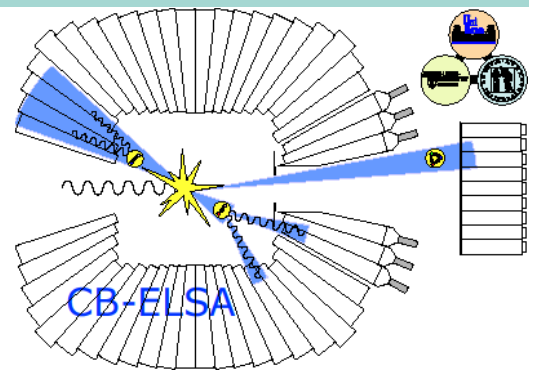
University of Basel

Experimental study of polarization observables in π^0 and η photoproduction off quasifree nucleons

2022 Frontiers and Careers in Nuclear and Hadronic Physics

Nicolas Jermann - CBELSA/TAPS-Collaboration | 06 August 2022

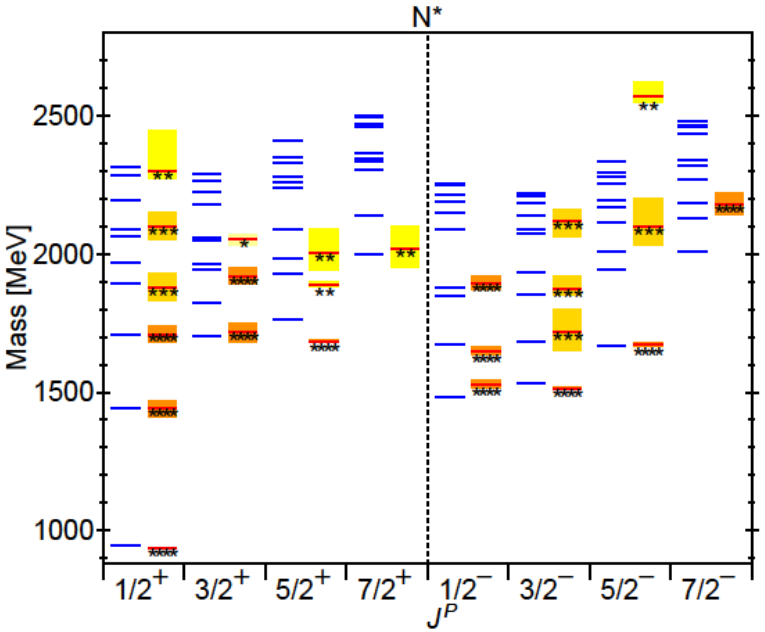


In loving memory of **Prof. Dr. Bernd Krusche** († June 1, 2022)

https://physik.unibas.ch/en/news/details/prof-dr-bernd-krusche-passed-away/

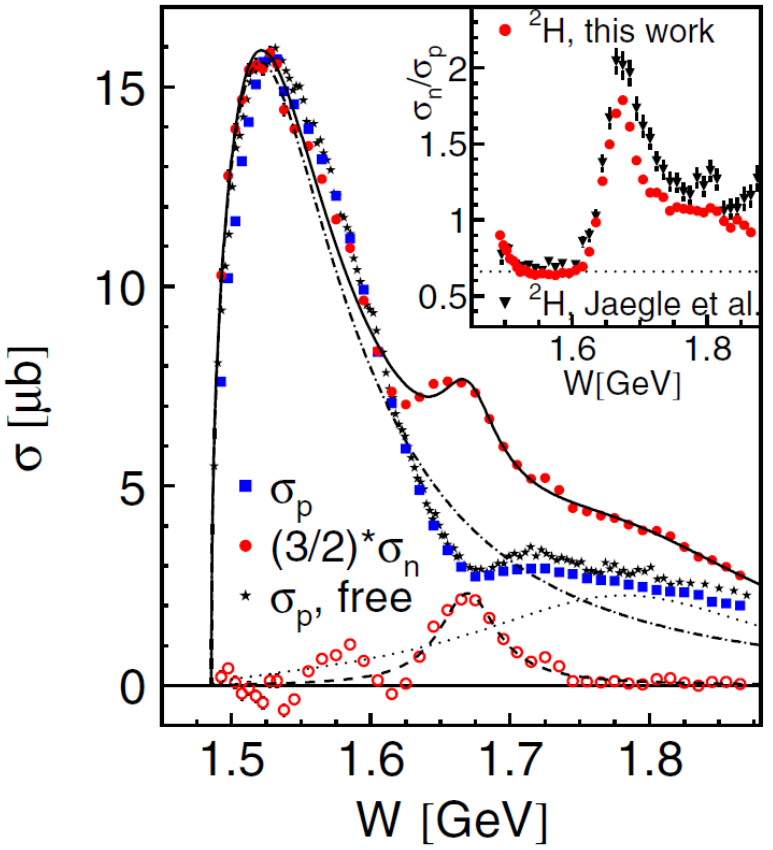
Motivation
Missing resonance problem

Quark model



model from EPJA 47, 162 (2011)

Narrow structure in ηn



PRL 111, 232001 (2013)

More details with polarisation

https://commons.wikimedia.org/wiki/File:Reflection_Polarizer2.jpg

⇒ polarisation observables give access to interference terms, i.e.

$\sigma_{unpol} \propto |\mathcal{A}_i|^2$ vs $\sigma_{pol} \propto \mathcal{A}_i \mathcal{A}_j^*$

Baseline & goal

Baseline

– Crystal Barrel/TAPS at ELSA

– $E_\gamma = 500 - 3150\ \mathrm{MeV}$

– Linearly polarized beam with coherent edge at $1200\ \mathrm{MeV}$

– Transversely polarized deuterated butanol target

Measurement goal

– Beam asymmetry Σ

– Target asymmetry T

– Recoil asymmetry P

– $\mathcal{BT}$-double-pol. observable H

Reactions

– $\gamma N \to \pi^0 N$ & $\gamma N \to \eta N$

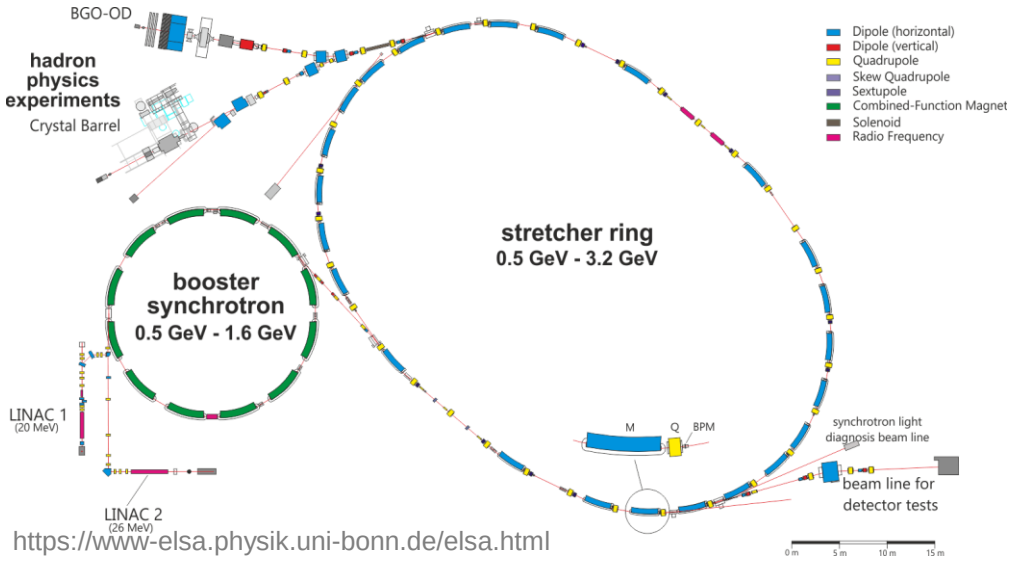
– $\pi^0/\eta \to 2\gamma$ & $\eta \to 3\pi^0 \to 6\gamma$

Beam pol.		Target pol.		
		x	y	z
–	σ_0	–	T	–
linear	$-\Sigma$	H	$-P$	G
cicular	–	F	–	$-E$

