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U.S. DEPARTMENT OF ENERGY
Office of Science

Studies of Inclusive Structure with A=3 Targets in CLAS*

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Berkeley Lab

CLAS Collaboration Meeting - March 15, 2024

Run Group Proposal with Tritium Target

PR12-20-005	H. Szumila-Vance	Precision measurements of A=3 nuclei in Hall B	B	60	60	A-	**Approved**	5

C12-21-004	L. Weinstein	Semi-Inclusive Deep Inelastic Scattering Measurement of A=3 Nuclei with CLAS12 in Hall B	B	58			C2	1

Two experiments with rich physics programs planned

Physics focus of coincident QE data, inclusive GMn, and SIDIS

A lot of beam time at 2.2 GeV (5.5 days), 6.6 GeV (54 days), and 10.6 GeV (58 days)

This data can be used for a thorough program studying inclusive structure!

Planned Data

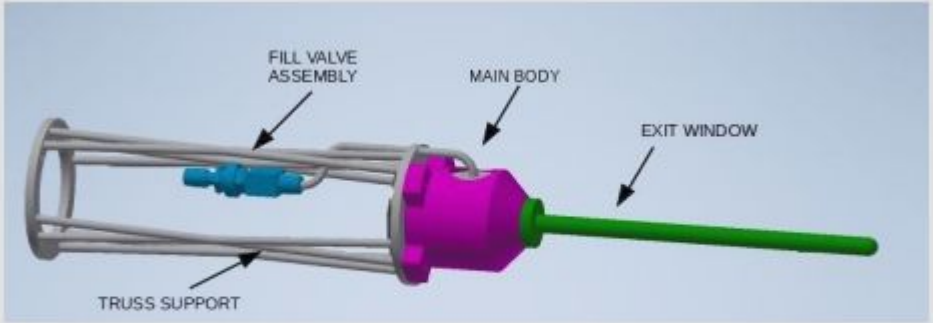

Figure 20: External side view of the conceptual design of the target cell as seen from the beam right side.

Material	Tritium	Al Windows	Be Window	Total
Length(g/cm^2)	0.085	0.21	0.037	0.33
Luminosity	3.54×10^{34}	8.42×10^{34}	1.54×10^{34}	1.35×10^{35}

Table 4: Assumed density and luminosity for each component. Note that the maximum luminosity of CLAS12 is 1.35×10^{35} nucleon/cm^2/s

- Slightly different density for each gas
  - H_2: 2.75 mg/cc 68.75 mg/cm^2
  - D_2: 5.00 mg/cc 125.0 mg/cm^2
  - T_2: 3.30 mg/cc 82.5 mg/cm^2
  - ^{3}He: 4.10 mg/cc 102.5 mg/cm^2

From E12-20-005 Proposal

From E12-20-005 PAC Presentation (A. Schmidt)

E12-20-005 Beam Time

Target:	^{1}H	^{2}H	^{3}He	^{3}H	Total
Measurement Days (6.6 GeV)	1	10	20	20	51
Calibration (inbending field)					1
Target Changes					2
				Total at 6.6 GeV:	54
Measurement Days (2.2 GeV)	0.5	0	1	1	2.5
Calibration (outbending field)					1
Target Changes					2
				Total at 2.2 GeV:	5.5
				Total beam time requested:	59.5

C12-21-004 Beam Time

Target:	^{2}D	^{3}He	^{3}H	Total
Measurement PAC Days (10.6 GeV)	10	20	20	50
Calibration: Luminosity, dummy, H				5
Target Changes				2
Torus polarity reversals				1
			Total at 10.6 GeV:	58

We propose the formation of a run group to measure precision inclusive ratios of ^{1}H, ^{2}H, ^{3}H, and ^{3}He nuclei using a 2.2 GeV, 6.6 GeV, and 10.6 GeV electron beam to study nucleon structure with a focus on isospin dependence.

