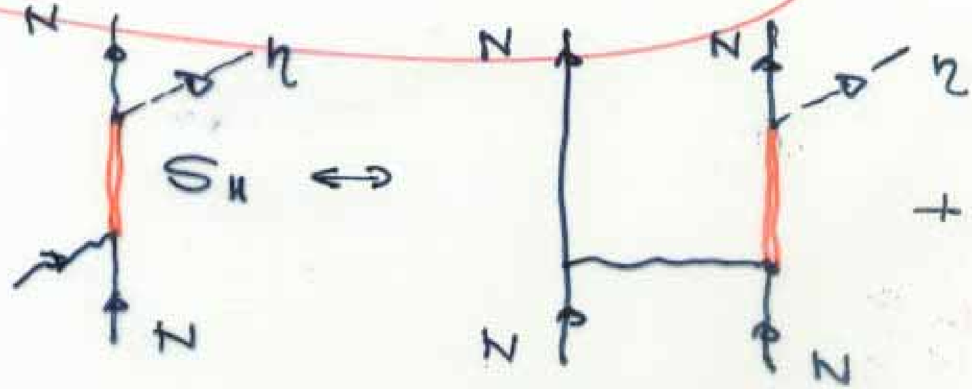
N^*_s in Meson Exchange - Quark Models

* S_{11} : η-mesic nuclei
* Formfactors $F(s,t,u)$
* N^* as $3q - q\bar{q}$; Roper
* Mesonproduction; $q\bar{q}$ interaction

* $S_{11}(1535)$ in medium: η-mesic nuclei.

Nieves

S_{11} dominance on N, NN



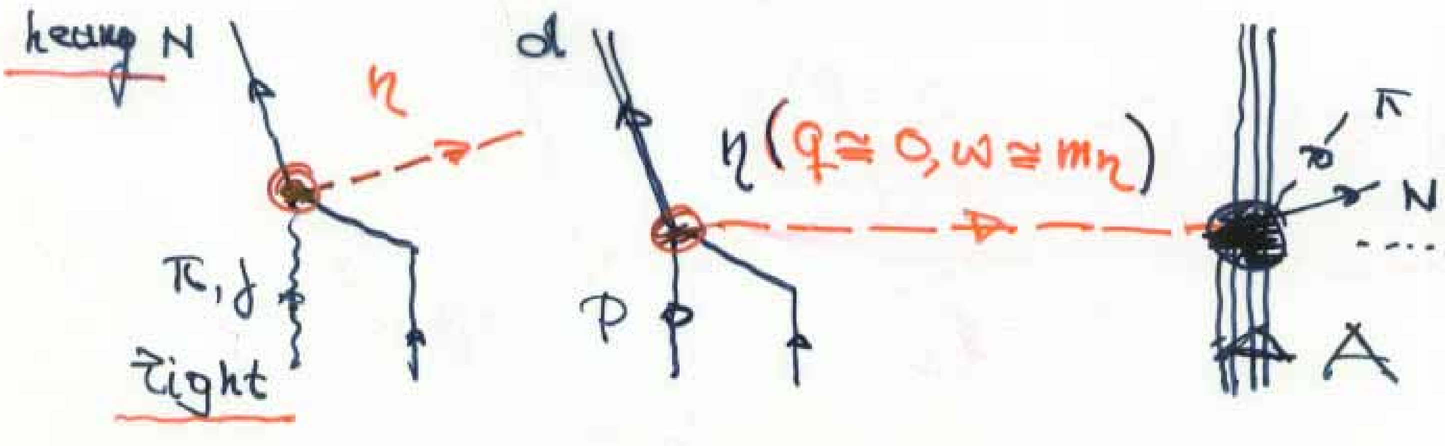
+ B. ground

$$\Gamma_{S_{11}} \sim (95-150\,\mathrm{MeV}) \begin{cases} \to N\eta \lesssim 50\% \\ \to N\pi \sim 45\% \\ \to N\pi\pi \sim 5\% \end{cases}$$

