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PHYSICS with the Medium Resolution Spectrometer

(Letter of Intent)

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PHYSICS

with the

Medium Resolution Spectrometer

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CONTENTS

SUMMARY

We propose to use the Medium Resolution Spectrometer (LAMPF, Los Alamos, USA) at the accelerator complex of the Laboratory of High Energies of the JINR (Dubna, RUSSIA). Installation of this spectrometer opens new opportunities for the LHE research program in relativistic nuclear physics and particle physics in the "transition regime" region using various nuclear beams as well as polarized deuteron and nucleon beams up to momenta of 6 GeV/c per nucleon. Common utilization with the polarized proton target (ANL-Saclay-JINR) opens unique opportunities for studies of spin effects in this energy region.

The proposed physics program covers a broad field of researches and includes different experiments on polarization phenomena studies, production of strange particles and antibaryons and excitations of various types of nucleon resonances. Part of this experiments have been approved by the JINR Scientific Committees. The "core" of the program consists from the experiments studying polarization phenomena in various processes.

The Letter of Intent is prepared by A.A. Baldin, S.N. Filippov, V.V.Glagolev, F.F. Guber, A.B. Kurepin, Yu.A. Panebratsev, N.M. Piskunov, M.G. Sapozhnikov, I.M. Sitnik, E.A. Strokovsky, M. Tokarev, Yu.A.Troyan.

The preliminary cost of this project is about 100 k$, 50 k$ is needed for transportation the MRS from Los Alamos to Dubna and 50 k$ for its installation at Laboratory of High Energies. We assume that the MRS will be available for experiments in 1997.

INTRODUCTION

Problems of understanding the nature of confinement in strong interactions, origin of nucleon spin and QCD vacuum structure pertain to the most fundamental problems of the modern nuclear and particle physics. The progress in solving of these problems is based on the intense experimental and theoretical studies of processes occurring at distances from the confinement radius, where nonperturbative effects dominate, up to those, where the perturbative QCD begins to be valid, i.e. in the so-called "transition region". Polarization phenomena in strong interactions are one of the most informative sources about physics of the "transition region".

The main goal of the present project consists in implementing an international collaborative research program of the experimental and theoretical studies of polarization phenomena in relativistic nuclear physics and particle physics. The Synchrophasotron - Nuclotron accelerating complex is the most suitable facility for realization of such scientific program at present time, and use of its potential for realizing suggested collaborative experiments is the cornerstone of this proposal.

The acceleration complex of the LHE JINR has now two accelerators. The first machine is the well–known Synchrophasotron, which accelerates protons up to $T_{kin} \simeq 9$ GeV, and nuclei (including ^{28}Si) with $Z/A = 1/2$ up to $T_{kin} \simeq 4$ GeV/A, in particular polarized deuterons; beams of polarized nucleons can be obtained by breakup of polarized deuterons. The new machine is the superconductive synchrotron, the Nuclotron, which will accelerate protons up to $T_{kin} \simeq 12.8$ GeV and nuclei (including ^{238}U) up to $T_{kin} \simeq 6$ GeV/A (for $Z/A = 1/2$). The completion of slow extraction system for the Nuclotron beams is one of the 1-st priority tasks of the LHE for nearest future. The main characteristics on the complex are given in the Appendix (6.1).

The proposed program is oriented on use of unpolarized and polarized beams from both machines of the existing acceleration complex of the LHE JINR and the polarized proton or deuteron target (the MPPT complex, described in Appendix, 6.2) as well as the conventional cryogenic and solid targets. It consists of two parts. This division is determined by features of the MRS spectrometer outlined below; technical characteristics of the MRS are given in Appendix, 6.3.

The first part of the program includes experiments with the MRS as the main detector; for some of the experiments simple detectors must be added and this part of the program can be started immediately after installation of the MRS in LHE (the "first generation" experiments). The second part contains experiments studying various multi-particle correlations, and the MRS will be used as one arm of an multi-arm setup (the "second generation" experiments).

The following features of the MRS spectrometer, determined by its design, technical characteristics and detectors, are essential for the proposed program and experiments:

advantages and capability:

- to detect secondaries emitted from the target in a wide angular interval in both forward or backward hemispheres, because the rotation (in the horizontal plane) of the whole spectrometer around the target center is possible;

- to have large momentum acceptance (up to ±20%) with rather good momentum resolution up to the maximal central momenta of 1.8 GeV/c (nominal);
- to perform correlation measurements detecting secondaries emitted from the target at a large angle in coincidence with the forward emitted leading particle detected in another spectrometer/detector.
- to measure polarization of secondaries;
- to identify particles on their masses (using TOF measurements) and charge (using dE/dx measurements in the MRS focal plane detector);
- to reconstruct completely the geometry of the "one track" events.

Table 1: **Main parameters of the MRS**

1.	Overall dimensions (length, width, height), m	9.25 * 4.0 * 5.5
2.	Optical configuration	$QD\vec{D}$
3.	Momentum range, GeV/c	0.2–1.8
4.	Nominal momentum (B=17 kG), GeV/c	1.5
5.	Momentum acceptance, $\Delta p/p$, %	±20
6.	Momentum resolution, $\delta p/p$. %	0.08 – 0.2
7.	Solid angle, msr	7 – 9
8.	Horizontal acceptance angles, mr	±60
9.	Vertical acceptance angles, mr	±40

restrictions:

- the MRS, being once installed, cannot be moved to another place for few runs in other experiments. It means that the place to install must be carefully chosen;
- the maximal central momentum measurable in the MRS (1.8 GeV/c) is much lower than the maximal momentum (or magnetic rigidity) of the beams provided by the Synchrophasotron or Nuclotron or possible secondaries (for example, from charge exchange reactions like $(^{Z}A,^{Z-1}A)$ with relativistic nuclei);
- the "multi-track" events in the MRS cannot be reconstructed without upgrade of its detection system (additional wire chambers must be added); option of detection of two-track events with particles of opposite charges is to be investigated;
- work with PPT or cryogenic targets could be possible only without the evacuated scattering chamber, but absence of the evacuated scattering chamber should result in degrading of the momentum resolution.

These features of the spectrometer imply that this spectrometer could be used in LHE without drastic changes in its design and/or detection system in experiments of the following classes:

1. **Single-particle experiments (exclusive and inclusive), including those with cumulative particles.**
2. **Correlation experiments with detection of one charged particle in the MRS and another one in a Forward Spectrometer or a Detector of Neutrals.**

Experiments in the "single-arm" configuration.

The experiments which can be performed with the MRS as the single-arm detector are described in this section. The material is organized so that first are listed those experiments which need small (if any) modification of the existing detection system and few (if any) additional detectors. These experiments of the 1-st generation can be completed within 2-3 years after completion of the installation of the MRS in LHE. Possible extension of the experimental program (experiments of the 2-nd generation) is outlined at the end of this section.

1a. Study of spin-induced effects in few body system: backward elastic scattering.

The *dp* backward elastic scattering (180° in c.m.) is one of the classic reactions to obtain information about the deuteron structure. It is commonly accepted that the reaction is dominated by the u-channel, which corresponds to the one nucleon exchange (ONE) process. In ONE the only kinematical parameter of the reaction, the total c.m. energy s, is directly related to the internal momentum k (which is the argument of the deuteron wave function (DWF) in the momentum space, when deuteron is treated as two nucleon system). That is serious advantage of this reaction (and of the deuteron electrodisintegration as well) in comparison with *ed* elastic scattering, where observables are connected with the argument of the DWF through integral relations.

