# Preliminary results of the helicity asymmetry $E$ for $\eta$ photoproduction on the proton

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***Arizona State University***

*Work at Arizona State University supported by the U.S. National Science Foundation

# Motivation for $\eta$ photoproduction experiments

- $\eta$ is an isospin zero meson, which limits possible resonance couplings to $N^*$s effectively working as an isospin filter.
- $\eta$ is one of the lightest non-strange pseudoscalar mesons.
- Very little current data available on double polarization observables.
- Predictions for observables for incident photon energies at and above threshold are available from different theoretical approaches, for example:
  - Effective Lagrangian theories (e.g. Nakayama and Haberzettl)
  - Partial wave analysis (e.g. SAID and Bonn-Gatchina)
  - Isobar analysis (e.g. eta-MAID)

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# Polarization observables

| Photon | Target | | | | Recoil | | | Target + Recoil | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | – | – | – | – | $x'$ | $y'$ | $z'$ | $x'$ | $x'$ | $z'$ | $z'$ |
| | – | $x$ | $y$ | $z$ | – | – | – | $x$ | $z$ | $x$ | $z$ |
| unpolarized | $\sigma_0$ | 0 | $T$ | 0 | 0 | $P$ | 0 | $T_{x'}$ | $-L_{x'}$ | $T_{z'}$ | $L_{z'}$ |
| linear pol. | $-\Sigma$ | $H$ | (-P) | $-G$ | $O_{x'}$ | (-T) | $O_{z'}$ | $(-L_{z'})$ | $(T_{z'})$ | $(-L_{x'})$ | $(-T_{x'})$ |
| circular pol. | 0 | $F$ | 0 | $-E$ | $-C_{x'}$ | 0 | $-C_{z'}$ | 0 | 0 | 0 | 0 |

Observables possible with beam-target polarization experiments

Observable of interest in this talk

Polarization observable E:

$$E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}$$

By convention we take 1/2 state minus the 3/2 state

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# Helicity asymmetry *E*

Raw asymmetry equation in terms of yield (N):

$$R = \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2}}$$

Equation for the observable *E* accounting for polarizations:

$$x = E_\gamma / E_e$$

$$P_{\text{photon}} = P_{\text{electron}} \cdot \frac{4x - x^2}{4 - 4x + 3x^4}$$

$$P_\circ = P_{\text{target}} \cdot P_{\text{photon}}$$

$$E = \frac{1}{P_\circ \cdot f_{(\text{Dilution})}} \cdot \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2}}$$

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# Constraints on *E*

- $S_{11}(1535)$ dominates $\eta$ photoproduction at threshold energies (W = 1500-1550 MeV)
  - Since the $S_{11}(1535)$ is a spin = ½ , $L = 0$ resonance, the resonance can only couple to a helicity ½ initial states.

- This dominance forces $E \approx 1$ at and near threshold for all scattering angles.

- This constraint of $E \approx 1$ provides an analysis check near threshold.

- For all energies, *E* must have a value of 1 at 0 and 180° due to conservation laws.



# Running conditions

- The data for this analysis was collected during the g9a running period of FroST using the CLAS detector at the Thomas Jefferson National Laboratory.
- Target:
  - Longitudinal polarized target
  - Average target polarization:
    - ~ 82% (+Pol) and 90% (-Pol)
- Photon beam:
  - Circularly and linearly polarized photon beam
  - 0.5 - 4.5GeV
  - Electron beam polarization ~ 85%
- Trigger:
  - At least one charged particle in CLAS
- 10.5 billion events taken

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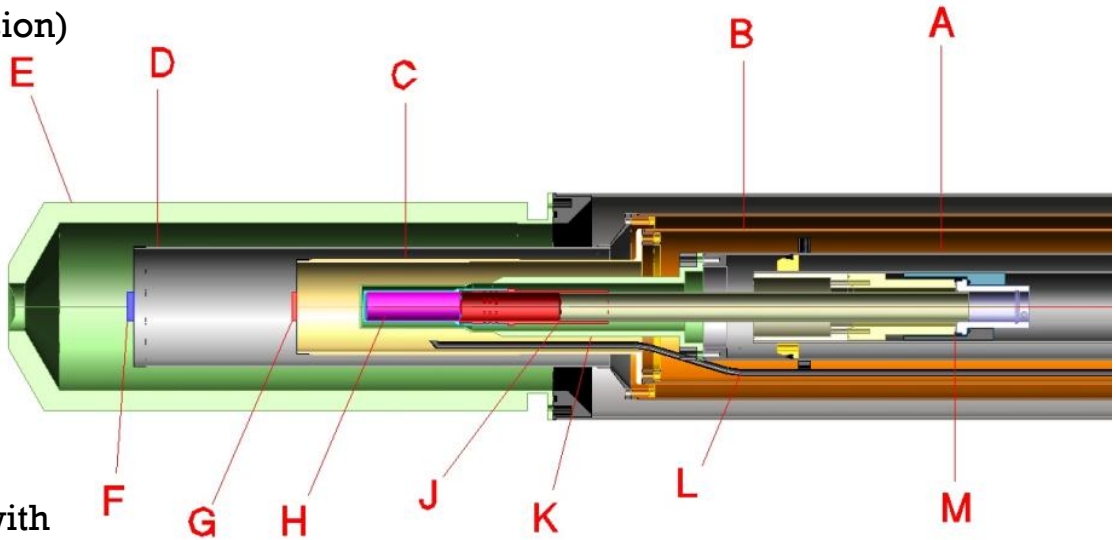
# FroST (Frozen Spin Target)

**The FroST target and its components**:
A: Primary heat exchanger
B: 1 K heat shield
C: Holding coil
D: 20 K heat shield
E: Outer vacuum can (Rohacell extension)
F: CH2 target
G: Carbon target
H: Butanol target
J: Target insert
K: Mixing chamber
L: Microwave waveguide
M: Kapton coldseal

Butanol Composition:
$C_4H_9OH$ + liquid He




**Performance Specs:**
Base Temp: 28 mK w/o beam, 30 mK with
Cooling Power: 800 μW @ 50 mK, 10 mW @ 100 mK, and 60 mW @ 300 mK
Polarization: +82%, -90%
1/e Relaxation Time: 2800 hours (+Pol), 1600 hours (-Pol)
Roughly 1% polarization loss per day.

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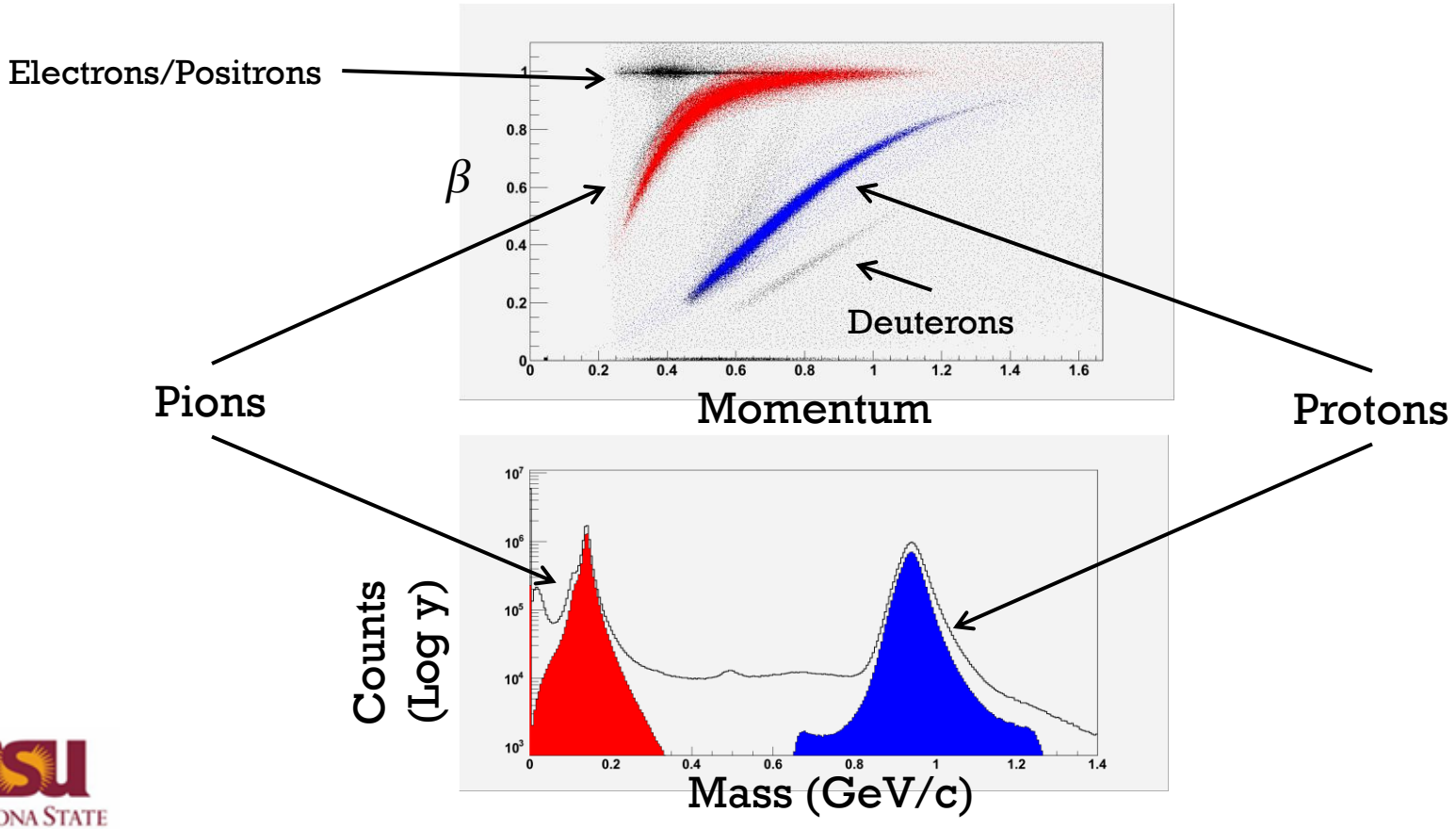
# Particle identification

