Preliminary results from MARATHON

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Hall A/C Collaboration Summer Meeting

MARATHON and tritium program made possible by many people!

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More than 140 Collaborators

Red-Boldfaced Names: Tritium Program grad students; **starred**: MARATHON Ph.D. students

Blue-Boldfaced Names: Tritium Program postdoctoral associates

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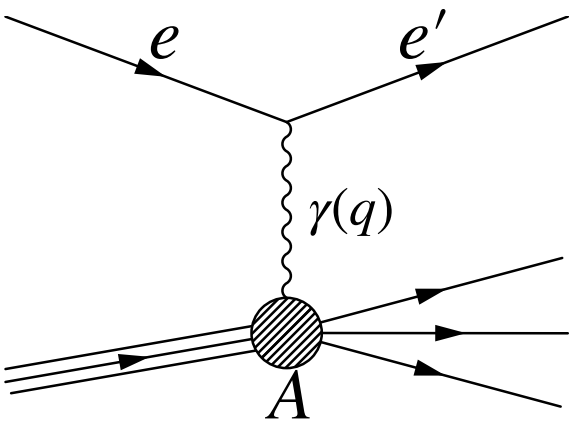
- Accelerator staff
- JLab management
- DOE and NSF
- Hall A tech/staff
- Shift crews
- Savannah River National Lab
- Roy Holt and Dave Meekins

Deep inelastic scattering



$$\nu = E - E'$$

$$Q^2 = 2EE'(1 - \cos\theta)$$

$$x = Q^2/2M\nu$$

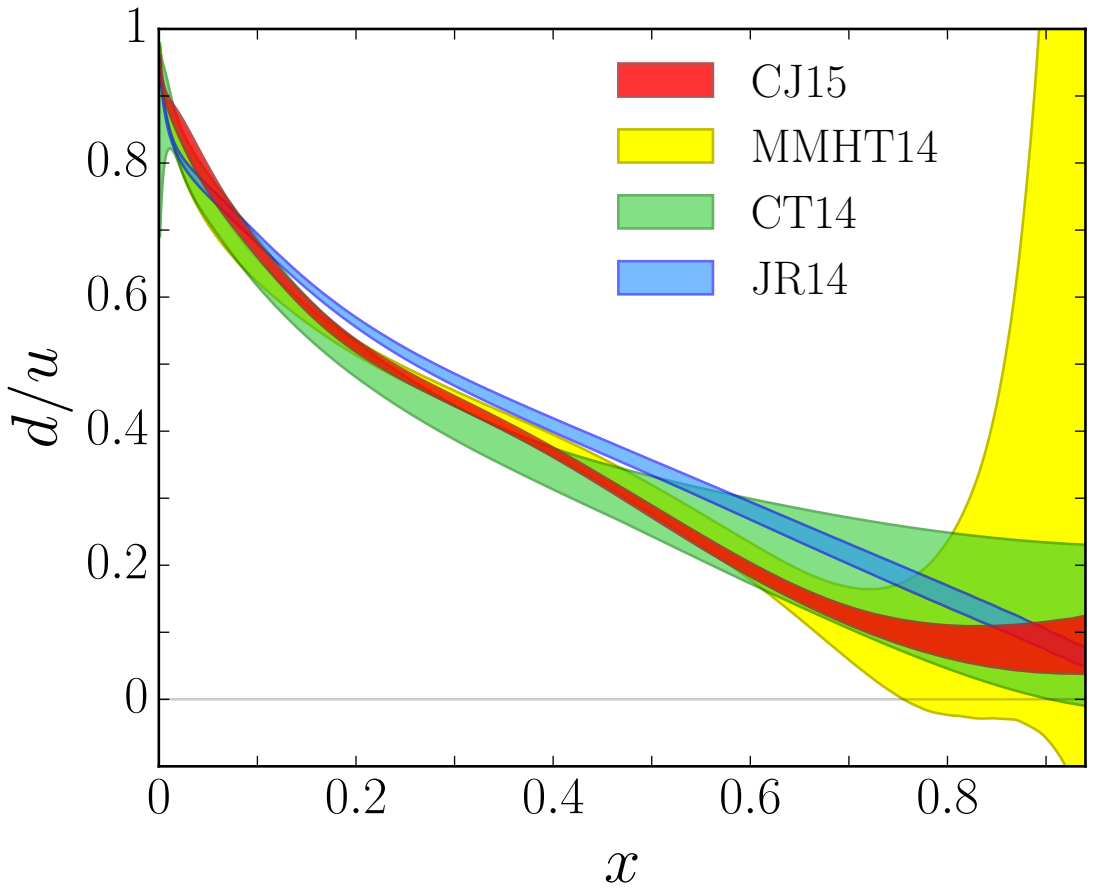
$$\frac{d^2\sigma}{dE'\,d\Omega} = \left(\frac{2\alpha E'}{Q^2}\right)^2 \cos^2\frac{\theta}{2}\left[\frac{F_2}{\nu} + \frac{2F_1}{M}\tan^2\frac{\theta}{2}\right]$$

Quark parton model:

$$F_1 = \frac{1}{2}\sum_i e_i^2 q_i(x)$$

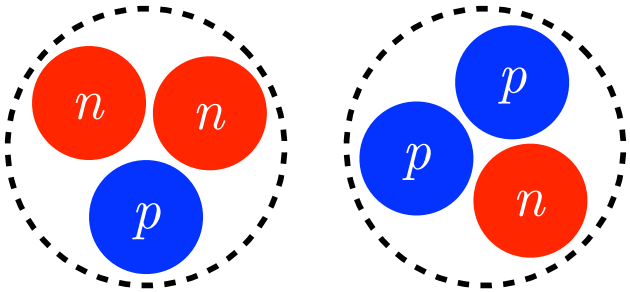
$$F_2 = x\sum_i e_i^2 q_i(x)$$

A. Accardi, et al. Phys. Rev. D 93 114017



d/u at large x sensitive to valence quark dynamics

High x determination of F_2^n/F_2^p constrains d/u



A = 3 mirror nuclei

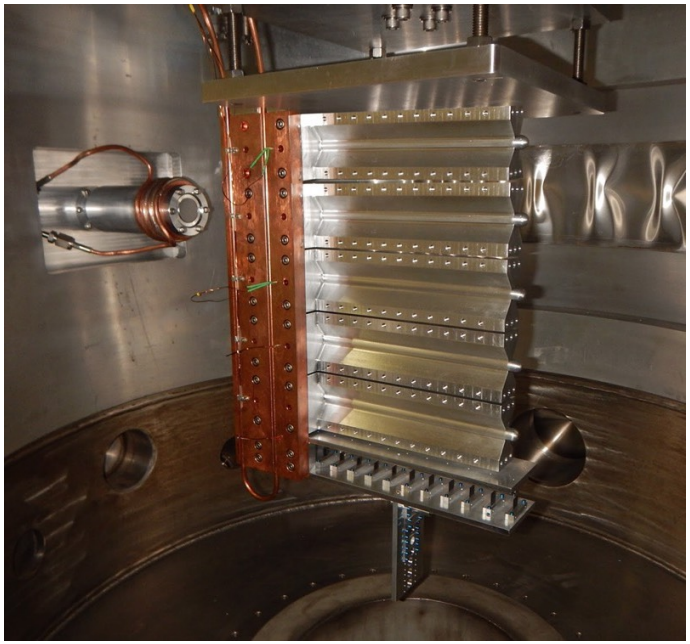
EMC-type ratios:

