Collaborative research center CRC 110

"Symmetries and the emergence of structure in QCD"

The Sino-German CRC

Annal reports and future plan from Chinese perspectives

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Deutsche Forschungsgemeinschaft DFG

国家自然科学基金委员会 National Natural Science Foundation of China

Annal reports to NSFC

- **Project approved from NSFC: Dec. 17, 2020**

  direct fund 13M CNY + indirect fund 2.1M CNY

- **Midterm CRC meeting: June 7-9, 2022**

- **Publication list in AR2021 & 2022: 79 & 87 papers**

  exotic hadrons, dibaryons &nuclei, precise test of SM & LQCD

- **Big NSFC funds by our CRC PLs & former students or postdocs:**

  Major project on Lattice QCD in 2022: Chuan Liu & Ying Chen (12M CNY)

  Outstanding young scientists in 2021: Feng-kun Guo, Xu Feng, Wei Wang

  Excellent young scientists: Jian Liang (2022), Ling-yun Dai (2023)

- **Awards**

  Humboldt research award in 2022: Jie Meng

  Hu Jimin nuclear award in 2023: Xiang-kun Dong

Research highlights 2021 & 2022

- **exotic hadrons :**

Dong, Guo, Zou, "Explaining the many **threshold structures** in hadron spectrum with heavy quarks", PRL126(2021)152001 76 cites

"A survey of heavy-antiheavy hadronic molecules", Prog.Phys.41(2021)65 105 cites

"A survey of heavy-heavy hadronic molecules", CTP 73 (2021) 125201 97 cites

Dong, Baru, Guo, Hanhart, Nefediev, "Coupled channel interpretation of the LHCb **double J/ψ spectrum** and hints of …", PRL126(2021)132001 73 cites

Meng, Wang[2], Zhu, "Probing the long-range structure of the T_{cc}^{+} with the strong and electromagnetic decays", PRD104(2021)L051502 53 cites

Ji, Dong, Guo, Zou, "Prediction of a narrow exotic hadronic state with $J^{PC} = 0^{--}$", PRL 129 (2022) 102002

Dong, Lin, Zou, "Interpretation of the **$\eta_1(1855)$** as a $\bar{K}K_1(1400)$+c.c. molecule", SCIENCE CHINA Physics, Mechanics & Astronomy 65 (2022) 261011

Yang, Wang, Wu, Oka, Zhu, "Novel coupled channel framework … for the **near-threshold D_s states**", PRL 128 (2022) 112001

Gong, Du, Zhao, "**Double η_c** interactions via Pomeron …", PRD 106(2022)054011

……

→ **talks by Feng-kun, Shi-lin, Qian, Qiang, …**

Research highlights 2021 & 2022 cont'd

- **dibaryons & nuclei:**

Lyu, Tong, Sugiura, Aoki, Doi, Hatsuda, Meng, Miyamoto, "**Dibaryon** with highest charm number near unitarity from lattice QCD, PRL127(2021) 072003
Zhang, He, Meng et al., "Predictive power for **superheavy nuclear mass and possible stability beyond the neutron drip line** …, PRC104(2021)024331
Sun, Zhou, "**Rotating deformed halo nuclei** and shape decoupling effects", Sci. Bulletin 66, 20 (2021) 2072
Ren, Vretenar, Nikšić, Zhao, Zhao, Meng, "**Dynamical synthesis of ^{4}He** in the scission phase of nuclear fission", PRL128 (2022) 172501
Ren, Zhao, Meng, "Dynamics of rotation in **chiral nuclei**", PRC105(2022)L011301
JYao, Meng, Niu, Ring, "Beyond-mean-field approaches for **nuclear neutrinoless double beta decay** in the standard mechanism", Prog. PNP 126(2022)103965
Dong, Shen, Zhang, "**d*(2380)** in a chiral constituent quark model", Prog. Part. Nucl. Phys. 131 (2023) 104045
……

→ **talks by Shan-gui, Yu-bing, Jie(Yang) , …**

Research highlights 2021 & 2022 cont'd

- **precise test of SM & LQCD :**

Feng, Jin, Riberdy, "Lattice QCD Calculation of the **Pion Mass Splitting**", PRL128(2022)052003

Li, Xia, Alexandrou, Cichy, Constantinou, Feng, Hadjiyiannakou, Jansen, Liu et al., "Lattice QCD Study of **TMD Soft Function**", PRL128 (2022) 062002

Fu, Feng, Jin, Lu, "Lattice QCD calculation of two-photon exchange contribution to the **muonic-hydrogen Lamb shift**", PRL128 (2022) 172002

Hua, Li, Lv, Wang, Xing, "Global analysis of **hadronic two-body B decays** in the perturbative QCD approach"， PRD 104 (2021) 016025

Feng, Huang, Jia, Sang, Xiong, Zhang, "Fragmentation **production of fully-charmed tetraquarks** at LHC", PRD106(2022)114029

Jiang, Chen[2], Gong, Li, Liu, Sun, Zhang, "**Radiative decay width of $J/\psi\to\gamma\eta(2)$** from Nf=2 Lattice QCD", PRL130 (2023) 061901

