CLAS12 Run Group B

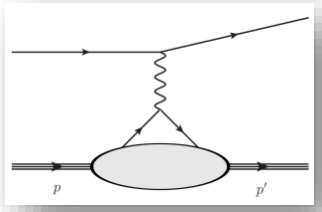
Electroproduction on deuterium with CLAS12

- RG-B experiments
- Overview of the data taking and processing
- Analysis updates and preliminary results
- Outlook and publication plans

Silvia Niccolai, IJCLab Orsay

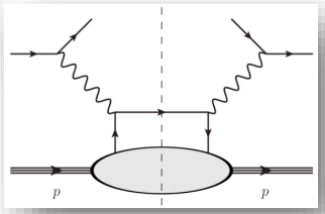
CLAS Collaboration Meeting, 3/2/2021

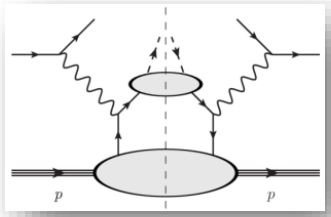
CLAS12 Run Group B: experiments & analyses/PhDs



Elastic Scattering (G^n_M)

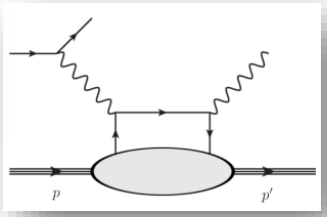
DIS (for SRC and EMC effect)

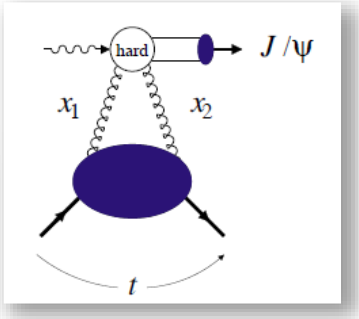




SIDIS (for PDFs and TMDs

nDVCS





J/ψ photoproduction

Run-Group B aims to measure FFs, PDFs, TMDs, GPDs, using **deuteron** as a **neutron target**
→ Quark-flavor separation, combining with proton results

E12-07-104	Neutron magnetic form factor
E12-09-007a	Study of parton distributions in K SIDIS
E12-09-008	Boer-Mulders asymmetry in K SIDIS
E12-11-003	Deeply virtual Compton scattering on the neutron
E12-09-008b	Collinear nucleon structure at twist-3 in dihadron SIDIS
E12-11-003a	In medium structure functions, SRC, and the EMC effect
E12-11-003b	Study of J/ψ photoproduction off the deuteron
E12-11-003c	Quasi-real photoproduction on deuterium (*)

L. Basheen (FIU), GMn
A. Hobart (IJCLab Orsay), nDVCS, pDVCS
P. Naidoo (Glasgow), $ed \rightarrow en\pi^0$
B. Tumeo (USC), J/ψ
Student TBD from Yerevan, J/ψ
E. P. Segarra (MIT), BAND experiment
R. C. Torres (MIT), BAND experiment
C. Fogler (ODU), BAND experiment

+ post-docs and undergrads: A. Movsisyan (INFNFe), O. Soto (LNF), J. Dickovick (Fairfield U)

(*) Joined RGB from fall run onwards

Run Group B running time

Scheduled beam time:
Spring: February 6th - March 25th 2019
Fall: December 3rd –20th 2019
Winter: January 6th – 30th 2020

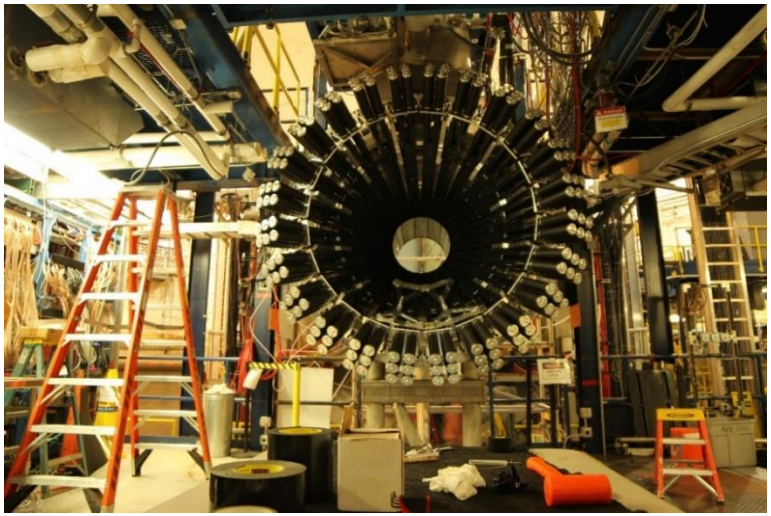
43.3 B triggers collected at 3 different beam energies:

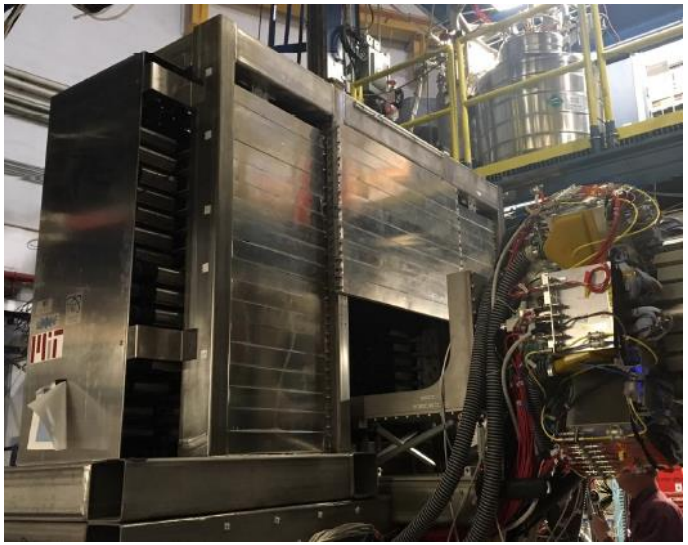
- 10.6 GeV (9.7 B inbending) **spring**
- 10.2 GeV (11.7 B inbending) **spring**
- 10.4 GeV (9 B outbending) **fall, (**12.9 B inbending) **winter**

