Status of PrimEx-η in Hall D at Jefferson Lab

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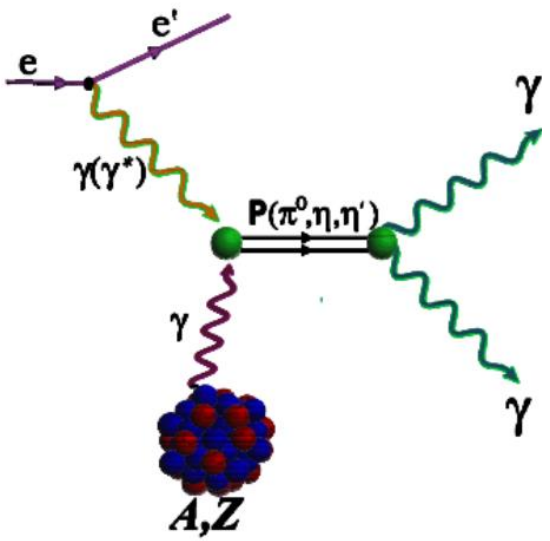
DNP Fall Meeting 2020

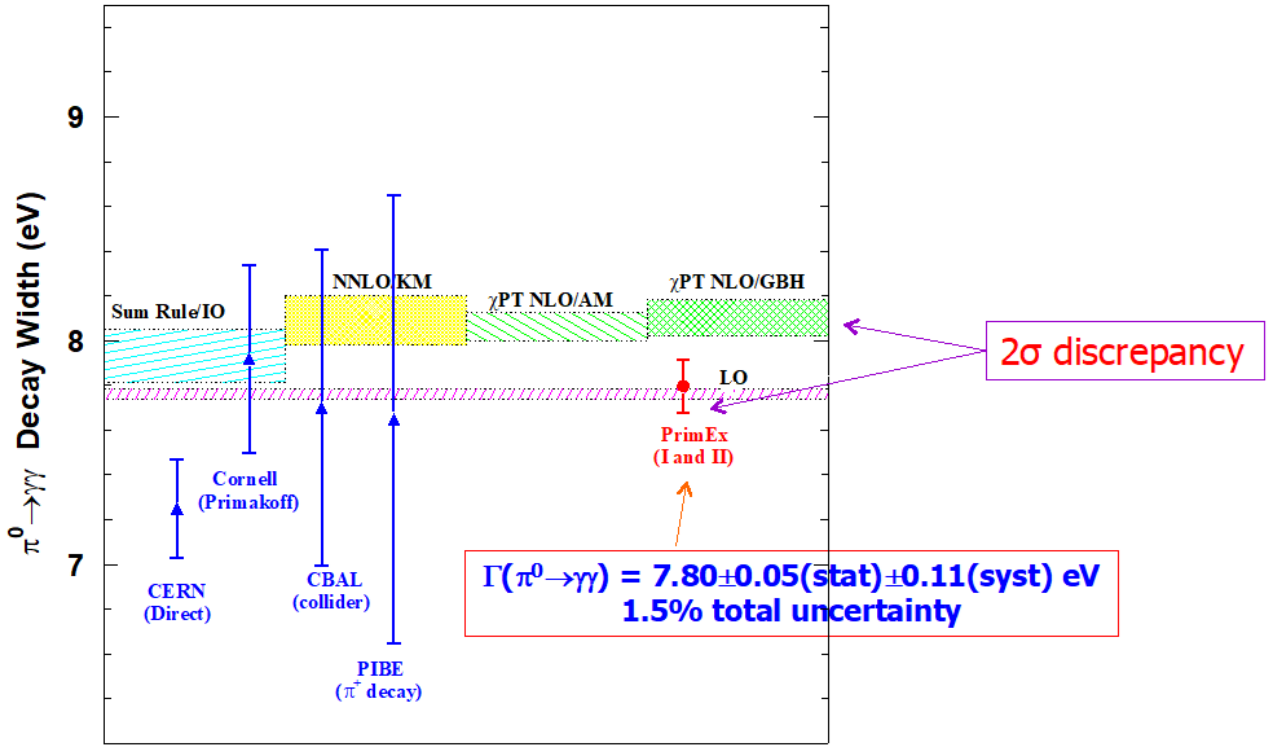
Primakoff Program at JLab

Precision measurements of electromagnetic properties of π^0, η, η' via Primakoff effect:

a) Two-Photon Decay Widths
b) Transition Form Factors at Low Q^2 (0.001-0.5 GeV^2/c^2)