- Particle identification used GPID.
- GPID compares measured velocity to known particles given the measured momentum.
- A cut of $|\beta_{measured} - \beta_{calculated}| <= .08$ was enforced for pions

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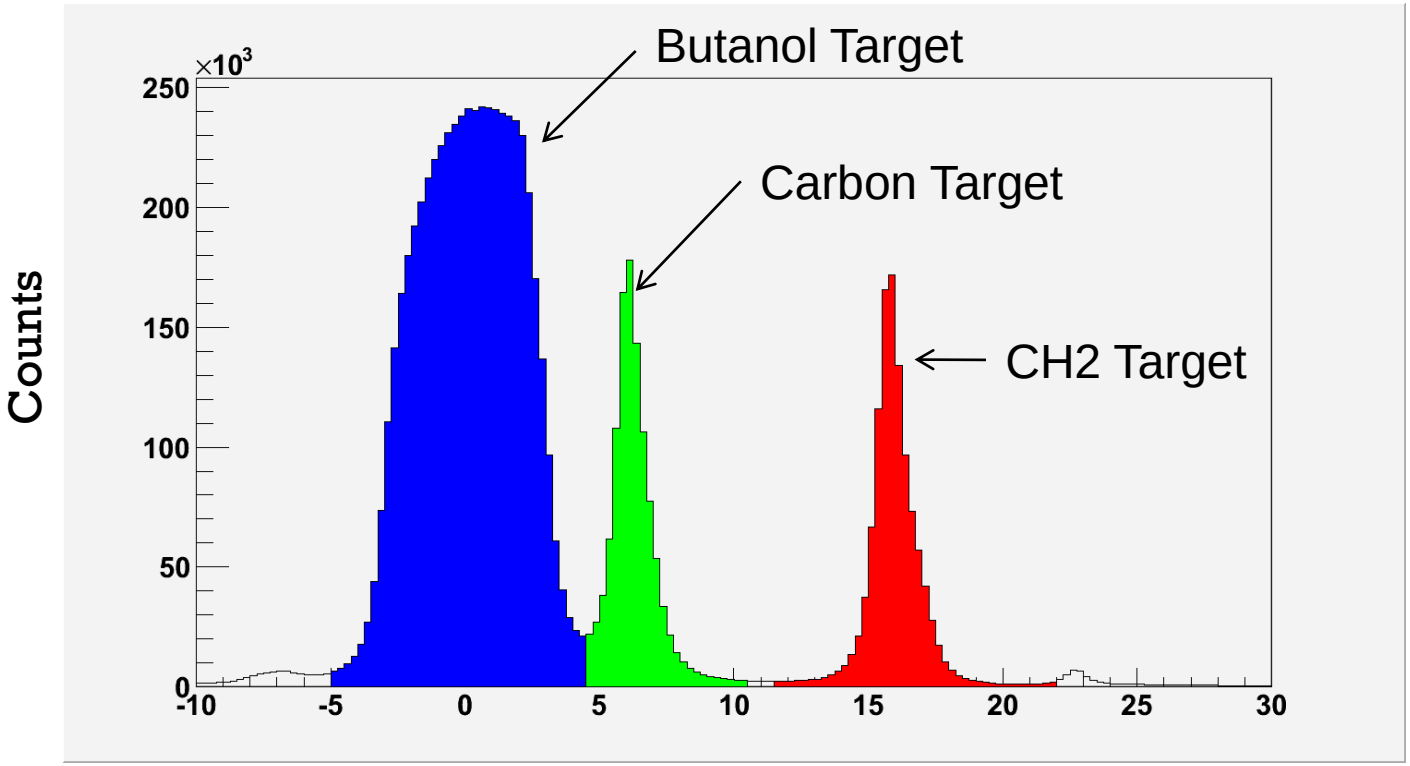
# Vertex resolution




Butanol Composition:
$C_4H_9OH$ + liquid He

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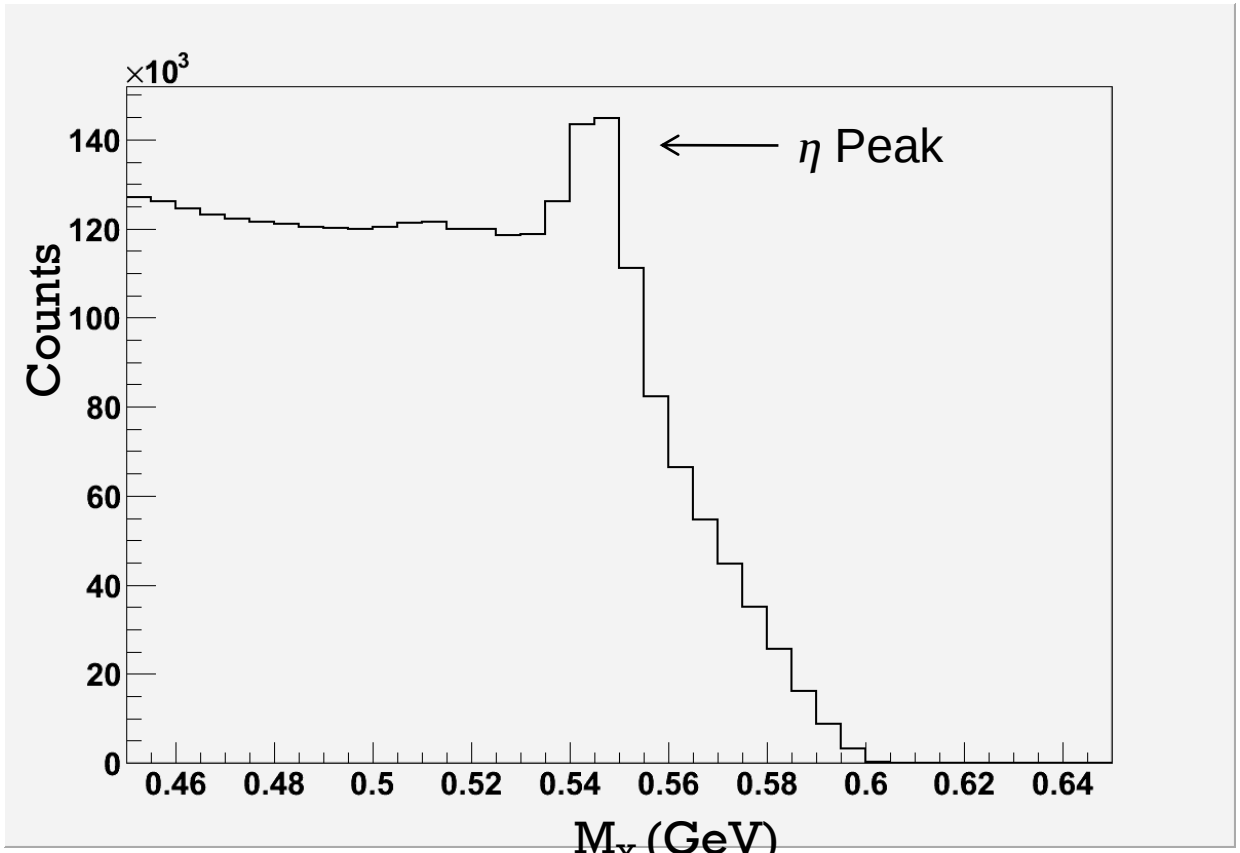
# Potential topologies:
# $\gamma + p \rightarrow p + X$ *(full CLAS acceptance)*