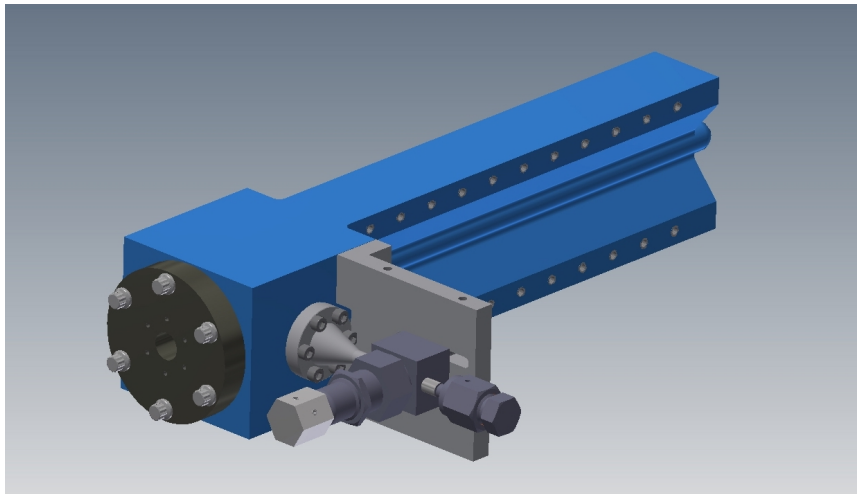
$$R(^3\mathrm{H}) = \frac{F_2^{^3\mathrm{H}}}{2F_2^n + F_2^p}, \quad R(^3\mathrm{He}) = \frac{F_2^{^3\mathrm{He}}}{F_2^n + 2F_2^p}$$

Super-ratio: $\mathcal{R} = \dfrac{R(^3\mathrm{He})}{R(^3\mathrm{H})}$

$$\frac{F_2^n}{F_2^p} = \frac{2\mathcal{R} - F_2^{^3\mathrm{He}}/F_2^{^3\mathrm{H}}}{2F_2^{^3\mathrm{He}}/F_2^{^3\mathrm{H}} - \mathcal{R}}$$

$\dfrac{\sigma_{^3\mathrm{He}}}{\sigma_{^3\mathrm{H}}} = \dfrac{F_2^{^3\mathrm{He}}}{F_2^{^3\mathrm{H}}}$, if nuclear independence of $R = \sigma_L/\sigma_T$ is assumed





Four gas target cells:

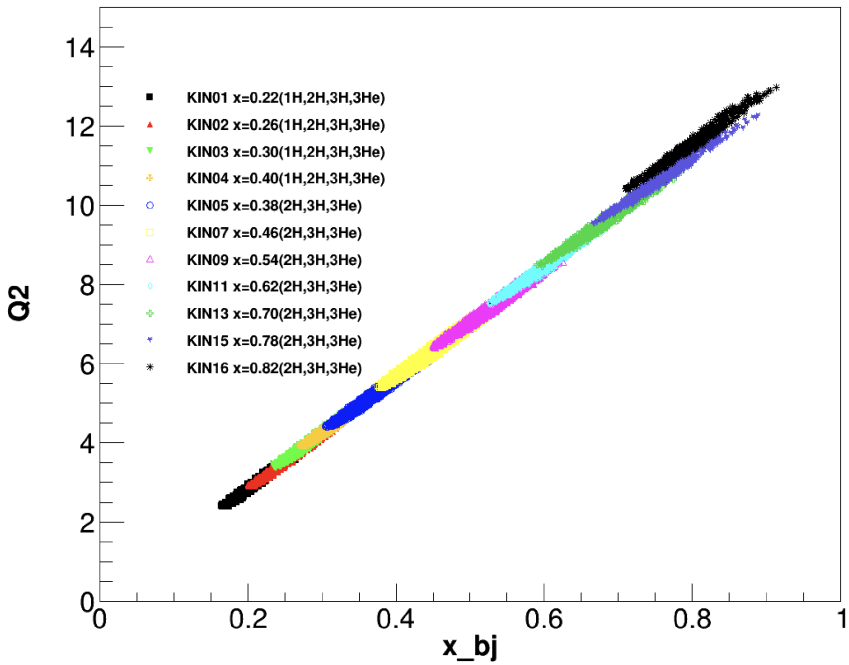
- Hydrogen ^{1}H
- Deuterium ^{2}H
- Tritium ^{3}H
  (filled by Savannah River)
- Helium ^{3}He
- Empty cell
  (for background measurement)

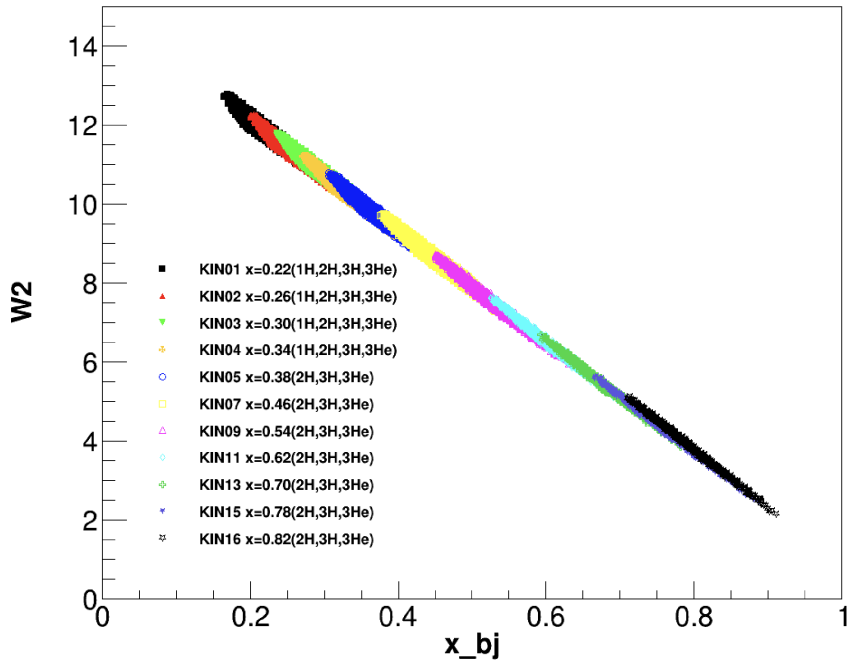
Measure DIS cross section ratios:

- ^{3}H/^{3}He for F_2^n/F_2^p extraction
- Tritium EMC ratio ^{3}H/^{2}H
- Helium EMC ratio ^{3}He/^{2}H
- ^{2}H/^{1}H (at low x only) for F_2^n/F_2^p normalization

MARATHON ran Spring 2018

- Beam energy $E = 10.6$ GeV
- LHRS (RHRS) momentum $E' = 3.1$ GeV ($E' = 2.9$ GeV)
- HRS angle from 17° to 36°

