Comparison of polarization observables for the $\overrightarrow{d}\ d \to {}^3He\ n$ and $\overrightarrow{d}\ d \to {}^3H\ p$ reactions.

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Motivation

The goal of **r308n** experiment is to study the angular dependences of the tensor and vector analyzing powers in the $d\ d \to {}^3H\ p$ and $d\ d \to {}^3He\ n$ reactions.

- to investigate spin structure of the ${}^3H$ and ${}^3He$ at short distancies unachievable with the use of electromagnetic probes.
- to search possible manifestation of Charge Symmetry Breaking in the polarization observables in the mirror channels: ${}^3H\ p$ and ${}^3He\ n$.

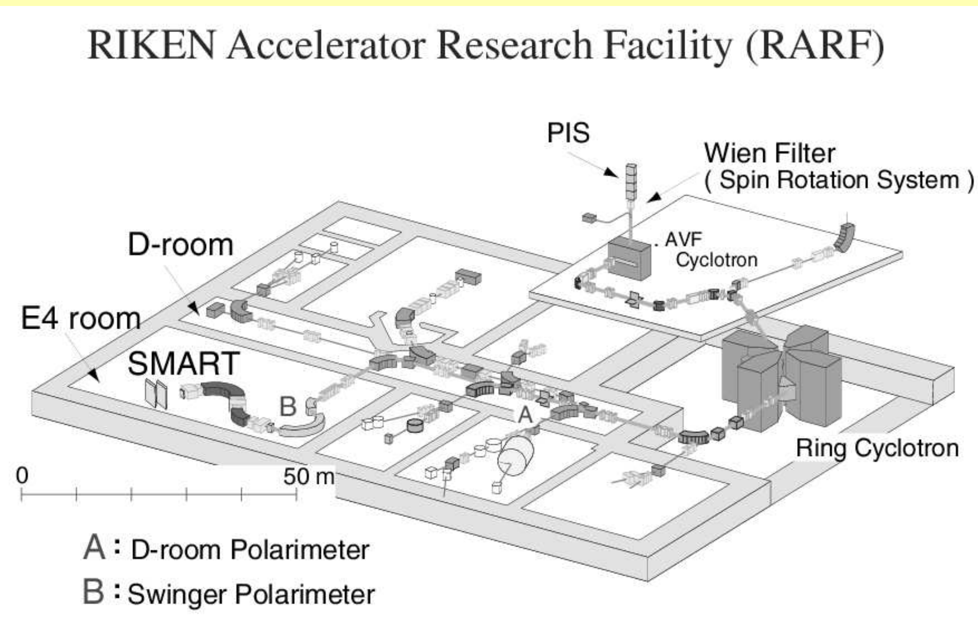
Introduction

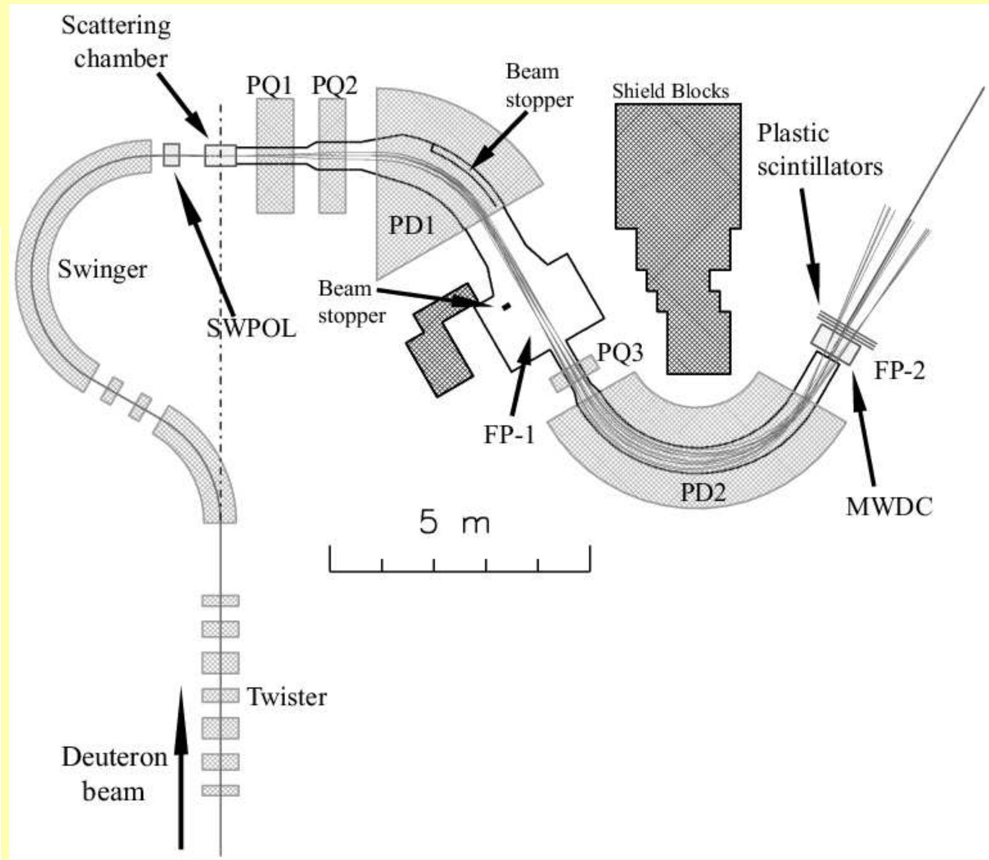
The structure of light nuclei may be investigated by electromagnetic and hadronic probes. Intensive theoretical and experimental efforts led to new generation of realistic NN potentials: AV18, Nijm I, II and 93, but these potentials fail in predictions of binding energies and cross section of Nd interaction. The non-relativistic Fadeev calculations