핵물리 이론 현황 전망

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Nuclear Physics: Understanding Strong interaction (QCD) at low and intermediate energy

Intimately related to Big experiments

1. 현황
2. 전망

High energy nuclear physics

1. J-Lab
2. EIC (Dec. 2019, Jan 2020)
3. JPARC : primary proton beam (30GeV) + pion Kaon
4. LHC: Heavy Ion Experiment, Exotic hadrons

Low energy nuclear physics

1. FRIB
2. RIKEN
3. RAON

Common

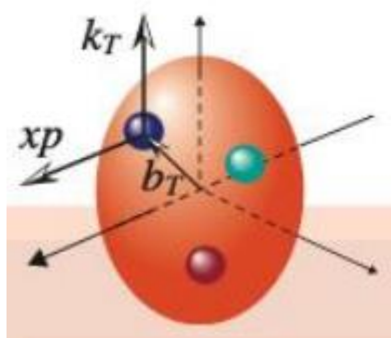
Nuclear Astrophysics: neutron star, nuclear equation of state

현황

1. J-Lab: 12 GeV, 20+ GeV upgrade plan
2. EIC (Dec. 2019 approved, Jan 2020 site)

Research topics

- Mapping quark gluon structure of hadrons (QCD)
- Origin of hadron mass
- Origin of proton spin
- Nucleon Resonances



Current theoretical tools

- Lattice QCD
- Light front QCD (C-R Ji, Ho-Meoyng Choi, Y. Oh etc.)
- Schwinger-Dyson approach
- Instanton models (Hyun-Chul Kim, Seung-il Nam, etc.)

3. JPARC : primary proton beam (30GeV) + pion Kaon

Research topics

- Origin of hadron mass: mass shift measurements, electromagnetic signal
- Hadrons and nuclei with strangeness: H-dibaryon, $N\Lambda$, $NN\Lambda$, ect

Extension of J-PARC Hadron Experimental Facility

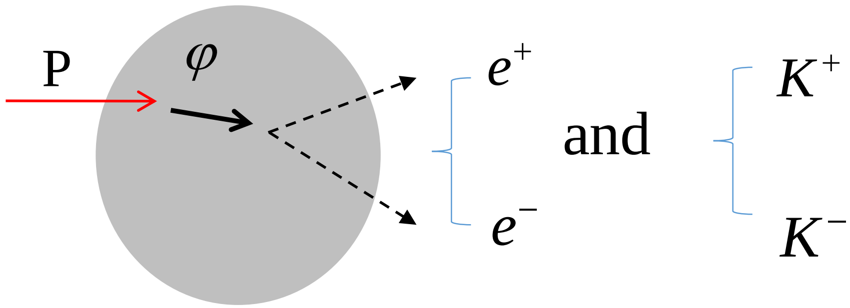
- Multistrange system
- Charmed baryons
- May be future heavy ion experiment

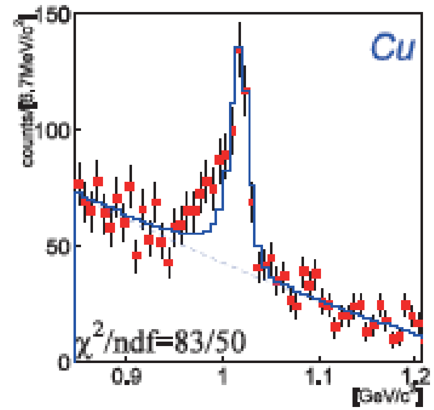
Theoretical tools

- Lattice QCD (Through Potential)
- Effective theories (Unitarized)
- Quark model (our group+ others)

Example 1

KEK E325, J-PARC E16





$$\frac{m(\rho)}{m(0)} = 1 - \left(0.034\,^{+0.006}_{-0.007}\right)\frac{\rho}{\rho_0}$$

$$\frac{\Gamma(\rho)}{\Gamma(0)} = 1 + \left(2.6\,^{+1.8}_{-1.2}\right)\frac{\rho}{\rho_0}$$

Vacuum values	Mass	Width
ϕ	1020 MeV	4.266 MeV

Effects of medium on spin1/2 particle

☞ in Vacuum $\omega\gamma^0 - \vec{\gamma}\vec{p} - M = 0$

☞ in medium characterized by $n^\mu = (1, 0, 0, 0)$

$$\omega\gamma^0 - \vec{\gamma}\vec{p} - M = 0 \xrightarrow{\vec{p}=0} \omega\gamma^0 - M = S + \gamma^0 V$$

Positive energy solution $E = M + (S + V) \approx M + (-400 + 300)\,\mathrm{MeV}$

Related to chiral symmetry breaking

Effects of medium on spin 1 particle

☞ in Vacuum $P_{\mu\nu}\left(q^2-m^2\right)A_\nu=0$ where $P_{\mu\nu}=\left(\frac{q_\mu q_\nu}{q^2}-g_{\mu\nu}\right)$

☞ in medium characterized by $n^\mu=\left(1,0,0,0\right)$

$$P_{\mu\nu}\left(q^2-m^2\right)=P^T_{\mu\nu}\Pi^T\left(\omega,\vec{q}\right)+P^L_{\mu\nu}\Pi^L\left(\omega,\vec{q}\right)$$

$$\text{where}\quad P^T_{ij}=\left(\delta_{ij}-\frac{\vec{q}_i\vec{q}_j}{\vec{q}^2}\right),\quad P^L_{\mu\nu}=\left(\frac{q_\mu q_\nu}{q^2}-g_{\mu\nu}-P^T_{\mu\nu}\right)$$

$$\text{when}\ \vec{q}=0\ \text{then}\ \Pi^T=\Pi^L \quad\rightarrow\quad P_{\mu\nu}\left(q^2-m^2\right)=P_{\mu\nu}\Pi\left(\omega,0\right)$$

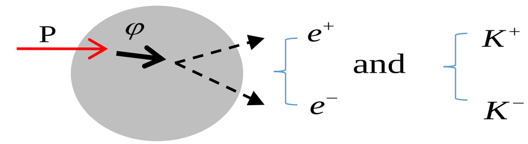
$$\rightarrow\quad \left(\omega^2-m^2\right)=\Pi\left(\omega,0\right)$$

$$\text{when}\ \vec{q}\neq 0\ \text{then}\ \Pi^T\neq\Pi^L \quad\rightarrow\quad \left(P^T_{\mu\nu}+P^L_{\mu\nu}\right)\left(q^2-m^2\right)=P^T_{\mu\nu}\Pi^T\left(\omega,\vec{q}\right)+P^L_{\mu\nu}\Pi^L\left(\omega,\vec{q}\right)$$

$$\rightarrow\begin{cases}\text{Transverse} & \left(q^2-m^2\right)=\Pi^T\left(\omega,\vec{q}\right)\\ \text{Longitudinal} & \left(q^2-m^2\right)=\Pi^L\left(\omega,\vec{q}\right)\end{cases}$$

but $\left(\Pi^T-\Pi^L\right)\sim$ Chiral symmetric

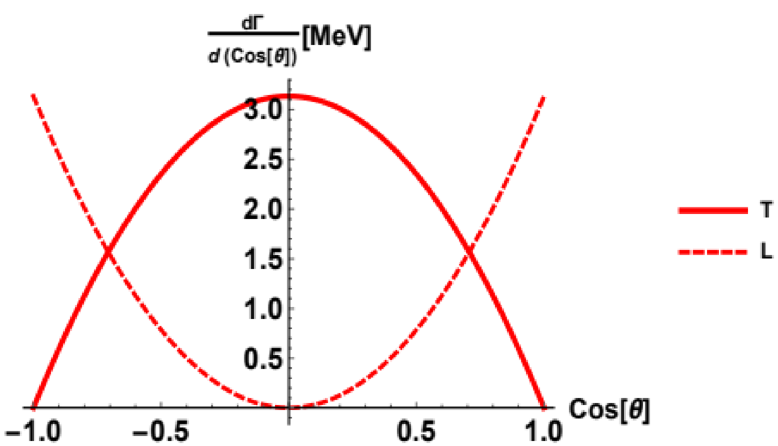
<u>J-Parc will disentangle T and L components</u>



