

Studies of the star configurations at intermediate energies with the use of the BINA detector

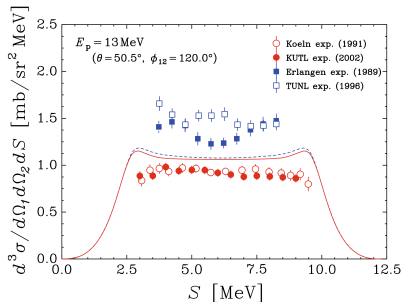
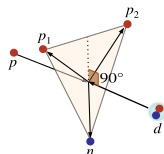
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What is the Space Star Anomaly

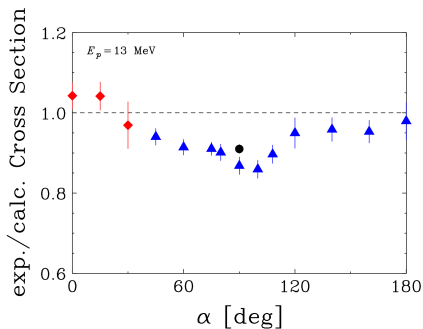
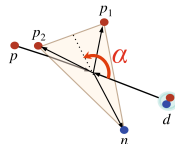
- Space Star is a specific configuration where momenta of the final state nucleons form an equilateral triangle and the decay plane is perpendicular to the beam direction
- The effect was discovered in 1989 in $n+d$ breakup by Erlangen group (Strate et al.) (30% above the predictions)
- It was confirmed TUNL in 1996 (Setze et al.)
- The effect is opposite in $p+d$ breakup (15% below theory)
- Mainly s -wave of binary NN interaction
- Energy too low for 3NF to be apparent (max. few %)
- Coulomb force and relativistic effects negligible



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

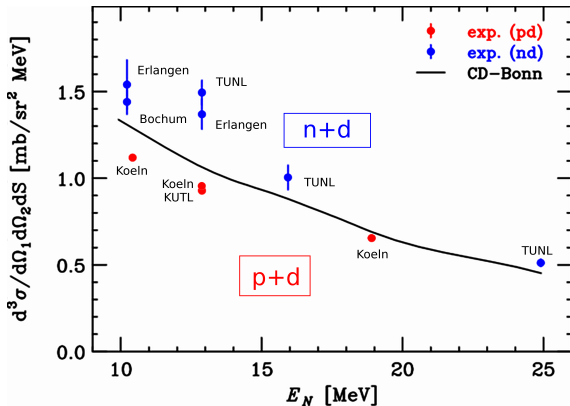
Inclination angle

- Ohnaka et al. measured the dependence of the cross section on inclination angle
- By varying α one finds the discrepancy peaks at the Space Star (90°)
- Forward and Backward Plane Star configurations follow the theoretical predictions



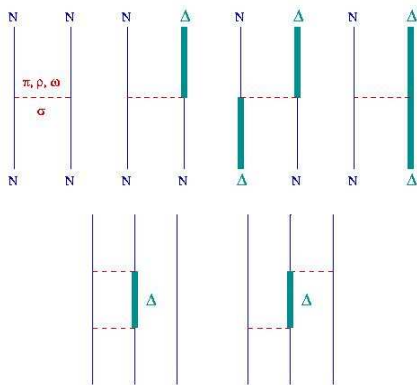
Energy dependence

- 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?



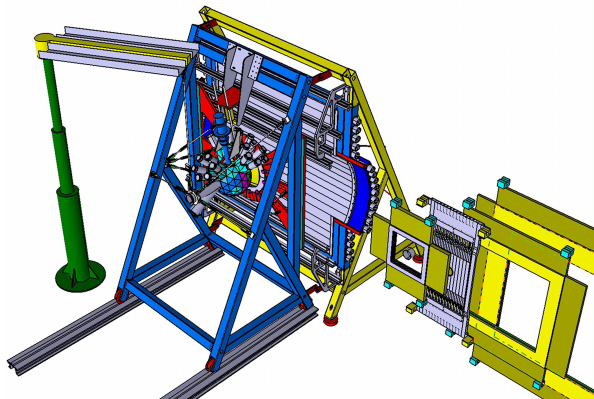
CD-Bonn+ Δ +C

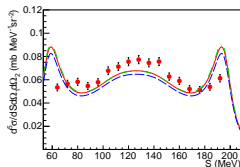
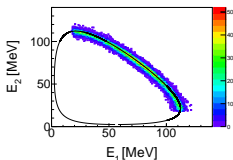
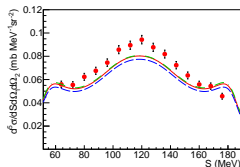
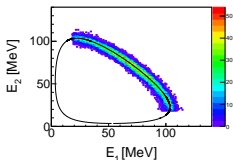
- CD-Bonn is a realistic potential
- Addition of Δ excitation enables to describe 3NF
- Coulomb effects are introduced by A. Deltuva



