Study of 2N and 3N short-range correlations at Nuclotron-M

V.P.Ladygin et al.

The XIX-th International Baldin Seminar on High Energy Physics Problems, 29.09-4.10 2008, Dubna

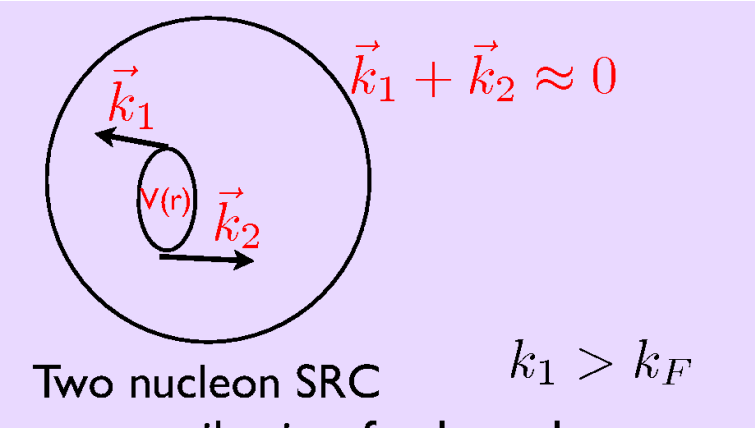
Outline of the talk

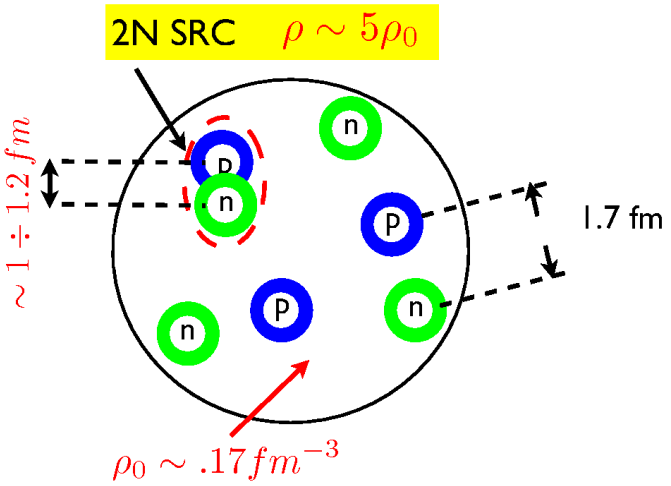
- Introduction
- Plans for Nuclotron-M
- Future for NICA at $\sqrt{s_{NN}} = 4 \div 9$ GeV/c
- Conclusions

Collaboration: Bulgaria-JINR-Japan-Romania-Russia-Slovakia

2N short-range correlations (SRC)

From the talk of M.Strikman held at the VI-th International Conference on Perspectives in Hadronic Physics, 12-16 May, 2008, Trieste, Italy





- SRC have densities comparable to the density in the center of a nucleon - drops of cold dense nuclear matter
- Connections to neutron star nn(I = 1) correlations, influence of np(I = 0), 3N SRC etc.

Status of 2N and 3N short-range correlations studies

Summary of the theoretical analysis of the experimental findings
practically all of which were predicted well before the data were obtained

More than ~90% all nucleons with momenta k≥300 MeV/c belong to two nucleon SRC correlations BNL + Jlab +SLAC

Probability for a given proton with momenta 600> k > 300 MeV/c to belong to **pn** correlation is ~ 18 times larger than for **pp** correlation BNL + Jlab

Probability for a nucleon to have momentum > 300 MeV/c in medium nuclei is ~25%
BNL + Jlab 04 +SLAC 93

Probability of non-nucleonic components within SRC is small - < 20% - 2N SRC mostly build of two nucleons not 6q, ΔΔ,... BNL + Jlab +SLAC

Three nucleon SRC are present in nuclei with a significant probability Jlab 05

Taken from the talk of M.Strikman held at the VI-th International Conference on Perspectives in Hadronic Physics, 12-16 May, 2008, Trieste, Italy

Tools to study 2N and 3N SRC with hadron beams

- Deuteron structure at large internal momenta - 2N SRC ($\mathbf{I=0}$).
- ^{3}He structure - 2N SRC ($\mathbf{I=1}$) and contribution of 3N SRC.
- SRC in nuclei from the $\mathbf{A(p,p'pp)X}$, $\mathbf{A(p,p'pn)X}$ and other reactions.

