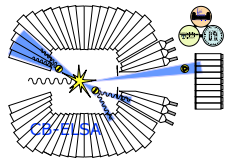
New insights into the narrow structure in ηn from polarisation observables at Bonn

Jan Hartmann

for the CBELSA/TAPS collaboration

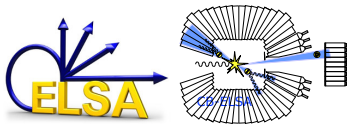
HISKP, University of Bonn

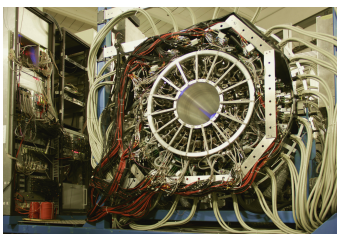


June 18, 2024

New insights into the narrow structure in ηn from polarisation observables at Bonn

1. Introduction
2. η Photoproduction off the neutron
3. The CBELSA/TAPS experiment
4. Event selection and reconstruction
5. Results: polarization observables T, P, H
6. Summary and Outlook





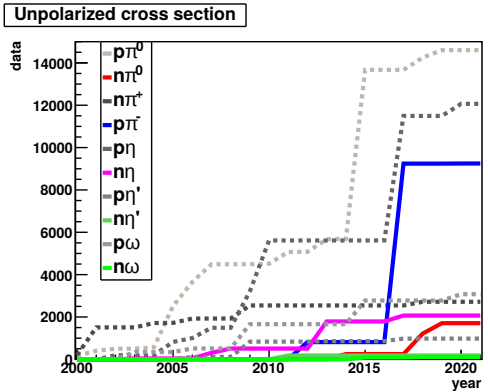
N^* and Δ^* from Photoproduction

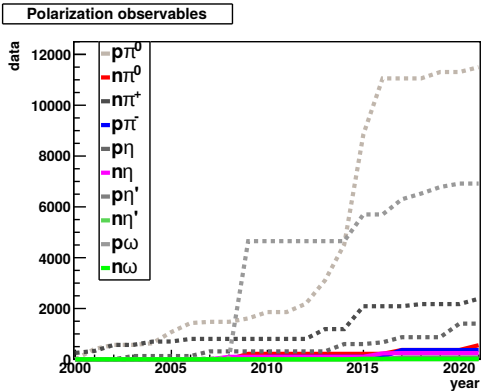
- Until 2010: Almost all resonances from πN scattering
- 2000–2010: no new baryon resonance considered by the PDG
- after 2012: photoproduction data included $\rightsquigarrow$ new baryons

  Multi-channel PWA based on data from: JLab, ELSA, MAMI, SPring-8, GRAAL, ...

	RPP 2010	BnGa	RPP'22 (2018-22)
N(1710)1/2$^+$	***	****	****
N(1860)5/2$^+$		*	**
N(1875)3/2$^-$		***	***
N(1880)1/2$^+$		***	***
N(1895)1/2$^-$		****	****
N(1900)3/2$^+$	**	****	****
N(2060)5/2$^-$		***	***
N(2100)1/2$^+$	*	***	***
N(2120)3/2$^-$		***	***
Δ(1600)3/2$^+$	***	***	****
Δ(1900)1/2$^-$	*	***	***
Δ(1940)3/2$^-$	*	**	**
Δ(2200)7/2$^-$	*	***	***

