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

Olga M. Cortés Becerra

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

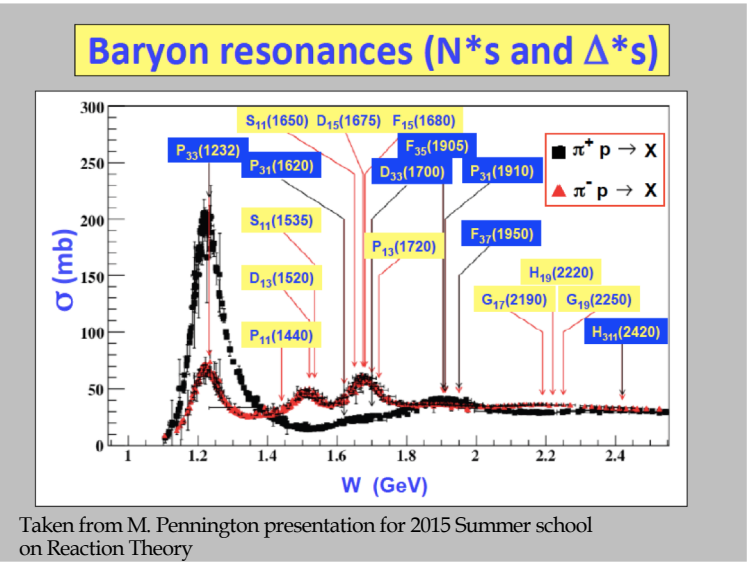
Overview

- ✓ 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

Multiple channel analysis machinery

Excited state parameters

QCD inspired models

Lattice QCD

QCD

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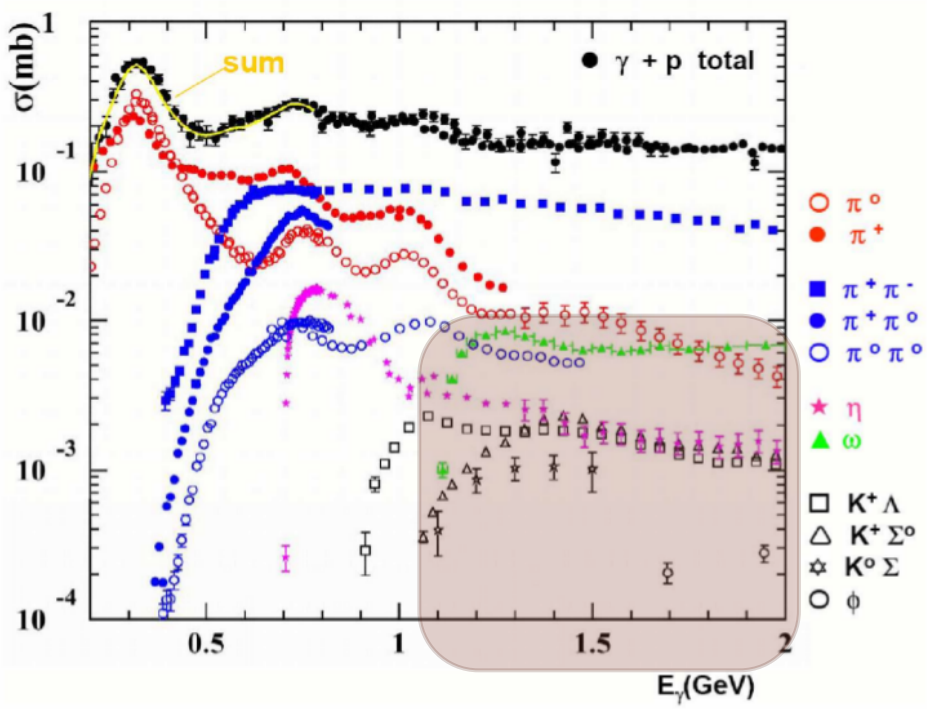
Why ω meson?



