# RGB Proposal: Quasi-Real Photoproduction on Deuterium

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# Run Group B Proposal: Quasi-real Photoproduction on Deuterium

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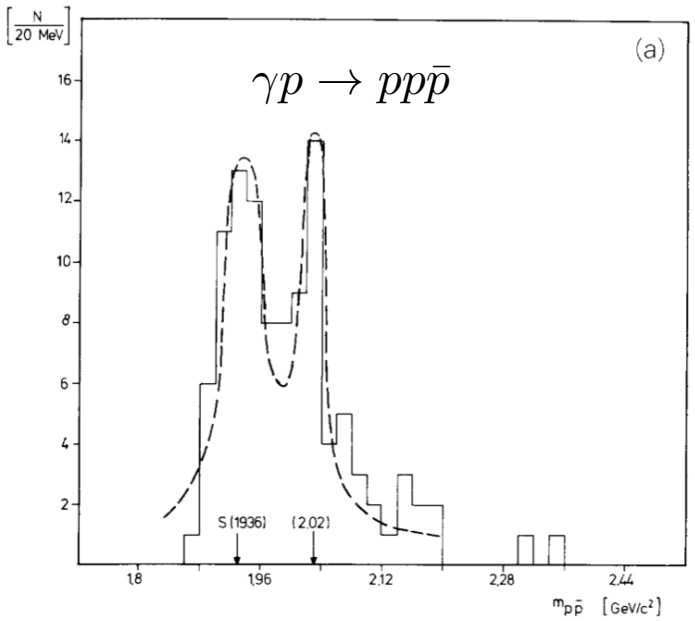
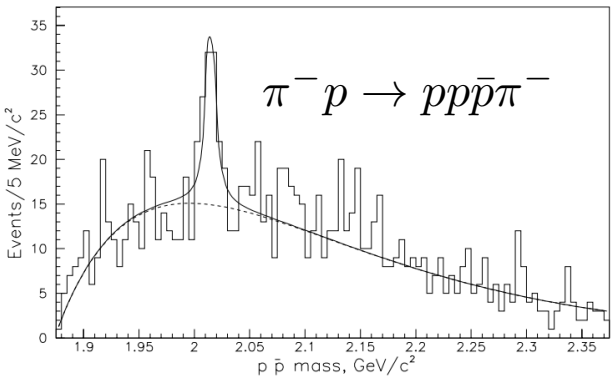
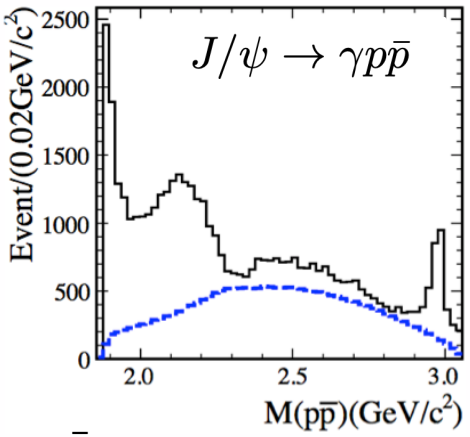
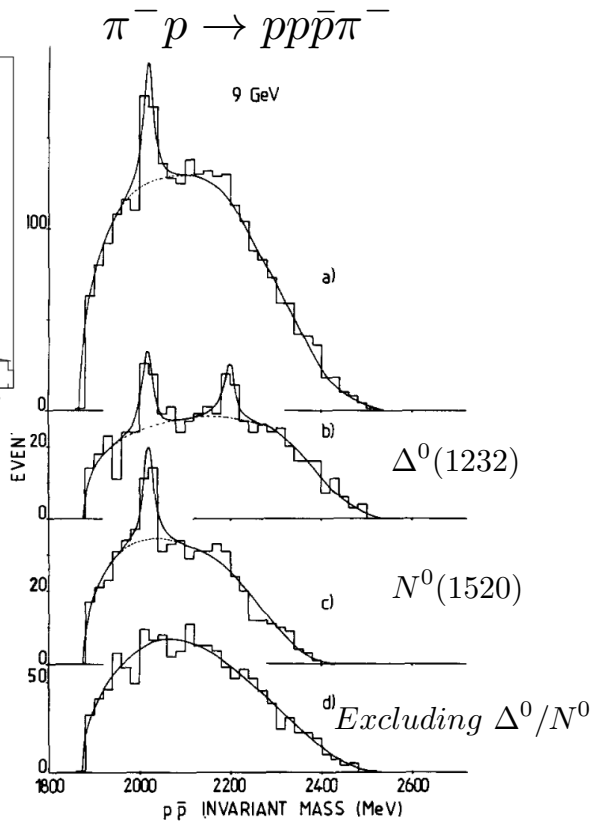
# Proton-Antiproton Resonances



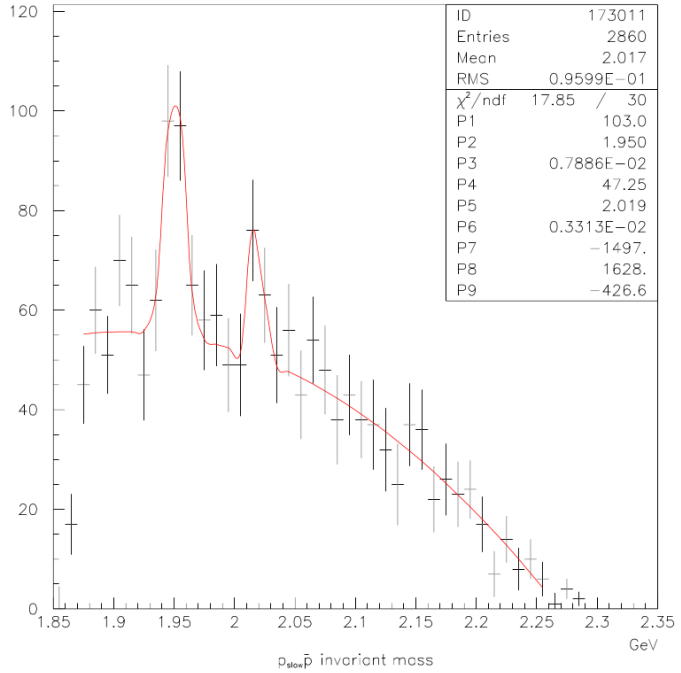




- Resonances seen at DESY in $\gamma p \to p p \bar{p}$
- Narrow resonances in pion production experiments at the CERN Omega Spectrometer
- Results from BESIII show some enhancements but no narrow resonances

➢ Long and conflicting history of proton-antiproton resonant states!

