Dalitz Plot Analysis of $\eta' \to \eta\ \pi^+\ \pi^-$

Sudeep Ghosh for the CLAS Collaboration
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Indian Institute of Technology Indore, India

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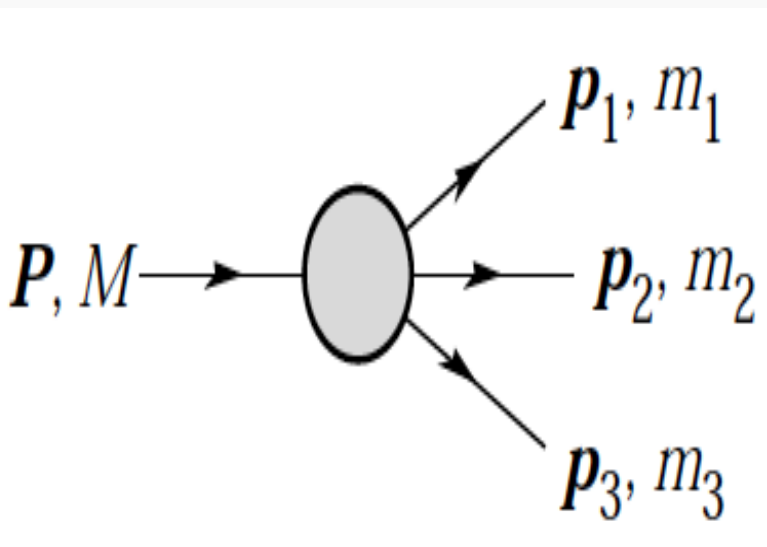
Plan of the talk

Motivation

- Highest statistics collected in the channel $\eta' \rightarrow \eta\ \pi^+\ \pi^-$ by CLAS in comparison to other experiments reported so far.
- Dalitz plot(DP) provides pure kinematic information of a three body decay.
- DP helps to understand the correct input in theoretical distribution of the effective chiral Lagrangian.
- The decay channel has a low Q-value, thus it will help to study effective chiral perturbation theory at a low Q limit.

Three body decay of scalar meson

Constraints	Degree of freedom
3 four-vectors	12
4-momentum conservation	-4
3 masses	-3
3 Euler angles	-3
TOT	2



So, we can describe the 3-body state with two variables

The Dalitz Plot

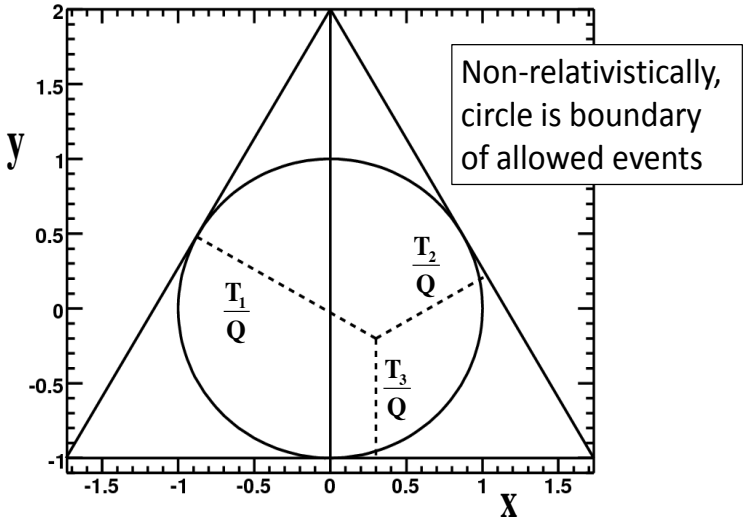
- We define a 2-D scatter plot,with one variable on the x-axis, and one on the y-axis.
- The Dalitz variables for $\eta' \rightarrow \eta + \pi^+ + \pi^-$ is defined as

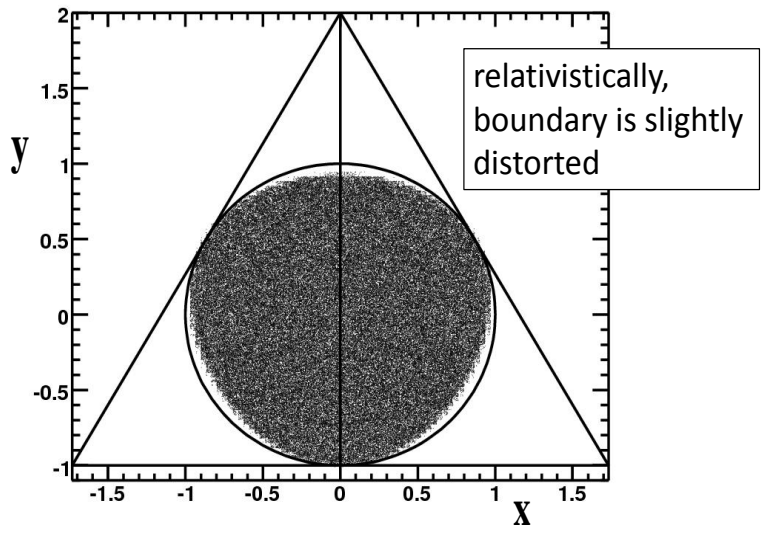
$$X = \frac{\sqrt{3}(T_{\pi^+} - T_{\pi^-})}{Q}, Y = \frac{(m_\eta + 2m_\pi)}{m_\pi} \cdot \frac{T_\eta}{Q} - 1, \qquad (1)$$

  where T_i $(i = \pi^+, \pi^-, \eta)$ is kinetic energy of a given particle in the rest frame of η' and $Q = T_{\pi^+} + T_{\pi^-} + T_\eta$.
- The boundary of the decay is given by

$$|{P_\eta}^2 - {P_{\pi+}}^2 - {P_{\pi-}}^2| \leq 2\vec{P}_{\pi+}.\vec{P}_{\pi-} \qquad (2)$$