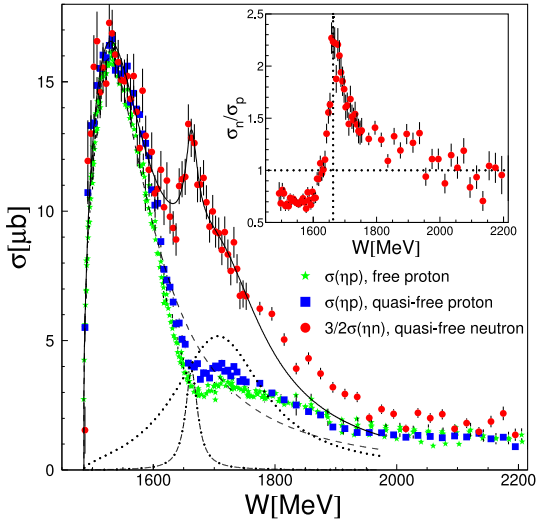
Available Photoproduction Data





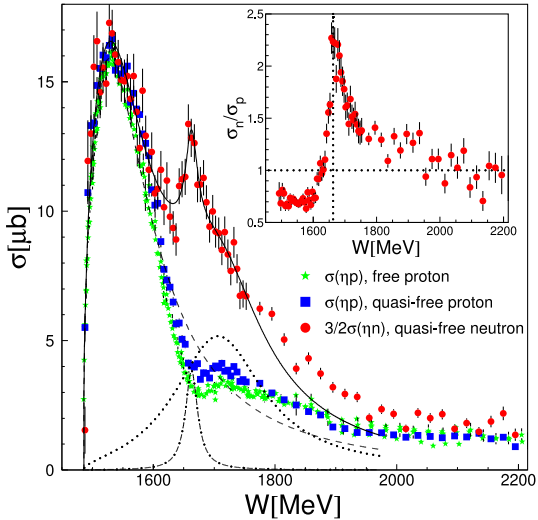
- Most existing data on proton target
- Data on neutron target: nearly only cross sections
- Almost no polarization data on neutron target

η Photoproduction off the neutron

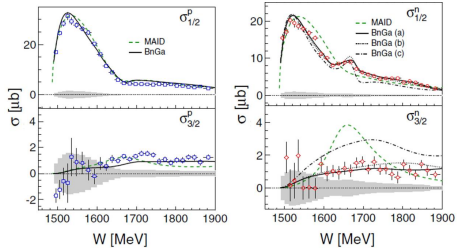


- Observed narrow structure in ηn around $W = 1.68\,\text{GeV}$
  - narrow resonance?
  - interference effect?
  - strangeness loops?
  - coupled channel effect?

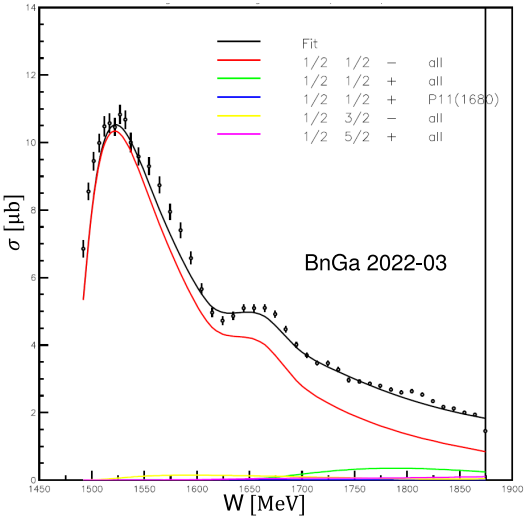
η Photoproduction off the neutron

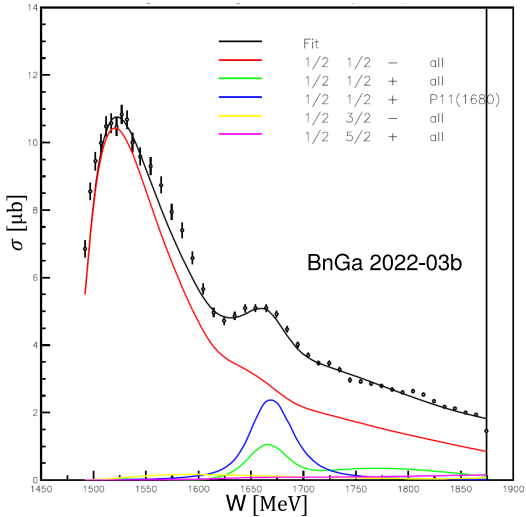


- Observed narrow structure in ηn around $W = 1.68\,\text{GeV}$
  - narrow resonance?
  - interference effect?
  - strangeness loops?
  - coupled channel effect?
- helicity dependent cross section: S_{11} or P_{11} partial waves ($J = \frac{1}{2}$)

