Status of JLab MARATHON Experiment

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

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For the JLab Hall A Collaboration

Hall A Collaboration Meeting

January 24, 2018

Overview of the Experiment

- MARATHON is measuring NOW! electron deep inelastic scattering (DIS) from 3H, 3He and 2H nuclei using the Hall A Spectrometer Facility of JLab.
- The experiment will extract using a novel method, which exploits the isospin symmetry of the *A=3* nuclei, 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.
- The forthcoming results are expected to be almost free of nuclear structure theoretical uncertainties that dominate the previous SLAC results (extracted from proton and deuteron DIS measurements).
- MARATHON will also measure the EMC effect for 3H and 3He. The expected *A=3* EMC data are considered crucial for the understanding of the effect.

Electron-Nucleus Inelastic Scattering

- Cross section for inelastic electron-nucleus scattering [E (E'): incident (scattered) electron energy, θ: electron scattering angle, M: nuclear mass] in terms of nuclear F_1 and F_2 structure functions:

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

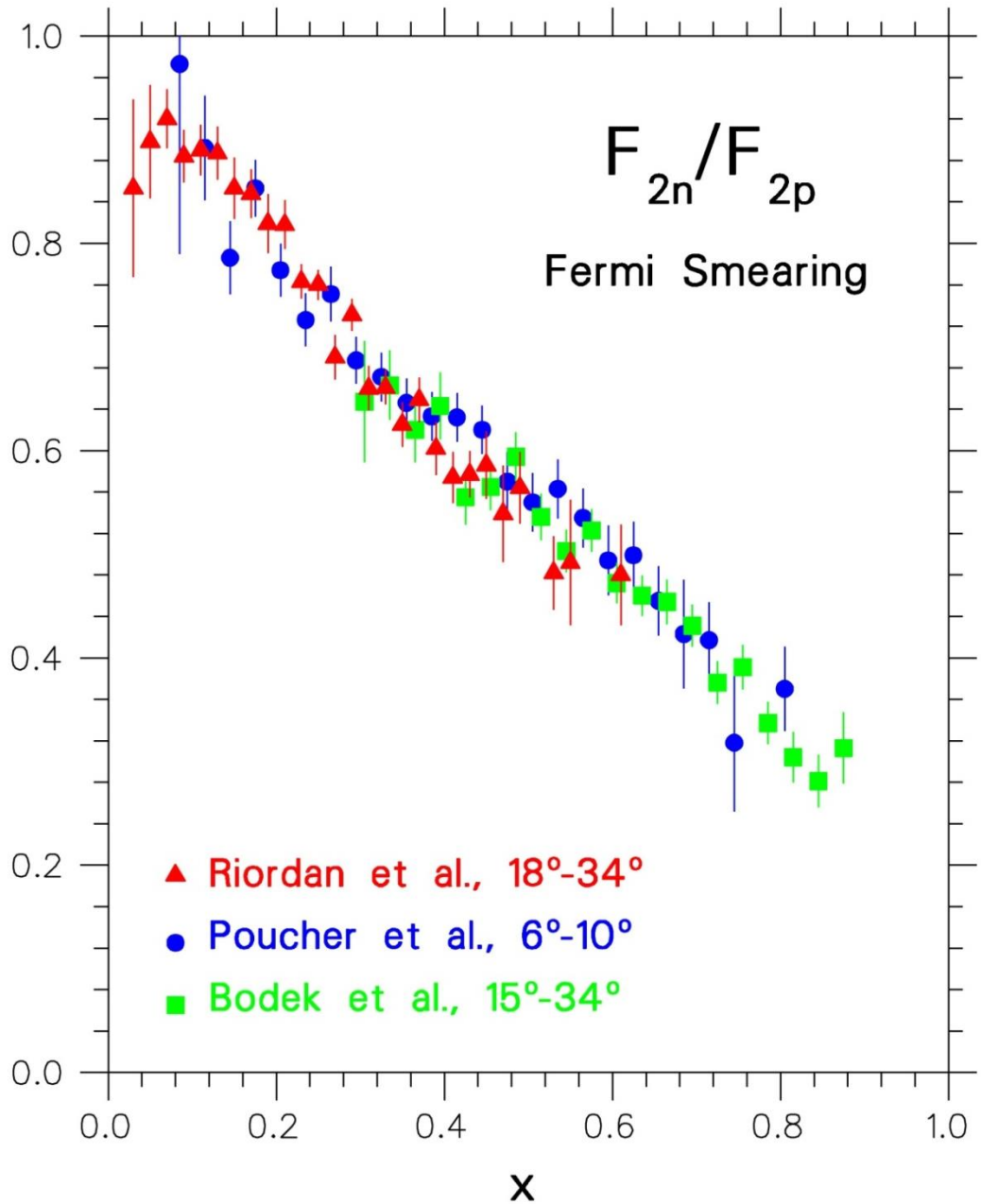
$$R = \frac{F_2 M}{F_1 \nu}\left(1 + \frac{\nu^2}{Q^2}\right) - 1$$

$$\nu = E - E'$$

$$Q^2 = 4EE' \sin^2(\theta/2)$$

- Ratio R has been measured to be the same for proton, deuteron and all other nuclear targets. Cross section ratio for two nuclei, say 3H and 3He, becomes equal to ratio of their F_2 structure functions.

$$\left[\frac{d\sigma(3H)}{d\Omega dE'} / \frac{d\sigma(3He)}{d\Omega dE'}\right] = \left[F_2(3H) / F_2(3He)\right]$$



SLAC 1968-1972

Friedman, Kendall, Taylor

Nobel 1991

F_2^n/F_2^p extracted from *p* and *d* DIS using a Fermi-smearing model and a non-relativistic *N*-*N* potential

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

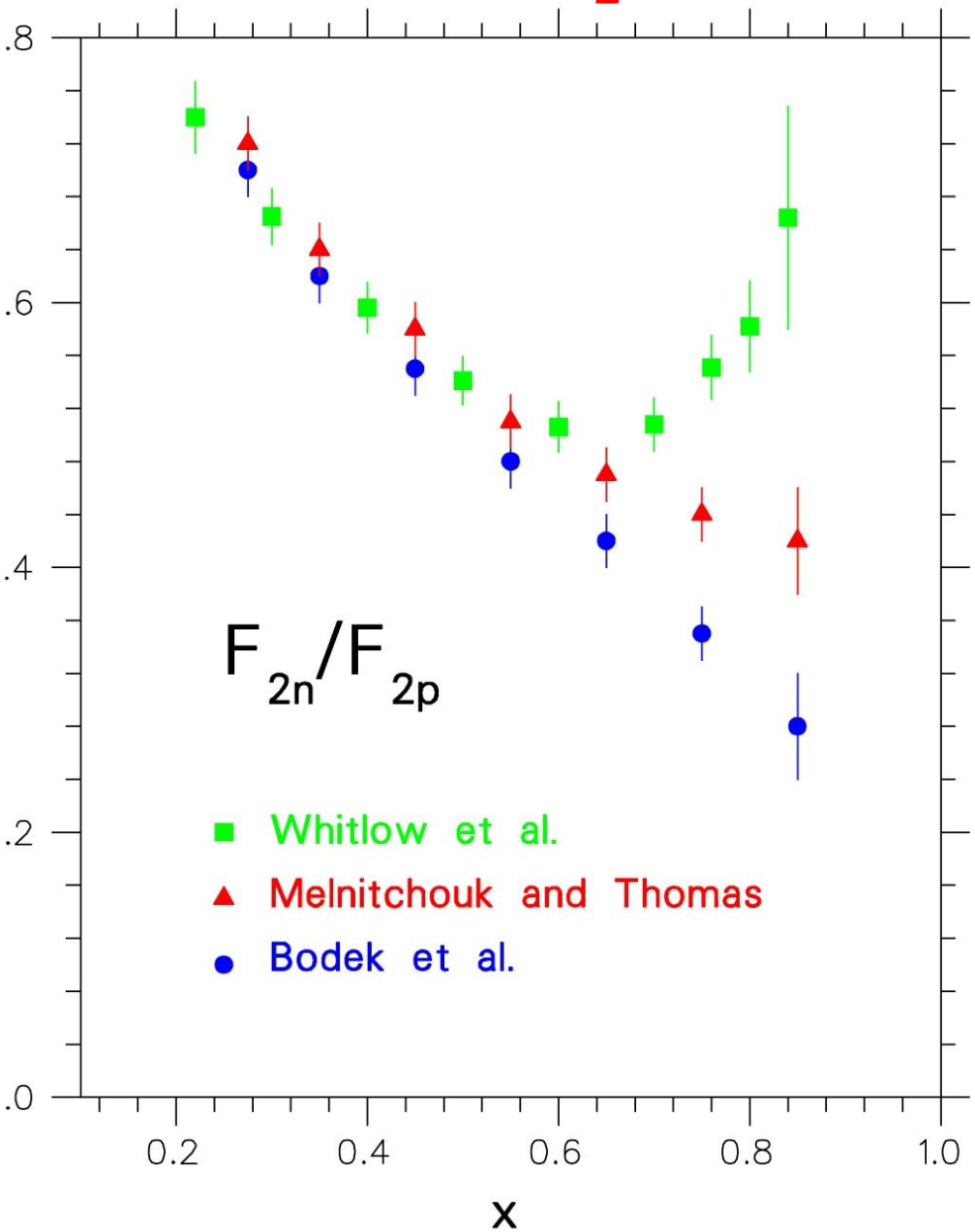
High momentum quarks in *p(n)* are *u(d)* valence quarks