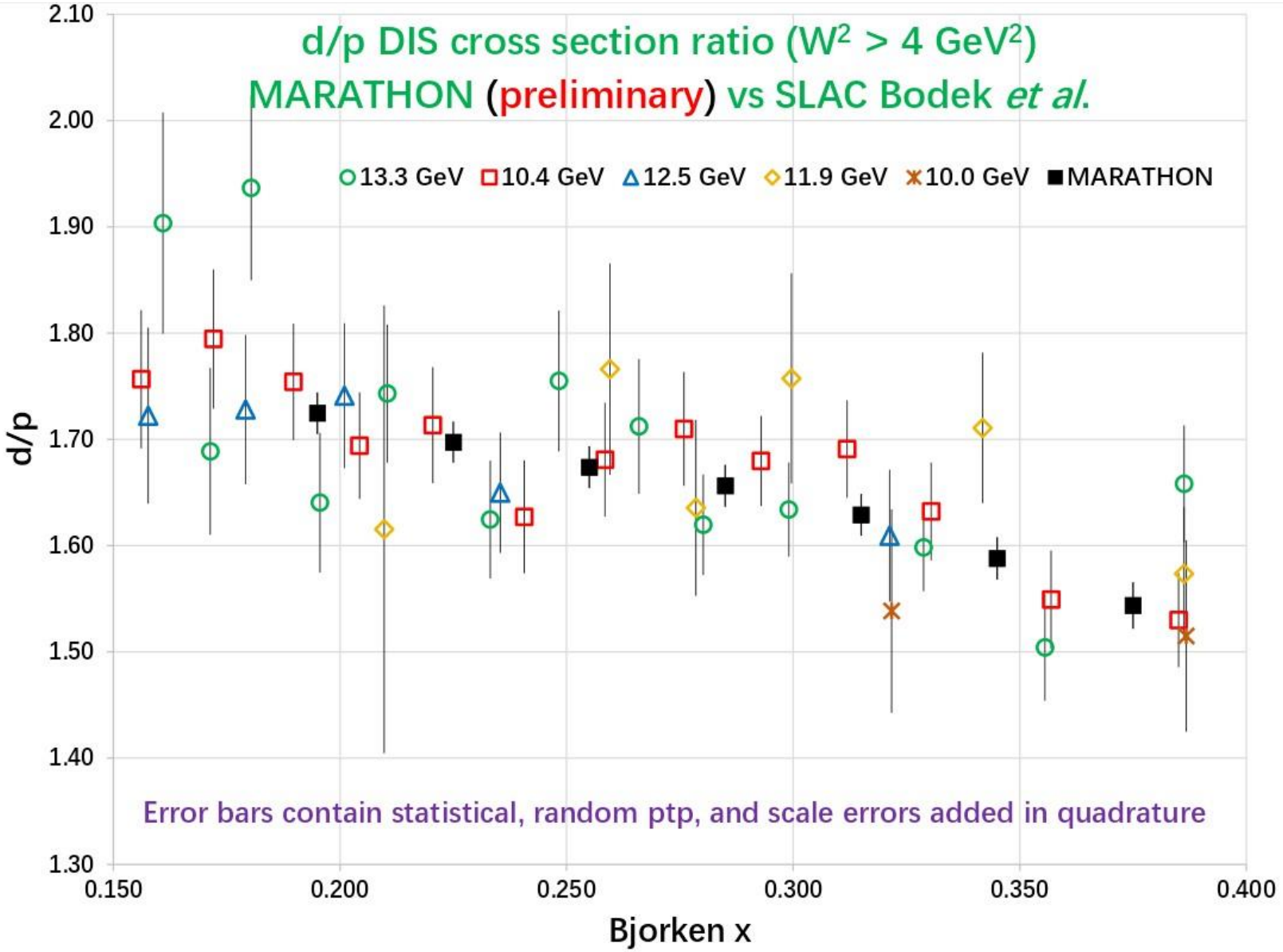




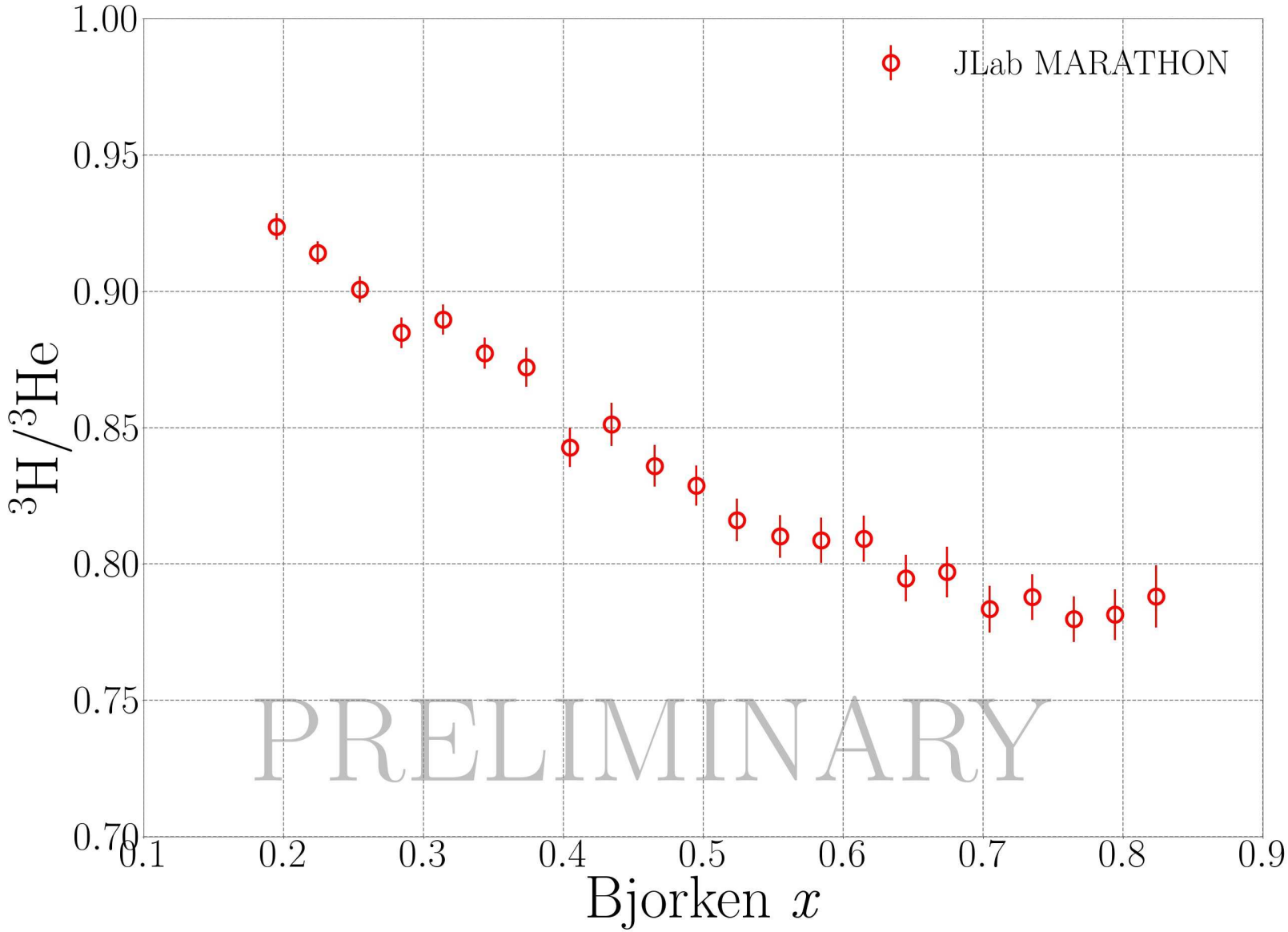
$$0.19 < x < 0.83$$

with

$$Q^2 > 2 \text{ GeV}^2 \text{ and } W^2 > 3 \text{ GeV}^2$$



^{2}H/^{1}He cross section ratio measured by MARATHON



^{3}H/^{3}He cross section ratio measured by MARATHON

We have...

