Comments

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1. Quark model descriptions

   Where it succeeds and where it does not

2. Multiquarks

   Can we see characteristic features
   with active (effective) degrees of freedom?

3. Reactions

   SU(3) relations studied in photon-reactions

1. Quark model descriptions: *qqq*

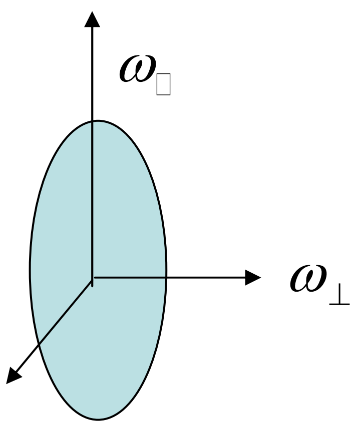
How good is the quark model?

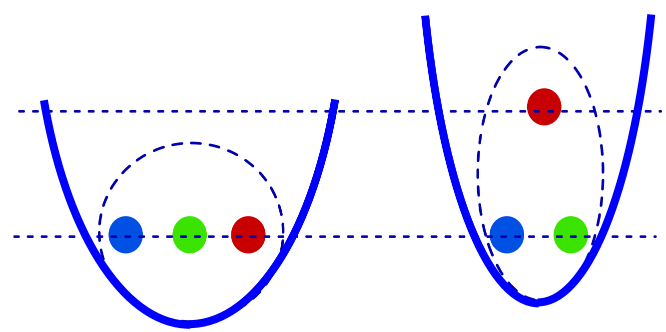
Takayama-Toki-Hosaka,
Prog. Theor. Phys. 101: 1271-1283 (1999)

$$H_{DOQ} = \sum_{i=1}^{3}\left(\frac{p_i^2}{2m} + \frac{m}{2}(\omega_\perp^2 x_i^2 + \omega_\perp^2 y_i^2 + \omega_\parallel^2 z_i^2)\right)$$

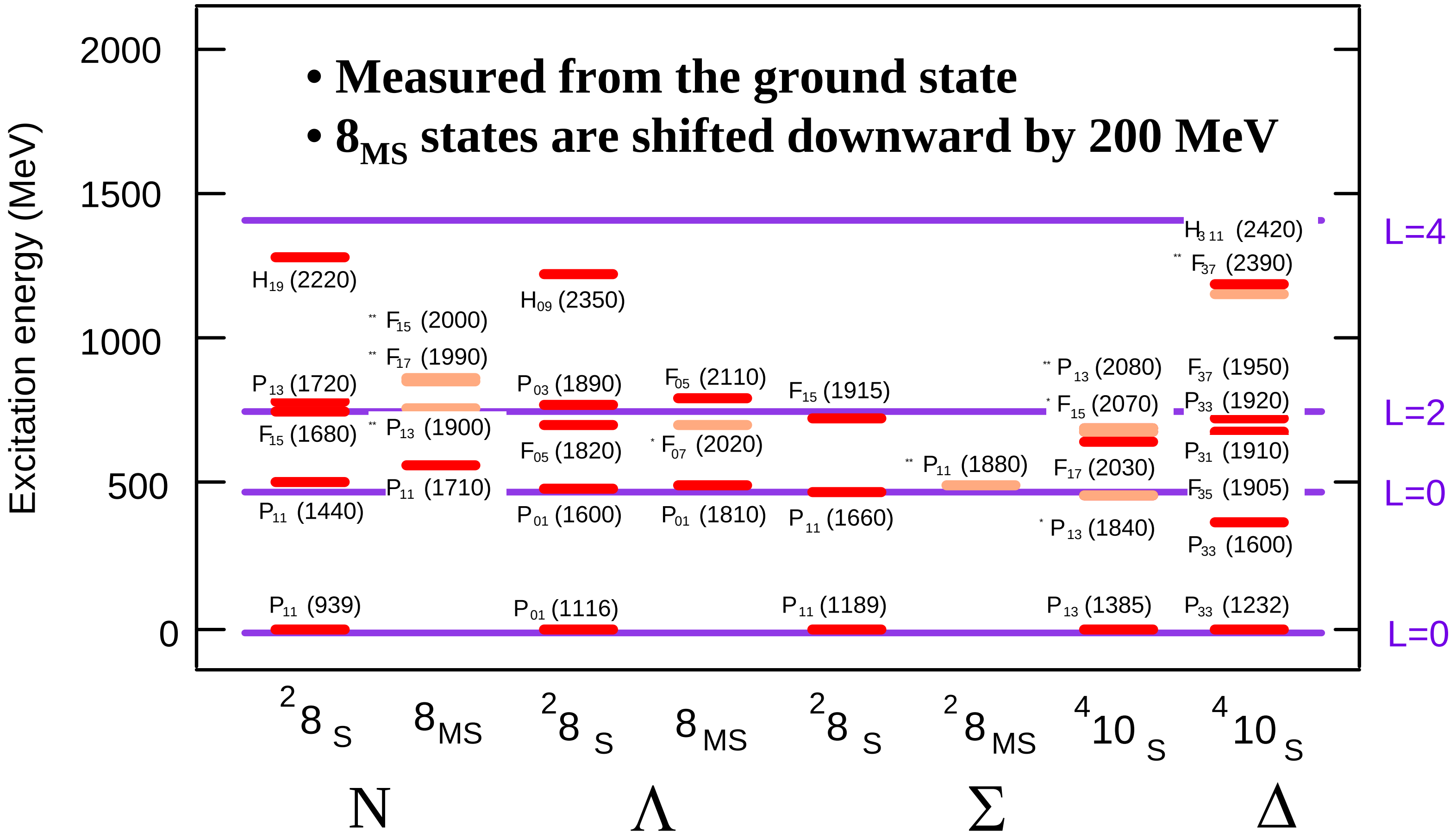
$$\omega_\perp^2 \omega_\parallel = const$$

