Experimental studies of few-nucleon systems.

I. Skwira-Chalot
for Collaboration of
Faculty of Physics, University of Warsaw, Warsaw, Poland
Institute of Physics, University of Silesia, Chorzów, Poland
Institute of Nuclear Physics, PAS, Kraków, Poland
Institute of Physics, Jagiellonian University, Kraków, Poland
KVI-CART, University of Groningen, The Netherlands

Experimental studies of few-nucleon systems.

I. Skwira-Chalot

1. Introduction.
2. Experiments - status.
3. Outlook.

Introduction - NN interaction

Modern NN potentials are in general able to reproduce:

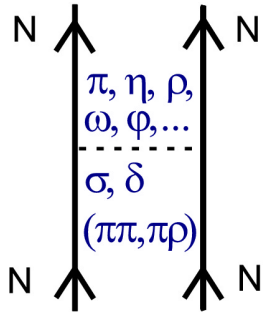
- properties of the nuclear matter (e.q. of state)
- binding energies of light nuclei
- global features of the bulk of the scattering observables in 2N and 3N systems

Role of precise knowledge of few-nucleon system dynamics

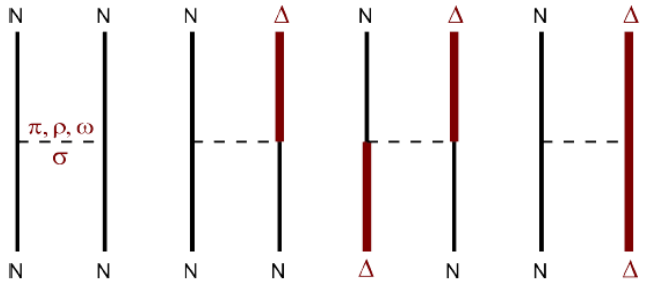
- fundamental for description of nuclei and nuclear processes,
- key feature for application in calculation/simulation codes (fast reaction stage – INC, QMD, etc.); radiation shielding, spallation targets, dosimetry, medical irradiation procedures, biological and astrophysical models, ...

Introduction - standard interaction models of 2N system

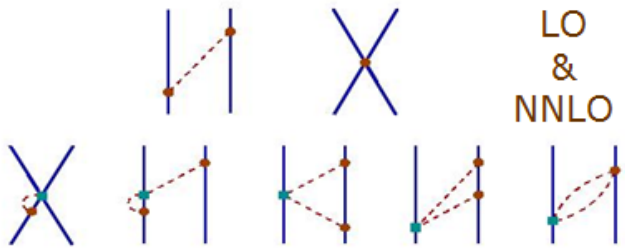
- Realistic potentials: meson exchange theory of NN forces - nucleonic degrees of freedom (AV18, CD Bonn, NijmI, NijmII)



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

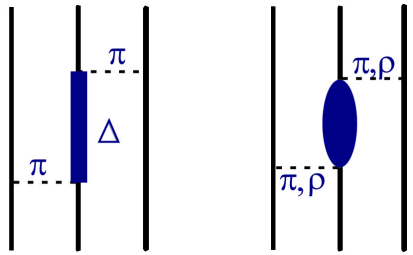


- Chiral Perturbation Theory (ChPT) potential: Effective Field Theory expansion of potential in powers ν of small external momenta Q, $(Q/\Lambda_\chi)^\nu$, with $\Lambda_\chi \approx 1$ GeV

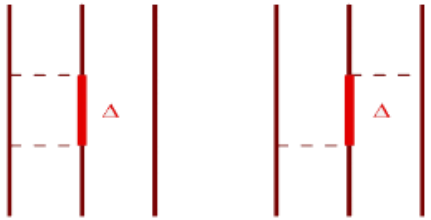


Introduction - 3NF models

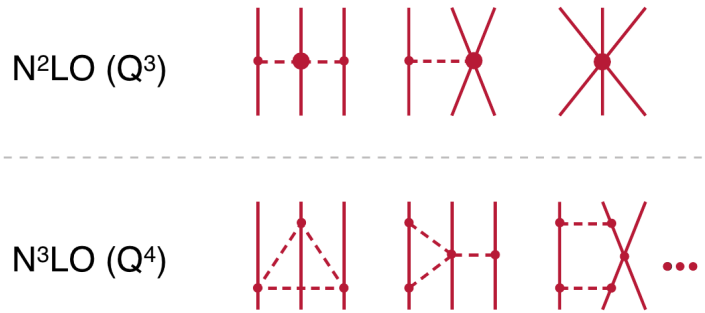
- Phenomenological three-nucleon forces: only weak connection to the NN potentials (e.g. TM99, Urbana IX, Brasil, Illinois);



