



Decay Kinematics for η Simulations

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Outline

- Basics of η decay kinematics for a few modes
 - Probably review for some, sorry
- And their implementation within GlueX software framework
- Top four decay modes implemented, more on to-do list



Simulation Framework

- genEtaRegge handles η production
 - Can input kinematics EvtGen handles η decays
 - for each decay mode in this framework
 - Also, by default uses PHOTOS for final state radiation
- For 3+ body decay modes, the kinematics may deviate from phase space quite significantly!



Decay Modes Implemented (so far)

- $\eta \rightarrow \gamma\gamma$ (is just phase space, nothing to add)
- $\eta \rightarrow \pi^+\pi^-\pi^0$ (all work by Sean + Daniel)
- $\eta \rightarrow \pi^0\pi^0\pi^0$ (new)
- $\eta \rightarrow \pi^+\pi^-\gamma$ (updated)

$$\eta \rightarrow \pi^+ \pi^- \pi^0$$

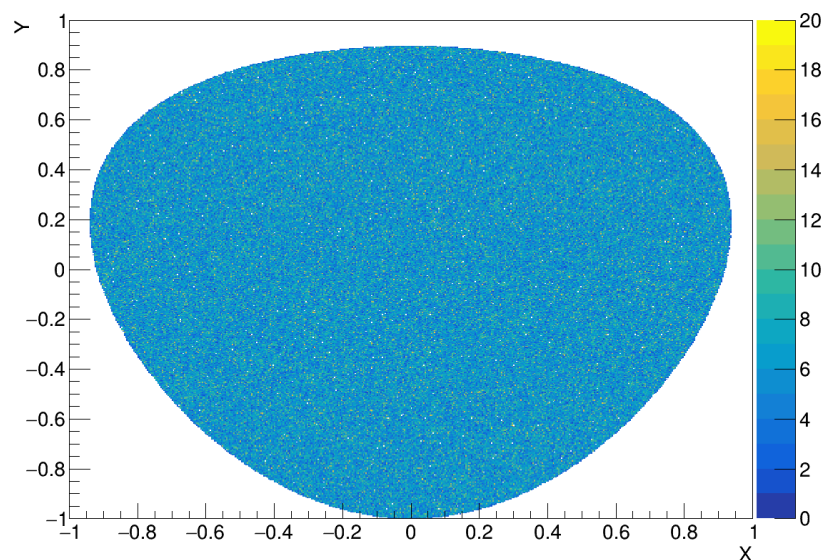
- Kinematic distribution usually expressed in terms of Dalitz parameters X, Y
 - $X \propto \pi^+, \pi^-$ momentum difference in rest frame
 - $Y \propto \pi^0$ momentum in rest frame
- Distribution of events (amplitude squared) expressed as Taylor expansion
$$|A(X, Y)|^2 = N (aY + bY^2 + cX + dX^2 + eXY + fY^3 + gX^2Y + \dots)$$
- Inputs to EvtGen: a, b, \dots, f, g constants measured from past experiments
 - Use “ETA_DALITZ_GLUEX”.
 - Not “ETA_DALITZ”! This is from the 70’s.



