(Techni-)Skyrmion from Holographic Models

In honor of Prof. Yu-Ping Kuang's 80th birthday.

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Outline

I. Introduction

II. Lessons from QCD Skyrmion calculation

III. Techni-Skyrmion properties (from a holographic model)

I. Introduction

- In many EFTs for SCG theories, baryons could be described in a mesonic theories.

8.C

Nuclear Physics **31** (1962) 556—569; © *North-Holland Publishing Co., Amsterdam*

A UNIFIED FIELD THEORY OF MESONS AND BARYONS

T. H. R. SKYRME †

A.E.R.E., Harwell, England

Received 29 September 1961

Abstract: Some aspects of a field theory, similar to but more realistic than, that examined in the preceding paper are discussed. The way in which a non-linear meson field theory of this type may contain its own sources, and how these may be idealised to point singularities, as in the conventional field theories of interacting linear systems, is formulated. The structure of the particle source in the classical theory is calculated, and some qualitative features of the interactions between these particles and mesons are described.

Skyrme model

$$\mathcal{L}_{\rm Skyr} = \frac{F_\pi^2}{4}{\rm Tr}\left[\partial_\mu U \partial^\mu U^\dagger\right] + \frac{\epsilon^2}{4}{\rm Tr}\left\{\left[U^\dagger\partial_\mu U, U^\dagger\partial_\nu U\right]\left[U^\dagger\partial^\mu U, U^\dagger\partial^\nu U\right]\right\}$$

Nonlinear Sigma model

Skyrme term

Parameters: F_π ,

.

Many physical quantities of baryons can be calculated, agree with data quite well !

Table 2a

The low-energy parameters and masses as predicted in the Skyrme model, together with the MIT bag model results are compared to experiment. (A.N.W.) and (J.R.) are the predictions of ref. [21] and ref. [20] respectively, for $m_\pi = 0$. (A.N.) and (M.) are the results of ref. [22a] and ref. [22b] respectively, for $m_\pi \neq 0$

	A.N.W.	A.N.	J.R.	M.	MIT	Expt
$10^3\varepsilon^2$	4.21	5.34	5.52	5.13	–	–
f_π (MeV)	64.5	54.	93*	94.3*	149	93
g_A^N	1.02	1.08	1.33*	1.23*	1.09	1.23
M_N (MeV)	939*	939*	1425	1385	939*	939
$M_\Delta - M_N$ (MeV)	293*	293*	283	310	293*	293

Table 2b

Same comparative table as in (a) for the electric and magnetic mean square radii together with the proton and neutron magnetic moments

	A.N.W.	A.W.	J.R.	M.	MIT	Expt
$\langle r_E^2\rangle_0^{1/2}$ (fm)	0.59	0.68	0.47	0.43	0.76	0.72
$\langle r_E^2\rangle_1^{1/2}$ (fm)	∞	1.04	∞		0.76	0.88
$\langle r_M^2\rangle_0^{1/2}$ (fm)	0.92	0.95			0.62	0.81
$\langle r_M^2\rangle_1^{1/2}$ (fm)	∞	1.04	∞		0	0.80
μ_p (n.m.)	1.87	1.97	2.74	2.43	1.90	2.79
μ_n (n.m.)	−1.31	−1.24	−2.24	−1.98	−1.27	−1.91

- I. ZAHED and G.E. BROWN, Phys. Rept. 142, (1986) 1—102.

It's straight forward to expect that such an approach can also be used to study baryons in SCG in EW sector.

Nuclear Physics B241 (1984) 109–128

SKYRMIONS AND / IN THE WEAK INTERACTIONS*

Eric D'HOKER[†] and Edward FARHI

Center for Theoretical Physics, Laboratory of Nuclear Science and Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Received 8 February 1984

We consider the Skyrme model coupled to the weak interactions. Due to weak instantons, the ordinary skyrmion is unstable and decays into an anti-lepton and pions. We study the role of the Weinberg-Salam Higgs field in this process and also discuss the absence of vacuum tunneling. Next the Higgs field is regarded as the Goldstone boson field of an underlying chiral symmetry breaking theory, like technicolor, in which the Higgs field can be described by a Skyrme model. The skyrmions in the Higgs sector correspond to techni-baryons. These techni-skyrmions carry the fermion number of any fermion with a large mass generated by a Yukawa coupling. The decays of the ordinary and techni-skyrmions are examined in these cases. We show that these phenomena can be understood at the techni-quark level.

- Indications on the Mass of the Lightest Electroweak Baryon, John Ellis, Marek Karliner, Phys.Lett. **B713** (2012) 233-236.

