SPIN 08

Symmetry and Supersymmtry in Basic Nuclear Force. Dibaryon Concept for NN Interactions.

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Content

1. Quark model description for short-range NN interaction: symmetry in NN-force.

   Where is basic NN attraction?
2. NN potential models describing NN quark-model wavefunctions and phase shits (the Moscow NN potential).
3. Supersymmetrical quantum mechanics and supersymmetry in NN interaction.
4. Dibaryon concept for nuclear force and ABC puzzle.
5. Roper-resonanse structure and σ-field in Roper.
6. Hybrid nature for σ-meson and dressed dibaryon.
7. Experimental evidences for the dibaryon concept.
8. Summary.

Experimental evidence for dibaryon production

1. Early evidences for dibaryon production in pp collisions.
2. New observation for the σ-channel in Roper decay.
3. ABC-puzzle (historically).
4. Exclusive (WASA- PROMICE) measurements for the ABC-puzzle: $p+d \rightarrow {}^{3}He + 2\pi$,

   $p+d \rightarrow d(\pi\,\pi) + p$, $p+n \rightarrow d + (\pi\,\pi)_0$ etc.

Roper Resonance
$N^*(1440)\frac{1}{2}^+$

- **πN and γN:**
  - Roper´s resonance
  - a resonance without seeing it
- **New generation of measurements:**
  - the „narrow“ Roper

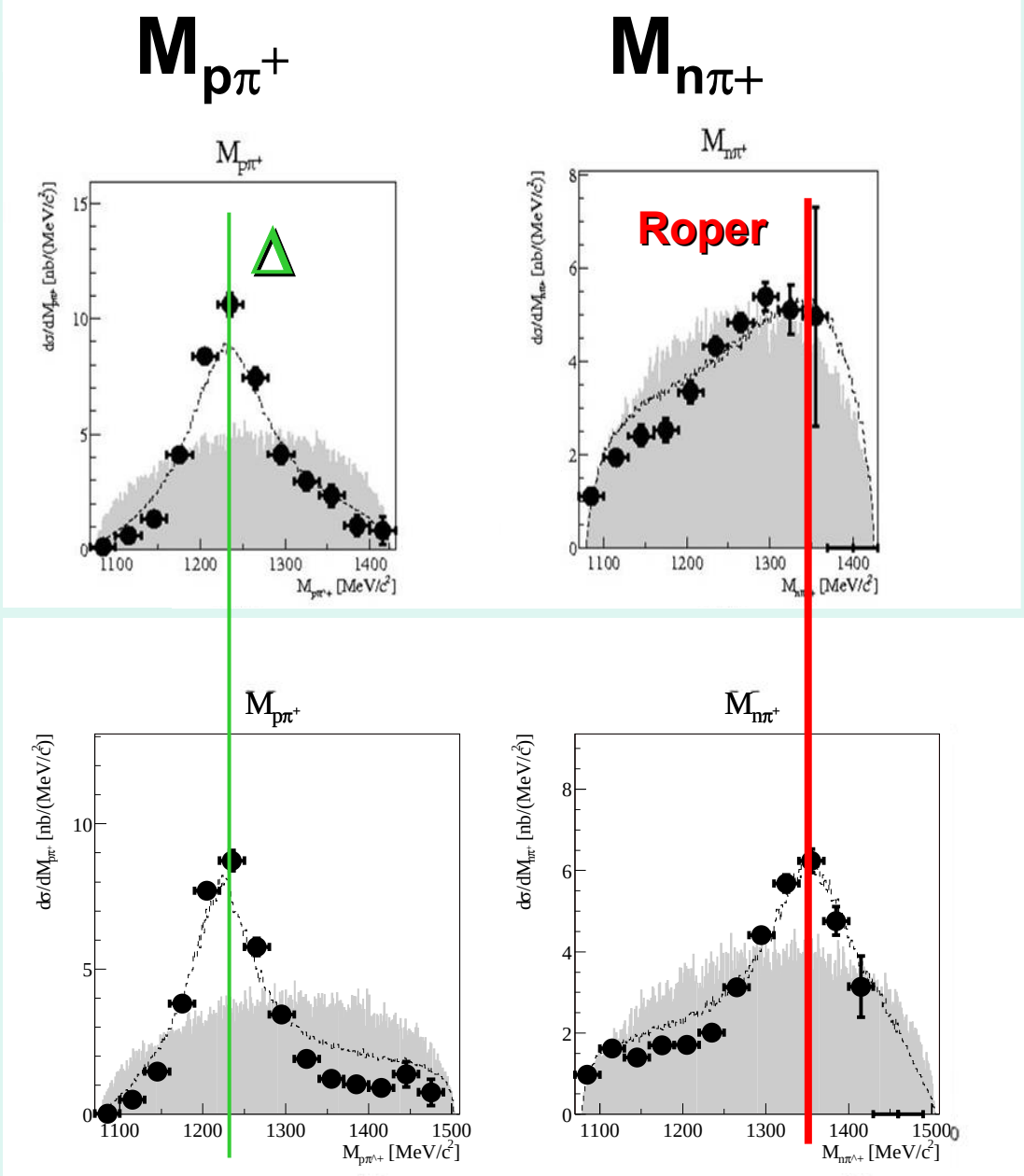
$pp \longrightarrow np\pi^+$

(WASA)

- T_p = 1.1 GeV

- T_p = 1.3 GeV

Data prefer Roper values:
M ≈ 1355 MeV
Γ≈ 140 MeV
(nucl-ex/0612015)