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

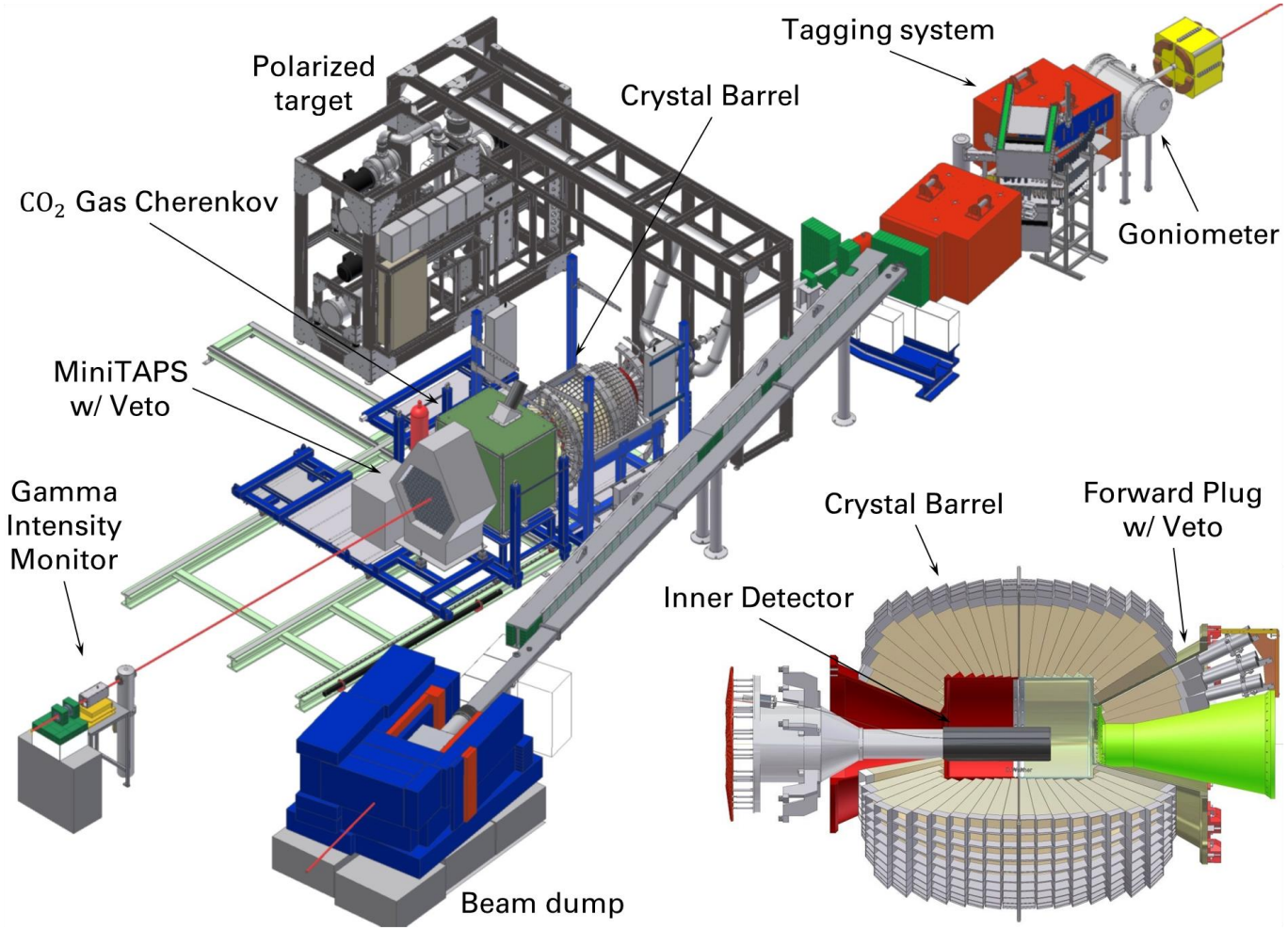
Experimental setup
Crystal Barrel/TAPS setup

Locate at the ELectron Stretcher Accelerator of the University of Bonn, Germany



https://www-elsa.physik.uni-bonn.de/elsa.html

	Oct2018	Nov2018	Nov2021	Dec2021
Target	dButanol	Carbon	Carbon	dButanol
Time $[\mathbf{h}]$	513	101	60	274
Events $[\cdot \mathbf{10^6}]$	2156	416	520	2327



adapted from EPJA 57, 40 (2021)

Data analysis
Particle identification

Event selection

– Exclusive reactions

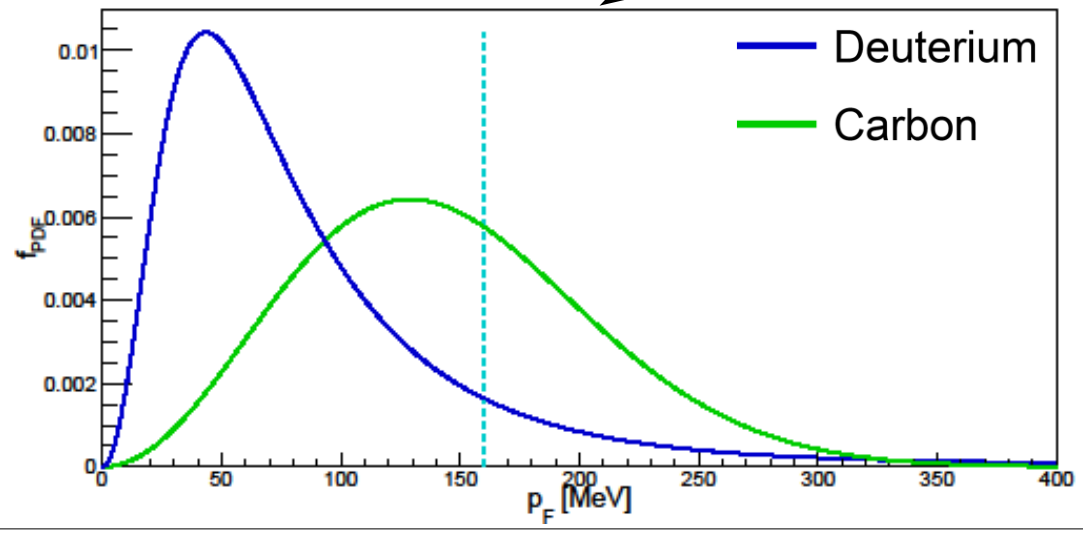
– Coincidence times

– χ^2 anti-cut for $\gamma\gamma n$ final states

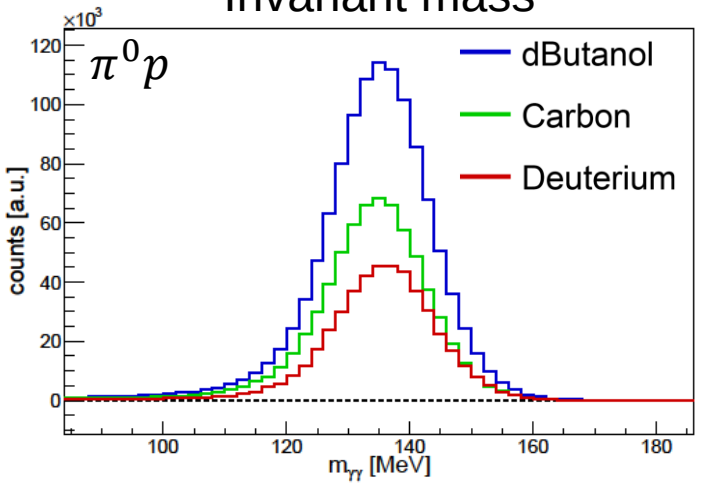
Background suppression

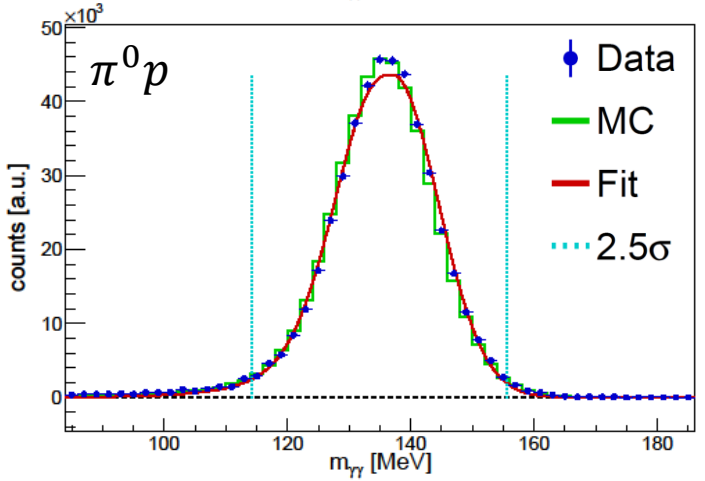
– Invariant mass, coplanarity, missing mass, polar angle diff.

– Fermi momentum



Invariant mass





Data analysis

Polarisation degrees

– Beam photon polarisation

$\delta \overset{!}{>} 0.1 \Rightarrow E_\gamma = 650 - 1750\ \mathrm{MeV}$

– Target nucleon polarisation

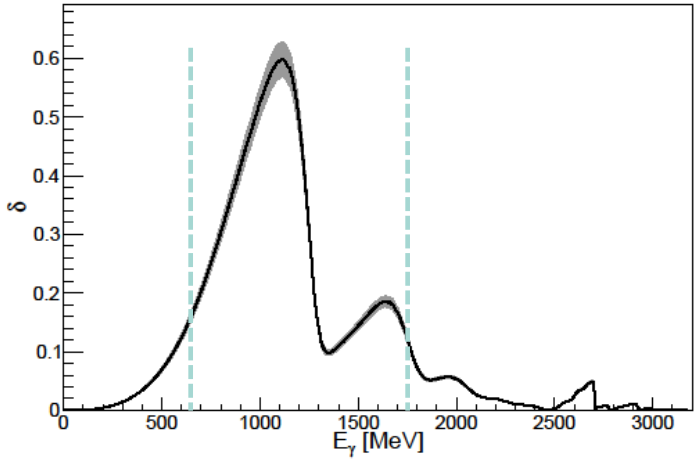
$\overline{\Lambda}_{NMR} \approx 69.9\%$

– $\Lambda_D \rightarrow \Lambda_N$ correction

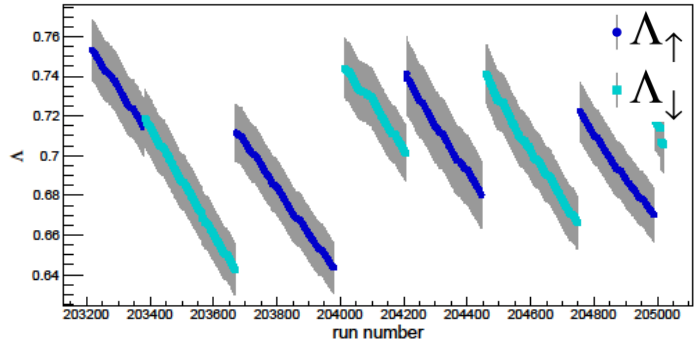
– $\Lambda_N \rightarrow \Lambda_N \cdot d$ correction with dilution factor

$$d = \frac{\widehat{N}_D}{\widehat{N}_{dB}} = \frac{\widehat{N}_{dB} - c_t \cdot \widehat{N}_C}{\widehat{N}_{dB}}$$