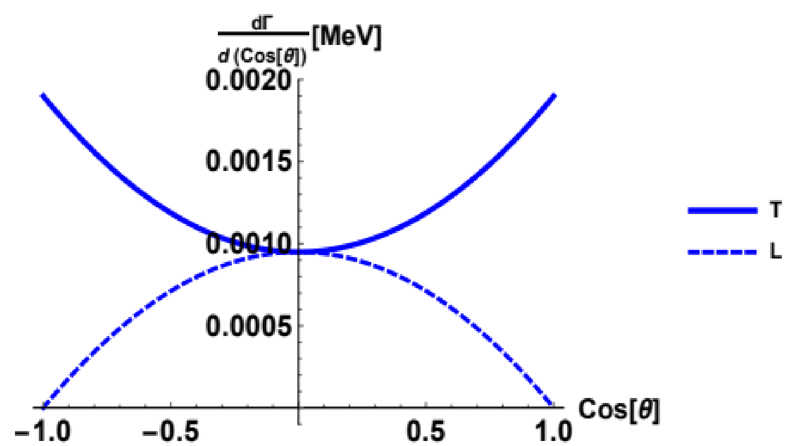
Disentangling longitudinal and transverse modes of the ϕ meson through dilepton and kaon decays

In Woo Park,[1,*] Hiroyuki Sako,[2] Kazuya Aoki,[3,4] Philipp Gubler,[2] and Su Houng Lee[1,†]

[1] *Department of Physics and Institute of Physics and Applied Physics, Yonsei University, Seoul 03722, Korea*
[2] *Advanced Science Research Center, Japan Atomic Energy Agency, Tokai, Naka, Ibaraki 319-1195, Japan*
[3] *KEK, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan*
[4] *RIKEN Nishina Center for Accelerator-Based Science, Wako, Saitama 351-0198, Japan*



(a) $\frac{d\Gamma}{d\cos\theta}$ of kaonic decay in the CM frame



(b) $\frac{d\Gamma}{d\cos\theta}$ of leptonic decay in the CM frame

FIG. 3: Angular distribution of decay rate of $\phi \to K^+ + K^-$ and $\phi \to e^+ + e^-$ in the CM frame for each polarization. T stands for transverse polarization and L stands for longitudinal polarization.

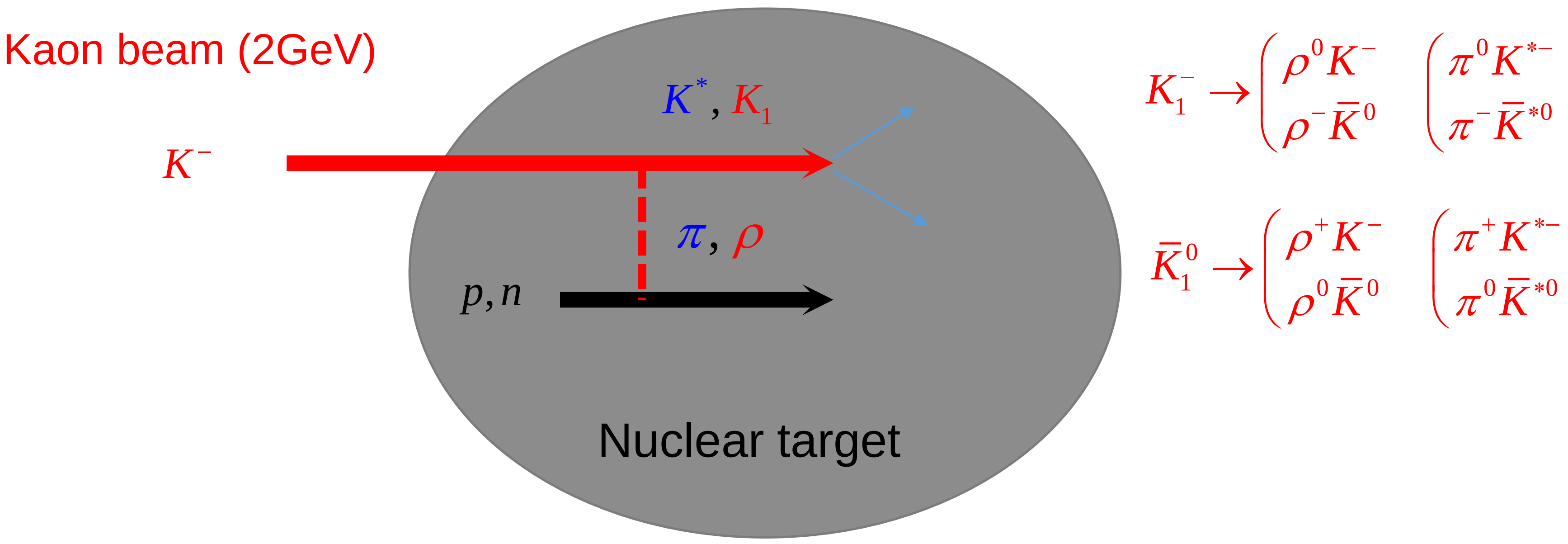
Example 2

Measuring chiral partners

→ K_1 excitation energy measurement at JPARC

Decay mode of K_1 (Γ=90MeV)

Decay mode	Fraction
K1(1270)→ K ρ	42 %
K1(1270)→ K* π	16 %



4. LHC: Heavy Ion Experiment, Exotic hadrons

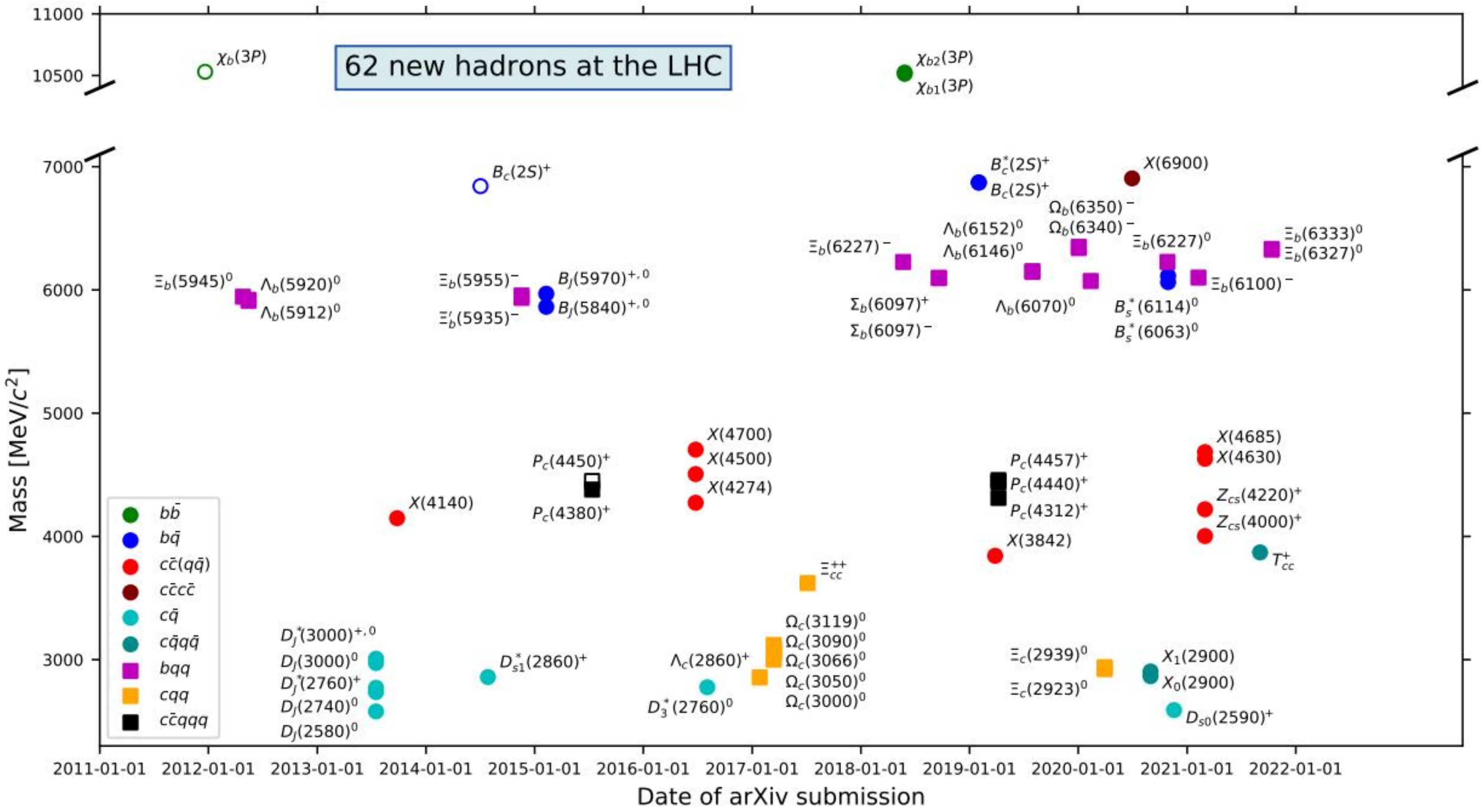
Research topics

- Properties of Quark-Gluon Plasma
- New hadrons, Exotics

Theoretical tools

- Lattice QCD (Through Potential)
- Duality?
- Statistical and Coalescence model
- Petrurbative QCD, and others

Recent LHCb publication arXiv:2206.15233…..



