

Pentaquarks with hidden charm and their strange beauty partners

Bing-Song Zou

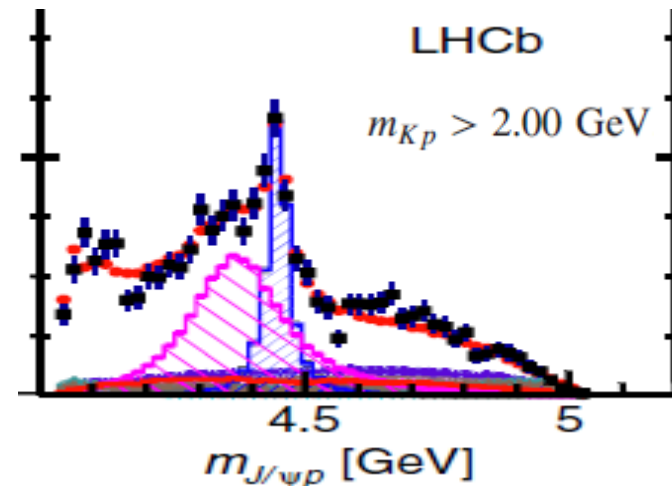
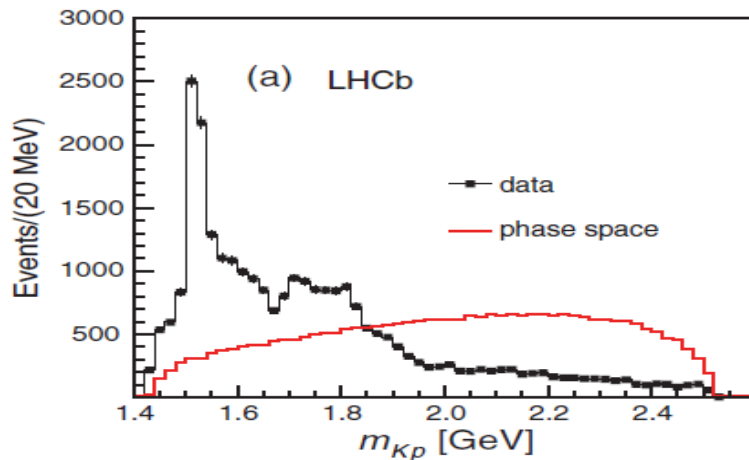
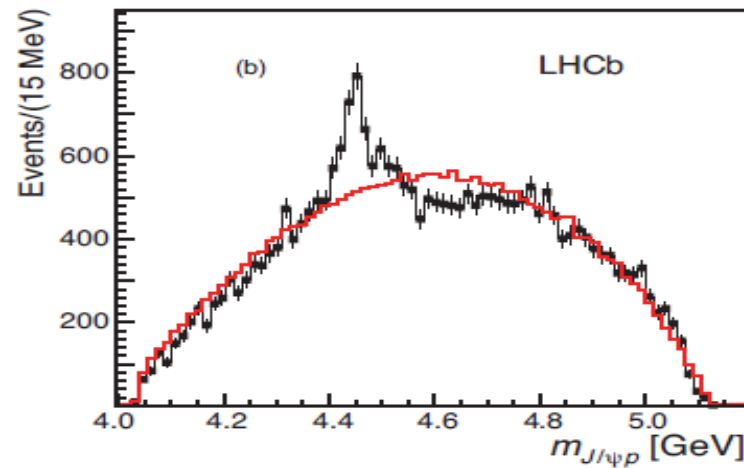
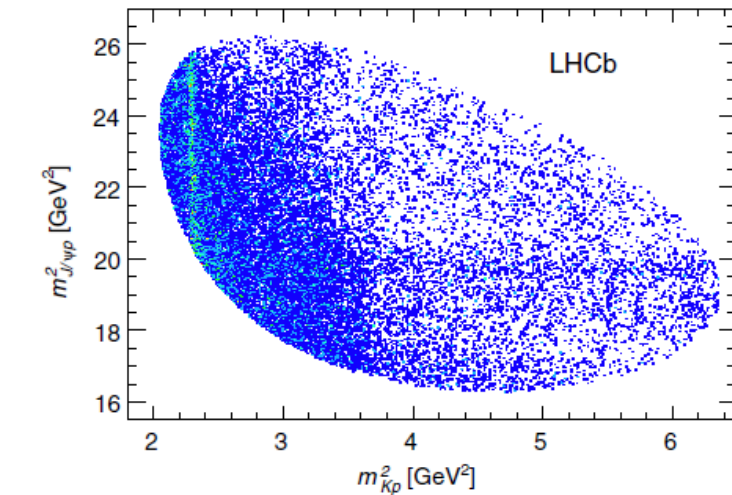
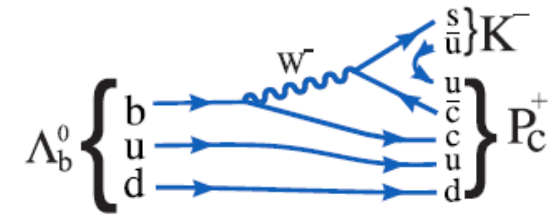
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Outline :

- 1. LHCb pentaquarks vs predictions**
- 2. Progress on P_c states after LHCb observation**
- 3. Strange & beauty partners of P_c states**
- 4. Prospects**

1. LHCb pentaquarks vs predictions

LHCb, Phys.Rev.Lett. 115 (2015) 072001 :
Observation of two N^* from $\Lambda_b^0 \rightarrow J/\psi K^- p$



1) $4380 \pm 8 \pm 29 \text{ MeV}$, $205 \pm 18 \pm 86 \text{ MeV}$, $\mathbf{P_c^+(4380)}$

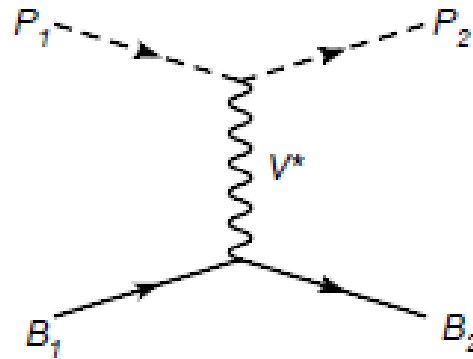
2) $4450 \pm 2 \pm 3 \text{ MeV}$, $39 \pm 5 \pm 19 \text{ MeV}$, $\mathbf{P_c^+(4450)}$

The preferred $\mathbf{J^P}$ assignments are of opposite parity, with one state having spin 3/2 and the other 5/2.

Significances $> 9\sigma$ for both $\mathbf{P_c^+}$ states

Predictions prior to LHCb observation

- [1] J.J.Wu, R.Molina, E.Oset, B.S.Zou, “Prediction of narrow N^* and Λ^* resonances with hidden charm above 4 GeV”, PRL105 (2010) 232001;
 “Dynamically generated N^* and Λ^* resonances in the hidden charm sector around 4.3 GeV,” PRC84 (2011) 015202



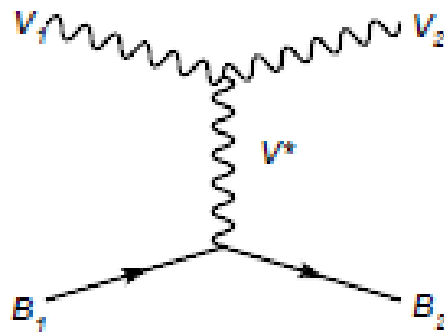
$$\mathcal{L}_{VVV} = ig \langle V^\mu [V^\nu, \partial_\mu V_\nu] \rangle$$

$$\mathcal{L}_{PPV} = -ig \langle V^\mu [P, \partial_\mu P] \rangle$$

$$\mathcal{L}_{BBV} = g(\langle \bar{B} \gamma_\mu [V^\mu, B] \rangle + \langle \bar{B} \gamma_\mu B \rangle \langle V^\mu \rangle)$$

$$V_{ab}(P_1 B_1 \rightarrow P_2 B_2) = \frac{C_{ab}}{4f^2} (E_{P_1} + E_{P_2}),$$

$$V_{ab}(V_1 B_1 \rightarrow V_2 B_2) = \frac{C_{ab}}{4f^2} (E_{V_1} + E_{V_2}) \vec{\epsilon}_1 \cdot \vec{\epsilon}_2,$$



$$T = [1 - VG]^{-1} V \quad T_{ab} = \frac{g_a g_b}{\sqrt{s} - z_R}$$

$K\Sigma, Kp \rightarrow \bar{D}^{(*)}\Sigma_c, \bar{D}_s^{(*)}\Lambda_c$ bound states

