My Research & Activities
@
the ASRC, JAEA

Hyun-Chul Kim
(金鉉哲: キムヒュンチュル)
Inha University (仁荷大學校)
&
ASRC, JAEA (日本原子力研究開發機構)

ASRC@東海村, February 25, 2019

Summary & Introduction

- 私は東海村、水戸、日立、 筑波、軽井沢、青森、
名古屋、富山、白川郷に訪問しました。

- I wrote 8 papers, among which three were published and five are now under review. Three papers are in preparation.

- I prepared 8 contributions to the Proceedings (FB22, QNP2018), of which 4 of them will appear in Few-Body Systems.

- I have collaborated with A. Hosaka, E. Hiyama, M. Oka, T. Sekihara during my stay at ASRC.

In this talk, I will report mainly what I have done while I was staying at the ASRC, JAEA.

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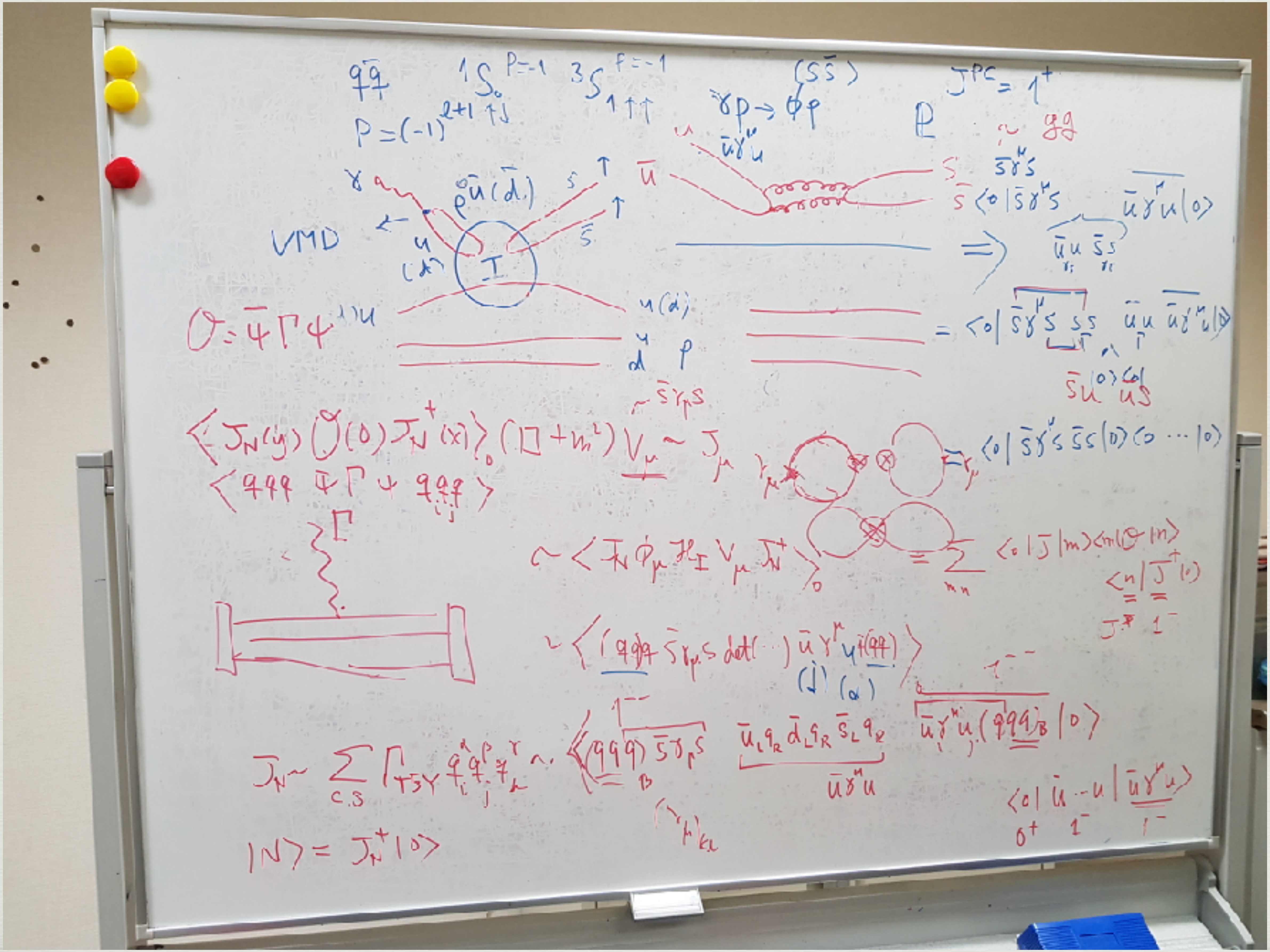

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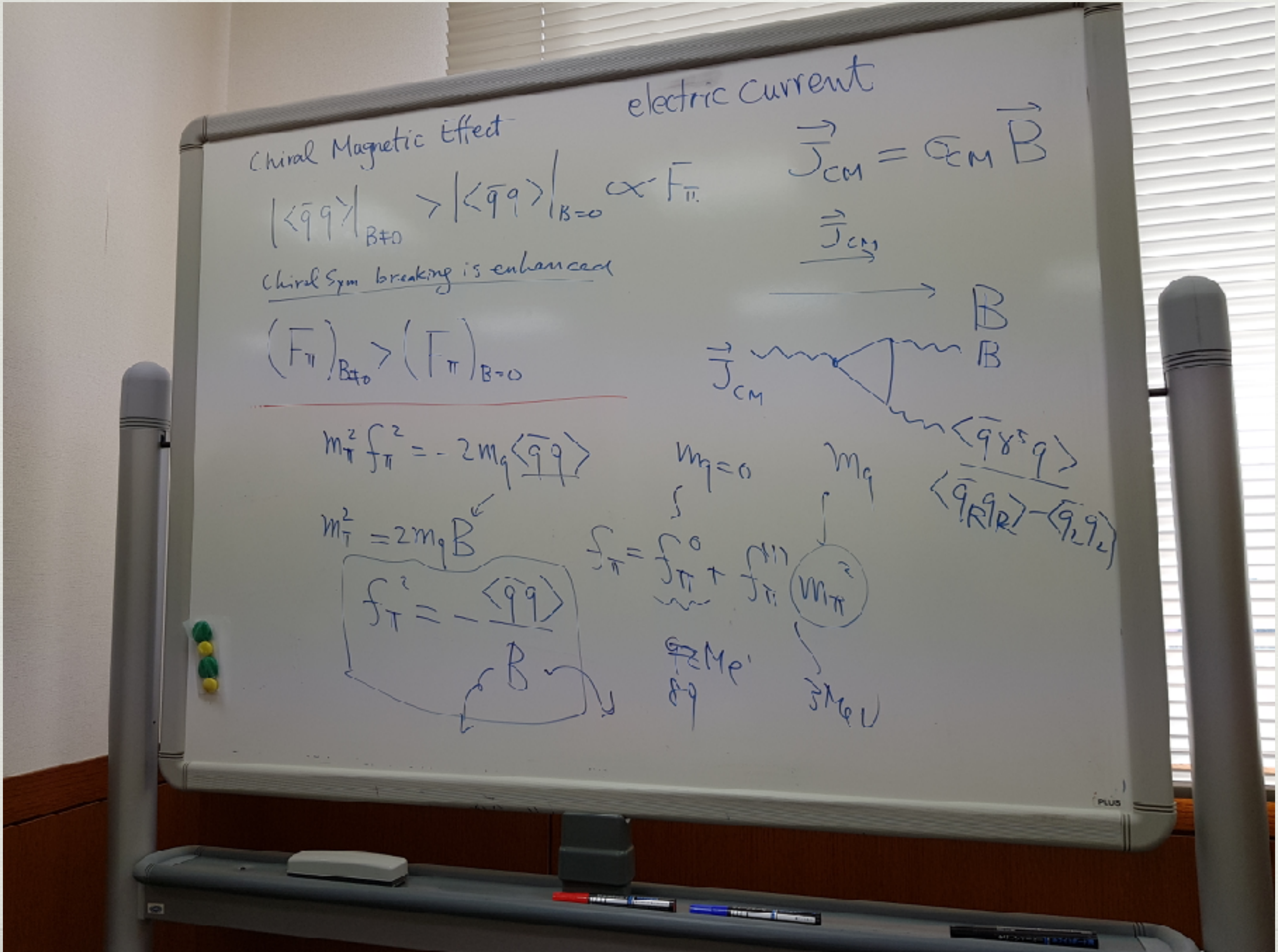
Chiral Magnetic Effect
electric current
chiral sym breaking is enhanced

