Photoprduction of ω mesons off bounded protons with the CLAS detector at JLab

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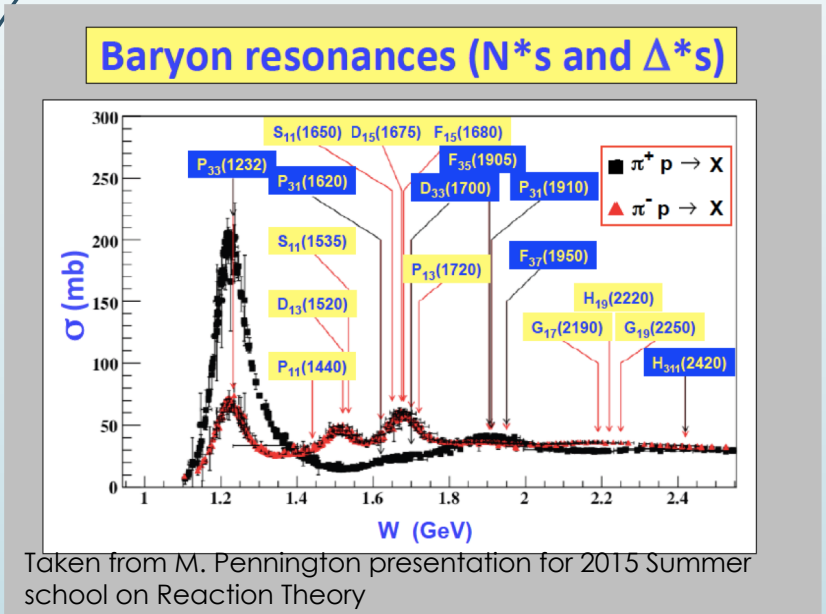
APS Meeting 2018

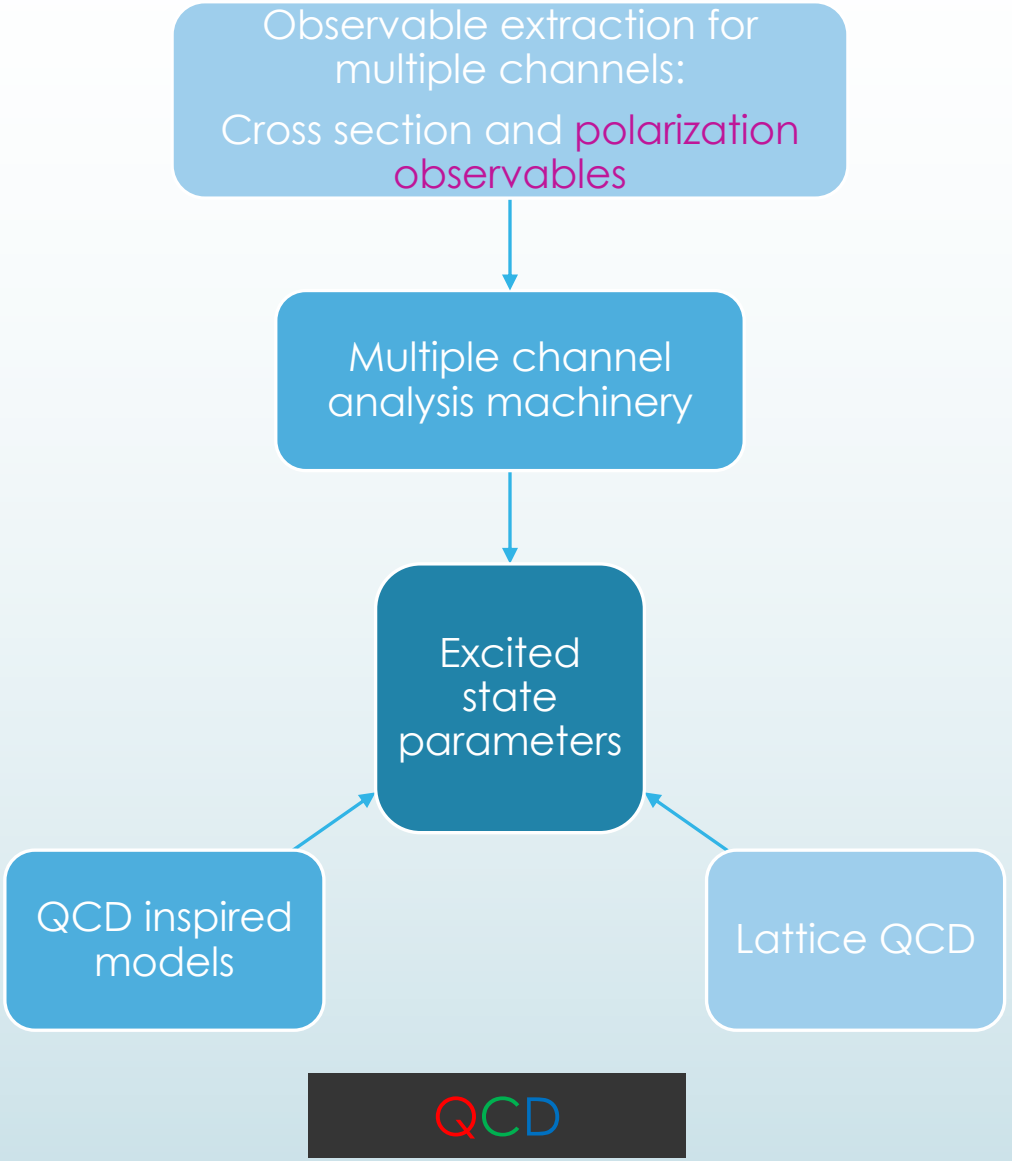
This work is funded by NSF Grant: PHY-1615146