$\Downarrow$

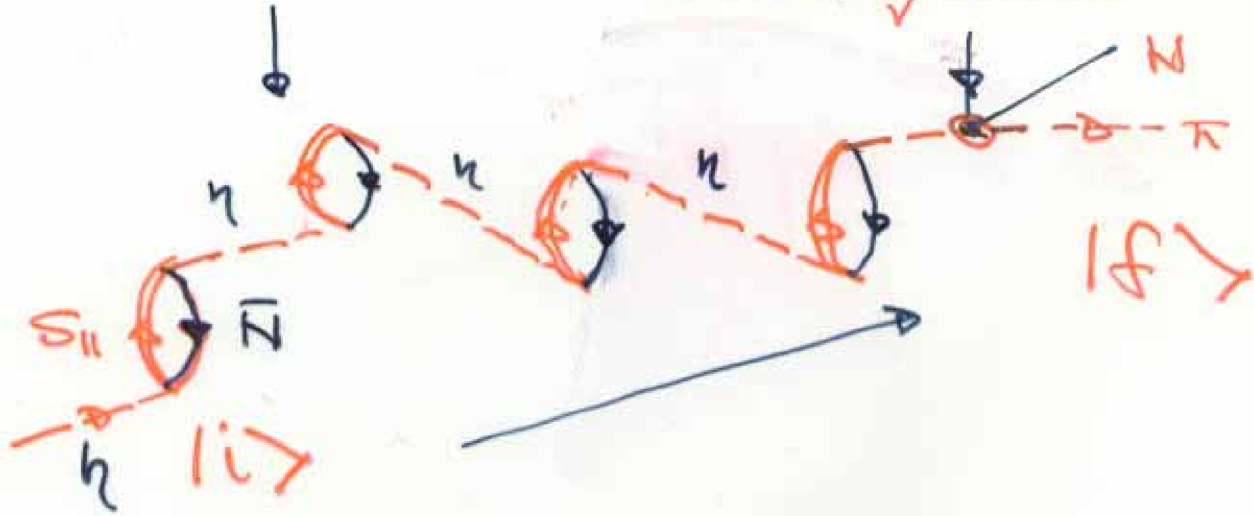
Recoilless production in medium:

η on shell ~ in rest!

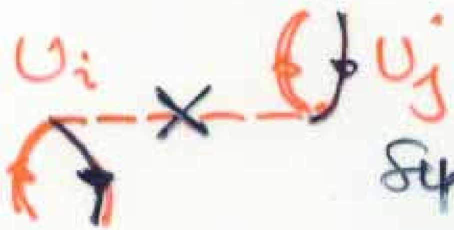


((closed shell) Nuclei: S_{11} N hole $= (N^*\bar{N})^{J^\pi}$

Doorway state



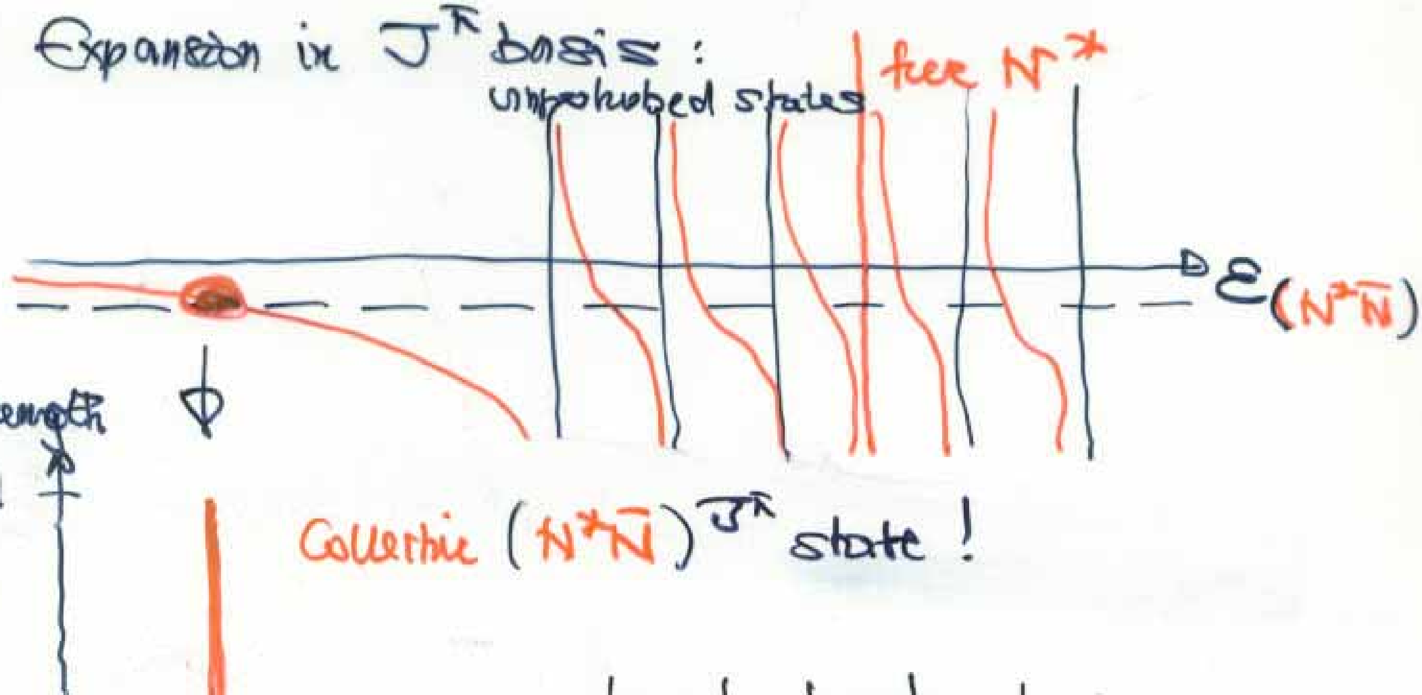
Summation TDA (RPA)



Separable Approximation:

Schematical model!