Average beam polarization ~86%

Experimental setup:

- Baseline CLAS12
- Liquid deuterium target
- Forward Tagger
- RICH (1 sector)
- Central Neutron Detector
- BAckward Neutron Detector





Status of data processing:

- Spring, fall, winter datasets calibrated
- spring and fall pass1 cooking completed
- **winter dataset: pass-1 review passed in Jan**
- **winter: cooking underway (50% done)**

NEW: J/Ψ in ed→(e')e⁺e⁻p

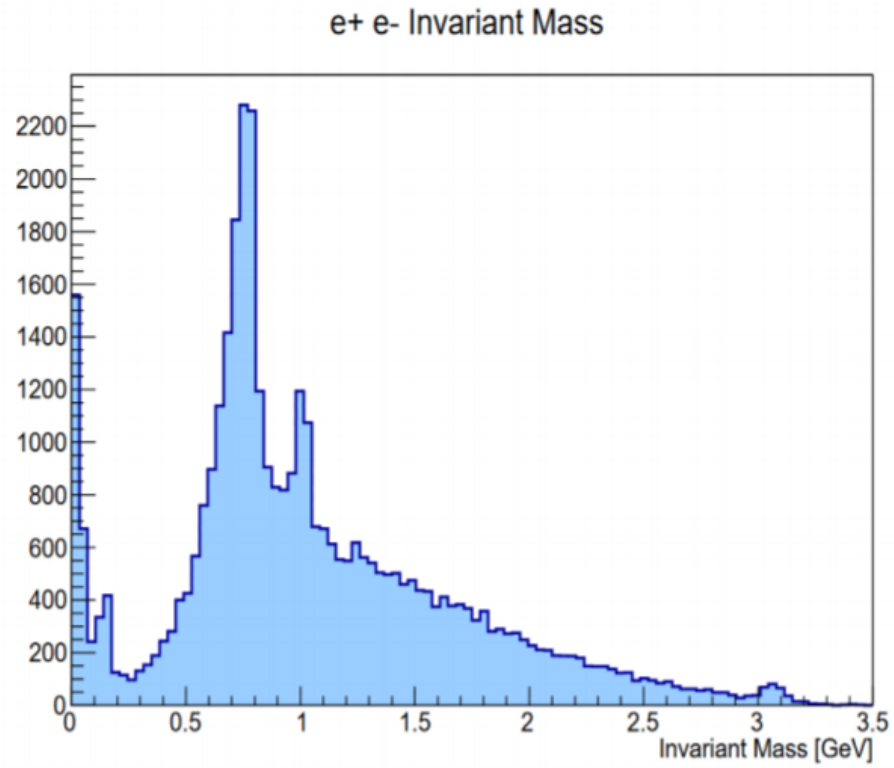
R. Tyson, Glasgow

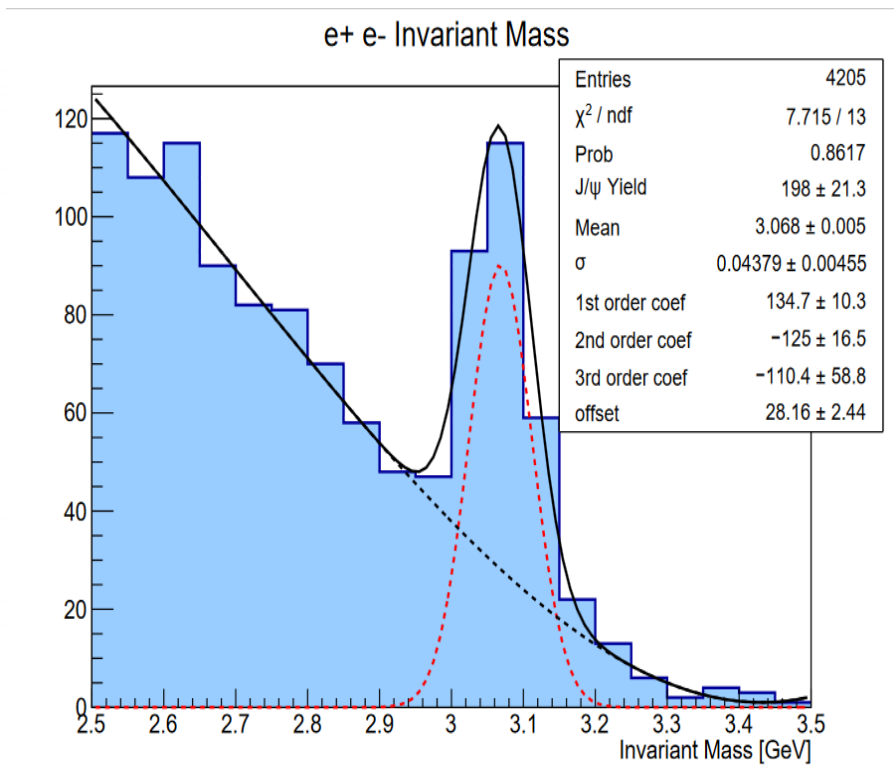
- Channel: ed → (e')e^+e^-p
- Motivation:
  - Verify the LHCb pentaquark results.
  - Study the production mechanism of J/ψ near threshold and the distribution of color charge in the nucleon.

Analysis status:

- Have well defined PID, fiducial cuts and exclusivity cuts.
- Next step is calculating the J/ψ near threshold cross section.