Example 3

Discriminating Structure -1

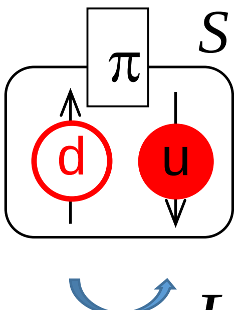
Ground state Mesons

$$J^P = (s+L)^{(-1)^{L+1}} \xrightarrow{\text{Ground states L=0}} (s)^{-1}$$

$J^P = 0^-$

$m_\pi^0 = 135 \text{ MeV}$

$S = 0$

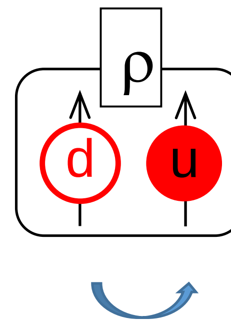


$L = 0$

$J^P = 1^-$

$m_\rho^0 = 775 \text{ MeV}$

$S = 1$



$L = 0$

P-wave Mesons

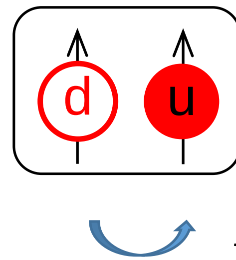
$$P = (-1)^{L+1}, \quad C = (-1)^{L+S}$$

$J^{PC} = 0^{++}$

$S = 1$

$m_{a_0}^{I=0} = 980\text{ MeV}$

$m_{f_0}^{I=1} = 980\text{ MeV}$



$L = 1$

or

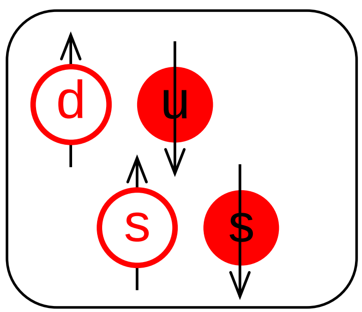
$J^{PC} = 0^{++}$

$S = L = 0$

$m_{a_0}^{I=0} = 980\text{ MeV}$

$m_{f_0}^{I=1} = 980\text{ MeV}$

Mass of 2 diquarks

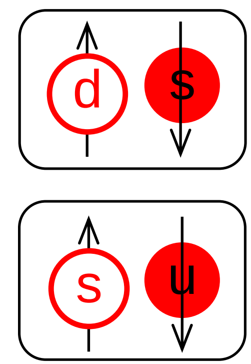


$J^{PC} = 0^{++}$

$m_{a_0}^{I=0} = 980\text{ MeV}$

$m_{f_0}^{I=1} = 980\text{ MeV}$

Mass of 2 Kaon



K^0

K^+

compact multiquark

Loosely bound molecule

ALICE measured f_0 $\rightarrow$ 전북대 김준이 김은주

Example 4   Exotics from Heavy Ion Collision

IOPscience

Heavy-ion collisions at the LHC—Last call for predictions

N Armesto[1], N Borghini[2], S Jeon[3], U A Wiedemann[4], S Abreu[5], S V Akkelin[6], J Alam[7], J L Albacete[8], A Andronic[9], D Antonov[10] + Show full author list

Published 18 April 2008 • 2008 IOP Publishing Ltd

Journal of Physics G: Nuclear and Particle Physics, Volume 35, Number 5

Citation N Armesto *et al* 2008 *J. Phys. G: Nucl. Part. Phys.* **35** 054001

Abstract

This writeup is a compilation of the predictions for the forthcoming Heavy Ion Program at the Large Hadron Collider, as presented at the CERN Theory Institute 'Heavy Ion Collisions at the LHC—Last Call for Predictions', held from 14th May to 10th June 2007.

Our contribution to the volume

10.3. Charmed exotics from heavy-ion collision

S H Lee, S Yasui, W Liu and C M Ko

We discuss why charmed multiquark hadrons are likely to exist and explore the possibility of observing such states in heavy-ion reactions at the LHC.

Multiquark hadronic states are usually unstable as their quark configurations are energetically above those of combined meson and/or baryon states. However, constituent quark model calculations suggest that multiquark states might become stable when some of the light quarks are replaced by heavy quarks. Two possible states that could be realistically observed in heavy-ion collisions at LHC are the tetraquark $T_{cc}(ud\bar{c}\bar{c})$ [385] and the pentaquark

J. Phys. G: Nucl. Part. Phys. **35** (2008) 054001 N Armesto *et al*

Table 10. Possible decay modes of T_{cc}. Additional $(\pi^+\pi^-)$'s are possible in the bracket.

Threshold	Decay mode	Lifetime
$M_{T_{cc}} > M_{D^*} + M_D$	$D^{*-}\bar{D}^0$	Hadronic decay
$2M_D + M_\pi < M_{T_{cc}} < M_{D^*} + M_D$	$\bar{D}^0\bar{D}^0\pi^-$	Hadronic decay
$M_{T_{cc}} < 2M_D + M_\pi$	$D^{*-}(K^+\pi^-)$	0.41×10^{-12} s
	$\bar{D}^0(\pi^-K^+\pi^-)$	Weak decay

nature physics

OPEN

Observation of an exotic narrow doubly charmed tetraquark

LHCb Collaboration*

Conventional, hadronic matter consists of baryons and mesons made of three quarks and a quark-antiquark pair, respectively[1,2]. Here, we report the observation of a hadronic state containing four quarks in the Large Hadron Collider beauty experiment. This so-called tetraquark contains two charm quarks, a $\bar{u}$ and a $\bar{d}$ quark. This exotic state has a mass of approximately 3,875 MeV and manifests as a narrow peak in the mass spectrum of $D^0D^0\pi^+$ mesons just below the $D^{*+}D^0$ mass threshold. The near-threshold mass together with the narrow width reveals the resonance nature of the state.

The similarity of the $cc\bar{u}\bar{d}$ tetraquark state and the Ξ_{cc}^{++} baryon containing two c quarks and a u quark leads to a relationship between the properties of the two states. In particular, the measured mass of the Ξ_{cc}^{++} baryon with quark content ccu[50–52] implies that the mass of the $cc\bar{u}\bar{d}$ tetraquark is close to the sum of the masses of the D^0 and D^{*+} mesons with quark content of $c\bar{u}$ and $c\bar{d}$, respectively, as suggested in ref. [53]. Theoretical predictions for the mass of the $cc\bar{u}\bar{d}$ ground state with spin-parity quantum numbers $J^P = 1^+$ and isospin $I = 0$, denoted hereafter as T_{cc}^+, relative to the $D^{*+}D^0$ mass threshold