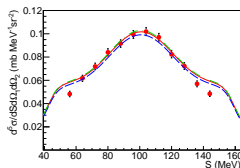
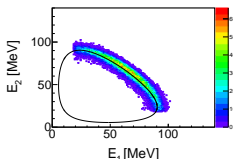
- A 4π geometry facilitates a simultaneous measurement of a set of the star configurations with different $\alpha \rightarrow$ the same luminosity

- Axial symmetry makes possible to rotate the configuration about the beam axis \rightarrow systematic effect
- MWPC and Wall $\theta \in 10\text{-}35^\circ$ (resolution 0.7°)
- Ball $\theta \in 40\text{-}165^\circ$ (resolution 10°)



First pre-preliminary $d(160\text{MeV})+p$ results $\alpha = 20^\circ$ CD-Bonn+
 Δ +CoulombCD-Bonn+ Δ $\alpha = 40^\circ$ CD-Bonn+
Coulomb

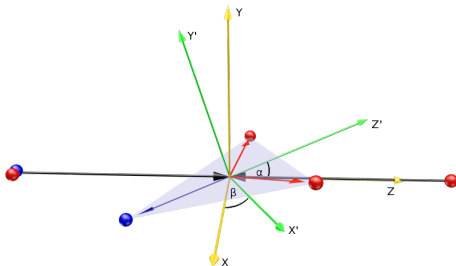
Current status:

 $\alpha = 60^\circ$ 

The theory is presented for the exact value of α , is to be averaged over all accepted configurations

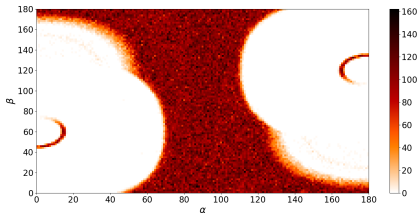
Another rotation angle β

- All $\alpha > 60^\circ$ configurations in p+d are at $\theta > 40^\circ$
- Poor resolution in ball-ball coincidences
- Definition of β (rotation angle about the axis perpendicular to the reaction plane) enables to analyse them as wall-ball coincidences

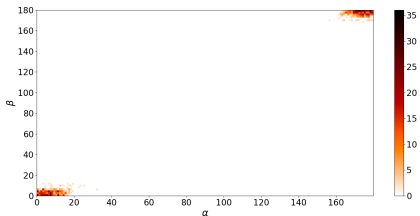
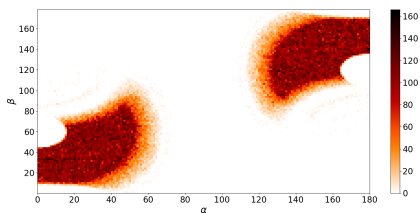


Detection possibility for BINA

Ball-Ball



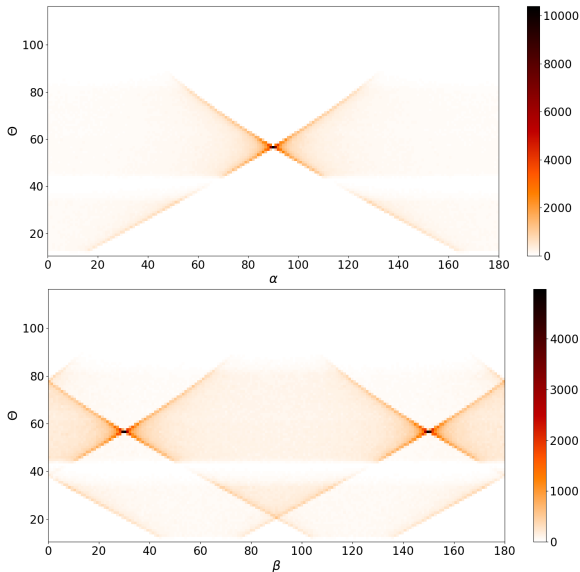
Ball-Wall



Wall-Wall

Thanks to the courtesy of A. Szadzinski

- The β angle is equivalent of azimuthal angle for $\alpha = 90^\circ$
- Rotation by α changes only the angle of one proton at the values $\beta = 30^\circ$ and $\beta = 150^\circ$



Thanks to the courtesy of A. Szadzinski

Outlook

- The project aims at obtaining cross sections for deuteron on proton breakup for energies 50, and 80 MeV/nucleon (already measured), as well as for proton beam of energy 108, 135, and 160 MeV (partially measured).
- The analysis should take into account also dependence 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, χ EFT).
- The experiment starts this month.