Antibaryon Photoproduction using CLAS at Jefferson Lab

HADRON 2015

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FIU FLORIDA INTERNATIONAL UNIVERSITY

Jefferson Lab
Thomas Jefferson National Accelerator Facility

clas
CEBAF Large Acceptance Spectrometer

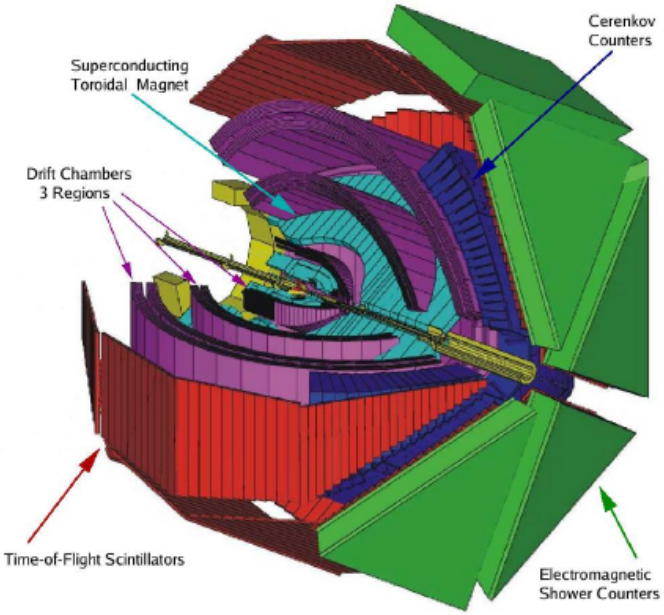
Motivation and Introduction

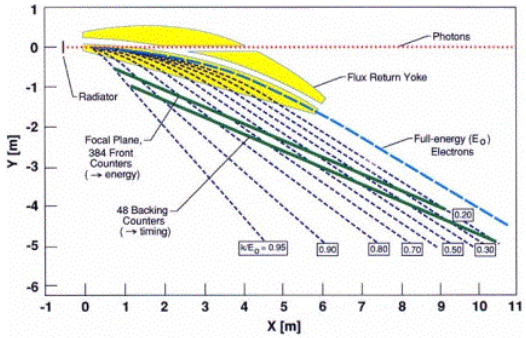
- Baryon-Antibaryon production has been studied since the early days of nuclear physics
- There is limited photoproduction data and the photoproduction mechanism is not well understood
- The main focus of this work is
  - Provide more details on the production mechanism through
    - Cross section measurements
    - A search for wide meson resonances using Partial Wave Analysis
  - Reactions studied include:

$$\gamma p \rightarrow pp\bar{p} \qquad \gamma p \rightarrow pp\pi^{-}\bar{n}$$

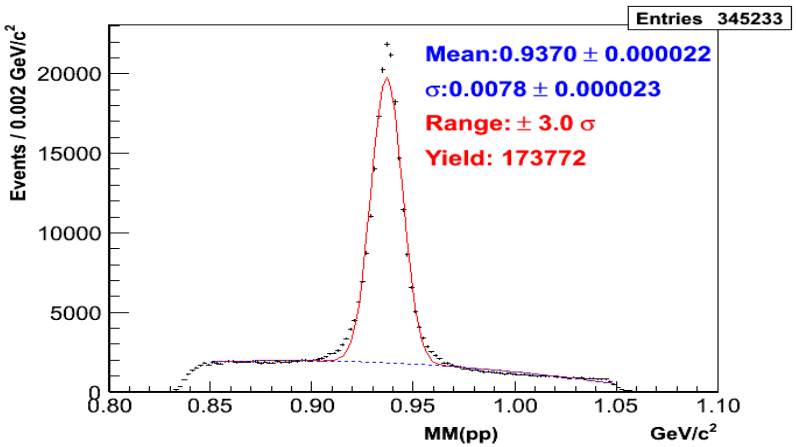
Experiment Overview

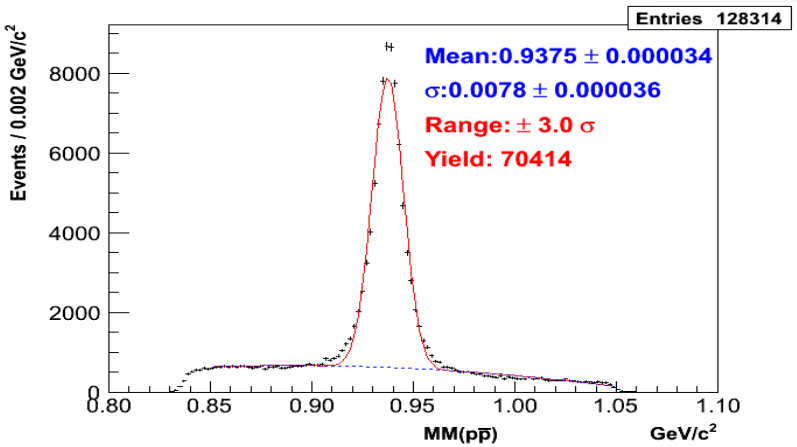
- *g*12 experiment
  - LH_2 target, ran in 2008
    - Target was -90 cm from center
  - Photoproduction: 1.1-5.45 GeV
    - Circularly polarized
  - Total Integrated Luminosity: 68 pb^{-1}
  - $7 \cdot 10^7$ tagged photons/s
  - Highest statistics photoproduction experiment to date in this energy range





Antiproton production in two topologies





$$\gamma p \rightarrow pp(\bar{p})$$

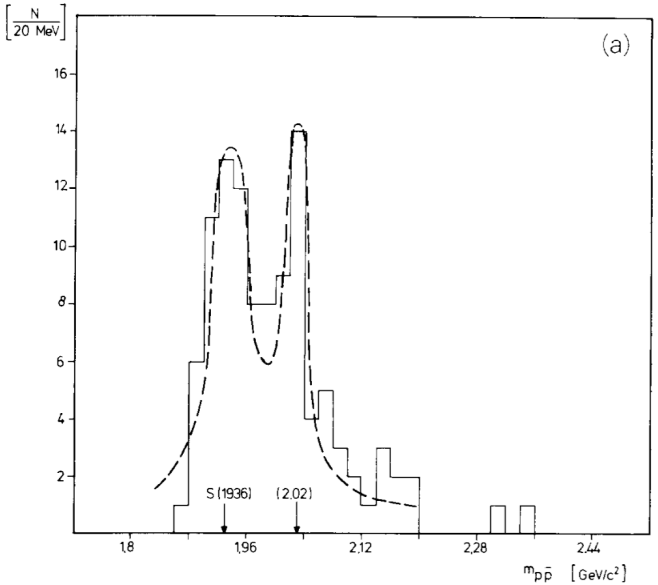
$$\gamma p \rightarrow p\bar{p}(p)$$

- E_γ from reaction threshold (3.9 GeV) to 5.45 GeV
- Missing particle selected using missing mass technique
- Unprecedented statistics in proton antiproton photoproduction
- $2.5*10^5$ events combined

Event selection:

- Timing cuts to remove out of time events
- Limit number of other detected charged particles and photons

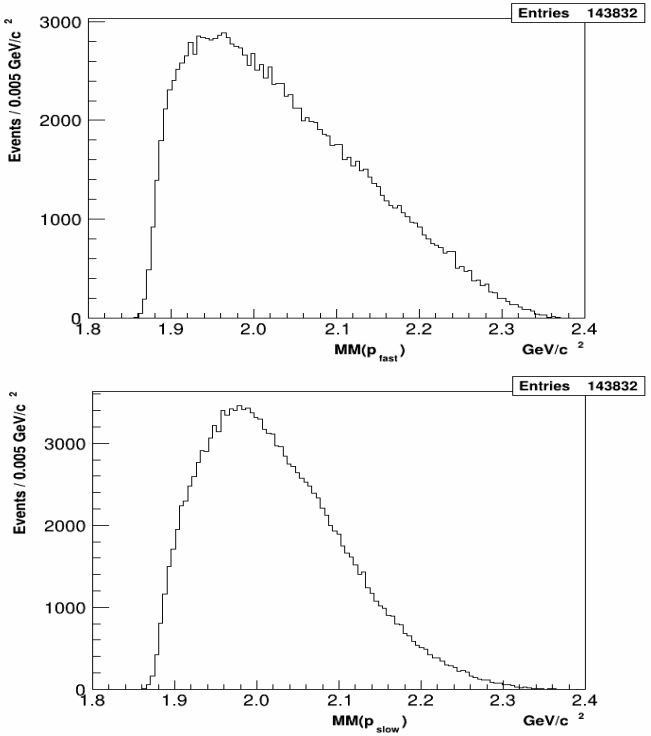
Search for narrow resonances



Bodenkamp et al, **Nucl. Phys. B255 717. (1985)**

- Narrow resonances have been observed in the past
- No evidence for narrow resonances in current analysis

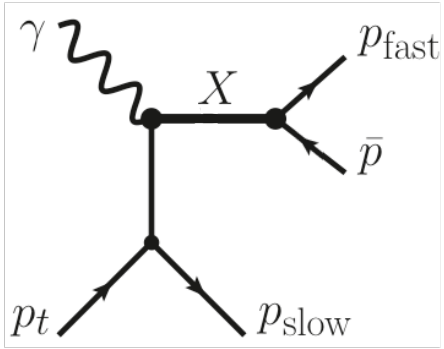
$$\gamma p \rightarrow pp(\bar{p})$$

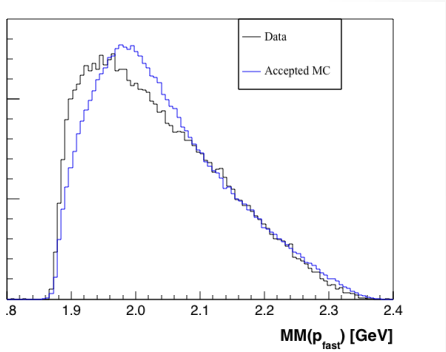


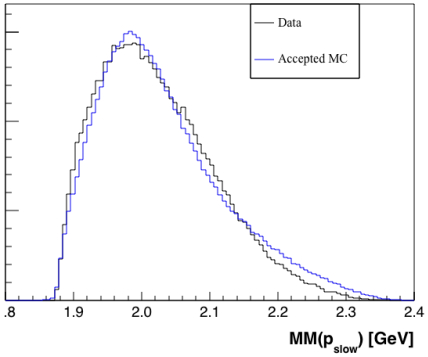
Note: E_γ from 3.9-5.5 GeV

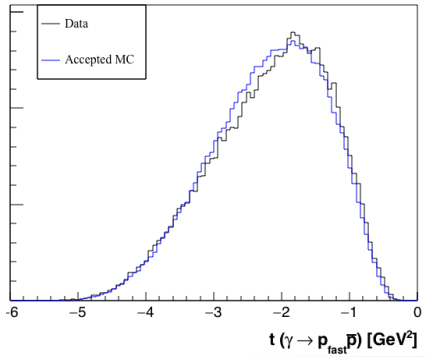
Current Monte Carlo Model

- Current model is a diffractive model tuned to be as close to data as possible
  - Similar to accuracy of previous measurements
- Differential cross sections will be used as a starting point for creating a more accurate model









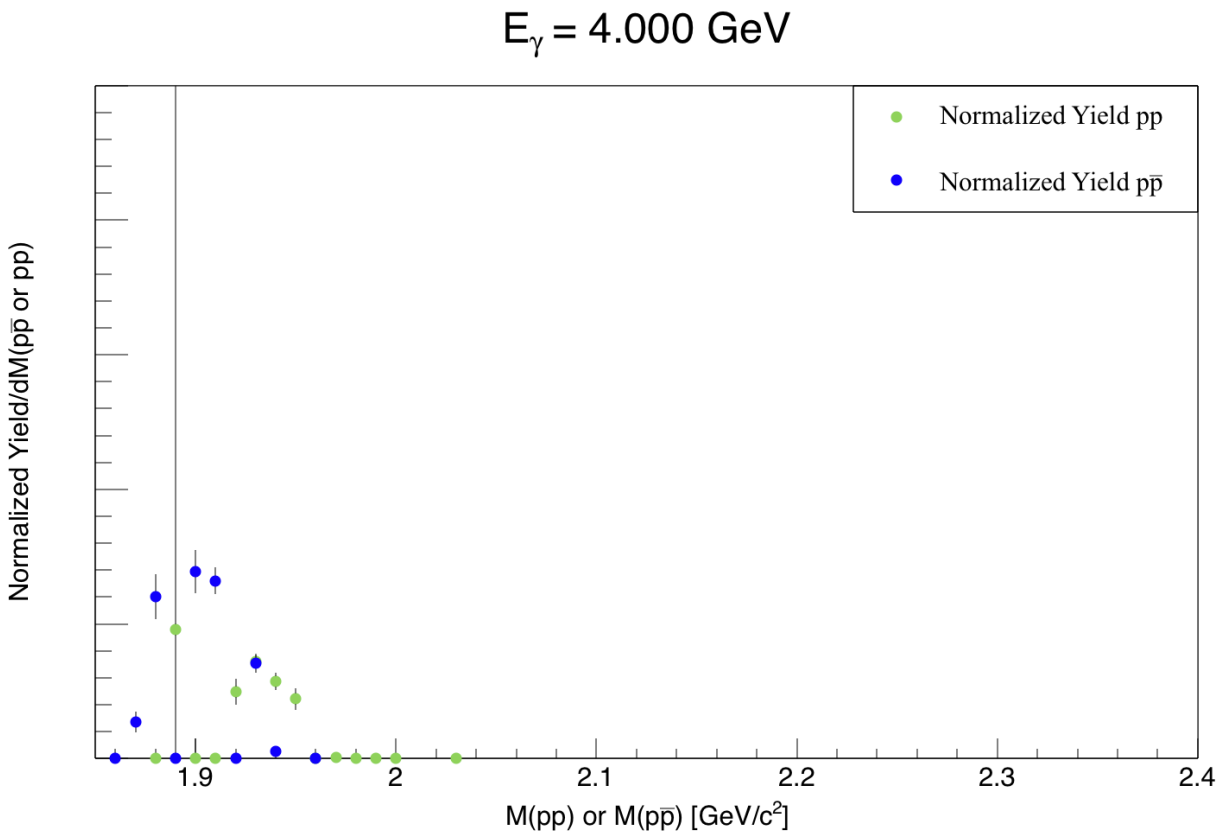
Modeling the Reaction

- Extracting a differential cross section for this reaction is not trivial
- Acceptance is very sensitive to model
- This particular reaction has been modeled in the past by mixing different production models to produce accurate acceptances (Diffractive, nucleon exchange and antinucleon exchange models)
- The alternatives include creating a model using calculated cross sections (PLUTO++)

Acceptance Corrected Mass Spectra

- Showing the invariant masses of the proton-proton pair and the proton-antiproton pair as a function of beam energy
- Proton-antiproton pair is double counted, as there are two combinations due to two protons in the final state
- This will be used to create a reaction model for generating Monte Carlo

Acceptance Corrected Mass Spectra



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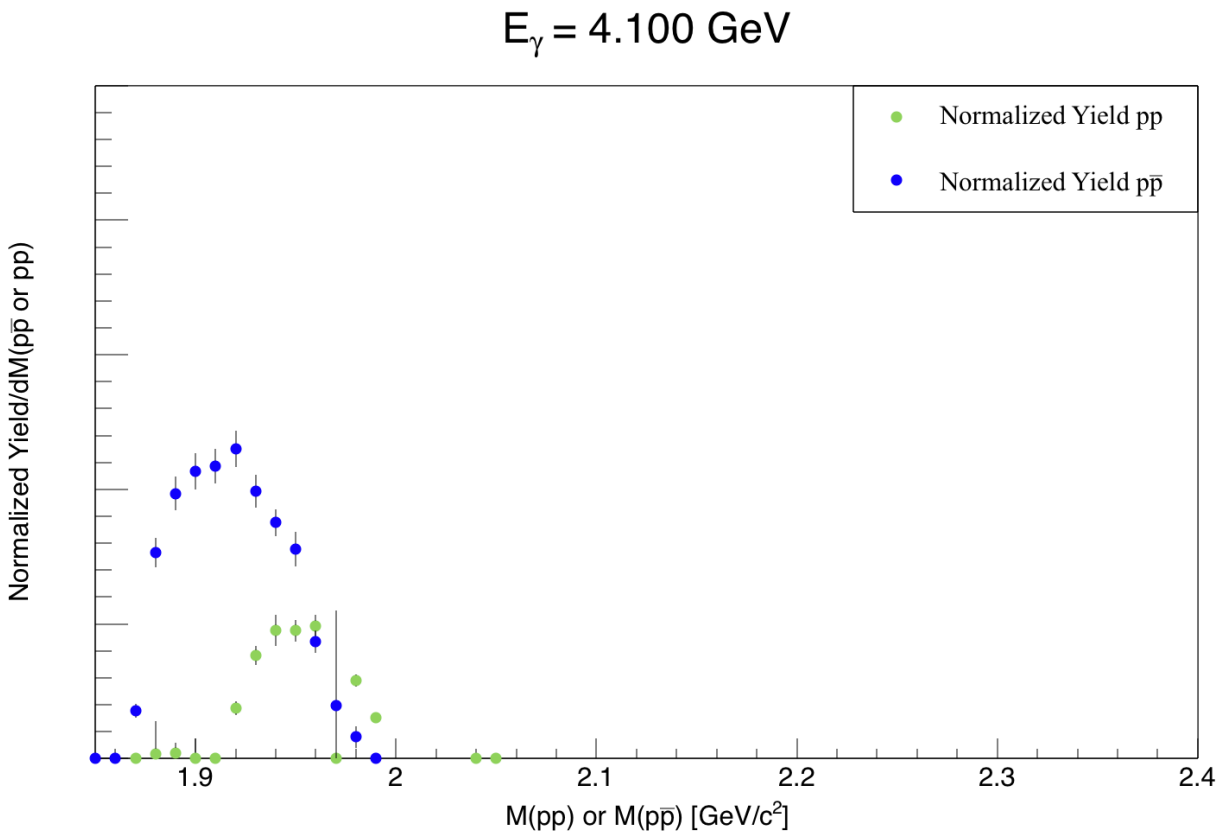

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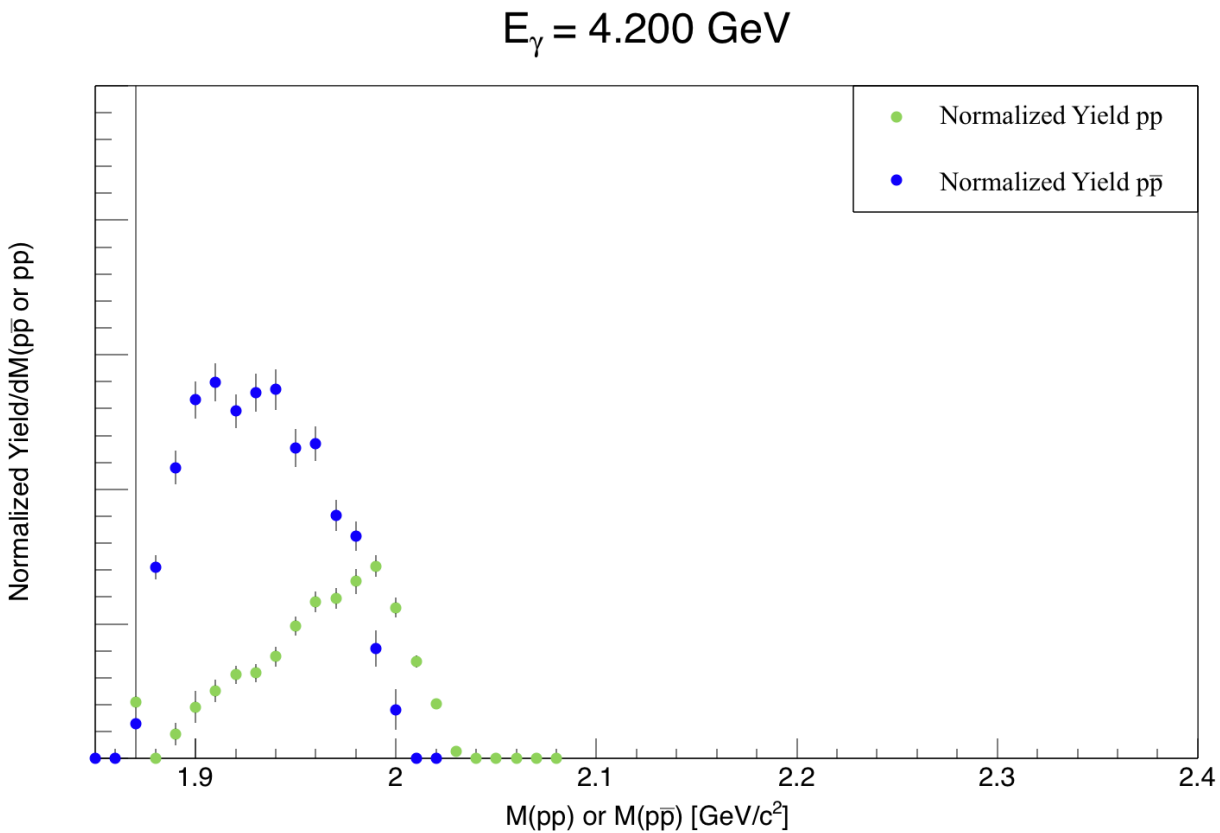

