Cross sections for the star configurations of the d(160 MeV)+p→p+p+n breakup reaction

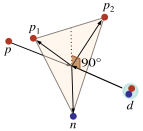
Andrzej Wilczek

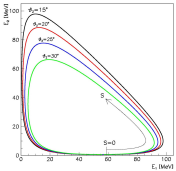
Institute of Physics, University of Silesia, Katowice

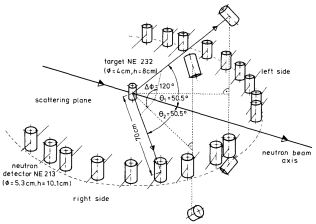
MENU 2023
19.10.2023

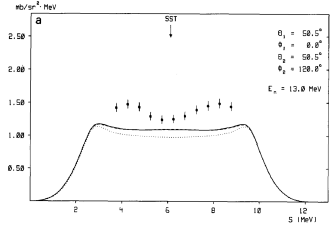
In the beginning...

- Erlangen group measured n+d→p+n+n breakup cross sections in 1989 (Strate et al.)
- Kinematics of breakup reaction – wide range of configurations with different sensitivities to NN potentials and three-nucleon force.
- One of the configurations, which are the least sensitive to the details of NN potentials is Symmetric Space Star (SST) (Kloet and Tjon 1973)
- SST is a specific configuration where momenta of the final state nucleons form an equilateral triangle and the decay plane is perpendicular to the beam direction







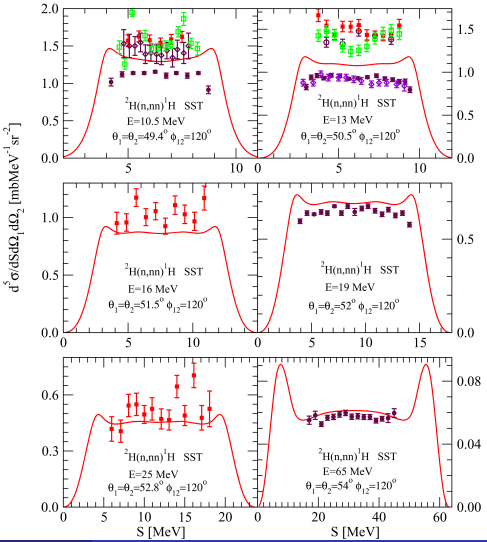


J. Strate et al. Nucl. Phys. AS01, 51 (1989)

Space Star Anomaly

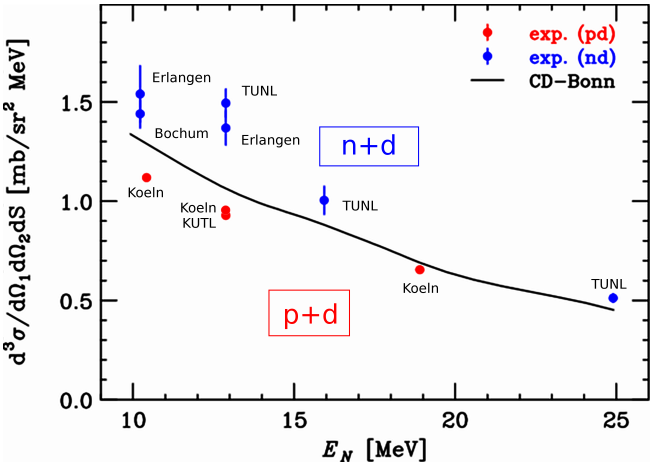
- While some other discrepancies reported by Strate et al. were found to be due to systematic problems with the subtraction of accidental coincidence background, Space Star Anomaly persists
- It was confirmed by TUNL in 1996 (Setze et al.)
- The effect is opposite in p+d breakup (15% below theory)
- Mainly $^1S_0$ of binary NN interaction (also $^3S_1$-$^3D_1$)
- Energy too low for 3NF to be apparent (max. few %)
- Coulomb force and relativistic effects negligible

Right panel: H. Witała et al. Phys. Rev. C 104, 014002 (2021)



The dependency on energy

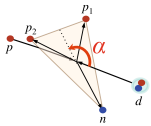
- The highest ever measured p+d energies are 19 and 65 MeV
- In both cases the data are consistent with the theoretical predictions
- The effect appears at energies about 9-13 MeV
- What about higher energies?