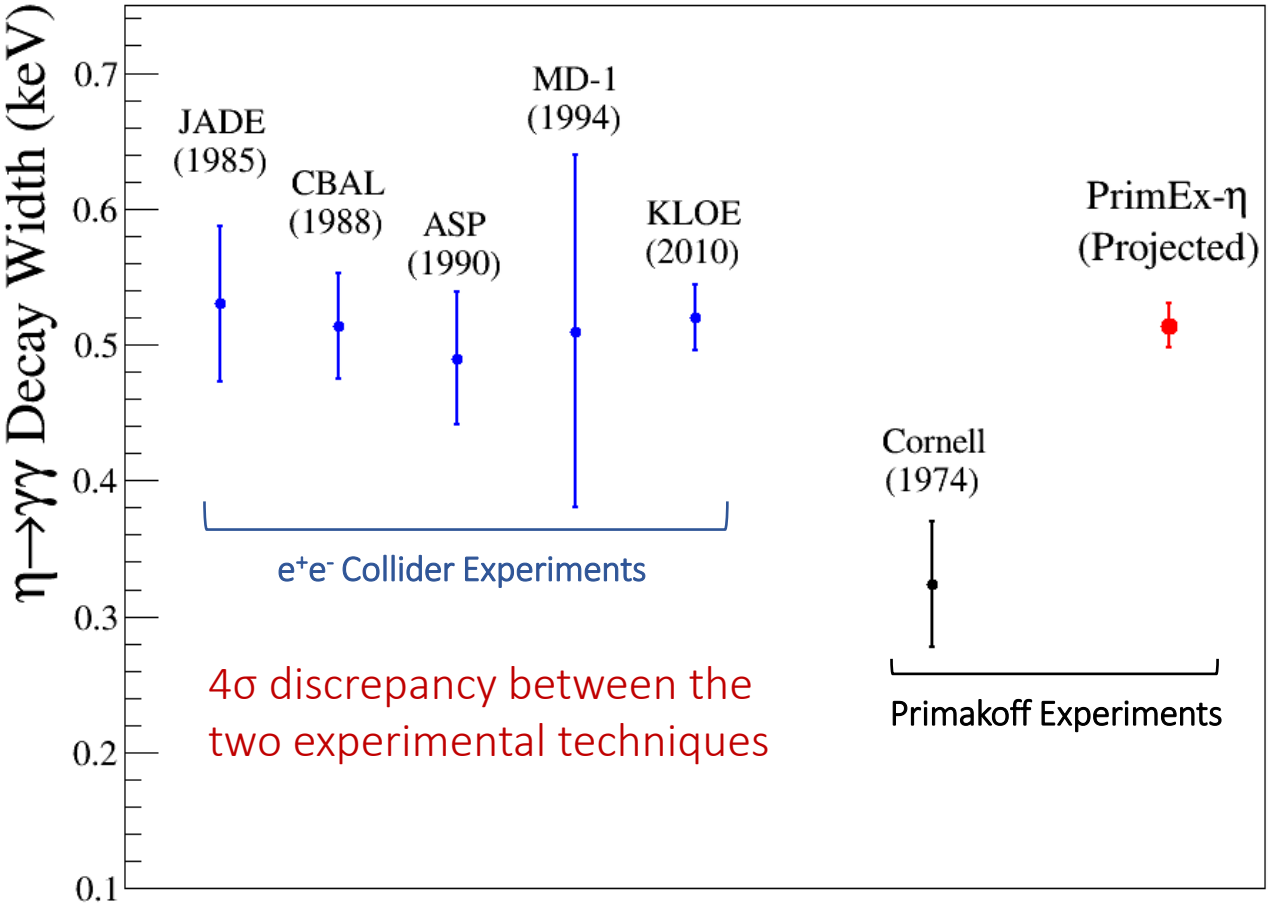


PrimEx-I and II in Hall B measured the $\pi^0 \rightarrow \gamma\gamma$ decay width with 1.5% total uncertainty.



I. I. Larin, et al. PRL **106**, 162303 (2008)
II. I. Larin, Y. Zhang, A. Gasparian, L. Gan, et al. Science **368**, 6490 (2020)

Current Status of $\Gamma(\eta \rightarrow \gamma\gamma)$ Measurements



PDG Average: $\Gamma(\eta \rightarrow \gamma\gamma)$ = 0.51 +/- 0.018 keV

PrimEx-η Experiment

Precision measurement of the η meson radiative decay width via the Primakoff method with a projected uncertainty of 3.2%

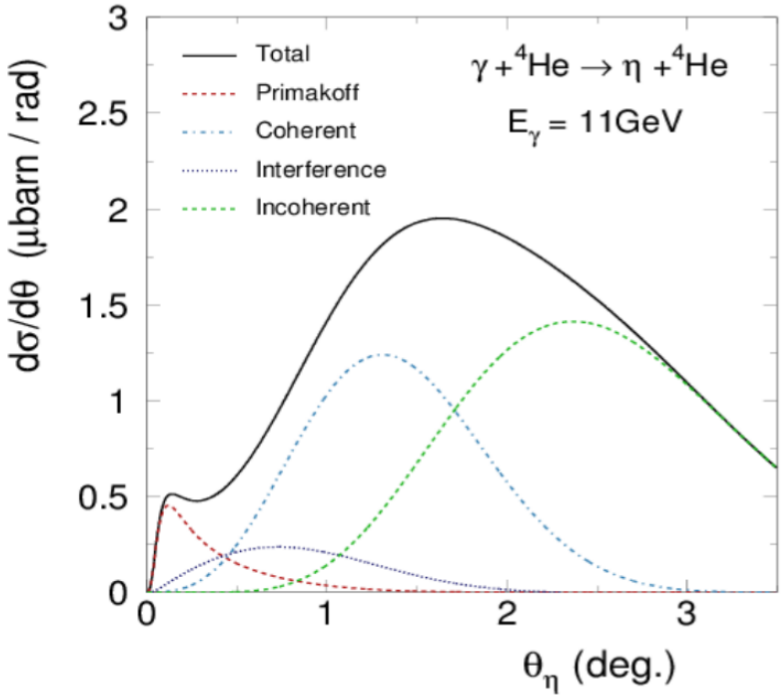
Compton scattering from atomic electrons is simultaneously measured to control systematic uncertainties.