There are no high momentum strange quarks in *p* and *n*

Sea quarks dominate at small *x*

Data consistent with di-quark model by Feynman and others

Nucleon F_2 Ratio Extraction Revisited



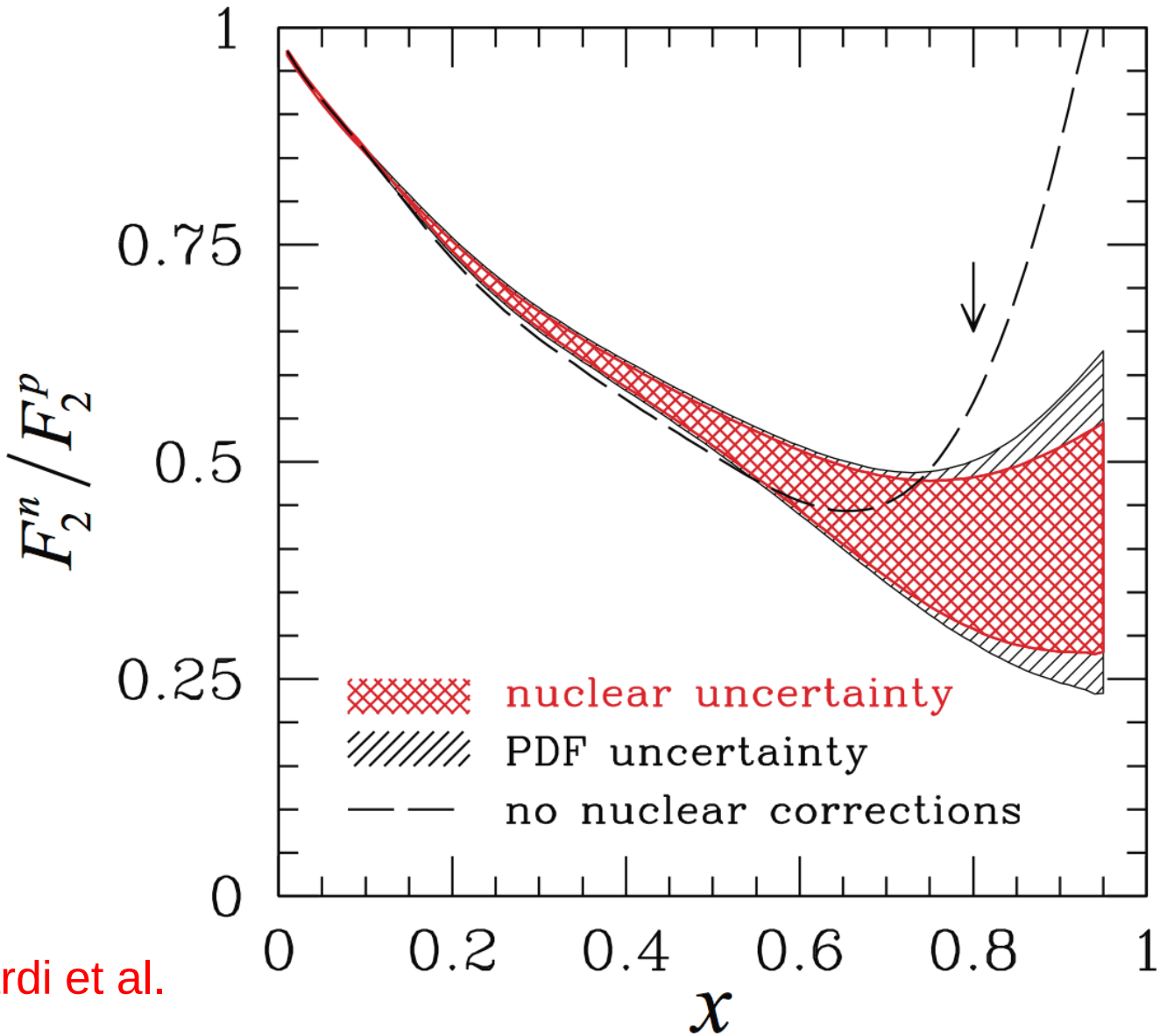
SLAC DIS Data

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

Melnitcouk &Thomas: Relativistic convolution model with empirical binding effects

Bodek: Non-relativistic Fermi-smearing-only model with Paris N-N potential

CJ (CTEQ-JLab) Recent Calculations



A. Accardi et al.

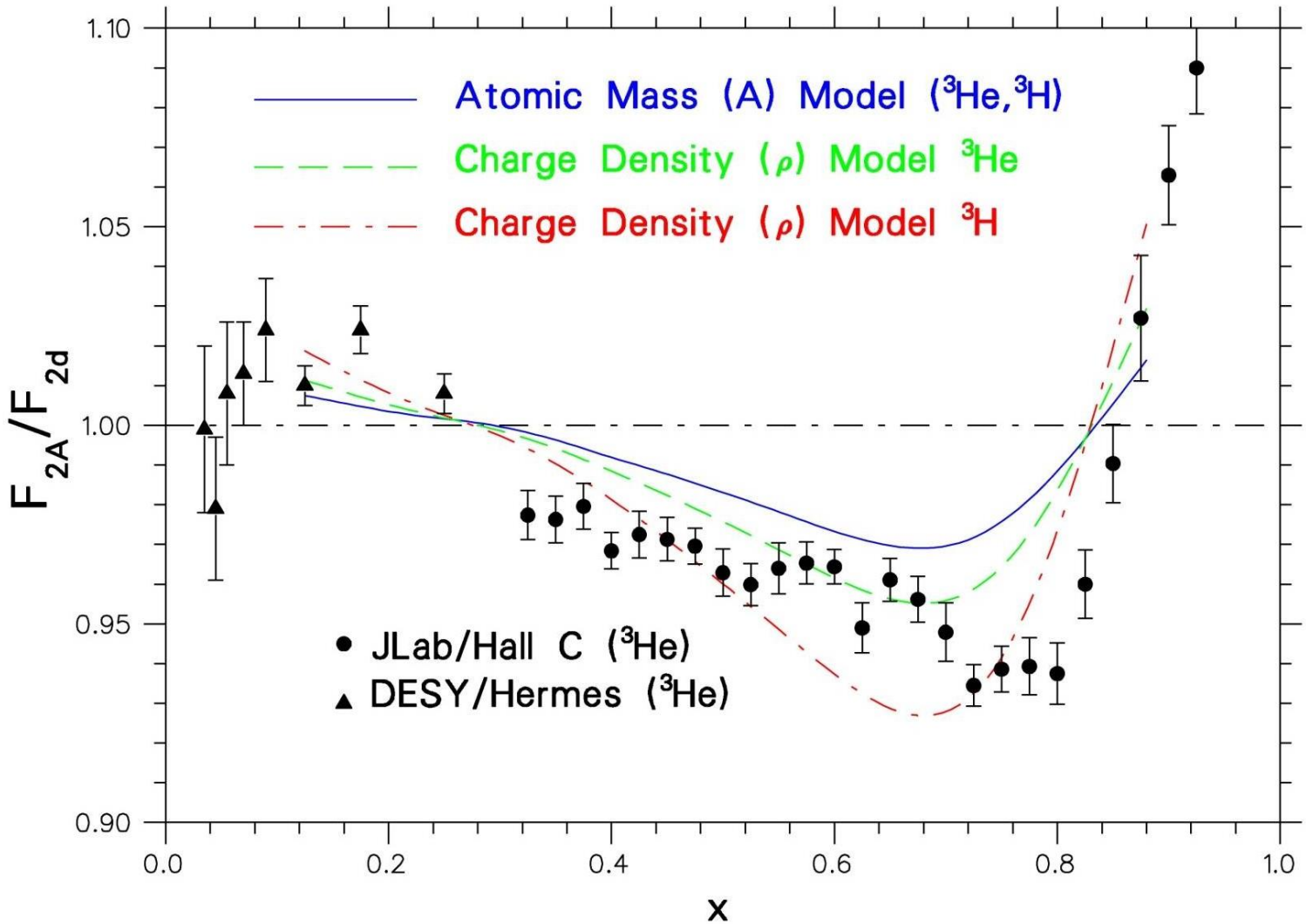
F_2^n / F_2^n, d/u Ratios and A_1 Limits for $x \rightarrow 1$

	F_2^n/F_2^p	d/u	A_1^n	A_1^p
SU(6)	2/3	1/2	0	5/9
Diquark/Feynman	1/4	0	1	1
Quark Model/Isgur	1/4	0	1	1
Perturbative QCD	3/7	1/5	1	1
Quark Counting Rules	3/7	1/5	1	1

A_1: Asymmetry measured with polarized electrons and nucleons. Equal in QPM to probability that the quark spins are aligned with the nucleon spin.

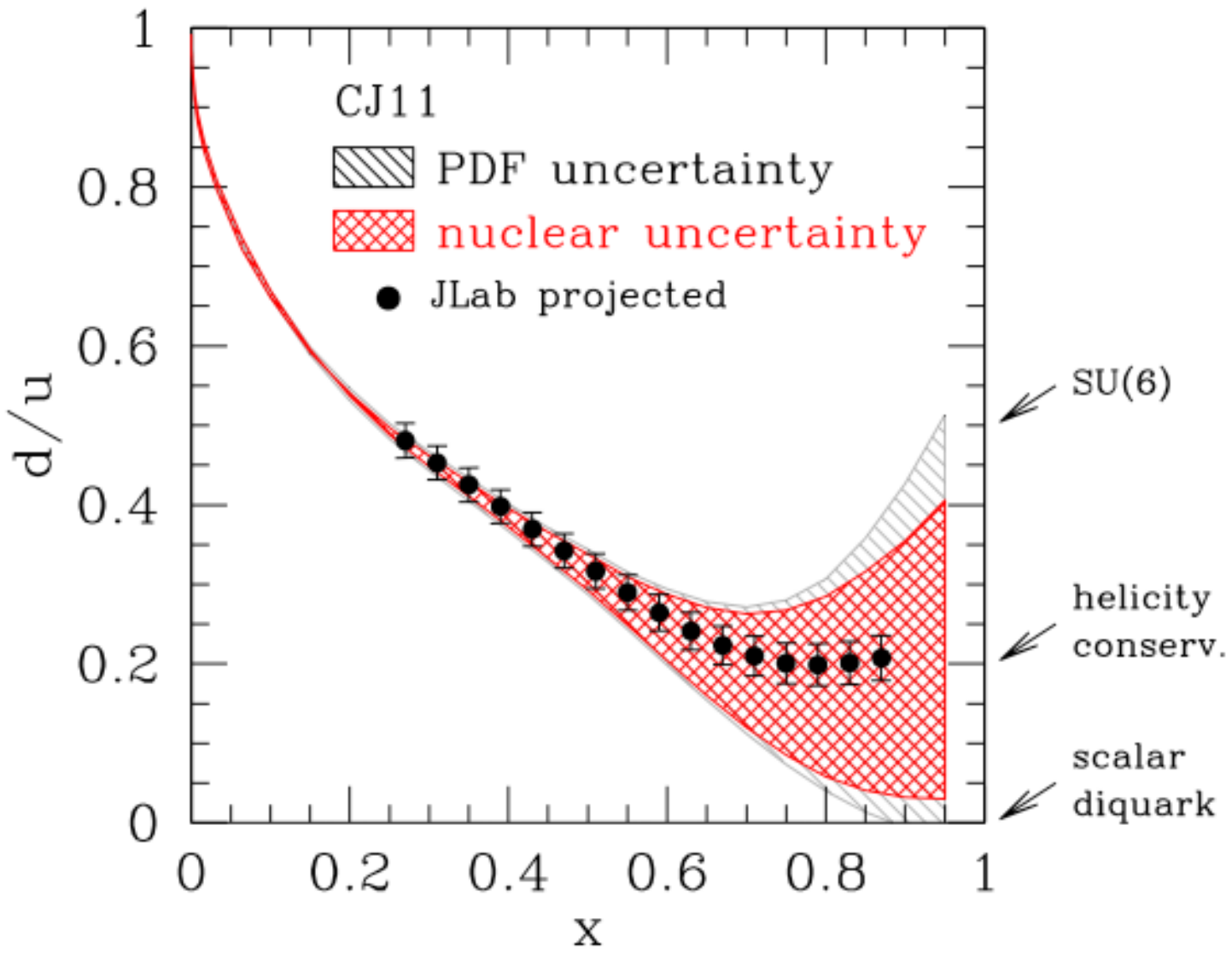
A_1^p, A_1^n: Extensive experimental programs at CERN, SLAC, DESY and JLab (6 GeV and 12 GeV Programs)

