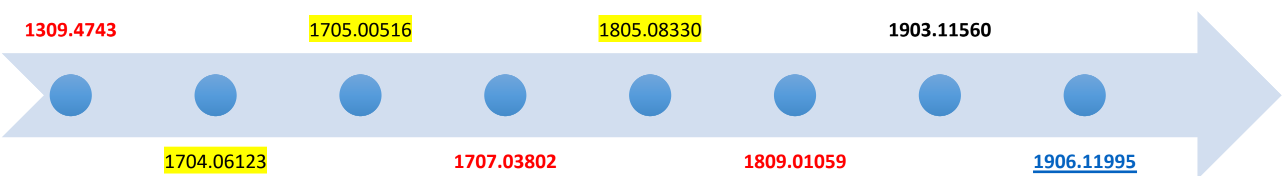
13th APCTP - BLTP JINR Joint Workshop
"Modern problems in nuclear and elementary particle physics"

北京航空航天大學
BEIHANG UNIVERSITY

DK interaction as a doorway to manifestly exotic mesons

Lisheng Geng @ Beihang U.



+some preliminary results

Contents

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- **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**

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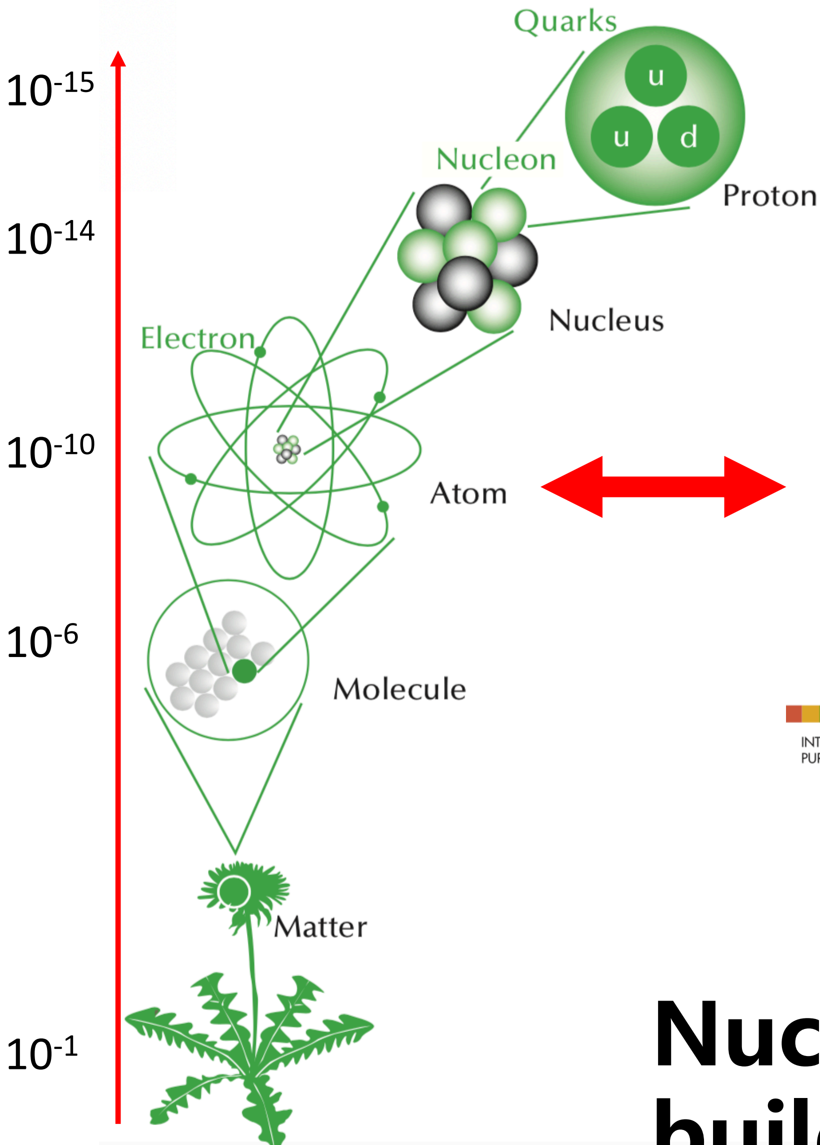
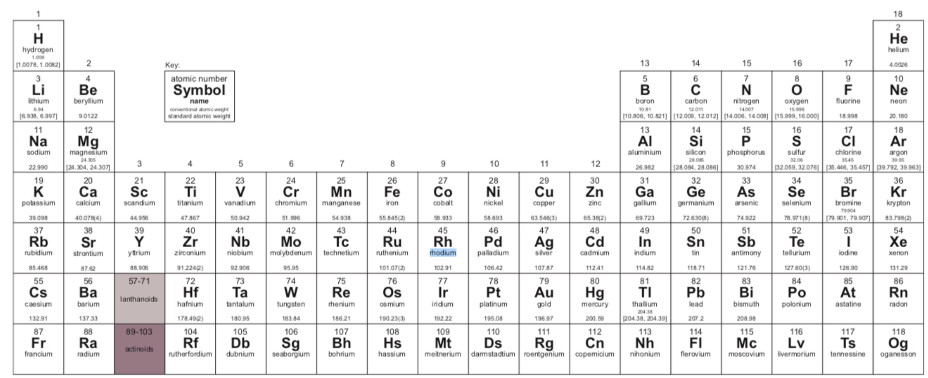


United Nations Educational, Scientific and Cultural Organization

2019 IYPT International Year of the Periodic Table of Chemical Elements



IUPAC Periodic Table of the Elements

Key: atomic number / Symbol / name / conventional atomic weight / standard atomic weight

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H hydrogen																	2 He helium
3 Li lithium	4 Be beryllium											5 B boron	6 C carbon	7 N nitrogen	8 O oxygen	9 F fluorine	10 Ne neon
11 Na sodium	12 Mg magnesium											13 Al aluminium	14 Si silicon	15 P phosphorus	16 S sulfur	17 Cl chlorine	18 Ar argon
19 K potassium	20 Ca calcium	21 Sc scandium	22 Ti titanium	23 V vanadium	24 Cr chromium	25 Mn manganese	26 Fe iron	27 Co cobalt	28 Ni nickel	29 Cu copper	30 Zn zinc	31 Ga gallium	32 Ge germanium	33 As arsenic	34 Se selenium	35 Br bromine	36 Kr krypton
37 Rb rubidium	38 Sr strontium	39 Y yttrium	40 Zr zirconium	41 Nb niobium	42 Mo molybdenum	43 Tc technetium	44 Ru ruthenium	45 Rh rhodium	46 Pd palladium	47 Ag silver	48 Cd cadmium	49 In indium	50 Sn tin	51 Sb antimony	52 Te tellurium	53 I iodine	54 Xe xenon
55 Cs caesium	56 Ba barium	57-71 lanthanoids	72 Hf hafnium	73 Ta tantalum	74 W tungsten	75 Re rhenium	76 Os osmium	77 Ir iridium	78 Pt platinum	79 Au gold	80 Hg mercury	81 Tl thallium	82 Pb lead	83 Bi bismuth	84 Po polonium	85 At astatine	86 Rn radon
87 Fr francium	88 Ra radium	89-103 actinoids	104 Rf rutherfordium	105 Db dubnium	106 Sg seaborgium	107 Bh bohrium	108 Hs hassium	109 Mt meitnerium	110 Ds darmstadtium	111 Rg roentgenium	112 Cn copernicium	113 Nh nihonium	114 Fl flerovium	115 Mc moscovium	116 Lv livermorium	117 Ts tennessine	118 Og oganesson

57 La lanthanum	58 Ce cerium	59 Pr praseodymium	60 Nd neodymium	61 Pm promethium	62 Sm samarium	63 Eu europium	64 Gd gadolinium	65 Tb terbium	66 Dy dysprosium	67 Ho holmium	68 Er erbium	69 Tm thulium	70 Yb ytterbium	71 Lu lutetium
89 Ac actinium	90 Th thorium	91 Pa protactinium	92 U uranium	93 Np neptunium	94 Pu plutonium	95 Am americium	96 Cm curium	97 Bk berkelium	98 Cf californium	99 Es einsteinium	100 Fm fermium	101 Md mendelevium	102 No nobelium	103 Lr lawrencium

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

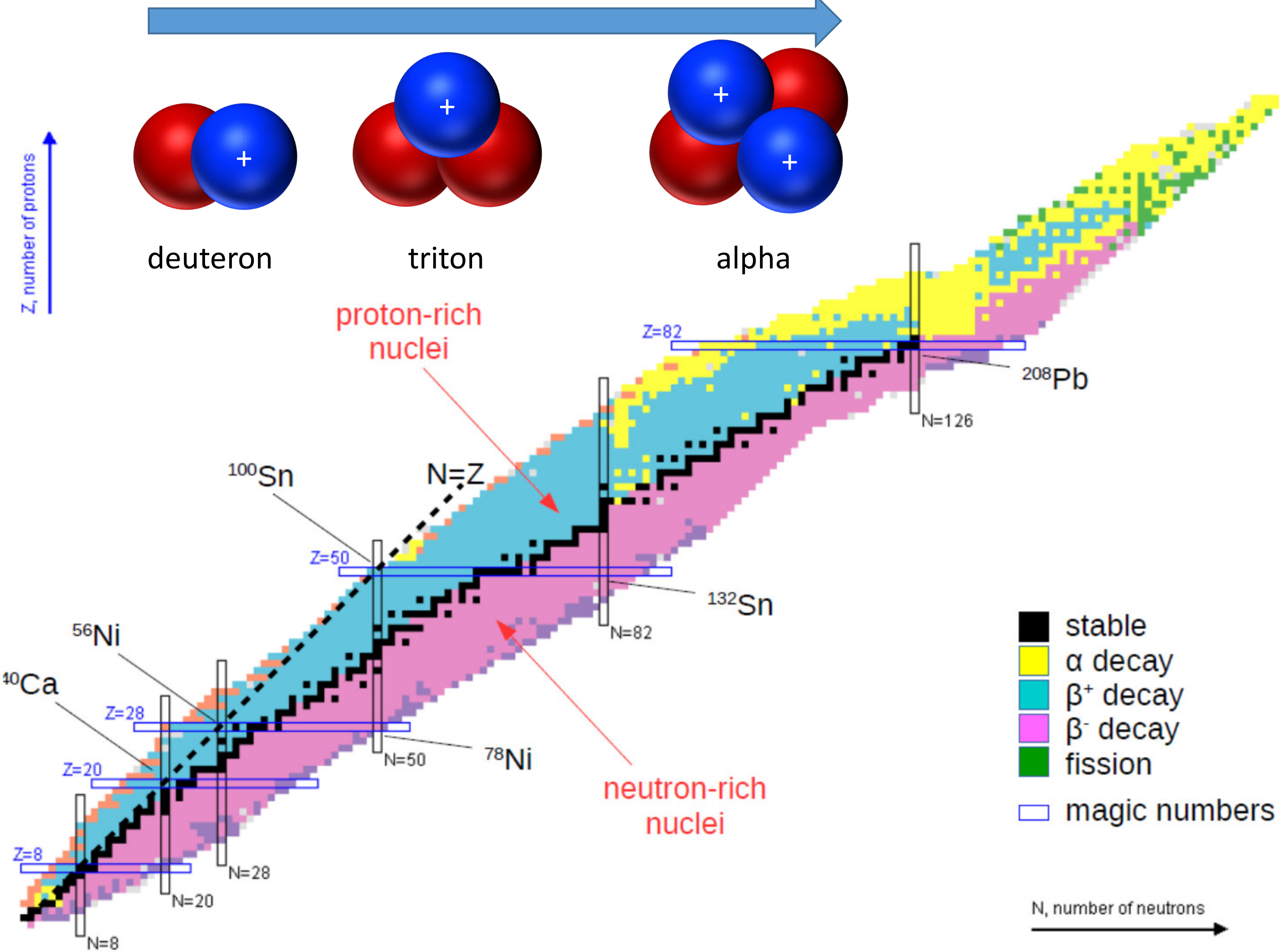
For notes and updates to this table, see www.iupac.org. This version is dated 1 December 2018.

United Nations Educational, Scientific and Cultural Organization · International Year of the Periodic Table of Chemical Elements

IUPAC

Nucleons are the essential building blocks of Matter!