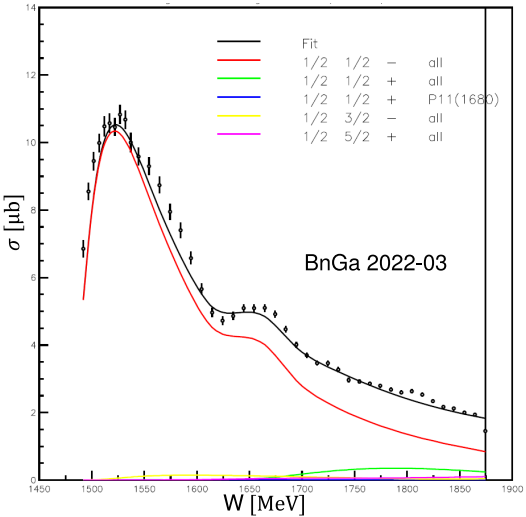


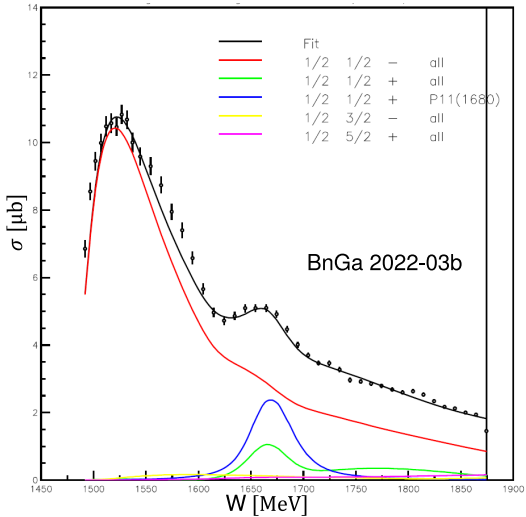
Narrow structure in ηn





Narrow structure in ηn

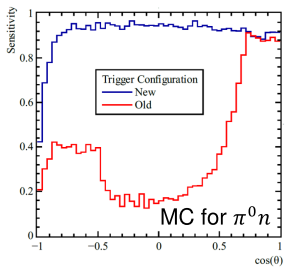


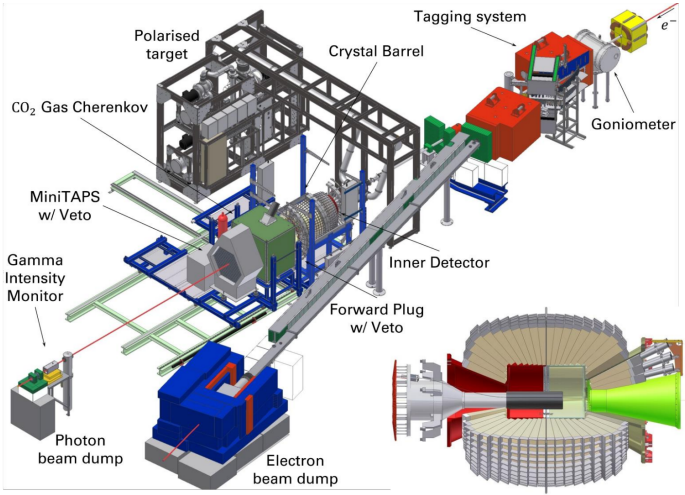


⇝ need polarization observables for unambiguous PWA (complete experiment)

The CBELSA/TAPS experiment

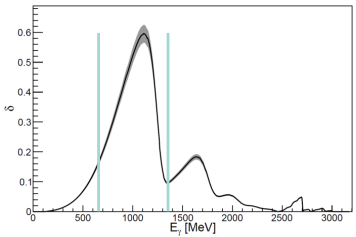
- electromagnetic calorimeter with nearly 4π coverage
- plastic scintillators to identify charged particles $\rightsquigarrow$ distinguish n from p
- trigger on CB calorimeter $\rightsquigarrow$ purely neutral final states

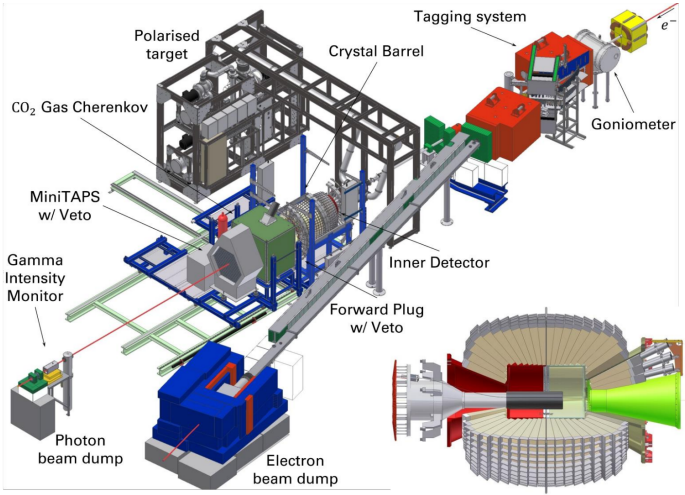




The CBELSA/TAPS experiment

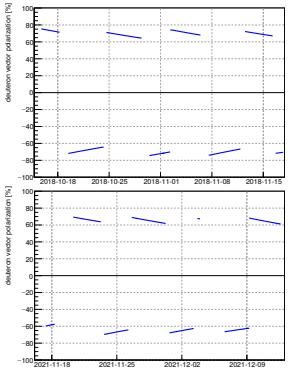
- linearly polarized photons: coherent bremsstrahlung
- coherent edge at 1200 MeV
- max. polarization: $\delta = 60\,\%$