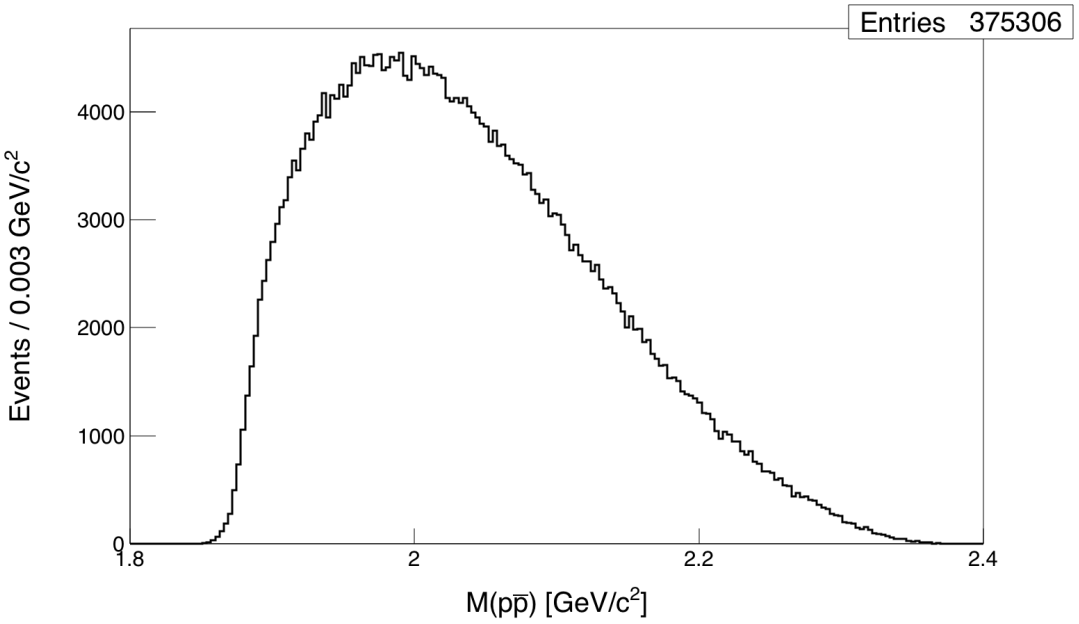
# Proton-Antiproton Resonances in CLAS6

Analysis note: V. Kubarovsky et. al (2003)




- Some structure seen in CLAS for g6b $\gamma p \rightarrow pp\bar{p}$

Thesis: William Phelps (2017)

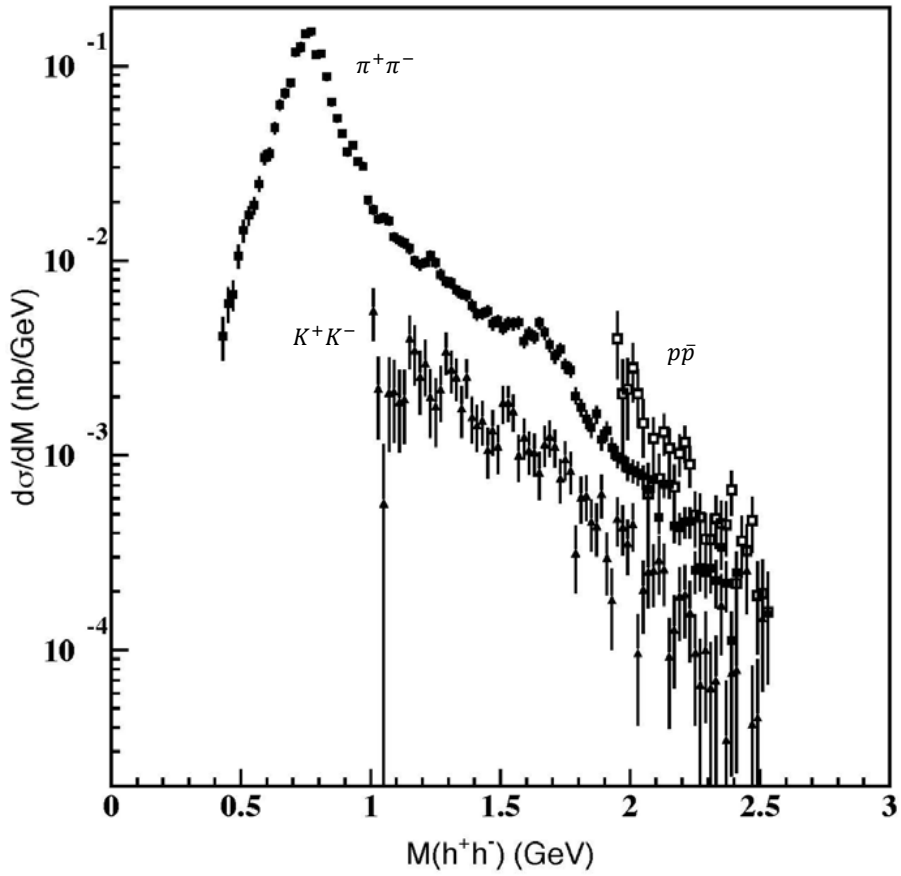


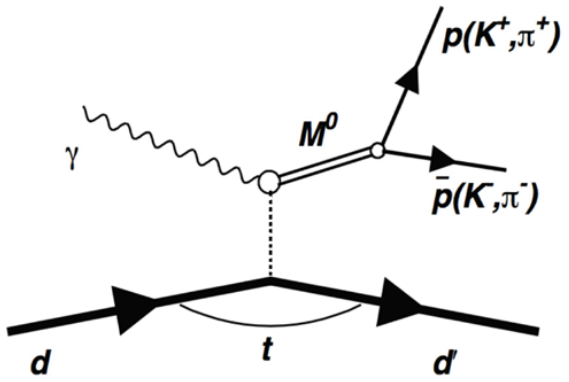

- No clear evidence for narrow resonances seen at CLAS g12 in $\gamma p \rightarrow pp\bar{p}$

➔ Ambiguities in the final state from the two protons that would not exist on a deuteron/neutron
➔ This proposal would allow us to search for resonances with a much wider invariant mass range

# Coherent Dihadron Production

Thesis: Yeranuhi Ghandilyan (2016)




- Preliminary result from eg3 analysis
- Unexpected large cross section for proton-antiproton than pion or Kaon production at masses > 2GeV
- Diquark pair production? $(qq) - \overline{q\,q}$
- Limited statistics at eg3: ~300 events

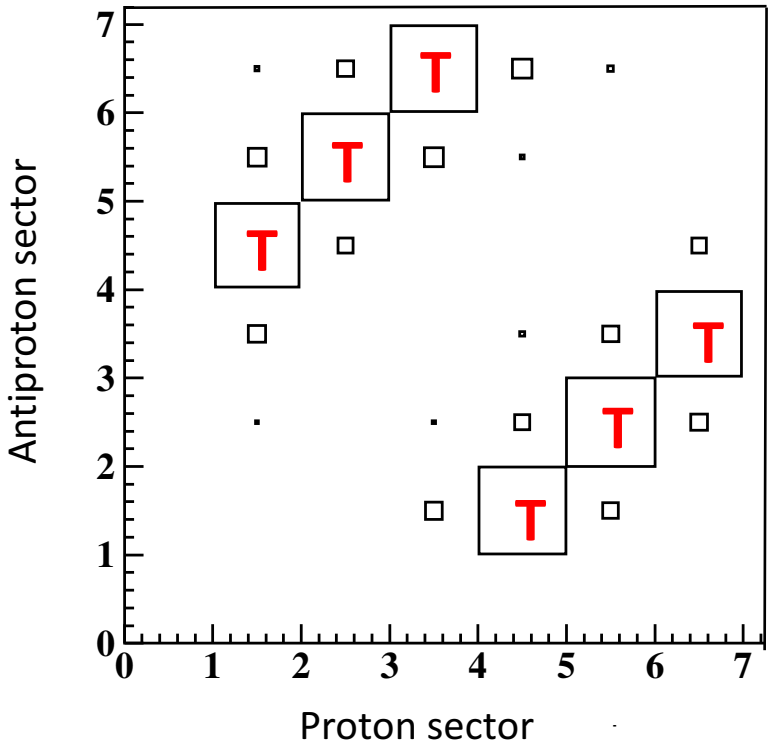
➔ Study invariant mass with higher statistics and larger invariant masses