	(I, S)	z_R (MeV)	g_a			J^P
N^*	$(1/2, 0)$		$\bar{D}\Sigma_c$	$\bar{D}\Lambda_c^+$		$1/2^-$
		4269	2.85	0		
Λ^*	$(0, -1)$		$\bar{D}_s\Lambda_c^+$	$\bar{D}\Xi_c$	$\bar{D}\Xi'_c$	
		4213	1.37	3.25	0	
		4403	0	0	2.64	

TABLE III: Pole positions z_R and coupling constants g_a for the states from $PB \rightarrow PB$.

	(I, S)	z_R (MeV)	g_a			
N^*	$(1/2, 0)$		$\bar{D}^*\Sigma_c$	$\bar{D}^*\Lambda_c^+$		$1/2^-, 3/2^-$
		4418	2.75	0		
Λ^*	$(0, -1)$		$\bar{D}_s^*\Lambda_c^+$	$\bar{D}^*\Xi_c$	$\bar{D}^*\Xi'_c$	
		4370	1.23	3.14	0	
		4550	0	0	2.53	

TABLE IV: Pole position and coupling constants for the bound states from $VB \rightarrow VB$.

	(I, S)	M	Γ	Γ_i					J^P
N^*	$(1/2, 0)$	4261	56.9	πN	ηN	$\eta' N$	$K\Sigma$	$\eta_c N$	$1/2^-$
				3.8	8.1	3.9	17.0	23.4	
Λ^*	$(0, -1)$	4209	32.4	KN	$\pi\Sigma$	$\eta\Lambda$	$\eta'\Lambda$	$K\Xi$	
		4394	43.3	15.8	2.9	3.2	1.7	2.4	
				0	10.6	7.1	3.3	5.8	
								16.3	

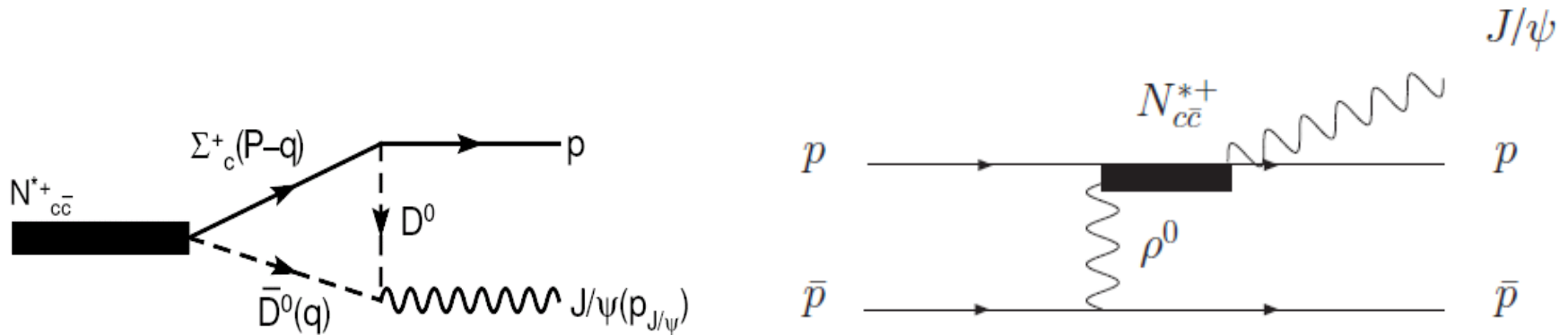
TABLE V: Mass (M), total width (Γ), and the partial decay width (Γ_i) for the states from $PB \rightarrow PB$, with units in MeV.

	(I, S)	M	Γ	Γ_i				
N^*	$(1/2, 0)$	4412	47.3	ρN	ωN	$K^* \Sigma$	$J/\psi N$	
				3.2	10.4	13.7	19.2	
	$(0, -1)$			$K^* N$	$\rho \Sigma$	$\omega \Lambda$	$\phi \Lambda$	$K^* \Xi$
Λ^*		4368	28.0	13.9	3.1	0.3	4.0	1.8
		4544	36.6	0	8.8	9.1	0	5.0
								13.8

1/2⁻, 3/2⁻

TABLE VI: Mass (M), total width (Γ), and the partial decay width (Γ_i) for the states from $VB \rightarrow VB$ with units in MeV.

Prediction for PANDA



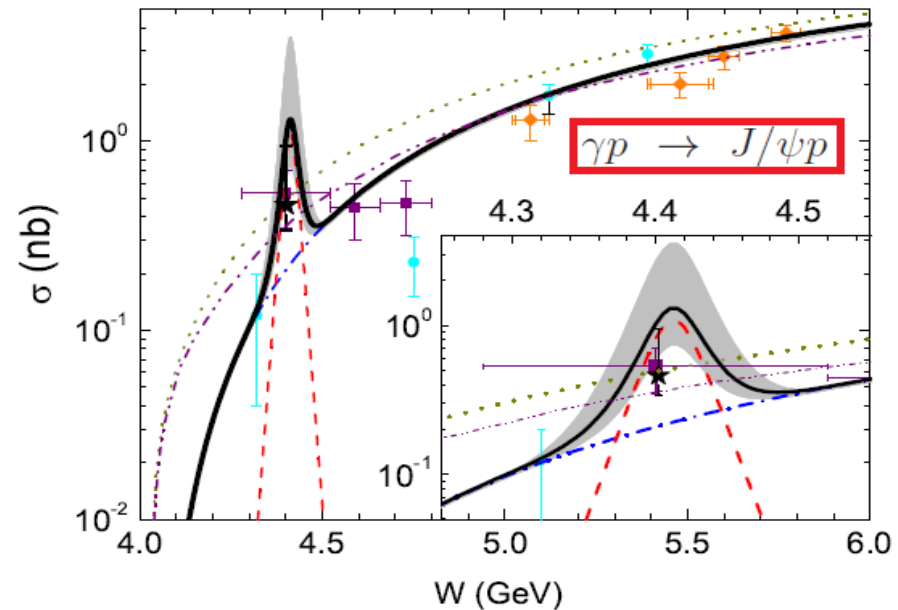
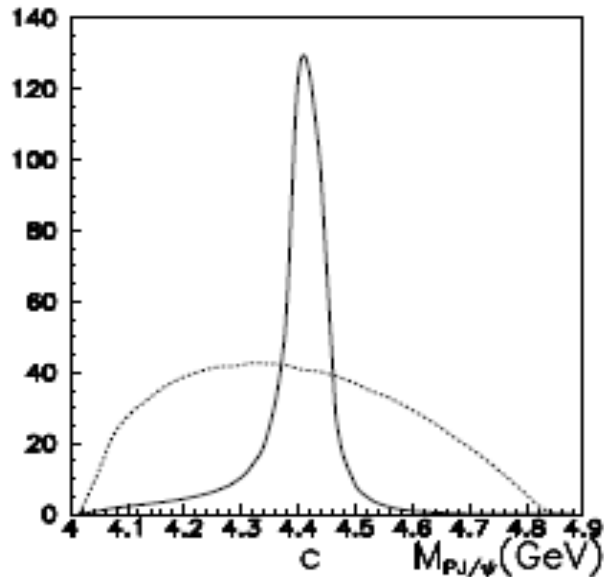
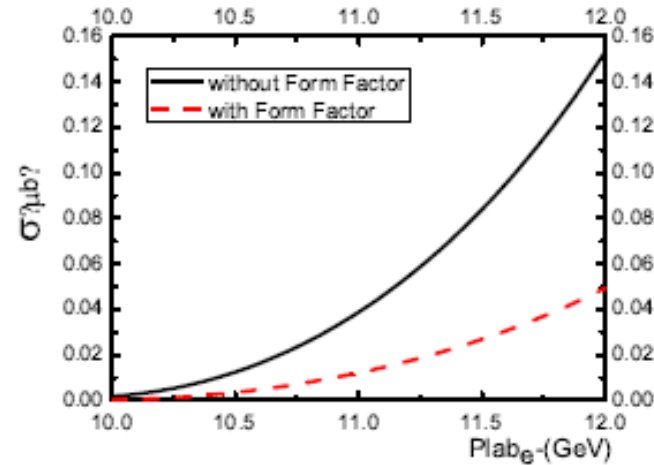
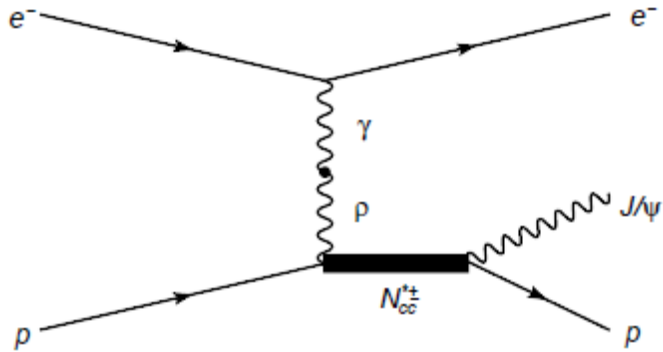
$$\bar{p}p \rightarrow \bar{p}pJ/\psi > 0.1 \text{ nb}$$

