CLAS12 run-group additions

Raffaella De Vita (INFN – Genova)
for the CLAS Collaboration

July 31, 2019

CLAS12 Run-Group Additions

E12-11-003C

Neutron DVCS Measurements with BONuS12 in CLAS12

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a CLAS Run-Group Addition Proposal

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E12-07-104A

Run Group B Proposal: Quasi-real Photoproduction on Deuterium

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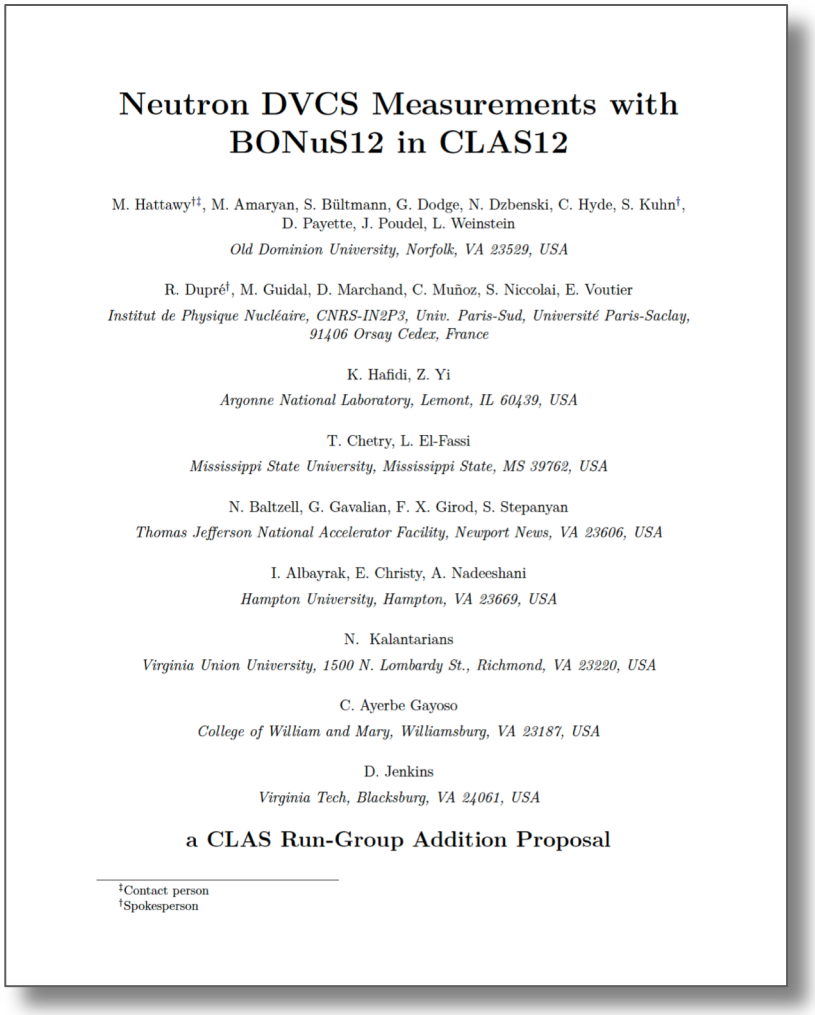
Outline

- Physics goals
- Experimental setup and compatibility with Run-Group configuration
- Expected results
- Collaboration review

E12-11-003C



Neutron DVCS Measurements with BONuS12 in CLAS12

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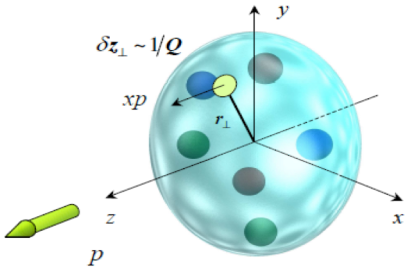
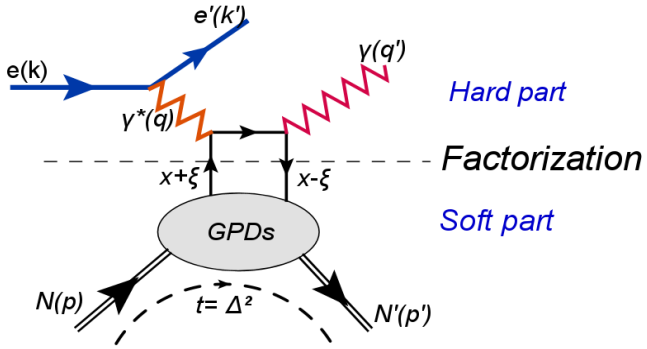
- Addition for CLAS12 RG-F (BONUS12): E12-06-113

