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 kinematicsEvtGen 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)

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

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

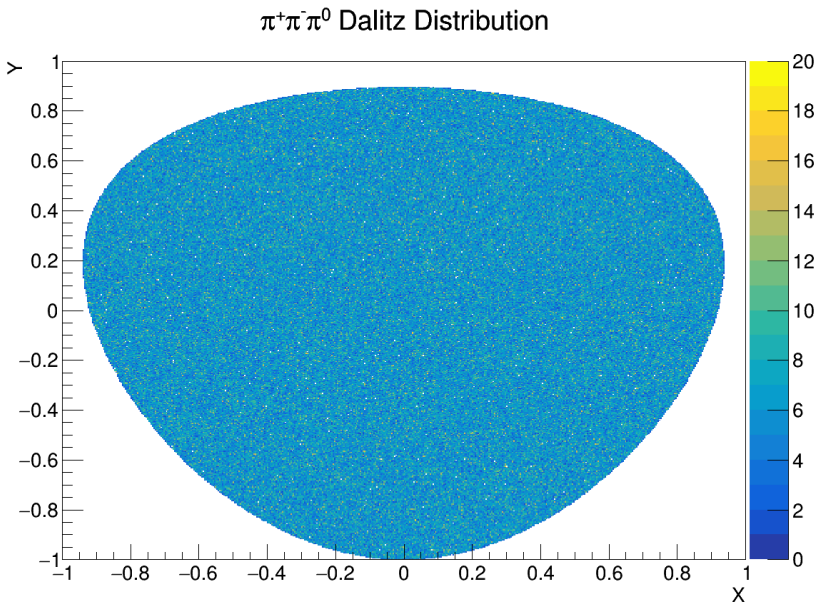
- Kinematic distribution usually expressed in terms of Dalitz parameters X, Y
  - X $\propto$ π^+, π^- momentum difference in rest frame
  - Y $\propto \pi^0$ momentum in rest frame
- Distribution of events (amplitude squared) expressed as Taylor expansion

$$|A(X,Y)|^2 = \mathrm{N}\,(\mathrm{aY} + \mathrm{bY}^2 + \mathrm{cX} + \mathrm{dX}^2 + \mathrm{eXY} + \mathrm{fY}^3 + \mathrm{gX}^2\mathrm{Y} + \cdots)$$

- Inputs to EvtGen: $a, b, \ldots, f, g$ constants measured from past experiments
  - Use “ETA_DALITZ_GLUEX”.
  - Not “ETA_DALITZ”! This is from the 70’s.

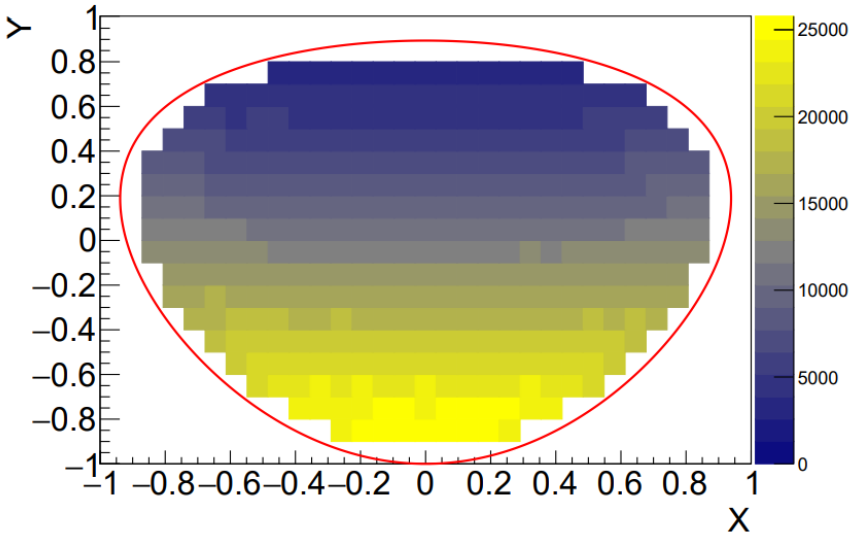
$\eta \rightarrow \pi^+\pi^-\pi^0$ Dalitz Distribution