See Richard's talk on Friday 8:30AM





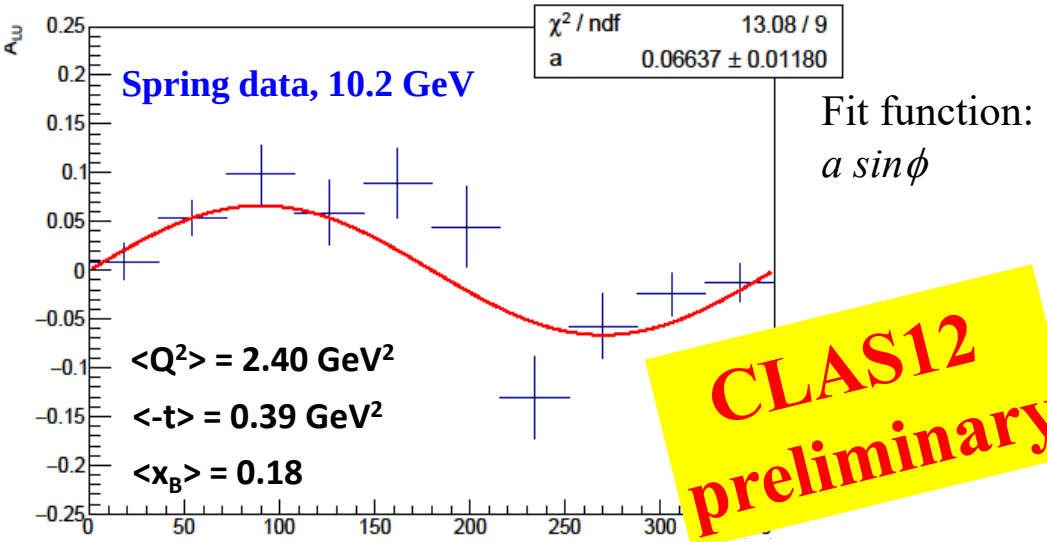
$\vec{e}d \rightarrow e n \gamma(p)$

nDVCS with RGB data

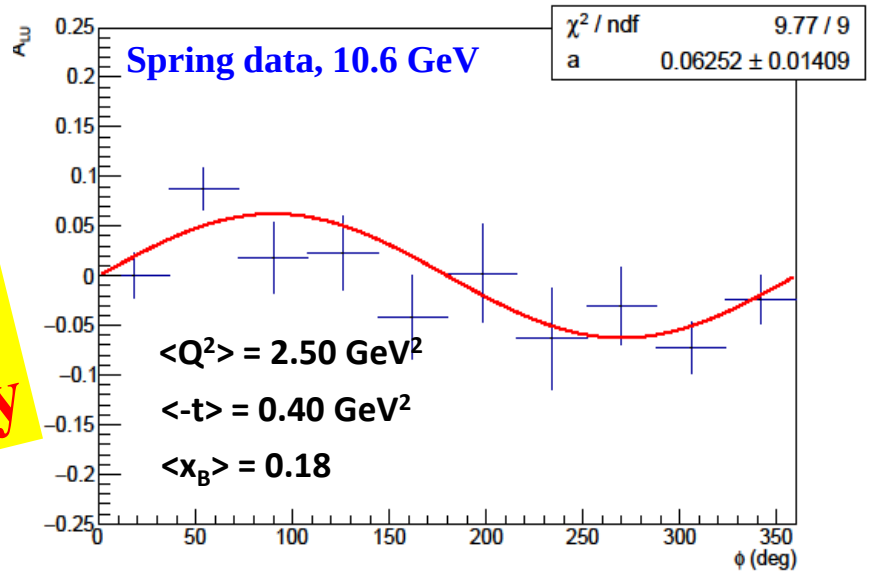
A. Hobart,
S. N. (IJCLab Orsay)

Raw BSA for three RGB datasets, no π^0 subtraction, integrated, tight cuts

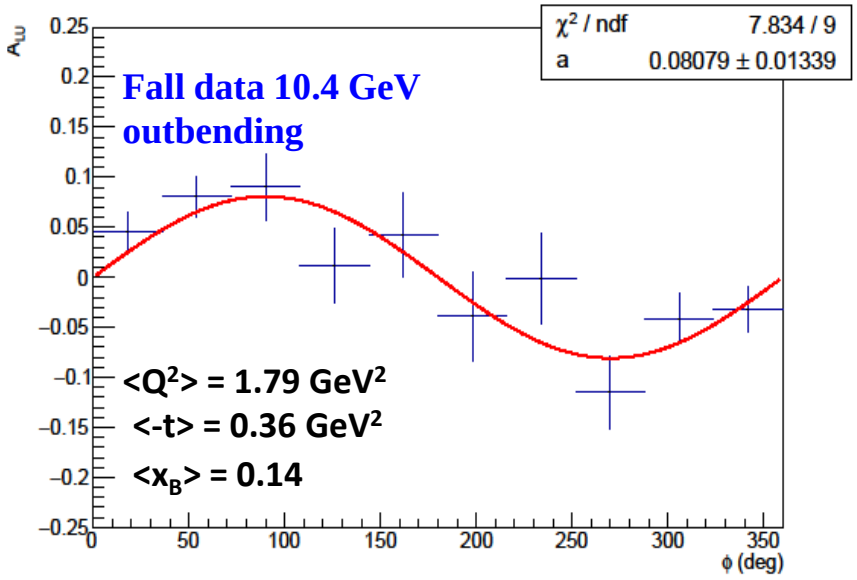
$$\Delta\sigma_{LU} \sim \sin\phi \; \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - kF_2\mathcal{E}\}$$



Fit function:
$a \sin\phi$



CLAS12 preliminary



- Fiducial cuts from RGA included (e, γ)
- Fiducial cuts on neutrons excluding dead regions of CVT
- Ongoing work on kinematic corrections (MC and data)
- Extensive ongoing studies on exclusivity cuts:
  - ✓ Minimize π^0 background
  - ✓ Minimize proton contamination
  - ✓ Cuts determined for each detector topology