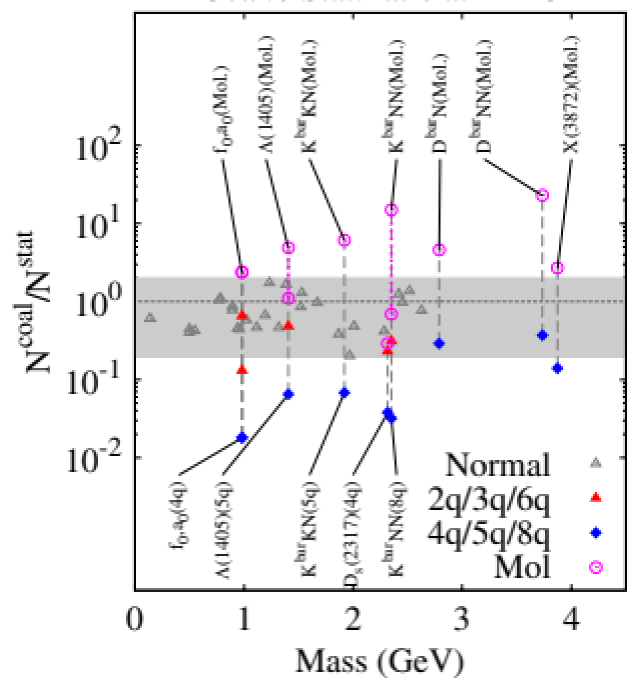
Theory prediction

PRL **106,** 212001 (2011) PHYSICAL REVIEW LETTERS week ending 27 MAY 2011

Identifying Multiquark Hadrons from Heavy Ion Collisions

Sungtae Cho,[1] Takenori Furumoto,[2,3] Tetsuo Hyodo,[4] Daisuke Jido,[2] Che Ming Ko,[5] Su Houng Lee,[1,2] Marina Nielsen,[6] Akira Ohnishi,[2] Takayasu Sekihara,[2,7] Shigehiro Yasui,[8] and Koichi Yazaki[2,3]

(ExHIC Collaboration)



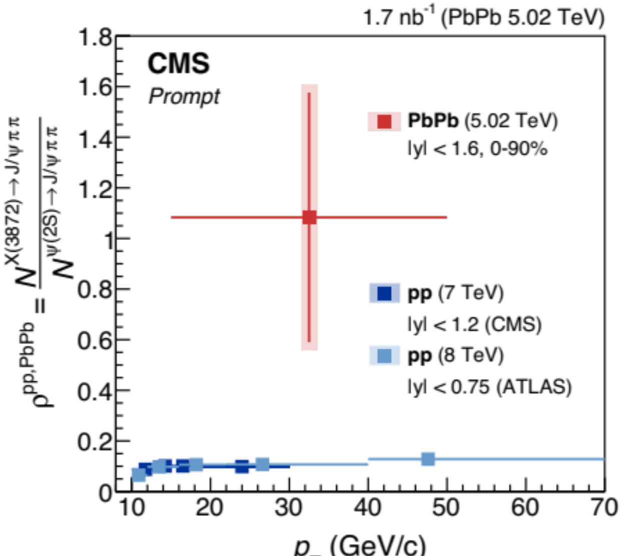
Experiment

PHYSICAL REVIEW LETTERS **128,** 032001 (2022)

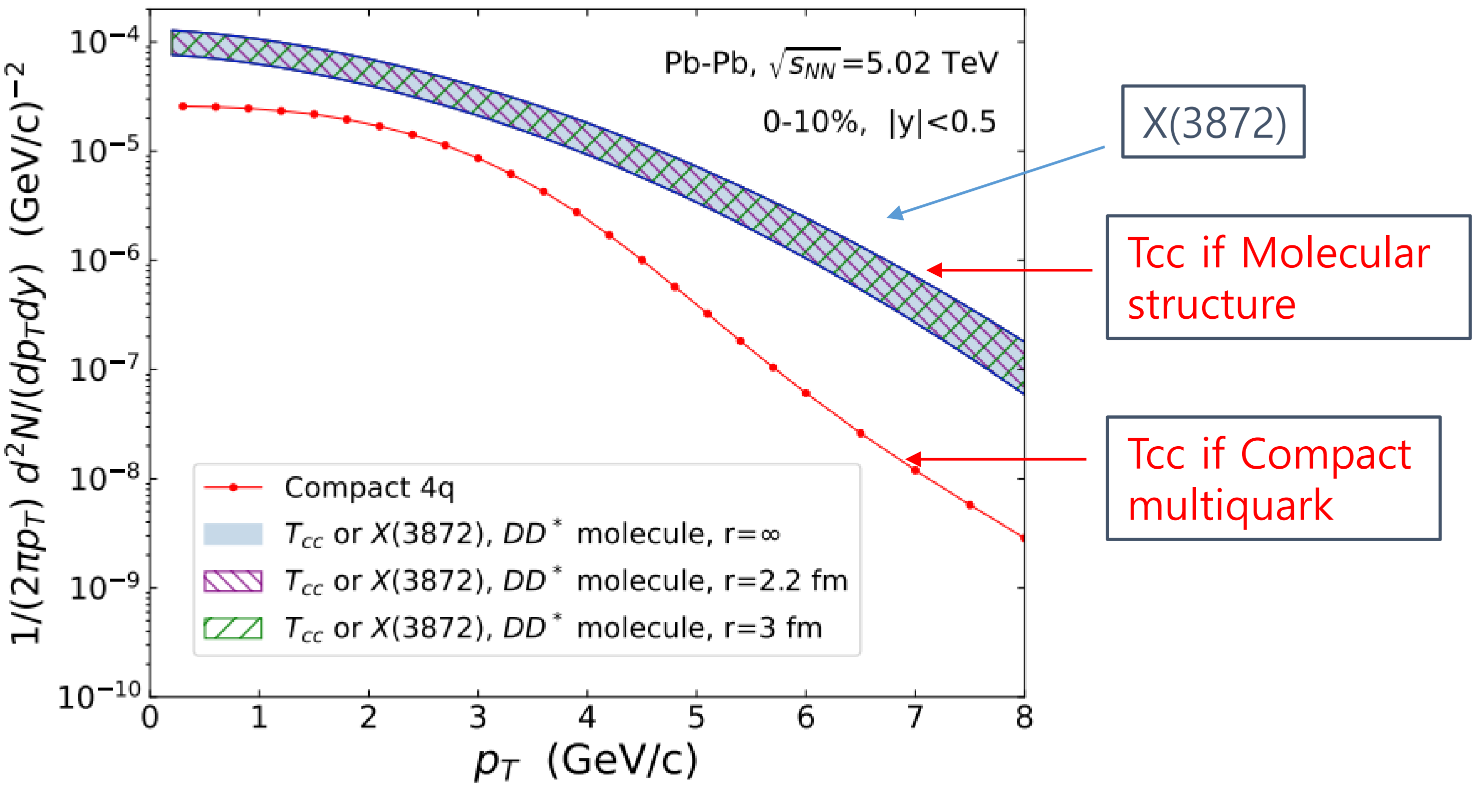
Evidence for X(3872) in Pb-Pb Collisions and Studies of its Prompt Production at $\sqrt{s_{NN}} = 5.02$ TeV

A. M. Sirunyan *et al.**

CMS Collaboration



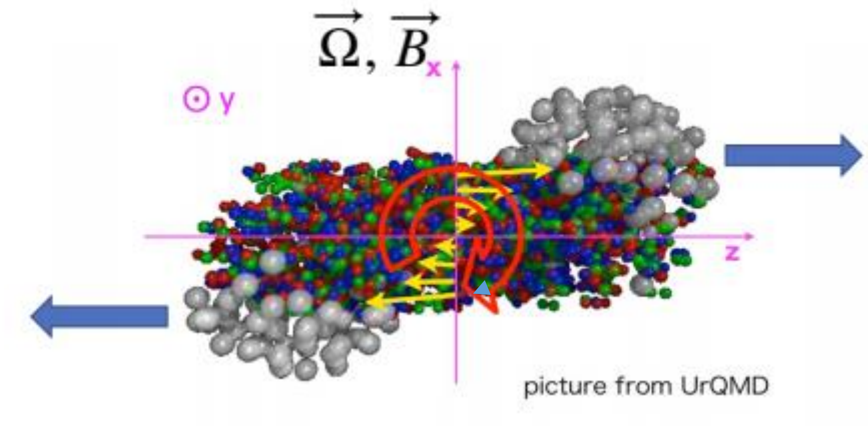
Can discriminate the structure by observing the PT dependence