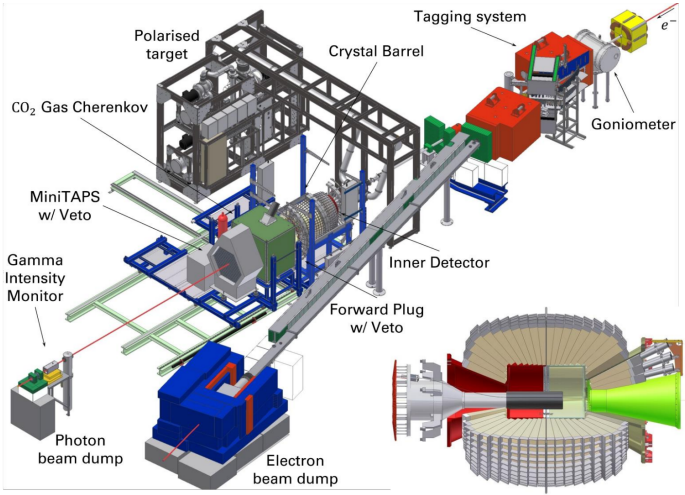




The CBELSA/TAPS experiment

- transv. pol. Mainz-Dubna Frozen Spin target
- D-butanol (C_4D_9OD)
- max. polarisation $\Lambda = 75\,\%$
- relaxation time: $\sim 1000\,\mathrm{h}$





Event selection and reconstruction

- open trigger: 2 or more clusters in calorimeters (and veto on CO_2 cherenkov)
- preselection: exactly 3 clusters in calorimeters

$\gamma p \to \pi^0/\eta\ p \to p\gamma\gamma$

- 1 charged, 2 uncharged
- unique assignment to p, γ

$\gamma n \to \pi^0/\eta\ n \to n\gamma\gamma$

- 3 uncharged
- 3 possible combinations
- best $\pi^0/\eta \to \gamma\gamma$ using χ^2 test
- for ηn: anticut on $\pi^0 \to \gamma\gamma$

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega} = \left(\frac{\mathrm{d}\sigma}{\mathrm{d}\Omega}\right)_0 \cdot \Big\{1 - \delta\Sigma\cos(2(\alpha-\phi)) + \Lambda T \sin(\beta-\phi) - \delta\Lambda P \cos(2(\alpha-\phi))\sin(\beta-\phi) - \delta\Lambda H \sin(2(\alpha-\phi))\cos(\beta-\phi)\Big\}$$

$\rightsquigarrow$ event-based maximum-likelihood fit to determine observables $(\Sigma), T, P, H$

Reconstruction of CM Energy W

initial state nucleons are bound in deuterium $\rightsquigarrow$ fermi momentum

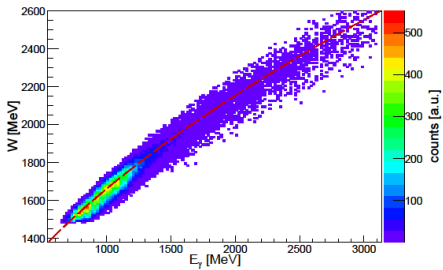
participant-spectator-model:

$$\gamma + D \to M + N_P + N_S$$

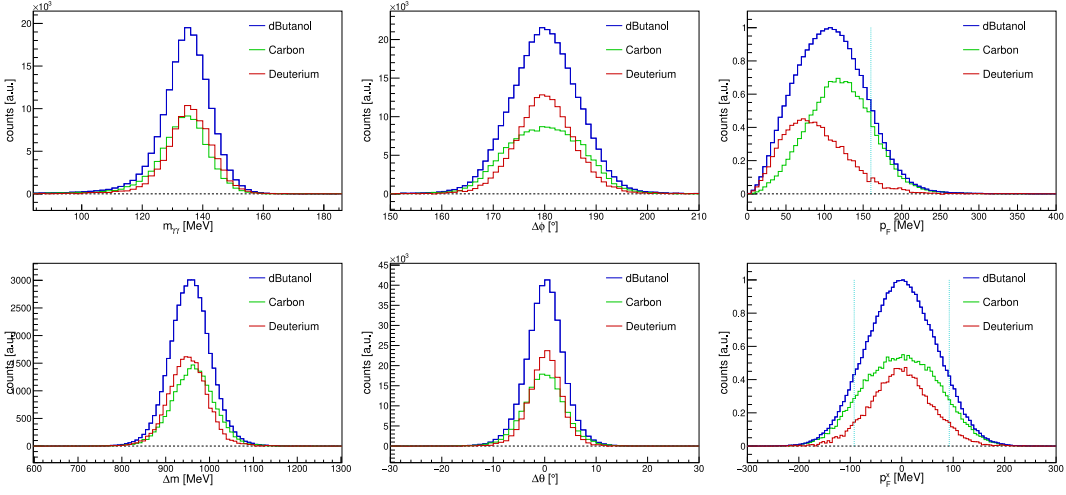
- meson M: 4-momentum measured
- participant (recoiling) nucleon N_P
  - direction measured
  - energy can be calculated from other measured quantities
- spectator nucleon N_S
  - no change in momentum
  - fermi momentum can be calculated

Caveat: final-state interaction neglected

$$W = m(M + N_P)$$
$$\neq \sqrt{m_{N_P}^2 + 2E_\gamma m_{N_P}}$$

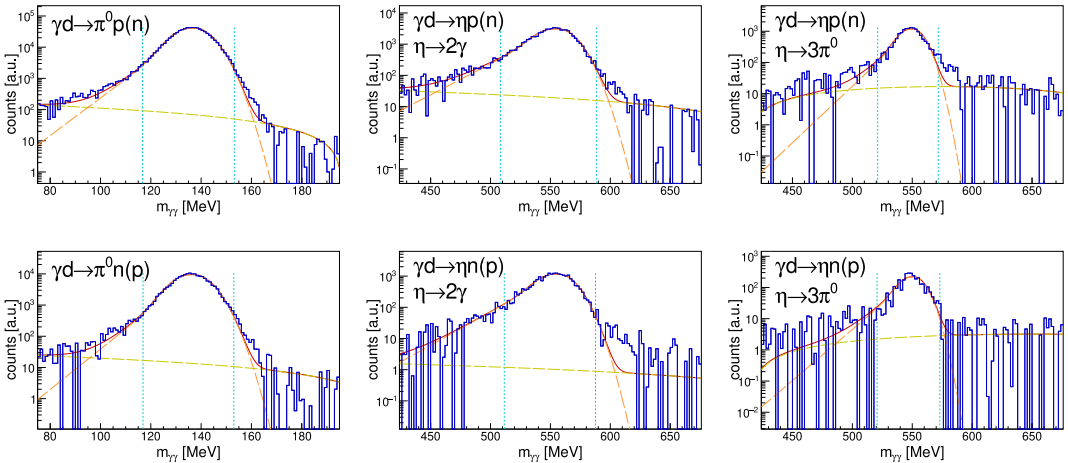


Background from unpolarized nucleons in D-butanol



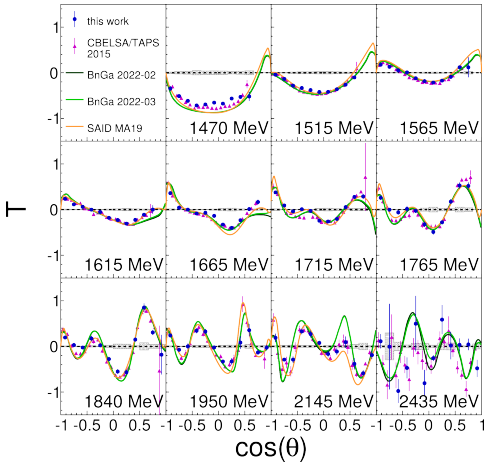
$\Lambda_{\text{eff}} = \Lambda_{\text{NMR}} \cdot d$ with dilution factor $d = \frac{N_{\text{butanol}} - c \cdot N_{\text{carbon}}}{N_{\text{butanol}}}$ (c: global normalization factor)

