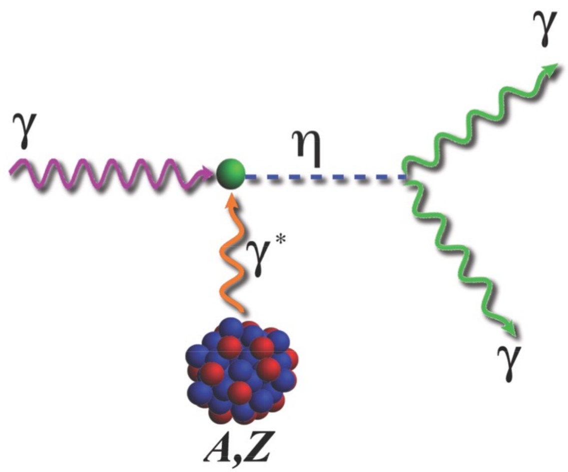

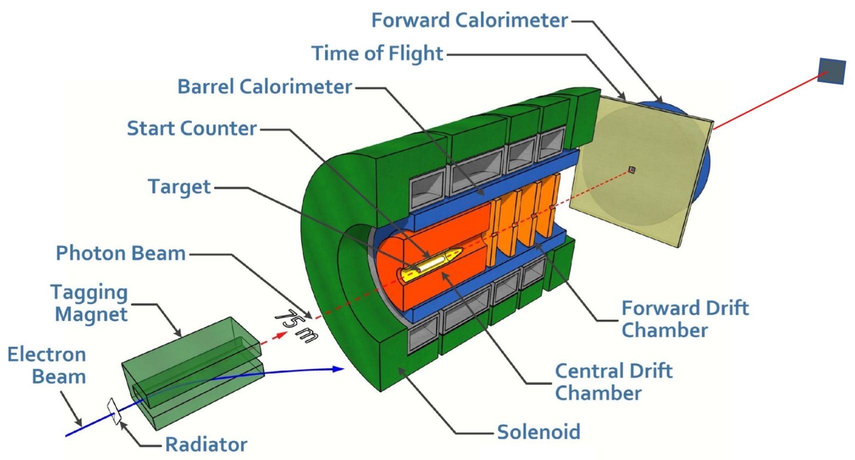

PrimeX-η experiment

Jlab Experiment E12-10-011

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On behalf of the GlueX Collaboration

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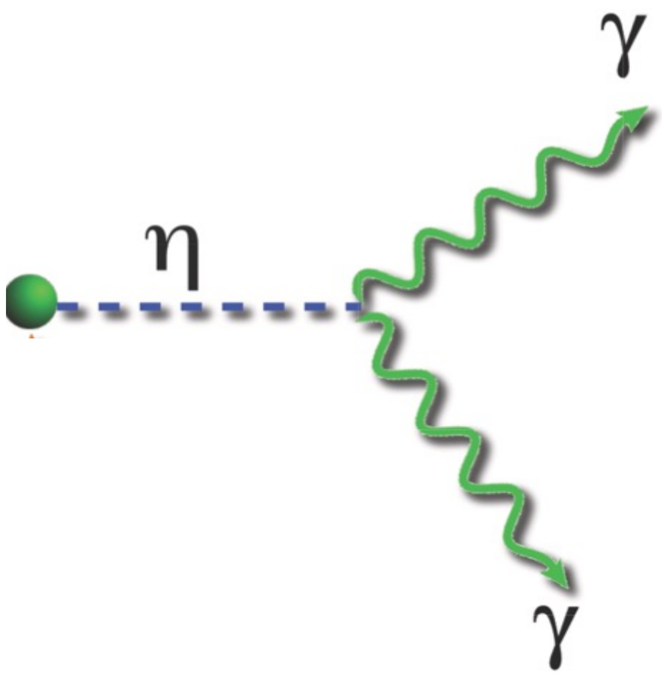
PrimEX D5.5

GLUEX

Outline

- Significance of $\Gamma_{\eta \to \gamma\gamma}$
- Previous/current production of eta
- Determination of the decay width
- Detector set up and description
- Current status



We are interested in $\boldsymbol{\Gamma_{\eta \to \gamma\gamma}}$

mixing angle $(\eta - \eta')$

From $SU(3)_{flavor}$ theory of quarks, the eta and eta prime states are:

$$\eta_0 = \frac{1}{\sqrt{3}}(u\bar{u} + d\bar{d} + s\bar{s})$$ singlet

$$\eta_8 = \frac{1}{\sqrt{6}}(u\bar{u} + d\bar{d} - 2s\bar{s})$$ octet

Due chiral symmetry breaking→ Mixing of the eigenstates

Goldstone bosons have mass & their masses are unequal

The η_8 and η_0 can be linked to the physical states η and η’ by the following expression:

$$\begin{pmatrix} \eta \\ \eta' \end{pmatrix} = M(\theta) \begin{pmatrix} \eta_8 \\ \eta_0 \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} \eta_8 \\ \eta_0 \end{pmatrix}$$

The mixing angle $(\eta - \eta')$ allows the study of QCD symmetry and symmetry breaking

Light Quark Mass Ratio

Decay widths of type:

$\eta \to \pi\pi\pi$

are linked to the determination the light mass ratio $\frac{m_d - m_u}{m_s}$

$$Q^2 = \frac{m_s^2 - \hat{m}^2}{m_d^2 - m_u^2}, \qquad \text{where } \hat{m} = \frac{1}{2}(m_u + m_d)$$

By isospin symmetry breaking →mass difference $m_d - m_u$

By improving $\Gamma_{\eta \to \gamma\gamma}$, other decay channels widths for η will also be improved, including decays widths:

$\Gamma_{\eta \to \pi\pi\pi}$

η DECAY MODES	Fraction (Γ_i/Γ)
	Neutral modes
neutral modes	(72.12 ± 0.34) %
2γ	(39.41 ± 0.20) %
$3\pi^0$	(32.68 ± 0.23) %
	Charged modes
charged modes	(27.89 ± 0.29) %
$\pi^+\pi^-\pi^0$	(22.92 ± 0.28) %
$\pi^+\pi^-\gamma$	(4.22 ± 0.08) %