→ Next step: neural nets (CD veto & channel ID)

See Adam's talk Wednesday 11AM

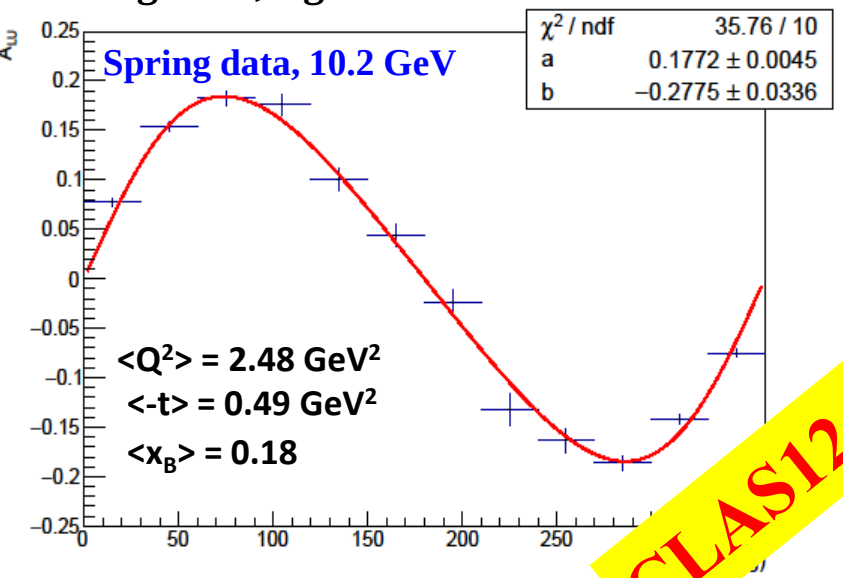
$\vec{e}d \rightarrow ep\gamma(n)$

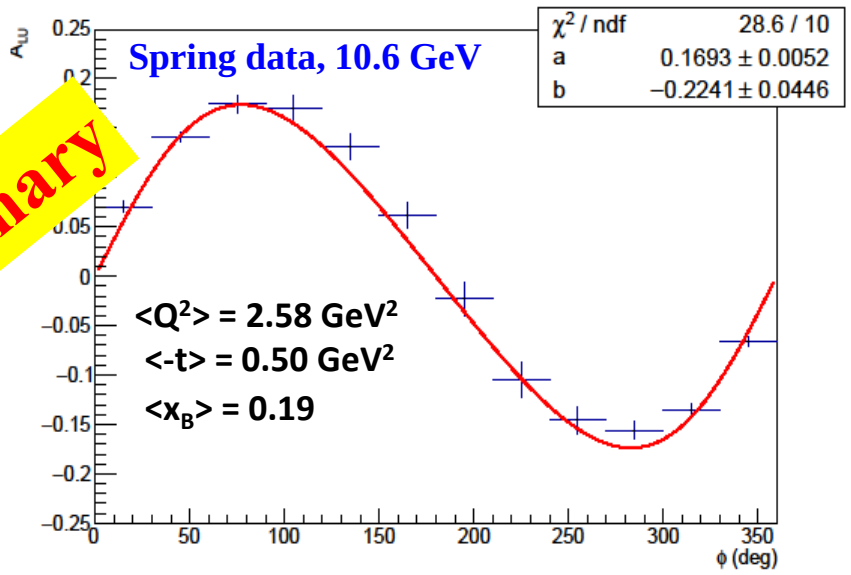
Incoherent pDVCS on deuterium

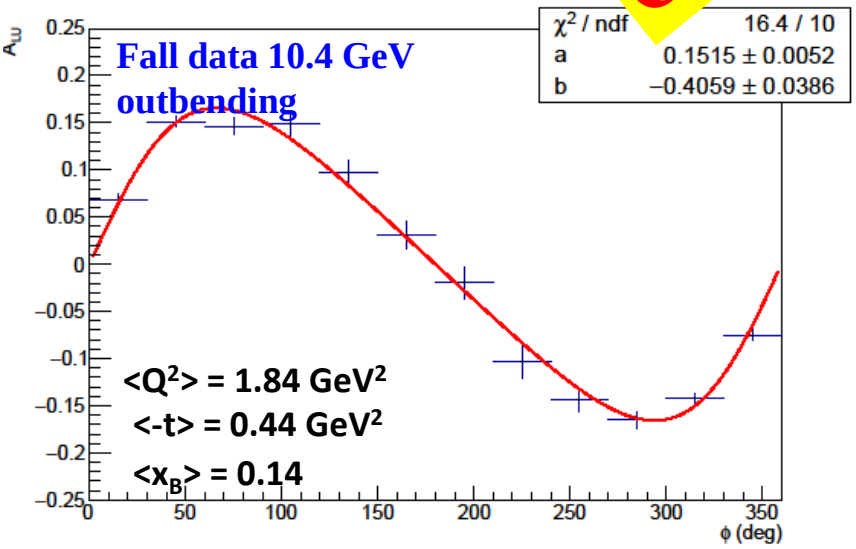
A. Hobart,
S. N. (IJCLab Orsay)

Raw BSA for three RGB datasets, no π^0 subtraction, integrated, tight cuts

$$\Delta\sigma_{LU} \sim \sin\phi\ \mathrm{Im}\{F_1\mathcal{H} + \xi(F_1+F_2)\widetilde{\mathcal{H}} - kF_2\mathcal{E}\}$$