$\eta \rightarrow \pi^+ \pi^- \pi^0$ Dalitz Distribution

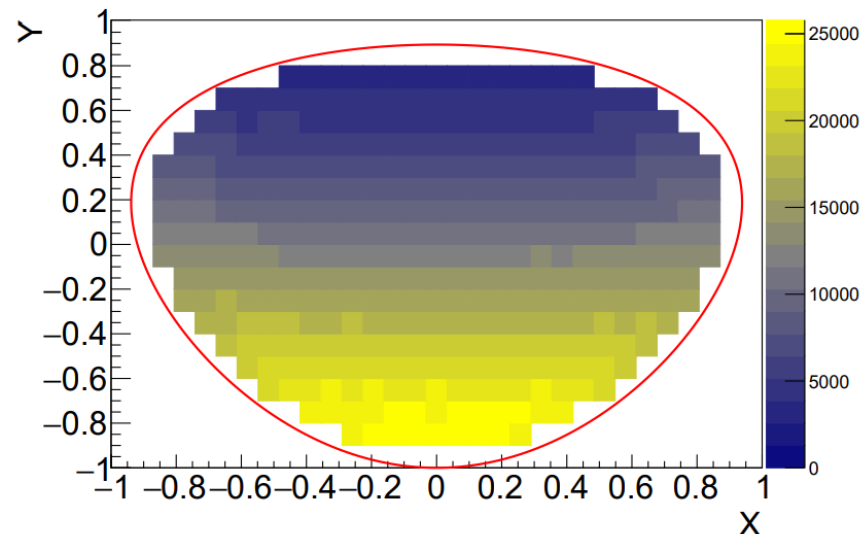
Phase space

$\pi^+ \pi^- \pi^0$ Dalitz Distribution



KLOE

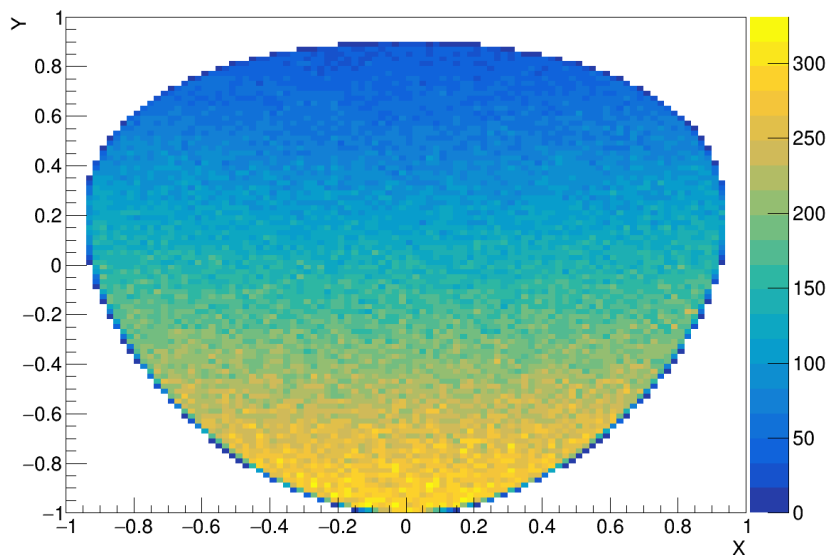
<https://arxiv.org/pdf/1601.06985.pdf>



$\eta \rightarrow \pi^+ \pi^- \pi^0$ Dalitz Distribution

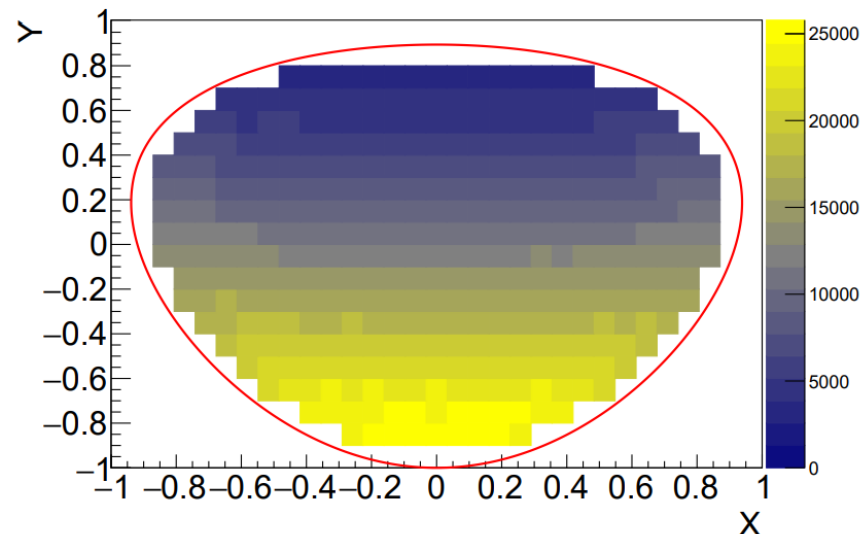
“ETA_DALITZ_GLUEX”