EMC Effect for *A*=3 Mirror Nuclei



Hall A data on ^{3}H, ^{3}He will be of similar precision to Hall C data

MARATHON Projected Data (Proposal)



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

- Just perform DIS from ^{3}He and ^{3}H. Binding of nucleons in the two nuclei is of same nature. Differences between bound and free nucleons in the two nuclei is calculable, summarized, for their ratio, by some parameter R^* (W. Melnitchouk *et al.*).

- 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 F_2 structure function ratio as calculated using R^*:

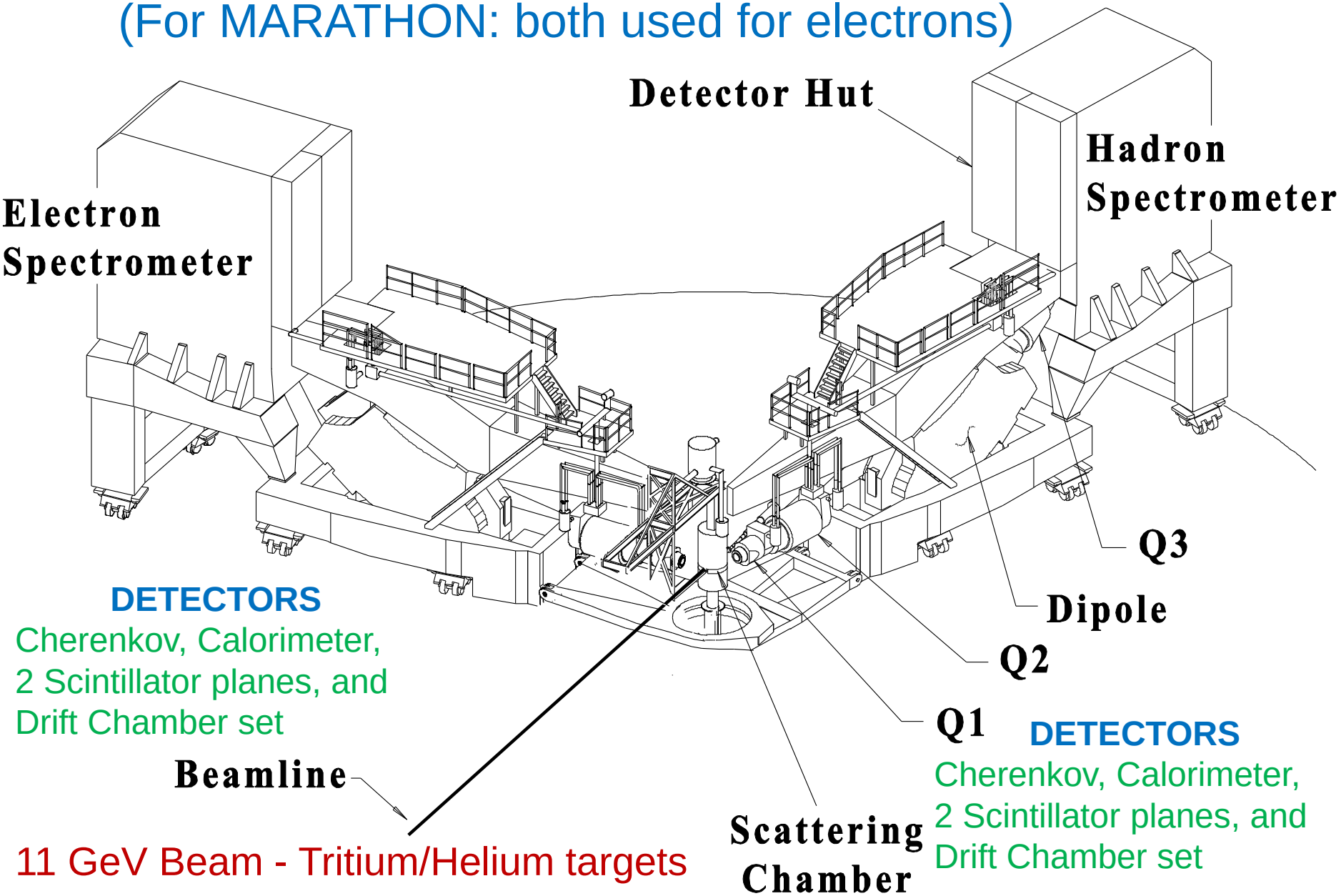
$$\frac{\sigma^{^3He}}{\sigma^{^3H}} = \frac{F_2^{^3He}}{F_2^{^3H}} = R^* \frac{2F_2^p + F_2^n}{F_2^p + 2F_2^n}$$

- Determine nucleon F_2 ratio using A=3 DIS cross section data and $R^*(\approx 1)$ from theory:

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

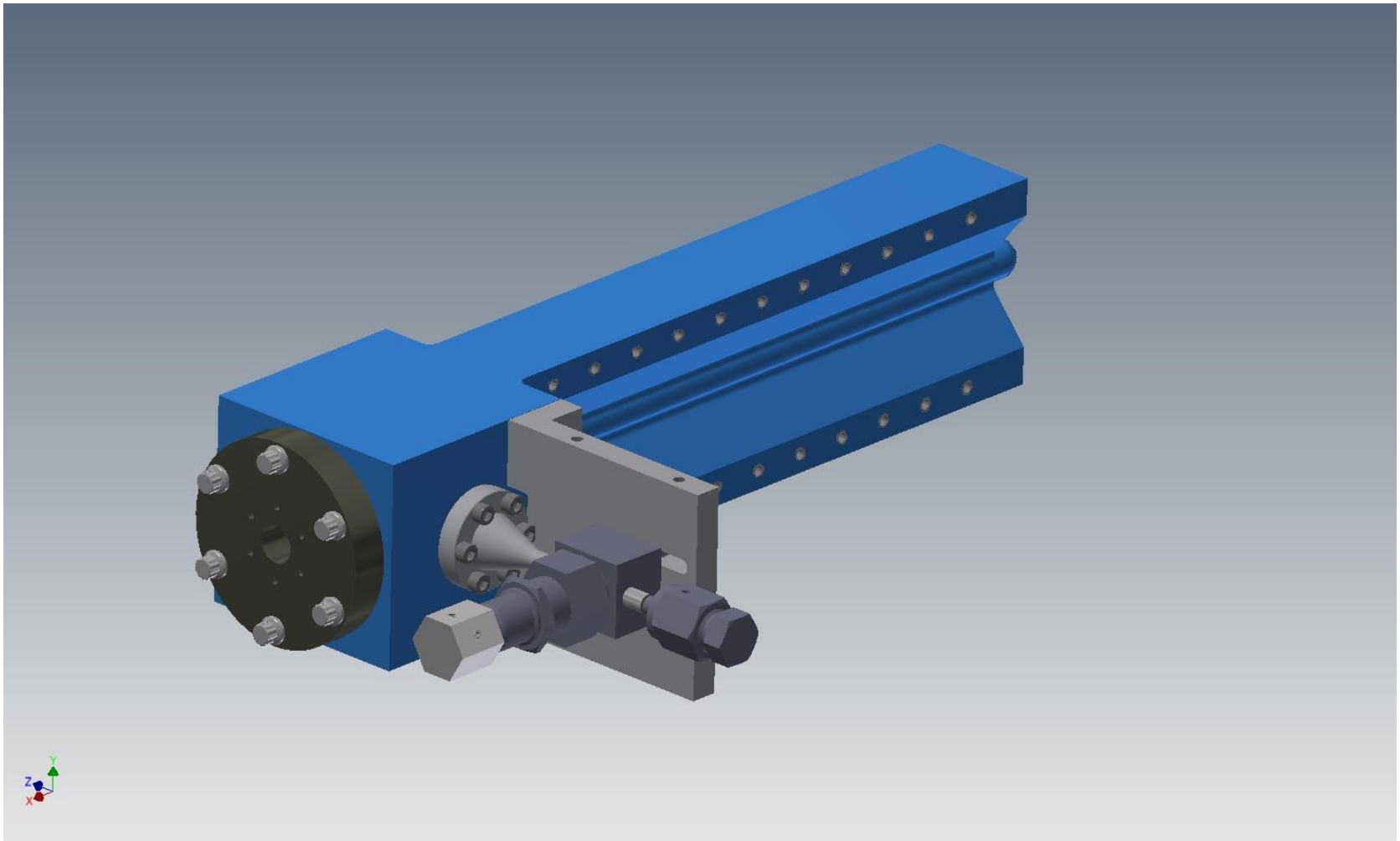
JLab Hall A High Resolution Spectrometers

(For MARATHON: both used for electrons)