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- 東海村の原研通り

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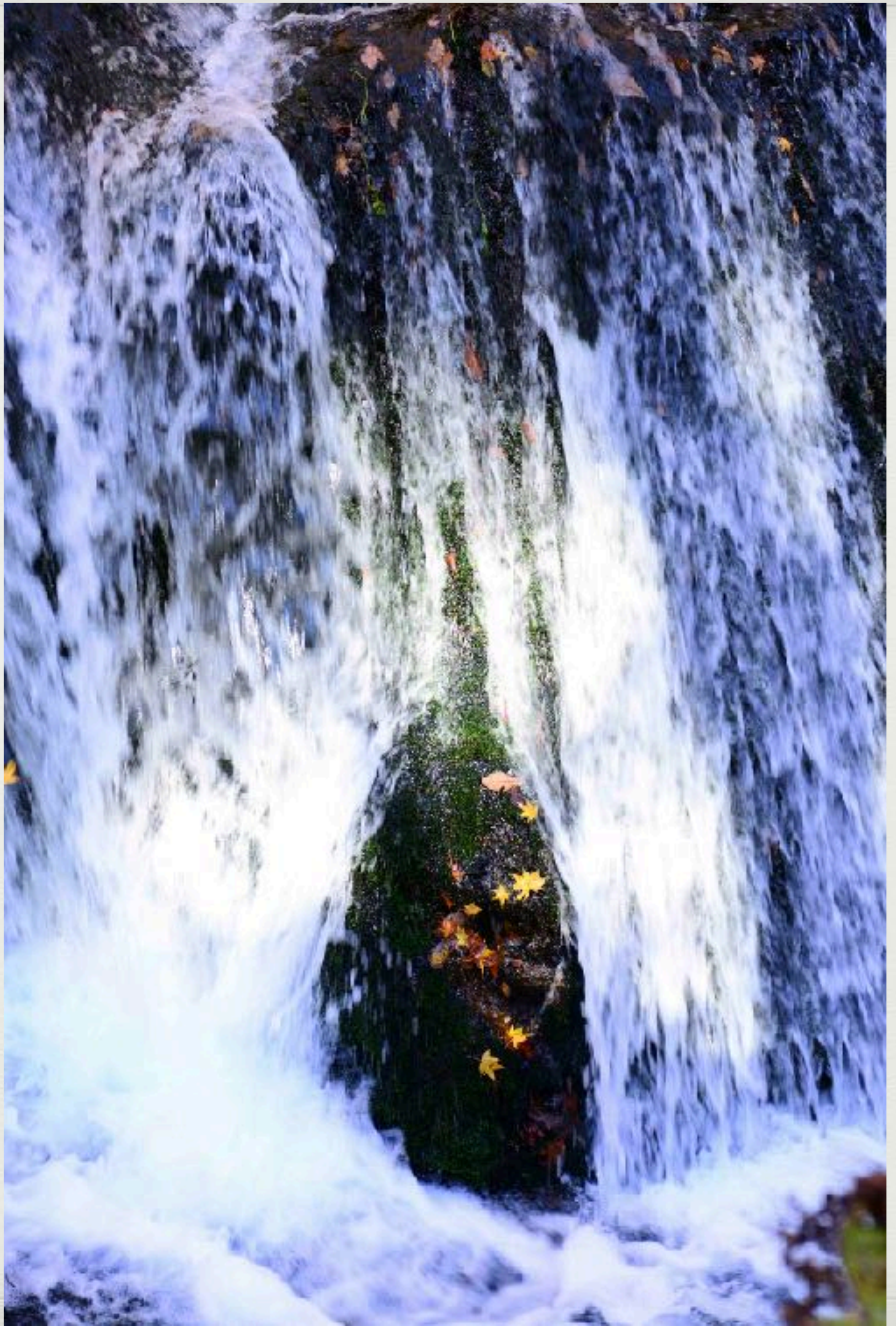

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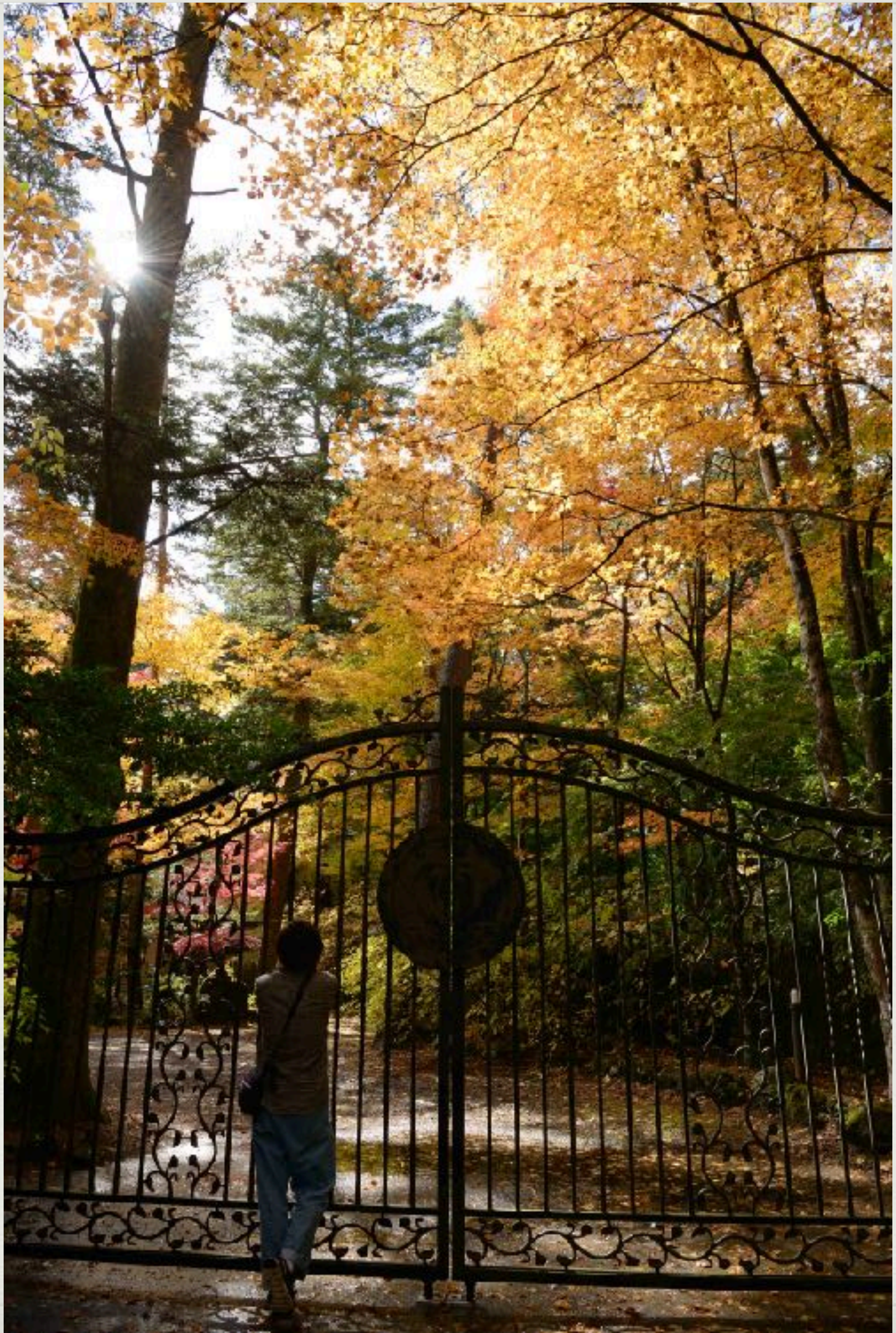

