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BURAPHA UNIVERSITY

Gaining wisdom provides happiness

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Strangeness configurations of the proton for ϕ meson production in $p\bar{p}$ annihilation

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Outline

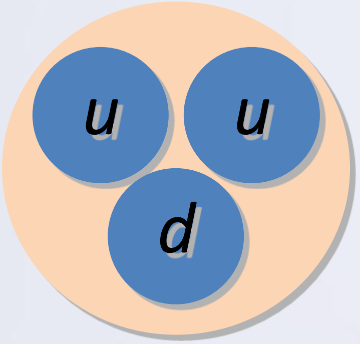
- Introduction
- Proton wave functions with pentaquark components
- The transition amplitude and the branching ratios for the reactions

$$p\bar{p} \to X\phi \ (X = \pi^0, \eta, \rho, \omega)$$

- Summary and Conclusions

1. Introduction

Baryons being bound states of three quarks.



proton

The proton might contain a substantial strange quark-antiquark component

The apparent OZI rule violation $\phi(s\bar{s})$ production nucleon-antinucleon annihilation reactions suggests the existence of strange quarks in the nucleon.

Deep Inelastic Scattering

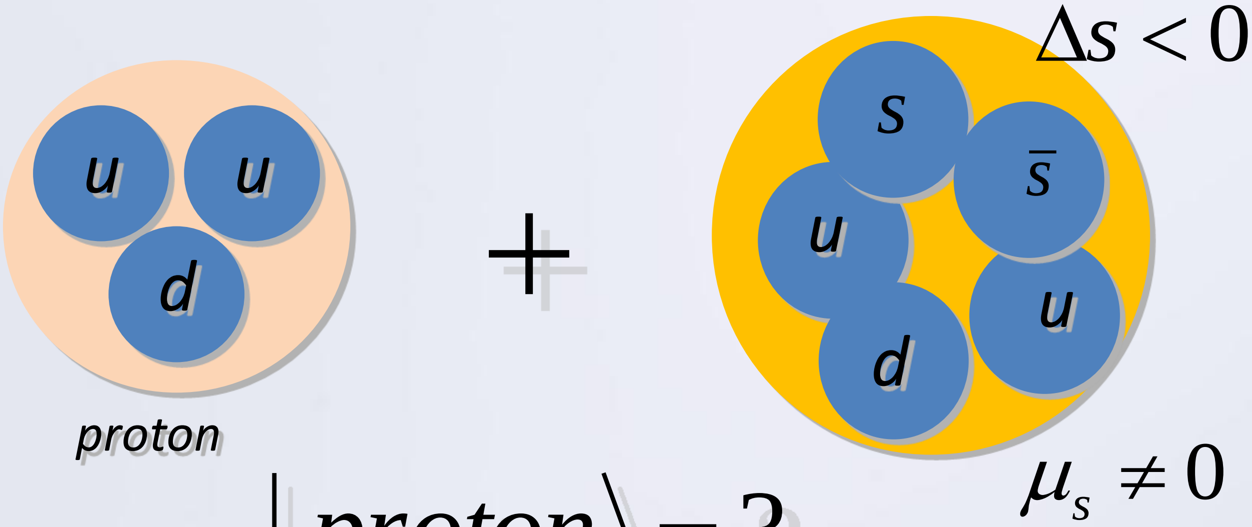
The non-zero strange spin of the proton

$$\Delta s = -0.10 \pm 0.03$$

The strangeness magnetic moment can be extrapolated from the strange magnetic form factor

$$G_M^S(Q=0) \equiv \mu_s \neq 0$$

The presence of $uuds\bar{s}$ piece in the proton wave function.



$$\left| proton \right\rangle = ?$$

Some experimental measurements suggest a ***positive value*** *for* μ_s

But most theoretical calculations of the proton derive a negative value for this observable !

$$\left| p \right\rangle = A\left| uud \right\rangle + B\left| uuds\bar{s} \right\rangle \qquad A^2 >> B^2$$

PHYSICAL REVIEW C **73**, 035207 (2006)

Strangeness spin, magnetic moment, and strangeness configurations of the proton

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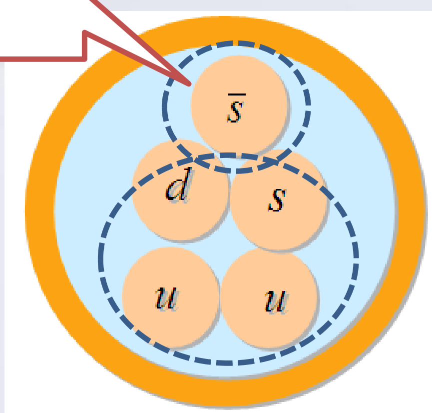
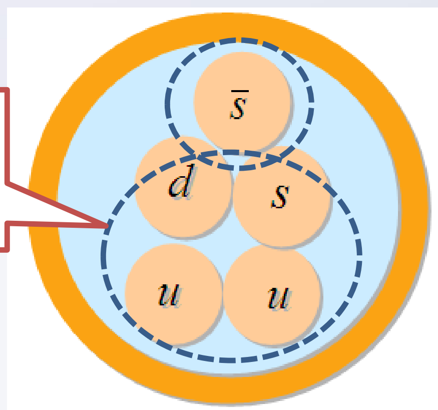
pentaquark