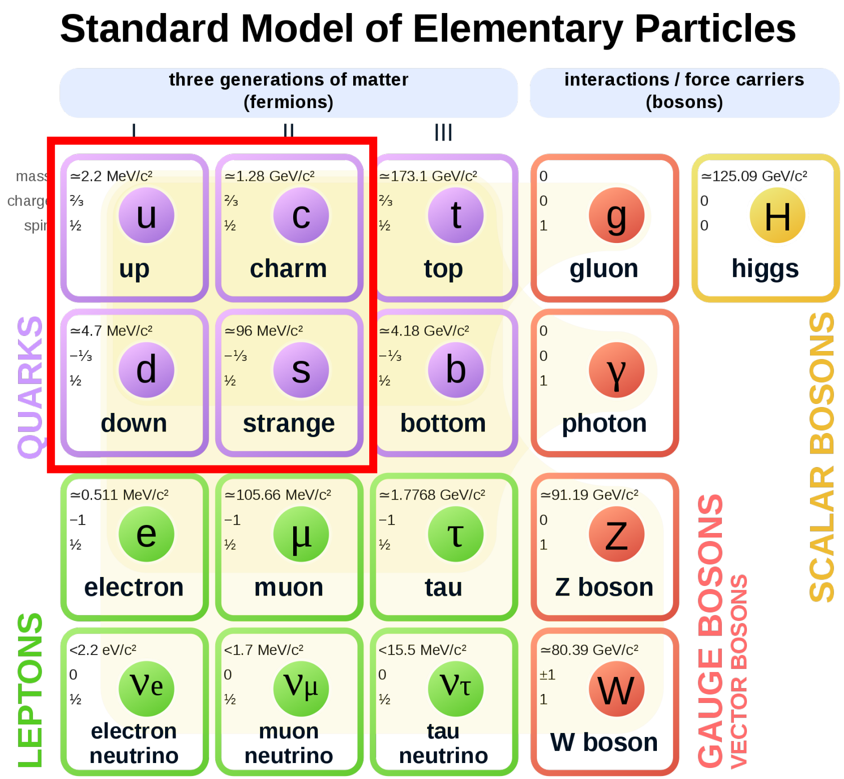
Adapted from LHC the guide

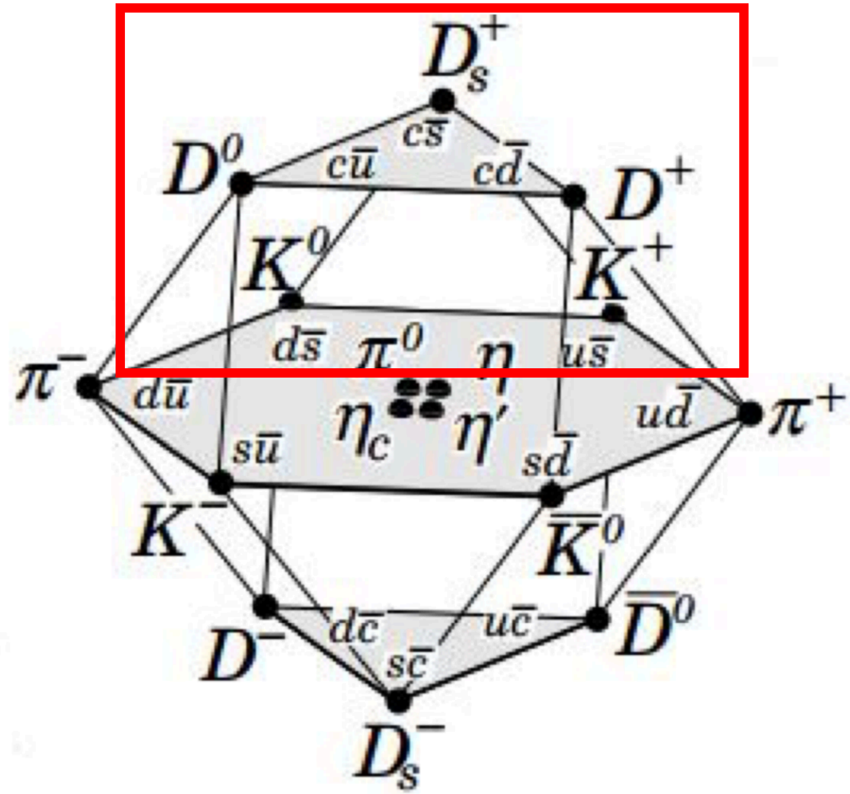


The existence of triton can be inferred from that of deuteron with reasonable confidence

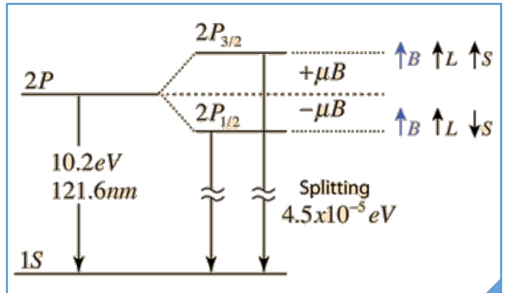
"In nature, are there other clusters of color singlet hadrons, similar to atomic nuclei, bound by the residual strong force？ ？ ？ "

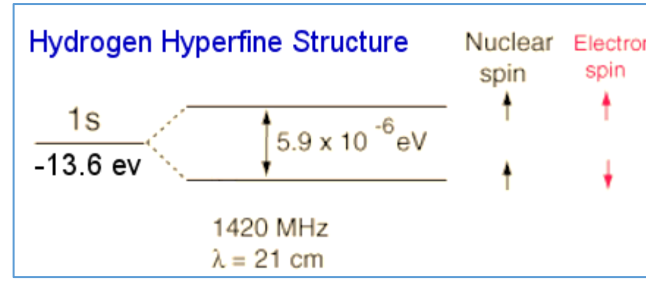
DK/DDK/DDDK molecules???





Why spectroscopy—Atomic





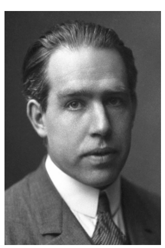
$$\frac{1}{\lambda_{\text{vac}}} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Rydberg formula

Fine structure

Hyperfine structure

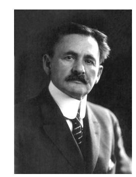
Johannes Rydberg



Niels Henrik David Bohr

Edward W. Morley

Arnold Sommerfeld

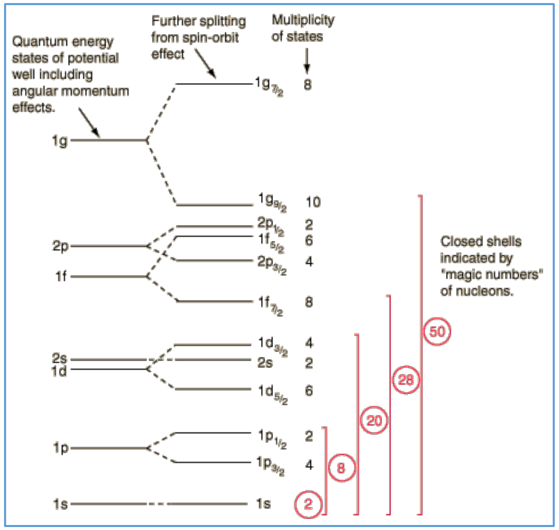


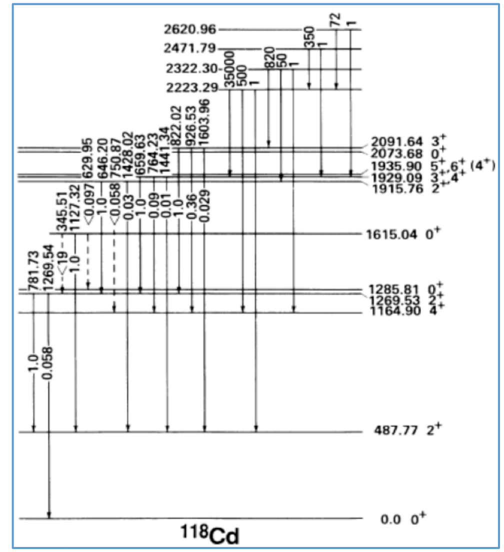
Albert Abraham Michelson

Wolfgang Pauli

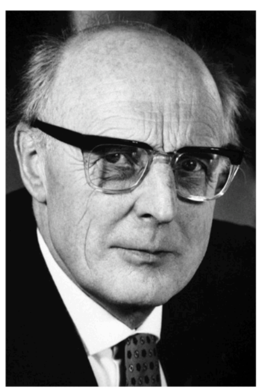
Why spectroscopy—Nuclear

Single particle motion

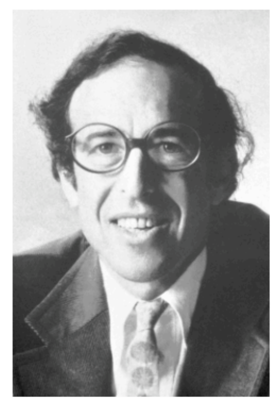




Collective motion

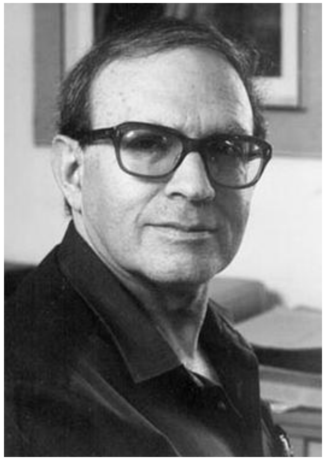
Maria Goeppert Mayer J. Hans D. Jensen

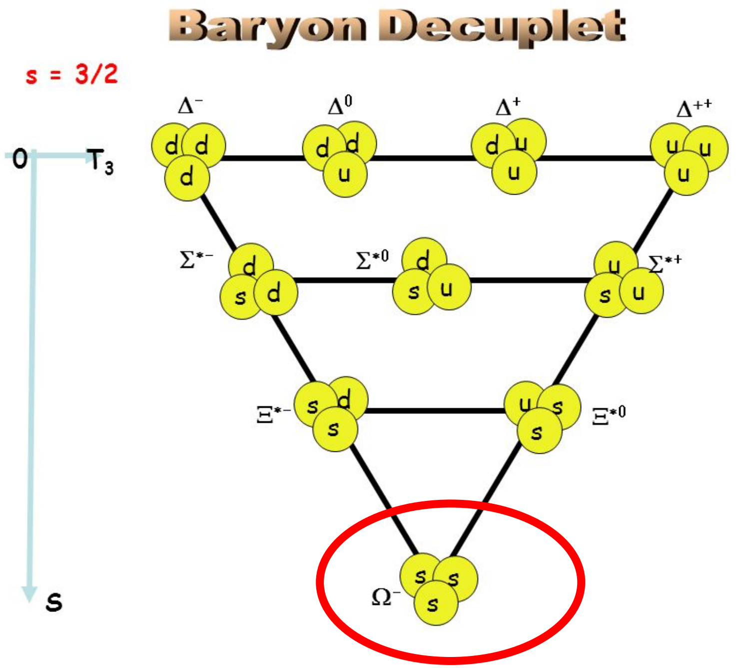

Aage Niels Bohr, Ben Roy Mottelson Leo James Rainwater

Why spectroscopy—particle/hadron

Murray Gell-Mann



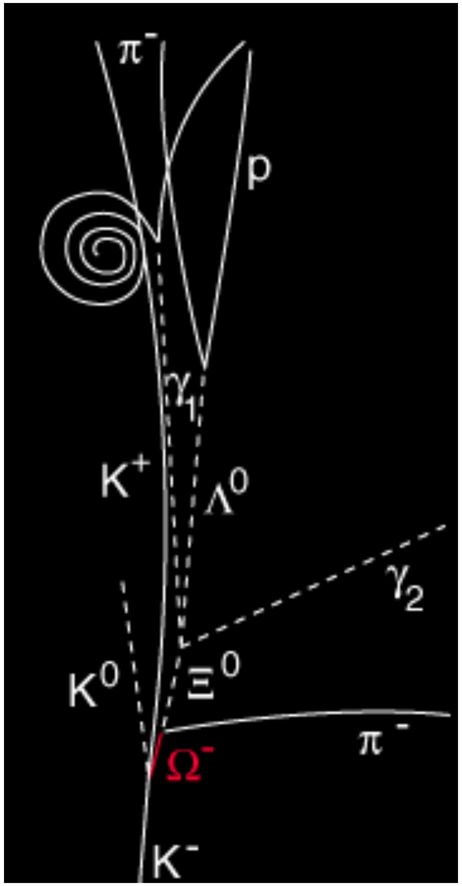
Yuval Ne'eman.