> 100 events per day at PANDA/FAIR by $L=10^{31} \text{ cm}^{-2}\text{s}^{-1}$

These Super-heavy narrow N^* and Λ^* can be found at PANDA !

Albrecht Gillitzer@Juelich had a plan to find them at PANDA

Prediction for 12GeV@JLab



Y. Huang, J.He, H.F.Zhang and X.R.Chen, JPG41, 115004 (2014)

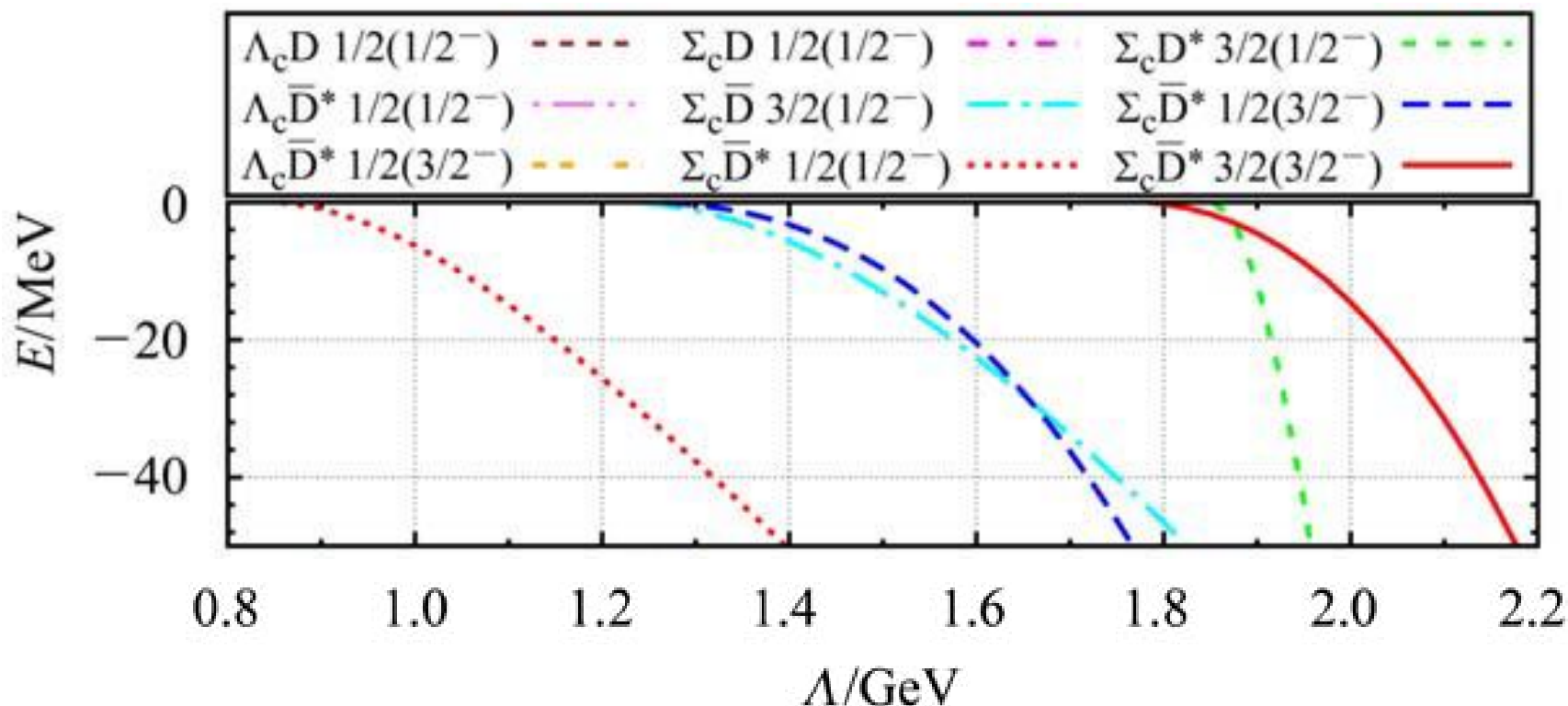
Proposals for looking for N_{cc}^- & Λ_{cc}^- with π^- , K beams at JPARC

- a) X.Y.Wang, X.R.Chen, “The production of hidden charm baryon $N^*(4261)$ from $\pi^- p \rightarrow \eta_c n$ reaction”, EPL109 (2015) 41001.
- b) E.J.Garzon, J.J.Xie, “Effects of a N_{cc}^- resonance with hidden charm in the $\pi^- p \rightarrow D^- \Sigma_c^+$ reaction near threshold”, PRC 92 (2015) 035201
- c) X.Y.Wang, X.R.Chen, “Production of the superheavy baryon $\Lambda^*(4209)$ in kaon-induced reaction”, EPJA51 (2015) 85

[2] Z.C.Yang, Z.F.Sun, J.He, X.Liu, S.L.Zhu, "The possible hidden-charm molecular baryons composed of anti-charmed meson and charmed baryon," Chin. Phys. C36 (2012) 6

Schoedinger Equation method with π , η , ρ , ω , σ exchanges:

$\bar{D}^*\Sigma_c$ ($3/2^-$) N^* state -- 4360 ~ 4460 MeV



[3] C.W.Xiao, J.Nieves, E.Oset, “Combining heavy quark spin and local hidden gauge symmetries in the dynamical generation of hidden charm baryons”, PRD 88 (2013) 056012

3 $J^P = 3/2^-$ P_c^+ states : $\bar{D}\Sigma_c^*$, $\bar{D}^*\Sigma_c$, $\bar{D}^*\Sigma_c^*$ states

TABLE II. The coupling constants to various channels for certain poles in the $J = 3/2$, $I = 1/2$ sector.