Experiments E12-20-005 and C12-21-004 have a rich program using these targets to study Semi-Inclusive Deep Inelastic Scattering (SIDIS) for flavor dependence of the EMC effect, coincidence Quasi-Elastic (QE) scattering for NN interactions and Short Range Correlations (SRCs), and inclusive QE scattering for the neutron magnetic form factor (G_M^n). We will use this data to measure the inclusive structure function ratios in the DIS, Resonance, and $x > 1$ regions. This proposal builds on the highly successful Hall A tritium program and is complementary to the physics of the already existing CLAS12 tritium proposals. The primary physics goal of this measurement is to study the isospin dependence and quark-hadron duality for the proton and neutron in the resonance region via the comparison of structure functions for the A=3 mirror nuclei. With the first ever resonance data on tritium, we will exploit the maximal N/Z asymmetry of these targets to assess any violations of duality, such as that seen near the Δ resonance in Hall C deuteron data and the BONuS experiment. The DIS data will serve as an independent cross-check of the MARATHON F_2^n/F_2^p and EMC effect results. We will also take advantage of the availability of multiple beam energies to examine the ϵ' dependence of the target ratios of these nuclei. The independence of target ratios with respect to ϵ' is a critical, and largely untested, assumption when equating cross section ratios to structure function ratios and these data will be maximally sensitive to any isospin-dependent effects. The inclusive structure function ratios will also be analyzed at $x > 1$ to examine the isospin structure of scattering from high-momentum nucleons over a broad kinematic range. The 2.2 GeV data will also provide low-Q^2 measurements across the resonance region which can be incorporated into global fits and which provide additional sensitivity than higher-energy data to meson-exchange corrections and the transverse response function. This physics is all possible by opportunistically using the 54 days of data at 6.6 GeV and 5.5 days of data at 2.2 GeV from E12-20-005 and the 58 days of data at 10.6 GeV from C12-21-004 which both use an open electron trigger.

Physics Goals

- Isospin Dependence and Duality in the Resonance Region
  - First resonance study on tritium
  - Maximal isospin asymmetry to study differences
- F2n/F2p from A=3 ratio
  - Independent cross check of MARATHON
- EMC effect of A=3
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- Study of ϵ` dependence of target ratios
  - Testing for A-dependence of R_{LT} in light nuclei
- Inclusive x > 1
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- Transverse Response and MECs
  - Low Q^2 needed for global fitting

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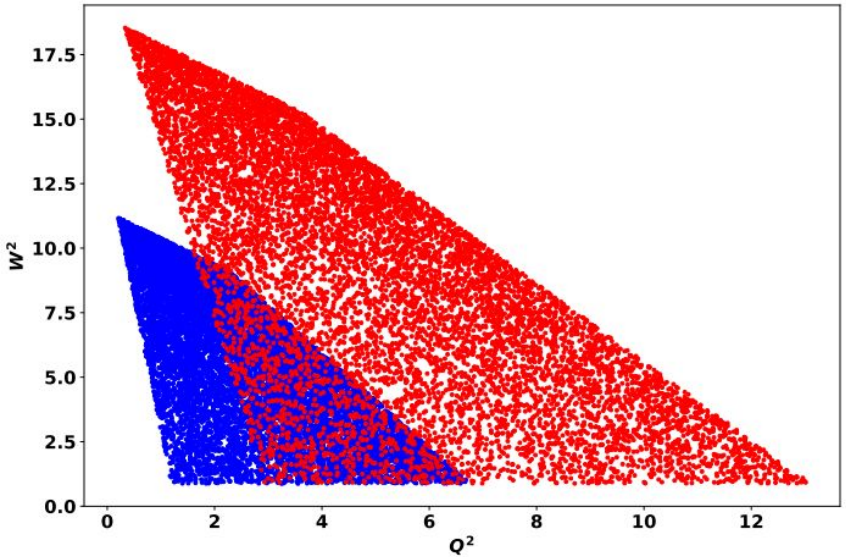

CLAS12 acceptance
Blue - 6.6 GeV
Red - 10.6 GeV

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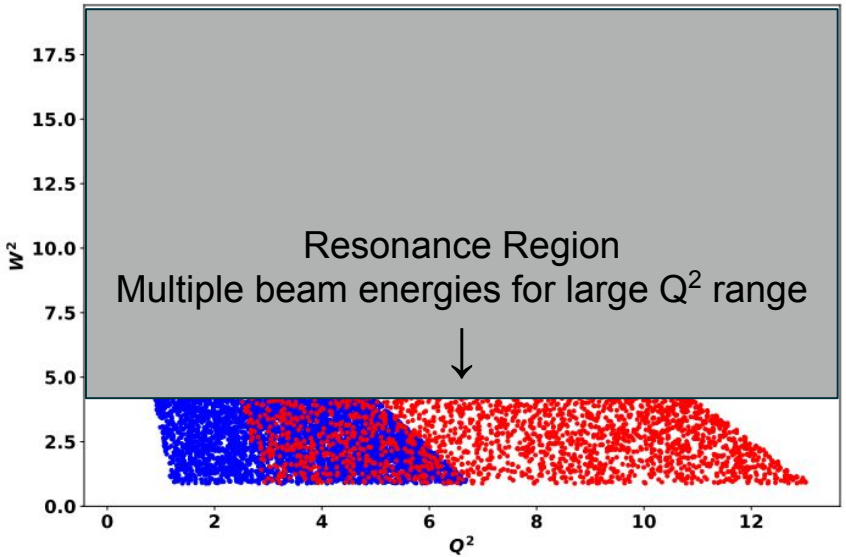

