

Neutrino/Electron scattering comparison

Similarities and differences between
electron on neutrino scattering

Comparing Neutrino simulations to
electron scattering data

Motivation

- Electron and neutrino scattering on nuclei should exhibit the same nuclear effects, particularly in final state interactions
- Interpretation of neutrino experiments is aided by neutrino scattering Monte-Carlo simulations
- Adapt neutrino simulations to check nuclear effects by comparing to electron scattering data

Comparisons

- Lepton scattering via virtual exchange Boson
 - Neutrino – Z or W
 - Electron – Photon
- Probe same nucleon/parton distributions in similar but not identical ways
- Electron scattering benefits
 - Intense beams of narrow and known energy. $\frac{\Delta E}{E} < 10^{-3}$
 - Scattered electron and one hadronic product measured to similar precision. Exclusive reactions.
 - High rates or rare processes (high momentum components)
 - Polarization

Comparisons

- ◆-----◆
- Propagators $\frac{1}{Q^2}$ $\frac{1}{(Q^2 + M_W^2)}$
 - Electron strongly angle dependent
 - Can't integrate
- Implications $\sigma_M = \frac{4\alpha^2 E'^2 \cos^2 \theta / 2}{Q^4} = \frac{\alpha^2 \cos^2 \theta / 2}{4 E^2 \sin^4 \theta / 2}$
 - L/T separations require careful attention to geometry
 - High small angle rates and other backgrounds make open detectors and small theta measurements challenging
- Typically measure final electron and 1 hadron in limited $\Delta\Omega$ ΔP bites
 - Limited coverage of final state processes (Hadron rescattering)

Radiative Corrections

- Electron charge and light mass make internal bremsstrahlung important
- Pre radiation changes kinematics at vertex (DIS)
- Post radiation changes apparent kinematics
- Terms interfere. Equivalent radiator method.
- Coulomb corrections needed for $Z > 1$ targets

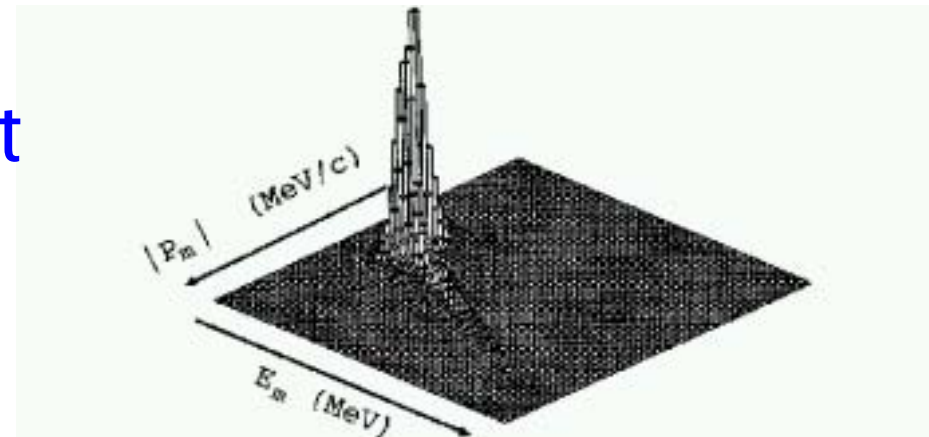
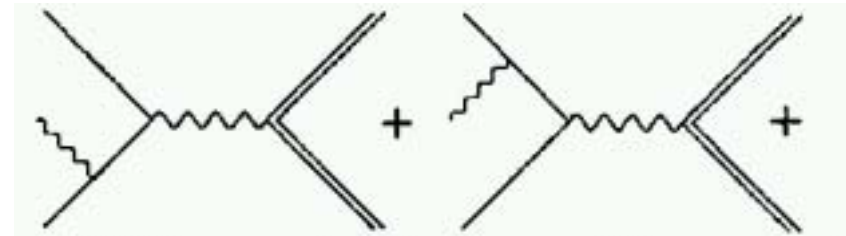
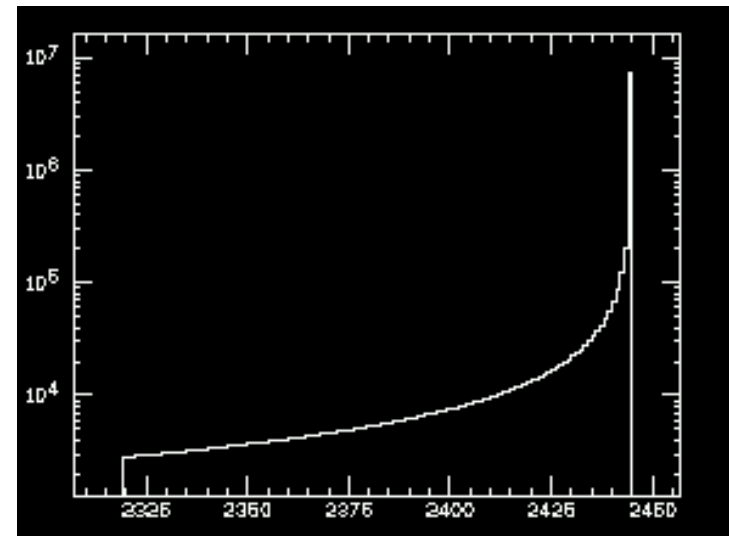


