# The angular distributions of the vector Ay and tensor Ayy, Axx, Axz analyzing powers for the $d\ d \rightarrow {}^3H\ p$ and $d\ d \rightarrow {}^3He\ n$ reactions at $E_d$ =200 and 270 MeV


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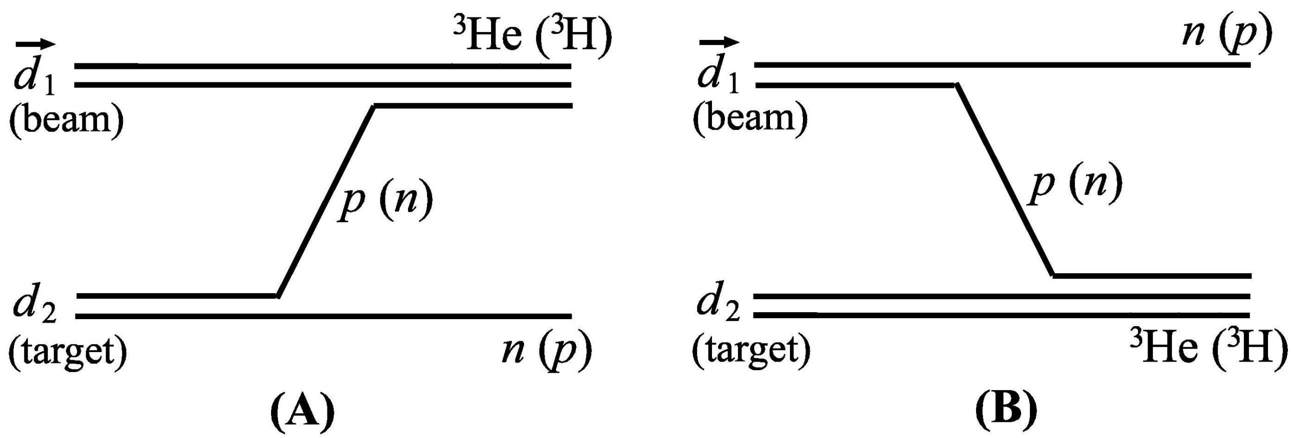
# Introduction

- **Intensive theoretical and experimental efforts led to new generation of realistic NN potentials: AV18, CD-Bonn, Nijm1,2 and 93. These potentials accurately reproduce the NN data set up to about 350 MeV, but they fail in predictions of binding energy and data on unpolarized dp elastic scattering and breakup reaction.**
- **Incorporation of three nucleon forces (3NF), when interaction depends on the quantum numbers of the all three nucleons, allows to reproduce binding energy of the three-nucleon systems and data on non-polarized dp reaction.**
- **However, the 3NF cannot reproduce polarization data intensively accumulated during last decade. One of the tools for the solution of this problem is the investigation of the processes sensitive to $^3He(^3H)$ spin structure.**

# $dd \to {}^3He\,n({}^3H\,p)$ in the model of ONE




Reactions $\vec{d}\,d \to {}^3He\,n$ and $\vec{d}\,d \to {}^3H\,p$ in the framework of the ONE model can be described by the sum of two diagrams.

The tensor analyzing powers for these reactions at the forward and backward angles are directly connected to D/S ratio of wave functions ${}^3He({}^3H)$ and deuteron, respectively.