The Dalitz Plot Geometry





$$\frac{T_1 + T_2 + T_3}{Q} = 1 \tag{3}$$

$$\rho(x, y) = \frac{1}{2J+1} \sum_{m_j} |A(m_j)|^2 \tag{4}$$

g12 Experiment in Hall B at Jefferson Lab

- g12 Run : Run taken from March - June 2008, 26 x 10^9 triggers recorded
- Beam : Bremsstrahlung process produces a real photon energy from 1.142 to 5.425 GeV
- Target : Unpolarised liquid hydrogen and its position was -90 cm from CLAS center

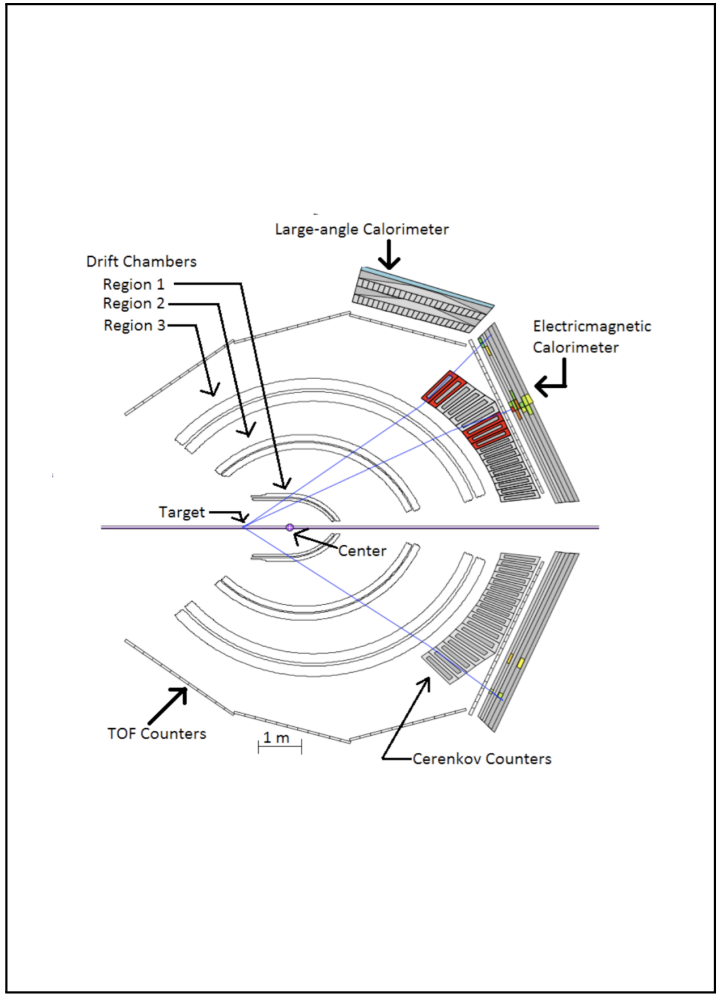
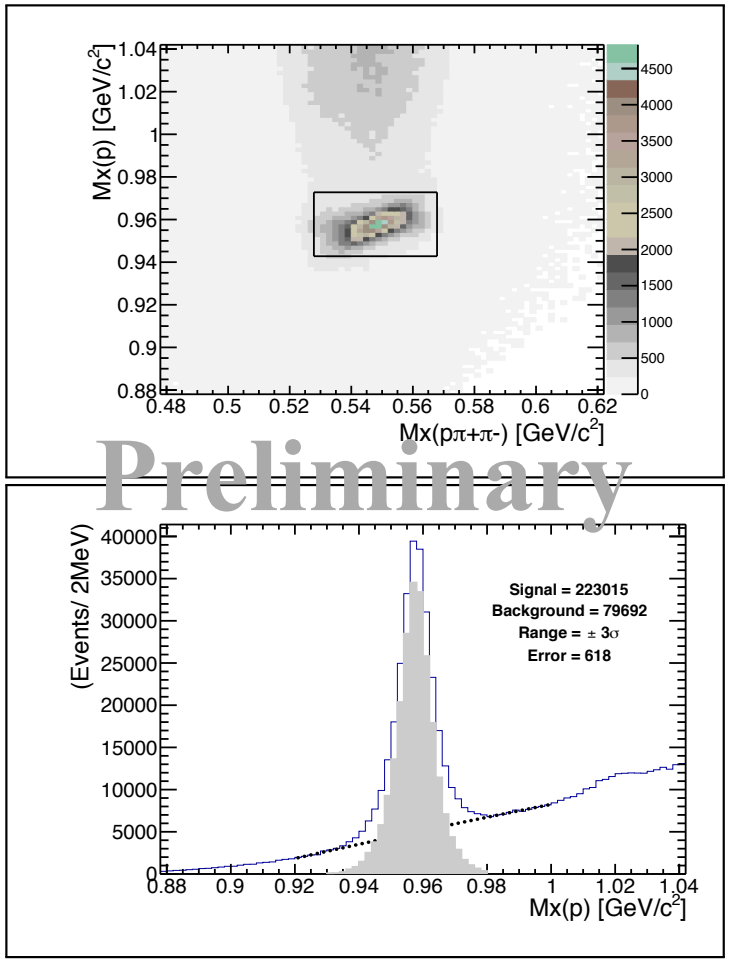


