Status report on A4:
Soliton spectroscopy, baryonic antidecuplet

Goeke/Polyakov

-Group and publications
-Some of results
-Conclusions
-Outlook

A4: Doktoranden Diplomanden

- **Doktoranden**
- Cedric Lorcé
- Tim Ledwig
- Christoph Cebulla
- Ghil-Seok Yang
- Jens Ossmann ←
- Antonio Silva ←

- **Diplomanden**
- Sebastian Starosielec
- Tobias Beranek
- Christoph Cebulla ←
- Tim Ledwig ←

A4: Publications

1) K*-couplings for the antidecuplet excitation.
By Ya. Azimov, V. Kuznetsov, M.V. Polyakov, I. Strakovsky.
[hep-ph/0611238] (Nov 2006) 7p.

2) Present status of the nonstrange and other flavor partners of the exotic Theta+ baryon.
By I.I. Strakovsky, R.A. Arndt, Ya.I. Azimov, M.V. Polyakov, R.L. Workman.
J.Phys.Conf.Ser.9:218,2005. [hep-ph/0501114]

3) SU(3) systematization of baryons.
By V. Guzey & M.V. Polyakov.
[hep-ph/0512355] RUB-TPII-20-2005 (Dec 2005) 77p.

4) Review of experimental aspects of pentaquark physics.
By I.I. Strakovsky, R.A. Arndt, Ya.I. Azimov, M.V. Polyakov, R.L. Workman.
AIP Conf.Proc.775:41-46,2005.

5) Theta(1540)+ and associated exotic states.
By I. Strakovsky, R. Arndt, R. Workman, Y. Azimov, M. Polyakov.
Acta Phys.Polon.B36:2247-2254,2005.

6) Dual parameterization of generalized parton distributions and description of DVCS data.
By V. Guzey & M.V. Polyakov.
Eur.Phys.J.C46:151-156,2006. [hep-ph/0507183]

7) Photoproduction of the Theta+ resonance on the nucleon in a Regge model.
By H. Kwee, M. Guidal, M.V. Polyakov, M. Vanderhaeghen.
Phys.Rev.D72:054012,2005. [hep-ph/0507180]

8) Extraction of radiative decay width for the non-strange partner of Theta+.
By Ya. Azimov, V. Kuznetsov, M.V. Polyakov, I. Strakovsky.
Eur.Phys.J.A25:325-327,2005. [hep-ph/0506236]

9) Checking Lorentz-invariance relations between parton distributions.
By M. Schlegel, K. Goeke, A. Metz, M.V. Polyakov.
Phys.Part.Nucl.35:S44-S46,2004.

10) Exotic and nonexotic magnetic transitions in the context of the SELEX and GRAAL experiments.
By Hyun-Chul Kim, Maxim Polyakov, Michal Praszalowicz, Ghil-Seok Yang, Klaus Goeke.
Phys.Rev.D71:094023,2005. [hep-ph/0503237]

11) SU(3) systematization of baryons: Theoretical methods and mixing with the antidecuplet.
By V. Guzey & M.V. Polyakov.
Annalen Phys.13:673-681,2004.

12) Present status of the nonstrange and other flavor partners of the exotic Theta+ baryon.
By I.I. Strakovsky, R.A. Arndt, Ya.I. Azimov, M.V. Polyakov, R.L. Workman.
J.Phys.Conf.Ser.9:218,2005. [hep-ph/0501114]

13) Pentaquark baryon: Predictions from chiral solitons.
By M.V. Polyakov.
AIP Conf.Proc.717:405-410,2004.

14) Mixing and decays of the antidecuplet in the context of approximate SU(3) symmetry.
By V. Guzey & M.V. Polyakov.
[hep-ph/0501010] RUB-TP2-04-14 (Jan 2005) 57p.

15) Notes on exotic anti-decuplet of baryons.
By M.V. Polyakov.
[hep-ph/0412274] (Dec 2004) 11p.

16) The Generalized parton distribution function (E**u + E**d)(x,xi,t) of the nucleon in the chiral quark soliton model.
By J. Ossmann, M.V. Polyakov, P. Schweitzer, D. Urbano, K. Goeke.
Phys.Rev.D71:034011,2005. [hep-ph/0411172]

17) Nucleon form-factors from generalized parton distributions.
By M. Guidal, M.V. Polyakov, A.V. Radyushkin, M. Vanderhaeghen.
Phys.Rev.D72:054013,2005. [hep-ph/0410251]

18) Soft pion emission from the nucleon induced by twist-2 light-cone operators.
By N. Kivel, M.V. Polyakov, S. Stratmann.
[nucl-th/0407052] RUB-TPH-21-03 (Jul 2004) 10p.

19) Comment on the Theta+ width and mass.
By Dmitri Diakonov, Victor Petrov, Maxim Polyakov.
[hep-ph/0404212] JLAB-THY-04-12 (Apr 2004) 4p.

20) Nonstrange and other unitarity partners of the exotic Theta+ baryon.
By R.A. Arndt, Ya.I. Azimov, M.V. Polyakov, I.I. Strakovsky, R.L. Workman.
Phys.Rev.C69:035208,2004. [nucl-th/0312126]

21) Strange nucleon form factors: Solitonic approach to G(M)**S, G(E)**S, ~G(A)**p and ~G(A)**n and comparison with world data.
By Klaus Goeke, Hyun-Chul Kim, Antonio Silva, Diana Urbano.
[hep-ph/0608262] PNU-NTG-04-2006 (Aug 2006) 5p.

A4: Publications

24) The pentaquark: A new kind of elementary particle?
By K. Goeke, Hyun-Chul Kim, M. Praszalowicz.
Europhys.News 36:151-154,2005.

25) Axial-vector form-factors of the nucleon within the chiral quark-soliton model and their strange components.
By Antonio Silva, Hyun-CHul Kim, Diana Urbano, Klaus Goeke.
Phys.Rev.D72:094011,2005. [hep-ph/0509281]

26) Strange form factors of the nucleon in the chiral quark soliton model.
By A. Silva, D. Urbano, H.C. Kim, K. Goeke.
Eur.Phys.J.A24S2:93-96,2005.

27) Exotic and nonexotic magnetic transitions in the context of the SELEX and GRAAL experiments.
By Hyun-Chul Kim, Maxim Polyakov, Michal Praszalowicz, Ghil-Seok Yang, Klaus Goeke.
Phys.Rev.D71:094023,2005. [hep-ph/0503237]

28) Magnetic moments of exotic pentaquark baryons.
By Hyun-Chul Kim, Ghil-Seok Yang, Michal Praszalowicz, Klaus Goeke.
Nucl.Phys.A755:419-422,2005. [hep-ph/0501092]

29) Magnetic moments of the pentaquarks.
By Hyun-Chul Kim, Ghil-Seok Yang, Michal Praszalowicz, Klaus Goeke.
In *Nishiharima 2004, Pentaquark* 231-23. [hep-ph/0412270]

30) Pentaquarks: Review on models and solitonic calculations of antidecuplet magnetic moments.
By Klaus Goeke, Hyun-Chul Kim, Michal Praszalowicz, Ghil-Seok Yang.
Prog.Part.Nucl.Phys.55:350-373,2005. [hep-ph/0411195]

31) Octet, decuplet and antidecuplet magnetic moments in the chiral quark soliton model revisited.
By Ghil-Seok Yang, Hyun-Chul Kim, Michal Praszalowicz, Klaus Goeke.
Phys.Rev.D70:114002,2004. [hep-ph/0410042]

32) Pion mass dependence of the nucleon mass and chiral extrapolation of lattice data in the chiral quark soliton model.
By K. Goeke, J. Ossmann, P. Schweitzer, A. Silva.
Eur.Phys.J.A27:77-90,2006. [hep-lat/0505010]

33) The Generalized parton distribution function (E**u + E**d)(x,xi,t) of the nucleon in the chiral quark soliton model.
By J. Ossmann, M.V. Polyakov, P. Schweitzer, D. Urbano, K. Goeke.
Phys.Rev.D71:034011,2005. [hep-ph/0411172]

Main directions of our research

- SU(3) classification of baryons
- Properties of antidecuplet in ChQSM: two approaches
    - quantization of slow soliton rotation
    - calculation of light-cone wave functions, Fock decomposition
- Predictions for processes where pentaquarks are produced
- Phenomenological analysis of the data

