Narrow N* and Λ* resonances with hidden charm above 4 GeV

Bing-song Zou

IHEP, Beijing

In collaboration with J.J.Wu, R.Molina and E.Oset

arXiv:1007.0573[nucl-th]

Outline

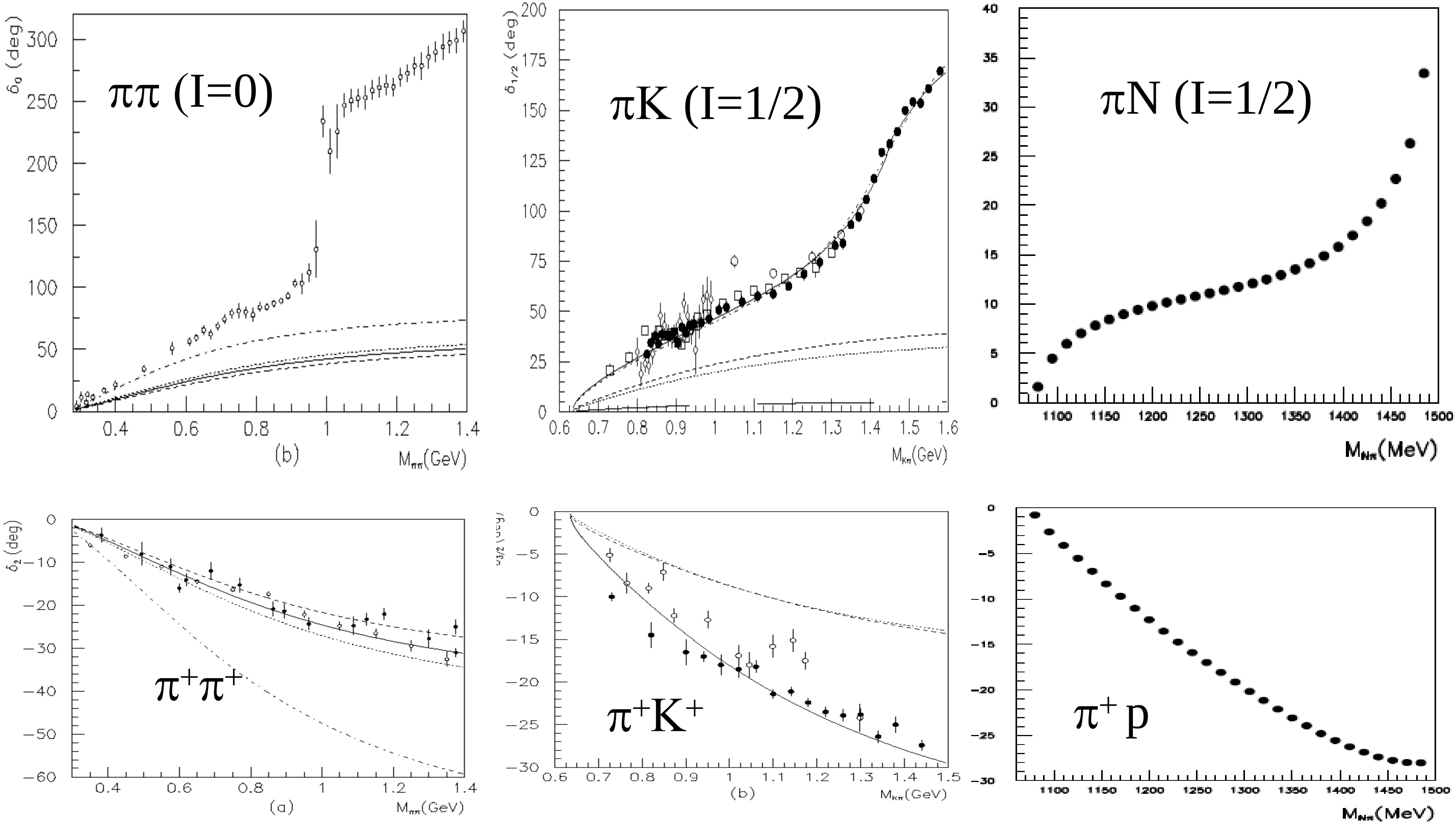
1. “Exotic” $\pi\pi$, πK and πN S-wave interactions

