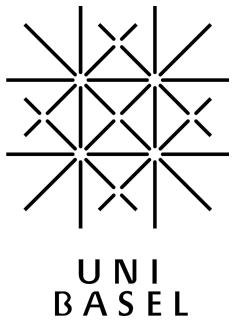
Recent Results in η and π Production with Crystal Ball/TAPS at MAMI



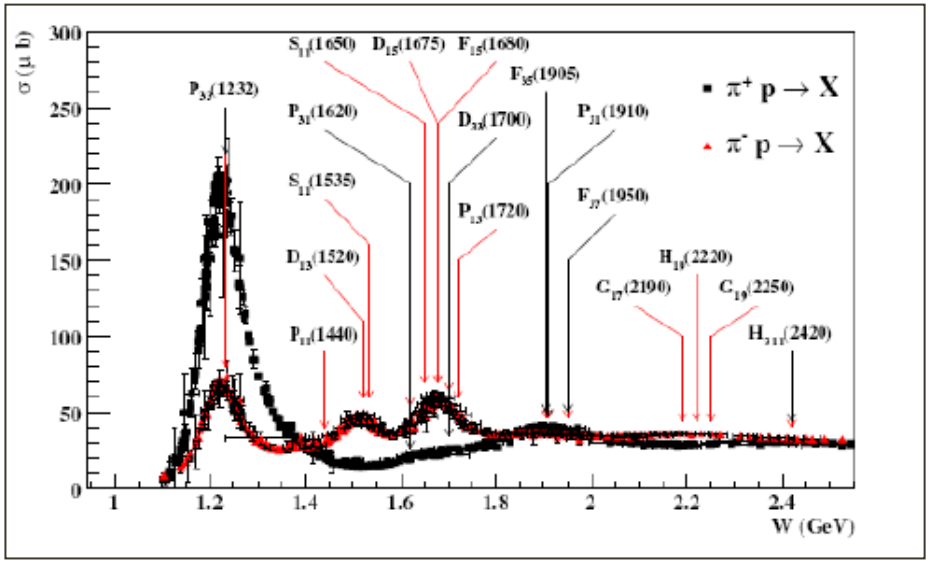
Natalie Walford
The University of Basel

Hadron 2015
Newport News, VA

Outline

- Motivation
- Experimental Setup
- Various Results
- Conclusion

Resonances



Particle	J^P	Status overall	πN	γN	$N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	***	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	***	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***
$N(1685)$	$?^?$	*									
$N(1700)$	$3/2^-$	***	***	**	*			*	*	*	***
$N(1710)$	$1/2^+$	***	***	***	***		**	***	**	*	**
$N(1720)$	$3/2^+$	****	****	***	***			**	**	**	*
$N(1860)$	$5/2^+$	**	**							*	*
$N(1875)$	$3/2^-$	***	*	***			**	***	**		***
$N(1880)$	$1/2^+$	**	*	*		**		*			
$N(1895)$	$1/2^-$	**	*	**	**			**	*		
$N(1900)$	$3/2^+$	***	**	***	**		**	***	**	*	**
$N(1990)$	$7/2^+$	**	**	**					*		
$N(2000)$	$5/2^+$	**	*	**	**			**	*	**	
$N(2040)$	$3/2^+$	*									
$N(2060)$	$5/2^-$	**	**	**	*				**		
$N(2100)$	$1/2^+$	*									
$N(2150)$	$3/2^-$	**	**	**				**			**
$N(2190)$	$7/2^-$	****	****	***			*	**		*	
$N(2220)$	$9/2^+$	****	****								
$N(2250)$	$9/2^-$	****	****								
$N(2600)$	$11/2^-$	***	***								
$N(2700)$	$13/2^+$	**	**								

- Baryon resonances are excitations of the nucleon
- More model states are predicted than have been experimentally observed
- Mass range above 1600 MeV is difficult to study due to many overlapping resonances

Polarization Observables

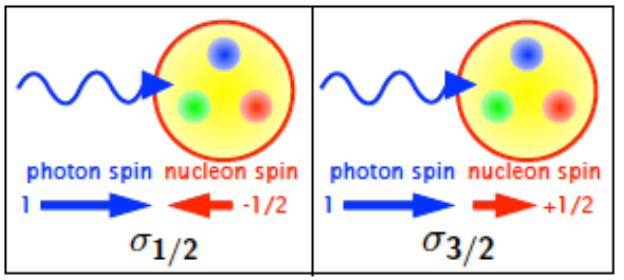
Spin Observable	Polarization Beam	Target	Recoil	Transversity Representation	Set
$\left(\frac{d\sigma}{d\Omega}\right)_u$	-	-	-	$\frac{1}{2}(\lvert b_1\rvert^2+\lvert b_2\rvert^2+\lvert b_3\rvert^2+\lvert b_4\rvert^2)$	
Σ	l	-	-	$\frac{1}{2}(\lvert b_1\rvert^2+\lvert b_2\rvert^2-\lvert b_3\rvert^2-\lvert b_4\rvert^2)$	$\mathcal{S}$
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	-	$\mathrm{Re}(b_1 b_3^* + b_2 b_4^*)$	
F	c	x	-	$\mathrm{Im}(b_1 b_3^* - b_2 b_4^*)$	$\mathcal{BT}$
G	l	z	-	$\mathrm{Im}(-b_1 b_3^* - b_2 b_4^*)$	
H	l	x	-	$\mathrm{Re}(b_1 b_3^* - b_2 b_4^*)$	
O_x	l	-	x'	$\mathrm{Re}(-b_1 b_4^* + b_2 b_3^*)$	
O_z	l	-	z'	$\mathrm{Im}(b_1 b_4^* + b_2 b_3^*)$	$\mathcal{BR}$
C_x	c	-	x'	$\mathrm{Im}(b_2 b_3^* - b_1 b_4^*)$	
C_z	c	-	z'	$\mathrm{Re}(-b_1 b_4^* - b_2 b_3^*)$	
T_x	-	x	z'	$\mathrm{Re}(b_1 b_2^* - b_3 b_4^*)$	
T_z	-	x	z'	$\mathrm{Im}(b_3 b_4^* - b_1 b_2^*)$	$\mathcal{TR}$
L_x	-	z	x'	$\mathrm{Im}(-b_1 b_2^* - b_3 b_4^*)$	
L_z	-	z	z'	$\mathrm{Re}(-b_1 b_2^* - b_3 b_4^*)$	

- Photoproduction described by four complex amplitudes
- 16 independent measurables calculated
- Extracted based on beam, target, and recoil polarization