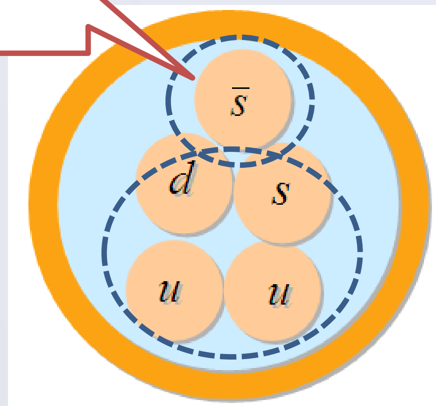
P -state



P -state



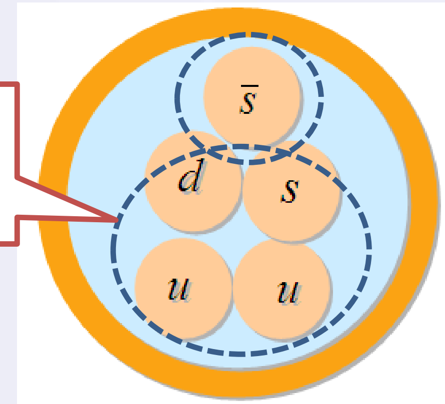
P -state



$\Delta s < 0 \quad \mu_s < 0$

2 configurations

P -state

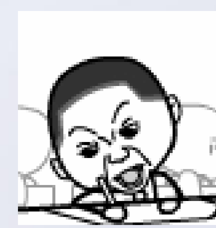


$\Delta s < 0 \quad \mu_s > 0$

15 configurations!

The branching ratios for the reactions

$$p\bar{p} \to X\phi \;\; (X = \pi^0, \eta, \rho, \omega)$$



2. Proton wave functions with pentaquark components

$$\boxed{|p\rangle = A|uud\rangle + B|uuds\bar{s}\rangle}$$

$$|uuds\rangle \otimes |\bar{s}\rangle$$

$$spatial \otimes spin \otimes flavor \otimes color$$

P -state

$|\bar{s}\rangle,\ |uuds\rangle$

$S_{5q} = 1/2$

proton

color singlet

$$|uuds\bar{s}\rangle$$

color singlet

The color state of the antiquark in pentaquarks is a [11] antitriplet

$$\bar{s} \rightarrow [11]$$

$$uuds \equiv [211] \otimes \bar{s} \equiv [11] \rightarrow uuds\bar{s} \equiv [222]$$

color singlet

The color wave function of the four-quark configuration must be a $[211]_3$ triplet

$$uuds \rightarrow [211]$$

$$\chi^c_{[211]_\lambda}(q^4) = \begin{array}{|c|c|}\hline 1 & 2 \\ \hline 3 \\ \cline{1-1} 4 \\ \cline{1-1}\end{array} \quad \chi^c_{[211]_\rho}(q^4) = \begin{array}{|c|c|}\hline 1 & 3 \\ \hline 2 \\ \cline{1-1} 4 \\ \cline{1-1}\end{array} \quad \chi^c_{[211]_\eta}(q^4) = \begin{array}{|c|c|}\hline 1 & 4 \\ \hline 2 \\ \cline{1-1} 3 \\ \cline{1-1}\end{array}$$

The color wave functions can be derived by applying the λ, ρ, η type projection operators of the irreducible representation IR[211] of the permutation group S_4 in Yamanouchi basis, onto single particle color states

$$\chi^{c}_{[211]_\lambda}(R) = \frac{1}{\sqrt{16}}(2|RRGB\rangle - 2|RRBG\rangle - |GRRB\rangle - |RGRB\rangle - |BRGR\rangle - |RBGR\rangle + |BRRG\rangle + |GRBR\rangle + |RBRG\rangle + |RGBR\rangle)$$

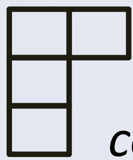
The corresponding singlet color wave function of the pentaquark at color symmetry pattern λ, ρ, η is given by

$$\chi^{C}_{[222]_j} = \frac{1}{\sqrt{3}}\left[\chi^{c}_{[211]_j}(R)\,\bar{R} + \chi^{c}_{[211]_j}(G)\,\bar{G} + \chi^{c}_{[211]_j}(B)\,\bar{B}\right]$$

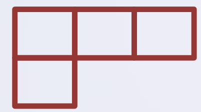
The total wave function of the four quark configuration is antisymmetric

$$\left|uuds\right\rangle^{OSFC} \rightarrow [1111]$$

the spatial-spin-flavor part must be a [31] state



color $[211]$ $\otimes$



spatial-flavor-spin $[31]$

$$\psi_{[1111]} = \sum_{i,j=\lambda,\rho,\eta} a_{ij}\, \chi^{c}_{[211]_i} \chi^{osf}_{[31]_j}$$