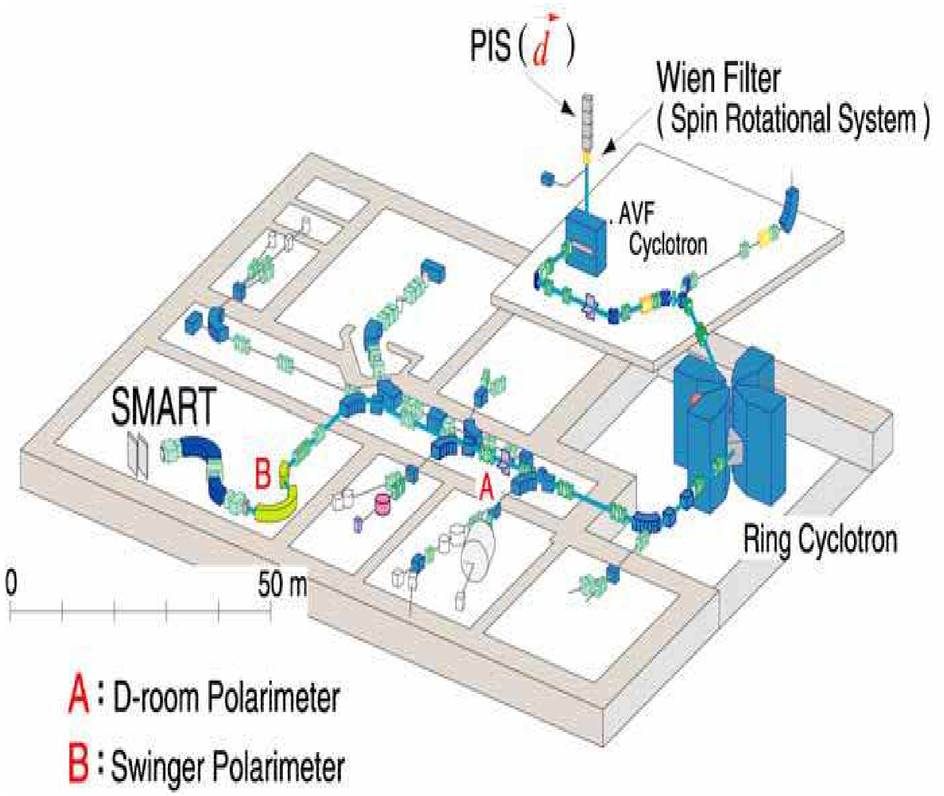
The diagram (A) give the largest contribution, when ${}^3H$ and ${}^3He$ are scattered at forward angles. The (B) diagram works in the case of backward scattering.

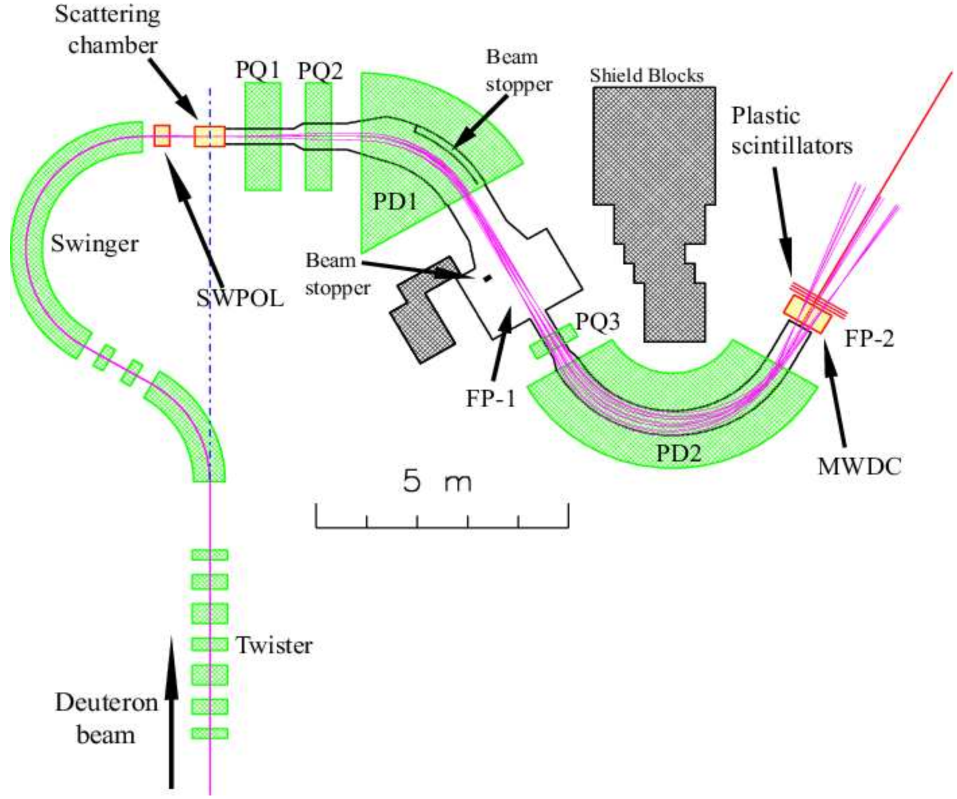
## Motivations of the R308n experiment

- **Investigation of the spin structure $^3H$, $^3He$ and deuteron at short distances at energy 140, 200, 270 MeV**