PAC Approved Schedule:

Configuration	PAC Approved Time
LH_2	40 days
L^4He	30 days
Empty Target	6 days
Setup, Calibration	3 days

First phase of data was collected in 2019.

- 80% of LHe data was collected



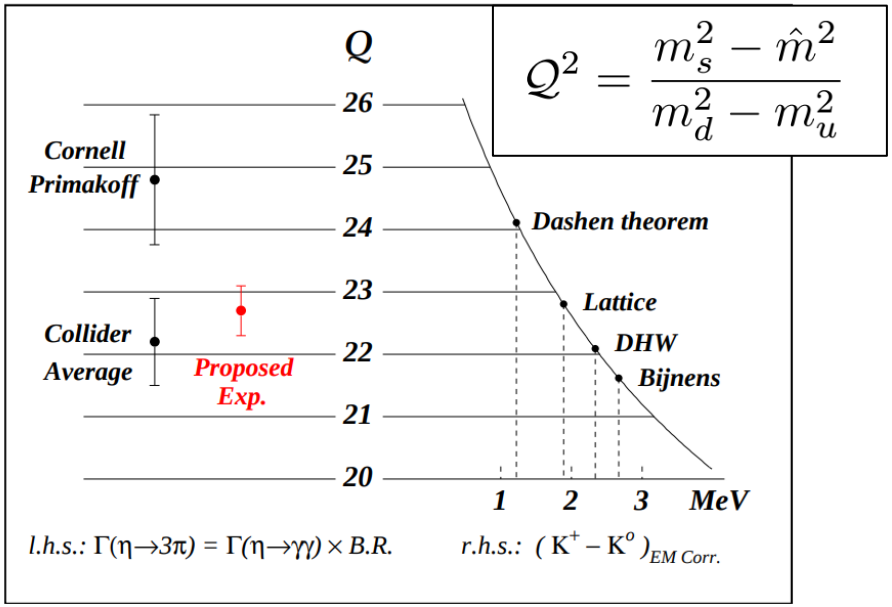
$$\frac{d\sigma_{Pr}}{d\Omega} = \Gamma(\eta \rightarrow \gamma\gamma)\,\frac{8\alpha Z^2}{m_\eta^3}\frac{\beta^3 E^4}{Q^4}|F_{em}(Q)|^2\sin^2(\theta_\eta)$$

The two-photon decay width is extracted as a parameter of the fit to the η meson photoproduction differential cross section.

Input to Physics

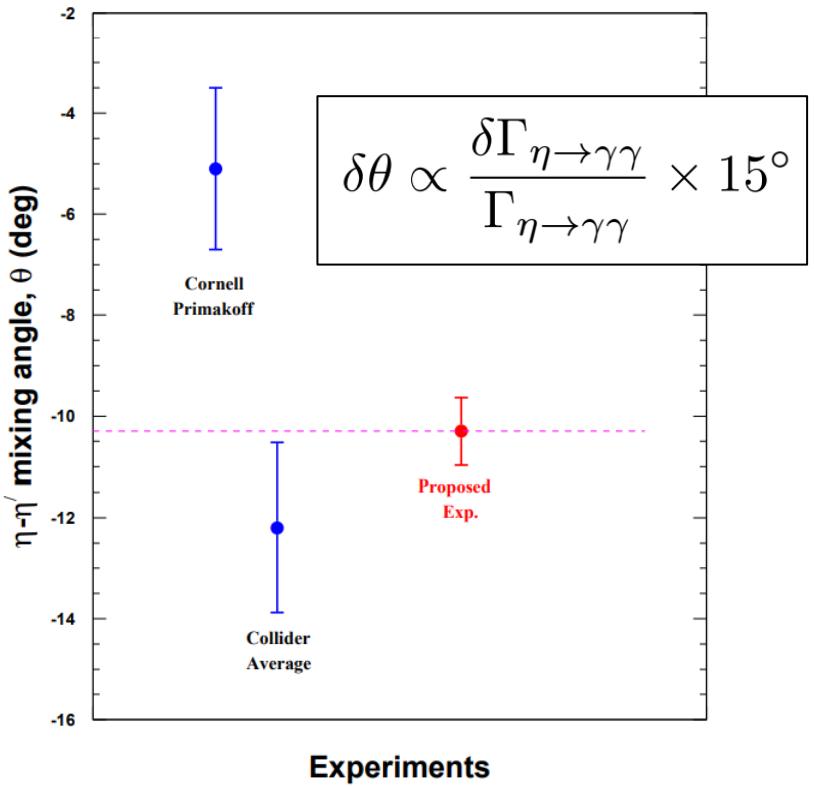
Light-Quark Mass Ratio

- Improvement to $\Gamma(\eta \rightarrow \gamma\gamma)$ will reduce uncertainties to all other decay branching ratios
- $\eta \rightarrow 3\pi$ decays provide insight to the mass difference between light quarks