*W = 1500 to 1550 MeV*

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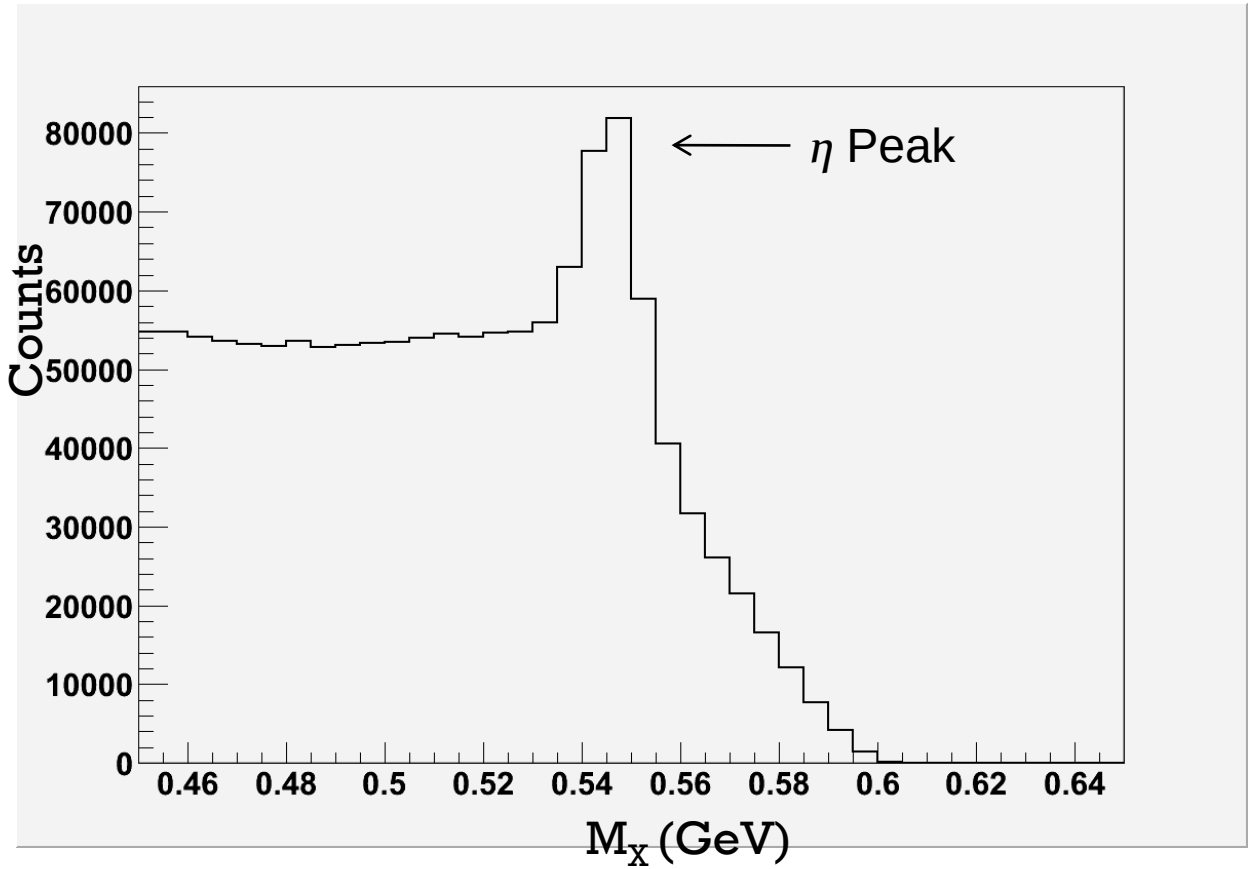
# Potential topologies:

## $\gamma + p \rightarrow p + X$ *(no charged particles other than the proton detected)*

*W = 1500 to 1550 MeV*

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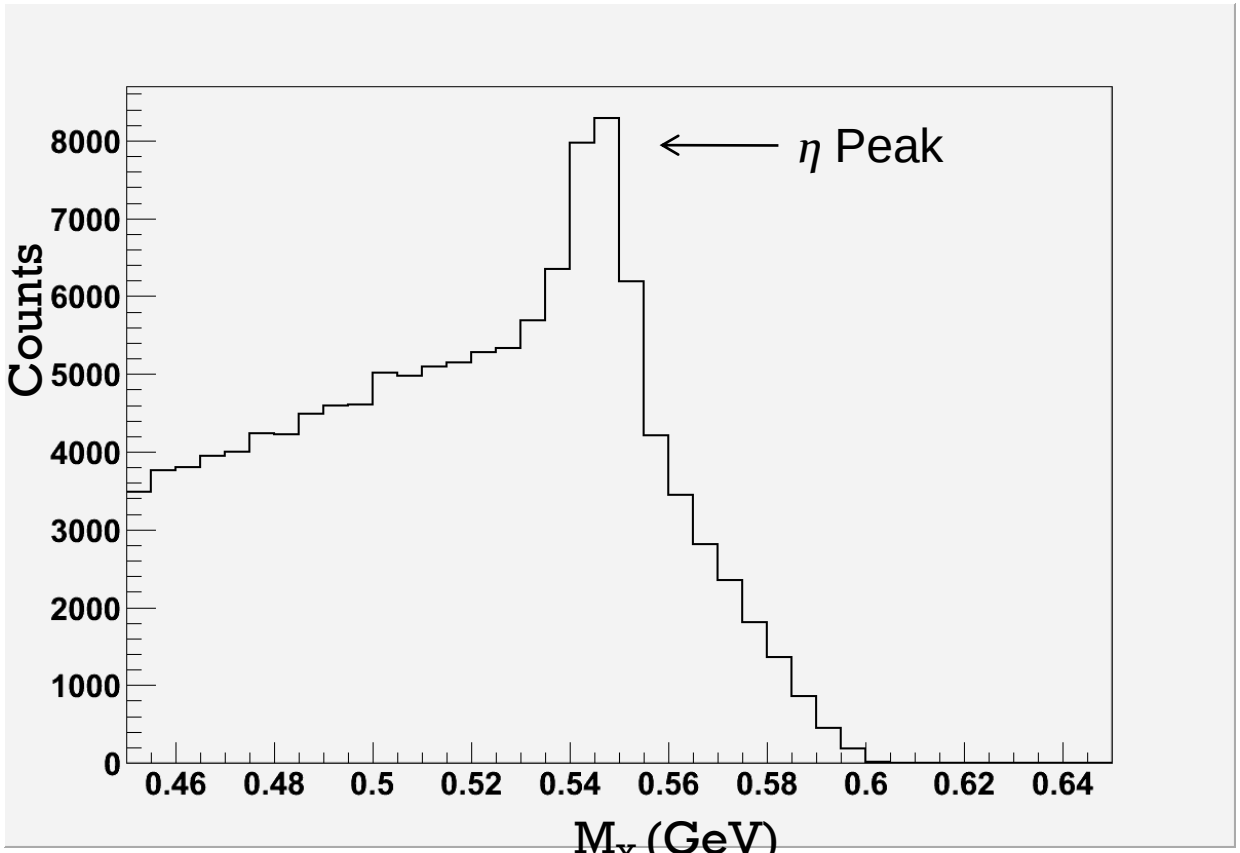
# Potential topologies:

$$\gamma + p \rightarrow p + \pi^{+/-} + X$$

*W = 1500 to 1550 MeV*

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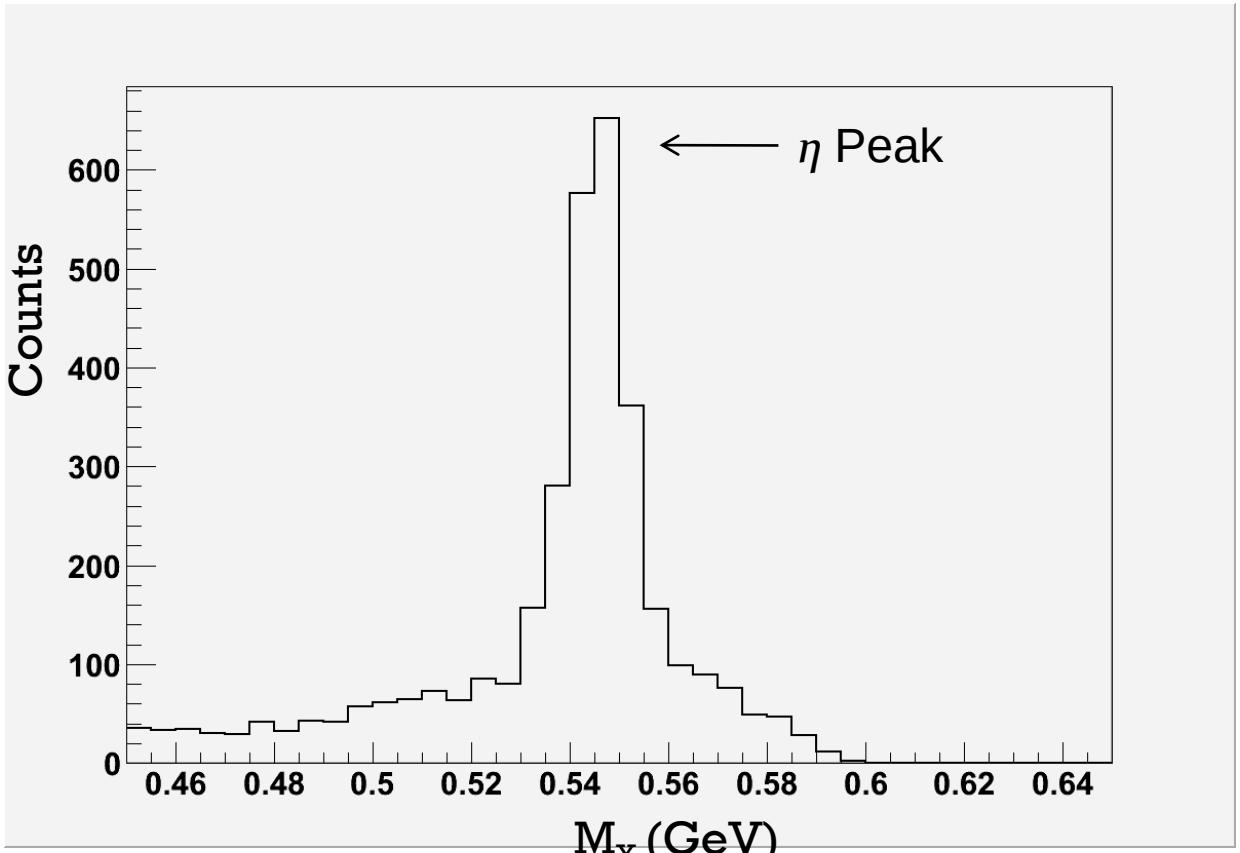
# Potential topologies:

$$\gamma + p \rightarrow p + \pi^+ + \pi^- + \pi^0$$

*W = 1500 to 1550 MeV*

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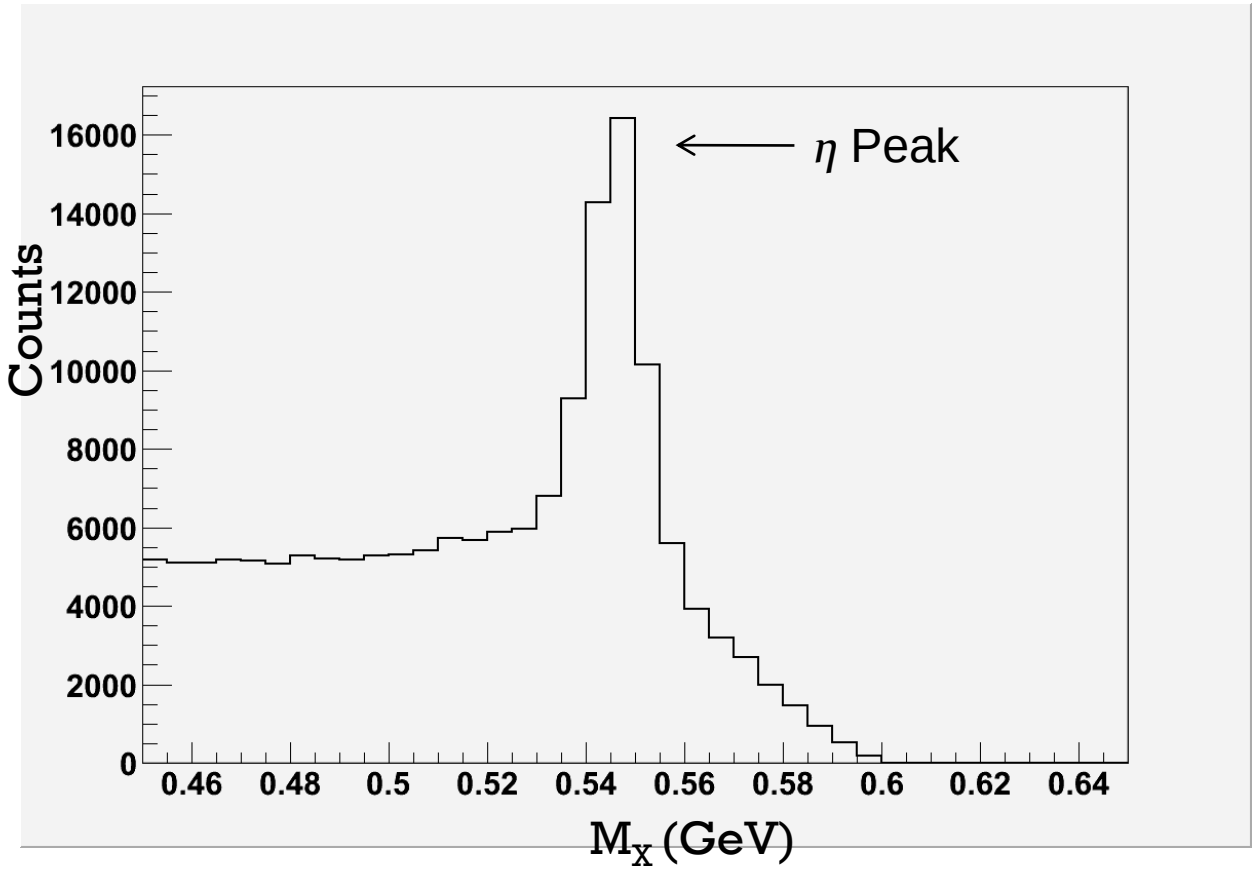
# Potential topologies:

## $\gamma + p \rightarrow p + X$ (photon detected)

*W = 1500 to 1550 MeV*

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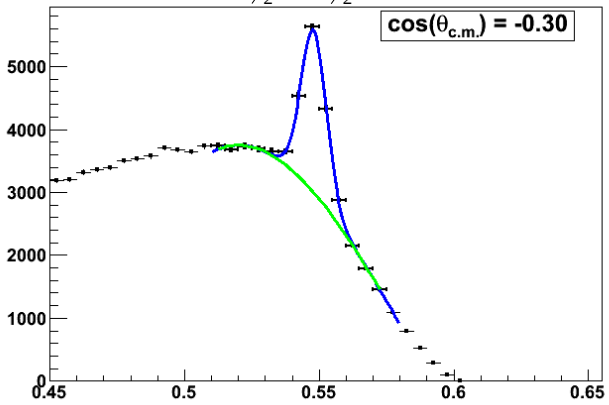
# Fits for $\gamma + p \rightarrow p + X$ *(no charged particles other than the proton detected)*

- $W$ = 1500 to 1550 MeV
- $\cos(\theta^{\eta}_{\text{c.m.}})$ = -.4 to -.2

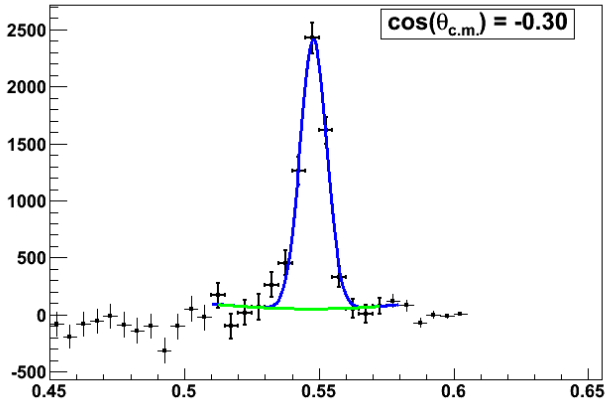
Denominator

$N_{1/2} + N_{3/2}$

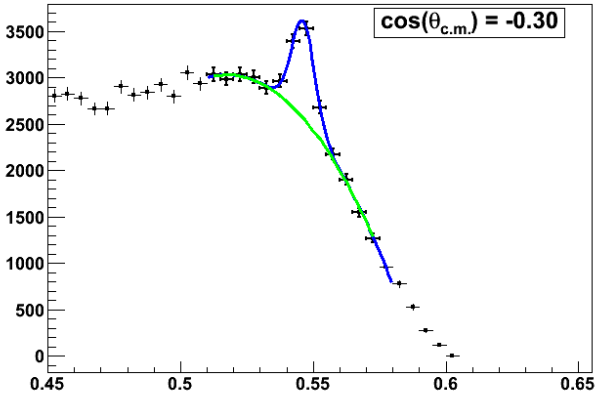



Numerator

$N_{1/2} - N_{3/2}$




Scaled Carbon

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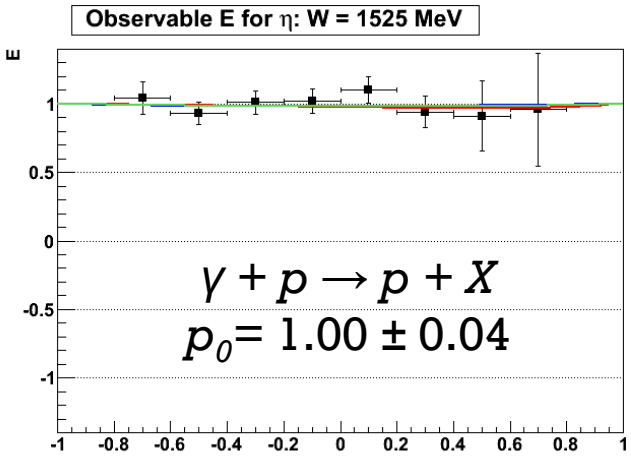
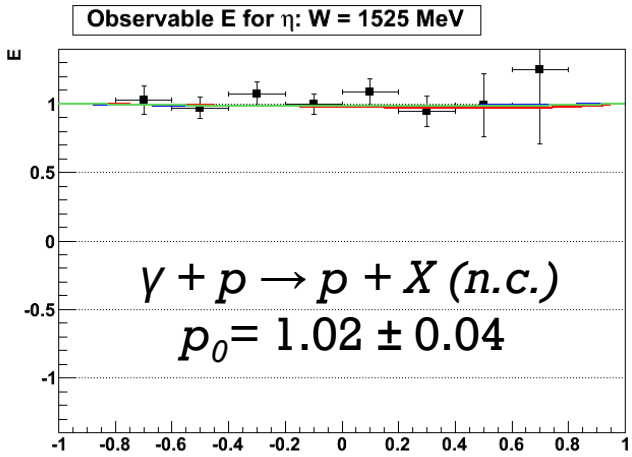
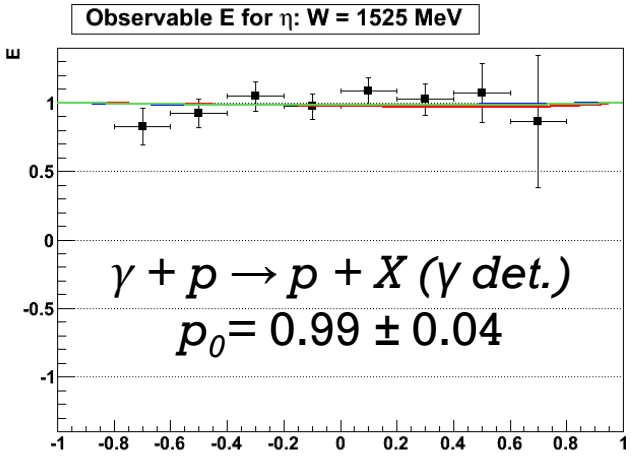
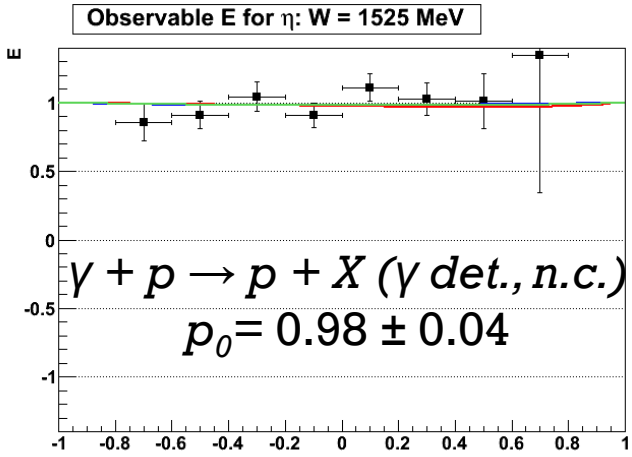
# *E* at threshold

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η-MAID

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*n.c. implies no charged particles other than the proton.