Recent measurements of the polarization observables (T_{20} and polarization transfer from the deuteron to proton) in the $dp \to pd$ and $dp \to pX$ reactions, performed in Dubna and Saclay[1, 2], have shown that treatment of this reaction in the framework of the ONE mechanism is not adequate. But obtained information is not sufficient to conclude unambiguously whether the observed effects come from the deuteron structure, which could be more complicated than the commonly accepted, or from the reaction mechanism mostly.

The wide program of investigations of the deuteron structure by an electron probe now is envisaged, in particular at TJNAF. But this approach is also not free from uncertainties about the reaction mechanism. So, the problem of the deuteron structure will hardly be solved using only such kind of information. Measurements of new polarization observables in backward elastic *dp* scattering will provide an important additional source of information about the deuteron structure.

In refs.[3, 4] it is shown that $dp \to pd$ reaction can be described by only four independent complex amplitudes. So, the complete experiment (7 polarization observables) for this reaction is quite realistic.

The spin-spin correlation experiment making use of the polarized proton target (PPT) and the polarized deuteron beam, now is adopted at Dubna[5] (BES project):

$$\vec{d} + \vec{p} \to p + d$$

This observable is, apparently, the most sensitive to presence of additional components, for example, the P-state component[6] (see Fig.), in the deuteron.

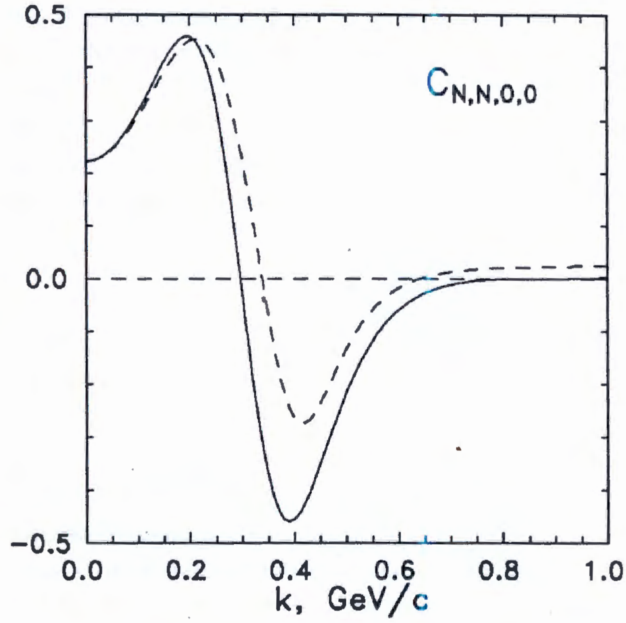

Figure 1: Spin correlation parameter $C_{N,N,0,0}$ calculated for standard DWF (Paris) (solid line) and for DWF with additional P-wave components[6] (dashed line)

We are planning to investigate this reaction at deuteron beam momenta from 3.0 up to 6.5 GeV/c; that will cover the internal momentum range from 0.3 to 0.85 GeV/c. Another proposal of measurement of the T-odd polarization observable[4] of this reaction at Dubna synchrophasotron is now under preparation.

Assembling of a new spectrometer is envisaged by project BES. It could be created on base of standard dipoles, more or less suitable for this task. The expected main parameters are following: angular acceptance is $\Delta\Omega \simeq 10^{-2}$ rad, momentum resolution is $\Delta p/p \simeq 1\%$.

The Polarized Proton Target contains about 85% of non-polarized background material (mostly carbon). So, a huge background of quasielastic scattering on nucleons in the material nuclei is expected. The momentum resolution mentioned above would allow suppression of this background to level of $\simeq 10\%$. The momentum resolution of MRS of $\Delta p/p = 0.1 - 0.2\%$ will allow to decrease this background to level of 1-2%.

The presence of a polarimeter as a part of MRS provides opportunity to measure two new polarization observables in backward elastic dp scattering, namely: the polarization transfers from the deuteron to deuteron

$$\vec{d} + p \to p + \vec{d},$$

and from the proton to deuteron:

$$d + \vec{p} \to p + \vec{d}.$$

So, the MRS will allow to measure at Dubna four polarization observables in this reaction instead of two. Together with two measured polarization observables, namely T_{20} and polarization transfer from the deuteron to proton, the total number of measured polarization observables will achieve six. That is almost the complete experiment.

It is possible, using MRS spectrometer, to study the polarization transfer from proton to ^3He in backward elastic $^3He, p$ reaction

$$^3He + \vec{p} \rightarrow p +^3 \vec{He}.$$

For this experiment the MRS is to be set at near forward angles; no additional forward spectrometer/detector is needed.

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1.b Study of spin-induced effects in few body system: spin effects in np→pn charge exchange on deuteron

The study of the deuteron break up reaction dp→(pp)n proceeding with charge exchange at small momentum transfer can give information on the spin structure of the elementary amplitude for the pn→np process. In principle it is possible to estimate the contribution of the spin-dependent elementary amplitude in terms of the impulse model throw study of differential cross section of this reaction in 4π-geometry [1–5]. But this method is model dependent and needs more complicated experimental equipment.

There exist a possibility of direct measurement of the spin-flip probability in the vectorially polarized deuteron breakup with charge–exchange on the proton target.

In this case almost zero momentum is transferred to two final protons which must have close momenta near 0.5 P_0 in the final state.

From the antisymmetry of the total wave function of the final state particles and charge symmetry of the strong interaction it follows, that there must be a spin flip of the scattered proton when two final protons are in the S-state.

For this kind of experiments the MRS is very useful and suitable instrument. Indeed, in our case the beam of vector polarized deuterons hits the hydrogen target. The spectrometer must be tuned for half of the incident deuteron momentum at zero angle. In this case it is necessary to distinguish only between one and two-proton events after the target and to measure left-right asymmetry in scattering of protons on analyzing target in the spectrometer focal plane. This asymmetry is just the signal about the spin-flip.

Similar asymmetry for one-proton events must be and can be measured as the base of reference in the same experiment.

Background for the two-proton events is negligible. For the most part proton-spectators go throw MRS in one-proton events. Assymetry in theirs scattering give additional information about change polarization in magnetic field of spectrometer.

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2. Study of strange content of the nucleon: a search for effects of the OZI rule violation in ϕ and ω mesons production in polarized deuteron beam interaction with polarized proton target

Here the study ϕ and ω mesons production in the polarized deuteron beam interaction with the polarized proton target is proposed:

$$\vec{d} + \vec{p} \longrightarrow {}^3He + \phi, \qquad (1)$$

$$\vec{d} + \vec{p} \longrightarrow {}^3He + \omega, \qquad (2)$$

The main goal of the experiment is the test of the prediction of ref.[1] that the intrinsic strangeness of the nucleon could manifest itself in the spin dependence of the ϕ-meson yield in the reaction (1). It is predicted that ϕ production will be enhanced when the proton and deuteron spins are parallel. Instead, when the spins of the beam and the target particles are antiparallel, the ϕ production is expected to be suppressed.

This effect of the strong dependence of the ϕ yield on the spin of the initial state has been observed recently in the experiments with stopped antiprotons at LEAR (CERN) (for a review, see ref.[2]). It is important to test this feature in the nucleon-nucleon interactions to verify if this effect is common for any baryon system, or it is only a peculiarity of the $\bar{p}p$ annihilation.

The measurements of the ϕ and ω yields in reactions (1)-(2) were performed at SATURNE II for the unpolarized beam and target configuration[3]. A large deviation from the OZI-rule prediction was revealed:

$$R(\phi/\omega) = (80 \pm 3^{+10}_{-4}) \cdot 10^{-3} \qquad (3)$$

It is much higher than the value $R(\phi/\omega) \approx 4 \cdot 10^{-3}$, which is expected from the OZI-rule. These results are promising and give credence to study the polarization effects of the OZI-rule violation in reactions (1)-(2).