Prog. Theor. Exp. Phys. **2022**, 083C01 (2022)

How can we determine $\eta \rightarrow \gamma\gamma$?

cross section for inverse process $\gamma + \gamma \rightarrow \eta$

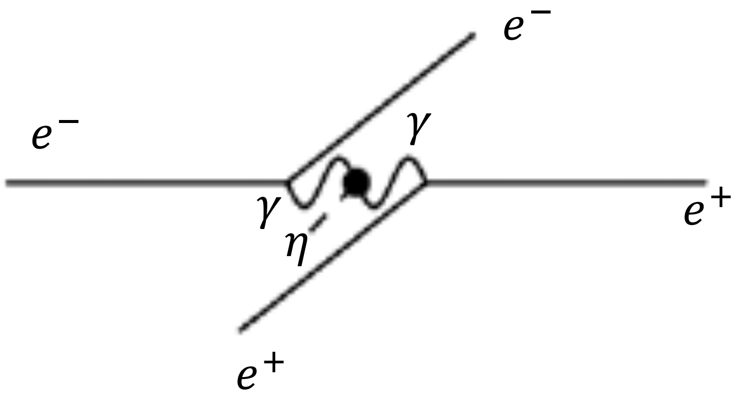
Since the radiative width of the η is in the keV scale, a direct measurement is not possible!!

$\Gamma_\eta = 1.31\ keV$

(total decay width)