2. Possible hadron-hadron bound states

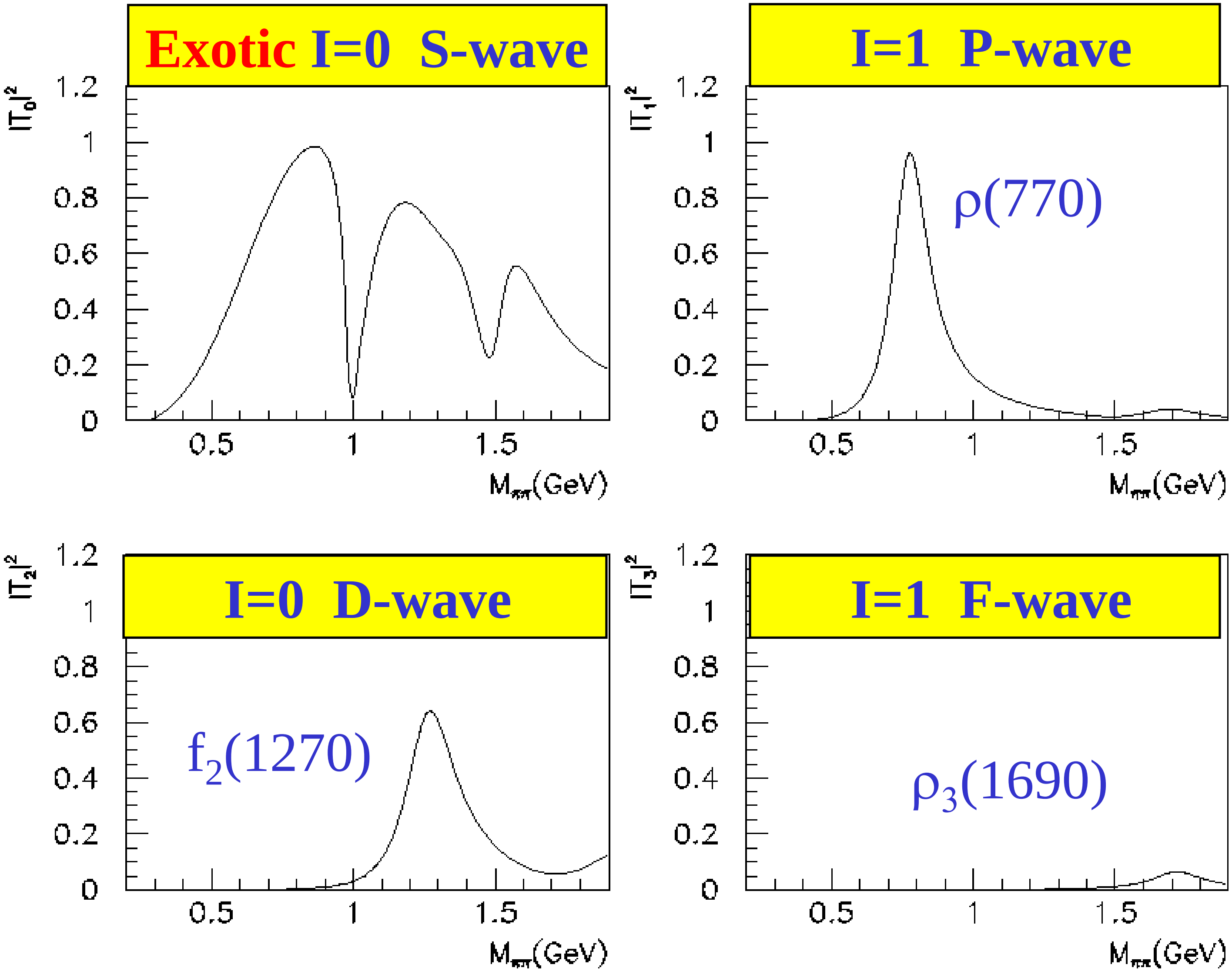
3. From $\bar{K}\Sigma$, $\bar{K}p$ bound states to $\bar{D}\Sigma_c$, $\bar{D}_s\Lambda_c$ bound states

1. “Exotic” ππ, πK and πN S-wave interactions

Similarity for ππ, πK and πN s-wave scattering



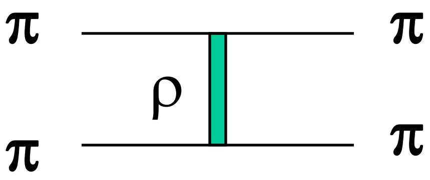
"Exotic" ππ S-wave interaction : broad σ–background with narrow resonances as dips instead of peaks



D.V.Bugg, A.Sarantsev,B.S.Zou, Nucl. Phys. B471 (1996) 59

What's the nature of the broad σ ?

Important role by t-channel ρ exchange for all these processes



ππ **πK & πN**

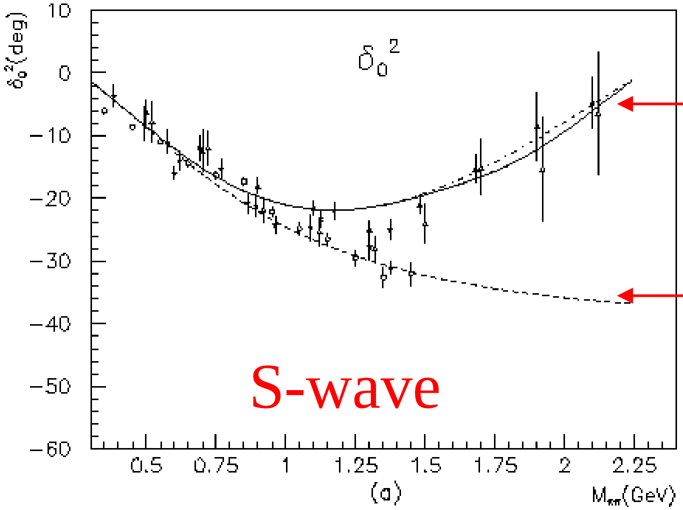
$K_\rho^{I=0} = -2\, K_\rho^{I=2}$, $K_\rho^{I=1/2} = -2\, K_\rho^{I=3/2}$

