Determination and status of the light baryon spectrum

Baryons2022 - International Conference on the Structure of Baryons

November 9, 2022 | Deborah Rönchen | Institute for Advanced Simulation, Forschungszentrum Jülich

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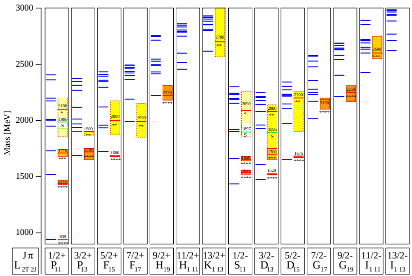
Motivation: N^* and Δ^* spectrum

- The excited baryon spectrum: connection between experiment and QCD in the non-perturbative regime
- In the past: most information from elastic or charge exchange πN scattering,
  e.g. Karlsruhe-Helsinki (KH), Carnegie-Mellon-Berkeley (CMB), George-Washington U (GWU)
- Theoretical predictions, e.g., from quark models (later: lattice calculations)
  $\rightarrow$ "Missing resonance problem": above 1.8 GeV much more states are predicted than observed

Relativistic quark model:



Löring *et al.* EPJ A 10, 395 (2001), experimental spectrum: PDG 2000

20 years later the "Missing resonance problem" is still not solved ...

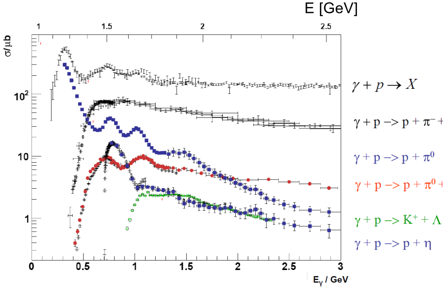
... but there has been progress.

Reviews on baryon spectroscopy:

Prog.Part.Nucl.Phys. 125, 103949 (2022),
Rev. Mod. Phys. 82, 1095 (2010)

Experimental studies of photoproduction reactions:

major progress in recent years e.g. from JLab, ELSA, MAMI, GRAAL, SPring-8, . . .



source: ELSA; data: ELSA, JLab, MAMI

- enlarged data base with high quality for different final states
  Reviews: Prog.Part.Nucl.Phys. 111 (2020) 103752, Rept. Prog. Phys. 76, 076301 (2013)
- (double) polarization observables
  - $\to$ alternative source of information besides $\pi N \to X$
  - $\to$ detect states that couple only weakly to πN
  - $\to$ towards a complete experiment

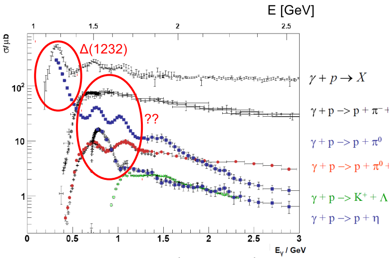
- Photoproduction of pseudoscalar mesons:

- 16 polarization observables: asymmetries composed of **beam**, **target** and/or **recoil** polarization measurements

- Complete Experiment: unambiguous determination of the amplitude Chiang, Tabakin, PRC 55, 2054 (1997), also PRC 95 (2017) 1, 015206

8 carefully selected observables e.g. $\{\sigma,\ \Sigma,\ T,\ P,\ E,\ G,\ C_x,\ C_z\}$

From experimental data to the resonance spectrum



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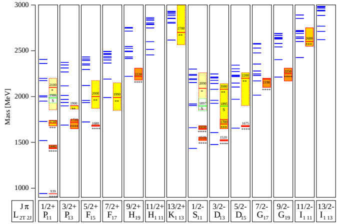
$\Longleftrightarrow$



Löring *et al.* EPJ A 10, 395 (2001), experimental spectrum: PDG 2000

$\Rightarrow$ Partial wave decomposition:

decompose data with respect to a conserved quantum number:

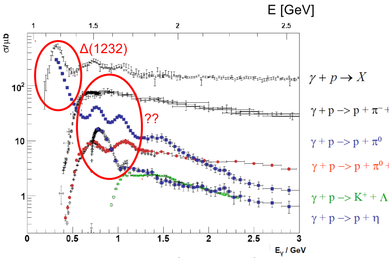
total angular momentum and parity J^P

$\Rightarrow$ search for resonances/excited states in those partial waves:

poles on the 2nd **Riemann sheet**

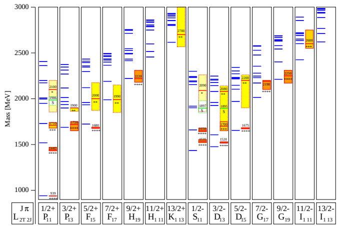
(Breit-Wigner problematic in baryon spectroscopy)

