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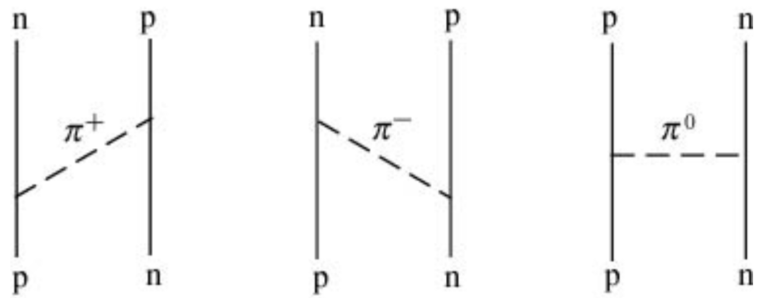
Quasi-free limit in the deuteron-deuteron three-body break-up process

Nasser Kalantar-Nayestanaki
Giving the talk on behalf of Reza Ramazani Sharifabadi

24th European Conference on Few-Body Problems in Physics,
Guilford, England, 3 September 2019

Why d-d scattering?

- N-N interaction is described by exchange of mesons.

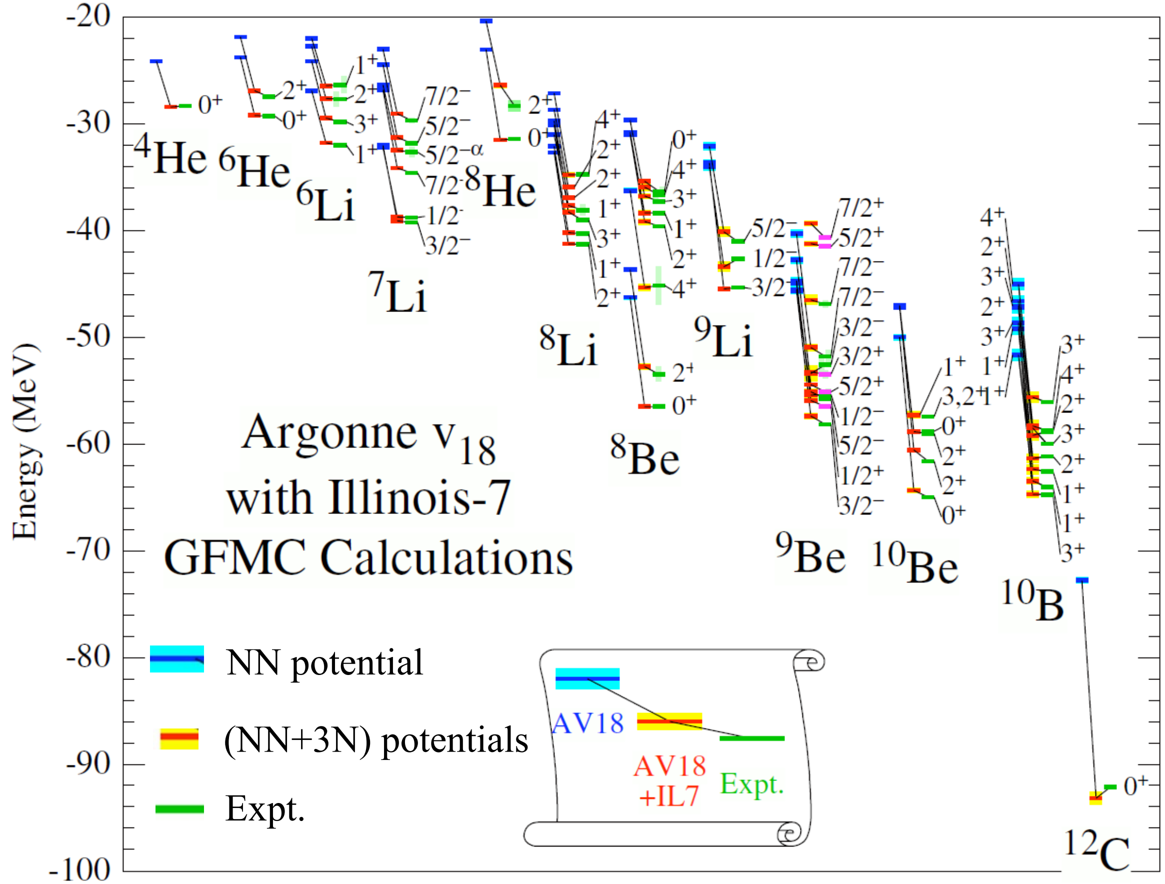


- High-precision NN models were developed based on Yukawa's theory:

CD-Bonn 2000
Argonne $V18$ (AV18)
Nijmegen I, II
…..

Why d-d scattering?

- Variational Monte-Carlo calculations of binding energies using NN and 3N potentials as input
- Two-nucleon force already gives discrepancies for A>2.
- Additional three-nucleon effects (3NF) generally gives a better agreement with experiment.



S. C. Pieper, private communication, (2011).

Why d-d scattering?

