POLARIZATION OBSERVABLES FROM THE PHOTOPRODUCTION OF ω MESONS USING LINEARLY POLARIZED PHOTONS

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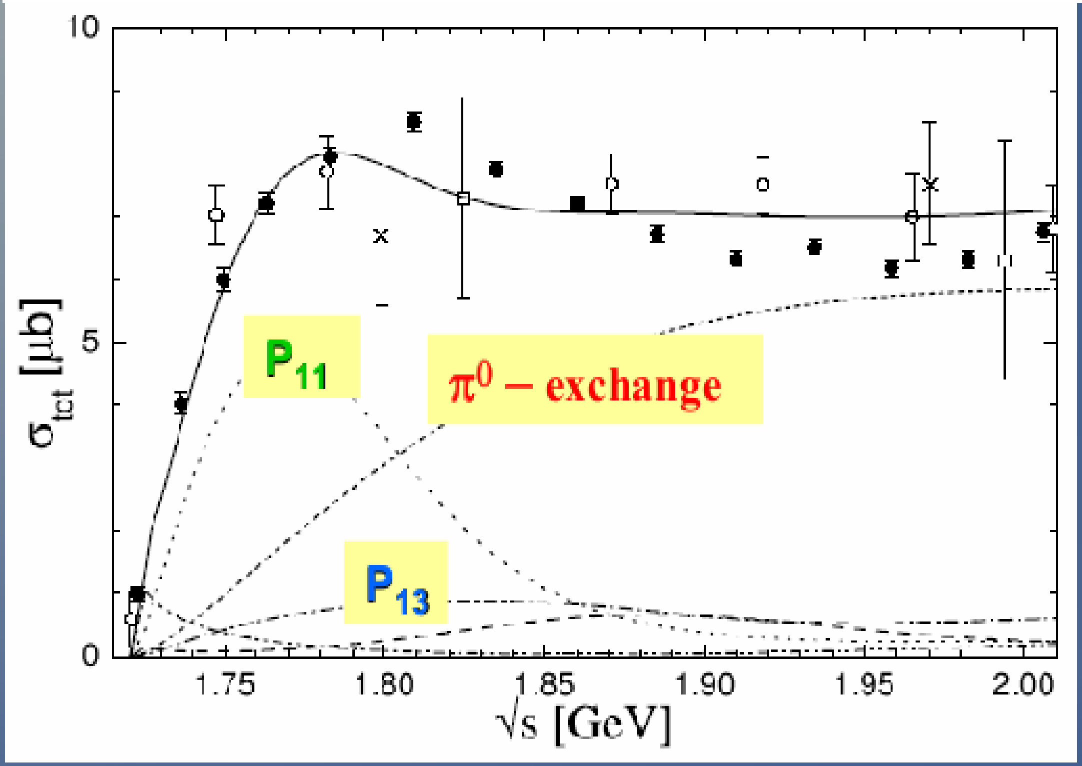
Figure 1: ● J. Barth *et al.*, ○ F.J. Klein *et al.*, × ABBHHM, and □ H.R. Crouch *et al.*, △ J.J. Manak (not used in the fitting procedure).



γp -> ωp Total Cross Section.

There are many baryon resonances that decay through vector meson channel.

They overlap because of their broad widths (~150 MeV).

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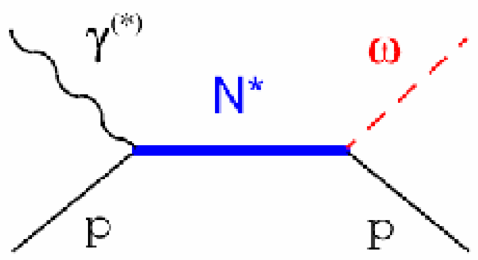
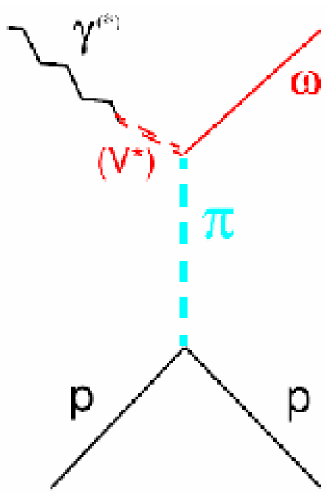
N*	Status	SU(6) ⊗ O(3)	Parity
P11(938)	****	$(56,0^+)$	+
S11(1535)[c]	****	$(70,1^-)$	
S11(1650)	****	$(70,1\ )$	
D13(1520)[c,d]	****	$(70,1^-)$	−
D13(1700)	***	$(70,1^-)$	
D15(1675)	****	$(70,1^-)$	
P11(1520)	****	$(56,0^+)$	
P11(1710)[b]	***	$(70,0^+)$	
P11(1880)		$(70,2^+)$	
P11(1975)		$(20,1^+)$	
P13(1720)[b,c]	****	$(56,2^+)$	
P13(1870)[b]	**	$(70,2^+)$	
P13(1910)[a]		$(70,2^+)$	+
P13(1950)		$(70,2^+)$	
P13(2030)		$(20,1^+)$	
F15(1680)[c,d]	****	$(56,2^+)$	
F15(2000)[a]	**	$(70,2^+)$	
F15(1995)		$(70,2^+)$	
F17(1990)	**	$(70,2^+)$	

Models predict more resonances than the ones that have been measured.

s-channel resonances

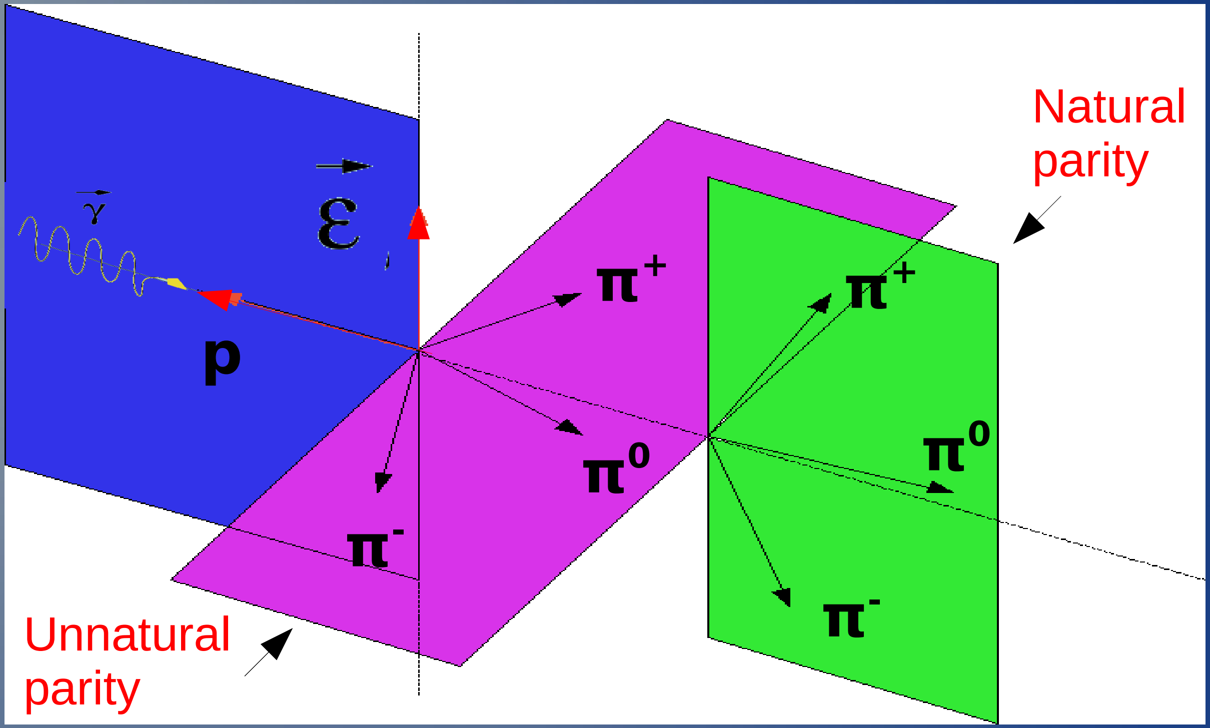


t-channel exchanges



Processes contributing to the reaction

$\gamma p \rightarrow \omega p$



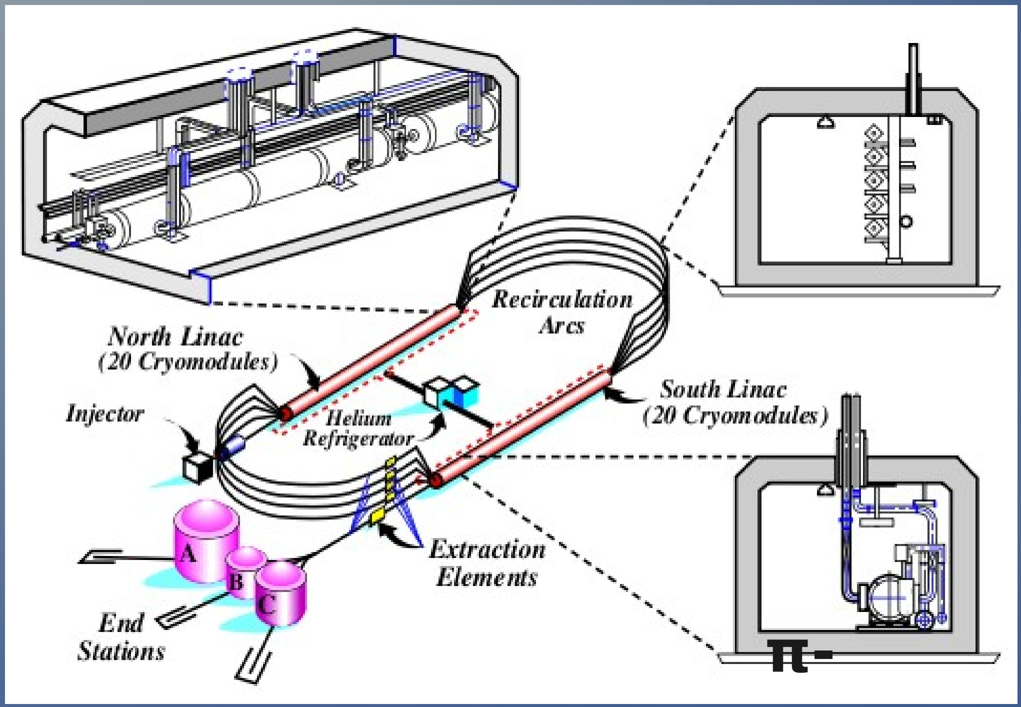
All models agree that:

π^0 exchange (unnatural parity) in the t-channel plays a significant role in the cross section of the electro- and photoproduction of ω mesons.

Baryon resonances contribute significantly to both the total and differential cross section in ω electro- and photoproduction.

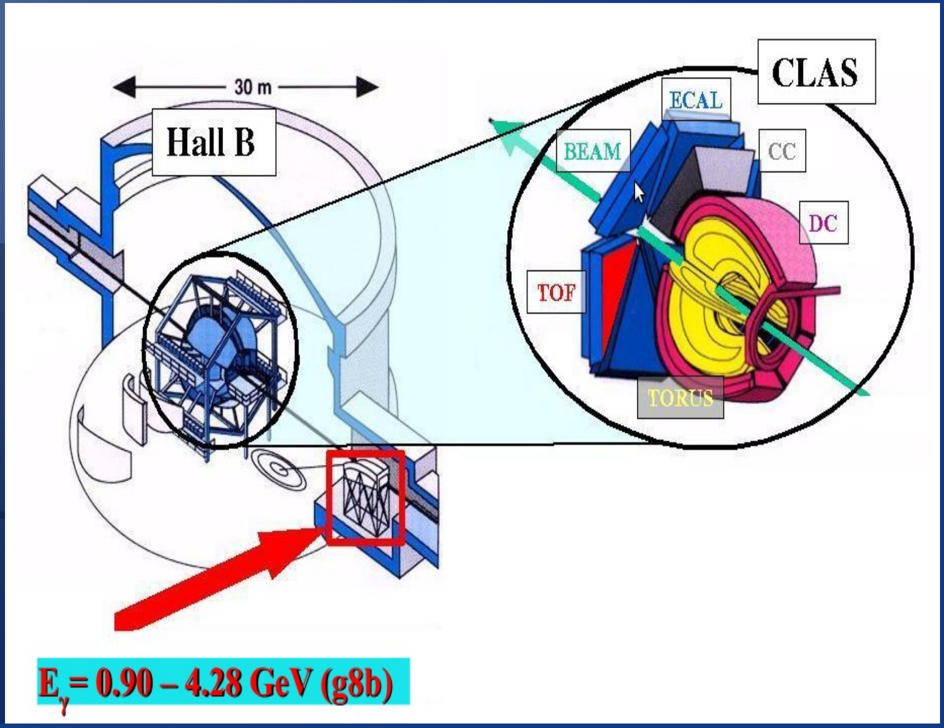
We urgently need polarized observables to disentangle which resonances and by how much these resonances contribute to the cross section.