- **Comparison of the polarization observables from mirror channels: $^3Hp$ and $^3Hen$**

# Experiment




RIKEN Accelerator Research Facility

Spectrometer SMART

The polarized beam of deuterons was accelerated by AVF and Ring Cyclotron up to energy 140, 200, 270 MeV. The accelerated beam was directed to the target, located in hall E4.

The polarization of beam was measured with help the Swinger and Droom polarimeters. The scattered particles were registered by spectrometer SMART.

# Vector ($p_z$) and tensor polarization ($p_{zz}$) of deuteron beam

**The data set was obtained with the different values of vector $(p_z)$ and tensor polarization $(p_{zz})$ of deuteron beam. They are determined as follows:**

$$p_z = N_+ + N_-$$
$$p_{zz} = N_+ + N_- - 2N_0$$

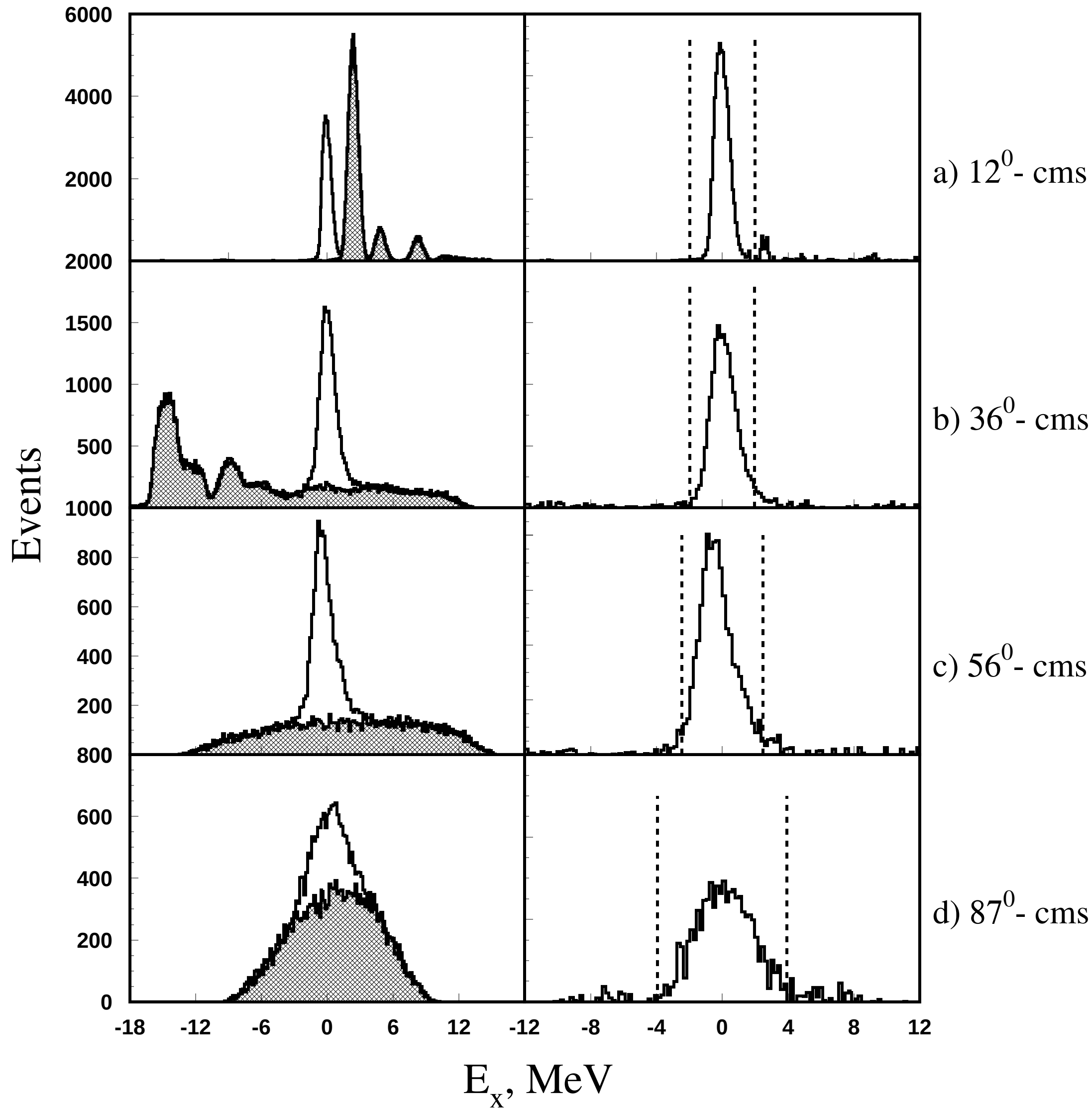
**where $N_+$, $N_-$, $N_0$ designate the population density of particles with the orientation of magnetic moment +1, -1, and 0 respectively.**

