Polarized measurements of energy dependence of the complete set of np observables at 1-6 GeV monochromatic neutron beams from the Nuclotron and direct reconstraction of the isosinglet NN-amplitudes of forward elastic scattering – for a search signals of phase transition of NN to 6-quarks

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Introduction

To advance studies of the **short range spin structure of *NN* interactions**, there were (*np*) spin observables measured for the first time at 0° up to the **highest nucleon internal momenta *k*** in *np*-core. **Both the bounded polarized (*np*)-couple** (in deuteron) and a **polarized free *np*-couple** were probed up to **$k \approx 5$ fm^{-1}** and **6 fm^{-1}** respectively. The **highest energy polarized deuteron (up to 9 GeV/c)** and polarized monochromatic neutron beams (up to 4.5 GeV/c), provided now only by the JINR accelerators, were used [2,3] **for energy dependence measurements $T_{20}(k)$** up to **$k \approx 5$ fm^{-1}** [2a] in the **$d \rightarrow p$ stripping up to kinematic limit of *k***, and **$\Delta\sigma_L(np)$ total *np* cross section differences** in new energy range of 1.2 – 3.7 GeV [3].

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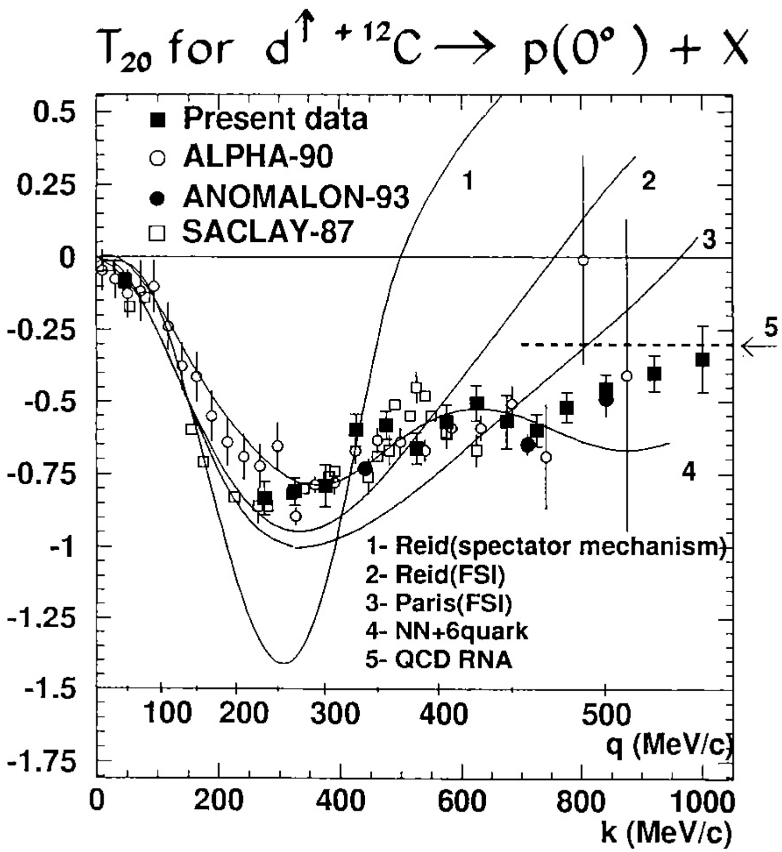
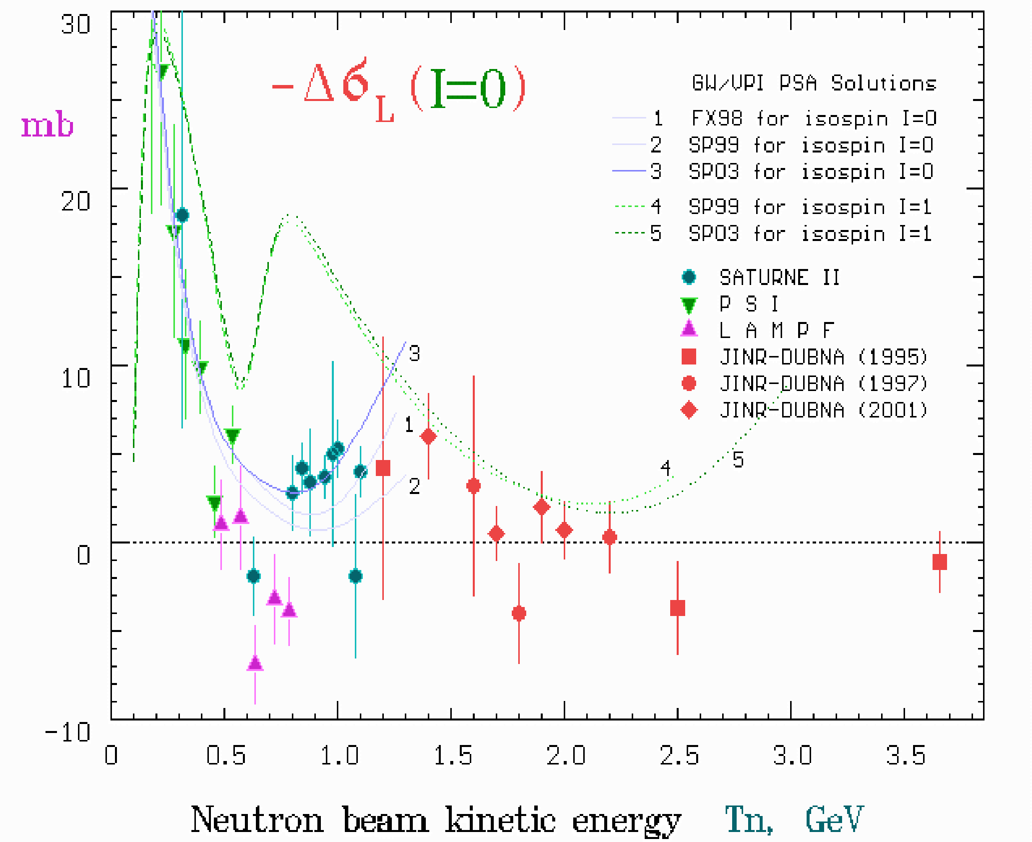
2 A.A.Nomofilov et al.,Phys.Lett. B325(1994),p.327; Phys.Rev.Lett.v.74,N25(1995),p.4997.

3 V.I.Sharov et al.,JINR Rapid Com.,3[77]-96, (1996) 13; 4[96]-99 (1999) 5; Z.Phys.C.71,N1, (1996) 65; Yad.Phys.68 N11(2005)p1857; Eur.Phys.J.C37,79(2004)



T20 for d↑ + 12C → p(0°) + X
Present data
ALPHA-90
ANOMALON-93
SACLAY-87
1- Reid(spectator mechanism)
2- Reid(FSI)
3- Paris(FSI)
4- NN+6quark
5- QCD RNA
q (MeV/c)
k (MeV/c)



mb
−Δσ_L (I=0)
GW/VPI PSA Solutions
1 FX98 for isospin I=0
2 SP99 for isospin I=0
3 SP03 for isospin I=0
4 SP99 for isospin I=1
5 SP03 for isospin I=1
SATURNE II
P S I
L A M P F
JINR-DUBNA (1995)
JINR-DUBNA (1997)
JINR-DUBNA (2001)
Neutron beam kinetic energy Tn, GeV

These data [2,3] are in agreement with the **SATURNE II ones over the lower *k*-momentum common range of 2.5 fm^{-1}**. Several years ago Dubna (in collaboration with groups from 12 laboratories) began the **transmission measurements [3] using both a polarized neutron beam and a polarized proton target**. For the first time we measured the **energy dependence of the $\Delta\sigma_L(np)$**, neutron-proton total cross section difference for the pure longitudinal (L) spin states for parallel and antiparallel (*np*) spins, over a **new kinetic energy range of 1.2--3.7 GeV** for a quasi-monochromatic polarized neutron beam. The **$-\Delta\sigma_L(np)$ energy dependence [3] shows an anomalous fast decrease to zero above 1.1 GeV** and a **structure around 1.8 GeV** predicted in Ref. [4]. The authors [4a] used the Cloudy Bag Model and an R-matrix connection to long-range meson-exchange force region with the short-range region of asymptotically free quarks; this **hybrid model gives the lowest exotic six-quark configurations in the isosinglet $^3S_1$ state with the mass M =2.63 GeV T_{kin} =1.81 GeV).** It is close to the energy where **the structure is discovered** by our **$-\Delta\sigma_L(I=0)$** energy dependence determination.

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4 E.L.Lomon et al. at the proper references in [3];

M.Matsuda et al, Few-Body Systems Suppl.12,457(2000)

Since $-\Delta\sigma_T$ contains no uncoupled spin-triplet contribution, a **$^3S_1$ resonance effect in this observable less deluted by other spin-states than in $-\Delta\sigma_L$**. The measurement **$-\Delta\sigma_T$ (*np*)** and the determination of the **$-\Delta\sigma_T(I=0)$** energy dependence provide a significant and **sensitive check of the predicted resonance**. Moreover, in difference ($\Delta\sigma_L-\Delta\sigma_T$) the spin-singlet contribution vanishes. For this reason, **the accurate $-\Delta\sigma_T$ (*np*) measurements near to T_{kin} = 1.8 GeV are desirable [3b,c]. The I=0 spin dependent total cross section differences represent a considerable advantage for studies of the $^3S_1$ state around 1.8 GeV, since this partial wave is expected to be dominant**. This is in contrast with the I=1 system where lowest lying exotic six-quark configuration was predicted in the spin-singlet state $^1S_0$ above 2 GeV. This state is not dominant and is strongly diluted in the forward direction.

The obtained high momentum dependences of these (*np*) spin observables **[2,3] are surprising for all traditional nuclear models**. Their predictions are **wrong for** the highest momentum (asymptotic) **behaviour of these observables related with almost fully overlapping nucleons in fact**.

In [3] we discussed the QCD motivated model of a nonperturbative flavour-dependent interaction between quarks, induced by a strong fluctuation of vacuum gluon fields, i.e. **instantons**. Concerning this model, we refer to our previos papers, since no new relevant prediction is available. The **former prediction at high energy disagree with the experimental data [3]** on $-\Delta\sigma_L$(*np*) energy dependence.

