# Tagged DIS Measurement with LAD

Florian Hauenstein for the LAD experiment, Joint HallA/C Summer Meeting 06/30/23

#### EMC and SRC Correlation



#### Probe EMC-SRC Correlation with Tagged DIS Measurements

• EMC-SRC: Large modification for SRC nucleons

 Determine modification with DIS scattering on nucleons with high momentum

- "Tag" SRC nucleon not part of the DIS interaction to select initial state
- --> New observable
- $\longrightarrow$  Modification dependence on  $\alpha$ 
  - strong —> SRCs
  - weak —> MF

#### Simplest Case: Tagged DIS with Deuterium



## Tagging Kinematics 101



$$Q^2 = -q^2 = |\overrightarrow{q}|^2 - \omega^2$$

Standing nucleon 
$$P_0 = (m_n, 0)$$

$$W)^{2} = (P_{0} + q)^{2}$$
$$x = \frac{Q^{2}}{2m_{n}\omega}$$

## Tagging Kinematics 101



## Measure Tagged Ratio

$$R_{tag} = \frac{\sigma_{tag}^{exp} \left(Q^2, p_T, \alpha_S, x'\right) / \sigma_{tag}^{exp} \left(Q_0^2, p_T, \alpha_S, x' = x_0\right)}{\sigma_{tag}^{theory} \left(Q^2, p_T, \alpha_S, x'\right) / \sigma_{tag}^{theory} \left(Q_0^2, p_T, \alpha_S, x' = x_0\right)}$$

$$\approx \frac{\text{bound nucleon } F_2^*}{\text{free nucleon } F_2}$$

Theory assumptions:

- Plane Wave Impuls Approximation
  - Factorization
  - no spectator rescattering (final state interaction)

## Tagged Experiments at JLab

#### Hall B: CLAS 12 + Backward Angle Neutron Detector (BAND)



- Run Group B
- Analysis under review

## Tagged Experiments at JLab

Hall B: CLAS 12 + Backward Angle Neutron Detector (BAND) Hall C: SHMS/HMS + Large Angle Detector (LAD)



- Run Group B
- Analysis under review

- Experiment ready
- Run in 2024!

## Tagged Experiments at JLab



d(e,e'N)X - Expected Results



Melnitchouk, Sargsian, Strikman, Z.Phys. A359, 99 (1997)

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#### Tagged Predictions for BAND with different models

Segarra et al, Phys. Rev. Research 3, 023240 (2021)



Predictions from convolution model fits to data up to A=3

#### BAND in HallB



E.P. Segarra et al., NIM A978 (2020), 164356

#### Preliminary Tagged Ratio from BAND



Strong modification observed! Positive slope implies opposite effect for LAD!

#### The LAD Experiment (E12-11-107)

- Approved for 40 PAC days
- Beam energy 11 GeV and 6.6 GeV (calibration)
- Beam currents ~ 0.5-2uA
- Standard HMS for electrons
  - Momentum: 4.4 GeV
  - Angles: 13.5°, 17° and 21.7° (calibration)
- Standard SHMS for electrons
  - Momentum: 4.4 GeV and 5.1 GeV (calibration)
  - Angles: 13.5° and 17°
- LAD detector for recoil protons
- PRAD GEMs for tracking
- Passed ERR in 2020



LAD

#### Kinematic Coverage



#### Rotated Scattering Chamber



## Target



- Modified HAPPEX cell to accommodate LAD acceptance
  - 20 cm length
  - 2 cm width
  - 2 cm height
- Fabrication by JLab target group





## LAD Detector

- CLAS TOF scintillators refurbished at ODU
  - install/purchase ~50 new 3-inch PMTS
  - stored in ESB
  - stands designed and ready for fabrication
- Laser calibration system
  - tested system from BAND (HallB)
  - fibers need to be installed
- DAQ/electronics in SHMS hut (110 channels)
  - 7 FADCs
  - 1 TDC
  - HV







## LAD Position



- 5-6 m away from target
- In-plane coverage 90° 157°
- Out-of-plane coverage +/-17°
- SHMS cable tray needs modification
  - plan developed
  - ~1 week work (3 people)



## GEMs

- Two refurbished 120 x 55 cm<sup>2</sup> PRAD GEMS
- Next to target chamber (<1m away from target)
- Readout:
  - MPD readout
  - experience from SBS
- Support stand in fabrication





(courtesy Holly)



## **Preparation Timeline**



## Summary

- Tagged DIS measurements on deuterium to probe EMC-SRC correlation
- Strong modification for high-momentum protons observed with CLAS12+BAND
- LAD experiment to measure modification of high-momentum neutrons
- Preparations are in progress
  - All components expected to be ready by next summer
  - No showstoppers for individual components
- Plans for preparation, installation and beam time exists in detail

#### We are excited to run LAD next year!

## Thank you for your attention

Axel Schmidt (Faculty)



Tyler Kutz

Holly Szumila-Vance (Staff)



+ New ODU Postdoc New graduate student



Sara Ratliff (Grad student)



Dien Nguyen (Faculty)

plus: Douglas Higinbotham, Eli Piasetzky, Larry Weinstein







#### Backup slides

## GEM Commissioning



**PRAD GEMs in test lab** 

#### Test lab emptied in April-May, ready for PRAD GEM testing



(courtesy Holly)

#### Minimize Final-State-Interaction in Tagged DIS



#### Minimize Final-State-Interaction in Tagged DIS



#### Previous Results $d(e, e'p_s)X$

$$\frac{F_2^{n^*}(x'=0.55, Q^2=2.8)}{F_2^{n^*}(x'=0.25, Q^2=1.8)}$$
$$\frac{F_2^n(x=0.55, Q^2=2.8)}{F_2^n(x=0.55, Q^2=2.8)}$$

 $F_2^n(x = 0.25, Q^2 = 1.8)$ 

Non ideal kinematics

- Not so high in  $Q^2$
- Low  $\alpha_S$  has  $\theta_{nq} \sim 90 \deg$
- $p_T = [0.25 0.35]$  [GeV/c]



A. V. Klimenko et al. Phys. Rev. C 73, 035212 (2006)

#### Impact on EMC studies with light nuclei

- Convolution model Segarra et al, Phys. Rev. Research 3 (2021)
- Allow isospin-dependent *n*, *p* modification
- Fit light nuclear structure functions with tagged double ratio as constraint



#### Preparation and Installation Plans Ready



## GEM Timetable



- General 1-year timeline achievable
- To be done ASAP for GEMs (this summer):
  - Install aluminized mylar
  - Produce faraday cage shielding
  - Flow nitrogen through detectors

(courtesy Holly)

#### EMC Effect in Deuterium



- EMC is small BUT
- SRC hypothesis predicts large modification of (rare) SRC states!

#### Estimated Counts and Reach