SU(3) analysis of antidecuplet

Guzey and Polyakov, hep-ph/0512355
hep-ph/0501010

Gell-Mann, Ne'eman, 1960s:
The hypothesis of approximate flavor SU(3) symmetry of strong interactions → existence of definite SU(3) multiplets

Non-exotic hadrons: $3 \otimes \bar{3} = 1 + 8$ mesons

$3 \otimes 3 \otimes 3 = 1 + 8_A + 8_S + 10$ baryons

Exotic hadrons: $3 \otimes 3 \otimes 3 \otimes 3 \otimes \bar{3} = 1_3 + 8_8 + 10_4 + \underbrace{10_2}_{\text{antidecuplet}} + 27_3 + 35$

Gell-Mann, Okubo, 1960s:

SU(3) symmetry is broken by mass of strange quark

→ mass splitting inside multiplets:
Gell-Mann—Okubo mass formulas

$$\frac{m_N + m_\Xi}{2} = \frac{3m_\Lambda + m_\Sigma}{4}$$ octet

$$m_\Sigma - m_\Delta = m_\Xi - m_\Sigma = m_\Omega - m_\Xi$$ decuplet

$$m_{N_{\overline{10}}} - m_{\Theta^+} = m_{\Sigma_{\overline{10}}} - m_{N_{\overline{10}}} = m_{\Xi_{\overline{10}}} - m_{\Sigma_{\overline{10}}}$$ antidecuplet

GMO mass formulas work with a few % precision!

Samios, Goldberg, Meadows, 1974:

Step 1:

Assuming that SU(3) symmetry is broken only by non-equal masses, but holds for coupling constants, SU(3) symmetry gives also a good description of strong decays. We performed a new analysis of all known baryons and suggested new SU(3) systematization of known baryons.

Step 2:

Apply methods of SU(3) symmetry to antidecuplet.

Goal:

Model-independent systematization of scarce experimental information on antidecuplet.

	1	$(8, \frac{1}{2}^+)$	(939, 1116, 1193, 1318)
	2	$(10, \frac{3}{2}^+)$	(1232, 1385, 1530, 1672)
$(56, L = 0)$	3	$(8, \frac{1}{2}^+)$	(1440, 1600, 1660, ...)
$(70, L = 0)$	4	$(8, \frac{1}{2}^+)$	(1710, 1810, 1880, ...)
	6	$(1, \frac{1}{2}^-)$	$\Lambda(1405)$
	7	$(1, \frac{3}{2}^-)$	$\Lambda(1520)$
	8	$(8, \frac{3}{2}^-)$	(1520, 1690, 1670, 1820)
$(70, L = 1)$	9	$(8, \frac{1}{2}^-)$	(1535, 1670, 1620, ...)
	10	$(10, \frac{1}{2}^-)$	(1620, ..., ..., ...)
	11	$(8, \frac{3}{2}^-)$	(1700, ..., ..., ...)
	12	$(8, \frac{5}{2}^-)$	(1675, 1830, 1775, ...)
	13	$(10, \frac{3}{2}^-)$	(1700, ..., ..., ...)
	14	$(8, \frac{1}{2}^-)$	(1650, 1800, 1750, ...)
	15	$(8, \frac{5}{2}^+)$	(1680, 1820, 1915, 2030)
$(56, L = 2)$	17	$(8, \frac{3}{2}^+)$	(1720, 1890, ..., ...)
	18	$(10, \frac{5}{2}^+)$	(1905, ..., ..., ...)
	20	$(10, \frac{7}{2}^+)$	(1950, 2030, ..., ...)

Table 2
SU(3) multiplets from the Review of Particle Physics 2004.

	1	$(8, \frac{1}{2}^+)$	(939, 1115, 1189, 1314)
	2	$(10, \frac{3}{2}^+)$	(1232, 1385, 1530, 1672)
$(56, L = 0)$	3	$(8, \frac{1}{2}^+)$	(1440, 1600, 1660, 1690)
	4	$(8, \frac{1}{2}^+)$	(1710, 1810, 1880, $\underline{1950}$)
	5	$(10, \frac{3}{2}^+)$	(1600, 1690, $\underline{1900}$, $\underline{2050}$)
	6	$(1, \frac{1}{2}^-)$	Λ(1405)
	7	$(1, \frac{3}{2}^-)$	Λ(1520)
	8	$(8, \frac{3}{2}^-)$	(1520, 1690, 1670, 1820)
$(70, L = 1)$	9	$(8, \frac{1}{2}^-)$	(1535, 1670, 1560, $\underline{1620\text{-}1725}$)
	10	$(10, \frac{1}{2}^-)$	(1620, 1750, $\underline{1900}$, $\underline{2050}$)
	11	$(8, \frac{3}{2}^-)$	(1700, $\underline{1850}$, 1940, $\underline{2045}$)
	12	$(8, \frac{5}{2}^-)$	(1675, 1830, 1775, 1950)
	13	$(10, \frac{3}{2}^-)$	(1700, $\underline{1850}$, $\underline{2000}$, $\underline{2150}$)
	14	$(8, \frac{1}{2}^-)$	(1650, 1800, 1620, $\underline{1860\text{-}1915}$)
	15	$(8, \frac{5}{2}^+)$	(1680, 1820, 1915, 2030)
	16	$(10, \frac{3}{2}^+)$	(1920, 2080, $\underline{2240}$, 2470)
$(56, L = 2)$	17	$(8, \frac{3}{2}^+)$	(1720, 1890, 1840, $\underline{2035}$)
	18	$(10, \frac{5}{2}^+)$	(1905, 2070, 2250, 2380)
	19	$(10, \frac{1}{2}^+)$	(1910, $\underline{2060}$, $\underline{2210}$, $\underline{2360}$)
	20	$(10, \frac{7}{2}^+)$	(1950, 2030, 2120, 2250)
	21	$(\overline{10}, \frac{1}{2}^+)$	(1540, 1670, $\underline{1760}$, 1862)

What is known about the antidecuplet?

- The lightest member is Θ^+ with $M_\Theta \approx 1540$ MeV
- The heaviest member is $\Xi_{\overline{10}}$ with $M_{\Xi_{\overline{10}}} = 1862$ MeV

Alt, NA49, CERN

- The $N_{\overline{10}}$ and $\Sigma_{\overline{10}}$ members are not established
- However, there is candidate $N_{\overline{10}}$ with $M_\Theta \approx 1680$ MeV
- Characteristic properties:

  - weakly couples to $N\pi$ state, narrow

Arndt et al., 2004

  - significantly couples to $N\eta$ state

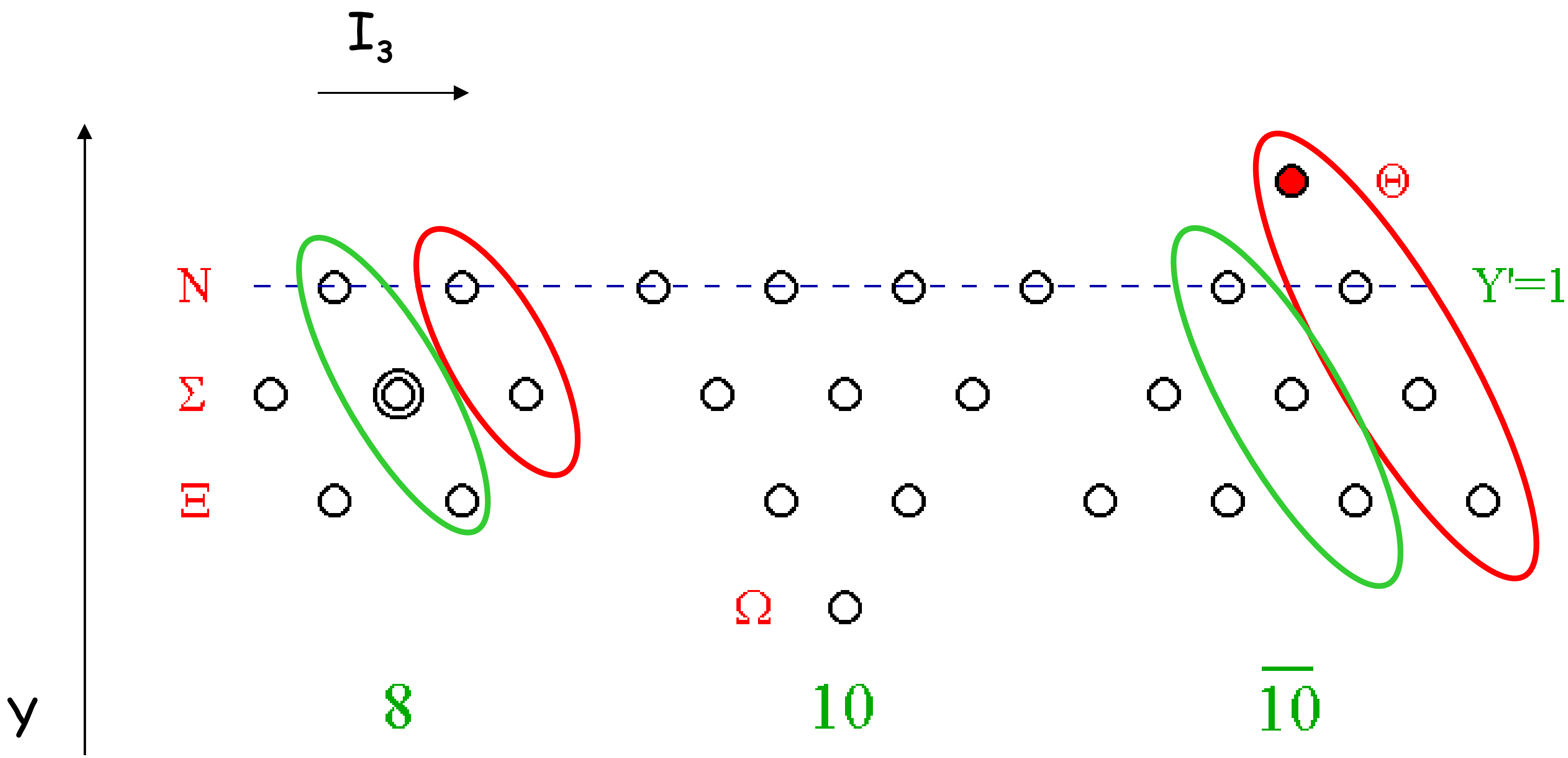
V. Kuznetsov, Graal, 2004

  - photoproduction on protons is suppressed

A. Rathke, MVP 2003

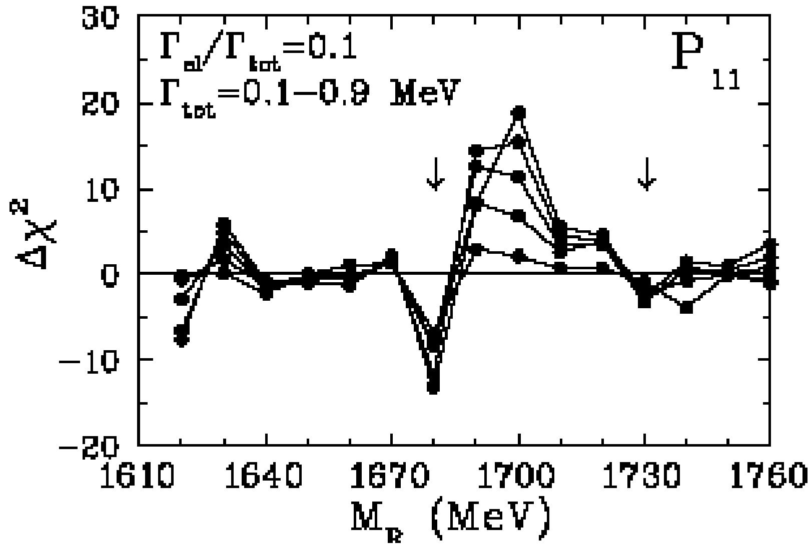
Photon has U-spin = 0. Good filter for multiplets

Anti-decuplet N can be photoexcited only from the neutron target (A. Rathke, MVP `03)



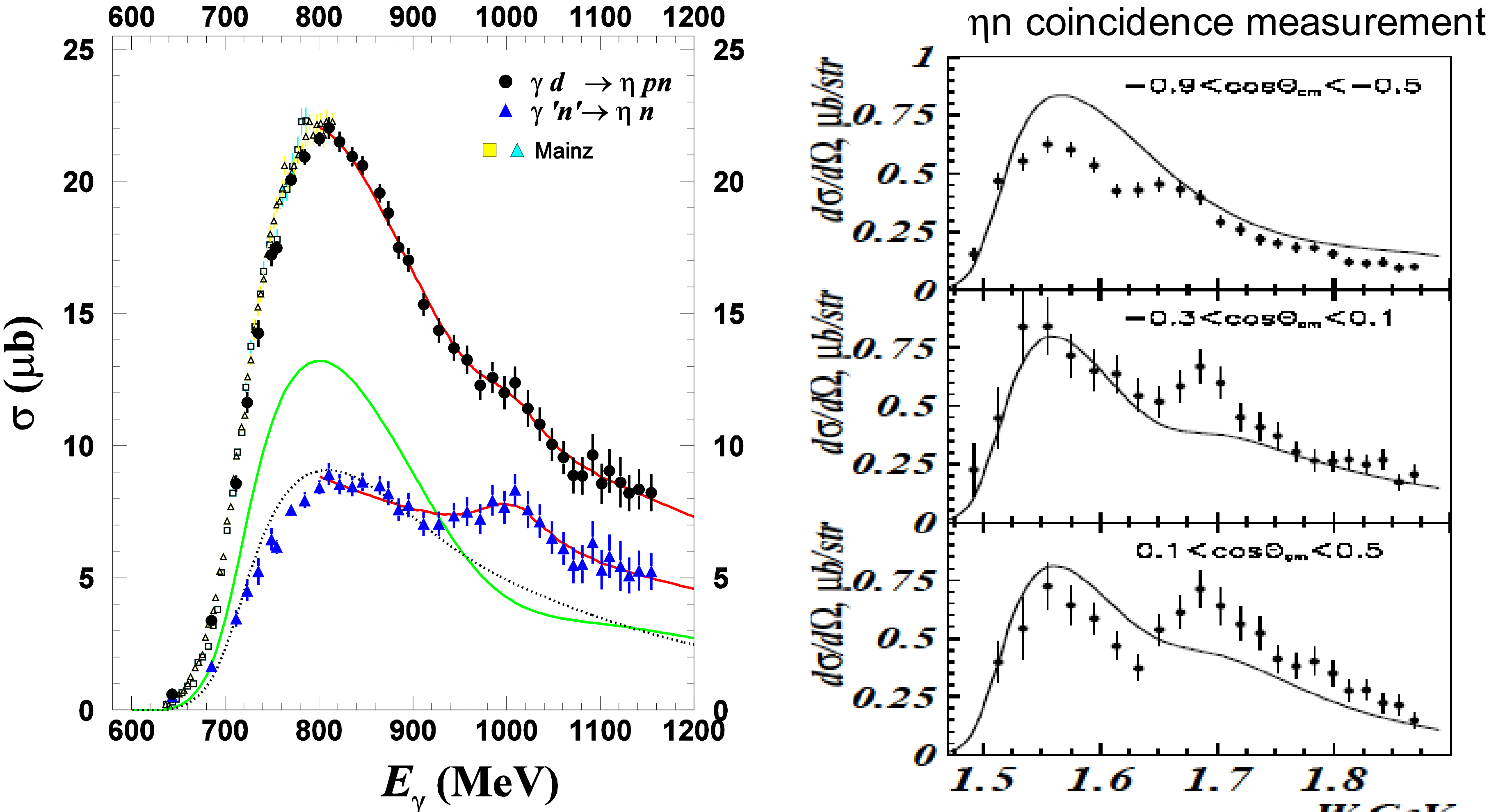
Modified PWA of pi N scattering

Arndt, Azimov, Strakovsky, Workman,MVP, PRD04



Simple analysis: compared with GRAAL

GRAAL, V. Kuznetsov et al.
hep-ex 0606065
ηn coincidence measurement



Breit-Wigner + smooth BG

M ~ 1666 MeV

Γ ≦ 40 MeV

M ~ 1680 MeV

Γ ≦ 30 MeV

J.Kasagi, talk in Kyoto 24.11

There is a resonance whose width smaller than 50 MeV,
however, resonance parameters strongly depend on BG shape!!