To exactly reveal a discovered structure at 1.8 GeV we are need in obtain the complete L,T data set [1] of np spin observables at 0° which is needed for the first direct reconstruction of all three isosinglet amplitudes of forward *NN* elastic scattering over a GeV energy range. With this **very ambitious aim the following will be simultaneously measured for the first time at each chosen T_n: $-\Delta\sigma_L$ and A_{00kk}, a spin correlation parameter for *np→pn*** charge-exchange (180° in the c.m.) **with the L polarization of n beam and p target; $-\Delta\sigma_T$ and A_{00nn} with the T-polarized beam and target.** The proper equipment mounted in the last year was successfully tested (in simultaneous measurements of n beam transmission through H_2/D_2 targets and *n→p* charge-exchange on them). The Dubna group fulfilled first measurements under 0° of the ratios R_{dp} "elastic" *np* charge-exchange yields on H/D targets and defined of the ratios $r^{nf/fl}(0)$ nonflip and spin-flip contributions to *np→pn* process. In the region of $T_n \approx 1.8$ GeV one can expect an anomaly [3] of $r^{nf/fl}$ - energy dependence (as in the case [3] of the measurements of $-\Delta\sigma_L$ **if one follows the QCD-motivated reasoning (Lomon et al., Matsuda et al.) [4] about a phase transition at this energy of the *NN* system into the exotic six-quark configuration** in the isosinglet and the spin-triplet state $^3S_1$ with the mass $M \approx 2.63$ GeV.

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1 In book ed. Baldin A.M. Research Program of LHE JINR (Dubna 1999) 37-43,"Delta-Sigma Experiment" Spokesmen V.I.Sharov, L.N.Strunov.

1b R.Binz Ph.D.Thesis.Freiburg (1991).

For **the exhaustive analysis of this structure [3] using Argand diagrams for *Re* and *Im* parts of each of the three *NN* forward scattering amplitudes** it is required to measure in Dubna not only the complete set [1] of np-spin observables at 0° but also to carry out **pilot measurements in the same energy region of the ratio $R_{dp}(0)$ = *dσdΩ*(*nd*) / *dσdΩ*(*np*) for yields of "elastic" *n→p* charge-exchange non-polarized neutrons on H/D targets that independently defines [1b] the $r^{nf/fl}$ ratio at 0° the spin-nonflip contribution in *np→pn* to the spin-flip contribution in this process: $r^{nf/fl} = 2/3R_{dp}^{-1} - 1$**.

The results of our measurements dependence $r^{nf/fl}$ ratio over 0.55 – 2 GeV will be done in the current report.

THE COMING RESEARCH PROGRAM "Delta-Sigma"

The coming research program under the project on 2006 – 2009 is following:

1) **Using suitable T-polarized neutron beam and T-polarized proton target to perform at T_n = 1.2 – 3.7 GeV:**
   a) **the measurements of the $\Delta\sigma_T$ (*np*) at the same energy points as for $\Delta\sigma_L$ (*np*) with energy steps of 100–200 MeV and expected statistical errors ~ 1 mb;**
   b) **the measurements of the energy dependencies of spin-correlation parameters A_{00nn}(*np*) at the same energy points as for $\Delta\sigma_T$ (*np*) with expected statistical errors 0.02–0.05. These measurements can be performed simultaneously.**
2) **Using suitable L-polarized neutron beam and L-polarized proton target to perform:**
   a) **the more precise and detailed measurements of the $\Delta\sigma_L$ (*np*) near Tn=1.8 GeV at 2–3 energy points with energy steps of 100 MeV and expected statistical errors less than 1 mb;**
   b) **the measurements of the energy dependencies of spin-correlation parameters A_{00kk}(*np*) at the same energy points as for $\Delta\sigma_L$(*np*) with expected statistical errors 0.02–0.05. These measurements can be performed independently with the $\Delta\sigma_T$(np) ones.**
3) **Using a high intensity unpolarized deuteron beam for preparing free neutron beam and liquid hydrogen and deuterium targets, the measurements of ratio Rdp = $d\sigma/d\Omega(nd)$ / $d\sigma/d\Omega(np)$ for defining the $r^{nf/fl}$ energy dependence – spin-nonflip/flip ratio in *np*→*pn* scattering on 180° c.m.**

Accelerators and Tools

1. THE SYNCHROPHASOTRON AND NUCLOTRON OF THE JINR VBLHE

2. RELATIVISTIC (1–6) GEV:
   POLARIZED NEUTRON BEAM WITH *L* OR *T* ORIENTATION OF POLARIZATION (WITH THE HELP OF NEW POLARIZED *d*-SOURCE “CIPIOS” WITH INTENSITY UP TO $5 \cdot 10^{10}$ *d/CYCLE*) , REVERSION OF POLARIZATION DIRECTION CYCLE BY CYCLE AND AVERAGE POLARIZATION VALUE OF ≈ 0.53
   AND *UNPOLARIZED DEUTERON BEAM*

3. *LARGE POLARIZED PROTON TARGET (PPT)* WITH VOLUME OF 140 cm^3
   AND POLARIZATION VALUE OF 0.7–0.8
   HYDROGEN-H_2 AND DEUTERIUM-D_2 TARGETS

4. EXPERIMENTAL SET-UP “DELTA-SIGMA” WITH :
   TRANSMISSION NEUTRON DETECTORS
   MAGNETIC SPECTROMETER WITH PROPORTIONAL CHAMBERS
   TIME-OF-FLIGHT SYSTEM TOF
   DETECTORS FOR D_2/H_2TARGET SURROUNDING DTS
   MODERN DATA ACQUISITION SYSTEM

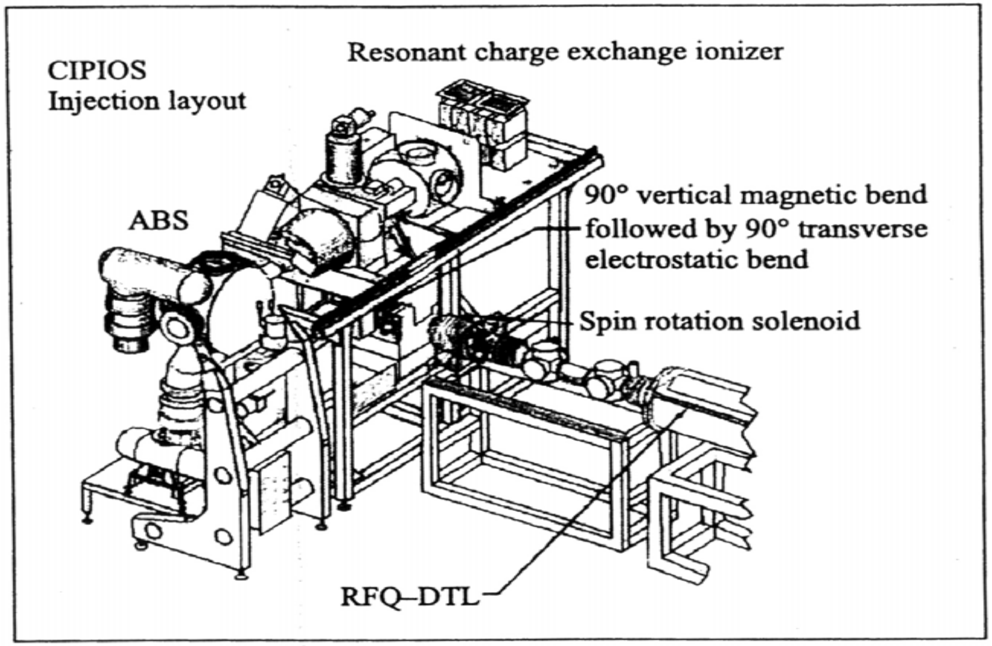
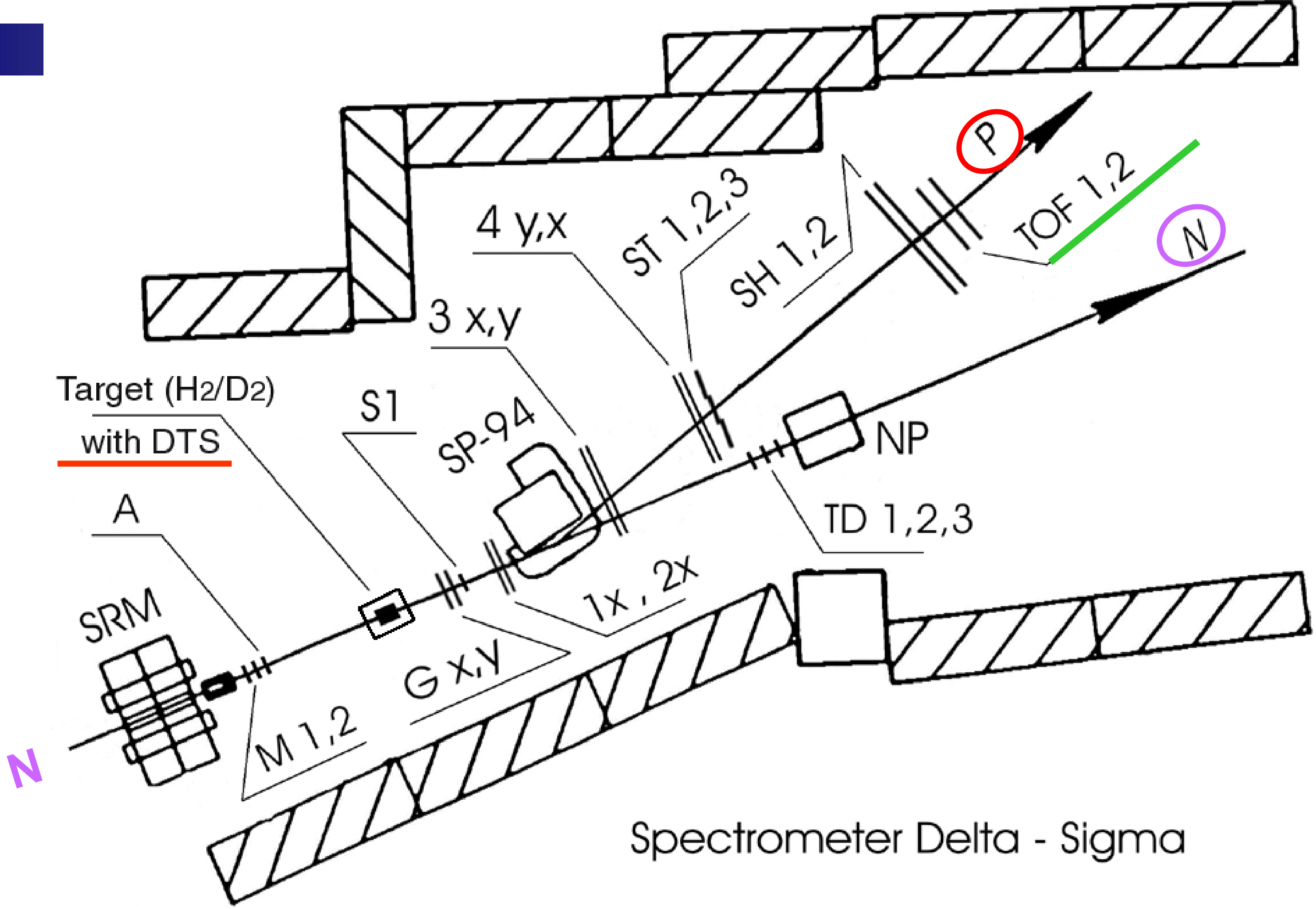