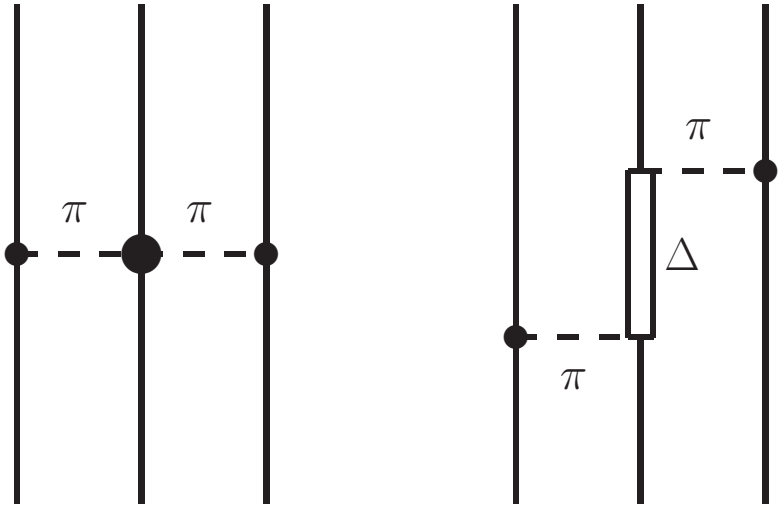
Data on the spin structure of SRC are almost absent!

Three nucleon forces manifestation

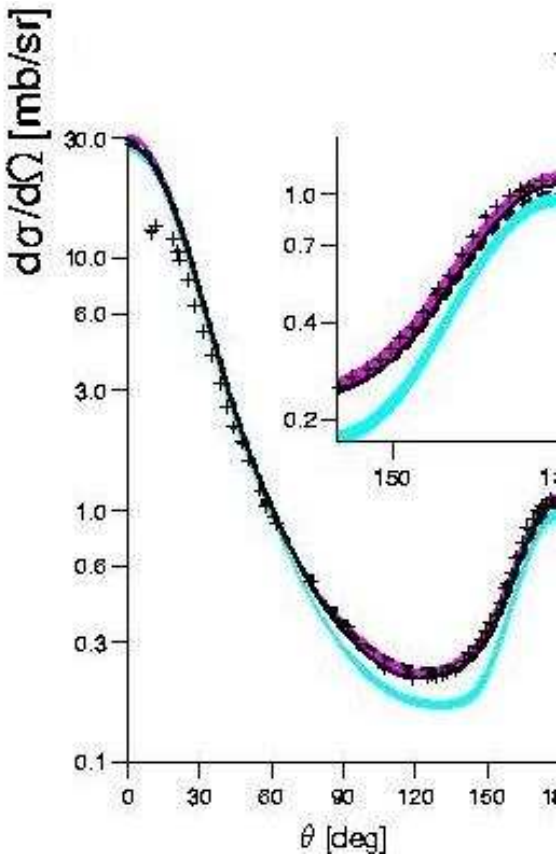
- During last several years a new generation of **NN** potentials are built (Nijmegen, CD-Bonn, AV-18 etc.). These potentials reproduced the **NN** scattering data up to 350 MeV with very good accuracy.
- But these potentials cannot reproduce triton binding energy (underbinding is 0.8 MeV for CD-Bonn), deuteron-proton scattering and breakup data.
- Incorporation of the 3 nucleon forces (**3NF**), when interaction depends on the quantum numbers of the all three nucleons, allows to reproduce triton binding energy and unpolarized deuteron-proton scattering and breakup data.
- However, the **3NF** cannot reproduce polarization data intensively accumulated during last decade.

