北京航空航天大學
BEIHANG UNIVERSITY

Three body mesonic and baryonic molecules from heavy quark and chiral symmetries

Lisheng Geng @ Beihang U.

第十八届全国中高能核物理大会暨第十二届全国中高能核物理专题研讨会
2019. 06. 21～25日, 湖南长沙

北京航空航天大學
BEIHANG UNIVERSITY

DK、DDK、DDDK molecules --new forms of matter

Lisheng Geng @ Beihang U.

1309.4743
1704.06123
1705.00516
1707.03802
1805.08330
1809.01059
1903.11560

+some preliminary results

Contents

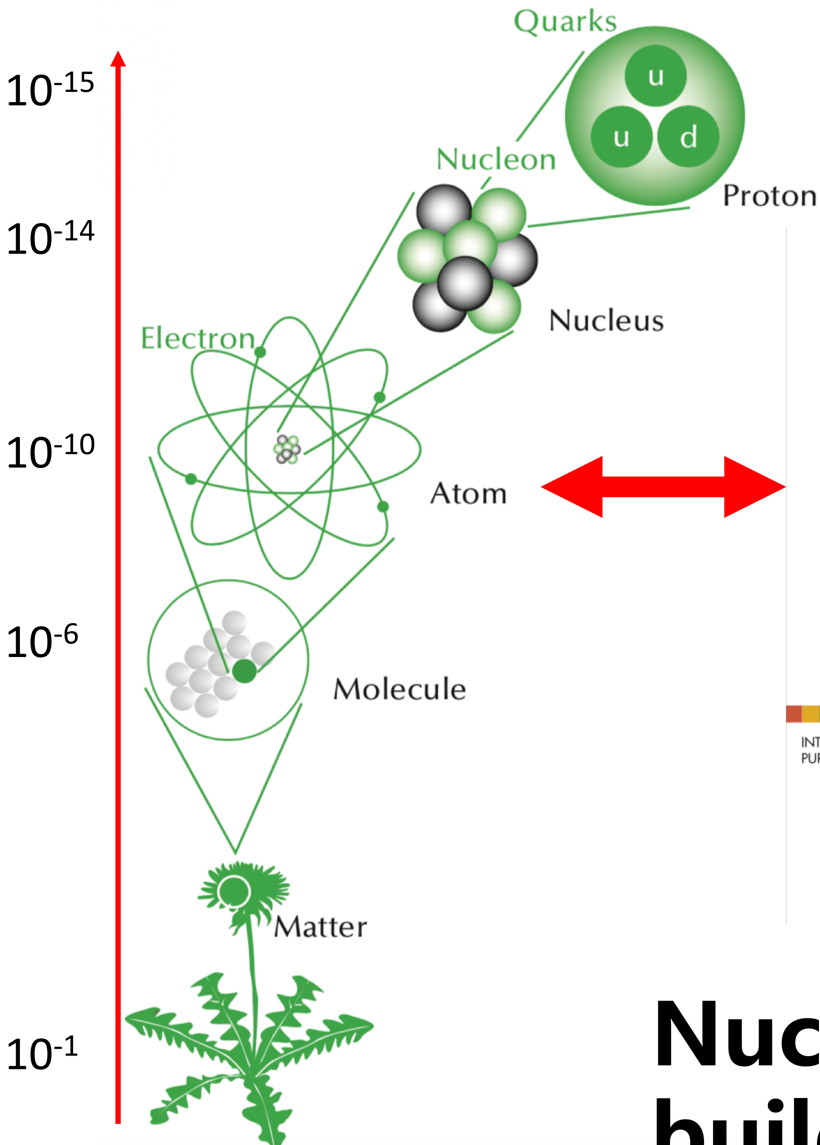
- **Motivation: new types of clusters of color singlets in addition to nuclei**
- **Ds0*(2317) and Ds1(2460) as DK/D*K molecules: theory & lattice**
- **Explicit studies of the DDK & DDDK** systems
- **A K*(4307) with hidden charm as KX(3872)/Zc(3900) molecule**
- **Summary and outlook**

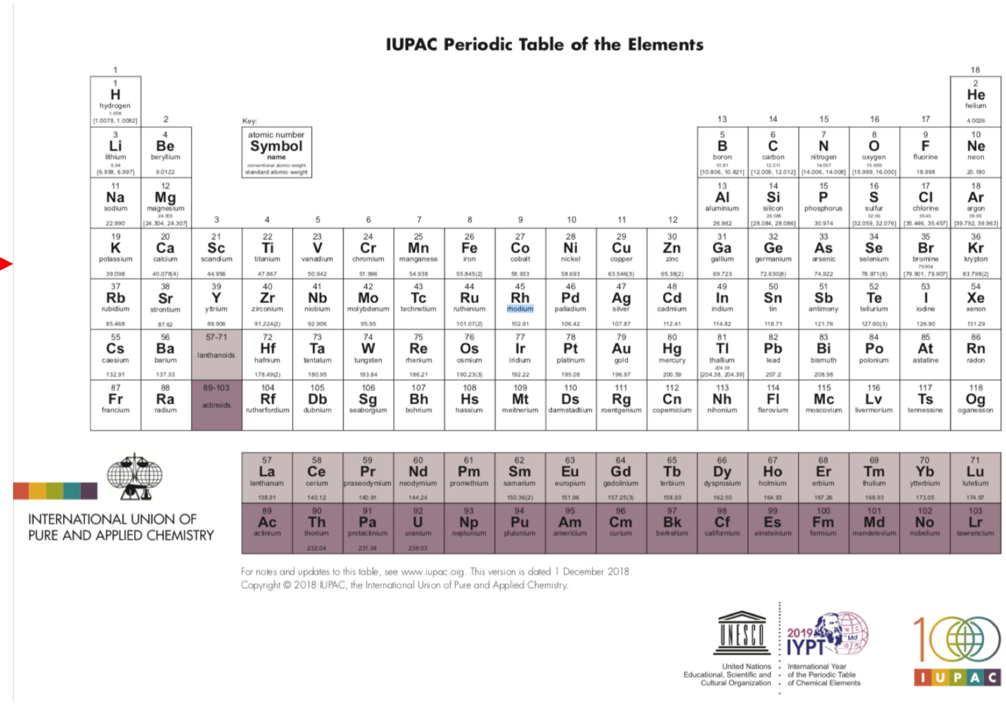
Contents

- **Motivation: new types of clusters of color singlets in addition to nuclei**
- **Ds0*(2317) and Ds1(2460) as DK/D*K molecules: theory & lattice**
- **Explicit studies of the DDK & DDDK** systems
- **A K*(4307) with hidden charm as KX(3872)/Zc(3900) molecule**
- **Summary and outlook**

United Nations
Educational, Scientific and
Cultural Organization

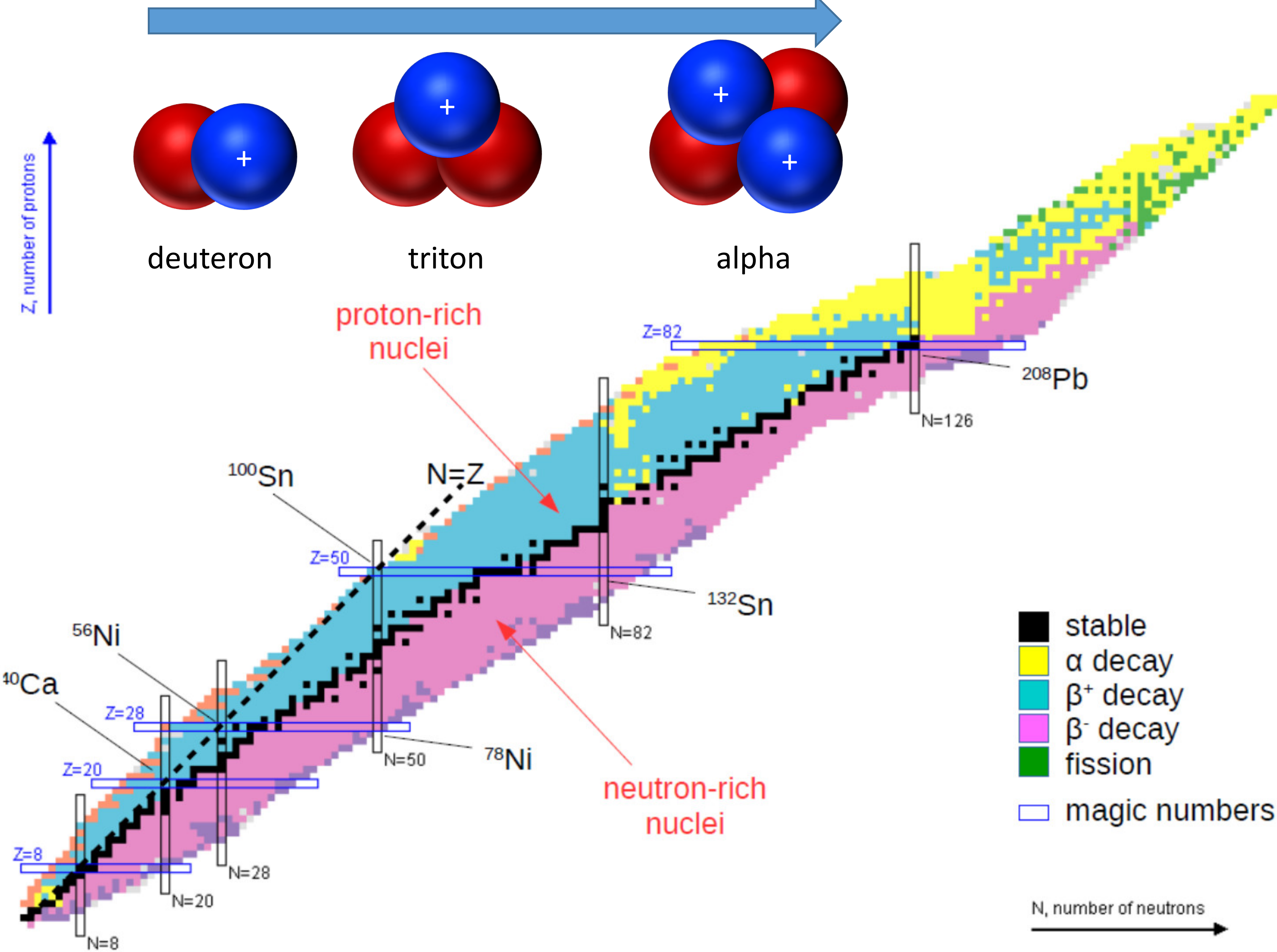
International Year
of the Periodic Table
of Chemical Elements





Nucleons are the essential building blocks of Matter!

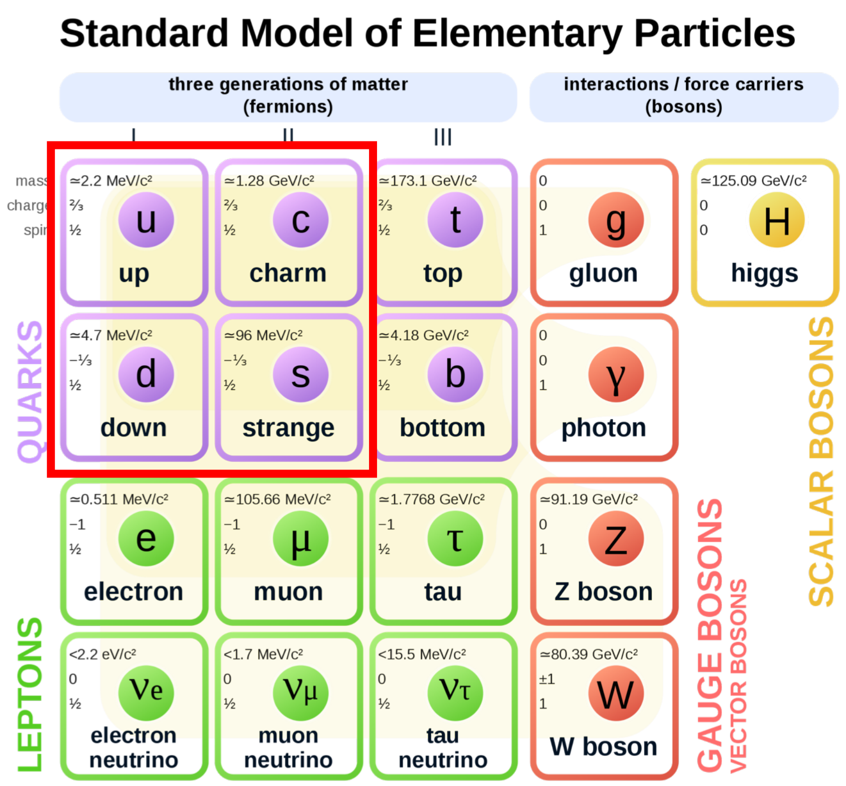
Adapted from LHC the guide

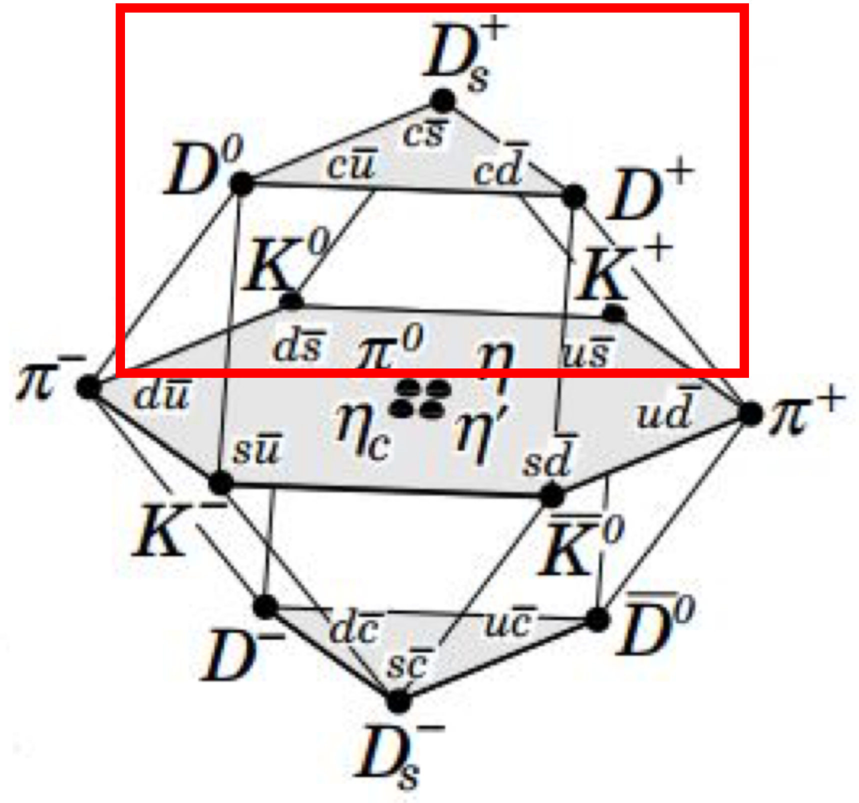


The existence of triton can be inferred from that of deuteron with reasonable confidence

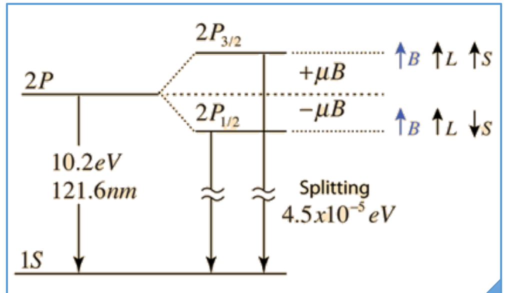
“In nature, are there other clusters of color singlet hadrons, similar to atomic nuclei, bound by the residual strong force？？？”

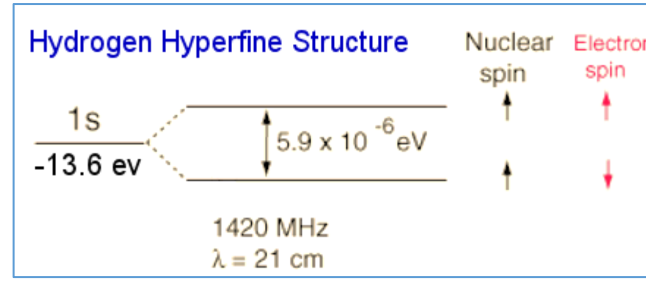
DK/DDK/DDDK molecules???