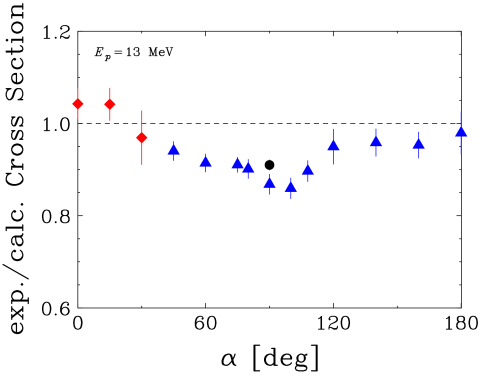


Y. Eguchi. Fb19 conference presentation.

Inclination angle

- Initially, Strate et al. reported deviation from the theory also for the coplanar star
- Setze et al (1996) did not found the effect
- Ohnaka et al. measured the dependency of the cross section on inclination angle
- By varying α one finds the discrepancy peaks at the SST (90°)
- Forward and Backward Plane Star configurations follow the theoretical predictions

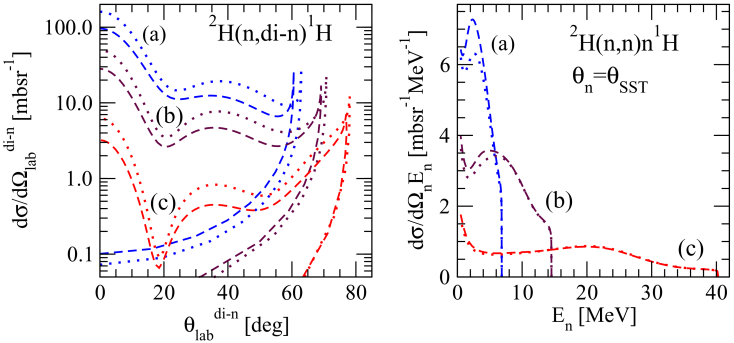




K. Ohnaka et al. Few-Body Syst. 55, 725 (2014)

Possible explanation

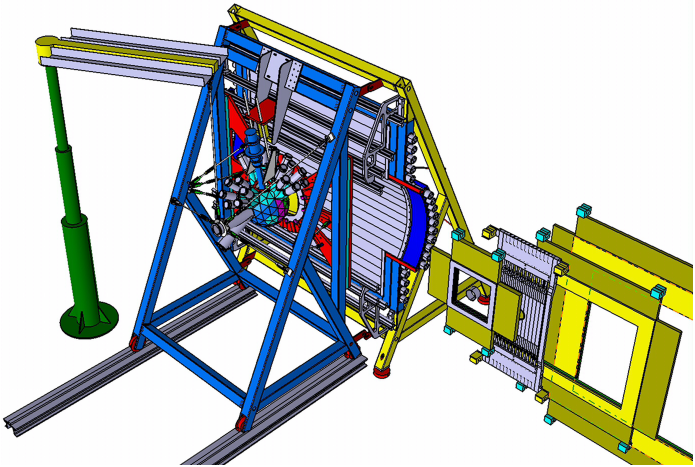
- Witała et al. proposes, this effect might be due to production of di-neutron
- This is very difficult to separate from the 3-body kinematics
- The angular distributions and the energy spectra for 13 MeV (a), 25 MeV (b) and 65 MeV (c) beam energy shown in the panel
- Plots for di-neutron bounding energies -0.144 MeV (dashed) and -0.411 MeV (dotted-dashed)



H. Witała et al. Phys. Rev. C 104, 014002 (2021)

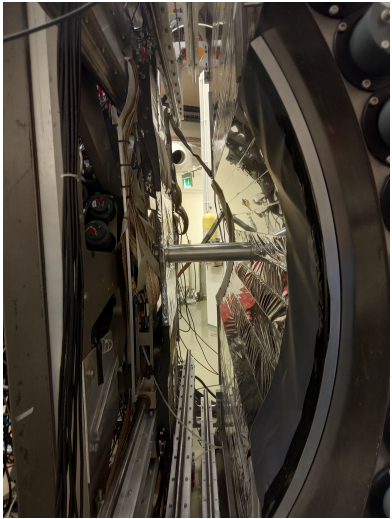
The BINA detector setup

- A 4π geometry facilitates a simultaneous measurement of a set of the star configurations with different α $\rightarrow$ the same luminosity
- Axial symmetry makes possible to rotate the configuration about the beam axis $\rightarrow$ systematic effect
- MWPC and Wall $\theta \in (12^\circ, 35^\circ)$ (resolution $(0.67^\circ, 1.39^\circ)$)
- Ball $\theta \in$ 40-165° (resolution 10°)