Energy dependence of 3NF spin structure via dp elastic scattering measurements

Different models of 3NF



- Tucson-Melbourne
- Brazil
- Urbana-IX
- Fujita-Miyazawa ($N\Delta$)
- Chiral Effective Field Theory



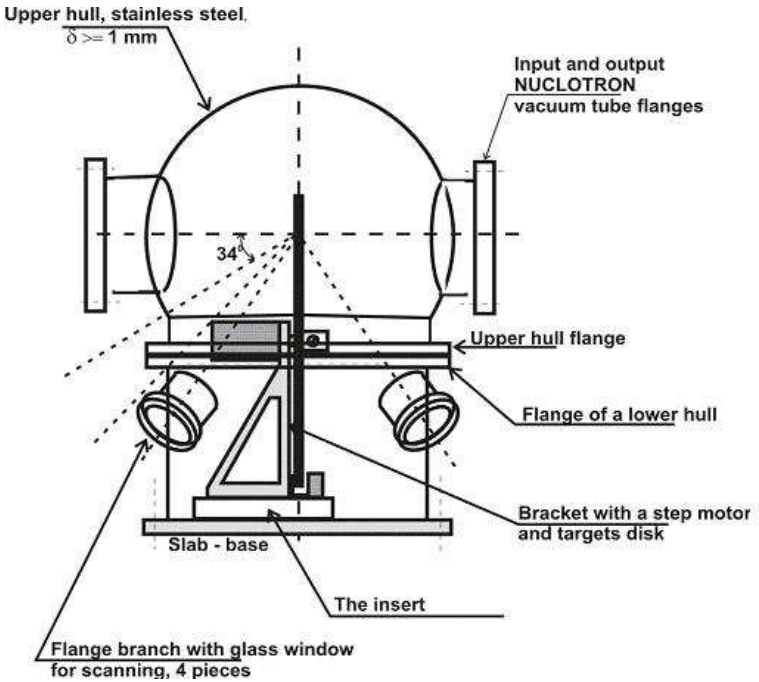
Manifestation of the three-nucleon forces effect in the cross section of dp- elastic scattering: up to 30% in the vicinity of Sagara discrepancy. At higher energies - SR 3NF.

Study of spin structure of 2N and 3N correlations

"classical 2NF&3NF" based on OBE models	below π-threshold	cyclotrons Nuclotron-M
SR 2NF&3NF	hundreds MeV	Nuclotron-M
SR 2N&3N correlations	GeV-region	Nuclotron-M NICA

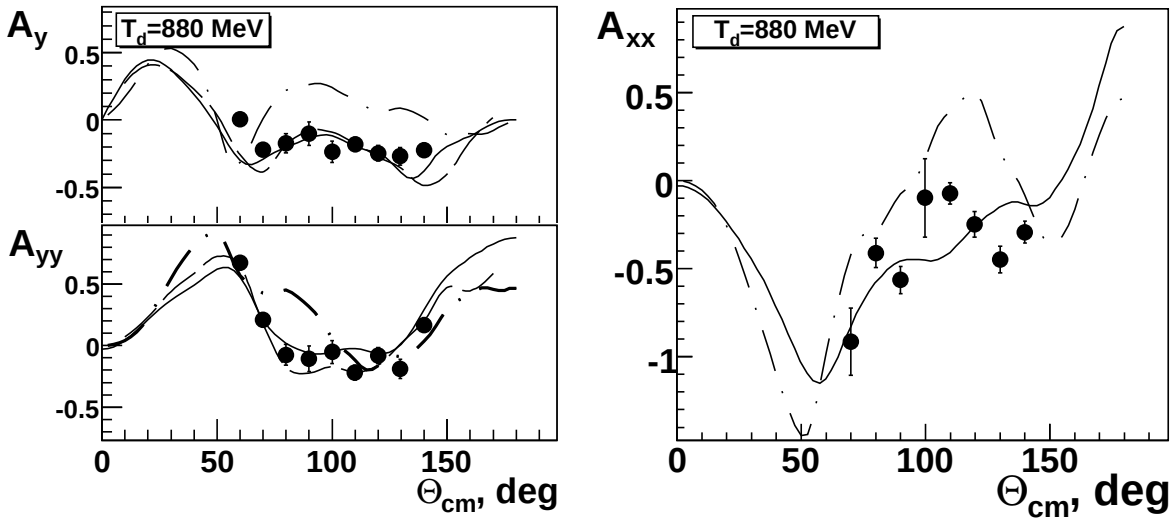
The study of hadronic reactions induced by polarized deuterons at Nuclotron-M will allow to study spin structure of 2N and 3N SRC.

Joint CNS-JINR experiment at Internal Target Station at Nuclotron (LNS-PHe3-projects)



New Internal Target Station is very well suited for the measurements of the dp- elastic scattering observables at large angles in the cms.