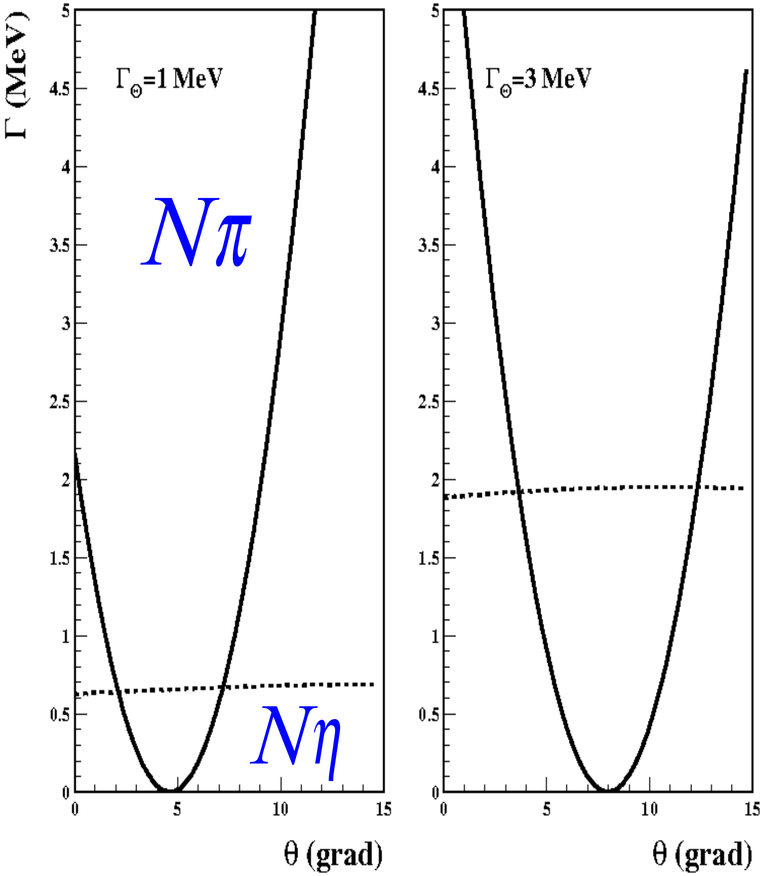
Antidecuplet decays: mixing with octet

$$g_{N_{\overline{10}}\to N\pi} = -\sin\theta\sqrt{3}A_8 + \cos\theta\frac{1}{2\sqrt{5}}A_{\overline{10}}\,,$$

$$g_{N_{\overline{10}}\to N\eta} = -\sin\theta\frac{(4\,\alpha-1)}{\sqrt{3}}A_8 - \cos\theta\frac{1}{2\sqrt{5}}A_{\overline{10}}\,,$$

mixing angle

octet coupling constants



Conclusion: A small mixing with non-exotic octet helps to understand the trend of the data. Range of mixing angles is in agreement with predictions of ChQSM

SU(3) predictions for antidecuplet decays

Partial decay widths (MeV)	$\Gamma_{\Theta^+} = 1$ MeV $3^0 < \theta < 7^0$	$\Gamma_{\Theta^+} = 3$ MeV $6^0 < \theta < 10^0$
$\Gamma_{N_{\overline{10}} \to N\pi}$	< 0.5	< 0.5
$\Gamma_{N_{\overline{10}} \to N\eta}$	$0.65 - 0.67$	$1.94 - 1.95$
$\Gamma_{N_{\overline{10}} \to \Lambda K}$	$0.16 - 0.29$	$0.56 - 0.76$
$\Gamma_{N_{\overline{10}} \to \Delta\pi}$	$2.6 - 15.6$	$12.9 - 34.8$
$\Gamma_{\Sigma_{\overline{10}} \to N\overline{K}}$	$0.11 - 0.50$	$0.49 - 1.18$
$\Gamma_{\Sigma_{\overline{10}} \to \Sigma\pi}$	$0.02 - 2.64$	$0.57 - 5.00$
$\Gamma_{\Sigma_{\overline{10}} \Sigma\eta}$	$0.04 - 0.08$	$0.15 - 0.20$
$\Gamma_{\Sigma_{\overline{10}} \to \Lambda\pi}$	$0.15 - 0.81$	$0.72 - 1.90$
$\Gamma_{\Sigma_{\overline{10}} \to \Sigma(1385)\pi}$	$0.33 - 1.96$	$1.6 - 4.3$
$\Gamma_{\Xi_{\overline{10}} \to \Xi\pi}$	1.98	5.94
$\Gamma_{\Xi_{\overline{10}} \to \Sigma\overline{K}}$	1.08	3.23

suppressed

sizable

only due to mixing

large branching

Can be looked for in existing data?

Photocoupling to antidecuplet

Transition magnetic moments of the nonexotic and exotic baryons in units of μ_N.

$$\int dW \, \frac{d\sigma_{\rm res}}{d\Omega}(W) = \frac{\pi}{4k_\gamma^2} \frac{\Gamma_{\gamma n}\Gamma_{\eta n}}{\Gamma_{\rm tot}} .$$

Azimov, Kuznetsov, Strakovsky, MVP, EPJ 05

Analysis of GRAAL data

$$|\mu(n^* \to n)| = (0.13 - 0.37)\, \mu_N$$

$\Sigma_{\pi N}$ [MeV]	$\mu_{N\Delta}$	$\mu_{\Lambda^0\Sigma^0}$	$\mu_{\Sigma^-\Sigma^{*-}}$	$\mu_{\Sigma^+\Sigma^{*+}}$	$\mu_{\Lambda^0\Sigma^{*0}}$	$\mu_{\Xi^0\Xi^{*0}}$	$\mu_{\Xi^-\Xi^{*-}}$	$\mu_{pp^*_{\overline{10}}}$	$\mu_{nn^*_{\overline{10}}}$
50	−3.06	1.54	−0.44	2.25	−2.54	2.25	−0.44	0.12	0.56
60	−3.16	1.58	−0.50	2.21	−2.63	2.24	−0.50	0.08	0.33
70	−3.31	1.64	−0.59	2.17	−2.74	2.23	−0.59	0.04	0.11

Kim, Yang et al. PRD 05

Model independent approach in ChQSM

General Formalism in the SU(3)$_f$ χQSM

$\mu_{B'B}$

$$\mu_{\mathbf{B}} = \mu_{\mathbf{B}}^{(0)} + \mu_{\mathbf{B}}^{(\mathbf{op})} + \mu_{\mathbf{B}}^{(\mathbf{wf})}$$

$$\hat{\mu}_B^{(0)} = \mathbf{w_1} D_{Q3}^{(8)} + \mathbf{w_2}\, d_{pq3}\, D_{Qp}^{(8)} \cdot \hat{J}_q + \frac{\mathbf{w_3}}{\sqrt{3}} D_{Q8}^{(8)} \cdot \hat{J}_3$$

$$\hat{\mu}_B^{(1)} = \frac{\mathbf{w_4}}{\sqrt{3}} d_{pq3}\, D_{Qp}^{(8)}\, D_{8q}^{(8)} + \mathbf{w_5} (D_{Q3}^{(8)}\, D_{88}^{(8)} + D_{Q8}^{(8)}\, D_{83}^{(8)}) + \mathbf{w_6} (D_{Q3}^{(8)}\, D_{88}^{(8)} - D_{Q8}^{(8)}\, D_{83}^{(8)})$$

$$\mu_{B'B} = \langle B' | \hat{\mu}_B | B \rangle = \int d\mathcal{R}\ \psi_{B'}^{*}(\mathcal{R})\ \hat{\mu}_B\ \psi_B(\mathcal{R})$$

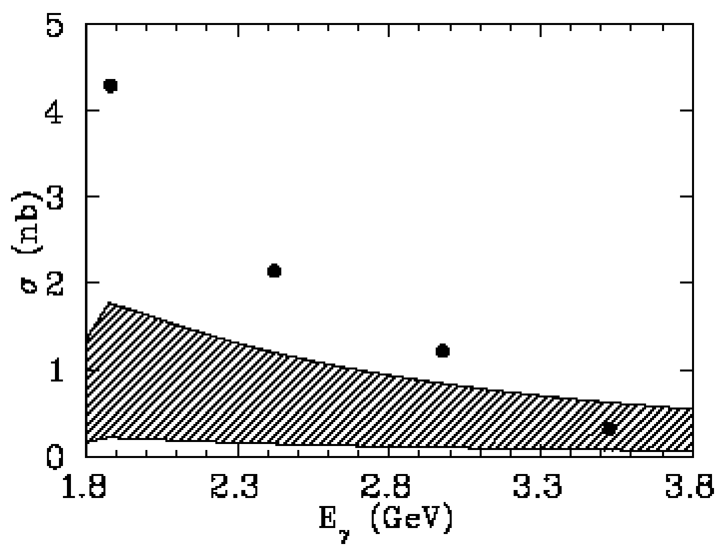
w's are universal constants, enter also magnetic moments of octet and decuplet. Obtained from fit to them.