Applying the IR[31] and IR[211] of the permutation group S_4 in Yamanouchi basis

$$\psi_{[1111]} = \frac{1}{\sqrt{3}} \left(\chi^{c}_{[211]_\lambda} \chi^{osf}_{[31]_\rho} - \chi^{c}_{[211]_\rho} \chi^{osf}_{[31]_\lambda} + \chi^{c}_{[211]_\eta} \chi^{osf}_{[31]_\eta} \right)$$

$$\psi_{[1111]} = \frac{1}{\sqrt{3}}\left(\chi^{c}_{[211]_\lambda}\chi^{osf}_{[31]_\rho} - \chi^{c}_{[211]_\rho}\chi^{osf}_{[31]_\lambda} + \chi^{c}_{[211]_\eta}\chi^{osf}_{[31]_\eta}\right)$$

The spatial-spin-flavor of the q^4

$$\chi^{osf}_{[31]} = \sum_{i,j} a_{ij}\chi^{o}_{[X]_i}\chi^{sf}_{[Y]_j}$$

$$\chi^{sf}_{[Z]} = \sum_{i,j} a_{ij}\chi^{f}_{[X]_i}\chi^{s}_{[Y]_j}$$

The spin-flavor of the q^4

$[31]_{OSF}$	
$[4]_O$	$[31]_{SF}$
$[1111]_O$	$[211]_{SF}$
$[22]_O$	$[31]_{SF}, [211]_{SF}$
$[211]_O$	$[31]_{SF}, [211]_{SF}, [22]_{SF}$
$[31]_O$	$[4]_{SF}, [31]_{SF}, [211]_{SF}, [22]_{SF}$

$[4]_{FS}$			
$[31]_{FS}$			
$[22]_{FS}$			
$[211]_{FS}$			
$[211]_F[22]_S$	$[211]_F[31]_S$	$[211]_F[4]_S$	$[22]_F[31]_S$
$[31]_F[22]_S$	$[31]_F[31]_S$		

spin

$$\left|[22]_S\right\rangle = \left|[22]_{S_1}\right\rangle, \left|[22]_{S_2}\right\rangle$$

1	2
3	4

$$\left|[22]_{S_1}\right\rangle = \left| \left[\overset{1}{\frac{1}{2}} \otimes \overset{2}{\frac{1}{2}} \right]_0 \otimes \left[\overset{3}{\frac{1}{2}} \otimes \overset{4}{\frac{1}{2}} \right]_0 \right\rangle_0$$

flavor

1	4
2	
3	

$$\left|[211]_{F_1}\right\rangle = \frac{1}{\sqrt{24}} \{2uuds + 2uusd + 2dsuu + 2sduu$$
$$- duus - udus - sudu - usdu$$
$$- suud - dusu - usud - udsu\}$$

spatial

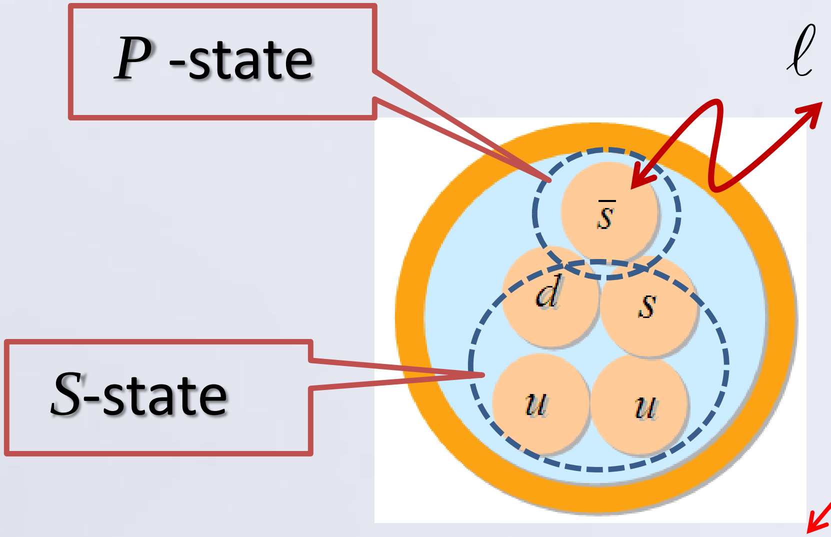
$[4]_O$ symmetry

1	2	3	4

$$\vec{\xi}_S = \frac{\vec{q}_2 + \vec{q}_3 + \vec{q}_4 + \vec{q}_5 - 4\vec{q}_1}{\sqrt{20}}$$

According to the requirement of positive parity for the proton wave function

$$\ell = 1 \Rightarrow P = (-1)^{\ell+1}$$



	$[31]_{OSF}$
$[4]_O$	$[31]_{SF}$
$[1111]_O$	$[211]_{SF}$
$[22]_O$	$[31]_{SF}, [211]_{SF}$
$[211]_O$	$[31]_{SF}, [211]_{SF}, [22]_{SF}$
$[31]_O$	$[4]_{SF}, [31]_{SF}, [211]_{SF}, [22]_{SF}$