Neutron Generalized Parton Distributions

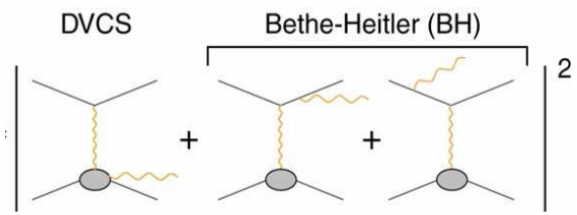
- **GPD**s contain information on:
  - → Correlation between longitudinal momentum and transverse spatial position of partons
  - → Correlation between quarks and anti-quarks
- Can be accessed via **hard exclusive processes** such as deeply virtual Compton scattering (DVCS)





- The **DVCS** signal in reaction eN → eNγ is enhanced by the **interference** with BH

$$d\sigma \propto |\tau_{BH}|^2 + \underbrace{(\tau^*_{DVCS}\tau_{BH} + \tau^*_{BH}\tau_{DVCS})}_{\mathcal{I}} + |\tau_{DVCS}|^2$$



Why Do We Need to Measure Neutron GPDs?

- While free proton 3D tomography has been extracted within the GPDs framework, much less is known about the neutron structure due to the unavailability of free neutron targets
- First dedicated nDVCS measurement at CLAS12, E12-11-003, γ* + d → n + γ + (p), looking for the flavor separation of GPDs:
  - → 90 days on D at L = 10 ^{35} cm^{-2} sec^{-1}
  - → Forward CLAS12 (+ Forward tagger) + Central CLAS12 detectors.
  - → Neutrons being detected using the central neutron detector (CND) (10% detection efficiency)
  - → First data taking in Spring19, to continue in the Fall

RG-F (BONuS12) Experimental Setup

- 10.6 GeV electron beam
- 35 days on D
- 5 days on H_2
- with $L = 2 \cdot 10^{34}\ cm^{-2}\ sec^{-1}$

Forward Detector:

→ Superconducting **Torus** magnet.

→ Standard detector configuration: HTCC, DC, LTCC, FTOF, PCAL and EC

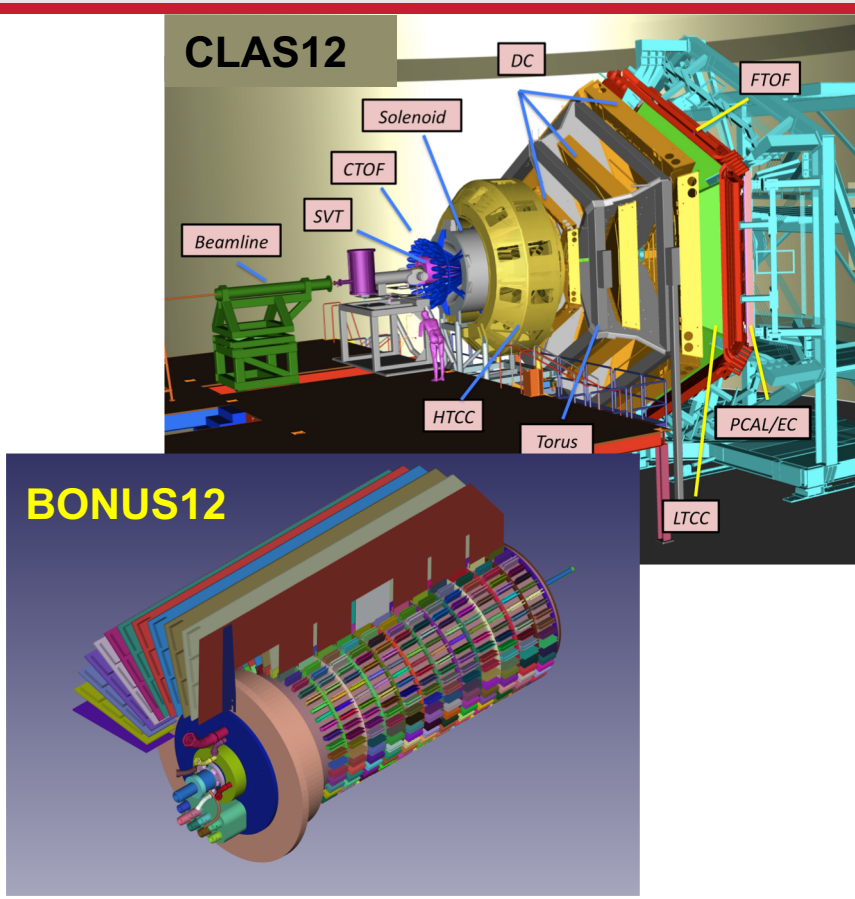
Central Detector:

→ **Target:** (400 mm long, 6 mm diameter) D gas @ 7.5 atm, 293 K

→ **BONuS12 RTPC:** detects low energy spectator protons

→ **Solenoid:** shields the detectors from Møller electrons, enabling tracking in the RTPC

→ **Additional detectors to be used:** CTOF, CND, and FMT

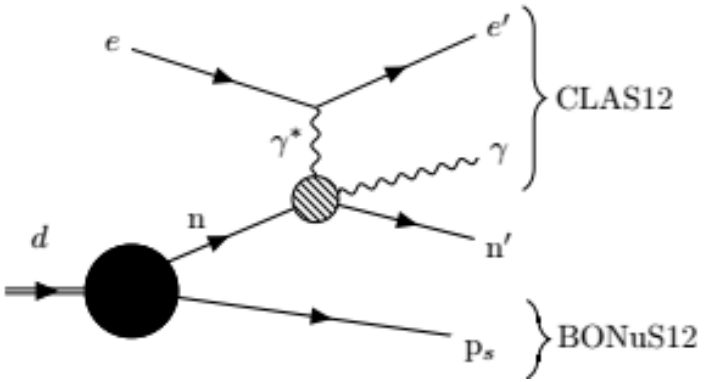


Need high electron beam polarization

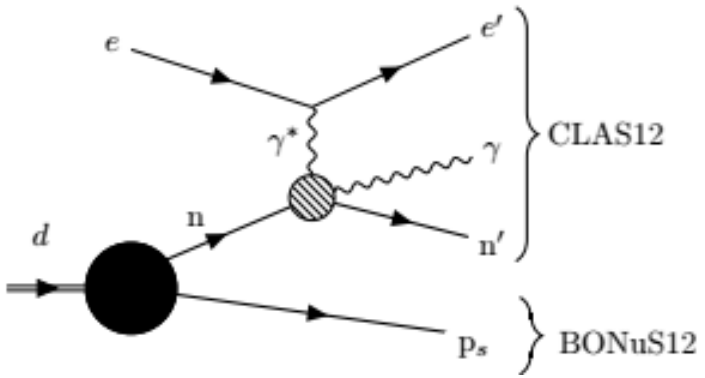
nDVCS Proposed Measurements

- **Tagged-proton nDVCS: $e^- D \rightarrow e^- p\gamma(n)$**
  → Study the partonic structure of the neutron via measuring the beam asymmetry A_{LU}

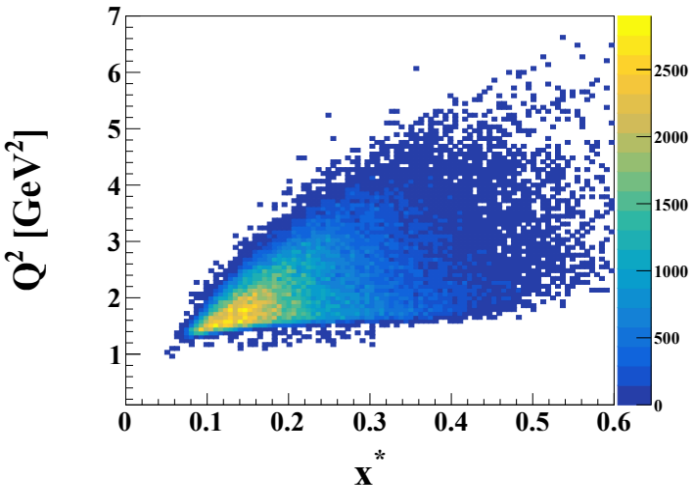
$$A_{LU} = \frac{d^4\sigma^+ - d^4\sigma^-}{d^4\sigma^+ + d^4\sigma^-} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$

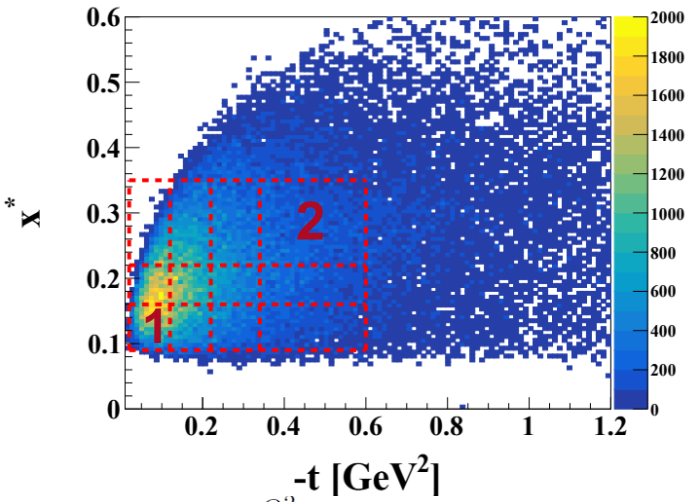


- **Fully exclusive nDVCS: $e^- D \rightarrow e^- n\gamma p$**
  → Study the Fermi motion effect on A_{LU}
  → Measure the size of the FSI on A_{LU}
  → Explore the size of the systematic uncertainties on RG-B measurement