- Generalized Skyrmions in QCD and the Electroweak Sector, John Ellis, Marek Karliner, Michal Praszalowicz, e-Print: **arXiv:1209.6430 [hep-ph]** .

$$\mathcal{L}_{\rm eff} = \mathcal{L}_2 + \mathcal{L}_4 ,$$

$$\mathcal{L}_2 = \frac{v^2}{4} \mathrm{Tr}\left(\partial_\mu U \partial^\mu U^\dagger\right)$$

$$\mathcal{L}_4 = 2s\,\mathrm{Tr}\left[(R_\mu R_\nu)(R^\mu R^\nu) - (R_\mu R^\mu)^2\right] + 2t\,\mathrm{Tr}\left[(R_\mu R_\nu)(R^\mu R^\nu) + (R_\mu R^\mu)^2\right]$$

Current upper bounds on the electroweak soliton mass range between 18 and 59 TeV, which would be reduced to 4.6 to 8.1 TeV with the likely sensitivity of LHC data to the fourth-order electroweak Lagrangian parameters.

What will happen when energy scale increases?

More resonances appear. ➡ More complicated model

E massive vector

mesons appear

Find redundancies in the chiral field and introduce associated gauge symmetry to capture the physics of vector mesons

The NL model is gauge-equivalent to HLS and the vector mesons so generated can be identified with the hidden local gauge fields.

To fix all the LECs, we resort to holographic models!

The effect of the heavier resonances on Skyrmion properties can be self-consistently calculated.

- *Skyrmions with vector mesons in the hidden local symmetry approach.*
  YM, G. –S. Yang, Y. Oh, M. Harada, e-Print: **arXiv:1209.3554 [hep-ph] .**
- *Hidden Local Symmetry and Infinite Tower of Vector Mesons for Baryons.*
  YM, Y. Oh, G.-S. Yang, M. Harada, H. K. Lee, B. –Y. Park, M. Rho
  Published in **Phys.Rev. D86 (2012) 074025**, e-Print: **arXiv:1206.5460 [hep-ph]**

II. Lessons from QCD for Skyrmion properties

- Skyrmion has been studied based on the $O(p^2)$ HLS (f , g, a). The HLS parameter a is normally taken to be 1 a 2.

$$M_{\rm sol} = (667 \sim 1575)\ \mathrm{MeV} \qquad 1 \le a \le 4$$

- The ambiguity in the value of a results in a large uncertainty on the soliton mass. And, the dependence of a on circumstances hinders systematic investigation on the properties of a single Skyrmion and baryonic matter.

- The description of baryons as Skyrmions is supported by the large N_c limit. In the HLS, the higher order terms such as the $O(p^4)$ terms are at $O(N_c)$ as well as the $O(p^2)$ terms. As a result, in the N_c counting, these higher order terms should be taken into account.

- However, including the higher order terms inevitably calls forth more complicated form of the Lagrangian and uncontrollably large number of low energy constants.

- By making use of the hQCD, we fix them in a controllable way. Furthermore, the meson is included through the hWZ terms whose parameters are also fixed by the hQCD.

Skyrmions from the Hidden Local Symmetry

Consider two flavor, to O(p^4)

$$\hat{\alpha}_{\parallel\mu} = \frac{1}{2i}\left(D_\mu \xi_R \xi_R^\dagger + D_\mu \xi_L \xi_L^\dagger\right)$$

$$\hat{\alpha}_{\perp\mu} = \frac{1}{2i}\left(D_\mu \xi_R \xi_R^\dagger - D_\mu \xi_L \xi_L^\dagger\right)$$

$$\xi_L^\dagger = \xi_R \equiv \xi = e^{i\pi/2f_\pi}$$

$$D_\mu \xi_{R,L} = (\partial_\mu - iV_\mu)\xi_{R,L}$$

$$V_\mu = \frac{g}{2}(\omega_\mu + \rho_\mu)$$

$$\mathcal{L}_{\rm HLS} = \mathcal{L}_{(2)} + \mathcal{L}_{(4)} + \mathcal{L}_{\rm anom}, - \mathcal{L}_{\rm anom},$$

$$\mathcal{L}_{(2)} = f_\pi^2 \,\mathrm{Tr}\,\left(\hat{\alpha}_{\perp\mu}\hat{\alpha}_\perp^\mu\right) + a f_\pi^2\,\mathrm{Tr}\,\left(\hat{\alpha}_{\parallel\mu}\hat{\alpha}_\parallel^\mu\right) - \frac{1}{2g^2}\mathrm{Tr}\,\left(V_{\mu\nu}V^{\mu\nu}\right)$$