of the three body bound state predict that the dominant components of the ground state is spatially symmetric S-state and D-state. The S-state dominates at smaller momenta, while the D-state becomes significant at large momenta.

In the framework of ONE approximation the polarization observables of these reactions are defined by the D/S-waves ratios in these nuclei.

Simple reactions with large transfer momentum and one-nucleon-exchange (ONE) mechanism are $d\,p \to p\,d$, $d\,{}^3He \to p\,{}^4He$ or $d\,{}^3He \to {}^3He\,d$. Therefore, One can study the high component of the ${}^3He$ through the measurement of the polarization observables which are sensitive to the D-state.

RIKEN and Magnetic Spectrometer **SMART**





Experiment

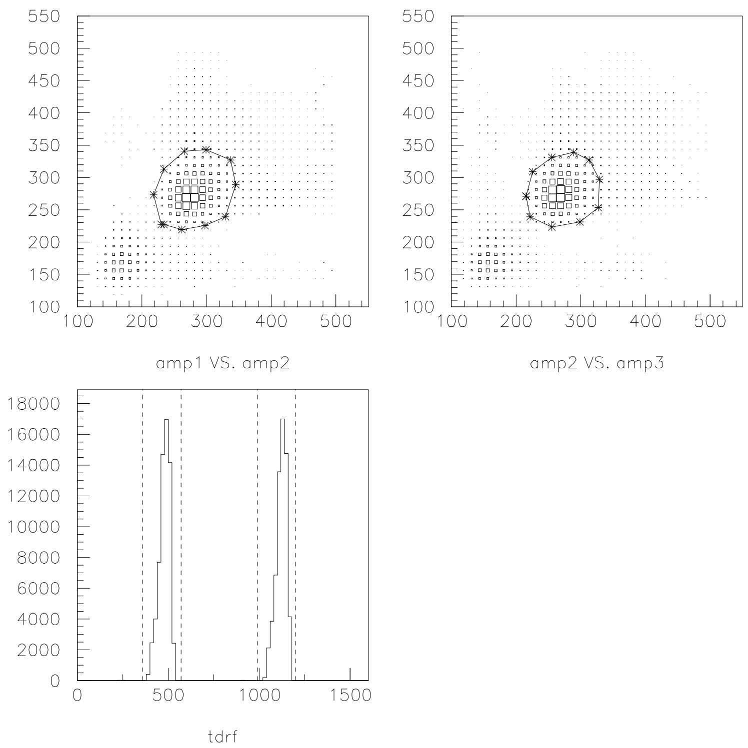
The experiment was performed at **RIKEN** Accelerator Research Facility (RARF). The deuteron vector (p_Z) and tensor (p_{ZZ}) beam polarization with respect to their cylindrically symmetric axis Z are defined by

$$
\begin{aligned}
p_Z &= N_+ - N_-, && (1)\\
p_{ZZ} &= N_+ + N_- - 2N_0. && (2)
\end{aligned}
$$

