Dynamics of three-nucleon systems in the deuteron-proton collisions at 100 MeV

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2. Experiment.
3. Results.
4. Outlook.

Introduction - NN interaction

Modern NN potentials are in general able to reproduce:

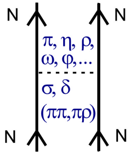
- properties of the nuclear matter (e.q. of state)
- binding energies of light nuclei
- global features of the bulk of the scattering observables in 2N and 3N systems

Role of precise knowledge of few-nucleon system dynamics

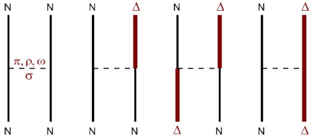
- fundamental for description of nuclei and nuclear processes,
- key feature for application in calculation/simulation codes (fast reaction stage – INC, QMD, etc.); radiation shielding, spallation targets, dosimetry, medical irradiation procedures, biological and astrophysical models, . . .

Introduction - standard interaction models of 2N system

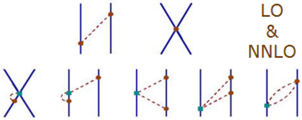
- Realistic potentials: meson exchange theory of NN forces - nucleonic degrees of freedom (AV18, CD Bonn, NijmI, NijmII)



- Coupled Channels (CC) potential: CD Bonn + explicit treatment of a single Δ-isobar degrees of freedom



- Chiral Perturbation Theory (ChPT) potential: Effective Field Theory expansion of potential in powers ν of small external momenta Q, $(Q/\Lambda_\chi)^\nu$, with $\Lambda_\chi \approx 1$ GeV



Introduction - 3NF models

The three-nucleon system is the simplest non-trivial environment to test predictions of observables obtained on the basis of NN potential models.

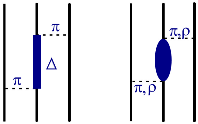
NN potentials:

- fail to reproduce binding energies of 3N systems;
- fail to reproduce minimum of the d(N,N)d elastic scattering cross section.

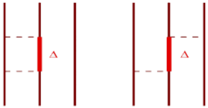
Introducing the concept of three-nucleon forces (3NF): genuine (irreducible) interaction of three nucleons.

Introduction - 3NF models

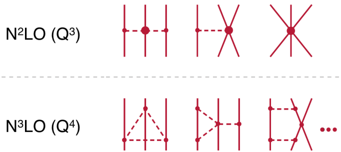
- Phenomenological three-nucleon forces: only weak connection to the NN potentials (e.g. TM99, Urbana IX, Brasil, Illinois);



- CC:Competing Δ-excitation effects (two nucleon dispersion and effective 3NF) – resulting net Δ influence is quite small;



- ChPT: three-nucleon forces appear naturally, fully consistent with the 2N graphs. (Under development, 3N system observables calculated up to N^2LO.)



Experiments

The $\vec{d}p$ system is one of the simplest to study dynamics of three nucleons. Experiments with polarized beams (or targets) give an opportunity to study a large number of observables (e.g. cross section) sensitive to dynamical components, which are hidden in the unpolarized case.

Experiments - 3N systems studied experimentally

Reaction mechanisms:

- elastic scattering $p + d \longrightarrow p + d$,
- breakup $p + d \longrightarrow p + p + d$,
- electromagnetic processes.

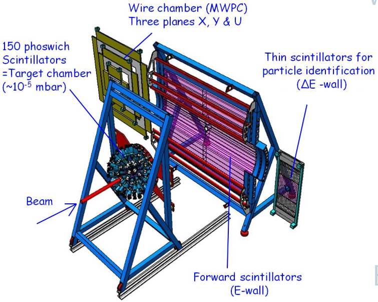
Observables:

- differential cross sections,
- vector and tensor analyzing powers,
- correlation, polarization transfer.

Different effects to be traced:

- comparisons between channels,
- influences of 3NF,
- Coulomb force action,
- relativistic effects.

Big Instrument for Nuclear-polarization Analysis (BINA)



WALL

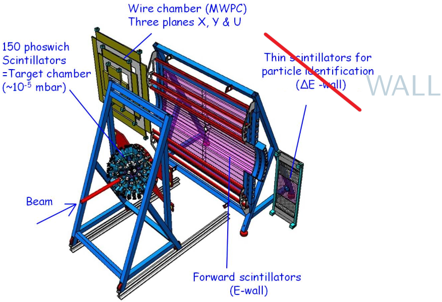
- MWPC – three-plane (x, y, u);
- scintilator hodoscope: 12 horizontal detectors (ΔE) and 10 vertical stopping detectors (E), arranged perpendicularly to one another.

It covers laboratory polar angles between 10° and 40° and the full range of azimuthal angles.

BALL 149 scintilators. Ball covers laboratory polar angles up to 160° and the full range of azimuthal angles.