K* coupling to antidecuplet and production x-section in photoreactions

Using estimated transition magnetic moments, VMD and SU(3) Symmetry one can estimate K* coupling

Azimov, Kuznetsov, Strakovsky, MVP `06

$$|f_2(K^{*0}p\,\Theta^+)| = |f_2(K^{*+}n\,\Theta^+)| = \sqrt{6}\,|f_2(\rho^0 n\, n^*)| = (1.10 - 3.14)\,.$$



With these range of values one computes production x-section for $\gamma+p \rightarrow Ks+\Theta$ and Compare with CLAS limits

Kwee, Guidal, Vanderhaeghen, MVP PRD05

CLAS null results do not exclude existence of pentaquark

Pentaquark width and Light-Cone baryon wave functions from ChQSM

Width of pentaquark is anomalously low!

$\boxed{\Gamma = 0.9 \pm 0.3 \text{ MeV}}$ Cahn and Trilling hep-ph/0311245

$\boxed{\Gamma = 0.36 \pm 0.11 \pm ? \text{ MeV}}$ DIANA coll. hep-ph/0603017

What ChQSM tells us about pentaquark width?

$\boxed{\Gamma < 15 \text{ MeV}}$ Original DPP97 prediction, w/o accounting all symmetry breaking effects

$\boxed{\Gamma < 2.5 \text{ MeV}}$ Ghil-Seok Yang et al., with full accounting all symmetry breaking effects and new data on axial charges and Sigma-term

χQSM, a low energy model of QCD

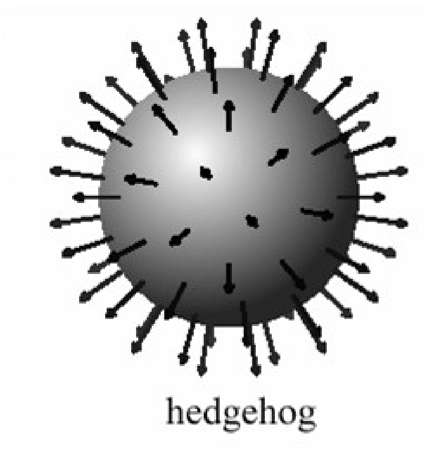
Large-N_C arguments allows us to consider a mean classical pion field

→ Relativistic Mean Field Approximation

We need a stable pion field configuration different from the vacuum → soliton

We suppose maximal symmetry
→ hedgehog ansatz

$$U^{\gamma_5} = \begin{pmatrix} \exp[i(\vec{n}\cdot\vec{\tau})P(r)] & \begin{matrix} 0 \\ 0 \end{matrix} \\ \begin{matrix} 0 & 0 \end{matrix} & 1 \end{pmatrix}$$



Light-cone baryon wave functions

Advantages of light-cone formulation:

- The vacuum of the free and interacting theory are the same
- The concept of wave function is meaningful and any particle is a superposition of Fock states

$$\left|\Psi_B\right\rangle = C_1\left|qqq\right\rangle + C_2\left|qqqq\bar{q}\right\rangle + \dots$$

- The vector and axial operators do not create or annihilate pairs

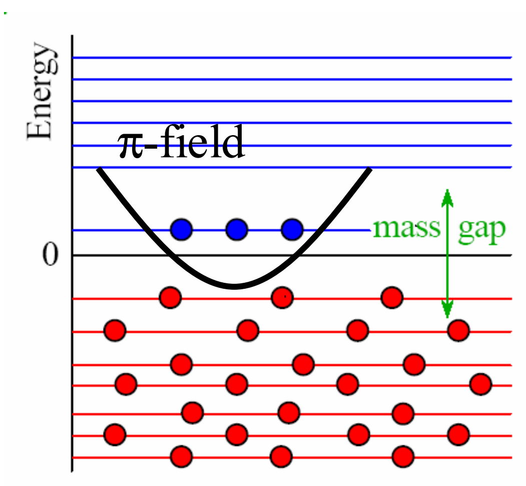
Light-cone baryon wave functions

In the χQSM it is easy to define the wave function at rest

Valence level

$$\left|\Psi_B\right\rangle = \mathcal{N} \prod_{couleur} \int dk\; F(k)\, a^{+}(k)$$

$$\times\, \underbrace{Exp\left[\int dk_1 dk_2\; a^{+}(k_1)\, W(k_1,k_2)\, b^{+}(k_2)\right]\left|0\right\rangle}$$



Quark-antiquark sea

Light-cone baryon wave functions

By definition light-cone wave functions are wave functions in the infinite-momentum frame (IMF)

We then perform a boost with

$$V \to 1$$

A particular baryon B with spin projection k is obtained thanks to its rotational wave function

$$\left|\Psi_k(B)\right\rangle = \int dR\, \boxed{B_k^*(R)}\, \varepsilon^{\alpha_1\alpha_2\alpha_3} \prod_{n=1}^{3} \int (dp_n)\, R^{f_n}_{j_n}\, F^{j_n\sigma_n}(\vec{p}_n)\, a^{+}_{\alpha_n f_n \sigma_n}(\vec{p}_n)$$

$$\times\, Exp[\int (dp_1)(dp_2)\, a^{+}_{\alpha f \sigma}(\vec{p}_1)\, R^{f}_{j}\, W^{j\sigma}_{j'\sigma'}(\vec{p}_1, \vec{p}_2)\, R^{+j'}_{f'}\, b^{+\alpha f'\sigma'}(\vec{p}_2)]\left|0\right\rangle$$

Light-cone baryon wave functions

Projection onto a particular Fock component is obtained by means of a *SU(3)* Clebsch-Gordan technique

We used instead explicit group integrals to see symmetries of the quarks wave functions

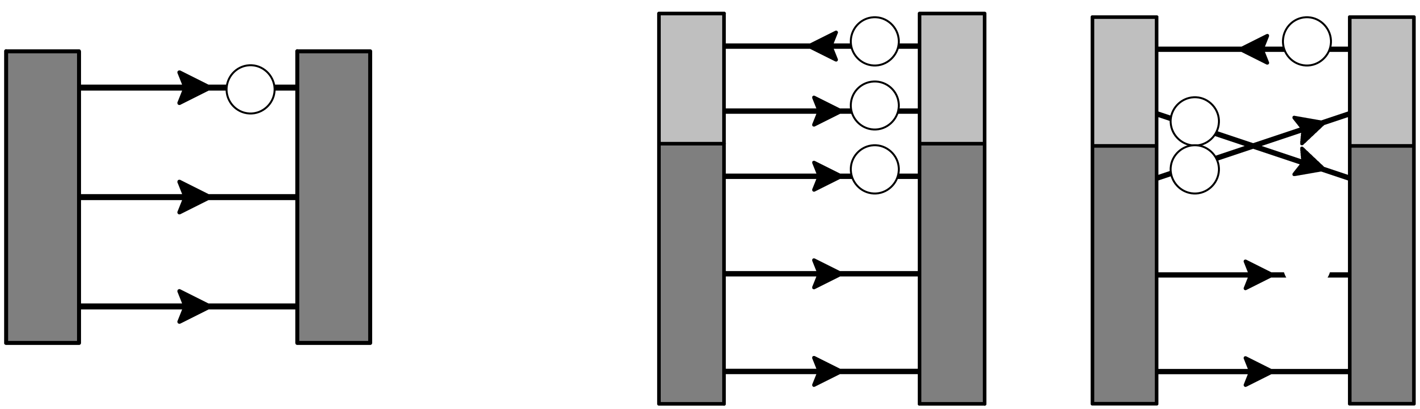
$$\int dR\, R^{f_1}_{j_1} R^{f_2}_{j_2} R^{f_3}_{j_3} R^{+\,j}_{g} R^{h}_{3} = \frac{1}{24}\left(\delta^{f_1}_{g}\delta^{j}_{j_1}\varepsilon^{f_2 f_3 h}\varepsilon_{j_2 j_3 3} + cycl.\ perm.\ of\ 1,2,3\right)$$

$$\begin{aligned}\int dR\, R^{f_1}_{j_1} R^{f_2}_{j_2} R^{f_3}_{j_3} (R^{f_4}_{j_4} R^{+\,j_5}_{f_5}) R^{+\,j}_{g} R^{h}_{3} = \frac{1}{360}\Big\{ & \varepsilon^{f_1 f_2 h}\varepsilon_{j_1 j_2 3}\left[\delta^{f_3}_{g}\delta^{f_4}_{f_5}\left(4\,\delta^{j_5}_{j_4}\delta^{j}_{j_3} - \delta^{j_5}_{j_3}\delta^{j}_{j_4}\right) + (3 \leftrightarrow 4)\right] \\ & + \varepsilon^{f_1 f_4 h}\varepsilon_{j_1 j_4 3}\left[\delta^{f_2}_{g}\delta^{f_3}_{f_5}\left(4\,\delta^{j_5}_{j_3}\delta^{j}_{j_2} - \delta^{j_5}_{j_2}\delta^{j}_{j_3}\right) + (2 \leftrightarrow 3)\right] \\ & + cycl.\ perm.\ of\ 1,2,3\Big\}\end{aligned}$$

