

ω -meson Σ beam asymmetry in photoproduction on the bound proton

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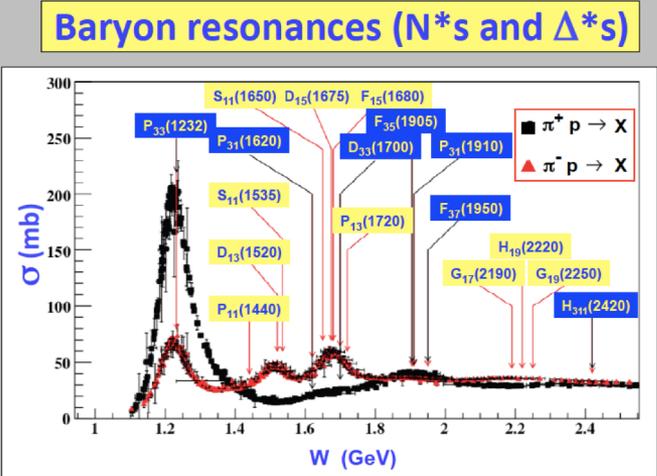
This presentation is part of the research done under
the supervision of Prof. Philip Cole

Overview

- ✓ Introduce the motivation for studying polarized observables in the context of baryon spectroscopy.
 - ✓ Why studying photoproduction of ω meson.
- ✓ Why studying photoproduction off the bound proton.
- ✓ Experimental Layout
- ✓ Methodology
- ✓ Results on the quasi-free region
 - ✓ Discussion

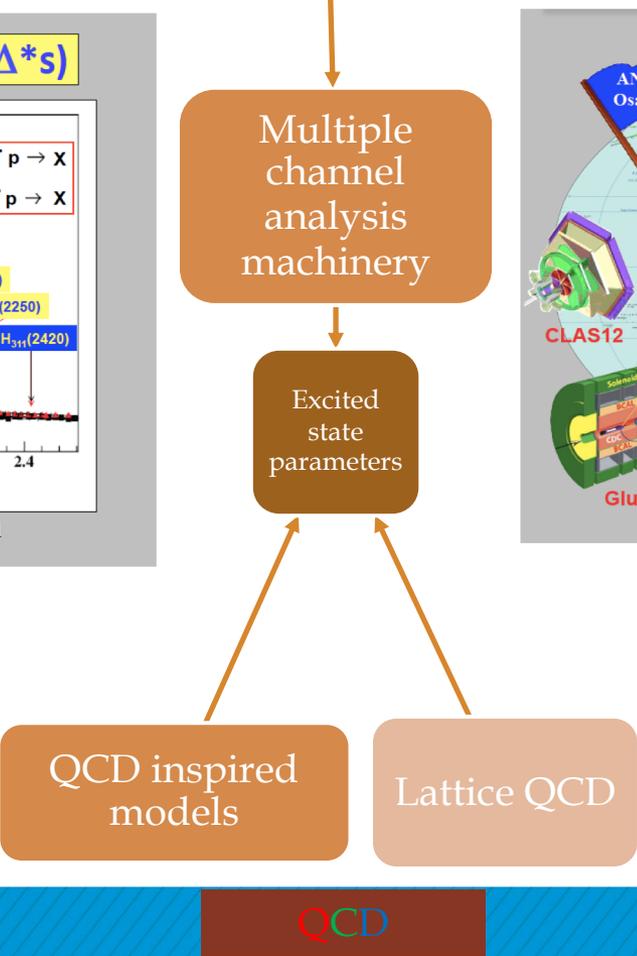
Motivation

Observable extraction for multiple channels:
Cross section and polarization observables