From experimental data to the resonance spectrum



source: ELSA; data: ELSA, JLab, MAMI

$\Longleftrightarrow$

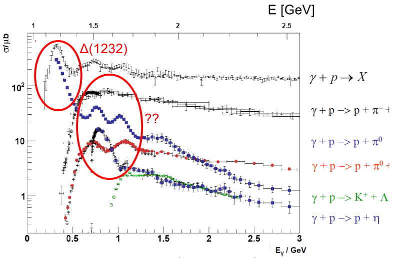


Löring *et al.* EPJ A 10, 395 (2001), experimental spectrum: PDG 2000

Different modern analyses frameworks:

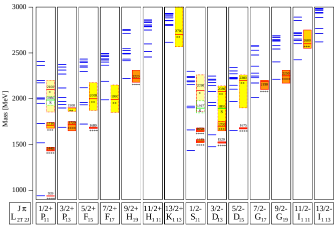
- **unitary isobar models:** unitary amplitudes + Breit-Wigner resonances
  MAID, Yerevan/JLab, KSU
- **(multi-channel) K-matrix:** GWU/SAID, BnGa (phenomenological),
  Gießen (microscopic Bgd)
- **dynamical coupled-channel (DCC):** 3d scattering eq., off-shell intermediate states
  ANL-Osaka (EBAC), Dubna-Mainz-Taipeh, Jülich-Bonn
- **other groups:** JPAC (amplitude analysis with Regge phenomenology), Mainz-Tuzla-Zagreb PWA (MAID + fixed-t dispersion relations, L+P), Ghent (Regge-plus-resonance), truncated PWA
- ...

From experimental data to the resonance spectrum



source: ELSA; data: ELSA, JLab, MAMI

$\Longleftrightarrow$



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The SAID, MAID, BnGa and JüBo approaches

Detailed comparison: EPJ A 52, 284 (2016)

SAID PWA (gwdac.phys.gwu.edu)

based on Chew-Mandelstam K-matrix

- K-matrix elements parameterized as energy-dependent polynomials
- resonance poles are dynamically generated (except for the $\Delta(1232)$)
- masses, width and hadronic couplings from fits to pion-induced πN and ηN production
- photocouplings from photoproduction

Bonn-Gatchina (BnGa) PWA

(pwa.hiskp.uni-bonn.de)

Multi-channel PWA based on K-matrix (N/D)

- mostly phenomenological model
- resonances added by hand
- resonance parameters determined from large experimental data base:
  pion-, photon-induced reactions, 3-body final states
- PWA of $\bar{K}N$ scattering, hyperon spectrum EPJA 55,179 & 180 (2019)

MAID PWA (maid.kph.uni-mainz.de)

unitary isobar model

- resonances as multi-channel Breit-Wigner amplitudes
- background: Born terms + Regge exchanges
- photo- and electroproduction of pions, etas & kaons
- Mainz-Tuzla-Zagreb collaboration: MAID + fixed-t dispersion relations, L+P (pwatuzla.com/p/mtz-collab.html)

Jülich-Bonn (JüBo) DCC model

(collaborations.fz-juelich.de/ikp/meson-baryon/main)

Lippmann-Schwinger eq. formulated in TOPT

- hadronic potential from effective Lagrangians
- photoproduction as energy-dependent polynomials
- resonances as s-channel states (“by hand”), dynamical generation possible
- resonance parameters from pion- and photon-induced data
- Jülich-Bonn-Washington model: CC electroproduction analysis (jbw.phys.gwu.edu)

Recent results from MAID, GWU/SAID, BnGa and JüBo

Selected examples

All 4 groups are constantly including new data sets, primarily from photoproduction

- Mainz-Tuzla-Zagreb: - coupled channels analysis of η, η' photoproduction: “EtaMAID2018” (EPJ A54 (2018) 210)
  - SE PWA of pion photoproduction with fixed-t analyticity PRC 104, 034605 (2021)
- GWU/SAID: - XP15 solution: including new $\pi^\pm p \to \pi^\pm p$ data (EPECUR, PRC 91 (2015) 025205, see also PRC 93 (2016) 062201(R))
  - MA19 solution: $\gamma n \to \pi^0 n$ (PRC 100 (2019) 065205)
    $\to$ first determination of photon decay amplitudes $N^* \to \gamma n$ at the pole for $N(1520)3/2^-$