Why spectroscopy—Atomic





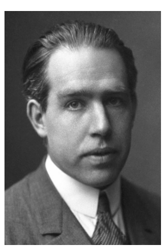
$$\frac{1}{\lambda_{\text{vac}}} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Rydberg formula

Fine structure

Hyperfine structure

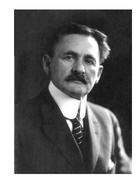
Johannes Rydberg



Niels Henrik David Bohr

Edward W. Morley

Arnold Sommerfeld

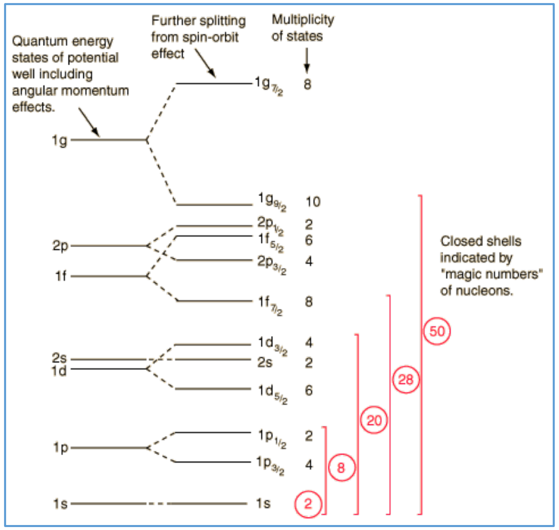


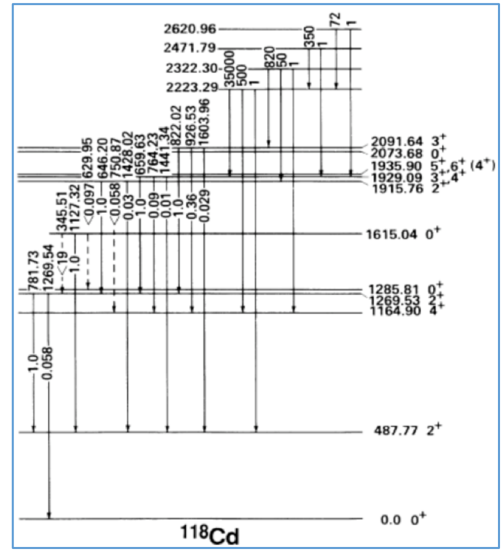
Albert Abraham Michelson

Wolfgang Pauli

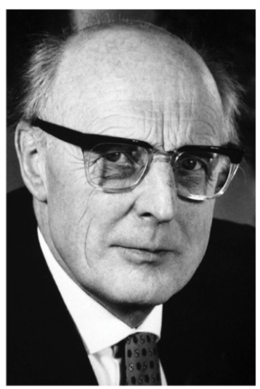
Why spectroscopy—Nuclear

Single particle motion

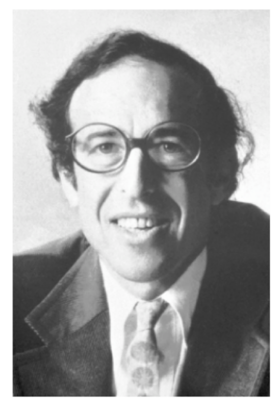




Collective motion

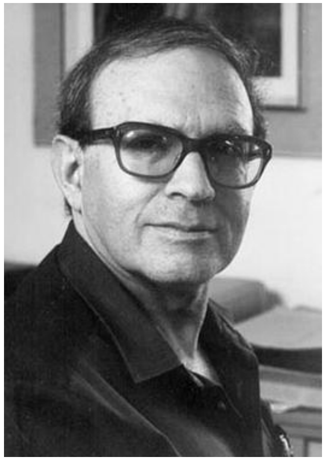
Maria Goeppert Mayer J. Hans D. Jensen

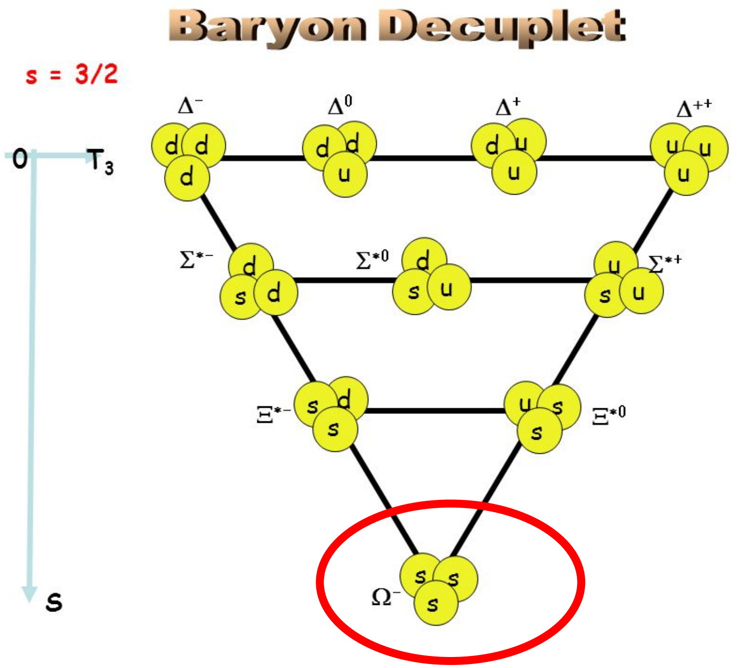

Aage Niels Bohr, Ben Roy Mottelson Leo James Rainwater

Why spectroscopy—particle/hadron

Murray Gell-Mann



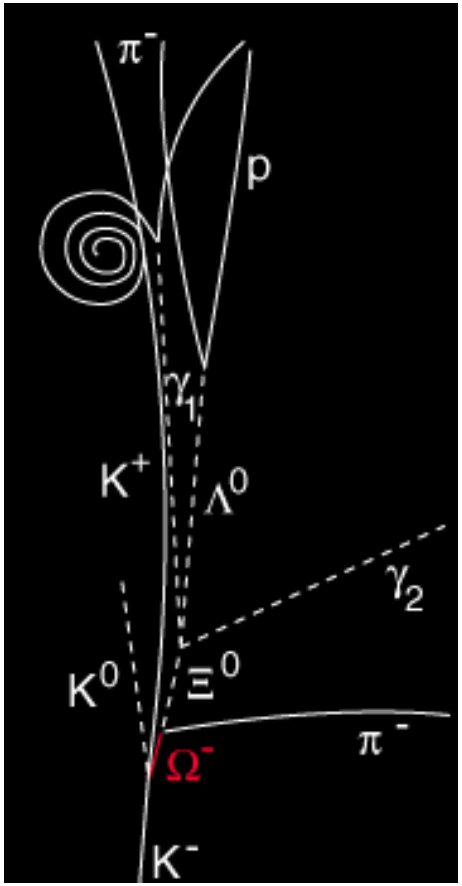
Yuval Ne'eman.



Eightfold way

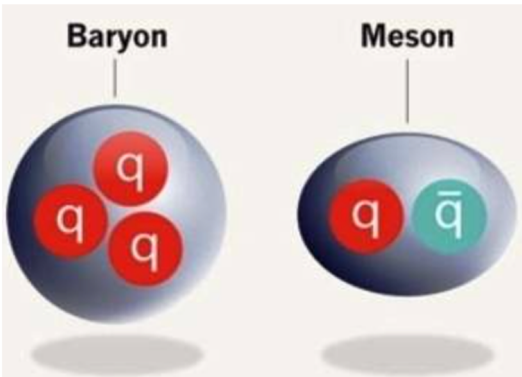
Quark model

QCD/SM



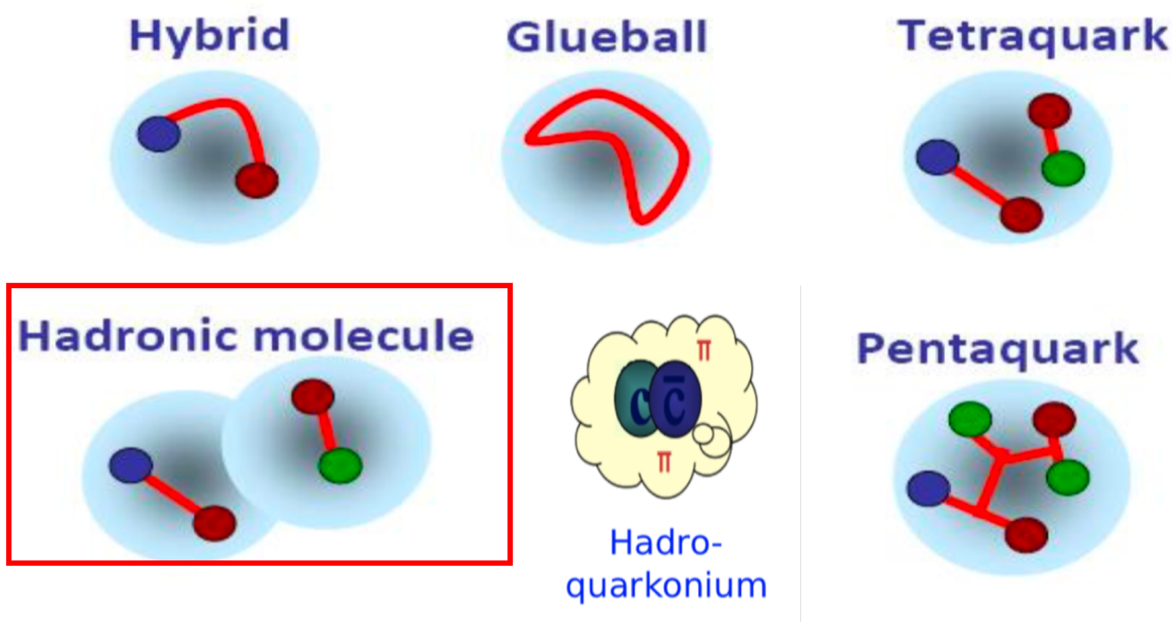
V. E. Barnes et al., Phys. Rev. Lett. 12, 204 (1964)

Why spectroscopy—particle/hadron



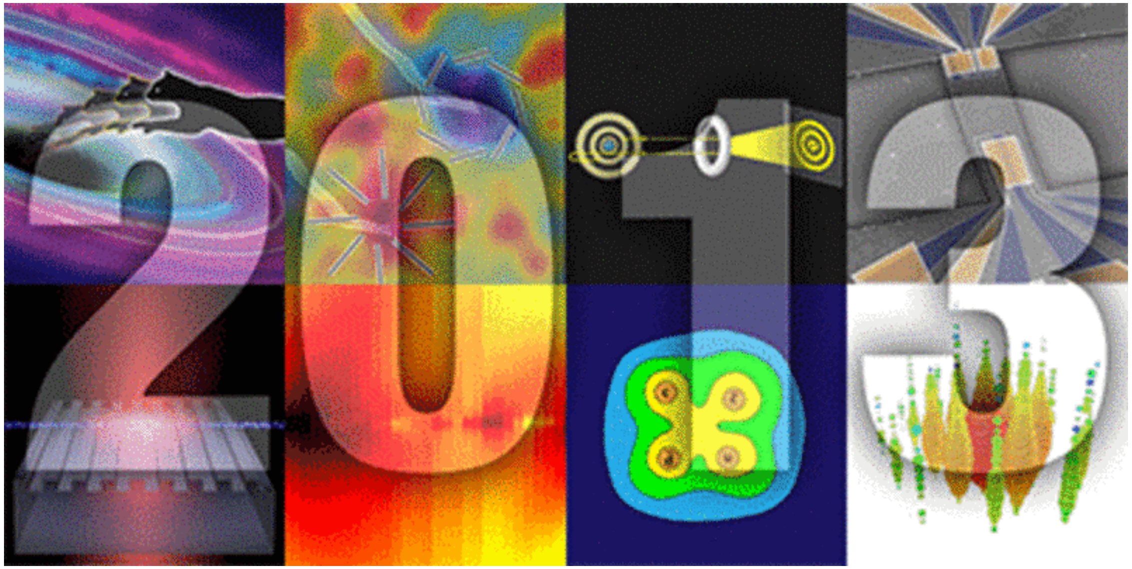
In the naïve quark model

In principle,
QCD allows

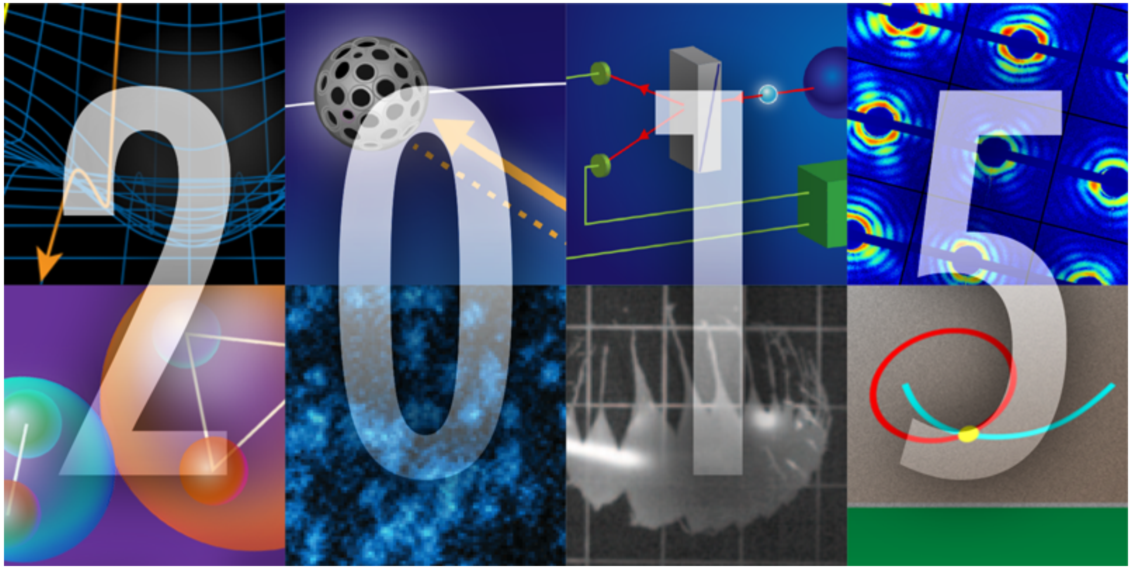


Highlights of the year

the research covered in Physics that **really made waves in and beyond the physics community.**



