MeAsurement of F2n/F2p, d/u RAtios and A=3 EMC Effect in Deep Inelastic Electron Scattering Off the Tritium and Helium MirrOr Nuclei

Hanjie Liu

Columbia University

Hall A Collaboration meeting, Jun 22

Outline

- Overview and goals
- Experiment settings
- Calibrations

Overview and goals

- MARATHON finished data taking this Spring!
- Almost 30 years since last time tritium target was used
- Perform inclusive electron deep inelastic scattering (DIS) on 3H, 3He, and 2H nuclei by using Hall A HRS;
- The goal is to extract the ratio of the neutron to proton structure functions F_2^n/F_2^p, and the ratio of the proton d/u quark distribution functions at high x;
- We will also measure the EMC effect for 3H and 3He;

- Why measure F_2^n/F_2^p at high x

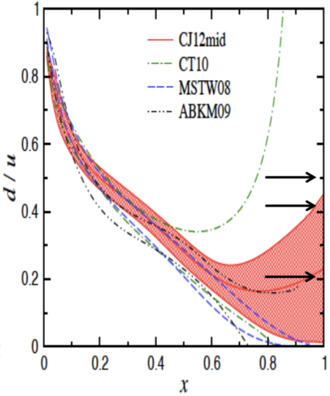
❑ Testing ground for hadron structure at x → 1:

✧ $d/u \to 1/2$ — **SU(6) Spin-flavor symmetry**

✧ $d/u \to 0$ — **Scalar diquark dominance**

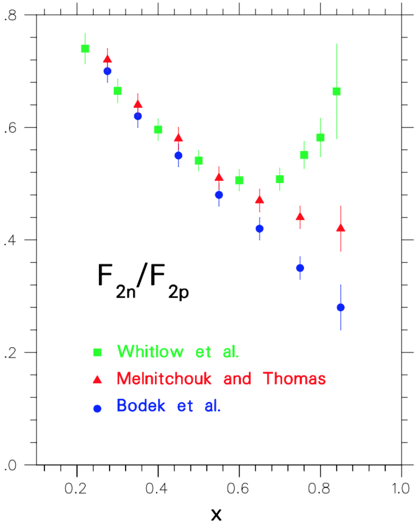
✧ $d/u \to 1/5$ — **pQCD power counting**

✧ $d/u \to \dfrac{4\mu_n^2/\mu_p^2 - 1}{4 - \mu_n^2/\mu_p^2} \approx 0.42$ — **Local quark-hadrc duality**



slide from Jianwei Qiu

F_2^n / F_2^p and d/u



SLAC DIS Data revisited

Bodek *et al.*: Non-relativistic Fermi-smearing-only model with Paris N-N potential

Melnitchouk and Thomas: Relativistic convolution model with empirical binding effects

Whitlow *et al.*: Assumes EMC effect in deuteron (Frankurt and Strikman data-based Density Model)

MARATHON

- Exploits the isospin symmetry of the A=3 nuclei 3He and 3H. The nuclear effect difference between these should be small;
- d/u extracted should be free of nuclear structure theoretical uncertainties;
- First measurement of the EMC effect in Tritium;

- Cross section for inelastic electron-nucleon scattering

E (E') incident (scattered) electron energy; θ: electron scattering angle; M: nuclear mass

$$\frac{d\sigma}{d\Omega dE'} = \frac{4\alpha^2(E')^2}{Q^4} cos^2(\theta/2)[\frac{F_2(\nu, Q^2)}{\nu} + \frac{2F_1(\nu, Q^2)}{M} tan^2(\theta/2)] \quad (1)$$

$$F_1 = \frac{F_2(1 + Q^2/\nu^2)}{2x(1 + R)} \qquad \nu = E - E' \qquad Q^2 = 4EE' sin^2(\theta/2)$$

- $R = \sigma_L/\sigma_T$ has been measured to be independent of the atomic mass number A

$$\frac{\sigma(3H)}{\sigma(3He)} = \frac{F_2(3H)}{F_2(3He)} \quad (2)$$

- Free neutron to proton structure functions:

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

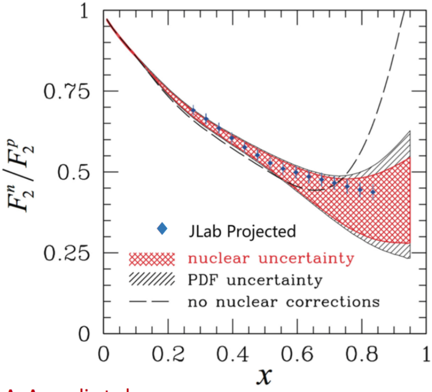
- Depends on the EMC-type ratios:

$$\mathcal{R} = \frac{R(3He)}{R(3H)}$$

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

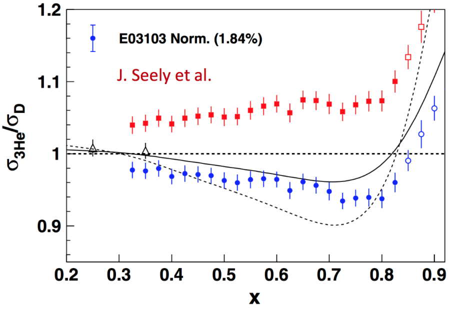
- $\mathcal{R}$ has been calculated in theory to deviate from 1 only up to 1.5% by taking into account all possible effects

CJ (CTEQ-JLab) Recent Calculations



A. Accardi et al.

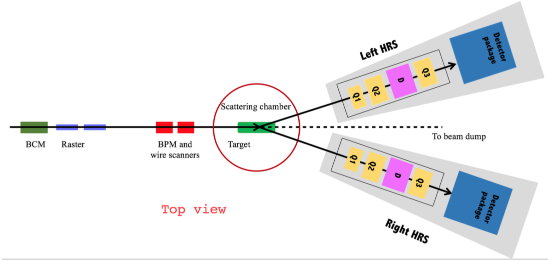
JLab Hall C data for He3 EMC Effect

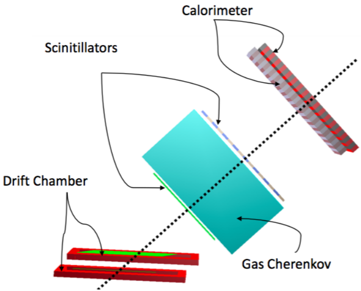


MARATHON data on 3H, 3He will be of similar precision to Hall C data

Experiment Configuration

- Beamline: BCM, Raster, BPM and harps
- Target:
  - Solid target: C-hole, Single Carbon foil, Multi-foils, Dummy, Empty Cell, thick Al, Ti;
  - Gas target: Hydrogen, Deuterium, Helium, Tritium
- Detector: LHRS and RHRS: VDC, S0, GAS Cherenkov, S2, Shower

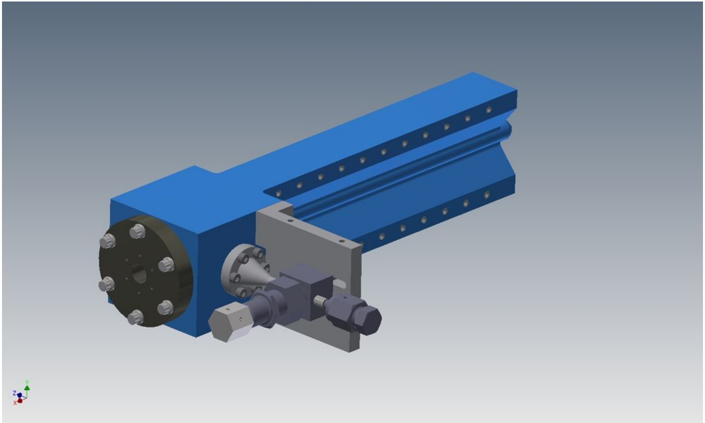




plots from Tong Su

Tritium Target

- Sealed-cell gas target



Thanks to Dave Meekins and the Target group!