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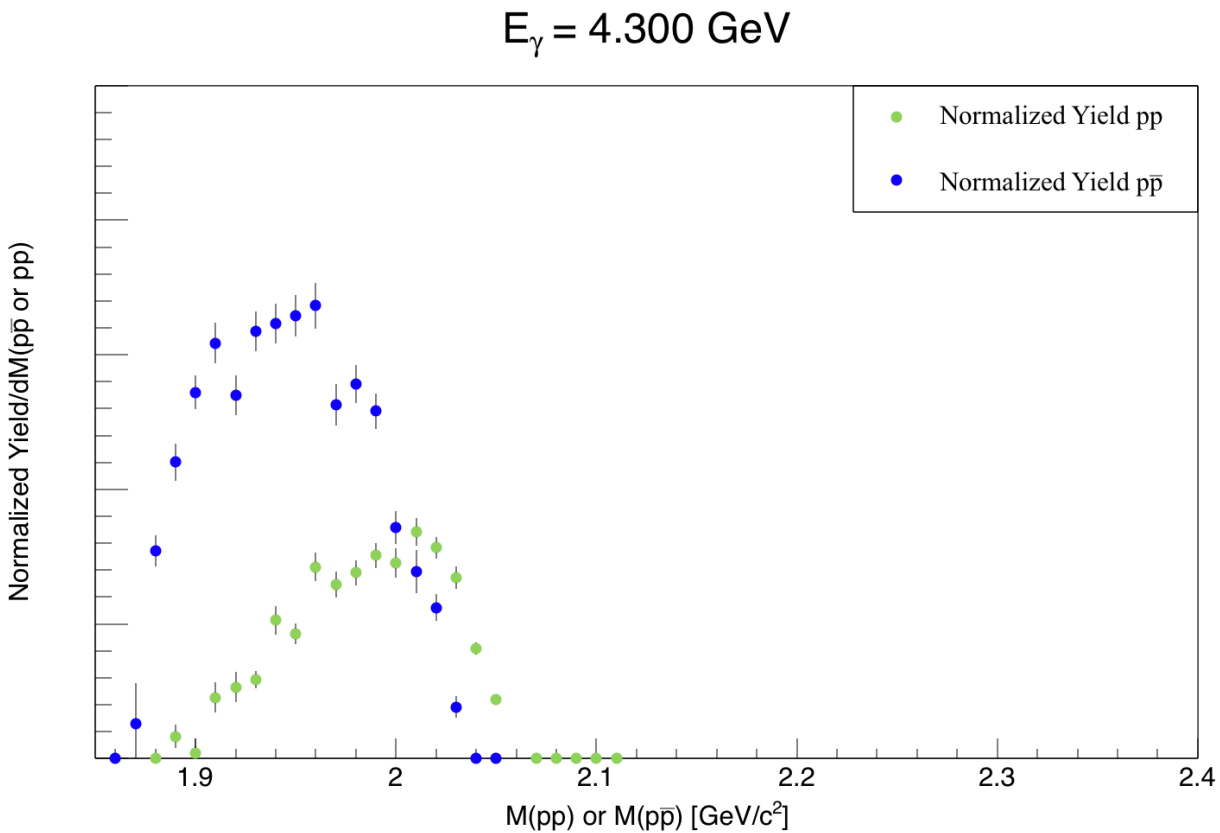

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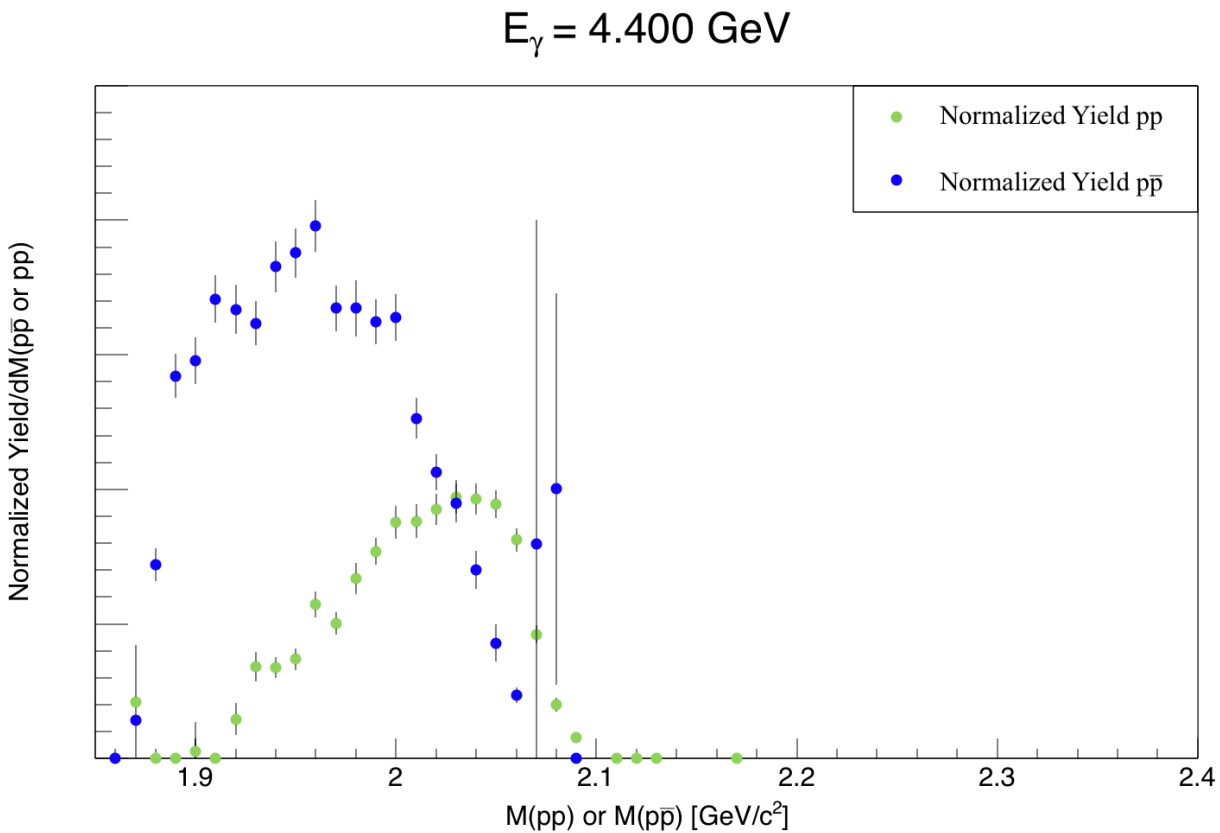

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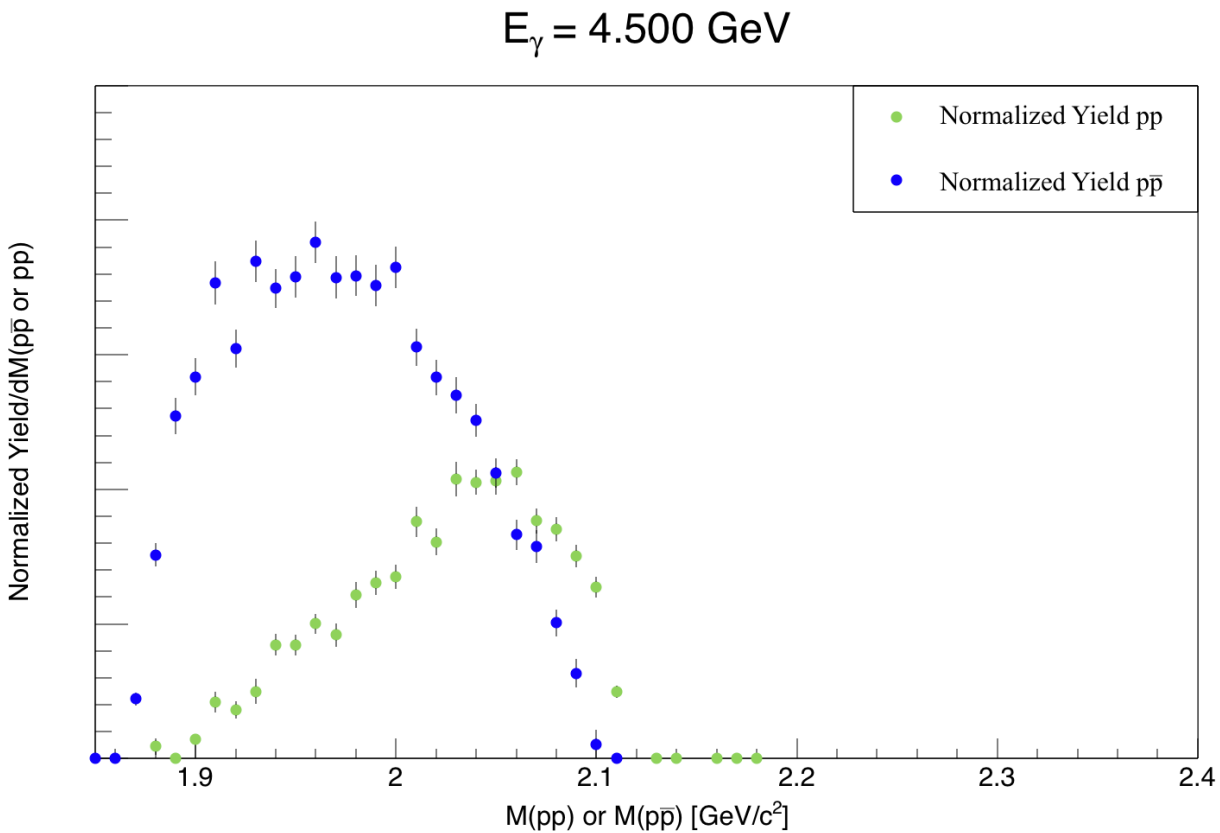

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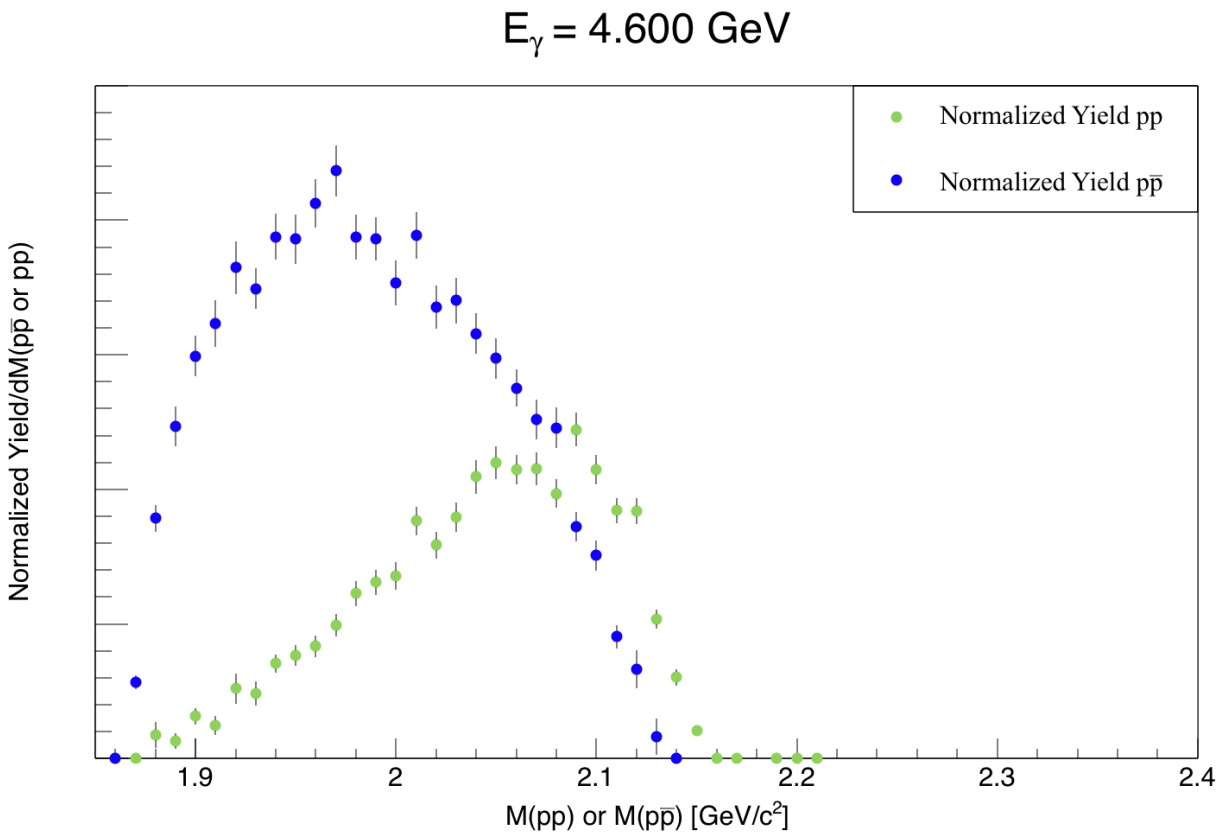

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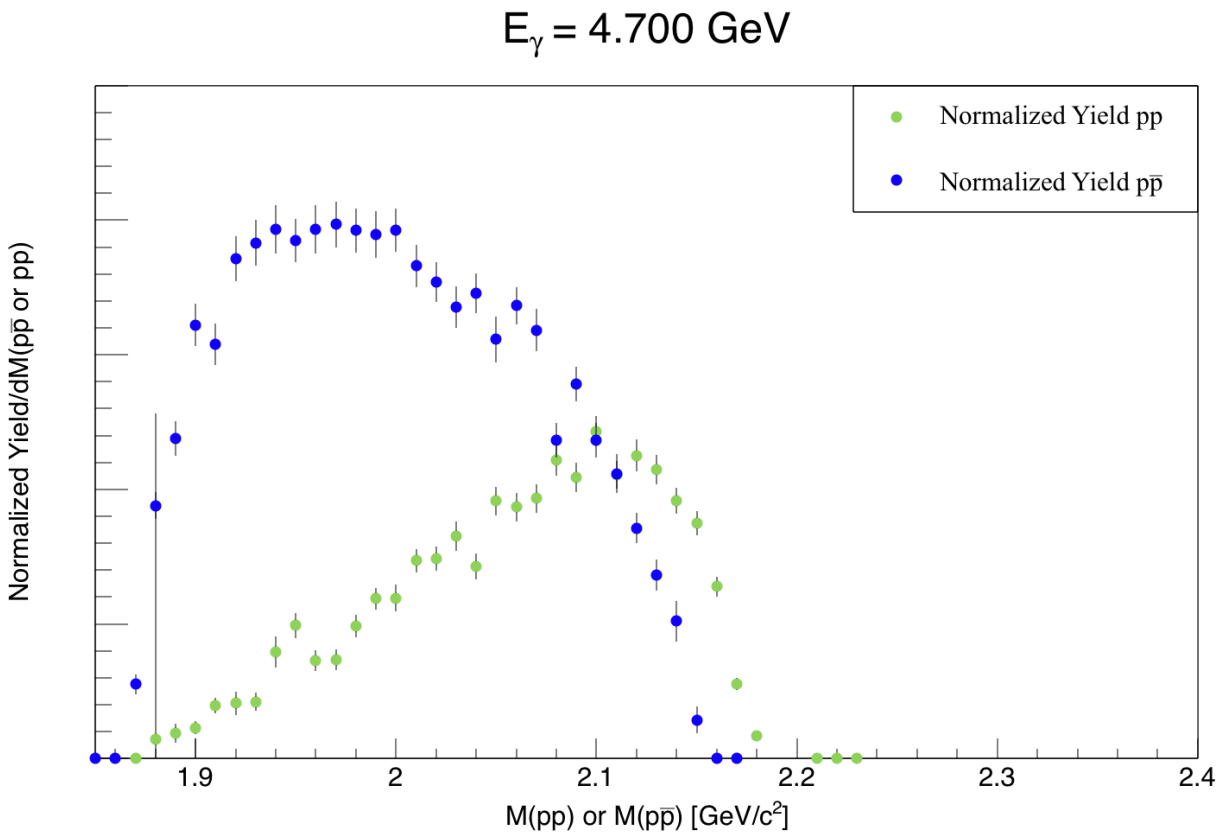

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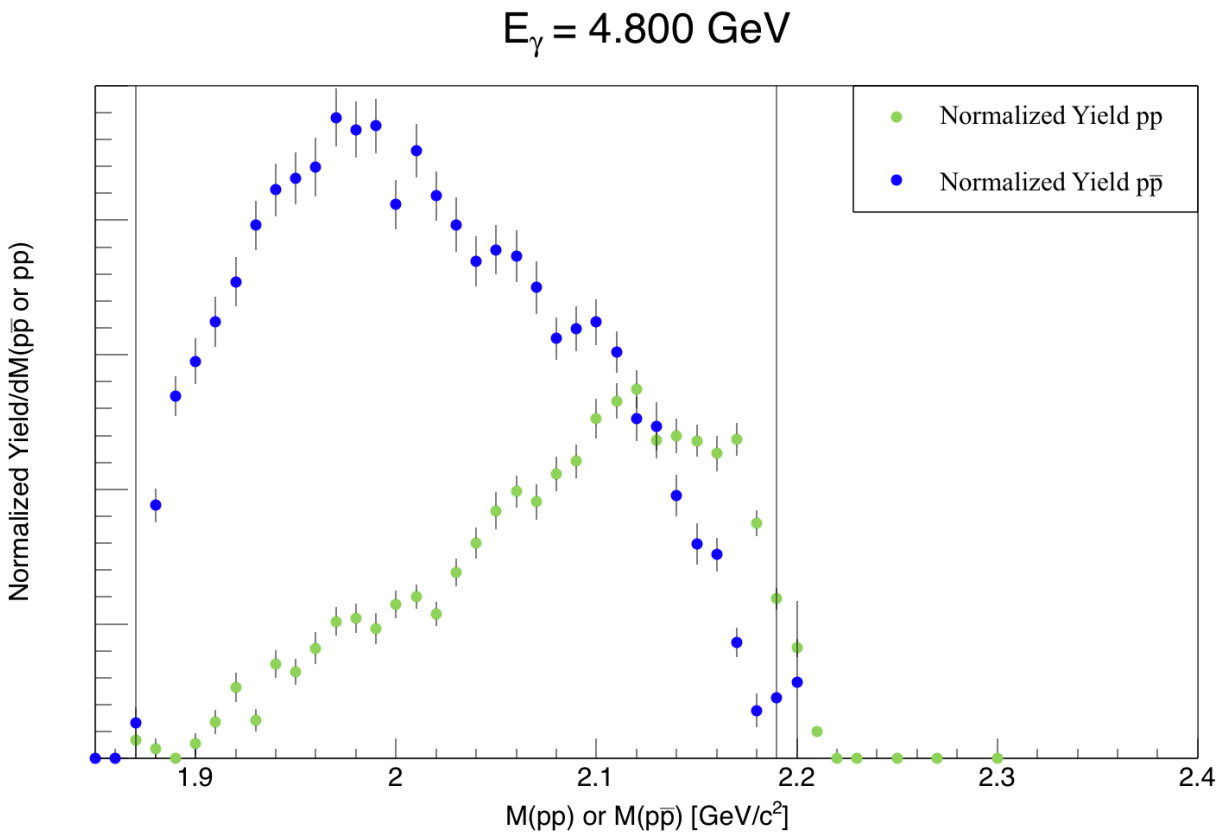

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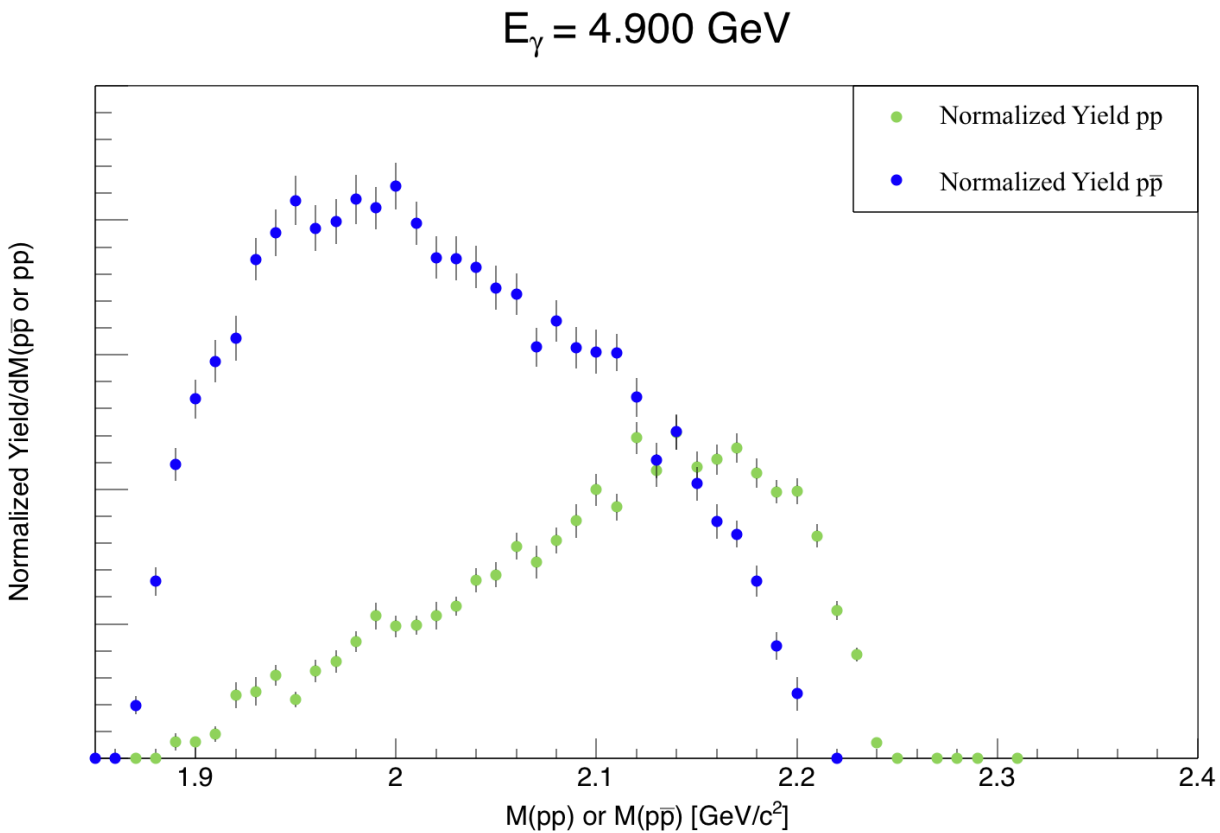