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和牛バラ焼

- 名古屋

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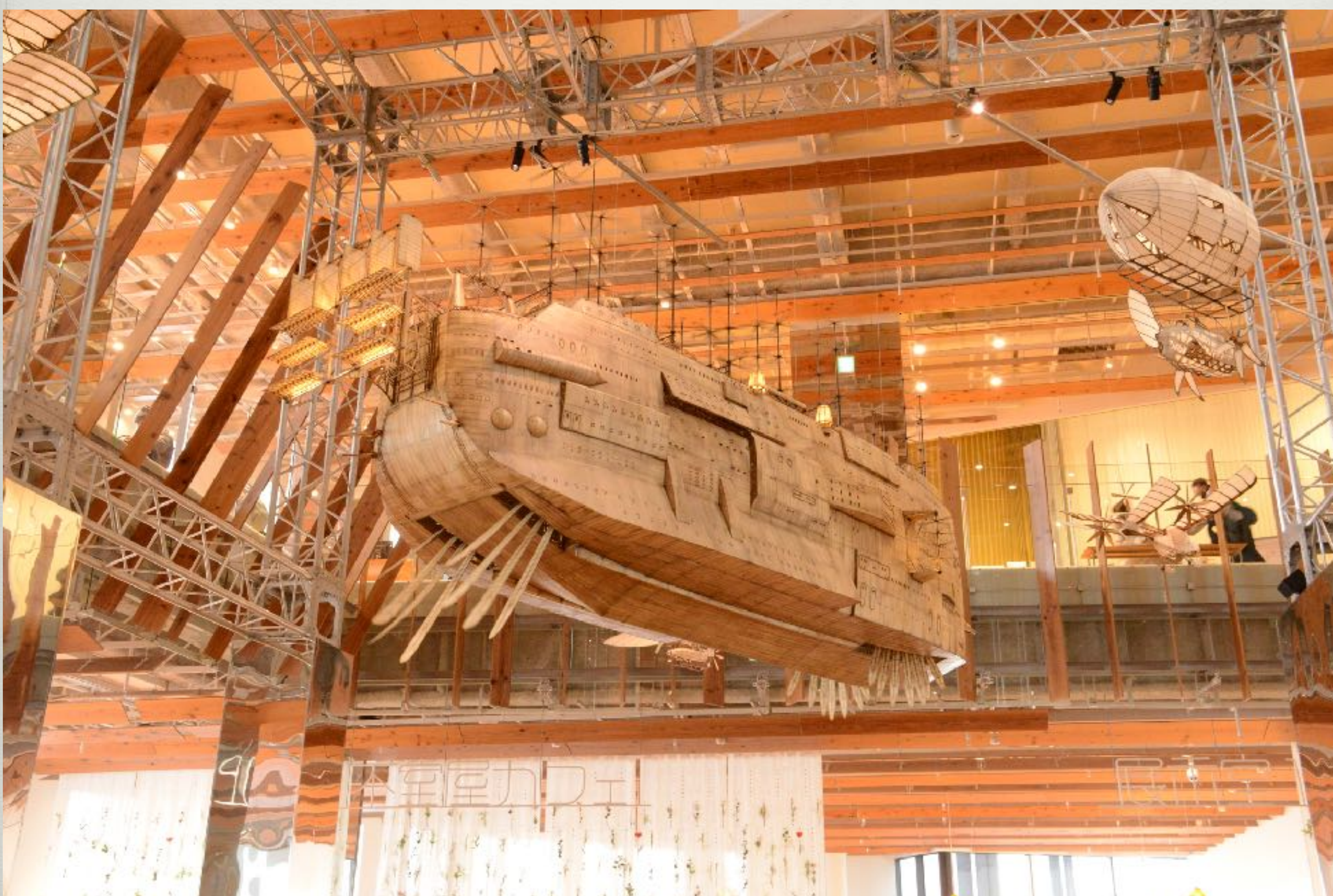
- 富山

- 富山


ジブリの大博覧会
2018.
12.8(土)～
2019.
2.24(日)
富山市ガラス美術館 展示室1・2・3
開館時間9:30～18:00
(休館日:12.31(月)、1.9(水)、2.6(水)の3日間)
[入場料]一般1,400円(1,200円)
中学・高校生1,000円(800円)
小学生800円(400円)、未就学児無料

- 富山



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- 水戸、偕楽園の梅祭り

- 水戸、偕楽園の梅祭り

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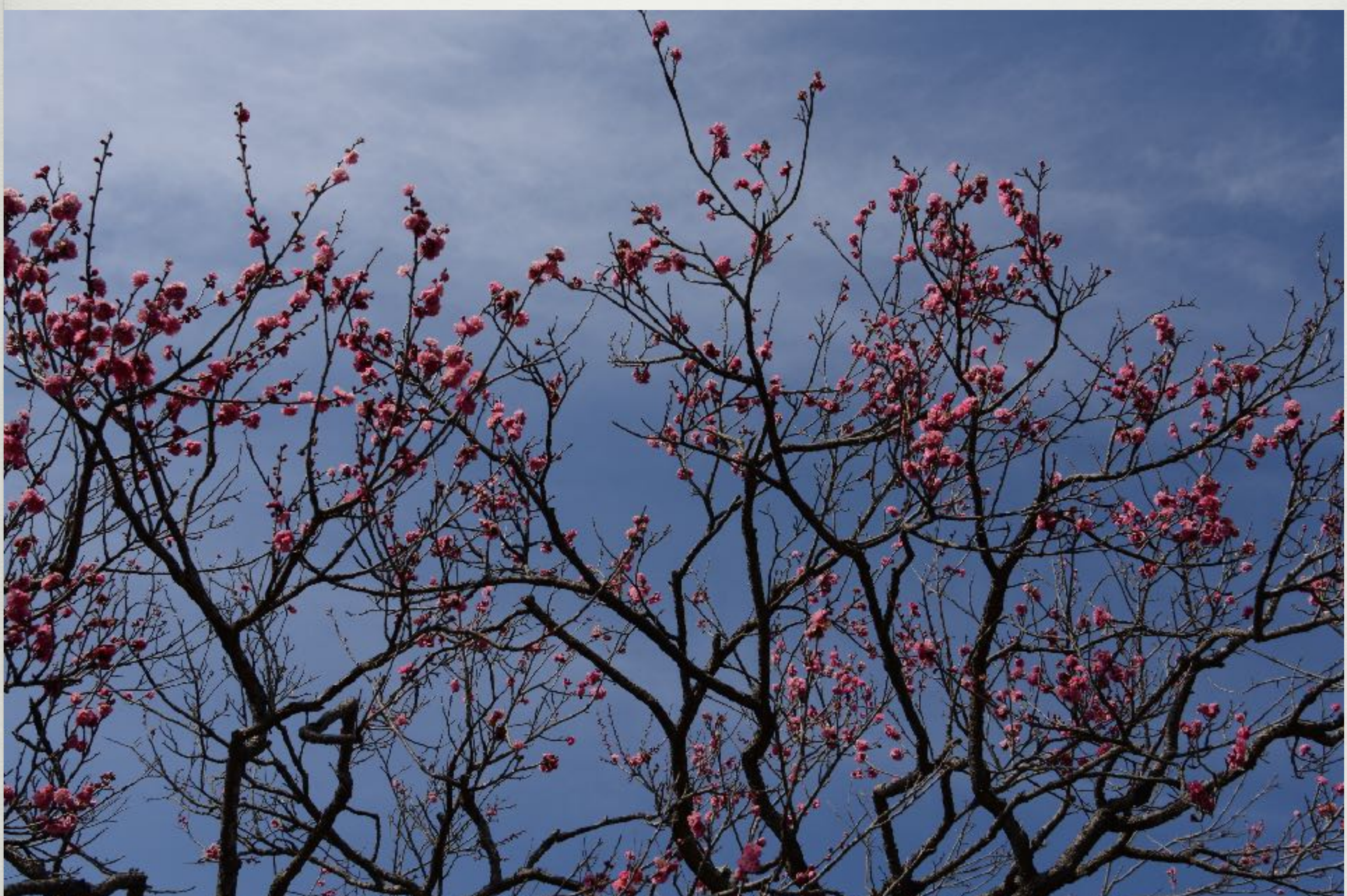