Fig. 1. The CIPIOS polarized source

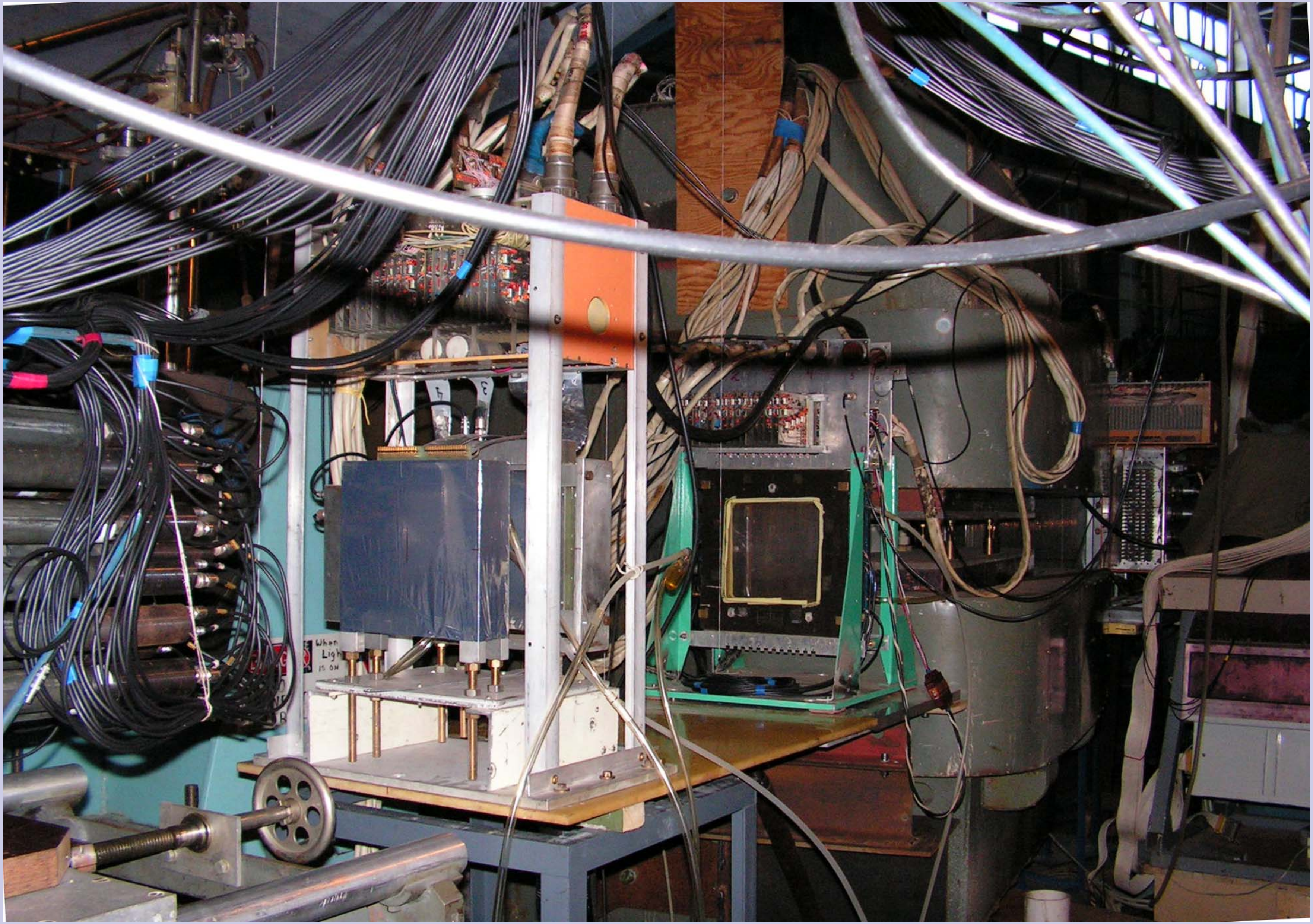
A very important event in 2004 was signing an agreement between the Indiana University and JINR on handing over the CIPIOS polarized ion source to be mounted at the Nuclotron. The source parameters are: pulsed 1 to 4 Hz; 25 keV beam energy; polarized H or d; normal polarization $> 80\%$; 1.5 mA (peak) from source; > 25 mA (peak) unpolarized.

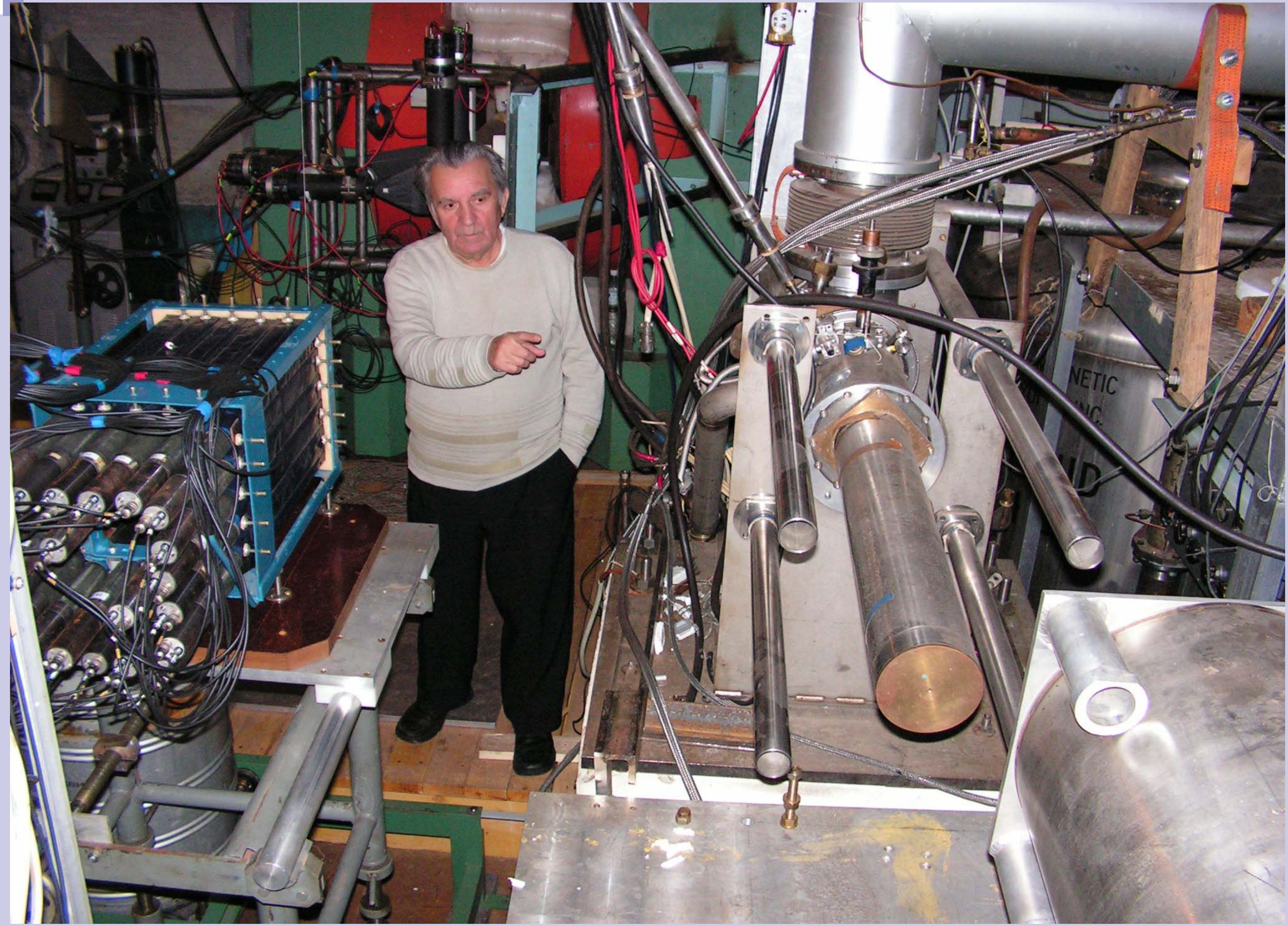
Using this source at the Nuclotron will make it possible to provide an intensity of the external beam of polarized deuterons up to $5 \cdot 10^{10}$ per cycle. Reaching such an intensity of polarized deuterons is the main task in 2005–2007. INR RAS (Troitsk) will take an active part in this work.

A.I. Malakhov: Czech. J. Phys. 55 (2005) A65--A74.

