Baryon octet and decuplet phenomenology from an extended linear sigma model

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Zimányi school, 02-06 December 2013, Budapest

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Motivation

Our ultimate goal: finite temperature/chemical potential investigations $\longrightarrow$ determine the position of the chiral phase boundary in the $T - \mu_B$ plane / determine existence of the CEP in

- an effective model based on global symmetries of QCD
- with all the lightest multiplets (scalar, pseudoscalar, vector, axialvector, baryon octet, baryon decuplet) to give a good approximation

At first $\longrightarrow$ need to describe the zero temperature spectrum as good as possible
$\longrightarrow$ through the parametrization of the model

included particles:

- scalars, pseudoscalars (2 nonets, 18 particles)
- vectors, axialvectors (2 nonets, 18 particles)
- octet baryons, decuplet baryons (1 octet, 1 decuplet; 18 particles)

Chiral symmetry

If the quark masses are zero (chiral limit) $\Longrightarrow$ QCD invariant under the following global transformation (chiral symmetry):

$$U(3)_L \times U(3)_R \simeq U(3)_V \times U(3)_A = SU(3)_V \times SU(3)_A \times U(1)_V \times U(1)_A$$

$U(1)_V$ term $\longrightarrow$ baryon number conservation

$U(1)_A$ term $\longrightarrow$ broken through axial anomaly

$SU(3)_A$ term $\longrightarrow$ broken down by any quark mass

$SU(3)_V$ term $\longrightarrow$ broken down to $SU(2)_V$ if $m_u = m_d \neq m_s$ (isospin symmetry)
$\longrightarrow$ totally broken if $m_u \neq m_d \neq m_s$ (realized in nature)

Since QCD is very hard to solve $\longrightarrow$ low energy effective models can be set up $\longrightarrow$ reflecting the global symmetries of QCD $\longrightarrow$ degrees of freedom: observable particles instead of quarks and gluons

Linear realization of the symmetry $\longrightarrow$ linear sigma model
(nonlinear representation $\longrightarrow$ chiral perturbation theory (ChPT))

Extended linear sigma model (meson part)

(based on: chiral symmetry)

$$\mathcal{L}_{\text{ext}} = \text{Tr}[(D_\mu\Phi)^\dagger(D_\mu\Phi)] - m_0^2\text{Tr}(\Phi^\dagger\Phi) - \lambda_1[\text{Tr}(\Phi^\dagger\Phi)]^2 - \lambda_2\text{Tr}(\Phi^\dagger\Phi)^2$$

$$- \frac{1}{4}\text{Tr}(L_{\mu\nu}^2 + R_{\mu\nu}^2) + \text{Tr}\left[\left(\frac{m_1^2}{2} + \Delta\right)(L_\mu^2 + R_\mu^2)\right] + \text{Tr}[\hat{\epsilon}(\Phi + \Phi^\dagger)]$$

$$+ c_1(\det\Phi - \det\Phi^\dagger)^2 + i\frac{g_2}{2}(\text{Tr}\{L_{\mu\nu}[L^\mu, L^\nu]\} + \text{Tr}\{R_{\mu\nu}[R^\mu, R^\nu]\})$$

$$+ \frac{h_1}{2}\text{Tr}(\Phi^\dagger\Phi)\text{Tr}(L_\mu^2 + R_\mu^2) + h_2\text{Tr}[(L_\mu\Phi)^2 + (\Phi R_\mu)^2] + 2h_3\text{Tr}(L_\mu\Phi R^\mu\Phi^\dagger).$$

$$+ g_3[\text{Tr}(L_\mu L_\nu L^\mu L^\nu) + \text{Tr}(R_\mu R_\nu R^\mu R^\nu)] + g_4[\text{Tr}(L_\mu L^\mu L_\nu L^\nu) + \text{Tr}(R_\mu R^\mu R_\nu R^\nu)]$$

$$+ g_5\text{Tr}(L_\mu L^\mu)\,\text{Tr}(R_\nu R^\nu) + g_6[\text{Tr}(L_\mu L^\mu)\,\text{Tr}(L_\nu L^\nu) + \text{Tr}(R_\mu R^\mu)\,\text{Tr}(R_\nu R^\nu)]$$

$$+ \mathcal{L}_{\text{baryon}},$$

Pseudoscalar- and scalarmeson nonets

$$\Phi_{PS} = \sum_{i=0}^{8} \pi_i T_i = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\eta_N+\pi^0}{\sqrt{2}} & \pi^+ & K^+ \\ \pi^- & \frac{\eta_N-\pi^0}{\sqrt{2}} & K^0 \\ K^- & \bar{K}^0 & \eta_S \end{pmatrix} \quad (\sim \bar{q}_i \gamma_5 q_j)$$