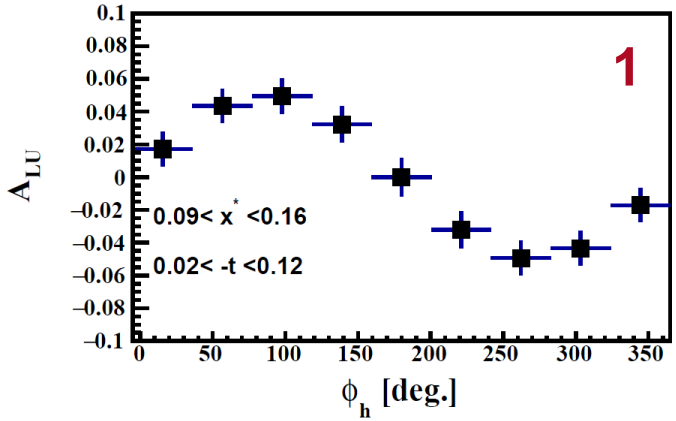
Tagged-proton nDVCS projections

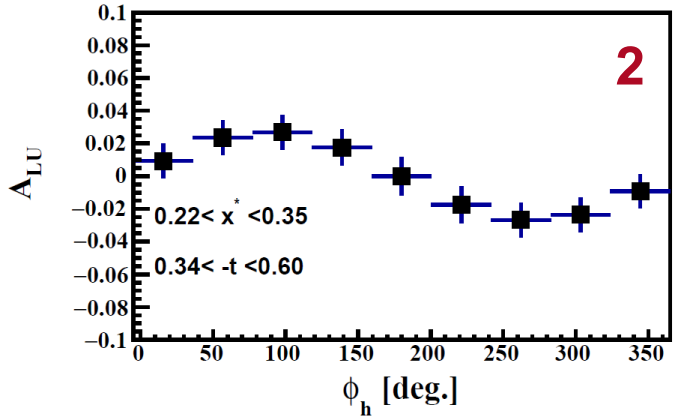




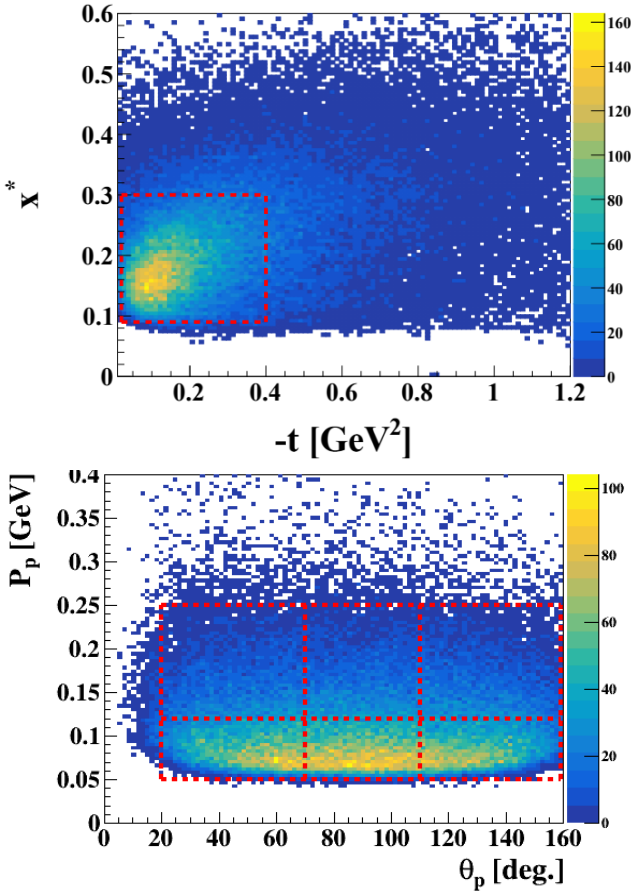
$$x^* = \frac{Q^2}{2M_N E y(2-\alpha_{sp})} = \frac{x_B}{2-\alpha_{sp}}, \qquad \alpha_{sp} = \frac{E_s - p_s^z}{M_N}$$

- 9M expected events.
- Total of 108 bins in x* vs. t vs. phi
- 20% conservative sys. uncertainties
- Exploring the neutron's CFF via the BSA
- Compare the nDVCS to free proton DVCS