Expansion in J^π basis:



S_{11} Interaction in medium

F : $\bar{N}$ $N\pi$

H_{DF}

D : $S_{11}\bar{N}$

H_{QD}

Q : NN, NNπ, ..

H_{DQ}

D : $S_{11}\bar{N}$

H_{DP}

P : η

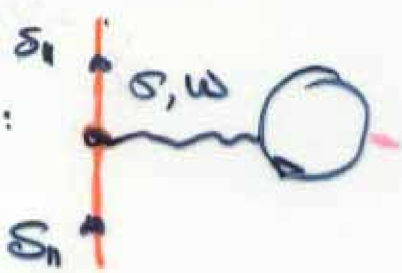
Projector formalism :

$T_\eta A \to (A-1) N\pi$ —

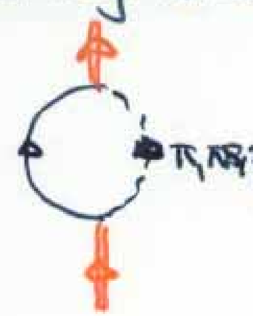
$$\langle (A-1), N\pi \,|\, H_{FD} \frac{1}{H^{*}_{shell\,M.} + H_{residual} - E} H_{DP} \,|\, \eta A \rangle$$

Mean field :

H^{*}_{SM} :

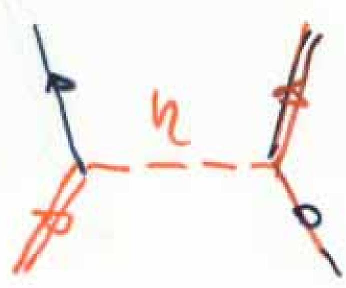


Leading channels :



: Self Energy

+



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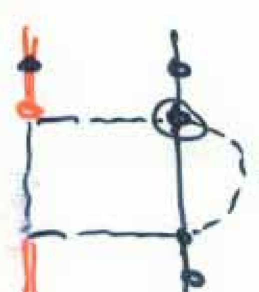


+ ....

+ background (different N^*, nonresonant)

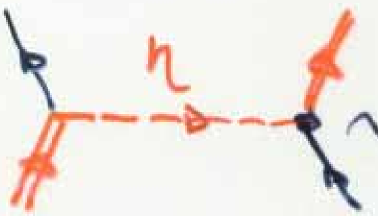
Comparison $\Delta(1232)$ isobar; π-mesic nuclei:

* Less absorptive: collectivity $\uparrow$

* NN hadronic suppressed; $NN\pi\pi, \ldots$ phase space $\downarrow$

* Crossing η-threshold!

Leading attraction:



$q,\ m_\eta - \omega$

$$\sim \frac{g^{*2}}{4\pi}\frac{1}{r}\cdot\begin{cases} e^{-\sqrt{m_\eta^2-\omega^2}\,r} & \text{Yukawa} \quad m_\eta>\omega:\ \text{below} \\ 1 & \text{Coulomb} \quad m_\eta=\omega:\ \text{at} \\ \cos\sqrt{\omega^2-m_\eta^2}\,r + i\sin\sqrt{\omega^2-m_\eta^2}\,r & m_\eta<\omega:\ \text{above} \end{cases}$$

$-N\eta$ threshold!

$\downarrow$

Dramatic change

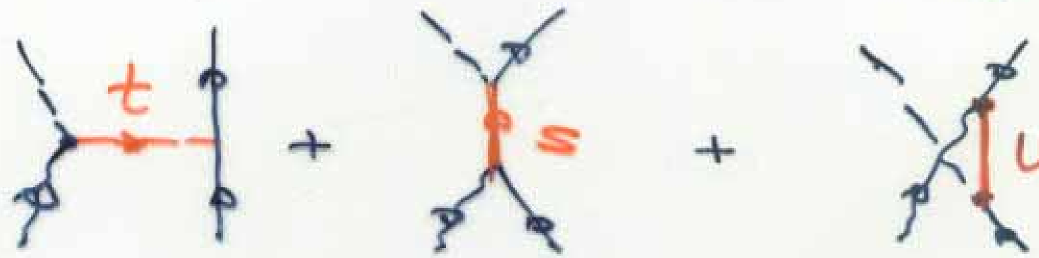
attraction, width!

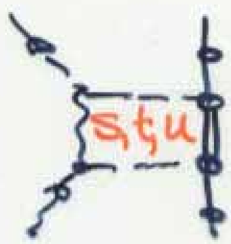
$E_{N^*N} \sim -40 + i\,20$ MeV ?! Collective states ?!

$\longrightarrow$ Experiment: Signatures $N\pi, N\pi\pi, \ldots$ final states!

Parametrization of $F(s,t,u)$

- Mesonproduction: MEC-Models: (γ,π)



+ FSI: Box 

+ crossed + ...

$F(s,t,u)$: factorization ?

consistent parametrization ?!