The Continuous Electron Beam Accelerator Facility CEBAF

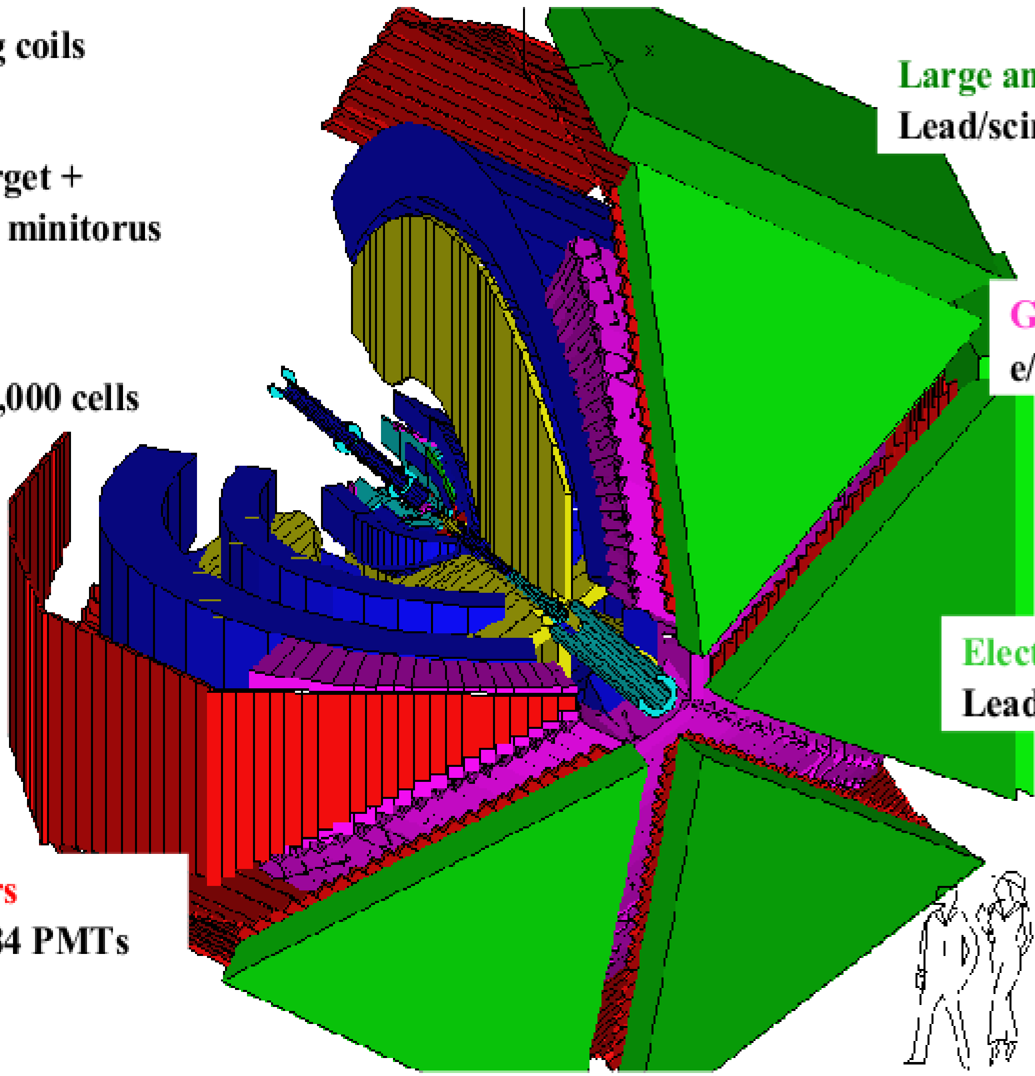


CLAS:
Multi-layer spherical array of detectors for charged and neutral particles.

Very **large angular coverage**: **Near full coverage** in azimuthal angle and from **8° to 140°** in scattering angle.



CEBAF Large Acceptance Spectrometer

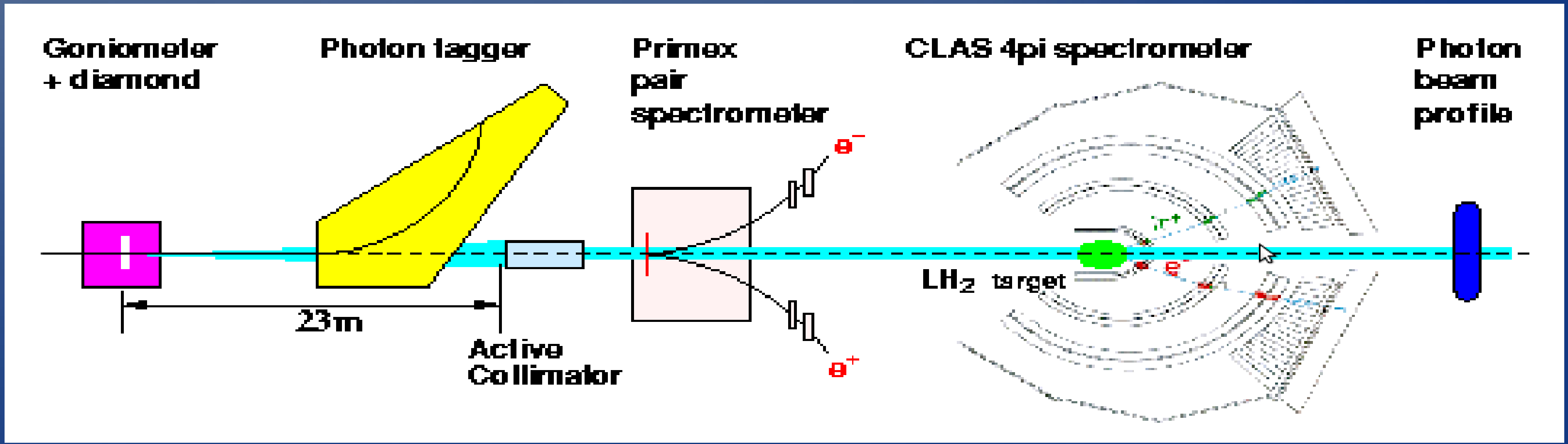


G8b RUN

Target type: Liquid H2

Electron end-point energy: 4.544 GeV

E_γ at the coherent peak (GeV)	Events (billion)
1.3	1.5
1.5	1.5
1.7	1.5
1.9	1.0
2.1	1.0
Amorphous data	1.8



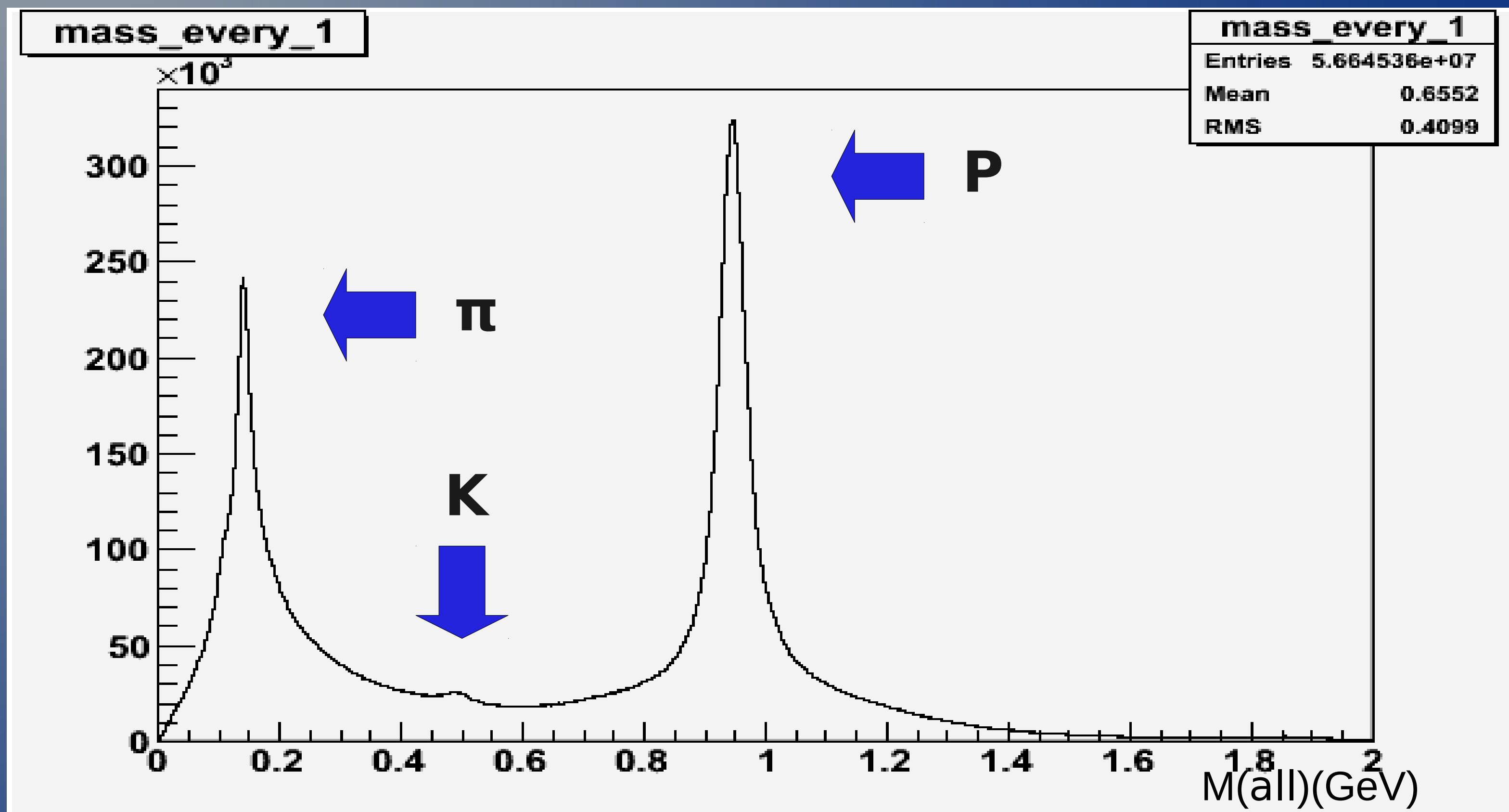
SELECTION PROCESS

We start by requiring three particles in the final state: proton, π^+, and π^-.

The PID process encompasses cuts on the values for mass, beta, time, momentum and TOF time to best identify good events.

A track in the drift chambers and a coincidence in the TOF detector are required flags to accept a candidate event.

SELECTION PROCESS



The mass distribution as given by EVNT bank. Peaks correspond to pion, kaon and proton mass.

