# Chiral Symmetry Restoration in Double-Pion Production

***Vladimir Kukulin*** ***and Maria Platonova***
*Lomonosov Moscow State University*

Mini-workshop on two-pion production
in the HADES and WASA experiments
3-4 April 2013, IPN Orsay


*We are very sorry that we are not with you now* ☹

*But we hope you will enjoy our talk somehow* ☺

# The Puzzle of a σ-meson

- The light scalar meson (σ or $f_0$(500)) plays a fundamental role in the physics of strong interactions. It is often referred to as a "Higgs boson of strong interactions", as it is responsible for the generation of hadron masses through the chiral symmetry breaking.
- The nature and properties of a σ-meson are still under investigation.
- The current PDG tables give the σ pole position in a broad range:

$$m_\sigma = (400 - 550) + i(200 - 350)\ \mathrm{MeV}$$

What is the reason of such a large spread of σ-meson parameters?

- If the σ-meson is not just a $q\bar{q}$ pair, then what is it:

- tetraquark state
- glueball
- hybrid
- …?

# The Puzzle of a σ-meson

- The hybrid nature of a σ-meson was suggested by Kisslinger et al. From the solution of QCD sum rules for glueballs and mixed meson-glueball hadrons, they found:

$$\sigma = qq\overline{qq} + 2g$$

[L. S. Kisslinger, J. Gardner, C. Vanderstraeten, Phys. Lett. **B410**, 1 (1997)]

- I.e. the puzzling low-mass scalar glueball can be understood as coupled-channel glueball/σ(ππ) state in the region below 1 GeV, with σ(ππ) being a two-pion phenomenon
- Tight interrelation between σ mesons and soft pomerons (which are understood as two-gluon phenomena) was predicted by many authors.

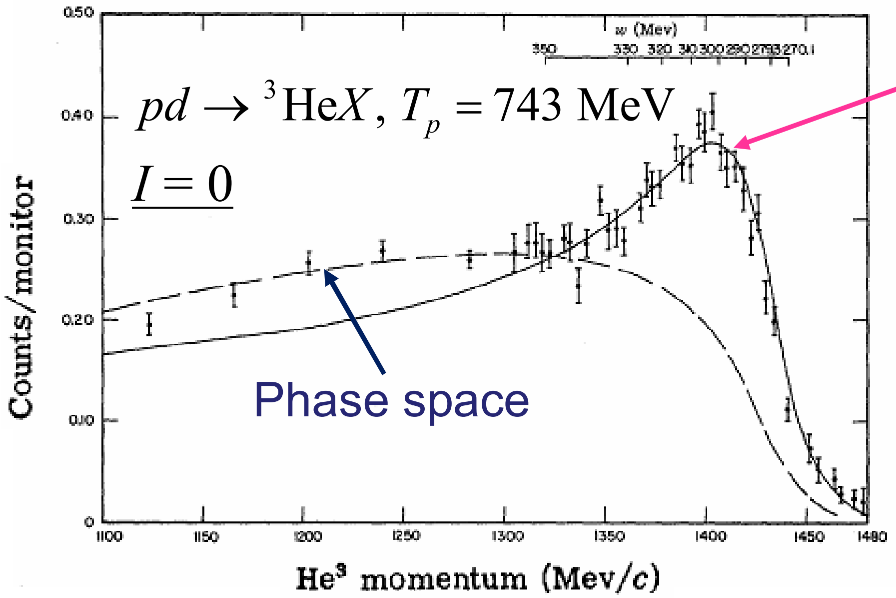
---

- We claim in the talk that the recent exclusive experiments on two-pion production concerning the long-standing ABC puzzle may shed light on the nature of a light scalar meson
- So, the main purpose of the talk is to reveal the interrelation between the physics of a σ-meson and the ABC puzzle

# Discovery and First Interpretations of the ABC Effect

As you are aware the puzzle with ABC effect exists more than 50 years.

It was first observed by A. Abashian, N.E. Booth & K.M. Crowe [PRL **5**, 258 (1960); **7**, 35 (1961)] in **inclusive experiments on p+d fusion to $^3$He** as an **unexpected enhancement near the 2π threshold**.




ABC effect: $I = 0$,
$m_X \approx 300\ \mathrm{MeV} = 2m_{\pi^0} + 30\ \mathrm{MeV}$

Later on the similar anomaly was found also in the reactions

$$np \to dX,$$

$$dd \to {}^4\mathrm{He}X$$

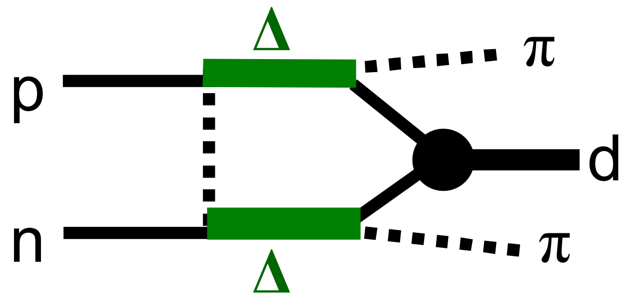
**<u>The initial interpretation</u>** was a resonance enhancement in ππ rescattering in the scalar-isoscalar channel. So, the effect was considered as evidence of a σ-meson.

But the required scattering length was $a_{s0} \approx 2\text{–}3\ m_\pi^{-1}$. And actually: $a_{s0} = 0.2\ m_\pi^{-1}$.
NO ABC effect was observed in free ππ scattering! So, the σ-meson interpretation has been abandoned very soon.

# Discovery and First Interpretations of the ABC Effect

- The first quantitative attempt to explain the ABC effect was due to T. Risser & M.D. Shuster [Phys. Lett. **B43**, 68 (1973)]:

  the **t-channel ΔΔ model**




- The model predicted two peaks in the $\pi\pi$ invariant-mass spectrum – at low and high invariant masses (referred to as ABC and "DEF" effects)
- Qualitative description of some **inclusive** data was achieved within this model
- However in the resent **exclusive** experiments NO "DEF" effect has been observed

# The Novel Exclusive Experiments of the CELSIUS-WASA and WASA@COSY Collaborations

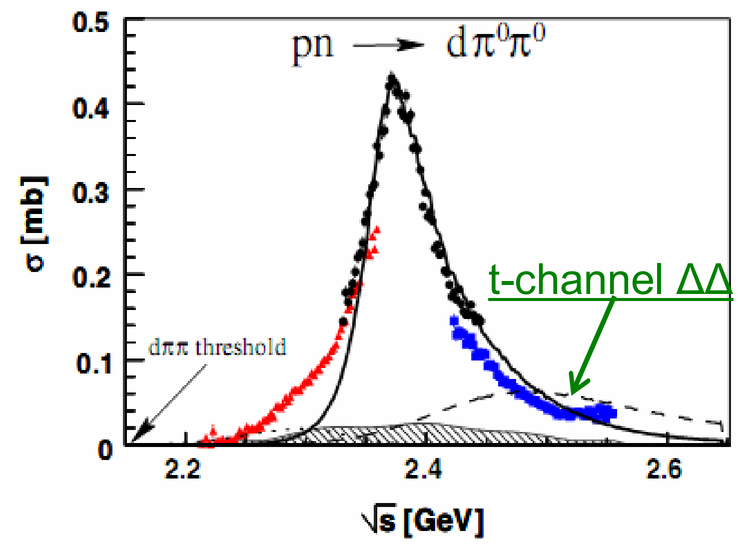
(presented in the talk by M. Bashkanov)

**The first exclusive high-statistics experiments in full 4π-geometry**

$$p + d \to p_{\text{spectator}} + d + \pi^0\pi^0,\ T_p = 1.0 - 1.4\ \text{GeV}$$

[M. Bashkanov et al., PRL **102**, 052301 (2009); P. Adlarson *et al.*, PRL **106**, 242302 (2011)]

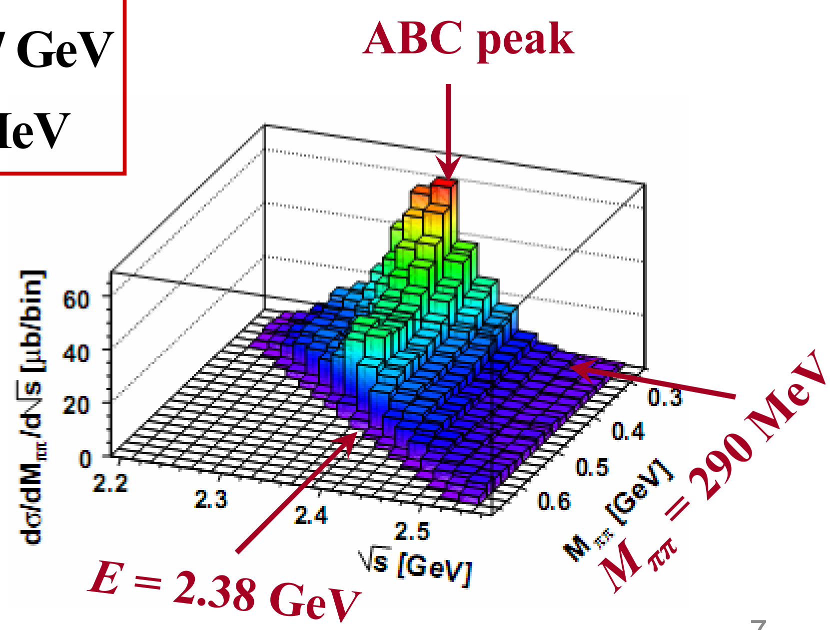
- Dibaryon resonance production in *pn* collisions was discovered




