Recent Results from Photoproduction of Mesons

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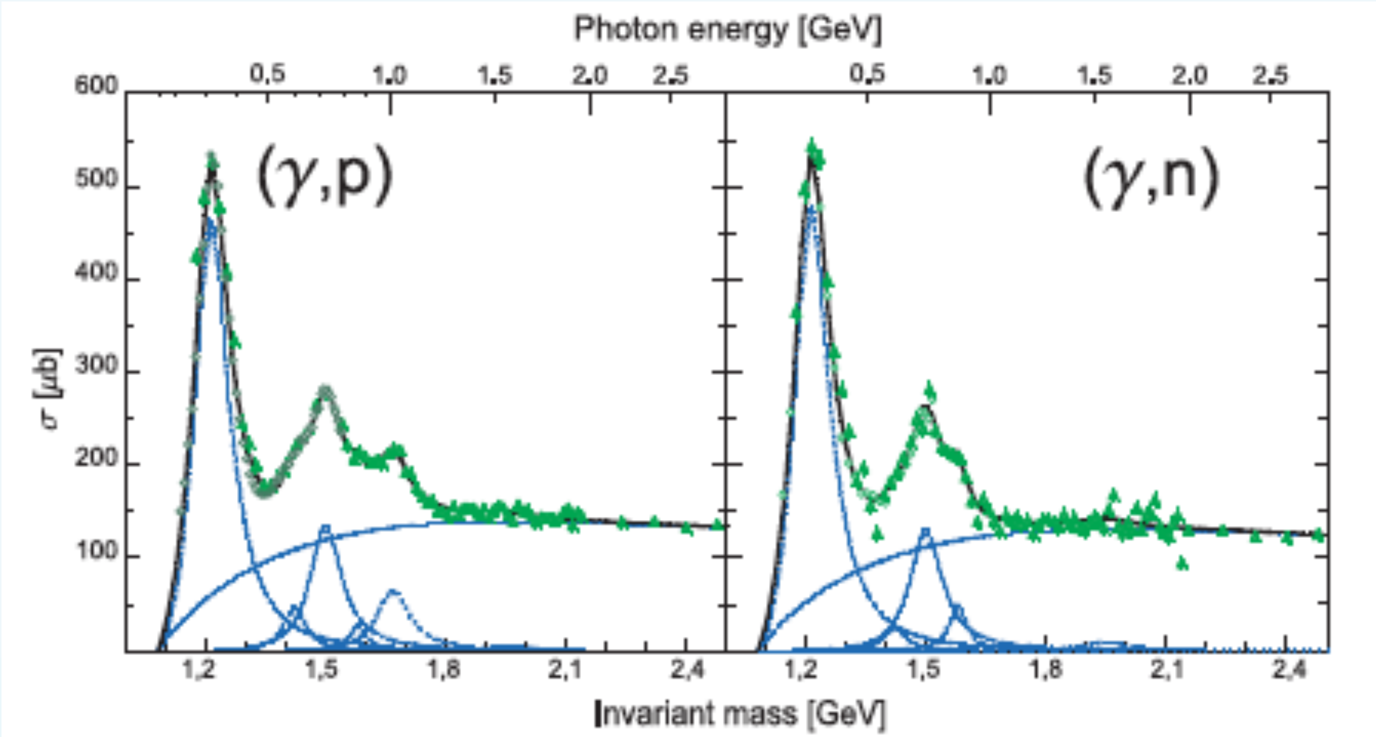
Outline

- **Motivation**
- Experiment
- Extraction of Asymmetries
- Results
- Conclusion

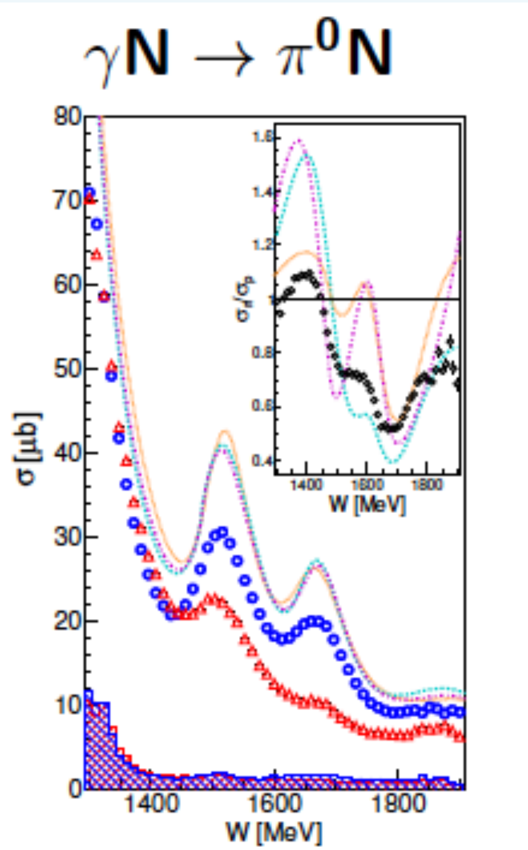
Total Cross Section

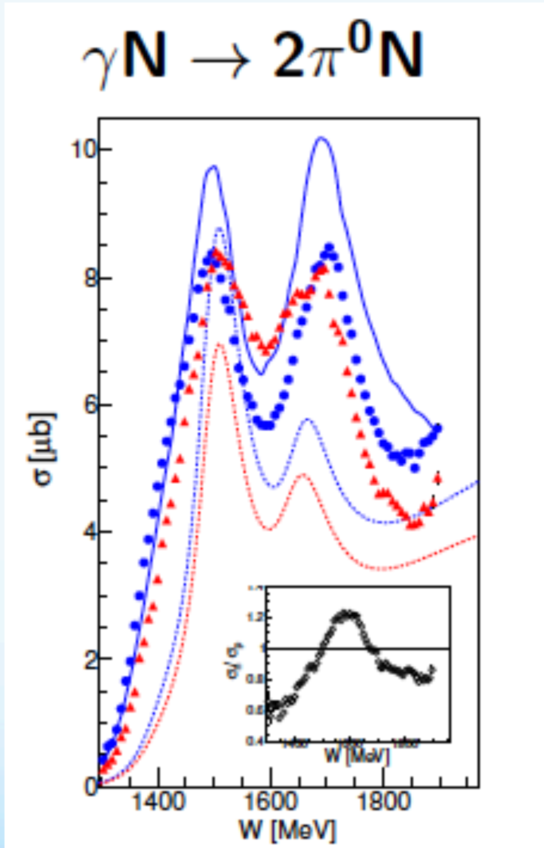


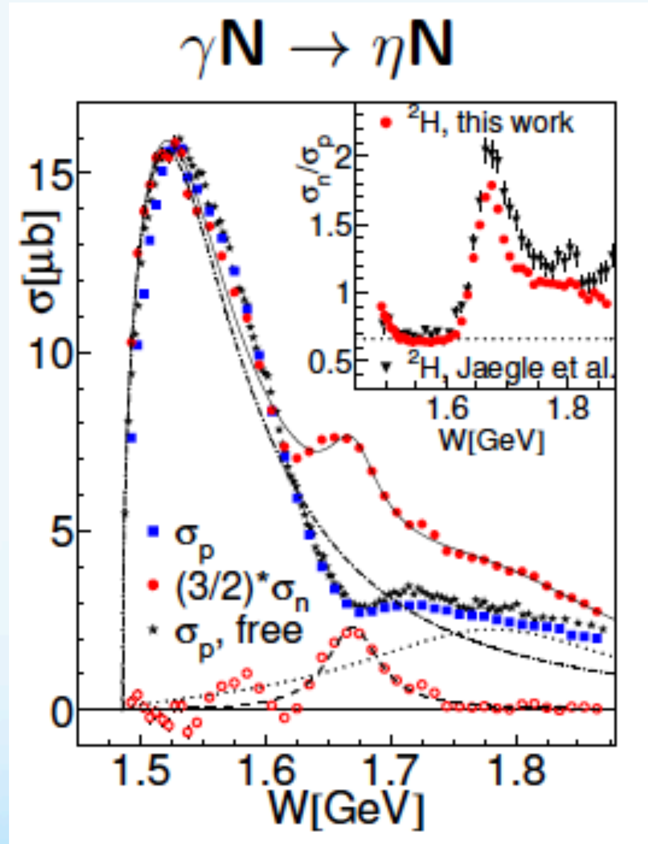
- Different structures observed on proton and neutron data
- Neutron has different resonance contributions
- Neutron targets more difficult to deal with due to Fermi motion, FSI
- Sparse database requires more data
- Isospin decomposition of el. mag. transition amplitudes needs neutron measurements

Resonance Contributions

Different contributions for proton and neutron!!!!





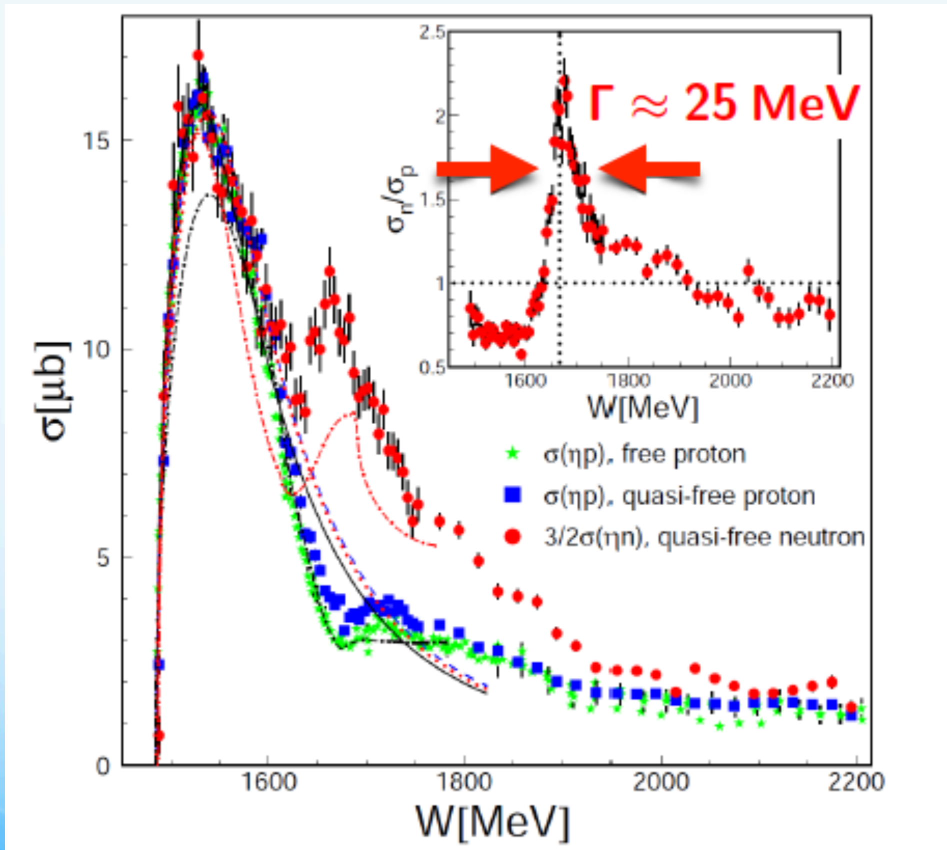


Dieterle *et al.*, PRL112,142001

Dieterle *et al.*, EPJ A51 142

Werthmüller *et al.*, PRL111,232001

Narrow Structure seen in η Photoproduction



ELSA, I.Jaeglé et al. Eur. Phys. J A47 (2011) 89

- Narrow structure visible around W=1.66 GeV
- Seen by A2, GRAAL, CBELSA/TAPS, and Sendai collaborations
- Different properties compared to other nucleon resonances (Γ~150 MeV)
- Input from polarization observables necessary to identify quantum numbers