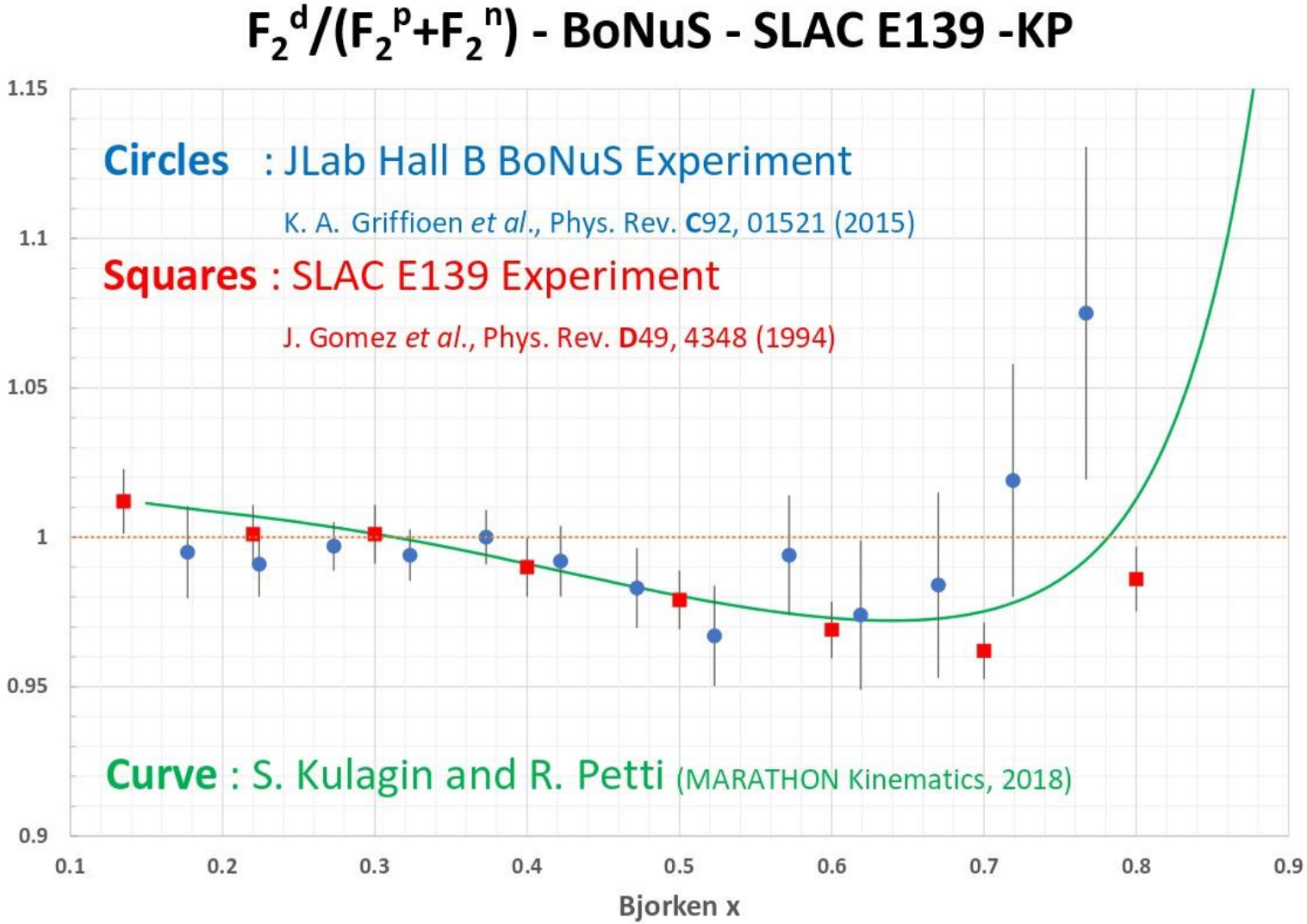
- ^{2}H/^{1}H
- ^{3}H/^{3}He
- ^{3}H/^{2}H
- ^{3}He/^{2}H

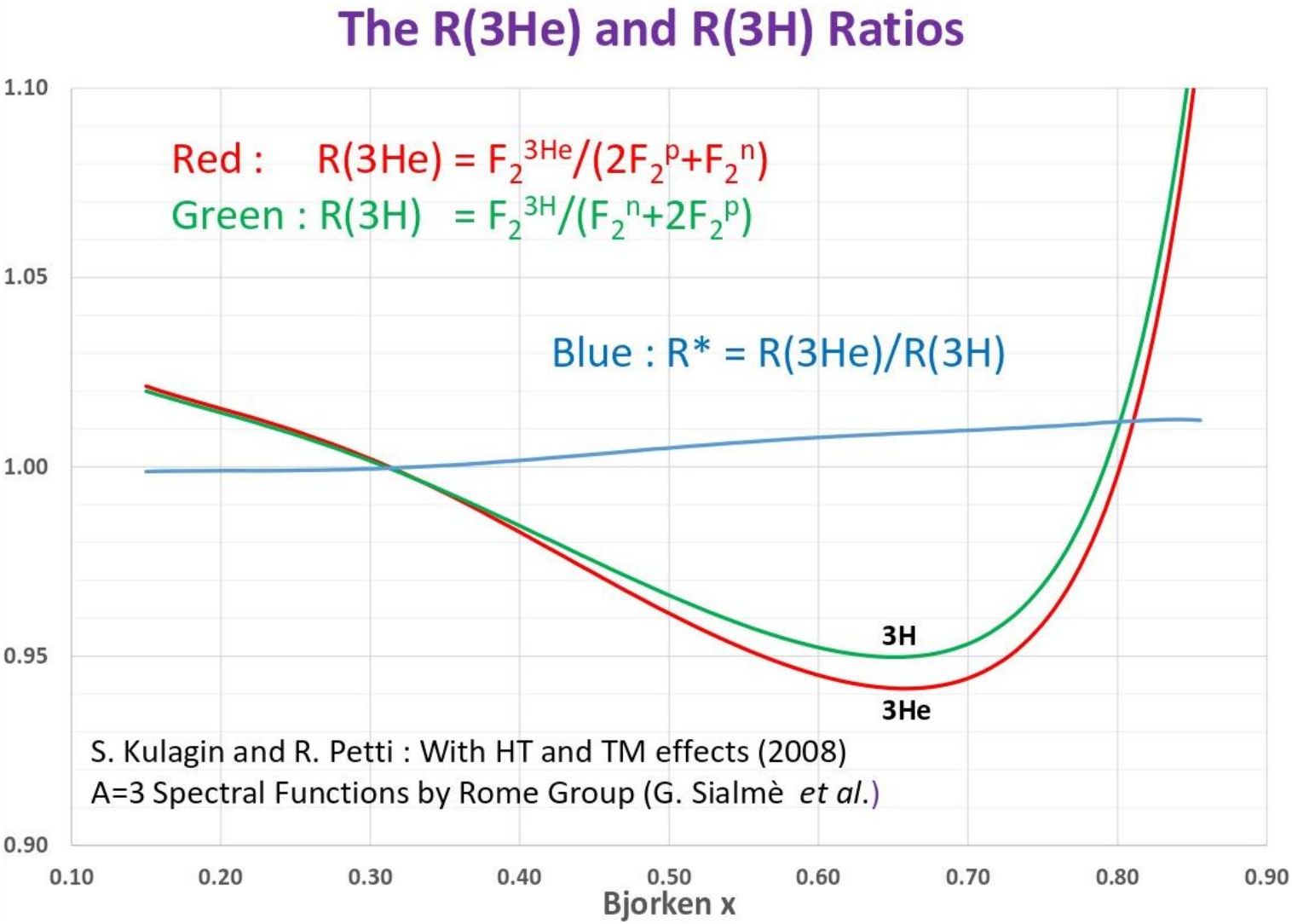
We want...