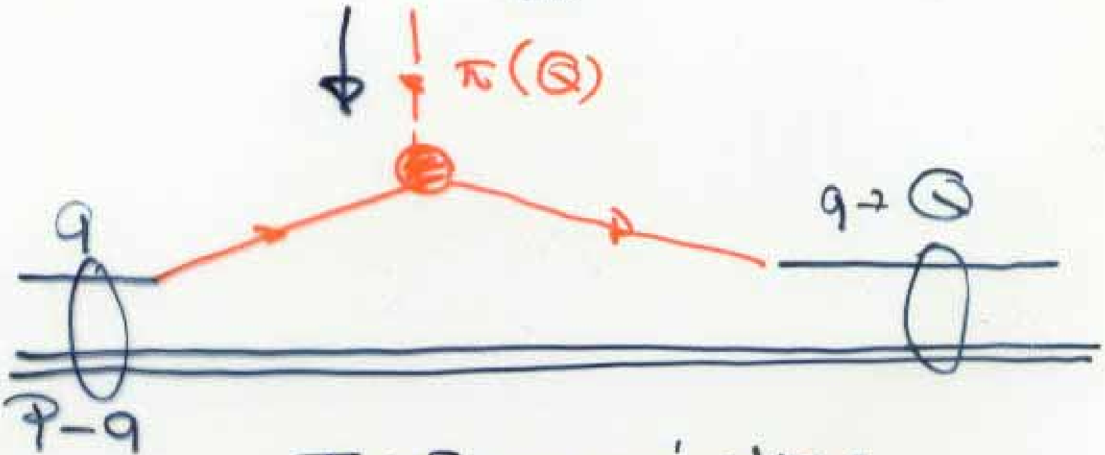
↓

$$F(t) = \frac{\Lambda^2}{\Lambda^2+t} \;;\leftrightarrow\; F(u) = \frac{\Lambda^4}{\Lambda^4+(u-m^2)^2}$$

→ Analytical model ↔ crossing channels, ...

↳ Covariant BS ↔ Bernhard; Plessas; Mike

$L_{\pi NN} - i\gamma_5 \dfrac{F_{\pi NN}(s,t,u)}{f_\pi}$: Projection on external N spinors !



Impuls approximation;

N : q - diquark ; π: G. Boson

↓

BS :

$$\psi(P,q) = \frac{(\not q + m_q)}{(q^2-m_q^2-i\epsilon)((P-q)^2-m_Q^2)} \left\{ \begin{array}{c} \int K(P,q,k)\,\psi(P,k)\,dk \\ \text{separable} \\ \downarrow \\ \dfrac{1}{(q^2-\Lambda^2-i\epsilon)} \end{array} \right.$$

↓

Projection on p. waves: M. Lutz:

$Y_0^{(+)} = \left(\dfrac{\not P}{P} + 1\right)$, Projection on spin component $\frac{1}{2}(1+\not s\gamma_5)$

$$F_{\pi NN}(P,Q) = \int dq\, \frac{f(\not q, \not Q, \not P, \not s, m_q, m_Q, \Lambda)}{(q^2-m_q^2)^n((P-q)^2-m_Q^2)^n((q+Q)^2-m_q^2)^n\cdots}$$

Standard Feynman parametrization:

$$F_{\pi NN}(Q,P) \sim \frac{\partial}{\partial m_q^2}\frac{\partial}{\partial m_q'^2}\cdots\int_0^1 d\alpha\int_0^1 d\alpha'\ldots$$

$$\int dq\,\frac{\text{Numerator}}{\left(\alpha(q^2-m_q^2)+(\alpha-\alpha')((P-q)^2-m_Q^2)+\cdots\right)^n}$$

No analytical result!

$\hookrightarrow$ Euclidean + expansion:

$$\frac{1}{((P-q)^2+m_Q^{*2})} = \frac{1}{(P^2+m_Q^{*2})}\sum(-1)^n\frac{(Pq)^n}{(P^2+m_Q^{*2})^n}$$

$\downarrow$

$$F_{\pi NN}(P^2,Q^2,PQ) \sim \sum\int\frac{dq\cdot q^{2n}}{D(q^2;P^2;Q^2)}$$

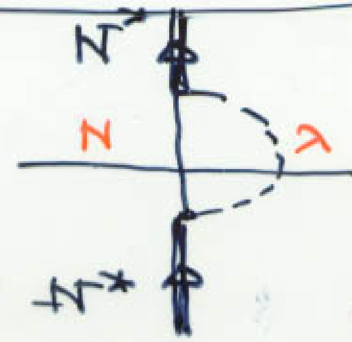
$\downarrow$ finite + analytical!

Summation: Natural coefficients $\leftrightarrow$ Padé

$F(s,t,u)$

$q\bar{q}$ - admixture in N^*; Roper

N^* continuum:



$\sim \dfrac{1}{(E_N+\omega_\lambda-E_{N^*})}$

↓

Large!

Fock space expansion:

Thresholds!