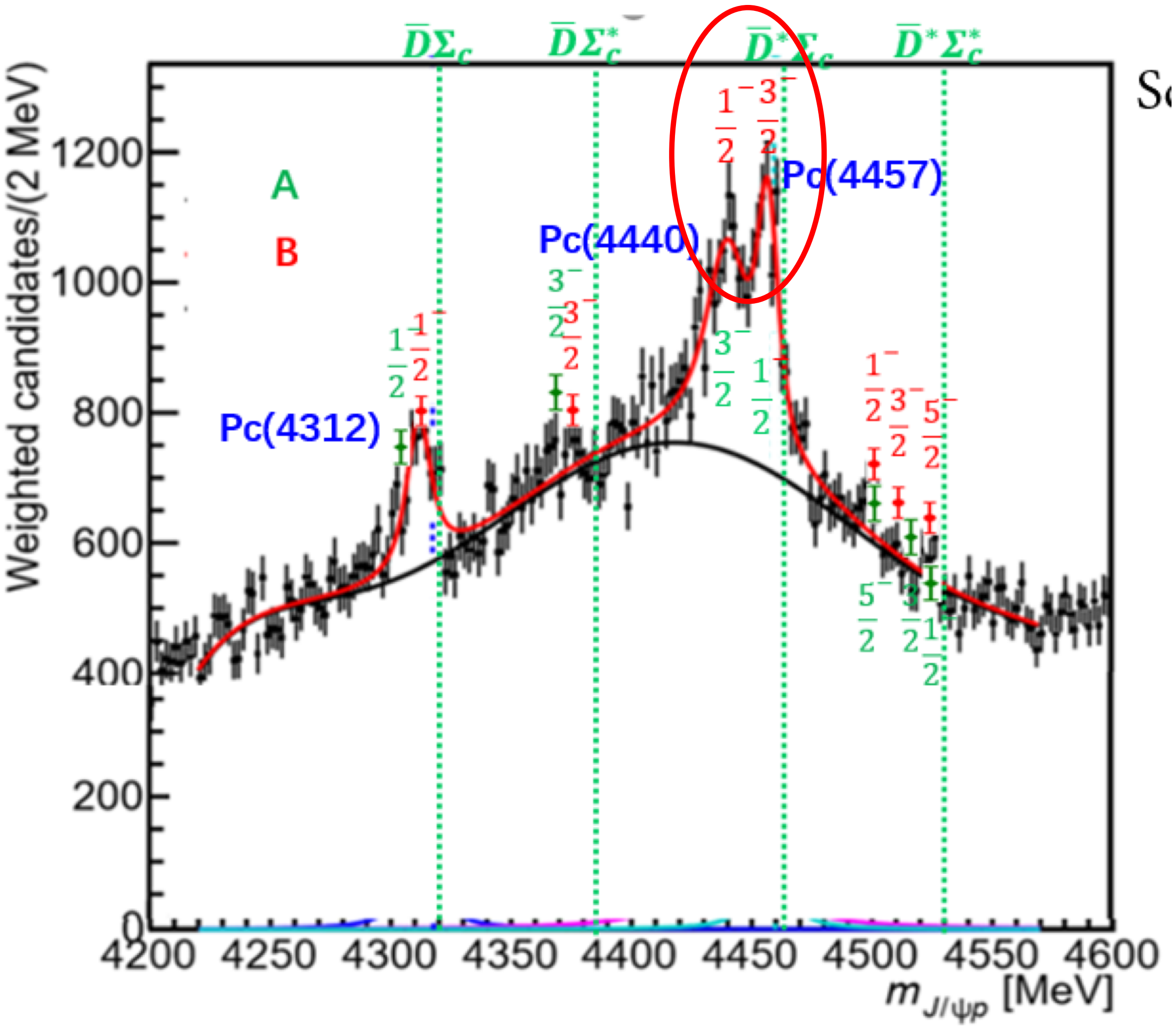
Four-Quark Matter



Particle High Five

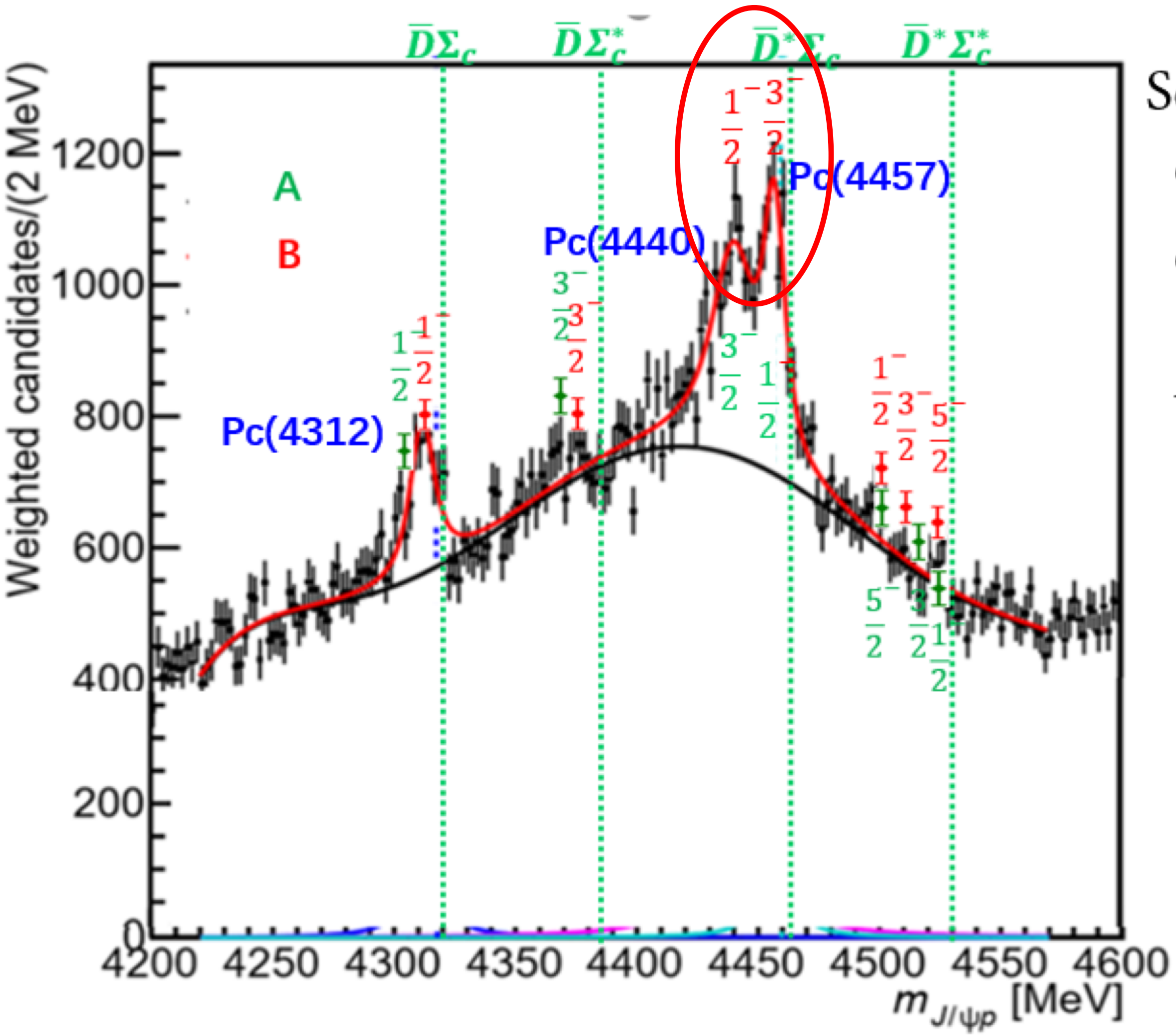
Latest LHCb discovery:

Fine structure observed by LHCb,1904.03947



Latest LHCb discovery:

Fine structure observed by LHCb,1904.03947



09:00 **Pentaquark theory overview** *30′*
Speaker: 邹冰松 (中国科学院高能物理研究所)

09:30 **LHCb 上强子谱学的实验进展** *30′*
Speaker: 张黎明 (清华大学)

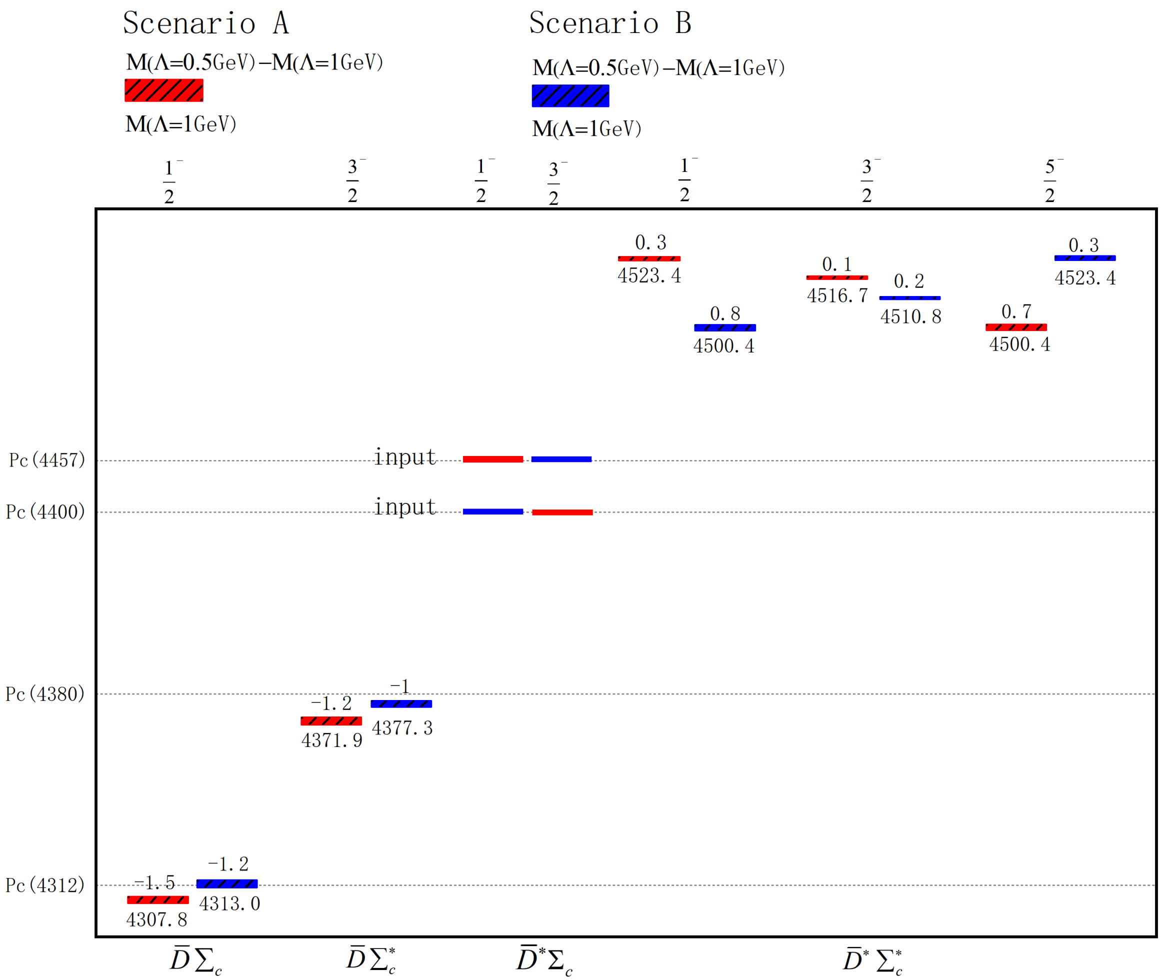
10:00 **Pentaquark and tetraquark states** *30′*
Speaker: 陈伟 (University of Saskatchewan)

11:50 **近阈共振结构与强子分子态** *30′*
Speaker: 何军 (Nanjing Normal University)

孟璐
刘明珠
肖楮文
刘雪杰
…

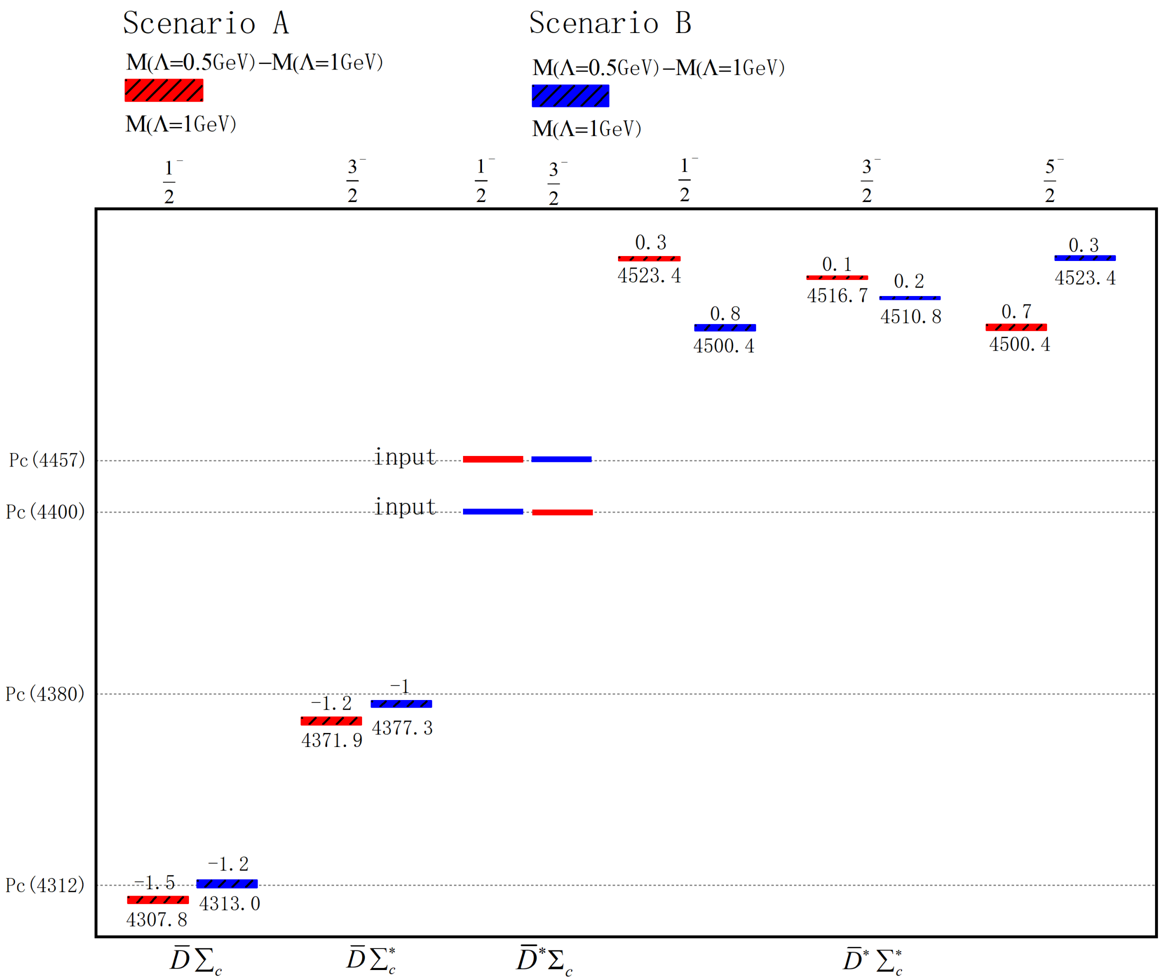
Emergence of a complete heavy-quark spin symmetry multiplet

1903.11560



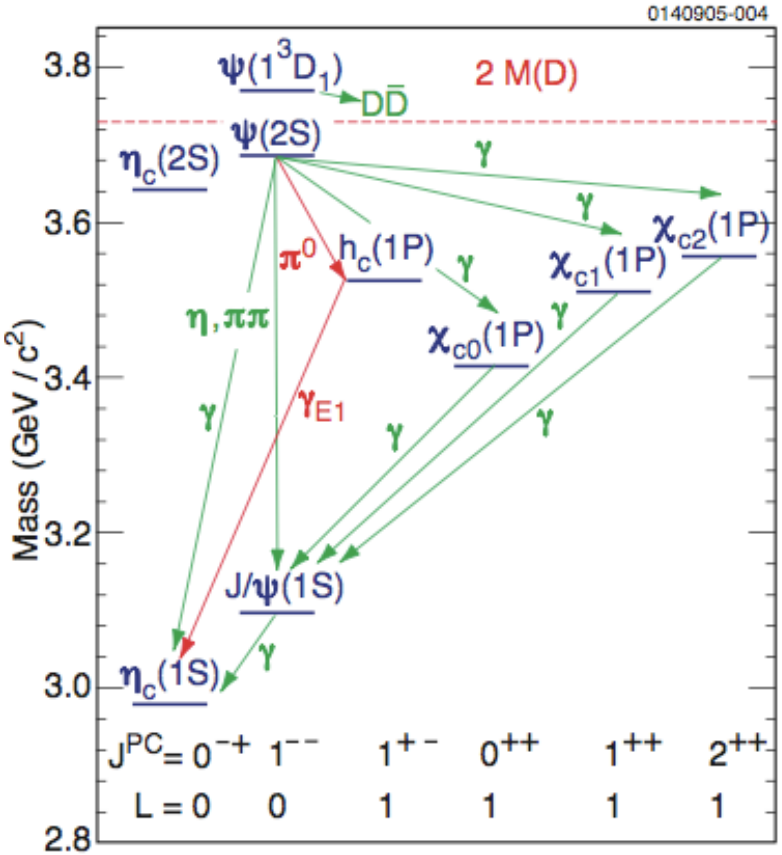
Emergence of a complete heavy-quark spin symmetry multiplet