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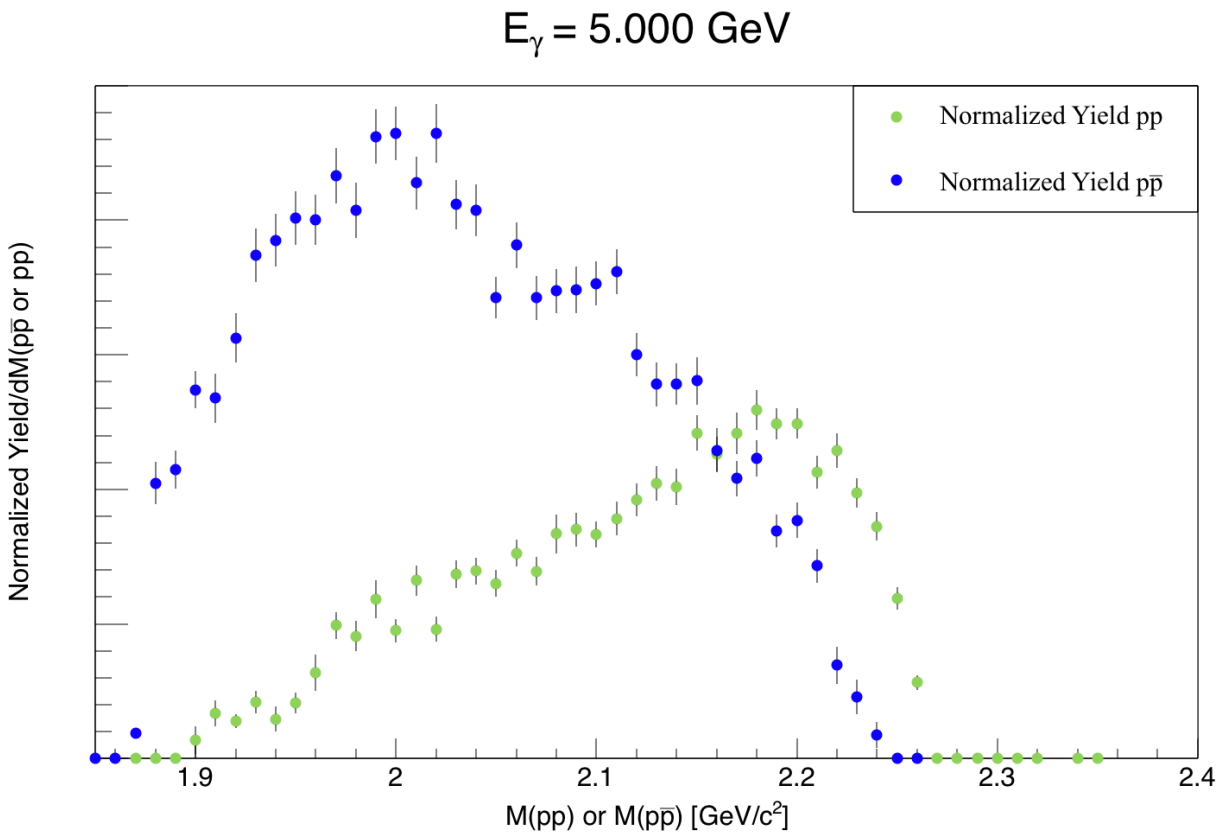

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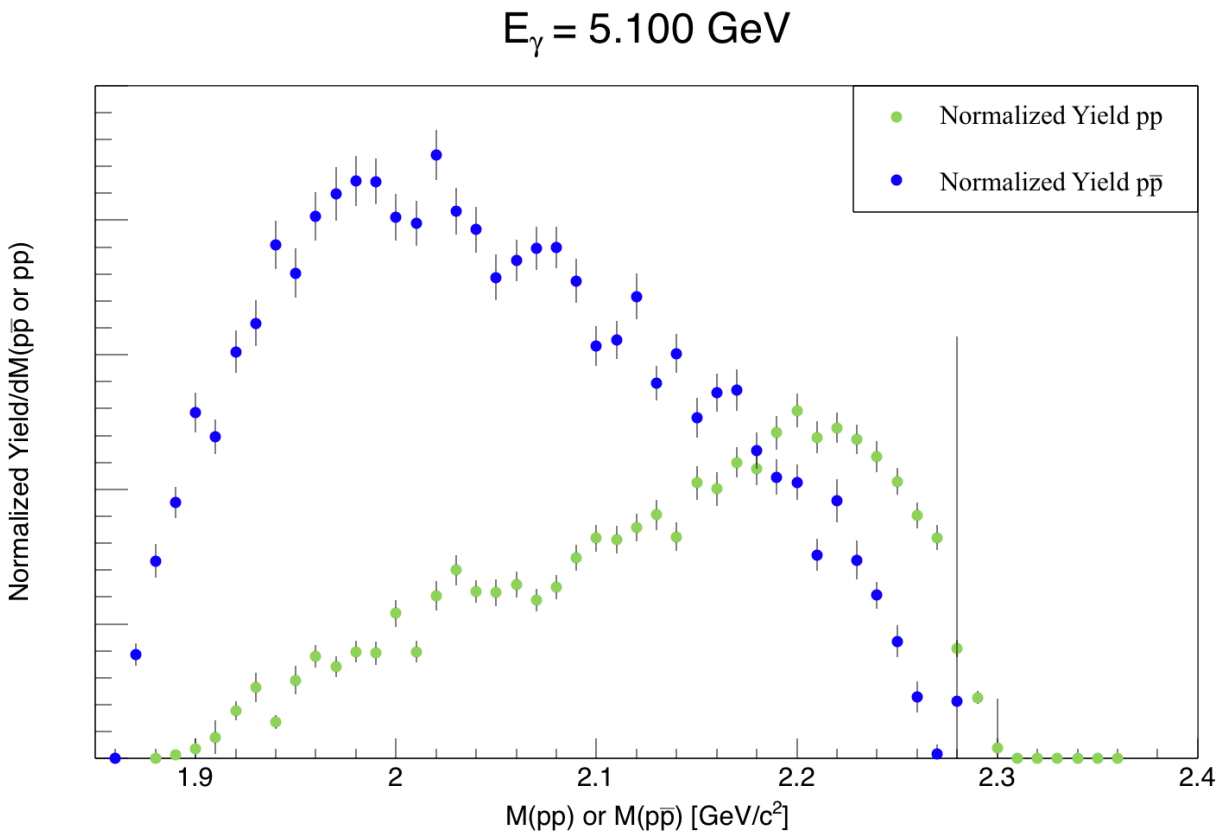

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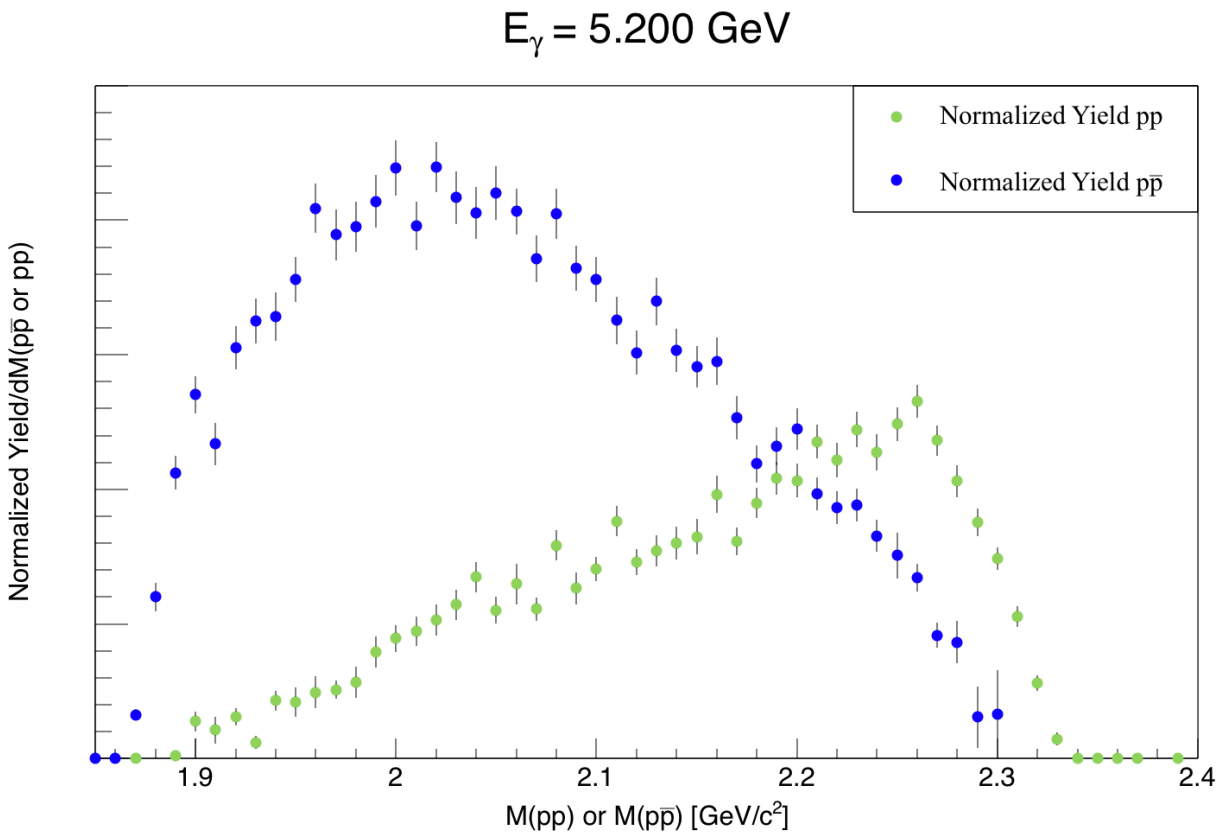

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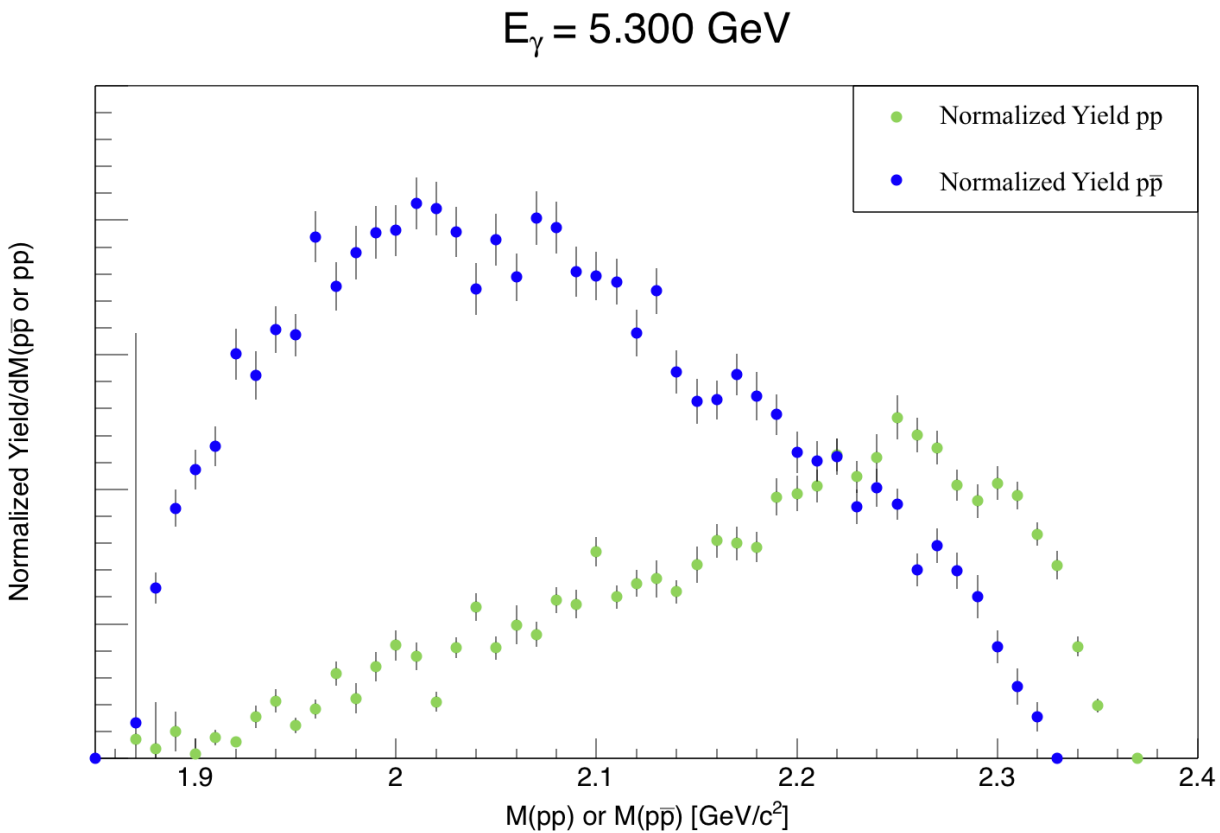

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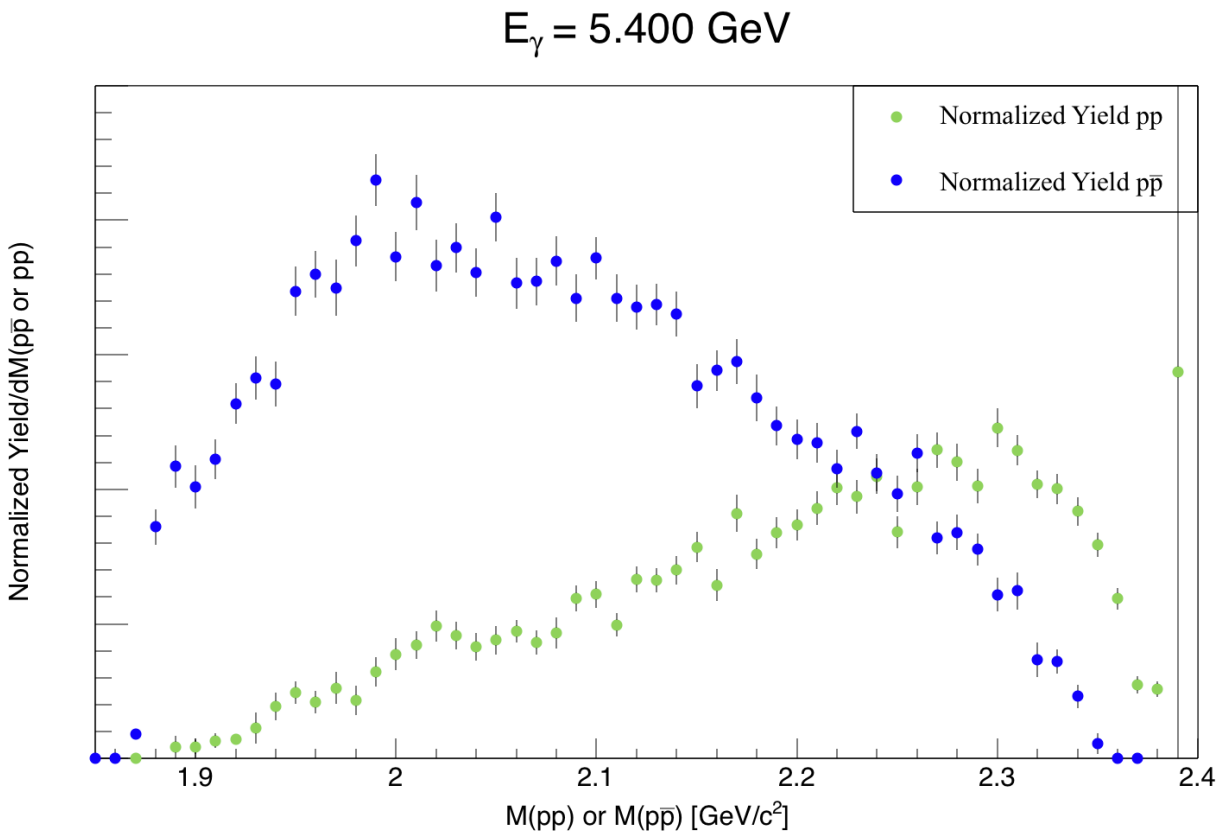

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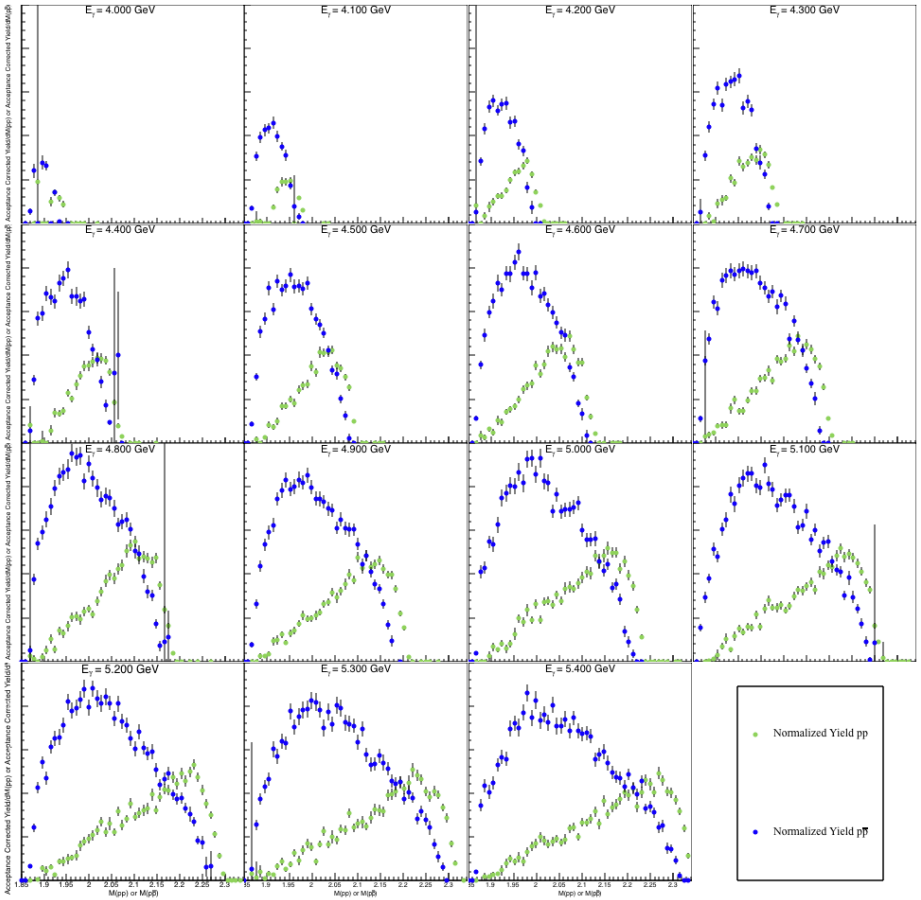
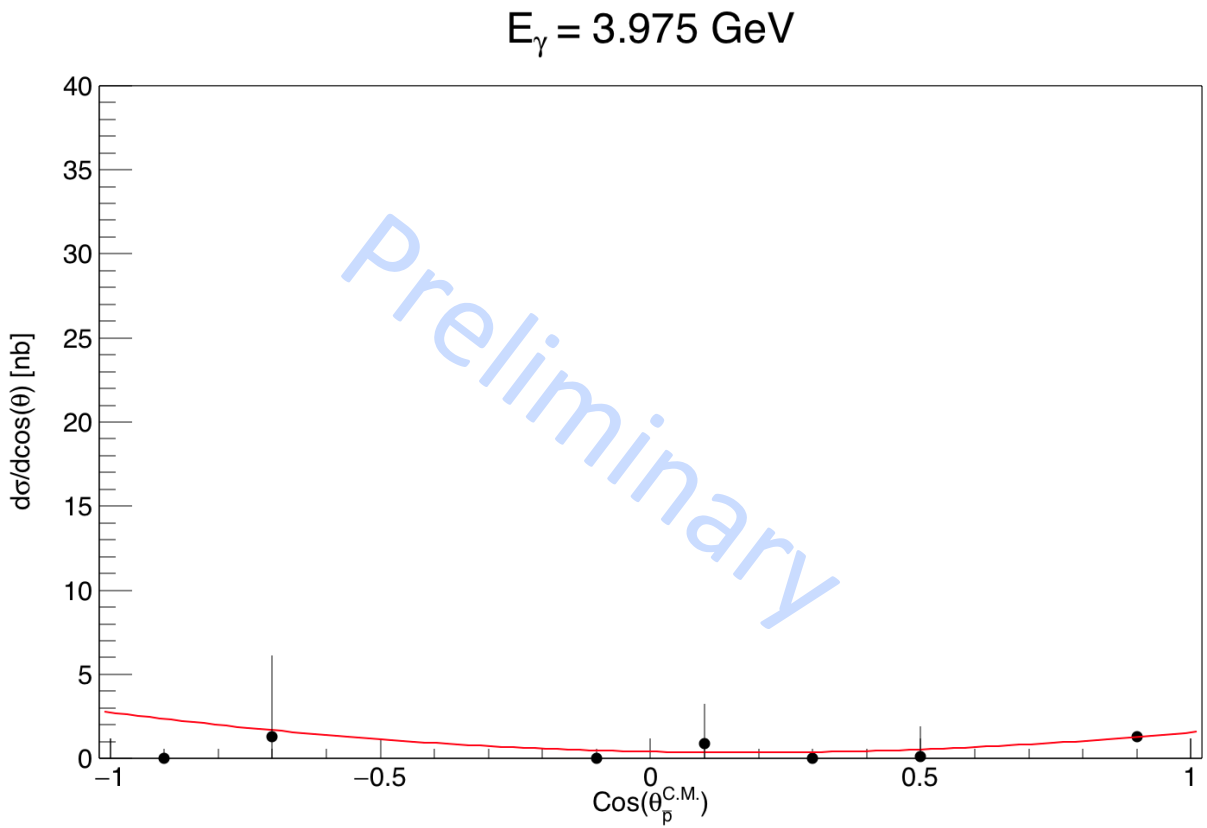