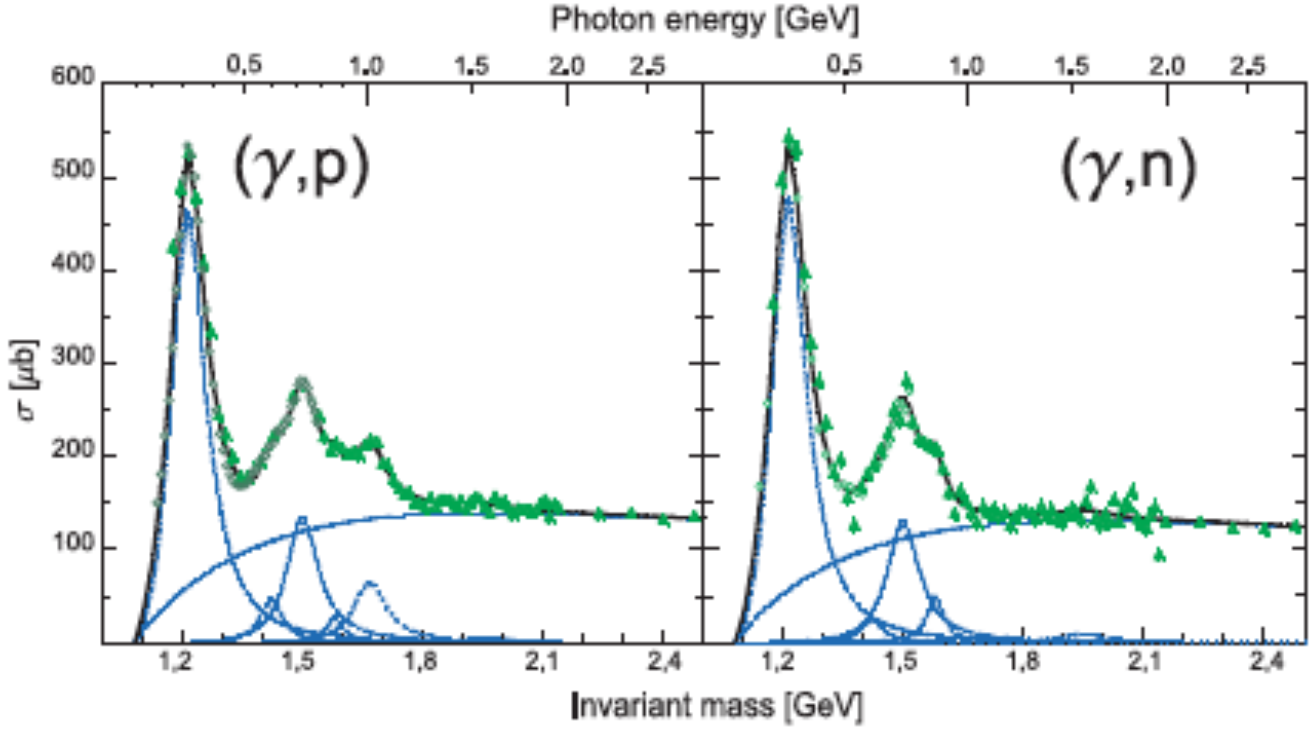
$$E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}} = \frac{1}{P_\gamma \cdot P_T} \cdot \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2} + 2N_C}$$

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

$$F\cos(\phi) = \frac{1}{P^T P^\gamma} \frac{d\sigma^{-}(\phi) - d\sigma^{+}(\phi)}{d\sigma^{-}(\phi) + d\sigma^{+}(\phi)}$$

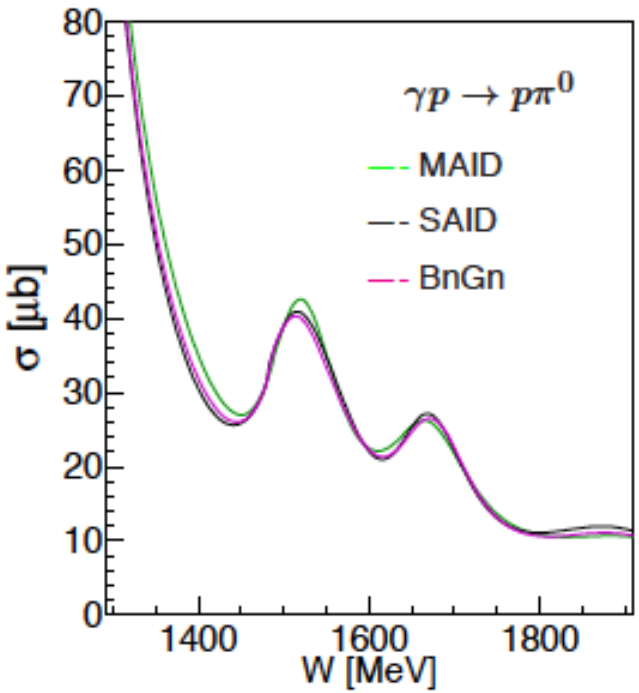


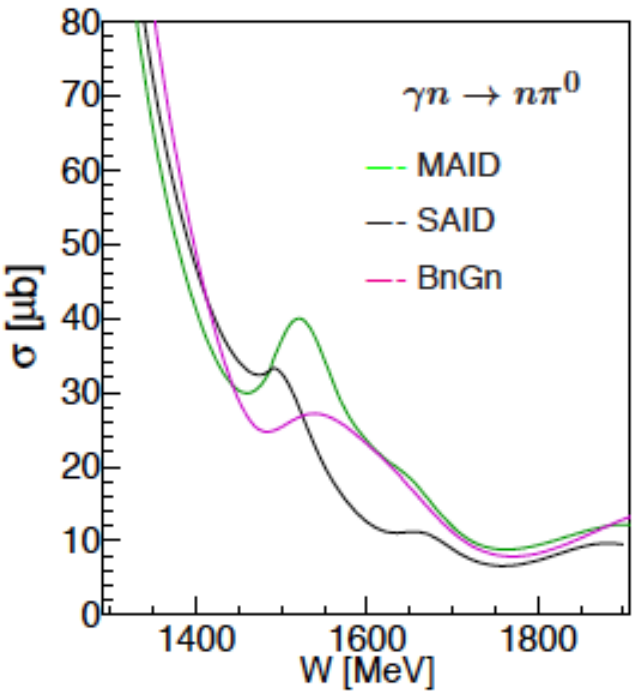
Total Cross Section



- 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

$\gamma N \rightarrow N\pi^0$





- Results for proton agree, but for neutron there is a disagreement!
- Data from $p\pi^-$ on neutron not sufficient to constrain fits due to different non-resonant backgrounds

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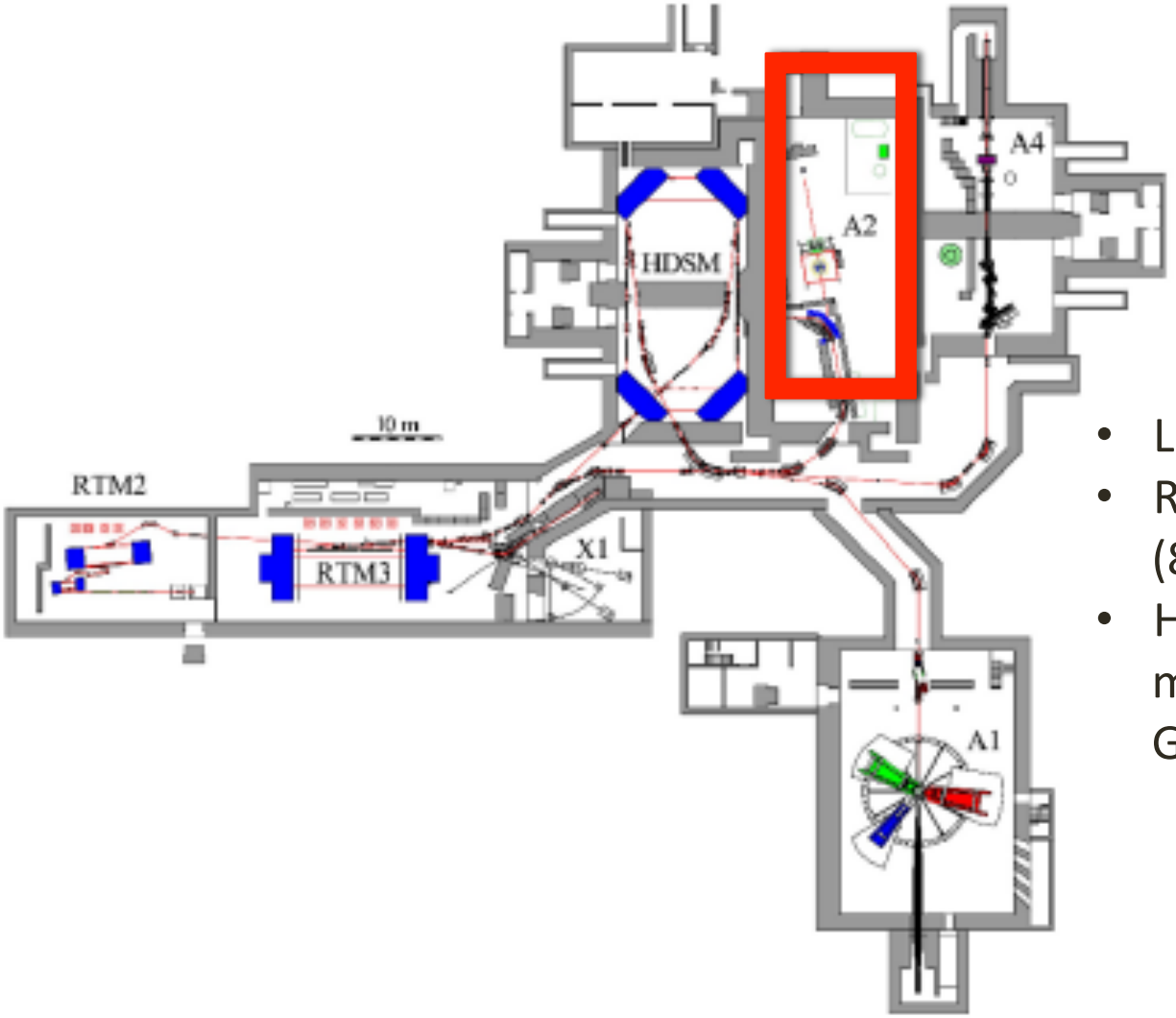
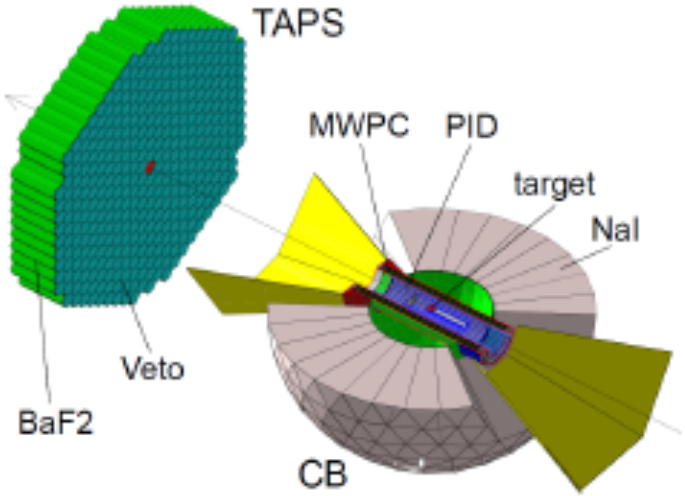
The Mainz Microtron - MAMI