$\pi^+ \pi^- \pi^0$ Dalitz Distribution



KLOE

<https://arxiv.org/pdf/1601.06985.pdf>

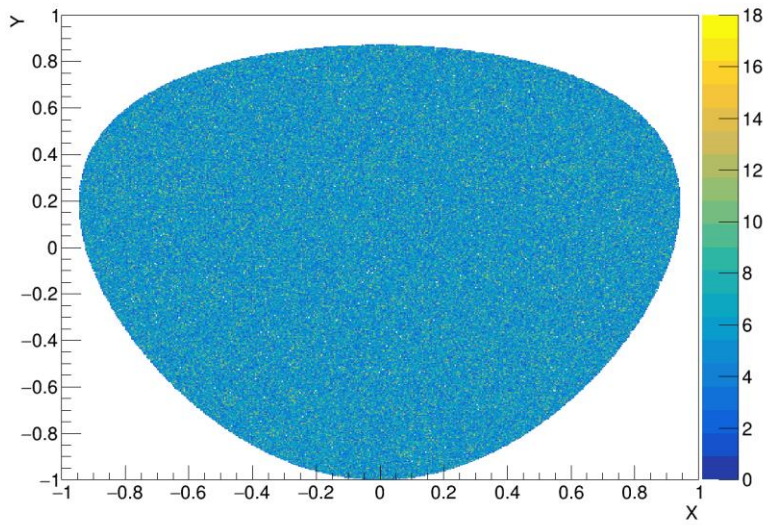


$$\eta \rightarrow \pi^0 \pi^0 \pi^0$$

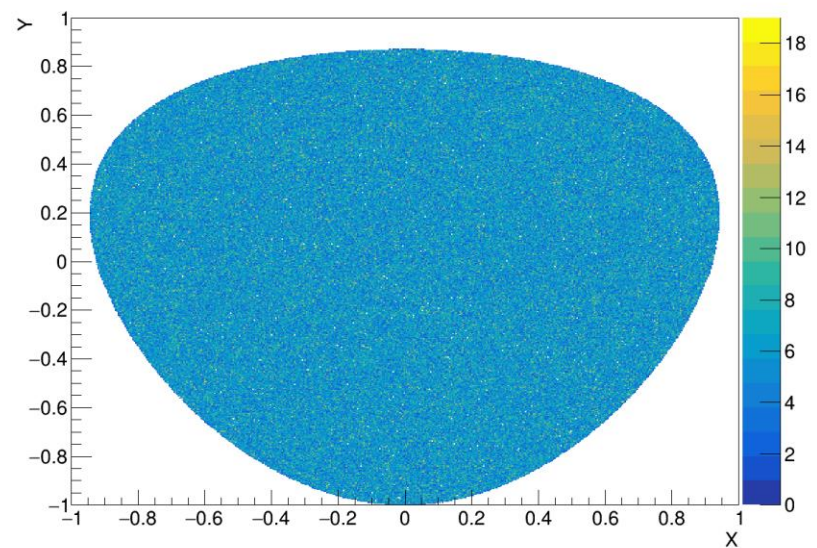
- Same formalism as $\eta \rightarrow \pi^+ \pi^- \pi^0$
 - Except the three π^0 s are identical particles
 - Only radial direction of (X,Y) plot matters ($z \equiv X^2 + Y^2$)
- Event distribution:
 - $|A(z)|^2 = N(1 + 2\alpha z + \beta z^{3/2} \sin(3\phi) + 2\gamma z^2 + \dots)$
 - Input parameters α, β, γ
- Deviations from phase space quite small
 - α measured reasonably well
 - β, γ small, less precisely known