Polarization Observables

Spin Observable	Polarization Beam	Target	Recoil	Transversity Representation	Set
$\left(\frac{d\sigma}{d\Omega}\right)_u$	-	-	-	$\frac{1}{2}(\lvert b_1\rvert^2+\lvert b_2\rvert^2+\lvert b_3\rvert^2+\lvert b_4\rvert^2)$	
Σ	l	-	-	$\frac{1}{2}(\lvert b_1\rvert^2+\lvert b_2\rvert^2-\lvert b_3\rvert^2-\lvert b_4\rvert^2)$	$\mathcal{S}$
T	-	y	-	$\frac{1}{2}(\lvert b_1\rvert^2-\lvert b_2\rvert^2-\lvert b_3\rvert^2+\lvert b_4\rvert^2)$	
P	-	-	y'	$\frac{1}{2}(\lvert b_2\rvert^2+\lvert b_4\rvert^2-\lvert b_1\rvert^2-\lvert b_3\rvert^2)$	
E	c	z	-	$\mathrm{Re}(b_1b_3^*+b_2b_4^*)$	
F	c	x	-	$\mathrm{Im}(b_1b_3^*-b_2b_4^*)$	$\mathcal{BT}$
G	l	z	-	$\mathrm{Im}(-b_1b_3^*-b_2b_4^*)$	
H	l	x	-	$\mathrm{Re}(b_1b_3^*-b_2b_4^*)$	
O_x	l	-	x'	$\mathrm{Re}(-b_1b_4^*+b_2b_3^*)$	
O_z	l	-	z'	$\mathrm{Im}(b_1b_4^*+b_2b_3^*)$	$\mathcal{BR}$
C_x	c	-	x'	$\mathrm{Im}(b_2b_3^*-b_1b_4^*)$	
C_z	c	-	z'	$\mathrm{Re}(-b_1b_4^*-b_2b_3^*)$	
T_x	-	x	z'	$\mathrm{Re}(b_1b_2^*-b_3b_4^*)$	
T_z	-	x	z'	$\mathrm{Im}(b_3b_4^*-b_1b_2^*)$	$\mathcal{TR}$
L_x	-	z	x'	$\mathrm{Im}(-b_1b_2^*-b_3b_4^*)$	
L_z	-	z	z'	$\mathrm{Re}(-b_1b_2^*-b_3b_4^*)$	

- Photoproduction described by four complex amplitudes
- 16 independent measurables calculated
- Extracted based on beam, target, and recoil polarization
- Not all observables are independent from each other

Photon		Target			Recoil			Target + Recoil			
	–	–	–	–	x'	y'	z'	x'	x'	z'	z'
	–	x	y	z	–	–	–	x	z	x	z
unpolarized	σ_0	0	$\boxed{T}$	0	0	P	0	$T_{x'}$	$-L_{x'}$	$T_{z'}$	$L_{z'}$
linear pol.	$-\Sigma$	H	(-P)	$-G$	$O_{x'}$	(-T)	$O_{z'}$	$(-L_{z'})$	$(T_{z'})$	$(-L_{x'})$	$(-T_{x'})$
circular pol.	0	$\boxed{F}$	0	$\boxed{-E}$	$-C_{x'}$	0	$-C_{z'}$	0	0	0	0

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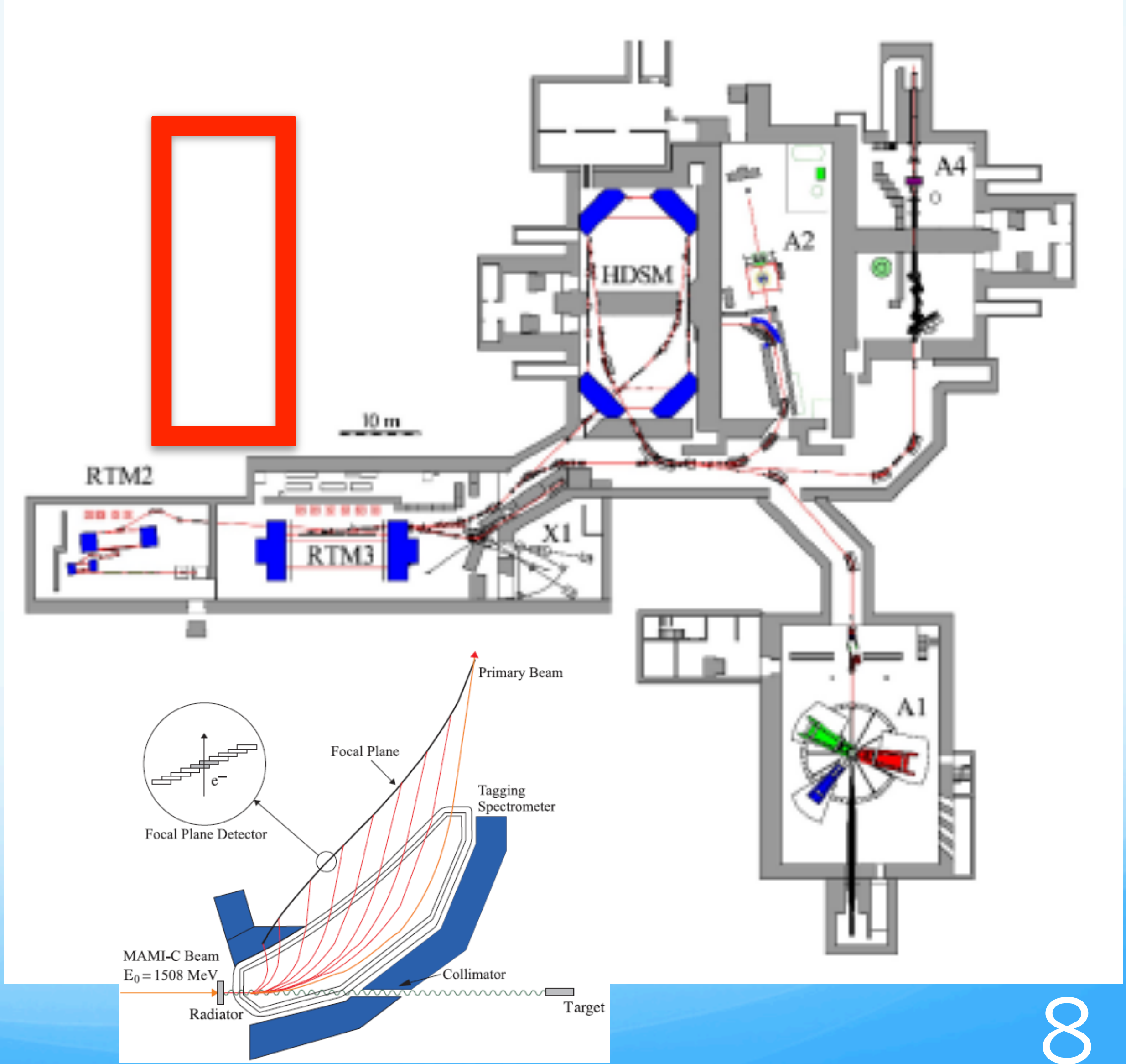
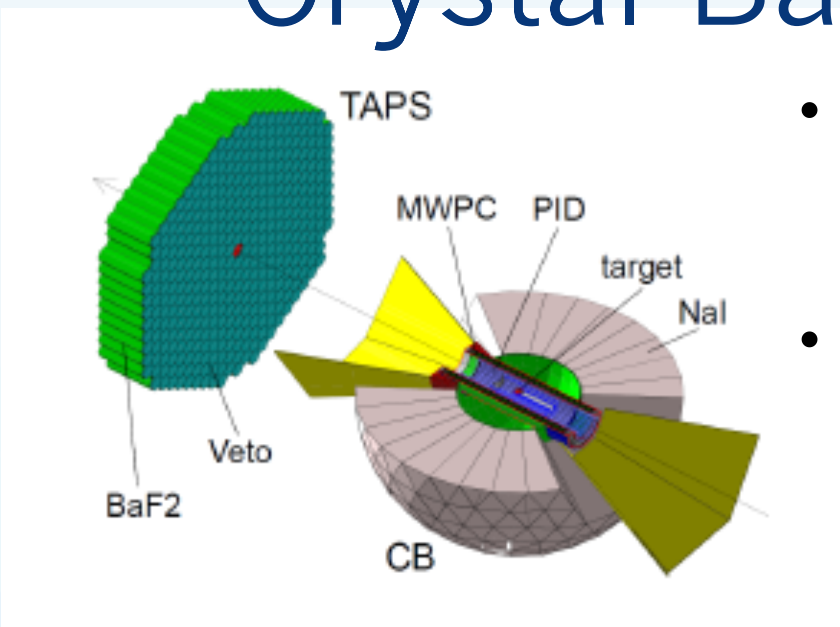
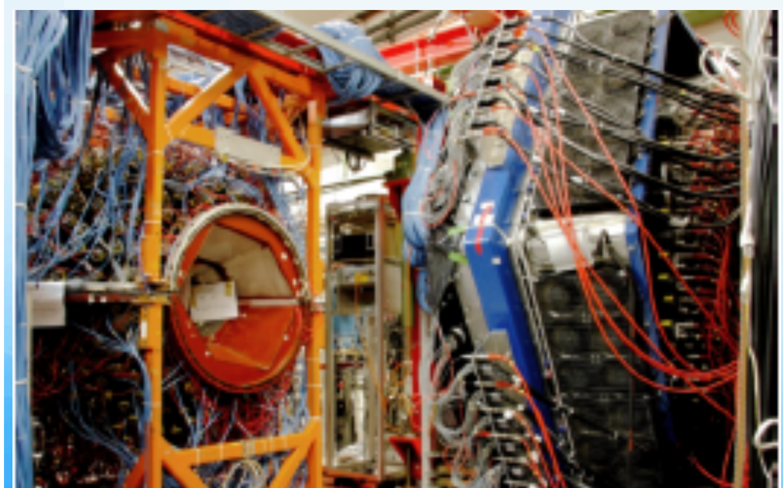
The Mainz Microtron - MAMI

- LINAC (3.97 MeV)
- Racetrack microtrons (855 MeV)
- Harmonic double sided microtron (up to 1.6 GeV)
  - Linear and circular beam available
- Glasgow Tagging Spectrometer used