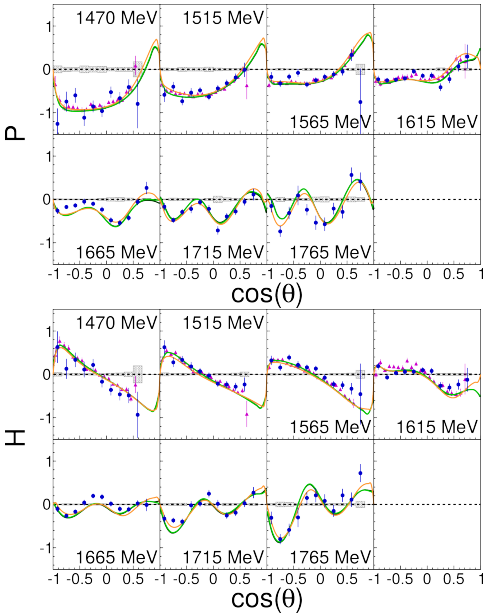
Background from other channels



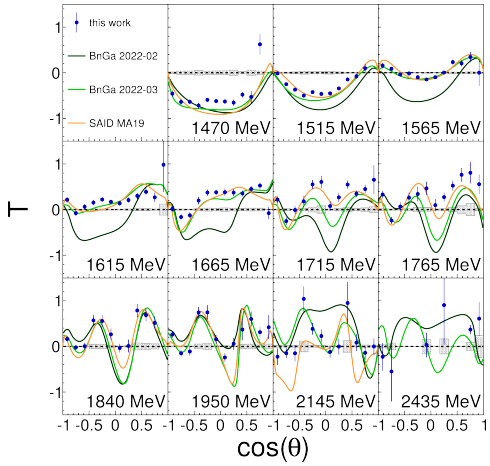
background: $< 1\,\%$ $< 1.2\,\%$ $< 1.4\,\%$