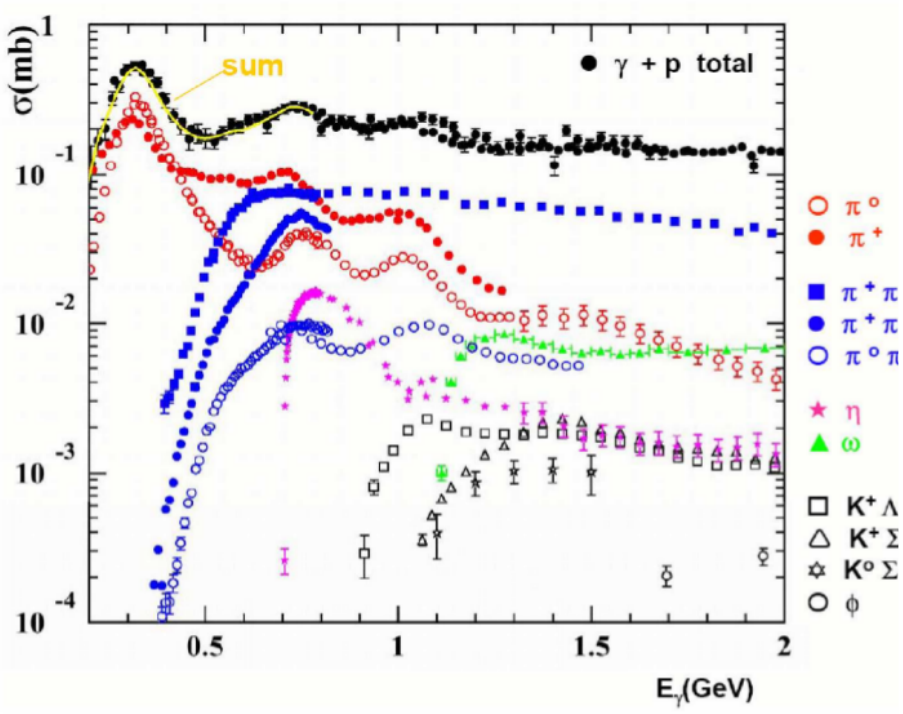
- $E_\gamma > 1.7$ GeV
- Isospin filter only N*
- Narrow peak, easy to identify

			Status as seen in								
Particle	J^P	overall	$N\gamma$	$N\pi$	$N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$	****	****	****	***			***	**	**	***
$N(1675)$	$5/2^-$	****	****	****	*			*		*	***
$N(1680)$	$5/2^+$	****	****	****	*	**				***	***
$N(1700)$	$3/2^-$	***	**	***	*			*	*	*	***
$N(1710)$	$1/2^+$	****	****	****	***		**	****	**	*	**
$N(1720)$	$3/2^+$	****	****	****	***			**	**	**	*
$N(1860)$	$5/2^+$	**		**						*	*
$N(1875)$	$3/2^-$	***	***	*			**	***	**		***
$N(1880)$	$1/2^+$	**	*	*		**		*			
$N(1895)$	$1/2^-$	**	**	*	**			**	*		
$N(1900)$	$3/2^+$	***	***	**	**		**	***	**	*	**
$N(1990)$	$7/2^+$	**	**	**					*		
$N(2000)$	$5/2^+$	**	**	*	**			**	*	**	
$N(2040)$	$3/2^+$	*		*							
$N(2060)$	$5/2^-$	**	**	**	*				**		
$N(2100)$	$1/2^+$	*		*							
$N(2120)$	$3/2^-$	**	**	**				*	*		
$N(2190)$	$7/2^-$	****	***	****			*	**		*	
$N(2220)$	$9/2^+$	****		****							
$N(2250)$	$9/2^-$	****		****							
$N(2300)$	$1/2^+$	**		**							
$N(2570)$	$5/2^-$	**		**							
$N(2600)$	$11/2^-$	***		***							
$N(2700)$	$13/2^+$	**		**							

**** 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

			Status as seen in									
Particle	J^P	overall	$N\gamma$	$N\pi$	$\Delta\pi$	$N\sigma$	$N\eta$	ΛK	ΣK	$N\rho$	$N\omega$	$N\eta'$
N	$1/2^+$	****										
$N(1440)$	$1/2^+$	****	****	****	****	***						
$N(1520)$	$3/2^-$	****	****	****	****	**	****					
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$N(1710)$	$1/2^+$	****	****	****	*		***	**	*	*	*	
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$N(1860)$	$5/2^+$	**	*	**		*	*					
$N(1875)$	$3/2^-$	***	**	**	*	**	*	*	*	*	*	
$N(1880)$	$1/2^+$	***	**	*	**	*	*	**	**		**	
$N(1895)$	$1/2^-$	****	****	*	*	*	****	**	**	*	*	****
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$N(2100)$	$1/2^+$	***	**	***	**	**	*	*		*	*	**
$N(2120)$	$3/2^-$	***	***	**	**	**		**	*		*	*
$N(2190)$	$7/2^-$	****	****	****	****	**	*	**	*	*	*	
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**** Existence is certain.
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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