11 GeV Beam - Tritium/Helium targets

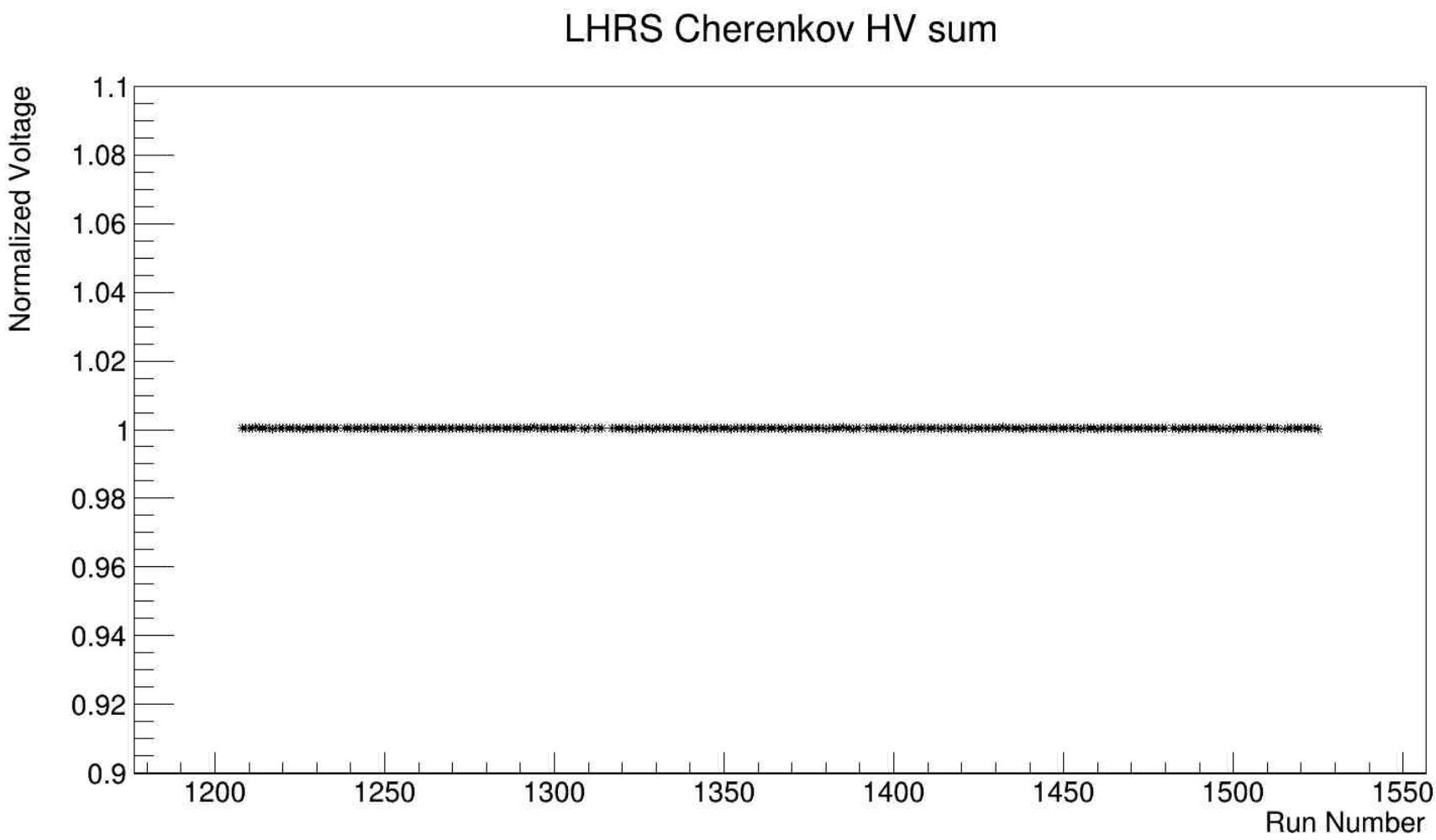
3H, 3He, 2H, 1H Gas Cells of Tritium Program
(See Hall A Tritium Wiki, Dave Meekins)



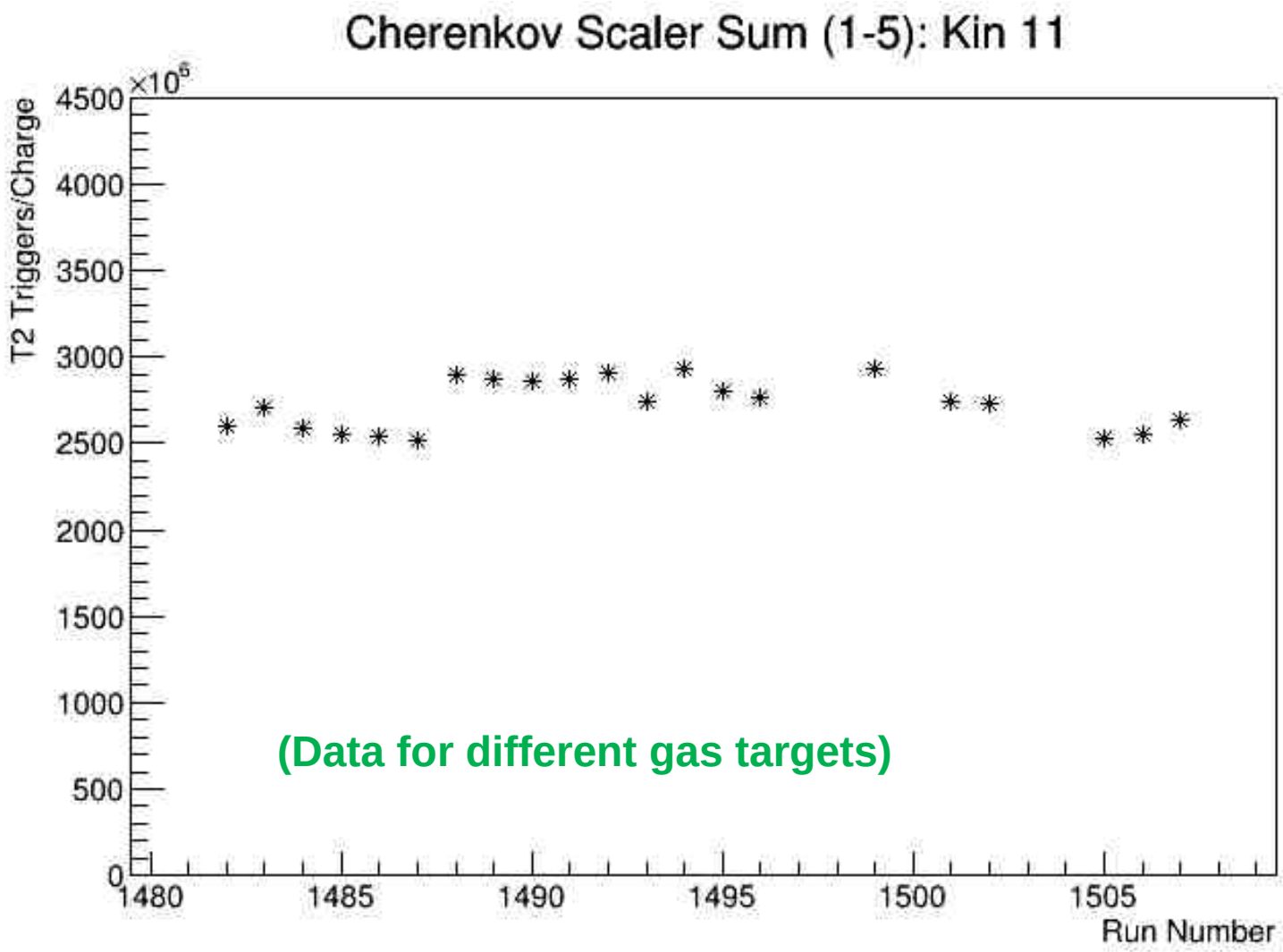
Today's Status of MARATHON

- Experiment has been running since January 12.
- Currently taking data with the Left-HRS, which has been checked out and calibrated.
- We have high statistics data for 3H, 3He and 2H for x = 0.22-0.62 (7 pts), and for 1H for x = 0.22-0.30 (3 pts).
- The Right-HRS has had problems with its dipole. As of this morning it appears to be stable at E' = 2.9 GeV, which is the momentum required for the lowest-rate, highest-x point (=0.82) of the proposal.
- There are problems with the motor motion of the Right-HRS. May have to move it to large angle(s) "manually".
- PRELIMINARY results (not to be shown) indicate that the deuteron/proton and triton/helion cross section ratios are, at low x, consistent with expectations.

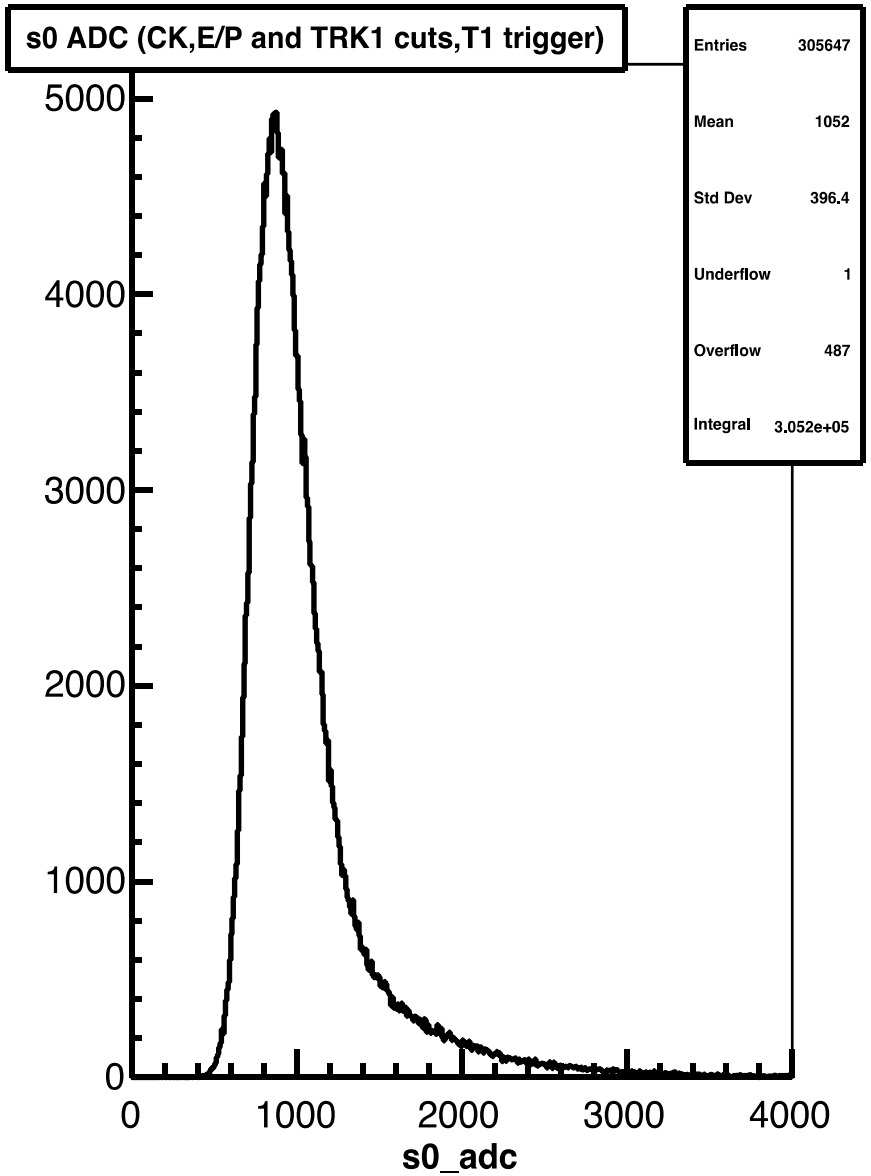
MARATHON High Voltage Monitoring (Example)