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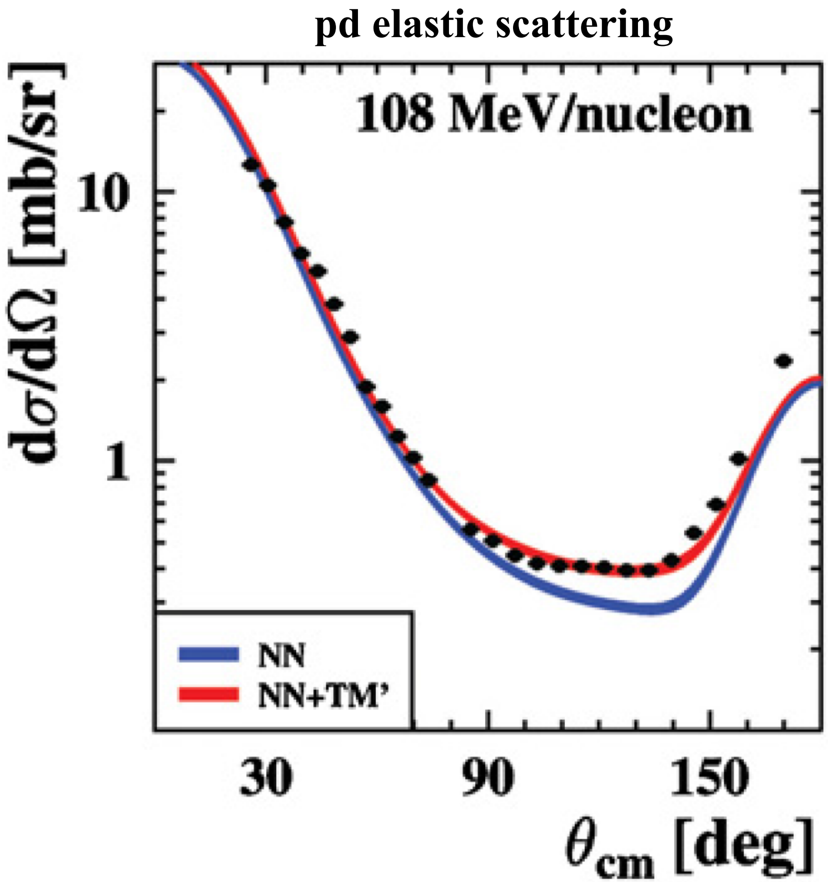
- Two-nucleon force shows discrepancies also in scattering phenomena.
- Additional 3NF generally gives a better agreement with experimental results for cross sections, but for the spin observables shows different trends.



K. Ermisch, *et al . Phys. Rev. Lett.* **86** 5862, (2001).

Why d-d scattering?

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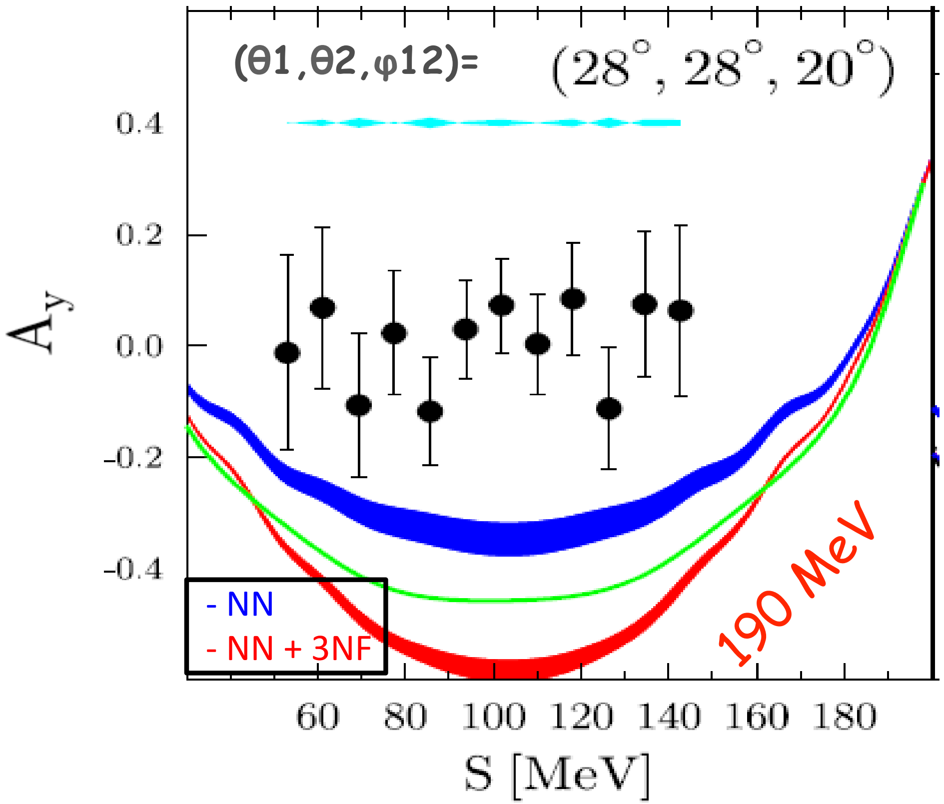
pd break-up reaction



H. Mardanpour, Ph.D. thesis, KVI, University of Groningen, (2008).

Why d-d scattering?