$I(J^P) = 0(3^+)$

$M_R \approx 2.37\ \text{GeV}$

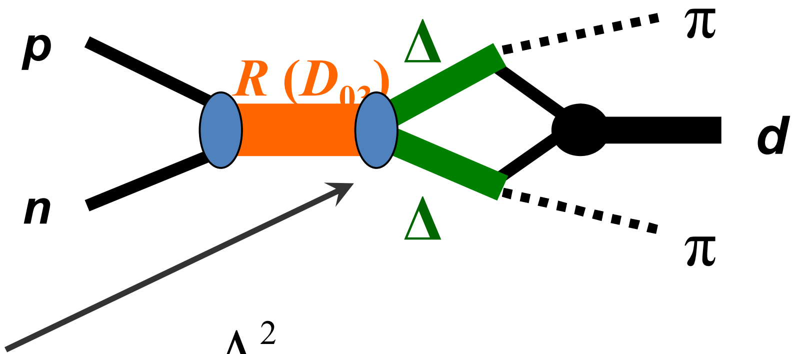
$\Gamma_R \approx 70\ \text{MeV}$




- Interrelation between the observed resonance and ABC effect was revealed:

# The s-channel Resonance Ansatz and Dibaryon Radius

The experimental results have been interpreted in terms of a Δ-Δ deeply bound state (M. Bashkanov et al.)




$$F(\vec{q}_{\Delta\Delta}) = \frac{\Lambda^2}{\Lambda^2 + \vec{q}_{\Delta\Delta}^{\,2}}, \quad \Lambda \simeq 0.15\ \mathrm{GeV}/c$$

<u>With this interpretation, the following difficulties arise</u>:

- Such a low value of $\Lambda$ means that the $D_{03}$ state is a deuteron-like object. However the Δ-Δ binding energy in the $D_{03}$ state is much larger than that of the deuteron: $\varepsilon_B(D_{03}) \approx 90$ MeV.
- Microscopic quark model calculations all predict a radius for the $0(3+)$ Δ-Δ bound state **$r(D_{03}) \approx 0.7$–$0.9$ fm**, i.e., of the order of the nucleon size. [see, e.g., X. Q. Yuan et al., PRC **60**, 045203 (1999)]
- Thus, the $D_{03}$ resonance appears to be the <u>truly dibaryon state</u> in which the quark cores of two Δ's are almost fully overlapped with each other.

# First Prediction of Dibaryon States

- It is very interesting that the $D_{03}$ resonance was first predicted still in 1964. By using SU(6)-symmetry, Dyson and Xuong predicted six zero-strangeness low-lying dibaryons:
  [F.J. Dyson and N.-H. Xuong, PRL **13**, 815 (1964)]

Table I. $Y=2$ states with zero strangeness predicted by the $\underline{490}$ multiplet.

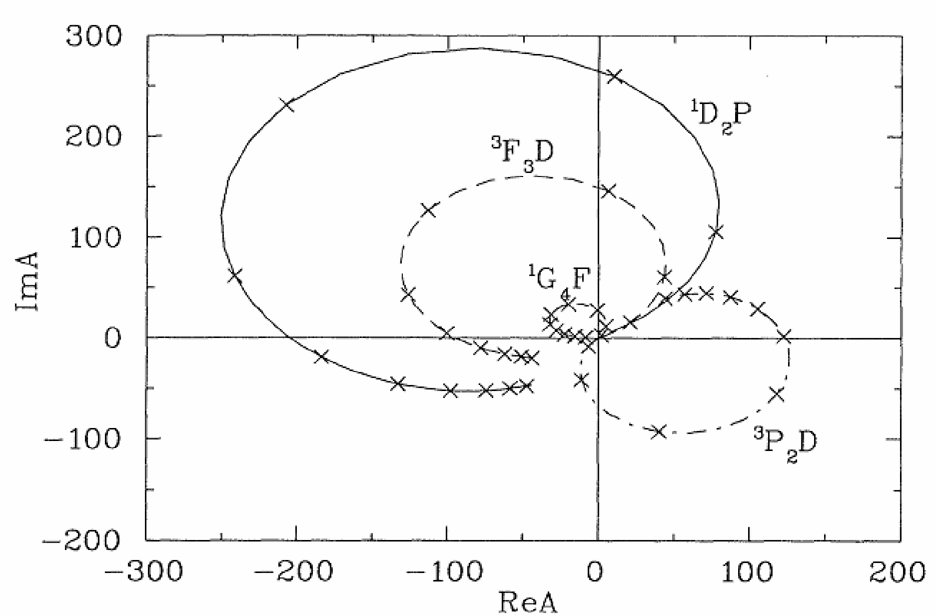
| Particle | $T$ | $J$ | SU(3) multiplet | Comment | Predicted mass |
|---|---|---|---|---|---|
| $D_{01}$ | 0 | 1 | $\underline{10^*}$ | Deuteron | $A$ |
| $D_{10}$ | 1 | 0 | $\underline{27}$ | Deuteron singlet state | $A$ |
| $D_{12}$ | 1 | 2 | $\underline{27}$ | $S$-wave $N$-$N^*$ resonance | $A+6B$ |
| $D_{21}$ | 2 | 1 | $\underline{35}$ | Charge-3 resonance | $A+6B$ |
| $D_{03}$ | 0 | 3 | $\underline{10^*}$ | $S$-wave $N^*$-$N^*$ resonance | $A+10B$ |
| $D_{30}$ | 3 | 0 | $\underline{28}$ | Charge-4 resonance | $A+10B$ |

- From the simple SU(6) mass formula $M = A+B[T(T+1)+J(J+1)\text{-}2]$, $A$ being the deuteron mass and $B$ – some parameter assumed to be around 50 MeV, the $\boldsymbol{D_{03}}$ mass was predicted to be ≈2380 MeV!
- So, the predicted $\boldsymbol{D_{03}}$ resonance has been observed in pn collisions. And what is about other predicted dibaryons?

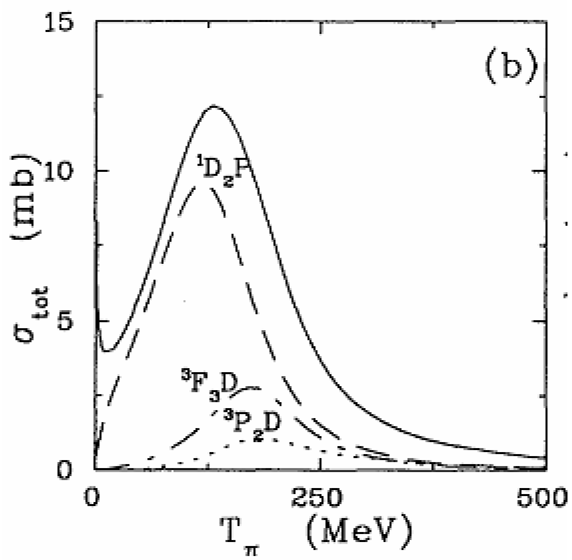
# Isovector Dibaryons

- The isovector dibaryons were discovered still in 70ies in the analysis of pp scattering and then confirmed in $\pi^+$d elastic scattering and particularly in the reaction $\pi^+ d \rightarrow pp$.
- The dominant pp partial wave is $^1D_2$ which corresponds to production of a dibaryon resonance $D_{12}$ with quantum numbers $I(J^P) = 1(2^+)$, the mass $M(D_{12}) \approx 2.15$ GeV and total width $\Gamma(D_{12}) \approx \Gamma(\Delta) = 120$ MeV .

**Argand plot of dominant partial-wave amplitudes in $\pi^+ d \rightarrow pp$ reaction**




**Contributions of dominant $^1D_2P$, $^3F_3D$ and $^3P_2D$ amplitudes to the total unpolarized X-section**



- Thus, we have now good candidates for three basic dibaryon resonances predicted by Dyson and Xuong:

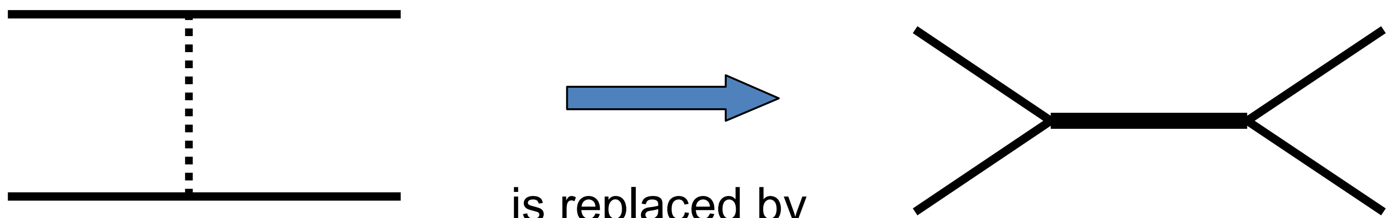
✓ $D_{01}$ (deuteron) near *NN* threshold
✓ $D_{12}$ $(M \approx 2.15\ \text{GeV})$ near *NΔ* threshold
✓ $D_{03}$ $(M \approx 2.37\ \text{GeV})$ near *ΔΔ* threshold

- There are also indications in literature to other dibaryon states, such as *pp* resonances $^3F_3$ and $^3P_2$, strange dibaryons, etc.