FIG. 1. Distribution of counts in E_m and $|p_m|$ for $(e, e'p)$ from hydrogen at $Q^2 = 1 \text{ (GeV}/c)^2$, demonstrating the existence of "tails" due to bremsstrahlung radiation. The E_m axis runs in the bottom-right direction, from -25 to 125 MeV in bins of 2.5 MeV; the $|p_m|$ axis runs towards bottom-left, from -160 to 160 MeV/c in bins of 5 MeV/c.

Electron scattering with Neutrino MC

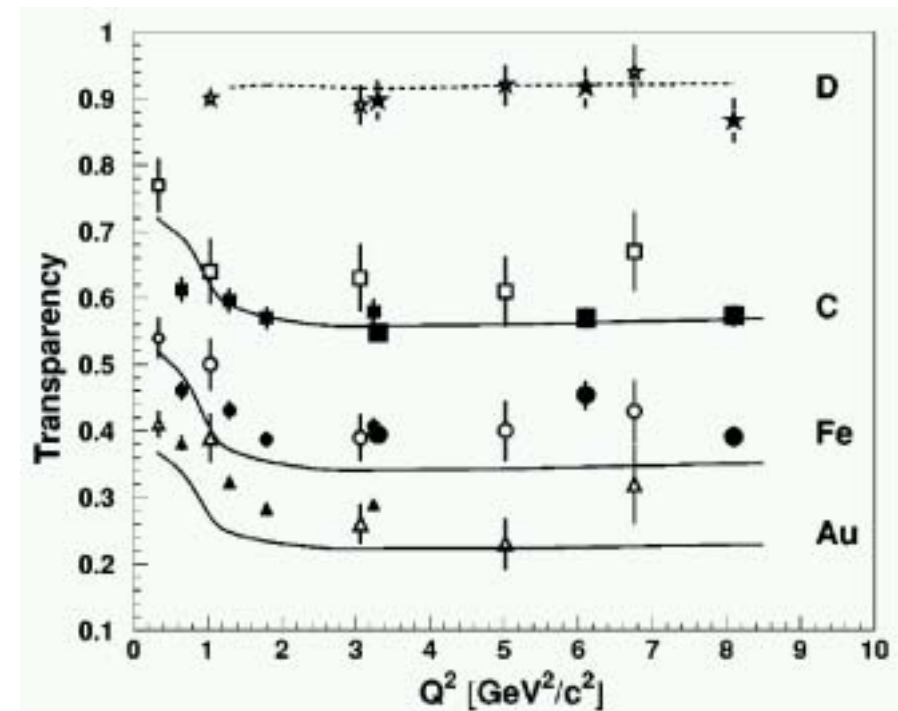
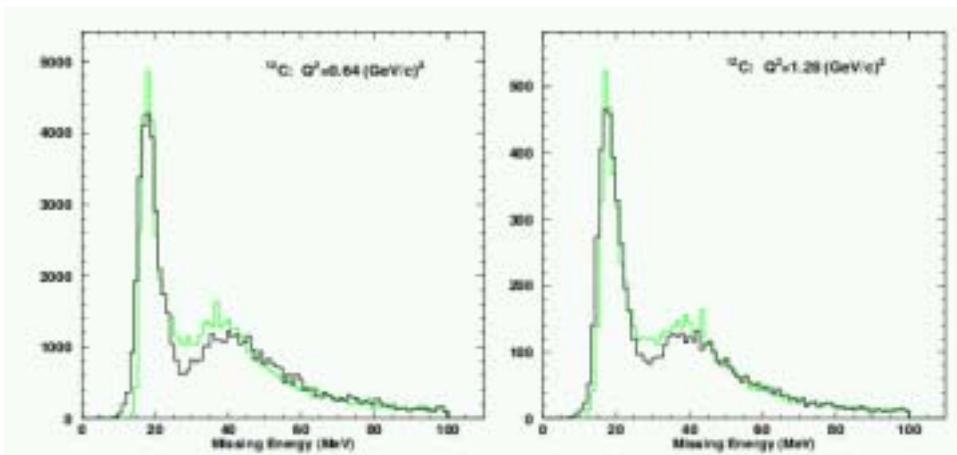
- Seems sensible to modify MC codes to generate electron scattering events
- Feed events into existing spectrometer simulations
- How to deal with $1/Q^4$ behaviour and radiative corrections?
- Spectrometer simulations use weighted events
 - Run NC simulation, but calculate $\frac{\sigma_e}{\sigma_\nu}$ for each event
- Use “radiated beam” as input
 - MC expect smooth beam dist
- Radiate final “electron”