- With students & friend

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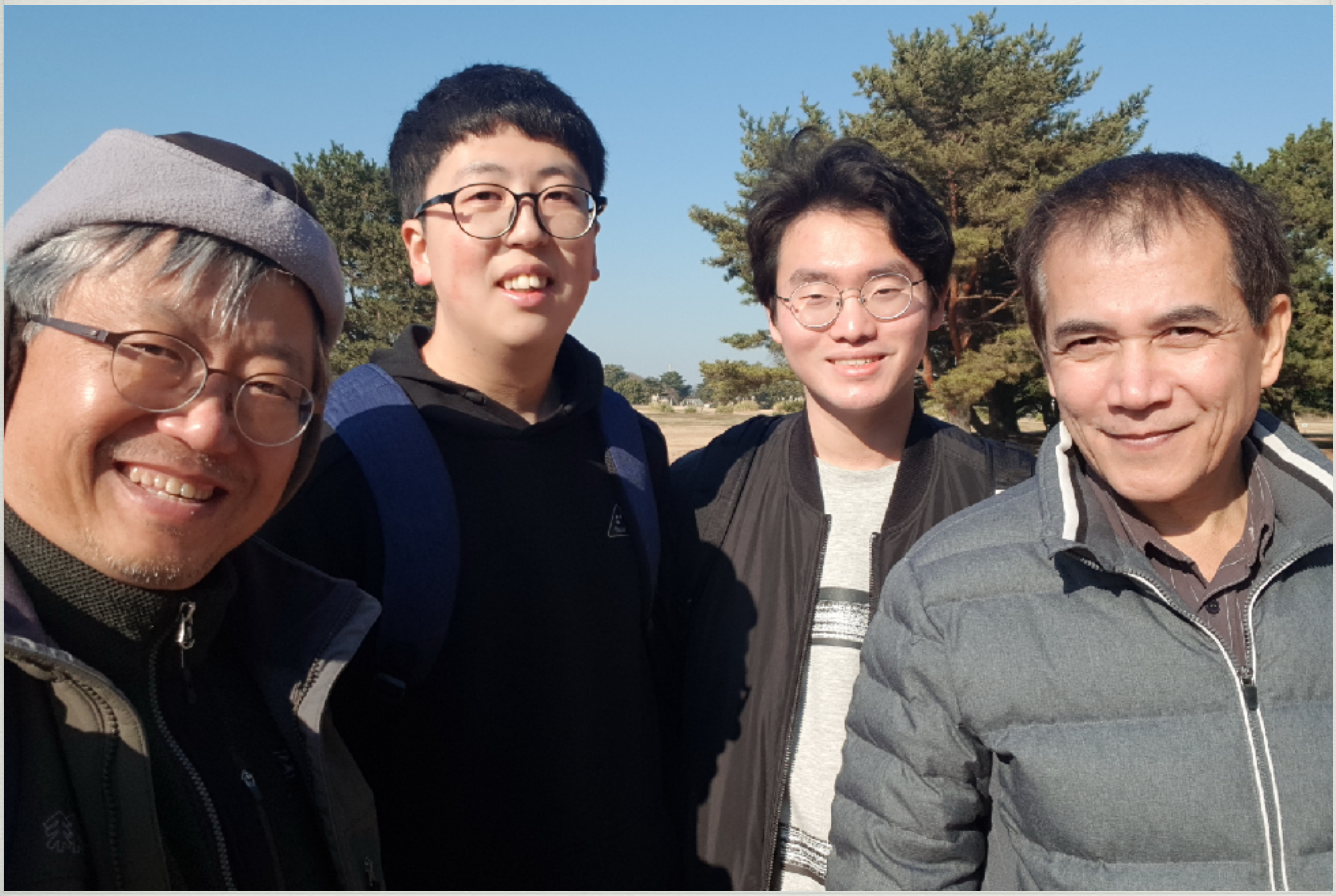

- First published paper at ASRC

Physics Letters B 786 (2018) 156–164

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

$K^0\Lambda$ photoproduction off the neutron with nucleon resonances

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t-channel Regge trajectories
Nucleon resonances

ABSTRACT

We investigate kaon photoproduction off the neutron target, i.e., $\gamma n \to K^0\Lambda$, focusing on the role of nucleon resonances given in the Review of Particle Data Group in the range of $\sqrt{s} \approx 1600$–2200 MeV. We employ an effective Lagrangian method and a Regge approach. The strong couplings of nucleon resonances with $K\Lambda$ vertices are constrained by quark model predictions. The numerical results of the total and differential cross sections are found to be in qualitative agreement with the recent CLAS and FOREST experimental data. We discuss the effects of the narrow nucleon resonance $N(1685, 1/2^+)$ on both the total and differential cross sections near the threshold energy. In addition, we present the results of the beam asymmetry as a prediction.

- Second published paper at ASRC

PTEP

Prog. Theor. Exp. Phys. **2018**, 123D01 (10 pages)
DOI: 10.1093/ptep/pty135

Mass spectra of heavy mesons with instanton effects

Qian Wu,[1,*] Emiko Hiyama,[2,3,*] Hyun-Chul Kim,[4,5,6,*] Ulugbek Yakhshiev,[4,*] and Hongshi Zong[1,7,8,*]

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Received August 28, 2018; Revised October 25, 2018; Accepted November 12, 2018; Published December 28, 2018

We investigate the mass spectra of ordinary heavy mesons, based on a nonrelativistic potential approach. The heavy–light quark potential contains the Coulomb-type potential arising from one-gluon exchange, the confining potential, and the instanton-induced nonperturbative local heavy–light quark potential. All parameters are theoretically constrained and fixed. We carefully examine the effects from the instanton vacuum. Within the present form of the local potential from the instanton vacuum, we conclude that the instanton effects are rather marginal on the charmed mesons.

Subject Index D32

- Third published paper at ASRC

PHYSICAL REVIEW D **98,** 114036 (2018)

Instanton effects on charmonium states

Ulugbek Yakhshiev,[1,*] Hyun-Chul Kim,[1,2,3,†] and Emiko Hiyama[2,4,5,‡]

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(Received 14 November 2018; published 28 December 2018)

The instanton effects on the charmonium spectrum are discussed in the framework of the nonrelativistic potential model. The results from the constituent quark model without inclusion of instanton effects are compared with the results for the potential from the constituent quark model plus the contribution from the instanton liquid model. We consider two models with the corresponding instanton potentials and discuss their relevance to explanations of the origin of phenomenological parameters used in the nonrelativistic potential models. We also present the universal instanton potential in a parametrized form, which can be useful in practical calculations.

- Submitted manuscripts

New narrow nucleon resonances $N^*(1685)$ and $N^*(1726)$ within the chiral quark-soliton model

Ghil-Seok Yang[1,*] and Hyun-Chul Kim[2,3,4,†]

[1] *Department of Physics, Soongsil University, Seoul 06978, Republic of Korea*
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[3] *Advanced Science Research Center, Japan Atomic Energy Agency, Shirakata, Tokai, Ibaraki, 319-1195, Japan*
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(Dated: September 21, 2018)

We investigate the strong and radiative decay widths of the narrow nucleon resonances $N^*(1685)$ and $N^*(1726)$ within the framework of the SU(3) chiral quark-soliton model. All the relevant parameters are taken from those used to describe the properties of the baryon octet and decuplet in previous works. The masses of the antidecuplet nucleon and the eikosiheptaplet (27-plet) nucleon with spin 3/2 are determined respectively to be (1690.2 ± 10.5) MeV and (1719.6 ± 7.4) MeV. The decay width for $N^*(1685) \to \eta + N$ is found to be approximately three times larger than that for $N^*(1685) \to \pi + N$. The width of the decay $N^*\,(1726)\,3/2^+ \to \eta + N$ is even about 31 times larger than that of $N^*\,(1726)\,3/2^+ \to \pi + N$. The ratio of the radiative decays for $N^*(1685)$ is obtained to be $\Gamma_{nn^*(1685)}/\Gamma_{pp^*(1685)} = 8.62 \pm 3.45$ which explains very well the neutron anomaly. In contrast, we find $\Gamma_{pp^*(1726)}/\Gamma_{nn^*(1726)} = 3.72 \pm 0.64$, which indicates that the production of $N^*(1726)$ is more likely to be observed in the proton channel. We also examined the decay modes of these narrow nucleon resonances with the strangeness hadrons involved.