Fig : CLAS detector

Event Selection of γ p $\rightarrow \eta'(\rightarrow \eta\ \pi^+\ \pi^-)$ p

- The presorted data with one p, one π^+, one π^- and Xn number of neutral particles selected for analysis
- Beam Energy : 1.4553 to 3.2 GeV
- Kinematic Fitting : 1C fit to the missing mass of p, π^+ and π^- to be an η ie. Mx(p$\pi^+\pi^-$)=0.547 GeV is applied. All events with Prob $<$ 1% are rejected.
- -0.85 $<$ cos$(\theta)_{cm}$ of $\eta' <$ 0.85



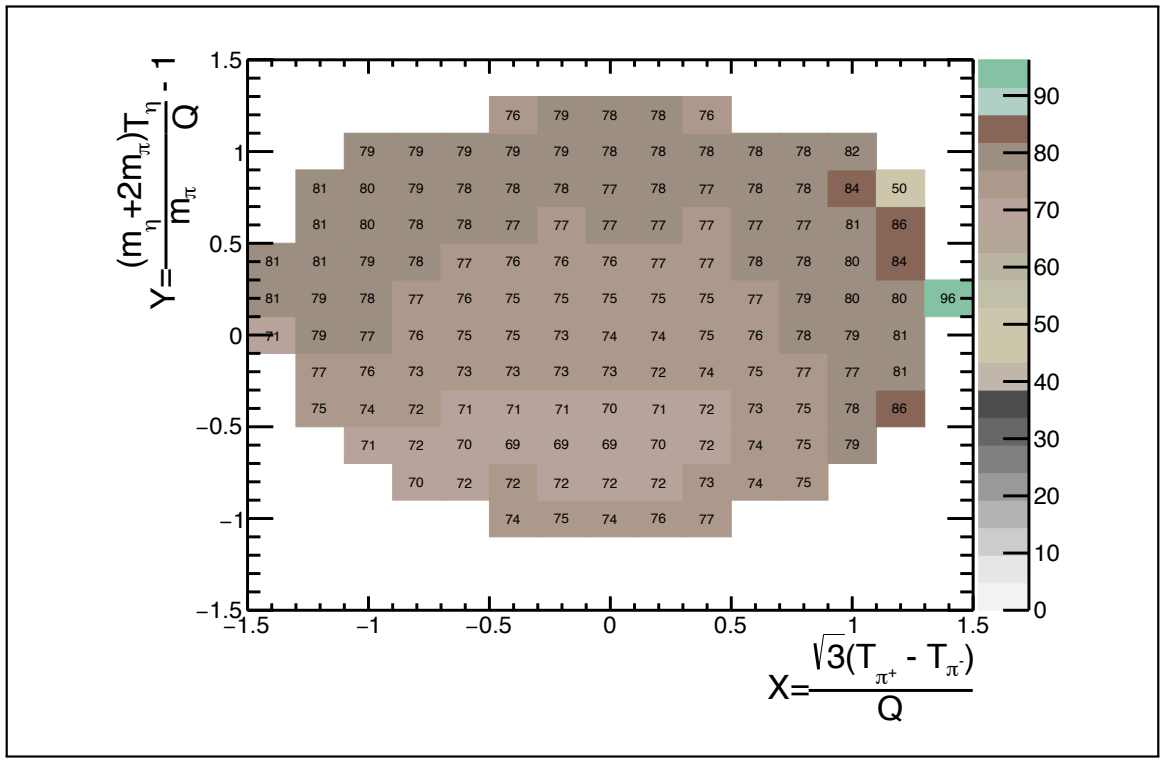
In Peak contribution

- $\eta' \to \eta\pi^+\pi^-$ decay generated with DP parameters a=-0.047, b=-0.069, c=0.019, d=-0.073 from BESIII[1]
  - Signal Channel : $\eta' \to (\eta)\pi^+\pi^-$ [42.9] $\to (\gamma\gamma)\pi^+\pi^-$ [72.90] [$BR_1 = \frac{(42.9*72.09)}{100} = 30.92$]
  - In Peak background Channel : $\eta' \to (\eta)\pi^+\pi^-$ [42.9] $\to (\pi^+\pi^-\pi^0)\pi^+\pi^-$ [27.14] [$BR_2 = \frac{(42.9*27.14)}{100} = 11.64$]
    - Secondary decay $\eta \to \pi^+\pi^-\pi^0$ are produced in phase space.
    - Channel produces combinatorics and has different acceptance to signal
- Background Channel : $\eta' \to (\eta)\pi^0\pi^0$ [22.2] $\to (\pi^+\pi^-\pi^0)\pi^0\pi^0$ [27.14] [$BR_3 = \frac{(22.2*27.14)}{100} = 6.02$] is generated with DP parameters a=-0.067, b=-0.064, c=0.0, d=-0.067 from GAMP[2]
  - Secondary decay $\eta \to \pi^+\pi^-\pi^0$ are produced in phase space.
  - Channel produces in peak contribution