D. Lohse, J.W. Durso, K. Holinde, J. Speth, Nucl.Phys.A516, 513 (1990)
B.S.Zou, D.V.Bugg, Phys. Rev. D50, 591 (1994)

An interesting paper by T.Hyodo, D.Jido, A.Hosaka, PRL 97 (2006) 192002
"Exotic hadrons in s-wave chiral dynamics"

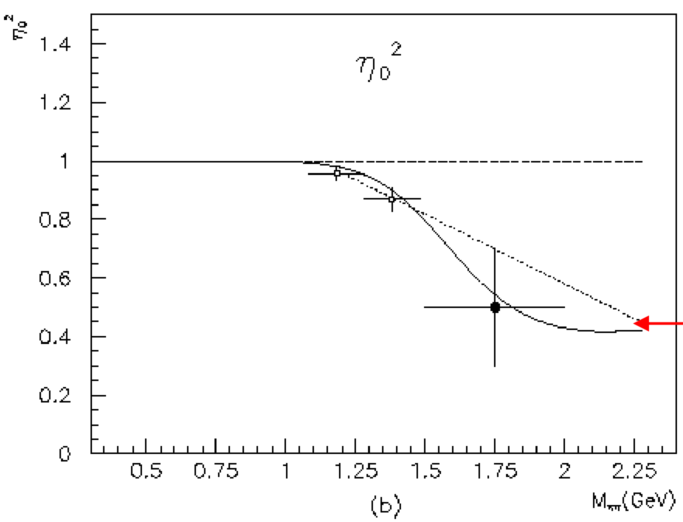
Basic features of I=2 ππ Interaction

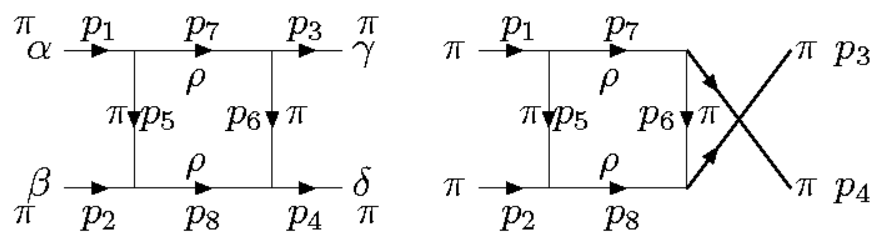
F.Q.Wu, B.S.Zou et al., Nucl. Phys.A735 (2004) 111



attractive force by t-channel f_2

repulsive force by t-channel ρ





Inelasticity by ππ ↔ ρρ

An important cause for hadron-hadron S-wave interactions appearing "exotic" is

t-channel meson-exchange amplitude has a comparable strength as s-channel resonance contribution for S-waves.

For higher partial waves, s-channel resonance contribution dominates.

2. Possible hadron-hadron bound states

$f_0(980)$ -- $\bar{K}K$ bound state ?

Yes, if dropping q-dependent term

S.Krewald et al., PRD69 (2004) 016003

No, if keeping q-dependent term

Y.J.Zhang et al., PRD74 (2006) 014013

N*(1535) -- $\bar{K}\Sigma$ bound state ?

Yes, coupled with other meson-baryon channels

Weise, Oset, …

Not purely meson-baryon state

Hyodo-Jido-Hosaka, PRC78 (2008)025203

Possible S-wave bound-states of two pseudoscalar mesons

Y.J.Zhang, H.C.Chiang, P.N.Shen and B.S.Zou, PRD74 (2006) 014013

Λ(GeV) \ E(MeV)	DB	$D\bar{D}$	$B\bar{B}$	$B\bar{K}$	$B\bar{D}$	$D\bar{K}$
1.4	-1.2	-	-	-	-	-
1.5	-5.7	-	-	-	-	-
1.6	-13.4	-	-	-	-	-
1.7	-24.3	-	-	-	-	-
1.8	-38.1	-9.3	-0.8	-	-	-
1.9	-54.6	-17.7	-4.3	-	-	-
2.0	-73.6	-28.7	-10.9	-	-	-
2.1	-95.0	-42.4	-21.0	-	-	-
2.2	-118.6	-58.8	-35.1	-1.4	-	-
2.3	-144.2	-77.9	-53.8	-3.1	-	-
2.4	-171.8	-100.0	-78.2	-5.4	-	-
2.5	-201.3	-125.1	-110.1	-8.2	-0.3	-5.8
2.6	-232.7	-153.7	-152.4	-11.6	-2.5	-55.2
2.7	-265.8	-186.0	-210.3	-15.5	-6.9	-302.7
2.8	-300.6	-222.8	-295.9	-19.9	-13.9	
2.9	-337.2	-264.8	-450.9	-24.7	-24.3	
3.0	-375.6	-313.3		-30.0	-39.0	