Summary about Roper-resonance characteristics

- **Roper resonance now:**

	M	Γ (MeV)
– **SAID** π**N** partial wave analysis:	**1357**	**160**
– **Bonn** *(Sarantsev et al)* π**N** + γ**N**	**1371(2)**	**184(20)**
– **Explicitly seen in:**		
– α **p** $\rightarrow \alpha$ **X**	**1390**	**190 (?)**
– **J/**$\psi \rightarrow$ **n p**π^-	**1358**	**160**
– **p p** $\rightarrow$ **p n**π^+	**1355**	**140**

- **Roper decay** $N^* \rightarrow N\,\pi\pi$
- **pp** $\rightarrow$ **NN**$\pi\pi$ $\Rightarrow$ dominantly $N^* \rightarrow N\,\sigma$
- **Scalar-isoscalar probes (**σ **exchange) see „narrow“ monopole excitation at very low excitation energy :**

breathing mode @ $\omega \approx$ **400 MeV !**

$\pi\pi$ Production in Nuclei

- medium effects of the $\pi\pi$ system

- nuclei as isospin filter:

	$\pi^0\pi^0$ – system
– pp $\rightarrow$ pp $\pi\pi$	I = 0, ~~1~~, 2
– pn $\rightarrow$ d $\pi\pi$	0, ~~1~~
– pd $\rightarrow$ ^{3}He $\pi\pi$:	0, ~~1~~
– dd $\rightarrow$ ^{4}He $\pi\pi$:	0

} **ABC effect**

ABC effect

(Abashian, Both, Crowe)

Inclusive measurements:

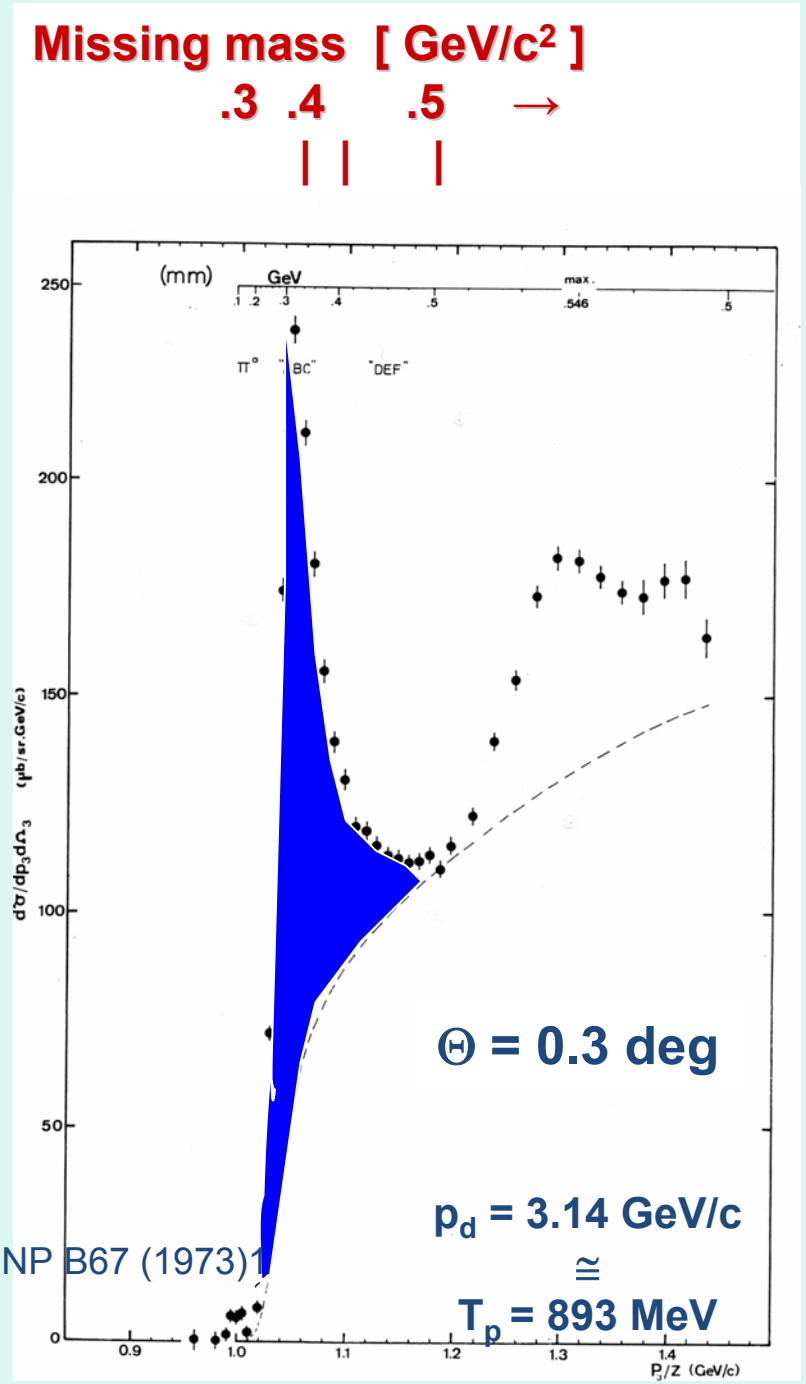
pd → ^{3}He X

Abashian et al. Berkeley

Banaigs et al. Saclay

⇒

low-mass enhancement !