Collider

$$e^+ + e^- \rightarrow \eta + e^+ + e^-$$

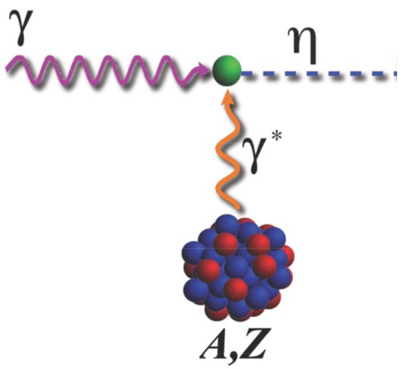


Photon-photon interaction : photoproduction of η

e^+e^- colliding beams are also $\gamma\gamma$ colliding beams

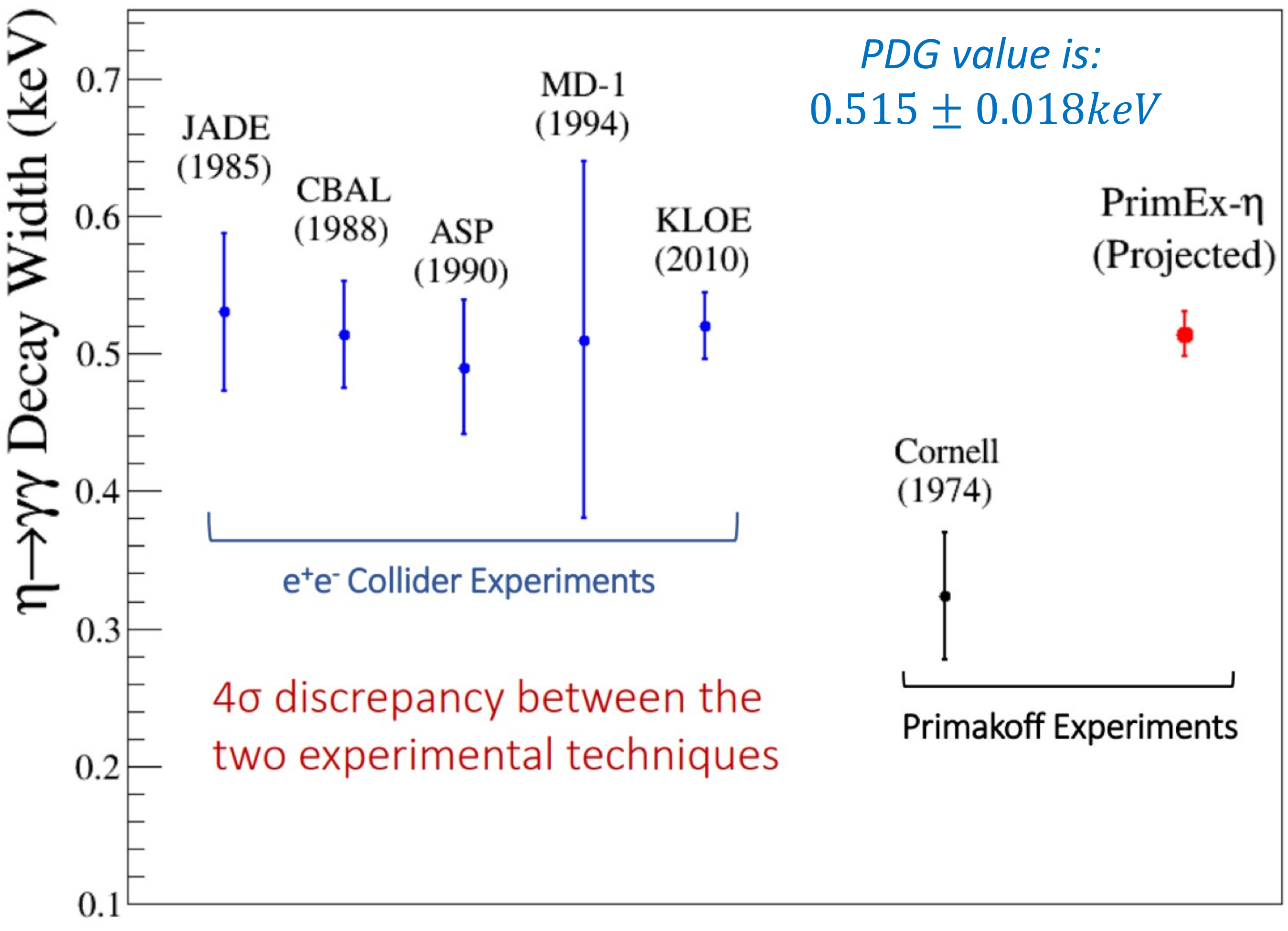
Primakoff

$$\gamma + A \rightarrow \eta + A$$



Interaction of real photon and virtual photon to produce η

Previous Measurements



Proposed uncertainty for PrimEx is 3.2%

The ideal would be to lower the uncertainty compared to previous experiments

Add another data point to the decay width chart

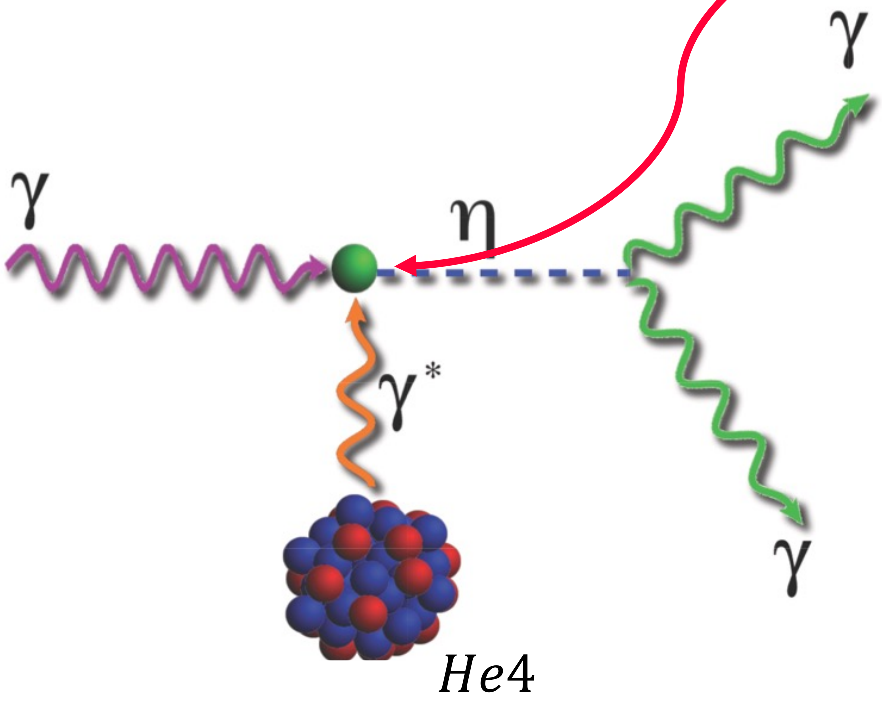
Hopefully resolve the "discrepancy" between collider and Primakoff values

Primakoff Effect

We want to get the cross section of the inverse process

we are interested in

$$\eta \rightarrow \gamma + \gamma$$



Then, production of η by the interaction of high energy photons with a Coulomb field

$$\gamma + \gamma * \rightarrow \eta$$

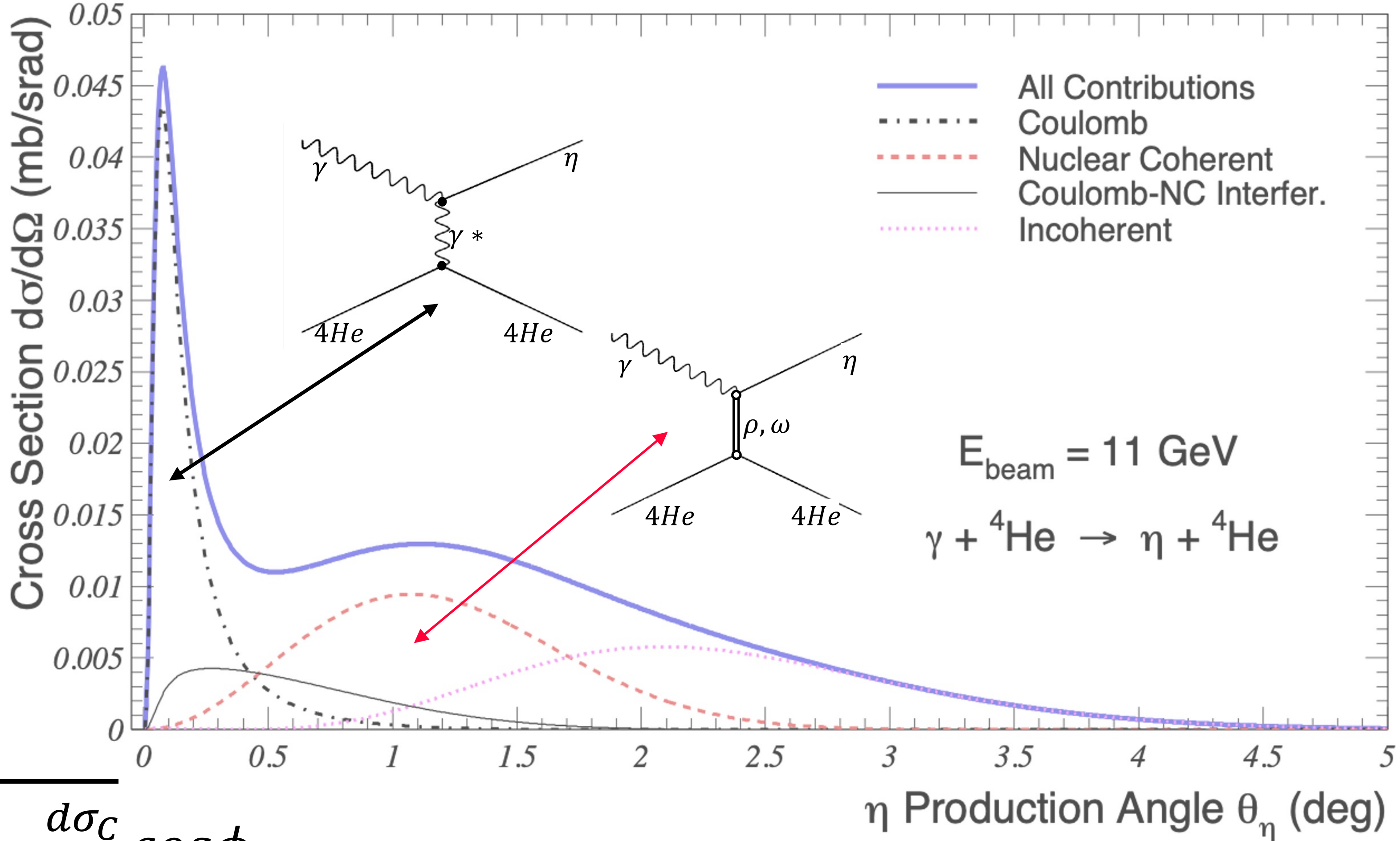
Our measurements are:
the incoming energy of the real photon on the target and the energy from the two decaying photons