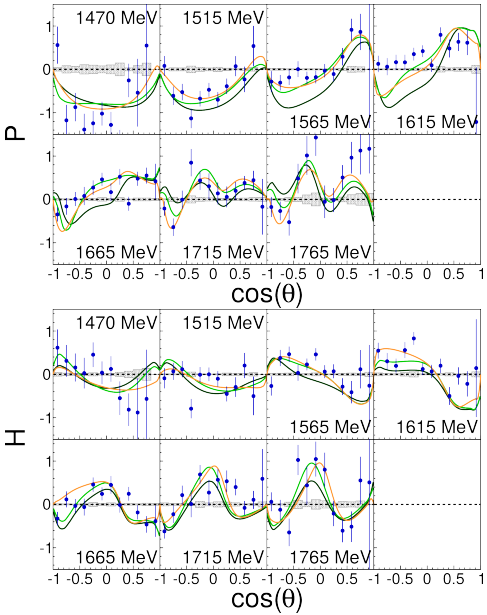
Results: $\gamma d \to \pi^0 p(n)$



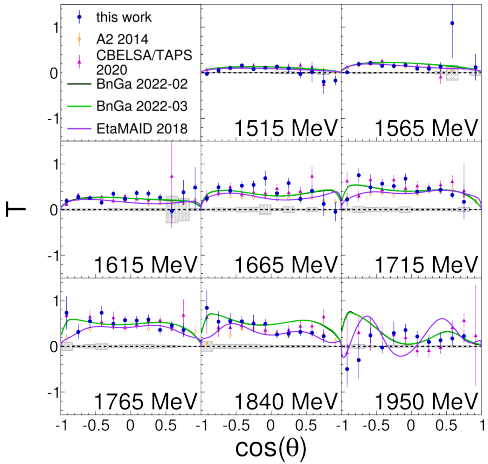


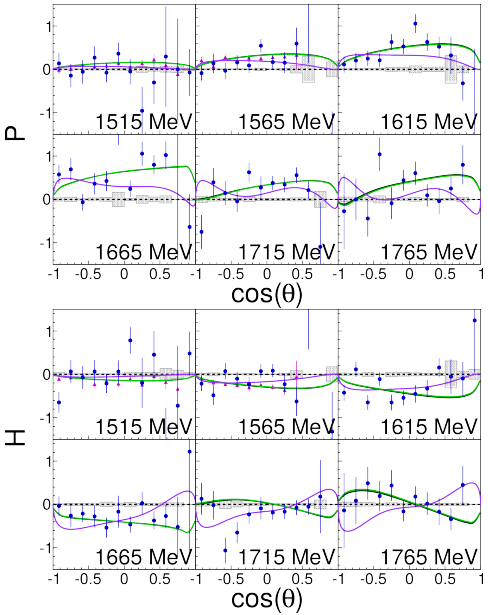
Results: $\gamma d \to \pi^0 n(p)$



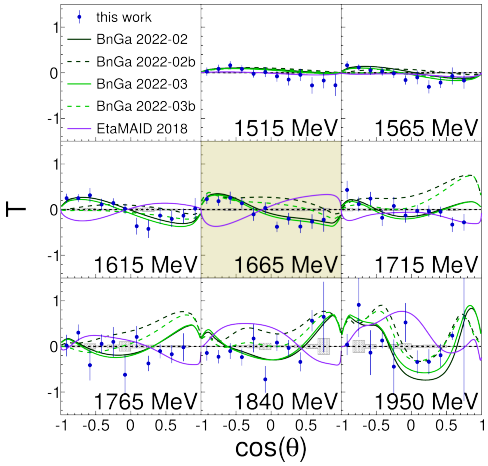


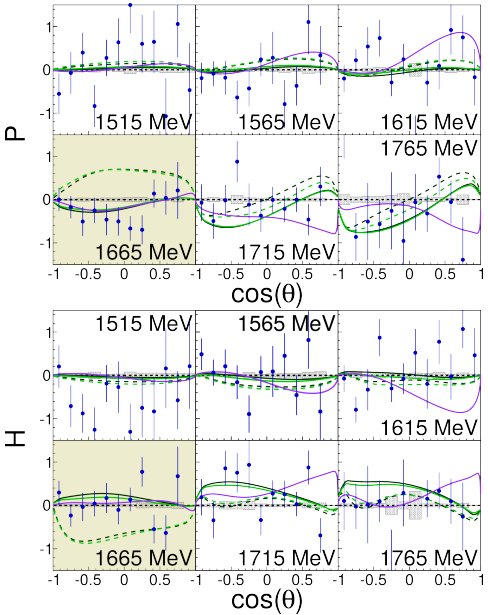
Results: $\gamma d \to \eta p(n)$





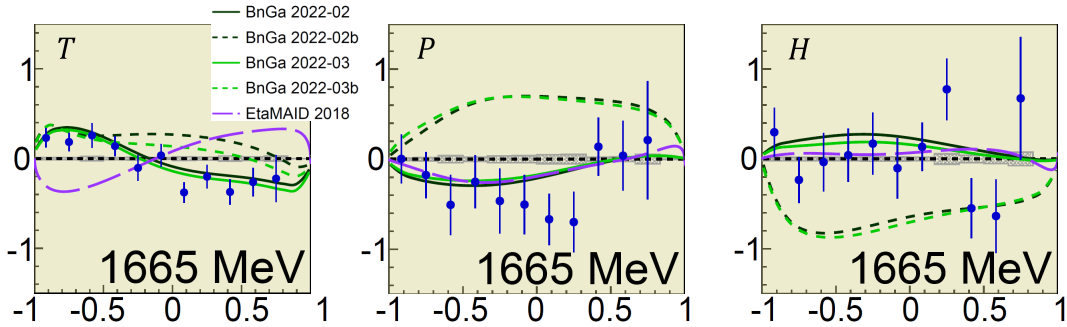
Results: $\gamma d \to \eta n(p)$



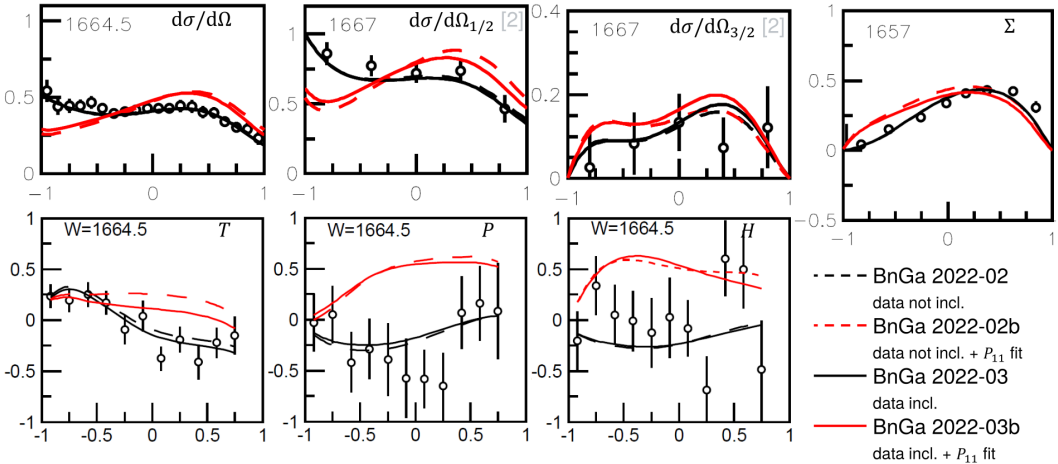


Narrow structure in ηn around $W = 1.68\,\text{GeV}$

$\chi^2/ndf, W = 1.64-1.69\,(1.59-1.74)\text{GeV}$			T	P	H	all
BnGa 2022-02	S_{11} interference	pred.	1.01 (1.08)	**0.74** (1.38)	1.53 (1.75)	1.10 (1.39)
BnGa 2022-02b	narrow $P_{11}(1680)$	pred.	7.10 (6.85)	8.24 (3.77)	5.51 (3.14)	6.95 (4.09)
BnGa 2022-03	S_{11} interference	fit	**0.69** (**1.07**)	0.84 (**1.37**)	1.34 (**1.66**)	**0.96** (**1.36**)
BnGa 2022-03b	narrow $P_{11}(1680)$	fit	3.83 (4.55)	8.27 (3.68)	6.10 (3.35)	6.07 (3.63)
EtaMAID 2018	$S_{11} - P_{11}$ interf.	pred.	13.32 (7.63)	0.78 (1.52)	**1.33** (2.68)	5.14 (3.95)



Narrow structure in ηn around $W = 1.68\,\text{GeV}$



Narrow structure in ηn around $W = 1.68\,\text{GeV}$

Total energy range:

reaction	PWA	T	P	H	all
$\gamma d \to \pi^0 p\,(n)$	BnGa 2022-02	6.29	1.85	2.13	3.93
	BnGa 2022-03	**5.77**	**1.82**	**1.98**	**3.64**
$\gamma d \to \pi^0 n\,(p)$	BnGa 2022-02	26.65	4.26	2.28	13.29
	BnGa 2022-03	**5.20**	**1.71**	**1.69**	**3.20**
$\gamma d \to \eta p\,(n)$	BnGa 2022-02	1.48	1.02	1.28	1.28
	BnGa 2022-03	**1.47**	**0.99**	**1.26**	**1.27**