Comparison of the ϕ-meson production with the ω-meson one could help in discrimination of the complications related to the effects of the nuclear dynamics.

The main physical advantage of the reactions (1)-(2) of ${}^3He$ production is that they provide a possibility to study OZI-rule violation at high momentum transfer region.

For the experiment it is proposed to use the Polarized Proton Target which is currently in operation in the beamline of synchrophasotron at JINR Laboratory of High Energy. The MRS magnetic spectrometer will be used to detect the ${}^3He$ produced in reactions (1)-(2).

It will be interesting to accomplish this program by the investigation of energy dependence of the yield of the reactions

$$\vec{d} + \vec{p} \longrightarrow {}^3He + X \qquad (4)$$

where $X = \eta, \eta'$.

For unpolarized pd interaction it was done at Saturne experiments, the unique feature of the JINR complex is the Polarized Proton Target and the polarized deuteron beam. It is difficult to overestimate the importance of the adequate precise spectrometer like the MRS for this kind of experiments.

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3. Study of strange particle and antibaryon production in relativistic nuclei collisions. (A) Nuclear beams.

Nucleus-nucleus collisions at high energies are of great importance to study the properties of exited nuclear matter. Systematics of available data show[1] that while in the energy range 0.2–2 GeV/u the increase of the incident beam energy leads to a considerable heating of the collision zone, at higher energies there is an appreciable conversion of translational energy into mass, i.e. excitation of nuclear resonances, so that up to one third of the baryons are exited at 2 GeV/u. We intend to perform exploratory studies of $K^{\pm}$, $\overline{p}$ and $\overline{d}$ production in the energy range 2–5 GeV/u, that is complementary to the SIS (up to 2 GeV/u) and AGS (14.5 GeV/u) energies, where the transition to thermal and chemical equilibrium seems to occur [2]. The region of secondary particles momenta of 0.2–2.1 GeV/c in the angular range of 15°–150° degrees will be covered using the Medium Resolution Spectrometer. Existent experimental data in this energy and rapidity regions are scarce and do not allow unambiguous interpretation.

The experimental program includes:

- Measurement of inclusive cross sections of $K^{\pm}$ production at low meson momenta down to 200 MeV/c with d, C, Si, Fe and Kr beams on C, Si, Fe and Pb targets. Of a particular interest is a possible K^{+}/π^{+} relative abundance as a signal of partial chiral symmetry restoration in the compressed nuclear matter.
- Comparative study of p_t and y distributions for pions and kaons in d + A and A + A reactions. These data are essential for further analysis within existing models.
- Investigation of $\overline{p}$ production in d + A and A + A collisions. Comparison of deuteron and nuclei induced reactions enables one to check validity of different production mechanisms suggested so far.
- Search for possible $\overline{d}$ production. This process is directly related with antinucleon abundance but is obviously much deeper under the threshold at our energies than the processes listed above.

It is assumed that strange particle production by heavy ions could provide information on the space-time evolution of the baryon matter formed in the collision. Kaons have been proposed[3] as one of the most promising probes of the primary stage of relativistic heavy-ion collisions. Theoretical calculations indicate [4] an appreciable sensitivity of the K^+–yield on the compressibility of nuclear matter which make them a very valuable probe for the nuclear equation of state. It has been shown also that kaons are useful in studies of in-medium properties of hadrons in the hot and dense zone formed in the reaction [5] while antiprotons probe the collectivity associated with high densities in the collision [6].

First measurements of antiproton yield were made in proton-nucleus collisions [7]. These data were successfully described [8] by including multiple nucleon-nucleon collisions and introducing reaction channels with pion production in the intermediate state. Use of relativistic ion beams gave rise to new results in the energy range near the production threshold of kaons (1.58 GeV/u) and antiprotons (5.6 GeV/u). The cross sections for $K^\pm$mesons and antiprotons were studied at the KASPIY installation of the Institute for Nuclear Research (RAS) using deuteron and carbon beams of the Synchrophasotron of LHE, JINR, Dubna [9, 10]. A strong enhancement of the yield of these particles in comparison with their yield in p+A collisions has been observed: the ratio of the antiproton to pion yields in case of nuclei-nuclei collisions was greater by factor of 40–50 (see Fig.1) [13] and for the positive and negative kaons this value is about of 2–3. An extended study of kaon and antiproton production have been made at BEVALAC and SIS energies. These studies have stimulated much interest and theoretical work on the mechanism of kaon and antiproton production.

An unambiguous picture of particle production and annihilation has not yet emerged for several reasons, including the simultaneous lack of complete kinematic coverage and "centrality" information as well as the not sufficient statistics. Theoretical descriptions of these processes are rather contradictory. While dynamical models like RQMD are able to describe available data by relying on the enhanced production of antiprotons followed by the annihilation of a large fraction of the produced antiprotons, transport models describe the data by producing less antiprotons initially, but the annihilation of antiprotons is "screened" in the high density environment. Presently systematic and statistical uncertainties in both the measurements and the calculations preclude a detailed quantitative understanding of antiproton production.

The enhancement in production cross sections of strange particles at near- and subthreshold energies may point on a substantial role of collective effects in nucleus-nucleus interactions. Some theoretical models predict this phenomenon as a result of fluctuations of nuclear matter in the critical regime on the way to formation of quark-gluon plasma [11]. Using a scaling behavior of cross sections as predicted by parton model, it is possible to evaluate qualitatively for what extent such collective effects are involved.

Production of antideuterons is much more subthreshold process at our energies. It probes latter stages of evolution of collisions, because nucleosynthethis occurs after expansion when nucleons are in close proximity and moving with small relative momenta. Abundances in antideuteron production are sensitive to baryon density of the system and to the collective processes. The measurement done by exp. E858 at the BNL-AGS [12] gives $\overline{d}$ to $\overline{p}$ ratio $\approx 10^{-5}$. There are theoretical arguments that this ratio should grows up with decreasing of the beam energy. The enhanced yield of antibarions may lead to increased production of $\overline{d}$.

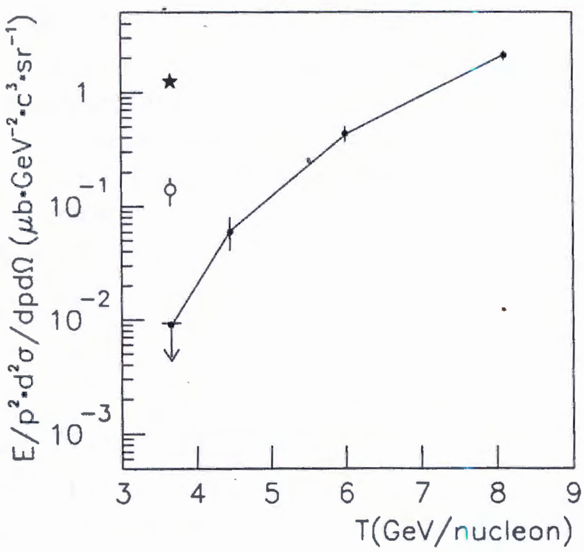

Figure 2: Antiproton production invariant cross-section *vs.* kinetic energy per nucleon of incident nucleus at antiproton momentum 0.8 GeV/c . Points are for p + C, open circles for d + C and stars for C + C data.