Only one parameter

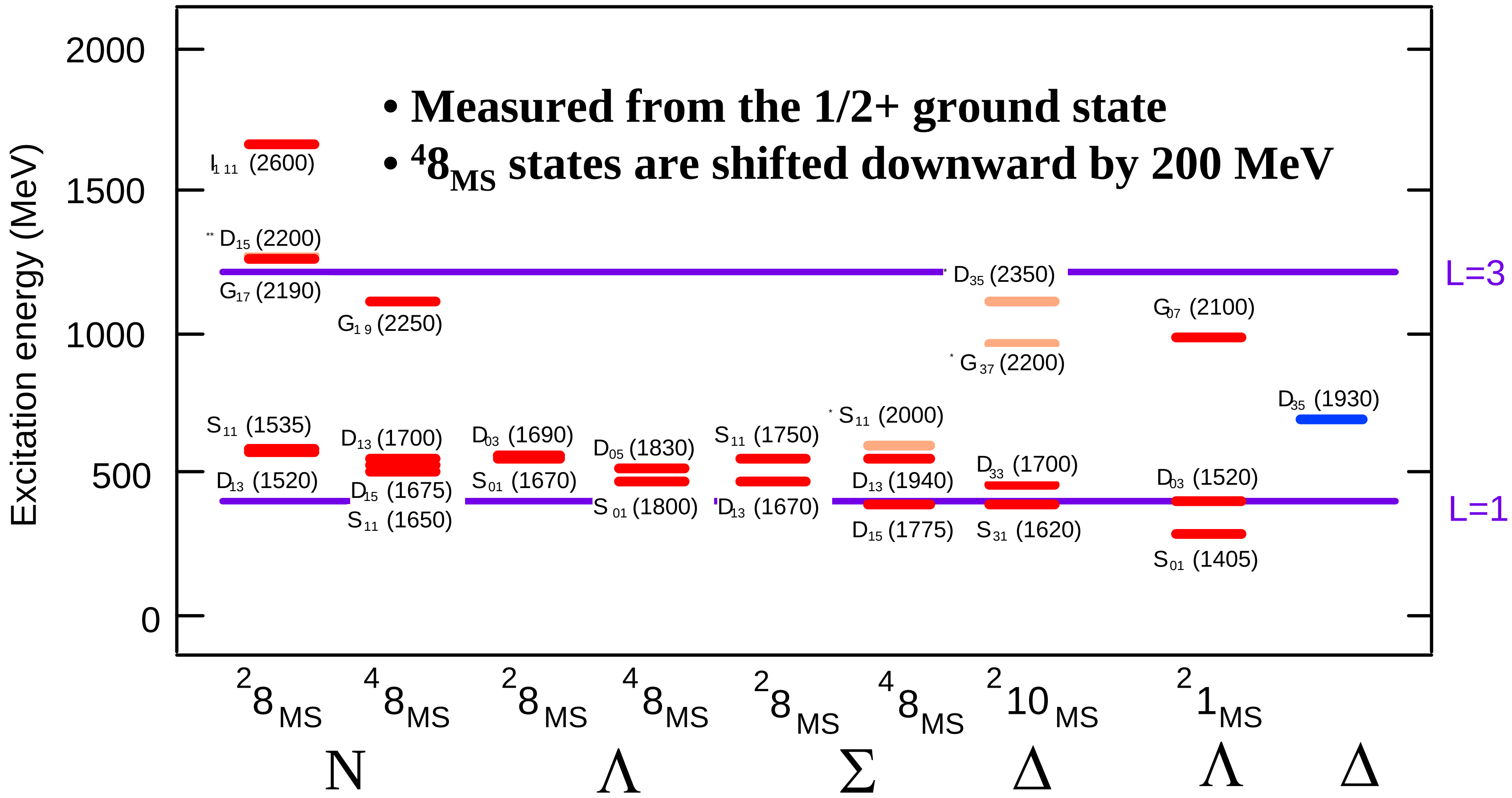




Poitive parity baryons

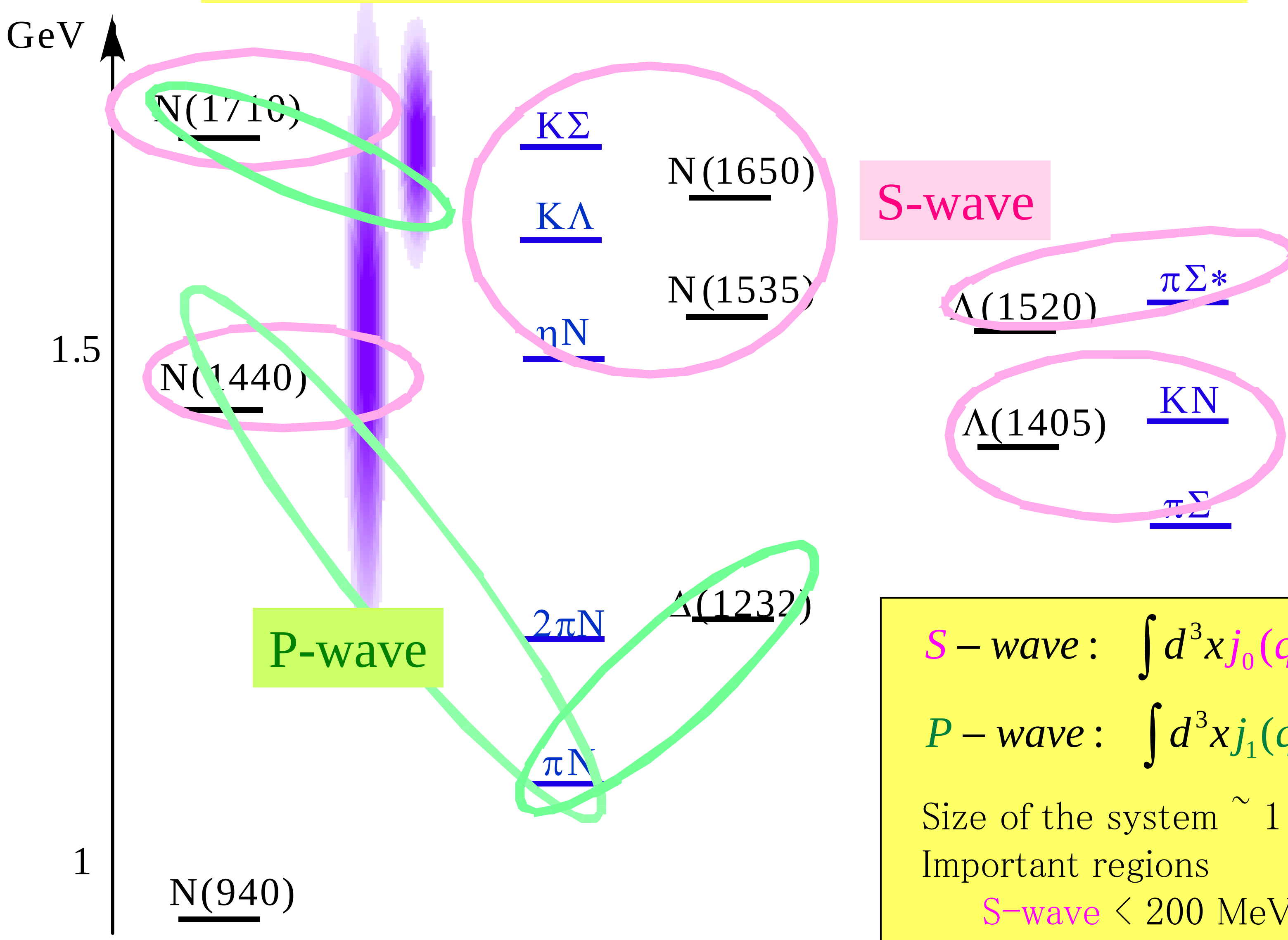


Negative parity baryons



Where is *Meson-Baryons dynamics*?

Resonances and coupled channels



$S-wave: \int d^3x j_0(qr)\rho(x)$

$P-wave: \int d^3x j_1(qr)\rho(x)$

Size of the system ~ 1 fm

Important regions

S−wave < 200 MeV

P−wave > 200 MeV

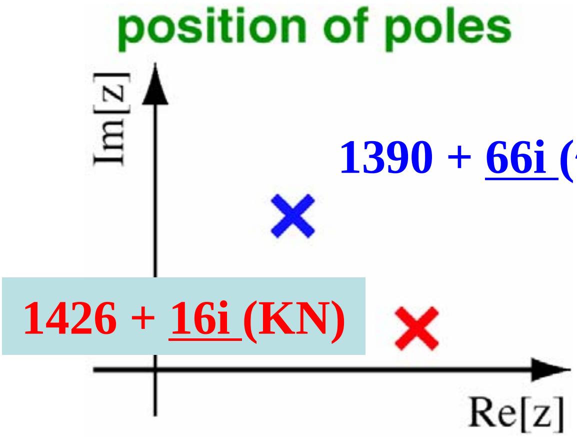
- Λ(1405) *$\bar{K}N$ or πΣ quasi-boundstate*