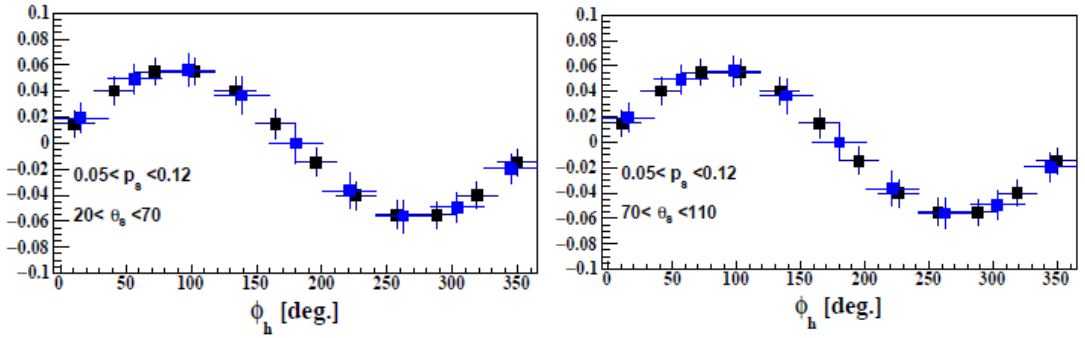


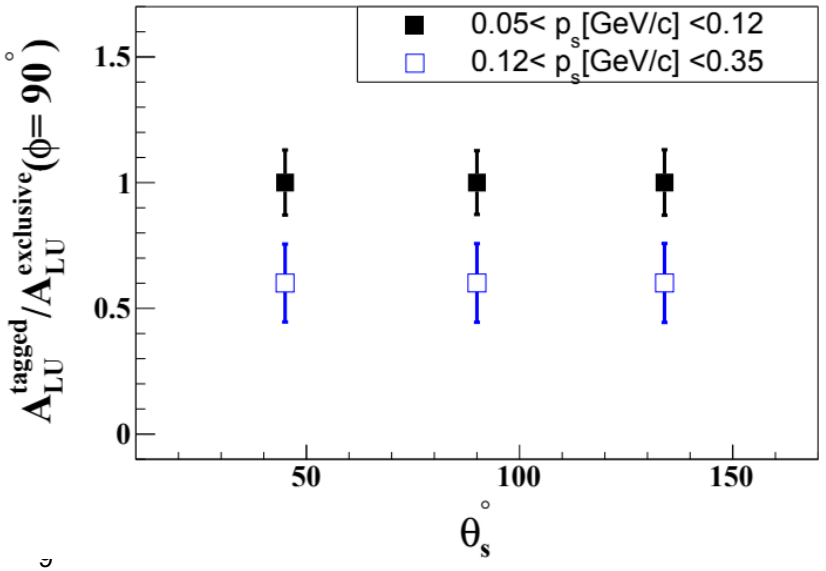
Fully exclusive nDVCS projections



- Initial bin in x* vs. t
- 6 bins in p_s vs. θ_s
- Binning in φ

- 9M tagged nDVCS events (black)
- ~ 0.8M fully exclusive nDVCS (blue)
- Exploring Fermi motion and FSI effects





E12-11-003C: summary

- Addition for CLAS12 RG-F (BONUS12), E12-06-113
- Unique opportunity to study neutron DVCS on a “free” neutron target, accessing QCD within the GPD framework
- Complementary to the approved E12-11-003 experiment, $\gamma^* d \rightarrow n\gamma(p)$
- Measurement of the neutron DVCS beam-spin asymmetry by:
  - tagging the spectator slow-recoiling proton
  - measuring the fully exclusive neutron DVCS channel
- Additional physics topics (π^0 production off D, coherent and incoherent DVCS and DVMP off D, …) would become accessible
- Proposal reviewed by the CLAS Collaboration receiving full endorsement
- Requires high beam polarization:
  - High polarization expected for beam energy of 10.5 GeV
  - Agreement with RG-F spokesperson on time necessary to measure the beam polarization