The **main difference** between our approach and other existing models of dibaryon states is as follows:

- Dibaryons are usually considered as some exotic modes in a six-quark system which may manifest themselves under some special conditions (like in ABC-type experiments);
- In contrast, we consider the dibaryons as carriers of strong short-range interaction between baryons.

Thus, in case of nucleons an intermediate dibaryon production is assumed to be responsible for the basic *NN* attraction, i.e. for the short-range nuclear force – that is the cornerstone of the dibaryon concept for nuclear force proposed by Moscow-Tuebingen group (see references below).



*t*-channel meson exchange is replaced by *s*-channel dibaryon production

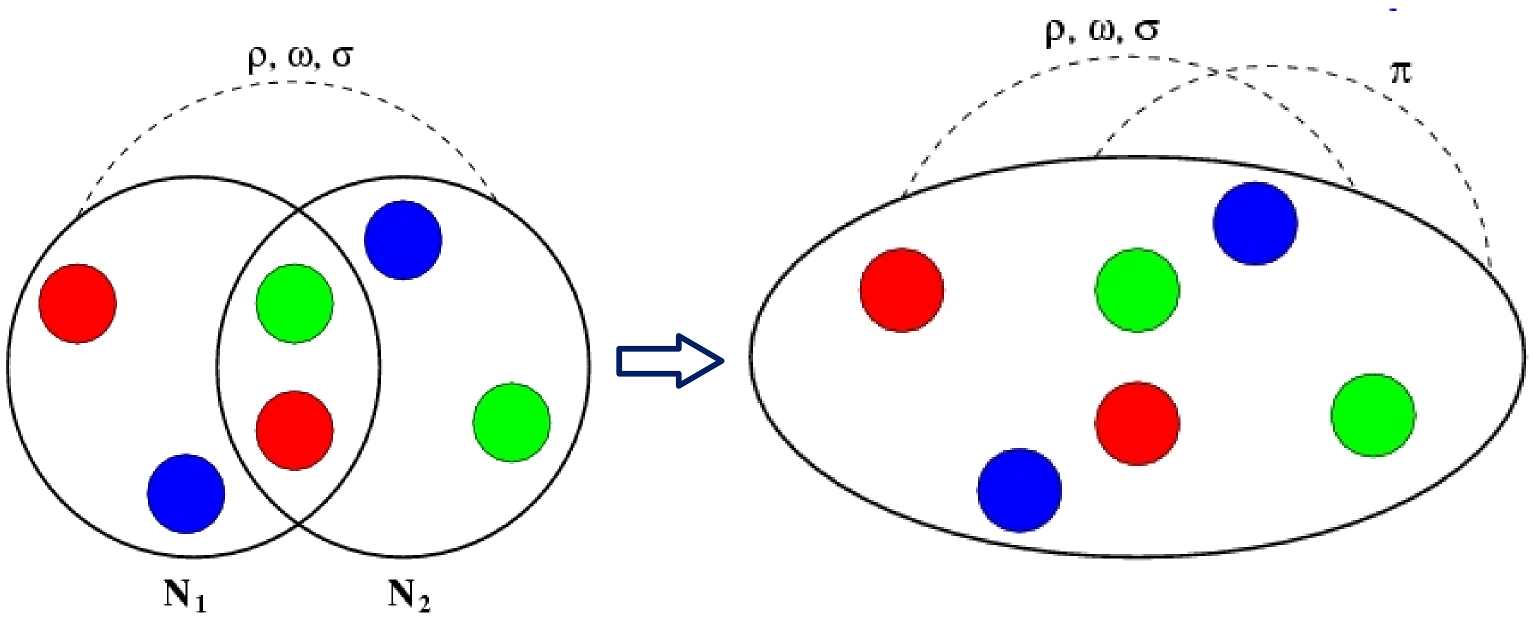
# Basic References to the Dibaryon Model of Nuclear Force

**(by V.I. Kukulin, A. Faessler, P. Grabmayr, I.T. Obukhovsky, V.N. Pomerantsev, *et al*.)**

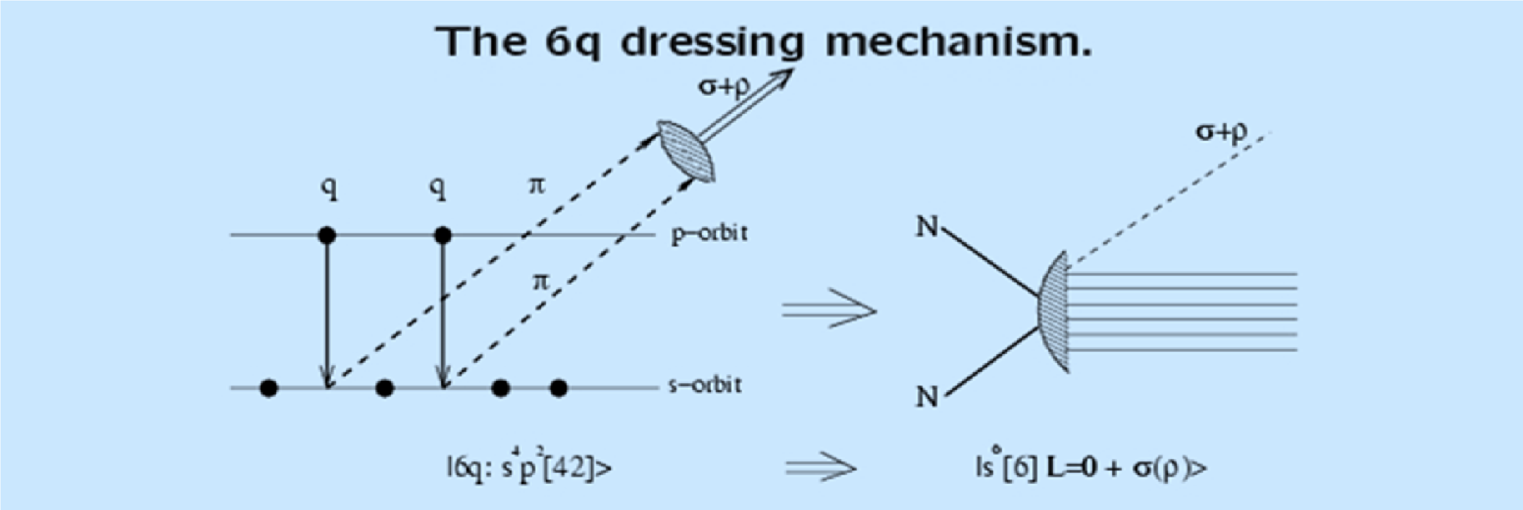

1. *Dressed six-quark bags at short and intermediate NN ranges.* // Nucl. Phys. **A689**, 327c (2001).
2. *The new mechanism for intermediate- and short-range nucleon-nucleon interaction.* J. Phys. G **27**, 1851 (2001).
3. *Two-component dressed-bag model for NN interaction: deuteron structure and phase shifts up to 1 GeV.* // Int. J. Mod. Phys. E **11**, 1 (2002).
4. *A six-quark dressed bag description of np → dγ radiative capture.* // Int. J. Mod. Phys. E **12**, 449 (2003).
5. *The properties of the three-nucleon system with the dressed-bag model for NN interaction: I. New scalar three-body force.* // J. Phys. G **30**, 287 (2004).
6. *The properties of the three-nucleon system within the dressed-bag model for 2N and 3N forces: II. Coulomb and CSB effects.* // J. Phys. G **30**, 287 (2004).
7. *Description of intermediate- and short-range NN nuclear force within a covariant effective field theory.* // Ann. Phys. (NY) **320**, 71 (2005).
8. *Isoscalar short-range current in the deuteron induced by an intermediate dibaryon.* // Phys. Rev. C **74**, 064005 (2006).
9. *Photon-induced neutron polarization from the 2H(γ,n)1H reaction within the NN-force model with an intermediate dibaryon.* // Phys. Rev. C **77**, 041001(R) (2008).
10. *Experimental and theoretical indications for an intermediate σ-dressed dibaryon in the NN interaction. //* Ann. Phys. **325**, 1173 (2010).