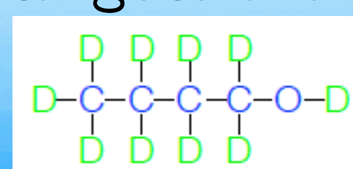


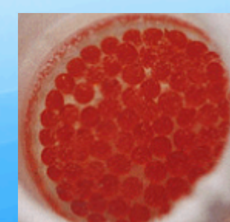
Crystal Ball/TAPS setup





- Crystal Ball:
  - 672 NaI crystals
    $20° < \theta < 160°$
- TAPS:
  - 366 BaF_2 crystals and 72 $PbWO_4$ crystals
    $2° < \theta < 20°$
- PID done using $\Delta E - E$ with a plastic scintillator barrel
- Charged particles accessible with MWPC, no magnetic field
- Frozen D-Butanol and H-Butanol targets available





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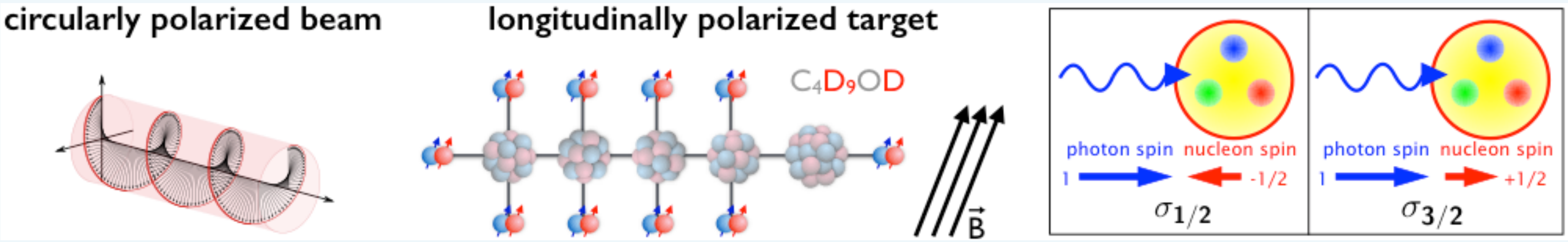
Extraction of E, $\sigma_{1/2}$, and $\sigma_{3/2}$



2 extraction methods for E:

$$E^{vers1} = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{\sigma_{diff}}{\sigma_{sum}}$$

$$E^{vers2} = \frac{\sigma_{diff}}{2\sigma_{unpol}}$$

3 extraction methods for $\sigma_{N/2}$:

$$\sigma_{1/2}^{vers1} = \sigma_{unpol}(1 + E^{vers1})$$
$$\sigma_{3/2}^{vers1} = \sigma_{unpol}(1 - E^{vers1})$$

$$\sigma_{1/2}^{vers2} = \sigma_{unpol}(1 + E^{vers2}) = \frac{2\sigma_{unpol} + \sigma_{diff}}{2}$$
$$\sigma_{3/2}^{vers2} = \sigma_{unpol}(1 - E^{vers2}) = \frac{2\sigma_{unpol} - \sigma_{diff}}{2}$$

$$\sigma_{1/2}^{vers3} = \frac{\sigma_{sum} + \sigma_{diff}}{2}$$
$$\sigma_{3/2}^{vers3} = \frac{\sigma_{sum} - \sigma_{diff}}{2}$$

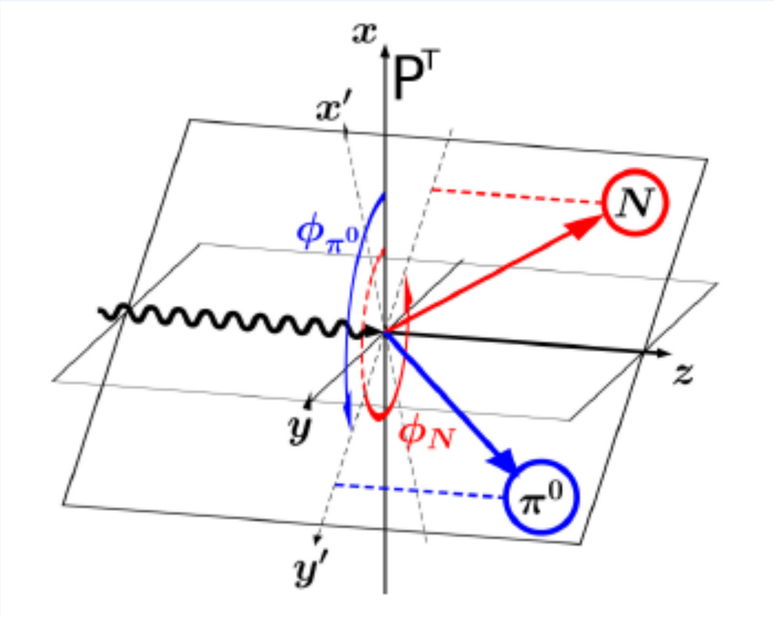
Extraction of *T* and *F*

$$T cos\phi' = \frac{1}{P_T}\frac{d\sigma^{\uparrow}\phi' - d\sigma^{\downarrow}\phi'}{d\sigma^{\uparrow}\phi' + d\sigma^{\downarrow}\phi'}$$

$\uparrow$, $\downarrow$ denote target polarization state

$$F cos\phi = \frac{1}{P_T P_{circ}}\frac{d\sigma^{-}\phi - d\sigma^{+}\phi}{d\sigma^{-}\phi + d\sigma^{+}\phi}$$

+, - denote photon helicity state



2 methods to extract:

- Normalize with deuterium target (needs flux and efficiency correction)
- Normalize with D-Butanol/H-Butanol target (no flux or efficiency correction, but uses dilution factor)

- Φ is the angle between target polarization plane and production plane
- Φ' is the angle between target polarization plane and normal to production plane

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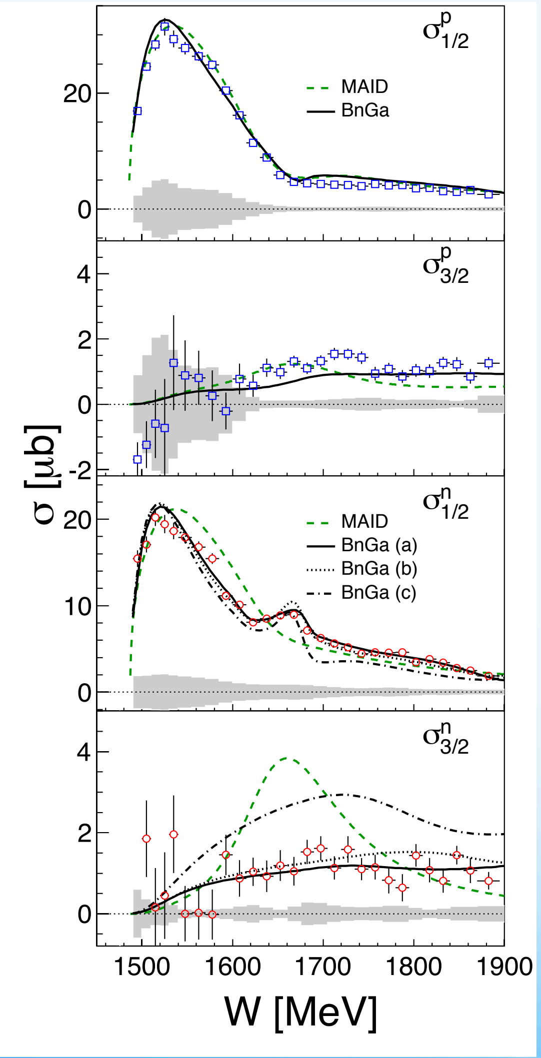
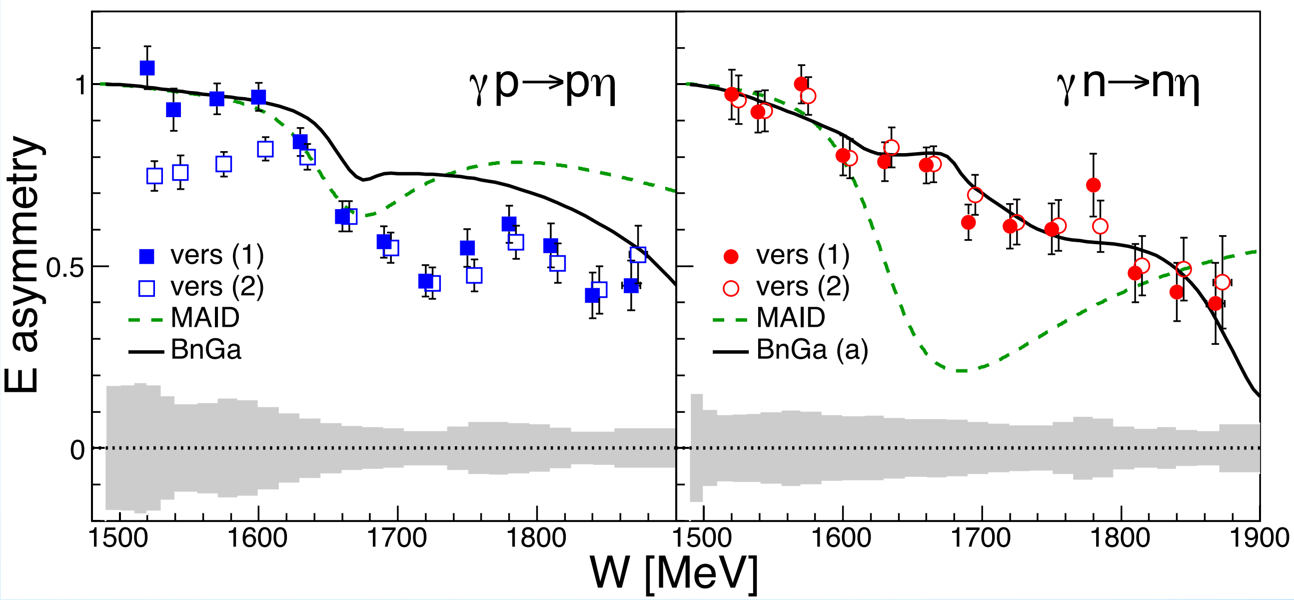
E and $\sigma_{N/2}$ for η N