H. Leutwyler, Phys. Lett. B374 (1996) 181

η-η' Mixing Angle

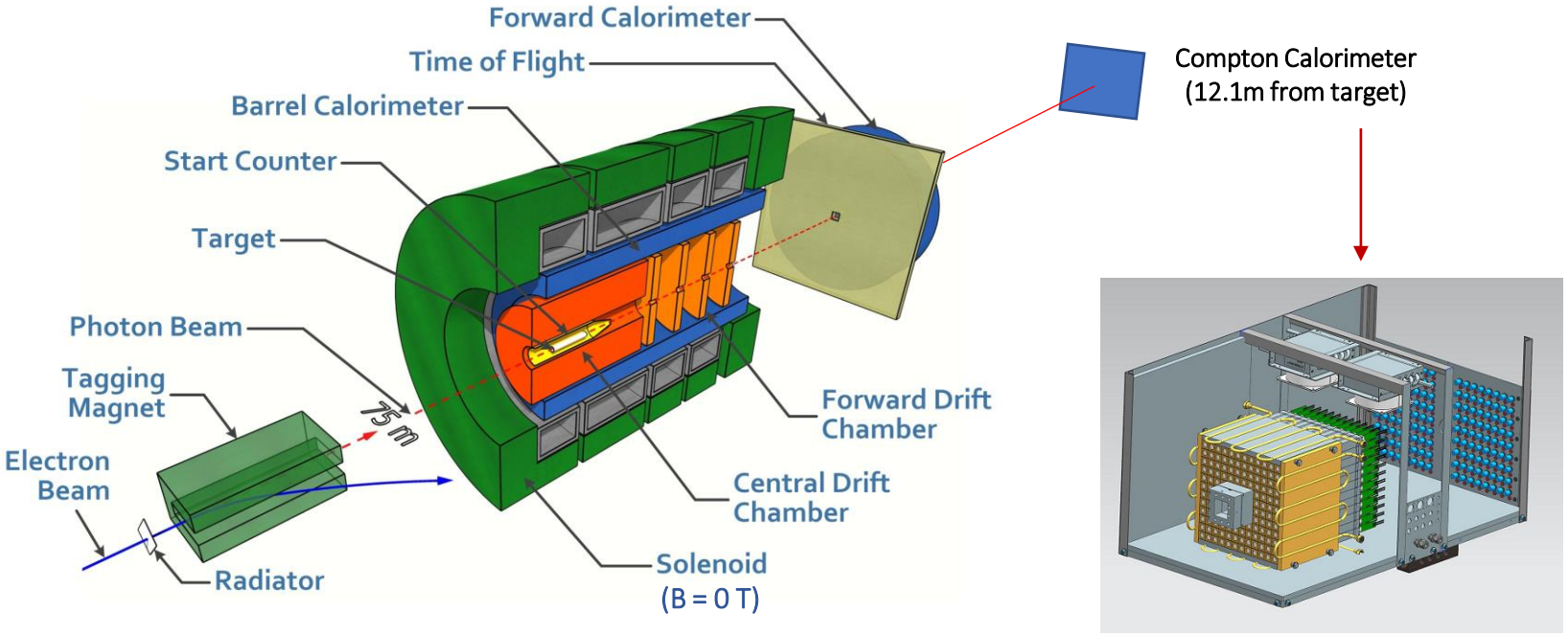


J.L. Goity, A.M. Bernstein and B.R. Holstein, Phys. Rev. D66 (2002) 076014

Hall D at Jefferson Lab

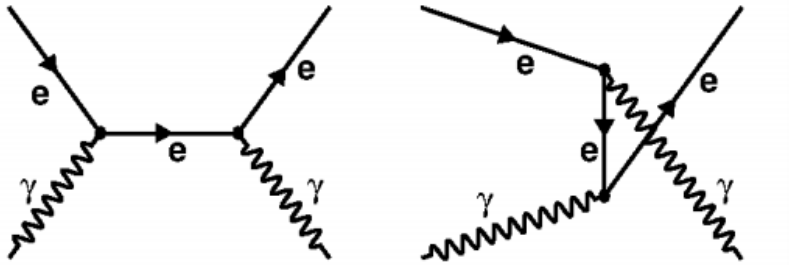
PrimEx-η uses the standard GlueX spectrometer with a few modifications:

- An aluminum radiator is used to produce an *unpolarized* Bremsstrahlung photon beam
- The superconducting magnet is turned off for detection of electrons in forward calorimeters
- A new $PbWO_4$ calorimeter was inserted into the beamline to allow for detection of more forward angle particles (0.19° – 0.8°)