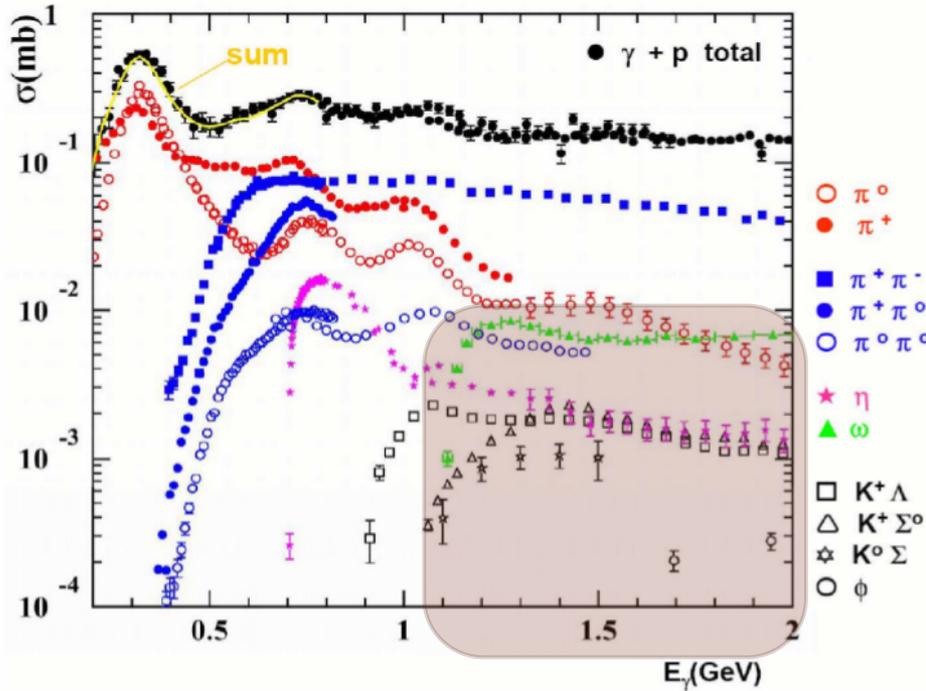


Taken from M. Pennington presentation for 2015 Summer school on Reaction Theory

- No bump hunt
- Information of the underlying degrees of freedom in the non-perturbative regime



Why ω meson?



- $E_\gamma > 1.7$ GeV
- Isospin filter only N^*
- Narrow peak, easy to identify

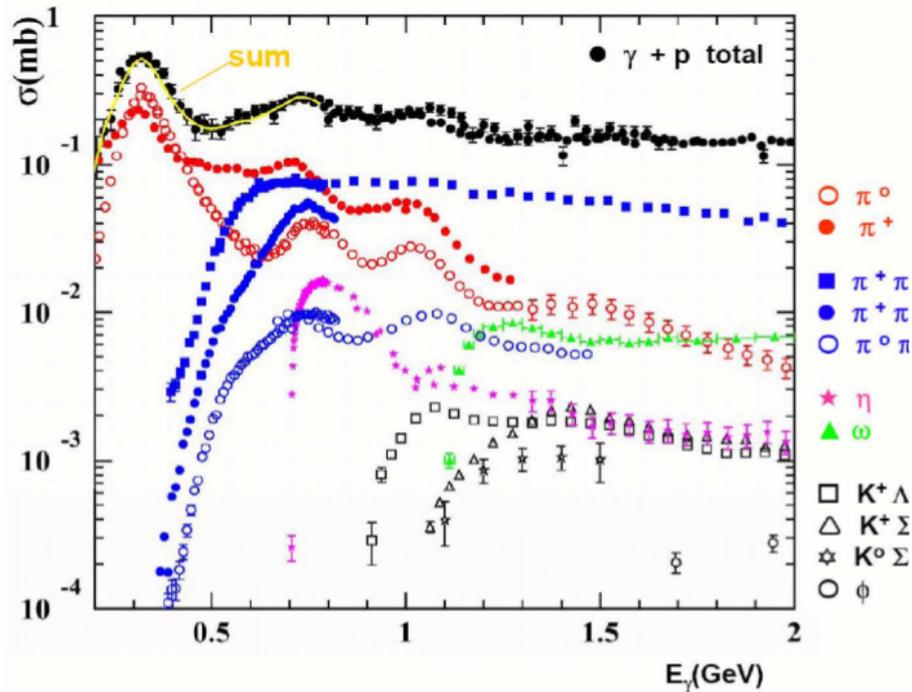
Status as seen in

Particle	J^P	overall	N_γ	N_π	N_η	N_σ	N_ω	ΔK	ΣK	N_ρ	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	****	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	****	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***
$N(1700)$	$3/2^-$	***	**	***	*			*	*	*	***
$N(1710)$	$1/2^+$	****	****	****	***	**		****	**	*	**
$N(1720)$	$3/2^+$	****	****	****	***			**	**	**	*
$N(1860)$	$5/2^+$	**		**						*	*
$N(1875)$	$3/2^-$	***	***	*		**	**	***	**		***
$N(1880)$	$1/2^+$	**	*	*		**		*			
$N(1895)$	$1/2^-$	**	**	*	**			**	*		
$N(1900)$	$3/2^+$	***	***	**	**	**	**	***	**	*	**
$N(1990)$	$7/2^+$	**	**	**				**	*	**	
$N(2000)$	$5/2^+$	**	**	*	**			**	*	**	
$N(2040)$	$3/2^+$	*		*							
$N(2060)$	$5/2^-$	**	**	**	*				**		
$N(2100)$	$1/2^+$	*		*							
$N(2120)$	$3/2^-$	**	**	**				*	*		
$N(2190)$	$7/2^-$	****	***	****		*	*	**		*	
$N(2220)$	$9/2^+$	****	****	****							
$N(2250)$	$9/2^-$	****	****	****							
$N(2300)$	$1/2^+$	**	**	**							
$N(2570)$	$5/2^-$	**	**	**							
$N(2600)$	$11/2^-$	***	***	***							
$N(2700)$	$13/2^+$	**	**	**							

**** Existence is certain, and properties are at least fairly well explored.
 *** Existence is very likely but further confirmation of decay modes is required.
 ** Evidence of existence is only fair.
 * Evidence of existence is poor.