$\gamma p \to \eta p$

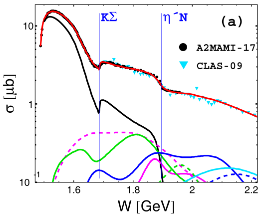
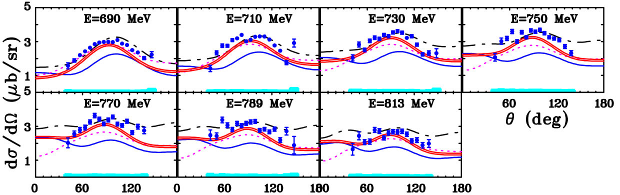


figure: EPJ A 54, 210. Red: EtaMAID2018. Black: S_{11}



← Figure from PRC 100 (2019) 065205

Data: A2 at MAMI (PRC 100 (2019) 065205)
Lines: red: MA19,
blue solid: MA27,
black dash-dotted: MAID2007,
magenta dotted: BnGa2014-02

Recent results from MAID, GWU/SAID, BnGa and JüBo

Selected examples

All 4 groups are constantly including new data sets, primarily from photoproduct

- BnGa: analyses of recent $\gamma p \to \eta p$ data (CBELSA/TAPS):
  - Σ PRL 125, 152002 (2020): further evidence for $N(1895)1/2^-$
  - T, E, P, G, H PLB 803, 135323 (2020): difference in ηN branching ratio of $N(1535)1/2^-$ and $N(1650)1/2^-$ reduced significantly
- JüBo: extension to $K\Sigma$ photoproduction, inclusion of other recent photoproduction data 2208.00089 [nucl-th]: $N(1900)3/2^+$ important, more information on Δ states

Σ in $\gamma p \to \eta p$

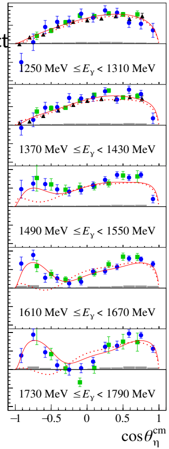
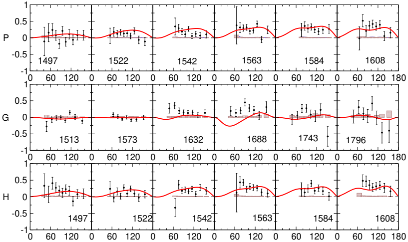


Figure and data (blue points) from Afzal et al. [CBELSA/TAPS] PRL 125 (2020). Black triangles: GRAAL EPJA 33 (2007). Green squares: CLAS PLB 771 (2017)

Red solid lines: BnGa fit

$\gamma p \to \eta p$



Data from Müller et al. [CBELSA/TAPS] PLB 803, 135323 (2020).

Red lines: JüBo fit 2208.00089 [nucl-th]

$\hookrightarrow$ reduced difference of ηN residue of S_{11} states confirmed in JüBo

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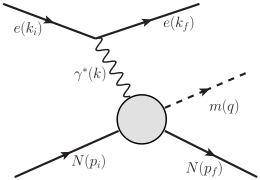
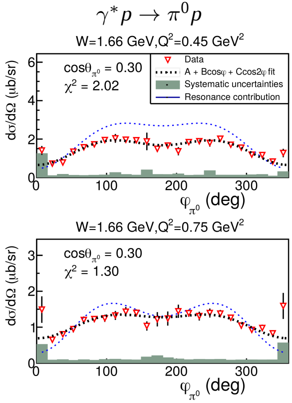
Electroproduction of pseudoscalar mesons



Experimental studies of electroproduction:

major progress in recent years, e.g., from JLab, MAMI, ...



- 10^5 data points for πN, ηN, KY, $\pi\pi N$ electroproduction
- access the Q^2 dependence of the amplitude

  $\rightarrow$ expected to provide a link between perturbative QCD and the region where quark confinement sets in

  $\rightarrow$ information on the internal structure of resonances

Electroproduction of pseudoscalar mesons:

$\Rightarrow$ 36 (polarization) observables,
complete experiment = 12 observables

V. Dmitrasinovic, T.W. Donnelly, and F. Gross, in *Research Program at CEBAF (III)*, *RPACIII* (CEBAF, Newport News, 1988). Tiator et al. Phys.Rev.C 96 (2017) 2, 025210

Figure and data from Markov et al. (CLAS) PRC 101 (2020),

resonance contribution: JLab/YerPhI

- so far, no new N^* or Δ^* established from electroproduction: data have not yet been analyzed on the same level as photoproduction data

Review theory and experiment: Aznauryan and Burkert, Prog.Part.Nucl.Phys. 67 (2012); Mokeev and Carman 2202.04180 [nucl-ex]

Phenomenological analyses of electroproduction

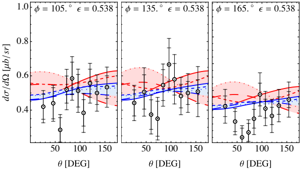
Single-channels analyses, e.g.:

- MAID: π, η electroproduction (EPJA 34, 69 (2007), NPA 700, 429 (2002),)
- JLab: π electroproduction covering the resonance region (PRC 80 (2009) 055203)
  Study of $\pi^+\pi^- p$ photo- and electroproduction: evidence for a new $N'(1720)3/2^+$ (PLB 805, 135457 (2020)) (needs confirmation!)