*Statistical errors only

Differential Cross Section

- First measurement of the differential cross section in photoproduction
- This measurement is made with respect to the antiproton cos(θ) angle in the center of momentum frame
- Will be used in combination with a beam profile and differential cross section with respect to the two proton invariant mass
- Fit with a 3rd order Chebyshev polynomial

Differential Cross Section



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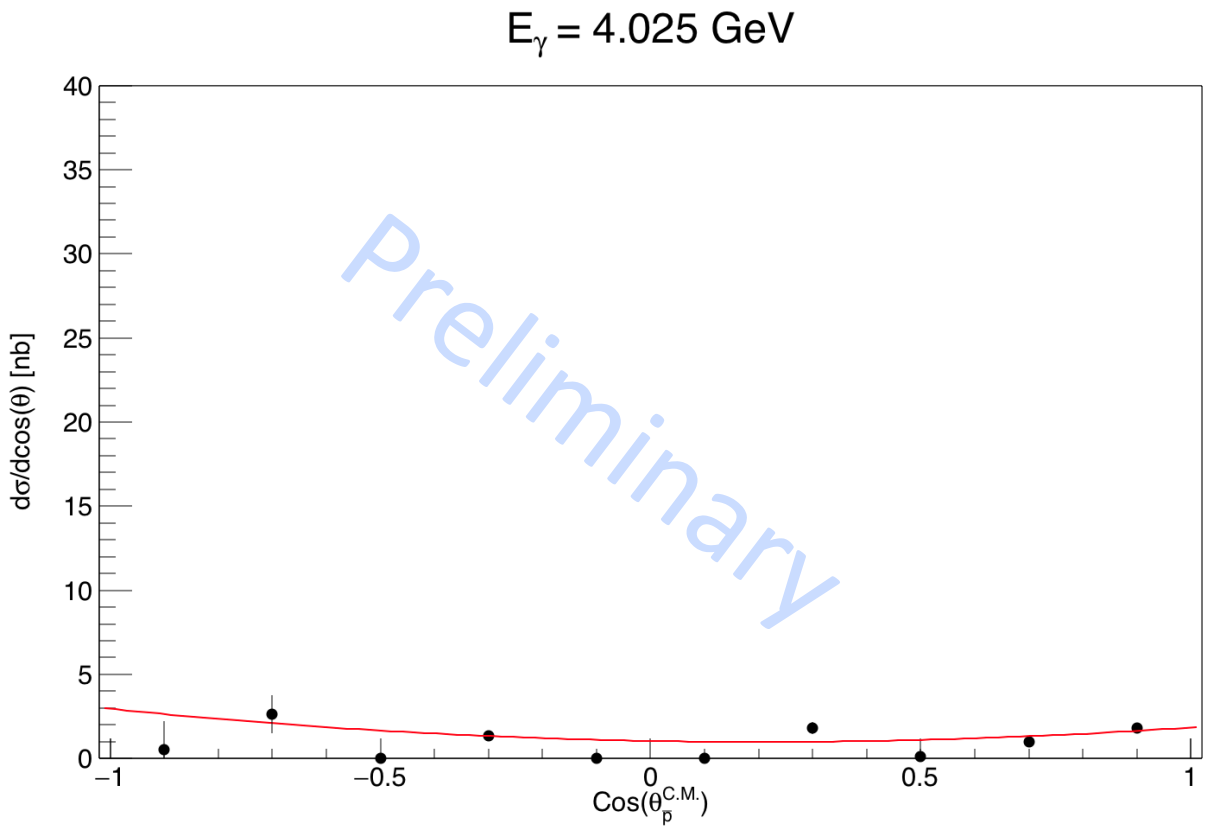

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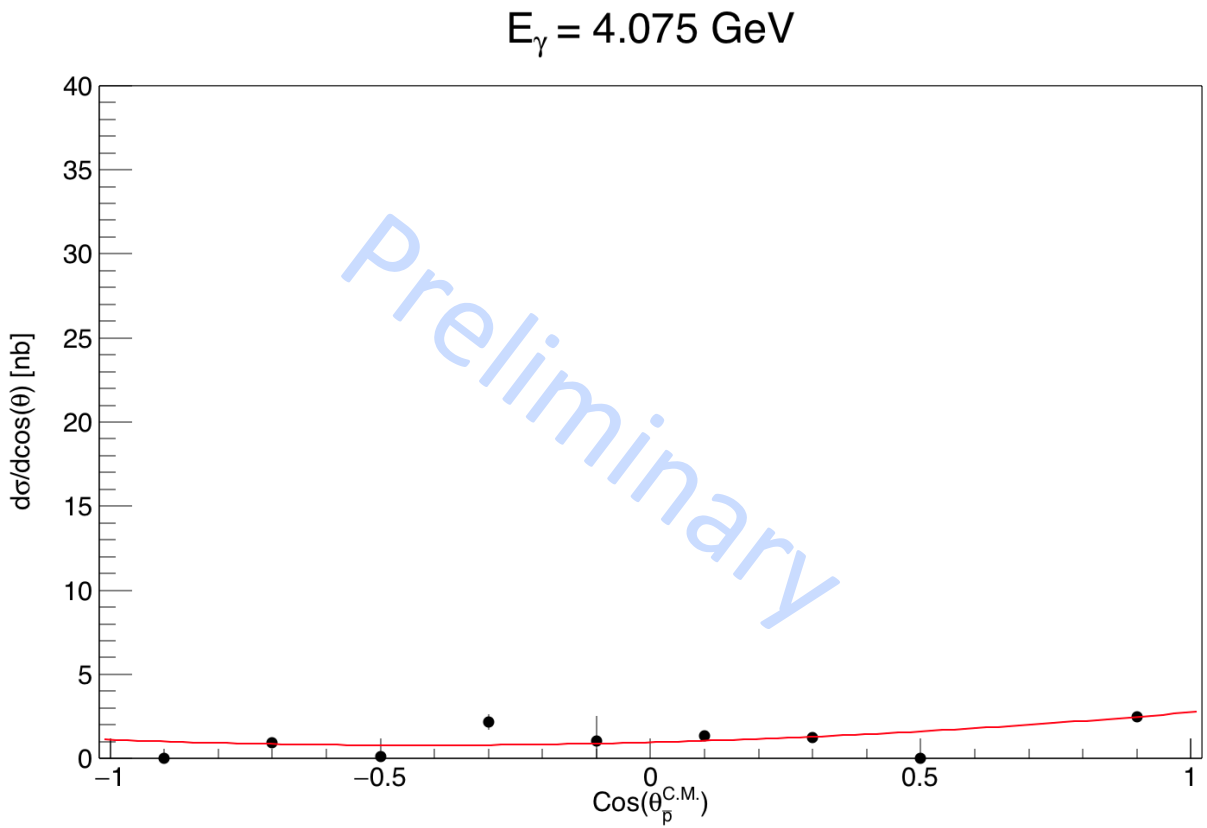

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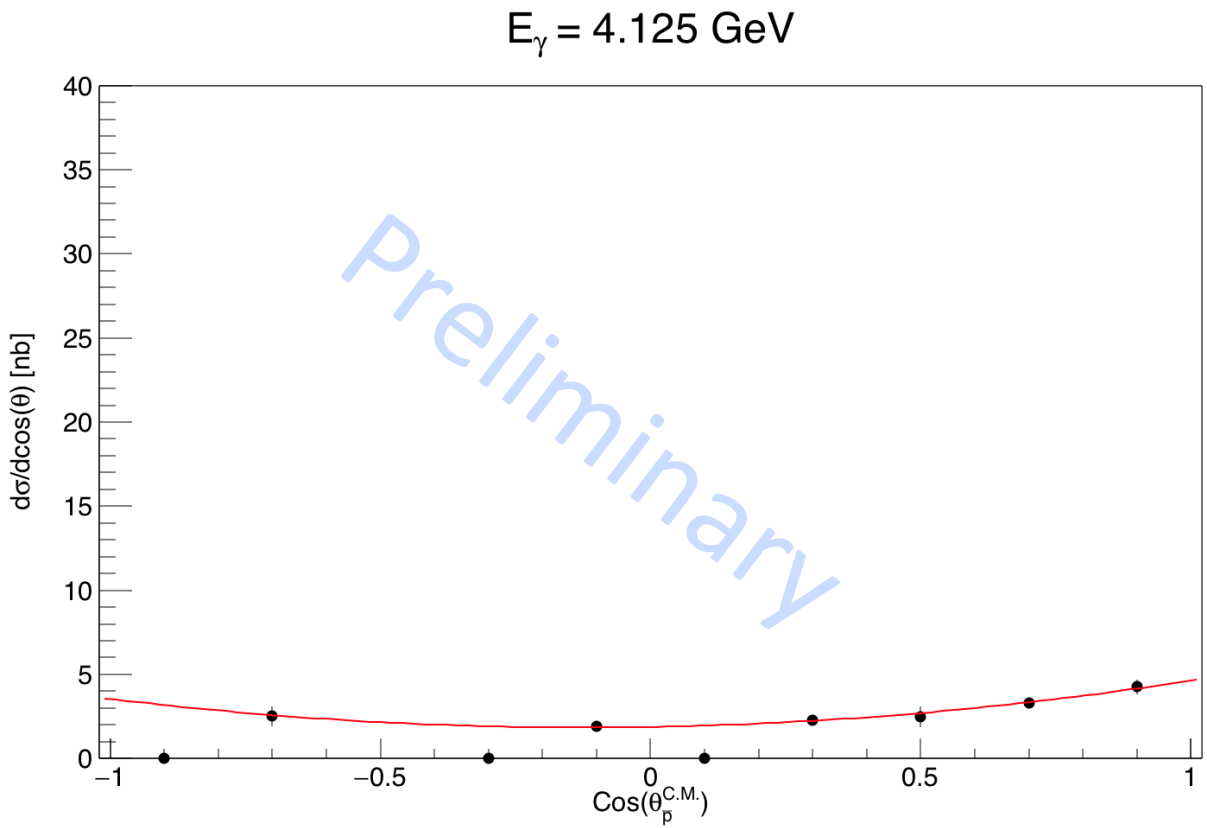

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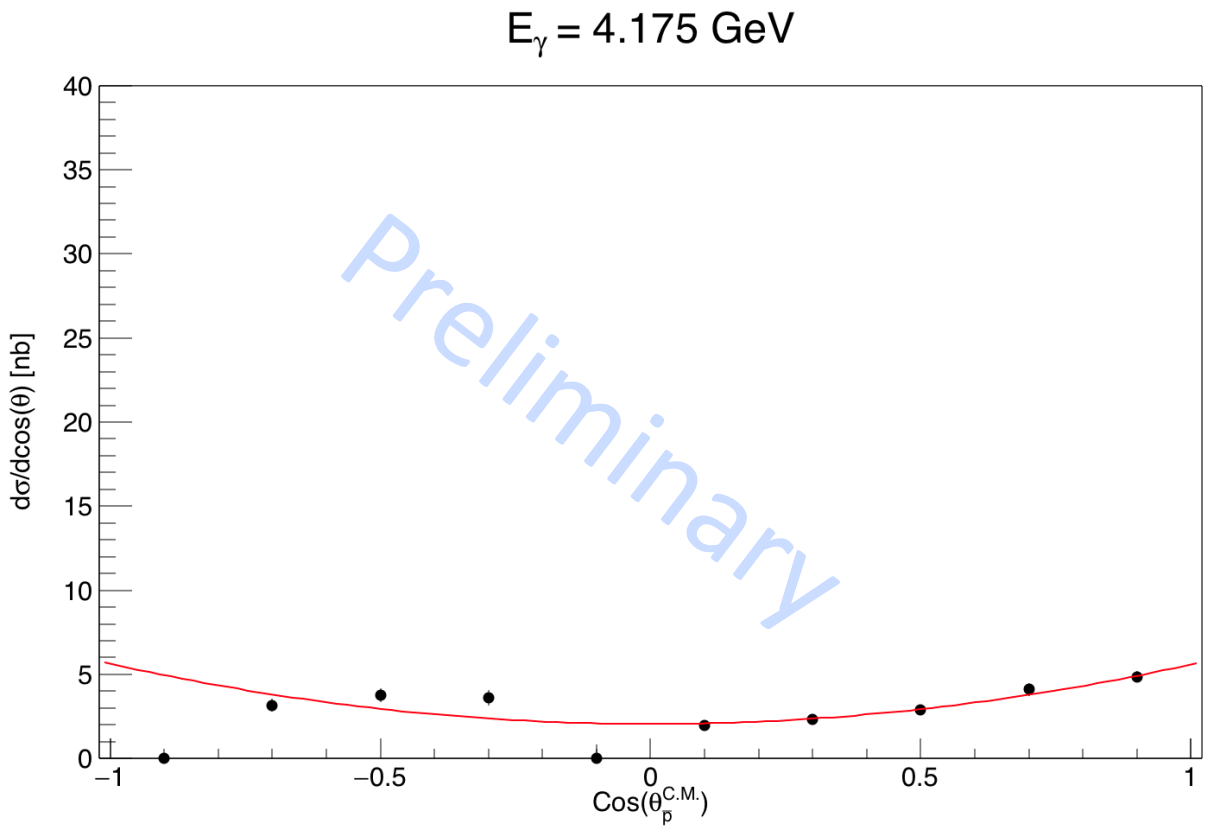

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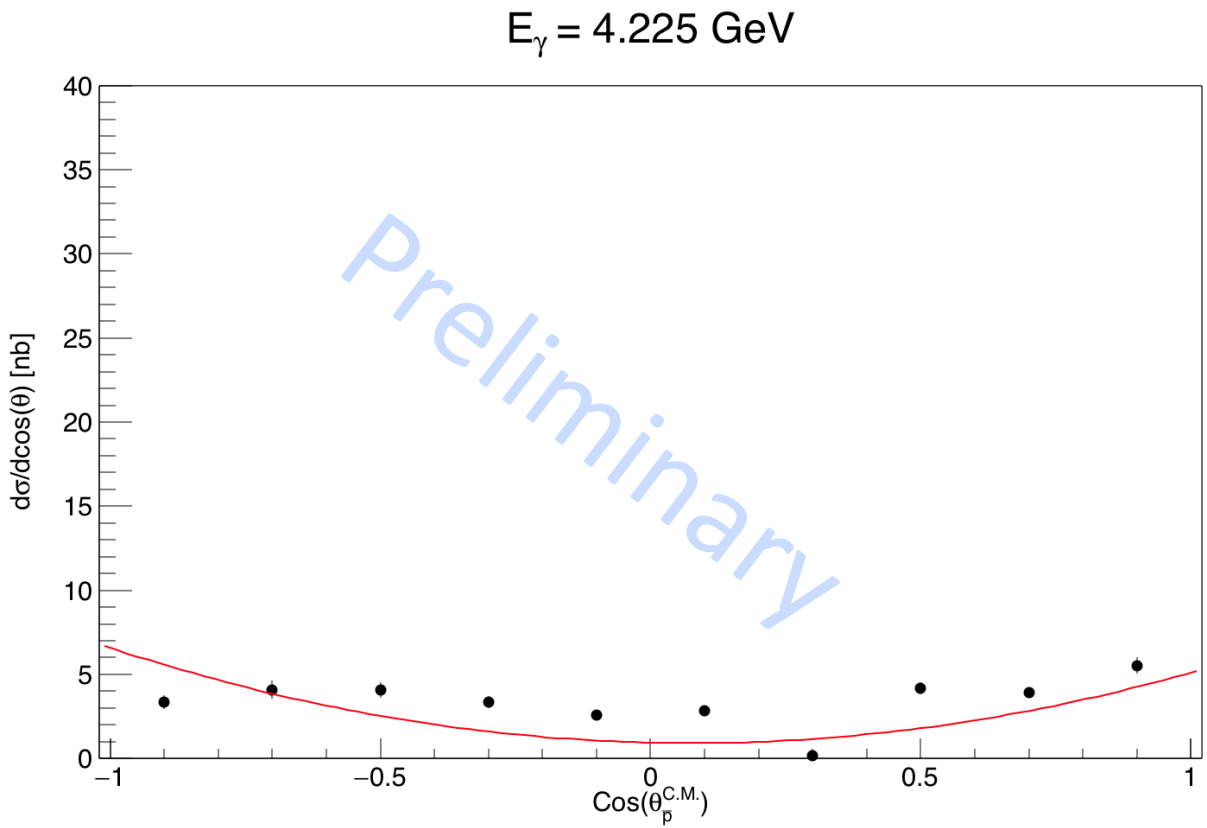

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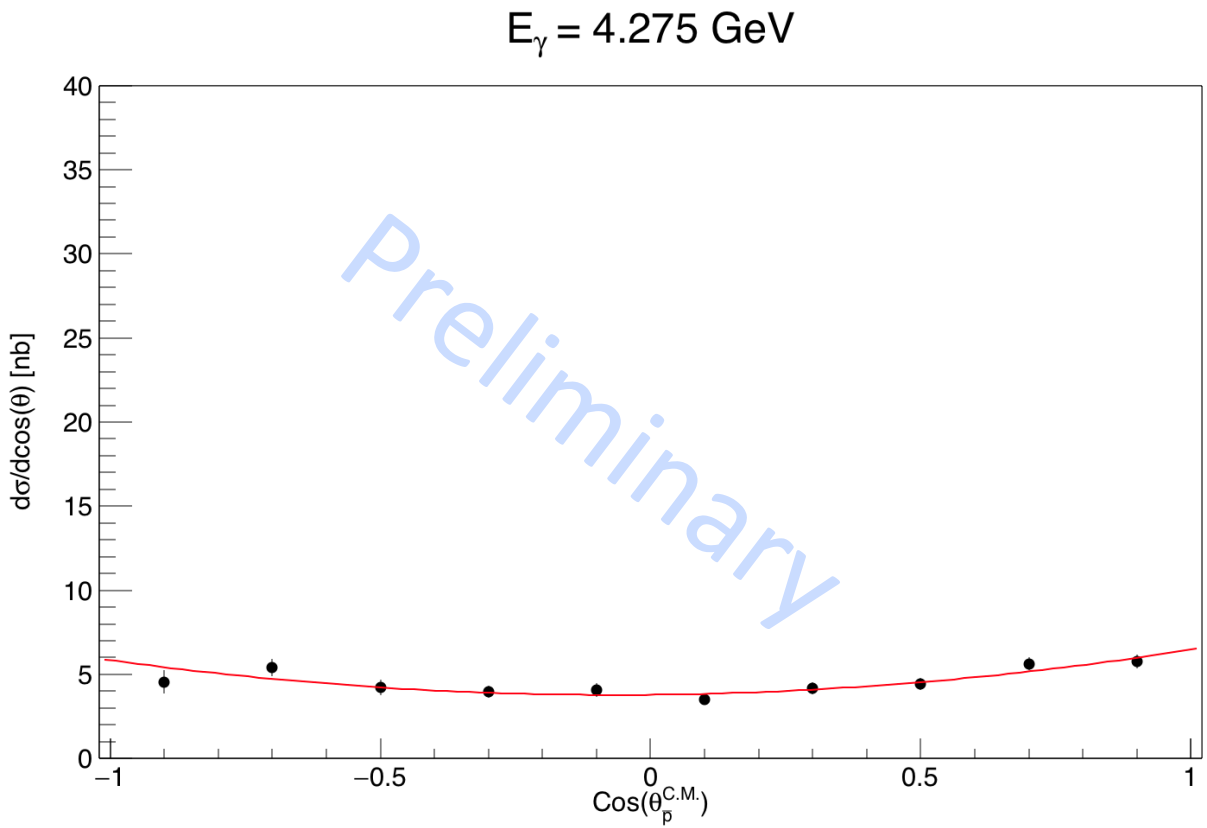