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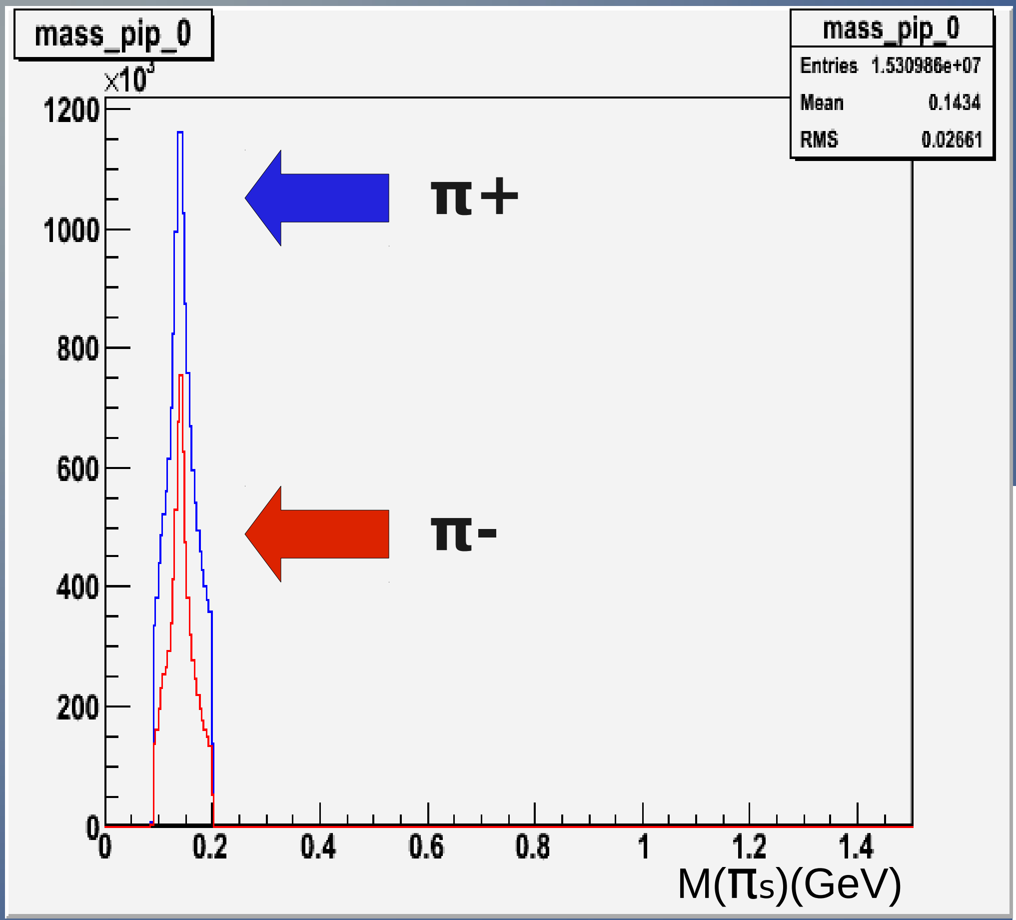
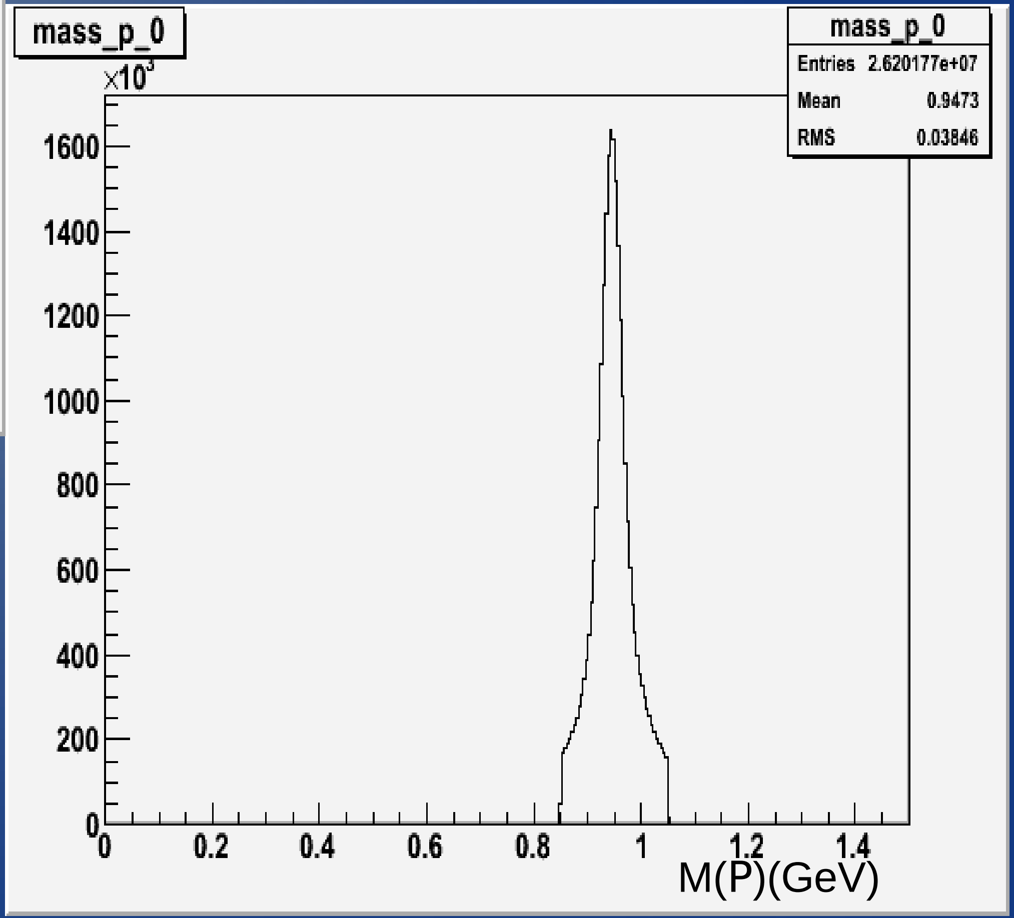


A comparison between π^+ and π^- cut is seen.



Zooming on proton mass cut.

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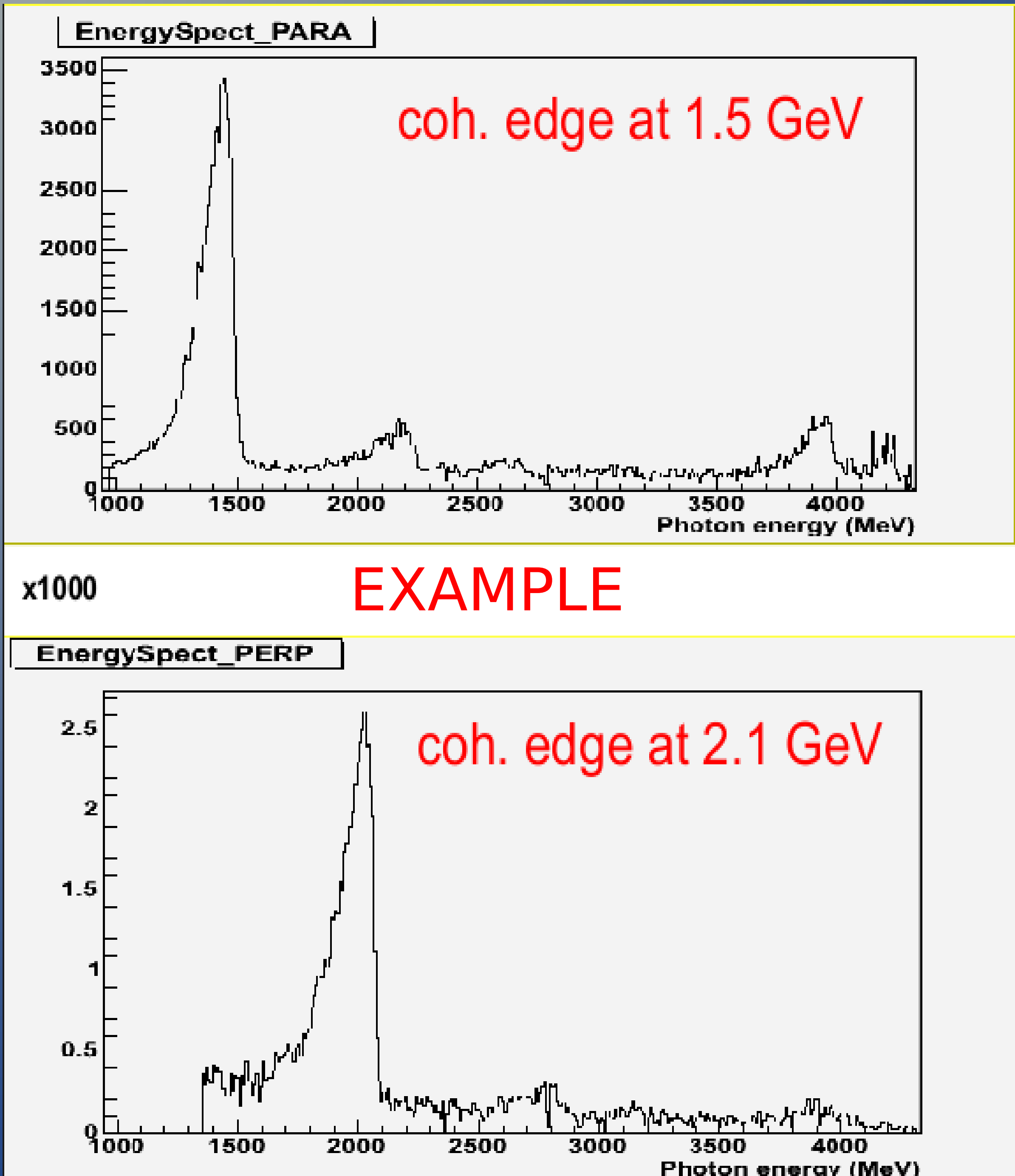

Cuts to the photon energy range are established for each data set.

The initial cuts for the data sets are:

1.3 GeV –> 1.1 to 1.325 GeV
1.7 GeV –> 1.3 to 1.525 GeV
1.7 GeV –> 1.5 to 1.725 GeV
1.9 GeV –> 1.7 to 1.925 GeV
2.1 GeV –> 1.8 to 2.125 GeV

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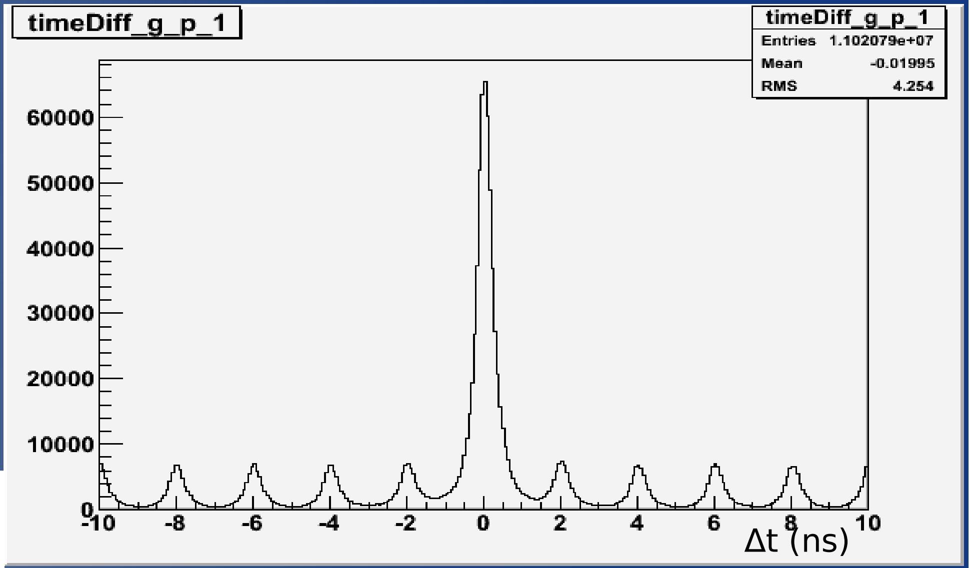
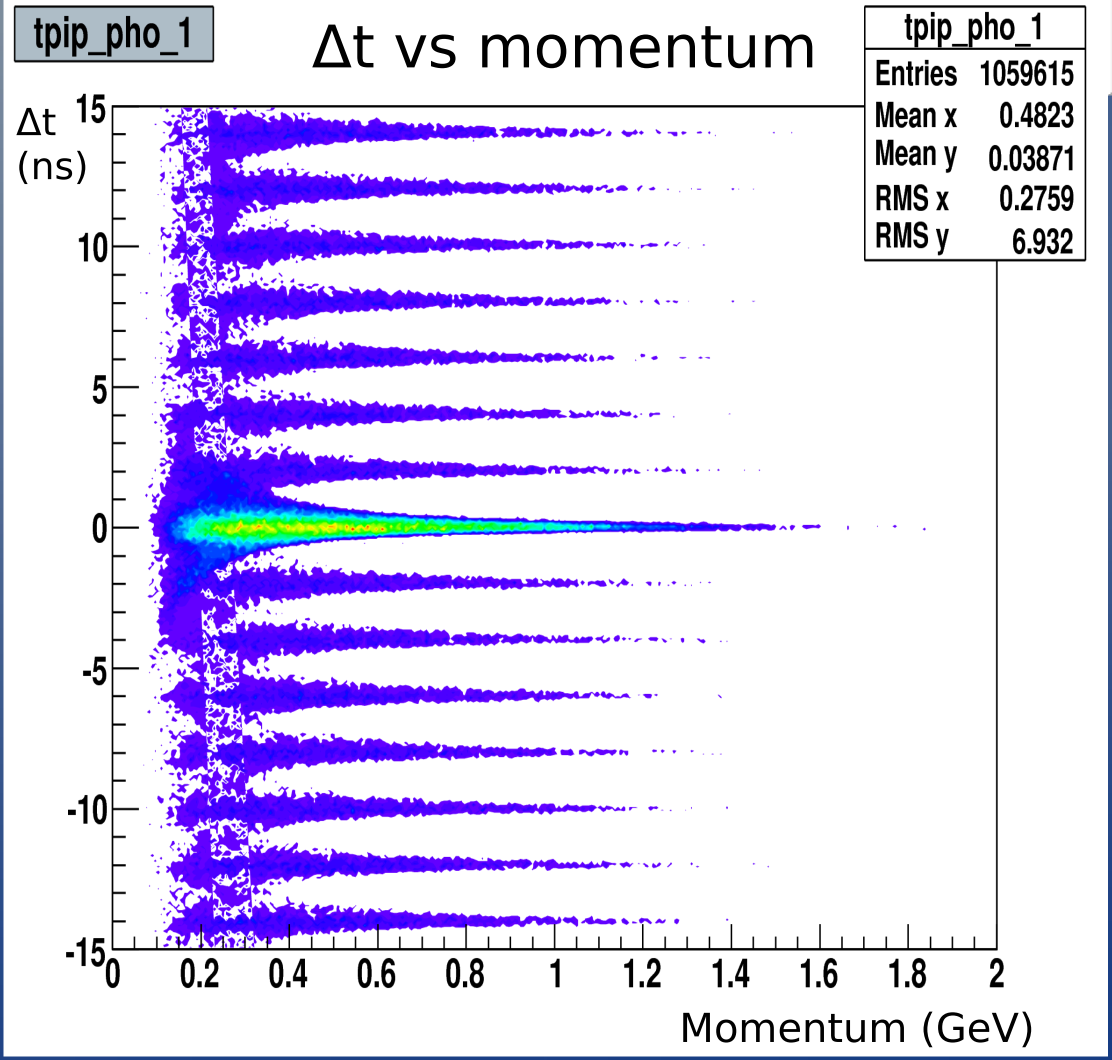
The RF bucket timing structure.