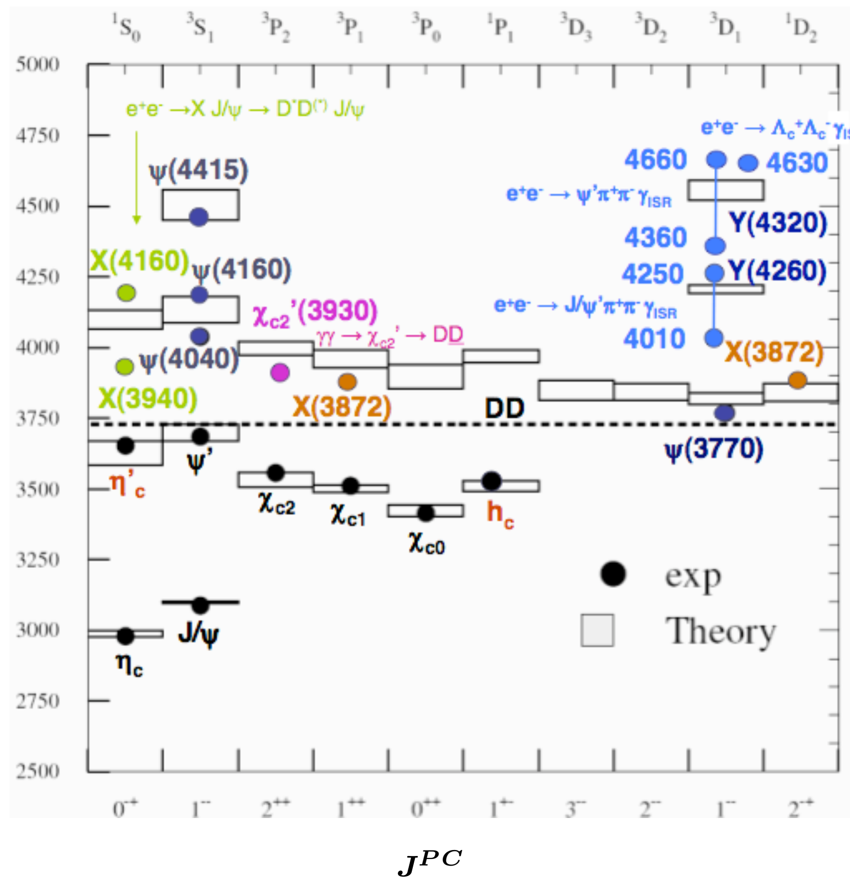
1903.11560



三楼1 号厅， 周日下午18：05， 刘明珠

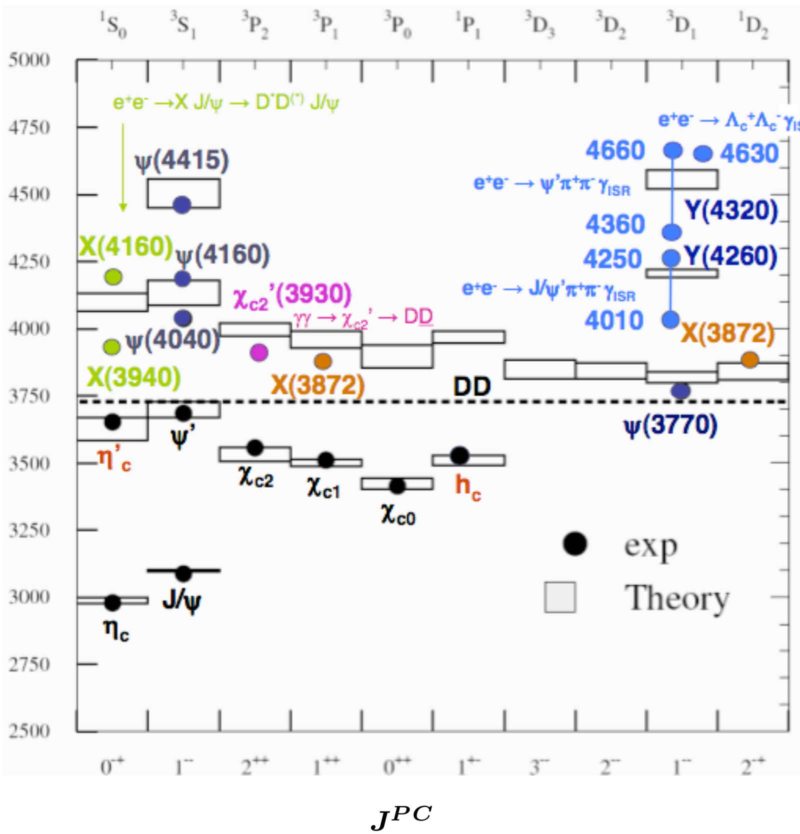
Charmonium spectroscopy before/after B factories





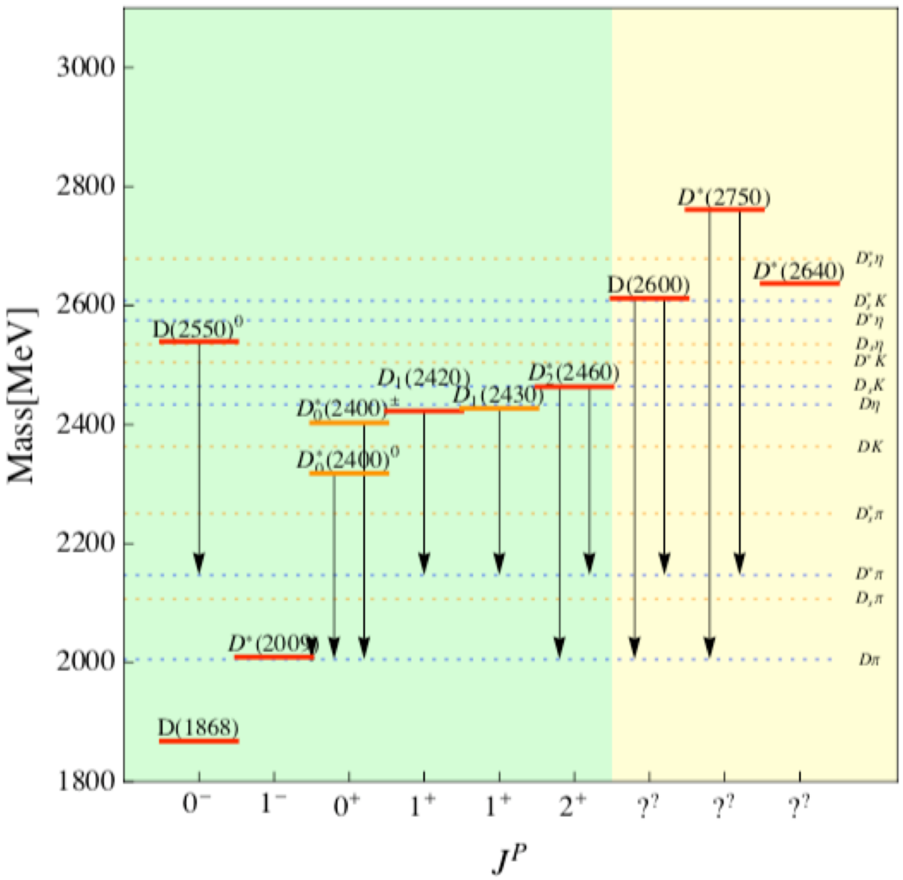
- A lot of new states, but the nature of some states are not well understood, e.g. Y(4260), X(3872), Zc(3900)
- In complete contrast to the before-B-factory period, when potential models worked quite well.

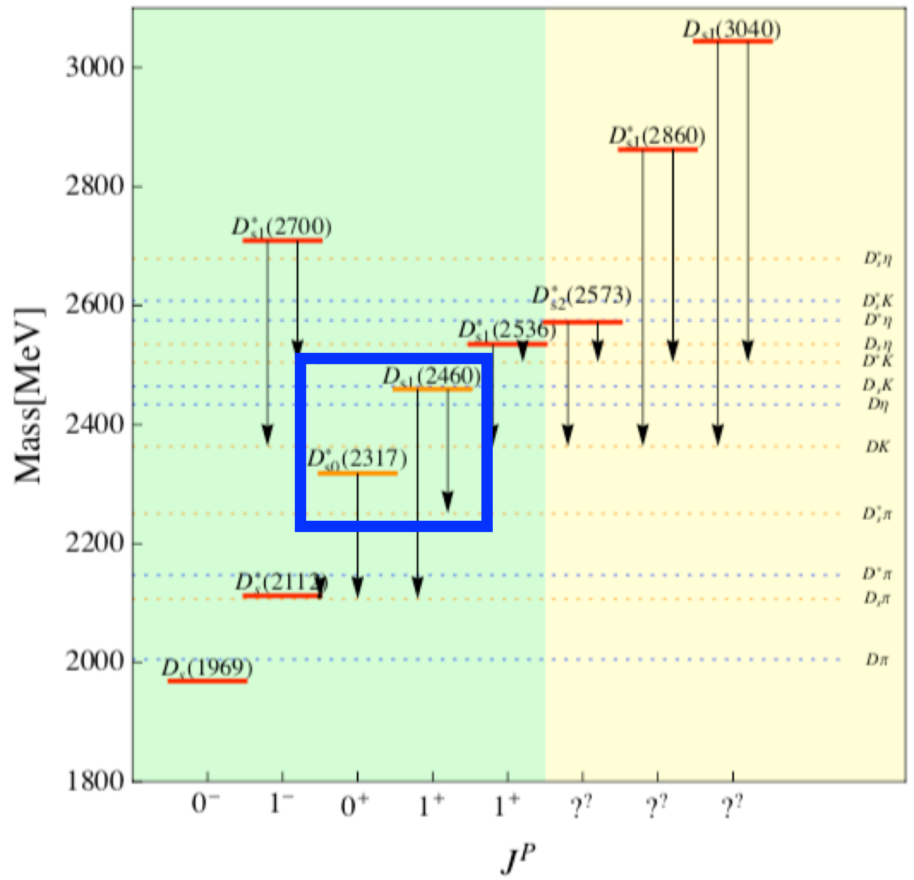
Coupled channel effects?



Channel	Threshold Energy (MeV)	
$D^0\bar{D}^0$	3729.4	
D^+D^-	3738.8	
$D^0\bar{D}^{*0}$ or D^*	3871.5	X(3872)
$\rho^0 J/\psi$	3872.7	
$D^\pm D^{*\mp}$	3879.5	
$\omega^0 J/\psi$	3879.6	
$D_s^+ D_s^-$	3936.2	
$D^{*0}\bar{D}^{*0}$	4013.6	
$D^{*+}D^{*-}$	4020.2	
$\eta' J/\psi$	4054.7	
$f^0 J/\psi$	$\approx$ 4077	
$D_s^+\bar{D}_s^{*-}$ or D_s^*	4080.0	
$a^0 J/\psi$	4081.6	
$\varphi^0 J/\psi$	4116.4	
$D_s^{*+}D_s^{*-}$	4223.8	

Open charm systems

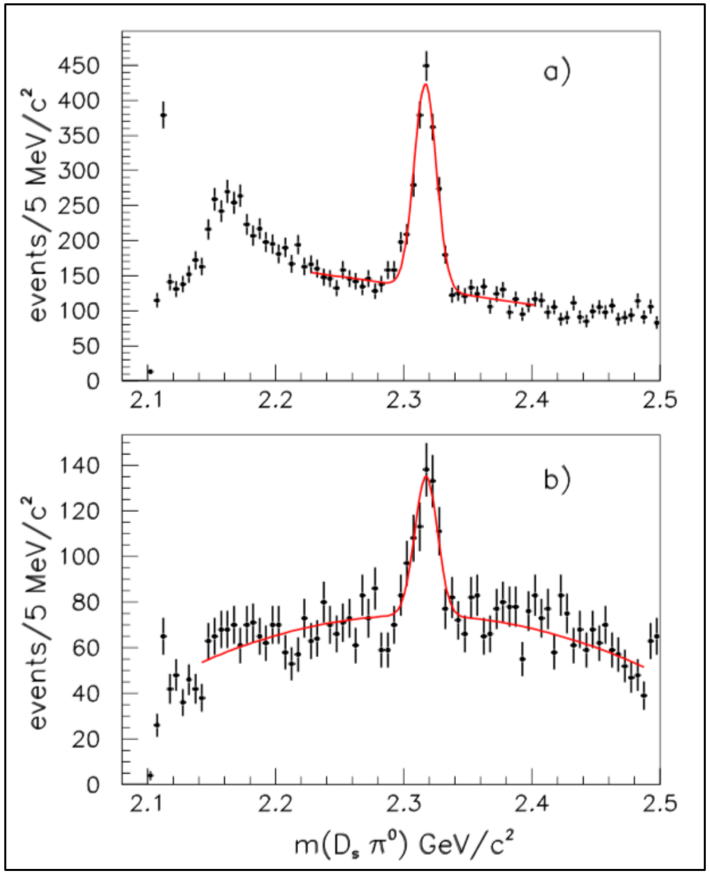




Ds0*(2317) **Ds1(2460)**

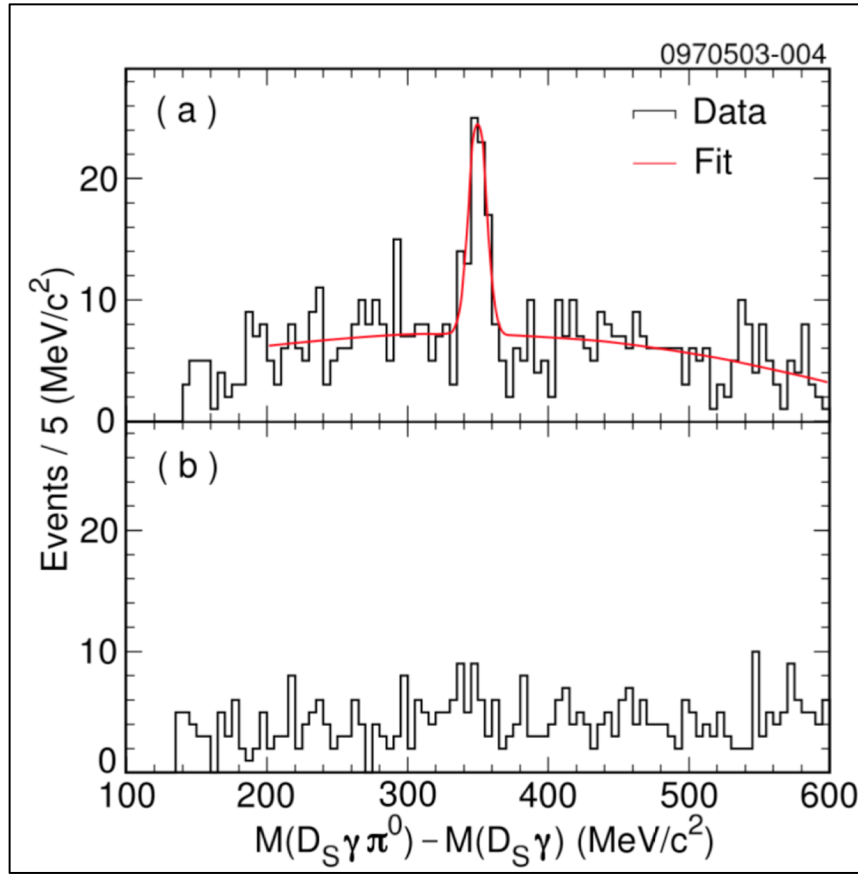
Two peculiar states

Ds0*(2317)



BaBar PRL90,242001(2003)

Ds1(2460)



CLEO PRD68,032002(2003)

Two peculiar states

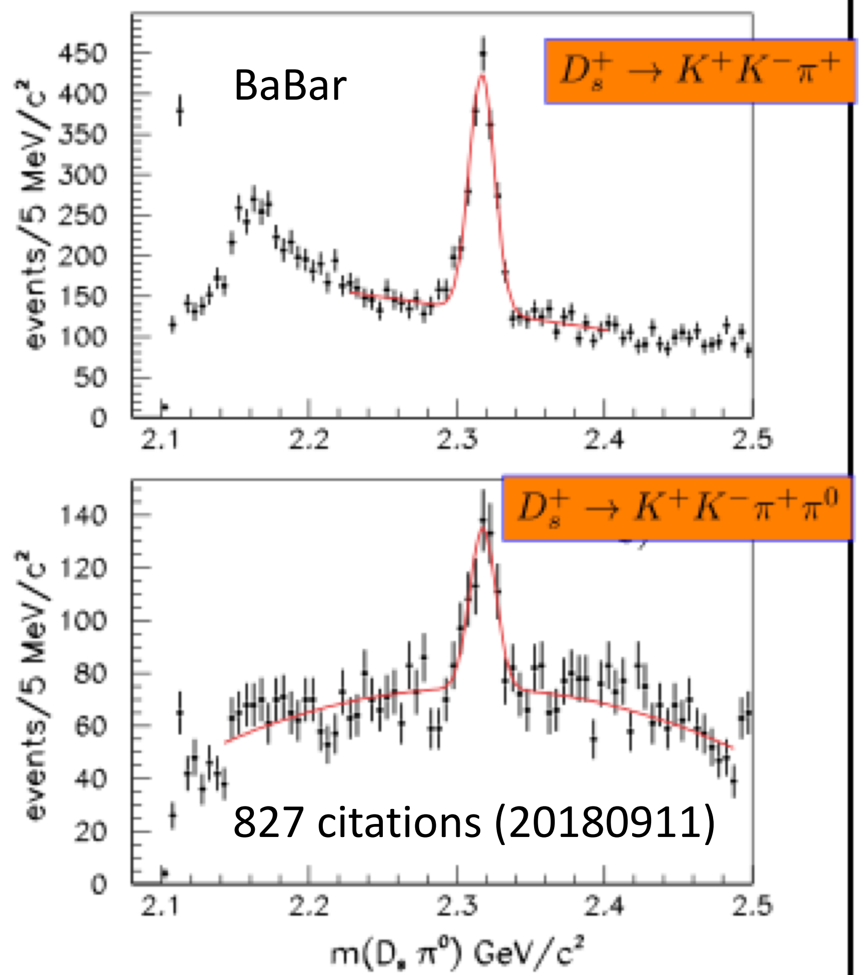
- $\mathbf{D^*_{s0}(2317),\ D_{s1}(2460)}$

- 160/70 MeV lower than quark model predictions--difficult to be understood as conventional csbar states.