PACS numbers: 13.30.Eg, 13.60.Rj, 14.20.-c, 14.20.Gk, 14.20.Pt
Keywords: narrow nucleon resonances, hadronic decays, exotic baryons, pentaquarks, the chiral quark-soliton model

- Submitted manuscripts

Modification of hyperon masses in nuclear matter

Ki-Hoon Hong,[1,*] Ulugbek Yakhshiev,[1,†] and Hyun-Chul Kim[1,2,3,‡]

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[3] *School of Physics, Korea Institute for Advanced Study (KIAS), Seoul 02455, Republic of Korea*

(Dated: February 18, 2019)

We investigate the properties of baryons within the framework of the in-medium modified SU(3) Skyrme model. The modification is performed by a minimal way, the medium functionals in the SU(2) sector being introduced. These functionals are then related to nuclear matter properties near the saturation point. The modifications in the SU(3) sector are performed by changing additionally kaon properties in nuclear matter. The results show that the properties of baryons in the strange sector are sensitive to the in-medium modifications of the kaon properties. We discuss the consistency of the in-medium modifications of hadron properties in this approach, comparing the present results with those from other models.

PACS numbers: 12.39.Dc,12.39.Fe,14.20.Dh, 14.20.Jn, 21.65.+f
Keywords: Skyrmions, nucleons, hyperons, nuclear matter

- Submitted manuscripts

Effects of nucleon resonances on η photoproduction off the neutron reexamined

Jung-Min Suh,[1,*] Sang-Ho Kim,[2,3,†] and Hyun-Chul Kim[1,4,5,‡]

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(Dated: October 12, 2018)

We investigate η photoproduction off the neutron target, i.e., $\gamma n \to \eta n$, employing an effective Lagrangian method combining with a Regge approach. As a background, we consider nucleon exchange in the s-channel diagram and ρ- and ω-meson Regge trajectories in the t channel. The role of nucleon resonances given in the Review of Particle Data Group in the range of $W \approx 1500 - 2100$ MeV and the narrow nucleon resonance $N(1685, 1/2^+)$ is extensively studied. The numerical results of the total and differential cross sections, double polarization observable E, and helicity-dependent cross sections $\sigma_{1/2}$, $\sigma_{3/2}$ are found to be in qualitative agreement with the recent A2 experimental data. The predictions of the beam asymmetry are also given.

Keywords: η photoproduction off the neutron, narrow nucleon resonances, effective Lagrangian approach, t-channel Regge trajectories

- Submitted manuscripts

Vector and Axial-vector form factors in radiative kaon decay and flavor SU(3) symmetry breaking

Sang-In Shim,[1,*] Atsushi Hosaka,[1,2,†] and Hyun-Chul Kim[3,2,4,‡]

[1] *Research Center for Nuclear Physics (RCNP), Osaka University, Ibaraki, Osaka, 567-0047, Japan*

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[4] *School of Physics, Korea Institute for Advanced Study (KIAS), Seoul 02455, Republic of Korea*

(Dated: October 17, 2018)

We study the vector and axial-vector form factors of radiative kaon decay within the framework of the gauged nonlocal effective chiral action from the instanton vacuum, focusing on the effects of flavor SU(3) symmetry breaking. The general tendency of the results are rather similar to those of radiative pion decays: The nonlocal contributions make the results of the vector form factor increased by about 20 %, whereas they reduce those of the axial-vector form factor by almost 30 %. Suppressing the prefactors consisting of the kaon mass and the pion decay constant, we scrutinize how the kaon form factors undergo changes as the mass of the strange current quark is varied. Those related to the vector and second axial-vector form factors tend to decrease monotonically as the strange quark mass increases, whereas that for the axial-vector form factor decreases. When $K \to e\nu\gamma$ decay is considered, both the results of the vector and axial-vector form factors at the zero momentum transfer are in good agreement with the experimental data. The results are also compared with those from chiral perturbation theory to p^6 order.

Almost accepted by PLB.

- Submitted manuscripts

Nucleon and Δ isobar in a strong magnetic field

Ulugbek Yakhshiev,[1,*] Hyun-Chul Kim,[1,2,3,†] and Makoto Oka[2,‡]

[1] *Department of Physics, Inha University, Incheon 22212, Republic of Korea*

[2] *Advanced Science Research Center, Japan Atomic Energy Agency, Shirakata, Tokai, Ibaraki, 319-1195, Japan*

[3] *School of Physics, Korea Institute for Advanced Study (KIAS), Seoul 02455, Republic of Korea*

(Dated: February 4, 2019)

We investigate the static properties of the nucleon in the presence of strong magnetic fields and discuss the consequent changes of the nucleon structure, based on the Skyrme model. The results show that at large values of the magnetic field ($\sim 10^{17}$ to 10^{18}G), which is supposed to appear in heavy-ion collision experiments at RHIC energies, the soliton starts to deviate from the spherically symmetric form and its size starts to change. At extremely large values of the magnetic field ($\sim 10^{19}$ G), which may be found at the LHC experiments, the soliton becomes more compact than in free space. The results also show that in the presence of the external magnetic field, the mass of the nucleon tends to increase in general and the mass degeneracy of the Δ isobars from isospin symmetry will be lifted. We also discuss the changes in the mass difference between the Δ and the nucleon, $\Delta m_{\Delta \mathrm{N}}$, due to the influence of the external magnetic field. We find that $\Delta m_{\Delta \mathrm{N}}$ increases as the strength of the magnetic field grows.

- Manuscripts in preparation

- Electromagnetic form factors of the baryon decuplet (June-Young Kim & HChK)

- Electromagnetic transition form factors of the baryon decuplet to the octet (June-Young Kim, HChK, and Makoto Oka)

- **Killing or Saving the Pentaquark: Feasibility of the K+D -> K0 pp reaction for Theta+ (Takayasu Sekihara, HChK, and Atsushi Hosaka)**

- Manuscript in preparation

Electromagnetic form factors of the baryon decuplet with flavor SU(3) symmetry breaking

June-Young Kim[1,*] and Hyun-Chul Kim[1,2,3,†]

[1] *Department of Physics, Inha University, Incheon 22212, Republic of Korea*
[2] *Advanced Science Research Center, Japan Atomic Energy Agency, Shirakata, Tokai, Ibaraki, 319-1195, Japan*
[3] *School of Physics, Korea Institute for Advanced Study (KIAS), Seoul 02455, Republic of Korea*

(Dated: February 13, 2019)

Electromagnetic transitions of the light baryons in the self-consistent SU(3) chiral quark-soliton model

June-Young Kim[1,*] and Hyun-Chul Kim[1,2,†]

[1] *Department of Physics, Inha University, Incheon 22212, Republic of Korea*
[2] *School of Physics, Korea Institute for Advanced Study (KIAS), Seoul 02455, Republic of Korea*

(Dated: November 7, 2018)

- Pentaquark revisited

Prog. Theor. Exp. Phys. **2019**, 00000 (9 pages)
DOI: 10.1093/ptep/0000000000

Killing or saving the Θ^+ pentaquark? Feasibility in the $K^+d \to K^0pp$ reaction

Takayasu Sekihara[1,*] Hyun-Chul Kim[1,2,3] and Atsushi Hosaka[1,4]

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Japan Atomic Energy Agency

Killing or Saving pentaquarks

Hyun-Chul Kim
Inha University
ASRC, JAEA

In the Last October, 2018

Selected work

Instanton effects on quarkonia

QCD Lagrangian

$$\mathcal{L} = \bar{\psi}(i\not{D} - m)\psi - \frac{1}{4}G^a_{\mu\nu}G^{\mu\nu\, a}$$

This classical Lagrangian looks simple but has profound nonperturbative nature.

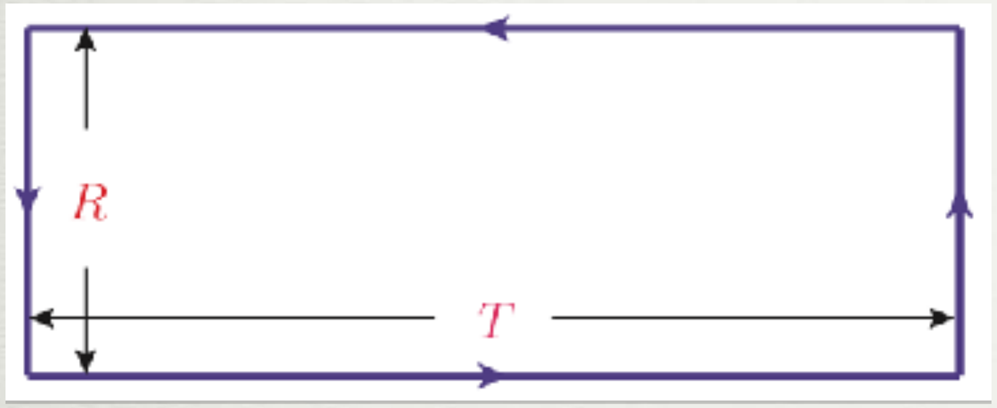
1.Confinement (Understood only qualitatively)

2.Chiral symmetry and its spontaneous breakdown

Chiral symmetry comes into play for light-quark systems.