A loose cut between -1.5 and 1.5 ns is performed. The plot shows Δt vs momentum.

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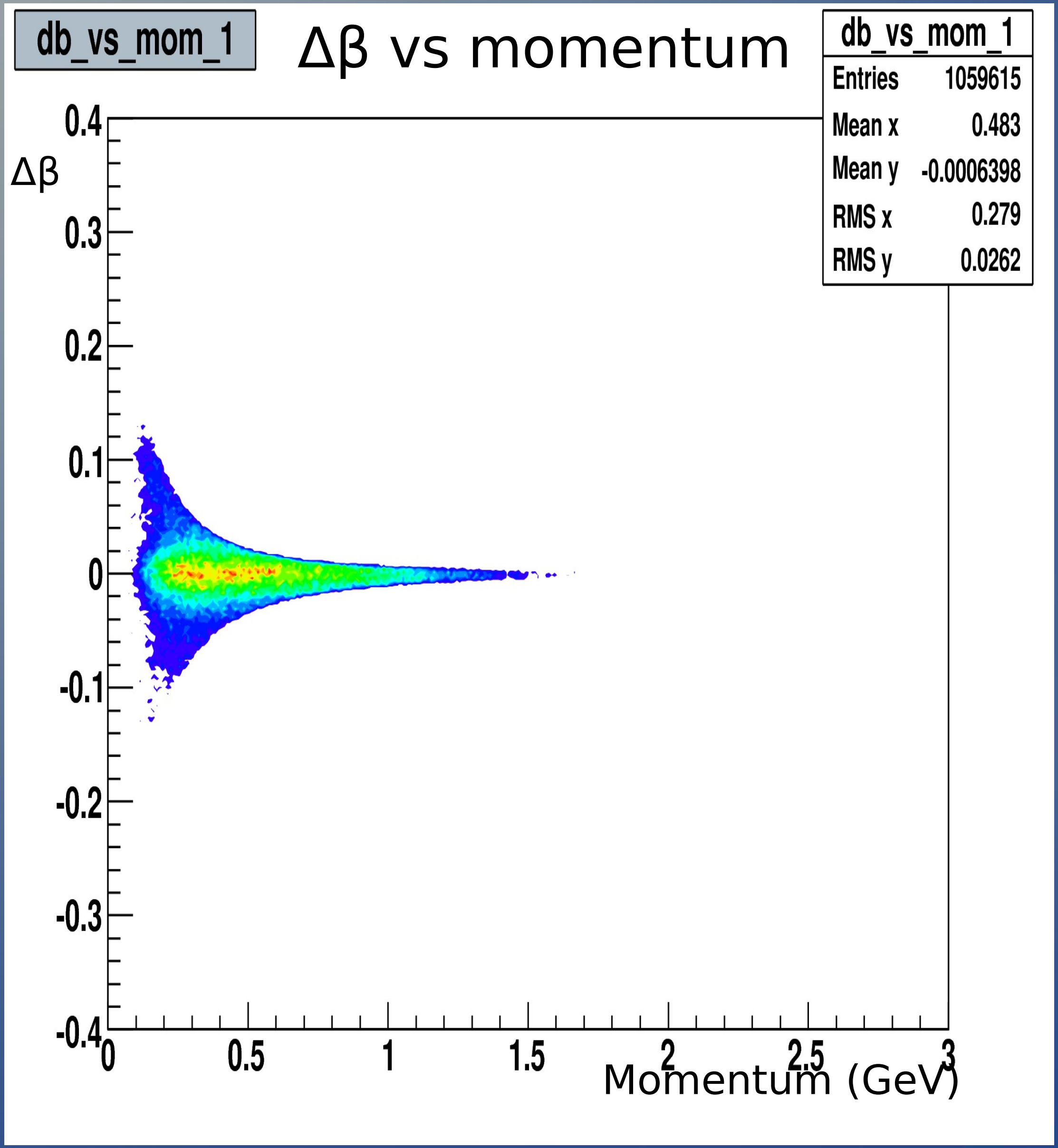
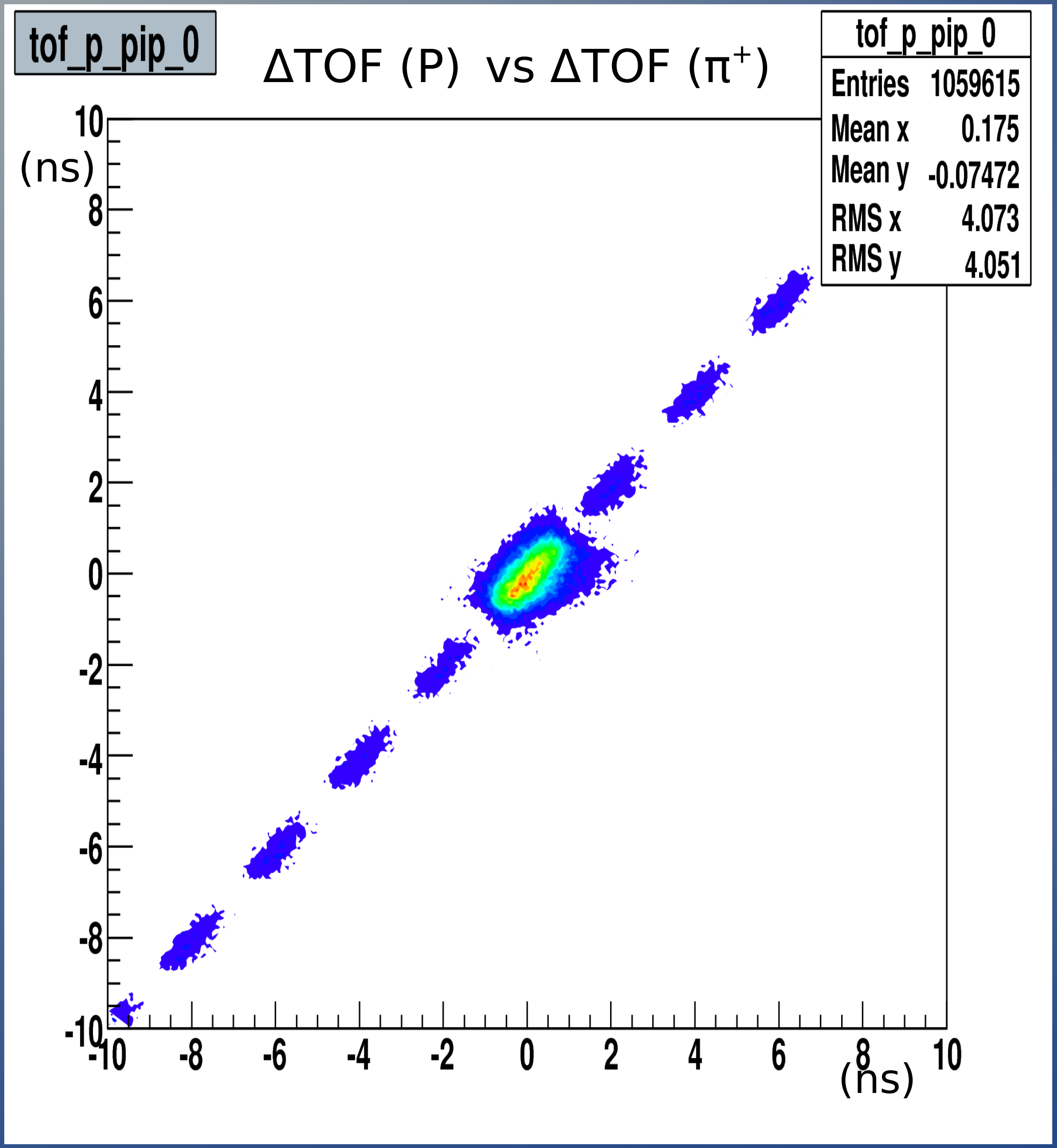


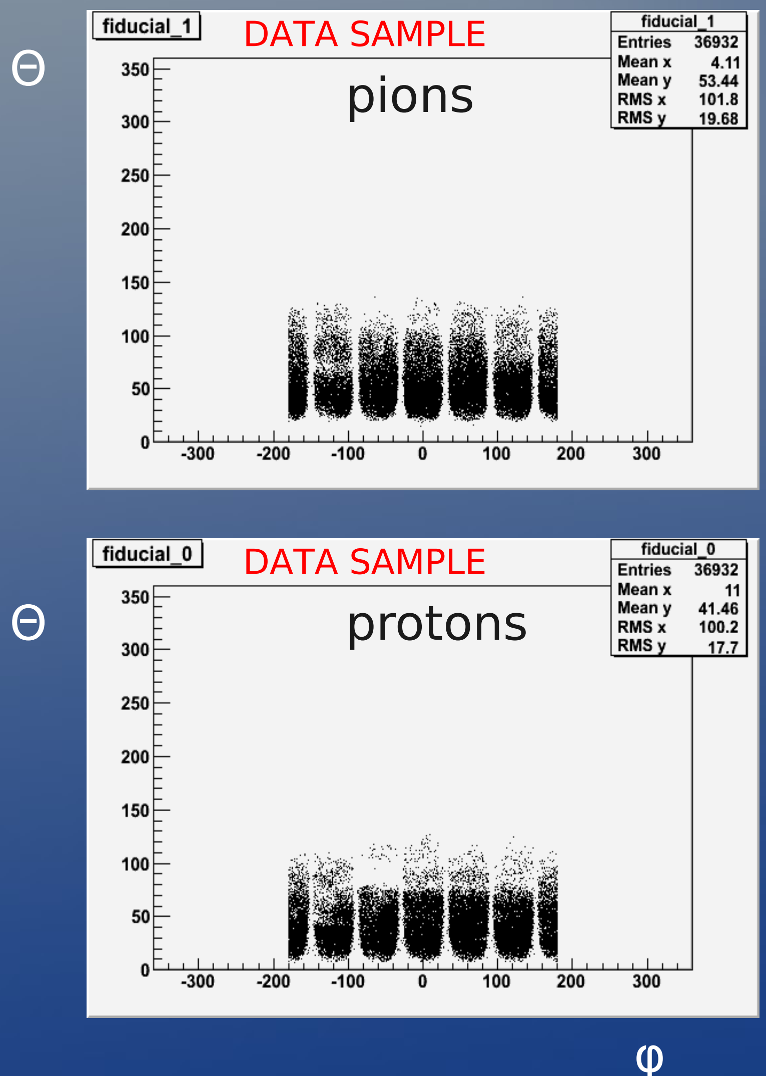
A cut for Δβ (as given by EVNT bank - calculated β) is performed between -0.05 and 0.05.



To distinguish positively charged particles, i.e proton and π^+ a cut from -1 to 1 ns is performed. The clusters of events around (+-2,+-2), (+-4,+-4) are due to photons associated with the wrong RF bucket.