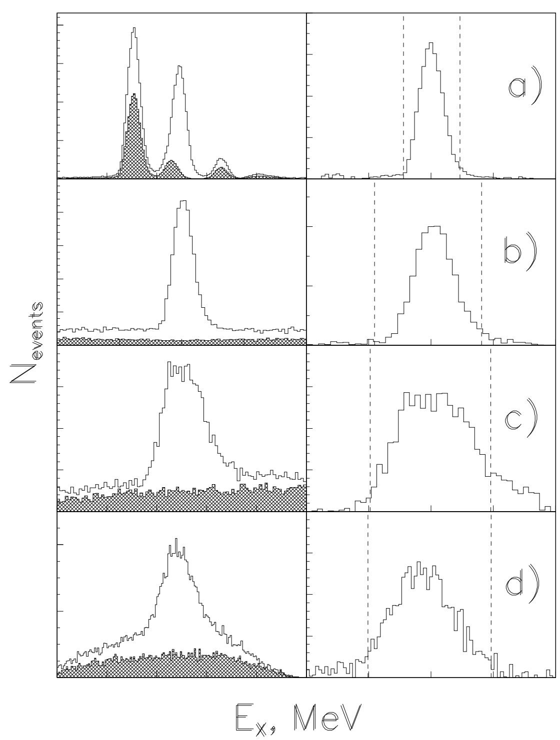
where N_+, N_- and N_0 denote the fraction of the deuteron beam in magnetic substates of $+1$, -1 and 0, respectively.

In this experiment, were used four spin modes. whose ideal magnitudes of polarizations are

$$
\begin{aligned}
\text{mode 0: } (p_Z,p_{ZZ}) &= (0,0) && (3)\\
\text{mode 1: } (p_Z,p_{ZZ}) &= (0,-2) && (4)\\
\text{mode 2: } (p_Z,p_{ZZ}) &= (-2/3,0) && (5)\\
\text{mode 3: } (p_Z,p_{ZZ}) &= (1/3,1). && (6)
\end{aligned}
$$



Typical examples of 2-dimensional plots and imposed gates (solid curves) for the particle identification. Up-left and up-right are amplitude correlation plots for ^3He, down-left is a typical RF-TDC spectra.



The obtained energy spectra for the $d + d \rightarrow {}^3He + n$ *reactions at* $E_d = 270$ *MeV. The nonshaded and shaded histograms are the spectra of the* CD_2 *and carbon target, respectively. On the right panels the* CD_2 *- C subtractions are shown. The angles of the scattered particles are* 5°, 32°, 54° *and* 94° *for the case a), b), c) and d), respectively.*