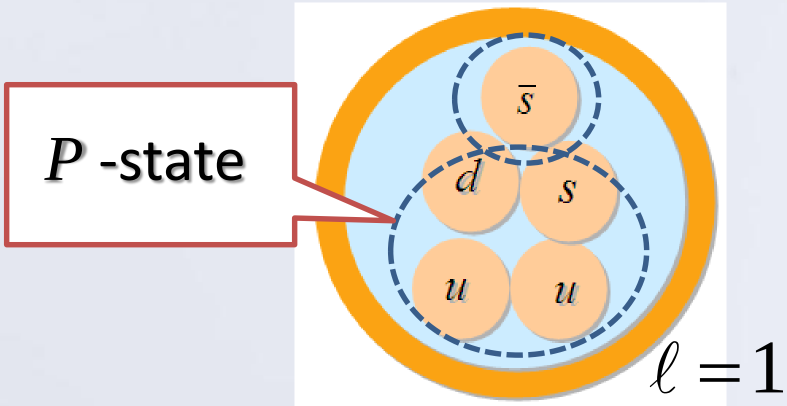
the spatial part takes the $[4]_O$ symmetry

$[31]_{FS}$			
$[31]_F[22]_S$	$[31]_F[31]_S$	$[31]_F[4]_S$	$[211]_F[22]_S$
$[211]_F[31]_S$	$[22]_F[31]_S$	$[4]_F[31]_S$	

$\Delta s < 0$

$\mu_s < 0$

$$|uuds\bar{s}\rangle = [|\frac{1}{2}, m_{\bar{s}}\rangle \otimes |1,\mu\rangle]_{\frac{1}{2},m_{5q}} \frac{1}{\sqrt{3}}\left(\chi^C_{[222]_\lambda}(\bar{s}\chi^{FS}_{[31]_\rho}) - \chi^C_{[222]_\rho}(\bar{s}\chi^{FS}_{[31]_\lambda}) + \chi^C_{[222]_\eta}(\bar{s}\chi^{FS}_{[31]_\eta})\right)$$



$[31]_{OSF}$	
$[4]_O$	$[31]_{SF}$
$[1111]_O$	$[211]_{SF}$
$[22]_O$	$[31]_{SF}, [211]_{SF}$
$[211]_O$	$[31]_{SF}, [211]_{SF}, [22]_{SF}$
$[31]_O$	$[4]_{SF}, [31]_{SF}, [211]_{SF}, [22]_{SF}$

the spatial wave function of the subsystem has the mixed symmetry $[31]_O$

$$\psi_{uuds\bar{s}} = \sum_{J_{4q}} \left[|\frac{1}{2}, m_{\bar{s}}\rangle \otimes \left[\bar{s}\, \chi^{FS}_{[\ ]_{S_{4q}, m_{4q}}} (uuds) \otimes \chi^{OC}_{\ell,\mu} \right]_{J_{4q}, m_{4q}} \right]$$

orbital

1	3	4
2		

$$\vec{\xi}_\rho \Rightarrow Y_{1,\mu}\left(\frac{\vec{q}_1 - \vec{q}_2}{\sqrt{2}}\right)$$

1	2	4
3		

$$\vec{\xi}_\lambda \Rightarrow Y_{1,\mu}\left(\frac{\vec{q}_1 + \vec{q}_2 - 2\vec{q}_3}{\sqrt{6}}\right)$$

1	2	3
4		

$$\vec{\xi}_\eta \Rightarrow Y_{1,\mu}\left(\frac{\vec{q}_1 + \vec{q}_2 + \vec{q}_3 - 3\vec{q}_4}{\sqrt{12}}\right)$$

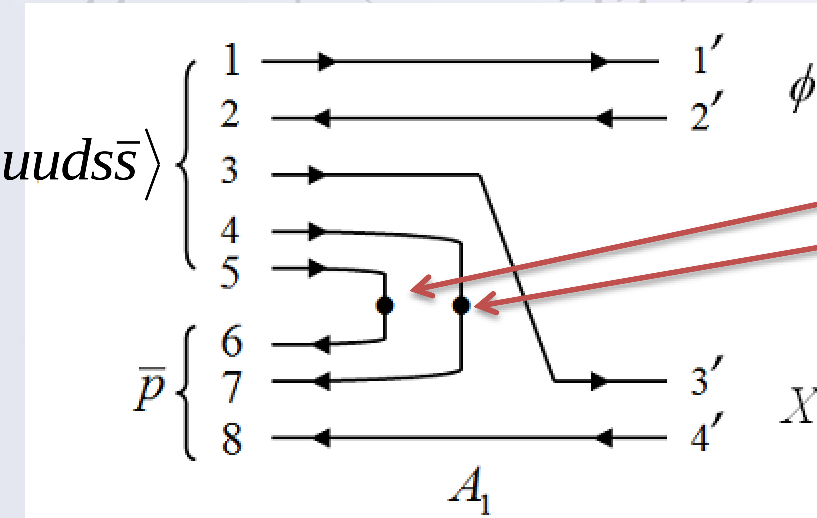
15 configurations

$\Delta s < 0 \quad \mu_s > 0$

3. The $p\bar{p}$ transition amplitude and branching ratios

$$p\bar{p} \to X\phi \;\; (X = \pi^0, \eta, \rho, \omega)$$

$$|\,p\rangle = A|uud\rangle + B|uuds\bar{s}\rangle$$



$^3P_0$

$$|\psi_{p\bar{p}}\rangle = |uuds\bar{s}\rangle \otimes |\bar{u}\bar{u}\bar{d}\rangle$$