Experiment dp@100MeV

Big **I**nstrument for **N**uclear-polarization **A**nalysis **(BINA)**



- MWPC – three-plane (x, y, u);
- scintilator: 10 vertical stopping detectors (E).

It covers laboratory polar angles between 10° and 40° and the full range of azimuthal angles.

Current analysis:

- all particles have been registered only in WALL;
- $P_z = 0$ and $P_{zz} = 0$.

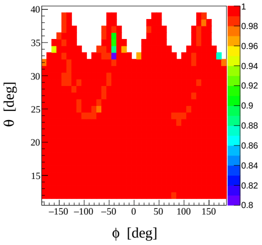
The procedure was performed by counting the number of events in the angular segments of $\Delta\theta = 1^\circ$ and $\Delta\phi = 5^\circ$.

The probability of registration of a particle in a given MWPC plane for a given angular segment centered at (θ, ϕ)

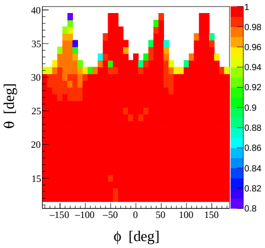
$$\epsilon_x = \frac{N_{xyu}(\theta,\phi)}{N_{yu}(\theta,\phi)}, \qquad \epsilon_y = \frac{N_{xyu}(\theta,\phi)}{N_{xu}(\theta,\phi)}, \qquad \epsilon_u = \frac{N_{xyu}(\theta,\phi)}{N_{xy}(\theta,\phi)}.$$

Single events - MWPC efficiency

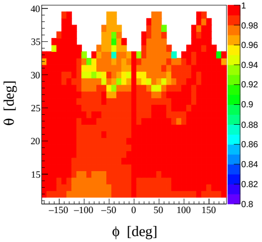
x-plane



y-plane



u-plane



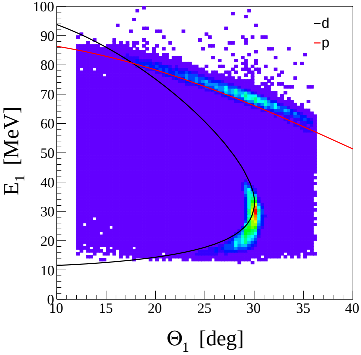
MWPC
Total efficiency:

$$\epsilon_{xyu}(\theta,\phi) = \epsilon_x(\theta,\phi)\cdot\epsilon_y(\theta,\phi)\cdot\epsilon_u(\theta,\phi).$$

Binary events - elastic scattering

Selection of elastic scattering events:

1. $\phi_{pd} = 180° \pm 5°$
2. identification of protons and deuterons based on
   - their energies



Selection of elastic scattering events:

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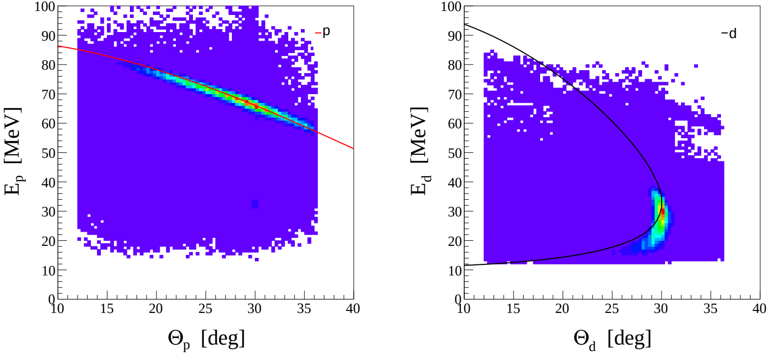

Selection of elastic scattering events:

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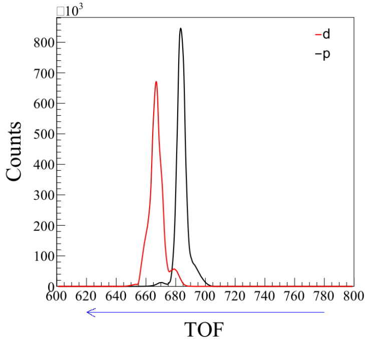
2. identification of protons and deuterons based on
   - their energies $E_p > E_d$
   - TOF from the target to scintillators $TOF = \frac{t_L + t_r}{2}$