Proton Transparency

- Measurements don't deal with where “absorbed” protons “reappear”
- Missing $E < 100$ MeV explained by combination of spectral function and radiative tails

$$T(Q^2) = \frac{\int_V d^3 p_m dE_m Y_{exp}(E_m, \vec{p}_m)}{\int_V d^3 p_m dE_m Y_{PWIA}(E_m, \vec{p}_m)}$$



Pion Transparency

- No major studies of $A(e, e' \pi^\pm)$ vs A & Q^2
- JLAB E01-107 will be done for $P_\pi > 1 \text{ GeV}/c$
- But, JLAB pion production on p, d, He (Pion Form Factor, Pion Excess) include Carbon and Aluminum data to subtract target wall contributions.

Ebeam	W	Q2	Ppi	Targets
0.845	1.15	0.4	0.29	C12(pi+), Al(pi+-)
1.645	1.15	0.4	0.29	C12(pi+), Al(pi+-)
1.645	1.6	0.4	1	C12(pi+), Al(pi+-)
3.245	1.6	0.4	1	C12(pi+-), Al(pi+-)

Inclusive scattering



$$\theta_e = 20.5^\circ$$

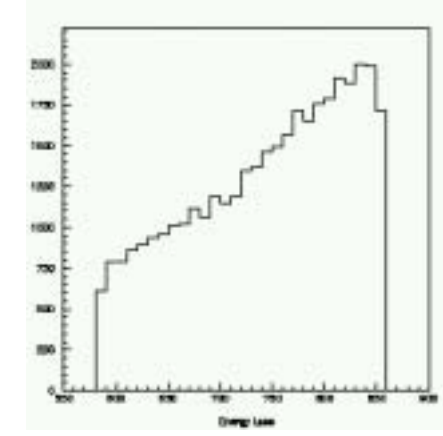
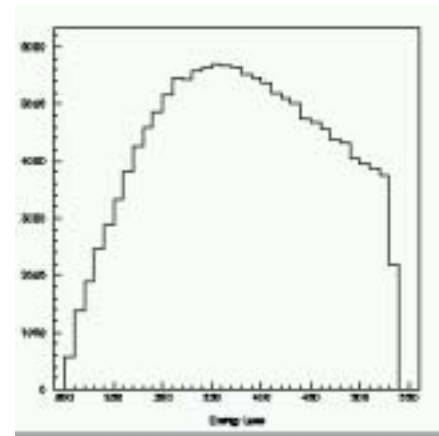
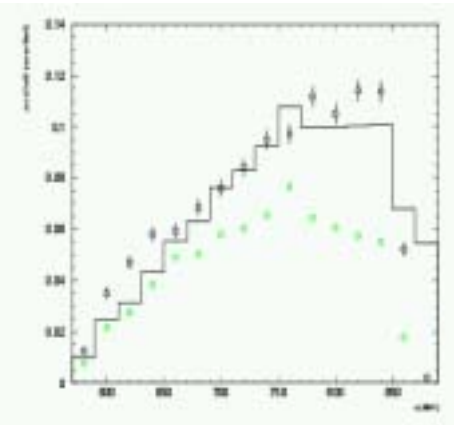
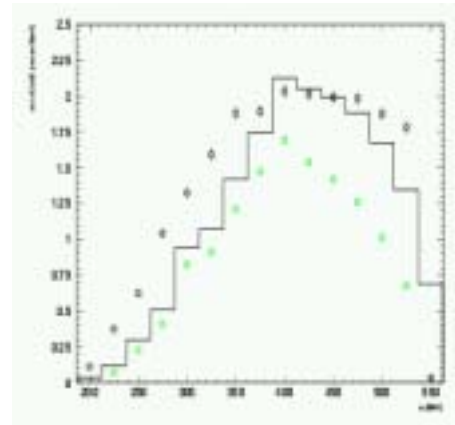
$$Q^2 = 0.6 \text{ GeV}^2$$