**In this experiment we used four spin modes (0-3), one of which was not polarized. Their ideal values of polarization were:**

$$Mode(0) : (p_z, p_{zz}) = (0, 0),$$
$$Mode(1) : (p_z, p_{zz}) = (0, -2),$$
$$Mode(2) : (p_z, p_{zz}) = (-2/3, 0),$$
$$Mode(3) : (p_z, p_{zz}) = (1/3, 1).$$

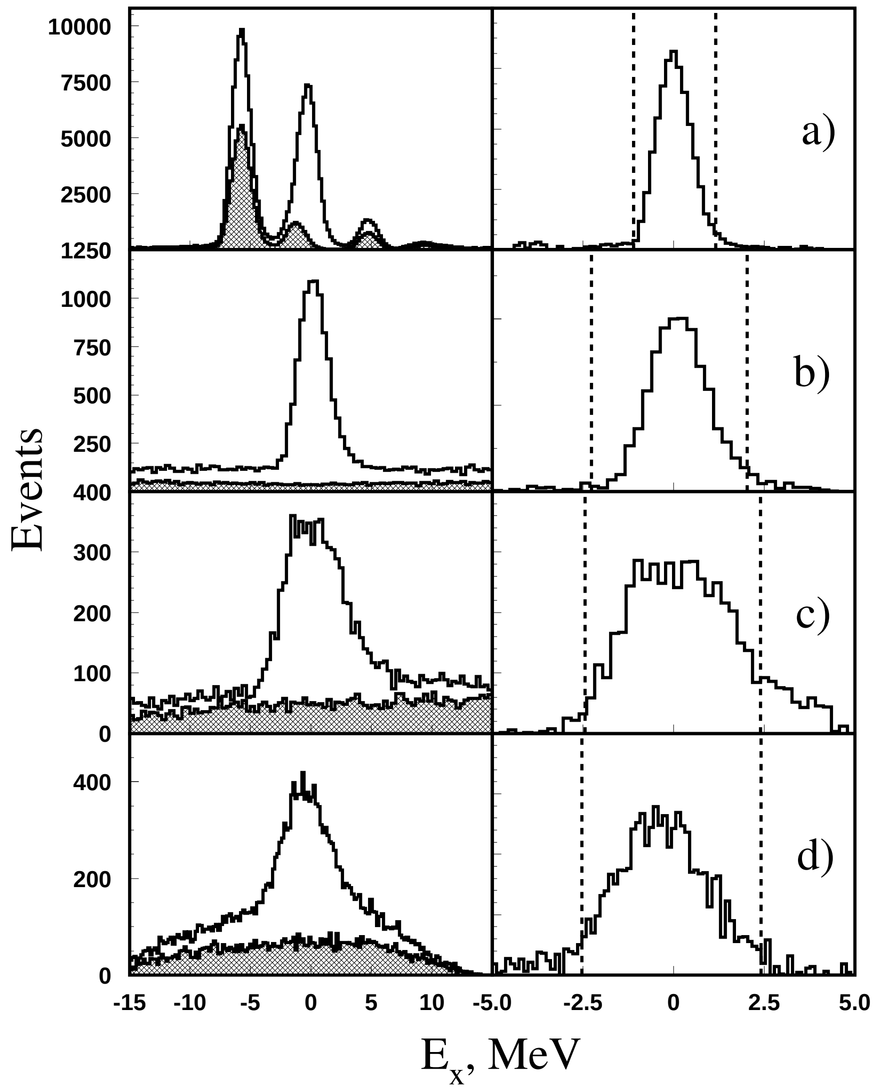
**Mode(2), purely vector mode were used only in the case of the $A_y$ measurement.**

