MeAsurement of F_2^n/F_2^p, d/u RAtios and $A=3$ EMC Effect in Deep Inelastic Electron Scattering Off the Tritium and Helium MirrOr Nuclei

(JLab Experiment E12-10-103)

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for the

JLab MARATHON Collaboration

DIS2011 April 12, 2011

DIS and Quark Parton Model

✓ Cross Section – Nucleon structure functions F_1 and F_2:

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

$$R = \frac{\sigma_L}{\sigma_T} = \frac{M}{\nu} \frac{F_2}{F_1} \left(1 + \frac{\nu^2}{Q^2} \right) - 1 \qquad \begin{aligned} \nu &= E - E' \\ Q^2 &= 4EE' \sin^2(\theta/2) \end{aligned}$$

✓ Quark-Parton Model (QPM) interpretation in terms of quark probability distributions $q_i(x)$ (large Q^2 and ν):

$$F_1(x) = \frac{1}{2} \sum_i e_i^2 q_i(x) \qquad F_2(x) = x \sum_i e_i^2 q_i(x)$$

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

F_2^n/F_2^p in Quark Parton Model

- ✓ Assume isospin symmetry:

$$u^p(x) \equiv d^n(x) \equiv u(x) \qquad \overline{u}^p(x) \equiv \overline{d}^n(x) \equiv \overline{u}(x)$$

$$d^p(x) \equiv u^n(x) \equiv d(x) \qquad \overline{d}^p(x) \equiv \overline{u}^n(x) \equiv \overline{d}(x)$$

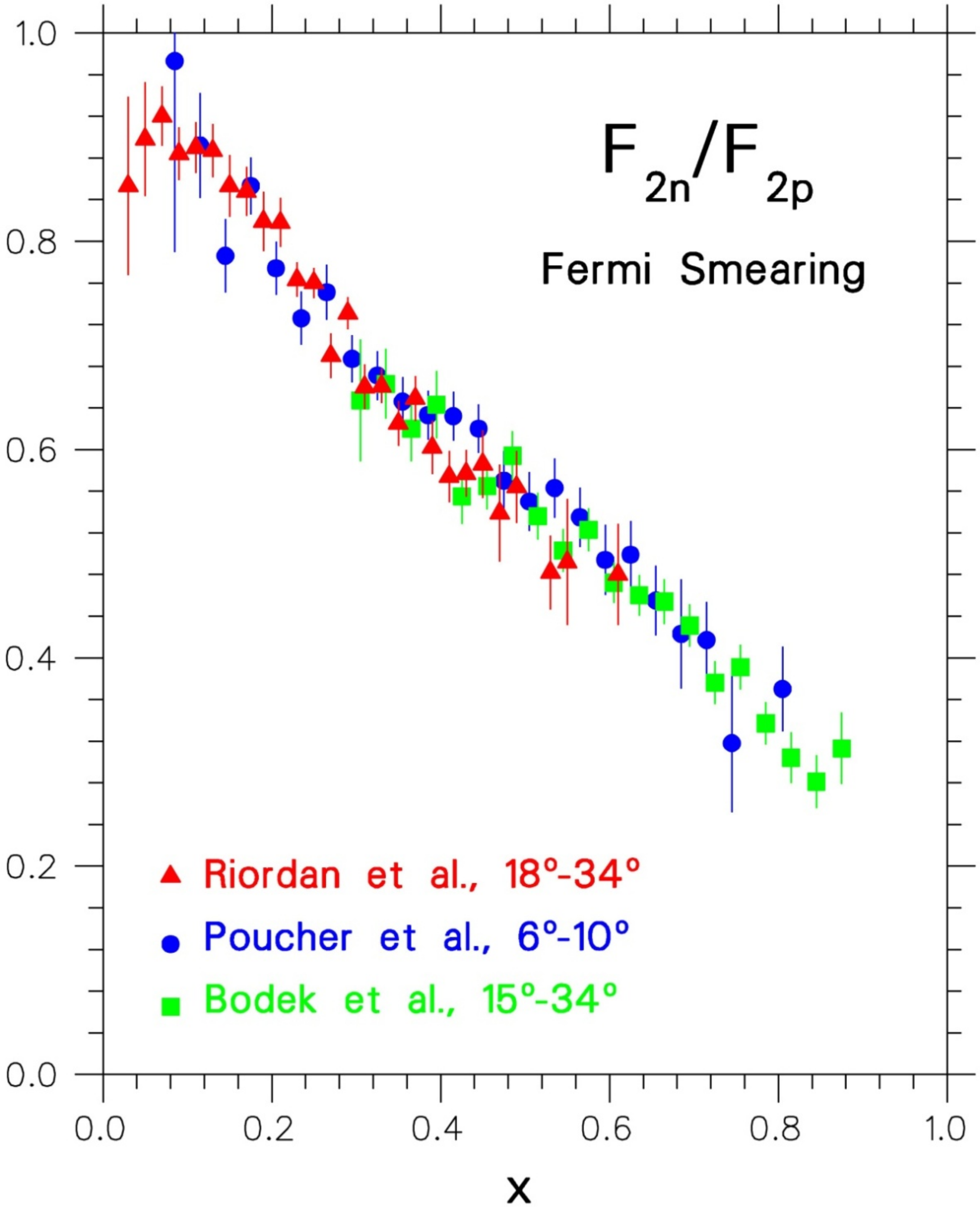
$$s^p(x) \equiv s^n(x) \equiv s(x) \qquad \overline{s}^p(x) \equiv \overline{s}^n(x) \equiv \overline{s}(x)$$