Because cross sections of the reactions to be investigated are rather small compared to large physical background of pions and protons, only rather limited number of experimental data exist. It is necessary to perform more detailed studies in wide ranges of energy and rapidity and for different combinations of projectiles and targets. By comparing the observed antiproton rates for different systems and for different antiproton momenta, the strong reabsorption effects might be separated from the initial production process.

To detect charged kaons and antiprotons in the vicinity of a large background of produced pions, some special requirements to the magnetic spectrometer are necessary. It should be short enough in order to minimize the loss of kaons due to their decay in flight. It should have big momentum and angular acceptances because production rate of kaons is small. Momentum range of the spectrometer should be from 0.2–0.3 GeV/c up to about 2 GeV/c. It should have at least two dipole magnets for background minimization due to proton rescattering from the poles of the magnets. In order to be able to compare particle yields it is necessary to select the same limits in y and p_t for all particles. The MRS matches these requirements in the best way. The MRS should be equipped with some additional detectors specific to our tasks. To make experimental data sensitive to geometry of the collision it is necessary to make selection on the "centrality" of the collision. It can be done with two multiplicity detectors: the large angle scintillator hodoscope of 60 counters around 45° in the target region for participant–like particles and the small–angle one for projectile–like reaction products at forward angles. The latter should have rather large number of channels (≈ 500). As a cost–effective decision we plan to design a multiplicity detector based on microchannel plates. Together with high granularity it can provide excellent timing resolution, being not sensitive to the gamma background and stray magnetic fields.

Identification of antiprotons will be done using TOF–ΔE method combined with Cherenkov counters for suppression of huge trigger rates from pions. In case of the deeply subthreshold antiproton production, were the high signal to noise ratio is essential, an existing antiproton annihilation detector mounted just behind the focal plane of the MRS will be used. It has shown good reliability and efficiency in our previous experiments[13].

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3. Study of strange particle and antibaryon production in relativistic nuclei collisions. (B) Deuteron beams.

The study of $p(d, \vec{d}, A) + A \to \pi(K, p, \bar{p}) + h_i...$, reactions where the fast particle is detected in coincidence with forward hadrons, h_i, can be very informative for investigation of cumulative and subthreshold production mechanisms.

With the selection of central AA-interactions at AGS energy the ten-order of magnitude difference in cross-section of the antiproton production was observed, depending on the multiplicity [1].

The investigation of vector analyzing power (A_y) in the reaction

$$\vec{d} + C \to p(p, d) + X,$$

where the fast proton at a large angle (75° and 90°) is detected in coincidence with forward protons (deuterons), has given an unexpected result [2]. In this semi-exclusive reaction when the trigger proton emitted in the forward direction is fast, the negative value of A_y was observed, while when it is slow, the A_y is large in absolute value and positive. However, these measurements were performed at deuteron energy up to 2.1 GeV/nucleon and had rather poor statistics.

Use of the MRS with a multiplicity detector of high granularity and with a "Zero Degree Calorimeter" makes it possible to continue this important research in the following directions:

1. To investigate the transition regime in the energy region of 2-5 GeV/nucleon.
2. To study flower structure of such effects (measuring cumulative π, K, $\bar{p}$... secondaries).
3. By varying angles from 30° to 90°, momenta 0.2- 2.0 GeV/c and type of the cumulative particle, it is possible to select different kinematical condition and scan the available rapidity interval from the target to projectile fragmentation region.
4. Investigation of the A-dependence of single spin asymmetries in $\vec{d} - A$ - interactions is interesting in order to study how the production when spin degrees of freedom are involved. The first measurements of single spin asymmetries in the reactions $\vec{d} + A \to \pi, K, p + X$, on the Synhrophasotron beams [3] have shown that increasing of the acceptance of magnetic spectrometer and covering of larger interval of momenta and emission angles of the detected particles is very important for these studies. The MRS spectrometer will give us this possibility.

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EXPERIMENTS WITH ADDITIONAL SPECTROMETERS (MULTI-ARM CONFIGURATION)

4. Study of resonance production and "single-spin asymmetries".

4.a Studies of excitation of exotic narrow resonances and their parameters

This class of experiments continues pioneering research of the 1 meter Hydrogen Bubble Chamber [1, 2], where evidences were found for existing of narrow ($\Gamma_{tot} < 10$ MeV/c^2) resonances in different systems of particles (NN, $NN\pi$, $N\pi$, $N\pi\pi$, $\pi\pi$, $\pi\pi\pi$). For excitation energies of hadrons from 0 to 1 GeV it was found a lot of peculiarities in different systems of particles, which are considered as a reflection of the structure of QCD - vacuum at large distance.

It was noted [3], that the set of the resonances of one sort (NN) could be obtained from the set of the resonances of another sort ($\pi\pi$–resonances) by a simple replacement of the rest masses of π–mesons to the rest masses of nucleons. The similar symmetry can be a result of excitation of one substance – QCD-vacuum of large distances (instanton transitions) in all cases. Really, a number of predictions about narrow-low-masses resonances are obtained from the similar mechanism considered in QCD-sum rules. As an example, in the fig.1 the mass spectrum of $\pi^+\pi^-$–combinations from the reaction $np \to np\pi^+\pi^-$ at $P_n = 5.20$ GeV/c is shown. This spectrum was obtained in the analysis of the films from 1 m Hydrogen Bubble Chamber of the LHE JINR, irradiated by the monochromatic neutrons.

The resonance with mass 730 MeV/c^2 is very intensively discussed in literature as a possible candidate for low-masses scalar glueball. The events in fig.1 are selected using special criteria to intensify the contribution from the double-gluon interactions.

Use of quasimonochromatic polarized neutron beams together with the Polarized Proton Target will give opportunity to perform careful phase analysis for the resonance region and to determine the quantum numbers of resonances.

Copious examples of another observed resonances are not presented here for brevity. It is worthwhile to note, that the transition energy region (0,6÷5 GeV) is characterized by the abundant production of different resonances. Some of these resonances can give an information about the structure of QCD–vacuum at large distances, clear up the problem of confinement and define more precisely the structure of inter-particle potentials.

All these investigations demand to detect at least two particles in the final state of the investigated reaction.

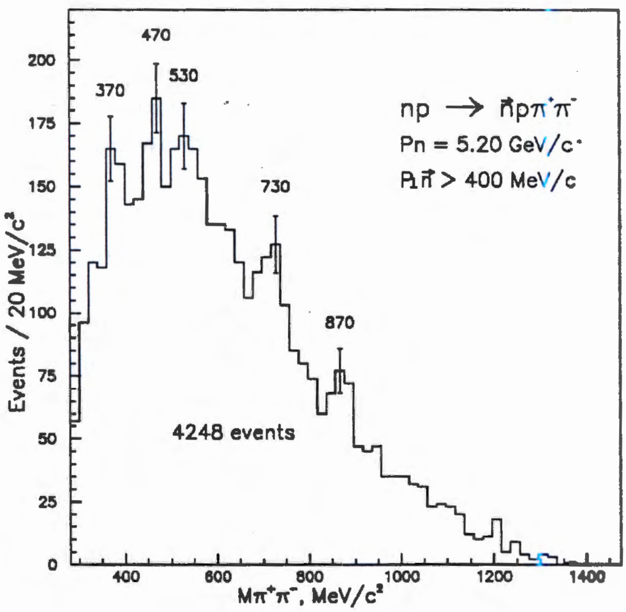

Figure 3: The effective Mass spectrum of $\pi^+\pi^-$–combinations from the reaction $np \to np\pi^+\pi^-$ at $P_n = 5.20$ GeV/c.