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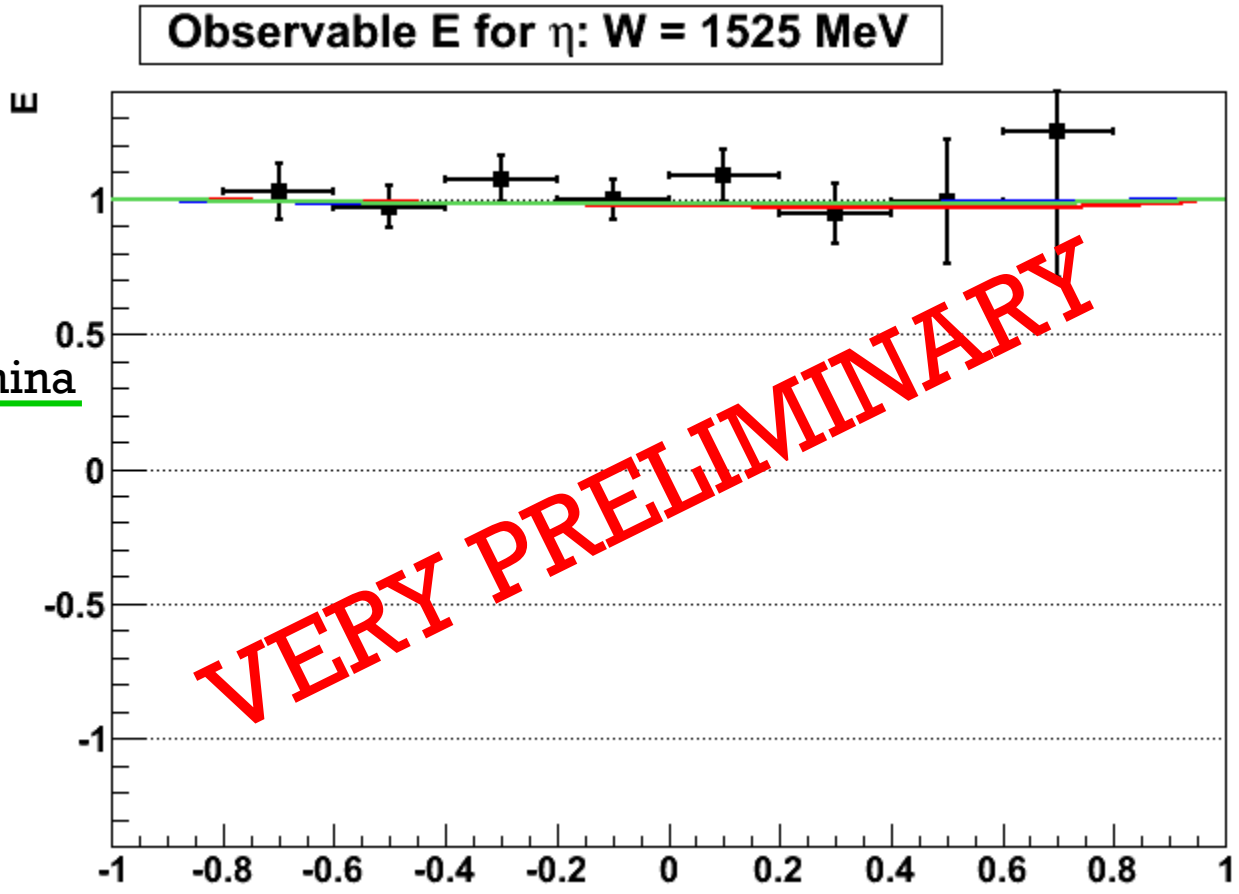
# $E$ for $\eta$: $\gamma + p \rightarrow p + X$ (n.c.)

SAID

$\eta$-MAID

Bonn-Gatchina

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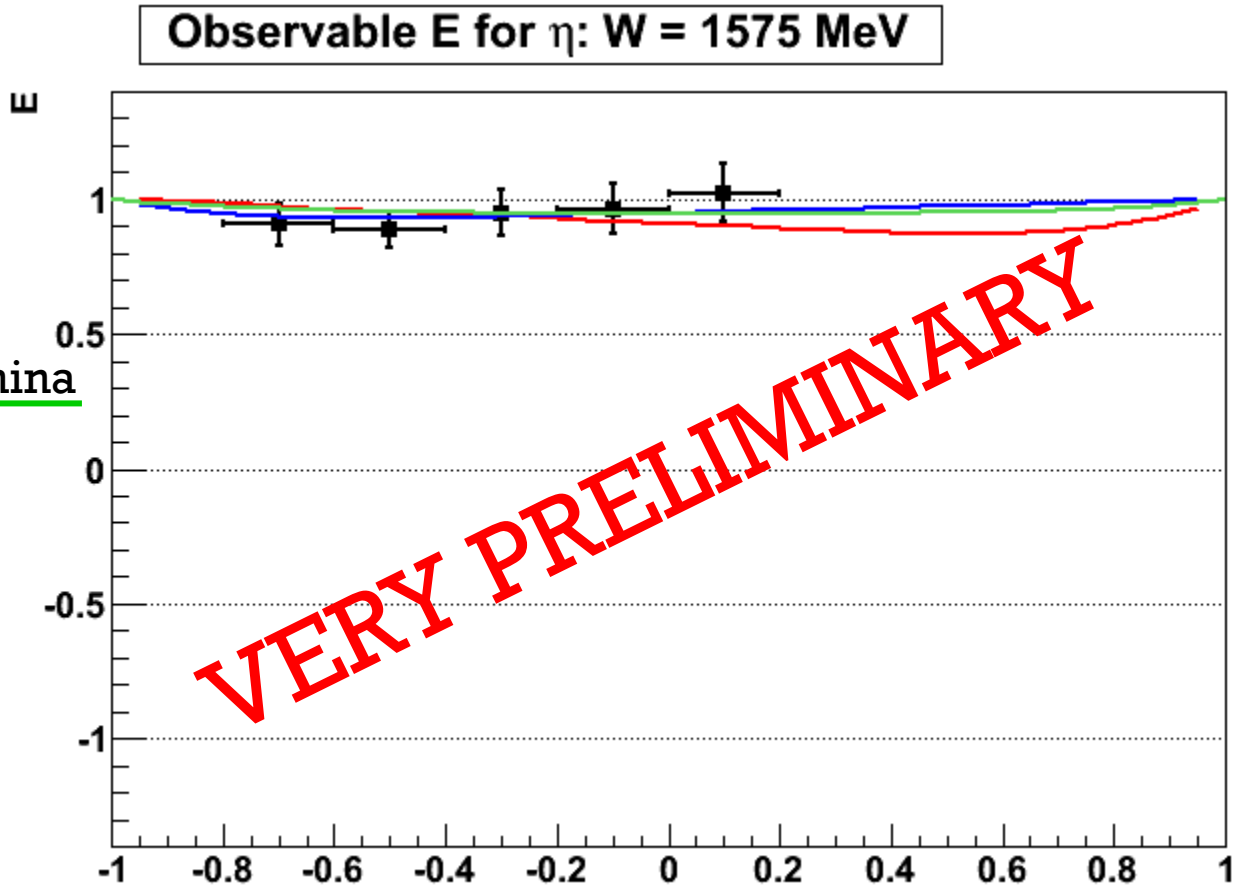