$\gamma d \to \eta n\,(p)$	BnGa 2022-02	1.57	1.04	**1.12**	1.28
	BnGa 2022-02b	4.77	1.83	1.51	2.90
	BnGa 2022-03	**1.37**	**1.03**	1.13	**1.20**
	BnGa 2022-03b	2.85	1.73	1.58	2.13
	EtaMAID 2018	4.73	1.38	1.96	2.63

Summary and Outlook

Summary

- new CBELSA/TAPS with polarized D-butanol target
- no significant final-state interaction
- T, P, H measured for the first time in:
  - $\gamma n \to \pi^0 n$
  - $\gamma n \to \eta n$
- structure in ηn around $W = 1.68\,\text{GeV}$ no resonance, but $N(1535)1/2^-$ - $N(1650)1/2^-$ interference

Summary and Outlook

Summary

- new CBELSA/TAPS with polarized D-butanol target
- no significant final-state interaction
- T, P, H measured for the first time in:
  - $\gamma n \to \pi^0 n$
  - $\gamma n \to \eta n$
- structure in ηn around $W = 1.68\,\text{GeV}$ no resonance, but $N(1535)1/2^-$ - $N(1650)1/2^-$ interference

Outlook

- just completed another beam-time with polarized D-butanol target last week
- coherent edge at 1400 MeV
- $\rightsquigarrow P, H$ up to $W = 1900\,\text{MeV}$

Summary and Outlook

Summary

- new CBELSA/TAPS with polarized D-butanol target
- no significant final-state interaction
- T, P, H measured for the first time in:
  - $\gamma n \to \pi^0 n$
  - $\gamma n \to \eta n$
- structure in ηn around $W = 1.68\,\text{GeV}$ no resonance, but $N(1535)1/2^-$ - $N(1650)1/2^-$ interference

Outlook

- just completed another beam-time with polarized D-butanol target last week
- coherent edge at 1400 MeV
- $\rightsquigarrow P, H$ up to $W = 1900\,\text{MeV}$

Bernd Krusche † June 2022