Primakoff Effect

$$\frac{d\sigma_P}{d\Omega} = \Gamma_{\gamma\gamma} \frac{8\alpha Z^2}{m_\eta^3} \frac{\beta^3 E^4}{Q^4} |F_{e.m.}(Q)|^2 \sin^2\theta_\eta$$

Goal is to extract $\Gamma_{\gamma\gamma}$ from Primakoff cross section

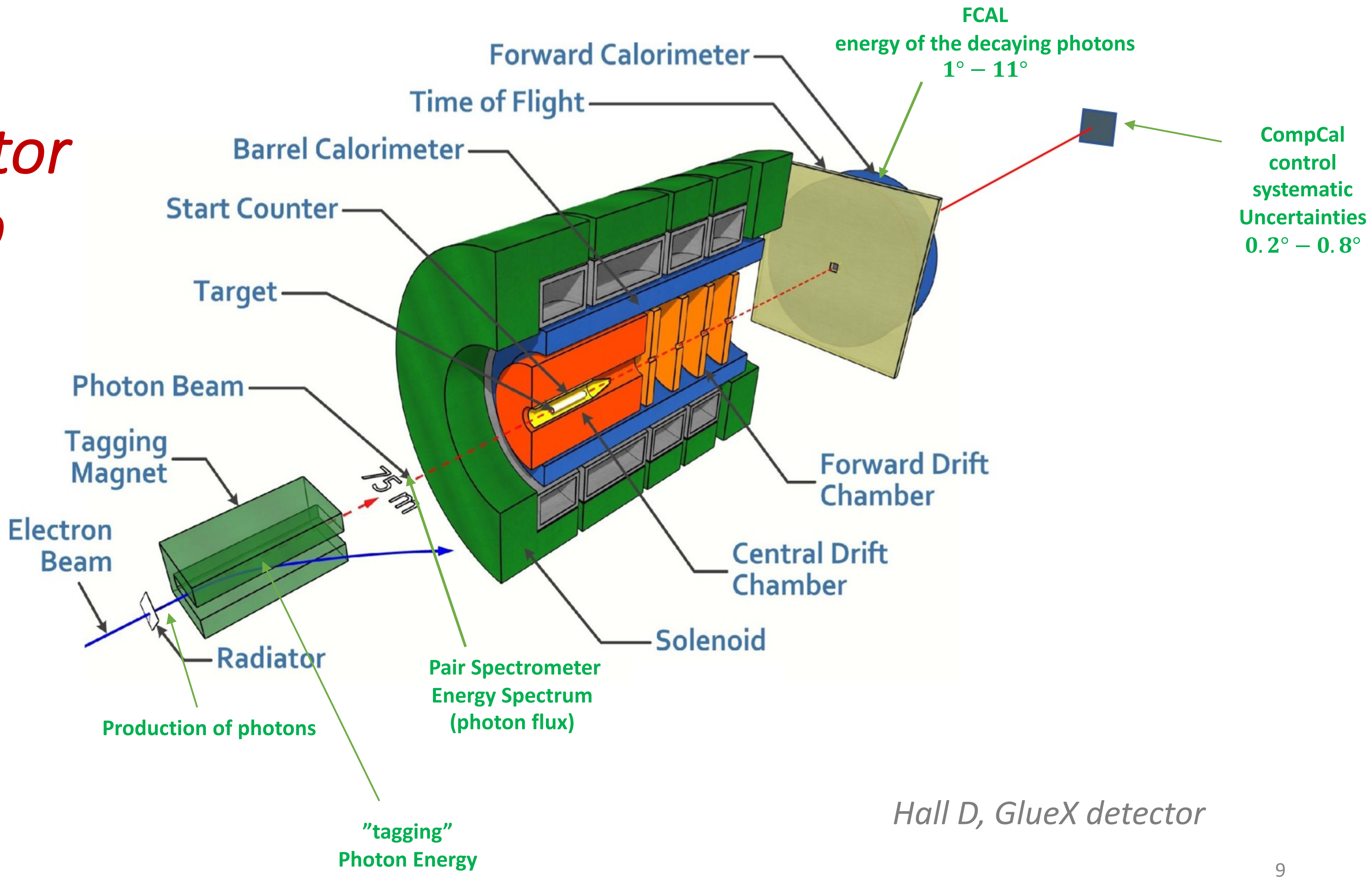
Primakoff cross section peak at very small forward angle, also proportional to energy $\frac{d\sigma_P}{d\Omega} \propto E^4$



Total Cross Section:

$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_P}{d\Omega} + \frac{d\sigma_C}{d\Omega} + \frac{d\sigma_I}{d\Omega} + 2 \cdot \sqrt{\frac{d\sigma_p}{d\Omega} \cdot \frac{d\sigma_C}{d\Omega}} \cos\phi$$