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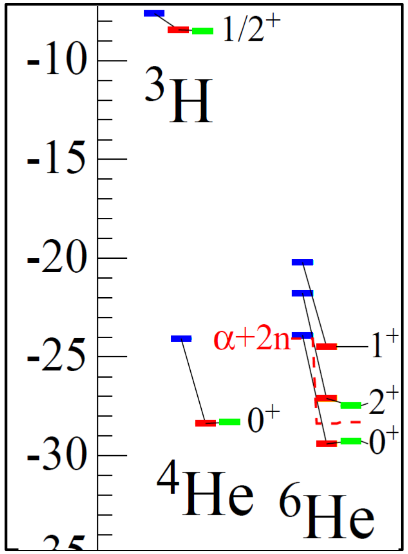
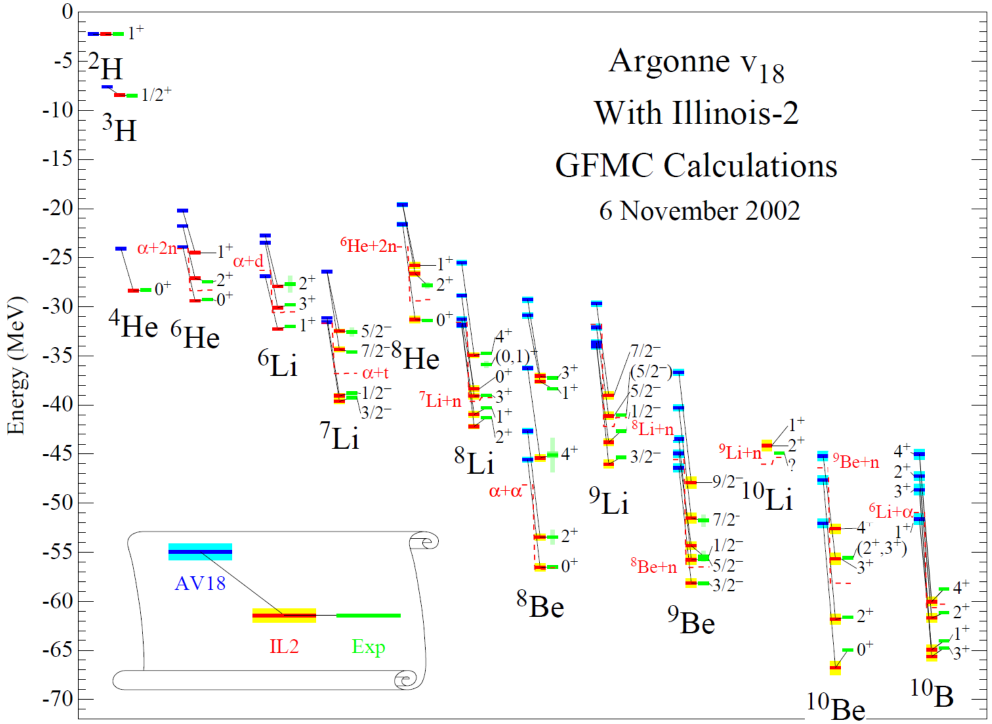
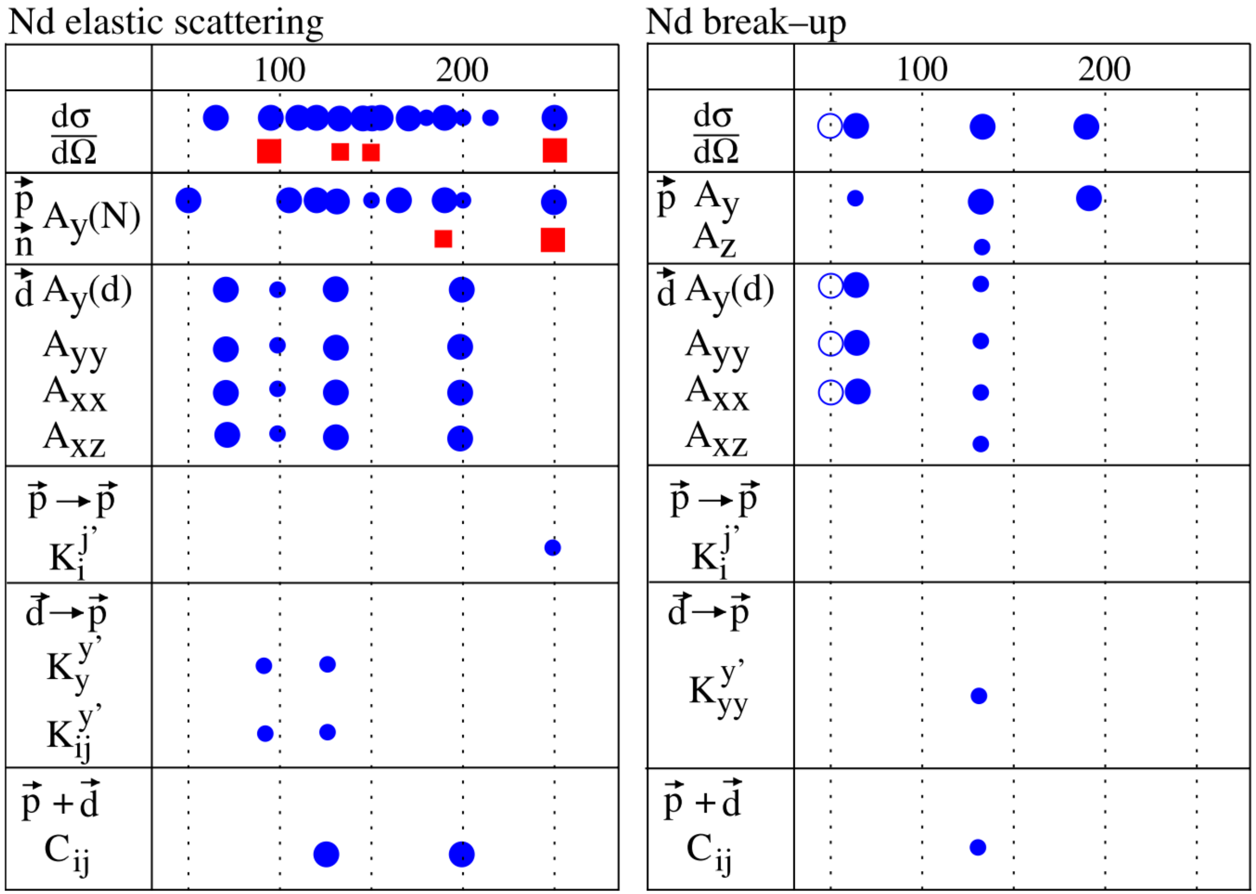
- **3NF effects are significantly enhanced in magnitude in systems with more than 3 bodies.**