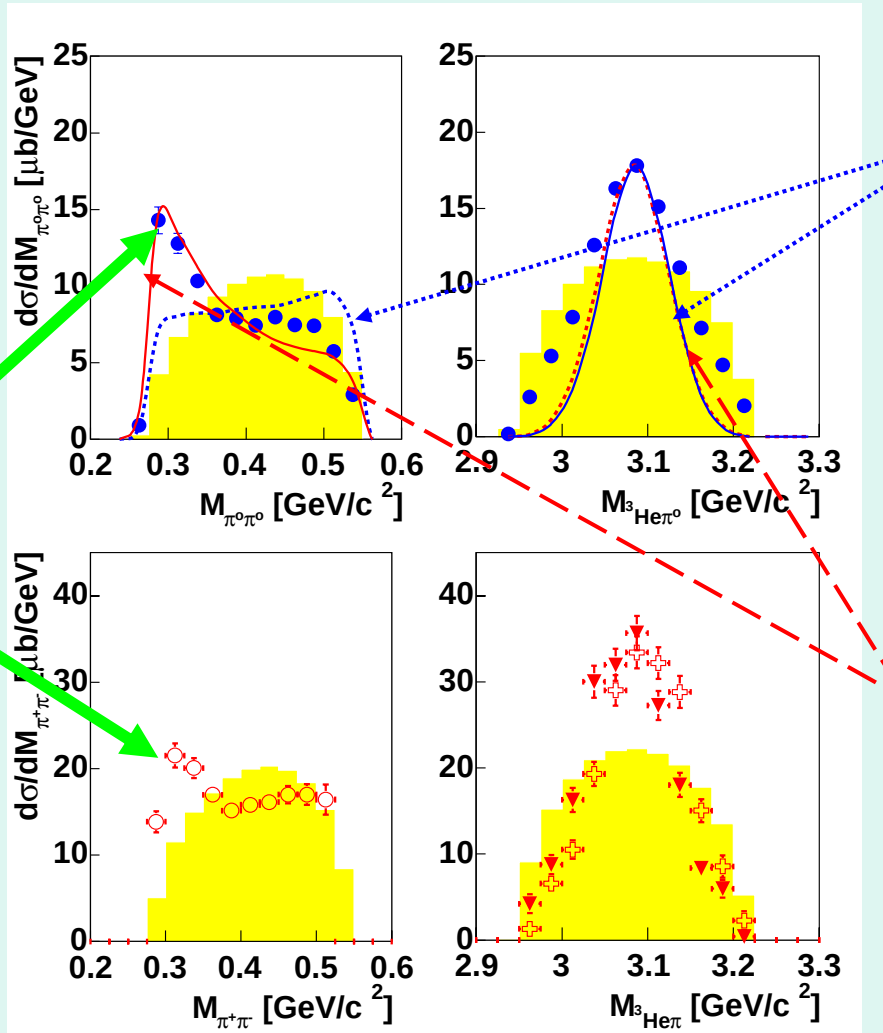


NP B67 (1973)1

First exclusive measurement: @ CELSIUS-WASA

$p\,d \rightarrow {}^3He\ \pi\pi$ @ T_p = 895 MeV

$M_{\pi\pi}$ $M_{^3He\,\pi}$



$\pi^0\pi^0$

(I = 0)

ABC

$\pi^+\pi^-$

(I = 0, 1)

$(\Delta\Delta)_{conventiona}$

$(\Delta\Delta)_{int}$

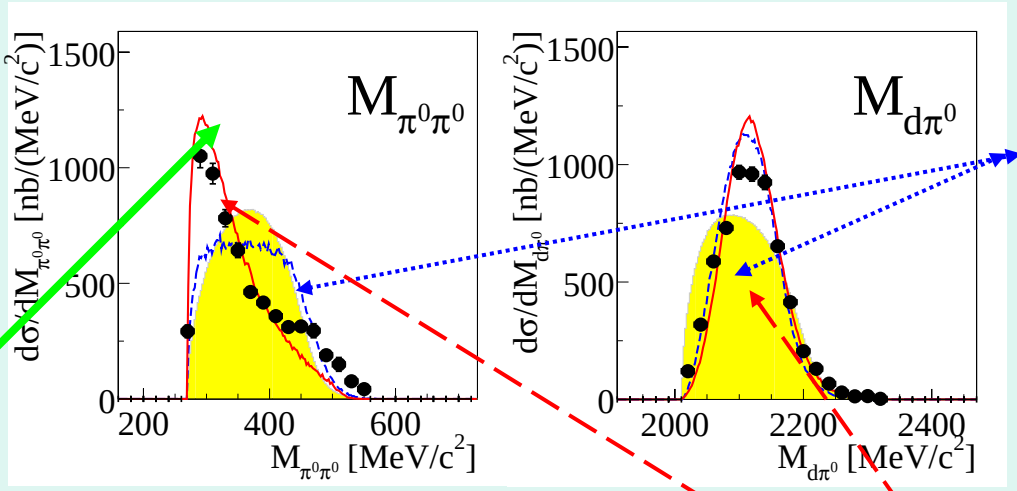
Phys. Lett. B637, 223 (2006)