$$\Phi_{S} = \sum_{i=0}^{8} \sigma_i T_i = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\sigma_N+a_0^0}{\sqrt{2}} & a_0^+ & K_S^+ \\ a_0^- & \frac{\sigma_N-a_0^0}{\sqrt{2}} & K_S^0 \\ K_S^- & \bar{K}_S^0 & \sigma_S \end{pmatrix} \quad (\sim \bar{q}_i q_j)$$

Particle content:

Pseudoscalars: $\pi(138), K(495), \eta(548), \eta'(958)$

Scalars: $a_0(980 \text{ or } 1450), K_0^\star(800 \text{ or } 1430)$,

$(\sigma_N, \sigma_S) : 2 \text{ of } f_0(500, 980, 1370, 1500, 1710)$

Vector- and axialvectormeson nonets

$$V^\mu = \sum_{i=0}^{8} \rho_i^\mu T_i = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{\omega_N + \rho^0}{\sqrt{2}} & \rho^+ & K^{\star +} \\ \rho^- & \frac{\omega_N - \rho^0}{\sqrt{2}} & K^{\star 0} \\ K^{\star -} & \bar{K}^{\star 0} & \omega_S \end{pmatrix}^\mu$$

$$A_V^\mu = \sum_{i=0}^{8} b_i^\mu T_i = \frac{1}{\sqrt{2}} \begin{pmatrix} \frac{f_{1N} + a_1^0}{\sqrt{2}} & a_1^+ & K_1^+ \\ a_1^- & \frac{f_{1N} - a_1^0}{\sqrt{2}} & K_1^0 \\ K_1^- & \bar{K}_1^0 & f_{1S} \end{pmatrix}^\mu$$

Particle content:
Vector mesons: $\rho(770), K^\star(892), \omega_N = \omega(782), \omega_S = \phi(1020)$
Axial vectors: $a_1(1230), K_1(1270), f_{1N}(1280), f_{1S}(1426)$

Extended linear sigma model (baryon part)

$$
\begin{aligned}
\mathcal{L}_{\text{baryon}} &= \text{Tr}\left[\bar{B}\left(i\not{D} - M_{(8)}\right) B\right] \\
&- \text{Tr}\left\{\bar{\Delta}_\mu\left[\left(i\not{D} - M_{(10)}\right) g^{\mu\nu} - i\left(\gamma^\mu D^\nu + \gamma^\nu D^\mu\right)\gamma^\mu\left(i\not{D} + M_{(10)}\right)\gamma^\nu\right]\Delta_\nu\right\} \\
&+ C\text{Tr}\left[\bar{\Delta}^\mu \cdot \left(-\frac{1}{f}(\partial_\mu - ieA^e_\mu[T_3,\Phi]) - \frac{g_1}{f}[\Phi, V_\mu] + g_1 A_\mu\right) B\right] + \text{h. c.} \\
&- \xi_1 \text{Tr}\left(\bar{B}B\right)\text{Tr}\left(\Phi^\dagger\Phi\right) - \xi_2\text{Tr}\left(\bar{B}\{\{\Phi,\Phi^\dagger\},B\}\right) - \xi_3\text{Tr}\left(\bar{B}[\{\Phi,\Phi^\dagger\},B]\right) \\
&- \xi_4\left(\text{Tr}\left(\bar{B}\Phi\right)\text{Tr}\left(\Phi^\dagger B\right) + \text{Tr}\left(\bar{B}\Phi^\dagger\right)\text{Tr}\left(\Phi B\right)\right) - \xi_5\text{Tr}\left(\bar{B}\{[\Phi,\Phi^\dagger],B\}\right) \\
&- \xi_6\text{Tr}\left(\bar{B}[[\Phi,\Phi^\dagger],B]\right) - \xi_7\left(\text{Tr}\left(\bar{B}\Phi\right)\text{Tr}\left(\Phi^\dagger B\right) - \text{Tr}\left(\bar{B}\Phi^\dagger\right)\text{Tr}\left(\Phi B\right)\right) \\
&- \xi_8\left(\text{Tr}\left(\bar{B}\Phi B\Phi^\dagger\right) - \text{Tr}\left(\bar{B}\Phi^\dagger B\Phi\right)\right) + \chi_1\text{Tr}\left(\bar{\Delta}\cdot\Delta\right)\text{Tr}\left(\Phi^\dagger\Phi\right) \\
&+ \chi_2\text{Tr}\left((\bar{\Delta}\cdot\Delta)\{\Phi,\Phi^\dagger\}\right) + \chi_3\text{Tr}\left((\bar{\Delta}\cdot\Phi)(\Phi^\dagger\cdot\Delta) + (\bar{\Delta}\cdot\Phi^\dagger)(\Phi\cdot\Delta)\right) \\
&+ \chi_4\text{Tr}\left((\bar{\Delta}\cdot\Delta)[\Phi,\Phi^\dagger]\right)
\end{aligned}
$$