- “Dynamically generated” from strong DK interaction
  - ✓ E. E. Kolomeitsev 2004,
  - ✓ F. K. Guo 2006,
  - ✓ D. Gamermann 2007

$$m_{D_{s1}(2460)} - m_{D^*_{s0}(2317)} \approx m_{D^*} - m_D$$

$\mathbf{M = 2317.8 \pm 0.6}$ and $\mathbf{\Gamma < 3.8}$ MeV

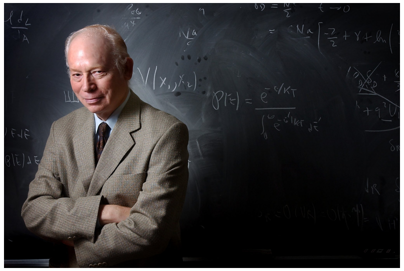


Feng-Kun Guo, EPJ Web of Conferences **202**, 02001 (2019)

Contents

- Motivation: new types of clusters of color singlets in addition to nuclei
- Ds0*(2317) and Ds1(2460) as DK/D*K molecules: theory&lattice
- Explicit studies of the DDK & DDDK systems
- A K*(4307) with hidden charm as KX(3872)/Zc(3900) molecule
- Summary and outlook

UChPT in Bethe-Salpeter equation



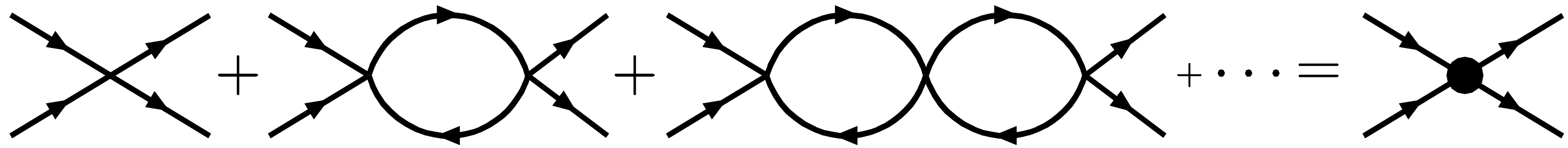
- Model independent DK interaction from ChPT

$$\mathcal{V}_{\rm WT}(P(p_1)\phi(p_2)\to P(p_3)\phi(p_4)) = \frac{1}{4f_0^2}\mathcal{C}_{\rm LO}\,(s-u)$$

Weinberg-Tomazawa

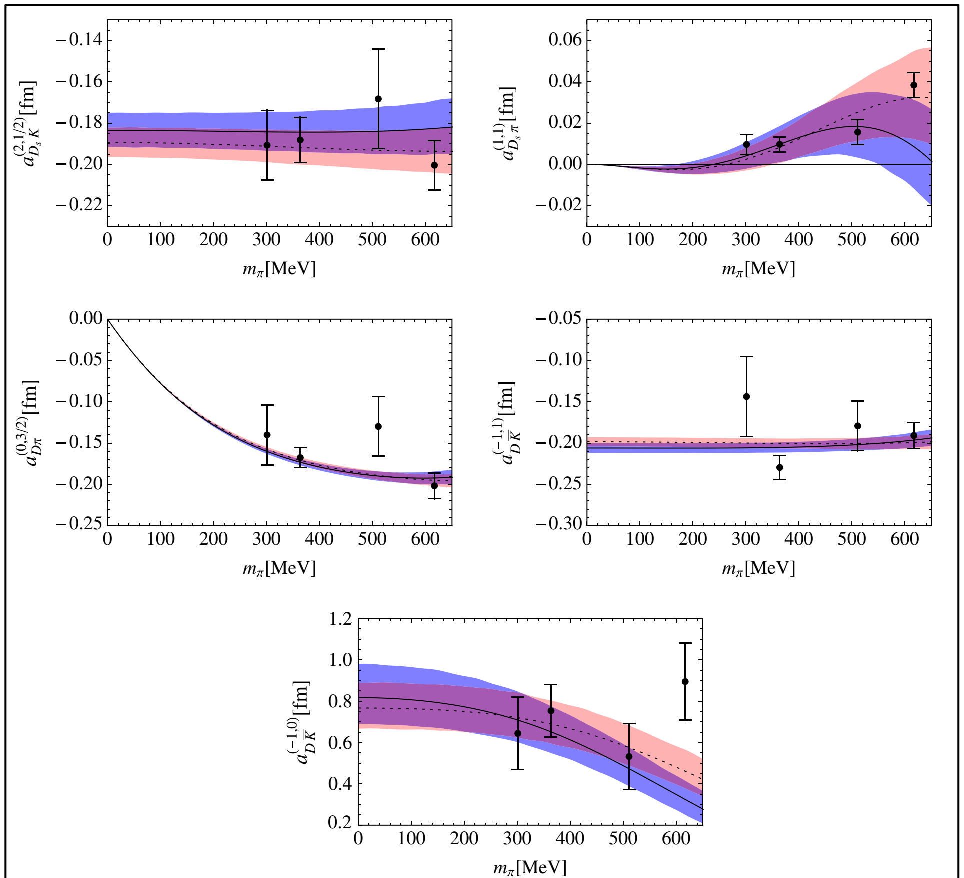
$$\begin{aligned}\mathcal{V}_{\rm NLO}(P(p_1)\phi(p_2)\to P(p_3)\phi(p_4)) = &-\frac{8}{f_0^2}C_{24}\left(c_2\,p_2\cdot p_4 - \frac{c_4}{m_P^2}\,(p_1\cdot p_4\;p_2\cdot p_3 + p_1\cdot p_2\;p_3\cdot p_4)\right)\\ &-\frac{4}{f_0^2}\mathcal{C}_{35}\left(c_3\,p_2\cdot p_4 - \frac{c_5}{m_P^2}\,(p_1\cdot p_4\;p_2\cdot p_3 + p_1\cdot p_2\;p_3\cdot p_4)\right)\\ &-\frac{4}{f_0^2}\mathcal{C}_6\,\frac{c_6}{m_P^2}\,(p_1\cdot p_4\;p_2\cdot p_3 - p_1\cdot p_2\;p_3\cdot p_4)\\ &-\frac{8}{f_0^2}\mathcal{C}_0\,c_0 + \frac{4}{f_0^2}\mathcal{C}_1\,c_1\,, \qquad (11)\end{aligned}$$

- Resumed in the Bethe-Salpeter equation (two-body elastic unitarity)

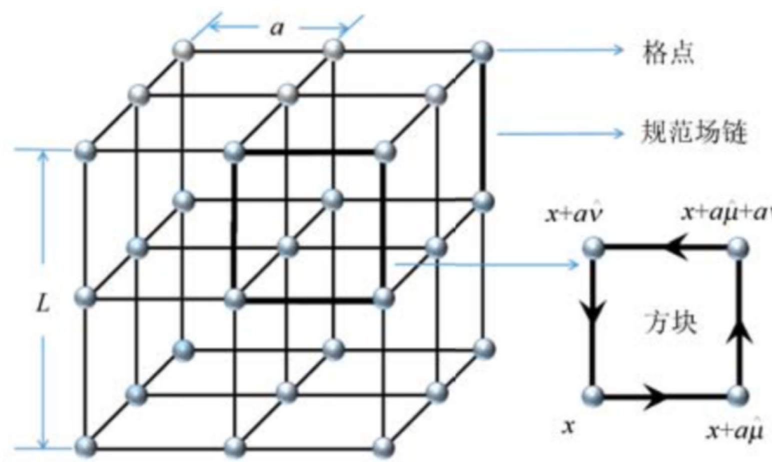


Fixing the LECs using latest LQCD* data

Liuming Liu et al., PRD87 (2013) 014508



- NLO ChPT kernel: 5 LECs
- A quite good description of the 20 Lattice **scattering lengths of pseudoscalar mesons and D mesons （I=0 DK excluded）** can be achieved.



Ds0 and Ds1 dynamically generated

- **Charm sector**

"Post-diction"

$\mathbf{D^*_{s0}(2317),\ D_{s1}(2460)}$

TABLE V. Pole positions $\sqrt{s} = M - i\frac{\Gamma}{2}$ (in units of MeV) of charm mesons dynamically generated in the HQS UChPT.

(S, I)	$J^P = 0^+$	$J^P = 1^+$
(1, 0)	2317 ± 10	2457 ± 17
(0, 1/2)	$(2105 \pm 4) - i(103 \pm 7)$	$(2248 \pm 6) - i(106 \pm 13)$

- **Bottom Sector**

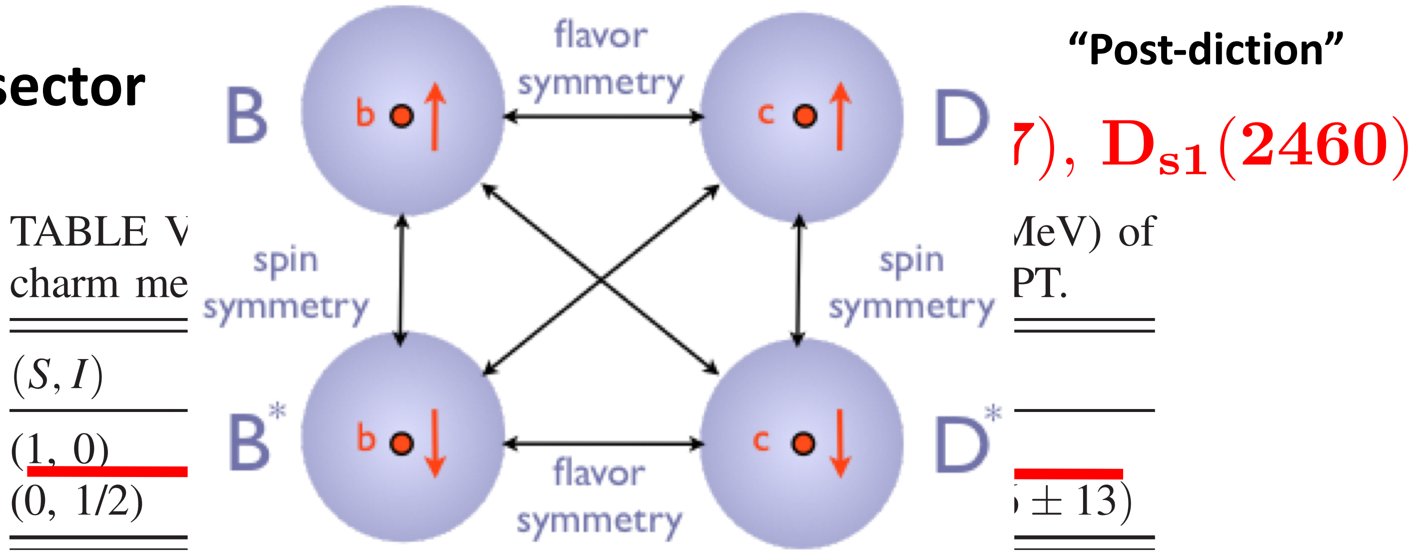
TABLE VI. Pole positions $\sqrt{s} = M - i\frac{\Gamma}{2}$ (in units of MeV) of bottom mesons dynamically generated in the HQS UChPT.

(S, I)	$J^P = 0^+$	$J^P = 1^+$
(1, 0)	5726 ± 28	5778 ± 26
(0, 1/2)	$(5537 \pm 14) - i(118 \pm 22)$	$(5586 \pm 16) - i(124 \pm 25)$

Ds0 and Ds1 dynamically generated

- **Charm sector**

"Post-diction"



- **Bottom Sector**

TABLE VI. Pole positions $\sqrt{s} = M - i\frac{\Gamma}{2}$ (in units of MeV) of bottom mesons dynamically generated in the HQS UChPT.

(S, I)	$J^P = 0^+$	$J^P = 1^+$
(1, 0)	5726 ± 28	5778 ± 26
(0, 1/2)	$(5537\pm14)-i(118\pm22)$	$(5586\pm16)-i(124\pm25)$

Predicted Bs0 and Bs1 states

Physics Letters B 750 (2015) 17–21

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

Predicting positive parity B_s mesons from lattice QCD

C.B. Lang [a], Daniel Mohler [b,*], Sasa Prelovsek [c,d], R.M. Woloshyn [e]

[a] Institute of Physics, University of Graz, A-8010 Graz, Austria
[b] Fermi National Accelerator Laboratory, Batavia, IL 60510-5011, USA
[c] Department of Physics, University of Ljubljana, 1000 Ljubljana, Slovenia
[d] Jozef Stefan Institute, 1000 Ljubljana, Slovenia
[e] TRIUMF, 4004 Wesbrook Mall, Vancouver, BC V6T 2A3, Canada

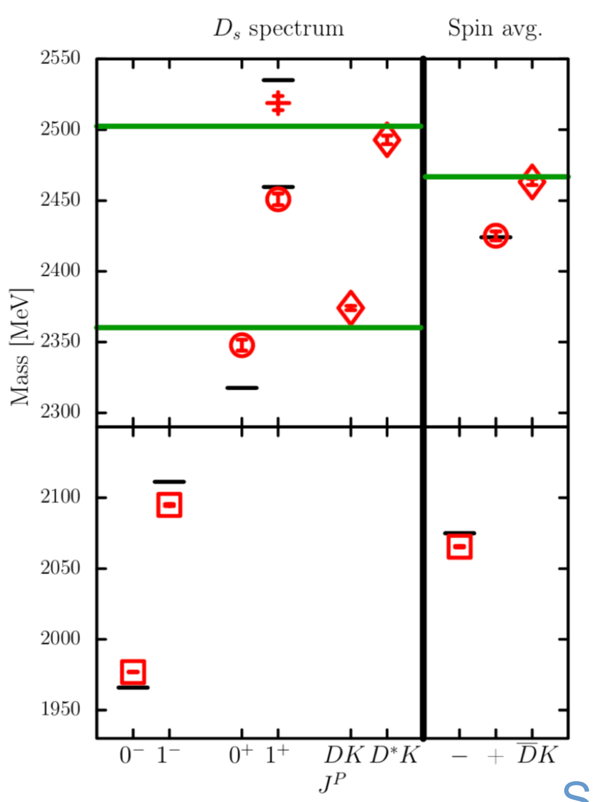
Table 5
Comparison of masses from this work to results from various model based calculations; all masses in MeV.

J^P	0^+	1^+
Covariant (U)ChPT [24]	5726(28)	5778(26)
NLO UHMChPT [19]	5696(20)(30)	5742(20)(30)
LO UChPT [17,18]	5725(39)	5778(7)
LO χ-SU(3) [16]	5643	5690
HQET + ChPT [20]	5706.6(1.2)	5765.6(1.2)
Bardeen, Eichten, Hill [15]	5718(35)	5765(35)
rel. quark model [5]	5804	5842
rel. quark model [22]	5833	5865
rel. quark model [23]	5830	5858
HPQCD [30]	5752(16)(5)(25)	5806(15)(5)(25)
this work	5713(11)(19)	5750(17)(19)

In agreement with lQCD

Support from lattice QCD studies

- G. S. Bali et al., arXiv:1706.01247 [hep-lat].
- C. B. Lang et al., arXiv:1403.8103 [hep-lat].
- D. Mohler et al., arXiv:1308.3175 [hep-lat].



"DK components substantial"

FIG. 12. On the left, our final results for the lower lying D_s spectrum as detailed in Table VII. The short horizontal black lines indicate the corrected experimental values (see Section II) while the green horizontal lines give the positions of the DK and D^*K non-interacting thresholds. Our lattice results for the finite volume thresholds are labelled DK and D^*K, respectively. The errors indicated are statistical only. On the right, the negative parity spin-averaged $1S$ mass $m_- = \frac{1}{4}(m_{0^-} + 3m_{1^-})$ is shown and denoted $-$, while the same spin-average of the positive parity 0^+ and 1^+ states is labelled with $+$ and the weighted average of the threshold is labelled as $\overline{D}K$.