[1] M. Ablikim et al. [BESIII Collaboration], Phys. Rev. D 83, 012003 (2011)
[2] *A.M.Bliketal.*, "Measurement of the matrix element for the decay $\eta' \to \eta\pi^0\pi^0$ with the GAMS-4π spectrometer," *Phys.Atom.Nucl.*72, 231(2009)

Channel contribution

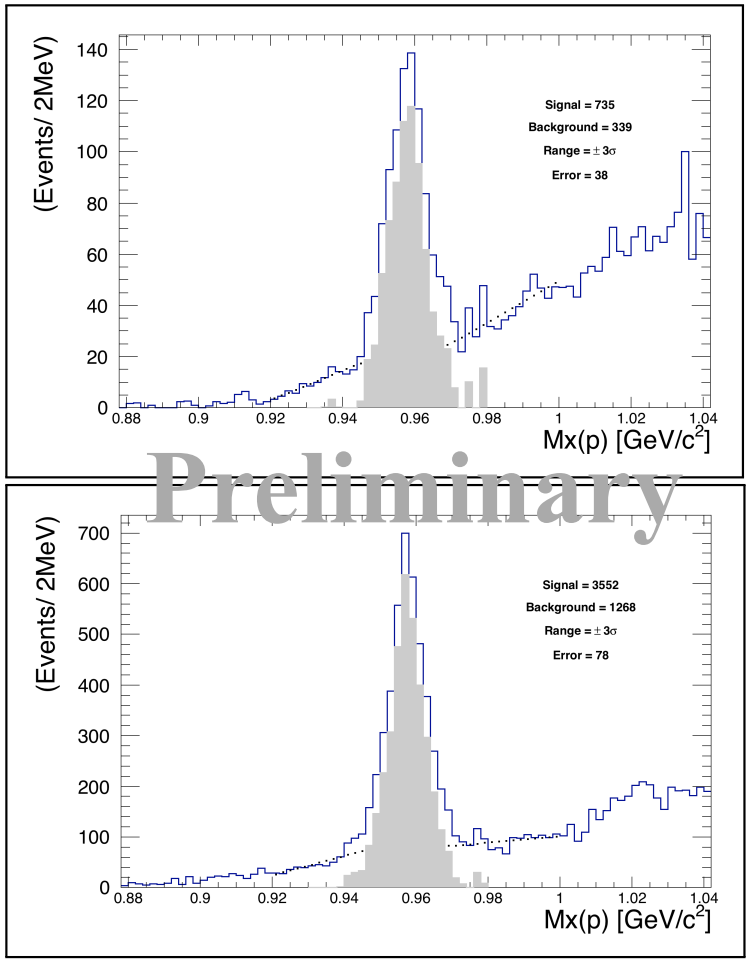
- Generated with input Bremsstrahlung beam and DP parameters.
- Normalised with differential cross section and branching ratio.



Efficiency of $\eta' \to (\eta)\pi^+\pi^- \to (\gamma\gamma)\pi^+\pi^-$

Subtraction of Background

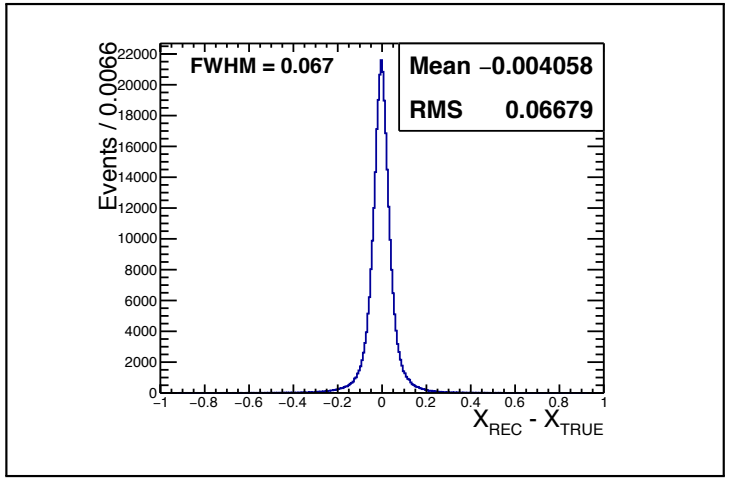
- 15 x 15 DP bins in X and Y
- The multi pionic background is subtracted with a polynomial of order 2
- Yield after non-resonant background subtraction is reduced by the "Percentage contribution of $\eta' \rightarrow (\eta)\pi^+\pi^- \rightarrow (\gamma\gamma)\pi^+\pi^-$ " DP bin
- So we have the not acceptance corrected DP

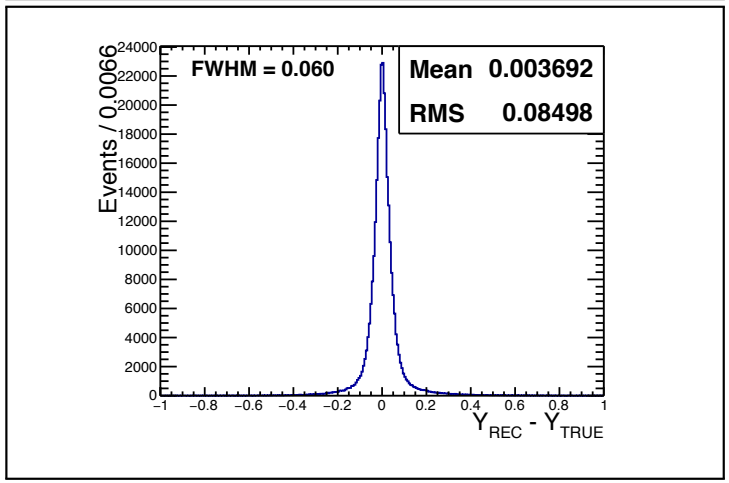


The bins with least and most number of events are shown in Fig. (Before reducing percentage contribution of yield)