- F_2^n/F_2^p
- Isoscalar ^{3}H EMC ratio
- Isoscalar ^{3}He EMC ratio

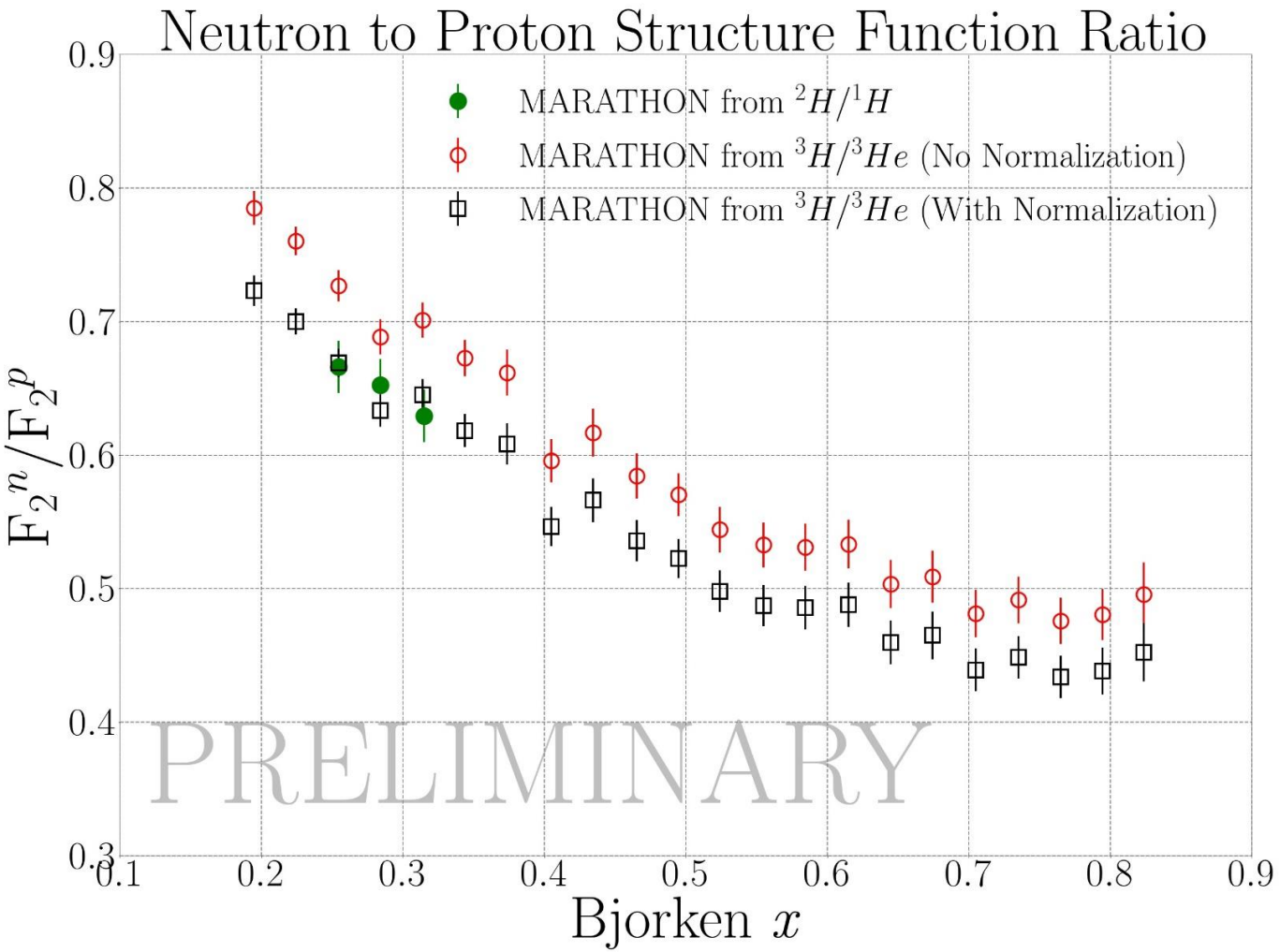
Approach:

- Use Kulagin & Petti model to extract F_2^n/F_2^p from ^{2}H/^{1}H and ^{3}H/^{3}He
- Perform internally-consistent renormalization of cross section ratios based on physical and phenomenological arguments