E12-07-104A

Run Group B Proposal: Quasi-real Photoproduction on Deuterium

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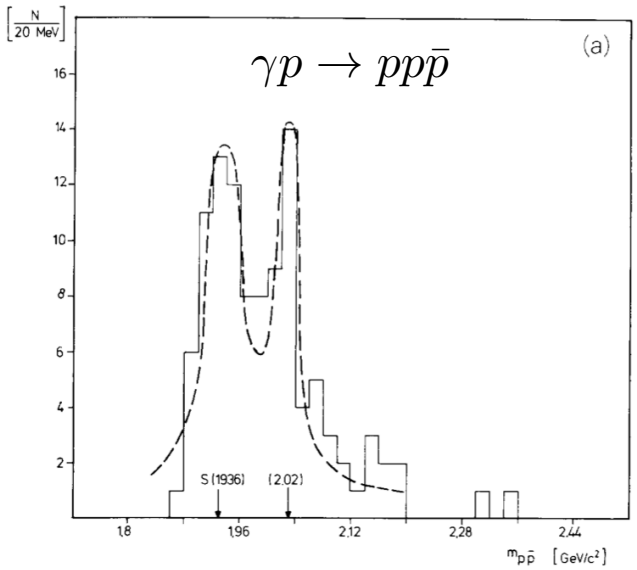
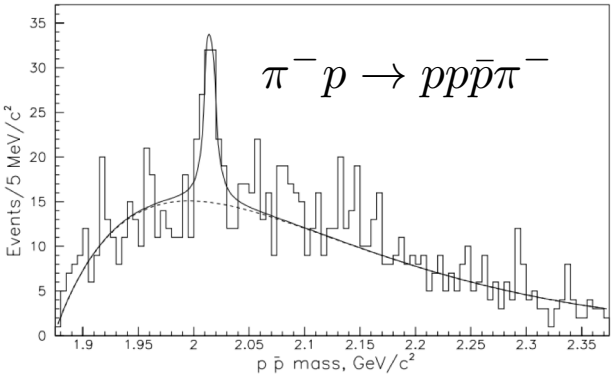
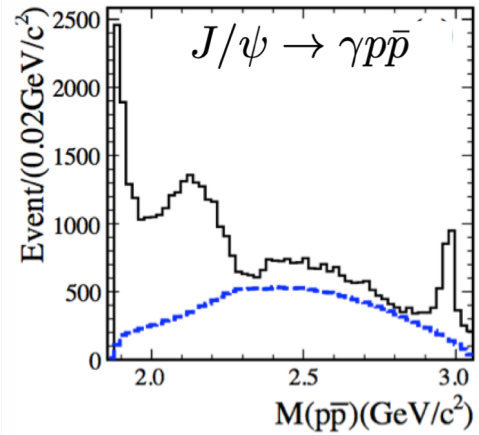
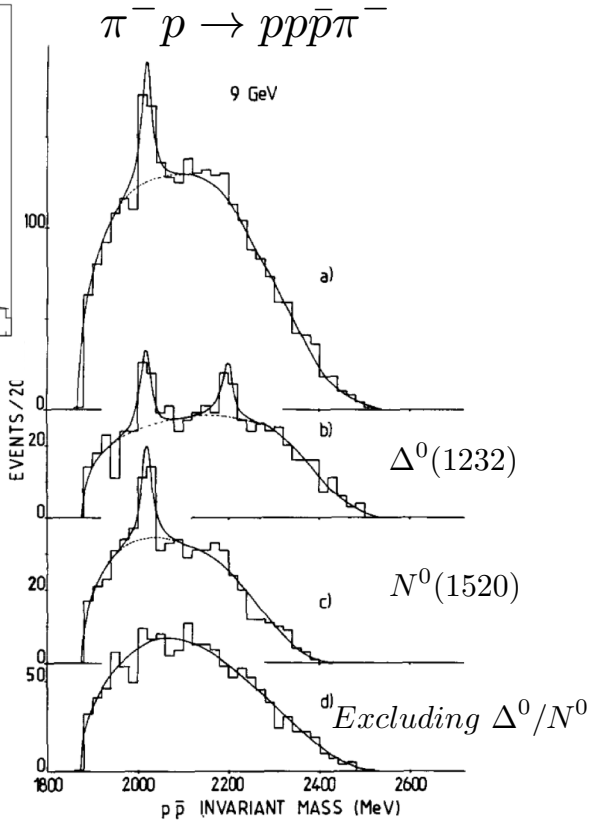
- Addition for CLAS12 RG-B (liquid deuteron target):
  - E12-07-104
  - E12-09-007
  - E12-09-008
  - E12-09-008B
  - E12-11-003
  - E12-11-003A
  - E12-11-003B