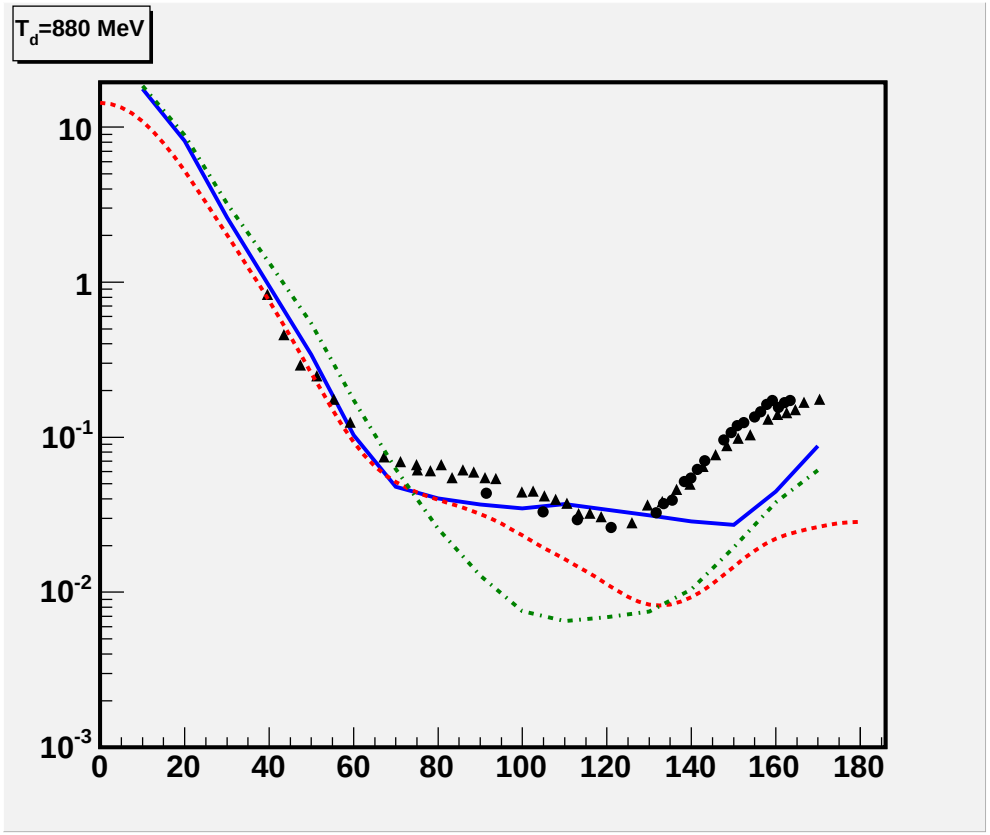
A_y, A_{yy} and A_{xx} in dp- elastic scattering at 880 MeV



From the talk of P.K.Kurilkin.

- Dashed lines are the multiple scattering model calculations using CD-Bonn DWF (N.B.Ladygina, arXiv:0705.3149[nucl-th], Phys.Atom.Nucl. 2008);
- Solid lines are the Faddeev calculations using CD-Bonn potential (H.Witala, private communication);
- Dott-dashed lines are the optical-potential calculations using Dibaryon DWF (M.Shikhalev, to be published in Phys.Atom.Nucl.)