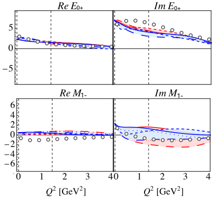
Coupled-channels analyses:

- so far, no coupled-channel analysis of photo & electroproduction with simultaneous study of πN, ηN, KY final states
- Jülich-Bonn-Washington approach M. Mai *et al.* PRC 103 (2021): $\gamma^* p \to \pi^0 p$, $\pi^+ n$ and ηp (photoproduction as boundary condition at $Q^2 = 0$) PRC 106, 015201 (2022)

Selected fit results: $\gamma^* p \to \eta p$ at $W = 1.5$ GeV, $Q^2 = 1.2$ GeV^2. Data: Denizli et al. (CLAS) PRC 76 (2007)

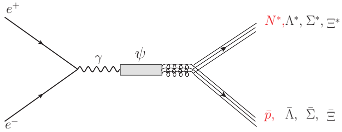


Selected multipoles at $W = 1535$ MeV

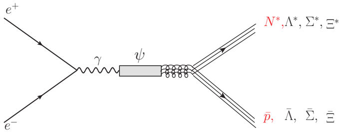


- ANL-Osaka: extension of DCC analysis of pion electroproduction (PRC 80, 025207 (2009)) in progress (Few Body Syst. 59 (2018) 3, 24)

N^* production from e^+e^- annihilation



N^* production from e^+e^- annihilation



- PWA simpler compared to πN, γN:
  - isospin filter: no Δ^*'s
  - high spin states suppressed
- observation of 3 new states by BESIII:

  - $N^*(2040)3/2^+$ $(*)$ (PRD 80, 052004 (2009))

  - $N^*(2300)1/2^+$ $(**)$ (PRL 110, 022001 (2013))

  - $N^*(2570)5/2^-$ $(**)$ (PRL 110, 022001 (2013))

$\psi(3686) \to p\bar{p}\pi^0$

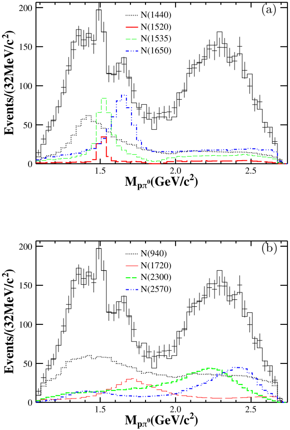


Fig. from Ablikim (BESIII) PRL 110, 022001 (2013)

PDG N^* ratings 2009 (left) vs 2020 (right)

- New states, e.g. $N(1900)3/2^+$, $N(1895)1/2^-$, observed especially in kaon and eta photoproduction e.g. PRL 119, 062004 (2017), PRL 125, 152002 (2020)
- new values for Λ decay parameter α_- from kaon photoproduction (Ireland PRL 123 (2019) 182301) (see also Ablikim (BESIII), Nature (2019)) $\longrightarrow$ polarization observables affected by α_- are $\sim$ 17% too large!

			Status as seen in —						
Particle	$L_{2I \cdot 2J}$	Overall status	$N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$
$N(939)$	P_{11}	****							
$N(1440)$	P_{11}	****	****	*			***	*	***
$N(1520)$	D_{13}	****	****	***			****	****	****
$N(1535)$	S_{11}	****	****	****			*	**	***
$N(1650)$	S_{11}	****	****	*	***	**	***	**	***
$N(1675)$	D_{15}	****	****	*	*		****	*	****
$N(1680)$	F_{15}	****	****	*			****	****	****
$N(1700)$	D_{13}	***	***	*	**	*	**	*	**
$N(1710)$	P_{11}	***	***	**	**	*	**	*	***
$N(1720)$	P_{13}	****	****	*	**	*	*	**	**
$N(1900)$	P_{13}	**	**					*	
$N(1990)$	F_{17}	**	**	*	*	*			*
$N(2000)$	F_{15}	**	**	*	*	*	*	**	
$N(2080)$	D_{13}	**	**	*	*				*
$N(2090)$	S_{11}	*	*						
$N(2100)$	P_{11}	*	*	*					
$N(2190)$	G_{17}	****	****	*	*	*		*	*
$N(2200)$	D_{15}	**	**	*	*				
$N(2220)$	H_{19}	****	****	*					
$N(2250)$	G_{19}	****	****	*					
$N(2600)$	$I_{1\,11}$	***	***						
$N(2700)$	$K_{1\,13}$	**	**						