- ✓ Proton and neutron structure functions:

$$F_2^p = x\left[\frac{4}{9}(u+\overline{u}) + \frac{1}{9}(d+\overline{d}) + \frac{1}{9}(s+\overline{s})\right]$$

$$F_2^n = x\left[\frac{4}{9}(d+\overline{d}) + \frac{1}{9}(u+\overline{u}) + \frac{1}{9}(s+\overline{s})\right]$$

- ✓ Nachtmann inequality: $1/4 \le F_2^n / F_2^p \le 4$

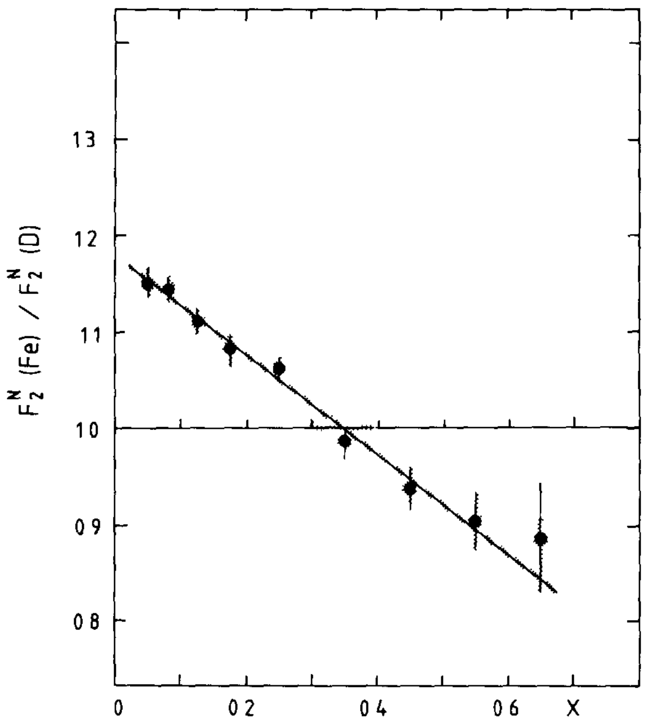


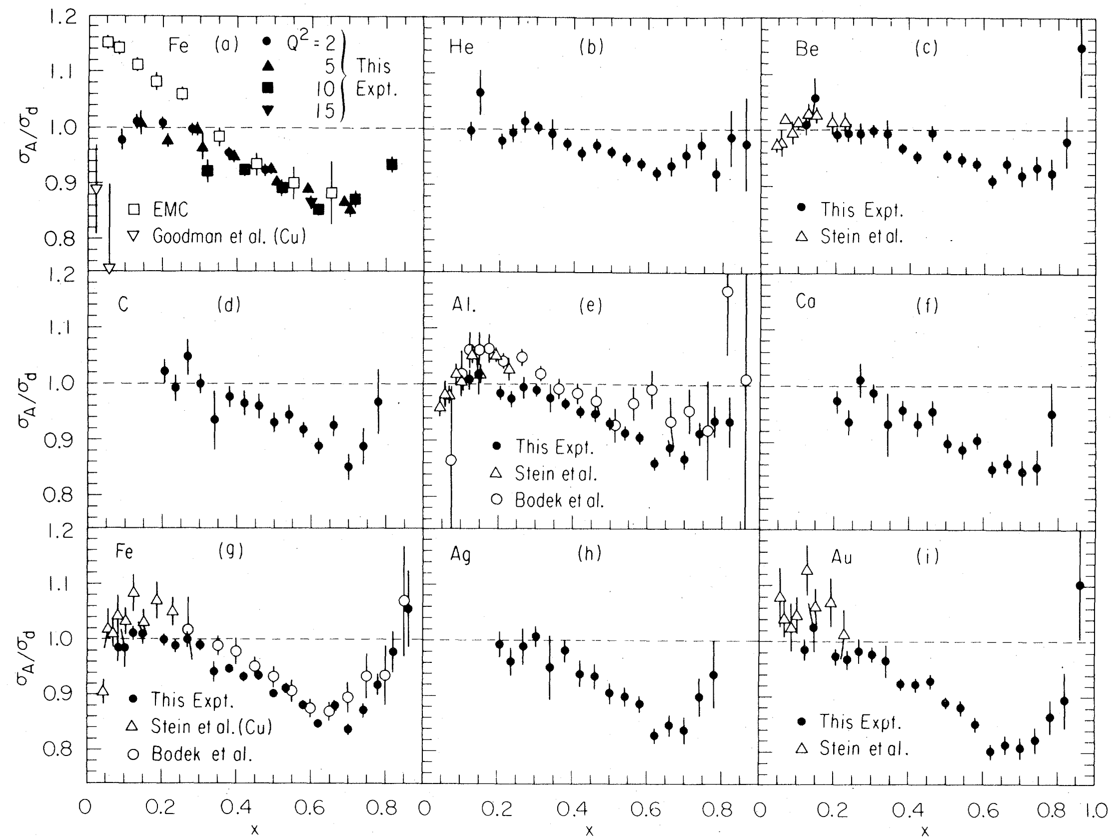
F_2^n/F_2^p extracted from hydrogen and deuterium deep-inelastic data using Hamada-Johnston potential in a Fermi-smearing model.