Particle Data group 2016

Why ω meson?



Evolving Spectrum

Particle	J^P	overall	Status as seen in												
			N_γ	N_π	$\Delta\pi$	N_σ	N_η	ΛK	ΣK	N_ρ	N_ω	$N_{\eta'}$			
N	$1/2^+$	****													
$N(1440)$	$1/2^+$	****	****	****	****	***									
$N(1520)$	$3/2^-$	****	****	****	****	**	****								
$N(1535)$	$1/2^-$	****	****	****	***	*	****								
$N(1650)$	$1/2^-$	****	****	****	***	*	****	*							
$N(1675)$	$5/2^-$	****	****	****	****	***	*	*	*						
$N(1680)$	$5/2^+$	****	****	****	****	***	*	*	*						
$N(1700)$	$3/2^-$	***	**	***	***	*	*				*				
$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*				*
$N(1720)$	$3/2^+$	****	****	****	***	*	*	****	*	*	*				*
$N(1860)$	$5/2^+$	**	*	**		*	*								
$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*			*	*
$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**	*	*			**	*
$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*			*	****
$N(1900)$	$3/2^+$	****	****	**	**	*	*	**	**	*	*			*	**
$N(1990)$	$7/2^+$	**	**	**		*	*	*	*					*	*
$N(2000)$	$5/2^+$	**	**	*	**	*	*				*			*	*
$N(2040)$	$3/2^+$	*		*											
$N(2060)$	$5/2^-$	***	***	**	*	*	*	*	*	*	*			*	*
$N(2100)$	$1/2^+$	***	**	***	**	**	*	*	*	*	*			*	**
$N(2120)$	$3/2^-$	***	***	**	**	**	**			**	*			*	*
$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*			*	*
$N(2220)$	$9/2^+$	****	**	****			*	*	*					*	*
$N(2250)$	$9/2^-$	****	**	****			*	*	*					*	*
$N(2300)$	$1/2^+$	**		**											
$N(2570)$	$5/2^-$	**		**											
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$N(2700)$	$13/2^+$	**		**											

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Particle Data group 2018

Polarization observables

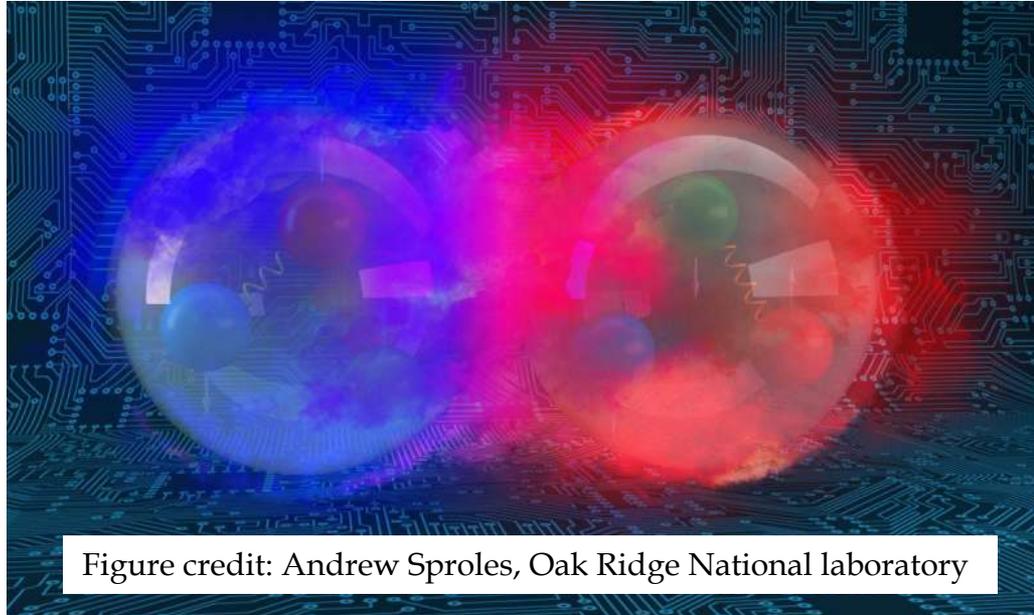


Polarization observables for vector meson photoproduction:

- Single polarized:
 - Σ spin beam asymmetry, T target polarization,
- Double polarized (H, P, F, G, E)
- SDME

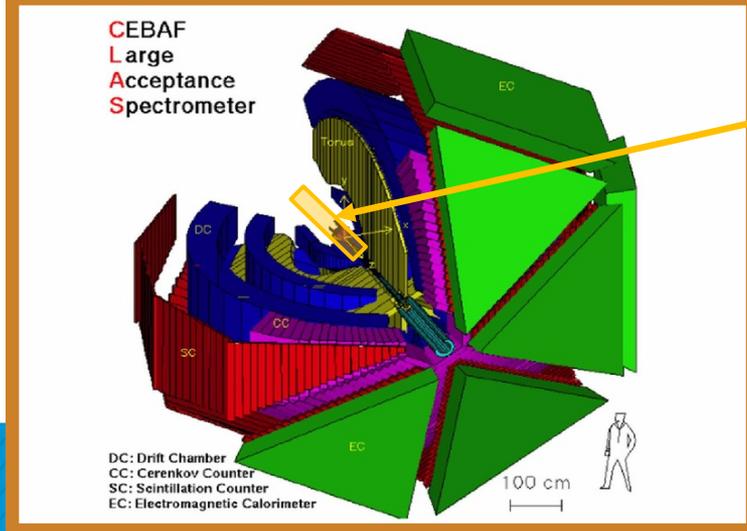
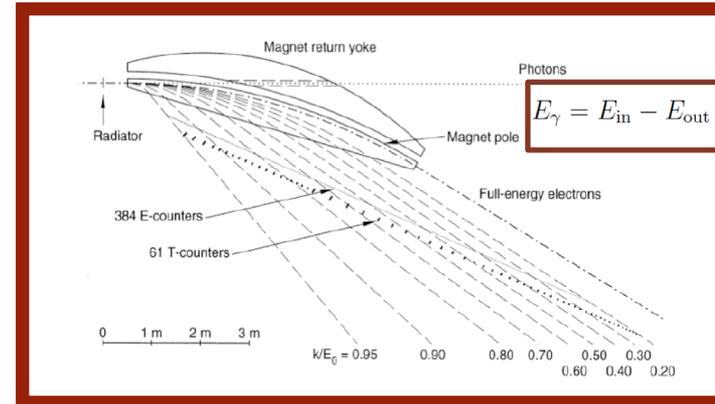
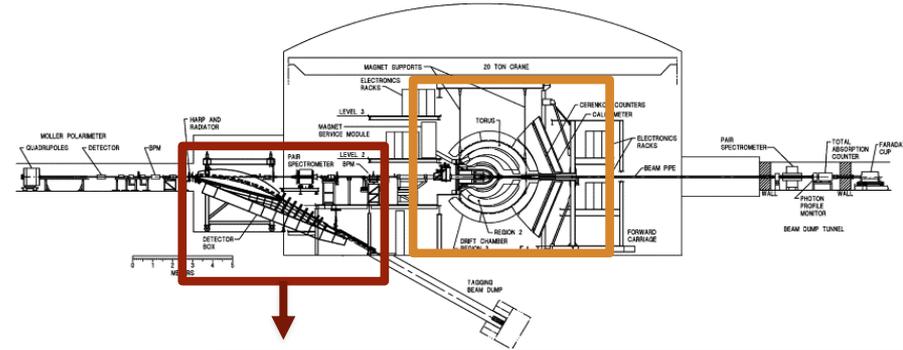
Unpolarized cross-section

Why studying photoproduction off the bound proton



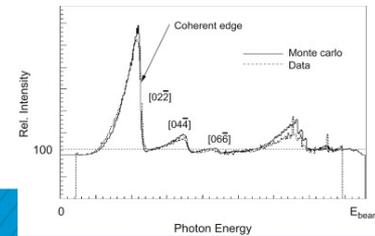
- We consider the neutron is on-shell while proton is off-shell.
- The higher the missing momentum is, more Final State Interactions (FSI) events will be present.
- What is the effect of the “off-shellness” of the nucleon in the observables?
- When the medium starts to affect the observables? (particularly important to interpret bound neutron data)

Experimental Layout

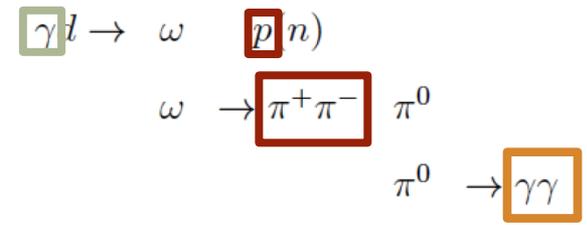


g13 b:

- Real photon. $E_\gamma = 1.1 - 2.3 \text{ GeV}$
- Linearly polarized photons: Coherent Bremsstrahlung
- 40 cm deuteron target

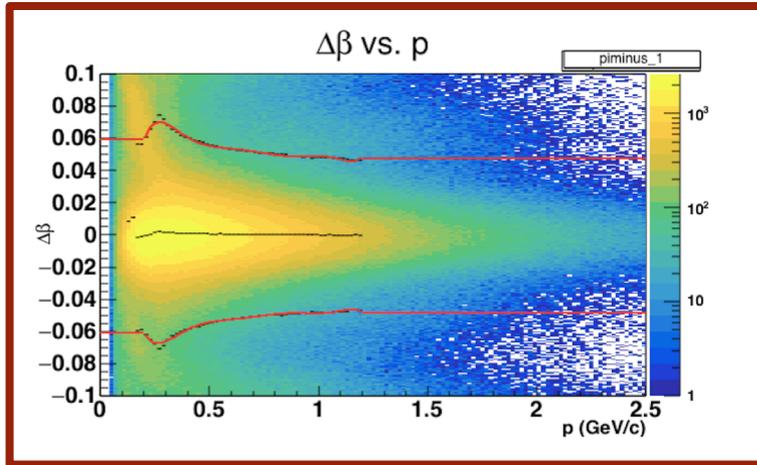


Data Analysis: Event Reconstruction

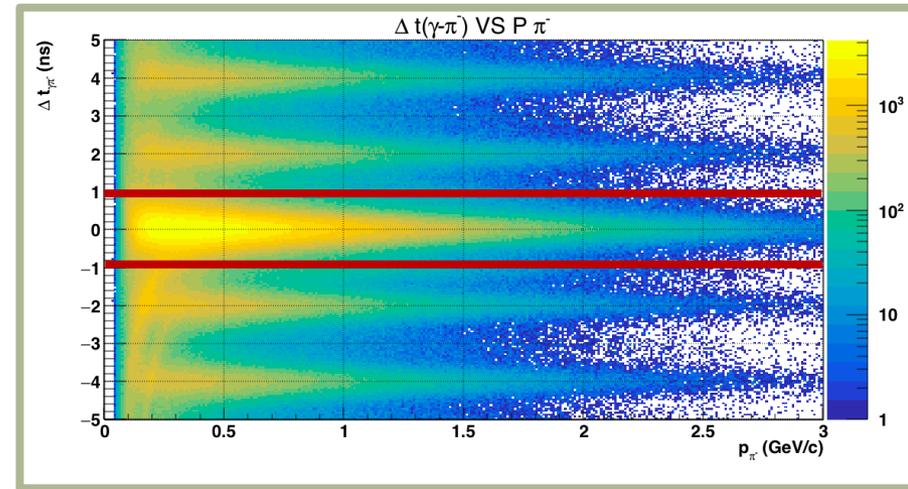


Standard cuts and corrections

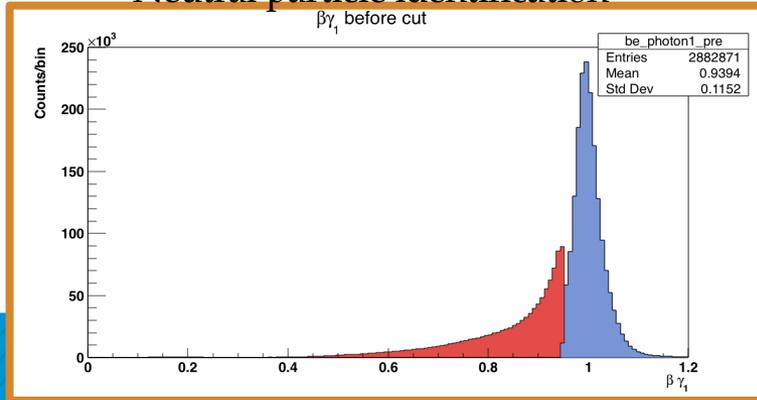
Charged particle identification



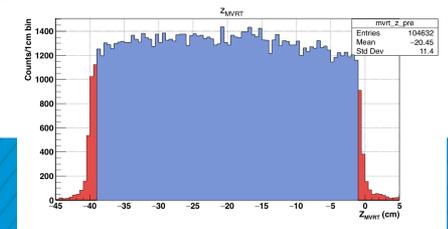
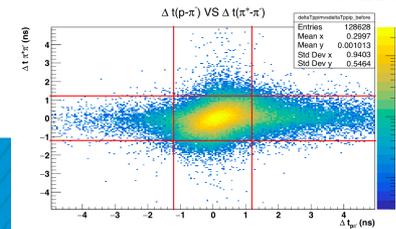
Incident photon identification