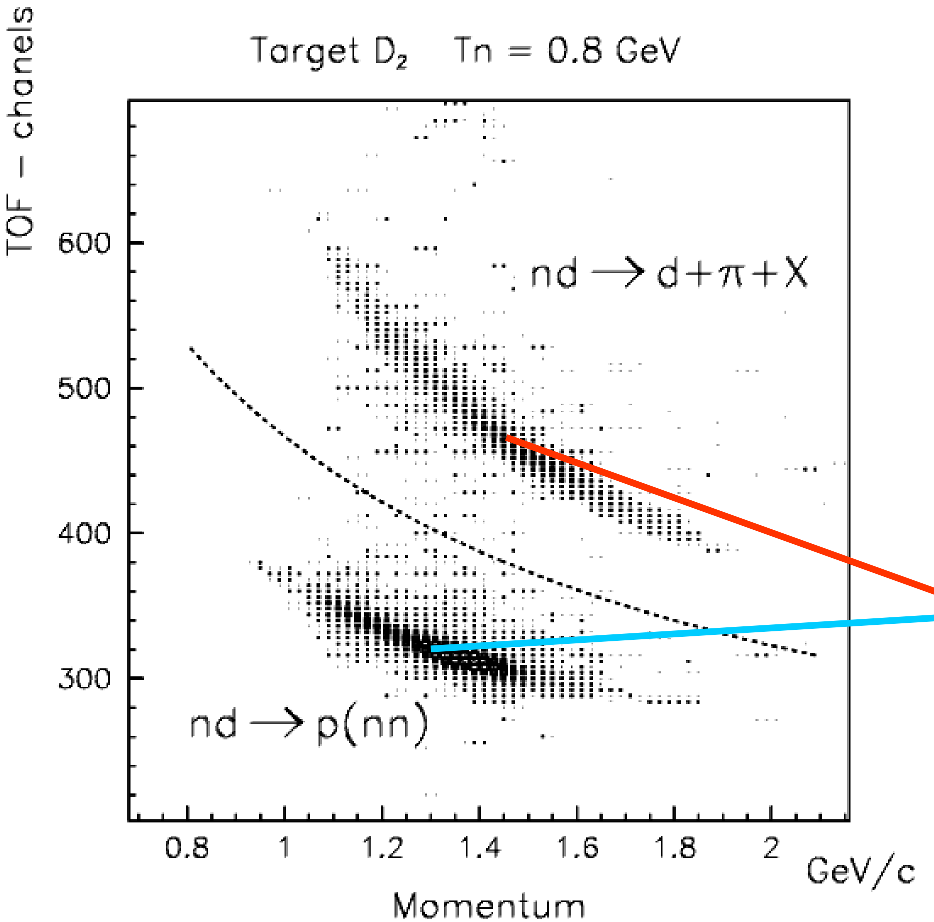


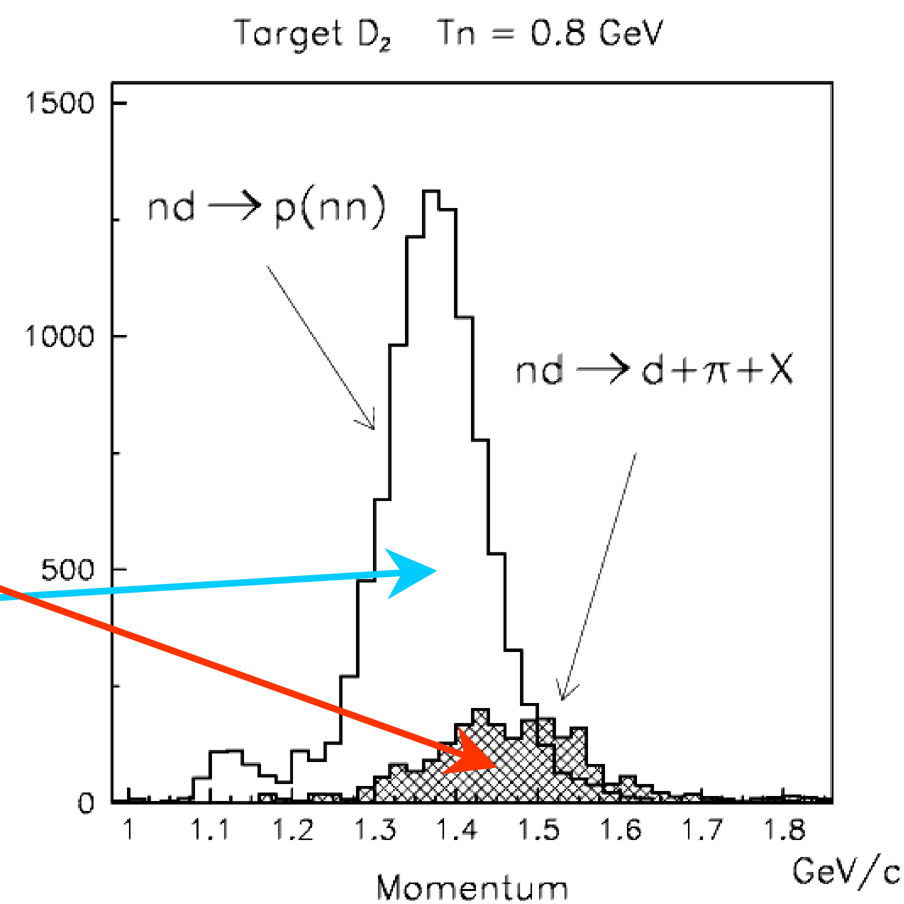
Delta Sigma **setup: SP-94 - analyzing magnetic dipole; Gx,y, 1x, 2x, 3x,y, 4x,y - two sets of multiwire propotional chambers; MPT- polarized proton target or liquid D_2/H_2 target, surrounded by DTS system for detecting of Δ recoils which decay to π, *p* and γ; trigger counters – A, S1, ST1,2,3 and time-of-flight system – S1, TOF1,2, TD1,2,3 – neutron transmission counters, M1,2 – monitors.**



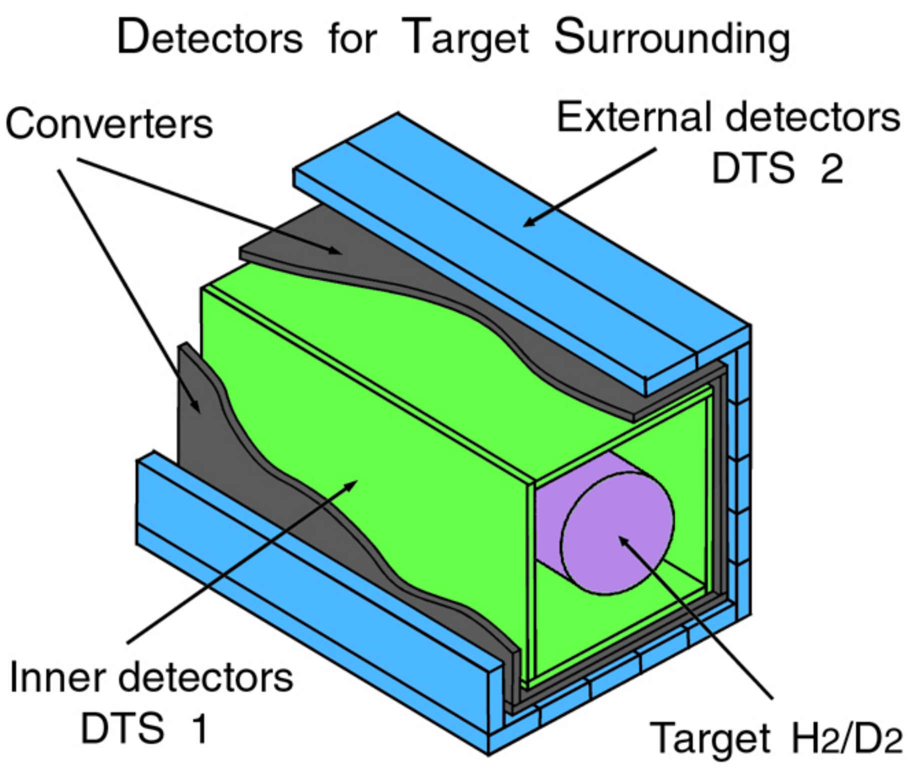


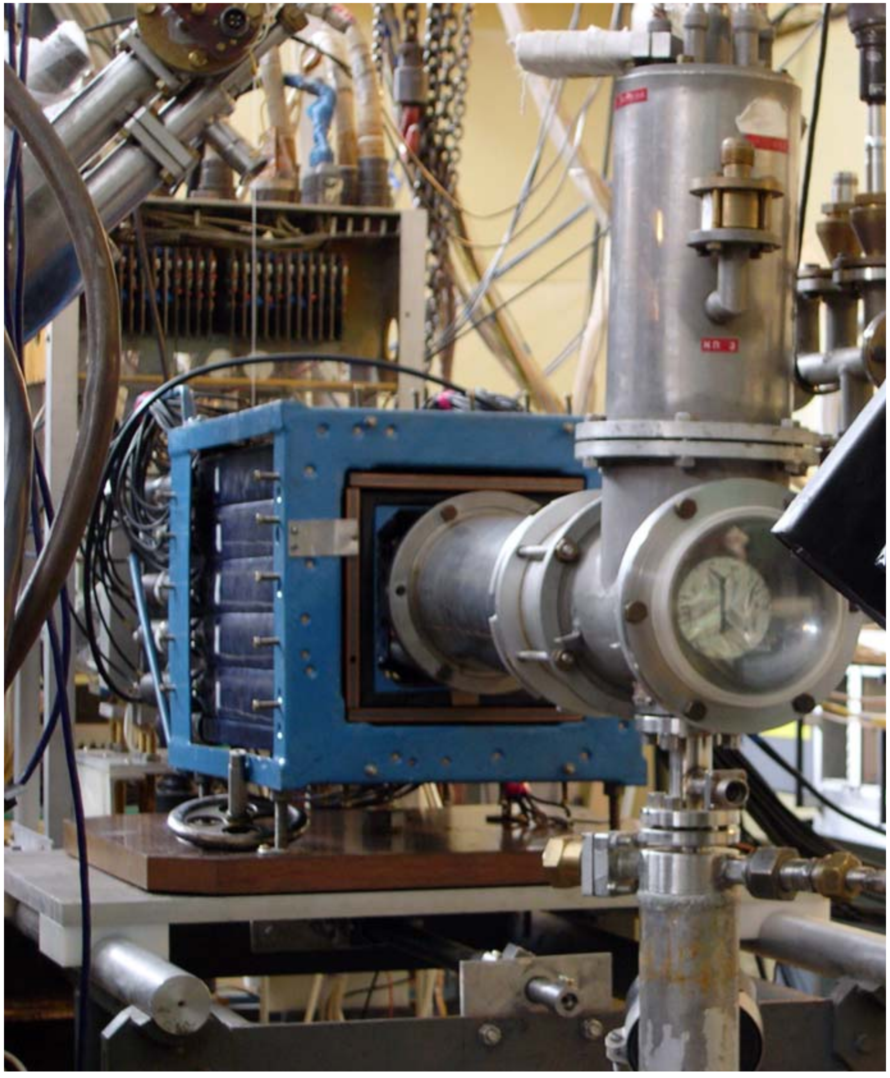
Separation the *nd→d+π+X* yield from the *nd→p(nn)* process with the help of **TOF** system and momentum spectrum magnetic analyzis