- 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.)

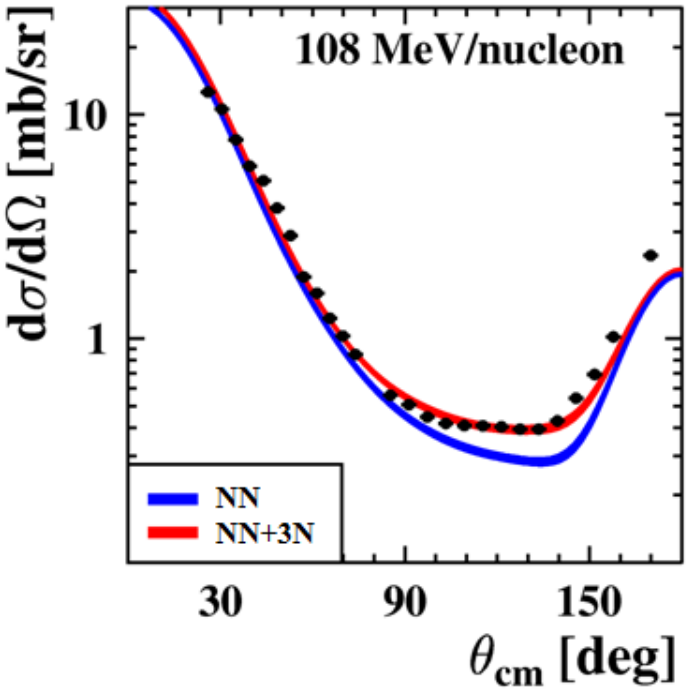


Introduction - 3N systems

Binding energies ...

Model	^3H	^3He
CD Bonn	8.01	7.29
Nijm II	7.66	7.01
AV18	7.62	6.92
CD Bonn + TM99	8.48	7.73
Nijm II + TM99	8.39	7.72
AV18 + TM99	8.48	7.76
AV18 + UIX	8.48	7.76
CC CD Bonn + Δ	8.36	7.64
Experiment	**8.48**	**7.72**

Elastic scattering N + d



K. Ermisch, et al., Phys. Rev. C **68** (2003) 051001(R)

Experiments

The *Nd* 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. analyzing powers) sensitive to dynamical components, which are hidden in the unpolarized case.

Experiments - 3N systems studied experimentally

Reaction mechanisms:

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

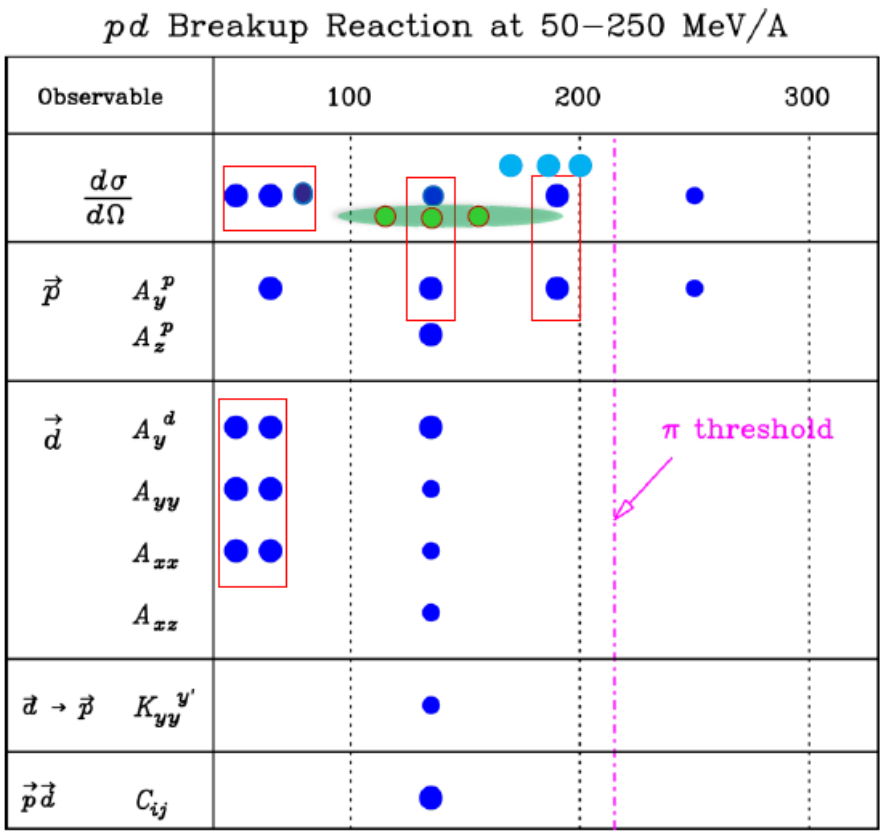
Observables:

- 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.

Experiment - Nucleon-deuteron breakup



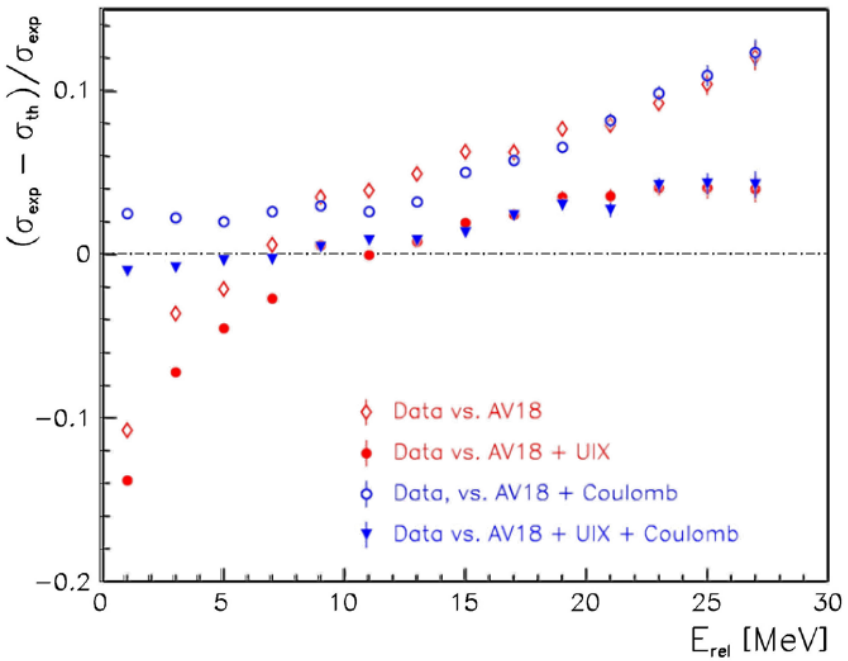
WASA@COSY
SALAD&BINA@KVI
BINA@CCB

A. Łobejko - poster

- A variety of observables and configurations (wide phase space) for the breakup reaction, field of tests for different dynamic ingredients;
- a few hundreds data points per observable;
- sets (a few only) of rich, systematic and precise data are (at last) available.

Experiment - Nucleon-deuteron breakup

3NF & Coulomb force $^1H(d, pp)n$ @ 130 MeV (KVI & FZ-Juelich)



- Effects of 3NF observed at large E_{rel}
  - clear signature of Coulomb force effects
  - the best agreement between experiment and theory is reached when the 3NF and the Coulomb force are taken into account.