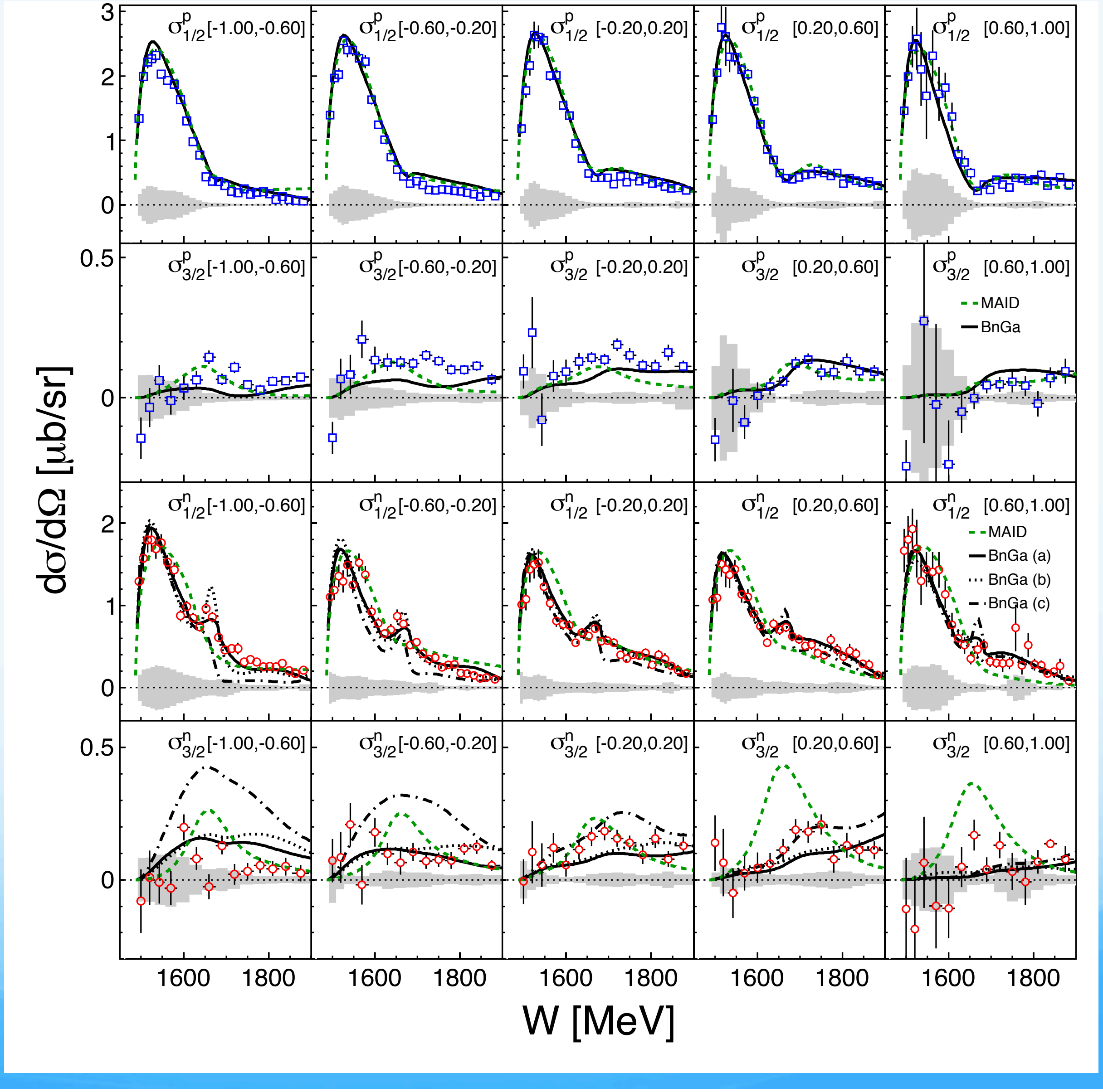




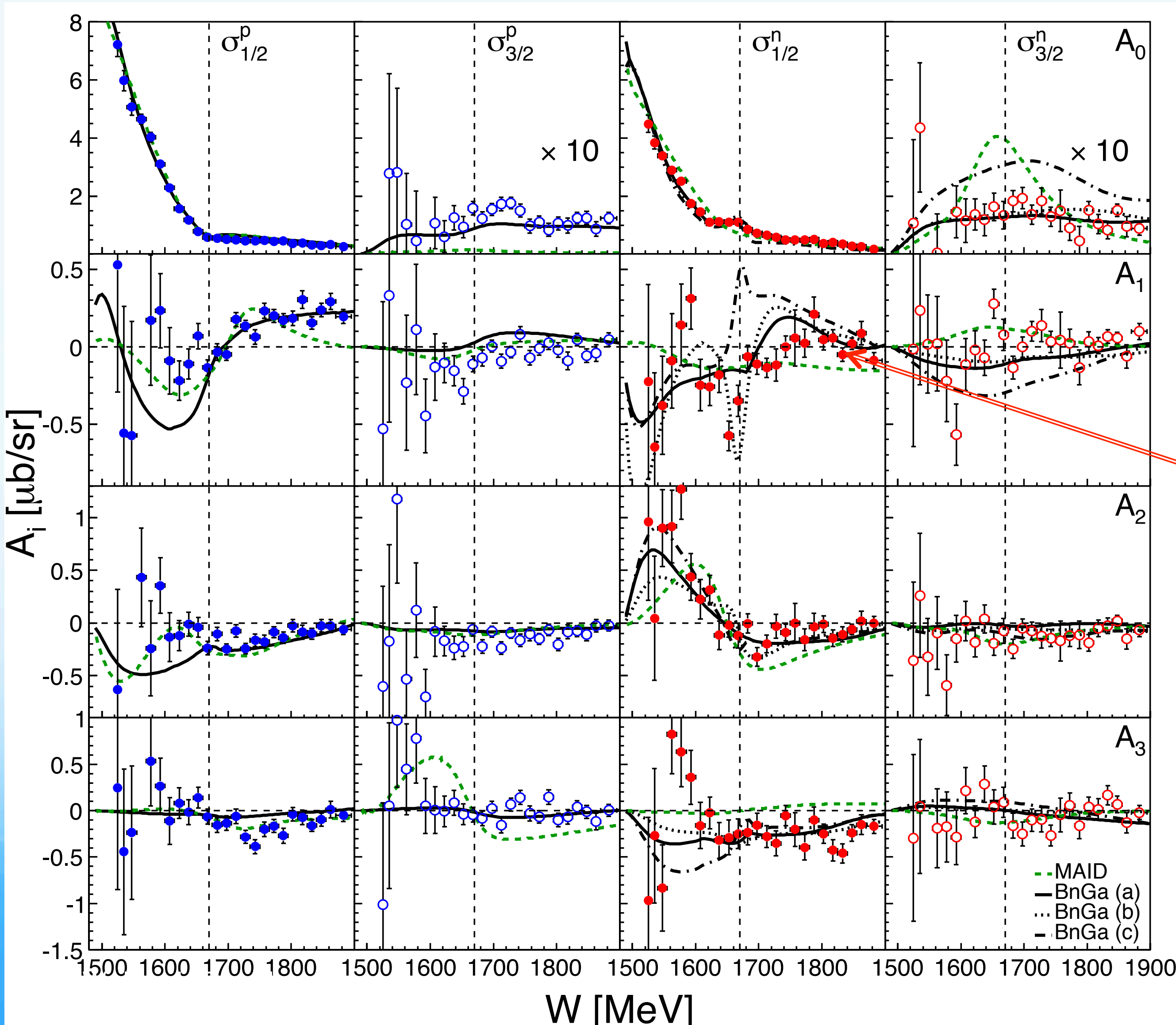
Witthauer *et al.*, accepted to PRL

Angular Asymmetries for η N

Witthauer *et al.*, accepted to PRL



Legendre Coefficients for η N

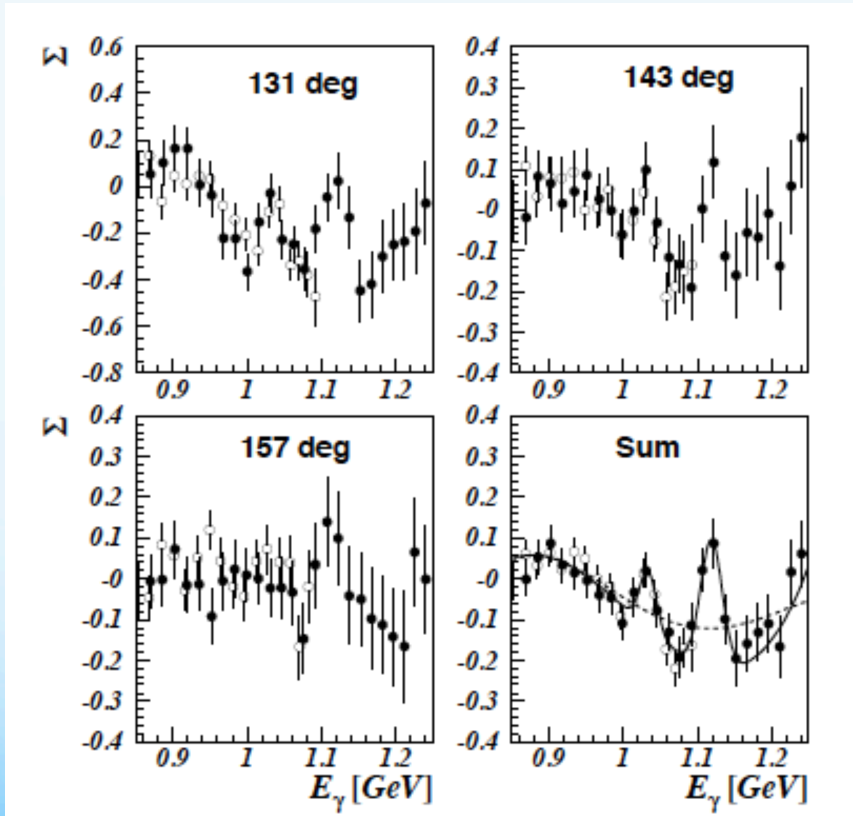


Model results with a positive interference sign of P_{11} and S_{11} are more similar to the measured data than the predictions without the addition of a narrow P_{11} state

Witthauer *et al.*, accepted to PRL

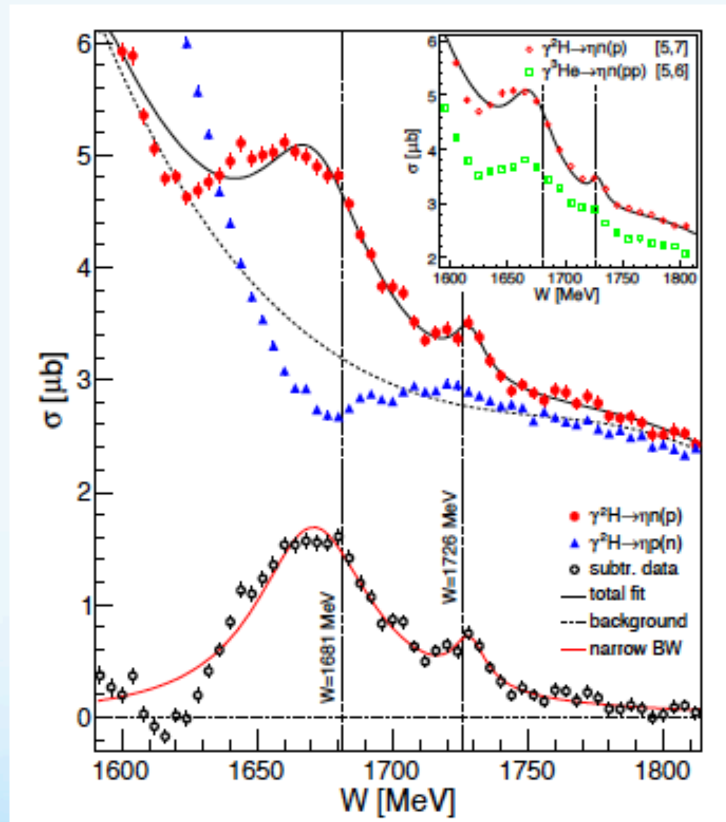
Another look at η n

Narrow structure seen in **Compton scattering** off proton:



GRAAL experiment: Kuznetsov *et al.*, PRC 91 042201

Peak at same *W* significant in relation to η n in **total cross section**:

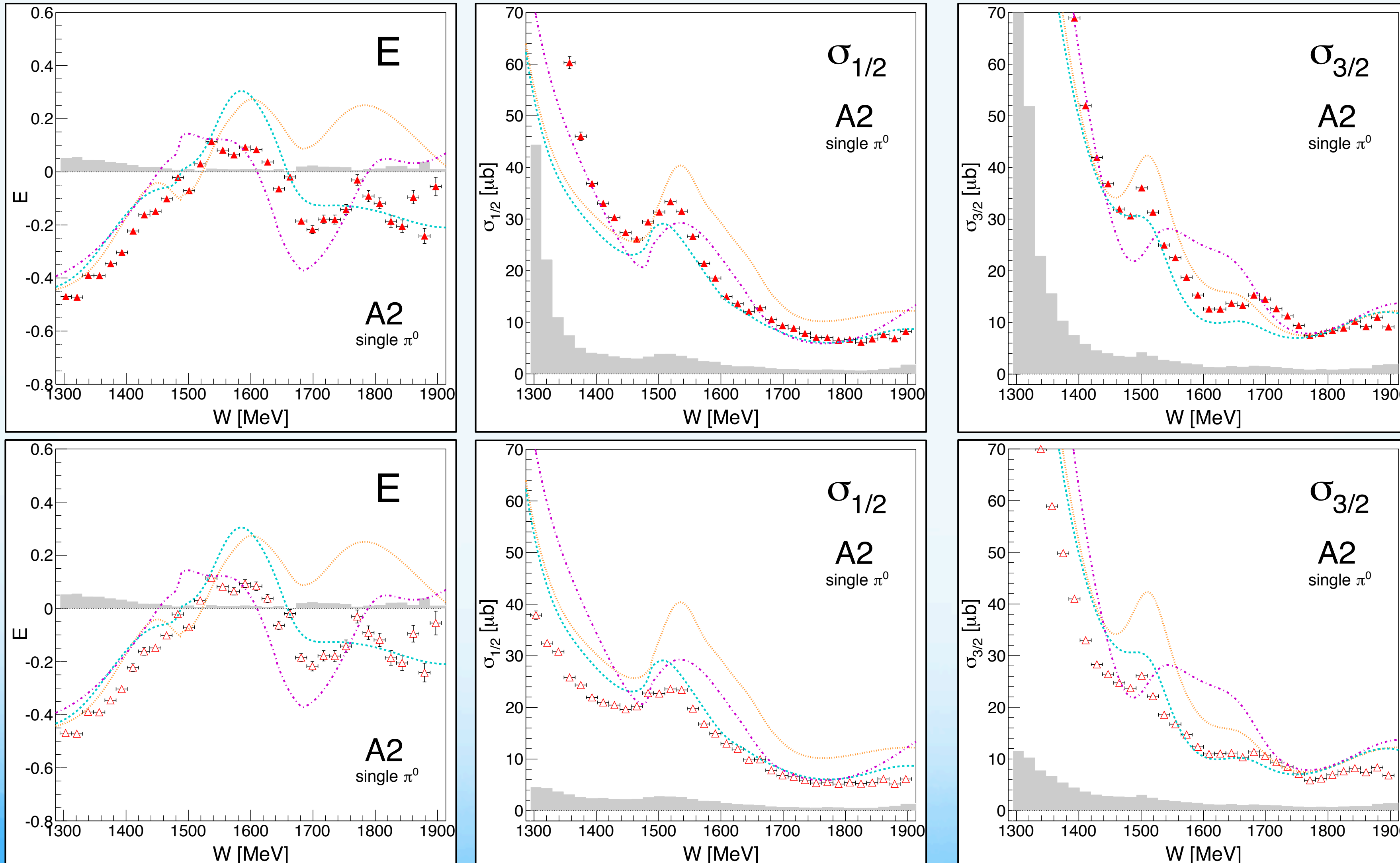


A2 experiment: Werthmueller *et al.*, PRC 92 069801

MAID
SAID
BnGA

E for $\pi^0 n$

Full-free
Open-quasifree

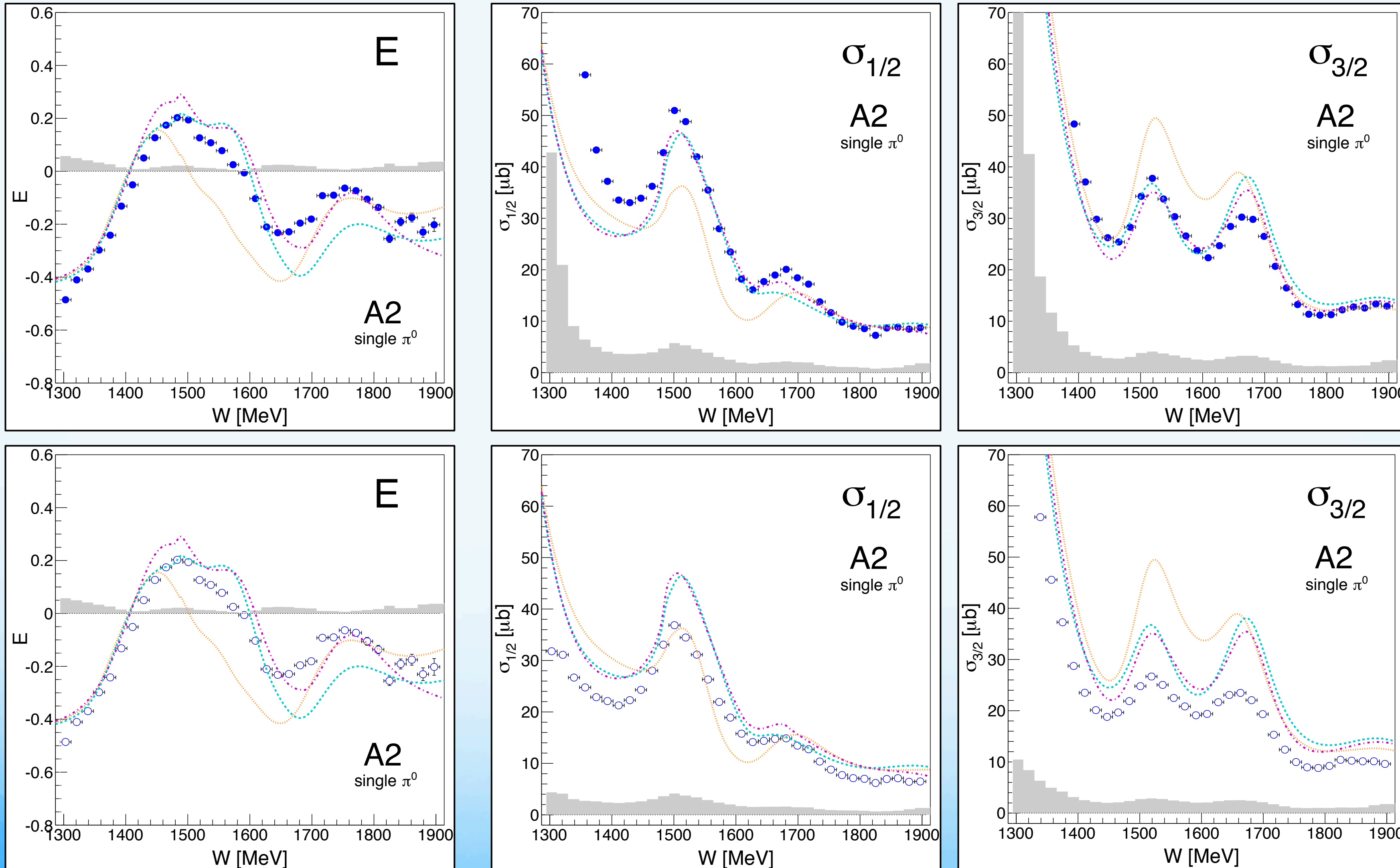


Dieterle *et al.*, in preparation

MAID
SAID
BnGA

E for $\pi^0 p$

Full-free
Open-quasifree