Data in disagreement with *SU(6)* prediction: 2/3=0.67!

SLAC 1968-1972
Friedman, Kendall, Taylor
(1990 Nobel)

... and then came the EMC effect





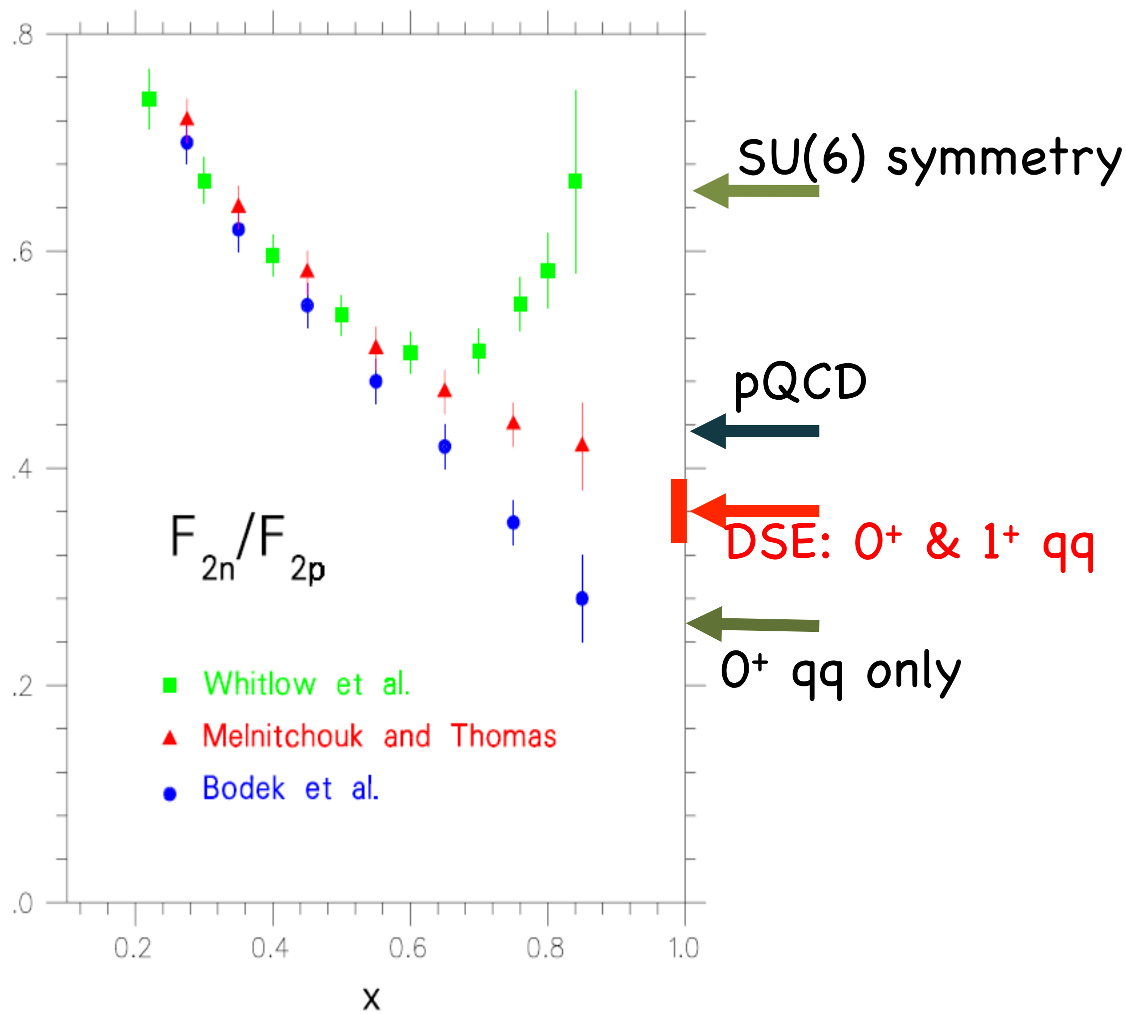
EMC
Phys. Lett. B123, 275 (1983)

SLAC E139
Phys. Rev. Lett. 52, 727 (1984)

IF DEUTERIUM ALSO AFFECTED
F_2^n/F_2^p, d/u extraction and conclusions could be wrong

The "new & improved" F_2^n/F_2^p ratio

(according to some of the proposed EMC effect models)



Review: Rev. Mod. Phys. 82, 2991 (2010)

Nucleon F_2 Ratio Extraction from ^{3}He/^{3}H

[Phys. Rev. C68, 035201 (2003)]

✓ Form the "SuperRatio" of EMC ratios for A=3 mirror nuclei:

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

✓ If $R=\sigma_L/\sigma_T$ is the same for ^{3}He and ^{3}H, measured DIS cross section ratio must be equal to the structure function ratio as calculated from above equations:

$$\frac{\sigma^{^3He}}{\sigma^{^3H}} = \frac{F_2^{^3He}}{F_2^{^3H}} = R^* \frac{2F_2^p + F_2^n}{F_2^p + 2F_2^n}$$

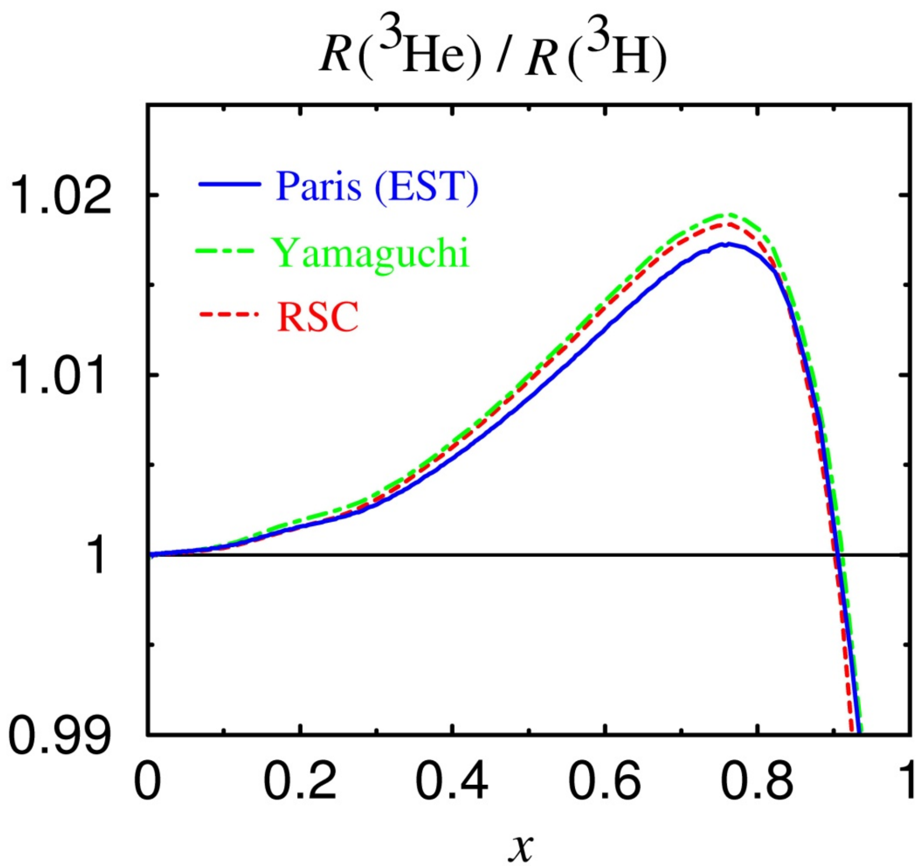
✓ Solve for the nucleon F_2 ratio and calculate R^* (expected to be very close to unity) using a theory model:

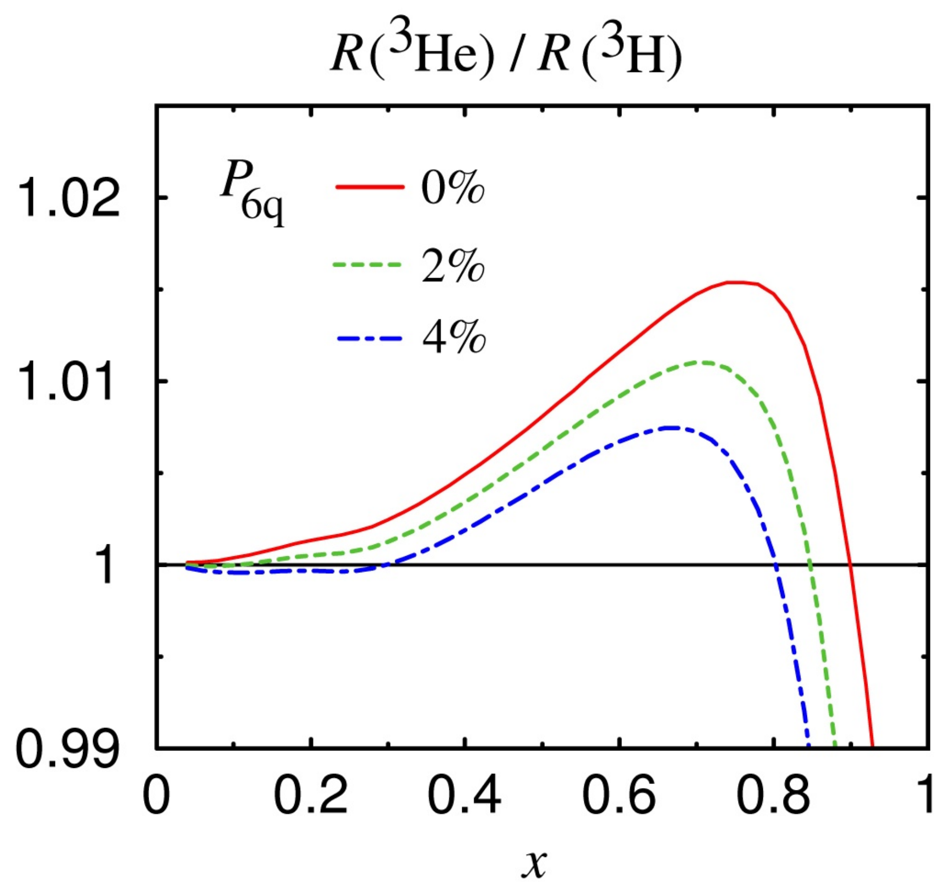
$$\frac{F_2^n}{F_2^p} = \frac{2R^* - F_2^{^3He}/F_2^{^3H}}{2F_2^{^3He}/F_2^{^3H} - R^*}$$

SuperRatio $R^* = R(^3He)/R(^3H)$ has been calculated by several groups.