Eightfold way

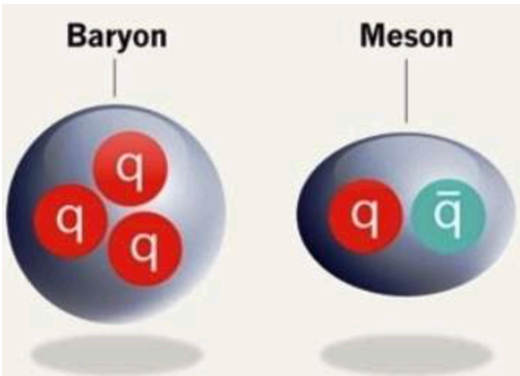
Quark model

QCD/SM



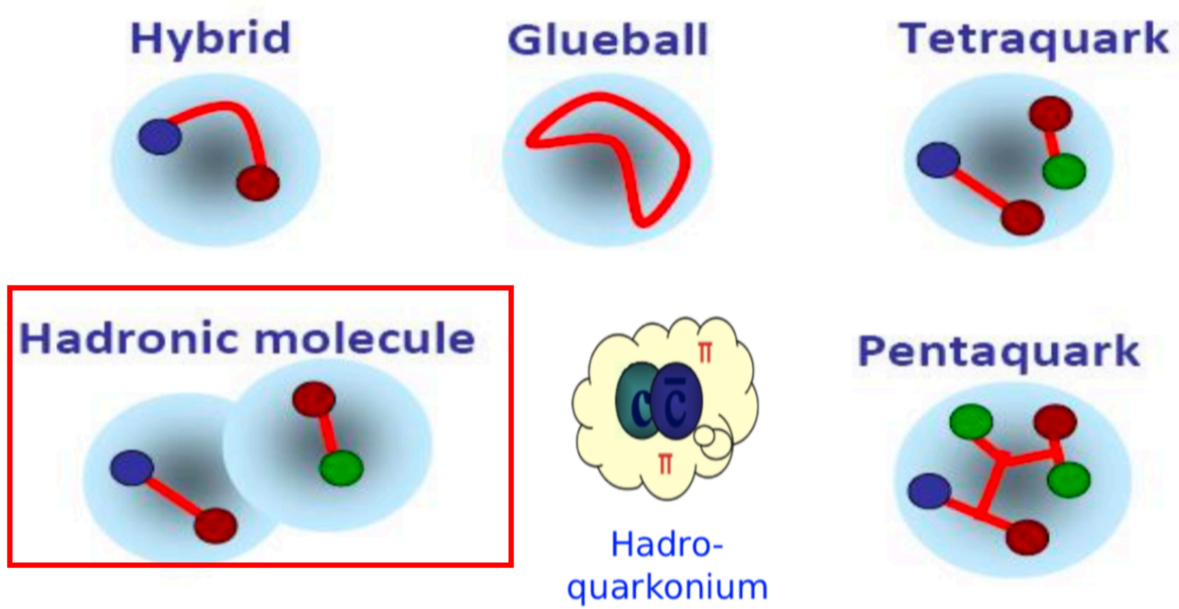
V. E. Barnes et al., Phys. Rev. Lett. 12, 204 (1964)

Why spectroscopy—particle/hadron



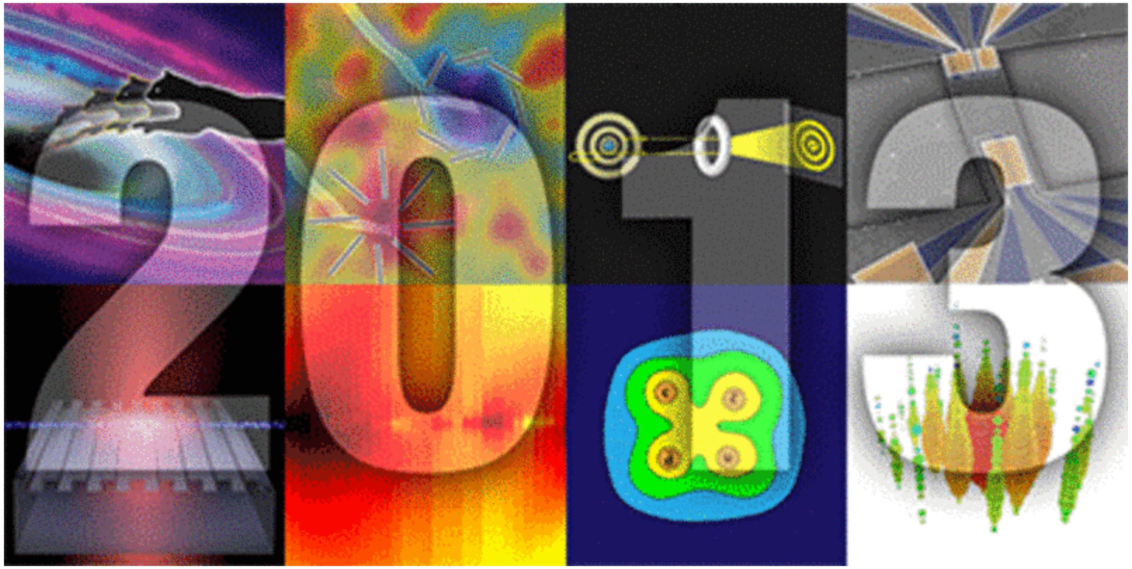
In the naïve quark model

In principle, QCD allows



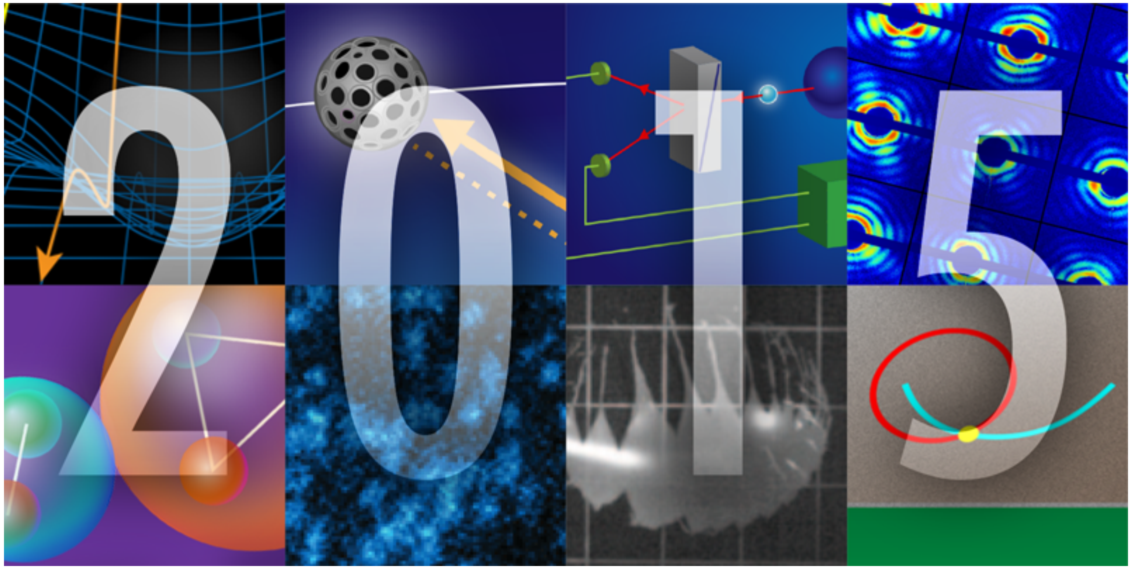
Highlights of the year

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



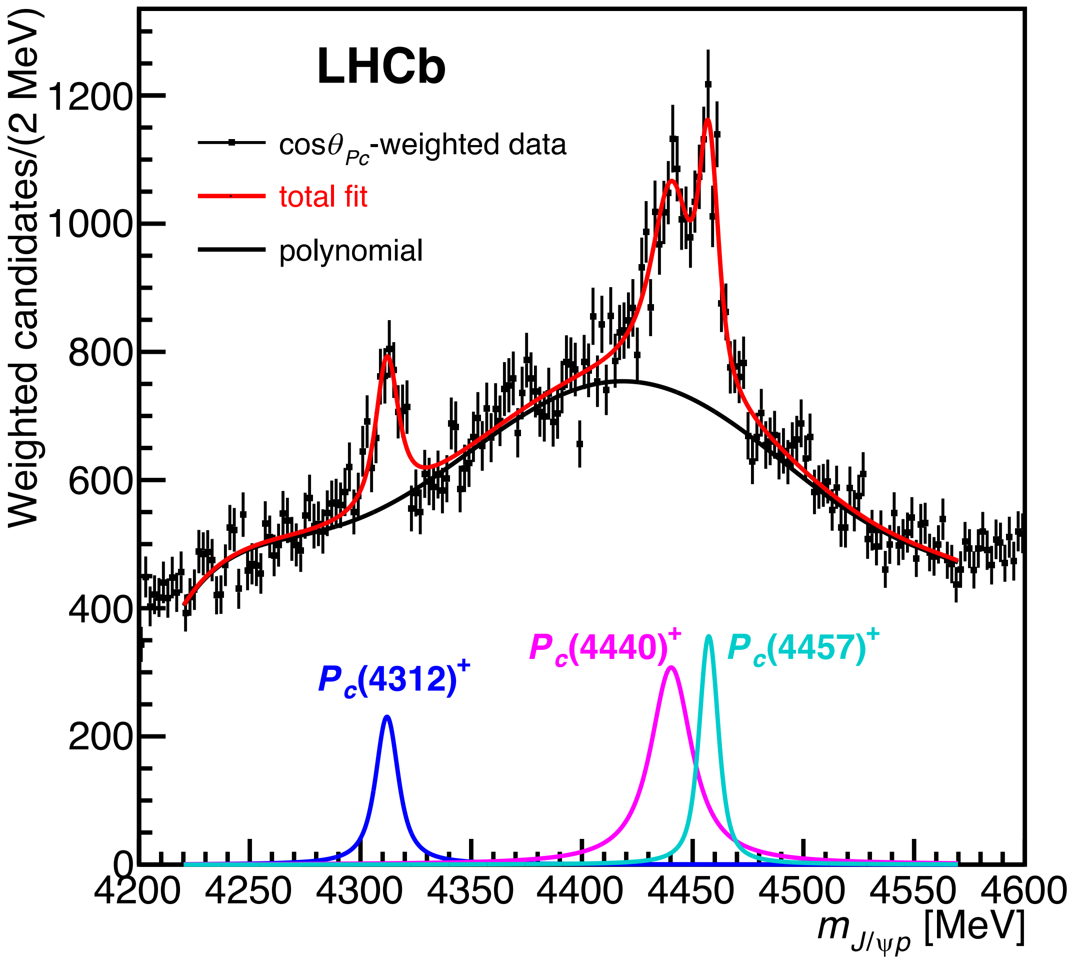
Four-Quark Matter

Particle High Five



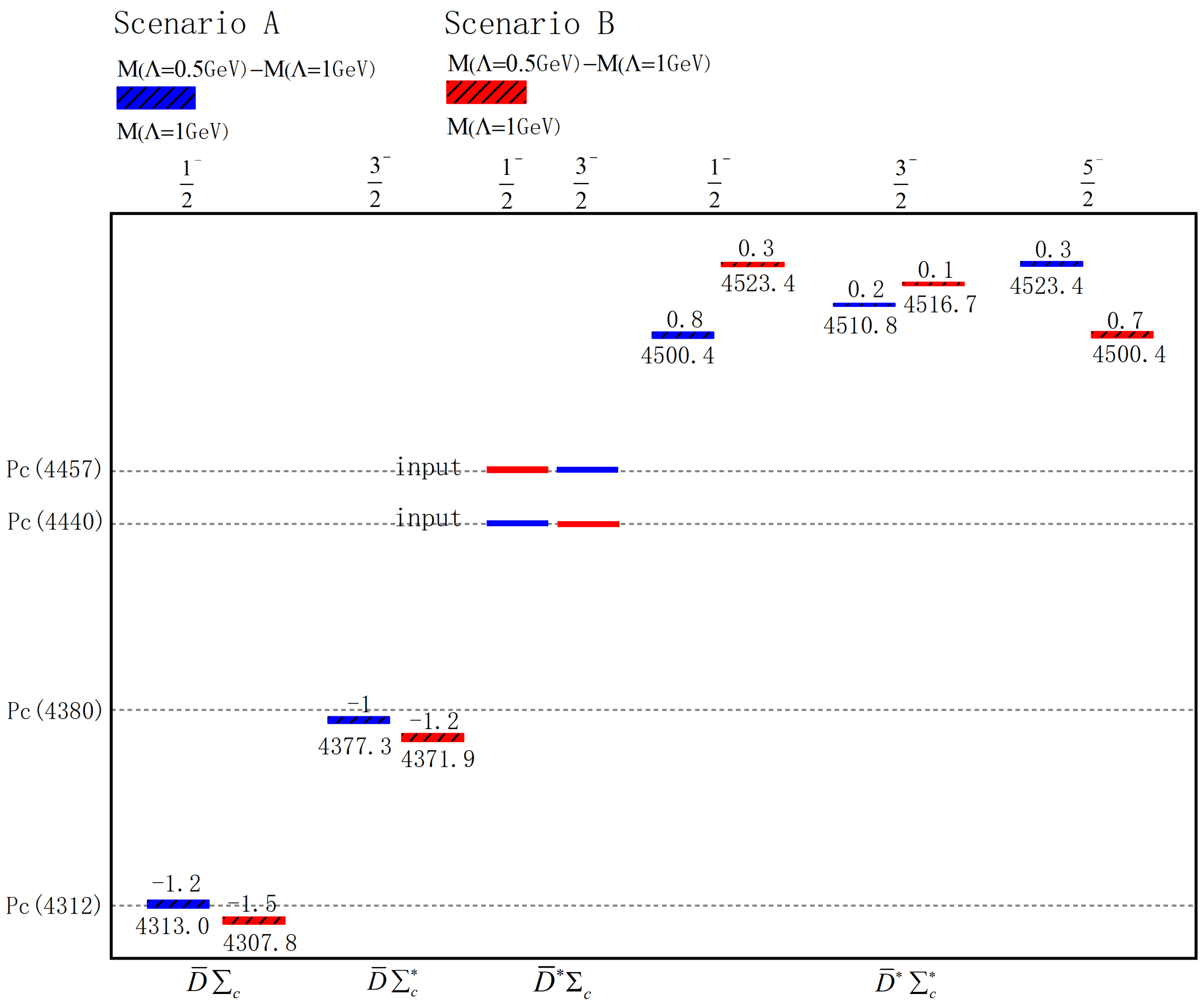
Latest LHCb discovery:

Fine structure observed by LHCb,1904.03947

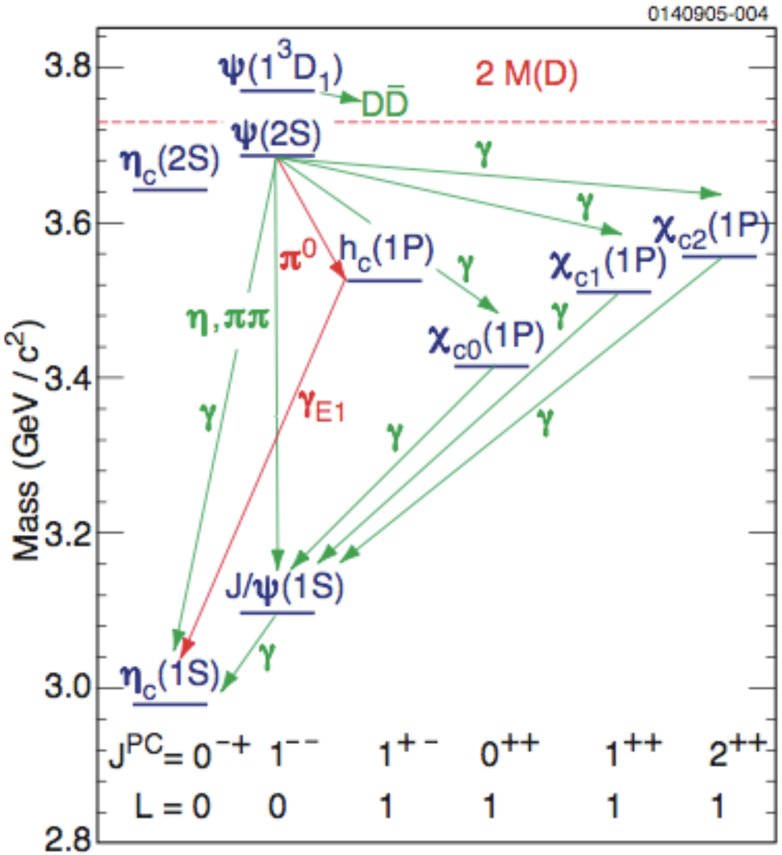


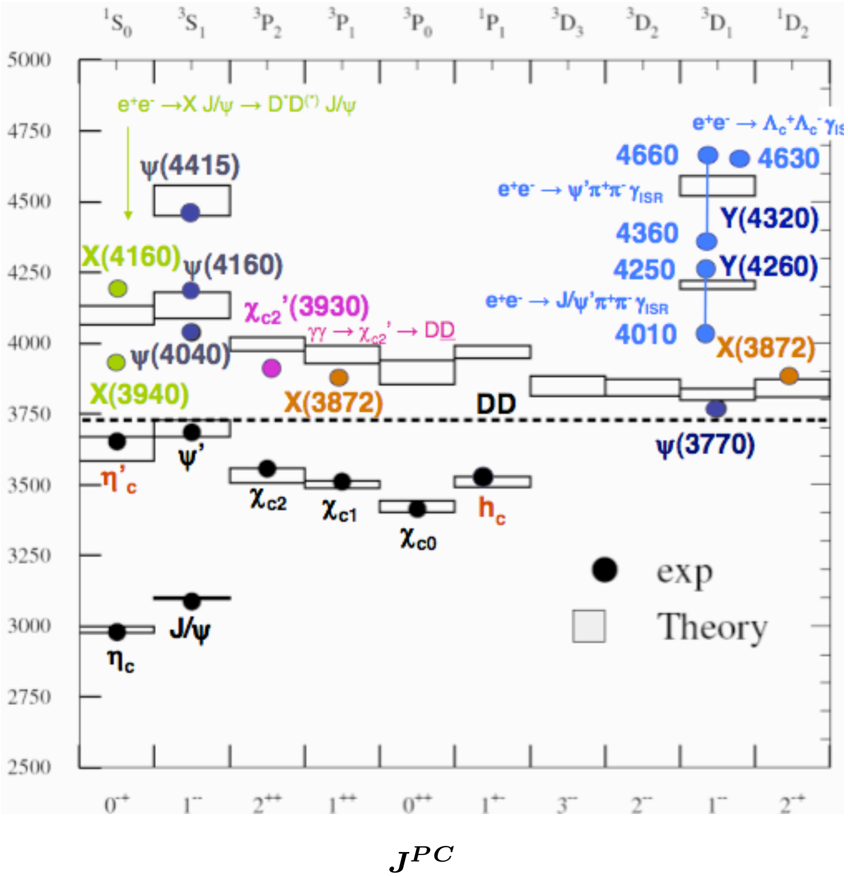
Emergence of a complete heavy-quark spin symmetry multiplet

1903.11560



Charmonium spectroscopy before/after B factories

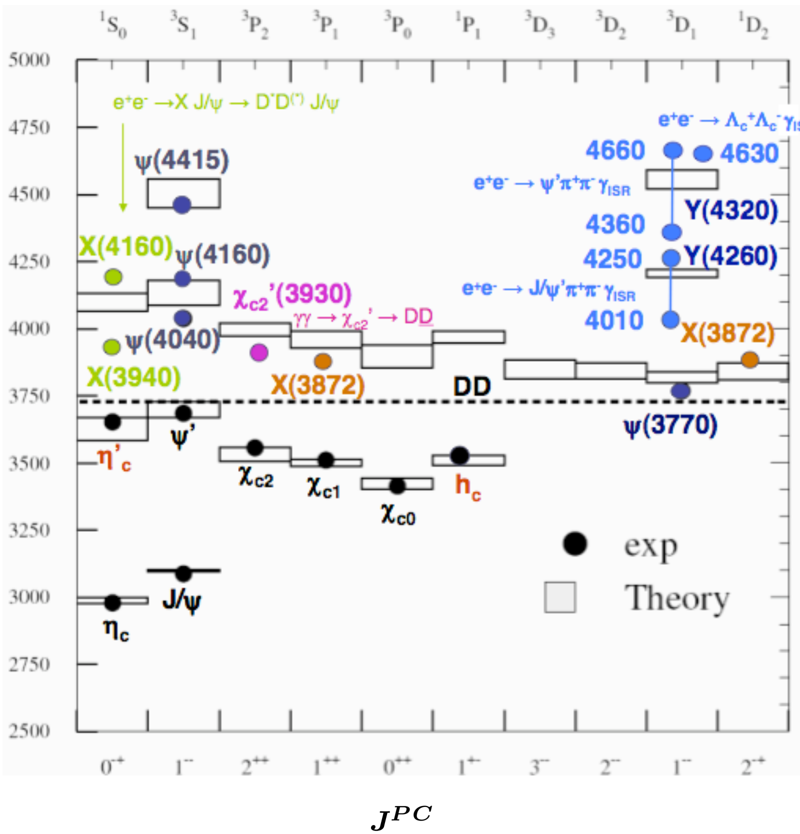




•A lot of new states, but the nature of some states are not well understood, e.g. Y(4260), X(3872), Zc(3900)

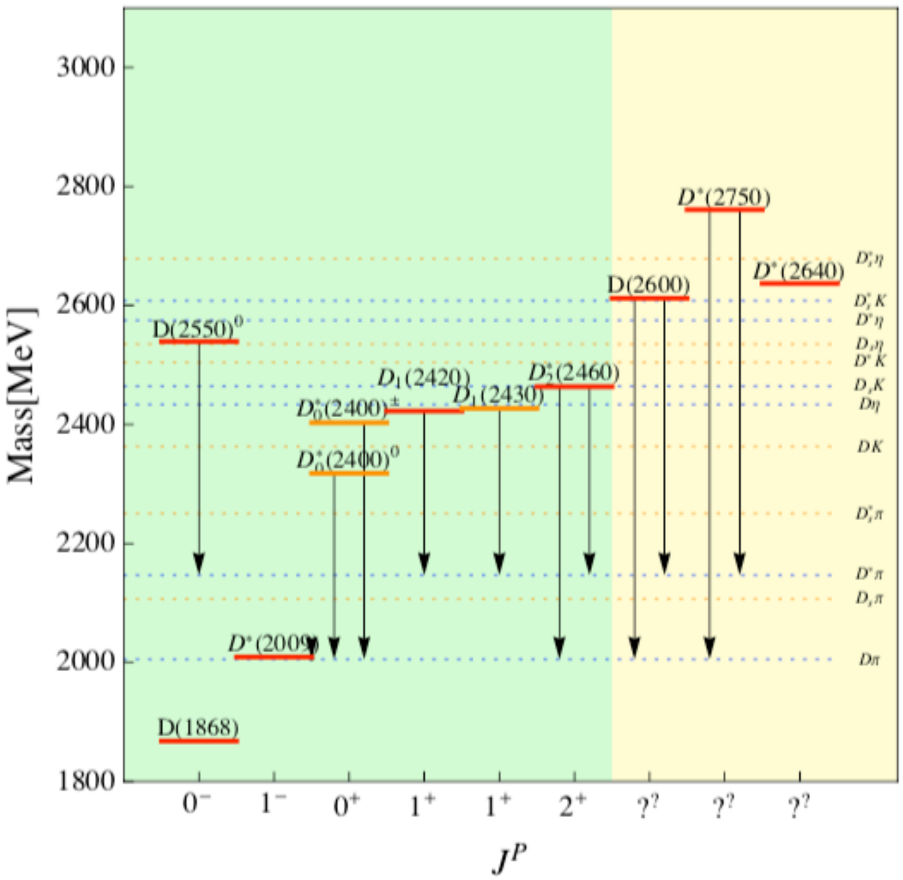
•In complete contrast to the before-B-factory period, when potential models worked quite well.

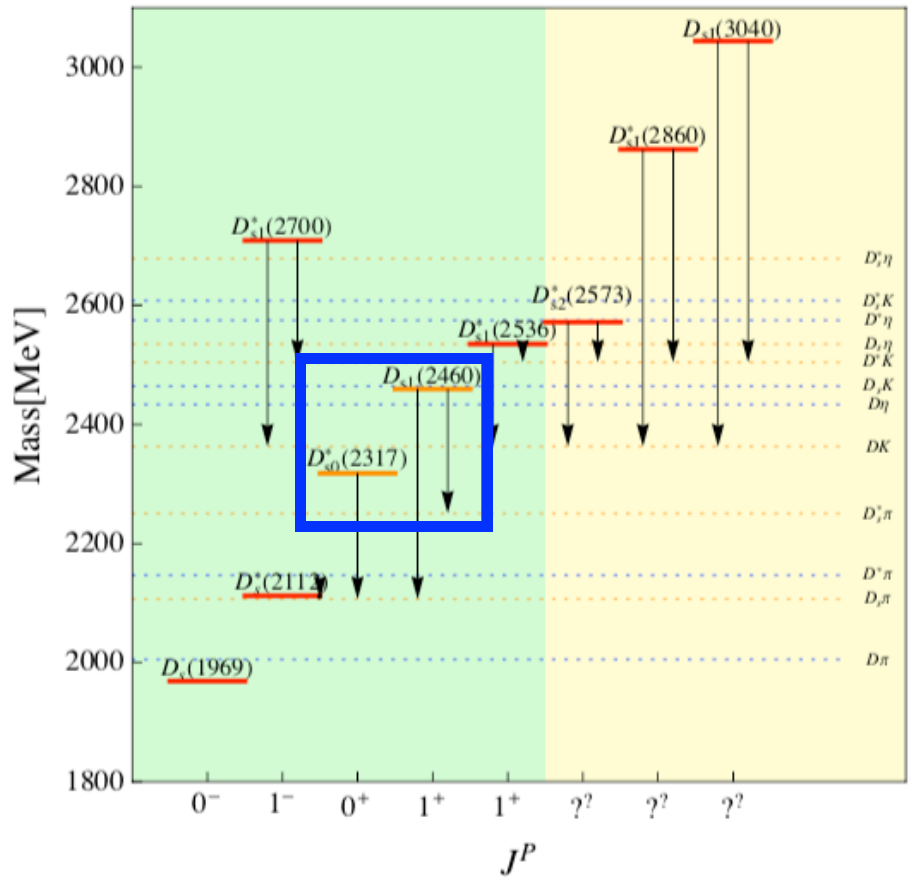
Coupled channel effects?