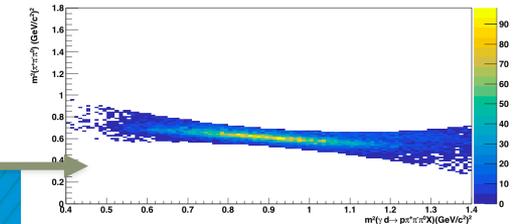
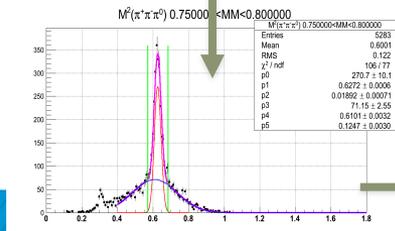
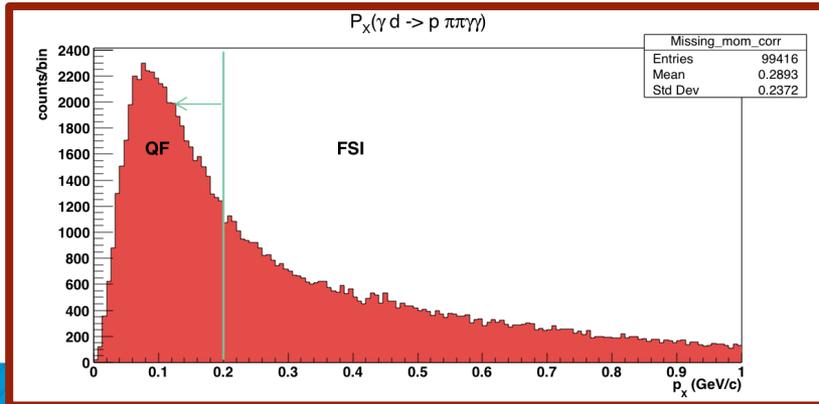
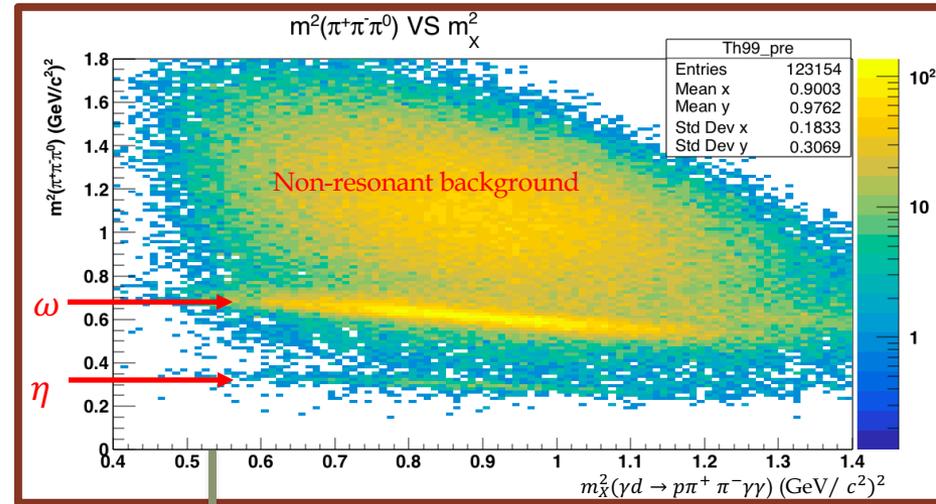
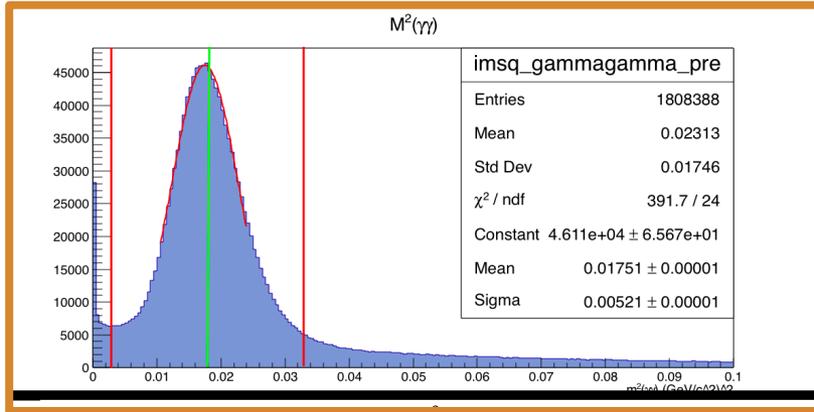
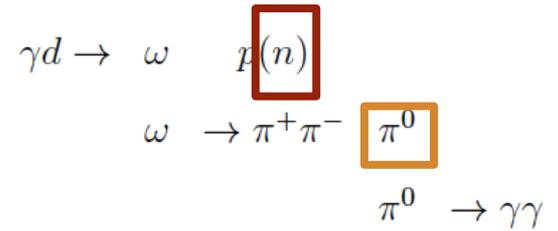
Neutral particle identification