C. Amsler *et al.* (Particle Data Group), PL B667, 1 (2008)

			Status as seen in									
Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	$N\sigma$	$N\eta$	ΛK	ΣK	$N\rho$	$N\omega$	$N\eta\prime$
N	$1/2^+$	****										
$N(1440)$	$1/2^+$	****	****	****	****	***						
$N(1520)$	$3/2^-$	****	****	****	****	**	****					
$N(1535)$	$1/2^-$	****	****	****	***	*	****					
$N(1650)$	$1/2^-$	****	****	****	***	*	****	*				
$N(1675)$	$5/2^-$	****	****	****	****	***	*	*	*			
$N(1680)$	$5/2^+$	****	****	****	****	***	*	*	*			
$N(1700)$	$3/2^-$	***	**	***	***	*	*			*		
$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*	
$N(1720)$	$3/2^+$	****	****	****	***	*	*	****	*	*	*	
$N(1860)$	$5/2^+$	**	*	**		*	*					
$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*	
$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**		**	
$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*	****
$N(1900)$	$3/2^+$	****	****	**	**	*	*	**	**		*	**
$N(1990)$	$7/2^+$	**	**	**			*	*	*			
$N(2000)$	$5/2^+$	**	**	*	**	*	*				*	
$N(2040)$	$3/2^+$	*		*								
$N(2060)$	$5/2^-$	***	***	**	*	*	*	*	*	*	*	
$N(2100)$	$1/2^+$	***	**	***	**	**	*	*		*	*	**
$N(2120)$	$3/2^-$	***	***	**	**	**		**	*		*	*
$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*	
$N(2220)$	$9/2^+$	****	**	****			*	*	*			
$N(2250)$	$9/2^-$	****	**	****			*	*	*			
$N(2300)$	$1/2^+$	**		**								
$N(2570)$	$5/2^-$	**		**								
$N(2600)$	$11/2^-$	***		***								
$N(2700)$	$13/2^+$	**		**								

P. A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys.2020 083C01 (2020)

new   upgraded

PDG Δ^* ratings 2009 (left) vs 2020 (right)

- no new states observed
- more data from $I = 3/2$ channels could be helpful, e.g $\gamma p \to K^0\Sigma^+$, $K^+\Sigma^0$

Particle	$L_{2I\cdot 2J}$	Overall status	Status as seen in —						
			$N\pi$	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\rho$	$N\gamma$
$\Delta(1232)$	P_{33}	****	****	F					****
$\Delta(1600)$	P_{33}	***	***	o			***	*	**
$\Delta(1620)$	S_{31}	****	****	r			****	****	***
$\Delta(1700)$	D_{33}	****	****	b		*	***	**	***
$\Delta(1750)$	P_{31}	*	*	i					
$\Delta(1900)$	S_{31}	**	**	d		*	*	**	*
$\Delta(1905)$	F_{35}	****	****	d		*	**	**	***
$\Delta(1910)$	P_{31}	****	****	e		*	*	*	*
$\Delta(1920)$	P_{33}	***	***	n		*	**		*
$\Delta(1930)$	D_{35}	***	***			*			**
$\Delta(1940)$	D_{33}	*	*	F					
$\Delta(1950)$	F_{37}	****	****	o		*	****	*	****
$\Delta(2000)$	F_{35}	**		r			**		
$\Delta(2150)$	S_{31}	*	*	b					
$\Delta(2200)$	G_{37}	*	*	i					
$\Delta(2300)$	H_{39}	**	**	d					
$\Delta(2350)$	D_{35}	*	*	d					
$\Delta(2390)$	F_{37}	*	*	e					
$\Delta(2400)$	G_{39}	**	**	n					
$\Delta(2420)$	$H_{3\,11}$	****	****						*
$\Delta(2750)$	$I_{3\,13}$	**	**						
$\Delta(2950)$	$K_{3\,15}$	**	**						