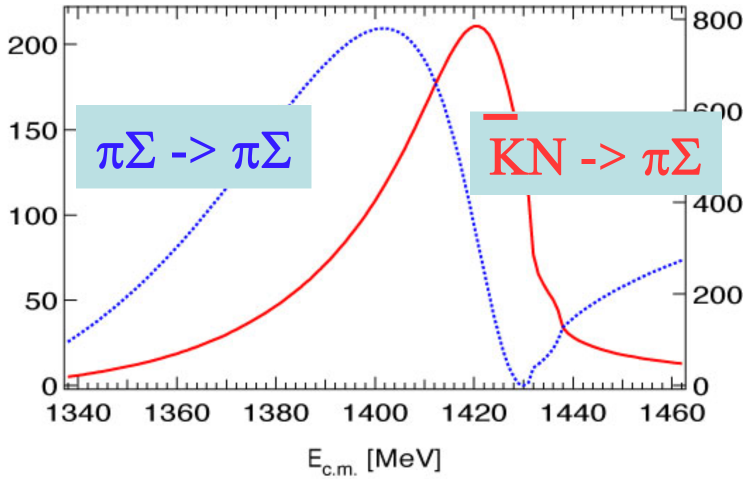
Jido-Oller-Oset-Ramos-Meissner, NPA725,181 (2003)

$\bar{K}N$ ~ **8 x 8 = 1, 8, 8, 10, 10, 27**

attractive **repulsive**

Two poles near 1405 MeV



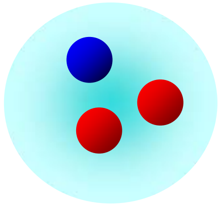


- Λ(1520) *πΣ*(1385) quasi-boundstate*

2. Multiquarks

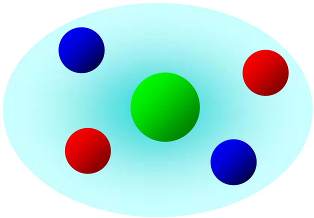
$q\bar{q}$ number is not conserved

Hadrons contain multiquark components…



$$|p\rangle = |uud\rangle + |uud(u\bar{u})\rangle + \ldots$$

3q + 5q + . . .



$$|\Theta^{+}\rangle = |uudd\bar{s}\rangle + |uudd\bar{s}(u\bar{u})\rangle + \ldots$$

5q + 7q + . . .

Constituents of (approx.) definite number?

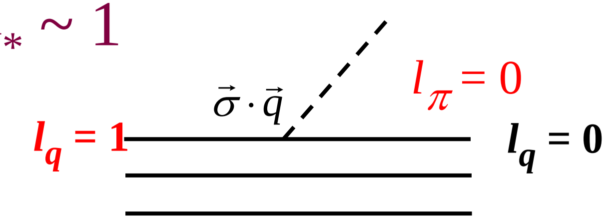
BUT

Having (minimal number) configurations,
one can test the structure of the wave functions

Decay is very sensitive

Example: baryon decay

$N(1535)$ –> πN (s-wave) $\Gamma \sim 70$ MeV, $g_{\pi NN^*} \sim 1$

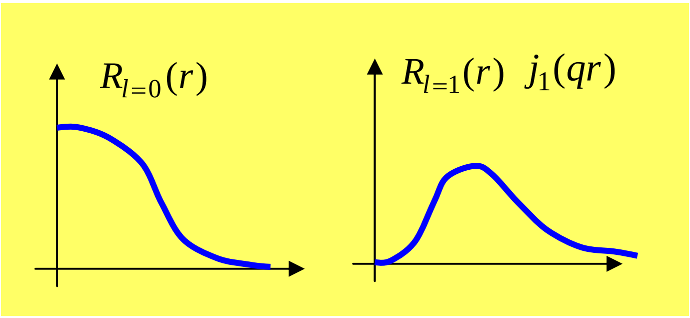


$$T_{fi} \sim \int d^3x \left\langle \psi_f(l=0) \right| e^{-iqx} \vec{\sigma}\cdot\vec{q} \left| \underline{\psi_i(l=1)} \right\rangle$$

$$\sim \vec{\sigma}\cdot\hat{r}\, R_{l=1}(r)$$

$$\sim \int d^3x\, R^*_{l=0}(r) j_1(qr) R_{l=1}(r)\, \underline{\vec{\sigma}\cdot\vec{q}\,\vec{\sigma}\cdot\hat{q}}$$

$$\sim 1$$

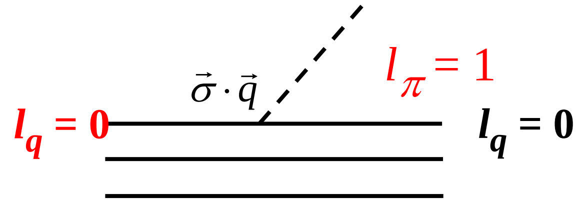


This integral is suppressed

$\Delta(1232)$ –> πN (p-wave) $\Gamma \sim 110$ MeV, $g_{\pi N\Delta} \sim 10$

$$T_{fi} \sim \int d^3x \left\langle \psi_f(l=0) \right| e^{-iqx} \vec{\sigma}\cdot\vec{q} \left| \psi_i(l=0) \right\rangle$$