Phase space



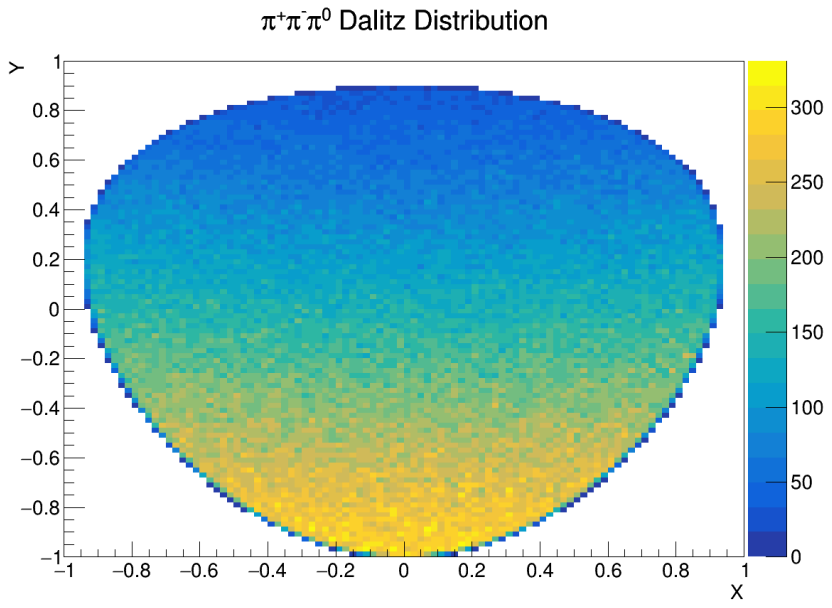
KLOE

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



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

"ETA_DALITZ_GLUEX"



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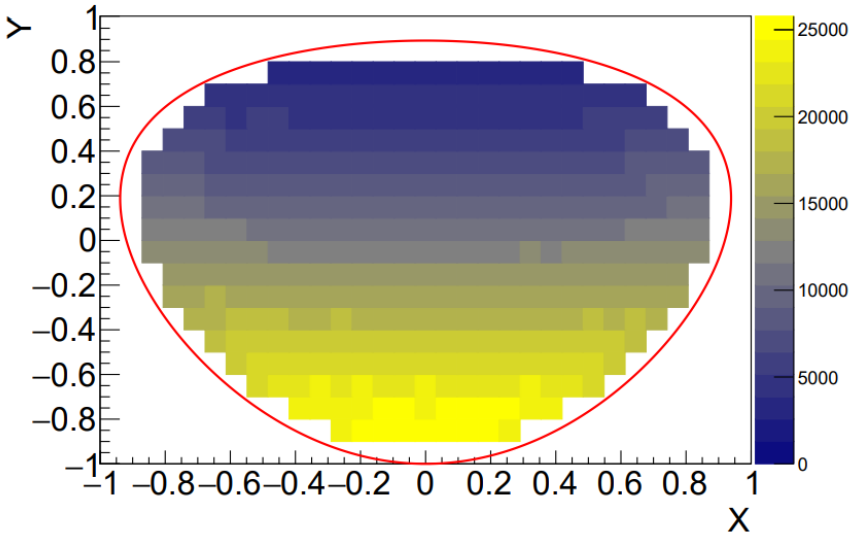