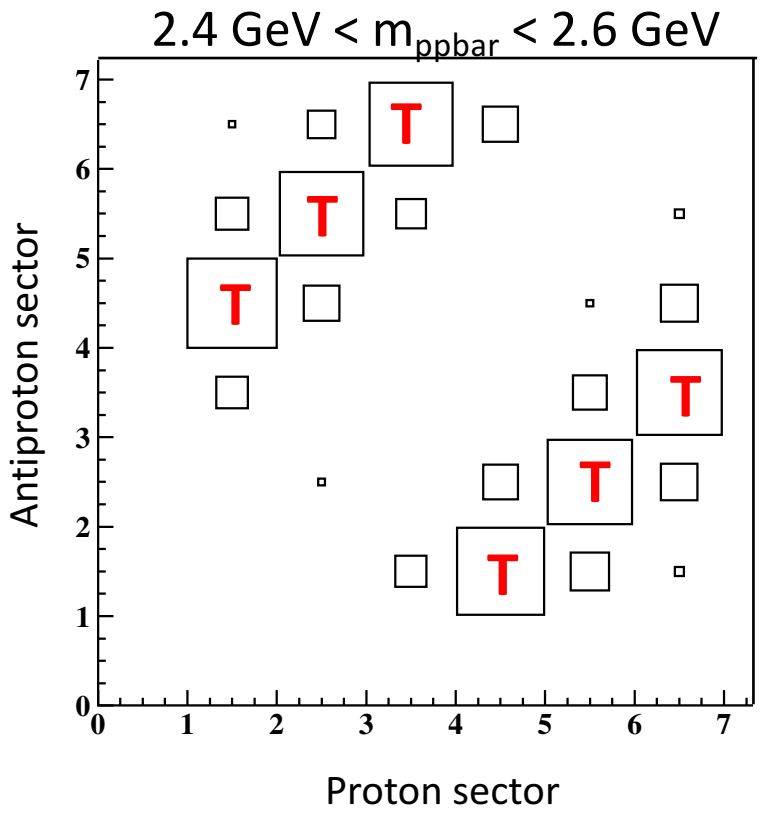
➔ Learn about production mechanism

# Proposal Request

| | |
|---|---|
| Beam time | Remaining RGB (~69 PAC days) |
| Beam energy | 11 GeV (at least > 10 GeV) |
| Beam current | ≥ 50nA |
| Polarization | N/A |
| Trigger | 2 particles in FD, opposite charge and sector |
| Setup | CLAS12 and FT (as Spring 2019) |
| Torus | Inbending |

# Trigger Condition: Opposite Sector and Charge in Forward Detector




- Proton and Antiproton predominantly in opposite sectors → Proposed trigger sufficient for this reaction
- Opposite Sector condition independent on invariant mass or photon energy

# DAQ Rates

RGB Spring 2019, 50nA @ 10.5 GeV

| Bit | Description | Raw (Hz) | Normalized (Hz/nA) | Norm. Limit (Hz/nA) |
|---|---|---|---|---|
| 0 | Electron - OR of 1-6 | 5503 | 108.8 | 95.0 |
| 1 | Sector 1 | 871 | 17.2 | 13.0 |
| 2 | Sector 2 | 922 | 18.2 | 13.0 |
| 3 | Sector 3 | 930 | 18.4 | 13.0 |
| 4 | Sector 4 | 965 | 19.1 | 13.0 |
| 5 | Sector 5 | 950 | 18.8 | 13.0 |
| 6 | Sector 6 | 881 | 17.4 | 13.0 |
| 7 | Muon S1- S4+,EMAX | 2167 | 42.8 | 35.5 |
| 8 | Muon S2- S5+,EMAX | 1986 | 39.2 | 34.5 |
| 9 | Muon S3- S6+,EMAX | 1945 | 38.4 | 32.3 |
| 10 | Muon S4- S1+,EMAX | 2126 | 42.0 | 36.7 |
| 11 | Muon S5- S2+,EMAX | 2054 | 40.6 | 34.8 |
| 12 | Muon S6- S3+,EMAX | 1975 | 39.0 | 32.9 |
| 13 | Electron OR no DC | 13422 | 265.3 | 200.0 |
| 14 | Muon S1- S4+ | 3478 | 68.7 | 60.2 |
| 15 | Muon S2- S5+ | 3390 | 67.0 | 60.0 |
| 16 | Muon S3- S6+ | 3339 | 66.0 | 58.0 |
| 17 | Muon S4- S1+ | 3428 | 67.8 | 60.0 |
| 18 | Muon S5- S2+ | 3595 | 71.1 | 60.0 |
| 19 | Muon S6- S3+ | 3381 | 66.8 | 60.0 |
| 20 | FTH(>.3)xFTOFUxCTOF | 36860 | 728.5 | 700.0 |
| 21 | FTH(.2-4)x[FTOFUxDC]^2 | 13001 | 257.0 | 240.0 |
| 22 | FT(>.5) 2 clusters | 12358 | 244.3 | 200.0 |
| 23 | FT(.1-8) | 2044000 | 40397.9 | 35000.0 |
| 24 | - | 0 | 0.0 | -1.0 |

- J/$\psi$ Dimuon trigger (RGB):
  - Opposite sector
  - Opposite charge
  - EMAX cut in ECAL
  - **≈ 8 kHz rate**
- Proposed Dihadron trigger
  - Opposite sector
  - Opposite charge
  - No EMAX cut
  - **≈ 12 kHz rate (50% increase)**
- Electrons ≈ 6 kHz rate
- **Total (proposal) ≈ 18 kHz rate < DAQ limit**