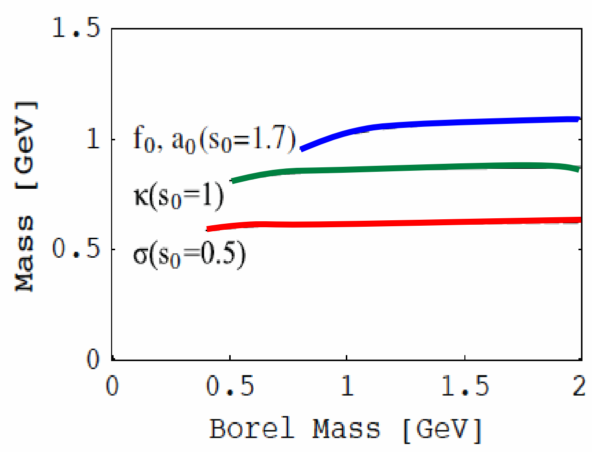
$$\sim \int d^3x\, R^*_{l=0}(r) j_0(qr) R_{l=0}(r)\, \vec{\sigma}\cdot\hat{q}$$

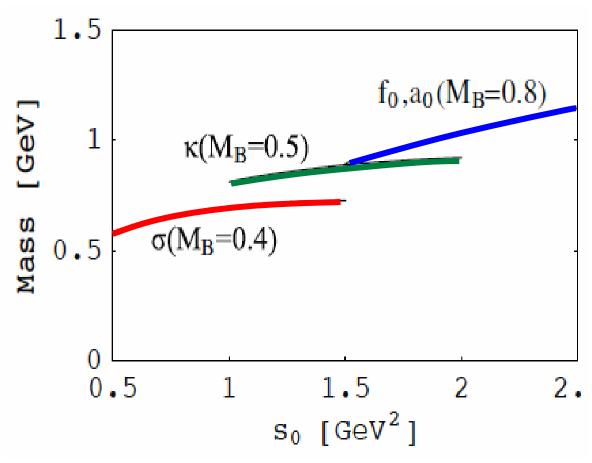


Tetraquark?

σ(600)

QCD sum rule using $qq\bar{q}\bar{q}$ currents, Chen-Hosaka-Zhu, hep-ph/0609163

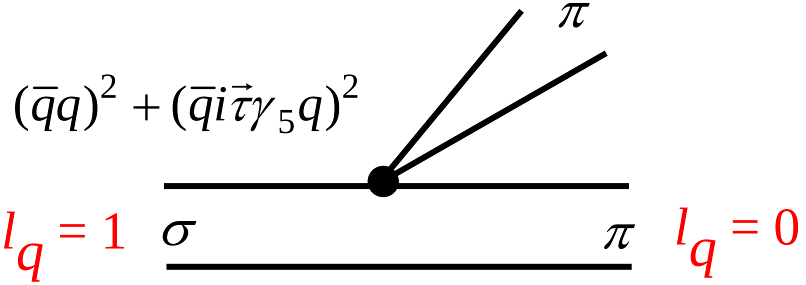




BUT $q\bar{q}$ current predicts $m_\sigma \sim 1.5$ GeV

Decay of σ(600)

• qq state: $J^P = 0^+$, ${}^3P_0$

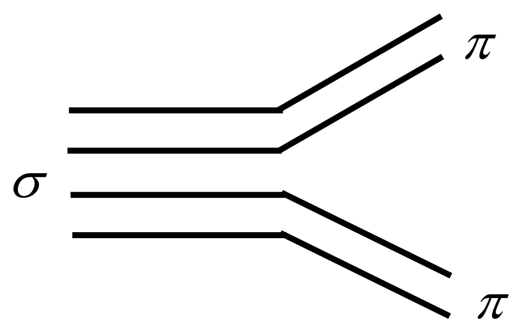


Transition includes $p \rightarrow s$ states
=> Suppressed integral

Too small decay rate
K. Yoshihara, Master thesis

• $qq\bar{q}\bar{q}$ state: $J^P = 0^+$, $(0s)^4$

Being investigated



3. Reactions

Strangeness production

Pion production: well known

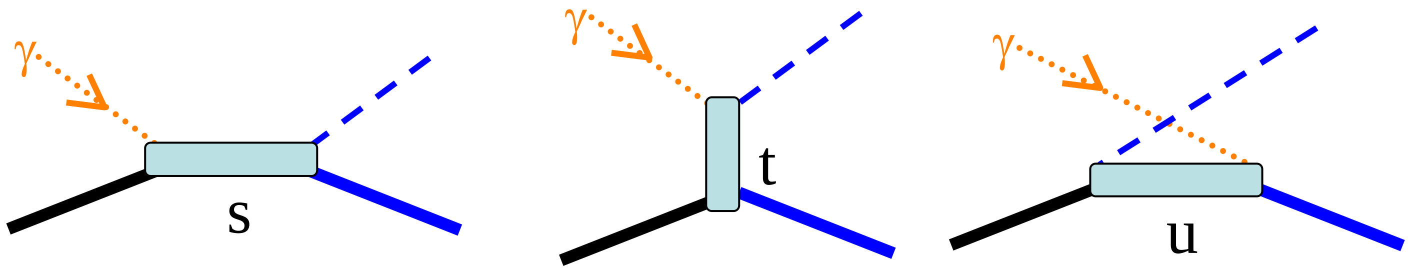
Kaon production: less understood

- Can SU(3) relations be used?
- How does strongly the K* couples to N and Y?