$$T = \langle \psi_{\phi X} | \hat{O}_{A_1} | \psi_{p\bar{p}} \rangle$$

$$A^2 >> B^2$$

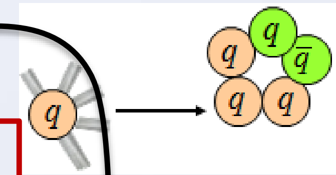
$$T = 2AB\underbrace{\langle \phi X | \hat{O} | uuds\bar{s} \otimes \bar{u}\bar{u}\bar{d} \rangle}_{T_{A_1}}$$

$$\langle \phi X | \hat{O} | uuds\bar{s} \otimes \bar{u}\bar{u}\bar{d} \rangle = T_{A_I} = \int d^3q_1 ... d^3q_8 d^3q'_1 ... d^3q'_4 \langle \phi X | \vec{q}'_1 ... \vec{q}'_4 \rangle$$

$$\langle \vec{q}'_1 ... \vec{q}' | \hat{O}_{A_1} | \vec{q}_1 ... \vec{q}_8 \rangle \langle \vec{q}_1 ... \vec{q}_8 | (uuds\bar{s}) \otimes (\bar{u}\bar{u}\bar{d}) \rangle$$

The internal spatial wave functions are approximated as the harmonic oscillator forms

$$\langle uuds\bar{s} | \vec{q}_1 ... \vec{q}_5 \rangle = \varphi_{uuds\bar{s}}(\vec{q}_1, .., \vec{q}_5) \underline{\psi_{uuds\bar{s}}}$$



$$\varphi_{uuds\bar{s}}(\vec{q}_{1,..,}\vec{q}_5) = N_{uuds\bar{s}} \exp\{-\frac{R_{5q}^2}{4}[(\vec{q}_2 - \vec{q}_3)^2 + \frac{1}{3}(\vec{q}_2 + \vec{q}_3 - 2\vec{q}_4)^2 + \frac{1}{6}(\vec{q}_2 + \vec{q}_3 + \vec{q}_4 - 3\vec{q}_5)^2 + (\frac{\vec{q}_2 + \vec{q}_3 + \vec{q}_4 + \vec{q}_5 - 4\vec{q}_1}{10})^2]\}$$

$$\psi_{uuds\bar{s}} = \sum_{J_{4q}} \left[|\frac{1}{2}, m_{\bar{s}}\rangle \otimes \left[\bar{s}\, \chi^{FS}_{[\ ]_{S_{4q}, m_{4q}}}(uuds) \otimes \chi^{OC}_{\ell,\mu} \right]_{J_{4q}, m_{4q}} \right]_{\frac{1}{2}, m_{5q}}$$

$[4]_{SF}, [31]_{SF}, [211]_{SF}, [22]_{SF}$

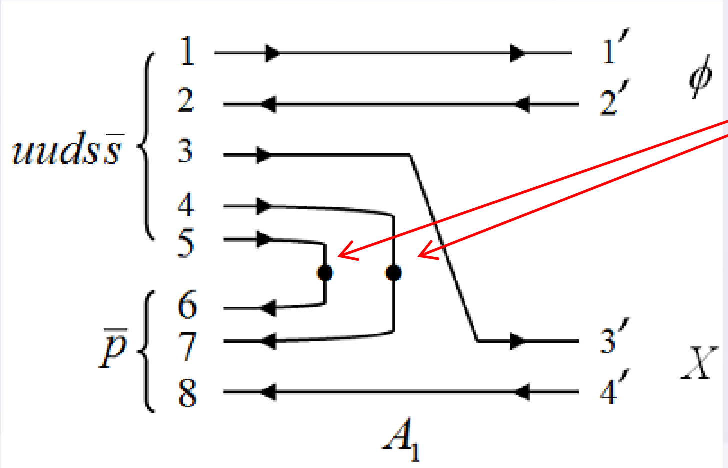
$$\chi^{OC}_{1,\mu} = \frac{1}{\sqrt{3}} \left[\chi^C_{[222]_\lambda} Y_{1\mu}\left(\frac{\vec{q}_2 - \vec{q}_3}{\sqrt{2}}\right) - \chi^C_{[222]_\rho} Y_{1\mu}\left(\frac{\vec{q}_2 + \vec{q}_3 - 2\vec{q}_4}{\sqrt{6}}\right) + \chi^C_{[222]_\eta} Y_{1\mu}\left(\frac{\vec{q}_2 + \vec{q}_3 + \vec{q}_4 - 3\vec{q}_5}{\sqrt{12}}\right) \right]$$