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4.b Studies of excitation of nucleon resonances and their parameters

Studies of baryonic resonances properties in nuclear medium and mechanisms of their excitation are performed intensively during last decade. The main reasons of interest to these problems and main difficulties as well, come from the simple circumstance that the behaviour of nuclear matter at high excitation energies (or short inter-nucleon distances) is governed not only by the nucleonic degrees of freedom but also by the internal degrees of freedom of the constituent nucleons: those cannot be treated independently when the energy transferred to the medium is close to the characteristic energy of excitation of the internal degrees of freedom. Such excitations reveal themselves as $N \rightarrow N^*$, Δ transitions followed by radiation of particles from nuclei. A strong coupling between "internal" and "external" degrees of freedom may result in difference between the resonance properties in the nuclear medium and in the "empty space".

On the other hand, properties of the nucleonic resonances are intimately related with fundamental characteristics of nucleons and interactions responsible for the origin of nuclear forces.

A non-trivial difference between resonance excitation off free protons and off nuclei was observed for the Δ-resonance in inclusive charge exchange experiments. A significant contribution of non-quasi-free mechanisms was observed. This difference with the free proton case was confirmed in dedicated exclusive experiments, but a number of theoretical uncertainties concerning the reaction mechanisms persist (see reviews[1] and references therein).

These new mechanisms can be "filtered" using several ways; each of them enhance or exclude different classes of contributing diagrams. For example, as was demonstrated in refs.[3, 1, 2], changing of the initial energy for a chosen reaction results in change of relative contributions from processes called "excitation of a resonance in projectile" and "excitation of a resonance in target"; change of quantum numbers in the initial state results in absence of some classes of possible exchanges due to isospin and spin selection rules[2, 6, 5]; switching of the spin degrees of freedom on gives possibility to distinguish between different exchanges involved[1, 2, 5]. Moreover, differences between proton and nuclear targets may be expected for some polarization observables (see ref.[4, 2, 5] and references therein) However on this subject, much more theoretical input is necessary to prepare well focused experiments of the next generation.

In the energy domain of the Dubna accelerator complex, which is optimal for studies of the Roper resonance properties[1, 2, 6], new data could be obtained on the energy dependence of the polarization characteristics and cross sections of inelastic deuteron and ^4He scattering off protons and nuclei with excitation of the Delta and Roper resonances. Such studies were pioneered at Dubna[8] (see fig.4) and Saclay[9].

With the MRS complemented by a dedicated Forward spectrometer for charged particles and by the Neutral detector, it would be possible to realize the following experimental program of extensive studies of nucleonic resonances properties in nuclear medium:

- Inelastic $p(d, d')$ and $A(d, d')$ scattering of polarized deuterons with detection by the MRS of secondary protons or pions in coincidence with the forward scattered

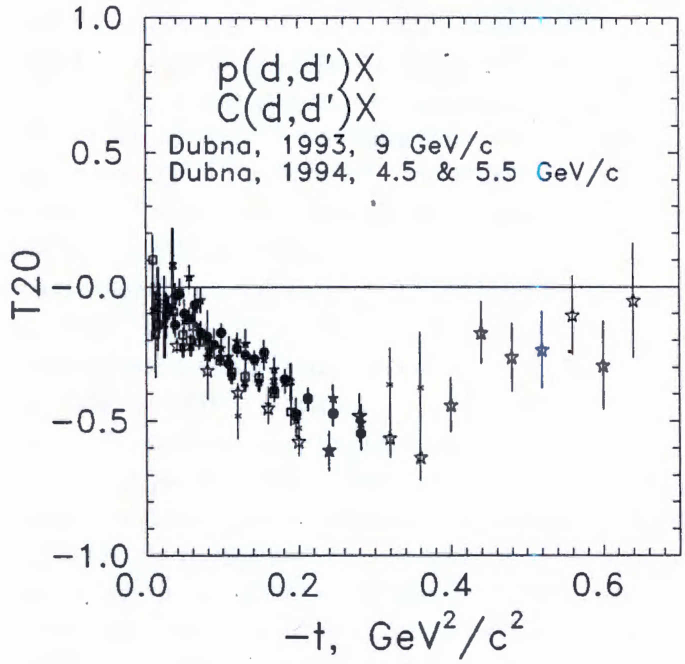

Figure 4: Tensor analysing power T_{20} of the inelastic $d, d')X$ scattering on protons and carbon nuclei at different incident momenta in dependence on the 4-momentum transfer t.

deuterons; this will allow to study energy dependence of these reactions when data will be analysed together with future data from experiments of ref.[10]): T_{20}, polarization transfer coefficients, spin asymmetry of the pion yield should be measured.

- Inelastic $p(\alpha, \alpha')$ and $A(\alpha, \alpha')$ scattering with excitation of the Roper resonance with detection by the MRS of secondary protons or pions in coincidence with the forward scattered deuterons [10]: the cross section measurements.
- Study of the reaction $d(d, \alpha)X$, where X is a neutral isospin 0 meson (ω, S,ϕ etc.) close to 0° and 180° in the c.m.: measurements of the spin observables (T_{20}, spin-spin correlations) and cross sections in dependence on the α energy at fixed deuteron energy and in dependence on the incident deuteron energy. The α will be detected by the MRS, the neutrals is to be detected by the forward detector for neutrals. Experiment with polarized deuteron target is possible. The final goal of this study: investigation of the spin structure of the α particle at short distances.

The important feature of this reaction is that in this case the isospin selection rules forbid production at 0° and 180° of the isospin-non-zero mesons as well as mesons with spin-parity 1^-. Some restrictions imposed on the reaction amplitudes appear because of the axial symmetry of the "collinear" kinematics what results in an additional selectivity of this reaction to the responsible mechanisms.

- Study of the $d(n,^3He)X$ reaction where X is a neutral meson (π, ρ, ω, S,ϕ etc.) close to 0° and 180° in the c.m. with polarized and unpolarized neutron beam. Measurements of the spin observables (T_{20}, spin-spin correlations) and cross sections in dependence on the ^3He energy at fixed neutron energy and in dependence on the incident neutron energy. The final goal: information about the spin structure of the ^3He at short distances. The ^3He will be detected by MRS; measurements of its polarization would be important. The neutrals is to be detected by the forward detector for neutrals. Experiment with polarized deuteron target is possible.
- Inelastic charge exchange of polarized neutrons on protons and nuclei with detection of the "soft" pions in the MRS and hard secondary protons in the Forward Spectrometer; polarization transfer coefficients and the "single-spin asymmetry" of the pion yield is to be measured.
- Inelastic $d(p,p')$ scattering of polarized protons with detection of recoiled deuterons and/or pions in the MRS and the scattered protons in the Forward Spectrometer. Measurements of the polarization transfer coefficients and the pion "single-spin asymmetries" can be planned. The polarized proton beam can be obtained from the breakup of polarized deuterons; feasibility of experiments with beams of this kind have been demonstrated (see ref.[7]). Experiment with unpolarized proton beam and polarized deuteron target is apparently interesting.