$$\mathcal{L}_{(4)} = \mathcal{L}_{(4)y} + \mathcal{L}_{(4)z}$$

$$\begin{aligned}
\mathcal{L}_{(4)y} = {}& y_1 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_\perp^\mu\hat{\alpha}_{\perp\nu}\hat{\alpha}_\perp^\nu\right] + y_2 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_{\perp\nu}\hat{\alpha}_\perp^\mu\hat{\alpha}_\perp^\nu\right] + y_3 \mathrm{Tr}\left[\hat{\alpha}_{\parallel\mu}\hat{\alpha}_\parallel^\mu\hat{\alpha}_{\parallel\nu}\hat{\alpha}_\parallel^\nu\right] + y_4 \mathrm{Tr}\left[\hat{\alpha}_{\parallel\mu}\hat{\alpha}_{\parallel\nu}\hat{\alpha}_\parallel^\mu\hat{\alpha}_\parallel^\nu\right] \\
&+ y_5 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_\perp^\mu\hat{\alpha}_{\parallel\nu}\hat{\alpha}_\parallel^\nu\right] + y_6 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_{\perp\nu}\hat{\alpha}_\parallel^\mu\hat{\alpha}_\parallel^\nu\right] + y_7 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_{\perp\nu}\hat{\alpha}_\parallel^\nu\hat{\alpha}_\parallel^\mu\right] \\
&+ y_8 \left\{\mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_\parallel^\mu\hat{\alpha}_{\perp\nu}\hat{\alpha}_\parallel^\nu\right] + \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_{\parallel\nu}\hat{\alpha}_\perp^\nu\hat{\alpha}_\parallel^\mu\right]\right\} + y_9 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_{\parallel\nu}\hat{\alpha}_\perp^\mu\hat{\alpha}_\parallel^\nu\right],
\end{aligned}$$

$$\mathcal{L}_{(4)z} = iz_4 \mathrm{Tr}\left[V_{\mu\nu}\hat{\alpha}_\perp^\mu\hat{\alpha}_\perp^\nu\right] + iz_5 \mathrm{Tr}\left[V_{\mu\nu}\hat{\alpha}_\parallel^\mu\hat{\alpha}_\parallel^\nu\right].$$

$$\mathcal{L}_{\rm anom} = \frac{N_c}{16\pi^2}\sum_{i=1}^{3} c_i \mathcal{L}_i,$$

$$\mathcal{L}_1 = i\,\mathrm{Tr}\left[\hat{\alpha}_{\rm L}^3\hat{\alpha}_{\rm R} - \hat{\alpha}_{\rm R}^3\hat{\alpha}_{\rm L}\right],$$

$$\mathcal{L}_2 = i\,\mathrm{Tr}\left[\hat{\alpha}_{\rm L}\hat{\alpha}_{\rm R}\hat{\alpha}_{\rm L}\hat{\alpha}_{\rm R}\right],$$

$$\mathcal{L}_3 = \mathrm{Tr}\left[F_{\rm V}\left(\hat{\alpha}_{\rm L}\hat{\alpha}_{\rm R} - \hat{\alpha}_{\rm R}\hat{\alpha}_{\rm L}\right)\right],$$

Parameters (17):

f , g, a, y_1 y_9, z_4, z_5, c_1 c_3

- M. Harada and K. Yamawaki, Phys. Rep. 381, 1 (2003).

HLS from hQCD models

- M. Harada, S. Matsuzaki, and K. Yamawaki, Phys. Rev. D 82, 076010 (2010).

$$S_5 = S_5^{\rm DBI} + S_5^{\rm CS}$$

$$S_5^{\rm DBI} = N_c G_{\rm YM} \int d^4x dz \Big\{ -\frac{1}{2} K_1(z) {\rm Tr}\left[\mathcal{F}_{\mu\nu}\mathcal{F}^{\mu\nu}\right] + K_2(z) M_{KK}^2 {\rm Tr}\left[\mathcal{F}_{\mu z}\mathcal{F}^{\mu z}\right] \Big\},$$

$$S_5^{\rm CS} = \frac{N_c}{24\pi^2} \int_{M^4\times R} w_5(A)$$

$$w_5(A) = {\rm Tr}\left[\mathcal{A}\mathcal{F}^2 + \frac{i}{2}\mathcal{A}^3\mathcal{F} - \frac{1}{10}\mathcal{A}^5 \right]$$

A_z = 0 gauge

Mode expansion

$$A_\mu^{\rm integ}(x,z) = \hat{\alpha}_{\mu\perp}(x)\psi_0(z) + \left[\hat{\alpha}_{\mu\parallel}(x) + V_\mu(x)\right] + \hat{\alpha}_{\mu\parallel}(x)\psi_1(z),$$

$$-K_1(z)\partial_z\left[K_2(z)\partial_z\psi_n(z)\right] = \lambda_n \psi_n(z),$$

$$f_\pi^2 = N_c G_{\rm YM} M_{KK}^2 \int dz K_2(z) \left[\dot{\psi}_0(z)\right]^2,$$

$$a f_\pi^2 = N_c G_{\rm YM} M_{KK}^2 \lambda_1 \langle \psi_1^2 \rangle,$$

$$\frac{1}{g^2} = N_c G_{\rm YM} \langle \psi_1^2 \rangle,$$

$$y_1 = -y_2 = -N_c G_{\rm YM} \left\langle \left(1+\psi_1-\psi_0^2\right)^2 \right\rangle,$$