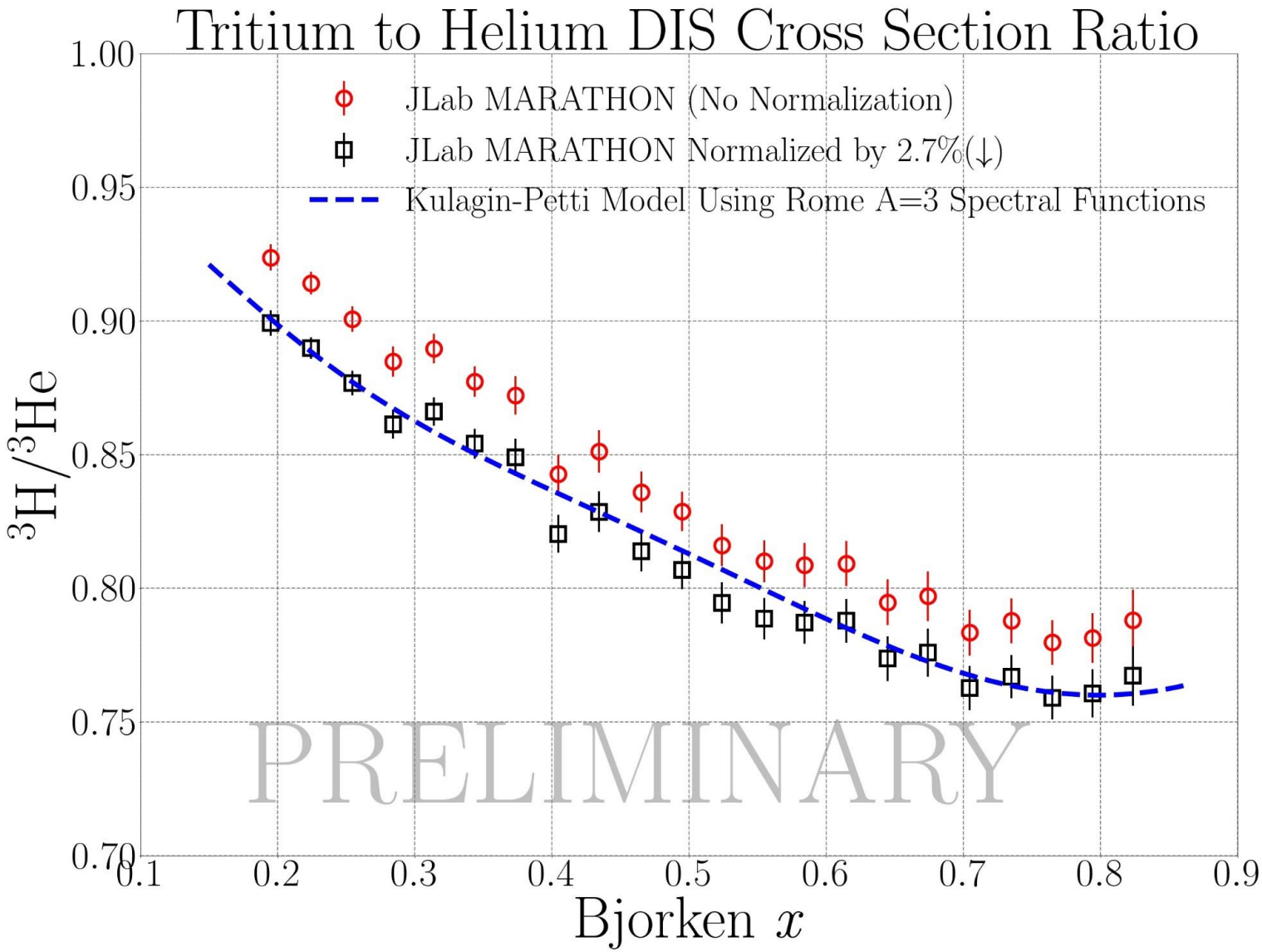

$F_2^d/(F_2^p+F_2^n)$ - BoNuS - SLAC E139 -KP
Circles : JLab Hall B BoNuS Experiment
K. A. Griffioen et al., Phys. Rev. C92, 01521 (2015)
Squares : SLAC E139 Experiment
J. Gomez et al., Phys. Rev. D49, 4348 (1994)
Curve : S. Kulagin and R. Petti (MARATHON Kinematics, 2018)
1.15
1.1
1.05
1
0.95
0.9
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
Bjorken x


The R(3He) and R(3H) Ratios
Red : R(3He) = $F_2^{3He}/(2F_2^p+F_2^n)$
Green : R(3H) = $F_2^{3H}/(F_2^n+2F_2^p)$
Blue : R* = R(3He)/R(3H)
3H
3He
S. Kulagin and R. Petti : With HT and TM effects (2008)
A=3 Spectral Functions by Rome Group (G. Sialmè *et al.*)
1.10
1.05
1.00
0.95
0.90
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
Bjorken x

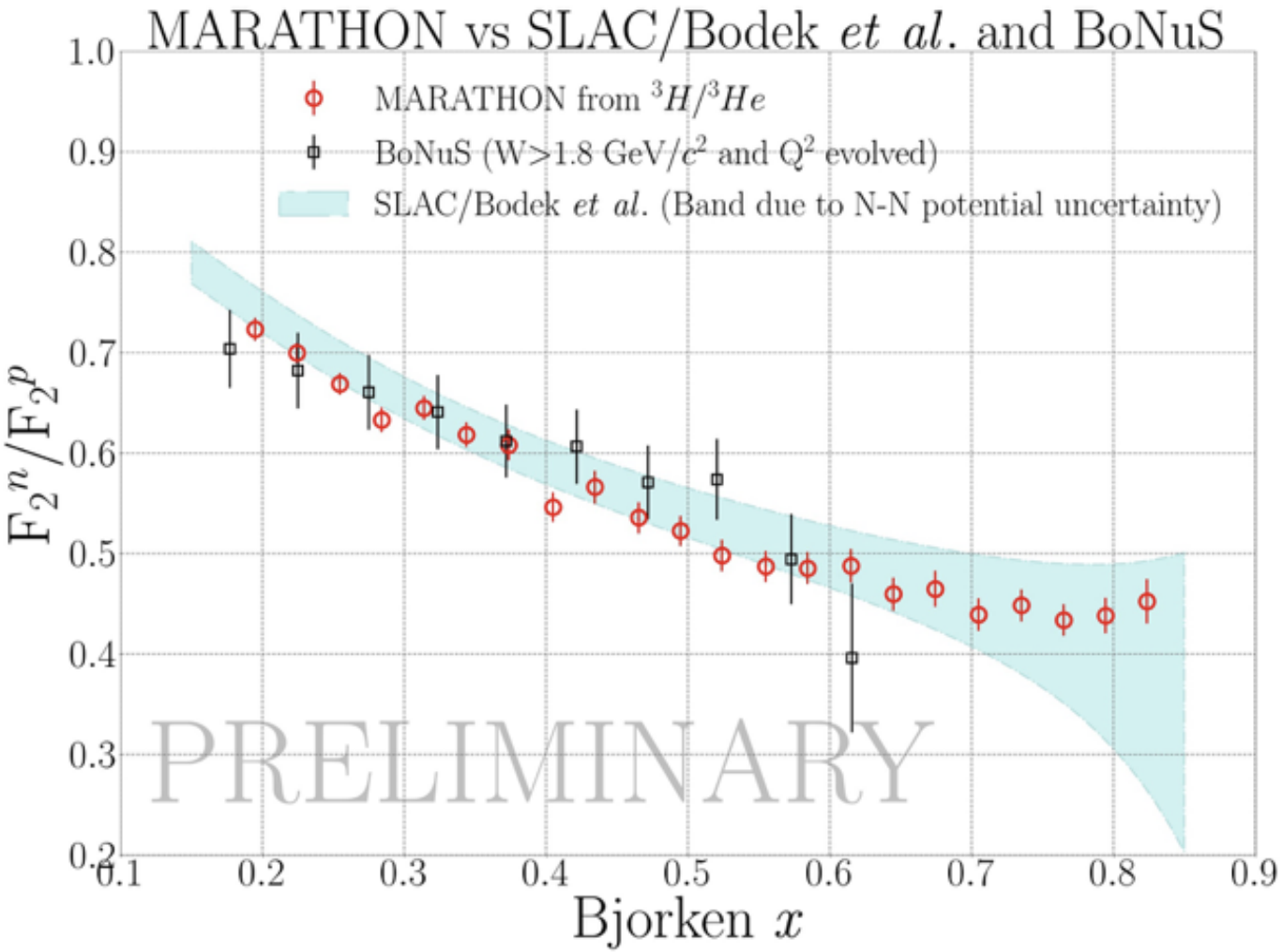
Match F_2^n/F_2^p at $x \approx 0.3$ (nuclear effects are small)



