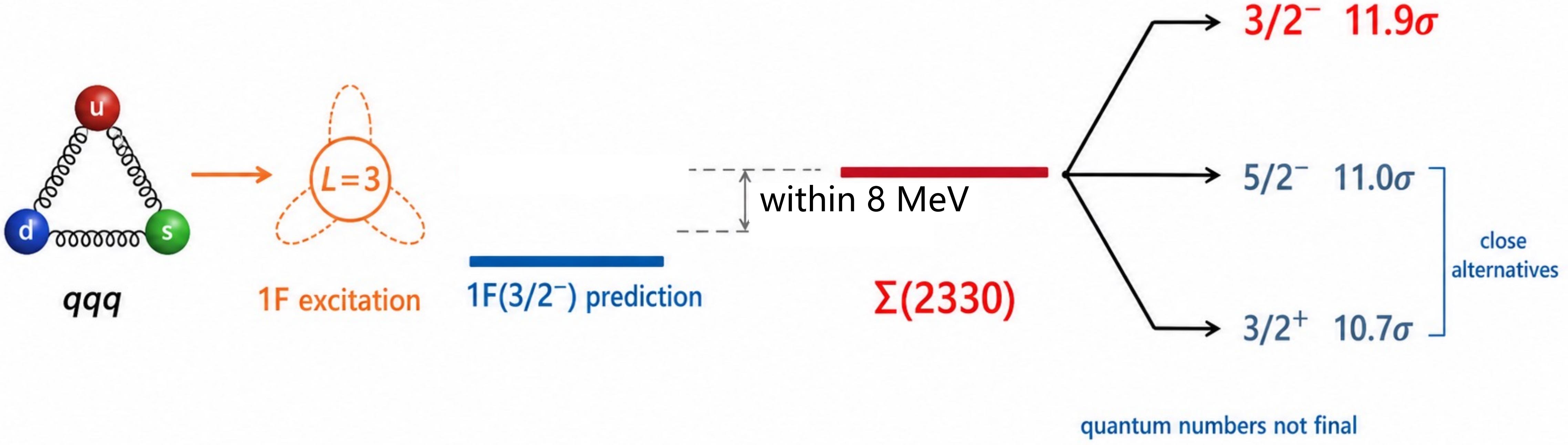
More Analysis

Extend amplitude analyses and radiative-decay measurements with the more BESIII data sets

Thanks for your attention!

Backup

03 Key Results II: Observation of $\Sigma(2330)$



- Mass agreement
- 1F($3/2^-$) prediction: within 8 MeV
- 1F assignment is plausible

- Spin-parity test
- $3/2^-$ favored, $5/2^-$ and $3/2^+$ are close
- Quantum numbers are not final

Mass agrees with the predicted 1F family — spin-parity is not yet unique