$\eta \rightarrow \pi^+ \pi^- \pi^0$ Dalitz Distribution

$\pi^0 \pi^0 \pi^0$ Dalitz Distribution



$\pi^0 \pi^0 \pi^0$ Dalitz Distribution





Z distribution

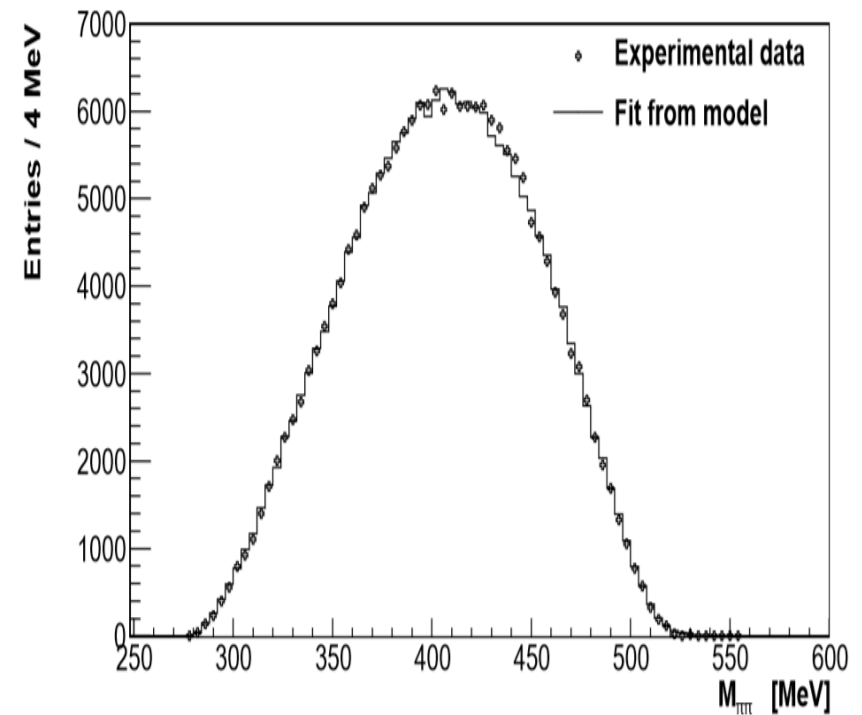
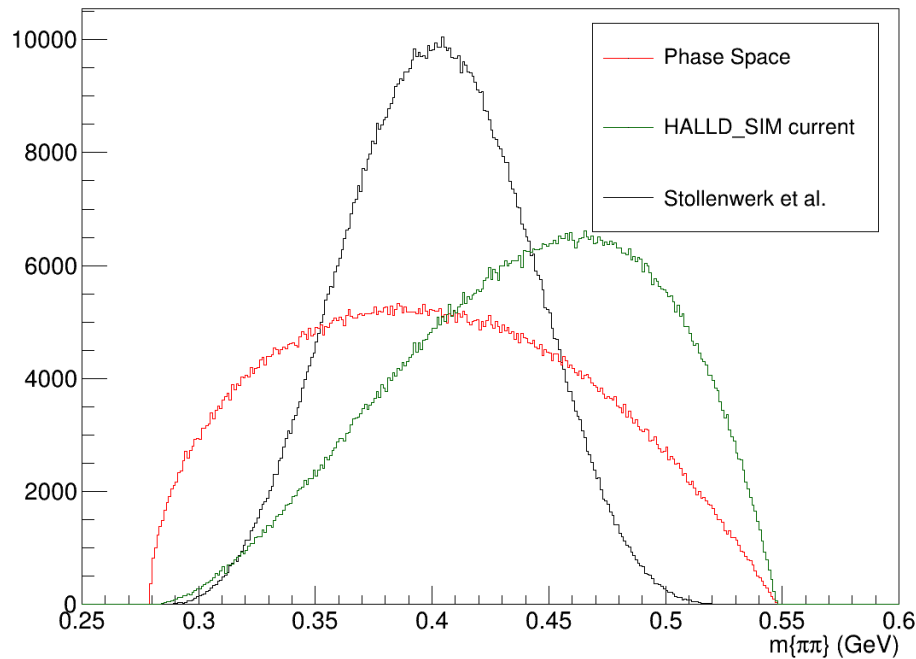
$$\eta \rightarrow \pi^+ \pi^- \gamma$$

- Assuming P-wave dominance
- Event distribution as a function of $s_{\pi\pi} (\equiv m_{\pi\pi}^2)$:
 - $A(s) = |P(s)F_V(s)|^2 \Gamma_0(s)$
 - $P(s)$ a process specific part, must be measured
 - F_V vector form factory, process independent
 - Γ_0 kinematical factors
- Quantities described: $m_{\pi\pi}$ and E_γ distributions
- Ref: F. Stollenwerk et al. <https://arxiv.org/abs/1108.2419v3>