Requires -2.7% renormalization of ^{3}H/^{3}He ratio

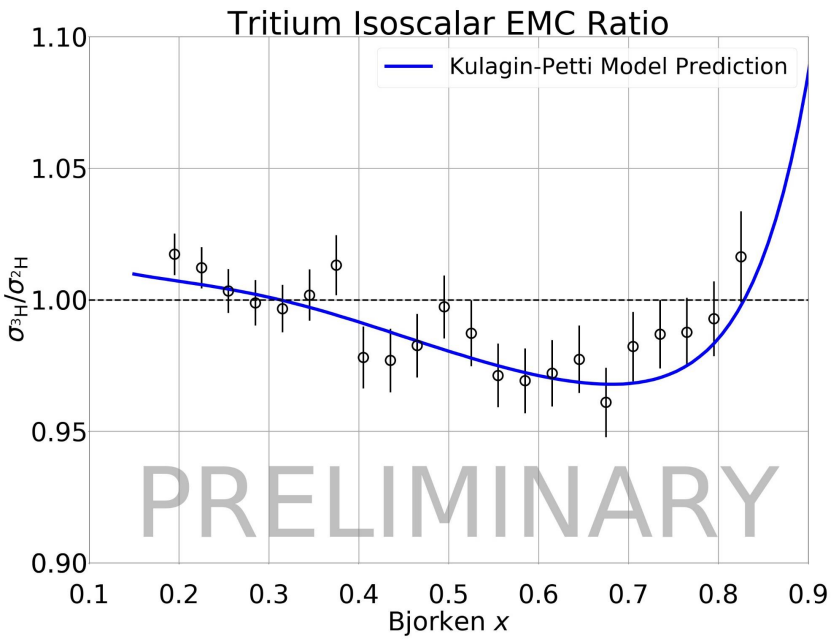


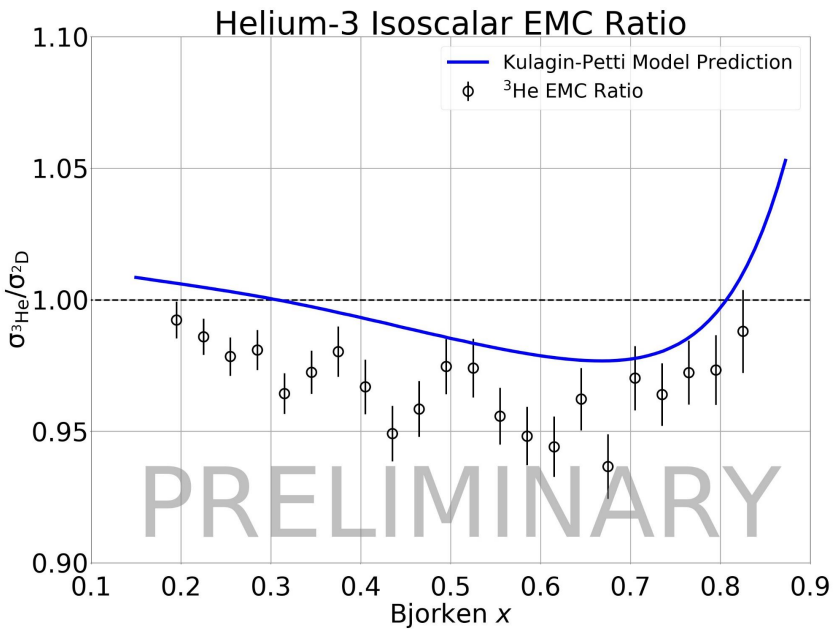
Kulagin & Petti A = 3 model agrees with MARATHON ^{3}H/^{3}He (-2.7% renormalization)



With this procedure, MARATHON F_2^n/F_2^p agrees with Kulagin & Petti model

Apply isoscalar correction to EMC ratios using MARATHON F_2^n/F_2^p

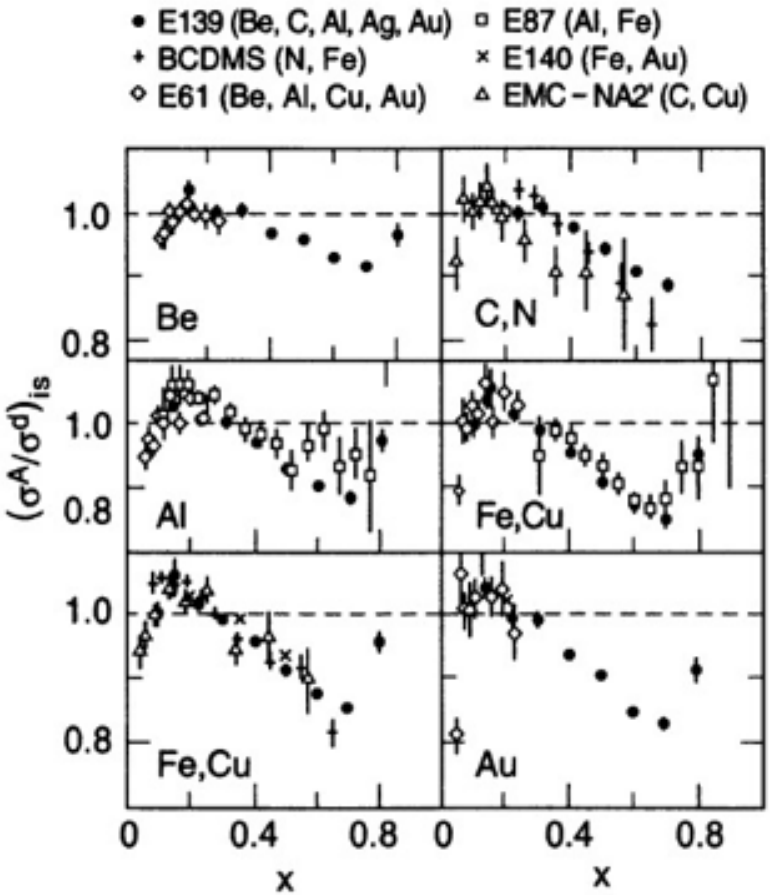




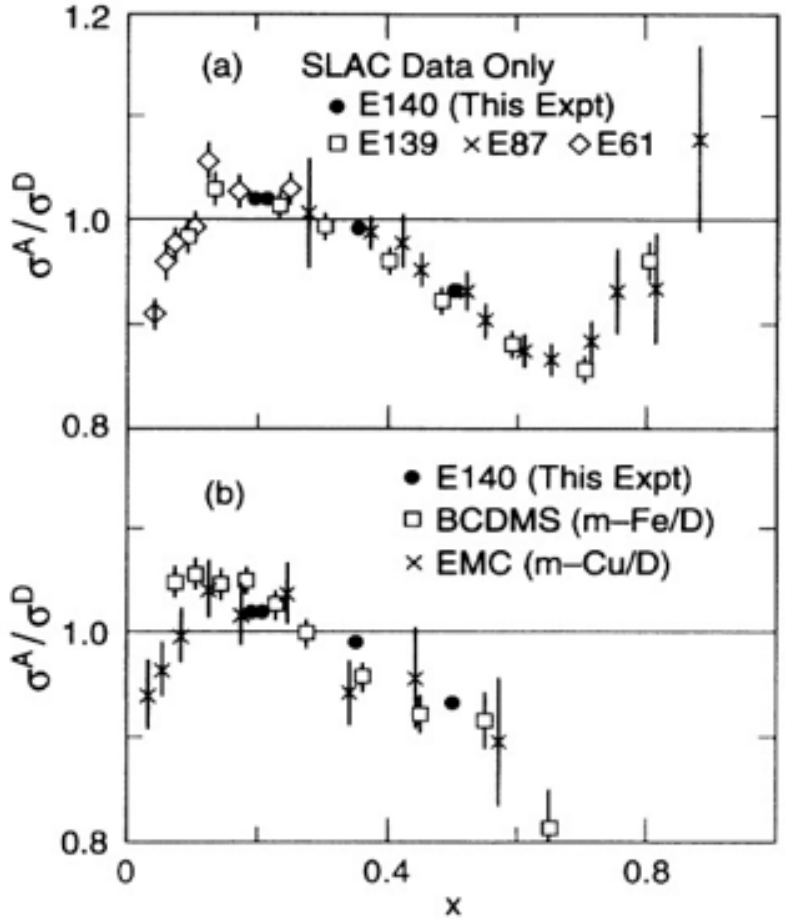
$^3\mathrm{H}/^2\mathrm{H}$ ratio ≈ 1 at $x \approx 0.3$