See as well Miguel Albaladejo et al. arXiv:1805.07104

Further **tests** of the DK interaction

- **Experiments, theory, and lattice QCD all show that** DK or D^*K interaction is strong enough to form the Ds0*(2317) or Ds1(2460)
- A natural question is: if we add one more $D(\bar{D})$ or $D^*(\overline{D^*})$, can they form molecules of three hadrons?
- This seems to be a rather straightforward and naive question, but remains unexplored until quite recently

Contents

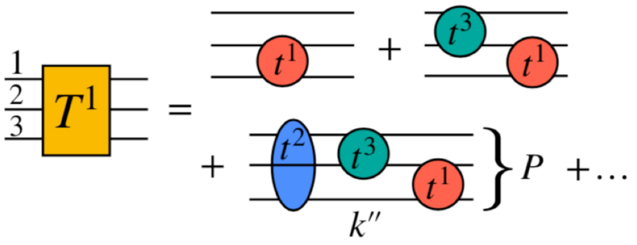
- **Motivation: new types of clusters of color singlets in addition to nuclei**
- **Ds0*(2317) and Ds1(2460) as DK/D*K molecules**
- **Explicit studies of the DDK & DDDK** systems
- **A K*(4307) with hidden charm as KX(3872)/Zc(3900) molecule**
- **Summary and outlook**

An explicit three-body study of DDK

*A. Mart́ ınez Torres, K. P. Khemchandani, and **LSG** 1809.01059*

- **Coupled-three-channel problem:** $\mathrm{D}(\mathrm{DK} - D_s\pi - D_s\eta)$
- **Three-body scattering matrix (Faddeev)**

$$T = \sum_{i=1}^{3} T^i$$



$$T^i = t^i \delta^3(\vec{k}_i' - \vec{k}_i) + \sum_{j \neq i = 1}^{3} T_R^{ij}, \quad i = 1, 2, 3,$$

$$T_R^{ij} = t^i g^{ij} t^j + t^i \left[G^{iji} T_R^{ji} + G^{ijk} T_R^{jk} \right],$$

__A. Martínez Torres__, K. P. Khemchandani, and E. Oset PRC __77__, 042203(R)

A__. Martinez Torres__, K.P. Khemchandani, __LSG__, M. Napsuciale, E. Oset, PRD78 (2008) 074031

Two-body inputs

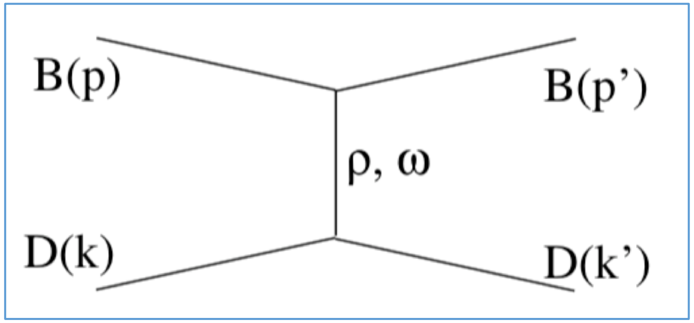
- **DK: leading order UChPT** DK, $D_s\eta$ and $D_s\pi$

$$V_{ij} = -\frac{C_{ij}}{4f^2}(s-u)$$

$a(\mu) = -1.846, \mu = 1000\ MeV \Rightarrow$
Pole=2318 MeV

F.-K. Guo, P.-N. Shen, H.-C. Chiang, R.-G. Ping, and B.-S. Zou, PL B641, 278 (2006).

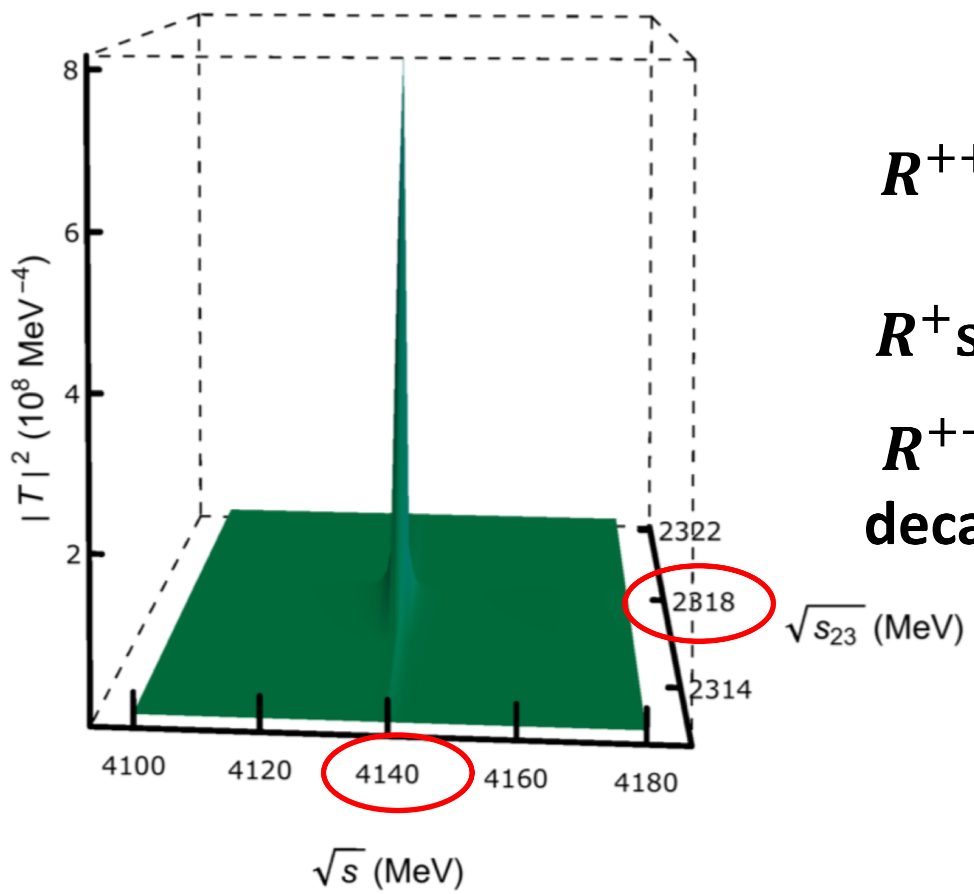
- **DD(Ds): local hidden gauge theory**



$a(\mu) = -1.3 \sim -1.5, \mu = 1500\ MeV \Leftarrow$ fixed from $D\bar{D}/D\bar{D}^*$--X(3700）/X(3872)

S. Sakai, L. Roca, and E. Oset, PRD96, 054023 (2017).

Three-body amplitudes



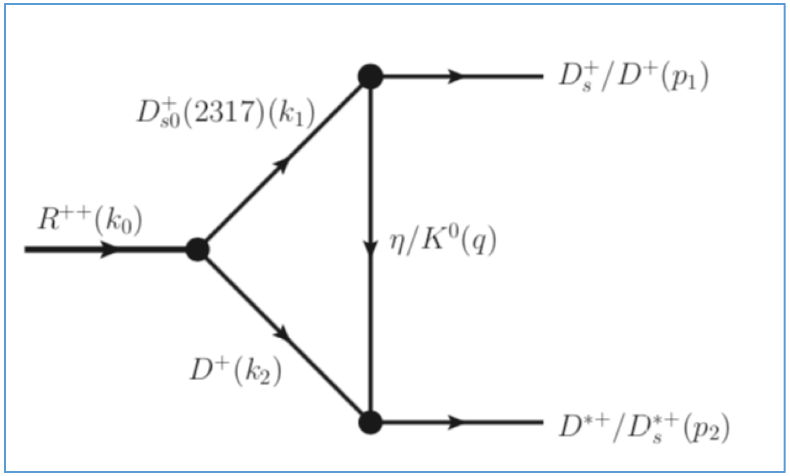
$$R^{++} = (I, I_{23}) = (\frac{1}{2}, 0)$$

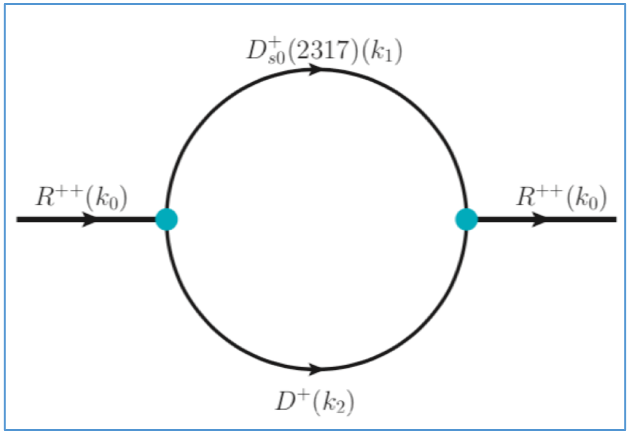
R^{+} should also exist

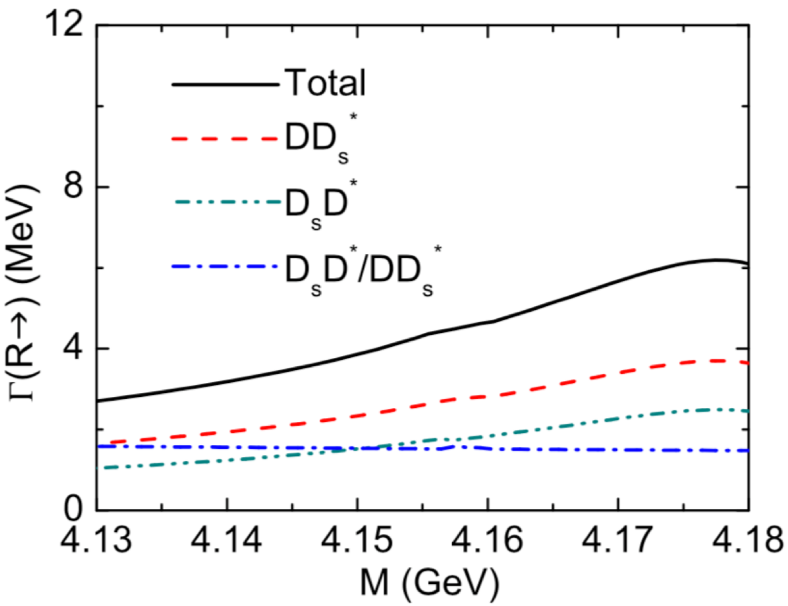
R^{++} is a bound state, but can decay strongly

Two-body decay width

*Yin Huang, **LSG**, et al., in preparation*







Preliminary result:
$\Gamma \sim 10$ MeV

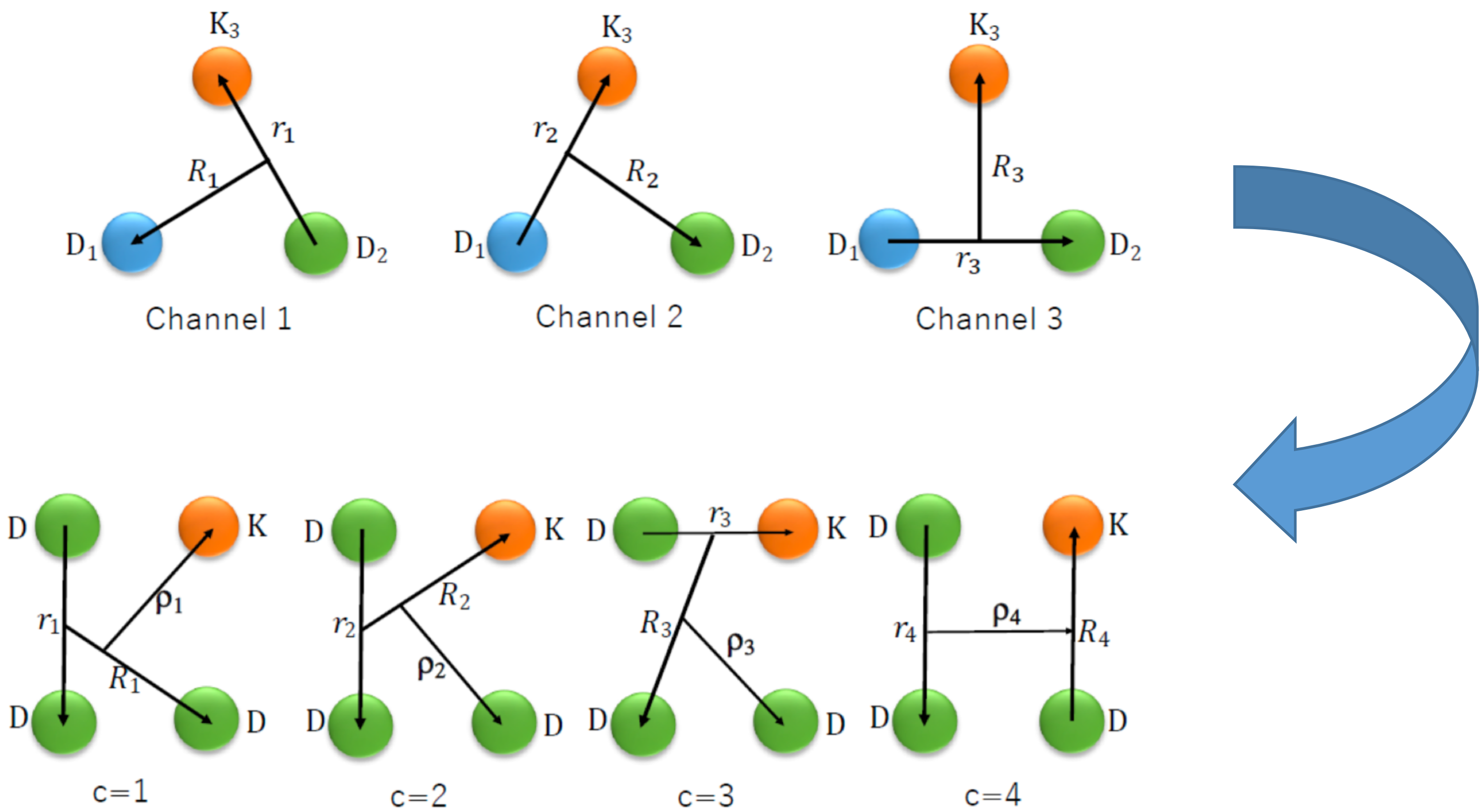
*Tian-Wei Wu, **LSG**, et al., in preparation*

A DDDK state

1(0+)

Gaussian Expansion Method

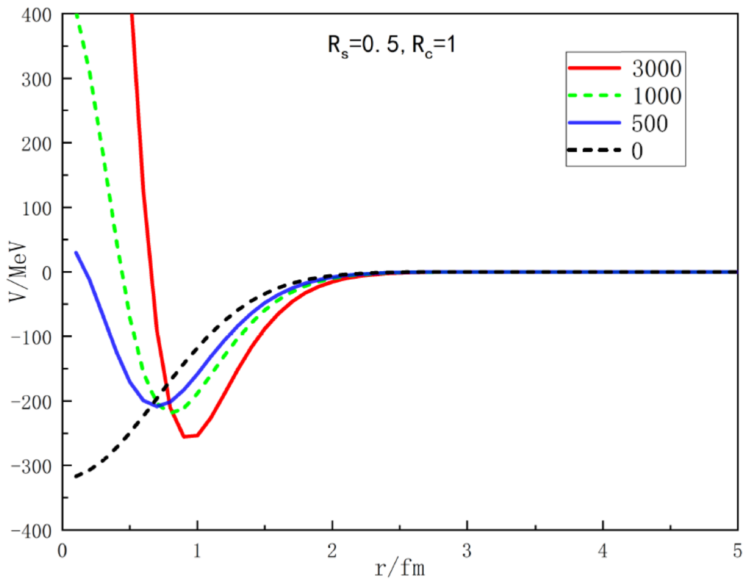
What if we add one more D?