$$y_3 = -y_4 = -N_c G_{\rm YM} \left\langle \psi_1^2 \left(1+\psi_1\right)^2 \right\rangle,$$

$$y_5 = 2y_8 = -y_9 = -2N_c G_{\rm YM} \left\langle \psi_1^2 \psi_0^2 \right\rangle,$$

$$y_6 = -\left(y_5 + y_7\right),$$

$$y_7 = 2N_c G_{\rm YM} \left\langle \psi_1 \left(1+\psi_1\right)\left(1+\psi_1-\psi_0^2\right) \right\rangle,$$

$$z_4 = 2N_c G_{\rm YM} \left\langle \psi_1 \left(1+\psi_1-\psi_0^2\right) \right\rangle,$$

$$z_5 = -2N_c G_{\rm YM} \left\langle \psi_1^2 \left(1+\psi_1\right) \right\rangle,$$

$$c_1 = \left\langle\!\left\langle \dot{\psi}_0 \psi_1 \left(\frac{1}{2}\psi_0^2 + \frac{1}{6}\psi_1^2 - \frac{1}{2} \right) \right\rangle\!\right\rangle,$$

$$c_2 = \left\langle\!\left\langle \dot{\psi}_0 \psi_1 \left(-\frac{1}{2}\psi_0^2 + \frac{1}{6}\psi_1^2 + \frac{1}{2}\psi_1 + \frac{1}{2} \right) \right\rangle\!\right\rangle,$$

$$c_3 = \left\langle\!\left\langle \frac{1}{2}\dot{\psi}_0 \psi_1^2 \right\rangle\!\right\rangle,$$

16 parameters in terms of
2 parameters: $G_{\rm YM}$, $M_{\rm KK}$
Inputs: f , m .

- Physical quantities are parameter a independent.
- CS terms are responsible for the omega meson repulsive interaction.

Skyrme parameter from hQCD models

Original Skyrme model

$$\mathcal{L}_{\rm Sk} = \frac{f_\pi^2}{4}\mathrm{Tr}\left(\partial_\mu U \partial^\mu U^\dagger\right) + \frac{1}{32e^2}\mathrm{Tr}\left[\partial_\mu U U^\dagger, \partial_\nu U U^\dagger\right]^2$$

Integrate out all vector modes

$$\mathcal{L}_{\rm ChPT} = f_\pi^2 \mathrm{Tr}\left[\alpha_{\perp\mu}\alpha_\perp^\mu\right] + \left(\frac{1}{2g^2} - \frac{z_4}{2} - \frac{y_1 - y_2}{4}\right)\mathrm{Tr}\left[\alpha_{\perp\mu}, \alpha_{\perp\nu}\right]^2 + \frac{y_1 + y_2}{4}\mathrm{Tr}\left\{\alpha_{\perp\mu}, \alpha_{\perp\nu}\right\}^2 , \quad (5$$

$$\frac{1}{2e^2} = \frac{1}{2g^2} - \frac{z_4}{2} - \frac{y_1 - y_2}{4}$$

$$\frac{1}{2e^2} = \frac{N_c G_{\rm YM}}{2}\left\langle (1 - \psi_0^2)^2 \right\rangle$$

$$e \simeq 7.31$$

- Both values are larger than that used in the original Skyrme model because of the contributions from y1, y2, and z4 terms at O(p4).

Numerical results:

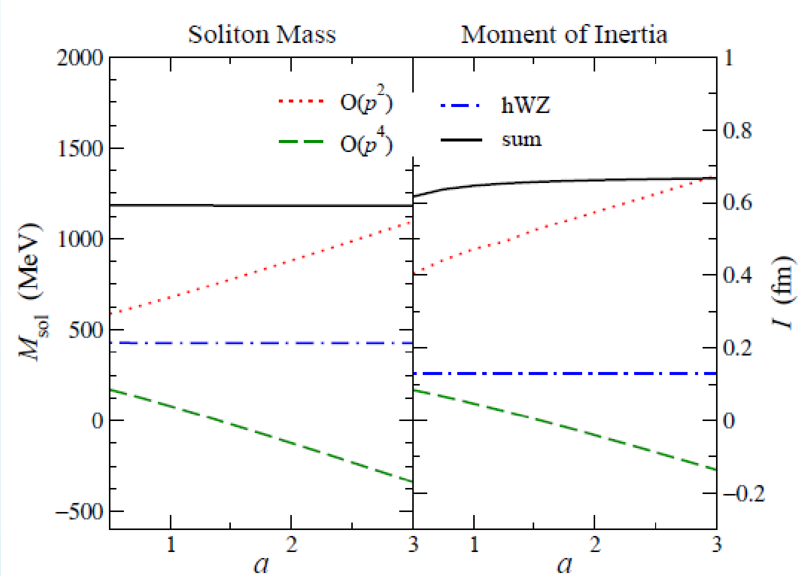
In hQCD models, the mass scale M_{KK} and the 't Hooft coupling G_{YM} are free parameters.