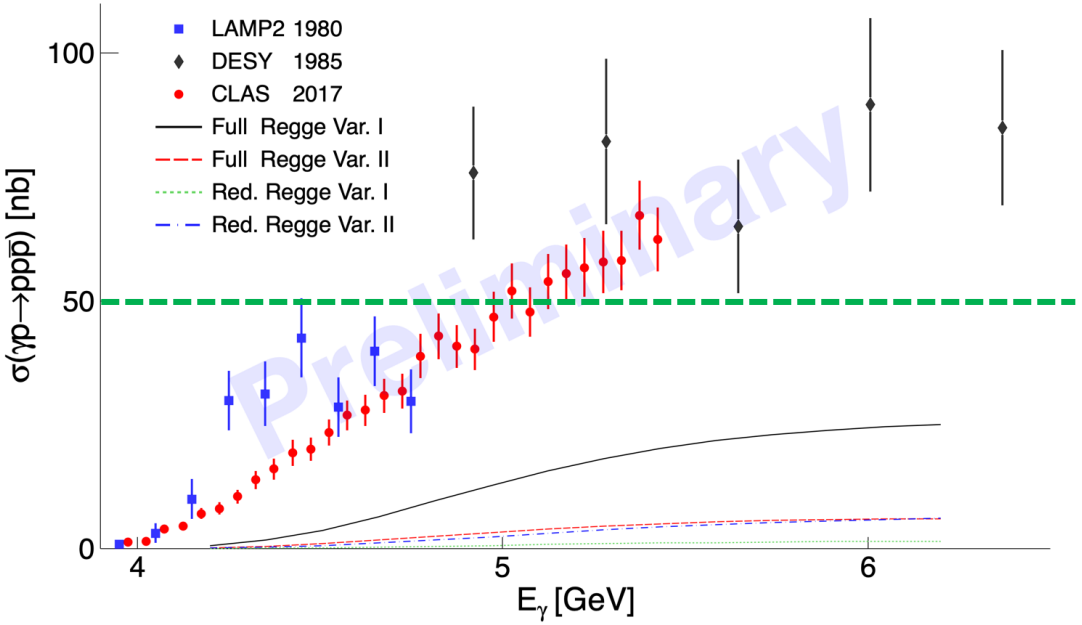
# Luminosity Estimates

- Luminosity for 69 PAC days
  - Electron beam: 50nA, 50% efficiency → 300mC
  - Target density 0.163 g/cm$^3$, length 5cm → 0.24 b$^{-1}$
  - Electron luminosity ≈ **450 fb$^{-1}$**
  - #Photons from bremsstrahlung ≈ **0.002** per electron (virtual photon flux 2-3x larger)

- Untagged photon luminosity ≈ **1 fb$^{-1}$**
- Tagged photon luminosity ≈ **100 pb$^{-1}$** (~factor 10 for FT acceptance)

# Event Estimates: $\gamma n \to n p \bar{p}$

- Cross section: $\sigma \approx$ **50nb** (conservative estimate)
- Acceptance and efficiency from GEMC for 3 particles: **1.6%**




William Phelps Thesis (2017)

- $N_{\text{e-tagged}} \approx$ 75000 events
- No tagging ≈ 750k events
- 1/3 of data in Fall 2019

# Event Estimates: $\gamma d \rightarrow dp\bar{p}$

- Scaling from eg3 data (Thesis Yeranuhi Ghandilyan (2016))
  - 15 $pb^{-1}$ luminosity
  - 300 events with 12.5% acceptance and efficiency
- Acceptance and efficiency from GEMC for final state: **2%**

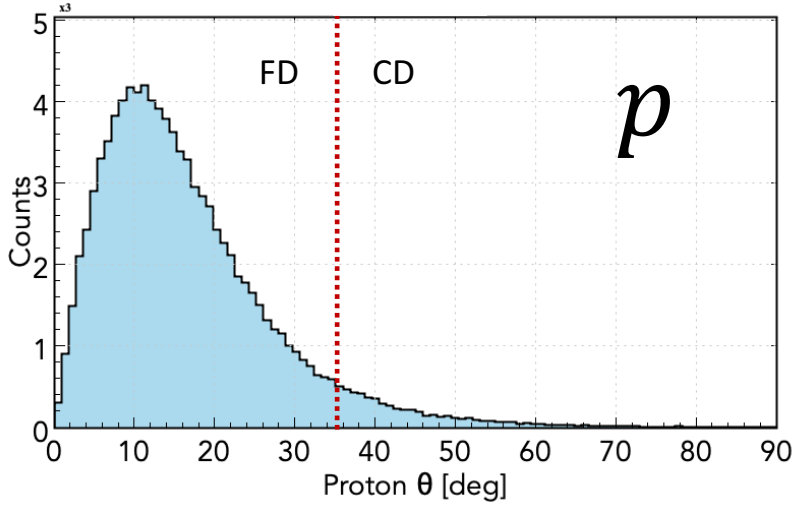
- $N_{untagged}$ and exclusive final state ≈ 3300 events (eg3 had 300 events)

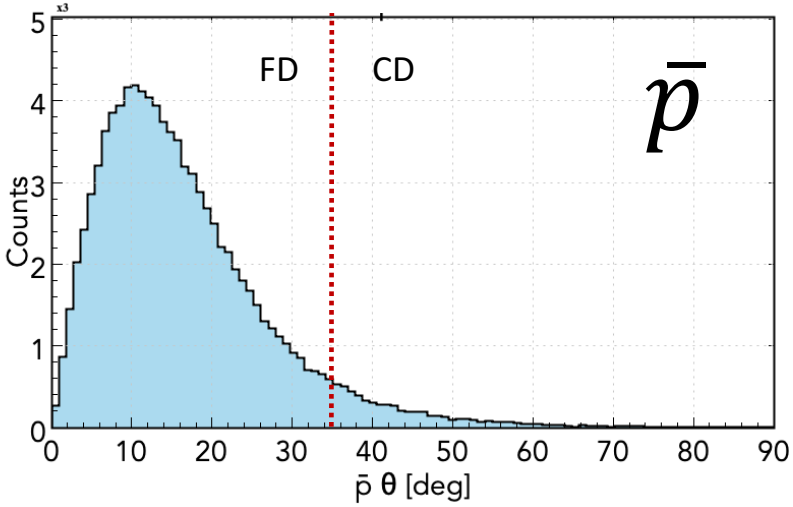
- Coherent production in same mass range of
  - Pion pairs ≈ factor 2 lower
  - Kaon pairs ≈ factor 6 lower

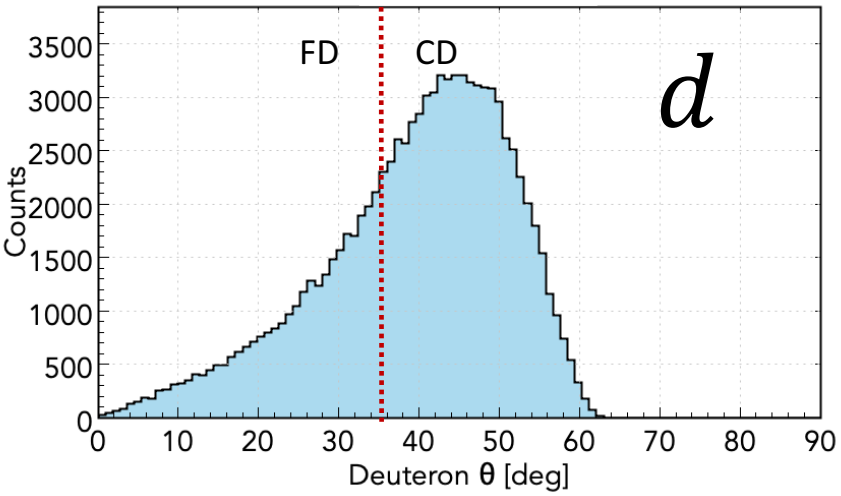
# Simulation Details

- t-channel generator
  - Bremsstrahlung spectrum: 6.5 – 10.5 GeV
  - t-slope = 1.5 $(GeV/c)^{-2}$
  - ppbar decay as two-body phase space
  - 400k events
- GEMC 4.3.0
- coatjava 5b.7.8