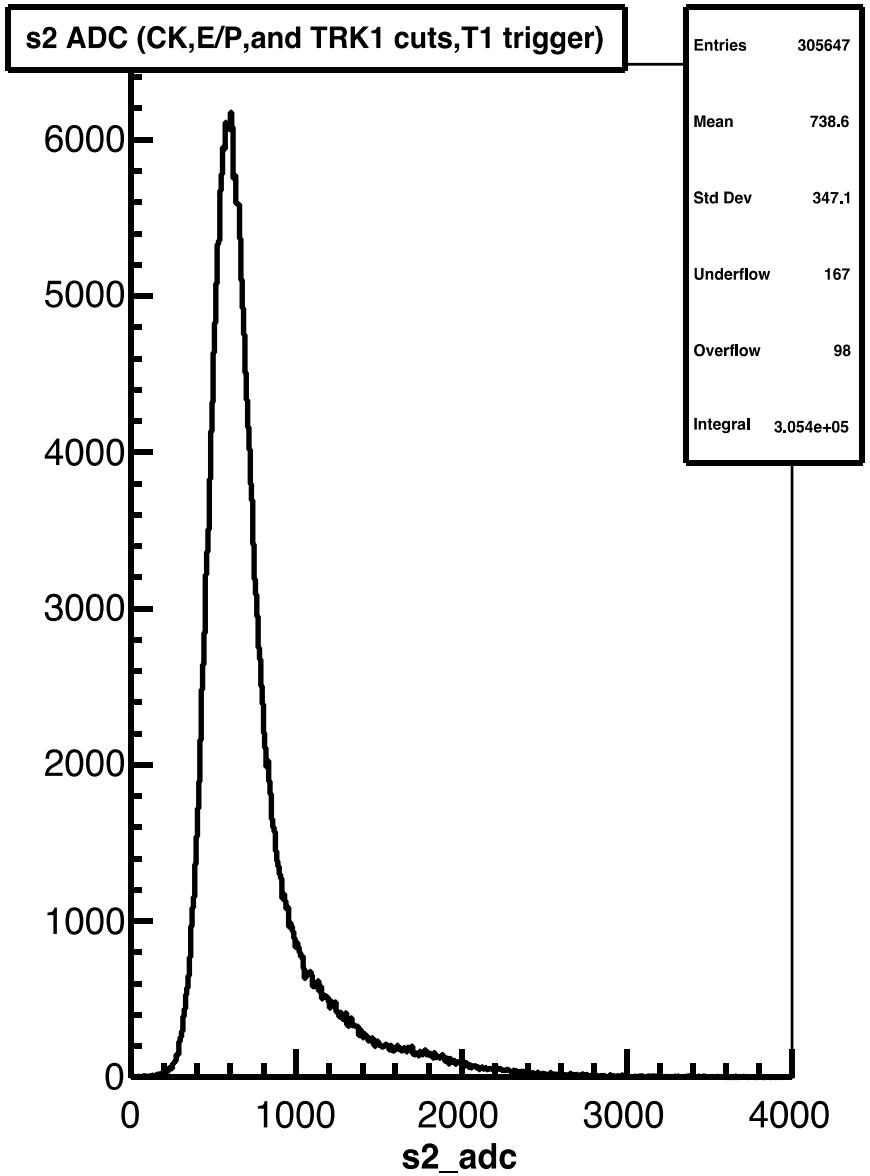


MARATHON Scaler Rate Monitoring (Example)

