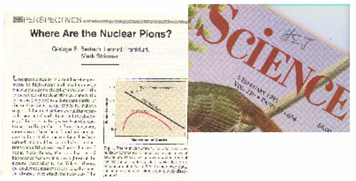
Pion Electroproduction in Light Nuclei

D. Gaskell, S. Avery, H. E. Jackson, J. Arrington
(for the E91-003 collaboration)

"Where are the Nuclear Pions?"

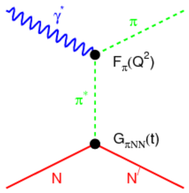


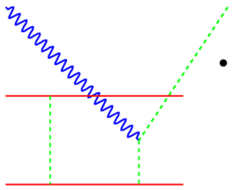
G. Bertsch, L. Frankfurt, and M. Strikman, Science **259**, 773 (1993)

- Yukawa theory - pions mediate the nuclear force
- Refined theory
  - → Additional mesons
  - → Form factors control pion contribution at short distances
  - → Pion contribution not large at short distances, but could still be important at intermediate distances
- 1983 - EMC sees mass dependence of F_2
- Later experiments interpreted as evidence for no (or small) pion excess
  - → Later DIS experiments see less mass dependence
  - → Drell-Yan sees no mass dependence
  - → $(\vec{p},\vec{p}\,')$ and $(\vec{p},\vec{n})$ see no mass dependence in R_L/R_T

Pion Electroproduction as Probe of Nuclear Pion Field

- Pole process single biggest piece of σ_L
- $G_{\pi NN}$ describes the probability for a nucleon to emit a virtual pion



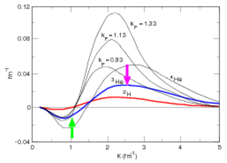


- "Pionic enhancement" in nuclei would be perceived as an enhancement of $G_{\pi NN}$ → enhancement of σ_L

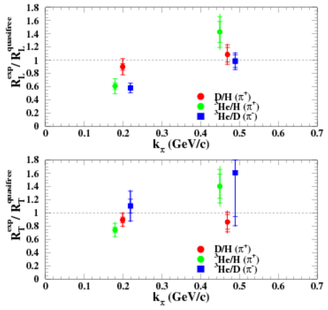
Jefferson Lab Experiment E91003

- Motivation
  - → Measure charged pion electroproduction from H, ^{2}H and ^{3}He (^{4}He)
  - → Extract σ_L via Rosenbluth separation → compare nuclei to free proton to look for effects of pion excess
- Experiment
  - → Ran in Hall C at Jefferson Lab (a.k.a. CEBAF) Feb.-Apr. 1998
  - → Measured (e,e'π) coincidences - electrons in the HMS, π in the SOS
  - → Took data at two ϵ to extract σ_L
  - → Goal = 1% statistics (on unseparated cross sections) Result = 0.6-3.0%
- E91003 Kinematics

$k_\pi = 0.20$ GeV/c $\quad k_\pi = 0.47$ GeV/c
$W = 1.60$ GeV $\quad W = 1.15$ GeV
$\epsilon = 0.49, 0.89$ $\quad \epsilon = 0.44, 0.86$
$Q^2 = 0.4$ (GeV/c)^2
$\theta_{pq} \approx 0$



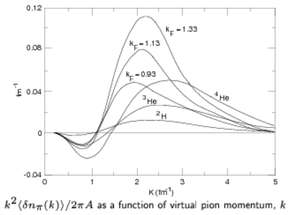
Separated Ratios Compared to Quasifree Calculations



- These ratios measure deviation from quasifree production *over the region measured*
- Low k_π, ^{3}He π^+ includes Dn+pnn final states only: (coherent ^{3}He(e,e'π^+)^{3}H process contributes significantly (30%) to integrated cross section)
- At high k_π, ^{3}He π^+, ^{3}H final state suppressed by form factor - should only be ≈ 4-5% of H cross section

The Pion Excess

- Random Phase Approximation
  - → $\delta n_\pi^A(k) = \frac{1}{(2\pi)^4 2E_\pi(k)} \int d\omega \frac{R_L(k,\omega)}{\omega + E_\pi(k)} - n_\pi^N(k)$
  - → $R_L(k,\omega) = -\frac{3\pi^2}{2k_F^3} Im \left[\frac{\Pi^0(k,\omega)}{1-\left(\frac{1}{\omega^2 - E_\pi^2(k)} + \frac{g'}{k^2}\right)\Pi^0(k,\omega)} \right]$
  - → Π^0 is self energy of pion from nucleon-hole, Δ-hole interactions
- Realistic Nuclear Model
  - → Construct number operator in Static Potential Approximation
  - → Calculate excess using variational wave functions derived from realistic Hamiltonian (Argonne v_{28})

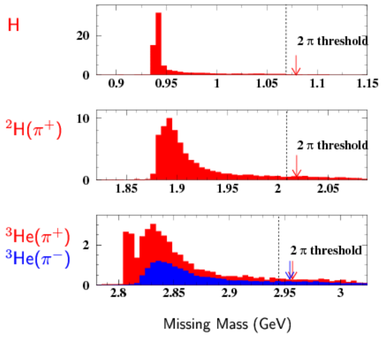


$k^2\langle\delta n_\pi(k)\rangle/2\pi A$ as a function of virtual pion momentum, k

(Friman, Pandharipande, and Wiringa, Phys. Rev. Lett. **51** 763 (1983))

Good Event Selection: Cuts

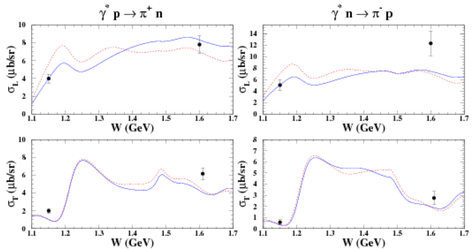
- Spectrometer Cuts
  - → Restrict $\delta P/P$ to nominal good region (HMS: ±8%, SOS: -15% to +20%)
  - → Loose angular cuts: let HEAVYMET collimator set the acceptance
- Missing Mass Cuts
  Restrict missing mass to < 2 pion threshold



Separated Proton/Neutron Results Compared to MAID* Model

*D. Drechsel, O. Hanstein, S. S. Kamalov, and L. Tiator, Nucl. Phys. **A645**, 145 (1999)

- Separated cross sections in $\gamma^* - N$ center of mass
- Neutron cross sections extracted via ratio method: $\sigma_n = \sigma_D(\pi^-)\,\frac{\sigma_p(\pi^+)}{\sigma_D(\pi^+)}$



MAID
MAID 2000

Summary of Pion Electroproduction Results

- E91003 quasifree results consistent with naive estimate of pion excess effects, but also basically consistent with no effect
  - → Large effects from $\pi - N$ FSI make ^{3}He(π^+) data hard to interpret
  - → Incomplete M_x coverage - must compare to model
  - → Low W gives threshold effects
- Mainz ^{3}He$(e,e'\pi^+)^3$H result hints at medium modification of pion propagator
  - → Large FSI effects (30%)
  - → No proton data! Had to use proton model
- JLAB E91003 ^{3}He$(e,e'\pi^+)^3$H result also hints at some kind of medim modification of pion electroproduction amplitude
  - → σ_L close to naive estimate – maybe no modification of pion propagator
  - → Large difference in suppression between σ_L and σ_T relative to Hydrogen – same mechanism as Mainz result?

POSTER TEMPLATE BY:
www.POSTERPRESENTATIONS.com