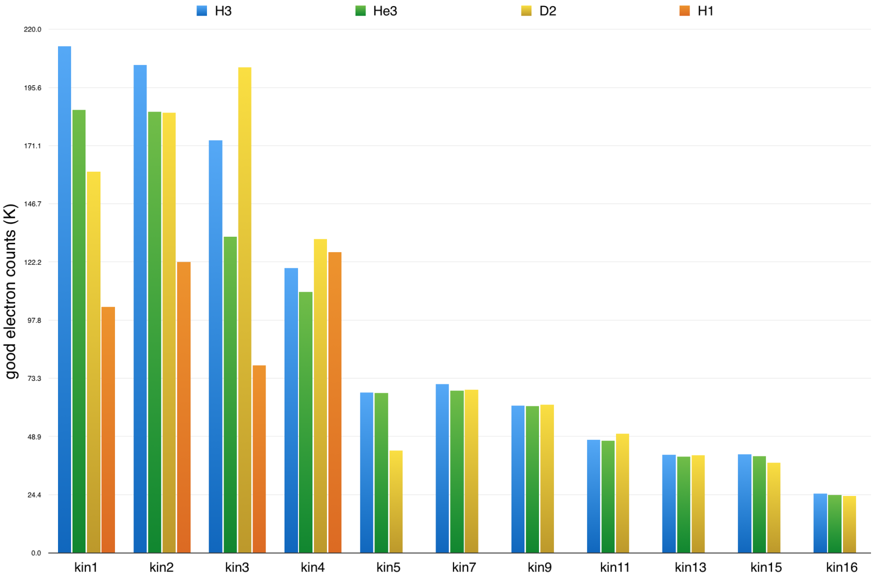
Run Overview

- Run period:
  Jan 13 – Mar 5; Mar 24 – Mar 28; Mar 28 – Apr 12;
- E=10.6 GeV; I=22.5 uA
- Both HRS detect electrons;
- RHRS dipole can only stable at 2.9 GeV; RHRS stays at the highest x point angle (kin16) through the entire run
- LHRS finished:
  - 10 kinematic settings:
    kin1, kin2, kin3, kin4, kin5, kin7, kin9, kin11, kin13, kin15;
  - Positron: kin0, kin1, kin3, kin5;
  - Boiling: 11uA, 16uA, 22.5uA;
  - Optics;

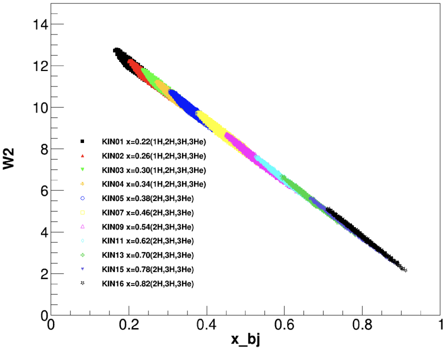
Kinematic Settings

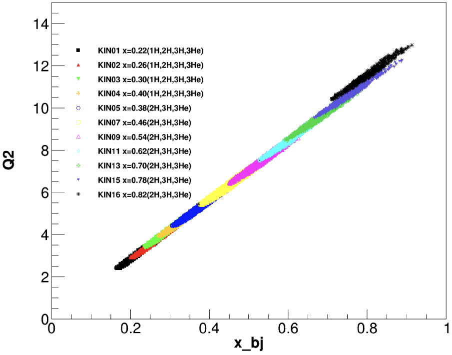
	x	E' (GeV)	θ (deg)	$W^2 (GeV)^2$	$Q^2 (GeV/c)^2$
kin1	0.218	3.1	17.58	11.89	3.07
kin2	0.258	3.1	19.14	11.32	3.63
kin3	0.298	3.1	20.58	10.76	4.19
kin4	0.338	3.1	21.93	10.20	4.76
kin5	0.378	3.1	23.21	9.63	5.32
kin7	0.458	3.1	25.59	8.51	6.45
kin9	0.538	3.1	27.77	7.38	7.57
kin11	0.618	3.1	29.81	6.26	8.70
kin13	0.698	3.1	31.73	5.13	9.82
kin15	0.778	3.1	33.55	4.00	10.95
kin16	0.818	2.9	36.12	3.51	11.82