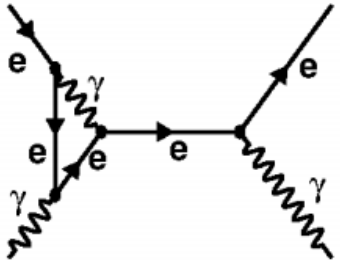


Compton Scattering ($\gamma e^- \rightarrow \gamma e^-$)

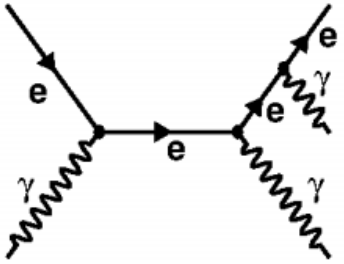
- Compton scattering on atomic electrons is used as a reference process:
  - Monitor changes in luminosity
  - Measure detection efficiency in Forward Calorimeter
  - Verify overall systematics in absolute cross section measurement
- 2 days were dedicated to measuring Compton scattering on a solid ^{9}Be target for luminosity normalization of the liquid He target measurements.
- Will provide most precise measurement of the total cross section in the energy range E_γ = 6 GeV – 11 GeV
  - PrimEx-II Compton result (E_γ = 4.5 GeV – 5.5 GeV) [P. Ambrozewicz, L. Ye, I. Larin, et al. Phys Lett B 797 (2019) 134884]



Lowest order diagrams – described by the Klein-Nishina Equation

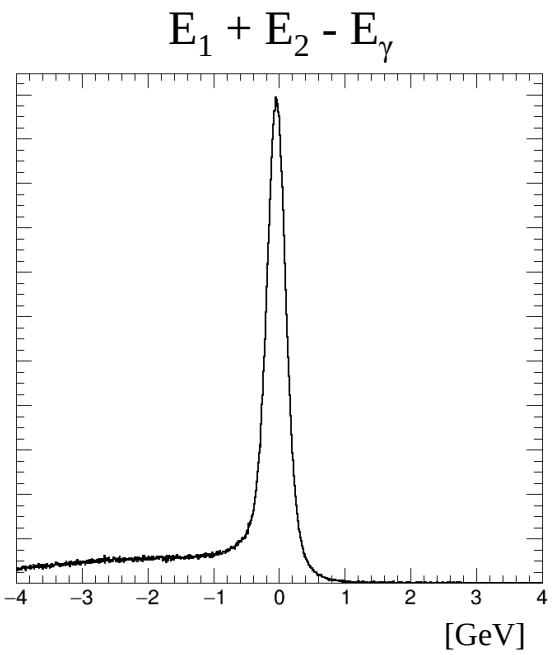


Emission and reabsorption of a virtual photon

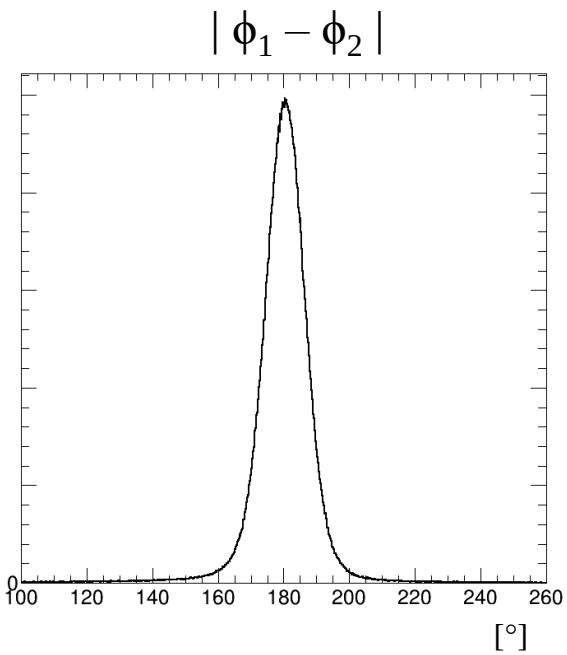


Double Compton scattering

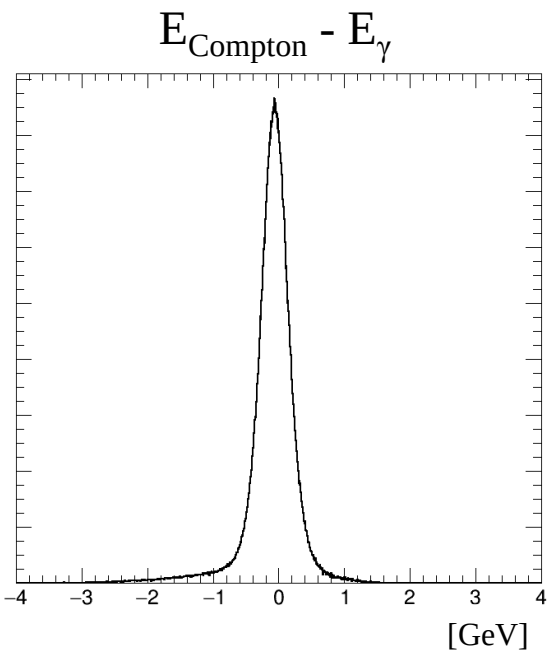
Compton Scattering ($\gamma e^- \rightarrow \gamma e^-$)