Largest deviation from 1 for 0 < x < 0.93 is ~1.5% after taking into account all known effects

* I. Afnan et al., Phys. Lett. B493, 36 (2000); Phys. Rev. C68, 035201 (2003)
* E. Pace, G Salme, S. Scopetta, A. Kievsky, Phys. Rev. C64, 055203 (2001)
* M. Sargsian, S. Simula, M. Strikman, Phys. Rev. C66, 024001 (2002)



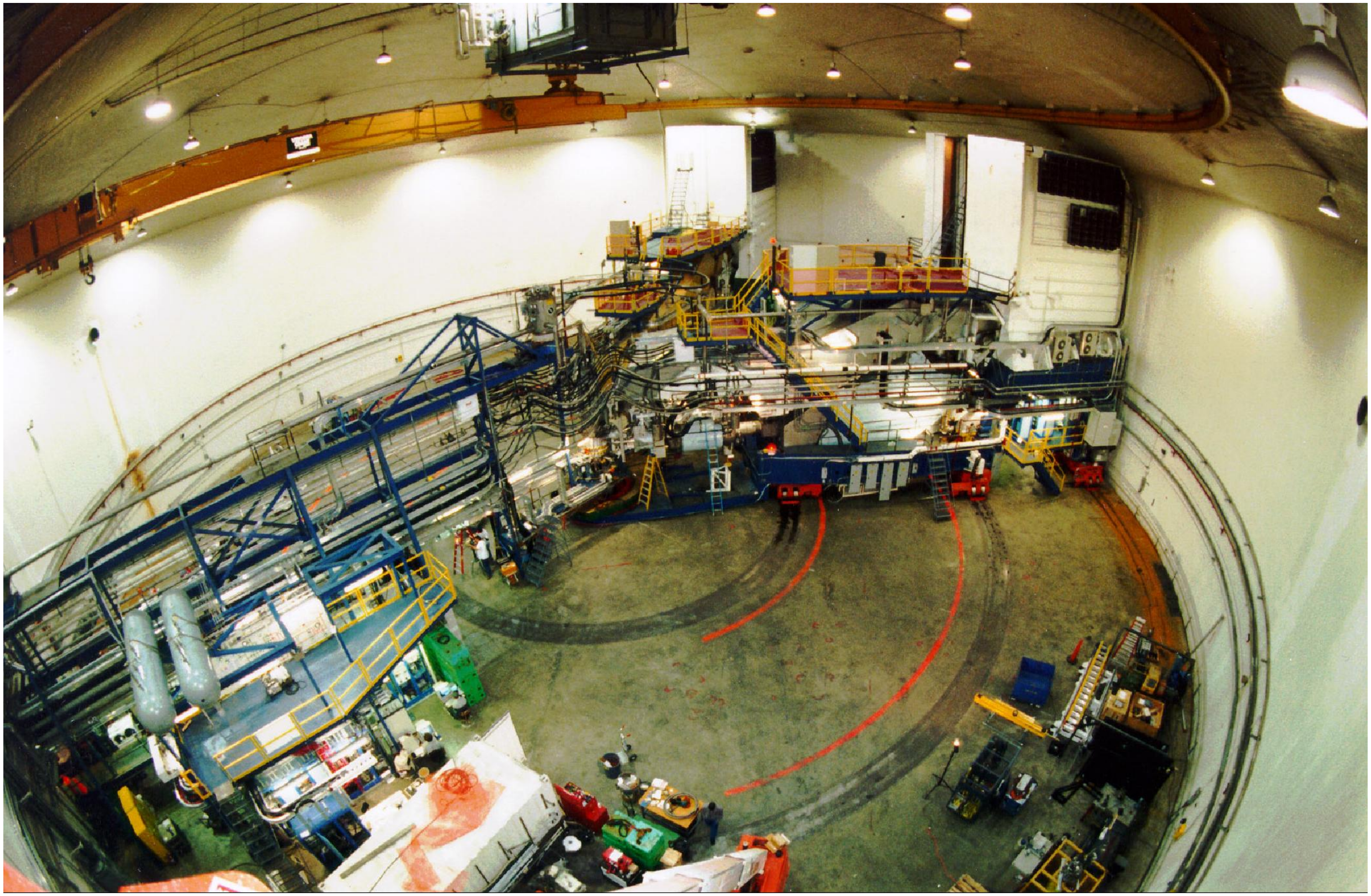


Experiment Overview

- ✓ Target system with helium/tritium/deuterium cells.
- ✓ Perform experiment in Hall A:
  - Beam Energy (Current): 11.0 GeV (25 μA)
  - Simultaneous use of left-HRS for $0.23 < x < 0.55$ and BigBite for $0.59 < x < 0.87$
  - ~ 700 hours for *d/u* measurement (@ 100% efficiency)
- ✓ Measure $R = \sigma_L / \sigma_T$ for ^3He and ^3H:
  - Use left-HRS
  - Beam energies of 3.3, 5.5 and 7.7 GeV
  - ~ 300 hours (@ 100% efficiency)