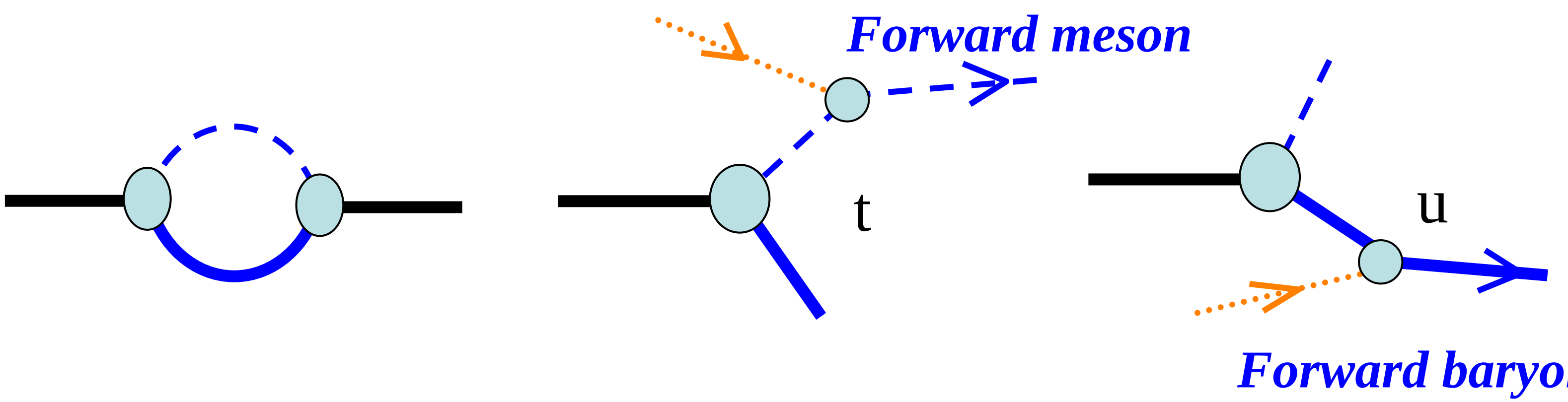
Sample values

	Bennhold Set1	Bennhold Set2	Ozaki
$g_{K\Lambda N}/\sqrt{4\pi}$	– 3.09	–3.80	–4.09
$g_{K\Sigma N}/\sqrt{4\pi}$	1.23	1.20	0.78
$g_{KK^*\gamma}g^V_{K^*\Lambda N}/4\pi$	–0.19	–0.51	–0.07
$g_{K^*K\gamma}g^T_{K^*\Lambda N}/4\pi$	–0.12	0.67	0.16
$g_{K^*K\gamma}g^V_{K^*\Sigma N}/4\pi$	–0.08	–0.31	–0.11
$g_{K^*K\gamma}g^T_{K^*\Sigma N}/4\pi$	-0.08	–0.61	–0.37