Light-cone baryon wave functions

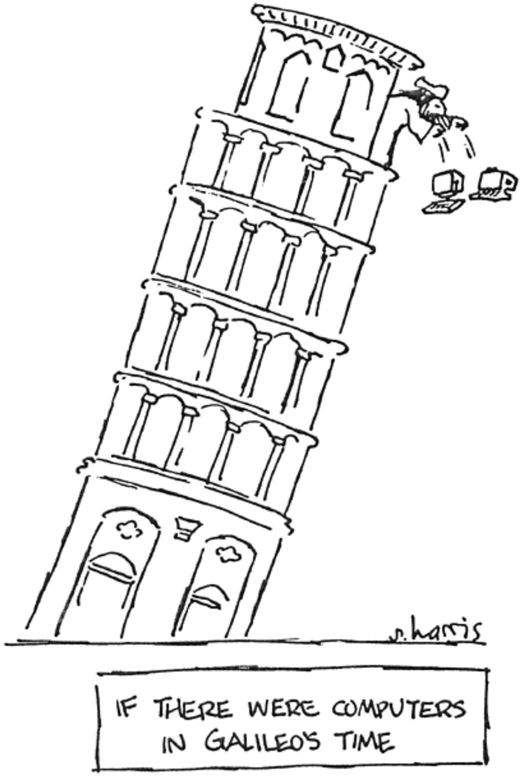
Properties of baryons are then obtained by sandwiching the corresponding operator

Charges: $$\mathcal{N}(B) = \frac{1}{2}\begin{Bmatrix} \delta_l^k \\ (-\sigma_3)_l^k \end{Bmatrix} \left\langle \Psi^{+Bl} \hat{O} \Psi_k^B \right\rangle$$



$\Rightarrow$ g_A, $g_{\Theta KN}$, μ_N, μ_Δ, ...

Results and comments

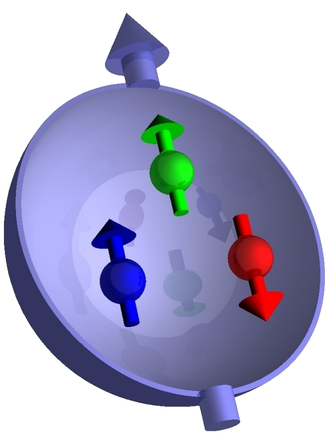


Results and comments

Axial charges are defined as

$$\langle N(p)|\overline{\psi}\gamma_0\gamma_5\lambda^a\psi|N(p)\rangle = g_A^{(a)}\overline{u}(p)\gamma_0\gamma_5\lambda^a u(p) \qquad a = 0, 3, 8$$

They are related to the first moment of polarized quark distribution



$$\Delta q = \int_0^1 dx\,[q_\uparrow(x) - q_\downarrow(x) + \bar{q}_\uparrow(x) - \bar{q}_\downarrow(x)]$$

$$g_A^{(3)} = \Delta u - \Delta d$$

$$g_A^{(8)} = (\Delta u + \Delta d - 2\Delta s)/\sqrt{3}$$

$$g_A^{(0)} = \Delta u + \Delta d + \Delta s$$

Means that the proton spends 0.3 of ist life-time as a 5-quark

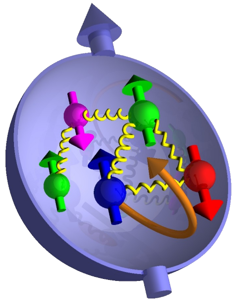
Results and comments

Proton axial results

	$g_A^{(3)}$	$g_A^{(8)}$	$g_A^{(0)}$	Δu	Δd	Δs	$\mathcal{N}(5)/\mathcal{N}(3)$
CQM	5/3	$1/\sqrt{3}$	1	4/3	-1/3	0	0
χQSM (5q dir)	1.359	0.499	0.900	1.123	-0.236	0.012	0.536
χQSM (5q dir+ex)	1.360	0.500	0,901	1.125	-0.235	0.012	0.550
χQSM (rel. 5q dir)	1.241	0.444	0.787	1.011	-0.230	0.006	0.289
Exp.	1.257 $\pm$0.003	0.34 $\pm$0.02	0.31 $\pm$0.07	0.83 $\pm$0.03	-0.43 $\pm$0.03	-0.10 $\pm$0.03	-

C. Lorce hep-ph/0603231 (published in Phys. Rev. D74; 054019, 2006)

Results and comments



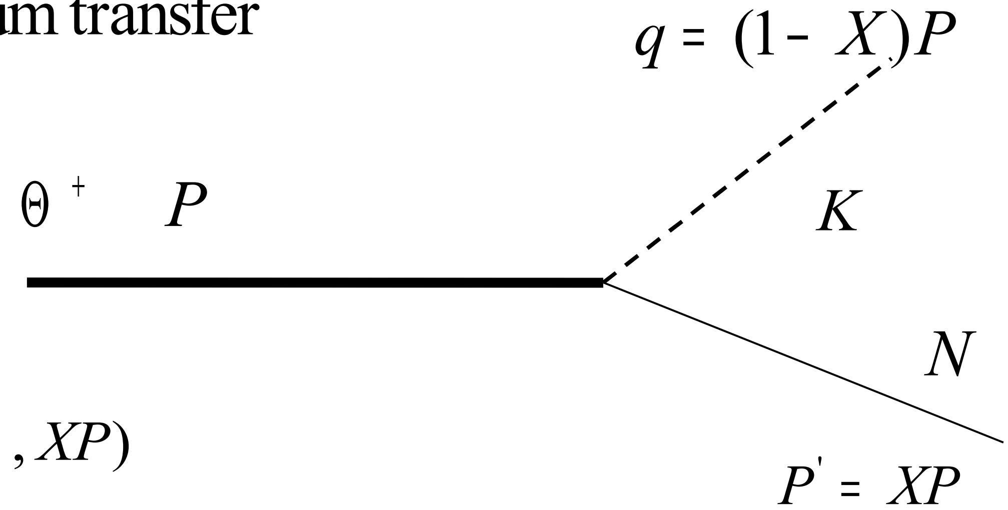
Θ^+ pentaquark width result

	$g_A(\Theta\rightarrow KN)$	$g_{\Theta KN}$	Γ_Θ
χQSM (5q dir)	0.202	2.23	4.427 MeV
χQSM (5q dir+ex)	0.203	2.242	4.472 MeV
χQSM (rel 5q dir)	0.144	1.592	2.256 MeV
Exp.	-	-	If confirmed <1MeV

C. Lorce hep-ph/0603231 (published in Phys. Rev. D74; 054019, 2006)

Results and comments

A more accurate estimation of Θ^+ width by computing form factors at non-zero momentum transfer



$$P = (\sqrt{P^2 + M_\Theta^2}, \vec{0}, P)$$

$$P' = (\sqrt{X^2 P^2 + q_\perp^2 + M_N^2}, -\vec{q}_\perp, XP)$$

$$q = (\sqrt{(1 - X)^2 P^2 + q_\perp^2 + m_K^2}, \vec{q}_\perp, (1 - X)P)$$

We impose energy conservation in IMF $\quad P \to \infty$

$$M_\Theta^2 = \frac{M_N^2 + q_\perp^2}{X} + \frac{m_K^2 + q_\perp^2}{1 - X} \quad \Rightarrow \quad X \in [0.468, 0.803]$$