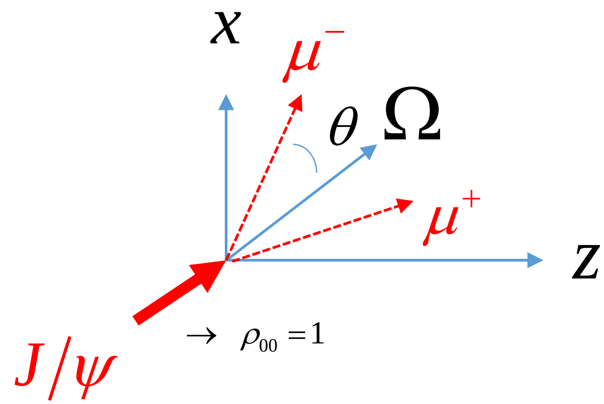


전망

Prospect -1 where does vector meson spin come from

- Spin of composite particle





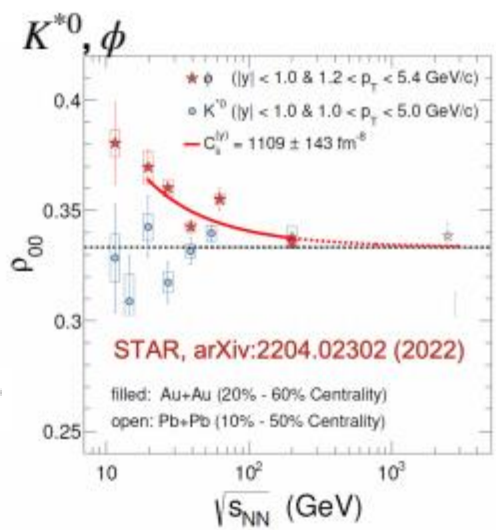
$$d\Gamma \propto (1+\lambda_\theta \cos\theta), \quad \lambda_\theta \propto (3\rho_{00}-1)$$

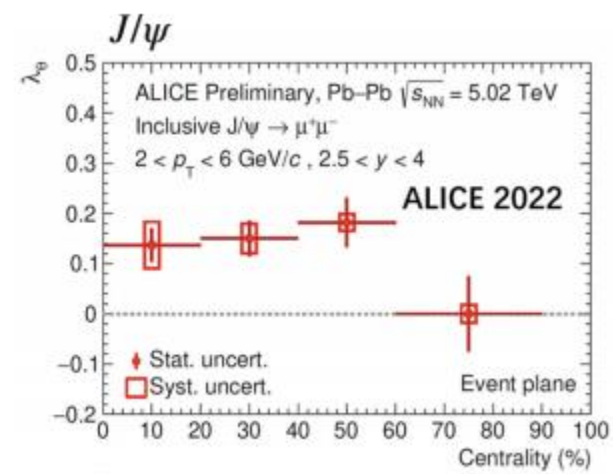
Scalar: $H_r = H_i - L\cdot\Omega.$

Spin1/2: $H_r = H_i - (L+S)\cdot\Omega$

Then, Spin1: $H_r = H_i - (L+S)\cdot\Omega$?

HyungJoo Kim (Yonsei U)





Prospect -2 Neutron star equation of state

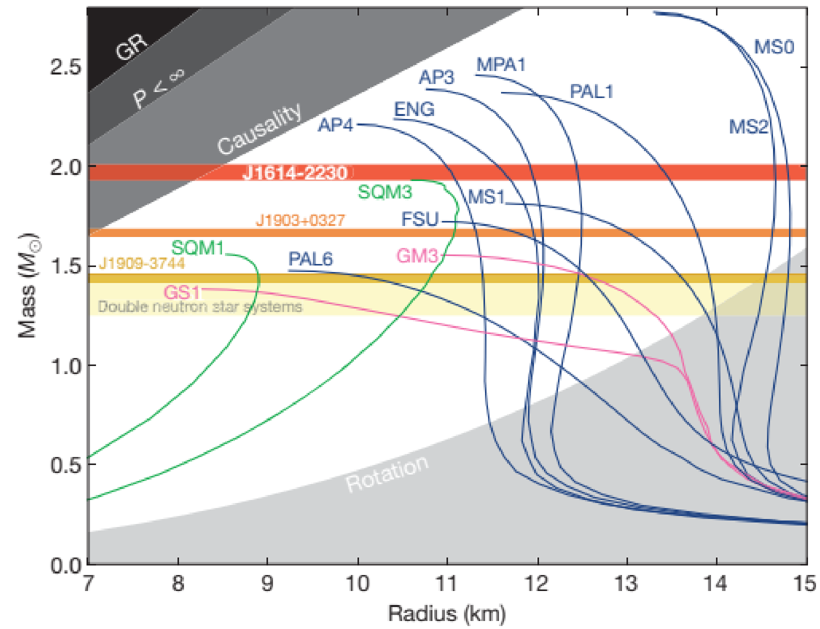
- Multi-messanger astrophysics: Neutron star: anomalous property of speed of sound, quarkyonic matter

LETTER

doi:10.1038/nature09466

A two-solar-mass neutron star measured using Shapiro delay

P. B. Demorest[1], T. Pennucci[2], S. M. Ransom[1], M. S. E. Roberts[3] & J. W. T. Hessels[4,5]



To support the massive neutron stars whose masses are larger than two times the solar mass, it was found that the equation of states for dense matter had to be sufficiently hard.

Prospect -2 Neutron star equation of state

PHYSICAL REVIEW LETTERS **121**, 161101 (2018)

Editors' Suggestion

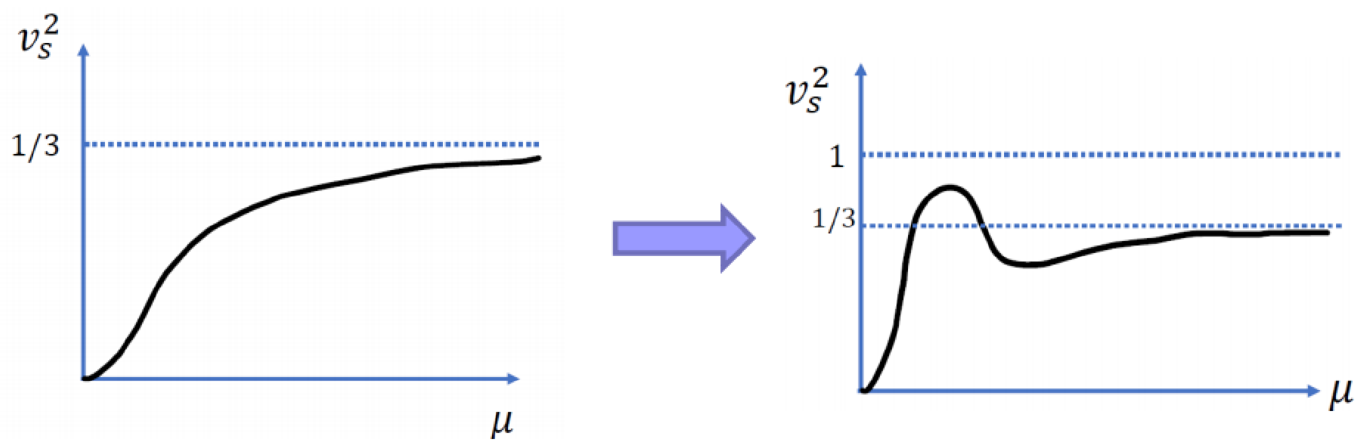
GW170817: Measurements of Neutron Star Radii and Equation of State

B. P. Abbott *et al.*[*]
(The LIGO Scientific Collaboration and the Virgo Collaboration)

The tidal deformability constrained via the GW170817 observation requires a relatively soft equation of states.