$\eta \to \pi^0\pi^0\,\pi^0$

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

Z distribution

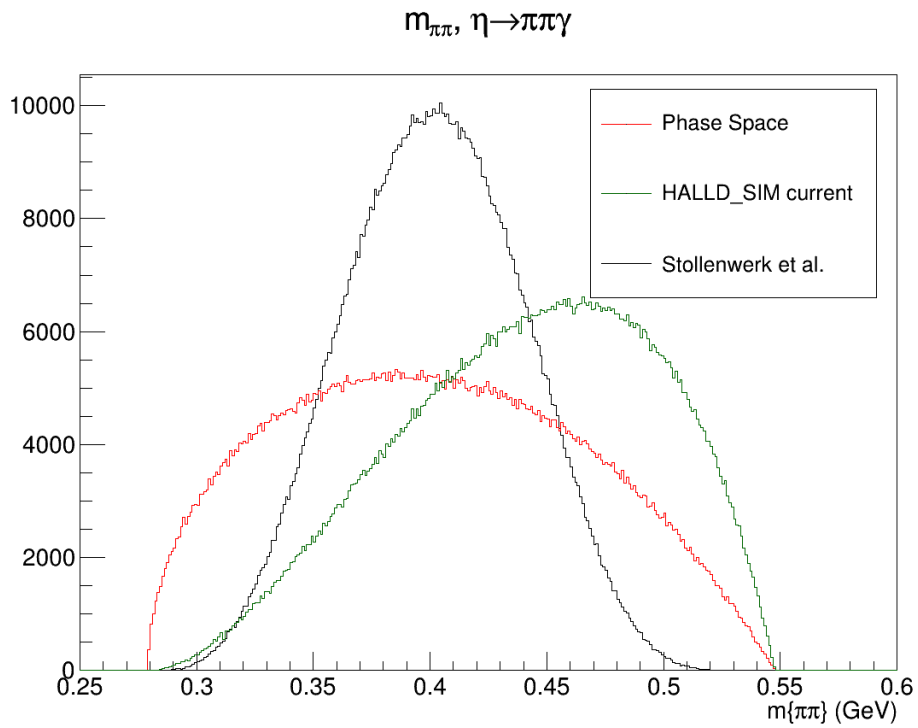
- [bug found, need to fix]

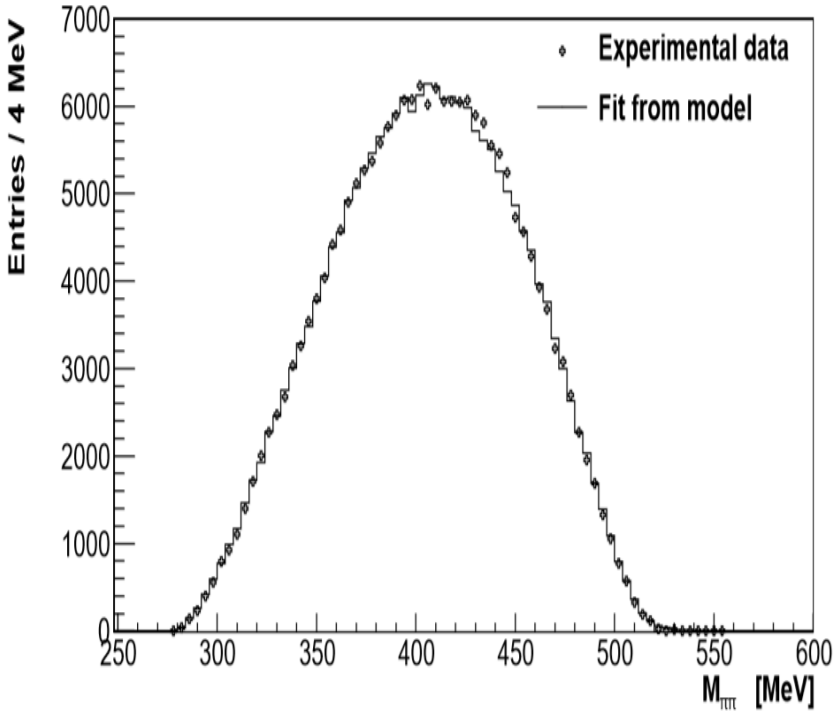
$\eta \to \pi^+\pi^-\gamma$

- Assuming P-wave dominance
- Event distribution as a function of $s_{\pi\pi}(\equiv m^2_{\pi\pi})$:
  - $A(s) = |P(s)F_V(s)|^2\Gamma_0(s)$
  - 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