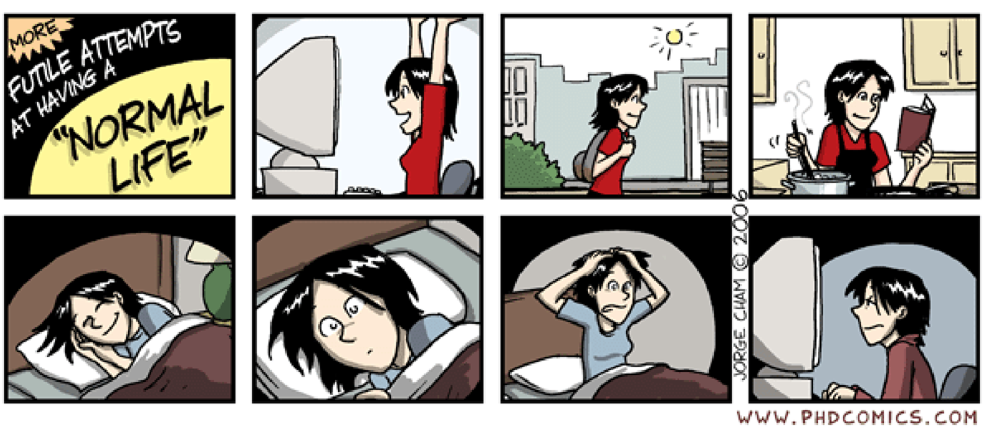
Results and comments

Momentum conservation allows only part of quark configurations to decay into a nucleon and a kaon

$$z_{j\neq i} = Xz'_{j\neq i} \quad \Rightarrow \quad z_{j\neq i} \in [0, X]$$

$$z_i = Xz'_i + (1 - X) \quad \Rightarrow \quad z_i \in [X, 1]$$

One can then expect a reduction of the width



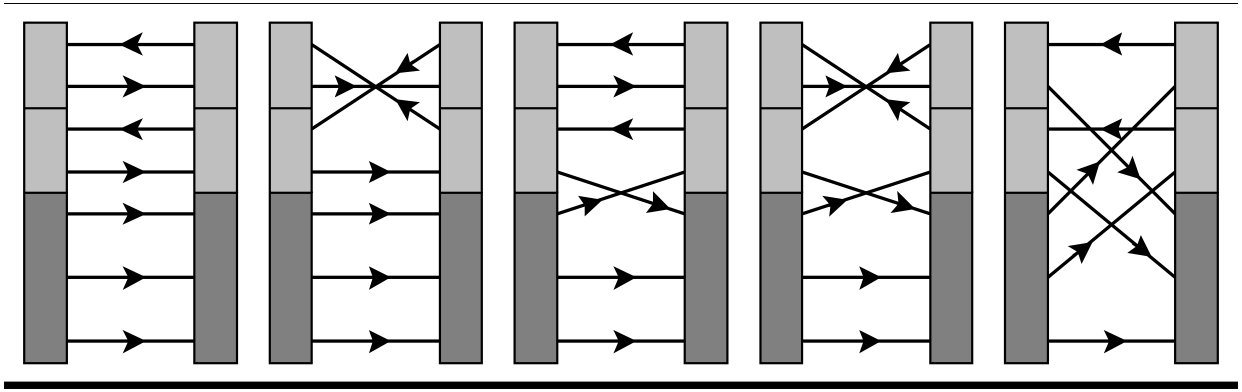
"Particles, particles, particles."

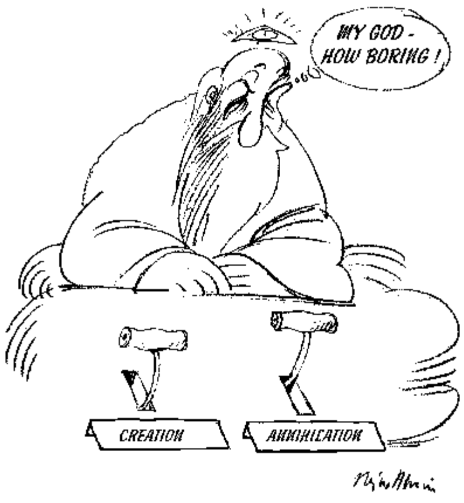
Results and comments

One can see that the 5-quark component in nucleon has a non-negiligible impact on its physical observables

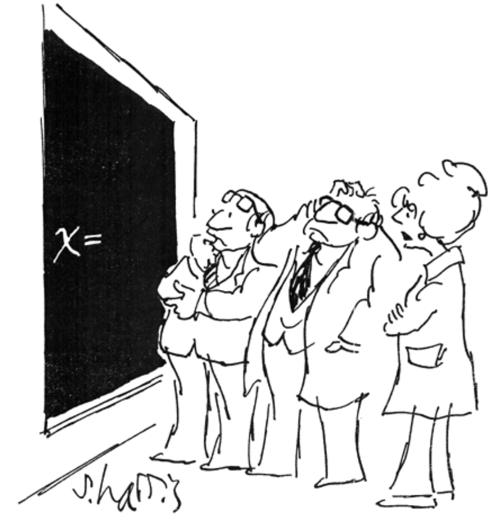
One can then expect the same happening when considering the 7-quark component for the pentaquark

Here are all the possible diagrams



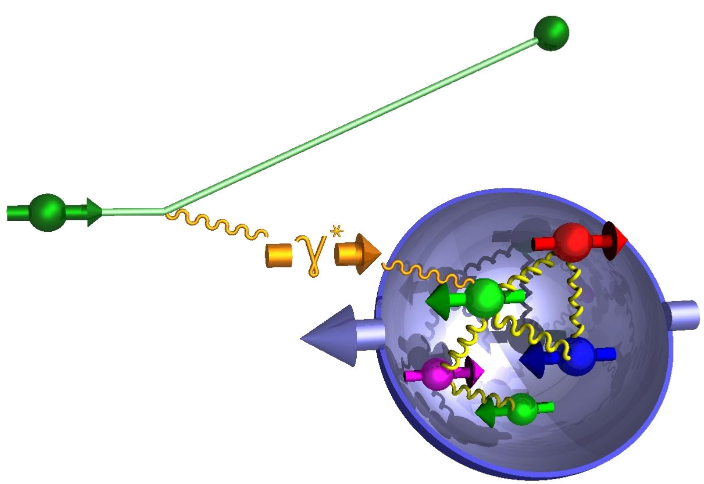


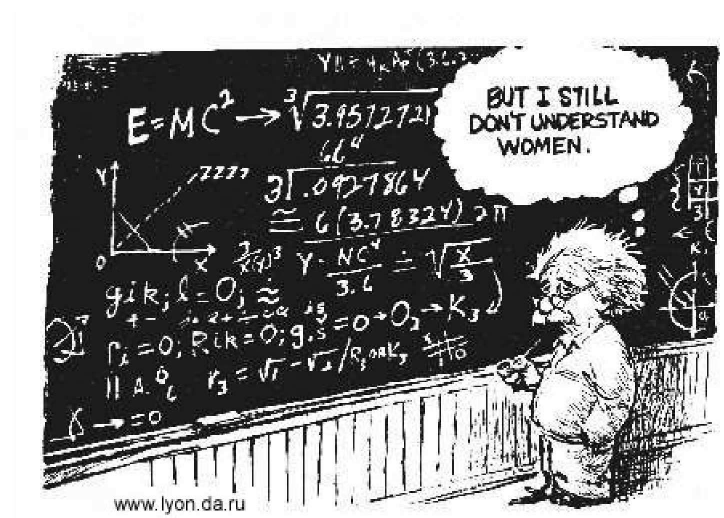
Conclusion and outlook



Outlook:

- Compute the 7-quark component
- Study the quark-antiquark content in details
- Study magnetic moments and magnetic transitions
- Parton distributions