Possible 0^{++} $\bar{D}D$ bound state X(3720)

Y.J.Zhang, H.C.Chiang, P.N.Shen, B.S.Zou, PRD74 (2006) 014013

With t-channel ρ, ω exchange and FF :

$$F^t(\mathbf{q}) = \left(\frac{\Lambda^2 - M_V^2}{\Lambda^2 + \mathbf{q}^2}\right)^2$$

$M_X = 3709 \sim 3729$ MeV with $\Lambda = 1.8 \sim 2.0$ GeV

D.Gamermann, E.Oset et al., PRD76 (2007) 074016

Dynamically generated resonance with chiral unitary approach

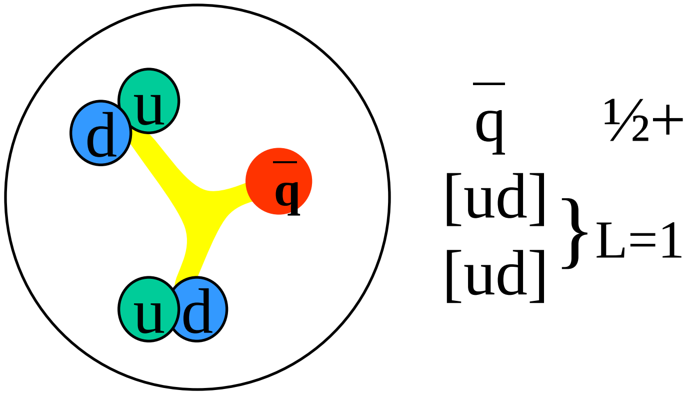
$M_X \sim 3719$ MeV

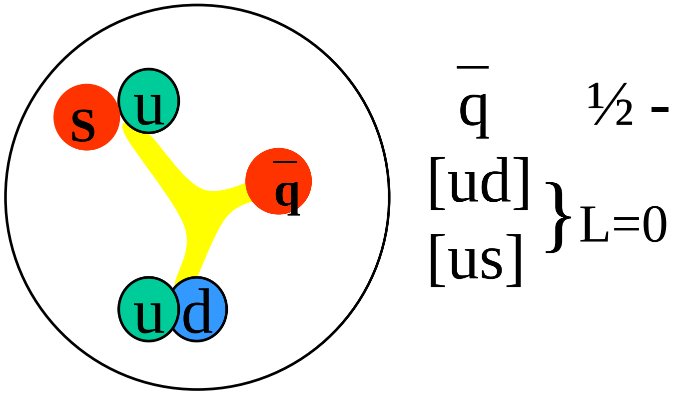
Look for X(3720) from ψ(3770) → γ X(3720)

D.Gamermann, E.Oset, B.S.Zou, EPJA41 (2009) 85

New Scheme for N*(1535) and its 1/2⁻ nonet partners

B.S.Zou, EPJA35(2008)325





Zhang et al, hep-ph/0403210

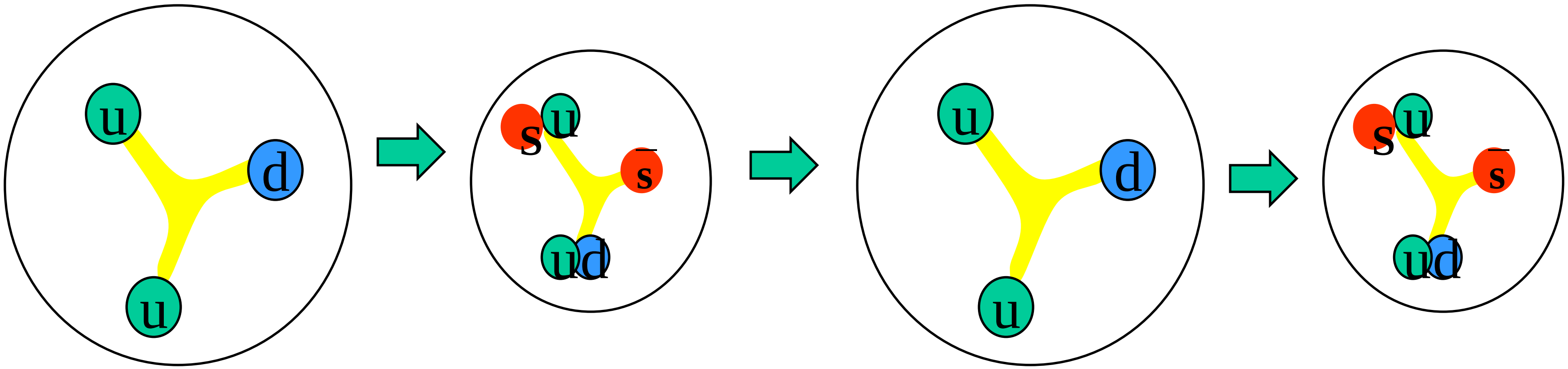
N*(1535) ~ uud (L=1) + ε [ud][us] $\bar{s}$ + …