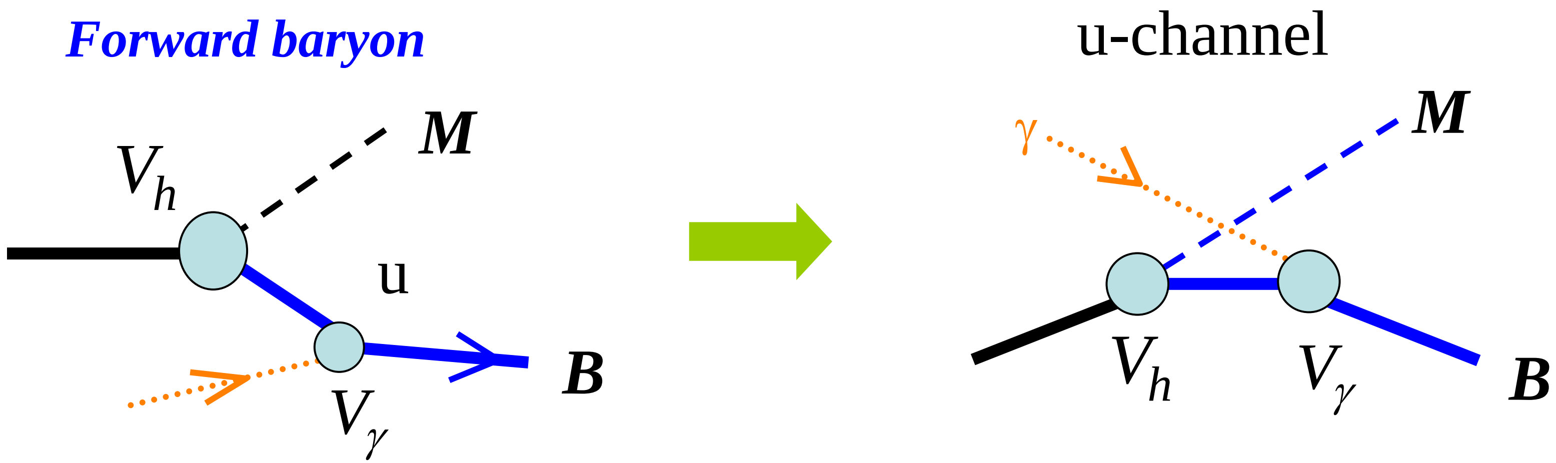
K-production



t and u-channels => Virtual components



Sa(i)mple estimation



$$T_{fi} \sim \frac{\langle f | V_\gamma | n \rangle \langle n | V_h | i \rangle}{\Delta E_n} \qquad R \sim \left| T_{fi} \right|^2 d\Phi$$