Motivation

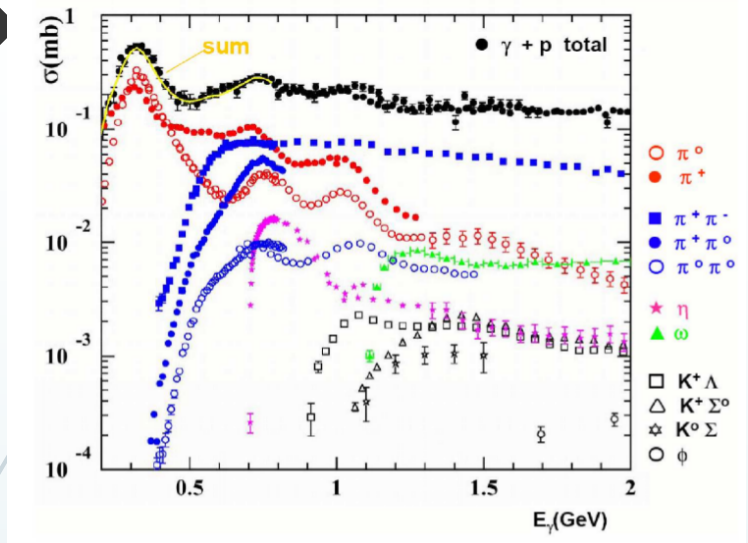
- Spectrum of excited states provides information that is complementary to studies of structure of the ground state
  - Information of underlying degrees of freedom
- "missing resonances" issue
  - Study of multiple channels that might couple strongly with missing resonances
- Not a "bump hunt"
  - Need of cross section and polarization observables



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



Why ω meson?



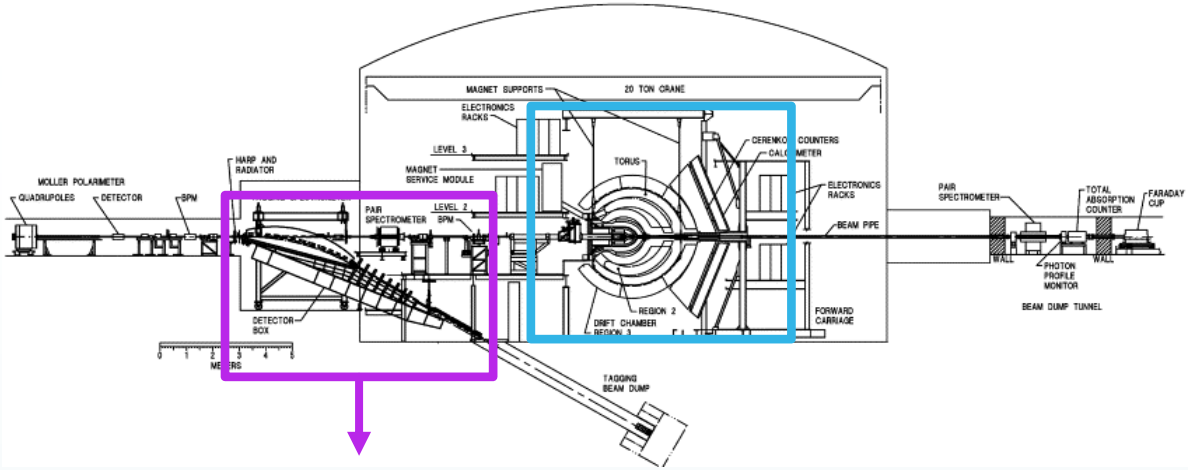
- Spectrum is poorly understood over 1700 MeV. Since threshold for ω meson is higher than π and η mesons thresholds, it should give information of higher mass resonance
- Isospin filter: only N* contribute
- Understanding the difference between quasi free and free channels will give us important insight for the bound nucleon data.