# CD2-C subtraction at 200 MeV



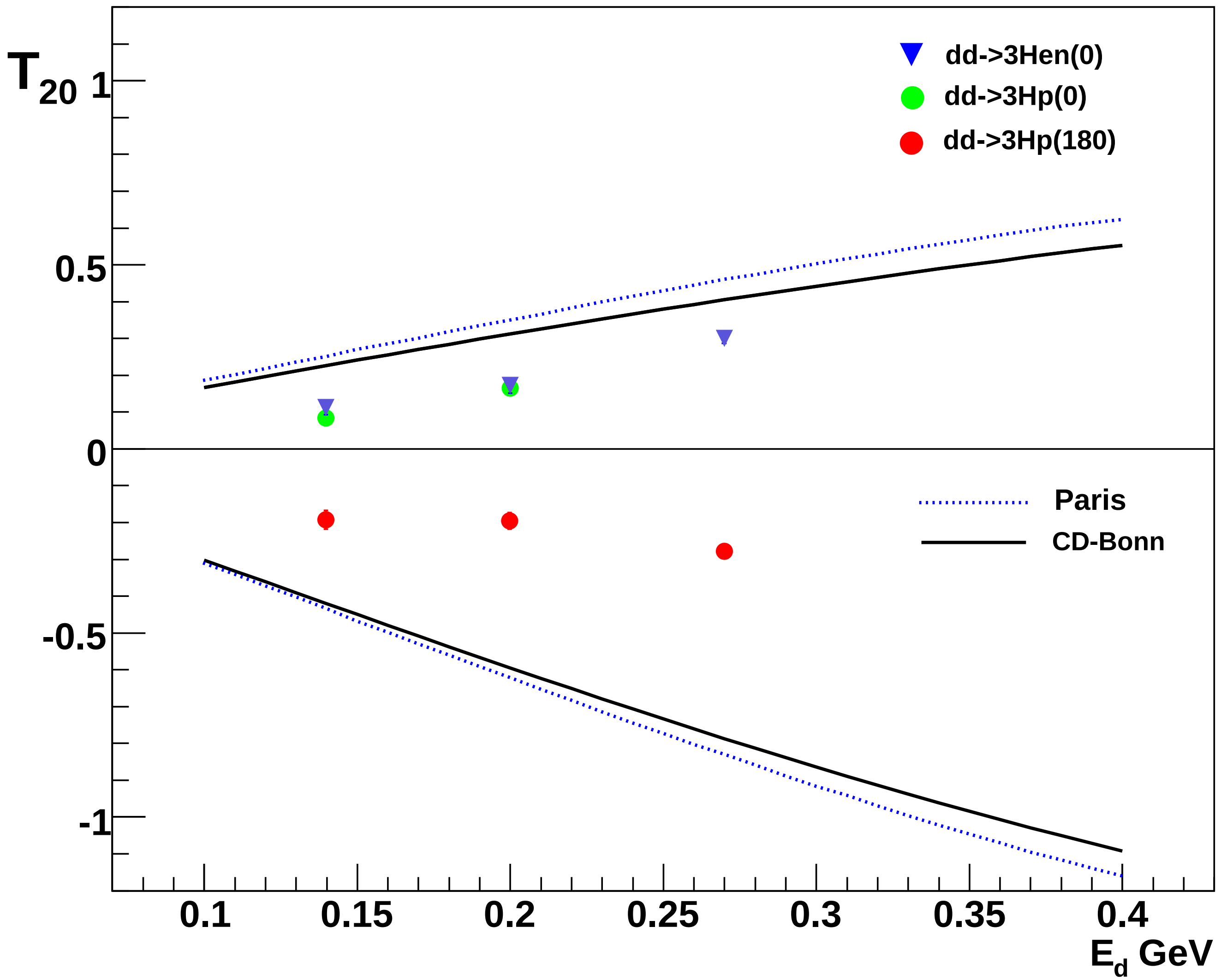

**The quality of subtraction of the carbon contribution for $^3H$ is presented for several angles in the center of mass system.**