Production rate

@ k = 0.8 GeV => $\sqrt{s}$ = 2.03 GeV

R_{π} $0.75\, g_{\pi}^{2}$

R_{η} $0.41\, g_{\eta}^{2}$

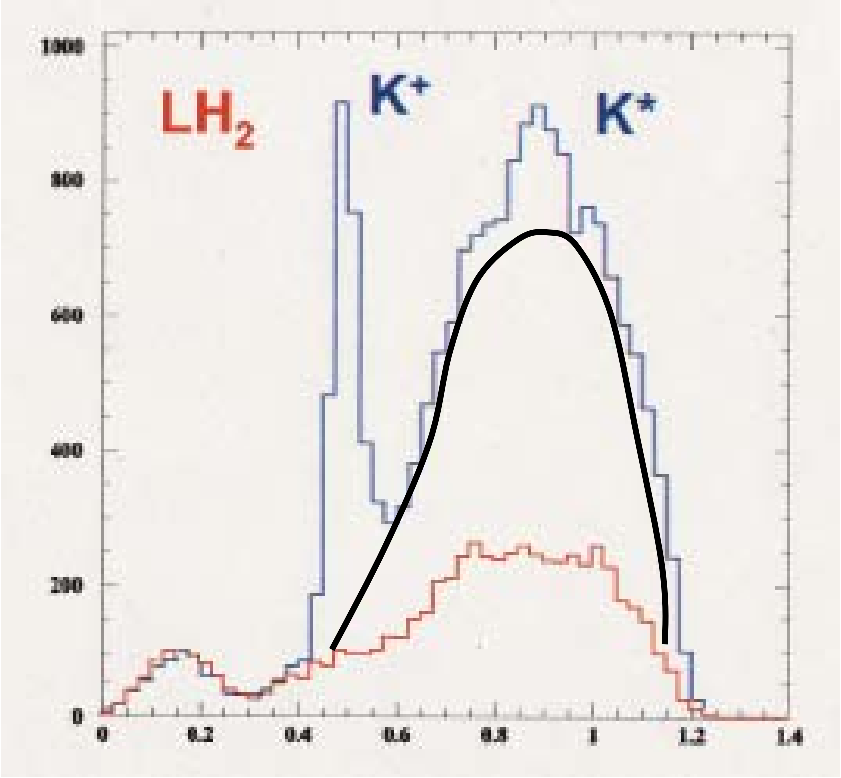
$R_{\eta'}$ $0.05\, g_{\eta'}^{2}$

R_{ω} $1.02\, g_{\omega}^{2}$ ⇐ Small $\kappa \sim 0$

R_{K} $0.45\, g\;\;^{2}$

R_{K^*} $2.16\, g\;\;_{*}^{2}$ ⇐ Large $\kappa \sim 2$

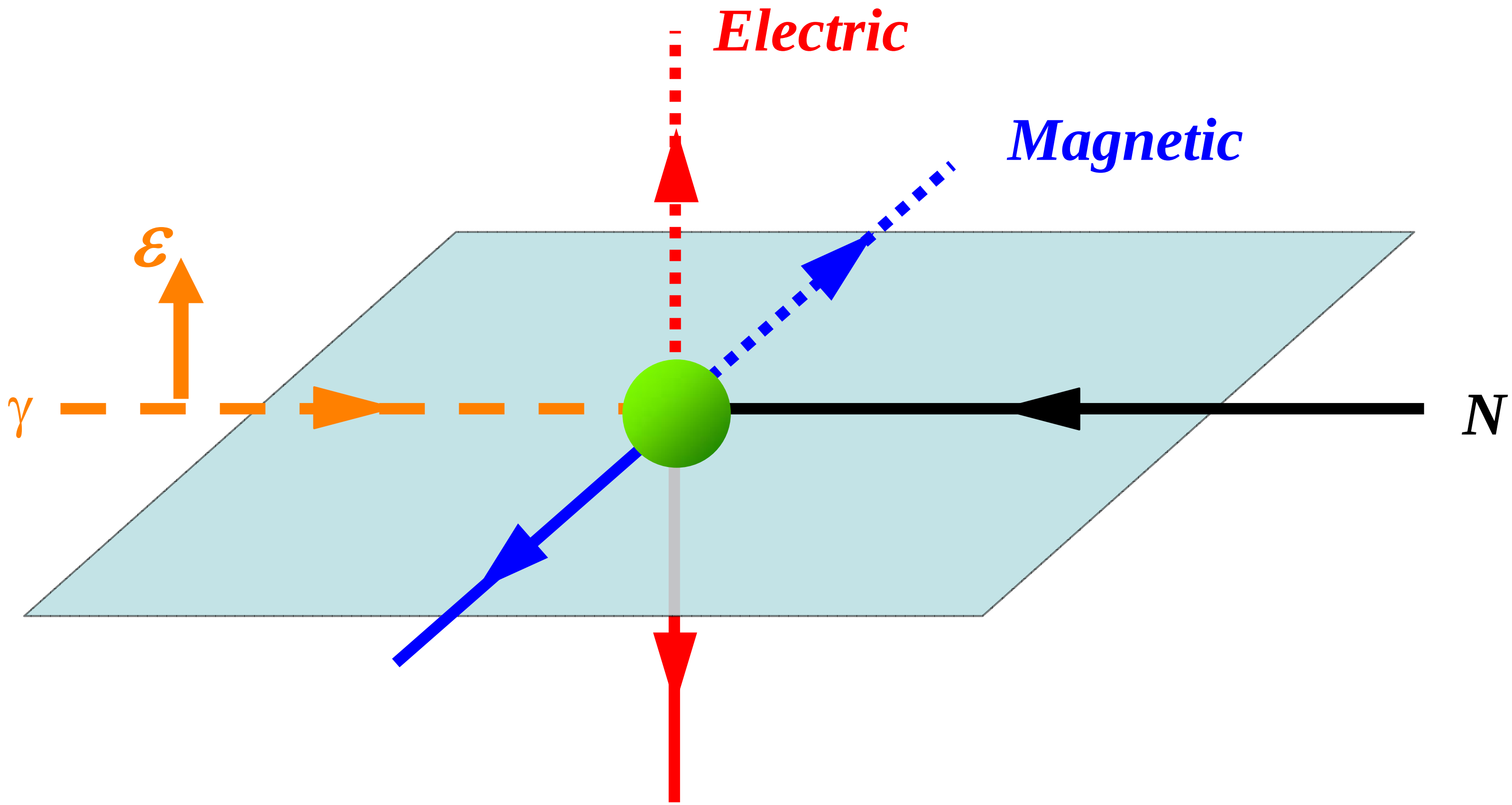
K* coupling



Nakano, priv. comm.

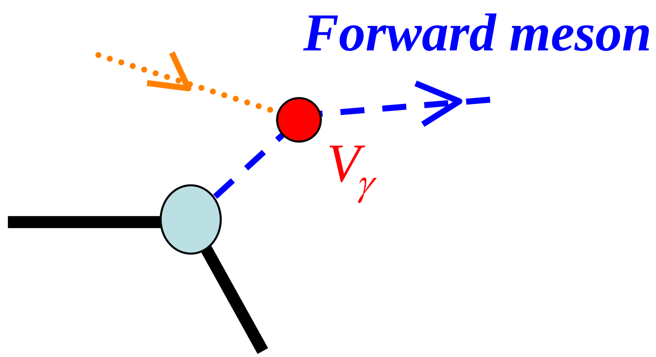
R(*K*) > R(*K**) …?

Asymmetry of photo-production

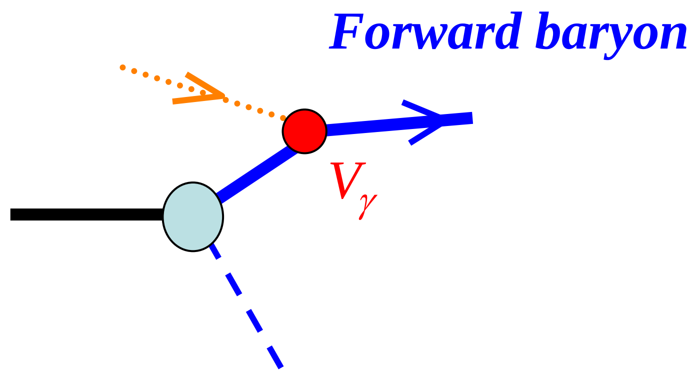


t and *u*-channels

t-channel



u-channel



- Asymmetry depends on the nature of V_γ
- Both t and u channel dynamics affects the asymmetry

  K*-exchange in t-channel

  Delta(spin3/2)-exchange in u-channel *Magnetic coupling*

Summary

There are many interesting not yet understood physics

- Are there relevant degrees of freedom?
  Constituent quarks and some mesons (pions and kaons)

- Are there evidences of multiquark components?

- SU(3) relations holds? As well as vector meson couplings.

Accumulation of the knowledge must be mandatory to explore more exotic physics