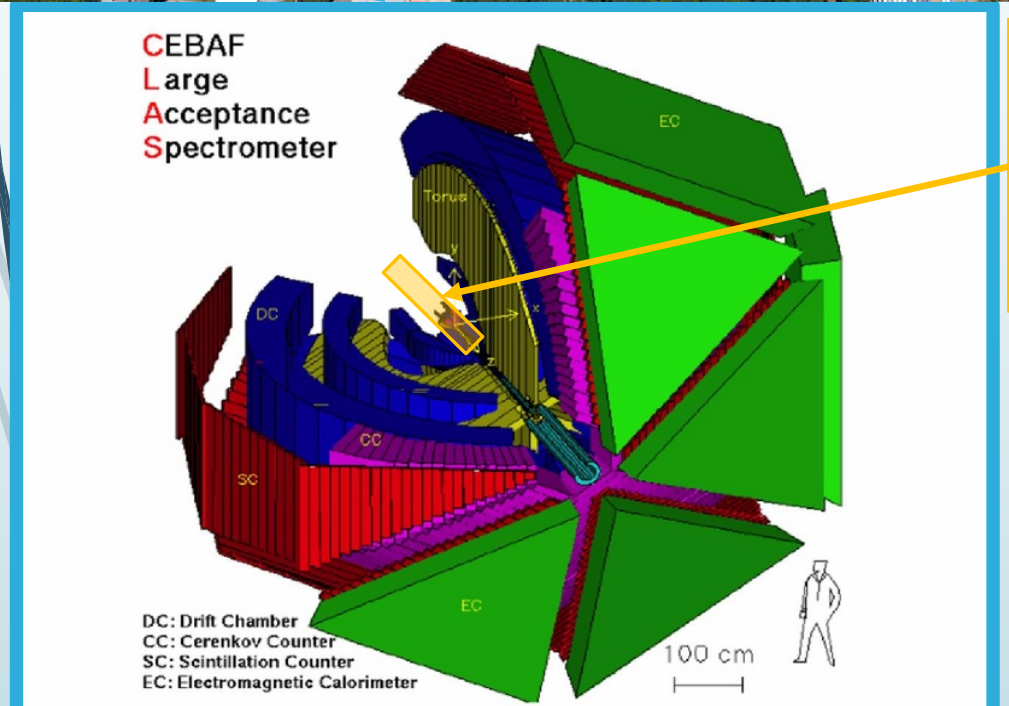
			Status as seen in								
Particle	J^P	overall	$N\gamma$	$N\pi$	$N\eta$	$N\sigma$	$N\omega$	ΛK	ΣK	$N\rho$	$\Delta\pi$
N	$1/2^+$	****									
$N(1440)$	$1/2^+$	****	****	****		***				*	***
$N(1520)$	$3/2^-$	****	****	****	***					***	***
$N(1535)$	$1/2^-$	****	****	****	****					**	*
$N(1650)$	$1/2^-$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

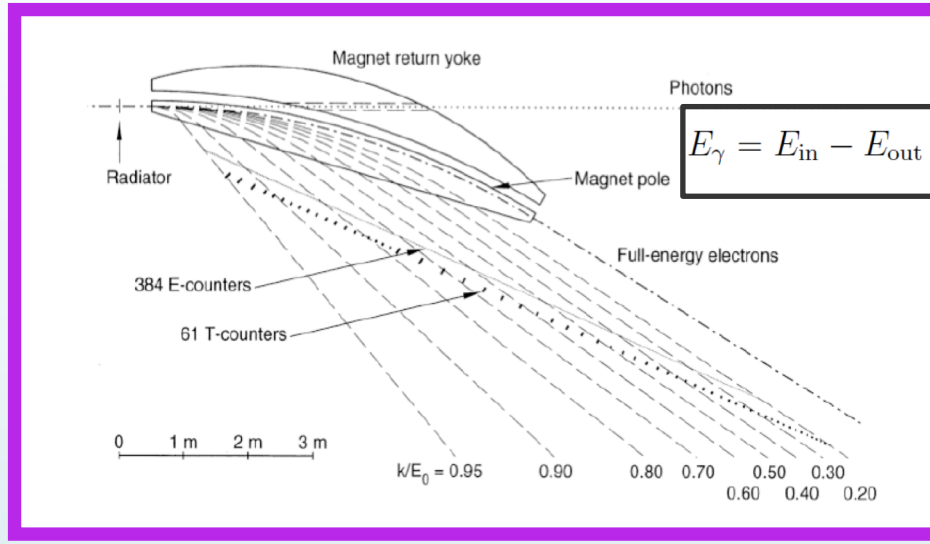
**** Existence is certain, and properties are at least fairly well explored.
*** Existence is very likely but further confirmation of decay modes is required.
** Evidence of existence is only fair.
* Evidence of existence is poor.