INITIAL CUTS/CORRECTIONS

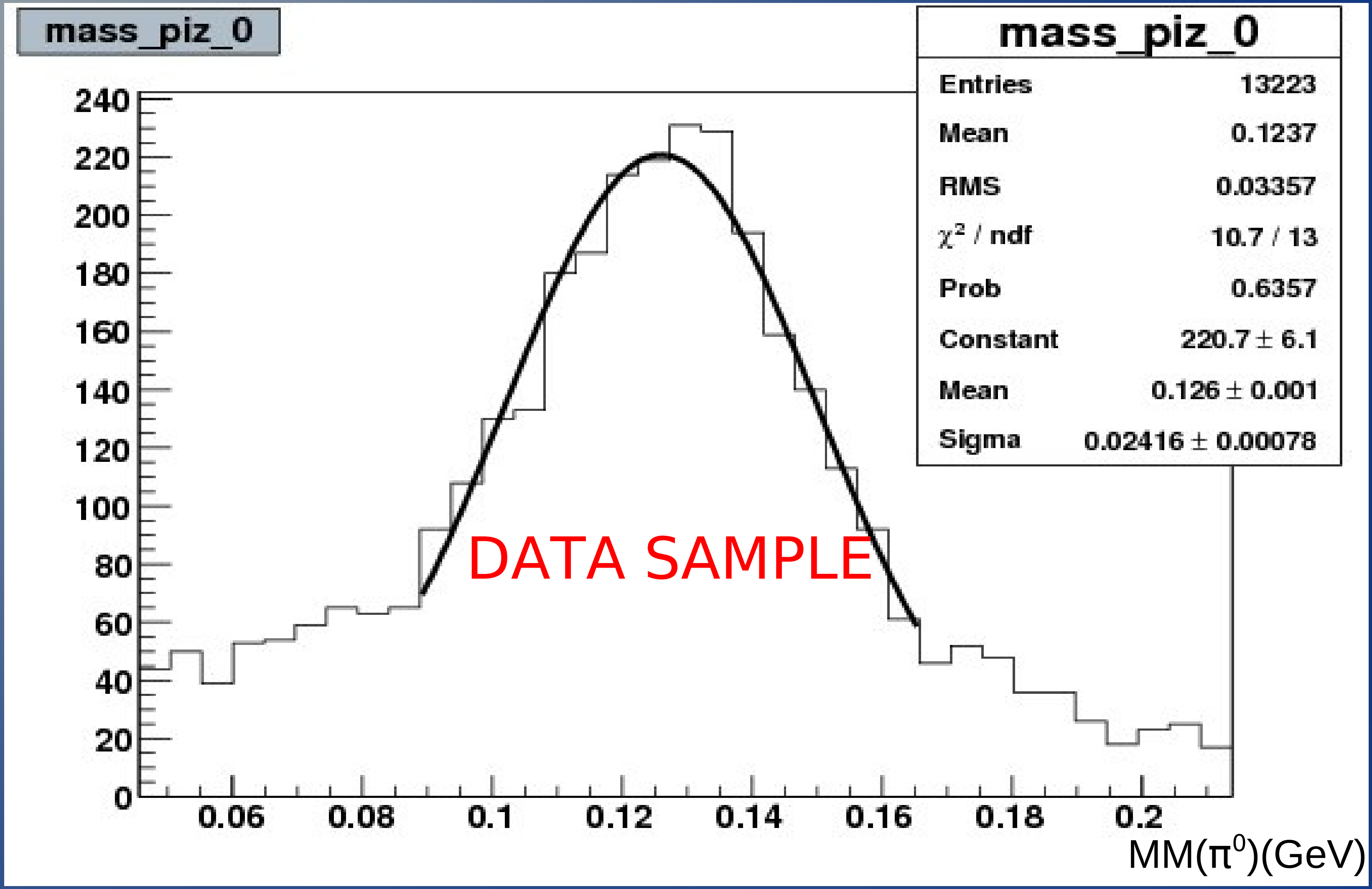
- *Fiducial cuts (angular)*



- *Energy loss corrections (by using* **eloss** *package written by Eugene Pasyuk)*

- *Momentum corrections are less than 1%, so for now they are neglected in the analysis.*

π^0 RECONSTRUCTION



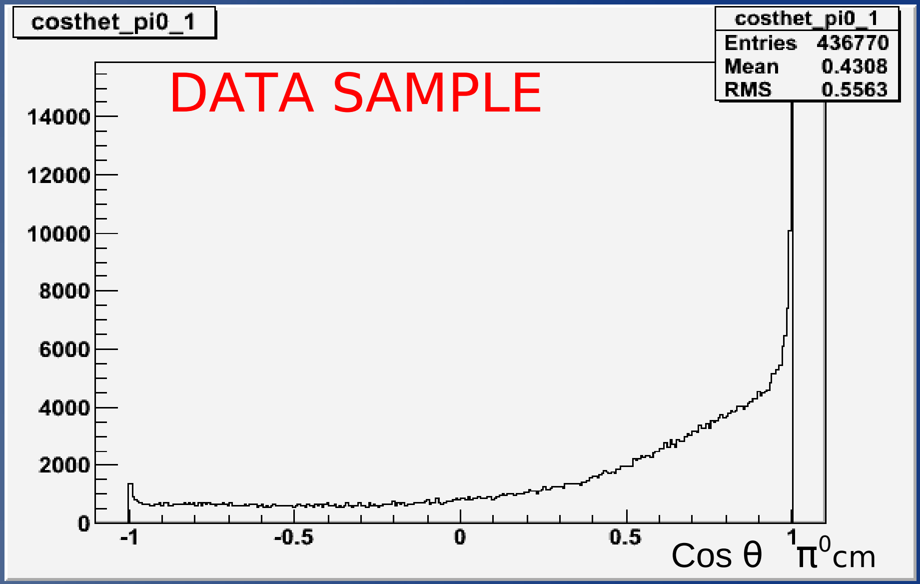
A rough fit (Gaussian) to the π^0 mass peak, found by using missing mass technique, from which the 3 to 5 sigma cut is made.

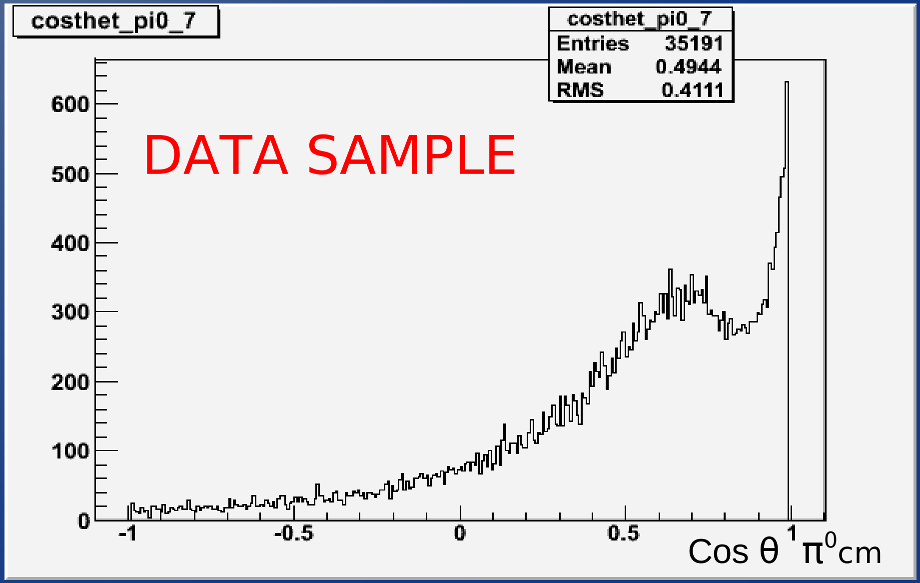
EXTRA CUTS

- *Cos Θ cut for bad photons:*

  A cut of 0.01 for Cos θ distribution for π^0 is done to ensure non-π^0 misidentified events are ruled out of the analysis. Notice how at the most forward part there is an excess of events. These belong to the wrong photon assignation to a non-π^0 event.

- *Vertex cuts*





Cos θ distribution after a 3 sigma cut on the π^0 mass and the cut mentioned above.

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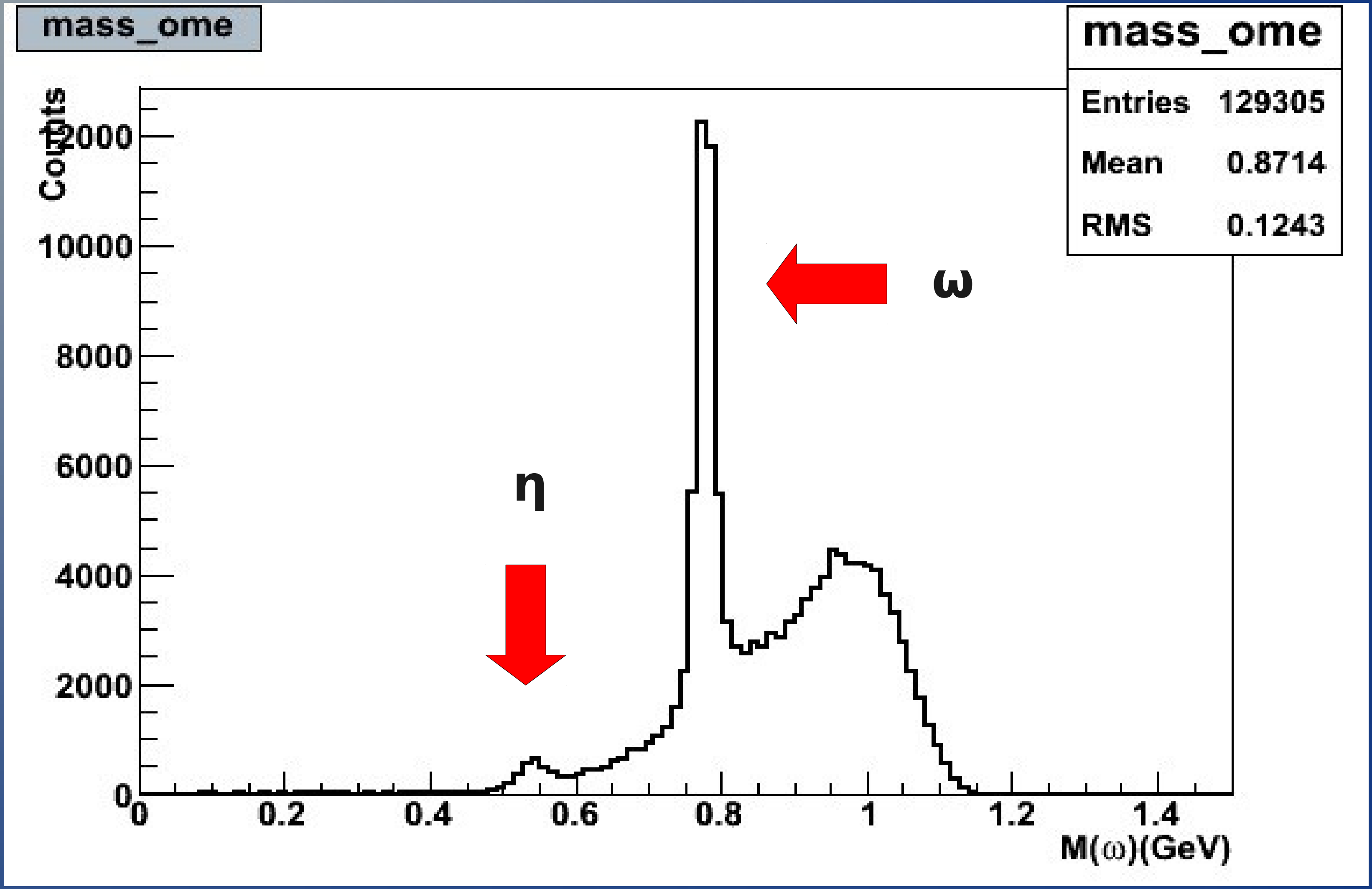
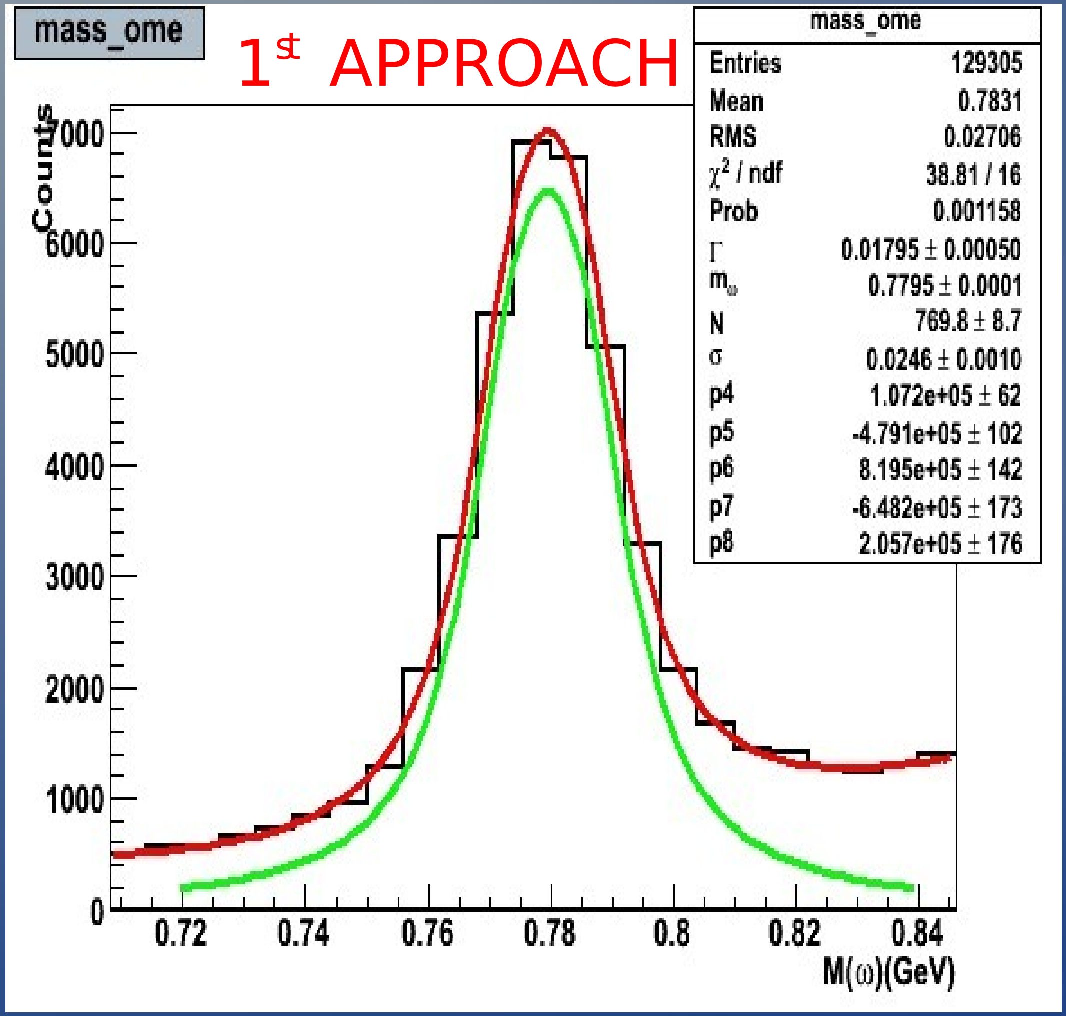
ω RECONSTRUCTION