Energy Conservation



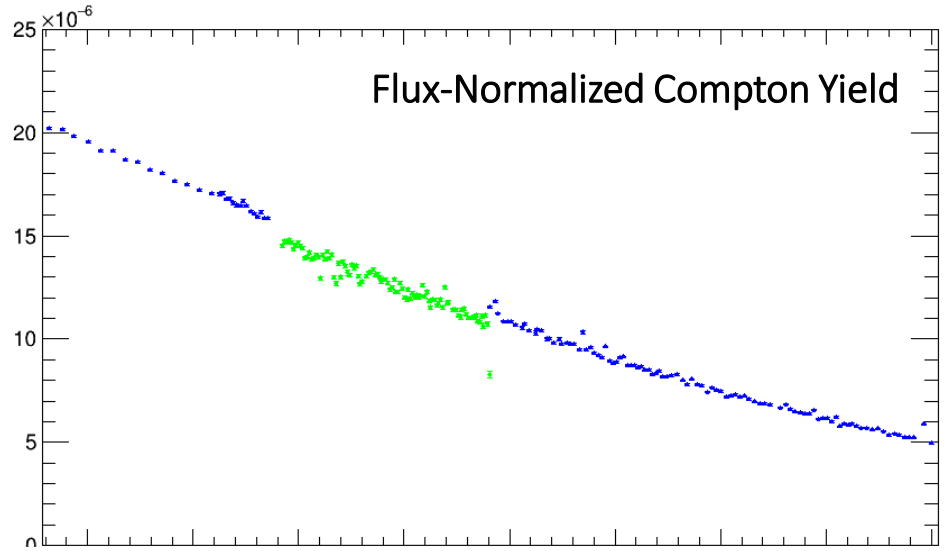
Coplanarity

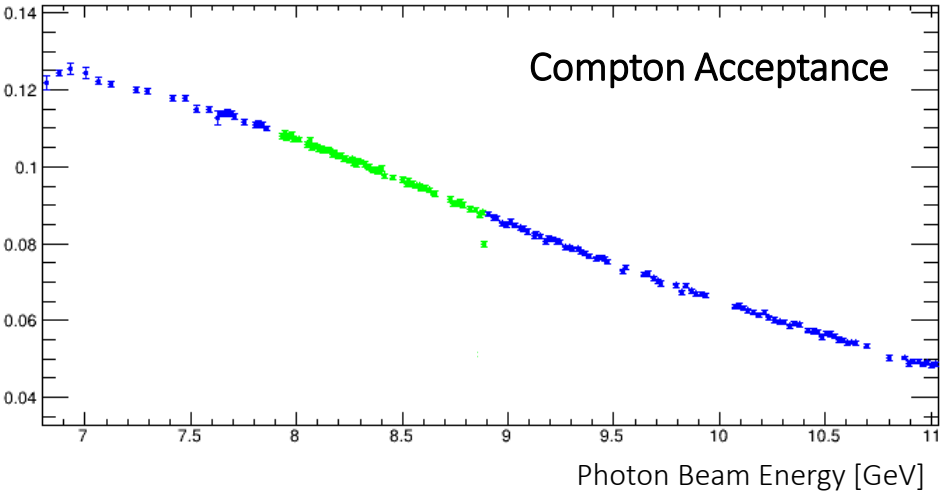


Kinematic Energy Difference

Compton scattering events with one particle in the FCAL and one particle in CCAL is a relatively clean signal. Background from e^+e^- pair production is on the level of a few percent.

Compton Scattering ($\gamma e^- \rightarrow \gamma e^-$)





Very close to measuring total cross section on the ^{9}Be target.

- Photon flux for all photon tagging counters is being finalized
- Relative alignment of calorimeters is crucial to understanding geometric acceptance and is still being finalized.
- Further systematic uncertainties are being estimated.