note: meson-baryon interaction terms based on every possible invariants which contains $2\ B$ (or $2\ \Delta$) and $2\ \Phi$ fields $\longrightarrow$ only blue terms contribute to the masses

Baryon octet, decuplet

$$B = \sqrt{2}\sum_{i=0}^{8} b_a T_a = \begin{pmatrix} \frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & \Sigma^+ & p \\ \Sigma^- & -\frac{1}{\sqrt{2}}\Sigma^0 + \frac{1}{\sqrt{6}}\Lambda^0 & n \\ -\Xi^- & \Xi^0 & -\frac{2}{\sqrt{2}}\Lambda^0 \end{pmatrix}$$

$$\Delta_\mu^{111} = \Delta_\mu^{++}, \quad \Delta_\mu^{112} = \frac{1}{\sqrt{3}}\Delta_\mu^{+}, \quad \Delta_\mu^{122} = \frac{1}{\sqrt{3}}\Delta_\mu^{0}, \quad \Delta_\mu^{222} = \Delta_\mu^{-},$$

$$\Delta_\mu^{113} = \frac{1}{\sqrt{3}}\Sigma_\mu^{\star +}, \quad \Delta_\mu^{123} = \frac{1}{\sqrt{6}}\Sigma_\mu^{\star 0}, \quad \Delta_\mu^{223} = \frac{1}{\sqrt{3}}\Sigma_\mu^{\star -},$$

$$\Delta_\mu^{133} = \frac{1}{\sqrt{3}}\Xi_\mu^{\star 0}, \quad \Delta_\mu^{233} = \frac{1}{\sqrt{3}}\Xi_\mu^{\star -},$$

$$\Delta_\mu^{333} = \Omega_\mu^{-}$$

Particle content:
Octet baryons: $p/n(938), \Sigma(1193), \Xi(1315), \Lambda(1116)$
Decuplet baryons: $\Delta(1232), \Sigma^\star(1385), \Xi^\star(1530), \Omega(1672)$

Spontaneous symmetry breaking and particle mixing

SSB $\longrightarrow$ through Higgs mechanism generates particle masses $\longrightarrow$ since vacuum has zero quantum numbers $\longrightarrow$ only $\sigma_0, \sigma_8, \sigma_3$ (equivalently $\sigma_N, \sigma_S, \sigma_3$) can have non-zero vev ($\sigma_3 \longrightarrow$ isospin violation $\longrightarrow$ neglected)

shifting with vev in the Lagrangian: $\sigma_i \to \sigma_i + \phi_i$ ($\longrightarrow$ mass generation)

Technical dificulty:

- For (pseudo)scalars this shifting results in particle mixing in the $N - S$ sector $\longrightarrow \sigma_N/\pi_N, \sigma_S/\pi_S$ fields are not mass eigenstates $\longrightarrow$ orthogonal transformations needed to resolve

- For (axial)vectors $\longrightarrow$ mixing between different nonets $\longrightarrow$ resolved by certain field shiftings $\longrightarrow$ results in: field renormalization constants

For baryons there is no mixing

Tree-level meson masses

Pseudoscalar mass squares:

$$m_\pi^2 = Z_\pi^2 \left[m_0^2 + \Lambda_N \Phi_N^2 + \lambda_1 \Phi_S^2\right]$$

$$m_K^2 = Z_K^2 \left[m_0^2 + \Lambda_N \Phi_N^2 - \frac{\lambda_2}{\sqrt{2}} \Phi_N \Phi_S + \Lambda_S \Phi_S^2\right]$$

$$m_{\eta_N}^2 = Z_\pi^2 \left[m_0^2 + \Lambda_N \Phi_N^2 + \lambda_1 \Phi_S^2 + c_1 \, \Phi_N^2 \Phi_S^2\right]$$