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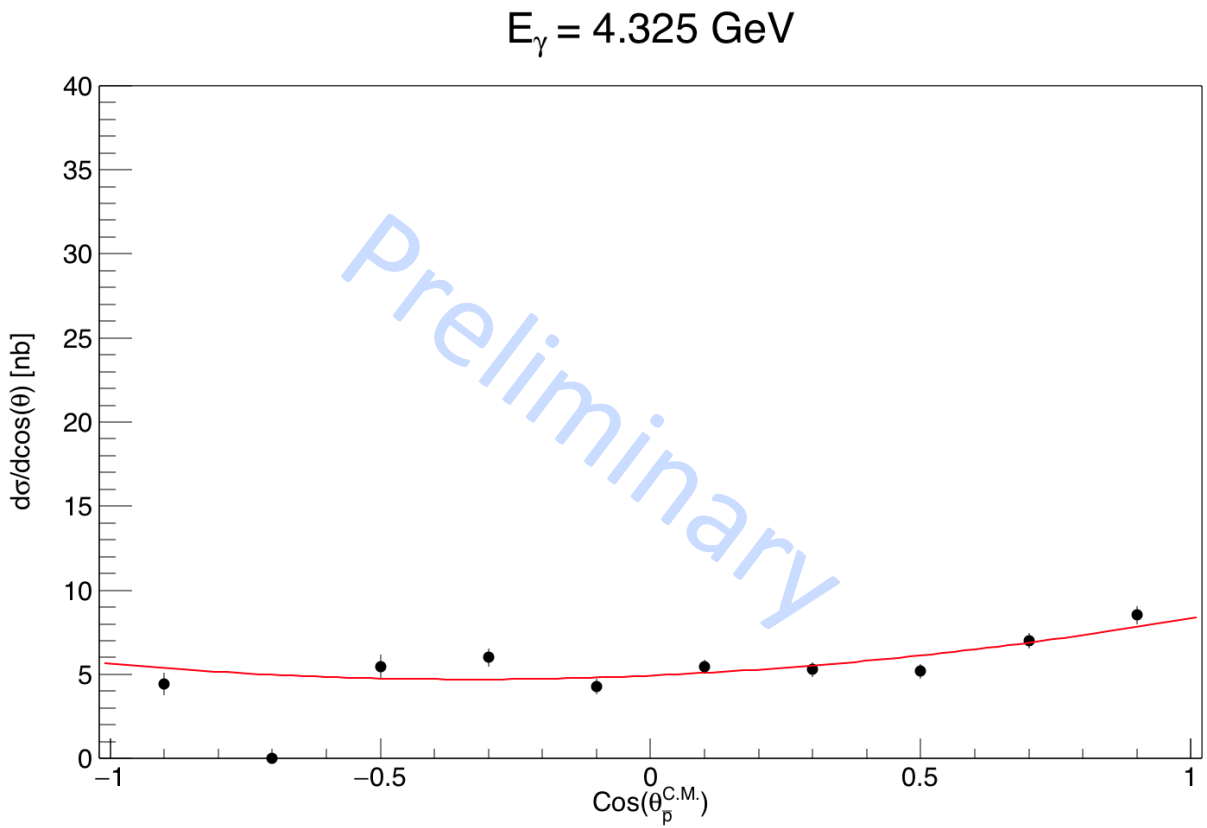

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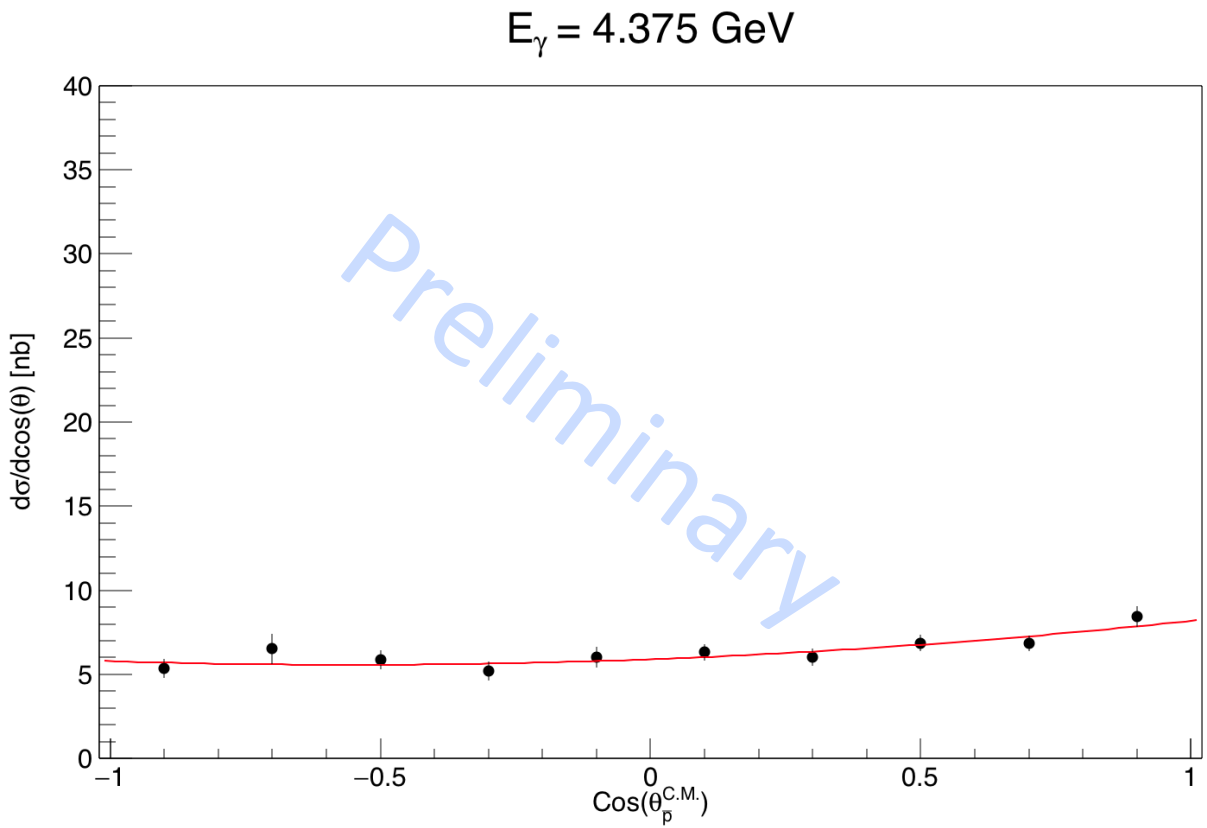

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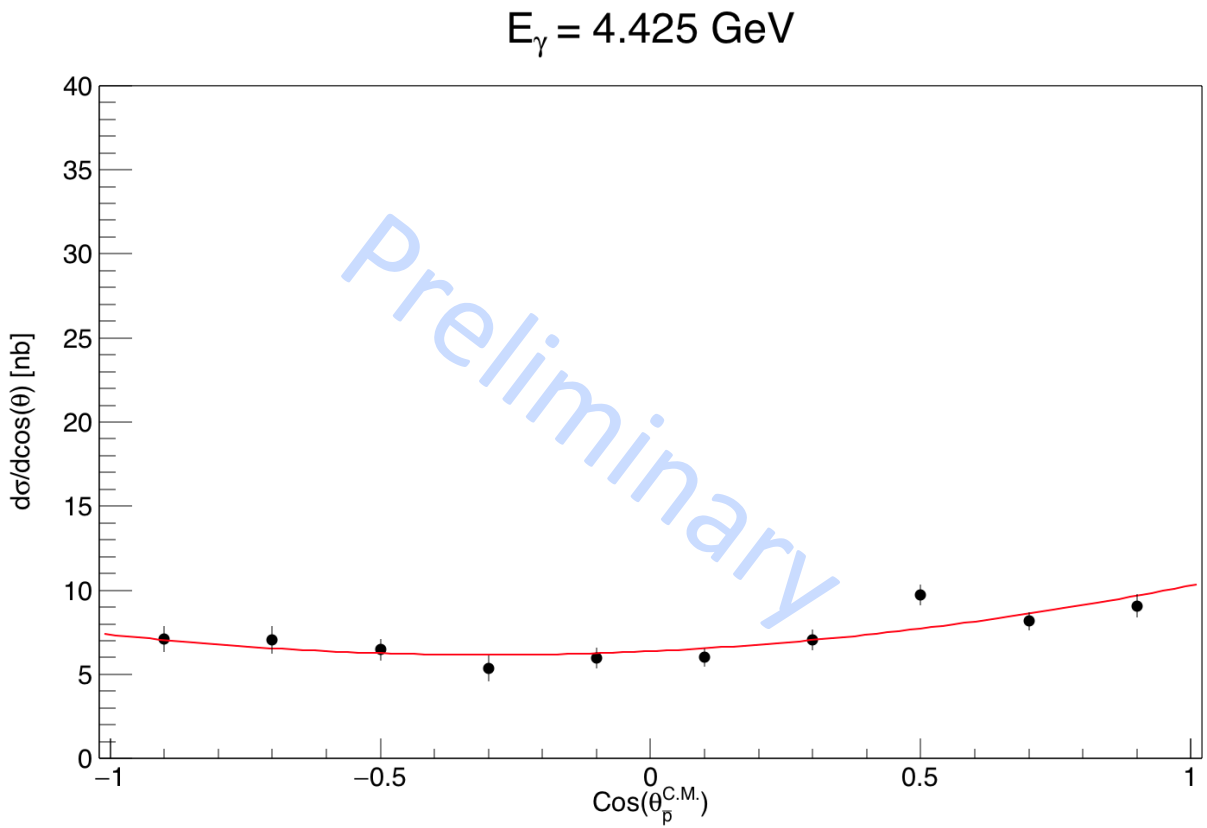

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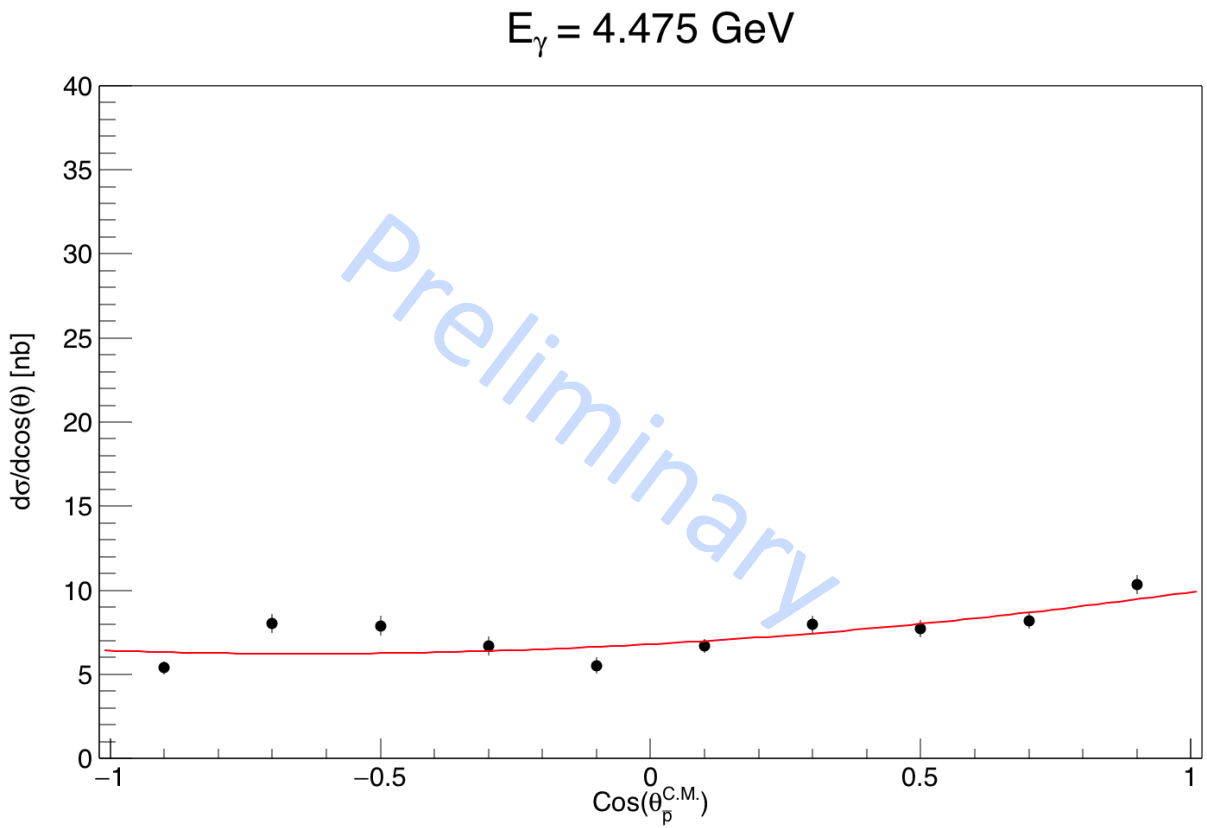

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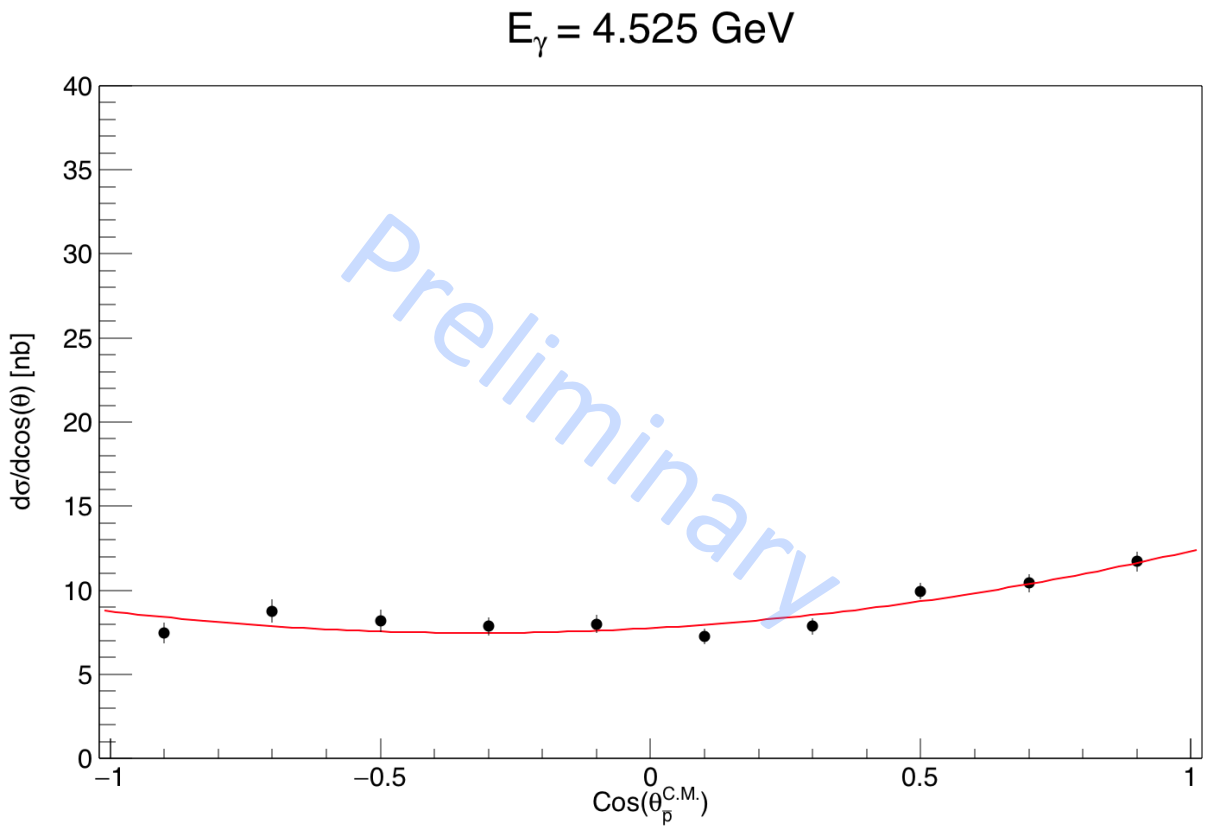

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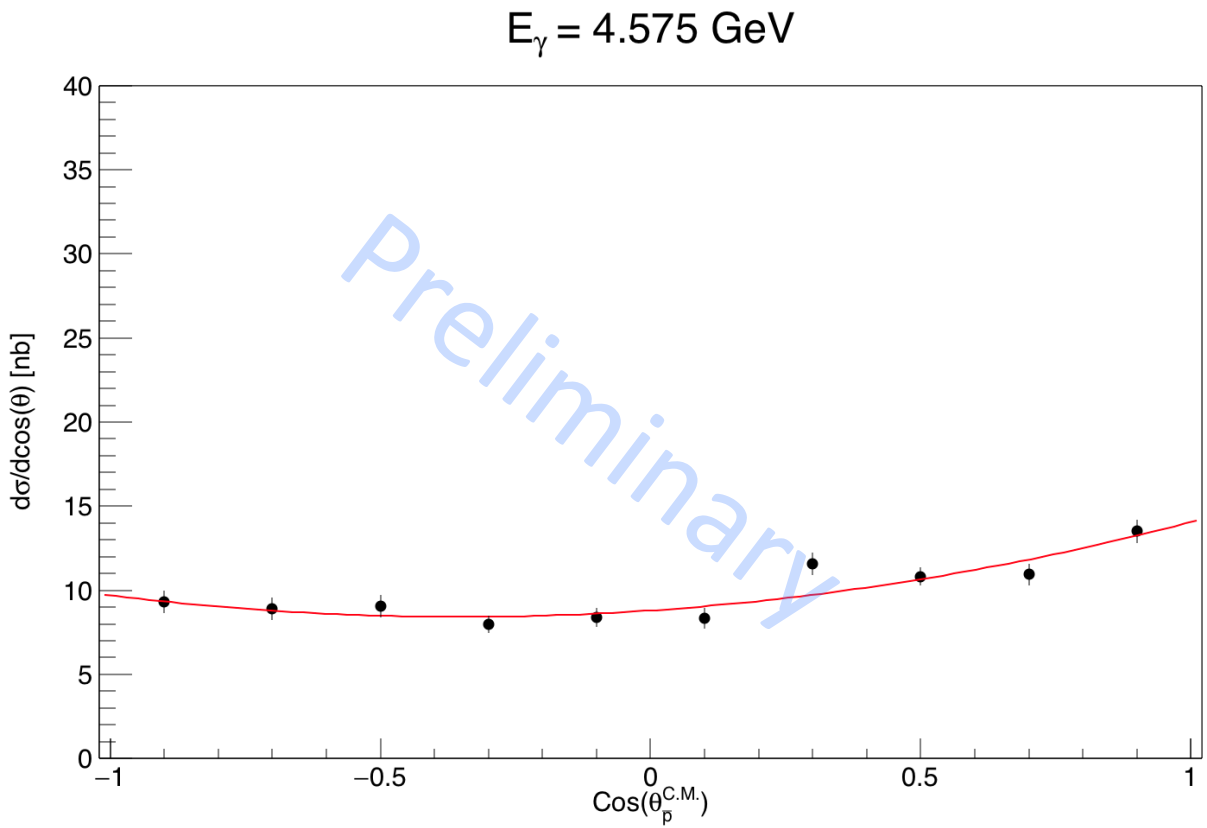

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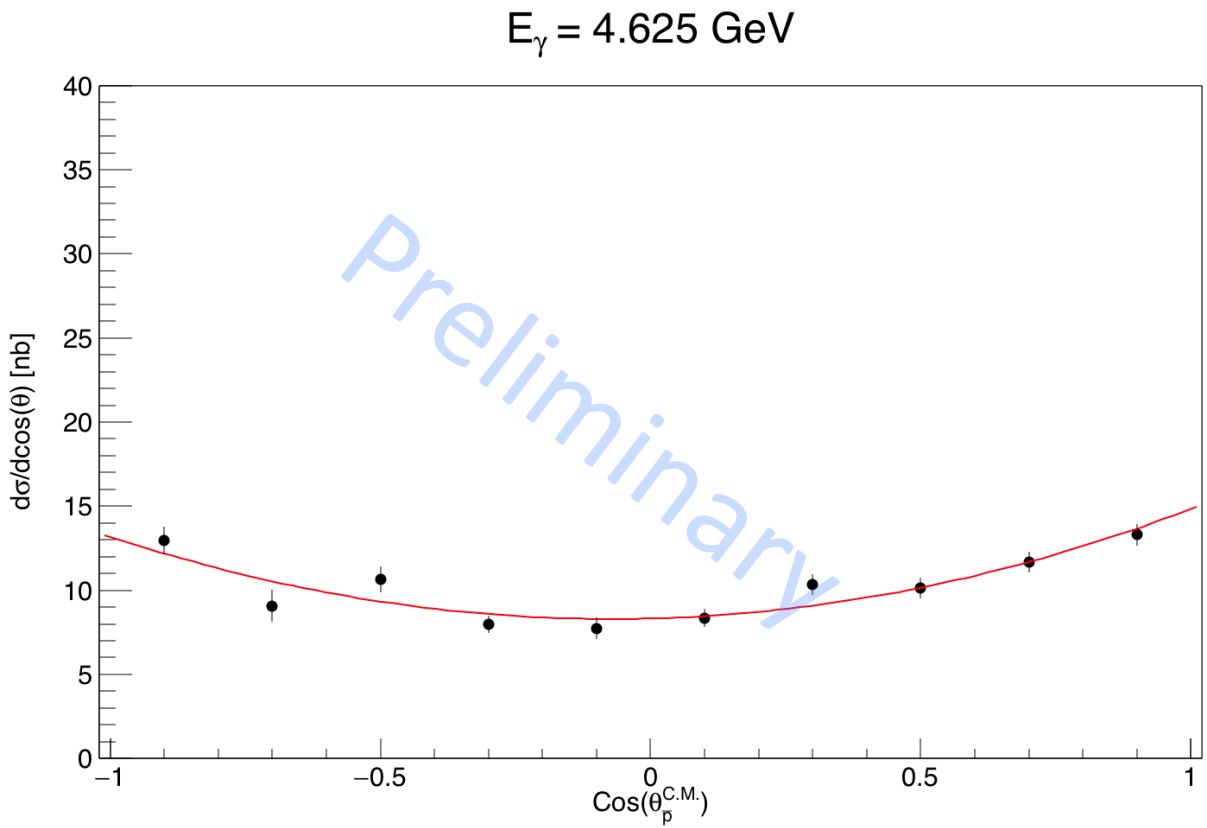