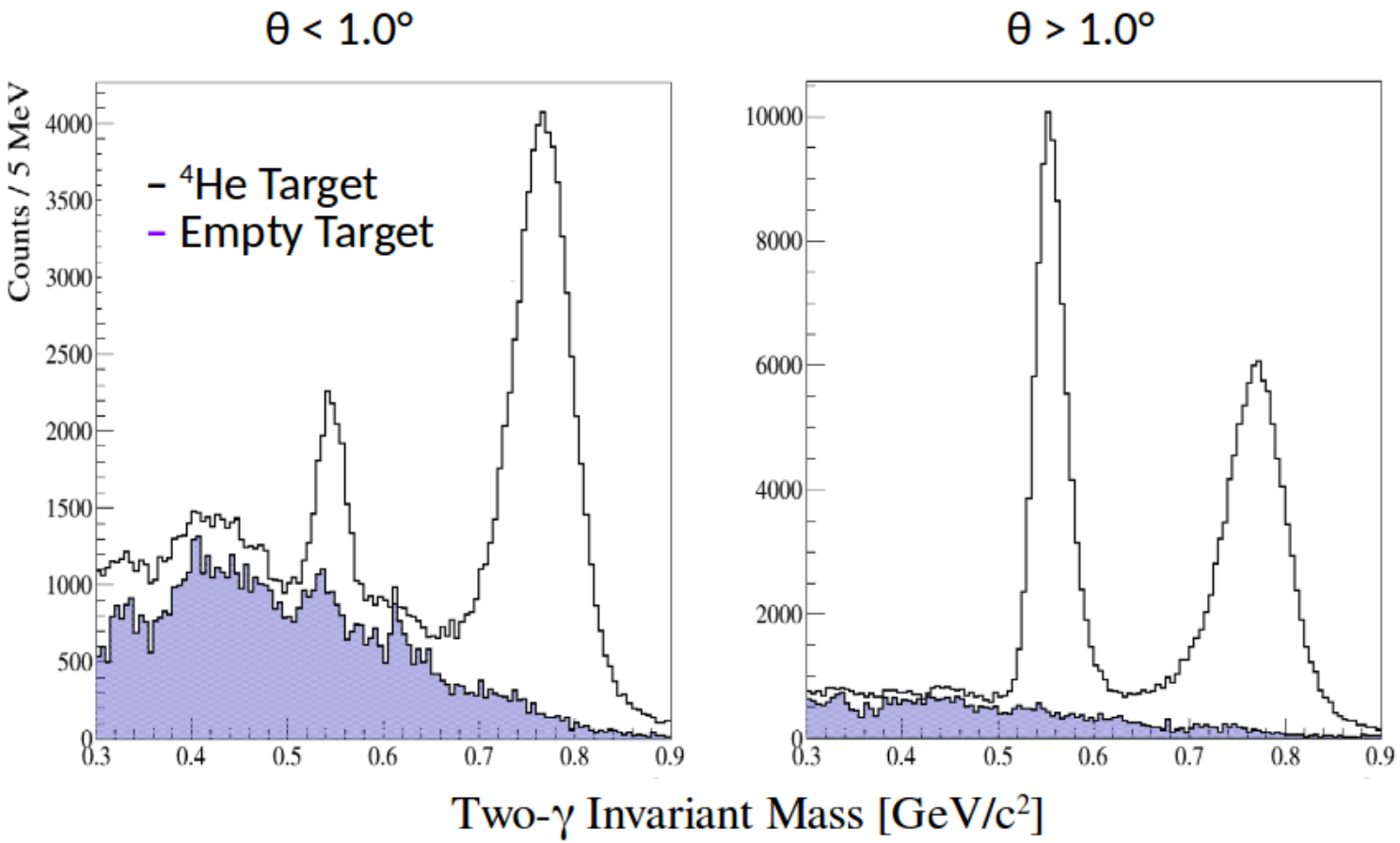
Compton acceptance measured from MC using Compton event generator which includes NLO corrections:

- Virtual photon emission and reabsorption + soft double Compton
- Double Compton with hard secondary photon

Two-Photon Events

Invariant mass distribution has large contribution from hadronic background

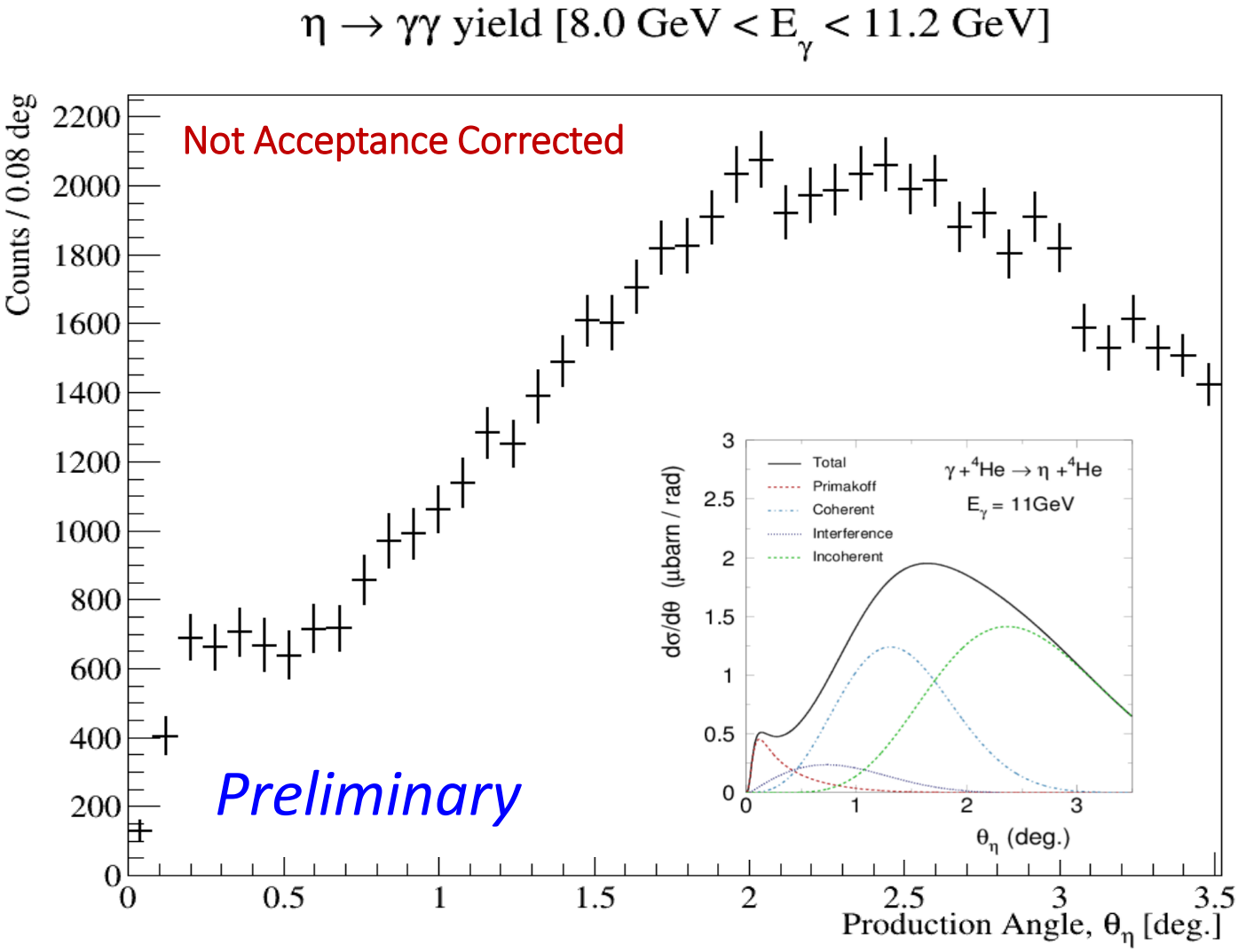
- e.g. $\omega \rightarrow \pi^0\gamma$ where one photon is not detected by forward calorimeter