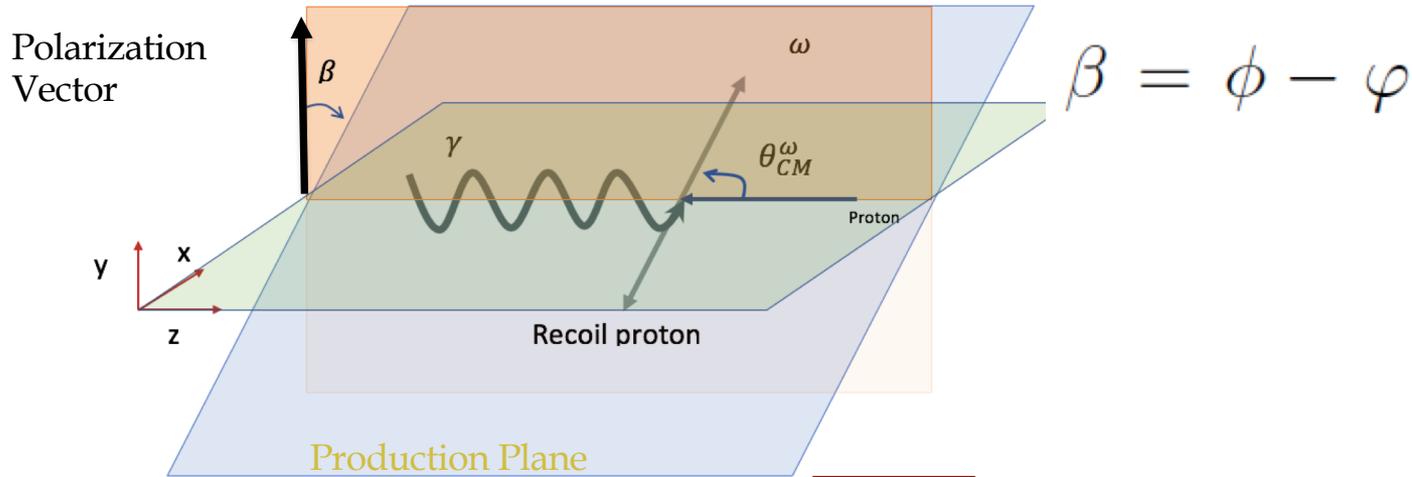
Other cuts



Data analysis: Event reconstruction



Beam Asymmetry



Perpendicular:

$$\psi = \pi/2,$$

Parallel:

$$\psi = 0$$

$$P_R = \frac{P_{\parallel}}{P_{\perp}}$$

$$\frac{(\frac{dN}{d\phi})^{\perp} - (\frac{dN}{d\phi})^{\parallel}}{(\frac{dN}{d\phi})^{\parallel} + (\frac{dN}{d\phi})^{\perp}} = \frac{1 - F_R + \frac{F_R P_R + 1}{P_R + 1} 2\bar{P} \Sigma \frac{\sin \Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))}{1 + F_R + \frac{F_R P_R - 1}{P_R + 1} 2\bar{P} \Sigma \frac{\sin \Delta\phi}{\Delta\phi} \cos(2(\phi - \phi_0))} \quad (1)$$