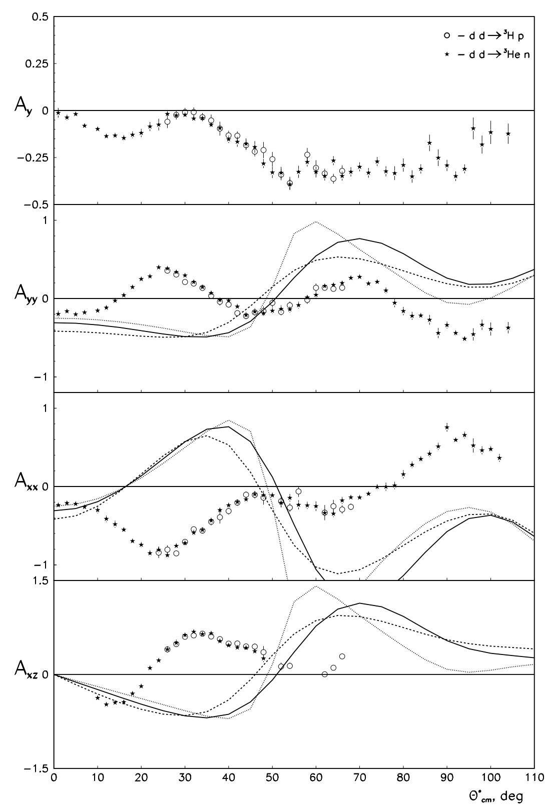
Detection and analysis

Criteries used for the selection of the scattered particles ^3H (^3He) from the reaction $d\ d \rightarrow {}^3H\ p$ ($d\ d \rightarrow {}^3He\ n$):

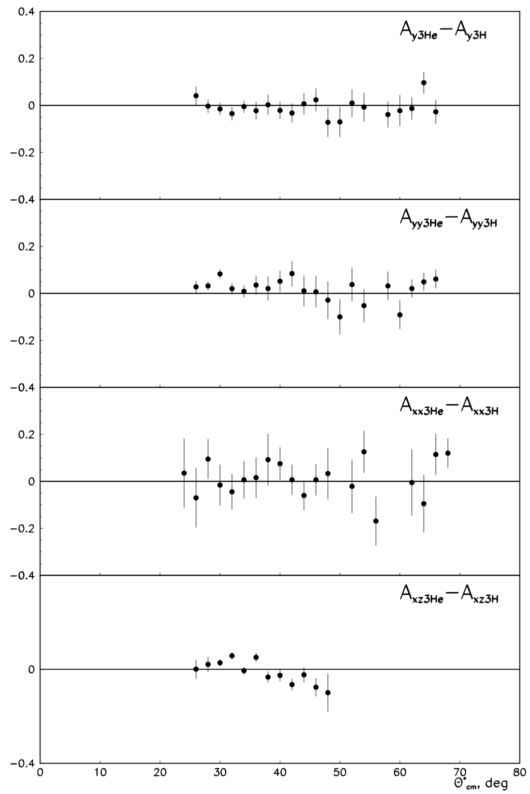
- Particle must be registered in the all three scintillation detetectors and it was selected by the correlation of the energy losses between in 1st and 2nd and 1st and 3rd scintillation detectors.
- Radio Frequency signal of the cyclotron (RF-TDC) must be synchronized with the signals from the plastic scintillators.

The main source of the background were particles ^3He and ^3H from the $d + {}^{12}C$ interaction. The number of useful events were obtained by the subtraction of the momenta spectra on the C from CD_2 foils.