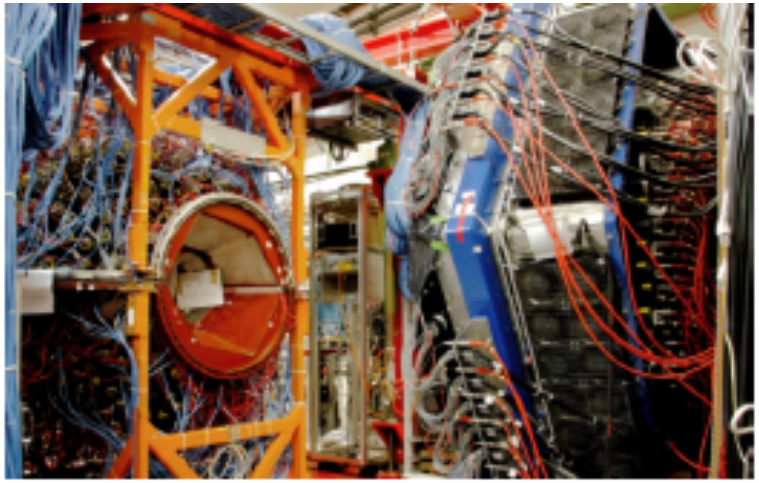


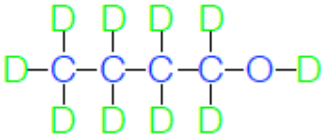
- LINAC (3.97 MeV)
- Racetrack microtrons (855 MeV)
- Harmonic double sided microtron (up to 1.6 GeV)
  - Linear beam available
  - Circular beam available

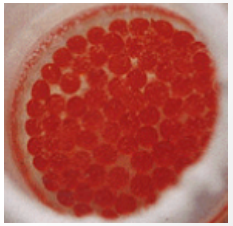
Crystal Ball/TAPS setup



- 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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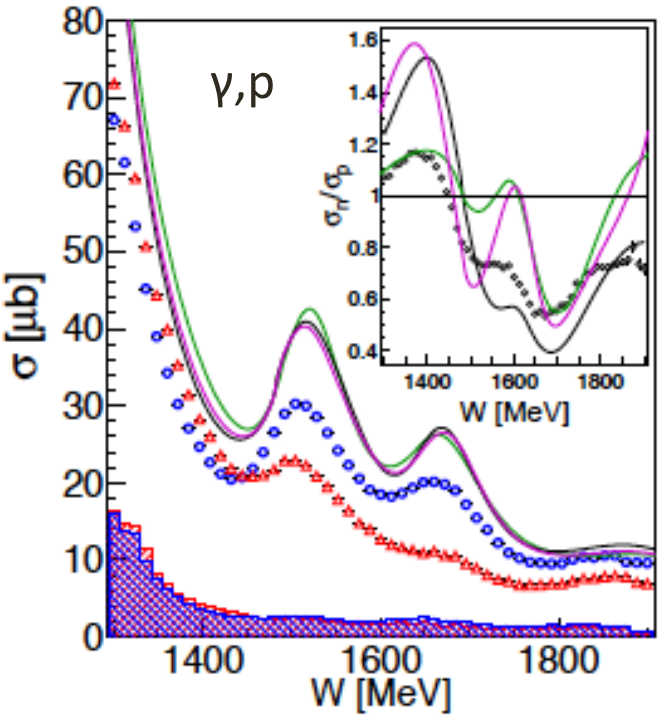
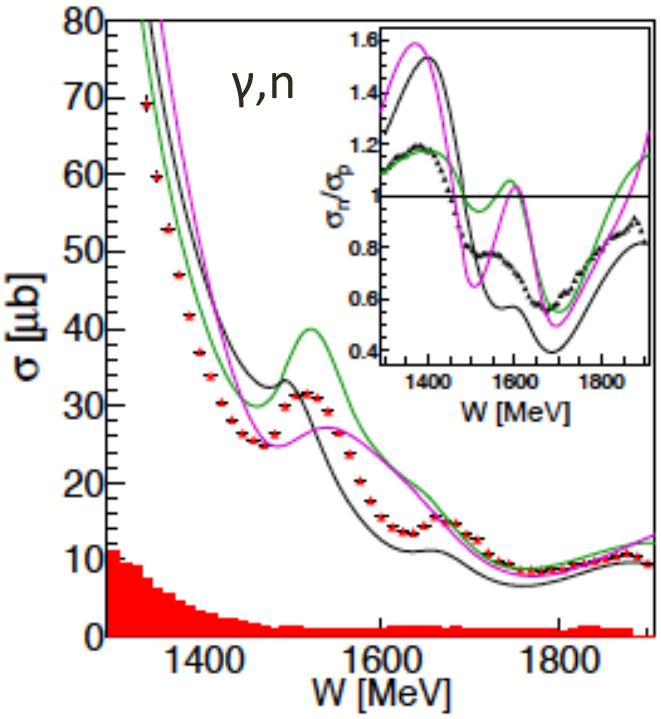
σ for γN -> π^0N