$$m_\rho = 775.49 \text{ MeV},$$
$$f_\pi = 92.4 \text{ MeV}.$$

Three versions of HLS:

1. HLS including , , .
2. HLS without hWZ.
3. Skyrme model from HLS

	HLS$_1(\pi,\rho,\omega)$	HLS$_1(\pi,\rho)$	HLS$_1(\pi)$
$M_{\rm sol}$	1184	834	922
Δ_M	448	1707	1014
$\sqrt{\langle r^2\rangle_W}$	0.433	0.247	0.309
$\sqrt{\langle r^2\rangle_E}$	0.608	0.371	0.417



- Lessons from nuclear physics indicates that, the omega meson brings repulsive interaction which prevents the nuclei from collapsing and the sigma meson brings attractive interaction and the near cancellation of the these to interactions gives the small binding energy of nuclear matter. Sigma meson is important!

Lessons:

- Scalar meson affects skyrmion properties. Skyrmion model including scalar, ~ -400 MeV.
  F. Meier, H. Walliser , ***Phys.Rept. 289 (1997) 383-450***

- Holographic models, a possible way to determine the LECs with few input.

IV. Techni-Skyrmion properties

Purpose:

- To investigate the effect of scalar resonance on Skyrmion properties.
- To investigate the Skyrmion properties using a holographic model for TC theories.

Warm-up:

$$
\begin{aligned}
\mathcal{L} &= \mathcal{L}_{\rm Sigma} + \mathcal{L}_{\sigma-\pi} + \mathcal{L}_{\rm Skyrme} \\
\mathcal{L}_{\rm Sigma} &= \frac{1}{2}\partial_\mu \sigma(x)\partial^\mu \sigma(x) - \frac{1}{2}m_\sigma^2 \sigma(x)^2 \\
\mathcal{L}_{\sigma-\pi} &= g_s \sigma(x) \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_\perp^\mu\right] \\
\mathcal{L}_{\rm Skyrme} &= f_\pi^2 \mathrm{Tr}\left[\hat{\alpha}_{\perp\mu}\hat{\alpha}_\perp^\mu\right] + \frac{1}{2e^2}\mathrm{Tr}\left[\left[\hat{\alpha}_{\perp\mu}, \hat{\alpha}_{\perp\nu}\right]\left[\hat{\alpha}_\perp^\mu, \hat{\alpha}_\perp^\nu\right]\right]
\end{aligned}
$$