Cross section in dp- elastic scattering at 880 MeV

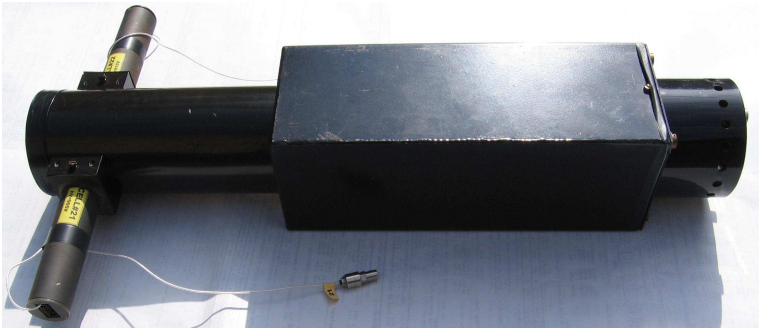


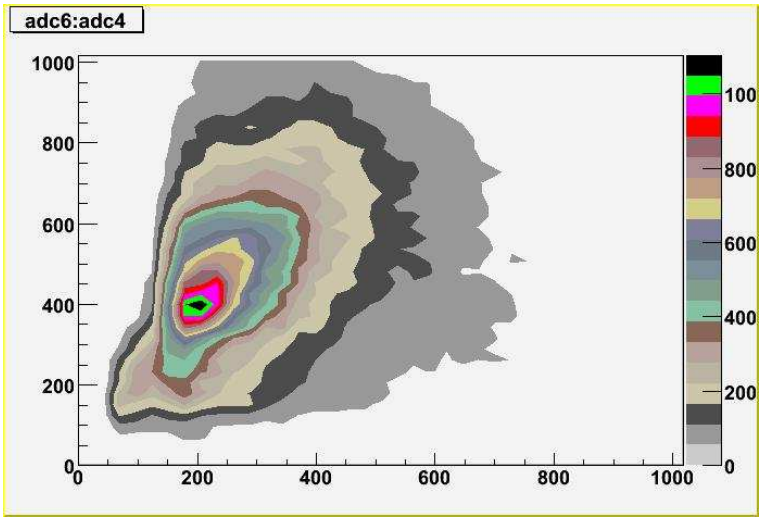
- The results of the multiple scattering model are in agreement with the cross section data in the range **30 – 130°**.
- Double scattering dominates over single scattering at the angles larger than **70°**
- The deviation of the data on the calculations at backward angles are related with the **s – type** of **FM 3NF**.
- Is the deviation of the data on the calculations around **90°** manifestation of **3N SRC**?

  (See talk of N.B.Ladygina)

Status of the preparation of the cross section measurements at ITS is given in the talk of Yu.V.Gurchin.

dp- breakup study at ITS



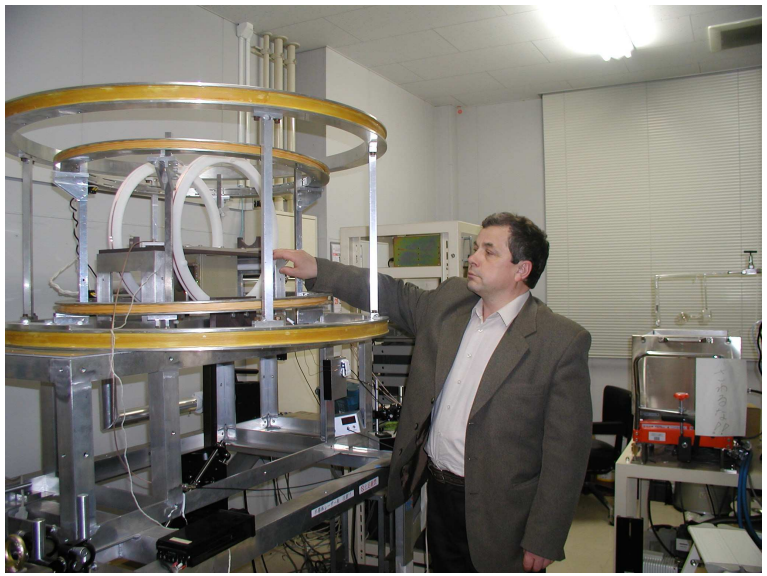


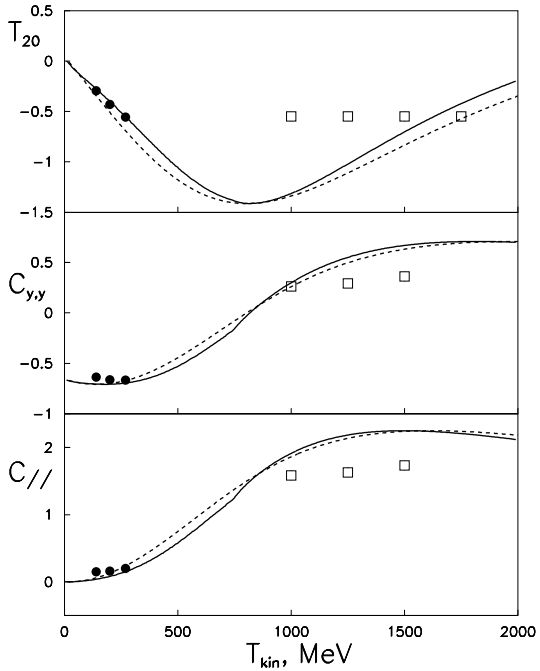
See talk of S.M.Piyadin

- Study of dp- breakup in different parts of the phase space allows to separate contribution of 2N and 3N correlations.
- These studies can be done at ITS of Nuclotron-M.