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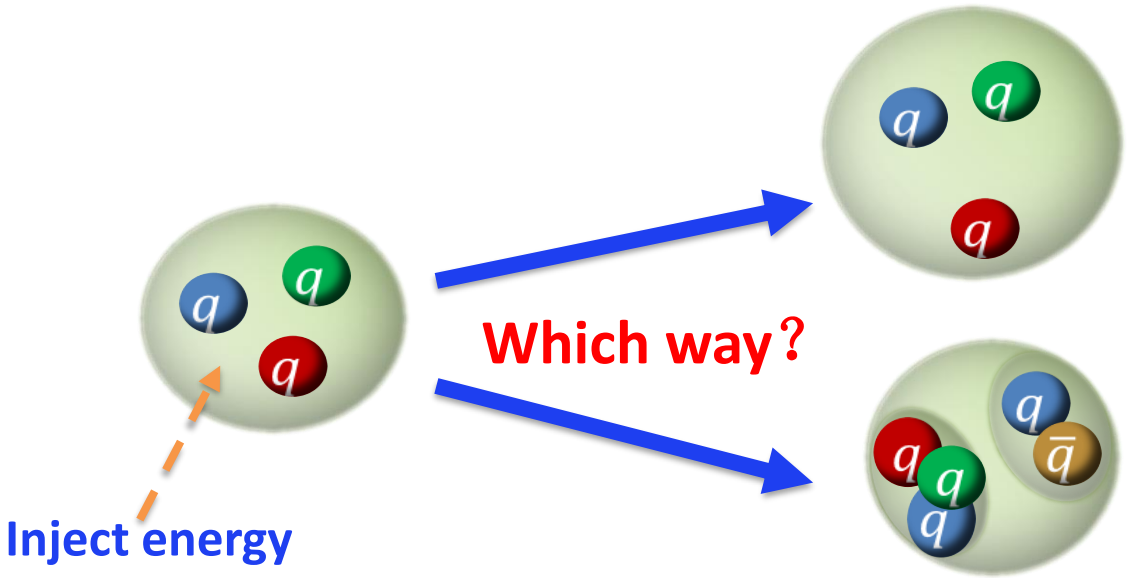
→ **talks by Xu, Chuan, Ying, Yu, Caidian (Li) , …**

Physics at B2 & B11: **Hadronic molecules**



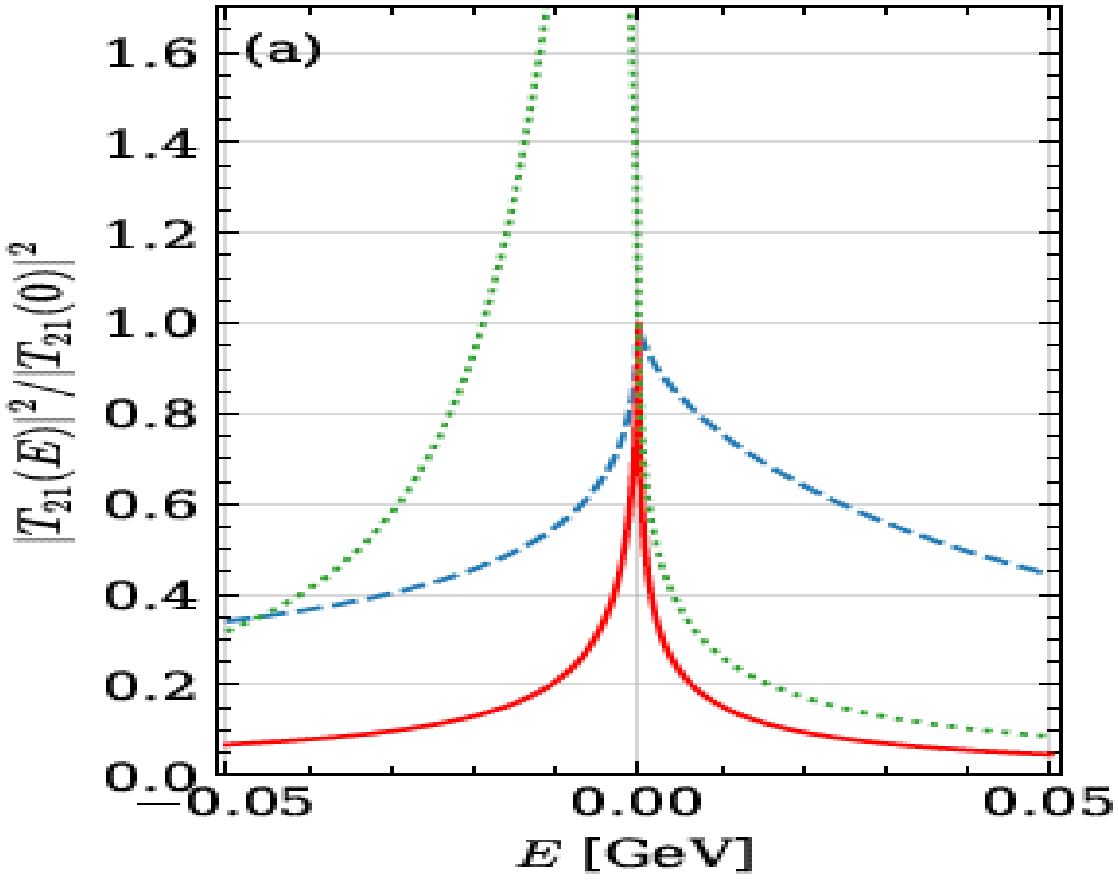
Classical Quark model

Our new view

unquenching dynamics -- key ingredient for hadron spectroscopy !