# Generated MC: $\gamma d \rightarrow dp\bar{p}$

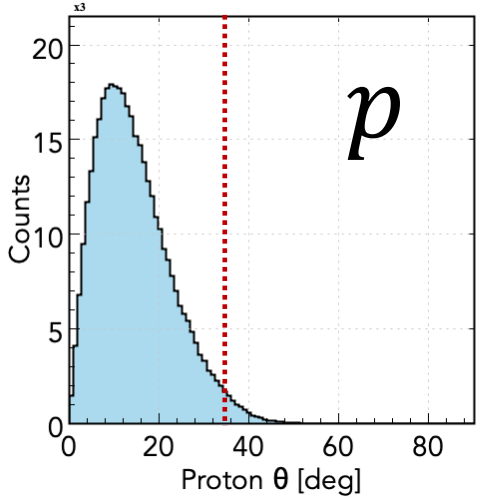


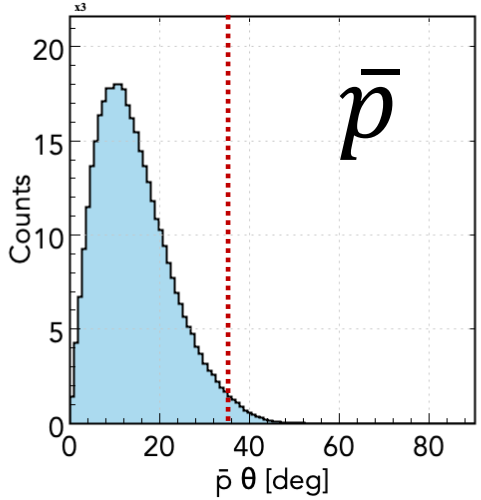



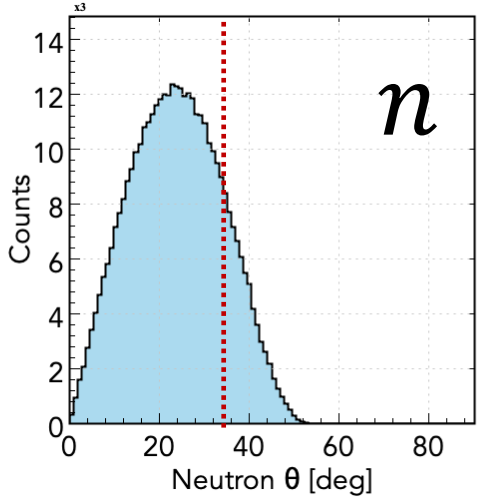



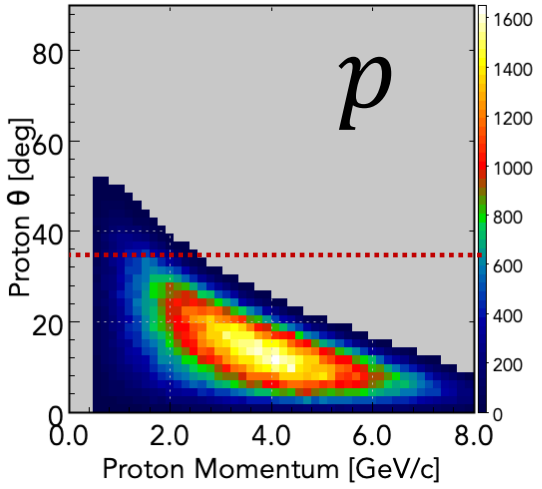

- Proton and Antiproton predominantly in Forward Detector
- Deuteron in FD and CD
- Misidentification of *p* and *d* in EB
  → Reconstructed values not shown

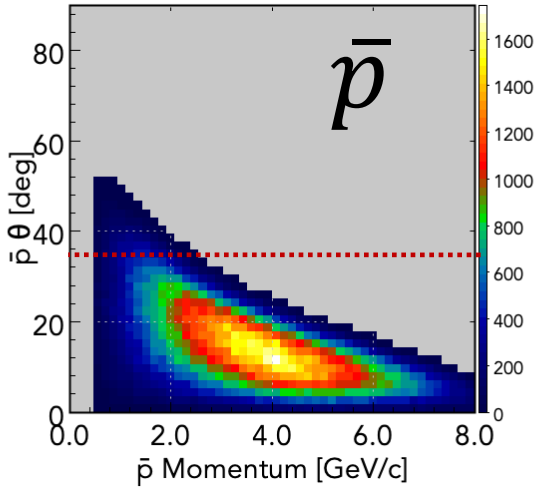
# Generated MC: $\gamma n \rightarrow np\bar{p}$