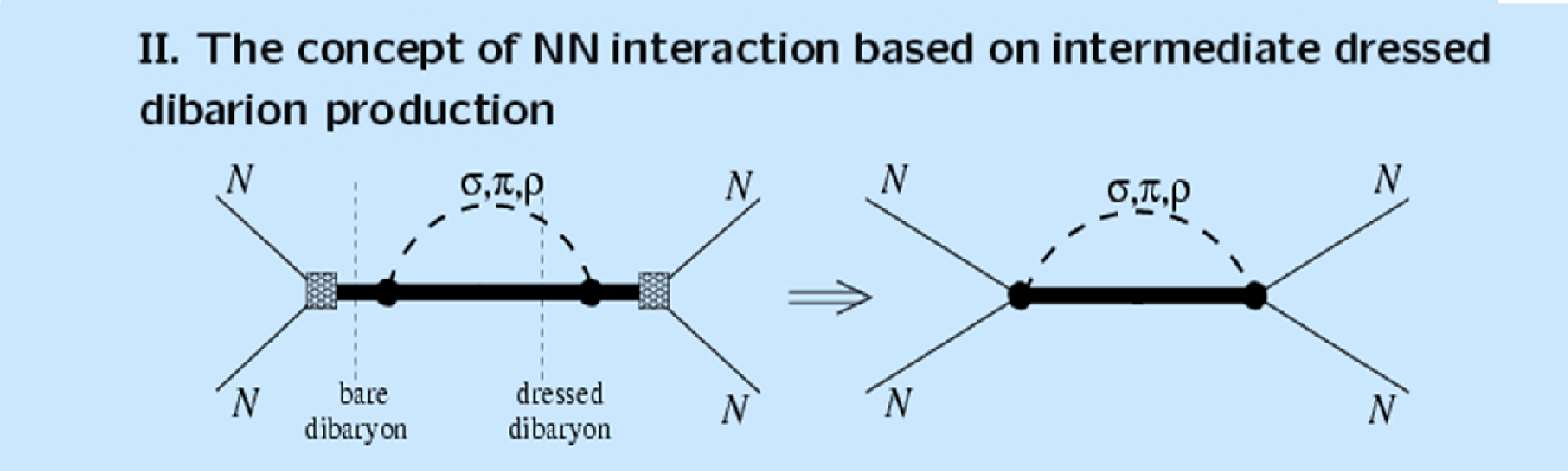
# Paradox in Meson-Exchange Models for Short-Range Nuclear Force

- In the OBE-like models the short-range nuclear force is assumed to originate from the heavy meson ($\rho$ and $\omega$) exchange with mass $m_V \cong 800$ MeV.
- However, for the mass ~0.8 GeV the characteristic scale is $\lambda_V$~0.2 fm (the Compton wave length $\lambda = \hbar/mc$). So, such meson exchanges should happen when two nucleons are strongly overlapped with each other.
- In this case the 6q bag is formed, and the meson exchange between isolated nucleons transforms into meson fields surrounding the whole 6q bag.



# The Dibaryon Mechanism for Scalar Field Generation in *NN* System




Formally, it may be interpreted in a way that the conventional *t*-channel σ-exchange between two nucleons at $r_{NN} \lesssim 1$ fm is replaced in dibaryon model by the *s*-channel σ-exchange associated with the itermediate dibaryon production.

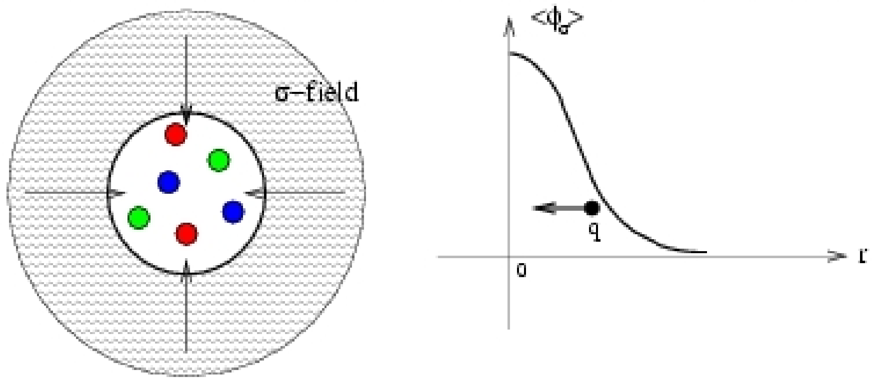
# Effects of Strong Scalar (σ) Field around Six-quark Bag

This strong $\sigma$-field leads to highly non-linear effects:

— *(partial) restoration of chiral symmetry in the dressed bag;*

— *shrinking the multi-quark bag due to strong 'pressure' of scalar field;*

— *enhancement of scalar diquark correlations in the bag.*




The $\sigma$-field has mainly spherical symmetry due to $L_\sigma = 0$ and high space symmetry ($s^6[6]L_q = 0$) of the bag, and thus the field pulls quarks to the center of the bag and results in effective strong attraction among all the six quarks in the bag in this dressed bag state (DBS). As a net result of this inter-quark effective attraction there arises a strong attraction between two nucleons in NN-channel.

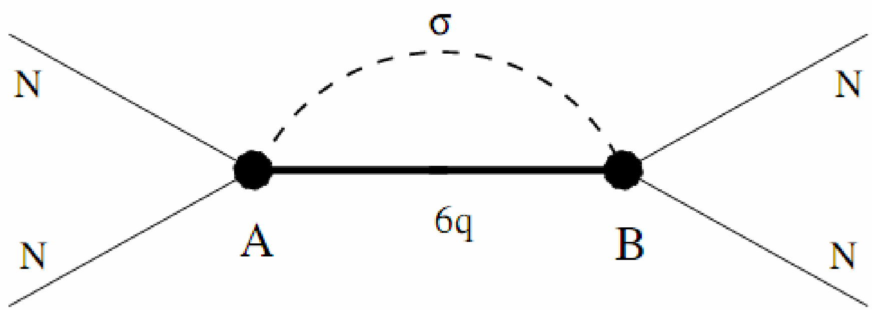
# Effective *NN* Potential in Dibaryon Model

$$V_{NN} = V_{\mathrm{OPE}} + V_{\mathrm{TPE}} + V_{NqN} + V_{\mathrm{orth}}$$

1) One- and two-pion exchange potentials at large distances $r_{NN}$ >1.5 fm: $V_{\mathrm{OPE}}$ and $V_{\mathrm{TPE}}$

2) Effective *NN* potential induced by an intermediate σ-dressed dibaryon production (carries the main *NN* attraction at intermediate distances $r_{NN}$ ~ 1 fm):

$$V_{NqN} =$$




3) Orthogonality condition between the $s^4p^2$ and $s^6$ quark configurations: $V_{\mathrm{orth}}$. This part of the potential gives repulsion at very short distances $r_{NN}$ < 0.5 fm; it also allows to exclude the quark coordinates and to operate in the *NN* channel only.

The effective potential $V_{NqN}$ induced by coupling the $NN$-channel to the intermediate-dibaryon channel in form of a sum over simple separable terms for each partial wave:

$$V_{NqN} = \sum_{S,J,L,L'} V^{SJ}_{LL'}(\mathrm{r}, \mathrm{r}'), \tag{15}$$

with

$$V^{SJ}_{LL'}(\mathrm{r}, \mathrm{r}') = \sum_{M} Z^{JM}_{LS}(\mathrm{r})\, \lambda^{J}_{SLL'}(E)\, Z^{JM^*}_{L'S}(\mathrm{r}'), \tag{16}$$

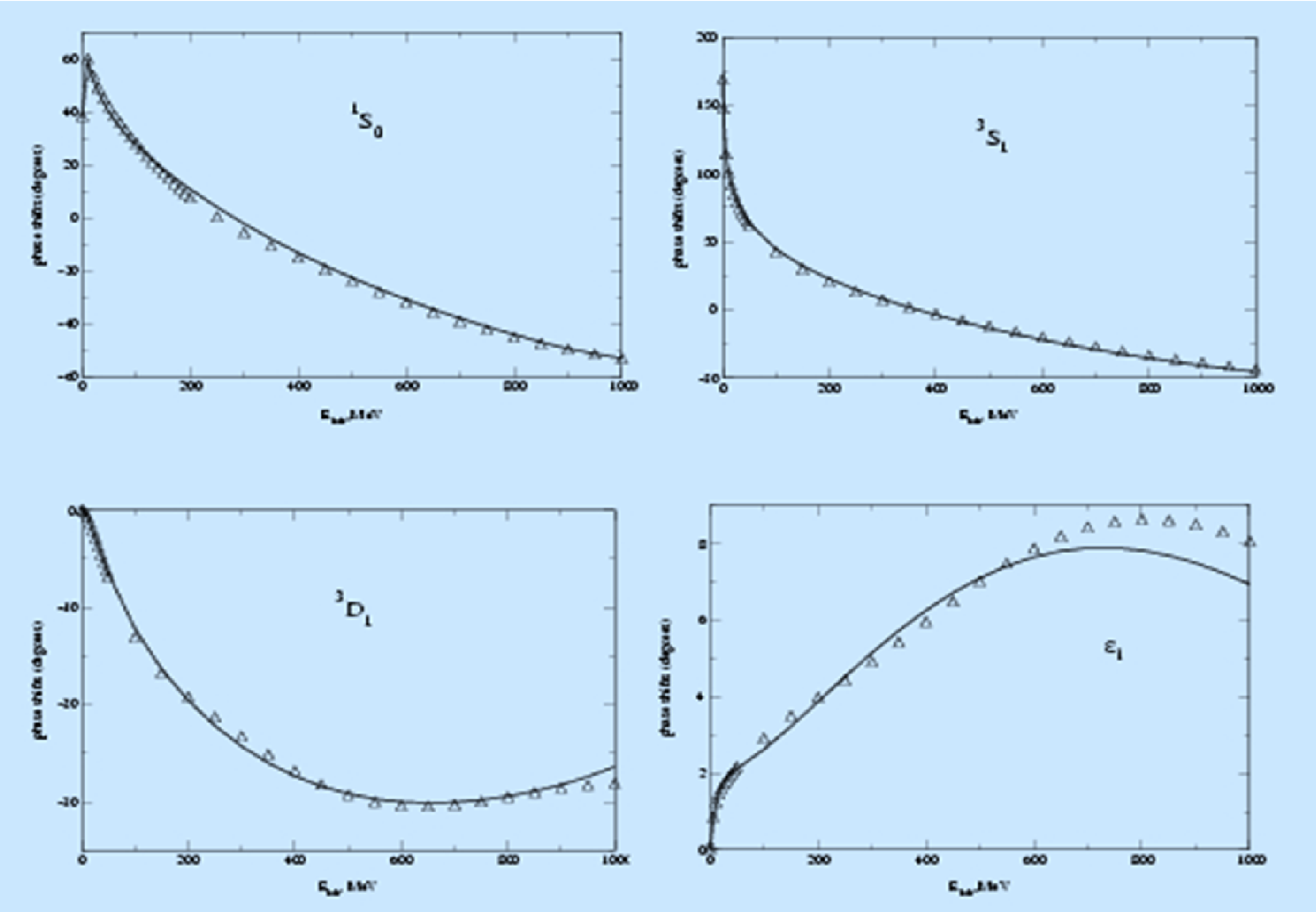
where $Z^{JM}_{LS}(\mathrm{r})$ are the potential form factors (vertex)