  The experiment is in preparation.

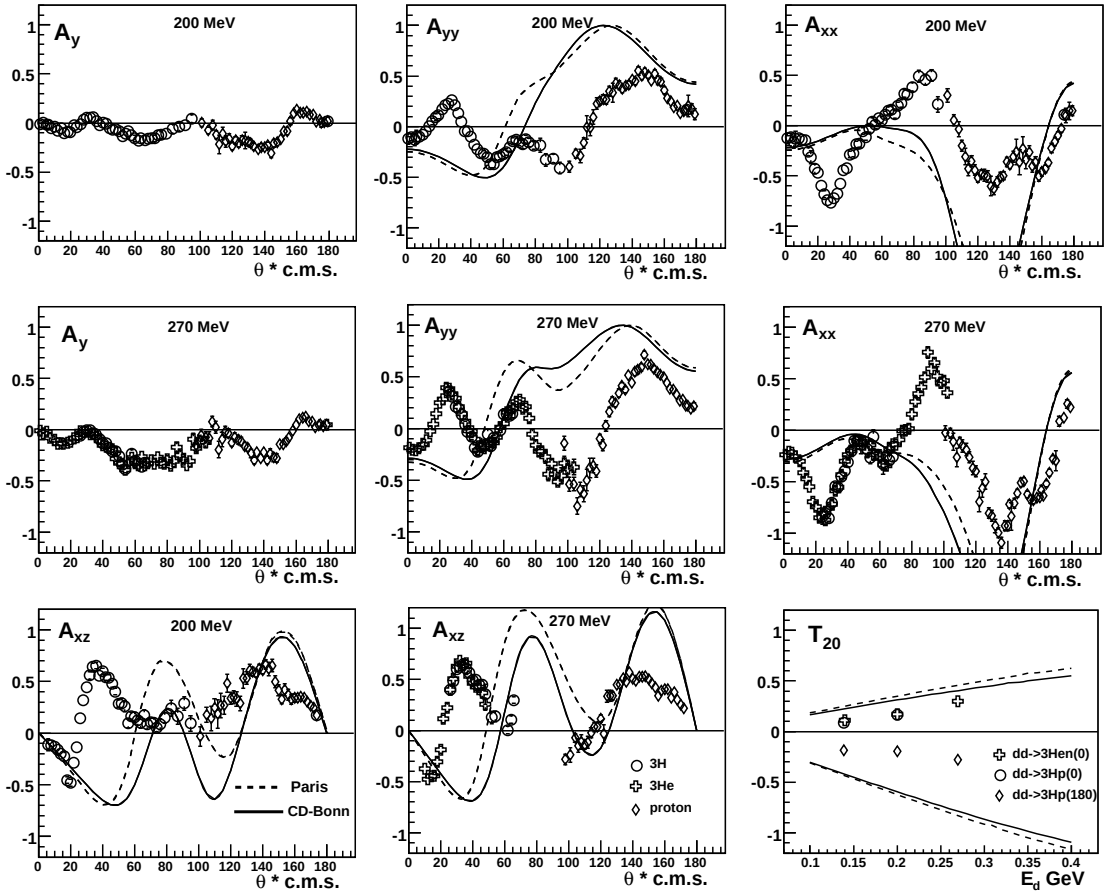
Polarization observables for the ^{3}He$(\mathbf{d},\mathbf{p})^4$He reaction (PHe3-project)





The main goal of the project is the measurements of the tensor analyzing power $\mathbf{T_{20}}$ and spin correlation $\mathbf{C_{y,y}}$ in the ^{3}**He**$(\mathbf{d},\mathbf{p})^4$**He** reaction in the deuteron kinetic energy range between 1.0 and 1.75 GeV.