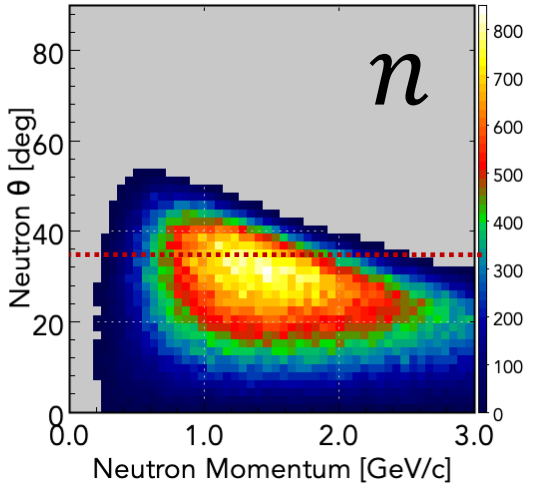


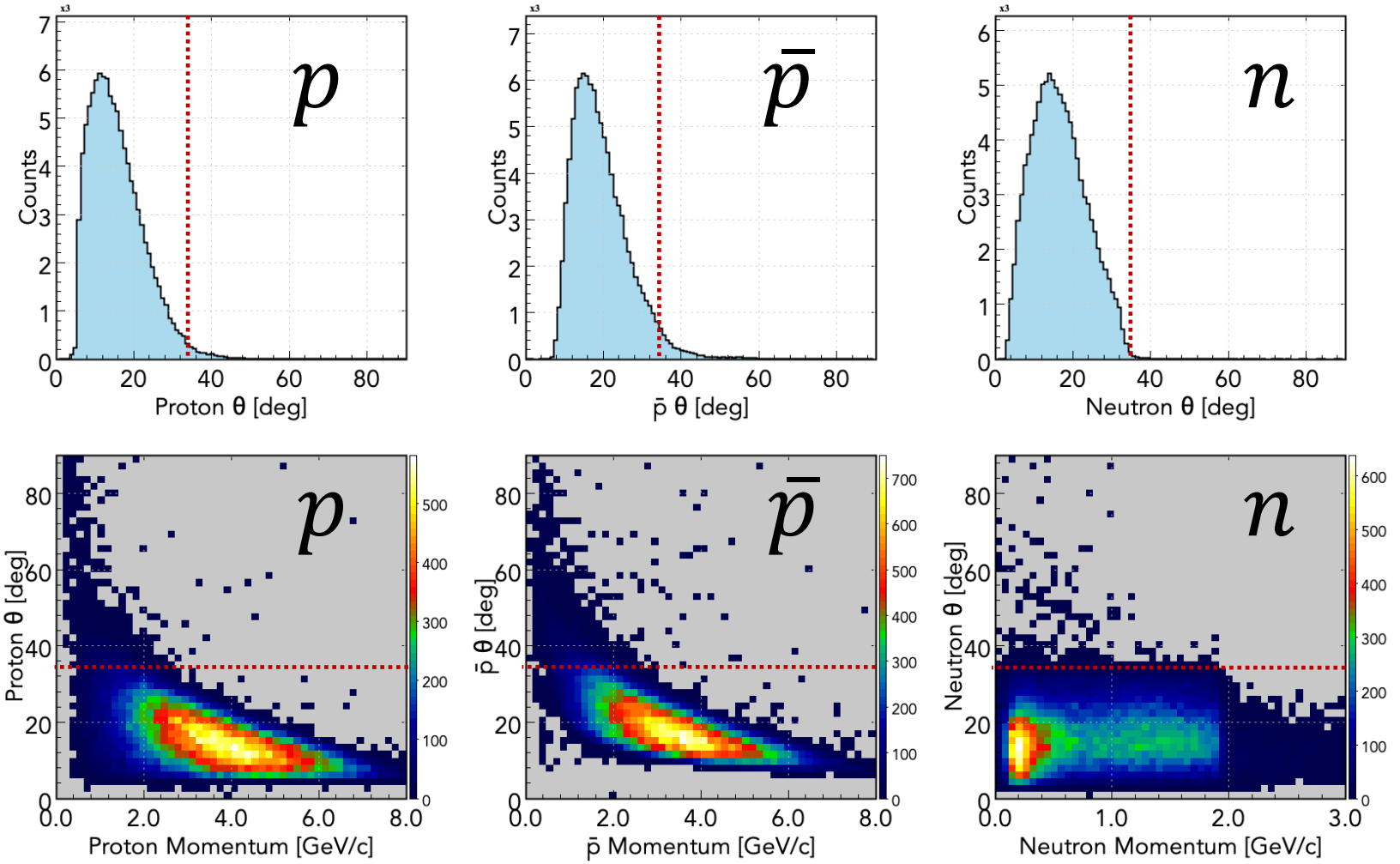



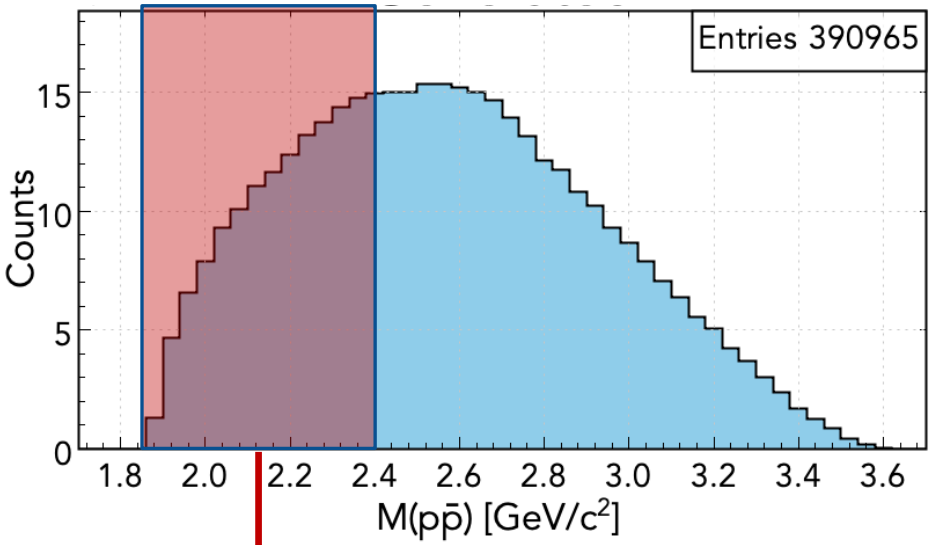



# Reconstructed MC: $\gamma n \rightarrow np\bar{p}$



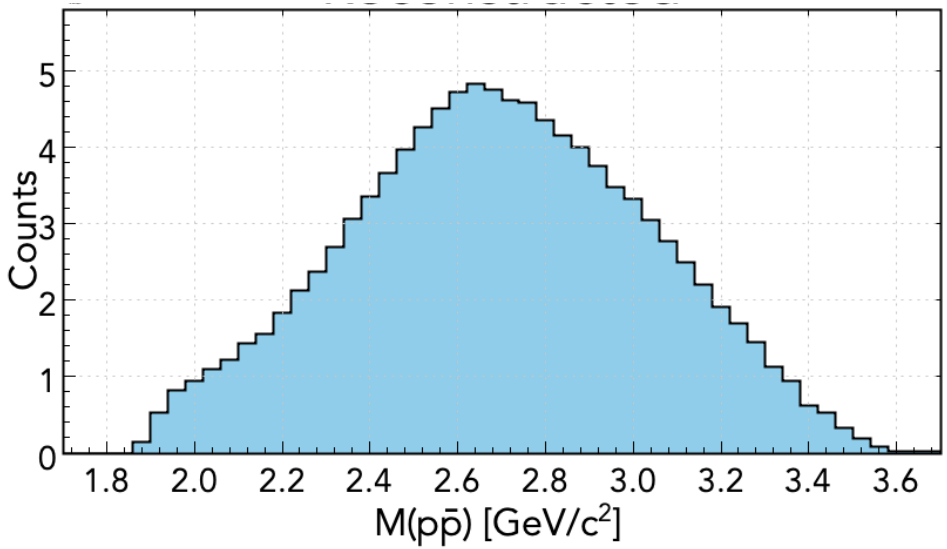

- PID is determined by charge of reconstructed track, neutral hit is assumed to be a neutron