C. Amsler *et al.* (Particle Data Group), PL B667, 1 (2008)

Particle	J^P	overall	Status as seen in					
			$N\gamma$	$N\pi$	$\Delta\pi$	ΣK	$N\rho$	$\Delta\eta$
$\Delta(1232)$	$3/2^+$	****	****	****				
$\Delta(1600)$	$3/2^+$	****	****	***	****			
$\Delta(1620)$	$1/2^-$	****	****	****	****			
$\Delta(1700)$	$3/2^-$	****	****	****	****	*	*	
$\Delta(1750)$	$1/2^+$	*	*	*		*		
$\Delta(1900)$	$1/2^-$	***	***	***	*	**	*	
$\Delta(1905)$	$5/2^+$	****	****	****	**	*	*	**
$\Delta(1910)$	$1/2^+$	****	***	****	**	**		*
$\Delta(1920)$	$3/2^+$	***	***	***	***	**		**
$\Delta(1930)$	$5/2^-$	***	*	***	*	*		
$\Delta(1940)$	$3/2^-$	**	*	**	*			*
$\Delta(1950)$	$7/2^+$	****	****	****	**	***		
$\Delta(2000)$	$5/2^+$	**	*	**	*		*	
$\Delta(2150)$	$1/2^-$	*		*				
$\Delta(2200)$	$7/2^-$	***	***	**	***	**		
$\Delta(2300)$	$9/2^+$	**		**				
$\Delta(2350)$	$5/2^-$	*		*				
$\Delta(2390)$	$7/2^+$	*		*				
$\Delta(2400)$	$9/2^-$	**	**	**				
$\Delta(2420)$	$11/2^+$	****	*	****				
$\Delta(2750)$	$13/2^-$	**		**				
$\Delta(2950)$	$15/2^+$	**		**				

P. A. Zyla *et al.* (Particle Data Group), Prog. Theor. Exp. Phys.2020, 083C01 (2020)

new

upgraded

Summary and Outlook

Extraction of the N^* and Δ spectrum from experimental data: major progress in last decade

- new information from photoproduction data $\rightarrow$ new and upgraded states in PDG table
- wealth of high-quality electroproduction data, more at high Q^2 in the future (CLAS12)
  $\rightarrow$ to be included in modern coupled-channel analyses (in progress)
- 3 new states from $e^+ e^-$ annihilation ($*$, $**$ states)

Challenges, i.a.:

- πN scattering: improved data situation highly desirable
- γN scattering: data sets for a "complete experiment"
- thorough determination of uncertainties of resonance parameters:
  - correlated χ^2 fits $\pi N \rightarrow \pi N$ PW,
  - error propagation data $\rightarrow$ fit parameters $\rightarrow$ derived quantities
- model selection: significance of resonance signals with Bayesian evidence (PRL 108, 182002; PRC 86, 015212 (2012)) or LASSO (PRC 95, 015203 (2017); J. R. Stat. Soc. B 58, 267 (1996)

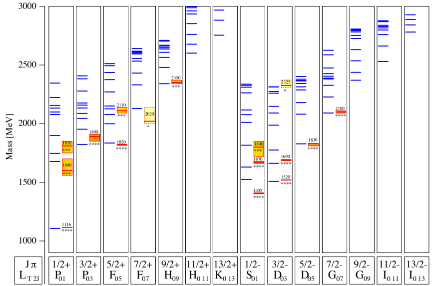
Thank you for your attention!

Appendix

The Hyperon Spectrum: Λ^* and Σ^* resonances

The Hyperon Spectrum (Λ^*'s and Σ^*'s)

Relativistic quark model: Λ^*'s



Löring *et al.* EPJ A 10, 447 (2001), Model A, exp. spectrum: PDG 2000

- Testing ground for theories of the strong force: what happens if we replace a light quark with an s quark?
- even more missing resonances than for N^*'s and Δ^*'s
- high interest in low-energy region and $\Lambda(1405)$ Review: Mai, Eur.Phys.J.ST 230 (2021)
- very little new experimental data in the last decades for the complete resonance region

Review on Hyperon spectroscopy:

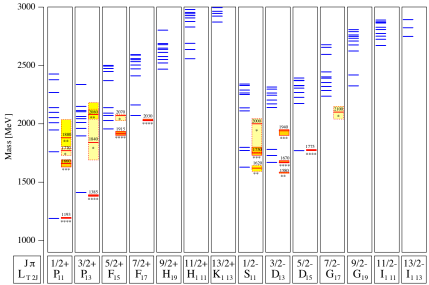
E. Klempt et al. Eur.Phys.J.A 56 (2020)

4 groups re-analyzed old $K^- p$ data over the complete resonance region:

- Kent: multi-channel PWA of $\bar{K}N$ scattering, $W = 1480$ to 2100 MeV PRC 88, 035204 & PRC 88, 035205 (2013)
- JPAC: unitary multichannel model for $\bar{K}N$ scattering, fit to Kent SE PWA PRD 93, 034029 (2016)
- ANL/Osaka: dynamical coupled-channel model for $\bar{K}N$ reactions PRC 90, 065204 (2014) & PRC 92, 025205 (2015)
- BnGa: multi-channel PWA based on a modified K-matrix approach EPJA 55,179 & 180 (2019)
- JüBo: in progress