Why d-d scattering?

- **3NF effects are significantly enhanced in magnitude in systems with more than 3 bodies.**
- **One needs to expand the database to four-body systems.**



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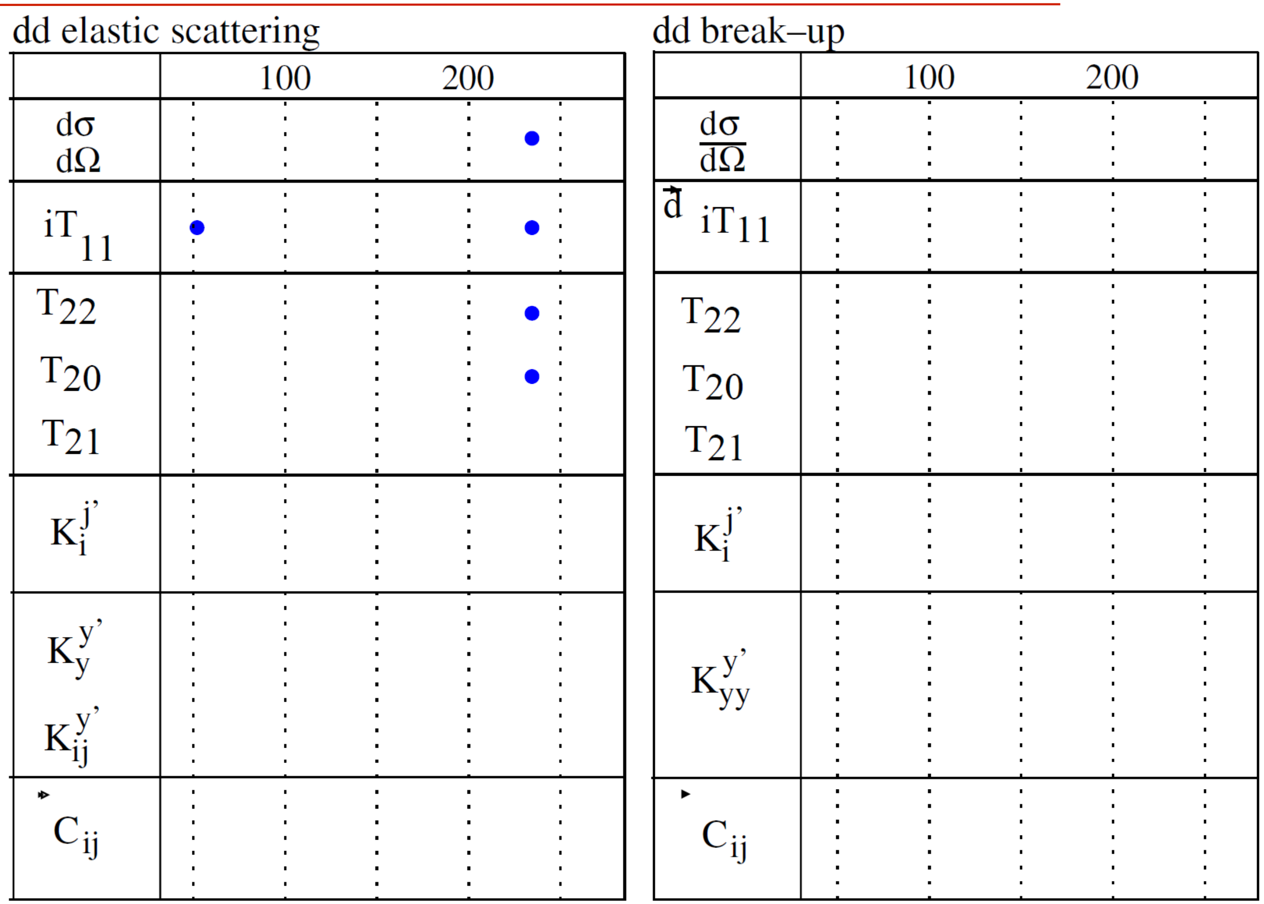
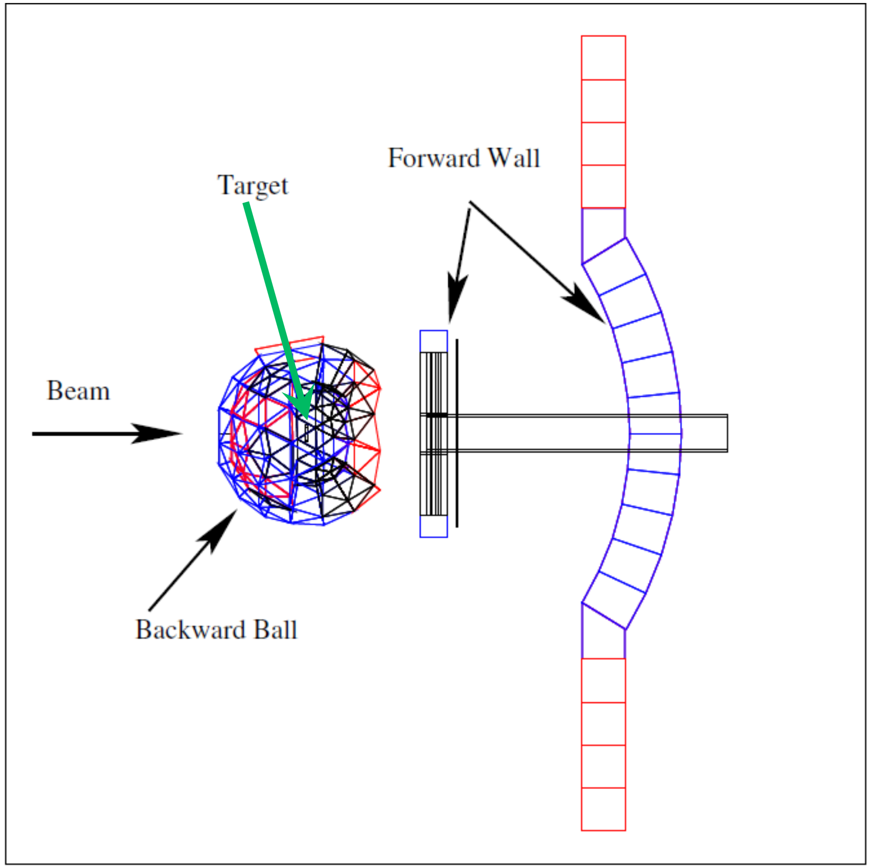