Explaining the many threshold structures in hadron spectrum with heavy quarks

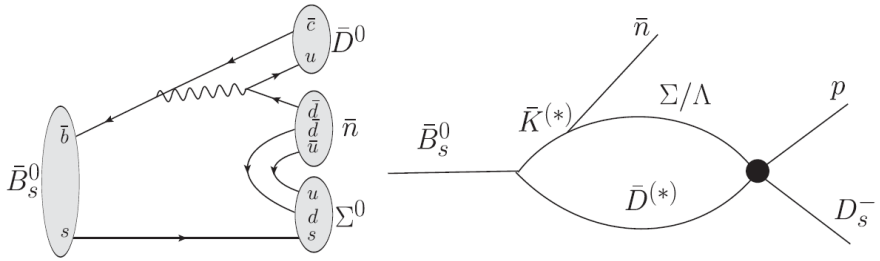
X.K.Dong, F.K.Guo, B.S.Zou, PRL126 (2021) 152001



More pentaquark hadronic molecules

N.Yalikun, B.S.Zou, Phys. Rev. D105 (2022) 094026:

Prediction of $\bar{D}\Sigma$ & $\bar{D}^*\Sigma$ hadronic molecules to be looked for from $\bar{B}_s \to \bar{n}pD_s^-$



Z.L.Wang, C.W.Shen, D.Rönchen, U.-G. Meißner, B.S.Zou, Eur. Phys. J. C82 (2022) 497

$\bar{D}\Lambda_c$ - $\bar{D}\Sigma_c$ - $\bar{D}^*\Lambda_c$ - $\bar{D}^*\Sigma_c$ - $\bar{D}\Sigma_c^*$ coupled channel interactions

Table 3 Pole positions z_R and spin-parities J^P for the states in other partial waves. Some poles with even larger widths are not listed

J^P	z_R[MeV]
$\frac{1}{2}^+$	$4339.3 - i\,106.3$
$\frac{3}{2}^+$	$4401.4 - i\,128.8$
$\frac{3}{2}^+$	$4463.1 - i\,90.1$
$\frac{5}{2}^+$	$4386.0 - i\,95.2$
$\frac{7}{2}^-$	$4430.8 - i\,214.1$

Prediction of a narrow exotic hadronic state with $J^{PC} = 0^{--}$

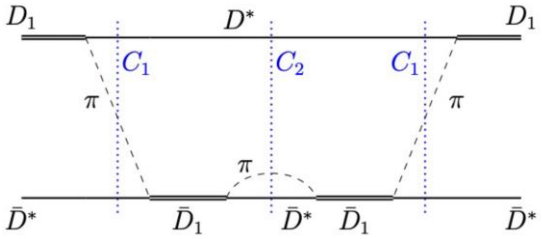
T.Ji, X.K.Dong, F.K.Guo, B.S.Zou, Phys. Rev. Lett. 129 (2022) 102002

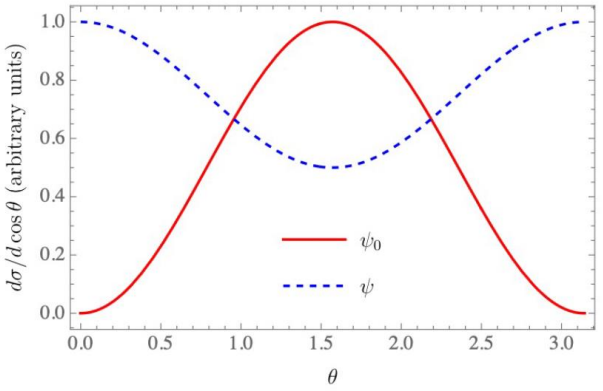
Molecule	Components	J^{PC}	Threshold	E_B
$\psi(4230)$	$\frac{1}{\sqrt{2}}(D\bar{D}_1 - \bar{D}D_1)$	1^{--}	4287	67 ± 15
$\psi(4360)$	$\frac{1}{\sqrt{2}}(D^*\bar{D}_1 - \bar{D}^*D_1)$	1^{--}	4429	62 ± 14
$\psi(4415)$	$\frac{1}{\sqrt{2}}(D^*\bar{D}_2^* - \bar{D}^*D_2^*)$	1^{--}	4472	49 ± 4
ψ_0	$\frac{1}{\sqrt{2}}(D^*\bar{D}_1 + \bar{D}^*D_1)$	0^{--}	4429	$\mathbf{63 \pm 18}$

May be searched for using $e^+e^- \to \psi_0\eta, \psi_0 \to J/\psi\eta, D\bar{D}^*, D^*\bar{D}^*\pi, \ldots$

$M = (4366 \pm 18)$ MeV,

$\Gamma < 10$ MeV





Hybrid, Glueball or hadronic molecules ?