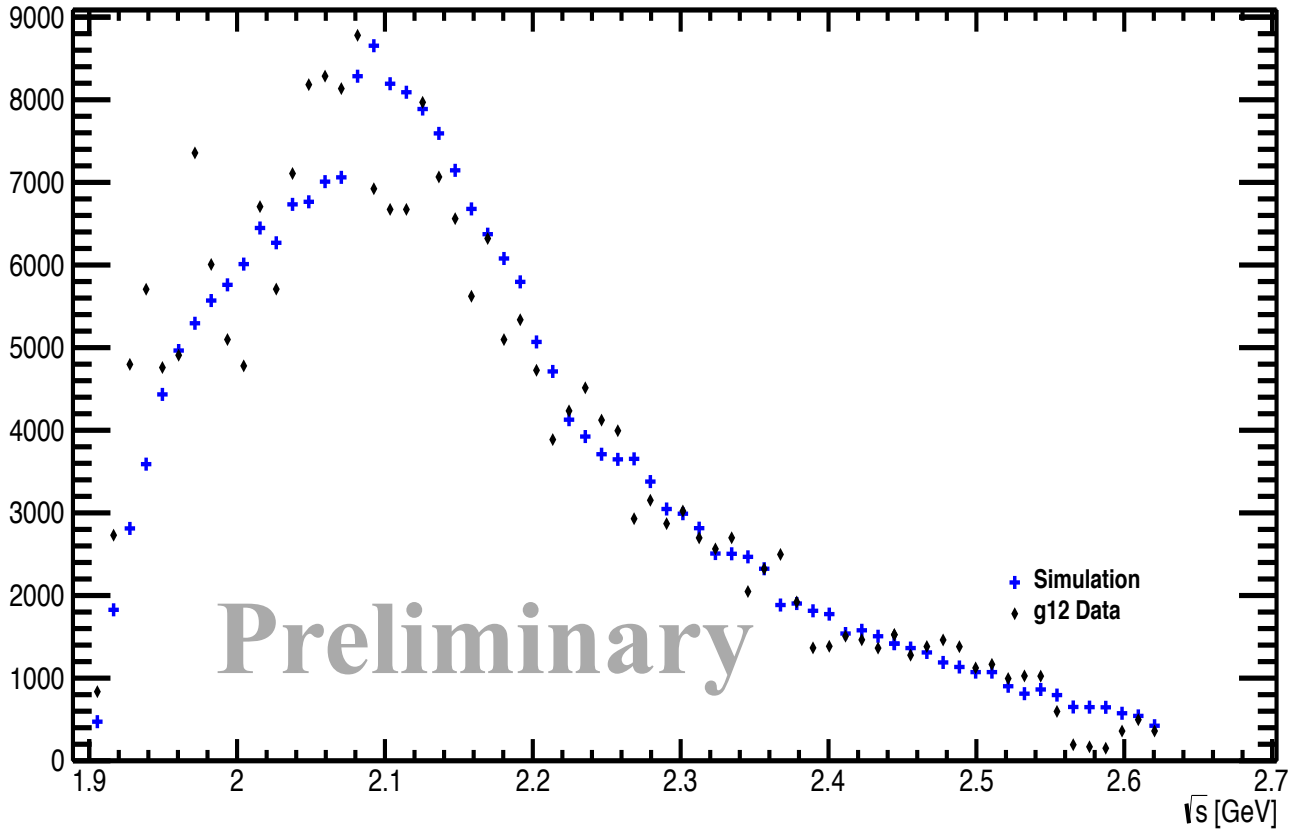
Simulation

- Using Pluto 2 x 10^7 events generated
  - Generated with input Bremsstrahlung beam and Differential Cross section information
  - Decay generated with input $\eta' \rightarrow \eta\ \pi^+\ \pi^-$ DP parameters from BESIII measurement
- Simulation take care of all the cuts into account as in data
- 15 x 15 DP selected for analysis, the bin-width is 0.2 to both X and Y.
- Boundary bins of $\eta' \rightarrow \eta\ \pi^+\ \pi^-$ DP are rejected