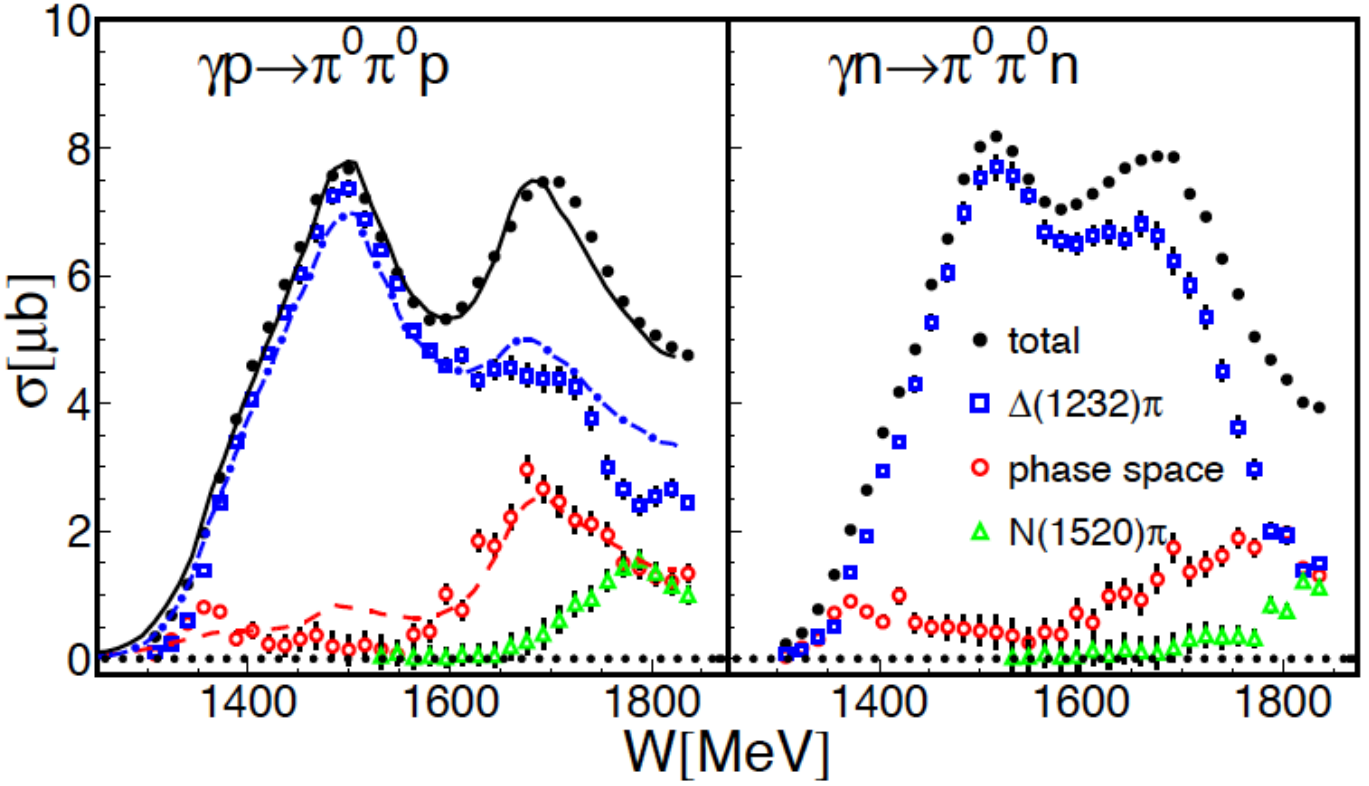




- Proton and neutron data has significant effects from FSI
- Phenomenological FSI correction for neutron data
- Large disagreement between neutron data and models

M. Dieterle *et al.*, PRL 112 (2014) 142001

σ for γN -> $\pi^0\pi^0$N

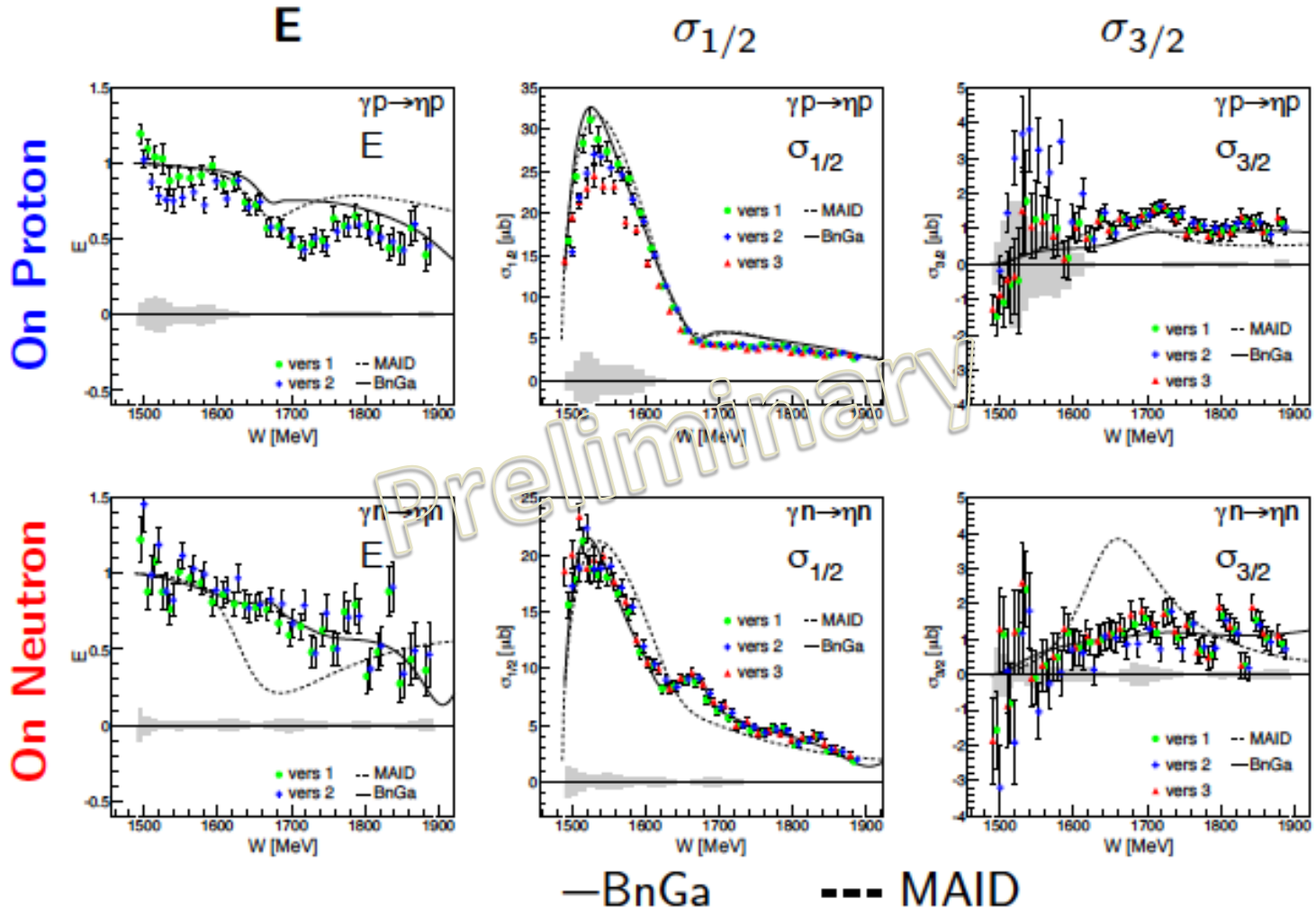


- Double peak structure seen in both proton and neutron data
- Difference between proton and neutron around 1600 MeV