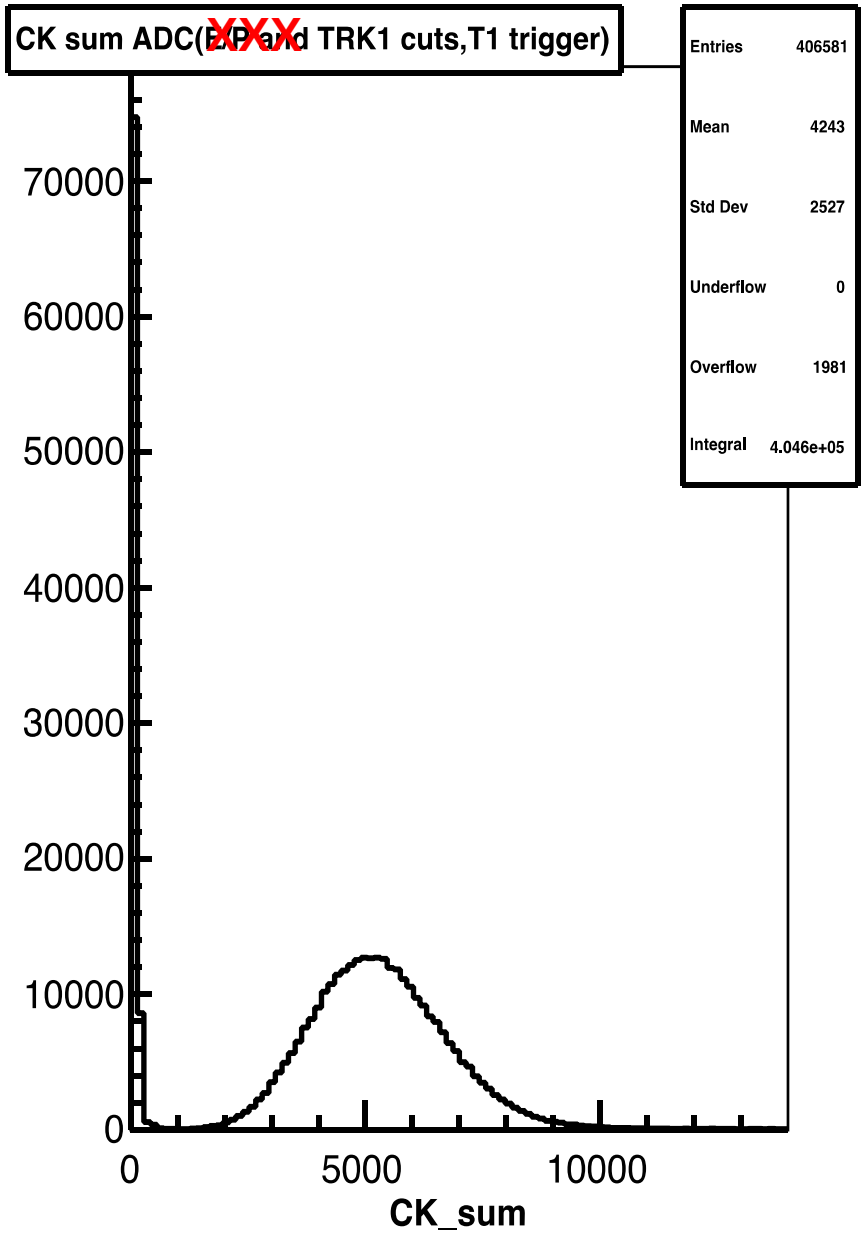


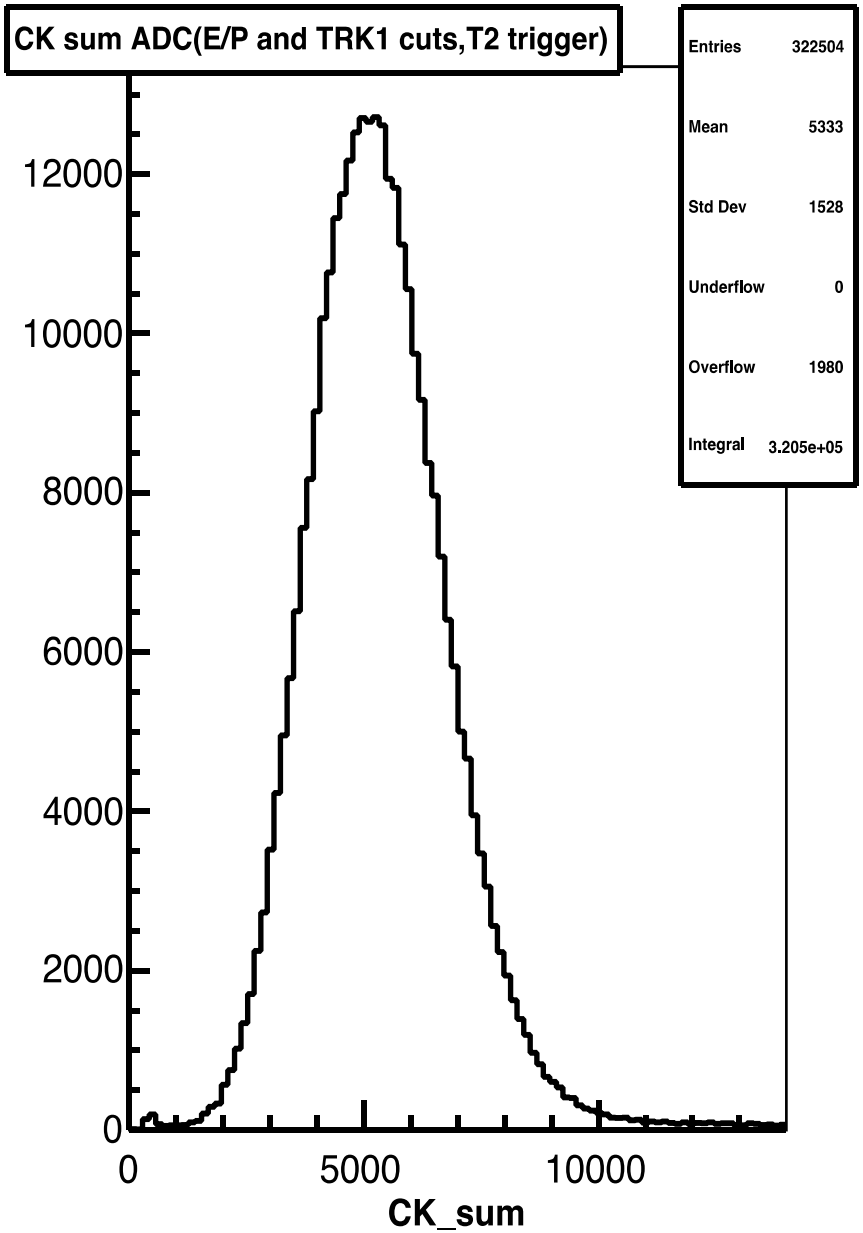
Left HRS Scintillator Performance



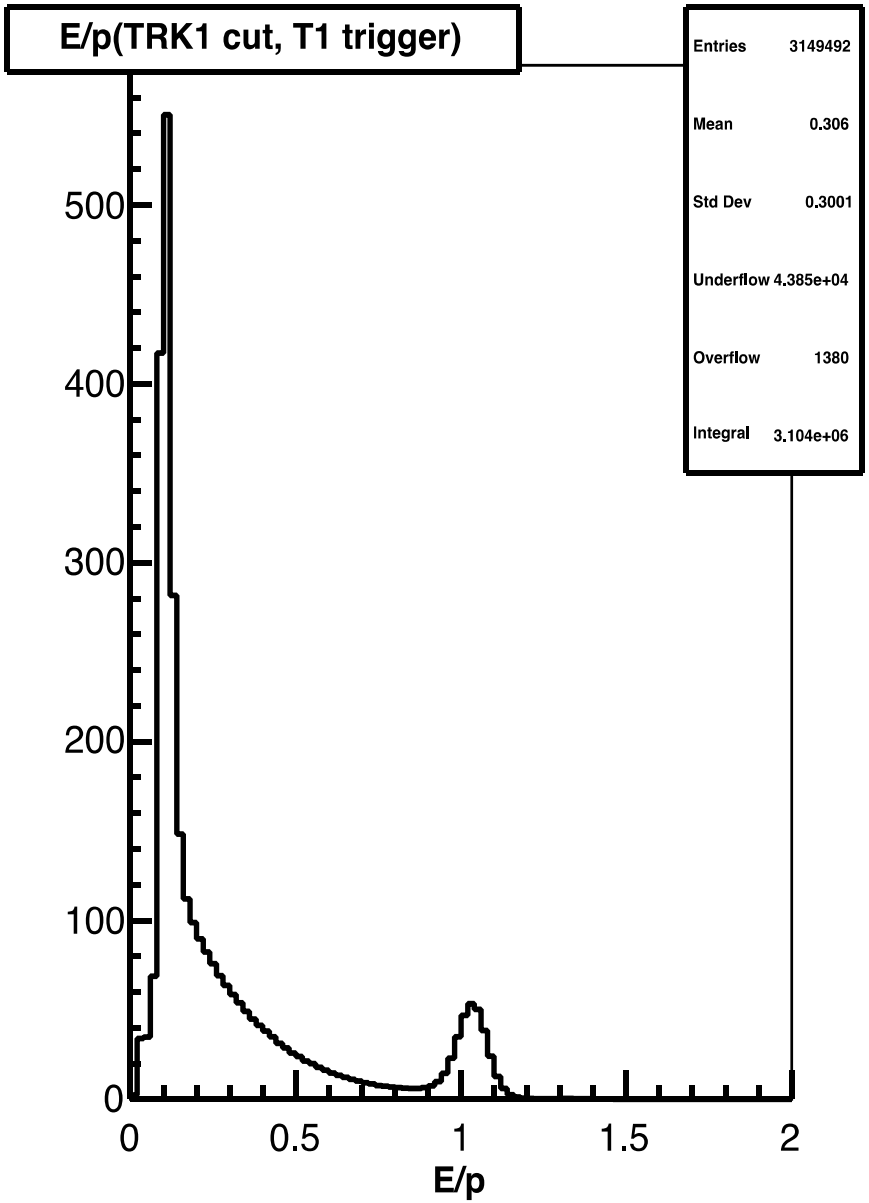


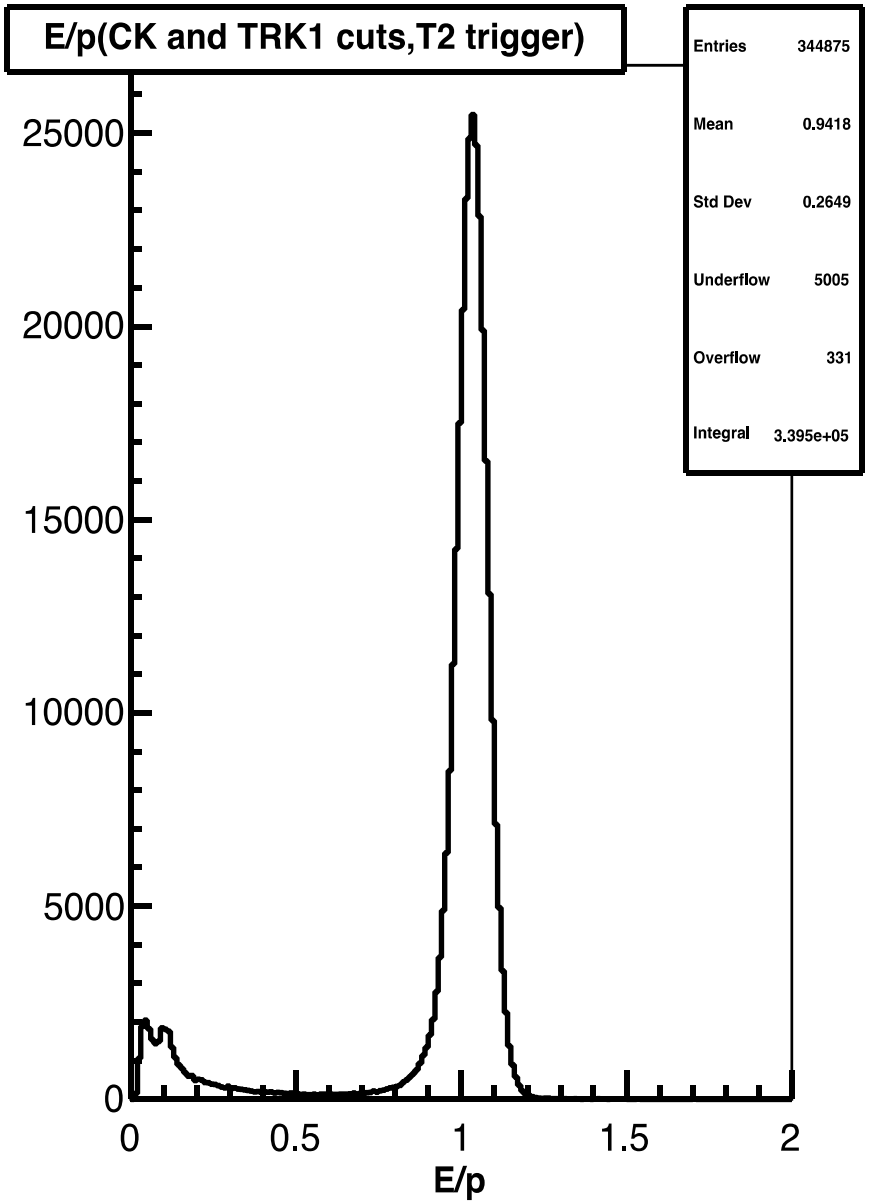
Left HRS Cherenkov Performance