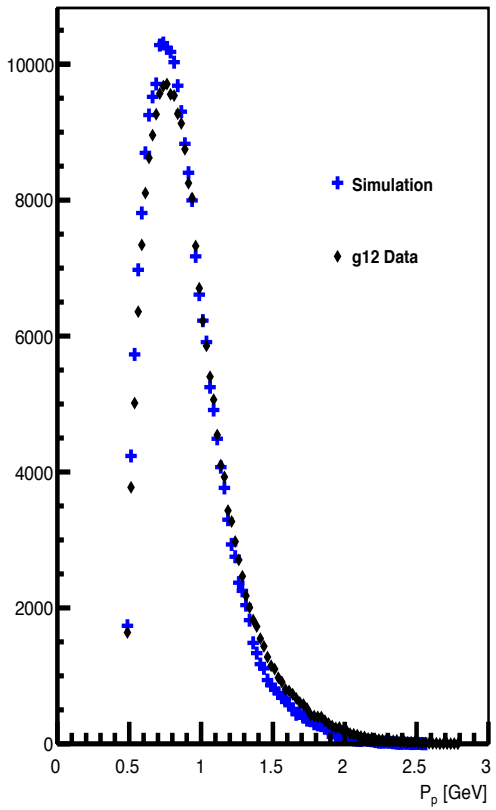


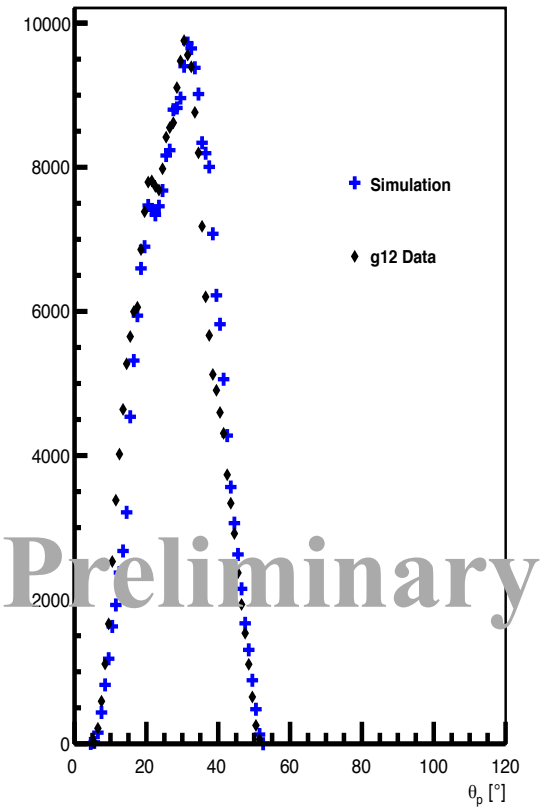


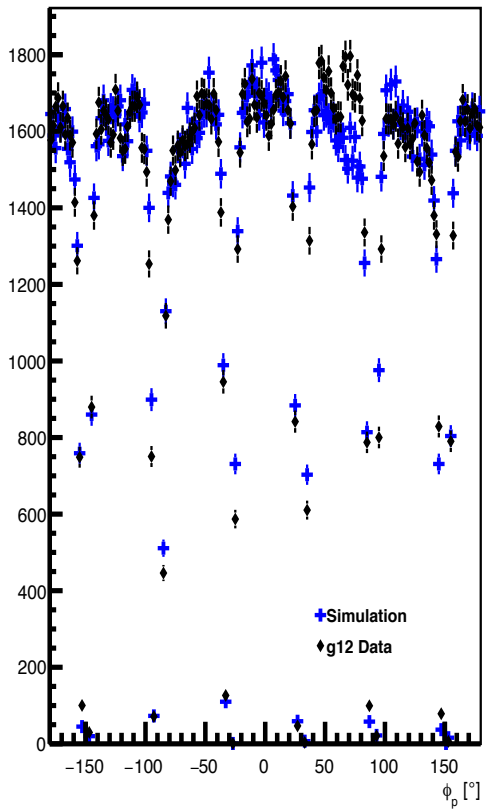
Comparison of the incident photon beam energy in center-of-mass



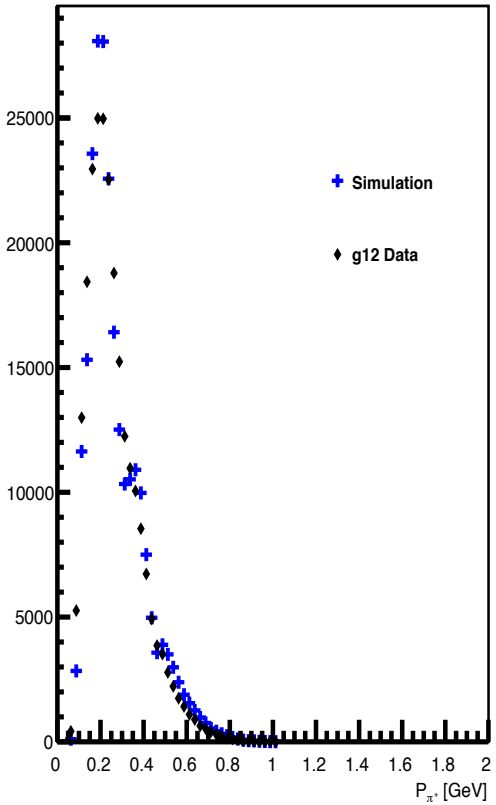
Comparison of Momentum, θ and ϕ of Proton