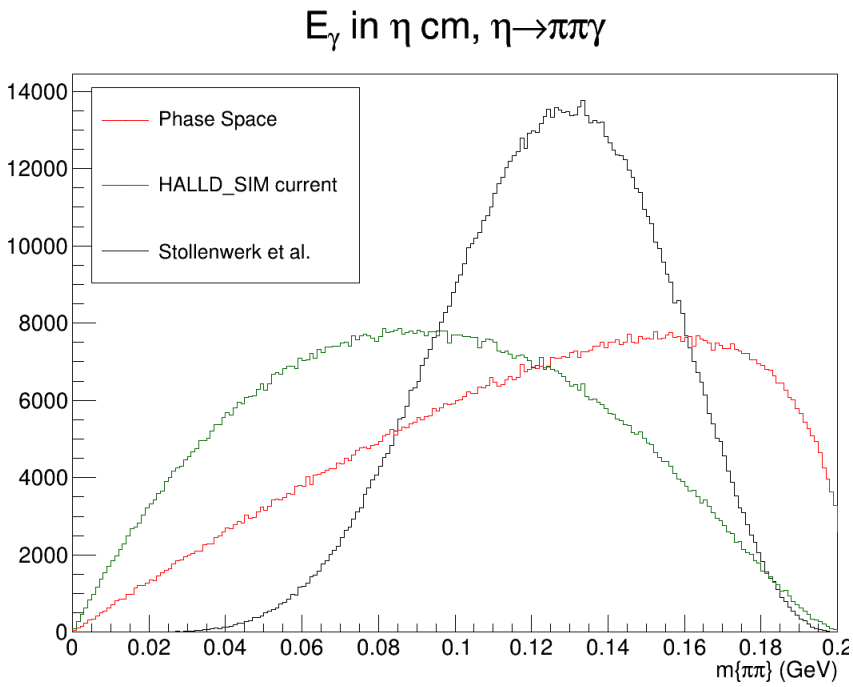
- Ref: F. Stollenwerk et al. https://arxiv.org/abs/1108.2419v3