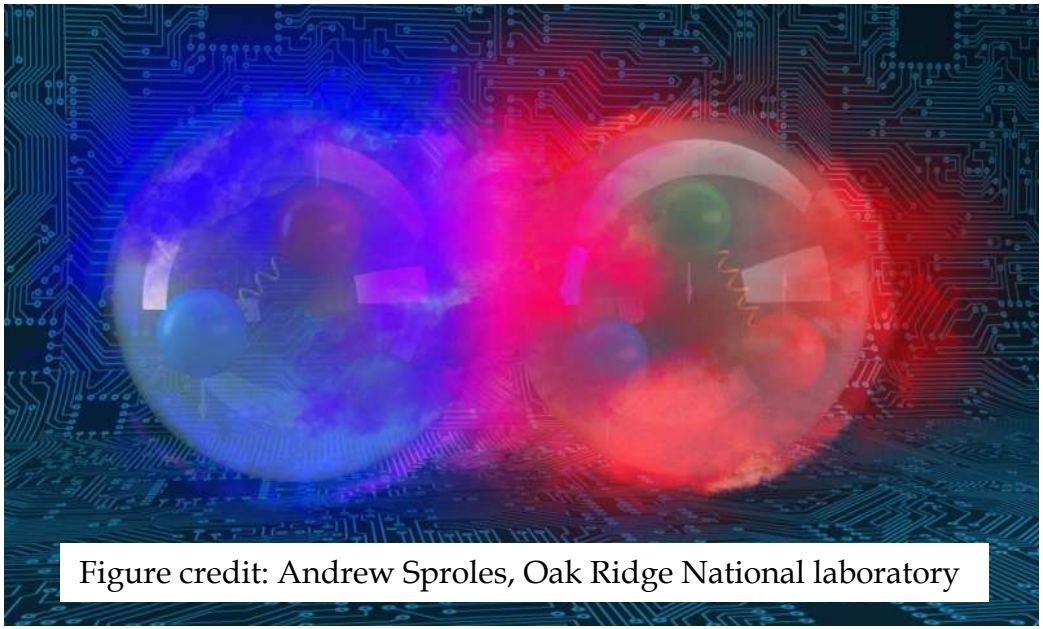
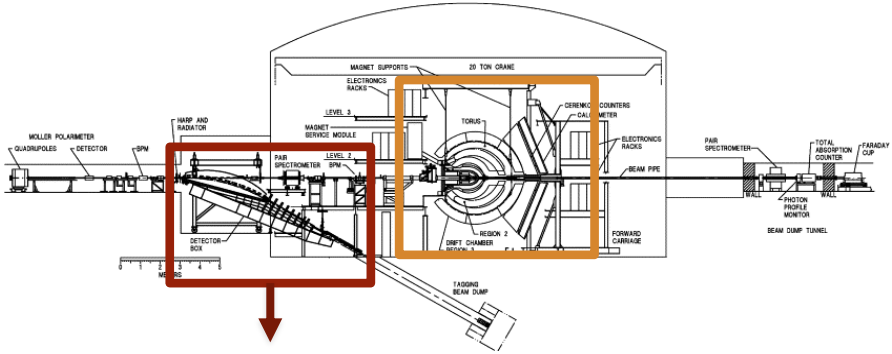
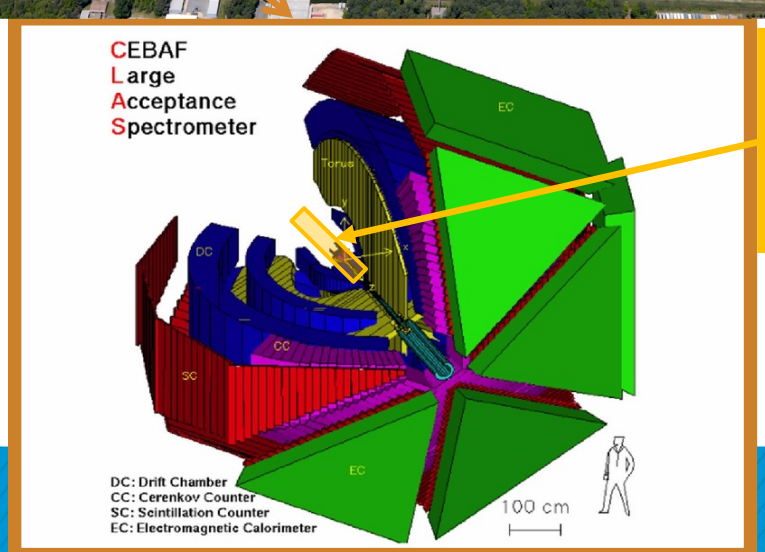