Observation of $\eta_1(1855)$ with exotic $J^{PC}=1^{-+}$ in $J/\psi \to \gamma\eta\eta'$

BESIII Collaboration, PRL129 (2022) 192002

Interpretation of the $\eta_1(1855)$ as a $\bar{K}K_1(1400)$+ c.c. molecule

X.K.Dong, Y.H.Lin, B.S.Zou, SCIENCE CHINA PMA 65 (2022) 261011

Two dynamical generated a_0 resonances by VV interactions

Z.L.Wang, B.S.Zou, EPJC 82 (2022) 509

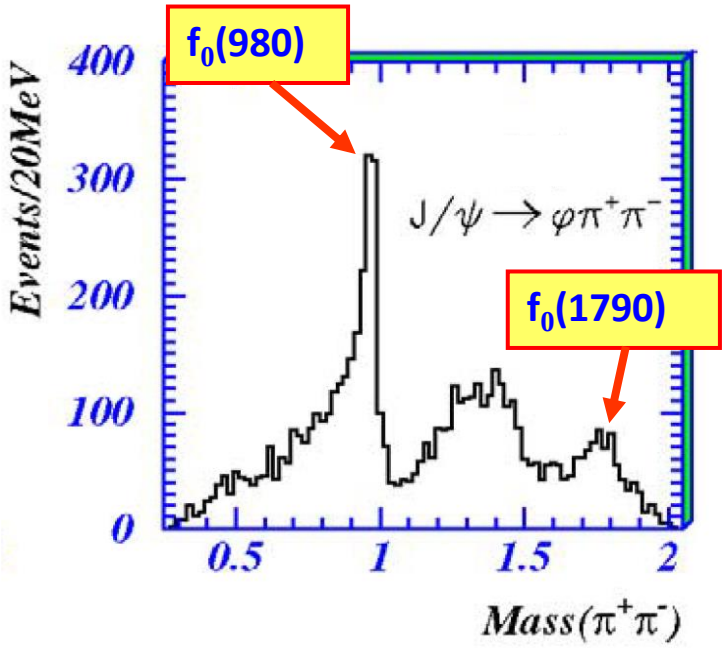
$\rho\rho$ / $\rho\omega$ molecules → $f_0(1500)$ / $a_0(1450)$

$\bar{K}^*K^*$(I=0,1) molecules → $f_0(1750)$ / $a_0(1750)$

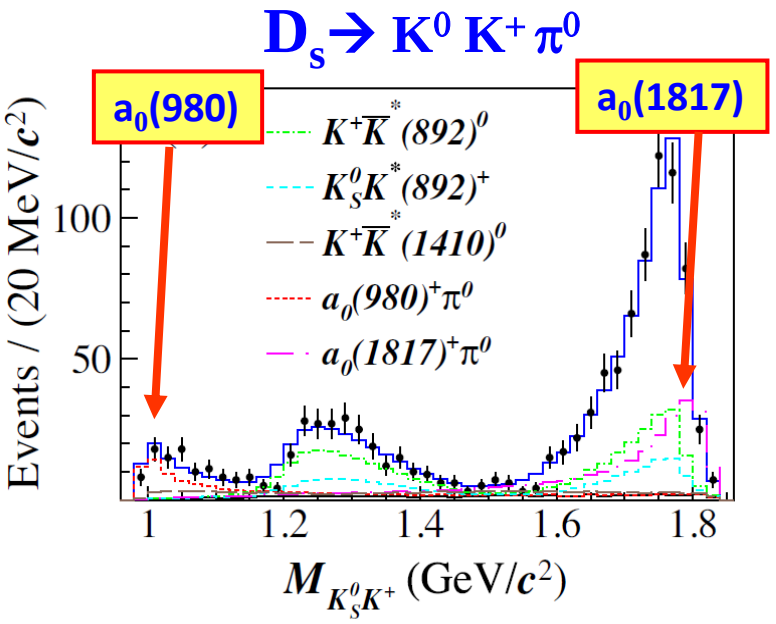
Observation of $a_0(1817) \to K_S^0K^+$ in $D_s^+ \to K_S^0K^+\pi^0$ decay