# CD2-C subtraction at 270 MeV

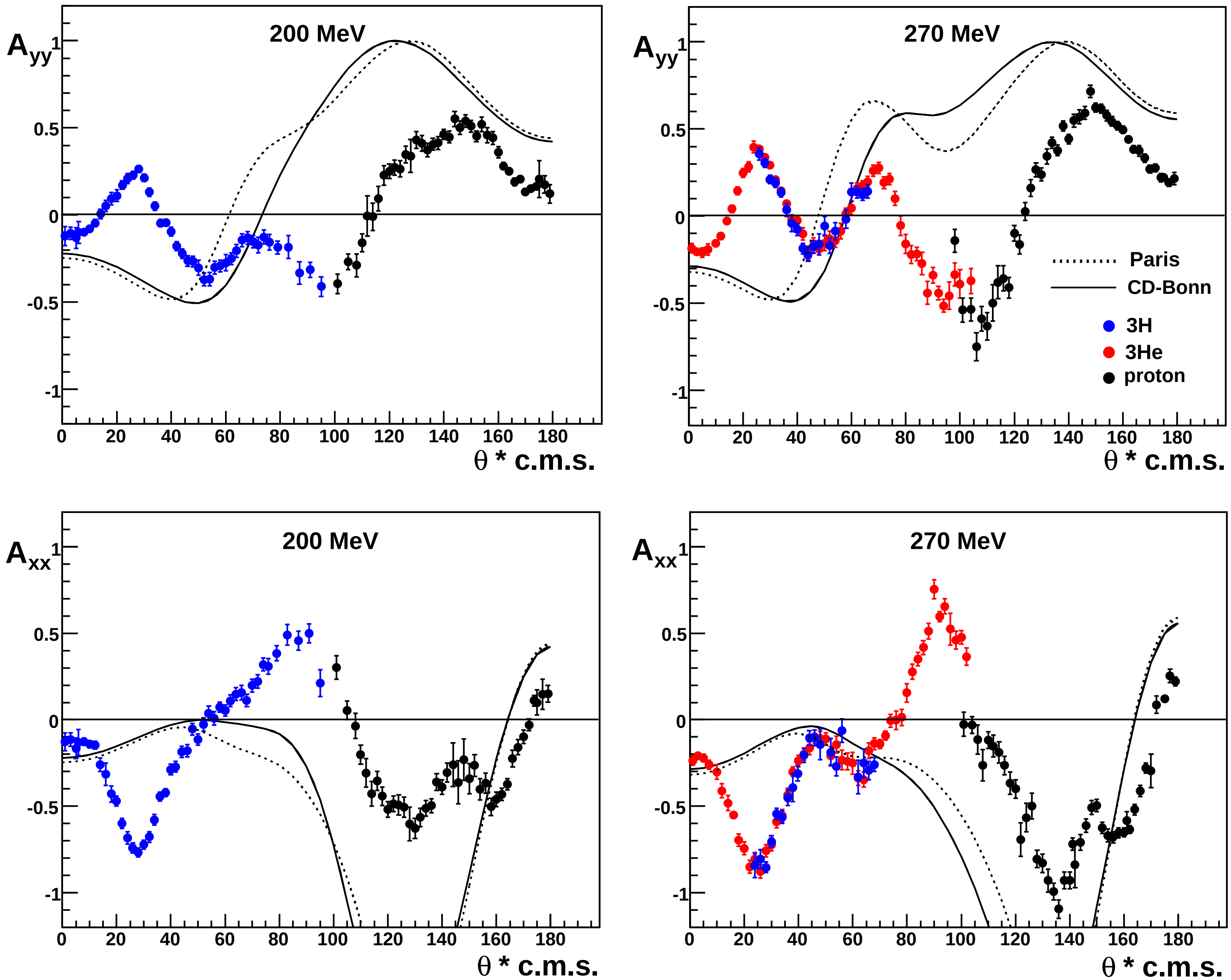



The quality of subtraction of the carbon contribution for $^3He$ is presented for $5°$, $32°$, $54°$, $94°$ angles in the c.m.s.