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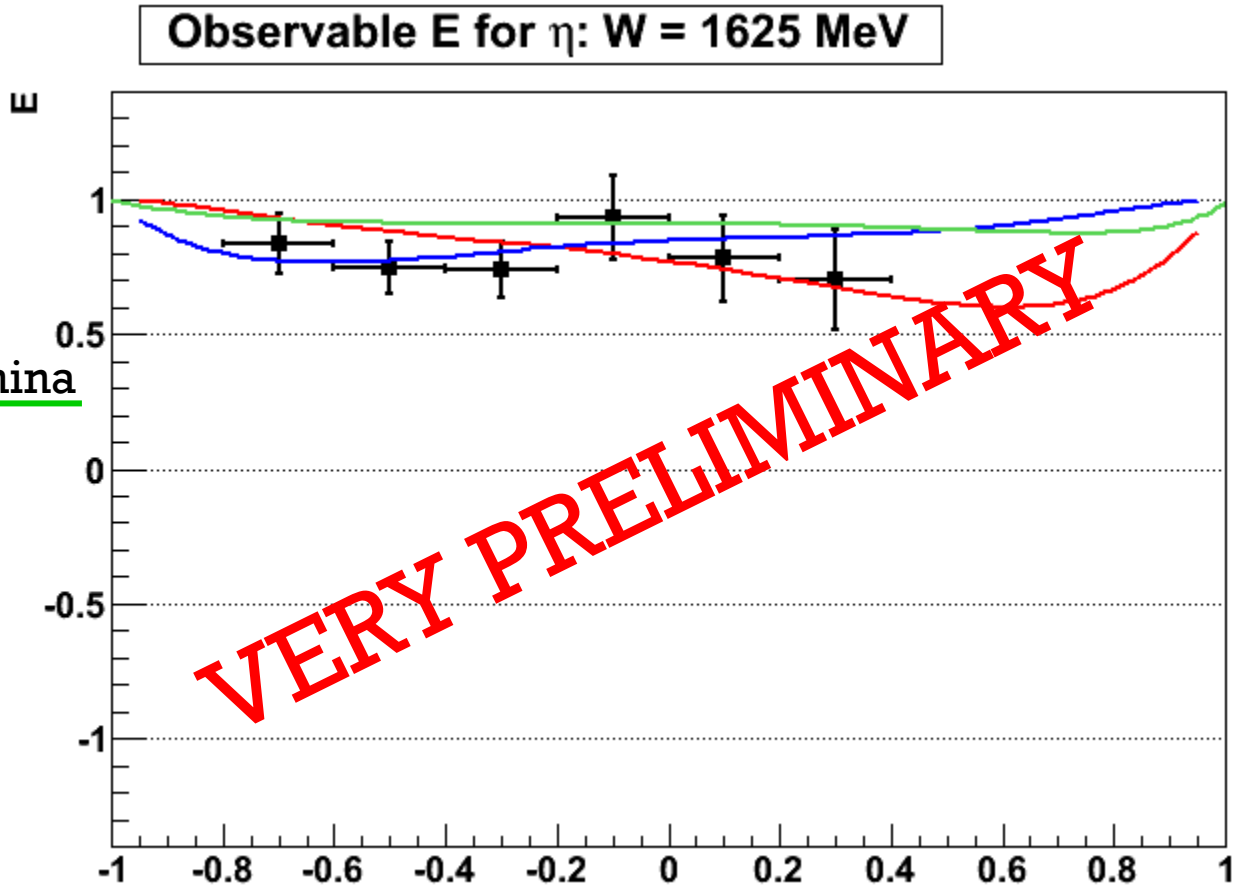


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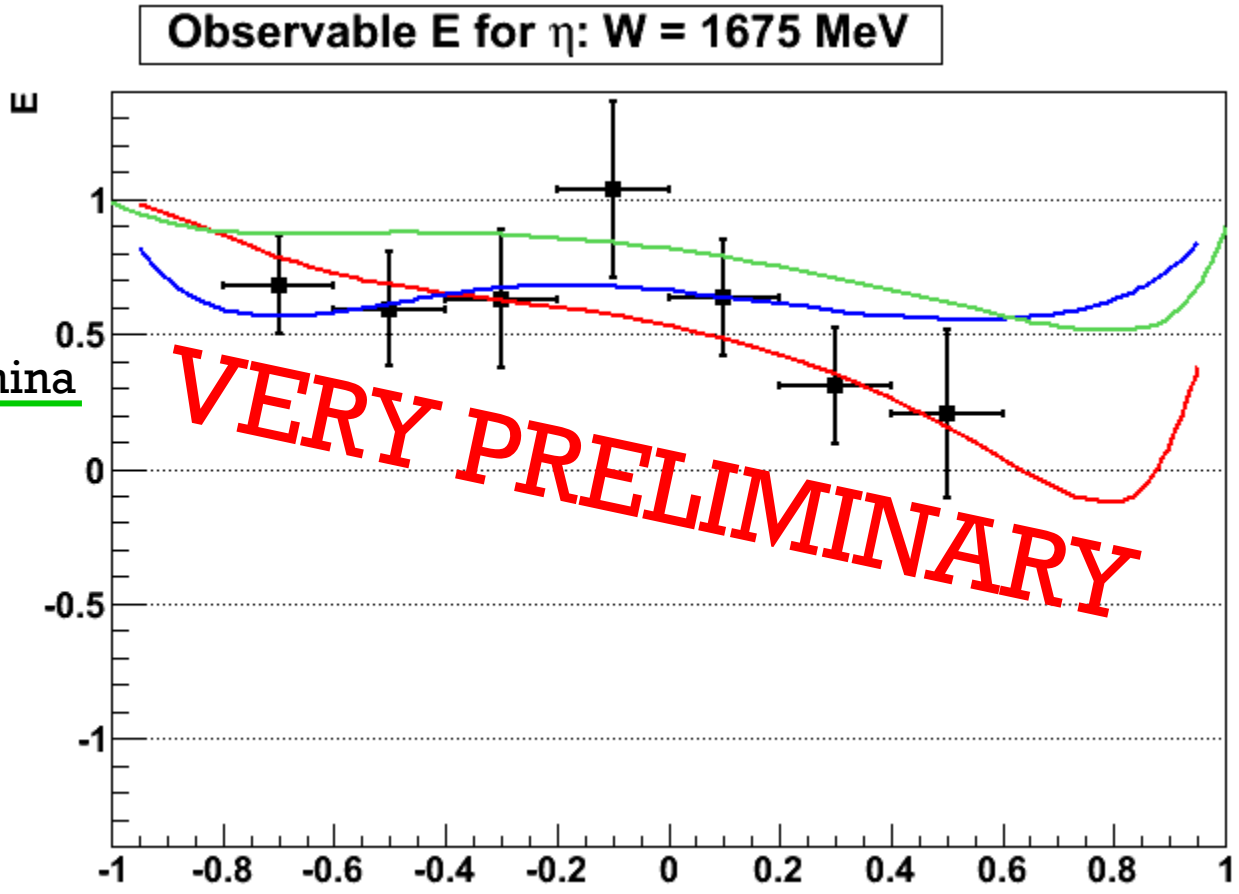


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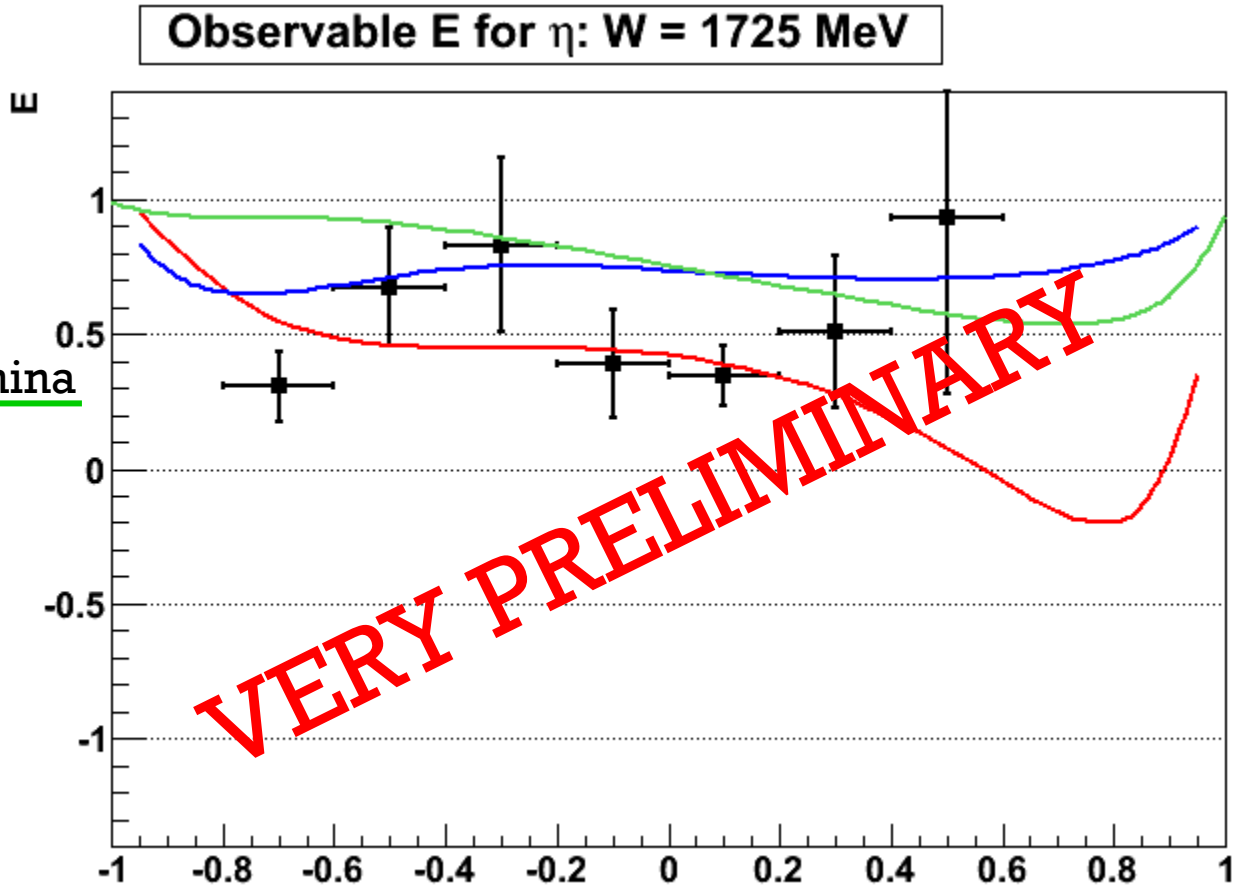