BESIII Collaboration, PRL129 (2022) 182001

$\bar{K}K$ & $\bar{K}^*K^*$ molecules – f_0/a_0 (980) & f_0/a_0 (1790) at BES



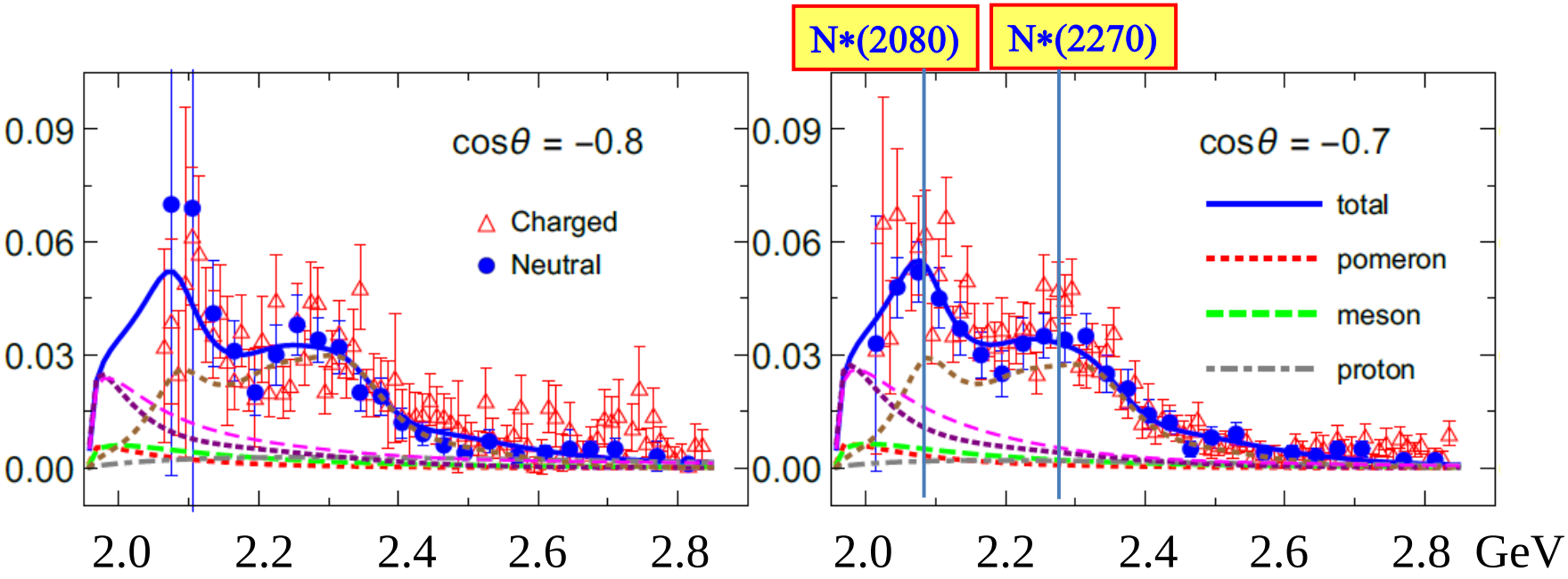
BESII, PLB607 (2005) 243



BESIII, PRL129 (2022) 182001

$\gamma p \to \phi p$

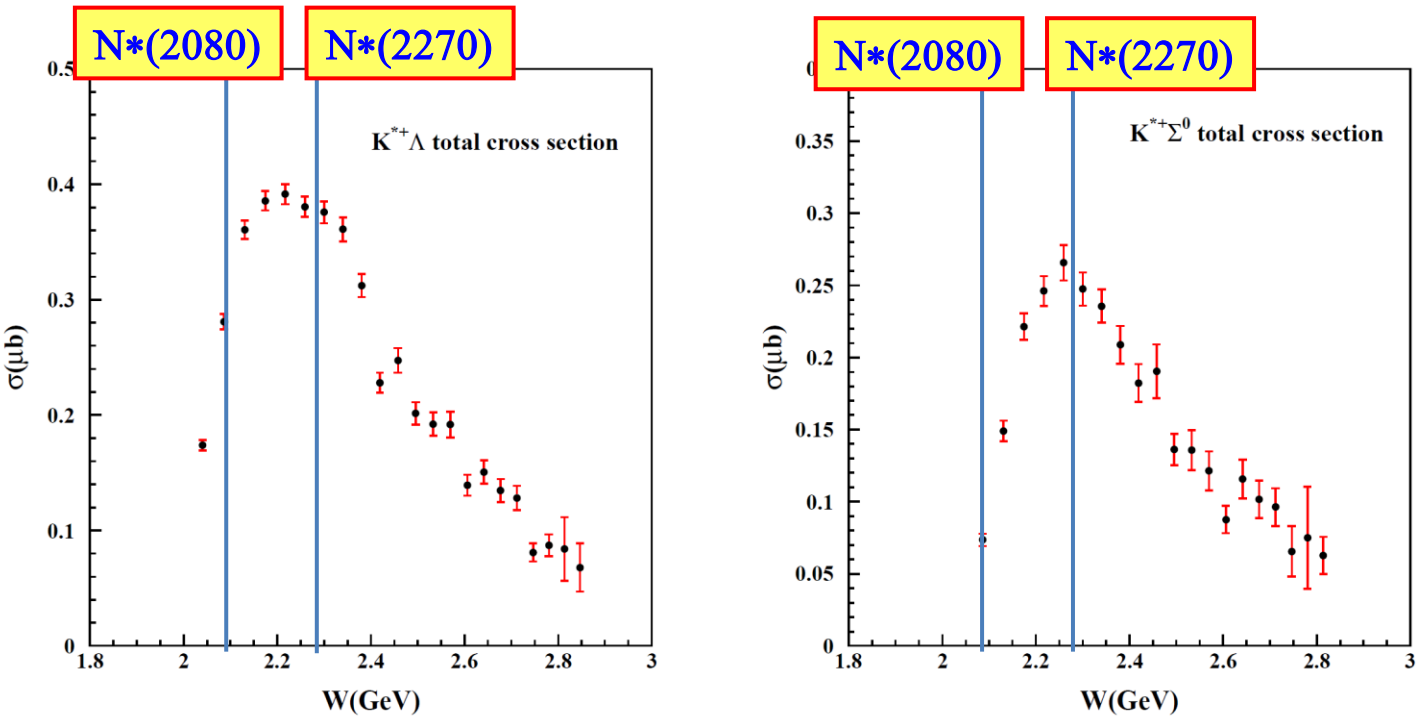
CLAS, PRC89(2014)019901



S.M.Wu, F.Wang, B.S.Zou, ArXiv: 2306.15385

Total cross sections of the reaction $\gamma p \to K^{*+}\Lambda$ (left) and $\gamma p \to K^{*+}\Sigma^0$ (right)