# Invariant Mass Coverage $\gamma n \rightarrow n p \bar{p}$

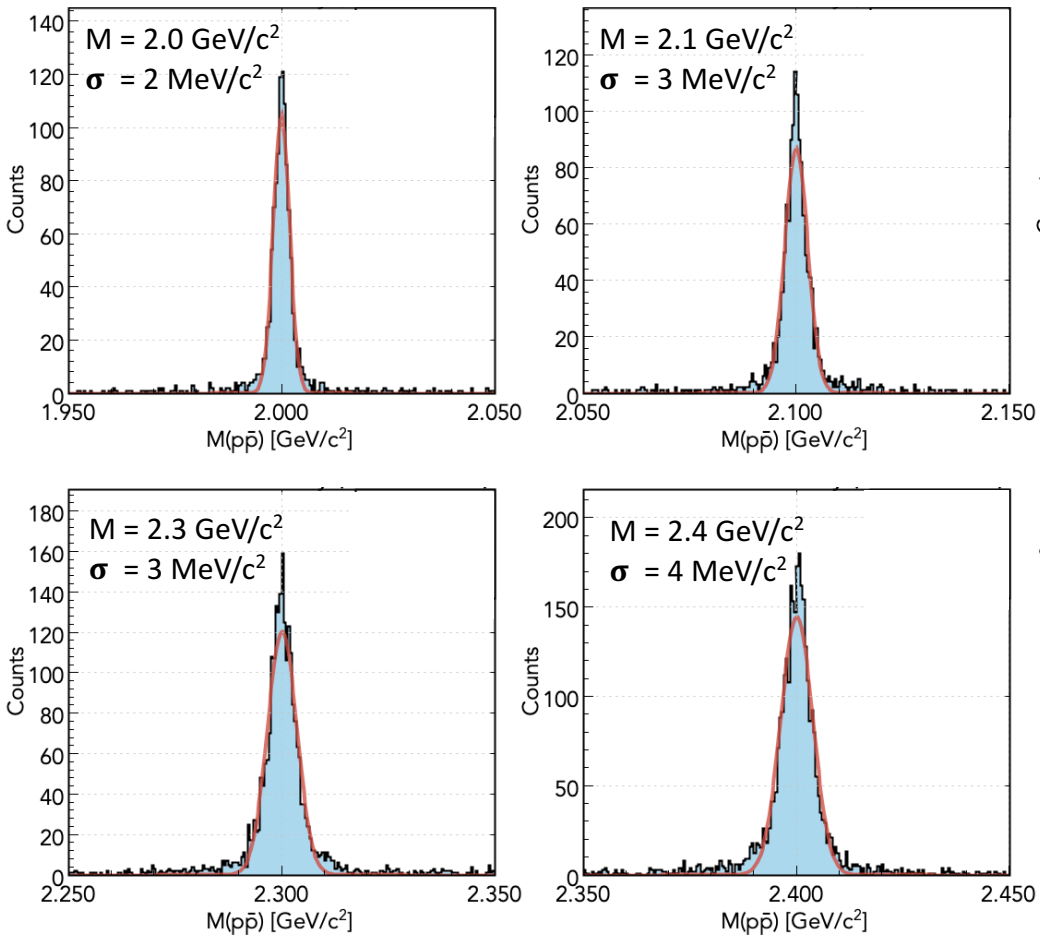


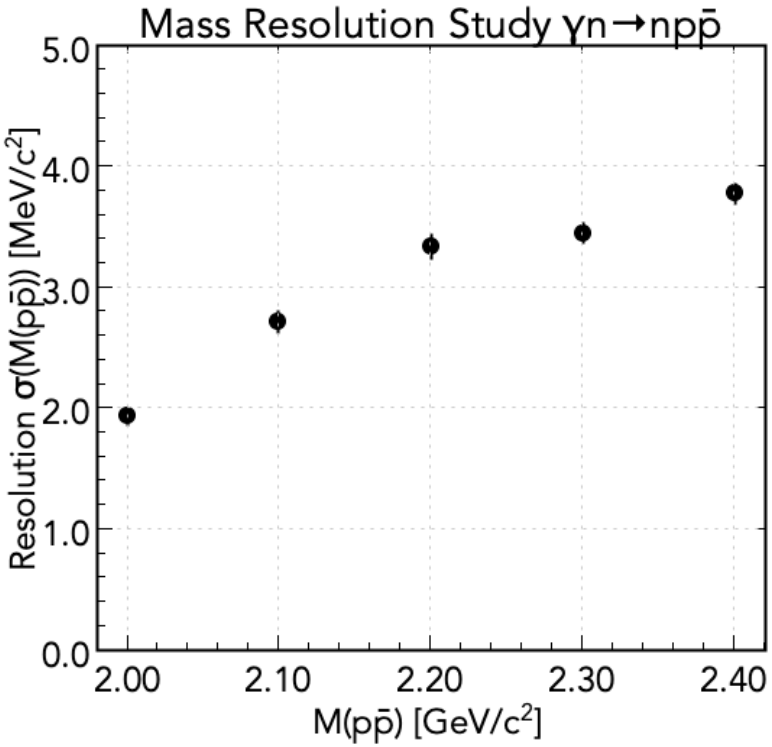

Coverage of CLAS6

CLAS12
Coverage up to 3.5 GeV/$c^2$



# Invariant Mass Resolution Study




- Simulation for $\gamma n \rightarrow np\bar{p}$ with fixed $p\bar{p}$ mass
- Resolutions are suitable to study the narrow resonances