Beam photon polarisation δ



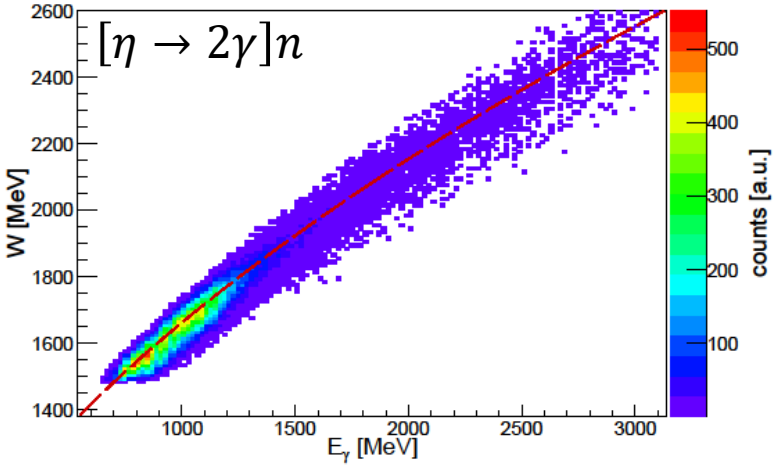
Target nucleon polarisation Λ_{NMR}



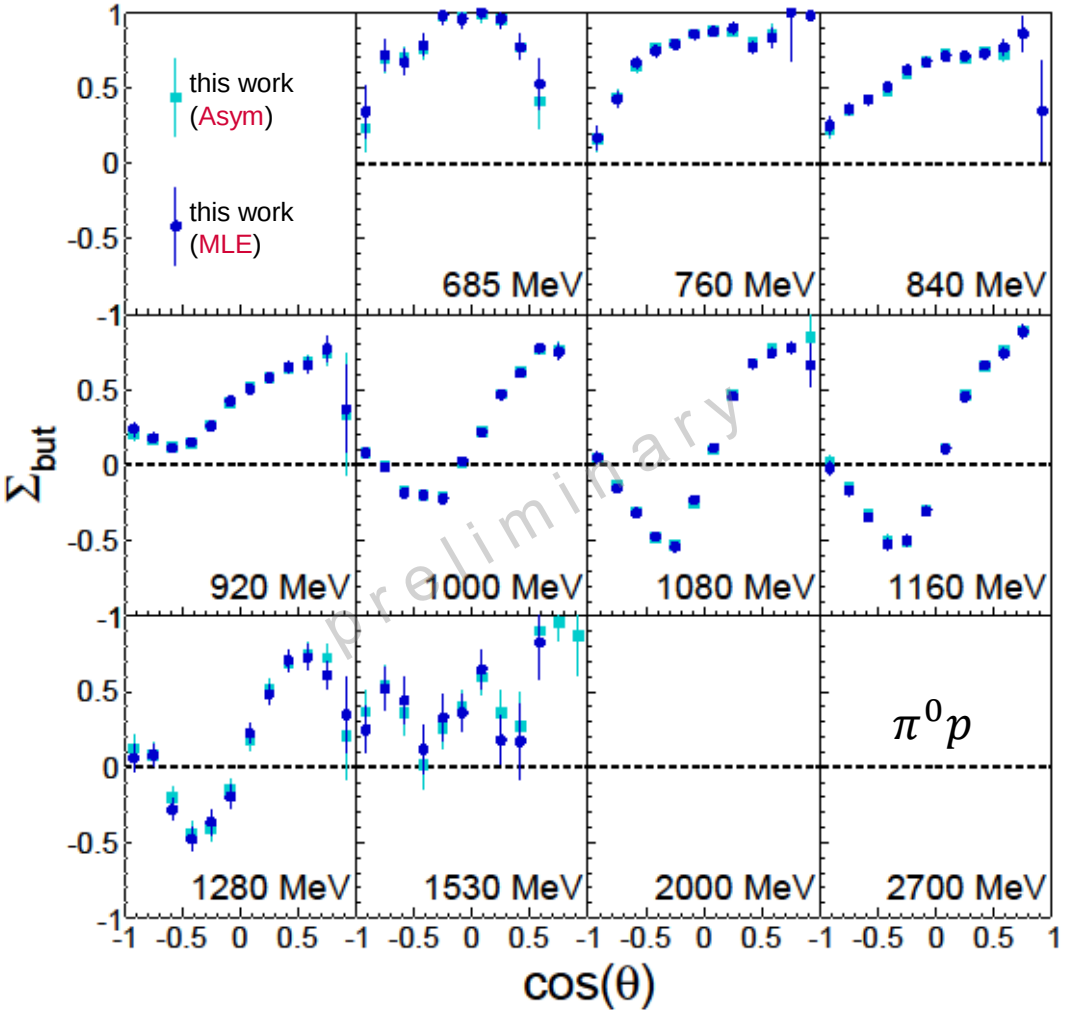
W reconstruction from final state

– $\gamma + D \rightarrow m + N_P + N_S$

– Use $W = \sqrt{s} = m(mN_P)$



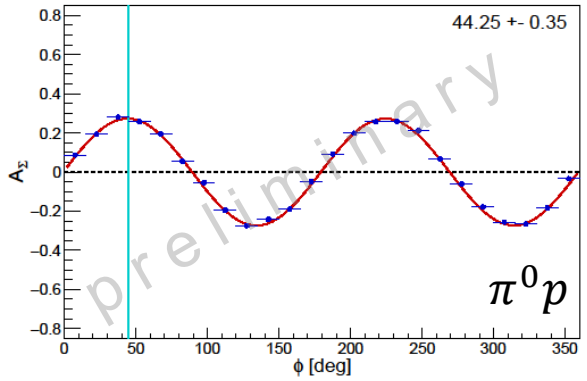
Data analysis
Extraction methods



Two methods are used for extraction of polarisation observables:

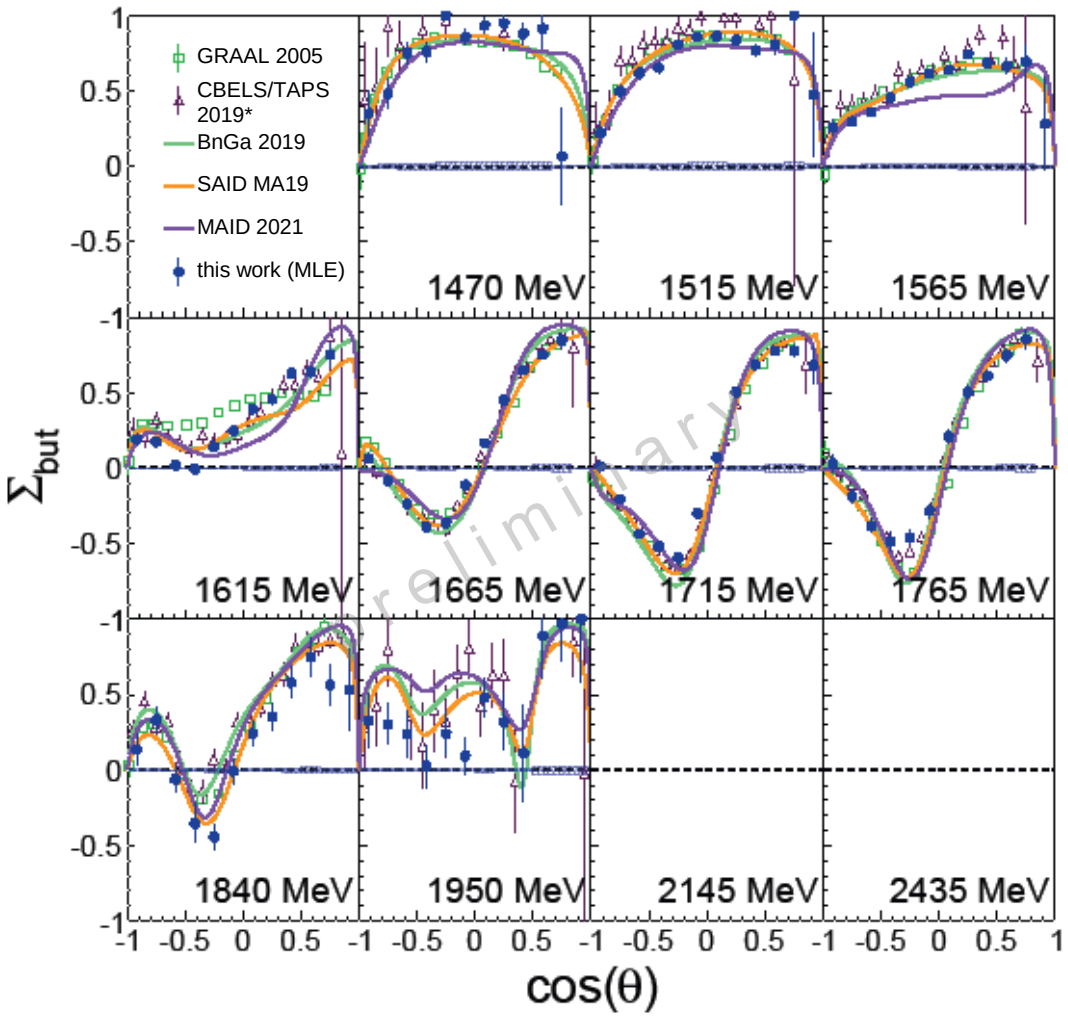
1. Asymmetry method (Asym): Calculate asymmetry from event yields and fit the spectra, e.g.