$4334.45 + i19.41$	$J/\psi N$	$\bar{D}^*\Lambda_c$	$\bar{D}^*\Sigma_c$	$\bar{D}\Sigma_c^*$	$\bar{D}^*\Sigma_c^*$
g_i	$1.31 - i0.18$	$0.16 - i0.23$	$0.20 - i0.48$	$2.97 - i0.36$	$0.24 - i0.76$
$ g_i $	1.32	0.28	0.52	2.99	0.80
$4417.04 + i4.11$	$J/\psi N$	$\bar{D}^*\Lambda_c$	$\bar{D}^*\Sigma_c$	$\bar{D}\Sigma_c^*$	$\bar{D}^*\Sigma_c^*$
g_i	$0.53 - i0.07$	$0.08 - i0.07$	$2.81 - i0.07$	$0.12 - i0.10$	$0.11 - i0.51$
$ g_i $	0.53	0.11	2.81	0.16	0.52
$4481.04 + i17.38$	$J/\psi N$	$\bar{D}^*\Lambda_c$	$\bar{D}^*\Sigma_c$	$\bar{D}\Sigma_c^*$	$\bar{D}^*\Sigma_c^*$
g_i	$1.05 + i0.10$	$0.18 - i0.09$	$0.12 - i0.10$	$0.22 - i0.05$	$2.84 - i0.34$
$ g_i $	1.05	0.20	0.16	0.22	2.86

a $J^P = 5/2^-$ P_c^+ state : $\bar{D}^*\Sigma_c^*$ bound states at 4487 MeV

**Hidden charm N^* above 4 GeV decaying to pJ/ψ
are supported by other approaches**

$\bar{D}\Sigma_c$ state in a chiral quark model ~ 4.3 GeV

W.L.Wang, F.Huang, Z.Y.Zhang, B.S.Zou, PRC84(2011)015203

$\bar{D}\Sigma_c$ state in EBAC-DCC model ~ 4.3 GeV

J.J.Wu, T.S.H.Lee, B.S.Zou, PRC85(2012)044002

[4] S.G.Yuan, K.W.Wei, J.He, H.S.Xu, B.S.Zou, “Study of $\bar{c}cqqq$ five quark system with three kinds of quark-quark hyperfine interaction,”
Eur. Phys. J. A48 (2012) 61

	<i>CM</i>		<i>FS</i>		<i>Inst.</i>	
J^P	$udsc\bar{c}$	$uudc\bar{c}$	$udsc\bar{c}$	$uudc\bar{c}$	$udsc\bar{c}$	$uudc\bar{c}$
$\frac{1}{2}^-$	4273	4267	4084	3933	4209	4114
$\frac{1}{2}^-$	4377	4363	4154	4013	4216	4131
$\frac{1}{2}^-$	4453	4377	4160	4119	4277	4204
$\frac{1}{2}^-$	4469	4471	4171	4136	4295	4207
$\frac{1}{2}^-$	4494	4541	4253	4156	4360	4272
$\frac{1}{2}^-$	4576		4263		4362	
$\frac{1}{2}^-$	4649		4278		4416	
$\frac{3}{2}^-$	4431	<u>4389</u>	4154	4013	4216	4131
$\frac{3}{2}^-$	4503	<u>4445</u>	4171	4119	4295	4204
$\frac{3}{2}^-$	4549	4476	4263	4136	4362	4272
$\frac{3}{2}^-$	4577	4526	4278	4236	4416	<u>4322</u>
$\frac{3}{2}^-$	4629		4362		4461	
$\frac{5}{2}^-$	4719	4616	4362	4236	4461	4322

	<i>CM</i>		<i>FS</i>		<i>Inst.</i>	
J^P	$udsc\bar{c}$	$uudc\bar{c}$	$udsc\bar{c}$	$uudc\bar{c}$	$udsc\bar{c}$	$uudc\bar{c}$
$\frac{1}{2}^+$	4622	4456	4291	4138	4487	4396
$\frac{1}{2}^+$	4636	4480	4297	4140	4501	4426
$\frac{1}{2}^+$	4645	4557	4363	4238	4520	4426
$\frac{1}{2}^+$	4658	4581	4439	4320	4540	4470
$\frac{1}{2}^+$	4690	4593	4439	4367	4557	4482
$\frac{1}{2}^+$	4696	4632	4467	4377	4587	4490
$\frac{1}{2}^+$	4714	4654	4469	4404	4590	4517
$\frac{1}{2}^+$	4728	4676	4486	4489	4614	4518
$\frac{1}{2}^+$	4737	4714	4492	4508	4616	4549
$\frac{1}{2}^+$	4766	4720	4510	4515	4626	4566
$\frac{3}{2}^+$	4623	<u>4457</u>	4291	4138	4487	4396
$\frac{3}{2}^+$	4638	4515	4297	4140	4501	4426
$\frac{3}{2}^+$	4680	4561	4363	4238	4520	4426
$\frac{3}{2}^+$	4692	4582	4439	4320	4540	4470
$\frac{3}{2}^+$	4695	4625	4439	4367	4557	4482
$\frac{5}{2}^+$	4705	4539	4297	4140	4501	<u>4426</u>
$\frac{5}{2}^+$	4719	4649	4439	4320	4540	4470
$\frac{5}{2}^+$	4773	4689	4467	4367	4587	4482
$\frac{5}{2}^+$	4793	4696	4486	4404	4615	4490
$\frac{5}{2}^+$	4821	4710	4492	4515	4632	4517
$\frac{7}{2}^+$	4945	4841	4638	4508	4698	4566
$\frac{7}{2}^+$	4955	4862	4671	4551	4712	4634
$\frac{7}{2}^+$	4974	4919	4705	4587	4765	4669
$\frac{7}{2}^+$	5010		4759		4797	

M(5/2⁺) – M(3/2⁻) : 130 ~300 MeV

LHCb pentaquark states vs Predictions

Consistence : mass of $P_c(3/2^-)$, pJ/ψ decay mode

Problems:

- 1) $P_c^+(4380)$ -- larger decay width than prediction
- 2) Where are lower $P_c(1/2^-)$ states ?

3. Progress on P_c states after LHCb observation

Thresholds $\bar{D}\Sigma_c^*$ (4383MeV), $\bar{D}^*\Sigma_c$ (4460MeV), $p\chi_{c1}$ (4449MeV)

1) $\bar{D}\Sigma_c^*$, $\bar{D}^*\Sigma_c$, $\bar{D}^*\Sigma_c^*$ molecular states

R.Chen, X.Liu, X.Q.Li, S.L.Zhu, PRL115 (2015) 132002;

H.X.Chen, W.Chen, X.Liu, T.G.Steele, S.L.Zhu, PRL115 (2015)172001

L.Roca, J.Nieves, E.Oset, PRD92 (2015) 094003;

J.He, PLB 753 (2016)547 ;

2) diquark cu & triquark $\bar{c}(ud)$ states

L.Maiani, A.D.Polosa, V. Riquer, PLB749 (2015) 289;

R.Lebed, PLB749 (2015) 454;

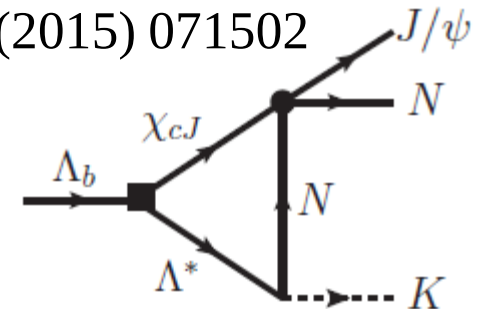
G.N.Li, M.He, X.G.He, JHEP 1512 (2015) 128;

R.Zhu, C.F.Qiao, PLB756 (2016) 259;

3) Kinematic triangle-singularity

F.K.Guo, Ulf-G.Meißner, W.Wang, Z.Yang, PRD92 (2015) 071502

X.H.Liu, Q.Wang, Q.Zhao, PLB757 (2016) 231



For comprehensive reviews, cf.:

H.X.Chen, W.Chen, X.Liu, S.L.Zhu, Phys.Rept. 639 (2016) 1

F.K.Guo, C.Hanhart, U.Meissner, Q.Wang, Q.Zhao, B.S.Zou, RMP 90 (2018)015004

$\bar{D}\Sigma_c^*$, $\bar{D}^*\Sigma_c$, $\bar{D}^*\Sigma_c^*$ bound states

[1] R.Chen, X.Liu, X.Q.Li, S.L.Zhu, PRL115 (2015) 132002;

$$P_c^+(4380) \text{ -- } \bar{D}^*\Sigma_c \quad 3/2^- ; \quad P_c^+(4450) \text{ -- } \bar{D}^*\Sigma_c^* \quad 5/2^-$$

[2] Y.Yamaguchi, E. Santopinto, PRD96 (2017) 014018

$$P_c^+(4380) \text{ -- } \bar{D}^{(*)}\Sigma_c^{(*)} - \bar{D}^{(*)}\Lambda_c \quad 3/2^+ ; \quad P_c^+(4450) \text{ -- } \bar{D}^{(*)}\Sigma_c^{(*)} - \bar{D}^{(*)}\Lambda_c \quad 5/2^-$$

[3] J.He, PLB 753 (2016)547 ; PRD95 (2017)074004

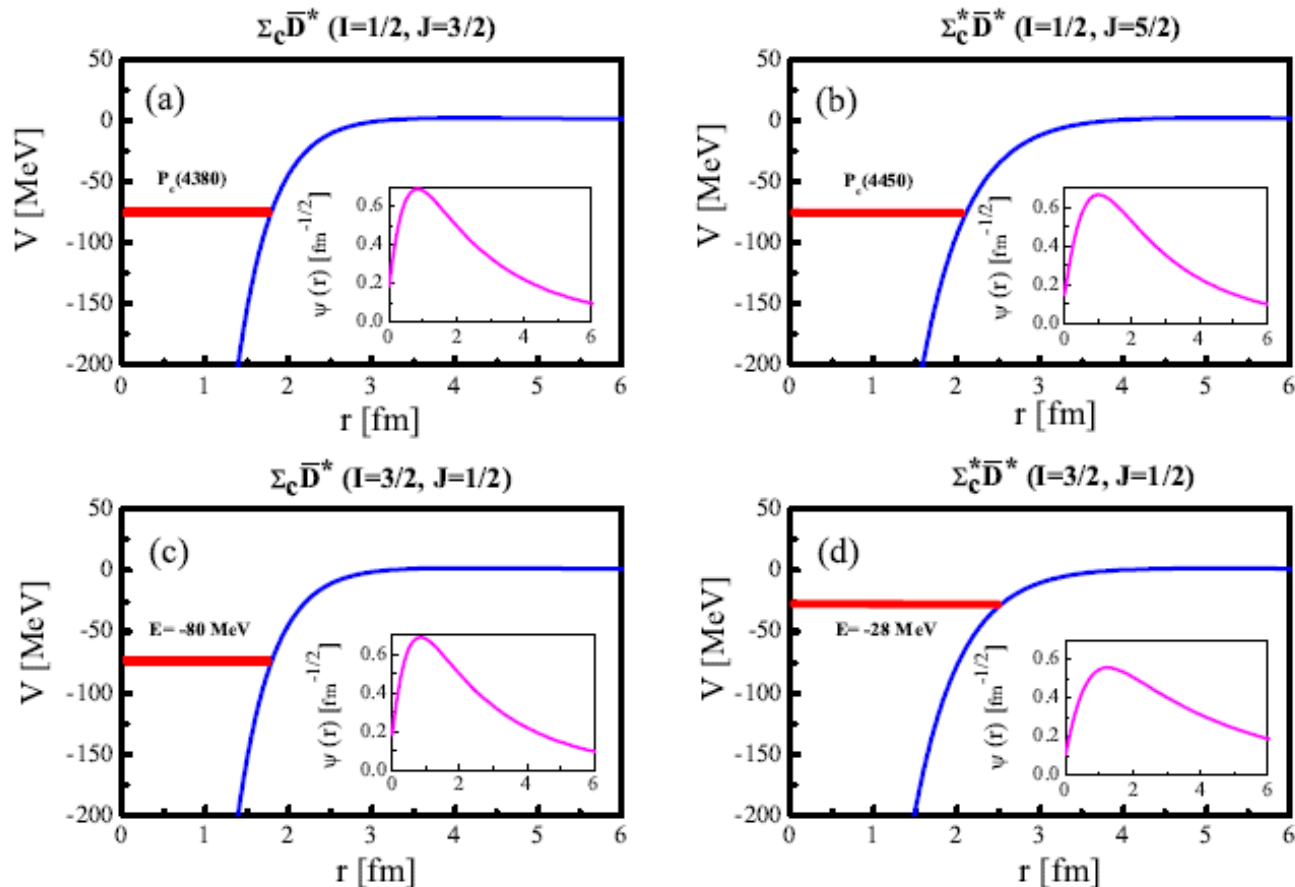
Y.H.Lin, C.W.Shen, F.K.Guo, B.S.Zou, PRD95(2017)114017

$$P_c^+(4380) \text{ -- } \bar{D}\Sigma_c^*/ \bar{D}^*\Sigma_c \quad 3/2^- ; \quad P_c^+(4450) \text{ -- } \bar{D}^*\Sigma_c \quad 5/2^+$$

→ Different predictions to be checked !

[1] R.Chen, X.Liu, X.Q.Li, S.L.Zhu, PRL115 (2015) 132002

OPE: Prediction of I=3/2 pentaquarks !



[2] Y.Yamaguchi, E. Santopinto, PRD96 (2017) 014018

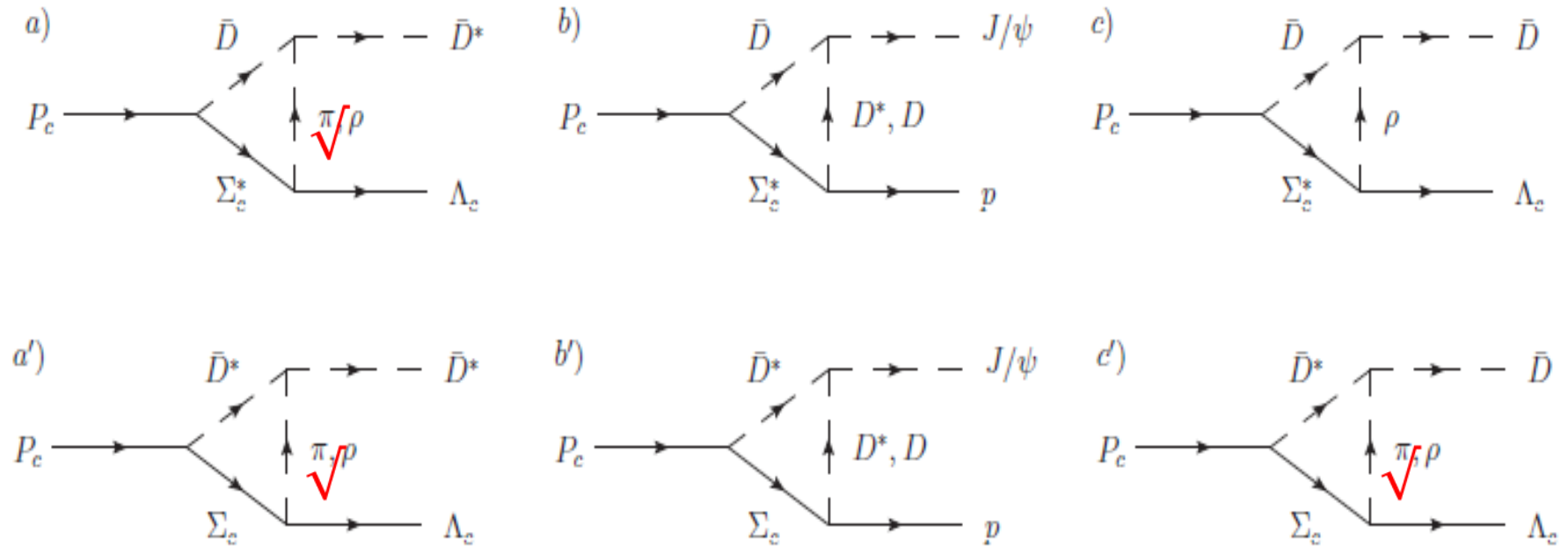
Prediction of a few more $J=3/2$ pentaquarks !