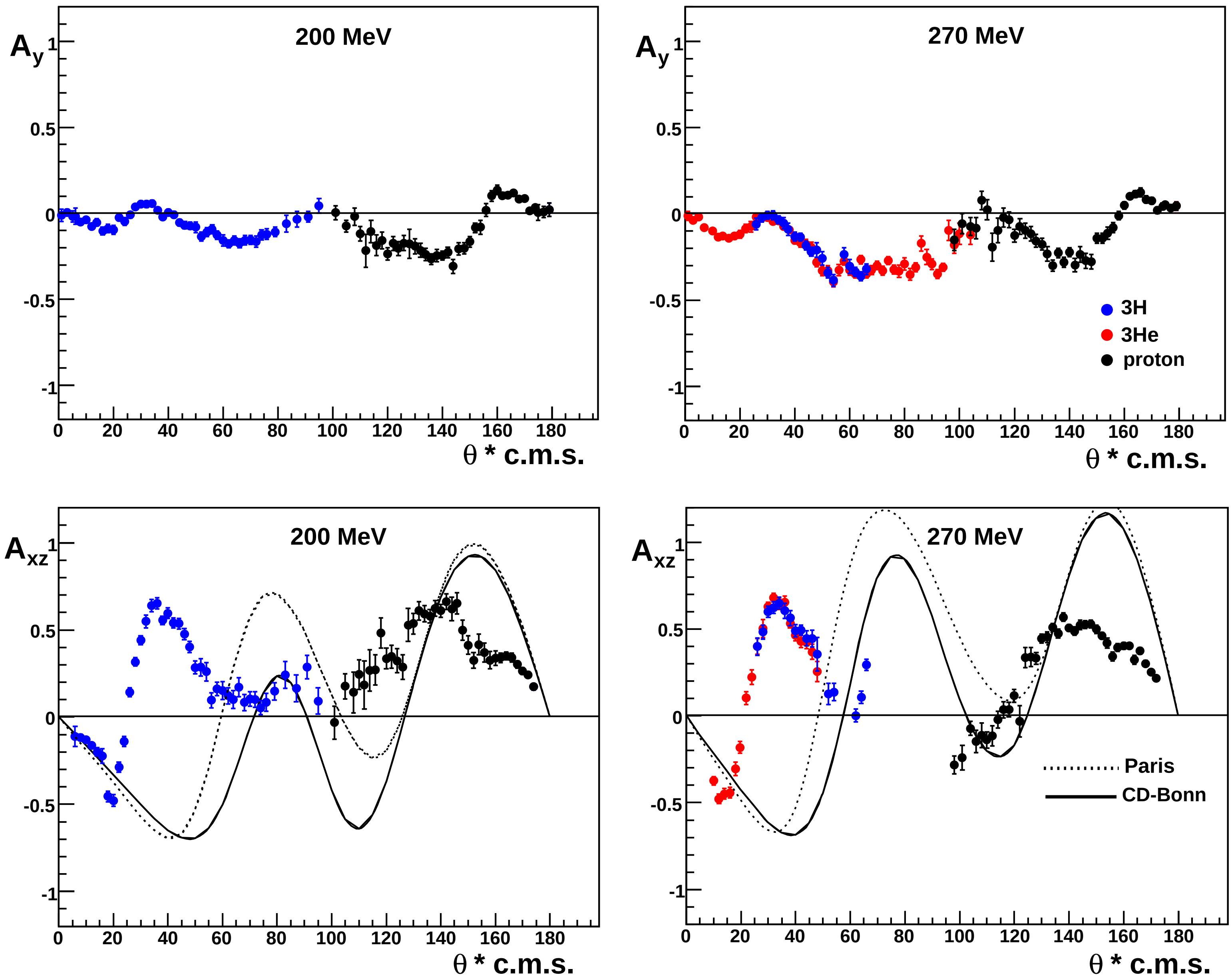
# Experimental results on $T_{20}$




The solid curve is the result of ONE calculations using CD-Bonn $^3He$ and deuteron wave functions. The dotted curve is the result of ONE calculations using $^3He$ and deuteron wave functions derived from Paris potential. The $^3He$ wave functions were taken from the work(V.Baru Eur.Phys.J.A16:437-446, 2003).