Particle Data group 2016

Experimental Layout

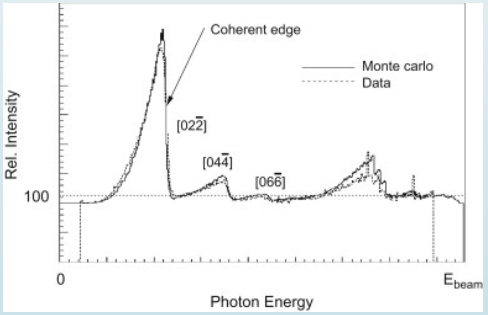






g13 b:

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



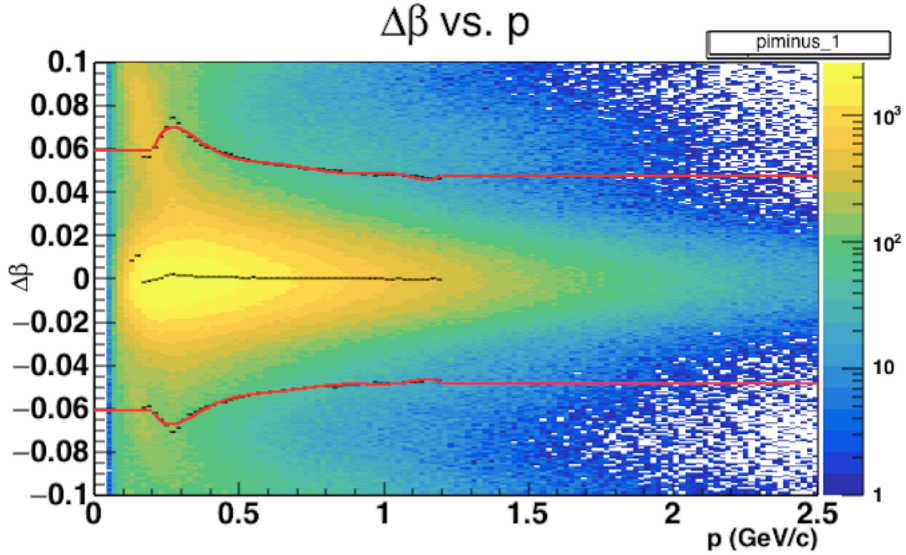
Data Analysis: Event Reconstruction

$$\gamma d \rightarrow \omega \; p(n)$$

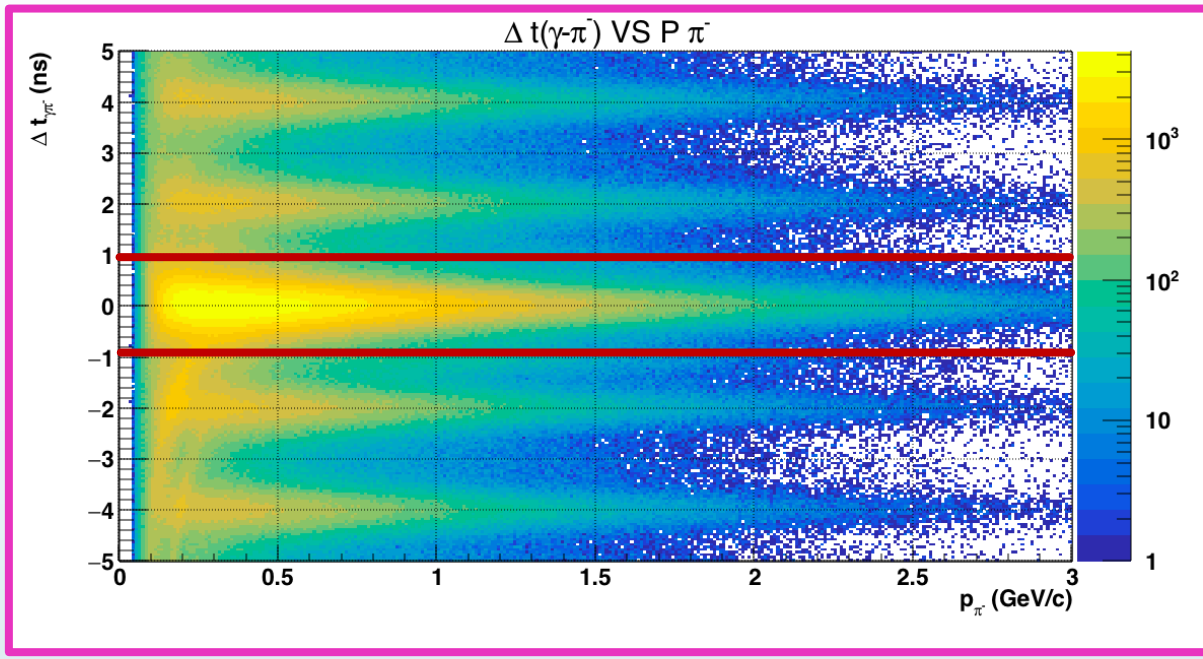
$$\omega \rightarrow \pi^+\pi^- \; \pi^0$$