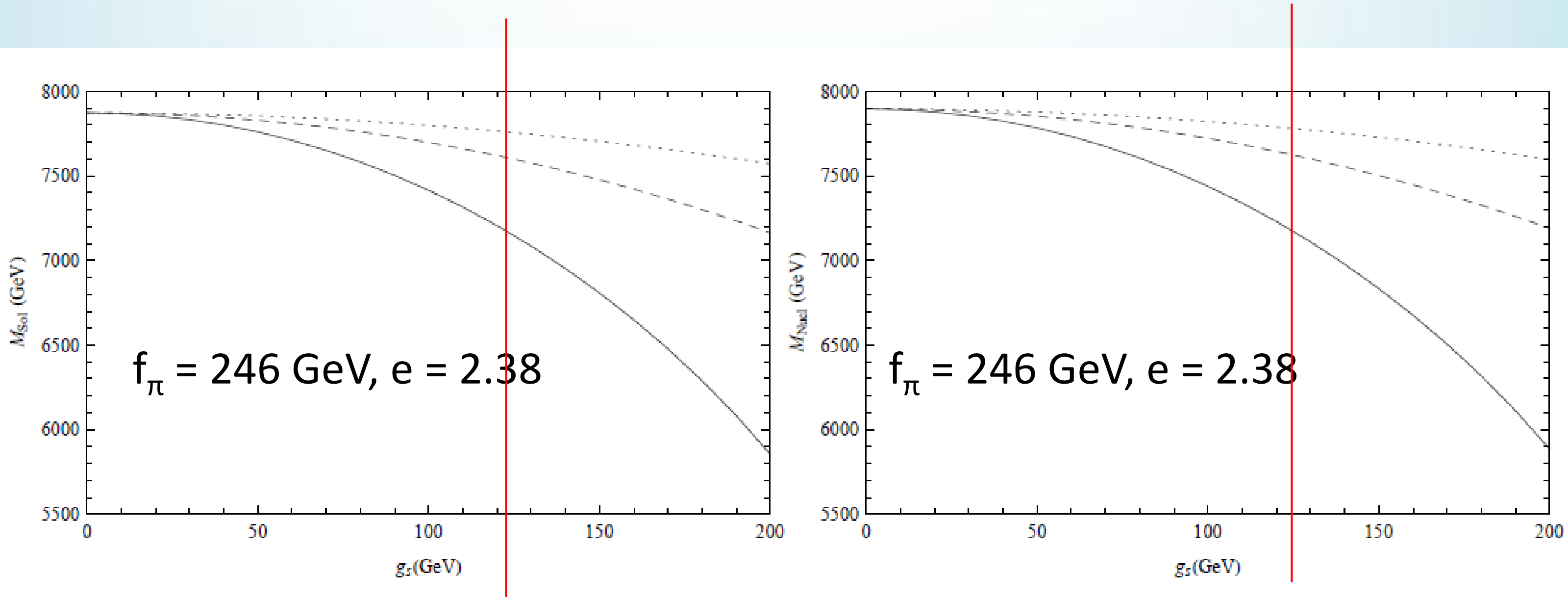
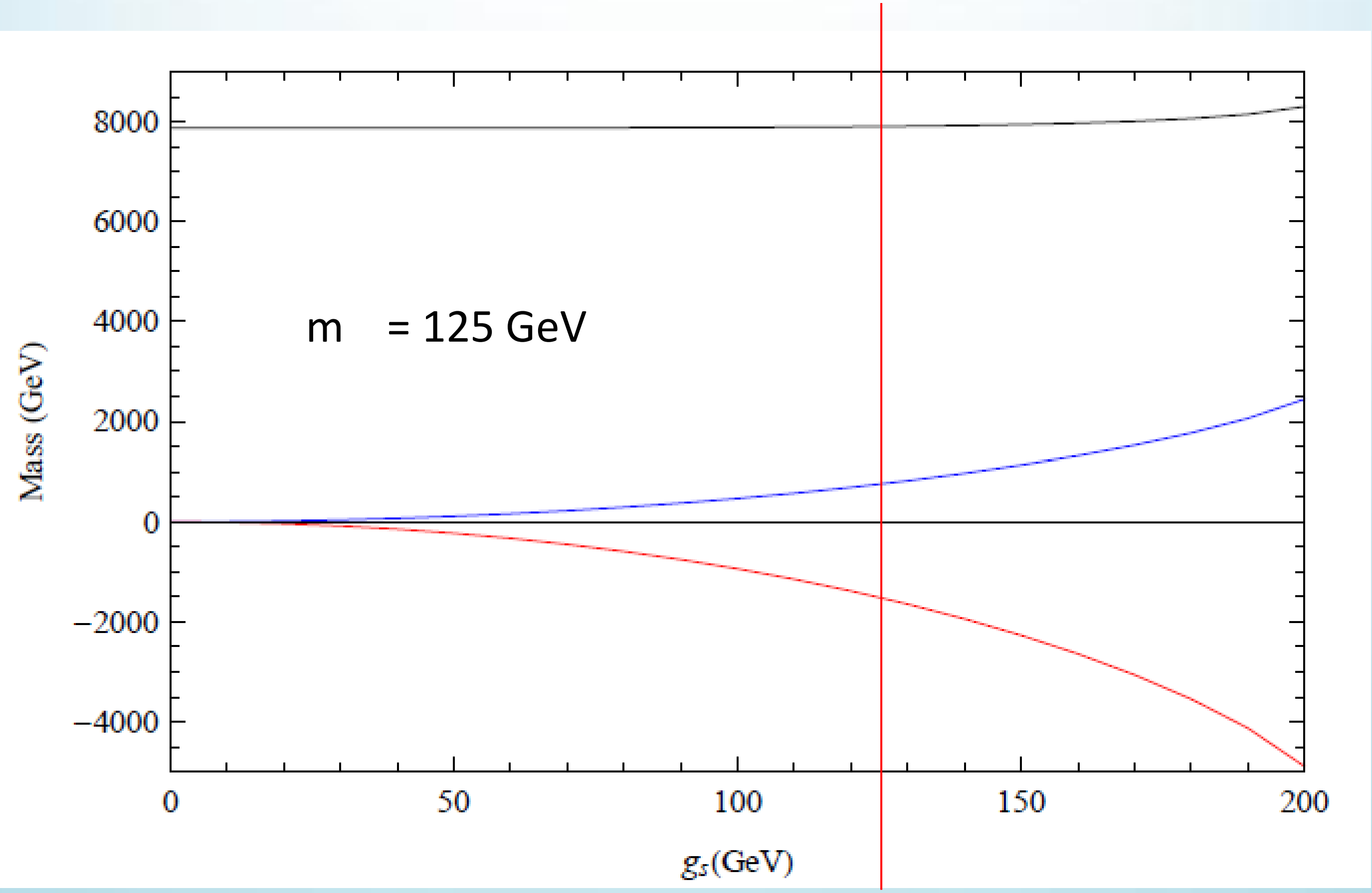


FIG. 1: g_s and sigma mass dependence of the Soliton (left panel) and Nucleon (right panel) mass. I took $m_\sigma = 125$ GeV (solid line), 600 GeV (dashed line) and 1200 GeV (dotted line). $g_s = 0$ corresponds to the result in Ref.