$$m_{\eta_S}^2 = Z_{\eta_S}^2 \left[m_0^2 + \lambda_1 \Phi_N^2 + \Lambda_s \Phi_S^2 + \frac{c_1}{4} \Phi_N^4\right]$$

$$m_{\eta_{NS}}^2 = Z_\pi Z_{\pi_S} \frac{c_1}{2} \Phi_N^3 \Phi_S$$

Scalar mass squares:

$$m_{a_0}^2 = m_0^2 + \Lambda'_N \Phi_N^2 + \lambda_1 \Phi_S^2$$

$$m_{K_S}^2 = Z_{K_S}^2 \left[m_0^2 + \Lambda_N \Phi_N^2 + \frac{\lambda_2}{\sqrt{2}} \Phi_N \Phi_S + \Lambda_S \Phi_S^2\right]$$

$$m_{\sigma_N}^2 = m_0^2 + 3\Lambda_N \Phi_N^2 + \lambda_1 \Phi_S^2$$

$$m_{\sigma_S}^2 = m_0^2 + \lambda_1 \Phi_N^2 + 3\Lambda_s \Phi_S^2$$

$$m_{\sigma_{NS}}^2 = 2\lambda_1 \Phi_N \Phi_S$$

Mass square eigenvalues for σ and π in the $N-S$ sector

$$m^2_{f_0^H/f_0^L} = \frac{1}{2}\left[m^2_{\sigma_N} + m^2_{\sigma_S} \pm \sqrt{(m^2_{\sigma_N} - m^2_{\sigma_S})^2 + 4m^2_{\sigma_{NS}}}\right]$$

$$m^2_{\eta'/\eta} = \frac{1}{2}\left[m^2_{\eta_N} + m^2_{\eta_S} \pm \sqrt{(m^2_{\eta_N} - m^2_{\eta_S})^2 + 4m^2_{\eta_{NS}}}\right]$$

Vector mass squares:

$$m^2_\rho = m^2_1 + \frac{1}{2}(h_1 + h_2 + h_3)\Phi^2_N + \frac{h_1}{2}\Phi^2_S + 2\delta_N$$

$$m^2_{K^\star} = m^2_1 + H_N\Phi^2_N + \frac{1}{\sqrt{2}}\Phi_N\Phi_S(h_3 - g^2_1) + H_S\Phi^2_S + \delta_N + \delta_S$$

$$m^2_{\omega_N} = m^2_\rho$$

$$m^2_{\omega_S} = m^2_1 + \frac{h_1}{2}\Phi^2_N + \left(\frac{h_1}{2} + h_2 + h_3\right)\Phi^2_S + 2\delta_S$$

Axialvector meson mass squares:

$$m^2_{a_1} = m^2_1 + \frac{1}{2}(2g^2_1 + h_1 + h_2 - h_3)\Phi^2_N + \frac{h_1}{2}\Phi^2_S + 2\delta_N$$

$$m^2_{K_1} = m^2_1 + H_N\Phi^2_N - \frac{1}{\sqrt{2}}\Phi_N\Phi_S(h_3 - g^2_1) + H_S\Phi^2_S + \delta_N + \delta_S$$

$$m^2_{f_{1N}} = m^2_{a_1}$$

$$m^2_{f_{1S}} = m^2_1 + \frac{h_1}{2}\Phi^2_N + \left(2g^2_1 + \frac{h_1}{2} + h_2 - h_3\right)\Phi^2_S + 2\delta_S$$

Tree-level baryon masses

Octet masses:

$$m_p = m_n = \frac{1}{2}\xi_1(\Phi_N^2 + \Phi_S^2) + \frac{1}{2}\xi_2(\Phi_N^2 + 2\Phi_S^2) + \frac{1}{2}\xi_3(\Phi_N^2 - 2\Phi_S^2)$$

$$m_\Xi = \frac{1}{2}\xi_1(\Phi_N^2 + \Phi_S^2) + \frac{1}{2}\xi_2(\Phi_N^2 + 2\Phi_S^2) - \frac{1}{2}\xi_3(\Phi_N^2 - 2\Phi_S^2)$$

$$m_\Sigma = \frac{1}{2}\xi_1(\Phi_N^2 + \Phi_S^2) + \xi_2\Phi_N^2$$

$$m_\Lambda = \frac{1}{2}\xi_1(\Phi_N^2 + \Phi_S^2) + \frac{1}{3}\xi_2(\Phi_N^2 + 4\Phi_S^2) + \frac{1}{3}\xi_4(\Phi_N - \sqrt{2}\Phi_S)^2$$