M. Dieterle *et al.*, submitted to EPJ

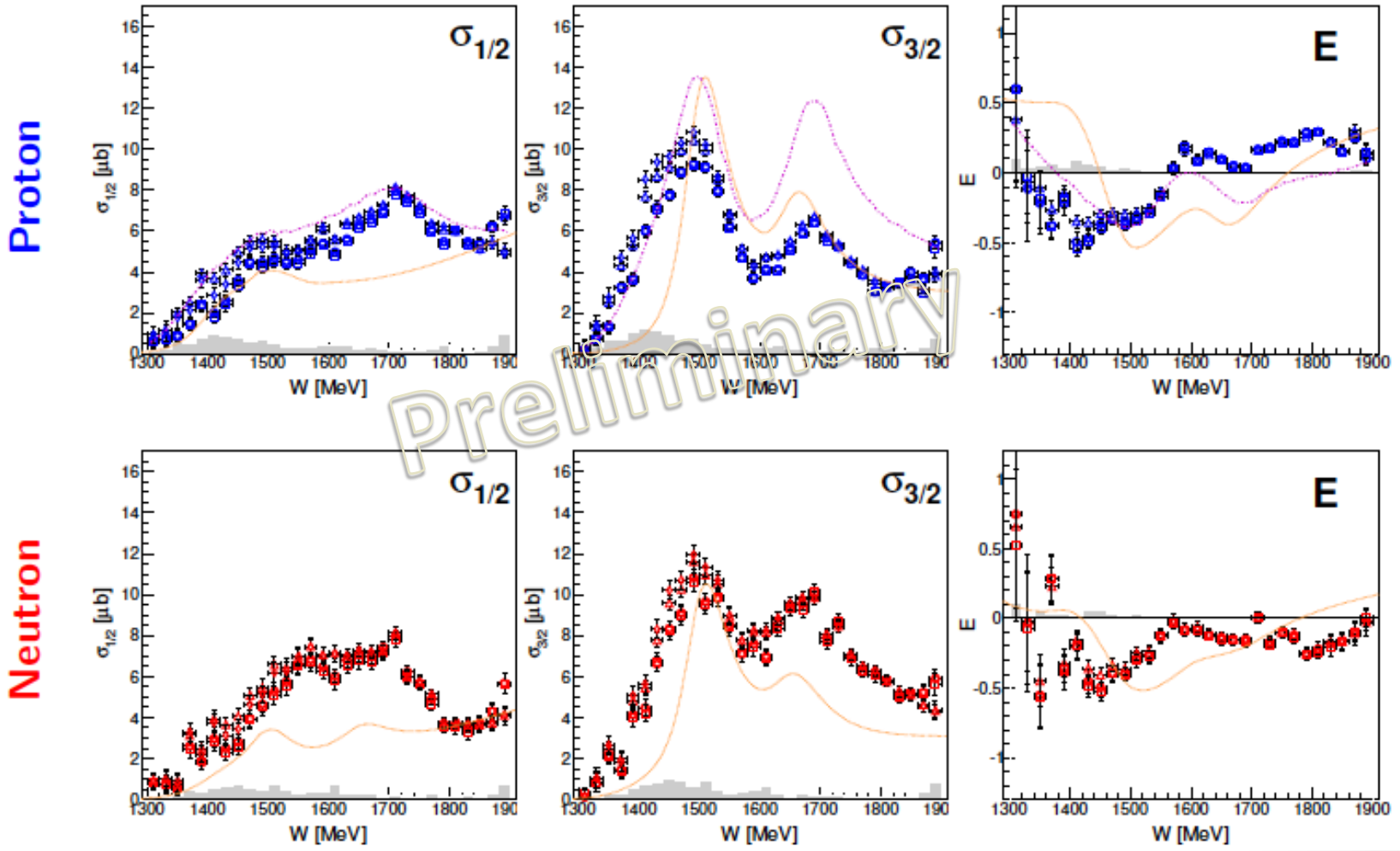
But
Cross Section data is not enough
.....
!!!

E for γN -> ηN



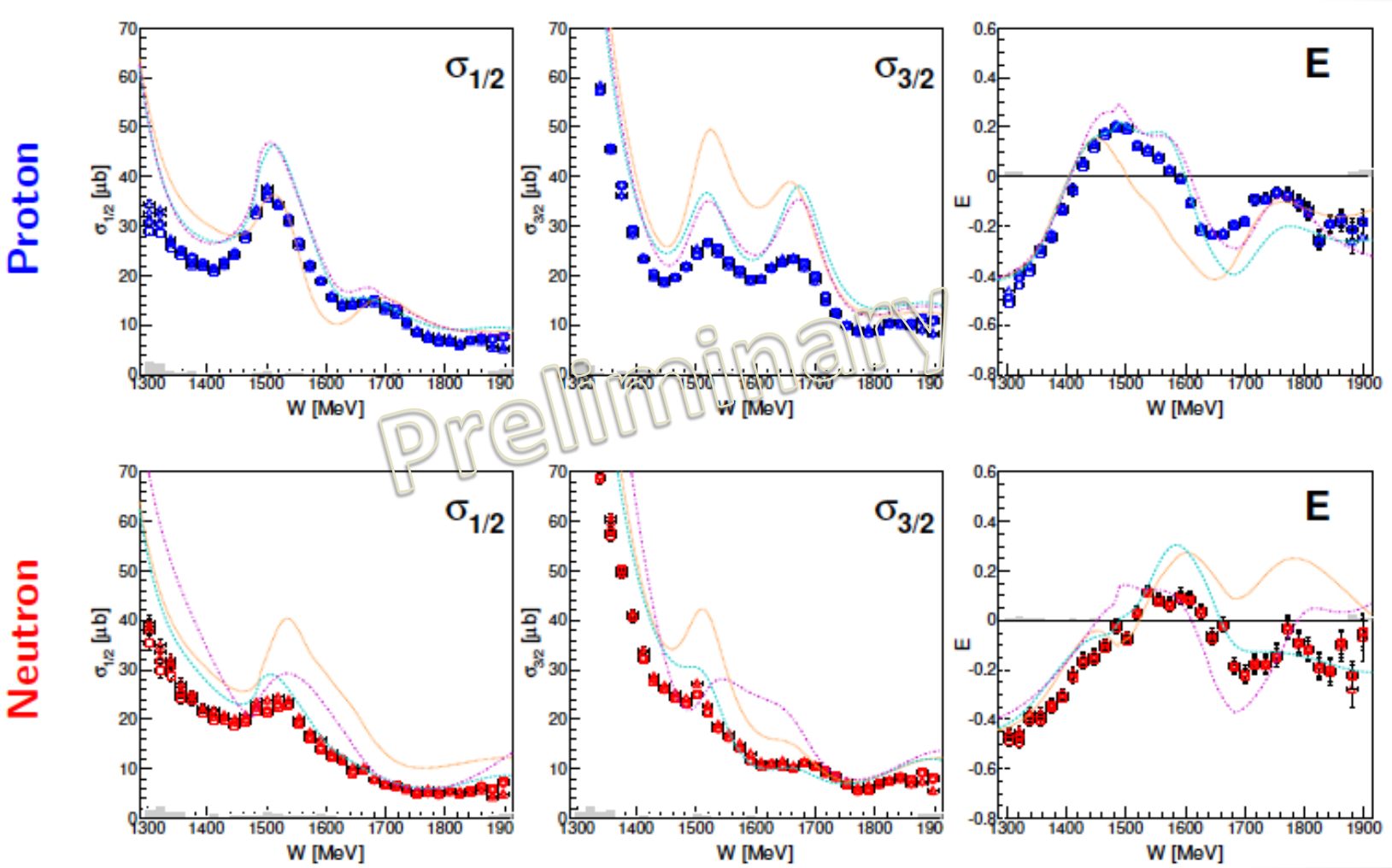
Work done by L. Witthauer (D-Butanol data)

E for $\gamma N \rightarrow \pi^0\pi^0 N$



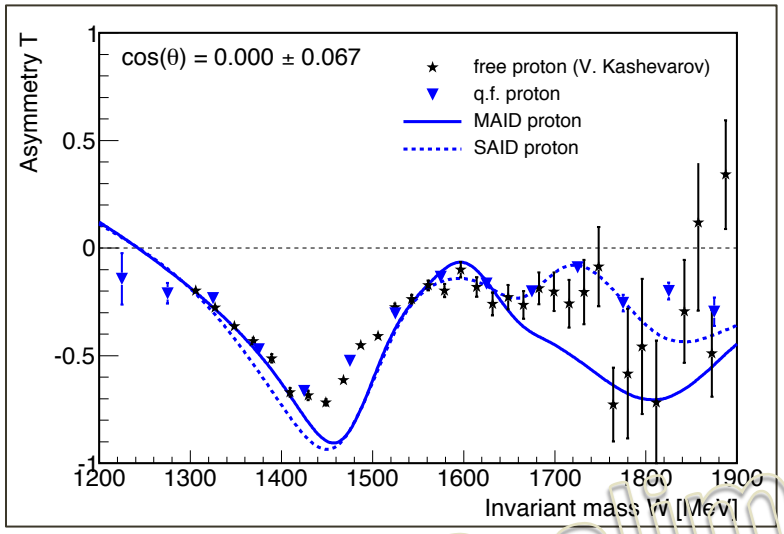
Work done by M. Dieterle (D-Butanol data)