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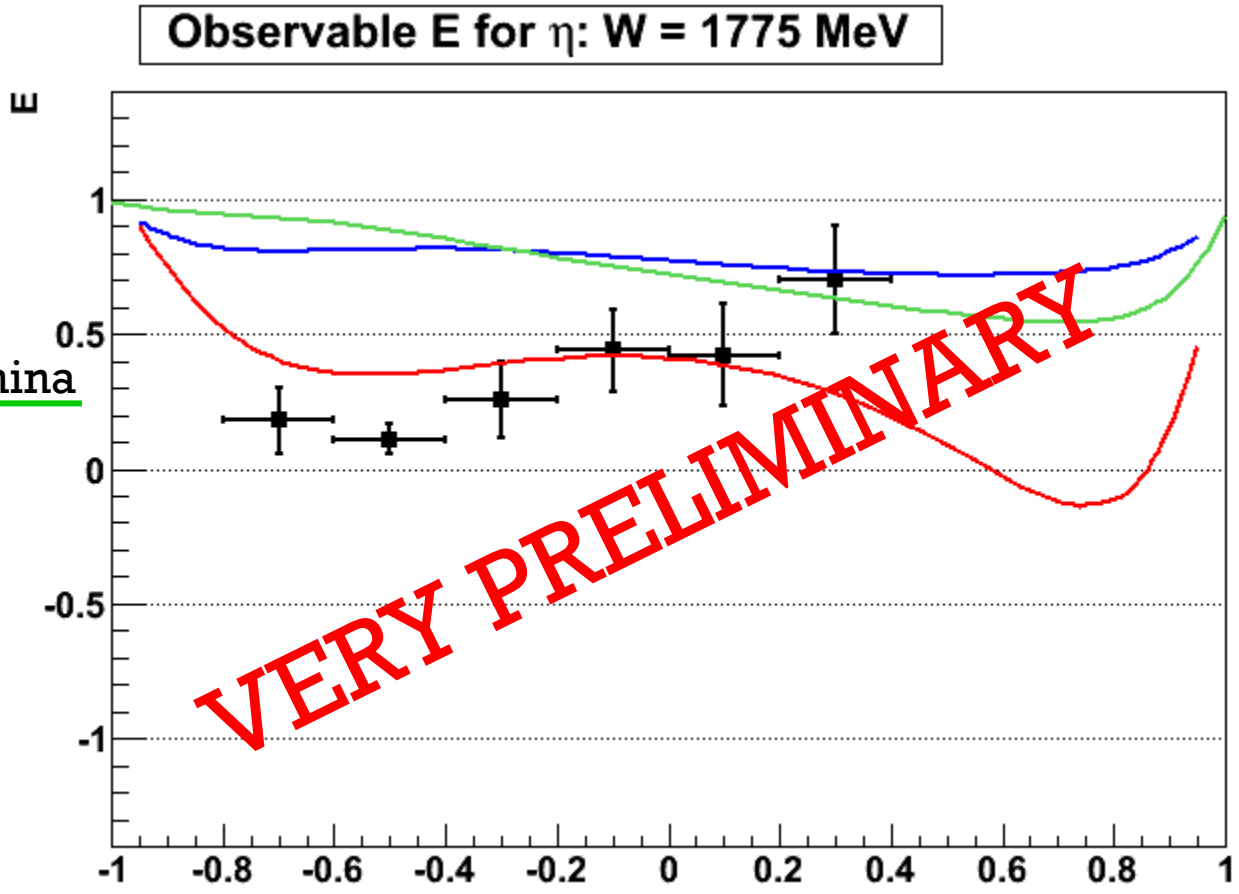


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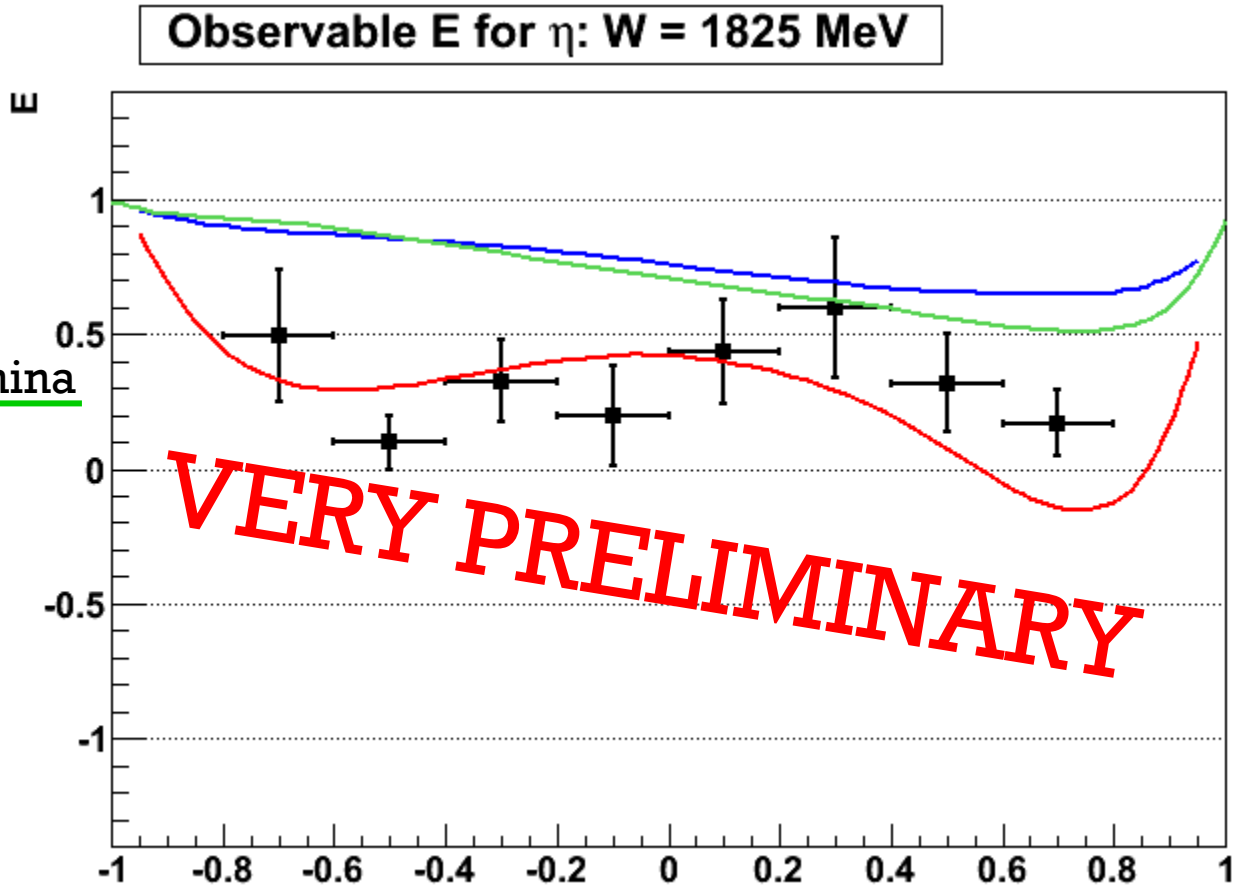


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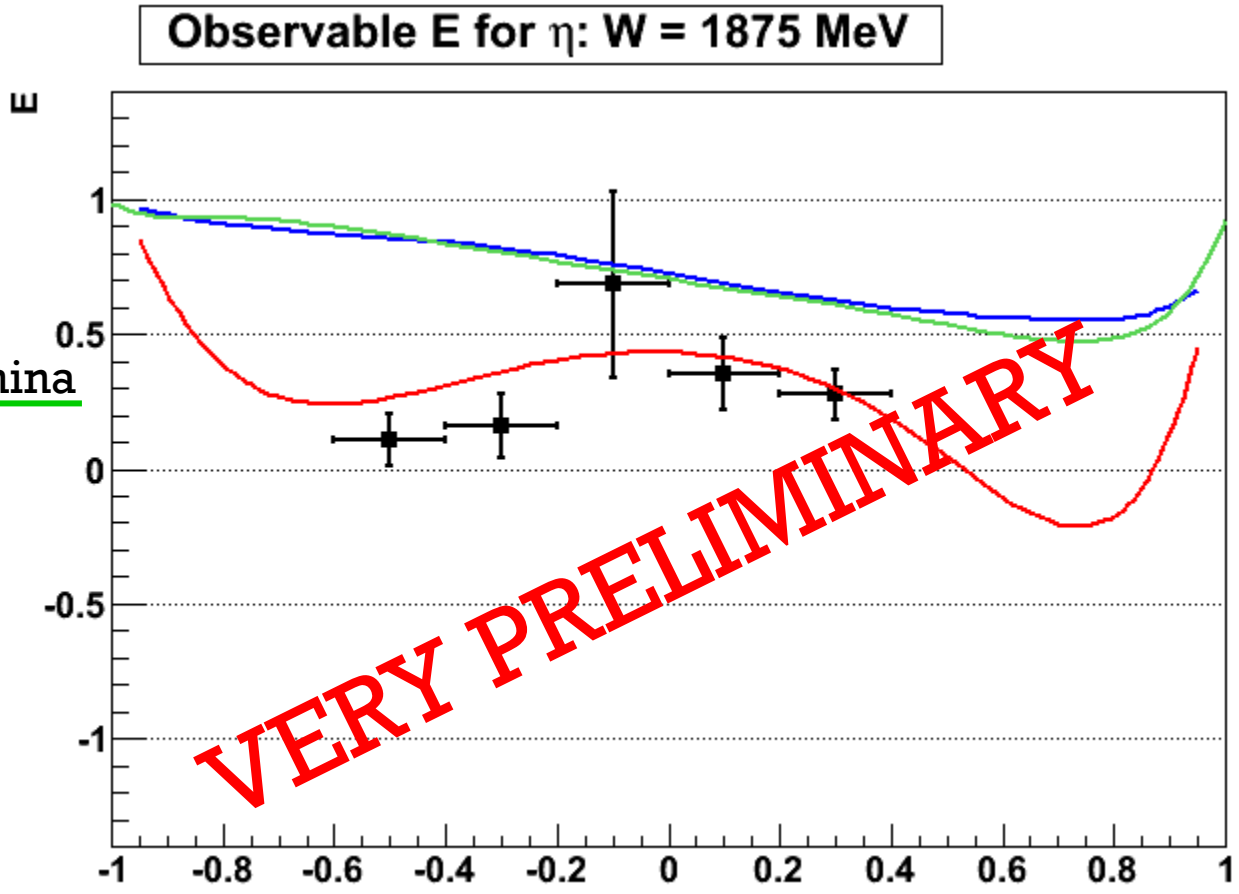