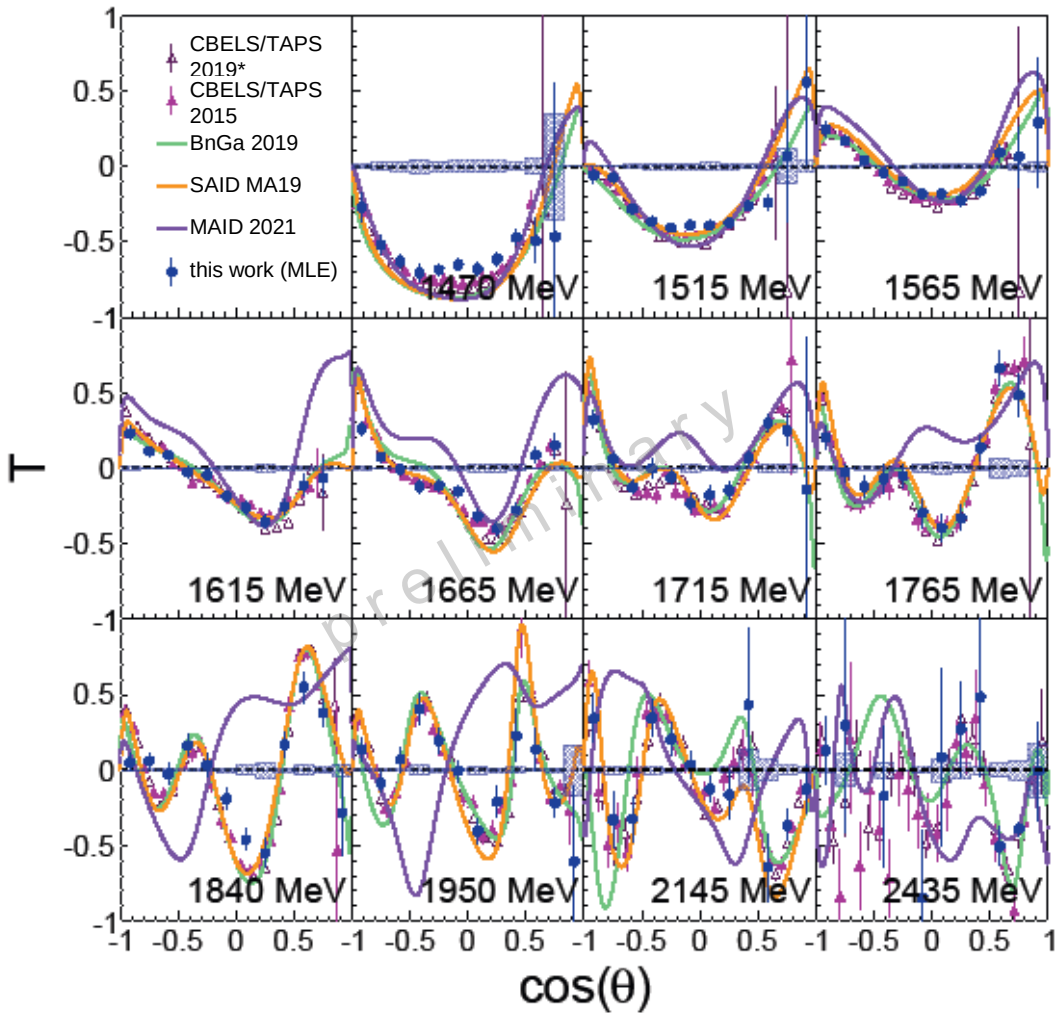
$$A_\Sigma = \frac{1}{\delta}\frac{\hat{N}^\perp - \hat{N}^\parallel}{\hat{N}^\perp + \hat{N}^\parallel} = \Sigma \cos\big(2(\alpha - \phi)\big)$$



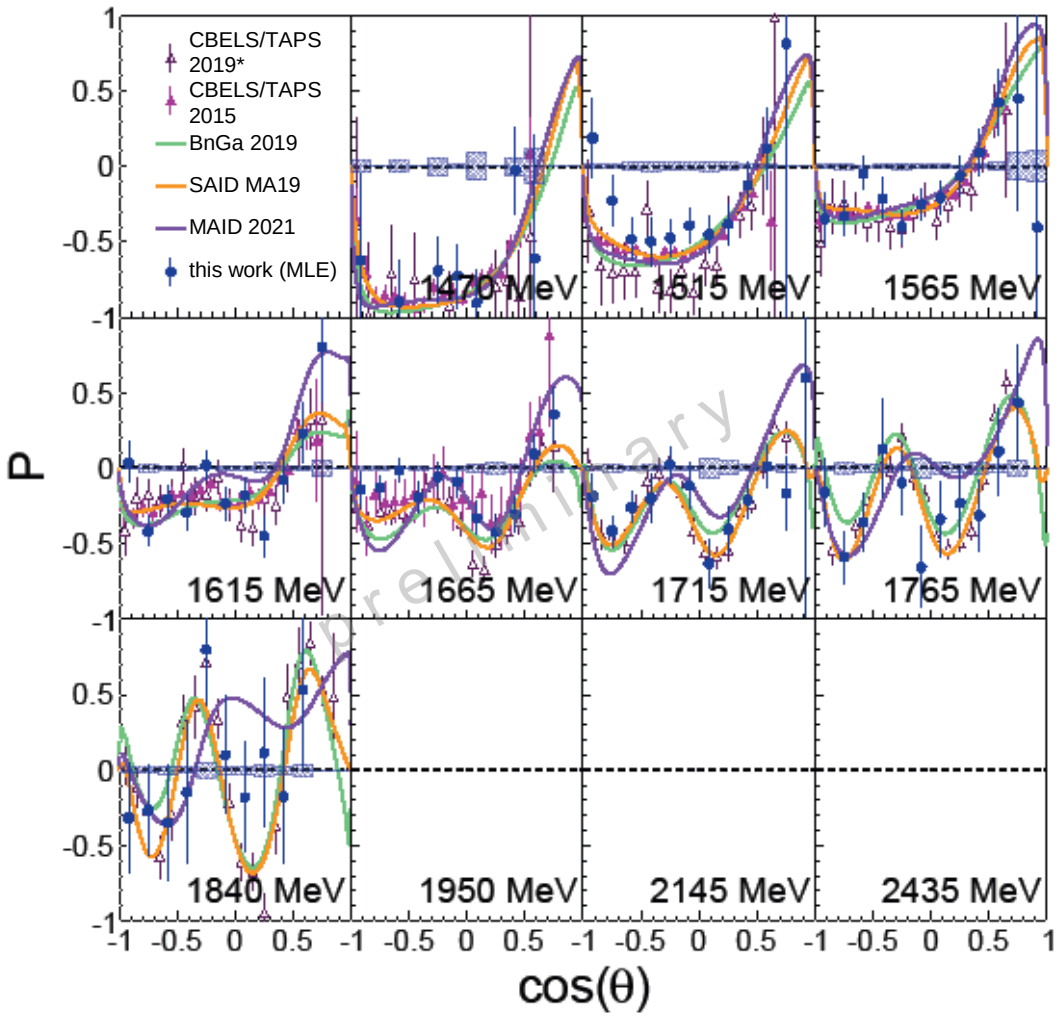
2. Maximum likelihood estimation method (MLE): Event based minimisation of $(-\ln \mathcal{L})$