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

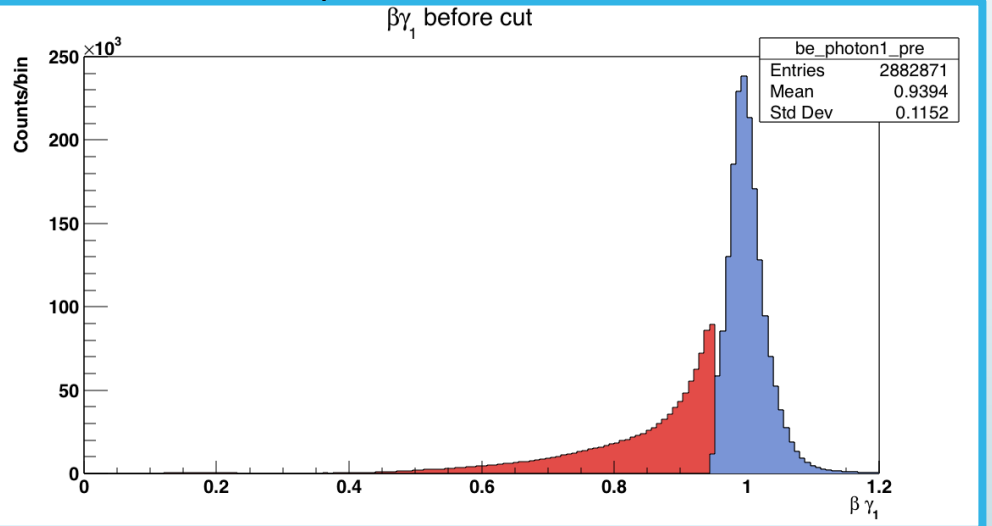
Charged particle identification



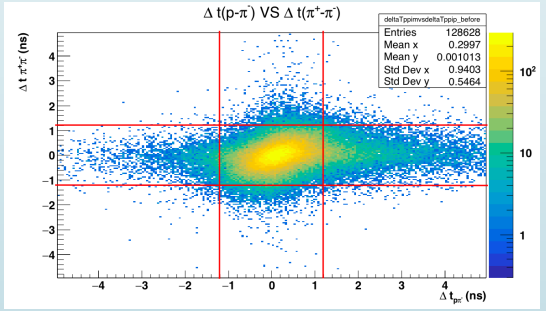
Incident photon identification

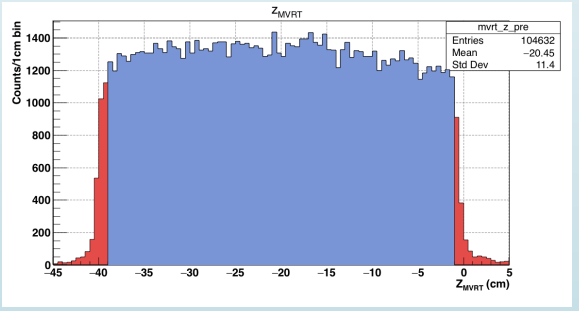


Neutral particle identification