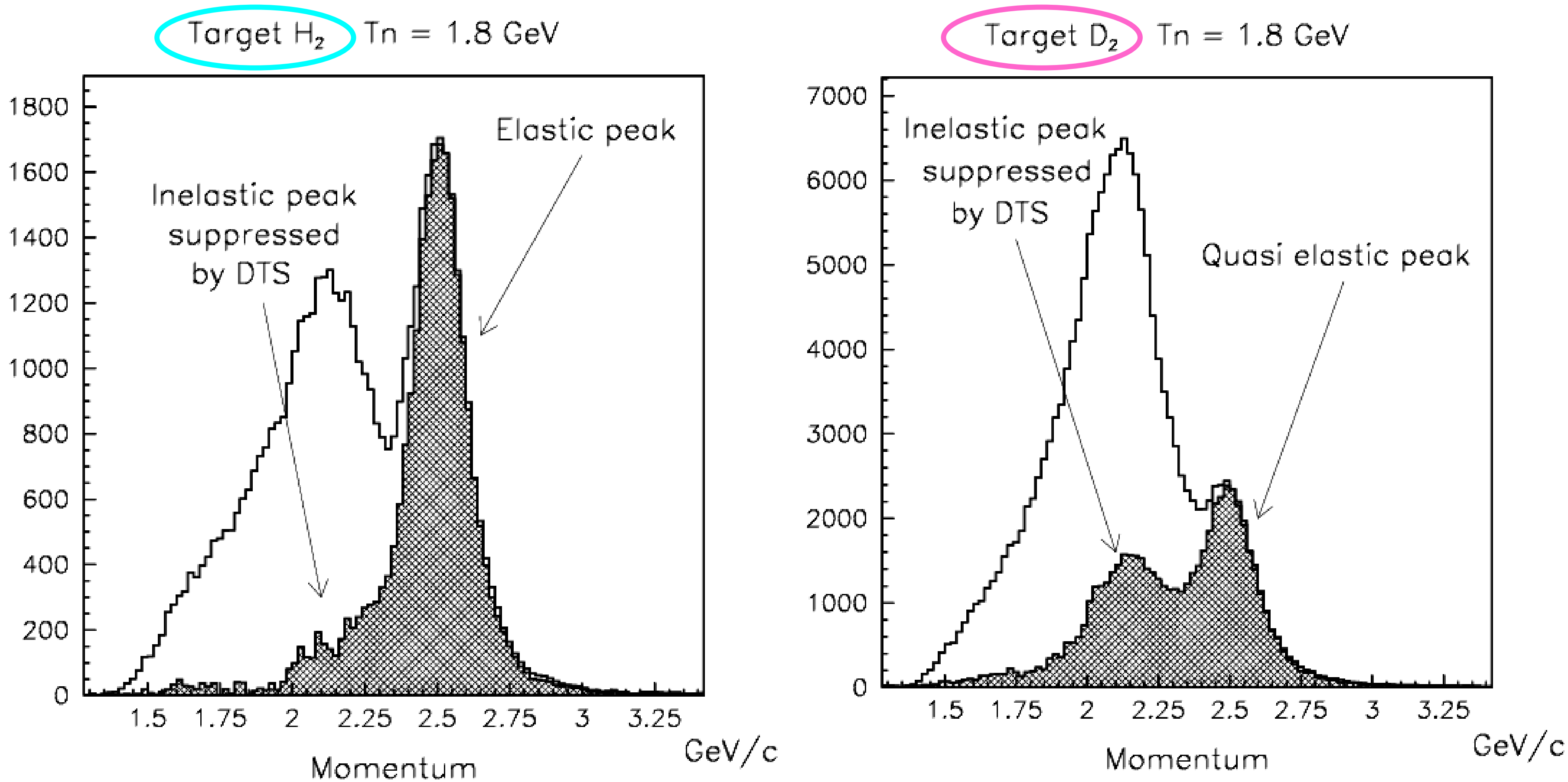




DTS system for detecting of Δ recoils which decay to π, p and γ







The rejection of the inelastic background using **DTS**. The ***shaden hists*** in the both figures present momenta spectra of charged secondaries when the signal from the DTS is in anticoincidence with the spectrometer trigger. The ***transparent hists*** show the same as ones but without the information from the DTS.

The $\Delta\sigma_{L,T}$ *(np) observables*

In this contribution, we use *NN* formalism and notations for elastic nucleon-nucleon scattering observables.

The general expression for the total cross section of a polarized nucleon beam trasmitted through a polarized proton target, with arbitrary directions of beam and target polarizations is (S.M.Bilenky and R.M.Ryndin, Phys.Lett. 6 (1963) 217, R.J.N. Phillips, Nucl.Phys. 43 (1963) 413):

$$\sigma_{tot} = \sigma_{0tot} + \sigma_{1tot}\,(P_B\, P_T) + \sigma_{2tot}(P_B\, k)(P_T\, k) \qquad (1)$$

where P_B and P_T are the beam and target polarizations, and k is the unit vector in the incident beam direction.

The term σ_{0tot} is the spin-independent total cross section, and σ_{1tot} and σ_{2tot} are the spin-dependent contributions which connect with the observables $\Delta\sigma_T$ and $\Delta\sigma_L$ by the relations:

$$-\Delta\sigma_T = 2\,\sigma_{1tot} \qquad (2)$$

$$-\Delta\sigma_L = 2\,(\sigma_{1tot} + \sigma_{2tot}) \qquad (3)$$

Values of σ_{0tot}, $\Delta\sigma_{T}$ and $\Delta\sigma_{T}$ are connected with the imaginary parts of three invariant forward scattering amplitudes *a* + *b*, *c* and *d* via three optical theorems:

$$\sigma_{0tot} = (2\pi/K)\ Im\ [a(0) + b(0)], \qquad (4)$$

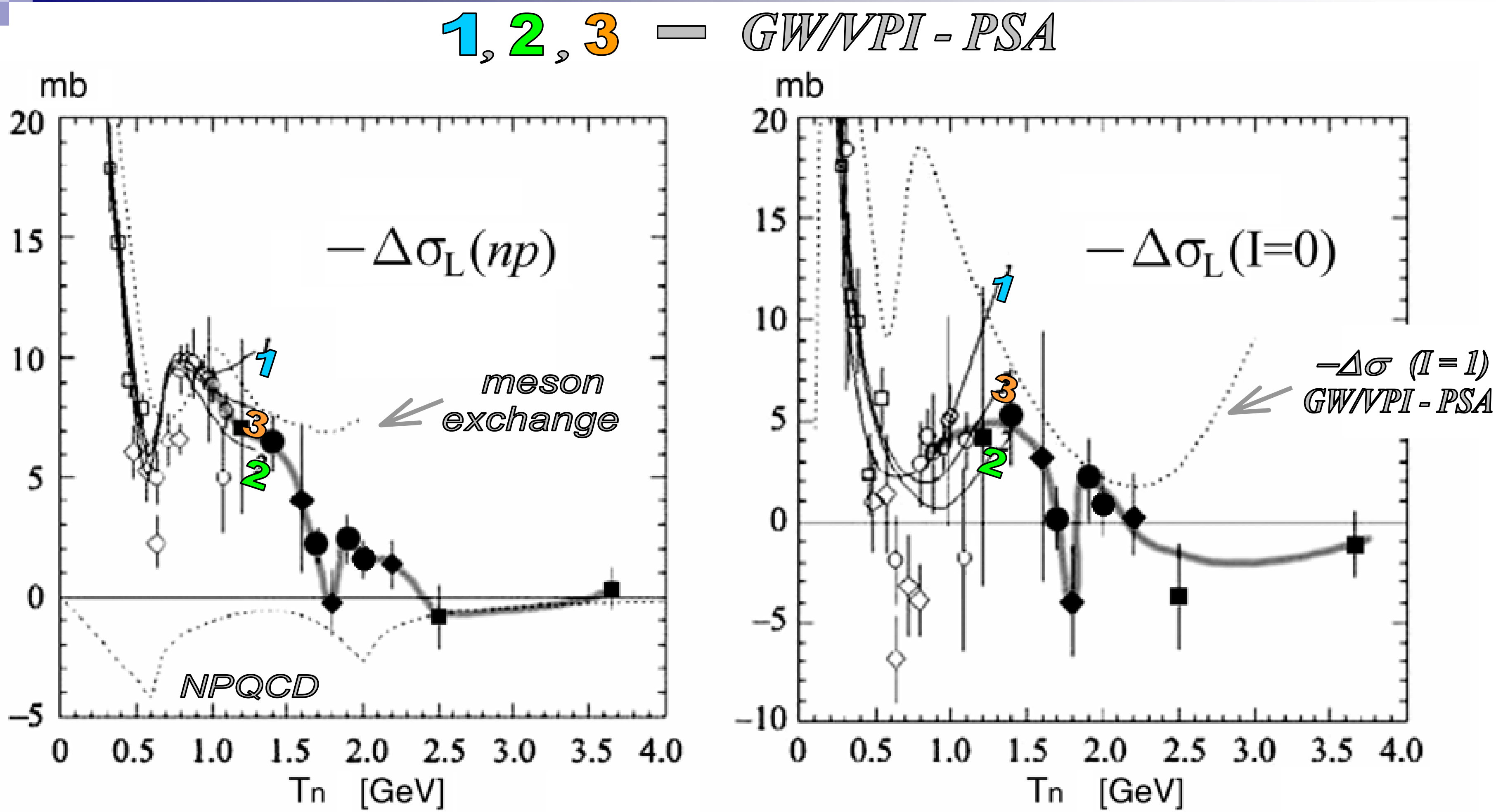
$$-\Delta\sigma_{T} = (4\pi/K)\ Im\ [c(0) + d(0)], \qquad (5)$$

$$-\Delta\sigma_{L} = (4\pi/K)\ Im\ [c(0) - d(0)]. \qquad (6)$$

where K is the c.m. momentum of the incident nucleon. Relations (5) and (6) allow one to extract the imaginary parts of the spin-dependent invariant amplitudes *c*(0) and *d*(0) at an angle 0° from the measurement values of $\Delta\sigma_{L}$ *and* $\Delta\sigma_{T}$.