     $TOF_p > TOF_d$



Binary events - elastic scattering

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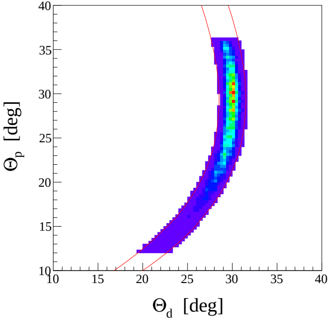
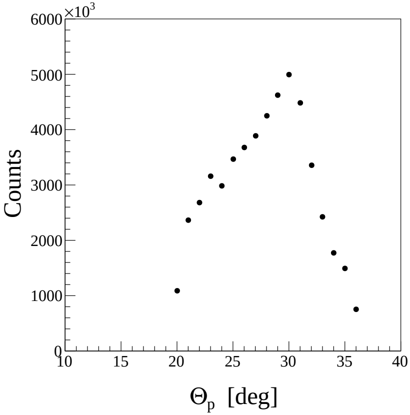
   - TOF from the target to scintillators $TOF = \frac{t_L + t_r}{2}$
     $TOF_p > TOF_d$
3. p - d coincidence



Proton - deuteron coincidences were registered in limited range of θ_p, because of threshold for low energy deuterons.

$$\theta_p \geq 20^\circ$$

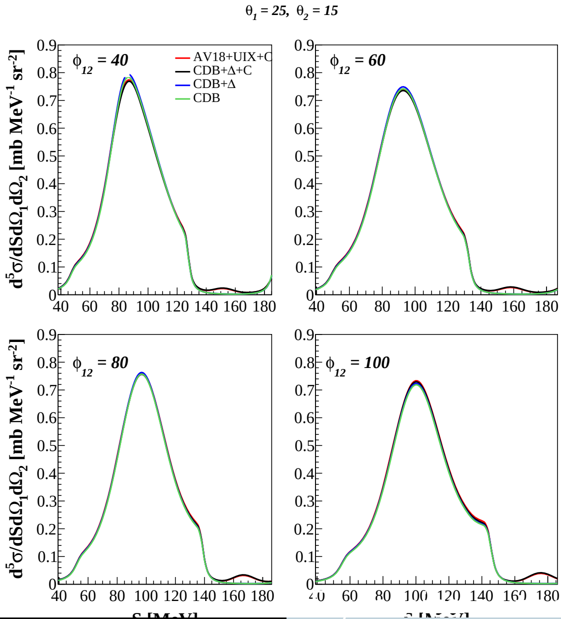
Preliminary results.



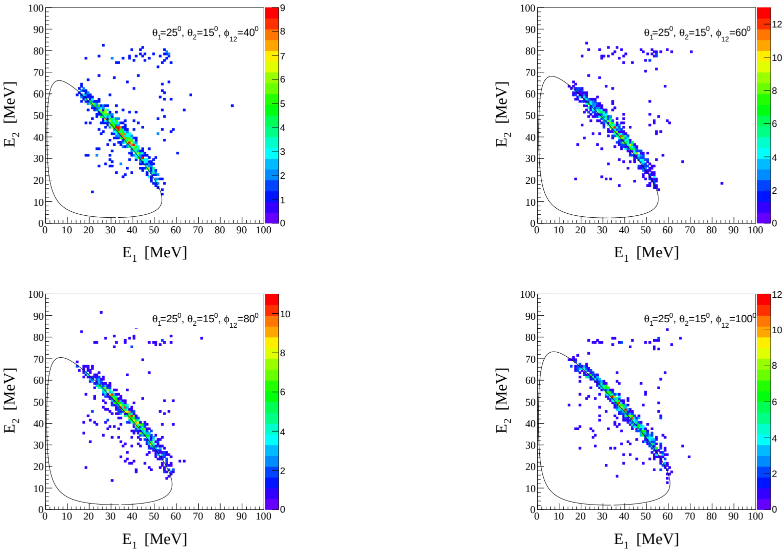
Towards cross section:

- solid angle correction;
- detection efficiency;
- normalization to beam current and target thickness;
- dead time correction.

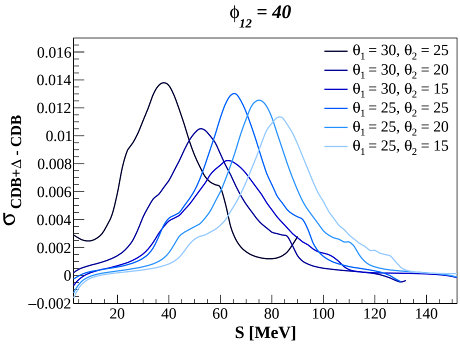
Outlook - breakup

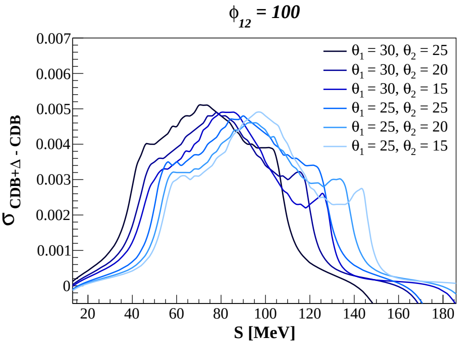


Outlook - breakup



Outlook - breakup





Outlook - breakup