First exclusive measurement: @ CELSIUS-WASA

$p\,d \rightarrow d\,\pi^0\pi^0 + p_{spectator}$

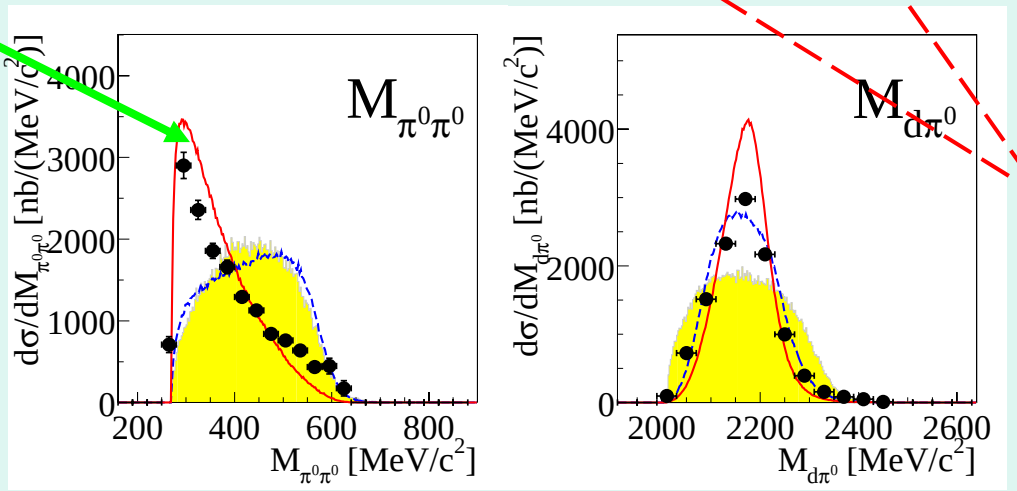
$M_{\pi\pi}$ $M_{d\pi}$

T_p = 1.04 GeV



ABC

T_p = 1.36 GeV

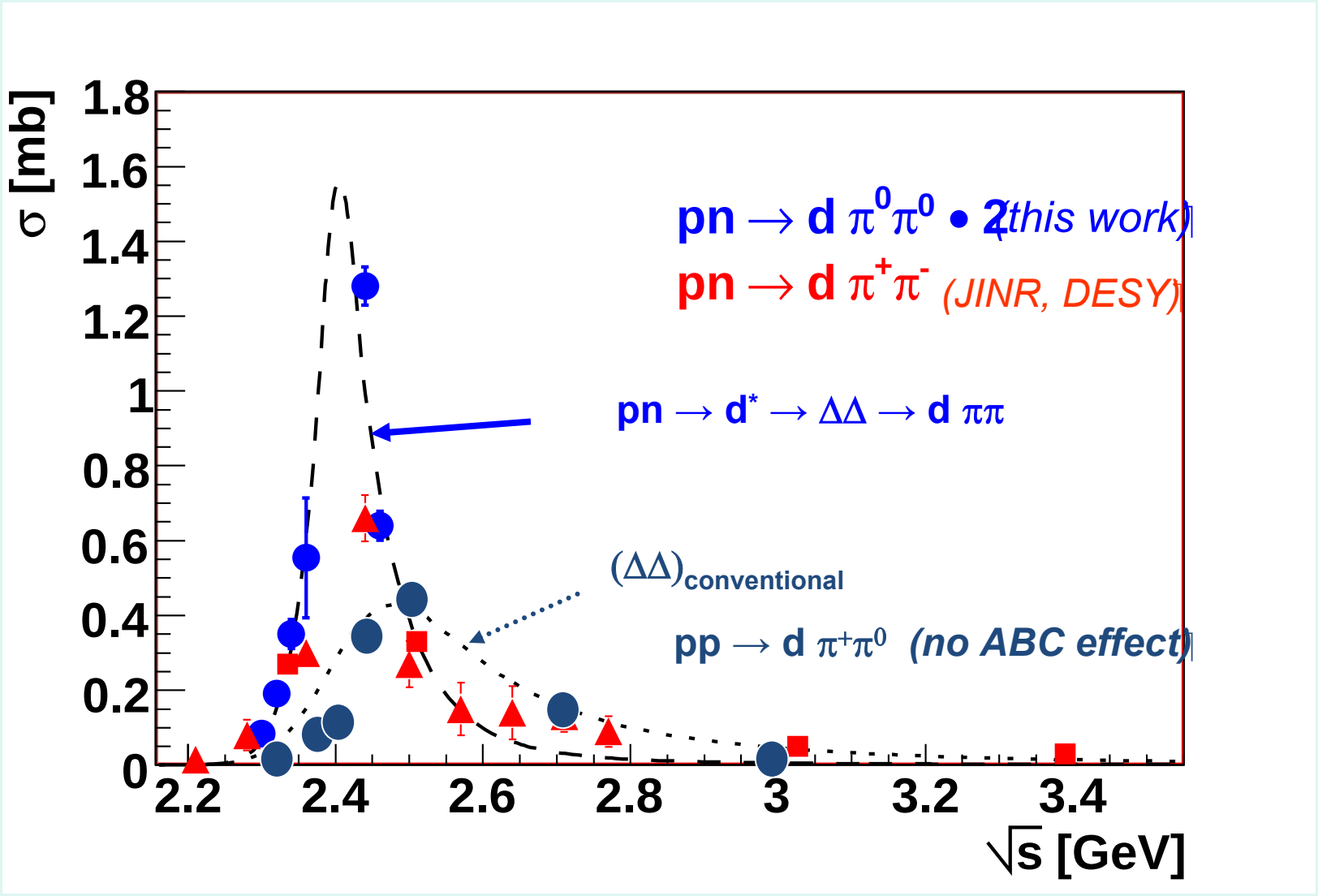


$(\Delta\Delta)_{conventiona}$

$(\Delta\Delta)_{int}$

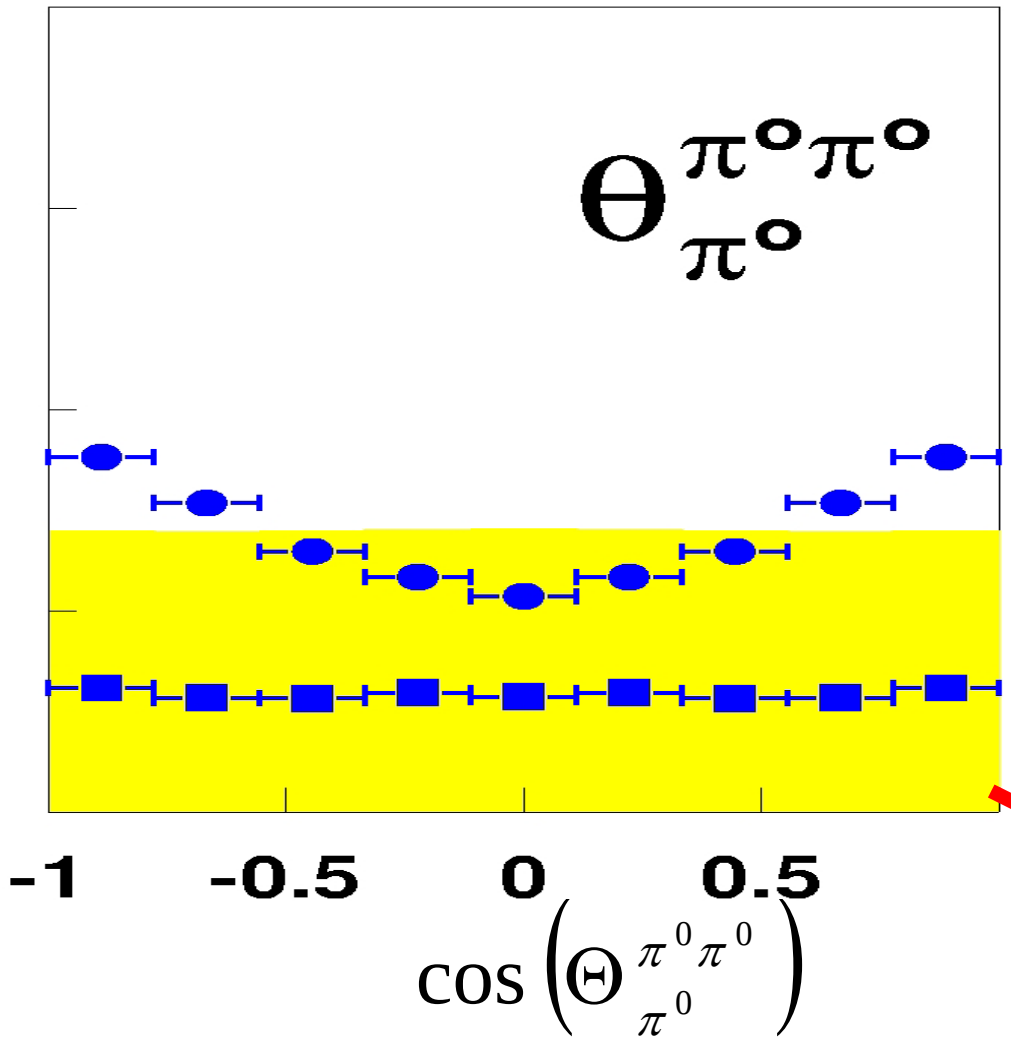
Proc. MESON 06, Int. J. Mod. Phys. A22 (2007) 617

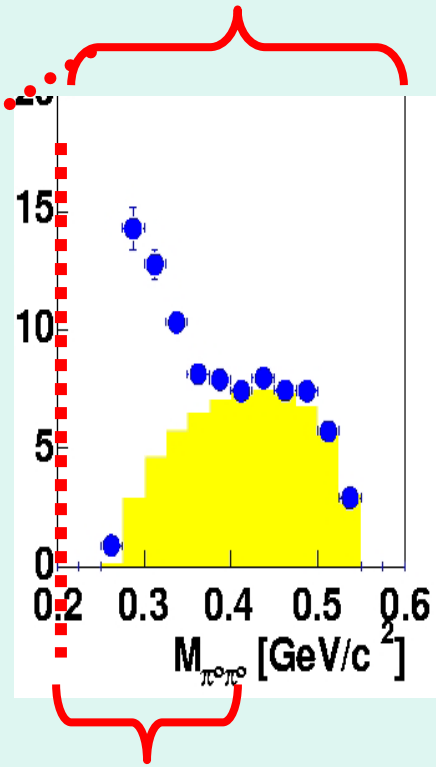
Energy Dependence of ABC



Angular Distribution of Isoscalar Low-Mass Enhancement ?

Phys. Lett. **B637**, 223 (2006)





scalar – isoscalar !

Direct experimental evidence for the *s*-channel dibaryon induced σ-meson production

Observation of a Structure in $pp \to pp\gamma\gamma$ near the $\pi\pi$ Threshold and its Possible Interpretation by $\gamma\gamma$ Radiation from Chiral Loops in the Mesonic σ Channel

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(CELSIUS-WASA Collaboration)

(Dated: February 7, 2008)

The $pp \to pp\gamma\gamma$ reaction has been measured at CELSIUS using the WASA 4π-detector with hydrogen pellet target. At $T_p = 1.20$ and 1.36 GeV, where most of the statistics has been accumulated, the $\gamma\gamma$ invariant mass spectrum exhibits a narrow structure around the $\pi\pi$ threshold, which possibly may be associated with two-photon radiation of $\pi^+\pi^-$ loops in the mesonic σ channel.