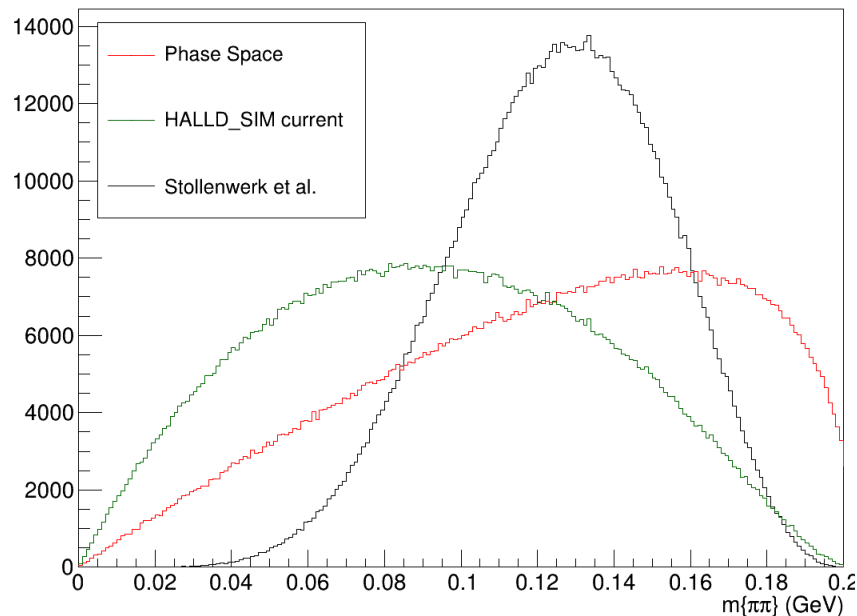
$\eta \rightarrow \pi^+ \pi^- \gamma: m_{\pi\pi}$ Distribution

$m_{\pi\pi}, \eta \rightarrow \pi\pi\gamma$



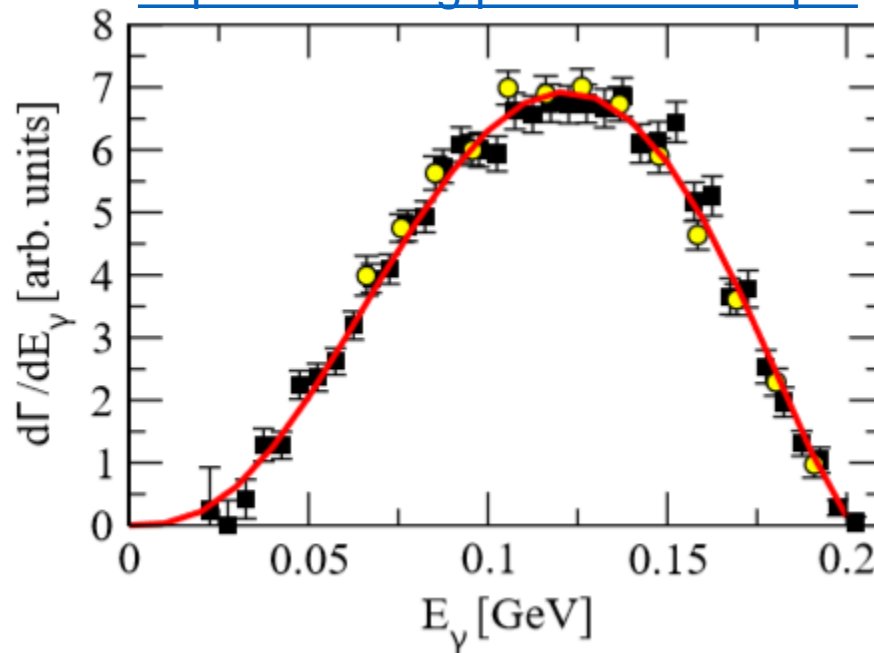
$\eta \rightarrow \pi^+ \pi^- \gamma: E_\gamma$ Distribution