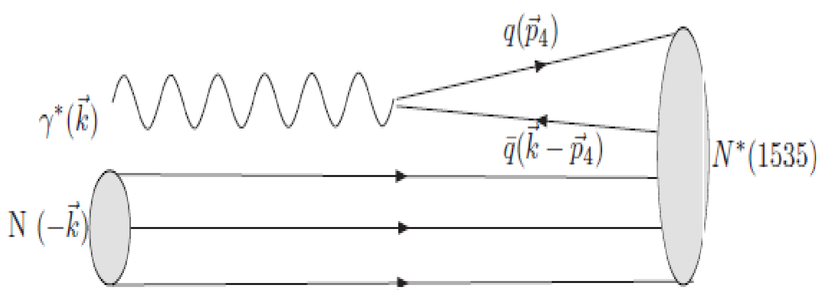
N*(1440) ~ uud (n=1) + ξ [ud][ud] $\bar{d}$ + …

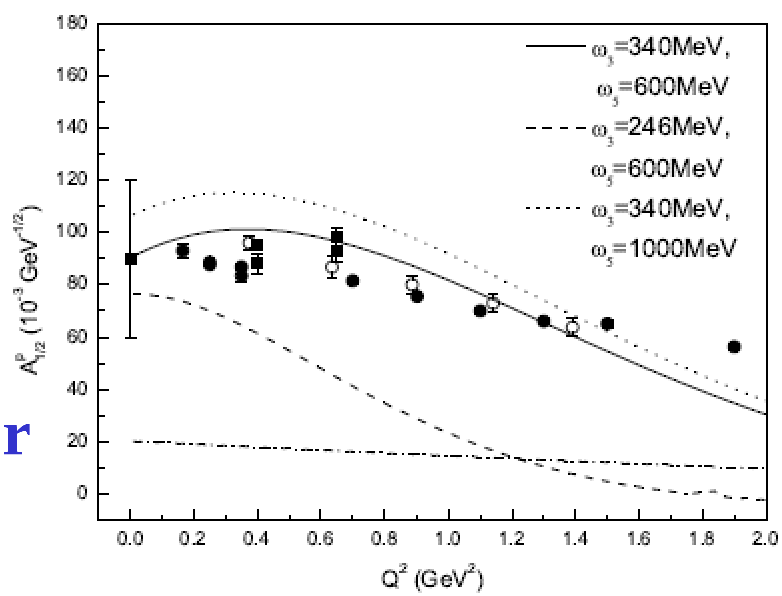
Λ*(1405) ~ uds (L=1) + ε [ud][su] $\bar{u}$ + …

N*(1535): [ud][us] $\bar{s}$ → larger coupling to Nη, Nη', Nϕ & KΛ, weaker to Nπ & KΣ, and heavier !

The breathing mode for the N*(1535)







Important role for N* EM form factor

An & Zou, EPJA39(2009)195

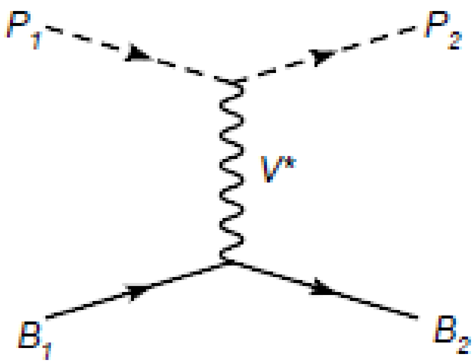
Many other proposed dynamically generated states

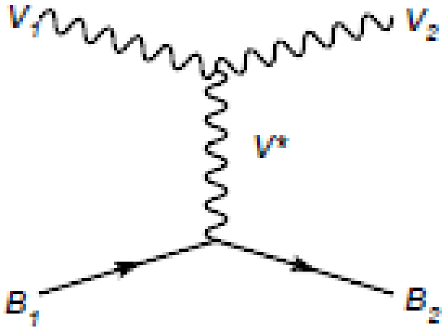
Problem:

None of them can be clearly distinguished from qqq or $\bar{q}q$ due to tunable ingredients and possible large mixing of various configurations