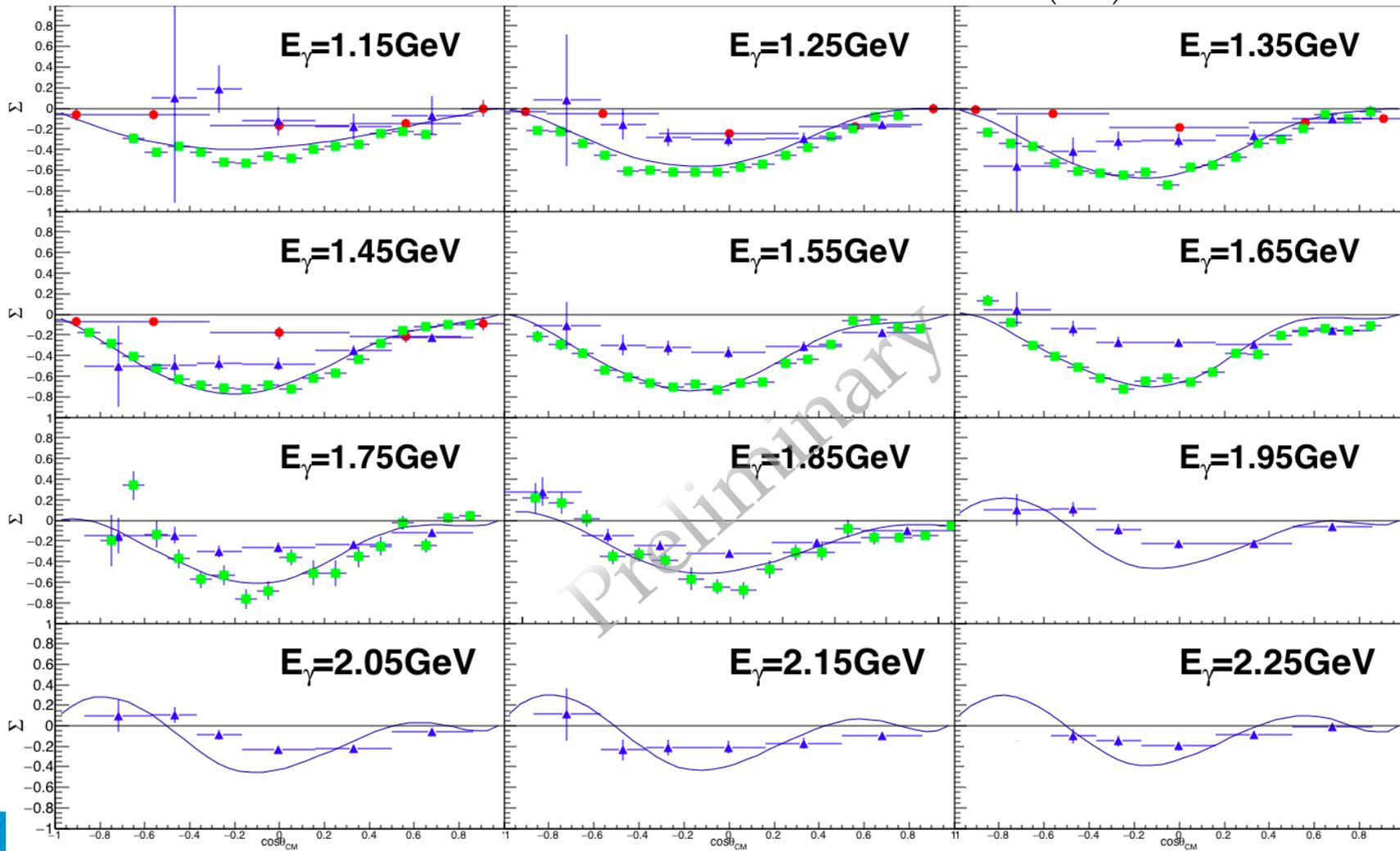
Background corrected

$$\text{flux ratio } F_R = \frac{F_{\perp}}{F_{\parallel}}$$

$$\bar{P} = \frac{P_{\parallel} + P_{\perp}}{2}$$

Preliminary Results

This work
Quasi free GRAAL (Vegna et al. 2015)
Free proton CLAS (Collins et a..2017)
Bonn-Gatchina (2016)



Systematic Uncertainty Estimate

Source of uncertainty	$ \mu_{\Delta\Sigma} $
ϕ_0 offset	10^{-6}
Photon flux ratio	~ 0.001
Polarization ratio	$< 1\%$
Mean polarization	5%
Neutral particle cut	0.017
Incident photon identification	0.001
Out of time cut	0.000
z -vertex cut	0.009
Missing momentum cut	0.021
Dilution factor and $3 - \sigma$ cut	0.010

Largest source of uncertainty

Compared 0.2 GeV/c with
0.15 GeV/c cut

Discussion

- The ω channel is relevant in the study of missing resonances predicted constituent quark models
- We extracted the Beam Spin asymmetry for the photoproduced ω mesons off the bounded proton in the deuteron for $E_\gamma = 1.1 - 2.3$ GeV.
- Comparison with previous quasi-free data from GRAAL collaboration (V. Vegna et al.) agrees at low energy bins. The amplitude of the asymmetry reported in this work is larger than GRAAL reported results at $E_\gamma = 1.45$ GeV.
- Our results, compared to the free events reported from CLAS collaboration (P. Collins et al. and P. Roy) are in general smaller in amplitude for middle angle range.
- We estimated the systematic uncertainty of the beam asymmetry due to the missing momentum cut as 0.021.
- Possible small FSI background over the quasi-free events.
- There are very interesting proposals to study photoproduction of meson in medium for CLAS12 and GlueX. Very interesting physics coming up!

Thank you!!!

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