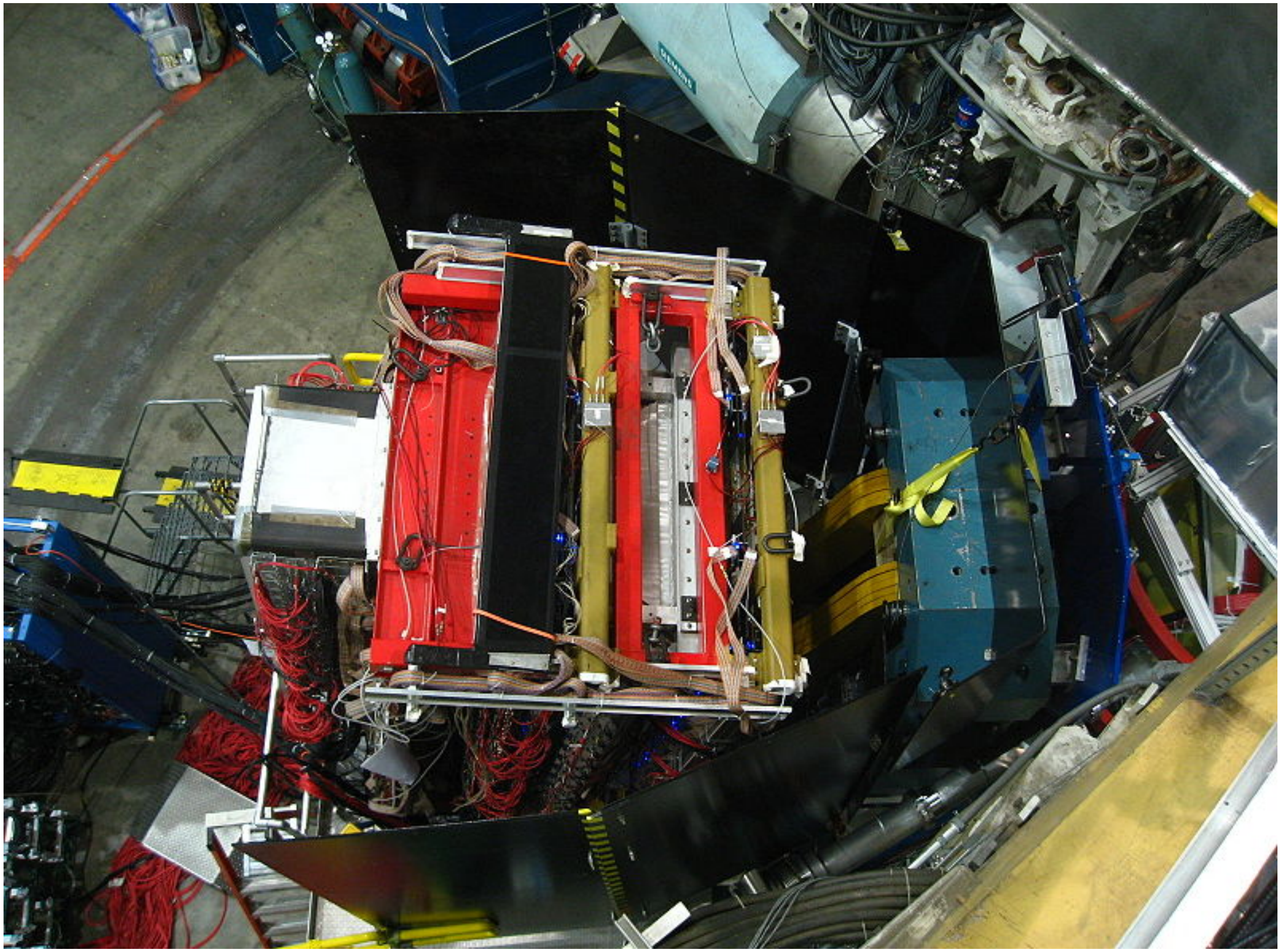
Hardware Overview I (Hall A)

High Resolution Spectrometers (HRS): QQDQ, $p0_{max}$~4 GeV, $\Delta p/p$ ~10^{-4}, $\Delta\Omega$ ~6.5 msr,
TTL: +/- 5 cm; $\Delta\theta_L$ = 12.5–160 deg; $\Delta\theta_R$ = 12.5–135 deg; L ~ 26 m, H ~ 16 m , W ~ 2 kt;



Hardware Overview II (Hall A)

BigBite: D, $p0_{max}$~1 GeV, $\Delta p/p$ ~10^{-2}, $\Delta\Omega$ ~40-50 msr,
Drift-chambers, scintillator hodoscope, Pb-glass calorimeter & gas threshold Cerenkov