Experimental Setup

BINA (**B**ig **I**nstrument for **N**uclear-Polarization **A**nalysis)

- Forward Wall:
  - MWPC (Multi-Wire Proportional Chamber)
  - ΔE-E detectors
- Backward Ball:
  - 149 Phoswich Scintillators
  - Simultaneously as detector and scattering chamber



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Outline of data analysis

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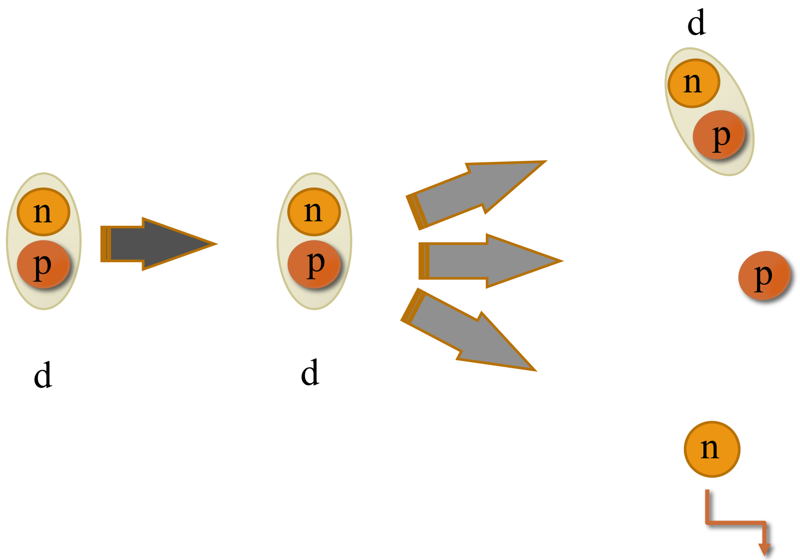
d-d scattering channels:

- $d + d \rightarrow d + d$, d-d elastic channel
- $d + d \rightarrow d + p + n$, Three-body break-up channel
- $d + d \rightarrow {}^{3}H + p$, neutron transfer channel
- $d + d \rightarrow {}^{3}He + n$, proton transfer channel
- $d + d \rightarrow p + p + n + n$, four-body break-up

Analysis of 3-body break-up channel

Kinematics of three-body break-up channel:



Quasi-free limit:

Kinetic energy, $E_n \sim 0$

Analysis of 3-body break-up channel

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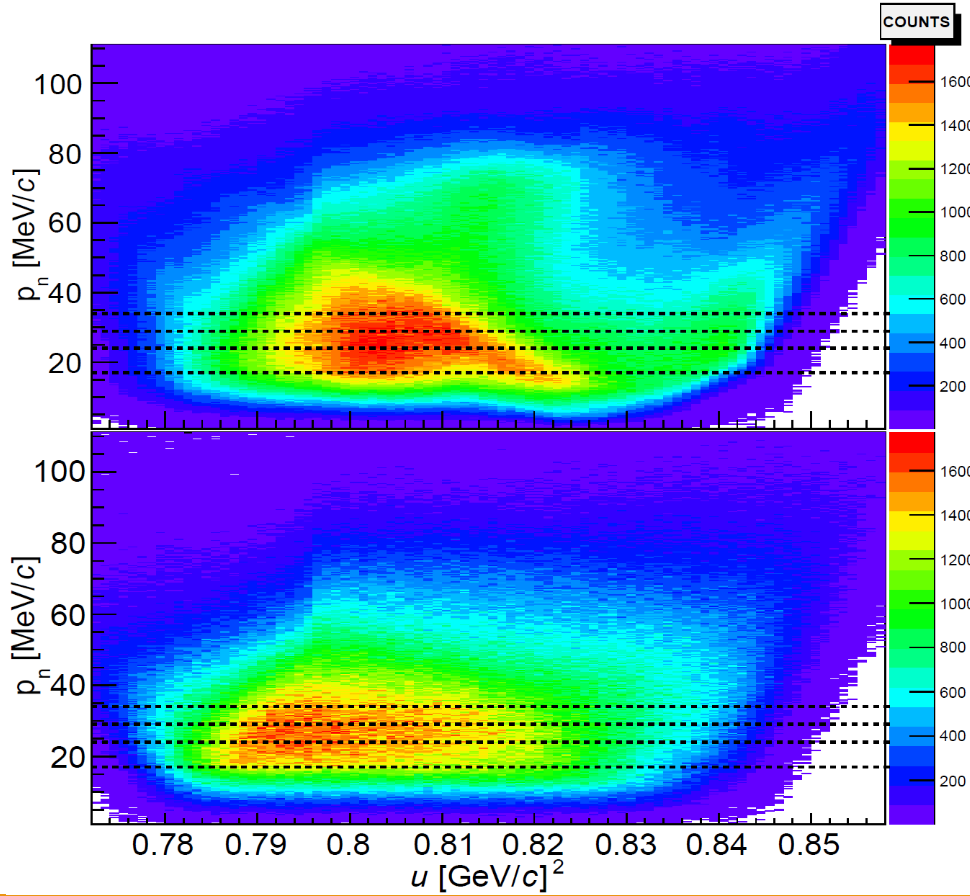
Quasi-free domain:

- Top panel: Correlation between neutron energy and Mandelstam variable u as the square of the four-momentum transfer between the incident deuteron and the final-state proton, $u = (p_{beam} - p_p)^2$.

- Bottom panel: Corresponding PLUTO simulation



Analysis of 3-body break-up channel

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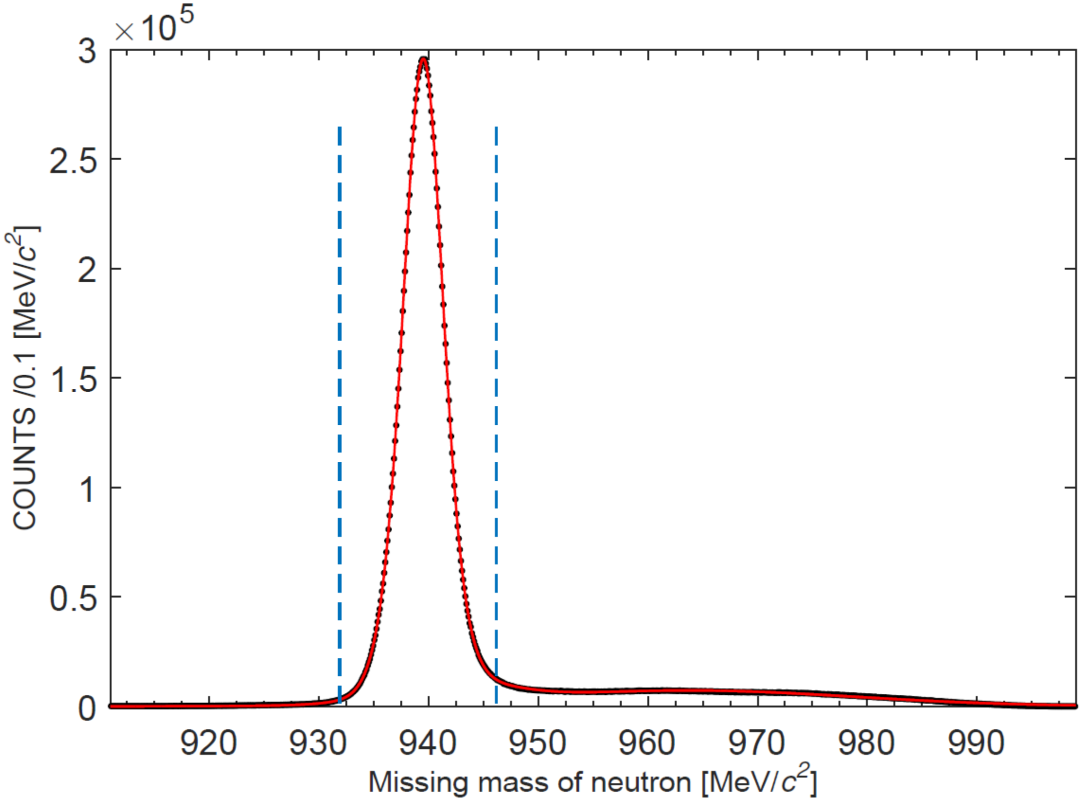
- Missing-mass spectrum of neutron to investigate the quality of energy calibration and the contribution of the remaining background.

- A peak around 939.50 ± 0.05 MeV is observed.