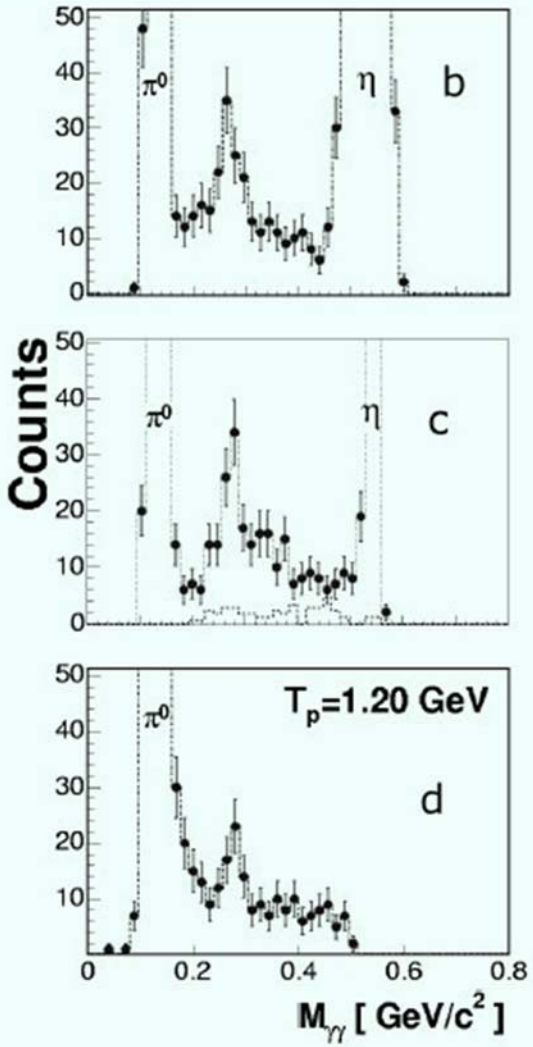

FIG. 1: (a): Scatterplot of $M_{\gamma\gamma}$ versus the MM_{pp} for all selected events at $T_p = 1.36$ GeV. The dashed line shows the cut $(M_{\gamma\gamma} - MM_{pp})/MM_{pp} < 0.4$ to exclude events, where protons have undergone large hadronic interactions in the detector. (b) - (c): $M_{\gamma\gamma}$ spectrum (projection of the scatterplot above) before (b) and after (c) kinematic fit.The dotted histogram in (c) shows background expected from misidentified $\pi^0\pi^0$ events. (d): The same as (c), but for $T_p = 1.2$ GeV.

The spike around 2π-threshold turns out to be very stable against cuts. E.g., increase of the threshold E_γ= 50 MeV to E_γ = 100 MeV has no significant effect on this intermediate spike.
Moreover, the model which incorporates very well the γγ events and $M_{\gamma\gamma}$ from π^0 and η production gives practically no events in the intermediate area with $M_{\gamma\gamma}$ ~300 – 400 MeV! Also from MC simulation of $\pi^+\pi^-$ production we do not get any contributions in the $M_{\gamma\gamma}$ spectrum.

Then the experimentalists (CELSIUS-WASA) conlude:

"Since none of these simulated processes is able to account for the structure observed near the ππ threshold and also detailed and comprehensive tests of detector performance and event structures have **not given** any hint for an artifact, we are led to consider seriously the possibility that the observed structure (at $M_{\gamma\gamma}$ ~300 – 400 MeV) is real and might be due to the process $pp \rightarrow pp\sigma \rightarrow pp\gamma\gamma$, in particular also since $pp \rightarrow pp\pi^+\pi^-$ and $pp \rightarrow pp\pi^0\pi^0$ reactions are dominated by σ production."

The new γγ-data with large statistics

In these nice experiments done at the Dubna Nuclotron machine the authors analyzed the γγ-spectra from pC and dC collisions at 5.5 GeV/c (for protons) and 1.7-3.8 GeV/c per nucleon (for deuterons).

Observation of a Resonance-like Structure in the Invariant Mass Spectrum of two photons from pC- and dC-Interactions