Proton-Antiproton resonances





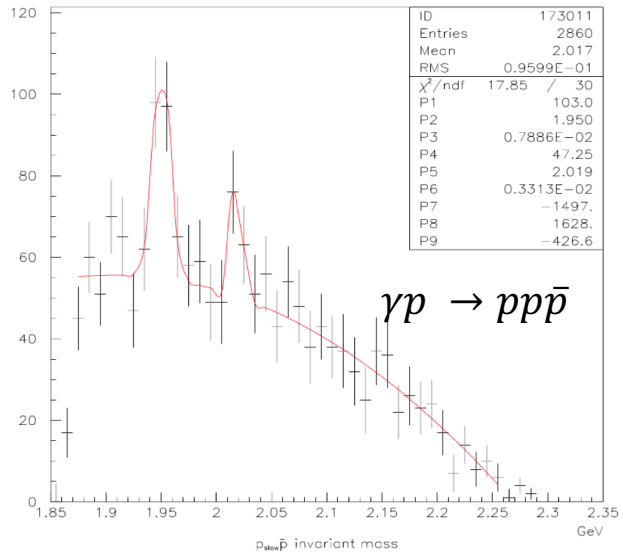




- Resonances seen at DESY in $\gamma p \to pp\bar{p}$
- Narrow resonances in pion production experiments at the CERN Omega Spectrometer
- Results from BESIII show enhancements but no narrow resonances
- Long and conflicting history of proton-antiproton resonant states!

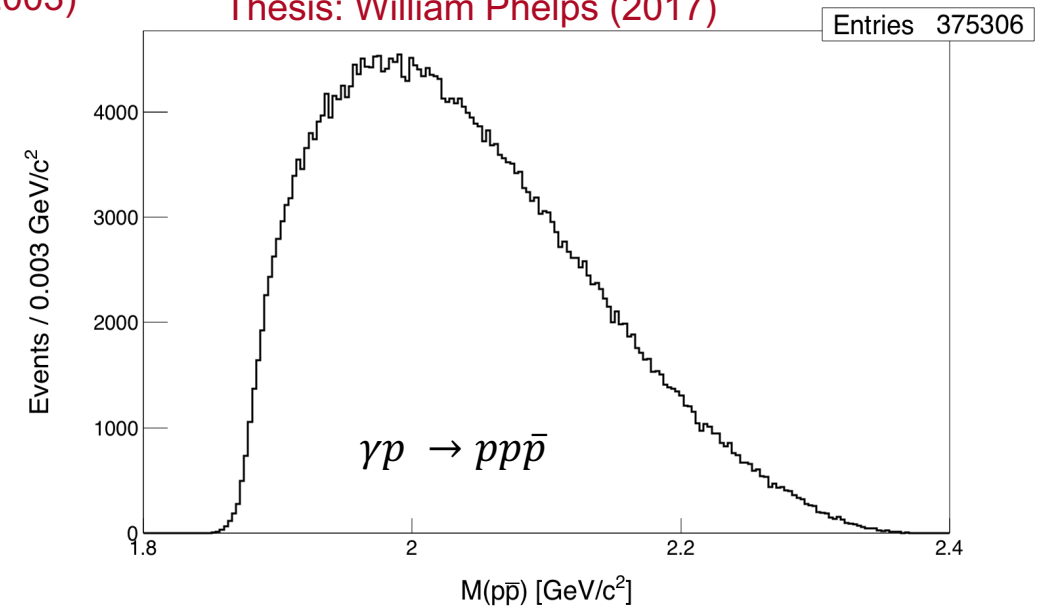
Proton-Antiproton in CLAS

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



- Some structure seen in CLAS-g6b run with limited statistics

Thesis: William Phelps (2017)