$$Z^{JM}_{LS}(\mathrm{r}) = \zeta^{J}_{LS}(r)\, \mathcal{Y}^{JM}_{LS}(\hat{\mathrm{r}}) \tag{17}$$

and the energy-dependent coupling constants $\lambda^{J}_{SLL'}(E)$ are expressed by integration of the product of two transition vertices $B$ and convolution of the product of meson and quark-bag propagators over the momentum $k$:

$$\lambda^{J}_{SLL'}(E) = \sum_{L_\sigma} \int_0^\infty k^2\, dk \frac{B^{J}_{L_\sigma LS}(k, E)\, {B^{J}_{L_\sigma L'S}}^*(k, E)}{E - m_{d_0} - \frac{k^2}{2m_{d_0}} - \omega_\sigma(k)}. \tag{18}$$

# The Phase Shifts of *NN* Scattering in Low Partial Waves Calculated within the Dibaryon Model




Note that very good fits to the empirical *NN* phase shifts were obtained from zero energy up to 1 GeV.

# Deuteron Wave Function in Dibaryon Model

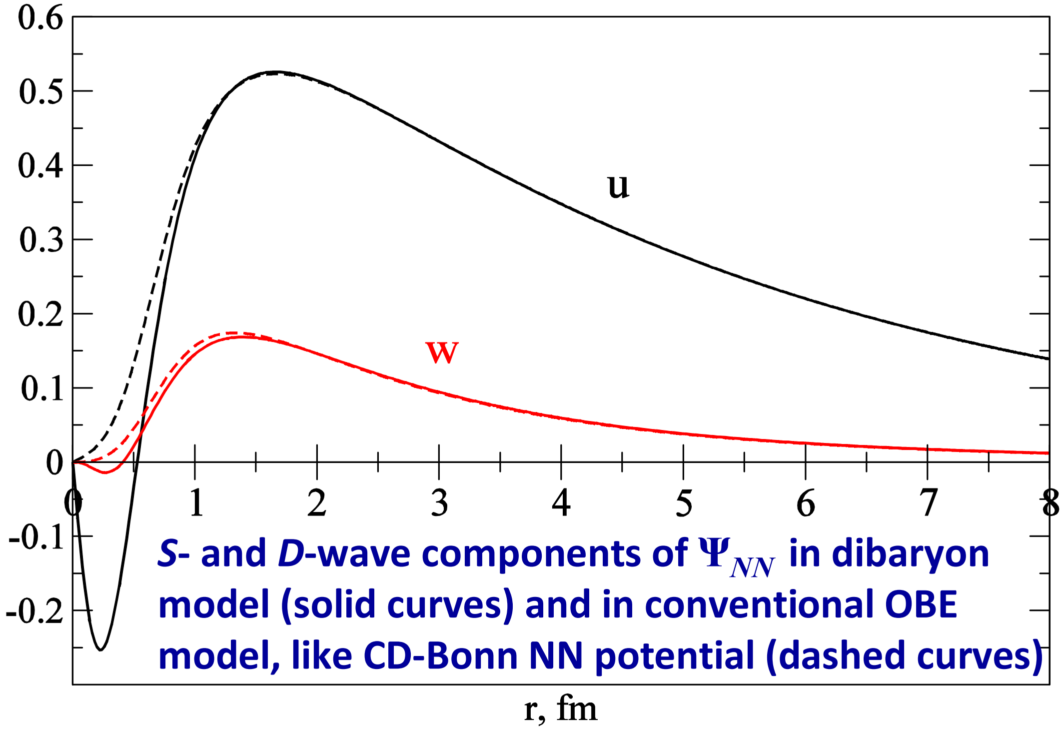
The wave function of the deuteron can be described as a two-component Fock column:

$$\Psi_d = \begin{pmatrix} \Psi_{NN} \\ \Psi_{6q+\sigma} \end{pmatrix},$$

$$\Psi_{NN}(\vec{r}) = \frac{1}{\sqrt{4\pi}r}\left(u(r) + \frac{1}{2\sqrt{2}}\hat{S}_{12}w(r)\right),$$

$$\Psi_{6q+\sigma}(\vec{r}_\sigma) = \lambda B(\vec{r}_\sigma)\int \varphi(\vec{r})\Psi_{NN}(\vec{r})d\vec{r}.$$

The quark-meson component $\Psi_{6q+\sigma}$ gives a small contribution (~2–3%) to the total deuteron wave-function normalization, so it should be visible only when probing the deuteron structure with high-momentum probes.

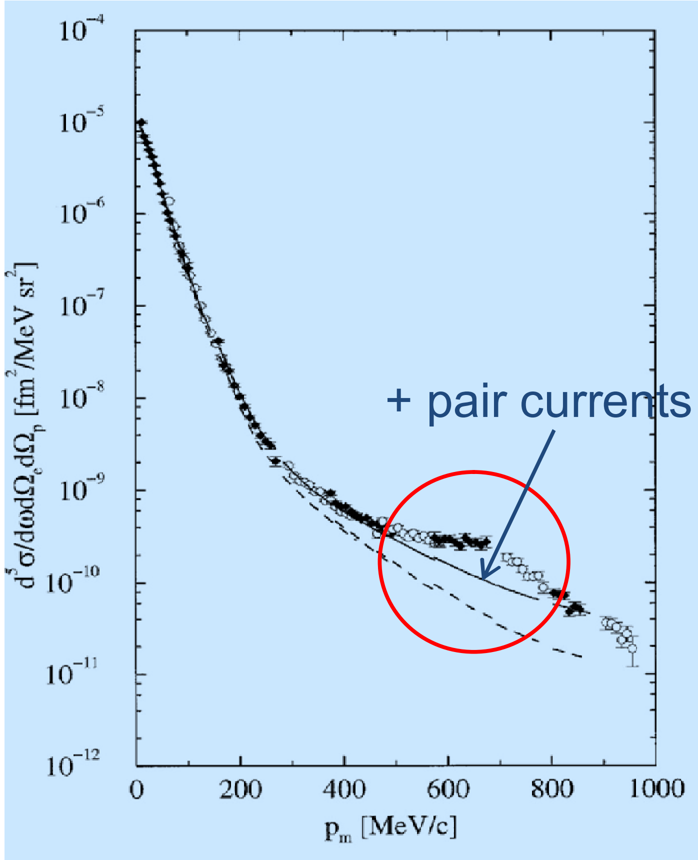



***S*- and *D*-wave components of $\Psi_{NN}$ in dibaryon model (solid curves) and in conventional OBE model, like CD-Bonn NN potential (dashed curves)**

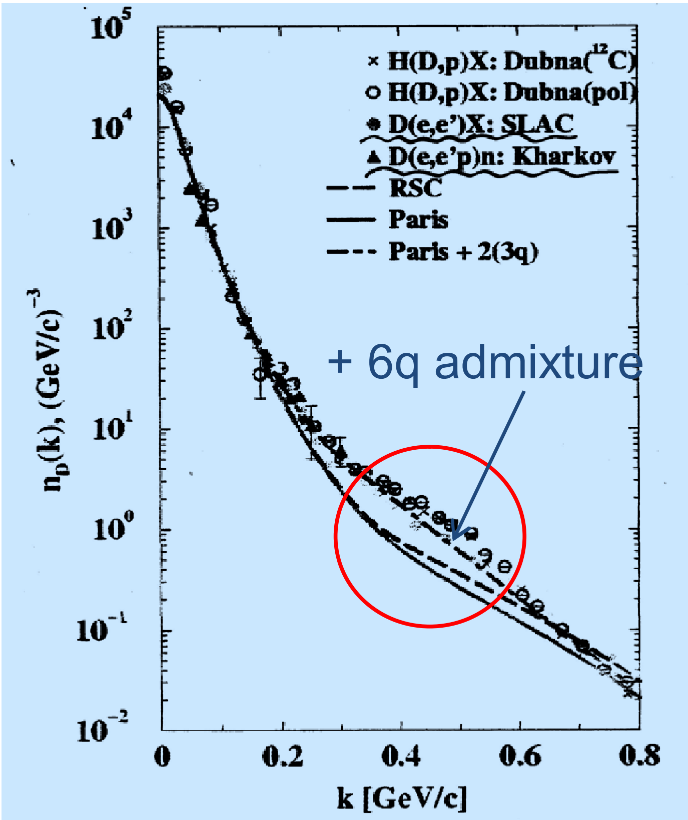
# Manifestation of Non-Nucleonic (Quark) Degrees of Freedom in Deuteron