Preliminary Angular Yield

We see good agreement between the η→γγ angular yield and the predicted differential cross section.

Much more work is needed to extract the two-photon decay width from the measured cross section.



Summary

- 1/3rd of total proposed statistics were collected in 2019.
  - Early results from Compton scattering analysis show good agreement between measured cross section and theory, though more work is needed to finalize result.
  - Roughly 70k exclusive $\eta \rightarrow \gamma\gamma$ decays were detected
- 54 more calendar days have been scheduled for Spring 2021.

Analysis is underway, early results provide confidence in a successful measurement of the η meson decay width.

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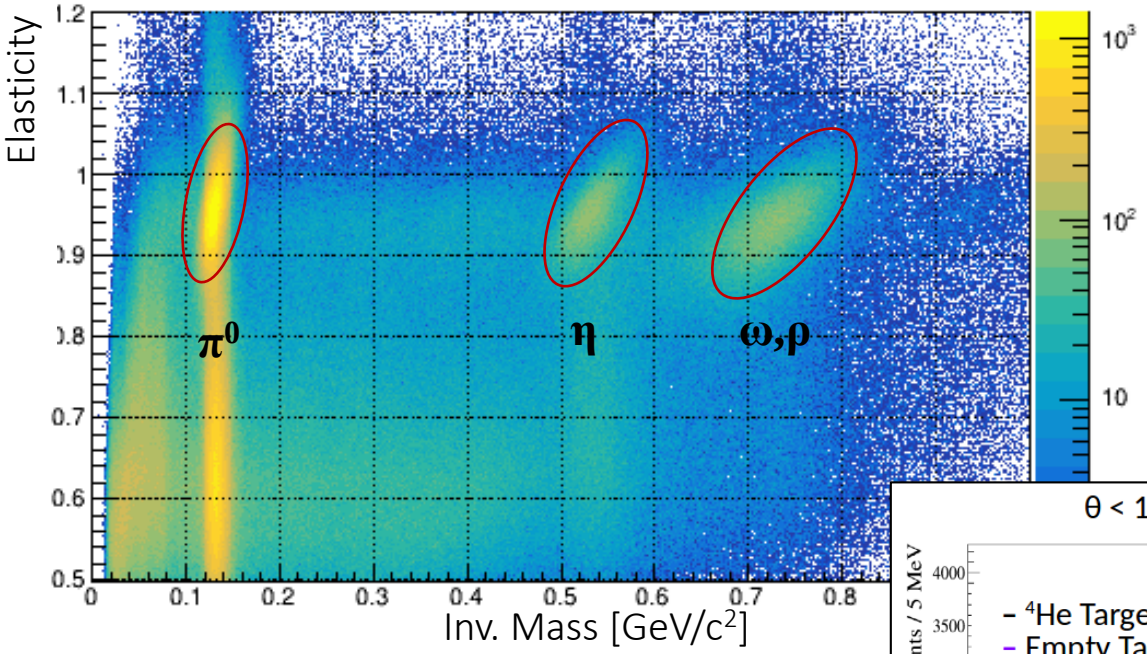
Backup Slides

Two-Photon Events



Clear signals of exclusive meson production is seen by reconstructing events with two photons detected in the calorimeter.

Invariant mass distribution shows large contribution from hadronic background:

- E.g. $\omega \rightarrow \eta\gamma$, and $\omega \rightarrow \pi^0\gamma$ events where one photon goes undetected leads to tail from ω peak leaking into η peak