Kinematic Settings



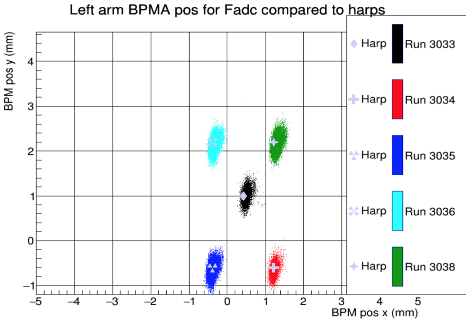
Kinematic Settings

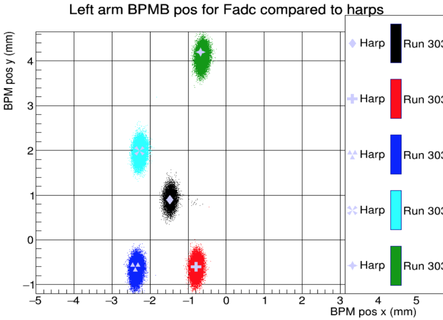




plots from Tong Su

- BPM

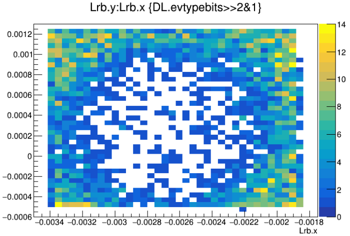




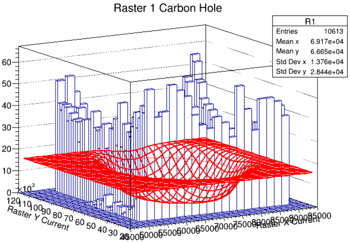
plots from Jason Bane

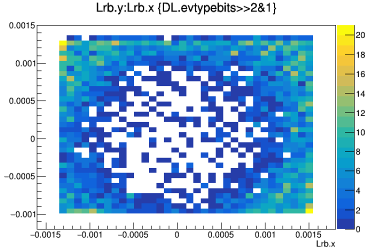
Raster

- Traditional Raster calibration



- Fit Carbon hole by sigmod function

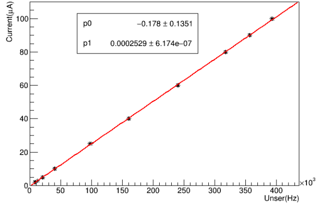


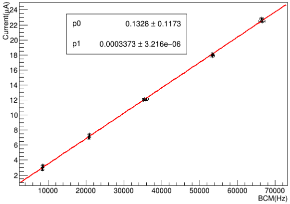


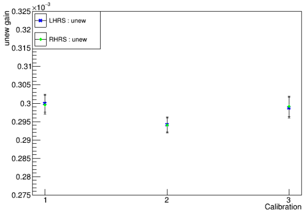
plots from Tyler Hague

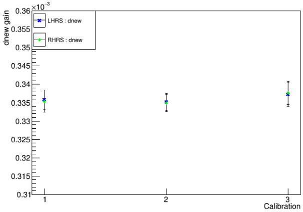
BCM

- 3 BCM calibrations are performed during MARATHON, and the Receiver's gains were stable to 1%