**(only few examples from a big collection)**

**D(e,e'p) cross section**




**Nucleon momentum distribution in deuteron extracted from different experiments**

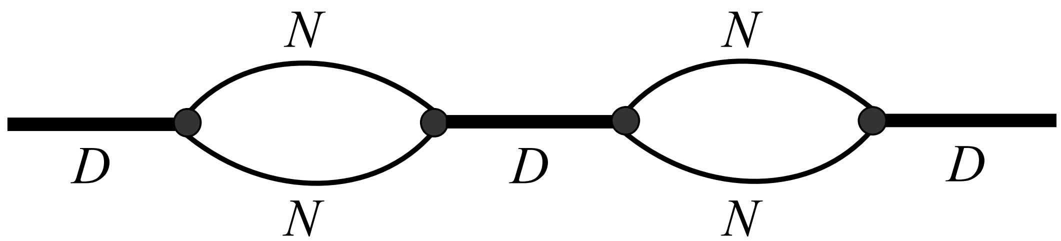



The observed "bump" in the nucleon momentum distribution in deuteron cannot be consistently explained without the 6*q* admixture in the deuteron wave function

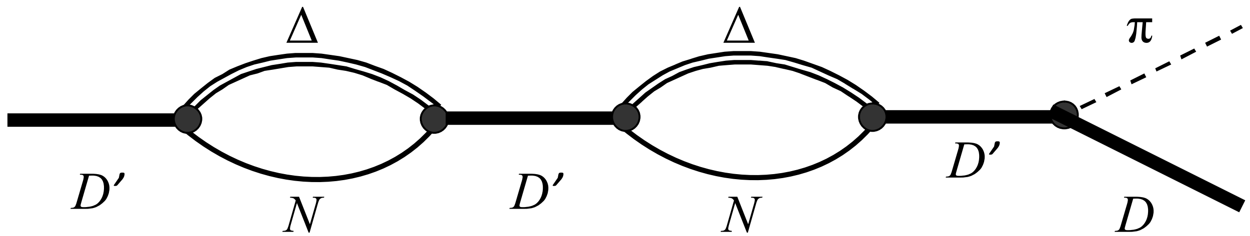
# Dibaryon Model Predictions

- Dibaryon model predicts dibaryons to exist in all nuclei and in nuclear matter via a superposition of quark-meson and hadronic channels coupled strongly with each other.

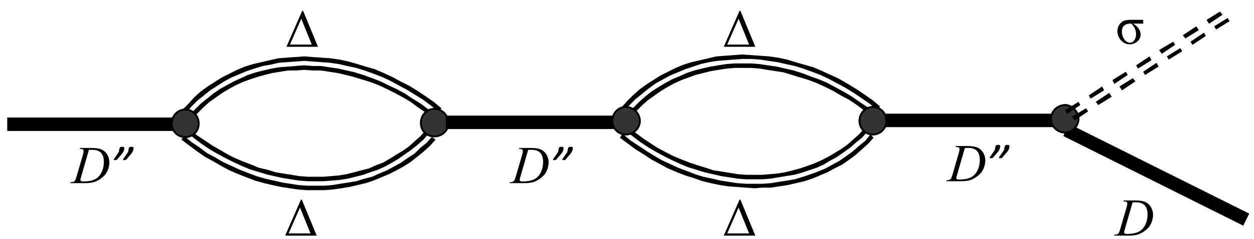
1) $D \rightleftarrows NN \quad (T=0)$ – $NN(^3S_1)$-dibaryon (the deuteron, or $D_{01}$)




2) $D' \rightleftarrows N\Delta \quad (T=1)$ $-N\Delta(^5S_2)$-dibaryon ($D_{12}$)




3) $D'' \rightleftarrows \Delta\Delta \quad (T=0)$ $-\Delta\Delta(^7S_3)$-dibaryon ($D_{03}$)

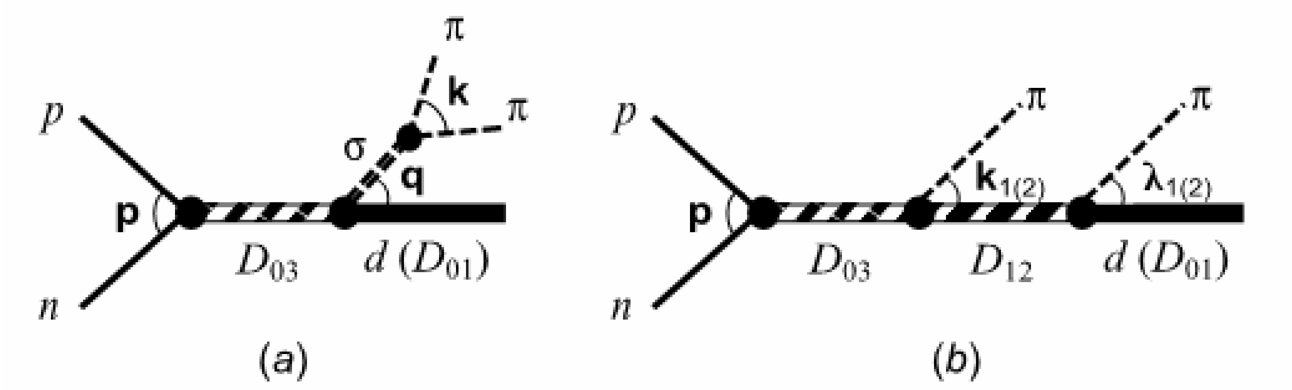


# The New Model for the Basic 2π Fusion Reaction in the ABC Region

- In a model proposed in [M.N. Platonova, V.I. Kukulin, PRC **87**, 025202 (2013)] the leading contribution to the reaction $p+n \rightarrow d+(\pi\pi)_0$ in the ABC region ($T_p$ = 1.0–1.4 GeV) is given by the $D_{03}$ $(I(J^P) = 0(3^+))$ dibaryon production and its subsequent decay into the deuteron (i.e. $D_{01}$ $(I(J^P) = 0(1^+))$ and isoscalar ππ pair via two interfering modes:

  (*a*) emission of a σ meson, which the decays into *s*-wave ππ pair,

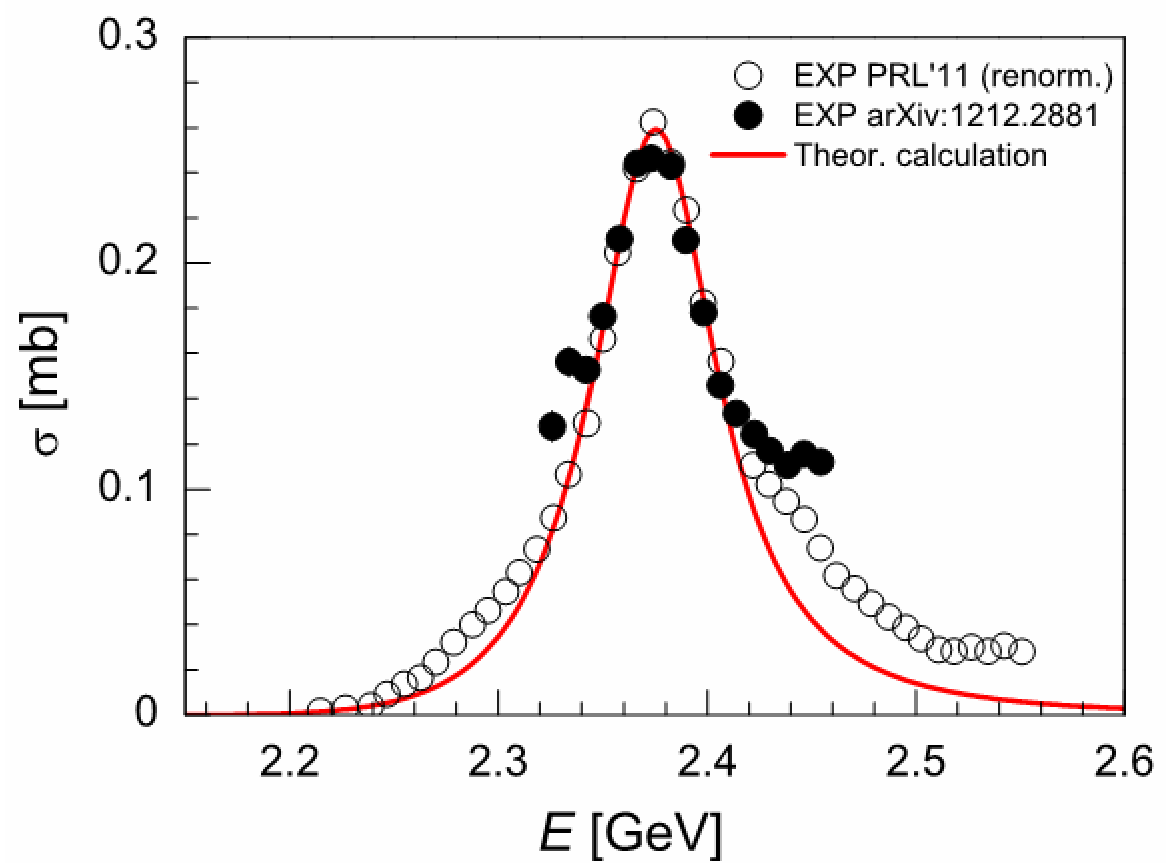
  (*b*) sequential emission of two *p*-wave pions via an intermediate isovector dibaryon $D_{12}$ $(I(J^P) = 1(2^+))$ production.