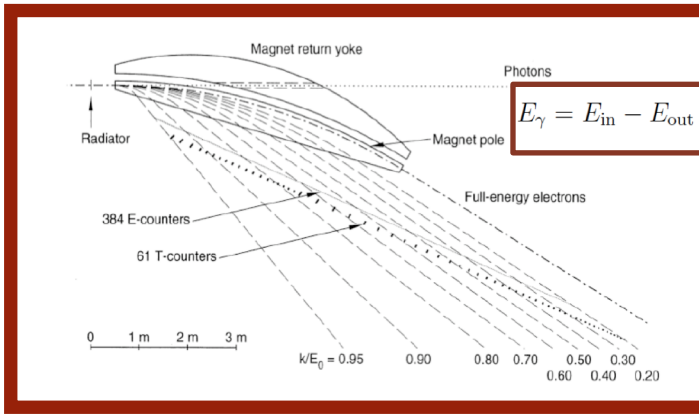
Figure credit: Andrew Sproles, Oak Ridge National laboratory

- 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

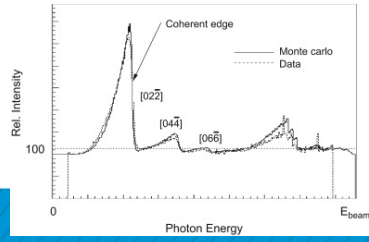






g13 b:

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

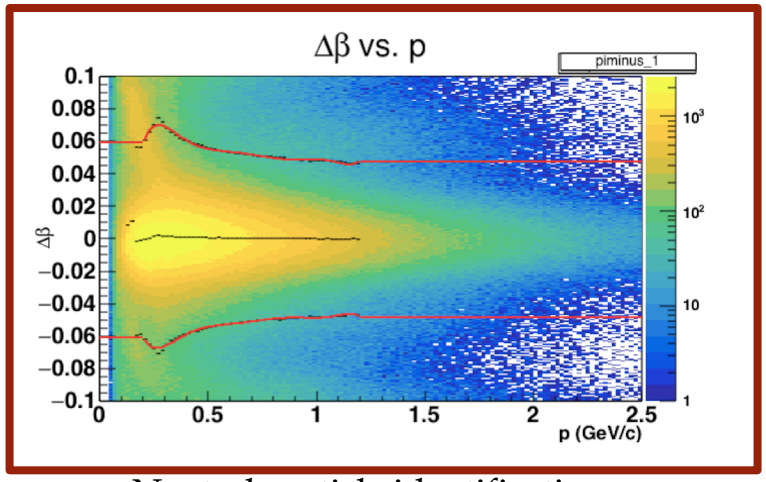


Data Analysis: Event Reconstruction

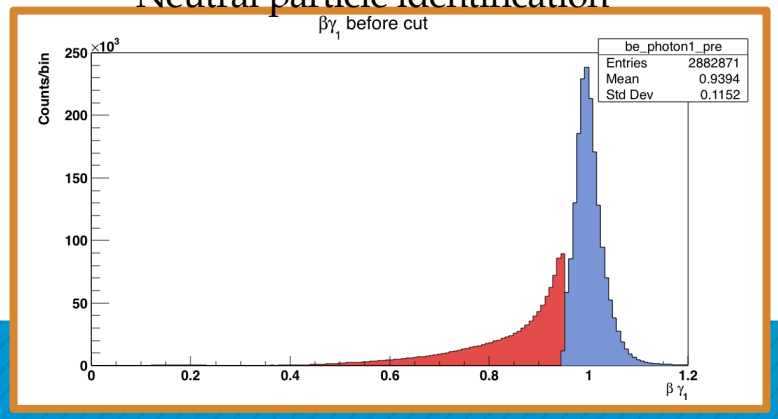
$$\gamma d \rightarrow \omega\, p(n)$$
$$\omega \rightarrow \pi^+\pi^-\,\pi^0$$
$$\pi^0 \rightarrow \gamma\gamma$$