8000
6000
4000
2000
0
−2000
−4000
Mass (GeV)
m = 125 GeV
0
50
100
150
200
g_s(GeV)

Bottom-up approach:

J. Erlich, E. Katz , D. T. Son, M. A. Stephanov , **Phys.Rev.Lett. 95 (2005) 261602**

$$ds^2 = g_{MN} dx^M dx^N = (1/z)^2 (\eta_{\mu\nu} dx^\mu dx^\nu - dz^2)$$

(x,) : source

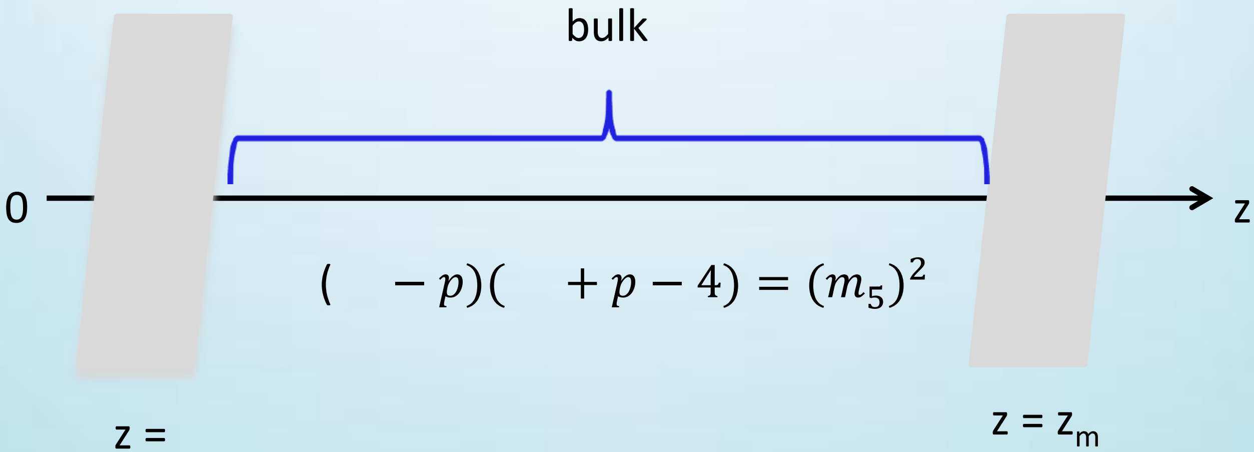


TABLE I: Operators/fields of the model

4D: $\mathcal{O}(x)$	5D: $\phi(x,z)$	p	Δ	$(m_5)^2$
$\bar{q}_L \gamma^\mu t^a q_L$	$A^a_{L\mu}$	1	3	0
$\bar{q}_R \gamma^\mu t^a q_R$	$A^a_{R\mu}$	1	3	0
$\bar{q}^\alpha_R q^\beta_L$	$(2/z) X^{\alpha\beta}$	0	3	-3

$$W_{4D}[\phi_0(x)] = S_{5D,\text{eff}}[\phi(x,\epsilon)] \quad \text{at} \quad \phi(x,\epsilon) = \phi_0(x)$$

$$S_5 = S_{\text{bulk}} + S_{\text{UV}} + S_{\text{IR}}$$

where the bulk sector S_{bulk} is given by

$$S_{\text{bulk}} = \frac{1}{g_5^2} \int d^4x \int_\epsilon^{z_m} dz \sqrt{-g} e^{c_G g_5^2 \Phi_G} \times \Bigg[\frac{1}{2} \partial_M \Phi_G \partial^M \Phi_G + \text{Tr}\left[D_M \Phi_S^\dagger D^M \Phi_S - m_{\Phi_S}^2 \Phi_S^\dagger \Phi_S \right] - \frac{1}{4} \text{Tr}\left[L_{MN} L^{MN} + R_{MN} R^{MN} \right] \Bigg]$$

S. Matsuzaki, K. Yamawaki,
e-Print: **arXiv:1209.2017** **[hep-ph]**

BCs:

$$L_M|_{z=\epsilon} = R_M|_{z=\epsilon} = 0\,.$$

$$m_{\Phi_S}^2 = -(3-\gamma_m)(1+\gamma_m)$$

Transformations which preserve these BCs satisfy $\partial_M g_{L,R}(x,z)\Big|_{z=\epsilon} = 0$ can be identified with the chiral $SU(N_{TF})_L \times SU(N_{TF})_R$ in four dimensional space-time characterized by $g_{L,R} = g_{L,R}(x,\epsilon)$.