CLAS12 preliminary

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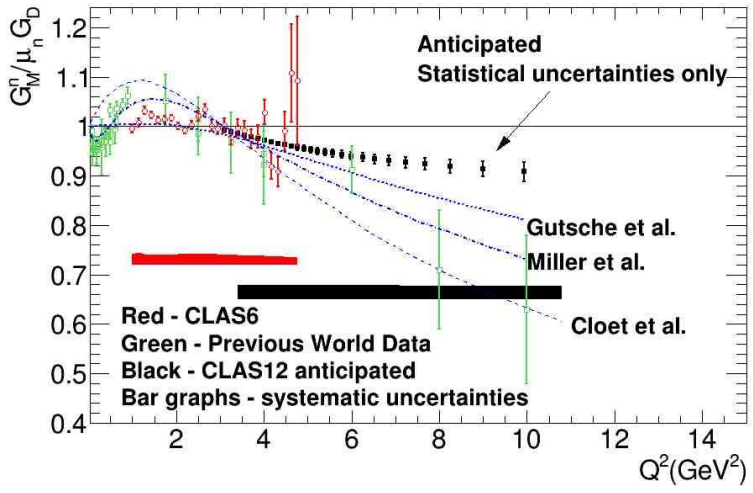
⟶ Next step: neural nets (channel ID)

See Adam's talk Wednesday 11AM

Measurement of the Neutron Magnetic Form Factor G_M^n at High Q^2 Using the Ratio Method on Deuterium

Work by L.Baashen (FIU), B.A. Raue (FIU), G. Gilfoyle (Richmond), L.C. Smith (UVA)



World's data for G_M^n, including anticipated results. Calculations from Gutsche et al. (PRD 97, 054011, 2018)), Miller et al. (arXiv 1912.07797 [nucl-th], 2020) and Cloet et al (Few Body syst., 46:1-36, 2009)

Motivation:

1- The neutron magnetic form factor is a fundamental observable related to the distribution of magnetization in the neutron.

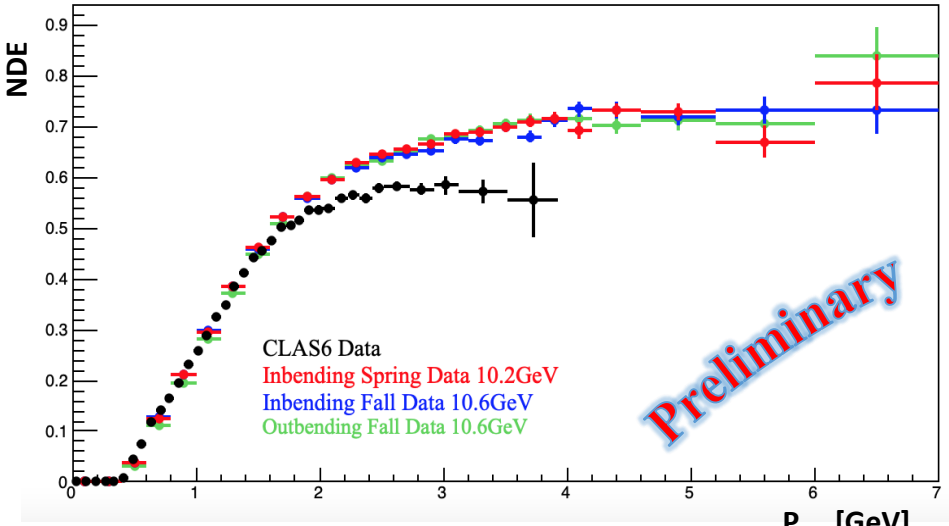
2- The form factors provide important constraints for GPDs.

Goal:

Extract G_M^n at high Q^2 using the ratio of quasi-elastic e-n and quasi-elastic e-p on deuteron: $R = \frac{d(e,e'n)p}{d(e,e'p)n}$

Requires:

Precise measurement of the neutron detection efficiency (NDE).



NDE computed using RG-A data from fall 2018 and spring 2019

Measurement of the Neutron Magnetic Form Factor G_M^n at High Q^2 Using the Ratio Method on Deuterium

Work by L.Baashen (FIU), B.A. Raue (FIU), G. Gilfoyle (Richmond), L.C. Smith (UVA)

Analysis status for quasi-elastic (QE) e-p/e-n:

1. Using RG-B data from spring 2019 (pass 1 cooking) ~ 223 production runs.
2. For e-p events: Select two tracks, one electron in Forward Detector and one proton in PCAL/ECAL Detector.
3. For e-n events: Select one track, one electron in Forward Detector.

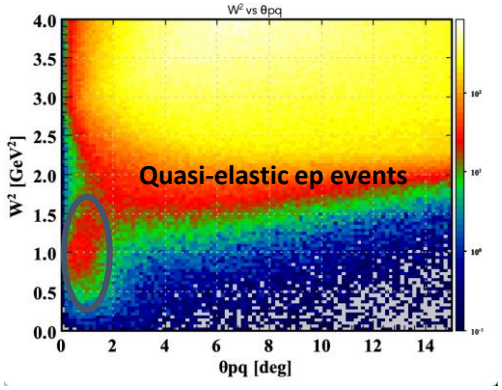
Quasi-elastic event selection:

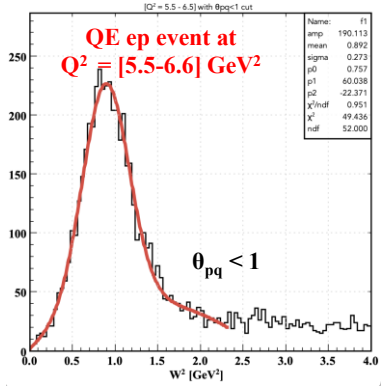
1. Apply cut on $W^2 < 4.0$ to both e-p and e-n events.
2. Apply cut on $\theta_{pq} < 1$ (angle between the virtual photon and scattered nucleon 3-momenta) to both to select QE events and reduce inelastic background.