Standard cuts and corrections

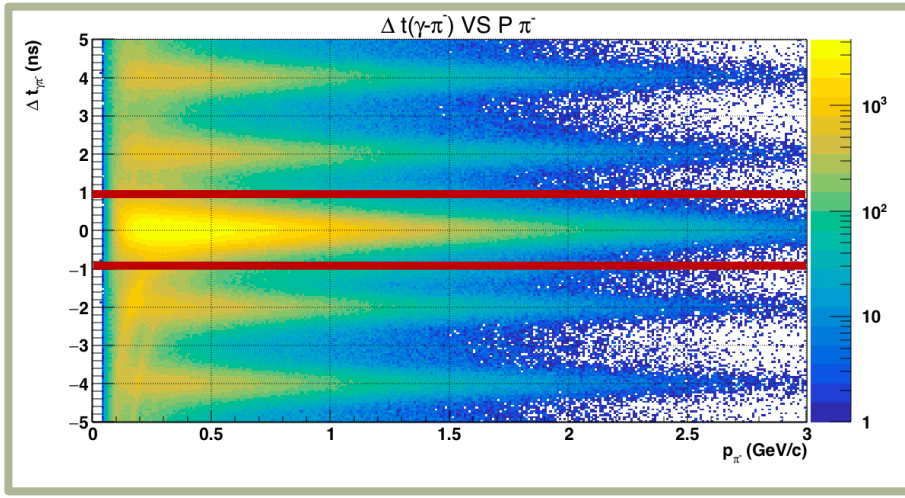
Charged particle identification



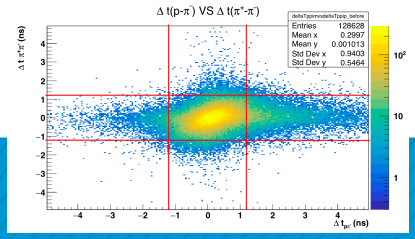
Neutral particle identification

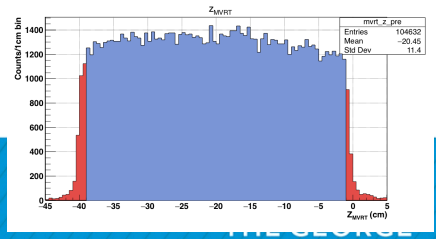


Incident photon identification



Other cuts





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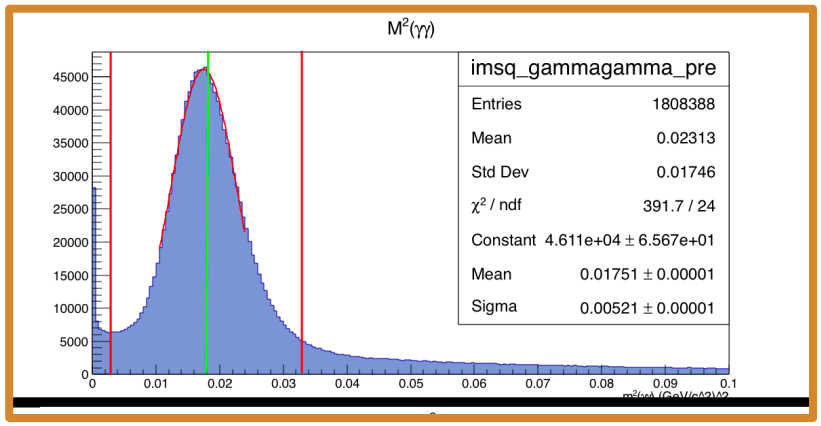
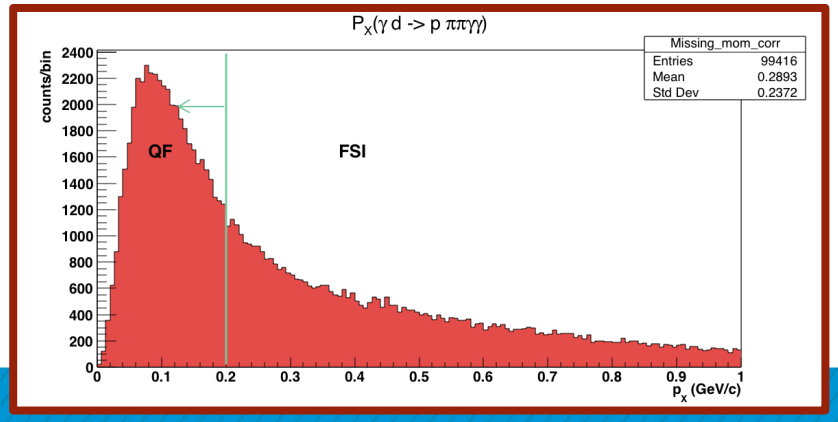