Other cuts





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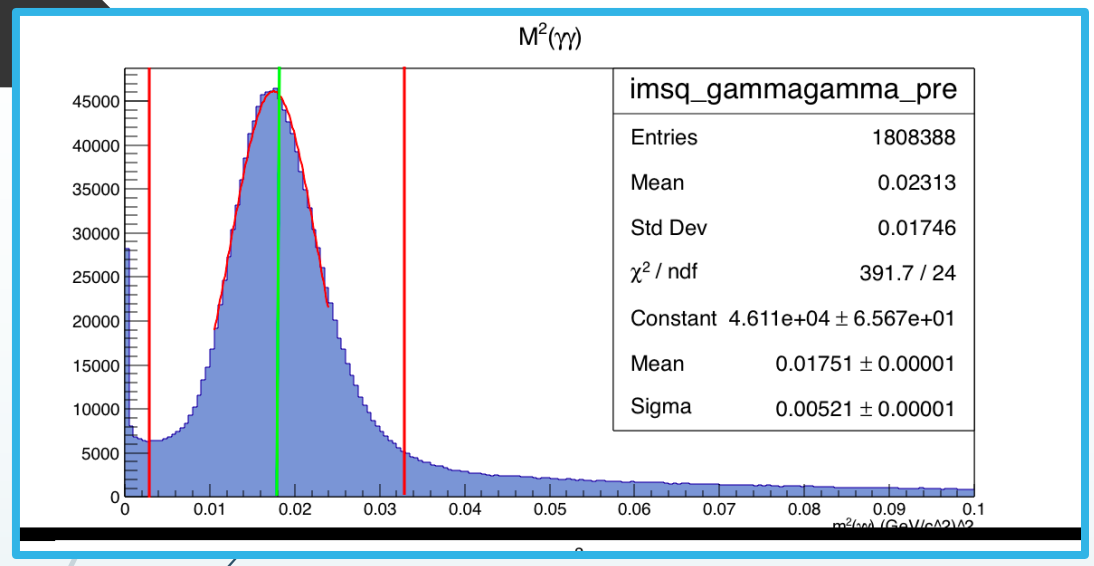
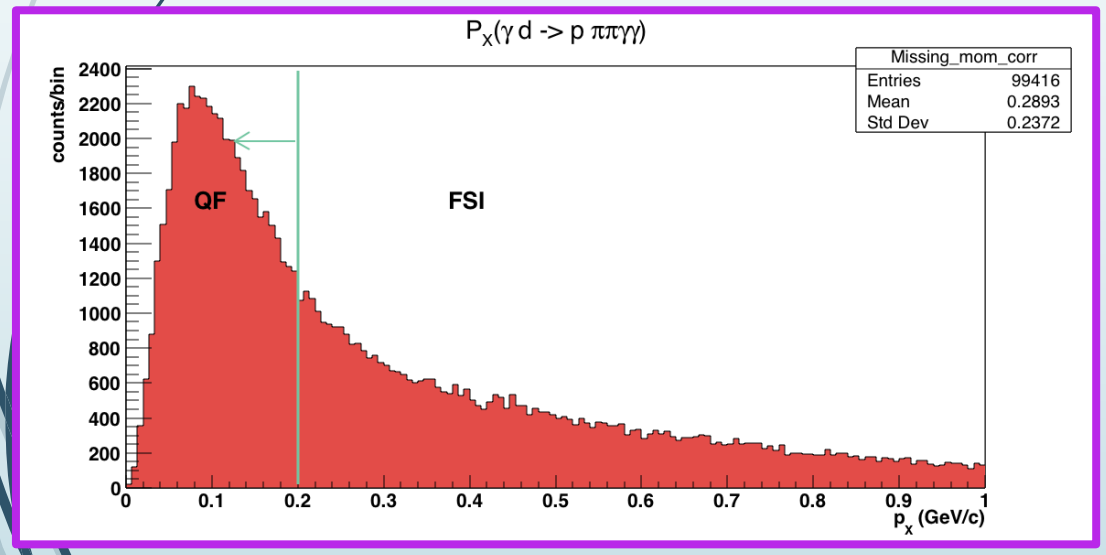
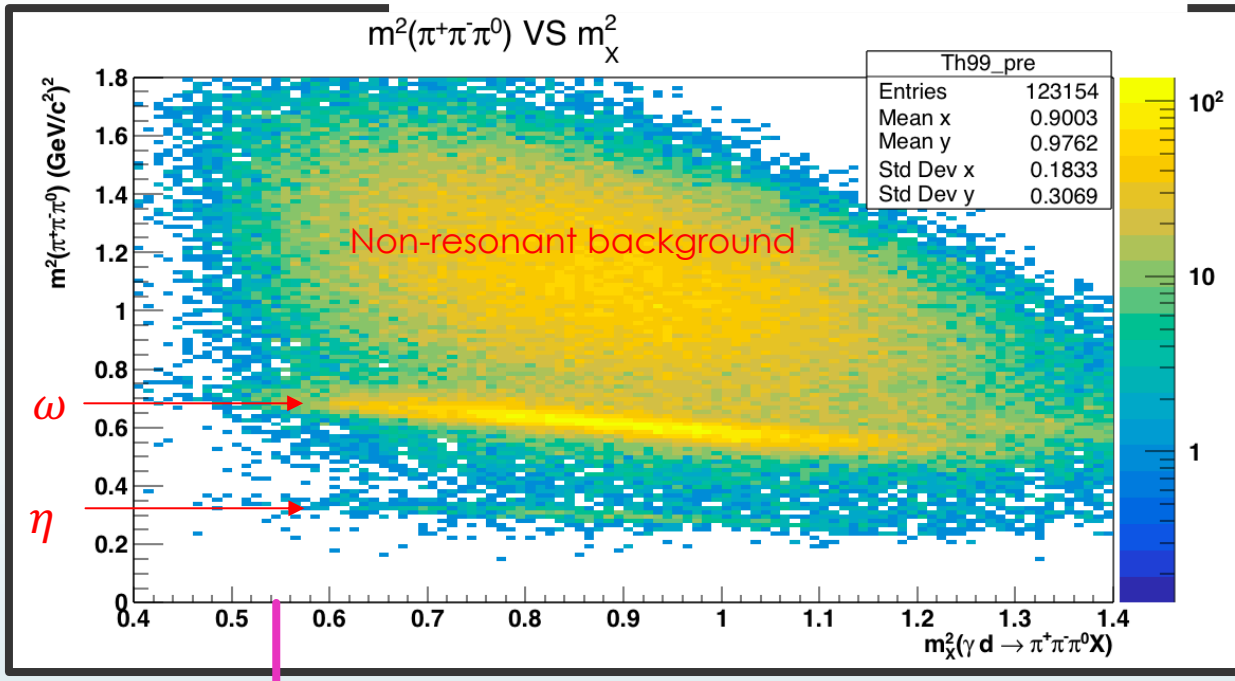
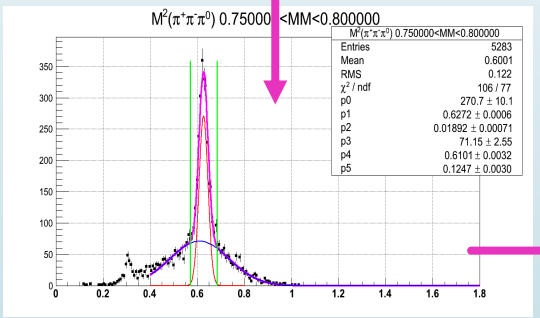
$$\omega \to \pi^+\pi^- \; \pi^0$$