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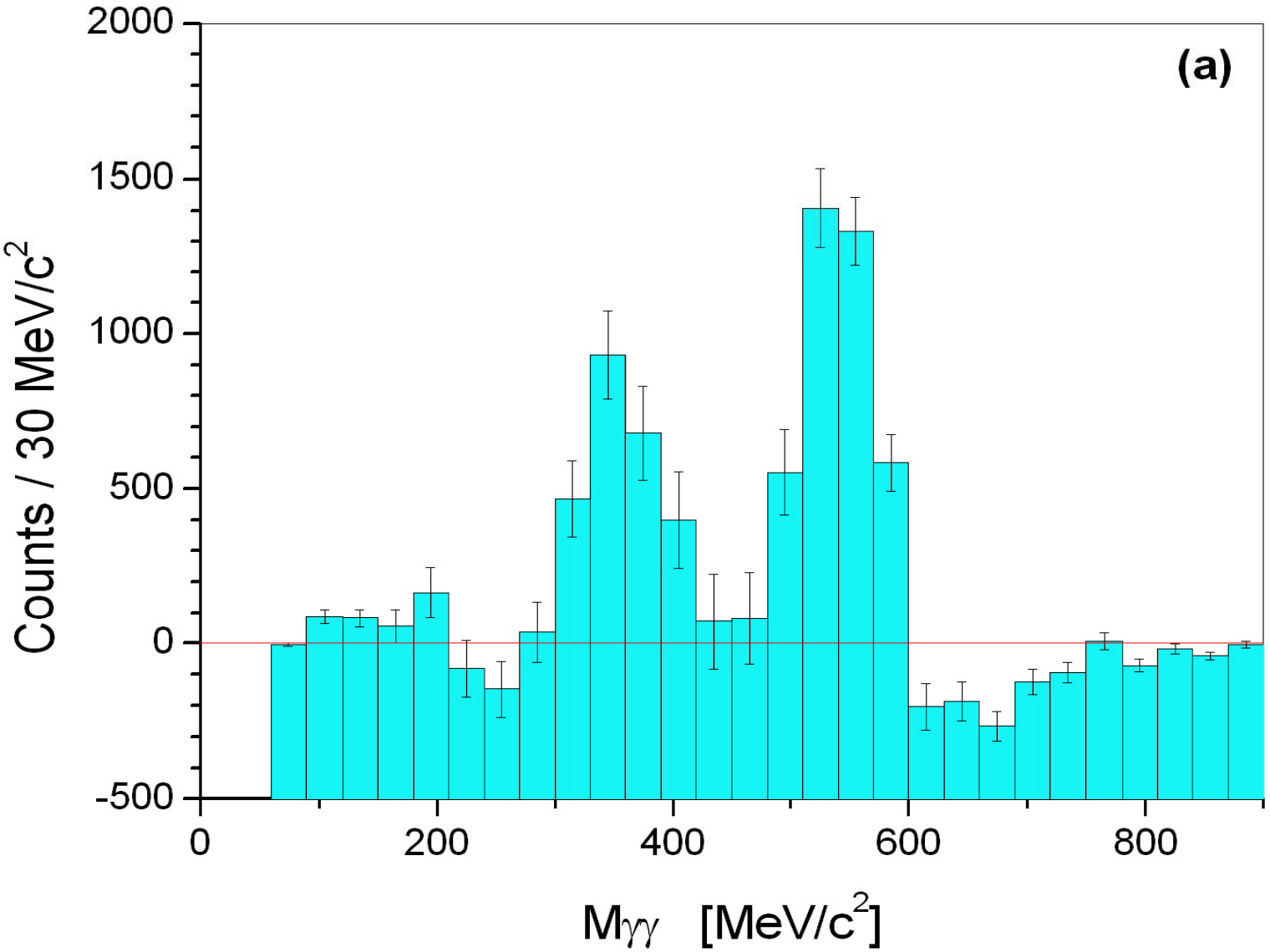
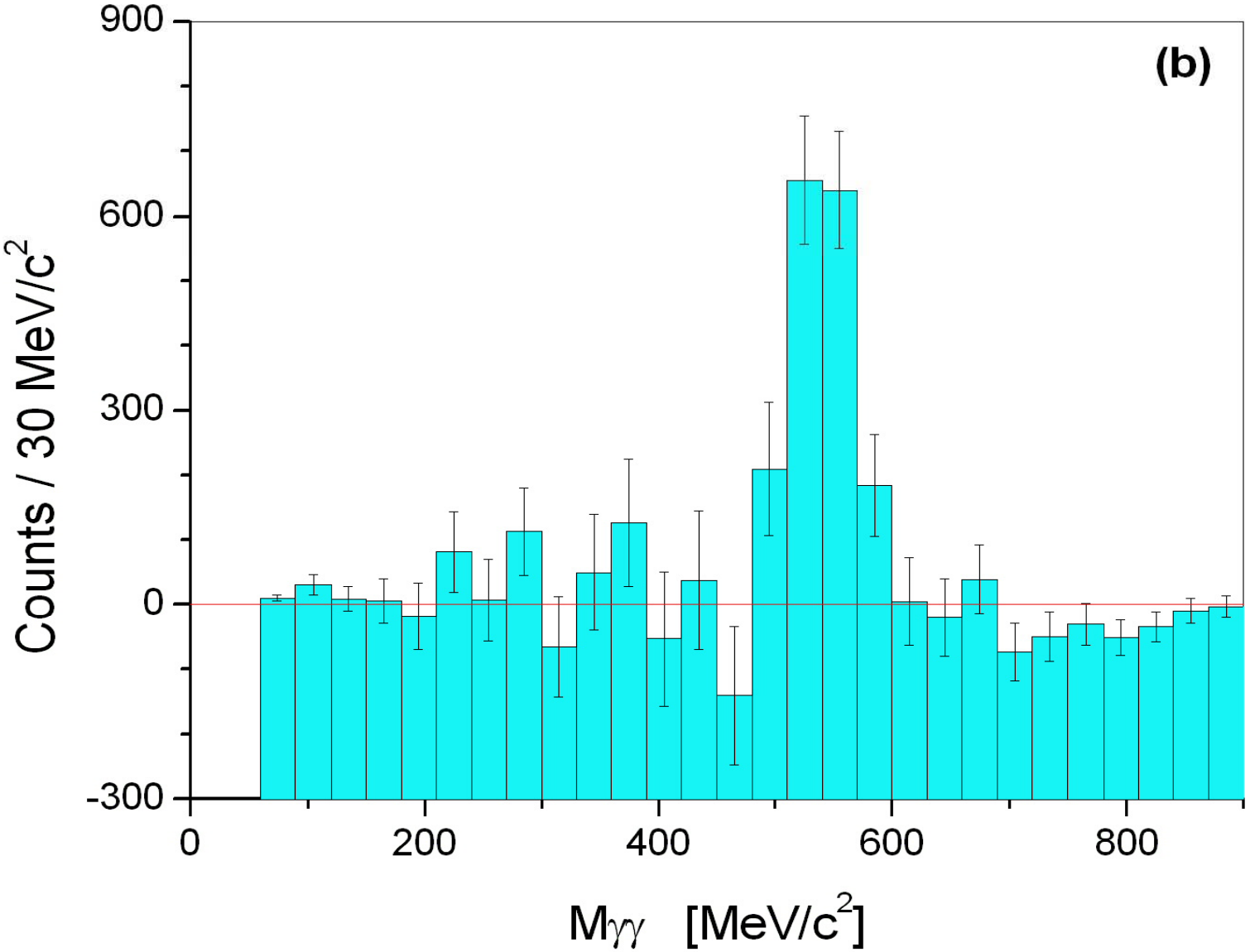
Abstract