The mass of the ω meson is obtained by using the 4-momentum of the detected π^+ and π^-, and also from the reconstructed π^0.

ω RECONSTRUCTION



Fitting function:

- Voigtian function for the ω signal.
- 4th degree polynomial for the background.
- No constraints to the parameters.

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BEAM ASYMMETRY EXTRACTION

- 10 bins in Cos Θ and
- 18 bins in φ are used.

The asymmetry parameter was checked for three E_γ values, for future comparison with the data obtained by P. Collins.

- 27 MeV wide E_γ bins. The E_γ bin cuts are:

$$1.861 < E_\gamma < 1.888$$
$$1.834 < E_\gamma < 1.861$$
$$1.807 < E_\gamma < 1.834$$

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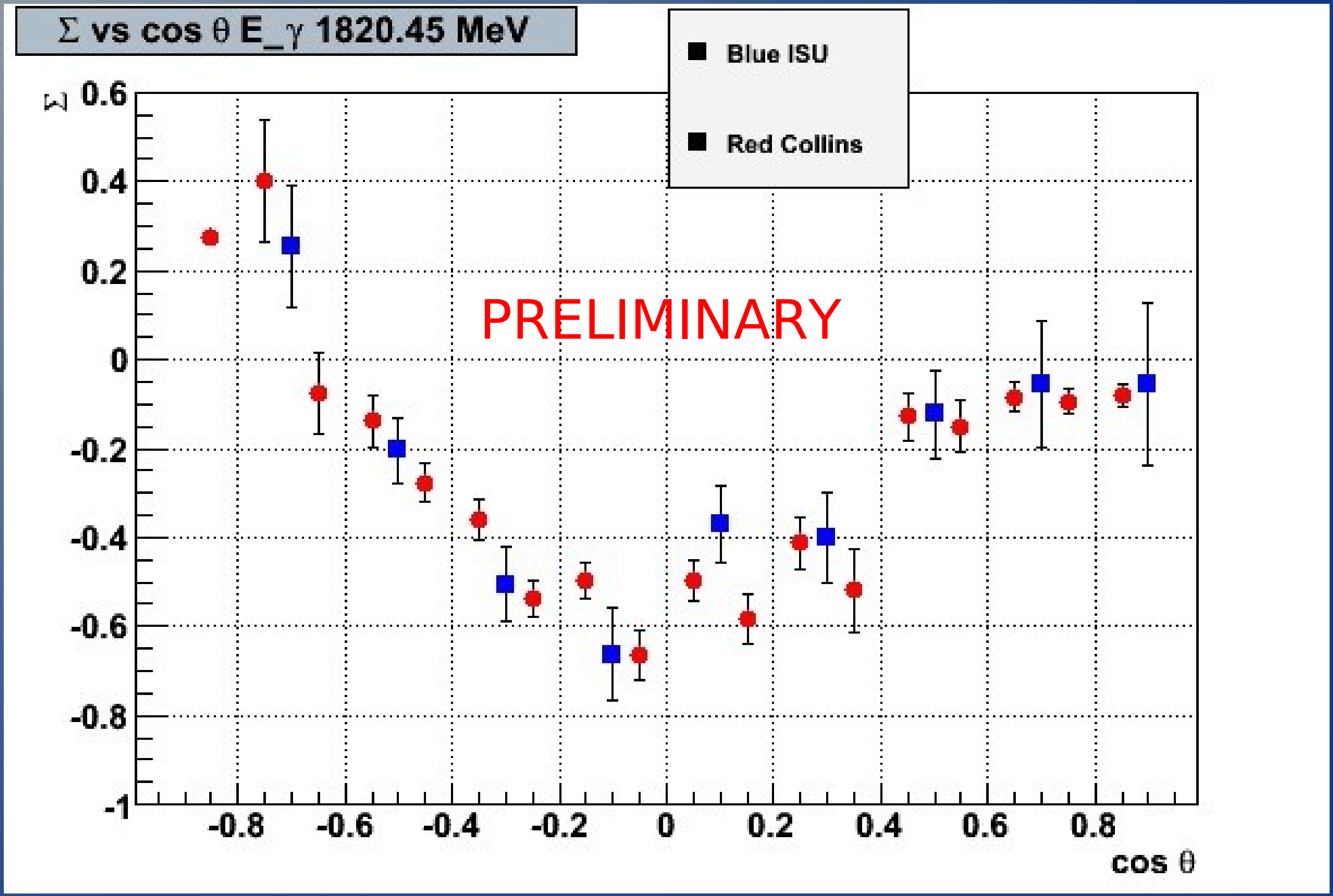
BEAM ASYMMETRY EXTRACTION

The Beam Asymmetry is determined by fitting the ratio PERP-PARA/PERP+PARA for each Cos Θ and E_γ bin, to a cosine 2φ like function.

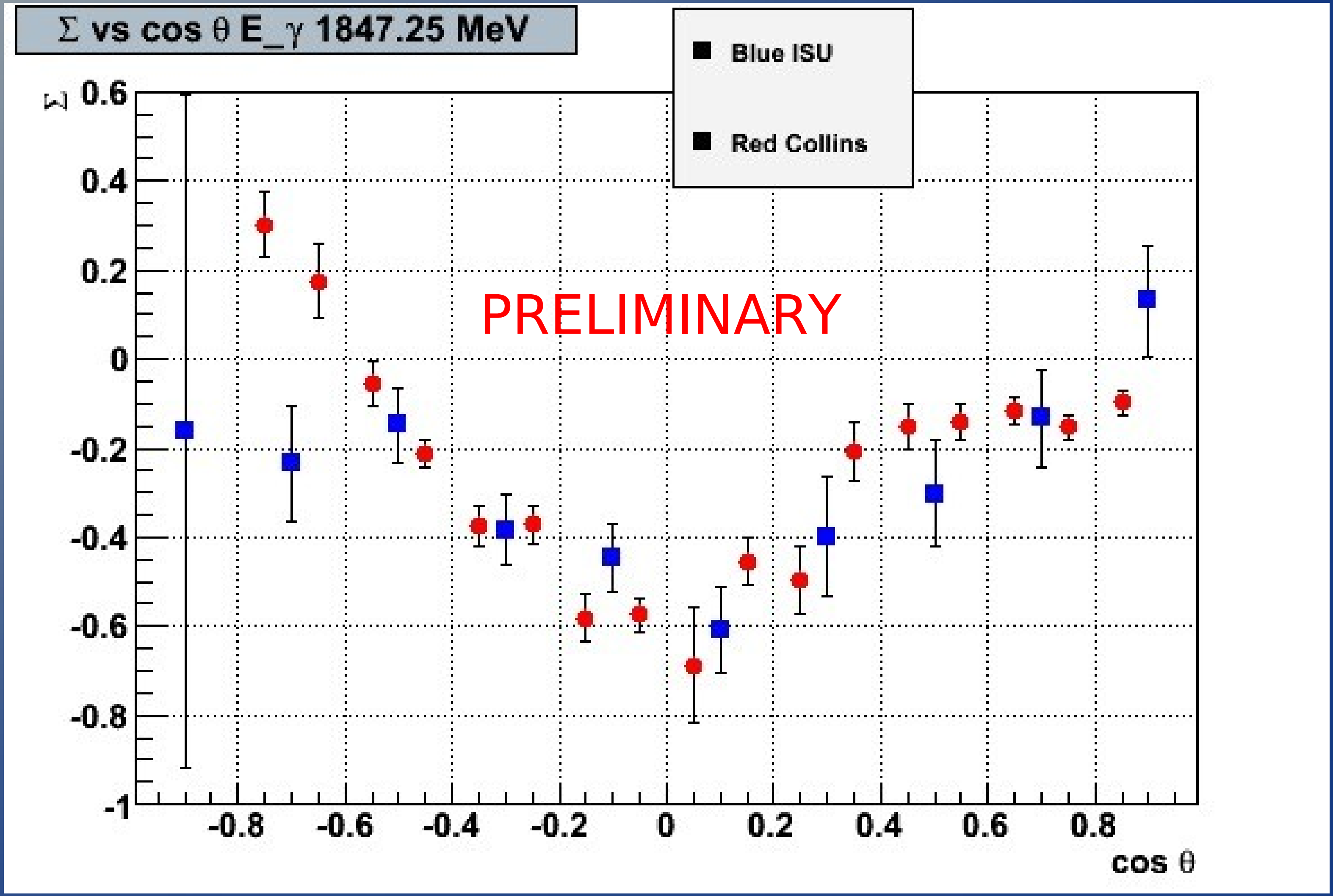
$$
\begin{aligned}
\sigma_\perp &= \sigma_0(1 + P_\perp \Sigma \cos 2\phi) \\
\sigma_\parallel &= \sigma_0(1 + P_\parallel \Sigma \cos 2\phi + \pi) \\
\sigma_\parallel &= \sigma_0(1 - P_\parallel \Sigma \cos 2\phi)
\end{aligned}
$$

$$
\frac{\sigma_\perp - \sigma_\parallel}{\sigma_\perp + \sigma_\parallel} = \frac{(\frac{N_\perp}{N_\parallel} - 1) - (\frac{N_\perp}{N_\parallel} P_\perp + P_\parallel)\Sigma \cos(2(\phi))}{(\frac{N_\perp}{N_\parallel} + 1) - (\frac{N_\perp}{N_\parallel} P_\perp - P_\parallel)\Sigma \cos(2(\phi))}
$$