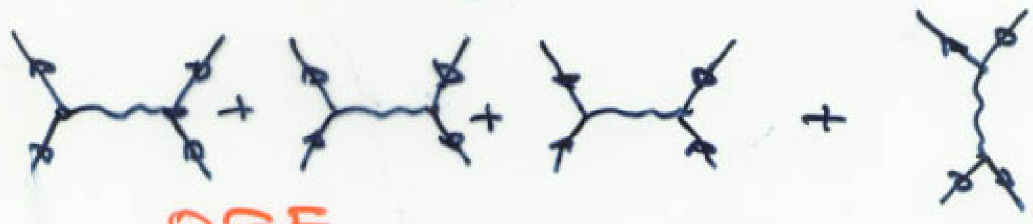
$$|N^*\rangle = \sum_{n\geq 0} \alpha_n \,|(qqq)(q\bar{q})^n\rangle$$

Perturbative evaluation ?

Nonperturbative resonating group N, Δ

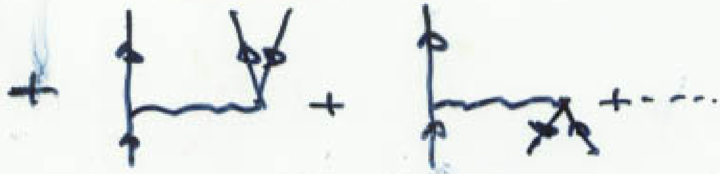
$$\delta\langle\psi_B|H-E|\psi_B\rangle = 0$$

↓



annihilation

OGE



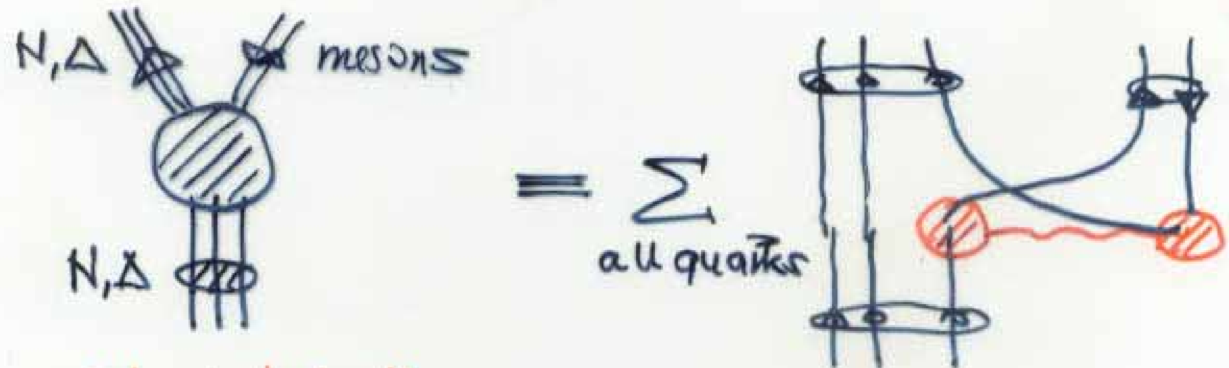
+ Harmonic conf. !

+ $E=\sqrt{q^2+m_q^2}$

No R.G. calculation in continuum:

↓

Effective 1-loop approximation with regularized vertices:



–Nonperturbative

↓

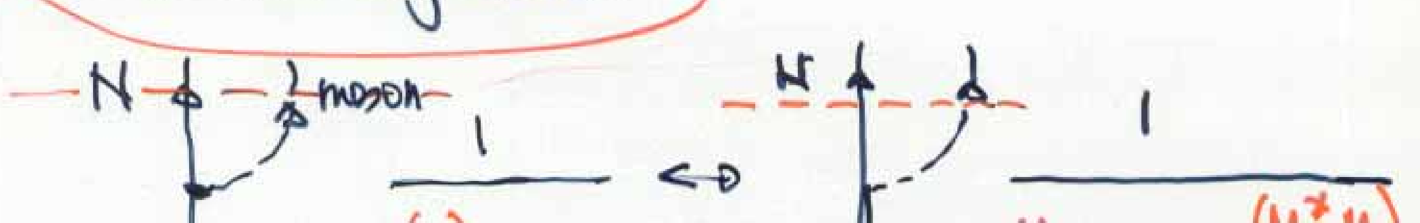
$$\text{Eff. coupling, FF} = \frac{\Lambda^2}{\Lambda^2+q^2}$$

↓

$$|N^*\rangle_{\text{continuum}} = |qqq\rangle_{QM} + |(qqq)_B\,(q\bar{q})_{\text{meson}}\rangle$$

(+ higher order $(q\bar{q})$)

Difference to g. state:



Scalar(σ) content of Roper:

$$|R\rangle \sim \alpha|qqq_{2s}\rangle + \beta|(qqq)_N (q\bar{q})_\sigma\rangle$$

Just for idea: $\sigma \equiv q\bar{q}$

$$|\sigma\rangle \sim \phi_\sigma(r)\left[Y_1(\hat{r})\left[\tfrac{1}{2}\tfrac{1}{2}\right]^1\right]^{00}$$

p-wave!