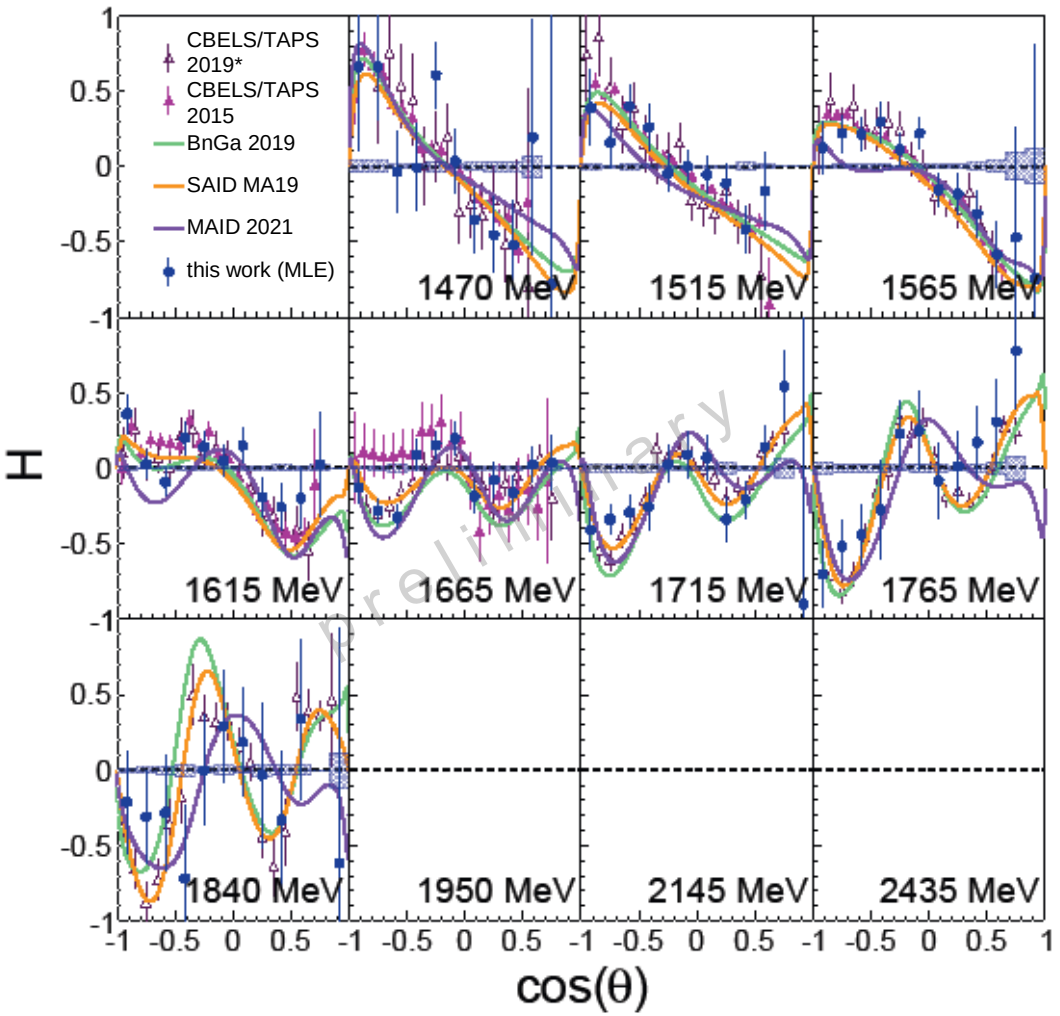
Results (preliminary)
$\pi^0 p$



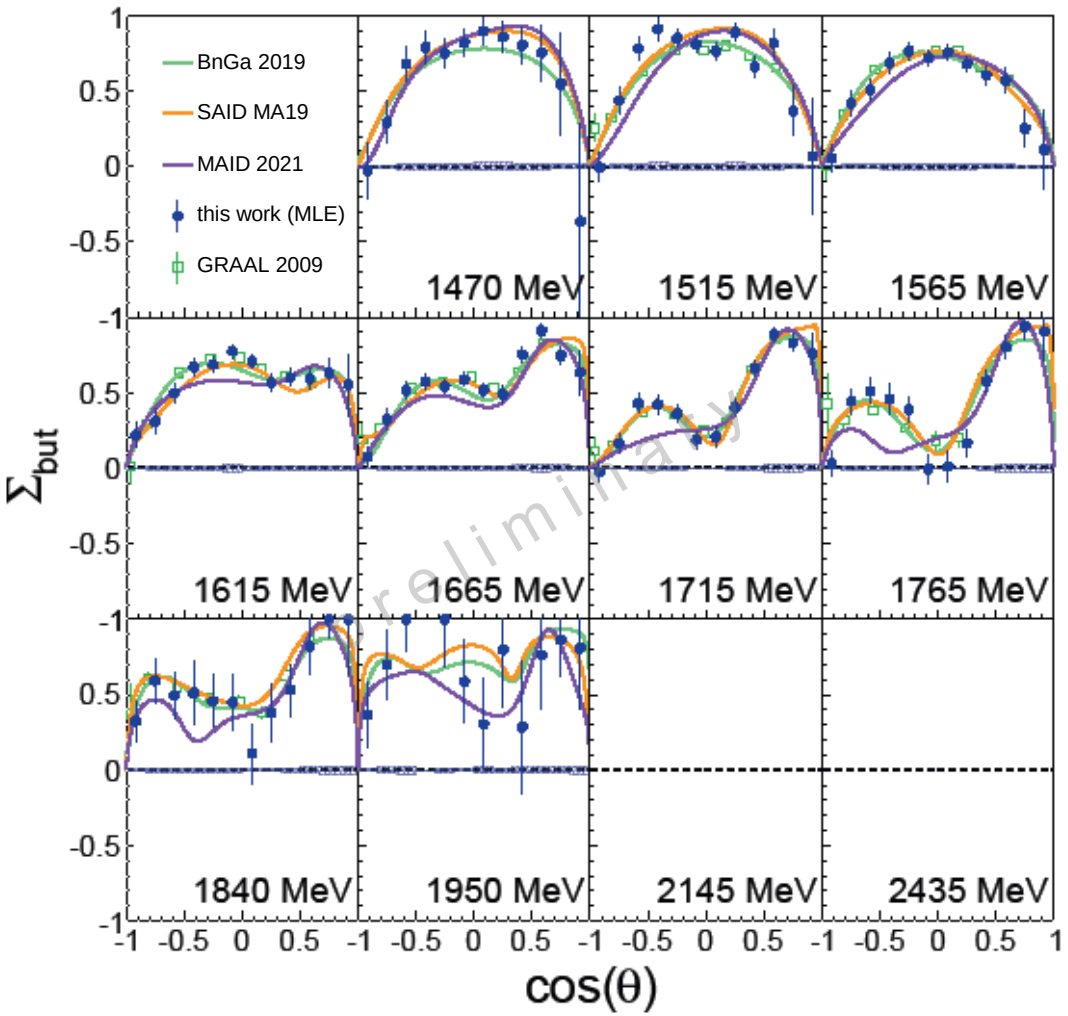


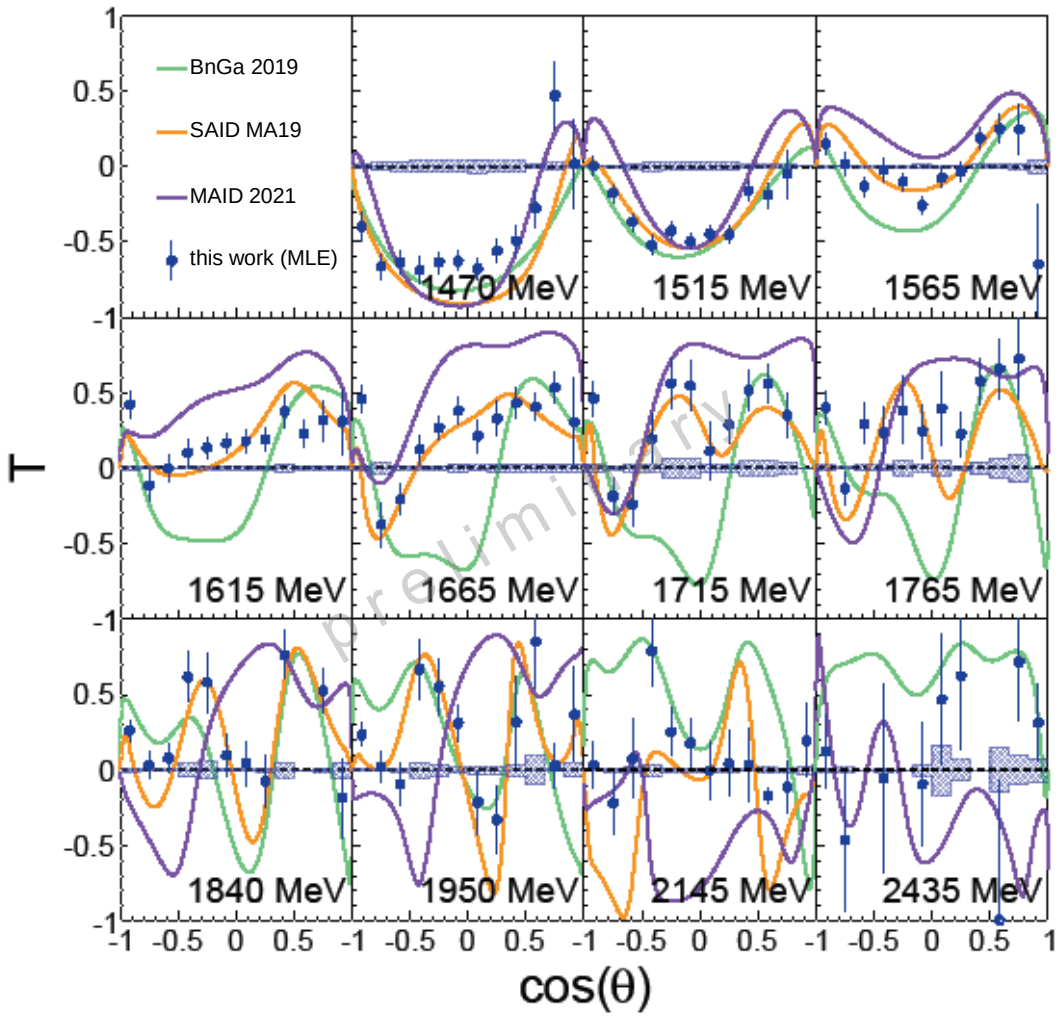
Results (preliminary)
$\pi^0 p$



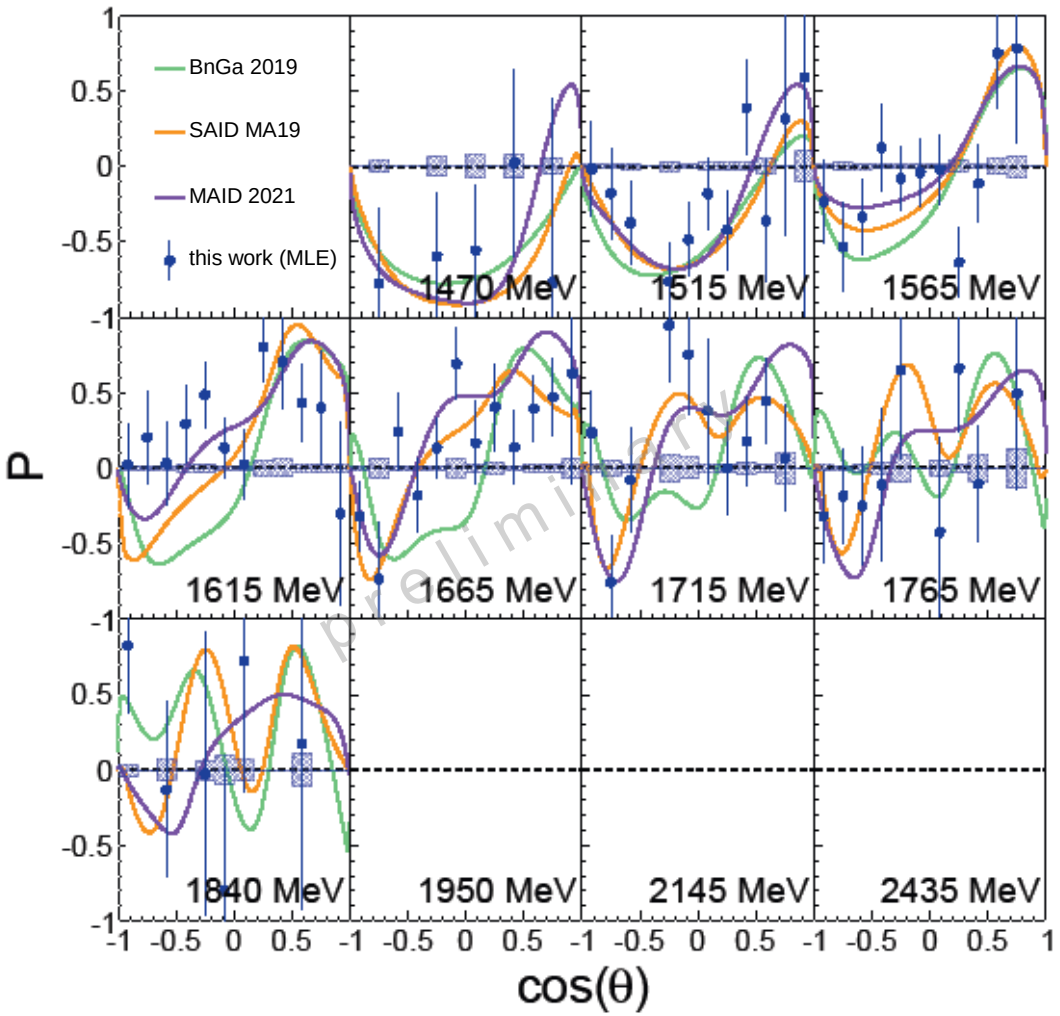


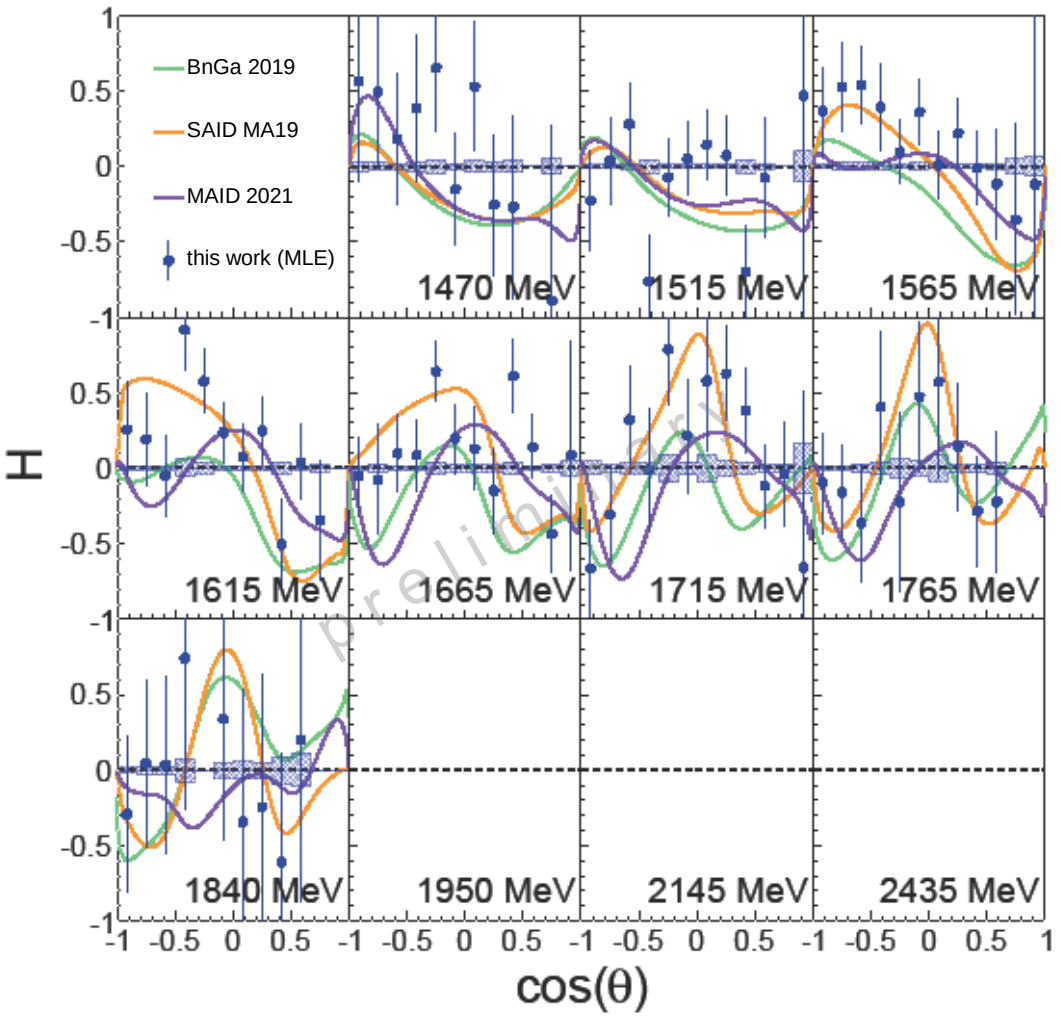
Results (preliminary)
$\pi^0 n$



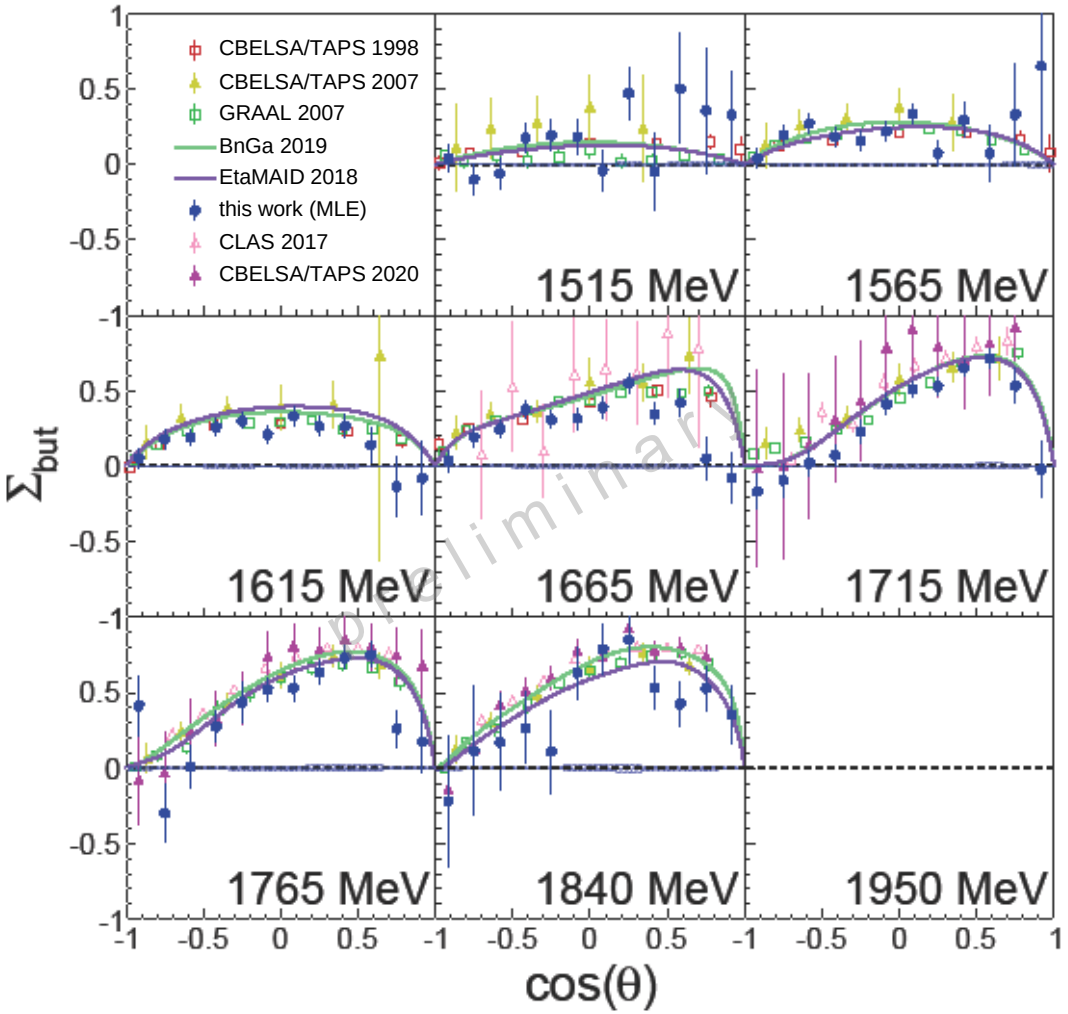


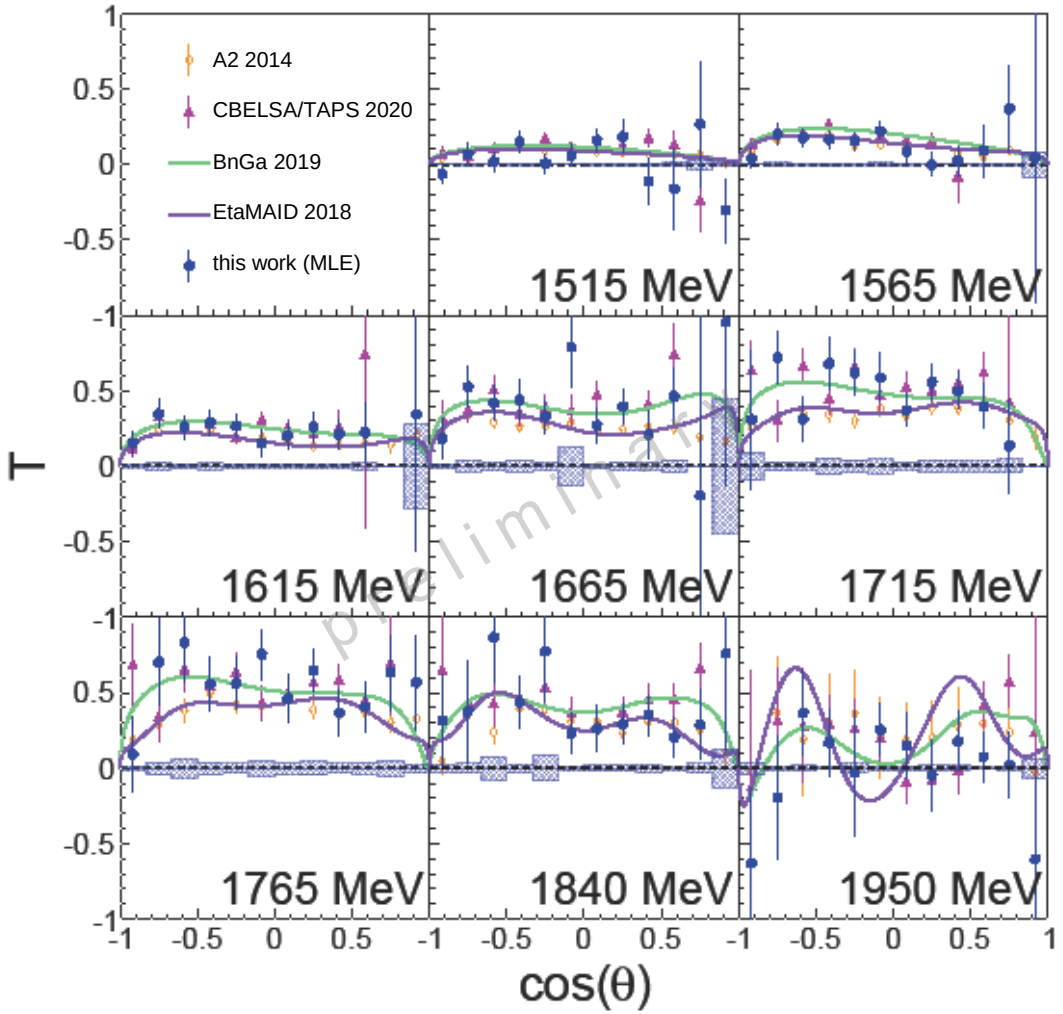
Results (preliminary)
$\pi^0 n$



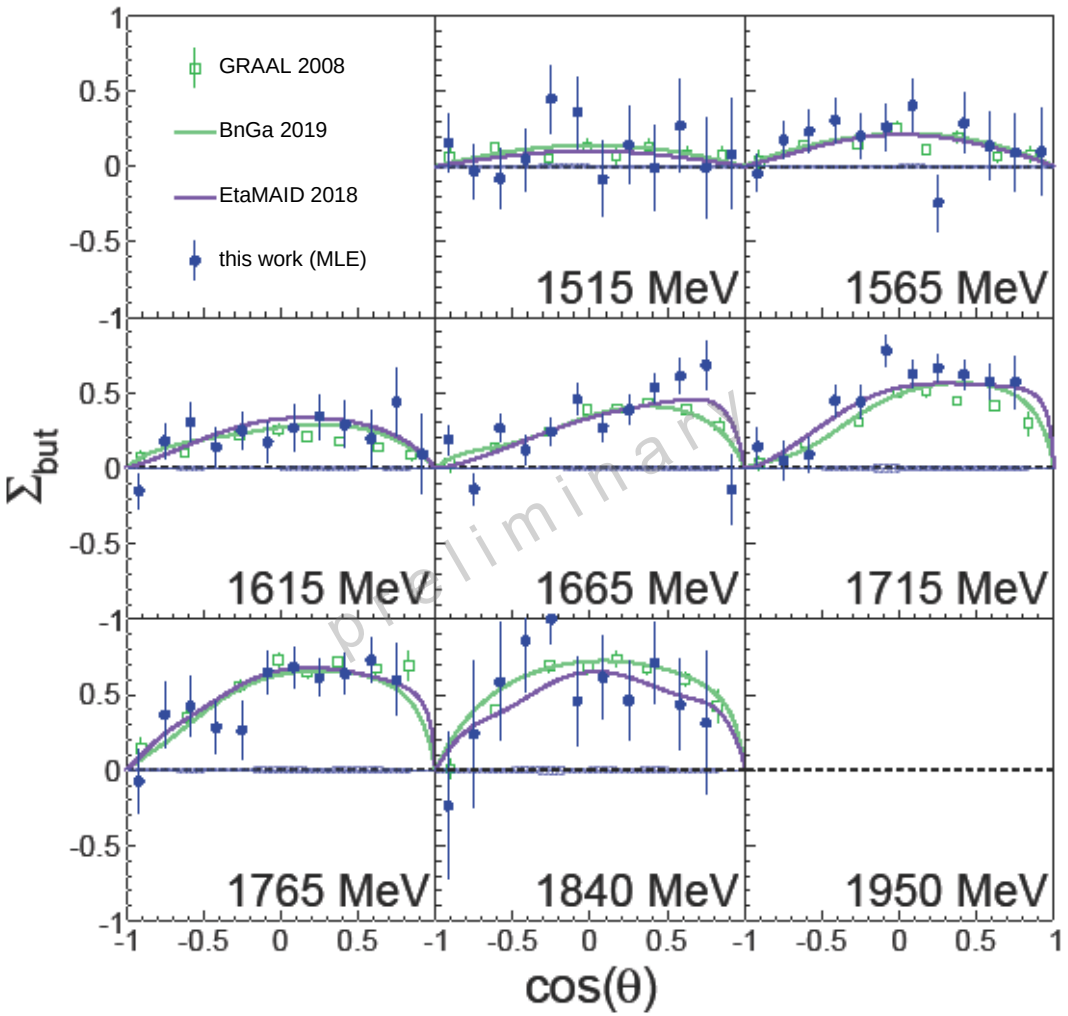


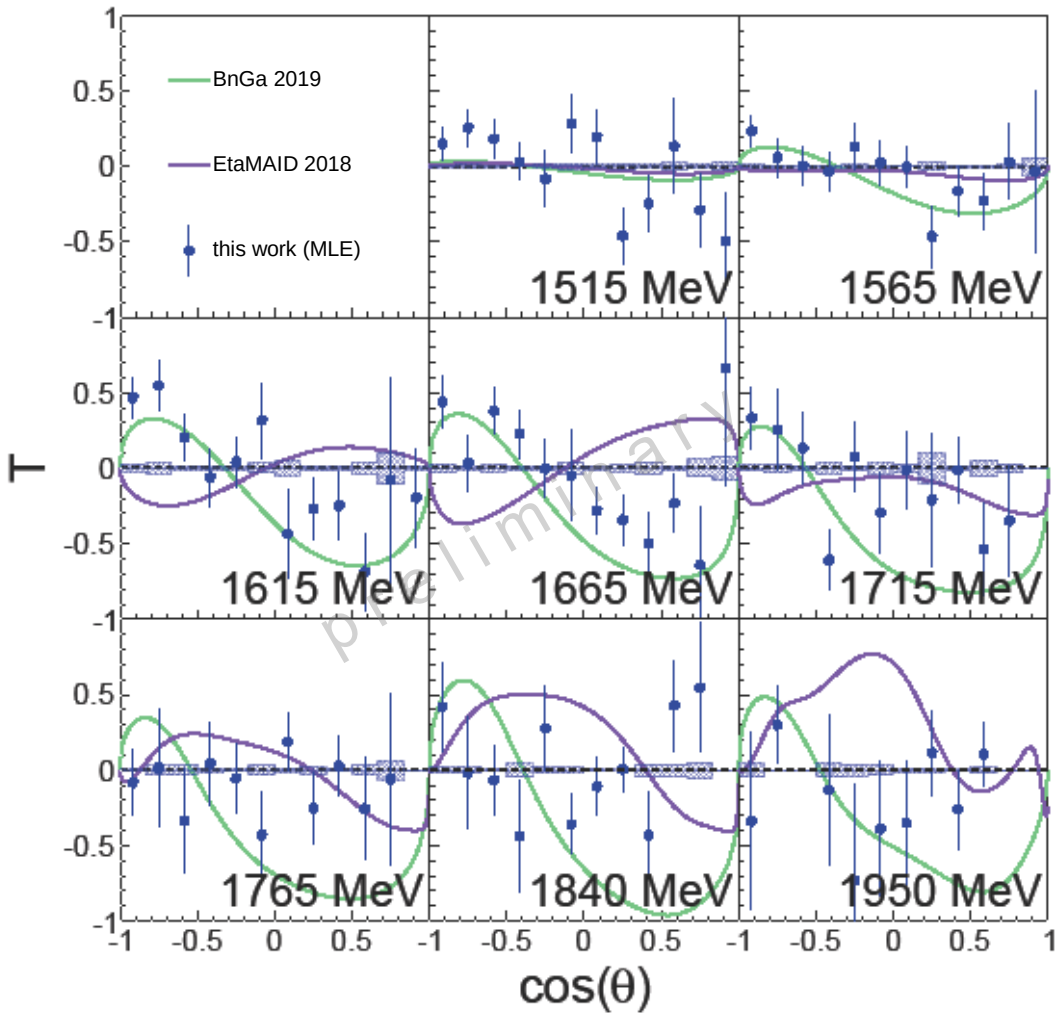
Results (preliminary)
ηp



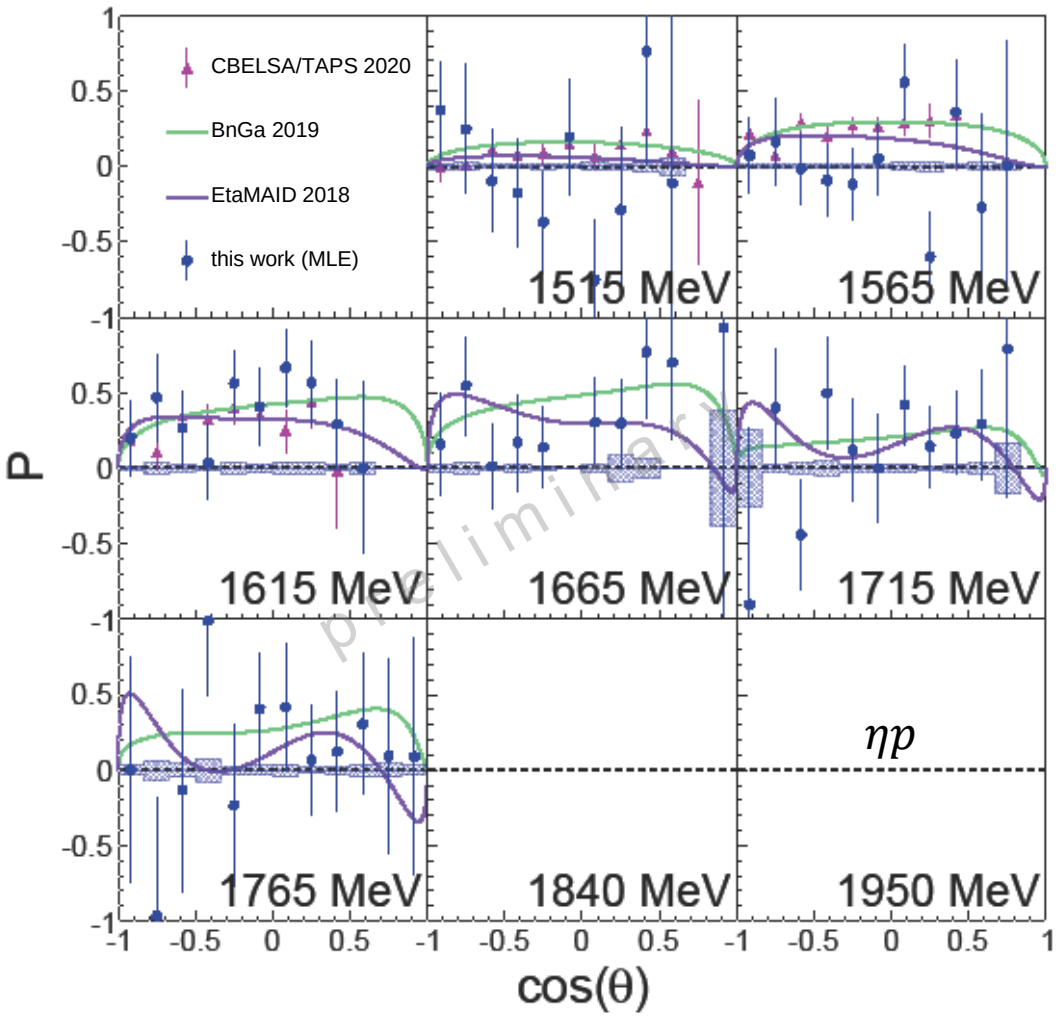