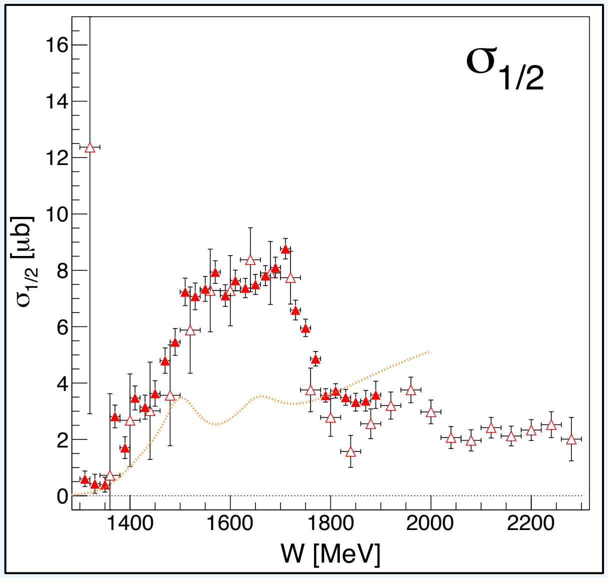


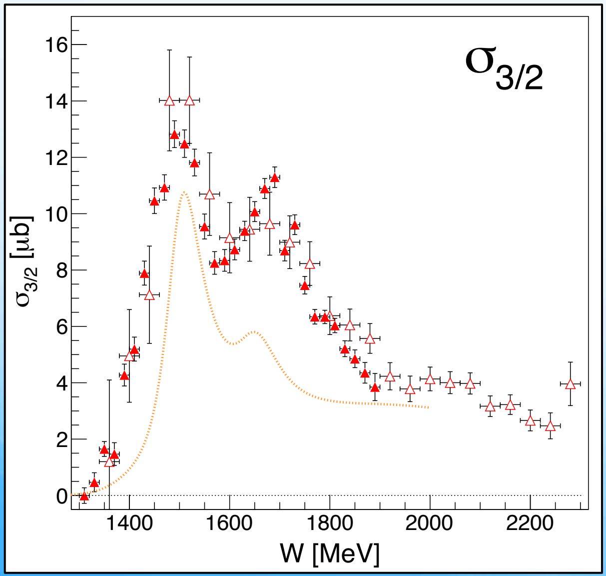
Dieterle *et al.*, in preparation

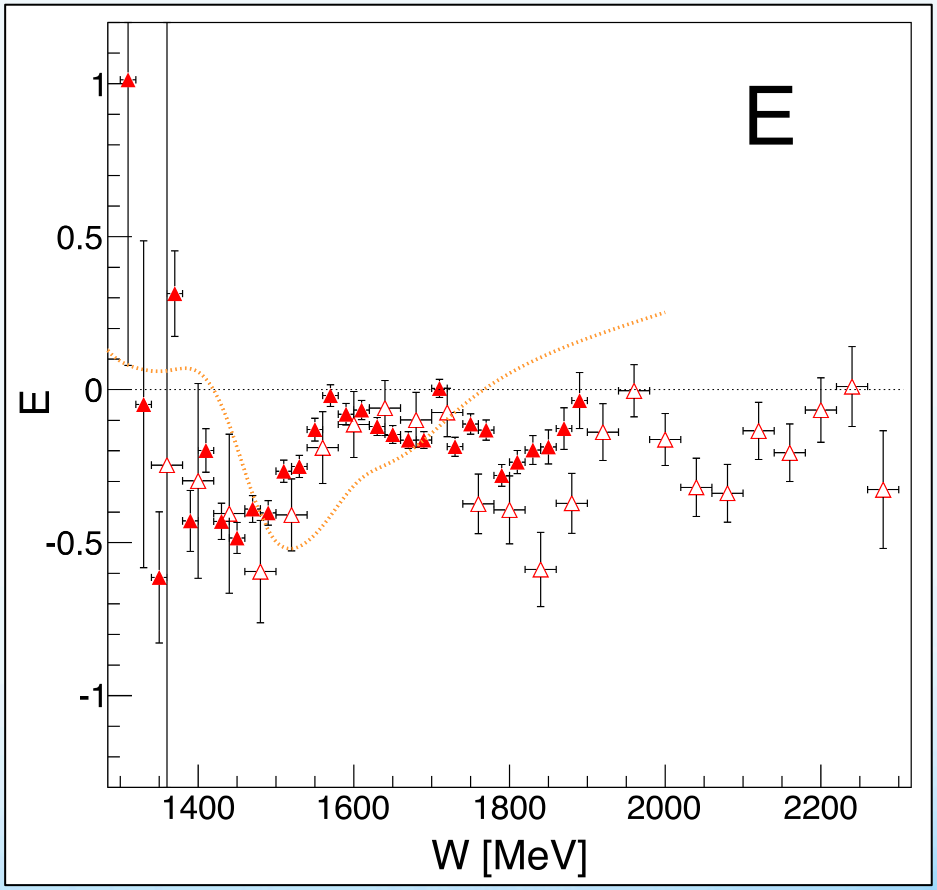
MAID

E for $\pi^0\pi^0 n$

Full-Crystal Ball
Open-CBELSA







Dieterle *et al.*, in preparation

MAID
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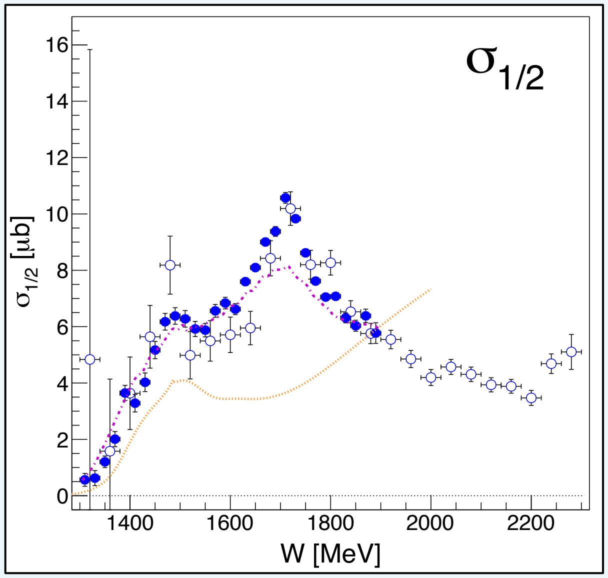
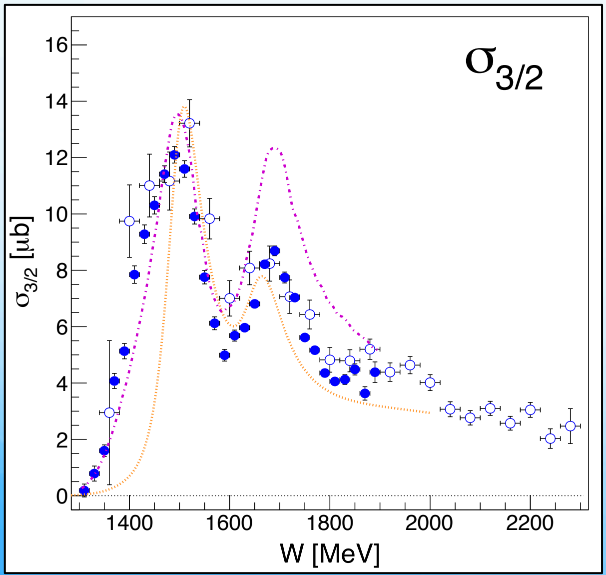
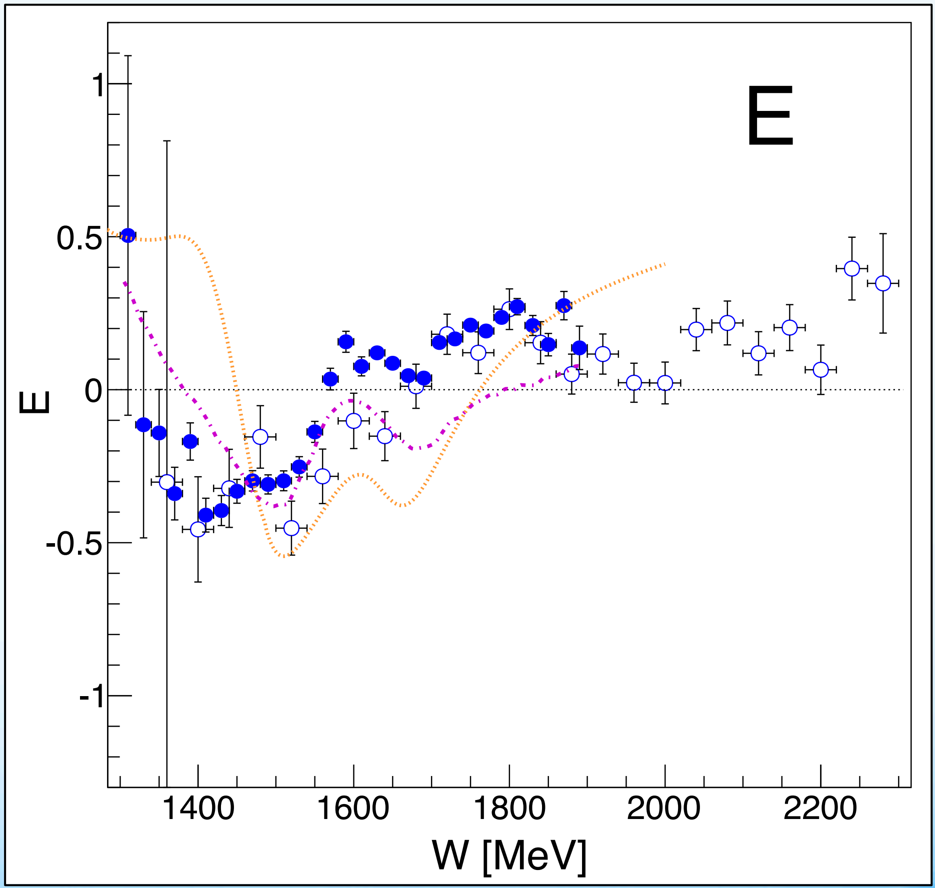
E for $\pi^0\pi^0 p$