Using the measured values of $\Delta\sigma_{L,T}$ (*np*) and the existing $\Delta\sigma_{L,T}$ (*pp*) data at the same energy, one can deduce $\Delta\sigma_{L,T}$ (I=0) *as:*

$$\boxed{\Delta\sigma_{L,T}\ (I=0) = 2\Delta\sigma_{L,T}\ (np) - \Delta\sigma_{L,T}\ (pp).} \qquad (7)$$



Energy dependences of the $-\Delta\sigma_L(np)$ and $-\Delta\sigma_L(I=0)$ respectively (black simbols – data of our experiment Delta-Sigma; open simbols – other world data; dotted curves at the left hist are the meson exchange model [16] (top curve) and the NPQCD by N.Kochelev (down curve); dotted curve at the right hist is the $-\Delta\sigma_L(I=1)$ dependence from GW/VPI-PSA; full curves 1,2,3 at the both hists: 1) **FA95 solution**, 2) **SP99 solution** and 3) **SP03 solution**.

The $-\Delta\sigma_L(np)$ data measured in Dubna, inclusive the **new accurate latest data [3b,c]** between 1.4 and 2 GeV, are plotted in Fig.5. Their **energy dependence (see darkned curve in Fig.5) connect well with the** also free-neutron **$-\Delta\sigma_L$ data from Saclay**. The JINR data show a **fast unexpected decrease above 1.1 GeV**, and suggest a minimum in the vicinity of 1.8 GeV. The solid curves 1–3 represent the fits of $\Delta\sigma_L$ from solution of the energy dependence (ED) phase shift analisis below 1.3 GeV. **Above 0.6 GeV the PSA fits are only in qualitative** agreement with the measured values. Moreover, **above 1.0–1.3 GeV the tendencies of the ED PSA (curves 1–3) are in disagreement** with the energy dependence of the Dubna data.

Below 2.0 GeV, a usual meson exchange theory gives the $-\Delta\sigma_L(np)$ energy dependences [8] which disagree with data above 1 GeV Fig.5, the left panel).

The presented values of isosinglet I=0 part of $-\Delta\sigma_L$ are calculated from *np* results and from *pp* data using Eq.7 (see Fig.5, the right panel).The Dubna results show a plateau around 1.4 GeV, followed by a fast decrease and suggest a **minimum in the vicinity 1.8 GeV**. **This structure is better pronounced in the $-\Delta\sigma_L$(I=0) energy dependence than in the $-\Delta\sigma_L(np)$ one**. **Above 0.5 GeV the PSA olutions are not in agreement with data**.

In [3] we discussed the Kochelev model of a nonperturbative contribution to $\Delta\sigma_L$ flavour-dependent interaction between quarks, induced by a strong fluctuation of vacuum gluon fields, i.e. instantons. The **former prediction disagrees with the latest experimental $\Delta\sigma_L$ data [3].**

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8 **T.-S.H. Lee.: Phys. Rev. 29 (1984) 59.**

The manifestation of exotic dibaryons in the energy $\Delta\sigma_L$ dependence of *np* observables was predicted [4] by the Cloudy Bag Model and R-matrix connection to long-range meson-exchange force region with the short-range region of asymptotically free quarks. **This hybrid model gives the lowest lying exotic six-quark configurations in the isosinglet $^3S_1$ state with the mass M = 2.63 GeV and $T_{kin}(n)$ = 1.81 GeV). It is close to the energy where the structure is suggested by our results**.

A complete *np* data set at 0°/180° and DRSA for (I=0) would allow to discuss possible energy-dependent structures at the level of complex scattering amplitudes and not only at the level observables.

What can be deduced from the existing and planned $\Delta\sigma_L(np)$ experiments? First of all **$-\Delta\sigma_T$** contains no uncoupled spin-triplet contribution, hence a $^3S_1$ resonance effect in this observable may be **less diluted by other spin-states than in $-\Delta\sigma_L$**. **The measurement $-\Delta\sigma_T(np)$ and the determination of the $-\Delta\sigma_T$(I=0) energy dependence provide a significant and sensitive check of the predicted resonance**. Moreover, in difference ($\Delta\sigma_L - \Delta\sigma_T$) the spin-singlet contribution vanishes. For this reason, the **accurate $-\Delta\sigma_{L,T}(np)$ measurements, in small energy steps, near to T_{kin} = 1.8 GeV are desirable**. **The I=0 spin dependent total cross section differences represent a considerable advantage for studies of the $^3S_1$ state around 1.8 GeV**, **since this partial wave is expected to be dominant**. This is In contrast with the I=1 system.

Measurements of the $A_{00kk}(np)$ and $A_{00nn}(np)$ from $np \to pn$ process.

According to [**F.Lehar, Private Comm. May 11.2005**]:

$$[d\sigma/d\Omega]_{pol}(E,\theta) = d\sigma/d\Omega(E,\theta)\,[1 + A_{00n0}(E,\theta)\,P_B^{\,n} + A_{000n}(E,\theta)\,P_T^{\,n} + A_{00nn}(E,\theta)\,P_B^{\,n} P_T^{\,n} + A_{00ss}(E,\theta)\,P_B^{\,s} P_T^{\,s} + A_{00kk}(E,\theta)\,P_B^{\,k} P_T^{\,k} + A_{00sk}(E,\theta)\,(P_B^{\,s} P_T^{\,k} + P_B^{\,k} P_T^{\,s})], \qquad (8)$$

where $d\sigma/d\Omega$ is a cross section for unpolarized nucleons.

If the scattered particles are detected at 0° angle then analyzing powers $A_{00n0}(E,0) = A_{000n}(E,0) = 0$ and parameters $A_{00sk}(E,0) = 0$ and $A_{00ss}(E,0) = A_{00nn}(E,0)$. Thus, only two non-vanishing spin-dependent quantities $A_{00nn}(E,0)$ and $A_{00kk}(E,0)$ remain in (8).

Due to symmetries of amplitudes, which hold separately for isospins I=0 and I=1, the same relations are valid at Θ c.m = π. Moreover the amplitude e(0) = e(π) for any isospin. The measurement *np* observables at Θ c.m = π are connected with the invariant amplitudes as follows:

$$d\sigma/d\Omega\,(\pi) = \tfrac{1}{2}\,[\,|a|^2 + |b|^2 + |c|^2 + |d|^2\,], \qquad (9)$$

$$d\sigma/d\Omega\,A_{00nn}(\pi) = \tfrac{1}{2}\,[\,|a|^2 - |b|^2 - |c|^2 + |d|^2\,], \qquad (10)$$

$$d\sigma/d\Omega\,A_{00kk}(\pi) = Re\,a^*\,d + Re\,b^*\,c. \qquad (11)$$

where all experimental quantities and amplitudes are Θ c.m = π.

These equations can be transformed to:

$$d\sigma/d\Omega\ (1 + A_{00kk}) = |b + c|^2 = A + (Re\ b + Re\ c)^2, \qquad (12)$$

$$d\sigma/d\Omega\ (1 - A_{00kk} - 2A_{00nn}) = |b - c|^2 = B + (Re\ b - Re\ c)^2, \qquad (13)$$

$$d\sigma/d\Omega\ (1 - A_{00kk} + 2A_{00nn}) = |b + c - 2d|^2 = C + (Re\ b + Re\ c - 2Re\ d)^2, \qquad (14)$$

where terms A, B, C contain the imaginary parts of amplitudes only. The real parts of the amplitudes b, c and d can be determined from Eqs. (12-14) using known imaginary ones. A knowledge of I = 1 system is assumed in order to use the amplitude symmetries for the transformation of I = 0 amplitudes from $\Theta = 0$ to $\Theta = \pi$ and vice versa.

R_{dp} ratio for charge-exchange at t = 0 and ratio $r^{nf/fl}(np \to pn)$

Energy dependence of the ratio

$$\mathrm{R}_{dp} = d\sigma / d\Omega(nd \to pnn) \;/\; d\sigma / d\Omega(np \to pn) \qquad (15)$$

Energy for the charge exchange process at 0° in Lab.(or elastic $np \to pn$ and quasi elastic $nd \to pnn$) in backward scattering in c.m.) was measured at high intensity non-polarized neutron beam from the Nuclotron using the magnetic spectrometer and hydrogen and deuterium targets. R_{dp} is connected [5] with helicity *NN* amplitudes by:

$$\mathrm{R}_{dp} = \frac{d\sigma / d\Omega(nd)}{d\sigma / d\Omega(nd)} = \frac{2}{3}\frac{1}{(1+R')} \qquad (16)$$

, where:

$$R' = \frac{\left|\phi_4 - \phi_2\right|^2}{2\left|\phi_1\right|^2 - \left|\phi_4 + \phi_2\right|^2} = r^{nfl/fl}_{np\to pn}(\pi) \qquad (17)$$

or used in Sacly formalizm (**F.Lehar, Private Comm. May 11.2005**):

$$r^{nfl/fl}_{np\to pn}(\pi) = \frac{\left|a+b\right|^2}{\left|a+b\right|^2 + 2\left|c\right|^2 - d^2} \qquad (18)$$

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5 R. Binz et al.: Helvetica Phys. Acta 65 (1992) 880

where φ_i are the helicity *NN* amplitudes and $R' = r^{nf/fl}$ (or R^{ID}) **is the ratio of 'spin non-flip' to 'spinflip' cross sections for *np* → *pn* process**,

$$d\sigma/d\Omega(np)(\pi) = (d\sigma/d\Omega)^{nfl}_{np} + (d\sigma/d\Omega)^{fl}_{np} \tag{19}$$

We have [6] in the impulse approximation frame:

$$d\sigma/d\Omega(nd \to pnn) = \left[1 - F\right](d\sigma/d\Omega)^{nfl}_{np} + \left[1 - \frac{1}{3}F\right](d\sigma/d\Omega)^{fl}_{np} \tag{20}$$

F(π)=1, in backward direction, hence we have:

$$\boxed{d\sigma/d\Omega\ (nd) = \frac{2}{3}(d\sigma/d\Omega)^{sfl}_{np}} \tag{21}$$

and according to (19), (21)

$$R' = r^{nfl/fl}_{np\to pn}(\pi) = \frac{2}{3}\frac{1}{R_{dp}} - 1 \tag{22}$$

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6 **R. Lednicky, V.L. Lyuboshitz et al.: in Proc. XVI Int. Seminar ISHEPP Dubna} June (2002), Dubna JINR (2004) v.1 p.199.**

Relation (21) demonstrates the using of a deuteron as a filter for non spin-flip amplitudes at $t \approx 0$, i.e. non spin-flip contribution, due to the Pauli principle, vanishes for $nd \rightarrow p(nn)$ quasi-elastic reaction with two low neutrons with parallel spins. The obtained values of **$r^{nf/fl}$ give an additional relation (18) or (17) which allows to avoid ambiguities of the real parts φ_i extraction by DRSA procedure**.