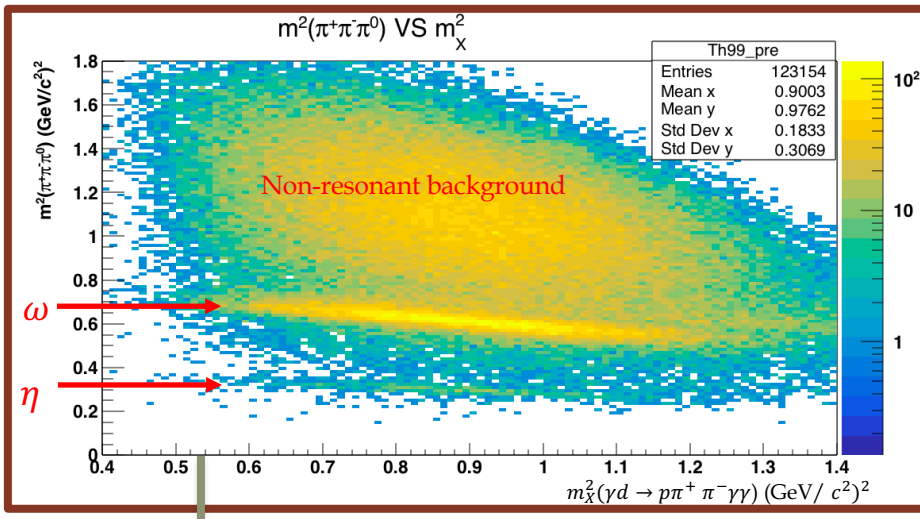
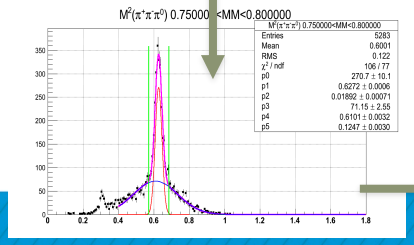
Data analysis: Event reconstruction

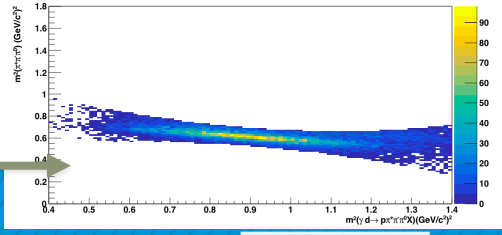
$$\gamma d \rightarrow \omega \; p(n)$$
$$\omega \rightarrow \pi^+\pi^- \pi^0$$
$$\pi^0 \rightarrow \gamma\gamma$$











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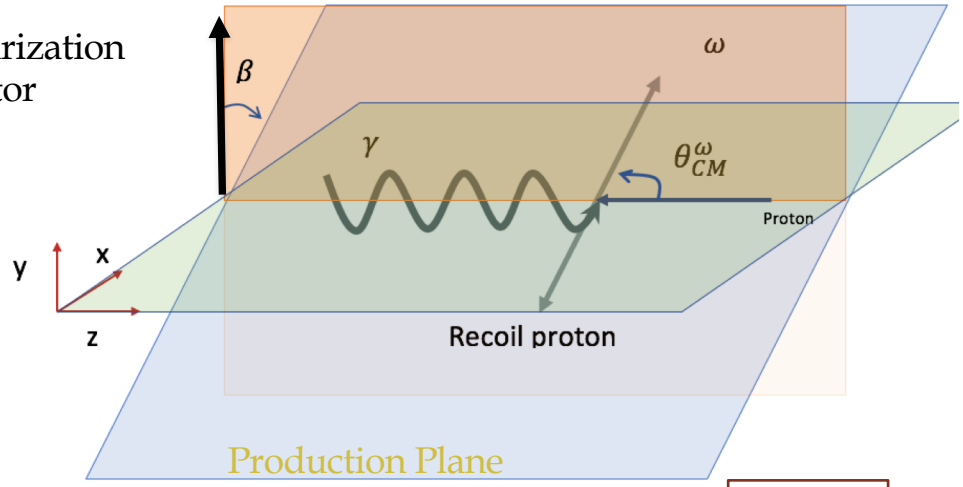
Beam Asymmetry