Proposed Target System

- ✓ Five-cell target structure (^1H, ^2H, ^3H, ^3He, Al Dummy):
  - ➢ All cells: 25 cm long, 1.25 cm ID, 25 μA max current
  - ➢ ^3H cell: 10 atm, 1000 Ci activity
  - ➢ ^1H, ^2H, ^3He cells: 25 atm

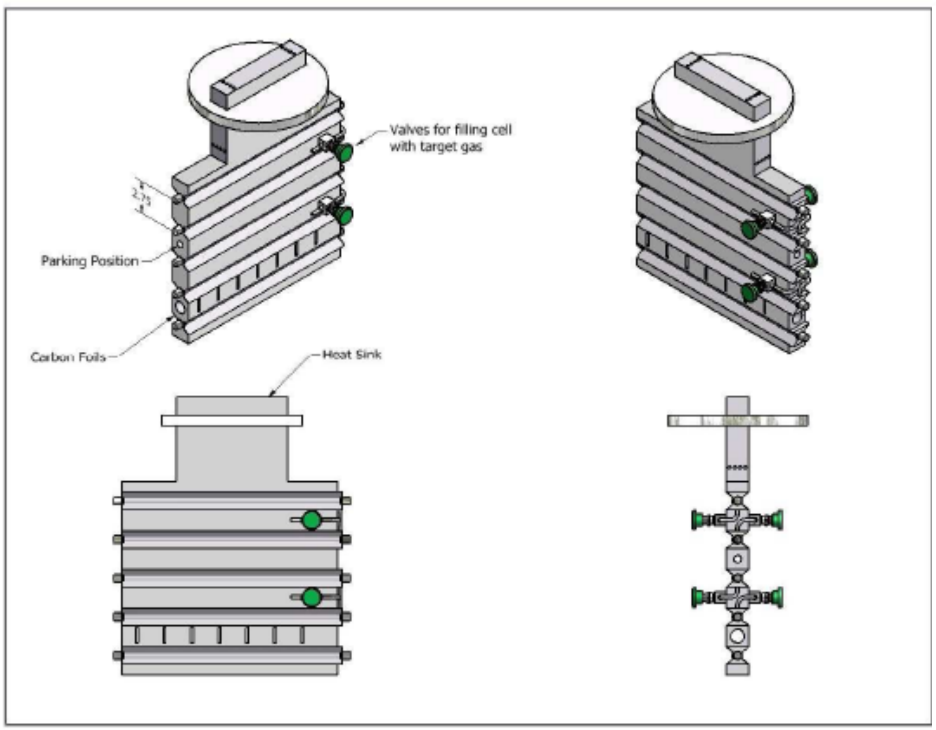
- ✓ *Conceptual Design of a Tritium Gas Target for Jlab,*
  Tritium Target Task Force, Roy J. Holt *et al.*, May 2010
  External consultants:
  - ➢ Bruce Napier of Pacific Northwest National Laboratory (PNNL), author of GENII-NESHAPS code
  - ➢ Phil Sharpe, Director of Safety and Tritium Applications Research (STAR) Facility at Idaho National Laboratory (INL)
  - ➢ R. Wayne Kanady, Radiological Engineer at INL.

- ✓ 1st Jlab Review – June 3, 2010 – "no direct show stoppers" for further development. 45 items identified. Move on to establish,
  - ➢ Design authority – person responsible for project
  - ➢ Engineering team
  - ➢ Responsibility lines for INL, Jlab and collaboration
  - ➢ Approving authority for safety checkout plans

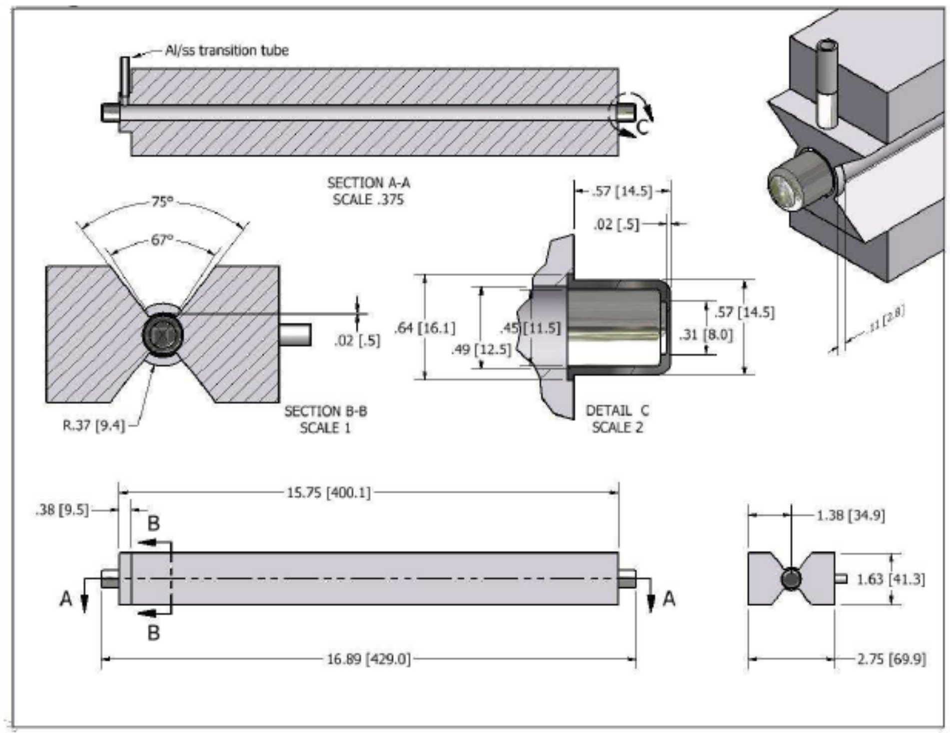
Proposed Target System – II

- ✓ All cells Al 2219 alloy – ^3H compatible, weldable, age hardens after welding and relative high yield strength
- ✓ Fill cells at Safety and Tritium Applications Research (STAR) Facility of Idaho National Lab