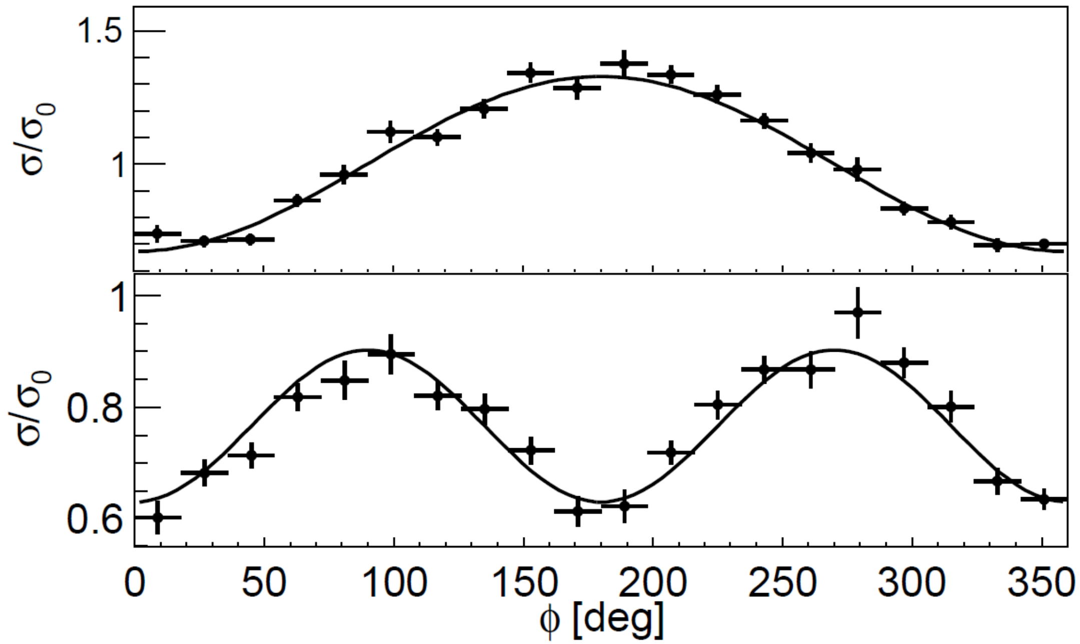
- Suppress the background using a cut around the nominal neutron mass with ±3σ.



Analysis of 3-body break-up channel

Analyzing powers for *d-d* break-up channel:

$$\sigma(\xi,\phi) = \sigma_0(\xi)[1 + \sqrt{3}p_Z Re(iT_{11}(\xi))\cos(\phi) - \frac{1}{\sqrt{8}}p_{ZZ}T_{20}(\xi) - \frac{\sqrt{3}}{2}p_{ZZ}Re(T_{22}(\xi))\cos(2\phi)]$$



Analysis of 3-body break-up channel

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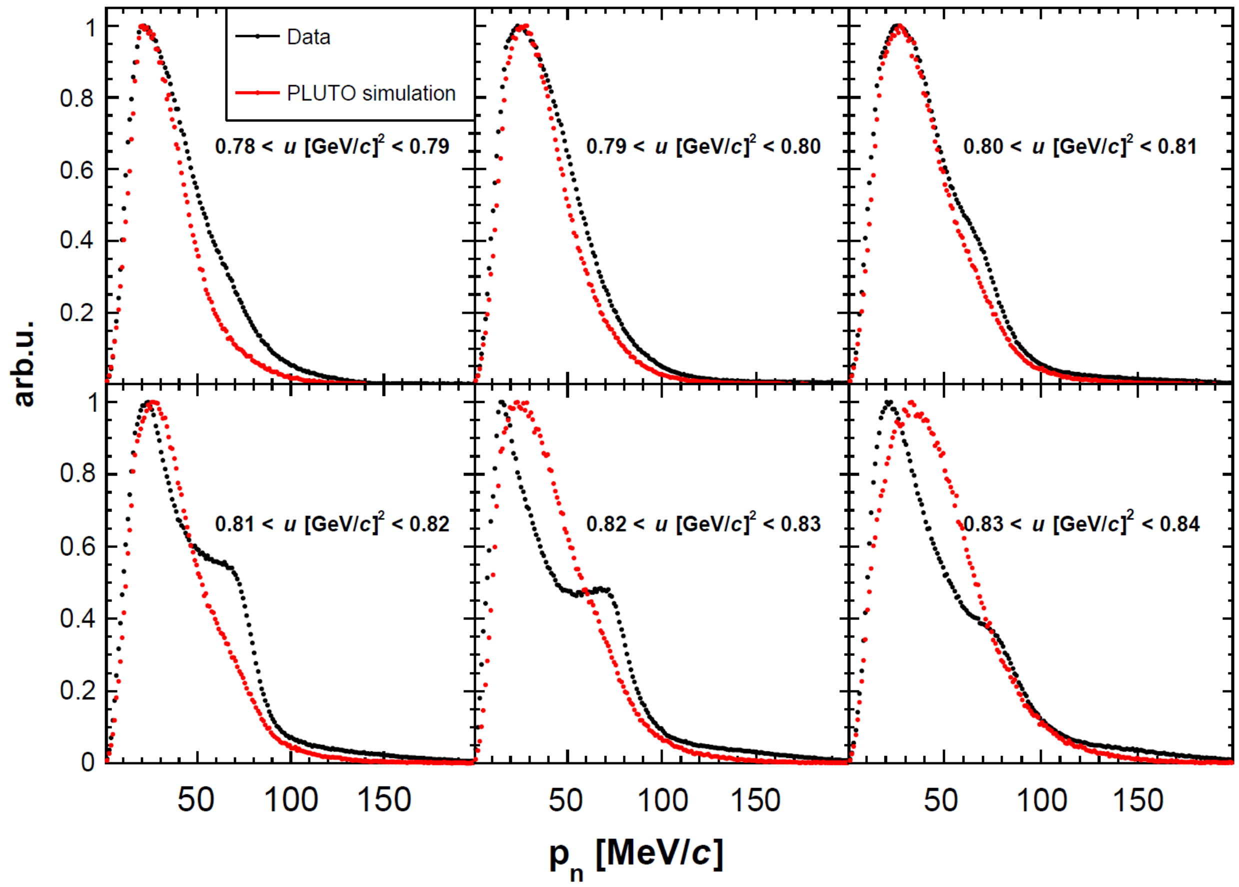
- Comparison between the reconstructed momentum distribution of the missing neutron for different intervals of Mandelstam variable u and the expected momentum distribution of the nucleon derived from the wave function of deuteron.