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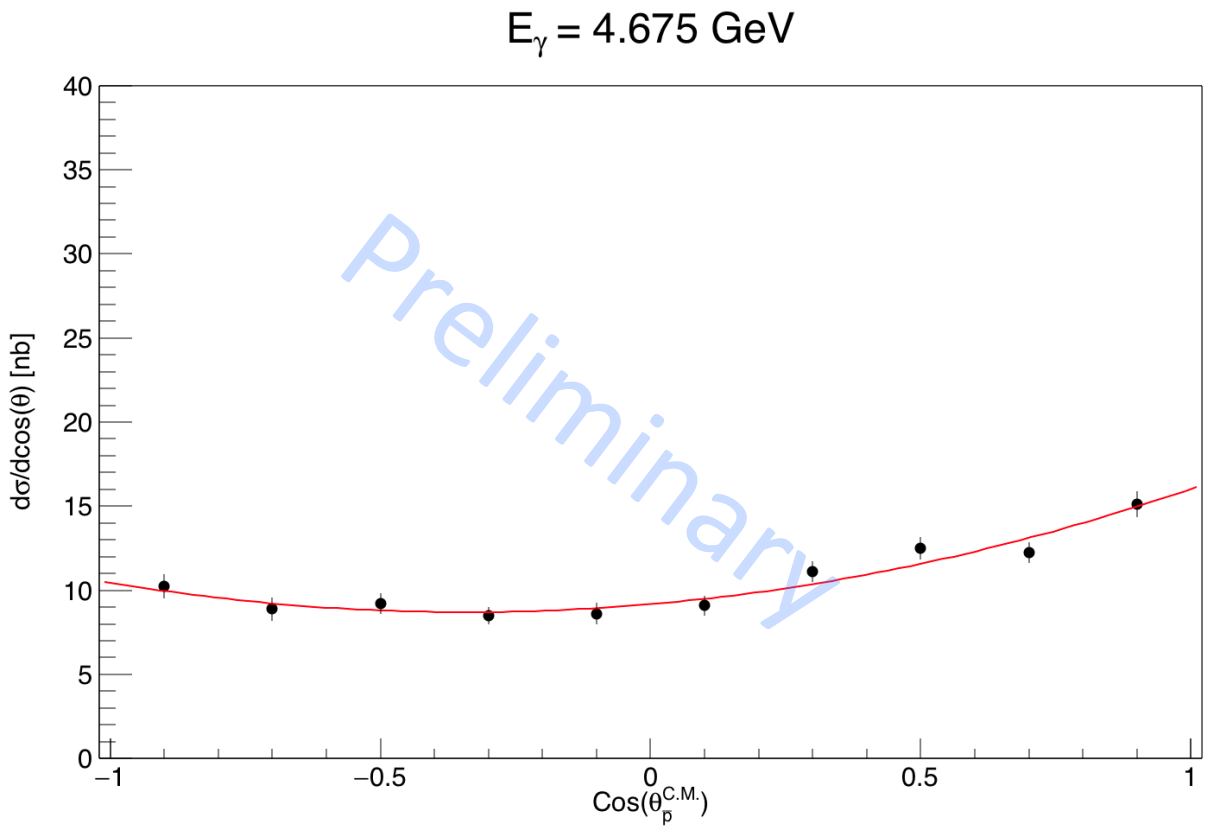

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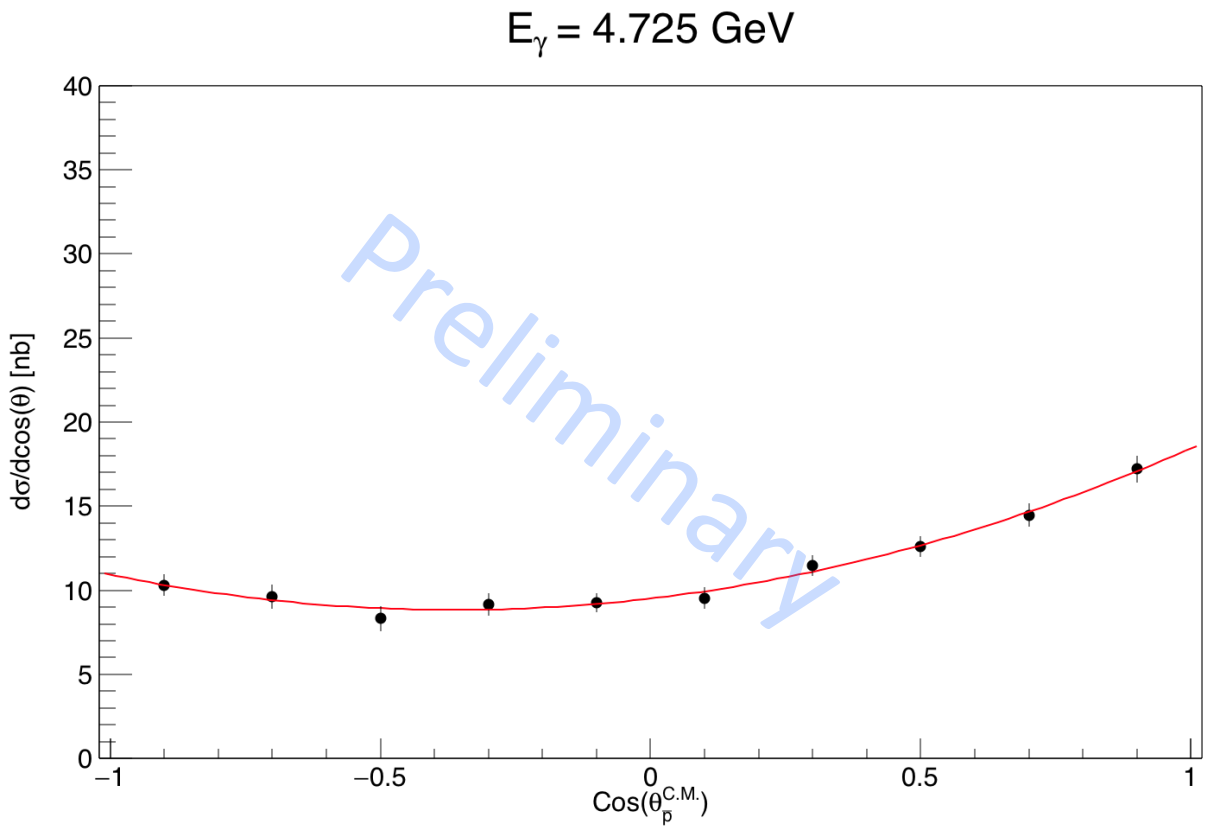

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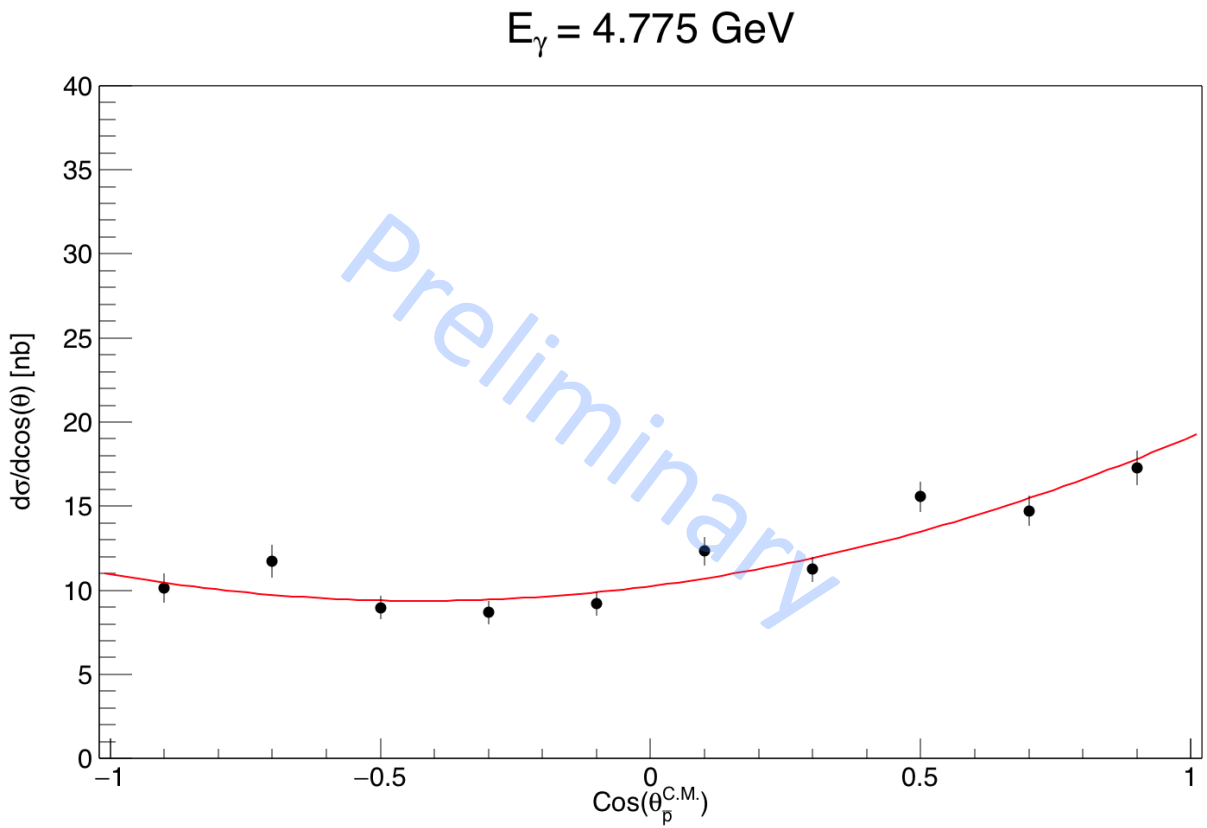

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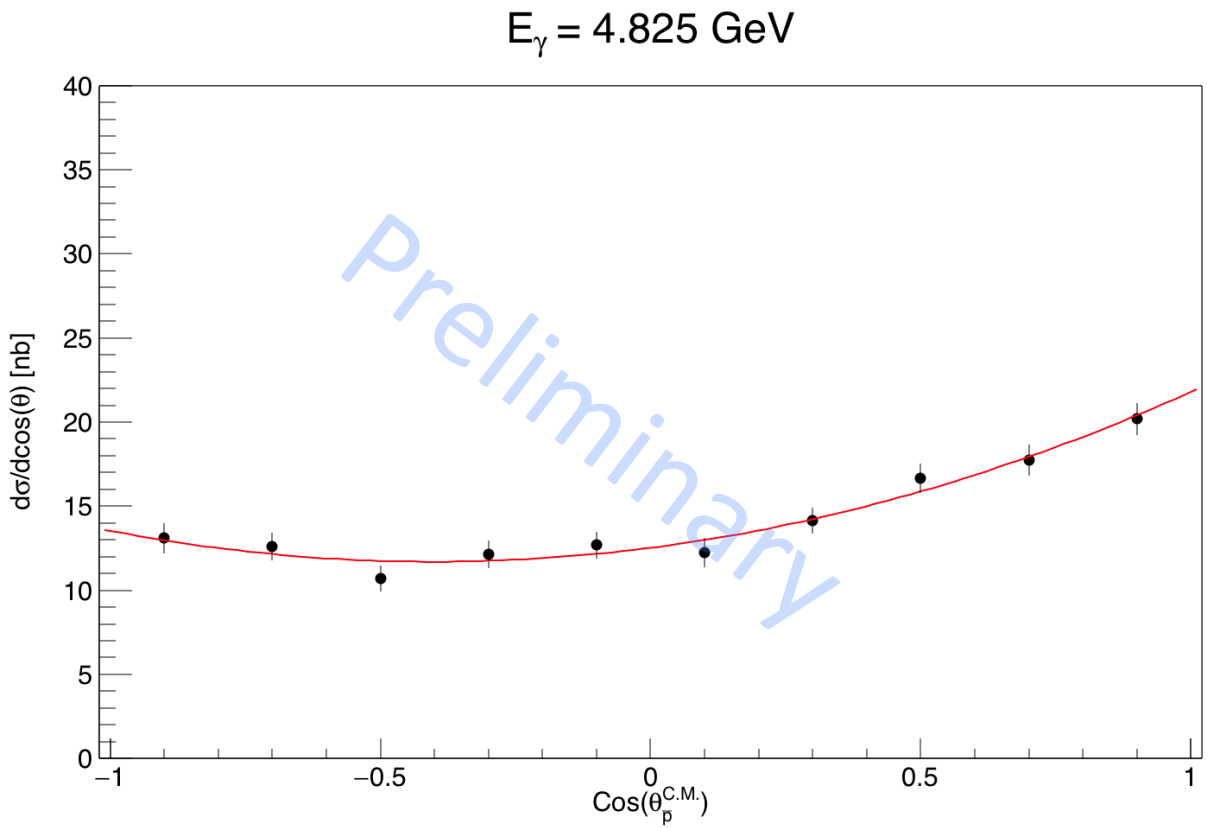

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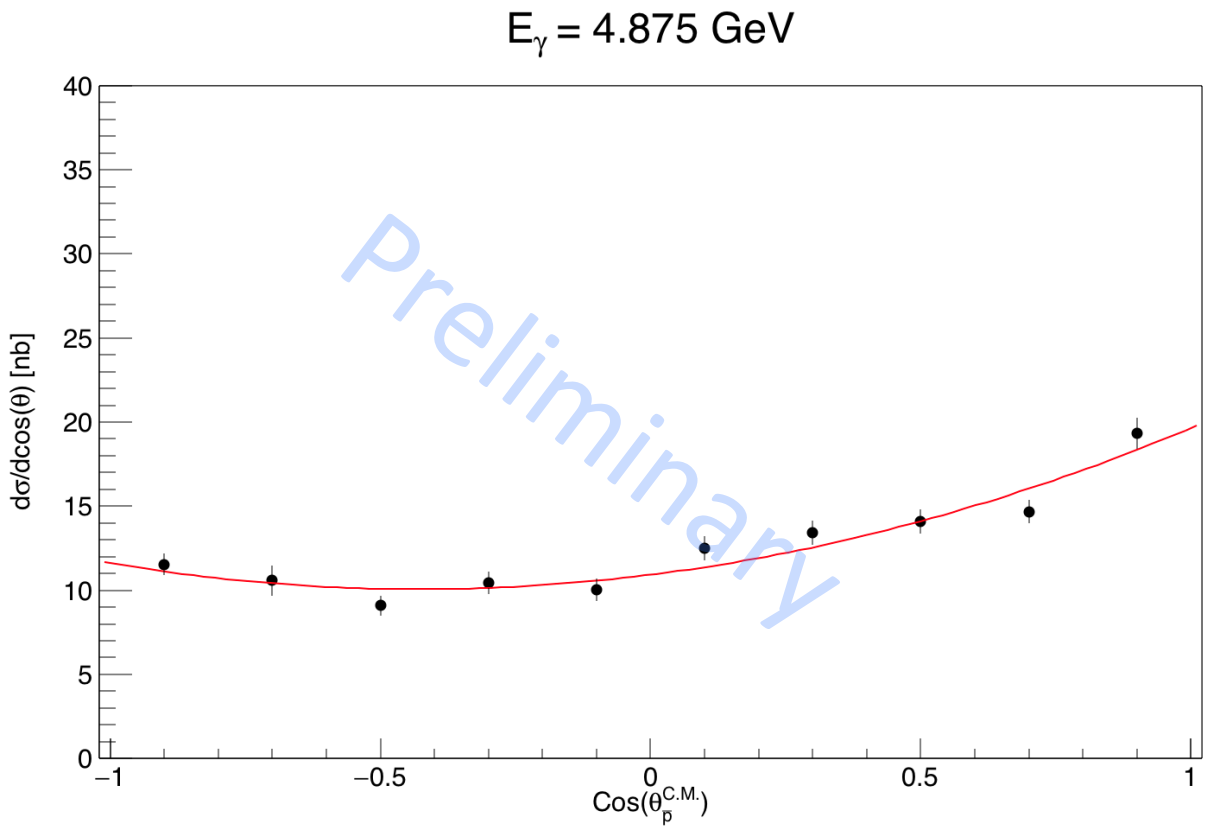

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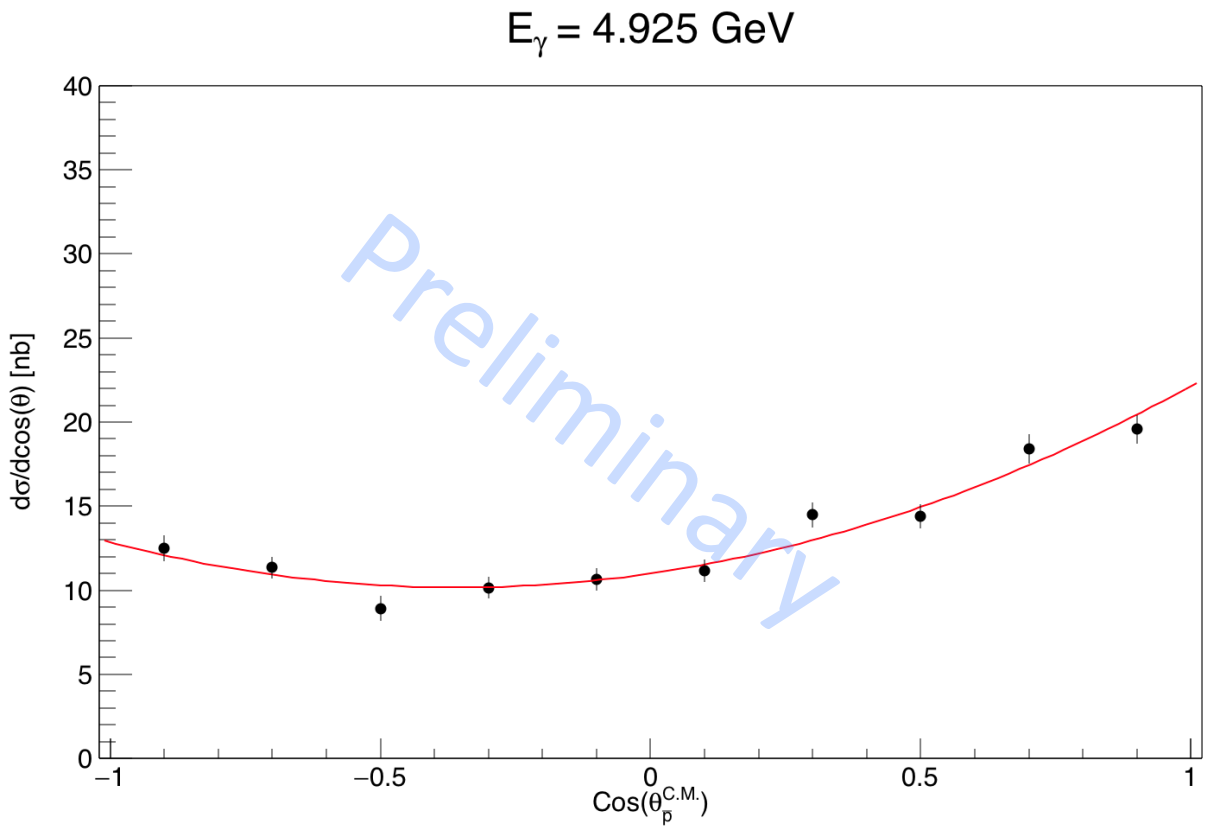

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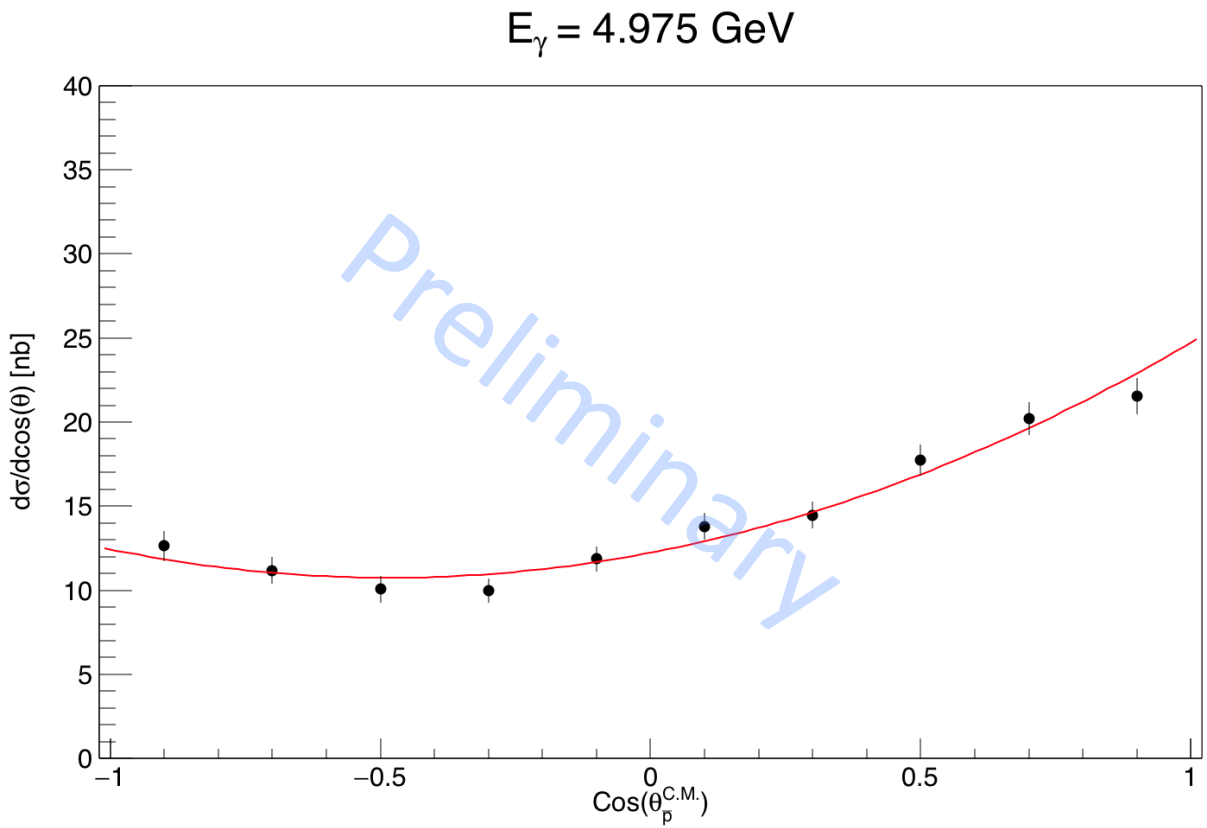