The effective operators

$$O_{A_1} = \lambda_{A_1}\delta^{(3)}(\vec{q}_1 - \vec{q}_{1'})\delta^{(3)}(\vec{q}_2 - \vec{q}_{2'})\delta^{(3)}(\vec{q}_3 - \vec{q}_{3'})\delta^{(3)}(\vec{q}_8 - \vec{q}_{4'})\, V^{56} V^{47}$$

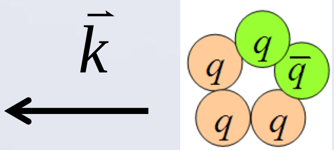
the effective strength parameter

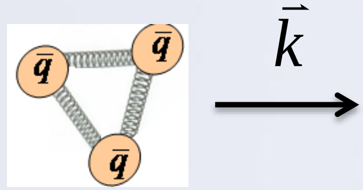
$^3P_0$

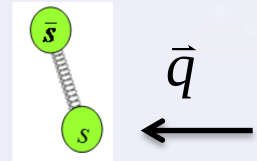


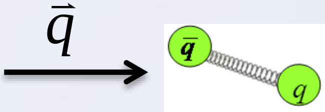
$$V^{ij} = \sum_{\gamma} \sigma^{ij}_{-\gamma} Y_{1\gamma}(\vec{q}_i - \vec{q}_j)\delta^{(3)}(\vec{q}_i + \vec{q}_j)(-1)^{1+\gamma} 1^{ij}_F 1^{ij}_C$$

Choosing the plane wave basis for the relative motion of the proton and antiproton









$$\delta^{(3)}(\vec{q}_1+\vec{q}_2+\vec{q}_3+\vec{q}_4+\vec{q}_5-\vec{k})\;\delta^{(3)}(\vec{q}_6+\vec{q}_7+\vec{q}_8+\vec{k})\qquad \delta^{(3)}(\vec{q}-\vec{q}_{1'}+\vec{q}_{2'})\;\delta^{(3)}(\vec{q}+\vec{q}_{3'}+\vec{q}_{4'})$$

In the low-momentum approximation, we have the transition amplitude

$$T_{fi}(\vec{q},\vec{k})=\lambda_{A_1}\exp\{-Q_q^2q^2-Q_k^2k^2\}\langle f|O_{A_I}|i\rangle$$

the spin-color-flavor weight

$$\langle f|O_{A_1}|i\rangle=\langle f|\sum_{\nu,\lambda}(-1)^{\nu+\lambda}\sum_{m,n}\Omega_{m,n}^{SP(PS)}f_{m,n}^{SP(PS)}\sigma_{-\nu}^{56}\sigma_{-\lambda}^{47}1_F^{56}1_F^{47}1_C^{56}1_C^{47}f(\nu,\lambda,\mu,m_f,M)|i\rangle$$

Q_q^2, Q_k^2 and $\Omega_{m,n}^{SP(PS)}$ are geometrical constants depending on the radial parameters R_B, R_M

$$T_{fi}(\vec{q},\vec{k}) = \lambda_{A_1} \exp\{-Q_q^2 q^2 - Q_k^2 k^2\} \langle f | O_{A_I} | i \rangle$$

the spin-color-flavor weight

$$\langle f | O_{A_1} | i \rangle = \langle f | \sum_{\nu,\lambda} (-1)^{\nu+\lambda} \sum_{m,n} \Omega_{m,n}^{SP(PS)} f_{m,n}^{SP(PS)} \sigma_{-\nu}^{56} \sigma_{-\lambda}^{47} 1_F^{56} 1_F^{47} 1_C^{56} 1_C^{47} f(\nu,\lambda,\mu,m_f,M) | i \rangle$$

The spin-angular momentum functions

$$f_{1,1}^{SP} = f_{1,2}^{SP} = f_{1,3}^{SP} = (-1)^{\nu} \delta_{\lambda,-\nu} \delta_{\mu,m_f}$$

$$f_{2,1}^{SP} = f_{2,2}^{SP} = f_{2,3}^{SP} = (-1)^{\mu} \delta_{\mu,-\nu} \delta_{\lambda,m_f}$$

$$f_{3,1}^{SP} = f_{3,2}^{SP} = f_{3,3}^{SP} = (-1)^{\mu} \delta_{\mu,-\lambda} \delta_{\nu,m_f}$$

$$f_{1,1}^{PS} = f_{1,2}^{PS} = f_{1,3}^{PS} = (-1)^{\lambda+\mu} \delta_{\lambda,-\nu} \delta_{\mu,-M}$$

$$f_{2,1}^{PS} = f_{2,2}^{PS} = f_{2,3}^{PS} = (-1)^{\lambda+\mu} \delta_{\mu,-\nu} \delta_{\lambda,-M}$$

$$f_{3,1}^{PS} = f_{3,2}^{PS} = f_{3,3}^{PS} = (-1)^{\nu+\mu} \delta_{\mu,-\lambda} \delta_{\nu,-M}$$

$$|i\rangle = |\{\chi_{\frac{1}{2},m_{5q}}(uuds\bar{s}) \otimes \chi_{\frac{1}{2},m_{\bar{p}}}(\bar{u}\bar{u}\bar{d})\}_{S,S_z} \otimes (L,M)\rangle_{J,J_z},$$

$$|f\rangle = |\{\chi_{1,m_\alpha}(\phi) \otimes \chi_{j_m,m_{3',4'}}(X)\}_{j,m_\epsilon} \otimes (\ell_f,m_f)\rangle_{J,J_z},$$