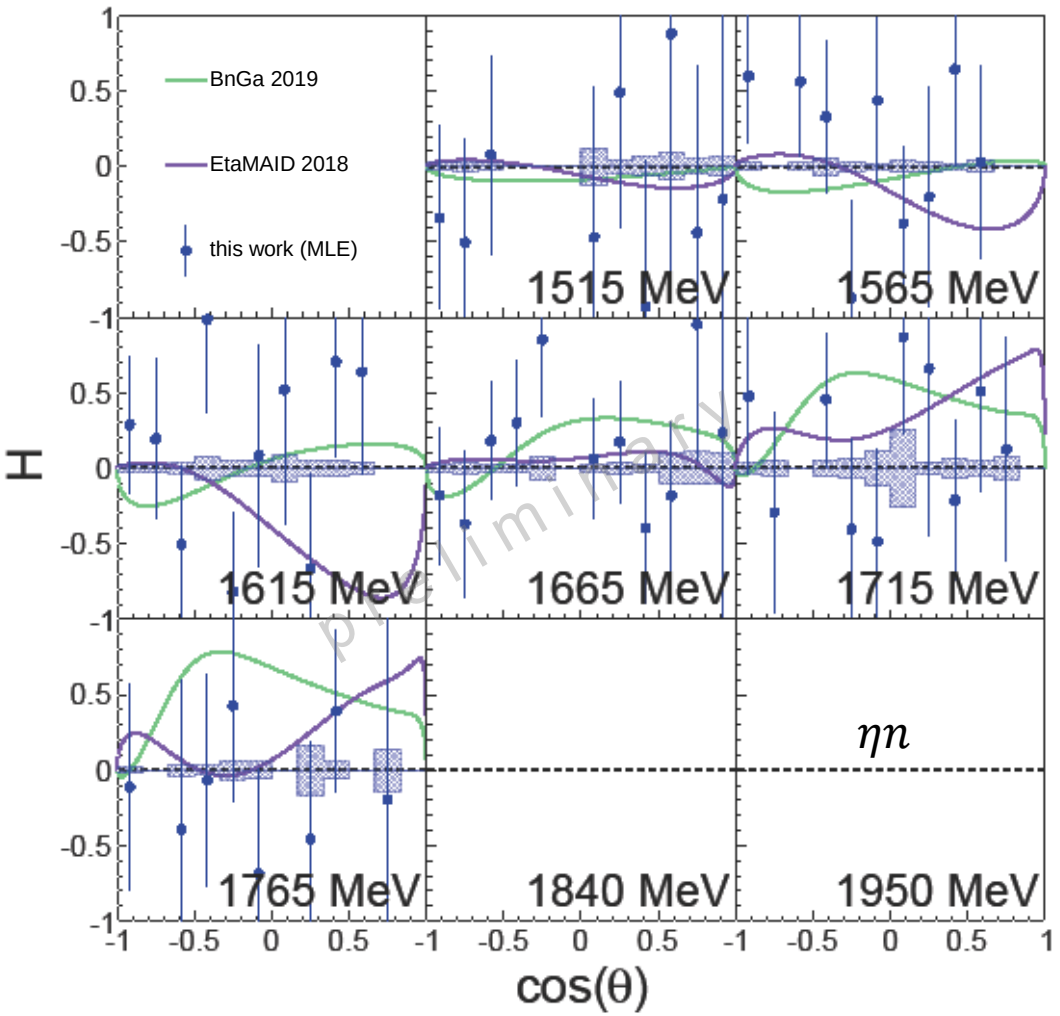
Results (preliminary)
ηn





Results (preliminary)
ηp and ηn





Summary & outlook

Summary

– Clean event selection for all reactions

– Preliminary results for observables Σ, T, P and H are presented for $\pi^0 N$ and ηN final states

– Results in good agreement with existing data

Outlook

– Improvement of statistics with second beam time, especially for P and H in ηN

– Including data in PWA models, e.g. MAID 2021

Sources

Reference data

- GRAAL (Bartalini, 2005): EPJA 26, 399 (2005)
  - Σ in $\pi^0 p$