Static quark confinement

Wilson's criteria of the quark confinement



Heavy-quark propagator

$$W_J = \mathrm{Tr}\left[P \exp i \oint dx^\mu A_\mu^a t_J^a\right]$$

$$\langle W_J \rangle = \exp\left[-V(R)T\right] \text{ at } T \to \infty$$

$Q\bar{Q}$ potential at separation R

Wilson's Area Law

$$W \sim \exp(-\sigma \mathrm{Area})$$

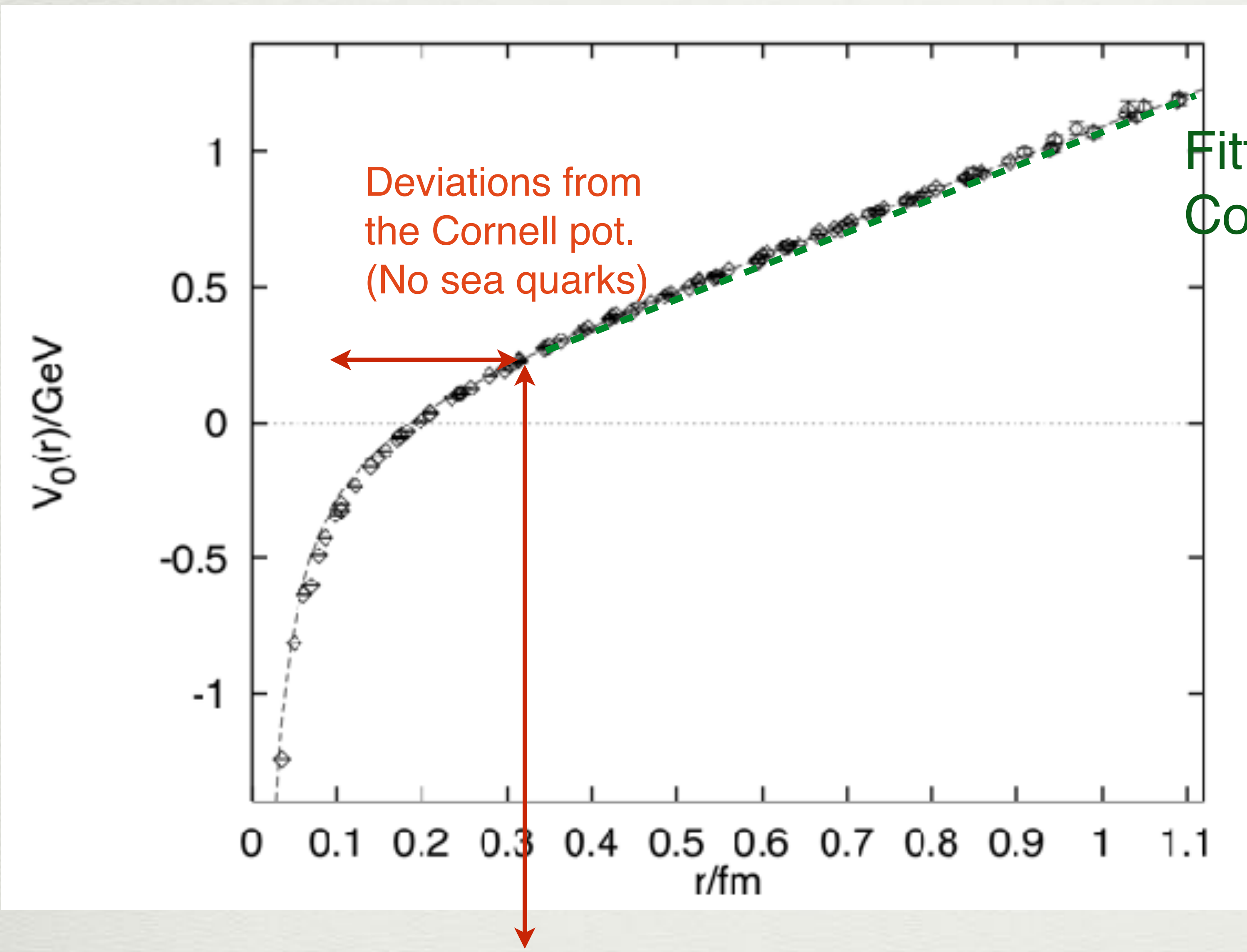
⇒ a linearly rising potential

$$V(R) \sim \sigma R$$

String tension $\sqrt{\sigma} = 420\,\mathrm{MeV}$

Heavy-quark potential

In the limit of infinitely heavy quark mass



Lattice results

Fitted to the phenomenological Cornell potential $r \geq 3\,\mathrm{fm}$

$$V_{\mathrm{Cornell}} = \sigma r - \frac{e}{r}$$

$\sqrt{\sigma} = 420\,\mathrm{MeV}$

Linear confining potential

Coulomb-type potential from one-gluon exchange

G. S. Bali, K. Schilling, A. Wachter, hep-lat/9506017 (RCNP, Confinement 1995)

Heavy-quark potential

Motivations

$$V_C^{(P)} = \kappa r - \frac{4\alpha_s}{3r} \qquad \kappa \approx 0.18\,\mathrm{GeV}^2$$

- Almost all potential models are based on perturbative QCD.
- Values of parameters are arbitrary.

$$\alpha_s(\mu) = \frac{4\pi}{\beta_0}\frac{1}{\ln(\mu^2/\Lambda_{\mathrm{QCD}}^2)} \qquad \beta_0 = (11N_c - 2N_f)/3$$

$$\mu \approx m_c$$

$$\Lambda_{\mathrm{QCD}} = 0.217\,\mathrm{GeV}$$

Heavy-quark potential

Motivations

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$$\mu \approx m_c$$

$$\Lambda_{\mathrm{QCD}} = 0.217\,\mathrm{GeV}$$

- Instanton effects may lead us to improve the physical understanding of the heavy-quark potential.

Heavy-quark potential

Motivations

- In order to proceed to heavy-light quark systems,
  it is essential to understand first the heavy-quark propagator
  from the instanton vacuum.

↓

Conventional mesons and Tetraquarks (X, Y, Z, Tcc)

Heavy-quark propagator

- Decompose the QCD Lagrangian

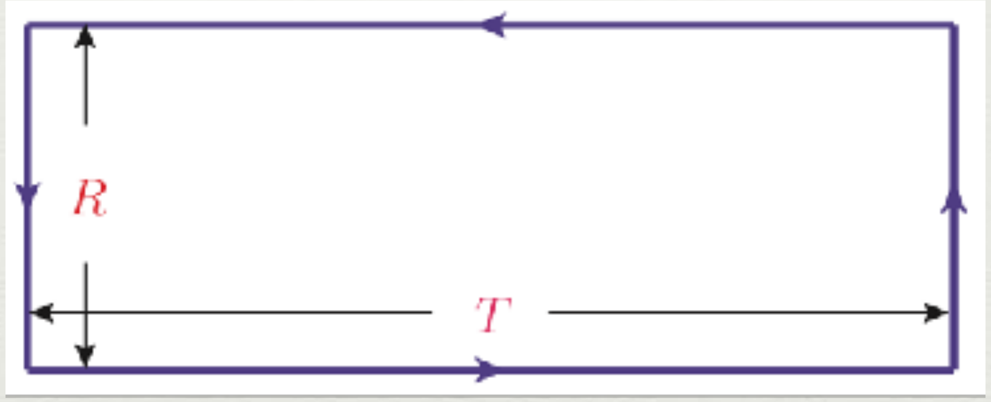
$$\mathcal{L}_{\mathrm{QCD}} = q^\dagger(i\not{D} + im)q + Q^\dagger(i\not{D} + iM)Q - \frac{1}{4g^2}G^2$$