$(q\bar{q})$-pair creation:

Instanton, G-exchange, $^3P_0$:  $\equiv \underline{\sigma}\,\underline{\nabla}\, f(r)$

Pseudoscalar

$$\sim \left[Y_1(\hat{r})\,\sigma\right]^{00}$$

ME:

$$\beta \sim \left\langle N\left[\tfrac{1}{2}\tfrac{1}{2}\tfrac{1}{2}\right]^{1/2} \sigma \left[Y_1(\hat{r})\left[\tfrac{1}{2}\tfrac{1}{2}\right]^1\right]^{00} \middle| \left[Y_1(\hat{r})\underline{\sigma}\right]^{00} \middle| R\left[\tfrac{1}{2}\tfrac{1}{2}\tfrac{1}{2}\right]^{1/2}\right\rangle$$

Zero range limit:

Instanton size ~ 0.3 fm

Effective gluon ~ 700 MeV → $[Y_1 \underline{\sigma}]\,\delta(\underline{r}_1 - \underline{r}_2)$

~ 0.3 fm

↓

- Angular momentum matching:

$$[Y_1[\tfrac{1}{2}\tfrac{1}{2}]^1]^0_\sigma \; [Y_1 \sigma]^0_\phi \sim \begin{bmatrix}1 & 1 & 0\\ 1 & 1 & 0\\ 0 & 0 & 0\end{bmatrix} Y_0[[\tfrac{1}{2}\tfrac{1}{2}]^1 \sigma]^0$$

↓ $\times \begin{pmatrix}1 & 1 & 0\\ 0 & 0 & 0\end{pmatrix}$ parity check

Selection rule for S-state baryons!

Scalar content large!

↓

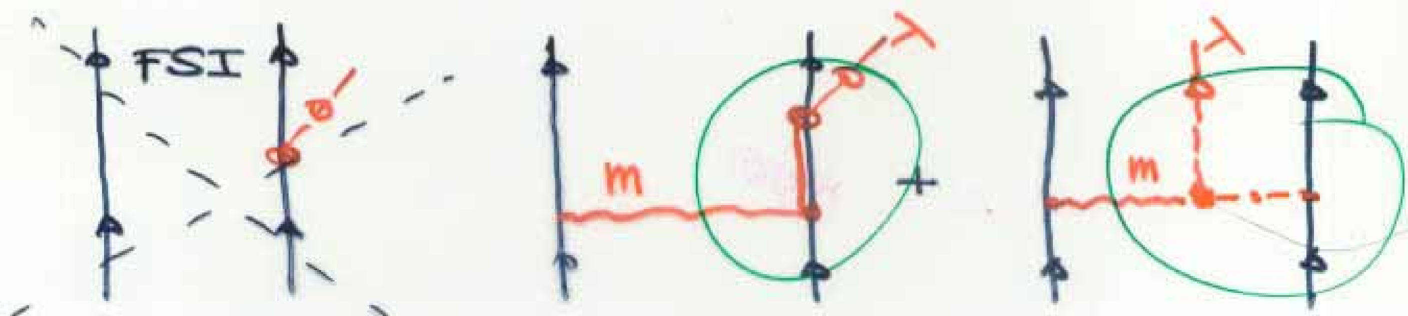
Coupled channel: 

$$\left(H_{Roper} - E - \frac{|V_{R\to N\sigma}|^2}{H_{N\sigma} - E}\right)|R\rangle = 0$$

Exclusive Mesonproduction; qq, $q\bar{q}$ interaction

N^*: Exclusive Mesonproduction

Meson ex. models:



no momentum sharing: small

$NN \to NN\lambda \leftrightarrow mN \to N\lambda$

COSY CELSIUS	$\leftrightarrow$	MAMI ELSA JLAB ⋮

$\updownarrow$

Quark models:

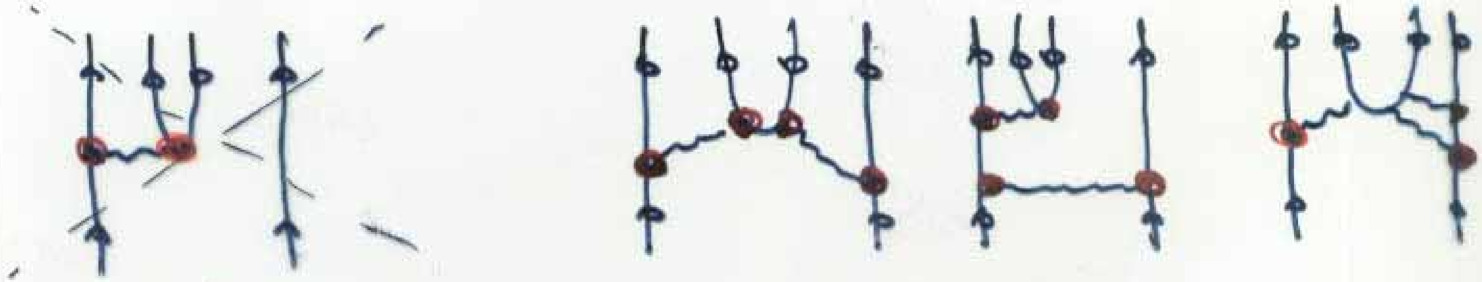
$q\bar{q}$ creation: $^3P_0$, Instanton

$qq \to qq(q\bar{q})$

6 q interaction

Gluon exchange: modelling MEC + N^*

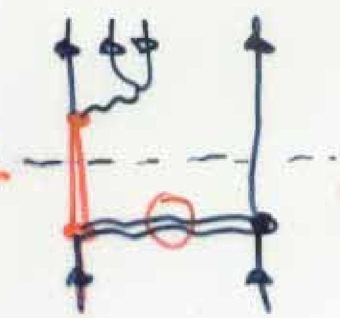
Expansion in eff. c.c α^n



α^1 α^2 α^3

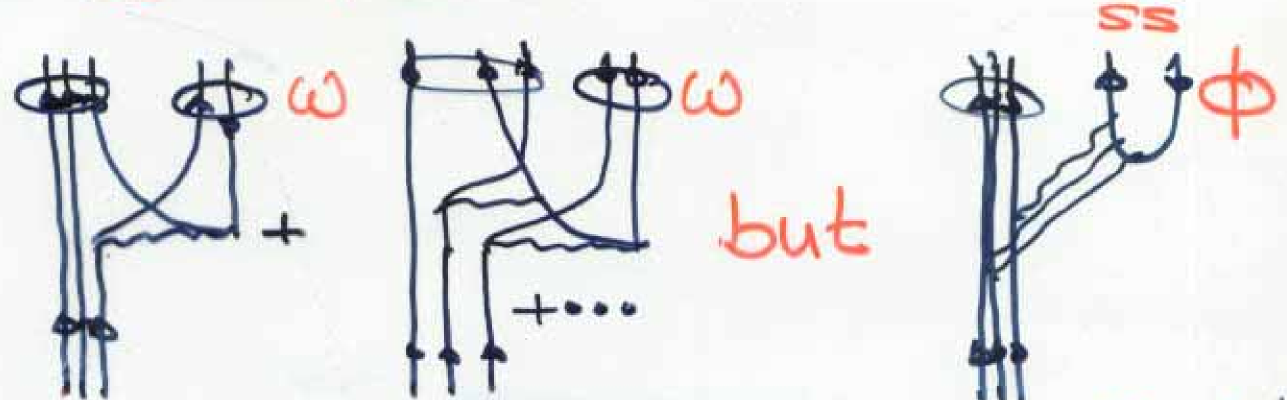
OGE

no sharing, small + momentum sharing



\+ N^* excitation   colourless 2GE "Pomeron"

\+ $\omega \leftrightarrow \phi(s\bar{s})$



OGE   2GE + 3GE   3GE only!

Lebed ← N_c ↔ OZI

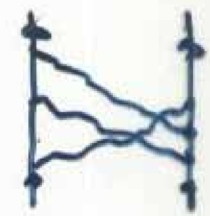
$\Longrightarrow$ $q\bar{q}$, qq interaction:

↳ Bernhard, Jleras, Capstick

↓

Expansion irreducible kernel: Mike

q $\bar{q}$ α^1 ⊕ α^2 ⊕ . α^3

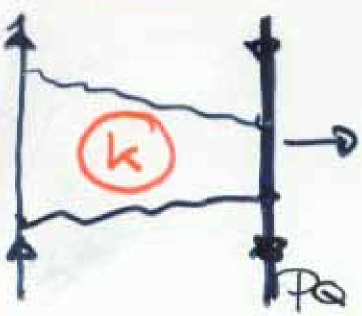


Selected set! ⊕ . . .

$\sum$ all orders!

Example: $q_{\text{light}}\,\bar{Q}_{\text{heavy}}$ $(u\bar{s}, u\bar{c}, u\bar{b}, \ldots)$

α^2



Heavy q onshell for $m_Q \to \infty$:

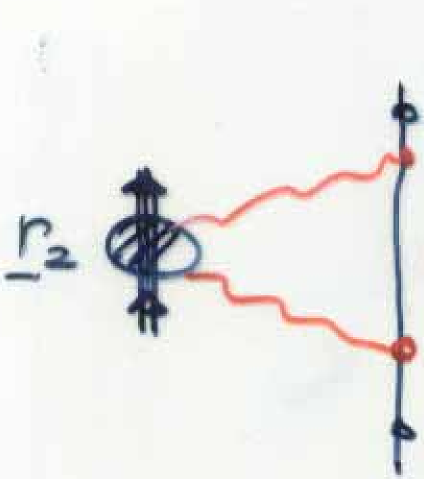
$$\frac{1}{(p_Q+k)^2 - m_Q^2 + i\epsilon} \to -i\pi\,\delta\left((p_Q+k)^2 - m_Q^2\right)$$

↓

$$-i\pi\,\delta\left(k_0 - \varepsilon_{\text{[illegible]}}\right)$$

⇒ Static "spin less" heavy quark

→ HQETh



$\longrightarrow V_{OGE}(\underline{r}_1' - \underline{r}_2)$

m_q -- $V_{2GE} \Longrightarrow \cdot \dfrac{e^{-m_q|\underline{r}_1'-\underline{r}_1|}}{|\underline{r}_1-\underline{r}_1'|}$

$\underline{r}_1 \longrightarrow \cdot V_{OGE}(\underline{r}_1-\underline{r}_2)$

Nonlocal: light q propagates!