3. From $\bar{K}\Sigma$, $\bar{K}p$ bound states to $\bar{D}\Sigma_c$, $\bar{D}_s\Lambda_c$ bound states

J.J.Wu, R.Molina, E.Oset, B.S.Zou. arXiv:1007.0573[nucl-th]





$$\mathcal{L}_{VVV} = ig\langle V^\mu [V^\nu, \partial_\mu V_\nu]\rangle$$
$$\mathcal{L}_{PPV} = -ig\langle V^\mu [P, \partial_\mu P]\rangle$$
$$\mathcal{L}_{BBV} = g(\langle \bar{B}\gamma_\mu [V^\mu, B]\rangle + \langle \bar{B}\gamma_\mu B\rangle \langle V^\mu\rangle)$$

$$V_{ab(P_1 B_1 \to P_2 B_2)} = \frac{C_{ab}}{4f^2}(E_{P_1} + E_{P_2}),$$
$$V_{ab(V_1 B_1 \to V_2 B_2)} = \frac{C_{ab}}{4f^2}(E_{V_1} + E_{V_2})\vec{\epsilon}_1 \cdot \vec{\epsilon}_2,$$

$$T = [1 - VG]^{-1} V$$

$$T_{ab} = \frac{g_a g_b}{\sqrt{s} - z_R}$$

	(I,S)	z_R (MeV)		g_a	
N*	$(1/2,0)$		$\bar{D}\Sigma_c$	$\bar{D}\Lambda_c^+$	
		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 $PB \to PB$.

	(I,S)	z_R (MeV)		g_a	
N*	$(1/2,0)$		$\bar{D}^*\Sigma_c$	$\bar{D}^*\Lambda_c^+$	
		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 $VB \to VB$.

	(I,S)	M	Γ	Γ_i					
N*	$(1/2,0)$			πN	ηN	$\eta' N$	$K\Sigma$		$\eta_c N$
		4261	56.9	3.8	8.1	3.9	17.0		23.4
	$(0,-1)$			$\bar{K}N$	$\pi\Sigma$	$\eta\Lambda$	$\eta'\Lambda$	$K\Xi$	$\eta_c\Lambda$
Λ*		4209	32.4	15.8	2.9	3.2	1.7	2.4	5.8
		4394	43.3	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 $PB \to PB$, with units in MeV.

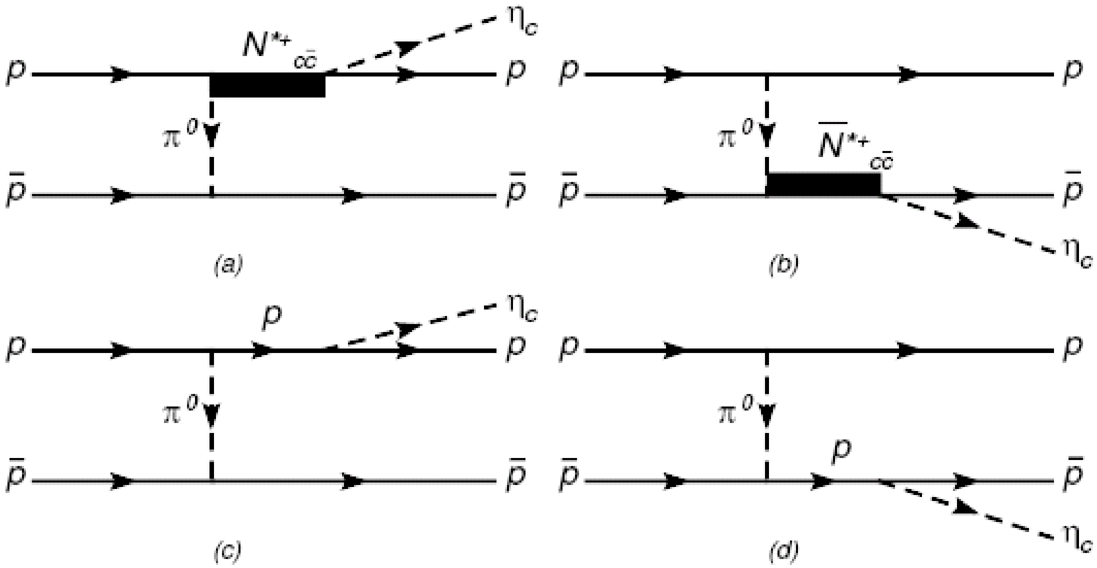
	(I,S)	M	Γ	Γ_i					
N*	$(1/2,0)$			ρN	ωN	$K^*\Sigma$			$J/\psi N$
		4412	47.3	3.2	10.4	13.7			19.2
	$(0,-1)$			K^*N	$\rho\Sigma$	$\omega\Lambda$	$\phi\Lambda$	$K^*\Xi$	$J/\psi\Lambda$
Λ*		4368	28.0	13.9	3.1	0.3	4.0	1.8	5.4
		4544	36.6	0	8.8	9.1	0	5.0	13.8