Speed of sound

$$v_s^2 = \frac{dP}{d\epsilon}$$

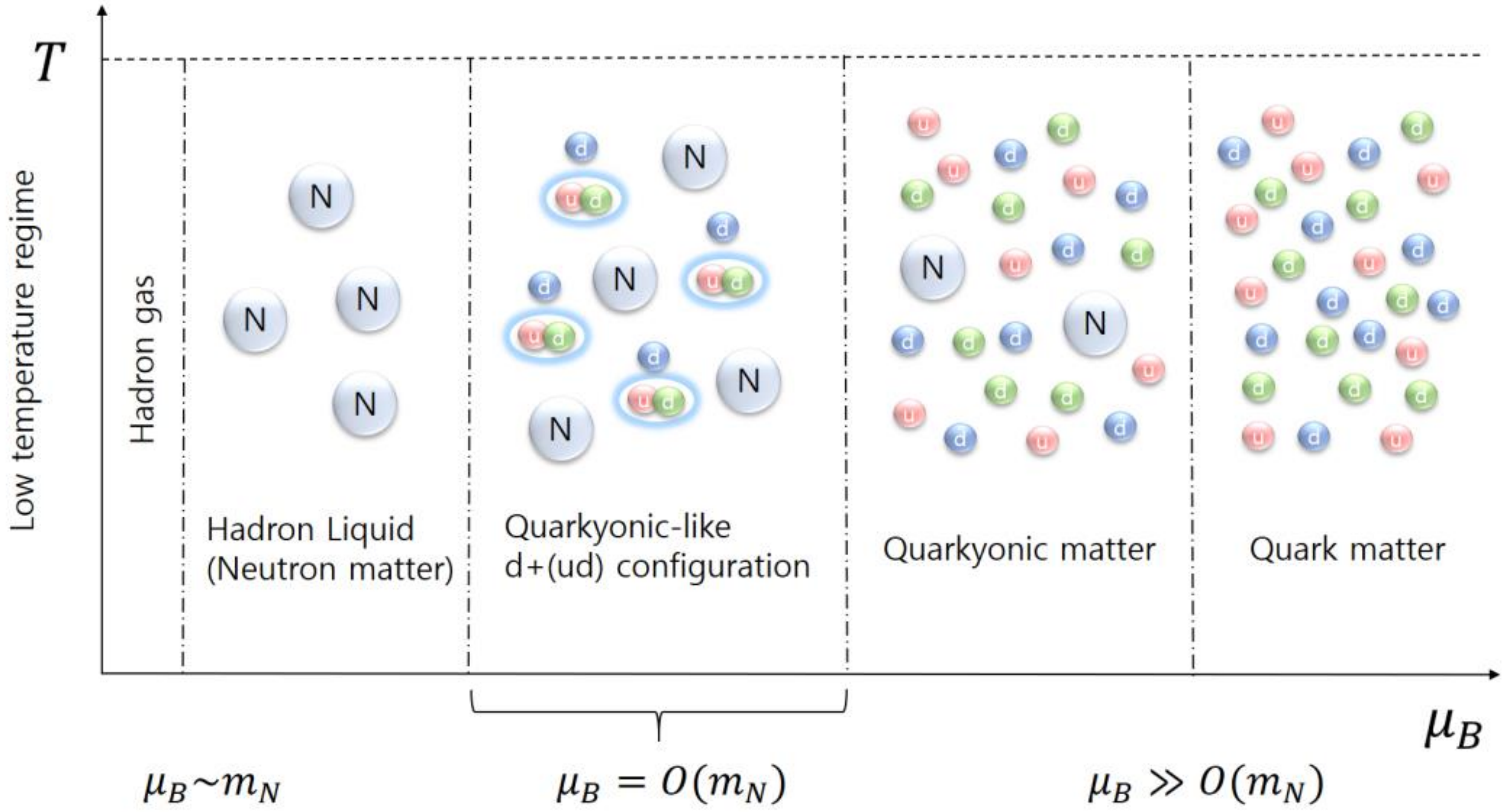


PHYSICAL REVIEW LETTERS **122**, 122701 (2019)

Quarkyonic Matter and Neutron Stars

Larry McLerran and Sanjay Reddy
Institute for Nuclear Theory and Department of Physics, University of Washington, Seattle, Washington 98195, USA

Prospect -2 Neutron star equation of state




PHYSICAL REVIEW D **104,** 094024 (2021)

Case for quarkyoniclike matter from a constituent quark model

Aaron Park,[1,*] Kie Sang Jeong,[2,†] and Su Houng Lee[1,‡]

Prospect -3 : Nuclear Physics and High Energy Physics

- KSHEP can be a place for collaboration to tackle these problems

Extra

$$H=\sum_{i=1}^{n}\left(m_i+\frac{p_i^2}{2m_i}\right)-\sum_{i<j}^{n}\left(\lambda_i^c\lambda_j^c\right)V_{ij}^C\left(r_{ij}\right)-\sum_{i<j}^{n}\frac{\left(\lambda_i^c\lambda_j^c\right)\left(\sigma_i\sigma_j\right)}{m_im_j}V_{ij}^{SS}\left(r_{ij}\right)$$

☞ Color-Color interaction is not important for short range N-N interaction

$$\sum_{i<j}^{N}\left(\lambda_i^c\lambda_j^c\right)=\frac{1}{2}\left[\left(\lambda_1^c+\ldots+\lambda_N^c\right)^2-\lambda_1^2-\ldots\lambda_N^2\right]=\sum_{i<j}^{N_{B_1}}\left(\lambda_i^c\lambda_j^c\right)+\sum_{i<j}^{N_{B_2}}\left(\lambda_i^c\lambda_j^c\right)$$

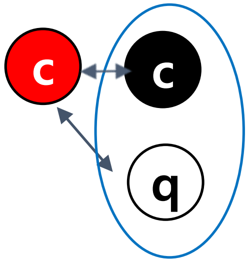
☞ Color-spin interaction for 2 body:

$$K=-\sum_{i<j}^{N}\left(\lambda_i^c\lambda_j^c\right)\left(\sigma_i^s\sigma_j^s\right)\longrightarrow$$

	$Q-Q$				$Q-\bar{Q}$			
Color	A	S	A	S	1	8	1	8
Flavor	A	A	S	S				
Spin	A(0)	S(1)	S(1)	A(0)	0	0	1	1
K	-8	-4/3	8/3	4	-16	2	16/3	-2/3

$K<0$ attraction; $K>0$ repulsion

☞ Coulomb interaction



$$H_{cc} = \ldots + \lambda_i^c \lambda_j^c \left(\frac{g}{r_{ij}} \right) + \ldots. \qquad r \approx \frac{1}{mg^2}, \qquad E_C \approx -mg^4$$

☞ Color-Color interaction between c and color singlet $c\bar{q}$

if the color state of cc is attractive, $\lambda_c^a \left(\lambda_c^a \right) < 0$, then since $r_{cc} < r_{cq}$,

there will be attraction

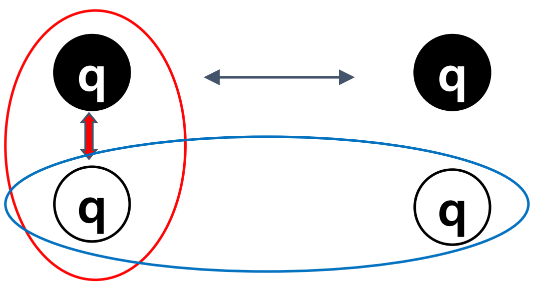
$$H_{cc} + H_{c\bar{q}} = \ldots.\lambda_c^a \left(\lambda_c^a \frac{g}{r_{cc}} + \lambda_q^a \frac{g}{r_{cq}} \right) < 0$$

Mass effect in Color-Spin interaction: Example Tcc (Ballot, Richard 83)

	Q–Q				$Q-\bar{Q}$			
Color	A	S	A	S	1	8	1	8
Flavor	A	A	S	S				
Spin	A(0)	S(1)	S(1)	A(0)	0	0	1	1
K	-8	-4/3	8/3	4	-16	2	16/3	-2/3

Fall apart into two mesons

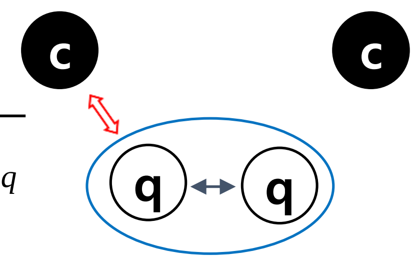
$$-16\frac{1}{m_q m_q}$$



$$-8\frac{1}{m_q m_q}$$

When heavy quarks, could be compact

$$-16\frac{1}{m_c m_q}$$



$$-8\frac{1}{m_q m_q}$$

Indeed many heavy exotics were found

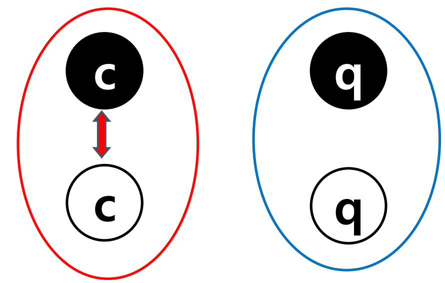
But still not clear about their structure

Compact multiquarks or loosely bound molecules

Will Look at X(3872) and Tcc(3875)

Can they be compact?