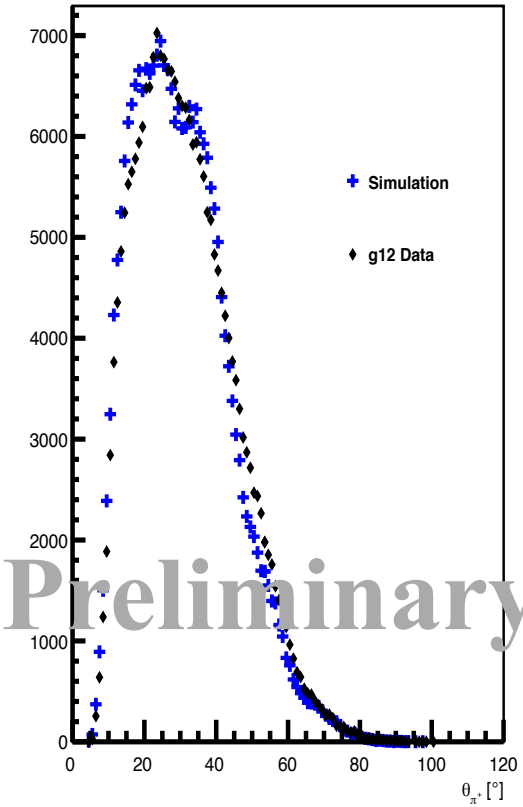


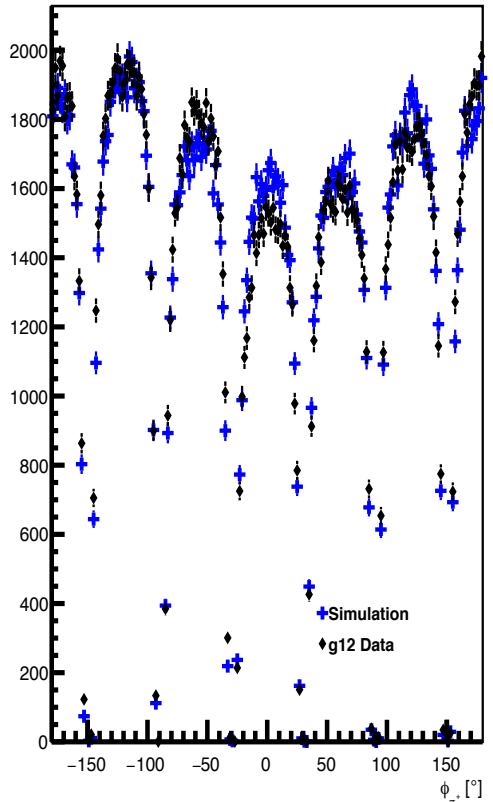




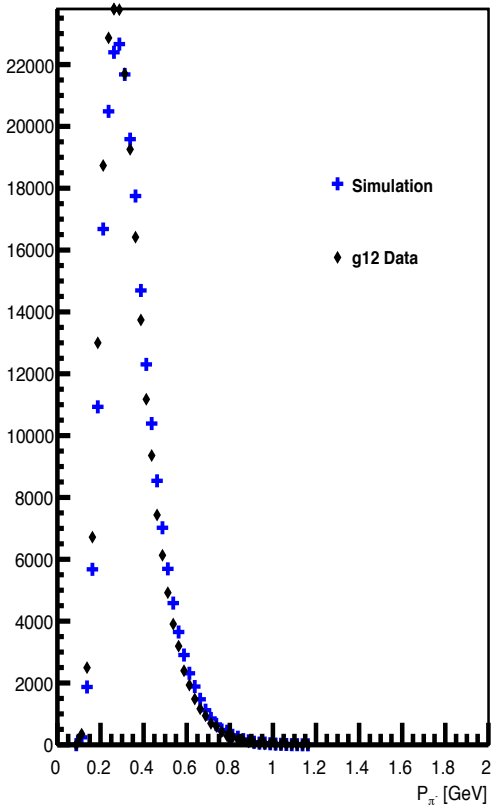
Comparison of Momentum, θ and ϕ of $\pi+$