- The mechanisms (a) and (b) are in a full analogy with the respective two modes of the N*(1440) → N+ ππ decay which give the dominant contribution to the reaction $p+n \rightarrow d+(\pi\pi)_0$ at lower energies $T_p < 1$ GeV.

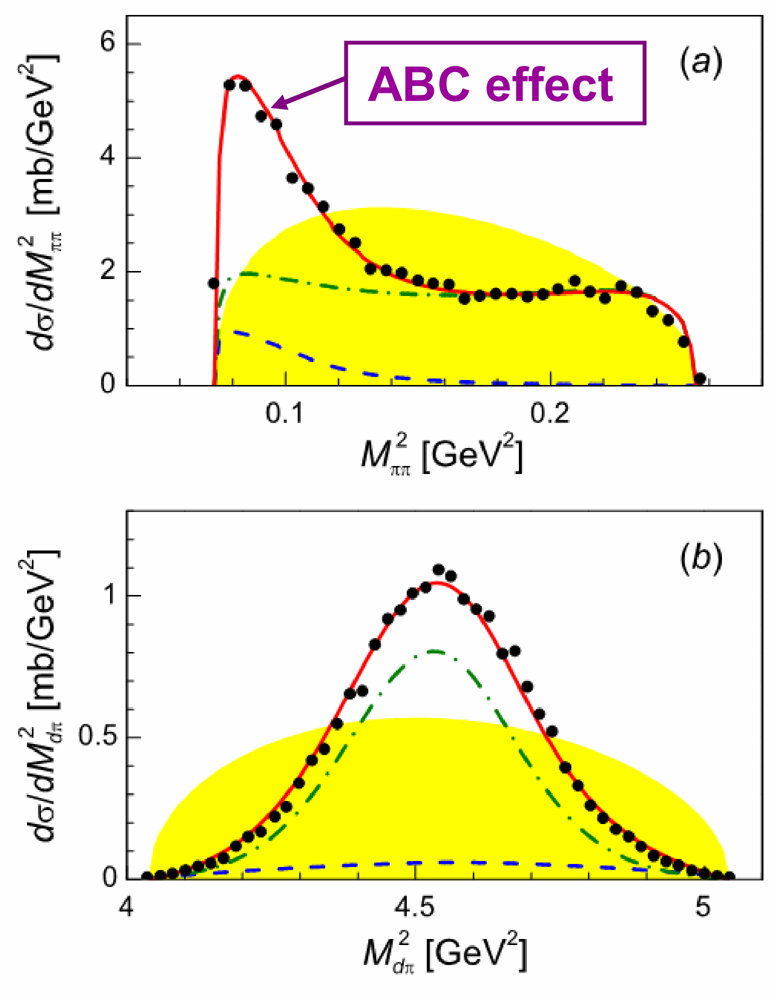
# Results of the Model Calculations.
# I. Total Cross Section

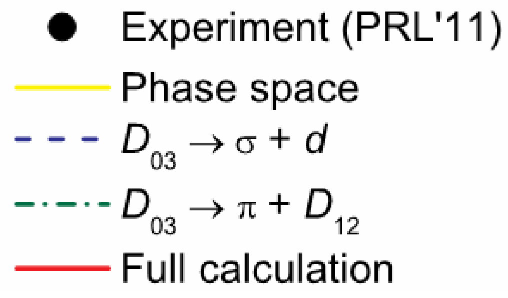
## Comparison with the WASA@COSY Experimental Data



# Results of the Model Calculations.
# II. Invariant-mass spectra at E=2.38 GeV

## Comparison with the WASA@COSY Experimental Data




Each of two mechanisms proposed gives a resonance enhancement in the respective invariant-mass spectrum, i.e.:

- ABC effect is a consequence of a σ-meson production;
- The peak in $M_{d\pi}$ spectrum reflects the isovector dibaryon $D_{12}$ production. But the $D_{12}$ is strongly coupled to the $N$+Δ channel, so that intermediate Δ-production is not excluded by a new dibaryon mechanism

# Parameters of a σ-meson

- As extracted from our model fit to the ABC peak

$$m_\sigma \simeq 300\ \text{MeV}, \quad \Gamma_\sigma \simeq 100\ \text{MeV}.$$

[M.N. Platonova, V.I. Kukulin, PRC **87**, 025202 (2013)]

- As found from dispersion analysis of $\pi\pi$-scattering amplitude:

$$m_\sigma = 441^{+16}_{-8}\ \text{MeV}, \quad \Gamma_\sigma = 544^{+18}_{-25}\ \text{MeV}.$$

[I. Caprini, G. Colangelo, H. Leutwyler, PRL **96**, 132001 (2006)]

**Is there any contradiction?**

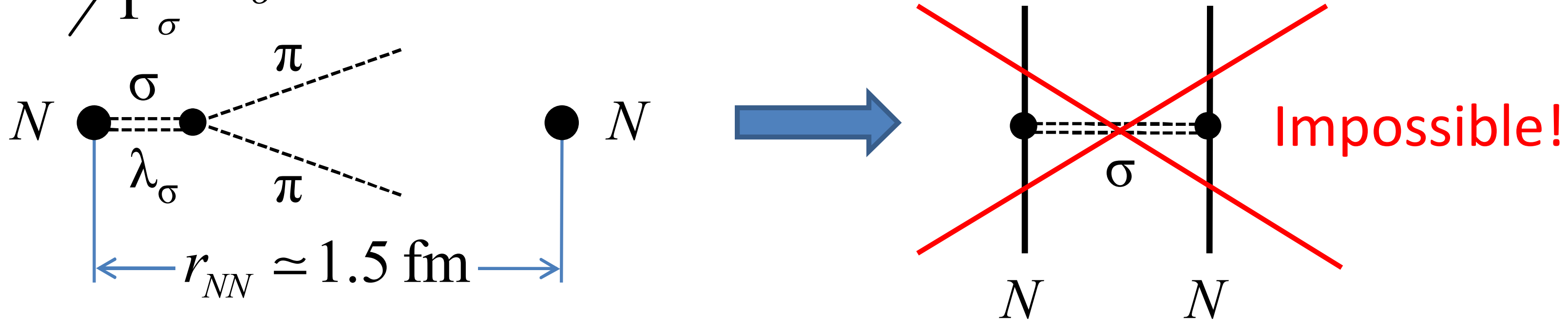
# Problem with σ-exchange and *NN* Attraction

- $\pi + \pi \rightleftarrows \sigma$ — a very broad resonance in ππ-scattering, i.e.

$$m_\sigma \simeq 400\ \text{MeV}, \Gamma_\sigma \simeq 500\ \text{MeV}.$$

- If we accepted this huge width of the σ-meson and then compared the σ path length to an average *NN* distance in nuclei $r_{NN}$~1.5 fm, <u>the probability for the σ-meson to be exchanged between nucleons would be very small</u>:

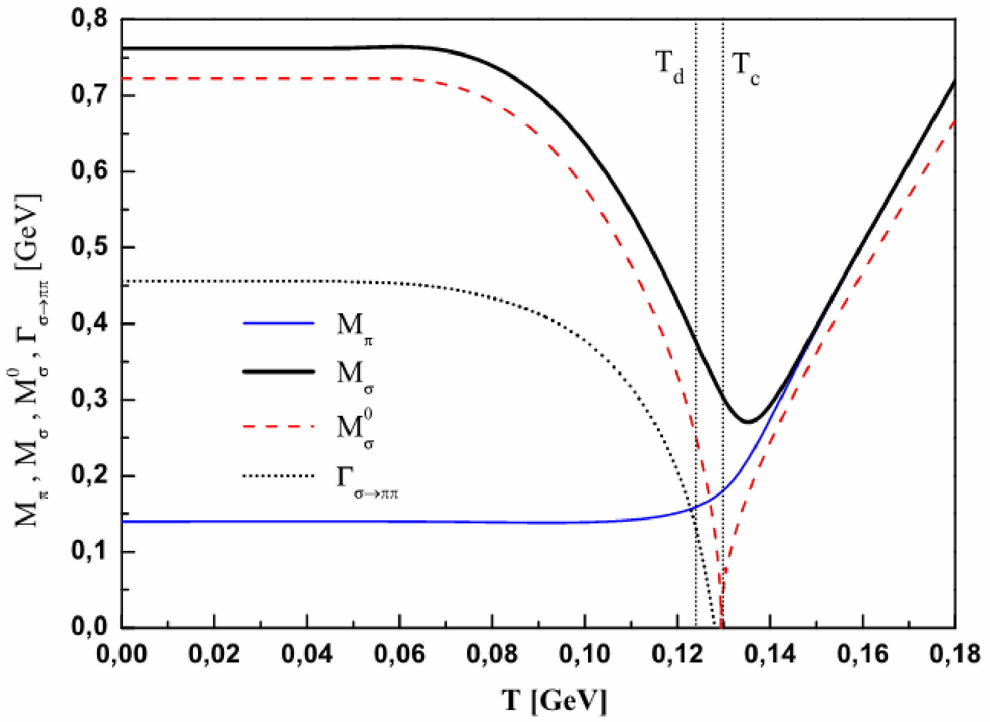
$\tau_\sigma \simeq \hbar / \Gamma_\sigma\ ;\ \lambda_\sigma \simeq c \cdot \tau \leq 0.2\ \text{fm}$ — path length for a highly unstable σ-meson