Dominant $\left(C=\text{color},\ S=\text{spin}\right)$ state?



$\left(c\bar{c}\right)\otimes\left(q\bar{q}\right)$

Color-spin (K factor)

$$I^G\left(J^{PC}\right)=0^+\left(1^{++}\right)$$

$\sim +140$ MeV

$$K_{X(3872)}-K_D-K_{D*}=\begin{pmatrix} \frac{16}{3}\frac{1}{m_c^2}+\frac{16}{3}\frac{1}{m_q^2}+\frac{32}{3}\frac{1}{m_c m_q} & 0 \\ 0 & -\frac{2}{3}\frac{1}{m_c^2}-\frac{2}{3}\frac{1}{m_q^2}-\frac{4}{3}\frac{1}{m_c m_q} \end{pmatrix}$$

$(1,1)\otimes(1,1)$

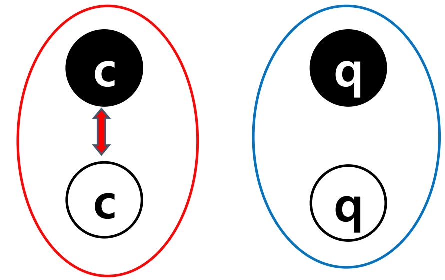
$(8,1)\otimes(8,1)$

~ -20 MeV

Hence X(3872) could be in
$$\begin{cases} \left(c\bar{c}\right)\rightarrow\left(C=8,S=1\right) \\ \left(q\bar{q}\right)\rightarrow\left(C=8.S=1\right) \end{cases}$$

$$\text{X(3872)} \begin{cases} (c\bar{c}) \rightarrow (C=8, S=1) \\ (q\bar{q}) \rightarrow (C=8.S=1) \end{cases}$$

$$H_{cc} = \lambda_c^a \left(\lambda_c^a \frac{g}{r_{cc}} \right) \ ?$$



Color-Color

$$\lambda_c^a \left(\lambda_c^a \right) = \frac{1}{2} \left[\left(\lambda_c^a + \lambda_c^a \right)^2 - \lambda_c^2 - \left(\lambda_c^a \right)^2 \right]$$

$$\frac{1}{4}\lambda^2 = C = \frac{1}{3}\left(p^2 + q^2 + pq + 3(p+q)\right) \quad C(p=1, q=1) = 3, \quad C_f(p=1, q=0) = \frac{4}{3}$$

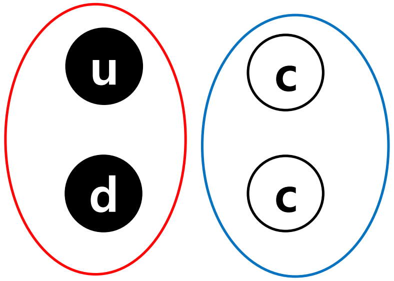
If cc is in $(C=8, S=1)$ $\qquad \lambda_c^a \left(\lambda_c^a \right) = \frac{4}{2}\left[3 - 2\frac{4}{3}\right] = \frac{2}{3} > 0$

No additional attraction from color-color interaction

→ X(3872) can not be compact multiquark state

Tcc(3875) : W. Park, SHLee, NPA924(2014) 161

Dominant $\left(C = \text{color},\ S = \text{spin}\right)$ state?



Color-spin (K factor)

$$I^G\left(J^P\right) = 0^+\left(1^+\right) \qquad (ud)\otimes(\overline{c}\overline{c})$$

~ -100 MeV

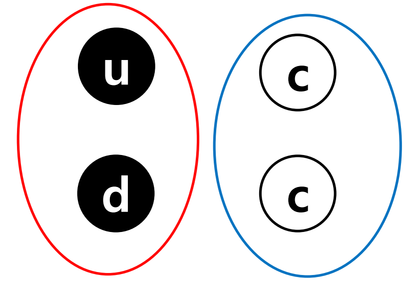
$$K_{T_{cc}(3875)} - K_D - K_{D^*} = \begin{pmatrix} -8\dfrac{1}{m_q^2} + \dfrac{8}{3}\dfrac{1}{m_c^2} + \dfrac{32}{3}\dfrac{1}{m_c m_q} & -8\sqrt{2}\dfrac{1}{m_c m_q} \\ -8\sqrt{2}\dfrac{1}{m_c m_q} & -\dfrac{4}{3}\dfrac{1}{m_q^2} + 4\dfrac{1}{m_c^2} + \dfrac{32}{3}\dfrac{1}{m_c m_q} \end{pmatrix} \begin{matrix} (\overline{3},0)\otimes(3,1) \\ (6,1)\otimes(\overline{6},0) \end{matrix}$$

$\sim +17$ MeV

Hence Tcc(3875) could be in $\begin{cases} (ud) \to \left(C = \overline{3}, S = 0\right) \\ (\overline{c}\overline{c}) \to \left(C = 3.S = 1\right) \end{cases}$

Tcc(3875) : W. Park, SHLee, NPA924(2014) 161

Tcc(3875) $\begin{cases}(ud)\to\left(C=\bar{3},S=0\right)\\ \left(\overline{cc}\right)\to\left(C=3.S=1\right)\end{cases}$ $H_{cc}=\lambda_c^a\left(\lambda_c^a\frac{g}{r_{cc}}\right)$?



Color-Color

$$\lambda_c^a\left(\lambda_c^a\right)=\frac{1}{2}\left[\left(\lambda_c^a+\lambda_c^a\right)^2-\lambda_c^2-\left(\lambda_c^a\right)^2\right]$$

$$\frac{1}{4}\lambda^2=C=\frac{1}{3}\left(p^2+q^2+pq+3\left(p+q\right)\right)\quad C\left(p=0,q=1\right)=\frac{4}{3},\quad C\left(p=1,q=0\right)=\frac{4}{3}$$

If $\overline{cc}$ is in $\left(C=3,S=1\right)$ $\lambda_c^a\left(\lambda_c^a\right)=\frac{4}{2}\left[\frac{4}{3}-2\frac{4}{3}\right]=-\frac{8}{3}<0$

Hence there is additional attraction

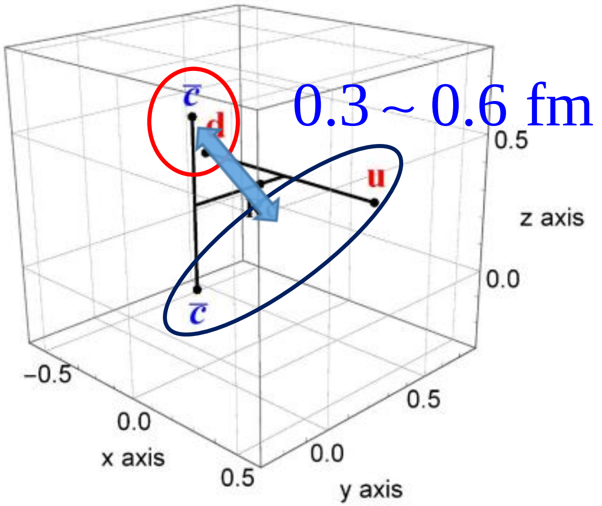
→ Tcc(3875) could be a compact multiquark state

Attraction expected from quark Model: S.Noh, A.Park, D.Park Lee (in preparation)

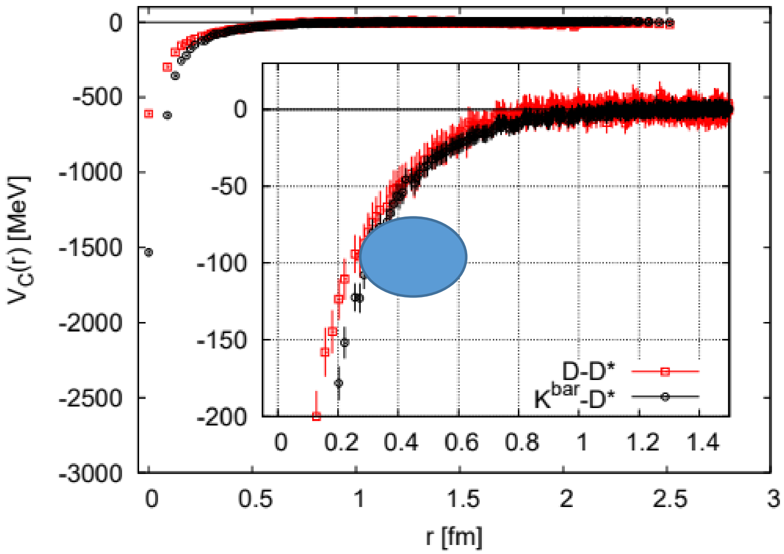
T_{cc}(3875) $I^G\left(J^P\right)=0^+\left(1^+\right)$