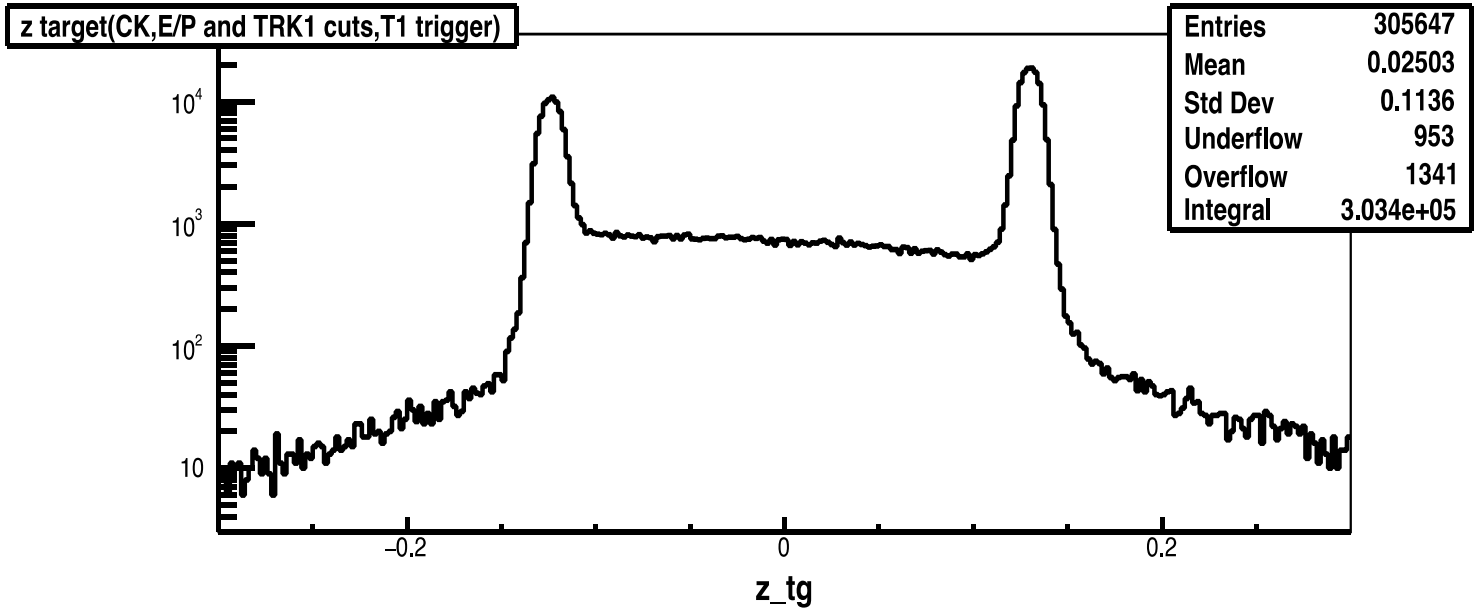


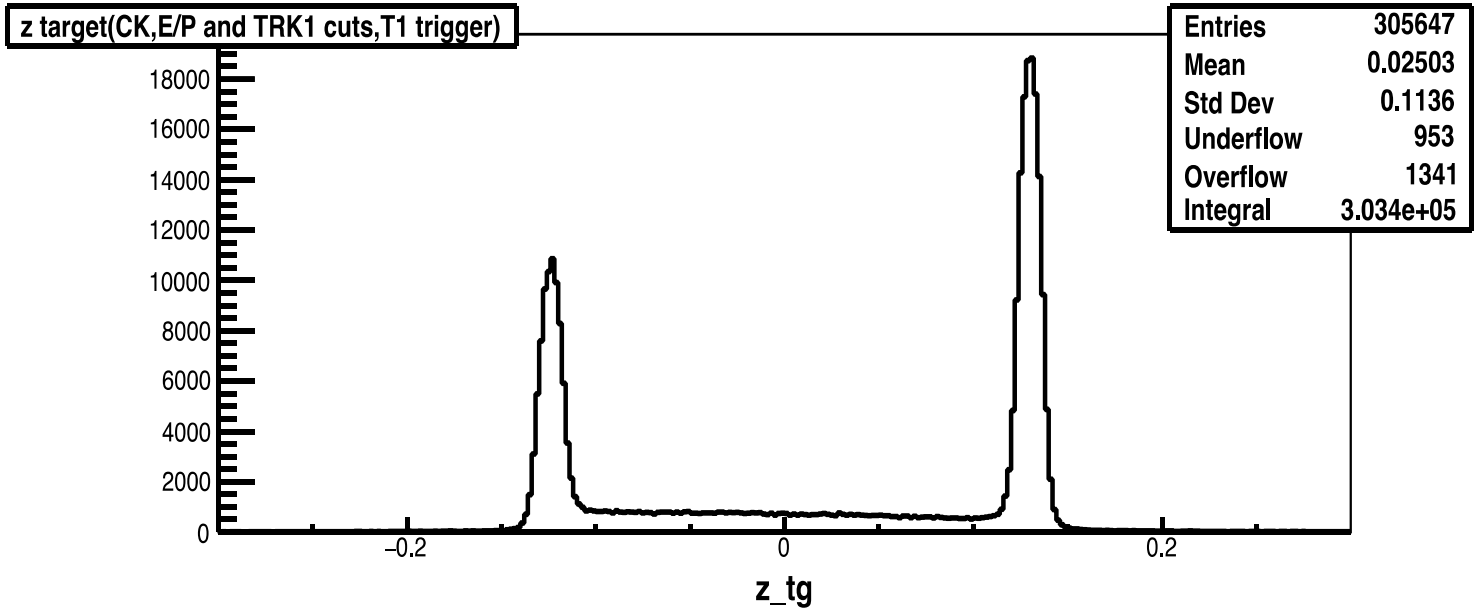
Left HRS Calorimeter Performance



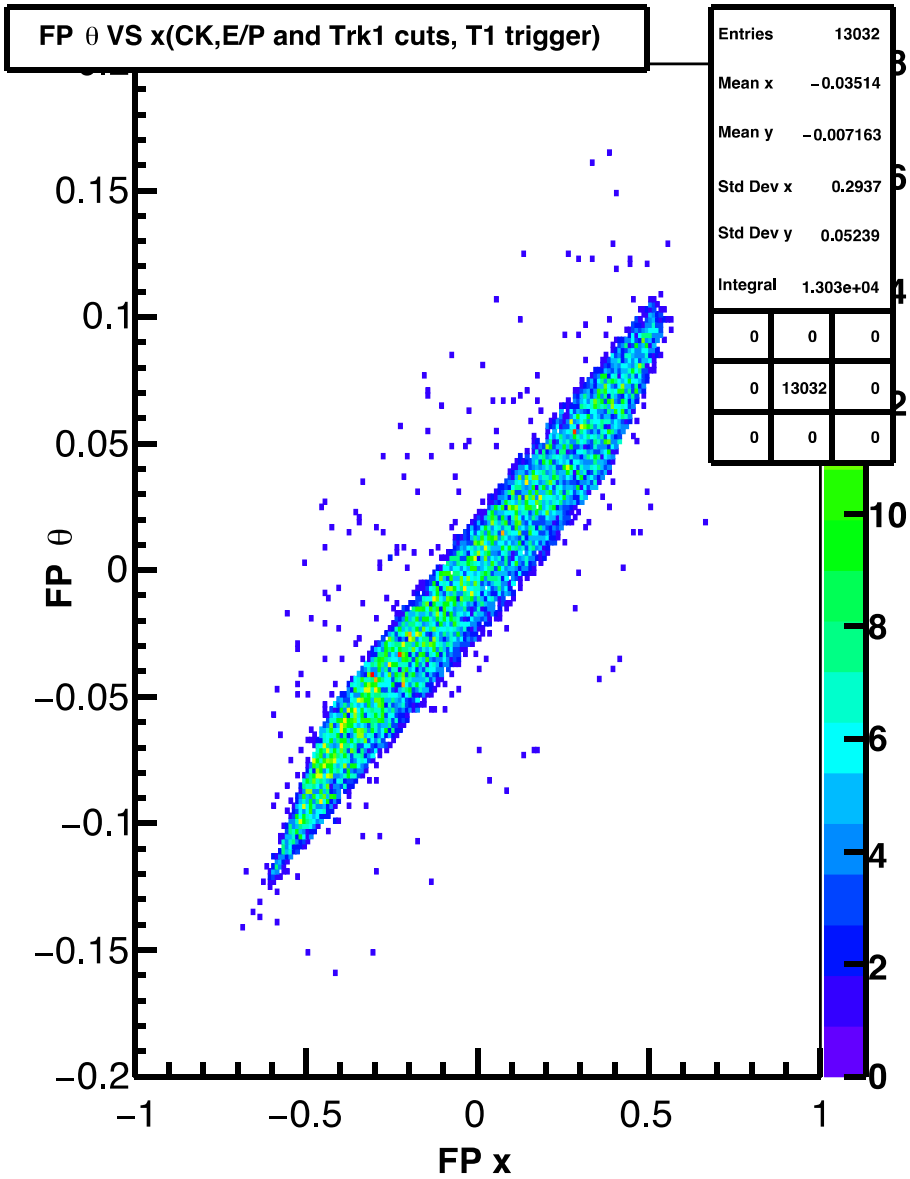


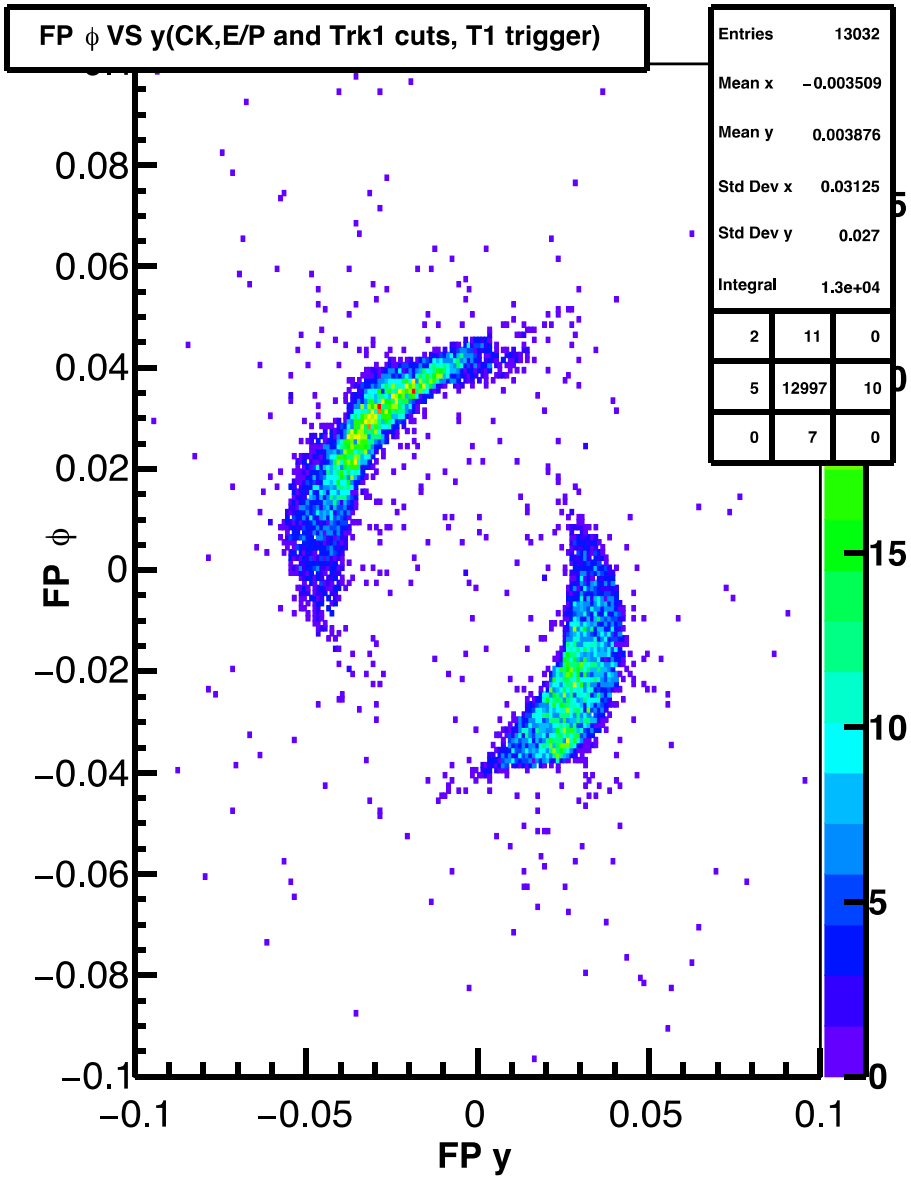
Left HRS - Origin of Events Along the Target