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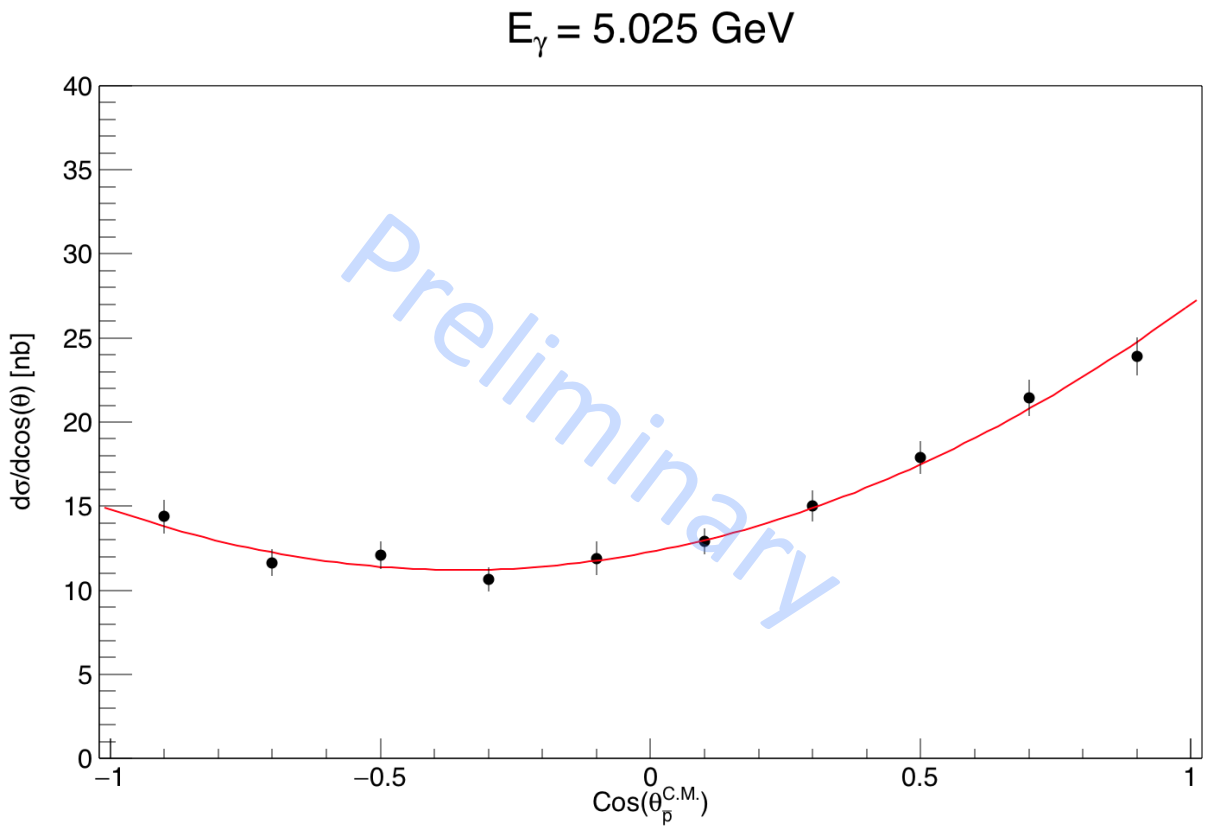

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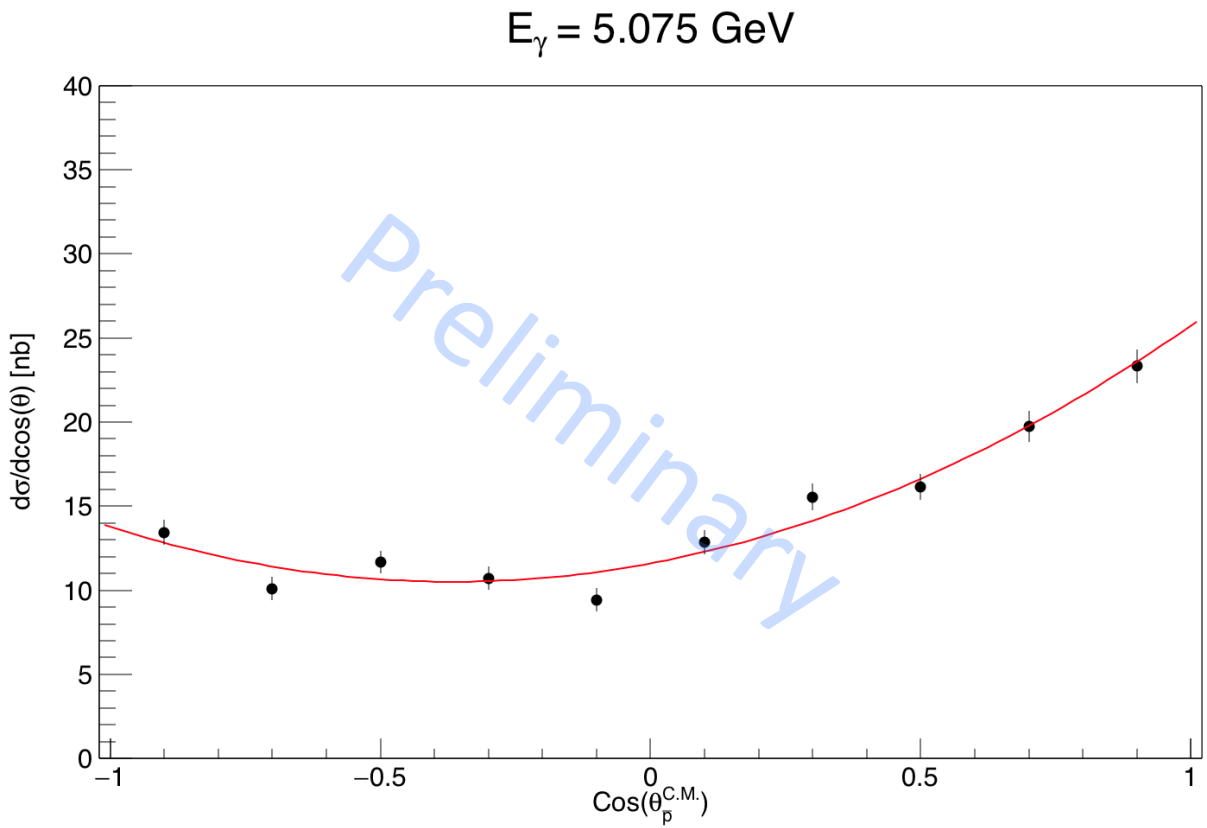

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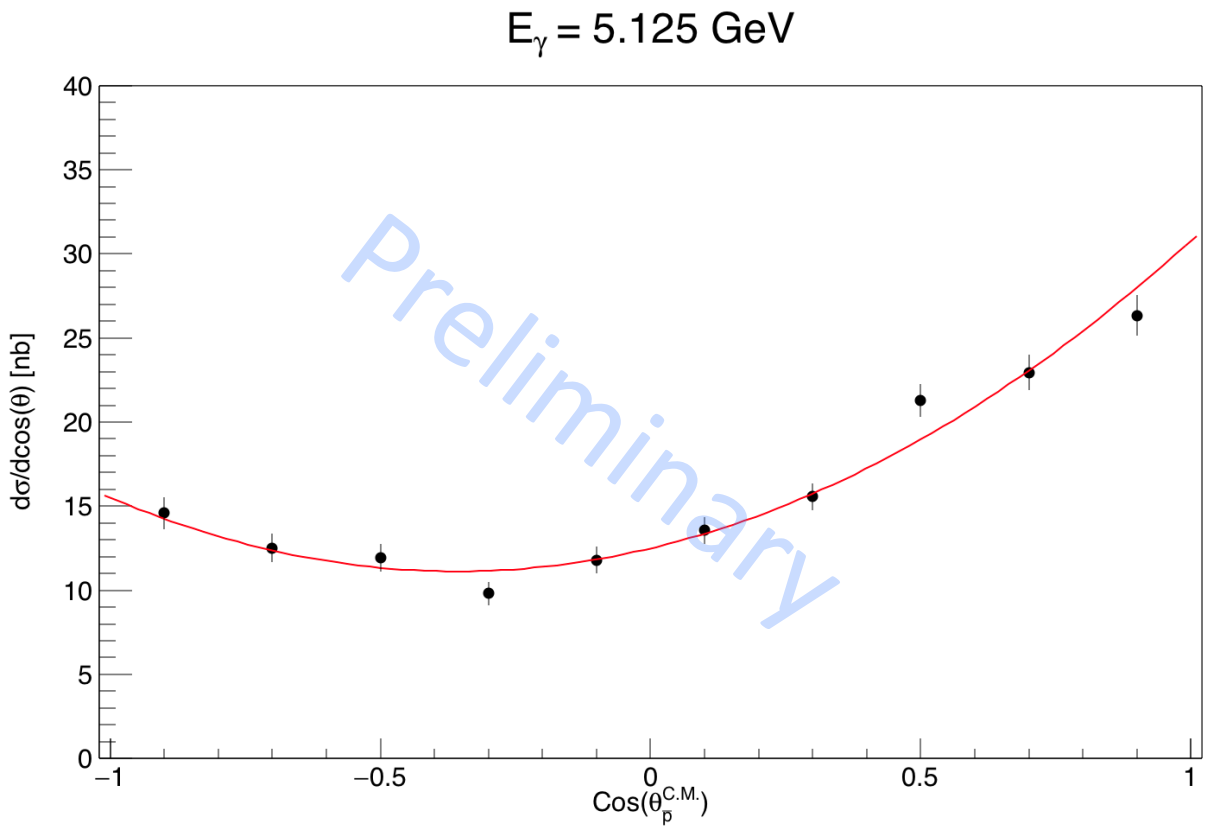

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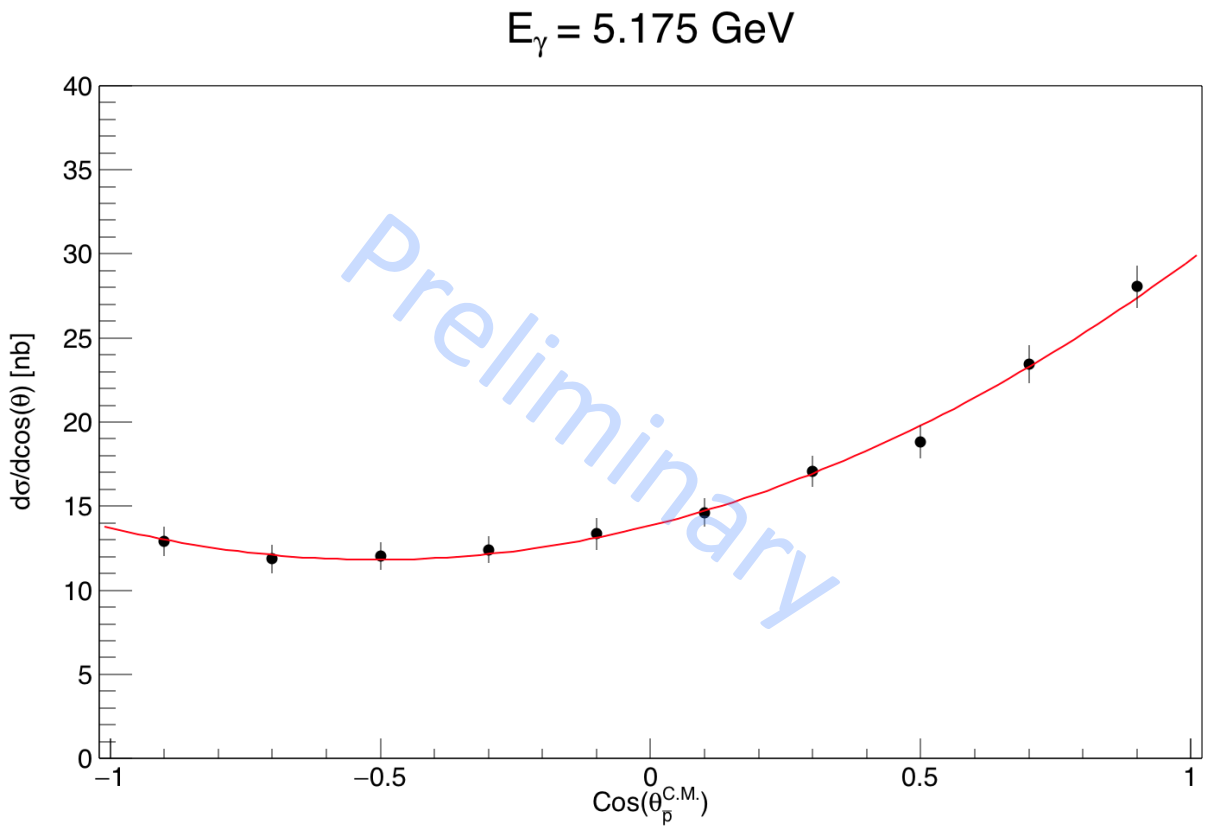

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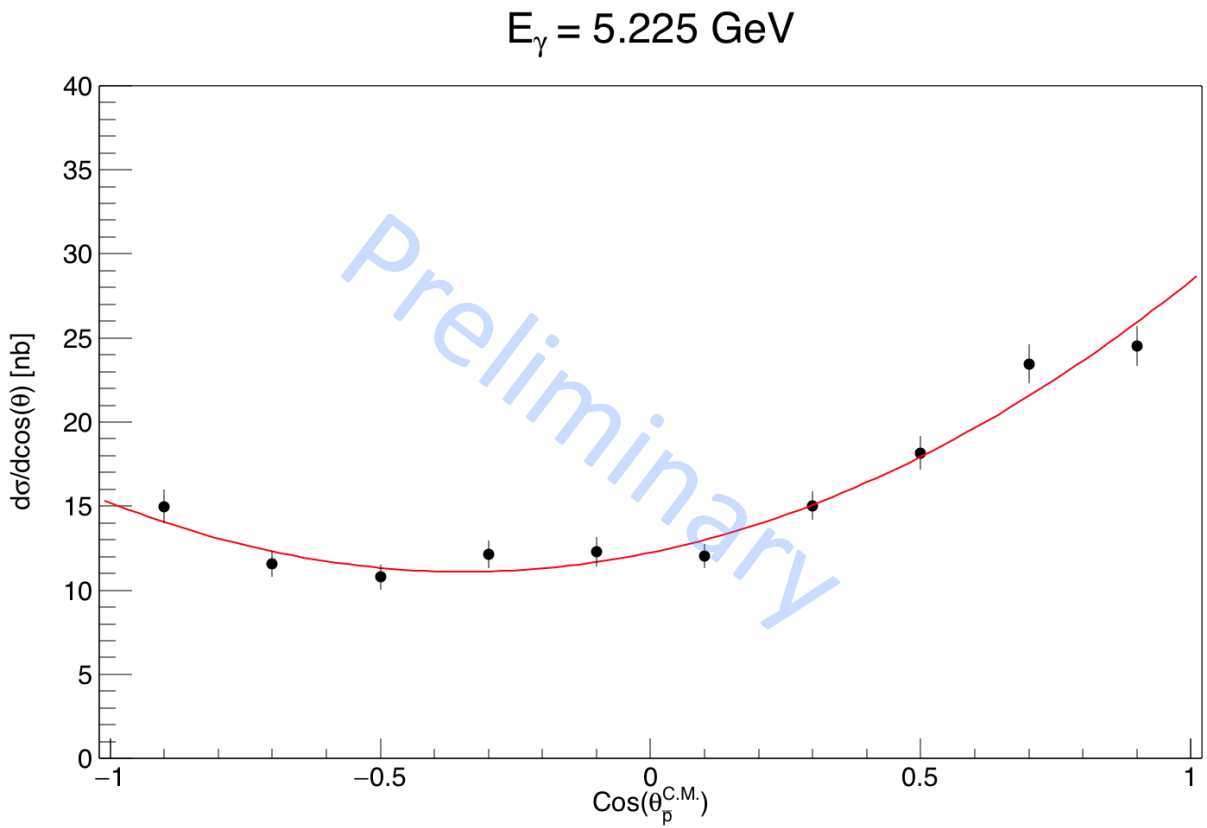

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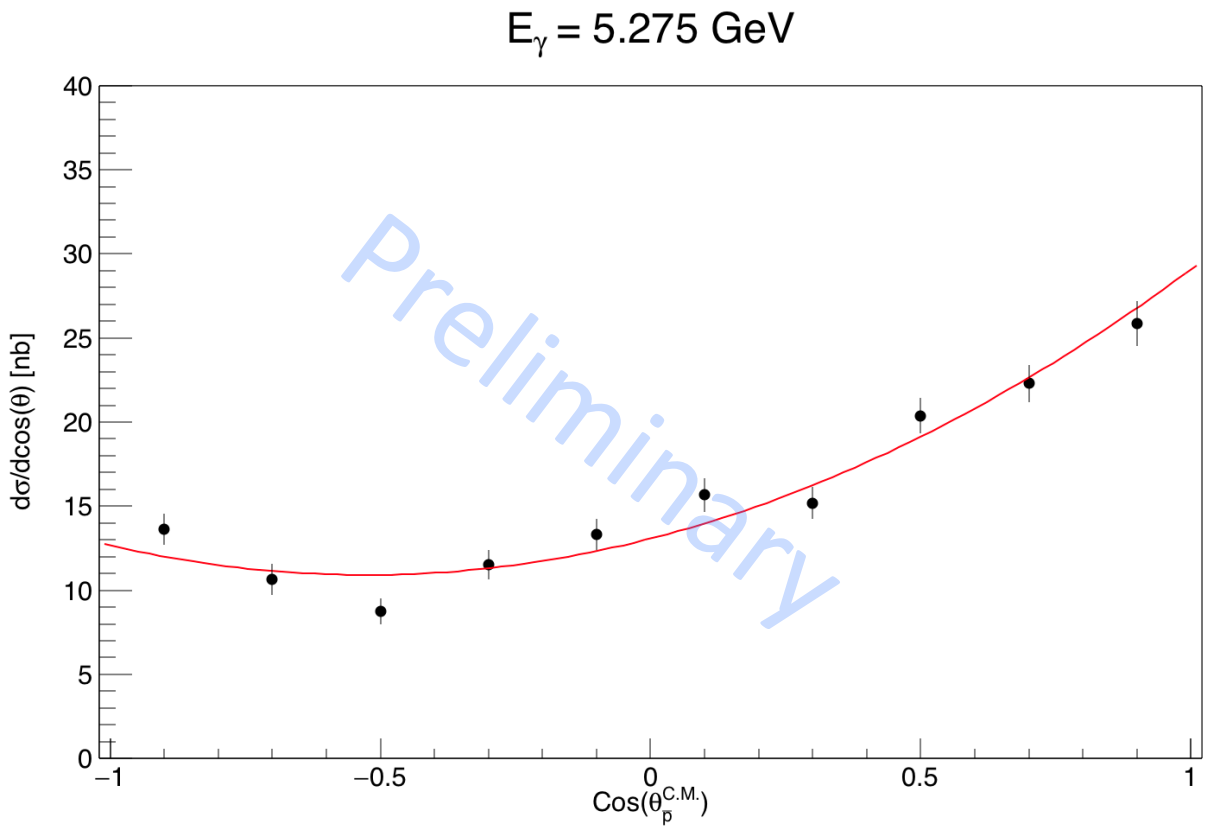
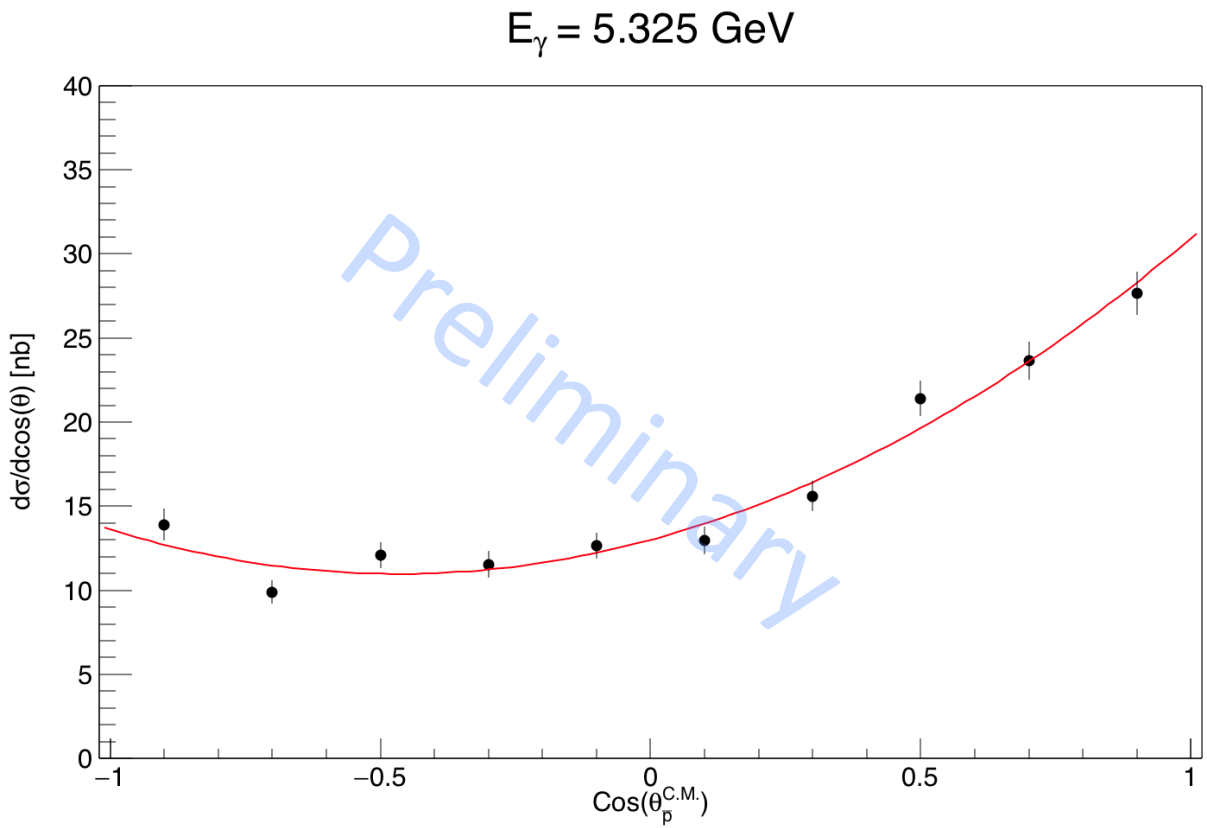