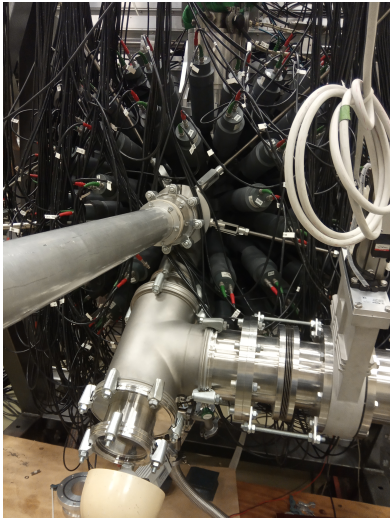


BINA@CCB

- Forward Wall

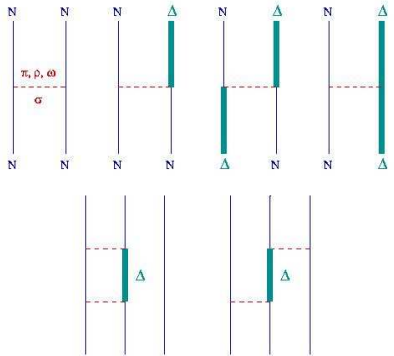


- Backward Ball



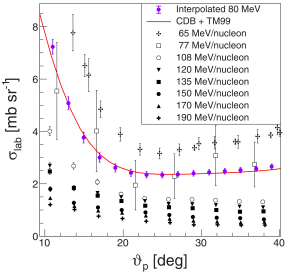
CD-Bonn+Δ+C

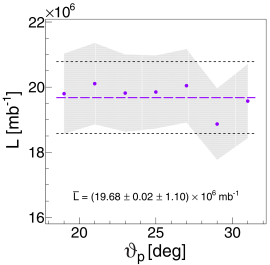
- CD-Bonn is a realistic potential
- Addition of Δ excitation enables to describe 3NF
- Coulomb effects are introduced by A. Deltuva

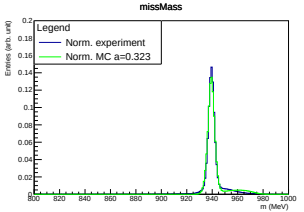


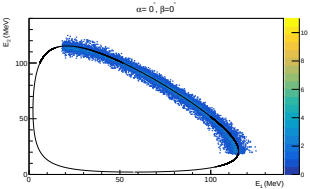
Data analysis

- Track reconstruction
- Particle identification
- Energy reconstruction
- Process identification
- Detector efficiency
- Correction for hadronic effects
- Luminosity calculation



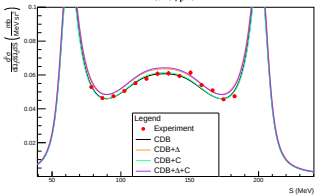


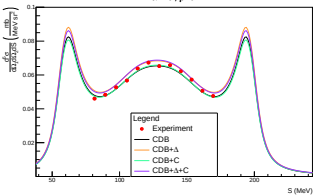


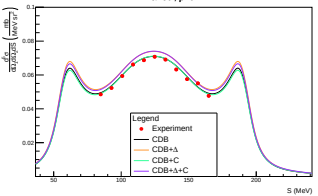


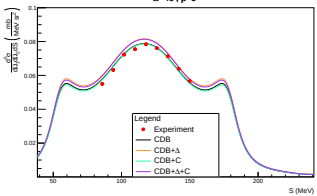
Top panel: W. Parol et al. Phys. Rev. C 102, 054002 (2020)