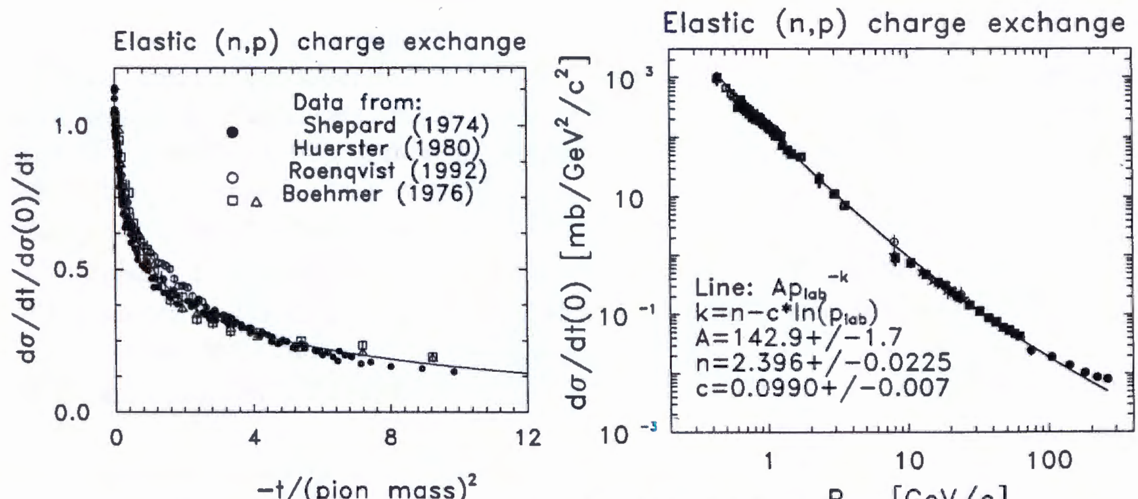

Figure 5: Left: The universal pattern of the $d\sigma/dt$ (solid line) in dependence on the dimensionless ratio $|\ t\ |/m_\pi^2$. Right: The $d\sigma/dt(0)$ in dependence on laboratory momentum.

- The same measurements can be performed with polarized neutron beam; in this case the Forward Neutron Spectrometer is necessary.
- Inelastic charge exchange of polarized protons into neutrons on protons and nuclei with detection of the "soft" pions in the MRS and hard secondary neutrons in the Forward Neutron Spectrometer; polarization transfer coefficients and the "single-spin asymmetry" of the pion yield is to be measured.

  The Forward Neutron Spectrometer measures momentum of the secondary neutron; for energies below 1 GeV traditional method of time-of-flight measurements can be used but at higher energies it requires too long baselines and is not precise enough. Therefore another method, which uses as the detection reaction the forward elastic charge exchange of neutrons to protons with subsequent measurement of the proton momentum, must be used. This method is well known and their exists extensive data base on the elastic $p(n,p)n$ charge exchange for energies from few hundreds MeV up to several hundreds GeV (see, for example, fig.5).
- Study of the nuclear fragments (d, ^3He, α etc.) yield at large lab. angles in the collisions of relativistic nuclei with protons, deuterons and nuclei: measurements of the dependencies of the cross sections on energy of fragments, the beam, on the atomic numbers of the beam and target nuclei etc; in experiments with polarized deuteron and proton targets it would be possible to study spin asymmetries for the fragments yield; using polarized NH_3 target some spin-spin correlations could be studied for nuclei-N scattering.

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4.c Studies of cumulative particle production in correlation experiments

The DISK spectrometer is the specialized setup to study the particle production in the kinematic region forbidden for free nucleon collision [1]. The region is known as a cumulative one. Here is considered another option for the MRS installation place, namely – in the $F3'$ focus of the slowly extracted Nuclotron beam. In this case the MRS will be used as a basic part of the DISK setup; DISK's cryogenic targets can be installed in the scattering chamber and the following tasks can be solved experimentally:

- In the correlation experiments with detecting cumulative particle in the KP1 arm of the DISK setup and detection of pions in the MRS (KP2–arm) it is possible to study cumulative production of resonances (Δ, ρ). Such methodics is well investigated in the DISK experiments [2].
- The cumulative production of K-mesons was pioneered in the DISK experiments. These data have given evidences for existing of a "hard" sea in the nuclear quark-parton structure functions in the region of cumulative numbers of 1.0–2.5 [2]. In the paper [3] a hypothesis was formulated about existing of a new element of the nuclear quark-parton structure function: a collective nuclear quark-antiquark sea. This hypothesis can be checked crucially in experiments on $K^{\pm}$-meson production from deuterium and helium nuclei. These experiments can be done with help of the MRS.
- High momentum resolution and a large momentum acceptance of the MRS allow to create extensive data base on inclusive cross section for pion and proton production on the lightest nuclei (d, α) in the momentum region from 200 MeV/c up to the absolute kinematical limit and in the angular interval from $15° - 150°$ of the lab. angles.
- With polarized deuteron beams it is possible to study "single-spin asymmetry" of the process
$$\vec{d} + A \rightarrow h + X$$
with the production of pions and kaons from protons and lightest nuclei, including cumulative region, pioneered with the DISK [4]. Resonance contribution can be isolated in these experiments with MRS. The study of asymmetry can give the new information on polarization mechanism in cumulative region and allow to verify the "asymmetry sign rule" [5].
- The principle of the "minimal economic interaction" was suggested by V.S.Stavinsky [6] years ago; this idea was developed further to a hypothesis of existing of a new kind of dynamical correlations; one of the predictions is that there must exist a kinematical region where 2-particle dynamical correlator satisfies a relation $R_2 \gg 1$. This prediction can be checked in the correlation experiments using arms KP1 and MRS. The particles with momenta $p \geq 1,5$ GeV/c will be detected by the MRS in the lab. angular interval of $10^0 - 20^0$.
- Using existing and new detectors and triggers of the DISK setup (including the multiplicity detector) and magneticless spectrometers for detection of neutrons and γ-s, it would be possible to create a cycle of experiments on study of nuclear-nuclear collisions with strange particles production, resonances, narrow and wide correlations in cumulative particle production.

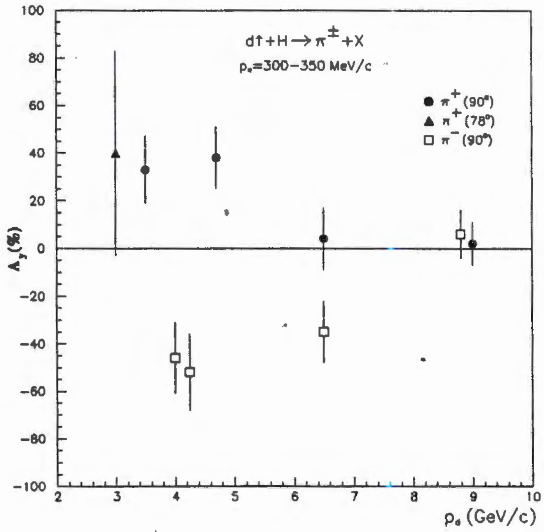

Figure 6. Single-spin pion asymmetry of the $\vec{d} + H \rightarrow \pi + X$ process as function of incident deuteron momentum p_d [4].

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5. INSTALLATION of the MRS at LHE

There are three places in the experimental area of the LHE accelerator complex for installation of the MRS. Each of them has its own advantages and shortcomings.

The first one is located in focus F3. It's the best case to use this spectrometer simultaneously with the other experimental setups. The beam parameters at the target location point are expected to be much better than in other options, what is an obvious advantage of this point. But this place will be available only after commissioning of slow extraction beam system of Nuclotron. Moreover, further development to the multi–arm configuration with the Forward Spectrometer/Neutral Detector is hardly possible what put restrictions on the possible experimental program. Another disadvantage is that experiments with the MPT are apparently not possible at this place in the nearest future.

The second one is located beyond the polarized proton target. This location gives possibility to study polarization phenomena. There also is enough room for installation additional experimental equipment to do different types of correlation experiments. There exists an opportunity to build a spectrometer to detect forward particle with momentum (or magnetic rigidity) close to the initial one. The beam-sharing with other experiments can be provided by means of installation of a special modules in the slow extracted beam transportation line.

As a relative disadvantage, installation of the MRS at this point will require more menpower and work on upgrade the existing infrastructure at this place.