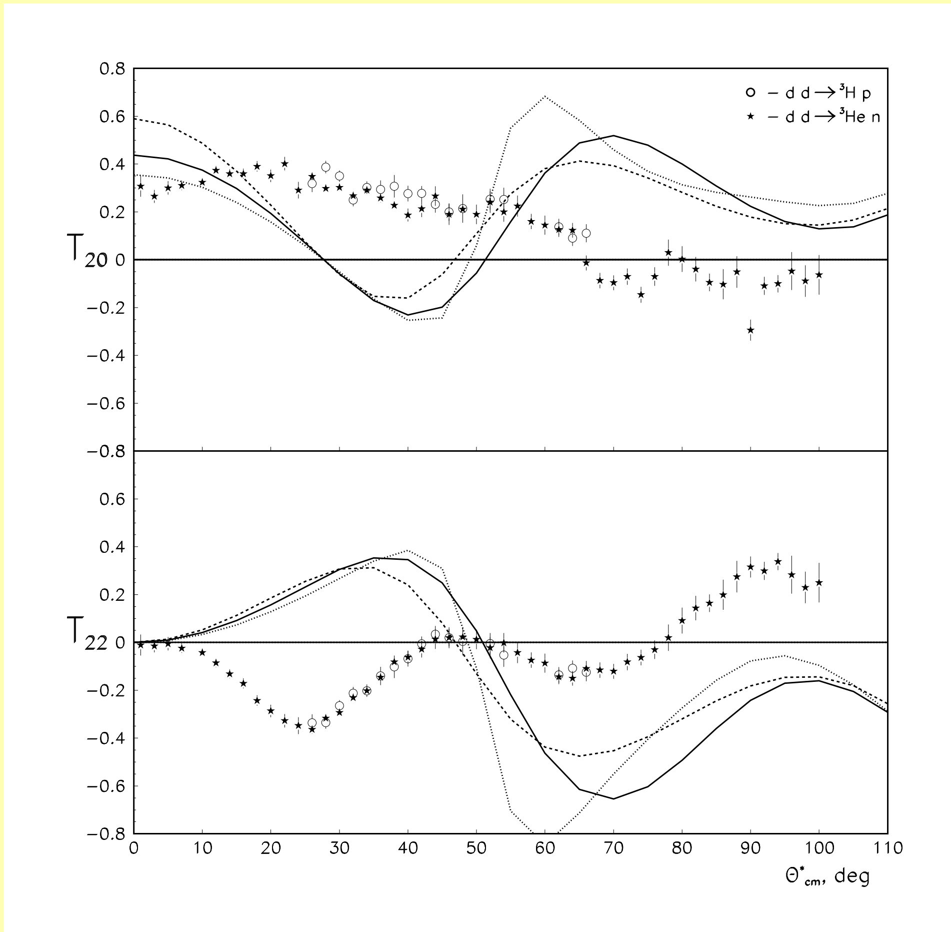
To obtain the analyzing powers A_y, A_{xx}, A_{yy} and A_{xz} for the $d\ d \rightarrow {}^3H\ p$ ($^3He\ n$) reactions we used the asymmetries and beam polarization values for the three different spin modes.



The results for the A_y, A_{yy}, A_{xx} and the A_{xz} analyzing powers in the centre-of-mass frame at energy $E_d = 270 MeV$. The opened and filled circles are for case of the ^3H p and ^3He n channels, respectively. The solid, dot-dashed and long-dashed curves are the results of ONE calculations using Urbana, Paris and Reid soft core ^3He wave functions, respectively.



The $A_{y3He} - A_{y3H}$, $A_{yy3He} - A_{yy3H}$, $A_{xx3He} - A_{xx3H}$ *and* $A_{xz3He} - A_{xz3H}$ *differences.*



Angular dependences of tensor analyzing powers T_{20} ($T_{20} = \frac{1}{\sqrt{2}}\frac{2\sqrt{2}u(k)w(k)-w(k)^2}{u(k)^2+w(k)^2}$) *and* T_{22} ($T_{22} = \frac{(A_{xx}-A_{yy})}{2\sqrt{3}}$) *at* E_d= *270 MeV. The* ^3He *n* (^3H *p*) *channel are presented by filled (opened) symbols.*

Results and discussion

- The results for the tensor A_{xx}, A_{yy}, A_{xz} and vector A_y analyzing power for $d\ d \to {}^3H\ p$ and $d\ d \to {}^3He\ n$ at energy $E_d = 270 MeV$ are obtained.
- ONE calculations predict that the tensor analyzing powers A_{xx} and A_{yy} and A_{xz} at forward angles are sensitive to the structure ${}^3H$ (${}^3He$) but they are remarkable deviation from the experimental results. These results imply that may a be problem in the realistic ${}^3H$ (${}^3He$) wave functions used in the ONE calculations.
- In the ONE approximation the vector analyzing power A_y is equals to zero, but in the experimental results we see some structures. These results will be a clue to investigated the reaction mechanism beyond the ONE model.
- The experimental results for the ${}^3H$ and ${}^3He$ are in the agreement within achieved errors, therefore we cannot conclude that the effect of charge symmetry breaking was observed.
- The angular dependences for the tensor T_{20} and T_{22} analyzing powers at energy E_d=270 MeV are presented. It is expressed directly via D/S wave ratio in ^{3}He. The reason of discrepancy between the data and calculation can be in the reaction mechanism. One of the additional mechanism can be excitation of the Δ isobar.