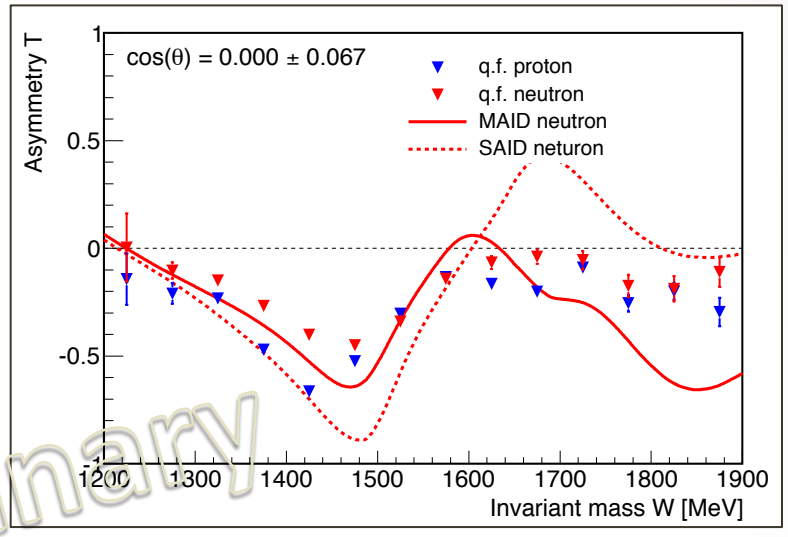
E for $\gamma N \rightarrow \pi^0 N$

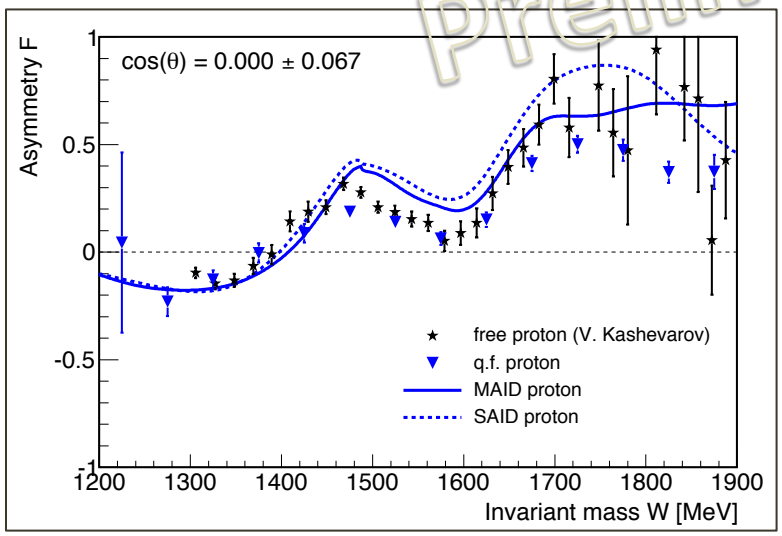


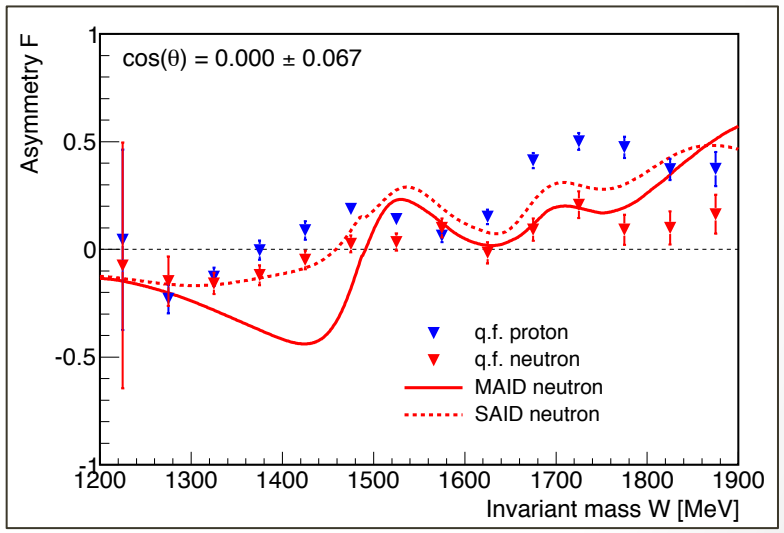
Work done by M. Dieterle (D-Butanol data)