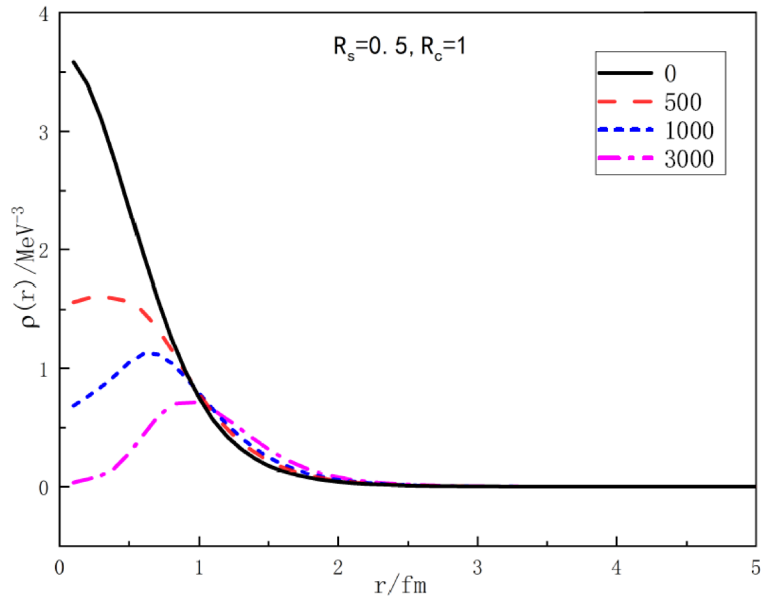


A DDDK state 1(0^+)

Gaussian Expansion Method

What if we add one more D? Preliminary results show that such a state exists as well





Uncertainties are at **the order of 10-20 MeV**

$$V_{DK}(\vec{r}; R_c) = C_S \frac{e^{-(r/R_S)^2}}{\pi^{3/2} R_S^3} + C(R_C) \frac{e^{-(r/R_c)^2}}{\pi^{3/2} R_c^3},$$

	DK*	DDK	DDDK
Binding	45 MeV	(67-71) MeV	91-107 MeV

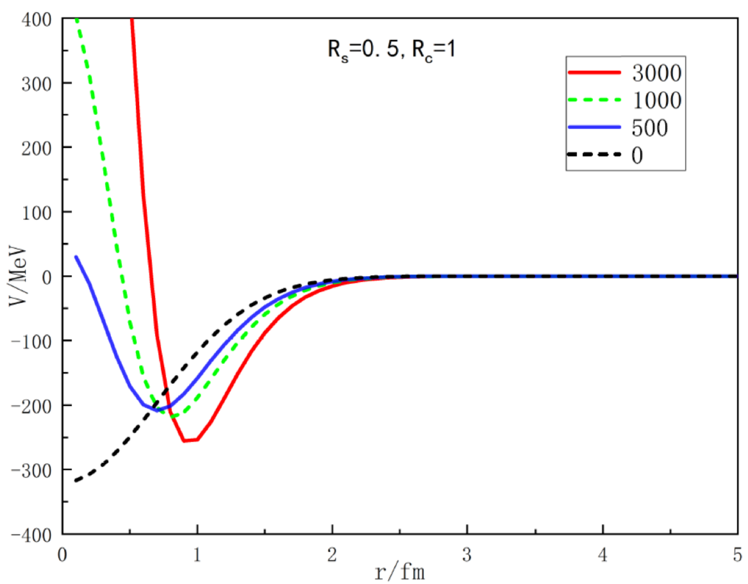
四楼长沙厅，周一下午15：25，吴天伟

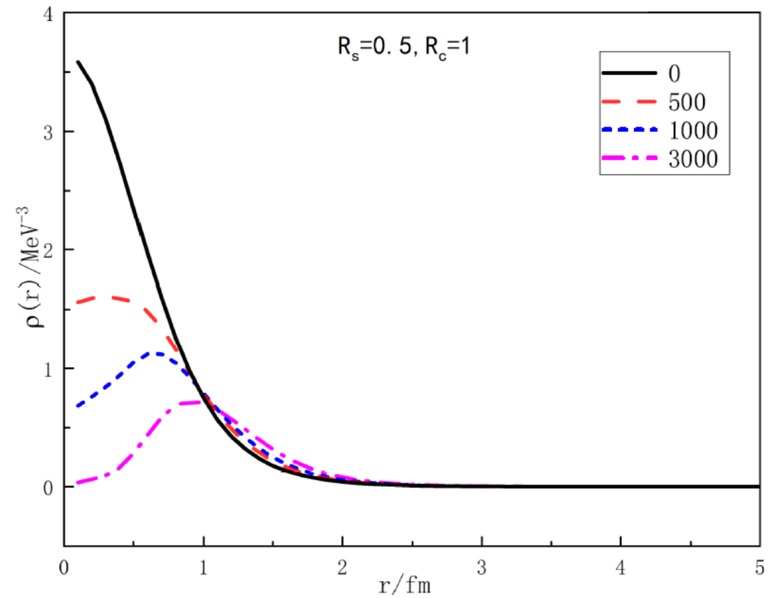
A DDDK state

1(0⁺)

Gaussian Expansion Method

What if we add one more D? Preliminary results show that such a state exists as well





Uncertainties are at **the order of 10-20 MeV**

$$V_{DK}(\vec{r};R_c) = C_S\,\frac{e^{-(r/R_S)^2}}{\pi^{3/2}R_S^3} + C(R_C)\,\frac{e^{-(r/R_c)^2}}{\pi^{3/2}R_c^3},$$

	DK*	DDK	DDDK
Binding	45 MeV	(67-71) MeV	91-107 MeV

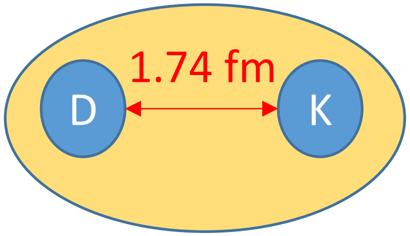
DD interactions play a minor role

$\frac{C_S}{\pi R_S^3}$	$\frac{C(R_c)}{\pi R_c^3}$	E_2	E_3(only V_{DK})	$E_3(V_{DK}+V_{DD})$	E_4(onlyV_{DK})	$E_4(V_{DK}+V_{DD})$
		$R_S=0.5$fm		$R_c=1$fm		
0	−320.1	−45.0	−65.8	−71.2	−89.4	−106.8
500	−455.4	−45.0	−65.8	−70.4	−89.2	−103.5
1000	−562.6	−45.0	−65.7	−69.7	−88.8	−101.4
3000	−838.7	−45.0	−65.0	−68.4	−87.0	−97.3
		$R_S=0.5$fm		$R_c=2$fm		
0	−149.1	−45.0	−66.0	−68.8, −45.1	−88.7, −66.3	−97.6, −70.7
500	−178.4	−45.0	−65.9	−68.2, −45.5	−88.5, −66.7	−95.5, −70.9
1000	−195.0	−45.0	−65.8, −45.2	−67.9, −45.8	−88.2, −66.9	−94.5, −71.2
3000	−225.9	−45.0	−65.3, −45.6	−67.2, −46.6	−87.0, −67.0	−92.6, −71.7
		$R_S=0.5$fm		$R_c=3$fm		
0	−107.0	−45.0	−66.2, −47.3	−68.0, −48.3	−88.8, −70.2	−94.4, −74.3
500	−119.4	−45.0	−66.2, −48.2	−67.7, −49.3	−88.7, −71.0	−93.2, −74.8
1000	−125.6	−45.0	−66.1, −48.7	−67.5, −49.8	−88.4, −71.3	−92.5, −75.2
3000	−136.2	−45.0	−65.8, −49.4	−67.1, −50.7	−87.6, −71.7	−91.4, −75.7

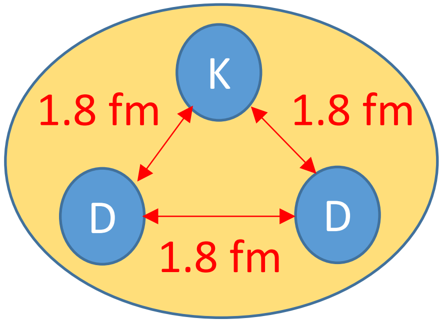
Spatial distributions

$\frac{C_S}{\pi R_S^3}$	$\frac{C(R_c)}{\pi R_c^3}$	$r_2(DK)$	$r_3(DK)$	$r_3(DD)$	$< T >$	$< V_{DK} >$	$< V_{DD} >$
$R_S = 0.5$fm $R_c = 1$fm							
0	−320.1	1.28	1.32	1.36	124.37	−189.61	−5.98
500	−455.4	1.39	1.44	1.47	99.51	−164.83	−5.03
1000	−562.6	1.46	1.53	1.54	91.43	−156.67	−4.51
3000	−838.7	1.61	1.69	1.68	93.24	−157.80	−3.82
$R_S = 0.5$fm $R_c = 2$fm							
0	−149.1	1.74	1.80	1.80	60.20	−125.74	−3.23
500	−178.4	1.91	1.98	1.96	51.00	−116.59	−2.64
1000	−195.0	1.99	2.07	2.04	50.63	−116.12	−2.43
3000	−225.9	2.13	2.22	2.15	53.61	−118.59	−2.24
$R_S = 0.5$fm $R_c = 3$fm							
0	−107.0	2.13	2.19	2.17	39.49	−105.35	−2.13
500	−119.4	2.31	2.38	2.34	34.80	−100.73	−1.77
1000	−125.6	2.37	2.47	2.42	34.90	−100.77	−1.65
3000	−136.2	2.53	2.61	2.53	36.66	−102.24	−1.54

Ds0*(2317)



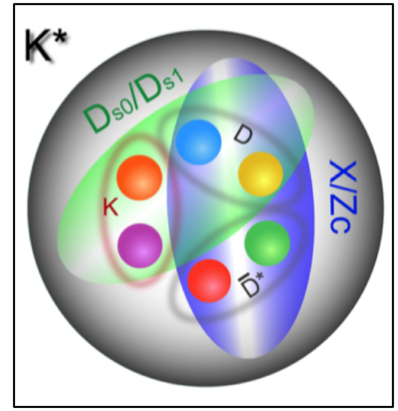
R(4140)



Contents

- **Motivation: new types of clusters of color singlets in addition to nuclei**
- **Ds0*(2317) and Ds1(2460) as DK/D*K molecules**
- **Explicit studies of the DDK & DDDK** systems
- **A K*(4307) with hidden charm as KX(3872)/Zc(3900) molecule**
- **Summary and outlook**

K*(4307)



Instead of a D, what happens if we add a $\overline{D}^*$ to the DK pair

Physics Letters B 785 (2018) 112–117

Contents lists available at ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb

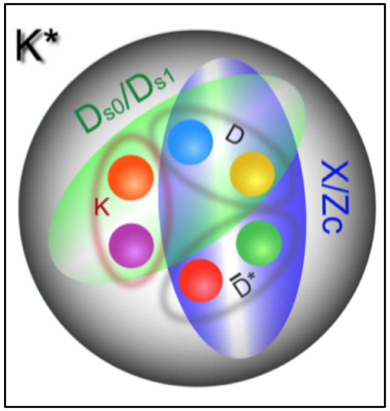
K^* mesons with hidden charm arising from $KX(3872)$ and $KZ_c(3900)$ dynamics

Xiu-Lei Ren [a], Brenda B. Malabarba [b], Li-Sheng Geng [c,d], K.P. Khemchandani [e,c], A. Martínez Torres [b,c,*]

[a] Institut für Theoretische Physik II, Ruhr-Universität Bochum, D-44780 Bochum, Germany
[b] Instituto de Física, Universidade de São Paulo, C.P. 66318, 05389-970 São Paulo, São Paulo, Brazil
[c] School of Physics and Nuclear Energy Engineering & Beijing Key Laboratory of Advanced Nuclear Materials and Physics, Beihang University, Beijing 100191, China
[d] Beijing Advanced Innovation Center for Big Date-Based Precision Medicine, Beihang University, Beijing 100191, China
[e] Universidade Federal de São Paulo, C.P. 01302-907, São Paulo, Brazil

D

K*(4307)



- **Fixed center approximation (FCA):**

$$K(D\overline{D^*} + \overline{D}D^*) \sim KX(3872)/Zc(3900)$$

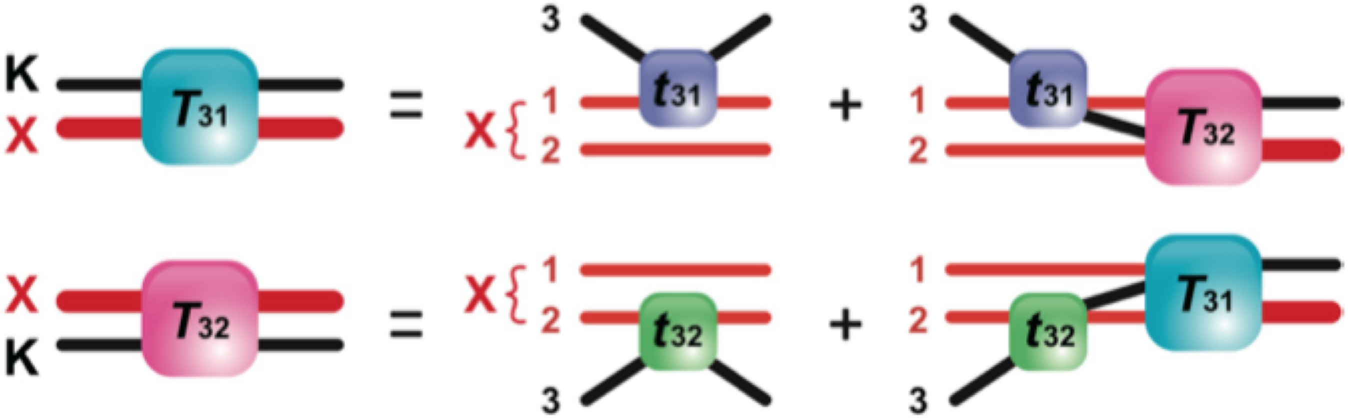
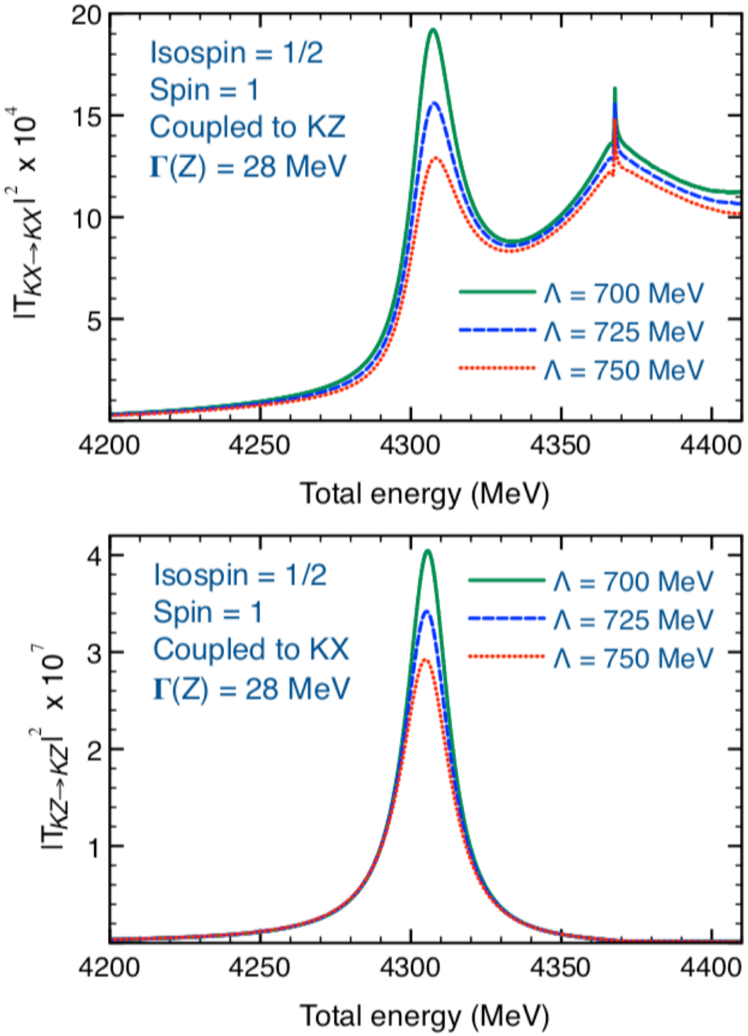
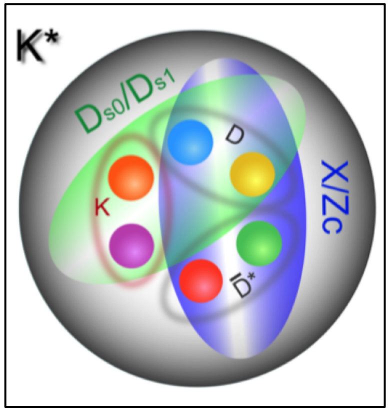


Figure 2: Diagrams showing the scattering of the particle labeled "3" (K) on a cluster (X) made of particles 1 (D) and 2 ($\bar{D}^*$).