The last location is in the end of the 205 experimental hall. This place is free now and has a good floor. But in this case it's impossible to build a forward particle spectrometer as well as in the 1-st option. Another disadvantage is that the beam parameters are expected to be worse then in the previous cases.

6. APPENDIX
6.1 The acceleration complex of the LHE

The acceleration complex of the LHE JINR consists of two machines: the well-known Synchrophasotron and the superconductive synchrotron, the Nuclotron, described in brief in the Introduction. The main characteristics on the complex are given in this section.

Table 2: **Main parameters of the LHE Accelerator Complex**

Parameter	Synchro-phasotron	Nuclotron
Max kin. energy (protons), GeV	9	12.8
Max. kin. energy ($Z/A = 1/2$), GeV/A	4	6
Repetition rate, p.p.s.	0.1	0.5 – 1.0
Extraction time, s	0.5	10
Vacuum, torr	$10^{-6} - 10^{-7}$	$10^{-10} - 10^{-11}$
Consumed power, MW	8	1.5
Max. field in dipoles, T	1.1	2.2
Circumference, m	207.3	251.5
SC dipoles, N		96
SC quadrupoles, N		64
Dipol aperture, mm		110
He refrigerator capacity, kW		2 ×1.6 at 4.5°K

Nuclotron structure and modules: 8 superperiods; 3 regular FODO cells in the each of the superperiods; the 4-th SP is without a dipole magnet. The regular cell includes: F and D quadrupoles, 4 dipoles, 2 drift spaces reserved for correctors, beam monitors etc.

In total: 96 dipoles, 32 correcting SC magnets; betatron osc. freq. $Q_x \simeq Q_z \simeq 6.75$.

The Nuclotron Dipoles are designed for max. field 2 T, ironed SC fast cycling, have window-like yoke 1.4 m long, 110 × 55 mm^2.

The Nuclotron Quadrupoles have 0.45 m long magnet yoke, hyperbolic shaped poles. The cooling is performed by 2-phase helium flow.

The Cryogenic supply system is based on 3 refrigerator/liquifiers 1.6 kW at 4.5°K capacity; the nominal pressure of He at the entrance is 2.5 MPa; the pressure in the liquid He receiver is ~ 0.13 MPa.

The total cold mass of the Nuclotron is about of 80 tons; the total time of the cooling is about 70 hours.

Table 3: **Intensity of available beams (particles per cycle)**

Beam	Synchro-phasotron	Nuclotron (I)	Nuclotron (II)
p	$4 \cdot 10^{12}$	10^{11}	10^{13}
n	10^{10}	$5 \cdot 10^{9}$	10^{13}
d	10^{12}	$5 \cdot 10^{10}$	10^{13}
d_{pol}	$(1\text{–}5) \cdot 10^{9}$	$3 \cdot 10^{8}$	10^{11}
$^{(*)}p_{pol}$	$\sim 2 \cdot 10^{6}$		
$^{(*)}n_{pol}$	$\sim 10^{6}$		
^{3}He	$2 \cdot 10^{10}$		
^{4}He	$5 \cdot 10^{10}$	$5 \cdot 10^{9}$	$2 \cdot 10^{12}$
^{7}Li	$2 \cdot 10^{9}$	$2 \cdot 10^{10}$	$5 \cdot 10^{12}$
^{12}C	10^{9}	$7 \cdot 10^{9}$	$2 \cdot 10^{12}$
^{16}O	$5 \cdot 10^{7}$		
^{20}Ne	10^{4}	10^{8}	$5 \cdot 10^{9}$
^{24}Mg	$5 \cdot 10^{6}$	$3 \cdot 10^{8}$	$5 \cdot 10^{11}$
^{28}Si	$3 \cdot 10^{4}$		
^{40}Ar	—	$3 \cdot 10^{7}$	$2 \cdot 10^{9}$
^{56}Fe	—	—	10^{11}
^{65}Zn	—	—	$5 \cdot 10^{10}$
^{84}Kr	—	$2 \cdot 10^{7}$	$5 \cdot 10^{10}$
^{96}Mo	—	—	10^{10}
^{119}Sn	—	—	$2 \cdot 10^{8}$
^{131}Xe	—	10^{7}	$2 \cdot 10^{8}$
^{181}Ta	—	—	10^{8}
^{238}U	—	$3 \cdot 10^{6}$	10^{8}

(*) Secondary beam after deuteron stripping; the typical numbers are given for intensity $\sim 2 \cdot 10^9$ of the primary deuteron beam and the optimal thickness of the target $\sim (20-40)g/cm^2$; divergency of the neutron beam was ~ 1 mrad with the beam spot diameter at the target about of 2 cm.

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6.2 Polarized target

The Dubna target for present experiment contains main parts of the Saclay – Argonne frozen spin proton polarized target, used initially in the E704 experiment at FERMILAB (USA) [1, 2]. The target has been reassembled and upgraded adding the missing parts for the purposes of the Dubna physics program. With respect to the FERMILAB experiment, a concept of a "movable polarized target" (MPT) has been applied [3, 4]. It means that capability of transportation of the target from one experimental area to another is realised in the design. All the major parts of the target assembly located close to the beam line were mounted on two separate decks, which can be moved as an entire units in and out of the beam, even when the target is polarized.

The largest of the two movable decks contains the $^3He/^4He$ horizontal dilution refrigerator mounted on a 1.5 ton concrete cube, a 30 l service helium dewar of the refrigerator, a 1000 l supply helium dewar, ^3He pumping system, the NMR system and a microwave generator. These last two items are used for dynamic nuclear polarization measurement and build-up. The quality of the vibrational insulation was demonstrated by the fact that it was possible to work in the frozen polarization mode at a working temperature of 50 mK without any additional thermal load to the refrigerator, and only a negligible phonic noise on the NMR coils was observed.

A polarizing superconducting solenoid, its 300 l service helium dewar and power supplies are mounted on the smaller deck. For easier operation and for a free access to detectors, the target equipment not mounted on the decks is placed outside of the radiation controlled area.

Remote control of the entire operation of the MPT consisted of the ^3He and ^4He control panels, an interlock system, and controls for the NMR and microwave systems. A new powerful two-arm cleaning system for ^3He was built (warm silicagel traps and charcoal traps cooled by liquid nitrogen).

The target material used in the experiment was 1,2 – propanediol $C_3H_6(OH)_2$ with paparamagnetic Cr^V impurity, having a spin concentration of $1.5 \times 10^{20} cm^{-3}$ ([5]). The propanediol beads were loaded in a hydrogen – free container placed inside the dilution refrigerator. The PPT contains $(8.93 \pm 0.27) \cdot 10^{23}/cm^{-2}$ polarized hydrogen atoms. The target characteristics at the room temperature and at the temperature of liquid nitrogen (70K) are given in Table 1.

The target polarization measurements were carried out using a computer controlled NMR system. Maximum values of proton polarization obtained were 0.842 and – 0.906 for positive and negative polarizations, respectively. The difference of microwave frequencies corresponding to polarization maxima was measured to be 340 MHz. The duration of one continuous run at a given sign of target polarization was about 12 hours. The polarization degradation during this period was insignificant since the nuclear spin relaxation time in the frozen spin mode (at a temperature 50 mK and magnetic field 2.69 Tesla) was over 1000 hour.

For further experiments a transverse polarization of protons (and deuterons) is foreseen and a set of transverse holding coils is under construction.