Λ [MeV]	1300	1400	1500	1600
$J^P = 3/2^-$	$4236.9 - i0.8$	4136.0	4006.3	3848.2
	$4381.3 - i11.4$	$4307.9 - i18.8$	$4242.6 - i1.4$	4150.1
	$4368.5 - i64.9$	$4348.7 - i21.1$	$4312.7 - i16.0$	$4261.0 - i7.0$
$J^P = 3/2^+$	$4223.0 - i97.9$	$4206.7 - i41.2$	$4169.3 - i5.3$	4104.2
	$4363.3 - i57.0$	<u>$4339.7 - i26.8$</u>	$4311.8 - i6.6$	$4268.5 - i1.3$
$J^P = 5/2^-$	—	<u>$4428.6 - i89.1$</u>	$4391.7 - i88.8$	$4338.2 - i56.2$
$J^P = 5/2^+$	—	—	$4368.0 - i9.2$	$4305.8 - i1.9$
	—	—	—	—

**Problem: much larger width than observed $P_c^+(4450)$
meanwhile too small width for $P_c^+(4380)$**

[3] Disentangling $\bar{D}\Sigma_c^* / \bar{D}^*\Sigma_c$ nature of P_c^+ states from their decays

Y.H.Lin, C.W.Shen, F.K.Guo, B.S.Zou, PRD95(2017)114017



One pion exchange is important !

Partial decay widths of $P_c^+(4380)$ & $P_c^+(4450)$

Mode	Widths (MeV)			
	$P_c(4380)$		$P_c(4450)$	
	$\bar{D}\Sigma_c^*(\frac{3}{2}^-)$	$\bar{D}^*\Sigma_c(\frac{3}{2}^-)$	$\bar{D}^*\Sigma_c(\frac{3}{2}^-)$	$\bar{D}^*\Sigma_c(\frac{5}{2}^+)$
$\bar{D}^*\Lambda_c$	131.3 ✓	35.3 ✓	72.3 ✓	20.5 ✓
$J/\psi p$	3.8	16.6	16.3	4.0
$\bar{D}\Lambda_c$	1.2	17.0 ✓	41.4 ✓	18.8 ✓
πN	0.06	0.07	0.07	0.2
$\chi_{c0} p$	0.9	0.004	0.02	0.002
$\eta_c p$	0.2	0.09	0.1	0.04
ρN	1.4	0.15	0.14	0.3
ωp	5.3	0.6	0.5	0.3
$\bar{D}\Sigma_c$	0.01	0.1	1.2	0.8
$\bar{D}\Sigma_c^*$	...	...	7.7	1.4
$\bar{D}\Lambda_c\pi$	11.6	...	...	...
Total	144.3	69.9	139.8	46.4

It is very important to study $P_c \rightarrow \bar{D}^*\Lambda$ & $\bar{D}\Lambda$!

LHCb pentaquark states vs Post-explanations

Consistent for $P_c^+(4380)$ to be a $\bar{D}\Sigma_c^* (3/2^-)$ molecule with a large decay width to $\bar{D}^*\Lambda_c$

Consistent for $P_c^+(4450)$ to be a $\bar{D}^*\Sigma_c (5/2^+)$ molecule

Problems:

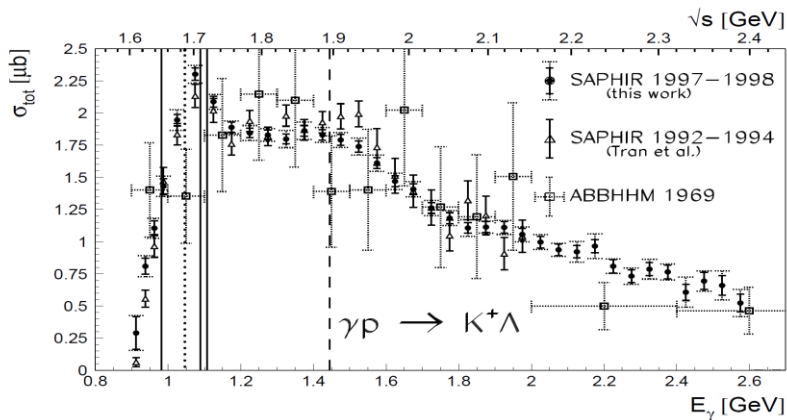
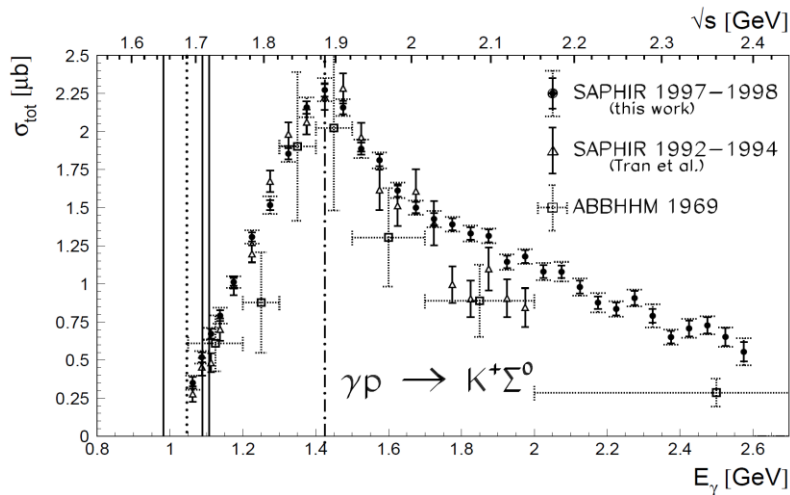
- 1) Where are lower $P_c (1/2^-)$ states ?
- 2) Where are predicted Λ_{cc}^- states ?

Many more pentaquarks are expected !

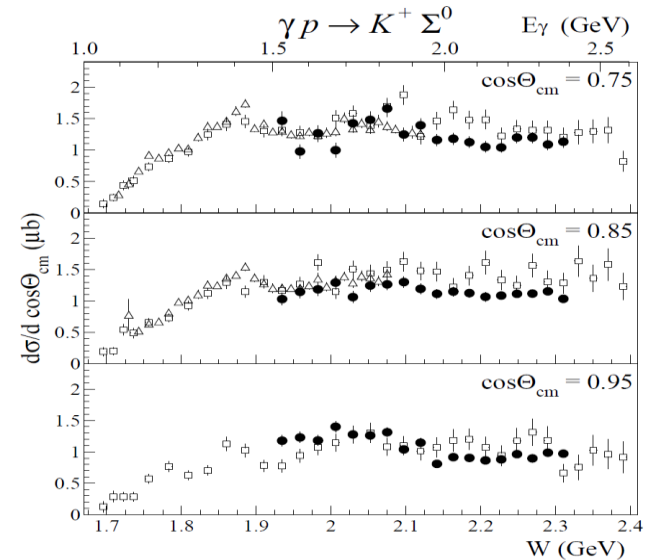
3. Strange & beauty partners of P_c states