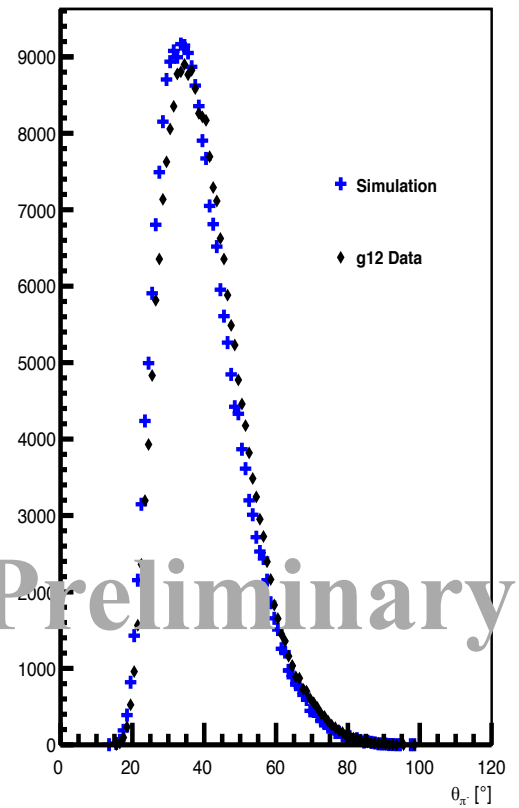


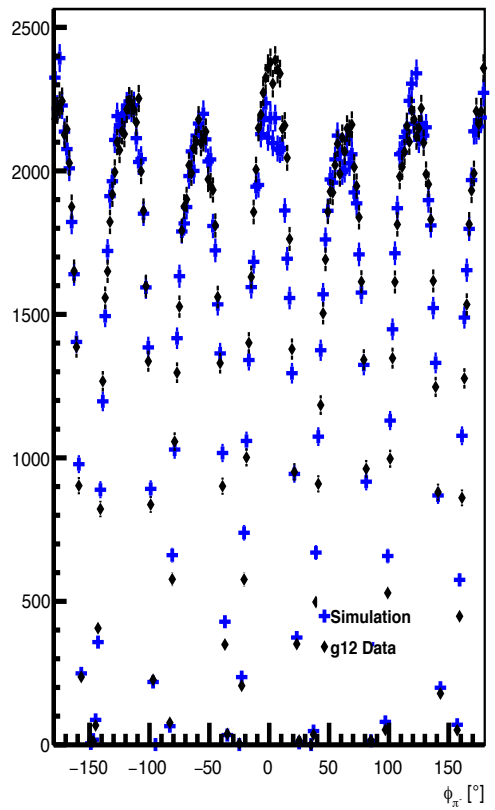




Comparison of Momentum, θ and ϕ of π-





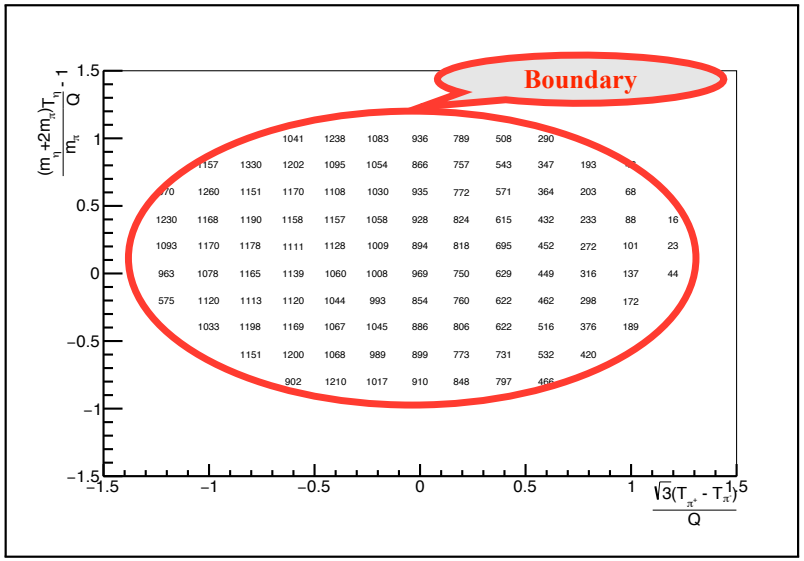


Fit to the Dalitz Plot

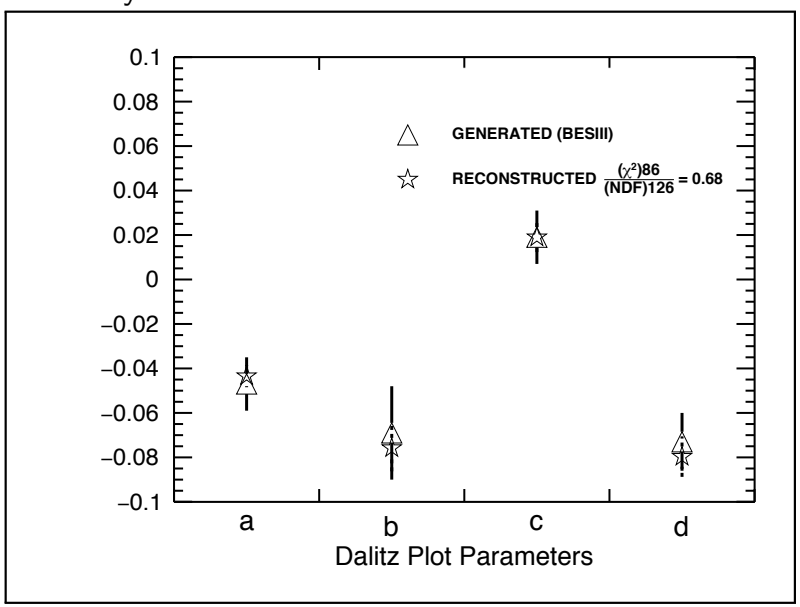
$$\chi^2 = \sum_{n=1}^{Nbins} \left(\frac{N_n - \sum_{m=1}^{Nbins} \epsilon_{n,m} N_{theory,m}}{\sigma_n} \right) 2$$

- N_n is no. of $\eta' \to \eta\ \pi^+\ \pi^-$ events in the n^{th} DP bin.
- $\epsilon_{n,m}$ is acceptance with smearing matrix, ie. it gives acceptance of m^{th} bin when events are generated in n^{th} bin.
- $N_{theory,m} = \int_{Boundary} A(1 + aY + bY^2 + cX + dX^2) dX dY$
- σ_n is the error associated with n^{th} DP bin.

Cross check to the analysis



Reconstructed events inside the Dalitz plot the boundary.



Comparison of generated and reconstructed DP parameters.

Parameters	Gen BESIII	CLAS Reco
a	-0.047±0.012	-0.043±0.005
b	-0.069±0.021	-0.075±0.010
c	+0.019±0.012	0.019±0.006
d	-0.073±0.013	-0.079±0.009

Conclusion

We obtain the Generated input parameters from the Simulated events, which cross-checks our analysis procedure.

Summary

Conclusion

We described the complete analysis and fitting technique in the talk, and obtained the proper input DP parameters from simulation to show a cross-check of the whole analysis procedure.

Future Plans

- Background subtraction in each bin of DP from data.
- Study the systematics.

Thank you

Email ID : sghosh@jlab.org