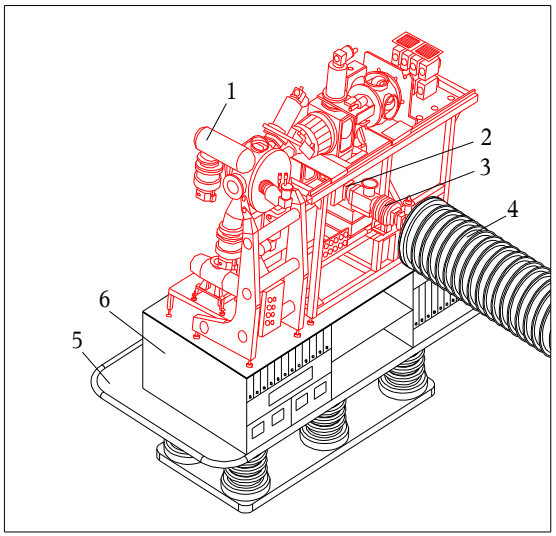
SRC from the dd → ^{3}Hen(^{3}Hp) reactions



From the talk of A.K.Kurilkin.

The study of T_{20} in the dd → ^{3}Hen(^{3}Hp) reactions at Nuclotron-M.

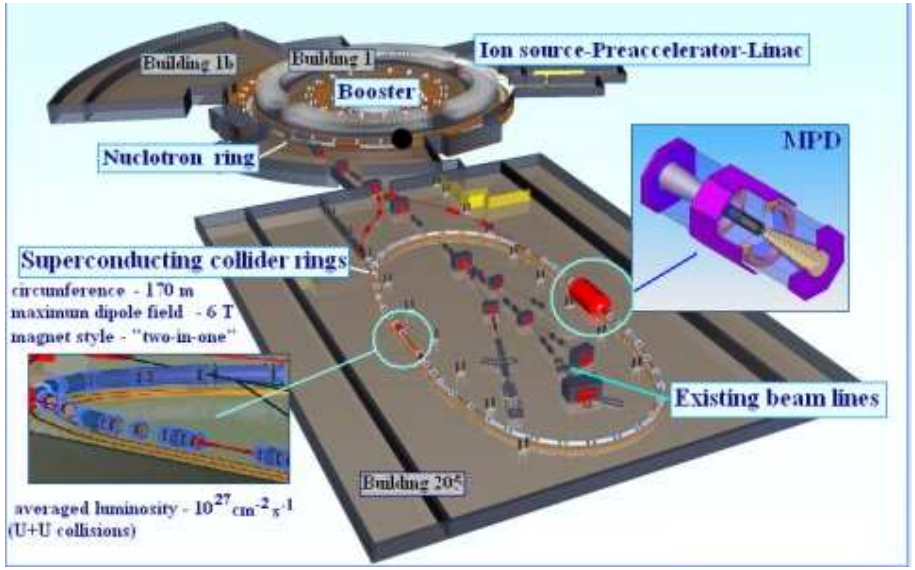
New Polarized Deuteron Source for LHEP



- New source will provide up to **10^{10}** ppp and higher values of polarization than **POLARIS**.
- Part of the **IUCF** source can be used for the construction.
- **350 k$** and **2** years are required to put into operation new source.
- First operation is planned in **2010 y**. (**see talk of V.D.Kekelidze at June-2007 JINR PAC-meeting**)

Figure of merit increasing by a factor $\sim 10^3$

2N and 3N correlations at NICA



New facility is planned to work at $\sqrt{s_{NN}} = 4 \div 12$ GeV for deuterons and up to $\sqrt{s_{NN}} = 27$ GeV for protons.

Serious advantage is the availability of polarized deuterons (neutrons).