Strangeness partners of P_c states: $N^*(1875)$ & $N^*(2080)$

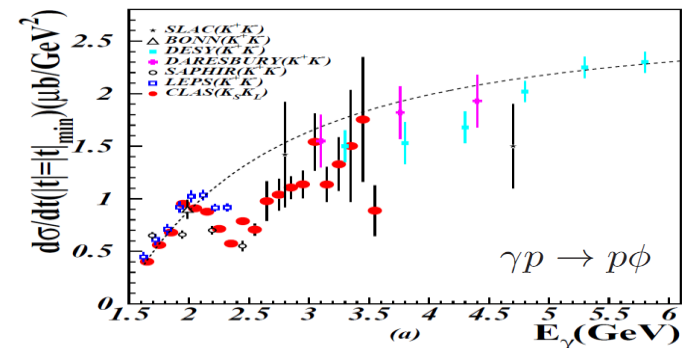
$K\Sigma^* \sim 1880$ $K^*\Sigma \sim 2086$



Glander, K.H. *et al.* EPJA19 (2004) 251-273

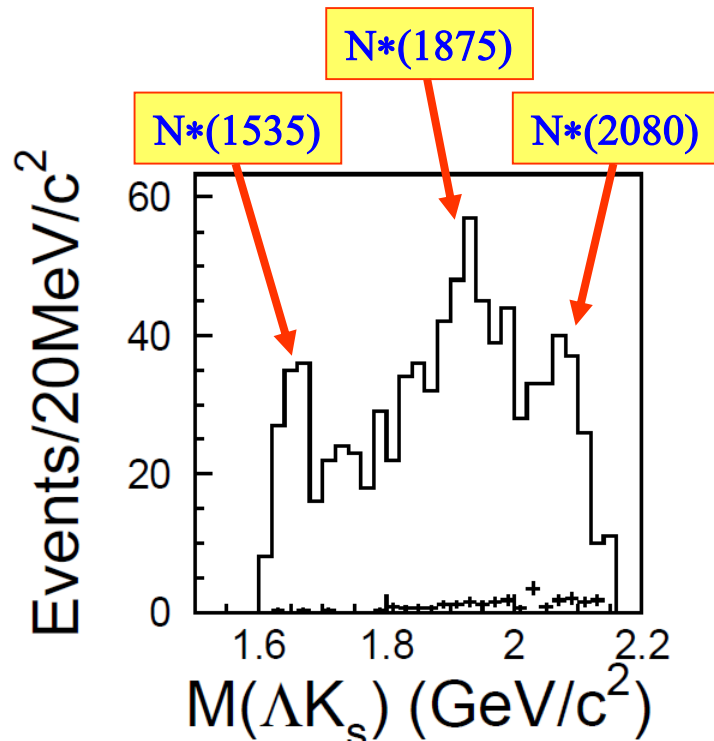


LEPS, PRC73 (2006) 035214

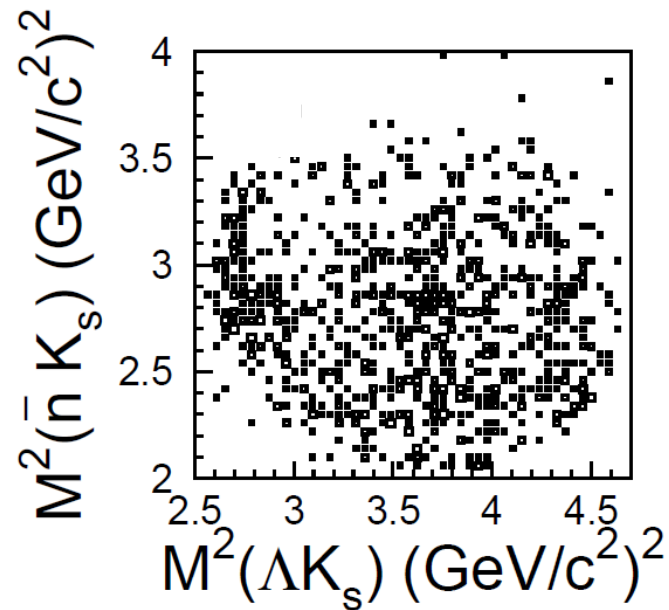


CLAS, PRC89 (2014) 055206

N_{ss}^- penta-quarks at BES ?!



$$J/\psi \rightarrow nK_s^0\bar{\Lambda}$$



BESII, Phys. Lett. B659 (2008) 789



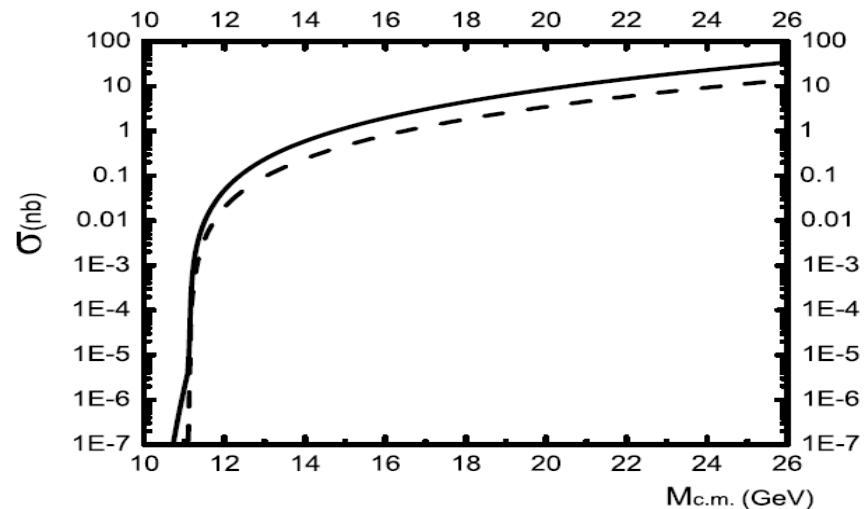
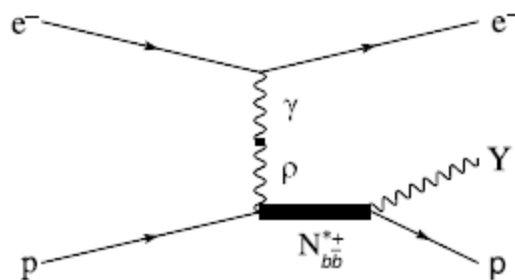
Prediction of super-heavy N^* and Λ^* resonances with hidden beauty

Jia-Jun Wu^{a,*}, Lu Zhao^a, B.S. Zou^{a,b}

M (MeV)	Γ (MeV)	Γ_i (MeV)				
		πN	ηN	$\eta' N$	$K \Sigma$	$\eta_b N$
11 052	1.38	0.10	0.21	0.11	0.42	0.52
		ρN	ωN	$K^* \Sigma$	ΥN	
11 100	1.33	0.09	0.30	0.39	0.51	