Progress:

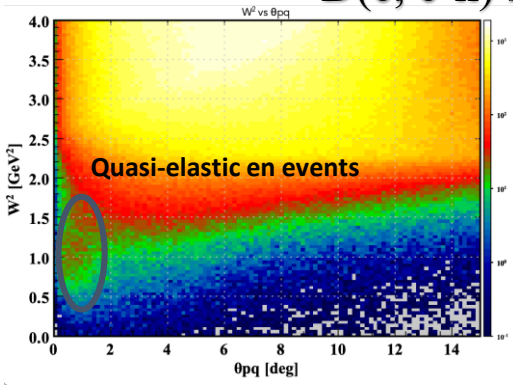
Studying impact of acceptance matching of e-p and e-n events.

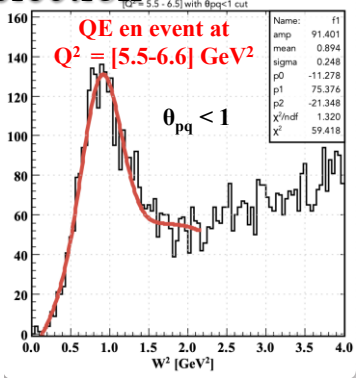
D(e, e`p) selection





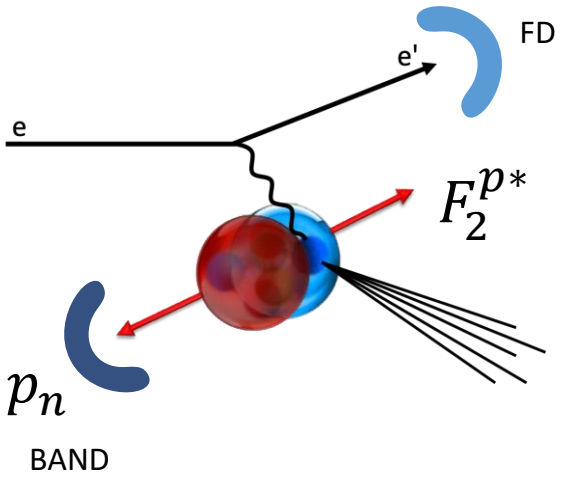
D(e, e`n) selection





Study bound proton structure by tagging neutron

E. Segarra (MIT)



Investigate deviations from tagged PWIA / no-modification simulation

$$R_{tag} = \frac{Y_{tagged,data}(Q^2, \theta_{nq}, x'; \alpha_S)}{Y_{tagged,sim}(Q^2, \theta_{nq}, x'; \alpha_S)}$$

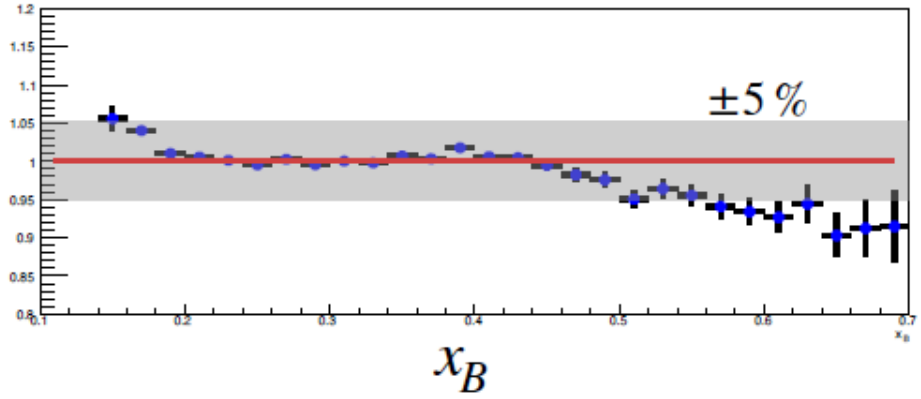
Can take ratio to inclusive to help reduce systematics:

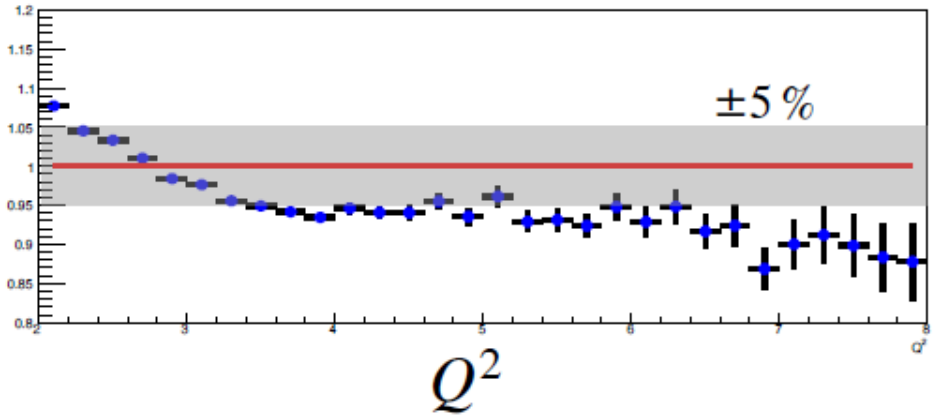
$$R(Q^2, \theta_{nq}, x'; \alpha_S) \equiv \frac{R_{tag}(Q^2, \theta_{nq}, x'; \alpha_S)}{R_{inc}(Q^2, x = x')}$$

$$\left[\left(\frac{\text{Data}}{\text{Sim}} \right)_{\text{tagged}} \Big/ \left(\frac{\text{Data}}{\text{Sim}} \right)_{\text{inclusive}} \right]$$

- 10.2 GeV inbending (Spring)
- Electron RGA-based fiducial & PID cuts
- W>2 GeV^2, Q2>2 GeV^2
- AV18 PWIA d(e,e') simulation