Foldy-Wouthuysen transformation (Heavy-quark expansion)

$$\Longrightarrow \quad Q^\dagger\left(iv\cdot D + \frac{1}{4M_Q}\sigma\cdot\mathbf{B} + \frac{1}{2M_Q}(iD)^2\right)Q$$

- Wilson-loop as a heavy-quark propagator

$$W = \mathrm{Tr}\left[P\exp i\oint dx_\mu \sum_{I\bar{I}} A^I_\mu\right]$$



Heavy-quark potential

- Gauge-invariant definition of the static potential

$$V(r) = -\lim_{T\to\infty}\frac{1}{T}\ln\langle 0|\mathrm{Tr}\{W_C[A]\}|0\rangle$$

- Wilson loop

$$W_C[A] = P\exp\left(i\oint_C \mathrm{d}z_\mu A_\mu(z)\right)$$

- Expectation value of the Wilson loop

$$\langle W_C[A]\rangle = \int DA_\mu \mathrm{Tr} P\exp\left(i\oint_C \mathrm{d}x_\mu A_\mu(x)\right)e^{-\mathcal{S}_{\mathrm{YM}}}$$

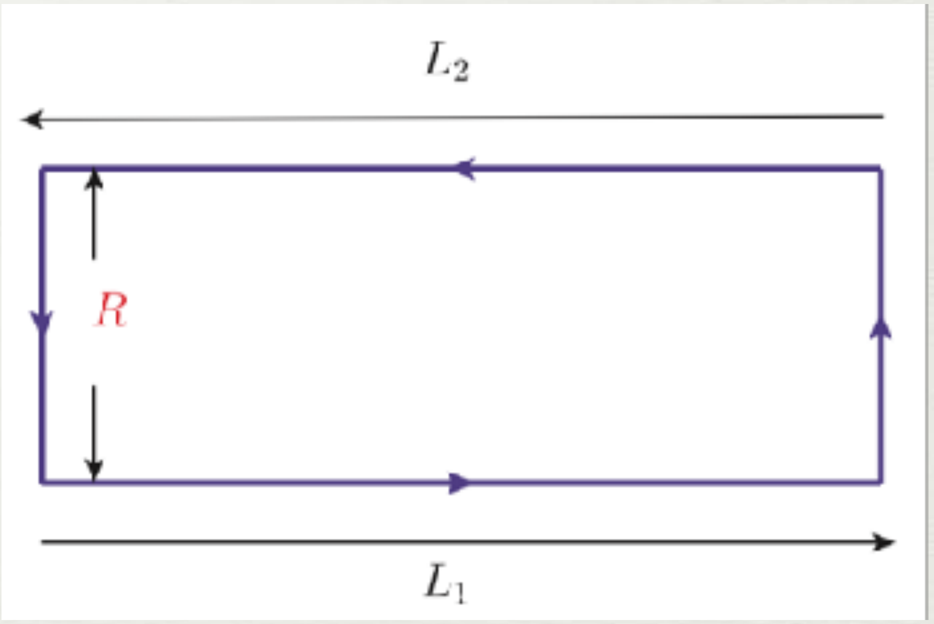
Yakhshiev, HChK et al., Chin. Phys. 41(2017) 083102

Heavy-quark potential

Wilson loop in the instanton vacuum

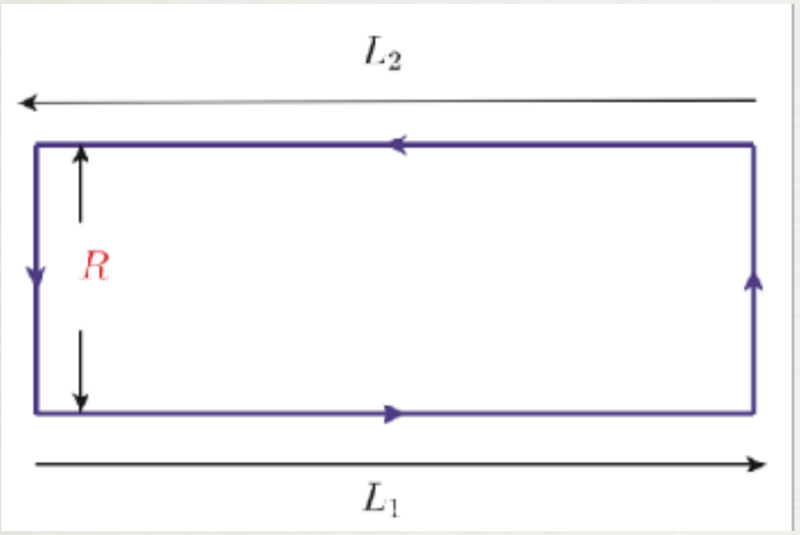
$$W_C[I,\bar{I}] = P\exp\left(i\oint_C \mathrm{d}t \sum_{I,\bar{I}} a_{I,\bar{I}}\right)$$

$$W(L_1 L_2) \sim \exp(-V(R)T)$$



Heavy-quark propagator: $S_0^{(i)}(x,y;a_{I,\bar{I}}) = \langle y| \left(\frac{d}{dt} - \sum_{I,\bar{I}} a^{(i)}_{I,\bar{I}} + i\epsilon\right)^{-1} |x\rangle$

Heavy-quark potential



$$W(L_1L_2) \sim \exp(-V(R)T)$$

$$\mathrm{Tr}W_C = \left\langle\!\!\left\langle \mathrm{Tr}\left[S_0^{(1)}(\boldsymbol{x}_1, -T/2, \boldsymbol{y}_1, T/2\,; a_{I,\bar{I}})S_0^{(2)}(\boldsymbol{x}_2, -T/2, \boldsymbol{y}_2, T/2\,; a_{I,\bar{I}})\rangle\right]\right\rangle\!\!\right\rangle$$

$$V(R) = \frac{N}{2VN_c}\int d^3z_I \mathrm{Tr}_c\left[1 - P\exp\left(i\int_{L_1} dx_4 A_{I4}\right)P\exp\left(-i\int_{L_2} dx_4 A_{I4}\right)\right] + (I \to \bar{I})$$

$V(0) = 0,\ V(\infty) = 2\Delta M$ $\quad\Delta M$ Instanton contribution to the heavy-qu

D. Diakonov, V. Petrov, P. Pobylitsa, PLB **226**, 372 (1989)

Heavy-quark potential

Instanton contribution to the heavy-quark mass: ΔM

- How to fix parameters: Two fundamental parameters
- Set I - phenomenological [E.V. Shuryak, Nucl.Phys. B203 (1982), D.Diakonov, V.Y.Petrov, Nucl.Phys. B245 (1984)]

$$\rho = \frac{1}{3}\,\mathrm{fm}, \qquad \bar{R} = 1\,\mathrm{fm}$$

$$\Delta M \simeq 66.6\,\mathrm{MeV}$$

- Set IIa - 1/Nc meson-loop contributions in the light quark sector [H.C.Kim, M.Musakhanov, M.Siddikov, Phys.Lett. B633 (2006)]

$$\rho = 0.35\,\mathrm{fm}, \qquad \bar{R} = 0.856\,\mathrm{fm}$$

$$\Delta M \simeq 143.06\,\mathrm{MeV}$$

- Set IIb - lattice simulations of instanton vacuum [M.C. Chu, J.M. Grandy, S.Huang, J.W. Negele, Phys.Rev. D49 (1994)]