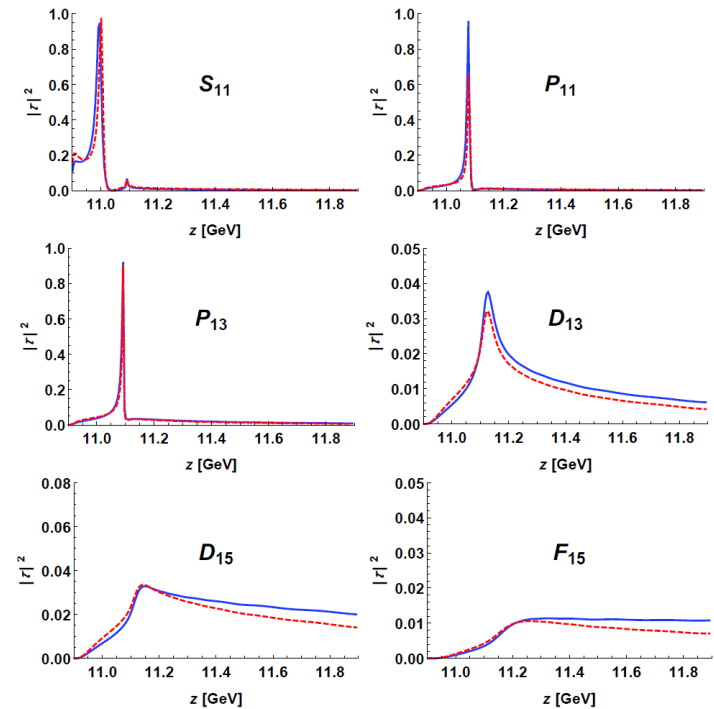
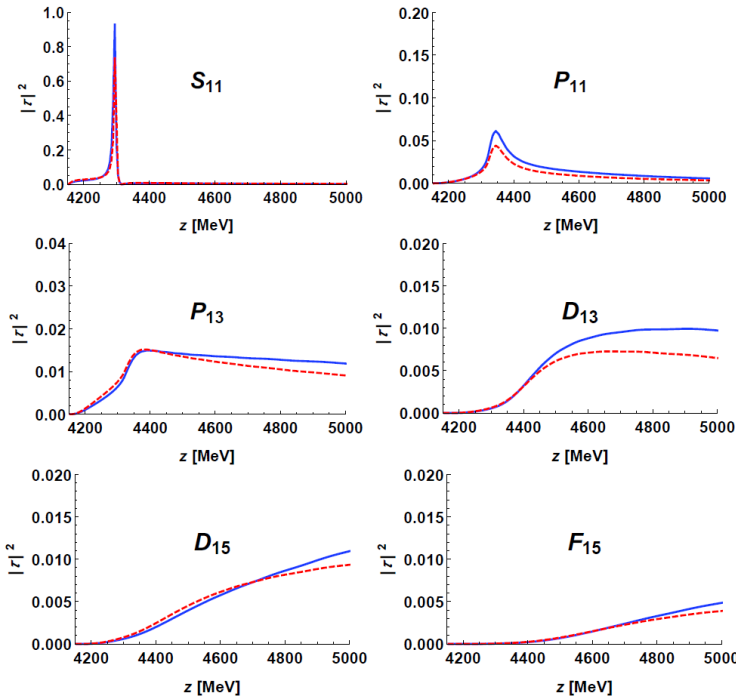
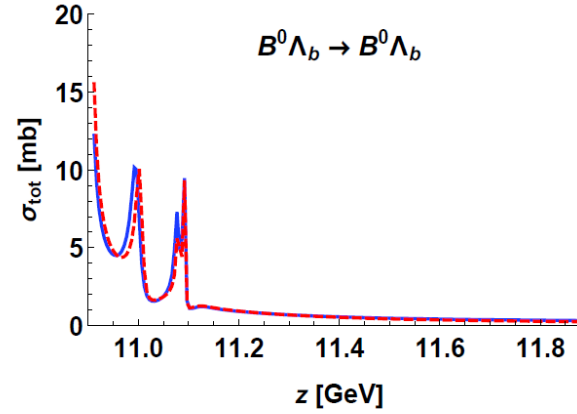
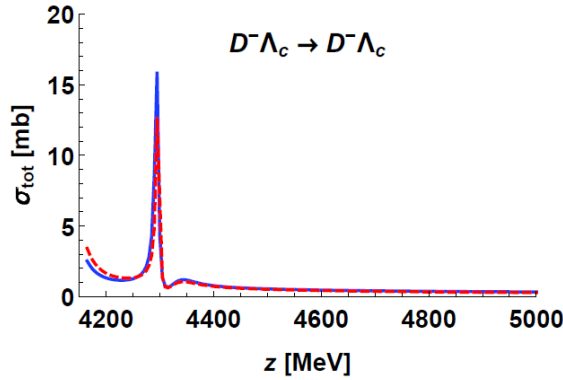
$1/2^-$

$1/2^-, 3/2^-$



$\bar{D}\Lambda_c - \bar{D}\Sigma_c$ and $B\Lambda_b - B\Sigma_b$ dynamical coupled channel study

C.W.Shen, Roehen, Meissner, Zou, CPC42(2018) 023106



More pentaquarks with hidden beauty than with hidden charm

Decay behavior of P_s & P_b pentaquark states

Y.H.Lin, C.W.Shen, B.S.Zou, ArXiv: 1805.06843

Mode	Widths (MeV)		
	$J^P = 3/2^-$		$J^P = 1/2^-$
	$N(1875) K\Sigma^*$	$N(2080) K^*\Sigma$	$N(2080) K^*\Sigma$
$N\sigma(500)$	2.6	0.05	0.3
πN	3.8	0.2	22.7
ρN	2.3	3.8	6.1
ωp	6.6	11.3	18.2
$K\Sigma$	0.03	1.4	9.1
$K\Lambda$	0.7	3.7	19.3
ηp	0.6	0.4	1.8
$\pi\Delta$	201.4	82.6	46.9
$K^*\Lambda$	-	2.4	7.9
ϕp	-	19.2	27.0
$K\Sigma^*$	-	7.3	1.3
$K\Lambda(1520)$	-	0.1	1.3
$K\Lambda(1405)$	-	8.0	8.8
$K\pi\Lambda$	10.1	-	-
$K\pi\Sigma$	-	41.3	46.1
Total	228.2	181.7	216.8

Mode	Widths (MeV)		
	$J^P = 3/2^-$		$J^P = 1/2^-$
	$B\Sigma_b^*$	$B^*\Sigma_b$	$B^*\Sigma_b$
$B^*\Lambda_b$	271.1	19.9	167.0
Υp	0.3	0.04	0.1
ρN	5.5	0.02	0.1
ωp	20.9	0.07	0.4
$B\Lambda_b$	-	7.3	135.9
$B\Sigma_b$	-	-	-
$\eta_b p$	0.02	0.0001	0.0009
$\chi_{b0} p$	1.4	0.0008	0.2
πN	0.7	0.005	0.003
$B\Sigma_b^*$	-	-	-
Total	299.9	27.4	303.8

Guidance for P_s & P_b search

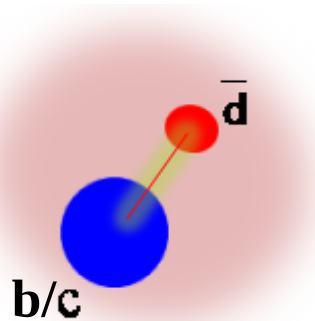
4. Prospects

◆ my favorite strategy for hadron spectroscopy:

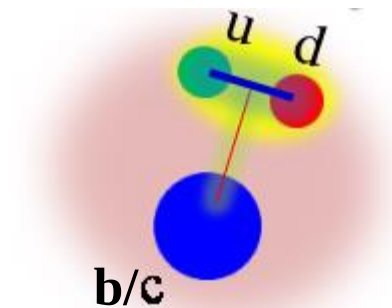
$\bar{c}c u u d$ & $\bar{c}c u d s \rightarrow s s s - \bar{q} q s s s \rightarrow c q q - \bar{q} q c q q$
 $\rightarrow$ hyperons $\rightarrow$ light baryons

$\bar{c}c \bar{u} d$ & $\bar{c} s \bar{u} d \rightarrow \bar{c}c - \bar{q} q \bar{c}c \rightarrow \bar{c}q - \bar{c}q \bar{q} q$
 $\rightarrow$ K mesons $\rightarrow$ light mesons

$s \rightarrow c \rightarrow b$



charm & beauty meson



charm & beauty baryon

- New penta-quark spectroscopy provides a new ideal platform for understanding multiquark dynamics
- Further experimental confirmation and extension for whole penta-quark spectroscopy from γN , πN , KN , $e^+e^- \rightarrow \bar{\Lambda}_b \Lambda_b$, etc.

$ep/\gamma p$ @JLab, $\pi 10/K 10$ @JPARC, BelleII, BESIII, Eic/EicC, PANDA@FAIR, STCF etc. may play important role here!

Thank you for
your attention!