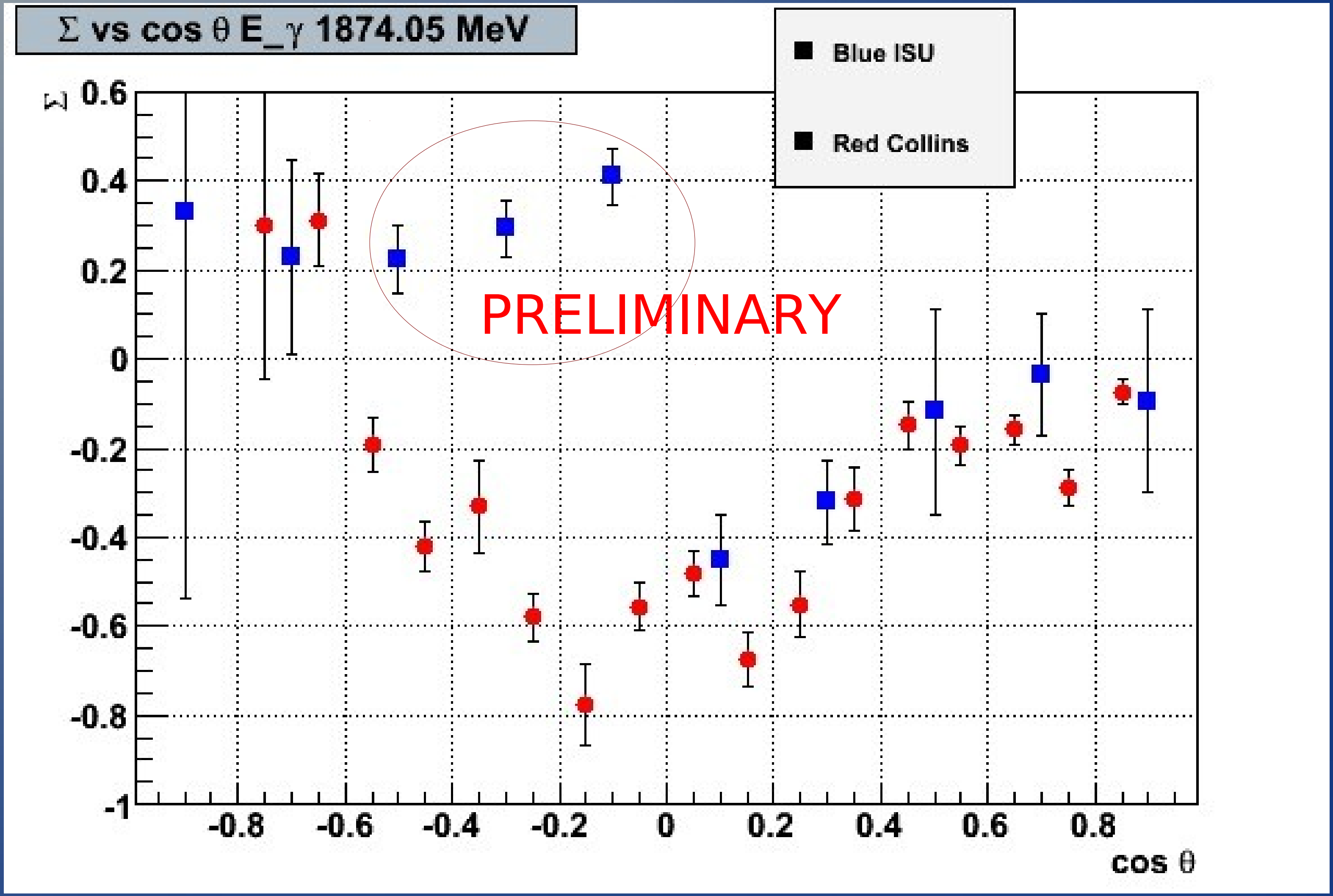
ω beam asymmetry
2σ cut

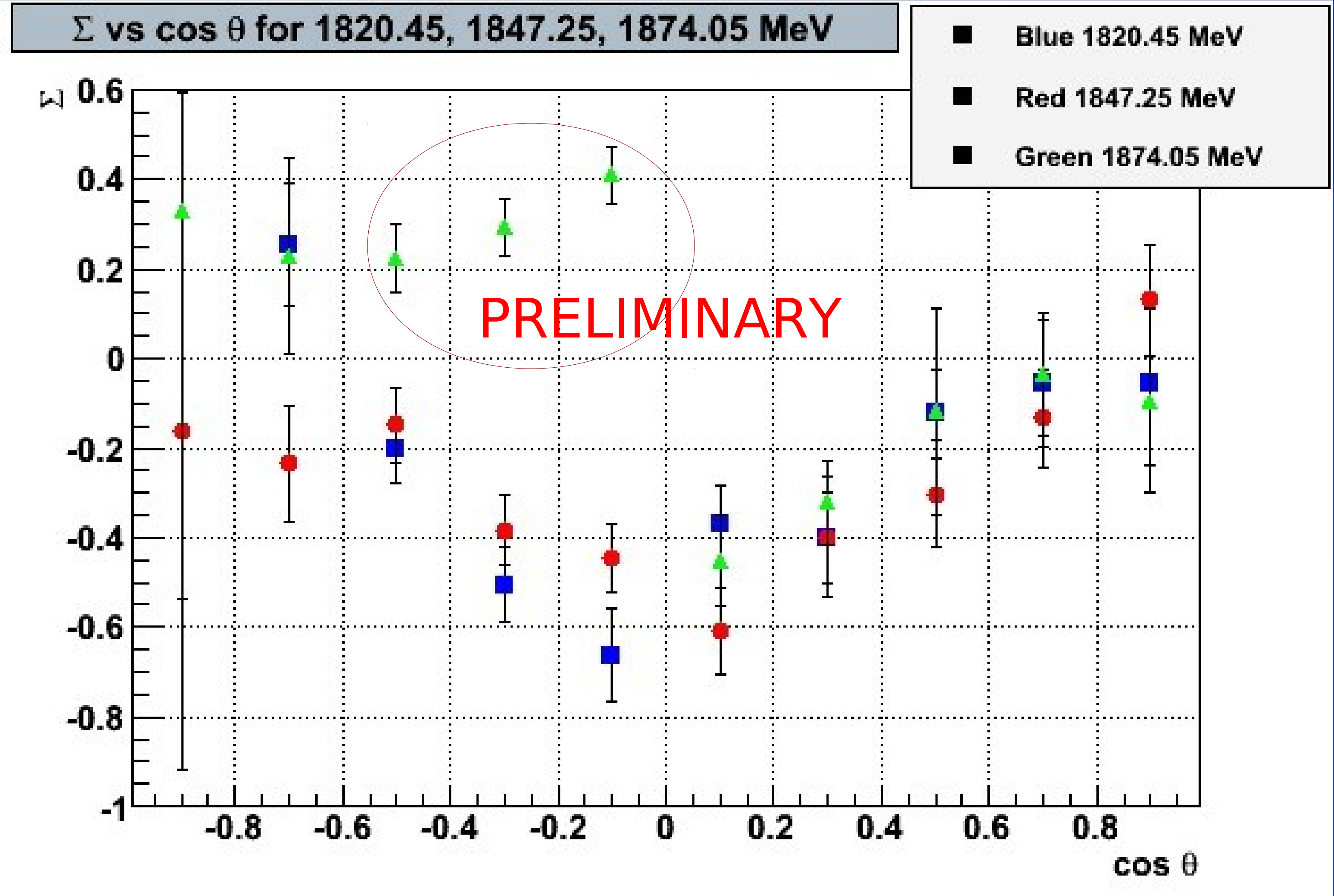


ω beam asymmetry
2σ cut

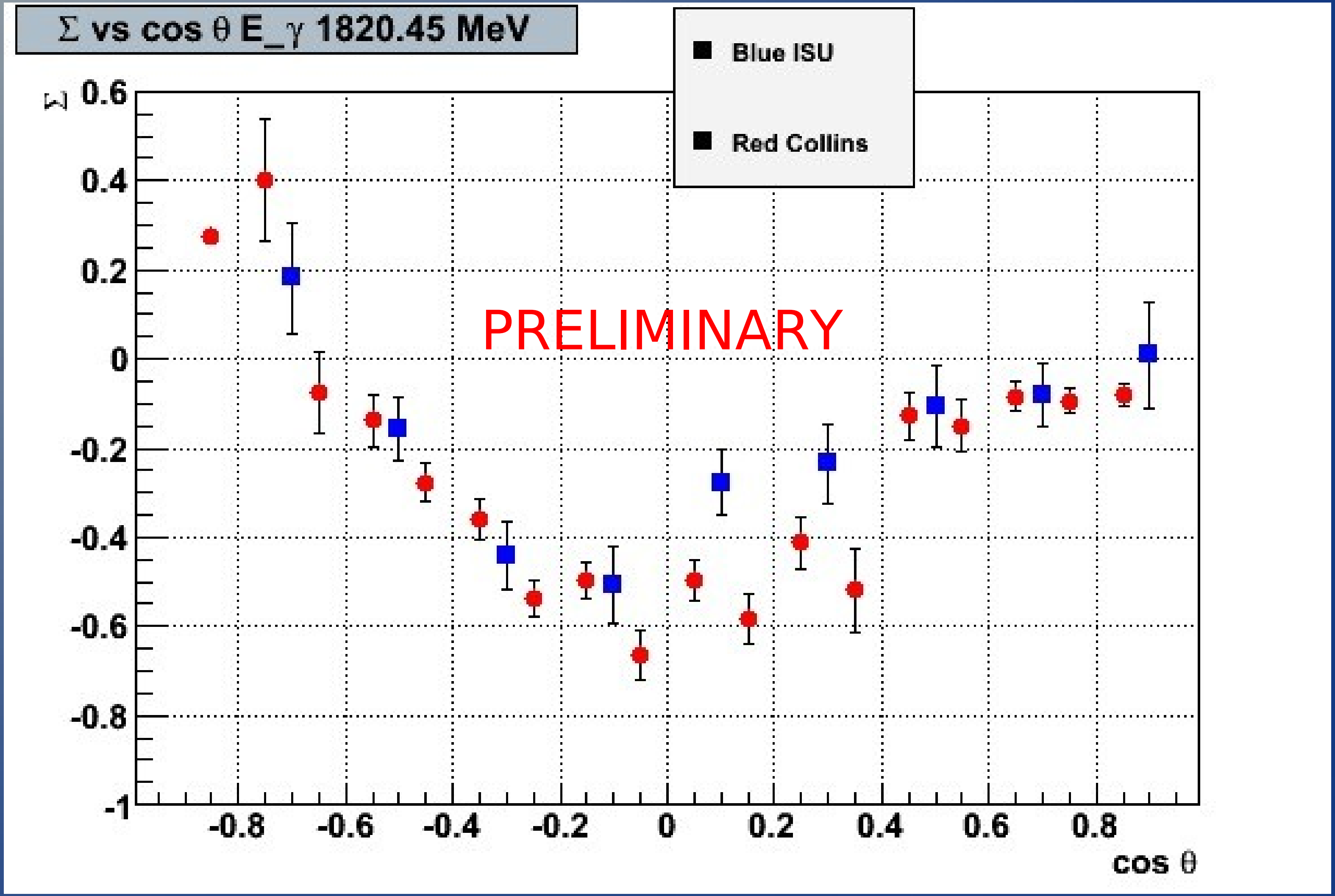


ω beam asymmetry
2σ cut

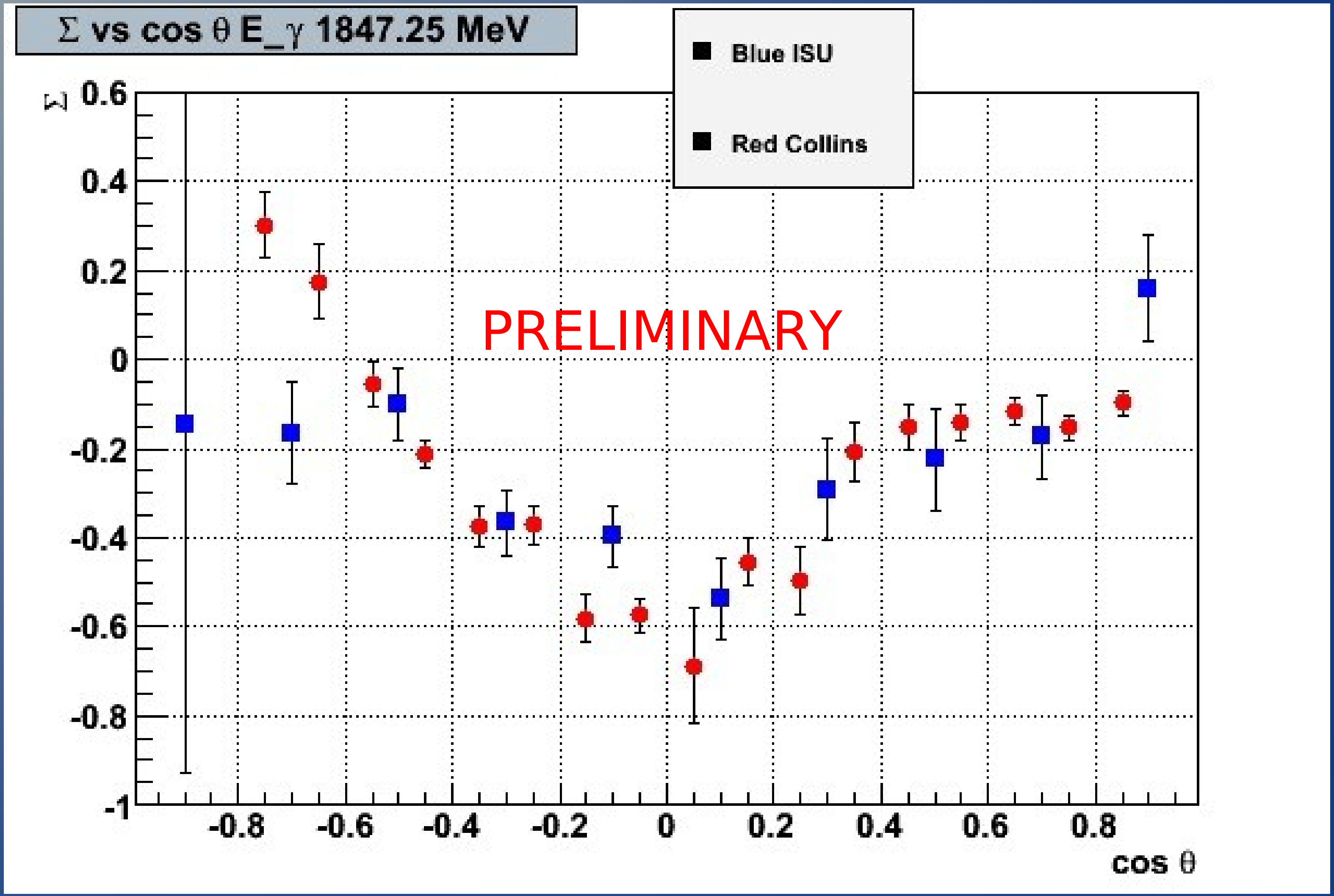



Σ vs cos θ for 1820.45, 1847.25, 1874.05 MeV
Blue 1820.45 MeV
Red 1847.25 MeV
Green 1874.05 MeV
Σ
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos θ
PRELIMINARY

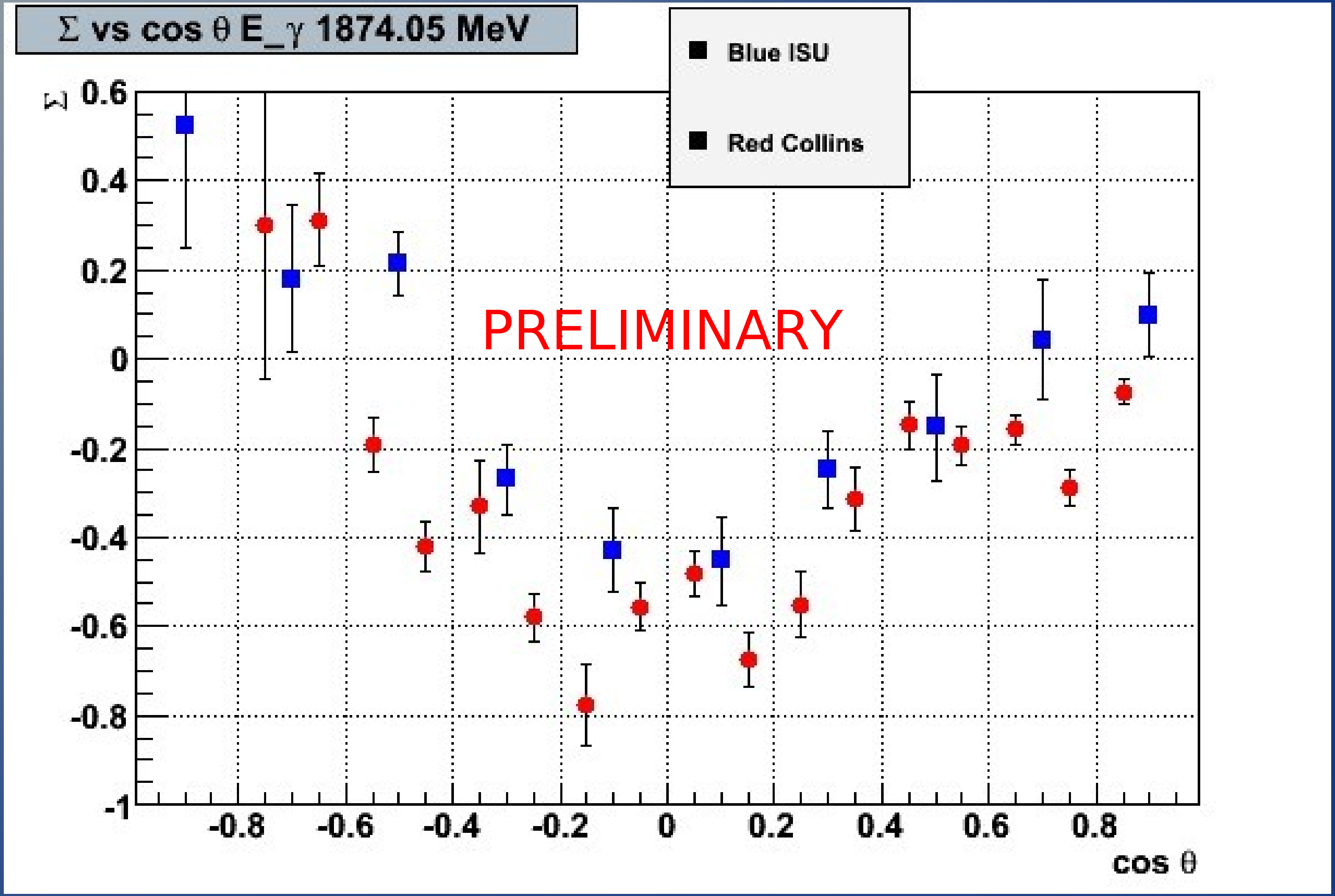
ω beam asymmetry
3σ cut

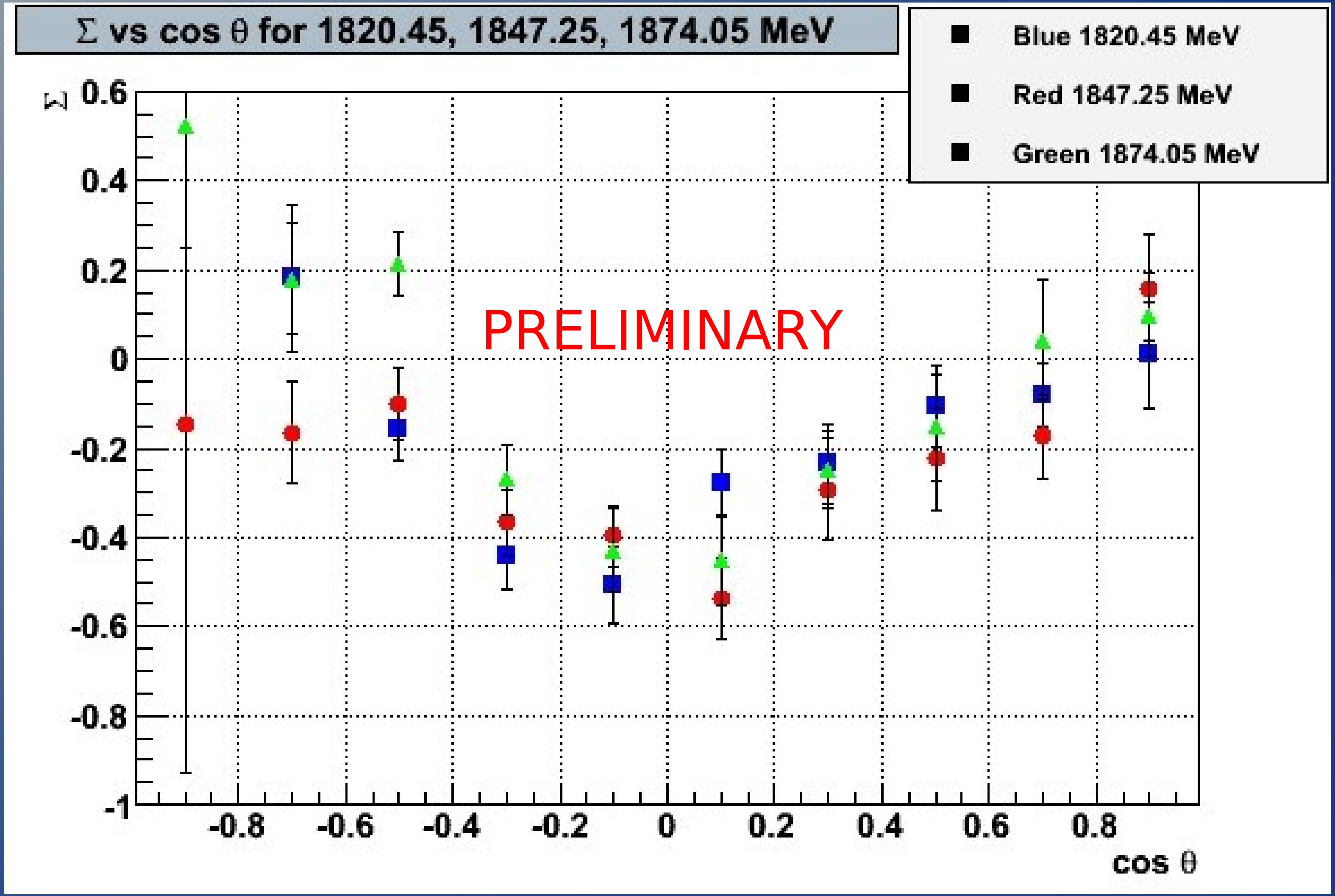


ω beam asymmetry
3σ cut



ω beam asymmetry
3σ cut





Σ vs cos θ for 1820.45, 1847.25, 1874.05 MeV
Blue 1820.45 MeV
Red 1847.25 MeV
Green 1874.05 MeV
PRELIMINARY
Σ
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos θ

PATH FORWARD

- Extraction of Σ.

  We have determined Σ through one technique.

  * *φ binning method*.

  And cross compared to:

  * *Moments method* (P. Collins).

  They agree → we have a good handle on our systematics.

  * Studies on the binning for both Cos Θ and φ are to be done.
  * Further studies have to be performed to reduce the background of the ω meson and thus clean up the signal.
  * 1.3, 1.5, and 1.7 data sets are yet to be studied.
  * 2.1 data set is currently being analyzed.

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PATH FORWARD

The first goal is to compare Σ with more mature analysis (Patrick Collins).