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

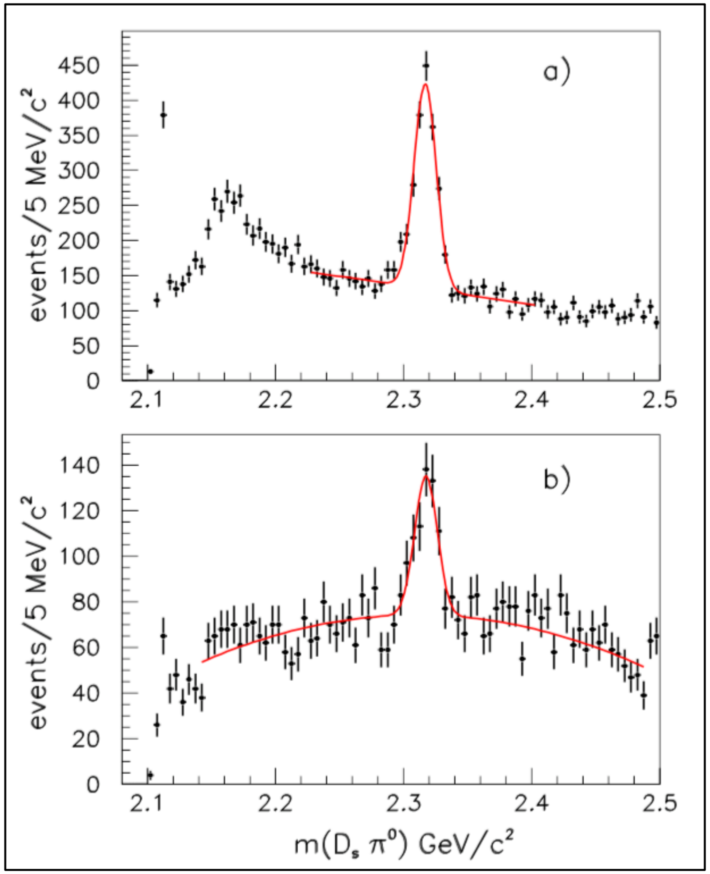




Ds0*(2317) **Ds1(2460)**

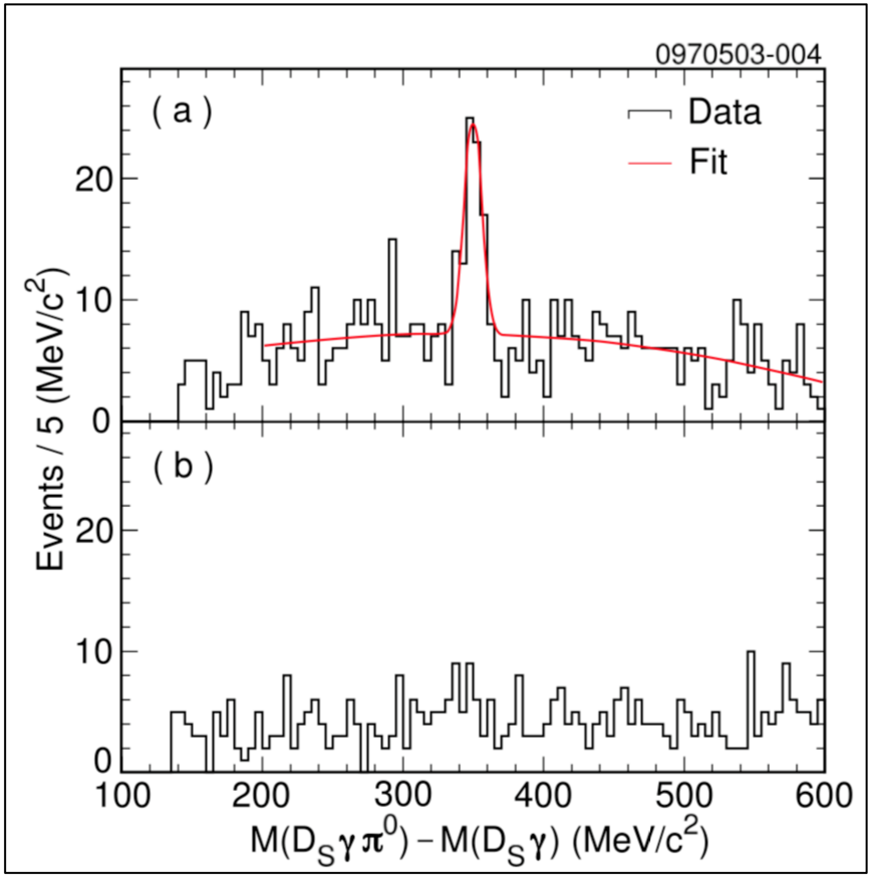
Two peculiar states

Ds0*(2317)



BaBar PRL90,242001(2003)

Ds1(2460)



CLEO PRD68,032002(2003)

Two peculiar states

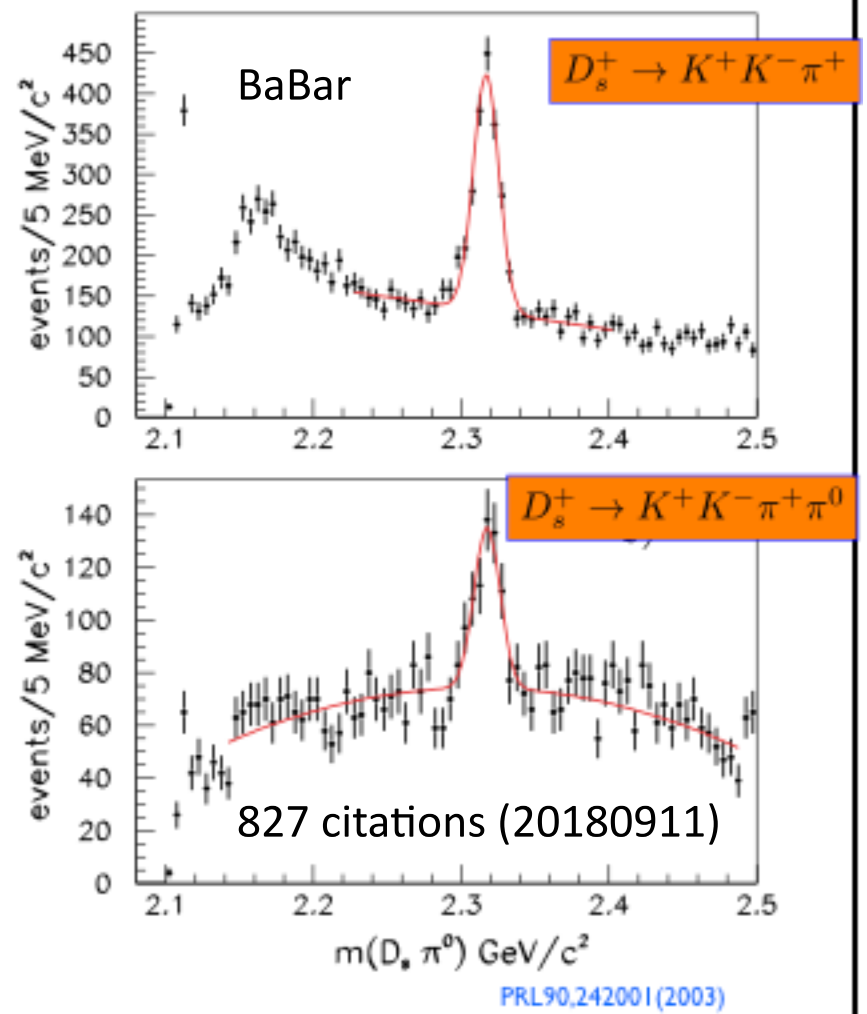
- $\mathbf{D}^*_{s0}(2317),\ \mathbf{D}_{s1}(2460)$

- 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)

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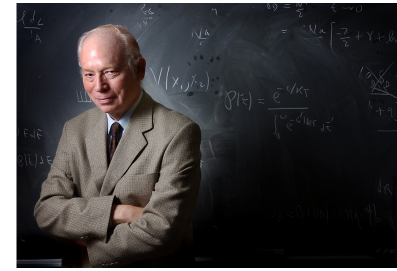
UChPT in Bethe-Salpeter equation



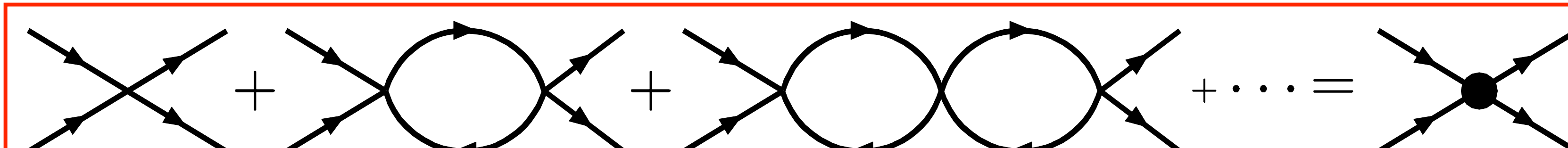
- **Model independent DK interaction from ChPT**

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

Weinberg-Tomazawa

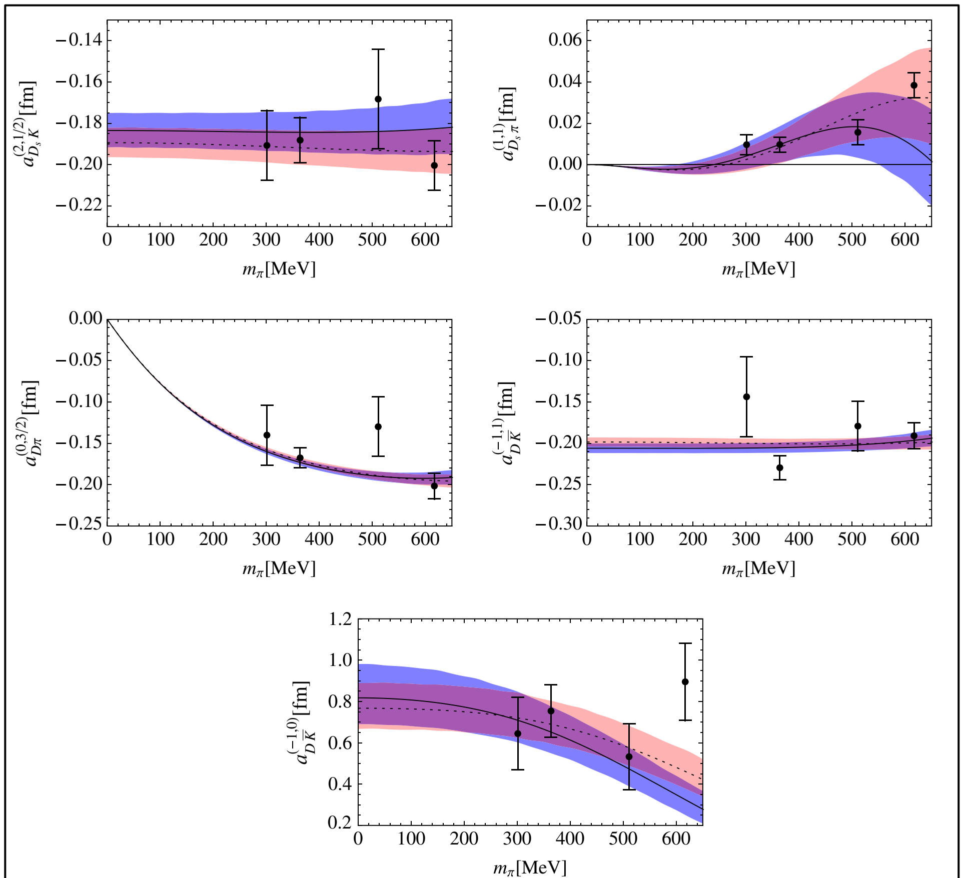
$$\begin{aligned}\mathcal{V}_{\rm NLO}(P(p_1)\phi(p_2) \to P(p_3)\phi(p_4)) = &-\frac{8}{f_0^2}C_{24}\left(c_2\,p_2\cdot p_4 - \frac{c_4}{m_P^2}\left(p_1\cdot p_4\;p_2\cdot p_3 + p_1\cdot p_2\;p_3\cdot p_4\right)\right)\\ &-\frac{4}{f_0^2}\mathcal{C}_{35}\left(c_3\,p_2\cdot p_4 - \frac{c_5}{m_P^2}\left(p_1\cdot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

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

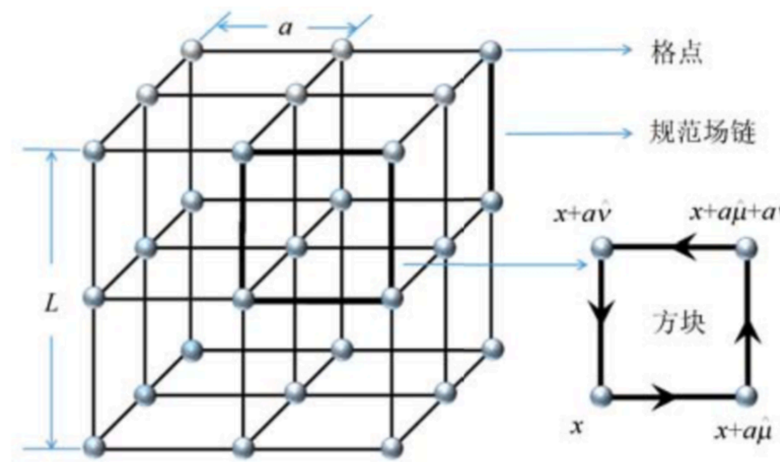


Fixing the LECs using latest LQCD* data

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)	$(2105 \pm 4) - i(103 \pm 7)$	$(2248 \pm 6) - i(106 \pm 13)$

Ds0 and Ds1 dynamically generated

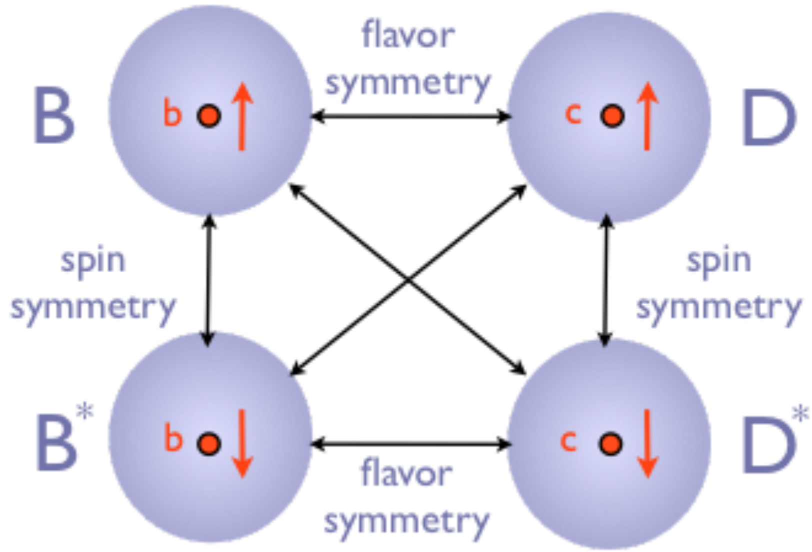
- **Charm sector**

"Post-diction"

7), $\mathbf{D_{s1}(2460)}$

TABLE V ... MeV) of
charm me ... PT.