Parameter fixing

Vector/axial-vector correlator

$$\frac{1}{g_5^2} = \frac{N_{\rm TC}}{12\pi^2}\,,$$
$$c_G = -\frac{N_{\rm TC}}{192\pi^3}\,.$$

Input: m = 125 GeV

f = 123 GeV

S = 0.1

$$L_z(x,z) = R_z(x,z) = 0 \text{ gauge}$$

$$g_L(x,z) = \exp\left[i\int_z^{z_m} L_z(x,z')dz'\right],$$
$$g_R(x,z) = \exp\left[i\int_z^{z_m} R_z(x,z')dz'\right].$$

BCs:

$$L_\mu(x,z)\Big|_{z=\epsilon} = i\partial_\mu g_L(x,z)\cdot g_L^\dagger(x,z)\Big|_{z=\epsilon},$$
$$R_\mu(x,z)\Big|_{z=\epsilon} = i\partial_\mu g_R(x,z)\cdot g_R^\dagger(x,z)\Big|_{z=\epsilon}.$$

$$\xi_L(x) = g_L(x,\epsilon) = \exp\left[i\int_\epsilon^{z_m} L_z(x,z')dz'\right]$$
$$\xi_R(x) = g_R(x,\epsilon) = \exp\left[i\int_\epsilon^{z_m} R_z(x,z')dz'\right]$$

$$L_\mu(x,z)\Big|_{z=\epsilon} = i\partial_\mu\xi_L(x,\epsilon)\cdot\xi_L^\dagger(x,\epsilon) = \alpha_\mu^L(x),$$
$$R_\mu(x,z)\Big|_{z=\epsilon} = i\partial_\mu\xi_R(x,\epsilon)\cdot\xi_R^\dagger(x,\epsilon) = \alpha_\mu^R(x).$$

KK mode expansion

$$L_\mu(x,z) = \phi_L(z)\alpha^L_\mu(x) + \sum_{n\geq 1}\left[\psi_V^{(n)} V_\mu^{(n)}(x) - \psi_A^{(n)} A_\mu^{(n)}(x)\right],$$

$$R_\mu(x,z) = \phi_R(z)\alpha^R_\mu(x) + \sum_{n\geq 1}\left[\psi_V^{(n)} V_\mu^{(n)}(x) + \psi_A^{(n)} A_\mu^{(n)}(x)\right].$$

$$V_\mu(x,z) = \phi_R(z)\alpha^R_\mu(x) + \phi_L(z)\alpha^L_\mu(x) + \sum_{n\geq 1}\psi_V^{(n)} V_\mu^{(n)}(x),$$

$$A_\mu(x,z) = \phi_R(z)\alpha^R_\mu(x) - \phi_L(z)\alpha^L_\mu(x) + \sum_{n\geq 1}\psi_A^{(n)} A_\mu^{(n)}(x).$$

EoM

$$\left[q^2 + w(z)^{-1}\partial_z w(z)\partial_z\right] V_\mu(q,z) = 0\,,$$

$$\left[q^2 + w(z)^{-1}\partial_z w(z)\partial_z - 2\left(\frac{L}{z}\right)^2 v^2(z)\right] A_\mu(q,z) = 0\,,$$

$$f_\pi^2 = \frac{1}{g_5^2}\omega\partial_z\psi_0(z)\cdot\psi_0(z)\Big|_\epsilon^{z_m}$$

$$\frac{1}{2e^2} = \frac{1}{g_5^2}\int_\epsilon^{z_m} dz\omega\frac{1}{2}\left(1-\psi_0^2(z)\right)^2$$

$$g_s = f_\pi\sqrt{\frac{2}{N_{TF}}}$$

$$N_{TF} = 2N_D + N_{\mathrm{new-singlet}}$$

$$N_D = 4, N_{\mathrm{new-singlet}} = 0, 4, 8, 12$$

Numerical simulation:

m = 125 GeV

f = 123 GeV

e = 315

$$M_{sol} = (27 - 22)\ \text{GeV for}\ \ N_{new\text{-}singlet} = (12 - 0)$$

Is there any trivial mistake in my calculation?

Using QCD parameters: e = 8, and $M_{neucleon}$ = 1140 MeV. Agree with literature

Questions raised:

1. Is it reasonable to use holographic model to study strongly coupled system with large anomalous dimension?

2. Is it reasonable to regard the new boson with mass 125 GeV as the N-G associated with dynamical breaking of chiral conformal symmetry?

3. Is there any other parameter space to get yield results agree with data and a smaller skyrme parameter, especially for order 1 parameter.

4. Can we get constraint from dark matter experiment by rearding techni-skyrmion as a dark matter candidate?