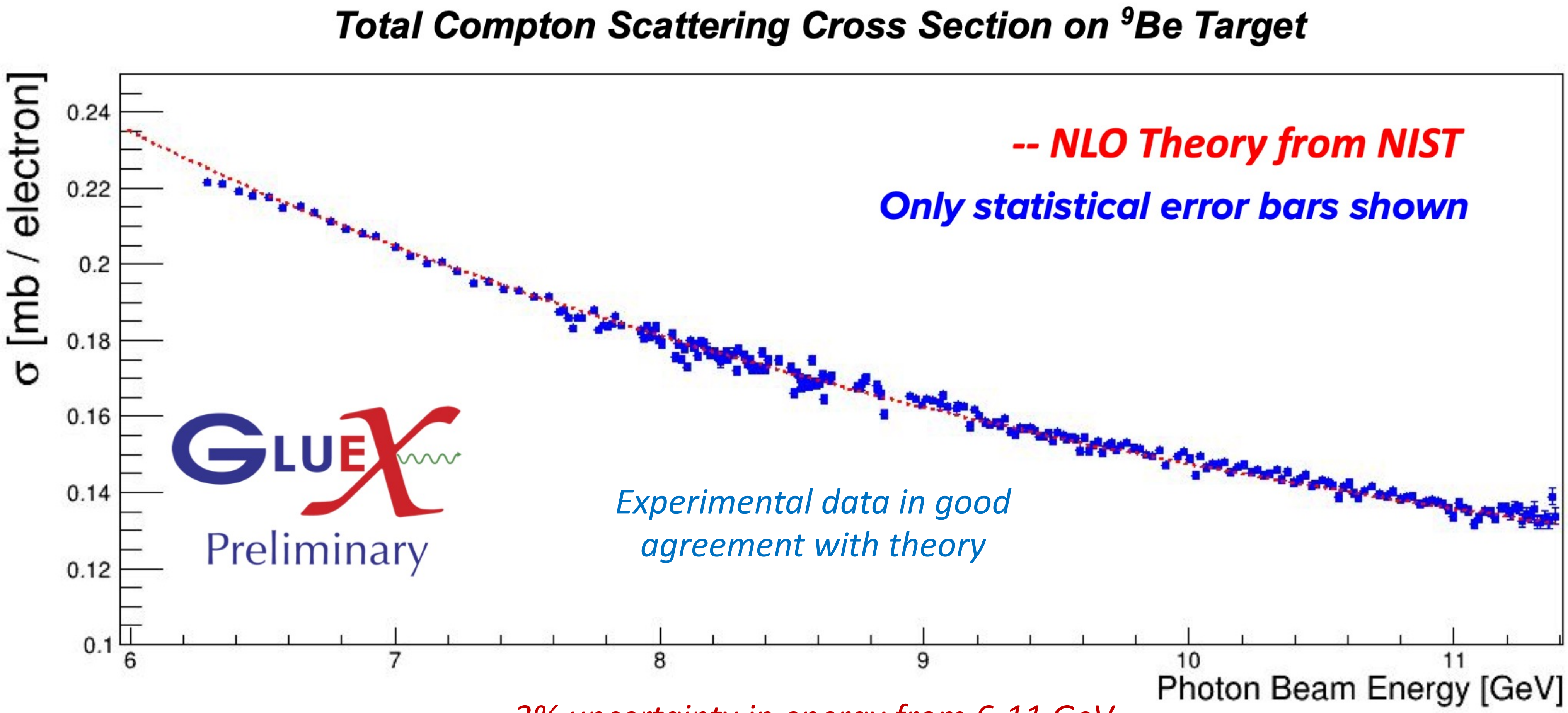
Detector Set-up



Hall D, GlueX detector

Compton Scattering

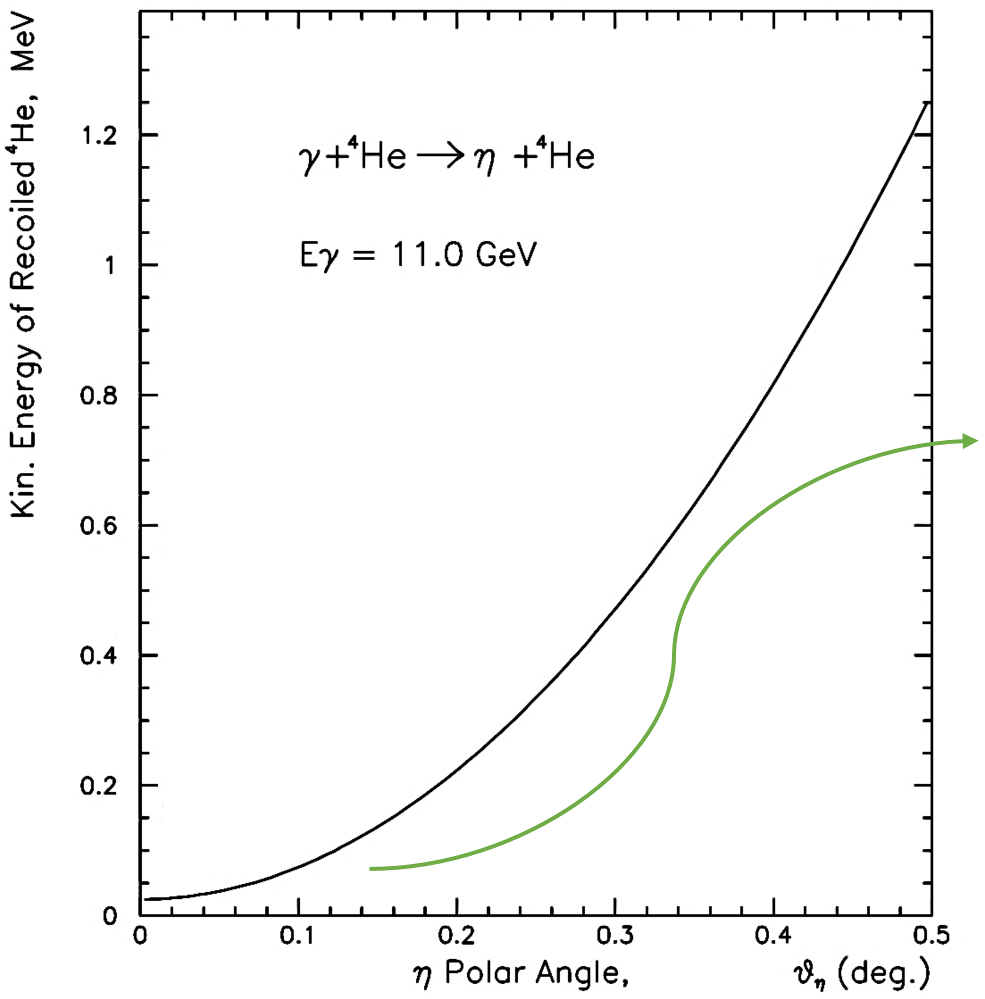
Control of systematic uncertainties



Experimental data in good agreement with theory

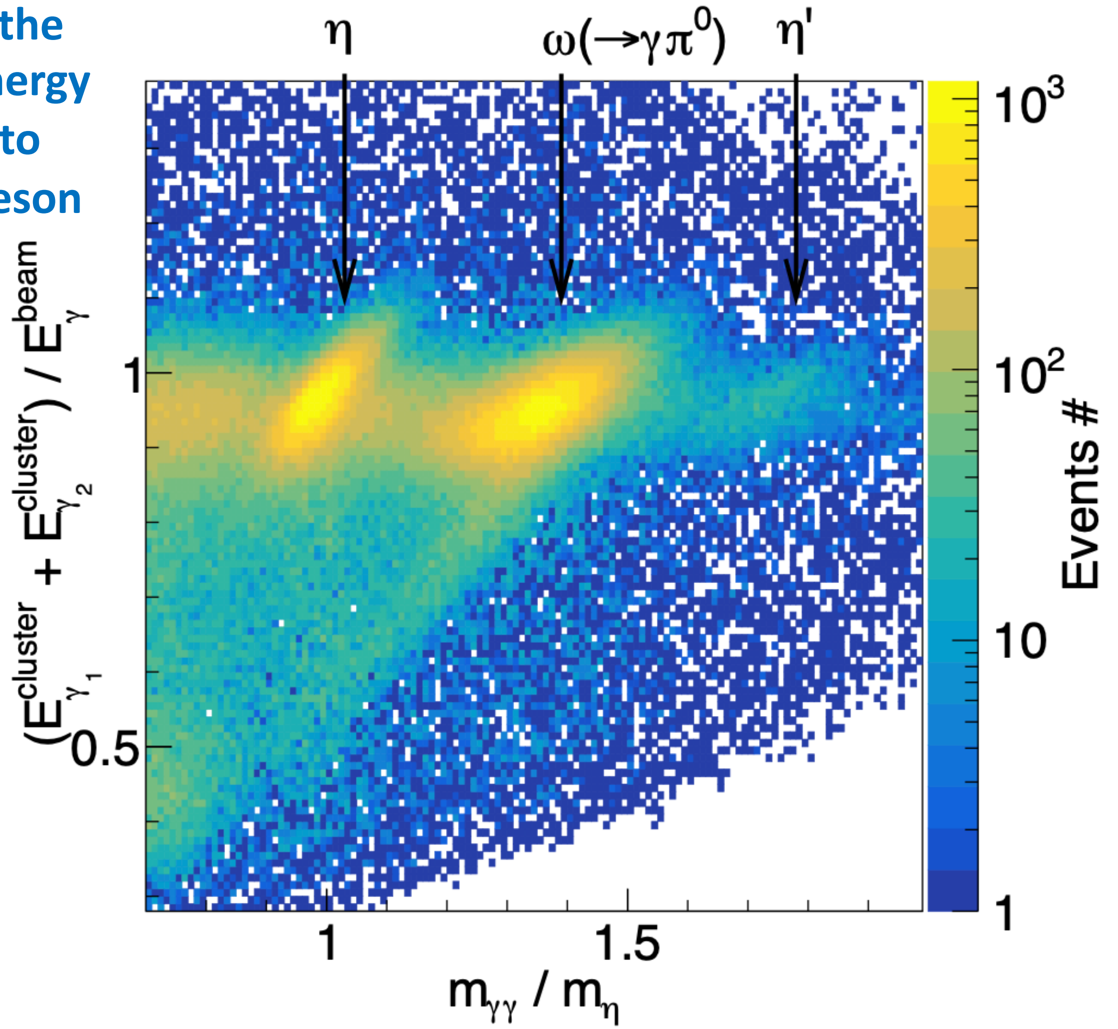
3% uncertainty in energy from 6-11 GeV