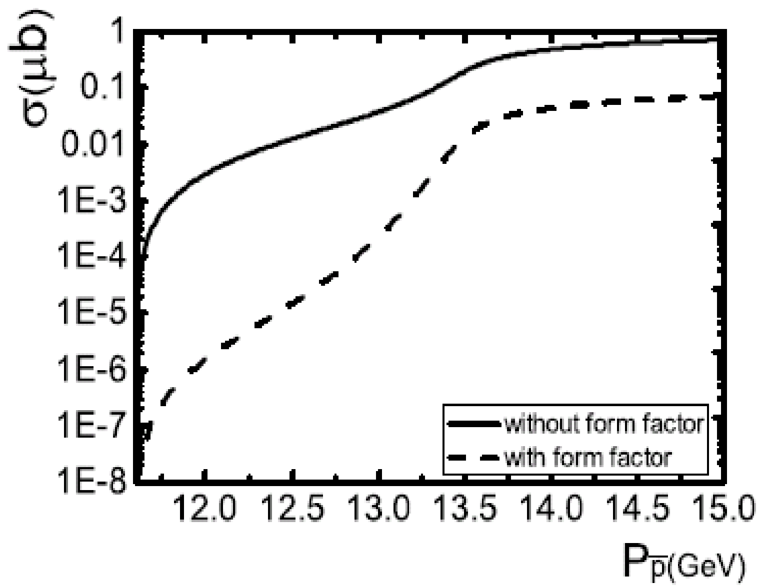
TABLE VI: Mass (M), total width (Γ), and the partial decay width (Γ_i) for the states from $VB \to VB$ with units in MeV.

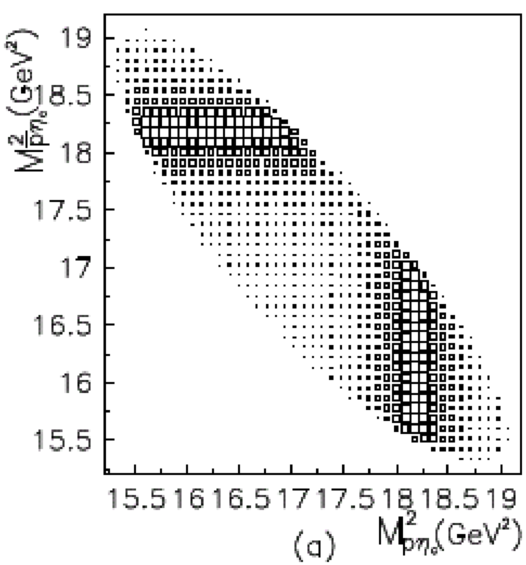
Super-heavy narrow N* and Λ* with hidden charm !

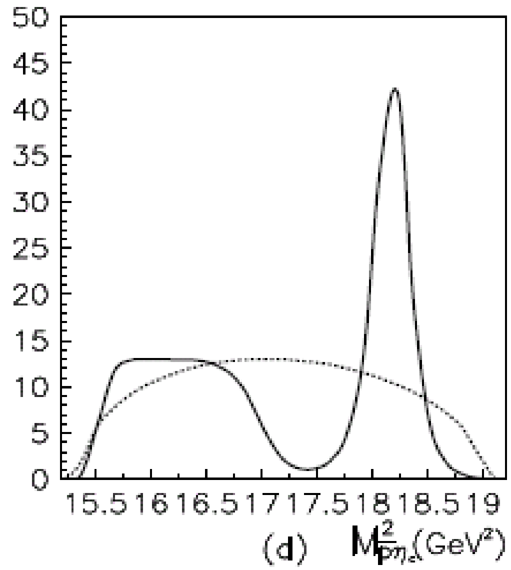
Definitely not qqq states !

Prediction for PANDA



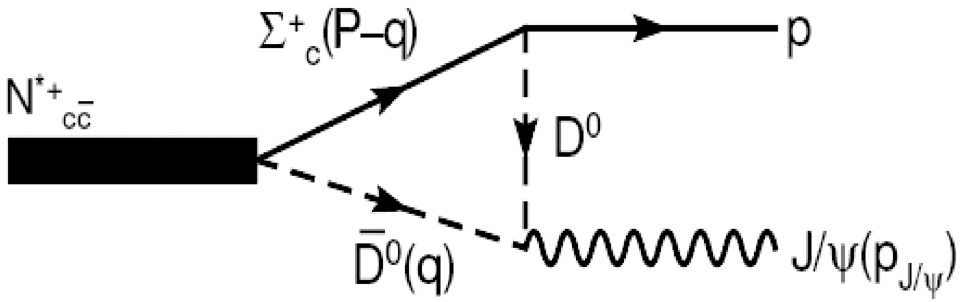






$\bar{p}p \rightarrow \bar{p}p\eta_c$

0.07 -- 0.7μb



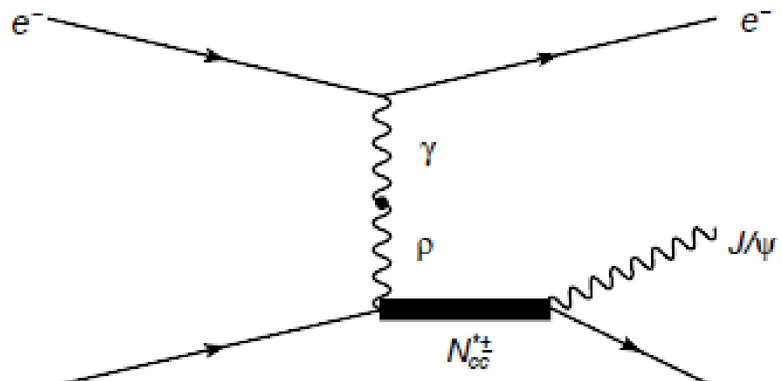
3 orders of magnitude smaller than N* → $p\eta_c$