The signs of the analyzing powers at forward and backward angles are same for the data and ONE calculations. However, the theoretical calculations cannot reproduce the data in the whole angular range of the measurement.




The vector analyzing power $A_y$ equals zero in the ONE model. Some structures in he experimental results on $A_y$ indicate possibility other than ONE mechanisms in these reactions, but they are small.

# Conclusion

- **The results on the vector $A_y$ and tensor $A_{yy}$, $A_{xx}$, $A_{xz}$ analyzing powers in the $\vec{d}\,d \to {}^3Hp({}^3Hen)$ reactions at the energy of initial deuterons 200 and 270 MeV have been obtained. The data demonstrate large values of the analyzing powers.**

- **The experimental data were compared with theoretical predictions of ONE calculations based on ${}^3He$ and deuteron wave functions derived from CD-Bonn and Paris potentials. The deviations between data and theoretical calculations indicate possibility other mechanisms in these reactions. Also, problem may be in inadequate description of the spin structure ${}^3He$ and ${}^3H$.**

- **The obtained experimental data require further development in theoretical approaches either for adequate description of the structure of light nuclei at short distances or taking into account mechanisms in addition to ONE.**

**Thank you for the attention!**

**$T_{20}$ is expressed as:**

$$\mathbf{T_{20}} = \frac{\mathbf{1}}{\sqrt{\mathbf{2}}} \frac{\mathbf{2\sqrt{2}u(k)w(k) - w(k)^2}}{\mathbf{u(k)^2 + w(k)^2}}$$

**where u(k) and w(k) denote S- and D-state components of the $^3He(^3H)$ wave function if $\Theta_{cm} = 0°$. They denote S- and D-state components of the deuteron wave function if $\Theta_{cm} = 180°$.**

**This equation is correctly, when the reduced 3He(3H) and deuteron wave functions are used in the ONE model.**

**Excitation Energy is expressed as:**

$$E_x = \sqrt{(E_0 - E_{3N})^2 - (P_0 - P_{3N})^2} - M_N$$

**where $P_0$ is the incident momentum; $E_0 = 2M_d + T_d$ is the total initial energy; $E_{3N}$ and $P_{3N}$ are the energy and the momentum of the three-nucleon system, respectively; $M_N$ is the nucleon mass.**

# Equations for analyzing powers

## $A_y$, $A_{yy}$ analyzing powers:

$$N^1_{exp}(\theta_{cm}) = 1 + \frac{1}{2}p^1_{yy}A_{yy}(\theta_{cm}) \tag{1}$$

$$N^2_{exp}(\theta_{cm}) = 1 + \frac{3}{2}p^2_{yy}A_{y}(\theta_{cm}) \tag{2}$$

$$N^3_{exp}(\theta_{cm}) = 1 + \frac{3}{2}p^3_{yy}A_{yy}(\theta_{cm}) + \frac{1}{2}p^3_{yy}A_{yy}(\theta_{cm}) \tag{3}$$

## $A_{xx}$ analyzing power:

$$N^1_{exp}(\theta_{cm}) = 1 + \frac{1}{2}p^1_{xx}A_{xx}(\theta_{cm}) \tag{4}$$

$$N^3_{exp}(\theta_{cm}) = 1 + \frac{1}{2}p^3_{xx}A_{xx}(\theta_{cm}) \tag{5}$$

## $A_{xz}$ analyzing power:

$$N^i_{exp}(\theta_{cm}) = 1 + \frac{2}{3}p^i_{xz}A_{xz}(\theta_{cm}) + C^i, (i = 1, 3) \tag{6}$$

$$C^i = \frac{3}{2}p^i_{y}A_{y}(\theta_{cm}) + \frac{1}{2}p^i_{yy}A_{yy}(\theta_{cm}) + \frac{1}{6}(2p^i_{xx} + p^i_{yy})2A_{xx}(\theta_{cm}) + A_{yy}(\theta_{cm}) \tag{7}$$