Challenges/ Analysis



Low momentum transfer at very small forward angles

Most of the beam energy transfer to the η meson



γγ Invariant Mass

Selection Criteria:

B-Field on

TOF veto (charged particles)

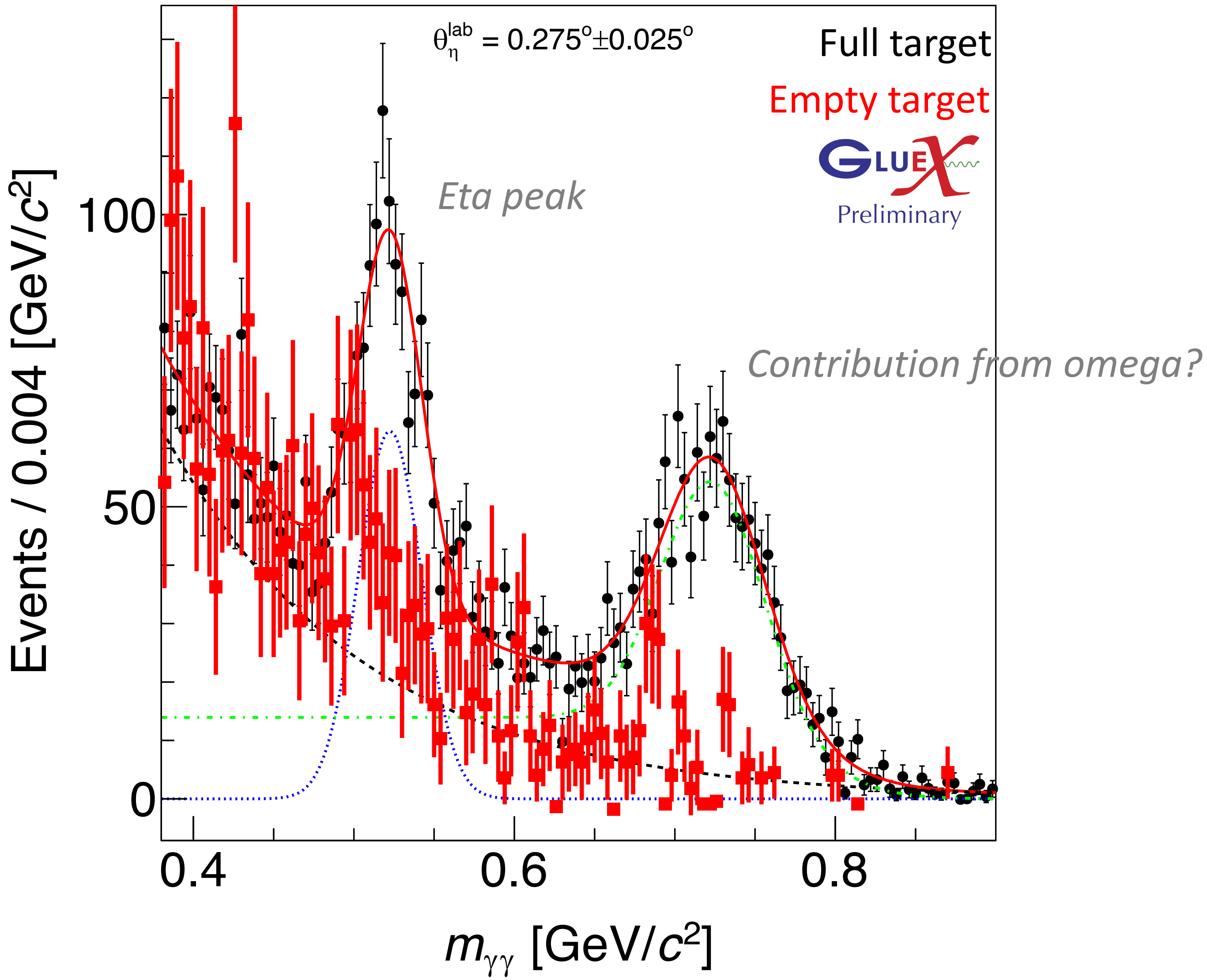
BCal Veto (hadronic background)