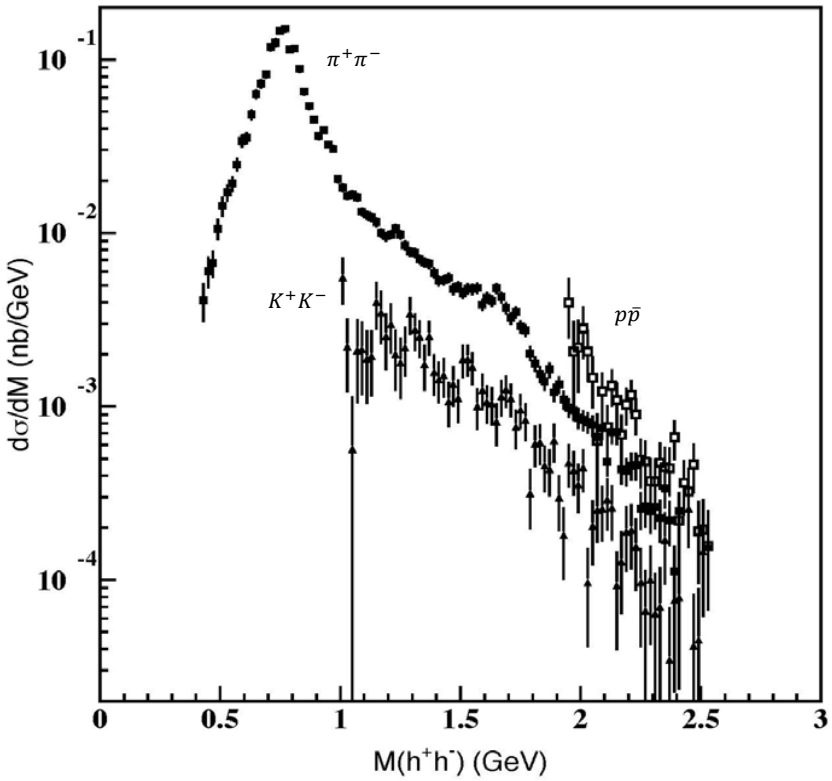


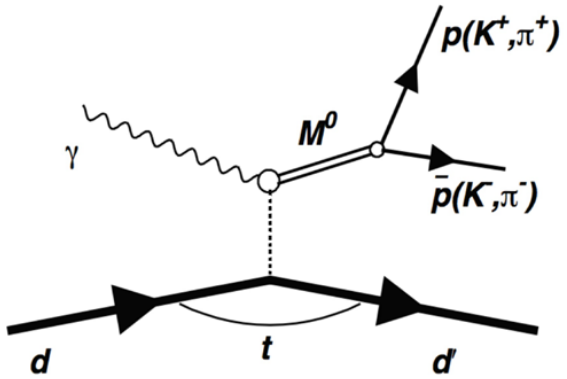
- No clear evidence for narrow resonances seen at CLAS-g12

- Past searches limited by ambiguities from the two final state protons
- This proposal:
  - Search for p-pbar states in $\boldsymbol{\gamma n \rightarrow np\bar{p}}$ and $\boldsymbol{\gamma d \rightarrow dp\bar{p}}$
  - Use quasi-real photoproduction with low-q electron tagging or untagged electron scattering
  - No ambiguities thanks to deuteron/neutron target
  - Search for resonances with a much wider invariant mass range

Coherent Dihadron Production

Thesis: Yeranuhi Ghandilyan (2016)



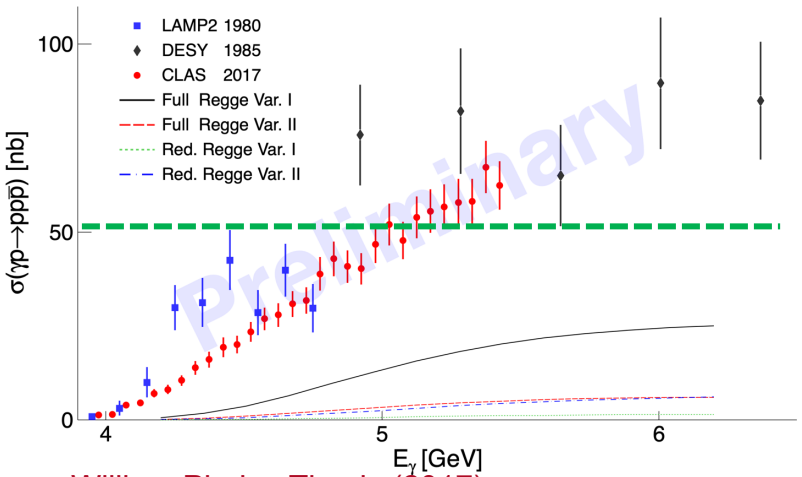


- Preliminary result from CLAS-eg3 analysis
- Unexpected larger cross section for proton-antiproton than pion or Kaon production at masses > 2GeV
- Diquark pair production? $(qq) - \overline{q\,q}$
- Limited statistics at eg3: ~300 events

- This proposal:
  - Study invariant mass with higher statistics and larger invariant masses
  - Learn about production mechanism

Proposal request and projections

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



William Phelps Thesis (2017)

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

- Cross section: $\sigma \approx$ **50nb** (conservative estimate)
- Acceptance and efficiency from GEANT4 simulations for 3 particles: **1.6%**
- $N_{e\text{-tagged}} \approx$ 75k events
- No tagging ≈ 750k events
- 1/3 of data in Fall 2019

E12-07-104A: summary

- Search for p-pbar resonances in quasi-real photoproduction on neutron and deuteron
- Study of coherent production, x10 higher statistics than previous CLAS data
- Increase invariant mass coverage up to 3.5 GeV/c2 (CLAS 2.4GeV/c2)
- Only requires change of RGB muon trigger
  - General dihadron trigger
  - Increase rate by 4kHz; total rate 18kHz < DAQ limit
- Access to other final states: $\gamma n \rightarrow K^+ \Sigma^-$ or $\gamma n \rightarrow \rho^- p$
- Fully compatible with other RG-B experiments
- Proposal reviewed by the CLAS Collaboration receiving full endorsement