Decuplet masses:

$$m_\Delta = \frac{1}{2}\chi_1(\Phi_N^2 + \Phi_S^2) + \frac{1}{2}\chi_2\Phi_N^2$$

$$m_{\Sigma^\star} = \left(\frac{1}{2}\chi_1 + \frac{1}{3}\chi_2\right)(\Phi_N^2 + \Phi_S^2) + \frac{1}{6}\chi_3(\Phi_N - \sqrt{2}\Phi_S)^2$$

$$m_{\Xi^\star} = \frac{1}{2}\chi_1(\Phi_N^2 + \Phi_S^2) + \frac{1}{6}\chi_2(\Phi_N^2 + 4\Phi_S^2) + \frac{1}{6}\chi_3(\Phi_N - \sqrt{2}\Phi_S)^2$$

$$m_\Omega = \frac{1}{2}\chi_1(\Phi_N^2 + \Phi_S^2) + \chi_2\Phi_N^2$$

Decay widths

For a $A \to BC$ decay process the decay with is:

$$\Gamma_{A\to BC} = \frac{k_A}{8\pi m_A^2} |\mathcal{M}_{A\to BC}|^2$$

$k_A \longrightarrow$ three momentum of the produced particles in the rest frame of A
$\mathcal{M}_{A\to BC} \longrightarrow$ transition matrix element

- If A vectormeson and $C = B^\dagger$ (pseudo)scalarmeson:

$$|\mathcal{M}_{A\to BB^\dagger}|^2 = \tfrac{4}{3} k_A^2 V_\mu V^{\mu\star}$$

$V_\mu \longrightarrow$ vertex function directly followed from the three-coupling terms of $\mathcal{L}$

- If A vectormeson, B scalarmeson and $C = \gamma$ (photon):

$$|\mathcal{M}_{A\to B\gamma}|^2 = \tfrac{1}{3} \left(g^{\alpha\beta} - \frac{k_A^\alpha k_A^\beta}{m_A^2} \right) V_{\alpha\alpha'} V_\beta^{\star\alpha'}$$

- If A vectorspinor B pseudoscalar and C spinor:

$$|\mathcal{M}_{A\to BC}|^2 = \tfrac{2}{3} |G|^2 k_A^2 m_A (m_C + E_C)$$

where the vertex function from the Lagrangian $V^\mu = iGk_B^\mu$

Some decay widths

- The $\rho \to \pi\pi$ decay width:

$$\Gamma_{\rho\to\pi\pi} = \frac{m_\rho^5}{48\pi m_{a_1}^4}\left[1-\left(\frac{2m_\pi}{m_\rho}\right)^2\right]^{3/2}\left[g_1 Z_\pi^2 - \frac{g_2}{2}\left(Z_\pi^2 - 1\right)\right]^2$$

The experimental value from the PDG: $\Gamma^{\text{(exp)}}_{\rho\to\pi\pi} = (149.1 \pm 0.8)$ MeV

- The $a_1 \to \pi\gamma$ decay width:

$$\Gamma_{a_1\to\pi\gamma} = \frac{e^2 g_1^2 \Phi_N^2}{96\pi m_{a_1}} Z_\pi^2 \left[1-\left(\frac{m_\pi}{m_{a_1}}\right)^2\right]^3$$

The experimental value: $\Gamma^{\text{(exp)}}_{a_1\to\pi\gamma} = (0.640 \pm 0.246)$ MeV

- The $\Delta \to \pi p$ decay width:

$$\Gamma_{\Delta\to\pi p} = \frac{k_\Delta^3}{24 m_\Delta}(m_p + E_p) C^2 Z_\pi^2 (\frac{1}{f^2} + g_1^2 w_{a_1}^2)$$

The experimental value: $\Gamma^{\text{(exp)}}_{\Delta\to\pi p} \approx 110$ MeV

Parametrization: general considerations

In order to make predictions $\longrightarrow$ unknown constants of the model must be determined

$\Longrightarrow$ choose a set of (well known) physical quantities/conditions for fitting procedure

For instance:

- PartiallyConservedAxialCurrent $\longrightarrow$ fix the condensates (2 parameter)
- Particle masses (which can be compared with PDG)
- Decay widths (which can be compared with PDG)

Finding a good parameter set $\longrightarrow$ non-trivial task (usually there are lots of solutions, but non of them is perfect)

The parameters are determined in several steps (mesons then baryons then global fit)