Along with π^0 and η mesons, a resonance structure in the invariant mass spectrum of two γ-quanta at $M = 360 \pm 7 \pm 9$ MeV is first observed in the reaction $dC \to \gamma + \gamma + X$ at momentum 2.75 GeV/c per nucleon. Preliminary estimates of its width and cross section are $\Gamma = 49.2 \pm 18.6$ MeV and $\sigma_{\gamma\gamma} \sim 98\ \mu b$. The collected statistics is 2339 ± 340 events of $1.5 \cdot 10^6$ triggered interactions of a total number of $\sim 10^{12}$ dC-interactions. This structure is not observed in pC collisions at the beam momentum 5.5 GeV/c. Possible mechanisms of this ABC-like effect are discussed.

γγ-yield from dC collisions at E=2.75 GeV/cA



γγ-yield from pC collisions at E=5.5 GeV/c



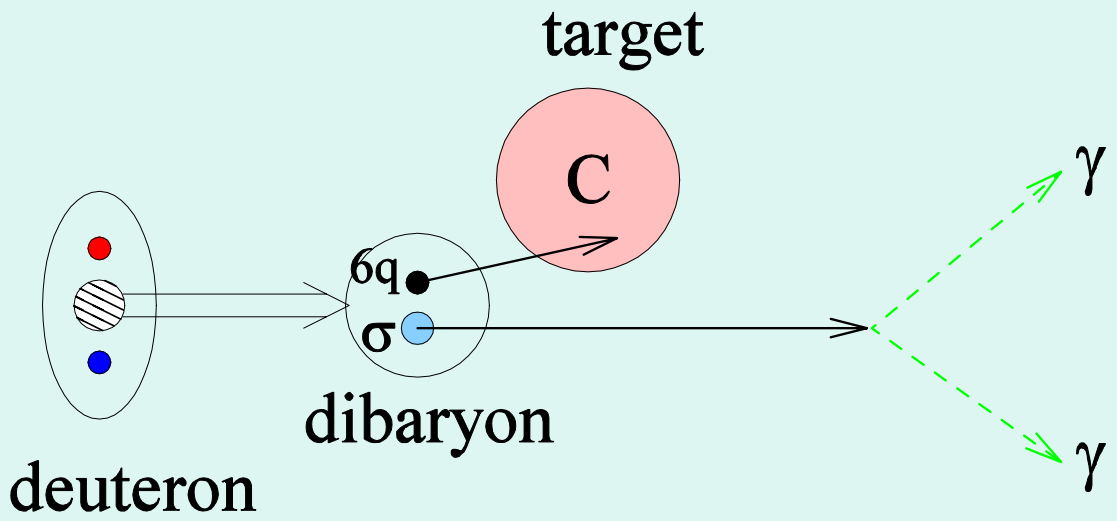
From authors' conclusion:

Thus, based on a thorough analysis of experimental data measured at the JINR Nuclotron and record statistics of 2339 ± 340 events of $1.5 \cdot 10^6$ triggered interactions of a total number $2 \cdot 10^{12}$ of dC interactions there was observed a resonance-like enhancement at the mass $M_{\gamma\gamma}$ = 360 ± 7 ± 9 MeV, width Γ= 49 ± 19 MeV at momentum of incident deuterons 2.75 GeV/c per nucleon. A structure like this is not observed in the $M_{\gamma\gamma}$ spectrum from pC (5.5 GeV/c) interactions while the η meson is clearly seen in both the cases.

…This enhancement at $M_{\gamma\gamma} \sim (2-3)m_{\pi}$ is similar to the puzzling ABC effect observed for two-pion pairs from nucleon-nucleon and lightest nuclei collisions at the near threshold energy.

…Several dynamic mechanisms were attempted: production of the hypothetic R resonance (really it is a renormalized σ-meson) in ππ interactions during the evolution of the nuclear collision, formation of the R resonance with participation of photons from the decay, the $\pi^0\pi^0$ interaction effect in the $3\pi^0$ channel of the η decay, a particular decoupled dibaryon mechanism. Unfortunately, none of these mechanisms is able to explain the measured value of the resonance-like enhancement

Production of two γ-quanta according to dibaryon model



Conclusions

1. The deficiency of scalar fields in OBE- and constituent quark models gives a very strong evidence in favour of existence of σ-dressed intermediate dibaryons in which the scalar field is generated in the string deexcitation process.
2. The similar mechanism for the scalar field generation is producing a large mass shift of the Roper resonance and leads to dominating N+σ channel in the Roper decay. (This conclusion is in a full agreement with QCD sum-rule solution of Kisslinger et al. and the Clement's et al experiments.)
3. The dibaryon model for nuclear force leads to numerous implications for nuclear physics – main of them is an appearance of a new non-nucleonic (i.e. the dressed dibaryon) components in nuclear wave functions with probability ≥10%. In turn, these new components leads to new e.-m. currents, new powerful 3N force, existence of cumulative processes in hadronic scattering off nuclei, etc.