Polarization Vector



$$\beta = \phi - \varphi$$

Perpendicular:

$$\varphi = \pi/2$$

Parallel:

$$\varphi = 0$$

$$P_R = \frac{P^{\parallel}}{P^{\perp}}$$

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

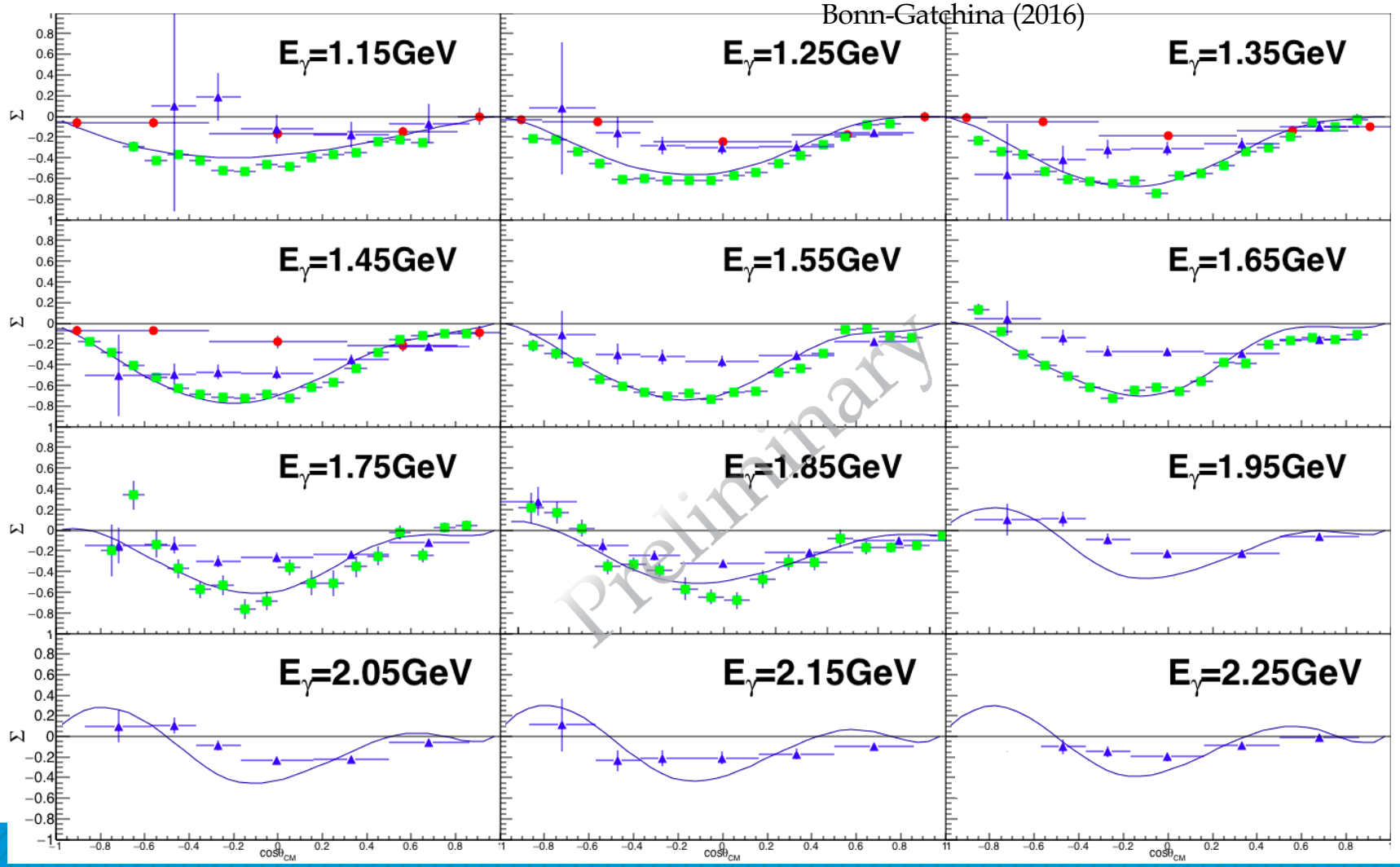
Background corrected

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	$\lvert\mu_{\Delta\Sigma}\rvert$
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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