E_γ in η cm, $\eta \rightarrow \pi\pi\gamma$



WASA-at-COSY

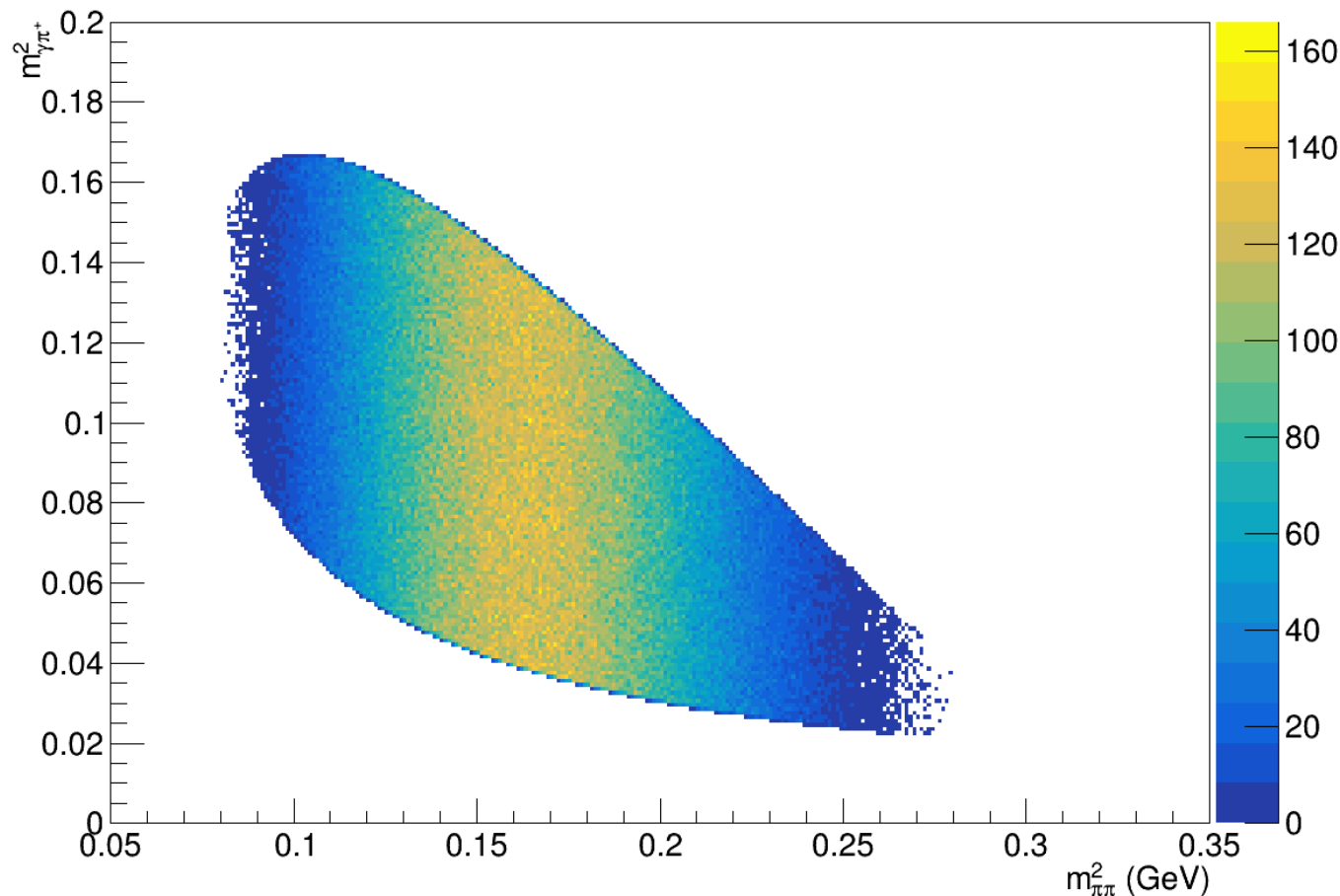
<https://arxiv.org/pdf/1107.5277.pdf>





Dalitz Mass² Plot, $\eta \rightarrow \pi^+ \pi^- \gamma$

$\eta \rightarrow \pi\pi\gamma$ Dalitz



This ok for $\pi^+ \pi^-$ in a P-wave?



Backup: How To Create η Decay Model

- All development happens in HALLD_SIM repository
 - `$HALLD_SIM_HOME/src/libraries/EVTGEN_MODELS`
 - Add model here (follow examples)
 - Be sure to recompile genEtaRegge and decay