Extraction of Spin Density Matrix Elements ρ^{α}_{ij} (SDME).

$$W^L(\cos\theta,\phi,\Phi) = W^0(\cos\theta,\phi) - P_\gamma \cos 2\Phi W^1(\cos\theta,\phi) - P_\gamma \cos 2\Phi W^2(\cos\theta,\phi)$$

with

$$\begin{aligned}
W^0(\cos\theta,\phi) &= \frac{3}{4}\left[\frac{1}{2}\left(1-\rho^0_{00}\right) + \frac{1}{2}\left(3\rho^0_{00}-1\right)\cos^2\theta - \sqrt{2}Re\rho^0_{10}\sin 2\theta cos\phi - \rho^0_{1-1}\sin^2\theta cos2\phi\right] \\
W^1(\cos\theta,\phi) &= \frac{3}{4}\left[\rho^1_{11}\sin^2\theta + \rho^1_{00}\cos^2\theta - \sqrt{2}\rho^1_{10}\sin 2\theta cos\phi - \rho^1_{1-1}\sin^2\theta cos2\phi\right] \\
W^2(\cos\theta,\phi) &= \frac{3}{4}\left[\sqrt{2}Im\rho^2_{10}\sin 2\theta\sin\phi + Im\rho^2_{1-1}\sin^2\theta\sin 2\phi\right]
\end{aligned}$$

Σ will be used as a constraint for this SDMEs, since:

$$\Sigma = P_\gamma \frac{2(\rho^1_{11} + \rho^1_{1-1})}{1 - \rho^0_{00} + 2\rho^0_{1-1}}$$

If Helicity is conserved in the s-channel, then only two of the nine SDMEs are nonzero: $\rho^1_{1-1} = 0.5$ and $Im\rho^2_{1-1} = 0.5$, hence $\Sigma = 1$ when $P_\gamma = 1$ (with θ, ϕ determined in the helicity frame). Any deviation from this value is an indication that nondiffractive processes are present. If we assume natural parity as the production mechanism, then

$$\rho^1_{1-1} = 0.5,\ \rho^1_{00} = 0$$

If unnatural-parity exchange dominates, then

$$\rho^1_{1-1} = -0.5,\ \rho^1_{00} = 0$$