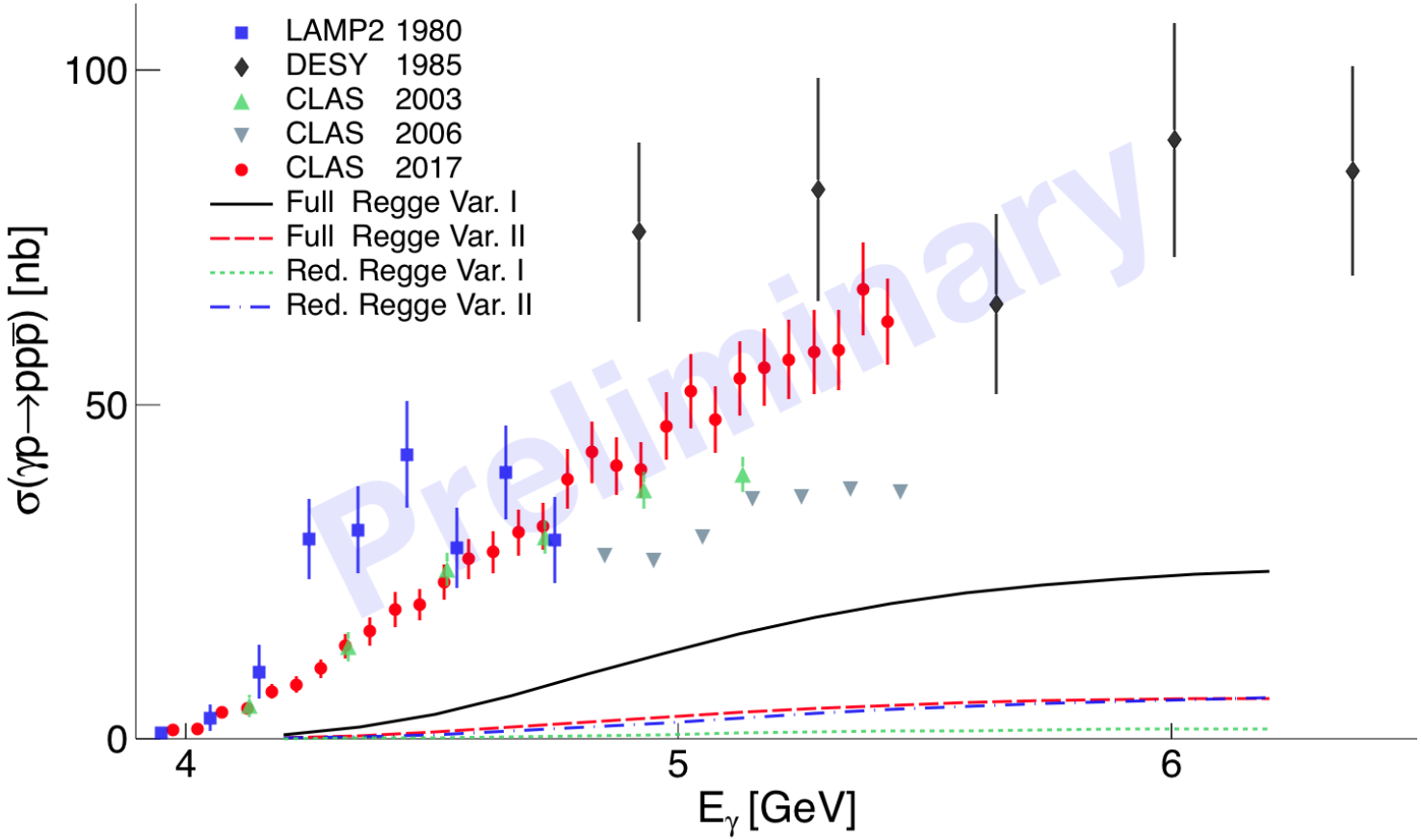
# Summary

- Search for ppbar resonances without ambiguities
- Study of coherent production, x10 higher statistics
- Increase invariant mass coverage up to 3.5 GeV/$c^2$ (CLAS6 2.4GeV/$c^2$)
- Only requires change of RGB muon trigger
  - General dihadron trigger
  - Increase rate by 4kHz; total rate 18kHz < DAQ limit
- Compatible with other RGB experiments

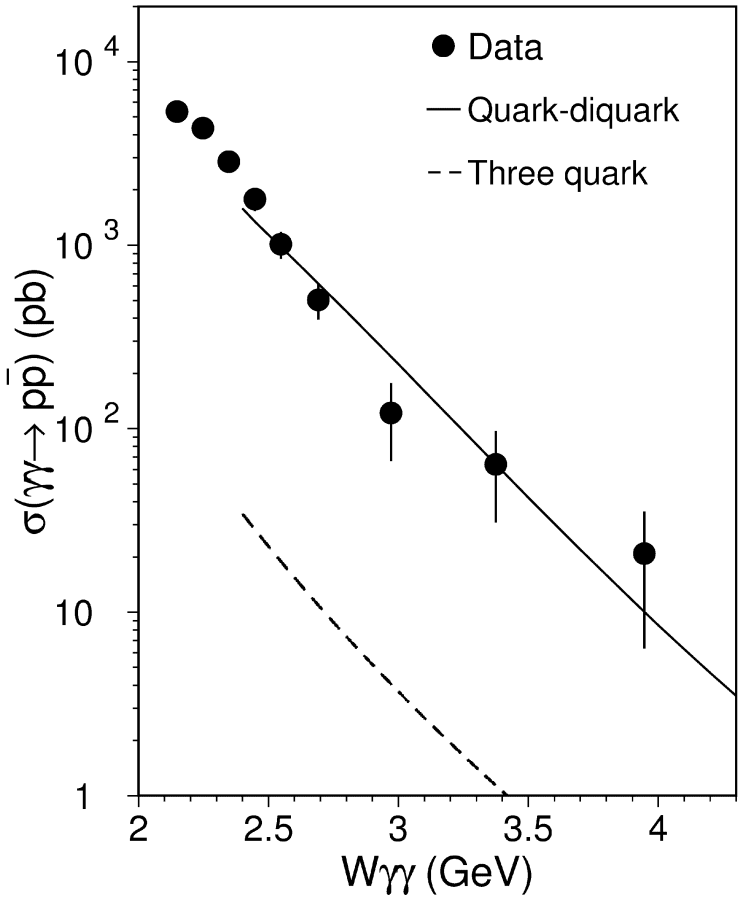
- Note: Trigger partially covers other channels i.e. $\gamma n \to K^+\Sigma^-$ or $\gamma n \to \rho^- p$

# Backup

# Cross Section W. Phelps Thesis

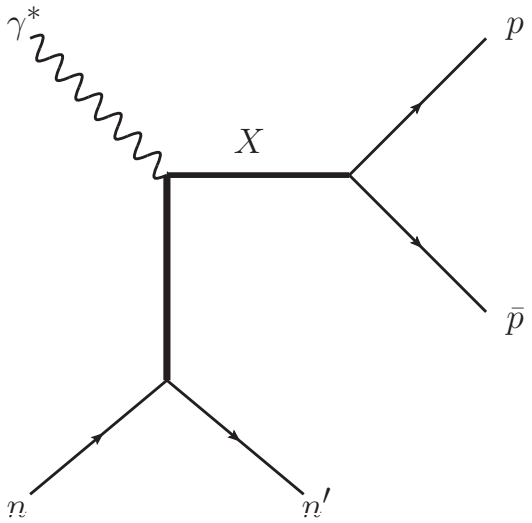


# L3 Result



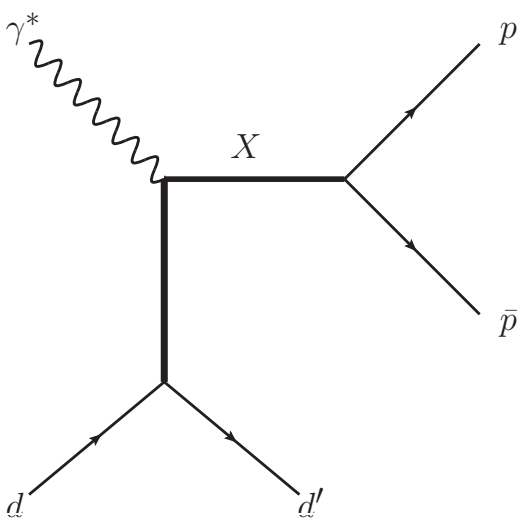

P. Achard *et al.*, Phys.Lett. B 571, 11 (2003)

# Production Mechanism



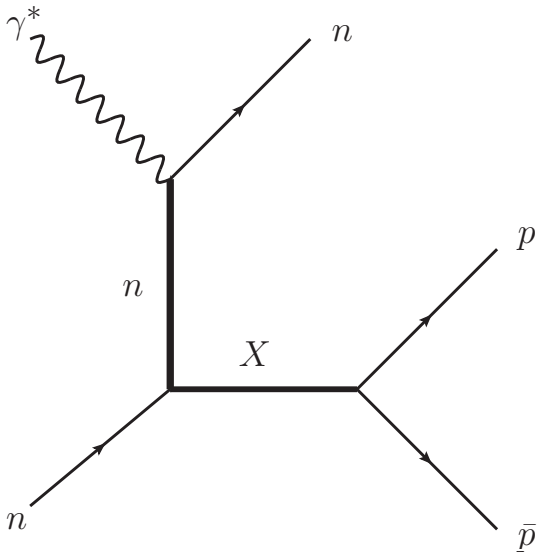

t-channel

$\gamma n \to np\bar{p}$




t-channel

$\gamma d \to dp\bar{p}$




u-channel

$\gamma n \to np\bar{p}$

# $M_{ppbar}$ versus t-distribution