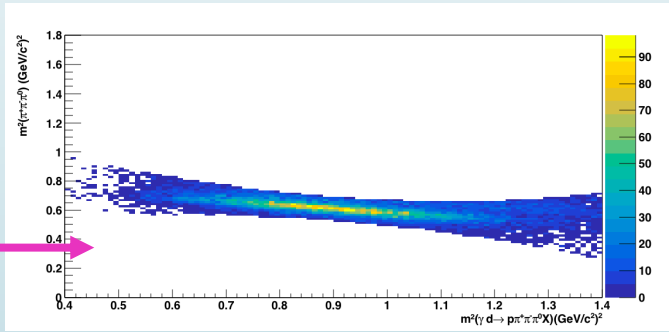
$$\pi^0 \to \gamma\gamma$$





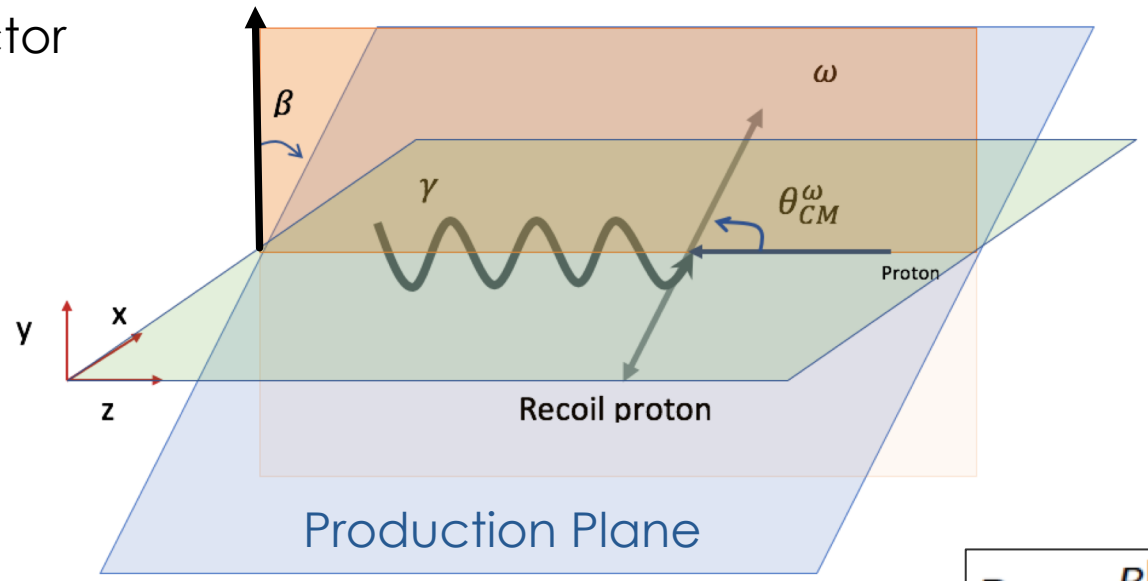






Beam Asymmetry

Polarization Vector



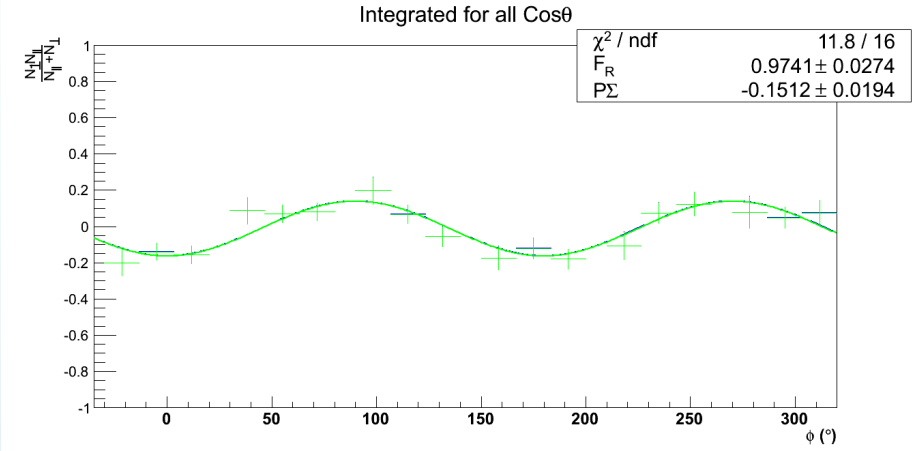
$$\beta = \phi - \varphi$$

Perpendicular:

$$\varphi = \pi/2$$

Parallel:

$$\varphi = 0$$



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

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

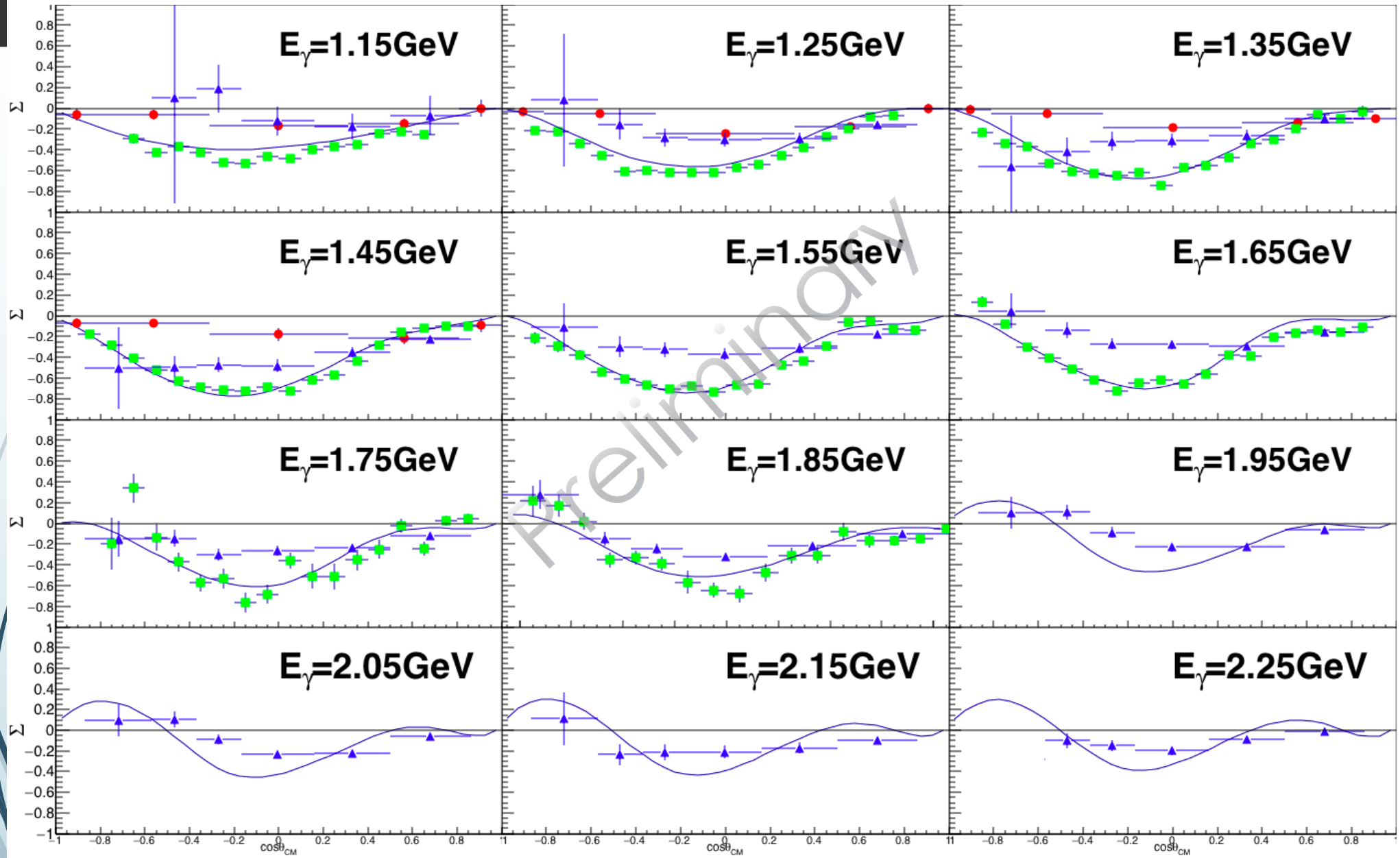
Background corrected

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)



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

Conclusions

- The ω channel is relevant in the study of missing resonances predicted constituent quark models
- We calculated the Beam Spin asymmetry for the photoproduced ω mesons off the bounded proton in the deuteron for $E_\gamma = 1.1 - 2.3\ \mathrm{GeV}$.
- 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 $E_\gamma = 1.45\ \mathrm{GeV}$.
- Our results, compared to the free events reported from CLAS collaboration (P. Collins et al.) 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. This needs to be furthered analyzed.

THANK YOU!