(S. No, W. Park, SHL, PRD10 (2021)114009)

$$K_{T_{cc}(3875)}-K_D-K_{D^*} \rightarrow \; -100 \text{ MeV}$$



☞ Consistent to Lattice (HAL QCD): Phys. Lett. B 729 (2014) 85



$m_\pi \simeq 410$ MeV

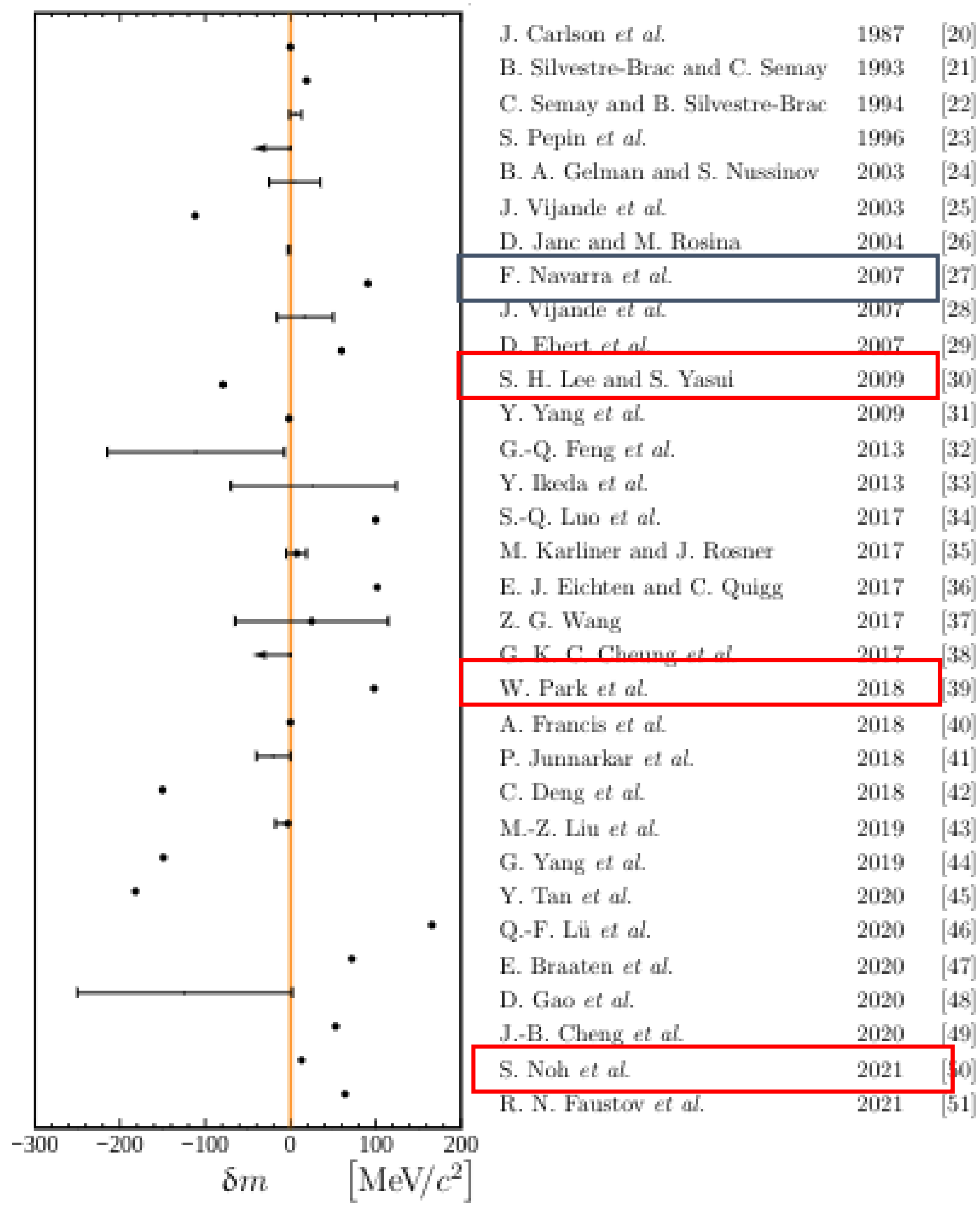
Full Quark Model calculation suggests: ex S.Noh, W.Park, Lee, PRD10(2021)114009

-2021- Tcc(3875) LHCb coll.

☞ There is a strong short range attraction for Tcc → Could be compact, but depends sensitively on parameters:

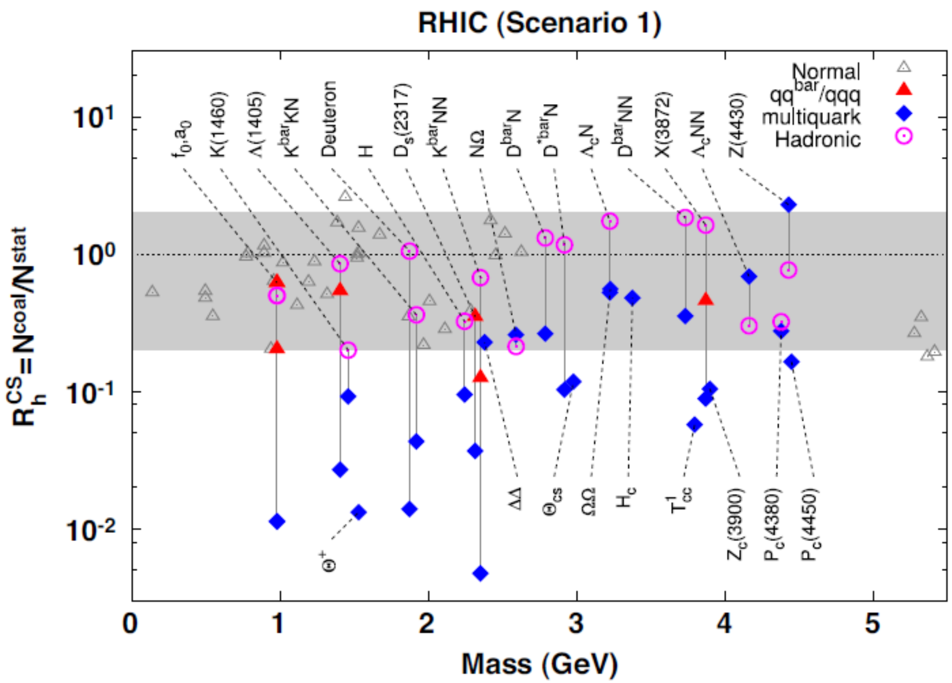
☞ The short range attraction for X(3872) is very weak

→ Can not be compact



Production of compact multiquark state in 2017

Production rate normalized to statistical model



Normal Hadron

Molecule

Compact multiquark

Progress in Particle and Nuclear Physics 95 (2017) 279–322

Exotic hadrons from heavy ion collisions☆

Sungtae Cho[a], Tetsuo Hyodo[b], Daisuke Jido[c], Che Ming Ko[d], Su Houng Lee[e,*], Saori Maeda[f], Kenta Miyahara[g], Kenji Morita[b], Marina Nielsen[h], Akira Ohnishi[b], Takayasu Sekihara[i], Taesoo Song[j], Shigehiro Yasui[f], Koichi Yazaki[k] (ExHIC Collaboration)

A simple fit to Deuteron and ^{3}He using (R_b ,V) - II

1. For r>1.9 fm result are similar to $\sigma \rightarrow$ infinity result
2. Both can be fit by choosing R_b=0.36 → similar to feed-down effects SHM
3. V(2-dim)=608 fm^2