$^3\mathrm{He}/^2\mathrm{H}$ ratio < 1 at $x \approx 0.3$

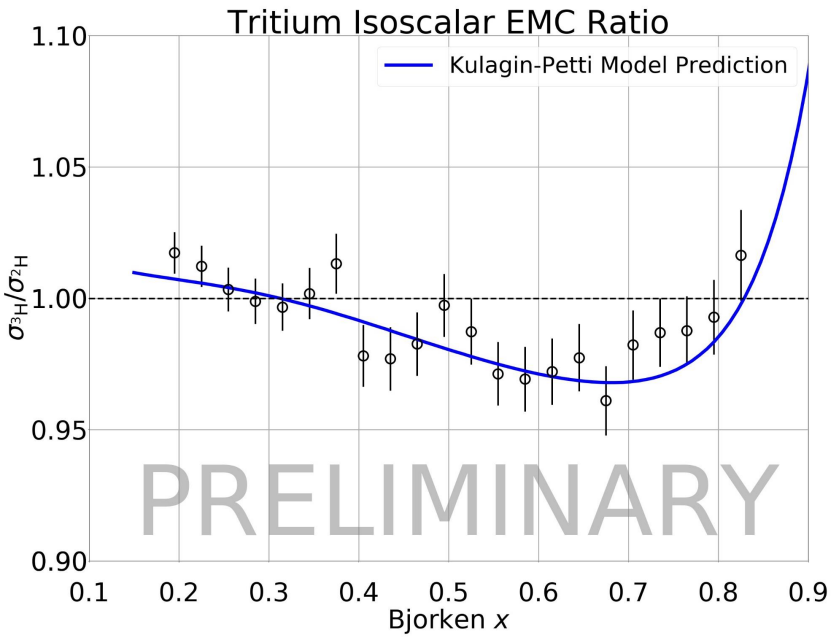
SLAC, CERN isoscalar EMC ratios ≈ 1 at $x \approx 0.3$

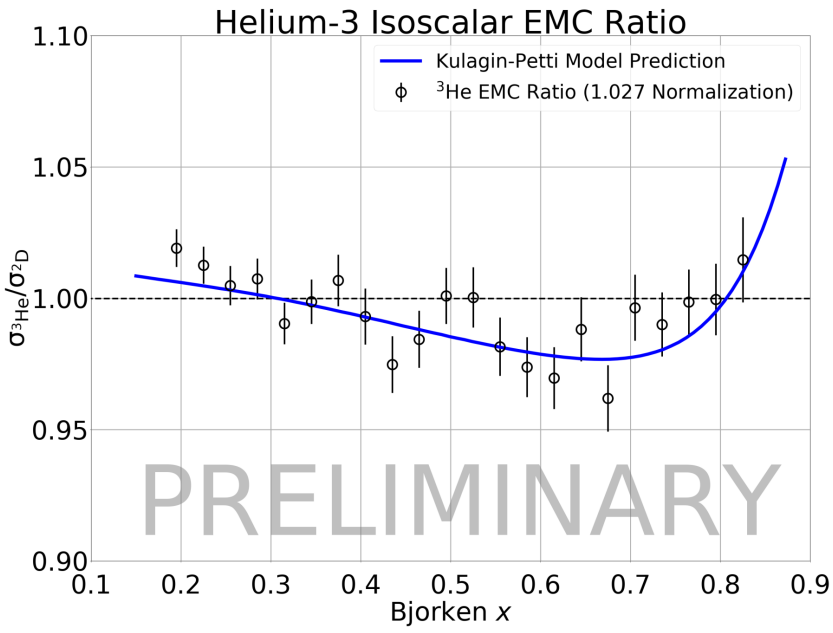


J. Gomez, et al.
Phys. Rev. D 49, 4348 (1994)



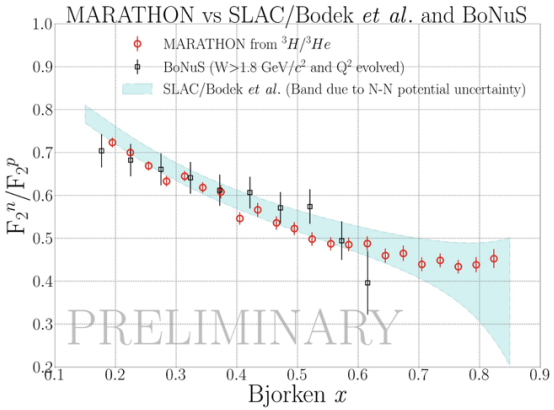
S. Dasu et al.
Phys. Rev. D 49, 5641 (1994)

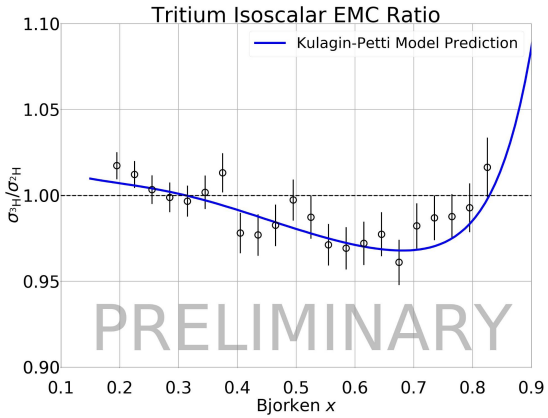


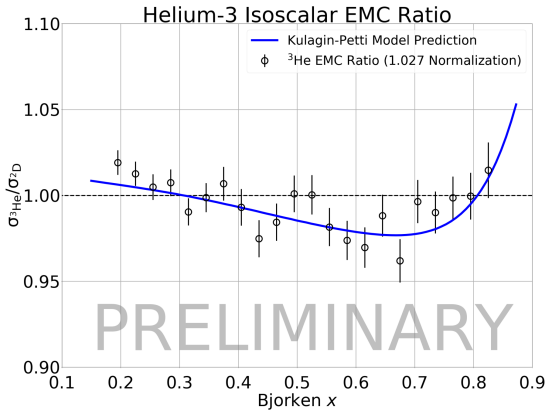


+2.7% renormalization of ^{3}He/^{2}H ratio results in crossing 1 at $x \approx 0.3$

2.7% *increase* in ^{3}He/^{2}H ratio consistent with 2.7% *decrease* in ^{3}H/^{3}He ratio







- MARATHON ^{2}H/^{1}H DIS data agrees well with SLAC Bodek et al. measurements and provides normalization for MARATHON ^{3}H/^{3}He DIS data.
- There may be no need to iterate F_2^n/F_2^p extraction, as the model used agrees very well with the data.
- MARATHON has provided the first measurement of the EMC effect in ^{3}H and new large x, W^2 data for the EMC effect in ^{3}He.
- Additional step: extraction of *leading-twist* F_2^n/F_2^p to determine d/u.

Thank you!