Few-nucleon systems - research program

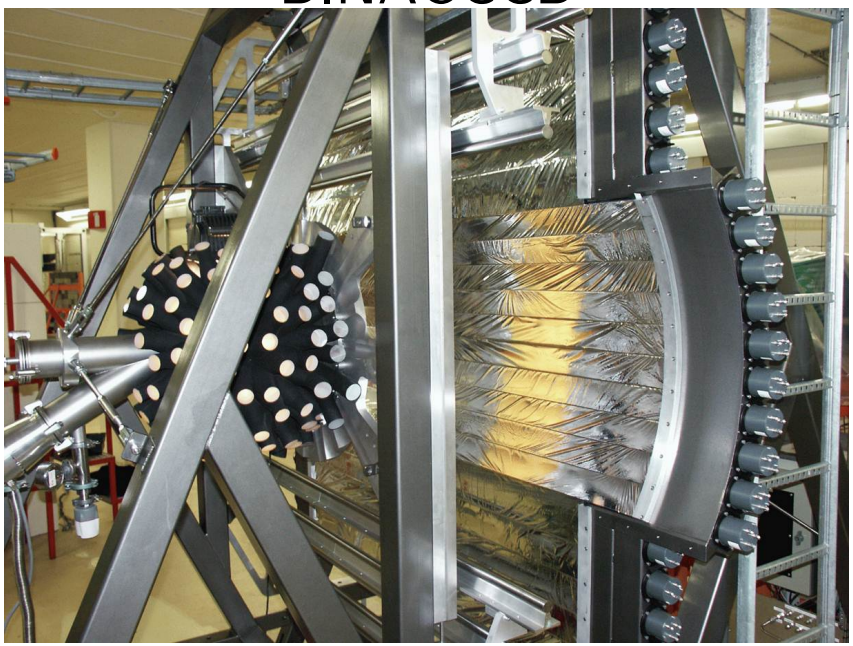
1. Testing 3N systems.
   - 3NF and Coulomb effects in wide range of energy;

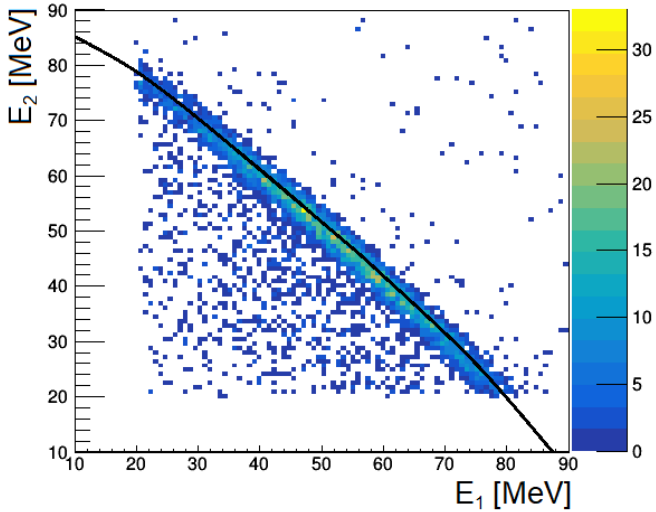
Few-nucleon systems - research program

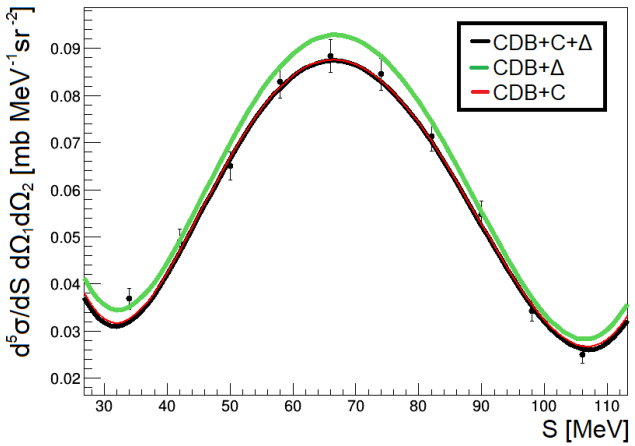
$^2H(p,pp)n$ @ **108**, 135 & 160 MeV

$\theta_1 = 28°$, $\theta_2 = 30°$, $\varphi = 180°$

BINA@CCB







Main targets: LD_2, CD_2.
Reference targets: CH_2, C.