T, F for $\gamma N \rightarrow \pi^0 N$



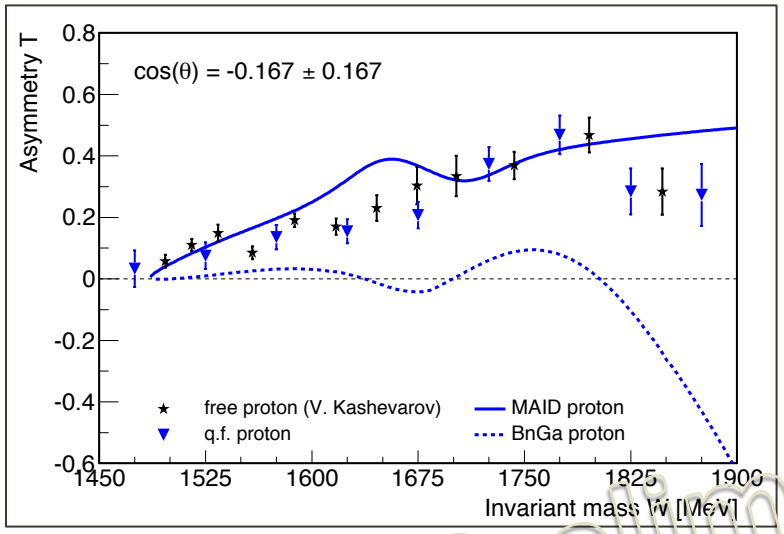


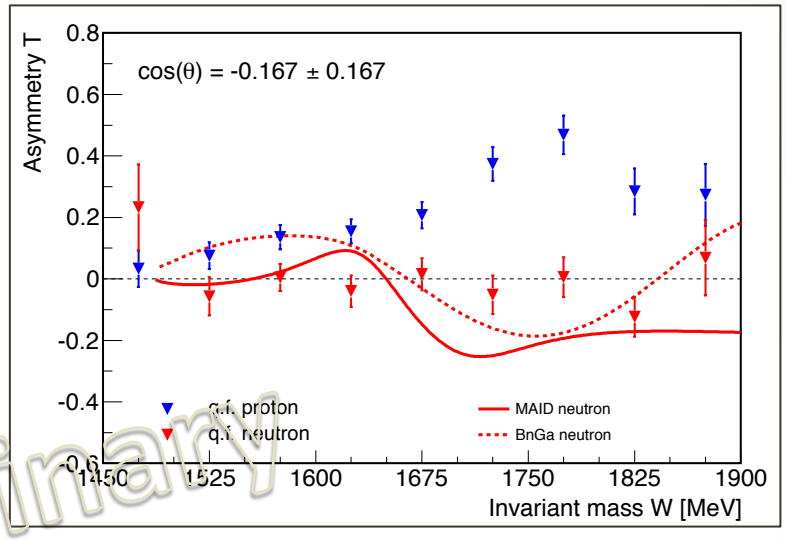


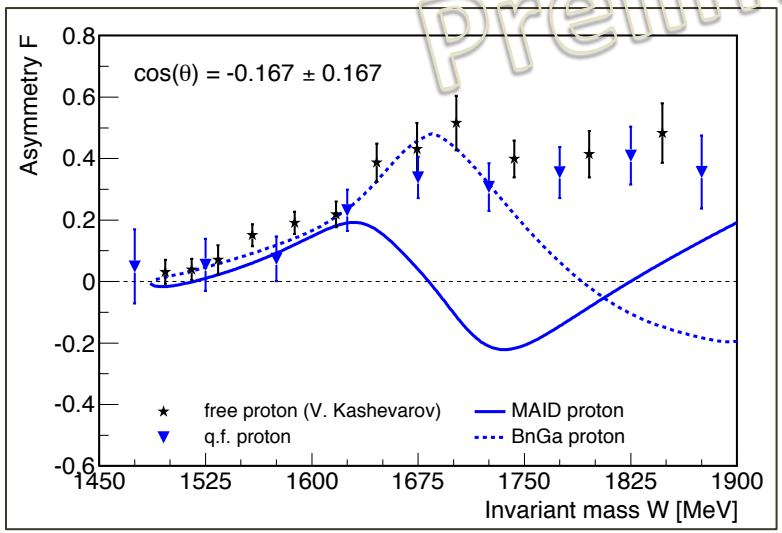


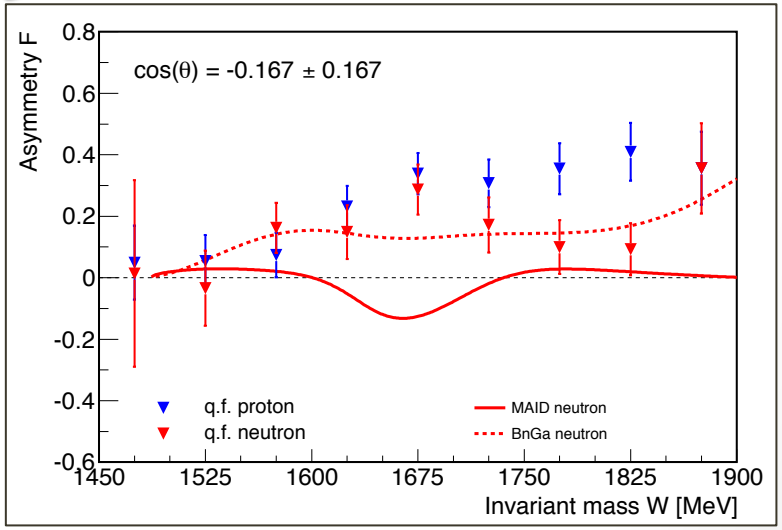
Work done by T. Strub (D-Butanol data)

T, F for γN -> ηN





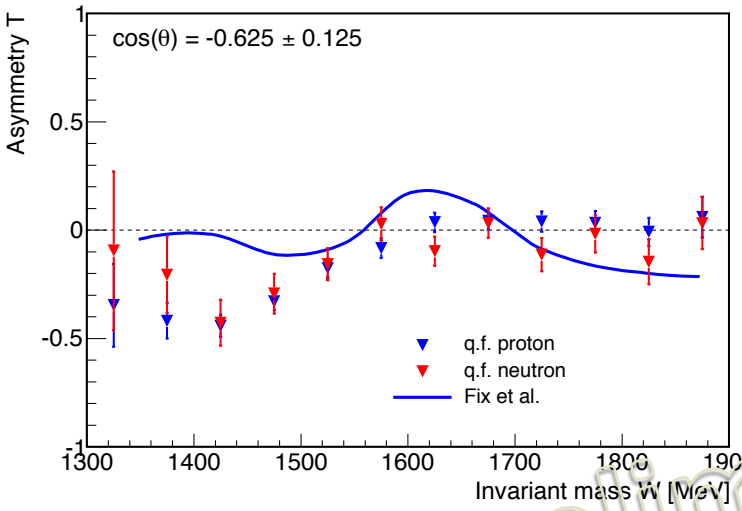


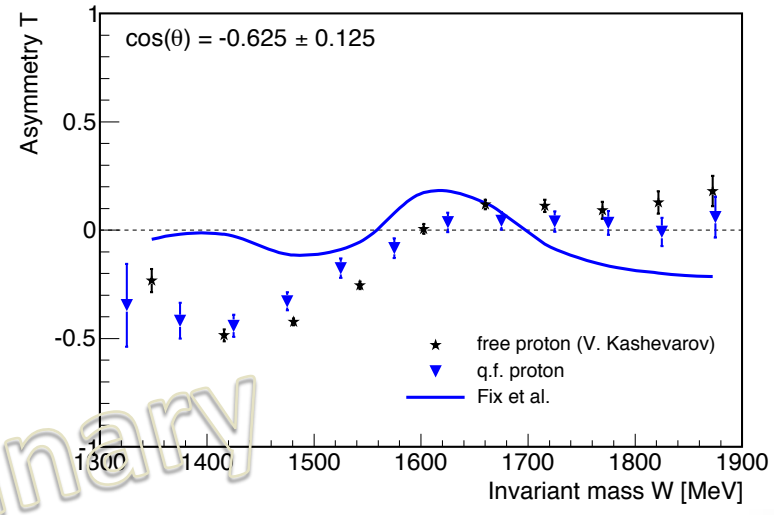


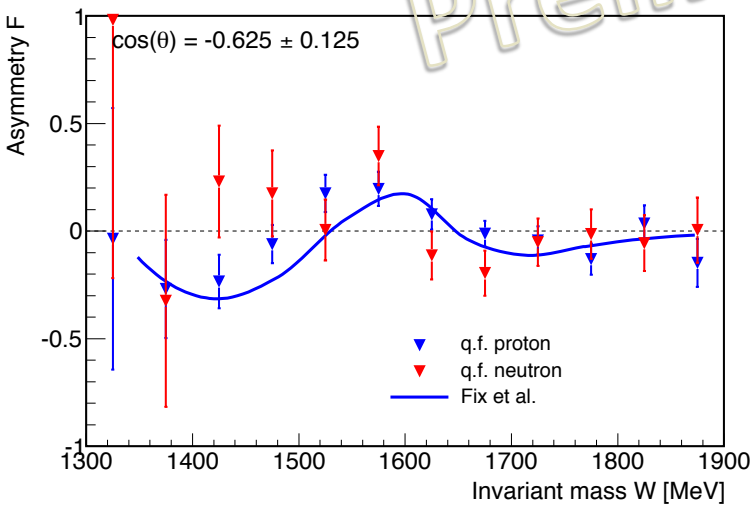
Preliminary

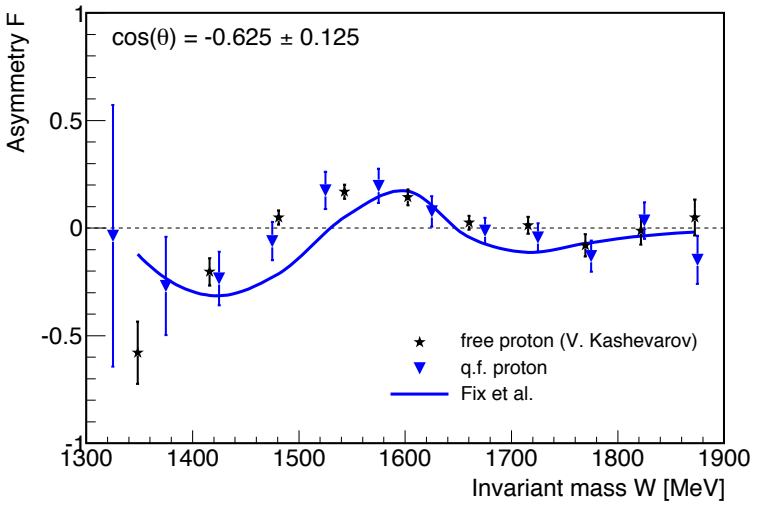
Work done by T. Strub (D-Butanol data)