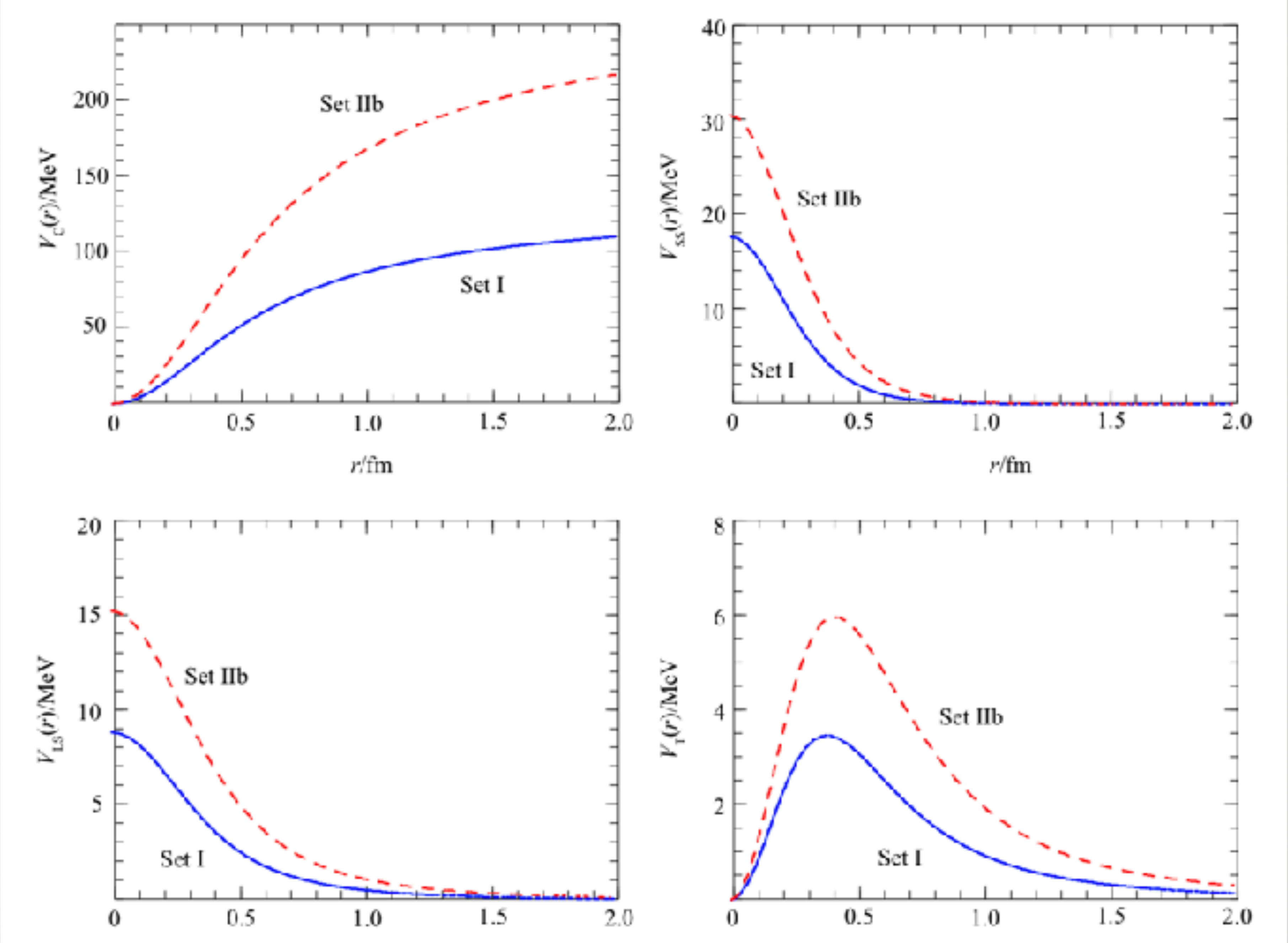
$$\rho = 0.36\,\mathrm{fm}, \qquad \bar{R} = 0.89\,\mathrm{fm}$$

$$\Delta M \simeq 135.72\,\mathrm{MeV}$$

Heavy-quark potential

Central part + spin-dependent part

$$V_{Q\bar{Q}}(\boldsymbol{r}) = V_C(r) + V_{SS}(r)(\boldsymbol{S}_Q \cdot \boldsymbol{S}_{\bar{Q}}) + V_{LS}(r)(\boldsymbol{L} \cdot \boldsymbol{S}) + V_T(r)\left[3(\boldsymbol{S}_Q \cdot \boldsymbol{n})(\boldsymbol{S}_{\bar{Q}} \cdot \boldsymbol{n}) - \boldsymbol{S}_Q \cdot \boldsymbol{S}_{\bar{Q}}\right]$$



Parameters

The model	ρ (fm)	R (fm)	Δm_1 (GeV)	α_s (GeV)	κ (GeV^2)	σ (GeV)
MWOI	Not applicable	Not applicable	Not applicable	0.2068	0.1746	5.0248
M-I	0.33	1.00	0.0676	0.3447	0.1520	0.9331
M-IIb	0.36	0.89	0.1357	0.4588	0.1279	0.5650

Note that we do not aim at fitting the experimental data but try to understand the physical implications of these parameters.

- Actual values of the strong coupling constants

$$\alpha_s(\mu = 1.275\,\mathrm{GeV}) = 0.4258, \quad \text{MWOI}$$
$$\alpha_s(\mu = 1.343\,\mathrm{GeV}) = 0.4137, \quad \text{M-I}$$
$$\alpha_s(\mu = 1.411\,\mathrm{GeV}) = 0.4029 \quad \text{M-IIb}$$

Yakhshiev, HChK, E. Hiyama, PHYS. REV. D 98, 114036 (2018)

Results

State	Input	MWOI	M-I	M-IIb	Exp. [52]
$J/\psi(1^3S_1)$	3097	3084	3094	3096	3096.900 ± 0.006
$\eta_c(1^1S_0)$	2983	3027	2998	2983	2983.9 ± 0.5
$\psi(2^3S_1)$	3686	3635	3656	3675	3686.097 ± 0.025
$\eta_c(2^1S_0)$	3640	3590	3615	3638	3637.6 ± 1.2
$\psi(3^3S_1)$	4040	4067	4069	4071	4039 ± 1
$\eta_c(3^1S_0)$		4026	4041	4047	
$\psi(4^3S_1)$	4415	4443	4422	4398	4421 ± 4
$\eta_c(4^1S_0)$		4405	4400	4379	
$\chi_{c2}(1^3P_2)$		3428	3607	3740	3556.17 ± 0.07
$\chi_{c1}(1^3P_1)$		3437	3589	3715	3510.67 ± 0.05
$\chi_{c0}(1^3P_0)$		3415	3551	3673	3414.71 ± 0.30
$h_c(1^1P_1)$		3430	3599	3727	3525.38 ± 0.11
$\chi_{c2}(2^3P_2)$		3888	4039	4138	3927.2 ± 2.6
$\chi_{c1}(2^3P_1)$		3890	4030	4125	
$\chi_{c0}(2^3P_0)$		3866	4006	4098	3862^{+26+40}_{-32-13}
$h_c(2^1P_1)$		3887	4039	4134	
$\chi_{c2}(3^3P_2)$		4281	4414	4466	
$\chi_{c1}(3^3P_1)$		4280	4394	4455	
$\chi_{c0}(3^3P_0)$		4256	4375	4436	
$h_c(3^1P_1)$		4278	4402	4463	
$\psi_3(1^3D_3)$		3692	3830	3929	
$\psi_2(1^3D_2)$		3718	3836	3927	3822.2 ± 1.2
$\psi(1^3D_1)$		3730	3830	3914	3778.1 ± 1.2
$\eta_{c2}(1^1D_2)$		3708	3837	3930	
$\psi_3(2^3D_3)$		4104	4238	4311	
$\psi_2(2^3D_2)$		4124	4242	4310	
$\psi(2^3D_1)$		4131	4241	4303	4191 ± 5
$\eta_{c2}(2^1D_2)$		4116	4245	4314	

Conclusions

- ★ Instanton effects are marginal and do not seem to show any significant improvement in comparison with the experimental data.
- ★ However, the constraint on the parameters can be achieved by introducing the nonperturbative instanton effects.

Outlook

- ★ Instanton contribution to the one-gluon exchange potential: the effective gluon mass: The Yukawa-type screened potential
- ★ Virtual light-quark contributions to the heavy-quark potential
- ★ Color-octet potential
- ★ We aim finally at deriving the heavy-light quark interactions from the instanton vacuum.

ACKNOWLEDGMENTS

- Oka Makoto & Hosaka Atsushi for invitation to the ASRC.
- Maruyama Toshiki, Philip Gubler as my office mates.
- 丸山さんに色々お世話になっておりました。
- In particular, I am very grateful to 飯岡さん for all administrative help and supports.
- I would like to continue to collaborate with members at ASRC in the future. My 6-month stay at ASRC is just the starting point.

Though this be madness, yet there is method in it.

Hamlet Act 2, Scene 2

by Shakespeare

以上で、今日のセミナーを終わります。

どうもありがとうございました。