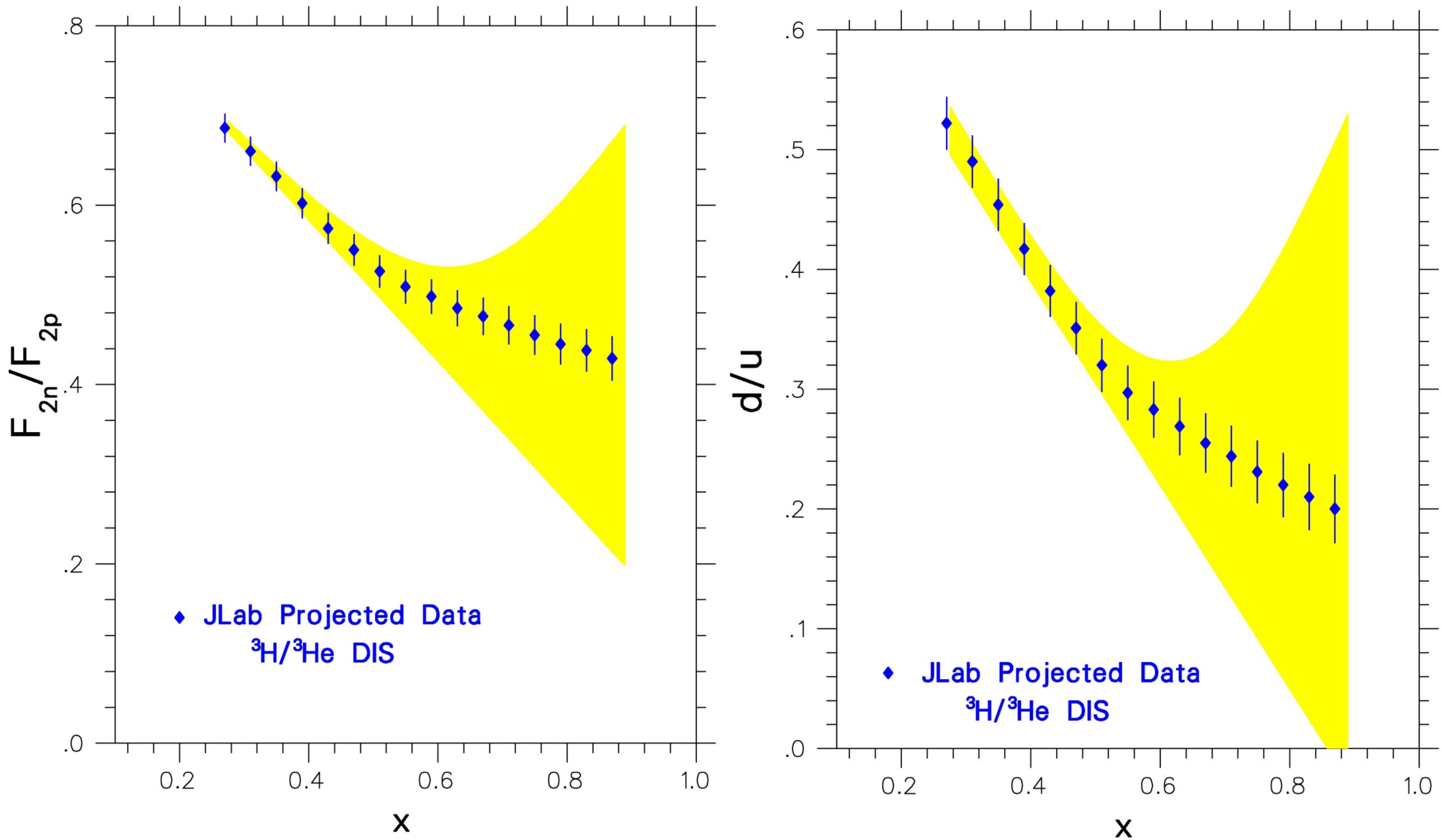
The 5-cell assembly



Single cell



Expected Results for F_2^n/F_2^p and d/u Ratios



Point-to-point uncertainties (in quadrature): statistical (less than +/- 1%), theoretical (negligible to +/- 1% @ 0.86) and +/- 0.5% in ratios (e.g. rad. corr.)

Other ….

Maximize physics output of ^3H target!

- Deep Inelastic scattering
- *x>1* Inelastic scattering
- Quasi-elastic scattering
- Elastic scattering
- Semi-inclusive scattering

>> thank you <<