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

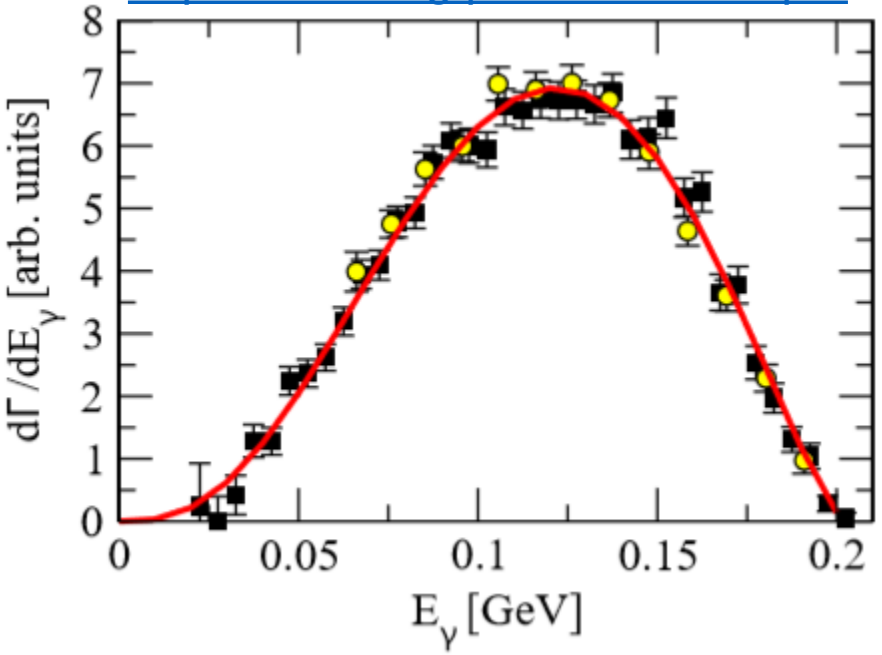




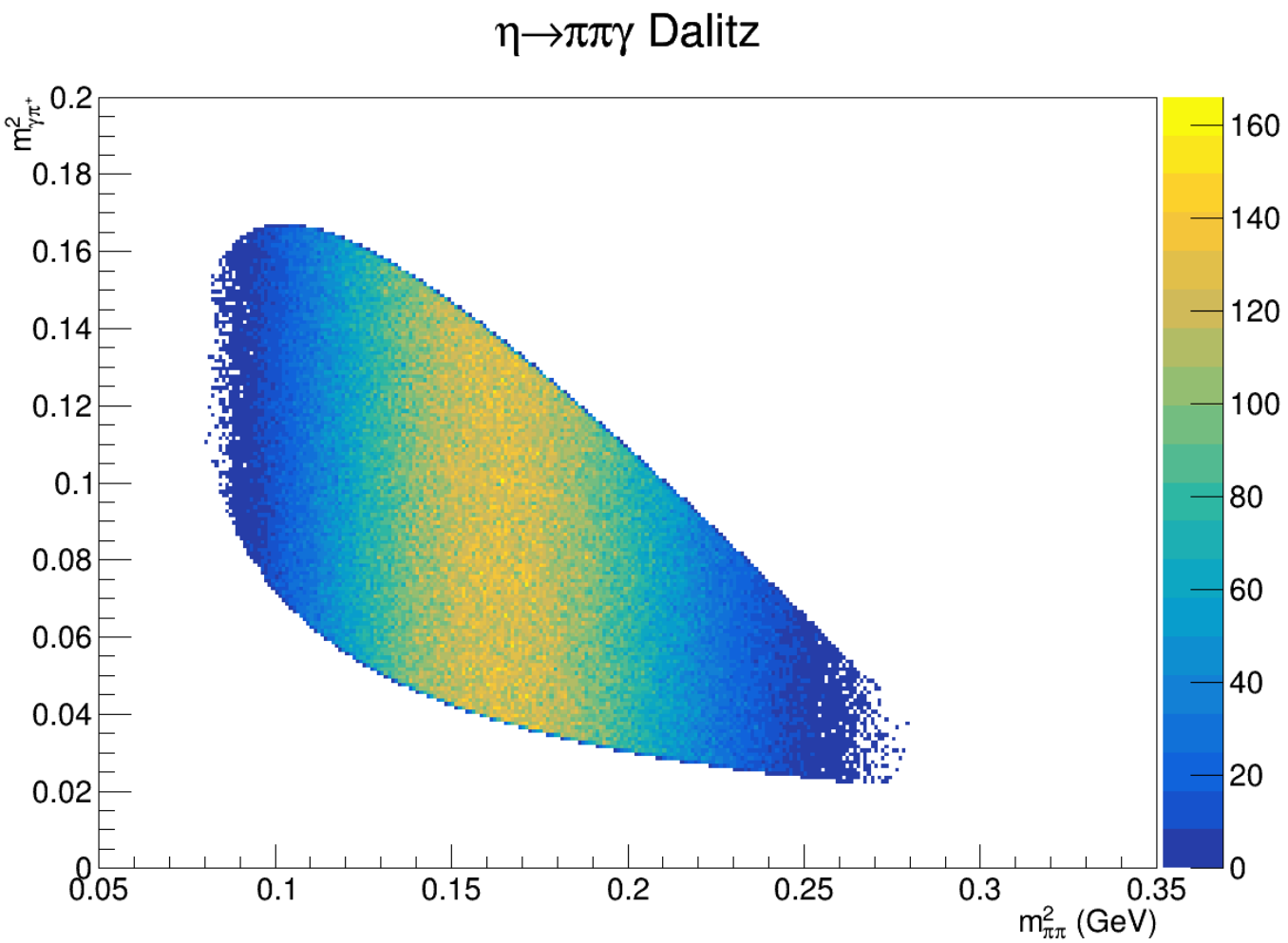
$\eta \to \pi^+\pi^-\gamma$: E_γ Distribution



WASA-at-COSY
https://arxiv.org/pdf/1107.5277.pdf



Dalitz Mass^2 Plot, $\eta \rightarrow \pi^+\pi^-\gamma$



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