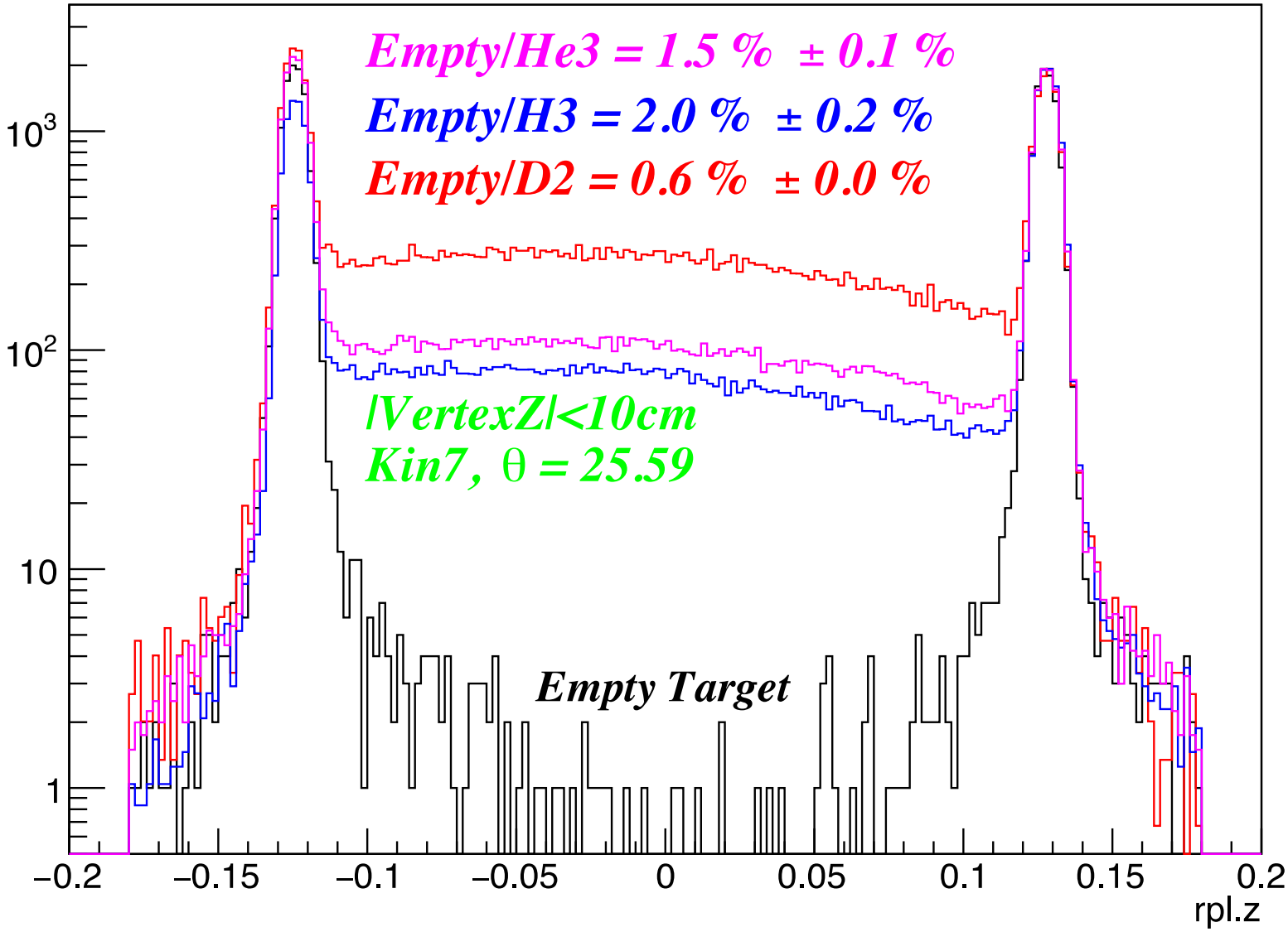


Left HRS – Empty Target Run
Focal Plane coordinates



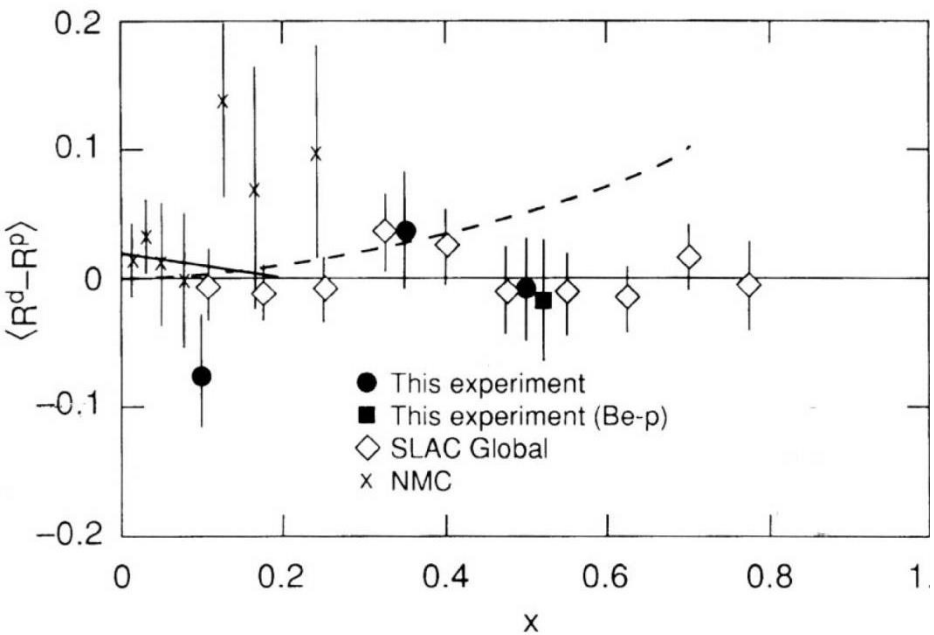
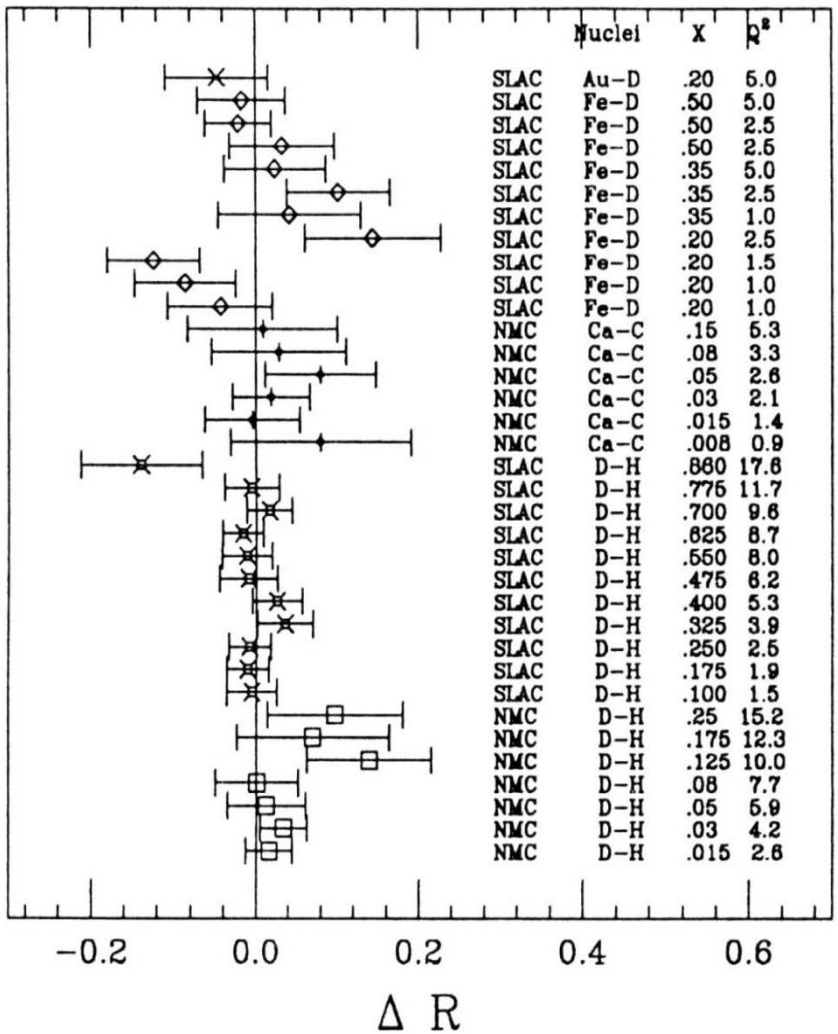


Events from Target Cell End Caps
Proposal Kinematics 7 x = 0.46



Summary-Thanks

- MARATHON has been **RUNNING** with the Left HRS for 11 days, taking low- and medium-x data (x = 0.22-0.62).
- Currently checking out the Right HRS (R-HRS), which has had problems with its dipole. Hope to be stable and use it to take low-rate, very high-x data (x = 0.82).
- We have about 55 days to go (after 18 years!).
- Offline analysis will start soon, after the R-HRS checkout.
- **THANKS TO:**
- THE OUTSTANDING STUDENTS OF THE TRITIUM FAMILY AND THE GMP/DVS COLLABORATIONS;
- THE OUTSTANDING POSTDOCTORAL ASSOCIATES OF THE TRITIUM FAMILY AND THE GMP/DVS COLLABORATIONS;
- Wally Melnitchouk, Roy Holt, Dave Meekins, and Doug Higinbotham for their invaluable contributions;
- All the Accelerator and Hall A Scientific and Technical Staff of JLab.

$R=\sigma_L/\sigma_T$ Measurements

SLAC/CERN data show that the ratio $R=\sigma_L/\sigma_T$ is the same for all nuclei within experimental errors