CLAS, PRC 87(2013)065204

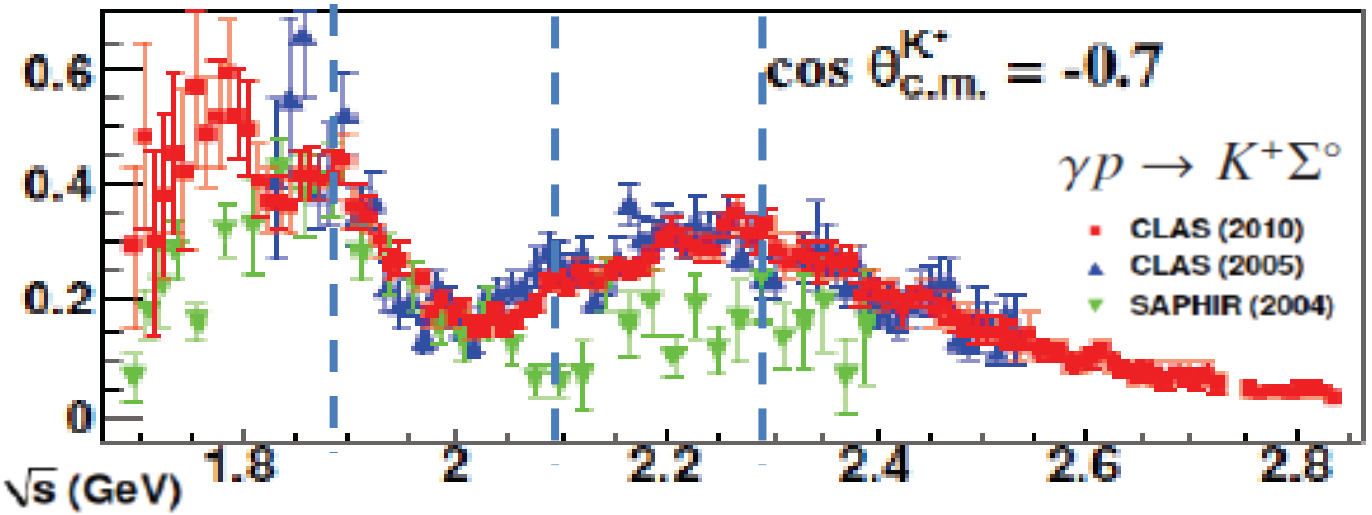


Di Ben, A.C.Wang, F.Huang, B.S.Zou, ArXiv: 2302.14308

Strange partners of P_c and P_{cs} states

KΣ* ~1880 **K*Σ ~ 2086** **K*Σ* ~ 2280**

N*(1875) **N*(2080)** **N*(2270)**



KΞ ~1810 **KΞ* ~ 2027** **K*Ξ ~ 2210** **K*Ξ* ~ 2427**

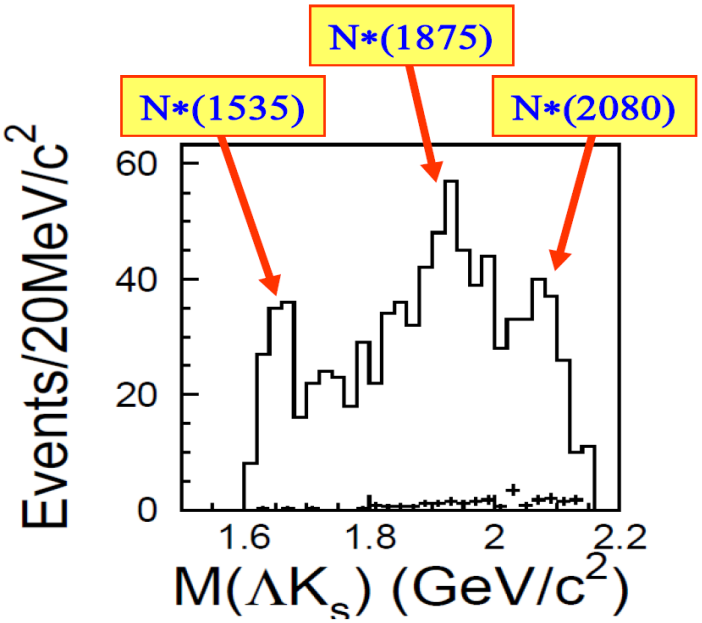
Λ(1/2⁻) **Λ(3/2⁻)** **Λ(1/2⁻,3/2⁻)** **Λ(1/2⁻,3/2⁻,5/2⁻)**

K*N ~1833 : Λ(1800)1/2⁻, Λ(3/2⁻)