K*(4307)

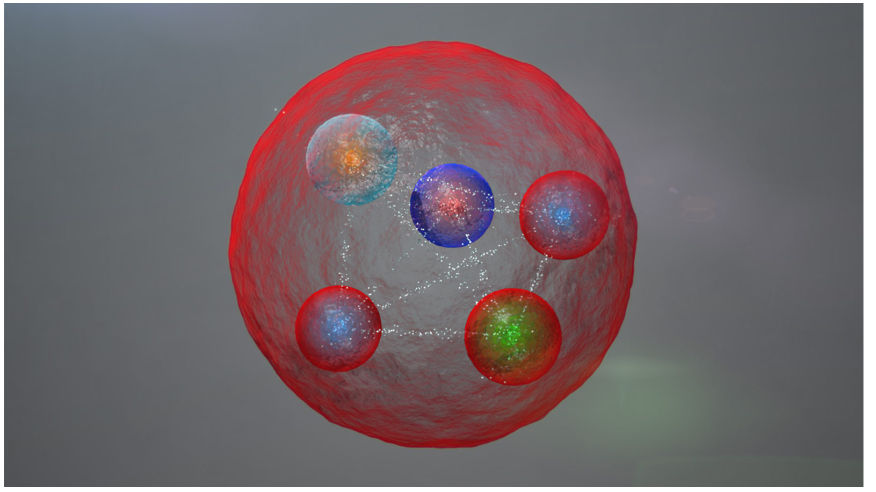




- **Treating KX and KZ as coupled channel systems**
- **A resonance with M=(4307 ± 2) – i(9 ± 2) MeV with $I(J^P) = 1/2(1^-)$**

In agreement with Li Ma, Qian Wang, Ulf-G. Meißner, 1711.06143, but with completely different dynamics

K*(4307)—bosonic counterpart of Pc



Pentaquark (N*) by LHCb

Phys.Rev.Lett. 115 (2015) 072001

Prediction of narrow N* and Λ* resonances with hidden charm above 4 GeV, Jia-Jun Wu, R. Molina, E. Oset, B.S. Zou, 1007.0573

Analogy between KD and Kbar N

$\mathbf{D}_{s0}^{*}(2317)$

- DK bound state
- **Dynamically generated**--
  Unitary heavy hadron
  chiral perturbation theory
- Coupled channels

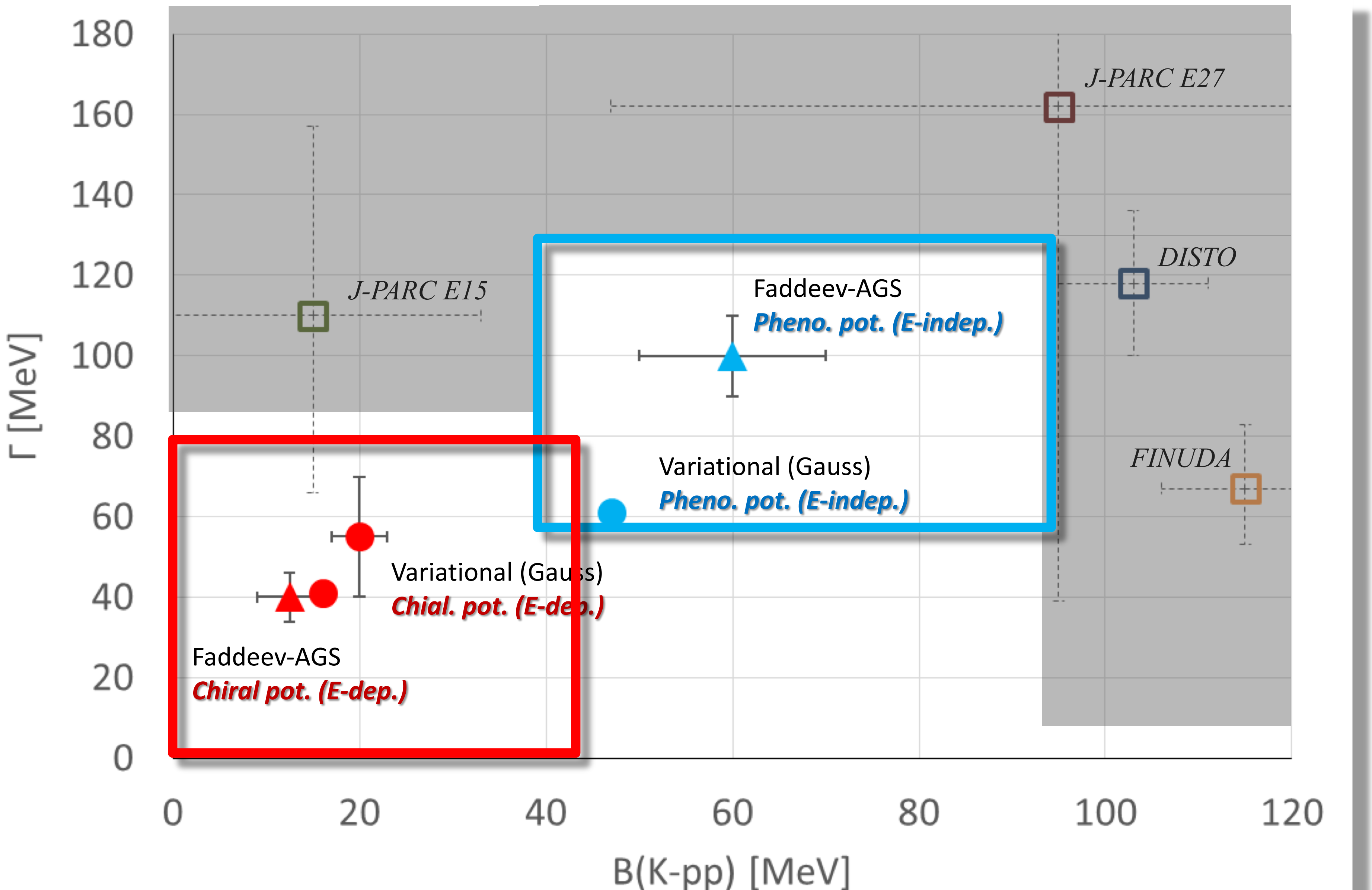
$\boldsymbol{\Lambda}(1405)$

- N-Kbar bound state
- **Dynamically generated**--
  Unitary baryon chiral
  perturbation theory
- Coupled channels

The interaction between **a kaon and a heavy particle** seems to play an important role

Current status on "$K^{-}pp$"

A. Dote, Menu2019



Summary and outlook

- From nucleons, we can build nuclei, based on which the whole visible universe is formed
- **If the Ds0*(2317) is indeed a molecule of DK**, then new forms of matter may be built upon them
- **We have performed explicit few-body studies**–demonstrating that indeed both DDK and DDDK bound states **exist**
- Now we need experimental or lattice QCD confirmations and further theoretical studies on their production and decay mechanisms

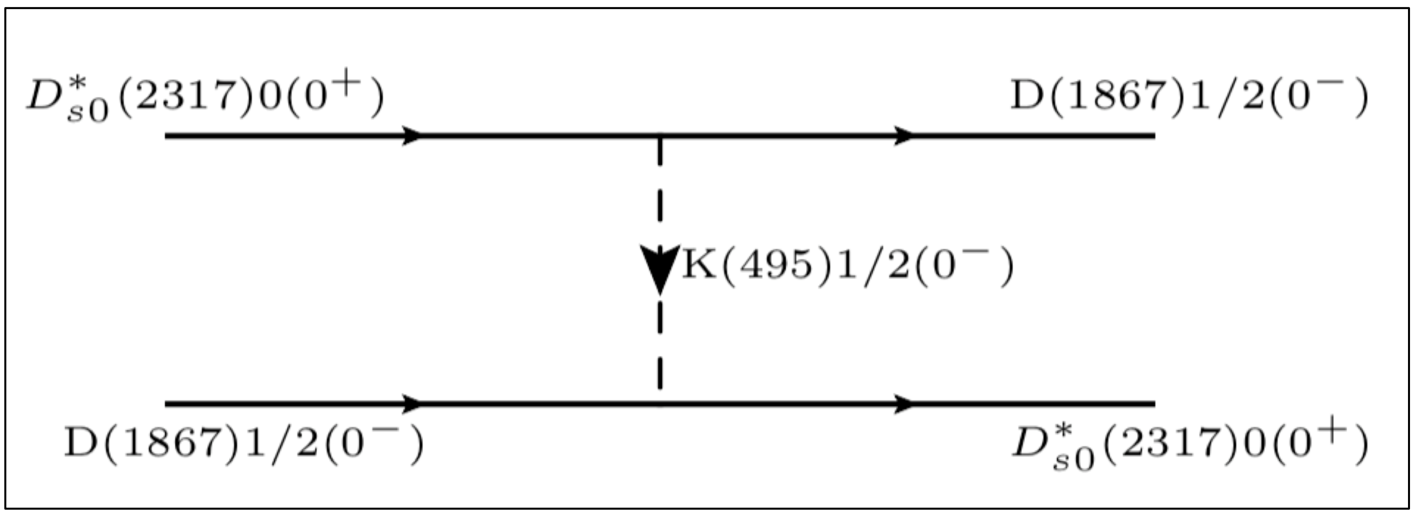
北京航空航天大學
BEIHANG UNIVERSITY

Thanks for your attention！

June 22, 2019

Even if the Ds0 is a csbar state, Ds0 D binds

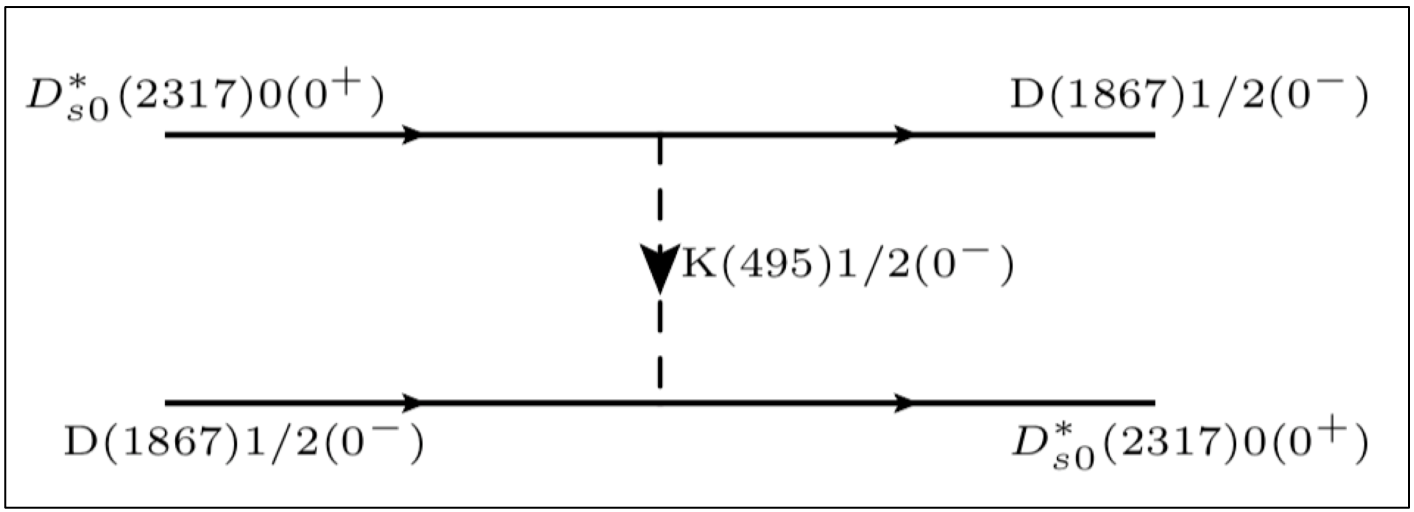
Interestingly, the explicit three-body result is consistent with the quasi two body study, where one treats the DK pair as the Ds0* and describes the interaction between the Ds0* with the D using one-kaon exchange



Mario Sanchez Sanchez, LSG, Jun-Xu Lu, Tetsuo Hyodo, Manuel Pavon Valderrama. 1707.03802

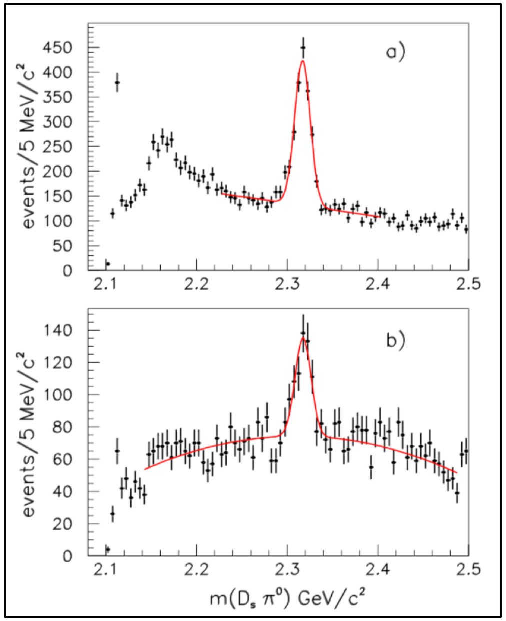
Even if the Ds0 is a $c\bar{s}$ state, Ds0 D binds

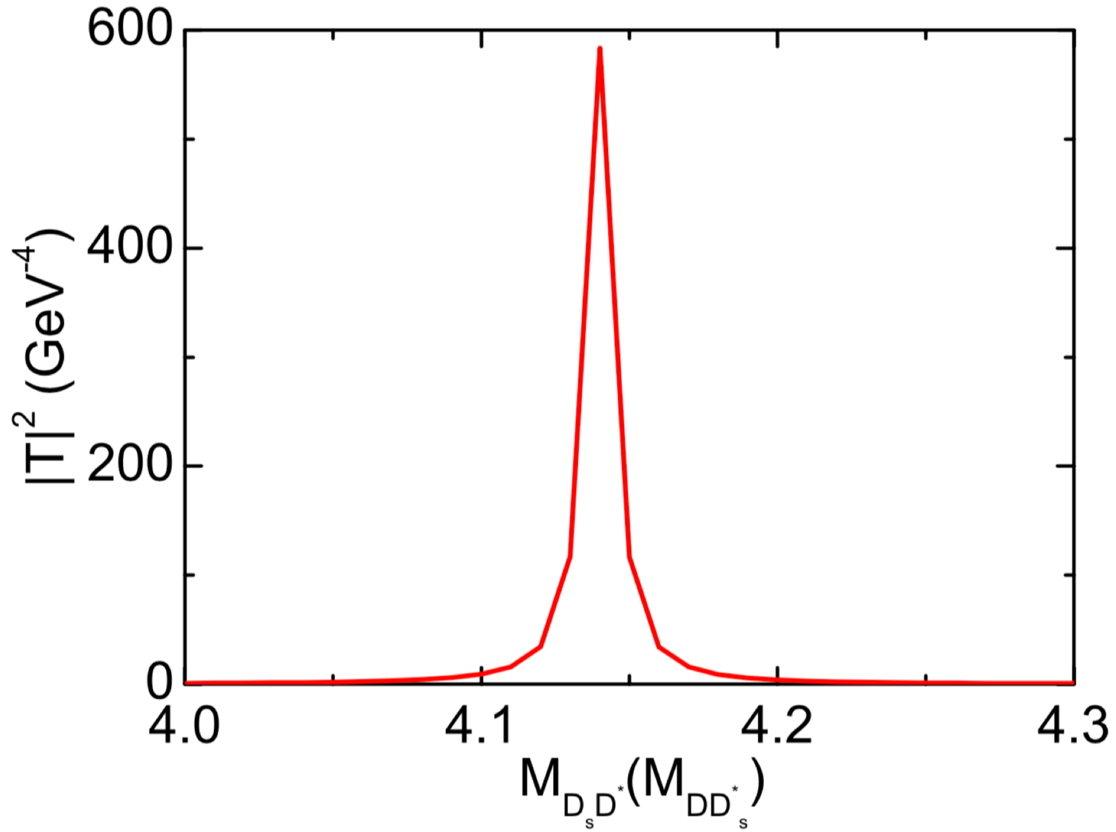
Interestingly, the explicit three-body result is consistent with the quasi two body study, where one treats the DK pair as the Ds0* and describes the interaction between the Ds0* with the D using one-kaon exchange



Mario Sanchez Sanchez, LSG, Jun-Xu Lu, Tetsuo Hyodo, Manuel Pavon Valderrama. 1707.03802

Where to look for the R^{++}/R^{+}





- **Belle/BelleII**

$$e^+e^- \to XR \to XD^+D_s^+\pi^0$$

- **LHCb**

$$p\bar{p} \to XR \to XD^+D_s^+\pi^0$$