Two-Arms Magnetic Spectrometer at NICA

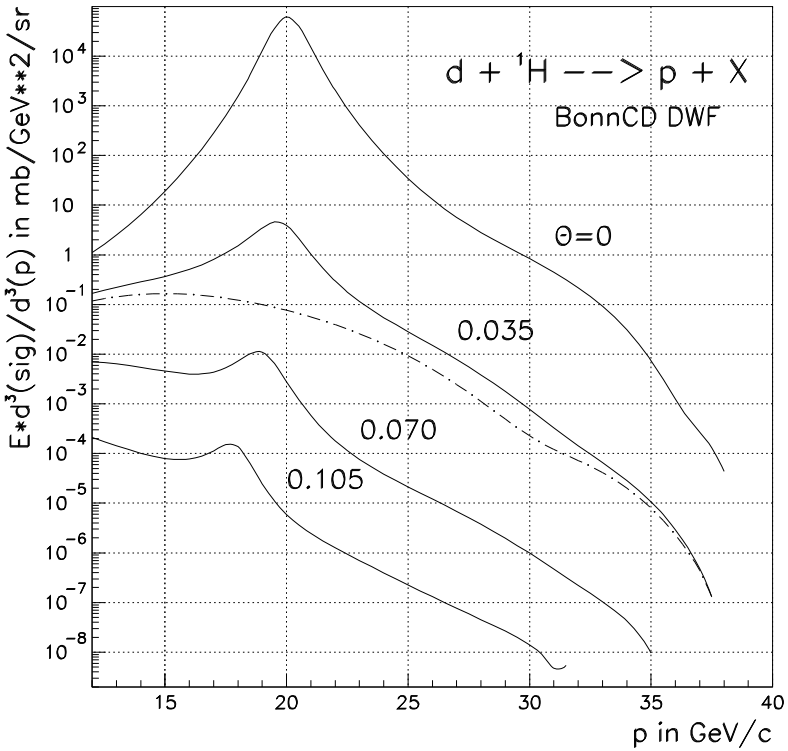
- Deuteron and ^{3}He(^{3}H) spin structure from $\vec{d}d \to pX$, $\vec{d}d \to {}^3$ Hen(^{3}Hp), $^3\vec{H}e^3\vec{H}e \to ppX$
- Short range 2N and 3N correlations in nuclei from the $A(p,pp)X$ and $A(p,pn)X$ processes.

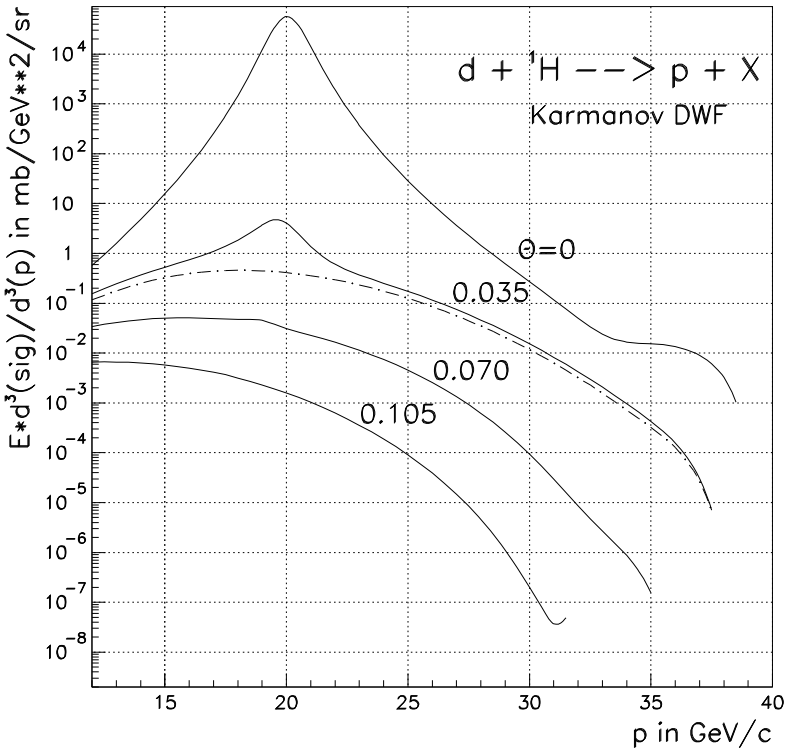
  Very serious advantage of the collider mode!
- Nuclear& color transparency in $\vec{d}A$ collisions.

These studies can be complimentary to U-70 and J-PARC

spin programs.

The ^{1}H(d, p)X reaction cross section at 40 GeV/c





- The deuteron internal structure can be probed up to $\mathbf{p_T}\sim$ 2–3 GeV/c.
- $\mathbf{x}$ and $\mathbf{p_T}$ dependences given by two models are very different.
- Hidden color in deuteron: $\mathbf{N(d, p\pi)X}$ vs $\mathbf{N(d, p)X}$.
- NICA will provide the opportunity to measure $\mathbf{A_{yy}}$ and $\mathbf{K^y_y}$.

Conclusions

- The spin structure of 2N and 3N correlations can be studied at Nuclotron-M both at internal and extracted beams in the few-nucleons interaction.
- The putting into operation new PIS will significantly increase the potentialities of these studies at Nuclotron-M.
- The collider mode and availability of polarized beams give serious advantages to study 2N and 3N SRC at NICA.