Strange partners of P_c states from charmonium decays at BES ?

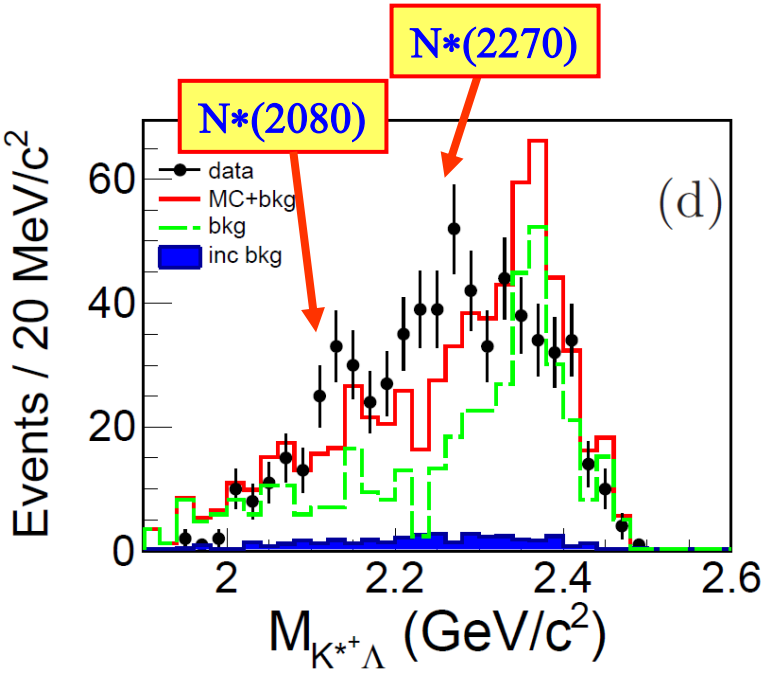
N*(1875) **N*(2080)** **N*(2270)**

KΣ* ~1880 K*Σ ~ 2086 K*Σ* ~ 2280



$J/\psi \rightarrow n\bar{K}^0_S\bar{\Lambda}$

BESII, PLB659 (2008) 789



$\chi_{c0} \rightarrow \bar{p}K^{*+}\Lambda$ +c.c.

BESIII, PRD100(2019)052010

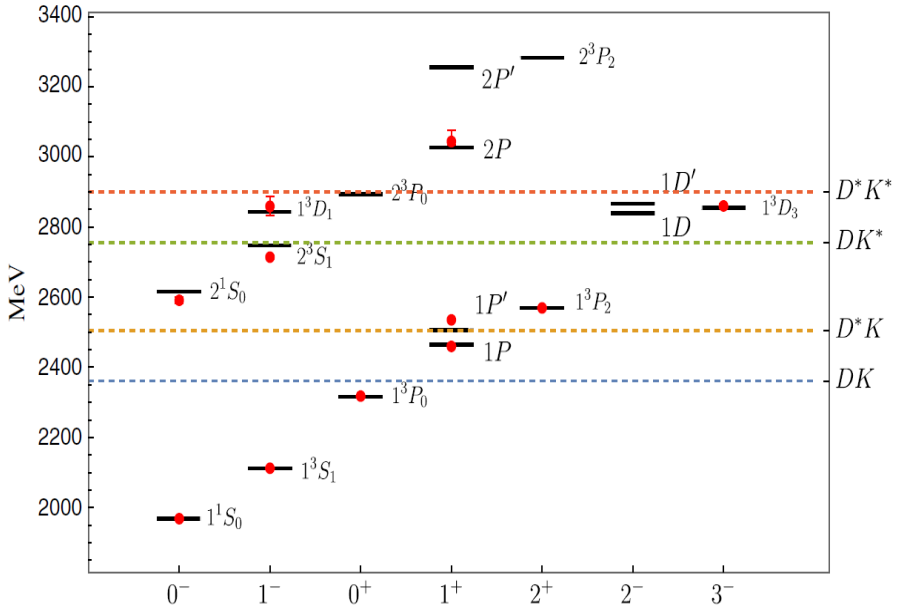
$\bar{K}\Sigma$ ~ Ξ(1680) , $\bar{K}\Sigma^*$ ~ Ξ(1860), $\bar{K}^*\Sigma$ ~ Ξ(2080), $\bar{K}^*\Sigma^*$ ~ Ξ(2270)