Including the initial state interaction for the atomic state of the $p\bar{p}$ system

$$T_{if}(\vec{q},\vec{k}) \Rightarrow T_{f,LSJ}(\vec{q}) = \int d^3k\, T_{fi}(\vec{q},\vec{k})\, \phi^I_{LSJ}(\vec{k})$$

The protonium wave function in momentum space for fixed isospin I

The partial decay width for the transition of the state to the two-meson state

$$\Gamma_{p\bar{p}\to\phi X} = \int \frac{d^3p_\phi}{2E_\phi}\frac{d^3p_X}{2E_X}\,\delta^{(3)}(\vec{p}_\phi + \vec{p}_X)\,\delta(E - E_\phi - E_X)\left|T_{f,LSJ}(\vec{q})\right|^2$$

Branching ratio → the partial decay width divided by the total width

$$J = 0 \rightarrow |0,0\rangle$$

$$J = 1 \rightarrow |1,1\rangle,\ |1,0\rangle,\ |1,-1\rangle$$

$$BR(\phi, X) = W(J)\frac{\Gamma_{p\bar{p}->\phi,X}}{\Gamma_{total}(J)}$$

statistical weight $W(J) = (2J+1)$

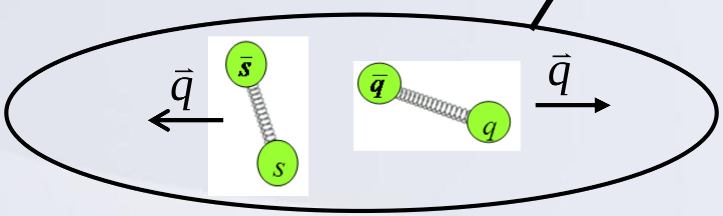
Reducing the model dependence

$$BR(\phi, X) = \frac{W(J)}{\Gamma_{total}(J)} \quad \lambda^2_{A_I} f(\phi, X) \langle f | O_{A_I} | i \rangle^2 \gamma(I, J)$$

Choosing a simplified phenomenological approach that has been applied in studies of two-meson branching ratios in nucleon-antinucleon and radiative protonium annihilation.

A. Kercek, T. Gutsche and A. Faessler, J. Phys. G **25**, 2271 (1999)

T. Gutsche, R. Vinh Mau, M. Strohmeier-Presicek and A. Faessler, Phys. Rev. C **59**, 630 (1999)



we use a kinematical phase-space factor of the phenomenological form

$$f(\phi, X) = q \exp\{-1.2\, GeV^{-1} (s - s_{\phi X})^{1/2}\}$$

$$\sqrt{s} = (m_\phi^2 + q^2)^{1/2} + (m_X^2 + q^2)^{1/2}$$

The initial-state interaction coefficients

$$\gamma(I, J) \propto \int d^3k\, \phi^I_{LSJ}(\vec{k}) \exp\{-Q_k^2 k^2\}$$

are related to the probability for a protonium state to have isospin I and spin J

State i	$\gamma_0(i)$	$\gamma_1(i)$	$\Gamma_{tot}(i)$
$^1S_0$	0.56	0.44	1.0
$^3S_1$-$^3D_1$	0.56	0.44	0.9

Results

	$^{11}S_0 \rightarrow \omega\phi$	$^{33}S_1 \rightarrow \pi^0\phi$	$^{31}S_0 \rightarrow \rho^0\phi$	$^{13}S_1 \rightarrow \eta\phi$
BR^{exp}	6.3±2.3	5.5 ± 0.7	3.4 ± 1.0	0.9 ± 0.3
[4][22][22]	6.3⋆	5.4	3.8	1.4 - 1.8
[4][31][31]	6.3⋆	5.4	3.8	1.4 - 1.8
[31][211][22]	6.3⋆	4.3	3.8	1.9 - 2.5
[31][211][31]	6.3⋆	3.8	2.7	1.2 - 1.5
[31][22][31]	6.3⋆	5.9	4.9	1.0 - 1.4
[31][31][22]	6.3⋆	7.3	3.9	0.90 - 1.0
[22][211][31]	6.3⋆	181.2	97.5	44.0 - 57.6