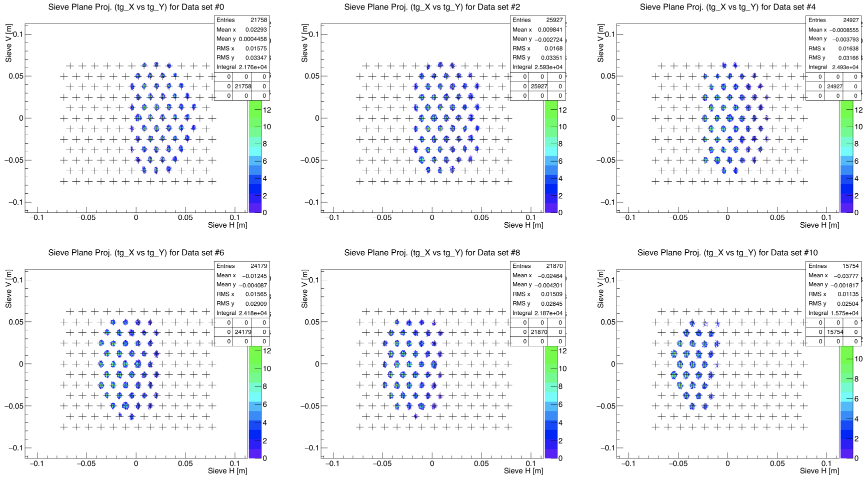






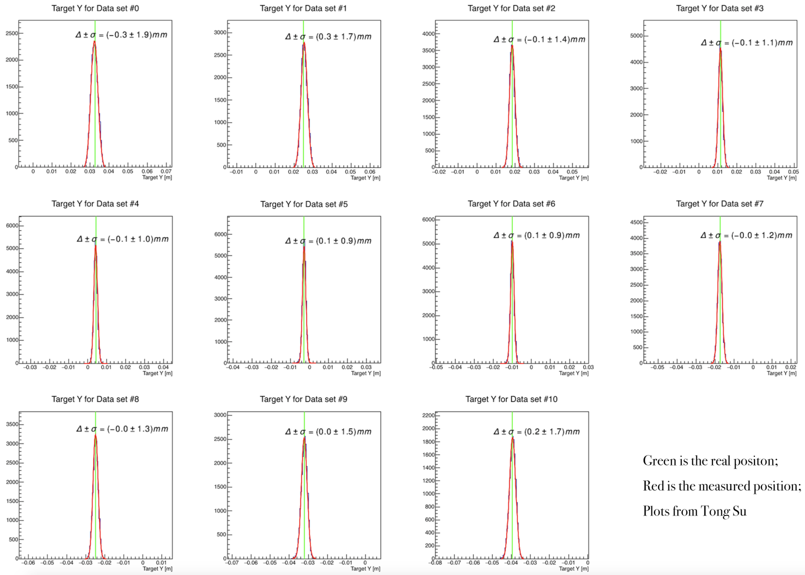
plots from Mike Nycz

Dec. optics run



plots from Tong Su

Calibrations



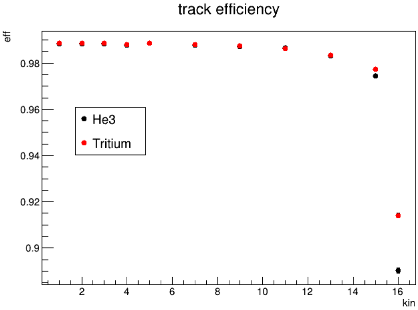
Green is the real positon;

Red is the measured position;

Plots from Tong Su

Track efficiency

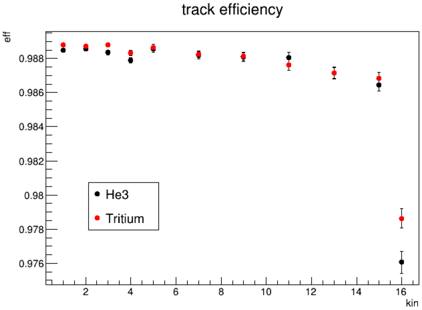
- Track efficiency $= \dfrac{\text{potential good electron events with tracks}}{\text{potential good electron events}}$
- potential good electron events: pass Cherenkov sum cut and have enough energy deposit in Calorimeter

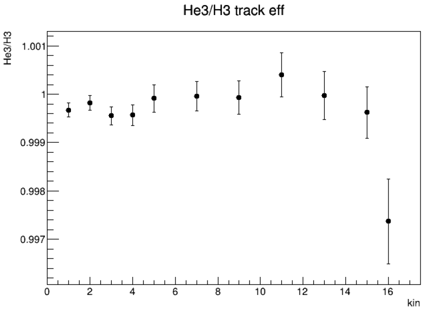


- At high x, the event rate is same order as Cosmic rate. Cosmic dilute the track efficiency

Track efficiency

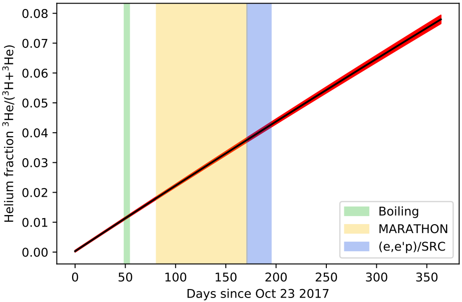
- Add cosmic cuts: good electron events have to go forward and pass central of S2



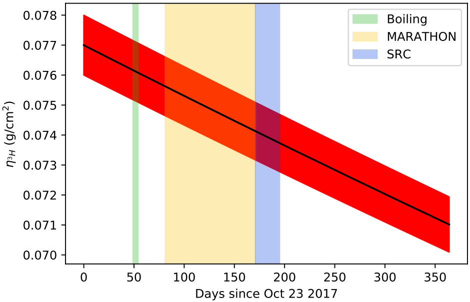


He^3contamination in Tritium target

- He^3 fraction in Tritium target



- Tritium target thickness



plots from Tyler Kutz

Summary

- After 18 years, MARATHON finished data taking this Spring!
- Measure d/u at high x point;
- Measure EMC effect for tritium and He^3;
- Six students will graduate with this data!

Thanks to all the people!