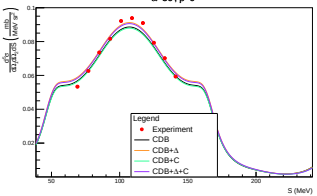
Preliminary d(160MeV)+p results

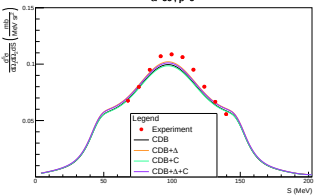




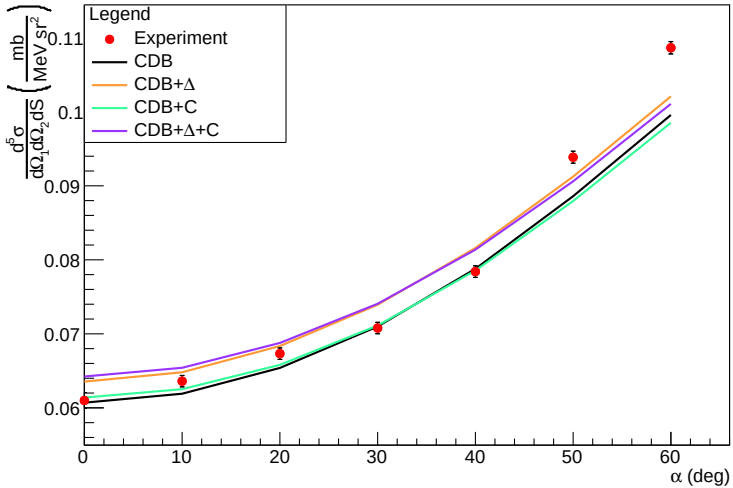






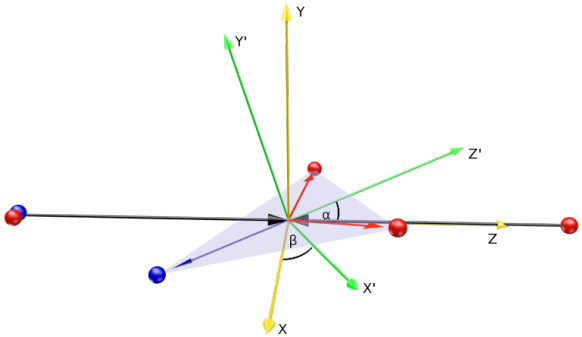


Preliminary d(160MeV)+p results



Another rotation angle β

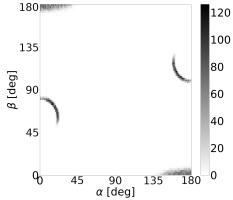
- All $\alpha > 60^\circ$ configurations in d+p are at $\theta > 30^\circ$
- Poor resolution in ball-ball coincidences (p+d)
- Definition of β (rotation angle about the axis perpendicular to the reaction plane) enables to analyse them as wall-ball coincidences



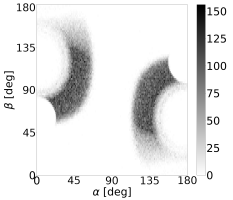
Outlook: Detection possiblity for BINA

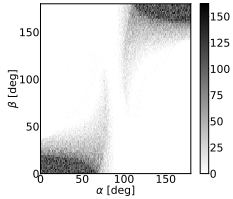
Reaction ^{1}H(d,pp)n for E_{beam} = 80 MeV/nucleon

Ball-Ball



Ball-Wall

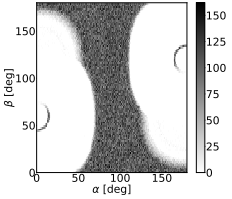




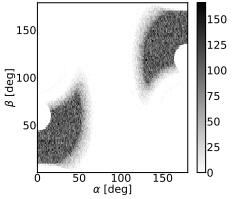
Wall-Wall

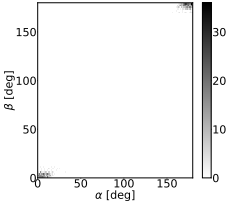
Reaction ^{2}H(p,pp)n for E_{beam} = 108 MeV

Ball-Ball



Ball-Wall



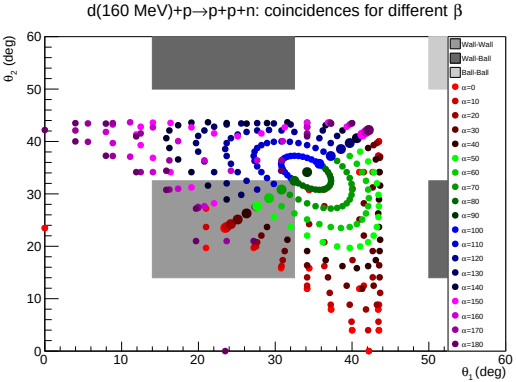


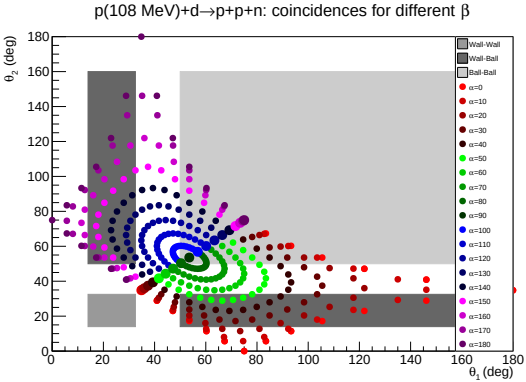
Wall-Wall

A. Szadziński et al.

Acta Phys. Pol. B 51, 763 (2020)

Outlook: Detection possiblity for BINA





Outlook

- The project aims at obtaining cross sections for deuteron on proton breakup for energies 50 and 80 MeV/nucleon, as well as for proton beam at 108 and 160 MeV
- The analysis should take into account also the dependency on β angle
- This will fill the gap in the energy scan of the process and find whether the SSA is characteristic only to the lowest energies
- Some new theoretical predictions are awaited (theories calculated in relativistic framework, χEFT)