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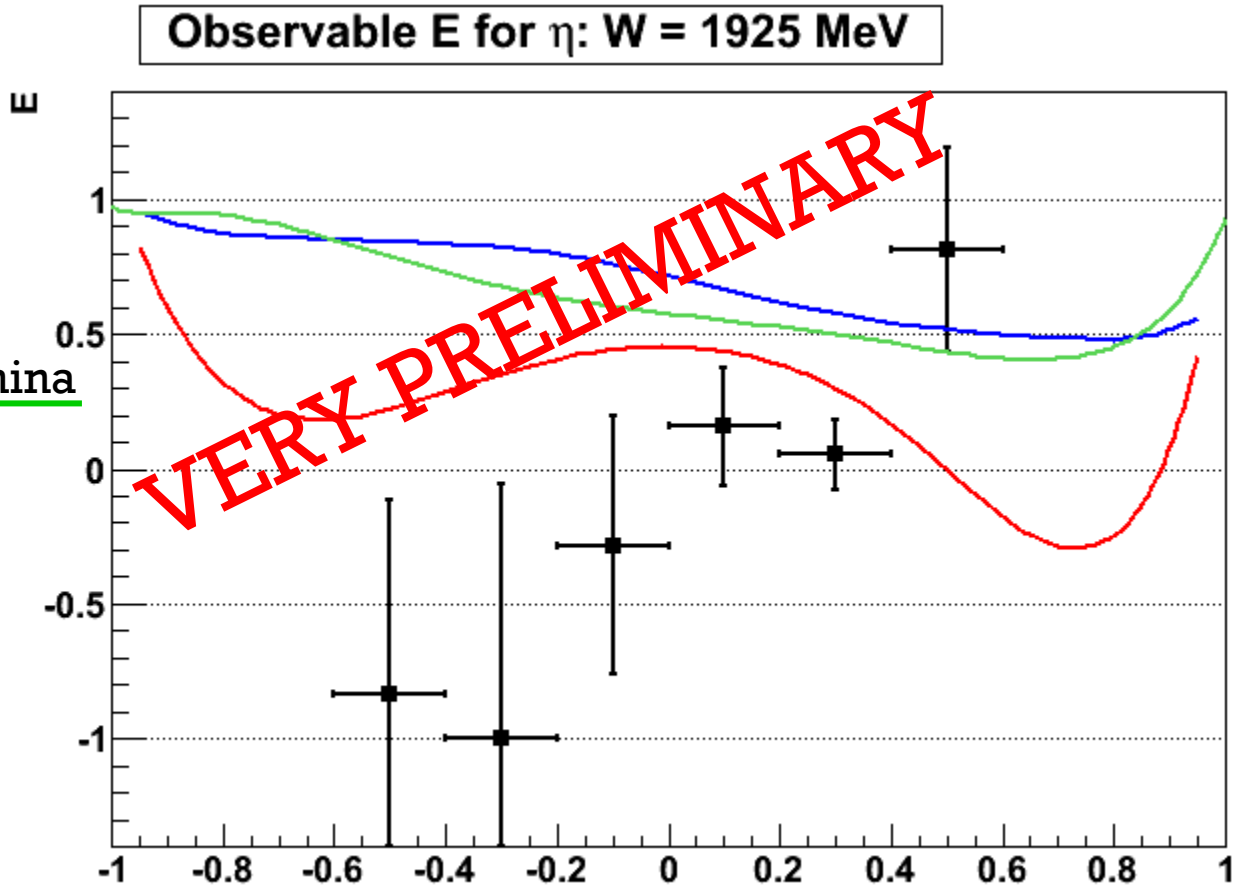


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# *E* vs *W*

## *Topology:* $\gamma + p \rightarrow p + X$ *(n.c.)*

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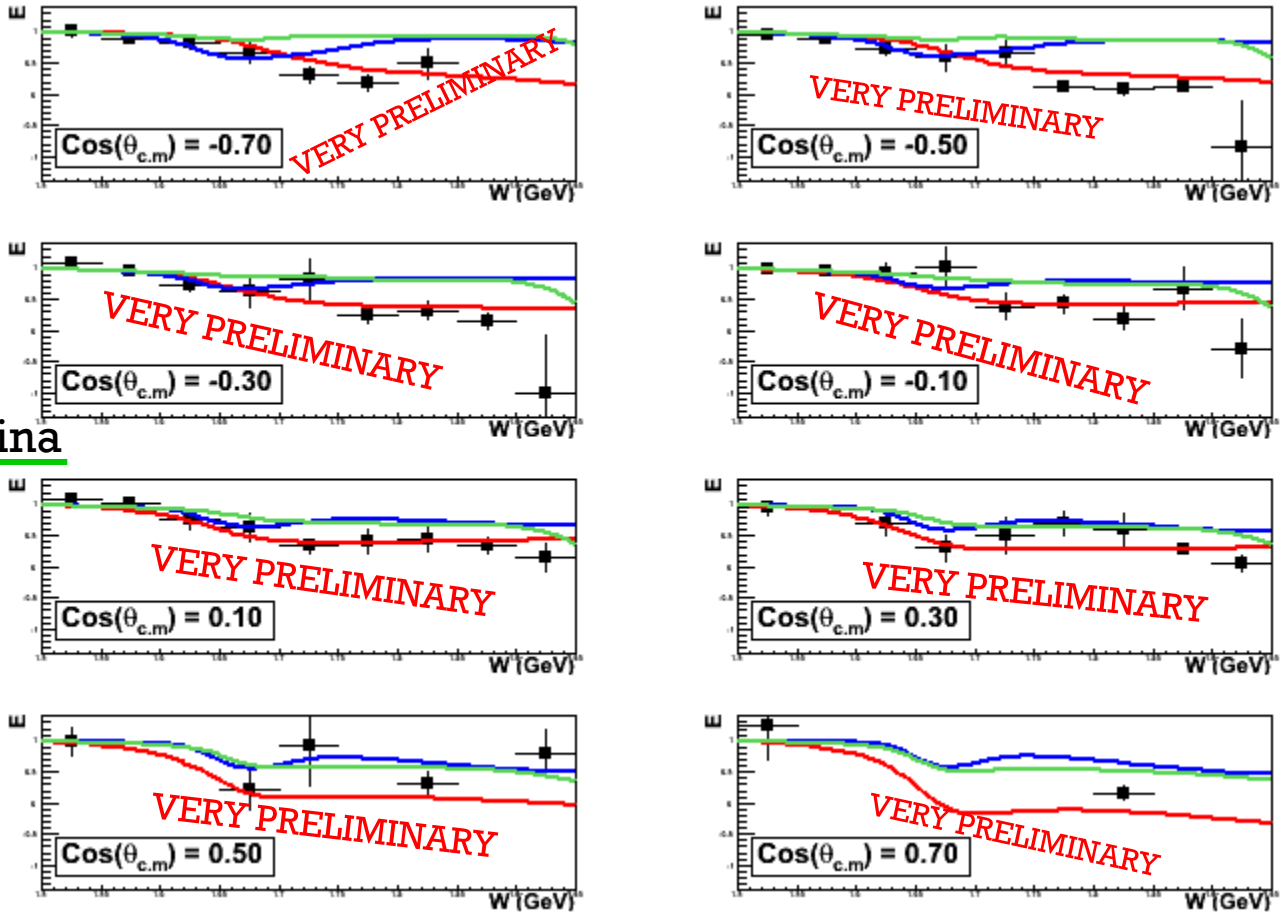
$\eta$-MAID

Bonn-Gatchina

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# Conclusions

- Preliminary measurements for $E$ near threshold demonstrate proper behavior. Very preliminary measurements for $E$ have been obtained up to 1925 MeV in W.
- Polarization observables from $\eta$ photoproduction will help constrain theoretical models.
- All other beam-target double polarization observables are accessible through FroST and will be analyzed.

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# Acknowledgements


- The CLAS colaboration
- The ASU working group:
  - Barry Ritchie
  - Michael Dugger
  - Eugene Pasyuk (now at Jlab)


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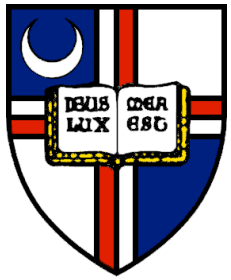



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# Polarization systematics

- Beam polarization: < 4%
- Target polarization: < 4%