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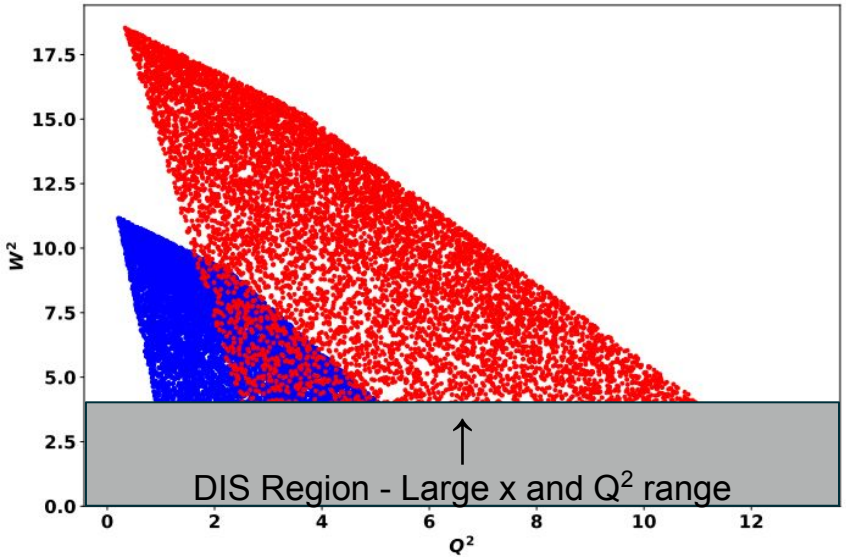

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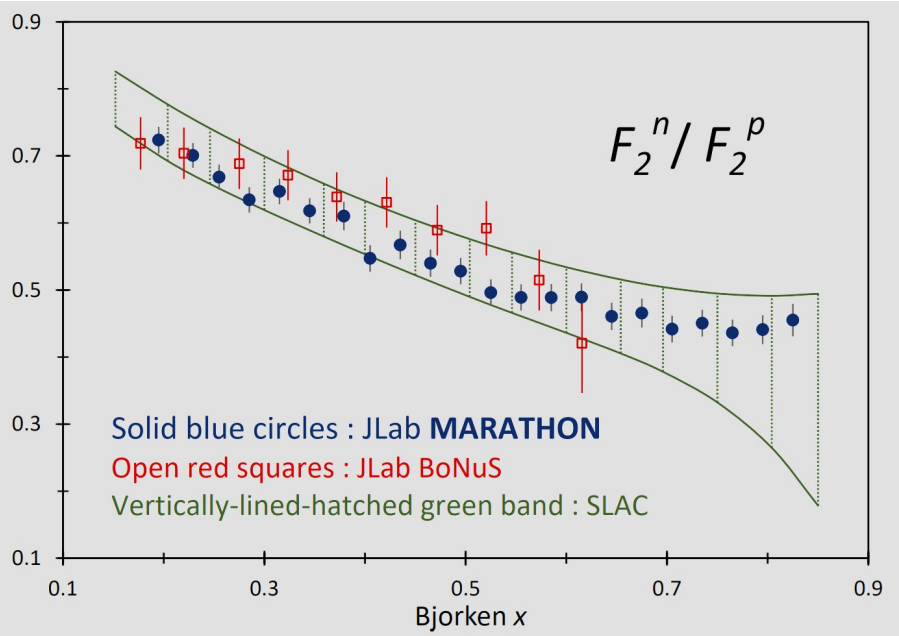

D. Abrams *et. al.* PRL (2022)

$$\frac{\sigma_A}{\sigma_D} = \frac{\sigma_A^T}{\sigma_D^T}\left[1 + \frac{\epsilon}{1+\epsilon R_D}(R_A - R_D)\right].$$