Full-Crystal Ball
Open-CBELSA

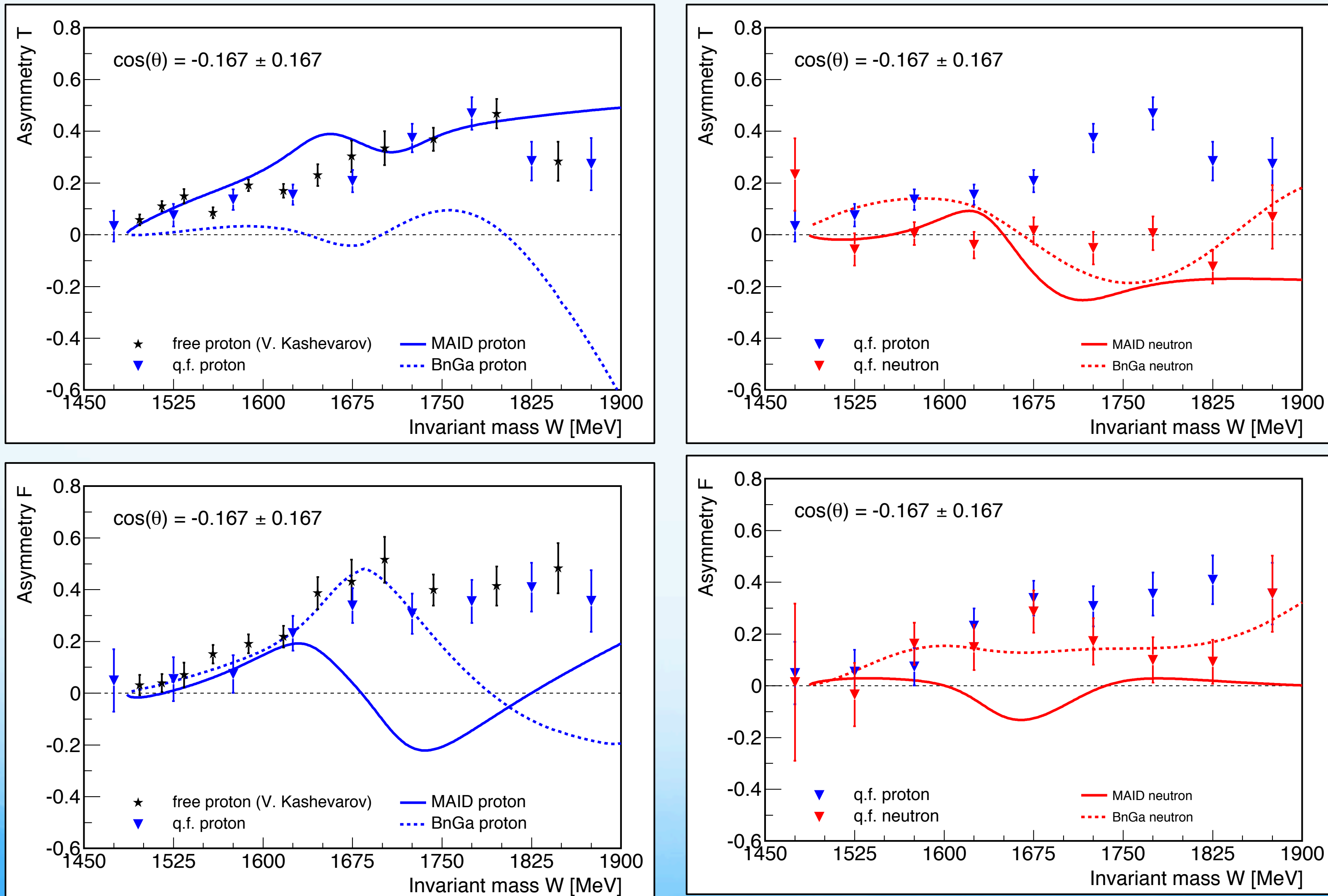






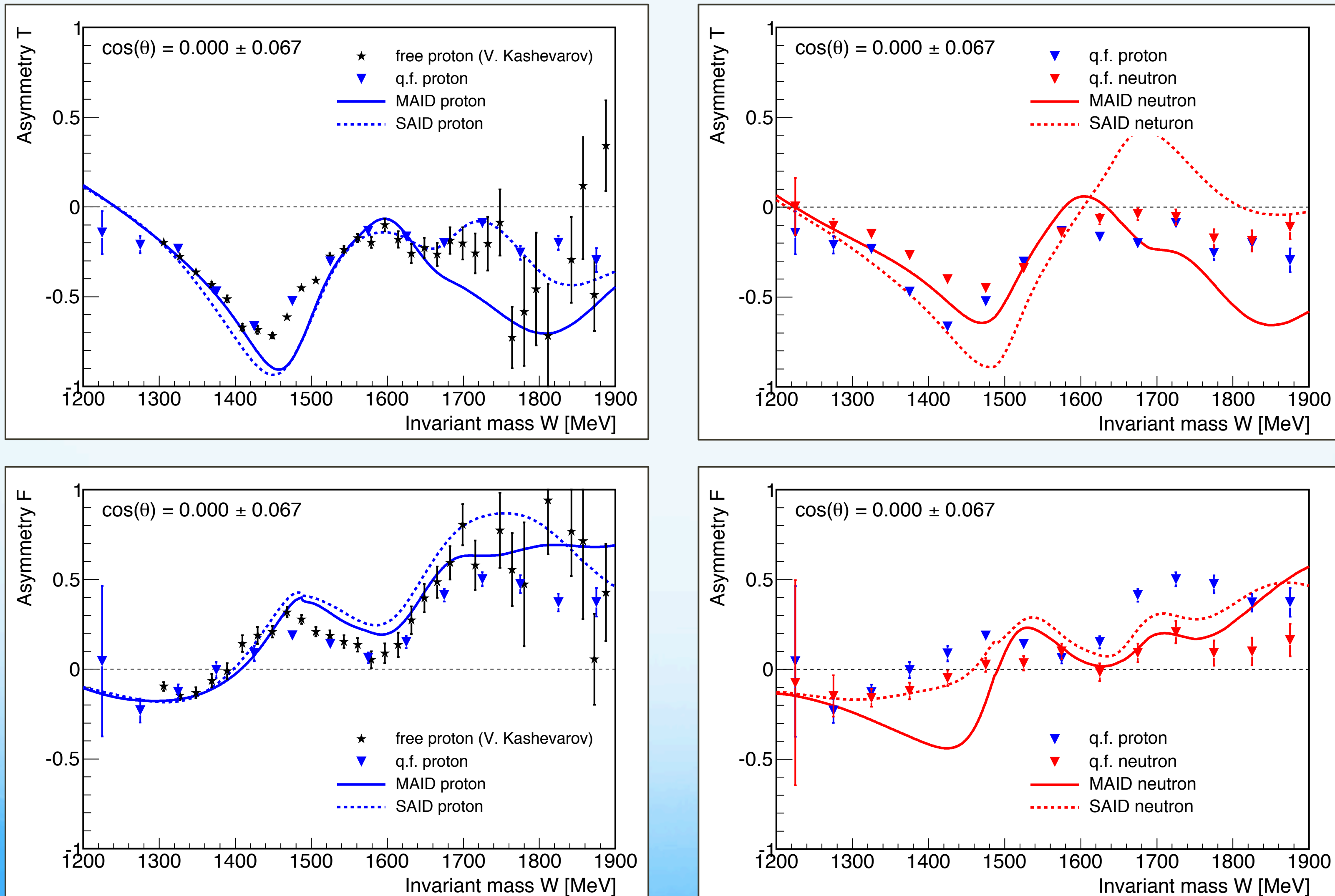
Dieterle *et al.*, in preparation

T, F for η N



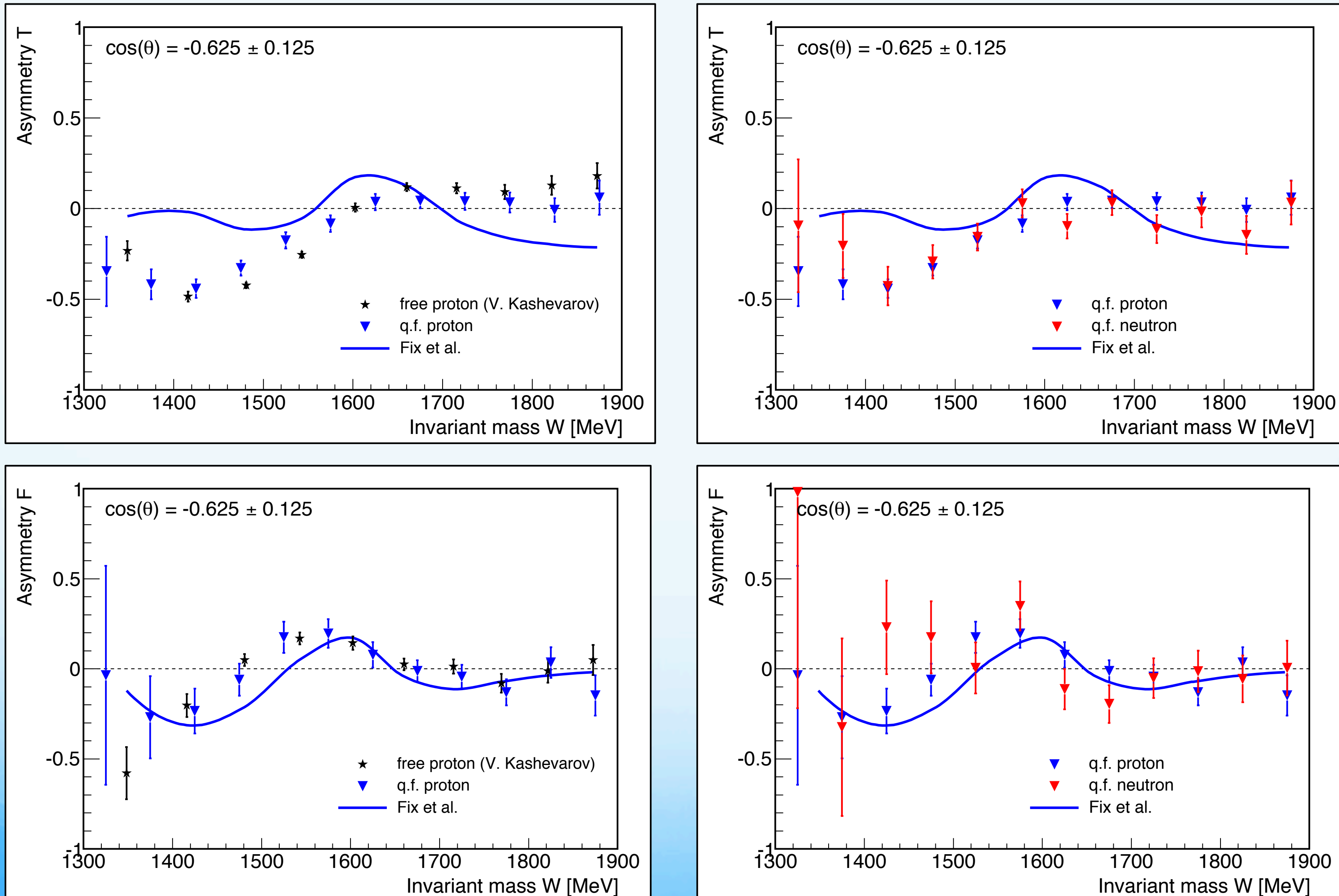
Strub *et al.*, very preliminary

T, *F* for single π^0N



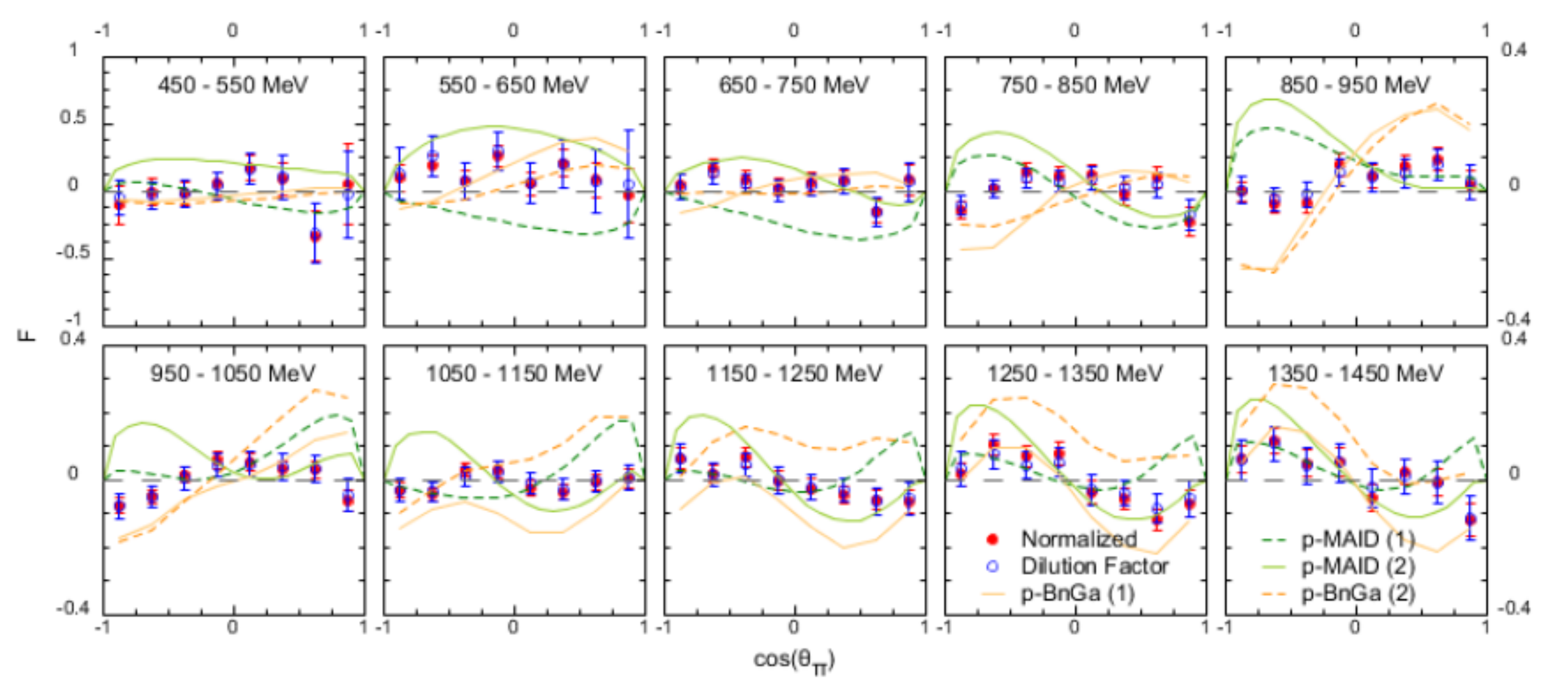
Strub *et al.*, very preliminary

T, *F* for $\pi^0\pi^0N$



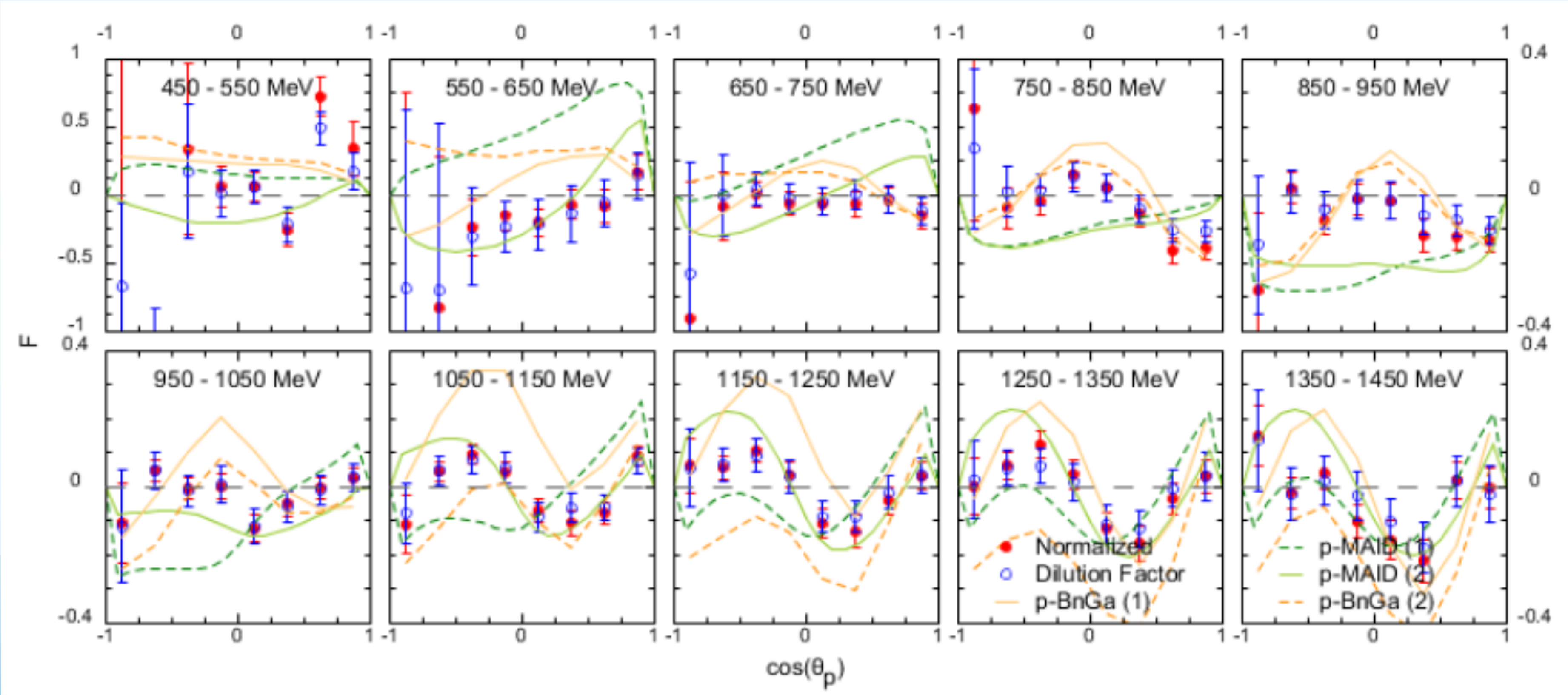
Strub *et al.*, very preliminary

F for $\pi^0\pi^0 p$



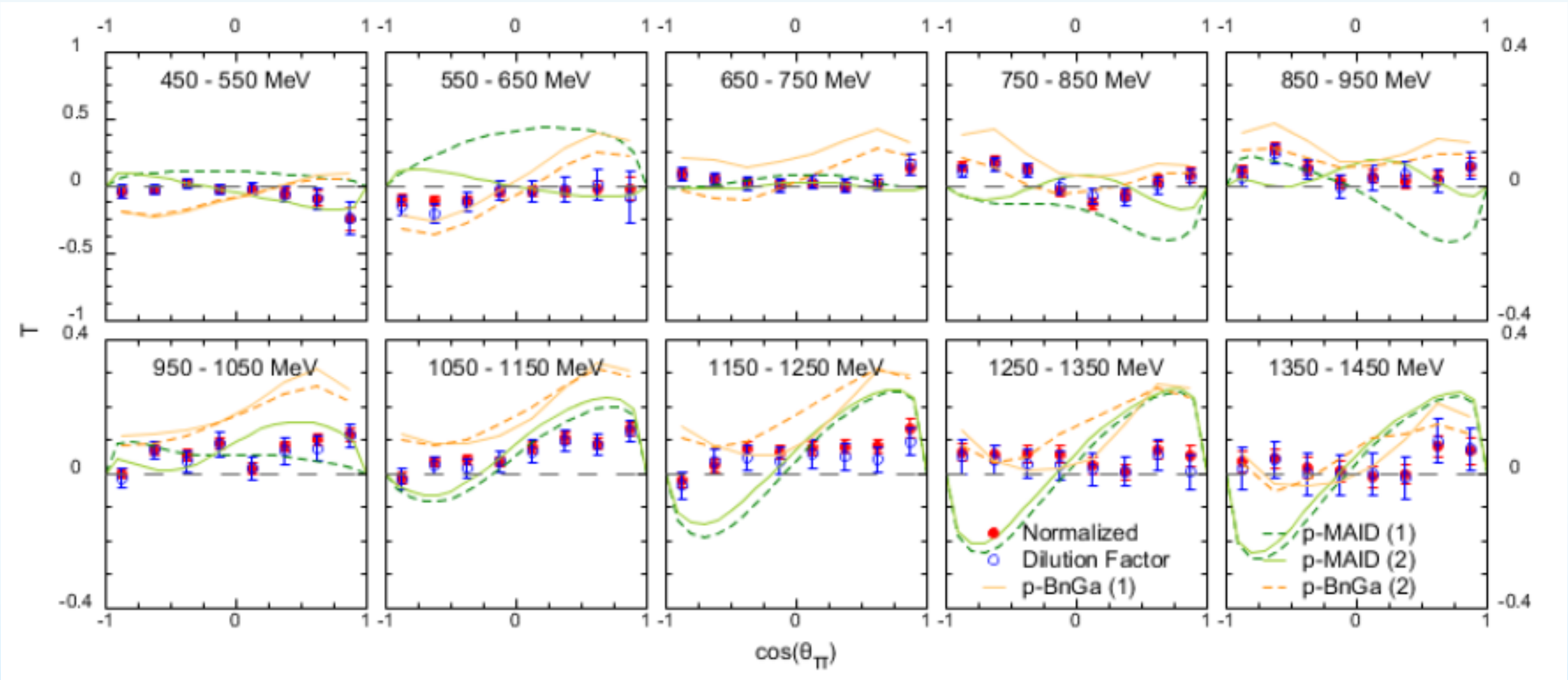
Garni *et al.*, preliminary

F for $\pi^0\pi^0 p$



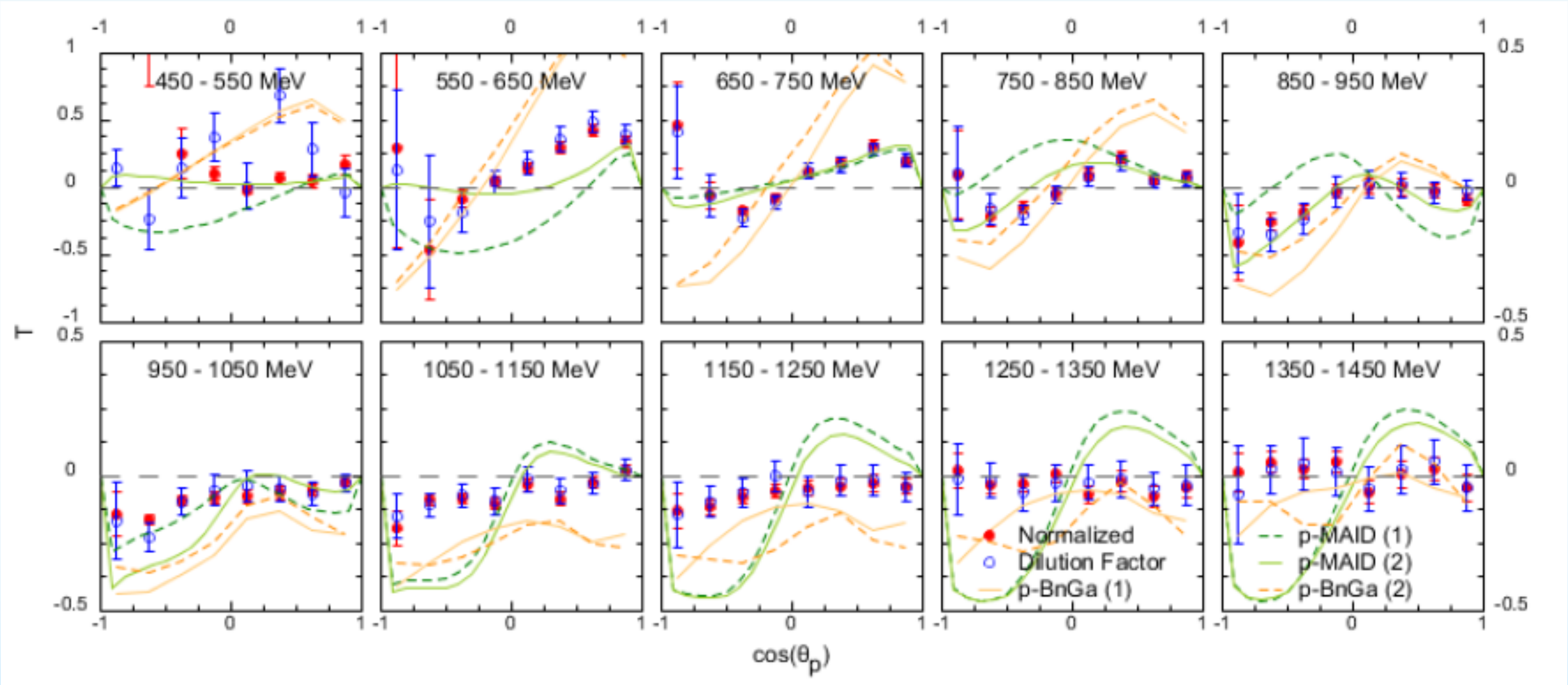
Garni *et al.*, preliminary

T for $\pi^0\pi^0p$



Garni *et al.*, preliminary

T for $\pi^0\pi^0 p$



Garni *et al.*, preliminary

Conclusion

- Database for neutrons is extremely sparse, more data required, but is coming
- New data will help to analyze N* properties
- Neutron measurements more difficult due to FSI and Fermi motion and require more time
- Channels investigated so far seem to have FSI effects less important for polarization observables than for cross sections
- Many upcoming results being prepared for publication

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