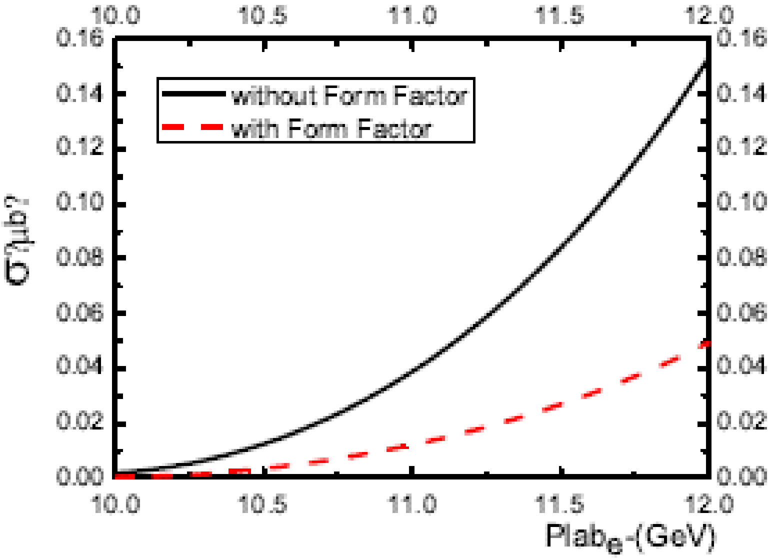
$\bar{p}p \rightarrow \bar{p}pJ/\psi$ ~ 0.03 nb

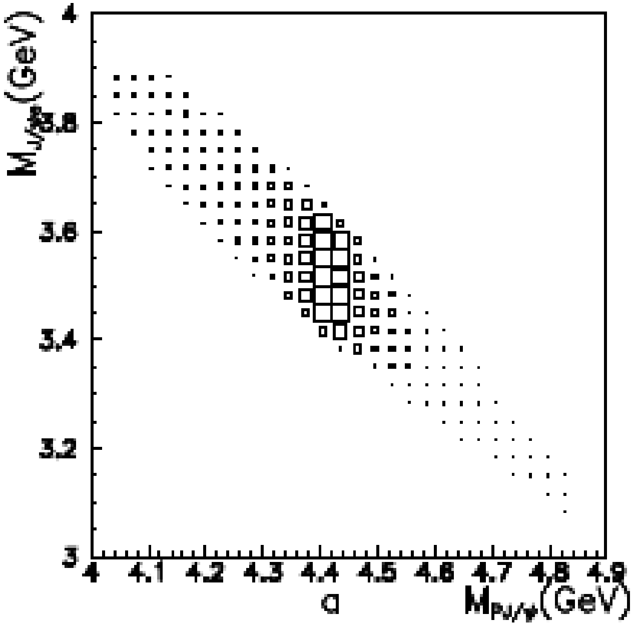
~ 250 events per day at PANDA/FAIR by $L=10^{31}$ $cm^{-2}s^{-1}$

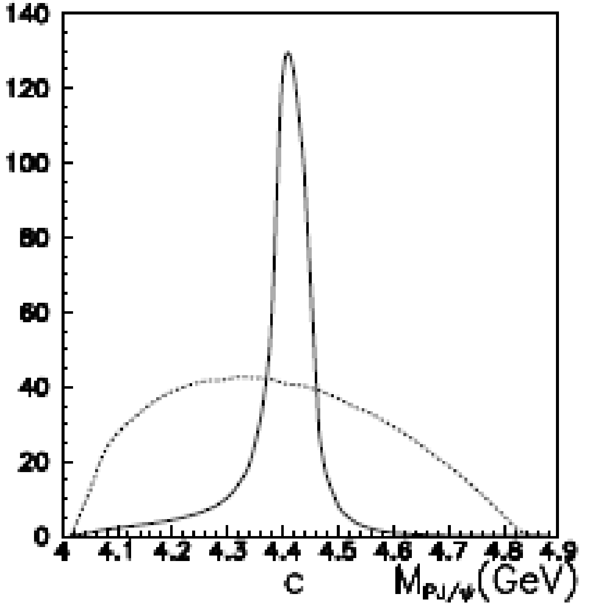
These Super-heavy narrow N* and Λ* can be found at PANDA !

Prediction for 12GeV@JLab









Conclusion

- **Super heavy narrow N* and Λ* are predicted to exist**
- **They are definitely not qqq baryons**
- **They can be looked for at 12GeV@Jlab and PANDA**

Thank You!