(S, I)	
(1, 0)	
(0, 1/2)	±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)	$(5537 \pm 14) - i(118 \pm 22)$	$(5586 \pm 16) - i(124 \pm 25)$

Predicted Bs0 and Bs1 states

Physics Letters B 750 (2015) 17–21

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Predicting positive parity B_s mesons from lattice QCD

CrossMark

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

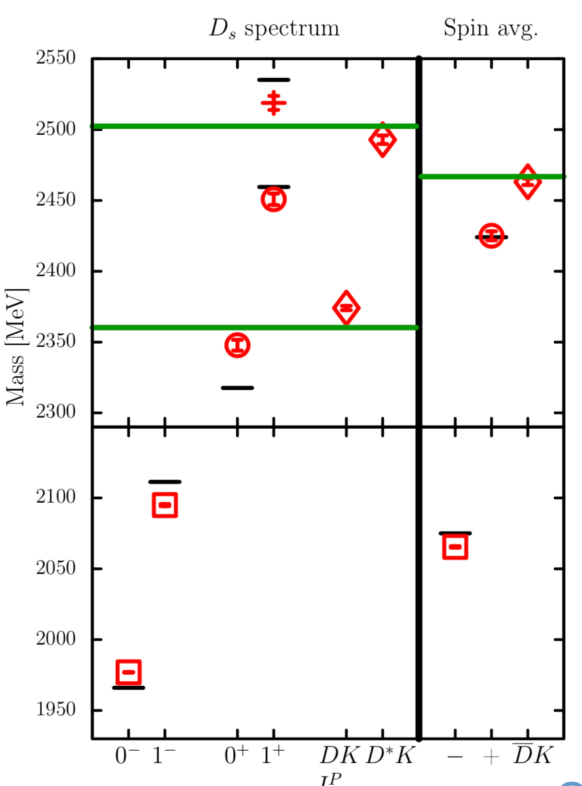
Table 5
Comparison of masses from this work to results from various model based calculations; all masses in MeV.

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

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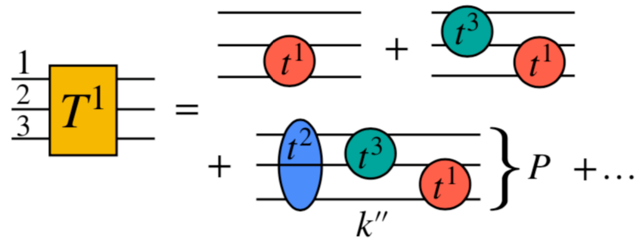
- **Summary and outlook**

An explicit three-body study of DDK

*A. Mart́ınez 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

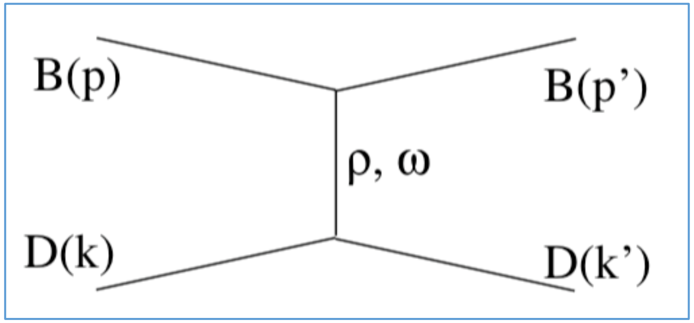
- **DK: leading order UChPT** DK, $D_s\eta$ and $D_s\pi$

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

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

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

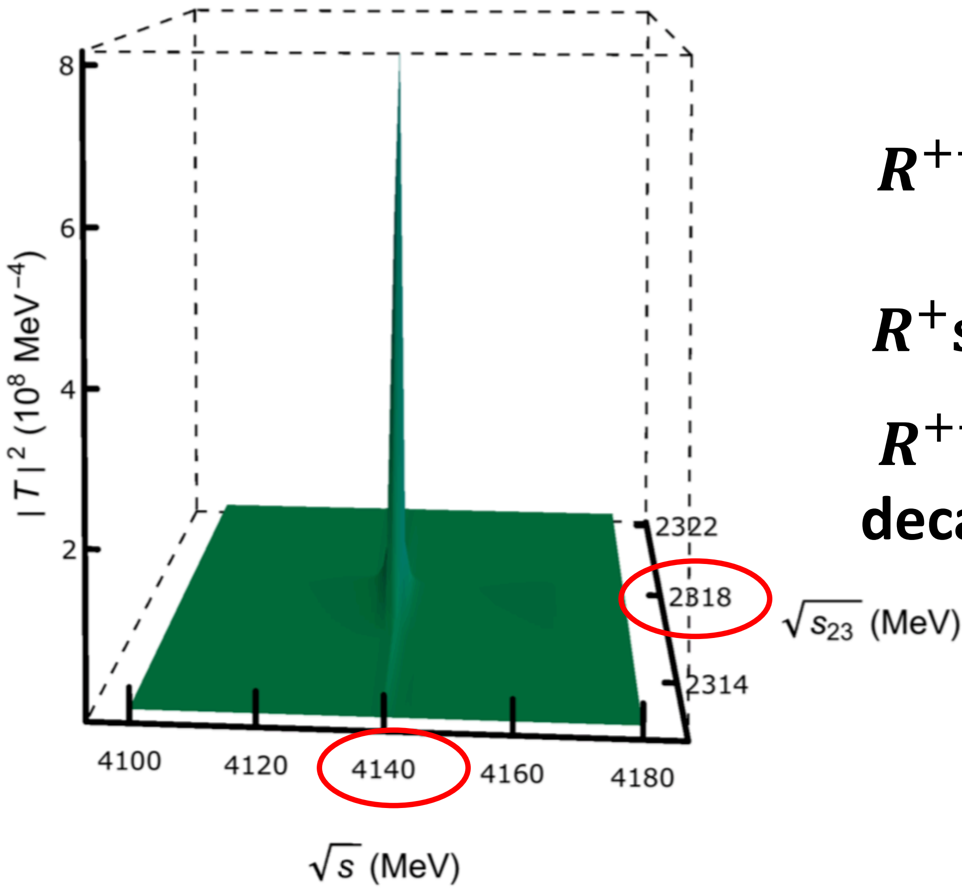
- **DD(Ds): local hidden gauge theory**



$a(\mu) = -1.3 \sim -1.5, \mu = 1500\ MeV \Leftarrow$ 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



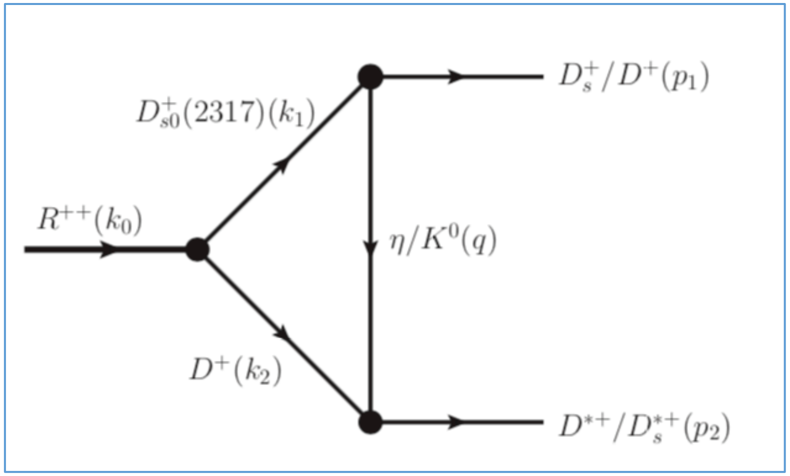
$$R^{++} = (I, I_{23}) = (\frac{1}{2}, 0)$$

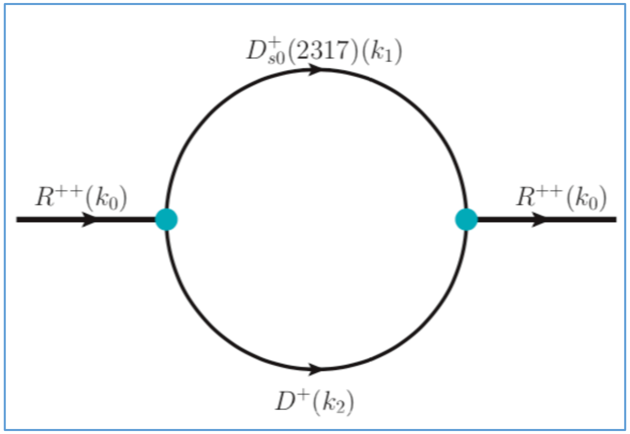
R^{+} should also exist

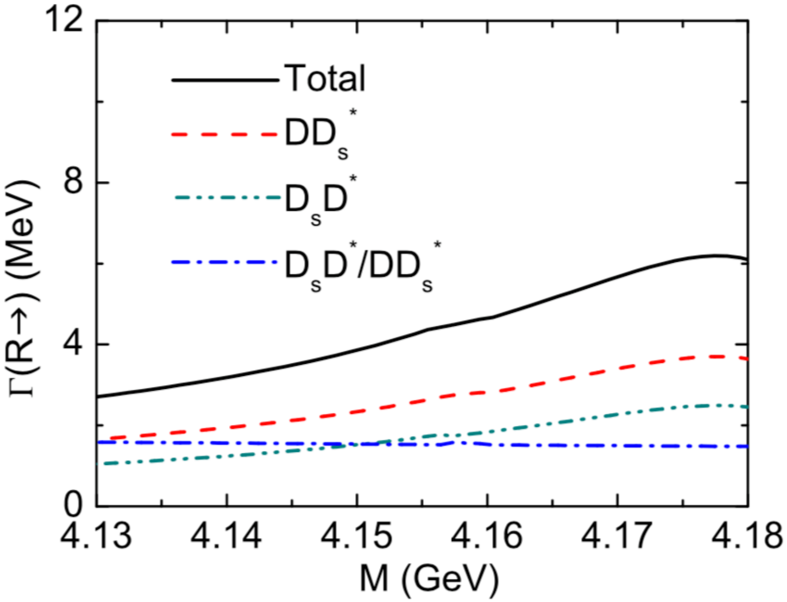
R^{++} is a bound state, but can decay strongly