Few-nucleon systems - research program

1. Testing 3N systems.
   - 3NF and Coulomb effects in wide range of energy;
   - Relativistic effects - $^2H(p, pp)n$ at 200 MeV. Theoretically predicted effect $\approx$ 60%. (R. Skibiński);

Few-nucleon systems - research program

1. Testing 3N systems.
   - 3NF and Coulomb effects in wide range of energy;
   - Relativistic effects - $^2H(p, pp)n$ at 200 MeV. Theoretically predicted effect $\approx$ 60%. (R. Skibiński);
2. Testing 4N systems.
   - higher sensitivity (than in 3N systems) for 3NF;
   - many input and output channels;
   - chance for investigation of isospin dependencies (T=3/2);
   - role of 4NF?

2. Testing 4N systems.
   - higher sensitivity (than in 3N systems) for 3NF;
   - many input and output channels;
   - chance for investigation of isospin dependencies (T=3/2);
   - role of 4NF?

$$p + {}^3\vec{H}e$$

2. Testing 4N systems.
   - higher sensitivity (than in 3N systems) for 3NF;
   - many input and output channels;
   - chance for investigation of isospin dependencies (T=3/2);
   - role of 4NF?

System: $p + {}^3\vec{H}e \longrightarrow p + {}^3He$

$\longrightarrow p + p + d$

$\longrightarrow p + p + p + n$

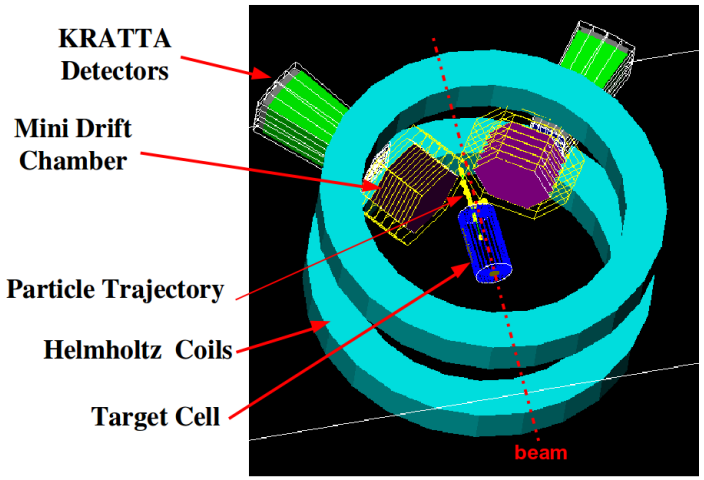
Few-nucleon systems - research program

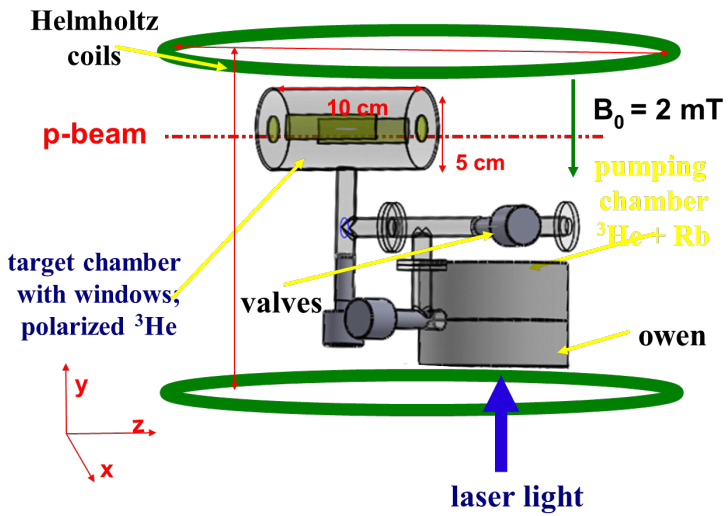
2. Testing 4N systems.
   - higher sensitivity (than in 3N systems) for 3NF;
   - many input and output channels;
   - chance for investigation of isospin dependencies (T=3/2);
   - role of 4NF?