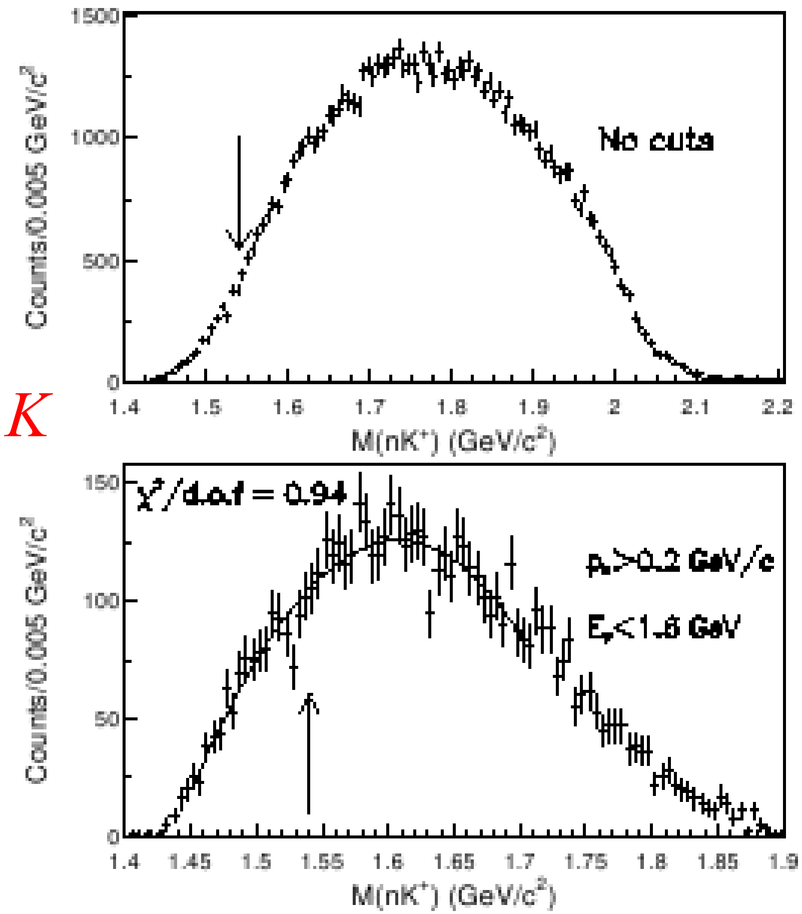
Back to estimates of various processes!

Analysis of Θ^+ production in $\gamma + D \to \Lambda + n + K$ reaction

V. Guzey, PRC 69 (2004);
hep-ph/0608129

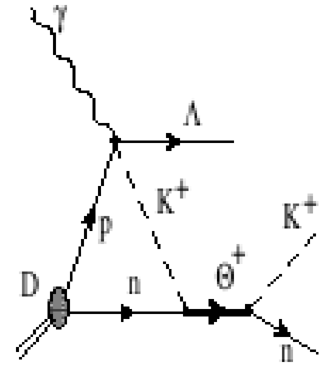
Motivation:
To understand the negative CLAS results of Θ^+ search in the reaction $\gamma + D \to \Lambda + n + K$

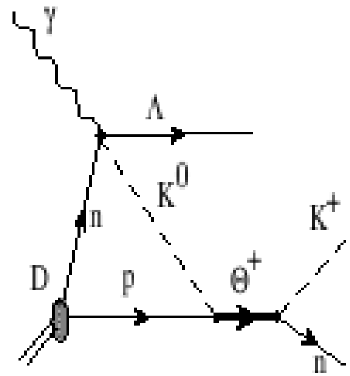
S. Niccolai, CLAS, hep-ex/0604047



Main idea and method:

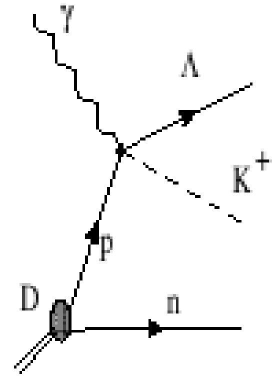
Assume a particular reaction mechanism for Θ^+ production





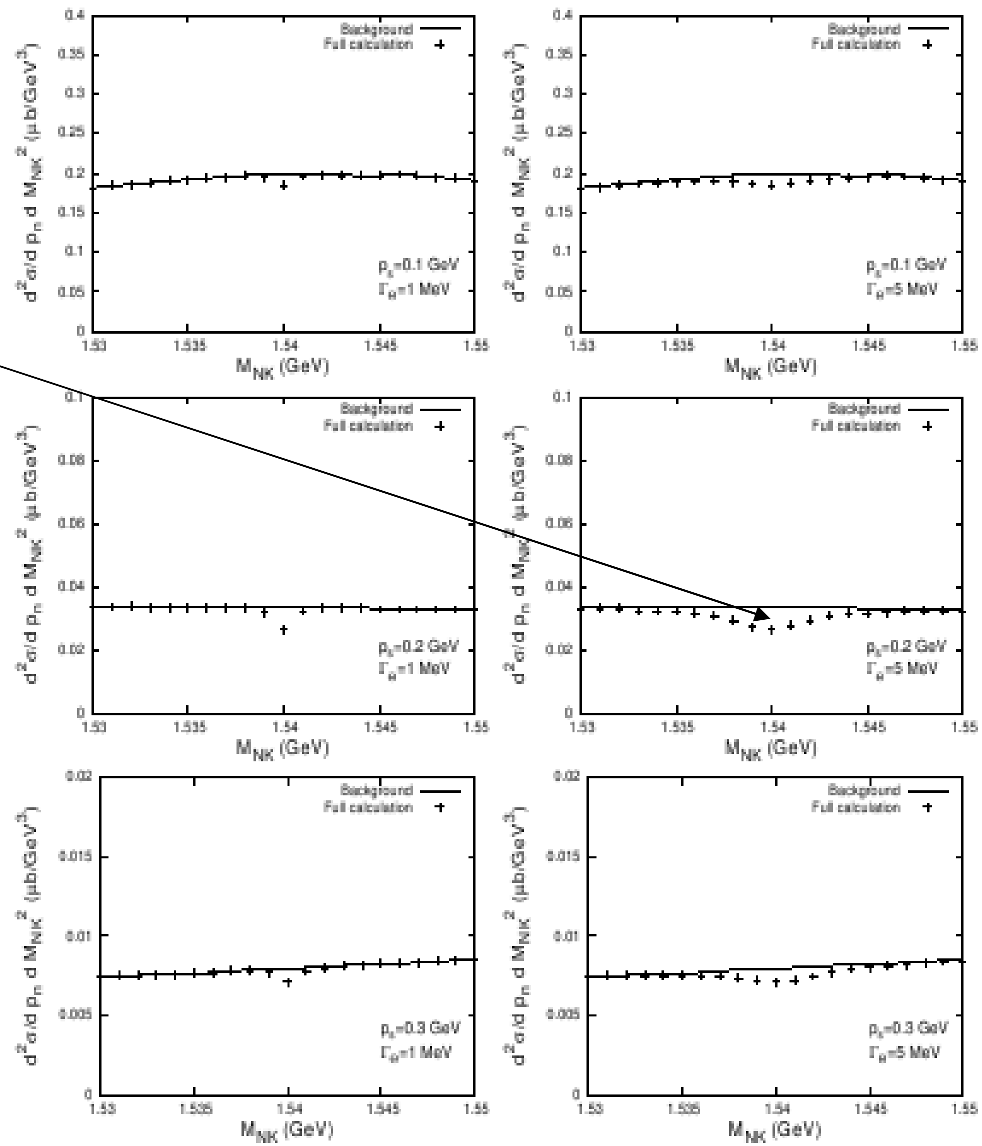
and

for the background reaction



Conclusion:

Cancellation between negative interference and positive signal contributions wash out any signs of Θ^+



CLAS data does not mean that Θ^+ does not exist!

Nice example how very small Theta signal can be enhanced by interference with strong background !!! Play with it !!!

Conclusions and Outlook

-We developed a new way to study properties of baryons through the LCWF computed in ChQSM

- usual baryons are NOT 3-quark states
- new systematic way to study various baryon properties

-ChQSM naturally accomodates sub-MeV pentaquark width, checked by two complimentary methods

- Global SU(3) analysis of baryons allows to restrict considerably properties of possible antidecouplet baryons. This analysis is also important for usual baryons, any new N resonance should open a new SU(3) multiplet.

-It seems that null results on pentaquark search do not mean its non-existence

Conclusions and Outlook

-We should not rush to the conclusion that pentaquarks are dead! Instead, we plan to suggest new ways to enhance aparently small signal of pentaquark, e.g. through interference

-To understand the nature of „anomaly“ in eta photoproduction on the neutron. I think that this should be one of central topics of our SFB:

- potential bright discovery, independently of anti-10 interpretation
- good possibility for collaborations of various groups (e.g A2, A4)
- if 5-quark, we expect good signal in 2 pi photoproduction on deuteron

-The pentaquark programme is still in the focus of several labs, further studies of 5-quark properties and estimates of processes are urgently needed to analyse new data and possibly reanalize old data.