- CBELSA/TAPS (Stausberg, 2019): Master's thesis, "Time calibration […]", R. F.-W.-Universität Bonn (2019)
  - Σ, T, P, H in $\pi^0 p$
- CBELSA/TAPS (Hartmann, 2015): PLB 748, 399 (2015)
  - T, P, H in $\pi^0 p$
- GRAAL (Di Salvo, 2009): EPJA 42, 151 (2009)
  - Σ in $\pi^0 n$
- CBELSA/TAPS (Ajaka, 1998): PRL 81, 9 (1998)
  - Σ in ηp
- CBELSA/TAPS (Elsner, 2007): EPJA 33, 147 (2007)
  - Σ in ηp
- GRAAL (Bartalini, 2007): EPJA 33, 169 (2007)
  - Σ in ηp
- CLAS (Collins, 2017): PLB 771, 213 (2017)
  - Σ in ηp
- CBELSA/TAPS (Afzal, 2020): PRL 125, 152002 (2020)
  - Σ in ηp
- CBELSA/TAPS (Müller, 2020): PLB 803, 135323 (2020)
  - T, P, H in ηp
- A2 (Akondi, 2014): PRL 113, 102001 (2014)
  - T in ηp
- GRAAL (Fantini, 2008): PRC 78, 015203 (2008)
  - Σ in ηn

PWA models

- BnGa 2019: PLB 803, 135323 (2020)
  - Σ, T, P, H in $\pi^0 N$ and ηN
- SAID MA19: PRC 100, 065205 (2019)
  - Σ, T, P, H in $\pi^0 N$
- MAID 2021: V. Kashevarov, private communication (2022)
  - Σ, T, P, H in $\pi^0 N$
- EtaMAID 2018: EPJA 54, 210 (2018)
  - Σ, T, P, H in ηN

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Thank you
for your attention.

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