Coupled channel effects for the charmed-strange mesons

Wei Hao, Yu Lu, B.S.Zou, Phys. Rev. D 106 (2022) 074014

$$H = H_A + H_{BC} + H_I$$

$$|\psi\rangle = c_0|\psi_0\rangle + \sum_{BC}\int d^3p\, c_{BC}(p)|BC;p\rangle$$

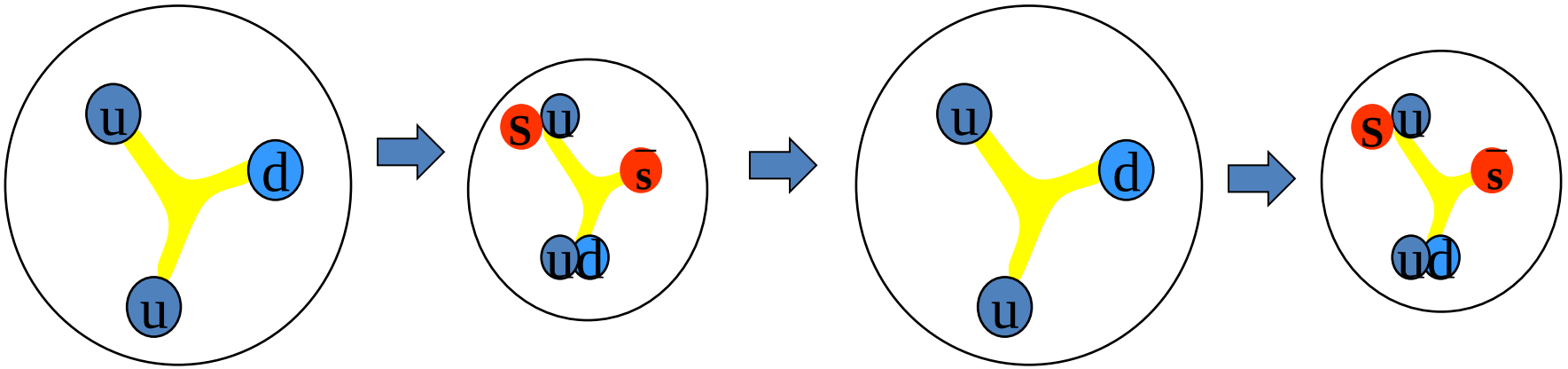


Channel		Width	Exp.
2^1S_0	$D_{s0}(2590)$	112	$89 \pm 16 \pm 12$ [16]
2^3S_1	$D^*_{s1}(2700)$	114	122 ± 10
1^3P_0	$D^*_{s0}(2317)$	–	<3.8
$1P$	$D_{s1}(2460)$	–	<3.5
$1P'$	$D_{s1}(2536)$	0.4	0.92 ± 0.05
1^3P_2	$D^*_{s2}(2573)$	17	16.9 ± 0.7
2^3P_0	–	47	–
$2P$	$D^*_{sJ}(3040)$	279	239 ± 60
$2P'$	–	331	–
2^3P_2	–	421	–
1^3D_1	$D^*_{s1}(2860)$	110	159 ± 80
$1D$	–	145	–
$1D'$	–	106	–
1^3D_3	$D^*_{s3}(2860)$	67	53 ± 10

Conclusions

◆ **all observed exotic states fit in hadronic molecule spectrum with VMD perfectly, many more to be observed.**

◆ **to understand hadron spectrum, quark model needs to be unquenched, with large hadronic molecule components when close to some thresholds.**



Future plan

SCNT

Southern Center for Nuclear-Science Theory

2023.05.04

SCNT

1) INT, Seattle, US
2) ECT*, Trento, Italy
3) FIAS, Frankfurt, Germany
4) YITP, Kyoto, Japan
5) …

1 Nuclear Structure

- Super Heavy Element
- New Isotopes
- Collision Dynamics
- Nuclear-astrophysics

2 Nuclear Matter Structure

- QCD phase boundary, critical point
- Hyper-nuclear production
- EOS at high baryon density
- CEE, CBM, NICA, STAR

3 Nucleon Structure

- Hadron spectroscopy
- 3D Imaging
- Origin of mass and spin
- EicC, EIC, BESIII, PANDA

4 Neutrino
Weak interactions in Nucl. Phys.

- Dirac or Majorana?
- Beyond SM physics
- Nuclear structure with neutrino
- N*ν*DEx, NEXT

CRC members are welcome to SCNT to participate its activities!

EicC@HIAF

Complementary to CBM and PANDA at FAIR etc.

UNIVERSITÄT BONN

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RUB

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Thank you for your attention !

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北京大學 PEKING UNIVERSITY