- If so, one has NO stable scalar meson field which can give a sufficient *NN* attraction to keep nucleons together in nuclei.
- **But nuclei DO exist! How to overcome this fundamental paradox?**
- It is the phenomenon of chiral symmetry restoration (CSR) that can make the scalar field almost stable. And due to dibaryon production CSR can occur in all nuclei rather than just in hot or dense nuclear matter, as it is usually thought.

# Chiral Symmetry Restoration.
# I. Dense/hot Nuclear (Baryonic) Matter

- Numerous theoretical investigations (by T. Kunihiro, M. Volkov, and others) show that the mass and width of the σ meson produced in hot and/or dense nuclear matter may be significantly shifted downwards in comparison with its free-space parameters due to the partial chiral symmetry restoration (CSR) effect.




Temperature dependence of $M_\pi$, $M_\sigma$ and $\Gamma_\sigma$
(from D. Blaschke et al., arXiv:0508264 [hep-ph])

# Chiral Symmetry Restoration.
# II. Highly Excited Hadrons

- Partial CSR was shown (by L. Ya. Glozman *et al*.) to take place also in strongly excited states of isolated hadrons (baryons and mesons).
- Thus, the appearance of approximately degenerate parity doublets in the spectra of highly excited baryons may be considered as a manifestation of partial CSR.

- In fact, the rise of baryon density or nuclear matter temperature as well as a high hadron excitation energy leads to an increase of quark kinetic energy, which results in the suppression of the chiral condensate in QCD vacuum.
- This means the reduction of the σ-meson mass and width for the $\sigma \to \pi\pi$ decay. **So, the σ meson, being a broad resonance in free space, becomes a sharp resonance in dense or excited hadronic media.**

# Chiral Symmetry Restoration.
# III. Excited Dibaryons

- Within the dibaryon model, the best description of *NN*-scattering phase shifts and properties of the lightest nuclei has been achieved with $m_\sigma \approx 300–400$ MeV, whereas the σ mass is assumed to be 500–600 MeV in the conventional OBE *NN*-force models.
- The 6q bag formed by two nucleons in the dibaryon model is a dense object ($r_{6q}$ = 0.5–0.6 fm) and is also the $2\hbar\omega$-excited hadronic state (it has the six-quark configuration $\mathbf{s^4p^2}$, while the ground dibaryon state has the symmetric $\mathbf{s^6}$ configuration). So, the renormalization of the σ mass in the field of the 6q bag appears as a signal of partial CSR.

# Chiral Symmetry Restoration.
# III. Excited Dibaryons

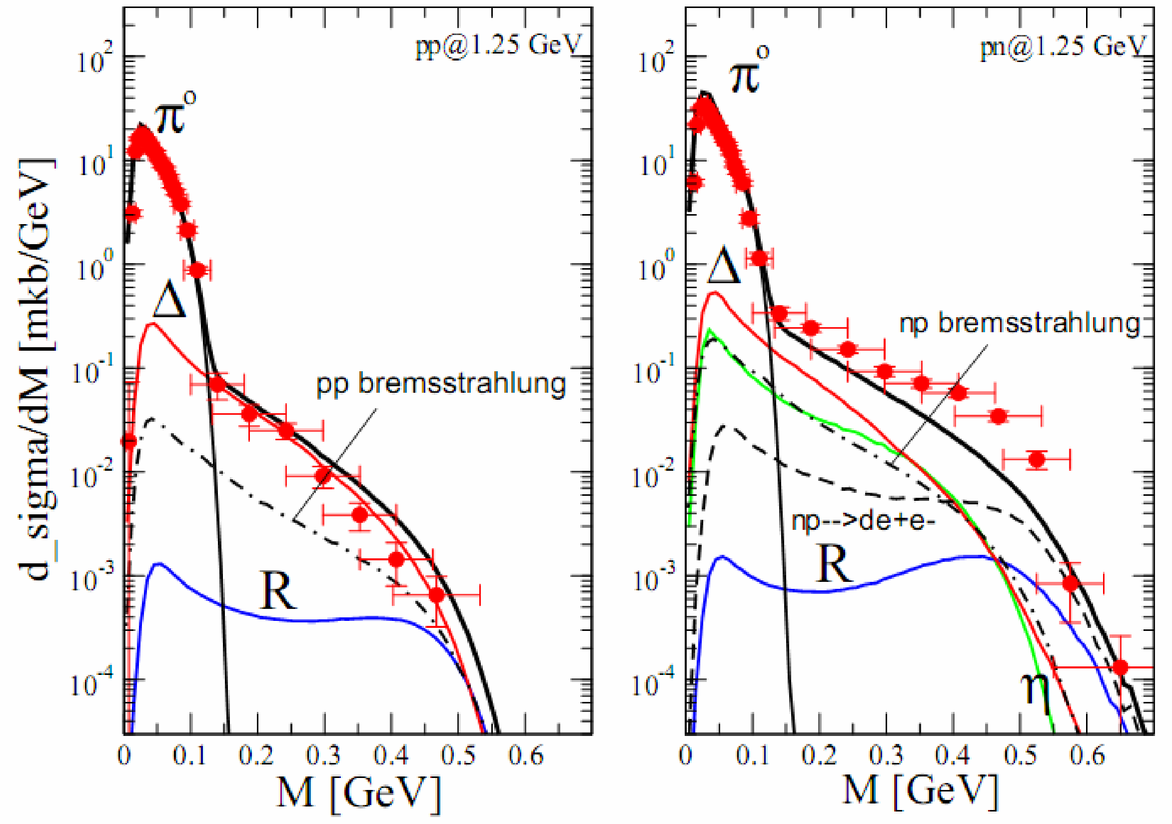
- The $D_{03}$ resonance observed in *pn* collisions also represents dense quark matter (r($D_{03}$) ≈ 0.8 fm corresponds to about a 6-fold normal nuclear density) and has an additional excitation energy of 500 MeV above the deuteron pole.
- Therefore, the σ meson produced from the $D_{03}$ decay should have the lower mass and width than those for the free σ meson. When measuring the ππ invariant mass spectrum in the ABC region, one should observe just that renormalized σ meson.
- **Thus, one can suggest that the low values for the σ-meson parameters extracted from the ABC peak indicate a partial CSR in the excited dibaryon state.**

Another important phenomenon that may demonstrate the CSR effects for the σ-mesons and dibaryons is the **dilepton production**, which we discuss below.

# Dilepton Production in HADES experiments

## Dilepton production in pp and np collisions at 1.25 GeV

B. V. Martemyanov, M. I. Krivoruchenko, and A. Faessler, arXiv:1108.4265 [nucl-th]:




*"The excess of the dileptons in comparison with the theoretical estimates at the high invariant masses indicates a lack of understanding the mechanism of the dilepton pair creation. Among the additional possible sources, we wish to point to a dibaryon resonance observed recently in the reaction np → $d\pi^0\pi^0$ in the energy region of interest".*

Experimental data are from G. Agakishiev et al. (HADES Collaboration), Phys. Lett. **B690**, 118 (2010)

- However the recent analysis made by the HADES Collaboration has discovered that if one uses as input of the dilepton production code the correct experimental yields of dileptons in p+n and p+p collisions, one gets a quite reasonable description for the dilepton emission in nuclear collisions as well.

- Thus, the whole problem is reduced to a quantitative interpretation for dilepton yields in p+n collisions at $E \sim 1$ GeV, i.e. to an explanation of the DLS puzzle.

# Conclusion

- If the σ-dressed dibaryon interpretation of the ABC effect is correct, then one should observe in general an intensive production of light scalar mesons in hadronic collisions such as p+n, p+d, etc., at energies $E \sim 1$ GeV/u under conditions of partial chiral symmetry restoration.
- The DLS puzzle in dilepton production as well as an enhanced yield of dileptons from fireball in heavy-ion collisions may be considered as independent tests for the above prediction.

# Thank You
# For Your Attention!

Please send your critics (if not very strong), questions and comments to:

kukulin@nucl-th.sinp.msu.ru or
platonova@nucl-th.sinp.msu.ru