Inclusive d(e,e')X: Data / Sim



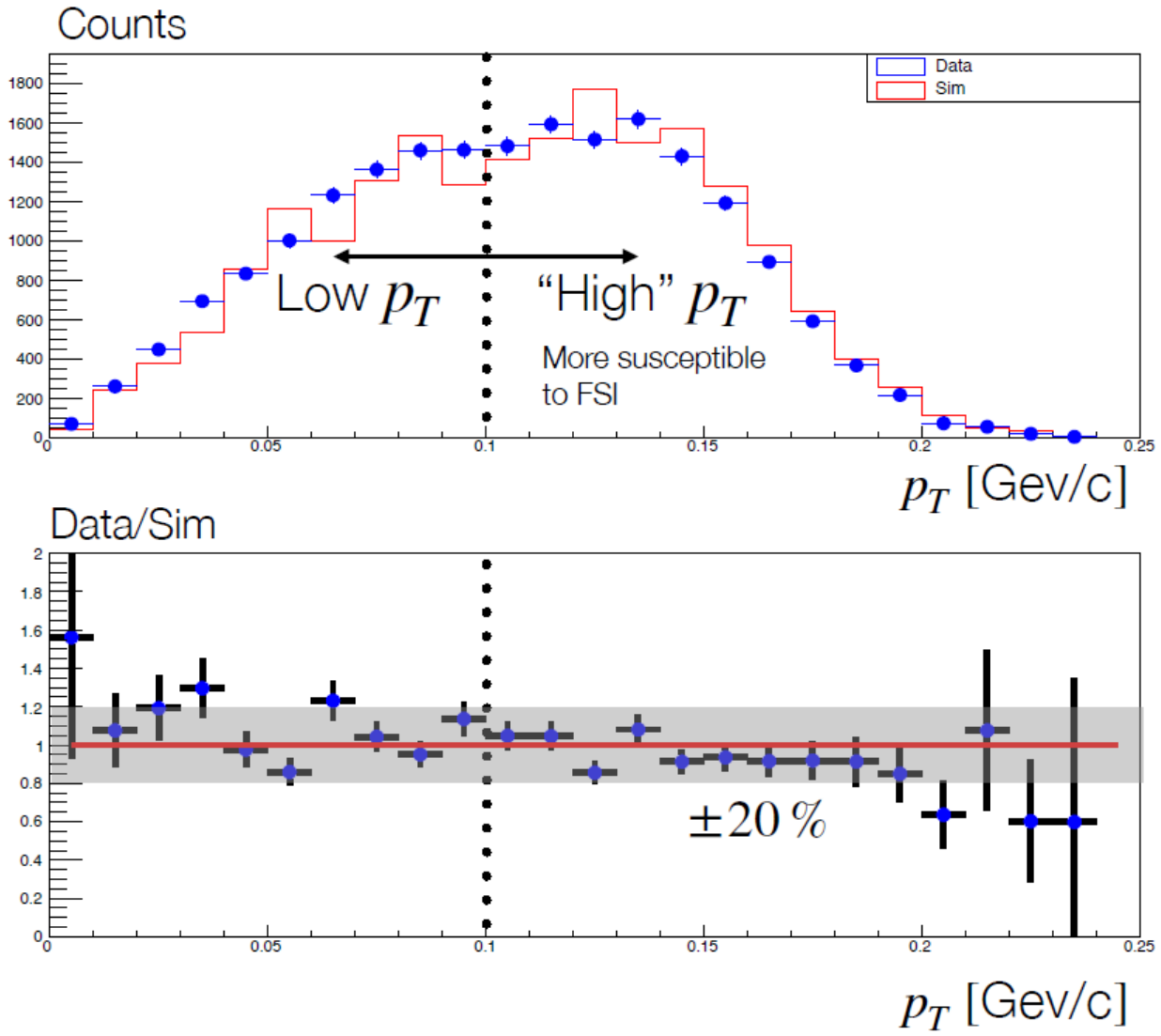


Study bound proton structure by tagging neutron

E. Segarra (MIT)

- Same electron cuts
- Neutron detected in BAND
- $|p_n| > 0.2$ GeV/c
- $-1 < \cos\theta_{nq} < -0.8$
- $W' > 1.8$
- $\alpha_S > 1.2$

Tagged d(e,e'n)X data



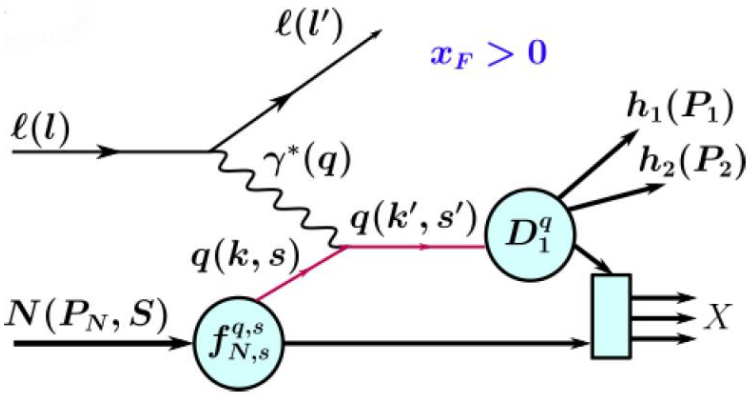
- Data has random neutron coincidence subtracted
- PWIA simulation with no modification of nucleons (no EMC effect)
- **Excellent agreement in comparing tagged data to simulation in spectator variables**

Di-hadron Multiplicities

e N → e' π^+ π^- X

Number of di-hadron pairs per DIS electron

$$M(x_B, z, M_{\pi\pi}; Q^2) = \frac{d\sigma^{dh}/dx_B dz dM_{\pi\pi} dQ^2}{d\sigma^{DIS}/dx_B dQ^2}$$



$$d\sigma^{dh} \propto \sum_q f_{1,q}(x_B) D_{1,q}^{dh}(z, M_{\pi\pi})$$

Di-hadron unpolarized Fragmentation Function (FF)
It enters in the denominator of every asymmetry

Assuming isospin symmetry, the analysis of <u>hydrogen</u> and <u>deuterium</u> data allows the extraction of u and d FF