T, F for $\gamma N \rightarrow \pi^0\pi^0 N$



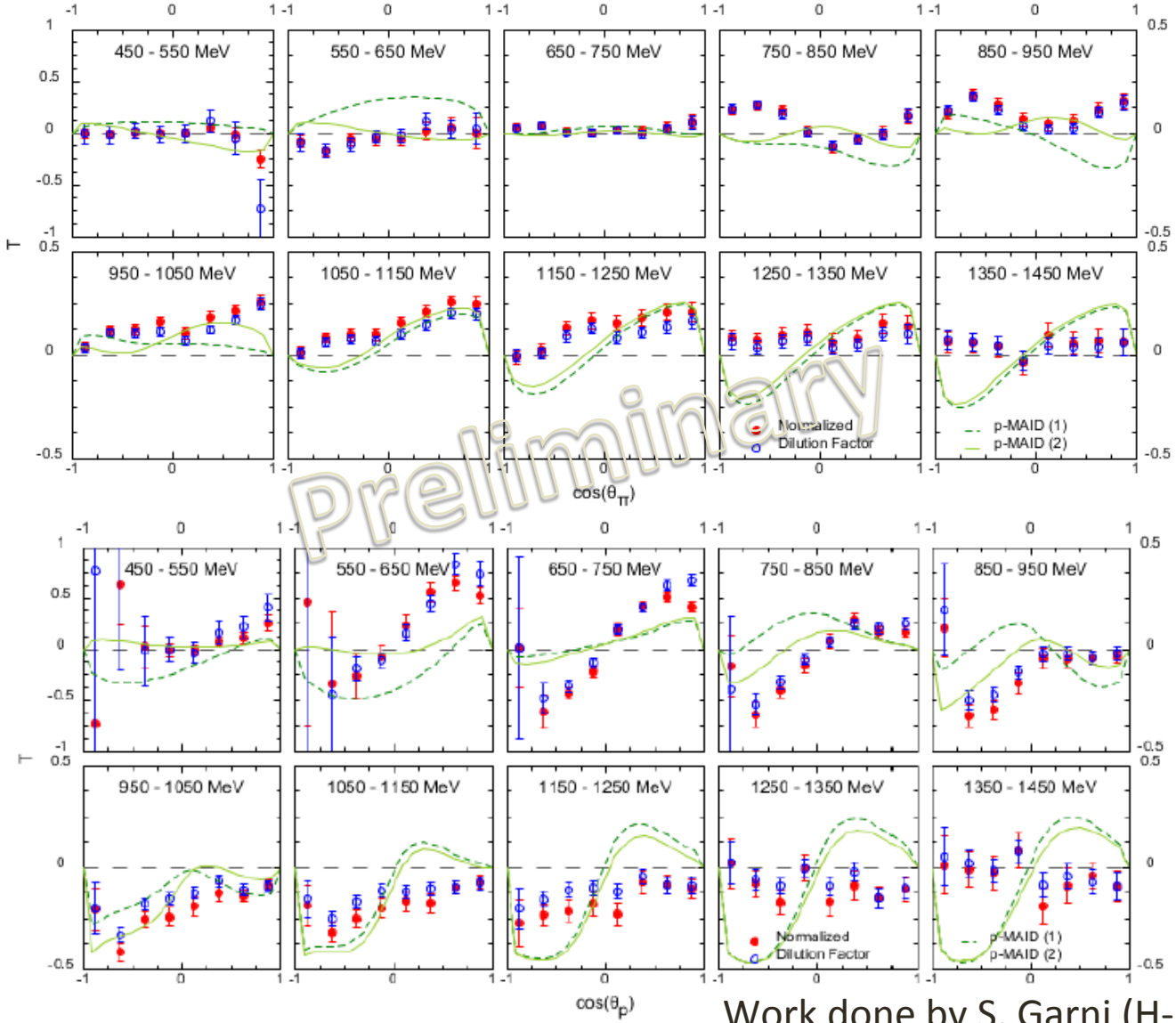






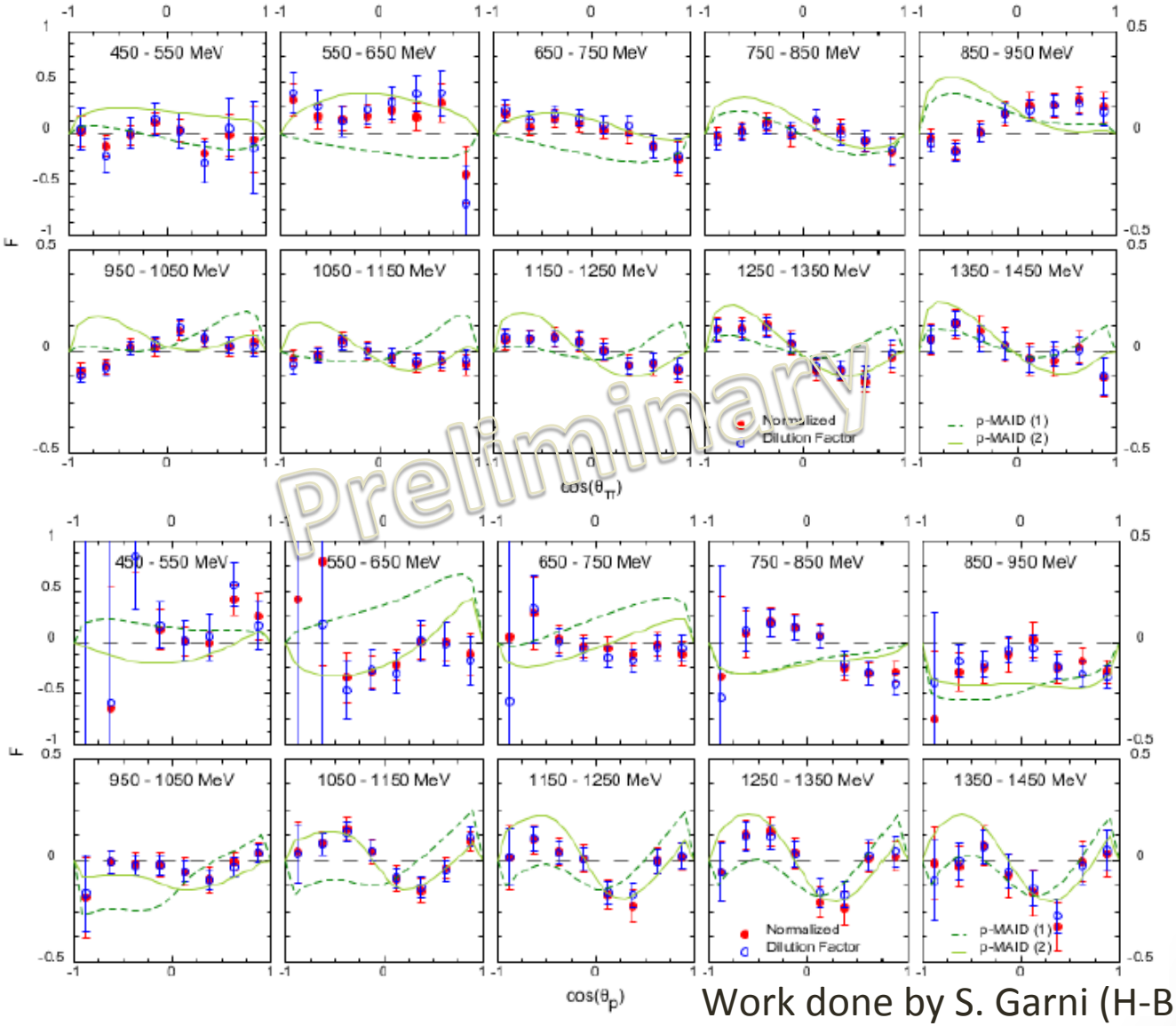
Work done by T. Strub (D-Butanol data)

T for γp -> $\pi^0\pi^0$p



Work done by S. Garni (H-Butanol data)

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



Work done by S. Garni (H-Butanol data)

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Conclusion

- Database for neutrons is extremely sparse, more data required, but is coming
- Neutron measurements more difficult due to FSI and Fermi motion
- Neutron measurements require more time
- Many upcoming results being prepared for publication

This work is supported by:

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SCHWEIZERISCHER NATIONALFONDS
FONDO NAZIONALE SVIZZERO
SWISS NATIONAL SCIENCE FOUNDATION

Deutsche Forschungsgemeinschaft
DFG