Two-body decay width

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







Preliminary result:
$\Gamma \sim 10$ MeV

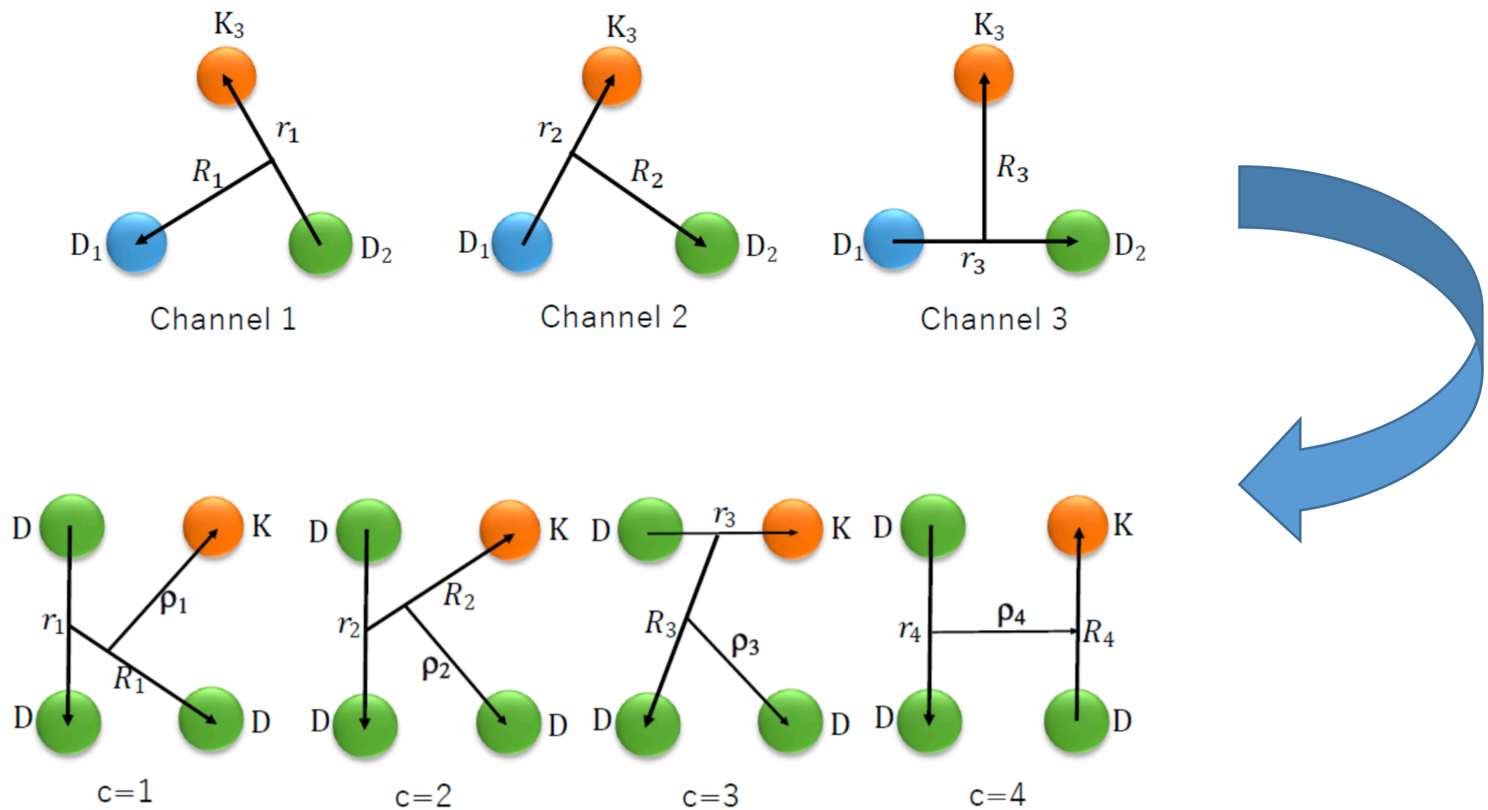
*Tian-Wei Wu, **LSG**, et al., in preparation*

A DDDK state

1(0+)

Gaussian Expansion Method

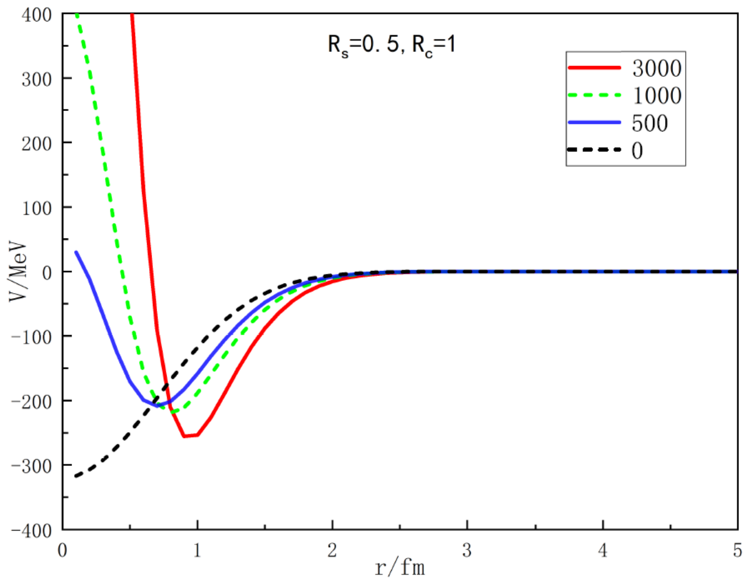
What if we add one more D?

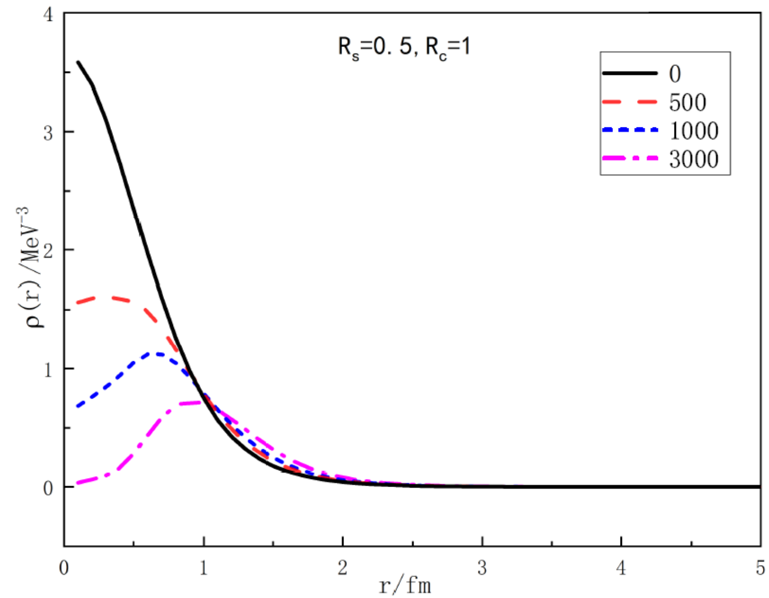


A DDDK state 1(0^+)

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

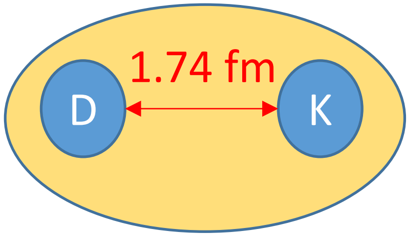
DD interactions play a minor role

$\frac{C_S}{\pi R_S^3}$	$\frac{C(R_c)}{\pi R_c^3}$	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

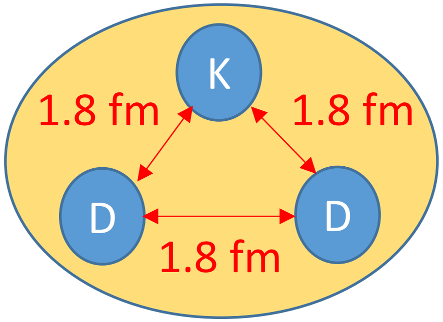
Spatial distributions

$\frac{C_S}{\pi R_S^3}$	$\frac{C(R_c)}{\pi R_c^3}$	$r_2(DK)$	$r_3(DK)$	$r_3(DD)$	$< T >$	$< V_{DK} >$	$< V_{DD} >$
$R_S = 0.5$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)



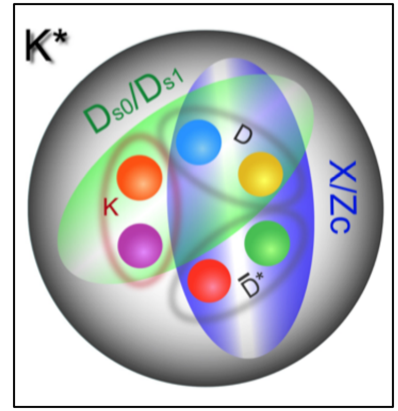
R(4140)



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

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

Check for updates

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

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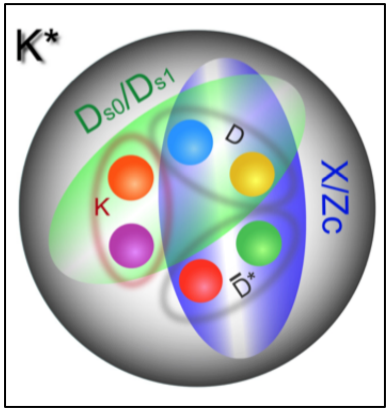
[b] *Instituto de Física, Universidade de São Paulo, C.P. 66318, 05389-970 São Paulo, São Paulo, Brazil*
[c] *School of Physics and Nuclear Energy Engineering & Beijing Key Laboratory of Advanced Nuclear Materials and Physics, Beihang University, Beijing 100191, China*
[d] *Beijing Advanced Innovation 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):**

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

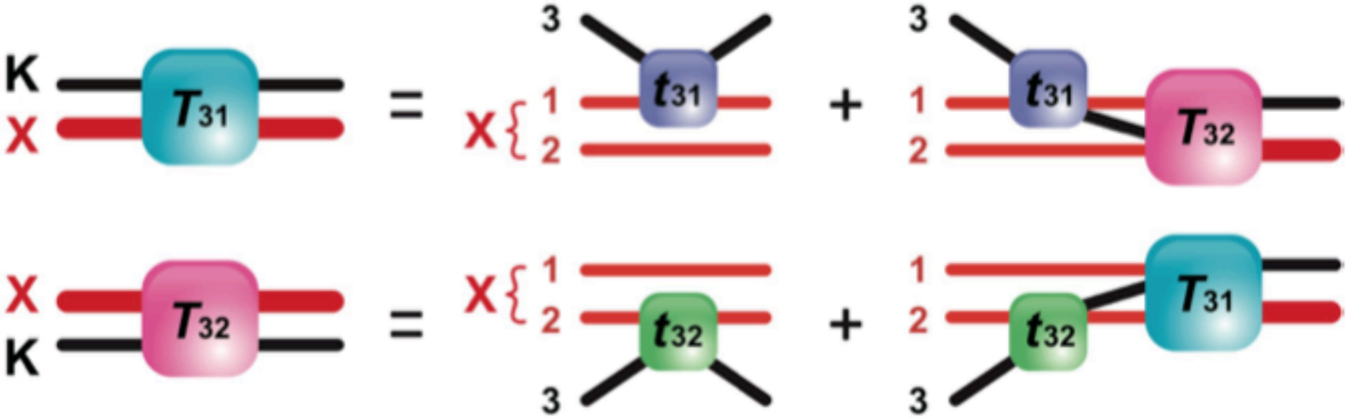
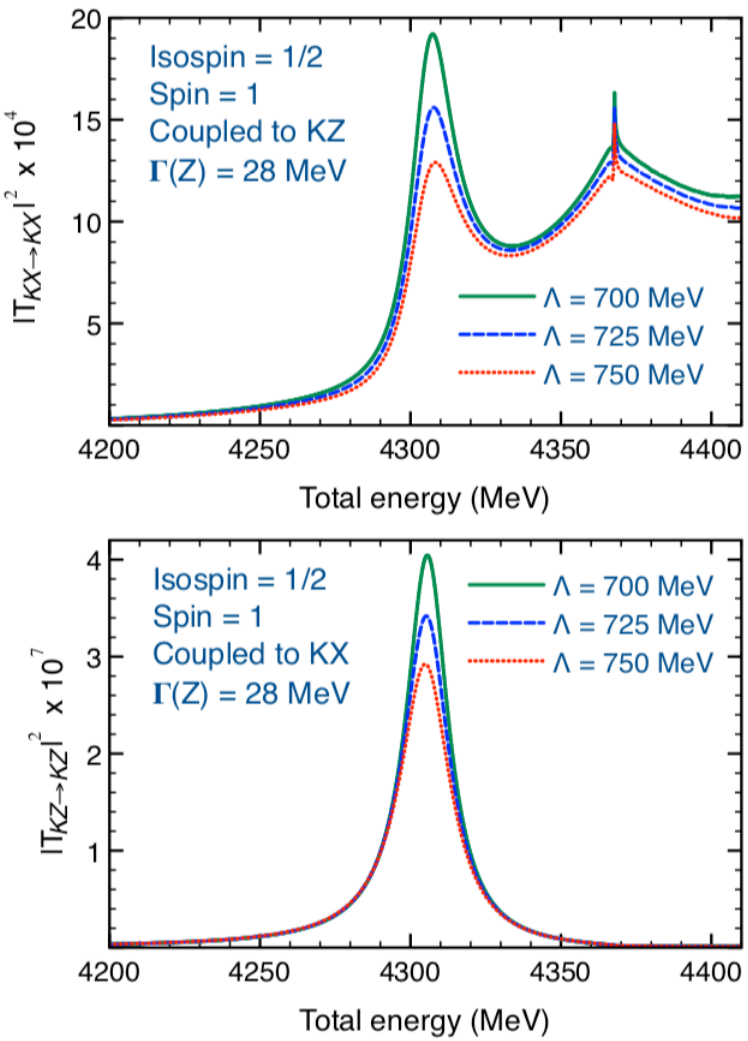
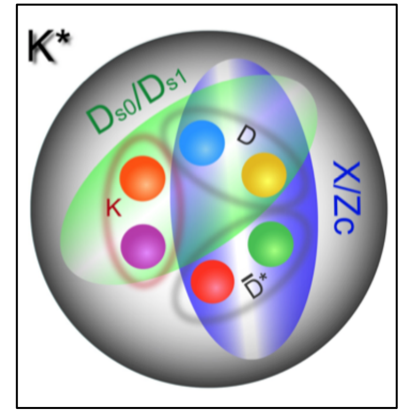


Figure 2: Diagrams showing the scattering of the particle labeled "3" (K) on a cluster (X) made of particles 1 (D) and 2 ($\bar{D}^*$).