$$\theta_e = 32.0^\circ$$

$$Q^2 = 1.3 \text{ GeV}^2$$

$$E = 2445 \text{ MeV} \quad {}^{12}\text{C}(e, e')$$

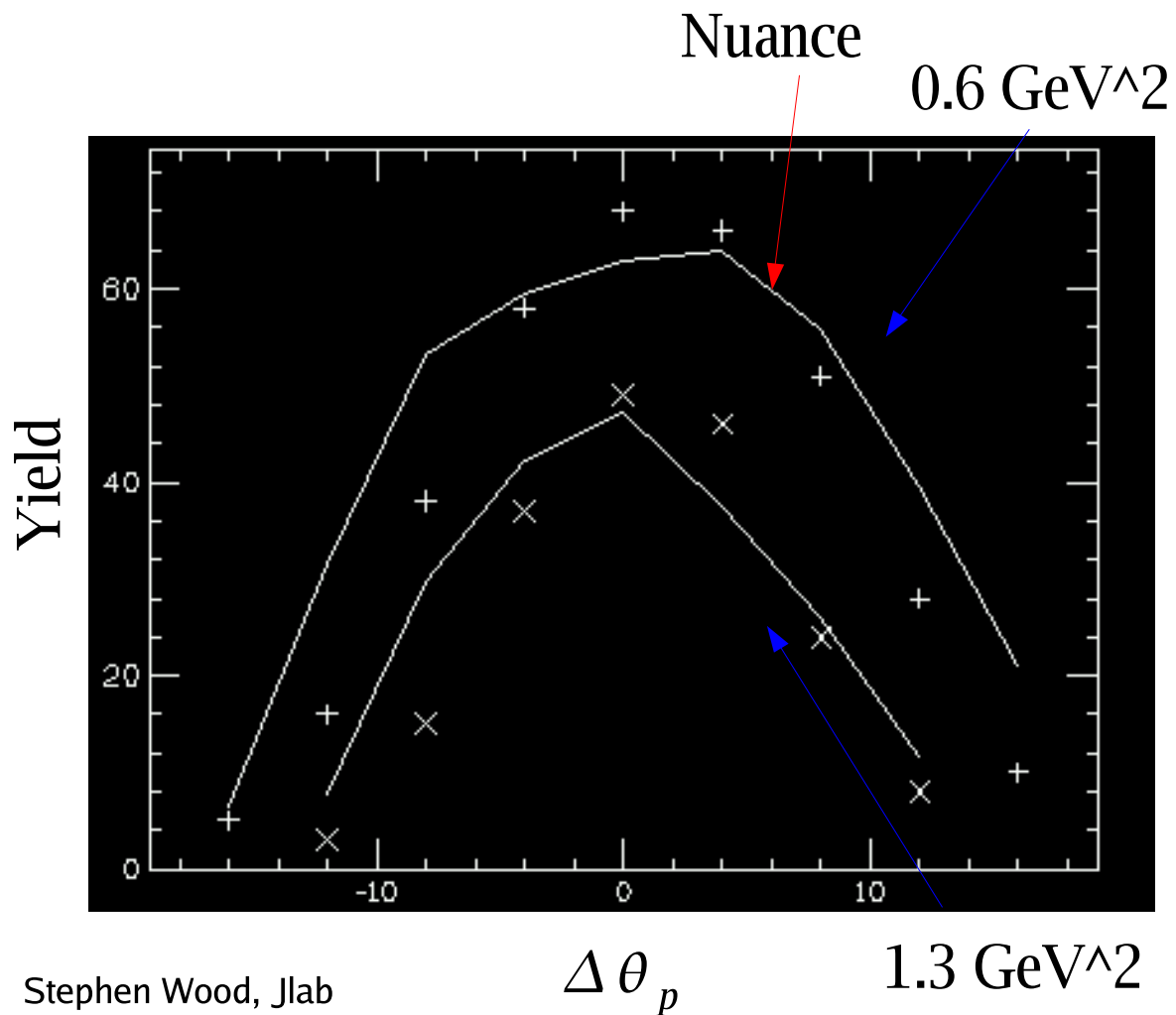
Data are black circles



NUANCE with spectrometer-like aperture ${}^{12}\text{C}(\nu, \nu')$

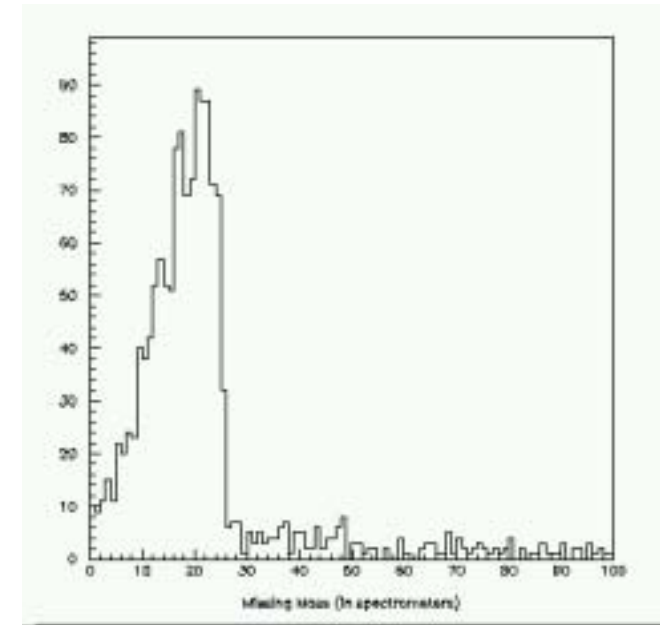
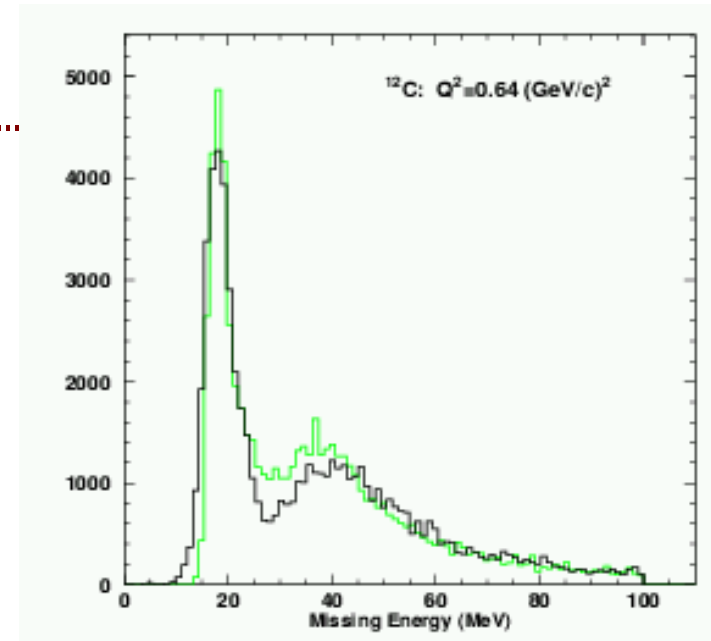
(e,e'p)

- Proton Yield vs angle relative to q
- Reflects Fermi motion



Stephen Wood, Jlab

$\Delta \theta_p$ 1.3 GeV²



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Final comments

- Comparisons of (e,e'h) data to Neutrino MC underway
- Is it a worthwhile exercise?
- CLAS spectrometer $A(e,e'X)$ data can provide wealth of information on hadron rescattering and multiparticle final states
- Make parasite $A_1(e,e'\pi)$ measurements during JLAB spring '03 p,d(e,e') ($Q^2 < 2$, F2/R/Duality)??
- More transparency measurements planned, but guidance to interesting kinematics needed