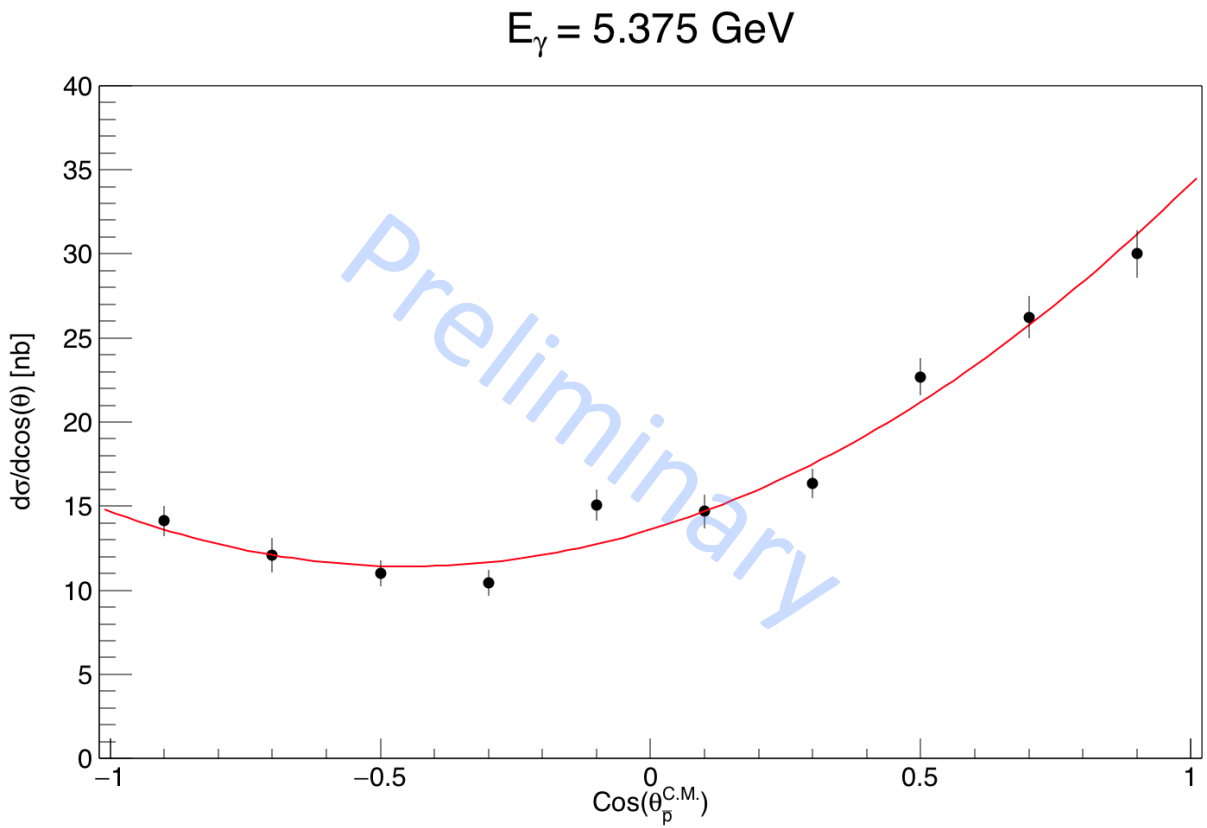
*Statistical errors only

Differential Cross Section



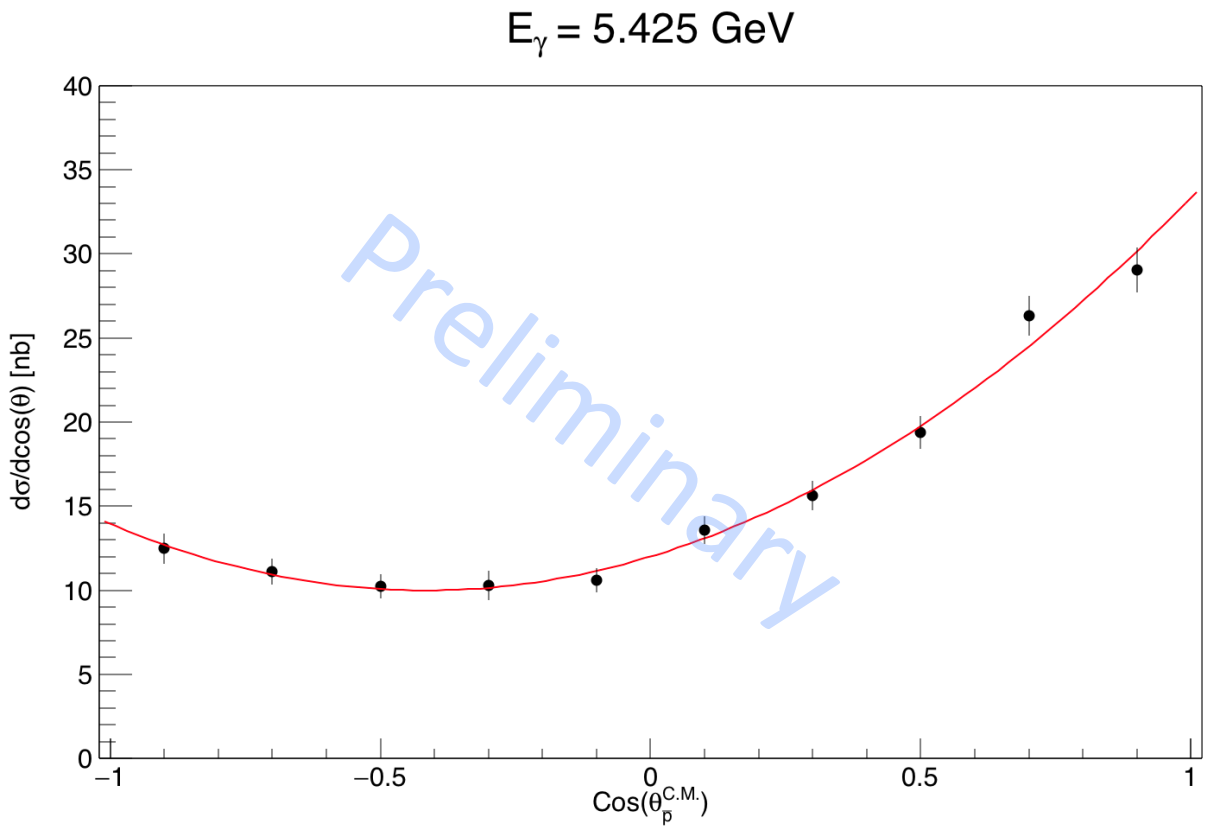
*Statistical errors only

Differential Cross Section



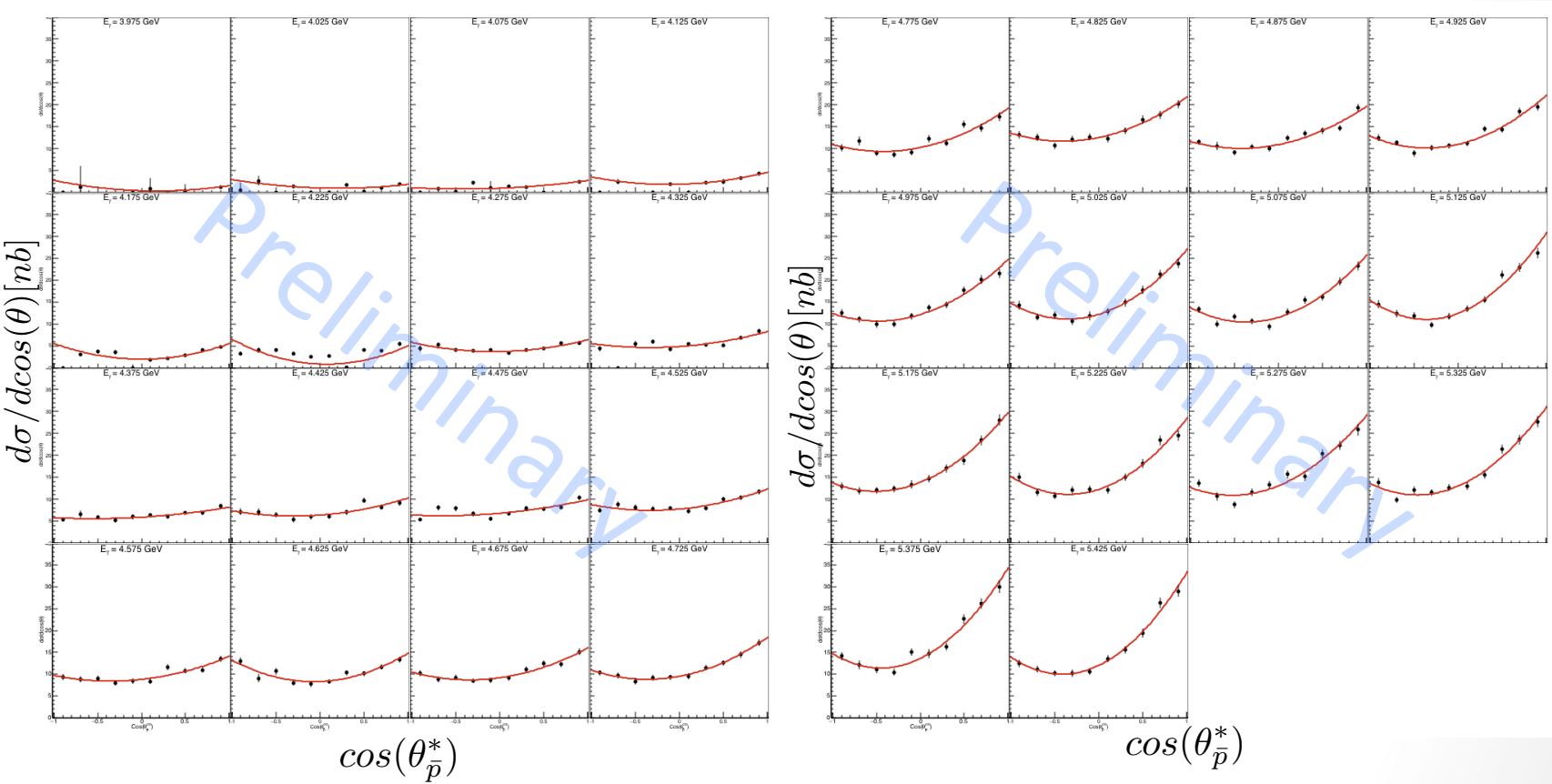
*Statistical errors only

Differential Cross Section



*Statistical errors only

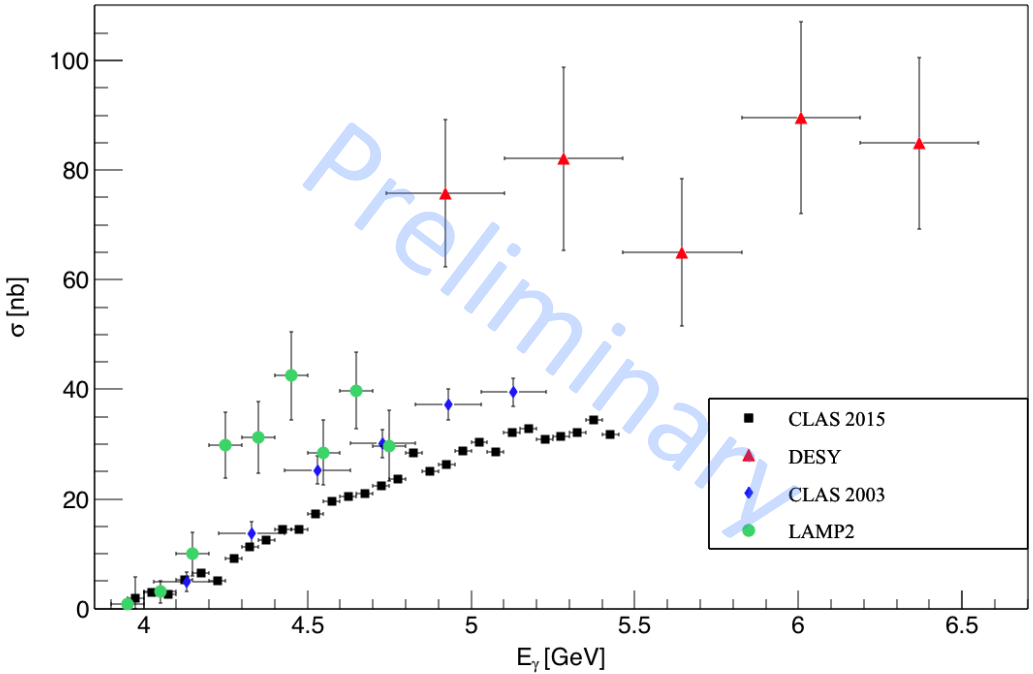
Differential Cross Section



*Statistical errors only

Total Cross Section

- Tuned diffractive production model
- Many corrections still need to be applied
- Comparison to world data shown
- Integrated 3rd order Chebyshev polynomial fits to $d\sigma/dcos(\theta_{\bar{p}}^{cm})$



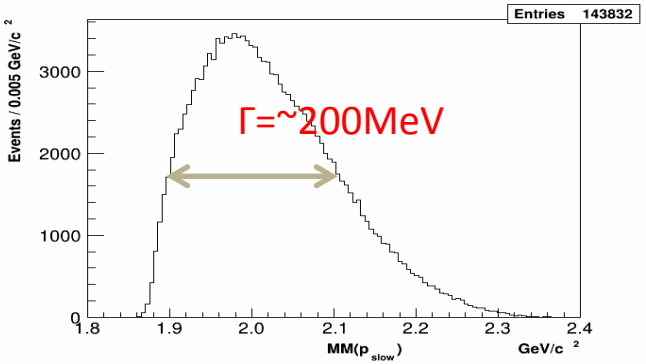
Note: CLAS 2003 results from unpublished CLAS analysis note

Bodenkamp et al, **Nucl. Phs. B255 717. (1985)**
Barber et al, **Phys. Lett. B 90 470. (1980)**
Kubarovsky et al, **CLAS-NOTE 2003-106-2 (2003)**

*Statistical errors only

Why perform a PWA?

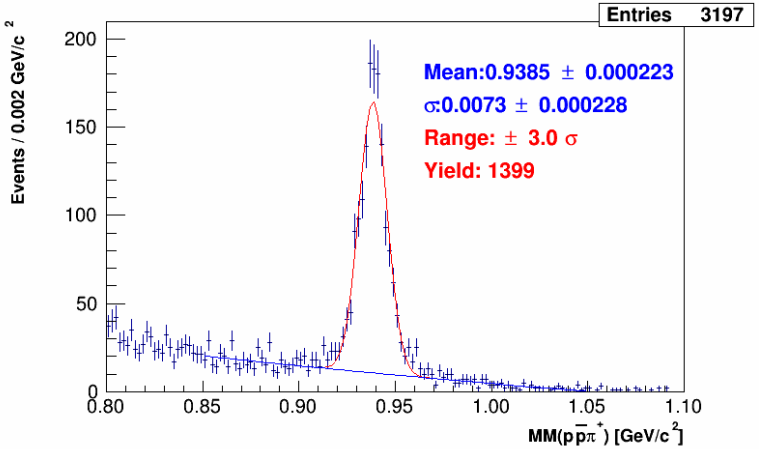
- Large number of mesons observed in proton antiproton annihilation
- Multiple high mass, broad width mesons could be contributing
- Creating accurate simulation is difficult
  - Performing a "Mother fit" with many waves will allow generation of accurate simulation

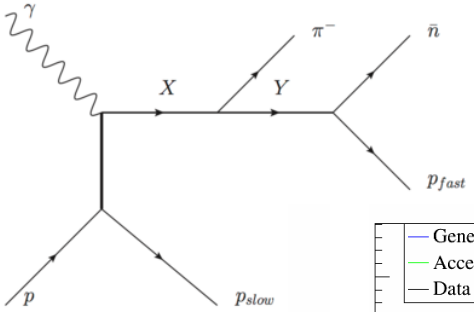


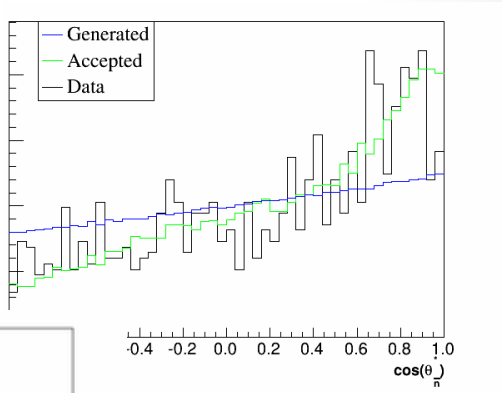
Abridged Resonance Candidates (MeV)	Γ (MeV)	J^{PC}
$rho_3(1990)$	196±31	3^{--}
$f_0(2020)$	442±60	0^{++}
$f_2(2150)$	152±30	2^{++}
rho(2150)	~250-320(?)	1^{--}
$rho_3(2250)$	~220	3^{--}
$rho_5(2350)$	400±100	5^{--}
$f_6(2510)$	283±40	6^{++}

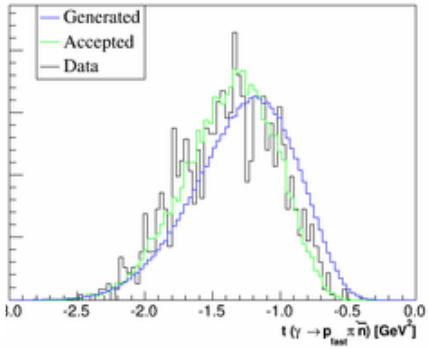
*PDG 2014

Antineutron Reaction Model









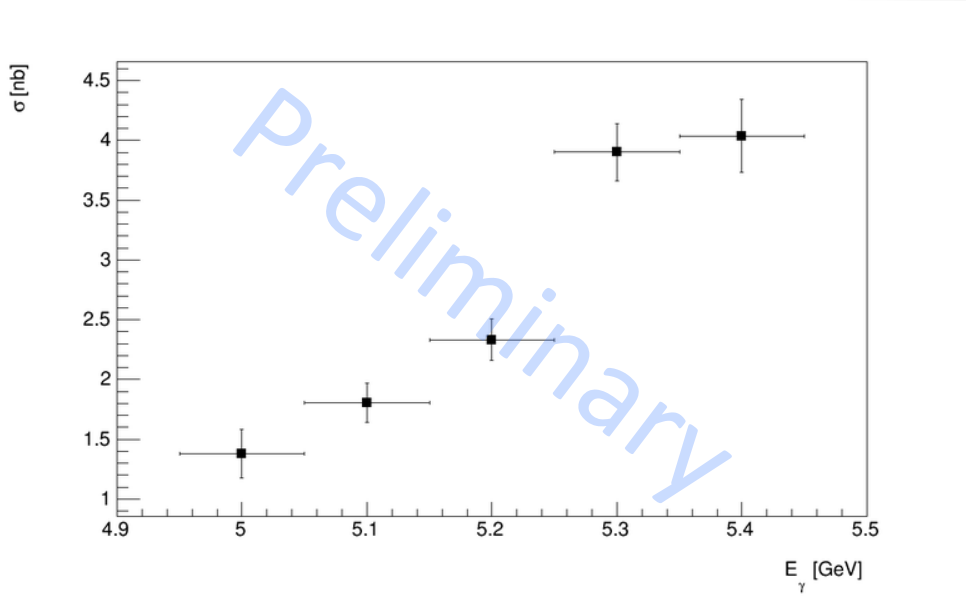
- After many iterations simulation that matches was generated
- Momentum, angles, and t distributions match

$$\gamma p \rightarrow pp\pi^-(\bar{n})$$

Antineutron Cross Section

$\gamma p \rightarrow pp\pi^{-}(\bar{n})$

- First measurement of total cross section
- ~1400 Events
- Tuned simulation
- ~10x lower cross section than the proton antiproton reaction



*Statistical errors only

Summary

- No obvious evidence of narrow resonance production
- Preliminary (First time) differential and total cross sections shown for proton antiproton reaction
- Model for generating Monte Carlo is in progress
  - Using PLUTO++ for differential cross section defined reaction model
- Partial Wave Analysis searching for broad resonances in the works
  - As a cross-check for the PLUTO++ simulation, use the production amplitudes from the fit to construct a model to generate Monte Carlo
- First time observation and cross section for an antineutron in photoproduction

Supplemental material

Acceptance