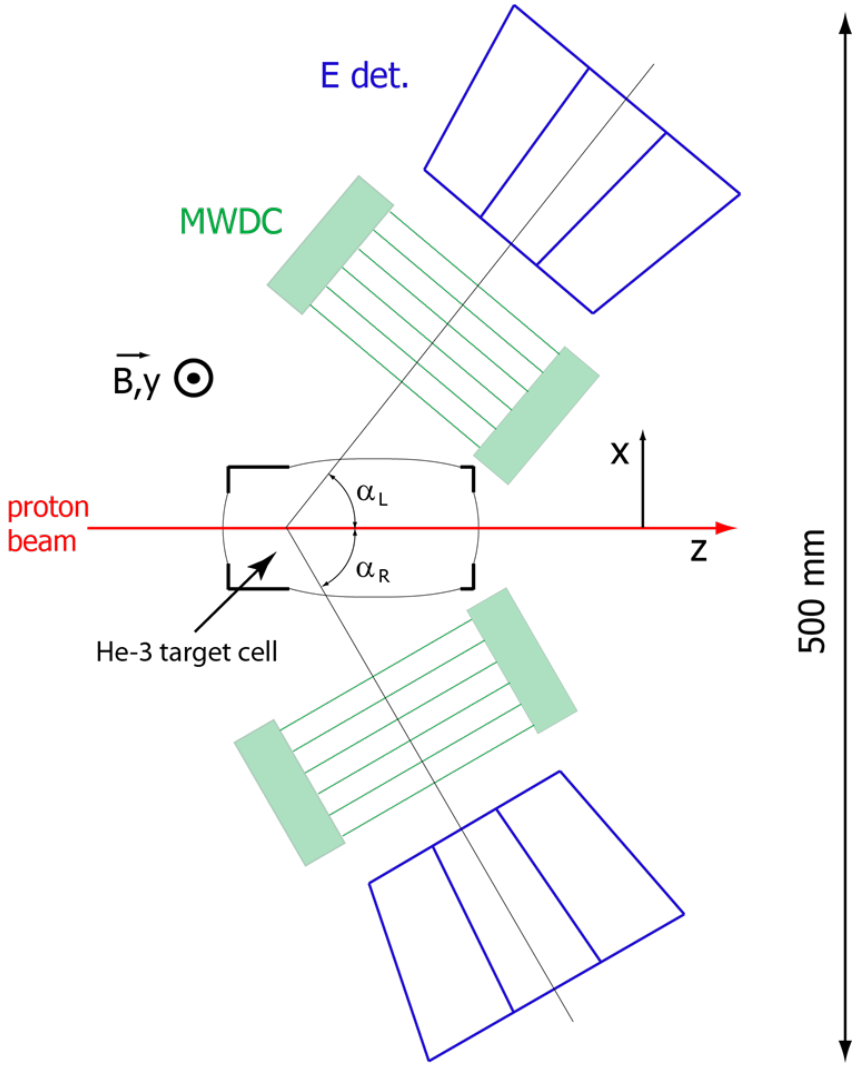
PolHe3 Collaboration:

Main goal of the project:
Precise and complete measurements of vector analyzing powers and differential cross sections of the $p^3\vec{H}e$ elastic and breakup reactions with the use of the polarized He-3 target, in wide range of phase-space and proton energy range of 70 – 230 MeV.

Few-nucleon systems - research program







Few-nucleon systems - research program

Ongoing activities:

- Mechanical tests of scattering cell and different window foils.

- Tests of polarizing cell.

- Fabrication and tests of prototype drift chamber.

Summary

- Nucleon-deuteron scattering is a great tool to investigate the dynamics of 3Ns.
- Significant effects of 3NF for cross sections.
- Coulomb and relativistic effects are not negligible for particular kinematical configuration.

Continuation of our research program at CCB:

- Studies of 3 and 4 nucleon systems with polarized and unpolarized targets in energy and phase space coverage.
- Systematic way of comparing experimental data with calculations.