ϵ`

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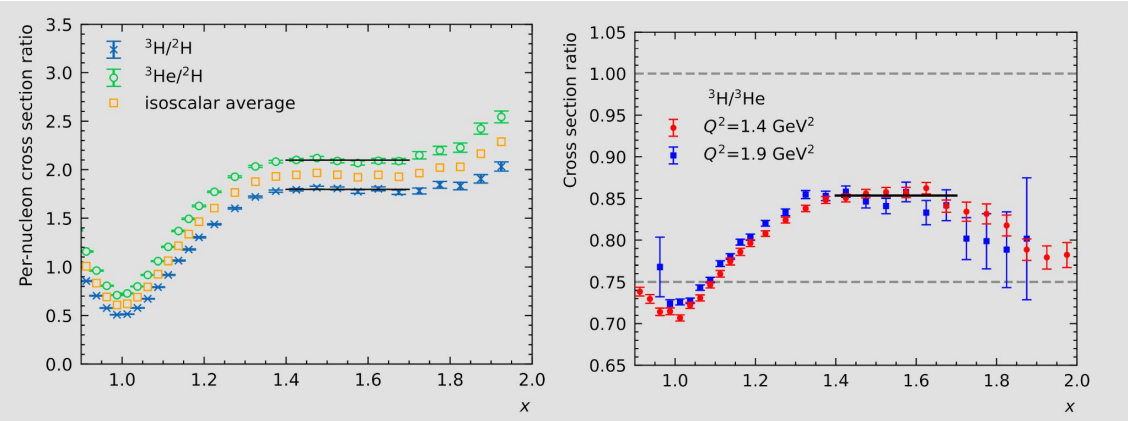
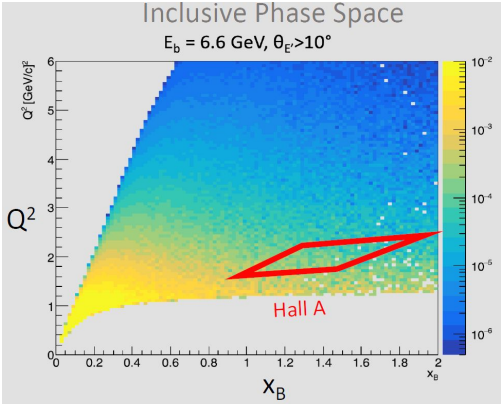
Requires multiple beam energies
6.6 GeV and 10.6 GeV will give us 2 points to do the separation



S. Li *et. al.* Nature (2022)



From E12-20-005 PAC Presentation (A. Schmidt)

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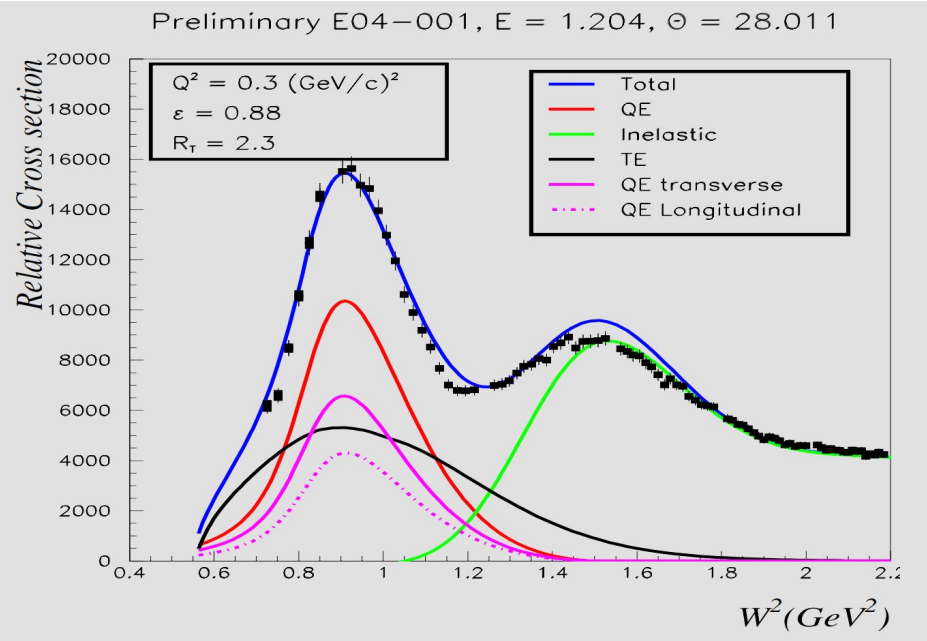

A. Bodek *et. al.* EPJC (2011)

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Conclusion

- A rich inclusive structure study is possible with the planned A=3 data set
- These analyses are complementary to the planned coincident QE, inclusive GMn, and SIDIS studies
- We welcome any involvement of those interested in seeing this come to fruition!

Thank You!