The Hyperon Spectrum (Λ^*'s and Σ^*'s)

Relativistic quark model: Σ^*'s



Löring *et al.* EPJ A 10, 447 (2001), Model A, exp. spectrum: PDG 2000

- Testing ground for theories of the strong force: what happens if we replace a light quark with an s quark?
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PDG Λ ratings 1984 (left) vs 2022 (right)

Particle	$L_{I \cdot 2J}$	Overall status	Status as seen in --			
			$N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
Λ(1116)	P_{01}	****				$N\pi$ (weakly)
Λ(1405)	S_{01}	****	****	F	****	
Λ(1520)	D_{03}	****	****	o	****	$\Lambda\pi\pi$, $\Lambda\gamma$
Λ(1600)	P_{01}	***	***	r	**	
Λ(1670)	S_{01}	****	****	b	****	$\Lambda\eta$
Λ(1690)	D_{03}	****	****	i	****	$\Lambda\pi\pi$, $\Sigma\pi\pi$
Λ(1800)	S_{01}	***	***	d	**	$N\overline{K}^*$, $\Sigma(1385)\pi$
Λ(1800)	P_{01}	***	***	d	**	$N\overline{K}^*$
Λ(1820)	F_{05}	****	****	e	****	$\Sigma(1385)\,\pi$
Λ(1830)	D_{05}	****	***	n	****	$\Sigma(1385)\,\pi$
Λ(1890)	P_{03}	****	****	F	**	$N\overline{K}^*$, $\Sigma(1385)\pi$
Λ(2000)		*		o	*	$\Lambda\omega$, $N\overline{K}^*$
Λ(2020)	F_{07}	*	*	r	*	
Λ(2100)	G_{07}	****	****	b	***	$\Lambda\omega$, $N\overline{K}^*$
Λ(2110)	F_{05}	***	**	i	*	$\Lambda\omega$, $N\overline{K}^*$
Λ(2325)	D_{03}	*	*	d		$\Lambda\omega$
Λ(2350)		***	***	d	*	
Λ(2585)		**	**	e		
				n		

C. G. Wohl *et al.* (Particle Data Group) Rev.Mod. Phys. 56 (1984)

Status updated | Quantum numbers updated | New

Particle	J^P	Overall status	Status as seen in —		
			$N\overline{K}$	$\Sigma\pi$	Other channels
Λ(1116)	$1/2^+$	****			$N\pi$ (weak decay)
Λ(1380)	$1/2^-$	**	**	**	
Λ(1405)	$1/2^-$	****	****	****	
Λ(1520)	$3/2^-$	****	****	****	$\Lambda\pi\pi, \Lambda\gamma, \Sigma\pi\pi$
Λ(1600)	$1/2^+$	****	***	****	$\Lambda\pi\pi, \Sigma(1385)\pi$
Λ(1670)	$1/2^-$	****	****	****	$\Lambda\eta$
Λ(1690)	$3/2^-$	****	****	***	$\Lambda\pi\pi, \Sigma(1385)\pi$
Λ(1710)	$1/2^+$	*	*	*	
Λ(1800)	$1/2^-$	***	***	**	$\Lambda\pi\pi, N\overline{K}^*$
Λ(1810)	$1/2^+$	***	**	**	$N\overline{K}^*$
Λ(1820)	$5/2^+$	****	****	****	$\Sigma(1385)\pi$
Λ(1830)	$5/2^-$	****	****	****	$\Sigma(1385)\pi$
Λ(1890)	$3/2^+$	****	****	**	$\Sigma(1385)\pi, N\overline{K}^*$
Λ(2000)	$1/2^-$	*	*	*	
Λ(2050)	$3/2^-$	*	*	*	
Λ(2070)	$3/2^+$	*	*	*	
Λ(2080)	$5/2^-$	*	*	*	
Λ(2085)	$7/2^+$	**	**	*	
Λ(2100)	$7/2^-$	****	****	**	$N\overline{K}^*$
Λ(2110)	$5/2^+$	***	**	**	$N\overline{K}^*$
Λ(2325)	$3/2^-$	*	*		
Λ(2350)	$9/2^+$	***	***	*	
Λ(2585)		*	*		

R. L. Workman *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. 2022, 083C01 (2022)

JÜLICH Forschungszentrum

PDG Σ ratings 1984 (left) vs 2022 (right)