$\lambda_{\text{Nonlocal}} \sim \frac{1}{m_q} \sim 0.5\,\text{fm}$

Localize:

$$\int \frac{dq}{q^2+m_q^2}\, e^{iq(\underline{r}_1-\underline{r}_1')} \simeq \frac{\delta(\underline{r}_1-\underline{r}_1')}{m_{q\,\text{eff}}^2}$$

$$V_{\text{many gluon}} = C_1 V_{OGE} - C_2 \frac{V_{OGE}^2}{m_{\text{eff}}} + C_3 \frac{V_{OGE}^3}{m_{\text{eff}}} - + \cdots$$

$$\simeq V_{OGE} \sum_n C_n (-1)^n \left(\frac{V_{OGE}}{m_{\text{eff}}}\right)^n$$

Colour coefficients

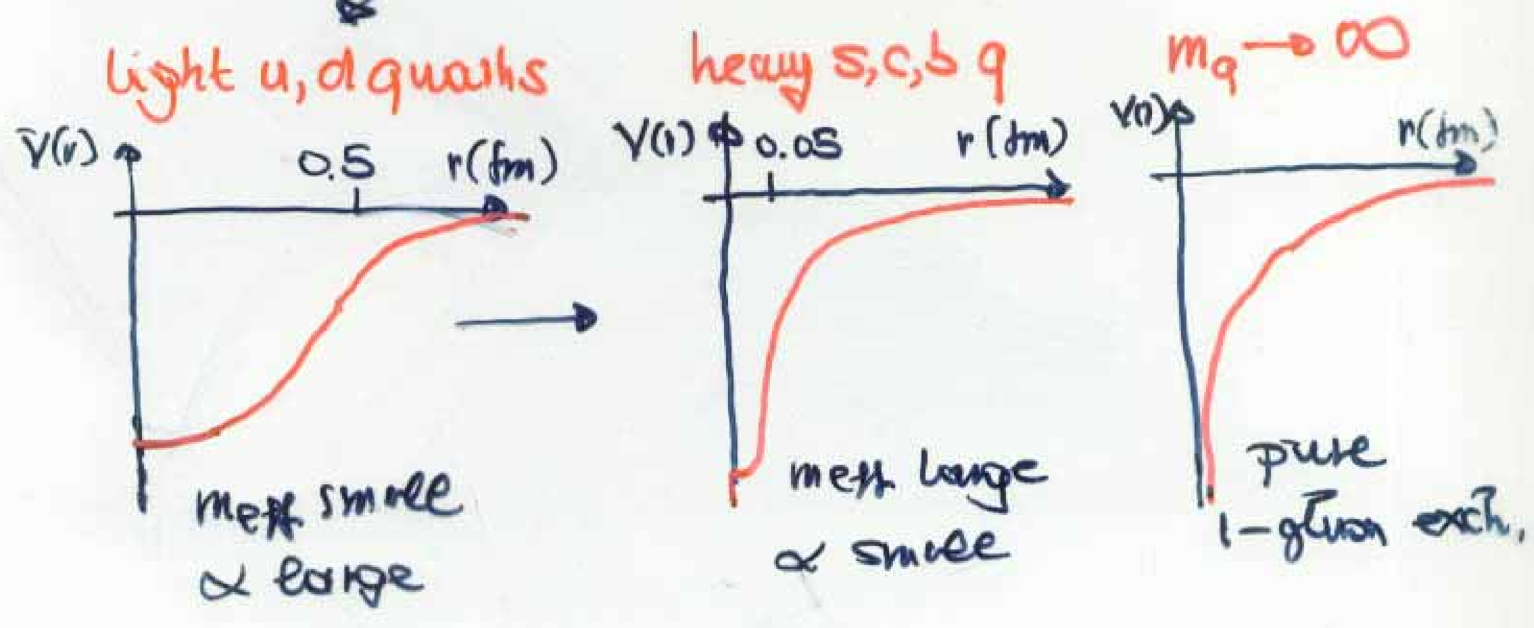
natural : $c_n \simeq N_c^n \sim 3^n$

$\downarrow$

Summation of series :

$$V_{\text{multi-gluon}} \simeq \frac{V_{OGE}}{1 + N_c\left(\frac{V_{OGE}}{m_{eff}}\right)}$$

↳ Form factor for OGE !



→ Interpolation

→ improve kernel !