Two FCal Showers only

In time with RF

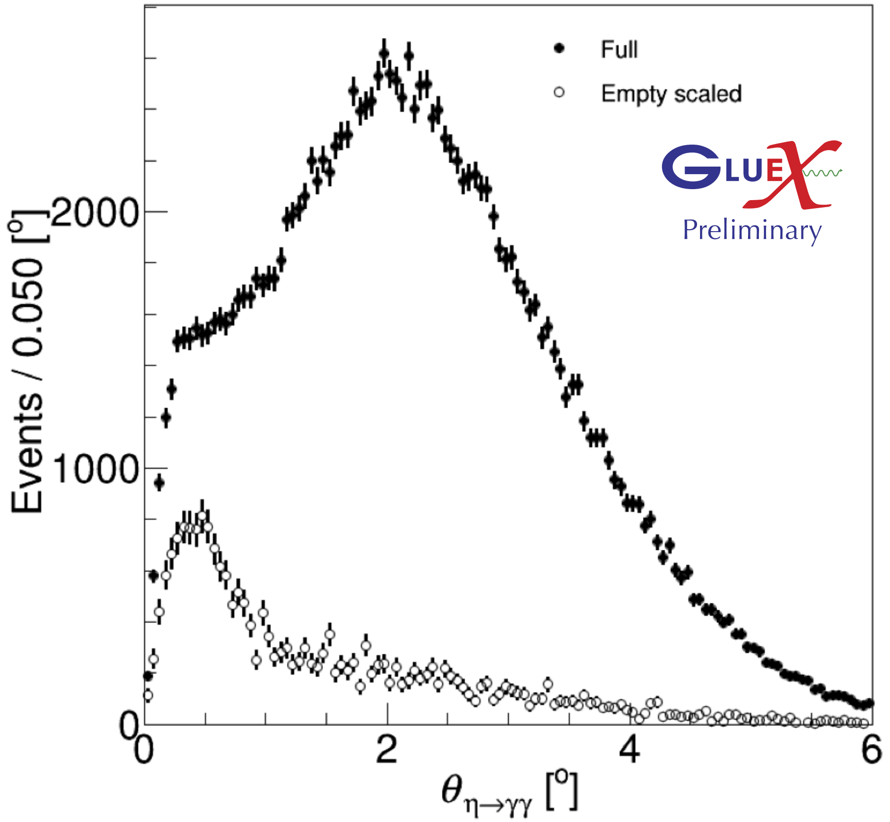
Elasticity

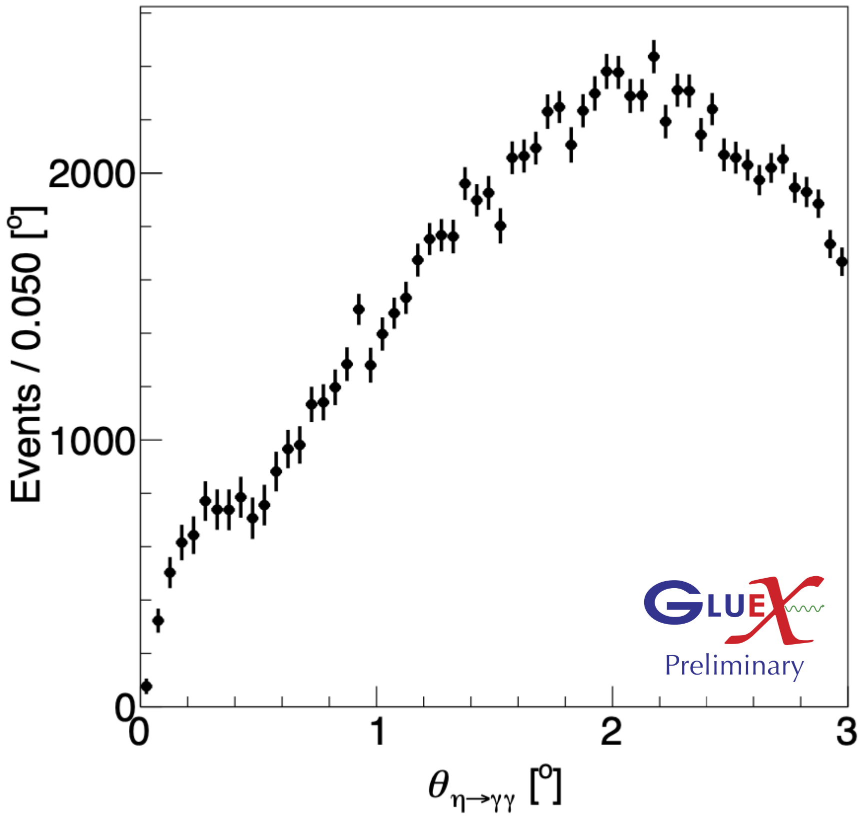
Background due to beamline can be seen with Empty Target