Analysis of 3-body break-up channel

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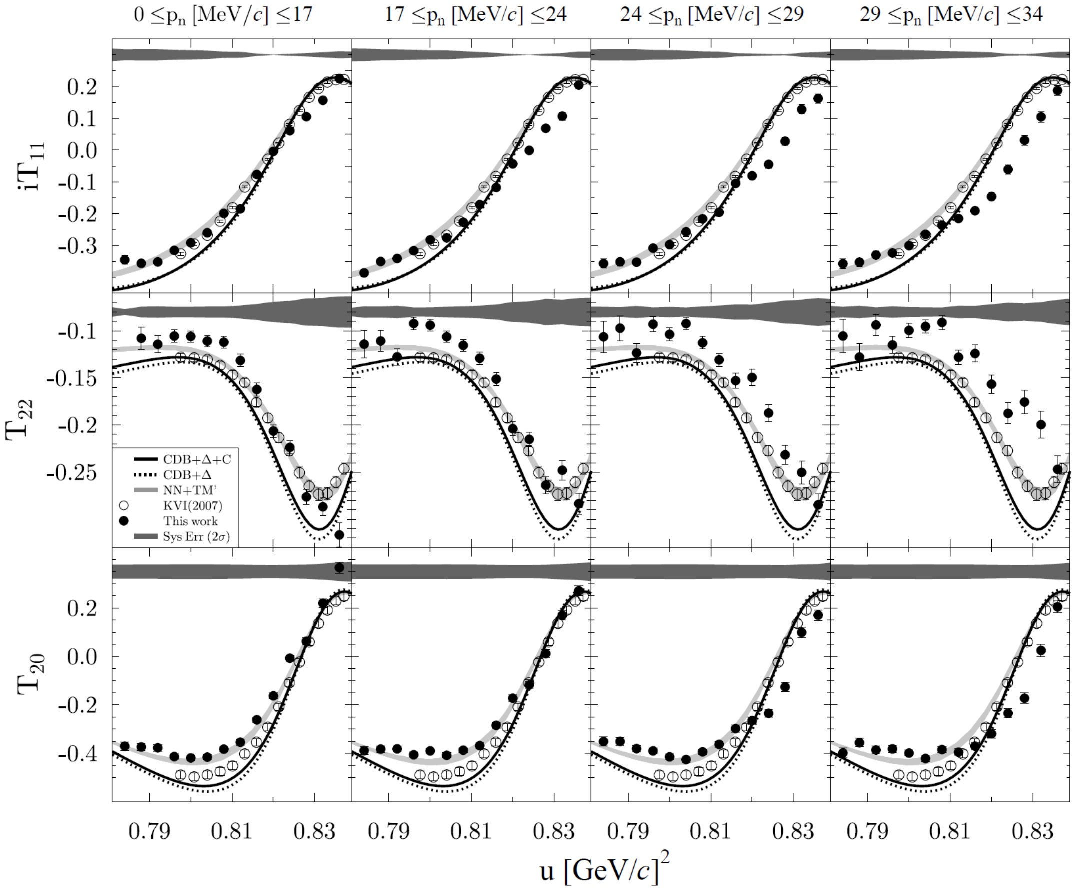
➢ Analyzing powers as a function of u for different intervals of neutron energy



Paper by R. Ramazani Sharifabadi accepted yesterday by EPJA.

Summary

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- Precision measurements of analyzing powers in low neutron momentum have been performed.

- In the limit of vanishing neutron momentum and at large deuteron-proton momentum transfer (small u), the data agree well with the measured and theoretically predicted spin observables of the elastic deuteron-proton scattering process.

- The agreement deteriorates rapidly with increasing neutron momentum and/or decreasing momentum transfer from the deuteron beam to the outgoing proton (large u).

Collaboration

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Dutch-Polish collaboration with BINA

R. Ramazani-Sharifabadi , M.T. Bayat, N. Kalantar-Nayestanaki,

St. Kistryn, A. Kozela, M. Mahjour-Shafiei, J. G. Messchendorp,

M . Mohammadi-Dadkan, A. Ramazani-Moghaddam-Arani,

E. Stephan, and H. Tavakoli-Zaniani

Thank you for your attention