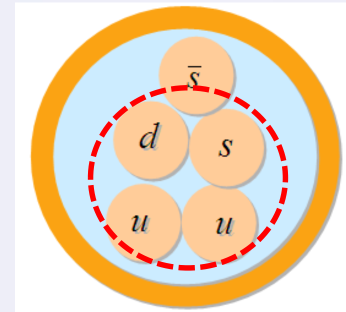
	$^{11}S_0\to\omega\phi$	$^{33}S_1\to\pi^0\phi$	$^{31}S_0\to\rho^0\phi$	$^{13}S_1\to\eta\phi$
BR^{exp}	6.3±2.3	5.5 ± 0.7	3.4 ± 1.0	0.9 ± 0.3
[22][22][22]	6.3⋆	0.85	3.4	5.3 - 6.9
[211][211][22]	6.3⋆	0.85	3.5	5.3 - 6.7
[211][211][31]	6.3⋆	7.7	4.0	3.2 - 4.2
[22][31][31]	6.3⋆	4.5	2.3	2.2 - 2.9
[211][22][31]	6.3⋆	181.2	97.5	44.0 - 57.6
[211][31][22]	6.3⋆	0.85	3.5	5.3 - 6.9
[211][31][31]	6.3⋆	0.24	0.17	0.090 - 0.11

	$^{33}P_{0,1,2} \to \rho^0\phi$	$^{31}P_1 \to \pi^0\phi$	$^{13}P_{0,1,2} \to \omega\phi$	$^{11}P_1 \to \eta\phi$
$\mathrm{BR}^{\mathrm{exp}}$	3.7±0.9	0 + 0.3	2.9 ± 1.4	0.4 ± 0.2
[4][22][22]	3.7⋆	0.31	1.6	0.10 - 0.14
[4][31][31]	3.7⋆	1.1	5.3	0.36 - 0.47
[31][211][22]	3.7⋆	0.48	1.3	0.17 - 0.22
[31][211][31]	3.7⋆	1.4	6.1	0.55 - 0.71
[31][22][31]	3.7⋆	0.65	5.1	0.18 - 0.23
[31][31][22]	3.7⋆	0.22	2.5	0.067 - 0.087
[22][211][31]	3.7⋆	0.012	0.23	1.2-1.5 ($\times 10^{-5}$)

	${}^{33}P_{0,1,2}\to \rho^0\phi$	${}^{31}P_1\to \pi^0\phi$	${}^{13}P_{0,1,2}\to \omega\phi$	${}^{11}P_1\to \eta\phi$
[31][31][31]	$3.7\star$	0.76	2.4	0.26 - 0.34
[22][22][22]	$3.7\star$	0.0029	13	0.0061 - 0.0080
[211][211][22]	$3.7\star$	0.0029	13	0.0061 - 0.0080
[211][211][31]	$3.7\star$	0.0029	3.6	0.23 - 0.30
[22][31][31]	$3.7\star$	5.1×10^{-4}	2.2	0.16 - 0.20
[211][22][31]	$3.7\star$	0.012	0.23	1.2-1.5 ($\times 10^{-5}$)
[211][31][22]	$3.7\star$	0.0029	13	0.0061 - 0.0080
[211][31][31]	$3.7\star$	7.4×10^{-4}	0.63	0.0062 - 0.0081

Conclusions

$$|\,p\rangle = A|uud\rangle + B|uuds\bar{s}\rangle$$

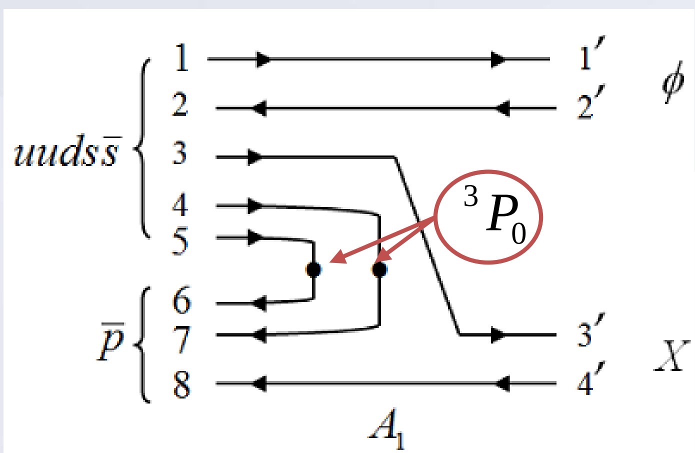


15 configurations

$\Delta s < 0$ $\mu_s > 0$

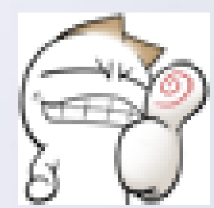
$$\left|\left[(uuds)_{S_{4q}} \otimes \ell = 1\right] \otimes (\bar{s})_{\frac{1}{2},m_s}\right\rangle$$

Branching ratios $p\bar{p} \to X\phi \;\; (X = \pi^0, \eta, \rho, \omega)$



The best agreement of theoretical results with the experimental data is found in the pentaquark configuration with the flavor-spin symmetry

$$[4]_{FS}\,[22]_F\,[22]_S$$



Thank you

for your attention