For the first time energy dependence $r^{nf/fl}$ over $0.2 \leq T_n \leq 540$ MeV was defined with the help of φ_i (I =1, 2, 4) amplitudes of $np \rightarrow pn$ c.ex. obtained from DRSA [5] at the Paul Scherer Institute (PSI), where a complete *np*-data set has been measured and used by R. Binz et al. [5] $\Delta\sigma_{L,T}$, σ_0 – In transmission experiment at 0°; spin correlation parameters $A_{00kk/nn}$ and I_0 differential $np \rightarrow pn$ cross section - in c.ex. experiment; the sign ambiguities were removed by using spin transfer parameters $K_{0n''n0}$ and $K_{0k''k0}$ data [14] for the free *np*–scattering at 180°). The 0° and 180° are closely related by the isospin decomposition, $\varphi^{np}=0.5(\varphi^{I=1}+\varphi^{I=0})$, and by the symmetry properties of the I=0, I=1 amplitudes. The $\varphi^{I=1}$ were taken from *pp*–scattering. **At Fig.7 the DRSA results for the three nonzero helicity amplitudes φ_1, φ_2 and φ_4 of the *np*-scattering at 180° are shown for T_n = 0.54 GeV. One can see that the value of *Re* φ_4 is deviating strongly enough from PSA**. **A proper deviations (Fig.8) one can see for $r^{nf/fl}$ value at 0.54 GeV** (drawn as black triangle), **obtained using Eq. (17) by Binz**, and `black circles', predicted by SG-PSA. The value $r^{nf/fl}$ at T_n = 0.38 GeV (open square in Fig.8), got from JINR R_{dp} measurements [9] agrees with Binz DRSA results and the LAMPF points (others open squares) got from the [11, 12, 13] R_{dp} measurements agree the tendency in Binz data for $r^{nf/fl}$ to decrease with the T_n increase.

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5 **R. Binz et al.: Helvetica Phys. Acta 65 (1992) 880**

11, 12, 13 **B.E. Bonner et al.: Phys. Rev. C17 (1978) 664**

The Dubna preliminary $r^{nf/fl}$ values (in Fig.~8) got from the seven measurements of R_{dp} points (Table 1, Fig.6) over the $0.8 \leq T_n \leq 2$ GeV energy region, are in a good agreement with the LAMPF results. However, they show that in this T_n region a steep fall down of the ratio $r^{nf/fl}$ with T_n increase stopped. PSA predictions for $r^{nf/fl}$ (drawn as black circles), got for $T_n \geq 0.8$ GeV give strongly irregular values when T_n increases (with large spread in many times (4, 14, 5, 10) exceeding the experimental estimates; and at $T_n \geq 1.1 - 1.3$ GeV the PSA *np* data do not exist. It will be interesting to look at the energy behavior of $r^{nf/fl}$ when the complete data set under 0°/180° for the Dubna's energies will be acquired, and as a result of the DRSA the φ_1, φ_2 and φ_4 amplitudes for the elastic scattering at 180° will become known, and using them to define the energy behavior of the ratio $r^{nf/fl}(180°)$ at $T_n \geq 0.8$ GeV as well. But this will occur as soon as the intensity of the polarized *d* beam of the Nuclotron increase, and correspondingly the intensity of the stripping neutrons beam increase.

In the following year we can possibly advance in the energy behavior investigations of $r^{nf/fl}$ up to $T_n \approx 2.5$ GeV using the R_{dp} measurements. But this is not very simple, because the elastic charge-exchange $np \rightarrow pn$ and $nd \rightarrow p(nn)$ cross section at 0° continues to decrease with T_n increase, so its separation from the inelastic one (with the Δ^0 and π production) becomes more difficult (Fig.3) using the momentum magnetic analysis, TOF and DTS-systems with the data treatment system elaborated by us, briefly described in item 3. **As to "theoretical" systematical errors, omitted in our data $r^{nf/fl}(0)$** (in Table 1 and Fig.8), concerned with using Eq.(21), (22) which were obtained in the **impulse-approximation**, we can give the encouraging latest references [7]. **The authors of Ref. [6,7] give the estimation of them as a some percents** (see for example Figs.2,4 from Ref.[7]).

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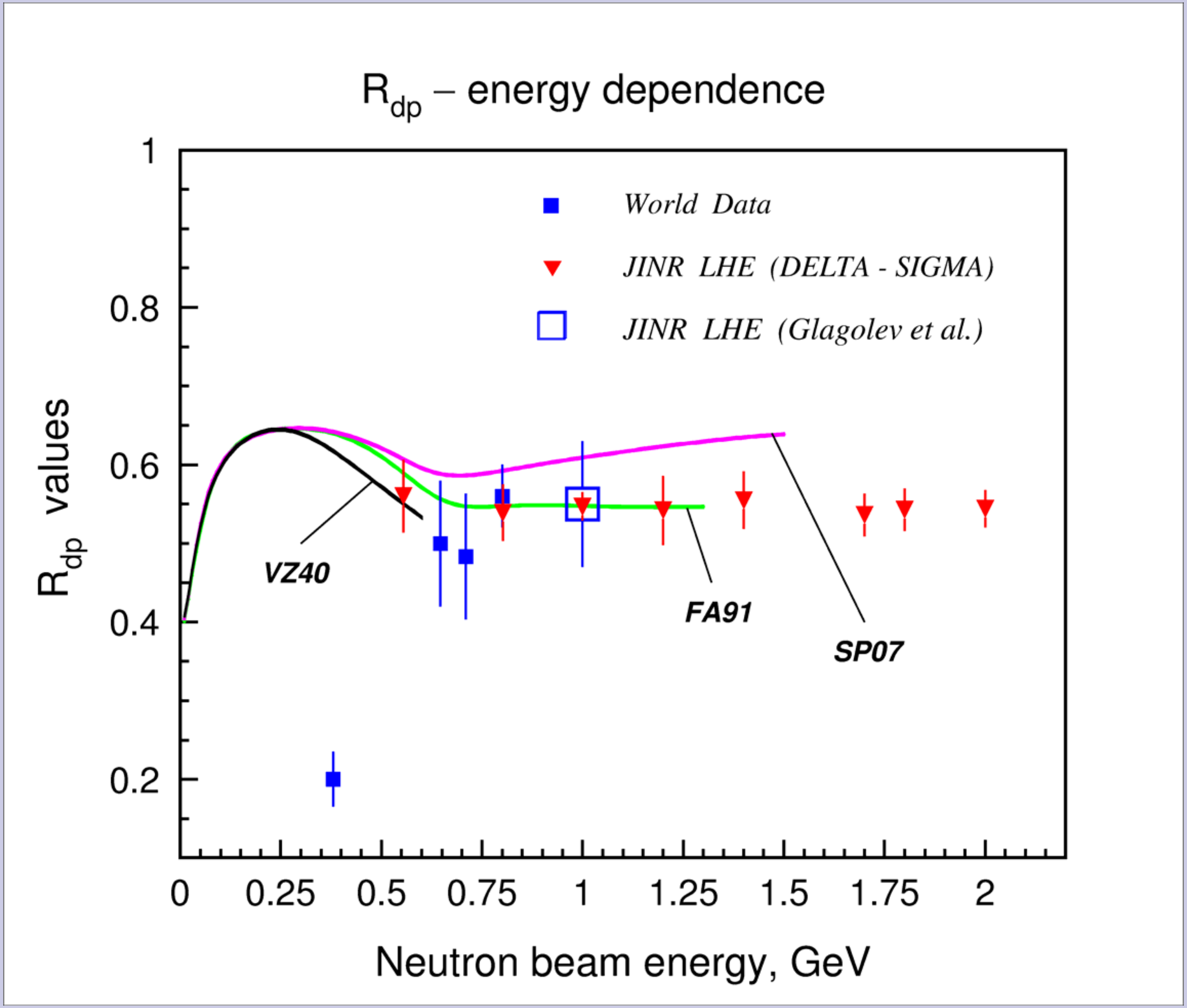
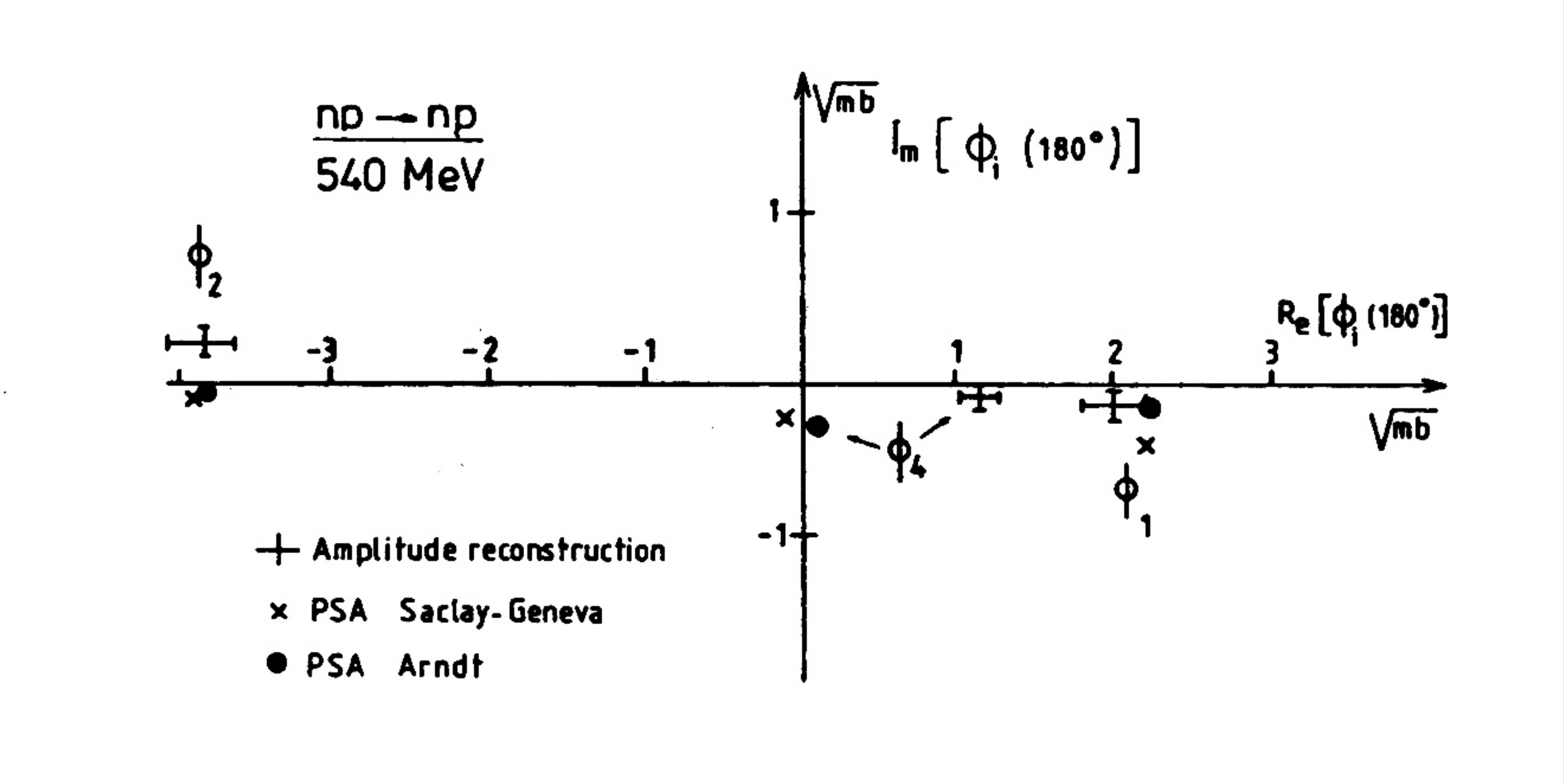
6 **R. Lednicky, V.L. Lyuboshitz et al.: in Proc. XVI Int. Seminar ISHEPP Dubna} June (2002), Dubna JINR (2004) v.1 p.199**