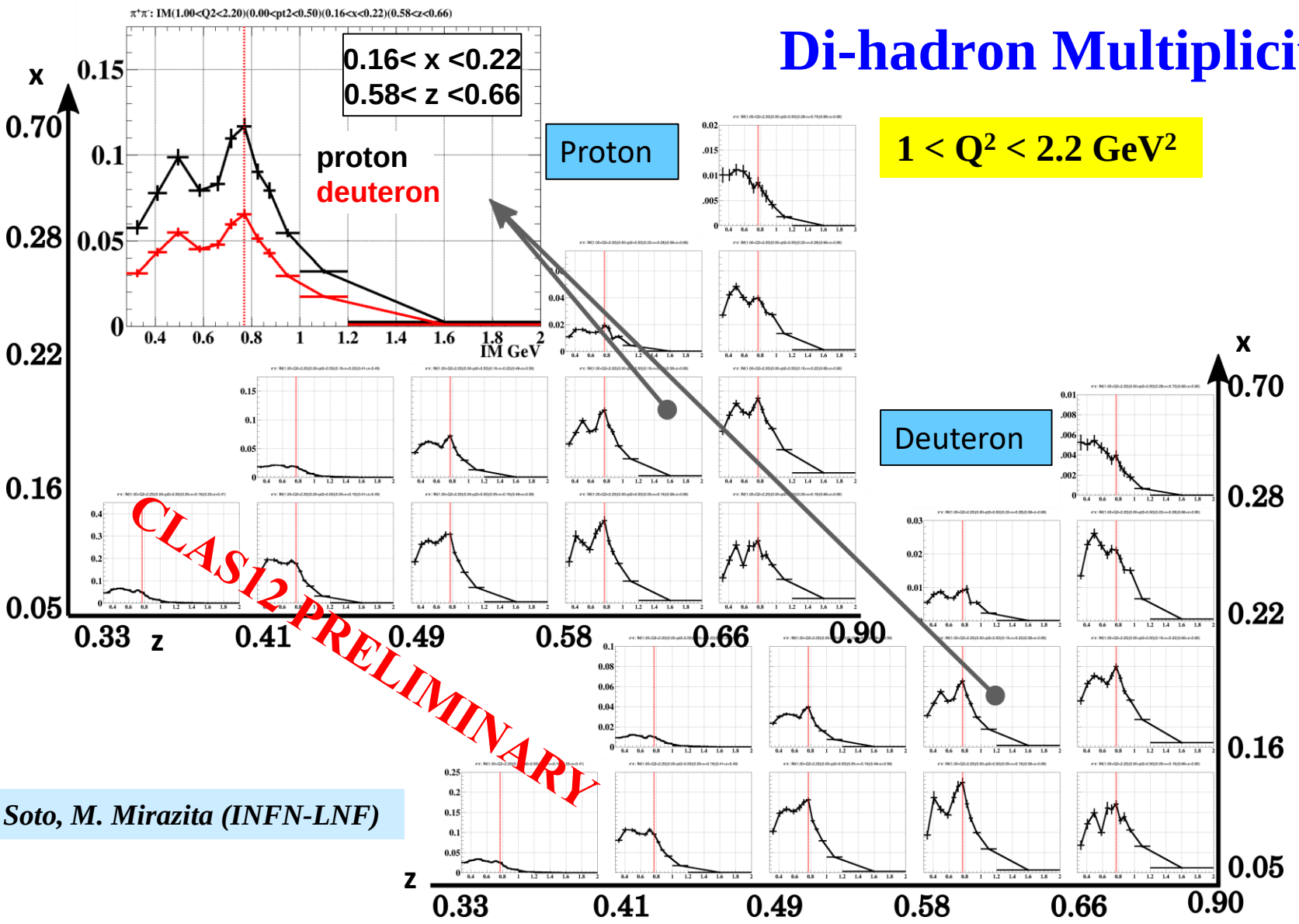
$$D_{1,u}^{dh} = 3\frac{M^p\left(\frac{4}{9}f_{1,u} + \frac{1}{9}f_{1,d}\right) - \frac{1}{9}M^d\left(f_{1,u} + f_{1,d}\right)}{K_f f_{1,u}}$$

$$D_{1,d}^{dh} = 3\frac{\frac{4}{9}M^d\left(f_{1,u} + f_{1,d}\right) - M^p\left(\frac{4}{9}f_{1,u} + \frac{1}{9}f_{1,d}\right)}{K_f f_{1,d}}$$

K_f → kinematic factors

The PDF f_{1q} of the proton are known

Di-hadron Multiplicities



O. Soto, M. Mirazita (INFN-LNF)

- **4D analysis in x_B, z, $M_{\pi\pi}$ and Q^2**
- **DIS cuts: $Q^2 > 1$, $W > 2$, $y<0.8$**
- **SIDIS cuts: $x_F^{+/-} > 0$, $0.1 < z < 0.95$, $MM>1.1$**

$$4M^p - M^d \rightarrow D_1^u$$

$$4M^d - M^p \rightarrow D_1^d$$

Conclusions

- RG-B aims at mapping the **3D structure of the neutron** via electroproduction on deuterium
- **Quark-flavor separation** of the measured structure functions combining with proton data
- The first « half » of RG-B run in 2019-early 2020
- ~38.9 PAC days collected out of the 90 PAC days approved for nDVCS
- Three different beam energies for the 3 periods
- **The Spring and Fall datasets are cooked**
- **Cooking well advanced for Winter**
- **Physics analyses underway**: n/p-DVCS, G^n_M, J/ψ, Tagged-DIS, Di-hadron SIDIS, n/p-DVMP(π^0), d-DVCS
- K-SIDIS: RG-A being analyzed first
- nDVCS: work ongoing to refine neutron PID and channel selection, analysis note in preparation
- Tagged-DIS: analysis note in preparation
- ***The current plan is to publish at least nDVCS, pDVCS, tagged DIS using the pass1 data***