Angular Distribution

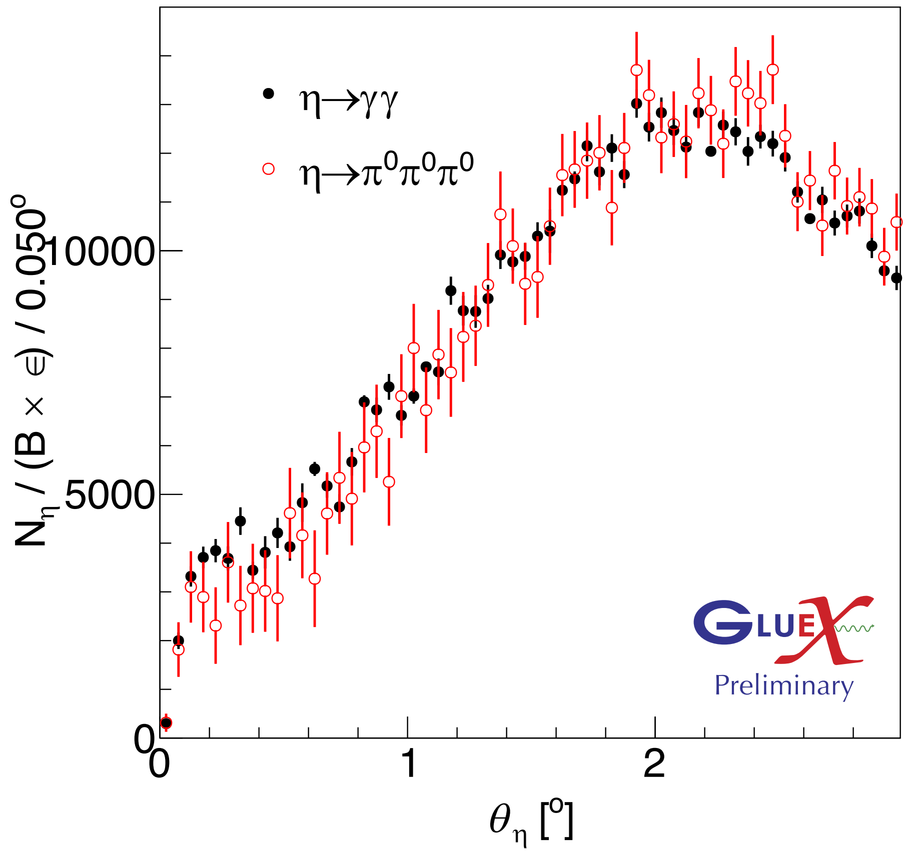
500 < $m_{\gamma\gamma} < 600.$ MeV/c2

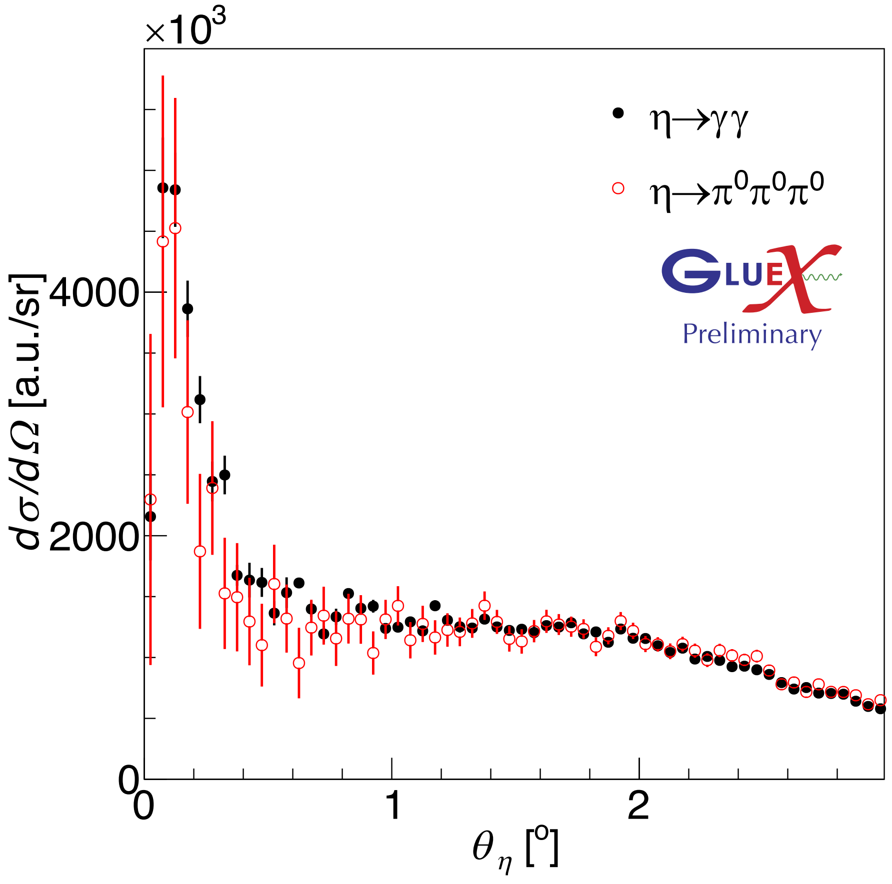




Empty target subtracted

Angular Distribution





Conclusions

Data collection was completed in Spring 2019, Fall 2021 and Fall 2022.

Phase I and Phase II is calibrated and reconstructed.

Phase III is being calibrated.

There is a very precise Compton cross section measurement.

Primakoff Peak is clearly identified, and cross section analysis is underway.

Stay tuned ☺

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