K*(4307)

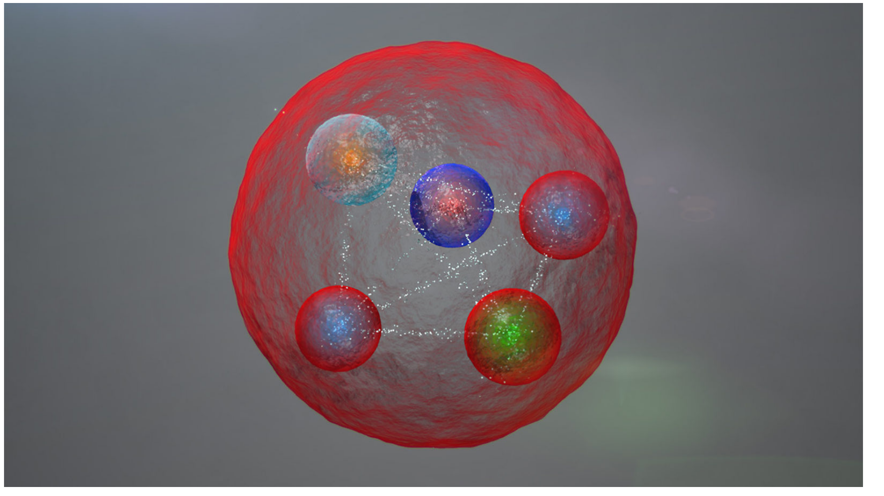




- **Treating KX and KZ as coupled channel systems**
- **A resonance with M=(4307 ± 2) – i(9 ± 2) MeV with $I(J^P) = 1/2(1^-)$**

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

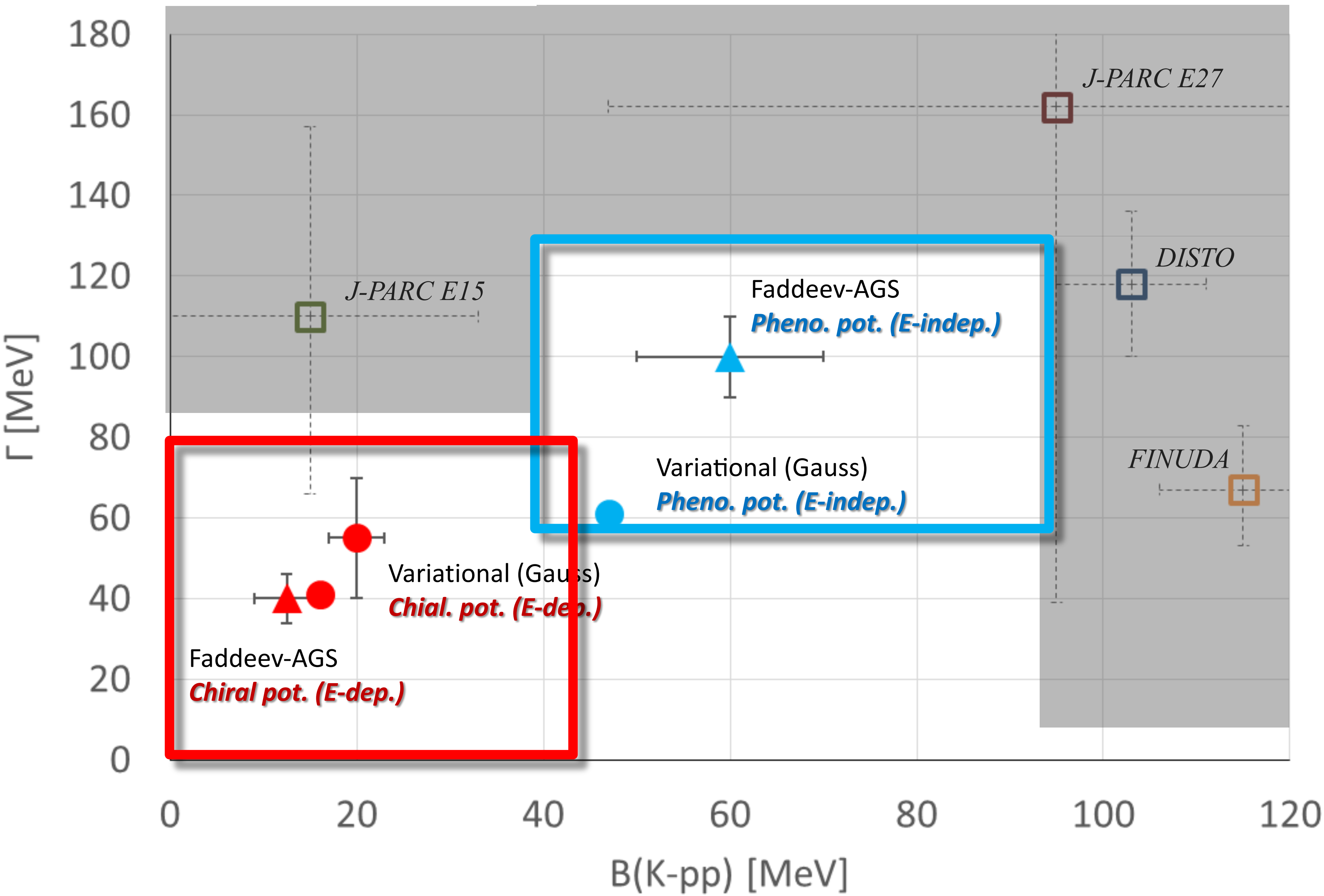
$\boldsymbol{\Lambda(1405)}$

- 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

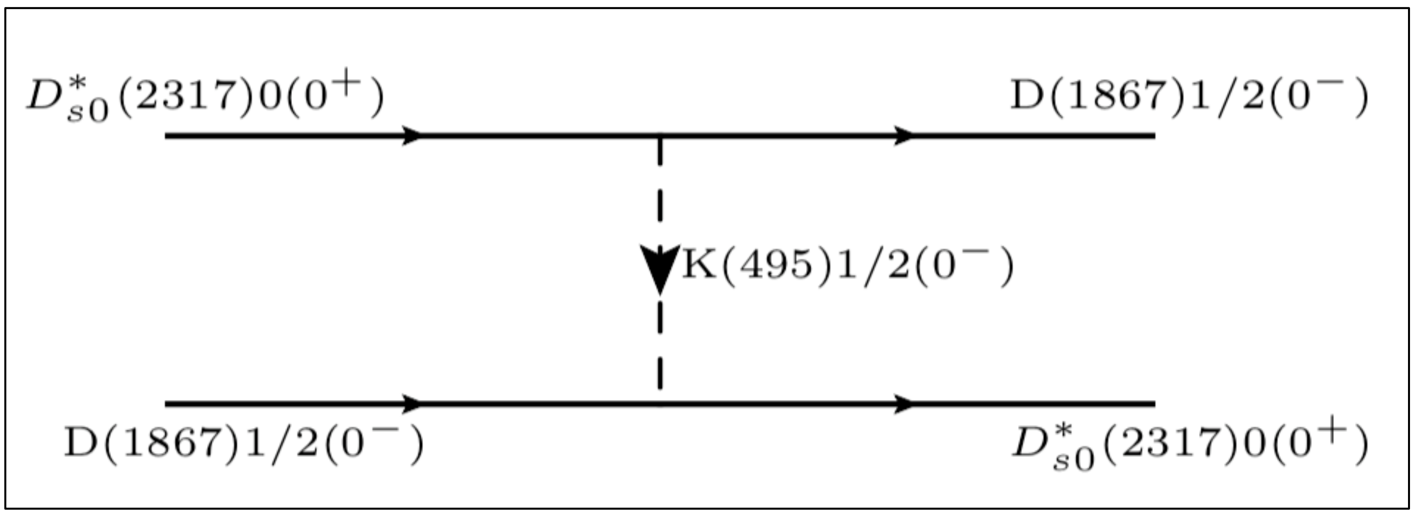
北京航空航天大學
BEIHANG UNIVERSITY

Thanks for your attention！

July 18, 2019

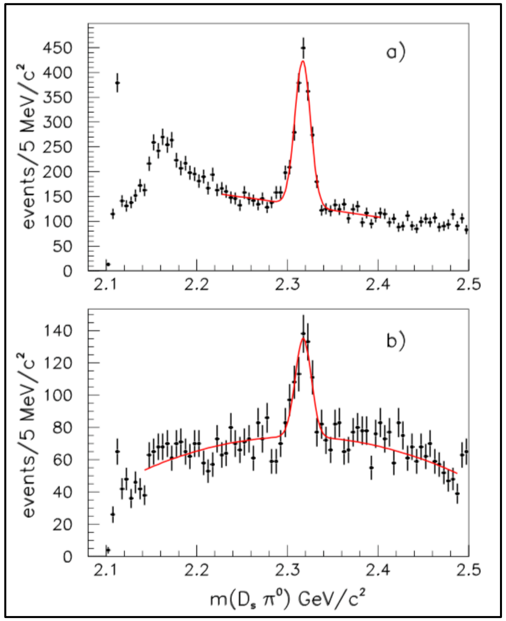
Even if the Ds0 is a $c\bar{s}$ state, Ds0 D binds

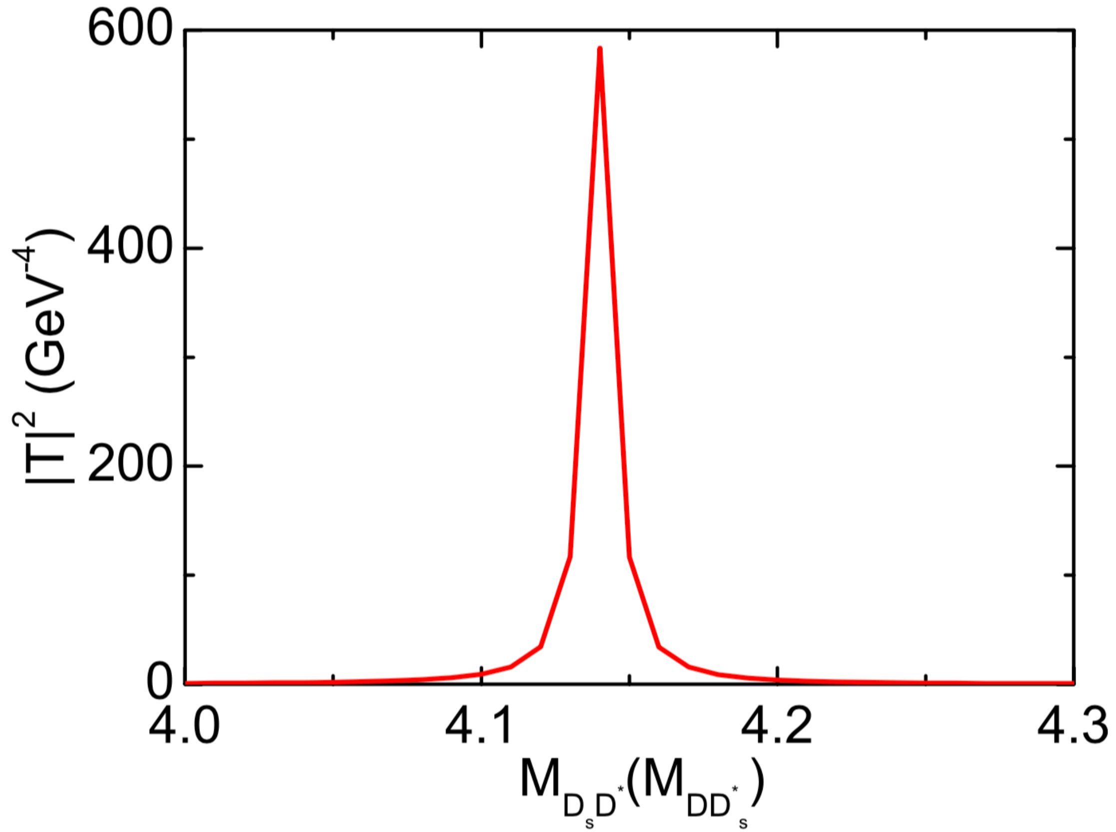
Interestingly, the explicit three-body result is consistent with the quasi two body study, where one treats the DK pair as the Ds0* and describes the interaction between the Ds0* with the D using one-kaon exchange



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**

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