Table 4: **Characteristics of the MPT.**

Target length (mm) [20°C]	Target diameter (mm) [20°C]	Container volume (cm^3) [20°C]	Sample weight (g) [70K]	Filling factor
200.0 ± 0.1	30.0 ± 0.1	141.37 ± 0.95	95.5 ± 0.3	0.67

The first experiment with the MPT was started in 1995; the difference of the total np cross sections for longitudinally polarized initial particles in states with parallel and antiparallel spins ($\Delta\sigma(np)_L$) was measured[6] up to the neutron energy $T_{kin} \simeq 3.6$ GeV.

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6.3 Main characteristics of the MRS

The MRS spectrometer consists of three basic elements: a quadrupole which mainly focuses in the transverse (horizontal) direction, a dipole that bends the central ray 33° upwards, and a second dipole that bends the central ray 15° downwards which leaves an overall bend angle of only 18°. Since the quadrupole focuses in horizontal direction it is mainly responsible for the large horizontal acceptance (±60 mrad) of the MRS. Both edge angles of the first dipole are slanted by 41° and provide radial focusing at the entrance as well at the exit. The curvature of the entrance edges introduces sextupole corrections to the system. The second dipole is quite short, bends in the reverse direction, and has rotated and curved edges at both the entrance and the exit. This dipole, roughly triangular in shape, acts primarily as a quadrupole doublet. The entrance edge focuses radially while exit edges focuses transversely.

Several features of the MRS design are rather unique. The large slants of the pole edges provide strong focusing over the full momentum width. The use of a reverse bend allows the separation between the two dipole to be quite small, and still the radial (vertical) quadrupole action at both of the interior edges is retained. This strong focusing results in a short distance from the exit of the second dipole to the nominal focal point, and overall a very short spectrometer for the momentum bite to be covered. The length of central trajectory of the spectrometer is only 7 m. Angular acceptance is 9 msr. Momentum acceptance ±20%. Momentum range - 0.2 – 2.1 GeV/c. In addition, spectrometer can be rotated around scattering target at the angle range from 15° to 150°.

The MRS has a focal plane detector system with full ray tracing capability. Two delay-line readout drift chambers are used to measure with high precision the trajectory of charged particles. Position resolution of 125 microns (FWHM) is obtained, while operating at counting rate up to 10^6 HZ. Plastic scintillators are employed for fast timing and particle identification.

The first chamber is located 40 cm away from the MRS exit vacuum window. A separation between the two chambers is 28 cm. It is sufficient to provide accurate angle information and also keeps the overall dimensions of the whole system small. The center of the second chamber intersects the optical focal plane, which is tilted -68° with respect to the x-axis. The position and angles of each charged particle trajectory is reconstructed to better than 200 microns and 2 mrad respectively. This gives momentum resolution of 0.2%.

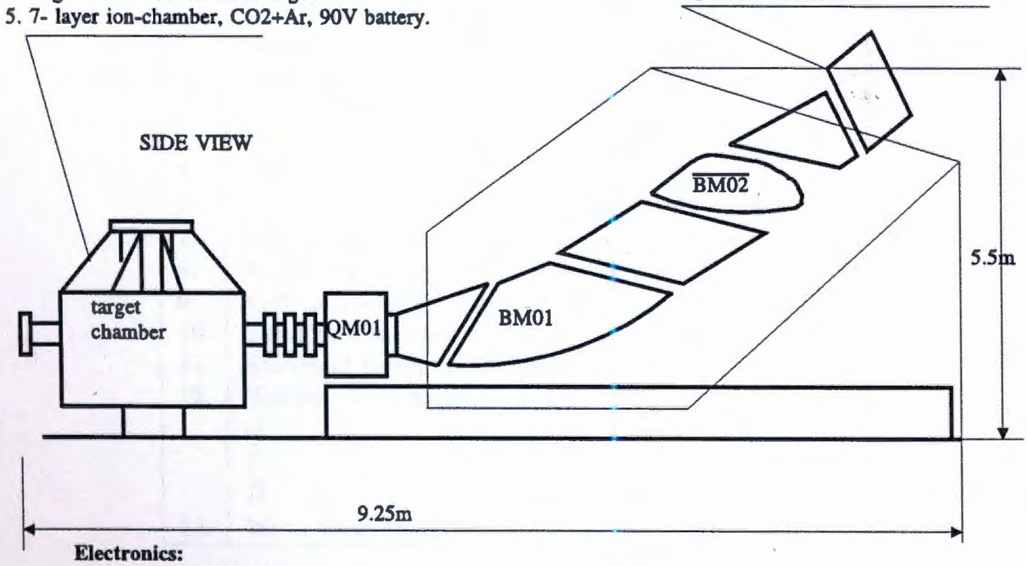
Two plastic scintillators are employed within the MRS detector system. Their signals are used for hardware trigger, for particle identification and a time reference for the delay line wire chambers. The hardware trigger of the MRS is solely derived from a coincidence between scintillator signals.

Medium-Resolution Spectrometer

1..Overall dimensions:	9.25x4.0x5.5 m (length,width,height)
2.Optical configuration:	QD$\overline{D}$
3.Momentum range:	0.2-1.8 Gev/c
4. Nominal momentum (B=17 kGauss):	1500 MeV/c (800 Mev protons)
5. Momentum acceptance:	+- 20% dp/p
6. Momentum resolution:	0.08-0.2 %
7. Solid angle:	7-9 msr
8. Horizontal acceptance angles:	+- 60 mrad
9. Vertical acceptance angles:	+- 40 mrad
I0. Total weight:	118 tons
11. Electrial power consumption:	350 kW
12. Voltage: QM01 -123V(100kW), BM01 -204V(161kW), BM02 -127V(89kW)	
13. Water flow:	460 l/min

1.internal radius: 94 cm
2. one input and six exit ports
3. angles interval: -30 deg.- +150 deg
4. target wheel: 12 different targets
5. 7- layer ion-chamber, CO2+Ar, 90V battery.

1.4 delay-line redout drift chambers- 30x60 cm-2;60x60 cm-2
2.6 plastic scintillators- 60x30cm;1ns



Electronics:

1. Digital micro-VAX IV computer, two 6250 bpi tape drives
2. Three CAMAC crates data acquisition system - A1 controllers
3.Modules:

3 A-1 CC	- crate controller		
1 CBS-2180	- Auxiliary CC	1 KS-3610	- input register
1 ECLmean	- 8 channel ECL meantimer	3 Phi 7106	- 16 channel discriminator
1 LRS 4508	- logic unit	1 LRS 2372	- memory lookup unit
1 LRS 4418	- delay unit	4 LRS 4300B	- FERA ADC
3 LRS 4303	- TAC	1 LRS 4301	- FERA driver module
1 LRS 4302	- memory unit	1 LRS 2372	- 32 channel scaler
1 LRS 2551	- 12 channel scaler		

Figure 6: Side view the MRS spectrometer.

Table 5: **Main parameters of the MRS**

1.	Overall dimensions (length, width, height), m	9.25 * 4.0 * 5.5
2.	Optical configuration	$QD\vec{D}$
3.	Momentum range, GeV/c	0.2–1.8
4.	Nominal momentum (B=17 kG), GeV/c	1.5
5.	Momentum acceptance, $\Delta p/p$, %	±20
6.	Momentum resolution, $\delta p/p$. %	0.08 – 0.2
7.	Solid angle, msr	7 – 9
8.	Horizontal acceptance angles, mr	±60
9.	Vertical acceptance angles, mr	±40
10.	Total weight, tons	118
11.	Electrical power consumption, kW	350
12.	Voltage, V (consumption, kW)	
	Q	123 (100)
	D	204 (161)
	$\vec{D}$	127 (89)
13.	Water flow, l/min	460