Particle	$L_{I\cdot 2J}$	Overall status	$N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
Σ(1193)	P_{11}	****				Nπ (weakly)
Σ(1385)	P_{13}	****		****	****	
Σ(1480)		*	*	*	*	
Σ(1560)		**		**	**	
Σ(1580)	D_{13}	**	*	*		
Σ(1620)	S_{11}	**	**	*	*	
Σ(1660)	P_{11}	***	***	*	**	
Σ(1670)	D_{13}	****	****	****	****	several others
Σ(1690)		**	*	**	*	Λππ
Σ(1750)	S_{11}	***	***	**	*	Ση
Σ(1770)	P_{11}	*				
Σ(1775)	D_{15}	****	****	****	***	several others
Σ(1840)	P_{13}	*	*	**	*	
Σ(1880)	P_{11}	**	**	**		$N\overline{K}^*$
Σ(1915)	F_{15}	****	***	****	***	Σ(1385)π
Σ(1940)	D_{13}	***	*	***	**	quasi-2-body
Σ(2000)	S_{11}	*		*		$N\overline{K}^*$, Λ(1520)π
Σ(2030)	F_{17}	****	****	****	**	several others
Σ(2070)	F_{15}	*	*		*	
Σ(2080)	P_{13}	**		**		
Σ(2100)	G_{17}	*		*	*	
Σ(2250)		***	***	*	*	
Σ(2455)		**	*			
Σ(2620)		**	*			
Σ(3000)		*	*	*		
Σ(3170)		*				multi-body

C. G. Wohl *et al.* (Particle Data Group) Rev.Mod. Phys. 56 (1984)

Particle	J^P	Overall status	$N\overline{K}$	$\Lambda\pi$	$\Sigma\pi$	Other channels
Σ(1193)	$1/2^+$	****				$N\pi$ (weak decay)
Σ(1385)	$3/2^+$	****		****	****	$\Lambda\gamma$
Σ(1580)	$3/2^-$	*	*	*	*	
Σ(1620)	$1/2^-$	*	*	*	*	
Σ(1660)	$1/2^+$	***	***	***	***	
Σ(1670)	$3/2^-$	****	****	****	****	
Σ(1750)	$1/2^-$	***	***	**	***	$\Sigma\eta$
Σ(1775)	$5/2^-$	****	****	****	**	
Σ(1780)	$3/2^+$	*	*	*	*	
Σ(1880)	$1/2^+$	**	**	*		
Σ(1900)	$1/2^-$	**	**	*	**	
Σ(1910)	$3/2^-$	***	*	*	**	
Σ(1915)	$5/2^+$	****	***	***	***	
Σ(1940)	$3/2^+$	*	*		*	
Σ(2010)	$3/2^-$	*	*	*		
Σ(2030)	$7/2^+$	****	****	****	**	$\Delta(1232)\overline{K}, N\overline{K}^*, \Sigma(1385)\pi$
Σ(2070)	$5/2^+$	*	*		*	
Σ(2080)	$3/2^+$	*		*		
Σ(2100)	$7/2^-$	*	*	*	*	
Σ(2110)	$1/2^-$	*	*	*	*	
Σ(2230)	$3/2^+$	*	*	*	*	
Σ(2250)		**	**	*	*	
Σ(2455)		*	*			
Σ(2620)		*	*			
Σ(3000)		*	*	*		
Σ(3170)		*				

R. L. Workman *et al.* (Particle Data Group), Prog. Theor. Exp. Phys. 2022, 083C01 (2022)

Status updated | Quantum numbers updated | New | Removed

Hyperon spectrum: Prospects for new data

Current experiments:

- Photoproduction (CLAS): Hyperon resonances abundantly produced as intermediate states in $\gamma p \to K^+(\Sigma\pi)$ and $K^+(K^- p)$ Phys. Rev. Lett. 112, 082004 (2014), Phys. Rev. C 88, 045201 (2013)
  Exploratory coupled-channel analysis: EPJA 57, 236 (2021): difficult to extract Y^* spectrum
- LHCb: $\Lambda_b^0 \to J/\psi\Lambda^* \to J/\psi K^- p$ decay Phys.Rev.Lett. 115 (2015) 072001

Future experiments:

- K_L facility at JLab: Strange Hadron Spectroscopy with a Secondary K_L Beam at GlueX (approved) 2008.08215 [nucl-ex]
  $\hookrightarrow$ Talk by Michael Döring later today
- J-PARC: extract $\bar{K}N$ amplitude from kaonic atom experiments JPS Conf. Proc. 26, 023013 (2019)
  $\hookrightarrow$ Talks on Friday
- PANDA at FAIR: $\bar{p}p \to \bar{Y}Y^*$: besides Ξ^* and Ω^* also Λ^* and Σ^* spectrum accessible 0903.3905 [hep-ex]