7 **S.S. Semikh et al.: ibid p.230**

DELTA-SIGMA results

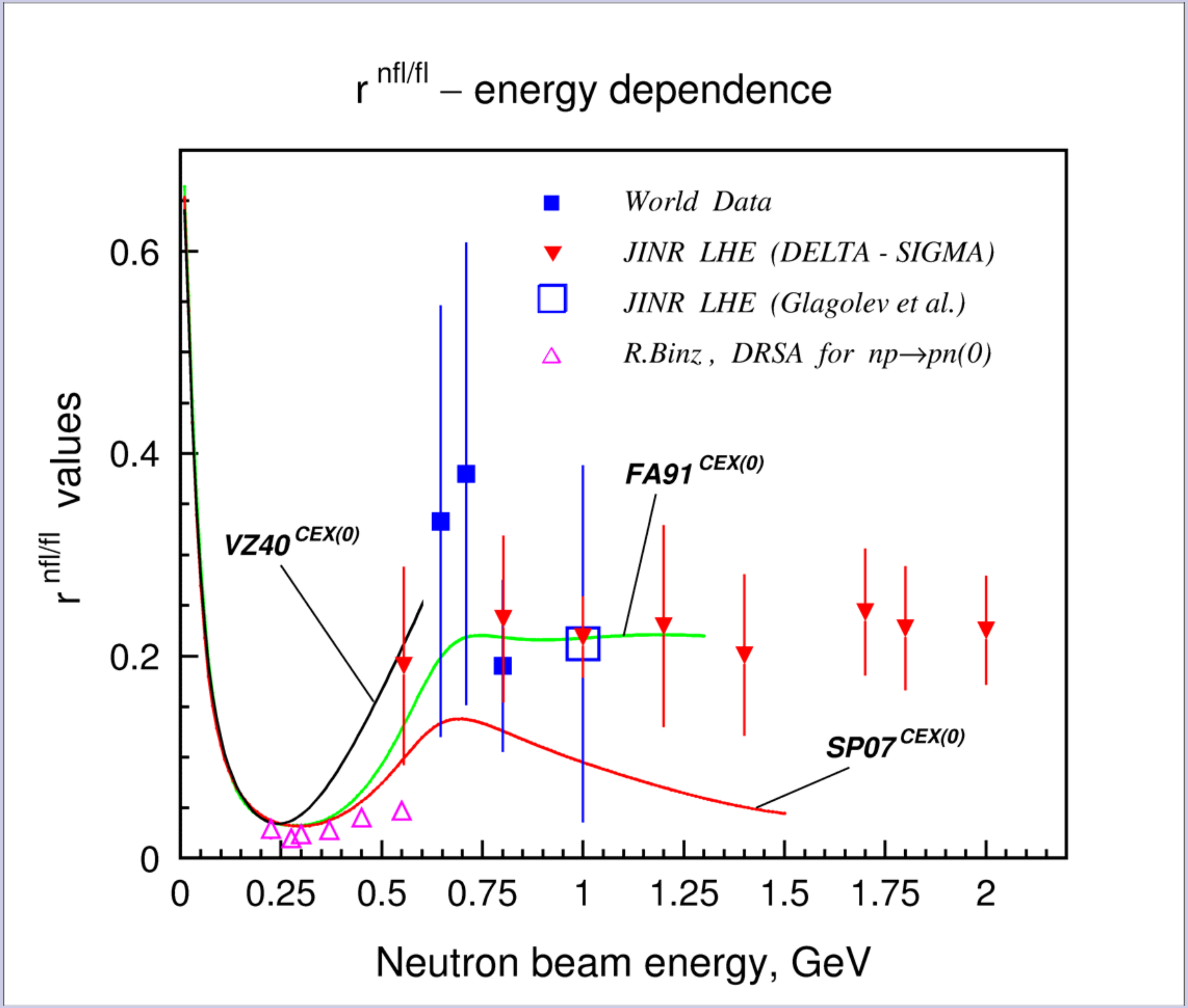




180°c.m. *np* amplitudes at 540 MeV,

DRSA reconstructed by R. Binz at PSI [5]

DELTA-SIGMA results



Conclusion

1 New $-\Delta\sigma_L(np)$ accurate results complete in the main the measurement of the $-\Delta\sigma_L(np)$ and $-\Delta\sigma_L(I=0)$ energy dependences at the Dubna Synchrophasotron region. The comparison of the **$\Delta\sigma_L(I=0)$ and $\Delta\sigma_L(I=1)$** energy behaviours shows that they are **significantly different** in the whole region of measured energies.

2 **An unexpected anomalous rapid decrease of $-\Delta\sigma_L(np)$, $-\Delta\sigma_L(I=0)$ values above 1.1 GeV** was confirmed in the latest run and a **minimum around 1.8 GeV** is observed, which **was predicted as a signal of *NN* system phase transition** at this energy, with excitation of lowest lying exotic 6q-state $^3S_1(I=0)$ with mass 2.63 GeV [4].

3 **The necessity of the complete *np* data set at 0°/180° for direct reconstruction of all three isosinglet amplitudes at 0° in the kinetic energy region above 1.1 GeV (especially around 1.8 GeV) is emphasized**.

4 The possibility of **such measurements was demonstrated** in $-\Delta\sigma_L(np)$ and $np\rightarrow pn$ at 180° investigation with Delta-Sigma set-up. A **number of physical and methodical results on investigation** of the quasielastic $nd\rightarrow p(nn)$ and the elastic $np\rightarrow pn$ charge exchange process at 0° over a few GeV region are also presented. **The possibilities for R_{dp} measurements, using prepared magnetic spectrometer, were demonstrated up to T_n = 2 GeV**. **The $r^{nf/fl}(\pi)$ ratio of non-spinflip to spinflip parts in $np\rightarrow pn$ backward scattering was firstly obtained, by R_{dp} measurements, at T_n = 0.55 — 2.0 GeV**.

5 Our “road map” **current “Delta Sigma” project** for the coming 2006-2010 years it needs to be done:

to continue our $r^{nf/fl}(\pi)$ measurements up to PSI energies ≈ 0.5 GeV, where the complete *np* data set and DRSA for all three nonzero helicity amplitudes φ_i has been obtained at 180° and $\varphi_{1,2,4}$ were reconstructed and used for obtaining $r^{nf/fl}(\pi)$; after comparing our $r^{nf/fl}(\pi)$ with one obtained at PSI, to continue our $r^{nf/fl}(\pi)$ measurements by $R_{dp}(0)$ up to highest Dubna T_n with small errors, especially around T_n = 1.8 GeV;

to prepare T-mode of PPT-target polarization and to obtain high intensity T/L-polarized *n* beam, with new polarized *d* source [15] at the Nuclotron (CIPIOS);

to exactly reveal the observed structure in $-\Delta\sigma_L(np)(I=0)$ at 1.8 GeV, to obtain a complete *np* data set at 0°/180° in the Nuclotron energy region and **to fulfill direct reconstruction of all three nonzero φ_1, φ_2, φ_4 forward *NN* scattering amplitudes (*Re* φ_i and *Im* φ_i),** and as a result (**to reach the discovery [4] of *NN*→6q phase transition**) **to fulfill the Argand diagram exhaustive analysis of energy dependencies φ_i of elastic scattering amplitudes i=1,2,4 at 0°, first of all around T_n = 1.8 GeV**.