Parametrization

21 unknown parameters $\longrightarrow$ Determined by the minimalization of the χ^2:

$$\chi^2(x_1,\ldots,x_N) = \sum_{i=1}^{M} \left[\frac{Q_i(x_1,\ldots,x_N) - Q_i^{\text{exp}}}{\delta Q_i} \right]^2 ,$$

where $(x_1,\ldots,x_N) = (m_0,\lambda_1,\lambda_2,\ldots)$, $Q_i(x_1,\ldots,x_N)$ calculated from the model
Q_i^{exp} taken from the PDG δQ_i artificially increased to $5 \sim 10\%$

multiparametric minimalization $\longrightarrow$ MINUIT

- PCAC $\rightarrow$ 2 physical quantities: f_π, f_K
- Tree-level masses $\rightarrow$ 22 physical quantities:
  - mesons: m_π, m_η, $m_{\eta'}$, m_K, m_ρ, m_Φ, $m_{K^\star}$, m_{a_1}, $m_{f_1^H}$, m_{K_1}, m_{a_0}, m_{K_s}, $m_{f_0^L}$, $m_{f_0^H}$
  - baryons: m_p, m_Ξ, m_Σ, m_Λ, m_Δ, $m_{\Sigma^\star}$, $m_{\Xi^\star}$, m_Ω
- Decay widths $\rightarrow$ 16 physical quantities:
  - mesons: $\Gamma_{\rho\to\pi\pi}$, $\Gamma_{\Phi\to KK}$, $\Gamma_{K^\star\to K\pi}$, $\Gamma_{a_1\to\pi\gamma}$, $\Gamma_{a_1\to\rho\pi}$, $\Gamma_{f_1\to KK^\star}$, Γ_{a_0}, $\Gamma_{K_S\to K\pi}$, $\Gamma_{f_0^L\to\pi\pi}$, $\Gamma_{f_0^L\to KK}$, $\Gamma_{f_0^H\to\pi\pi}$, $\Gamma_{f_0^H\to KK}$
  - baryons: $\Gamma_{\Delta\to\pi p}$, $\Gamma_{\Sigma^\star\to\pi\Lambda}$, $\Gamma_{\Sigma^\star\to\pi\Sigma}$, $\Gamma_{\Xi^\star\to\pi\Xi}$

Results in the baryon sector

Observable	Fit [MeV]	χ^2	PDG [MeV]	error [MeV]
m_p	939.0	0.0	939.0	± 47.0
m_Λ	1116.0	0.0	1116.0	± 55.8
m_Σ	1193.0	0.0	1193.0	± 59.7
m_Ξ	1318.0	0.0	1318.0	± 65.9
m_Δ	1231.9	$5.0 \cdot 10^{-6}$	1232.0	± 61.6
$m_{\Sigma^\star}$	1385.5	$6.1 \cdot 10^{-5}$	1385.0	± 69.3
$m_{\Xi^\star}$	1532.3	$7.4 \cdot 10^{-5}$	1533.0	± 76.7
m_Ω	1672.3	$1.0 \cdot 10^{-5}$	1672.0	± 83.6
$\Gamma_{\Delta \to p\pi}$	67.3	15.1	110.0	± 11.0
$\Gamma_{\Sigma^\star \to \Lambda\pi}$	27.0	2.4	32.0	± 3.2
$\Gamma_{\Sigma^\star \to \Sigma\pi}$	4.9	2.0	4.3	± 0.4
$\Gamma_{\Xi^\star \to \Xi\pi}$	11.2	3.1	9.5	± 1.0

- 4 octet masses with 4 parameter $\longrightarrow$ perfect fit (not so surprising)
- 4 decuplet masses with 3 parameters $\longrightarrow$ perfect fit (more surprising)
- 4 decuplet decays with 1 parameter (their ratios are purely kinematical) $\longrightarrow$ acceptable fit

Summary

- Vacuum baryon phenomenology was presented within the framework of an extended linear sigma model with the lowest lying particle multiplets including scalars, pseudoscalars, vectors, axialvectors, octet baryons, and decuplet baryons

- We used multiparametric χ^2 minimalization for the determination of Lagrangian parameters

- In the baryon sector we see that the octet and decuplet masses can be described with extremely good precision, while the decuplet decay width with acceptable precision

- The establishment of the vacuum phenomenology gives a good background to future finite temperature/density investigations

for details see: Phys. Rev. D **87**, 014011 (2013) arXiv:1208.0585 [hep-ph]
and in preparation: arXiv:1311.5991 [hep-ph]